Regional changes of precipitation in (southeastern) Europe

(results and uncertainties)

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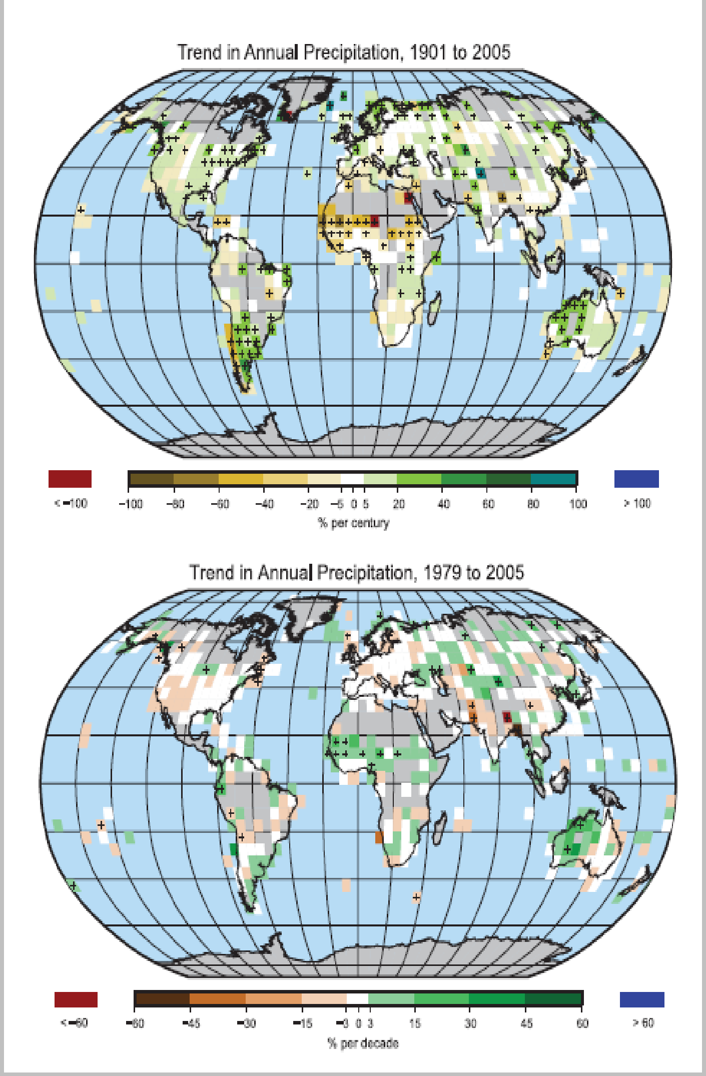
Topics Outlined

- Databases
- Data Errors (systematic and stochastic including the representativeness error)
- Precipitation Parameterization Schemes in models
- Local / Regional Changes
- General Atmospheric Circulation – Precipitation – Runoff Relations

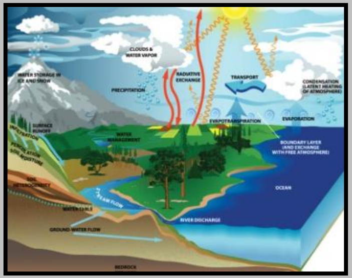
Motivation



Observed changes in large-scale precipitation are statistically insignificant. The global mean land precipitation changes are not at all linear, with an overall increase until the 1950s, a decline until the early 1990s and then a recovery (*Forth Assessment Report, Working Group 1*).

The focus of this study is to interpret regional anomalies in precipitation over Eastern Europe (trends, variability) as a part of the global hydrological cycle.

Quantitative estimates of the water cycle components are imperfect due to:



Observational errors:

- instrumental error (including different types of equipment and methodologies)
- problems with representativeness of the observational network

Complexity in precipitation nature:

- mesoscaling
- nonlinearity of microphysical processes responsible for precipitation formation

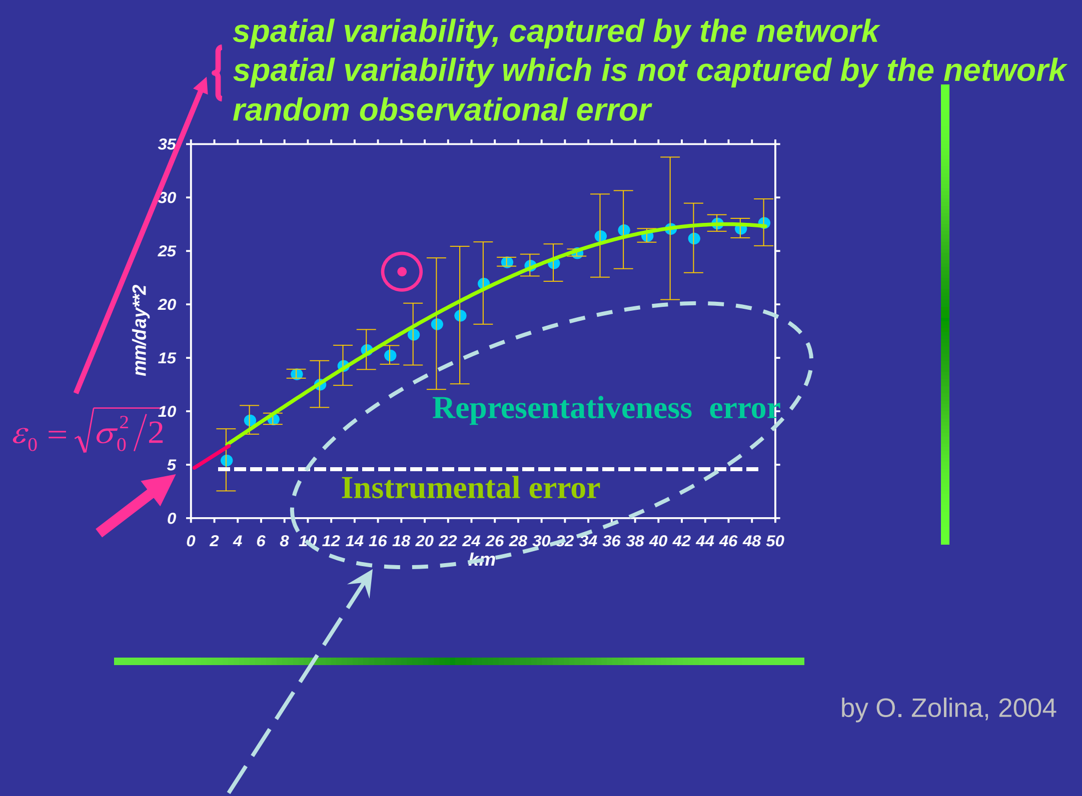
Insufficient knowledge:

- **“<u>You think that or you know that ?</u>” ➔** models’ parameterizations bring different results and are sensitive to parameters

Representativeness error

The representativeness error is a measure of accuracy with which the data gathered at a single point are able to describe a field over the study area.

Representativeness error



by O. Zolina, 2004

added by S.Ivanov et al, 2007

Representativeness error

Representativeness error and Network resolution

$$\overline{\varepsilon_i \, \varepsilon_j} = \overline{\left(\varepsilon_i^{inst} + \varepsilon_i^{rep}\right)\left(\varepsilon_j^{inst} + \varepsilon_j^{rep}\right)} =$$

$$= \overline{\varepsilon_i^{inst} \; \varepsilon_j^{inst}} + \overline{\varepsilon_i^{inst} \; \varepsilon_j^{rep}} + \overline{\varepsilon_i^{rep} \; \varepsilon_j^{inst}} + \overline{\varepsilon_i^{rep} \; \varepsilon_j^{rep}} =$$

$$= \overline{\varepsilon_i^{inst} \; \varepsilon_j^{inst}} + 0 + 0 + \overline{\varepsilon_i^{rep} \; \varepsilon_j^{rep}}$$

i, j – observation points
ε^{inst} – instrumental error with *a priori* known statistics (*Hollingsworth and Lonnberg, 1986* – in situ observations, *Eyre, 1997* – remote sensing)
ε^{rep} – representativeness error (noise due to the Gibbs effect in spectral space (*Коняев, 1981; Chen and Kuo, 1992*))

Indirect approach in estimating the representativeness error (*Ivanov and Palamarchuk, 2007*)

i = j, ε^{rep} ➔ *0*

$$\overline{\varepsilon_i \; \varepsilon_j} = \overline{\varepsilon_i \; \varepsilon_i} = \overline{\varepsilon_i^{inst} \; \varepsilon_i^{inst}} = \sigma_i^2$$

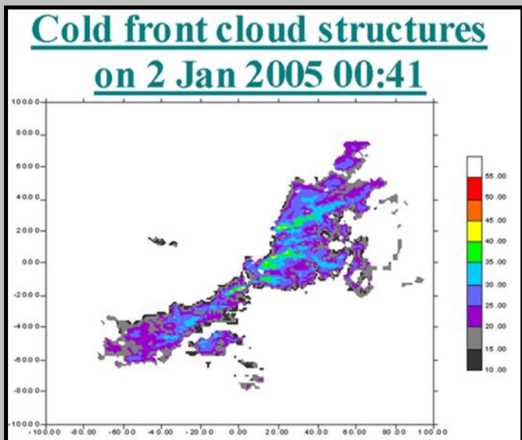
Observation error covariance matrix is equal to standard deviation of the instrumental error

i $\neq$ *j,*

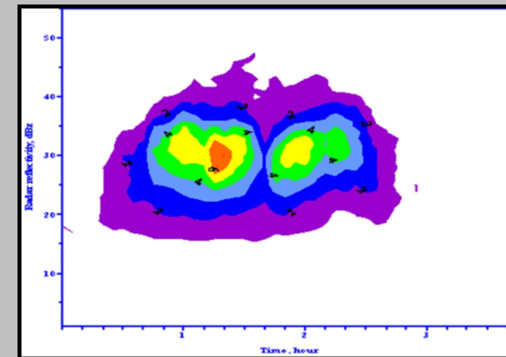
$$\overline{\varepsilon_i \; \varepsilon_j} = \overline{\varepsilon_i^{inst} \; \varepsilon_j^{inst}} + \overline{\varepsilon_i^{rep} \; \varepsilon_j^{rep}} = \left(\sigma^{inst}\right)^2 + \left(\overline{\varepsilon^{rep}}\right)^2$$

The observation error includes both the instrumental and representativeness errors

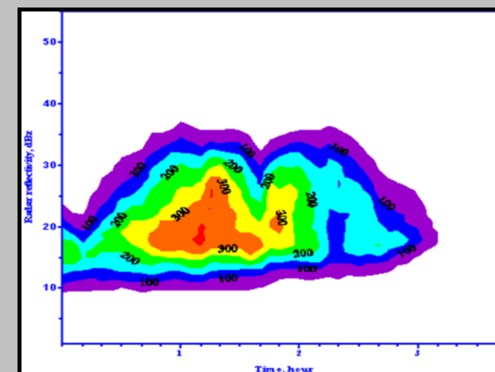
Frontal Precipitation



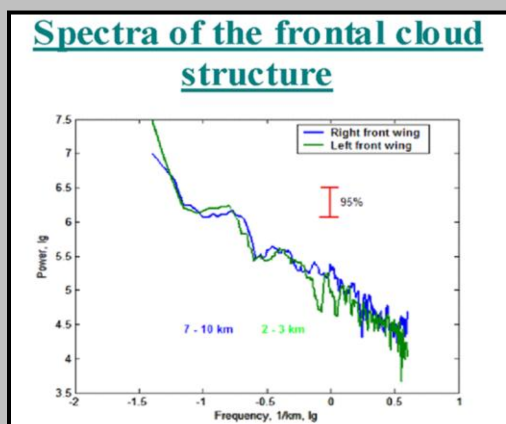
Radar network data, MIUB



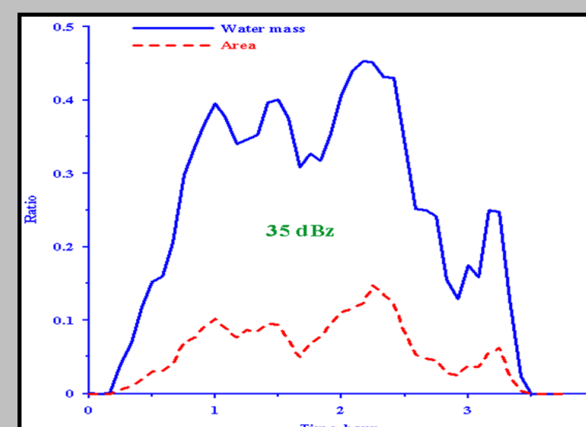
The water mass (10^5 m^3)



and area (km^2) associated with different radar reflectivity within the front.



The ratio of water mass and area covered by heavy precipitation cells to total values on the front ➔



Representativeness error

- Proper description of precipitation in both the total amount and distribution between scales requires an adequate resolution of networks. Current in situ precipitation networks do not match this. Thus, the precipitation representativeness error may considerably contribute in total observation error.
- High resolution regional model simulations (MM5/WRF) can partially overlay this gap.

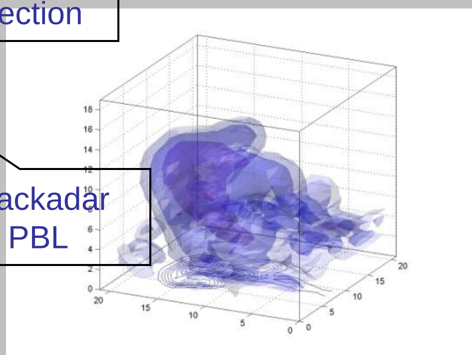
3D Cloud Water and Rain Water by different parameterization schemes

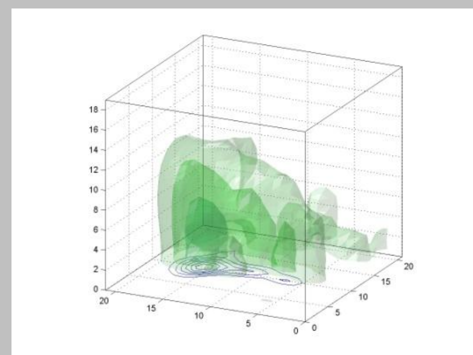
Cloud Water | Rain Water | 5324 5643

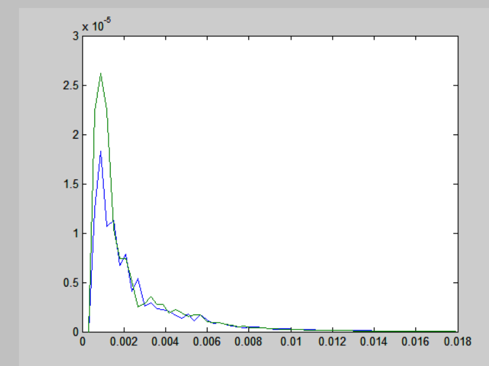
Grell convection

5324

Blackadar PBL





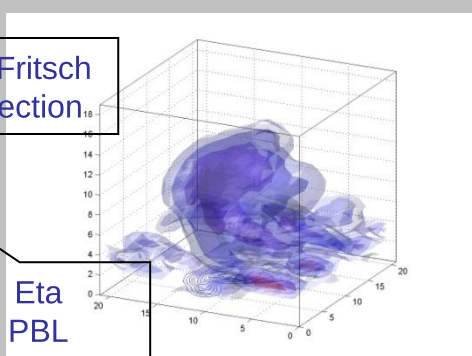


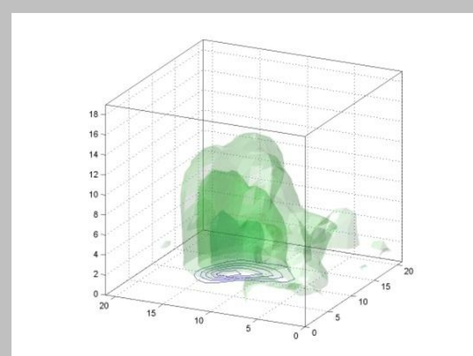
Average spectrum (no smoothing)

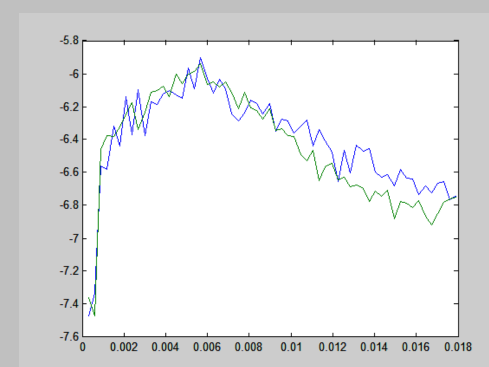
Kain-Fritsch convection

5643

Eta PBL

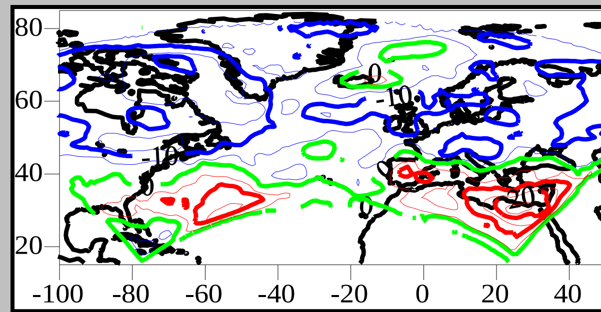




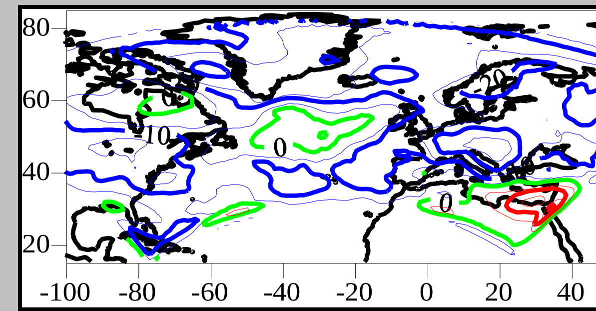


Difference filtering

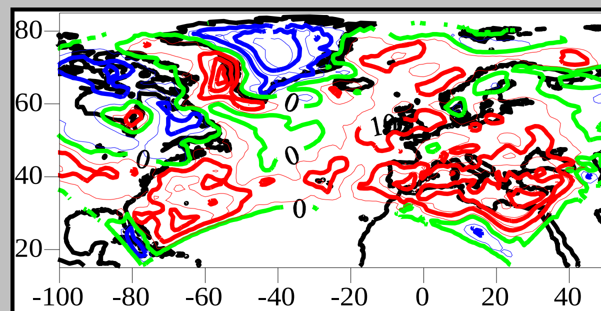
Spatial structure of the humidity systematic error in the model



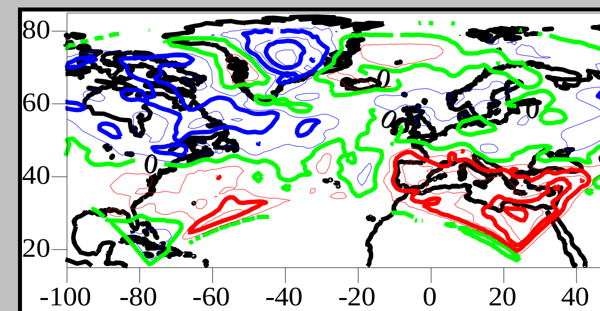
500 hPa



300 hPa



850 hPa

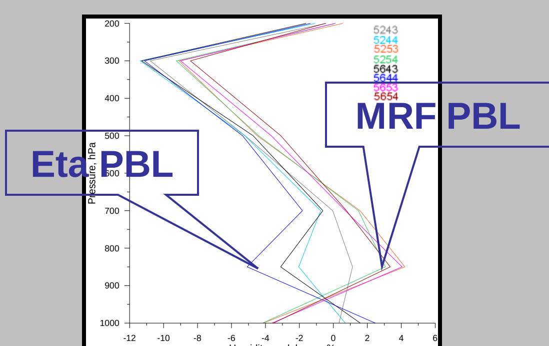


700 hPa

MM5 – ERA40 < 0 Underestimation in the upper troposphere

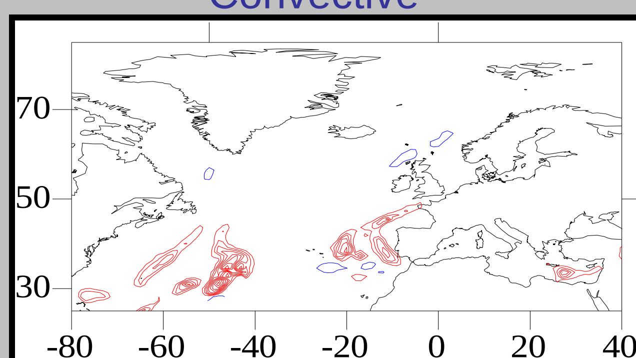
MM5 – ERA40 > 0 Overestimation in the low troposphere

Vertical profiles of the systematic model error

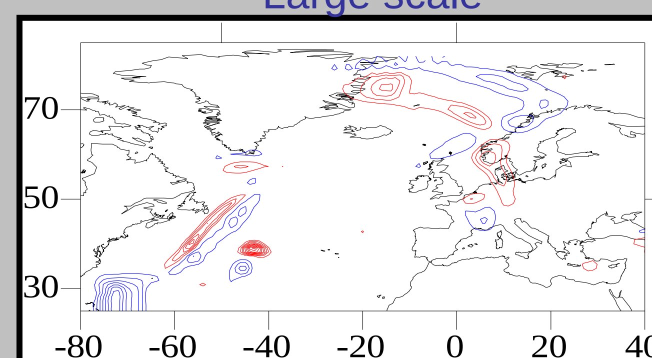


Discrepancy in precipitation MM5 {5653 (optimal)} – ERA40

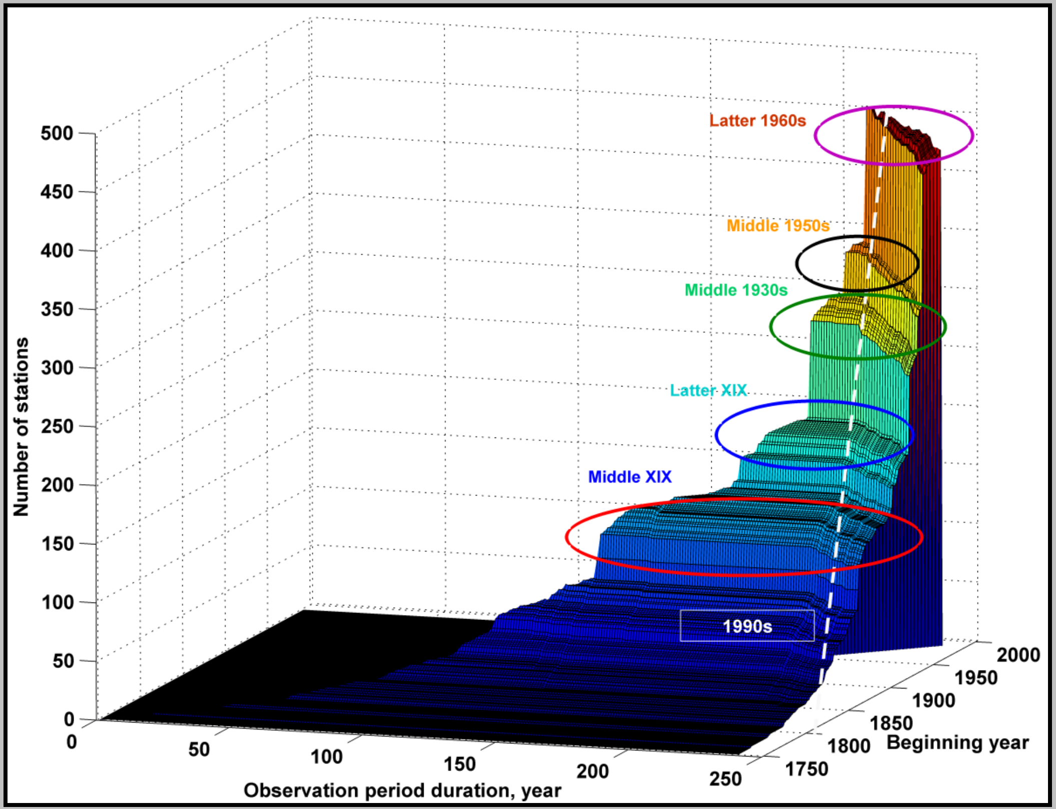
Convective

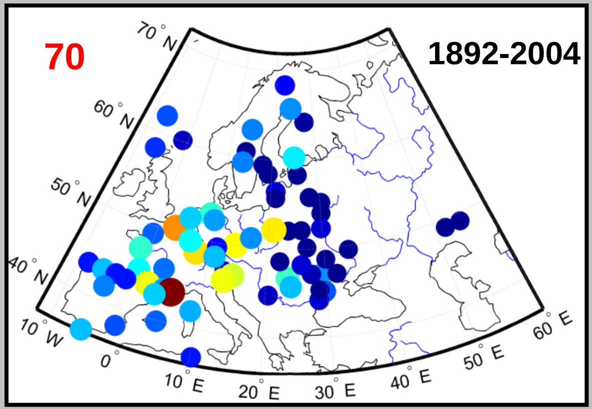


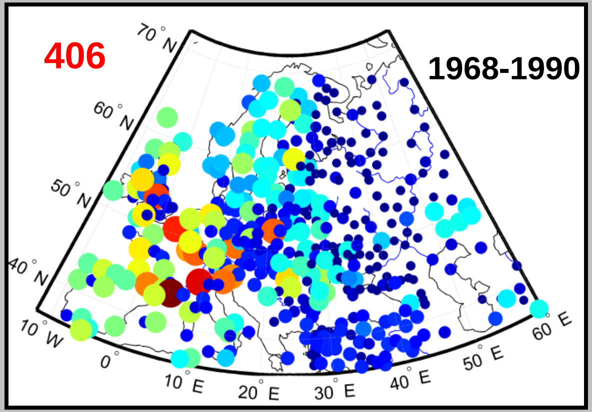
Large scale

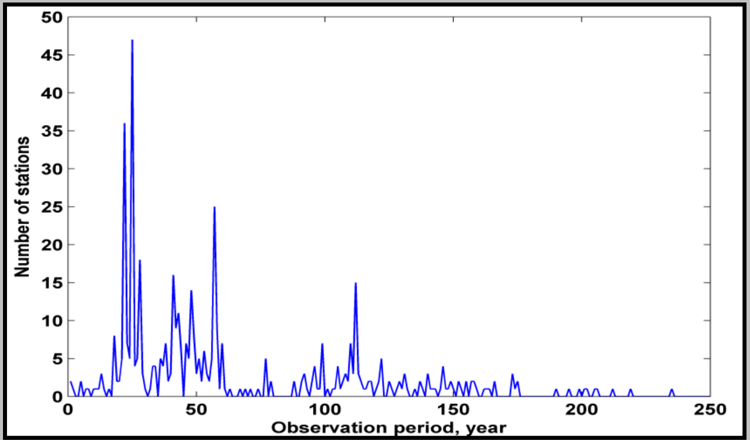


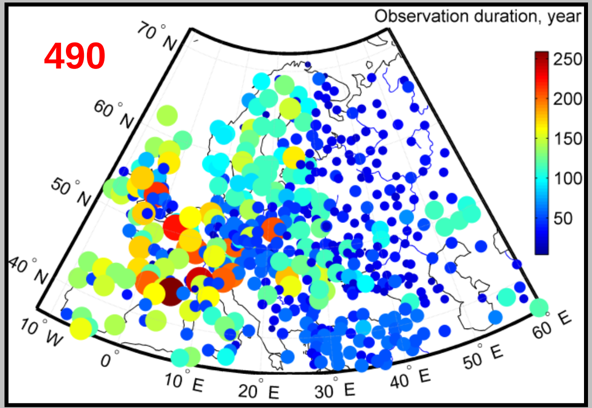
Precipitation Data Availability







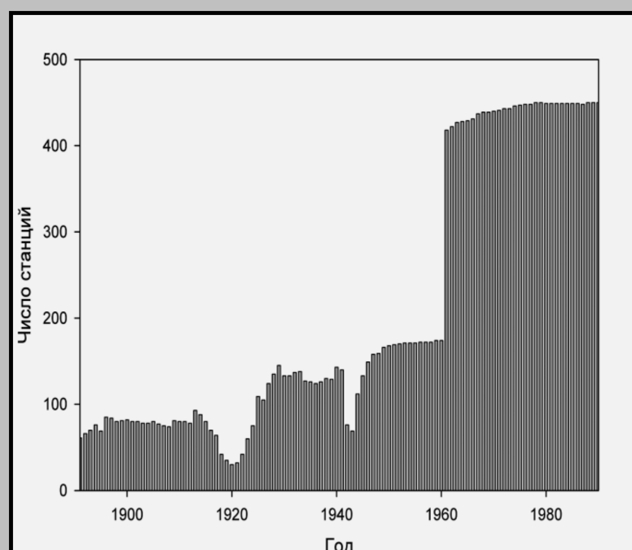


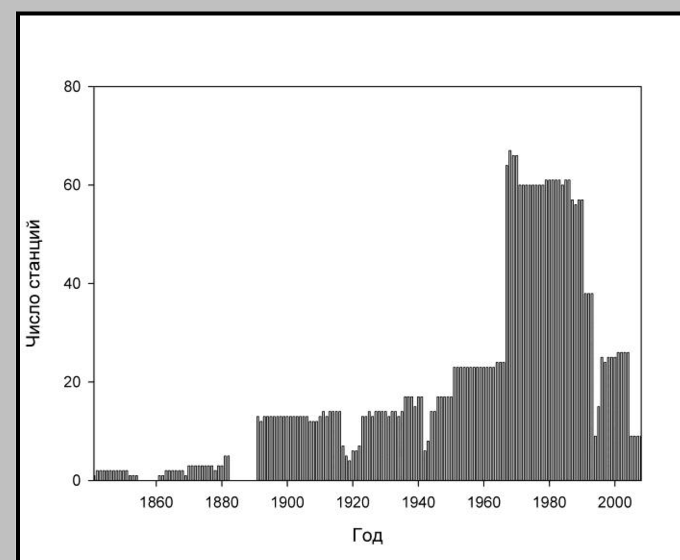


Observational network

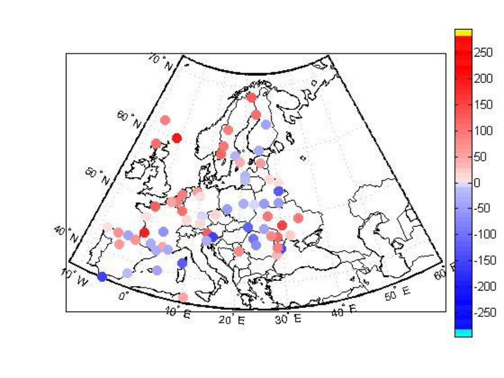
Data bases
Ukrainian Climate Cadastre (UCC), DB1 (1961-1990)/UHMS, (1965-1995), NCEP, DB2 (1841-2008)

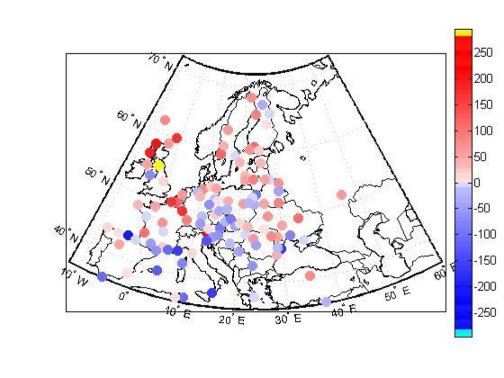
1936-59: Showers and daily precipitation at 115 stations from ~200
1960: at only 85 stations
1961-64: Annual reports for daily precipitations
1965-83: Annual reports with detailed daily precipitation data
1984-90: Annual reports contain only 15 stations with precipitation data
Since 1990: Commercial epoch, no data available for scientific and educational tasks

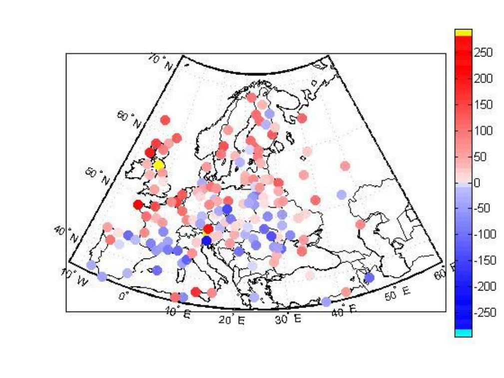




Trends in annual precipitation (observed)



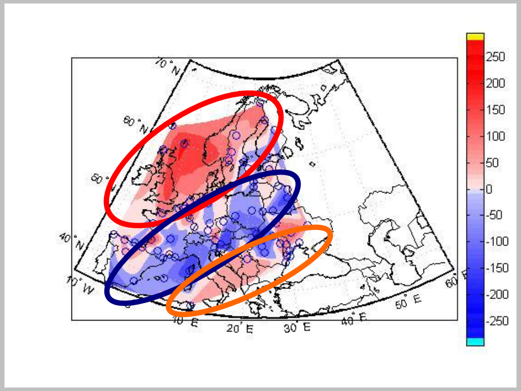


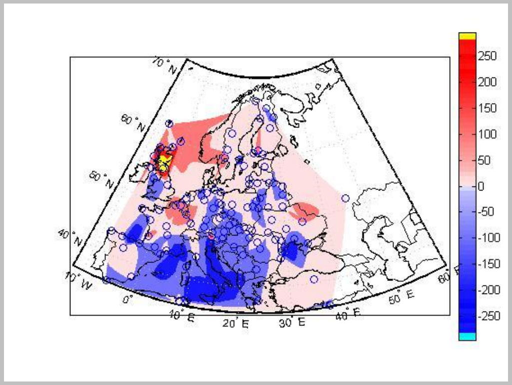


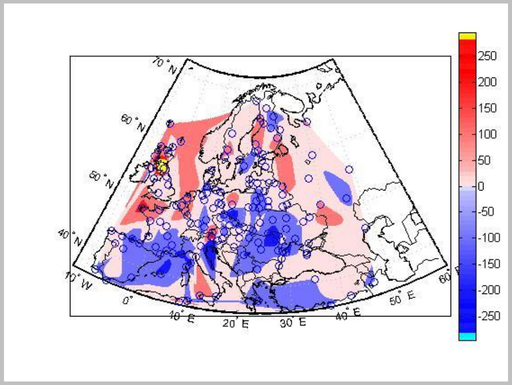
1892-2008

1951-2008

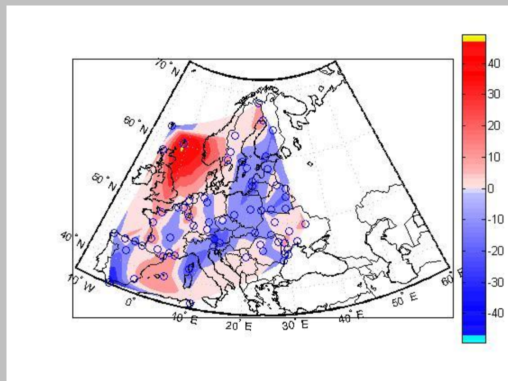
1968-2008



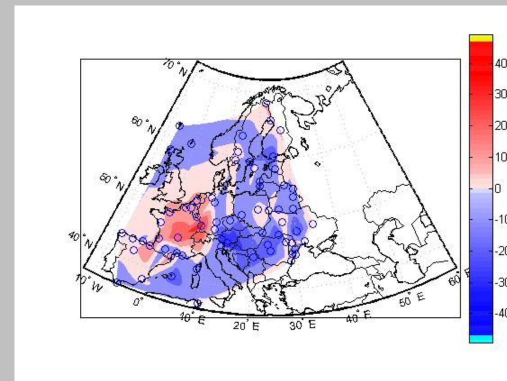




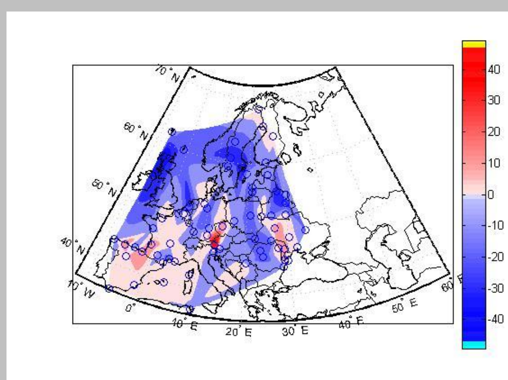
Trends in seasonal precipitation (observed; 1892-2008)



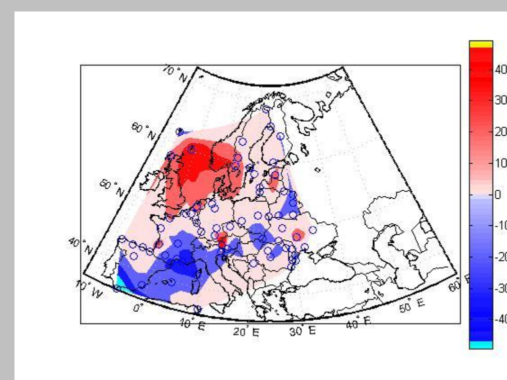
February



May

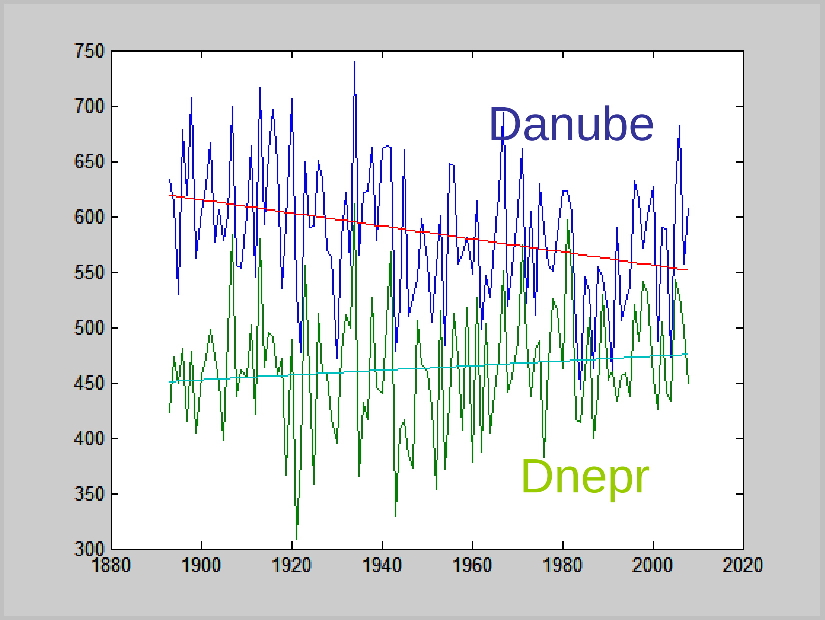


August



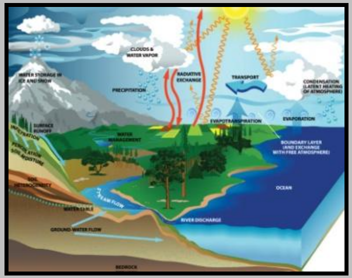
November

Precipitation over the Danube and Dnepr basins



Basin precipitation over the Danube and Dnepr rivers have opposite tendencies

Even a general idea is relatively simple …



Large-scale Atmospheric Flow

Regional Precipitation Regimes

Which atmospheric indexes being used?

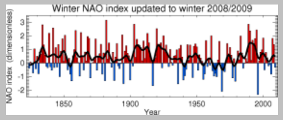
- North Atlantic Oscillation (NAO) ?

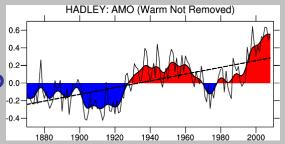
- Atlantic Multi-Decadal Sea Surface Oscillation (AMO) ?

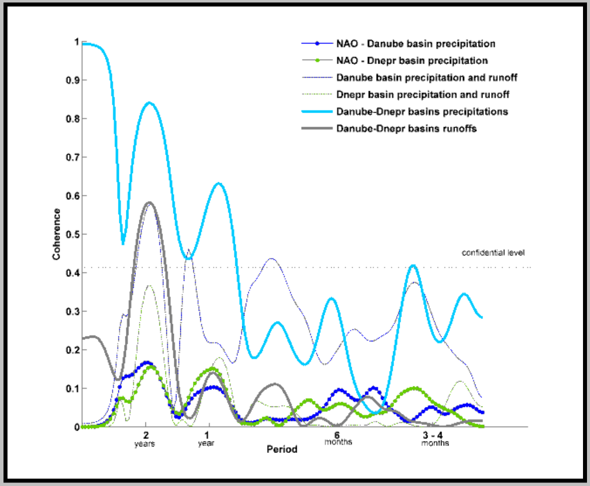
- Mediterranean Oscillation Index (MOI) ?

- Angular Moment (AM) ?

One value (index) is associated to regions with different (counterpart) tendencies

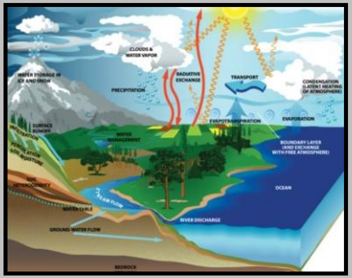






What is the metric to associate with 3D variability ?

Anthropogenic contribution to the water cycle changes

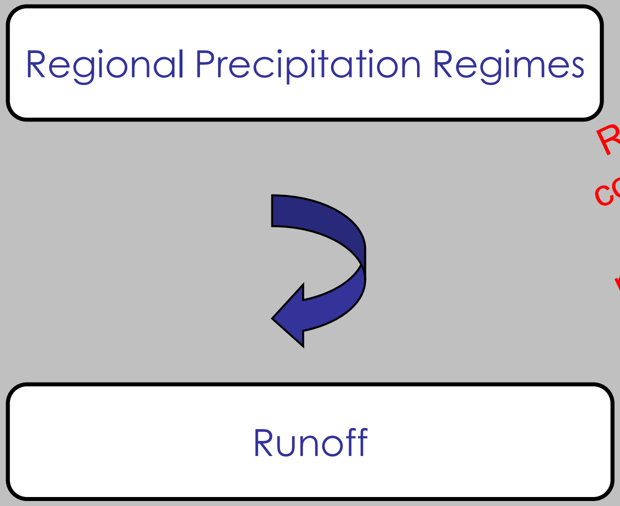


<u>Human factors in:</u>

- Fresh water consumption
- Agriculture
- Industry

The fresh water consumption in Ukraine has been reduced during last two decades approximately threefold, from 30 to 11 km^3, with the minimum observed in 2004 and equal to ~10 km^3.
The area of irrigation, which is the main factor for non-returnable water, has decreased from $2.5x10^6$ km^2 to the one by ten of this value since the early 90-s.
The amount of non-returnable water was reduced by approximately a factor of five from 10 to 2 km^3.

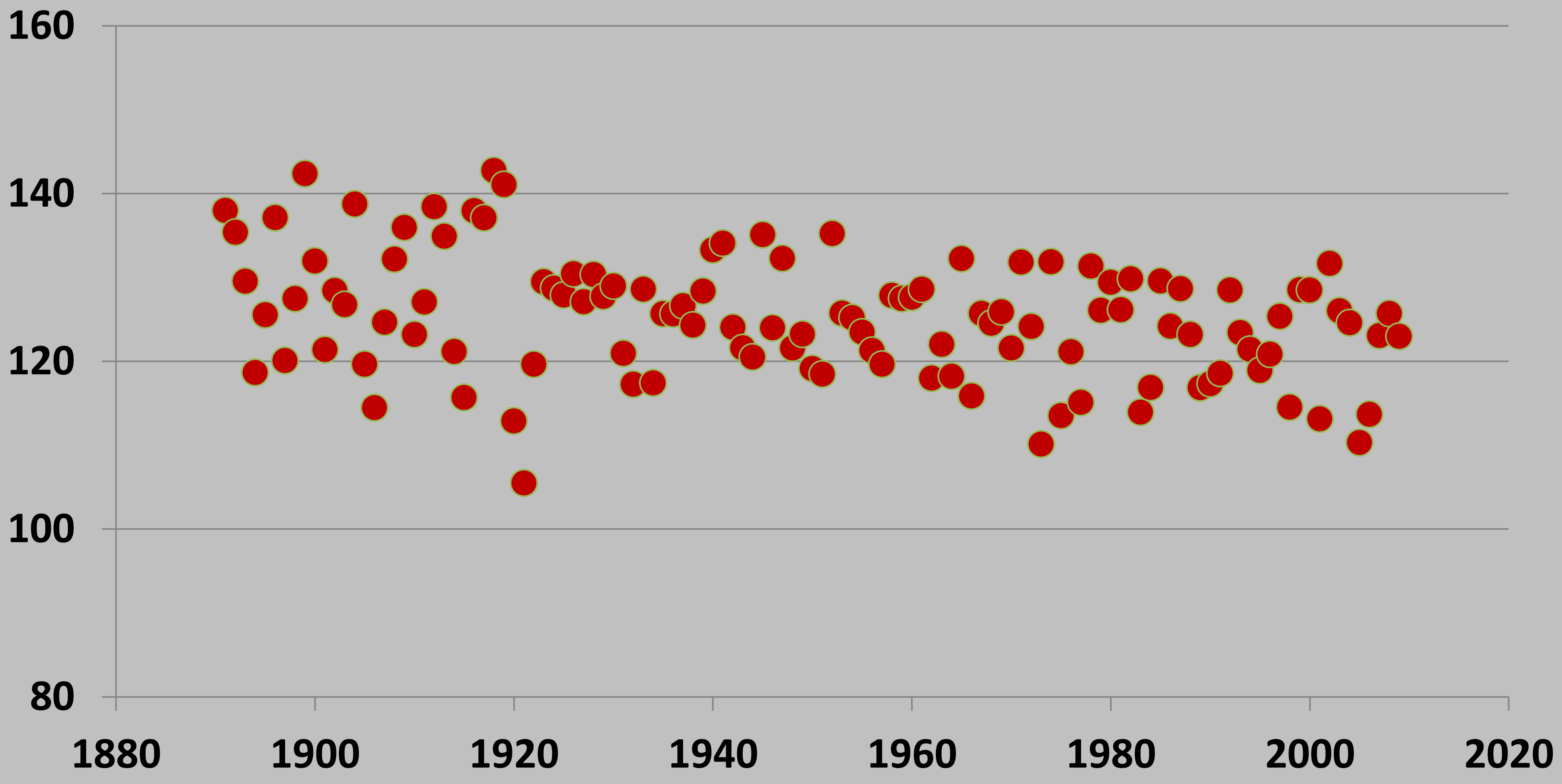
- ? Official reports ~ "In fact" consumption ?



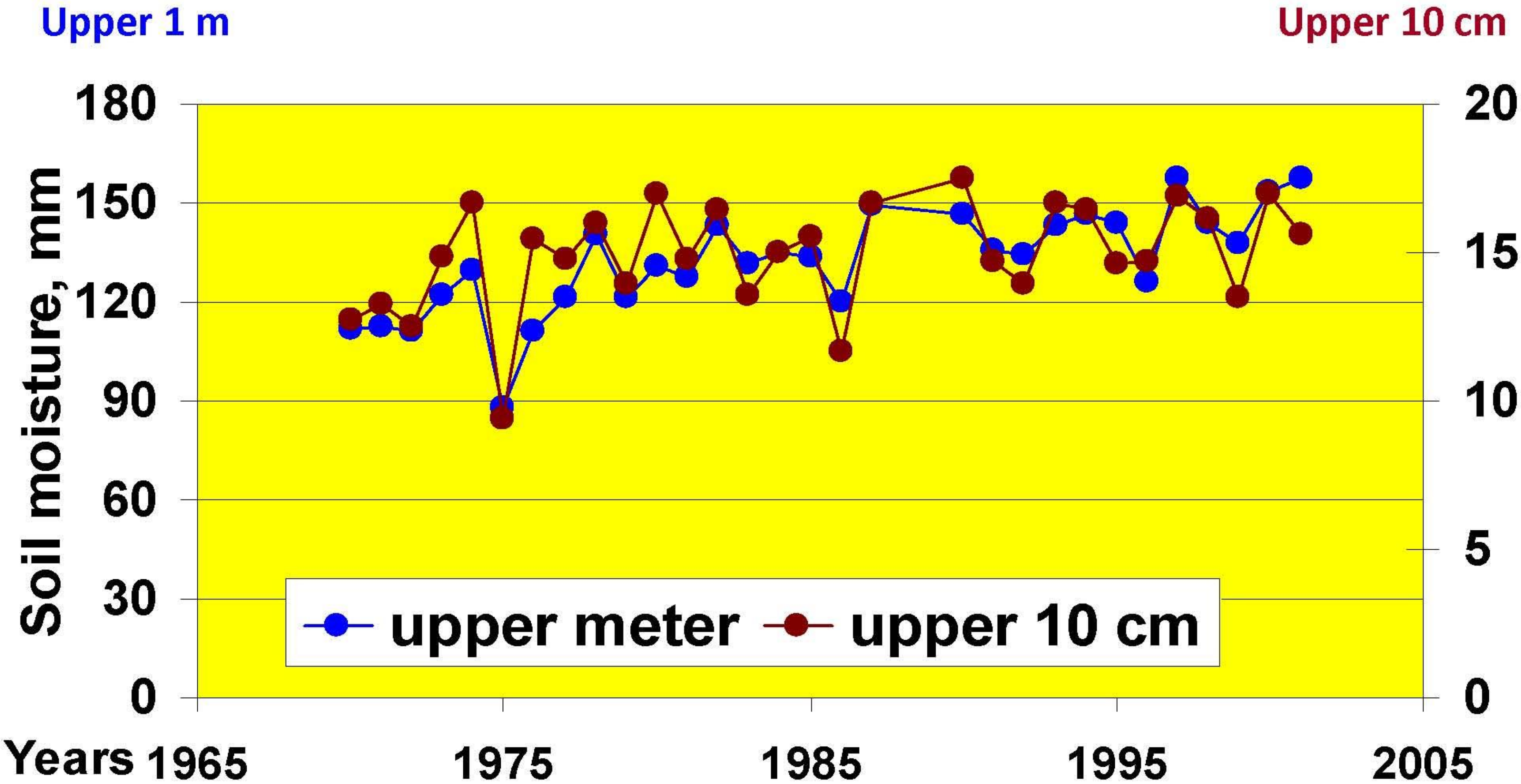
Runoff correlates with precipitation over a basin less than it may be expected

Dates of when vegetation season starts Julian day

European Russia south of 60N

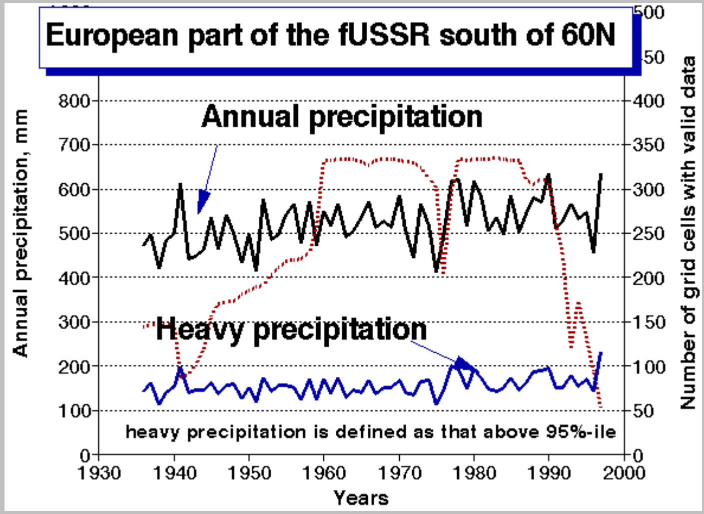


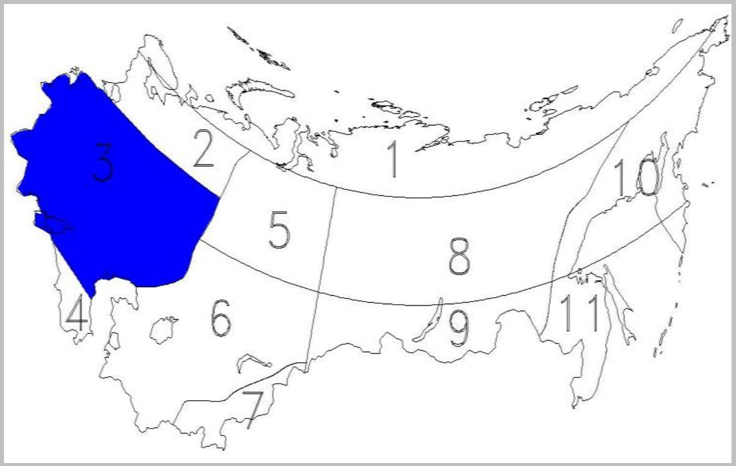
Soil moisture changes over European Russia south of 60°N during the warm season in the first upper 100 and 10 cm respectively (Speranskaya 2009)



r = 0.78; rates of change = 9.3%/10yr [R^2=0.58] and 5.5%/10yr [R^2=0.15] respectively.

Trend characteristics (1936-1997 years) of the annual precipitation for western USSR

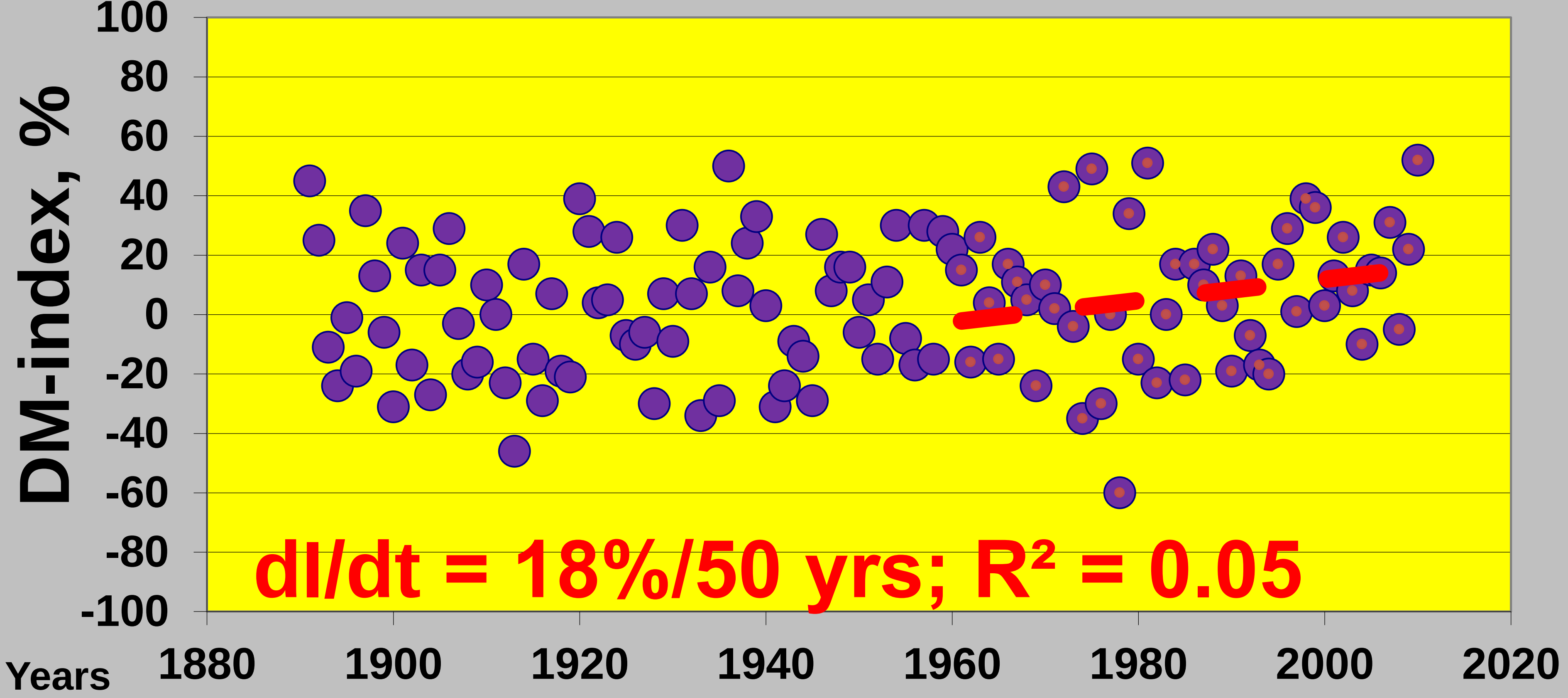




	Linear trend and its variance	
	%/10yrs	%
Total P:	2.4	18
"Heavy" (upper 10%)	2.9	15
Very heavy (upper 1%)	4.0	15
"Extreme" (upper 0.1%)	5.0	10

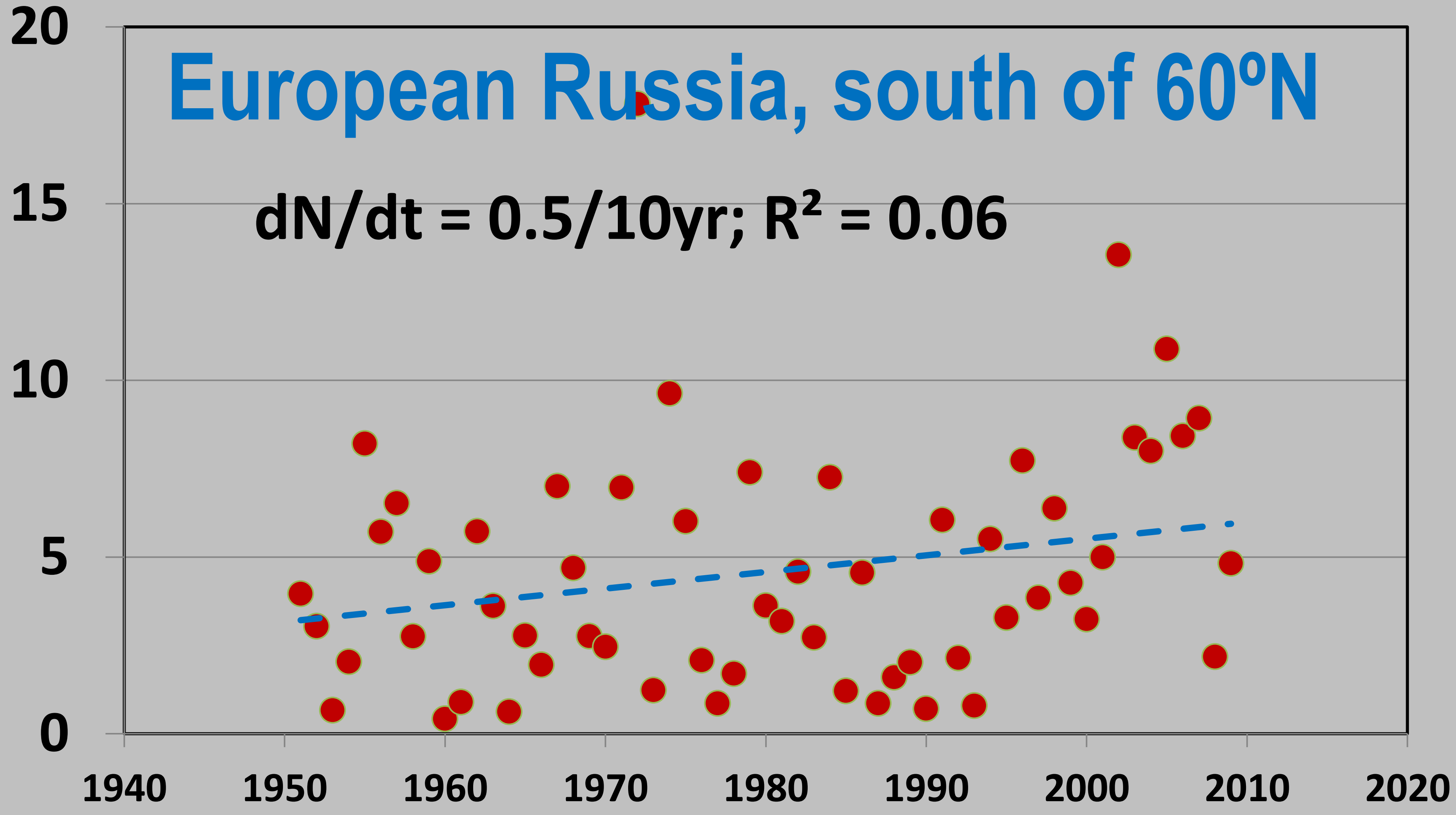
Agricultural regions of European Russia, Belarus, and Ukraine. May – July Drought Index.

Meshcherskaya and Blazhevich, 1997, updated to 2010

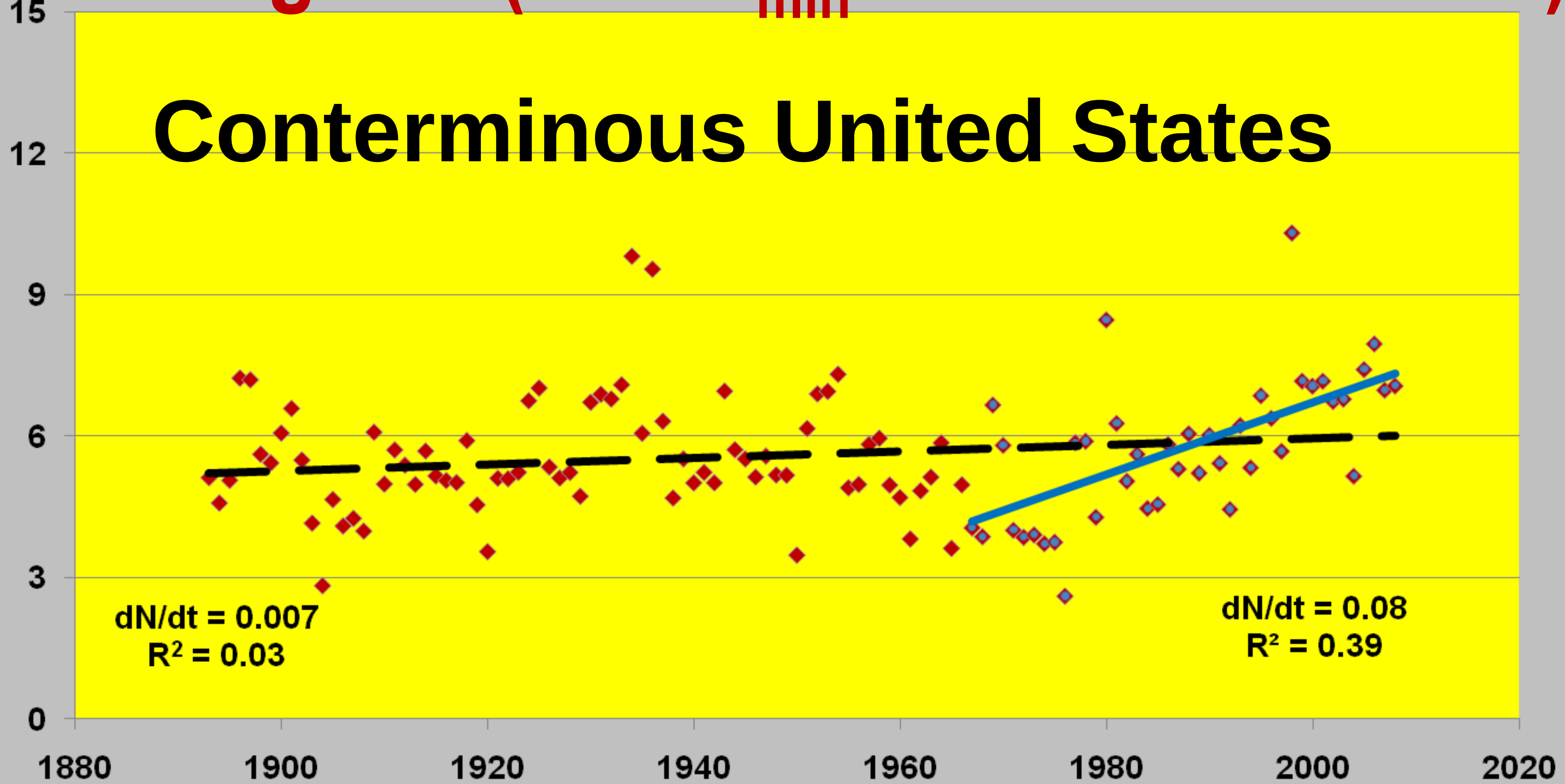


Areas with excessively dry conditions minus areas with excessively wet conditions, (% of total area)

Dry episodes above 30 days during the warm season

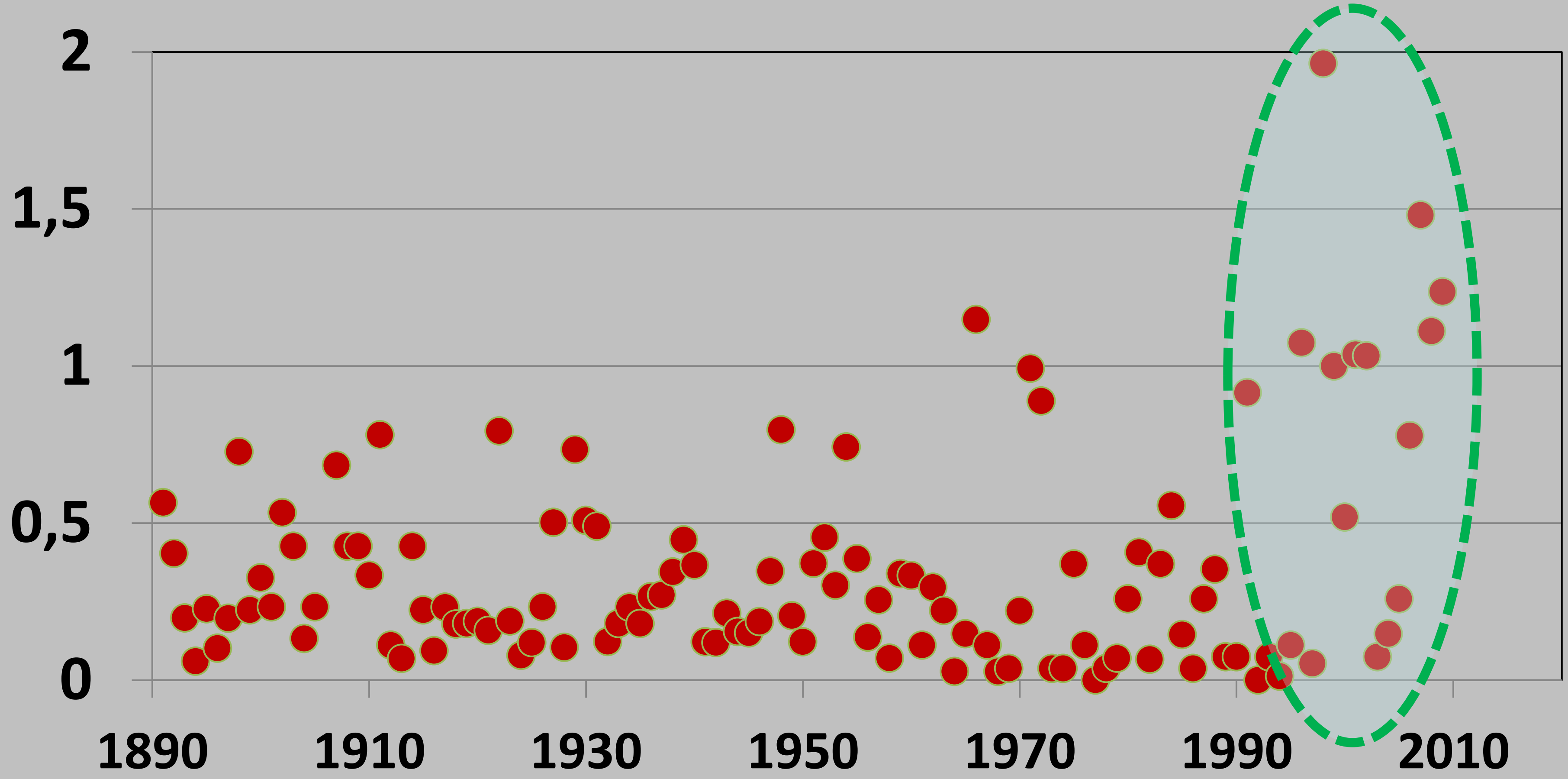


Nationwide-averaged annual number of “hot nights” (with T_{min} >75°F or > 23.9°C).

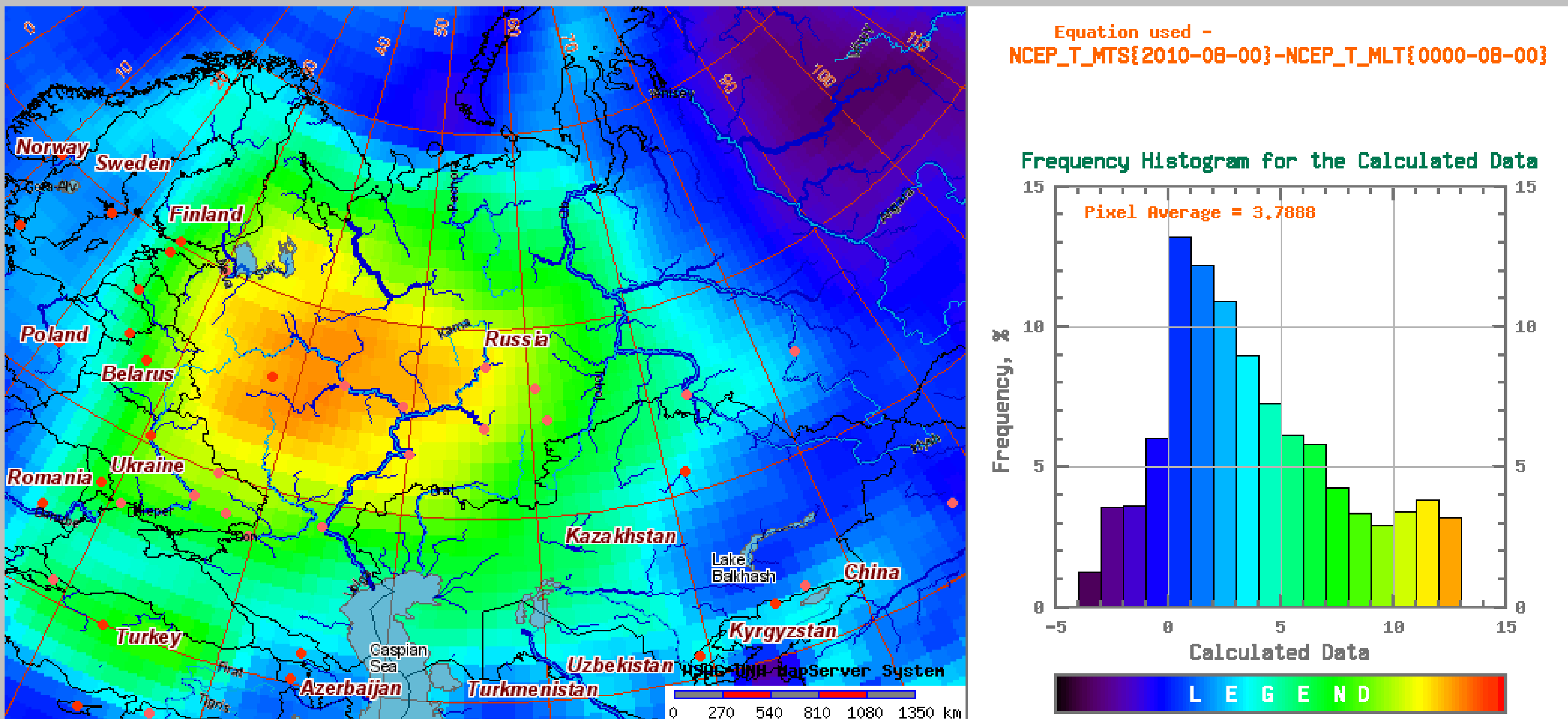


Impact of hot nights on human health (a relative frequency of heart attacks) is well established. Now, with minimum temperature continuing to rise, this impact became more severe everywhere in the eastern and southern United States. During the past four decades, there was an approximately 60% nationwide increase in the number of “hot nights” and in the Northeast the number of such nights increased by 170%.

European Russia south of 60°N, number of days with T_{min} above 75°F (≥23.9°C). 1891-2009

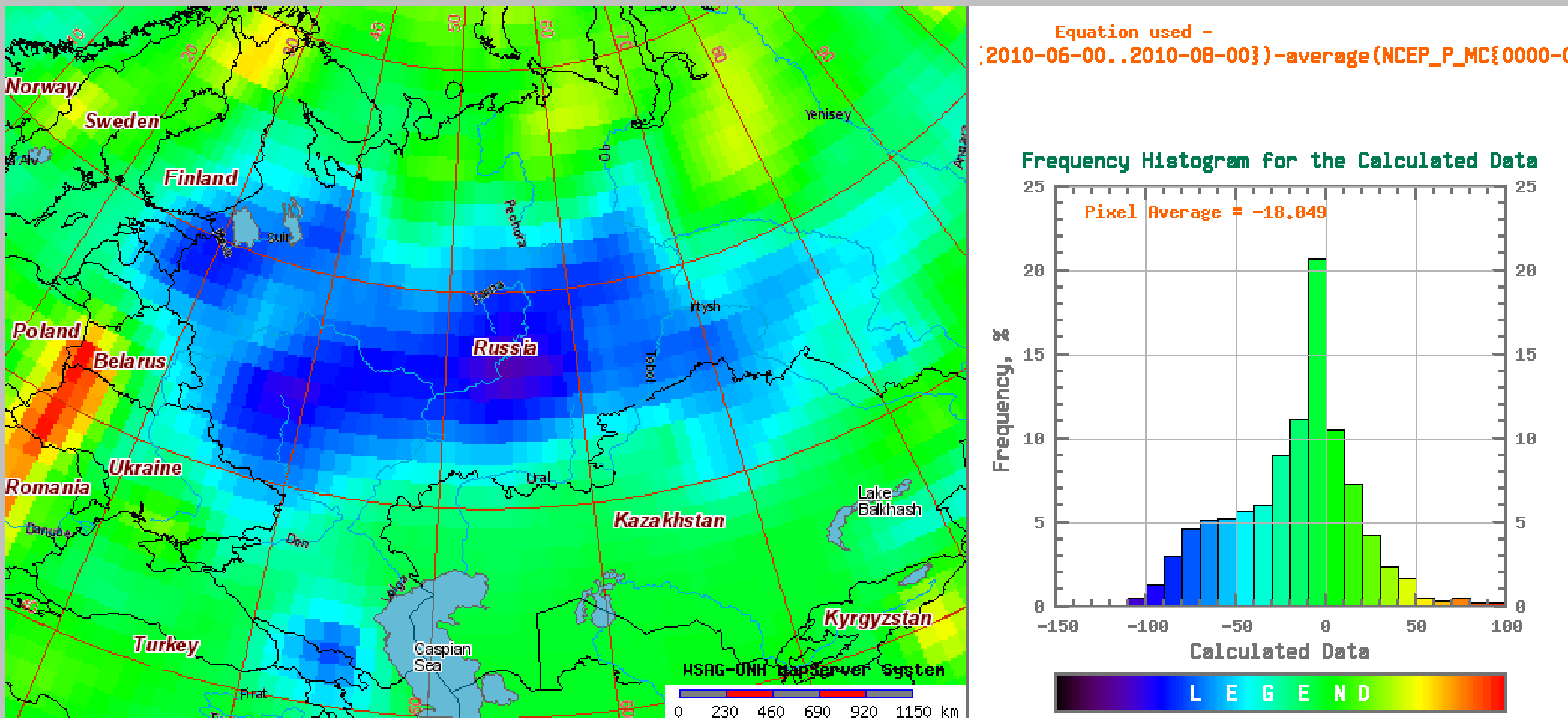


Preliminary estimates of temperature anomalies over Eastern Europe, August 2010



Analysis has been conducted using Data Analysis and Exploring System for Hydrology of the NEESPI domain"; http://neespi.sr.unh.edu/maps/ (courtesy of Prof. Alex Shiklomanov, University of New Hampshire) .

Preliminary estimates of precipitation anomalies over Eastern Europe; Summer 2010



Analysis has been conducted using Data Analysis and Exploring System for Hydrology of the NEESPI domain”; http://neespi.sr.unh.edu/maps/ (courtesy of Prof. Alex Shiklomanov, University of New Hampshire) .

Conclusions

- During the 20th century, we observed a considerable increase of annual precipitation over the Northwestern Europe; a drier regime was established over the entire Mediterranean; and wetter conditions have been observed over most of East Europe (northeastward from the Black Sea coast)
- The other variables such as Vegetation Date Start, Upper Layer Soil Moisture, Fire Danger Index, Drought Index, tendencies in Heavy and Extreme Precipitation, Dry Episode, Hot Nights as well as Temperature Anomalies confirms changes occurring in atmospheric regimes
- Runoff and basin precipitation weakly correlate mainly due to human factor and uncertainties in the fresh water consumption data
- We did not find a single general circulation parameter (index) that can unilaterally relate atmospheric and precipitation patterns
- In situ precipitation networks have an insufficient resolution for catching some mesoscale features with important characteristics (while remote sensing uses nonlinear and non-unique “weighting functions”)
- Model simulations of precipitation are sensitive to parameters