Commission for Water Sustainability

IGU UGI

Lomonosov Moscow State University

WATER REGIME TRANSFORMATION UNDER THE INFLUENCE OF CHANGING CLIMATE ON THE EUROPEAN PART OF RUSSIA

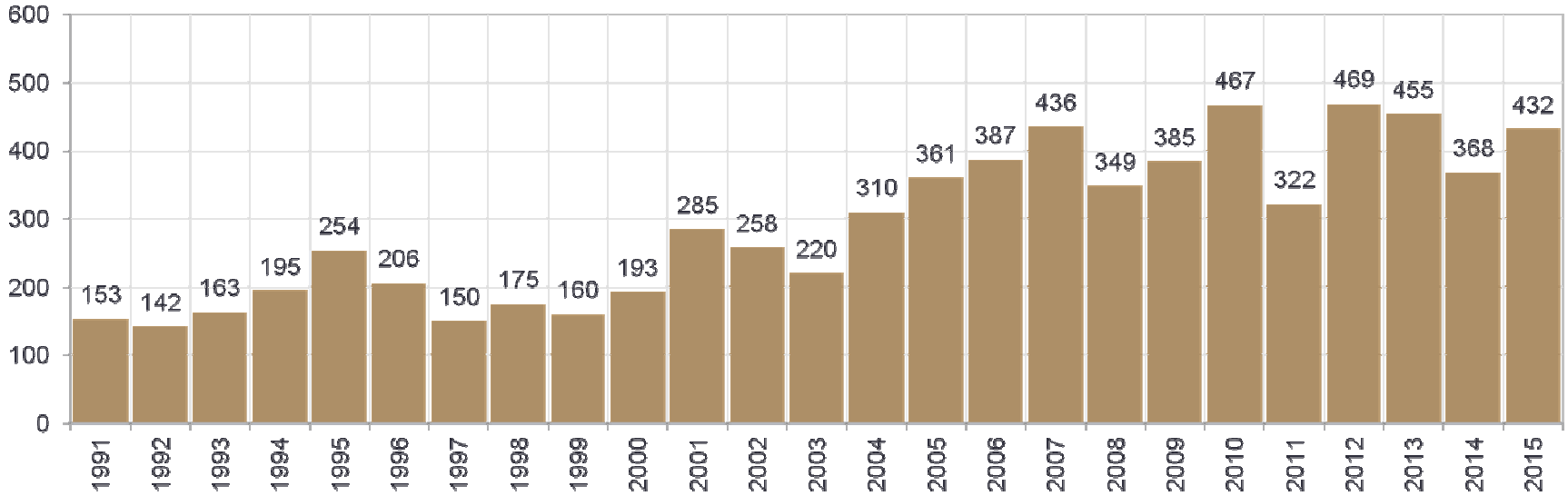
IGU WSC meeting – Istomino, Buryatia| Baikal 14-20 august 2017

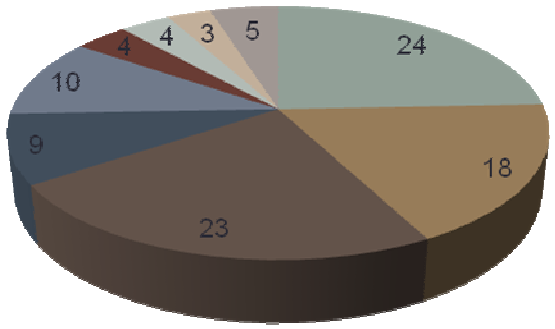
By: Maria Kireeva, Natalia Frolova
Ekaterina Rets, Ekaterina Telegina,
Vadim Grigoriev and Dmitriy Magritskiy

Problem statement

Floods	Ice-break phenomena	Extreme Low flow	Bad water quality	Extreme river bad transformation

Number of dangerous hydro meteorological events in Russia according to ROSHYDROMET-WDC





- Wind, Tornado
- Snow,
- Rain, Hail
- Heat wave
- Floods
- Avalanche
- Drought
- Wildfire
- Others

Motivation

Changes in river runoff are needed to bee identify by components and seasons to understand mechanisms and main drivers

Main questions:

1) How the runoff redistributed within the hydrological year?

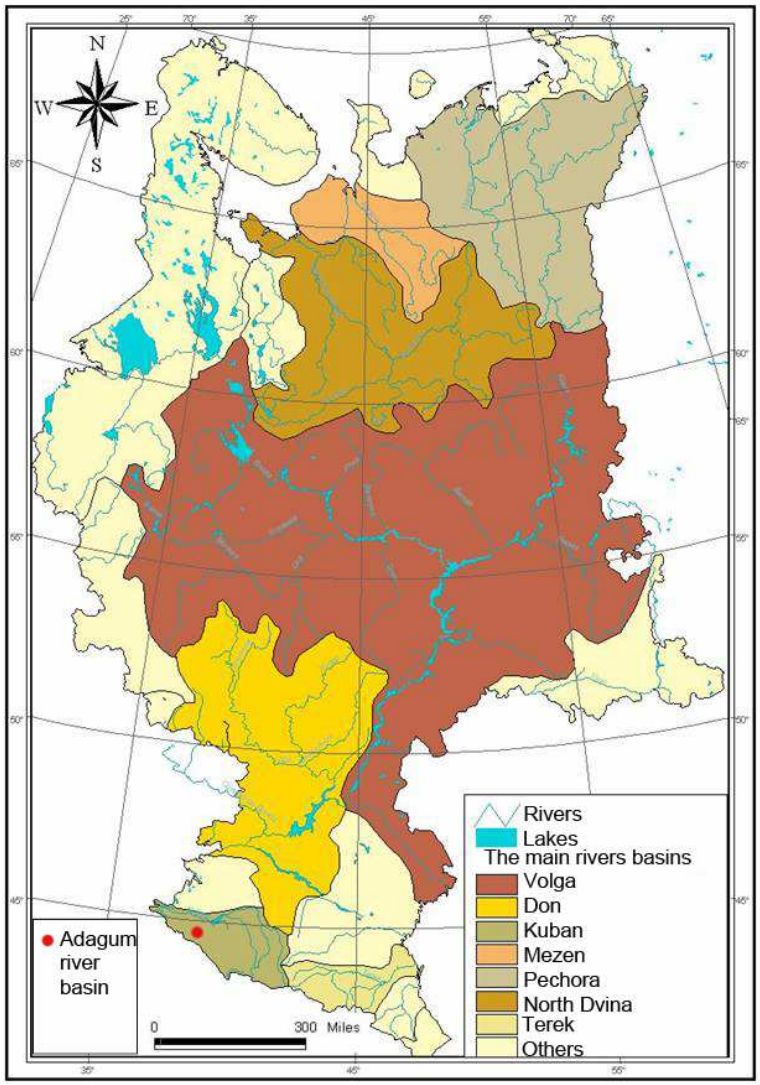
2) What is the main reason for water loss increase during spring?

3) Does the transformation of seasonal flood wave compensates by low flow period ?

4) What are the main drivers of the water regime transformation during last 35 years?

State-of-the Art: seasonal flood wave transformation

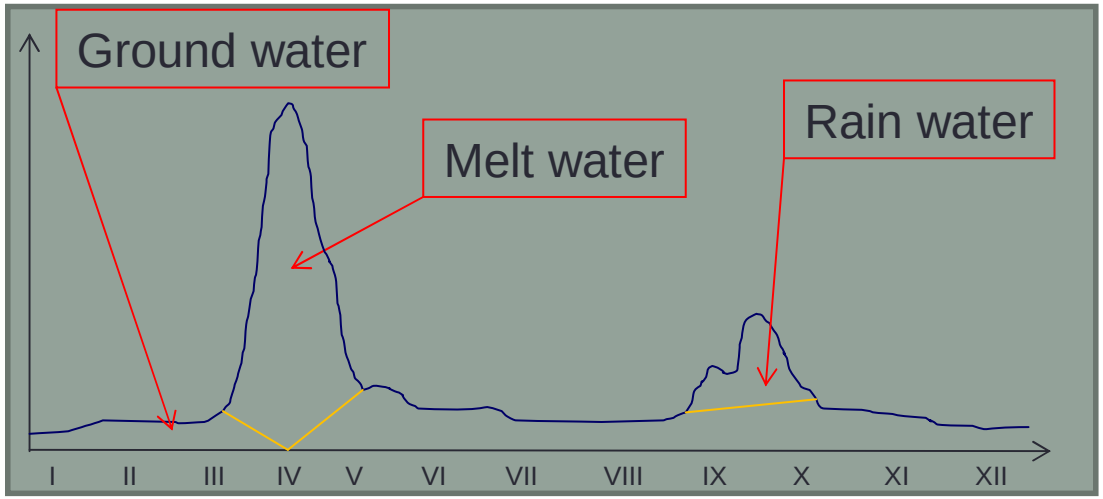
STADY AREA:



1. Volga river basin F=1360000 km²
2. Don river basin F=422000 km²
3. N.Dvina river basin F=357000 km²
4. Pechora river basin F=322000 km²
5. Neva river basin F=281000km²
6. Kuban river basin F=58000 km²
7. Terek river basin F=43000 km²

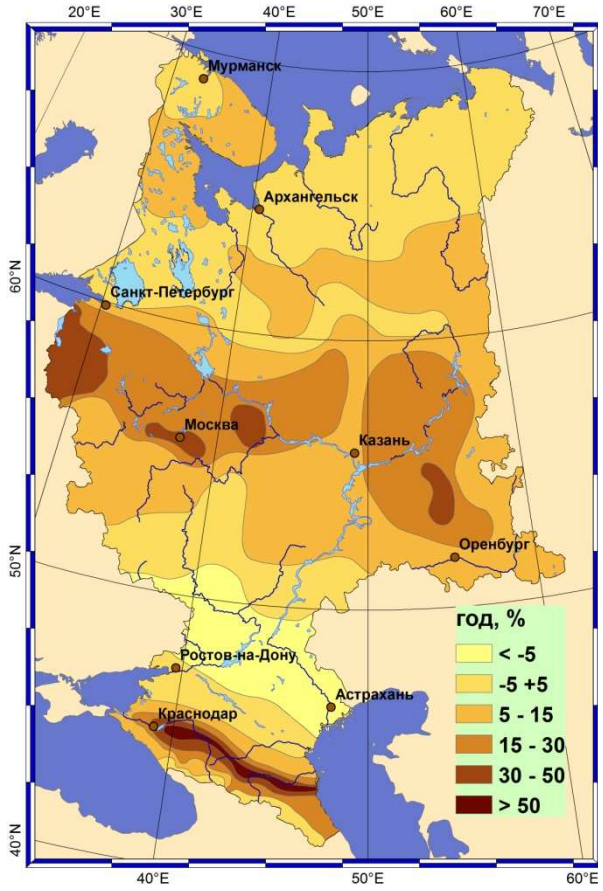
More then 300 hydrological gauging stations in total for 1880-2011

East-European type of water regime and hydrograph separation according to Kudelin (1973)

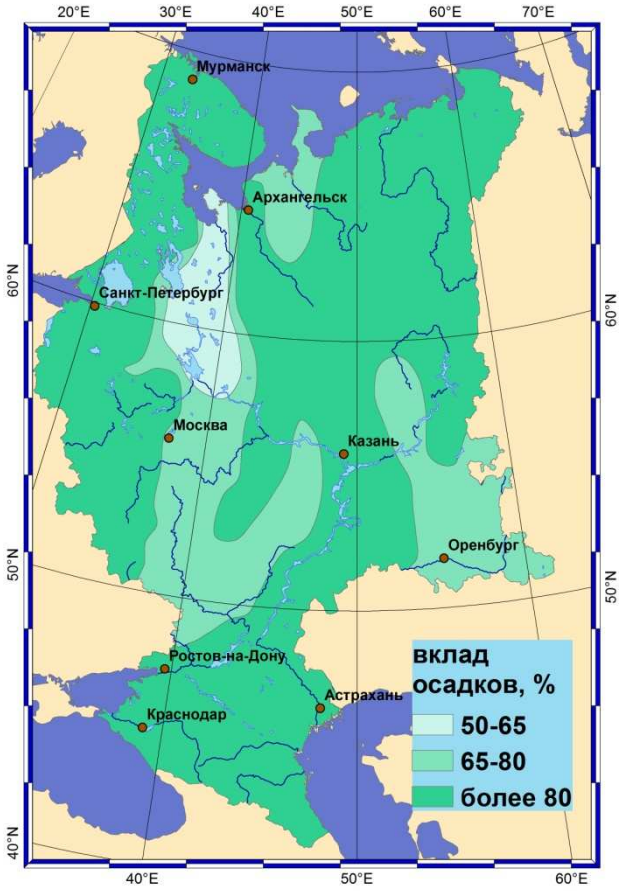


- Well-pronounced seasonal flood wave (> 50 % of runoff)
- Stable summer-autumn low flow period
- Autumn occasional flood period

Changes in annual flow and contribution of the precipitation to it



Annual flow changes 1978-2010 VS 1945-1977



Contribution of the precipitation in annual flow changes

$$R=P\cdot\exp(-PET/P)$$

$$dR/dP=(1+1/P)\cdot\exp(-PET/P)$$

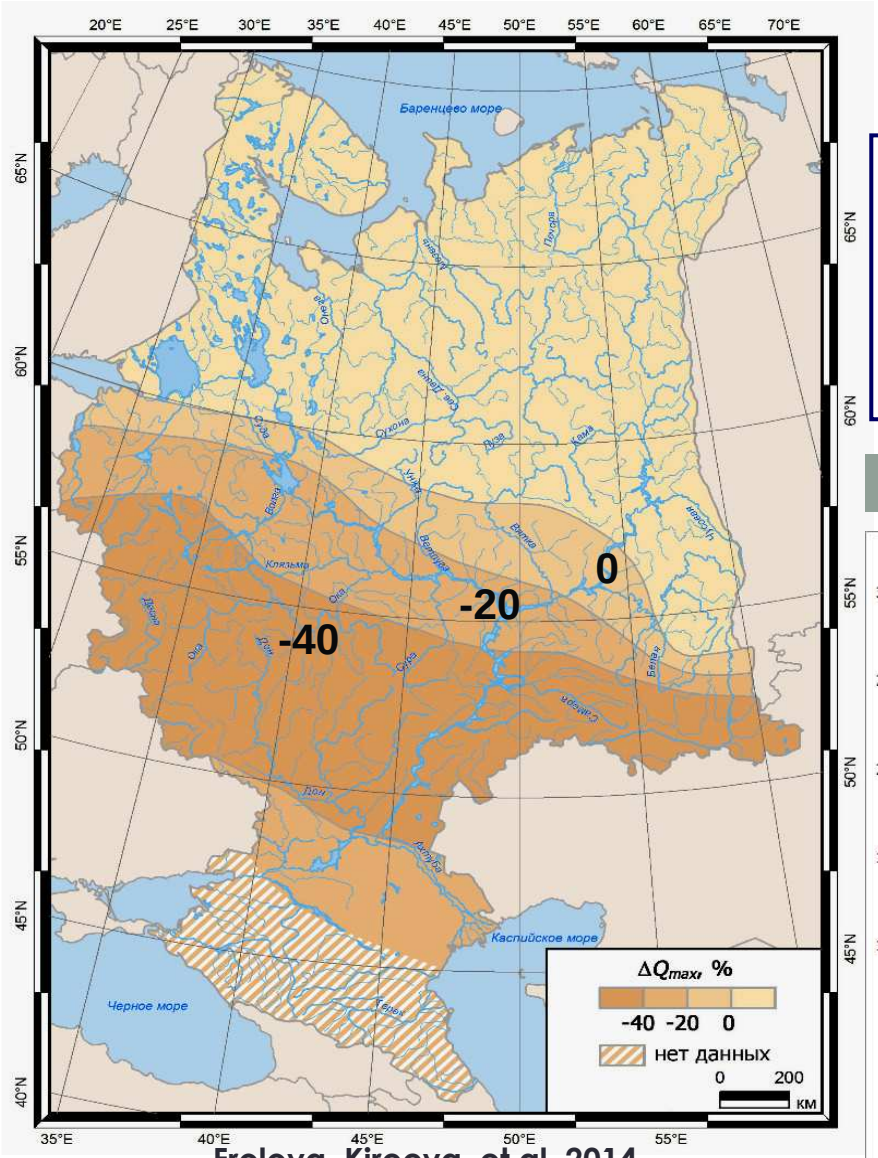
$$\Delta R_P \approx \Delta P \cdot dR/dP$$

$$dR/dPET=-\exp(-PET/P)$$

$$\Delta R_{PET} \approx \Delta PET \cdot dR/dPET$$

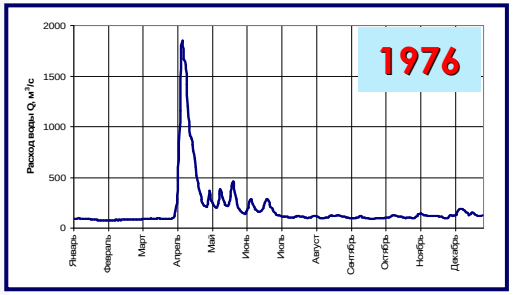
$$\text{Contribution P} = \frac{|\Delta R_P|*100\%}{(|\Delta R_P|+|\Delta R_{PET}|)}$$

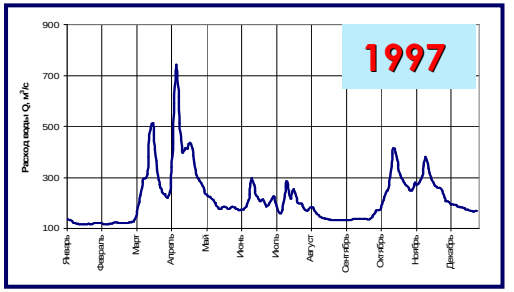
Seasonal flood wave transformation



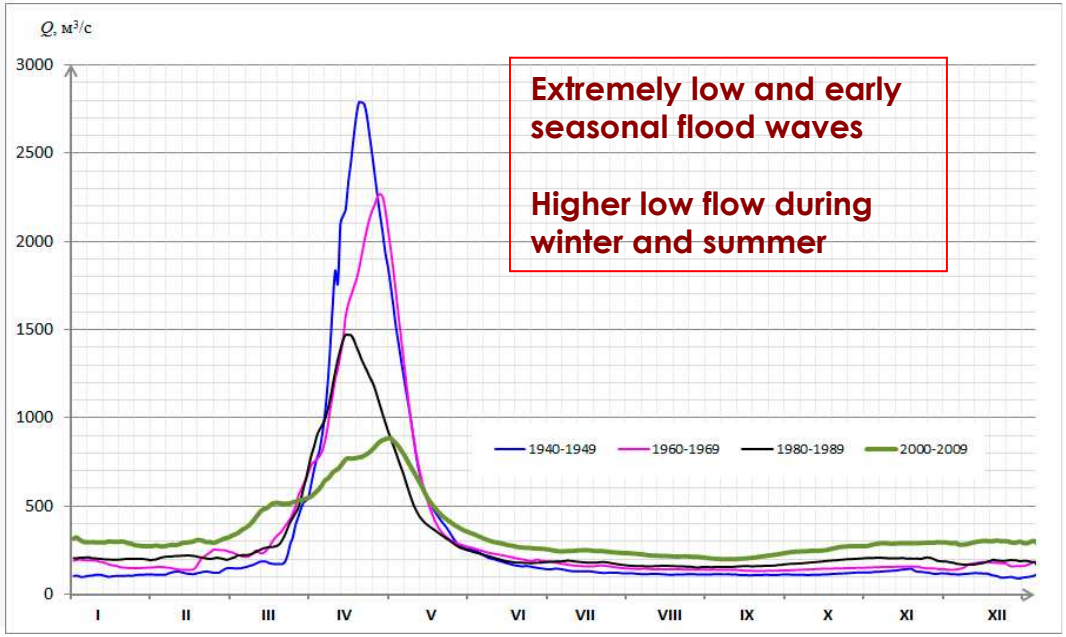
Frolova, Kireeva, et al, 2014

Typical hydrographs for Oka river



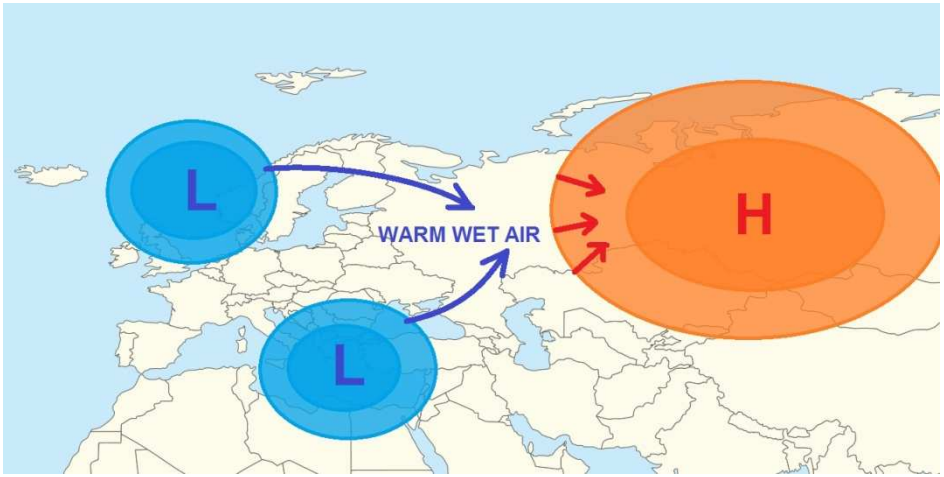


Averaged annual hydrographs for river Don – Kazanskaya

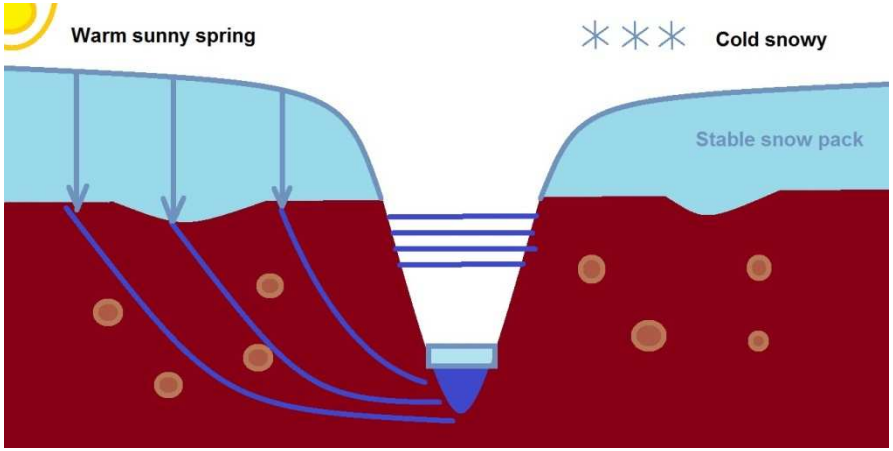


Assumed mechanisms

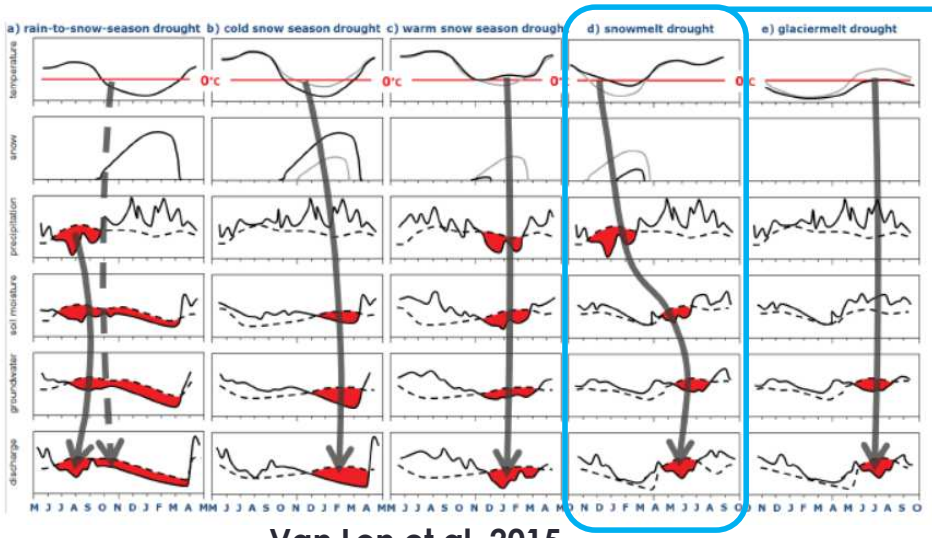
Atmospheric circulation above the European part of Russia in winter



previous period

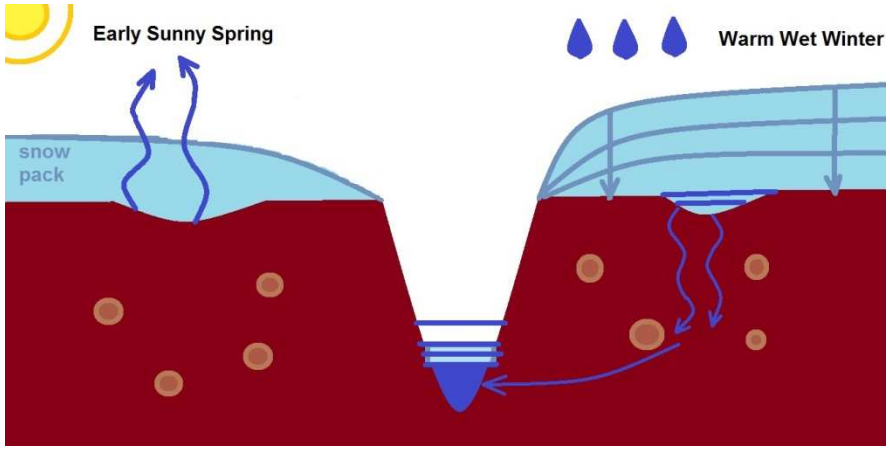


Synthetic time-series according to different hydrological Drought type



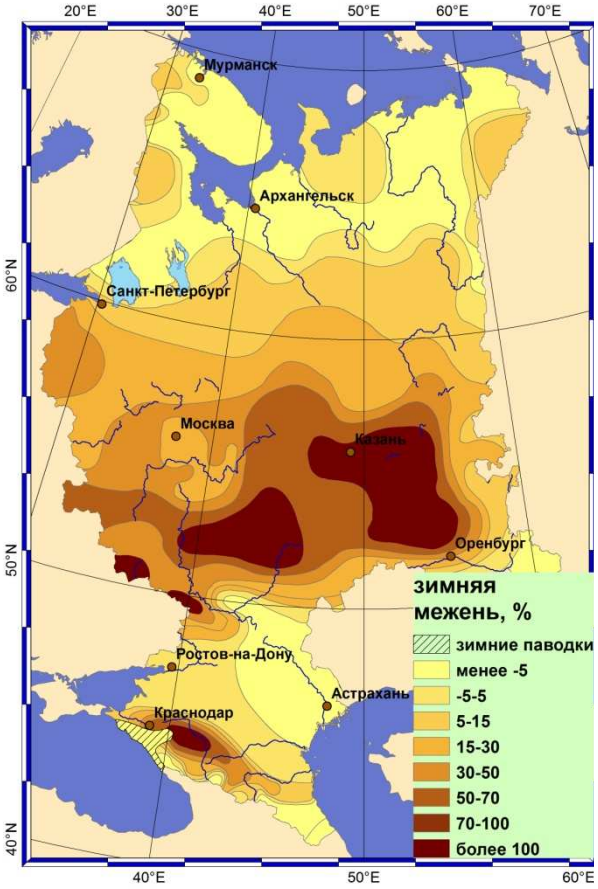
Van Lon et al, 2015

recient period

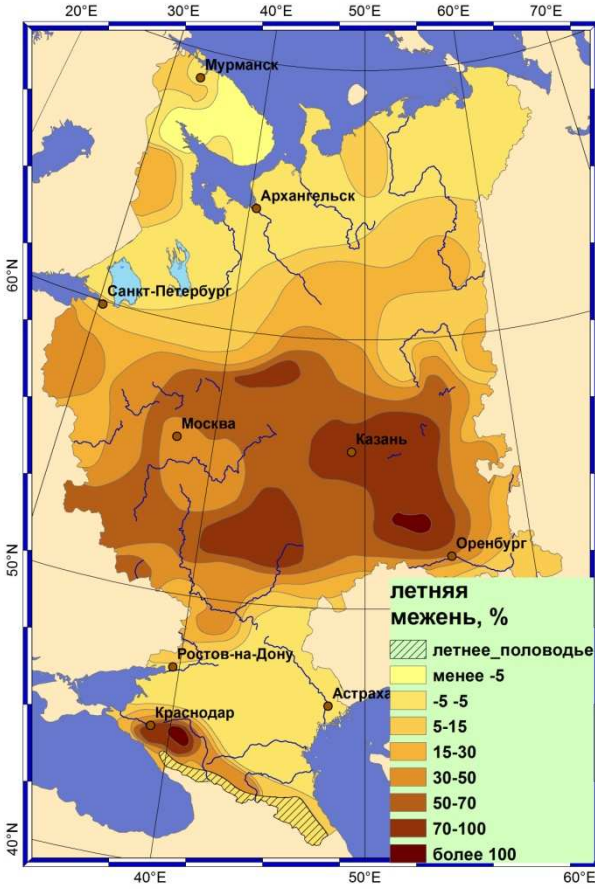


Frolova et al, 2016

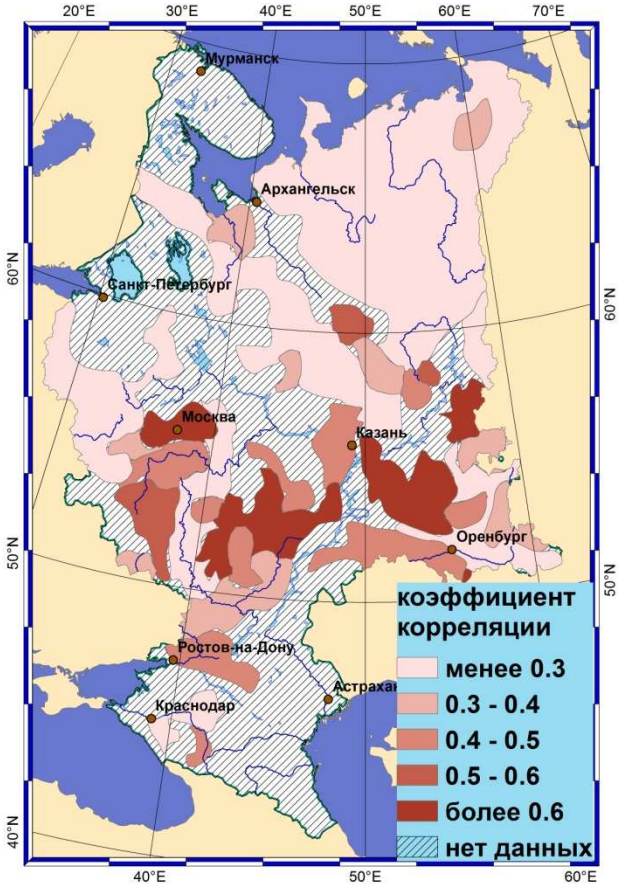
Changes in low flow and it's reasons



Changes in winter low flow

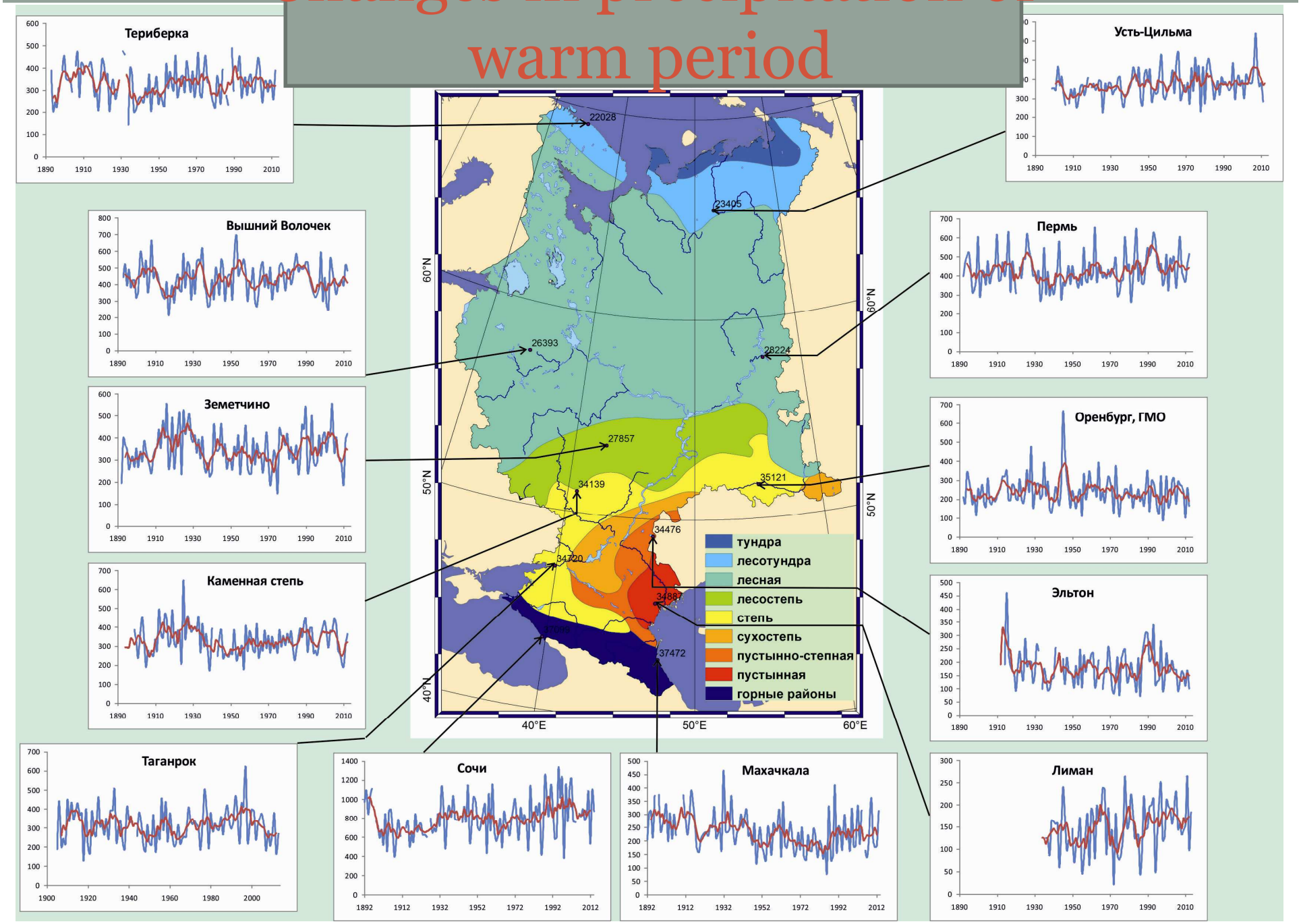


Changes in summer low flow

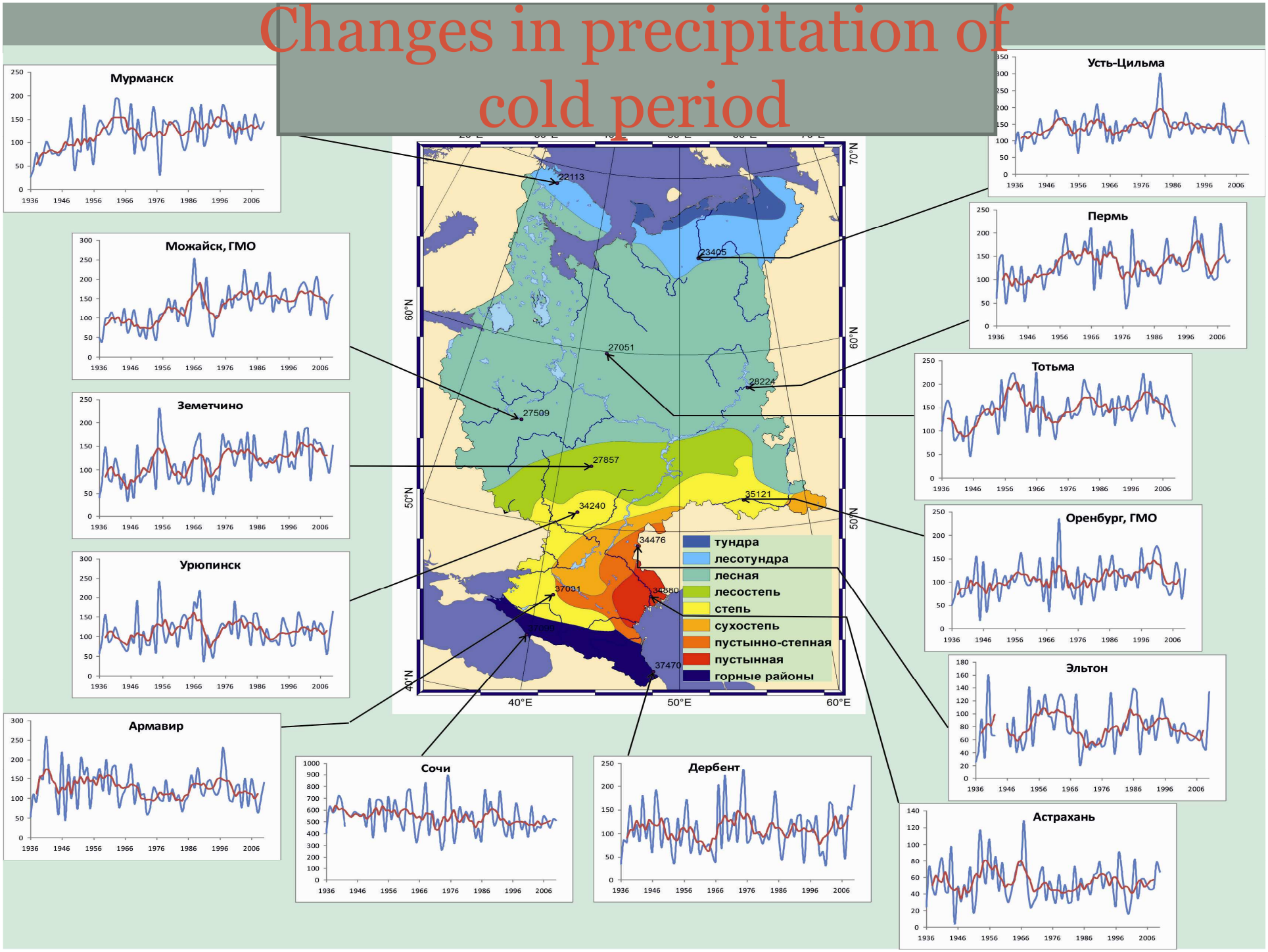


Correlation between winter and summer

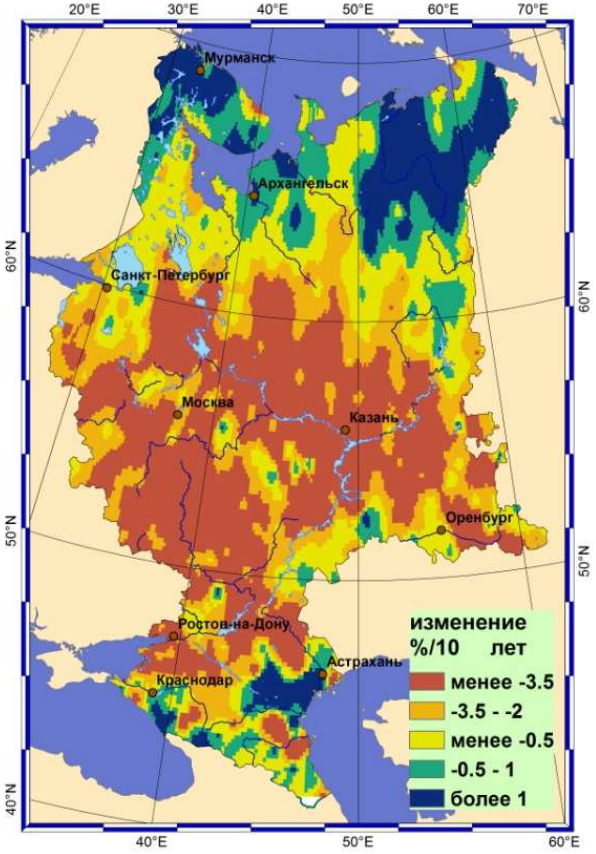
Changes in precipitation of warm period

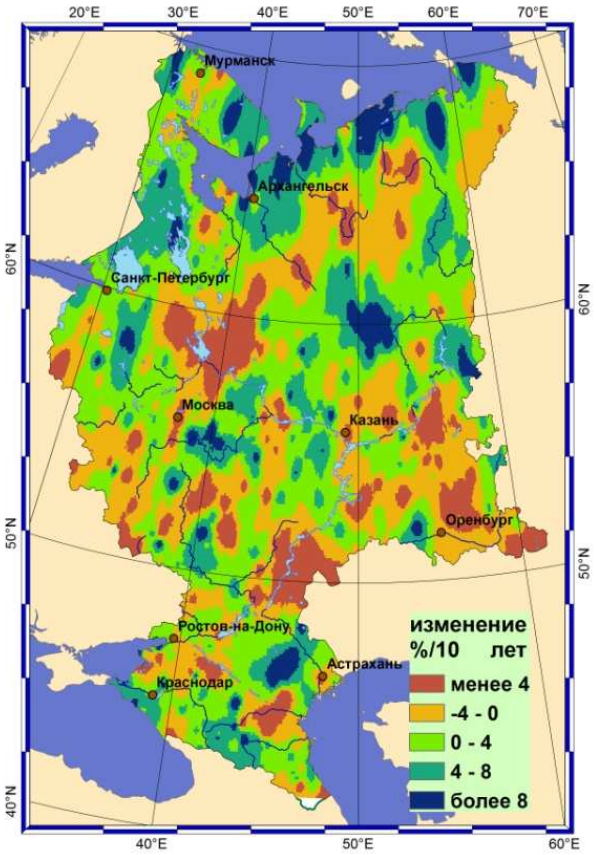


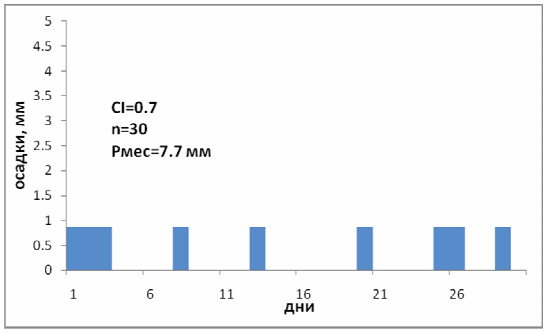
Changes in precipitation of cold period

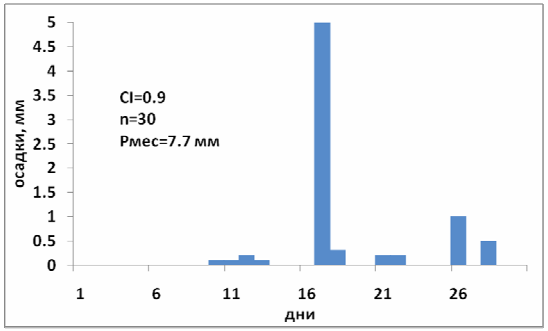


Changes in intensity and precipitation type





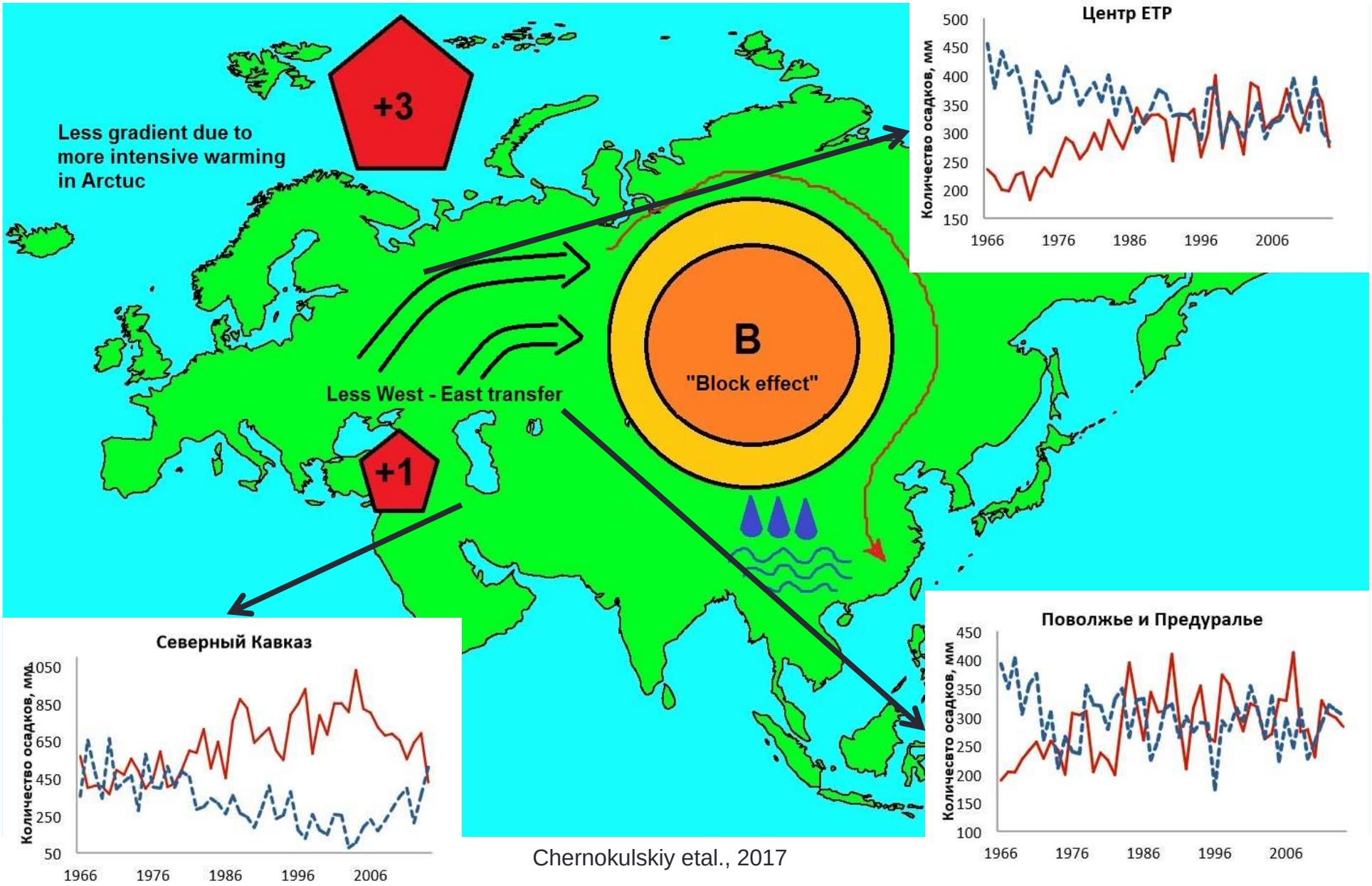




Changes in number of the day with precipitation (summer)

Changes in maximum daily precipitation (summer)

Changes in intensity and precipitation type



Chernokulskiy etal., 2017

Changes in evaporation capacity (PET)

$$PET = 0{,}0009384 \cdot H_0 \cdot (Tmean + 17.8) \cdot (Tmax - Tmin)^{0.5}$$

1976 – 2014

Radiation

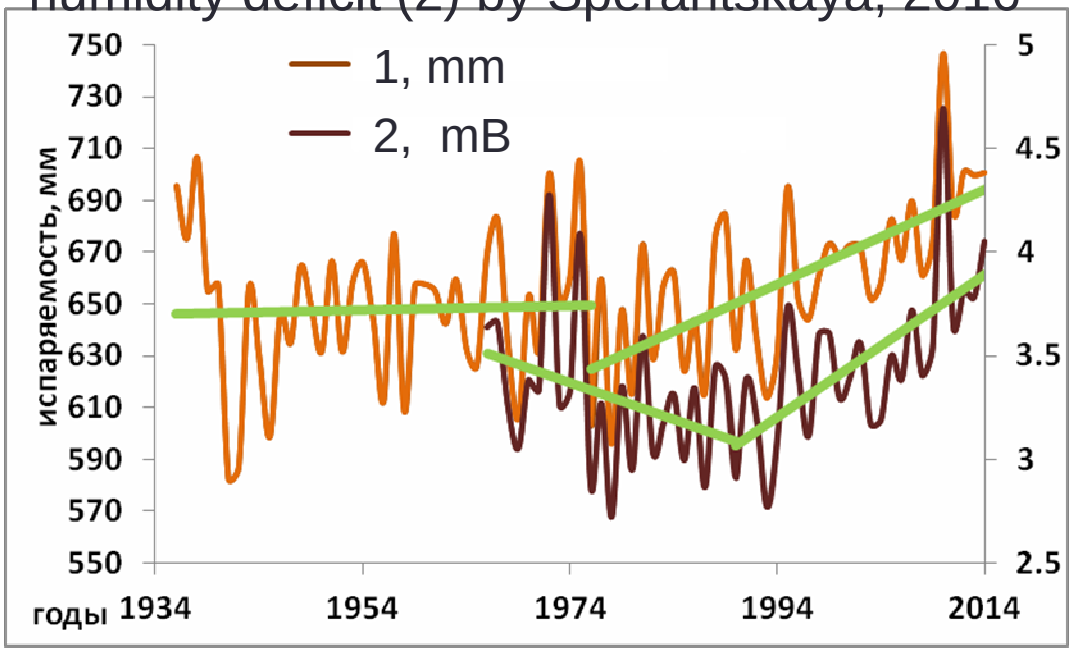
Daily max T

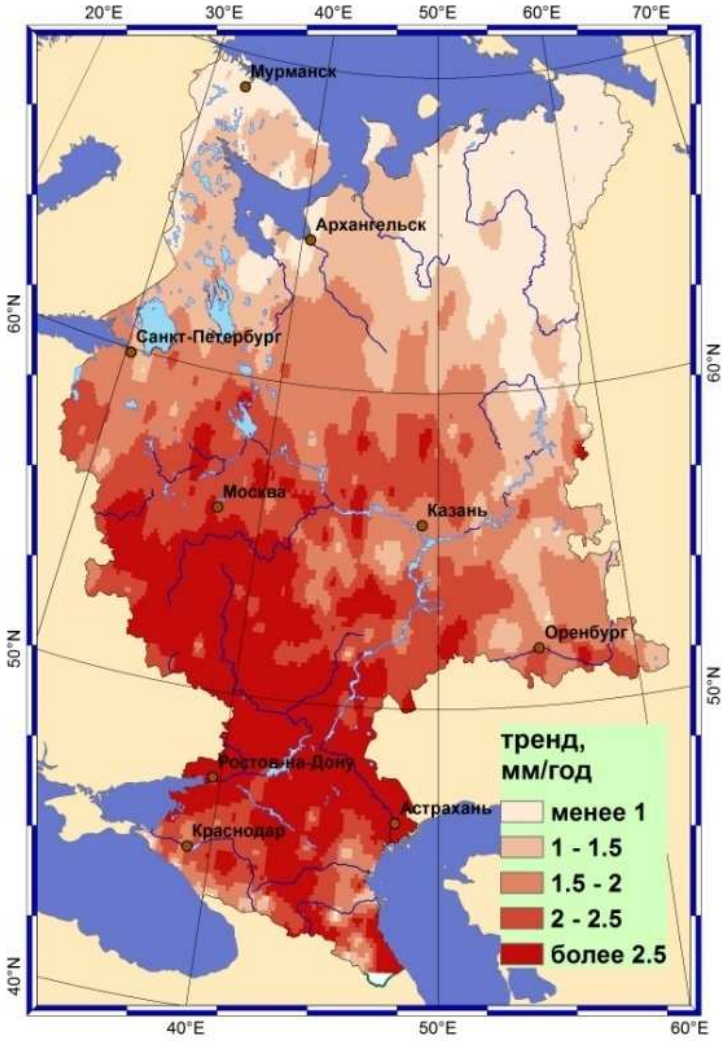
Daily mean T

Daily min T

Hargreaves and Samani (1982,1985), J. Almorox (2015)

Observed evaporation capacity (1) and humidity deficit (2) by Sperantskaya, 2016





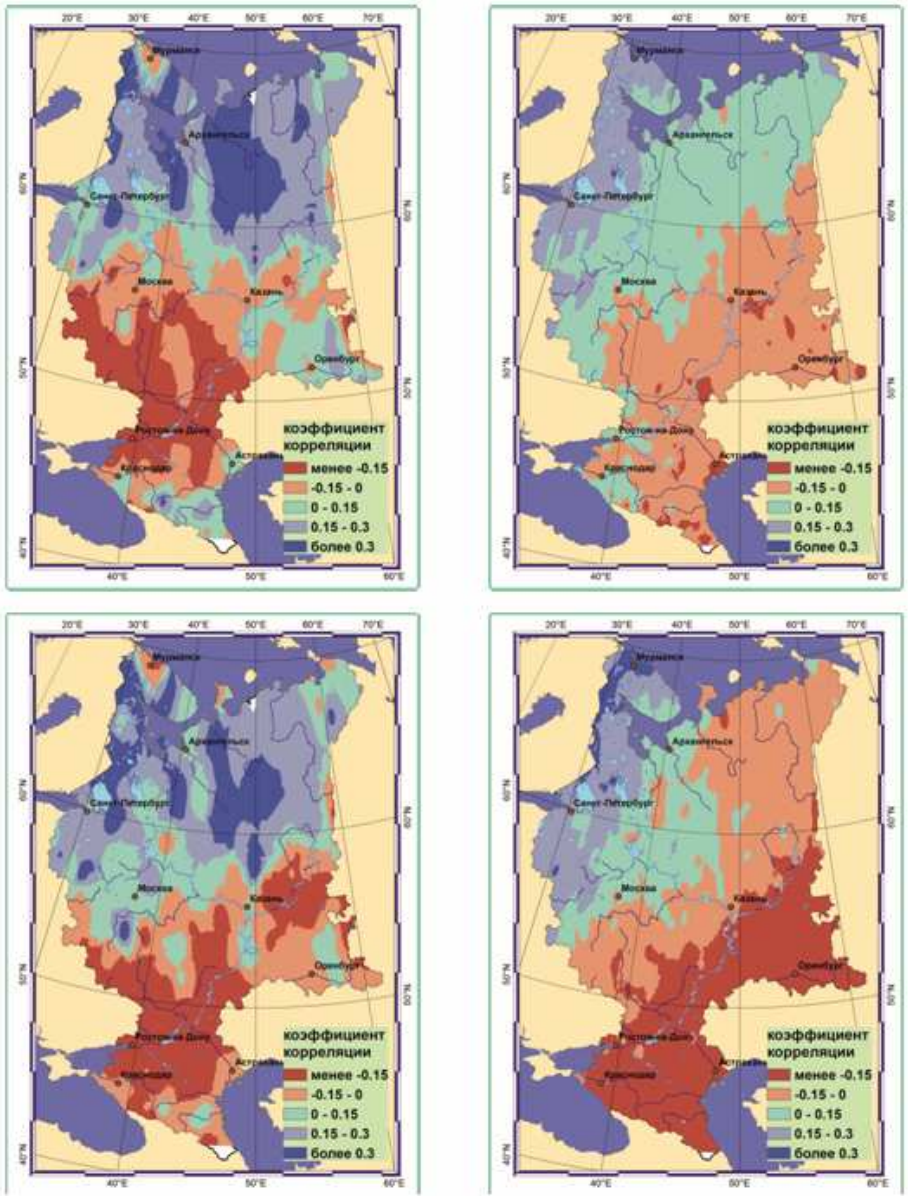
Winter P and PET correlation with NOA and AO

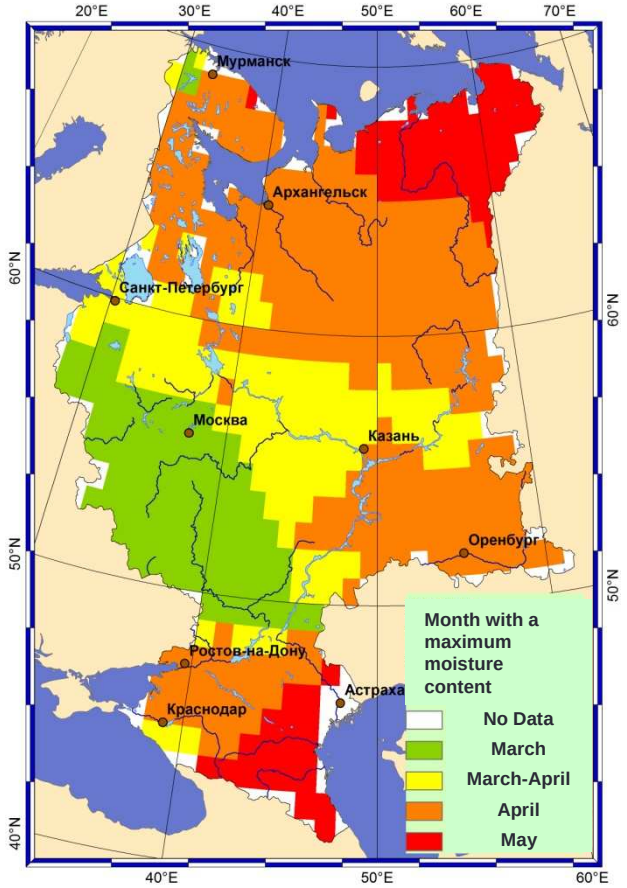
Winter P

PET

NAO

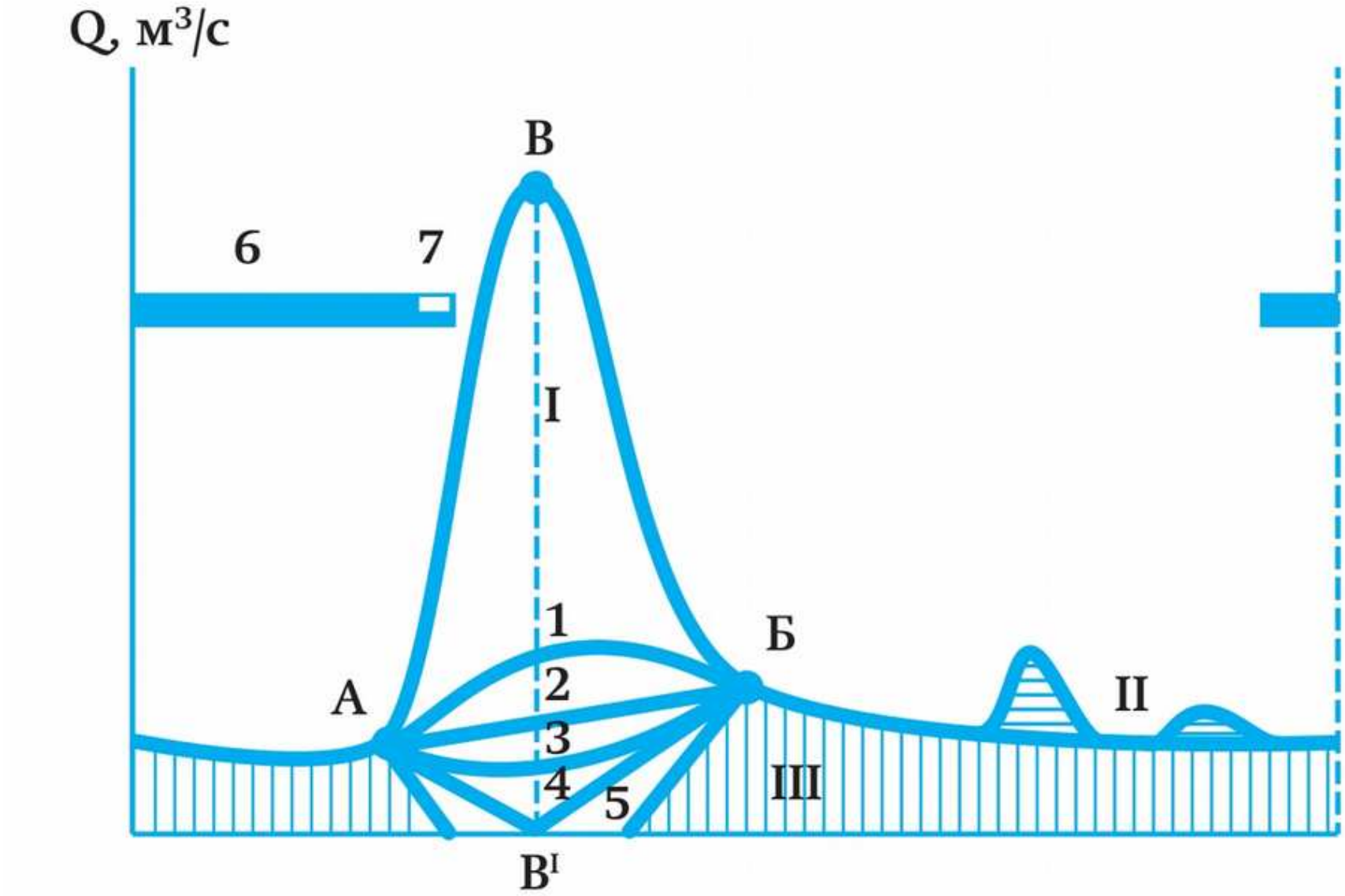
AO





Month with maximum moisture content

Hydrograph separation: Kudelin's scheme (1963)



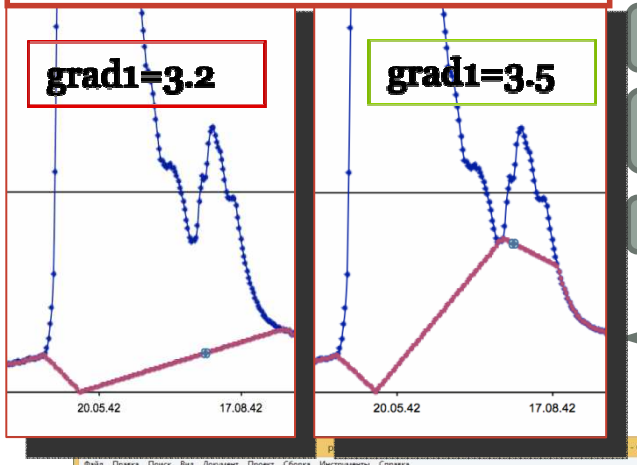
Study methods and Data: general idea

19 parameters, that are calibrated to match the hydrograph separation according to Kudelin scheme

GrWat software – algorithm for hydrograph separation based on daily data grapho-analitical and complex parallel analyses

3 Inside programs – calculating algorithms for
- Summer - autumn and winter low flow period
- Minimum low flow 5, 10, 30- days min discharge

Example of rain-flood wave separation from melt-water seasonal flood wave with different grad1 values



Input data: daily discharge. txt

19 parameters

Pre-calculation

Hydrological years separation

Seasonal flood separation

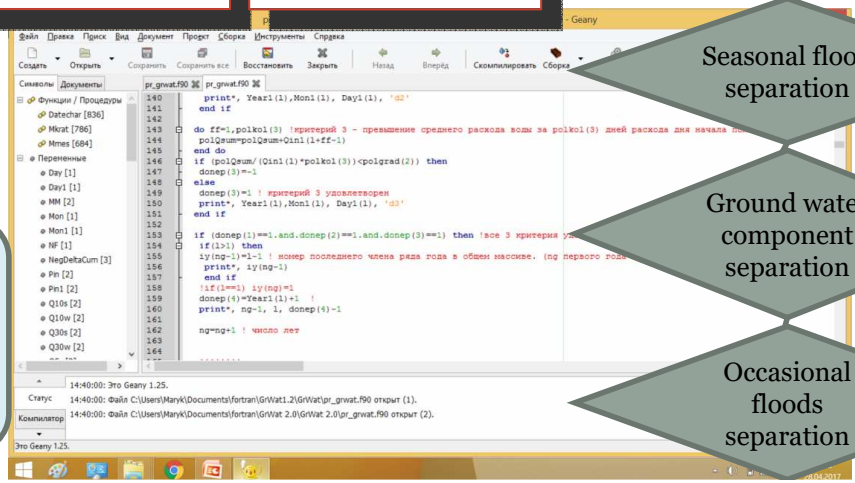
Ground water component separation

Occasional floods separation

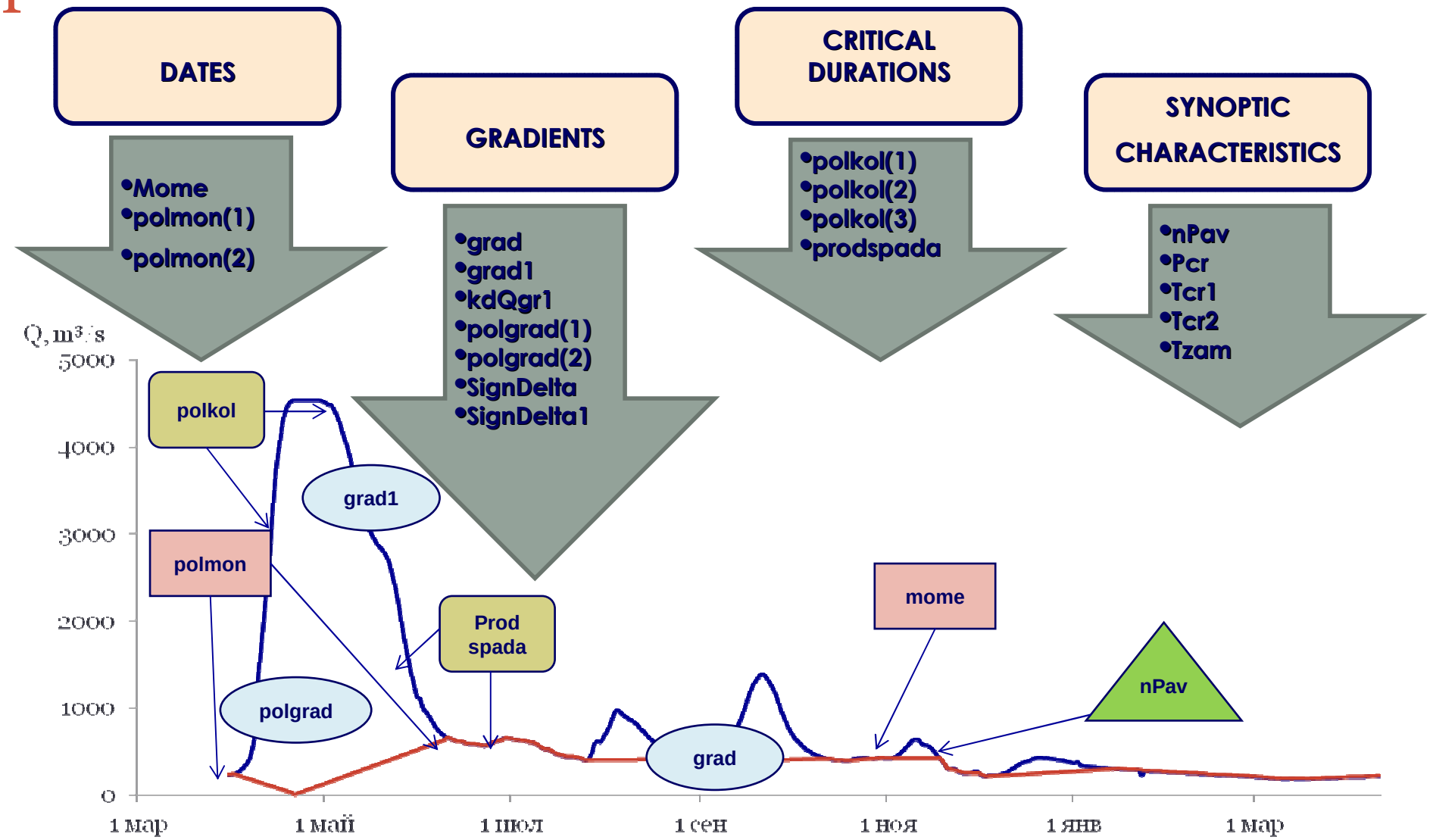
R-script block:
- input data checking,
- time-series period clarifying
- missing values replace
- virtual time-series of T, P creating

FORTRAN block:
- Identifying seasonal boarders
- Seasonal flow characteristics calculating
- Genetic types separation

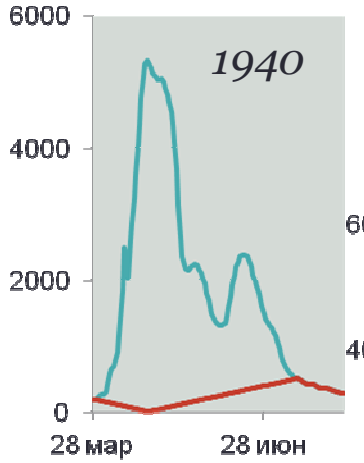
R-script block:
- Interpretation of the results
- Graph output report
- Complicated cases report

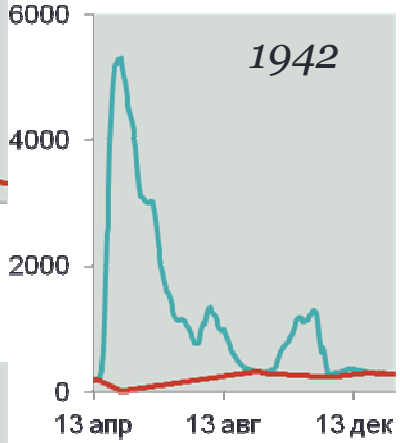


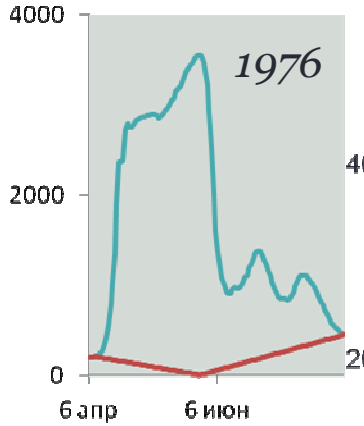
Study methods and Data: calibration parameters

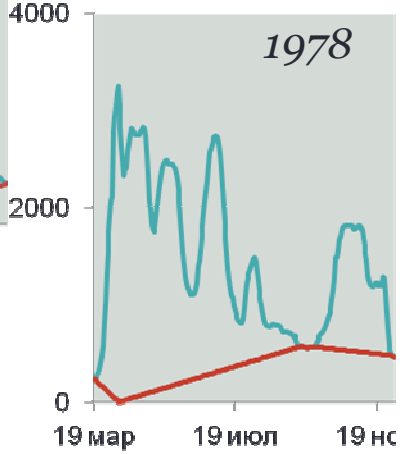


Study methods and Data: seasonal flood wave

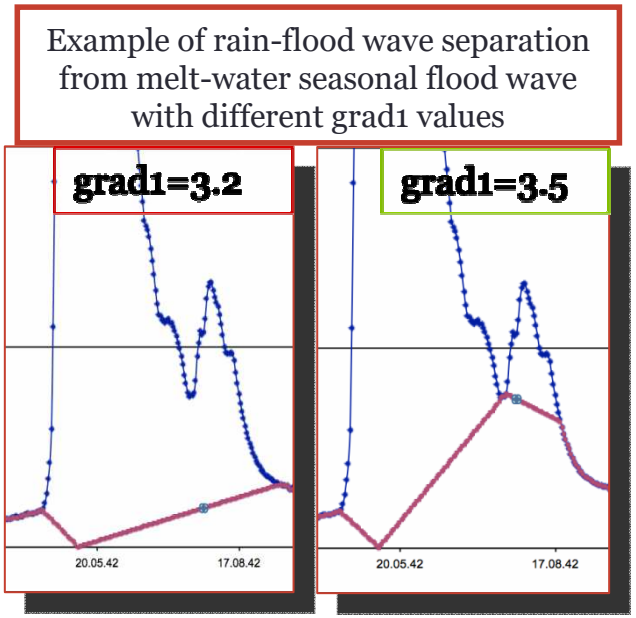




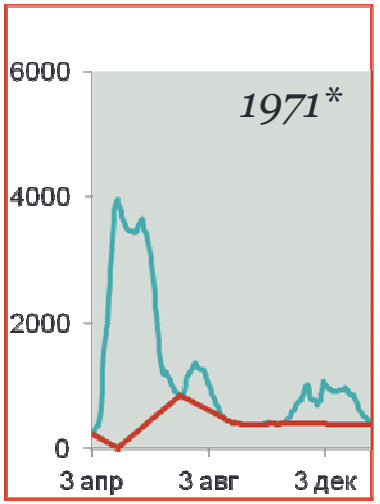


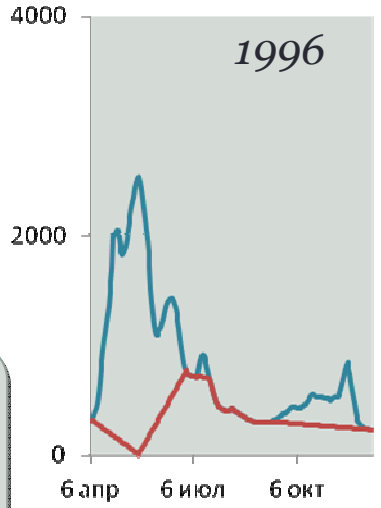


The great deal – declination phase of the seasonal flood wave

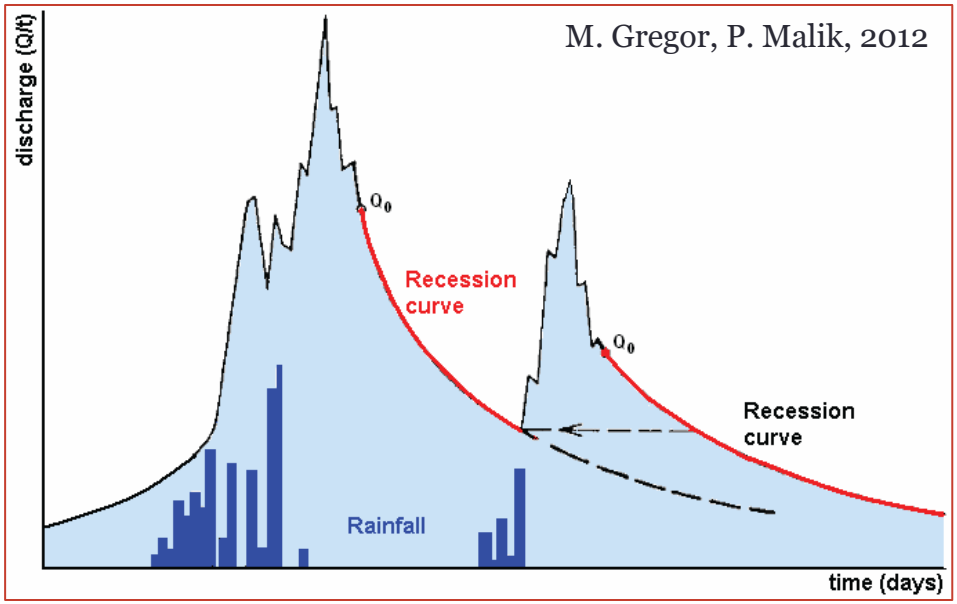


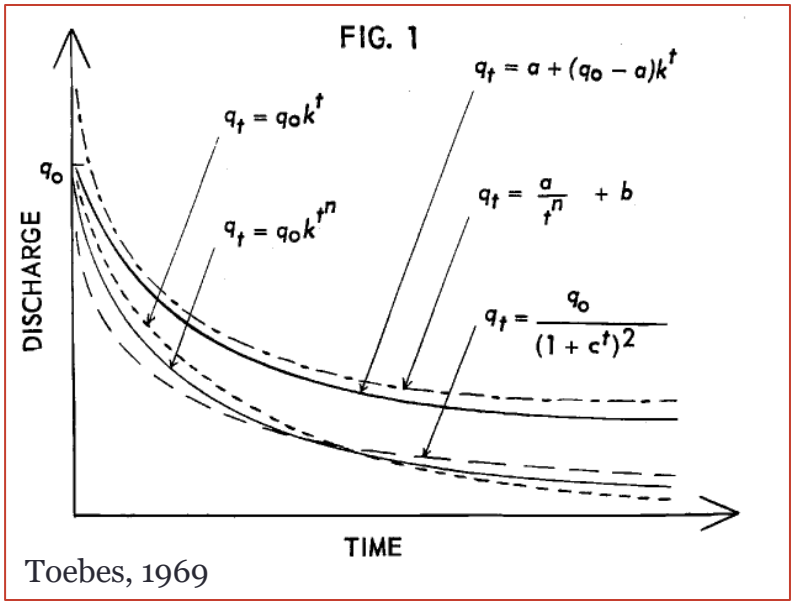
Incorrect separation with any parameters, inaccuracy ≈20 %
For Vyatka–Vyatskie Polyani: 15 from 75 years



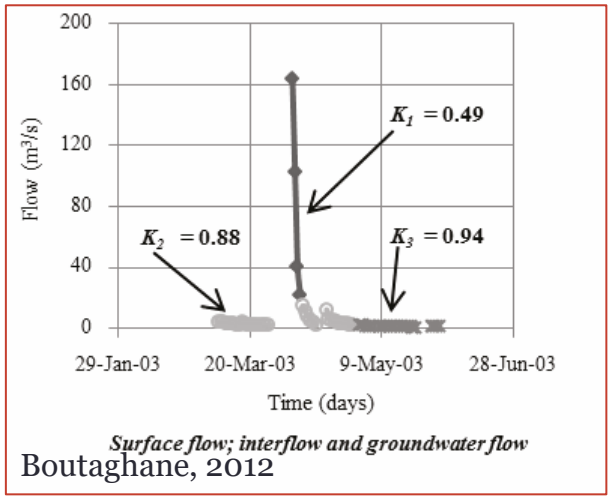


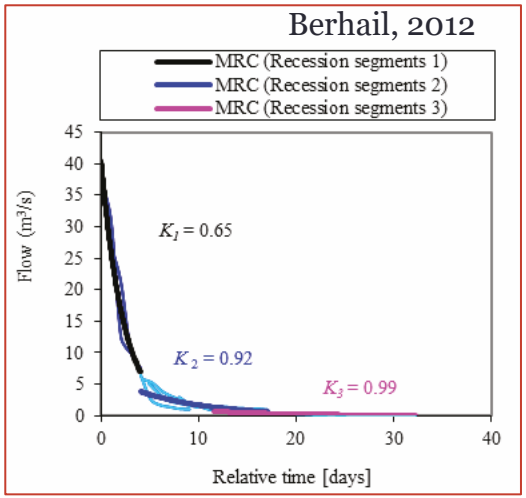
Recession curve as an instrument for occasional flood separation



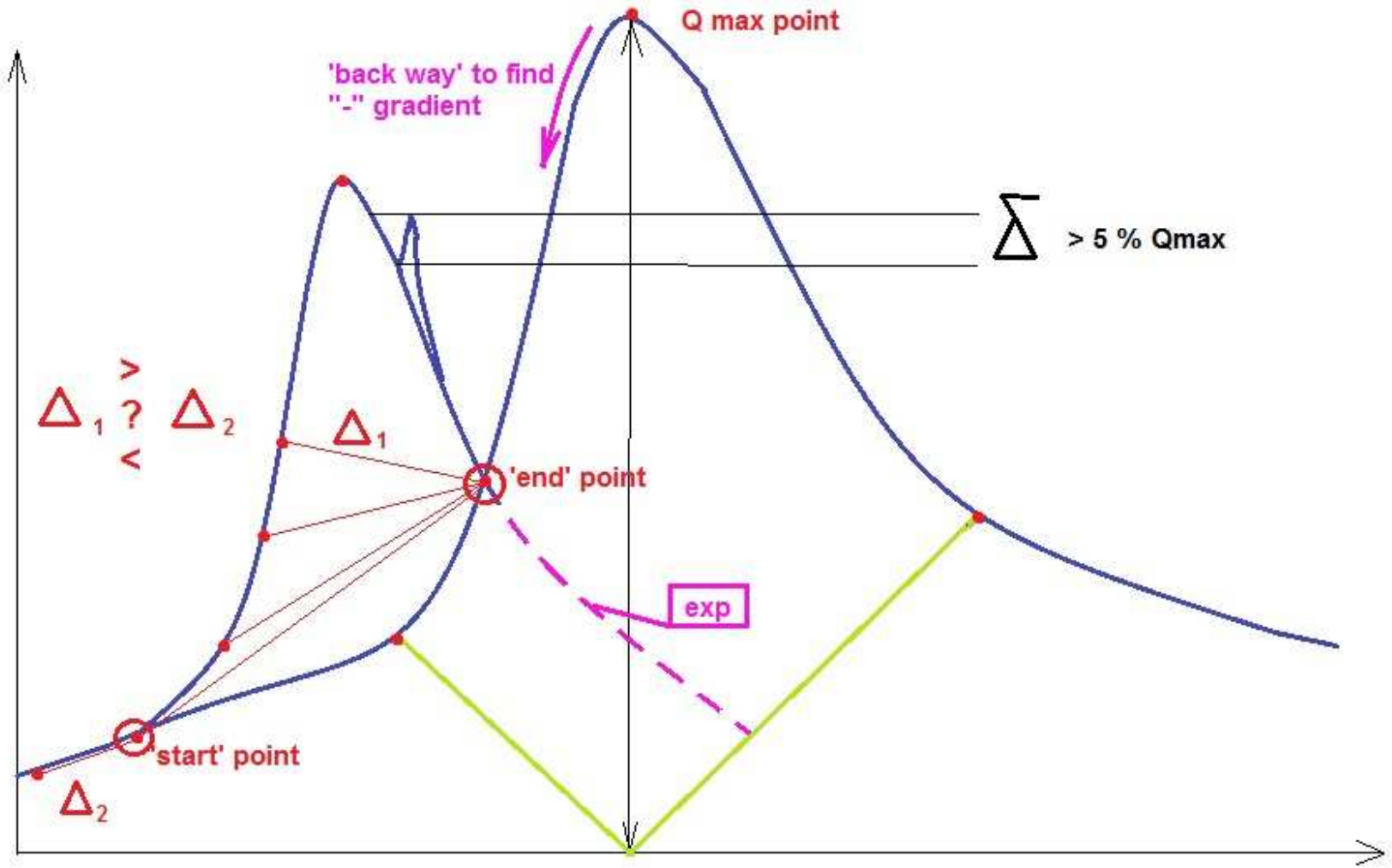


Recession curve **-**
represents decline of the basin water supply, includes river network capacity, sub-surface and ground water capacity





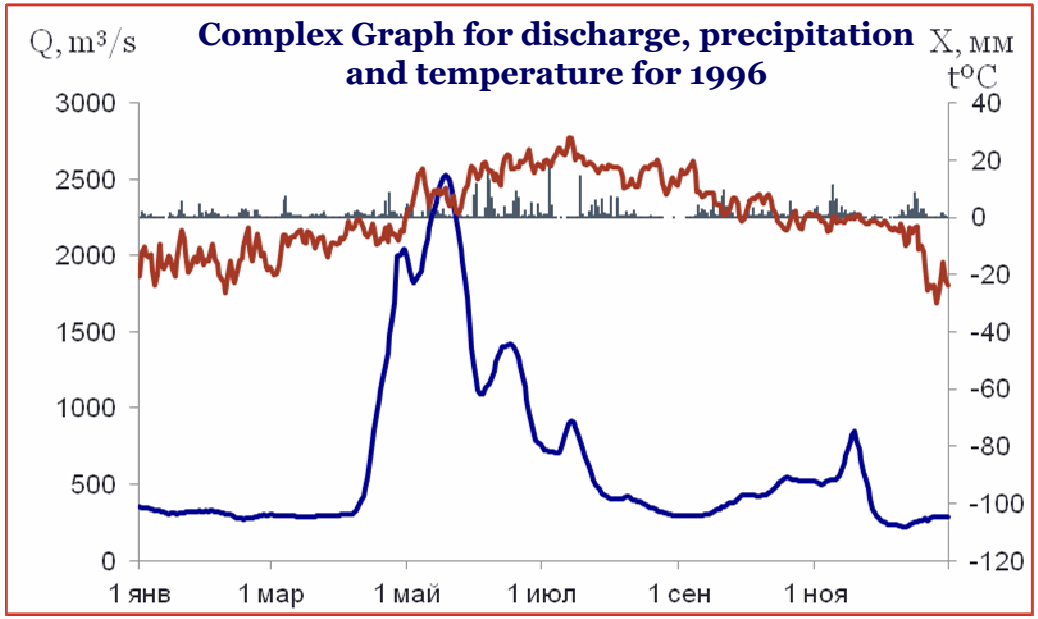
Thaws – Rain event separation

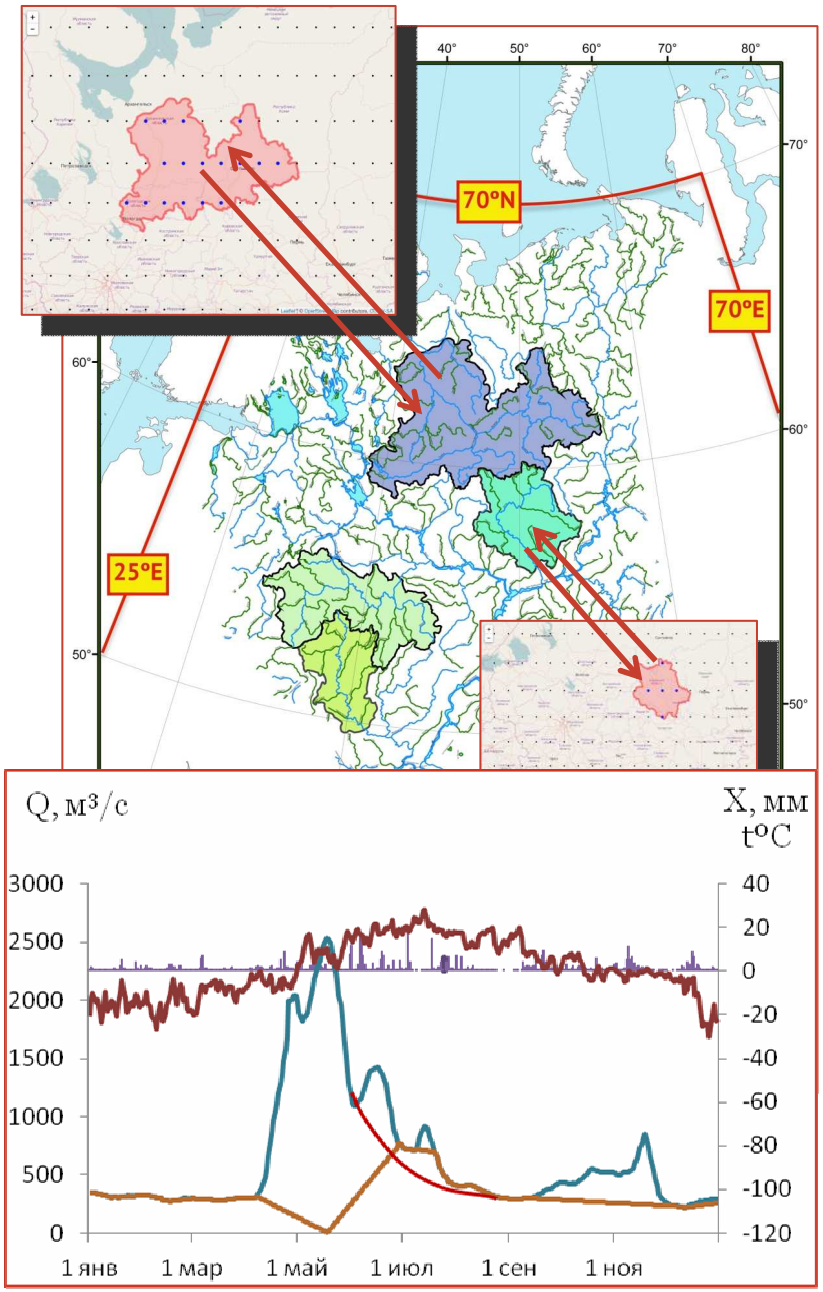


Study methods and Data

Combine Discharge data with Meteo Data

- Daily NOAA-CIRES 20th Century Reanalysis V2
- Period: 1948–2012 гг.



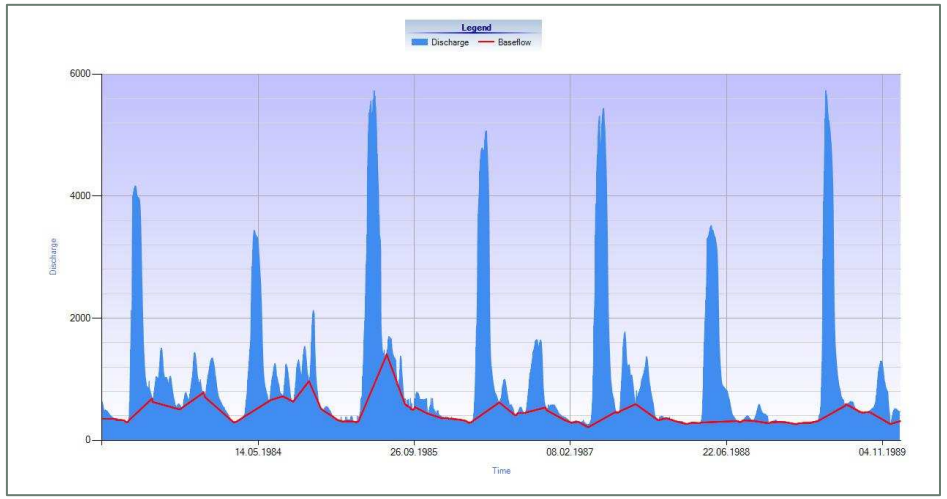


Single flood wave separation criteria $q > q_{кр}$

– $q(90\%) < q_{кр} < q(50\%)$, 10 – 50% of peaks – not significant;
– $q_{кр} < Q_{max}(95\%)$, all annual max $> q_{кр}$;
– $Q_{ср}(70\%) < q_{кр} < Q_{ср}(30\%)$, $q_{кр}$ close to $Q_{ср}$;
– $q_{кр} > q_{o}$ (5%), $q_{кр}$ is higher than local min (95% probability)

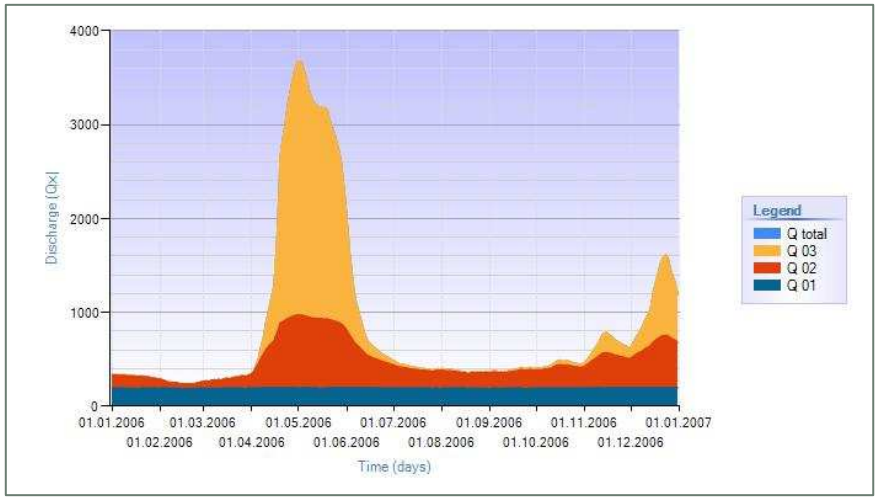
World wide practice

BFI+



Hydrograph separation in **BFI+** with Local Minimum Method

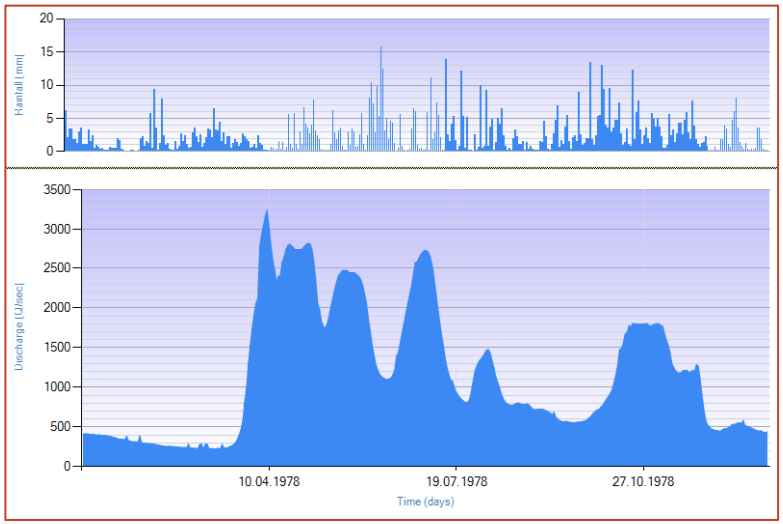
FlowComp



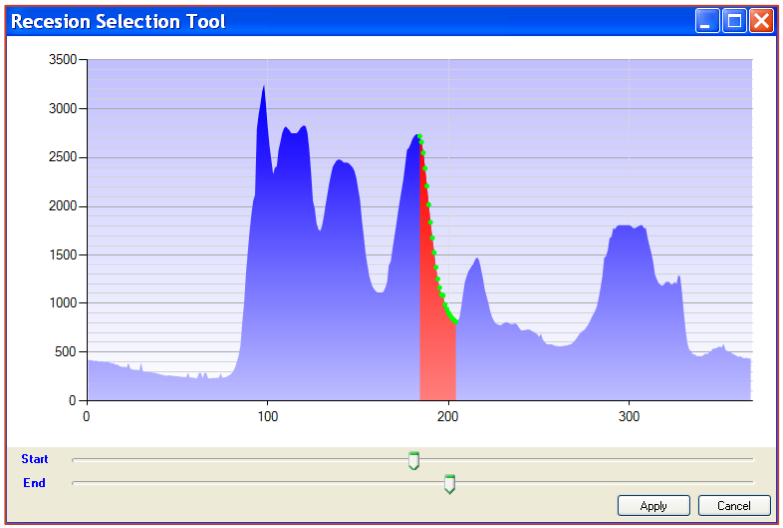
Drawn up three sub-regime (surface, sub-serface,groundwater) **FlowComp**

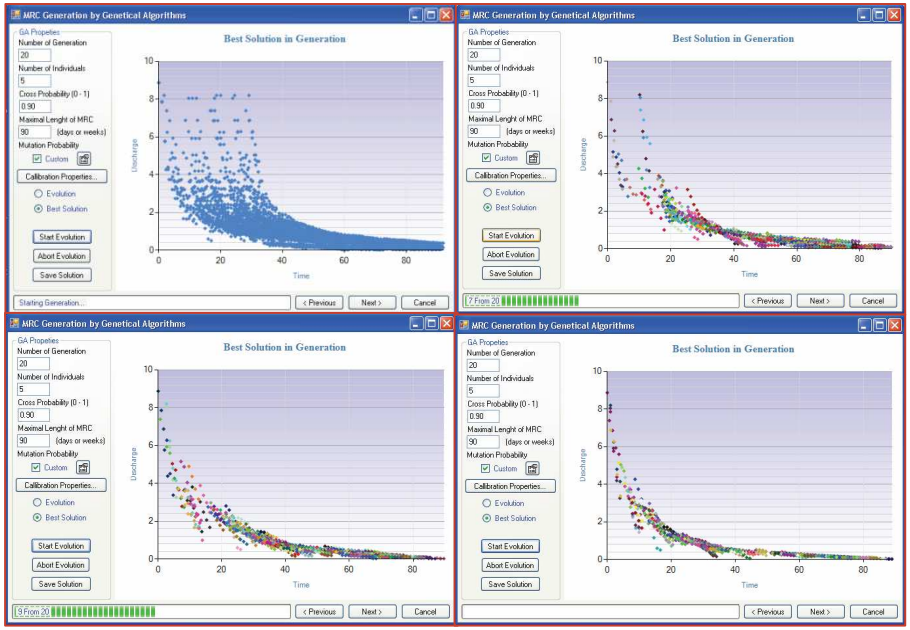
http://hydrooffice.org, (M.Gregor, 2013)

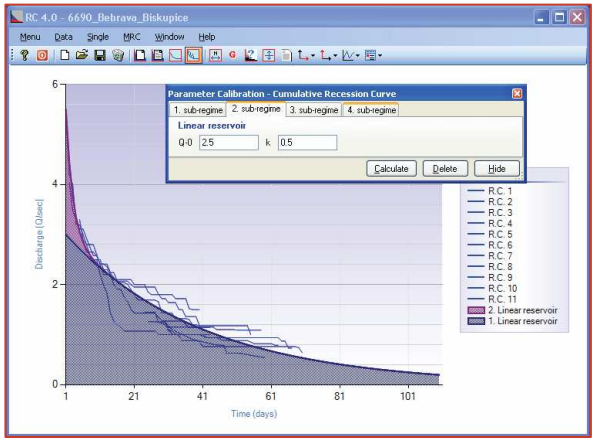
RC - software



Combined graph of discharge and precipitation



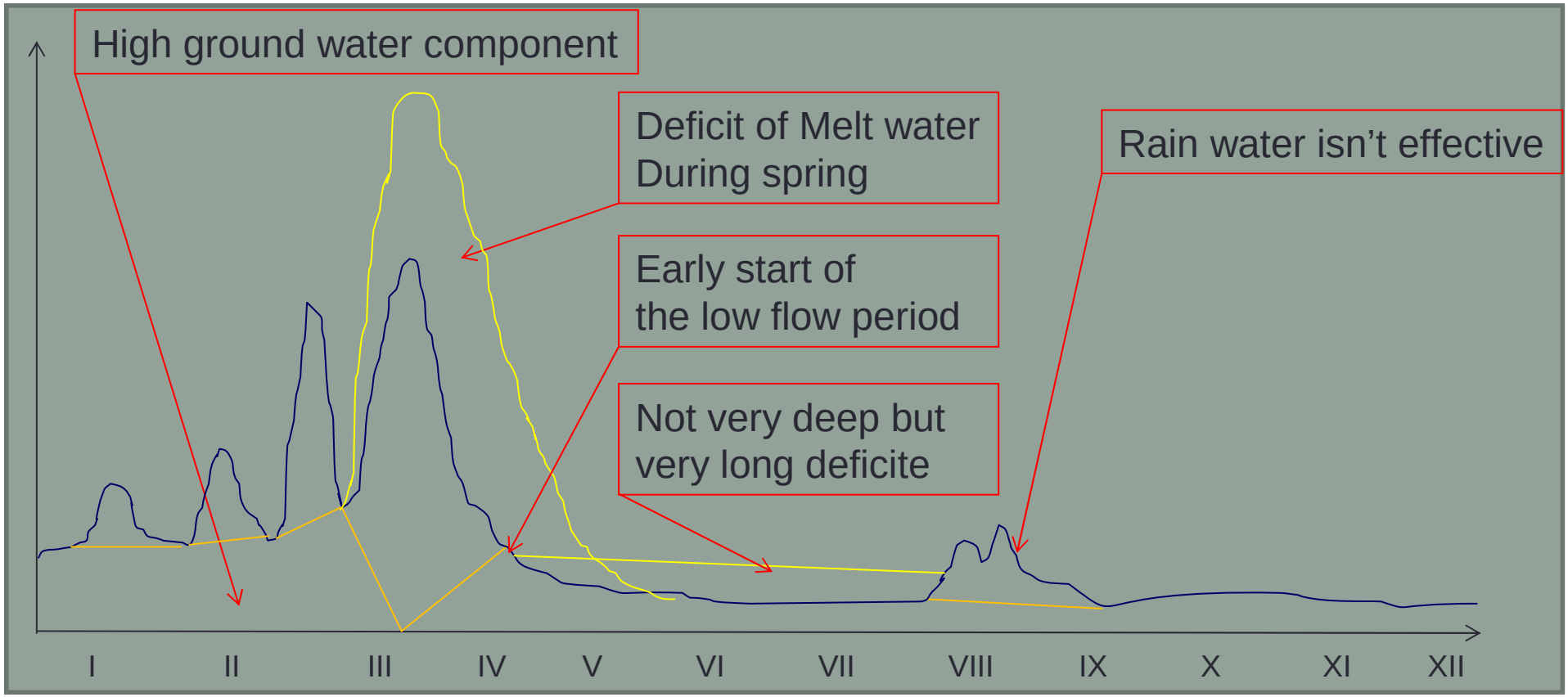




http://hydrooffice.org M. Gregor, P. Malik, 2012

Preliminary results

East-European type of water regime changed to West-European with wet and warm winter

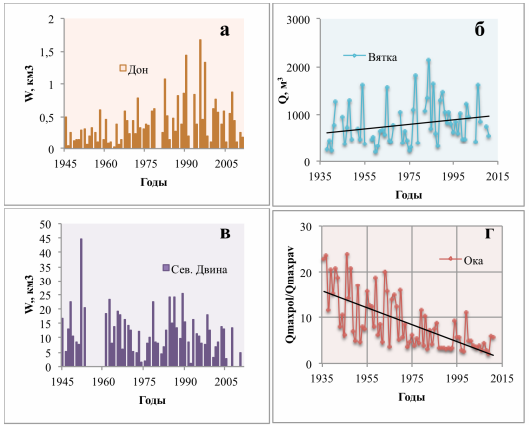


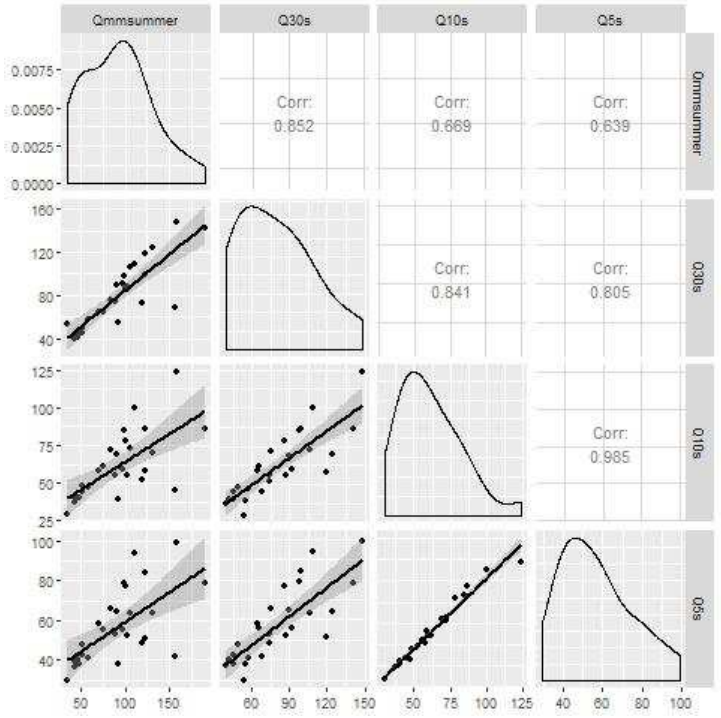
Thank you for your attention !!!

Correspondence to:
Maria Kireeva, Phd, Junior researcher at
Lomonosov Moscow State University
Kireeva_mb@mail.ru

Preliminary results

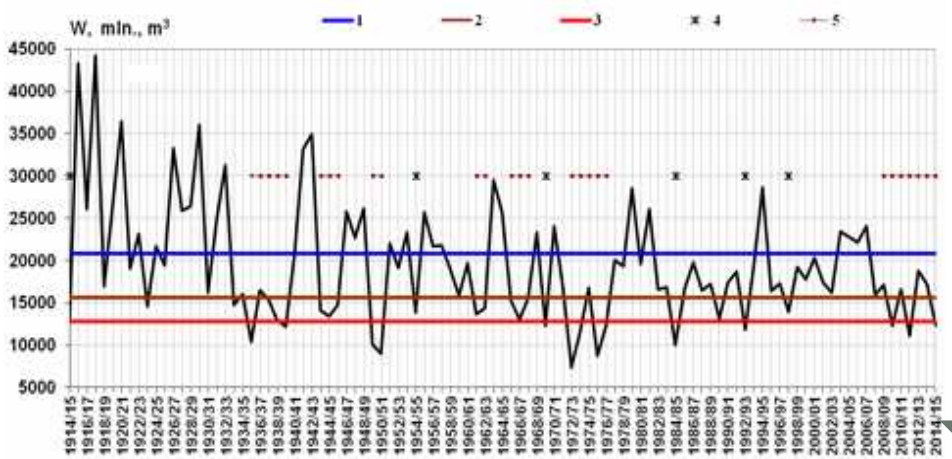
- Decrease in Seasonal flood volume and increase in occasional. (а, b)
- Drops in the rate of maximum annual discharge to maximum discharge during winter (б)
- Increase in duration of the deficit period
- Increase in number of the flood waves
- Shift to the earlier dates the start of the seasnoal flood



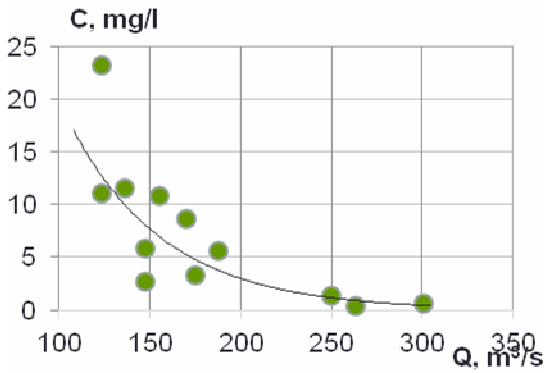


Problem statement: Don basin drought 2007 - … ???

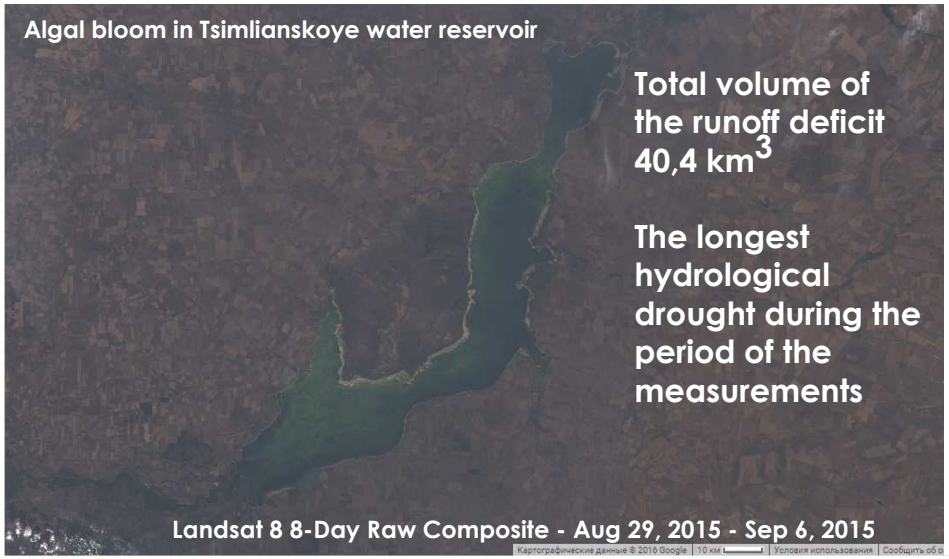
Annual runoff value of the Don in the Tsimlyansk HPS:
1 – annual runoff 50 % probability; 2 – annual runoff 75 % probability; 3 – annual runoff 90 % probability; 4 – extremely low flow years; 5 – extremely low flow time-series

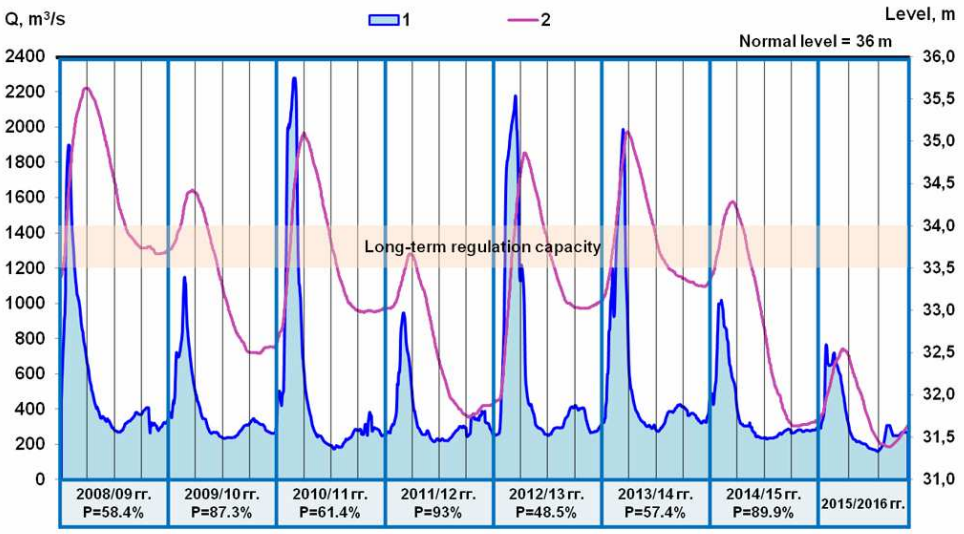


Fito-plankton concentration on the Don river VS runoff



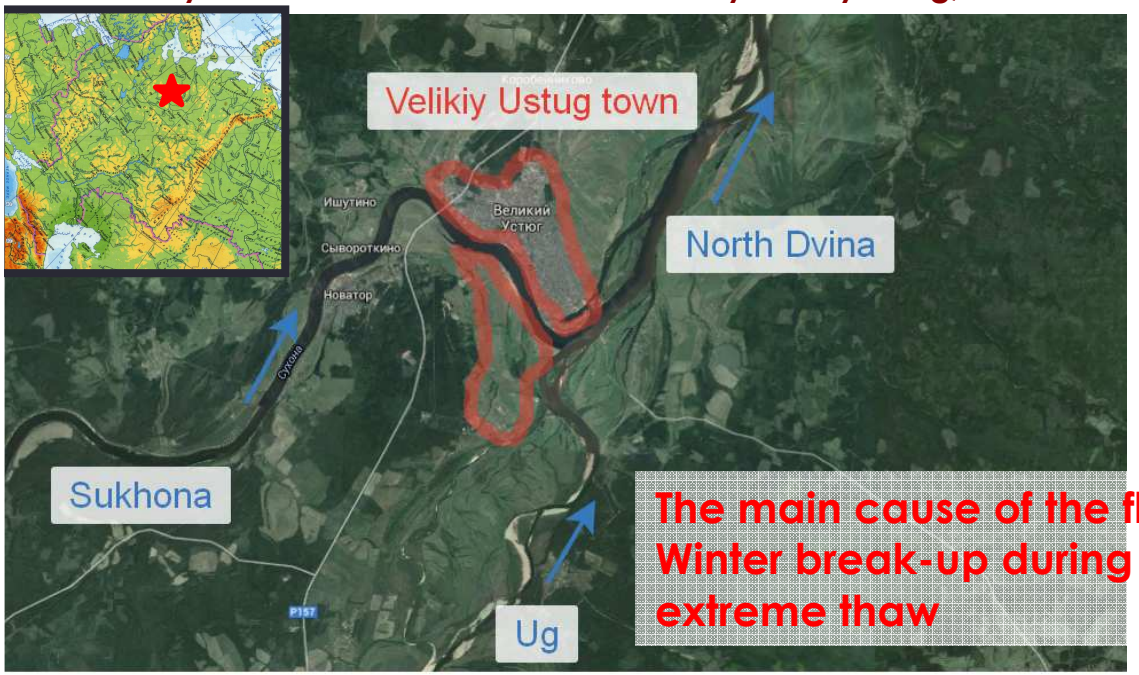
Long-term oscillation of the inflow to the reservoir (1) and water level in the Tsimlyanskoe reservoir (2)





Problem statement: North Dvina flooding 16.04 - … 2016 ???

Crushed by flakes and flooded houses near by Velikiy Ustug, 16.04.2016



The main cause of the flood: Winter break-up during extreme thaw

Total flooded area >10 000 hectares.
1350 houses, 5000 inhabitants