Comparative analysis of the assessment of hydrothermal conditions of the Tomsk region, using different droughts coefficients

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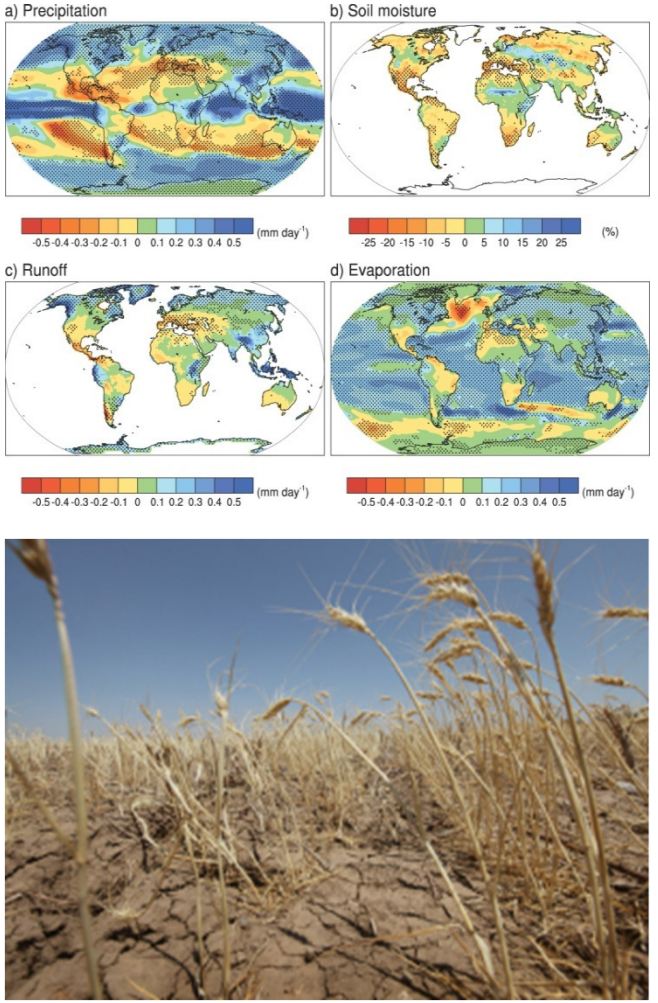
Introduction

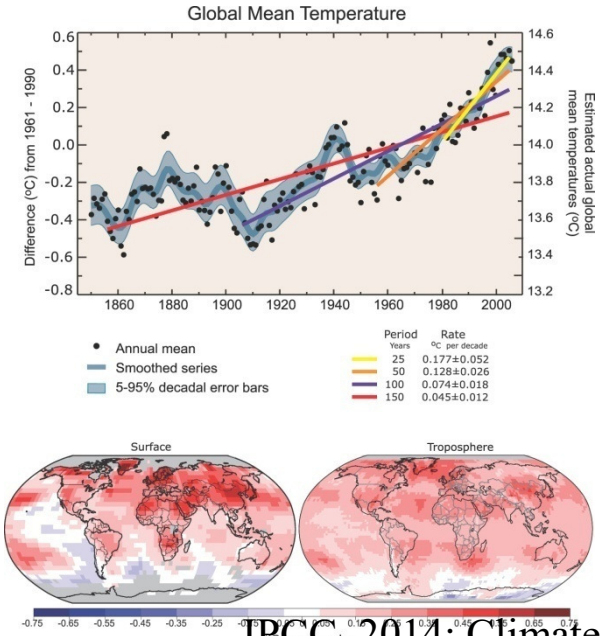
<u>Modern global climate changes are characterized by a significant warming in the end of XX – beginning of XXI centuries (starting from the second part of 1970s).</u>

A drought is a complex natural phenomenon with strong regional anomalies of temperature and humidification.

There are many different studies about droughts:

- their detection;
- determination of their characteristic types;
- forming condition;
- development of the most representative aridity indices;
- catastrophic droughts analysis
- Etc.





IPCC, 2014: Climate Change 2014: Synthesis Report.

This indices we use and compare:

The Selyaninov hydrothermal coefficient (HTC):

The HTC is used for the estimation of moistening and drought conditions of territories and the determination of moist and dry period.

$$HTC = \frac{\sum p}{0.1 \sum t_{>10}},$$

$\sum p$ - sum of precipitation during the vegetation period with air temperature above 10 °C,

$\sum t_{>10}$ - sum of precipitation during the vegetation period with air temperature above 10 °C.

For a more correct zonal comparison of results, we used HTC anomaly standardized on standard deviation.

The Ped drought index (S):

The S is the normalized ratio of air temperature and precipitation.

$$S_i = \frac{\Delta t_i}{\sigma_t} - \frac{\Delta p_i}{\sigma_p},$$

$\Delta t_i = t_i - t_{norm}$- temperature anomaly, σ_t - standard deviation of temperature. For precipitation is similar.

This indices we use and compare:

The Standardized precipitation index (SPI):

The SPI for any location is calculated, based on the long-term precipitation record for a desired period.

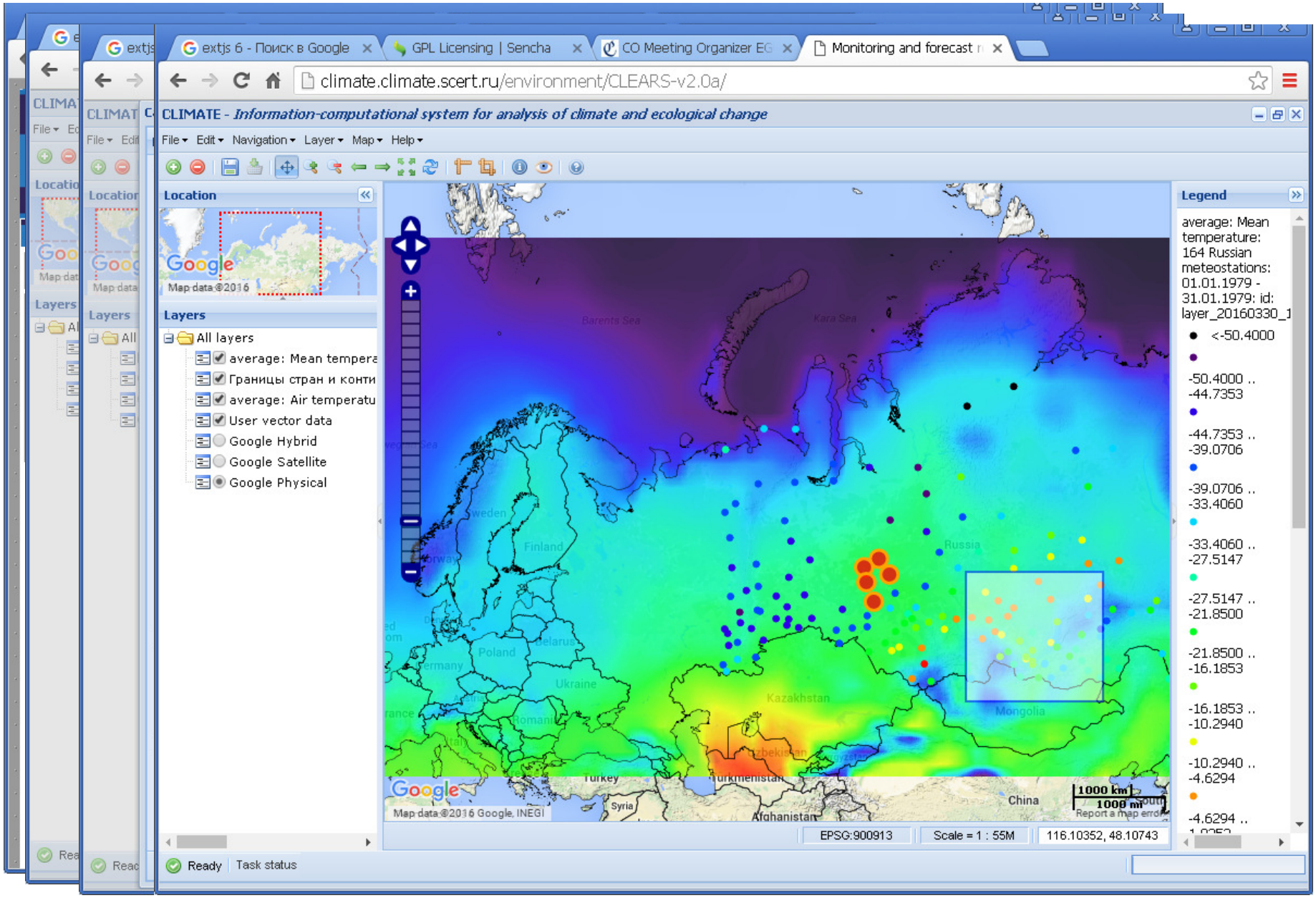
- The available long-term rainfall data is fitted to gamma probability distribution, which is then transformed to a normal distribution so that the mean SPI for the location and desired period is zero (**Mckee et al.,1993**).
- This transformed probability is the SPI value, which varies between -2.0 and +2.0, with extremes outside this range occurring at 5% of the time

The Standardized precipitation evapotranspiration index (SPEI):

The SPEI is calculated in the same way as SPI, but it based on the long-term precipitation and evapotranspiration (PET) record for a desired period.

- The available long-term rainfall and PET data is fitted to log-logistic probability distribution, which is then transformed to a normal distribution so that the mean SPEI for the location and desired period is zero (**S.M. Vicente-Serrano et al.,2010**).
- This transformed probability is the SPEI value, which varies between -2.0 and +2.0, with extremes outside this range occurring at 5% of the time

Dedicated software: The system "CLIMATE", based on web- and GIS-techniques, is a part of a hardware and software complex for "cloud" analysis of climate data.



Calculation of indices

To calculate drought indices web-GIS "CLIMATE" functionality was extended by a dedicated software modules.

1. Ped drought index and Selyaninov hydrothermal coefficient

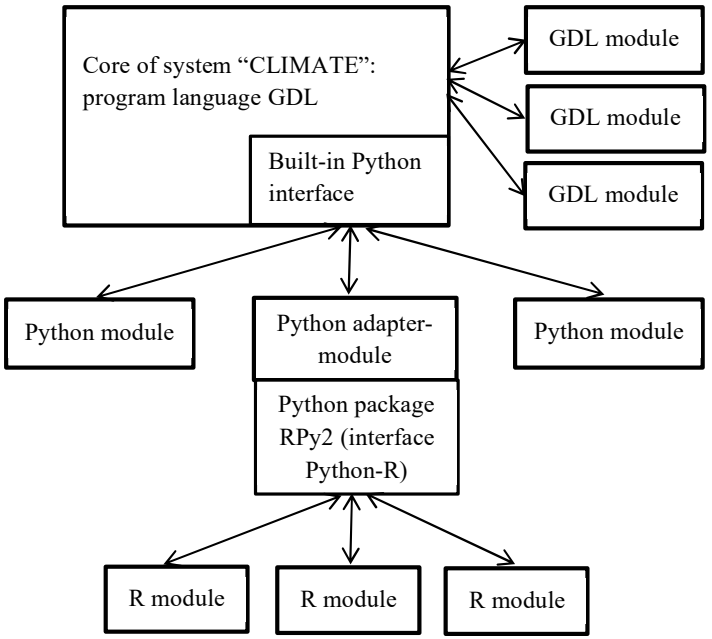
- The modules were developed using GNU Data Language (GDL, http://gnudatalanguage.sourceforge.net/).

2. SPI and SPEI indices

- The modules were developed using package "SPEI" (S.M. Vicente-Serrano et. al, 2010) of program language R.
- Procedure of integration R packages into system "CLIMATE" was described in (Ryazanova et. al, 2017) .

3. Ad-on modules (not yet available in the system)

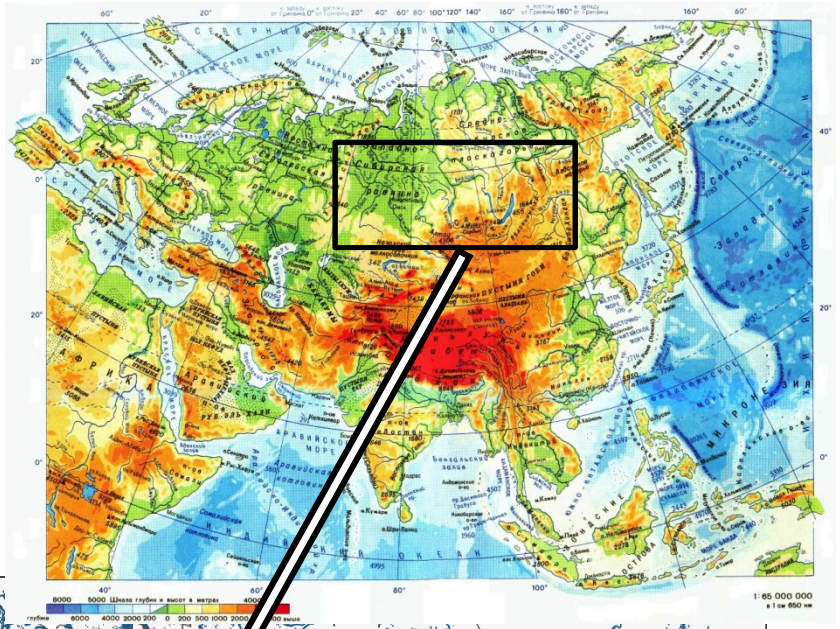
- to calculate correlation between indices an etc.



For calculation indices it is possible to use not only station data, but also all datasets that are in the system "CLIMATE" (Era Interim, Era 40, NCEP, JRA-55 and etc.). Also it is possible to choose area and time interval that is necessary for investigation.

Territory, data and time interval

- South Siberia (50-65 N, 60-120 E)
- May-September from 1979 to 2017

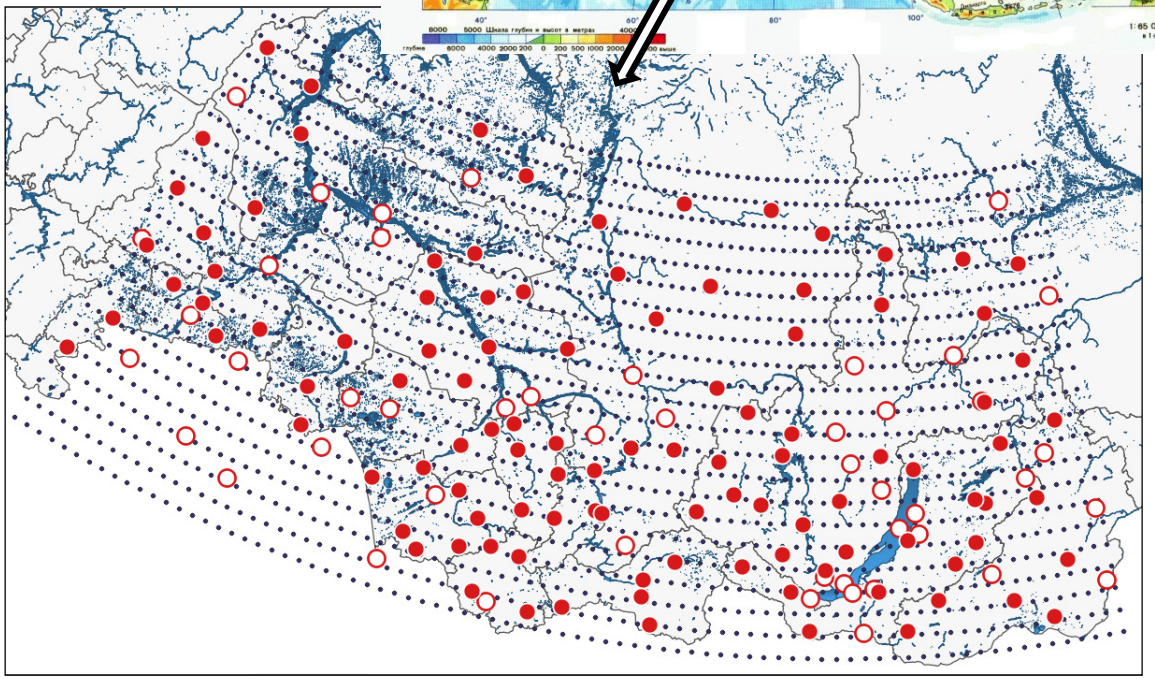


- Air temperature and precipitation:

- **ERA-Interim reanalysis (0.75 × 0.75° grid)**

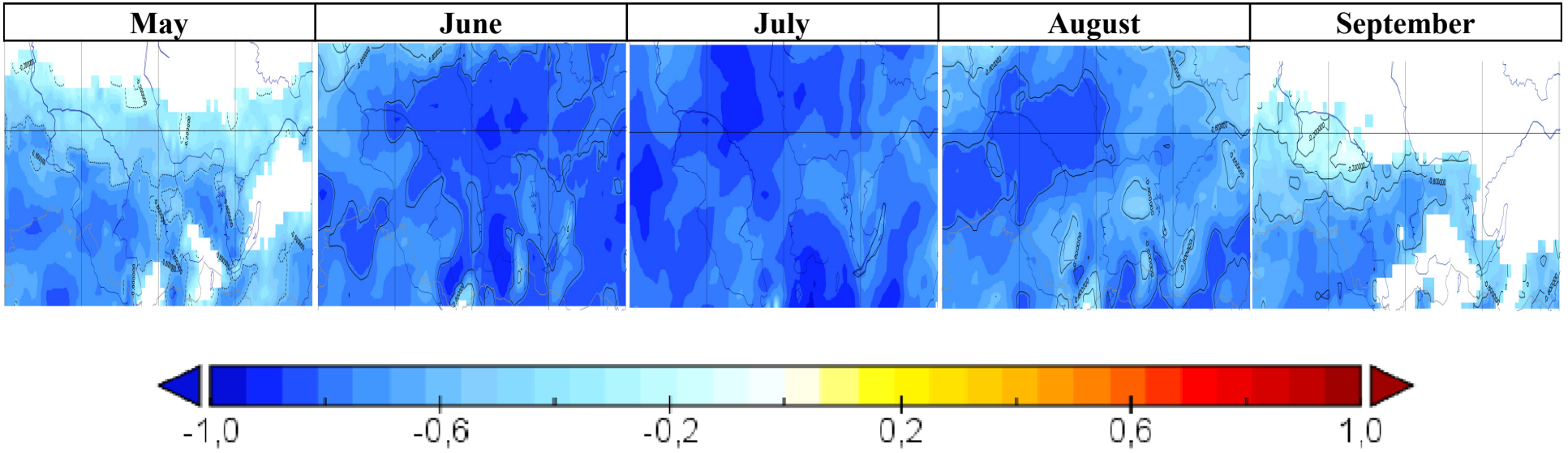
Weather stations

- Station with homogeneous series of observations (107)
- Station with non-homogeneous series of observations (46)

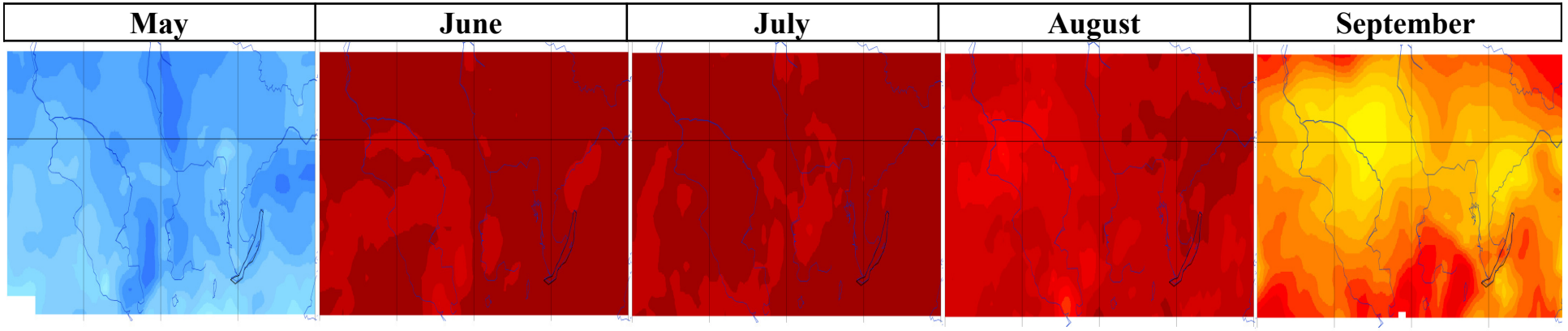


Spatial distribution (50-65N, 60-120E) of correlation coefficient

1. Between Ped drought index and anomaly of Selyaninov hydrothermal coefficient

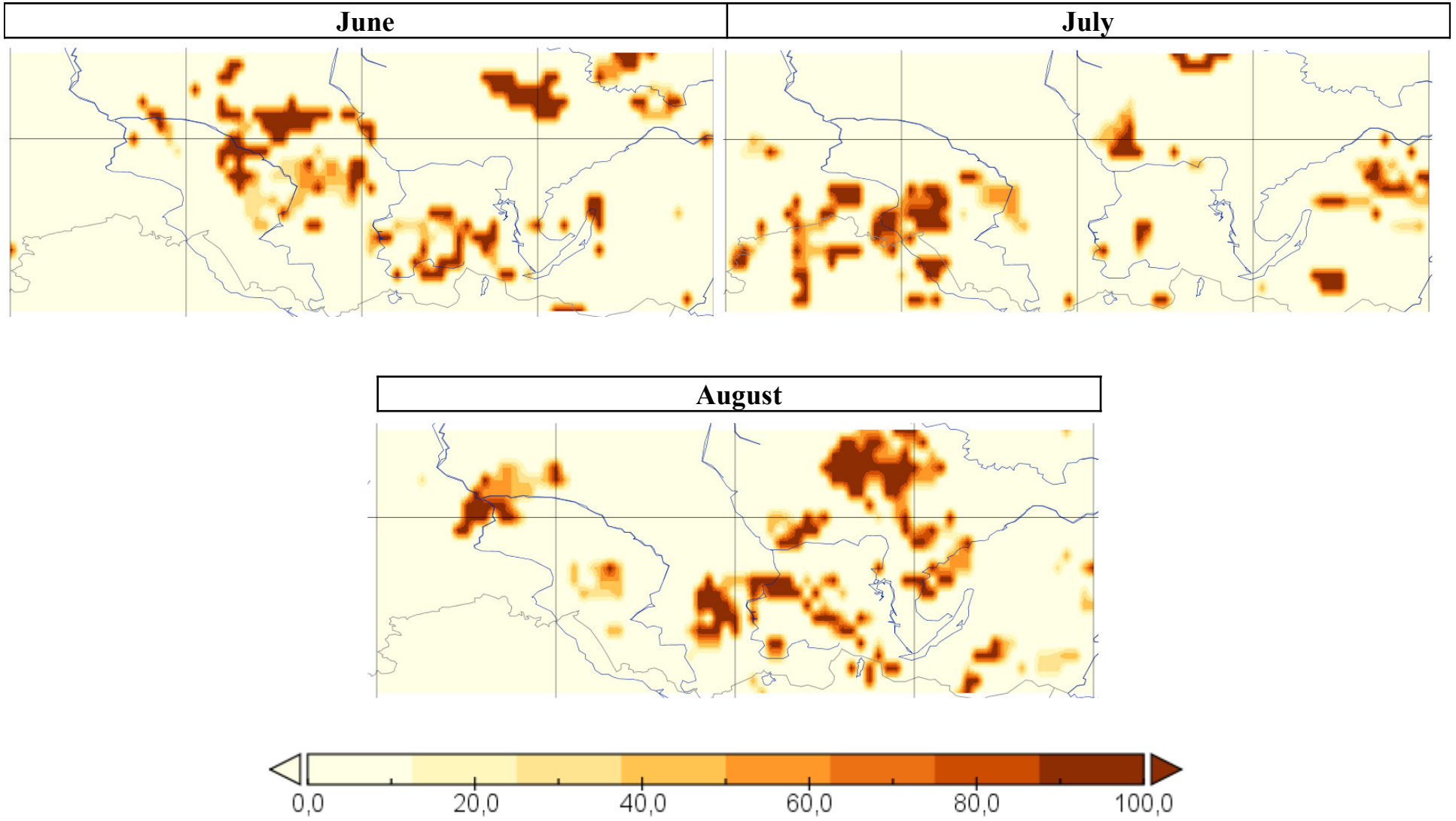


2. Between SPI and SPEI indices



Era Interim reanalysis, 0.75x0.75°.

Comparison of severe drought from 1979 to 2017 calculated using Ped index and Selyaninov HTC (% of coincidence)

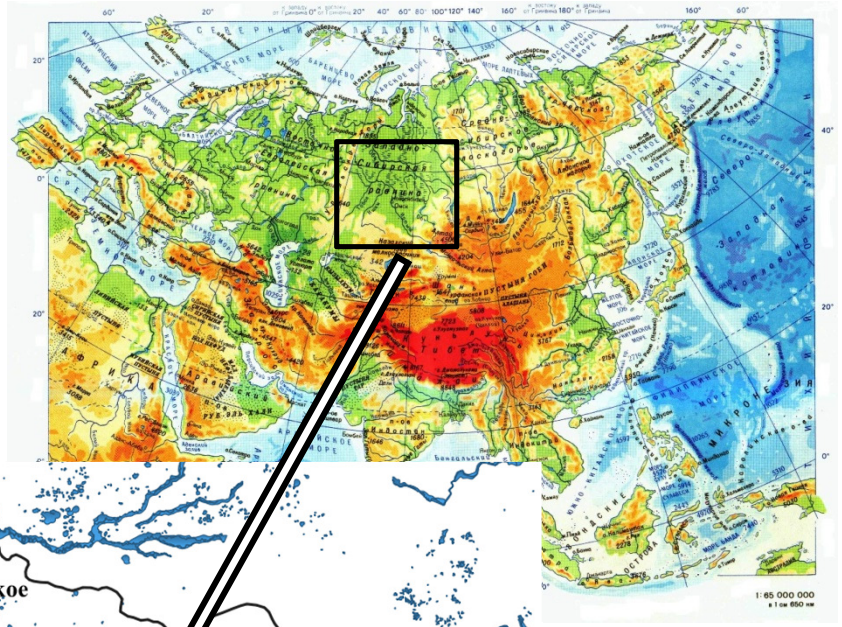


Era Interim reanalysis, 0.75x0.75°.

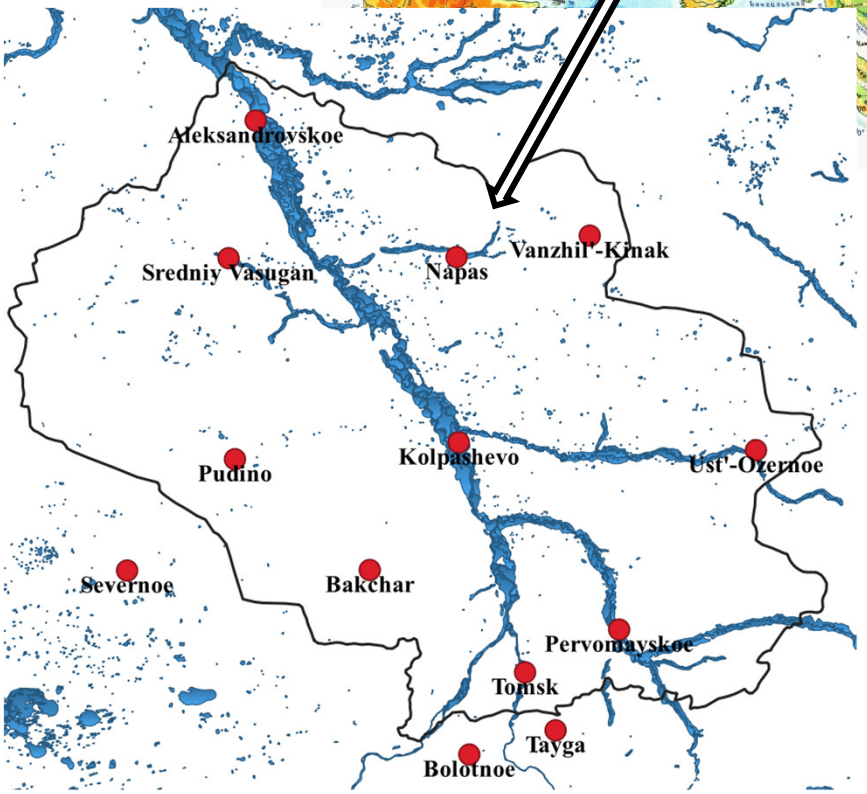
Territory, data and time interval of investigation

- **Tomsk region** (55.6-61 N, 74.9-84.9 E).

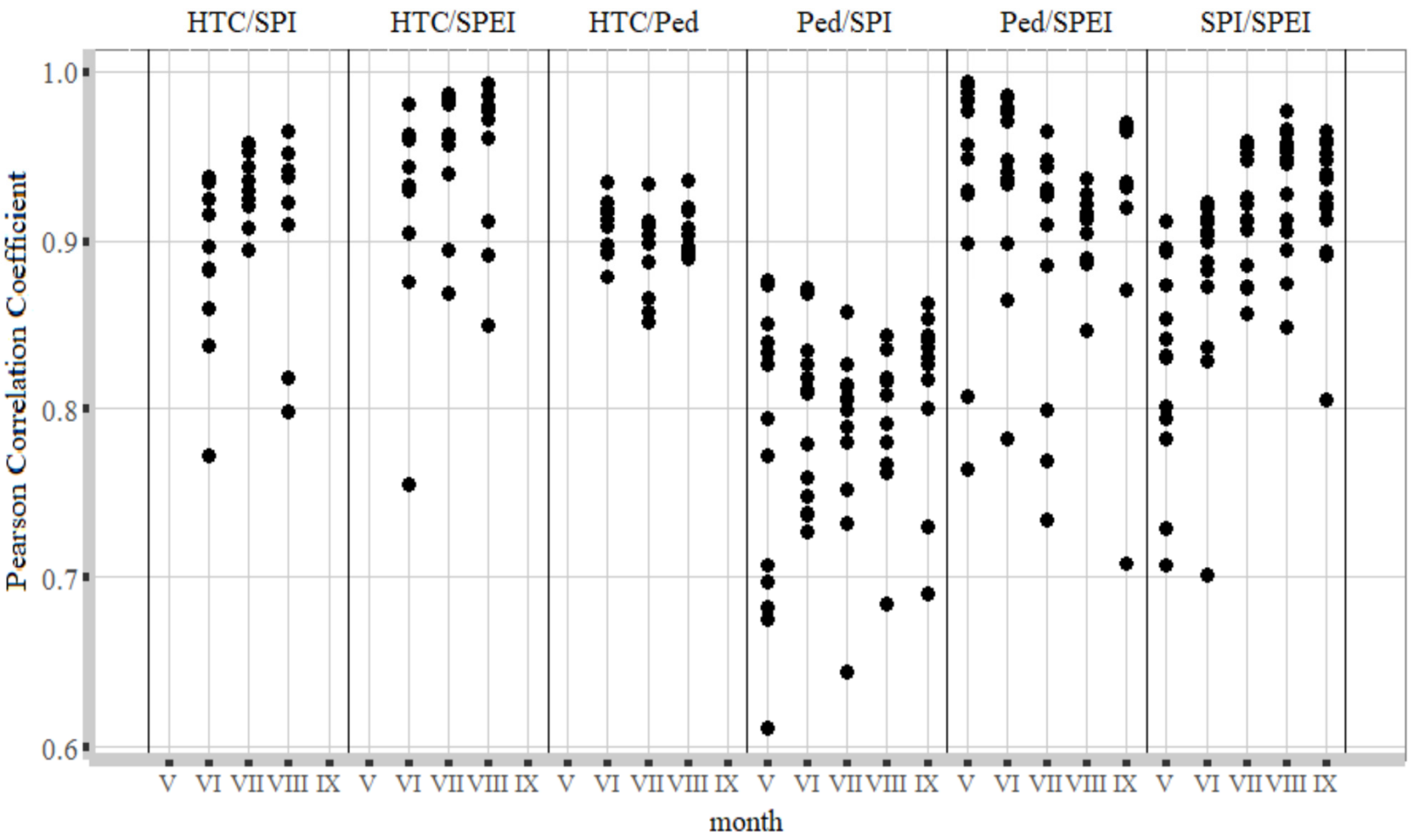
- **Interval of investigation:**
May-September from 1966 to 2017 years.



- **Data** from Roshydromet (RIHMI-WDC):
  - daily air temperature
  - daily precipitation

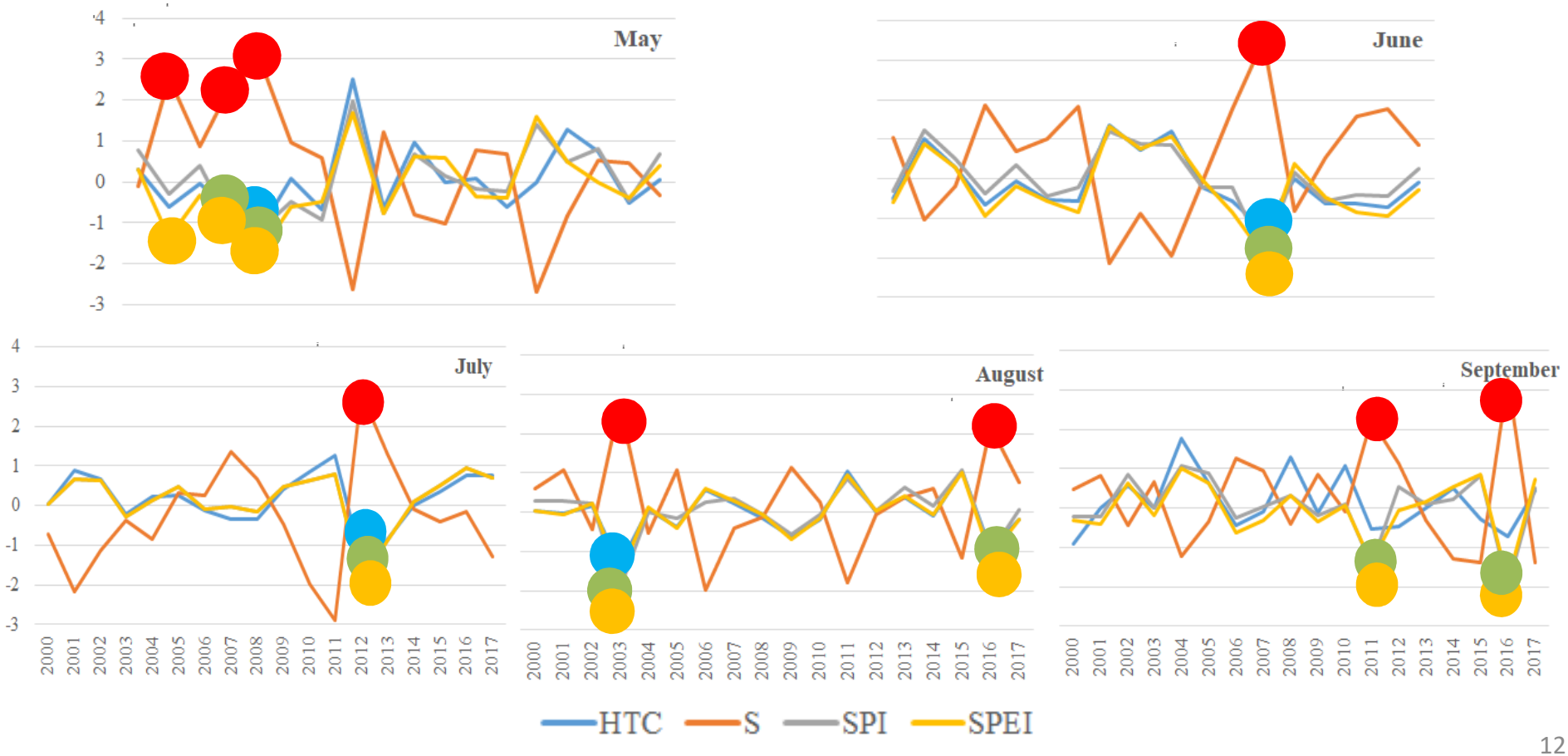


Correlation coefficients



Classification of droughts

Intensity of drougth	normilized HTC anomaly	Ped index	SPI/SPEI
weak	$-1{,}25<ГТК_{a\_norm}\leq-1$	$1 \leq S < 2$	$-2 < SPI/SPEI \leq -1$
medium	$-1{,}5<ГТК_{a\_norm}\leq-1{,}25$	$2 \leq S < 3$	$-3 < SPI/SPEI \leq -2$
severe	$-1{,}75<ГТК_{a\_norm}\leq-1{,}5$	$3 \leq S < 4$	$-4 < SPI/SPEI \leq -3$
extreme	$ГТК_{a\_norm}\leq-1{,}75$	$S \geq 4$	$SPI/SPEI \leq -4$



Result and plans.

1. To calculate drought indices web-GIS "CLIMATE" functionality was extended by a dedicated software modules:

1. Ped drought index;
2. Selyaninov hydrothermal coefficient;
3. SPI index;
4. SPEI index.

2. Correlation between indices was calculated and analyzed

3. Quantity of droughts and % of coincidence from 1966 to 2017 was calculated and analyzed

Plans

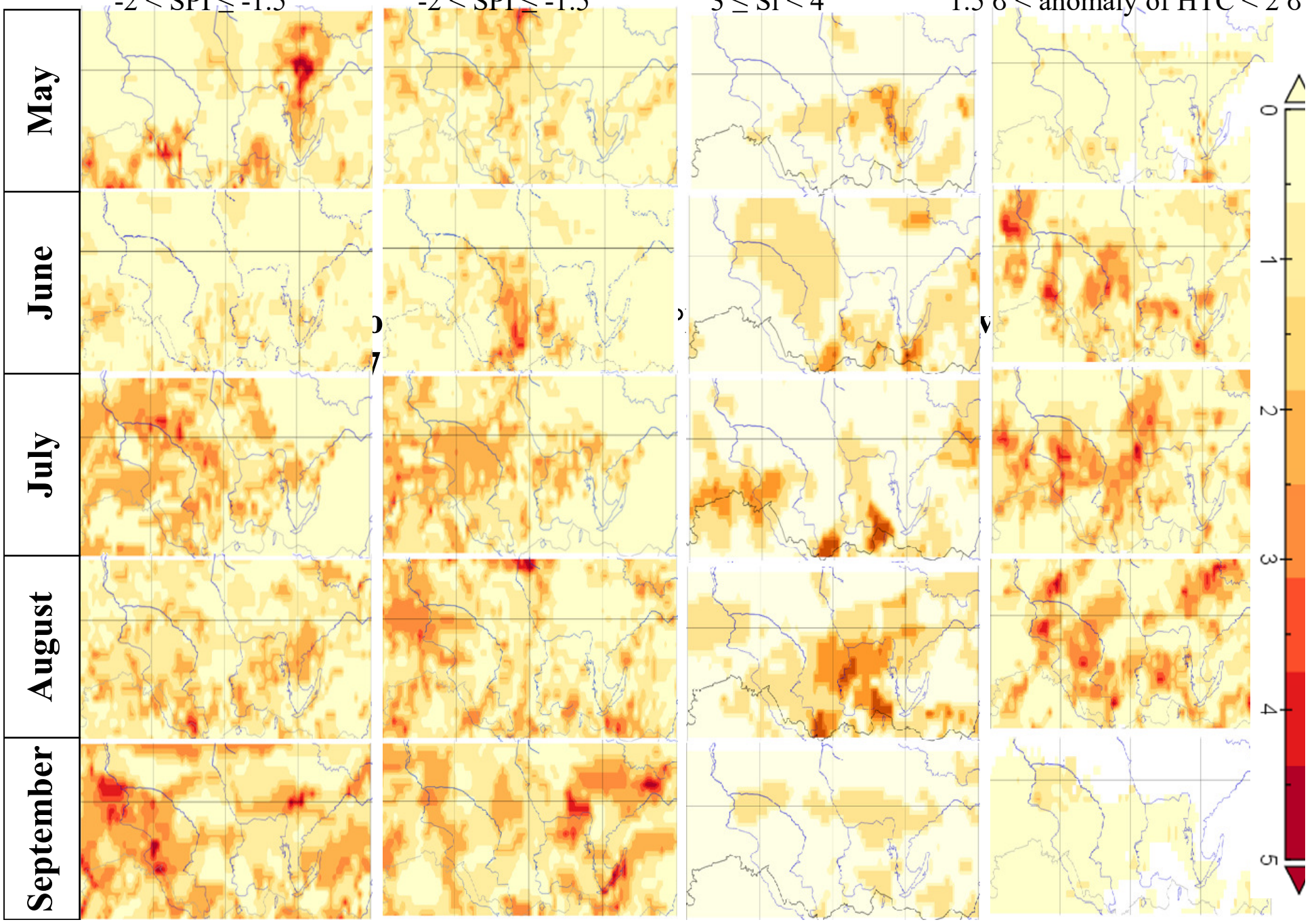
1. **Need to use some agriculture values or characteristics of growing season (maybe, indices based on NDVI) to compare they with drought indices in order to understand which index is adequate and how obtained results are consistent with reality.**

Thank you for attention!

Studies about comparison of some quantitative drought indices

- **E.A. Cherenkova, A.N. Zolotokrylin** On the comparability of some quantitative drought indices//Fundamental and applied climatology, 2016, №2, p. 79-94.
- **A. N. Zolotokrylin, V. V. Vinogradova, E. A. Cherenkova** Drought dynamics over European Russia in global warming situation//Problems of ecological monitoring and ecosystem modelling, St. Petersburg, Gidrometeoizdat 2007, v. 21, p. 160 – 181.
- **Strashnaya A.I., Tischenko V.A., Bereza O.V., Bogomolova N.A.** Using standardized precipitation index (SPI) for detection droughts and for forecast of quantitative assessment of yields of grain and grain-bean crops - Proceedings of the Hydrometcentre of Russia. 2015;(357):81-97. (In Russ.)
- **Zadornova O. I.** Comparative characteristics of the foreign indices for drought assessment main grain subjects of European Russia // Proceedings of Voeikov Main Geophysical Observatory. – St. Petersburg, 2015. - v. 578. – p. 126-139.
- **Solomina O. e tal.** Droughts of the East European Plain according to hydrometeorological and tree-ring data. — M . ; SPb. : Nestor-Historia, 2017. — 360 p.
- ***Vinit K.Jain, RajendraP.Pandey, Manoj K.Jain, Hi-Ryong Byun*** Comparison of drought indices for appraisal of drought characteristics in the Ken River Basin - Weather and Climate Extremes 8 (2015) 1-11
- ***Olivia Kellner, Dev Niyogi, Frank D.Marks*** Contribution of land falling tropical system rainfall to the hydroclimate of thee astern U.S.CornBelt 1981–2012 . - Weather and Climate Extremes 13 (2016) 54-67
- ***Ganeshchandra Mallya, Vimal Mishra, Dev Niyogi, Shivam Tripathi, Rao S.Govindaraju*** Trends and variability of droughts over the Indian monsoon region. - Weather and Climate Extremes 12 (2016) 43-68
- ***M.Pena-Gallardo, S.R.Gamiz-Fortis, Y.Castro-Diez, M.J.Esteban-Parra*** . Analisis comparativo de indices de sequia en Andalucia Para el periodo 1901-2012. – Cuadernos de Investigacion Geografica, 2016. - № 42(1). – pp. 67-88
- ***J.R. Coll, E.Aguilar, M.Prohom, J.Sigro***. Long-term drought variability and trends in Barselona (1787-2014). - Cuadernos de Investigacion Geografica, 2016. - № 42(1). – pp. 29-48
- ***S.Yuan, S.M.Quiring, S.Patil***. Spatial and temporal variations in the accuracy of meteorological drought maps. - Cuadernos de Investigacion Geografica, 2016. - № 42(1). – pp. 167-183

And etc.

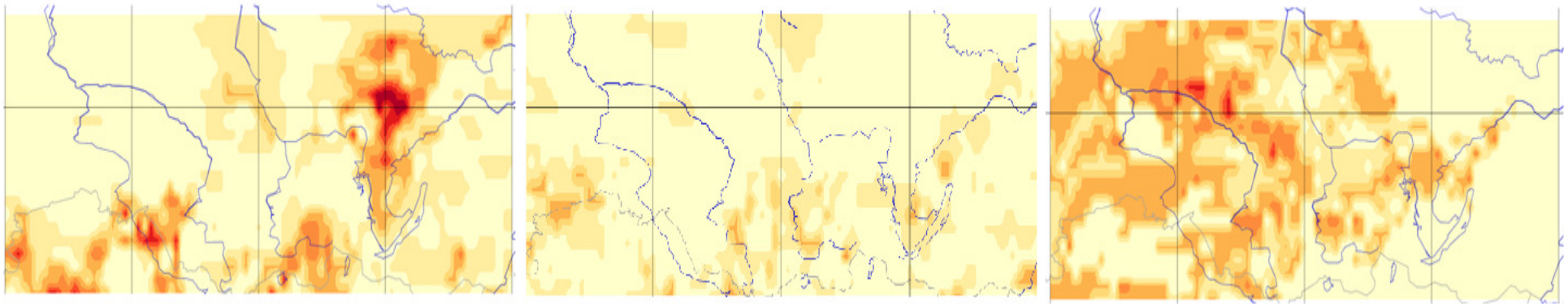

1. SPI index
-2 < SPI ≤ -1.5
2. SPEI index
-2 < SPI ≤ -1.5
3. Ped index
3 ≤ Si < 4
4. Anomaly of HTC
1.5 σ < anomaly of HTC < 2 σ
May
June
July
August
September
0
1
2
3
4
5

Spatial distribution (50-65°N, 60-120°E) of quantity of severe droughts from 1979 to 2017 calculated using:

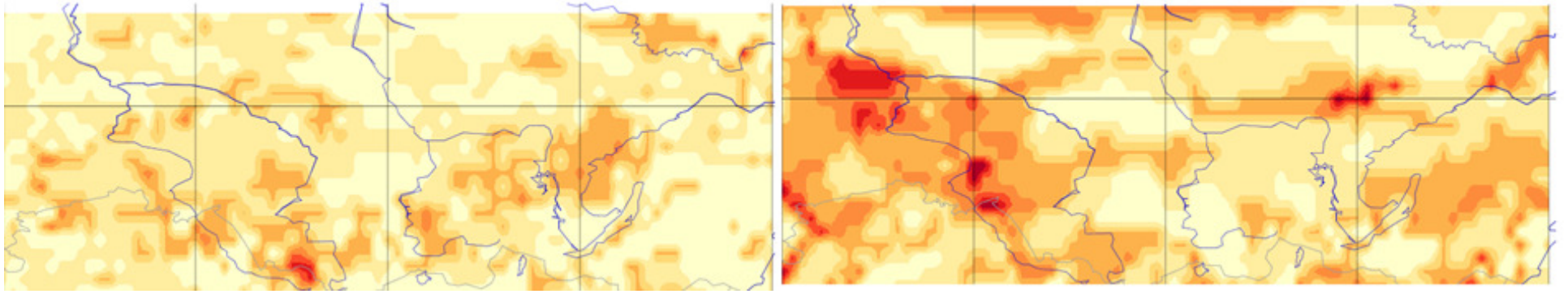
1. SPI index

$-2 < SPI \leq -1.5$

May	June	July



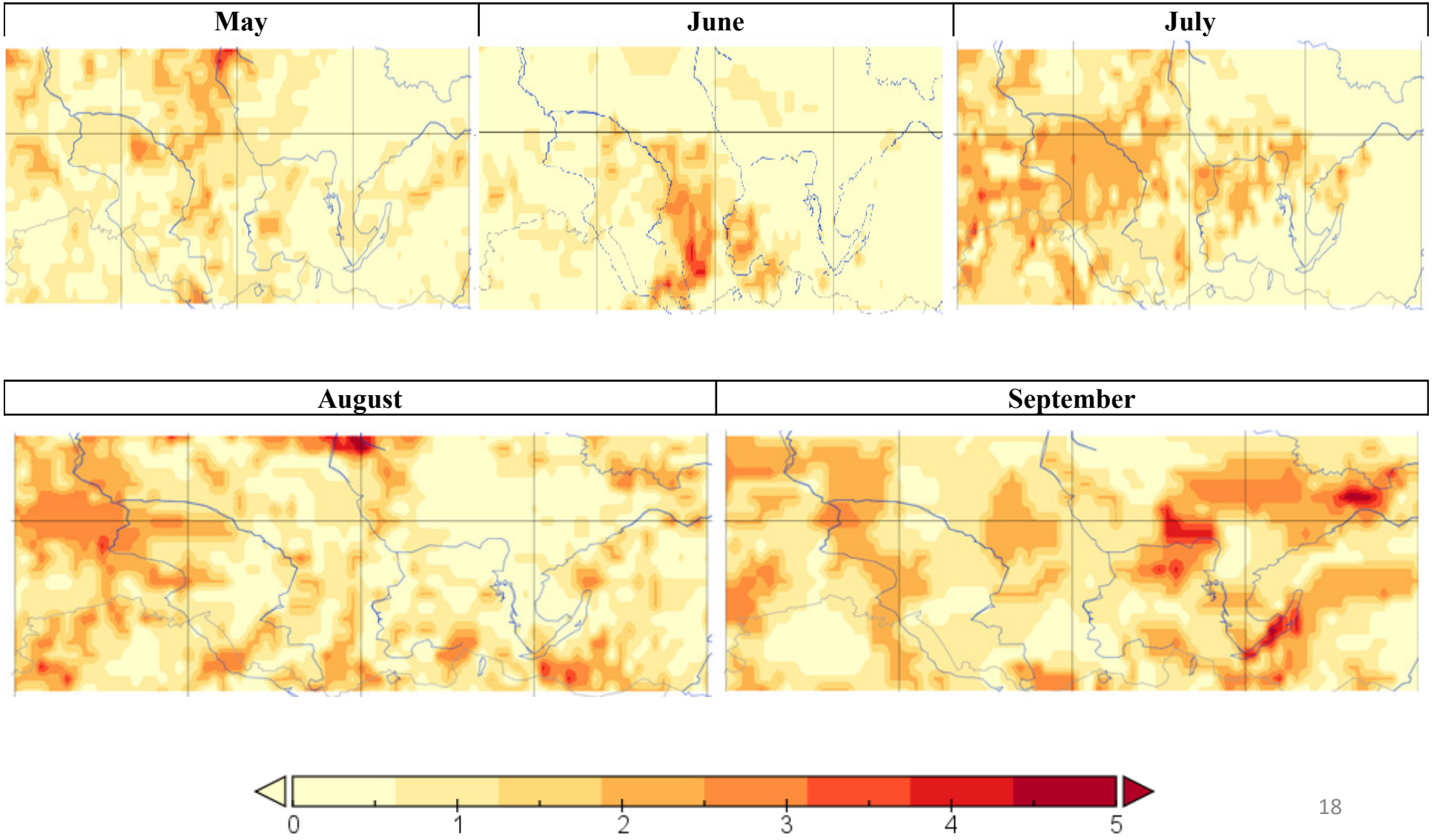
August	September



Spatial distribution (50-65°N, 60-120°E) of quantity of severe droughts from 1979 to 2017 calculated using:

1. SPEI index

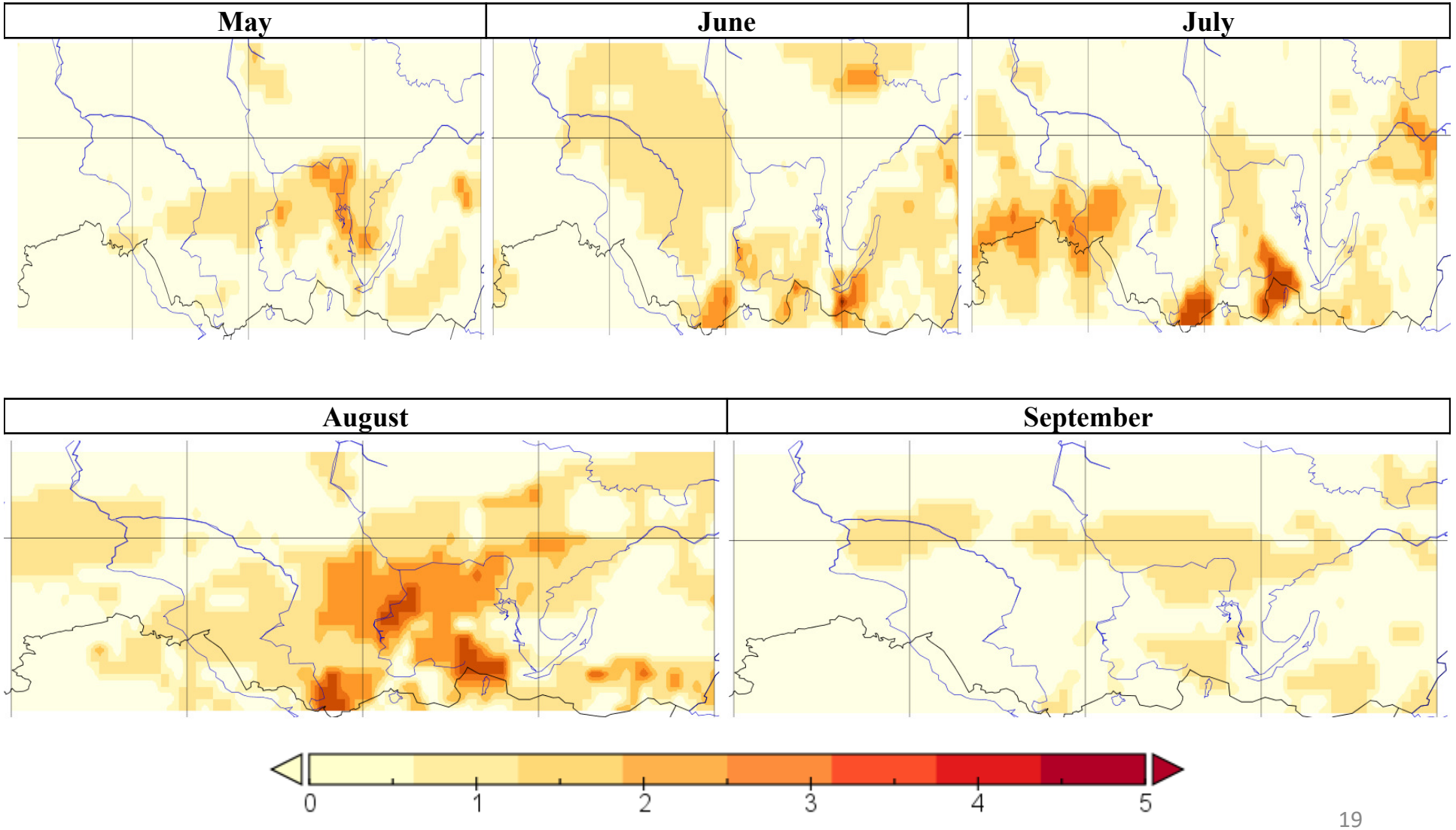
$-2 < SPI \leq -1.5$



Spatial distribution (50-65°N, 60-120°E) of quantity of severe droughts from 1979 to 2017 calculated using:

3. Ped index

$3 \leq Si < 4$



Spatial distribution (50-65°N, 60-120°E) of quantity of severe droughts from 1979 to 2017 calculated using:

4. Anomaly of HTC

1.5 σ < anomaly of HTC < 2 σ