Hydrological Change in the NEESPI Region

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contributions from

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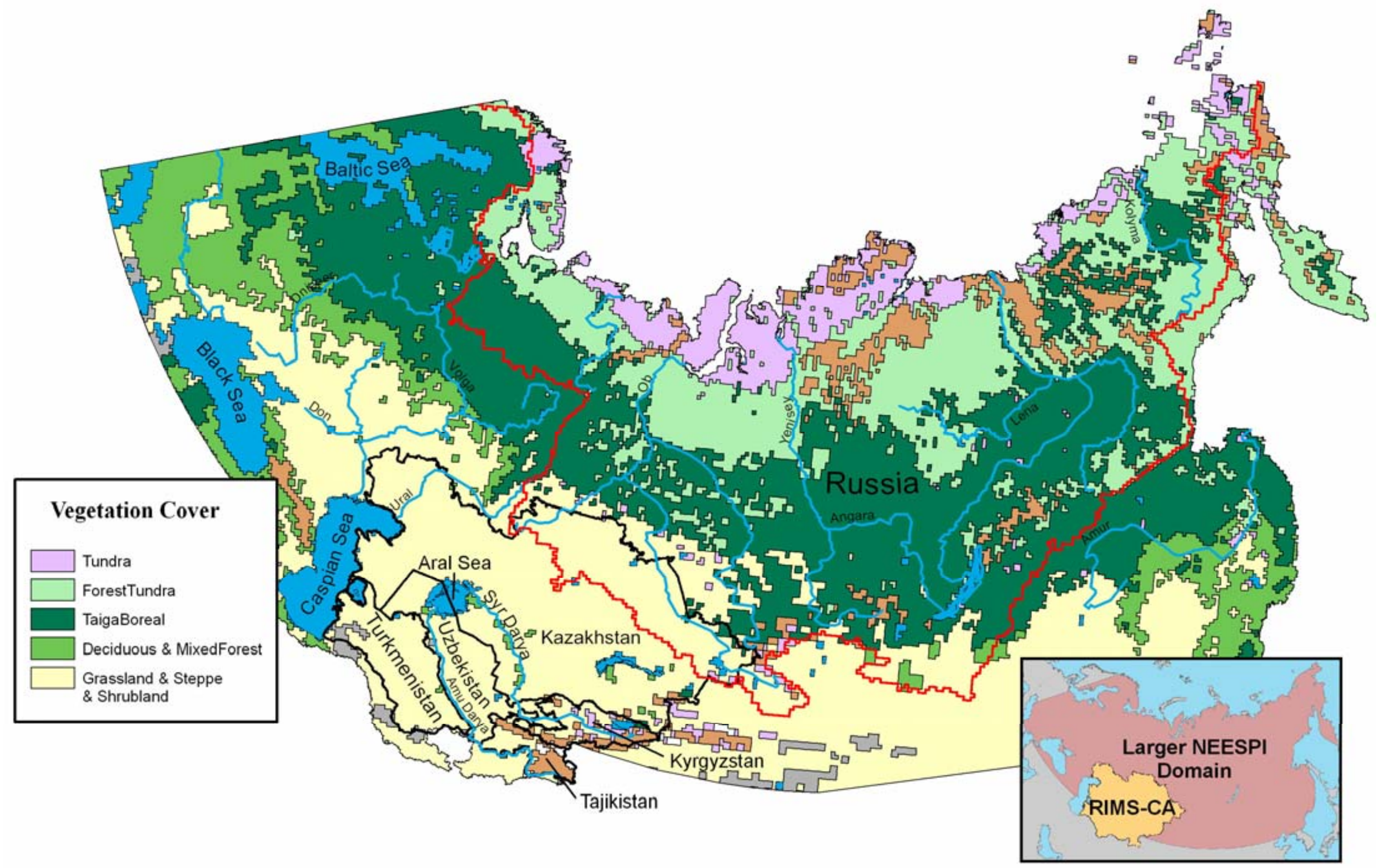
Domains for two NEESPI projects

Role of land cover and land use change in hydrology of Eurasian pan-Arctic



Contributions of Changes in Land Use/Land Cover, Water Use, and Climate to the Hydrological Cycle Across the Central Asian States

Challenges for progress

A) Bring together physical and human dimensions worlds

B) Ranking the major forcings on the water system.

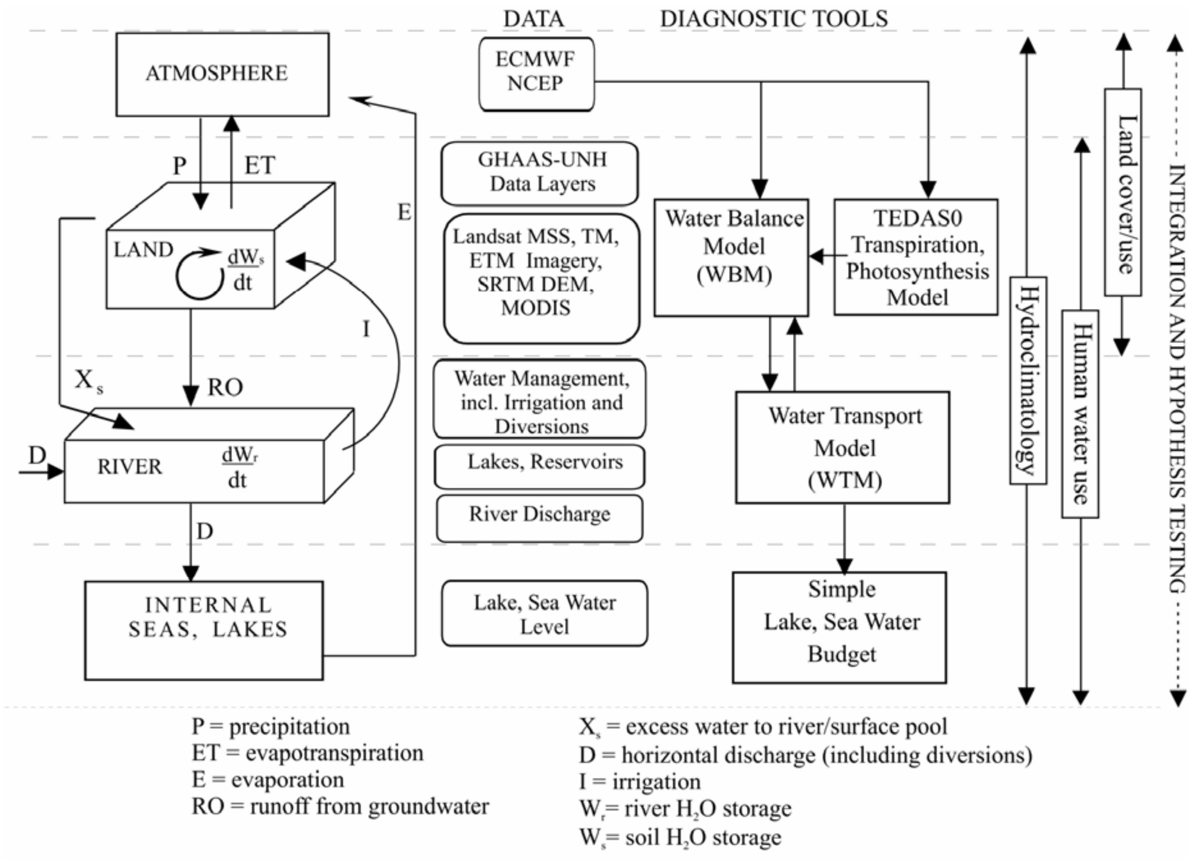
- **Climate change**
- **LCLUC**
- **Engineering (Water Use)**

for historical, contemporary and future system states

GOAL: Diagnostic Analysis: ***To execute a series of hydrological simulation experiments to test:***

Combined Impacts: ***To assess the net impact of the combined effects of natural and anthropogenic sources of change in the patterns of hydrological variability in Central Asia.***

Relative Contributions: ***To identify and rank the sources of change on the hydrology of Central Asian States.***



P = precipitation
ET = evapotranspiration
E = evaporation
RO = runoff from groundwater

X_s = excess water to river/surface pool
D = horizontal discharge (including diversions)
I = irrigation
W_r= river H_2O storage
W_s= soil H_2O storage

WBM/WTM ... WBMPlus

WBM/WTM

- 1-D physically based macroscale hydrological model (Vörösmarty, 1998)
- WTM Routing based on river network (STN)

WBMPlus

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

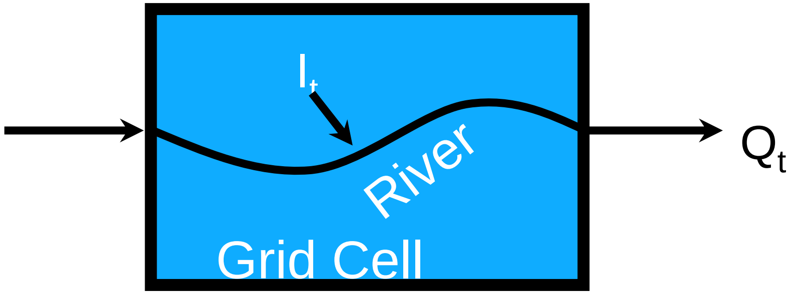
Flow routing model

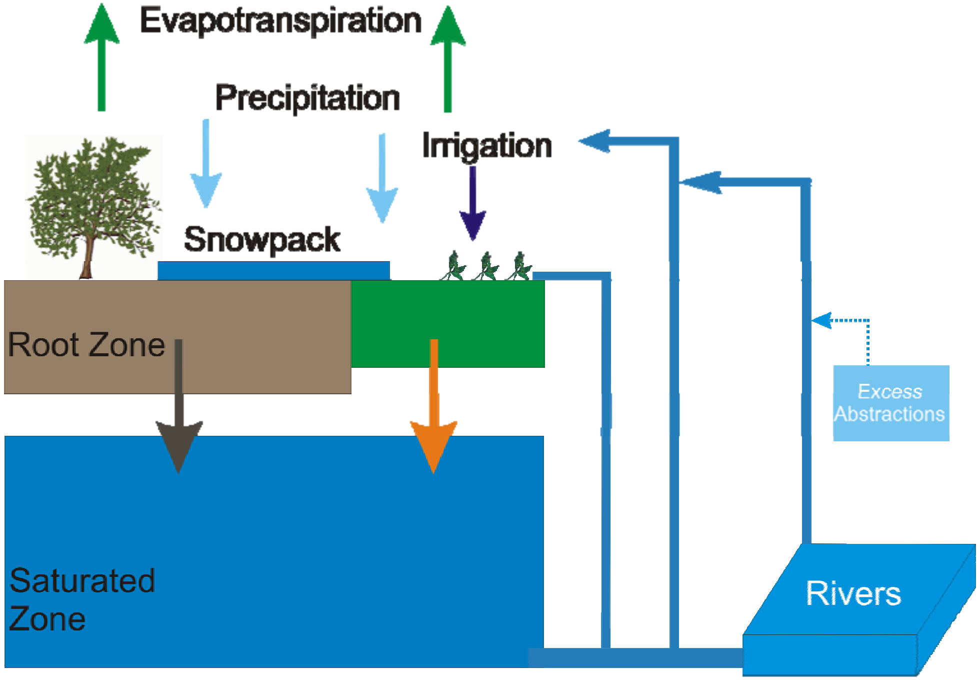
$Q_{t+1} = C_0 I_{t+1} + C_1 I_t + C_2 Q_t$

Coefficients C_0, C_1, C_2, = f(River Geometry)

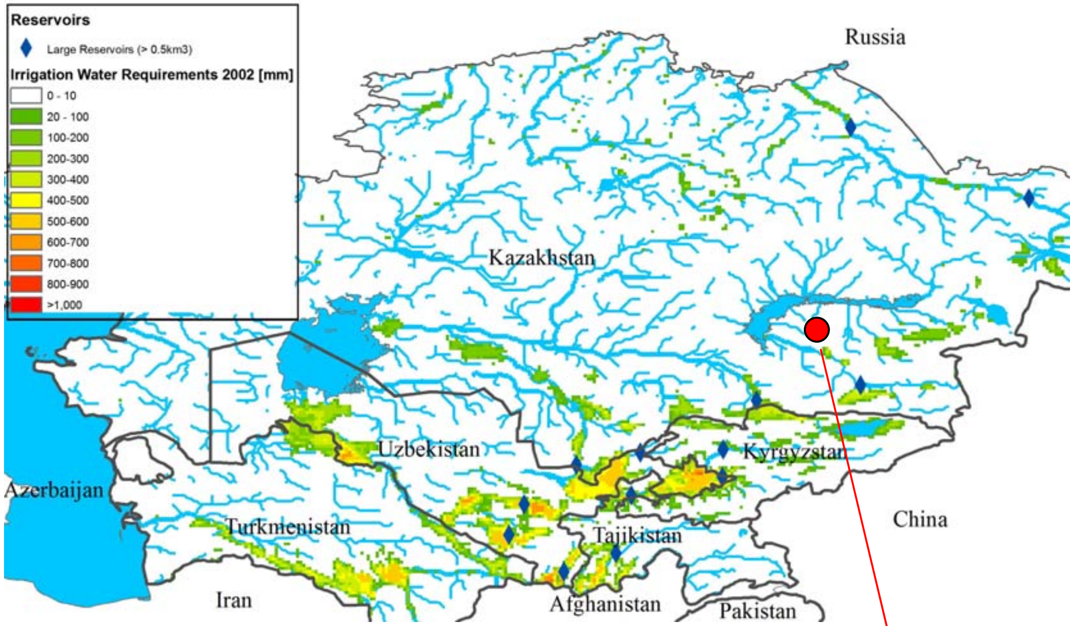
Q = river discharge from grid cell

I = locally generated inflow to river (less irrigation)



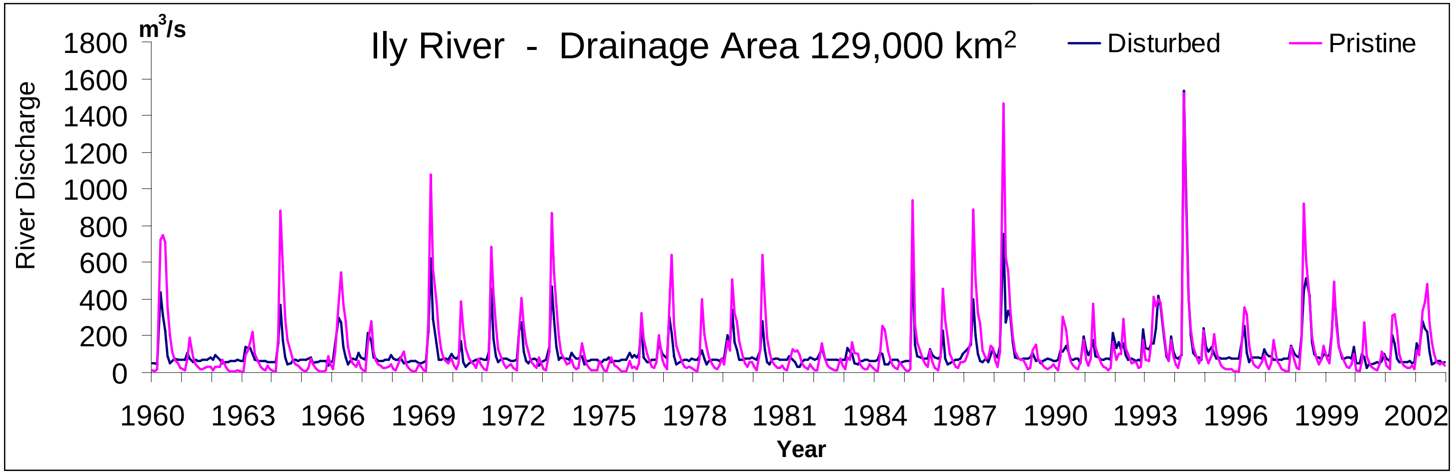


Irrigation water requirements 2002



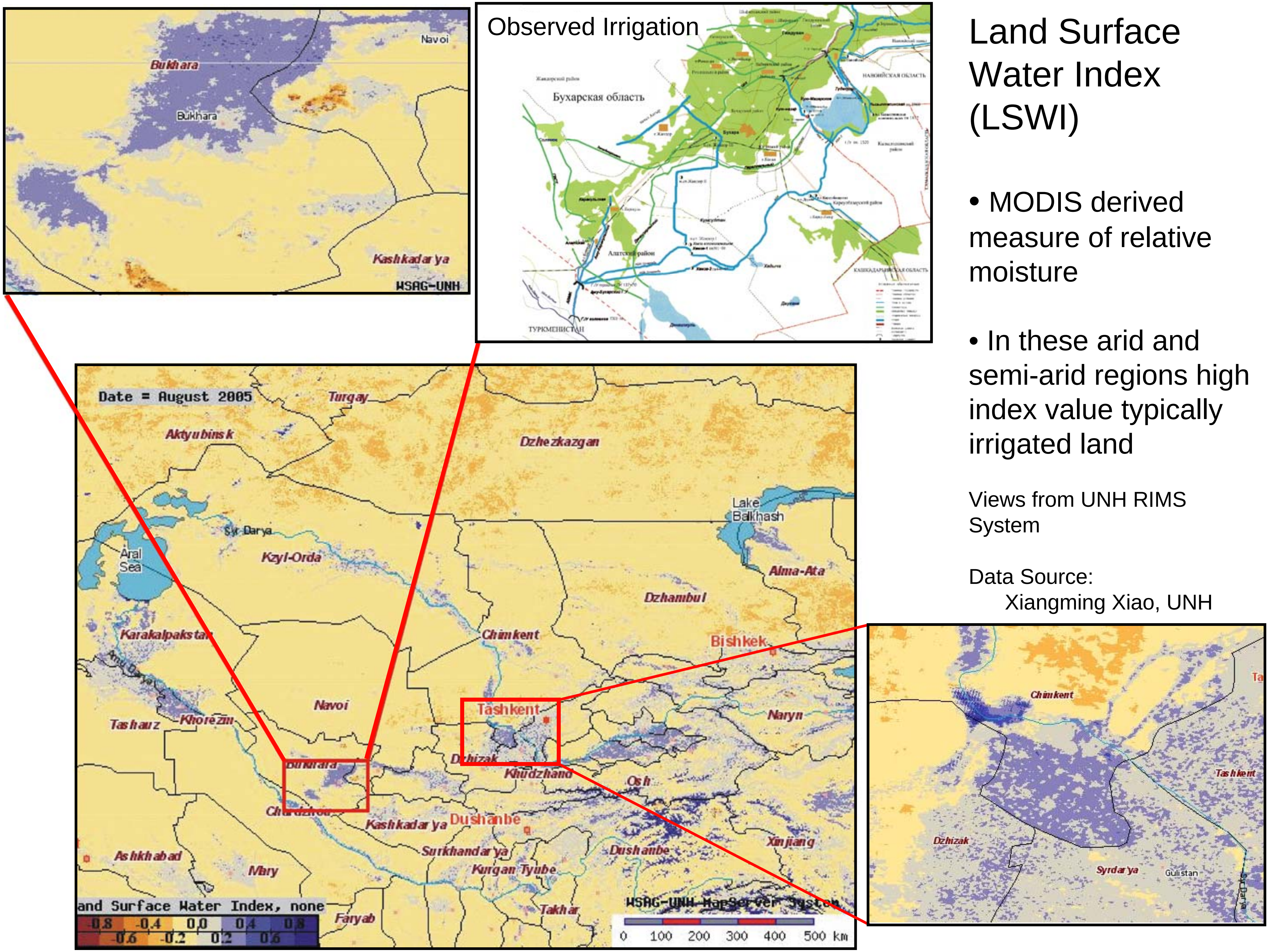
The UNH Water Balance Model has the capability to estimate potential irrigation using existing maps of irrigated regions. The map shows irrigation demand using the FAO irrigation map (Siebert et al. 2005).

We will switch to the newer IWMI product (Thenkabail et al. 2006) which is considered superior for Asia.



Example of simulations of hydrological regime with WBMPlus for pristine and disturbed conditions. Pristine has irrigation and reservoirs turned off. Climate drivers uncorrected.

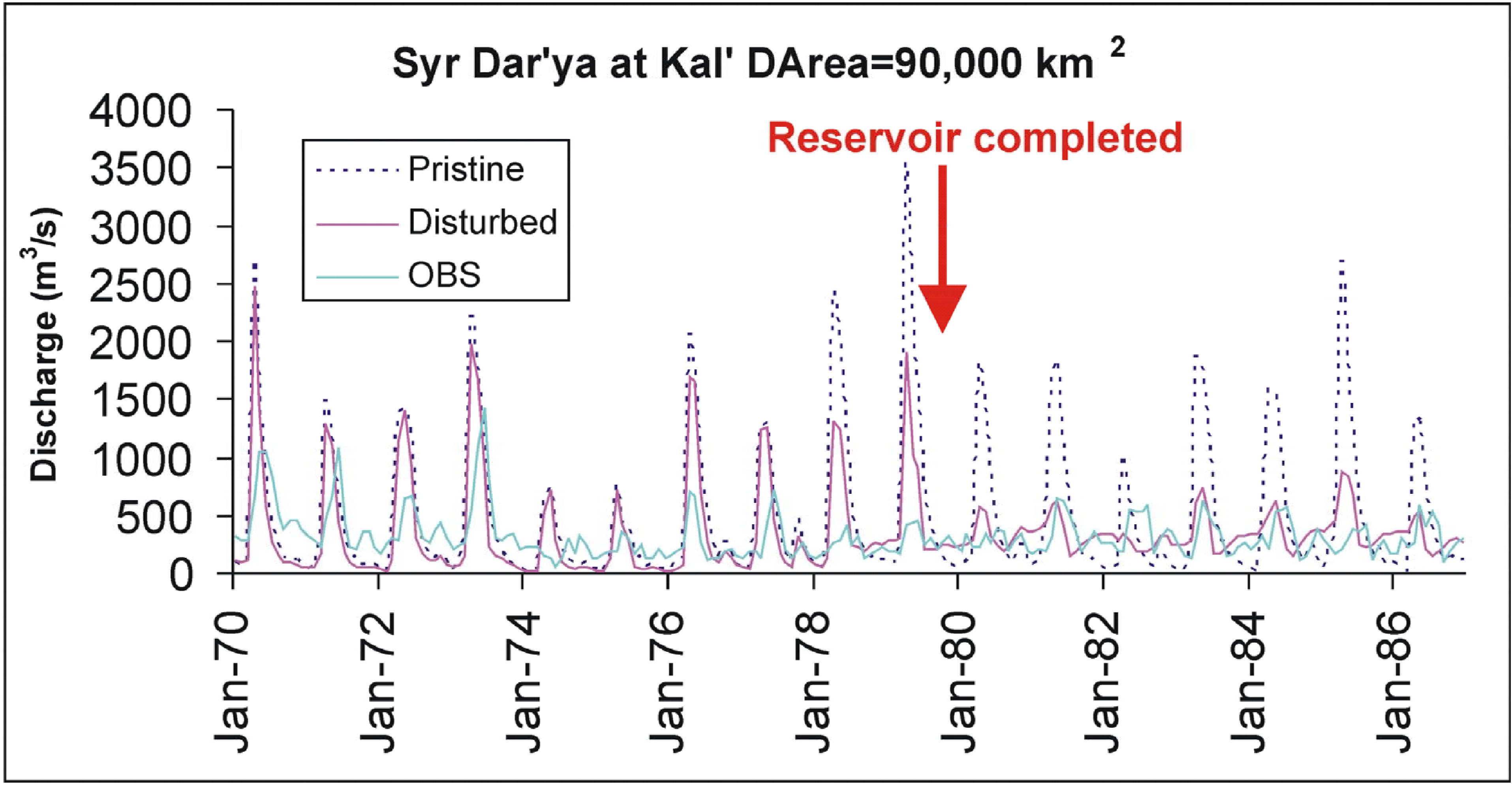
Land Surface Water Index (LSWI)



- MODIS derived measure of relative moisture
- In these arid and semi-arid regions high index value typically irrigated land

Views from UNH RIMS System

Data Source:
Xiangming Xiao, UNH



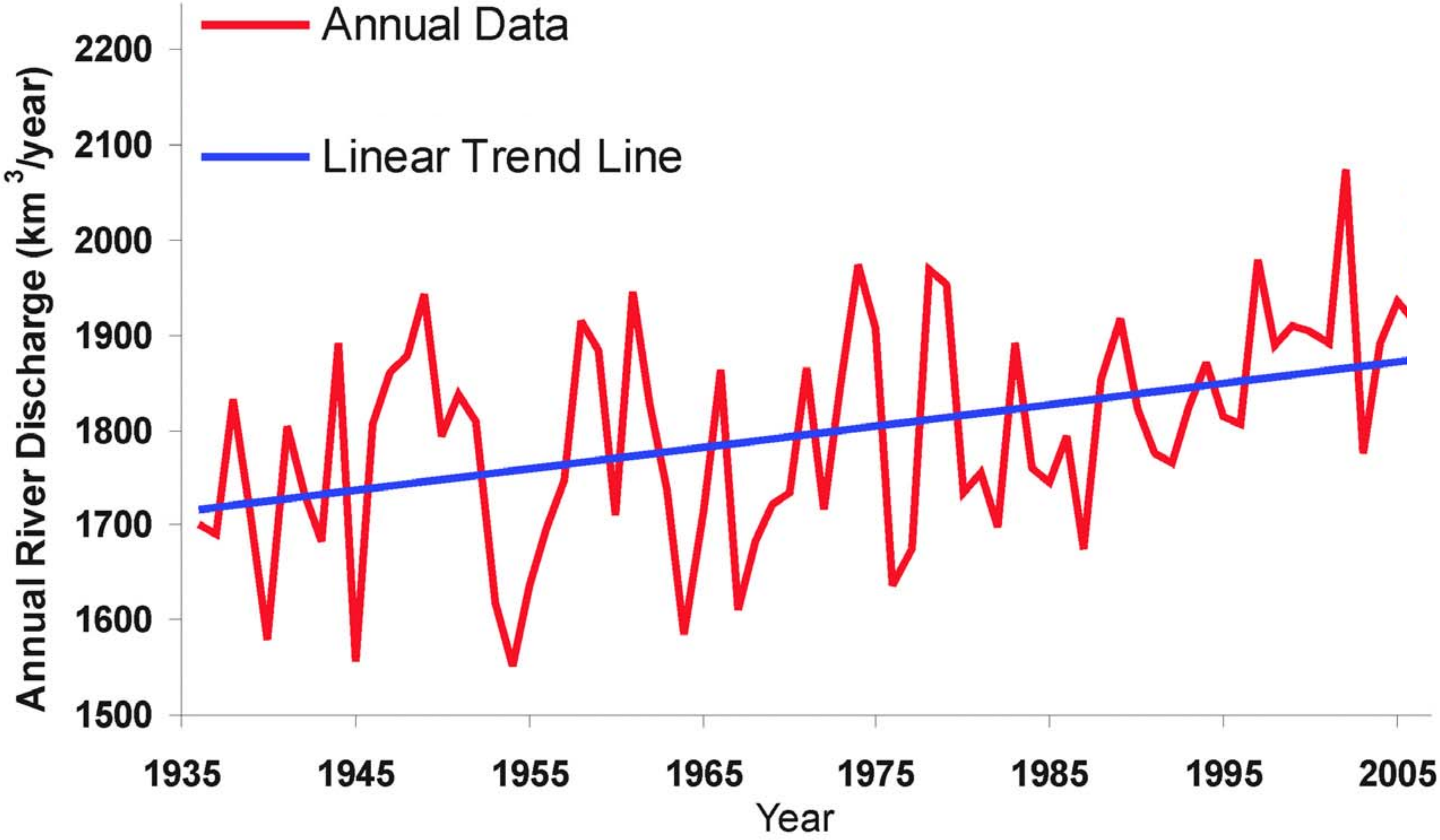
Example of two WBMPlus simulations from Central Asia for Pristine (Natural) and Disturbed (reservoir and irrigation) conditions. Note the divergence of disturbed from pristine runs in the late 1970s from reservoir filling.

Note: we do not expect matching of simulations to observed data due to coarse scale of grid cells used in these upstream runs and a lack of glacier sub-model.

Hydrology of Eurasian pan-Arctic

Historical Record

Eurasian River Discharge 1936-2006

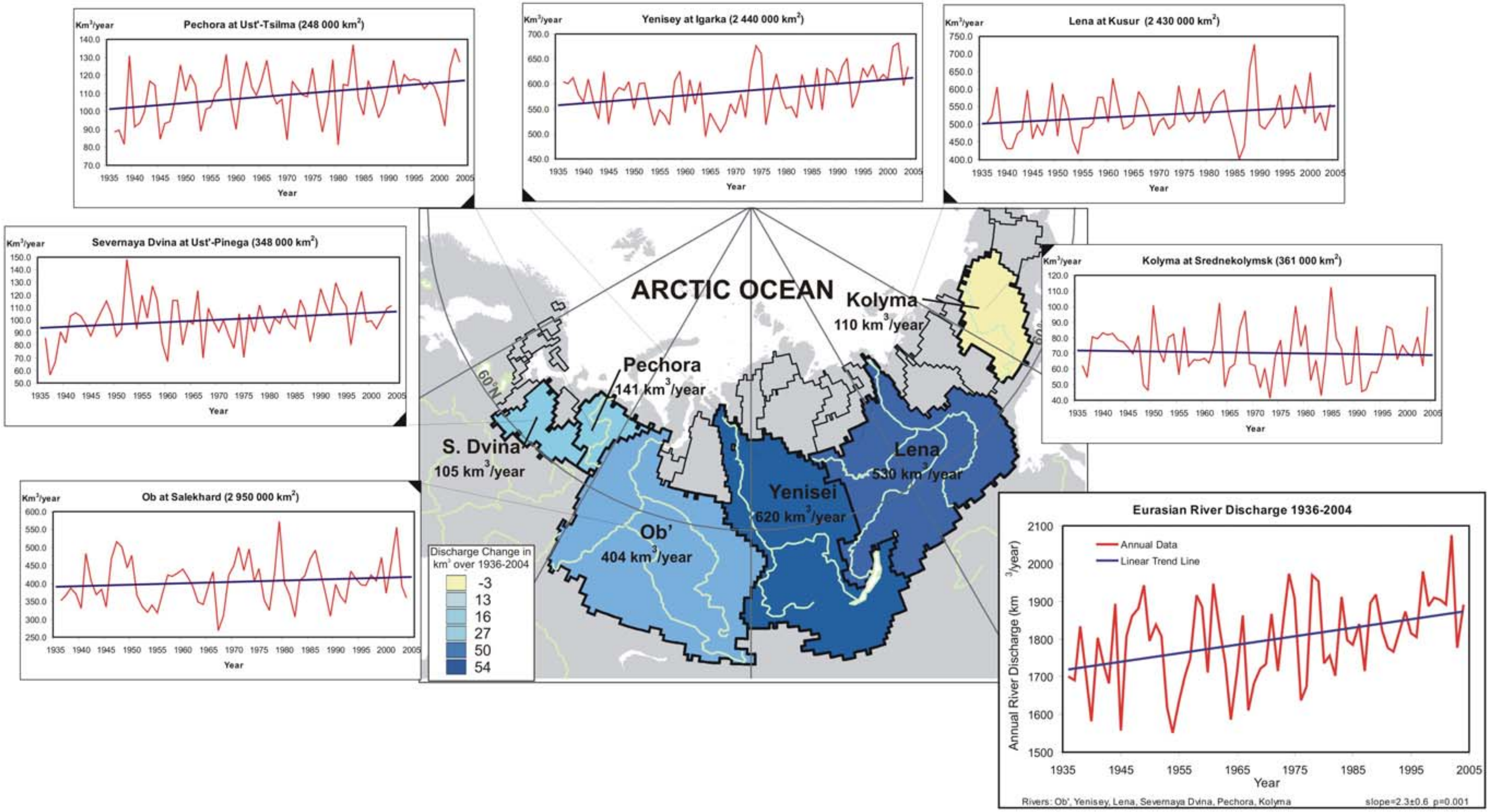


Rivers: Ob', Yenisey, Lena, Severnaya Dvina, Pechora, Kolyma

slope=2.3±0.6 p=0.0004

Changes in the hydrological cycle over the continent

effect on the fresh water transport to the Arctic Ocean, and may influence on ocean thermohaline circulation



(updated from Peterson et al. 2002)

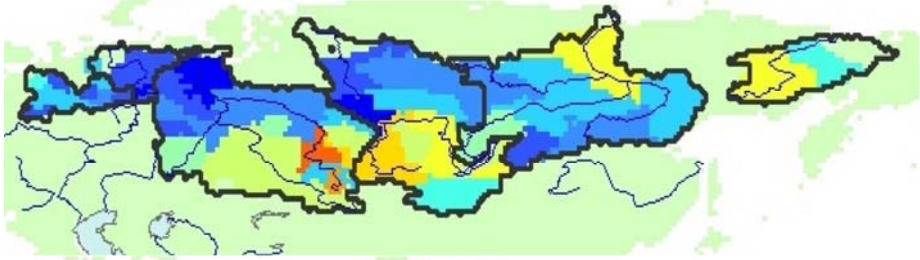
Combined Annual Discharge 6 Largest Eurasian Arctic Rivers
--- 8 % increase over period of record

- Aggregate Trend Detectable for Arctic
  - -Temporal character complex
  - -Geography of change complex

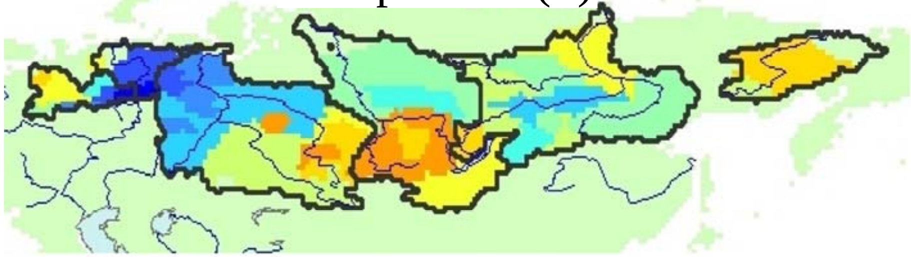
- Linked to NAO and global T rise
- 18-70% Increase in River Q to 2100

Changes in trends over 1936-1999 in mm

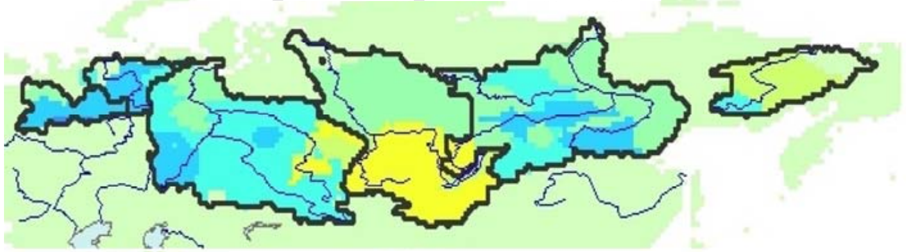
Runoff (R))



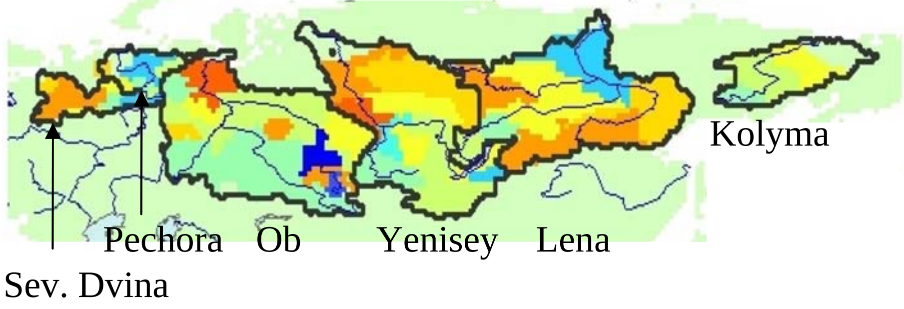
Precipitation (P)



Evapotranspiration (E)



Discrepancies P-R-E



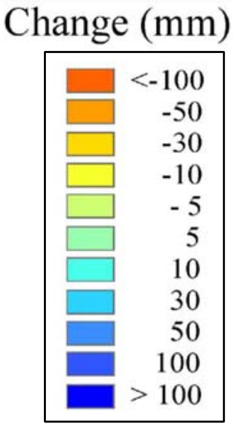
Runoff changes have complex spatial distribution

Direction and especially rate of change in precipitation are not consistent with runoff

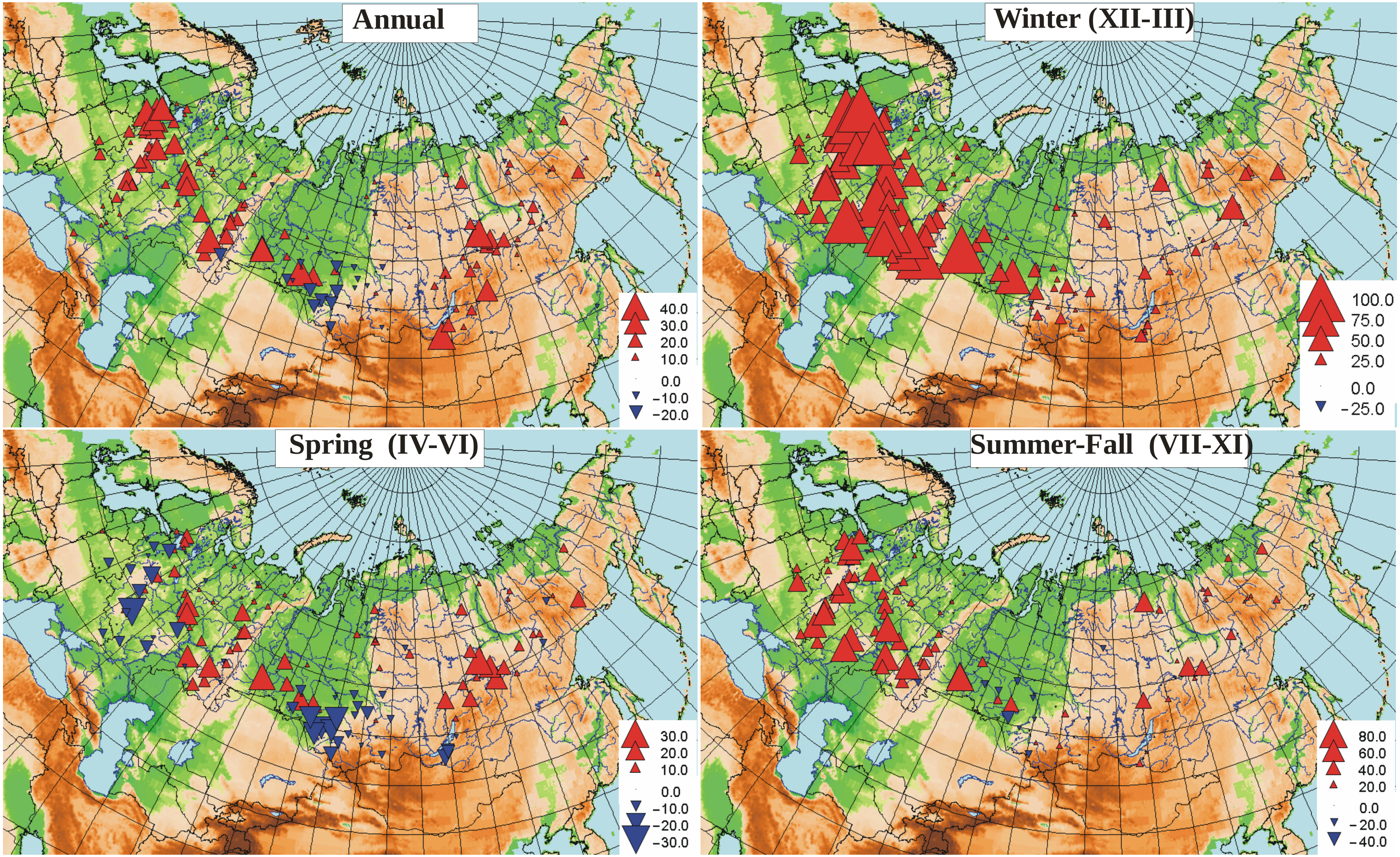
Precipitation cannot explain runoff change - especially in the north

ET change is minor

Negative discrepancies coincide with permafrost regions…

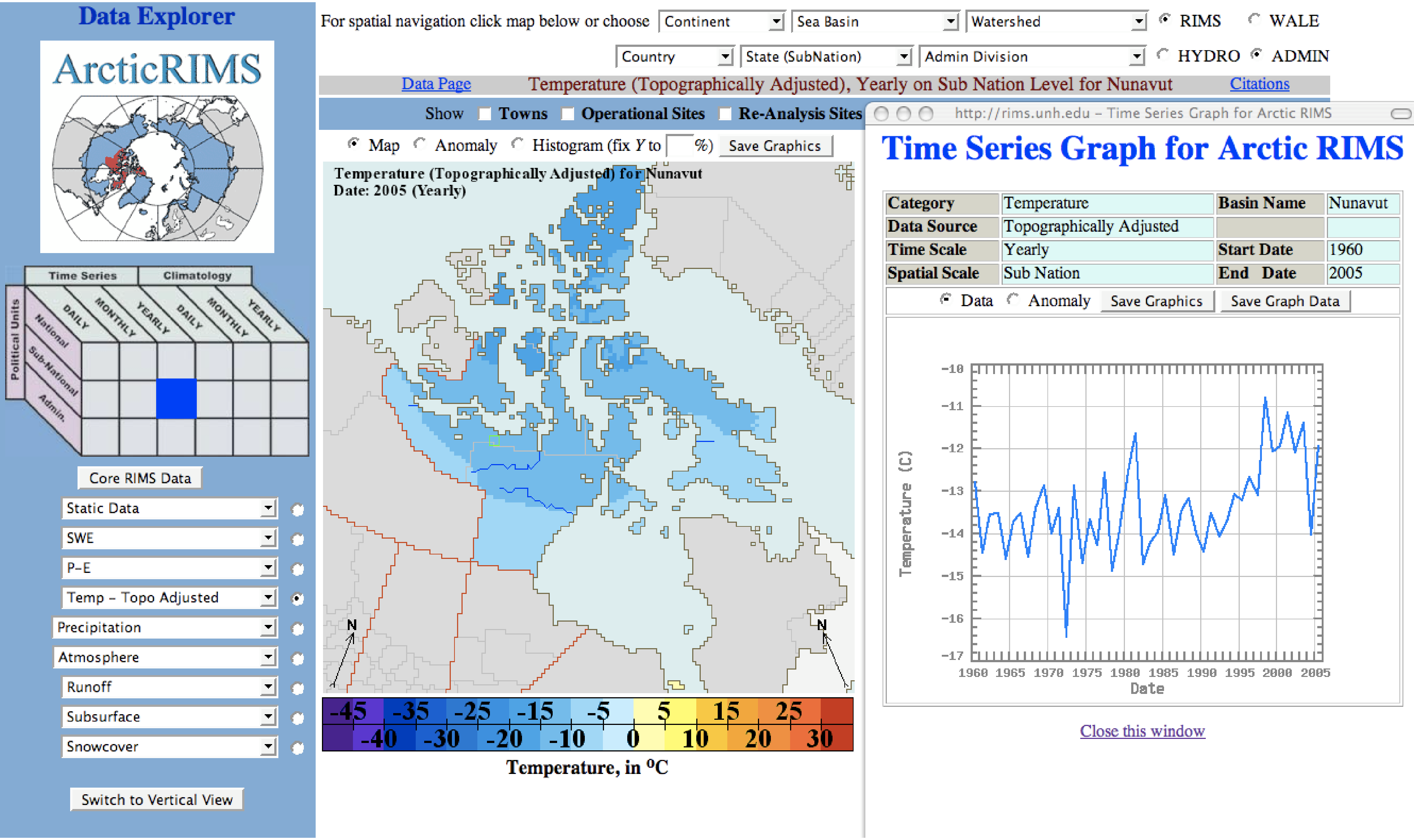


We cannot attribute all changes to direct climate change



Seasonal river discharge anomalies (1978-2000) showing winter with the largest changes (% change)

Unifying framework for data ArcticRIMS - http://RIMS.unh.edu



Data Explorer

For spatial navigation click map below or choose

● RIMS ○ WALE ○ HYDRO ● ADMIN

Data Page Temperature (Topographically Adjusted), Yearly on Sub Nation Level for Nunavut Citations

Show ☐ Towns ☐ Operational Sites ☐ Re-Analysis Sites

● Map ○ Anomaly ○ Histogram (fix *Y* to %) Save Graphics

Temperature (Topographically Adjusted) for Nunavut
Date: 2005 (Yearly)

Temperature, in °C

http://rims.unh.edu – Time Series Graph for Arctic RIMS

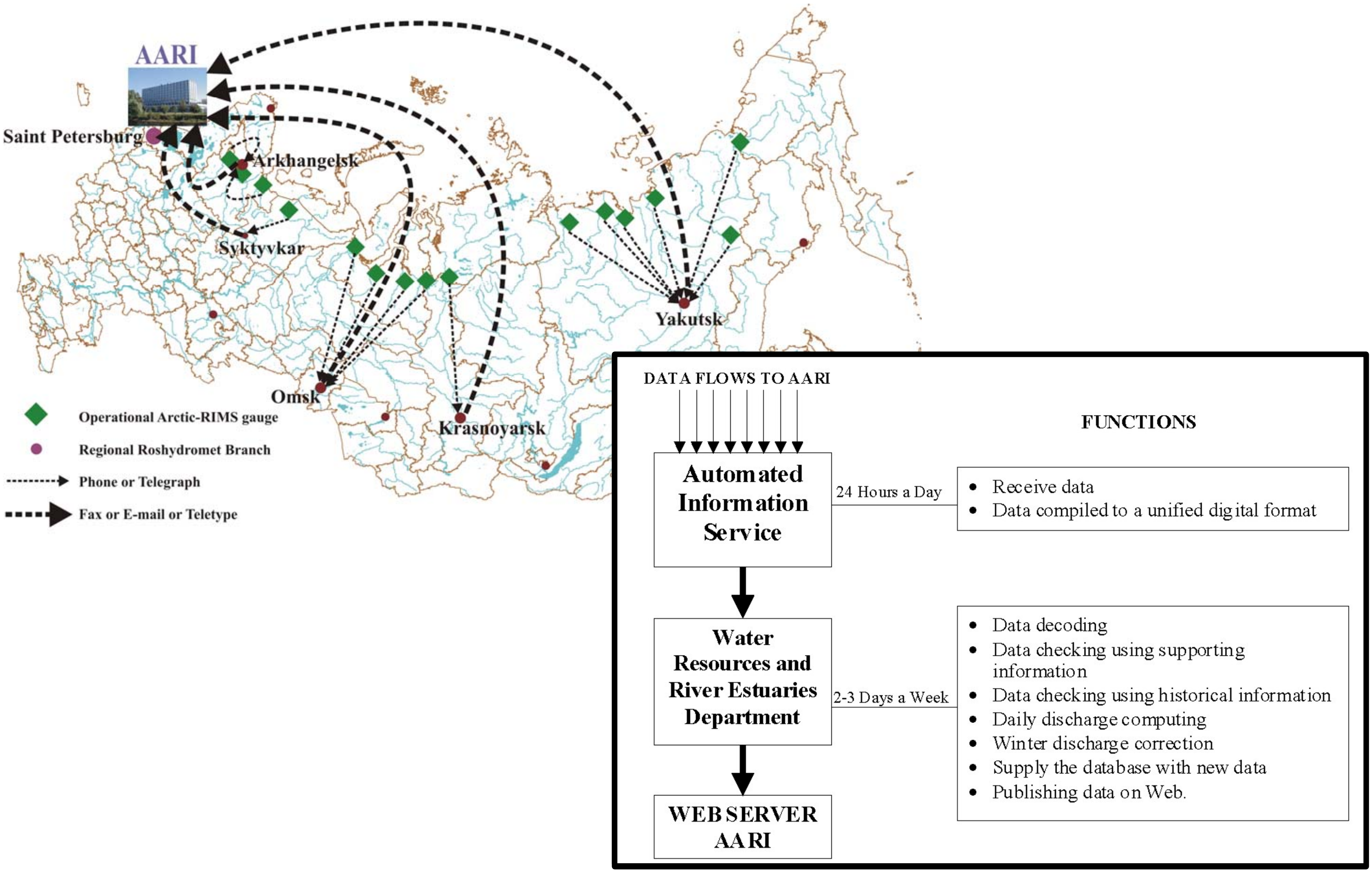
Time Series Graph for Arctic RIMS

Category	Temperature	**Basin Name**	Nunavut
Data Source	Topographically Adjusted		
Time Scale	Yearly	**Start Date**	1960
Spatial Scale	Sub Nation	**End Date**	2005

● Data ○ Anomaly Save Graphics Save Graph Data

Close this window

Russian Data Flow to the Arctic and Antarctic Research Institute (AARI)



DATA FLOWS TO AARI

Automated Information Service

24 Hours a Day

Water Resources and River Estuaries Department

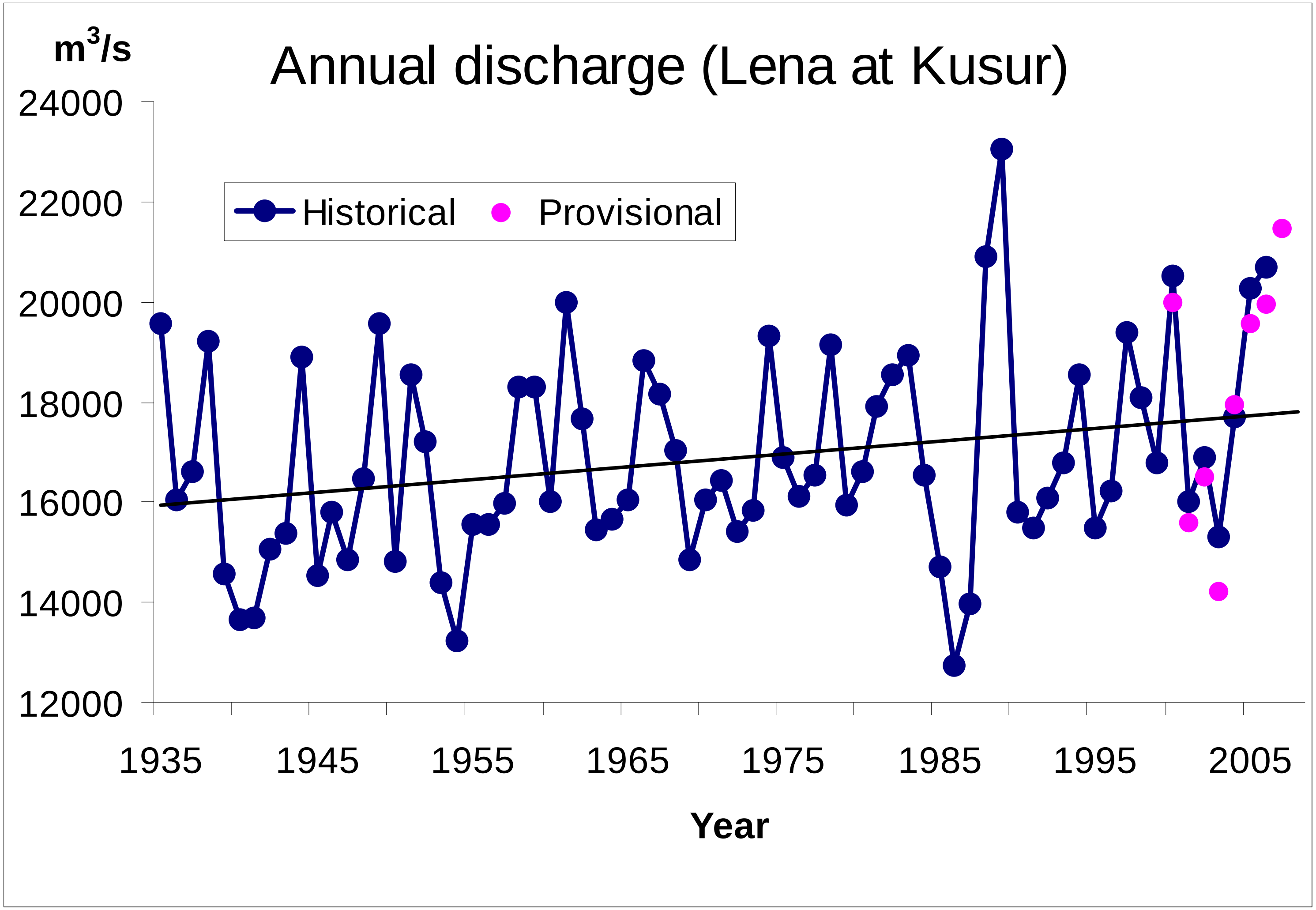
2-3 Days a Week

WEB SERVER AARI

FUNCTIONS

- Receive data
- Data compiled to a unified digital format

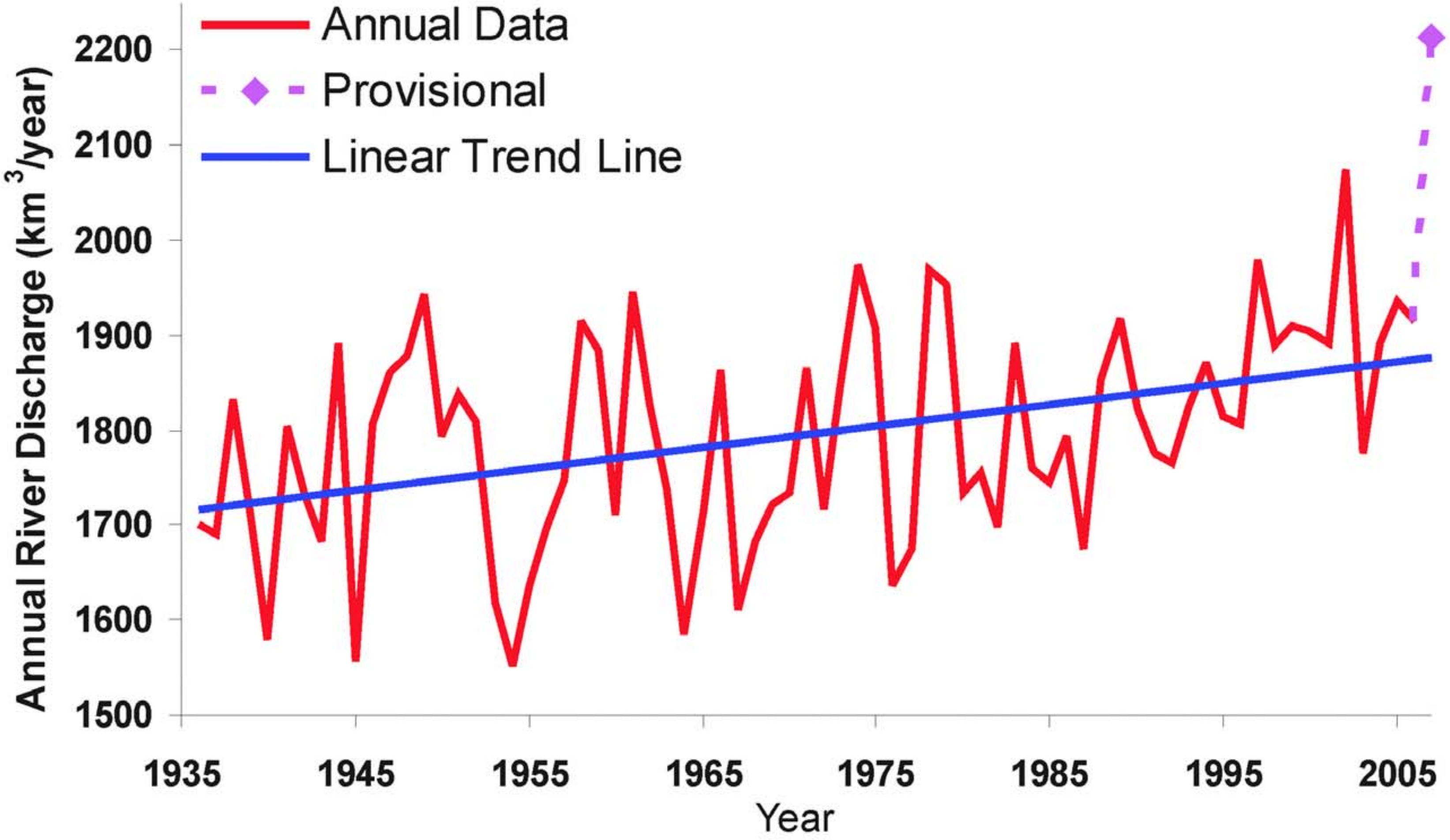
- Data decoding
- Data checking using supporting information
- Data checking using historical information
- Daily discharge computing
- Winter discharge correction
- Supply the database with new data
- Publishing data on Web.



Provisional river discharge data created from daily river stage height and other variables (e.g. ice conditions) combined in a model.

5 of 6 years we have slightly underestimated the historical data released by Roshydromet for the Lena. Overall error within few %.

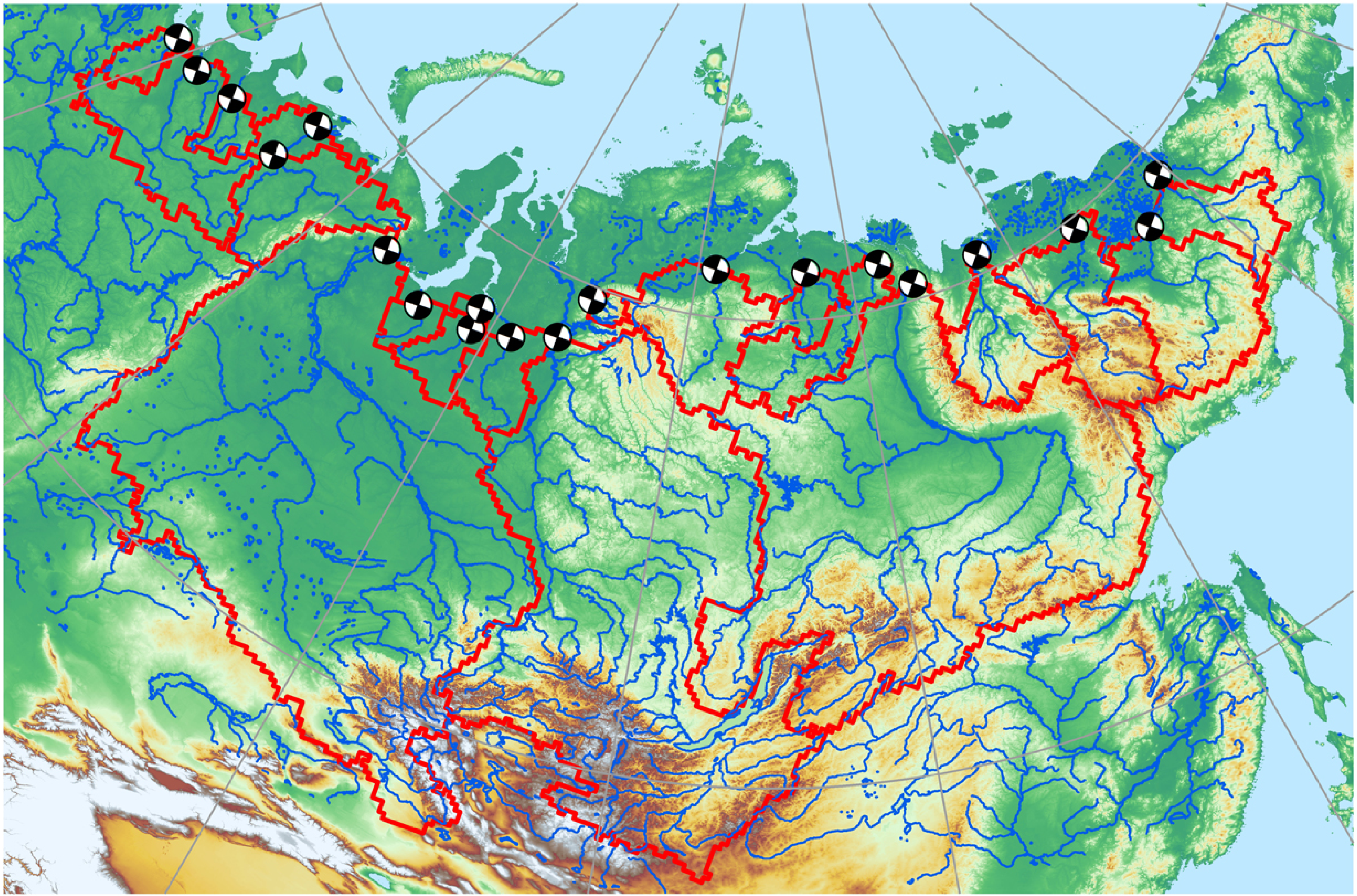
Eurasian River Discharge 1936-2006



Rivers: Ob', Yenisey, Lena, Severnaya Dvina, Pechora, Kolyma

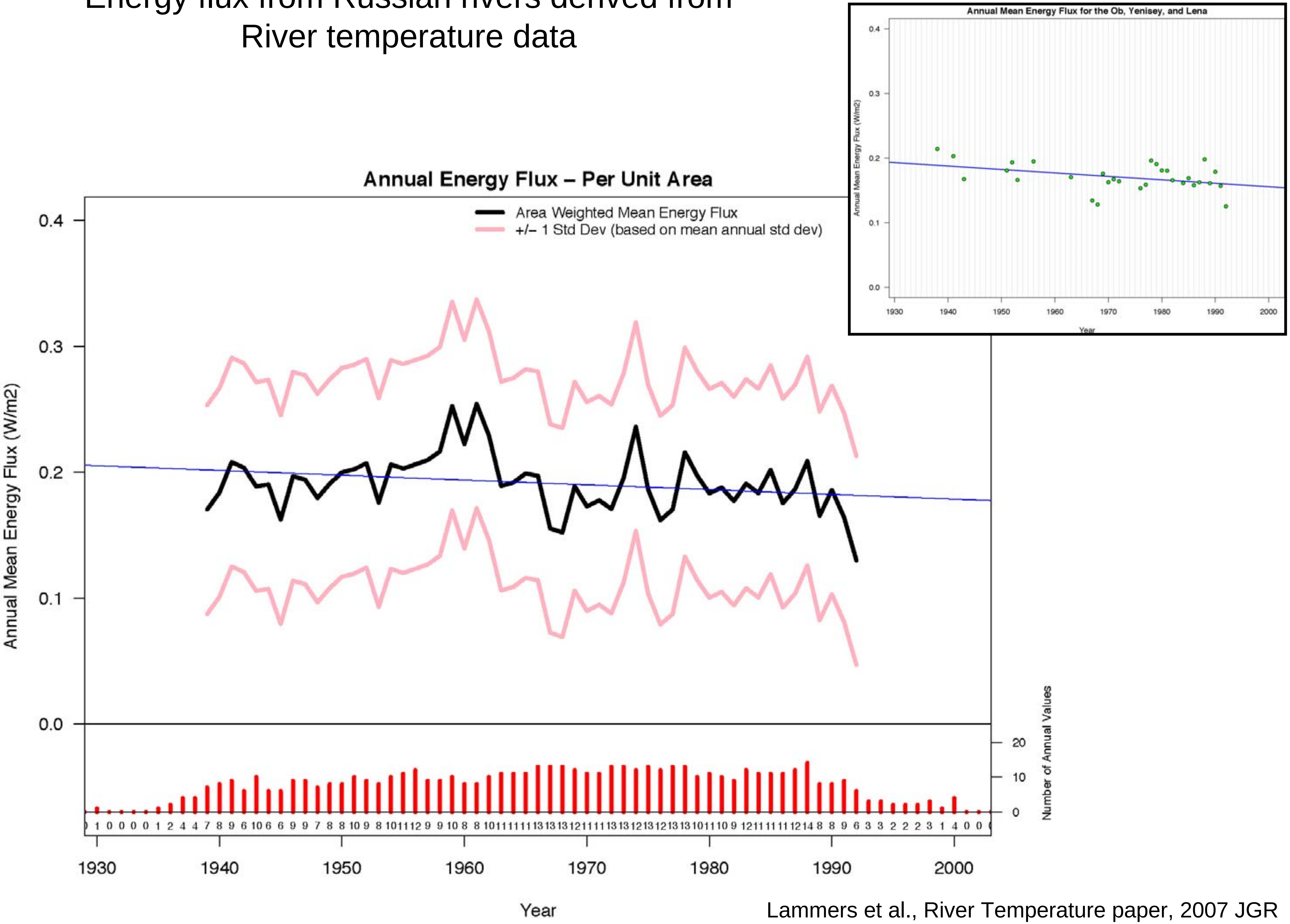
slope=2.3±0.6 p=0.0004

□Location of River Temperature Gauging Stations along the Northern Russian Pan-Arctic



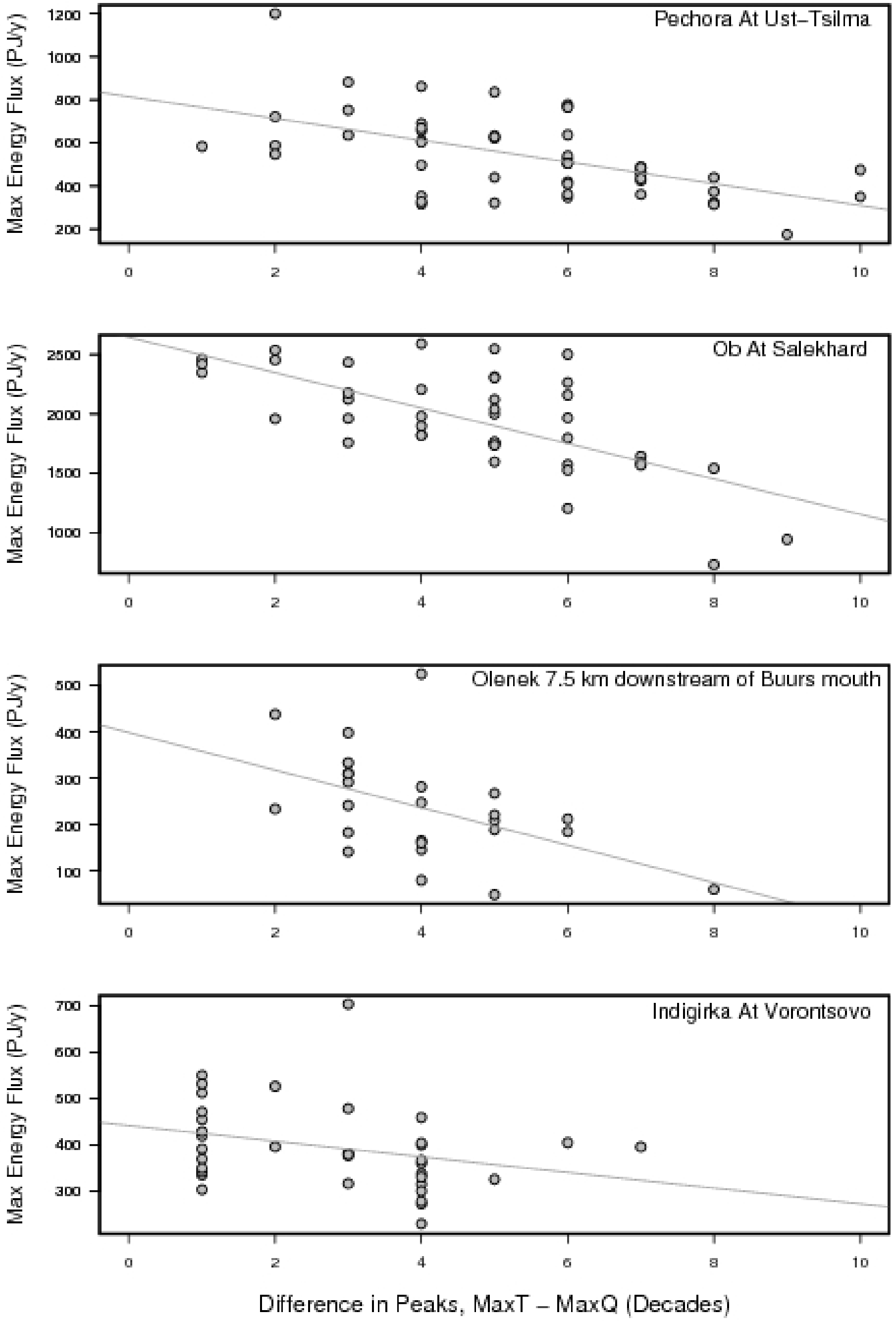
Energy flux from Russian rivers derived from River temperature data

Ob, Yenisey, Lena only



Lammers et al., River Temperature paper, 2007 JGR

Figure 6 – Maximum energy flux by difference in timing of maximum temperature and maximum discharge, selected gauges

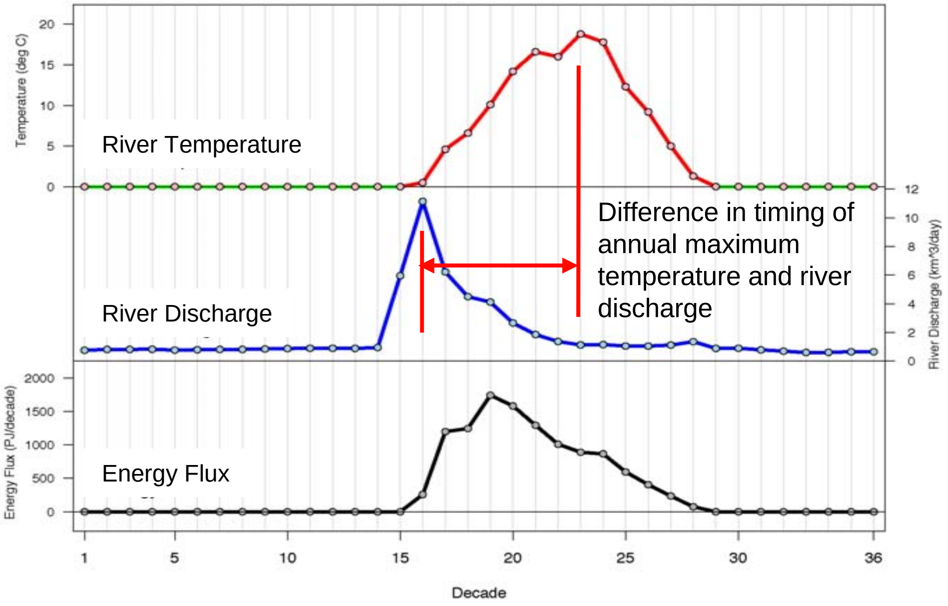


Russian river temperature data

As the difference in timing between peak temperature and discharge increases…

The energy flux declines.

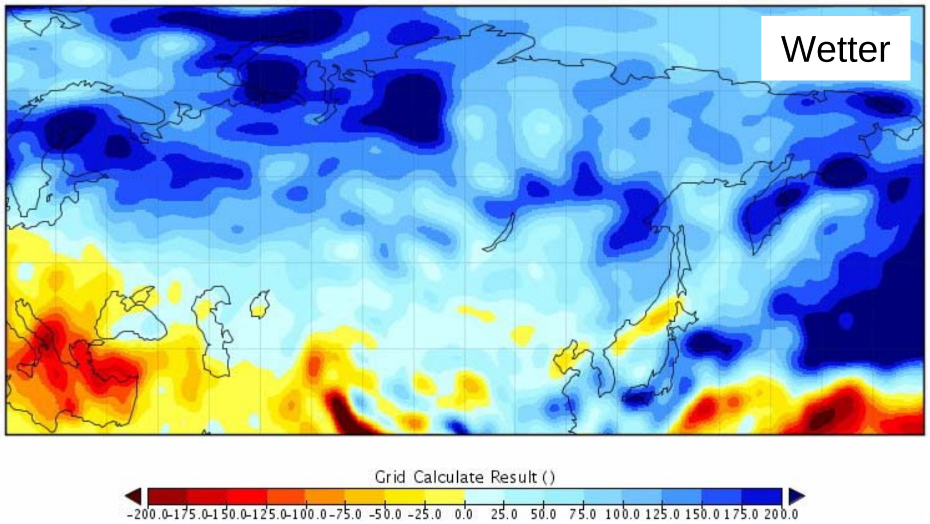
Yenisey at Igarka, Year 1992



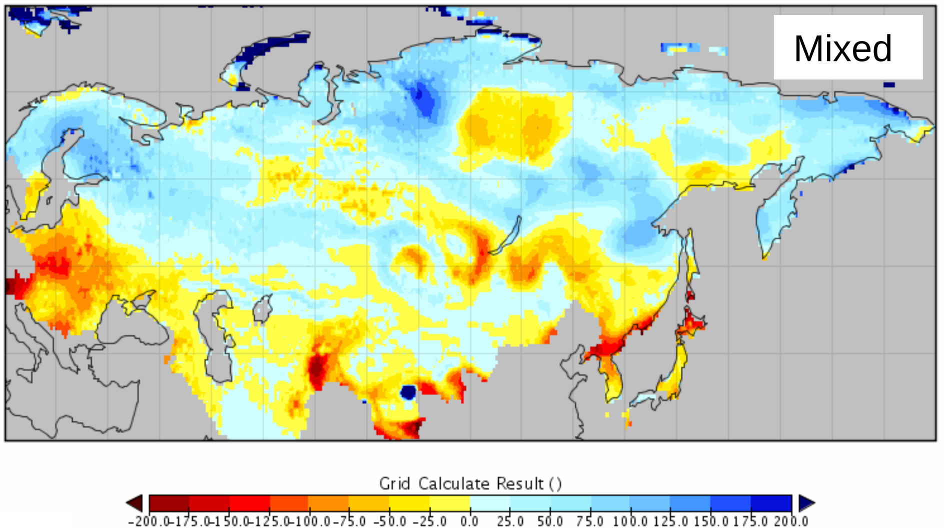
Lammers et al., River Temperature paper, 2007 JGR

Future Simulations

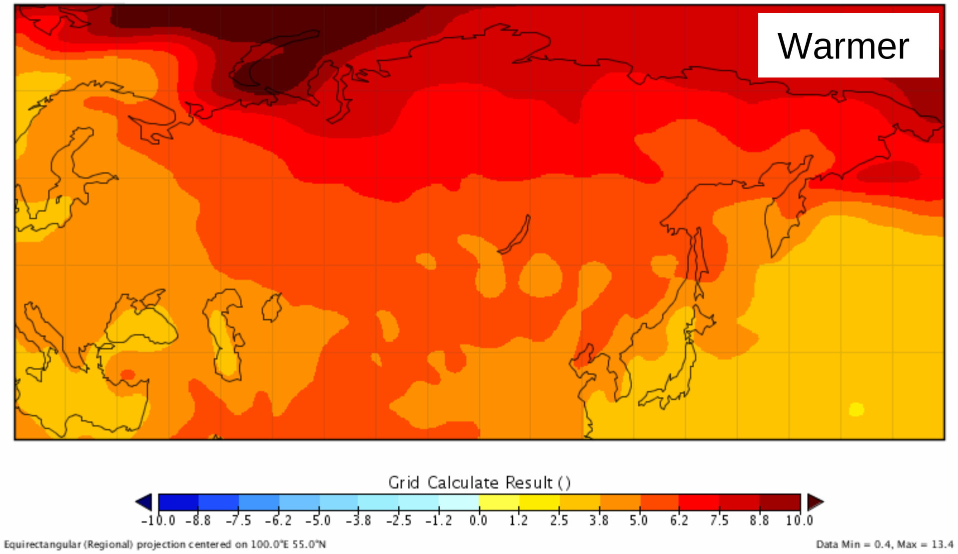
Annual Precipitation Change



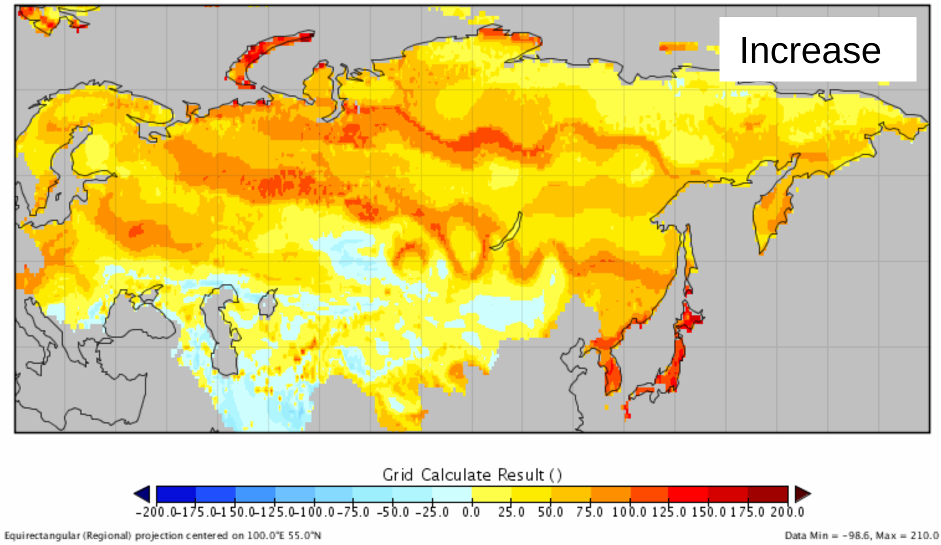
Annual Runoff Change



Annual Air Temperature Change

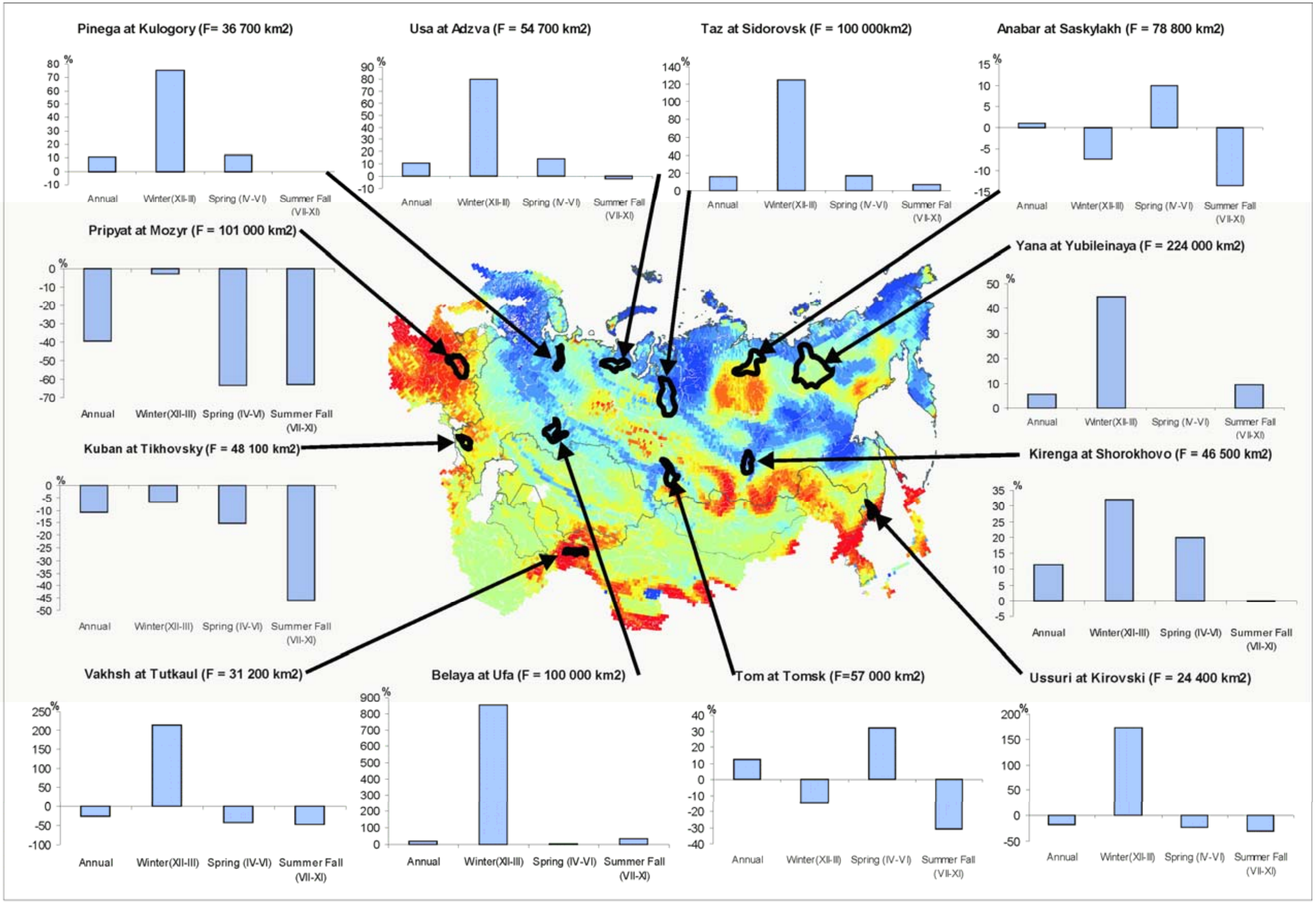


Annual Evapotranspiration Change



ECHAM5 A1b - Difference: (2080-2100) - (1961-2001)

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

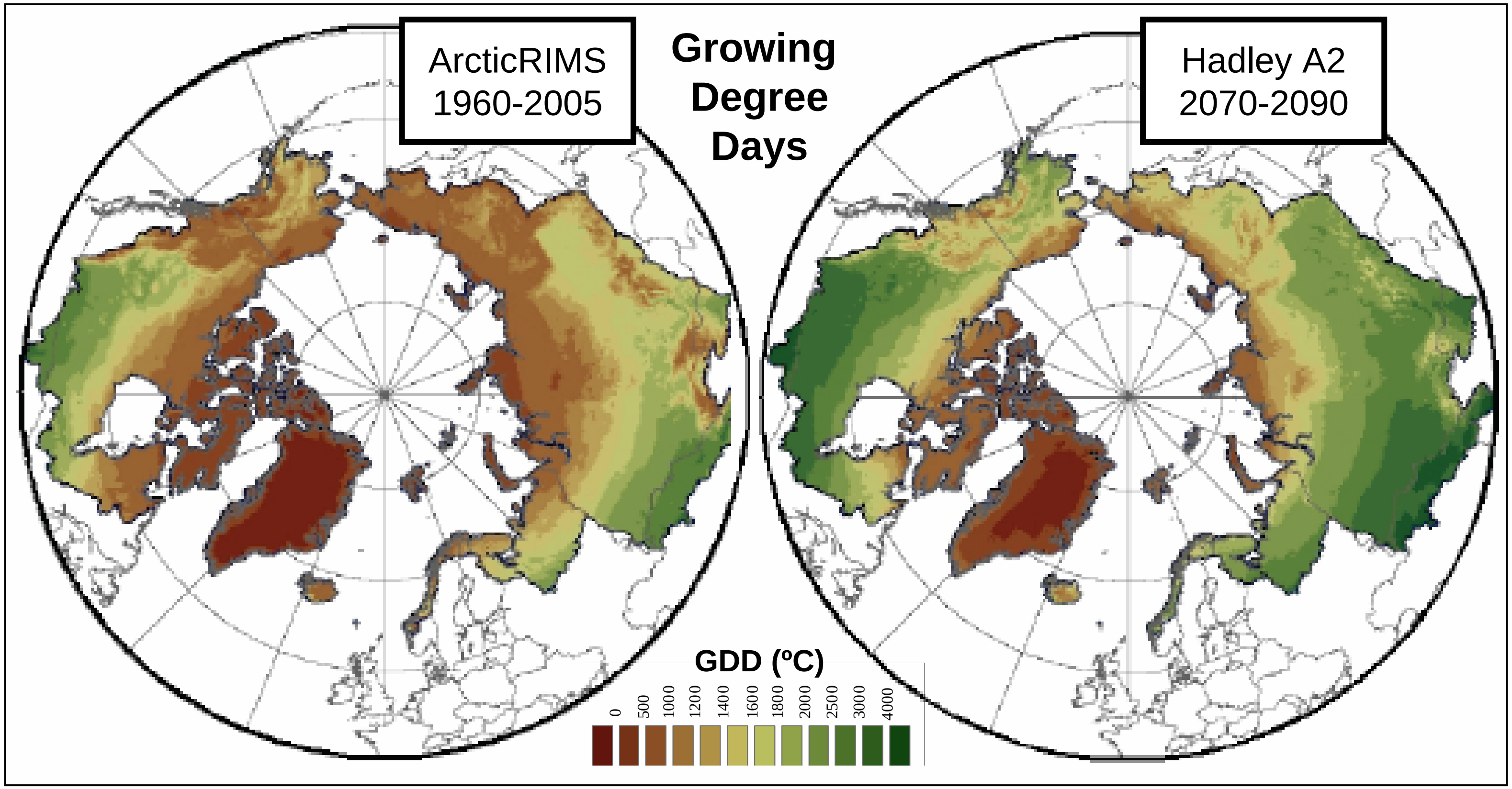


The change in seasonal discharge for watersheds located in different climatic and land cover zones.

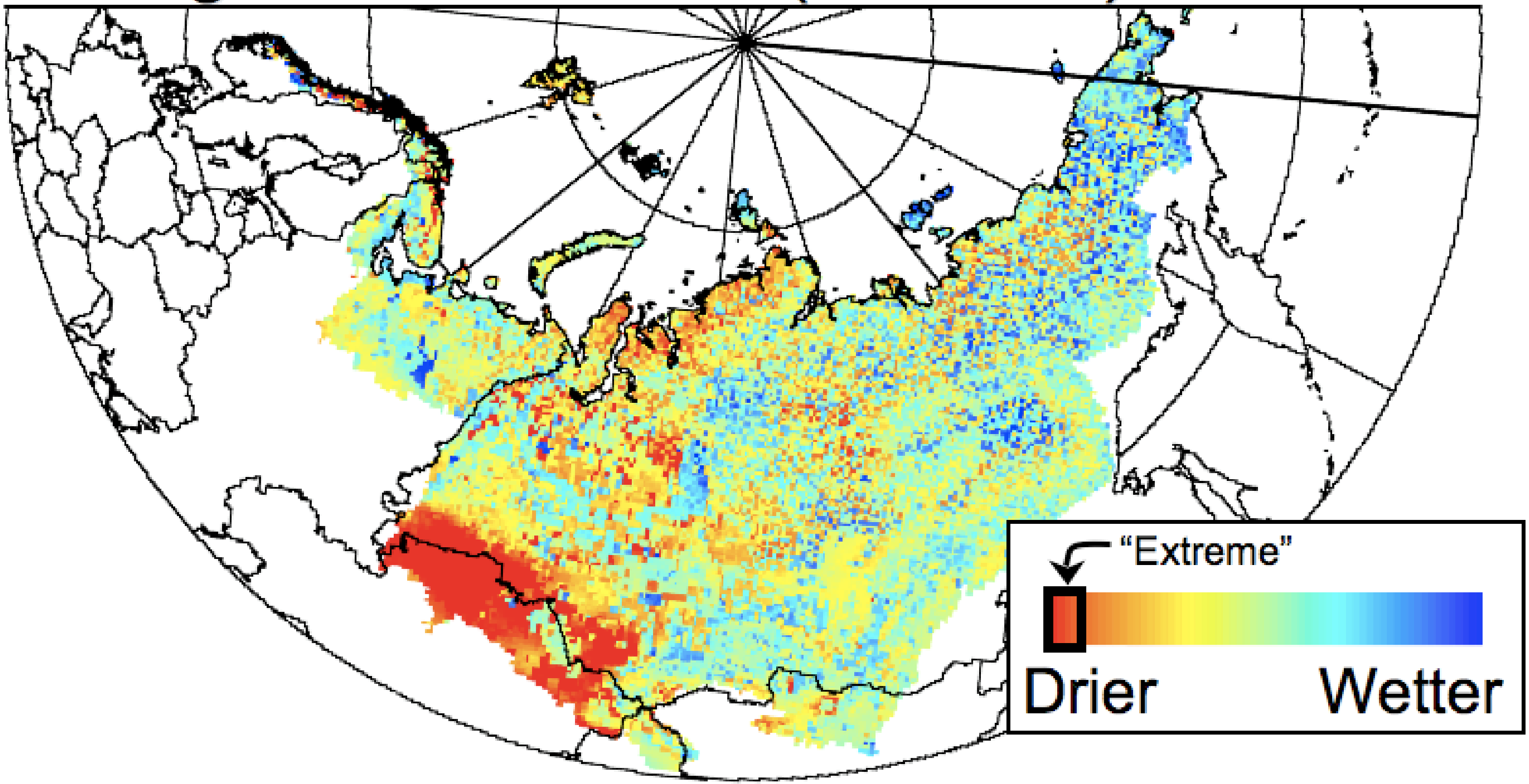
Annual discharge increases from increases in winter and spring discharge.

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.

Growing Degree Days



Change in Water Stress (AET/PET) 1980-2080

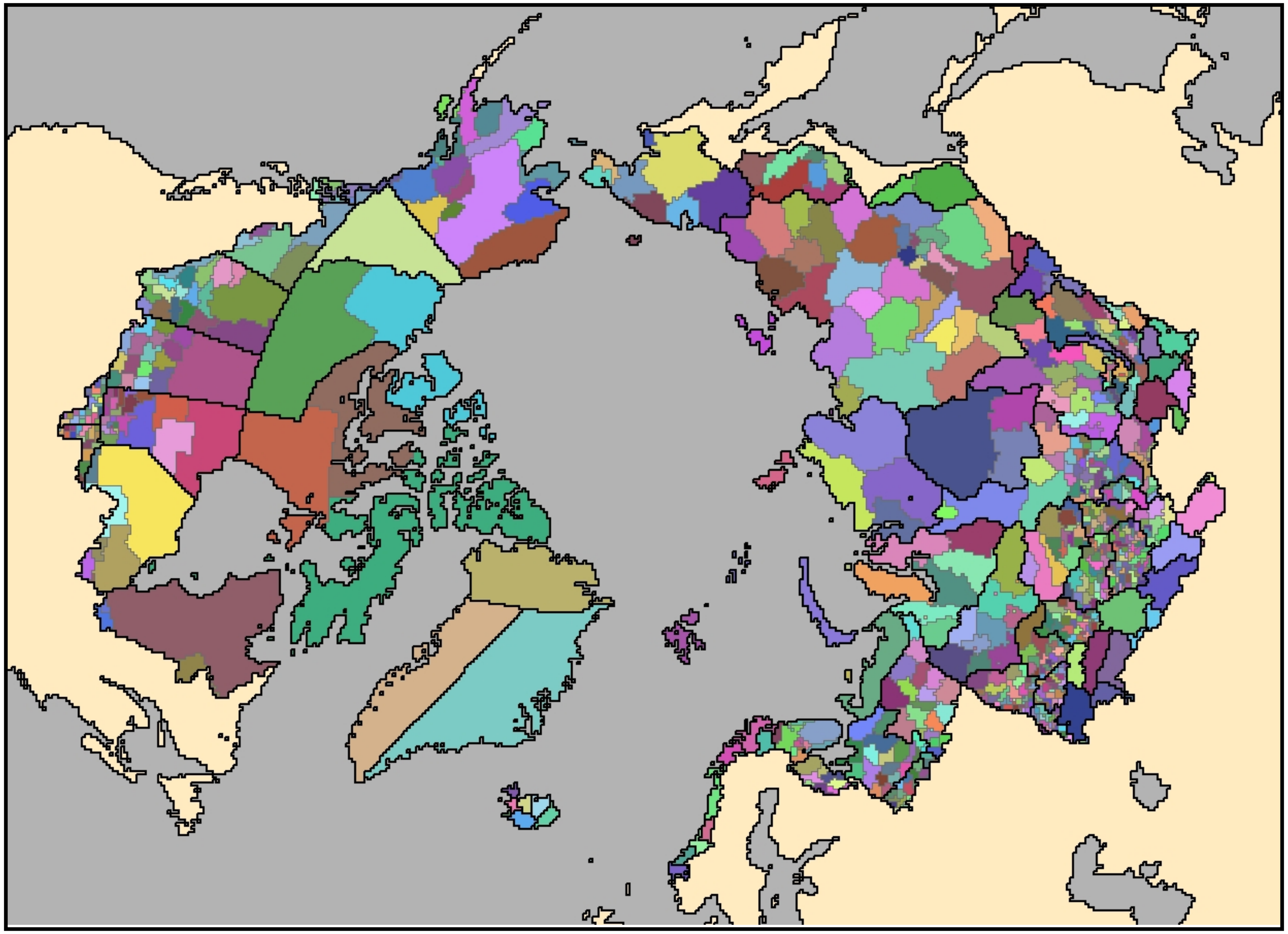


AET = Actual evapotranspiration

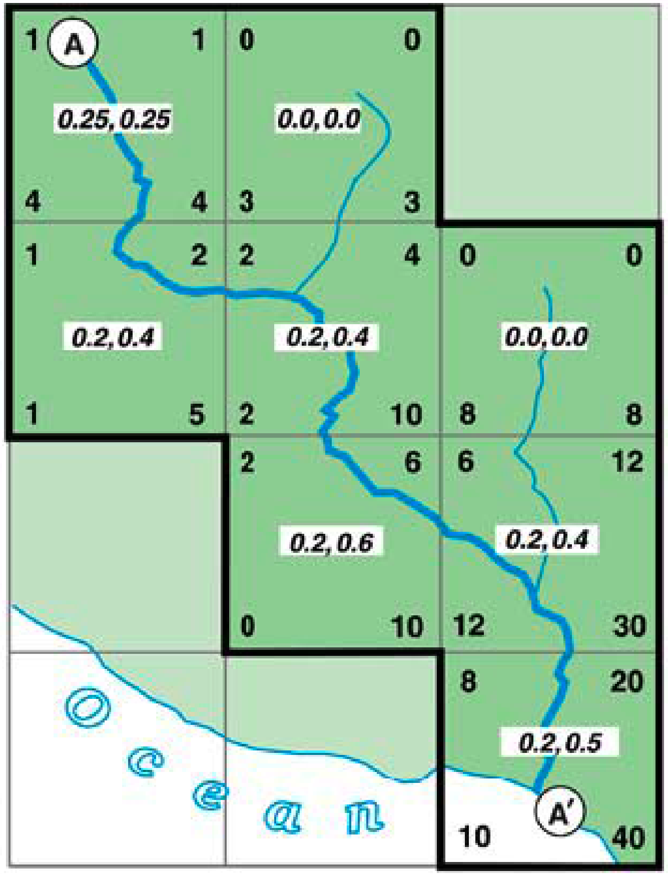
PET = Potential evapotranspiration

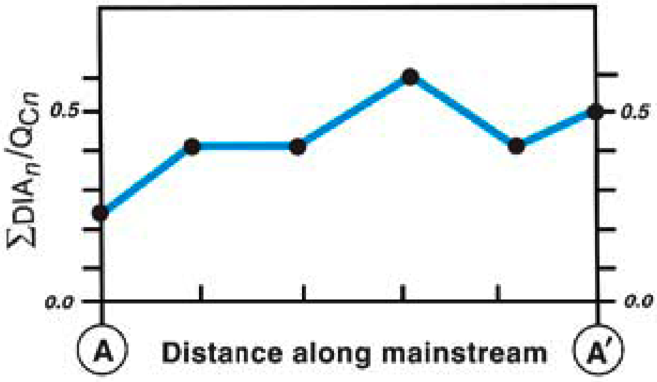
- Changes in vegetation (cropland)
- Geopolitical implications with food security

Pan-Arctic Political Subdivisions - Administrative Subdivisions   912 Units



CALCULATION OF KEY WATER INDICATORS





DIA_n = domestic, industrial, agricultural water use ($km^3\ yr^{-1}$) in cell n

$\sum DIA_n$ = DIA in cell n plus all upstream cells ($km^3\ yr^{-1}$) $= \sum_{i=1}^{n} DIA_i$

R_n = locally-generated runoff (mm/yr)

A_n = area of cell n (km^2)

$Q_{Ln} = 10^6 * R_n * A_n$ = locally generated discharge ($km^3\ yr^{-1}$)

$Q_{Cn} = \sum_{i=1}^{n} Q_{L_i}$ = river corridor discharge ($km^3\ yr^{-1}$)

DIA_n / Q_{Cn} = local relative water use (unitless)

$\sum DIA_n / Q_{Cn}$ = water reuse index (unitless)

n = position of cell in river network = total number of upstream cells plus cell in question

Key (cell n)

Our Primary High Latitude Web Sites

ArcticRIMS	http://rims.unh.edu
R-ArcticNet	http://www.r-arcticnet.sr.unh.edu/
Water Systems Analysis Group	http://www.wsag.unh.edu