ИВМиМГ

Modelling of the climatic river runoff for the Siberian region

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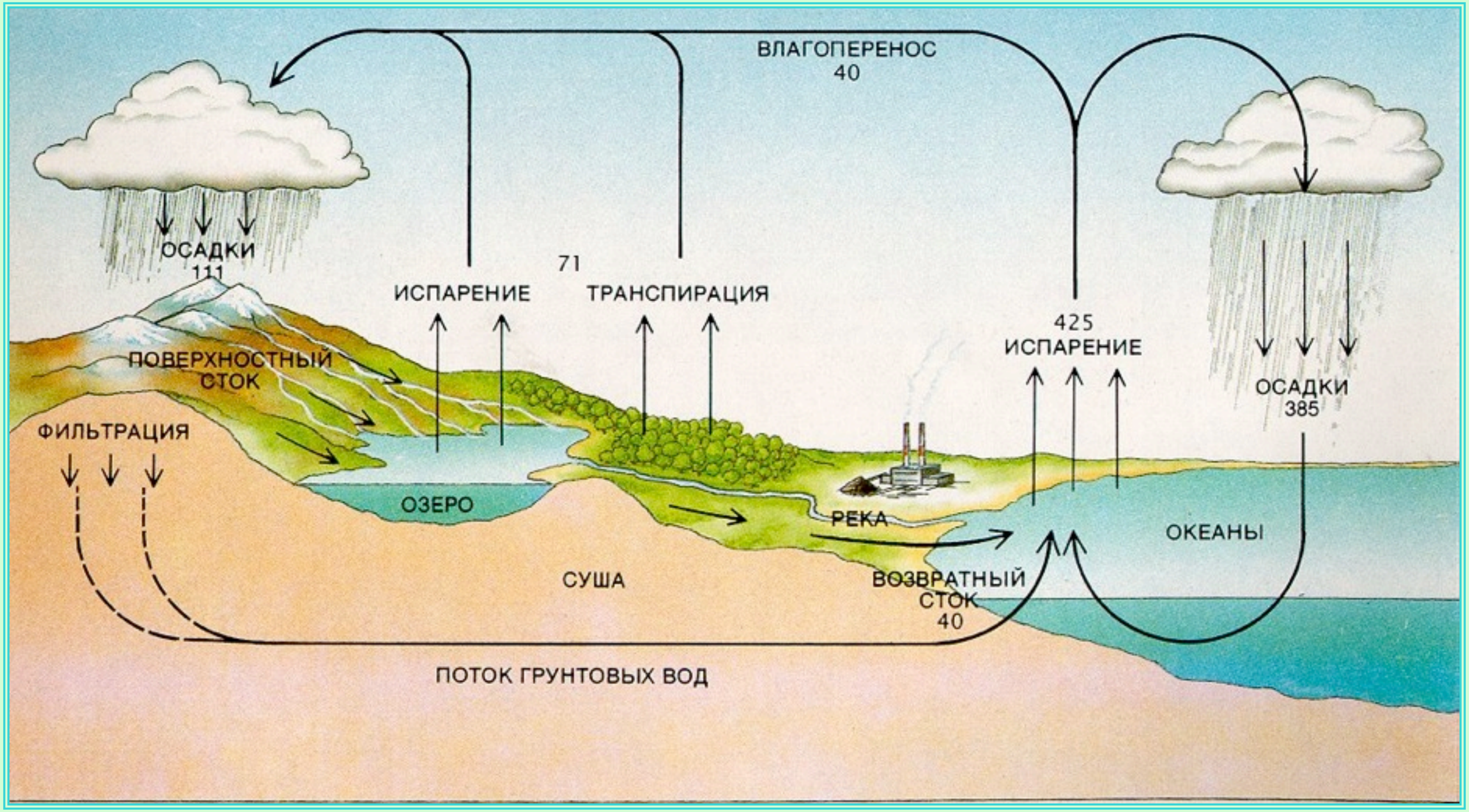
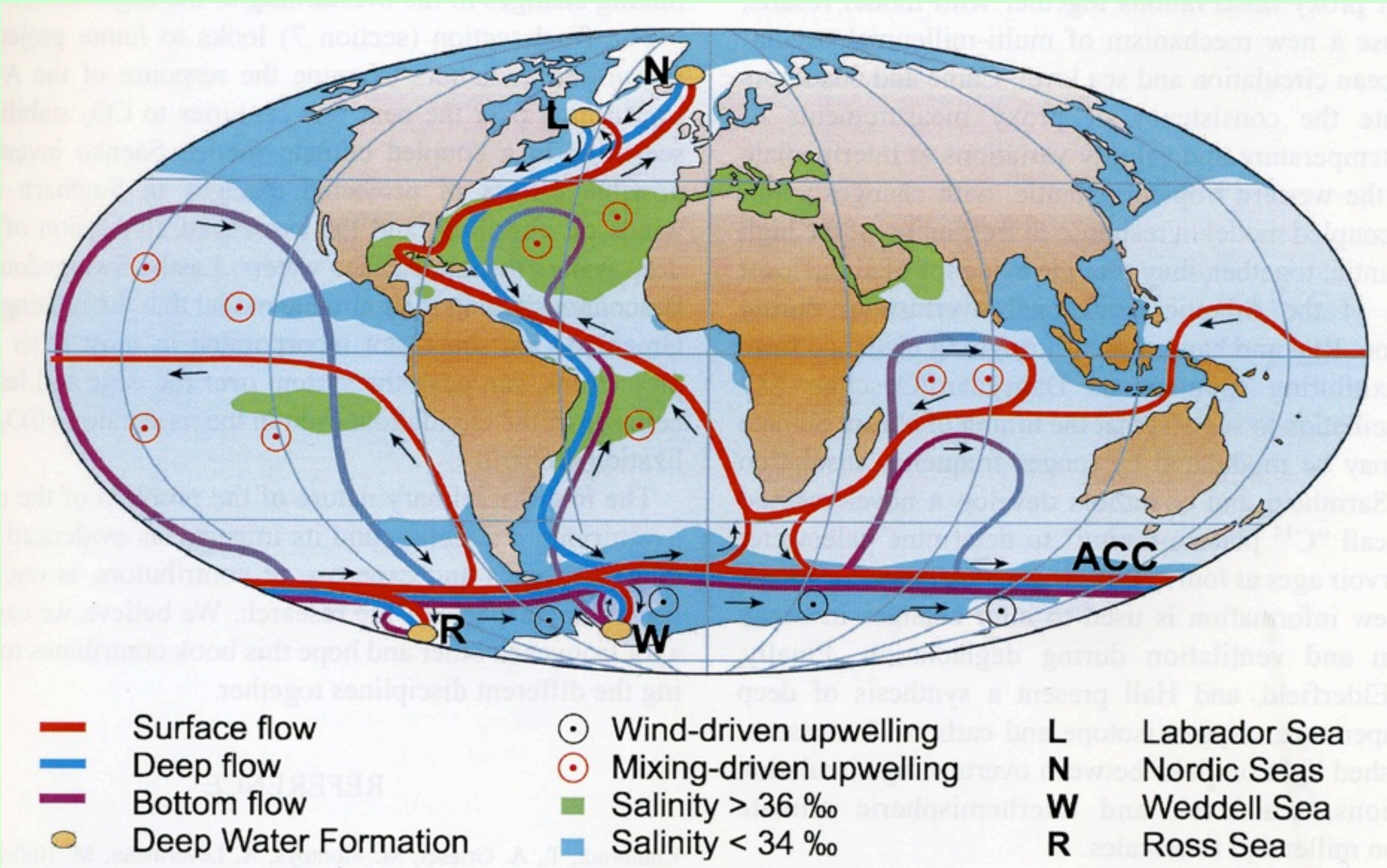
Content

- Role of the Arctic ocean in the global hydrological cycle
- Influence that interannual variability of the Siberian rivers has to the fresh water balance in the Arctic ocean
- Hydrological discharge model
- Simulation of the river runoff with the use of the NCEP/ NCAR and ERA40 reanalysis data
- Conclusion

Global hydrological cycle (th. km^3/y)



Scheme of the World ocean circulation



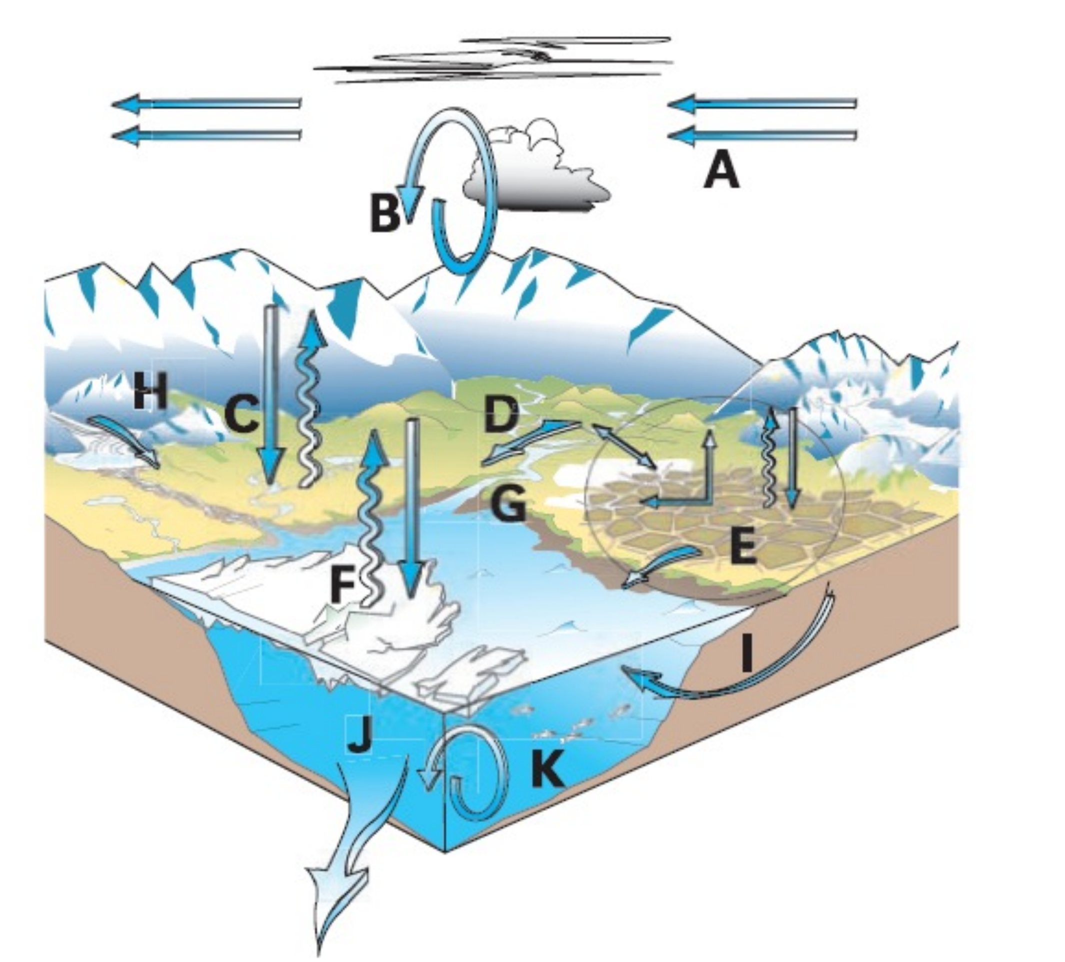
Arctic basin and the main rivers

Arctic ocean form 5% of total area of the World ocean (14.4 mln km^2, Ivanov, 1976) and 1% of its volume. However it gives input 11% of total rivers water into the World Ocean (Kalinin, Shiklomanov, 1972).

Siberian rivers gives about 55% of the total volume, McKenzie - 5 %, the Bering strait gives about 40% with variability 25-30%.

Increasing trend 2.9+0.4 km^3/y (Agaard, Karmak, 1989, Sereze et al, 2006, Woodgate et al, 2006, Shiklomanov, 2010).

Conceptual model of the Arctic hydrological cycle, with key linkages among land, ocean, and atmosphere (Water System Analysis Group, Univ. of New Hampshire)



A = atmospheric boundary fluxes

B = atmospheric dynamics

C = land-surface atmosphere exchanges (with vegetation and permafrost dynamics)

D= discharge through well-defined flow networks (with groundwater and river channel flow)

E = runoff from poorly organized lowland flow systems

F = sea ice mass balance and dynamics

G = estuarine controls on terrestrial/shelf interactions

H= changes in glacial mass balance and associated runoff

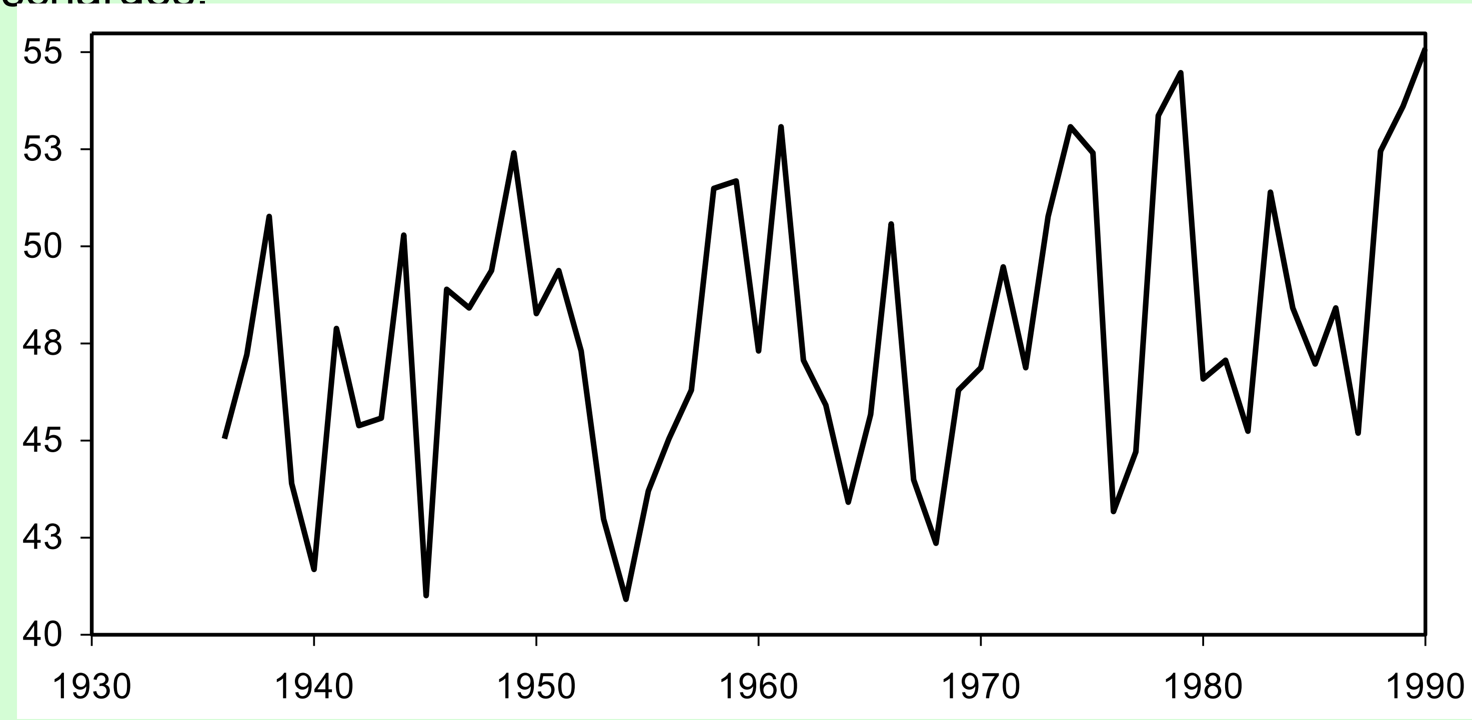
I = direct groundwater discharge to ocean

J = Arctic Ocean dynamics and deep water formation

K = biological dynamics and oceanic food chains

MOTIVATION FOR THE CONSTRUCTION THE RIVER RUNOFF MODEL

A numerical simulation with a 3D ICM&MG hydro-thermodynamical model of the Arctic and North Atlantic oceans is used to study the influence that the interannual variations in the Siberian river discharge have on the distribution and propagation of freshwater in this region. In numerical experiments we compared simulations with the use of observational data on the discharge of the most significant Siberian rivers (Ob, Yenisei, and Lena) against the results of climatic seasonally average variations of their discharges.



Total volume transport of Yenisei +Lena +Ob Rivers (th. cubic m/s)

Coupled Ice-Ocean Model

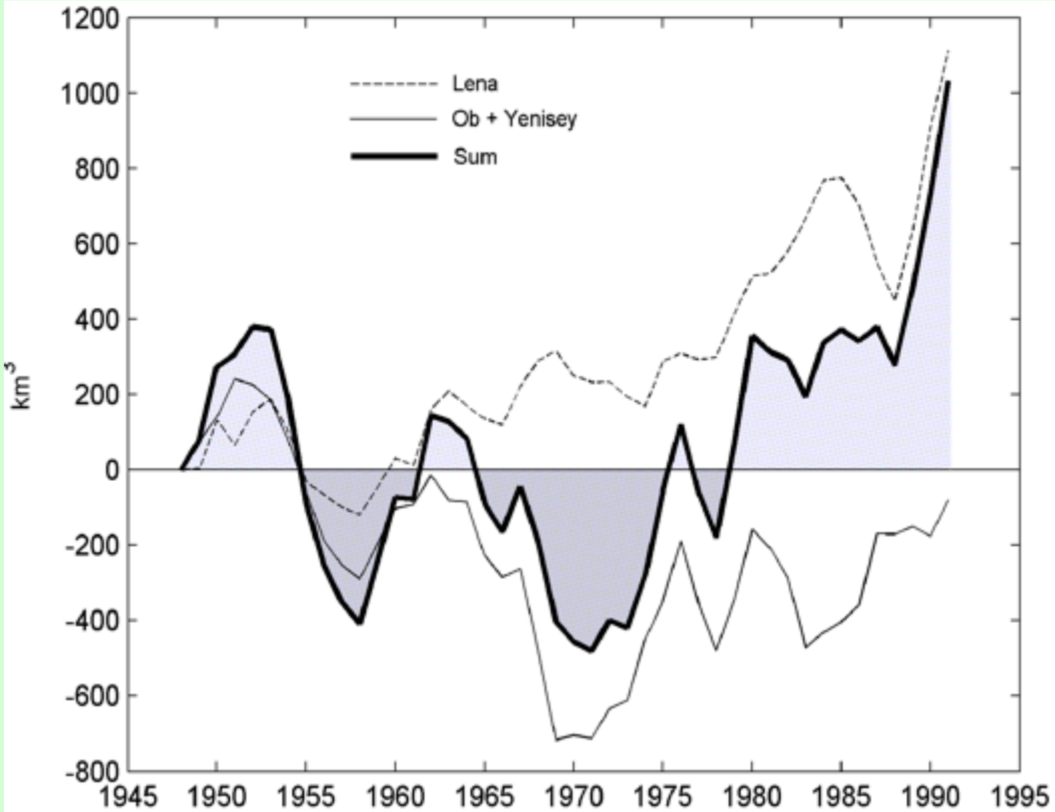
3D Ocean Circulation Model of ICMMG based on z-level vertical coordinate approach

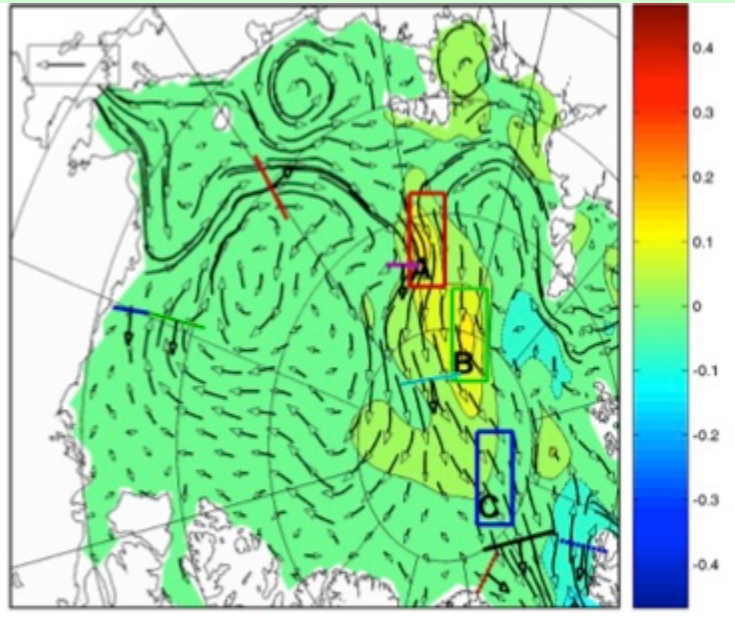
(Kuzin1982, Golubeva at al.,1992, Golubeva,[2001], Golubeva and Platov,[2007])

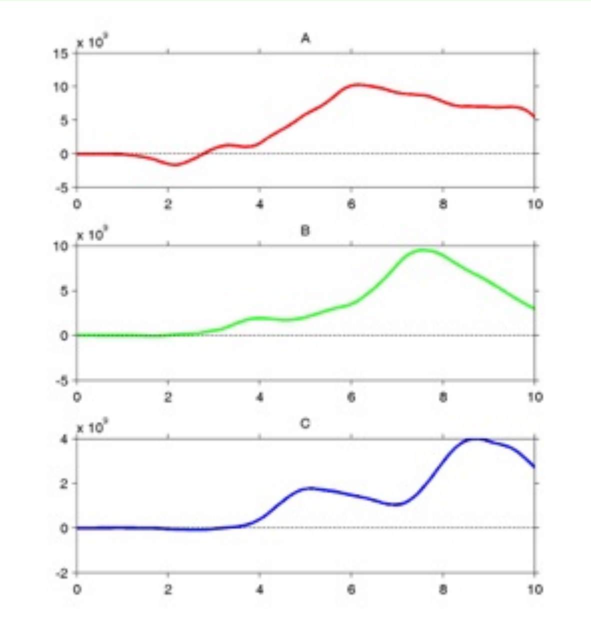
Ice model-CICE 3.14 (elastic-viscous-plastic)

W.D.Hibler ,1979, E.C.Hunke, J.K.Dukowicz,1997, G.A.Maykut 1971 C.M.Bitz, W.H.Lipscomb 1999,J.K.Dukowicz, J.R.Baumgardner 2000, W.H.Lipscomb, E.C.Hunke 2004

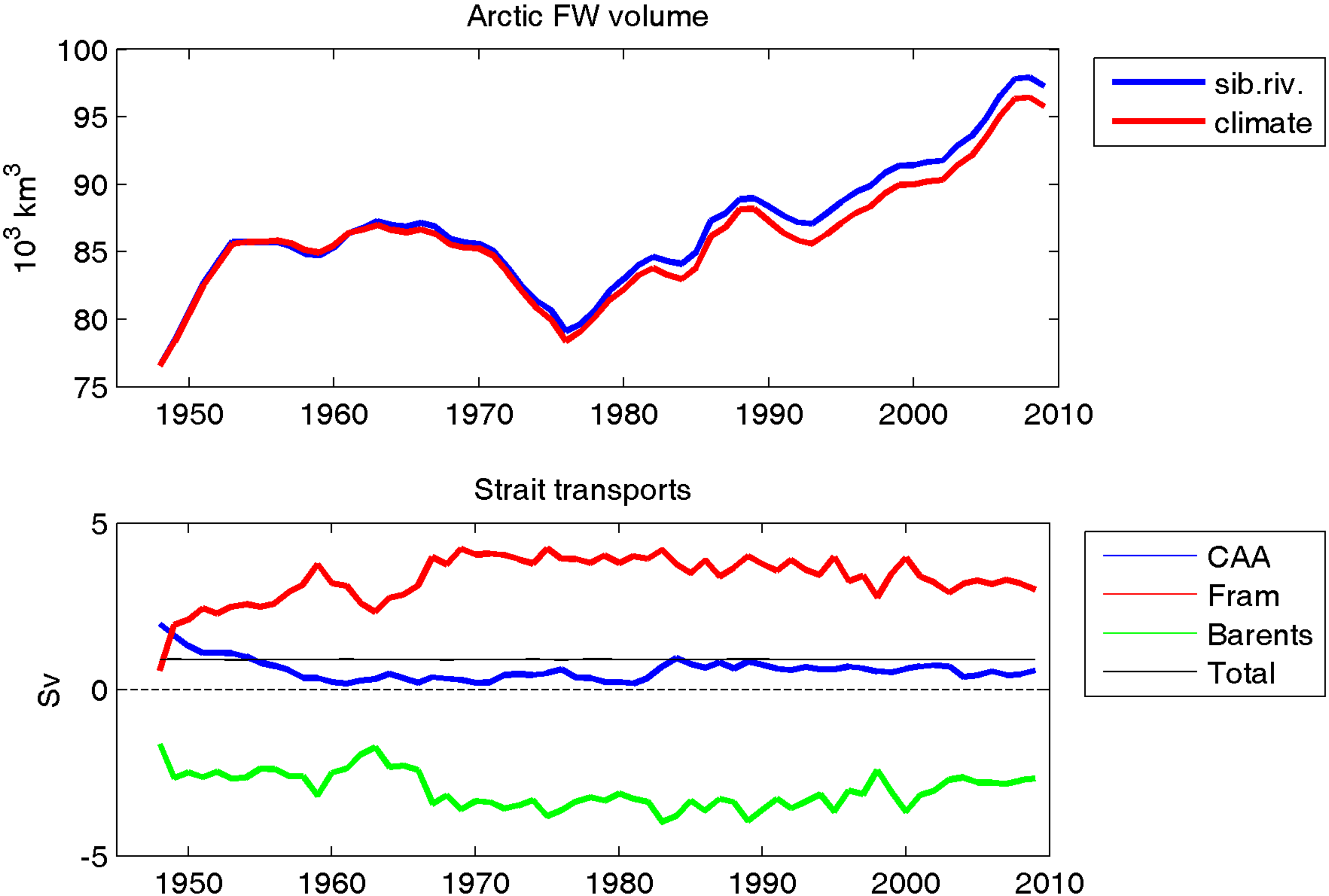
Interannual variability of the Siberian rivers discharge. Difference in the volumes between the observed and climatic discharges of Siberian rivers accumulated since 1948.



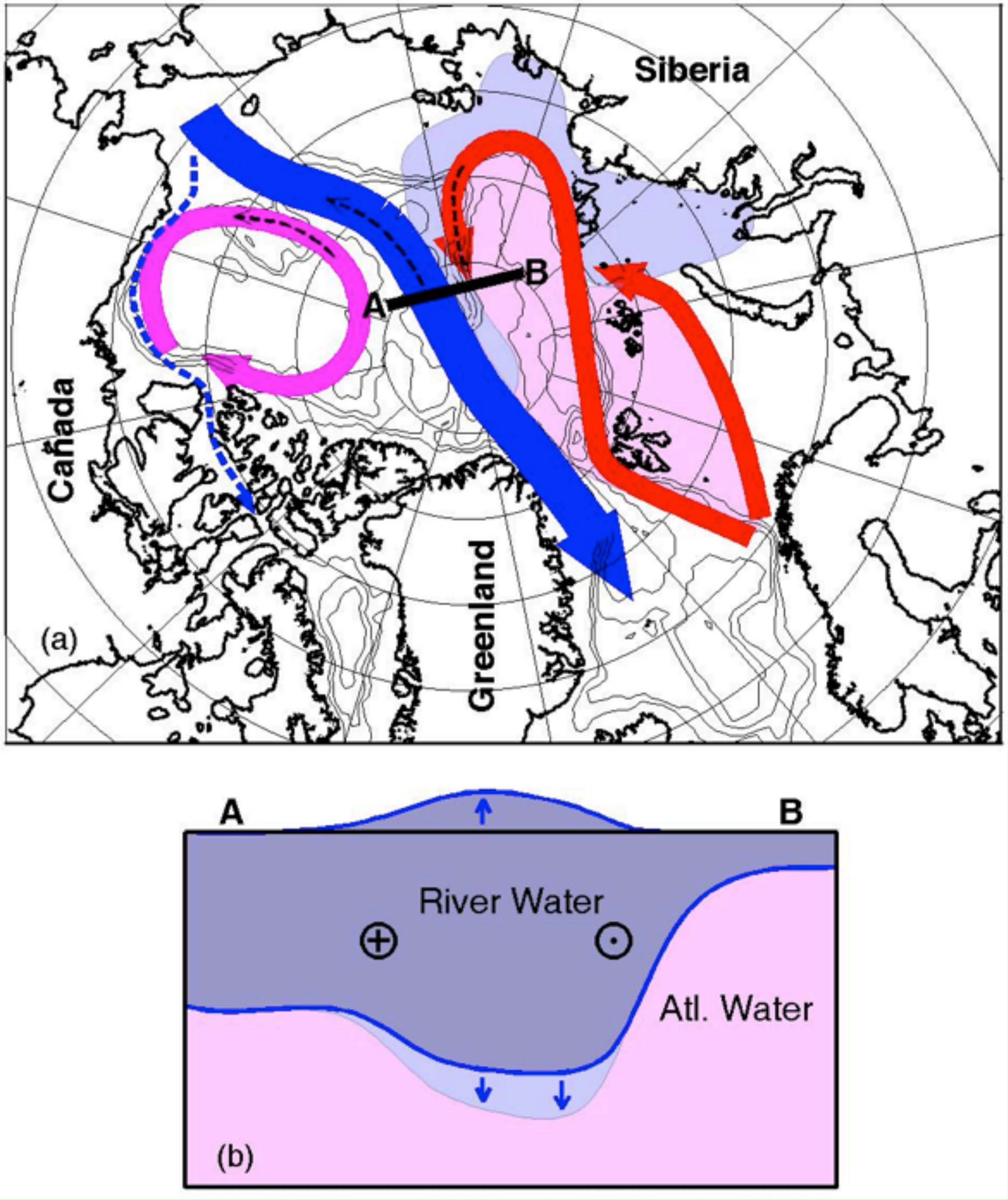




Movement of the positive anomaly of the fresh water since 1958.



Arctic FW volume
10^3 km^3
100
95
90
85
80
75
1950
1960
1970
1980
1990
2000
2010
sib.riv.
climate
Strait transports
Sv
5
0
-5
1950
1960
1970
1980
1990
2000
2010
CAA
Fram
Barents
Total

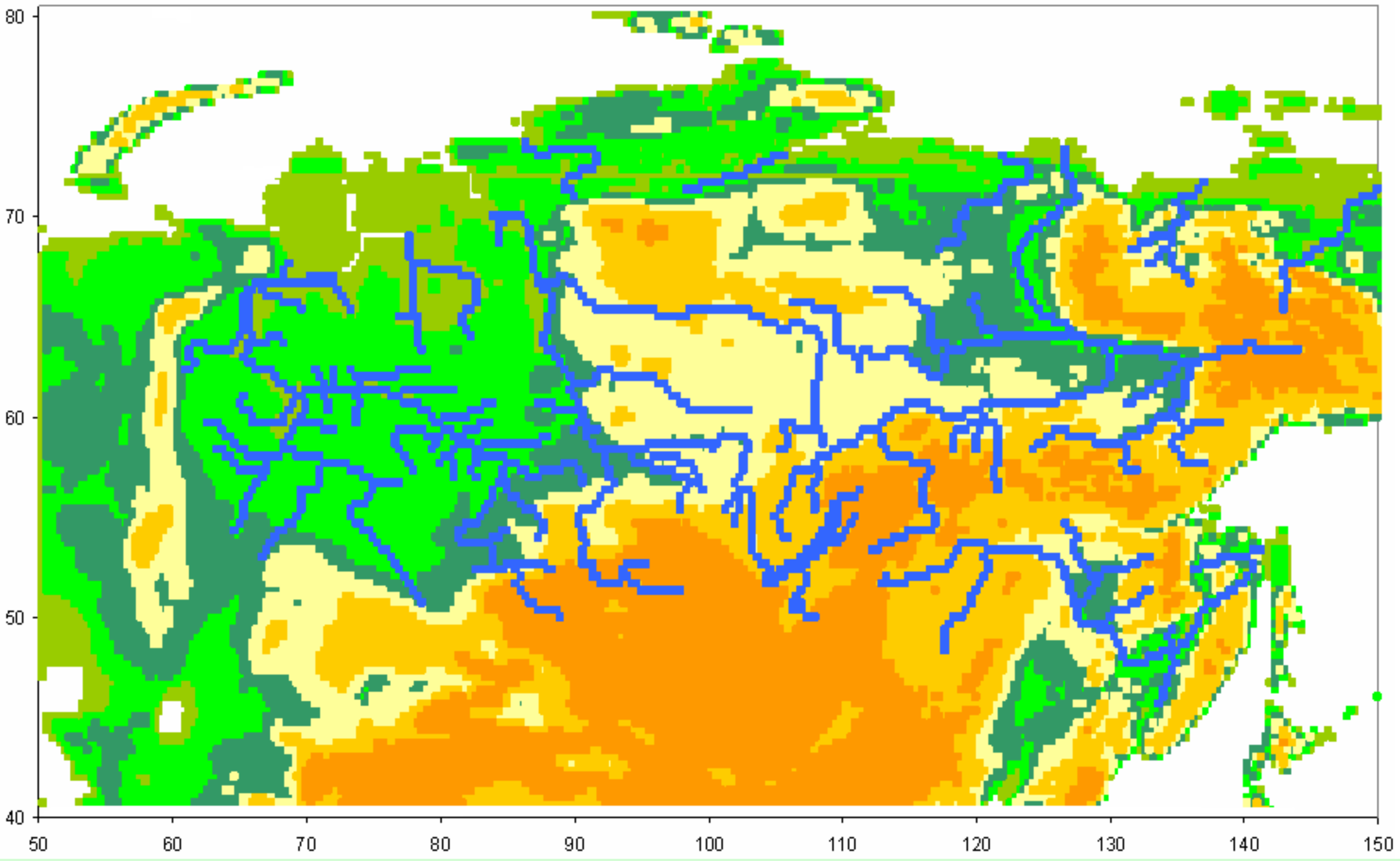


Scheme of regional subsurface circulation and changes made by fresh river waters. (a): Wide arrow line across the basin is Transpolar drift current (TDC), on its left - Atlantic water current, on its right - Beaufort Gyre. Line AB shows the section position presented on (b): vertical section across TDC. When FW volume grows, pressure gradient in subsurface layer increases also and makes the gradient component of velocity stronger (thin dashed arrows on (a)), thus the Atlantic water current and TDC weaken in subsurface layer.

Coefficients of correlation of accumulated river discharge with the total loss through the main straits, as well as losses of freshwater though these straits. (1) - correlation coefficient at the maximum level with respect to the significance level, (2) – time lag prior to the maximum response (in years) to the river discharge anomaly.

Straits	1	2
Total loss through the straits		
Fram Strait	-0,78	4
Canadian Archipelago	0,59 (0,71)	0 (12)
Barents Sea	0,74	4
Freshwater discharge		
Fram Strait	-0,75	6
Canadian Archipelago	0,57 (0,71)	0 (12)
Barents Sea	0,40	7

Relief of the regional climatic hydrological discharge model and the main Siberian rivers of the model (1/3 deg. res.)



Main features of the linear Hydrological Discharge Model

(Kutchment, 1972,1989, Burakov, 1978, etc.)

Structure of MPI, Hamburg, 1998,

Model is constructed from linear reservoirs in the grid boxes:

- **Velocity of the out flow depends linearly from the inflow and proportional to the slope of the grid box and untiproportional to the gridbox length.**
- **Velocity of the outflow from the reservoirs or cascade of the reservoirs are found on the basis of the solution of the ordinary differential equations**

The lateral water flow separates into three flow processes:

- **Overland flow**
- **Base flow**
- **River flow**
- **In the each gridbox the parameterization of the wetlands and lakes is included**

Velocity of the outflow from the reservoir or the cascade of the reservoirs are determined from the solution of the solution of the differential equations (for ex. Kalinin, Miliukov, 1958)

$$k \cdot \frac{dQ(t)}{dt} = I(t) - Q(t) \qquad (1)$$

where *k* –time retention coefficient for the reservoir,
I(t) – inflow, *Q(t)* –outflow from the reservoir.
For the cascade of *n* reservoirs the consequence of *n* equations is solved

$$k \cdot \frac{dQ_i(t)}{dt} = I_i(t) - Q_i(t) \qquad i = 1,\ldots,n \qquad (2)$$

$$Q_i = I_{i+1}, \quad I_1 = I(t), \quad Q_n = Q(t)$$

General solution of the equation (1) with the zero initial conditions is the convolution of I(t) with the function h(t)

$$Q(t) = \int_{0}^{\infty} I(\tau) \cdot h(t - \tau) \cdot d\tau \qquad (3)$$

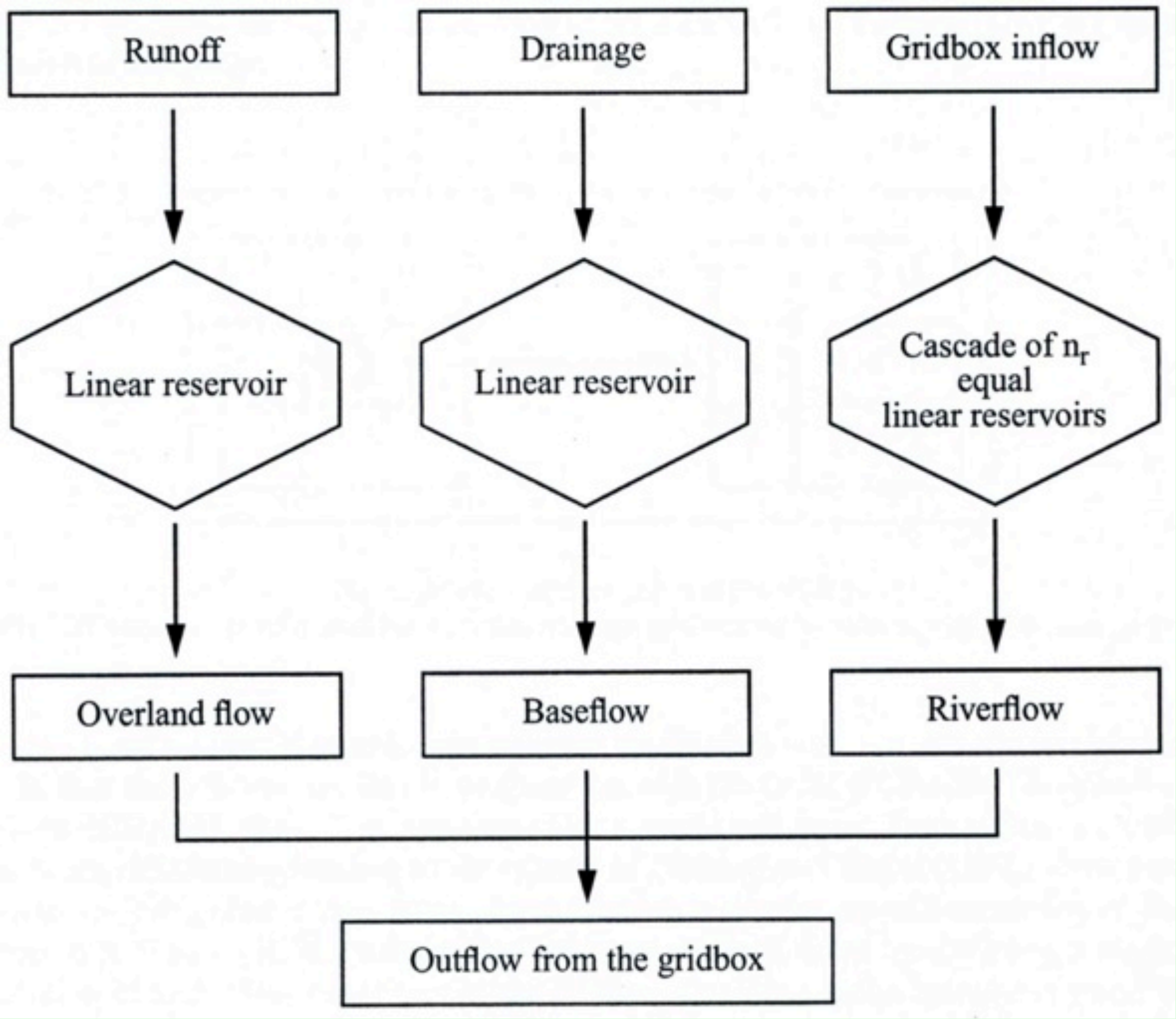
Here h(t) is system function, which is the simplest variant has the form

$$h(t) = \frac{1}{k} \cdot e^{-\frac{t}{k}} \qquad (4)$$

For the cascade of *n* reservoirs system function has a form

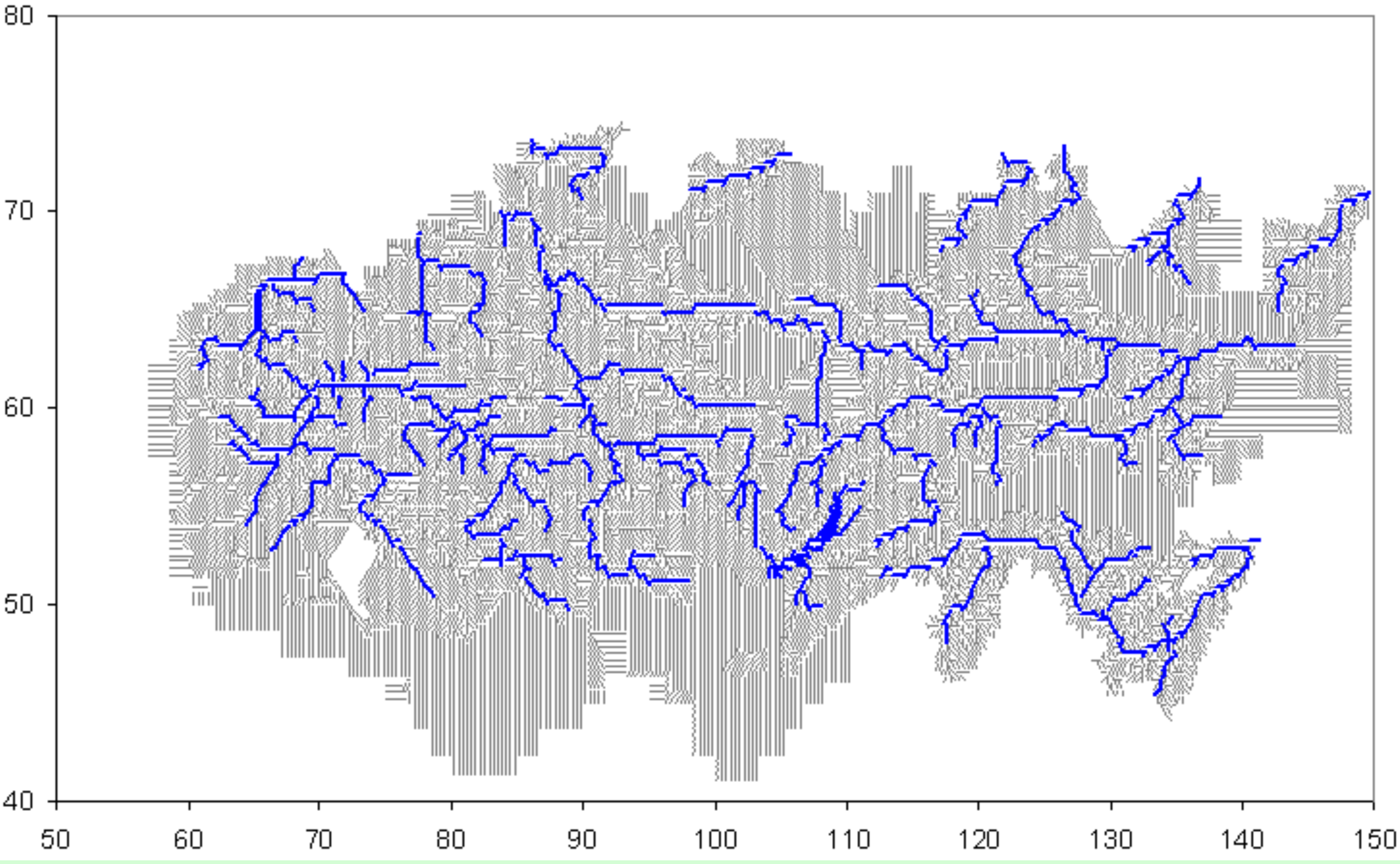
$$h(t) = \frac{t^{n-1}}{k^{n} \cdot (n-1)!} \cdot e^{-\frac{t}{k}} \qquad (5)$$

Structure of the HD MODEL

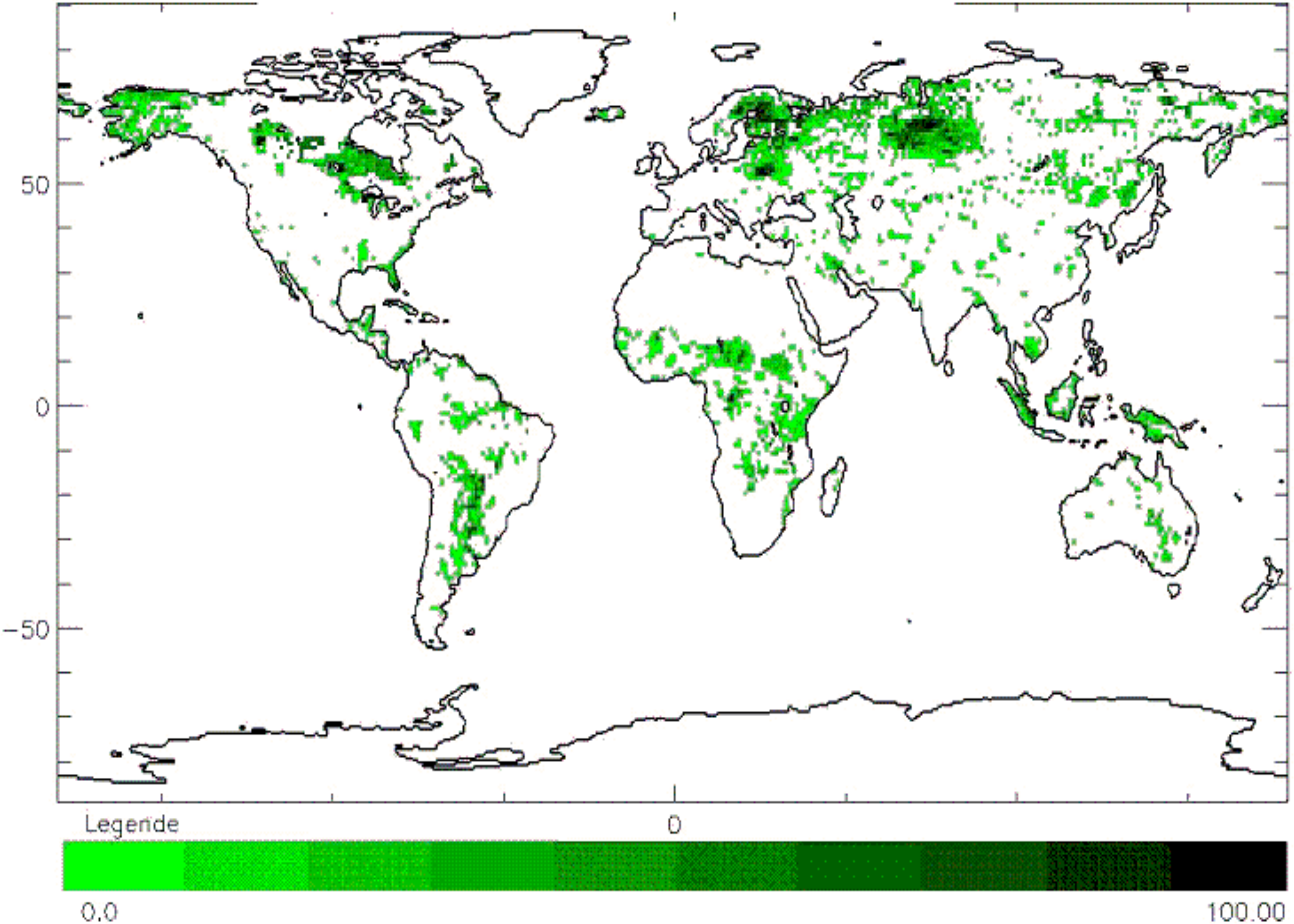


Each gridbox has 8 directions of the outflow to the neighboring grid boxes : N, E, S, W, NE, SE, SW, NW, which is defined by the slope of the gridbox by unique manner.

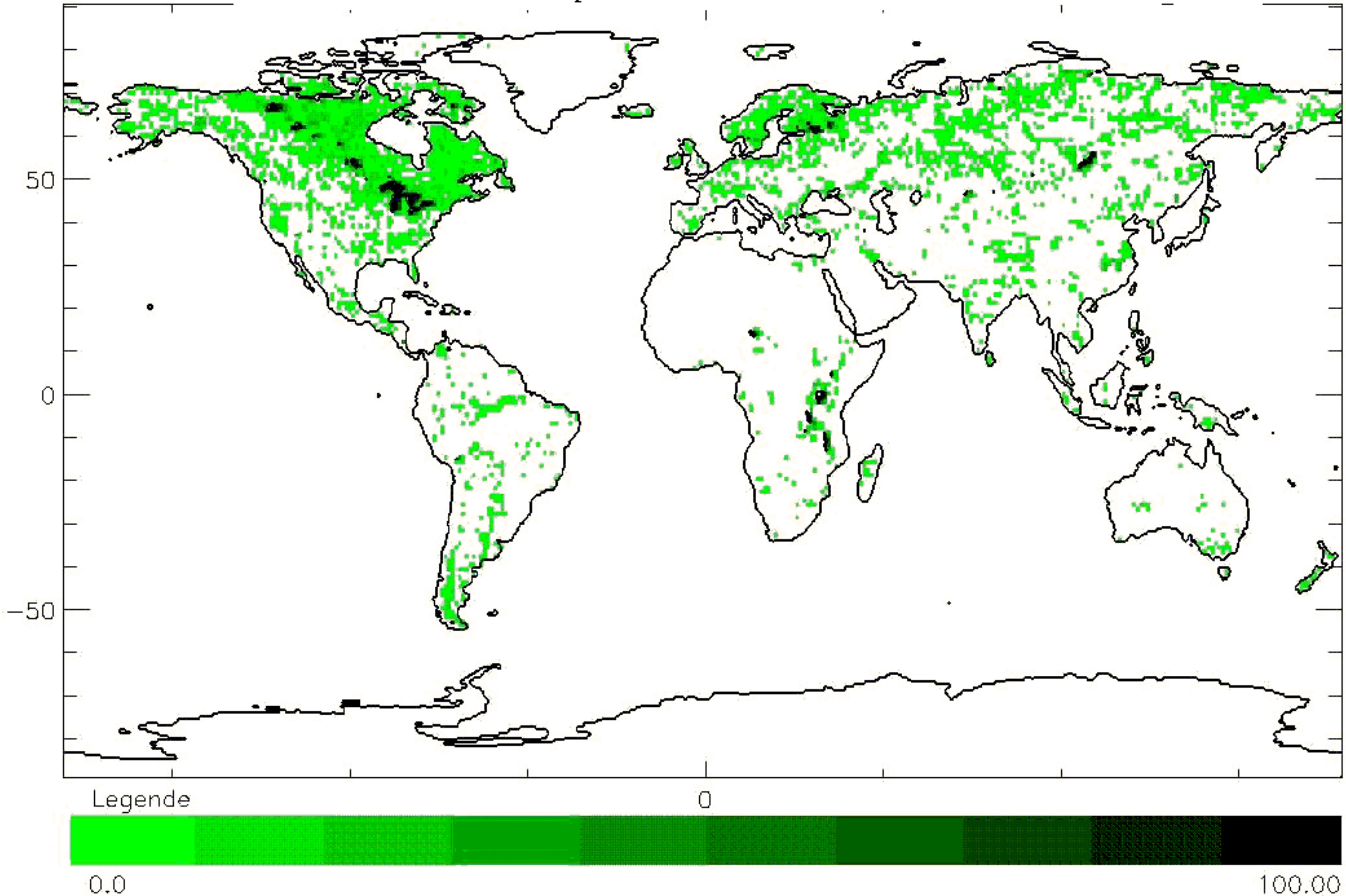
Siberian rivers watersheds. Discharge parsways.



Глобальное распределение концентрации ветландов на единицу площади поверхности в %



Глобальное распределение концентрации озер на единицу площади поверхности в %



Wetland and lakes parameterization in the HD model

Wetlands is parameterized by retention coefficient f_W, which influenced to the velocity of the overland flow and river flow and depends on the wetland fraction p_W:

$$f_{W,i} = 1 - \frac{1}{2}\left(1 - \frac{\nu_{W,i}}{\nu_{0,i}}\right) \cdot \left(\tanh\left(4\pi \cdot \left(p_W - p_c\right)\right) + 1\right) \qquad (10)$$

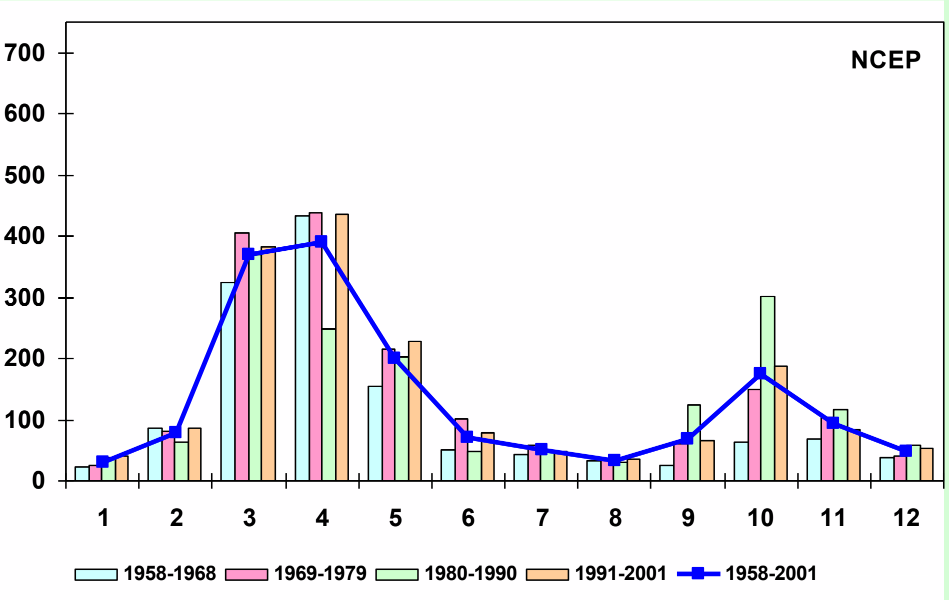
The retention time is determined as:

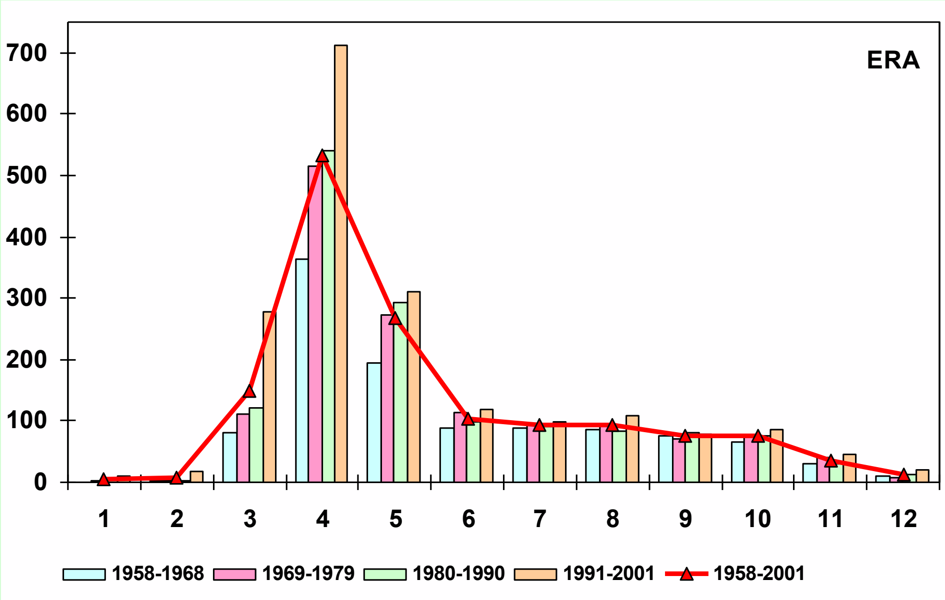
$$k_i = \frac{\Delta x}{f_{W,i} \cdot \nu_{0,i}} \qquad n_i = 1 \qquad (11)$$

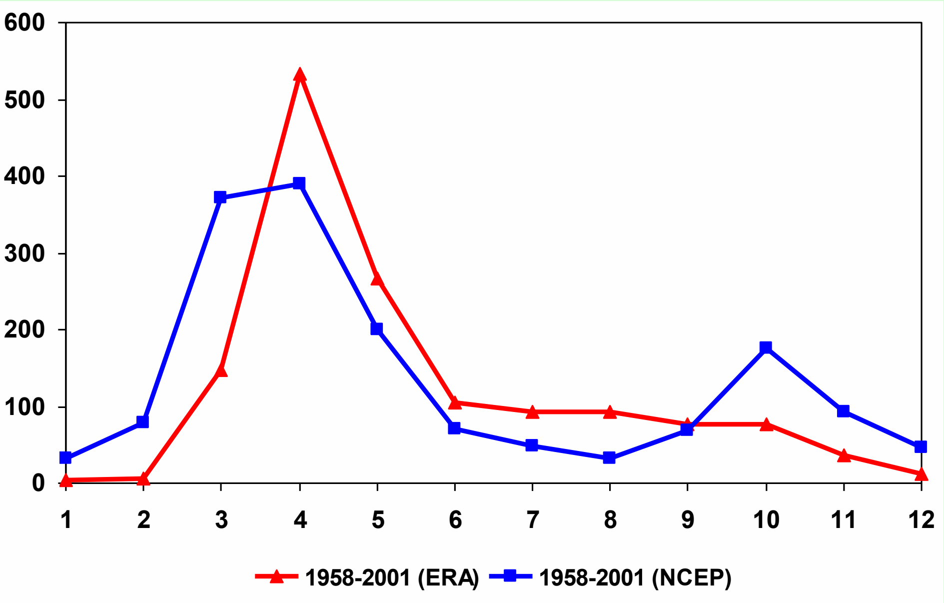
$$\nu_{0,i} = \frac{\Delta x}{n_i \cdot k_i} \qquad (12)$$

Lakes parameterization is introduced by the analogous formulas with the use of the pretension coefficient f_L.

Precipitation - Evaporation + Snowmelt (PES). Ob River watershed (km^3). NCEP, ERA40 reanalysis data.



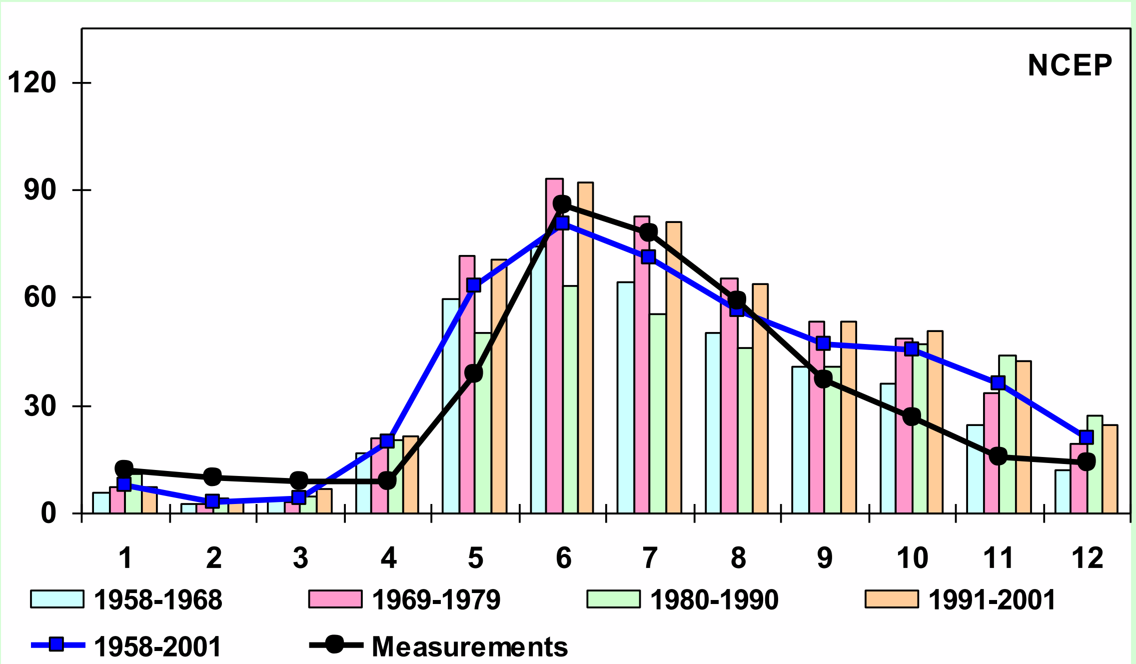


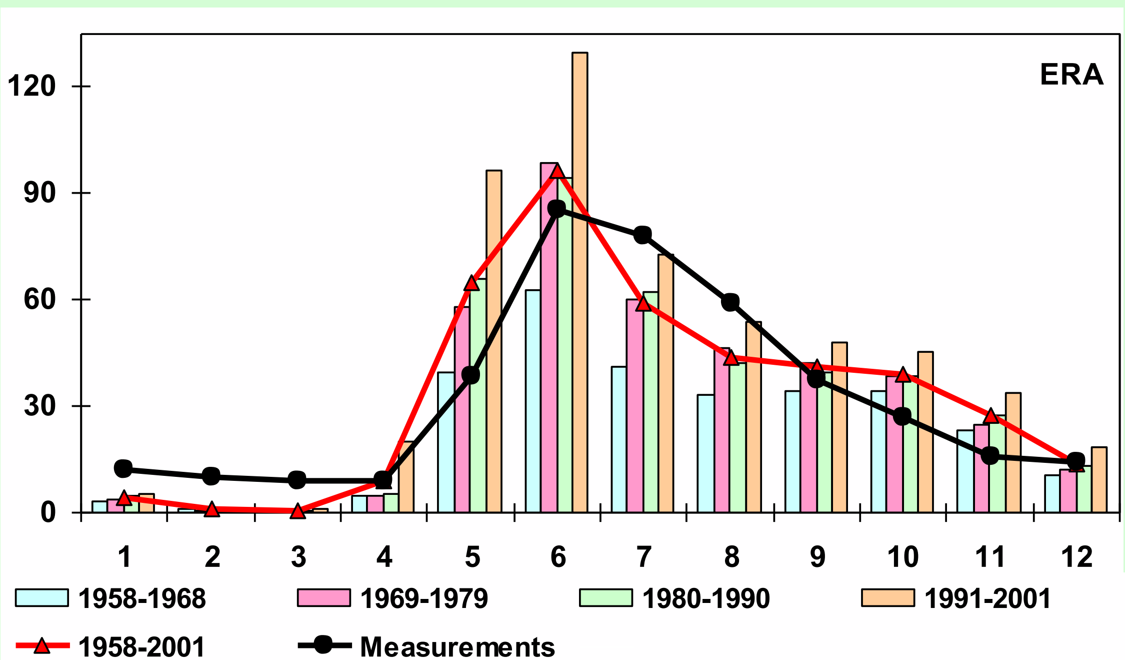


PES values for the 12 months averaged during 11 years periods from 1958-2001 (upper diagrams)

Climatic values of PES for the NCEP (blue) and ERA40 (red) reanalysis (bottom).

Ob River runoff



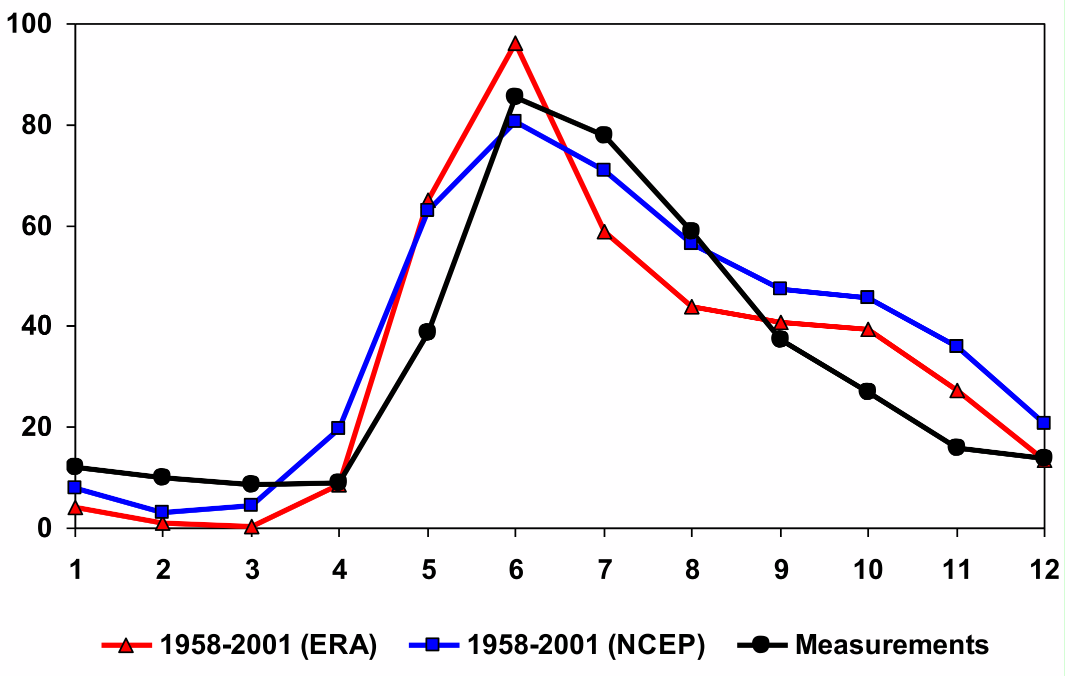


Runoff values for the 12 months averaged during period from 1958 - 2001
NCEP reanalysis (blue)
(upper diagram)

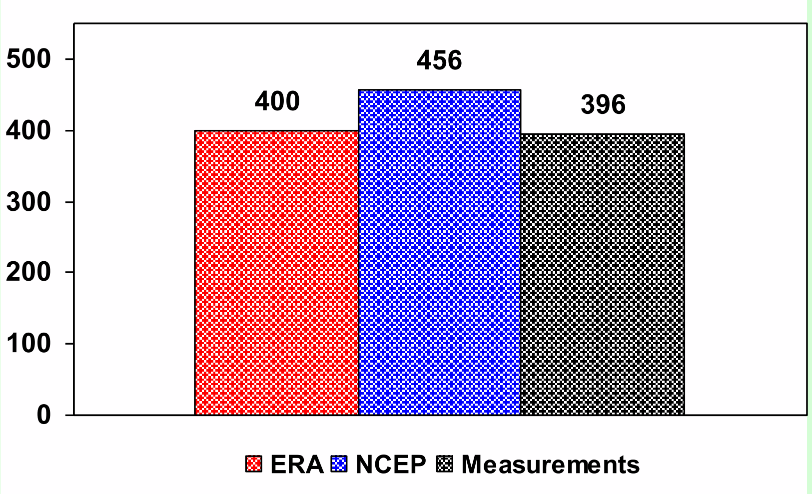
Climatic values of runoff for the ERA40 reanalysis (red)
(bottom).

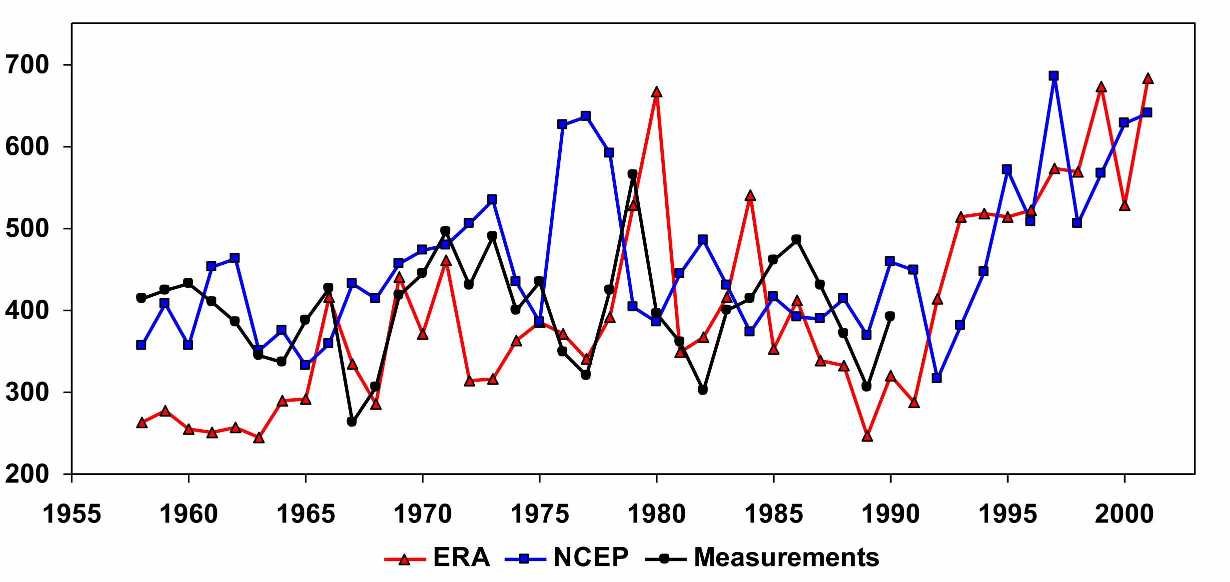
Climatic runoff from the measurements on the Ob – Salechard hydrometeostation 1936 – 1990 (black).

Ob River runoff (km^3)



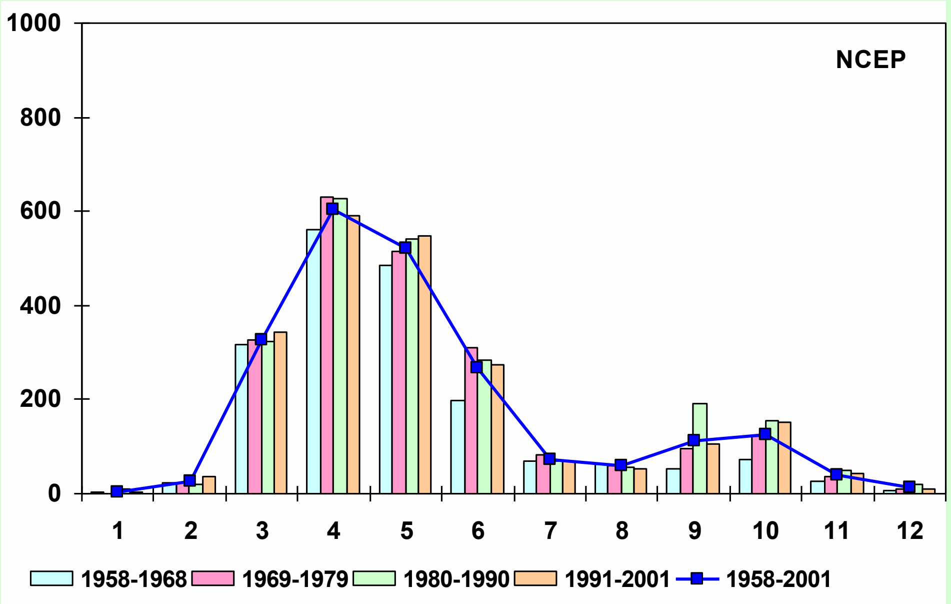
Annual runoff averaged for the period 1958-2001

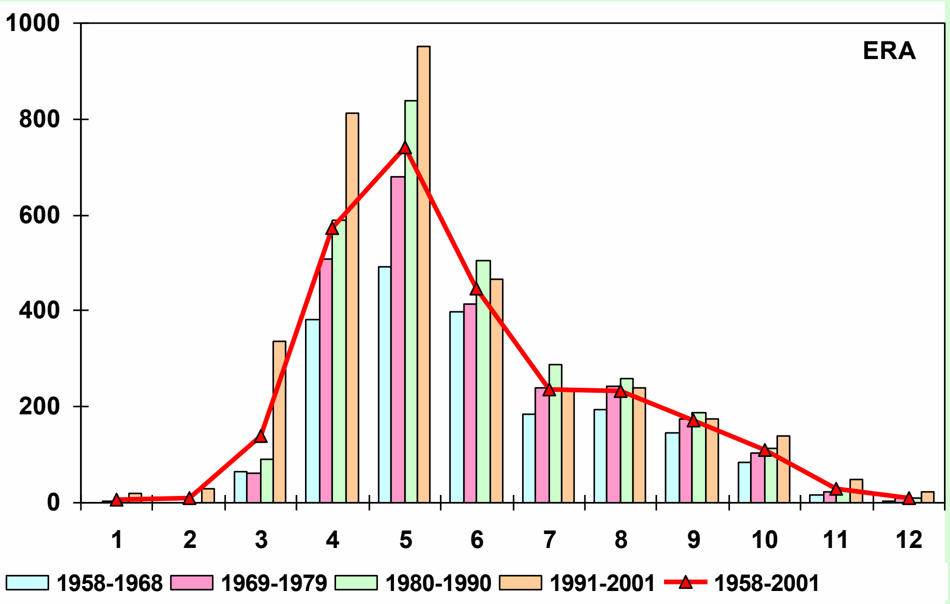


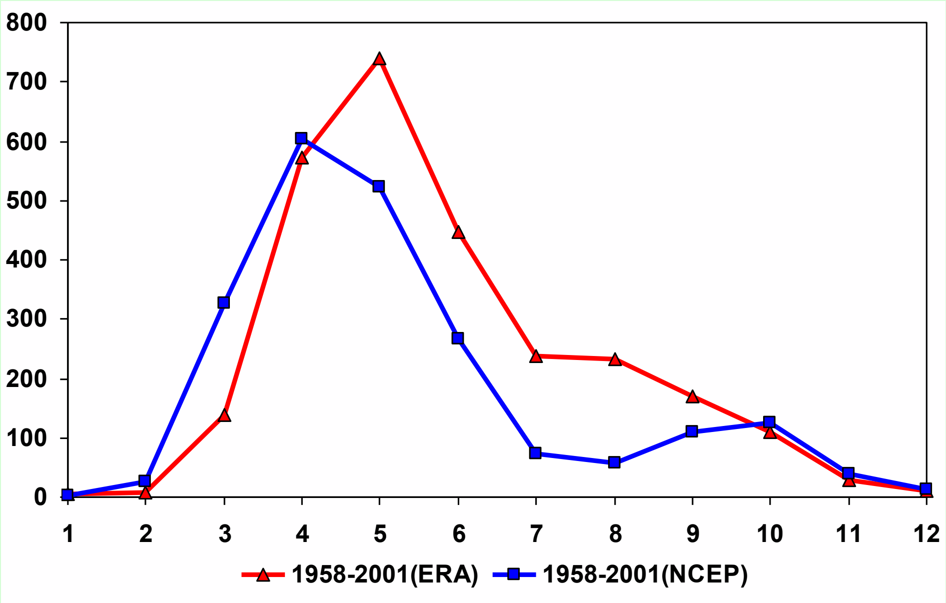


Annual runoff for the period 1958-2001

Precipitation - Evaporation + Snowmelt (PES). Yenisei River watershed (km^3).



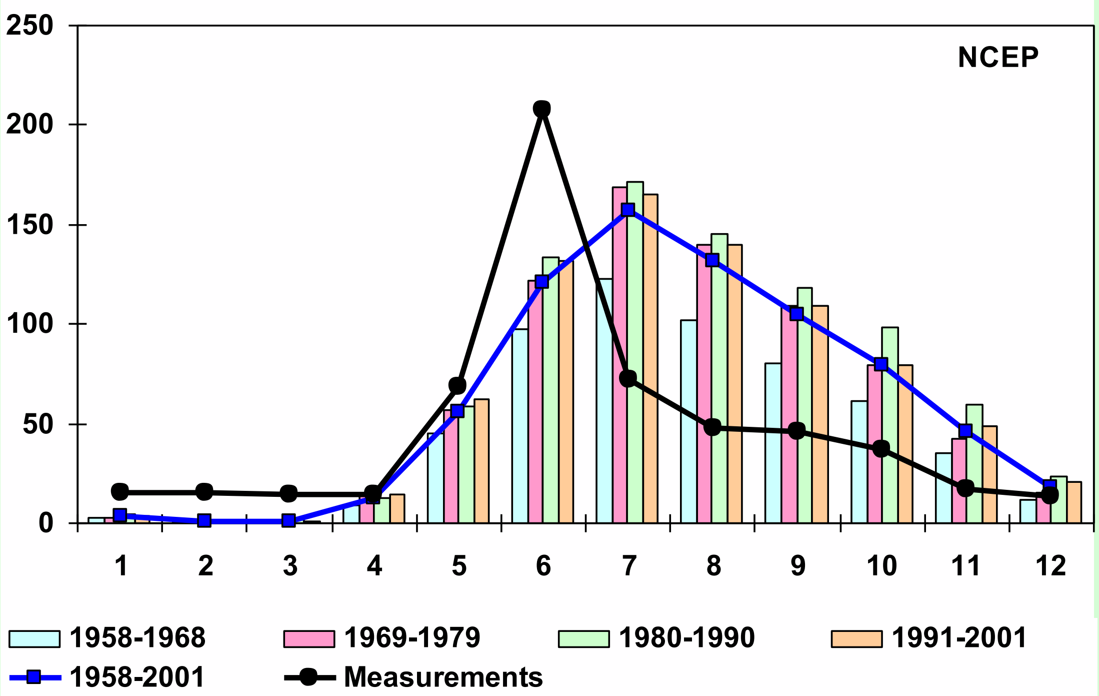


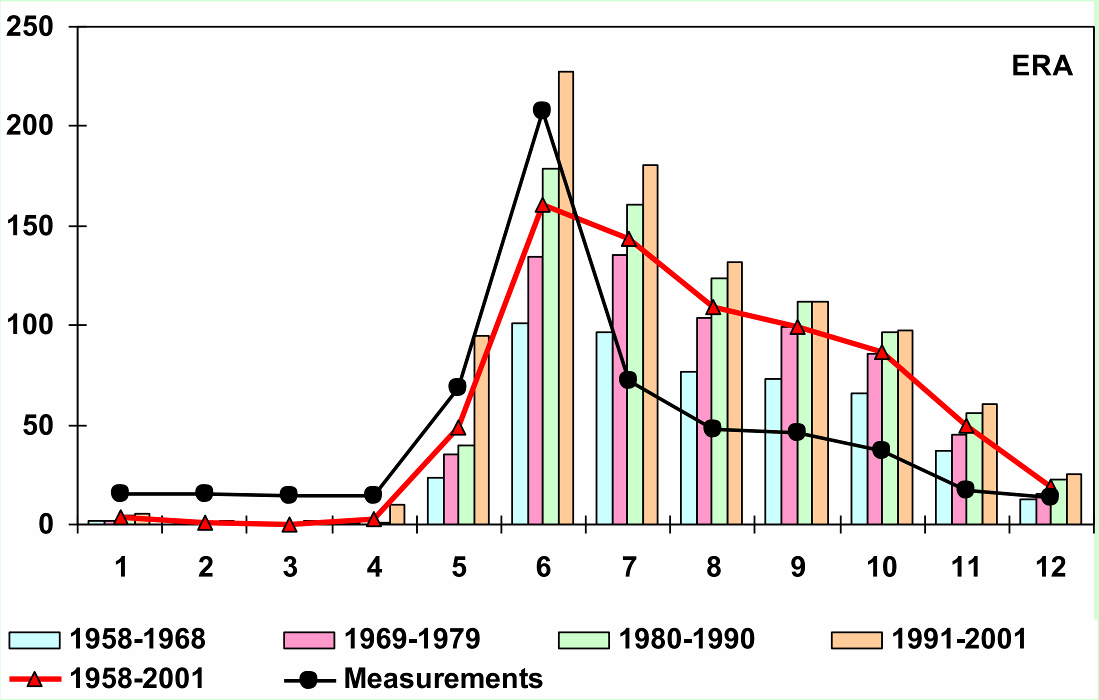


PES values for the 12 months averaged during 11 years periods from 1958-2001 (upper diagrams)

Climatic values of PES for the NCEP (blue) and ERA40 (red) reanalysis (bottom).

Yenisei River runoff



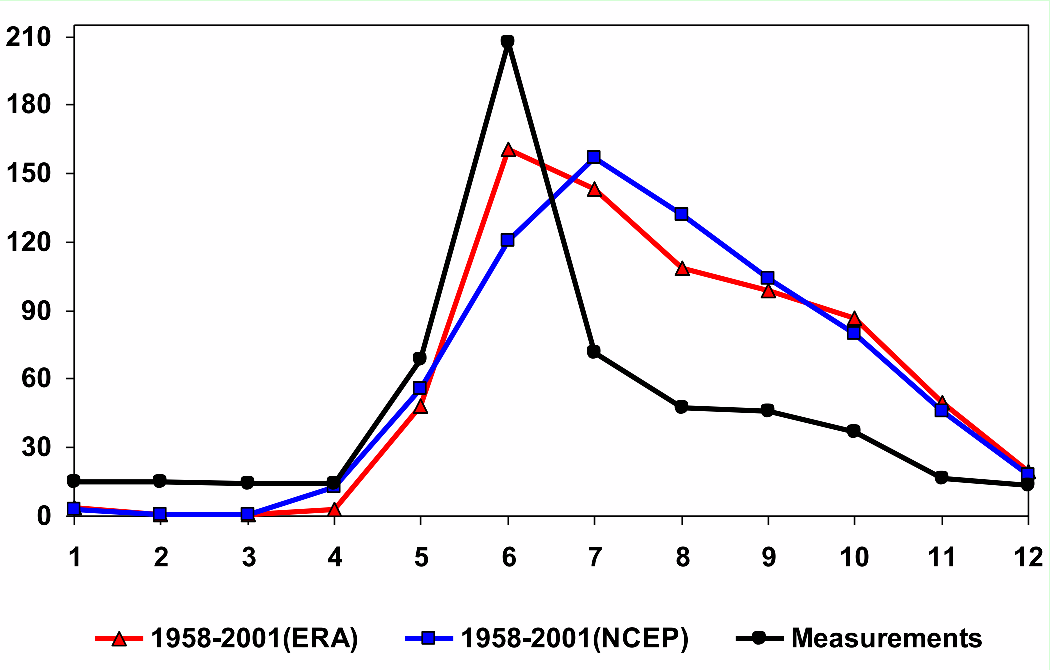


Runoff values for the 12 months averaged during period from 1958 - 2001
NCEP reanalysis (blue)
(upper diagram)

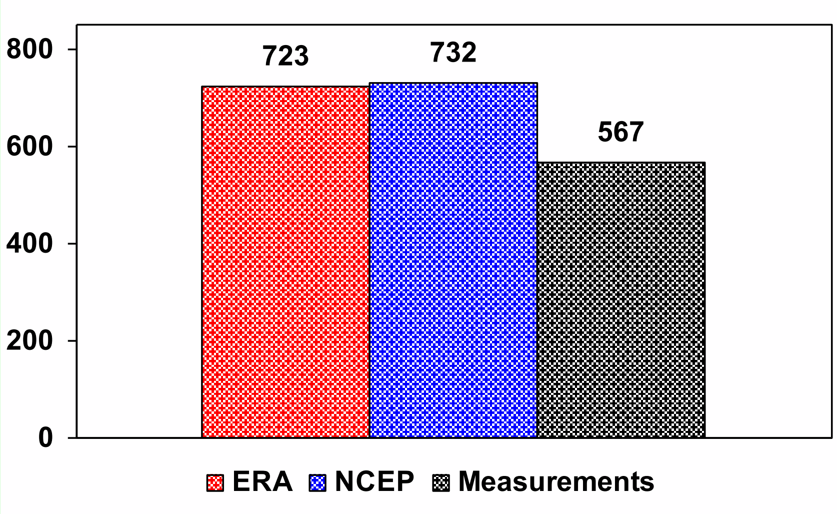
Climatic values of runoff for the ERA40 reanalysis (red) (bottom).

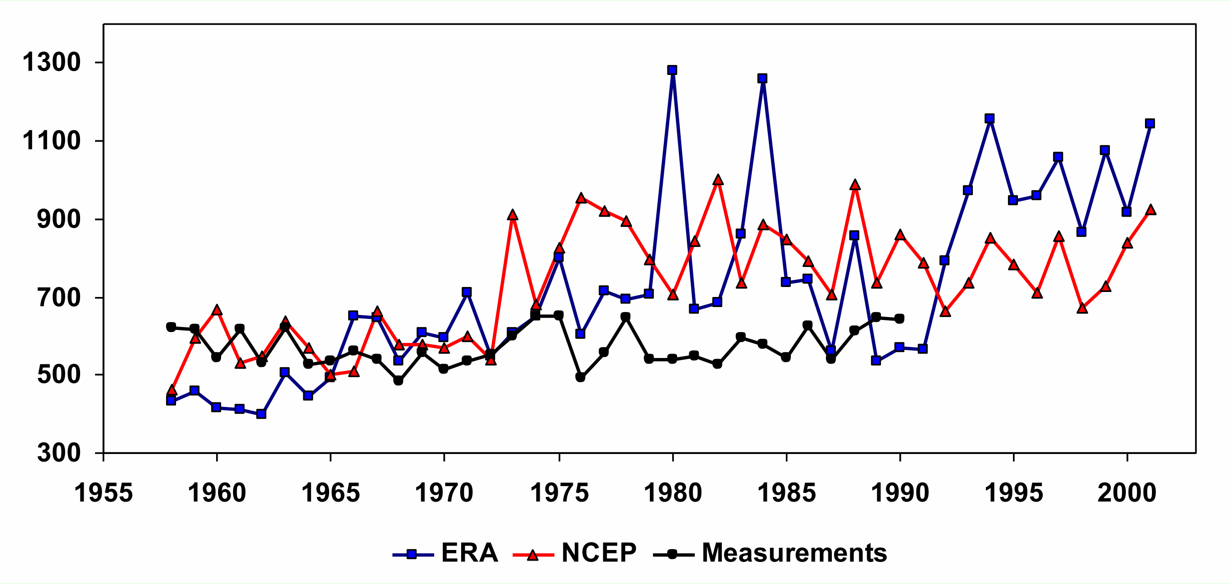
Climatic runoff from the measurements on the Yenisei – Igarka hydrometeostation 1936 – 1990 (black).

Yenisei River runoff (km^3)



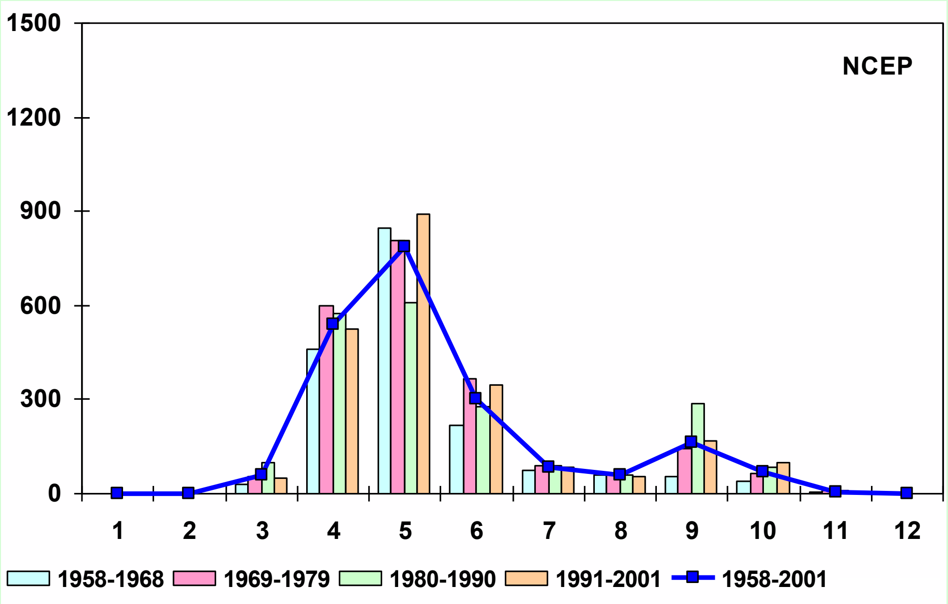
Annual runoff averaged for the period 1958-2001

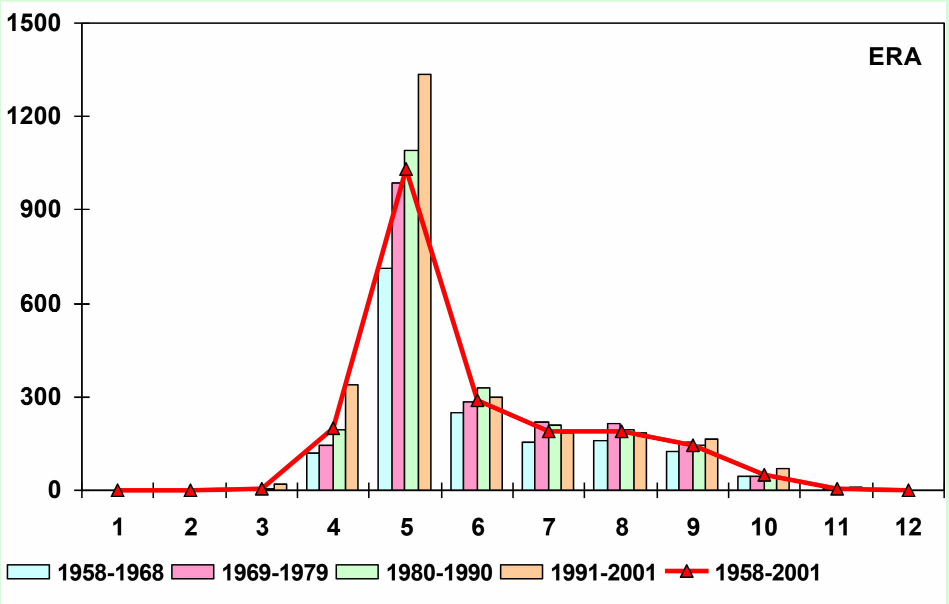


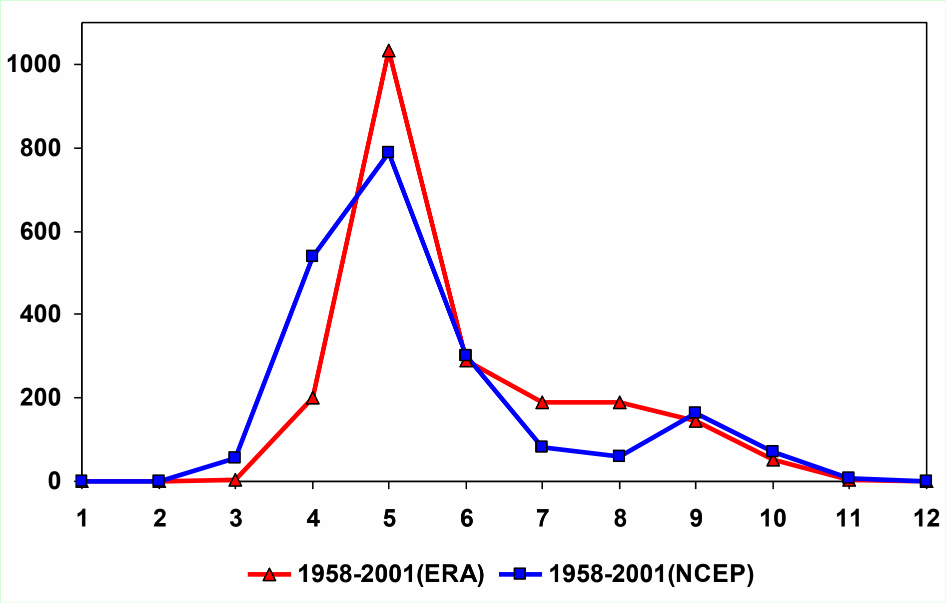


Annual runoff for the period 1958-2001

Precipitation - Evaporation + Snowmelt (PES). Lena River watershed (km^3).



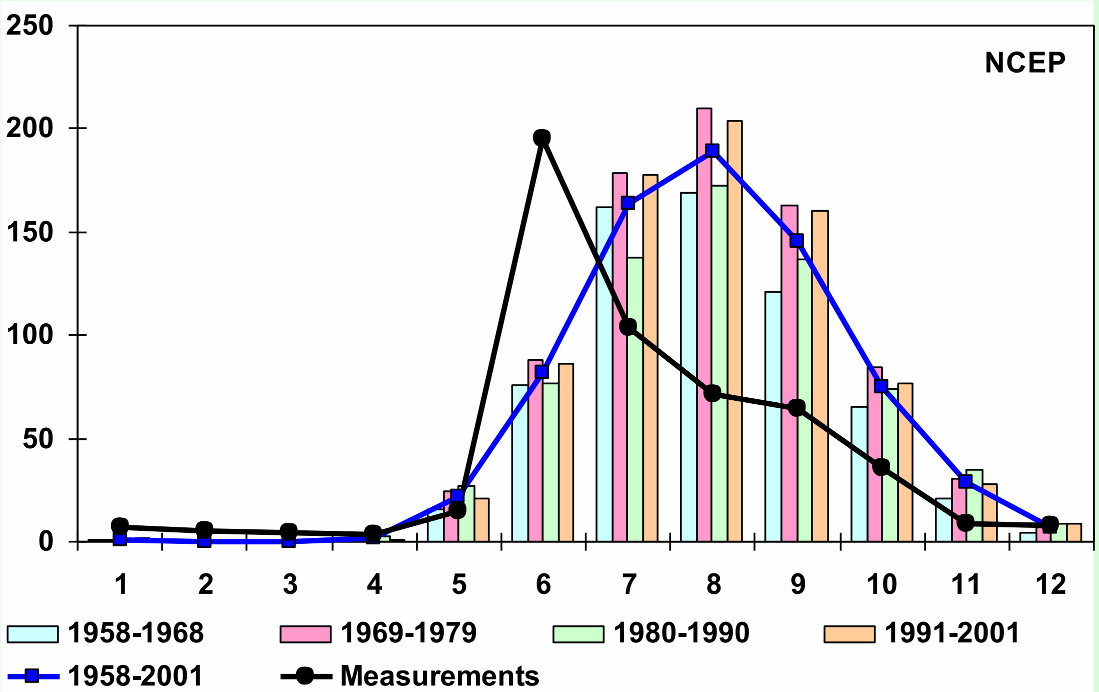


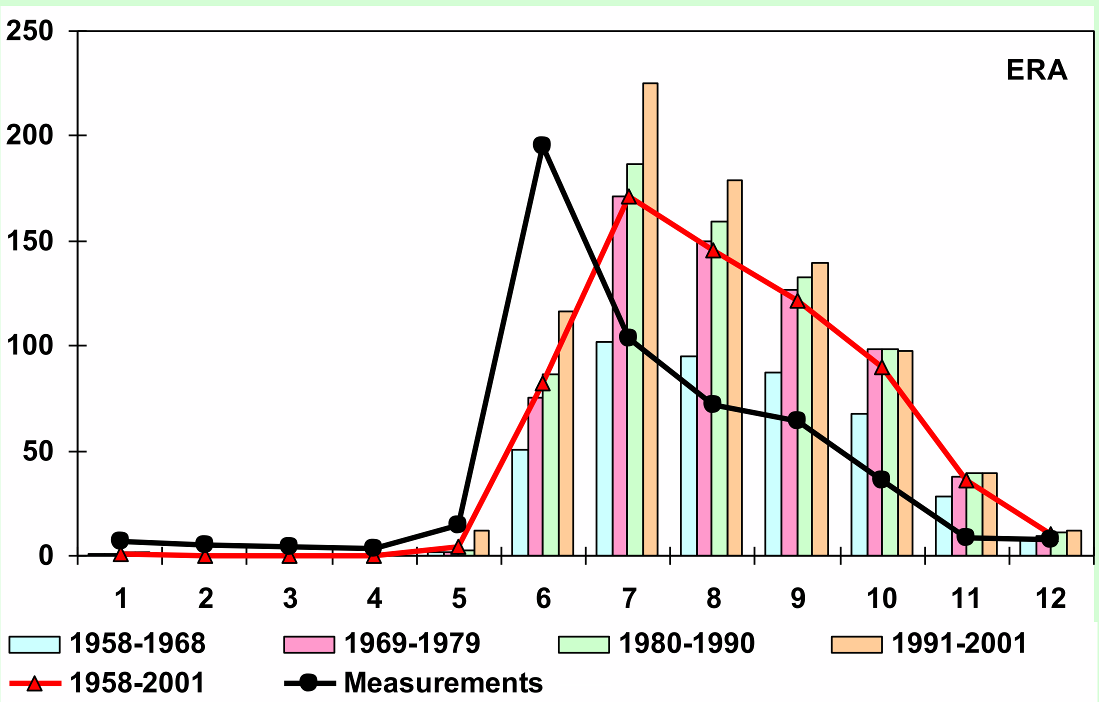


PES values for the 12 months averaged during 11 years periods from 1958-2001 (upper diagrams)

Climatic values of PES for the NCEP (blue) and ERA40 (red) reanalysis (bottom).

Lena River runoff



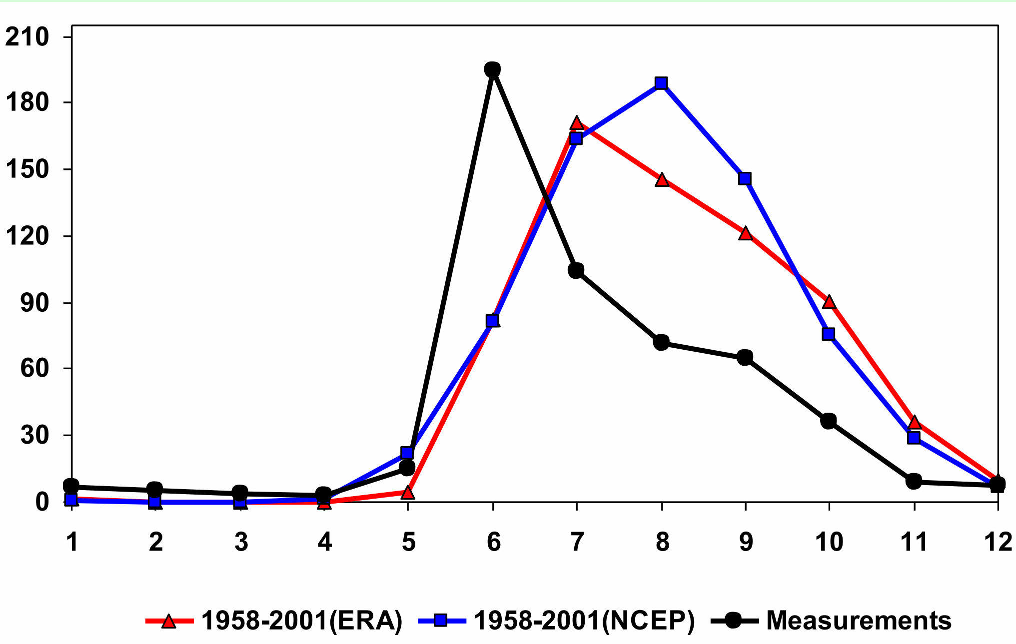


Runoff values for the 12 months averaged during period from 1958 - 2001
NCEP reanalysis (blue) (upper diagram)

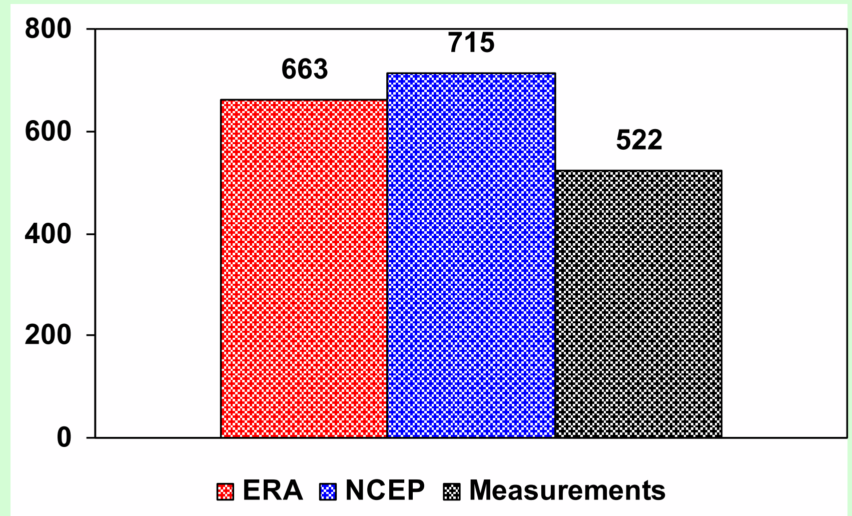
Climatic values of runoff for the ERA40 reanalysis (red) (bottom).

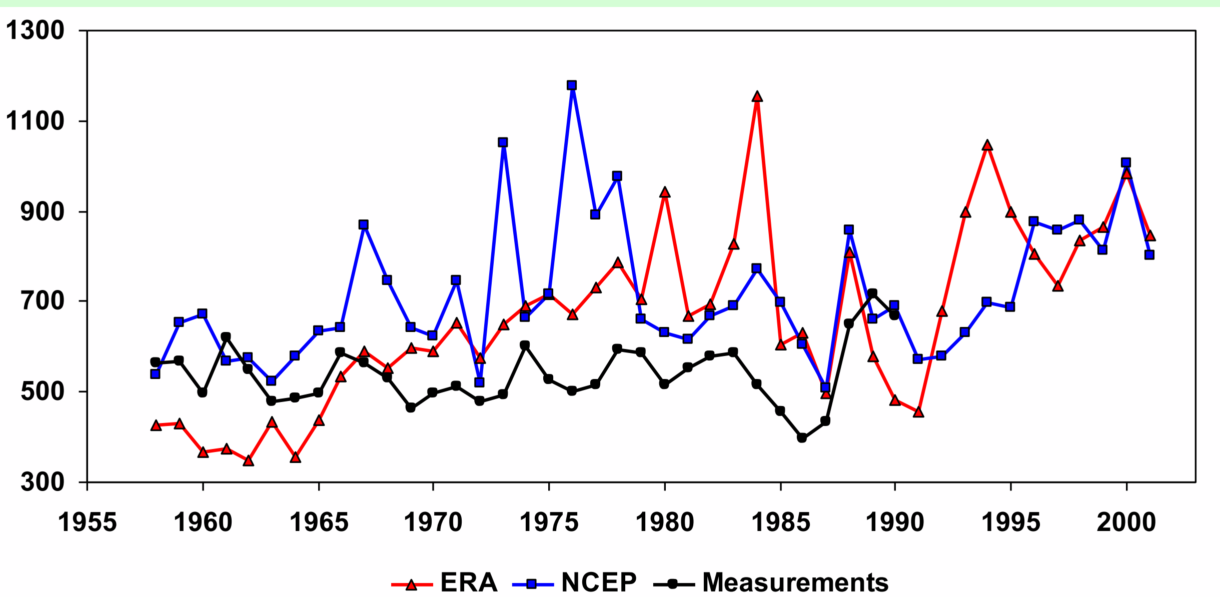
Climatic runoff from the measurements on the Lena – Kusur hydrometeostation 1936 – 1990 (black).

Lena River runoff (km^3)



Annual runoff averaged for the period 1958-2001





Annual runoff for the period 1958-2001

River	Ob		Yenisei		Lena	
Reanalysis	**NCEP**	**ERA**	**NCEP**	**ERA**	**NCEP**	**ERA**
Phase of max	**0**	**0**	**+1 month**	**0**	**+2 months**	**+1 month**
Max amplitude	**-5%**	**+12%**	**-25%**	**-22%**	**-4%**	**-12%**
Total runoff	**+15%**	**+1%**	**+29%**	**+27%**	**+37%**	**+27%**
Correlation Of runoff	Ob		Yenisei		Lena	
NCEP-DATA.	**0,88**		**0,61**		**0,62**	
ERA-DATA.	**0,87**		**0,77**		**0,66**	

Conclusions

- The role of the Siberian rivers in the global hydrological cycle is very important because of the essential fresh water input through the Arctic ocean to the World ocean what control the meridional thermohaline circulation.
- The interannual variability of the main Siberian rivers may play a significant influence to the fresh water balance in the Arctic ocean and to the formation of the “conveyor belt” in Atlantic.
- Linear reservoir hydrological discharge model is constructed to simulate the runoff from the Siberian rivers on the basis of the reanalysis data.
- The use of the NCEP/NCAR and ERA40 reanalysis data gives the main Siberian rivers annual climatic runoff compatible with the direct measurement on the stations for Ob, Yenisei, Lena rivers. The annual hydrographs has more essential deviations in the amplitudes and phases.
- Correlation between the averaged simulated annual hydrographs and measurements are high enough for all data .
- Comparisons of the simulated annual hydrographs with measurements for the total period gives very low correlation coefficients.

Thank you for your attention!