TETHYS GEOGRAPHICAL RESEARCH

I

Almaty Tethys Kazakhstan

TETHYS GEOGRAPHICAL RESEARCH I

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Volume

I

Kazakhstan Tethys Almaty, 2005

ББК 28.6+26.2
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Т39 **TETHYS GEOGRAPHICAL RESEARCH I — Almaty: "Tethys", 2005.—148 p.**

ISBN 9965-9457-8-0

В ежегодном издании Научного общества Тетис представлены статьи по теоретическим и прикладным вопросам географии, ГИС и космического зондирования. Издание рассчитано на географов, экологов, студентов и географов широкого профиля.

ББК 28.6

This Tethys Society annual edition presents scientific articles on basic and applied problems in geography, GIS and remote sensing. The edition is provided for geographists, ecologists, students and other readers with interests on geography.

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ISBN 9965-9457-8-0

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Introduction

The heavy growth of the population, industry and agriculture in the twentieth century, especially in its second half, have reduced in sharp growth of anthropogenic loads on natural environment of the Aral region and to disastrous impoverishment of water resources. The ecological crisis, which basic sources are negative manufactured activities, strongly demands search of the measures compensatory negative consequences. As show theoretical studies and location observations, the processes of a change of state of natural-climatic environment of region tend to the long-lived latent periods, education of new systems of interaction, and are capable to accumulate huge power. Most the strong influence of an anthropogenic factor is supervised in the most saturated by life low layer of biosphere near to a demarcation of a dry land, water reservoirs and atmosphere. High movement and instability of the natural climatic processes defining the vital parameters for the human existence define this sphere.

The problem of an evaluation of the most probable physical-climatic consequences of anthropogenic loads for elaboration of optimal water using strategies in arid zones is aim in this elaboration. Realization of the given purpose of scientific probes is carried out through serial stages of an approaching to the solution of the main task:

I. Detail study of regularities of interaction a component of natural-climatic environment in vivo;
II. Secretion of the influences irrelevant with these processes, and their time-space analysis;
III. Forecast of possible changes of natural-climatic environment for different scenarios of economic activities and selection of optimal solutions.

The analysis of main routes in scientific geographical probes shows, that now the main centre of gravity falls at study the delicate interactions of a climate and a underlying terrain, which determine their local features and on scales are commensurable with the modern influence of human activity. The method of classification of temperature-humidifying parameters of a climate is applied for detection and a quantitative assessment of such regularities on types of landscape.

Classification of climatic indexes

General principles

Basis of landscape classification temperature-humidifying parameters was the concept about close correlation of the natural environment and a climate. Its major principles are found out in the certain interrelation of landscapes and a climate both as natural-climatic zones, and as mountain high-altitude zones. That idea has been realized by the way numerous indexes and precipitation-evaporation ratios, dryness and aridity, which at a semiempirical level established the quantitative correlations between thermal and humidifying characteristics.

One more basis of now researching has become submission about the climatic characteristics as about some spectrum of more simple parameters specified by the causes of a miscellaneous scale: global, regional, and local. At such approach, each component is isolated from statistically representative extract of climatic parameters, the statistical analysis of its interrelations with elements of a underlying terrain is executed and verified on availability synergetic interrelation between them implements. Then decisive algorithms are made.

With this purpose the climatic database on 4300 meteorological stations of Asia, Africa and Europe in ranges gathered and parsed:

- from 5 degrees of Southern latitude up to 80 degrees of Northern latitude;
- from 18 degrees of Western longitude up to 150 degrees of Eastern longitude;
- from -150 up to 5023 m above sea level.

Main criteria at its integration was availability of most full enumeration of the basic types of the underlying terrain conforming to him of volume and quality of climatic indexes and concomitant landscape information.

For study the main water-balance parameters - an air temperature, precipitations and evaporation for the seasons have been elected:

- Winter (XII-II months);

- Spring (III-V months);
- Summer (VI-VIII months);
- Autumn (IX-XI months);
- Average annual.

Method of classification

The analysis of heat-balance equation, which describes a condition of a underlying terrain,

$$R + P + L^* E + B = 0,$$

where

R - radiation balance;

P - turbulent heat exchange between an active surface and air;

L - specific heat of evaporation (condensation);

E - quantity of evaporated (condensed) water;

B - heat exchange between an active surface and subjacent substrates.

The analysis shows, that the component of heat input on vaporization and condensation plays very large role and it is the most volatile parameter of an equation both on a mark, and on an absolute value. In conditions more or less homogeneous radiation modes given component also determines a diversification of local climates. At the conforming organization of the analysis has appeared possible quantitatively to evaluate influence of costs of transmission of latent heat on distribution of temperatures of ground air. Therefore essentially an important point of probe were optimal grading of types of a underlying terrain on degrees of their humidity and correct selection of background type of a underlying terrain, concerning which in consequent temperature deviations, were determined.

For different types of a underlying terrain in the capacity of categorizing values of hydrothermal parameters of a climate – precipitation-evaporation ratio of Mezentsev [1] and aridity index of De Martonn [2], which were modified for the taking into account of altitude influence. After corrective action, assumption formulas have a following view:

1) Mezentsev modified precipitation-evaporation ratio [3]:

$$K_y = \frac{W_i \cdot e^{-0,343 \cdot \frac{Hi}{Ti}}}{0.2 \cdot \sum t_{+10°C} + 306},$$

where

W_i – sum of precipitations for year, *(mm)*;

H_i – altitude of meteostations above sea level, (*m)*;

T_i – average annual temperature of a layer of air in the interval from *0* up to H_i в in absolute degrees;

$\sum t_{+10°C}$ – sum of air temperature above +10 °C.

2) Modified aridity index of De Martonn [3]:

$$I_a = \frac{W_i}{t^* + 10^\circ C},$$

where

$$t^* = 235 * \lg \frac{E_i}{6.1} \Bigg/ \left(7.45 - \lg \frac{E_i}{6.1}\right), \quad (1)$$

where

t^* – efficient air temperature in Celsius degrees for altitude – H_i,;

W_i – sum of precipitations for year *(sm)*;

E_i – average annual evaporability *(mm)* for altitude– H_i .

By results of cluster analysis are determined seven of significant discriminating between themselves groups of climatic conditioned gradations of humidifying for types of a underlying terrain (Table 1).

Table 1. Hydrothermal coefficients for types of vegetation

Gradations of humidifying on groups of underlying terrain types	K_y			I_a		
	min	max	avrg	min	max	avrg
1 Desert	0.0	0.2	0.1	0.0	2.2	0.7
2 Semidesert	0.2	0.5	0.3	0.8	3.2	1.5
3 Savannah, dry steppe	0.3	0.7	0.4	1.5	4.7	2.5
4 Meadow-steppe, forest-steppe, forest-meadow-steppe, including mountain	0.4	0.9	0.6	2.3	5.7	3.9
5 Meadow-bush, dry deciduous forests of subtropical and tropical zones, including mountain	0.5	0.9	0.7	2.3	5.8	3.9
6 Conifers and deciduous forests of a moderate belt, a meadow and tundra, a wood and bushes of a subtropical zones, the wet ever-green forests of tropical zone, the mountain conifers, coniferous and broadleaved woods of tropical zone	0.7	6.4	1.4	3.6	42.1	7.6
7 Glacial surfaces in the ablation zone	0.92	4.39	2.12	5.46	28.86	11.80

The calculated values of the modified hydrothermal coefficients are characterized by high mutual correlation r=0,94 and arithmetic means $I_a/K_y=5{,}6$. Standard deviation of their relation is equal σ=±0,32.

Air temperature

For the first time the method of landscape-climatic classification had been applied by the writer at the impact analysis of a underlying terrain on distribution of thermal parameters of climate [3]. At such approach, the air temperature was considered as an integral parameter of a spectrum of interacting factors: latitude, altitude, zonal, azonal and anthropogenic, which has the development in different types of vegetation and soil and influence of water surfaces.

The visual analysis for distributions of air temperatures on longitude, latitude and altitude shows (Figure 1, Figure 2, Figure 3) that the latitude factor is master (Figure 2).

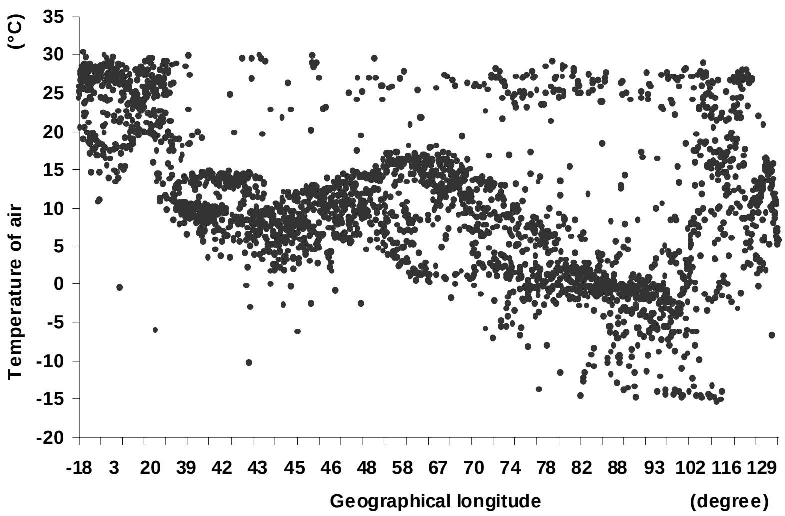

Figure 1. Distribution of average annual air temperatures on longitude

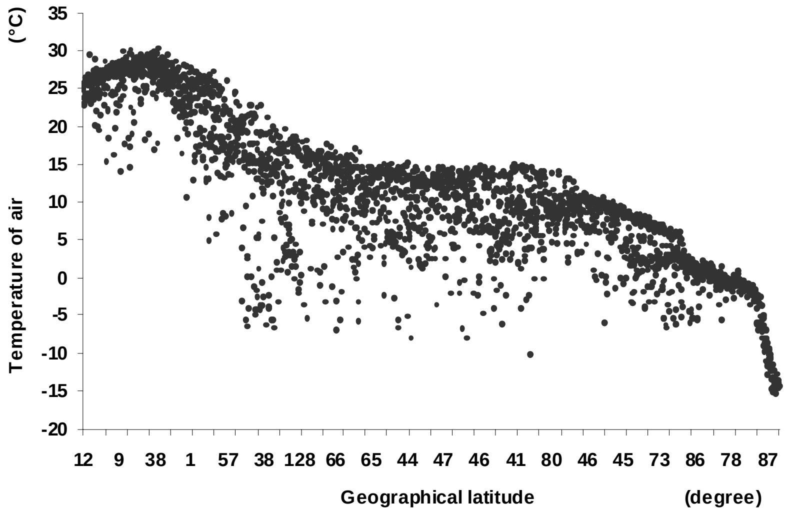

Figure 2. Distribution of average annual air temperatures on latitude.

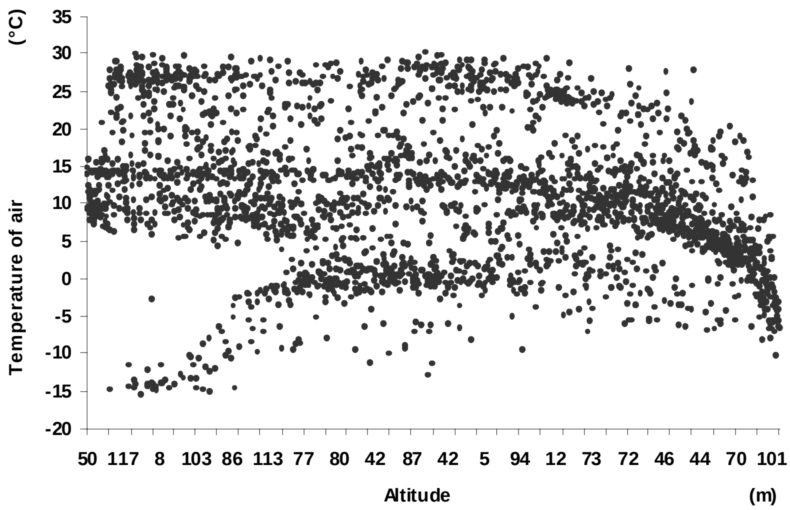

Figure 3. Distribution of annual air temperatures on altitude.

The large dispersion of a natural latitude trend at $\sigma = \pm 5.7°\boldsymbol{C}$ does not allow to use available data for calculations. Therefore, their preselection executed.

For a quantitative assessment of influence of the latitude factor in the capacity of background values of temperatures in smoothing landforms for arid types of vegetation, not complicated by additional influences are adopted. Such conditions are defined not only the least values of hydrothermal coefficients, but also the least variability. A background latitudinal distribution for the meteorological stations located in a flat land for arid types of vegetation on seasons have been approximated by polynomial regressions (Figure 4) with elimination of the values, which are not falling in a range $\pm 2\sigma_l$. Standard deviations of approximating have limit $\sigma_l = \pm 1.1$ ч ± 1.4°C.

The evaluation of seasonal distributions of air temperatures on altitude was realized under following scheme:

- for calculation of an equation the meteorological stations located in smoothing forms of a mountain relief - intermountain walleyes and intermountain depressions of arid types of vegetation were involved;
- altitude trends were calculated for air temperatures with the eliminated designed background latitudinal distributions.

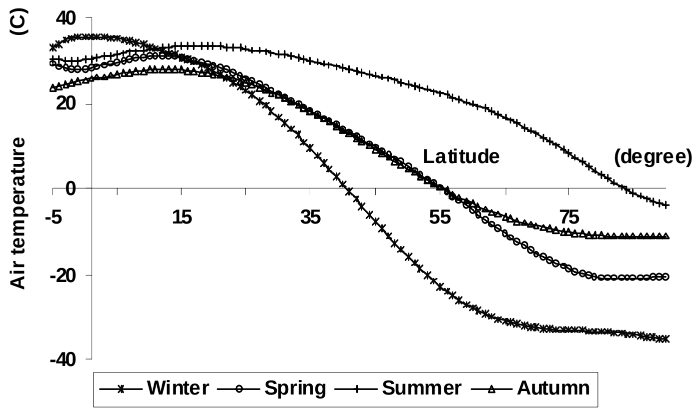

Figure 4. Calculated of background distribution seasonal for air temperatures on geographic latitude.

The extrapolation of trends for altitude more than 5000 m by formula is executed:

$$T_i=(H_e-H_{abs})*t_e+T_f,$$

where

H_e - altitude in zone of extrapolation;

H_{abs} - altitude of high part of empirical zone dependence;

t_e - constant value of altitude thermal gradient in the upper range of the diagram;

T_f - background value of air temperature fitted on latitude on high part of an empirical zone dependence, equal 5000 *m*.

Background distributions of "residual" seasonal temperatures of air on altitude are approximated by polynomial regresses (Figure 5) for standard deviation $\sigma_a = \pm 0.7 \div \pm 1.1$°C.

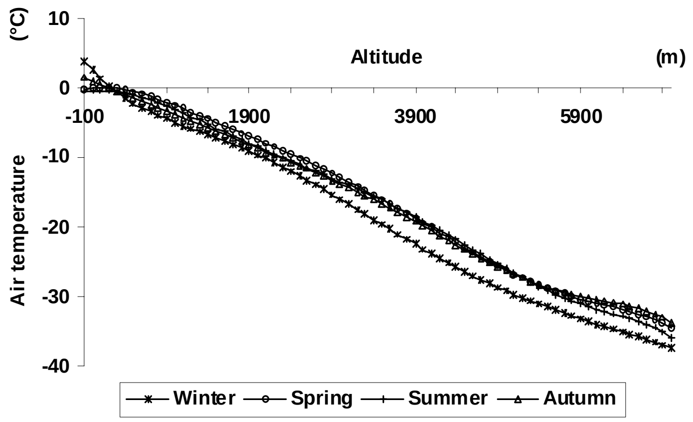

Figure 5. Calculated background distribution of seasonal air temperatures on altitude.

For the count of influence of a relief on a temperature regime all diversity is shown to two types, grouped on altitude tiers:

1. Smoothing relief - plains, poorly inclined piedmont plains, intermountain valleys and depressions of all altitude tiers and mountain plateau;
2. Broken relief - mountains ridge, tops, picks, and passes, slopes, bottoms of narrow mountain valleys.

After elimination of influence of latitude and altitude of value of "residual" temperatures, grouped on gradations of humidifying, are subjected to complex dispersion analysis.

Comprehensive analysis of seasonal temperature parameters on the meteorological stations, not entered in parameters climatic conditioned types of landscape, has allowed supplementing available relations intrazonal and/or anthropogenic factors, and the factor of influence of water surfaces.

Results have shown absence of the composite synergetic interactions and have been interpreted as hierarchically organized regularities connecting a seasonal temperature regime with elements of a underlying terrain.

Codification of elements for underlying terrain formed on the basis of grading types of vegetations, soils (Table 2,Table 3 , Table 4, Table 5, Table 6, Table 7) and grading of types of relief (Table 8):

In more detail, technology of codification of types of a underlying terrain is described in activities [3, 4].

Table 2. Climatic conditioned types of vegetation.

Codes	Description of types of vegetation
100000	Deserts
200000	Semi deserts
300000	Savannas
320000	Dry steps
350000	Meadow–steps
400000	Forest–steps
450000	Mountain forest–meadow–steps
500000	Meadow–bushes, including mountain
550000	Dry fall–of–leaf woods of subtropical and tropical zones
600000	Coniferous woods of temperate zone, including taiga
650000	Fall–of–leaf woods of temperate zone
700000	Meadows, including alpine, tundra, including mountain
750000	Woods and bushes of a subtropical zone
800000	Raining woods of a tropical zone
850000	Mountain coniferous–leaf and coniferous woods of a tropical zone
890000	Glacial surfaces in the ablation zone

Azonal types of a surface are submitted intrazonal and anthropogenic changed types of vegetation and influence of water surface.

Table 3. Anthropogenic changed types of landscapes.

Codes	Description of types of landscapes
0	Is absent
3200	Cereal crops (wheat, rye, oats)
3500	Corn, sunflower, fruits and berries, vegetables and fodder grass
7000	Cotton, sugar beet, melons and gourds
8700	Rice
9400	Inhabited localities
9600	Average cities
9800	Large cities

Table 4. Intrazonal types of soils.

Codes	Type of soils
0	Is absent
11000	Takyr
32000	Meadow dried salty soils, alluvial-meadow dried salty soils, takyric solonchak
35000	Meadow-brown soils, meadow salty soils, alluvial-meadow salty soils, meadow-swampy dried salty soils, usual solonchak, meadow solonchak, seaside solonchak, march solonchak, secondary solonchak
55000	Alluvial forest-meadow dried soils
70000	Meadow-swampy salty soils, swampy salty dried soils, alluvial swampy dried salty soils, seaside swampy dried soils
75000	Alluvial forest-meadow soils, alluvial meadow-swampy soils
35000	alluvial meadow-swampy dried salty soils
86000	Swampy salty soils, alluvial swampy soils, seaside swampy soils, shor solonchak

Table 5. Influence of water surfaces.

Codes	Description of types of vegetation
0	Is absent
100	Zone of the minimal influence of reservoirs
200	Zone of average influence of reservoirs
300	Zone of the maximal influence of reservoirs (shores of seas and lakes)
400	Water surface of reservoirs, lakes and seas (off shore).
500	Water surface of reservoirs, lakes and seas (far off shore).

Table 6. Intrazonal types of vegetation.

Codes	Description of types of vegetation
0	Is absent
10000	Deserts
11000	Takyrs
20000	Semideserts
30000	Savannas
32000	Dry steps
35000	Meadow–steps, solonchaks
40000	Forest–steps
45000	Mountain forest–meadow–steps
50000	Meadow–bushes, including mountain
55000	Dry fall–of–leaf woods of subtropical and tropical zones, tugay drained forests
60000	Coniferous woods of temperate zone, including taiga
65000	Fall–of–leaf woods of temperate zone
70000	Meadows, including alpine, meadow-marsh, march solonchaks, tundra, including mountain
75000	Woods and bushes of a subtropical zone, tugay forests
80000	Raining woods of a tropical zone, marshes
85000	Mountain coniferous–leaf and coniferous woods of a tropical zone
86000	Marshes, shor solonchaks
89000	Glacial surfaces in the ablation zone
90000	Glacial drifts, slide-rocks
91000	Rocks

For natural complexes of Syrdarya River basin, it has been developed the system of codification submitted below soils with using of the data soil mapping for the purpose of modelling.

Table 7. Anthropogenic changed types of soils.

Codes	Type of soils
3200	Brown desert irrigated soils, takyr-like irrigated soils
3500	Meadow irrigated soils
8700	Rice-swampy soils

Natural complexes can have the complex structure submitted by types of the spreading surface of the different order of hierarchy. Depending on a level of an enclosure calculation of codes for climatic caused and intrazonal types of vegetation or types soils is carried out under the general scheme:

$$COD_I = ((100 - Q2 - \ldots QN)*a + Q2*b + \ldots + QN*n)/100*N,$$

where

Q – value of percentage of type soils in n-th an investment;

a – code of belonging of type soils the first level of an investment;

b – code of belonging of type soils the second level of an investment;

n – code of belonging of type soils the n-th level of an investment;

N – amount of nonzero (absent) values of types soils.

Table 8. Types of relief.

Codes	Description of types relief on high-altitude tiers	Range of altitude (m)
SMOOTHING RELIEF:		
10	Plain *(incline 0 – 6°, exceeding of altitude 0 – 30m)*	0-600
5000	Foothill some slanting plains *(incline 7 – 12°, exceeding of altitude 0 – 50m)*	0-900
Intermountain depressions *(incline 0 – 10°, exceeding of altitude 0 –50m)*:		
100	Intermountain depressions of the bottom tier	0-1200
105	Intermountain valleys of the bottom tier	0-1200
200	Intermountain depressions of an average tier	1201-3000
205	Intermountain valleys of an average tier	1201-3000
300	Intermountain depressions of the top tier	> 3000
305	Intermountain valleys of the top tier	> 3000
BROKEN RELIEF *(incline > 15°)*:		
6000	Low-mountainous a relief, including small hills (*exceeding of altitude 50 – 200m)*	0-1200
7000	Middle-mountainous deeply broken relief of 1-st subtier (*exceeding of altitude 400 –*	1201-1600
7050	Middle-mountainous smoothed relief of 2-nd subtier (*exceeding of altitude 200 – 600m)*	1601-3000
8000	High-mountainous deeply broken periglacial relief (*exceeding of altitude 400 – 1500m)*	3001-4000
8050	High-mountainous middle broken glacial relief (*exceeding of altitude 200 – 800m)*	> 4000

If calculated value of COD_I is not equal to one of tabulated values it is accepted equal to the nearest tabulated value.

Influence of water surface pays off from a coastal line under formulas:

1. For the seas and oceans

$$COD_{500} = -0.04*(L + W),$$
$$COD_{400} = -0.02*(L + W),$$
$$COD_{200} = 0.04*(L + W),$$
$$COD_{100} = 0.12*(L + W),$$

Limiting distance for COD_{100} no more than 200 km from a coastal line.

2. For lakes

$$Cod_{200} = 0.10*(L + W),$$
$$Cod_{100} = 0.25*(L + W),$$

Limiting distance for Cod_{100} no more than 10 km from a coastal line.

3. For the rivers and channels

$$cod_{200} = 1.5*W,$$
$$cod_{100} = 4.0*W,$$

where

L – length of a reservoir;

W – width of a reservoir.

Limiting distance for cod_{100} no more than 3 km from a coastal line.

Quantitative assessments of distributions in a dispersion complex have formed the basis for argument of regularities between the revealed components of underlying terrain and residual values of temperature parameters. As a matter of convenience, their submissions and visualization were presented one-dimensional projections of arithmetic averages studied performances for each factor at a locked position of all remaining. Values of temperatures for conditions of ultraarid type of vegetation and smoothing relief are determined in the capacity of reference point. They are accepted equal to zero, and values on other gradations of all factors are shown as deviation from these of values of reference points.

The contribution of climatic conditioned types of vegetation in a seasonal thermal mode has appeared highest of all a component of underlying terrain (Figure 6) and concedes only to influence of the latitude and altitude factor. Standard deviations of approximating lay within the limits $\sigma_{cl} = \pm0.5 \div \pm0.9$°C.

The contribution ruggedness of relief in a thermal mode on seasons (Figure 7) shows small relative reduction of temperatures in a broken relief in comparison with smoothing relief. It reflects condition of atmosphere circulation in a mountainous country, which promotes the best ventilation of mountain slopes and to generation of adiabatic processes in intermountain reductions.

Corrections for types of relief are defined by smalls values at the high significance and consequently they stability influence on distribution of temperature parameters in a mountainous territories. Standard deviations on seasons $\sigma_{tr} = \pm 0.3 \div \pm 0.6°C$.

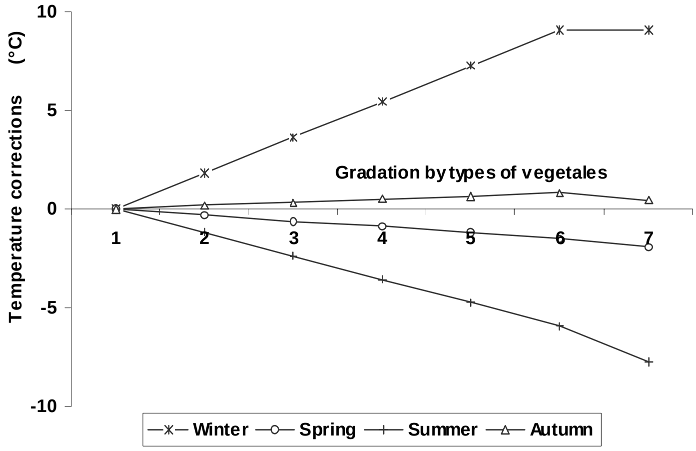

Figure 6. Influence the climatic caused types of humidifying on distribution of temperatures of air. (Symbols see Table 2)

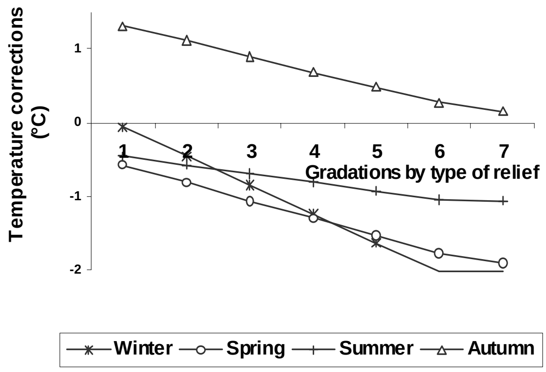

Figure 7. Influence of brokenness relief on distribution of air temperatures (Symbols see Table 8).

The temperature values, which are not including in, a confidence interval of climatic conditioned, have been interpreted as influence intrazonal, anthropogenic factors and influence of water surfaces. Their contribution is determined as deviations of thermal parameters from conforming climatic conditioned types of humidifying.

For an evaluation of relations following classification on gradations intrazonal and/or anthropogenically conditioned humidifying has been developed:

1. climatic conditioned type of vegetation;
2. solonchaks and takyrs;
3. intrazonal deserts;
4. intrazonal semideserts;
5. intrazonal dry steppes and/or crops;
6. intrazonal meadow-steppes and/or fodder grasses;
7. intrazonal meadow-bushes, bottomland forests and/or cottony fields;
8. intrazonal marshes, bogs, and/or rice fields;
9. cities.

Integrated trends of intrazonal and anthropogenic influence on thermal mode are shown below (Figure 8, Figure 9)

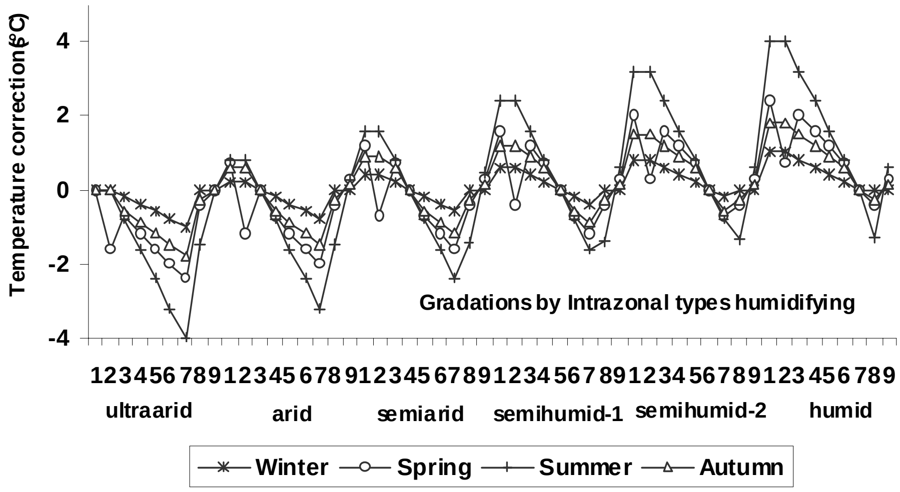

Figure 8. Influence of intrazonal types of a underlying terrain on seasonal air temperatures (Symbols see Table 2.).

Standard deviations of approximating have limits σ_{in} = ±0.5 ÷ ±0.9°C.

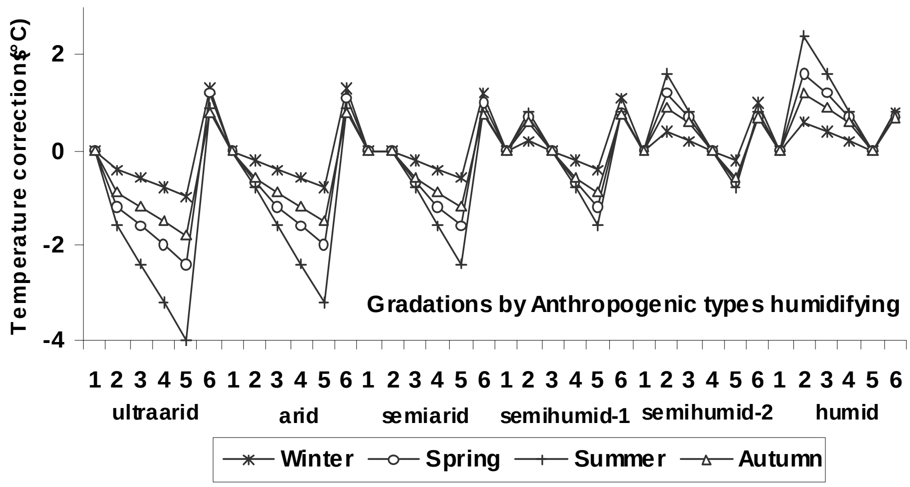

Figure 9. Influence of anthropogenically changed types of a underlying terrain on seasonal air temperatures (Symbols see Table 2).

Standard deviations of approximating have limits σ_{an} = ±0.8 ÷ ±1.1°C.

For an evaluation of influence of water surface of lakes and seas on formation of seasonal temperatures of a meteorological station are assorted on a degree of their remoteness from water reservoirs, which is determined in each concrete event at data analysis of neighbouring meteorological stations (Figure 10):

1. climatic conditioned zone of vegetation (zero line on the regime);
2. zone of minimum influence of water reservoirs;
3. zone of resistant influence of water reservoirs;
4. zone of maximum influence of water reservoirs;
5. water surface of lakes and seas.

Influence of water surface on a thermal mode shows accumulative effect of water on a background of climatic conditioned types of underlying terrain. With reference to the winter season, given conclusions are corrected only for areas, where at this time of year there are ice-free water spaces. In the same place, where water reservoirs are covered with ice, in accordance with increase of width of a fast ice the temperature effect "moving aside" a coastline show. Thus, ice is a barrier interfering active heat exchange between water and air and essentially smoothes temperature influence of reservoirs.

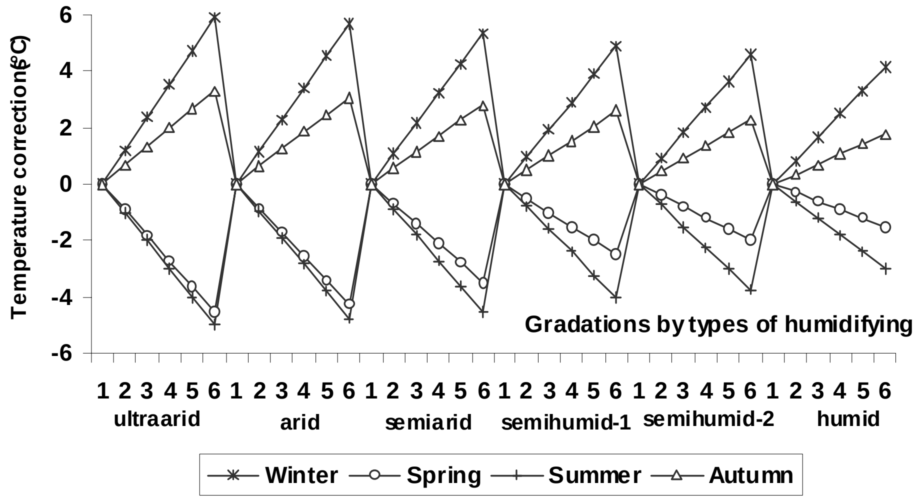

Figure 10. Influence of water surfaces of surface on seasonal air temperatures (Symbols see Table 2).

Standard deviations of approximating have limits $\sigma_{an} = \pm 0.4 \div \pm 0.7°C$.

Summarizing standard deviation of an evaluation of a spacing of seasonal air temperatures is designed by formula:

$$\sigma_r = \frac{\sum_i^k \sigma_i}{k} = \pm 1.3 \div 2.1°C$$

,

where

σ_I - partial standard deviations under analyzed factors;

k - number of partial standard deviations

They are equal for seasons: Winter = ±2.1°C; Spring = ±1.3°C; Summer = ±1.6°C; Autumn = ±1.4°C.

Precipitations

Precipitations are the most volatile climatic index, which hardly depends not only on conditions of common moisture transport, but also from local features of orography (Figure 11, Figure 12, Figure 13).

At the visual analysis of different distributions for the precipitations obtained on meteorological stations of database it is visible, that only in distribution of precipitations on latitude some tendency complicated with influences of the higher order is tracked (Figure 12).

The method of landscape grading has been applied for reduction of general high variability of precipitations on latitude. The essence of it comprised in following.

- For an evaluation of distribution of dispersions all latitude range has been split on intervals by step of 5 degrees, on which statistical parameters estimated.
- Because of a trace amount of meteorological stations on the interval, more than 60 degrees of northern latitude here have been adopted step, equal 10 degrees of geographic latitude.
- From the analysis of two stations with extremely high values of an annual precipitation have been eliminated: Cherrapunji - 10902 mm/year and Debundza - 9655 mm/year. It has been conditioned, that too the trace amount of basic data in this range of values of a precipitations has not allowed making safety enough conclusions.

The method of cluster analysis had been determined types of vegetation with statistically significant distinctions in a latitudinal distribution of annual precipitations. Data with close values have been grouped for five types of humidifying:

1. ultraarid;
2. arid;
3. semiarid;
4. semihumid;
5. humid.

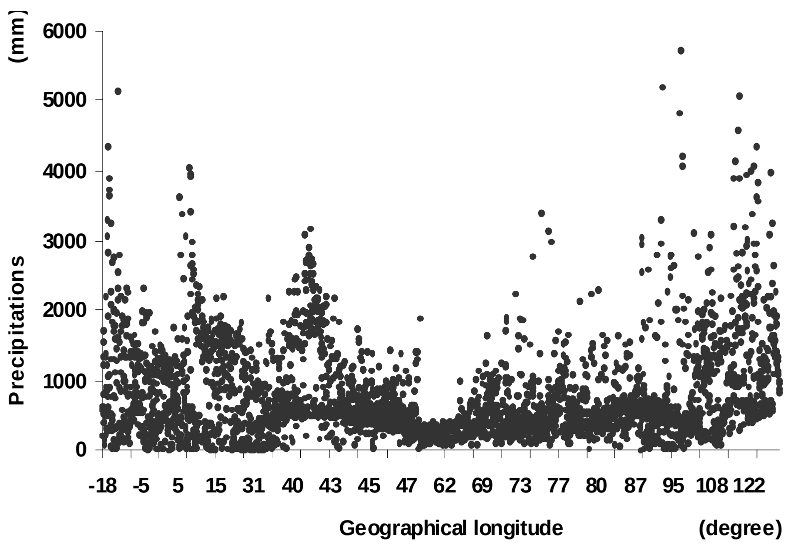

Figure 11. Distribution of annual precipitations on longitude.

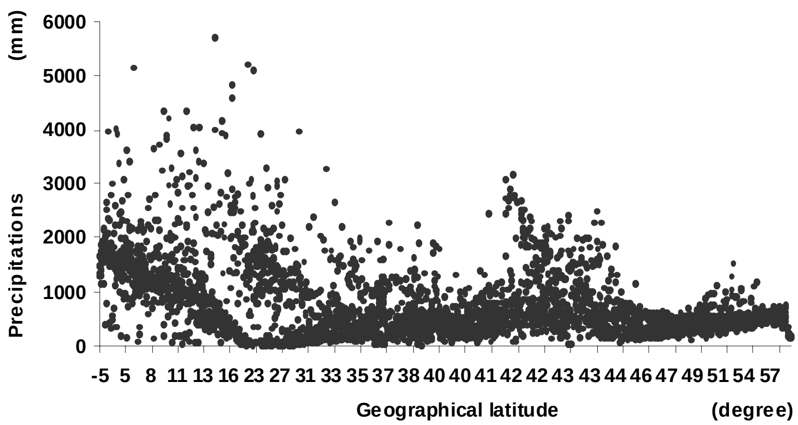

Figure 12. Distribution of annual precipitations on latitude.

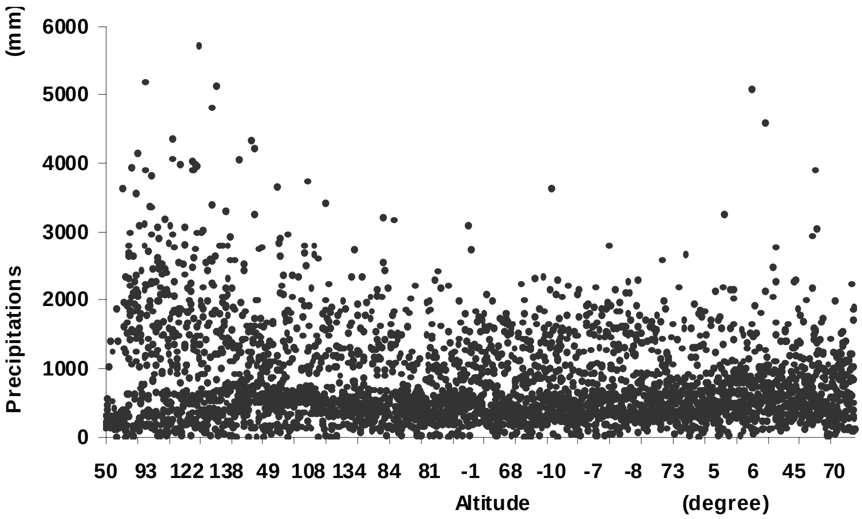

Figure 13. Distribution of annual precipitations on altitude.

Comparison of parameters of mixed distribution of precipitations (Figure 12) and categorized distributions is shown below (Figure 14).

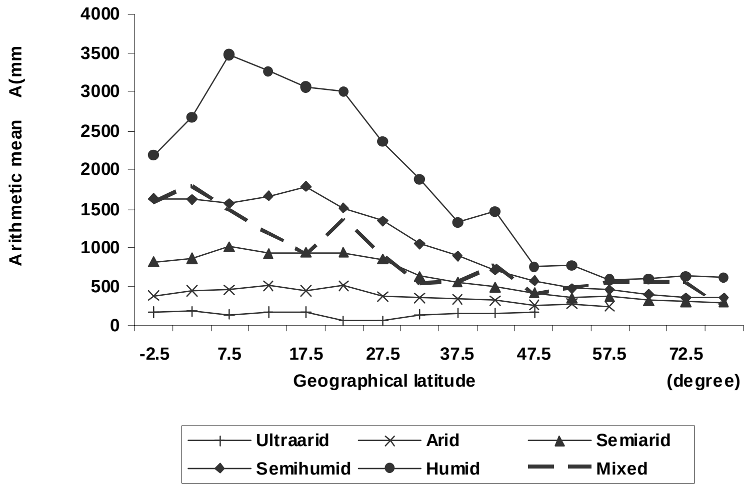

Figure 14. .Distributions of arithmetic means of values of annual precipitations on latitude and types of humidifying.

The cluster analysis has revealed significant difference for distribution of precipitations (Fisher's ratio test more than 99 %) as between undivided distribution of precipitations and classifying types of climatic conditioned humidifying (Figure 14). Standard deviations for mixed distribution of precipitations almost always is more, than even for most changeable precipitations of humid type and is much greater, than for remaining types (Figure 15).

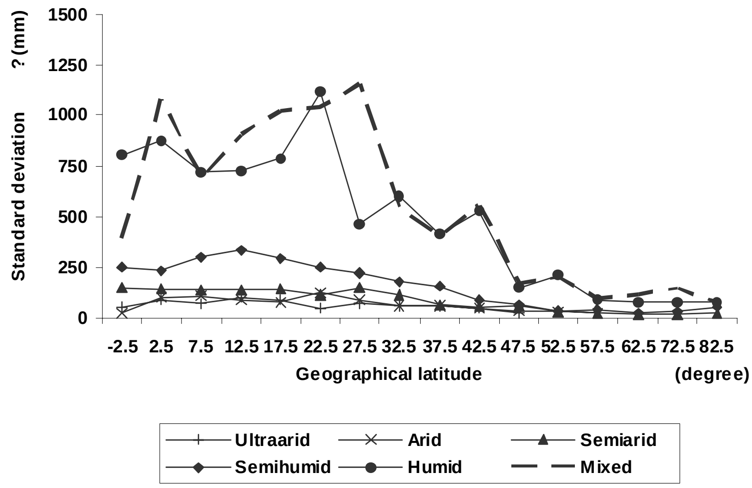

Figure 15. Distributions of standard deviations for annual precipitations on latitude and types of humidifying.

The analysis of relations of standard deviations to average values of precipitations demonstrates the considerable reduction of dispersion after grading precipitations for types humidifying (Figure 16).

Comparison of trend on latitude classifying precipitations with mixed distribution shows, that average values of mixed distribution reflect relative weight of each type of humidifying in the given latitude interval.

By results of grouping of polynomial trends of relation of precipitations from geographic latitude have been designed (Figure 17).

For assessment of influence of altitude on distribution of precipitations, grouped for types of humidifying, the technique of evaluation of "residual" values, which well itself has built up a reputation for analogous researches of temperature trends, has been applied**.** For this purpose all altitude range has been split on intervals by of 300 meters step, on which statistical parameters - arithmetic means estimated, standard deviations and confidence intervals.

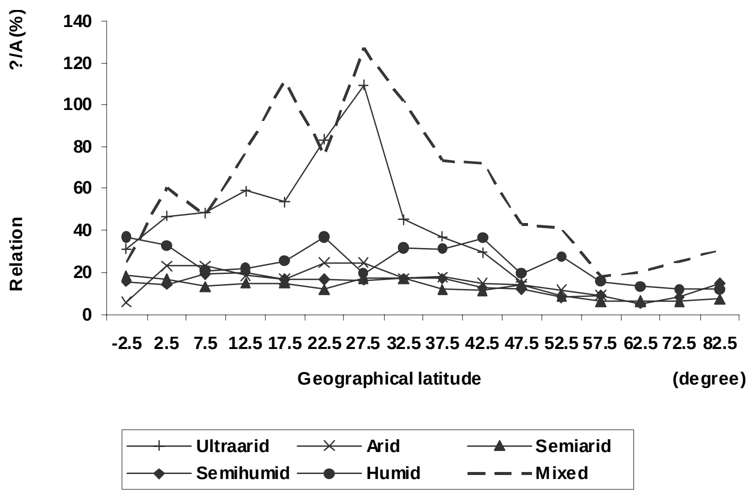

Figure 16. Relations of standard deviation to arithmetic mean annual precipitations on latitude and types of humidifying.

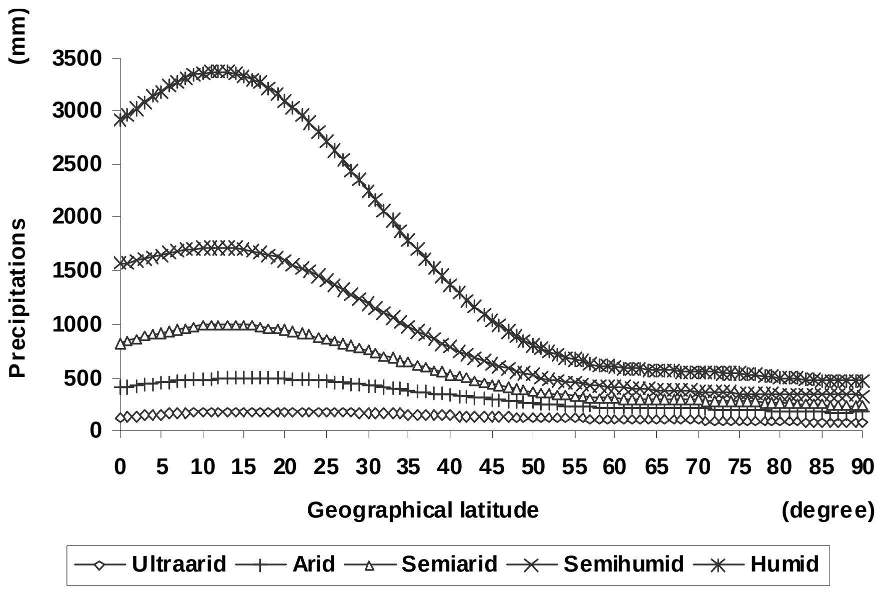

Figure 17. Calculated background distribution of annual precipitations on geographical latitude.

Results of dispersion analysis of distribution of residual values of precipitations on altitude are shown by charts of arithmetic means for each group of types of vegetation and concomitant ranges of confidence intervals ±95 % (Figure 18).

The analysis of results for each group and between them shows absence of something significant trends. The absolute majority of deviations from zero line are conditioned by local features of position of meteorological stations and cannot be confidently interpreted as change of an amount of precipitation for increase of altitude.

At first sight, such conclusion contradicts the stable submissions about character of change of precipitations on an altitude. But if to take into consideration the fact, that altitude zonality of vegetation types for mountain terrains is everywhere defined by changeover from less humidified landscapes to more humidified in direction from bottom to ridges of mountains obtained outcomes will be agreed the conventional submissions. After fulfilment of landscape grading distribution of precipitations the factor of influence of altitude on their distribution has not vanished, and acts in mediated view through altitude zonality of vegetation types. Thus, finds the argument for high territorial variability of distribution of precipitations on altitude defined as direct functional linkage is solved. For each concrete terrain trend of precipitations on altitude is much more safely determined on an elevation profile landscape on altitude tiers.

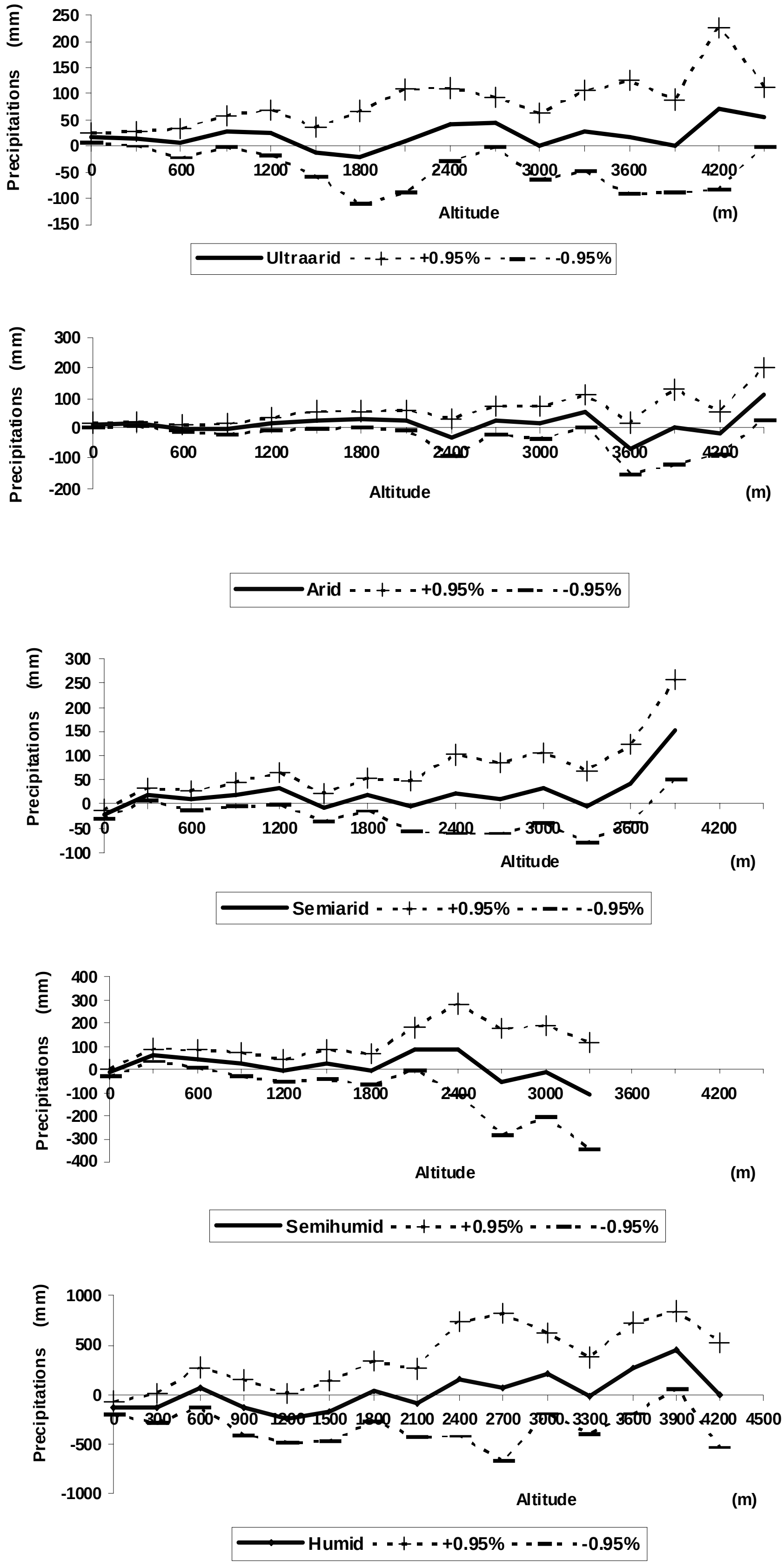

Figure 18. Distribution of average arithmetic values of annual precipitations on altitude and types of humidifying.

Depend on landscape diversification of the investigated areas it is possible to receive more detail outcomes for the leeward and upwind slopes, solar and shaded surfaces. Therefore, for climatic conditioned precipitations one general supposition is accepted. Range of deviations from calculated values is interpreted as area of resistant existence of those or other types of landscapes. Relations of residual variances to their average values are interpreted as index of openness to moisture transport, relating to the given group of types of landscapes. Ranges of relative oscillations of an index of openness for precipitations, grouped for types of vegetation, change in limits:

1. ultraarid – I=10 ÷ 162%;
2. arid – I=70 ÷ 125%;
3. semiarid – I=73 ÷ 123%;
4. semihumid – I=75 ÷ 135%;
5. humid – I=70 ÷ 220%.

Groups of humidifying, since arid up to semi humid type, are defined inclusively by marginal values of range of existence in limits ±25 ÷ ±35 % of change of precipitations. For marginal types of humidifying, it is possible to explain high values of range of existence by the following causes. On the one hand, it explains low values statistically a normal distribution of precipitations for ultraarid zone and availability in deserts of terrains with almost full absence of precipitations. On the other hand, it is practically not limited high bound of precipitations for over moisten landscapes.

The attention low-level relative intersection of ranges of precipitations for adjacent groups of humidifying for the limits pays to itself 3 ÷ 6 %. It is the indirect argument verifying the suppositions about acceptable variations of values of precipitations for maintenance of resistant existence of those or other groups of vegetation types, having common temperature-humidifying parameters. Transition zones for biological communities usually have much smaller dimensions as contrasted to ranges of steady existence of species.

Those conclusions are right only for climatic conditioned types of landscapes as their formation directly depends on moisture coming with precipitations. The dominating role in formation intrazonal and anthropogenically changed landscapes is played with the water component not linked with precipitations. Therefore, in the given activity for such landscapes distribution of precipitations is accepted to equal values of ambient climatic conditioned background.

Testing calculations on meteorological stations have show following. In case not account index of openness of terrain to moisture transport under condition of correct definition of landscape surrounding of each object relation of amounts of deflection of entries $\Delta_i = W_i - W_c$ to measured values of precipitations – W_i lay within the limits $100*\Delta_i/W_i = \pm 7 \div \pm 27\%$. Account of values of an index openness of terrain to moisture transport increases accuracy of a forecast up to $100*\Delta_i/W_i = \pm 3 \div \pm 14\%$.

Evaporation

In the basis of landscape, grading evaporation outcomes of investigations of A.R. Konstantinov have been fixed [6]. The first doubtless dignity of those researches is development of computational algorithms, based on easily gauged and widespread climatic characteristics – air temperatures and water vapour pressure. The second dignity of the recognized regularities was a good coherence of profiles of vaporization and the conforming profiles of precipitations. It expressed that at realization of control calculations has not been founded statistically significant excesses of the calculated values of evaporation above precipitations.

Imperfection of investigations of A.R. Konstantinov is the poor universality of working algorithms. Failure to take account of influences of barometric pressure and landscape diversification has caused the underestimated values of computational vaporization in mountains.

Analysis of parameters for meteorological stations, on which values of climatic indexes initial relations, have been obtained and has shown, that all of them are located in altitude range 0 ÷ 600 m. above sea level and dated, basically, to semidesert-steppe landscapes. Therefore, the procedure of updating of working algorithms was executed in two stages.

- At the first stage correction for the count of influence of an altitude through changing of a measured air temperature by efficient temperature with use of the *formula 1* was executed. It has improved on the average on 26 % an approaching of computational vaporization to substantial values, which have been received with use of the lysimeter. Besides publishing errors of values of vaporization in initial data have been corrected and polynomial smoothing trends executed.
- At the second stage detailed analyse of landscape surrounding of meteorological stations, which were used by A.R. Konstantinov for investigations, has been made.

After fulfilment of identification procedure and grouping of stations for types of humidifying has appeared possible to calculate the trend of correlation evaporation rates from soil and snow for the basic types of humidifying:

1. ultraarid – K=0.9;
2. arid – K=1.3;
3. semiarid – K=1.6;
4. semihumid – K=1.8;
5. humid – K=2.2.

A.R. Konstantinov obtained relations of evaporation to air temperature and water vapour pressure from water for special evaporating pool. At transition to the large water spaces it had been offered the improving coefficient *K=1.3 ÷ 2.2*. Test calculations for water reservoirs of Central Asia have shown that the most acceptable is the value of coefficient *K=1.95.*

The repaired and corrected trends of evaporation have been interpolated by cubic splines to scale 10:1 of an initial step. In result relations of evaporation to air temperature and water vapour pressure from soil, snow and water, which are submitted by like families of curves, are obtained. Actuarially they can be presented as the composite three-dimensional surfaces (Figure 19, Figure 20, Figure 21).

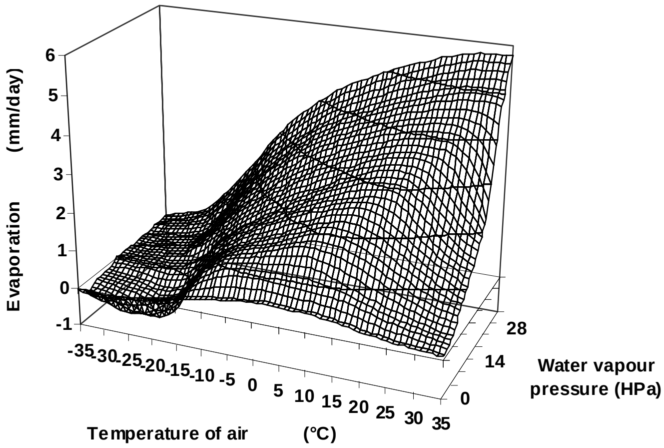

Figure 19. Dependence of evaporation from ground for effective air temperature and pressure water pair.

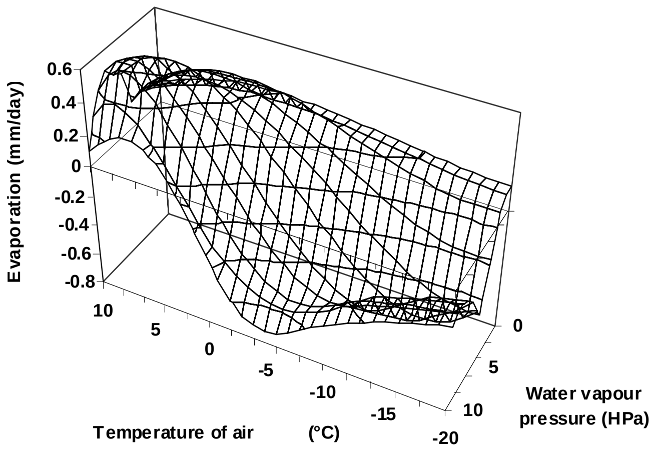

Figure 20. Dependence of evaporation from snow for effective air temperature and pressure water pair.

Necessary input data for calculation of values of vaporization are calculated as follows.

The air temperature is determined on a technique described in paragraph **Air temperature**.

Water vapour pressure is considered as the functional two-dimensional relation to altitude and latitude. The spacing distribution of water vapour pressure for each season is determined by statistical methods based on data analysis on meteorological stations under following scheme:

- partial distributions of water vapour pressure on altitude for separate latitude circles are appreciated by step of 10 degrees, which have been approximated by polynomial regressions;

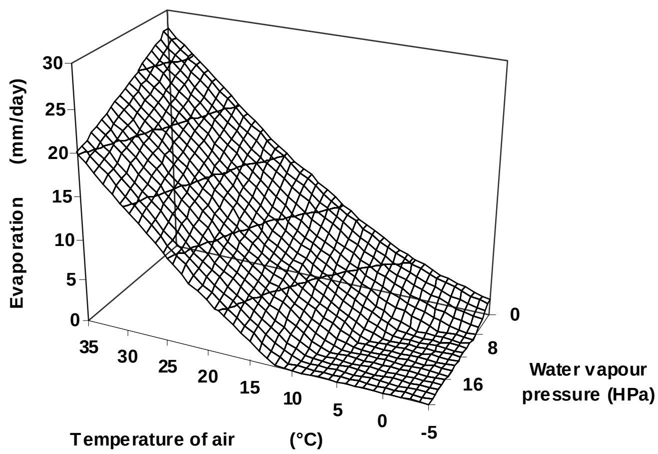

Figure 21. Dependence of evaporation from ground for effective air temperature and pressure water pair.

- for each season, the obtained family of trends have been subjected regression cross-analysis by results, of which surfaces of complex relations of water vapour pressure from altitude and latitude, are constructed (Figure 22, Figure 23, Figure 24, Figure 25).

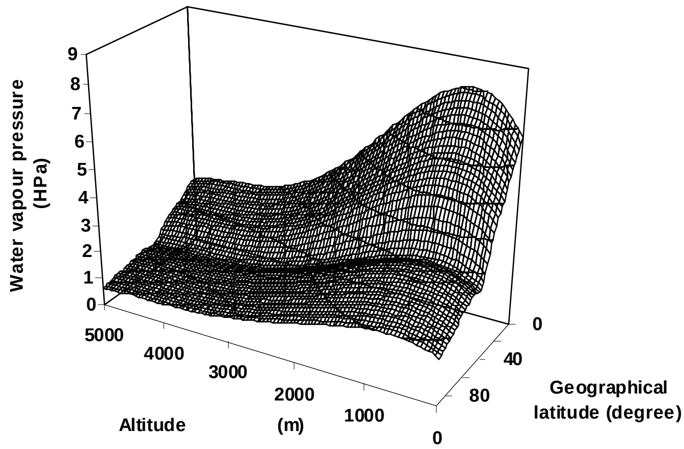

Figure 22. Trends of water vapour pressure on altitude and latitude for Winter.

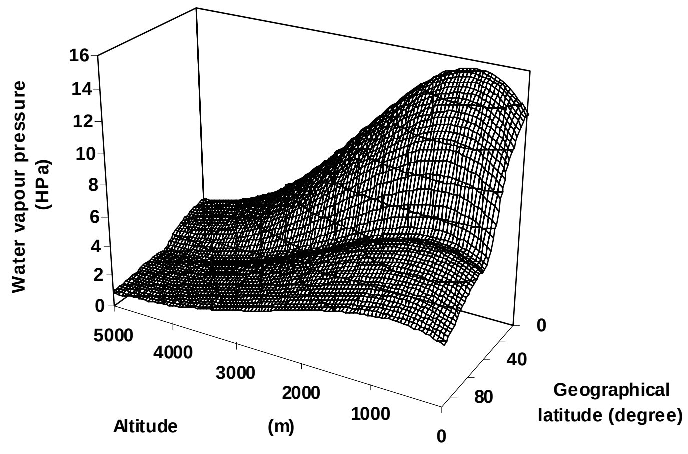

Figure 23. Trends of water vapour pressure on altitude and latitude for Spring.

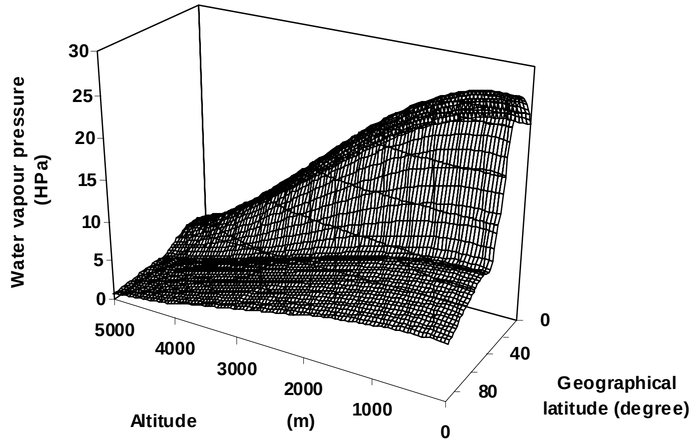

Figure 24. Trends of water vapour pressure on altitude and latitude for Summer.

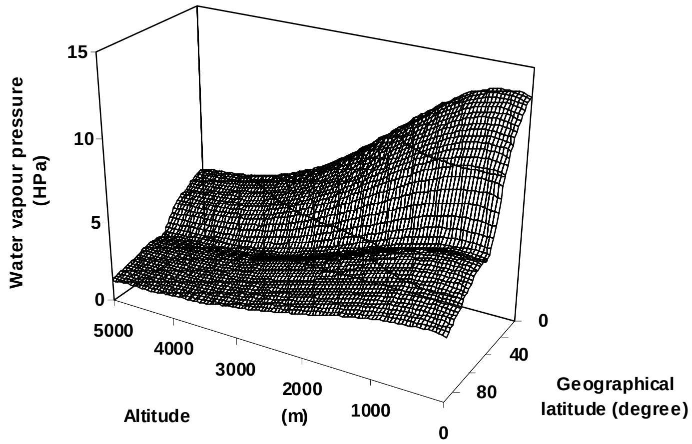

Figure 25. Trends of water vapour pressure on altitude and latitude for Autumn.

Evaporation is a calculated value and the direct assessment of certainty of its definition is inconvenient in a mass scale. Therefore following indirect methods of definition of certainty of values of vaporization were applied:

1. comparison of calculated value of water balance for local river basins and values of a river inflow on hydroposts;
2. the interdiction for significant excess of the calculated values of evaporation above values of precipitations on forecasting points.

The first method of evaluation is universal but not comprehensive while the second method does not usable to intrazonal, anthropogenic changed landscapes and water surfaces.

Testing calculations on local river basins have shown that differences between entries of a water balance and values of undisturbed river inflow lay within the limits 3.3 ÷ 8.2 %.

Share of calculated values of the evaporation on meteorological stations, which superior values of precipitations for ultraarid climatic conditioned zone, does not exceed 15 % from total number and 6 % for meteorological stations located in arid climatic conditioned zone. Thus, values of the overstated values of evaporation have no more than 19 % from precipitations values for these zones. It is not supervised not only excesses of the designed evaporation above of recorded precipitations for more humidified climatic zones and mountain tiers, but also their equalities.

Resume

- Method of landscape classification allows on the unified methodological to execute basis comprehensive analysis of correlation of climatic performances and underlying terrain, quantitative assessment of such important parameters, as air temperature, precipitations, evaporation, and also value of a water balance derivative of them for any time interval (month, season, year and decade).

- Doubtless dignity of the landscape-climatic approach is possibility of using in the analysis easily available and the most mass in measurement of recorded natural-climatic data.
- Landscape classification of evaporation is equitable only for natural evaporating systems: water reservoirs, ground, snow and transpiration of vegetation. The technogenic desiccations conditioned by activity mining and a manufacturing industry, together with municipal sector, have no clearly expressed connections within the framework of the given investigation system.
- At observance of requests of correct definition of landscape surrounding and aerographical characteristics reliability of definition of studied climatic indexes makes:
- standard deviation of an evaluation of a spacing of seasonal air temperatures have limit $\sigma_{an} = \pm1.3 \div \pm2.1$°C, and for seasons: Winter = ±2.1°C; Spring = ±1.3°C; Summer = ±1.6°C; Autumn = ±1.4°C;
- relation of amounts of deflection of calculated to measured values of precipitations have limit $100*\Delta_i/W_i = \pm3 \div \pm14\%$;
- indirect assessment of calculation reliability of evaporation through comparison of a difference between precipitations and evaporation with measured data on hydroposts for local basins with not anthropogenic changed river inflow is determined over the range 3.3 ÷ 8.2%.
- Formulas, relations and schemes of solutions are composed counting upon fast and their convenient adaptation in modelling systems of time-space mapping of climatic indexes and for the solution of engineering hydrodynamic problems.

Climatic model

The meso-climatic model of interaction of underlying terrain and temperature-humidifying characteristics is intended for the spatial-temporal analysis and a prediction of the most probable distribution of climatic parameters for flat and mountain territories for seasons: Winter (XII-II months), Spring (III-V months), Summer (VI-VIII months), an Autumn (IX-XI months) and Year.

The model is developed based on the landscape-climatic approach in an estimation of temperature-humidifying characteristics. Each climatic component is considered as certain integrated parameter of a spectrum of cooperating factors: latitude, altitude, zonal, azonal and anthropogenic, which has the manifestations in various types of vegetation and soils. Decision algorithms are constructed using of original soil-landscape classification of modelled climatic characteristics (Table 2, Table 8).

Structure of model and algorithms

The structure of model consists of the following mainframes (Figure 26):

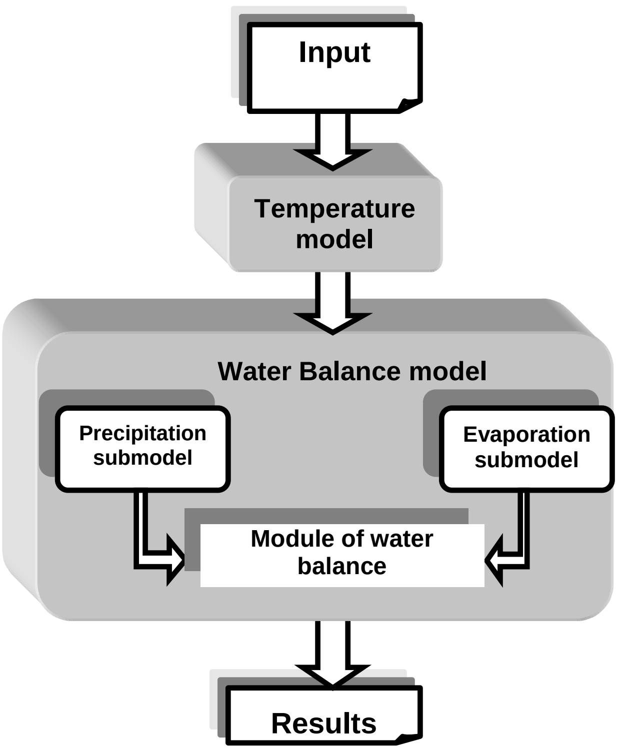

Figure 26. Block diagram of meso-climatic model.

Model allows receiving the following results, suitable for spatial mapping:

1. Seasonal changes of air temperatures, caused by influence of underlying terrain (*°C*);
2. Seasonal and annual distributions of air temperatures (*°C*);
3. Seasonal and annual distributions of precipitations (*mm*);
4. Seasonal and annual distributions of evaporation (*mm*);
5. Seasonal and annual balance between precipitations and evaporation (*mm*);
6. Seasonal and annual distributions of volumes of precipitated water from the elementary platforms (*m3*);
7. Seasonal and annual distributions of volumes of evaporated water from the elementary platforms (*m3*);
8. Seasonal and annual distributions of balance between volumes of precipitated and evaporated water from the elementary platforms (*m3*).

Above-listed parameters the model allows to obtain the summarizing values of water balance, distribution of the elementary platforms with the given characteristics of underlying terrain and grid files on each of predicted climatic parameters for visualization of the received results.

The model is supplied with the adjuster of a local temperature background whom allows to arrange model for concrete area, and also a regulator of amount of dropping out precipitations, which allows to receive not only long-term average water-balance characteristics, but also for separate years.

Algorithms of calculation of climatic parameters are elaborated based on the analysis of initial given meteorological stations of Asia, Europe and Africa.

Input data

Indata - Initial matrix including:

Indata (:,1) – Identical number
Indata (:,2) – Altitude (*m*);
Indata (:,3) – Latitude (*degrees, decimal*) / (km*);*
Indata (:,4) – Longitude (*degree, decimal*) / (*km*);
Indata (:,5) – Geographical azimuth (*degrees*);
Indata (:,6) – Skew of slope (*degrees*);
Indata (:,7) – Codes of types relief;
Indata (:,8) – Codes of the climatic caused types of vegetation;
Indata (:,9) – Codes of the intrazonal types of vegetation;
Indata (:,10) – Codes of the anthropogenic changed types of vegetation;
Indata(:,11) – Codes of influence of water reservoirs;
Indata (:,12) – Real square of elementary platform around of a calculation point *(км2)*
Indata (:,13) – Index of an openness to humid transfer (%)
Indata (:,14) – Share of Winter precipitations from annual (%);
Indata (:,15) – Share of Spring precipitations from annual (%);
Indata (:,16) – Share of Summer precipitations from annual (%);
Indata (:,17) – Share of Autumn precipitations from annual (%);
Indata (:,18) – Identification number of a local river basing;
Indata (:,19) – Corrections of regional background air temperatures for Winter (°C);
Indata (:,20) – Corrections of regional background air temperatures for Spring (°C);
Indata (:,21) – Corrections of regional background air temperatures for Summer (°C);
Indata (:,22) – Corrections of regional background air temperatures for Autumn (°C);
Indata (:,23) – Corrections for changes of annual precipitations (%).

Input modelling parameters should be unequivocally determined without misses of their values in initial matrixes of the data and attributes.

Air temperature model

The model solves tasks of an spatial-temporary prediction of temperature parameters of investigated territory based on the revealed connections between properties of underlying terrain and a thermal regime based on the following algorithm:

$$t_i=(t_{Lat} + t_{Alt} + t_{Ind})*k_{tas} + \Delta t_{ll} + \varepsilon, \qquad (2)$$

where

t_{lat} – trend of the temperature parameter on latitude for plains with deserted types of vegetation;

t_{alt} – trend of the temperature parameter on altitude corrected on latitude for plains with deserted types of vegetation;

t_{lnd} – temperature contribution of underlying terrain (3);
k_{tas} – adjusting multiplier for a angle of standing of the sun, an azimuth and skew of slope (4);
Δt_{ll} – adjusting correction for a local temperature background;
ε – error of modelling.

The background trend of temperatures on latitude is calculated under the formula:

$$t_{Lat} = \sum_{k=0}^{n} a_k * Lat_i$$

where
a_k – coefficient of approximating polynomial. The vector of polynomial coefficients is given in formulas of algorithm;
Lat_i – current value of latitude (*degrees, decimal or kilometres*);
i – number of a forecasting point;
k – current exponent of approximating polynomial;
n – maximal exponent of approximating polynomial.

The background trend of temperatures on altitude is calculated under the formula:

$$t_{Alt} = \sum_{k=0}^{n} a_k * Alt_i,$$

where
a_k – coefficient of approximating polynomial. The vector of polynomial coefficients is given in formulas of algorithm;
Alt_i – current value of altitude (*meters*);
i – number of a forecasting point;
k – current exponent of approximating polynomial;
n – maximal exponent of approximating polynomial.

The contribution of underlying terrain to a temperature regime may be separated into of its simpler components:

$$t_{lnd}=\Delta t_{cl}+\Delta t_{br}+\Delta t_{ia}+\Delta t_{wt}\ , \qquad (3)$$

where
Δt_{cl} – climatic the caused types of vegetation in a smoothing relief;
Δt_{br} – correction on type of relief;
Δt_{ia} – correction on intrazonal and/or anthropogenic influence for climatic the caused types of vegetation;
Δt_{wt} – correction on influence of water objects.

Adjusting correction for an angle of standing of the sun, an azimuth and skew of slope pays off under the formula:

$$K_{azsk}=cos(Lat_i)*k_{as}*kc_a, \qquad (4)$$

where
$kc_a= -cos(Az_i)$.
if $kc_a<=0$, $k_{as}=sin(kk_a)$, else $k_{as}=sin(kk_s)$.
if $Tilt-Skew_i>=Skew_i$, $kk_s=Skew_i$, else $kk_s=2*Tilt-Skew_i$.

$$Tilt=sin(30*(mn-3))*23.5+90-Lat_i,$$

where
$Tilt$ – angle of standing the sun (*degrees from horizon*);
m_n – number of month (middle month of season) for year (*1 - 12*);
Lat_i – current value of latitude (*degrees, decimal or kilometres*).
Az_i – geographical azimuth for forecasting point (*degrees*);
$Skew_i$ – skew of slope around forecasting point (*degrees from horizon*).

Adjusting correction for a local temperature background is not strictly obligatory. It is accepted to the equal regular mistake received as a result of preliminary modelling of temperatures of neighbouring meteorological stations, and is entered with same sign.

Result of modelling are forecasted values of seasonal changes of the temperatures (3), caused by influence of underlying terrain, and air temperatures for seasons and year (2).

In detail principles, a technique and reliability of an estimation of interaction of underlying terrain and a thermal regime it is submitted in works [3, 4, 5].

The structure of temperature model can be presented in the following kind (Figure 27):

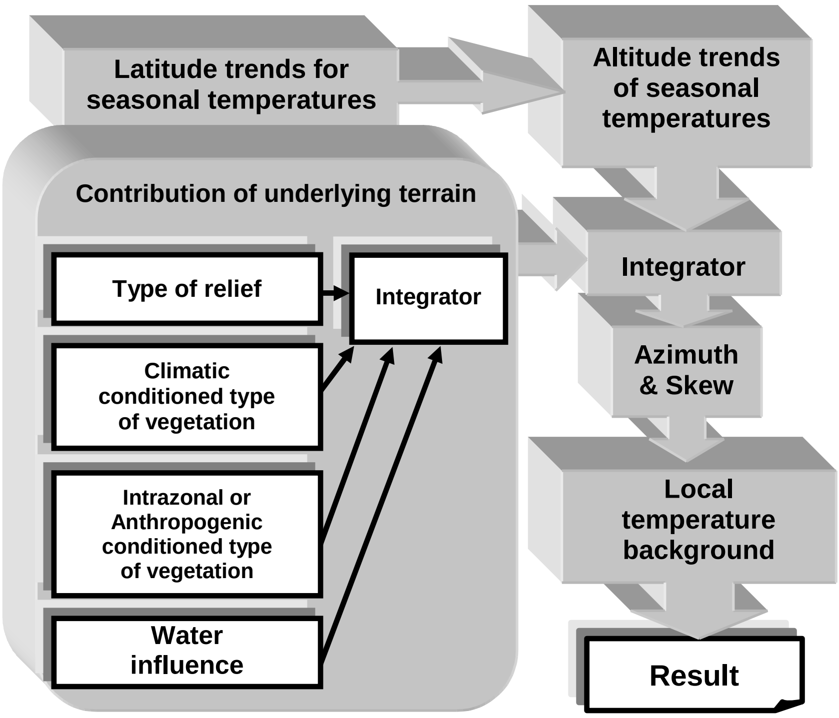

Figure 27. Block diagram of temperature model.

Water balance model

Water balance model consists of two submodels of precipitations, evaporation and the water balance block. From temperature model as the input data, it receives the designed values of air temperatures.

Precipitation submodel

Submodel of precipitations realizes the following sequence of procedures:

Estimation of distribution of precipitations for year on latitude for various groups of types of vegetation;

Correction of distribution of precipitations for year by additional algorithms of calculation of an openness of territory for precipitations transfer and shares of seasonal precipitations;

Calculation of precipitations (*mm*);

Calculation of volumes of precipitations from elementary platforms (*m3*).

Background distribution of precipitations on latitude for each group of types of vegetation is calculated under the formula:

$$Prc_i^0 = \sum_{k=0}^{n} a_k * Lat_i, \qquad (5)$$

where

a_k – coefficient of approximating polynomial;

Lat_i – current value of latitude (*degrees, decimal or kilometres*).

i – number of a forecasting point;

k – current exponent of approximating polynomial;

n – maximal exponent of approximating polynomial.

Correction of background distribution of precipitations by index for openness of terrain to precipitations transport is calculated under the formula:

$$Prc_i = Prc_i^0 * \frac{Index_i}{100} * \frac{\Delta Prc_i}{100}$$

where

i – number of a forecasting point;

Prc_i – corrected values of annual precipitations (*mm);*

$Index_i$ – index for openness of terrain to moisture transport *(%).*

ΔPrc_i – local changings of annual precipitations (*%*);

Calculation of seasonal precipitations is calculated under the formula:

$$Prc_i^j = \frac{Prc_i * Share_i^S}{100}$$

where

j – number of season (month);

Prc^j_i – corrected values of annual precipitations (*mm)*;

$Share^s_i$ – seasonal share of precipitations from year volume *(%/year).*

The volume of water seasonal and year precipitations (*m*^{3}) from each real elementary platform is equal:

$$VolPrc^j_i = Prc^j_i * S_i, \qquad (6)$$

where

S_i – real area of an elementary platform (*km2*);

where

$$S_i = \frac{S_i^0}{\cos Skew_i}, \qquad (7)$$

Result of modelling are forecasting values of spatial distribution of precipitations for elementary platforms (5), and their volumes for seasons and year (6).

The structure of submodel of precipitations can be presented in the following kind (***Figure 28***):

Evaporation submodel

The model solves tasks of an existential prediction of evaporation in investigated territory based on the revealed connections between properties of underlying terrain on algorithm of A.R. Konstantinov [6]. Its distinctive feature is the original design procedure of vertical gradients of humidity and temperatures as functions from humidity and temperatures at height of 2.0 m that considerably reduces requirements to selection of the initial data and simplifies calculations. To other advantages, it is necessary to relate universality of the decision algorithm and independent from local climatic conditions.

As a result of the transformations executed by A.R. Konstantinov, the formula for calculation of intensity of evaporation finally it is submitted as:

$$E_i = \frac{0.076 * \gamma * \alpha_e * u_f}{lg \frac{200}{z_0^1} * lg \frac{1000}{z_0^1}} * (e_0 - e_{2.0}) \quad mm/\,hour,$$

where

e_0 – air humidity on ground;

$e_{2.0}$ – air humidity at height of *2 m*.

γ – correction factor describing difference of natural profiles of meteorological elements from logarithmic;

$$\gamma = \frac{1}{\sqrt[4]{1-Ri_{1.0}}}$$

where

$Ri_{1.0}$ – Richardson number at height above ground *1m*;

$$Ri_{1.0} = -0.08 * \frac{lg^2 \frac{1000}{z_0^1}}{lg \frac{200}{z_0^1}} * \frac{T_o - T_{2.0}}{u_f^2},$$

where

u_f – function of a vertical profile of a wind speed measured on meteorological stations;

z^1_0 – height $z_{1.0}=1.0\ m$;

T_0 – air temperature on ground in Kelvin degrees;

$T_{2.0}$ – air temperature in Kelvin degrees at height - *2 m*.

$$\alpha_e = 1 + 0.72 \left(\sqrt{1 - 28 \left(\frac{z_0}{z_{00}} \right) * Ri_{1.0}} - 1 \right),$$

where

α_e – function of humidity of air measured on meteorological stations;

z_{00} – dimensional factor $z_{00}=1m$

By results of A.R. Konstantinov calculations matrixes of functional dependences of evaporation from snow, ground and water in recalculation on other dimension - mm/day, which have lain in a basis of algorithm of a submodel, were made.

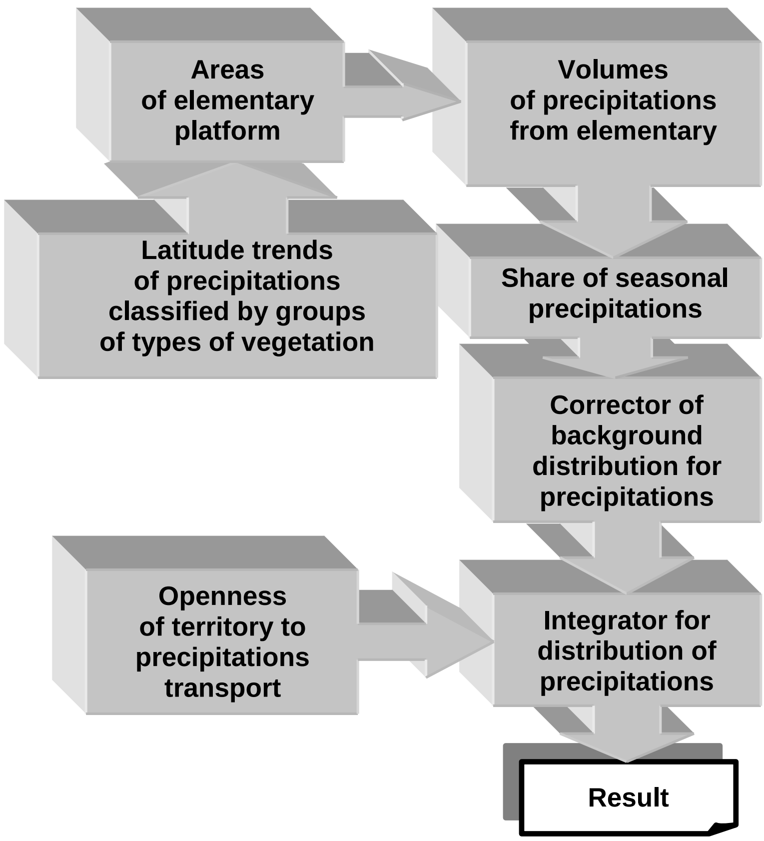

Figure 28. Block diagram of precipitations submodel.

Unfortunately, initial matrixes of the given distributions appeared are incomplete and designed for conditions of a flat relief. Therefore the developer of climatic model executed updating of initial matrixes with calculation of additional values, characteristic for area of research and with passing correction of publishing mistakes. The corrected and added settlement dependences of evaporation on air temperature and pressure water pair have the big resolution on the order and cover practically all range temperature-humidifying characteristics.

Besides formula Hann-Kuzmin [7] was used for correction of size of water vapour pressure on altitude:

$$E_i = E_t * 10^a,$$

where

a – empirically determined factor connecting change of water pair pressure on altitude:

$a=1/6.3 \div 2/6.3$ – for continental areas of Asia (P.P. Kuzmin, Y.Y. Grechanichenko);

$a=1/5$ – for free atmosphere (Hann).

Evaporation for snow of ground and water calculates pressure water pair under the formula:

$$E^{Alt} = \sum_{k=0}^{n} a_{ki} * Alt_i, \tag{8}$$

where

a_k – coefficient of approximating polynomial.;

Alt_i – current value of altitude (*meters*);

i – number of a forecasting point;

k – current exponent of approximating polynomial;

n – maximal exponent of approximating polynomial.

The background trend of water vapour pressure on latitude is calculated under the formula:

$$E_i^{Lat} = \sum_{k=0}^{n} a_k * Lat_i, \tag{9}$$

where

a_k – coefficient of approximating polynomial;

Lat_i – current value of latitude (*degrees, decimal or kilometres*).

i – number of a forecasting point;

k – current exponent of approximating polynomial;

n – maximal exponent of approximating polynomial.

Then, it is carried out procedure of a choice of the appropriate matrix of evaporation (snow, ground or water) with use of the input data of a temperature regime and is calculated evaporation.

$$Evp^j_i = f(E^{Alt}_i, E^{Lat}_i, t_i)$$

Seasonal evaporation in a water layer *(mm)* is calculated on the basis of the corrected data under the formula:

$$Evp^j_i = Evp^j_i * K_{azs}, \tag{10}$$

where

K_{azs} – correction for angle of sun standing, azimuth and skew of slope (4);

The volume of seasonal evaporation *(m^3)* is calculated under the formula.

$$VolEvp^j_i = Evp^j_i * S^j_i, \tag{11}$$

where

S^j_i – real area of elementary platform (*km^2*) (7).

Result of modelling is forecasting values of spatial distribution of evaporation for elementary platforms (10) and their volumes for seasons and year (11).

The structure of a submodel of evaporation can be presented in the following kind (Figure 29):

1.2.4.3 Module of water balance

Module of water balance carries out for correction and calculation of water balance on seasons and year for elementary platforms. Besides, for separate local river basin total values of precipitations, evaporations and water balance are calculated.

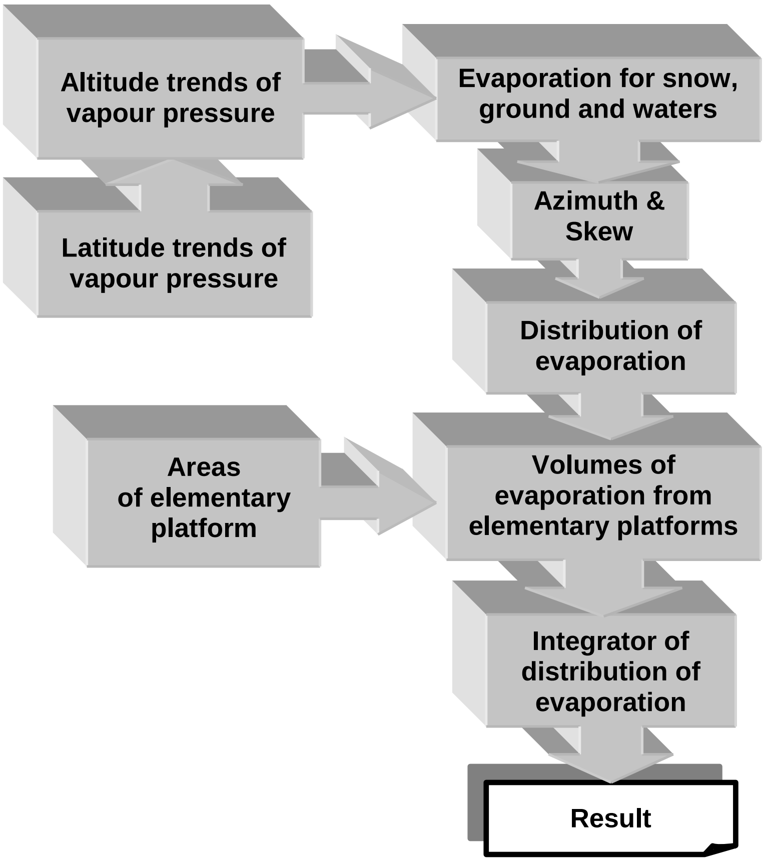

Figure 29. Block diagram of evaporation submodel.

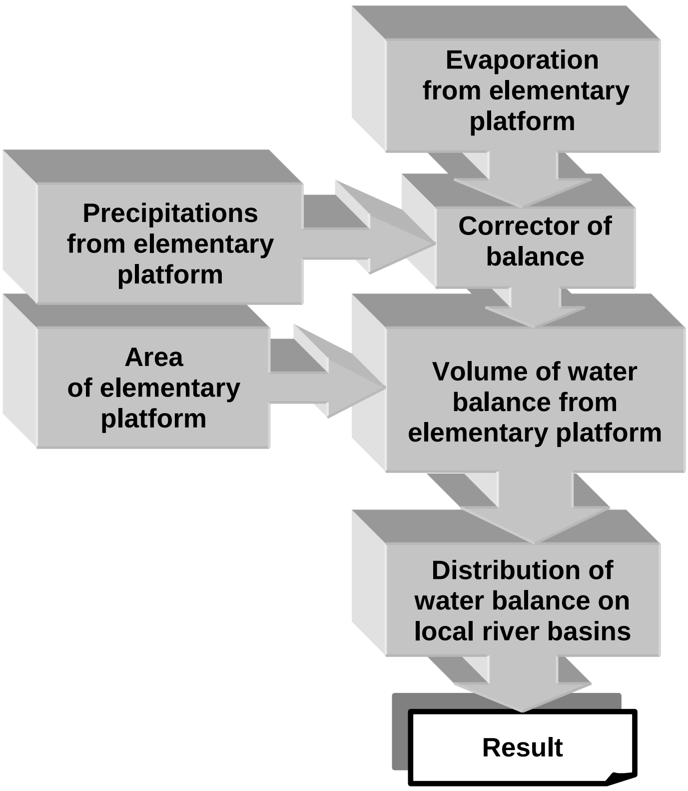

Figure 30. Block diagram of water balance module.

Calculation of water balance in a water layer *(mm)* is executed under the scheme of computing systems with previous memory:

$$Bln^j_i = Bln^{j-1}_i + Prc^j_i - Evp^j_i,$$

where

Bln^{j-1}_i – water balance in a water layer *(mm);*

Correction of water balance is fulfilled only for plants with climatic conditioned by groups of vegetable types on the following requirement:

if $Bln^j_i < 0$ $Evp^j_{i,} = Prc^j_i$ and $VolEvp^j_{i,} = VolPrc^j_i$

The essence of correction will be that for climatic conditioned types of humidification the aggregate volume of evaporated water cannot be more than volume of water falling out in precipitations. The volume water balance for a water layer *(mm)* of calculated points is equal:

$$VolBln^j_i = Bln^j_i * S^j_{i,}$$

where

S^j_i – real area of elementary platform (km^2) (7).

Result is forecasting values of spatial distribution of water balance in a water layer *(mm)* and volumes of water balance *(m^3)*.

The structure of module of water balance can be presented in the following kind (Figure 30):

Output data

Output data are submitted by matrixes ***- Output u BsnWtrBlnc:***

Output(:,1) - Changing of temperature for Winter (°*C*)
Output(:,2) - Changing of temperature for Spring (°*C*)
Output(:,3) - Changing of temperature for Summer (°*C*)
Output(:,4) - Changing of temperature for Autumn (°*C*)
Output(:,5) - Full temperature for Winter (°*C*)
Output(:,6) - Full temperature for Spring (°*C*)
Output(:,7) - Full temperature for Summer (°*C*)
Output(:,8) - Full temperature for Autumn (°*C*)
Output(:,9) - Full temperature for Year (°*C*)
Output(:,10) - Precipitations for Winter (*mm*)
Output(:,11) - Precipitations for Spring (*mm*)
Output(:,12) - Precipitations for Summer (*mm*)
Output(:,13) - Precipitations for Autumn (*mm*)
Output(:,14) - Precipitations for Year (*mm*)
Output(:,15) - Evaporation for Winter (*mm*)
Output(:,16) - Evaporation for Spring (*mm*)
Output(:,17) - Evaporation for Summer (*mm*)
Output(:,18) - Evaporation for Autumn (*mm*)
Output(:,19) - Evaporation for Year (*mm*)
Output(:,20) - Water balance for Winter (*mm*)
Output(:,21) - Water balance for Spring (*mm*)
Output(:,22) - Water balance for Summer (*mm*)
Output(:,23) - Water balance for Autumn (*mm*)
Output(:,24) - Water balance for Year (*mm*)
Output(:,25) - Volume of precipitating water for Winter from elementary platforms (*m3*)
Output(:,26) - Volume of precipitating water for Spring from elementary platforms (*m3*)
Output(:,27) - Volume of precipitating water for Summer from elementary platforms (*m3*)
Output(:,28) - Volume of precipitating water for Autumn from elementary platforms (*m3*)
Output(:,29) - Volume of precipitating water for Year from elementary platforms (*m3*)
Output(:,30) - Volume of evaporating water for Winter from elementary platforms (*m3*)
Output(:,31) - Volume of evaporating water for Spring from elementary platforms (*m3*)
Output(:,32) - Volume of evaporating water for Summer from elementary platforms (*m3*)
Output(:,33) - Volume of evaporating water for Autumn from elementary platforms (*m3*)

Output(:,34) - Volume of evaporating water for Year from elementary platforms (*m3*)
Output(:,35) - Volume of water balance for Winter from elementary platforms (*m3*)
Output(:,36) - Volume of water balance for Spring from elementary platforms (*m3*)
Output(:,37) - Volume of water balance for Summer from elementary platforms (*m3*)
Output(:,38) - Volume of water balance for Autumn from elementary platforms (*m3*)
Output(:,39) - Volume of water balance for Year from elementary platforms (*m3*)

BsnWtrBlnc – Water balance for local river basins, including:
BsnWtrBlnc(1,:) – First local river basin (m^3);
BsnWtrBlnc(2,:) - Second local river basin (m^3);
. . . . ;
BsnWtrBlnc(n,:) – Last local river basin (m^3).

Structure of output matrix for local water balance – *BsnWtrBlnc* is following:

1. Identification number of a local basin;
2. Sum of precipitations of a local basin for Winter (m^3);
3. Sum of precipitations of a local basin for Spring (m^3);
4. Sum of precipitations of a local basin for Summer (m^3);
5. Sum of precipitations of a local basin for Autumn (m^3);
6. Sum of precipitations of a local basin for Year (m^3);
7. Sum of evaporation of a local basin for Winter (m^3);
8. Sum of evaporation of a local basin for Spring (m^3);
9. Sum of evaporation of a local basin for Summer (m^3);
10. Sum of evaporation of a local basin for Autumn (m^3);
11. Sum of evaporation of a local basin for Year (m^3);
12. Sum of water balance of a local basin for Winter (m^3);
13. Sum of water balance of a local basin for Spring (m^3);
14. Sum of water balance of a local basin for Summer (m^3);
15. Sum of water balance of a local basin for Autumn (m^3);
16. Sum of water balance of a local basin for Year (m^3).

Presence in target given identification numbers and geographical coordinates allows to create on their basis of a database, and also it is easy to adapt climatic parameters in geoinformation systems (GIS) and others electronic mapping makers.

Resume

- Meso-climatic model constructed on principles of landscape classification of temperature-humidifying parameters is intended for a quantitative estimation of natural of climatic forming processes and does not estimate direct manufactured influence on a climate.
- The model allows obtaining settlement parameters with a high degree of existential detailed elaboration.
- Modern high-speed algorithms of matrix operations of modelling are realized. It is allows to process great volumes of the entrance information for comprehensible time and with comprehensible accuracy.
- The achieved accuracy of modelling in a combination to opportunities of flexible adjustment for local conditions of formation of climatic background allows using model for the decision of tasks of practical water use.
- Results of modelling are convenient for visualization and easily adapt in databases;
- The structure of model supposes its further development for more detailed estimation of intraannual changes of climatic parameters for modelling of natural systems.

Analysis of reliability of results

Approbation of the landscape-climatic approach for estimation of water balance norms was produced for mountain terrain of northeast Tien-Shan (China). Outcomes of modeling are introduced below (Table 9).

In full, the landscape-climatic modelling was executed by step of 30 sec of geographical coordinates (the dimension of cells ≈ *1*1 km*) for Syrdarya River basin with inclusion in accounts of Aral Sea aquatory. Climatic indexes are calculated for the period up to the middle of 60 years of XX century (standard), the decade of 70 years, the decade of 80 years and for the changes, which have occurred between these periods.

Matching of results of model operation and the previous scientific researches [8] reveal incompleteness of them assessments of distribution of climatic characteristics in region. It expresses in a volume, that precedent cartographical materials reflect a situation only in a mountain part of Syrdarya basin, not doing the complete regional description of climatic processes for all territory. Evaluation procedures of a water regime for linear objects were applied to an evaluation of module of inflow of a flat part of basin - the rivers and channels, or local - lakes and water reservoirs, on which it is rather difficult to make one-valued spatial conclusions. Therefore, for matching quality of model operation those areas of Syrdarya basin have been elected, for which there were maps of like climatic parameters (Figure 31, Figure 32, Figure 33, Figure 34).

Table 9 Calculated values of annual precipitations, evaporation and water balance of headstream the Ili River in matching with the measured values of a river flow.

River basin	Water balance *(km^3)*					River Inflow *(km^3)*	Difference *(%)*
	Winter	Spring	Summer	Autumn	YEAR		
Kash - Precipitations	1.577	2.383	1.599	1.457	7.143		
Kash - Evaporation	0.289	0.532	1.485	0.562	2.864		
Kash – Water balance	*1.287*	*1.855*	*0.114*	*0.889*	*4.137*	*4.080*	*1.38*
Kyunes - Precipitations	1.585	1.600	1.679	0.979	4.746		
Kyunes - Evaporation	0.328	0.473	1.290	0.554	2.388		
Kyunes - Water balance	*0.738*	*1.129*	*0.390*	*0.425*	*2.324*	*2.200*	*5.34*
Tekes - Precipitations	1.575	5.421	8.521	3.536	18.656		
Tekes - Evaporation	1.938	1.629	5.996	1.892	10.694		
Tekes - Water balance	*0.413*	*3.413*	*2.526*	*1.643*	*7.996*	*8.260*	*-3.30*
Water balance of Ili River for hydropost Jamadu					*14.458*	*14.540*	*-0.57*

The comparative analysis of various techniques shows, that at application of the landscape-climatic approach realized in the above described model, spacing of precipitations and a water balance (analogy of module of inflow) have more contrast view. The range of values variations for climatic indexes will essentially increase, attaining a difference - 30 %.

Modelled map of distribution of precipitations (Figure 32) at matching with the previous outcomes (Figure 31) reflects features of precipitations accumulation in a mountainous territories, which are conditioned by an exposition, skew of slopes and an openness to moisture transport in more details. These discrepancies show the more brightly, than discrepancies of types of the vegetation covering mountain slopes are more contrast.

Figure 31. Distribution of precipitations for Year (mm). Source of the data [8].

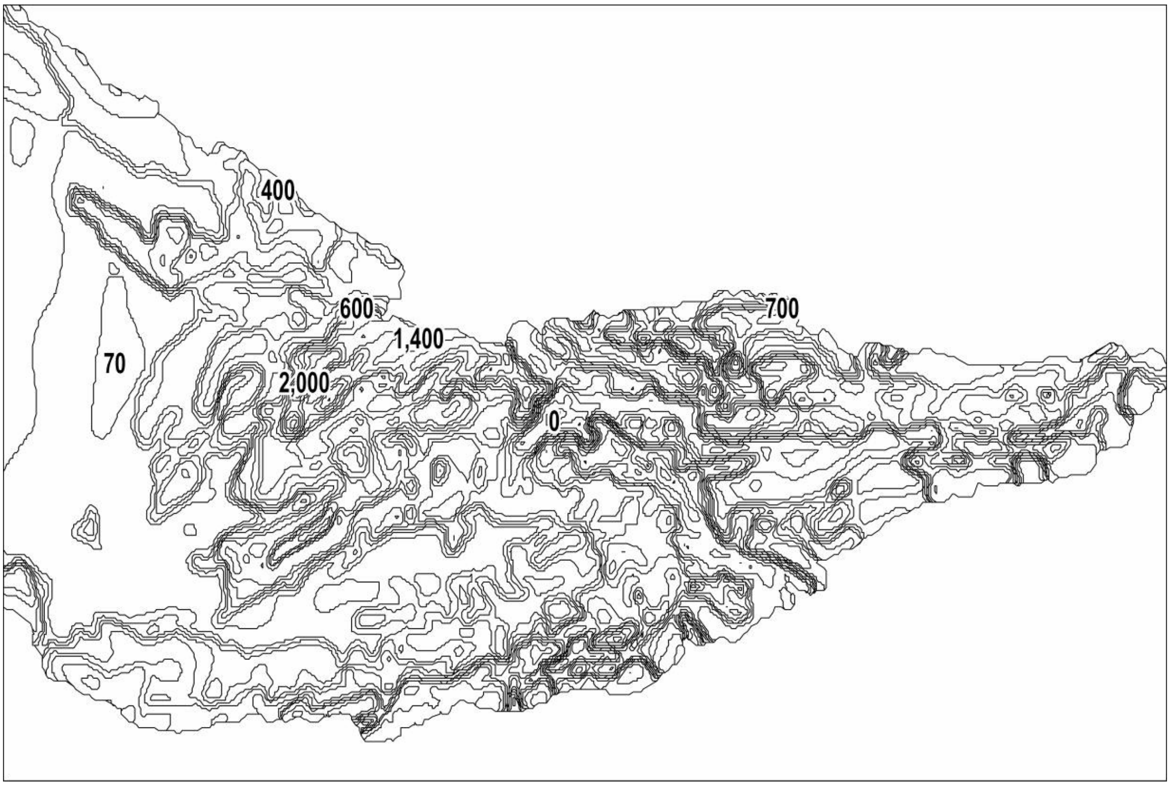

Figure 32. Distribution of precipitations for year (mm). Source of the data is Water balance modeling.

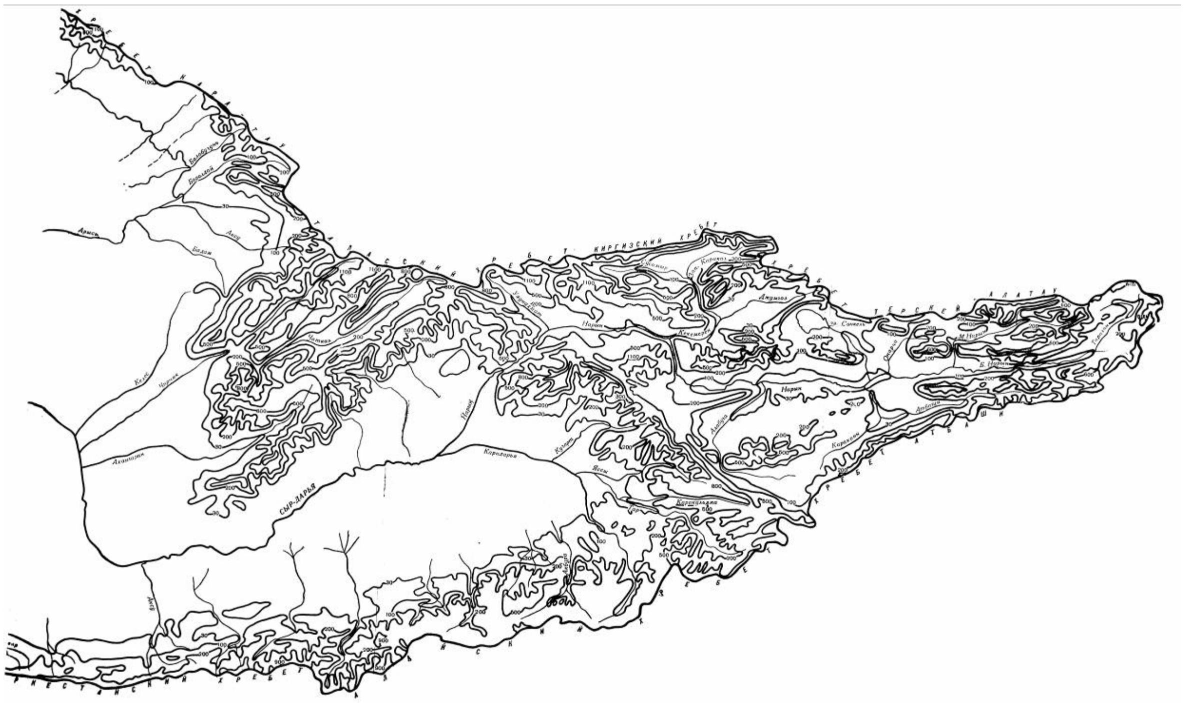

Figure 33. Distribution of module of inflow for Year (mm). Source of the data [8].

The map of a water balance contains the information in the integrated form about precipitations and evaporation, which is presented as function of air temperature, orientations, skew of slopes, and altitude. The combination of the given dependences realized in working algorithms of climatic model, have allowed to receive more legible picture of a spacing distribution for water balance (Figure 34). At the same time, it is visible, that at a map compilation of module of inflow, its authors were guided by predominary local dependences of distribution of a rated parameter on altitude (Figure 33). Therefore, in a mountain broken relief isolines for modulus of inflow move paralleled of isohypses and for smoothing relief they simply miss, because isohypses are practically absence. It, a known degree, explains the cause of absence of a map for module of inflow for whole Syrdarya basin.

Landscape-climatic mapping of water balance is based on more complex and thin dependences, which in various combinations enable to estimate continuously on territory climatic parameters, its components, as in mountain, and flat area.

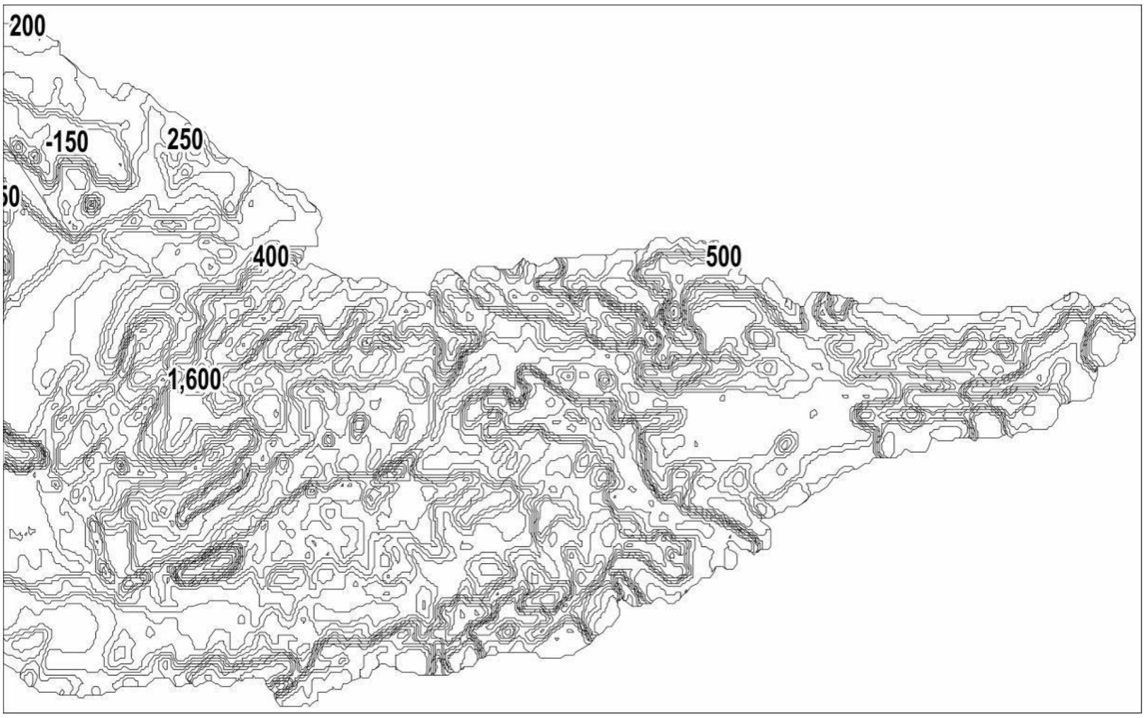

Figure 34. Distribution of water balance for Year (mm).

Conclusion

The landscape-climatic approach to estimation temperature-humidifying parameters is based on principles of stratification of set influencing of the climate forming factors on a series of simple and statistically authentic components, which confidently correlate with natural factors indicators, and reconstruction on the basis of the founded connections of quantitative characteristics of climatic parameters. Thus a critical requirement is not the weight separate influential ingredient in a complex, but a consistency and an exactitude of grouping exposition them of character space. The given approach does not claim for strict scientific description of thermodynamic processes of interaction of atmosphere and underlying terrain. The used procedure reveals statistically significant quantitative connections between explored climatic indexes and their connatural indicators.

By results of the analysis of partial dependences the hypermatrix of the most probable state of climatic indexes for the relevant geographical environment, geometries of a landforms and types of a underlying terrain is built. The step of clusterization of modelling algorithms is picked such that the computing exactitude matched to a representativeness of input data. The method of modelling operation for climatic indexes on their connatural indicators allows bypassing challenges of effect of fast local heterogeneities of heat exchange of an atmosphere and a underlying terrain, which render big effect on forming of a local climate.

For elaboration of simulative algorithms large analyzable database of the climatic and connatural data, which reflects the greatest possible spectrum of state of explored parameters and responses of an environment, is very important. Such unwieldy and single procedure of classification is completely cancelled by the relative simplicity of preparation of input data for practical calculations and a high-speed evaluation.

The methodology and structure of landscape-climatic modelling operation determines a sphere of its application in climatology and hydrology. Minimum stable time step is one month; minimum admissible spatial scale is determined by variety of connatural indicators.

All algorithms are invariant over the range geographical coordinates from 15° Southern latitude till 85° Northern latitude; from 20° Western longitude till 180° Eastern longitude. It allows calculating space distribution of climatic indexes in flat and mountain terrains of this part of a Globe.

The complex tasks of spatial-temporary allocation of precipitations and evaporation within the framework of landscape-climatic method with comprehensible reliability of modelling are solved. Precipitations are characterized by very high territorial variability, especially in mountain regions. Most of known formulas for calculation of evaporation from underlying terrain have a restricted diapason for spatial application and insufficiently completely take into account effect of geometry of landforms, air pressure and humidity. It was possible to solve and this problem at a comprehensible level of reliability in the given researching. In outcome, the possibility has appeared to estimate water resources of terrain through potential water balance. After realization of preliminary procedures of detailing, the given method can be applied to a solution of some engineering hydrological tasks.

Perspectives of the landscape-climatic approach for estimation of a thermal regime are not restricted only to air temperatures. The methodology admits dilation of a spectrum of modelling for such temperature performances, as the sum of air temperatures for the given intervals and soil temperatures.

In structure of model operations all investigated climatic indexes - temperature, precipitations and evaporation are interdependent by a principle of a feedback also compound the continuous whole of climatic processes.

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Manuscript received in 16 December 2004.

Резюме

Гречаниченко Ю. **Ландшафтно-климатическое моделирование**

В статье рассматриваются методические аспекты пространственно-временного моделирования климатических показателей в условиях недостаточного обеспечения климатическими данными наблюдений. Предложен и обоснован ландшафтно-климатический подход к оценке температур, осадков, испарения и производного от них водного баланса, как для равнин, так и для горных территорий. Данный подход основан на принципах расслоения совокупности климатообразующих факторов на серию простых и статистически достоверных составляющих, которые уверенно коррелируют с природными факторами - индикаторами, и реконструкцией на основе выявленных связей количественных характеристик климатических параметров.

Разработанная классификация температурно-влажностных показателей по типам подстилающей поверхности позволила создать рабочие алгоритмы для количественной оценки и предсказания температур воздуха, осадков, испарения и водного баланса на основе анализа орографических, ландшафтных и/или почвенных исходных данных. Приведены основные формулы, блок - схемы и оценка достоверности рабочих алгоритмов модели пространственно-временного предсказания климатических показателей.

Тестирование модели проведено на примере горных районов бассейнов рек Или и Сырдарья, результаты тестирования приводятся в настоящей статье. Работа климатической модели на реальных данных показала, что она может быть использована для решения задач климатологии, а также для оценки состояния и перспектив практического водопользования в речных бассейнах.

CLIMATIC CHARACTERISTIC OF SYRDARYA RIVER BASIN

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Introduction

Territory of Syrdarya River basin has complex geographical structure. Northern part for the middle and lower flow of Syrdarya River is submitted by extensive flat spaces with monotonous deserted and semidesert landscapes. For headwaters of Syrdarya River high altitude ridges and intramountain depressions of mountain systems with quickly varying numerous landscapes dominate (Figure 1). Territorial contrast and variety of landscapes reflects complexity of spatial distribution of climatic parameters and determines necessity of the detailed analysis with using of cartographical results of landscape-climatic modelling.

The analysis of existential distribution is executed for the following climatic characteristics:

1. Air temperature and its change depending on types of an underlying terrain;
2. The sums of a water layer and volumes for precipitations per elementary platform;
3. Evaporation in a water layer and volumes per elementary platform;
4. Water balance as a difference between precipitations and evaporation per elementary platform.

Besides for evaluating of a role of time transformation of a regional climate in time of intensive developing of Aralsky crisis for second part of twentieth century the analysis of interdecade changes for these climatic parameters is executed.

Evaluation of existential changes of climatic and water regime of Syrdarya River basin is executed on a basis of the measured climatic data, landscape and soil mapping, which a basis of landscape-climatic modelling were. Results of modelling are presented in the form of the tabulated data, charts and the thematic maps, which describing average conditions of the basic climatic indexes and a river flow.

Modelling is executed at observance of the following conditions:

- as a normal climatic status the period 1960-1969 is accepted;
- change of climatic parameters and river flow was estimated in relation to the normative period and among themselves on decades 1970-1979 and 1980-1989;
- for estimating of the average climatic status of each next decade as conditional date the middle of the period is accepted: 1965, 1975 and 1985;
- for each period parameters of winter, spring, summer and autumn seasons, and also the annual status were estimated.

As a result of modelling 224 maps of seasonal and annual temperatures, precipitations, evaporation and water balance and a map of change of their changes on decades have been received.

In total 224 maps of seasonal and annual temperature, precipitations, evaporation and water balance have been obtained.

General dynamic of water resources

According to the settled notion about Aralsk region in the season up to the middle of the sixtieth years economic activities are characterized by moderation and stability in use of water resources. The intensive attrition of water resources contacts breaking-in period of the new agricultural areas which most active phase falls at the seventh - eighth decades of XX century. In comparison by the sixtieth years in 1970-1989 years changes of a river flow of Syrdarya in the lower flow was characterized by resistant decreasing of volume of inflow in 1.2 ÷ 1.8 times. So, at a hydropost Kazalinsk in the sixtieth years the average river inflow on decades has made - 10.572 km^3, the seventieth years - 4.121 km^3, and the eightieth years - 2.256 km^3 (Figure 2).

Appreciable decreasing of inflow shows, beginning from a hydropost Uchkurgan where a difference between the sixtieth and seventieth years has made 22.8 %. Last significant relative decreasing of volumes of a river flow between the given seasons is marked in area of hydroposts Chinaz - Chardara where it values attains to 42.65 % for the seventh decade and 49.82 % for the eighth decade. These ratios are preserved down to a mouth of Syrdarya River.

Comparison of the modelled parameters of a water balance with the measured values of river inflow on closing hydroposts of the local basins composing whole Syrdarya River basin has revealed series of regularity**.**

The calculating water balance for local river inflows everywhere is higher than analogous parameters on a river flow. It speaks that on hydroposts the surface runoff while entries of a water balance give a total quantitative assessment surface and underground influx.

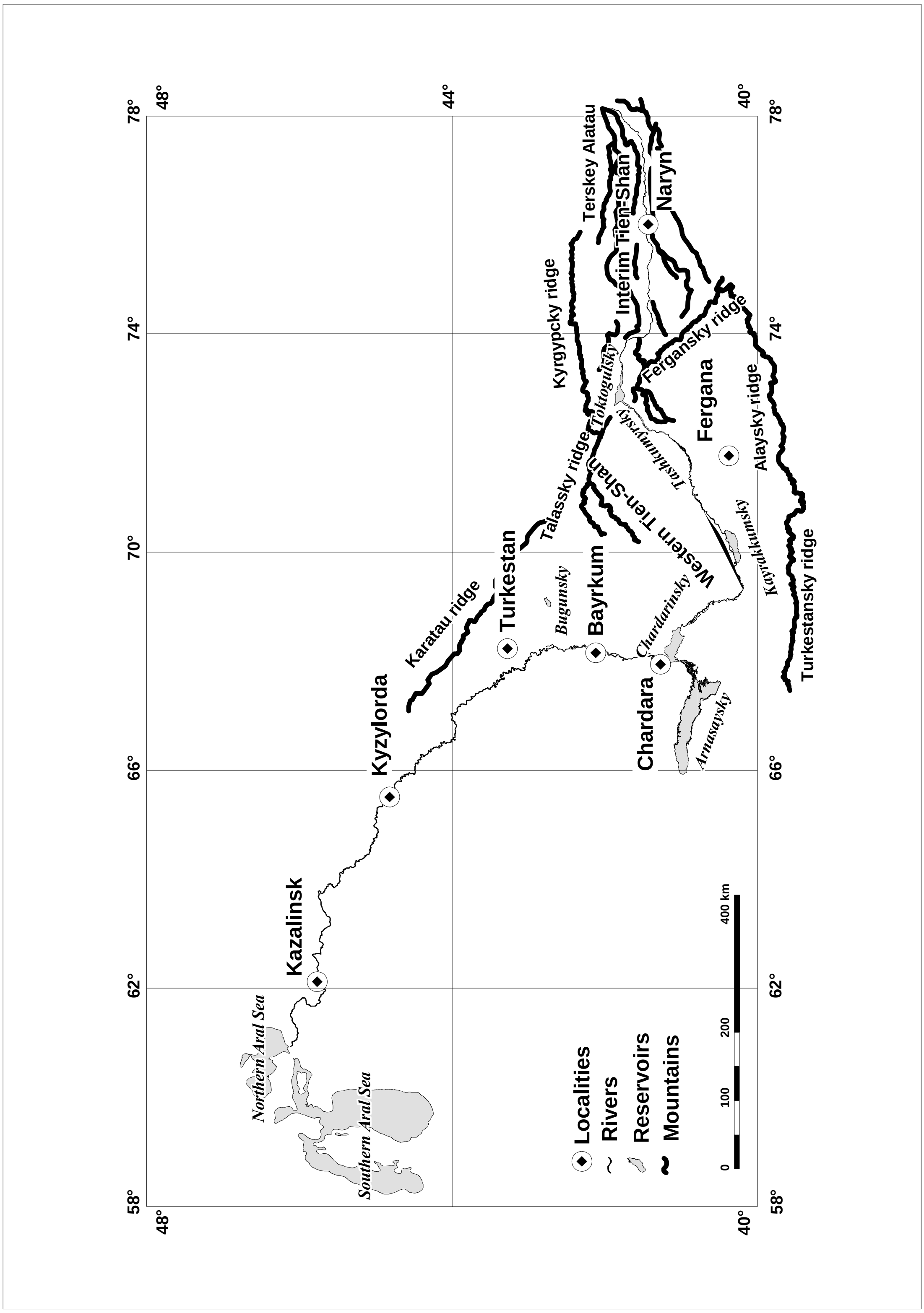

Figure 1. General map of Syrdarya River basin on 2003 year .

Insufficient using of a water potential of Syrdarya River basin it is possible to express through function of deficiency of real water storage by formula:

$$\Delta Vol\ (\%) = 100 * (Vol_{wb} - Vol_{in})/Vol_{wb},$$

where

Vol_{wb} – volume of a potential water balance;

Vol_{in} – volume of a river flow.

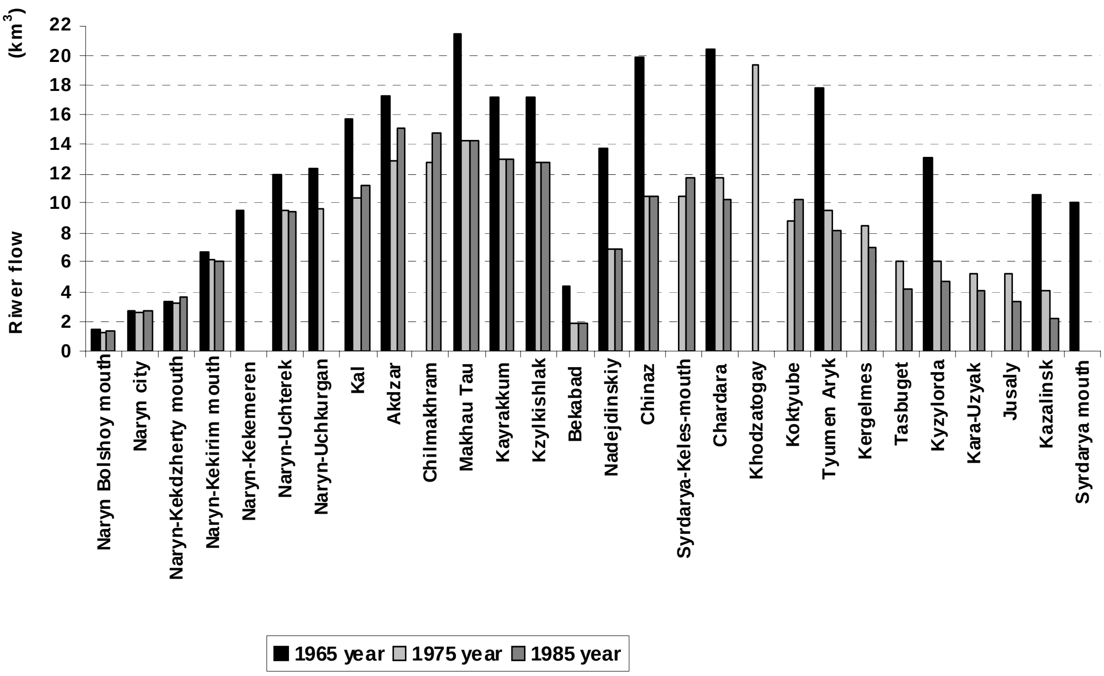

Figure 2. Change of Syrdarya River flow for 30 years.

Based on calculation of deficiency of water resources it is possible to estimate over-all profitableness of their use of resources by formula

$$Profitability=1/\Delta Vol.$$

The analysis of existential distribution of water deficiency has revealed specific regularity for use of water resources of Syrdarya River basin, which do not variate from decade by decade (Figure 3).

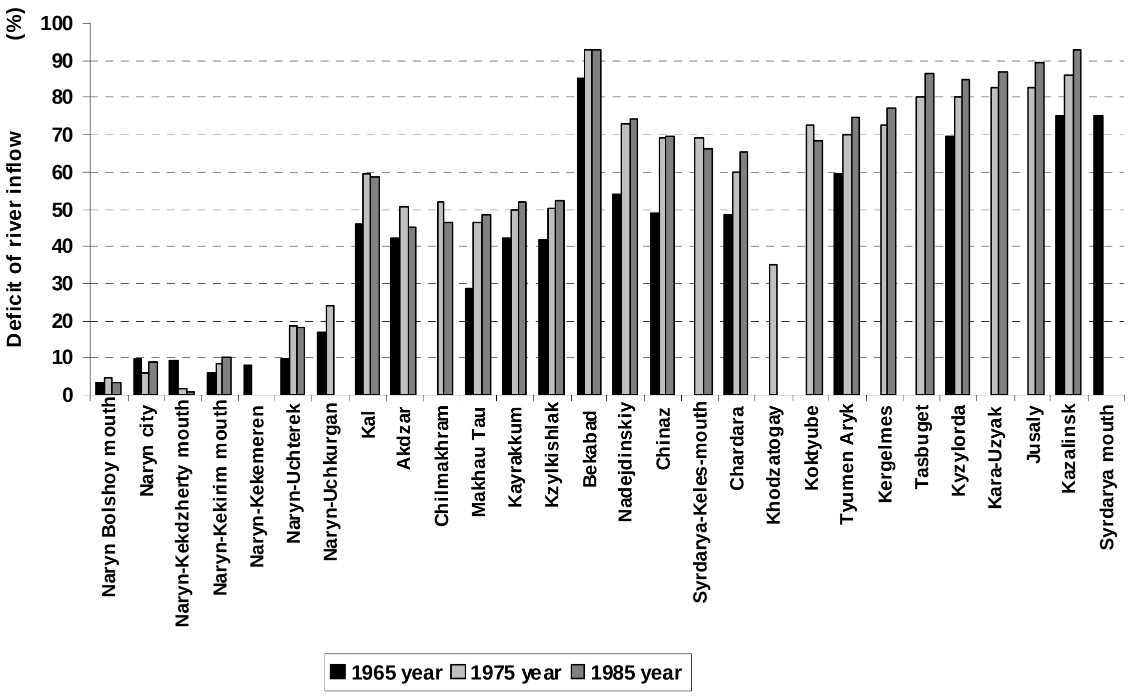

Figure 3. Deficiency of river inflow concerning of cumulative water balance (%).

Three are secreted confidently discernible zones of water management. The zone of headwaters of the basic inflows - the rivers Naryn and Karadarya from headstreams up to a hydropost Uchkurgan is characterized by a low level of retirement of water from the main race course, no more than 4÷22 %. In Fergansky valley from a hydropost Kal up to hydropost Kzylkishlak from the basic race course Syrdarya River it is withdrawn 30 ÷ 60 % of water stores. Thus magnitude of withdrawn volumes of water does not variate almost on all extent of Fergansky valley. Only in area of hydropost Bekabad the ratio of inflow to a potential water balance sharply contrasts with parameters typical for the given zone. For the lower flow Syrdarya River characteristic magnitudes of requisitioning are 65 ÷ 85 % from a total storage at steadily increasing deficiency of water resources on a direction to Syrdarya River mouth.

For the next decades the trends given considerably have amplified. Deficiency of water resources has increased up to 86.26 %. In area of hydropost Kazalinsk for seventieth years and for eightieth years deficiency of water resources has achieved 92.34 %. This was promoted by series of the causes, generalized, which analysis realized on summaries of landscape-climatic modelling.

At comparison of magnitudes of a potential water balance and a river influx it is possible to draw a resume that already to the sixtieth years all preconditions for fall of a level of Aral Sea have ripened. Losses about 75 % of annual water supply for Syrdarya River basin characterize a situation in region as intense and extremely non-resistant. At such regime of water using any intensification of economic activities unavoidably started the mechanism for the Aral catastrophe.

In the seventieth years group of large water reservoirs on the Naryn, Syrdarya rivers and their inflows are injected into exploitation. Besides as result of flood activity 1973 years on the Syrdarya River were created Arnasaysky reservoir, which functions and now.

The analysis of influence of the largest reservoirs on redistribution of water resources of Syrdarya River basin shows, that the biggest withdrawals of water account for three water reservoirs - Kayrakkumsky, Arnasaysky and Chardarinsky, which the territories located in southern hottest flat area (Figure 4).

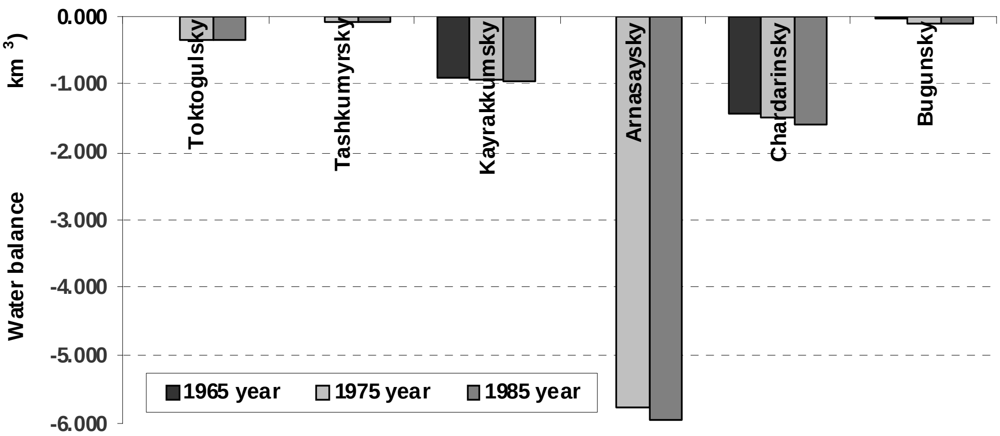

Figure 4. Water balance of more large reservoirs of Syrdarya River basin for 30 years.

For seventieth years common losses of water store conditioned of evaporation for all large reservoirs were equal -8.70 km^3/year and water losses from Kayrakkumsky, Arnasaysky and Chardarinsky reservoirs was equal -8.17 km^3/year or 94.97 % from total value. For eightieth years common water losses of same reservoirs were equal -8.97 km^3/year, water losses from Kayrakkumsky, Arnasaysky and Chardarinsky reservoirs were equal -8.46 km^3/year or 94.28 % from total value. Losses of water resources from only one Arnasaysky reservoir have made accordingly:

- for the seventieth years --5.76 km^3/year or 66.20 % from total amount;
- for the eightieth years --5.94 km^3/year or 66.29 % from total amount.

On the seventieth years it was necessary peak of construction and modernization of net cannels in zones for irrigation farming. All this has resulted in essential redistribution of water stores inside basin in such manner that the significant part of water remained in numerous water reservoirs and collector discharge water and not attaining to Aral Sea.

The given deduction proves to be true at comparison of regimes of water using and character economic activity of the seventieth and eightieth years (Figure 3). The basic difference of the season of 1980-89 from the last decade was that on change to a scale hydrotechnical construction there has come an intensification of exploitation of irrigated agricultural terrains in the lower flow of Syrdarya River due to expansion of the areas under water consumption crops of rice and cotton. As shows the relative analysis, expansion of the areas under water consumption crops in the eightieth years has resulted increasing of deficiency of a river inflow at 5 % from a level of 1970-79 years.

Detailed differentiation of the causes of decreasing of water resources of Syrdarya River basin and the evaluation of their contribution realized with use of cartographical results of modelling of climatic characteristics.

From all collections of the modelling cartographical data for an evaluation of climatic changes in Syrdarya River basin the most representative results picked. The analysis realized under the over-all circuit scheme:

1. The description of the status of climatic annual value of a parameter for the base season (it is conditional 1965 year);
2. The description of the annual status of value of a climatic index for the seventieth years (it is conditional 1975 year) and the eightieth years (is conditional 1985 year);
3. The detailed description of changes of the status of value of an annual climatic index on seasons and between the period of the sixtieth, seventieth and eightieth years.

For thirty years from 1960 until 1990 changes of a river drain of the basic bed of Syrdarya in area of hydropost Kazalinsk was characterized by steady decreasing in 2 ÷ 2.2 times for a decade. Decreasing of a drain Syrdarya River an absolute values looks even more impressing:

1965 year — 10.572 km^3,

1975 year — 4.121 km^3,

1985 year — 2.256 km^3.

The estimation of distinctions of values of water balance from a decade by a decade shows essential influence of changes of a climatic situation on fluctuations of a water mode Syrdarya River (Table 1). Last three columns of the table characterize changes of water balance between decades. They show on series of local basins of Tien-Shan decreasing of water balance in a zone of feed in the seventieth and eightieth years up to 38 % from a condition of the middle of the sixtieth years.

The detailed analysis of the reasons of degradation of water resources of Syrdarya River basin and the estimation of their contribution is executed using of cartographical results of modelling for climatic characteristics.

Results of modelling are submitted in the form of the tabulated data and thematic maps describing the annual status of the basic climatic parameters for the following periods:

For temperature-humidifying norms conditional date – 1965 is accepted:

For an estimation of the average climatic status of each next decade as conditional date the middle of decade is accepted;

For climatic differences between norms and average conditions on decades and between decades the conditional dates designated by last in two figures of norm or the next decade are accepted.

Comparison of the sums of annual water balance on local river basins, forming the whole Syrdarya basin, with the measured values of a river drain on closing hydroposts to local basins as of 1965 has revealed a range of regularities (Table 1).

The designed water balance for all decades everywhere appeared above the data on a river drain. It speaks that the calculated values of water balance comprise also an underground component of a drain while on hydroposts the superficial drain is registered only.

In the sixtieth years in local river basins, where economic activities were insignificant or was absent, excess of water balance over a river drain were in a range 1 ÷ 10 %. On the average and the bottom current Syrdarya River, essential divergences between forecasting and the measured data were observed within the limits of 11÷ 75 %. Check of a hydrological mode on independent sources [1] has shown that in local pools with the big deficiency of a river drain the ramified networks of irrigational channels are located. Therefore, the part of water proceeds on channels by a closing hydropost and is lost for it irrevocably.

For the given treatment the term - "irrevocable" is understood not only as the full loss of the water, which have come as a result of economic activities but also as the withdrawn water resources of local pool, it is in part or completely returned for its borders.

As example of last variant of interpretation of the term - "irrevocable" the situation developed in Karakoin River basin. Here the difference between the designed water balance and river drain made -24.41 %. At the same time, in area of hydropost Dzangistal, which is located below a confluence of inflow Karakoin to Atbashi River, the difference between the calculated value of water balance and the measured drain makes about 5 %. For direct value of this term irrevocable losses of water are observed in the bottom current Syrdarya River, starting from a place of junction Naryn and Karadarya Rivers up to a mouth Syrdarya River. Deficiency of water resources increasing to Aral Sea on the basic channel of the river in area of Kazalinsk achieved by 1965 of value -74.89 % from potential water balance.

Table 1. Comparison of calculated water balance and measured river inflow of Syrdarya River

Name of river basin (hydroposts)	Water balance 1965 (km^3)	River inflow 1965 (km^3)	Difference balance & inflow 1965 (%)	Water balance 1975 (km^3)	River inflow 1975 (km^3)	Difference balance & inflow 1975 (%)	Water balance 1985 (km^3)	River inflow 1965 (km^3)	Difference balance & inflow 1985 (%)	Delta water balance 75-65 (km^3)	Delta water balance 85-65 (km^3)	Delta water balance 85-75 (km^3)
1	2	3	4	5	6	7	8	9	10	11	12	13
Aral Sea	***-51.256***			***-56.715***			***-55.849***			***-5.459***	***-4.593***	***0.866***
Total Syrdarya basing, including:	***39.878***	***10.004***	***74.914***	***25.645***			***26.074***			***-13.885***	***-13.803***	***0.297***
Naryn Bolshoy mouth	1.579	1.524	3.466	1.328	1.268	4.495	1.469	1.419	3.402	-0.251	-0.110	0.142
Naryn Maly mouth	1.433	1.365	4.771	1.259	1.210	3.904	1.315	1.277	2.826	-0.174	-0.119	0.055
Naryn city	3.117	2.819	9.552	2.774	2.605	6.103	3.102	2.826	8.890	-0.343	-0.015	0.328
Onarcha - Onarcha	0.327	0.319	2.529	0.332	0.319	3.924	0.266	0.259	2.817	0.004	-0.061	-0.066
Dzhergetal - Dzhergetal	0.032	0.030	5.999	0.027	0.026	3.637	0.042	0.040	3.507	-0.005	0.010	0.014
Kekdzherty - Aktala	0.170	0.168	1.454	0.112	0.106	5.420	0.185	0.176	4.737	-0.058	0.014	0.072
Naryn - Kekdzherty mouth	3.672	3.326	9.431	3.302	3.254	1.451	3.707	3.679	0.776	-0.370	0.035	0.406
Atbashi - Ichke-Kamandy mouth	0.602	0.586	2.609	0.553	0.522	5.669	0.536	0.504	5.899	-0.049	-0.067	-0.017
Karakoin - Karakoin	0.055	0.044	20.663	0.049			0.046			-0.006	-0.009	-0.003
Atbashi - Dzangistal	1.094	1.045	4.533	1.017			0.919			-0.077	-0.175	-0.098
Alabuga - Koshtobe	0.860	0.829	3.590	0.958	0.920	3.986	1.137	1.104	2.882	0.098	0.276	0.178
Kekirim - Kara-Tabylga	0.698	0.666	4.602	0.648	0.604	6.709	0.587	0.574	2.229	-0.050	-0.110	-0.060
Naryn - Kekirim mouth	7.058	6.648	5.819	6.793	6.230	8.289	6.785	6.092	10.211	-0.265	-0.273	-0.008
Karakol mouth	0.739	0.707	4.404	0.612	0.585	4.354	0.848	0.819	3.453	-0.127	0.109	0.236
Kekemeren - Karakol	1.258	1.232	2.102	1.169	1.162	0.586	1.265	1.221	3.470	-0.089	0.007	0.096
Orto-Kugandy	0.121	0.116	4.473	0.100			0.129			-0.021	0.007	0.029
Dzhumgol - Chaek	0.365	0.339	7.143	0.263	0.248	5.560	0.274	0.252	8.056	-0.102	-0.091	0.012
Kekemeren - Dzhumgol	2.094	2.092	0.102	2.467	2.416	2.034	2.026			0.372	-0.068	-0.440
Kekemeren - Dzhumgol mouth	2.489	2.482	0.274	2.663	2.323	12.773	2.460	2.417	1.727	0.175	-0.029	-0.203
Naryn - Kekemeren	10.433	9.594	8.043	10.223			9.780			-0.209	-0.653	-0.443
Torkent - Torkent	0.397	0.373	5.954	0.362	0.349	3.638	0.283	0.271	4.194	-0.035	-0.114	-0.080
Chichkan - Bala-Chichkan	0.631	0.598	5.218	0.466	0.449	3.546	0.514	0.488	5.157	-0.165	-0.116	0.049
Uzunakhmat - Ustasay mouth	0.983	0.927	5.718	0.801	0.763	4.800	0.954	0.911	4.600	-0.182	-0.029	0.153
Naryn - Uchterek	13.219	11.912	9.887	11.703	9.548	18.409	11.509	9.461	17.795	-1.517	-1.710	-0.193
Aflatun - Aflatun	0.357	0.345	3.358	0.336	0.326	3.080	0.391	0.366	6.493	-0.021	0.035	0.055
Karasu right mouth	1.381	1.317	4.652	1.142	1.106	3.159	1.550			-0.239	0.169	0.408
Naryn - Uchkurgan	14.894	12.382	16.867	12.741	9.686	23.973	13.008			-2.153	-1.886	0.267

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12	13
Tar - Cholma	1.477	1.414	4.261	1.622	1.597	1.525	1.890	1.782	5.714	0.145	0.413	0.269
Karakuldzha - Aktash	0.709	0.674	4.914	0.741	0.728	1.715	0.838	0.785	6.392	0.032	0.130	0.097
Kulduk - Sarybulak	0.080	0.075	5.268	0.074	0.073	1.062	0.110	0.106	3.825	-0.006	0.030	0.036
Yassy - Salamalik	0.736	0.698	5.069	0.681	0.645	5.360	0.696	0.664	4.649	-0.055	-0.039	0.015
Donguztau - Donguztau	0.094	0.088	7.260	0.083	0.078	6.235	0.090	0.088	1.663	-0.012	-0.005	0.007
Zerger - Tassay	0.091	0.091	0.529	0.091	0.088	3.171	0.104	0.102	2.055	0.000	0.012	0.012
Yassy - Uzgen	1.187	1.057	10.924	1.097			1.170			-0.090	-0.017	0.073
Changet - Changet	0.074	0.070	5.425	0.066	0.064	2.659	0.075	0.071	5.641	-0.008	0.002	0.010
Kugart - Mikhaylovka	0.614	0.574	6.516	0.567	0.548	3.383	0.618	0.603	2.380	-0.047	0.004	0.051
Tentyaksay - Charvak	0.971	0.916	5.654	0.757	0.713	5.817	1.013	0.978	3.445	-0.214	0.042	0.256
Shaydansay - Shaydan	0.055	0.052	4.210	0.056	0.054	2.671	0.068	0.067	1.870	0.001	0.013	0.012
Maylisu - Kayragach mouth	0.295	0.276	6.362	0.310	0.294	5.181	0.306	0.297	2.957	0.015	0.010	-0.005
Kurshab - Gulcha	0.563	0.542	3.745	0.475	0.472	0.649	0.654	0.625	4.428	-0.089	0.090	0.179
Kurshab - Kochkor-Ata	0.835	0.779	6.643	0.709			0.931			-0.126	0.096	0.222
Akbura - Mynteke mouth	0.122	0.121	0.977	0.121			0.139			-0.001	0.017	0.018
Akbura - Papan	0.635	0.607	4.440	0.635	0.587	7.521	0.694	0.635	8.426	0.000	0.059	0.059
Akbura - Tuleken	0.688	0.668	2.926	0.677	0.588	13.121	0.742	0.714	3.805	-0.012	0.054	0.065
Karakol - Koschan	0.057	0.055	3.190	0.055	0.052	4.986	0.067	0.064	4.918	-0.002	0.011	0.012
Kirgizata - Kirgizata	0.138	0.131	5.029	0.140	0.133	4.770	0.148	0.142	4.253	0.002	0.011	0.009
Shankol - Shankol	0.031	0.029	4.740	0.031			0.031			0.000	0.000	0.000
Aravansay - Yanginaukat	0.206	0.196	5.205	0.205	0.194	5.298	0.207	0.194	6.179	-0.001	0.001	0.002
Aravansay - Karakol mouth	0.433	0.327	24.399	0.428	0.212	50.359	0.451	0.211	53.157	-0.005	0.019	0.024
Abshirsay - Uchterek	0.053	0.053	0.353	0.046	0.044	3.571	0.055	0.053	2.393	-0.007	0.002	0.009
Isfayramsay - Lyangar	0.293	0.277	5.217	0.247			0.270			-0.046	-0.023	0.023
Isfayramsay - Uchkorgon	0.787	0.705	10.484	0.650	0.613	5.633	0.766	0.672	12.284	-0.137	-0.022	0.116
Koksu mouth - Kurbankul	0.079	0.075	4.633	0.071			0.086			-0.008	0.008	0.016
Sakhimardan -Lyangar	0.349	0.311	10.903	0.333			0.371			-0.008	0.022	0.038
Sokh - Sarykanda	1.374	1.304	5.057	1.373	1.312	4.417	1.450			-0.016	0.076	0.077
Isfara - Tashkurgan	0.488	0.476	2.483	0.485	0.452	6.887	0.456	0.435	4.651	-0.003	-0.032	-0.029
Isfara - Isfara	0.589	0.451	23.400	0.564			0.525			-0.025	-0.064	-0.040
Khodzhabakirgan - Andarkhan	0.347	0.332	4.181	0.324	0.294	9.194	0.293	0.277	5.379	-0.023	-0.053	-0.031
Aksu-Dazgon	0.123	0.122	1.158	0.117	0.113	3.620	0.121	0.114	6.063	-0.006	-0.002	0.004
Padshaata - Tostu mouth	0.207	0.198	4.630	0.165	0.157	4.677	0.162	0.155	4.218	-0.042	-0.045	-0.003
Alabuka - Alabuka	0.084	0.080	4.990	0.068			0.079			-0.016	-0.005	0.011
Uryukty mouth	0.016	0.015	3.684	0.012			0.012			-0.003	-0.003	0.000
Kassansay - Uryukty mouth	0.311	0.282	4.475	0.270			0.286			-0.040	-0.025	0.016
Kassansay - Baymak	0.449	0.341	24.151	0.383			0.409			-0.067	-0.040	0.026

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12	13
Sumsar - Sumsarsay	0.033	0.032	2.879	0.027			0.025			-0.005	-0.007	-0.002
Syrdarya - Kal	29.079	15.733	45.897	25.752	10.386	59.669	27.054	11.238	58.461	-3.327	-2.025	1.302
Gavasay - Ters mouth	0.164	0.157	4.324	0.143			0.138			-0.020	-0.026	-0.005
Gavasay - Gava	0.253	0.190	24.764	0.220	0.164	25.476	0.212	0.132	37.723	-0.033	-0.041	-0.003
Chadak - Dzulaysay mouth	0.125	0.120	4.676	0.110			27.332			-0.016	-0.023	-0.008
Syrdarya - Akdzar	29.768	17.290	41.917	26.196	12.929	50.643	27.442	15.058	44.908	-3.573	-2.436	1.136
Syrdarya - Chilmakhram	29.991			26.357	12.707	51.789	27.452	14.743	46.276	-3.634	-2.549	1.085
Syrdarya - Makhau Tau	30.035	21.399	28.754	26.383	14.161	46.323	26.767	14.161	48.413	-3.653	-2.583	1.069
Syrdarya - Kayrakkum	29.489	17.143	41.866	25.740	12.950	49.690	26.800	12.950	51.620	-3.749	-2.722	1.027
Syrdarya - Kzylkishlak	29.555	17.218	41.742	25.786	12.805	50.341	26.832	12.805	52.221	-3.770	-2.755	1.014
Syrdarya - Bekabad	29.644	4.392	85.185	25.842	1.969	92.382	26.838	1.969	92.663	-3.802	-2.812	0.990
Syrdarya - Nadejdinsky	29.862	13.782	53.848	25.898	6.945	73.185	26.838	6.945	74.124	-3.964	-3.024	0.940
Akhangaran - Yakaarcha	0.472	0.448	4.997	0.478			0.470			0.006	-0.002	-0.008
Akhangaran - Turk	0.893	0.833	6.668	0.926			0.789			0.033	-0.104	-0.136
Akhangaran - Soldatskoe	0.843	0.738	12.381	0.857			0.712			0.014	-0.131	-0.145
Ters mouth	0.300	0.284	5.219	0.284	0.268	5.729	0.277			-0.016	-0.023	-0.007
Chatkal - Ters mouth	2.238	2.136	4.588	2.163	2.089	3.405	2.061	1.965	4.635	-0.076	-0.177	-0.102
Chatkal - Nayza mouth	2.775	2.657	4.240	2.634			2.535			-0.141	-0.240	-0.099
Koksu - Burchmulla	0.382	0.366	4.181	0.371			0.353			-0.011	-0.029	-0.019
Oygaing mouth - Karangitugayskaya	0.907	0.868	4.284	0.893			0.937			-0.014	0.030	0.044
Maidantal mouth - Karangitugayskaya	0.495	0.470	4.945	0.483			0.526			-0.012	0.031	0.043
Pskem mouth - Charvakskaya	2.737	2.553	6.710	2.654			2.706			-0.083	-0.031	0.052
Ugam - Khodzikent	0.695	0.660	5.065	0.653			0.638			-0.042	-0.057	-0.016
Chirchik - Khodzikent	7.017	6.954	0.901	6.707			6.591			-0.311	-0.426	-0.116
Chirchik - Gazalkent	7.211	7.132	1.095	6.896			6.757			-0.315	-0.454	-0.139
Chircik mouth	8.026	3.093	61.469	7.668			7.439			-0.358	-0.588	-0.230
Syrdarya - Chinaz	38.573	19.834	48.581	34.228	10.509	69.298	34.772	10.509	69.778	-4.345	-0.623	0.544
Syrdarya – Keles mouth	38.665			34.292	10.479	69.443	34.837	11.740	66.301	-4.373	-0.495	0.545
Keles - Stepnoe	0.227	0.164	27.574	0.372			0.478			0.145	0.251	0.106
Keles mouth	0.260	0.208	20.194	0.405	0.342	15.675	0.610	0.445	27.015	0.145	0.350	0.205
Syrdarya - Chardara	39.670	20.449	48.451	29.148	11.728	59.764	29.333	10.261	65.019	-10.521	-10.337	0.184
Syrdarya - Khodzatogay	40.465			29.596	19.282	34.850	29.846				-10.618	0.066
Sayram - Blinkovo	0.248	0.237	4.355	0.247			0.236			-0.001	-0.012	-0.011
Boldybrek - Sakharovka	0.099	0.095	3.972	0.098			0.106			-0.001	0.007	0.008
Aksu - Podgornoe	0.360	0.301	16.344	0.365			0.379			0.005	0.019	0.006
Dzebaglysu - Novo-Nikolaevka	0.078	0.074	4.164	0.083			0.085			0.005	0.007	0.002

Continuation of Table 1

1	2	3	4	5	6	7	8	9	10	11	12	13
Arys - Dzusansay	1.232	0.959	22.152	1.208			1.195			-0.024	-0.037	-0.017
Badam - Pervomayskoe	0.043	0.040	6.895	0.040			0.036			-0.003	-0.007	-0.004
Borolday - Karla Marksa	0.363	0.341	5.985	0.336			0.342			-0.026	-0.021	0.005
Balabugun - Kitaevka	0.042	0.039	7.367	0.037			0.038			-0.005	-0.004	0.001
Almaly - Orlovka	0.019	0.017	7.906	0.017			0.017			-0.002	-0.001	0.000
Kattabugun - Leontievka	0.109	0.098	10.372	0.099			0.100			-0.010	-0.008	0.001
Bugun - Red Bridge	0.434	0.138	68.188	0.378			0.390			-0.055	-0.043	0.009
Arys - Arys	2.927	1.019	65.181	2.636	0.646	75.494	2.593	0.454	82.494	-0.291	-0.334	-0.043
Arys - Shaulder	2.976	0.720	75.826	2.665			2.623			-0.311	-0.354	0.001
Shayan - Akbet	0.099	0.080	19.716	0.086			0.105			-0.013	0.006	0.019
Arystandy - Algabas	0.056	0.036	35.217	0.049			0.074			-0.007	0.018	0.025
Syrdarya - Koktyube	44.107			32.233	8.788	72.736	32.365	10.333	68.073	-11.045	-11.742	-0.120
Syrdarya - Tyumen Aryk	44.026	17.767	59.644	31.959	9.599	69.965	31.976	8.185	74.404	-11.719	-12.050	-0.116
Kergelmes	43.446			30.989	8.451	72.729	30.988	7.062	77.210	-12.110	-12.458	-0.017
Syrdarya - Tasbuget	43.350			30.876	6.165	80.034	30.893	4.202	86.398	-12.127	-12.457	0.018
Syrdarya - Kyzylorda	43.303	13.121	69.698	30.819	6.134	80.096	30.850	4.739	84.639	-12.137	-12.452	0.015
Syrdarya - Kara-Uzyak	43.226			30.721	5.312	82.710	30.784	4.061	86.808	-12.158	-12.442	0.031
Syrdarya - Jusaly	42.535			29.825	5.209	82.533	30.017	3.305	88.991	-12.363	-12.518	0.129
Syrdarya-Kazalinsk	42.157	10.572	74.923	29.313	4.121	85.941	29.445	2.256	92.338	-12.498	-12.712	-0.060

* *Source of data for Syrdarya River floe are Kazakhstan Hydrometeo Service and Kyrgyzstan Hydrometeo Service*

The next decades the tendencies given considerably have amplified. For hydropost Kazalinsk for the seventieth years deficiency of water resources has increased up to 86.26 %, and for the eightieth years it has achieved 92.34 %. This was promoted by a number of the reasons, generalized, which analysis is executed on results of landscape-climatic modelling.

Air temperature

Average of air temperature on decades

Average annual temperature regime of Syrdarya River basin as of 1965 year it is characterized by distribution of air temperatures as typical for arid climatic zones of moderate latitudes of the Central Asia (Figure 5). In a zone of arid plains of Syrdarya River basin character of temperature field in basic submits to regularity latitude distributions of temperatures with the small heterogeneities caused by effect humidified intrazonal and anthropogenic of changed landscapes. In mountain terrains it is determined by regularity of normal high-altitude distribution. Cooling effect of Aral Sea shows in extensive lowering average annual air temperatures above its aquatory on magnitude no more than 5 °C.

In more details the thermal regime of the Aral region for period up to the end of the sixtieth years circumscribed in publications [1, 2, 3, 4, 5].

At over-all similarity of a thermal regime of the seventieth and sixtieth decades the fields of average annual air temperatures of 1970 – 1979 years has some differences from the previous season (Figure 6). The space distribution of temperatures has got more mosaic character because of intensifying contrast of local heterogeneities of underlying terrain on the middle flow Syrdarya River.

The temperature regime of mountain areas of Internal Tien-Shan has the increased level on 0.5 ÷ 1 °C. Small increase of temperature on 0.8 ÷ 1.5 °C is registered for aquatory of Aral Sea and lower flow Syrdarya River.

In the eightieth years the field of average annual air temperatures differs from temperature field of antecedent decade a little, but has quieter character (Figure 7). Because of decreasing of aquatory of Aral Sea the regime of effect of underlying terrain in zone of a drained bottom has changed.

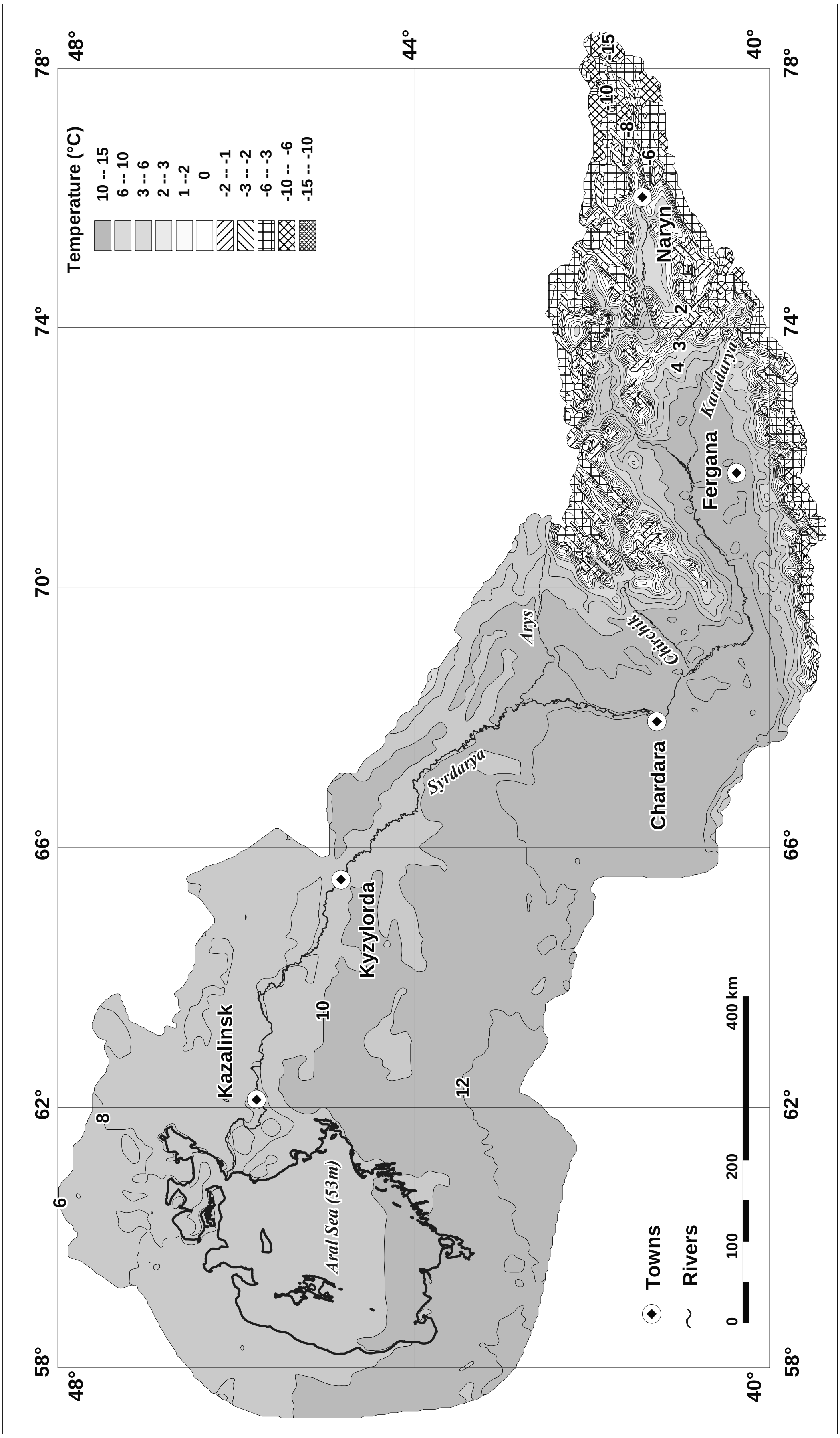

Figure 5. Map of average annual of air temperatures (°C) of Syrdarya River basin for the sixtieth years.

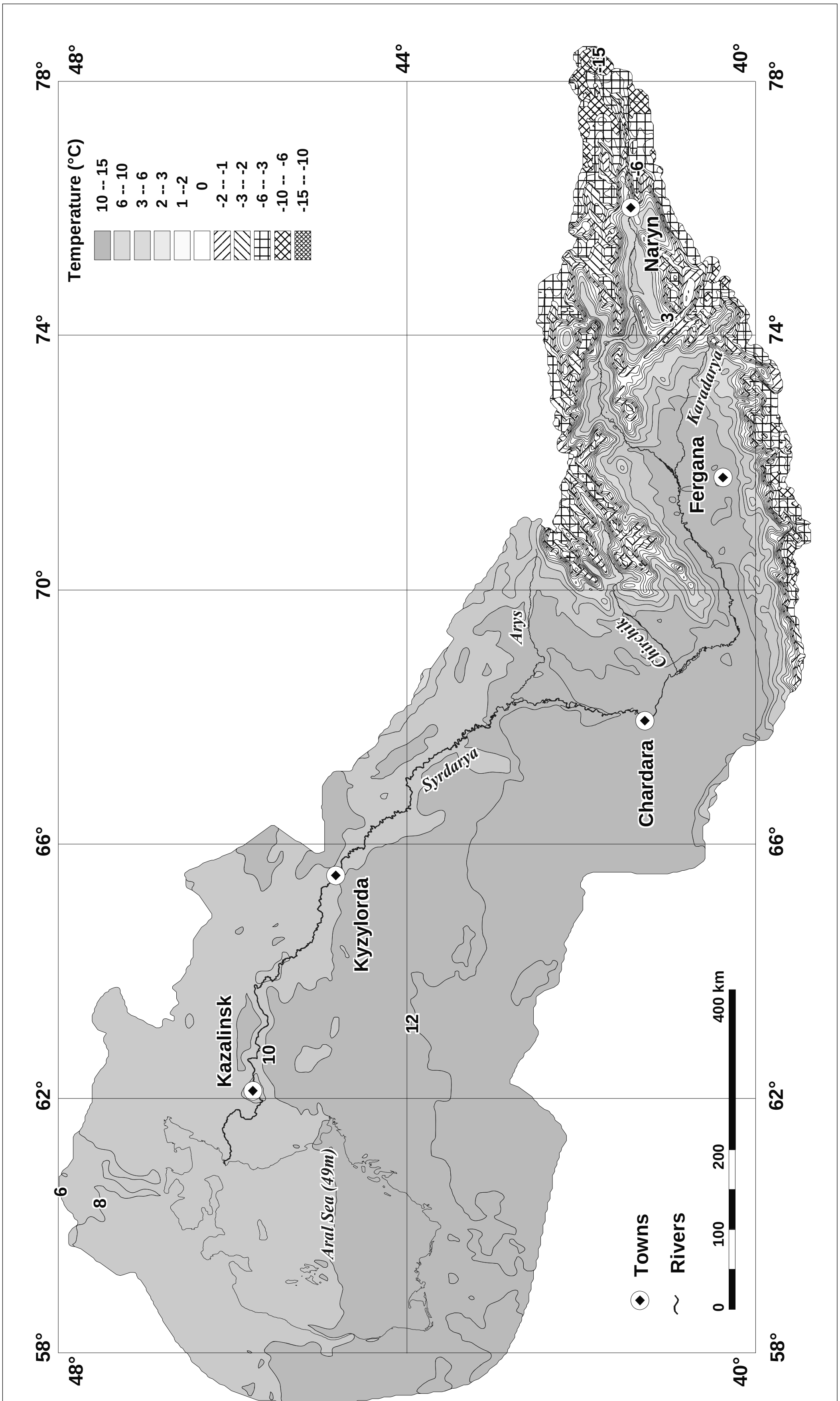

Figure 6. Map of average annual of air temperatures (°C) of Syrdarya River basin for the seventieth years.

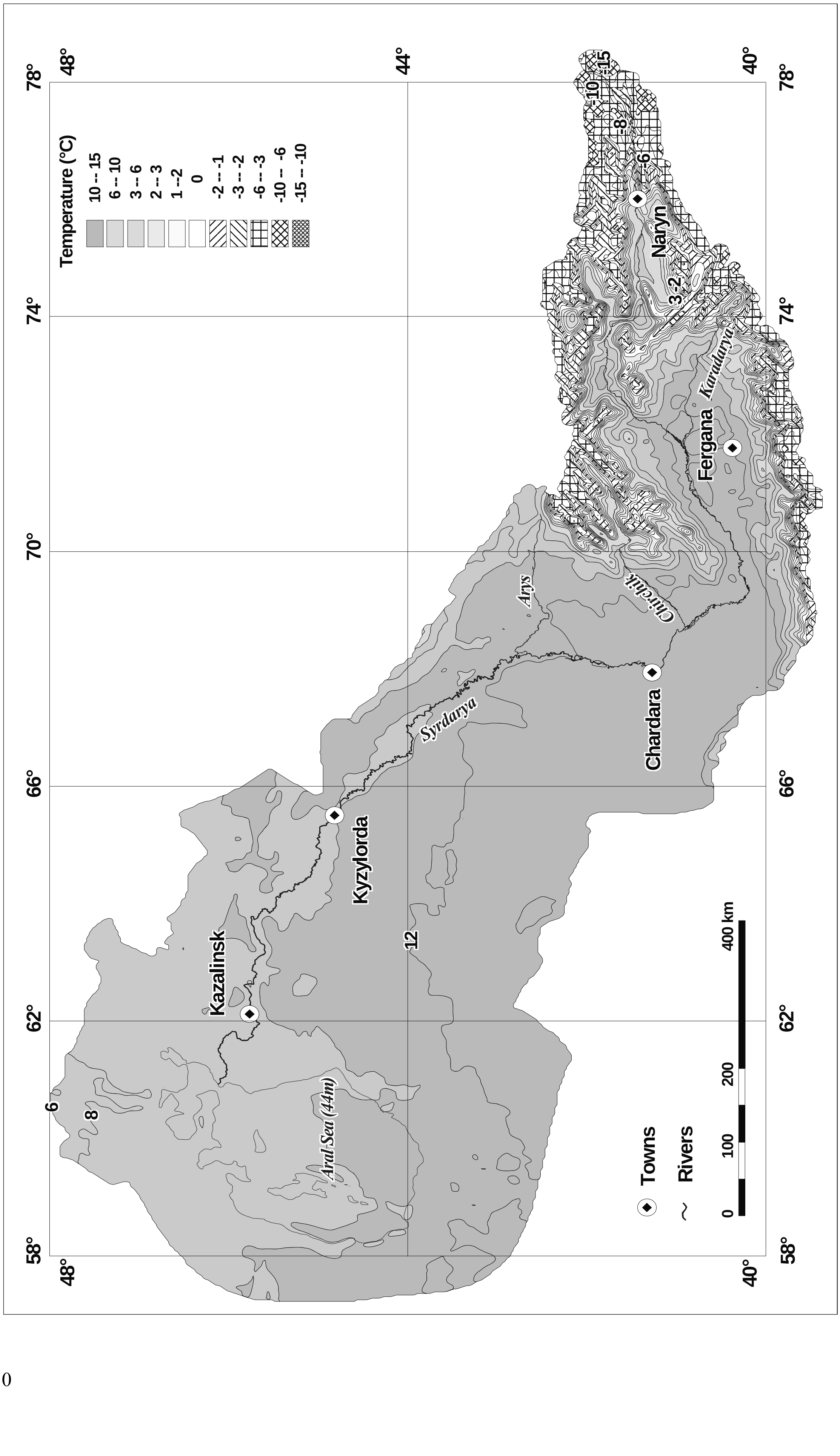

Figure 7. Map of average annual of air temperatures (°C) of Syrdarya River basin for the eightieth years.

On change to effect of water surface on a thermal regime there has come effect of the areas of development of solonchaks. In the spring and summer seasons air temperature above water surface of below surrounding temperature background, but an autumn season it is a little bit higher. It is superfluous humidified saline terrains in the spring and is little bit cooler than an environing background in the summer, and by the autumn they completely lose a humidifying and are indistinguishable in temperature field from surrounding background.

Variability of air temperature between decades

Features of changes for a thermal regime between decades are shown at the analysis of differential maps. Application of more detailed graduation of temperature fields allow distinctly to mark out aboriginal differences of temperature fields.

Over-all increase of level of average annual temperature field for a decade from 1970 till 1979 had heterogeneous character (Figure 8). In northern part of Syrdarya River basin and above aquatory of Aral Sea raise of average annual temperatures in limits 0.4 ÷ 1.5 °C for ten years was registered. South-western slopes of Karatau ridge, Fergansky valley and also surrounding mountain terrains of Western Tien-Shan, Turkestansky and Alaysky ridges, are characterized by relative lowering of temperature field in a range -0.4 ÷-0.8 °C.

In areas of Internal Tien-Shan raise of average annual air temperatures to 0.7 °C is observed.

In the period of 1980-1989 relative warming has got more homogeneous character and embraced whole Syrdarya River basin. Over-all raise of a level of average annual temperature field on 0.4 ÷ 0.8 °C concerning the sixtieth years specifies stabilization of regional warming (Figure 9). Level recession of Aral Sea to 44 m for twenty years was showed in change of temperature regime in a drying zone up to 0.5 ÷ 1.5 °C.

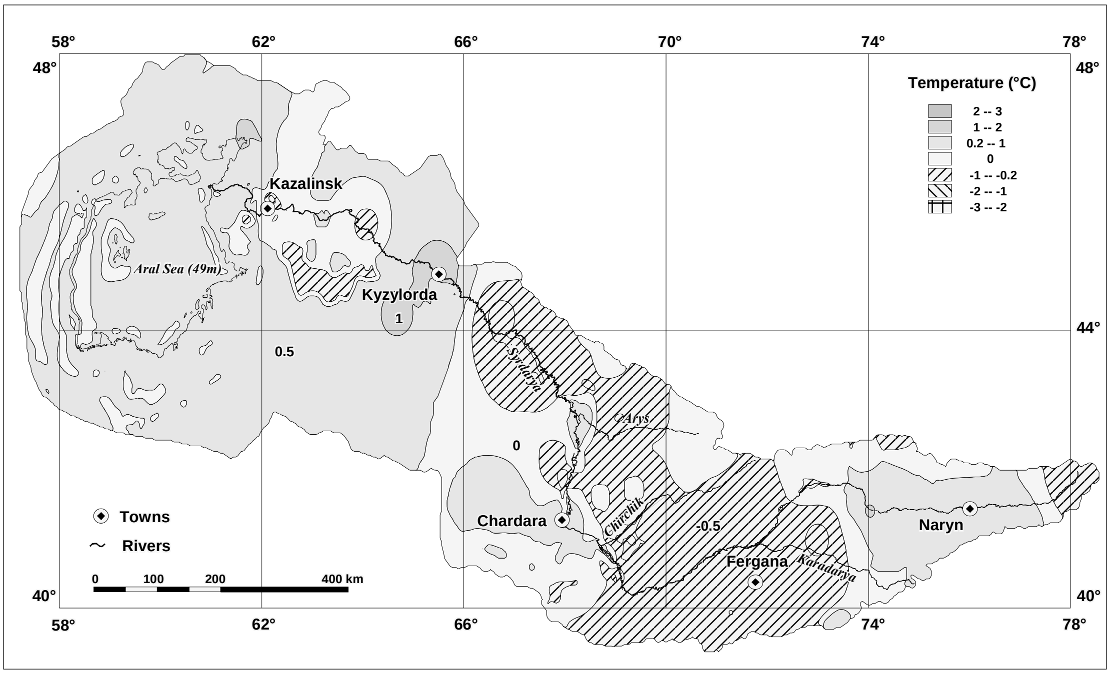

Figure 8. Map of differences between average annual of air temperatures (°C) of Syrdarya River basin for the seventieth and sixtieth years.

Changes of regional temperatures of air in the period from 1970 till 1989 years developed as follows:

- As a whole, the twentieth decade 1970 - 1989 years is characterized by regional raise of air temperatures on magnitude 0.3 ÷ 1.2 °C, including:
- for the seventieth years warming had fragmentary character and has mentioned in basic north-western and eastern parts of region while in the central part the relative cold snap was observed small on amplitude;
- for the eightieth years warming has amplified and embraced all terrain of Syrdarya River basin and Aral Sea;
- The basic contribution to regional warming was made with change of temperature background of a winter season;

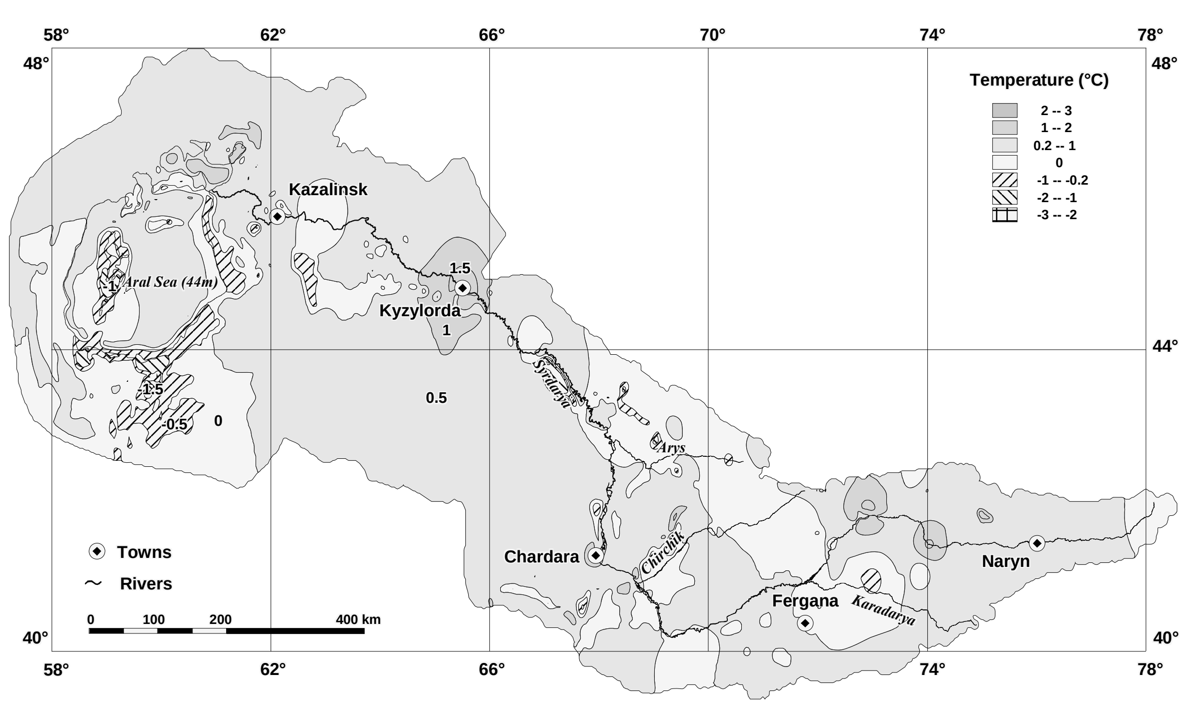

Figure 9. Map of differences between average annual of air temperatures (°C) of Syrdarya River basin for the eightieth and sixtieth years.

- Influence of anthropogenic activity on formation and change of a temperature regime were local character, is dated for large human settlements with the developed infrastructure, to the irrigated agricultural areas and rendered negligible effect on the over-all climatic status of Syrdarya River basin;
- The greatest influence of economic activities on an aboriginal climate was showed in area of Aral Sea and other water reservoirs in the period from 1965 till 1989. On a measure of decreasing of Aral Sea aquatory the temperature regime of dry land adjoining to it varied to the greater aridisation. Around again educated water reservoirs the aboriginal climate was softened. Range of influence of water surface on surrounding land does not exceed 10 ÷ 20 % from the dimensions of their aquatories.

Precipitations

The analysis of the causes of losses of the water resources being consequence of anthropogenic activity provides the count of share of climatic caused time variations of distribution of precipitations. The relative evaluation of changes of precipitations storage shows that in the seventieth – the eightieth years in Syrdarya River basin of precipitations fell out on 8.15 % and on 5.52 % accordingly less, than for previous period (Figure 10).

Total volume of precipitations for headstreams Syrdarya River and its main inflow - Naryn River in the period from 1970 until 1989 remained practically constant. Decreasing of precipitations amount in comparison with the sixtieth years is observed on the middle and the lower flow Syrdarya River.

Average precipitations on decades

By results of modelling for the season of the sixtieth years for Syrdarya River basin it is characterized by very wide range of a spacing of the sums of an average annual precipitations on terrain from 40 mm/year of arid plains and intermountain depressions up to 2000 mm/year in high mountain areas of Western Tien-Shan (Figure 11). Mountain terrains of Internal Tien-Shan, which are the main area of a inflow area for Naryn river, the largest inflow p. Syrdarya, gain on 600 ÷ 1000 mm/year of less precipitations, than other mountain areas. It is caused by shielding effect of the Fergansky crops, which contoured from the eastern Fergansky valley and has altitude 3500 ÷ 4500 m. above sea level. In the result, separate intramountain depressions of Internal Tien-Shan in its western range gain precipitations less, than in a zone of arid plains, up to 40 ÷ 120 mm/year. The windward High slopes of Western Tien-Shan is more east towards moisture-laden to air streams also work as a trap for a precipitations. Therefore in the given range the greatest are marked for all Syrdarya River basin average annual precipitations 1200 ÷ 1800 mm/year, and places up to 2000 mm/year. Aquatory of Aral Sea because of the lowered temperature regime (Figure 10) has more congenial conditions of a water condensation and consequently it is distinguished above an environing background the increased values of a precipitations 200 ÷ 300 mm/year.

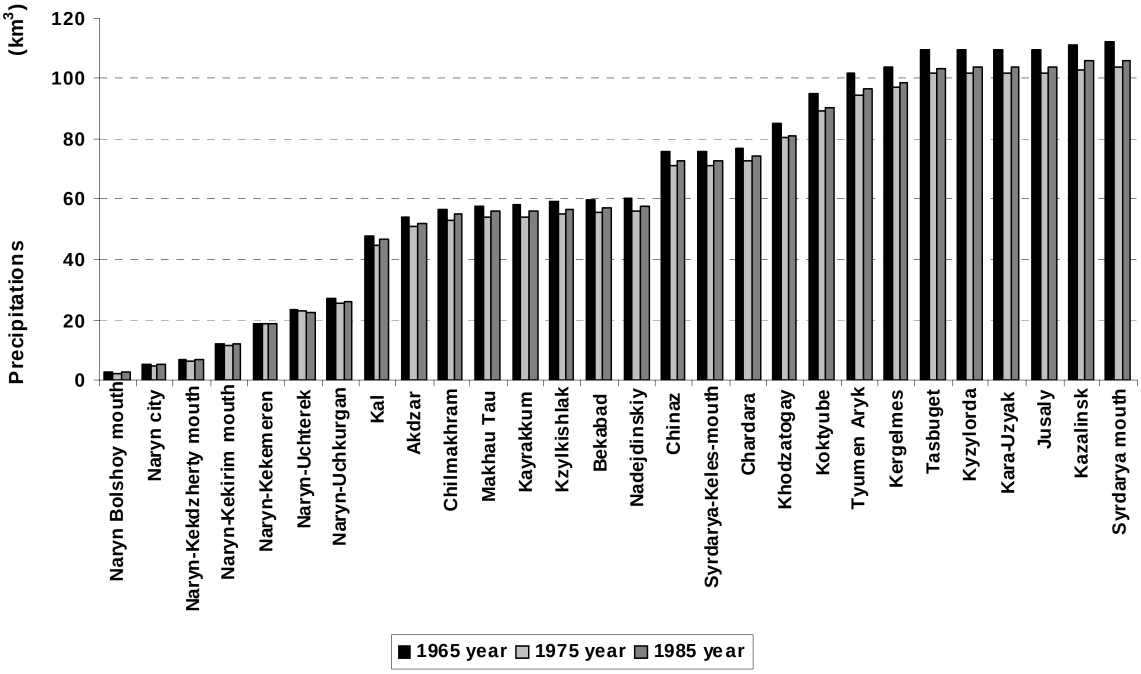

Figure 10. Changes of average annual precipitations on hydroposts Syrdarya River on decades.

The additional description of precipitations storage regime for the Aral basin down to the sixth decade of the twentieth century can be found in publications [1, 2, 3, 4, 5].

Occurred in 1970 – 1979 years lowering of intensity precipitations storage in Syrdarya River basin was distributed on terrain non-uniform (Figure 12). On a background of over-all decreasing of amount of an average annual precipitations on -50 ÷ -250 mm/year in comparison with an average level of the sixtieth years in a south-western part of Internal Tien-Shan there was an augmentation of a precipitations on 50 ÷ 70 mm/year. Local raises similar to them precipitations storage are marked and in Western Tien-Shan. High altitude territories variability of precipitations and the big ranges of values do not allow estimating completely changes precipitations storage for a decade at direct comparison of results of modelling. The detailed analysis of changes realized in the paragraph **Variability of precipitations between decades**.

Feature of a regime precipitations storage for the period 1980 – 1989 years shows in over-all small lowering a level of an average annual precipitations in comparison with the sixtieth years essential decreasing of their amount above aquatory of Aral Sea up to -100 mm/year is registered (Figure 13). It is on 150 mm/year less than average amount of the annual precipitations, which is falling out in this area in the sixtieth years. Besides high local variability of a regime precipitations storage in mountain areas is observed. In boundaries the same mountain ridges the areas as with be relative increased precipitations amount on 50 ÷ 300 mm/year, and with be relative lowered values on -100 ÷ -600 mm/year are revealed in comparison with the sixtieth years. High territorial variability of distribution of precipitations and big gradients complicate a qualitative assessment by results of modelling. Therefore, the detailed analysis of time changes in the paragraph **Variability of precipitations between decades** is realized.

Variability of precipitations between decades

In the seventieth years on the bulk of the area of Syrdarya River basin decreasing of average annual precipitations is observed (Figure 14) in comparison with the sixtieth years. For ten years of Syrdarya River basin the average precipitations amount has decreased on -10 ÷ -50 mm/year in a flat part and in mountain areas on -25 ÷ -130 mm/year. The most essential decrease of annual precipitations is marked in Talassky, and Fergansky ridges and places on southern slopes of crops Terskey Ala Tau. Here it was changes in limits from -200 up to -650 mm/year. In mountain areas of Western Tien-Shan, on joint Talassky and Kyrgyzsky ridges and a south-western part of Internal Tien-Shan the local areas with the increased values of changes of precipitations of the seventieth years 10 ÷ 700 mm/year are founded.

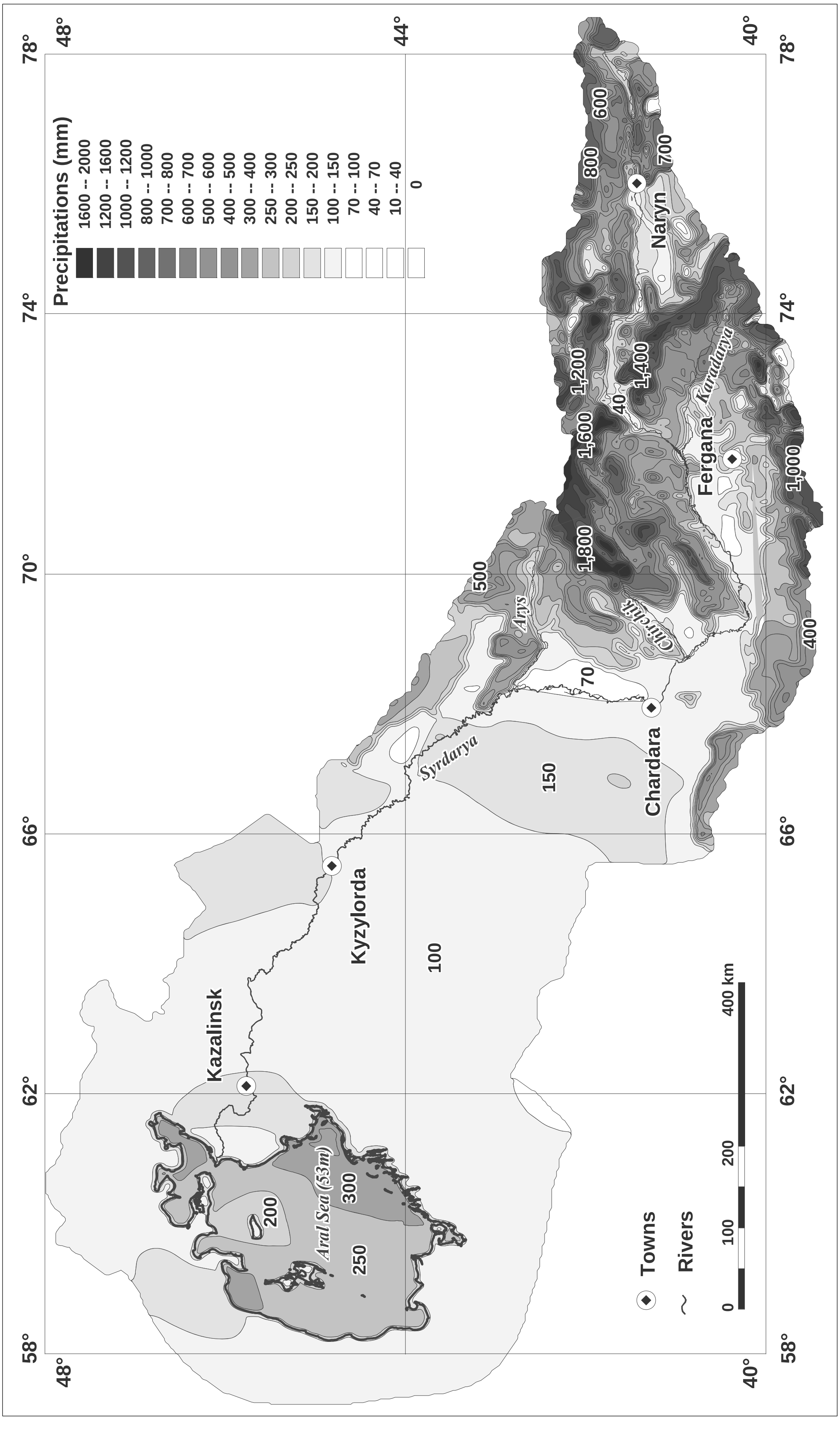

Figure 11. Map of average annual precipitations (mm) of Syrdarya River basin for the sixtieth years.

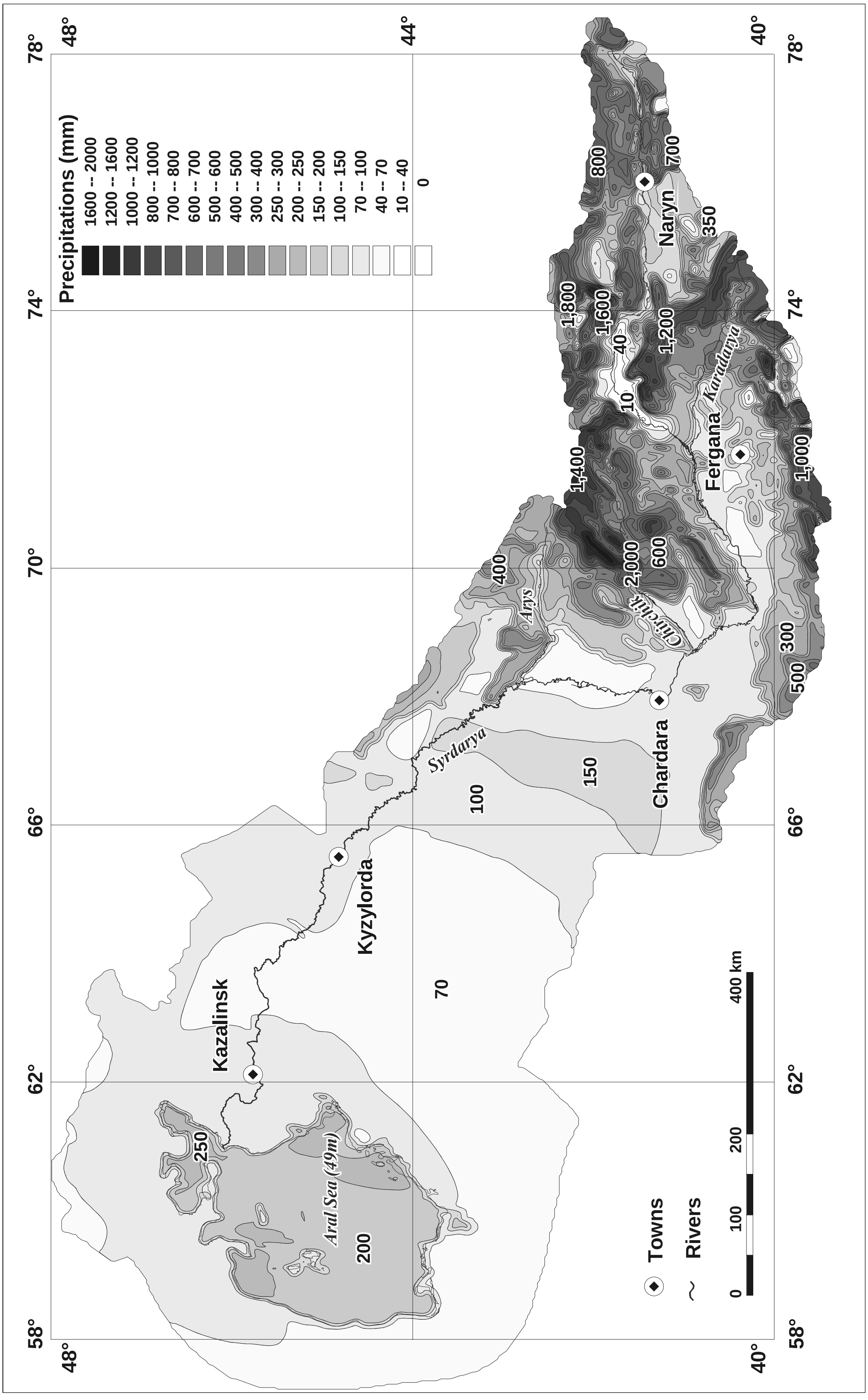

Figure 12. Map of average annual precipitations (mm) of Syrdarya River basin for the seventieth years.

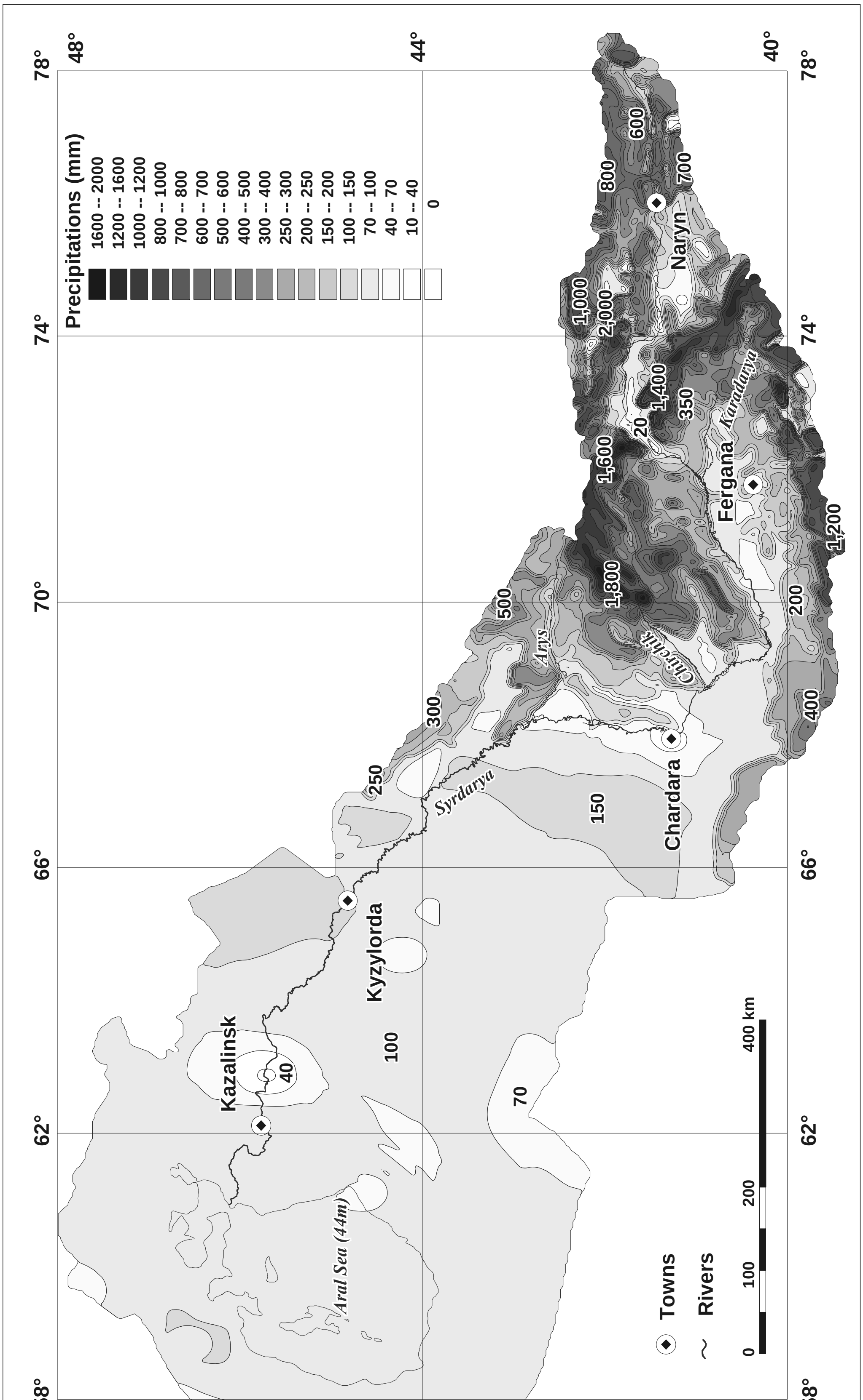

Figure 13 .Map of average annual precipitations (mm) of Syrdarya River basin for the eightieth years.

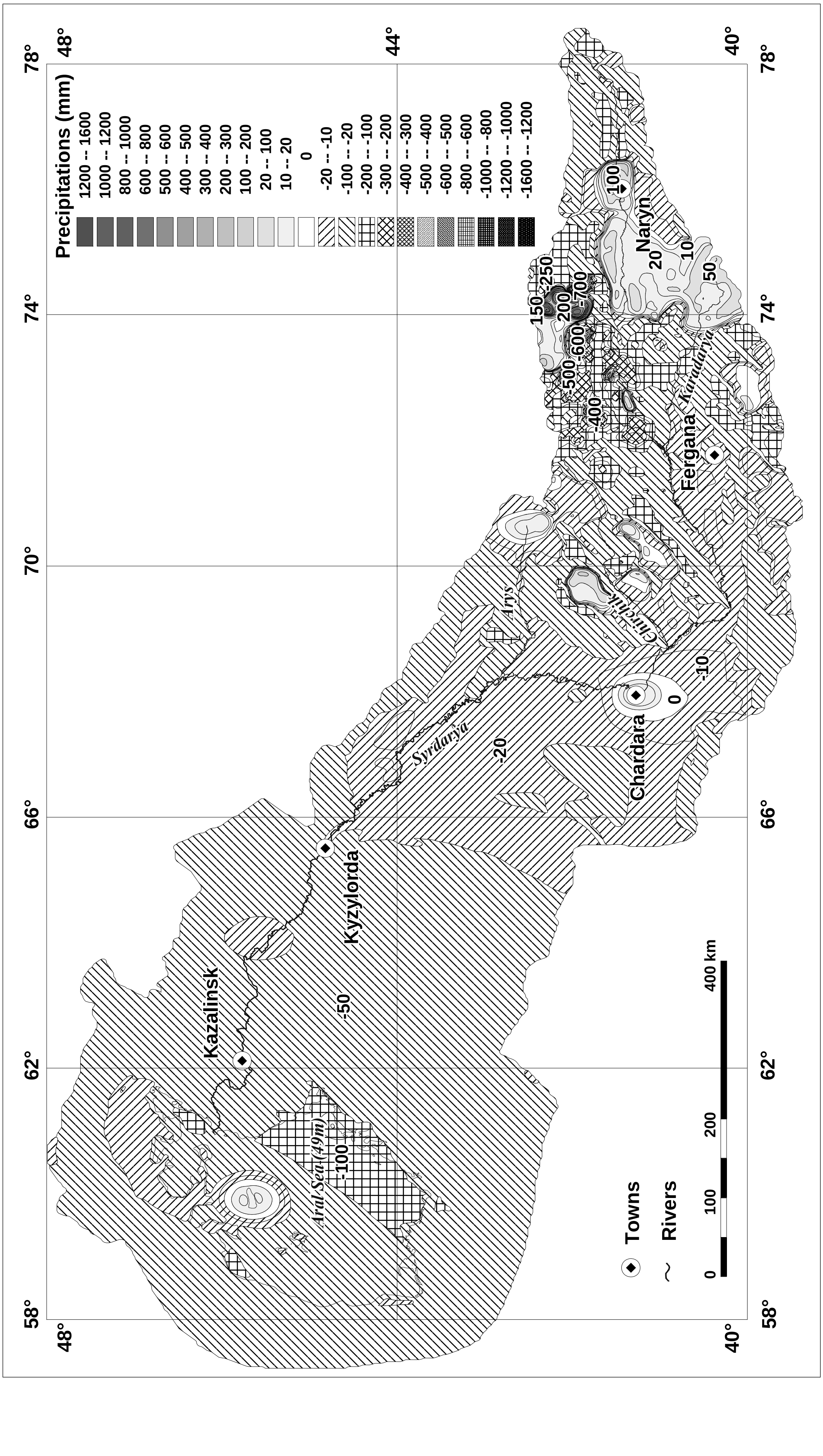

Figure 14. Map of differences between average annual precipitations (mm) of Syrdarya River basin of the seventieth and sixtieth years.

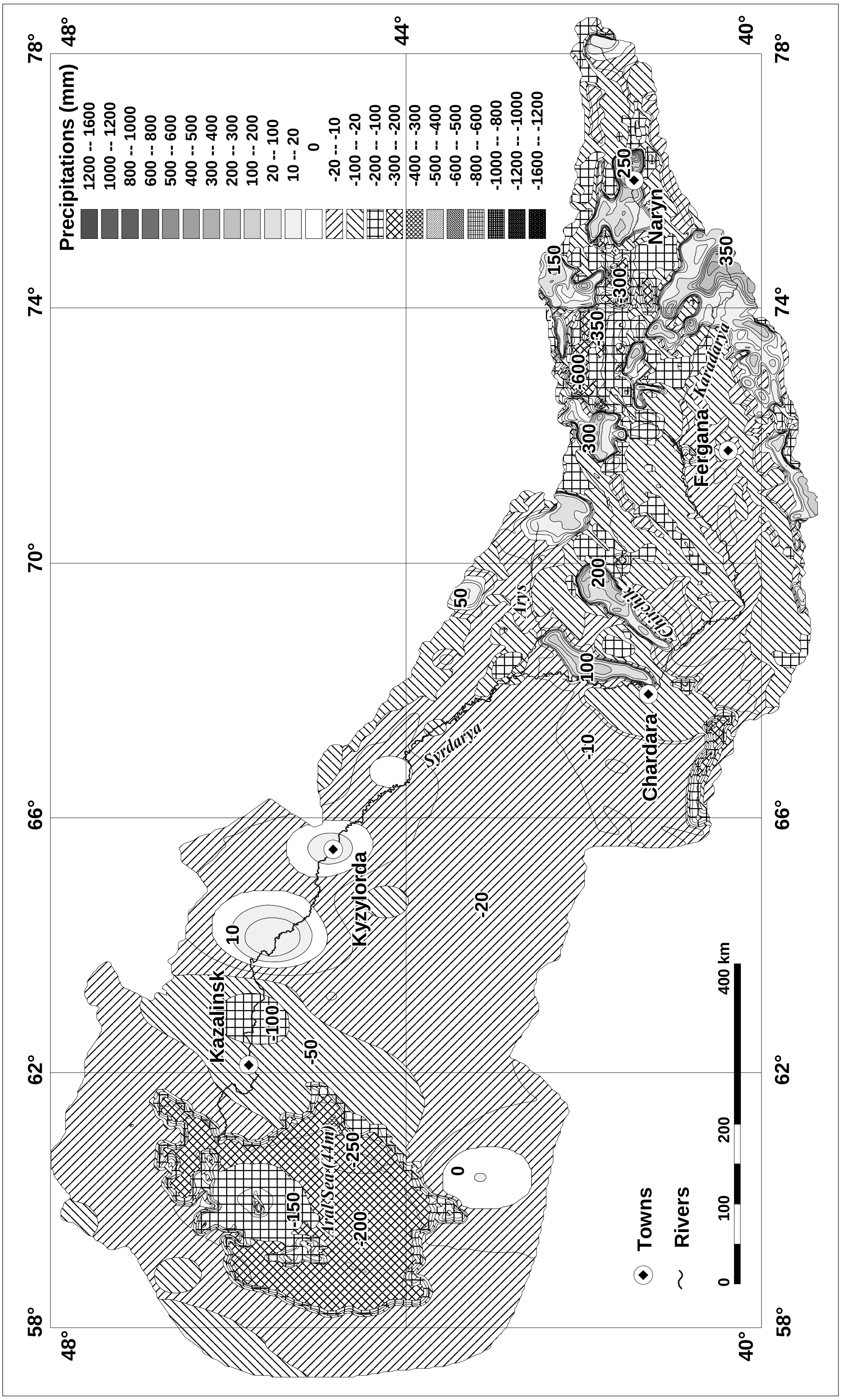

Figure 15. Map of differences between average annual precipitations (mm) of Syrdarya River basin of the eightieth and sixtieth years.

In the period from 1960 until 1989 years, the rearrangement of regional circulation, which has begun in the seventieth years, was stabilized also a regime of precipitations storage has got resistant character (Figure 15). It has found the reflectance in a field of change of precipitations with well contoured ranges of changes and high gradients in conversion zones. Decreasing of precipitations in a flat territory changes was in limits -5 ÷ -50 mm/year, for low-mountainous zones -50 ÷ -150 mm/year and for middle-high-mountainous zone of Internal Tien-Shan -200 ÷ -600 mm/year. In ranges of the increased humidifying Western Tien-Shan and the Fergansky ridge of the central part of Syrdarya River basin, Talassky and Kyrgyzsky ridges in north-east, Turkestansky and Alaysky ridges of the marginal south terrain the precipitations amount has increased on 50 ÷ 350 mm/year. For twenty years the precipitations for aquatory of Aral Sea has essentially decreased on -150 ÷ -250 mm/year.

Changes regional of precipitations storage in the seventieth - the eightieth years educed as follows:

- Over-all regional decrease of precipitations amount in the season 1970 – 1989 years allows to characterize it as moderately droughty;
- Conversion of regional circulation of an atmosphere, which result was decrease of average precipitations amount on decades in region, educed in a direction of total decreasing of precipitations for flat and low mountainous zones and particulate augmentation of their amount in middle and high-mountainous altitudinal zones;
- Stabilization of process of change such as atmospheric circulation has taken place in the eightieth years;
- The minimum of precipitations for the seventieth years had deficiency of 8.15 % from a level of the sixtieth years;
- In the eightieth years deficiency of precipitations has made 5.52 % from a level of the sixtieth years.

Evaporation

Evaporation is the main amounting account part of a water balance which in basic depends on the thermal status, atmospheric humidity and is limited by terrains precipitations storage regime. Evaporation is most sensitively reacting to changes of economic activities in regions with an arid climate from all investigated climatic parameters. An evaluation of integrated values of evaporation in Syrdarya River basin on decades 1970 – 1979 years and 1980 – 1989 years shows that it has increased in the seventieth years till 6.13 %, and in the eightieth years till 9.43 % from level of the sixtieth years (Figure 16).

Annual evaporation of the period 1970 – 1979 years for eastern part of Syrdarya River basin is not enough distinguishable from values of evaporation of the period up to 1969 years (Figure 18). Changes of quantity indicators of average annual evaporation in this part of basin basically are caused by change of regime precipitation storage in mountain areas, building of new reservoirs in zones of economic development and have restricted distribution. The most significant changes of evaporation regime have taken place in a north-eastern part of Syrdarya River basin at the turn of Talassky and Kyrgyzsky ridges. Here average annual evaporation has values 300 ÷ 400 mm/year. In this mountain area, on again built Toktogulsky water reservoir and evaporation for its area has increased up to 800 mm/year. Other potent source of evaporation – shallow Arnasaysky water reservoir has high intensity of average annual evaporation 1400 ÷ 1600 mm/year. In the central and north-western parts of region conversion of a spacing of evaporation was the result of a flooding of the new agricultural areas in Kazalinsk, Kyzylordinsky, Dzusalinsky and Shieli-Dzanakorgansky irrigation fields and also as a result of decreasing of the area of Aral Sea. Changes of average annual evaporation in new irrigated terrains had fractional character, which are introduced, as a rule, families of small areas of the increased values of evaporation by intensity 200 ÷ 250 mm/year. In the seventieth years, Aral Sea was in zone of small regional increase of air temperatures (Figure 8). In this decade, the level of Aral Sea has gone down on the average up to 44 m. The precipitations amount for its aquatory has decreased (Figure 14). The assemblage of these processes has become the cause of raise of evaporation from a surface of Aral Sea. The range of average annual evaporation 1200 mm/year in the seventieth year was passed round by magnitude the north further, than in the sixtieth years. At the same time, in a zone of a drained bottom evaporation has strongly decreased because of disappearance here free water.

The climatic changes, which have occurred for twenty flying from 1960 until 1989 years, were not reflected a little appreciably in an over-all regime the climatic caused average annual evaporation of Syrdarya River basin (Figure 19). Exclusion is the north-western part of Internal Tien-Shan, where in intermountain valleys of Naryn River basin and its inflows is observed small lowering evaporation with mean 100 ÷ 200 mm/year and for mountain ridges 250 ÷ 400 mm/year. Serious changes of an annual regime of evaporation in the eightieth years have taken place on the irrigated agricultural areas in the lower flow Syrdarya River. For this period is necessary maximum of intensity of economic development Kazalinsky, Kyzylordinsky, Dzusalinsky and Shieli-Dzanakorgansky areas of irrigation. In such terrains the essential augmentation of evaporation is observed. In the eightieth years in ranges of diffusion anthropogenic changed landscapes mean of evaporation change over a wide range 250 ÷ 800 mm/year. Common regional increase of air temperature in the eightieth years (Figure 9) promoted augmentation of average annual evaporation from a surface of water reservoirs in mountain areas of basin. For water Toktogulsky reservoir its magnitude is equal 1000. Evaporation in drained zone of Aral Sea has decreased up to 200 mm/year while it is strong the sea aquatory evaporated on the average 1200 mm/year.

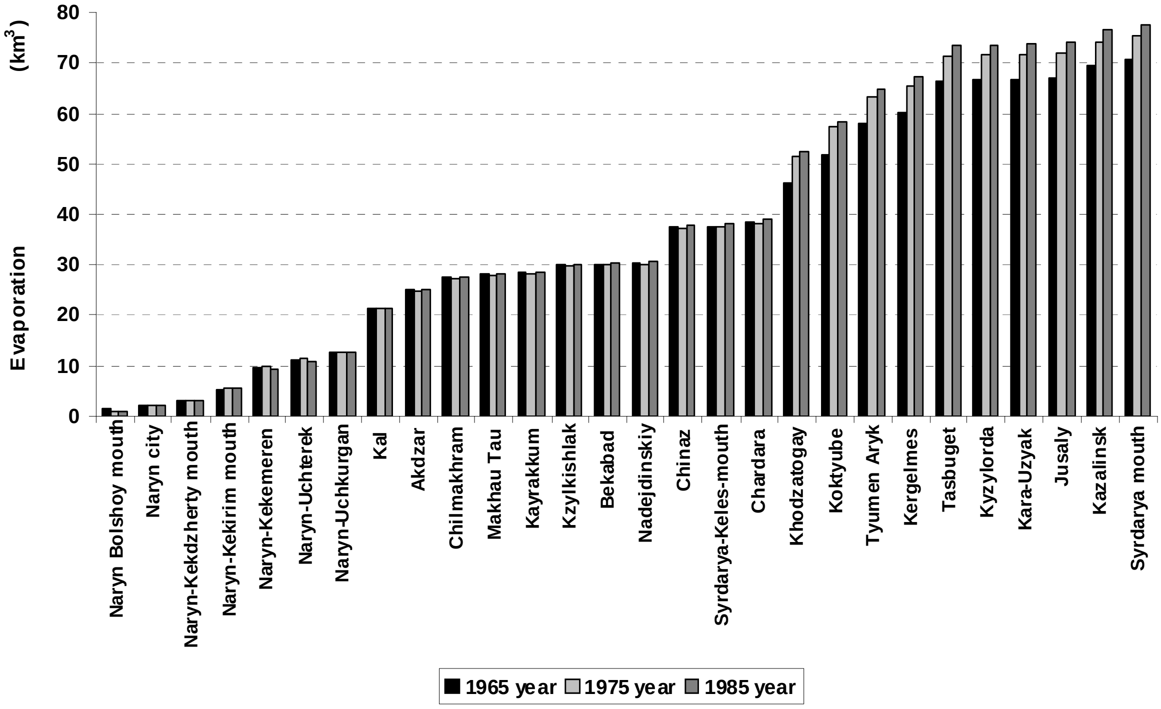

Figure 16. Changes of annual evaporation on hydroposts Syrdarya River on decades.

Variability of evaporation between decades

The detailed analysis occurred in the season 1960 – 1979 years of changes of a regime of annual evaporation in Syrdarya River basin shows that three factors influencing spacing and magnitudes of evaporation differently prove in dependence on developed conditions – thermal regime, regime precipitation storage and anthropogenic press on natural habitat. On a suppressing part of a dry land with an arid climate in the capacity of a primary factor influencing between decade's change of average annual evaporation variability between decade's of regime precipitations storage is. Decreasing in the seventieth years of amount of a falling out precipitations in comparison with a level of the sixtieth years (Figure 14) has predetermined decrease of evaporation rate on the average on -10 ÷ -50 mm/year, and in intermountain depressions of north-western area of Internal Tien-Shan most injured of a drought up to -100 ÷ -250 mm/year. At the same time, increase of precipitations amount in the central range of Internal Tien-Shan in a combination to increase of a regional temperature background promoted an intensification of average annual evaporation on 10 ÷ 20 mm/year. As against the climatic caused landscapes, evaporation with intrazonal and anthropogenic changed landscapes in the greater extent is determined by change of water requirement and a thermal regime. Despite of raise of a regional temperature background in the seventieth years (Figure 8), in range of diffusion of silted intrazonal landscapes of delta Syrdarya River between decade's decreases of magnitude of average annual evaporation on-10 ÷-20 mm/year was observed. Within a decade, natural inundated landscapes have kept a regime of evaporation by the constant season in comparison from the sixtieth years. In zones of development of anthropogenic landscapes – new irrigational nets and irrigated agricultural lands, there were significant changes of a regime of evaporation. All again mastered in the season 1970 – 1979 years agricultural terrains in Kazalinsky, Dzusalinsky, Kyzylordinsky and Shieli-Dzanakorgansky areas of an irrigation are characterized by raise of annual evaporation on the average on 50 ÷ 150 mm/year in comparison with a level of the sixtieth years.

The strongest changes of a regime of evaporation for ten years have taken place in areas for created of new water reservoirs and in a zone of a drained Aral Sea bottom. In middle mountainous zone in area of located of Toktogulsky water reservoir average annual evaporation has increased on 600 ÷ 800 mm/year in comparison with a level of the sixtieth years. Arnasaysky water reservoir, which located on plain of southern part of Syrdarya River basin, has increased intensity of annual evaporation for 1400 mm/year. Old large water reservoirs – Chardarinsky and Kayrakkumsky, for ten years have increased a level of average annual evaporation on 20 ÷ 50 mm/year. Change of a regime of evaporation of Aral Sea was affected with decreasing of the area of its aquatory and regional raise of a temperature background. The assemblage of these factors has become the cause of over-all between decade's raise of average annual evaporation on 20 ÷ 50 mm/year, and in places of education of new shoal waters on 200 ÷ 700 mm/year. In eastern and southern zones of a drained bottom of Aral Sea in the seventieth years strong level recession of evaporation is observed on -350 ÷ -1000 mm/year.

Changes of annual evaporation regime of Syrdarya River basin for the period 1960 – 1989 years have the fragmentary and limited spatial distribution (Figure 21). For the overwhelming majority climatic the caused landscapes the mode of annual evaporation of region of the eightieth years appeared is practically indistinguishable a similar mode of evaporation of the sixtieth years. Insignificant decreasing of intensity of evaporation on -10 ÷ -20 mm/year for twenty years is marked in middle-mountainous zone of the western Tien-Shan and a Turkestansky ridge. Middle-mountainous depressions of the western part of Internal Tien-Shan are characterized by relative decreasing by a level of average evaporation for the given period on -50 ÷ -100 mm/year. In the central part of Internal Tien-Shan is marked a small area of relative increase of annual evaporation on 20 ÷ 50 mm/year in comparison with the period up to the end of the sixtieth years. On a background of absence of changes of average annual evaporation on plains with natural ultraarid landscapes areas of change of evaporation in zones of agricultural activity which reason was the maximal intensification of water use for needs of irrigated agriculture in the eightieth years more contrast are marked. For twenty years, all irrigated agriculture areas of the lower flow of Syrdarya River – Kazalinsky, Dzusalinsky, Kyzylordinsky, Shieli-Dzanakorgansky and Chardarinsky Turkestansky and Bayrkum-Chardarinsky are distinguished in a field of changes of annual evaporation as compact families of local relative increases of evaporation on the average on 20 ÷ 150 mm/year, and places up to 300 ÷ 400 mm/year. For twenty years from 1960 until 1989 the strongest changes of a mode of evaporation have taken place in areas of education of new reservoirs and in a zone of Aral Sea drained bottom. For middle-mountainous Toktogulsky reservoir annual evaporation has increased by 800 mm/year in comparison with a level of the sixtieth years. For flat southern part of Syrdarya River basin for Arnasaysky reservoir is observed relative increase of annual evaporation on 1200 mm/year. Old water basins – Chardarinsky and Kayrakkumsky, for twenty years have increased a level of annual evaporation on 50 ÷ 100 mm/year. Change of a mode of evaporation of Aral Sea was affected with decreasing of the area of its water area on a background of total increase of regional air temperatures for the eightieth years. Set of these factors caused the general increase of average annual evaporation on 20 ÷ 50 mm/year for the period 1970 – 1989 years and in places of created of new shoalinesses on 200 ÷ 250 mm/year. For an extensive zone of the drained bottom of Aral Sea in the eightieth years strong decrease in a level of evaporation is observed on -600 ÷ -1200 mm/year.

Changes of regional evaporation in the season with 1969 on 1989 years educed as follows:

- Intra annual distribution of evaporation for the normative period shows:
  - on plains and in low mountain an altitudinal zone of a ultraarid climatic zone the maximum evaporation from a surface of a dry matter is limited by quantity(amount) of a falling out precipitations and consequently it is dated for the most humidified spring and autumn seasons;
  - in middle mountainous zone with semi-humid and humid types of landscapes, with a spring-and-summer maximum precipitations storage the season of intensive evaporation is extended due to inclusion in it of a summer season;
  - in a high-mountainous zone the season of the maximum evaporation is limited by a thermal regime and therefore restricted only by a summer season.
- The season 1970 – 1989 years is characterized by over-all raise of evaporation in the lower flow Syrdarya River and above aquatory of Aral Sea;
- The causes of increase of evaporation were:
  - regional raise of air temperatures;
  - appearance in the seventieth years in an southern part of basin of new shallow water reservoirs and shallows of Aral sea;
  - expansion of the areas of an irrigation farming mainly under water consumption agricultural crops – cotton and rice;
  - construction of new irrigational nets on old technologies.

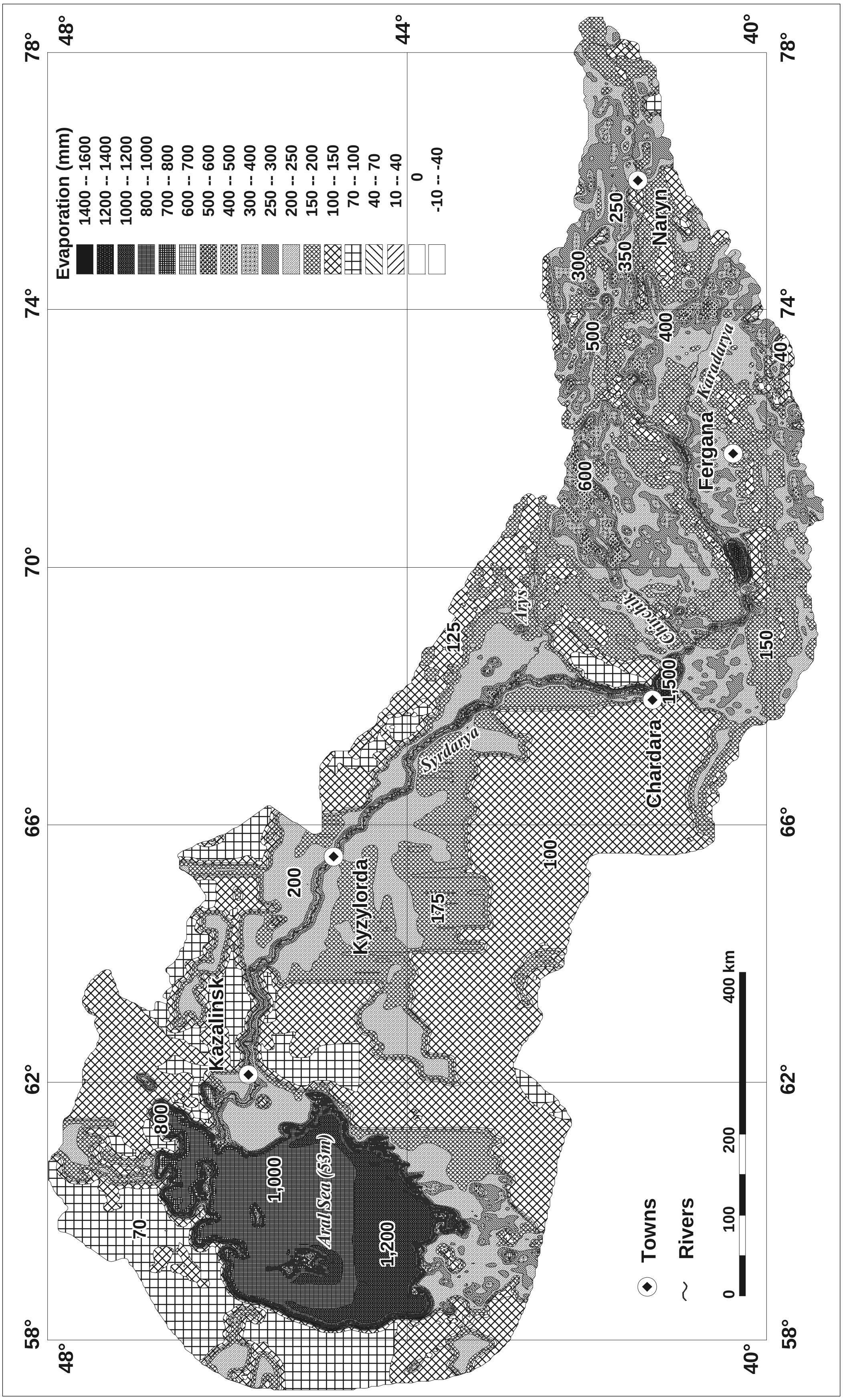

Figure 17. Map of average annual evaporation (mm) of Syrdarya River basin for the sixtieth years.

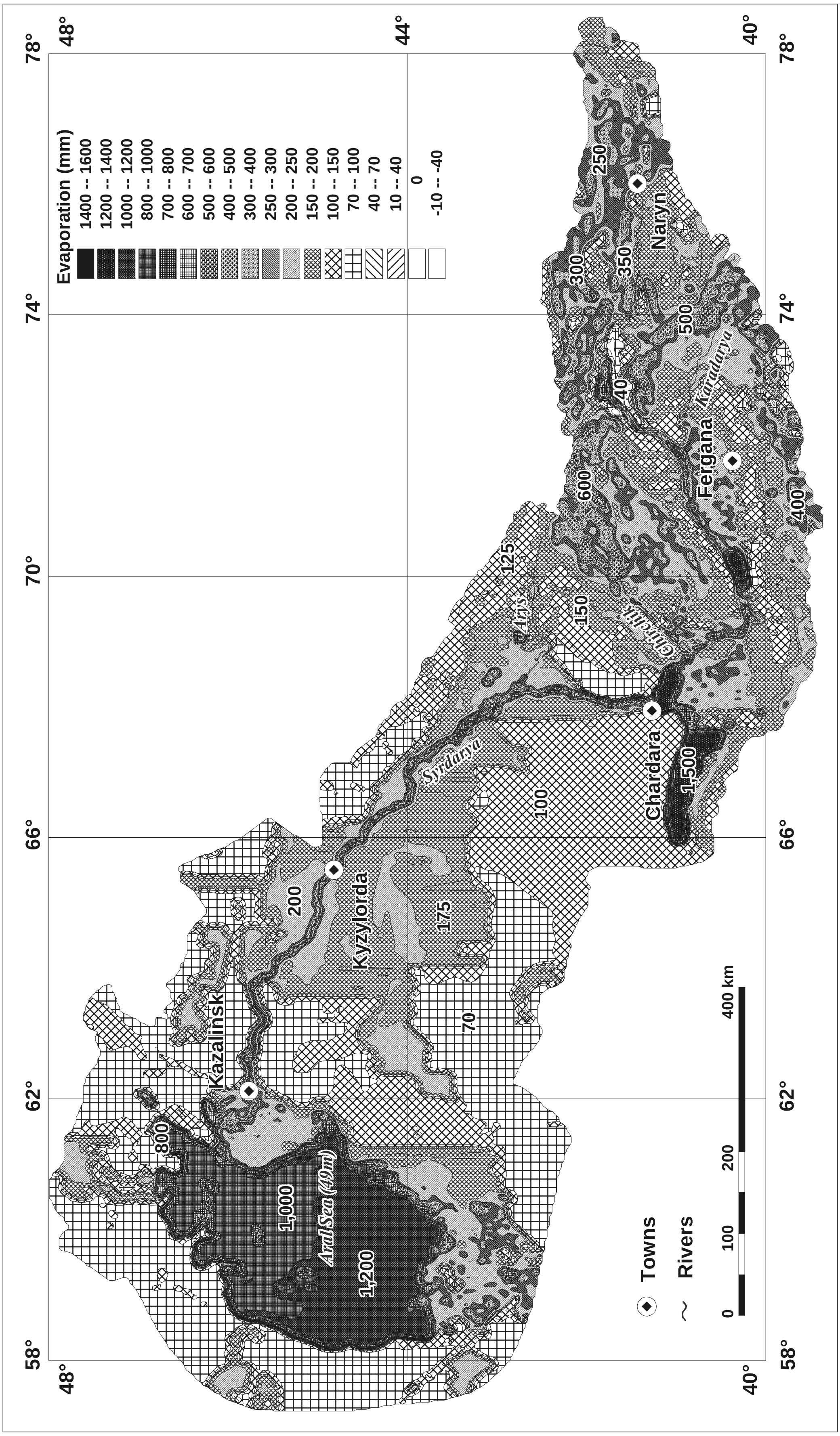

Figure 18. Map of average annual evaporation (mm) of Syrdarya River basin for the seventieth years.

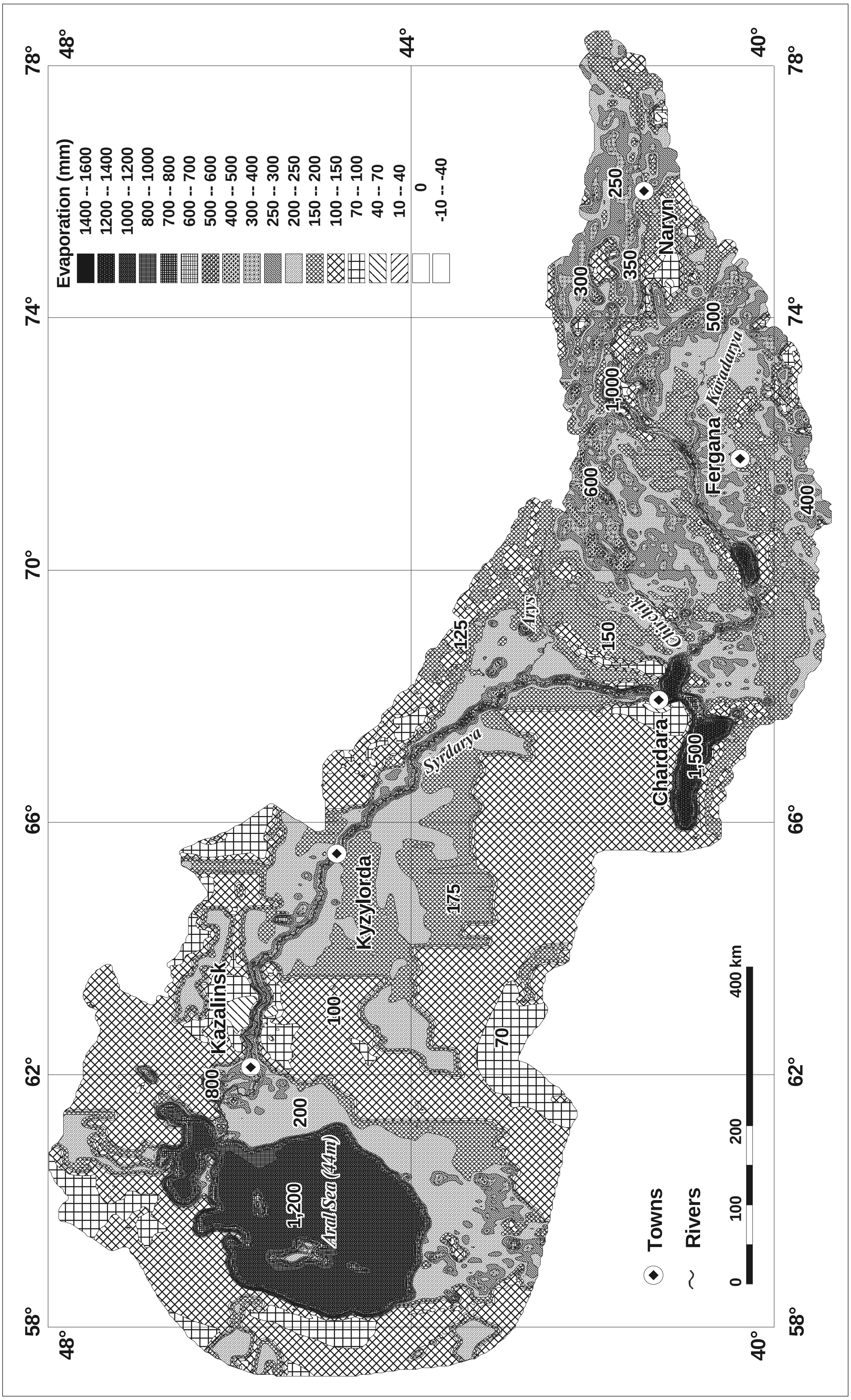

Figure 19. Map of average annual evaporation (mm) of Syrdarya River basin for the eightieth years.

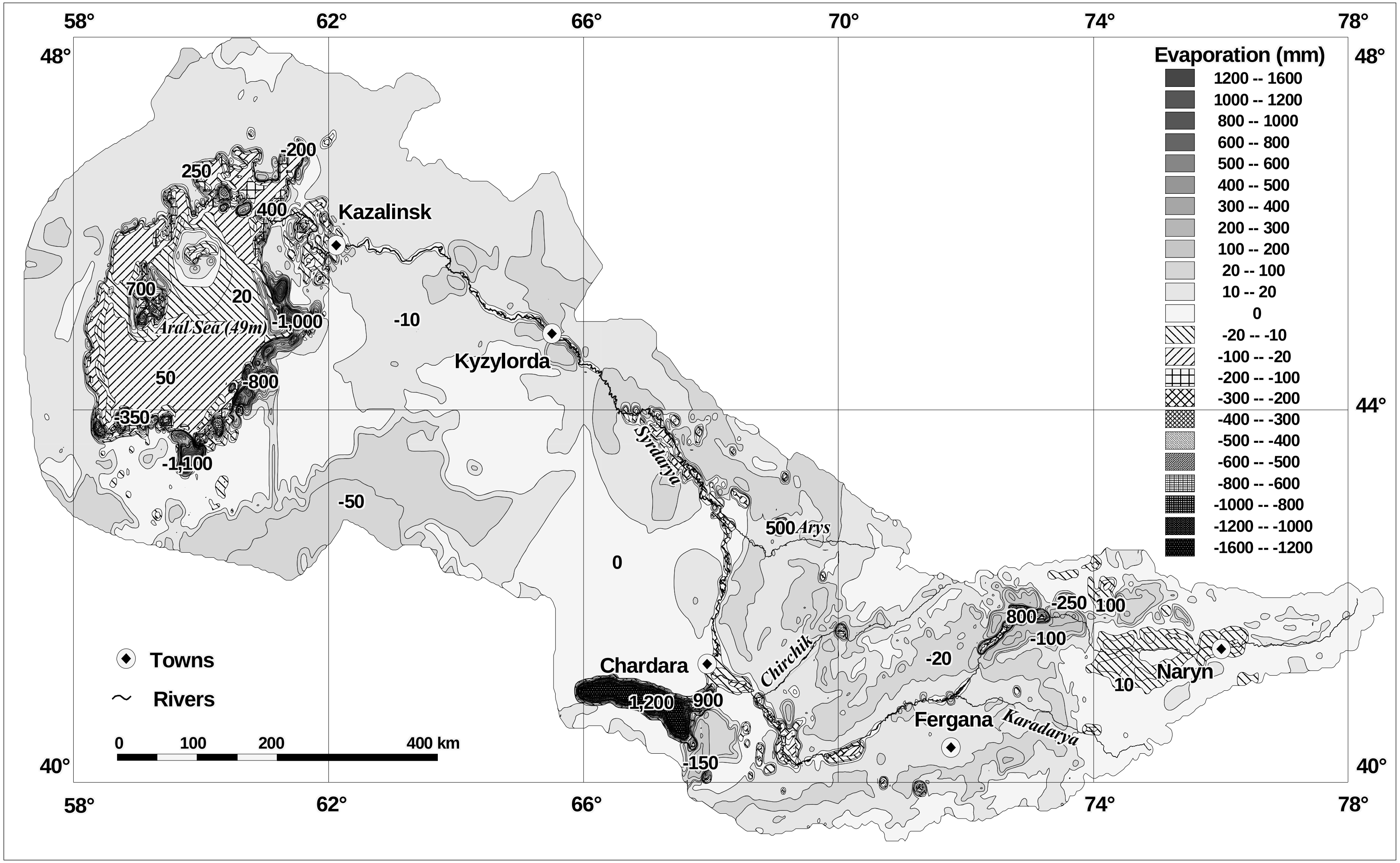

Figure 20. Map of differences between average annual evaporation (mm) of Syrdarya River basin for the seventieth and sixtieth years.

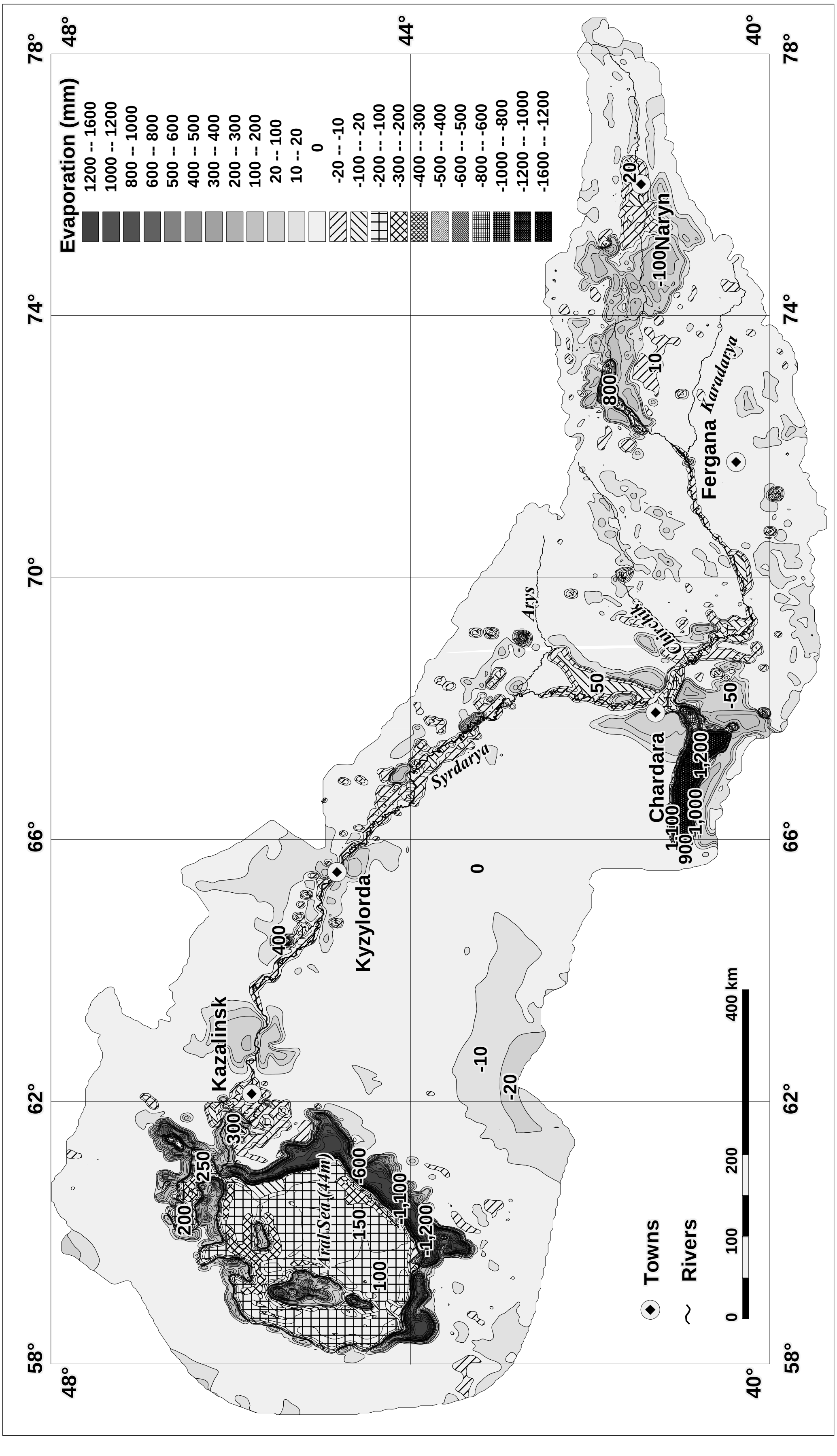

Figure 21. Map of differences between average annual evaporation (mm) of Syrdarya River basin for the eightieth and sixtieth years.

Water balance

The water balance is a parameter reflecting a ratio of a precipitations and evaporation and having the important practical value for economic activities. The analysis of time changes of a water balance in Syrdarya River basin for the periods 1970 – 1979 years and 1980 – 1989 years shows that it has decreased accordingly for -35.7 % and on -34.6 % from a base level of the sixtieth years (Figure 22).

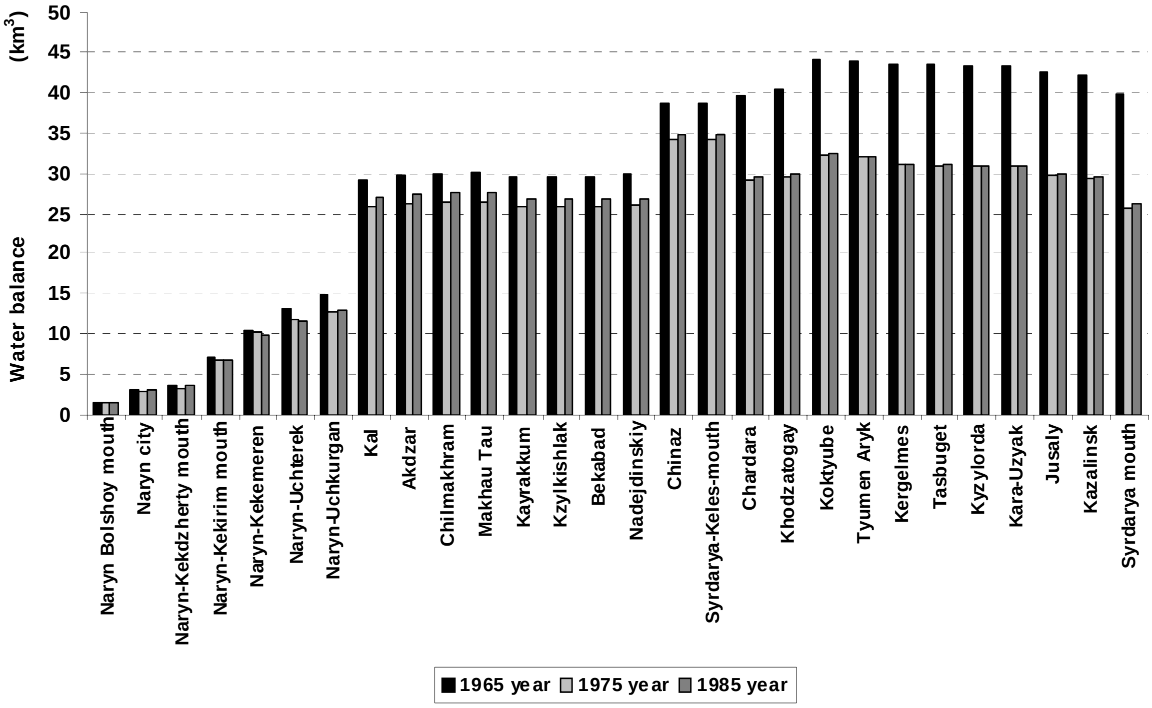

Figure 22. Changes of annual cumulative water balance on hydroposts Syrdarya River on decades.

The causes, which have caused existential changes of water balance, on the nature share on climatic, anthropogenic, on scale of influence on regional, and aboriginal. To the regional factors promoting its decreasing in Syrdarya River basin, raise of air temperature background and decreasing of precipitations amount refer to. Local factors are conditioned to anthropogenic activity.

Headstreams and average flow Syrdarya River for twenty flying less all has been mentioned by changes of economic activities. So, for the seventieth years on a background of a regional drought and filling Toktogulsky reservoir, in place of hydropost Uchterek on Naryn River decreasing of annual water balance on -14.46 % from a level of the sixtieth years is marked. In the eightieth years at small regional raise of precipitations amount and after commissioning Narynsky hydroelectric system decreasing of a water balance has made -12.66 % from a level of the sixtieth years. On the middle flow of Syrdarya River, for Nadejdinsky in the seventieth years decreasing of a water balance has made -13.27 %, in the eightieth years -10.13 % from a level of the sixtieth years.

Significant decreasing of water balance for the period 1970 – 1989 years in the lower flow of Syrdarya River is caused by expansion and an intensification of the agriculture irrigation areas for territory of Kazakhstansky Priaralie – Kazalinsky, Kyzylordinsky, Dzusalinsky, Shieli-Dzanakorgansky and Arys-Turkestansky irrigation fields. For area of hydropost of the mouth Keles River, which is located on an orifice Syrdarya River in Chardarinsky water reservoir, decreasing of magnitude of an annual water balance in the seventieth years has made -11.31 % and in the eightieth years -9.90 % concerning a level of the sixtieth years. For hydropost Chardara located at the inferior transit of Chardarinsky water reservoir on distance 65.4 km from a hydropost a mouth Keles River, in the period 1970 – 1989 years is observed intermittent decreasing of a water balance up to -25.52 % and -26.06 % accordingly in comparison with a level of the sixtieth years. As it was specified above (Figure 4), the greatest local losses of water are observed on Arnasaysky reservoir (Table 2).

Values of the total losses from Arnasaysky reservoir are computed as a difference between the measured data on hydroposts Syrdarya River - Chardara, and Syrdarya River - mouth of Keles River, minus of losses of water resources from Chardarinsky reservoir.

Table 2. The losses of water resources for Arnasaysky reservoir.

Time period	Losses of water resources km^3/year		
	Total, including	for evaporation	other
1970-1979	-5.76	-5.76	0
1980-1989	-6.41	-5.94	-0.47

The analysis of the received results shows, that for the seventieth years the Arnasayskiy water basin was not used in the economic purposes and consequently the general losses of water stocks are equal to losses on evaporation (*Table 2*). For the eightieth years on this area the agricultural irrigated fields were created. It was the reason of additional withdrawal water on irrigation in volume *-0.47 km^3/year*. The share of Arnasayskiy water reservoir in the general losses of water store relatively of value of potential water balance has made on the average for the period:

- 1970-1979 years 14.21 % from total water balance of Syrdarya River basin, which had value 25.64 km^3/year;
- 1980-1989 years 16.16 % from total water balance of Syrdarya River basin, which had value 25.07 km^3/year.

Cumulative losses of a water balance on the new agricultural areas and irrigational nets in areas of an irrigation farming of the Kazakhstan Priaralie estimates in limits -4.15 km^3/year for the seventieth years and -2.44 km^3/year for the eightieth years. Over-all climatic losses of a water store of Syrdarya River basin for twenty years of a drought estimate in limits -4.45 ÷ -4.95 km^3/year.

Average water balance on decades

Spacing distribution of average annual water balance volumes from elementary platforms *(area 30 geogr. sec.* 30 geogr. sec. ≈ 1 km^2)* in the season up to the end of the sixtieth years gives representation about potential water resources in Syrdarya River basin (Figure 23). In a zone of diffusion the climatic caused arid landscapes the water balance northern and north-western part of region is equal 0 ÷ 20000 m^3/km^{2}year. On plains of the central part of basin the average annual water balance changing in limits 20000 ÷ 50000 m^3/km^{2}year. All mountain terrains are characterized by positive values of an annual water balance and are the main supplier of water resources in basin p. Syrdarya. In mountain Karatau and Borolday ridges the average annual balance is equal 150000 ÷ 250000 m^3/km^{2}year. The highest values of an annual water balance in Western Tien-Shan are fixed in the interval of 800000 ÷ 1600000 m^3/km^{2}year. The little smaller values of an annual water balance in Talassky, Kyrgyzsky, Fergansky and Alaysky ridges, which are in limits 800000 ÷ 1300000 m^3/km^{2}year. In mountain areas of Internal Tien-Shan of magnitude of an annual water balance are in the interval 400000 ÷ 700000 m3/km2year. Droughty intra mountain depressions of a western part of this range have average annual balance of limits 0 ÷ 50000 m3/km2year. In a Turkestansky ridge an average annual water balance rather low 250000 ÷ 400000 m3/km2year. Intrazonal and anthropogenic changed landscapes are marked as range with negative values of average annual balance. Intrazonal landscapes are introduced to marshy deltas of the Syrdarya and Amudarya Rivers with numerous shallow lakes, the extensive areas of solonchaks to a left bank of the lower flow Syrdarya River and river's inundation meadows. Typical values of an average annual water balance in these zones for the sixtieth years -50000 ÷ -100000 m^3/km^{2}year. Bayrkum-Chardarinsky and Fergansky irrigation areas refer to anthropogenic landscapes on the middle flow of Syrdarya River, Kazalinsky, Kyzylordinsky, Dzusalinsky, Shieli-Dzanakorgansky agricultural irrigation areas in the lower flow of Syrdarya River, which have of volumes deficiency of a water balance -100000 ÷ -200000 m^3/km^{2}year, and places up to -350000 m^3/km^{2}year. The greatest losses of water resources in conversion per unit are dated the area for water reservoirs that is caused by very high intensity of average annual evaporation in this period (Figure 20). Chardarinsky, Kayrakkumsky water reservoirs, other numerous shallow lakes and artificial water reservoirs in the sixtieth years lost water on the average e-1400000 ÷ -1600000 m^3/km^{2}year. But the most potent user of water resources in region is Aral Sea. Ranging on marginal north-western of terrain, it does not differ of maximum high intensity of leakage of water -700000 ÷ -1100000 m^3/km^{2}year, but having the greatest area of evaporation Aral Sea is the main natural user of water resources of basin. In the period up to 1969 years average annual deficiency of a water balance from all area of aquatory has made -51256 m^3/km^{2}year.

The annual water balance for the season 1970 – 1979 years to the full reflects changes of a climatic regime and intensifying of economic activities in Syrdarya River basin (Figure 24). Owing to increase of air temperature (Figure 8) and decreasing of precipitations amount in north-western and eastern parts of basin (Figure 14) the annual water balance also has decreased also a zone of its zero values has extended. In ranges of diffusion of river river-delta and inundated landscapes deficiency of water balance has amplified up to -100000 ÷-150000 m^3/km^{2}year, and for the areas of intensive irrigation agriculture up to -150000 ÷ -250000 m^3/km^{2}year.

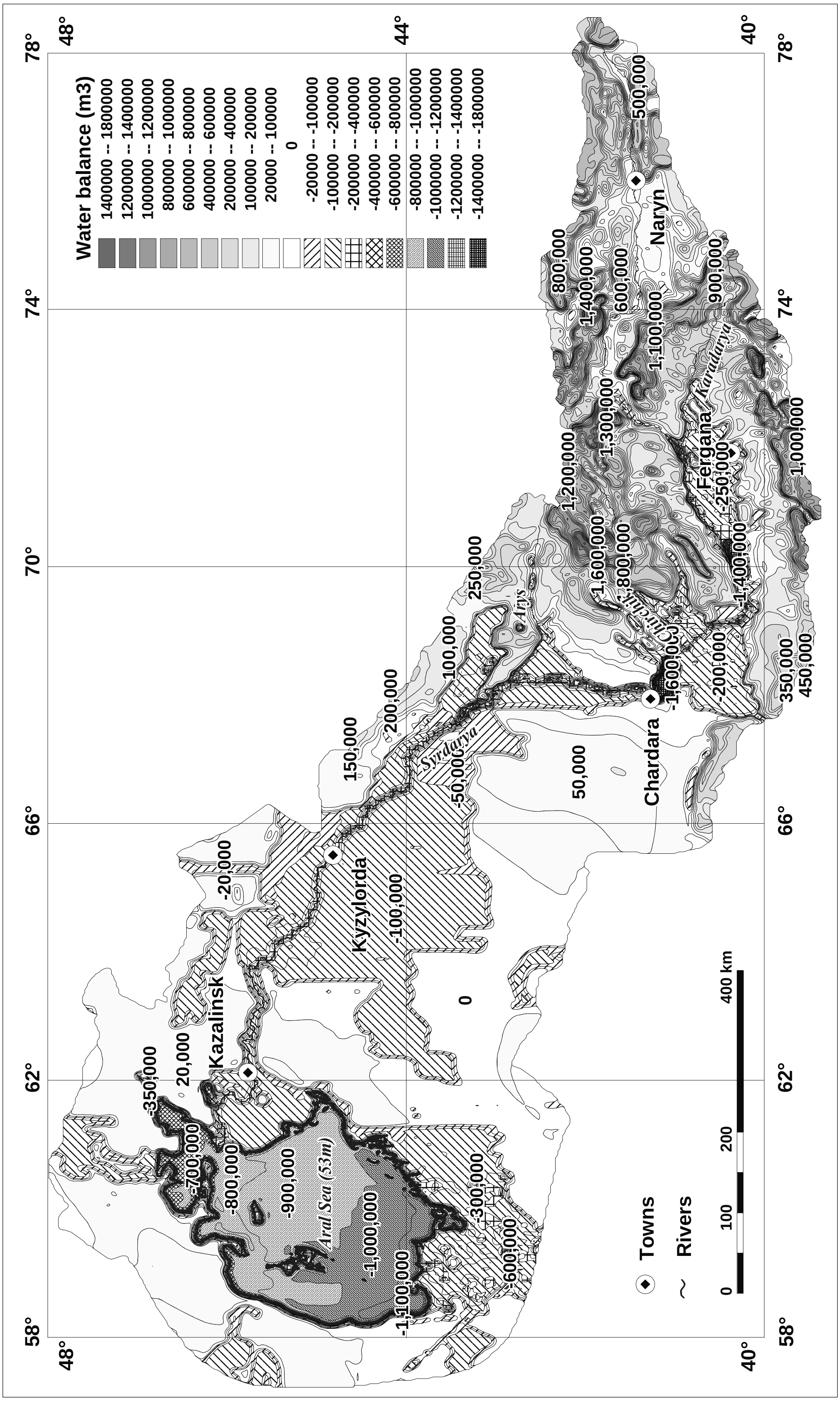

Figure 23. Map of average annual water balance (m^3) of Syrdarya River basin for the sixtieth years.

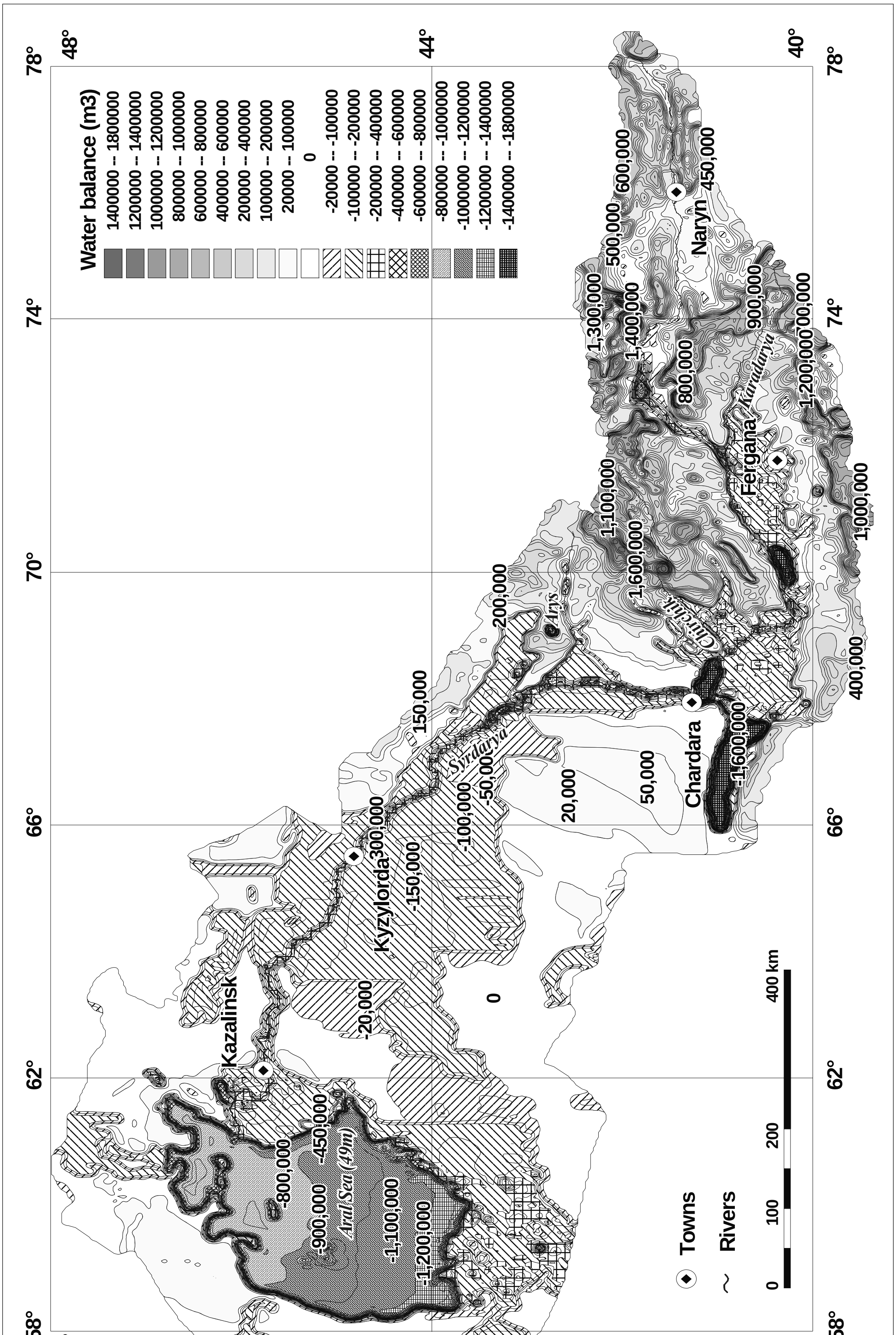

Figure 24. Map of average annual water balance (m^3) of Syrdarya River basin for the seventieth years.

Because of level rise of underground water, as consequences of an intensification of irrigation, the area of solonchaks in a left bank of the lower flow Syrdarya River has extended so, that has merged with the analogous areas of delta Amudarya River. In mountain Karatau and Borolday ridges the average annual balance has decreased up to 100000 ÷ 200000 m^3/km^2year maximum high values of an annual water balance 800000 ÷ 1600000 m^3/km^2year are dated for a middle-high-mountainous zone of Western Tien-Shan. Values of a water balance in Talassky, Kyrgyzsky, Fergansky and Alaysky ridges are limits 800000 ÷ 1400000 m^3/km^2year. In mountain areas of Internal Tien-Shan the annual water balance of the seventieth years varies in the interval 450000 ÷ 600000 m^3/km^2year. Average annual water balance for Turkestansky ridge has remained constant 250000 ÷ 400000 m^3/km^2year. Formed in the seventieth years middle-mountainous Toktogulsky water reservoir has negative average annual balance -1000000 m^3/km^2year. Flat Arnasaysky, Chardarinsky and Kayrakkumsky water reservoirs also has negative average annual balance up to -1600000 m^3/km^2year. Owing to decreasing of Aral Sea level in the period 1970 – 1979 years on the average up to 49 m augmentation of the shallow area with the increased level of evaporation (Figure 24), deficiency of a water balance of its aquatory has increased up to -800000 ÷ -1200000 m^3/km^2year. Average annual deficiency of water balance from whole area of aquatory has made -56715 km^3/year. In a zone of a drained seabed at this time have received development solonchaks with average annual balance is -100000 ÷ -150000 m^3/km^2year.

Spacing distribution of an average annual water balance in Syrdarya River basin in the period from 1980 till 1989 years as a whole is close to parameters of the seventieth years and reflects the local differences. Deficiency of a water balance in southern and south-eastern Priaralie up to -100000 ÷ -200000 m^3/km^2year has a little decreased were more precisely marked out contours of the new areas of agricultural development in the lower flow Syrdarya River though deficiency of an average annual water balance of the eightieth years has remained at the same level, as in the seventieth years -150000 ÷ -250000 m^3/km^2year. For Karatau and Borolday mountains the average annual balance of the eightieth years is equal 100000 ÷ 150000 m^3/km^2year. For twenty years in the ranges framing from the eastern part of Syrdarya River basin, there were appreciable changes of a spacing of an average annual water balance. In Western Tien-Shan the water balance has decreased up to 800000 ÷ 1400000 m^3/km^2year. The range of values of an average annual water balance of the eightieth years in Talassky, Kyrgyzsky, Fergansky and Alaysky ridges is in limits 1000000 ÷ 1600000 m^3/km^2year that shows small augmentation of a water balance in comparison with a level of the sixtieth years. In mountain areas of Internal Tien-Shan in the eightieth year raise of a level of an annual water balance up to 500000 ÷ 800000 m^3/km^2year is observed. Thus, in intramountain hollows of a western part of this range decreasing of average annual balance up to marks-20000 ÷ 20000 m^3/km^2year is registered. In a Turkestansky crops the average annual water balance also has increased up to 300000 ÷ 800000 m^3/km^2year. In the eightieth years of magnitude of negative annual balance for new and old water reservoirs have remained constant: for Toktogulsky-1000000 m^3/km^2year, for Arnasaysky, Chardarinsky and Kayrakkumsky -1600000 m^3/km^2year. In the eightieth years the average level of Aral Sea has gone down on the average to 44 m. The total amount of water has decreased, and the area of well warmed up shoal waters has essentially increased. Therefore deficiency of an average water balance of Aral Sea in the eightieth years has increased in comparison with the sixtieth and the seventieth up to -1100000 ÷ -1400000 m^3/km^2year, or -55.849 km^3/year. In connection with decreasing of the area of Aral Sea the zone of a drained seabed, and solonchaks concomitant it has extended with deficiency of average annual balance in limits-100000 ÷-150000 m^3/km^2year. Together with the solonchaks caused by rise of a groundwater table in river-delta ranges and a left bank in the lower flow Syrdarya River, in the eightieth years they formed an extensive float in north-western range.

Variability of water balance between decades

The analysis of annual water balance changes for Syrdarya River basin 1960 - 1979 confirms conclusions of the previous paragraphs of the present report about increase of aridisation level of a climate in region. Total deficiency of water resources during the given period is determined basically by interdecade general increase of air temperatures (Figure 8), lack of natural humidifying of mountains (Figure 14) and economic activities. On a background of the general decreasing of annual water balance of the seventieth years in an interval of values on -20000 ÷ -50000 m^3/km^2year are less, than in the sixtieth years, areas with specific changes of water balance regime (Figure 26) are contrasted marked. For central part of region in local small mountain areas of the east part of Karatau ridge, a south-west ending of Western Tien-Shan and the western ending of Turkestansky ridge areas of interdecade relative increase of annual water balance level on 10000 ÷ 100000 m^3/km^2year are marked. For seventieth years the central and south-west parts of Internal Tien-Shan the area of increased water balance on 20000 ÷ 100000 m^3/km^2year is marked in comparison with a level of the sixtieth years. The most complex and significant changes of annual water balance are observed on junction of Talassky, Kyrgyzsky ridges and north-west ridges of Internal Tien-Shan. Here areas of strong relative interdecade decreasing of water balance on -150000 ÷ -600000 m^3/km^2year closely adjoin to areas of strong relative interdecade increasing of water balance on 150000 ÷ 600000 m^3/km^2year. Zones of intensive development of irrigated fields for Kazalinsky, Kyzylordinsky and Shieli-Dzanakorgansky agriculture areas for the seventieth years are marked as families of local decreasing of values water balance on -50000÷ -100000 m^3/km^2year of less level of the sixtieth years. For new Arnasaysky reservoir interdecade relative deficiency of water balance on -1600000 m^3/km^2year is observed. Interdecade deficiency of annual water balance for Toktogulsky reservoir is equal -1000000 m^3/km^2year. As a result of a shallow water and increased of heating of Aral Sea deficiency of its annual water balance has increased on the average on -100000 ÷ -300000 m^3/km^2year. On separate sites it achieved values up to -800000 m^3/km^2year. Meanwhile, on the drained bottom of change of annual water balance for the period 1970 – 1979 years show positive changes of an increment of its values on 300000 ÷ 800000 m^3/km^2year.

Changes of regime of spatial distribution of annual water balance for the period 1960 – 1989 show its small increase in a northwest part of Syrdarya River basin and its relative decreasing in east part (Figure 27). On plains and for an overwhelming part of mountain territory of change of water balance is variate within the limits of -50000 ÷ 10000 m^3/km^2year. For the western and north-west intermountain depressions of Internal Tien-Shan in the eightieth years essential decreasing of annual balance on -200000 ÷ -600000 m^3/km^2year is marked in comparison with a level of the sixtieth years. On this background in Western Tien-Shan, Talassky, Kyrgyzsky, Fergansky, Alaysky and Turkestansky ridges, and also for separate local river basins of Internal Tien-Shan rather small areas with positive changes of twenty years' changes of annual water balance on 50000 ÷ 400000 m^3/km^2year above a level of the sixtieth years are marked. The eightieth years are characterized as the period of the maximal intensification of economic activity for whole Aral region. Therefore, changes of annual water balance of Kazalinsky, Kyzylordinsky, Dzusalinsky, Shieli-Dzanakorgansky, Arys-Turkestansky, Bayrkum-Chardarinsky and Fergansky irrigation fields are marked as areas of interdecade relative decreasing of its values on -75000 ÷ -100000 m^3/km^2year. For area of an arrangement of Arnasaysky reservoir interdecade relative deficiency of water balance on -1600000 m^3/km^2year is observed. Interdecade deficiency of average water balance of Toktogulsky reservoir is equal -1000000 m^3/km^2year. As a result of strong falling a level and a shallow water of Aral Sea for twenty years its water balance has essentially gone down on -250000 ÷ -450000 m^3/km^2year. For a zone of its drained bottom evaporation has sharply decreased, and consequently interdecade relative increase of annual water balance on 500000 ÷ 800000 m^3/km^2year here is observed.

According to modelling change of a water balance for the season with 1970 on 1989 years educed as follows:

- For the period 1970 – 1979 years the annual water balance has decreased for -14.23 km^3/year from a base level of the sixtieth years, including:
  - over-all the climatic caused deficiency of a water balance of Syrdarya River basin for ten years of a drought with 1970 on 1979 years estimated in limits -4.45 km^3/year;
  - annual leakage of water for Arnasaysky water reservoir, which formed in the beginning of seventh decade, had volume -5.63 km^3/year;
  - joint losses of a water balance on the new agricultural areas and irrigational nets in areas of irrigation farming of the Kazakhstan Priaralie estimated in limits -4.15 km^3/year.
- For the period 1980 – 1989 years the annual water balance has decreased -13.80 km^3/year from a base level of the sixtieth years, including:
  - over-all the climatic caused deficiency of a water balance of Syrdarya River basin for twenty years of a drought with 1970 on 1989 years estimates in limits -4.95 km^3/year;
  - annual losses of water resources with formed in the beginning of the seventieth years of Arnasaysky water reservoir had volume -6.41 km^3/year;
  - joint losses of water stores on the new agricultural areas and irrigational nets of the Kazakhstan Priaralie estimated -2.44 km^3/year.
- • Shallows of Aral Sea for twenty years has caused intensifying evaporation from its surface, decreasing of precipitations amount and increase of air temperatures has resulted in progressing deterioration of a water balance of its aquatory, including:
  - for the normative period up to 1969 years at the average area of aquatory is 57050 km2. The losses of annual balance are equal -51.26 km^3/year or -898510 m^3/km^2year;
  - for the period 1970 – 1979 years at the average area of aquatory decreased up to 56770 km^2. The losses of annual balance are achieved -56.72 km^3/year or -999119 m^3/km^2year;
  - for the period 1980 – 1989 years at the average area of aquatory decreased up to 46070 km^2. The losses of annual balance are equal -55.85 km^3/year or -1212286 m^3/km^2year.

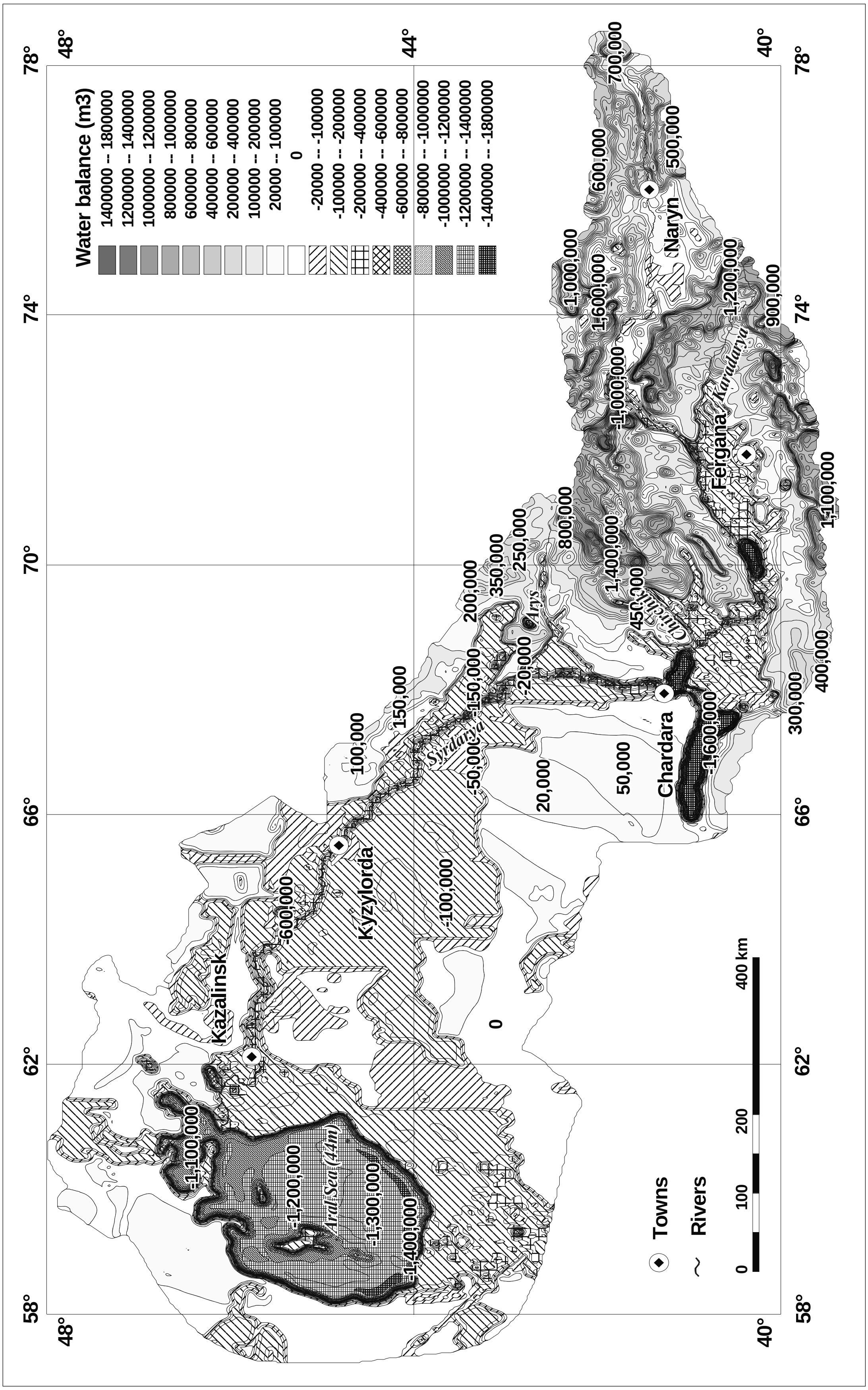

Figure 25. Map of average annual water balance (m^3) of Syrdarya River basin for the eightieth years.

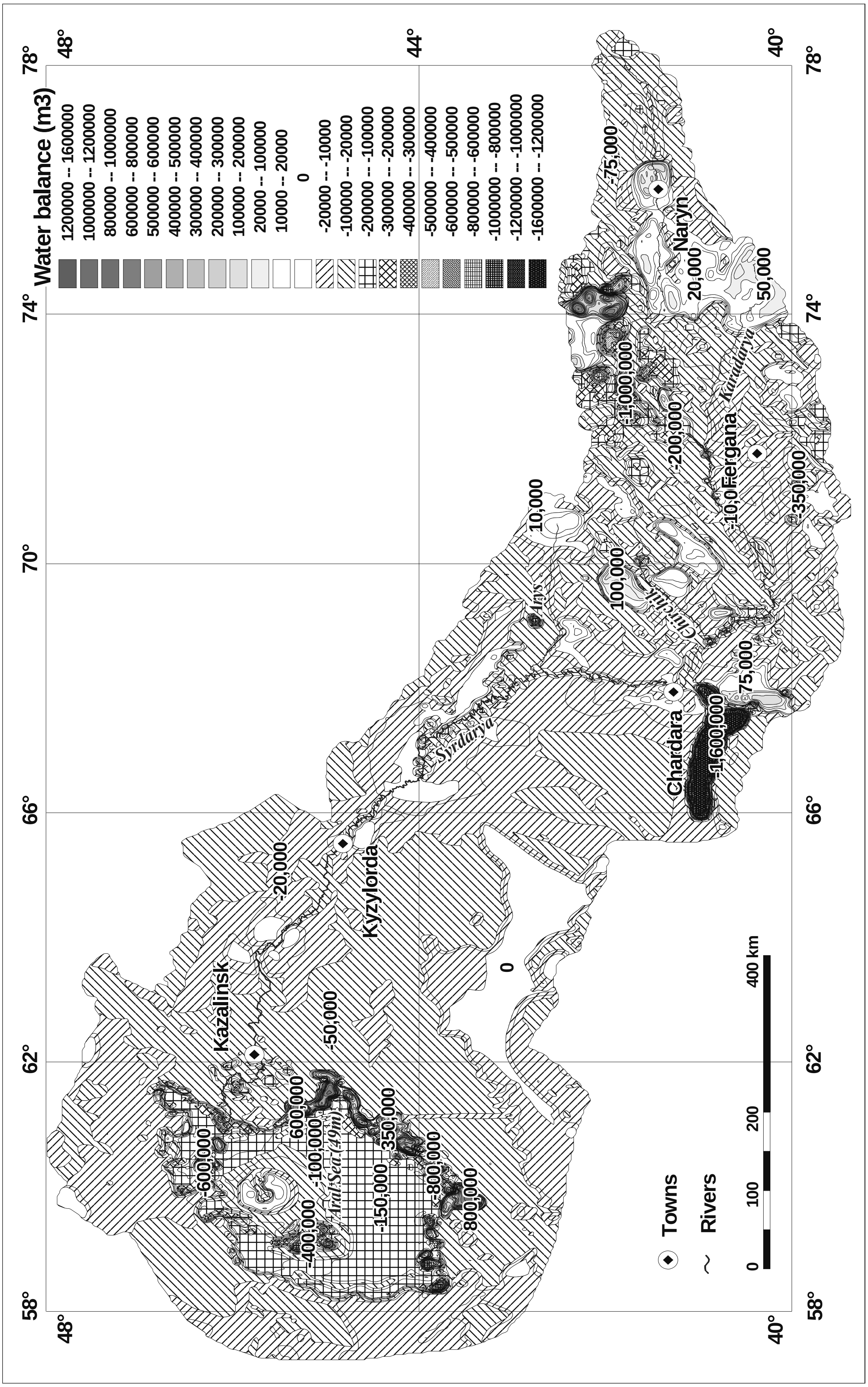

Figure 26. Map of differences between average annual water balances (m^3) of Syrdarya River basin for the seventieth and sixtieth years.

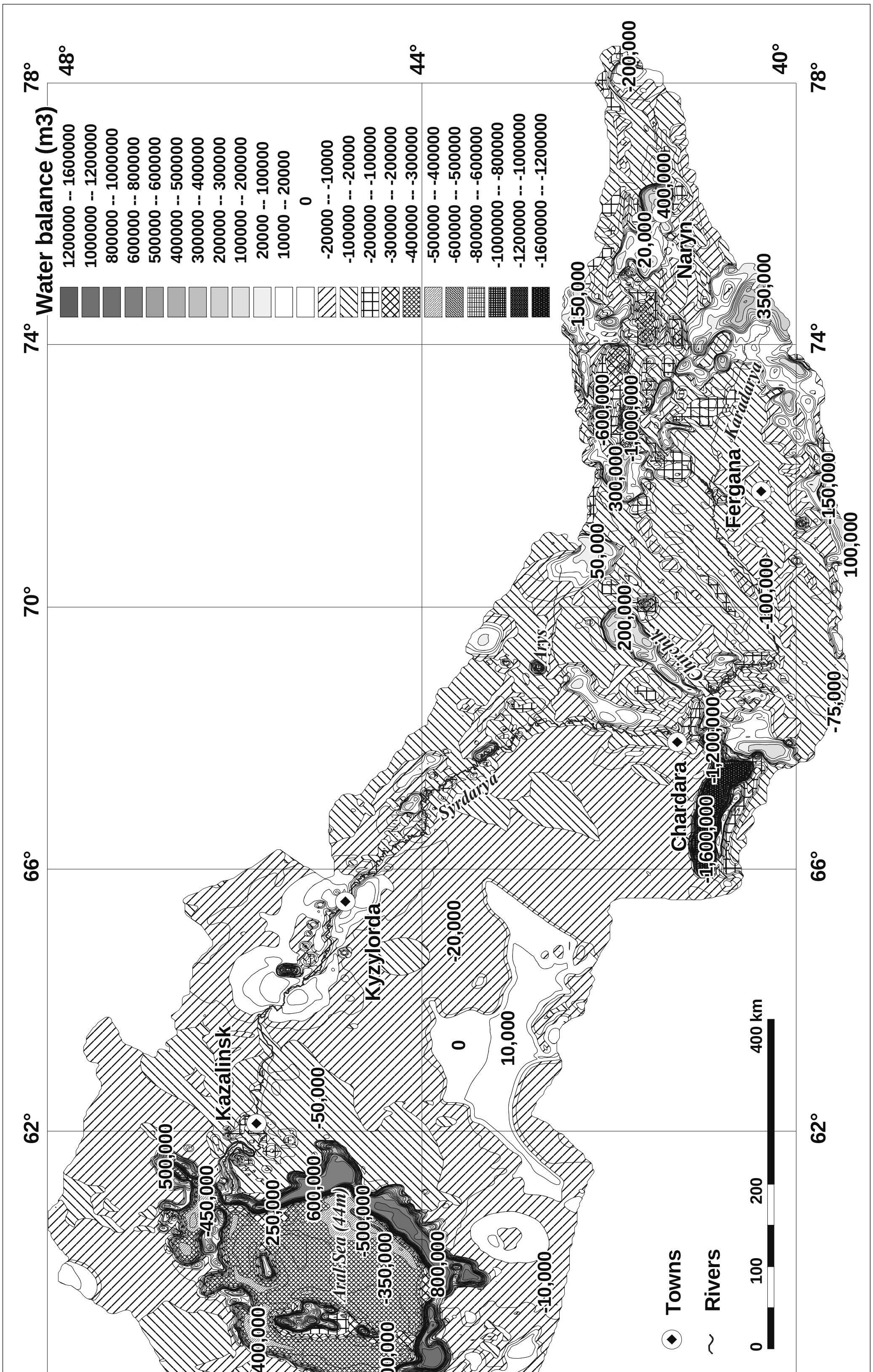

Figure 27. Map of differences between average annual water balances (m^3) of Syrdarya River basin for the eightieth and sixtieth years.

Conclusion

The analysis of existential changes of climatic indexes in Syrdarya River basin testifies that the twentieth years from 1970 until 1989 years is characterized by change such as regional atmospheric circulation, which began in the seventieth years and stabilized in the eightieth years. As a result of it due to increase of winter air temperatures in region, which was a increase of annual temperatures of air on magnitude ***0.3 ÷ 1.2 °C*** from a level of the sixtieth years. Influence of anthropogenic activity on formation and change of a temperature regime was local character and has been dated for large human settlements with the developed infrastructure, to irrigated agricultural areas and man-made reservoirs. On the after-effects anthropogenic loads did not render significant effect on the over-all climatic status of Syrdarya River basin. The greatest influence of economic activities on an aboriginal climate was showed in area of Aral Sea and other water reservoirs. On a measure of decreasing of the area of aquatory of Aral Sea the temperature regime of adjoining to it dry land varied aside the greater aridisation. Around of new created water reservoirs the aboriginal climate was softened due to relative lowering of summer air temperatures. Range of cooling influence of water surfaces on environing land does not exceed 10 ÷ 20 % from the dimensions of their aquatories and is profiled by dominating wind flows.

Over-all regional decrease of precipitations amount for the period 1970 – 1989 years on ***5.52 ÷ 8.15 %*** from a level of the sixtieth years allows to characterize it as moderately droughty. Conversion of regime precipitation storage educed in a direction of total decreasing of precipitations on plain, low mountainous zone and intra mountain depressions of Internal Tien-Shan. At the same time, the particulate increasing of precipitations amount in middle mountainous and high-mountainous zones, which opened for water transfer of mountains of Western Tien-Shan, was registered.

As whole changes of evaporation of Syrdarya River basin reflected processes of conversion of precipitation storage regime in region. Intra annual distribution of evaporation for the normative period 1960 –1969 years shows that on plains and in low mountainous zone for ultraarid climatic zone the maximum evaporation from dry ground is limited by amount of precipitations and consequently it is dated for the most humidified spring and autumn seasons. For middle mountainous zone with semi-humid both humid types of landscapes and spring-and-summer maximum precipitation storage the season of intensive evaporation is shifted aside summer season. For high-mountainous zone the season of the maximum evaporation is limited by thermal regime and consequently restricted only to summer season. Middle-high-mountainous zones are the most intensive evaporators of a dry land up to 600 mm/year. Ranges of the maximum evaporation in region are dated for aquatories of planting water reservoirs of southern part of basin and attain magnitudes 1400 ÷ 1600 mm/year.

The period 1970 – 1989 years is characterized by over-all increase of evaporation in the lower flow Syrdarya River and above aquatory of Aral Sea as a result of regional increase of air temperatures, appearance in the seventieth years in southern part of basin of new shallow water reservoirs and enhancing shallows of Aral Sea, expansion of the areas of irrigation farming under water consumption agricultural crops – cotton and rice, construction of new irrigational nets on old technologies. Water balance of Syrdarya River basin it is formed under effect of two factors – climatic and anthropogenic. The relative analysis of results of modelling of a potential water balance and the measured parameters of a river flow shows to the sixtieth years as a result of economic activities total losses of water stores in Syrdarya River basin for hydropost Kazalinsk was ***-74.91 %.*** It characterizes a situation with water resources to the beginning of the sixtieth years as the extremely stressed and unstable.

Changes of water balance of period from 1970 until 1989 years registers its decreasing from a base level of the sixtieth years up to ***-13.80 ÷ -14.23 km³/year***. It has finally inferred hydrosystem from unstable equilibrium and has resulted in a progressing degradation of Aral Sea. Thus, over-all climatic losses of water resources of Syrdarya River basin for the twenty years' of a drought period annually is estimated ***-4.95 km³/year***. Leakage of water only from aquatory of Arnasaysky water reservoir have made ***-5.63 ÷ -6.41 km³/year***. Taking into account the given circumstance and that fact, that the given reservoir carries out only function of the temporary store of seasonal flooding waters, conservation of this reservoir is represented inexpedient.

Total losses of water stores on the new agricultural areas and irrigational nets of irrigation farming areas of the Kazakhstan Priaralie estimates in limits ***-2.44 ÷ -4.15 km³/year***. Shallows of Aral Sea has caused augmentation of tempo of evaporation from its surface that together with decreasing of precipitations amount and increase of air temperatures has resulted in progressing deterioration of a water balance of its aquatory.

The analysis of a developed regime of water requirement in Syrdarya River basin evidences of the situation in region completely not hopeless and is not conditioned to an overpopulation or very big development agricultural sector. Huge volumes of withdrawn water resources are spent not so much on economic requiring, how many lost in sand in unlined main irrigation channels and also irrationally evaporates in extensive shallow man-made reservoirs of southern part of basin.

Measures on optimization of water use for Syrdarya River basin, which about eight cubic kilometres of water annually are capable to save and to secure local population against threat of flooding, are reduced to the following:

1. Systematic modernization of the main channels by a method of facing by waterproof materials and optimization of an irrigational network by means of the termination of access of water in not used irrigation canals can raise factor of their use from 0.50 till ÷ 0.70.
2. Reorientation of structure for local agricultural due to reduction of the areas borrowed by the most water-capacious cultures – rice and a clap about advantage of less water-capacious cultures and animal industries, and/or translation of rice and cotton fields to less water-permeable of soils will allow to lower water consumption agricultural sector on 10 ÷ 30 % at preservation or increase of its profitability.
3. Deepening and flattening of channel Syrdarya River bed for the its lower flow, and also carry of the settlements which are being a zone of seasonal flooding, to more safe places or construction of protective dams and drainage systems around of them will reduce social and economic consequences of seasonal high waters.
4. Gradual liquidation of Arnasaysky reservoir will enable for productive use of those water resources which now irrationally evaporate from a surface of the given reservoir.
5. The interstate coordination of an intraannual mode of water use for prevention of uncontrollable freshet dumps of water, and also development of scientifically proved national quotas and modes of use of water resources will help to remove intensity in the interstate attitudes connected and use of water resources of the Aral region. Maintenance of the independent and transparent tool control over execution of the accepted normative documents will allow to minimize probability of not authorized use of water resources.

These problems are economically expedient and quite solved at presence of political will of the states of the countries of the Aral region and financing of corresponding engineering projects.

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Manuscript received in 11 January 2005

Резюме

Гречаниченко Ю. **Климатическая характеристика бассейна р. Сырдарья**

В статье рассматриваются результаты пространственно-временного моделирования климатических показателей температуры воздуха, осадков, испарения и потенциального водного баланса бассейна р. Сырдарьи за период с 1960 по 1989 годов, времени наиболее интенсивного хозяйственного освоения Аральского региона. Представленный картографический материал наглядно иллюстрирует динамику этих процессов.

Анализ результатов моделирования позволяет оценить период семидесятых – восьмидесятых годов как умеренно засушливый с общим повышением средних годовых температур на 0.3 ÷ 1.2 °С и уменьшением сумм средних годовых осадков на 5.52 ÷ 8.15 % от уровня до шестидесятых годов двадцатого века.

Сравнительный анализ рассчитанных показателей водного баланса и результатов оценки гидрологического режима показывает, что уже в начале шестидесятых годов суммарные потери водных запасов в бассейне р. Сырдарьи составляли до 74.91%. Это характеризует ситуацию с водными ресурсами тех лет как крайне напряжённую и неустойчивую.

Строительство и ввод в эксплуатацию новых гидротехнических сооружений в конце шестидесятых семидесятые годы привело к существенному пространственному перераспределению водных ресурсов в бассейне за счёт их накопления в наиболее интенсивно испаряющей южной части территории. По модельным оценкам ежегодные потери воды только с акватории Арнасайского водохранилища составляют в среднем 5.63 ÷ 6.41 км^3/год, а совокупные потери водных запасов на новых сельскохозяйственных площадях и ирригационных сетях на массивах орошаемого земледелия Казахстанского Приаралья оцениваются в пределах 2.44 ÷ 4.15 км^3/год.

Оптимизация и планомерная модернизация ирригационной сети и доведения коэффициента их использования до 0.7, ликвидация многочисленных южных водохранилищ и углубление русла р. Сырдарьи в нижнем течении способно сэкономить до восьми кубических километров воды ежегодно.

INORGANIC POLLUTANTS OF THE SYR-DARIA RIVER (KAZAKH PRIARALIE)

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Detailed Summary

Within the framework of the INTAS program on the Aral Sea Basin, the "Aral 1072 project", a state of the water quality of the Syrdarya River was implemented during two field campaigns in September 2003 (low water period) and April 2004 (high water period) in the Kazakh Priaralie (Syrdarya valley in Kazakhstan). This paper presents the study of the dissolved inorganic species from key sampling places in the river. Attention was paid to the methodology of sampling by following international recommendations in handling, preservation of the samples, in physical-chemical measurements on site, in low level trace analytical methods and in an appraisal of the uncertainties from the field to the laboratory (duplicated samples, field blanks).

In agreement with the available former data the decrease of the Heavy Metals contents was confirmed. Although the aridisation, including a salinisation of the soils and of the precipitations is well established in the region (and particularly near the Aral Sea), no increase of the salinity was clearly demonstrated for the river neither for the last decade and for the Kazakh Priaralie. Nevertheless the salt content (TDS and SO_4) was the only parameter that does not comply constantly in some places with the local or European standards of water quality.

The current Syrdarya River water quality is influenced by several phenomena:

- most of major dissolved species (TDS) are mainly controlled by dilution and thus by the river flow rate that depends itself on the season and on the Chardara dam regulation.
- lakes of the delta zone may contribute to an increase of the salinity of the river on the flooding period when they are connected to it
- many heavy metals (Ni, Ti, Sn, Cu, Co,…) come from the leaching of upstream mining areas or agricultural wastes during the snow melting at spring
- the salt content (TDS), nitrates, silica and some heavy metals decreased in September 2003 in the Chardara reservoir because of phytoplankton absorption
- carbonate precipitation due to higher temperatures is also inferred in September in the Chardara reservoir
- various discharges contribute to the pollution of the river. Besides agricultural fertilizers (NO_3 at spring), the urban waste waters (bringing Suspended Particulate Materials, Dissolved Organic Carbon, lowering the oxygen content of the water,…) and some industrial (present or passed, local or upstream) activities may impact the river
- the geochemical regional background influences the composition of the river (Sr abnormal concentrations)

Introduction

Considering the Aral Sea environmental disaster, the Syrdarya River played a role both of a target and a vector. Just like the Aral Sea into which it flows, it suffered from the huge withdrawal of water resulting of the former intensive irrigation system. Its flow rate decreased from 43.3 km^3 during the 60's to 2 km^3 per year in the first half of the 80's (Lŭtolle and Mainguet, 1993). Along with the drop of the river flow rate, the aridisation of the climate, the soils degradation including their salinisation, the mineralization of the surface and shallow ground waters were strengthened. At the same time its waters transported dissolved and suspended pollutants that presumably ended in the Aral Lake. Those pollutants resulted mainly from the agricultural drainage canals net bringing fertilizers and pesticides on one side, from waste or run off waters, discharges from mining, industrial and/or urban centers all the river course along on the other side.

New projects of remediation in the Northern Aral Sea (Kok-Aral dam completed in August 2005) and in the Syrdarya valley (to double the river flow rate by heavy civil works) are coming. A common transboundary management of the whole Aral Basin water resources is in question between the 5 new independent states. Signs of starting up again appeared after the 2000's in the economy of Kazakhstan. This new situation justifies the implementation of an assessment of the river water quality.

This paper is a contribution to this purpose. It results from a European Union – BRGM co-funded project within the frame of INTAS, the “Aral 1072 project”.

Materials and Methods

We will mainly consider here, among the dissolved inorganic species of the Syrdarya River,

- the heavy metals and other trace elements
- the major chemical species that can result from the salinisation process (sulphates, sodium, chlorides, magnesium,…) and from fertilizers (nitrates)

The Kazakh Priaralie, i.e. the Kazakh part of the Syrdarya Basin starts upstream the Chardara reservoir (the Uzbek border) till the present sea shore of the Small Aral Sea, about 1500 km downstream.

Syrdarya River has one high water season (snow melting from April to May) and a low water one (from September to February).

Our analytical data result from two sampling campaigns: one at the low water period in September 2003 and a second one at the high water period in April 2004 (table 1a, 2a).

ISO 5667 recommendations were followed as much as possible during our sampling programme.

Sampling places were selected up and downstream 6 key-places supposed to play a role either in the contamination or in its attenuation: (1) the Chardara reservoir, (2) the confluence with Arys-Turkistan canal and Arys river, a right bank tributary crossing the industrial city of Chimkent, the cities of (3) Chi-Ili, (4) Kyzyl-Orda , (5) Jalagash and their respective irrigated areas, (6) the delta zone (and still some irrigated areas)

River waters were collected in the middle of the channel or at least in the main stream. In September 2003 two levels of the river water column were sampled: at 1m below the surface and 1m above the bottom. During the second mission all the samples were collected at one meter depth (table 1b).

Water samples were filtered under nitrogen pressure with 0.45 µm cellulose acetate filter. Filtrate samples were dispatched into 3 bottles: (1) one acidified to pH ≤ 2 with ultra-pure HNO_3 for the cations and trace elements analysis, (2) another one filled up to the top for the anions and (3) the last one acidified to pH ≤ 2 with ultra-pure H_2SO_4 for the Dissolved Organic Carbon (DOC). Filters had been weighed before and after the campaigns to quantify the Suspended Particulate Materials (SPM) content.

During the September 2003 campaign, all the samples were systematically duplicated and field blanks collected.

Specific Conductance, temperature, dissolved oxygen, redox potential and pH were determined on site.

Alkalinity was determined on filtered samples by the Gran method.

Transportation times exceed the recommended time limits for NO_3, and at a lesser extent for SO_4 and DOC. A few analytical controls (alkalinity measured on site and calculation of the ionic balance) did not show significant impacts on the results.

Laboratory analyses

The determination methods and the Lower Levels of Quantification of the BRGM laboratory comply with the standards of the COFRAC certification for the analyses of major species in the waters. The cations and silicium were analysed by emission ICP, Cl^-, SO_4^{-2} and NO_3^- by HPLC (Dionex), HCO_3^- by potentiometry and DOC by persulfate oxidation under heat.

A high performance ICP/MS (Thermo Plasma- Quad 3 model) analysed trace elements (table 1b and 2b). For each element and at each series of analyses Lower Levels of Detection and of Quantification were calculated. The Lower Levels of Quantification ranged from 1,2 for Fe till 0,01 µg/l for Mn, Rb Tl in both campaigns.

Appraisal of uncertainties

In several samples of both campaigns, some trace elements (B, Al, Fe, Zn, Pb, Mn, Cu, Cr, Sr,…) were detected in the field blanks at higher concentrations (and significantly higher than the determination threshold) than in the corresponding samples. We cannot preclude a contamination coming from the equipment although the width of the spectrum and the nature of the contaminating elements suggest that their origin are not (only) processed materials but natural source and namely an atmospheric origin. Savenko and Kulmatov (1997) already mentioned the curious anomaly of Zn concentration in the soils of the Aral Sea Basin. They suggested a link with the precipitation composition that is abnormally high for Zn in the region.

The standard deviations were calculated in order to estimate the relative uncertainties. Some elements (Al, Cr, Fe, Cd, Zn) presented a higher uncertainty due to the ICP/MS method and some more intricate matrices.

Table 1a . Results of the on site measurements - September 2003.

N° sample	Depth	Sampling time	Sampling place	GPS coordinates .			Water Temp	Elec.Cond.25°C	Diss. Oxy-gen	Redox Pot.	PH	Alka-linity	Equivalent TIC
				Longitude	Latitude	Altit.	(єc)	uS/cm	mg/l	mV		meq/l	mg/l
SD1	1m	12/09; 18:00	Bridge upstream Chardara reservoir	68° 31'08 E	41°01'78N		23.7	1855	9.67	474	7.8	3.94	47.3
	3,5m	12/09; 19:00					23.4	1873	10.31	433	7.8	3.97	47.6
SD2	1m	13/09; 12:30	Karasakal village, upstream and south, bank of Chardara reservoir	68° 08'18 E	41 ° 03'30 N		21.7	1969	9.21	415	7.8	1.76	21.1
SD3	1m	13/09; 19:30	Zolotye Pesky, 7 km before Chardara dam, south. Bank	67° 55'48 E	41° 12'19 N		22.5	1472	9.08	480	7.5	2.31	27.7
	2,5m	13/09; 19:45	Idem				20.9	1426	9.68	456	7.5	2.24	26.9
SD5	1m	14/09; 12:45	Chardara city downstream from the dam, right bank	67° 57'39 E	41°15'05N		24.4	1569		433	7	2.44	29.3
	2,5m	14/09; 13:00	Idem				23.9	1554	6.01	406	6.6	2.38	28.6
SD6	1,3 m	15/09; 9:00	60 Km upstream from the con-fluence of the Arys river, right bank	68° 15' 04 E	42° 18'11 N		19.1	1674	9.2	453	6.9	3.08	37.0
SD8	1,5m	16/09; 12:30	Near Aqkol hamlet	67°51' 04 E	43° 09' 37 N	168m	22.5	1507	17.05	380	7.02	2.22	26.6
SD9	1m	16/09; 19:00	Downstream from Chi-lli	66° 22'13 E	44° 16' 31 N	138m	25.1	1557		369	6.24	2.25	27.0
	5m	16/09;19:30	Idem				23	1630		211	6.02	2.42	29.0
SD10	1m	18/09; 9:00	Downstream from Kyzyl-Orda	65° 17' 4E	44° 59' 1 N	111m	17.2		0.78	351	7.75	2.5	30.0
	4,5m	18/09; 9:30	Idem				16.4			419	7.04	2.38	28.6
SD13	4m	19/09; 8:30	Jalagash bridge	64° 33' 05" E	45° 02'49" N	105m	16.9		0.89	425	7	2.46	29.5
SD14	5,5m	21/09; 12:00	Karateren bridge	61 ° 02'22" E	46° 02'14" N		17.8		9.34	433	6.73	2.71	32.5

Table 1b. Average values of the chemical analyses on duplicated water samples from the Syrdarya River.

n° sample	SPM	TDS	DOC	IB	Ca	Mg	Na	K	HCO_3	Cl	NO_3	SO_4	SiO_2	B	Al	Ti	Cr	Fe	Mn
	mg/l	mg/l	mg/l	%	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
SD1-1m	263	1456,7	2,2	-0,6	143,2	79,6	156,6	4,8	245,4	100,8	9,1	700,5	13,3	334	7,0	7,4	1,2	14,3	9,1
SD1-3.5m		1485,6	2,4	-1,3	147,7	79,4	156,1	4,8	249,4	102,0	10,0	719,5	13,2	358	10,9	10,7	1,6	25,2	11,6
SD2-1m	56	1446,0	5,4	-0,9	116,3	70,0	205,1	5,4	128,5	127,0	<0,1	775,5	14,2	419	13,2	13,0	0,5	21,6	12,1
SD3-1m		1080,1	3,4	-0,5	94,5	62,9	124,6	4,5	144,5	81,5	0,6	551,5	12,8	280	7,3	10,4	0,4	12,3	1,4
SD3-2,5m	49	1071,8	3,4	-1,5	92,8	60,8	122,6	4,3	144,0	81,8	0,4	550,0	12,3	289	8,7	10,3	0,4	15,0	3,7
SD5-1m		1205,6	4,7	-2,0	102,8	68,8	137,6	4,7	153,0	91,8	1,4	630,0	12,5	304	15,1	13,3	0,5	20,2	2,4
SD5-2.5m	48	1188,2	4,7	-1,0	103,3	68,5	137,1	4,7	153,0	91,3	1,6	613,5	12,1	310	8,9	13,0	0,4	15,6	3,8
SD6-1.3m	37	1267,6	2,3	2,3	119,3	76,2	151,6	4,9	158,5	99,0	1,8	641,0	12,1	326	6,4	12,5	0,6	12,2	1,0
SD8-1.5m	119	1145,0	7,1	-1,6	98,8	65,3	132,6	5,5	142,0	91,8	1,3	593,0	12,2	258	9,0	11,0	0,3	13,2	1,0
SD9-1m	171	1182,0	8,2	0,8	106,5	70,5	142,0	4,7	152,5	95,1	0,1	601,5	12,6	279	15,2	13,7	0,5	20,3	16,8
SD9-5m		1239,2	8,2	-3,6	103,3	67,5	142,1	4,7	155,5	99,4	0,4	652,0	11,6						
SD10-1m	179	1241,4	2,2	0,4	107,8	73,2	153,1	5,0	148,0	105,0	0,9	634,0	11,5	294	8,3	13,8	0,3	8,2	0,6
SD10-4.5m		1309,6	2,0	-2,9	108,8	73,0	154,1	5,0	149,0	104,0	0,4	701,0	11,6	279	8,6	13,4	0,3	8,4	0,8
SD13-4m	260	1294,5	2,1	-2,2	110,8	74,7	150,6	5,0	147,5	105,5	0,3	685,5	11,9	294	17,9	14,9	0,9	21,7	1,4
SD14-5.5m	218	1089,0	2,2	-0,6	100,3	64,4	128,1	4,7	152,5	92,2	0,1	533,0	11,4	230	11,7	11,2	0,5	14,6	16,3
n° sample	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Rb**	**Sr**	**Mo**	**Cd**	**Sn**	**Sb**	**Te**	**Cs**	**Hg**	**Tl**	**Pb**	**Bi**	**Th**	**U**
	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l
SD1 1m	0,3	3,6	2,0	1,4	1,8	*1,8*	3141	6,25	0,03	0,09	0,27	0,12	<0,01	0,03	0,07	0,73	0,16	0,05	18,89
SD1 4m	0,4	5,3	2,8	4,3	2,2	2,0	3218	6,81	0,08	0,06	0,27	0,09	<0,01	0,03	0,03	0,68	0,07	0,02	17,71
SD2	0,5	5,1	1,6	2,3	5,1	2,1	3712	11,94	0,04	0,03	0,64	0,11	<0,01	0,04	0,02	0,44	0,04	0,01	11,21
SD3 1m	0,3	4,0	1,3	1,4	3,2	1,8	2550	7,16	0,02	<0,02	0,49	<0,08	<0,01	<0,03	<0,01	0,12	0,01	<0,01	12,44
SD3 2.5	0,3	4,0	1,3	1,7	3,1	1,8	2555	7,15	0,02	<0,02	0,50	<0,08	<0,01	0,03	<0,01	0,08	0,01	<0,01	12,79
SD5 1m	0,4	5,1	2,4	3,1	*3,3*	2,1	2761	7,91	0,05	<0,02	0,52	<0,08	<0,01	<0,03	<0,01	0,16	<0,01	<0,01	13,73
SD5 3m	0,4	5,4	1,5	2,3	3,3	*2,1*	2820	8,25	0,02	<0,02	0,53	<0,08	<0,01	<0,03	<0,01	0,08	0,01	<0,01	14,08
SD6	0,3	4,7	2,4	2,7	2,4	1,9	3055	7,62	0,04	0,02	0,49	<0,08	<0,01	<0,03	<0,01	0,46	<0,01	<0,01	13,36
SD8	0,3	4,2	1,9	1,7	2,0	1,7	2397	7,41	0,04	0,07	0,52	0,11	<0,01	0,03	0,03	0,18	0,15	0,04	13,03
SD9 1m	0,4	5,5	2,4	2,4	2,0	1,9	2553	7,94	0,04	0,02	0,51	<0,08	<0,01	0,03	<0,01	0,11	0,05	0,02	12,92
SD10-1m	0,3	4,8	2,3	1,8	1,8	1,8	2666	7,70	0,03	<0,02	0,51	<0,08	<0,01	0,03	<0,01	0,08	<0,01	<0,01	12,53
SD10-4.5m	0,3	4,7	2,2	1,2	1,8	1,7	2491	7,66	0,02	<0,02	0,52	<0,08	<0,01	<0,03	<0,01	<0,05	<0,01	<0,01	12,23
SD13	0,4	5,5	2,7	1,8	1,9	1,8	2540	8,58	0,03	<0,02	0,54	<0,08	<0,01	<0,03	<0,01	<0,05	<0,01	<0,01	13,27
SD14	0,3	4,6	2,6	2,8	1,6	1,6	2130	7,68	0,03	<0,02	0,54	<0,08	<0,01	<0,03	<0,01	0,18	<0,01	<0,01	11,75

Table 2a. Results of the chemical analyses on water samples from the Syrdarya River - April 2004.

N°sample	Depth	Sampling time	Sampling place	GPS Coordinates			Water Temp.	Elec.Con d. (25°C)	Diss. Oxygen	Redox Pot.	PH	Alkalinity	Equivalent TIC
				Longitude	Latitude	Altit.(m a.s.l.)	(°C)	uS/cm	mg/l	(mV)		meq/l	mg/l
SD1-HE	2m	24/04; 13.45	Bridge upstream Chard-ara reservoir	68° 31'08 E	41°01'78 N		21.2	1319.26	8.22	387.459	8.17	3.23	38.76
SD2-HE	1m	24/04 ; 11.30	Karasakal village, upstr. and south, bank of Chardara reservoir	68° 08'15 E	41° 02'53 N	246	19.7	1295.3	9.02	376.531	8.47	2.80	33.60
SD3-HE	5m	24/04 ; 8.45	Zolotye Pesky, 7 km be-fore Chardara dam	67° 55'48 E	41° 12' 19 N		16	1223.17	9.56	378.173	8.35	3.04	36.48
SD5-HE	1m	23/04; 19.45	Chardara city down-stream from the dam	67° 57'39 E	41° 15'05 N		17.6	1267.61	8.99	403.03	8.22	3.00	36.00
SD8-HE	1 m	22/04 ; 19.40	NearAqkol hamlet, right bank	67° 51* 04 E	43° 09'37 N	168	15.9	1308.07	9.25	390.245	8.25	3.09	37.08
SD9-HE	1m	22/04 ; 14.00	Downstream from Chi-lli, right bank	66° 22' 13 E	44° 16' 31 N	138	13.2	1335.08	9.32	437.173	8.2	3.00	36.00
SD10-HE	1m	21/04; 19.30	Downstream from Kyzyi-Orda, right bank	65° 17' 47 E	44° 59' 26 N	146	13.8	1300.26	9.22	370.744	8.22	3.11	37.32
SD13-HE	2m	21/04; 17.45	Jalagash bridge	64° 33' 05" E	45° 02' 49" N	105	13.4	1291.67	9.94	382.03	8.2	3.08	36.96
SD14-HE	1 m	16/04; 19.00	Karateren bridge	61° 02' 33" E	46° 02' 12"N	40	11.6	1500	10.17	401.316	7.14	3.02	36.24

Table 2b. Results of the chemical analyses on water samples from the Syrdarya River– April 2004.
Legend: TDS: Total Dissolved Salts, SPM: Suspended Particulate Materials, IB: Ionic Balance, LLD: Lower Level of Determination, LLQ: Lower Level of Quantification.

N° Sample	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	HCO_3 mg/l	NO_3 mg/l	DOC mg/l	TDS mg/l	IB mg/l
SD1-HE	112.00	51.60	89.60	4.30	63.50	411.20	185.00	10.20	1.40	930.10	2.50
SD2-HE	104.00	51.70	95.30	4.30	64.80	400.30	160.00	6.60	2.50	889.70	6.44
SD3-HE	104.00	47.00	86.00	4.00	61.10	378.10	175.00	8.40	1.70	866.20	2.72
SD5-HE	108.00	49.40	90.10	4.40	62.60	388.40	176.00	8.60	1.70	890.10	4.98
SD8-HE	101.00	49.60	93.70	4.20	67.30	403.80	180.00	8.50	1.40	910.70	-0.30
SD9-HE	104.00	52.30	100.00	4.20	69.90	400.30	181.00	8.20	1.60	922.50	4.34
SD10-HE	98.00	49.50	95.70	4.00	68.20	377.80	182.00	8.20		885.90	2.84
SD13-HE	101.00	51.20	98.90	4.30	68.30	378.50	184.00	7.90	1.90	896.70	5.74
SD14-HE	105.00	59.30	118.00	5.00	94.00	442.30	183.00	6.00	2.50	1015.50	3.14
LLD	0,1	0,1	0,1	0,3	0,1	0,1	5,0	0,1	0,5		

N° Sample	B µg/l	Al µg/l	Ti µg/l	Cr µg/l	Fe µg/l	Mn µg/l	Co µg/l	Ni µg/l	Cu µg/l	Zn µg/l	As µg/l	Rb µg/l	Sr µg/l
SDHE1	192.60	9	32.58	1.77	13	3.63	0.95	19.9	3.39	3.39	2.93	1.70	2493
SDHE2	201.08	17	32.09	1.39	20	3.16	0.92	18.4	3.49	3.96	2.59	1.65	2447
SDHE3	195.30	8	30.49	1.66	13	0.84	0.81	17.9	3.01	3.69	2.48	1.52	2359
SDHE5	189.78	9	31.55	1.61	15	1.49	0.88	18.9	3.12	3.74	2.60	1.57	2371
SDHE8	185.64	29	32.62	1.40	23	1.58	0.82	18.0	3.12	4.14	2.03	1.44	2383
SDHE9	181.12	9	31.87	1.27	14	0.81	0.80	18.4	3.04	3.06	1.98	1.35	2447
SDHE10	152.06	10	26.83	1.00	13	1.34	0.69	15.5	2.52	2.37	1.72	1.14	2325
SDHE13	159.76	7	28.72	0.96	12	1.25	0.75	16.2	2.79	2.44	1.87	1.18	2447
SDHE14	176.36	17	30.75	0.81	17	2.22	0.77	16.5	3.01	2.85	2.09	1.47	2703
LLD	0,02	0,36	0,02	0,03	0,39	0,00	0,00	0,13	0,01	0,02	0,01	0,00	0,02
LLQ	0,07	1,08	0,05	0,08	1,18	0,01	0,00	0,38	0,02	0,06	0,04	0,01	0,05

N° Sample	Mo µg/l	Cd µg/l	Sn µg/l	Sb µg/l	Te µg/l	Cs µg/l	La µg/l	Ce µg/l	Tl µg/l	Pb µg/l	Bi µg/l	Th µg/l	U µg/l
SDHE1	10.21	0.08	0.2	0.44	0.2	0.01	0.02	0.04	0.01	0.09	0.02	0.02	18.97
SDHE2	10.32	0.07	0.3	0.44	0.2	0.01	0.02	0.04	0.02	0.15	0.03	0.02	18.43
SDHE3	8.58	0.07	0.2	0.38	0.1	<0,01	0.01	0.02	0.01	0.08	0.02	0.01	15.95
SDHE5	9.21	0.08	0.2	0.39	0.2	0.01	0.02	0.02	0.02	0.09	0.02	0.01	16.96
SDHE8	8.56	0.10	0.2	0.39	0.2	0.01	0.05	0.09	0.02	0.14	0.03	0.02	15.51
SDHE9	8.71	0.09	0.2	0.45	0.1	<0,01	0.01	0.02	0.01	0.06	0.03	0.02	15.66
SDHE10	7.65	0.06	0.1	0.44	0.1	<0,01	0.01	0.03	0.01	0.07	0.01	0.01	13.29
SDHE13	8.16	0.07	0.1	0.49	0.1	<0,01	0.01	0.02	0.01	0.08	0.01	0.02	14.67
SDHE14	8.76	0.06	0.1	0.56	0.1	0.01	0.03	0.06	0.01	0.16	0.02	0.01	15.51
LLD	0,01	0,02	0,04	0,01	0,05	0,00	0,00	0,00	0,00	0,01	0,01	0,01	0,01
LLQ	0,02	0,05	0,11	0,03	0,14	0,00	0,01	0,01	0,01	0,03	0,02	0,02	0,02

Results and discussion

Contribution of the "historic" data

Information concerning Syrdarya River water quality mainly comes from the Hydrometeorological Monitoring Survey of SSR and then Republics of Uzbekistan and Kazakhstan (Hydromet). At least from 1960 to 2002 (and beyond), Hydromet services gathered (even not systematically) water samples from around 24 posts distributed along 2000 km of the Syrdarya River (taking into account only the Uzbek, Tajik and Kazakh parts of the river).

Salinity variation

The SO_4 content can be considered as a reliable index of the water salinity as it tightly correlates with the TDS (Total Dissolved Solids). Three Hydromet posts distributed from the upper reaches of the river (near the Kyrgyz- Uzbek border) till the Uzbek - Kazakh border downstream, were selected. Data were collected there during a relatively long time, with shortest and scarcest interruptions. The latter were nevertheless significant: complete stops from 01/1985 to 12/1993, during 1995 and furthermore there was a systematic gap of November - December data during the first decade (1961-73).

It can be observed (Fig.1a and b) that the SO_4 concentrations roughly grow up

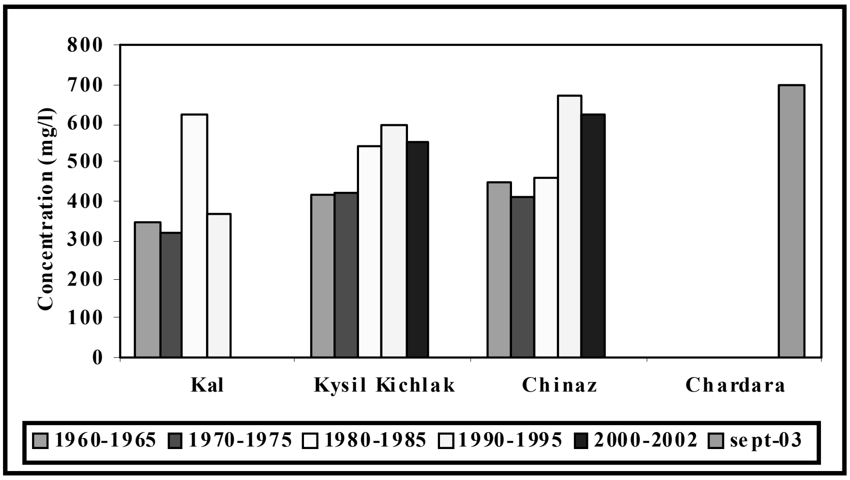
- from up (Kal) to downstream (Chinaz)
- from the High to the Low water period, the SO_4 content being controlled by dilution
- during the first decades (1960 to 1990)

This last trend is consistent with the increase of TDS content in the precipitations: from 24 mg/l in 1968-69 to 157.7 mg/l in 1979-80 (Letolle and Mainguet, 1993).

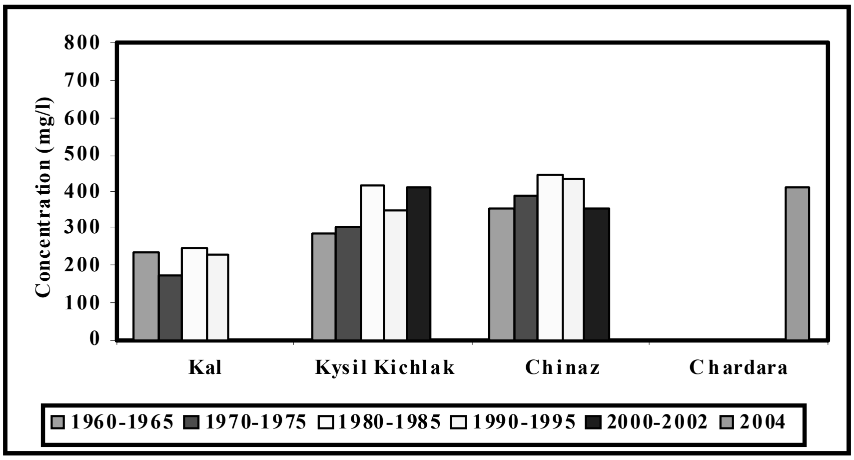
During the 90's the SO_4 content keeps on growing during the low water periods but starts to decrease during the high water periods. The last data (2000-2002) show a general decrease.

Long period data are lacking on the Kazakh course of the Syrdarya River. Thus the comparison of our data to the previous ones must be cautiously done:

- our data are time limited but not averaged
- the nearest sampling place (Chardara on the Fig.1a and b) from the post of Chinaz.(at about 60 km downstream) may be marked by a higher TDS content as it is located downstream from the confluence with the Chirchik River coming from the Tashkent valley.



a- Low Water periods



b- High Water Periods

Figure 1. Evolution of the SO_4 concentrations during the 45 last years in the Syrdarya River .

Thus the SO_4 contents of the analysed sample - upstream the Chardara reservoir - are consistent with the spatial increase (from up to downstream) but it cannot be concluded whether there is a new increase with respect to the previous data in the post of Chinaz or if it is merely due to the sample location.

Heavy metals

Annual reports of the Uzbek "Glavhydromet" mentioned average analyses of some monitored heavy metals (Cr, Cu and Zn). The number of samples is not known nor, mostly, the sampling places.

Those monitoring values (Table. 3) cannot be considered as representative of the whole period 1960 – 2001 (and especially of the 30 first years). The most ancient data (1983) are probably influenced by the accident that occurred at the Almalyk copper enrichment centre. The comparison with our data seems consistent with a constant decrease of zinc, a similar range of variation for chromium and a new copper increase. This last trend is nevertheless contradicted by the detailed analyses of Bragin *et al* (2000) (Fig. 2). Conversely, our data rather fit well with their conclusion of a general decrease of the heavy metals in the Syrdarya delta region.

Kochenov and Baturin (1967) analysed uranium from water samples collected in 1965. They found that the uranium content in Syrdarya River (in the delta zone) was 10 µg/l. It largely coincides with our recent results: 11 - 19 µg/l.

Table 3 Evolution of the Syrdarya River water Cr, Cu and Zn contents (µg/l) in the last years

	Uzbek Hydromet data					Our range of data
	1983	1990	1994	1996	2001	Sept.2003 – Apr.2004
Cr	12	1.6	1.7	0.3	1.4	0.3 – 1.8
Cu	79	3.9	1.9	0.8	0.8	1.3 – 3.5
Zn		13.6	14.1	7.2	5.6	2.4 – 4.1

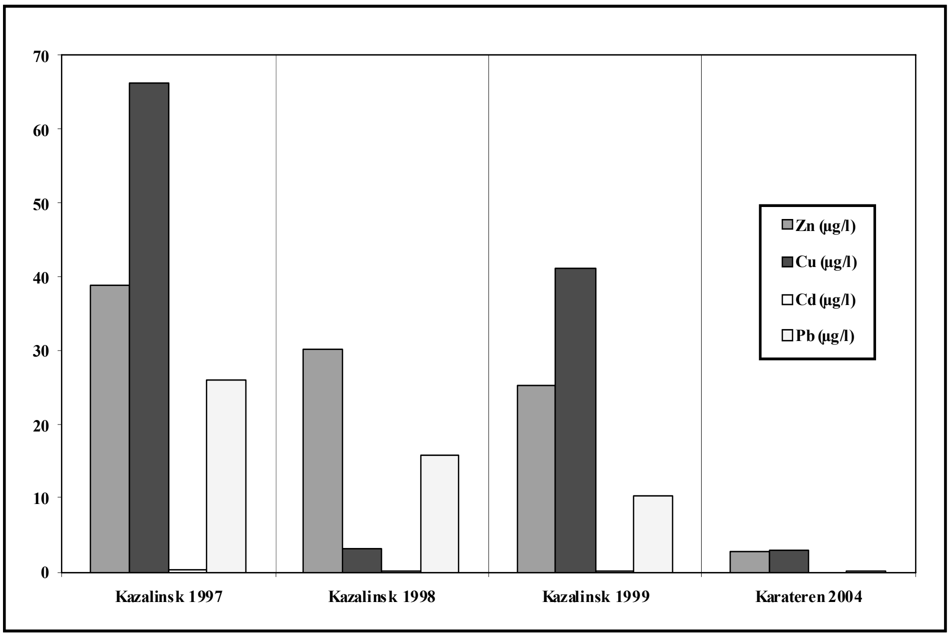


Figure 2. Heavy metals concentration/time in Syrdarya River delta zone (our data and Bragin et al., 2000).

River chemical trends

Seasonal variations

The seasonal variations of the Syrdarya River are mitigated by a series of facilities. The river is regulated by three dams and reservoirs: Toktogul in Kyrgyzstan, Kayrakum (15 km^3) and Farkhad (2 km^3) in Tajikistan and Uzbekistan, and Chardara in Kazakhstan (0.8 km^3). The overflow reservoir system of the Arnasay lakes (joining three previous lakes: Arnasay, Aydarkul and Tuzkan) has a volume varying between 7.4 and 25 km^3 according to the season.

Furthermore several systems of irrigation and drainage canals, reservoirs and discharge lakes along the Syrdarya River and in its delta impact the river regime.

The river flow rates measured by the hydrological posts of Kazhydromet (S. Kotleupov, pers. com.) in three points of the Syrdarya reaches coincide with three of our sampling times and places during both campaigns: Chardara city, Kyzyl-Orda and Karateren (Fig. 3a and b).

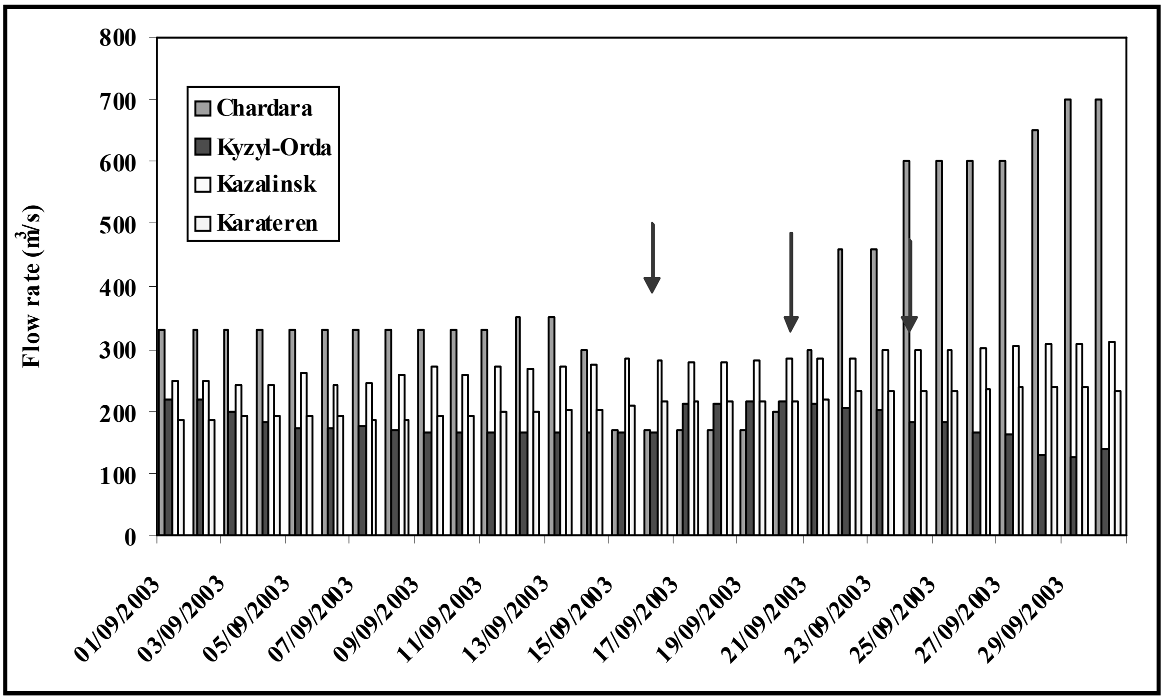


Figure 3a. Flow rates of the Syrdarya river (Sept. 2003).

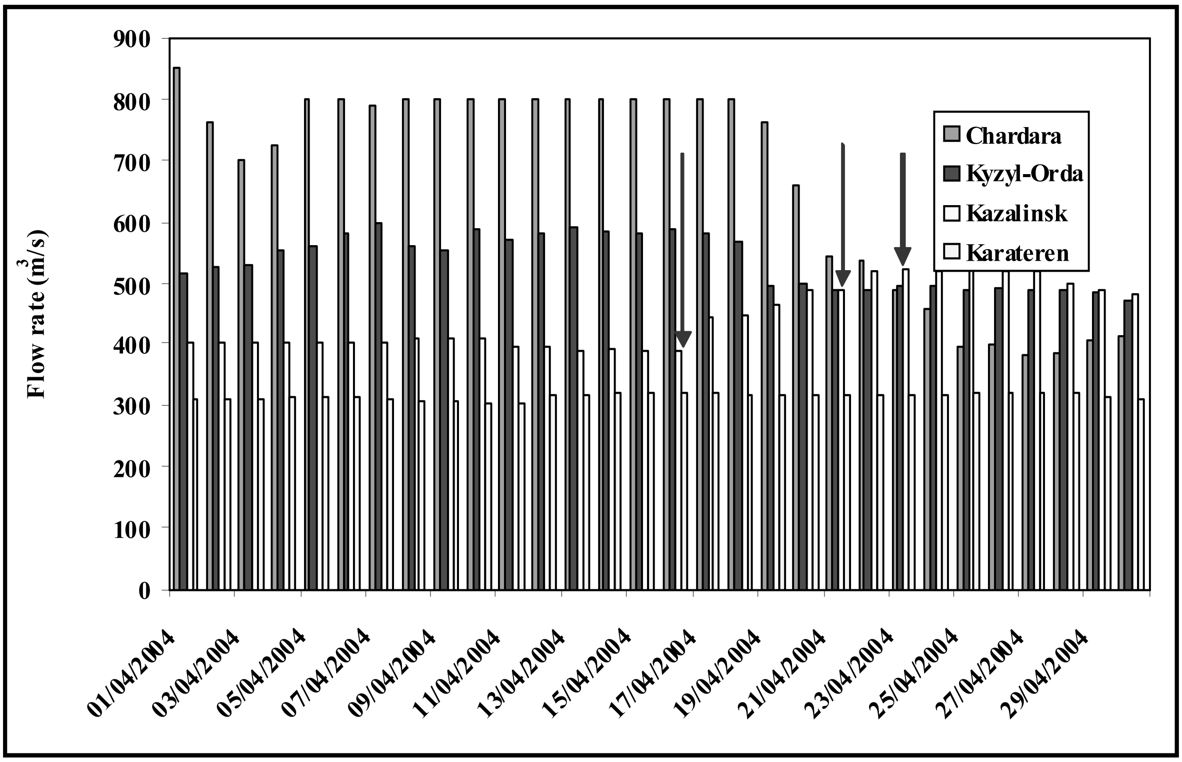


Figure 3b. Flow rates of the Syrdarya river (Apr. 2004).

Dilution trend

Dilution was already mentioned when considering the historic data (Fig 1a and b) and is clearly responsible of the TDS variations (Fig.4).

Environmental variations

Besides dilution, environmental variations influence the chemistry of the river water.

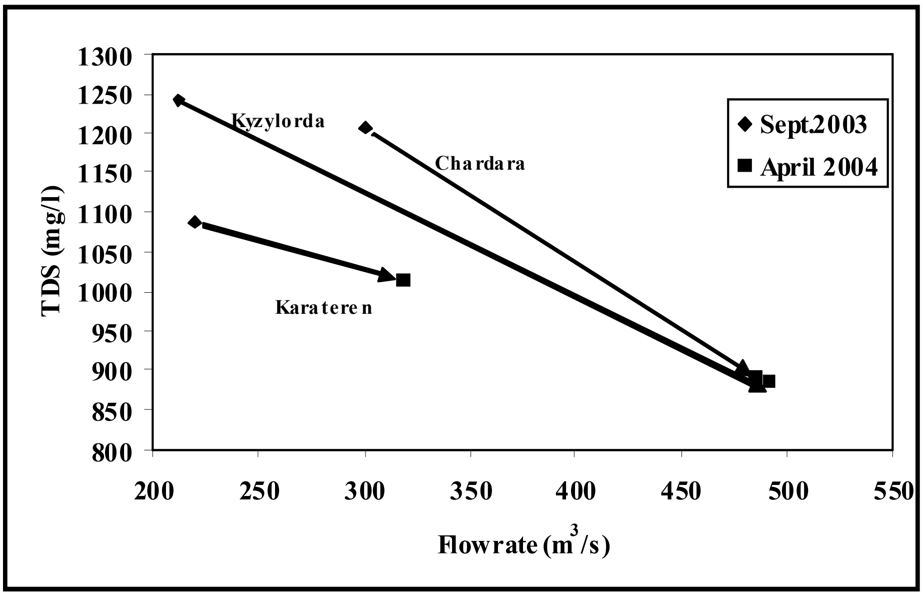


Figure 4. Syrdarya River TDS content / Flowrate.

Temperature

The water temperature varies with depth and day time but generally speaking the seasonal variations of the water temperature are stronger downstream the Chardara dam (the double in average). The temperature variation contributes to several other consequences.

Biomass

Chardara dam marks also a difference in the SPM composition. As most of the solid mineral phases settle down, an increase of phytoplankton can be inferred there from several parameters.

The diurnal variations of the dissolved oxygen and of the river water pH, near the Chardara reservoir and downstream from it are consistent with phytoplankton photosynthesis / respiration rhythms: oversaturation in dissolved oxygen and higher pH (in spite of higher temperature) at the end of the day and conversely low oxygen concentration and relatively low pH values early in the morning. The role of the phytoplankton was studied by Mamatov and Shirikova (2001) in the neighbouring Lake Arnasay (overflow of the Chardara reservoir): they observed diurnal oversaturations of dissolved oxygen (till 150%) and a nocturnal drop by a factor 2 or 3. A similar trend toward eutrophication was found here.

Carbonate system

Another consequence of average temperature variation is the correlated variation in HCO_3 content. According to our data, the Syrdarya River water is controlled by the bicarbonate equilibrium; so when temperature decreases (from September 2003 to April 2004) the equilibrium moves and more bicarbonate is dissolved.

This trend concerns Ca, Mg and Sr as well. A similar trend has been observed in the Loire River (Grosbois, 1998).

Metals

A striking aspect of the seasonal variations of the Syrdarya River composition is the increase in different dissolved metals from September to April in spite of a general decrease of the TDS (by around a factor of 1.5), confirming that those species are not merely controlled by a dilution phenomenon. Some trace elements increased by factors from 2 to 4 (Ni, Ti, Sn, Cu and Co) some other less (Cr, Zn, Mo, Cd, Te and U). Conversely others (Fe, Mn, Sb, Pb, As, Rb, Cs,…) decreased from September to April (Tab.1b and 2b). It is thus supposed that phytoplankton in September plays a better role as a filter than in April. Bragin and Matmuratov (1994) already stressed the role of phytoplankton in the Chardara reservoir as a bioaccumulator of heavy metals.

It may be assumed that those variations result from the leaching of either the upstream mining areas (in Uzbekistan and Kyrgyzstan) or the agricultural wastes (Bragin and Matmuratov, 1994) when snow melts.

Nitrate

The nitrate concentration grows up from September to April by a factor of around 5 for most of the samples (except SD1 that remains at 10 mg/l). Those analytical results show that nitrates fertilizers, at least, are used at the end of wintertime. Mamatov and Shirikova (2001) observed in the Lake Arnasay that the concentration in nitrogen compounds is higher at spring than in autumn.

Spatial variations

Variation with depth

The depth of Syrdarya River bed in Kazakh Priaralie varies between 5 to 10 m. Differences are significant (in September) only in the Chardara reservoir or just up and downstream from it: Mn and Fe contents, at least, grow up as the redox potential decreases from the superficial to the deeper sample.

Variation from up to downstream

The main source of spatial as well as seasonal variations is the Chardara reservoir.

TDS drop

The TDS of the river water dropped down by 18% in September and 4% in April when it passed the Chardara reservoir (Fig. 5). Two causes could explain this decrease. In September 2003 the pH variations due to Phytoplankton photosynthesis, the higher temperature and the lower flow rate of the waters favours the (1) carbonate precipitation or (2) consumption by the biomass. HCO_3 content decreased then in 37%, Ca in 45%, Sr in 27% and Mg in 14%. The other decreases of major elements (like some SiO_2 scavenged to build the diatomea shells) may also be due to consumption by the biomass.

Chardara denitrifying action

The decrease of NO_3 content especially in September 2003 (by a factor of 10) in the Chardara reservoir confirms the role of phytoplankton as a denitrifying agent. It can be noted that in April 2004 the NO_3 content increased again downstream from the reservoir probably as a result of both the agricultural practices of the surroundings and the lesser biomass.

The higher values in nitrate content upstream from Chardara reservoir in September 2003 may result both from a more intensive use of fertilizers in the upper part of the Syrdarya valley (from the Chirchik tributary or from the Fergana valleys) and from the waste waters of the city of Tashkent.

Chardara filtrating action

Most of trace elements do not decrease significantly after crossing the reservoir (a few of them as Ti, Mo and Sb even increased in September 2003). A group of metals (Mn, Cr and U) clearly dropped in both seasons. Then some elements decrease in April 2004 and not in September 2003 (Co, Ni, Cu, As, Rb) and vice versa (Sn, Pb). The reservoir seems to act as a selective, limited and seasonally changing trap for heavy metals.

Bragin and Matmuratov's analyses (1994) show that phytoplankton accumulates first Zn, then Cu, Pb and Cd (they analysed a more limited range of elements).

Delta lakes influence

In the delta zone, in April, when the Syrdarya River floods and connects with lakes, the river may be impacted by them. DOC of the Syrdarya River increases and NO_3 decreases in relation to the growth of phytoplankton. Furthermore TDS reaches its maximum as those lakes are mostly salted ones and / or drainage outlets like Kamyslybas.

Industrial and urban impact

The pollution impacts of the different cities, of the Arys River and of the drainage canals net (including the Arys – Turkestan system) can be detected especially in September by the increasing contents of DOC and SPM, by low oxygen concentrations. The most significant (albeit not strong) other impact of an urban contamination was detected in September downstream from the Chi-Ili city where contents in Dissolved Organic Carbon, Mn, Fe, Al and, at a lesser degree, Ni grew up.

Water quality

The Syrdarya River samples comply with the local and international standards except for TDS and Mn and mainly in September 2003. None was concerned by excess with neither NO_3 nor heavy metals versus local and/or European standards (European Commission Directive 98/83/CE of 03/11/1998).

Beyond the comparison with the standards, Syrdarya River water composition can be compared with other rivers of the world (Tab. 4). Taking into account that we are comparing average values and intervals (our data), it appears that Syrdarya River chemical composition is similar to the other rivers particularly with the Seine River. It has all the same two peculiarities with respect to other mentioned rivers: lower Fe, higher Sr and, at a lesser extent, Ni contents. The abnormally high Sr content, at least, is very likely due to regional geochemical anomaly as no anthropogenic Sr source is identified.

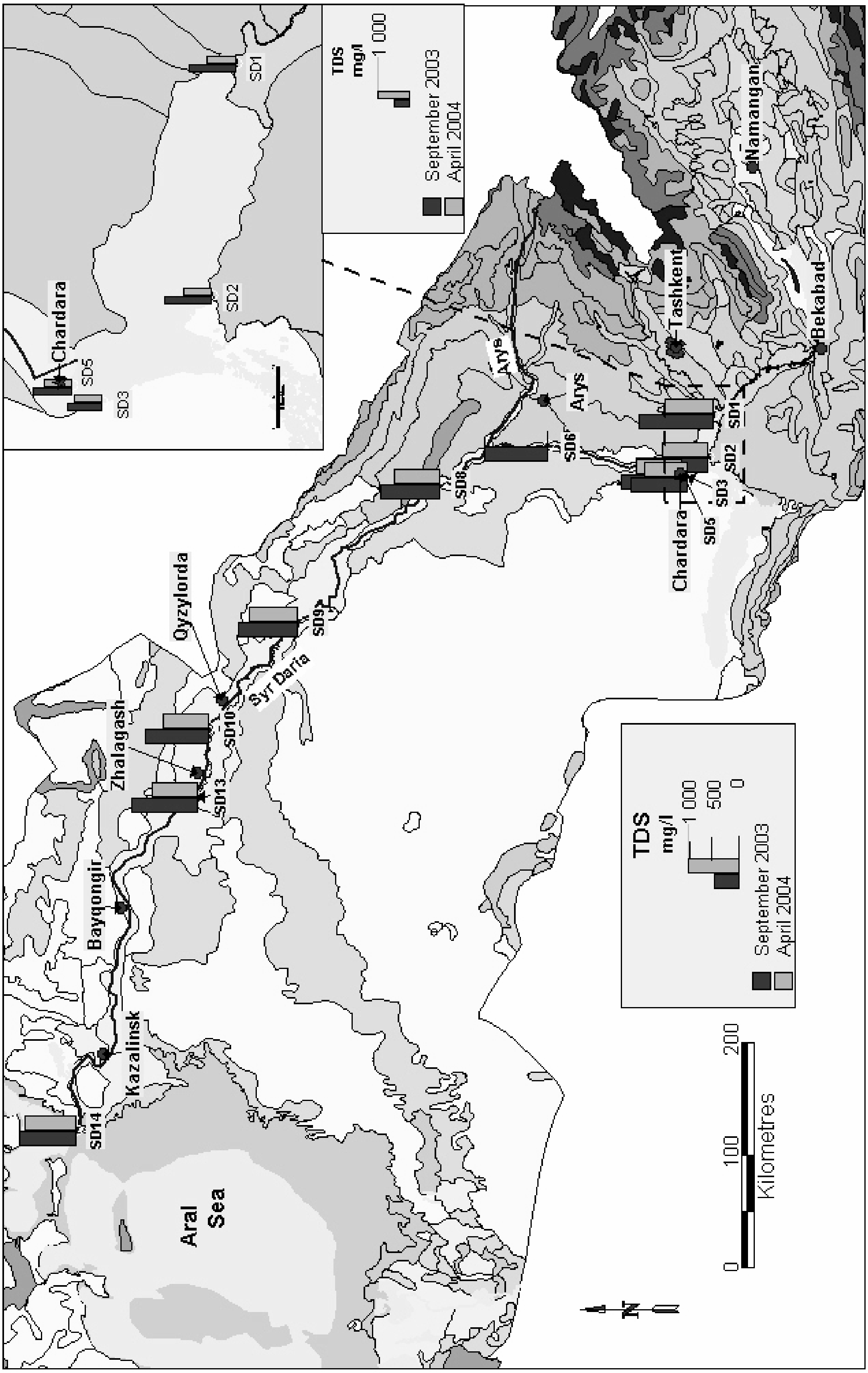


Figure 5. Total dissolved solids (TDS) in water samples of Syrdaria. River.

Table 4. Abundance of trace elements in various rivers of the world in µg/l (from Grosbois, 1998).

Element	Loire	Seine	Amazone	Congo	Mississipi	Yangtze	Syrdarya
Fe	63,78	331,45		179,16			8,20 - 25,20
Rb	3,42	0,95	0,98	2,07	0,78		0,77 -1,37
Sr	98,57	210,38	16,42	8,77			1357,58 - 1947,16
Mn	3,08	2,12	52,38		0,71		0,61 - 16,57
Pb	0,73	0,07 (0,13)	0,02		0,00		0,01 - 0,20
Cu	3,43	1,84 (1,51)	1,28		1,59	1,12	1,14 - 3,07
Cr	3,69	0,89	0,04	0,54	0,08	0,17	0,32 - 1,90
Zn	4,12	3,29 (7,87)	0,95		0,24	0,06	1,20 - 3,67
Ni	3,87	4,24	0,67	0,95	1,68	0,17	3,42 - 18,93

Conclusions

Relatively good agreements were found with the former scientific data concerning the decrease of the Heavy Metals contents of the Syrdarya River. The increase of the salinity linked to the regional aridisation, including a salinisation of the soils and of the precipitations could not clearly be demonstrated for the river during the last decade.

The inorganic pollutants of the current Syrdarya River are influenced by several phenomena:

- a lot of heavy metals (Ni, Ti, Sn, Cu, Co,…) probably coming from the leaching of upstream mining areas or agricultural wastes during the snow melting at spring
- phytoplankton, enhanced by the summer temperatures, the lower flow rates and probably by a new increase of nitrates, grows in the Chardara reservoir and consumes part of the salt content, nitrates, silica and some heavy metals in the low water period
- various discharges contribute to the pollution of the river. Besides agricultural fertilizers (NO_3,…), the urban waste waters (bringing SPM, DOC, lowering the oxidation level of the water,…) and some industrial (present or passed, local or upstream) activities may impact the river water quality.
- the geochemical regional background influences the composition of the river (Sr abnormal concentrations)

The water quality of the Syrdarya River currently complies with local and European Standards except for TDS and locally for Mn mainly in September.

Additional studies including our data concerning river SPM and sediments, other water bodies of the Kazakh Priaralie and geochemical modelling would allow to precise the origins and the fates of the inorganic pollutants by taking into account the hydrobiogeochemical reactions involving them.

Syrdarya River will play an important role in the future quality of the renewed Small Aral Sea as well as of the irrigation and drinking waters. The passed experience showed that it quickly moves and a serious monitoring of the river quality is a basic condition to improve the regional ecologic and economic situation.

Aknowledgements

We are grateful to K. M. Pachikin, R. M. Nasyrov, O. G. Erokhina from the Soils Institute of the Kazakh Academy of Sciences, to M. Iliushchenko and H. Mukhamedzhanov from the Chair of Environmental Chemistry of the AIPET University, to S. Kotleupov from the Institute of Geography in Novokazalinsk and J.P. Roux who efficiently helped in the implementation of the field campaigns in the Kazakh Priaralie.

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Received 30 November 2005

Резюме

Гадалиа А., Мотелика-Хейно М., Сера Х., Абу Акар Аффр, Джоун Ф., Чарпи Э. **Неорганические загрязнители реки Сырдарья (Казахстанское Приаралье).**

Статья посвящена проблемам Аральского Моря и реки Сырдарья. Проведены две интересные экспедиции и уникальные измерения содержания неорганических загрязнителей по всей казахстанской части течения реки Сырдарьи в рамках проекта INTAS – 1072.

DYNAMICS OF A SOIL COVER OF KAZAKHSTAN PRIARALIE AND SYRDARYA RIVER LOWER REACHES

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For the last 20 years Aral Sea Region draws the attention of not only Kazakhstan scientists, but also experts of the different countries of the world. It is connected to catastrophic Aral Sea level decrease, development of desertification processes, and that standard of living of the population got worse. Typical feature of Aral Sea region desertification is aeolian and hydrogenic salinization of lands. On the dried sea bottom there is a formation of new natural complexes of desert type.

Reduction of Syrdarya River flow and absence of incoming fresh waters has resulted in amplification of drying up of the territories, disappearance of lakes, decrease of ground water level and increase of mineralization of the river, ground and sea waters. In recent years the type chemism of river water in a lower reaches of Syrdarya River has changed into sulphate-sodium instead of hydro-carbonate-calcium has changed. In ion structure of river water salts the quantity of chlorine increased that worsens its irrigation qualities.

The soil cover of the region suffered considerable changes. Many non-saline soils became into saline and the area occupied by solonchaks was increased. Practically there are no unsalinized soils on this territory at present. Desertification is accompanied by a decrease in fertility of hydromorphic soils. Humus decreased by 30-35% in 50-cm layer of meadow and swamp soils (Akhanov and Karazhanov, 1998). As a result, the nitrogen level also decreased (Nekrasova, 1979).

Drying up of the Aral Sea has resulted in an exposure of its bottom where soils begin to be formed. Studying soils' various stages of drying up allows to learn the process of formation and development of soils from a zero point, to understand the genesis of soils, and to reveal features of soil formation in a desert zone.

Depending on granulometric compound of adjournment and relief of the sea bottom it is possible to observe several types of soil transformation.

On sandy grounds the following evolution of soil cover is observed: marsh solonchaks > seaside primitive soils > seaside primitive soils with blown sandy cover > sands. On clay grounds soils develop through the following stages: marsh solonchaks > seaside solonchaks > solonchaks common > solonchaks takyr-like > takyr-like soils. The presence of negative relief elements marsh solonchaks transform to shor solonchaks with the time (Karazhanov, K. and A. Haibullin, 2001).

The main task of the soil researches which were carried out within the framework of the project INTAS 1072 was an authentic estimation of soil cover transformation for the period 1987-2003 years.

In result soil maps of Kazakhstan Priaralie and Syrdarya River lower reaches, in the environment of Geo-Information system in Maplnfo Professional, were constructed on the basis of field researches of 2003-2004 and use of “Landsat” and "SPOT" space image geographically adhered on raster with tool accuracy of several pixels.

Maps cover territory within Syrdarya River valley, modern and ancient Syrdarya River deltas, its floodlands, the territory of dried up Aral Sea bed, and also territories with irrigational systems, soils and landscapes of which have been exposed to the greatest anthropogenous transformation connected with agricultural activity.

The map of 1987 was made on the basis of the retrospective data and satellite images “Landsat” 1987. Map of 2003 - on the basis of the data of field researches and satellite images “SPOT” 2003.

1987 was an average on water level and water surfaces on satellite image coincides with the ones on topographical map. 2003 was abounding in water and water surfaces on a satellite image occupy the significant areas, covering soils.

Soils cannot instantly transform, thus they remain the same soils but flooded. Therefore the water surfaces correspond to a topographical basis for map of 2003.

Both maps include contour databases containing up to three soil types with their area characteristics and data on structure of soil cover and its distribution by forms of relief. Besides, databases contain codes of different types of landscapes, necessary for calculation of climatic parameters, the area of contours, Russian and English names of soils.

Maps allowing to observe the transformation of a soil cover of characterized territory are presented in figures 1 and 2.

During its preparation zonality of soils was essentially specified and the structure of soil cover is shown. Various soil combinations, describing the diversity of soil cover caused by conditions of soil formation

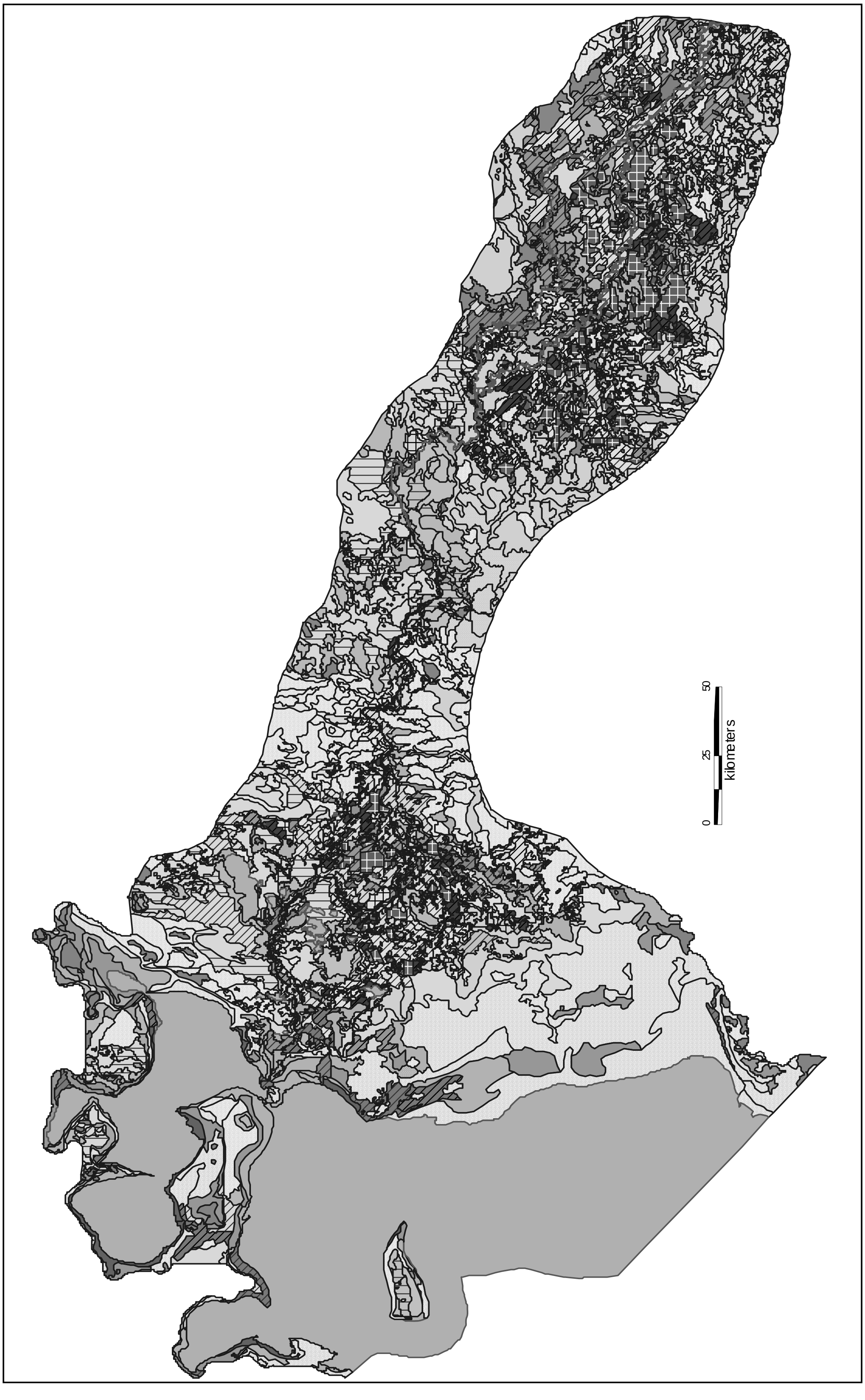

Figure 1. Soil map of Kazakhstan Priaralie and Syrdarya River lower reaches in 1987.

Figure 2. Soil map of Kazakhstan Priaralie and Syrdarya River lower reaches in 2003.

Soil maps legend

1 Brown desert non-salt soils	26 Alluvial meadow-swampy dried salty soils
2 Brown desert salty soils	27 Swampy salty soils
3 Brown desert solonetzic soils	28 Swampy salty dried soils
4 Brown desert undeveloped soils	29 Alluvial swampy soils
5 Brown desert irrigated soils	30 Swampy salty soils
6 Graybrown desert nonsalt soils	31 Seaside swampy soils
7 Gray-brown desert salty soils	32 Seaside swampy dried soils
8 Gray-brown desert solonetzic soils	33 Desert solonetz
9 Meadow-brown soils	34 Usual solonchak
10 Takyr-like soils	35 Meadow solonchak
11 Takyrlike soil swith sand cover	36 Shor solonchak
12 Takyr-like irrigated soils	37 Secondary solonchak
13 Takyr	38 Takyric solonchak
14 Seaside soils	39 Seaside solonchak
15 Seaside soils with sand cover	40 March solonchak
16 Meadow salty soils	41 Desert hilly sands
17 Meadow dried salty soils	42 Desert ridge-hilly sands
18 Meadow irrigated soils	43 Desert eroded sands
19 Alluvial-meadow salty soils	44 Desert flat sands
20 Alluvial-meadow dried salty soils	45 Seaside salty sands
21 Alluvial forest-meadow soils	46 Rice-swampy soils
22 Alluvial forest-meadow dried soils	47 Anthropogenic-broken soils (settlement)
23 Meadow-swampy salty soils	48 Paleogenous and neogenoys parent material
24 Meadow-swampy dried salty soils	49 Water
25 Alluvial meadow-swampy soils	50 Anthropogenic-broken soils (towns)

with relief, mother rocks, ground waters, vegetation, anthropogenous influences are allocated. The basic types and subtypes of soils are shown in the map. Soil genera, differing on carbonate compound, salinization level and other attributes, caused by influence of soil forming rocks, ground waters etc. are allocated among them.

Results of soils analytical research and generalization of the retrospective data have allowed to characterize the basic morphogenic properties of soils allocated on maps. They are resulted below.

Brown desert soils are a zone subtype of a subzone of northern deserts. Soils are formed in authomorphic conditions on watershed surfaces of smoothed hilloks and ridges and also are occured as homogeneous contours on the sandy and loamy-sandy plains adjoining or located among sand masiffs.

Water regime of soils is not flushing; their humidifying occurs only due to atmospheric precipitation. Thereof brown desert soils are carbonated on surface, oftenly they feature by residual alkalinity and salinization. Within the limits of characterized territory brown desert soils are presented by genera of not salinized, salinized and solonetzic.

Brown desert not salinized soils form large quite homogeneous contours on flat and slighly rolling sandy plains. In conditions of more brocken relief brown normal soils are located on mezo- and microrelief increases of light texture. They are formed in conditions of good drainage basically under rarefied diverse-wormwood vegetation at insignificant participation of ephemers and ephemeroids.

The soil profile is characterized by weak differenciation of genetic horizons by color: from grayish-light-brown accumulative-humus horizons up to yellowish-light-brown of underlaying sands. Surface (0-2 cm) - crust followed by little bit schistous, cloddy-powder-like horizon, frequently with fine roots (A2=7-8 cm). Below - brown lumpy illuvial-humus horizon (B), has more dense structure and followed by carbonated horizon which has light-pale-yellow color with spots of carbonates, and underlayed by unstructured sandy or loamy-sandy rocks.

Brown desert normal soils of characterized territory contain up to 2,5-5 % $_{\text{of } CO_2}$, poor in organic substance (its content does not exceed 0,5-1,0 %). The content of total nitrogen is 0,02-0,06%. Rather small content of silt fractions and humus causes low capacity of absorption (6-15 mg-equ/100 g of soil). Reaction of soil suspension alkalescent and alkaline, with gradual increase of alkalinity with depth up to pH=9. Soils with light (loamy-sandy) texture prevail.

Brown desert salinized soils are similar with brown desert not salinized soils by morphological structure and the basic physical and chemical properties, differing by presence of watrsoluble salts in a profile. The sum of salts from depth 50-60 cm reaches 0,7 % at sulphatic type of salinization on anions, and calcius one on cations with increase in salt amount with depth.

Brown desert solonetzic soils form homogeneous contours in some places, but mostly lie in a complex with desert solonetz. The vegetation cover of brown desert solonetzic soils is represented mainly by anabasis-wormwood associations with various share of ephemers and salsolas participation.

Soils unlike normal are characterized by presence of dark-colored illuvial-solonetzic horizon B in an average part of profile or the bottom part of humus horizon. It is characterized by firm consistence, cracking, nutty structure.

Brown desert solonetzic soils contain 0.7-1.5 % of humus, 0.05-0.1 % of total nitrogen. The capacity of absorption makes about 10-15 mg-equ./100 g of soil with a maximum in solonetzic horizons. The absorbed bases are presented mainly by calcium, alongside with it the essential role is played by sodium which amount can increase up to 20 % with depth . Reaction of soil solution is alkaline, amplifying in solonetzic horizon. Not deep deposit of the readily soluble salts presented mainly by sulfates of calcium is characteristic for brown solonetzic soils. The sum of salts of horizon of 60-80 cm reaches 0,5-1,5 %. The texture of soil changes from loamy-sandy on surface up to heavy-loamy, sometimes clay solonetzic horizons.

Brown desert undeveloped soils are formed in conditions of strongly brocken relief on low-thickness loamy-crushed stone elluvium of bedrocks and are located mainly on benches. Soils have truncated, strongly stony profile. Thickness of soil profile does not exceed, as a rule, 15-30 cm. More dark horizon, quite unclearly, is allocated in its top part. Sometimes the whole profile consists of horizon A, directly transfoming to marl of bedrocks.

Gray-brown desert soils are a zone soil subtype of desert zone, a subzone of central deserts. Genetic features of gray-brown desert soils, caused by arid bioclimatic conditions and properties of soil forming rocks, are low thickness of a soil profile, the low content of humus, significant accumulation of carbonates with a maximum in the top horizon, the high contents of gypsum on small depth.

Within the limits of the surveyed territory gray-brown desert soils are presented by genera not salinized, salinized and solonetzic.

Gray-brown desert not salinized soils form large enough homogeneous contours on flat and slightly rolling watershed surfaces; on flat slopes of ridges and the lowered sites of a relief lie in a complex and a combination with desert solonetz and gray-brown solonetzic soils. The vegetation cover is presented mainly by wormwood-salsola associations with insignificant participation of ephemers.

The profile of gray-brown normal soils is quite precisely differentiated on genetic horizons. Presence of pale-grey porous crust (2-5 cm), broken by cracks, with schistous loose light grey subcrustal horizon with thickness of 7-10 cm lying under, is typical for it in the top part. Average part of profile (horizon B) differs appreciable density and brown hue, large-cloddy, sometimes lumpy structure, eye-spot carbonates. Gypsum in the form of veins and druse-like congestions in the bottom part of profile is not rare.

Gray-brown desert soils are very poor with humus which content does not exceed 0,8-1 %. The sum of the exchange bases hardly reaches 10 mg-equ/100 g of soil from which 85-90 % are calcium, 10-12 % - magnesium and 1-3 % - sodium and potassium. High content of carbonates (up to 9-10 % CO_2 in superficial horizons), a little bit decreasing with depth, is characteristic for soils. Soils are characterized by alkaline reaction of a soil solution, pH water suspension changes within the limits of 7,5-8. The content of gypsum in the bottom part of a profile can reach 30 %. Light-loamy prevail in texture, at appreciable heavy texture in an average and bottom part of a profile .

Gray-brown desert saltinized soils are characterized by allocation of water-soluble salts in under-humus part of a profile (about 30-40 cm). Salinization is mainly of chloride-sulphatic type (on cation content - calcium-sodium).

Gray-brown solonetzic soils are developed mainly under wormwood-anabasis, wormood-salsola orientalis-anabasis vegetation and occupy the leveled surfaces of relief where form big homogeneous contours, or form complexes and combinations with takyrs and solonetzs. Dark-brown illuvial solonetzic horizon B is characteristic for the profile. It differs significant density, cloddy or lumpy structure, heavier texture. It is observed salinization; spots and eyes of carbonates from depth of 30-40 cm . Humus part of a profile (A+B) varies within the limits of 25-30 cm.

Gray-brown desert solonetzic soils are poor with humus (0,7-0,9 %). Capacity of absorption on sharply increases in solonetzic horizons in 2-3 times, at increase in share of sodium up to 15-20 % from the sum of the absorbed bases. Illuvial solonetzic horizons are characterized with heavier texture with increase of the content of silt fraction in 3-4 times.

Meadow-brown soils are semi-hydromorphic and are widespread within the limits of delta-alluvial plains, lying on the lowered sites of a surface, the broad gullies, the dried up river beds, low flood plain terraces. These soils are formed in conditions of the additional capillary-soil humidifying caused by close level of underground waters to surface (3-5m). High mineralization of underground waters causes salinization of soil profile. Mezophyte associations prevail in a vegetation cover of meado-brown soils.

Meadow-brown salinized soils in comparison with zone desert soils contain noticeably more humus and nitrogen (up to 1,5-2,3 % and 0,07-0,17 % accordingly). The sum of the absorbed bases varies significantly: in adjournment of light texture it makes 9-14, and in heavy texture reaches 20-30 мг-equ/100 g of soil. The absorbed complex is saturated basically by calcium. The contents of carbonates reaches 6-8 $\%_{CO2}$. Reaction of soil suspensions alkaline, with some increase of alkalinity with depth. Meadow-brown soils are characterized by a various degree of salinization of sulfate-chloride type. The content of soluble salts makes 0,5-2,0 %. Sodium prevails as cation. Soils are, as a rule, non-homogenous and layered in texture.

Desert solonetzs are widespread within the limits of characterized territory and lie as continuous masiffs, and also as forming various combinations with other soils. In a vegetation cover black wormwood and anabasis with rare participation of ephemers and practically universal - lichens prevail.

Desrt solonetz contain little humus (0,8-1,0 %) and nitrogen (0,03-0,07 %). The sum of the absorbed bases in over-solonetzic horizons low - 8-10 mg-equ/100 g of soil, increasing in solonetzic up to 20-25 mg-equ/100 g of soil. The content of the absorbed sodium in solonetzic horizons reaches 25-35 %. Reaction of a soil solution alkaline (pH=7,5-8,5), with increase of alkalinity in solonetzic horizon that is connected with the high content of the absorbed sodium.

Eluvial horizons are light-loamy. Illuvial horizons are heavy-loamy with high quantity of silt particles. Soils are not salinized from surface, lightly salinized in horizon B, and salt amount of salt increases up to 1.5 % below solonetzic horizon.

Takyr-like soils are formed in conditions autho-morphic water regime under the rarefied vegetation on layered quanterary alluvial deposits of ancient delta plains of Syrdarya river and occupy extensive flat surfaces, or lying among hillok sand massiffs, under rarefied vegetation presented by saxaul, wormwood, anabasis, salsola.

Soils are characterized by hard porous crust broken by vertical cracks (A=7cm).

Takyr-like not salinized soils are poor with organic substance. The content of humus from a surface does not exceed 1 %. Distribution of humus is non-uniform in profile, that is connected with ancient alluvial genesis of characterized soils and presence of burried horizons. The content of total nitrogen also is insignificant (0,06-0,10 %), its maximum corresponds to horizons with the greatest humus content.

Takyr-like soils with blown sandy cover are formed on border of sandy massifs and in inter-range downturns under rare salsola orientalis and wormwoods. The sand cover has thickness of 10-50 cm, the below profile is mainly loamy. Favourable conditions of humidifying due to formation of sandy cover cause disappearance of crust. Maximum of salts (up to 2,5 %) is on depth 60-200 cm. Salinization is chloride-sulfate. The content of humus up to 0,4-0,6 %, its maximum quantity is in blown horizons where the greatest amount of roots is concentrated.

Takyrs are formed on negative elements of a relief - the closed depressions and negative elements of relief of various sizes (from several square meters up to several kilometers), accumulating atmospheric precipitation, fine silt mineral substances and soluble salts, washed out from surrounding higher surfaces. It is characterized by presence of very dense porous crust (1-2 cm) with the smooth matte surface broken into polygonal separateness, underlayed by lamellar horizon with thickness from 10-15 till 20-25 cm.

Soils are carbonated from surface; content of $_{CO2}$ in carbonates changes from 2-3 up to 8-10 %. Takyrs contain insignificant amount of humus (0,4-0,5 %). Reaction of soil suspension alkaline. The sum absorbed cations low (7-8 mg/equ/100 g of soil). The content of soluble salts reaches 0,7-0,9 %, they are presented mainly by bicarbonates Na and K at significant prevalence of sodium salts. Mechanical composition is clay.

Seaside primitive salinized soils have a wide circulation within the limits of the dried bottom of Aral sea. Their formation is connected with initial stages of soil formation in a mode salts washeing out, caused by light mechanical composition of the top horizons and lowering level of underground waters. A vegetation cover is non-uniform, basically presented by psammaphytes with appreciable participation of halophytes, on downturns with reed, aeloropis litoralis and others mezophytes cereals which share is insignificant.

Seaside primitive soils differ practically by not formed profile; they have no developed humus horizon. From a surface they are combined by draft-sandy-shelly deposits, from depth in 30-60 cm their profile is, as a rule, layered, variegated colored, with attributes of residual and modern gleying. From a surface - not salinized, visible allocation of salts in the form of specks and veins are marked from depth of 15 cm.

Distinctive feature of all seaside primitive soils is their high degree of salinization. The sum of salts in a sady-shelly layer (0-10-15 sm) does not exceed one percent, but the amount of salts sharply increases up to 1-2 % with depth. Type of salinization, as a rule, sulfate-chloride-sodium. Described soil contain low amount of humus upt to 0,5 %.

Seaside primitive soil with blown sandy cover are formed under very poor halophyte-psammophyte vegetation on sites of the seaside plain, adjoining to seaside sand massiffs. Thickness of blown layer can change in significant limits (10-70 cm), it differs by absence of attributes of soil formed processes, friable and schistous by consistence, is not salinized. Profile structure corresponds to those at seaside primitive soils without a sand cover with depth.

Meadow salinized soils are formed on downturns with close level of mineralized underground waters (1,5-3). The vegetation is presented by meadow associations with smaller or greater participation of halophytes.

Meadow soils are formed in conditions of unstable mode of humidifying and differ weakly formed profile, which is characterized by cleavage and presence of burried horizons. Morphological and physical and chemical properties of soils reflect both attributes of previous stages of development, and the features determined by modern soil forming processes, and differ by wide variability.

The content of humus and nitrogen, as a rule, does not exceed 2,5 % and 0,17 % accordingly. The sum of the absorbed bases makes 10-13 mg-equ/100 g of soil. Soils are high carbonated - 5-15 $\%_{CaCO3}$. The sum of salts reaches 1-1,5 % and more. Type of salinization mainly sulphatic and chloride-sulphatic.

Formation of *meadow drying salinized soils* is connected with level decrease of underground waters and change of soil forming process to a zone type. Meadow cereals drop out of structure of vegetation and are replaced by halophyte and xerophyte grasses, that leads to destruction of sod horizon with formation broken by cracks crust on a surface. In the rest morphological structure of soils long time keeps attributes of a meadow stage of development. Changes in chemical properties of soils are connected first of all with decrease of humus in superficial horizons (up to 0,7-1,5 %) and displacement of a salt maximum from a surface on depth of 15-25 cm at increase in the content of salts.

Alluvial meadow soils are a dominating element of a soil cover of alluvial and low high water bed terraces of Syrdarya river. Underground waters lie on depth of 2-4 m. With the distance from Syrdarya river and decrease in level of underground waters characterized soils are replaced by alluvial meadow drying soils. The vegetation cover is presented by shrub thrickets with the rarefied grass-cereal vegetation.

Now alluvial-meadow soils are not flooded during high waters, and soils get mainly capillary-soil humidifying, and only incidentally - additional superficial one.

For a morphological structure alluvial meadow soils it is characteristic: a grey shade of the top horizon, clevage of the whole profile, frequently presence of soluble salts in medium or superficial horizons , attributes of gleying in the form of glaucescent tones of soil thickness and rusty spots in the bottom part of profile, and also presence of burried humus horizons.

Degree of soils salinizatiom is various - from not salinized up to solonchaks, with more than 1 % of salts with sulfates prevail. The maximum of salts is usually in superficial horizons.

Soils are layered by mechanical structure. Clay prolayers lie from a surface, as a rule, the light layer on mechanical structure is marked further.

Alluvial meadow drying soil are formed under rarefied salsola-grass (weeds) vegetation with participation of trees and bushes. They form combinations with alluvial meadow soils, being formed under more raised forms of a relief, or form extensive homogeneous contours on suburb parts of flood delta and Syrdarya river bed. Humus coloring of the top horizons is usually poorly appreciable. The morphological shape of the bottom and medium part of profile corresponds to that of alluvial-meadow soils.

Owing to weak sod vegetation accumulating-humus horizon is noticeably schistous, practically without roots, friable consistence and rough lumpy structure. Lying below horizon B is more dense, brown color. The structure of a profile is typical for alluvial soil in deeper horizons. Allocation of small-crystallic salts and numerous ochre spots of iron oxide are observed from 10-15 cm. Visible allocation of carbonates are absent.

The contents of humus varies over a wide range (0,5-2,5 %), as well as capacity of absorption (15-30 mg-equ/100 g of soil) depending on a stage of drying. The soil complex is saturated basically with calcium (up to 70-75 % from the sum of the absorbed bases), partly magnesium. Alluvial meadow drying soil are characterized mainly by average (0,6 %) and sometimes strong (up to 1,5 %) degree of chloride-sulphatic salinization at a maximum in superficial horizons.

Alluvial forest-meadow soils are formed on near river bed banks of Syrdarya river under grass-shrub-wood vegetation and have the extremely insignificant distribution. The top horizon (up to 20 cm) of alluvial forest-meadow soils has dark grey color. From a surface the small sod horizon is allocated. By consistence soils are layered, mainly light mechanical composition. Burried horizons on different depth reflecting dynamism of alluvial processes are occured in profile. Traces of gleying are marked almost from a surface of profile.

The humus content in alluvial forest-meadow soils varies within the limits of 1,6-3,0 %. A degree of salinization of alluvial forest-meadow soils is various. Salts are usually concentrated in the top horizons (up to 0,7-0,8 %) at less salinized bottom (more deeply 50-80см) parts of profile. The sum of salts varies from 0,1 up to 1,5 %, with deviations on separate layers depending on their mechanical composition. Salinization chloride-sulphatic, with prevalence of sulfates over chlorides more, than five times.

Meadow-swampy and swampy salted soil lie depressions with very close subsoil waters under moisture-loving vegetation. On a morphological structure and chemical properties it noticeably differ, as the part from them is situated on drying up lakes, near the channels, former river-beds and former gulfs of Aral sea, and the part is formed in zones of flooding by waste waters of irrigational channels.

In general profile of this has well expressed, but truncated humus horizon (30-50 cm). Lower lie gleyed grey, sometimes spotty ochra-grey with insignificant content of humus horizon. Visible carbonates are absent. In the top part of profile can be observed krystals and spangles of the salts.

Soil are characterized by high enough contents of humus and nitrogen (3-4 % and 0,2 % accordingly), sharply decreasing with depth. As the capacity of absorption sharply decreases from 20-25 mg-equ/100 g on surface to 6-7 mg-equ in gley horizons. Soils possess significant cloride-sulphatic sodium salinisation in all profile (0,4-0,7 %). Reaction of water soil suspensions is alkaline.

Alluvial meadow-swampy and swampy salted soil have insignificant distribution owing to sharp reduction of freshet floods. In a high water underground water level lie on depth less than 1 m, during between high waters they fall up to 1,5-2,5 m, providing capillary humidifying of superficial horizons of soils and their solinisation. Profile are like to above described medow-swampy and swampy salted soils, differing strong lamination, presence buried horizons. The contents of humus and nitrogen fluctuate in significant limits (2-7 % and 0,1-0,5 % accordingly), with sharp reduction with depth. Content of carbonates usually high (up to 30 %), varying on horizons. Superficial horizons are noticeably salted (0,2-0,4 %). Reaction of soil suspensions is alkaline.

Meadow-swampy and swampy drying salted soil, including alluvial, long time is kept with attributes of previous stages of development though up to 2-5 m do not test soil humidifying. At dying off vegetation the surface of soil becomes bare, crast is forming. Change of periodically washing water regim to exudational leads to strong salinisation of profile. The maximum of salts is charactered for superficial horizons. Amount of the salts reach more then 2 %. Salinisation is cloride-sulphatic and sulphatic.

Solonchaks within the limits of characterized territory occured very widely, being formed on least drained areas representing the favorable environment for salt-accumulation due to ascending transit of a underground-capillary water and soluble salts due to intensive evaporation. A diagnostic parameter of solonchaks is strong salinity of profile from the surface (more than 1 %).

Meadow solonchaks are formed within the limits of flood areas of Syrdarya delta and, as a rule, do not form large homogeneous contours, but form complex with alluvial meadow soils and ordinary solonchaks. The basic vegetation formed by Tamarix and Aeloropis. The top horizons are coloredby humus, from a surface are saturated with salts and often loosened. Soils contain up to 2-5 % of salts in superficial horizons which quantity decreases with depth. Type of salinization - chloride-sulfate.

Common solonchaks are formed under mainly perennial salsola vegetation on surfaces with higher level, than meadow ones, in conditions of sharply expressed exudational mode at superficial level of mineralized underground waters. Surface of soil is chubby (up to 7 cm), hilly, with salt fragile crust of pale-light grey color. Underlaying horizons are motley, layered, humidified, with numerous vein form salts. Soil boil from a surface; reaction of a soil solution is alkaline. The maximum of the salts consisting mainly from chlorides, is at a surface (up to 2-5 %). The content of humus makes less than 1 %; capacity of absorption is low (8-12 mg/equ/100 g of soil).

Shor solonchaks occupy the closed depressions of the various sizes. Close level of strong mineralized underground waters provides high salinization of profile, interfering the development of vegetation. Shor solonchaks are poor in soil formation. The structure of profile is characterized by presence of small-crystallic salt crust, formed as a result of intensive summer evaporation of underground waters, moist viscous clay, sometimes sandy unstructured mass lies under it. Underground water is on depth less than 100 cm. Reaction of soil solution is alkaline. Visible allocation of salts is on the whole profile. A degree of salinization is high: crust contains up to 30-40 % of salts. Salinization is sulfate-chloride.

Secondary solonchaks are to some extent inevitable consequence of an irrigation in desert zone at cultivation of this soils, formed on salinized soil forming rocks. Especially big areas of secondary solonchaks are located on thrown rice checks and territories adjoining them. As a whole the external shape and character of distribution of salts on profile of secondary solonchaks is similar to those at ordinary solonchaks, especially in superficial horizons. Distinctive features are a little increased humus content, higher density of profile on depth of 20-40 cm, residual attributes of recent bogging.

Takyric solonchaks widespread in ancient delta plain of Syrdarya , also lie as homogeneous contours, and forming spots with brown desert salinized soils or complexes with solonetzs. Takyric solonchaks are formed under rarefied perennial salsola vegetation, sometimes with rare ephemers and annual salsolas. Morphological structure is characterized by sometimes dense, porous, schitose, broken on polygonal separateness, crust up to 4-5 cm thickness, lying from a surface and replaced by loose structures, horizon. As a whole the profile is characterized by lamination, presence of attributes of gleying, numerous salts from 15-20 cm. Humus horizon is poorly expressed, reaches 20-30 cm.

Superficial crust is not salinized (0,2-0,3 % of salts). Their amount sharply increases in subcrustal horizon up to 1-1,5 %, increases up to 2,5-3 % in medium part of profile with depth. In superficial horizons type of salinization is sulphatic, in medium and bottom part of profile - chloride-sulphatic.

Seaside solonchaks. Formation of these soils is connected with recent regression of Aral sea and initial stage of development of soil forming processes. Soils are formed at close level of highly mineralized underground waters to a surface (1-2,5) under the rarefied vegetation cover presented by annual salsola, ephemers-perennial salsola associations.

Seaside solonchaks are characterized by the humidified, layered, floridly colored profile with prevalence rather dirty-grey, dove-grey tones, from a surface having thin crust, sometimes with salts. Humus layer is poorly generated, its thickness does not exceed 15-25 cm. It frequently followed by layered salinized soil forming rock. Attributes of gleying are shown from depth at 20-30 cm.

Seaside solonchaks have strong degree of salinization of soils from a surface (more than 1 %), in medium part of profile (40-80 cm) the amount of salts increases up to 8 %. It basically sulfate-chloride solonchaks by type of salinization.

March solonchaks are formed in periodically flooded seaside strip. The vegetation generally is absent, or is presented by annual salsolas. The morphological structure of profile is characterized by humidification, strong lamination, absence of humus horizon, attributes of gleying are from a surface. As a whole on the basic chemical properties march solonchaks are close to seaside ones.

Sand within the limits of the mapped territory occupy the significant areas.

Hill and range-hill sands are a prevailing kind of sandy massiffs. On ancient alluvial plains sands have homogeneous structure and absence of salinization, basically fixed.

Flat sands border massiffs of hill sands, and also occupy flat-lowered sites of wide hollows, making transition from shor-solonchak depressions to hill sands. A surface of flat sands is almost flat. Sometimes poorly hilly sites and not deep superficial downturn occured.

Seaside salty sands are located on the sea shore, sometimes forming coastal shaft. Seaside sands are characterized by an abundance of inclusions of a cockleshell, a pebble, fragments of bedrocks, remains of sea flora, lamination. They differ by significant degree (more than 1-2 %) of chloride-sodium salinization from a surface though visible salts are not found out.

Formation *eroded sands* is connected with intensive anthropogenous influence both agricultural, and technogenic. The organic substance in loose sands is less than 0,3 %. The amount of carbonic acid in superficial thickness reaches 2,4-2,6 %. Loose sands consist basically of fine-grained sand. The contents of dust particles does not exceed 1 %.

Irrigated soils irrespective their type undergo the deep transformation caused, besides the mechanical and chemical influences connected with agrotechnical actions on processing of an arable land, change of a water regime with not percolative on percolative. For irrigated soils in comparison with virgin analogues it is characteristic less differentiated on color and mechanical structure dense profile with stretched humus horizon and clarified arable one. Losses of humus in arable horizon can reach 50-60 %, especially in the first years of an irrigation. In under-plough horizon, on the contrary, there is a relative increase in the content of humus.

At long-term irrigation of soils in bottom (under-plough) parts of profile mechanical composition is getting heavier, mainly due to silt fraction. The mechanical composition of arable horizon can essentially vary even within the limits of one field owing to appearance of the irrigational erosion causing increase of sandy fractions in the washed off zone, and clay and silt fractions - in accumulative.

Rice-marsh soils are formed in conditions of periodical flooding. Crops are developed on meadow, meadow-marsh, marsh, takyr-like soils. Duration of constant flooding of rice fields makes 90-110 days, up to 15 thousand m^3/hectares of water is filtered during this time through soil. As a result of it level of underground waters varies seasonally - from 2,5 m in the beginning of irrigation to levelling out with irrigating waters during vegetation of rice in autumn.

Due to regenerative processes in anaerobic environment there is a black layer on depth of 0,5-1,5 cm, containing sulphurous compounds (hydrogen sulphide, iron protoxide). Salt wash out occurs in an arable layer and increase in density of under-ploughed horizon, increases alkalinity of soil solution, the amount of humus decreases, and humus horizon is stretched. The rest basic chemical properties of rice-marsh soils are close to virgin marsh soils.

Soil maps and data on the main morphogenic properties of soils are necessary for revealing tendencies of change of soils and soil cover of the territory, and also for forecasting further transformation. For the given project, which has a social and economic orientation, it is very important to reveal and coordinate the transformation of the territory connected with natural and social and economic conditions.

One of possibilities for this is the relative evaluation of soils based on ball system (balls of bonitet), showing value of soils relative to each other and most fertile soils (in case of Kazakhstan chernozems). In this case the soil is evaluated on its natural fertility and includes key parameters of fertility - humus content, presence of exchange cations of sodium in an absorbing complex, level of salinization, extra moistening, stoniness, etc. (The collection of temporary methodical instructions according to lands, 1979).Balls of bonitet of soils for considered territory have been calculated by the technique accepted in Kazakhstan.

The maps of bonitet indexes on 1987 and 2003 are created on the basis soil maps. Soil maps contain up to three types of soils in each contour with their area characteristic, thus for the specific intervals weighted average balls of bonitet on area of soils have been calculated. Scale of bonitet indexes are shown on table 1 and maps of bonitet balls for 1987 and 2003 are presented on Fig. 3, 4.

For creation of more evident picture of the general tendencies of soils properties changes on the basis of two introduced maps the map of dynamics of a soil cover has been created (Fig. 5). On the base of this map it is possible to count up the general increase in value or damage of territory in standard units or in any currency.

For maintenance of sustanable development of territory following measures and activities are offered.

Measures on improvement of a condition of an irrigated arable lands:

For prevention of a secondary salinization and restoration of the salted soils - carrying out of washings with obligatory removal of drainage waters for borders of territory.

Agronomical practices for an arable land - increase in depth of plowing, change of water-physical properties and culturing of ploughland (increase in thickness of an arable layer, enrichment by organic substances), flat, subsoiling plowing and zero cultivation, strip disposition of a fallow and row crop, mulching.

Organizational-economic measures and restoration are recommended for the long-irrigated arable lands dated for natural complexes of an alluvial plain - realization of re-planning of rice fields, regular levelling of a surface of a field.

The differentiated application organic and mineral fertilizers in view of a degree of degradation of arable lands

Definition of an optimum ratio of the area of farmland and exclusion from a crop rotation of unprofitable arable lands

Leading of soil-protective and water-saving technologies of watering, its qualitative improvement, realization of antierosion watering technique, reconstruction of an old irrigating network with use of polythene pipes and concrete trays).

Protection and rational use of pastures and haymakings:

Temporary interdiction of a grazing on plots, are exposed strong degradation. Such degraded pastures are usually widespread near to villages, winterings, wells.

Measures on a flooding of pastures are recommended for all natural-territorial complexes where there are no water sources and provide reconstruction old and arrangement of new wells, chinks.

Selective hay-mowing is recommended within the limits of natural complexes of the alluvial plains, described a stable and satisfactory landscape-ecological condition in view of a season and agroclimatic conditions current year.

Table 1. Scale of bonitet indexes.

Soils	Index of bonitet
Meadow irrigated soils	8
Brown desert irrigated soils	5
Takyr-like irrigated soils	5
Alluval forest-meadow dried soils	5
Meadow-swampy dried salty soils	4
Brown desert non-salt soils	4
Meadow-brown soils	4
Meadow salty soils	4
Alluvial-meadow salty soils	4
Alluvial-meadow dried salty soils	4
Alluval forest-meadow soils	4
Meadow-swampy salty soils	4
Gray-brown desert non-salt soils	3
Rice-swampy soils	3
Meadow dried salty soils	3
Alluvial meadow-swampy soils	3
Alluvial meadow-swampy dried salty soils	3
Desert solonetz	3
Gray-brown desert solonetzic soils	2
Swampy salty dried soils	2
Takyr-like soil swith sand cover	2
Brown desert solonetzic soils	2
Brown desert undeveloped soils	2
Gray-brown desert salty soils	2
Alluvial swampy soils	2
Alluvial swampy dried salty soils	2
Desert flat sands	2
Takyr-like soils	2
Swampy salty soils	2
Brown desert salty soils	2
Takyr	1
Seaside soils	1
Seaside soils with sand cover	1
Seaside swampy soils	1
Seaside swampy dried soils	1
Meadow solonchak	1
Secondary solonchak	1
Seaside solonchak	1
Desert hilly sands	1
Desert ridge-hilly sands	1
Anthropogenic-broken soils (settlements)	1
Anthropogenic-broken soils(towns)	1
Takyric solonchak	1
Usual solonchak	1
Shor solonchak	0
March solonchak	0
Desert eroded sands	0
Seaside salty sands	0
Paleogenous and neogenoys parent material	0
Water	0

Fig. 3.. Map of of bonitet indexes on 1987.

Fig. 4.. Map of of bonitet indexes on 2003.

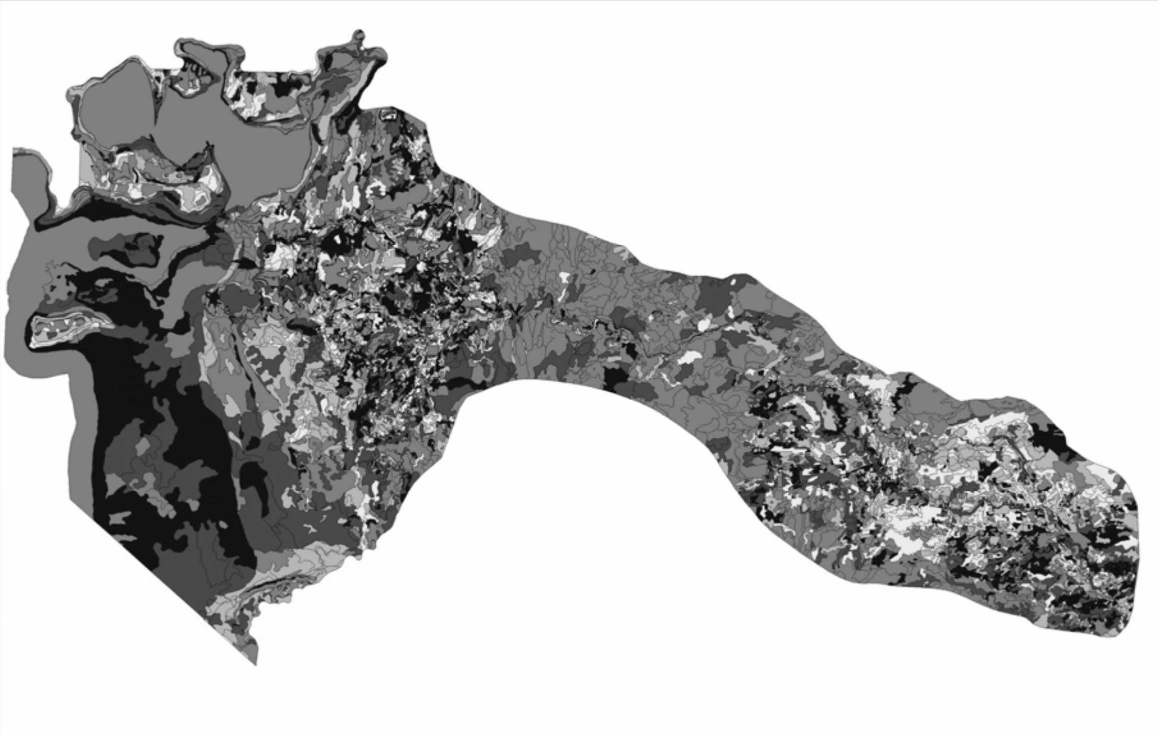

Fig. 5. Map of dynamics of a soil cover (grey color – not changed territories, light color – positive bonitet, dark color – degradation).

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Manuscript received in 04 January 2005.

Резюме

Пачикин К., Кривенко В., Ерохина О., Шильдебаева С. **Динамика почвенного покрова Казахстанского Приаралья и нижнего течения р. Сырдарья**

Прогрессирующее развитие процессов опустынивания в Приаральском регионе вызывает настоятельную необходимость достоверной оценки степени трансформации почвенного покрова в результате снижения уровня Аральского моря, зарегулирования стока реки Сыр-Дарьи и нерационального водопользования. Созданные с использованием космических изображений SPOT и Landsat и фактических данных, полученных во время полевых исследований, почвенные карты по состоянию на 1987 и 2003 год, с одной стороны, фиксируют изменения, произошедшие за этот период, а с другой, могут служить основой для составления прогнозных и других специальных карт, в качестве которых представлены карты бонитета почв и карта динамики почвенного покрова региона.

INTEGRATED SYSTEM FOR MODELLING AND EVALUATION OF NATURAL-ECONOMIC RESOURCES IN THE KAZAKHSTAN PRIARALIE

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In September, 2002, at the World summit on steady development in Johannesburg, the European Union (EU) has officially declared the beginning of realization of the Global water initiative: " Water for a life - health, well-being, economic development and safety

The question of an estimation of the future, let even the confidant, always was important for planning strategy of perspective development for each state.

The important tool for such purpose are mathematical models Calculations on model can promote acceptance of more progressive decision better approaching to an overall objective.

One of main tasks in project INTAS ARAL SEA – 1072 became build of a kernel of the Integrated system for Kazakhstan Priaralie**.** And on the one side the main database incorporated in GIS should describe scale processes at a level of basin of Syrdarya , and with another – to correspond to needs of concrete region for an estimation both water, and soil resources.

Structure of regional system for Kazakhstan Priaralie.

The kernel – the integrator of system (fig. 1) is constructed on the basis of the final logic automatic device, (as the majority of problems of the project are well enough formalizable) and represents the standard console interface with 3D – a visual analyzer. At construction of system opportunities DirectX Software Developer Kit were widely used. The kernel of system created by Vladimir Krivenko in the ISOTOPE Association.

Derivative geoinformation system and its representative block interface it is constructed on the basis of MapInfo Professional and actively uses toolkit GEOLINK. This popular GIS is effective enough and accessible economically to the majority of potential users in Kazakhstan. The set of accompanying maps in format MapInfo Professional has been created. For example, maps of rice checks of Khazalinskiy and Kzylordinskiy arrays for 1963, 1987, 1998 both 2003 according to Kazgiprozem and to data of remote sounding.

The block naturally – scientific models includes base soil dynamic model, climatic model, model of a relief and can be added. Also the set of the special utilities intended for preparation of the information for modelling and construction of base model of a relief, and also the utility of calculation bonitification here enters.

The block socially – economic models includes analytical model of development of the Kazakhstan subpopulation and an infrastructure of region and can be added.

The derivative geoinformation system can display socio – economic scripts and parameters of an estimation of territory and can form a basis of classic visualization on time cuts of processes and the phenomena.

The background database consists of the survey maps caused in a mode 3D. The Basis for data of the system, containing the detailed information on territory, is divided on segments. The principle of segmentation allows to work on a personal computer of middle class. For a basis the usual text file. In general the system does not contain any complex for specialists components in development, except for the models working in the environment of mathematical package MATLAB and is compatible to any popular GIS – system. All initial data are entered in GIS environment.

In a general view work of system looks as follows:

The kernel of system is started. Originally the system loads an abstract landscape for guide for the user (Look a Fig. 2). In the bottom of the screen there is an information panel of a conclusion of parameters of the volumetric cursor – a sonde, geographical coordinates and height of a sonde on a surface within the limits of a survey map or a segment and distance from spacecraft up to a sonde. The user can freely move a probe on a surface of a map and move in space of model. Below a line of parameters of a sonde there is a line of parameters of a segment – its position on a survey map and base number for a call.

Following step – a call of the utility of creation of a primary matrix the button " Create Matrix Database " This program creates three matrixes of heights:

- matrix in the size 5000 x 5000 elements with step approximately 100 m
- matrix with step of 1000 m for maps of scale 1:1000000 (maps of pools, etc.)

- matrix with step approximately 5000 m for the survey maps loaded by system

All three primary matrixes have in each line number of an element, number of a segment and coordinates in a projection "longitude - latitude" in decimal degrees to within six signs after a comma. Then for point objects of matrices in GIS environment on preliminary created topographical maps or radar data the grid of heights is created and data from it are transferred on an initial matrix.

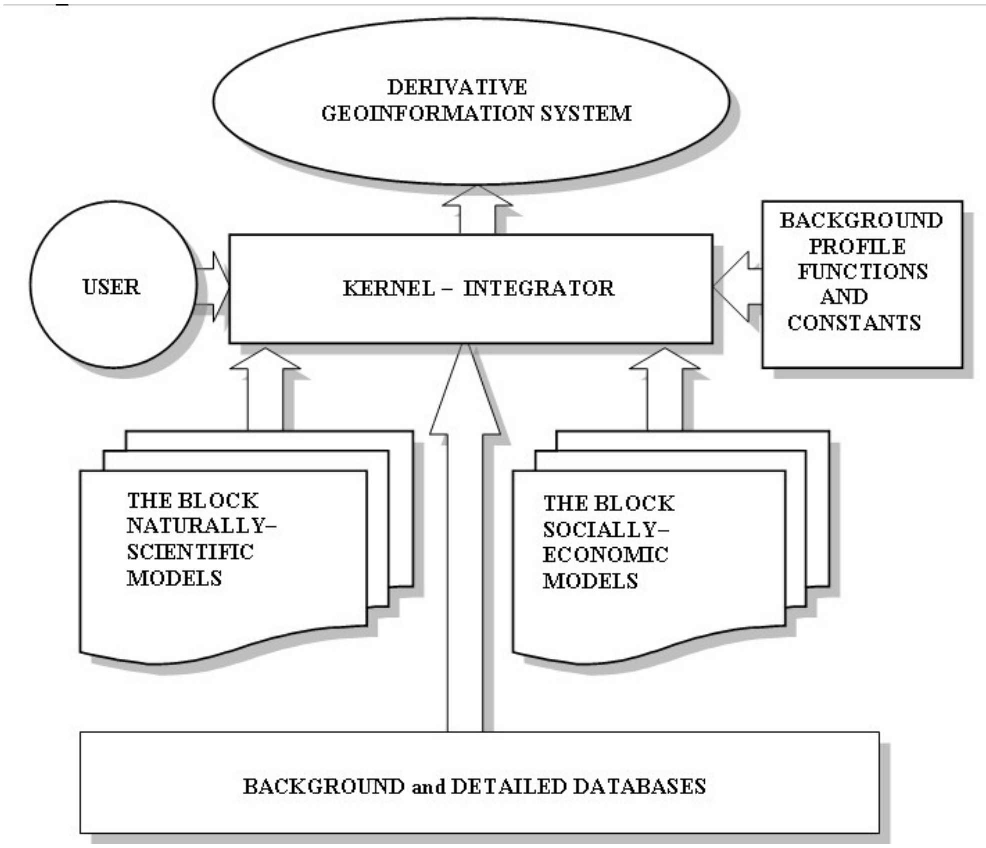

Figure 1. Block scheme of system.

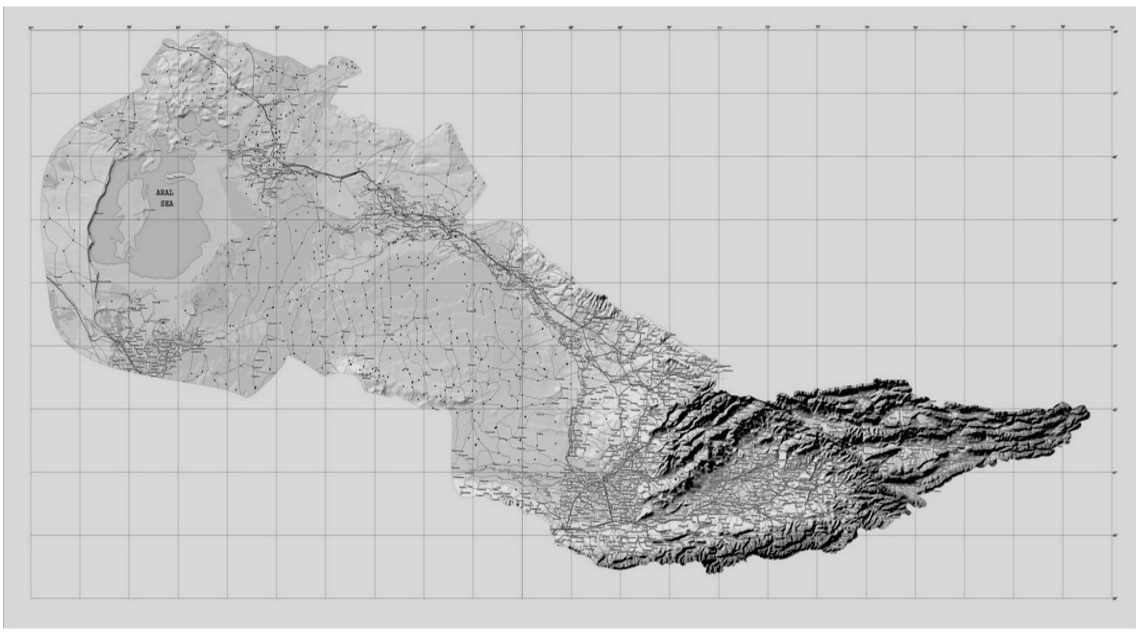

Figure 2. Example of use of a topographical map on the basis of digital model 1km This map is in derivative GIS and contains the previous information about detailed territories of the project, soil profiles and levels of Aral Sea in it vector model.

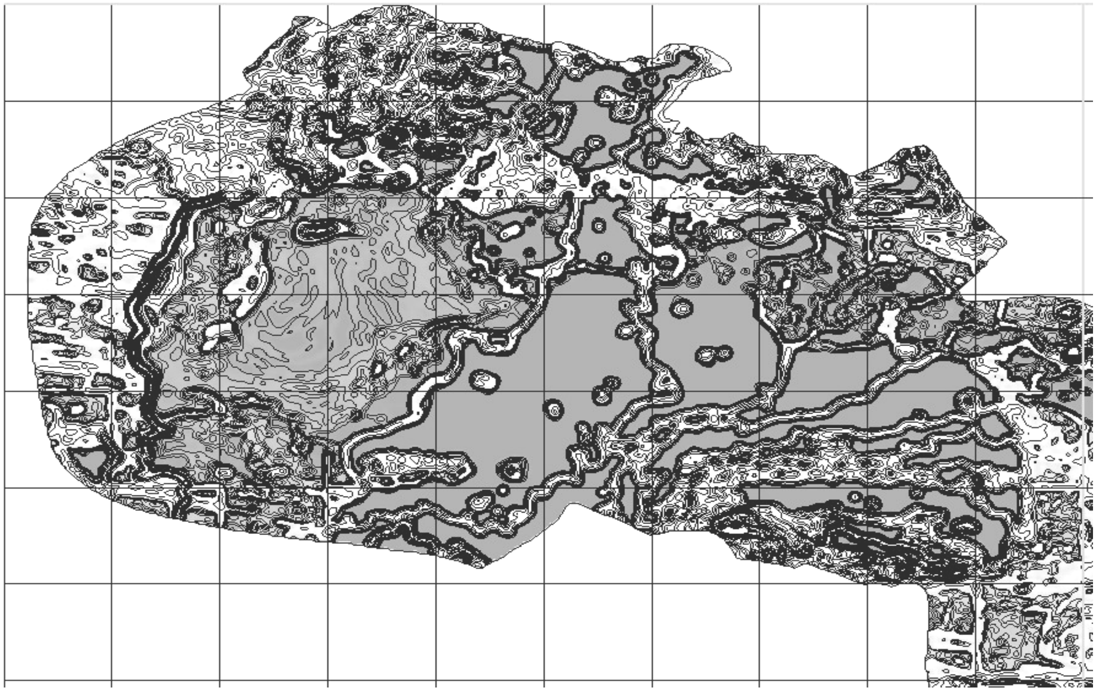

Figure 3. Example of use of a basis digital model 1km. Map of morphometry structures - angles of slopes. Are well visible radial structures of ancient delta of the Syrdarya river and terrace of the ancient Sea. We use for this Space Shuttle radar data.

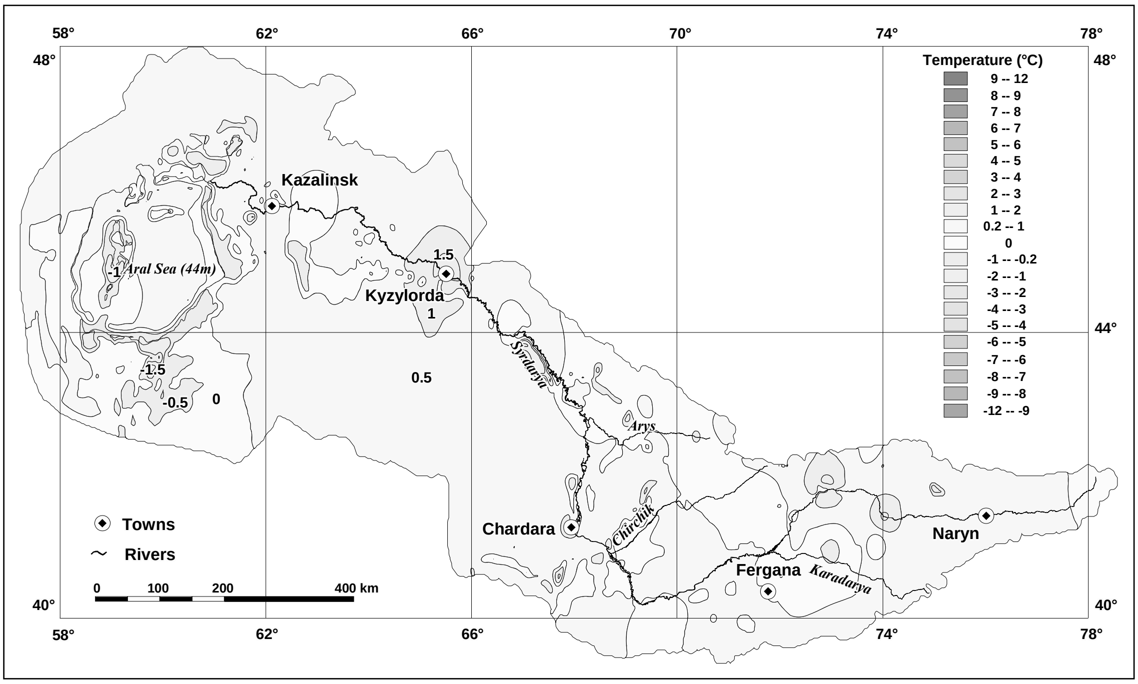

Figure 6. Changing of annual air temperature (C°) between 1985 and 1965.

During performance of the project in the ISOTOPE Association two basic grids of heights – one for all territory of a river basin of Syrdarya with step of 1000 m and the second with step nearby 100м for detailed territory have been created. The detailed territory got out according to primary climatic modelling for pool by criteria of the greatest changes for the period.

For work of climatic model and definition of correct parameters of the soil maps created under space images, it is necessary to count morphological parameters of a relief: the elementary area of a surface, a corner of a bias and an azimuth of its orientation. For this purpose by the corresponding button the utility “Compute Matrix” also is started. Parameters pay off by Evans – Young method well-known technique when parameters of surrounding points are considered.

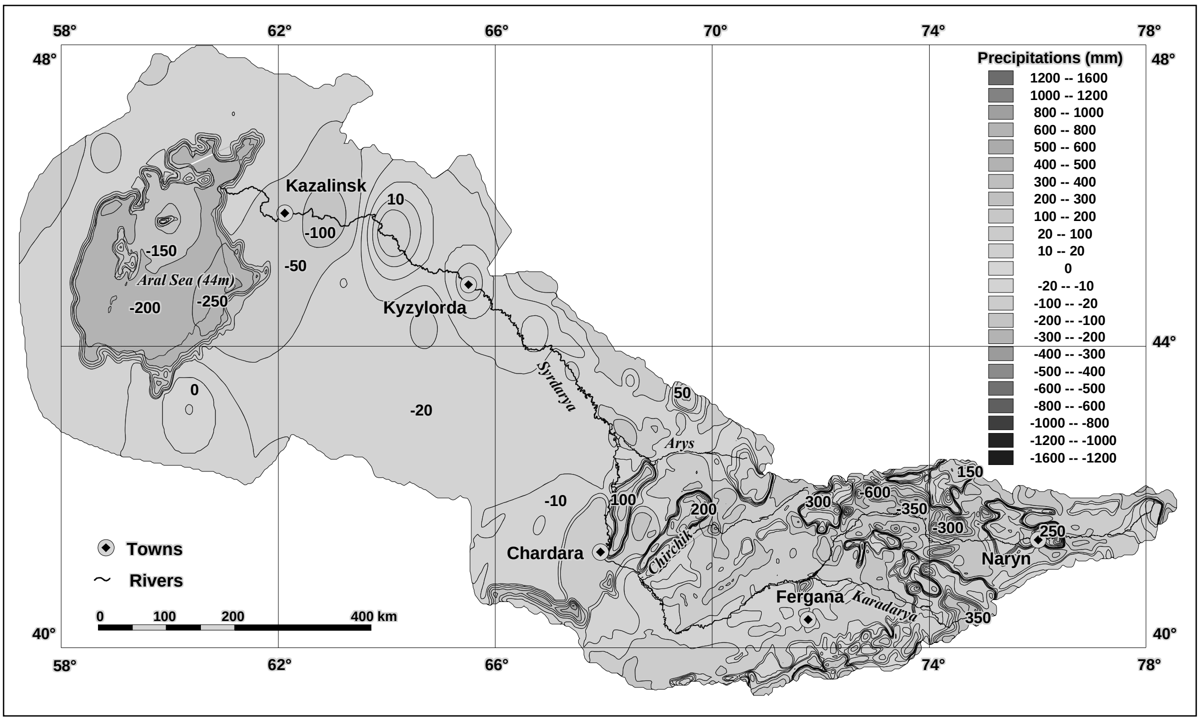

Figure 7. Changing of annual precipitations (mm) between 1985 and 1965.

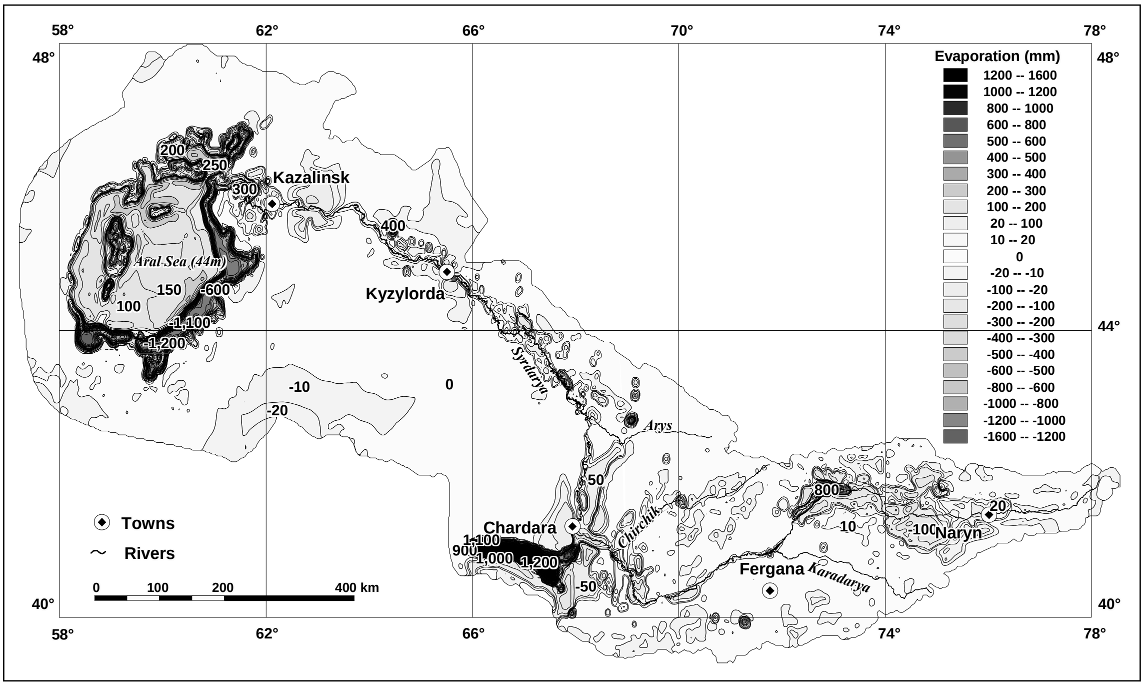

Figure 8. Changing of annual evaporation (mm) between 1985 and 1965.

For work of climatic model and definition of correct parameters of the soil maps created under space images, it is necessary to count morphological parameters of a relief: the elementary area of a surface, a corner of a bias and an azimuth of its orientation. For this purpose by the corresponding button the utility “Compute Matrix” also is started. Parameters pay off by Evans – Young method well-known technique when parameters of surrounding points are considered.

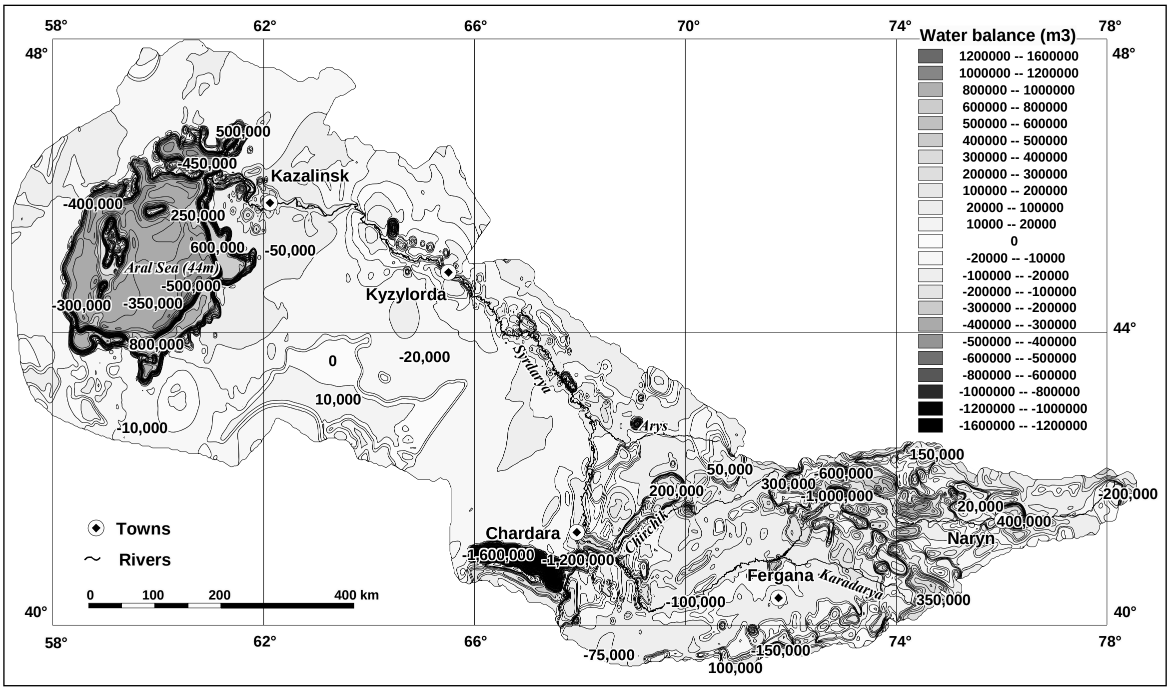

Figure 9. Changing of annual water balance (m3) between 1985 and 1965.

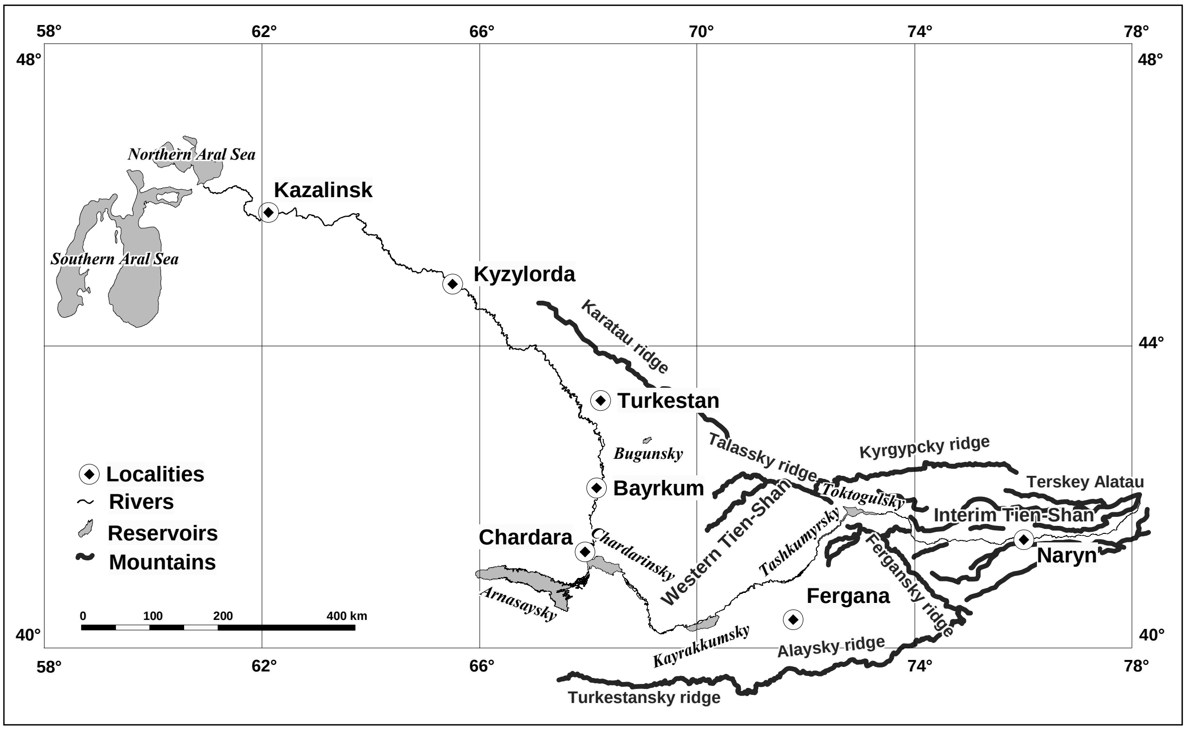

Figure 10. Map of water reservoirs of Syrdarya river basin.

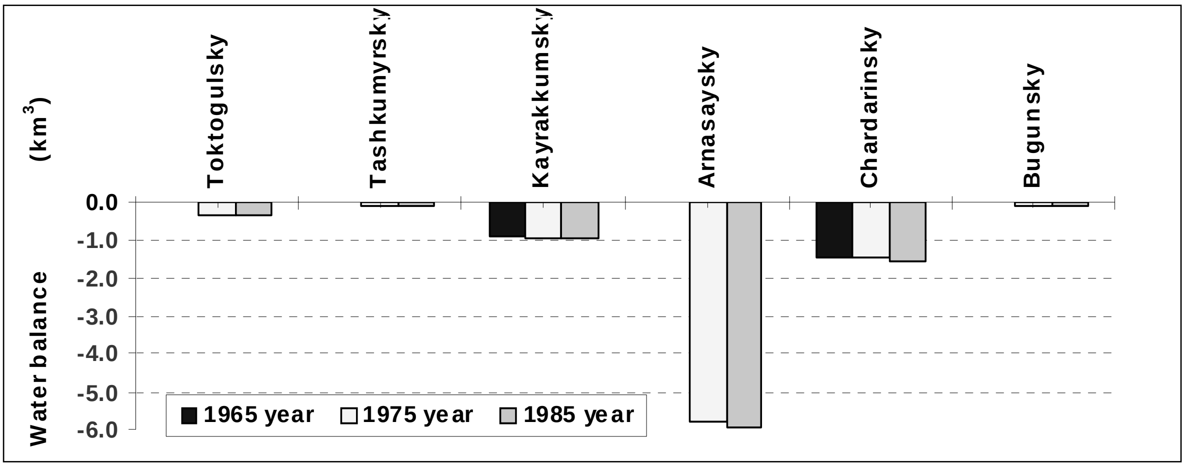

Figure 11. Water balance of more large reservoirs of Syrdarya River basin on three decades 1960-1990.

For seventieth years total losses of water store conditioned of evaporation for all large reservoirs were equal *-8.70 km3/year* and water losses from Kayrakkumsky, Arnasaysky and Chardarinsky reservoirs was equal *-8.17 km3/year* or *94.97 %* from total value. For eightieth years common water losses of same reservoirs were equal *-8.97 km3/year*, water losses from Kayrakkumsky, Arnasaysky and Chardarinsky reservoirs were equal *-8.46 km3/year* or *94.28 %* from total value. Losses of water resources from only one Arnasaysky reservoir have made accordingly:

for the seventieth years *-5.76 km3/year* or *66.20 %* from total amount;

for the eightieth years - *-5.94 km3/year* or *66.29 %* from total amount.

Following stage – prepared under space images and ground data soil maps (Konstantin Pachikin, Olga Yerokhina, Institute of Soil science KZ), "are put on" digital model of a relief by means of GIS and thus data for work of climatic model are prepared.

The climatic model developed by Jury Grechanichenko (Institute of Geography KZ), has no in the given configuration of executed files and be executed in the environment of mathematical package MATLAB. Result of work of model – maps of temperature modes, maps of modes of humidifying, etc., in conformity with properties of a spreading surface, type of a relief and data of ground meteorological stations.

During debugging system in the ISOTOPE Association climatic parameters for 1987 and 2003 have been computing.

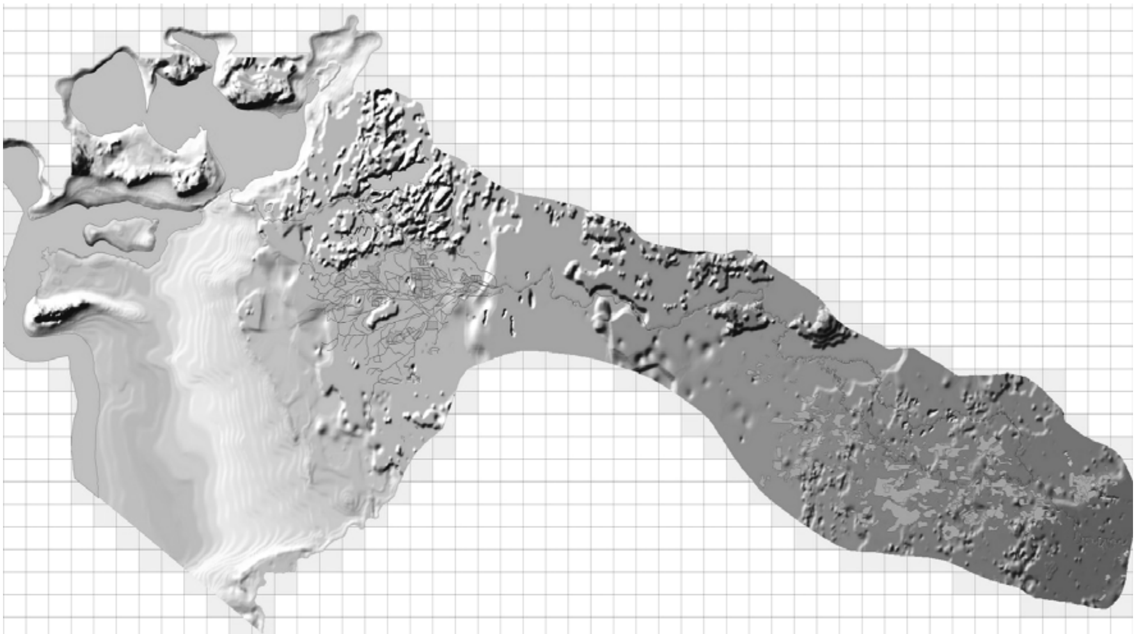

Figure 4. Digital model of a relief of 100 m and survey map (water area of Aral sea for 2003 is shown.

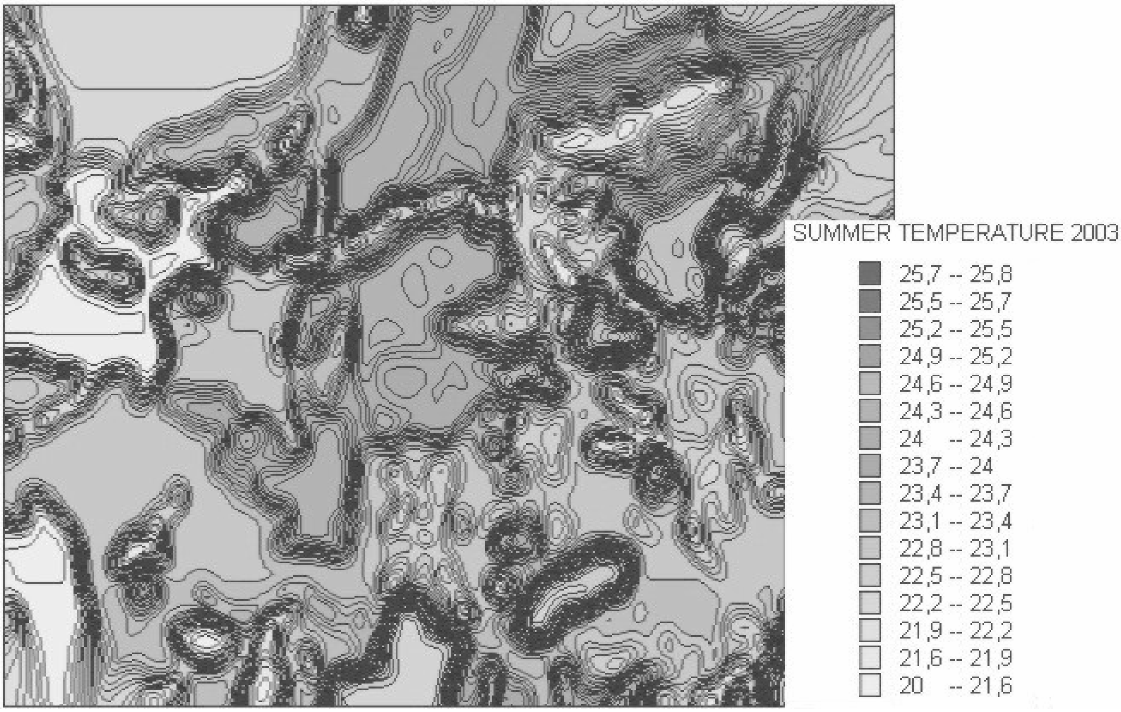

Figure 5. Fragment of a map of a temperature mode. Delta of Syrdarya River, a part of Khazalinsk irrigation system. Real step of model 0.1 ^{0}C. Grid 100 m.

Further it is necessary to compute dynamics of investigated territory for the period. By means of GIS maps of differences of temperatures easily pay off. Has more difficultly put is with a soil cover. For investigated territory the Institute of Soil science had been created a database of morphogenetic and physical - chemical soil properties and a classical appraisal scale on the basis of this database and to actually soil maps.

Figure 6. Map of dynamics of territory. Grey color – not changed territories, light – positive, dark color – degradation (it is well visible a dried bottom at the left below).

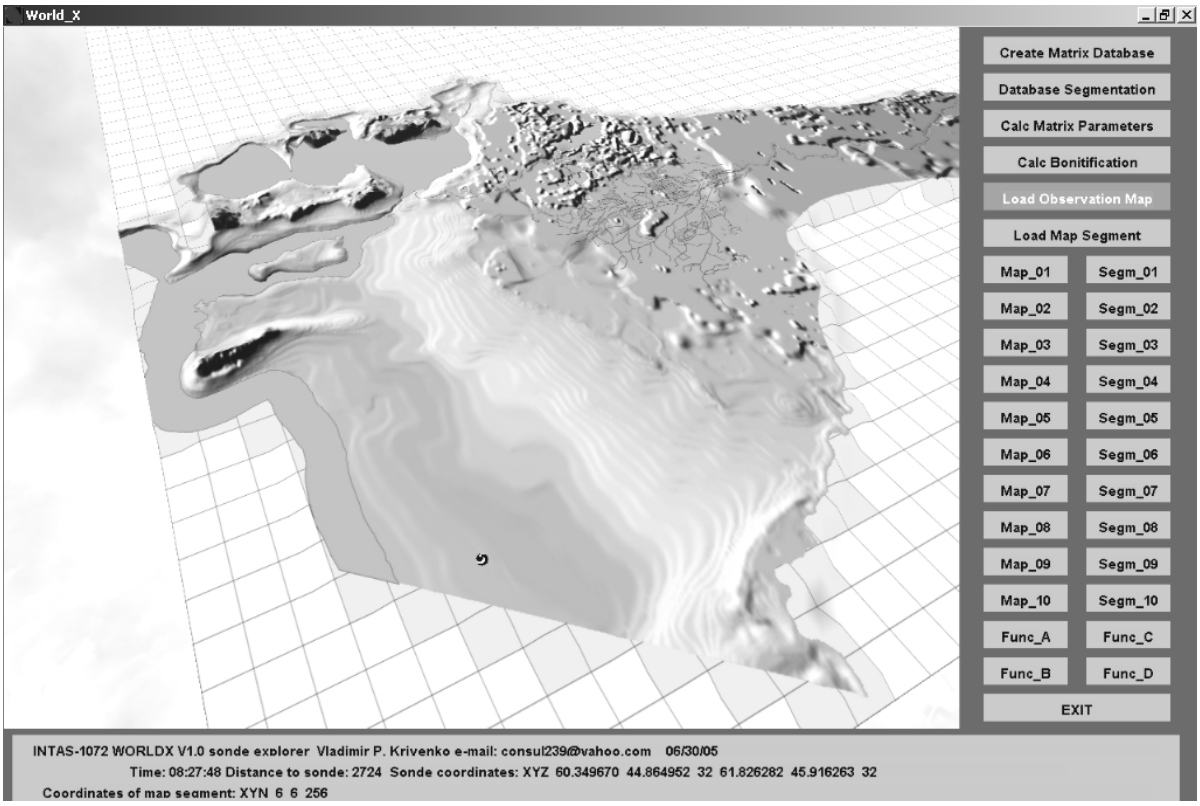

Figure 7. Survey map of Priaralie loaded into system.

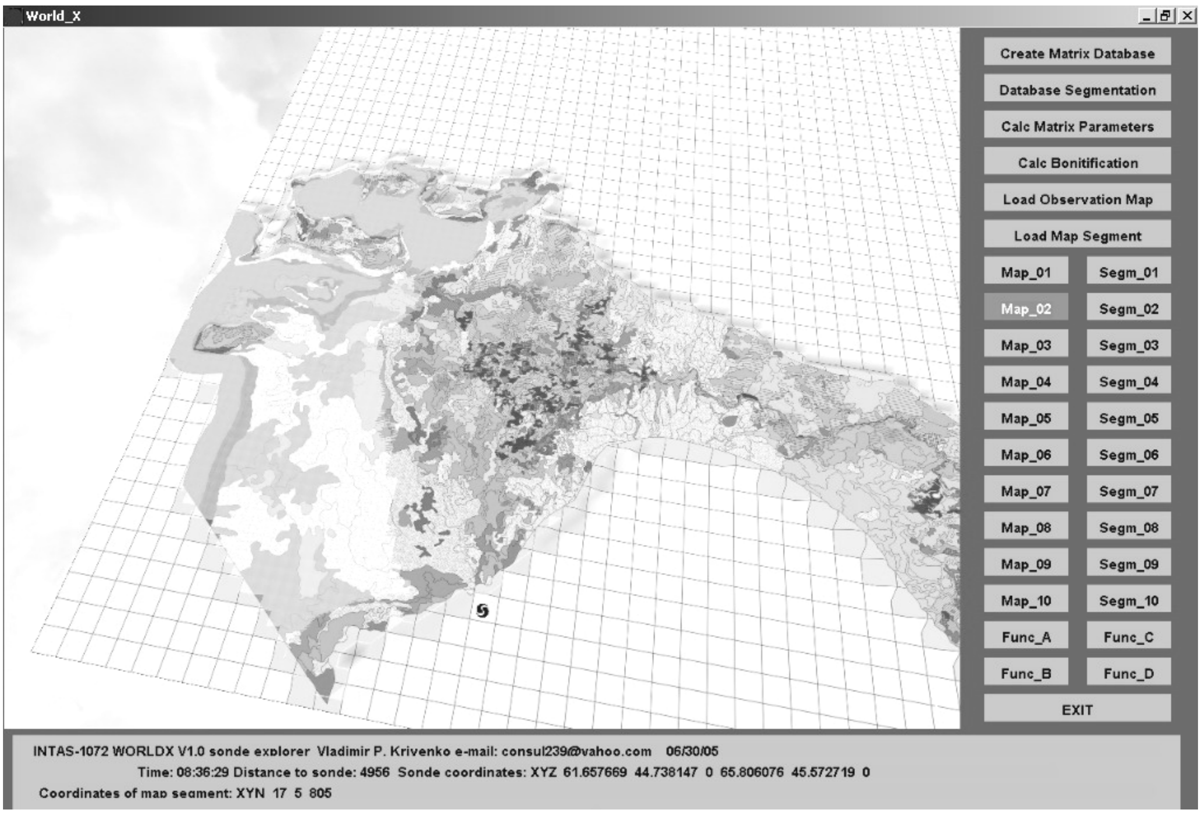

Figure 8. Soil map of Priaralie 2003 loaded into system. The water level of 45 meters is shown.

On the basis of this scale Vladimir Krivenko had been created the synthetic estimated scale and general vector map by a method of mutual crossing. The scale has the concrete not approximated values of points corresponding physical parameters of ground and the point "0" for a water table in it is changed on 1. It is made for an estimation of presence of a water table.

Thus, the basic block of the utility of appraisal numbers contains the program for an estimation of territory as on soil databases with various appraisal numbers scales, and on non-standard scales, including water resources.

The estimation is conducted according to indexes of the first, second and third components of soils and their percentage.

After calculation on each database for the period means, has been created a general vector map by a method of mutual crossing. It provides decomposition of data and allows to place a difference of parameters in a free column of a database.

Result of this operation is the map of relative dynamics of territory.

Zero values in it – stable ground or water tables, not to changes, negative values correspond to degradation. Certainly, at such estimation much depends on accuracy and quality of soil maps, surf water maps, climatic maps and databases.

Now, having climatic data and data on dynamics of a soil cover, the expert – the landowner can quite state a real economic estimation of territory. Having an estimation as on natural complexes of territory and results and scripts classical social – economic model can make better decisions on management of region. The economic model also is developed for mathematical package MATLAB by Jury Grechanichenko (Institute of Geography) and can use both the given estimations of territory, and standard data of Statistical Committee of Republic of Kazakhstan.

Quite really to create a corresponding detailed database on water resources, to add detailed data about a crop rotation at a level of separate facilities and will receive an estimation of territory at a level of separate commercial structures. Well-known, that both Khazalinskiy and Kyzylordinskiy irrigation system have low efficiency and greater losses due to bad quality of channels.

If to eliminate these lacks, to establish gauges and executive mechanisms with remote control and to automate process of an irrigation, the system can be used as means of scheduling and monitoring of an irrigating fields in a real time mode.

For effective introduction of such system additional innovational project INTAS is required. The direct communication with the consumer and its help in filling base by more detailed data in this case should be provided. Interdictions on use given KazHydroMet the scientific organizations also should be taken off. For today of the price for these data in Kazakhstan are unreasonably high. Full version of system can be constructed and use for any territory at condition of presence of enough of the data.

Manuscript received in 25 August 2005

Резюме

Кривенко В., Пачикин К., Гречаниченко Ю.. **Интегрированная система для моделирования и оценки природно-экономических ресурсов для Казахстанского Приаралья.**

В статье приводится краткий обзор интегрированной системы моделирования для Казахстанского Приаралья, разработанной в рамках проекта INTAS – 1072.

THE ANALYSIS OF CHARACTERISTIC PROPERTIES OF SOLID RUN-OFF REGIME OF SOUTH-EAST KAZAKHSTAN'S MOUNTAIN RIVERS TAKING INTO CONSIDERATION THE METEOROLOGICAL FACTORS

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The solid run-off of the rivers has a very important role in formation of the Earth face and from here - in processes on its surface, including the factors, which form climate. The rivers are basic carriers of firm substance on our planet. Initial parts of cause - consequence chain: climate – rate of stream-flow of the rivers – solid run-off. But this chain can be complemented further by new parts and eventually becomes isolated by influence on a climate. Five hundred million years ago in absolutely another climate conditions the run-off deposits of the river were at least 4 times bigger, than now /1/.

In the conditions of today the climate determines the solid run-off. So, now the greatest intensity of erosion is in the zones with precipitation of 250-500 mm - from semidesert up to forest-steppe. At the same time, 40 % of run-off of weighed deposits fall only on 10 large rivers of the world /2/, and as it was formulated by A. N. Voeikov: "The rivers - a product of a climate of their basins."

In regional scale the influence of solid run-off on natural and anthropogenous processes is also great, especially in foothills. Due to the river adjournments, there is a fertile soil on the river fan, and here the main settlements. According to the change of a climate the conditions of carry of firm substance by the rivers vary also.

On a global scale the lithogenous transport of substance is connected directly to climatic inconstancy. The redistribution of moisture between continents and ocean produce the directed changes of its level and hence the intensification of transport or, by the contrary, accumulation of a solid material on land /3/. The reduction of mountain glaciation means accumulation of moraine material and repeatedly strengthens torrential danger, and every mudflow, as it is known, by way of redistribution of a crumbly-conglomerated material is equivalent to tens and hundreds years of transport of firm particles by a water flow /4/. In the given direction in long-term prospect the hydrological process in the Zailiyiskiy and Dzhungarskiy Alatau Mountains is focused. And the long-term tendencies of solid run-off, its current mode, and each instant value, are basically determined by the meteorological factors, and first of all by their derivative - liquid river and slope run-off. At the same time solid run-off is more «sensitive» to meteorological fluctuations, rather than liquid one, and its long-term changes have more ordered character.

It is known also, that the rivers are the nurses of their basins, they carry away the collected products of weathering, chemically harmful substances, and therefore the analysis of solid run-off allows estimating ecological condition of basin also.

The data on the solid run-off, water turbidity, granulometric structure of river deposits and bed load are widely applied to decision of various scientific and practical tasks: for a development of measures on rational and complex use and protection of water resources, at designing and operating of water - economical structures and objects (large and small reservoirs, clearing structures and desilter, irrigative channels etc.), in power engineering at use of water of the rivers on irrigation, household and industrial water supply and other purposes. The run-off of river deposits is an integrated parameter of slope and riverbed erosion; therefore an information about river deposits is necessary at an estimation of intensity of erosive processes and development of erosion-preventive measures. The solid run-off characterizes the quality of water and opportunity of use of water resources and concrete water objects for the various economic purposes.

In spite of the large importance, the run-off of river deposits remains to be one of the most poorly investigated hydrological characteristics, especially in mountain areas, that is caused by the large labour input of field works, difficulties of methodical and technical character, and also frequently by complexity of interpretation of available materials of supervision.

The fundamental works, available in CIS, on research of run-off of river deposits basically concern the plain rivers with sandy riverbed. They are works of M.A. Velikanov (1948 year), G.V. Lopatin (1952), I.I. Levi (1957), G.I. Shamov (1959), A.V. Karaushev (1960, 1977), V.N. Goncharov (1962), K.V. Razumihina (1969), I.F. Karasev (1965, 1991), M.A. Licitzena (1974) etc.

For the mountain rivers of CIS such works are rather poor. There are only 2-3 works are available on each mountain area. The best-known of them - the researches of V. L. Shultz (1963) and O.P. Sheglova (1972)- on territory of Central Asia, of I. V. Bogolubova (1972) - on territory of CIS, G.N. Skladchikova (1969)- on territory of Mountain Altai, A. I. Samedov (1981)- on territory of Southeast Caucasus, of S.A. Ahundov (1978) and V.A. Ayubova (1979) - on territory of Azerbaijan, of U.N. Ivanov - on basin of r. Syrdaria; of G.A. Hmaladze (1964) - on territory of Armenia, of A.I. Stepanova (1971)- for the rivers of basin of Pacific ocean (within the limits of Soviet Far East), of H.K. Tashmetov (1983)- on territory of Central Asia and some other. The majority of these works is devoted to the analysis of regional conditions of solid run-off, formation exposure of major factors of formation of river deposits run-off and estimation of size of river deposits run-off of examined mountain areas. From the mentioned works it is necessary to note the researches of V.L. Shultz and O.P. Sheglova, which are devoted to general regularity of formation of a liquid and firm run-off of the mountain rivers and which results are widely used at study of a firm and liquid run-off on many mountain areas. The work of O.P. Sheglova differs from the other works in that the method of allocation of genetic components of river deposits run-off is given in it.

The authors of the given work choose typical mountain areas of the Republic of Kazakhstan - Zailiyiskiy and Dzhungarskiy Alatau for their research work. Representativity of chosen areas on conditions of a relief, climate, glaciation is evidently shown in works of N.N. Palgov, I.S. Sosedov, E.N. Vilesov, P.A. Cherkasov, L.P. Mazur etc. Both mountain areas belong to basin of lake Balhash. Three high-altitude belts of a relief of the Zailiyiskiy Alatau (are allocated usually in the Zailiyiskiy Alatau): highland - englacial (is higher than 2800-3000 m. absl.), a middle mountain belt (from 1400-1500 m absl. up to 2800-3000 m absl.) and a low mountain - foothill belt (from 800- 900 m absl. up to 1400-1500 m absl.). There is the same allocation of high-altitude belts in the Dzhungarskiy Alatau, but their borders are 200 m below. During the last decades degradation of glaciation both in the Zailiyiskiy, and in the Dzhungarskiy Alatau, in connection with global warming of climate (E.N. Vilesov, P.A. Cherkasov) is observed.

In the Zailiyiskiy and Dzhungarskiy Alatau in high-mountain and middle mountain belts the crystal breeds of high durable properties prevail, and in low mountain zone loess dauk, which are well washed away. The basic features of climate of considered area are its continentality, natural change of the climatic characteristics with height level, significant aggravation of frontal processes. The basic regularity of distribution of a soil-vegetative cover is the high-altitude zonality and exposition distinctions.

The border of a zone of run-off formation in the Zailiyiskiy Alatau follows on the average on the height (800-900)- m absl. All rivers of the Zailiyiskiy Alatau belong to the basin of r. Ili, and the largest rivers are its left – bank inflows. There are 11 basic rivers in the Zailiyiskiy Alatau: Chilic, Turgen, Esik, Talgar, Malaya Almatinka, Bolshaya Almatinka, Kargalinka, Aksay, Kaskelen, Chemolgan, and Uzunkargali. One part of the rivers of the Dzhungarskiy Alatau belong to the basin of lake Balhash, and the other part to the basins of the rivers of Alakol hollow. The basic rivers of the Dzhungarskiy Alatau are Usek, Borohudzir, Aksu, Lepsi, Karatal, Kokterek, Tishkan, Dos, Bizhe, Tentek, Sarkand, Baskan, Aganakti, Rgayti, and Terekti.

The run-off of river deposits of examined areas, as well as of many other mountain areas, is investigated insufficiently, and the scientific generalizations on it are poor. The study of a solid run-off of the rivers of Kazakhstan hydrometeorological service has begun in the Zailiyiskiy Alatau in years 1933 - 1934, and in the Dzhungarskiy Alatau - from 1935-1936. The supervisions were made on a regime of water turbidity, the run-off of bed loads and dissolved in water mineral substances and on some posts a drain of bed loads was also measured. Except for the data of Kazakhstan hydrometeorological service and departmental organizations, the materials of special field researches on weighed and bed loads carried out under a management of N.P. Pavlenko /5/ on the characteristic rivers of the Zailiyiskiy Alatau in the period from 1949 fill 1954, and also R.K.Kromera, who measured by a volumetric way a drain bed loads of the rivers Talgar, Turgen, Kaskelen at intakes in the years of 1973, 1976, 1979.

As it was mentioned above, there are only a few scientific works devoted to sediment run-off of considered areas. The best known works were written by G. B. Lopatin, G.I. Shamov, Z.T. Berkaliev (1960), N.N. Palgov (1959), S.P. Kavetskiy (1953), E. M. Kalmynkina, N.P. Pavlenko (1960), R.K. Kromer (1985), K.K. Duskaev (1990, 1991, 1992 г.г.). The works of E.N. Piven, R.K. Iafiazova, B. S. Stepanov were made in the last years.

Basically in these works the run-off weighed sediment is considered. Only in the works of N.P. Pavlenko, R. K. Kromer, and K.K. Duskaev the run-off bed load is investigated as well. In works of G. V. Lopatin /6/ and G. I. Shamov /7/ the norm of a sediment run-off of the basic rivers of the Zailiyiskiy Alatau and Dzhungarskiy Alatau for the first time was determined at drawing up of maps of average water turbidity distribution of the rivers on the USSR territory.

Z.T. Berkaliev (1960) investigated the conditions of formation, regime of river deposits run-off of both areas made for a hydrological substantiation of measures on water-economic use of river Ili. The detailed researches of a solid run-off of the rivers of the Zailiyiskiy Alatau are carried out by E. M. Kalmynkina and S. P. Kavetskiy /8/ for a substantiation of erosion-preventive measures in mountain and foothill areas, and for the rivers of its northern slope and for power engineering and other purposes by N. P. Pavlenko.

In 1970 the «Resources of superficial waters» /9/ were published, in which the researches /5/ and other researches are generalized. In this edition the information about conditions of formation, regime, an average long-term sediment run-off of basin of lake Balhash are given, including mountain rivers of examined areas according to the data, including 1966 - 1967 years. From this time the regional generalizations on a sediment run-off of areas till the last years were not made. Some of the works of the last year's listed above are only partially devoted to a sediment run-off. In the work of E.N. Piven the anthropogenous changes of run-off of water and sediment in a zone of dispersion of a liquid drain are considered. For the decision of this task she constructed the combined integrated curves of fluctuations of an annual run-off of water, sediment runoff and turbidity of water on a number of hydrological posts at an output from mountains and compared them to the similar data on hydroposts in the mouth of these rivers; the sizes of a sediment run-off and water at the beginning and the end of a zone of dispersion were also compared.

In the works of R.K Iafiazova and B.S Stepanov the features of formation of solid run-off of the Zailiyiskiy Alatau rivers, connected with passage of torrential flood flows, are revealed. The most full researches of a run-off of weighed sediments as soon as of bed load sediments of the extremely large labour input were carried out by N.P. Pavlenko, where he used results of his own field researches. However, both from the time of these works, and from the moment of issue of " Resources of superficial waters " /9/ more than 30 years have passed already.

Thus, the regime of a sediment run-off is investigated insufficiently, even within the CIS. So, there is no information about its temporary changes. As to the territory of Kazakhstan and particularly of examined region, the studies of a solid run-off are obviously weak here. The information placed in /5/ and /9/, is based on short series, and these works could not illuminate temporary features of a course of a solid run-off, all the attention in the work /10/ is inverted on anthropogenous influence. In the presented work the data on hydrological posts in drenge area is used, where anthropogenous influence is rather small. The results reflect basically natural processes. From above-stated follows, that the available data on a solid runoff of examined areas requires addition and specification, as it is made in the presented work.

The purpose of the work: research of solid run-off of the mountain rivers of Southeast Kazakhstan, estimation of influence of the meteorological factors and directed changes of a climate on it, eduction of regularities of spatial - temporary change of run-off of river deposits and development of methods of account of the solid run-off characteristics for the unexplored and poorly investigated mountain rivers.

The estimated purpose was achieved by the consecutive decision of the following basic tasks:

- Research of the factors of solid run-off formation in examined region;
- Collection and generalization of the supervision data and information about studies of a run -off water, of sediments and of water turbidity, estimation of completeness and quality of supervision;
- Research of regime features of a solid run-off and water turbidity of the rivers in the researched region.
- Calculation of the basic characteristics of a solid run-off with use of the data for the available periods of supervision, including materials of the last years.
- Development of techniques of a sediment run-off and water turbidity calculations for the unexplored and poorly investigated mountain rivers;

Consideration of some ecological aspects of the data application about a solid run-off on an example of the rivers of the Zailiyiskiy and Dzhungarskiy Alatau.

Long-term characteristics of the solid run-off

We generalize the information about studies of the solid run-off as of 1996 inclusive. According to this data, on the rivers of the Zailiyiskiy and Dzhungarskiy Alatau in a zone of formation of a run-off there are totally 52 (45 of «Hydrometeorological service» and other 7 -of departments) of working and closed points of supervision on a solid run-off (table 1). From 52 supervision points on the solid run-off, working in various times, the norm of an annual drain is calculated on 46 of them. On 6 points the data is defective because of it's very poor quality /11/.

Table 1. Distribution of a watersheds on height.

Average weighted height of watershed, m. absl.					
1000-2000	2000-2500	2500-3000	3000-3500	>3500	In total
Zailiyiskiy Alatau					
-	5	11	6	3	25
Dzhungarskiy Alatau					
7	10	9	1	-	27
Zailiyiskiy и Dzhungarskiy Alatau					
7	15	20	7	3	52

Table 2. Average for the long-term period the charges of weighed sediments (R, kg/s),charges of water (Q, m^3/s) and water turbidity (p, g/m^3) and their deviation(rejection) from the data published in "Resources of superficial waters"/9/.

№	The river - point	The area of a watershed, km^2	Average height of a water-shed, m absl.	The period of supervision, including years with a restored runoff	Number of years	Average long-term			Deviation from the data published in «Resourses of superficial waters», %
						Q, m^3s	R, kg/s	ρ, g/m^3	
1	Chilic-village Malibay	4300	2560	1934-1991	58	31,9	23,6	740	-4,80
2	Turgen- city Turgen	614	2750	1959-1996	38	6,91	1,59	230	32,5
3	Talgar-. cityTalgar	444	3260	1934-1993	60	10,3	6,41	622	-8,40
4	Bolshaya Almatinka- 2 km higher then the Bolshoe Almatinskoe lake	71,8	3590	1957-78,1981-95	37	1,60	0,32	200	-13,6
5	Bolshaya Almatinka - 2 km higher then the embouchment Prokhodnaia river	155	3120	1955-72	18	2,88	0,43	149	16,2
6	Kumbel- embouchment	22,4	3250	1959-64	6	0,68	0,022	32	-31,2
7	Bolshaya Almatinka- 2 km below then the embouchment Teresbutak river	280	2990	1933-44,1947-49	18	4,92	1,15	234	-17,9
8	Prokhodnaia - embouchment	82	3160	1959-64	6	1,56	0,11	70	32,5
9	Teresbutak - embouchment	31	2250	1953,1959-64	7	0,41	0,05	122	31,6
10	Kaskelen - city Kaskelen	290	2680	1934-1996	63	4.15	0,88	212	-45,0
11	Aganakty - village Zhalanash	440	2890	1935-39	5	11,0	0,20	19	11,1
12	Baskan -v.Novopokrovka	883	2265	1935-41,1962-72	18	10,5	1,12	107	38,3
13	Sarkand - city Sarkand	645	2490	1935-41,1944-57	21	6,95	0,70	101	-10,3
14	Kyzylagash- village Kyzylagash	1080	1260	1959-78	20	2,71	1,50	553	25,0
15	Karatal - village Karatalskoe	1160	2400	1936-48	13	26,2	4,86	185	21,5
16	r.Karoi - city Tekeli	484	2680	1941,1947-55,1960-64	15	13,5	2,42	179	-13,6
17	r.Kaindysai - village Beriozovka	25,5	1380	1960-64	5	0,24	0,02	83	33,3
18	r. Koksu - village Koksu	1590	2950	1954-64	11	34,7	2,00	58	-4,8
19	r.Bizhe - village Krasnogorovka	825,2	1490	1950-1952,1959-61	6	2,63	0,67	255	13,6
20	r. Borokhudzir- village Kiytin	470	2100	1958-1993	36	2,24	0,51	228	112,5
21	r. Usek - 1,7 km above mouth r.Mal. Usek	724	2980	1934-51,1961-77, 1980-86,1988-96	51	11,7	0,63	54	-8,7
22	r.Mal. Usek -2 km higher confluence with r. Usek	407	2880	1934-41,1945-49	13	6.08	0,49	81	-38,8

The long-term characteristics of a solid run-off from a mountain part of Southeast Kazakhstan /12/ are calculated. Partially this data is reflected in the table 2. For the analysis of long-term fluctuations of a liquid and solid run-off by us were constructed subtractive integrated curves of modular coefficients of mean annual charges of water, charges of sediment and turbidity of water (figures 1, 2).

Water turbidity of the rivers on the territory with average heights of watershed from 1,4 up to 3,6 kms changes over a wide range - from 20-80 up to 500-700 g/m^3 and even more. Laws of characteristics distribution of solid run-off on the territory are complex. So, for the rivers of the Zailiyiskiy and Dzhungarskiy Alatau 6 dependencies are allocated such as:

$$\rho = \mathrm{A} - \mathrm{B} \lg \mathrm{H} , \qquad (1)$$

$$\rho = \mathrm{A} - \mathrm{BH} , \qquad (2)$$

$$\rho = \mathrm{AH}^{-n} , \qquad (3)$$

where ρ- water turbidity, m^3/sec,
H- average altitude of watershed, m
A, b, n - regional parameters.

The similar dependencies are received for the module of the solid run-off; there are 7 of them revealed. The layer of elution in the Zailiyiskiy Alatau makes from 0,39 till 0,03 mm / year, in the Dzhungarskiy Alatau – from 0.09 till 0,01 mm/year, the dependencies on height of watershed /13/ are traced here too.

The total fan of a firm material by the basic rivers at an exit from the mountains comprises for the Zailiyiskiy Alatau 1140 km^3/year, and for the Dzhungarskiy Alatau -1265 km^3/year. Thus, the characteristics of the solid run-off are related to a high-altitude situation of watershed and reflect its morfometric and climatic parameters.

The changes of these characteristics in time are related to meteorological features of different years and climatic inconstancy. Coefficient of variation of the charges of sediments on the rivers with the longest series of supervision makes from 0,5 up to 2,1 that surpasses C_v of an annual drain in 3-7 times. At the same time between these sizes there is a certain direct relation coefficient of correlation r = 0.79).

So, at conformity of fluctuations of these characteristics, scope of changes of the solid run-off is always much greater, than of a liquid, that means the large sensitivity of the solid run-off to the climatic changes and meteorological fluctuations. The directed changes of the hydrological characteristics are related to the global warming (figure 3).

There was especially significant global warming from the middle of 70's. As a result, from the middle of 50$^{/}$s, the area of glaciation in Zailiyiskiy Alatau reduced to triens /14/. The reduction of glaciation may course either an increase of a liquid river run-off (expenditure of century stocks), or its reduction of the ablation area. Tendencies of a liquid river run-off are diverse.

In the work /15/ the general reduction of drainage rate of stream –flow of the rivers in region is marked, but in a zone of formation of run-off the trend is statistically nonsignificant, whereas in closing locations of the rivers it is significant and caused mainly by anthropogenous factor. At all individuality of run-off course of the different rivers in a zone of its formation, three types of it /16/ are allocated:

- " Dzhungarskiy " (for the rivers of the Dzhungarskiy Alatau with significant glaciation of basins) - the trend is positive, till the beginning – middle of 60's it was significant, and then is weakened;
- " Zailiyiskiy " – the trend is negative, and up to the middle of 50$^{/}$s it was not expressed, and then it is significant;

"Mixed" - is tupical for the majority of the rivers; a negative one replaced an obvious positive trend from the beginning 70's.

Thus, for the majority of the rivers in the beginning of the supervision period the increase of a water drain, or its provisional constancy is marked.

There is a negative trend line of run-off weather for the whole period of supervision, or for the last decades in the Zailiyiskiy Alatau. There is a positive trend line of run-off on a number of rivers in the Dzhungarskiy Alatau (the glaciation is more powerful here, than in Zailiyiskiy), or its complex course /16/. Spending age-long reserves of glacier moisture compensated climatic tendency of decrease of liquid run-off in some degree. The directed changes of solid run-off are more certain. In the Zailiyiskiy Alatau and on the southern slope of the Dzhungarskiy Alatau the trend line is negative (it means that the firm material accumulates in the depression of relief), on the northern slope of the Dzhungarskiy Alatau the trend line is positive. The characteristics of trend line for some rivers, which are calculated on sliding 10-years average values of the discharge of weighed deposits are submitted in the table 3. Rating of linear trend and parameters of the equation are given there

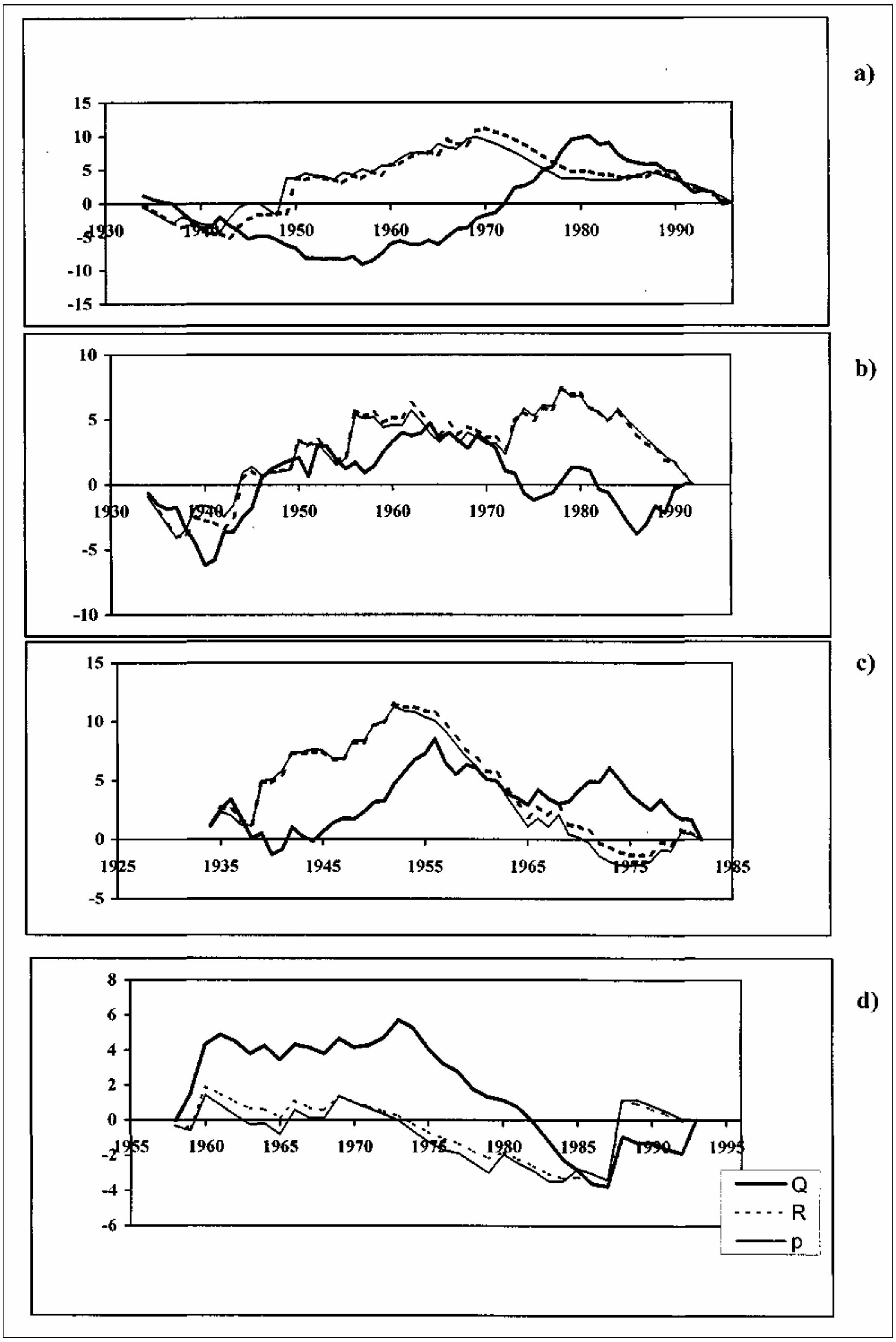

Figure 1. Combined subtractive integrated curves of modular coefficients of the average charges of water ($Q, m^3/s$), of suspended load (R, kg/s) and of water turbidity (p, g/m^3)

Axis of abscissa - years, axis of ordinates - relation of ordinates subtractive integrated curves (mass curve) to the coefficient of variation ($\sum(k-1)/Cv$)

a) Kaskelen—Kaskelen, b) Talgar—Talgar, c) Chilic—Mailibay, d) Borokhudzir—Kiytin.

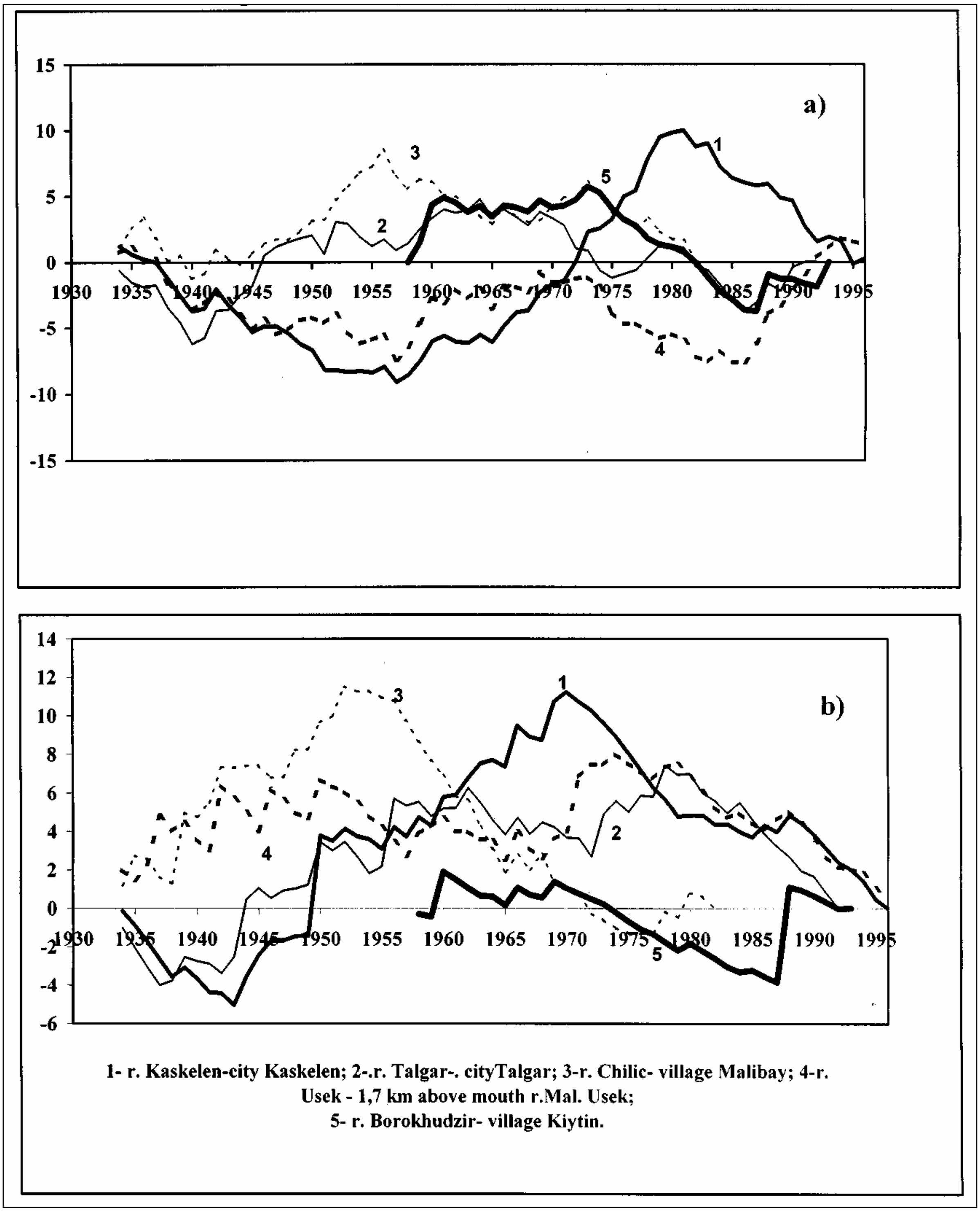

Figure 2. Combined subtractive integrated curves of modular coefficients of the average charges of water ($Q, m^3/s$) (a), and of suspended load (R, kg/s) (b) for basic hydrological posts

Axis of abscissa - years, axis of ordinates—relation of ordinates subtractive integrated curves to the coefficient of variation ($\sum(k-1)/Cv$).

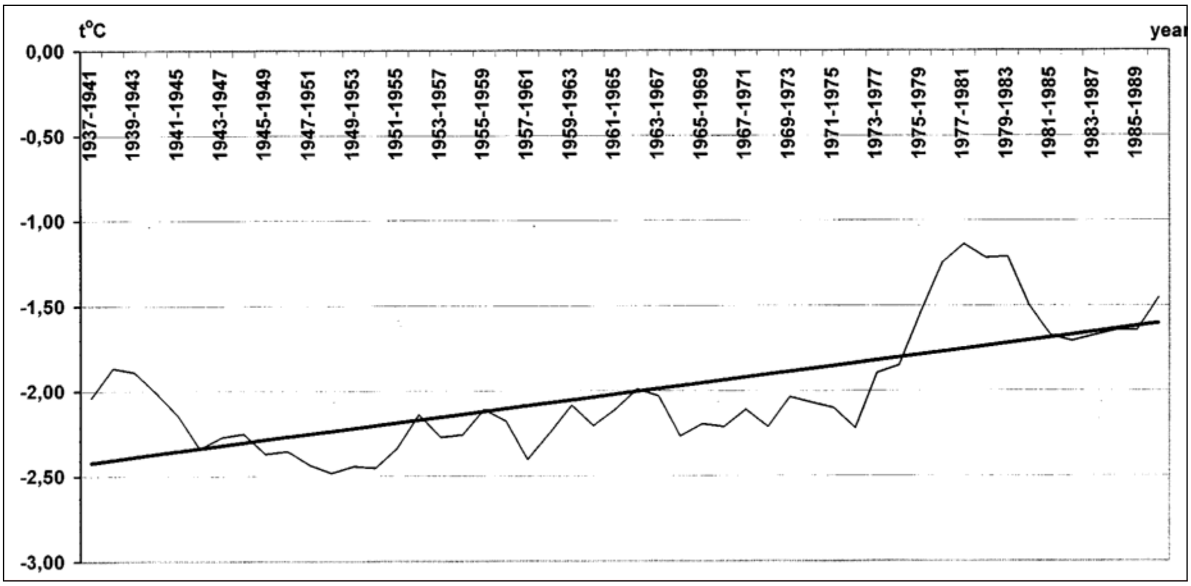

Figure 3. Sliding 5-years average temperature of the air on the data of the meteorological station Mynzhylki.

$$Ri = a\,(t-t_0) + R_0\,,\ kg\,/\,sec\ , \qquad (4)$$

where t - number of the current decade, beginning from the average;

t_0 - the average decade of set, and $t_0 = 0$;

R_0 - norm of a solid run-off, kg / sec;

a - empirical parameter showing intensity of the directed long-term change of solid run-off.

All values of the correlation coefficients given in table 3, are significant at a level less than 1 %.

There is an obvious reduction of a solid run-off from the beginning of the period of supervision till its end on all rivers of Zailiyiskiy Alatau. More precisely this trend is expressed on r. Bolshaya Almatinka (as well as on a liquid run-off) and on river Talgar. The trend on r. Usek, which flowes down from the southern slope of the Dzhungarskiy Alatau is also negative. On the rivers of northern and western slopes of the Dzhungarskiy Alatau - Koksu, Baskan - on the contrary the trend is significantly positive (figure 4). With an exception of a number dry thirtieth years the trend becomes absolutely obvious. Usually it is statistically significant at a level of 1 %. If on the river Chilic to take a short row, from the middle of 60s the positive trend can be revealed.

The occurred changes of the solid run-off are rather significant. On the rivers of the Zailiyiskiy Alatau for the period of supervision it has decreased in 1,5 - 2 times, and on the river Kaskelen - almost in 5 times. On northern and western slopes of the Dzhungarskiy Alatau the solid run-off has increased in 2-3 times. The marked tendencies concern the period of the so-called unbroken mode, that is these changes basically occurred not at the expense of economic activity. There is a definite coordination of the long-term tendencies of liquid and solid run-off, on the majority of the rivers the details of their long-term course are substantially coordinated also, at the same time solid run-off immediately reacts to the significant rains (figure 5). As a result the scope of fluctuations of solid run-off is much more, than liquid one.

Table 3. Evaluation of the trend of solid run-off under 10-years average charges of of weighed deposits.

	River - Point	Period	r ± E	t_0	Ro, kg/s	a
1	Bolshaya Almatinka - 2 km higher then the Bolshoe Almatinskoe lake	1957-1995	-0,88 ± 0,03	1971-1980	0,32	-0,075
2	Talgar - Talgar	1934-1992	-0,67 ± 0,05	1958-1967	6,99	-0,077
3	Talgar - Talgar	1943-1992	-0,7 ± 0,05	1963-1972	6,77	-0,096
4	Kaskelen - Kaskelen	1934-1996	-0,63 ± 0,06	1960-1969	0,28	-0,021
5	Kaskelen - Kaskelen	1943-1996	-0,84 ± 0,03	1965-1974	0,96	-0,032
6	Turgen - Turgen	1959-1996	-0,65 ± 0,07	1973-1982	1,59	-0,0208
7	Chilic - Malibay	1934-1982	-0,69 ± 0,06	1953-1962	23,6	-0,401
8	Chilic - Malibay	1965-1982	0,94 ± 0,03	1969-1978	21,3	0,82
9	Usek - 1,7 km above mouth of Malyi Usek river	1934-1996	-0,44 ± 0,07	1960-1969	0,63	-0,0046
10	Baskan - Novopokrovka	1935-1972	0,97 ± 0,01	1948-1957	1,12	0,03
11	Koksu - Kuk-Kreu	1935-1969	0,87 + 0,03	1947-1956	6,05	0,267

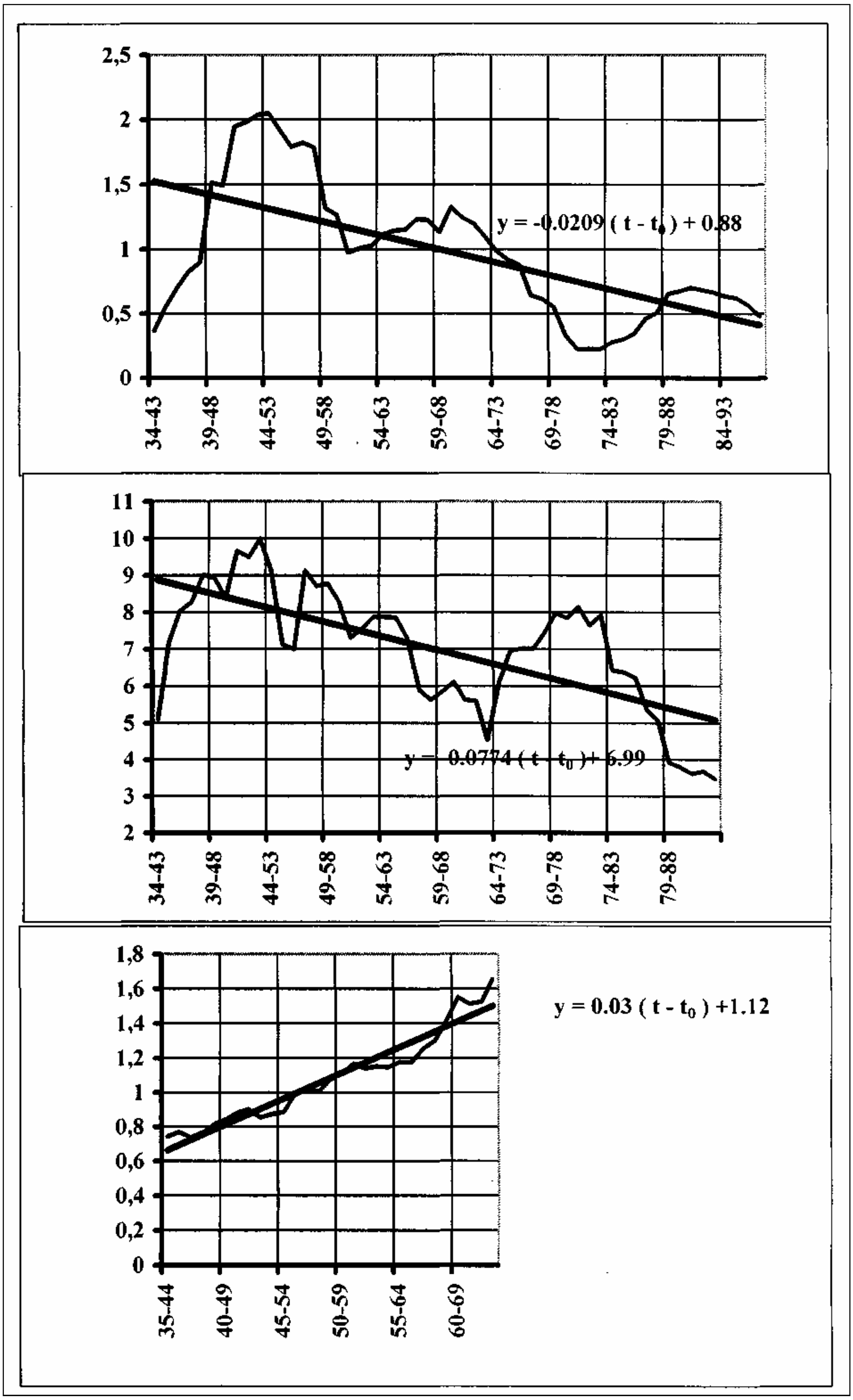

Figure 4. Sliding 10-years averages charges of weighed sediment of the Zailiysky and Dzhungarsky Alatau rivers.

Axis abscissa - years, axis of ordinates of average charges of suspended load, fine still (R, kg/s)
a) Kaskelen - Kaskelen, b) Talgar - Talgar, c) Koksu - Kuk-Krew

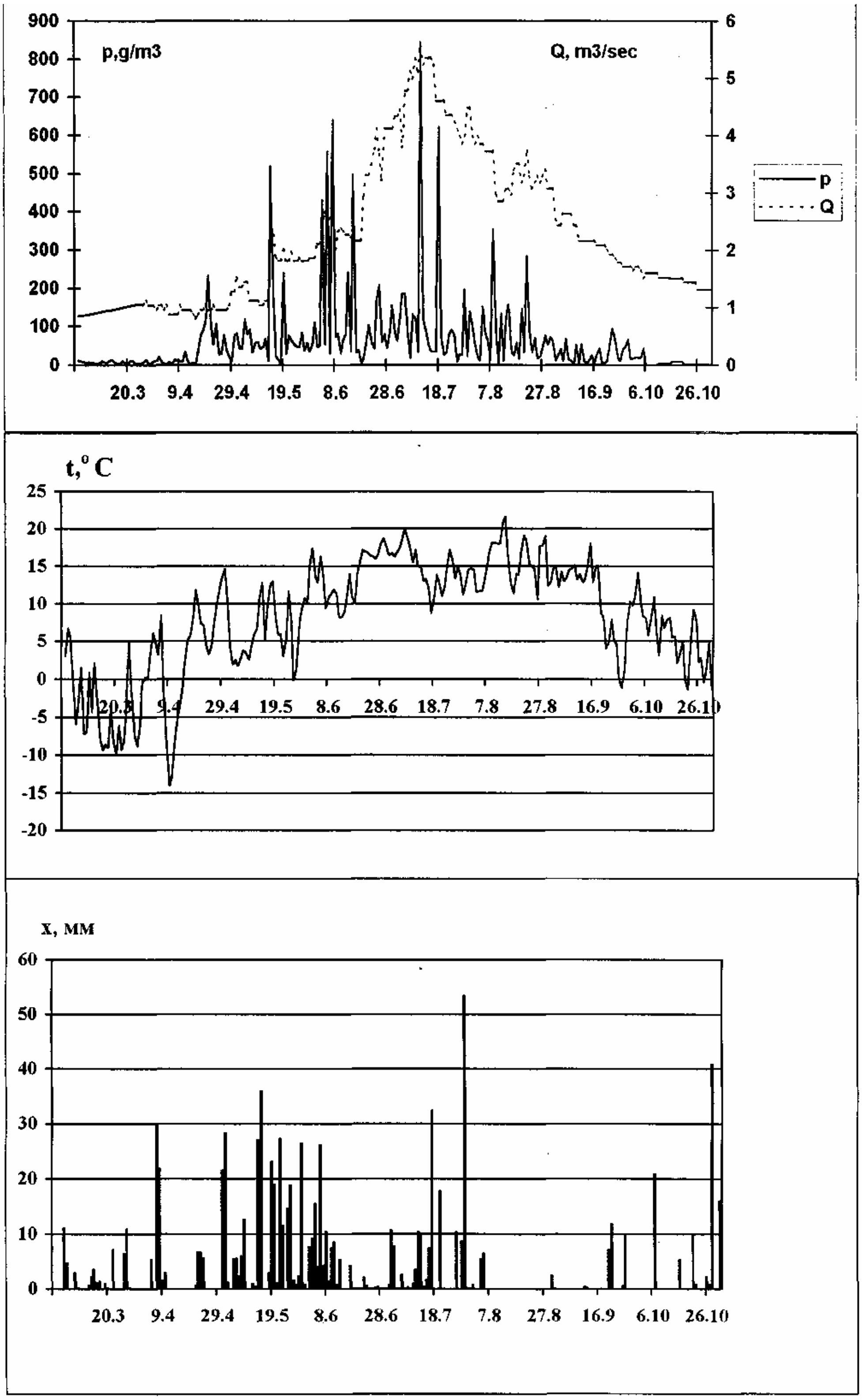

Figure 5. Combined chronological course of the daily average discharges of water, water turbidity, air temperature and daily sums of precipitation on hydrologic station of Small Almatinka river - for 1960 year.

Abscissa - dates; ordinate - daily average discharges of water (Q, m3/sec), water turbidity (p, g/m3), temperature of air (t, °C) and daily sums of precipitation (x, mm)

Even the average annual values of water turbidity on the same river can differ at 40-70 times. As a result, a coefficient of variation of the solid run-off (Cv, s.) is some times more than the one for the charges of water (Cv, w). These sizes are related by a ratio:

Cv, s = 5.75 Cv,w - 0,08.

This connection is characterized by coefficient of correlation 0,79 ± 0,08, and values of coefficient of a variation of a solid run-off reach 1 ± 2.

Thus, the climatic changes cause ambiguous reaction of river basins, various changes of formation conditions of the solid run-off.

The cycles of the characteristics of the solid run-off.

Fluctuations of a hydrometeorological complex are multi-ruthmical. The whole set of cycles, unequal on territory and unequally shown in time is allocated. So, for the territory of Kazakhstan in the run-off of the rivers, course of precipitation and some other hydrometeorological characteristics the 10-13 and 5-6 -years cycles, and also small 2, 3 and 4 -year's rhythms / 17,18/ are shown.

Such researches concerning the solid run-off were not carried out. 10-13 and 5-6 - the years rhythms are fairly connected to solar activity, they are shown more precisely during high solar cycles. Till now the nature of minor cycles is not quite clear, though the 2-years rhythms are logical to connect with auto oscillatory processes.

For the selection of a regular component of fluctuations of the solid run-off the correlation function of the average annual charges of weighed deposits is designed /19/. The most expressed correlation functions are submitted in figure 6. The precise 10-11- years variability of the solid run-off of the river Turgen does not cause any doubts. Positive bursts on τ = 10 and 21 years are significant practically at any level of significance. The form of correlogram of the solid run-off of the river Talgur with evidence testifies about 6-years cycles. Sawtooth correlogram of a solid run-off of the river Kaskelen testifies an obvious two years rhythm of the solid run off, alongside with it 18-year's cycles is planned. The main burst of function of the river Koksy falls into τ =17-18 years. Correlation function of solid run-off of river Baskan has the main bursts at τ = 3, 10 and 13 years.

Thus, concerning the solid run-off the set of prevailing rhythms is more various, than for theliquid one, and it is in the greater degree individual for various basins, that reflects more complex character of formation of the solid run-off. Here, in particular, a rhythmic component of fluctuations of the meteorological characteristics finds its reflection. Certainly, the past mudflows influence the solid run-off during a number of the next years. They result in substantial growth of solid run-off. But as it was shown earlier /20/, general tendencies of a long-term course of the discharges of deposits and water turbidity do not vary essentially.

Annual fluctuation of the characteristics of the solid run-off

These fluctuations are connected to phases of a water regime of the rivers, meteorological features of a year, but also with accumulation and expenditure of incoherent material in basin, with phases of water regime. In figure 7 the combined chronological diagrams of fluctuations of average annual values of water turbidity on 5 basic hydrological posts on the rivers of Zailiyiskiy and Dzhungarskiy Alatau are given: Talgar river - Talgar city (H = 3260 m absl.); Kaskelen river – Kaskelen city (H = 2680 m absl.); Usek river - 1,7 kms above from in flowing of Malyi Usek river (H = 3040 m absl.); Shilik river - Shilik village

Malybai (H = 2560 m absl.); r. Borohudzir - Kiytin (H = 2090 m absl). The analysis of this figure testifies that most muddy of the rivers, on which the basic points are located, is the river Talgar: average annual water turbidity fluctuated from 2270 g/m^3 (1956) up to 110 g/m^3 (1981).Then follows r. Shilik - village Malybai: average annual water turbidity - from 2240 g/m^3 (1939) up to 59 g/m^3 (1969). On a hydropost r. Kaskelen – city Kaskelen water turbidity changed from 1290 g/m^3 (1949) up to 22 g/m^3 (1976). In location of a hydrological post r. Borohudzir - Kiytin the maximal value of an average annual water turbidity was 1300 g/m^3, and minimal was 18,2 g/m^3 (1975). The lowest value of a water turbidity on the basic posts was marked on r. Usek - 1,7 kms above from the mouth of r. Malyi Usek: its maximal average annual value was 189 g/m^3 (1942) and minimal - 4,5 g/m^3 (1965).

It is significant, that r. Talgar in location of Talgar city has a number of high peaks of water turbidity, a part from them coincides with an increase of water turbidity on many rivers of the area and is caused by a plenty of precipitation on the large areas during these years and by observed mudflows (1939,1944,1950,1962,1966 and other years). A number of peaks is caused by an increased glacial feed caused by high temperatures and passage of glacial mudflows (1956,1963,1973,1974,1977 and other years) /21/ (figure 7).

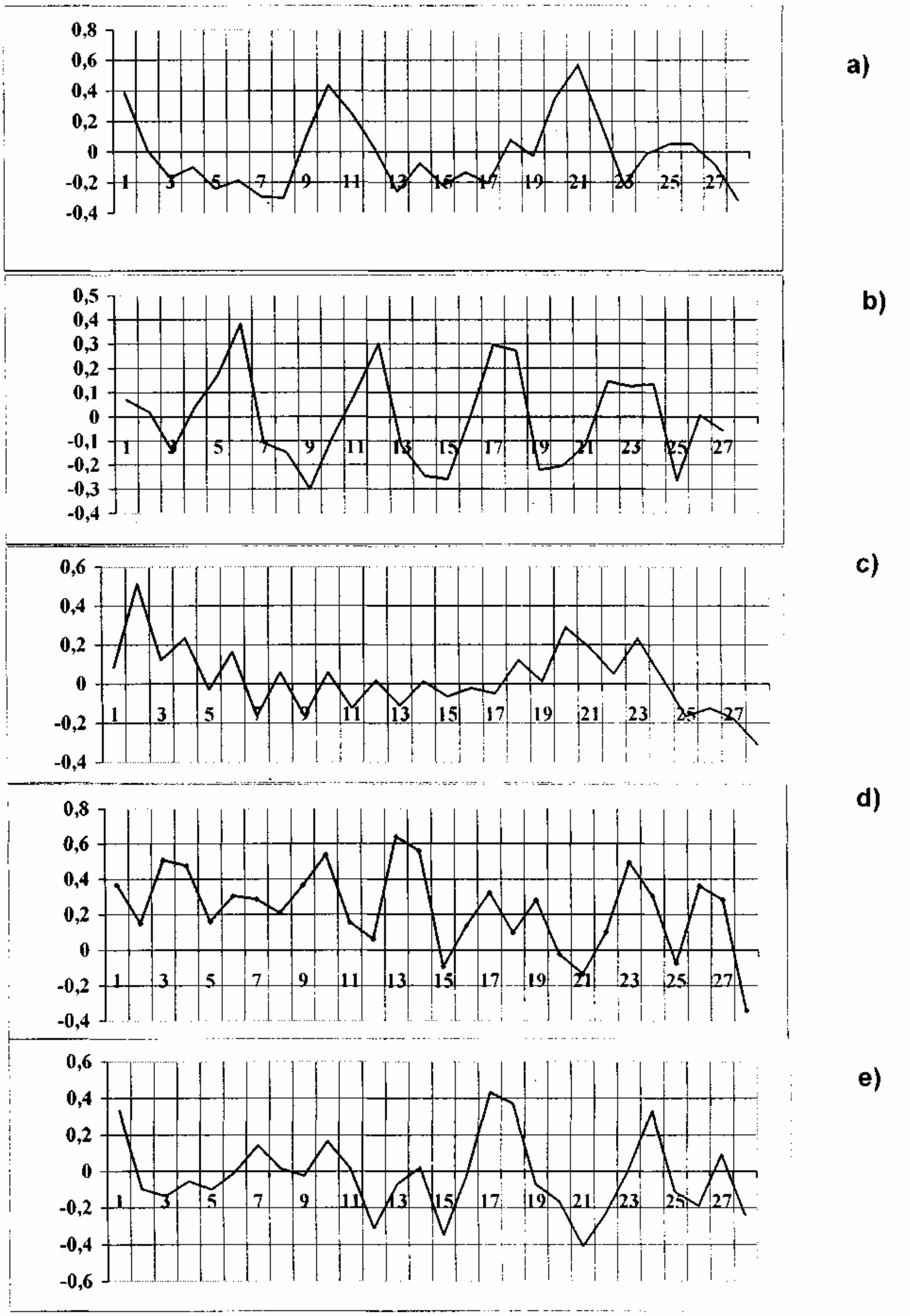

Figure 6. Correlation functions of annual average discharges of weighed deposits

Abscissa - years (τ, years); ordinate - correlation function (r (t)).

a) Turgen - Turgen, Talgar - Talgar, Kaskelen - Kaskelen, Baskan - Novopokrovka, Koksu - Kok-Krew

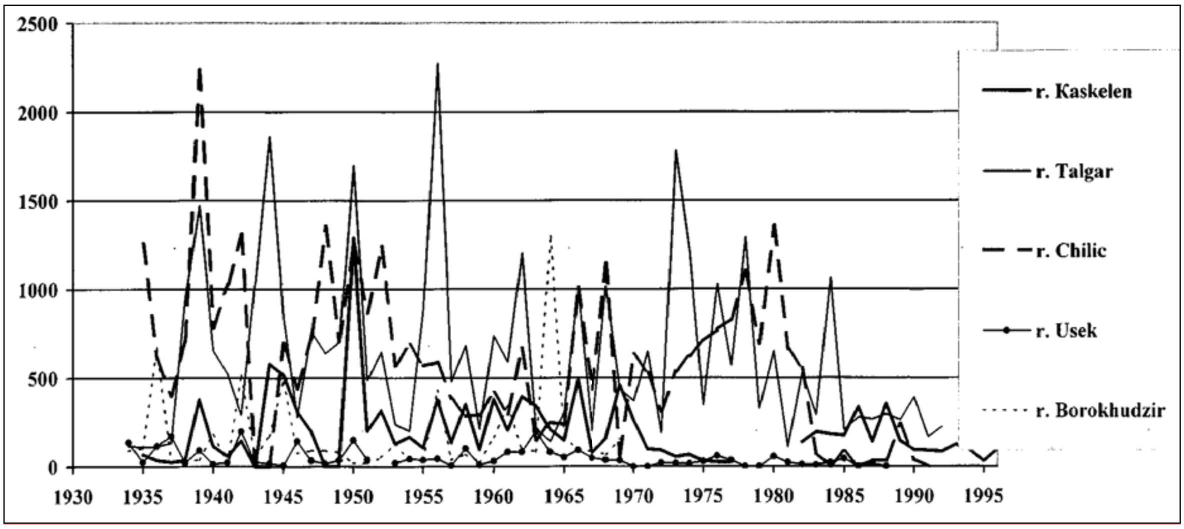

Figure 7. Combined chronological diagrams of fluctuations of average annual values of water turbidity on the rivers of Zailiyiskiy and Dzhungarskiy Alatau.

Axis abscissa - years, axis ordinates - water turbidity (p, g/m^3)

Annual fluctuation of the run-off of the weighed sediment and water turbidity are determined first of all by water regime of the rivers, conditions of hillside and river bed erosion, which in their turn depend on a complex of the natural factors: amount and intensity of atmospheric precipitation, relief of the area, vegetation, lithology of soil etc.

The charge of suspended load and turbidity of water change strongly during one year. Usually turbidity of water and charge of weighed sediment are getting higher with an increase of the water charge. But their peaks not always coincide. Sometimes maximum of water turbidity comes before a maximum of the water charges especially in the first half of high flood. This phenomenon can be explained so: before a peak of high flood occurs the thawed waters intensively wash off the products of erosion, which accumulate during the autumn – winter period, and can be caused out mouth of a river above considered location of inflows, which water at the given moment has higher turbidity than water of the basic river. So, for example, sharp rises of solid run-off on the hydrological post on r. Malaia Almatinka -. City Almaty from April till May are explained by an a huge amount of inflows to Malaia Almatinka in the middle mountain and low mountain zones (Kimasar, Kazachka, Batareika etc.), which take out at this time plenty of sediments to the main channel. The maximum of water turbidity can also be a consequence of sharp increase of the charges of water, especially in a high-mountainous zone; in this case it comes after a maximum of the water charges. The period of intensive sediment carry on the rivers begins with increase of a level and charge of water on the rivers in spring, for the majority of the rivers it is in March - April, and comes to its end mainly in August – September.

The size of water turbidity and of weighed sediment charges essentially depends on quantity of water of the year. So, for a hydrologic post r. Kaskelen – city Kaskelen a maximal monthly average water turbidity has made 3147 g/m^3 for wet year 1950, 374 g/m^3 - for average year 1983; 198 g/m^3 for dry year 1991. The maximum monthly average water turbidity and monthly average sediment charge on the rivers with an average height less than 2000 м of watershed usually falls at April - May, and on the rivers with an average height more than 2000 м of watershed - at June - August. So, on a hydrologic post r. Usek- 1,7 km above from mouth of the r. Malyi Usek it is observed in June, July, rarely in August; on a hydrologic post r. Borohudzir - Kiytin - in May, June or in July; on a hydrologic post r. Talgar –City Talgar - in June, July, and more often - in August; on a hydrologic post r. Shilik – village Malybai - in July or August; and on a hydrologic post r. Kaskelen – city Kaskelen - in July, sometimes in August and even in September /21/.

The features of formation of a liquid drain within one year have an effect on change of a firm phase in a flow. In annual course of monthly average water turbidity and monthly average charges of weighed sediment on a number of rivers, especially on those which cross some altitude zones, two peaks of water turbidity are observed. One of them (as a rule less high) falls at April or May, and the second - at June, July or August. First of them is caused by snow melting in spring or has mixed thawed-rain origin, the second peak can have on the different rivers different origins: rain, glacial or mixed. For the period of intensive sediment transport on the rivers passes from 83 up to 100 % of an annual solid run-off.

A characteristic feature of fluctuations of water turbidity and of weighed sediment run-off during a year is their sharper and more often fluctuations in comparison with a liquid run-off. It is expressed especially precisely at the bigger heights, where a glacial feed of the rivers makes significant volume, for example, according to the data of a hydrologic post r. Malaia Almatinka – Mynjilki.

According to the information of E.M. Kalmynkina /8/, daily average water turbidity has made in usual conditions of its changes on a hydrologic post r. Malaia Almatinka - City Almaty in one of the dates 89 g/m^3, according to hourly supervisions, the daily average size turned to be equal to 172 g/m^3, and amplitude of water turbidity fluctuations - 512 g/m^3. According to the same information, water turbidity on a hydrologic post r. Malaia Almatinka – gorge Vorota in the second half of the day was 15000 g/m^3, while daily average water turbidity was much lower.

The influence of the man-made reservoirs on the solid run-off

In the previous abstract we told about hydrological process in conditions of a usual water flow. The artificial reservoirs render huge influence on the solid run-off. Some examples of estimation of quantitative changes of solid run-off and turbidity of water are resulted below: at the creation of Bartogay reservoir on r. Chilic; at flow of r. Bolshaya Almatinka through lake Bolshoe Almatinskoe; at destruction the crosspiece and disappearance of lake Issik (table 4).

Table 4. Quantitative estimation of influence of some lakes and reservoirs of the Zailiyiskiy Alatau on a run-off of water, suspended load and water turbidity of the rivers.

The period of supervision	Values in norm					
	discharge of water		discharge of suspended load		water turbidity	
	Q, m^3/s	Cv_Q	R, kg/s	Cv_R	ρ, g/m^3	Cv_ρ
Chilic river						
1934 - 1982	32,0	0,12	23,6	0,58	737,5	0,55
1983 - 1991	32,0	0,12	2,63	0,80	82,2	0,83
rBolshaya Almatinka river						
Above than lake 1957 - 1995	1,6	0,15	0,32	0,74	200	0,73
Below than lake 1934 - 1942	1,9	0,13	0,04	0,97	21	0,88
Issik river – Issik city						
Before the destruction of the lake 1934 - 1949	5,97	0,20	0,11	0,95	18,4	0,93
After destruction of the lake 1964 - 1971	5,97	0,20	1,34	0,94	224	0,86

In the table Cv_Q, Cv_R, Cv_ρ – coefficients of variation of the charges of water, charges of weighed deposits and water turbidity.

Comparison of the data about a run-off of water and of weighed deposits in hydrometric location of r. Chilic - village Malybay before commissioning the Bartogaysk reservoir (1934-1982 years) and during its work (1983 - 1996 years) has shown, that while an average annual discharge of water practically has not changed (by the carried out estimation a series of average annual discharges of water for all period of supervision is homogeneous), average annual discharge of deposits and of water turbidity in that location have decreased in 9 times. The discharge of water of r. Bolshaya Almatinka on the locations higher and below Bolshoy Almatinskoe lake differ on the average long-term in 0,3 m^3/sec, the discharges of weighed deposits below the lake decrease in 8 times, and water turbidity - in 9,5 times.

Norm of the annual discharges of water of r. Esik at presence and after disappearance of a lake, is identical, the norms of annual average discharges of weighed deposits and of water turbidity have increased in 12 times.

Conclusions

1) The solid run-off of the river is substantially determined by the size of the liquid run-off, therefore they have some common features in their long-term fluctuations.

2) As well as water run-off, the solid run-off directly reacts on meteorological fluctuations and climatic changes; however, the solid run-off is more sensitive to these changes.

3) There is a concentrated emission of firm substance by formation of mudflows. Further mudflow deposits in their turn strongly influence a solid run-off during a number of years.

4).A solid run-off is influenced not only by a size of a liquid run-off, but also by parity (ratio) of sources of its feed. So, a degradation of glaciers, connected with a global climate warming can cause as increase of a liquid run-off (expenditure of its century stocks), as its reduction (reduction of the ablation area). But the size of a solid run-off has to change, as a watershed surface qualitatively changes, from which a firm material is washed off.

5) The change of a solid run-off has an immediate effect on a quality of waters, on ecological condition of basin.

6) The solid run-off, which is connected in the greater degree with meteorological fluctuations than the liquid one is a subject also to more significant spatial - temporary changes. The average water turbidity values on the considered rivers differ almost in 40 times, fluctuation from one year to another on the same river can reach hundreds times and a coefficient of a variation of the sediment charge is 3-7 times more, than for a liquid run-off on the same rivers.

7) In connection with a climate change, a distinct trend of a solid run-off can be observed, but with another mark in different parts of territory. It is much better expressed, than a trend of a liquid run-off. On the rivers Zailiyiskiy Alatau during the supervision period a solid run-off has decreased in 1,5-5 times, on the northern slope of Dzhungarskiy Alatau increased in 2-3 times.

8) The cycles of a solid run-off are reflection of water run-off rhythms of the rivers and of meteorological factors. On the different rivers the cycles with continuance of 3,6,10-11,13,17 and 18 years are allocated.

9) The ponds, including the artificial ones, render an incomparably greater influence on the solid run-off, than on a liquid one.

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Manuscript received in 23 December 2005.

Резюме

Гальперин Р., Дускаев К., Чигринец Л. **Анализ особенностей стока наносов и мутности воды горных рек Заилийского и Джунгарского Алатау с учетом метеорологических факторов.**

Исследованы многолетние, годовые, сезонные и внутрисуточные колебания стока наносов и мутности воды на основе анализа главных и прежде всего климатических факторов формирования твердого стока. Анализировались данные наблюдений за стоком наносов по 52 пунктам.

Анализ многолетних колебаний стока наносов, жидкого стока, осадков и температуры воздуха, проведенный с использованием разностных интегральных кривых, скользящего осреднения, аналитического выражения трендовых составляющих, корреляционных функций, позволил выявить: причины асинхронности колебаний жидкого и твердого стока горных рек рассматриваемой территории, направленность трендов и циклы колебаний стока наносов. Выявлено, что изменение твердого стока в большей степени определяется осадками и эррозией на водосборе, чем температурой воздуха.

В результате анализа годовых колебаний стока взвешенных наносов выявлено совпадение высоких пиков мутности по разным рекам района, что обусловлено выпадением в эти годы большого количества осадков на значительной площади и наблюдавшимися селевыми потоками. Рассмотрены внутрисуточные колебания мутности воды и стока наносов и их связь с выпадением ливневых осадков, ледниковым питанием, колебаниями температуры воздуха в периоды снеготаяния и другими факторами. Исследованы характер и причины изменения стока наносов и мутности воды, а также гранулометрическог состава наносов по длине горных рек.

Полученные результаты позволили разработать новые способы расчета характеристик твердого стока неизученных горных рек.

THE ANALYSIS OF SPACE IMAGES WITH THE PURPOSE OF REVEALING THE RING STRUCTURES OF IMPACT TYPE

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Space pictures in geology have been applied from the early sixties. Remote sounding has given an opportunity to look at the terrestrial surface in a new fashion, having given a birth to new regional researches in the field of geology, geomorphology, tectonics, soil science, and opening of new deposits of minerals.

At remote sounding various wave bands are used: ultra-violet, visible infra-red, thermal, microwave. Thus the image varies depending on time of day and season. Using various filters and a combination of above-listed ranges the experts with the help of hardware methods achieve the best visibility of structures, processes and covers.

Then the information from space pictures is obtained with the help of images interpretation. Usually there are four kinds of objects in space pictures: linear, area, dot and ring.

Linear objects or lineaments are linear heterogeneities of the earth's crust in space pictures of different size and various genetic belonging. Lineaments can be caused by presence of geological breaks, flexure folds, dikes, anthropogenesis activity.

Area objects in space pictures have broken outlines and are submitted by structural, material complexes of rocks having an influence on genesis of soil and vegetative covers, and they, in their turn, are the indicators of materially-genetic belonging of tectonic infringements.

Dot objects are of various nature: sources of underground waters, single plants, man-caused objects. Frequently they are not considered as a separate kind of objects, but their presence in space pictures is without controversy figure1.

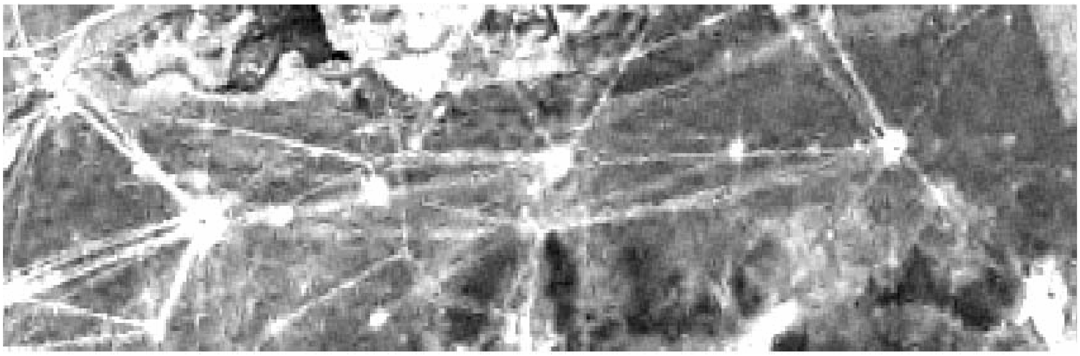

Figure 1. Chain of dot objects connected by linear ones (wells with potable water and a road network).

Ring structures are in special group. Part of them can be attributed to Area heterogeneities of the earth's crust, the other part to linear objects. The former are shown in pictures as color (continuous-tone) or morphological heterogeneity, the last are limited only by lines. Frequently their combination can be observed (Fig. 2).

In other words, ring structures in space pictures are expressed by spectrometer anomalies and quite often emphasized by system of concentric and arc linear objects.

Ring structures have been known for a long time, but with occurrence of space pictures an interest to them has increased. Also due to the fact that about 70 % of deposits are connected with them (Korchuganova N. I., 1998).

Ring structures are classified by genetic attributes, the sizes, geomorphologic attributes and expressiveness in space pictures

Monogenic structures are divided into endogenous, exogenous, man-caused and impact.

Endogenous structures can be tectonic i.e. formed as a result of tectonic movements, magmatogene - their source is the magmatic activity, and metamorphogene i.e. formed as a result of changes in rocks.

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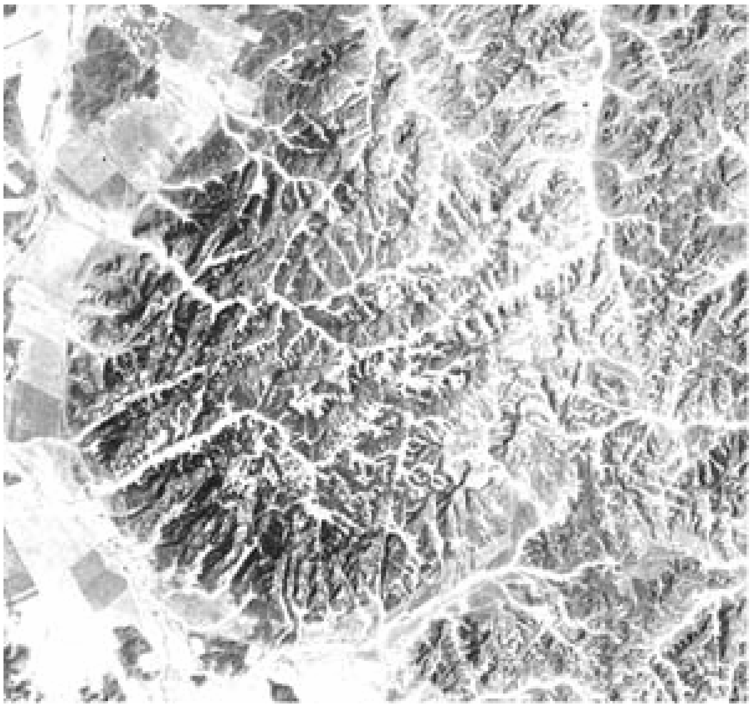

Figure 2. Ring structure. A combination of color (continuous-tone), morphological and linear heterogeneities (Kentish massif, the Central Kazakhstan).

Endogenous ring structures

Tectonic structures as a result of tectonic movements are connected with anticlines, salt domes, anticline folds (positive structures). Negative structures are connected with buried depression of the base, synclinal folds. Rotational structures are connected with horizontal turn of blocks and can be both positive and negative, or at all not expressed in a relief.

Magmatogene structures are widespread on platforms and in folded areas and make more than half of all ring structures revealed in space pictures. Formation of massifs of alkaline- ultrabasic composition and also small intrusives (including kimberlite, advanced on platforms) is connected with mantle magmatism.

Volcanic and volcanoplutonic structures of small diameter dated for zones of deep breaks are characteristic for trap fields of ancient platforms.

Plutonic structures are connected with crust magmatism, and they are widespread in folded belts. These structures are formed by granitoid plutonic rocks and represented by large batholite, with big vertical capacity, isometric rods, ring and conic intrusions.

Volcanic and volcanoplutonic structures are connected with crust magmatism and distributed in continental volcanic belts. They are represented by positive extensive raisings of the base of belts or by negative structures that is more often. The most typical among them are volcanic depressions of round or oval form; internal parts of such volcanic structures bear passive sag above devastated magmatic centers, and external ones are emphasized by the system of radial dumps.

Vulcanotectonic structures have large sizes up to 400-600 km across diameter and are formed by tectonic depressions filled with volcanic and vulcanosedimentary rocks.

Metamorphogene ring structures are divided into gneissic folded ovals and granitogneiss domes.

Exogenous ring structures

Superficial geological processes result in formation of karstic, suffosion, thermokarstic craters, failures of seismic character.

Man-caused ring structures.

In space pictures the ring structures coming out of industrial, agricultural, military, scientific or other activity of man (Figure 3) are observed. Approximately in 10-20 % of cases it is impossible to reveal their genetic belonging. Therefore they should be ascribed to an independent class of structures of unrevealed genesis. As a rule, this class includes the structures there is no data at the initial analysis to identify.

Figure 3. Ring man-caused ring structures: a. result of agricultural activity of man; b. result of development of deposits of minerals.

Impact ring structures.

In space pictures there are ring structures of impact or space origin, differently called astroblems. They appear as a result of falling of space bodies onto the Earth.

Impact craters or astroblems have always been attractive for researchers. There was not systematic character in astroblems studying till 1960, only several largest meteoric craters were known. Within the last forty years our vision of the Earth and its place in Solar system has appreciably changed.

The view on influence the impact phenomena have on terrestrial processes has also changed: from the exotic phenomenon to the strongest factor at geological and biological development of the Earth.

In the past of the Earth the impact phenomena more than once cardinally changed the composition and structure of biosphere, resulted in global dispositions of the earth's crust, generated global outpourings of magmatic rocks, formed large ore deposits and once at the least caused global extinction of kinds (French B. M. 1998). It happened about sixty five million years ago. Some researchers consider Chicxulub crater on Yucatan peninsula, in Mexico, about 170 kilometers in diameter to be the result of a terrible meeting with a heavenly body. Thus three quarters of living beings populated the Earth were lost at this accident. From cold and starvation the dinosaurs have died out; in the seas countless numbers of fishes and mollusks have disappeared.

Studying the Moon, and then other objects of Solar system the experts became firmly convinced that meteorites of the various sizes to some extent influence on planetary processes.

Thus on surface of all solid planets of Solar system it can be found traces of bombardment, even gas giants have traces of space impacts. The rings of Saturn can be considered to be the result of catastrophic bombardment of its satellite. Even fine asteroids have characteristic "wounds".

The best example of such catastrophic phenomena became a series of explosions in the atmosphere of Jupiter, caused by falling on it the fragments of comet Shumeiker-Levi 9 in July, 1994. The nucleus of the comet in July, 1992 as a result of approach to Jupiter broke up into fragments which subsequently collided with a planet - giant. In connection with the fact that collisions occurred on the night side of the Jupiter, terrestrial researchers could observe only the flashes reflected by satellites of the planet and impressing consequences on the surface of the planet. The analysis has shown that diameter of fragments of the comet is from one up to several kilometers. 20 splinters have fallen onto Jupiter.

Now on the Earth a little more than 170 meteoric craters are authentically confirmed. The majority of them were recognized in the fifties after studying space pictures, thus several impact craters are diagnosed and confirmed every year (Earth Impact Database, 2003.).

Comparison of the surface of the Earth with space pictures of the Moon or Mercury without effort allows to see, that there are a lot more ring impact structures on them. It is considered that the cause of it is an early

(3,8-3,9 billion years ago) termination of active development of these planets, absence at them the atmosphere and the hydrosphere, connected with them exogenous geological processes resulting to eroding or burying the impact structures. It is supposed that the Earth at the beginning of existence (4,5-3,9 billion years ago) was similar to the Moon or Mercury. Therefore studying the astroblems and comparing the results of these researches with planetary data allow to understand the history of our planet (Feldman V.I. 1999) better.

Comparing the number of known astroblems on the Earth and Venus (172 and 967 respectively), excepting the area of world ocean, ice sheet and lakes of the Earth, it turns out that a terrestrial astroblem accounts for the area of active surface of 760 thousand km2 and 380 thousand km2 on Venus. Thus, it is twice as more craters per area unit on Venus than on the Earth. The difference can be explained well by active erosive processes on the Earth.

Comparing the number of astroblems with planets without any atmosphere or their satellites it is necessary to remember that dense atmosphere brakes a space body the more strongly, the more its diameter as it moves gas ahead of itself, compressing it and gradually slowing down. If condensed mass of gas (M) is great enough (at M of gas > 10M of a meteorite the speed of movement falls by 90 % and more) then the speed of impact approaches to zero. There is the iron meteorite Hoba about 60 тonn by weight in Namibia (Southern Africa). Its falling has resulted in neither a crater nor even a hole. The meteorite has landed as though on an air pillow, with practically zero speed of impact (Feldman V.I, 1999).

The age of known astroblems is within the limits of 750 million years and for more than 60 % of them is within the limits of 250 million years. The size of 85 % of astroblems is up to 30 km (Figure 4). And about 15 % of astroblems concern to young formations, their age is up to 1 million years. Why do researchers take an active interest in impact ring structures?

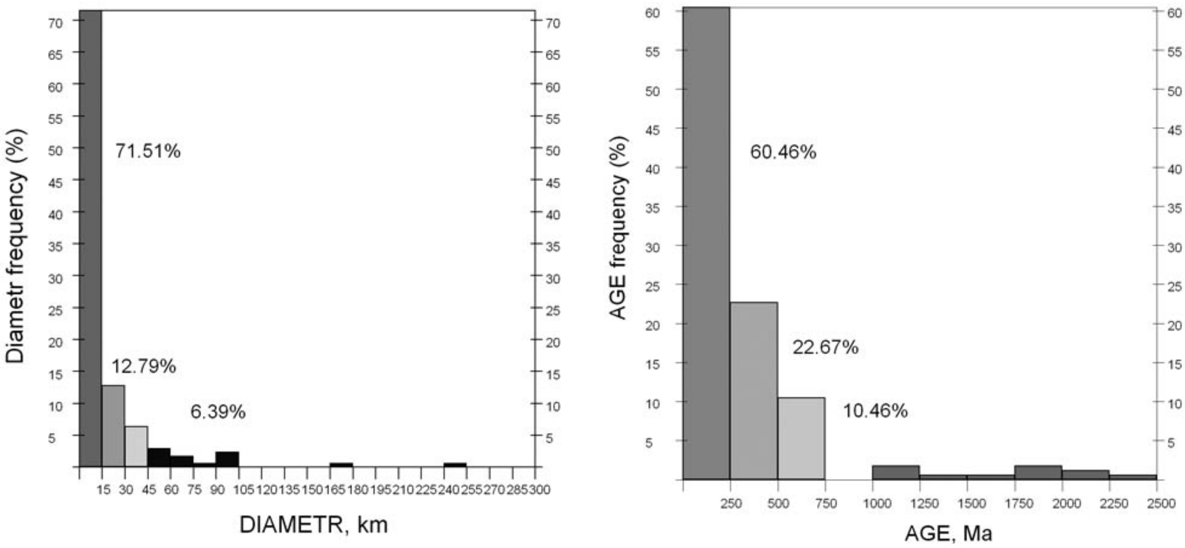

Figure 4. Frequency of distribution of known ring structures by age and sizes in percentage.

This is a practical question. There is a connection between these remarkable objects and minerals. Impact processes are catalysts, and the zones weakened by impact influence are the tank for accumulation of minerals. Presence of such kinds of minerals as building stone, diamonds and uranium is connected with them. Petroleum and gas are the basic products of impact structures (Donofrio, 1997; Johnsonand Campbell, 1997). Impact breccias under astroblems (Ames (Oklahoma); Red Wing Creek (North Dakota) are traps for petroleum and gas. An impact breccias inside and around astroblems [Ries Crater (Germany) represents an excellent building stone, oil shale [Boltysh (Ukraine)], diamonds diatomite [Ragozinka (Russia)], gypsum [Lake St. Martin (Canada)], and lead-zinc ores [Crooked Creek (Missouri)].

Only studying the impacts ring structures it is possible to reveal cyclicity, regularity of space impacts. In other words an opportunity to predict, when, as frequently and how big space bodies will meet the Earth. The example of bombardment of Jupiter by Shumeiker-Levi 9 comet proves that similar catastrophic processes have not stopped yet, and studying of these processes is a key to understanding and predicting the danger of space bombardment.

Studying of consequences of impact explosions gives invaluable scientific information. Any terrestrial process is not similar to impact one. The reasons of explosion are hard braking of space body at collision and transition of kinetic energy of moving body partially to mechanical, partially to thermal energy. The total energy implemented during an impact can exceed 1019-1023 joule. Comparison of this value with energy of catastrophic volcanic eruptions (1,44*1020 joule at eruption of Tambora volcano in 1815 or 1,81*1019 joule for Krakatau volcano in 1883), shows that it is of about the same order. However the results of volcanic explosion and impact event are completely non-comparable. It is connected with the fact that in volcanic process the energy spends not at once, but in a series of the following one by one emanations within 10^3-10^5 s. At impact process the realization of kinetic energy of a space body lasts from several milliard fractions of a second up to the first seconds (the longer the more the total energy). Such high density of energy determines the enormous gradients of parameters (pressure and temperature) and as a consequence -very high speeds of mechanical and thermal processes passing. For example, the speed of mechanical deformation of rocks in endogen geological processes makes 10^{-16}-10^{-13} s^{-1}, and at impacts 10^{-3}-10^{-4} s^{-1}, that is by 17-20 orders more. (Feldman V.I., 1999)

Morphology of impact craters

Meteoric craters are the circular depression, surrounded by a ring height i.e. swell. The morphology of impact craters depends on their sizes. Craters in diameter up to 3-5 km have the concave bottom. Bottom of larger craters is flat. There is quite often a height in its central part, the so-called central uplift, formed as a result of elastic reaction of rocks after impact of a meteorite. There are one more or several ring uplifts in craters in diameter more than 20-25 km, but they are lower than an external swell. Both in the crater and outside of it at the distance of radius the rocks are crushed and intermixed by explosion of a meteorite. At the bottom of swell, under crater emissions, a little bit raised bedrocks are deposited. It is so-called structural rise. Craters are surrounded with a system of radial-concentric breaks. Their sizes depend on diameter of the crater, conditioned in its turn on energy of explosion.

This energy is enormous. For formation of a crater of 25 - 35 kilometer it should be ten times more the energy of the severest earthquakes. And at formation of 100-kilometer Popigay crater in Eastern Siberia 50 - 60 million years ago the energy released was thousands times more the energy of the severest earthquakes called the world disasters.

Traces of falling on the ground

The problem of ascertainment of ring structures belonging to impact ones is that many ring structures with age of more than 10 million years have lost geomorphological outlines of circular depressions surrounded by a swell from emissions of rocks (Korchuganova N. I., 1998). And large meteoric craters appeared about 100 million of years ago and earlier have almost or completely lost their initial morphology. Traces of active impact influence have been transferred by terrestrial superficial processes to other places. Active exogenous and endogenous processes have erased all geological consequences of powerful explosions.

As a result of active geological processes impact structures are so deeply eroded that sometimes even have no ring form and can be identified only by presence of chaotic spots of an unusual breccias or strange "volcanic" formation (French B.M., 1998).

And the deeper erosion will result in only poorly appreciable signs as a ring system of breaks - the inherited ring form of relief on the ground surface. But in this case it is practically impossible to prove impact origin.

Technique of revealing the impact craters

Methodically works on revealing the new ring structures can be divided into the following basic parts:

1. Interpretation of space pictures to reveal the ring structures;

· Interpretation of ring structures independently of their genetic class;

· Determination of their morphological class with use of the topographical information;

· Division of the revealed ring structures into genetic classes with use of the geological information;

· The choice of the most perspective (conditional impact) ring structures to transfer them to the following stage of processing.

2. Field and laboratory researches.

Only field observations and laboratory analyses can confirm the impact nature of ring structures.

In field conditions it is necessary to search for traces of shock-metamorphism, in some cases finds of meteoric substance or its traces as an overabundance of iridium are possible. Many of well-known now structures have been found out as a result of regional geophysical researches.

Geological signs

First of all, at studying the area of ring structure it should contain the bed rocks sharply differing from geological environment. In the area it should be precisely determined the presence of deformations and breccia of rocks. The area should contain unusually looking igneous or intrusive rocks (sometimes such rocks look as quite usual magmatic rocks) (French B. M., 1998).

During explosion of a meteorite the bed rocks are exposed to influence of very high temperatures and pressure and consequently collapse, melt, evaporate, and in the centre of explosion even turn into plasma. Naturally, the changes occurring to rocks and minerals composing them have zonality i.e. the further from the centre of explosion, the less the changes. There, where the temperature is lower than melting point, but pressure is high, in minerals the changes occur, that allow determining the fact that the rocks have undergone an impact-explosive influence. For example, at pressure of 100-450 kilobar (that is 100-450 thousand atmospheres) and temperature of 100-900 °C quartz is squeezed, in its crystal lattice such qualitative changes occur (planar structures), that it turns into new minerals - stishovit and koesit, and graphite turns into peculiar diamonds not found in usual for the Earth kimberlite deposits. (Polocukhin V., 1981)

Shock-metamorphism in rocks results in formation of a system of cracks i.e. impact cones. These macrostructures in rocks are the result of only the influence of enormous pressure of more than 10 GPa Such structures are formed in all rocks, but most clearly traced in fine-grained rocks, and especially in limestones. There are frequently planar structures in impact cones rocks.

Geophysical signs

Shock - metamorphism results also in a change of physical properties of rocks.

Many impact ring structures show as a negative gravitational anomaly, but such anomalies are not a cogent feature and are absent of many known structures.

The magnetic field measured around impact ring structures is not noted for specific values but, nevertheless, in result of an impact process the natural anomalies get some characteristic features (Fig.5).

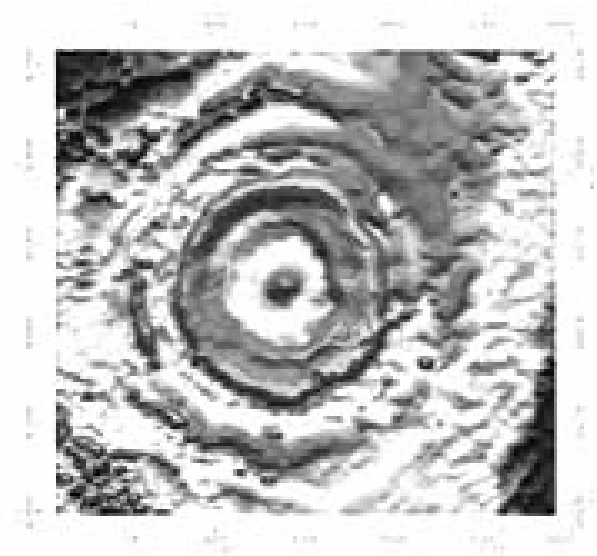

Figure 5. Yalali astroblem (Australia, diameter of 12 km), data of magnetic survey.

Seismic prospecting is the most effective way of determination of impact nature of structures, even the structures being under cover of younger rocks. With the help of seismic prospecting the following large and very important impact structures have been determined: Puchezh-Katunki (Russia) (D = 80 km), Chicxulub (Mexico) (D > 180 km), the Chesapeake Bay Crater (USA) (D = 90 km), and Morokweng (South Africa) (D > 70 km?), M'olnir astroblem (Norway, diameter of 40 km) (Figure 6)

Now the number of known impact structures makes about 25 % from total number of known structures on the surface of the Earth (Trefil and Raup, 1990; Grieve, 1991). To increase the number of recently found structures it is necessary to analyze the modern data. In this respect the territory of Central Kazakhstan is very promising.

Initially it is reasonable to use the materials on the most exposed and geologically-studied territory of Central Kazakhstan. Absence of forest cover, fine rock exposure gives a good opportunity to interpret geological and morphological conditions on space pictures. And space pictures of new generation have higher resolution.

Frequently at search for impact structures it was found out, that the nature of impact rocks was interpreted by various researchers from the position of terrestrial processes, as for example, Unusual volcanic activity or "cryptovolcanic" events. (French B. M., 1998). Among such structures, initially incorrectly identified, are well-known now as impact structures: Ries Crater (Germany), Sudbury (Canada), and Vredefort (South Africa). Probability to reveal a cosmogeneous structure is not very low. It is necessary to look at the territory under study, but now from the position of revealing the impact ring structures.

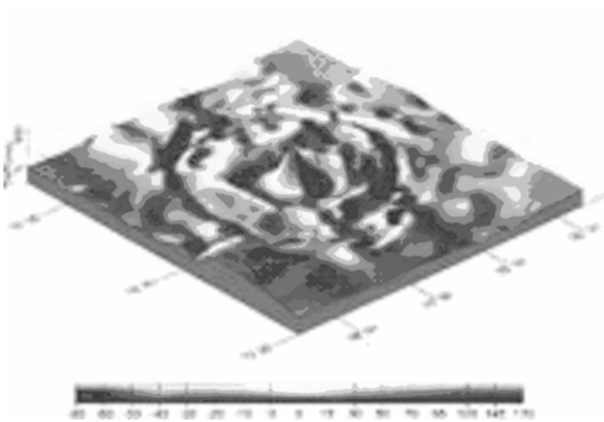

Figure 6. M'olnir astroblem (Norway, diameter of 40 km), the seismic data.

Thus on the territory of Kazakhstan it has been documentary revealed four astroblems. All of them are of different age and size (Tabl. 1), (Fig. 7, 8, 9, 10).

Table 1. Documentary revealed astroblems in Kazakhstan

CRATER NAME	Age (Ma)	DIAMETER (km)
Zhamanshin	0.9 ± 0.1	14
Bigach	5 ± 3	8
Chiyli	46 ± 7	5,5
Shunak	45 ± 10	2,8

Figure 7. Site of proved impact craters on the territory of Kazakhstan

Results of interpretation of M43-G map sheet

As a result of interpretation of space pictures it has been revealed 108 ring structures (Fig.12). By geomorphological signs 51 % of them are positive and 49 % negative and not expressed in relief. Just among these 49 % can be impact structures.

Figure 8. Impact craters Bigach, Age 5±3 Ma, Diameter 8 km.

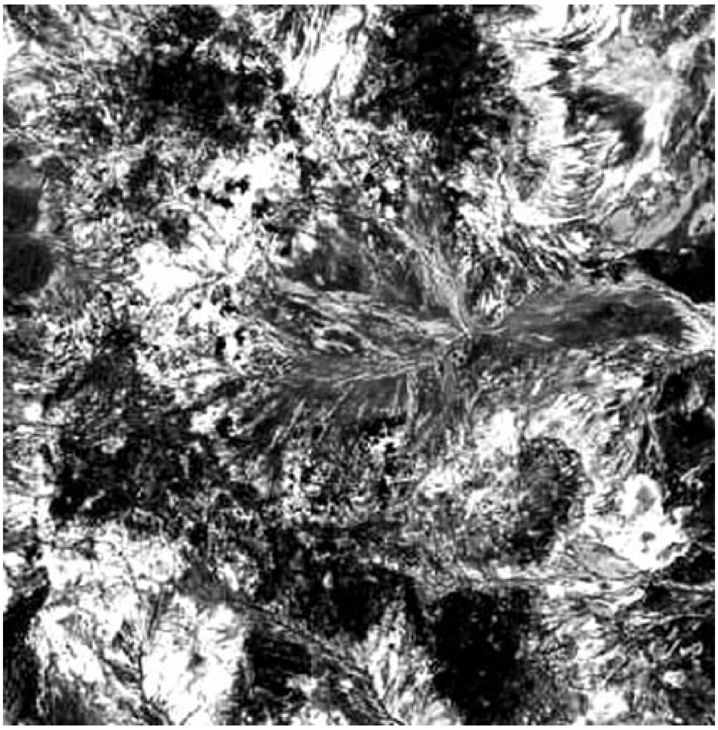

Figure 9. Impact craters Zhamanshin Age 0.9 ± 0.1 Ma, Diameter 2.8 km.

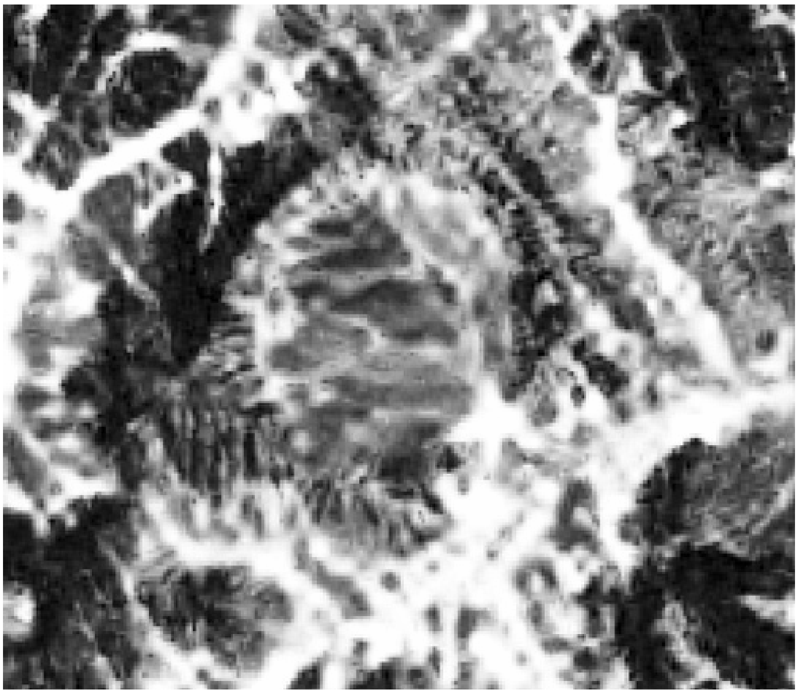

Figure10. Impact craters Shunak Age 45 ± 10Ma, Diameter 8 km

The genetic analysis of ring structures has shown that 8 % of them are conditional impact and about 5 % of unexplained nature (Fig. 11). Ring structures similar to described above by morphological signs have been placed among conditional impact structures. An example of such structures is given on Figure13. The sizes vary from 25 km up to 500 meters. The bottom of structures is rather flat. Central uplifts are not observed, this fact can be connected with active erosive processes. In most cases it is observed an edge uplift and a system of radial concentric breaks.

But as it was mentioned above, impact nature of the revealed structures can be proved only by field and laboratory researches.

Structures of unexplained nature can also be potentially impact ones, but they are not expressed morphologically, and it is impossible to identify them on a geological map.

The fact of revealing high rate (more than 15 %) of man-caused ring structures is of great interest (Fig. 13).

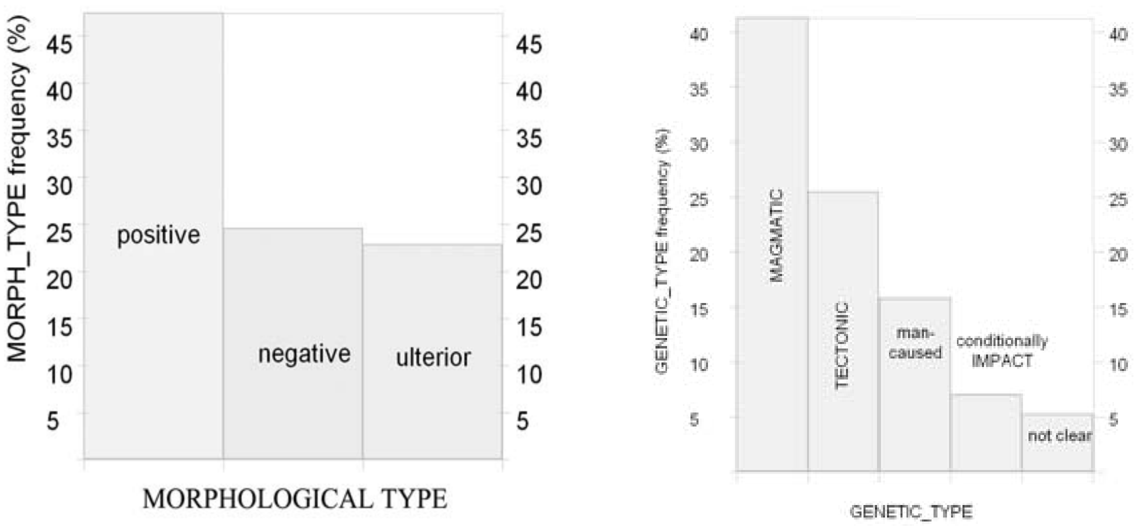

Figure 11. Frequency of ring structures distribution by morphological and genetic types.

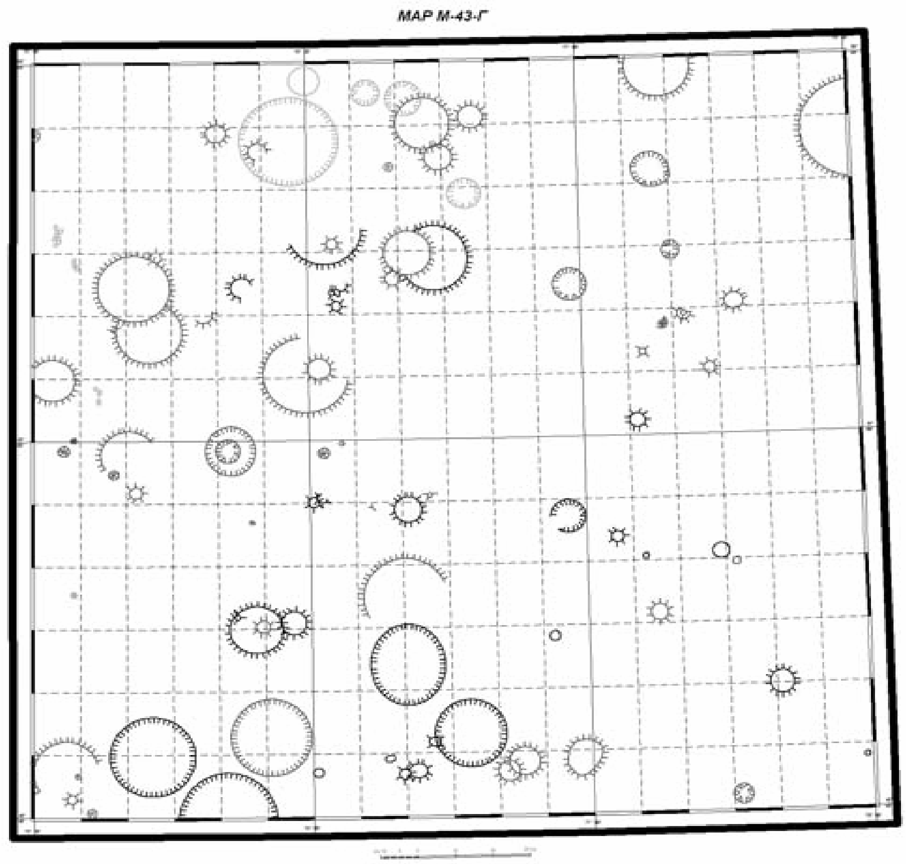

Figure 12. Map of revealed ring structures sheet M-43-G.

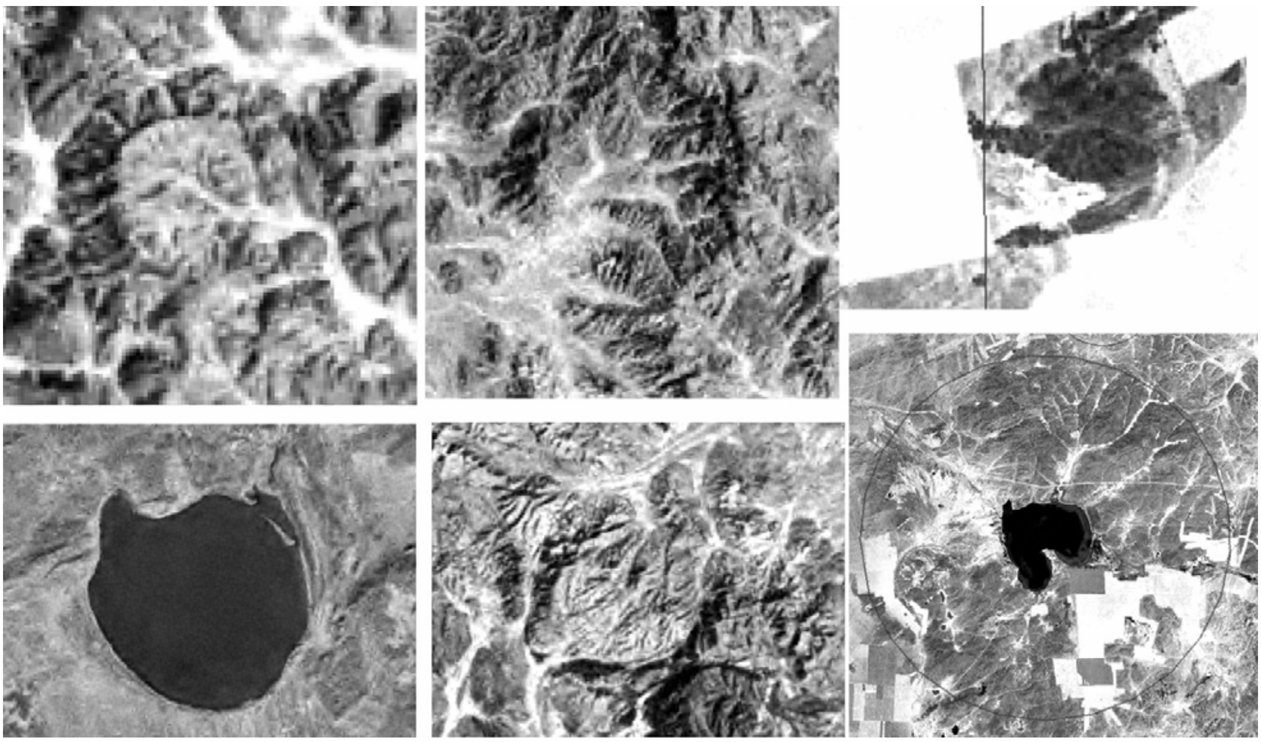

Figure 13. Chosen conditionally impact ring structures by results of interpretation of space images.

Resume

Space bodies of the various sizes reaching the solid surfaces of planets leave there some traces i.e. ring impact structures. These traces remind us of an opportunity of falling onto the Earth a space wanderer.

Falling the space bodies onto the Earth resulted in irreversible changes in the climate and biological diversity, and, only having compared paleoenvironmental, paleomagnetic and paleogeochemical data we can with full confidence say where and when it had taken place. Studying the astroblems we can say about the influence space bodies have on the Earth.

Experts find genetic connection between astroblems and various kinds of mineral resources: petroleum, gas, condensate, uranium, building stone, bitumen slate, diamonds, plaster, lead-zinc ores. Falling of space bodies is a catalyst of terrestrial processes. We can not consider the connection of deposits with impact structures to be implicit, in each individual case everything depends on degree of influence a space object has on the earth's crust and presence of favorable conditions on the Earth.

There is a difficult problem of discovering craters on the seabed for scientists to solve in the future. For that it is necessary to work out new techniques and technologies. For example, a sea astroblem, 11,5 km in diameter, was found out in 1987, not far off the coast of Nova Scotia (Canada).

Till now it has been poorly determined the scales and consequences of influence of early bombardments on the Earth.

Only one crater of more than 2 billion years age and sizes up to 300 km is known on the Earth. While in Venus, Moon and other planets it was discovered the craters of more than 4 billion years age and sizes exceeding 1000 km. The Earth was not an exception. Pre-geological stage of development of the Earth in more detail was studied and described by Soviet researchers Markov M.S. and Fedorovskii B.C., who assumed that the early Earth should have been exposed to meteoric bombardment, especially intensive to a boundary of 3,9 billion years ago. If to proceed from the density of meteoric stream uniform for system the Earth - the Moon then in first 600 million years of existence of our planet on its surface it should have been formed about 25 large craters with diameter of about 1000 kilometers and 2500-3000 craters with diameter of 100 kilometers.

Similar ancient huge astroblems are nuclears. Nuclears laid at initial stages of formation of the earth's crust and developed during all continental stage of its evolution (1600-1900 million years) (Katc Ya. G., Poletaev A.I., Sulidi-Kondrat'ev E.D.)

Impact space processes deserve more steadfast studying, and their influence on planetary processes is not limited by impact craters. During consolidation of the earth's crust the influence of space bodies was much more appreciable because of its low power and resulted in mass of magma flows and migration of substance.

Studying of impact ring structures and its connection with inherited relief is expected to give a key to understanding the geodynamic processes in the Earth's crust, to make a significant contribution on theoretical, regional, and applied geology.

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Manuscript received in 08 April 2005

Резюме

Селенко О. **Анализ космических изображений с целью выявления кольцевых структур импактного типа.**

Приводится классификация объектов на космических снимках: линеаменты, площадные, точечные и кольцевые. Обсуждаются механизмы выявлении кольцевых структур и в частности импактного типа. Раскрывается связь импактных кольцевых структур (астроблем) с полезными ископаемыми. Приводится методика выявления астроблем и пример обработки части территории Центрального Казахстана ─ листа карты масштаба 1:500000 с целью подготовки условно импактных структур к дальнейшим исследованиям.

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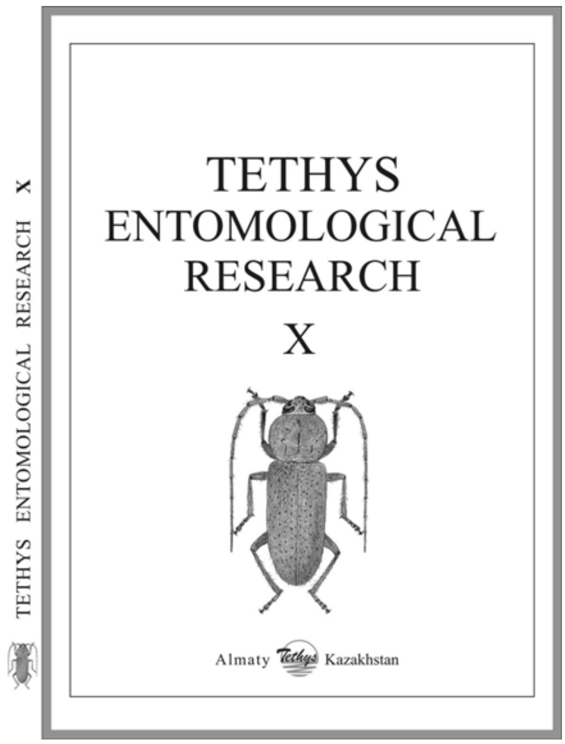

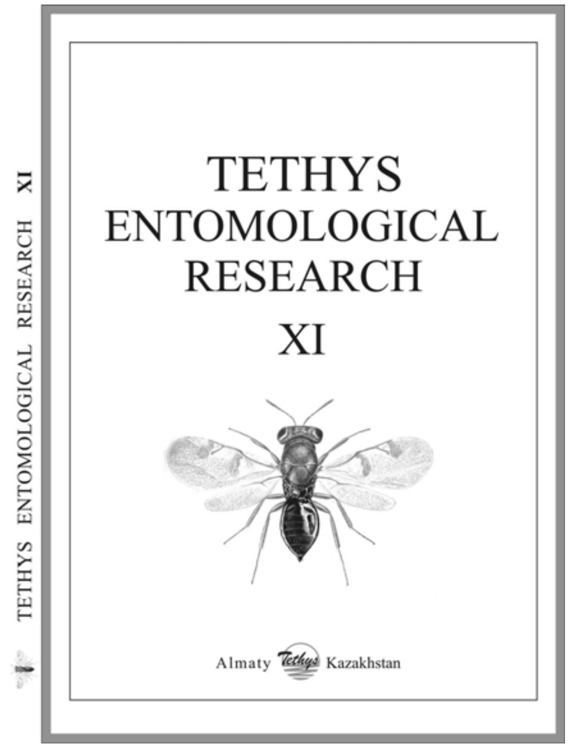

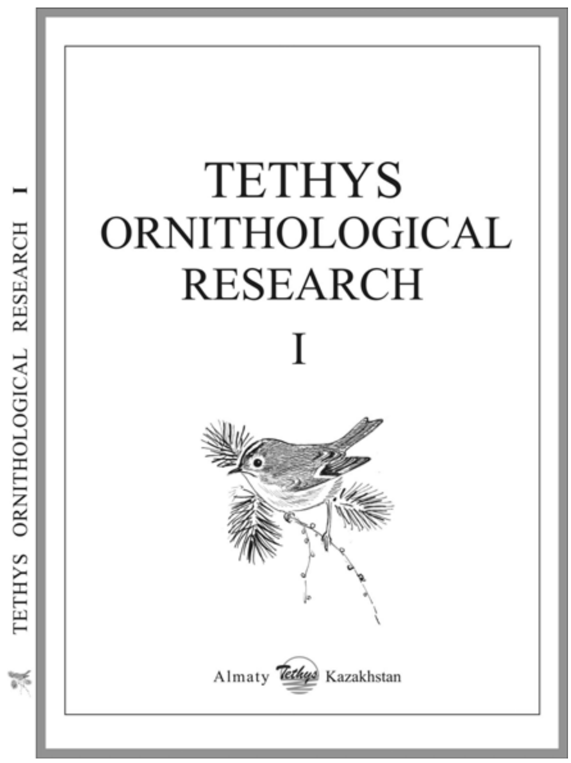

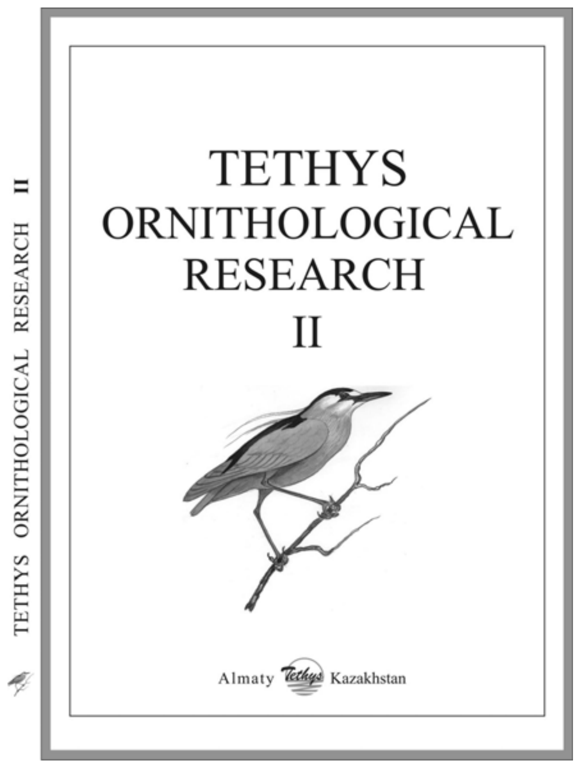

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Подписано в печать 25 декабря 2005 г.
Отпечатано в Научном обществе Тетис 15 января 2006 г.
Тираж 1000 экз. Первый завод—250 экз.