Northern Eurasian Landscapes: Interactions between Humans, Hydrology, Land Cover and Land Use Change

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NASA Land-Cover and Land-Use Change Science Team Meeting
Rockville, Maryland, 04/03/2012 : 04/05/2012

Land-Cover / Land-Use Change Program

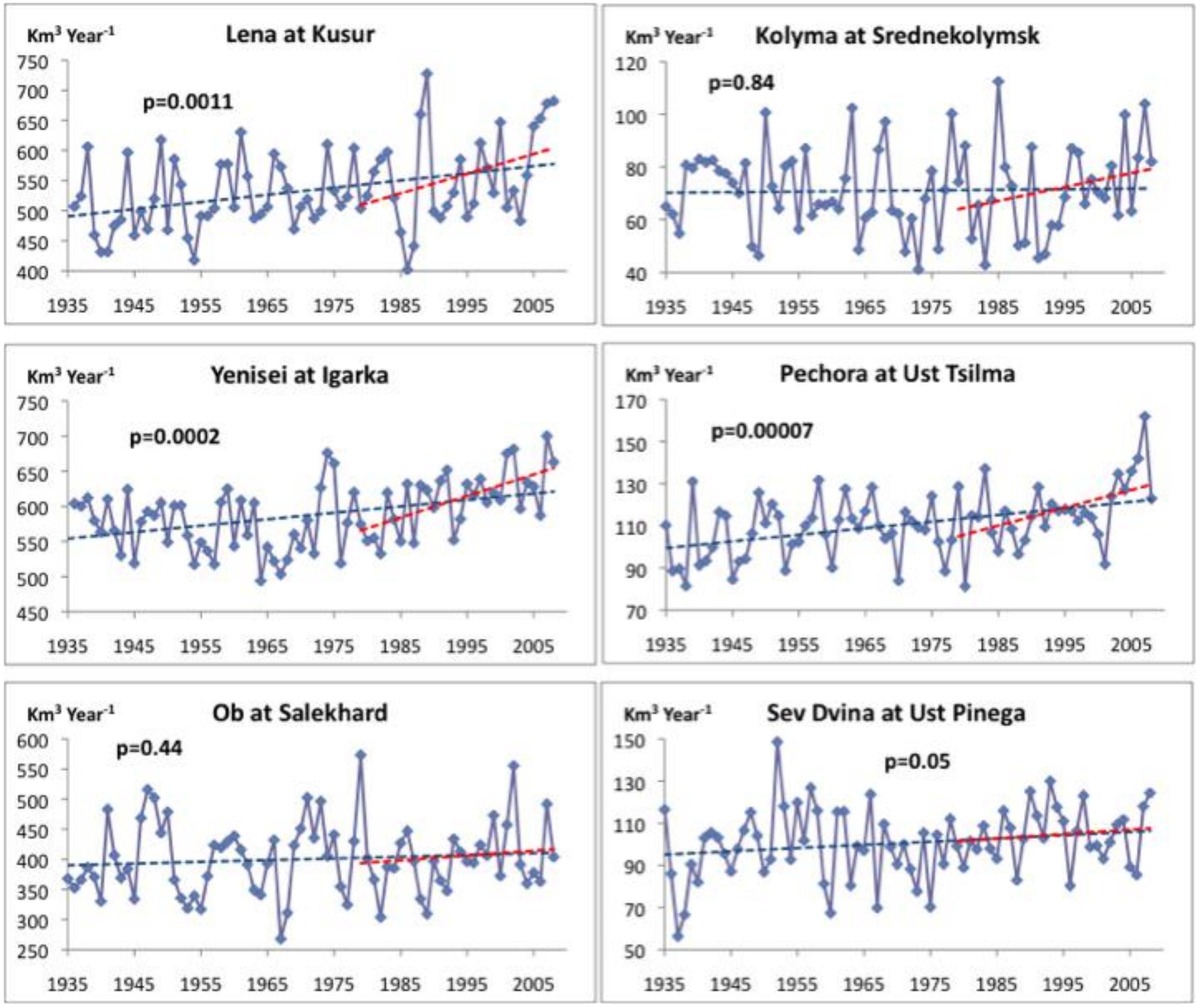
The research project is organized around three specific objectives:

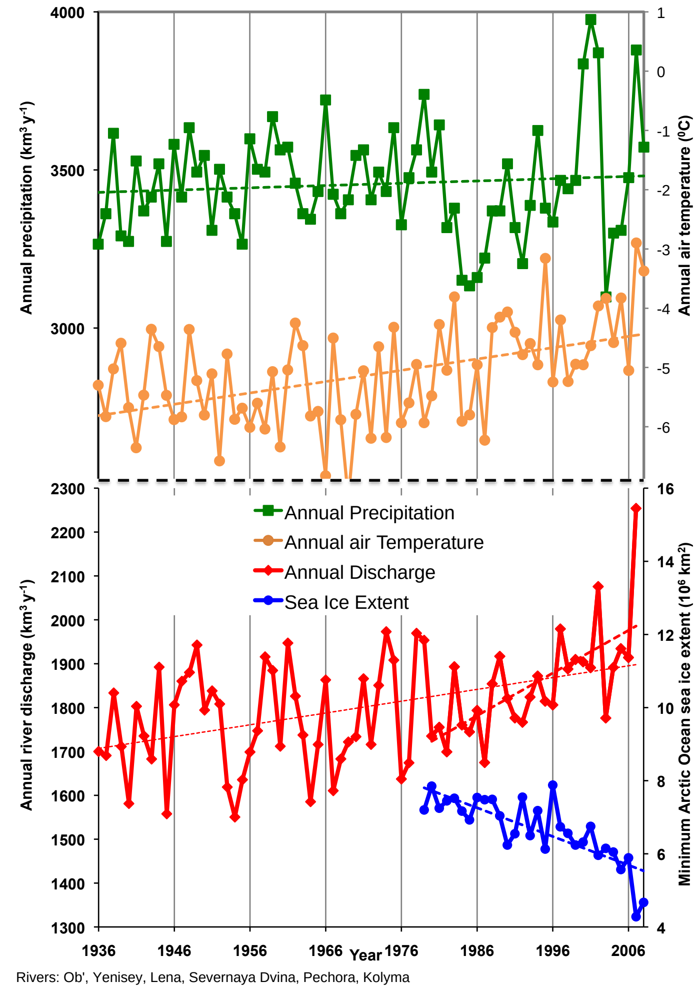
Objective 1: *Understand historical interactions between climate, land cover/land use, and hydrology and to project them into the future*

Objective 2: *Evaluate the effects of the interrelated changes in hydrology and land cover/land use on humans and identify the vulnerable areas for socio-economic development in Northern Eurasia.*

Objective 3: *Incorporate NASA and affiliated biogeophysical data products, in situ data, modeled results, and human dimensions information into a regional analysis and mapping system for Northern Eurasia. (RIMS)*

Acceleration of water cycle in the Eurasian pan-Arctic



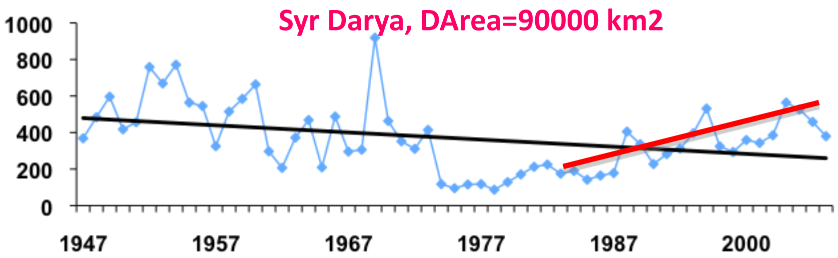


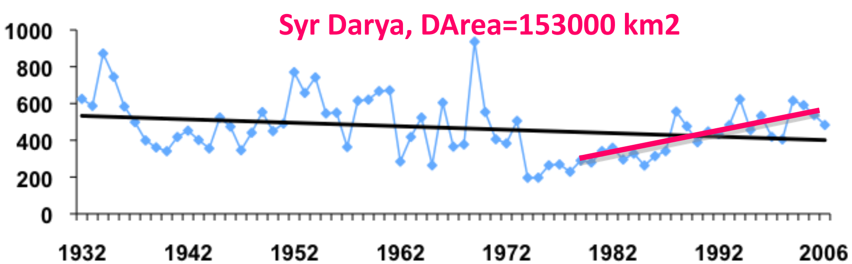
Annual discharge variabilities for largest Russian rivers flowing to the Arctic Ocean over 1936-2008. Dash lines show linear trend lines over 1936-2008 (blue) and over 1980-2008 (red).
(html://R-ArcticNet.sr.unh.edu)

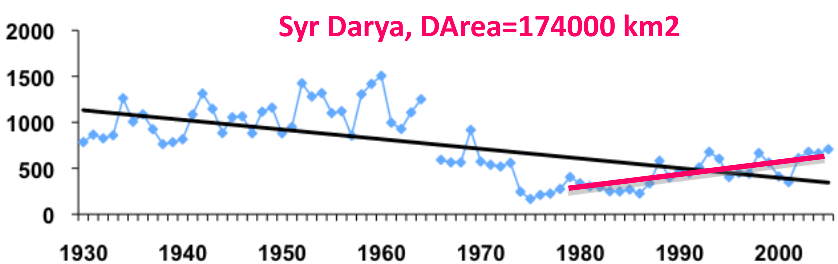
Annual time series of spatially aggregated river discharge over the 6 largest Russian basins, precipitation, air temperature and aggregated Arctic Ocean sea ice coverage.
(Updated from Shiklomanov & Lammers, 2009 ERL)

Analysis of water cycle components and impacts – Syr Darya R.

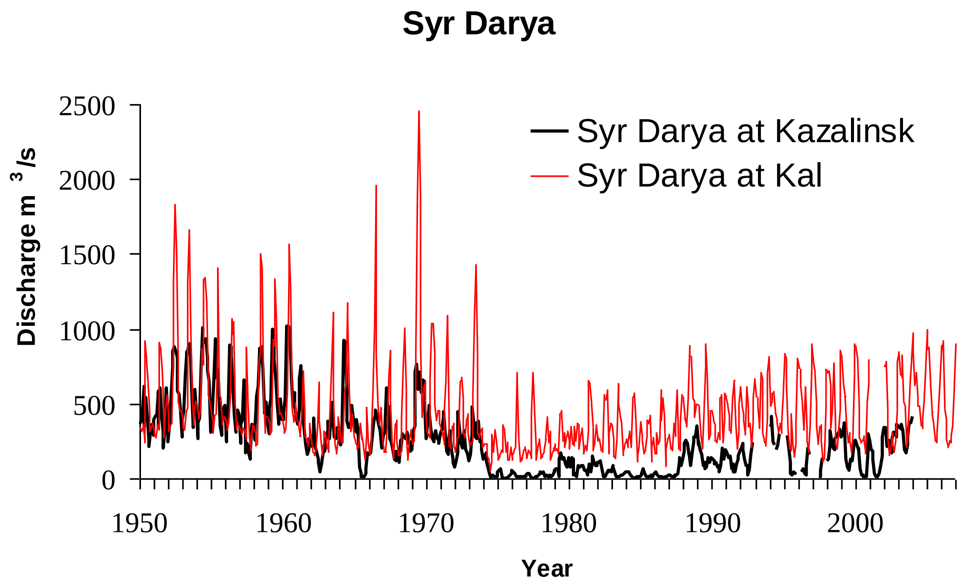
Annual discharge

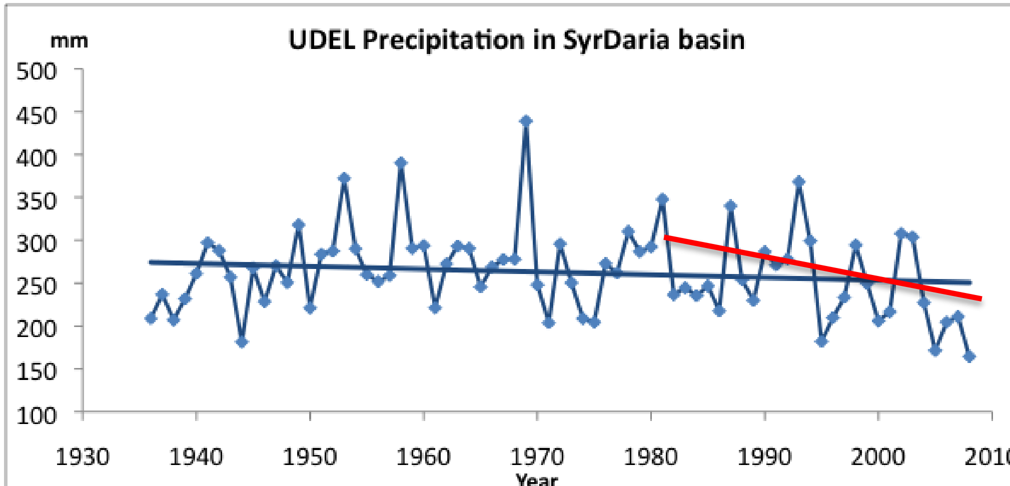






Monthly discharge

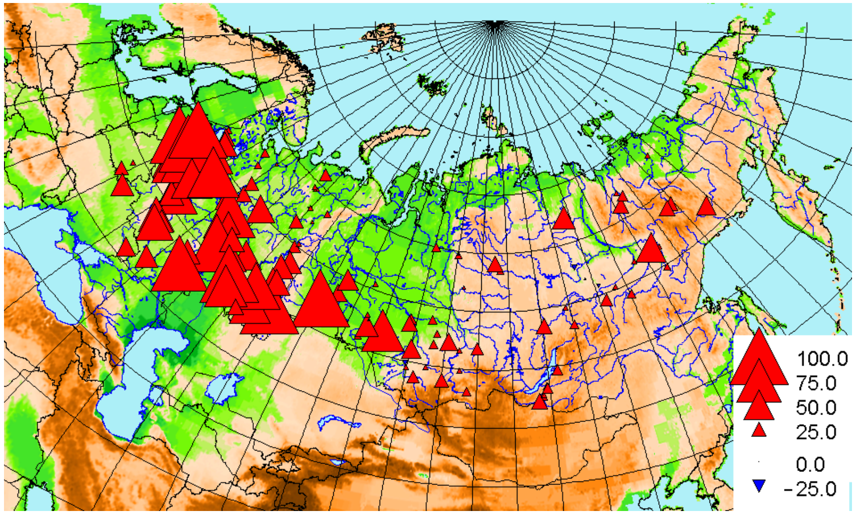




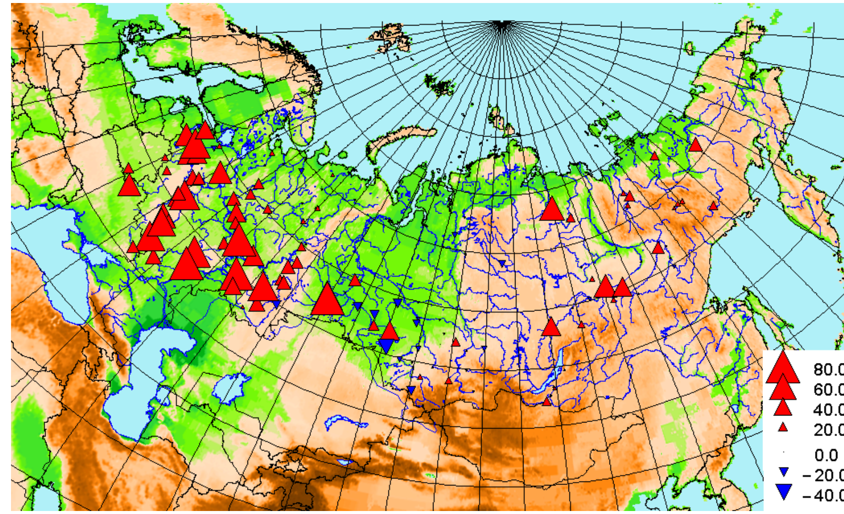
Recent Syr Darya R. discharge increases

1) Increased glacier and snow melt at high elevations
2) Decline in human water use
3) Increasing precipitation (but not all data sets show this)

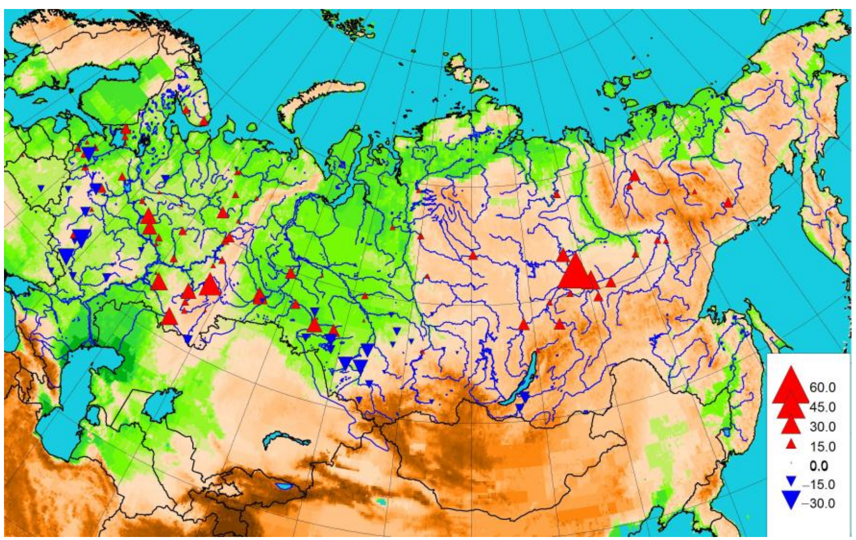
Anomalies of Winter runoff over 1978-2005 (%)



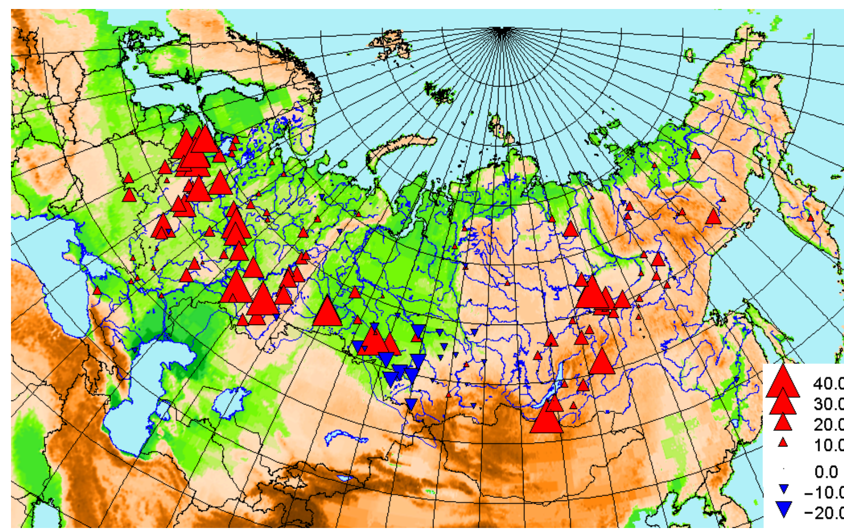
Anomalies of Summer-Fall runoff over 1978-2005 (%)



Anomalies of Spring runoff over 1978-2005 (%)



Anomalies of Annual runoff over 1978-2005 (%)



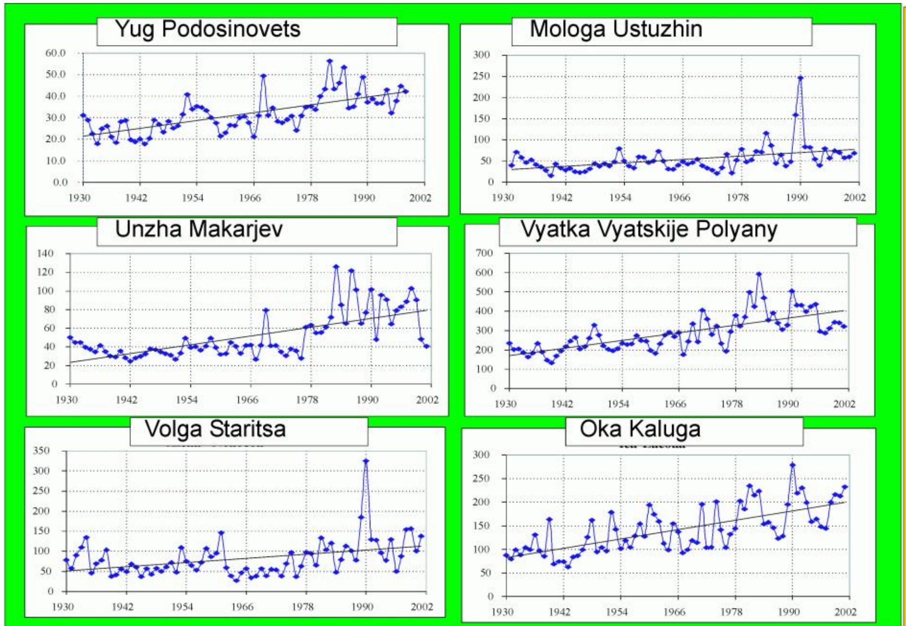
Anomalies of seasonal runoff over 1978-2005 from 1940-1977

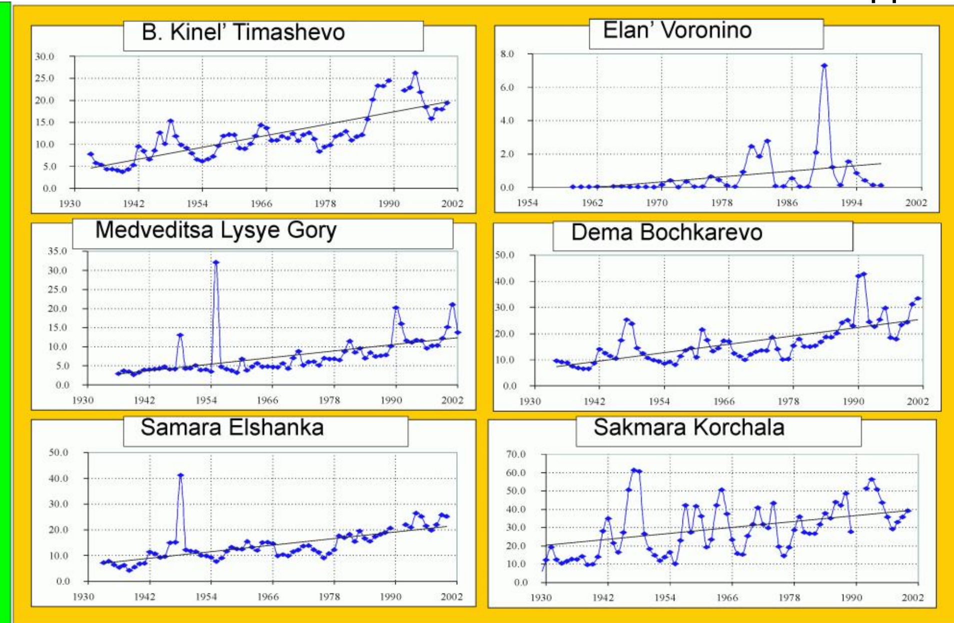
Updated from ACIA, 2005

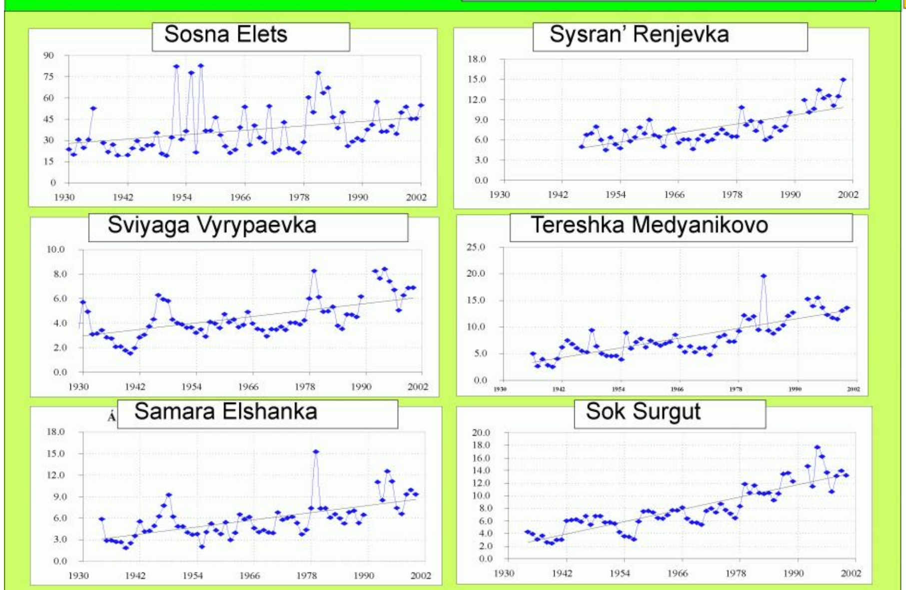
Annual mean winter river discharge (Dec. to March)

Forest

Steppe







Forest-Steppe

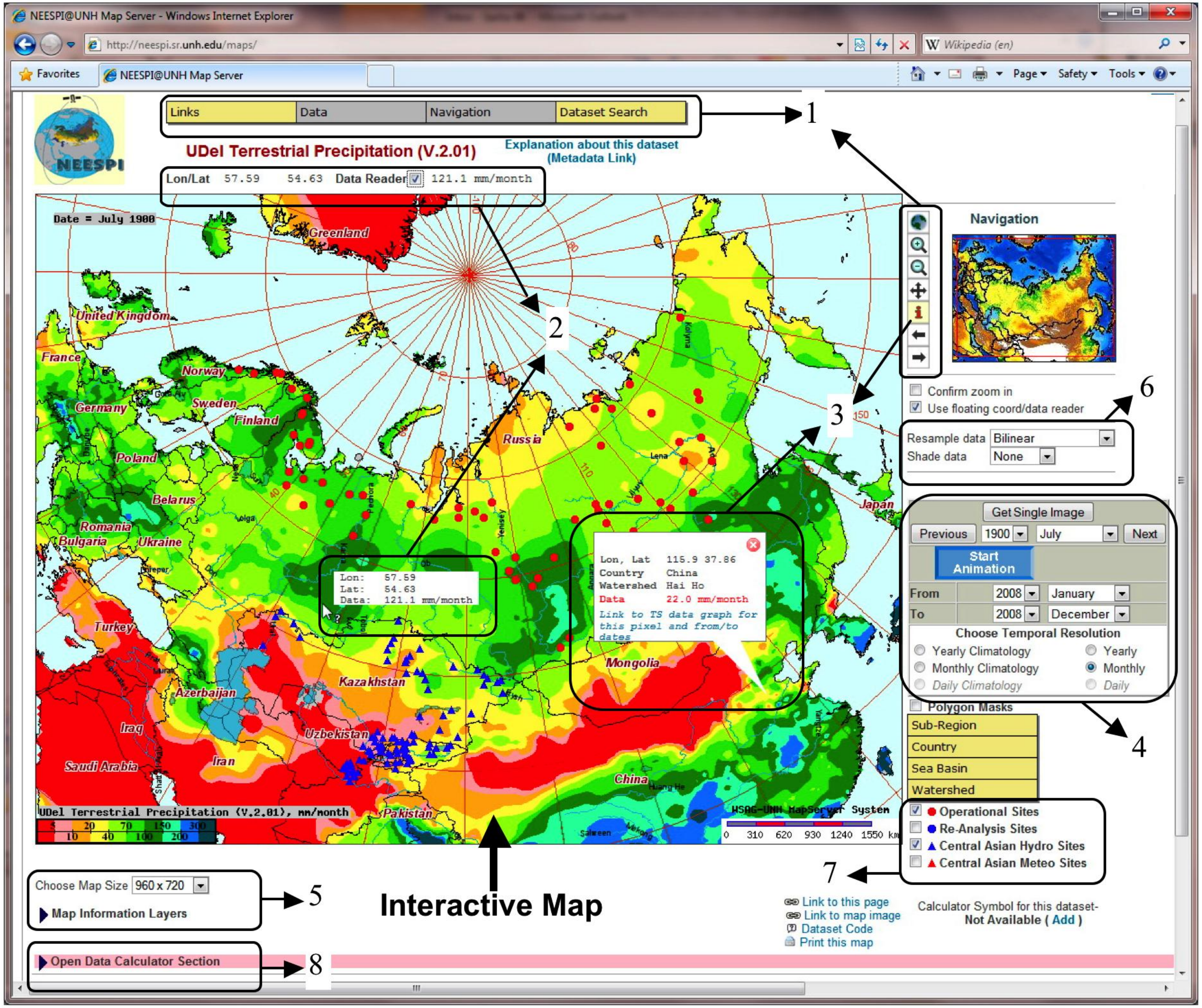
Medium-size drainage basins from European Russia (within NEESPI domain).

Understanding of causes of such significant changes in river discharge is one of our research tasks.

NEESPI RIMS

Regional Integrated Mapping and Analysis System

http://neespi.sr.unh.edu/maps



1) data search/selection, spatial navigation, metadata link, etc.;

2) coordinate and map data value reader;

3) pixel query tool (i-tool) gets coordinates, country, watershed, and map data value;

4) time series navigation tool;

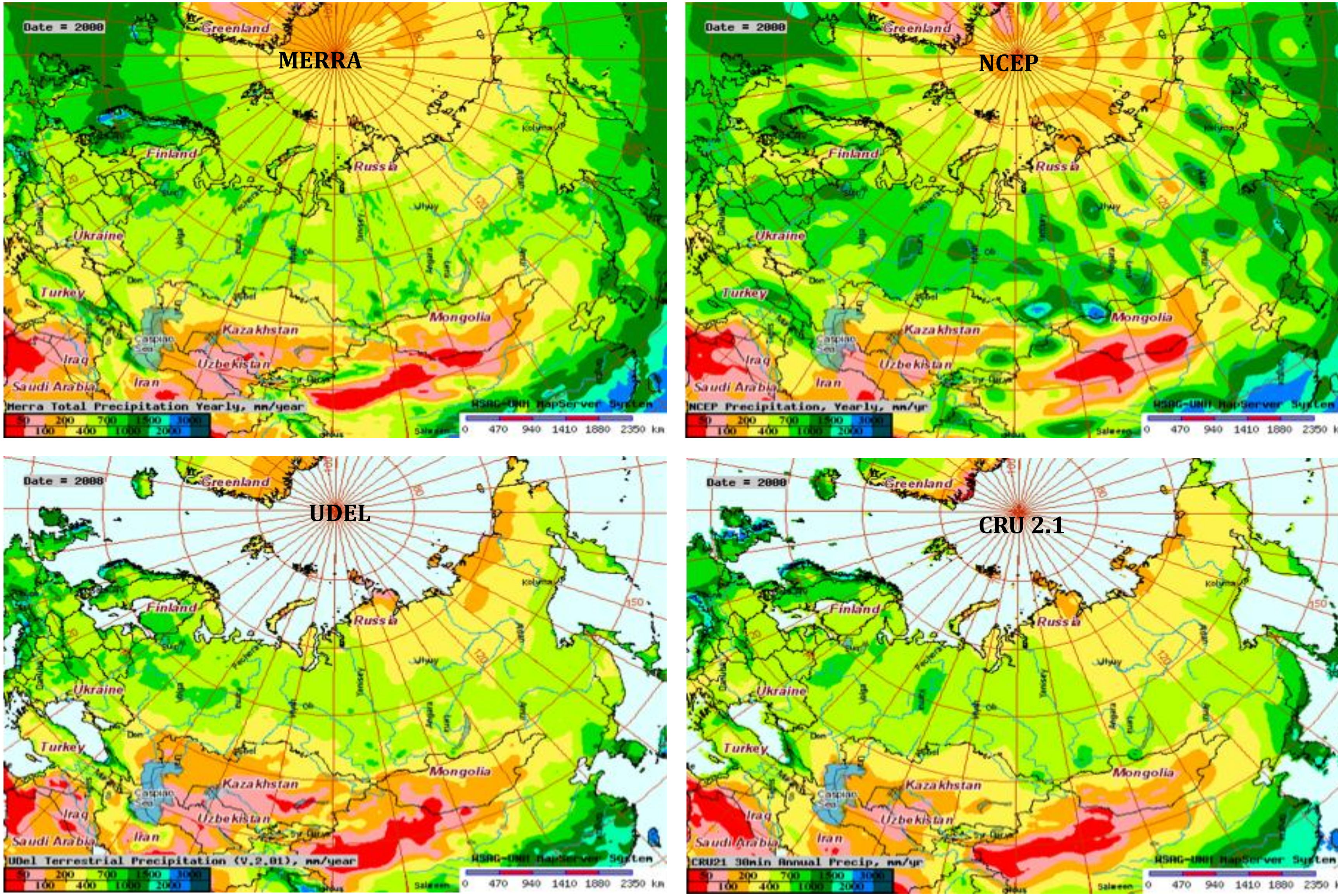
5) map size and base layer choices;

6) data interpolation and shading tools;

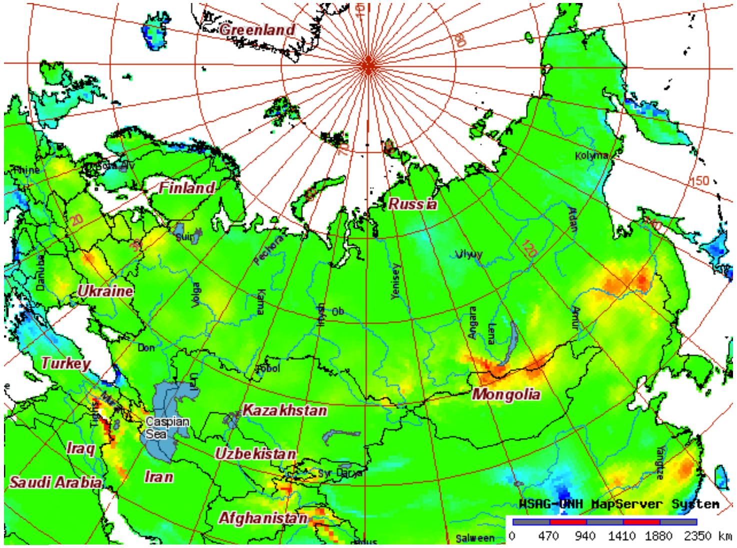
7) point/station data list with clickable symbols that open station pages in a separate browser window;

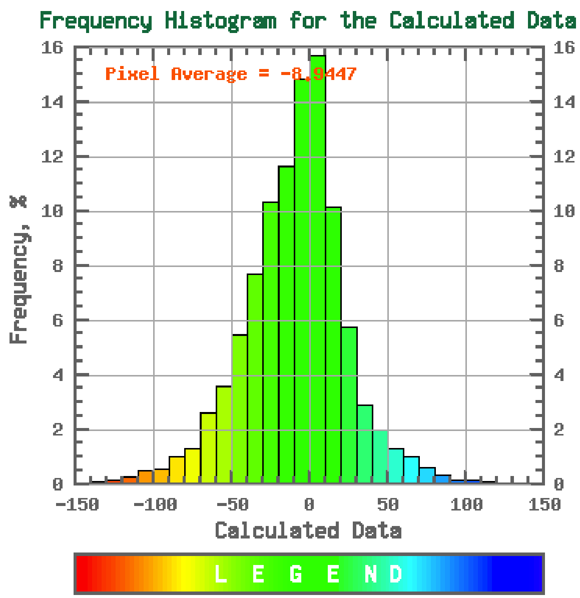
8) fold-out section to run the Data Calculator application to perform mathematical and logical functions over gridded or vector datasets;.

Intercomparison of mean annual precipitation for 2000 from NCEP and MERRA re-analysis with UDEL and CRU interpolated observations.

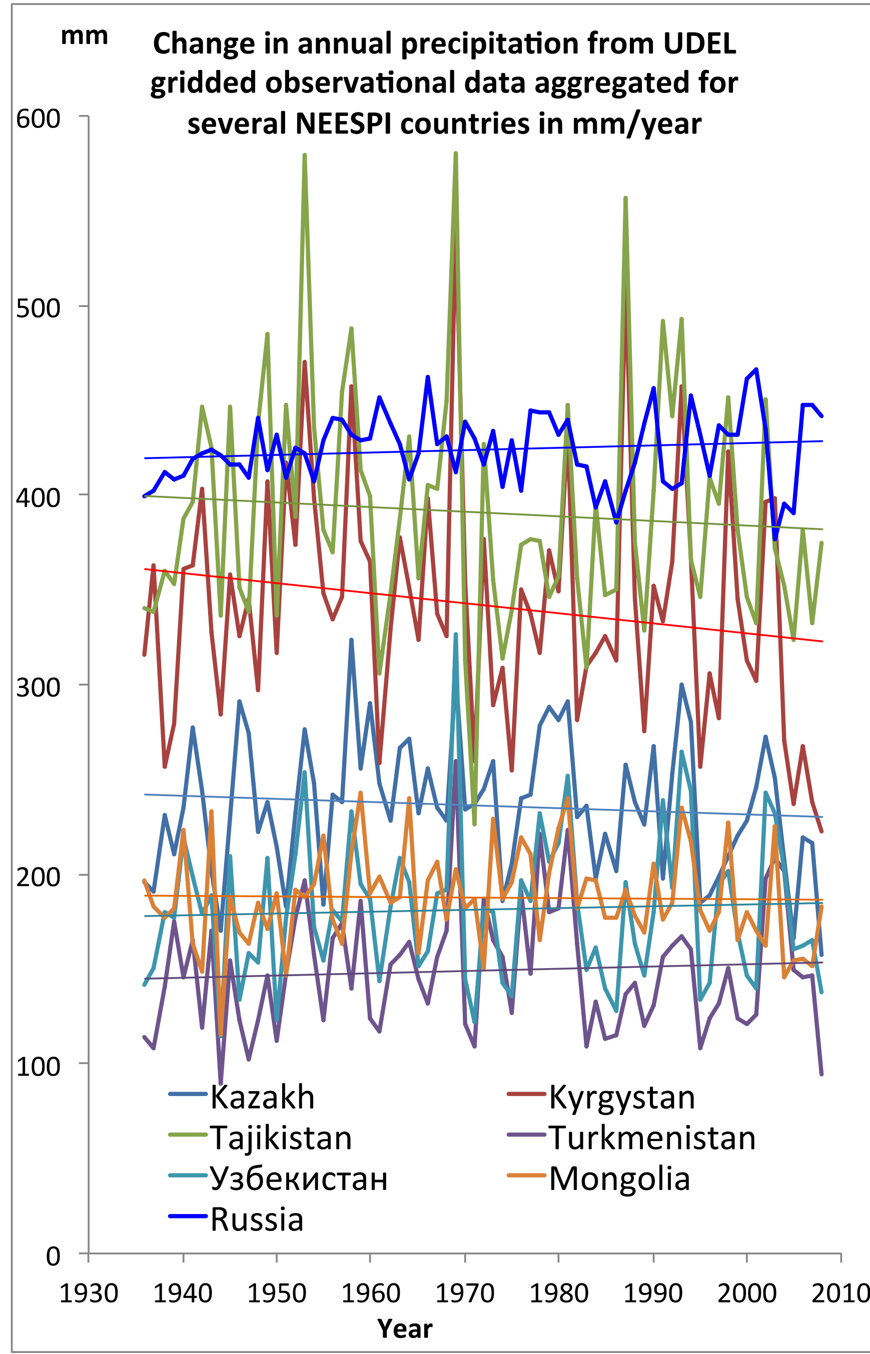


PRECIPITATION CHANGE



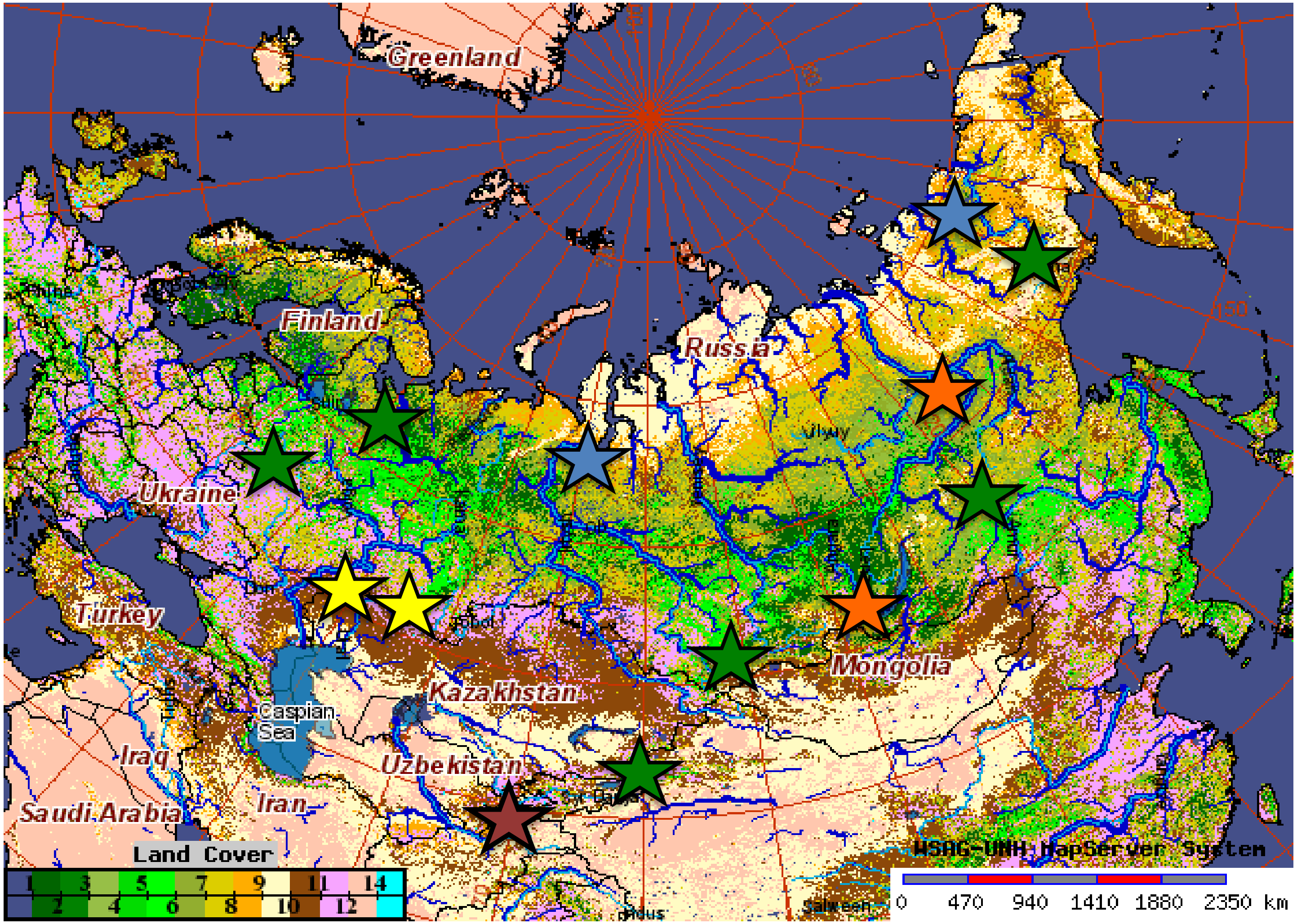


Deviation of mean annual MERRA precipitation over 1995-2011 from LTM over 1978-2011



- Water cycle across Northern Eurasia is accelerated
- The observed changes in river runoff cannot be fully explained with only climatic characteristics change
- Other potential causes of hydrological changes across the Northern Eurasia should be investigated

Study area and locations of experimental watersheds



Forest loss

Lake draining

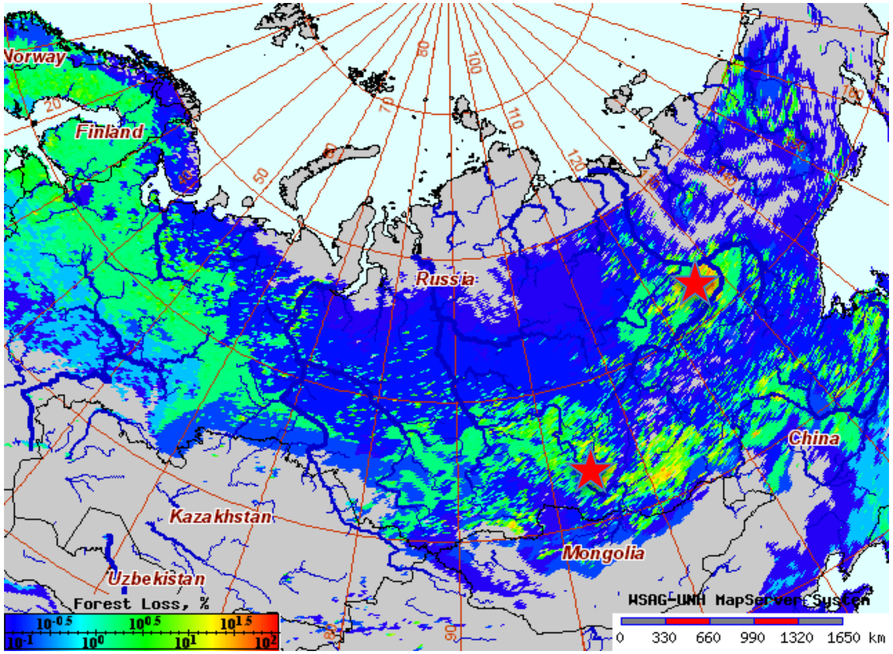
Vegetation change

Irrigation

Complex climate-related changes (freeze-thaw, glacier, wetlands, vegetation, snow etc.)

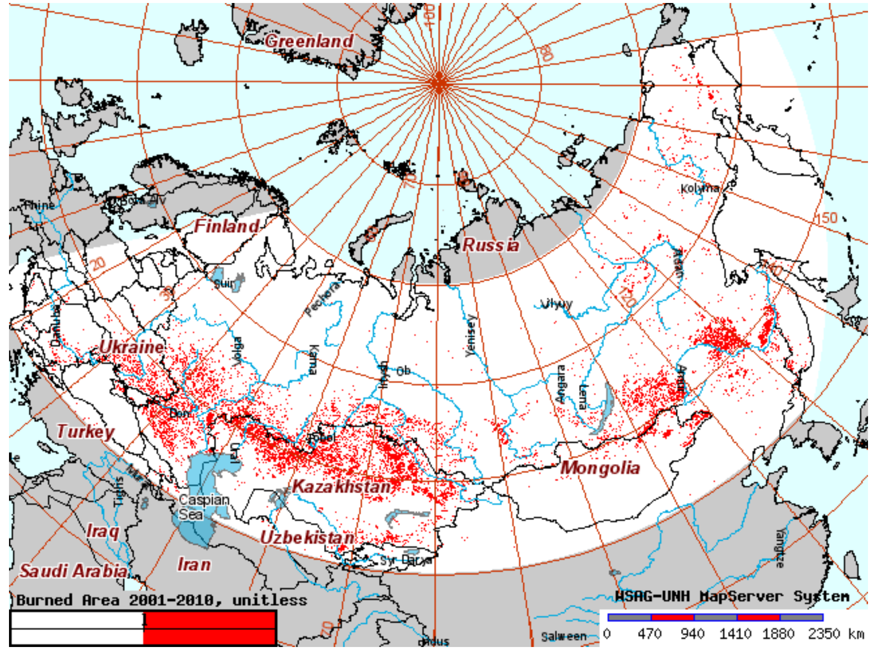
Land cover disturbances:

MODIS-derived 2000-2005 gross forest cover loss (SDSU)



Hansen M., Stehman S., Potapov P. (2010) Quantification of global gross forest cover loss. Proceedings of the National Academy of Sciences of the U.S.A

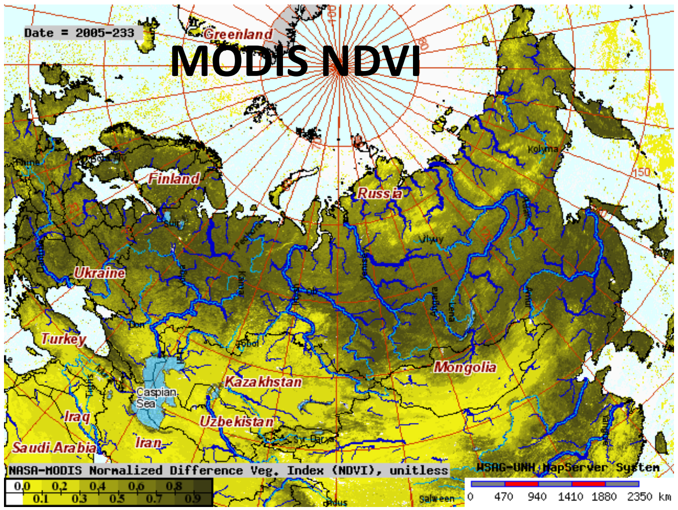
MODIS-derived 2000-2010 burned area (UMD)

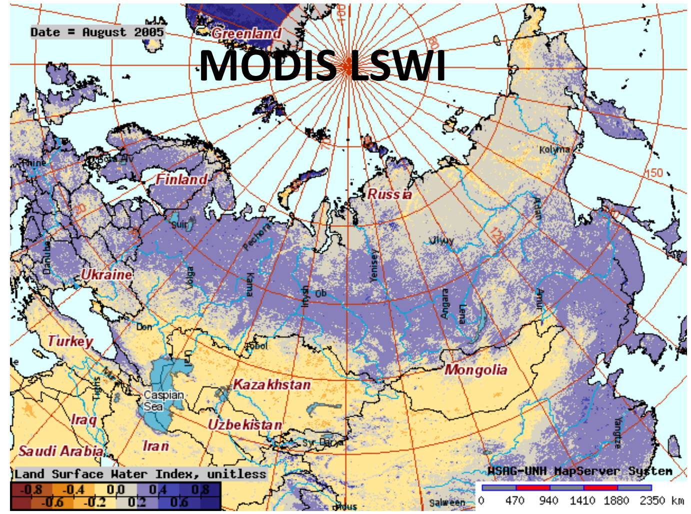


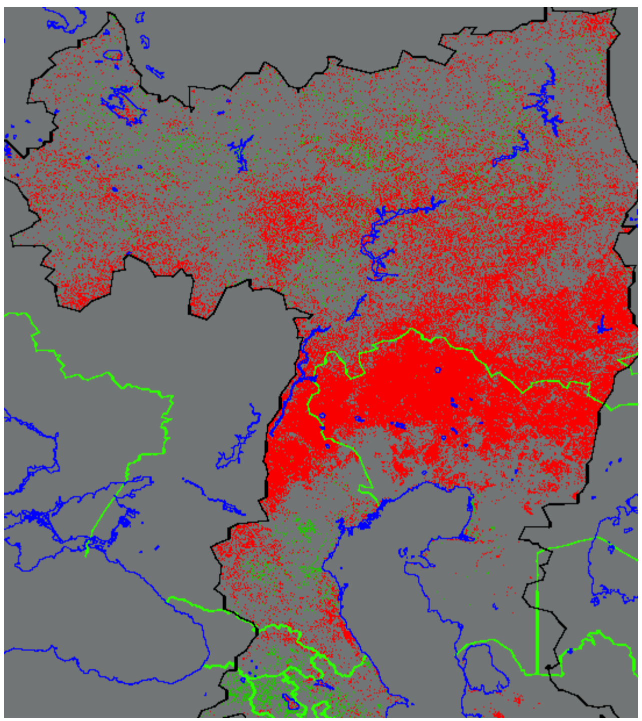
Courtesy to Tatiana Laboda, UMD

Data from the project supported website: http://neespi.sr.unh.edu/maps/

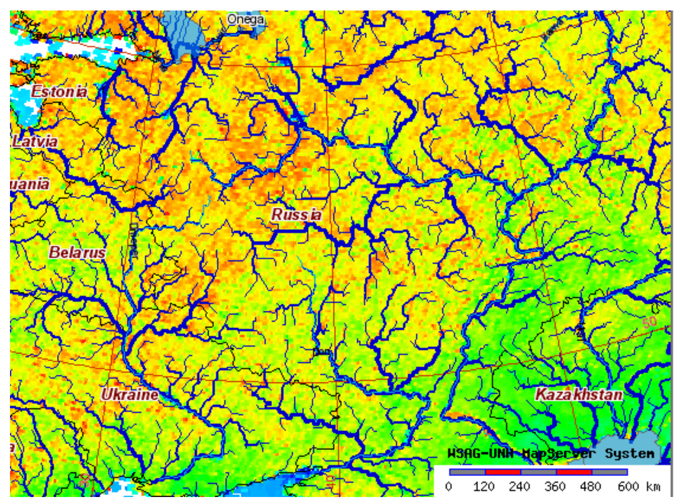
Change in Vegetation: Vegetation Indices derived from MODIS and AVHRR

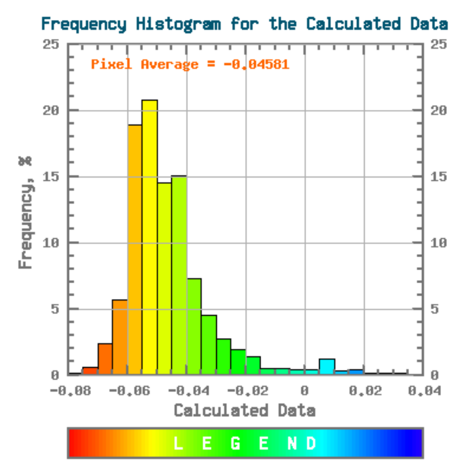






MODIS NDVI trends for Caspian Sea Basin 2000-09 (courtesy to Saachi Sassan) and for Central European Russia (2000-2007) from NEESPI.sr.unh.edu/maps

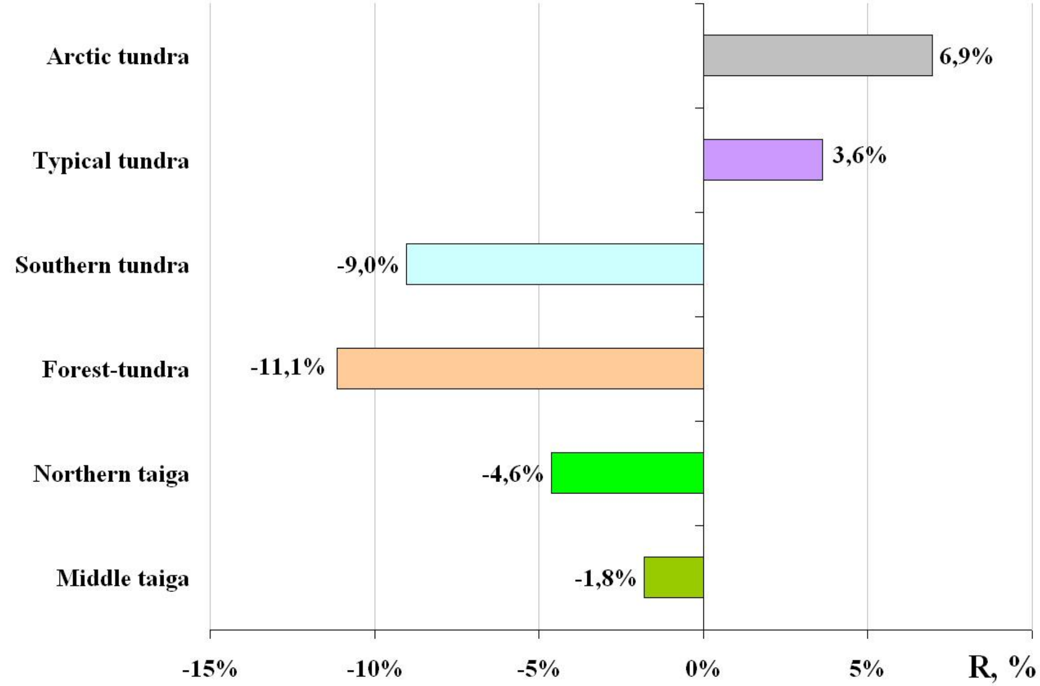


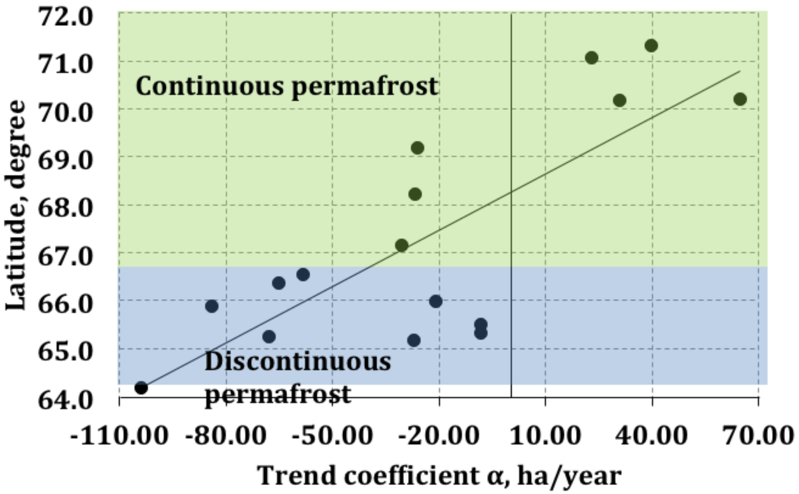


Changes in thermokarst lakes

Results of detailed analysis of Landsat TM for 30 test sites across the Western Siberia over 1973-2009

The average value of relative change of total lake area in different landscape zones.



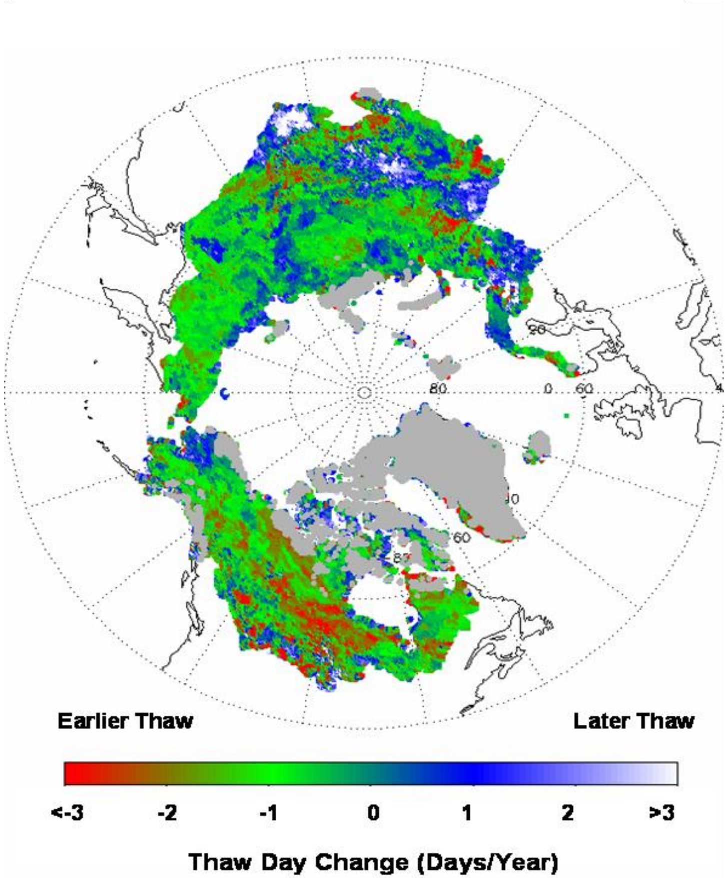


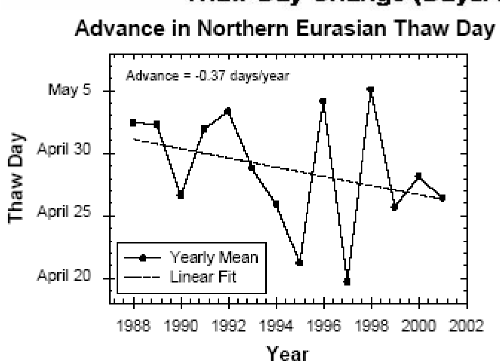
Linear trend coefficients for total area of lakes depending on latitude. Positive values of the coefficient indicate increasing lake area and negative values indicate an average reduction lake area

Shiklomanov, A.I. R.B. Lammers, D. Lettenmaier, Yu. Polischuk, O. Savichev, L.C. Smith, 2012: Hydrological changes: historical analysis, contemporary status and future projections [Chapter 4 in “Regional Environmental Changes in Siberia and Their Global Consequences”, Ed. Gutman and Groisman], Springer, in press.

Freeze-Thaw and SWE Change

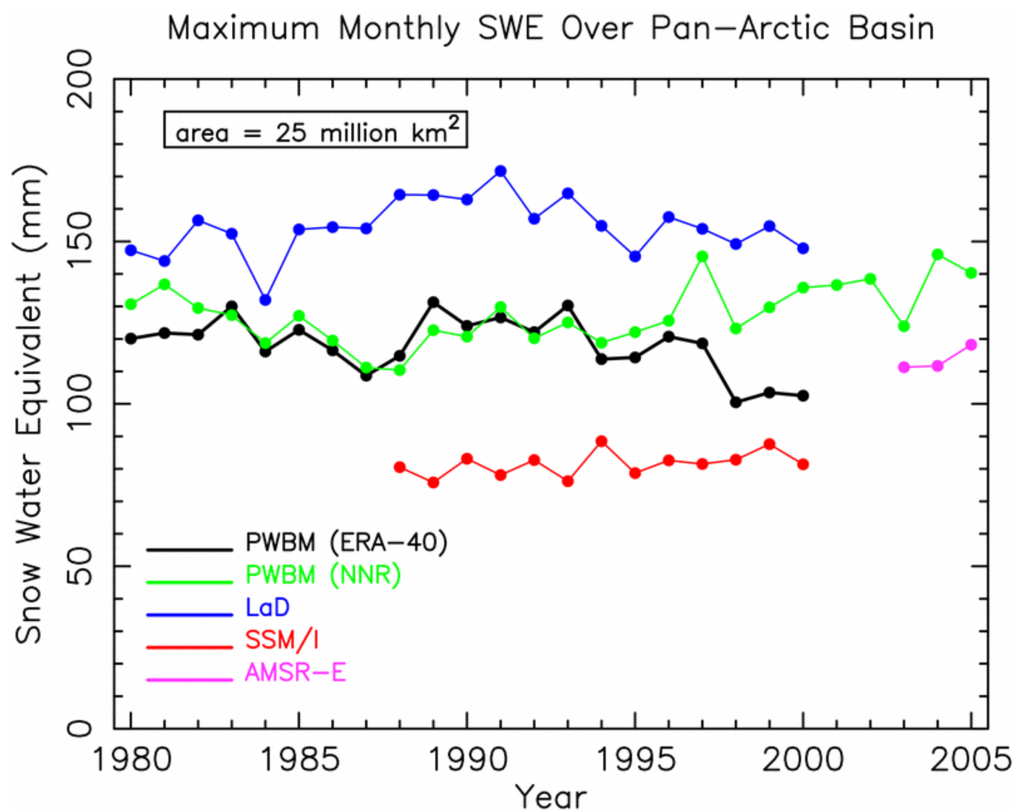
Pan-Arctic Spring Thaw Trend (SSM/I, 1988-2001)





Timing and trend in the timing of spring thaw derived from SSM/I have elucidated the thaw correspondence with regional anomalies in annual NPP derived from MODIS and AVHRR. **Mean annual variability in springtime thaw for Northern Eurasia (above) is on the order of ±7 days, with corresponding impacts to annual productivity of approximately 1% per day. (McDonald, Kimball, et al., 2004)**

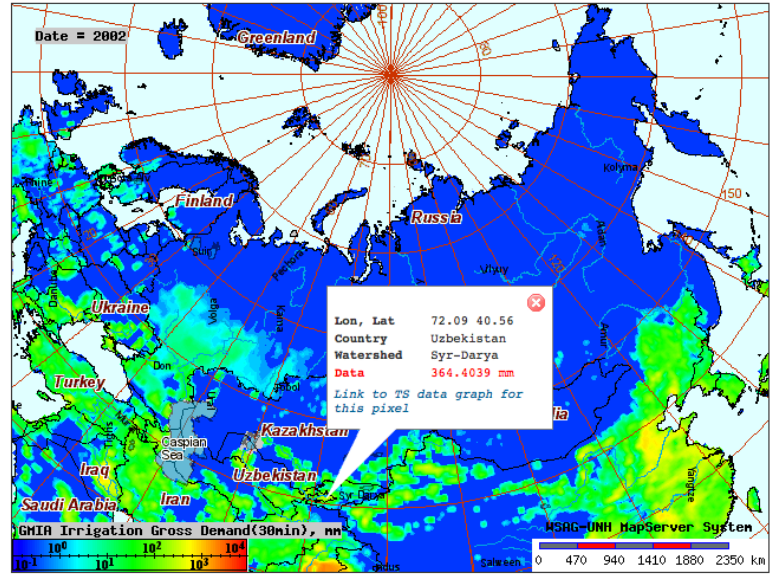
Comparison of SWE from model simulations and remote sensing products



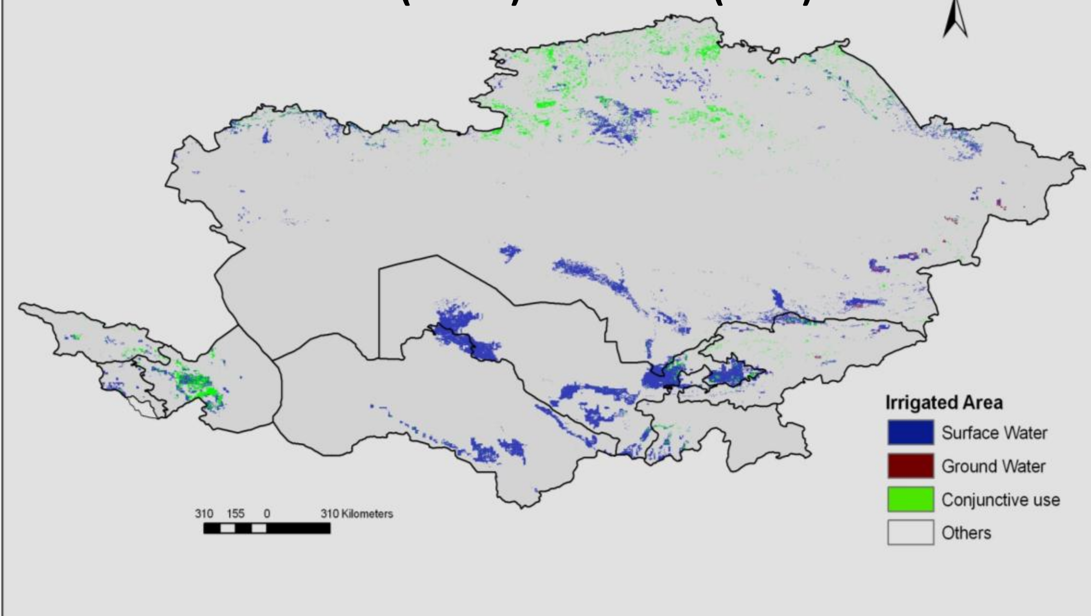
Rawlins, M.A. et al, 2007, Hydrological Processes

Irrigation impact analysis

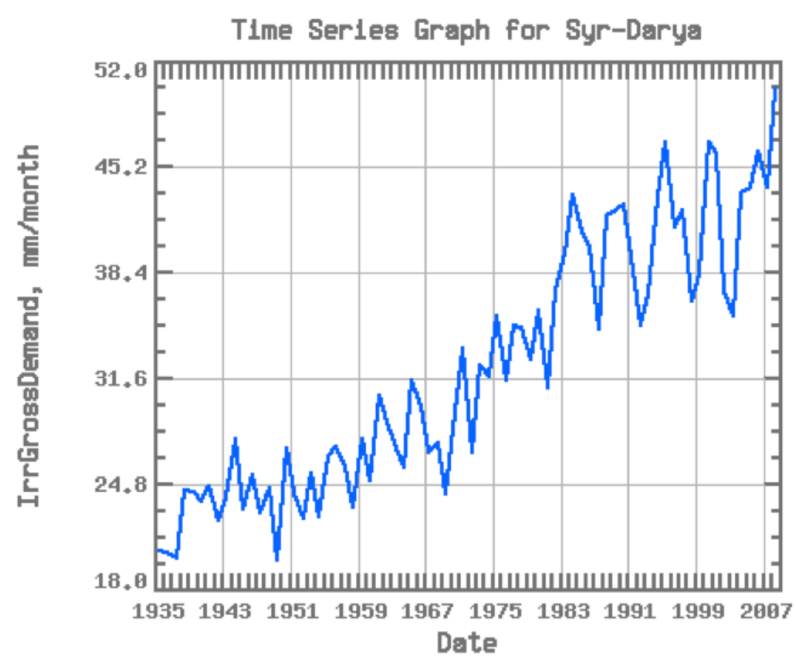
UNH Gridded Irrigation Area time-series for Northern Eurasia using **Global Irrigated Area Map** (1-km resolution derived from remote sensing data) and historical census data from FAO.



Using UNH hydrological model (WBMplus) we evaluated changes in water demand for irrigation over the long-term period



Irrigated Area Map of Central Asia Derived from AVHRR (10km) and SPOT (1km)



Irrigation water demand in the Syr Daria basin continues to increase

Research approach:

- Combined analysis of changes in climate, land cover and hydrological regime for test basins.
- Modeling experiments to understand causes of changes in hydrological regime.
- Simulation of future hydrology using IPCC climate data, water management and LCLUC information.

Future hydroclimatology with WBMPlus and IPCC GCMs

AO GCM presented in NEESPI RIMS web site

№	AO GCM	Country	Spatial resolution
1	ECHAM5/MPI-OM	Germany	1.9°x1.9°
2	CGCM3.1(T63) (ccc_t63)	Canada	2.8°x2.8°
3	UKMO-HadCM3	Great Britain	1.25°x1.875°
4	BCCR-BCM2	Norway	2.8°x2.8°
5	NCAR_CCSM3	USA	1.4°x1.4°
6	INM-CM3 PAH	Russia	3.0°x4.0°
7	GFDL-CM2.1	USA	2.0°x2.5°
8	MIROC3.2(medres) (ccsr_me)	Japan	2.8°x2.8°

Climate scenarios:

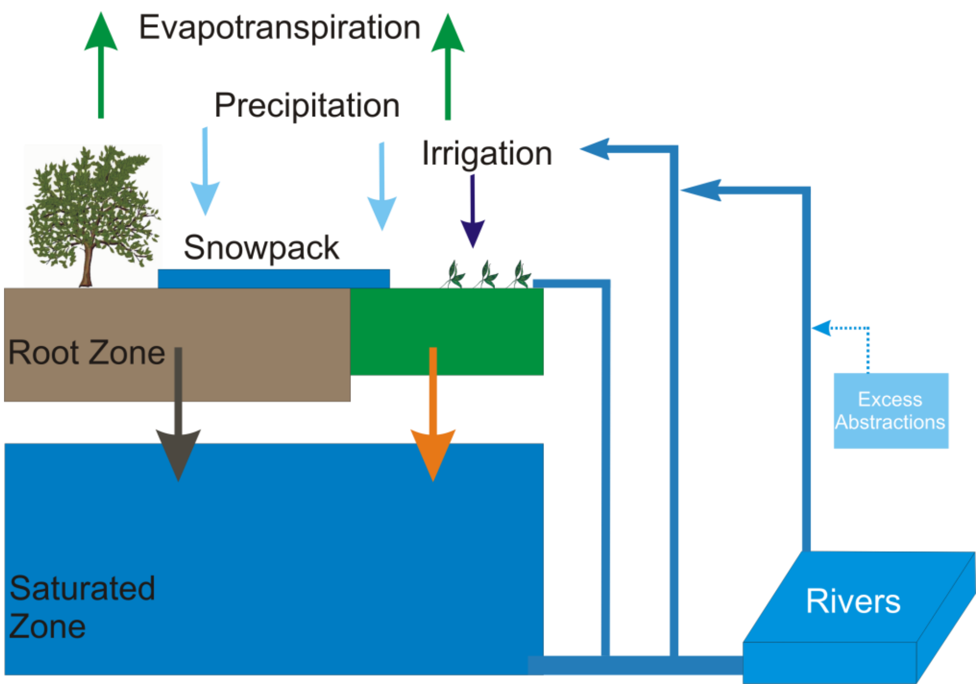
- 20C3M - contemporary
- SRES A1b- future
- SRES A2 - future
- SRES B1 - future

WBMPlus

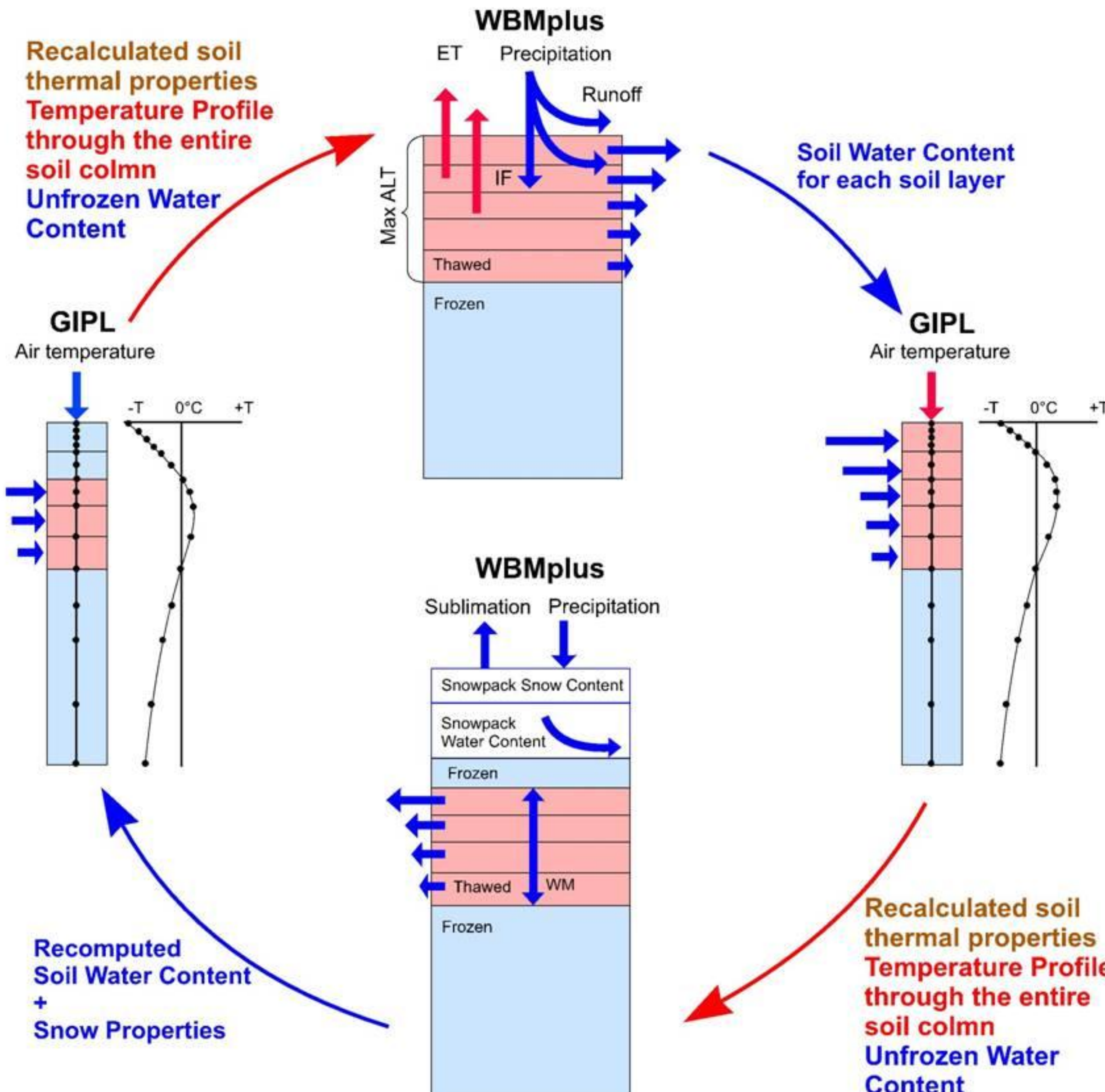
- **WBM + irrigation + reservoirs; daily time step (real time routing, irrigation, reservoirs)**

Model modes: Pristine and Disturbed

Basic Output Parameters: Discharge,
Runoff,
Evapotranspiration,
Soil Moisture,
Snow Depth,
Irrigation Demand

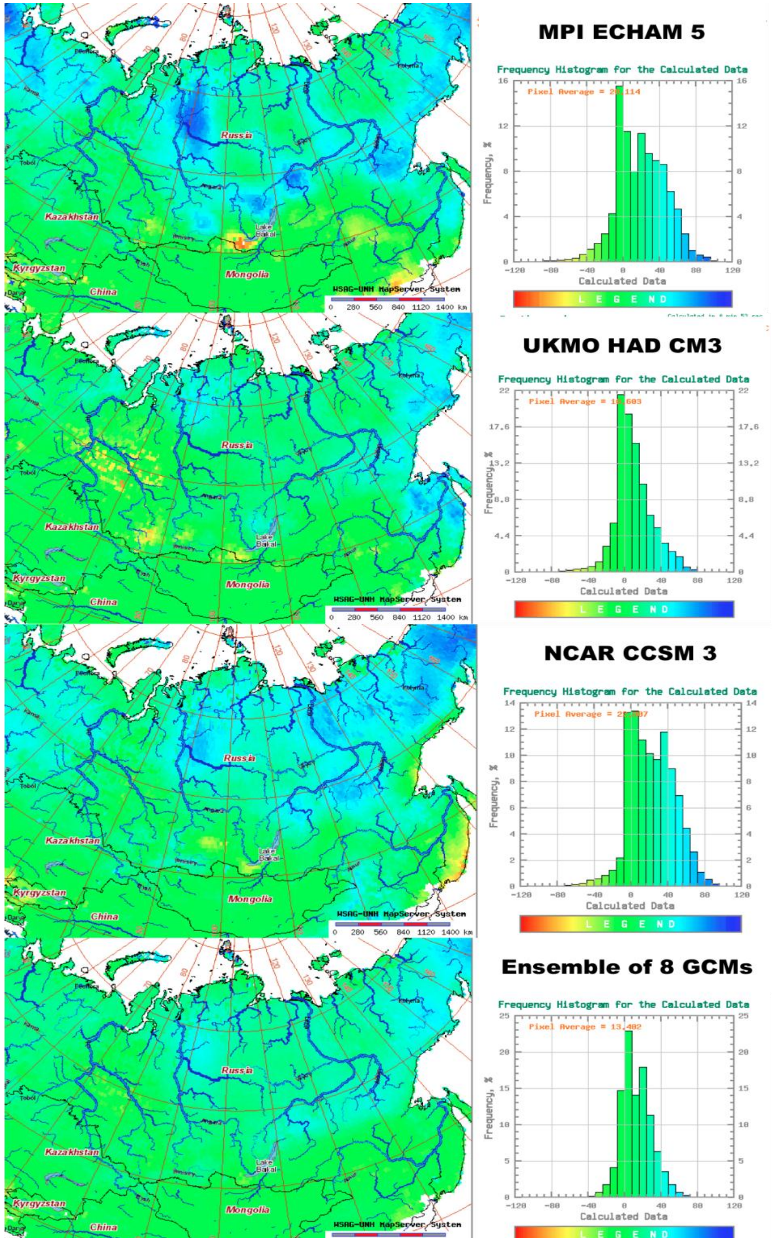


The HydroDynamic Model (HDTM 1.0)

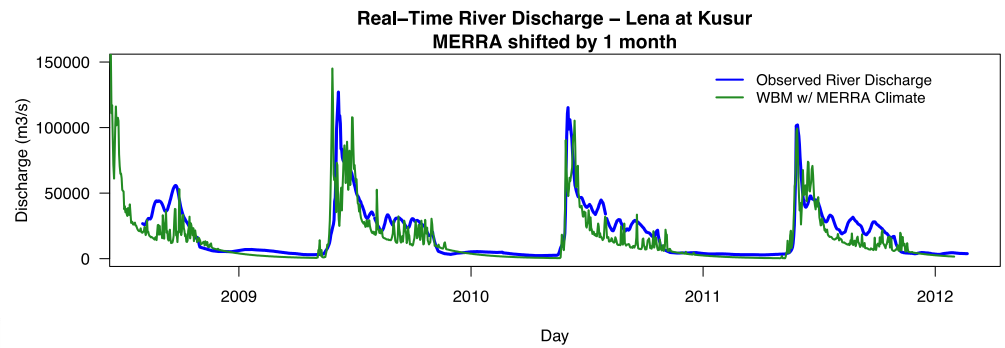


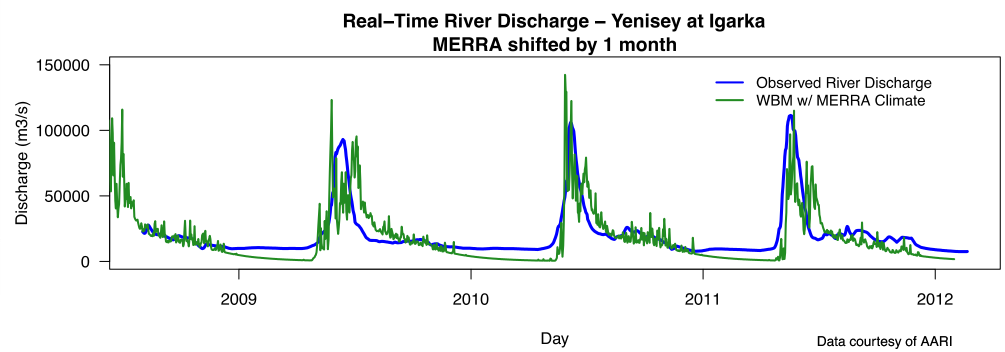
The HydroDynamic Model (HDTM 1.0) couples WBMplus with the Geophysical Institute Permafrost Lab permafrost model (GIPL 2.0, Marchenko et al., 2008) to numerically simulate permafrost and active layer parameters and components of the hydrological cycle taking into account the hydraulic properties of frozen soil.

UNH WBMPlus provides reasonable results for large river basins and monthly time steps.



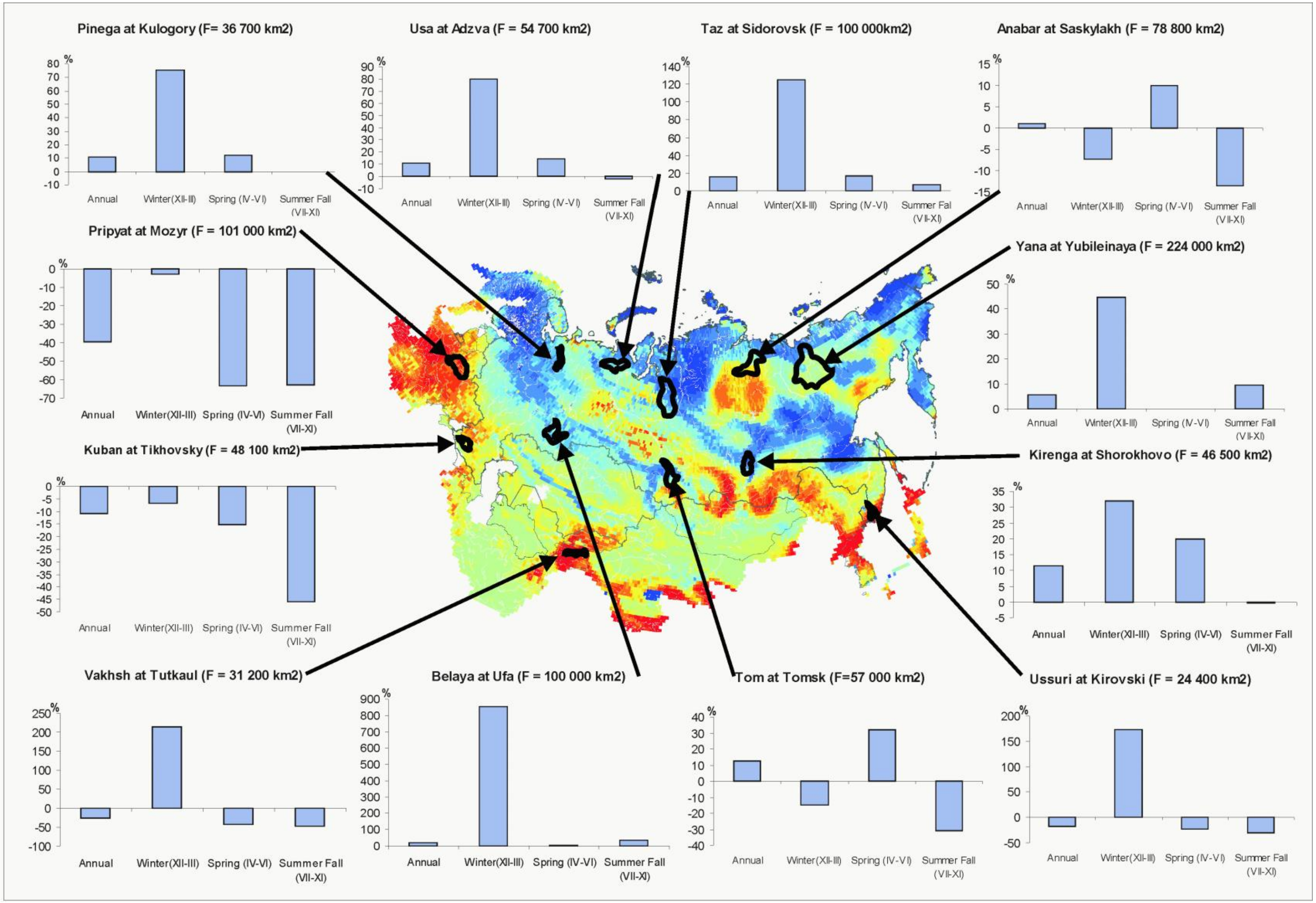
Deviation of simulated mean annual river runoff over 2040-2060 relative to the long-term observed mean (1959-1999).





Observed and WBMPlus simulated daily river discharge for Lena and Yenisey

Seasonal changes in runoff by 2080-2100 (ECHAM5 A1b scenario and UNH WBMPlus)
Annual, Winter (Dec-Mar), Spring (May-Jun), Summer-Fall (Jul-Nov)



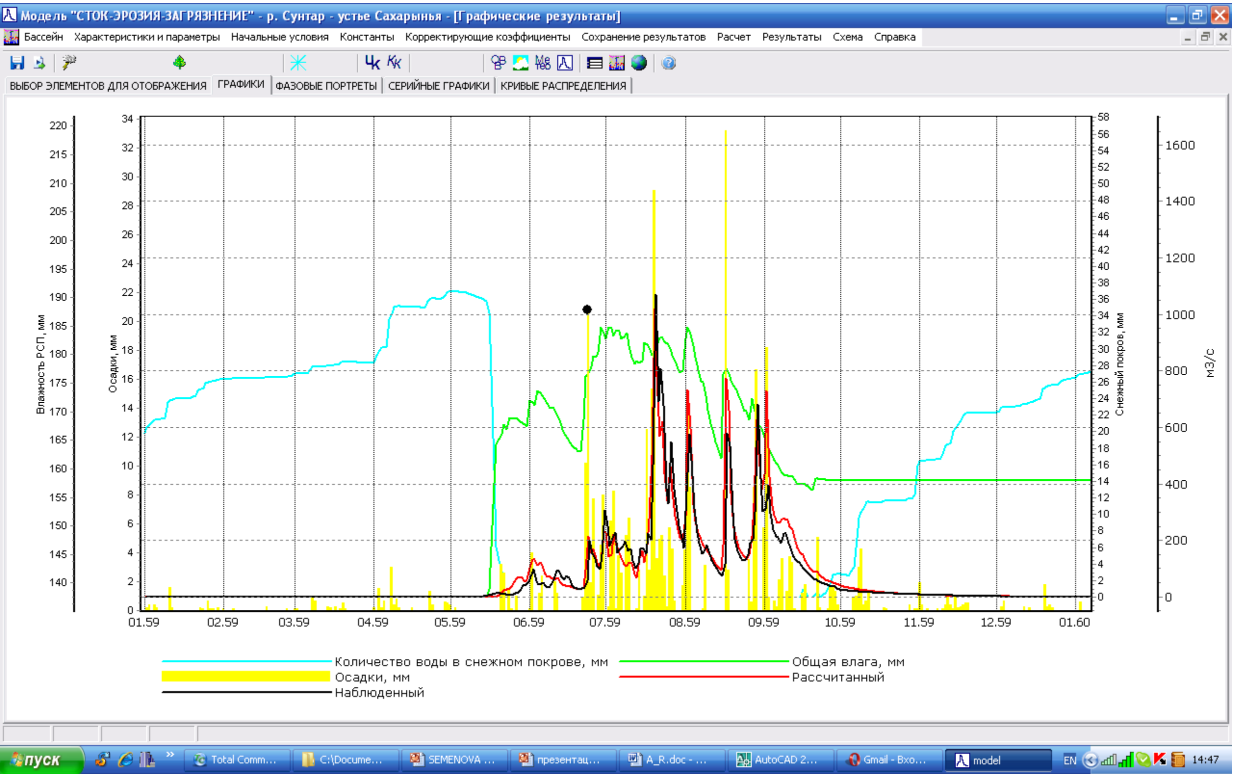
The change in seasonal discharge for watersheds located in different climatic and land cover zones.

Annual discharge increases from increases in winter and spring discharge.

Annual discharge in the southern part of the NEESPI region will significantly decline due to a discharge decrease in the spring and summer-fall periods.

Deterministic Modeling Hydrological System (DMHS or model “Hydrograph”)

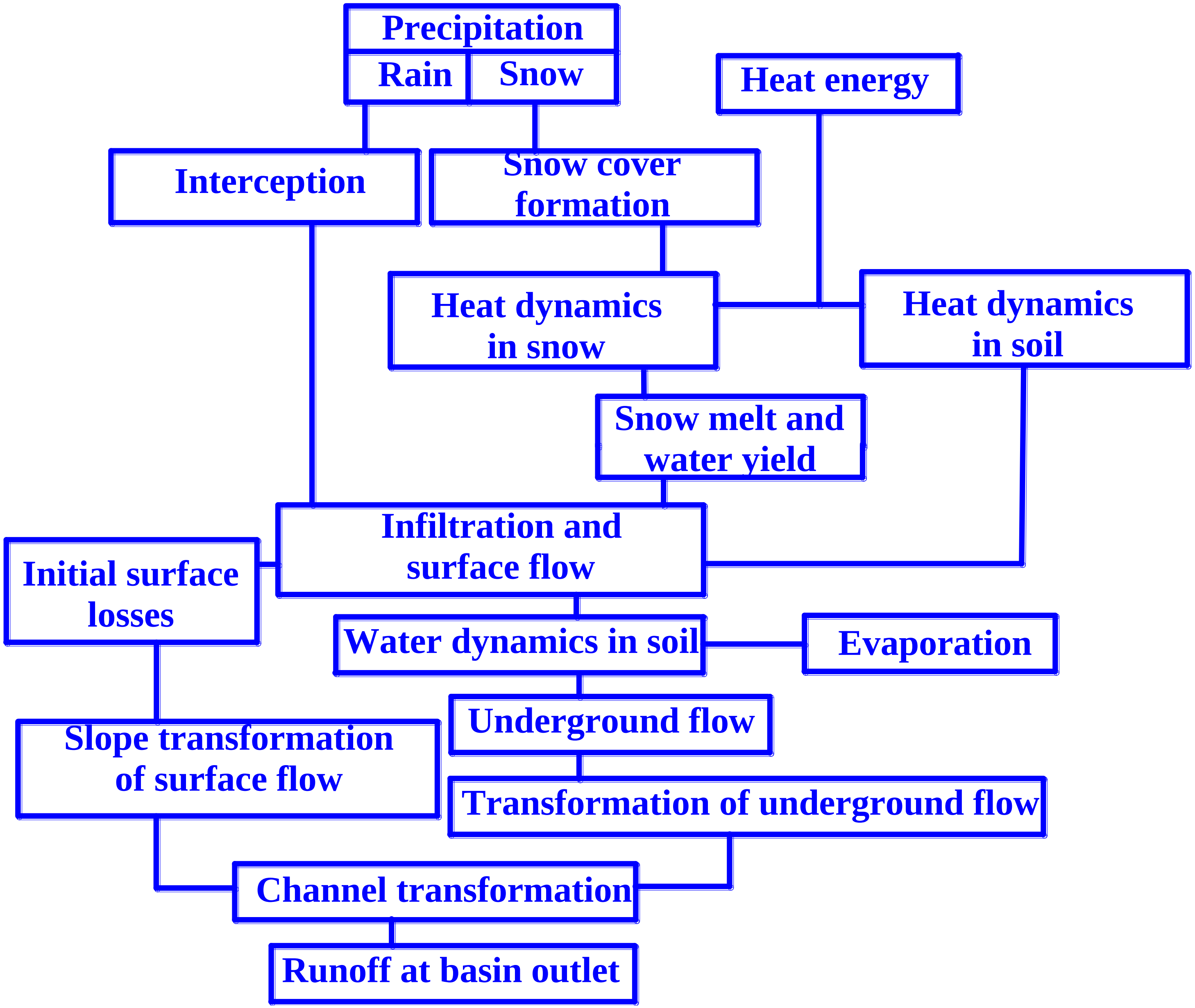
- Universal
- Apriori estimation of most parameters
- Distributed
- Time resolution – 24-hour or less
- Forcing climate, land cover, vegetation and soil data



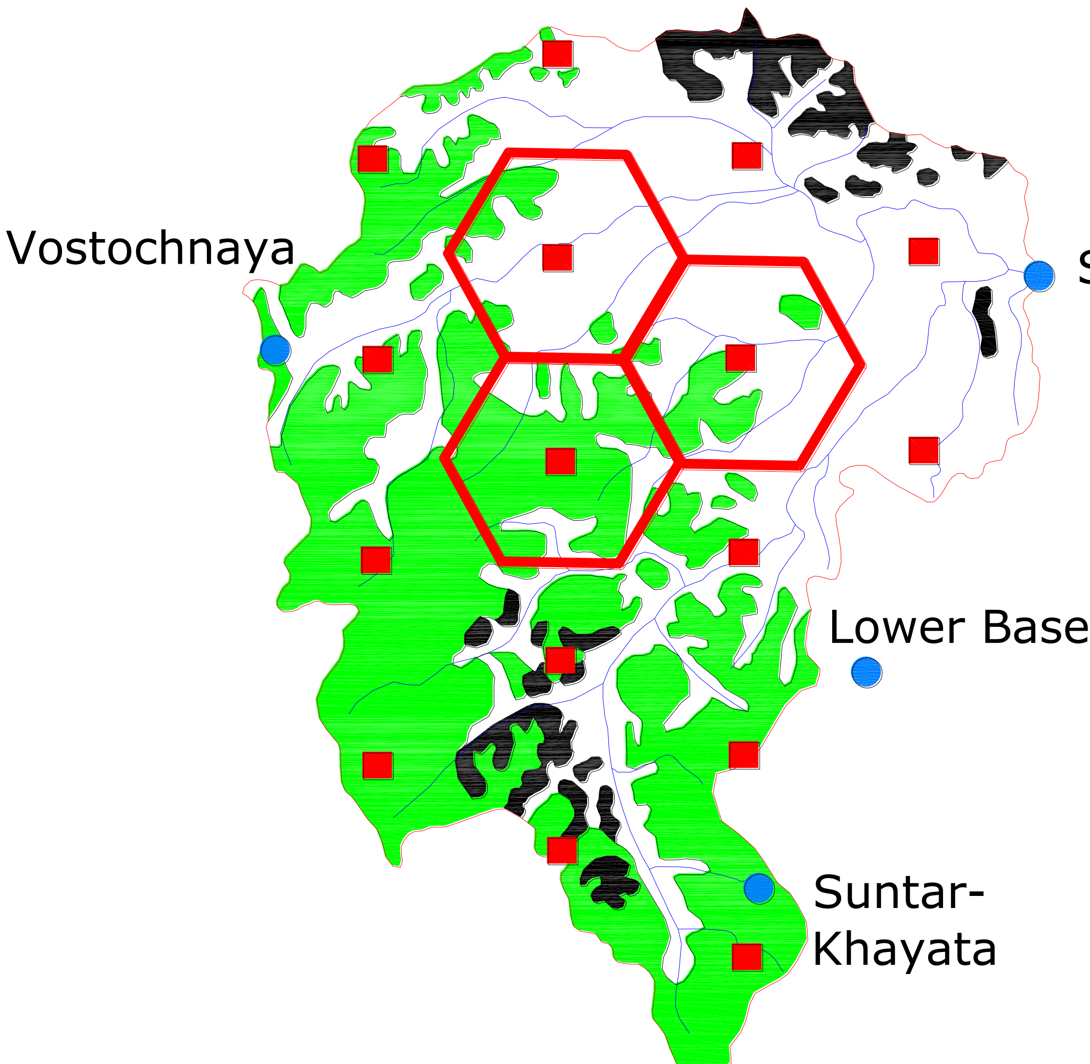
- Output – runoff hydrograph, water balance elements, state variables of soil and snow cover

Vinogradov, Y. B., Semenova, O. M. and Vinogradova, T. A. (2011), An approach to the scaling problem in hydrological modelling: the deterministic modelling hydrological system. Hydrol. Process., 25: 1055–1073. doi: 10.1002/hyp.7901

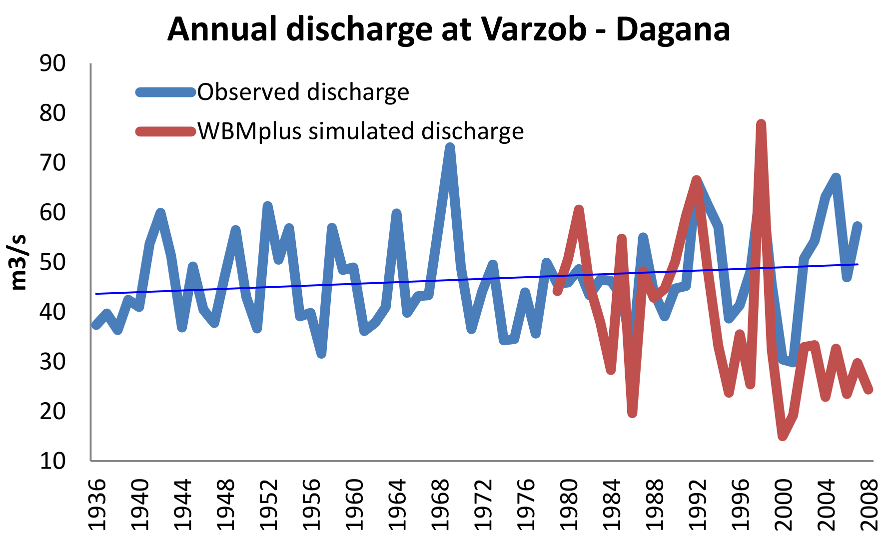
DMHS "HYDROGRAPH" flowchart

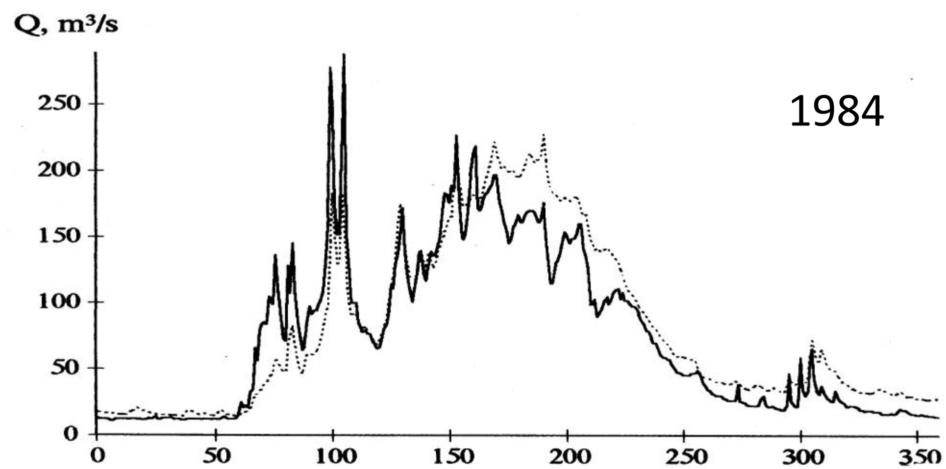


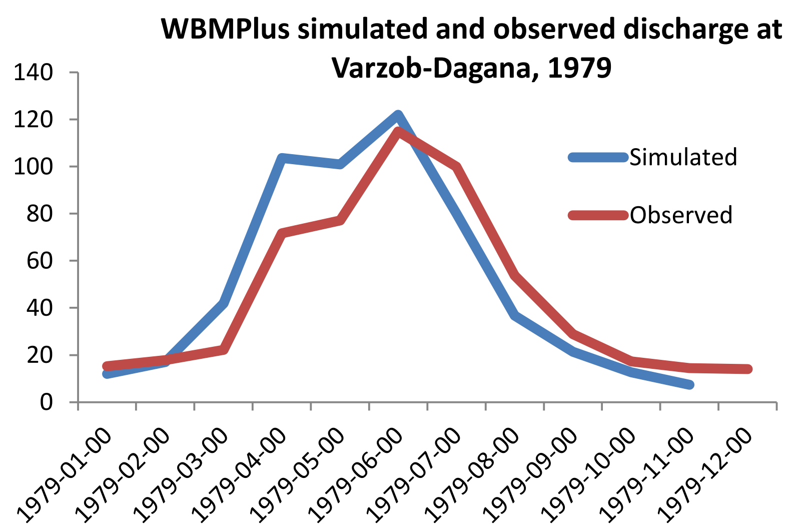
The spatial-computational schematization of the basin

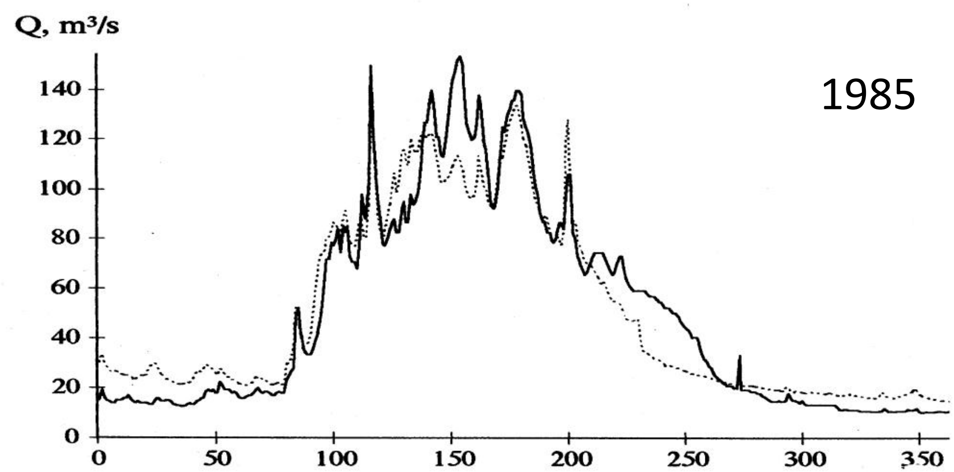


Simulations with models WBMPlus (left plots) and "HYDROGRAPH"(right plots) for Varzob at Dagana, altitude 1500-4500 m, basin area 1270 km²

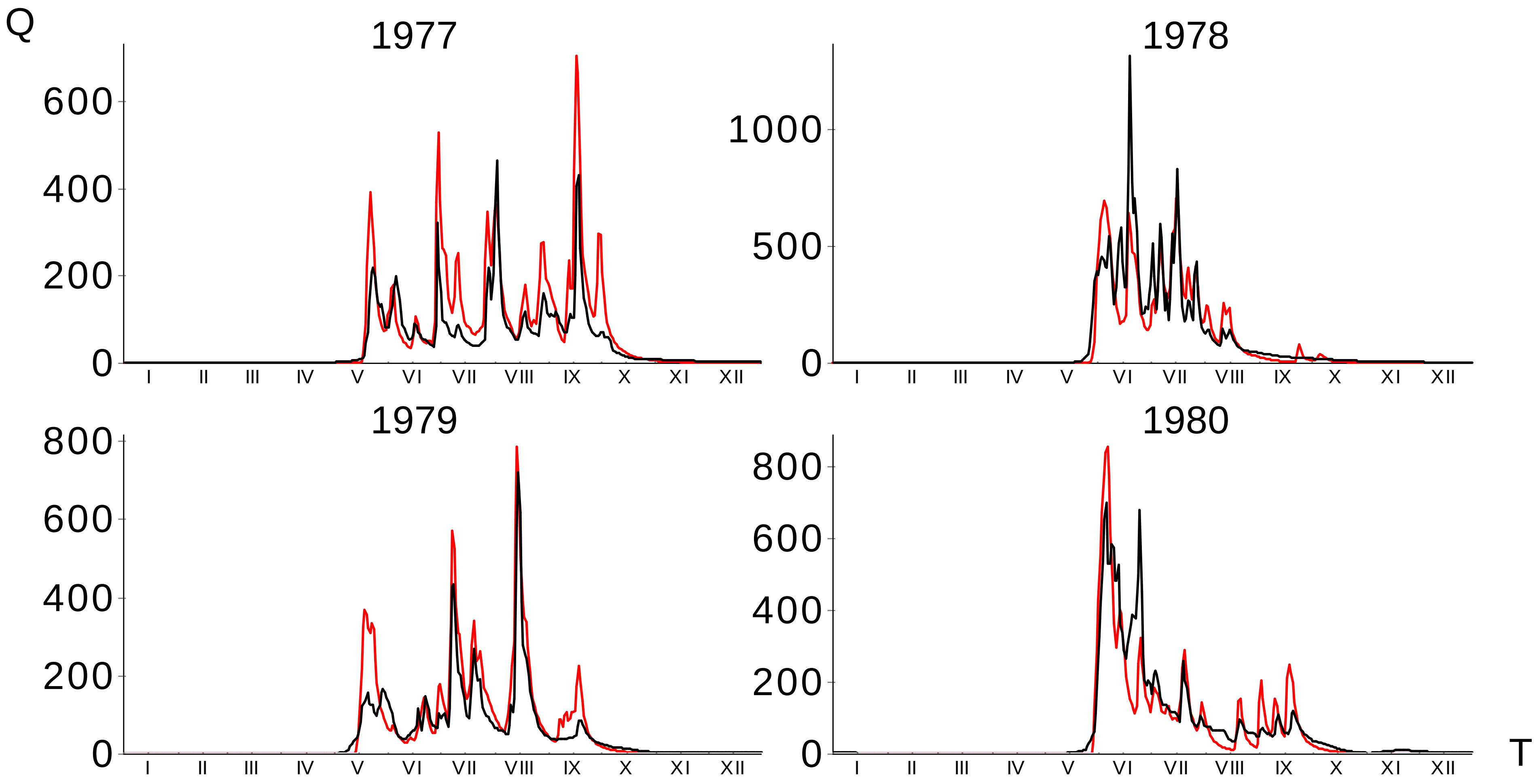






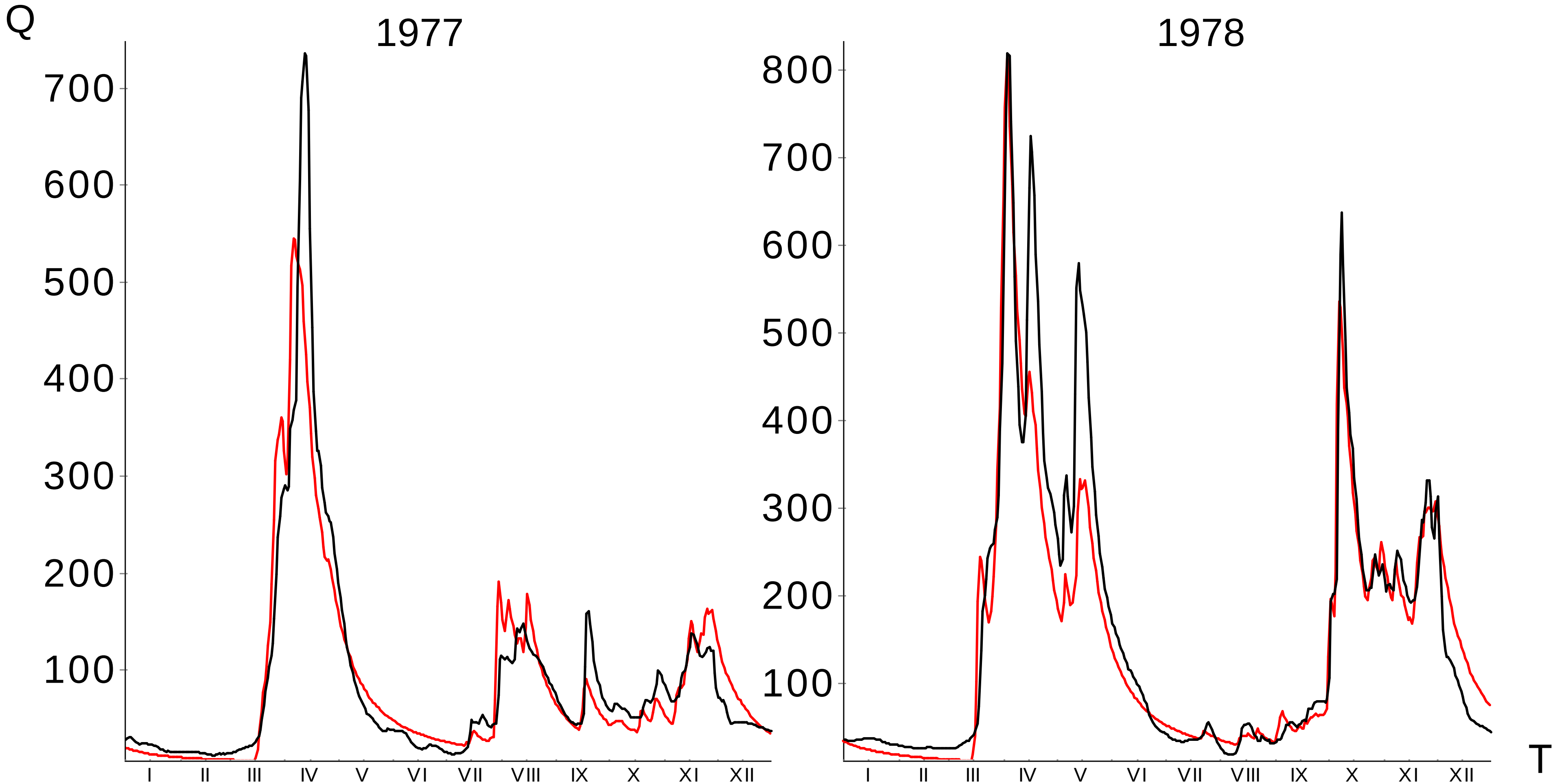


Detrin at Vakhanka river mouth, basin area 5630 km²



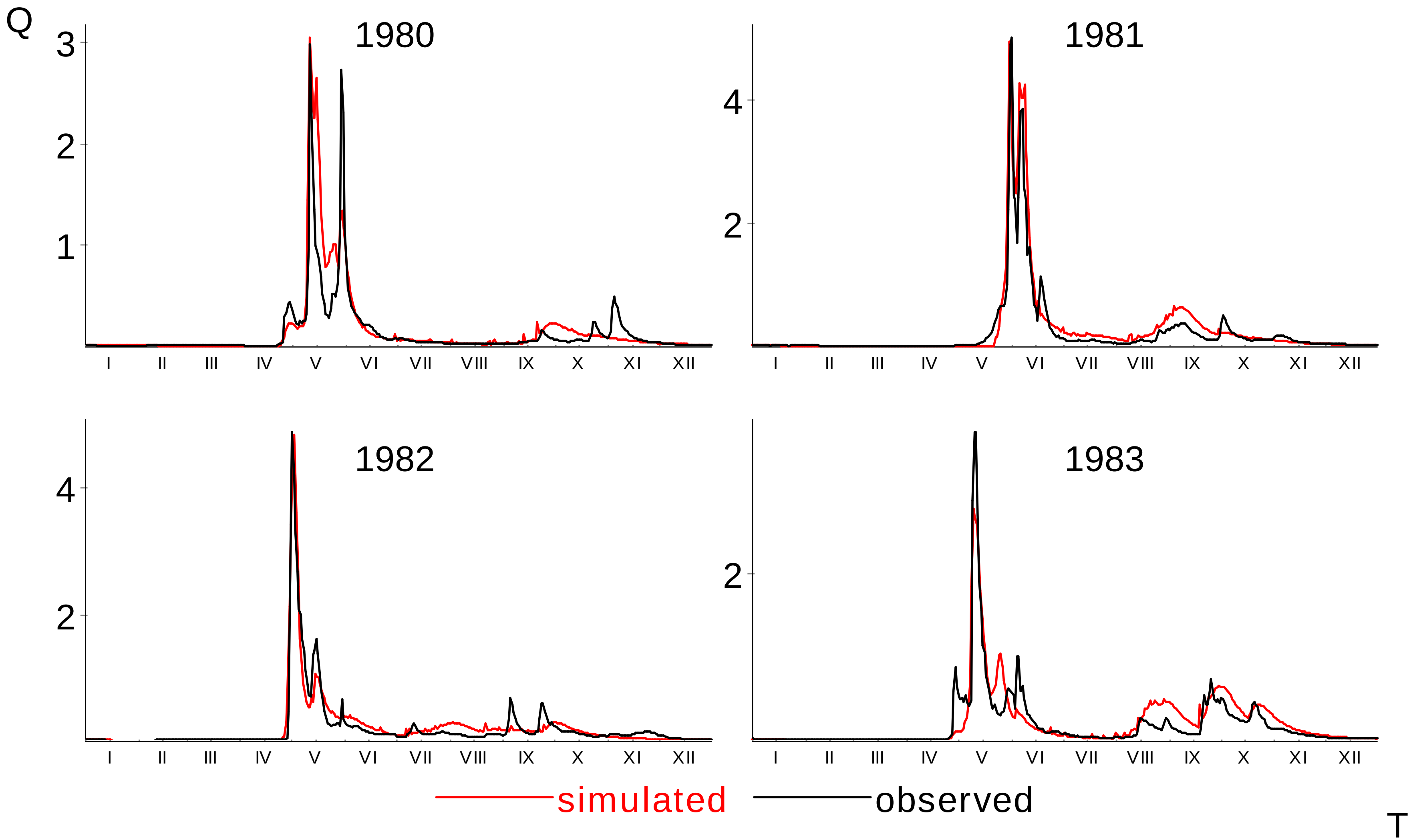
Baltic Sea Basin

Lovat at Holm, drainage area 14700 km^2



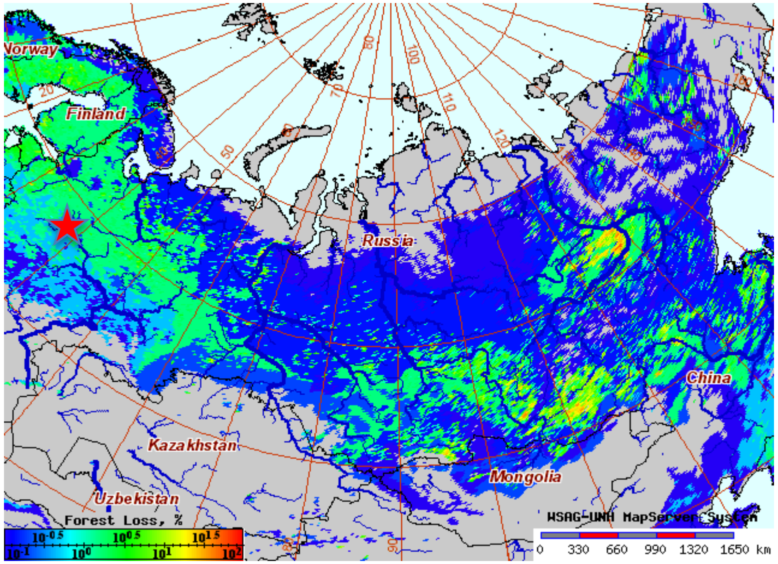
European North of Russia

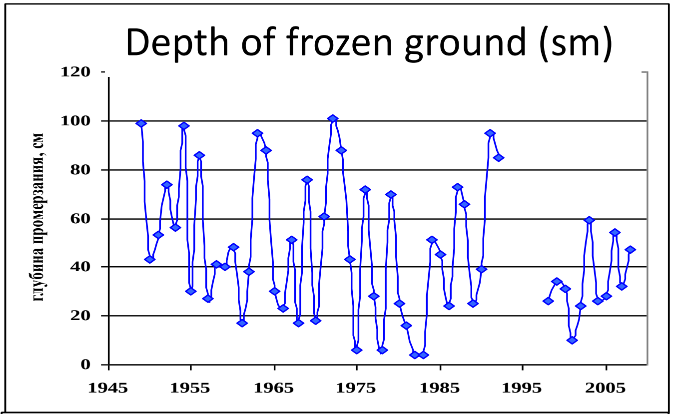
Nyashenny stream at Kotkino, basin area 16.1 km^2

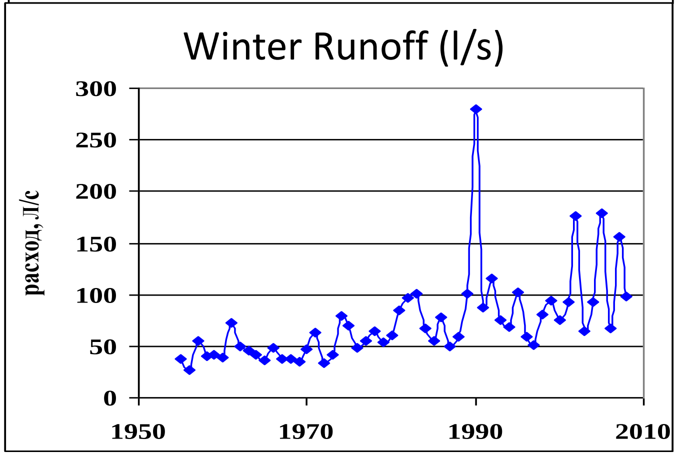


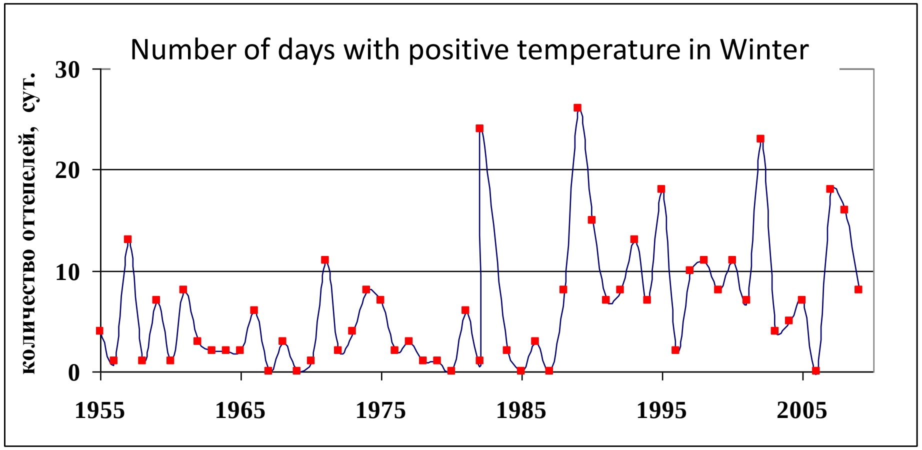
Understanding of changes in winter runoff

r. Medvenka $F=21.5\ km^2$







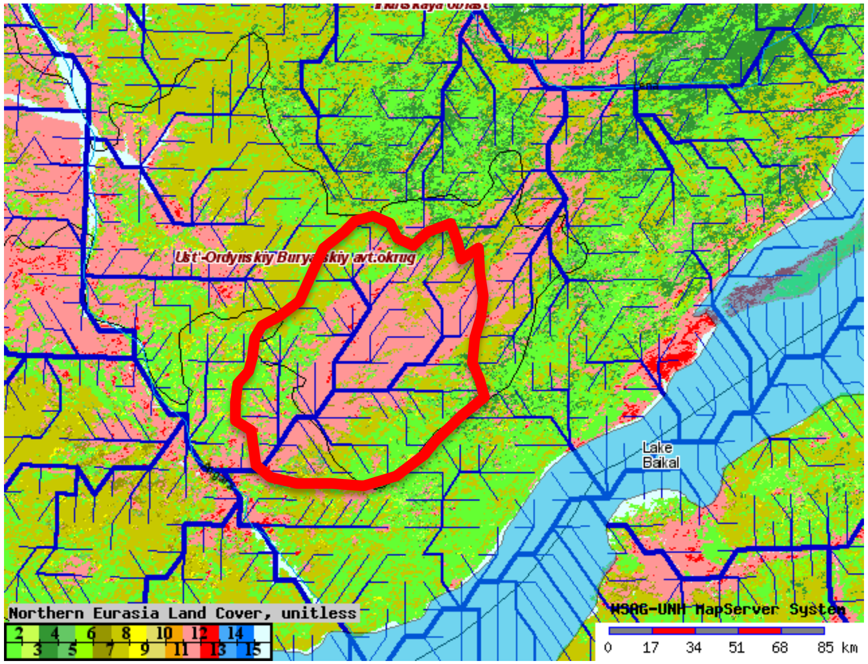


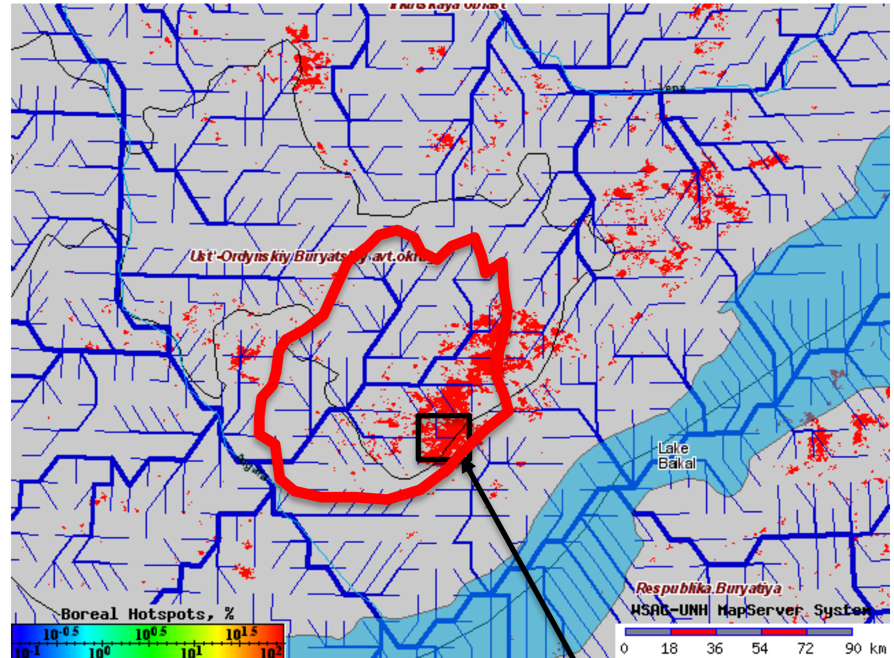
LTM winter runoff (l/s) 1958 -1980	Contribution of different elements into the winter runoff for Medvedka watershed			LTM winter runoff (l/s) 1981-2008
	Fall soil water content	Winter snowmelt	Depth of frozen ground	
49,6	**6**	**38**	**56**	**93,2**

Contribution to increase in winter river discharge: Depth of frozen ground – 56%
Winter snowmelt – 38%
Fall soil water content – 6%

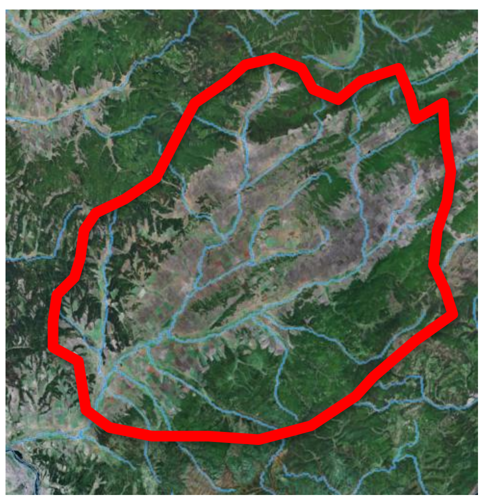
Change in forest cover

Kuda at Granovschina, Dranage Area = 7840 km^2

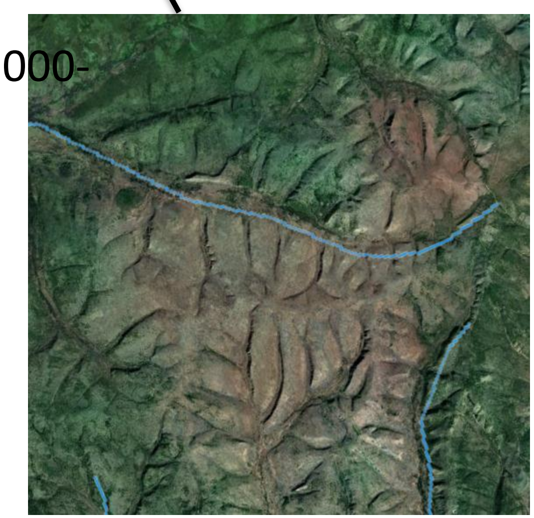




NELDA land cover



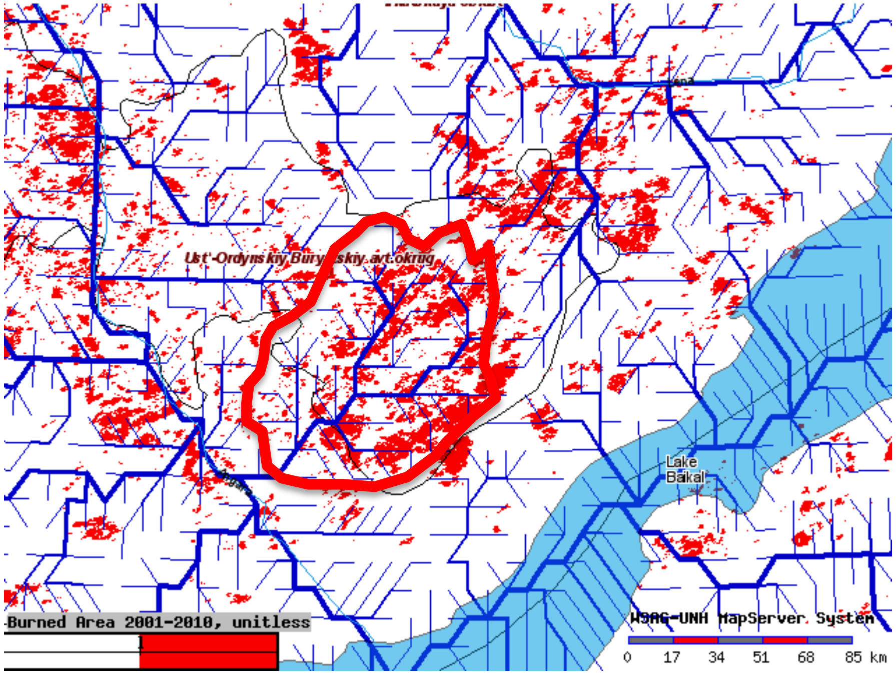
Forest cover loss 2000-2005 (SDSU)

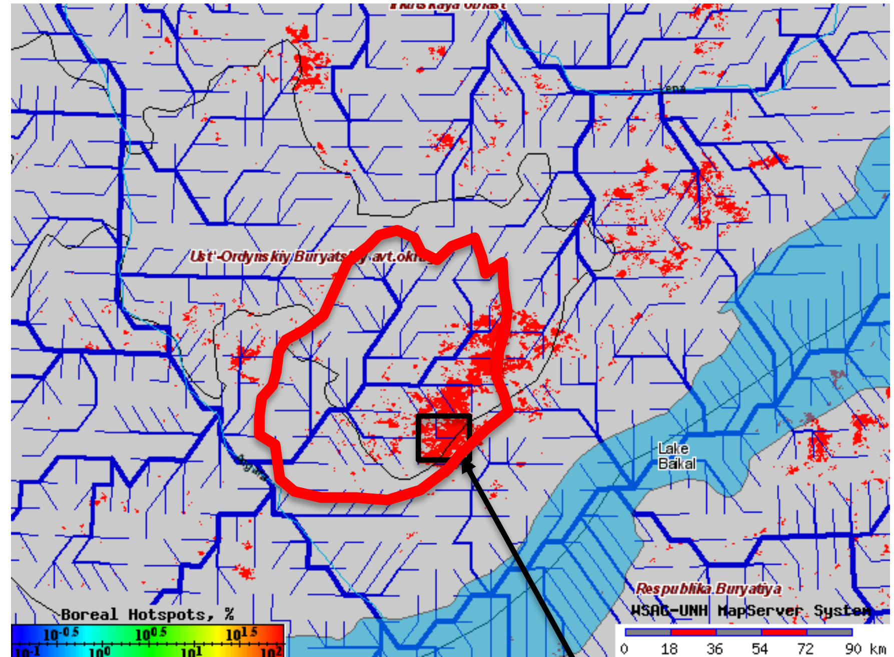


Most forest loss in the watershed due to forest cut and new developments

Change in forest cover

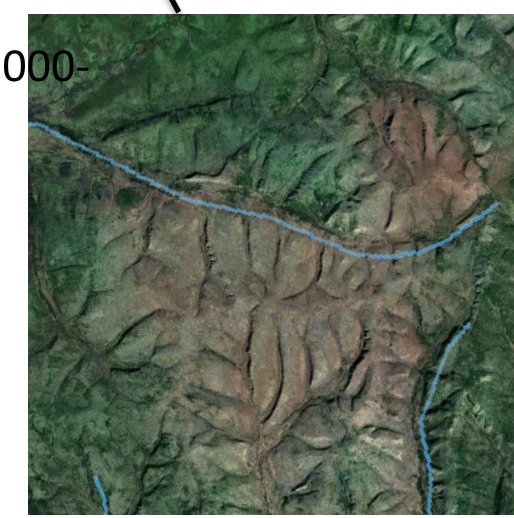
Kuda at Granovschina, Dranage Area = 7840 km^2





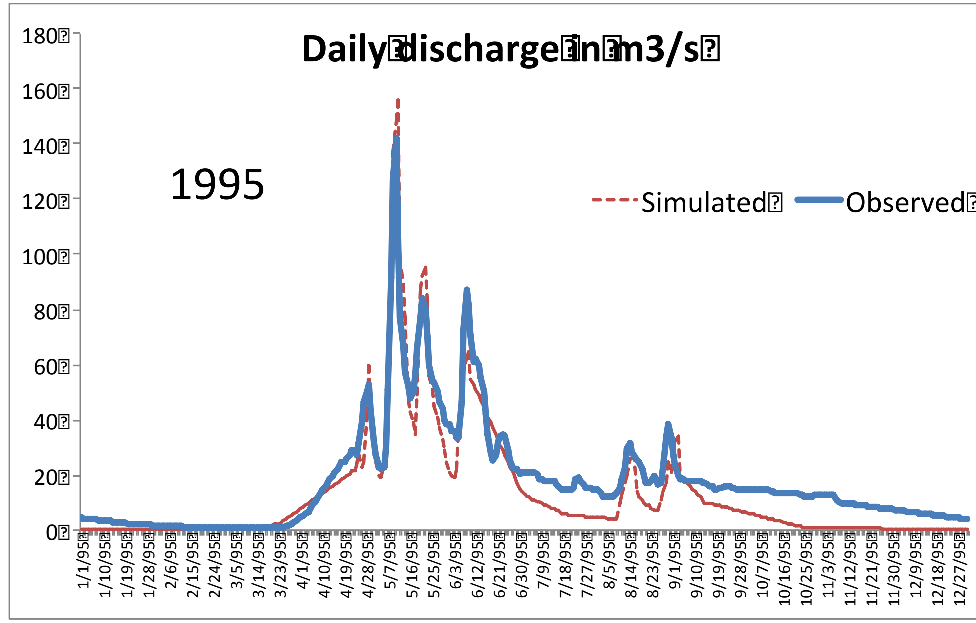
MODIS burned area 2000-10 (UMD)

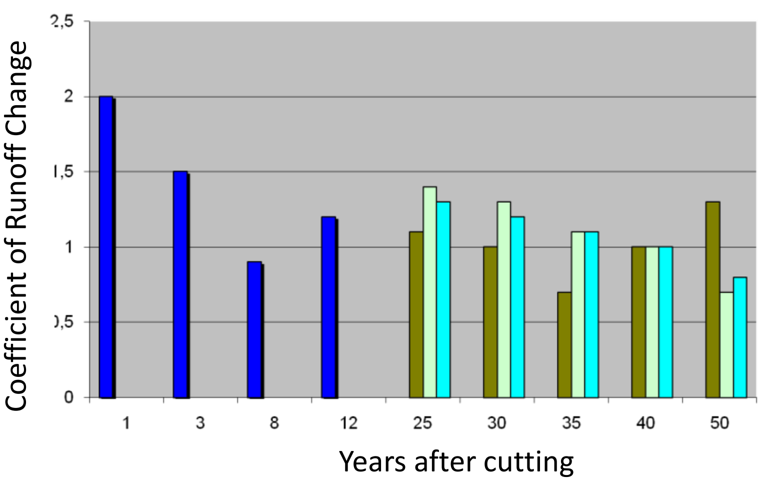
Forest cover loss 2000-2005 (SDSU)

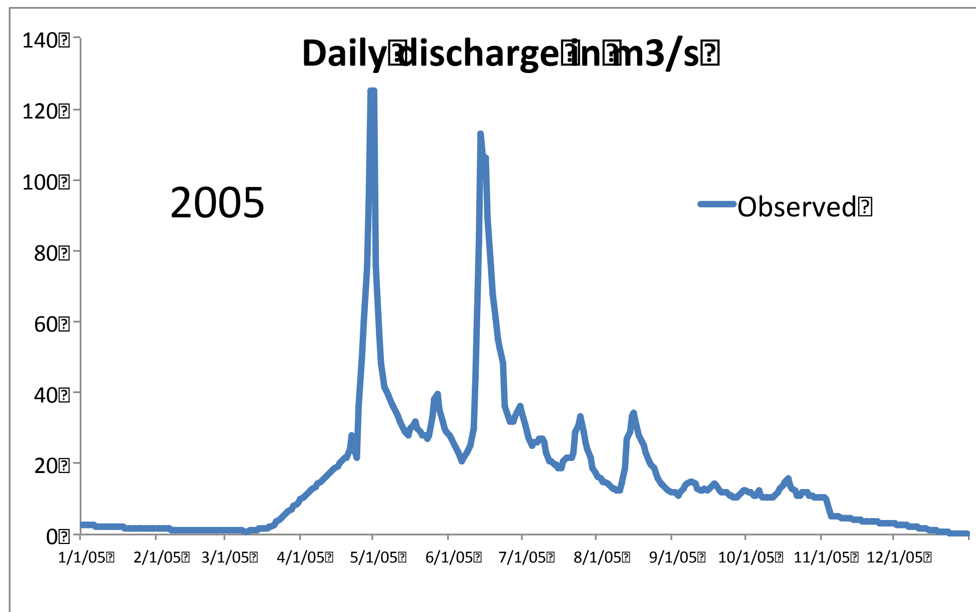


Most forest loss in the watershed due to forest cut and new developments

Without model experiments it is very difficult to evaluate effect of forest change on runoff



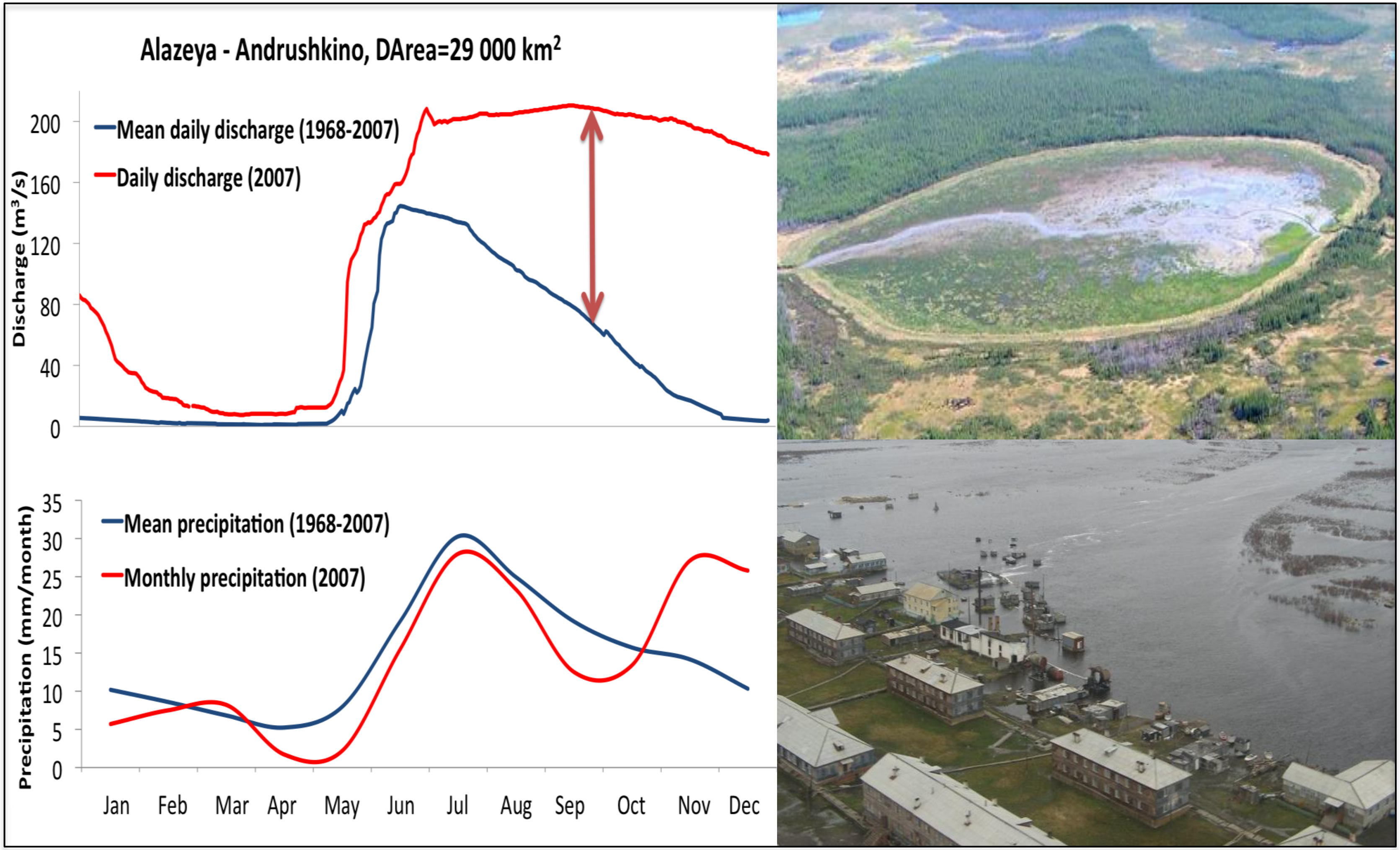




Change in relative runoff after forest cut

Shiklomanov, I., and O. Krestovsky. 1988. Influence of forests and forest reclamation practice on streamflow and water balance.

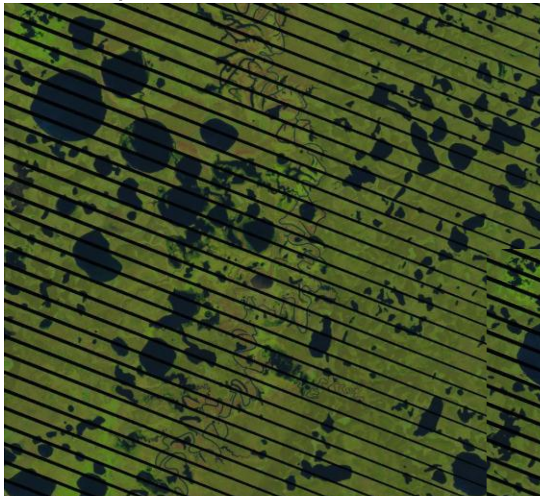
Draining of thermokarst lakes in permafrost zone



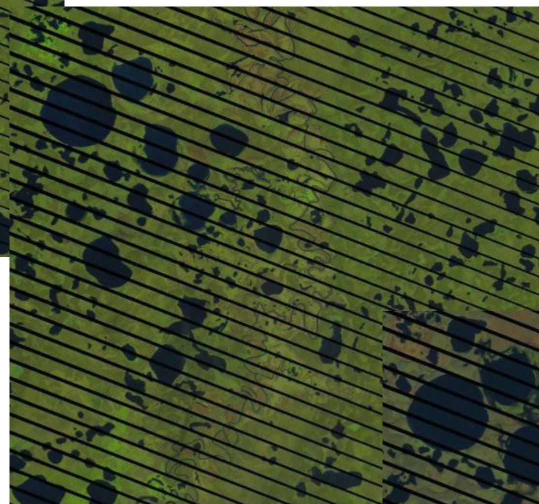
Example of a hydrological anomaly during the summer of 2007 in the Alazeya river basin. Significant flooding at Andrushkino (lower right) F= 19 800 km², resulting from anomalously high summer river discharge (red arrow, upper left) was not the result of basin-wide precipitation (lower left). Subsequent searches for causes yielded drained lakes (upper right).

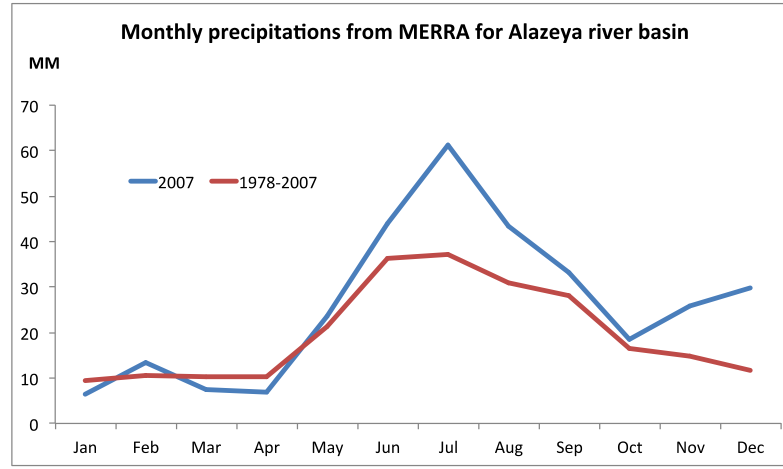
Extreme flood on Alazeya river in 2007

Sep, 2003

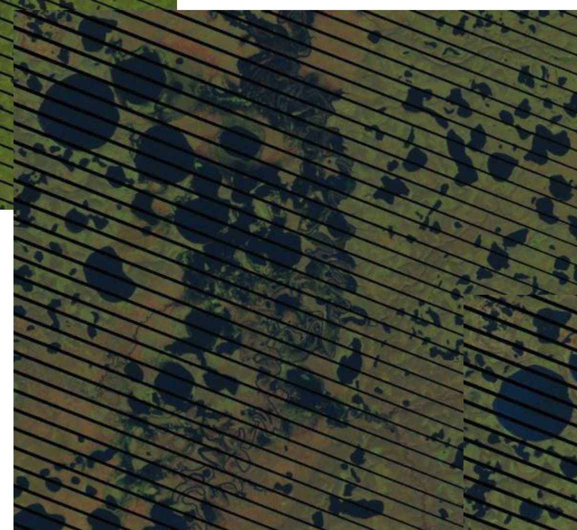


Sep, 2005

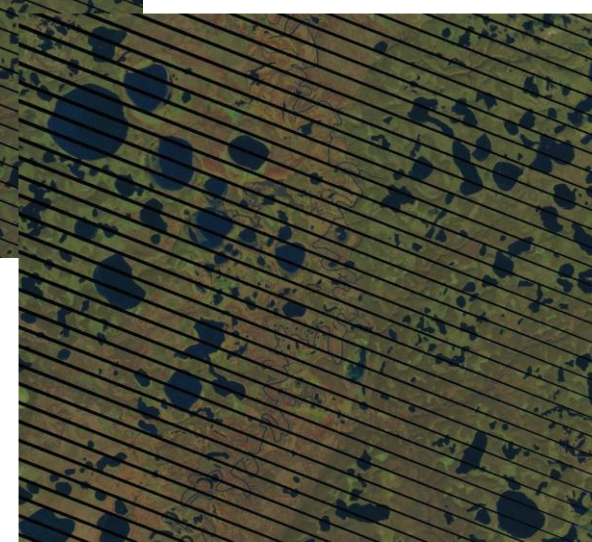


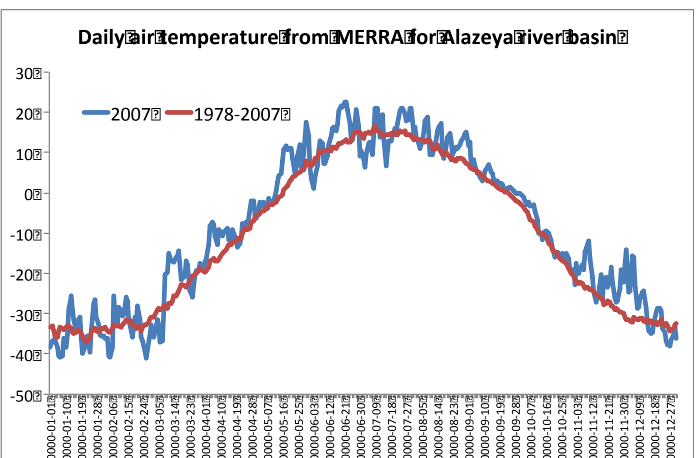


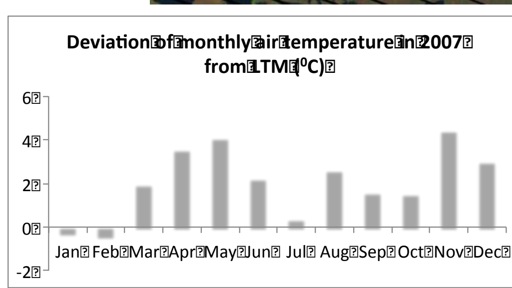
Sep, 2007



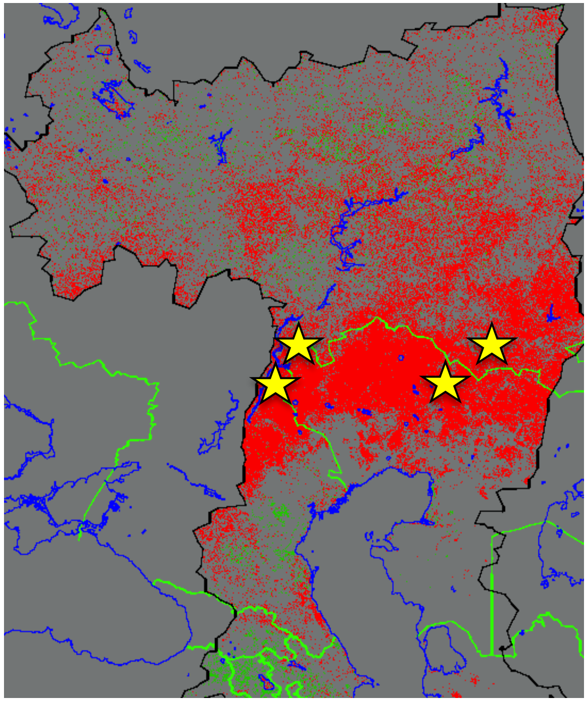
Sep, 2009

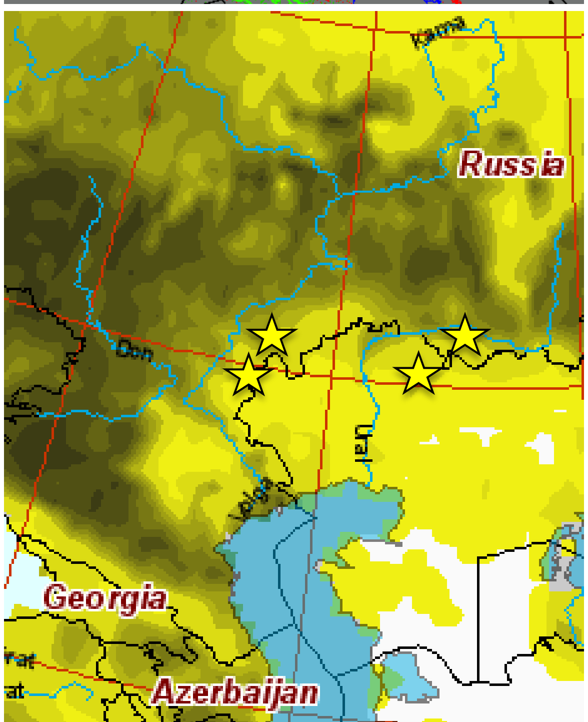


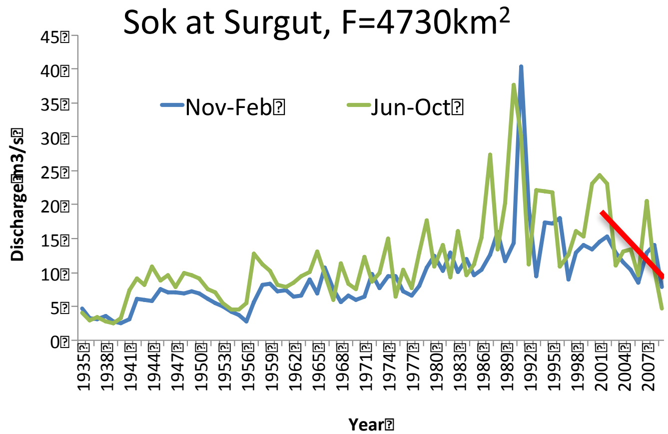


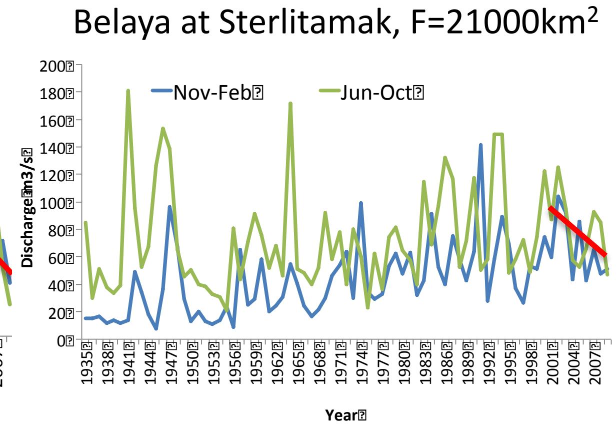


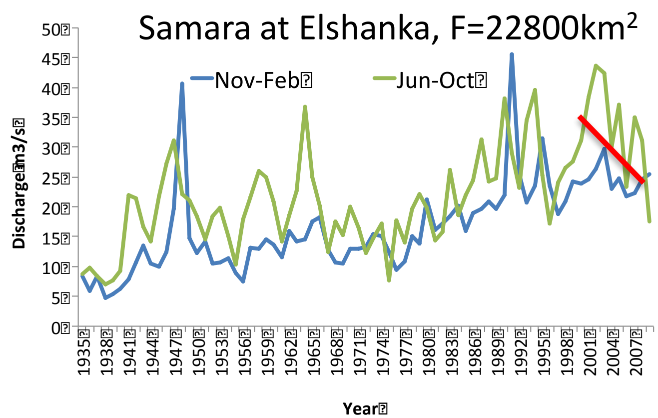
Vegetation change

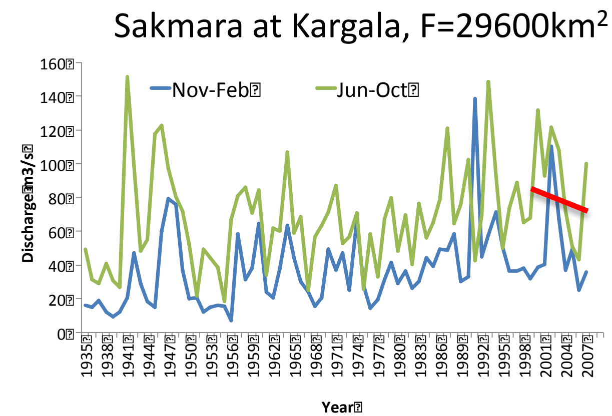




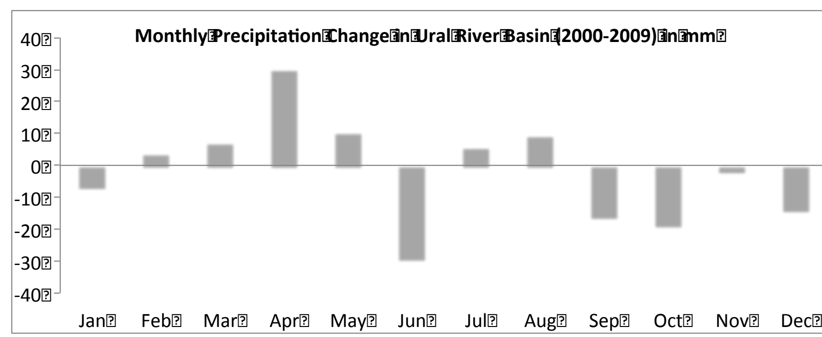






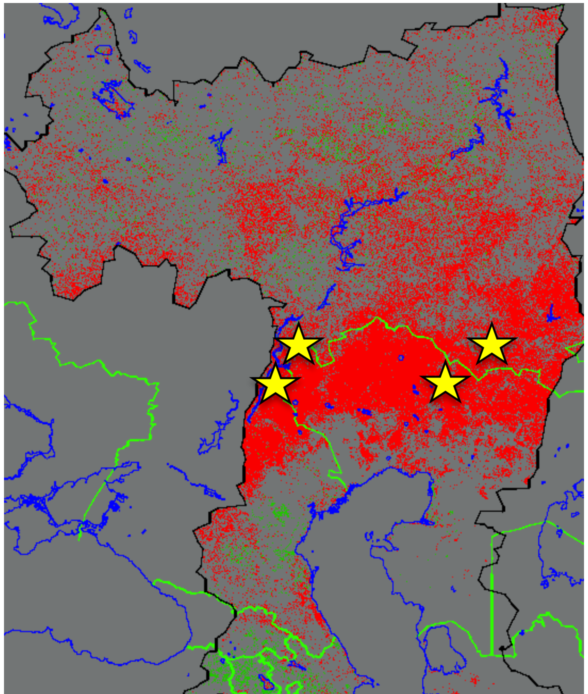


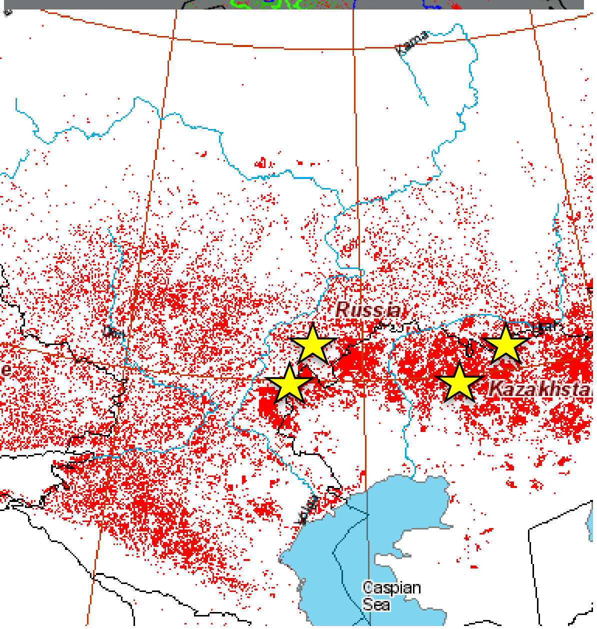
MODIS NDVI trends for Caspian Sea Basin 2000-09 (courtesy to Saachi Sassan)
Cropland distribution (lower map)

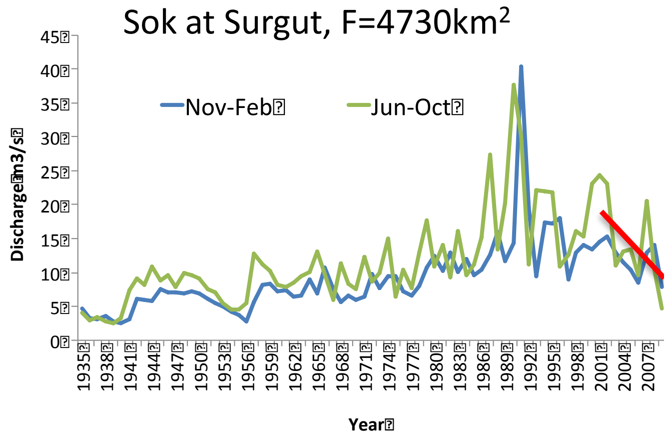


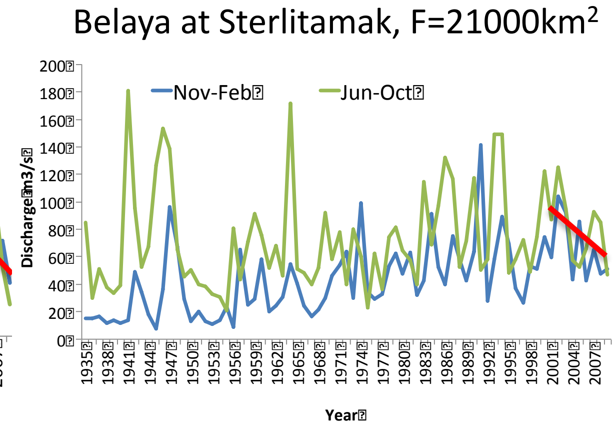
There is a significant positive trend in summer-fall runoff over long-term period. However, since 2000 this trend has shown negative tendency.

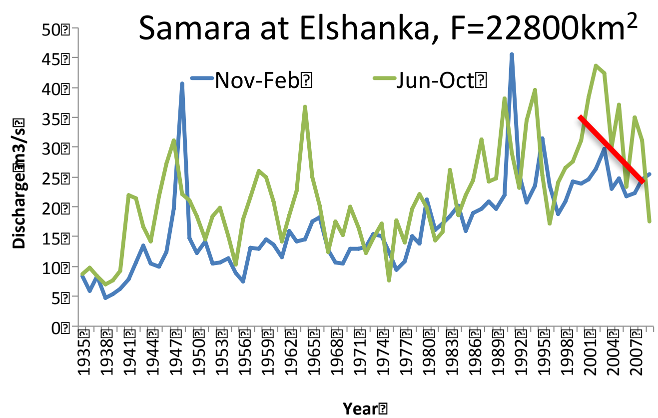
Vegetation change

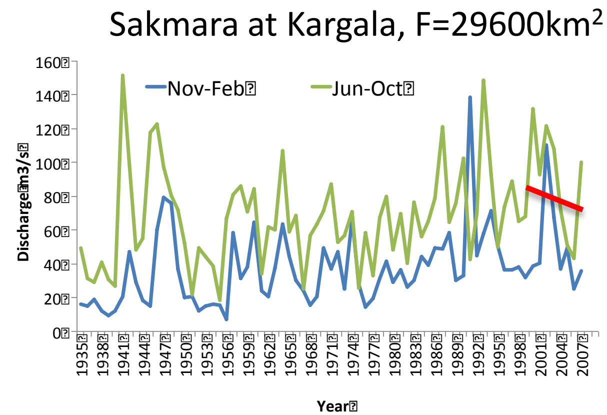




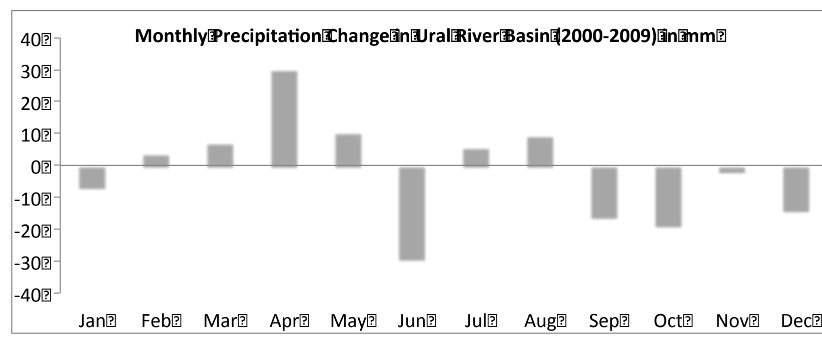








MODIS NDVI trends for Caspian Sea Basin 2000-09 (courtesy to Saachi Sassan) Cropland distribution (lower map)



There is a significant positive trend in summer-fall runoff over long-term period. However, since 2000 this trend has shown negative tendency.

Evaluation of the effects of the interrelated changes in climate and land cover/land use on human

RESEARCH QUESTIONS:

- How has environmental change effected Russian Arctic administrative regions through time?
- What are the socioeconomic implications of ongoing air temperature change?

GOAL:

To provide a quantitative cost benefit analysis assessment of environmental change implications for the Russian North

March 17th, 2010:
Dmitry Medvedev held a Security Council meeting on preventing national security threats arising from global climate change.

http://eng.kremlin.ru/news/140

"National Security Challenged by Climate Change" *The Barents Observer* (3-23-10) .

"The Russian Security Council believes climate change will pose a serious threat to national security, a council representative confirms in a newspaper interview."
http://www.barentsobserver.com

"Moscow Views Climate Change as a Security Threat, Mulls Creating 'Climatic Assistance' Program." *WindowonEurasia* (3-24-10).

"Russia, as experts around the world agree, is likely to be more profoundly affected by climate change than any other country, and Moscow is now focusing on the security threats global warming may entail not only within the country but in its relations with its closest neighbors."

http://windowoneurasia.blogspot.com/

Benifits

- Increase of heat supply and length of the growing season will improve the structure of crop production by expanding the planting heat-loving crops, as well as expansion of the north boundary of commercial agriculture.
- Climate change could lead to improved water availability across the Russia.
- Increase in annual runoff improves the conditions for hydropower development
- Air temperature increase will reduce energy consumption during the heating season

Dr. Yury Averyanov, a member of Russia's Security Council
***Rossiiskaya Gazeta* (3-19-10)**
(http://www.rg.ru/2010/03/19/klimat.html)

Challenges

- Climate change can create new international conflicts related to the exploration and production of energy, the use of marine biological resources and transportation routes, drinking water and so on.

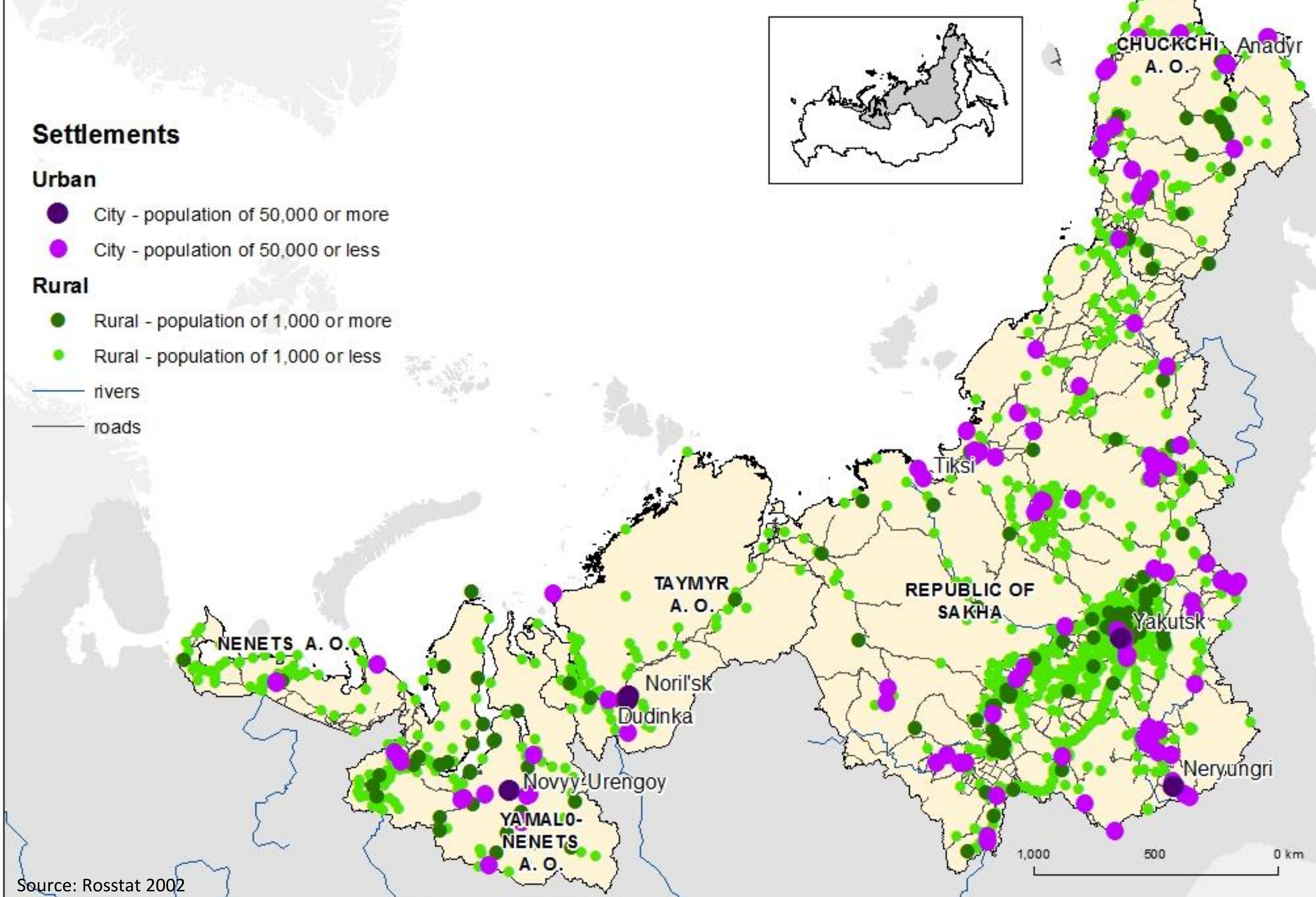
- Climate change can increase the risk of conflicts related to water scarcity and food production along the southern Russian borders.

- Polar countries, including the U.S. and its allies are actively expanding their scientific research, economic development and military presence in the Arctic zone. They are making efforts to зкумуте Russia's access to the exploration and development Arctic oil and gas fields.

- Permafrost occupies a two-thirds of the Russia and significant changes are possible in areas with unstable permafrost. Global change will lead to reducing the strength of buildings and engineering structures located in this zone.

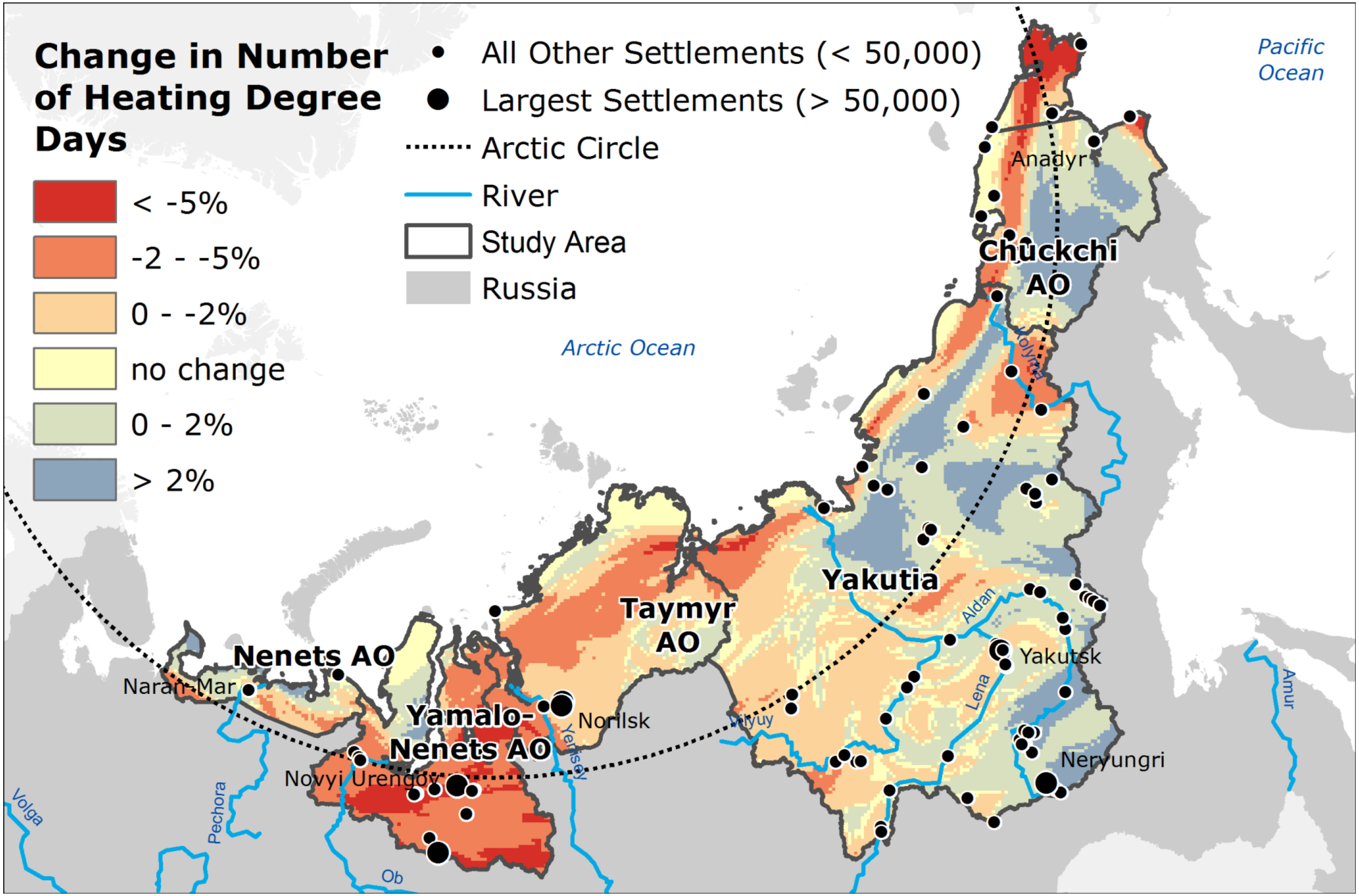
Dr. Yury Averyanov

Settlements of the Russian North



Source: Rosstat 2002

ENERGY CONSUMPTION:



- Number of heating degree days considers the number of days temperature falls below 8 degrees C
- Change from 2000s converted to % of change from 1960s period to show change in days

Source: NCEP 2m Temp Data

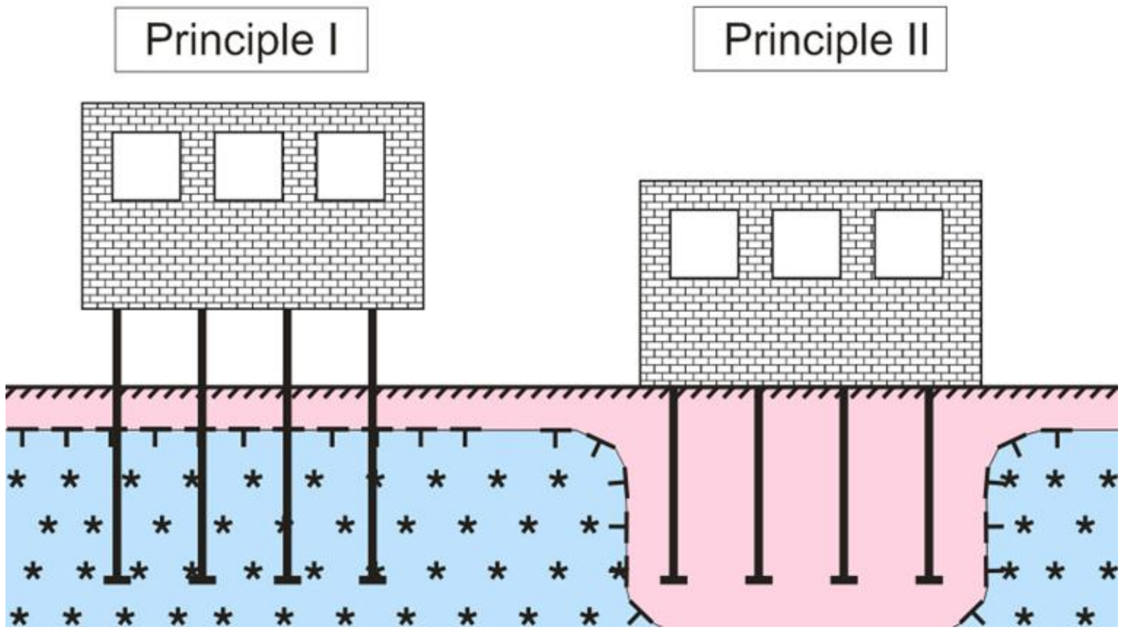
INFRASTRUCTURE:
Change in Bearing Capacity

"…One of the possible reasons of deformations occurred in the wall of "Agriculture of Far North" Research Institute is anomaly warm summer of 2009"

"…The institute was built in 1985"

News.NGS24.ru

Permafrost Construction Principals



More than 75% of engineering structures on permafrost in Russia are built according to the ”First Construction Principle”, which relies on the *freezing strength* (bearing capacity) of the frozen ground to support structures.

Bearing Capacity of a “Standard Foundation Pile” imbedded in permafrost is used in Russia as a primary variable for engineering assessment of the permafrost-affected territory.

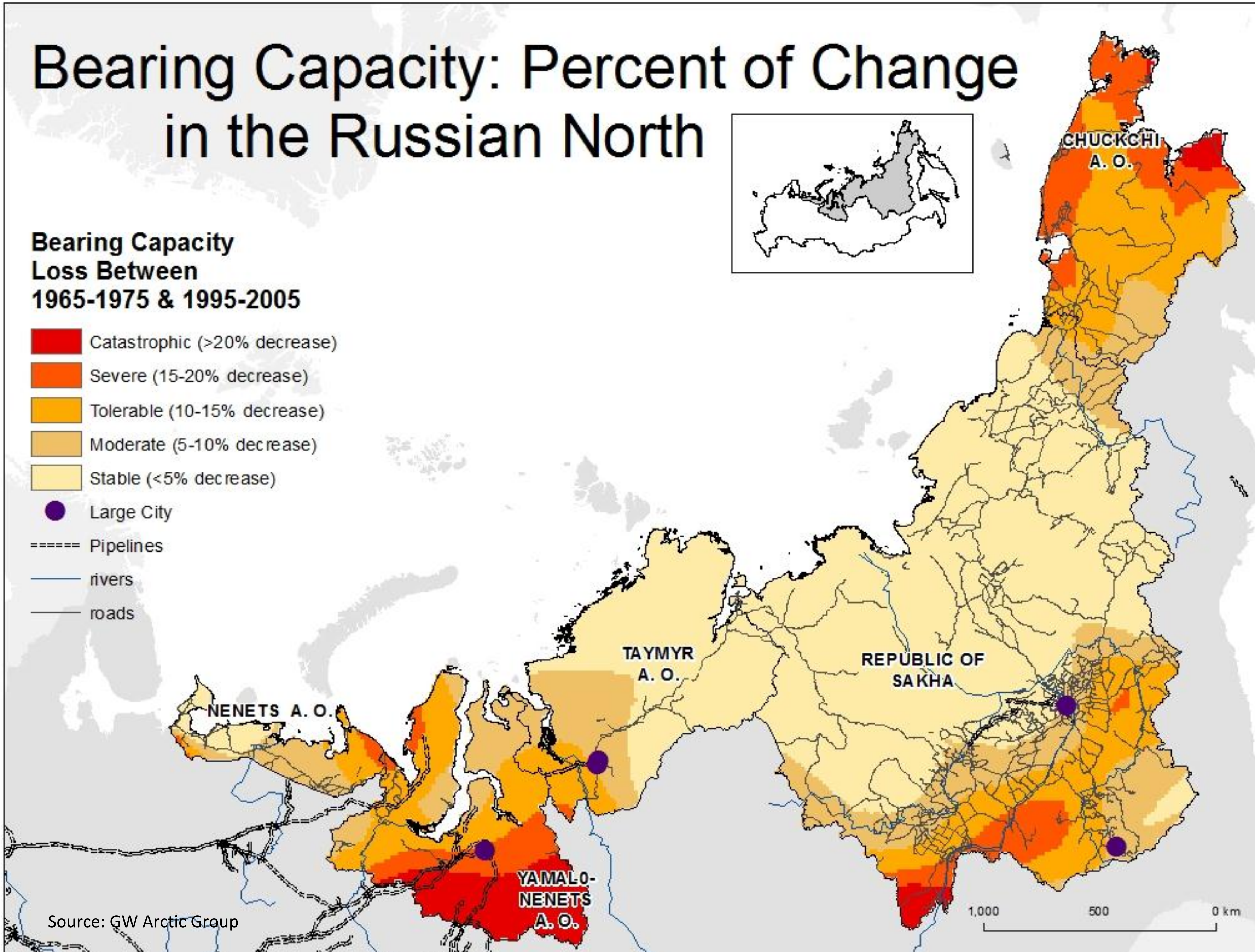
Buildings in Russian North

The percent of buildings with deformations in some of the Russian northern settlements

Location	Population*	Buildings with deformations**, %
Yakutsk	284,000	9
Norilsk	205,000	10
Tiksi	5,600	22
Dikson	600	35
Amderma	500	50
Magadan	99,000	55
Vorkuta	71,000	80
Chita	307,000	60

*Federal Department of Statistics on 01.01.2009

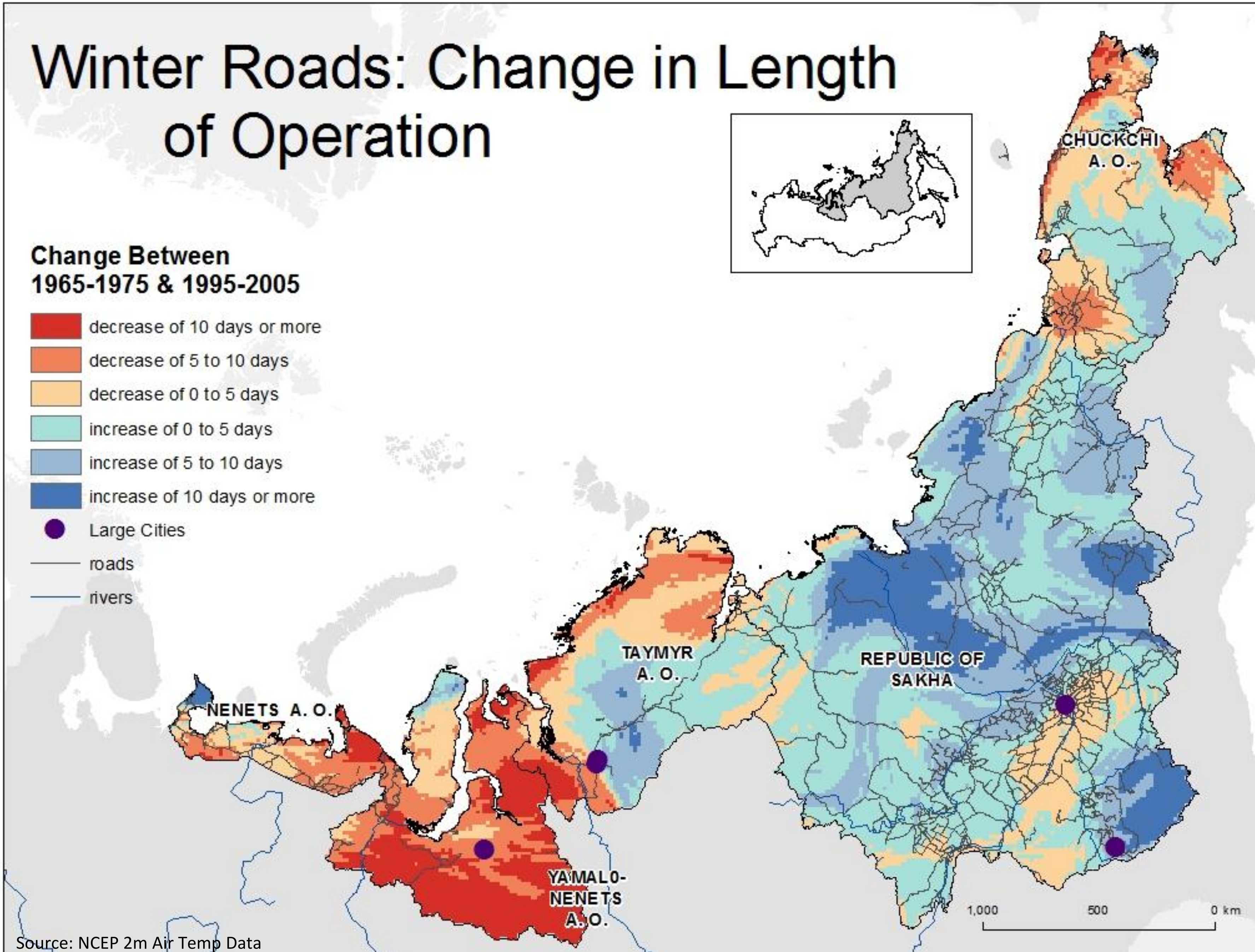
**Moscow State University of Civil Engineering (2003)


Bearing Capacity: Percent of Change
in the Russian North
Bearing Capacity
Loss Between
1965-1975 & 1995-2005
Catastrophic (>20% decrease)
Severe (15-20% decrease)
Tolerable (10-15% decrease)
Moderate (5-10% decrease)
Stable (<5% decrease)
Large City
Pipelines
rivers
roads
CHUCKCHI
A. O.
TAYMYR
A. O.
REPUBLIC OF
SAKHA
NENETS A. O.
YAMALO-
NENETS
A. O.
1,000
500
0 km
Source: GW Arctic Group

TRANSPORTATION:
Change in length of winter road season

- Parameter: Number of days for the reference periods as a change in %

- Method: Days include time from when winter road construction begins in the fall when temperatures drop to below -7°C, and are operational until the spring when temperatures reach 4°C and start to melt, change in number of days during the 1995 - 2005 as a % of 1965 - 1975


Winter Roads: Change in Length of Operation
Change Between 1965-1975 & 1995-2005
decrease of 10 days or more
decrease of 5 to 10 days
decrease of 0 to 5 days
increase of 0 to 5 days
increase of 5 to 10 days
increase of 10 days or more
Large Cities
roads
rivers
CHUCKCHI A. O.
TAYMYR A. O.
REPUBLIC OF SAKHA
NENETS A. O.
YAMAL0-NENETS A. O.
1,000
500
0 km
Source: NCEP 2m Air Temp Data

Supported under this project:

Edited volumes:

Anisimov O.A., Anohin Y.A., Lavrov S.A., Malkova G.V., Myach L.T., Pavlov A.V., Romanovsky V.A.**, Streletskiy D.A**., Kholodov A.L., **Shiklomanov N.I.** (in alphabetical order). 2012. Chapter 8: Continental Permafrost. In Semenov S.M. (ed.) Modern Methods of climate change assessments in Russia, Roshydromet, Moscow, Russia, 268-328 *(In Russian).*

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Shiklomanov, A.I. R.B. Lammers, D. Lettenmaier, Yu. Polischuk, O. Savichev, L.C. Smith, 2012: Hydrological changes: historical analysis, contemporary status and future projections [Chapter 4 in "Regional Environmental Changes in Siberia and Their Global Consequences", Ed. Gutman and Groisman], Springer, in press.

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Shiklomanov A. I. and **Lammers R. B**. (2009). Record Russian river discharge in 2007 and the limits of analysis. *Environ. Res. Lett.* **4** 045015 (9pp) doi: 10.1088/1748-9326/4/4/045015.

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Shiklomanov N.I., Streletskiy, D.A., Nelson F.E., Hinkel K.M., Brown J. 2012. Circumpolar Active Layer Monitoring (CALM). *Proceedings of the 10th International Conference on Permafrost, Salekhard, Russia, (in press)*

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Streletskiy, D.A., Shiklomanov N.I., *Hatleberg E. 2012.* Infrastructure and a Changing Climate in the Russian Arctic: A Geographic Impact Assessment. *Proceedings of the 10th International Conference on Permafrost, Salekhard, Russia, (in press)*

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held at the State Hydrological Institute (SHI), Saint Petersburg, Russia, on March 4-6, 2009.
(42 participants from 7 countries including USA, Russia, Belorussia, Ukraine, Kazakhstan, Uzbekistan, Kyrgyzstan)

Hydrological consequences of changes in land cover/use and climate across Northern Eurasia held at the State Hydrological Institute (SHI), Saint Petersburg, Russia, on February 7-9, 2012
(37 participants from 6 countries including USA, Russia, Belorussia, Kazakhstan, Uzbekistan, Tajikistan)

Thank you