

Change of hydrological cycle due to climate warming in northern Eurasia

V.P.Meleshko

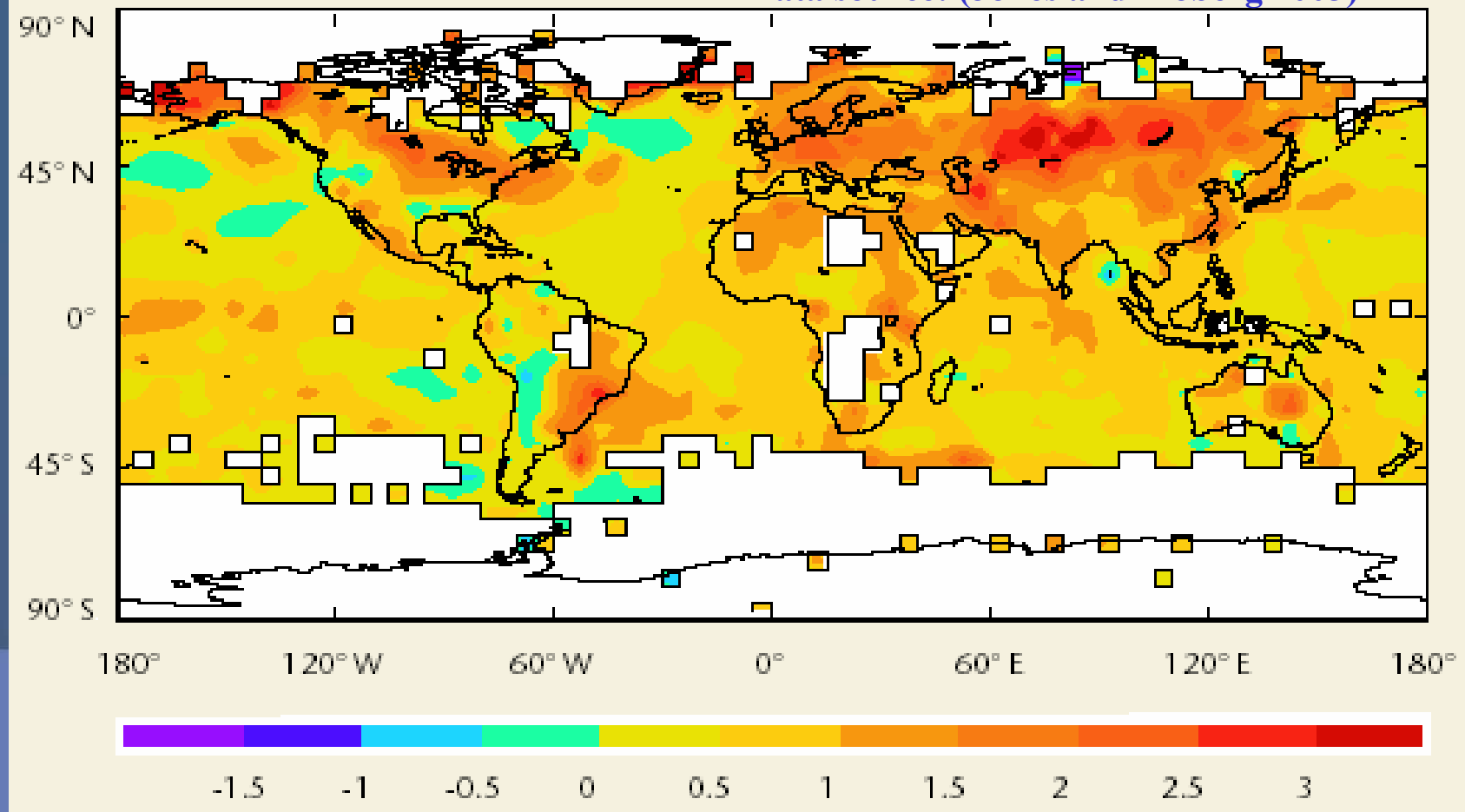
*Voeikov Main Geophysical Observatory, Roshydromet,
St. Petersburg, Russia*

Specific features of climate in the Northern Eurasia

- ✓ The region has variety of climates. It includes vast areas of tundra, boreal forests, semi-deserts and deserts.
- ✓ The surface air temperature increase reported for the last 30 years was the greatest in the northern hemisphere and the model simulations show that the climate of this region will undergo the most substantial changes in the future.
- ✓ The region plays an important role in transfer of energy, water, greenhouse gases and aerosols between the atmosphere, land surface, hydrosphere, and cryosphere.

Observed surface air temperature difference between end of the 19th century and beginning of 21st centuries.

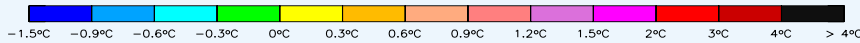
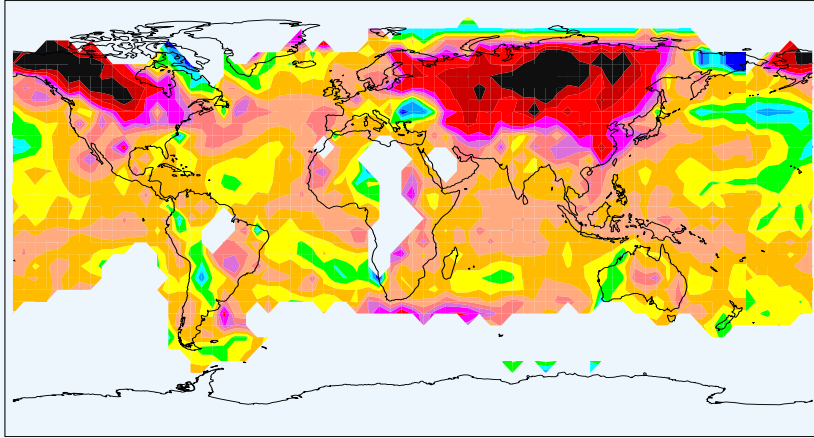
Data source: (Jones and Moberg 2003)



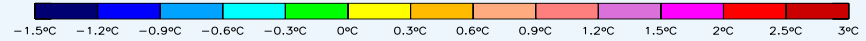
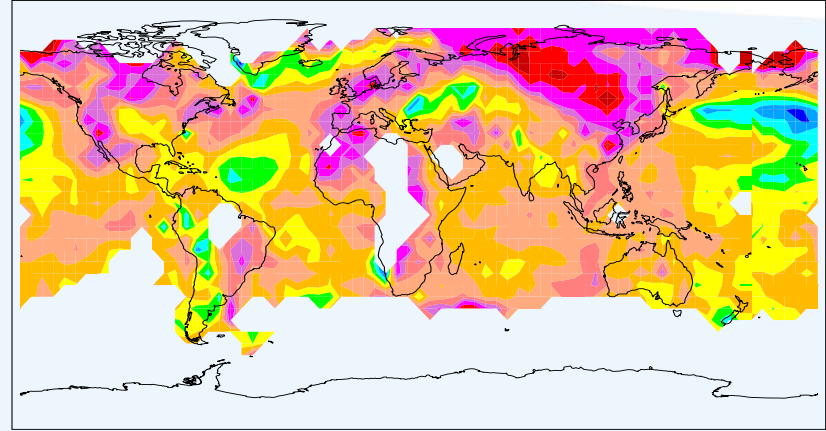
Mean seasonal surface air temperature change from 1965 to 2003 over the globe



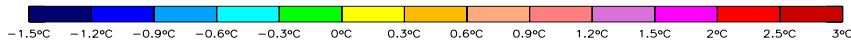
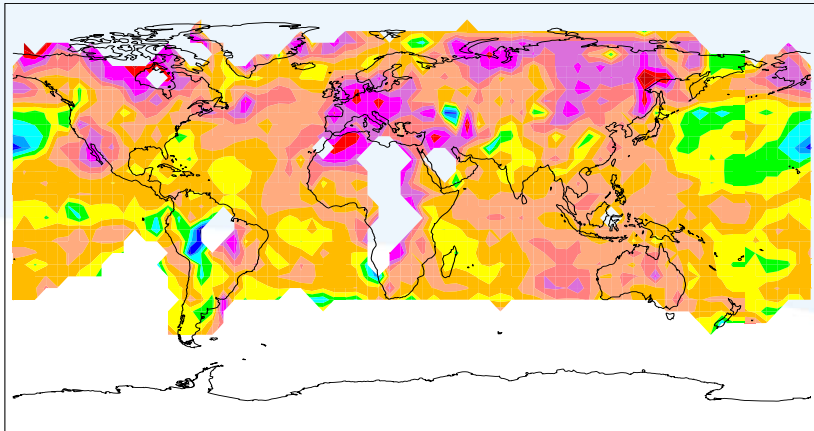
Winter



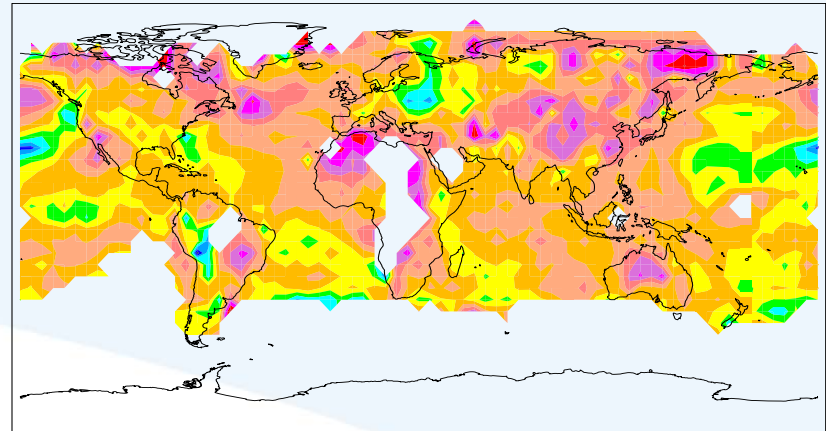
Spring



Summer



Autumn

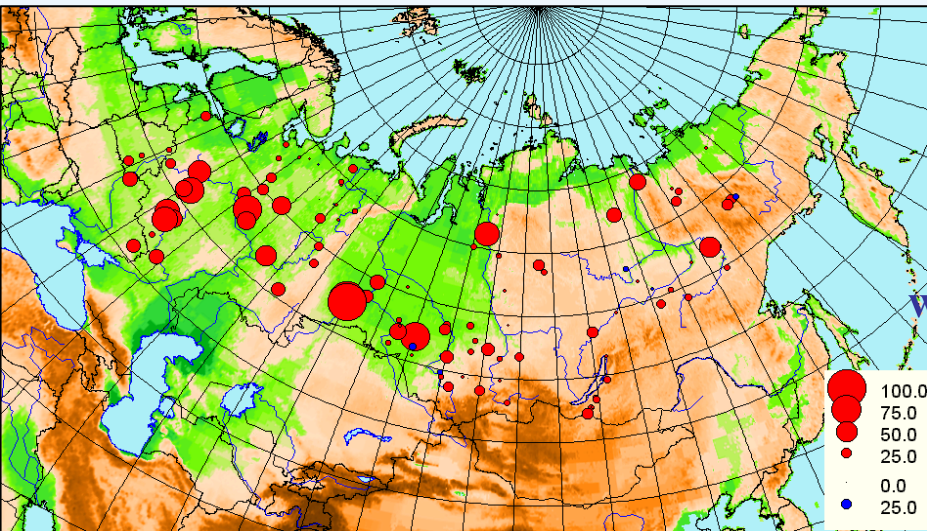


Data source: Jones and Moberg, 2003

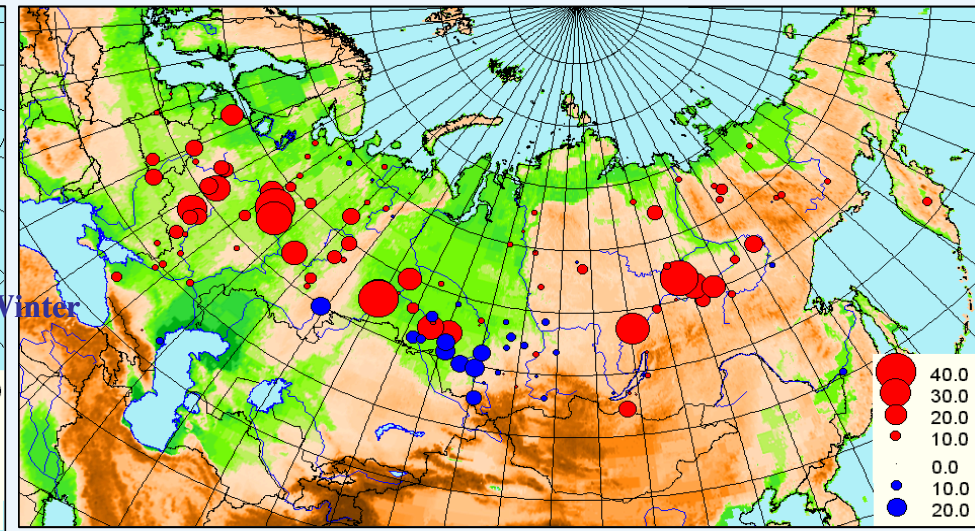


Change of streamflow (%) on major river basins

Winter anomalies



Annual anomalies



Runoff anomalies for the 1978-2000 period compared to the long-term mean values for previous 55 years.

Georgievsky et al. (2003)

CRYOSPHERE AND HYDROLOGY

Cryosphere plays significant role in determining pattern and seasonal intensity of hydrological cycle in the northern Eurasia.

- ✓ **Precipitation falls down in solid phase in winter and accumulates on the land since air temperature is far below freezing point.**
- ✓ **In spring snow melts and it results in extensive flooding everywhere.**

CRYOSPHERE AND HYDROLOGY

When climate warms and precipitation increases mostly in winter, three possibilities may occur depending on regions considered:

- All precipitation falls down in liquid phase, runoff increases. It favours flooding and contributes to soil drying in spring and particularly at the beginning of summer.**
- Snow mass accumulation decreases. It results in decreasing snow melt and flooding in spring, but increases drying of soil in at the beginning of summer.**
- Increase of solid precipitation in excessively cold regions results in larger accumulation of snow mass by the end of winter. It contributes to more frequent flooding in spring and favours development of wet condition in early summer.**

BASIC APPROACH

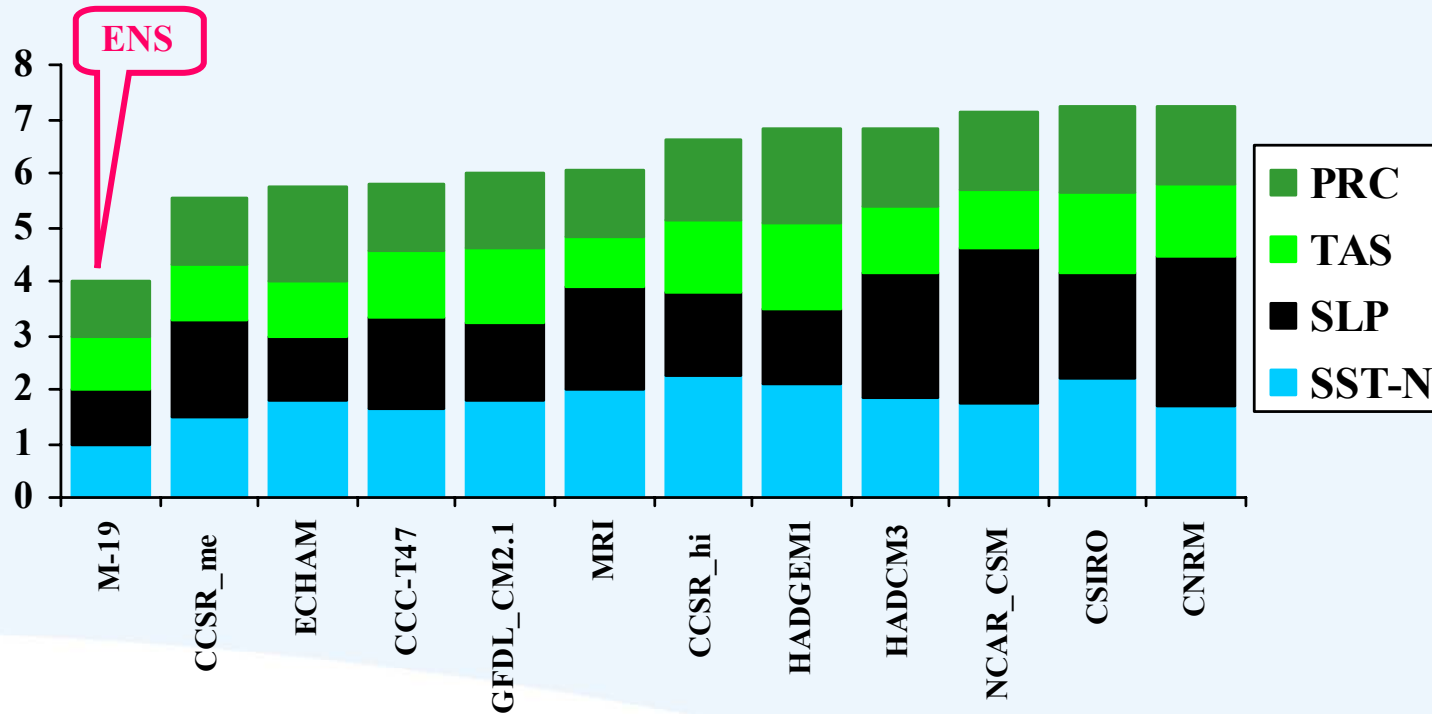
- **Application of multi-model ensemble comprising 11 IPCC AR4 runs**
- **Analysis of climate change over northern Eurasia and its major catchments**
- **Evaluation of quality of the mean multi-model simulation of current climate and spread of the ensemble**
- **Projection of climate change from multi-model simulation for 21st century**
- **Impact of climate warming on hydrology and cryosphere**

IPCC AR4 coupled climate models

| No. | Modelling groups | IPCC ID | Atmospheric resolution | Ocean resolution |
|-----|---|------------------|------------------------|--|
| 1 | Canadian Centre for Climate Modeling & Analysis, Canada | CGCM3.1(t47) | Spectral T47L32 | 192x96L29 |
| 2 | Center for Climate System Research, Japan. | HI MICCSR_ROC3.2 | Spectral T106L56 | |
| 3 | Center for Climate System Research, Japan. | ME MICCSR_ROC3.2 | Spectral T42L20 | 1.4 ⁰ x(0.5-1.4 ⁰)L44 |
| 4 | CSIRO Atmospheric Research, Australia | CSIRO Mk3.0 | Spectral T63L18 | |
| 5 | Meteo-France/Centre National de recherches Meteorologique | CNRM | Spectral T63L18 | 182x152L31 |
| 6 | Max Plank Institute for Meteorology, Germany | ECHAM5/MPI-OM | Spectral T63L31 | 1.5x1.5L40 |
| 7 | NOAA/Geophysical Fluid Dynamics Laboratory, USA | GFDL-CM2.1 | Grid point 144x90xL24 | Tripolar360x200 |
| 8 | Hadley Centre for Climate Prediction and Research/Met UK | HADCM3 | Grid point 96x73xL19 | 1.25x1.25L20 |
| 9 | Hadley Centre for Climate Prediction and Research/Met UK | HADGEM1 | Grid point 92x144xL21 | 1.0-0.3x1.0L40 |
| 10 | Meteorological Research Institute, Japan | MRI-CGCM2.3.2A | Spectral T42L30 | (0.5 ⁰ -2.5 ⁰)x2 ⁰ L23 |
| 11 | National Center for Atmospheric Research, USA | NCAR_CSM | Spectral T85L26 | 320x384L40 |

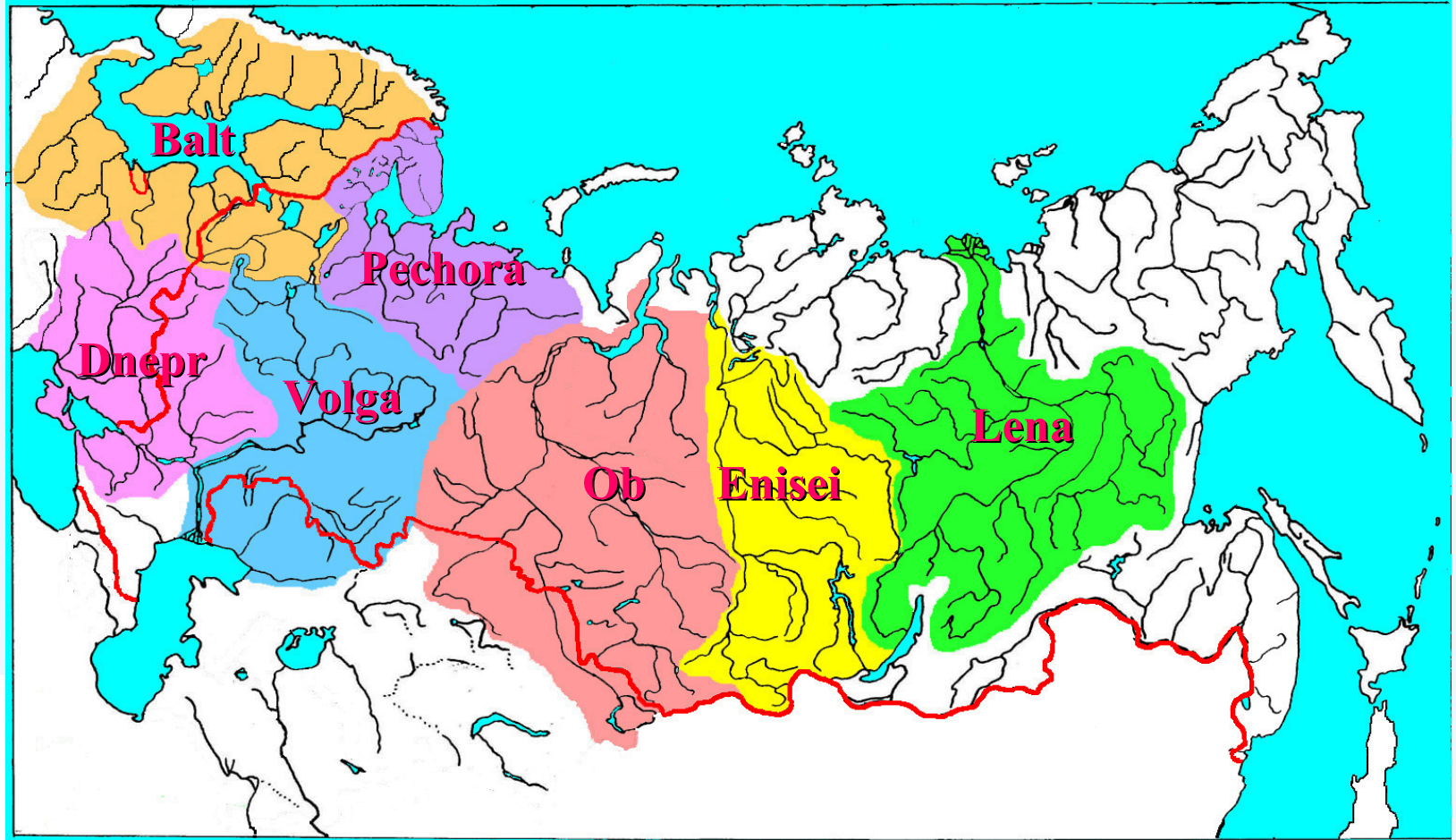


Composed annual RMSE of individual models for precipitation (PRC), surface air temperature (TAS), sea level pressure (SLP) and sea surface temperature (SST) in the northern hemisphere normalized at appropriate multi-model RMSEs.



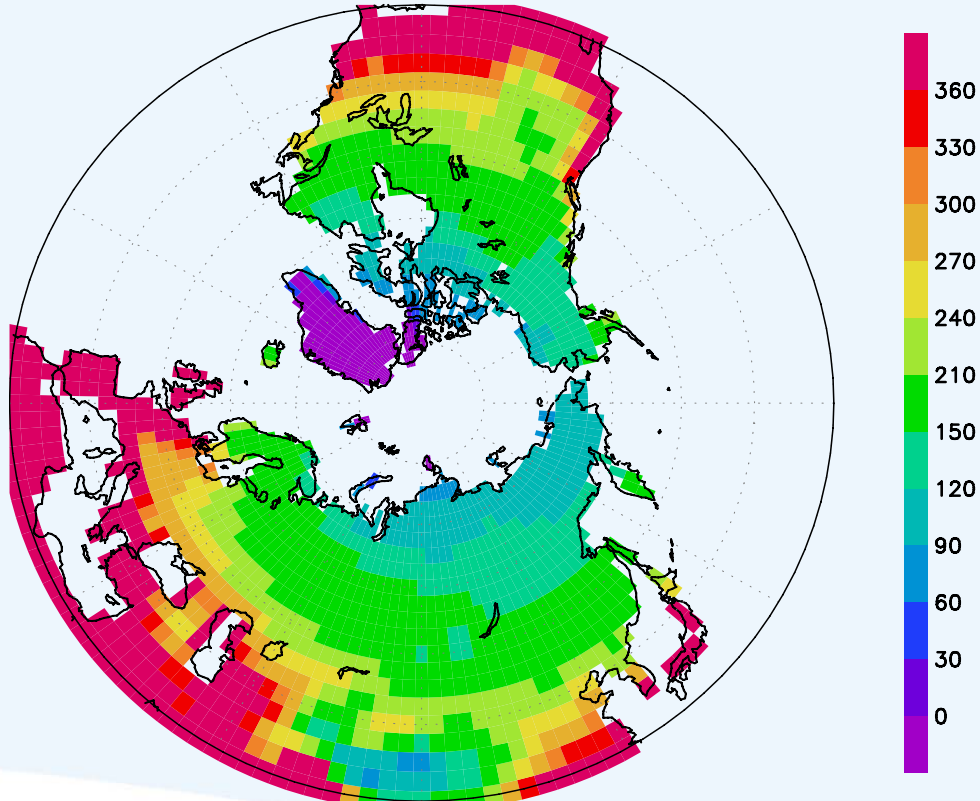


Major catchments





Number of non-frosty days for the current climate as computed from ensemble of IPCC AR4 models in the northern Hemisphere.



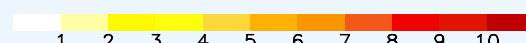
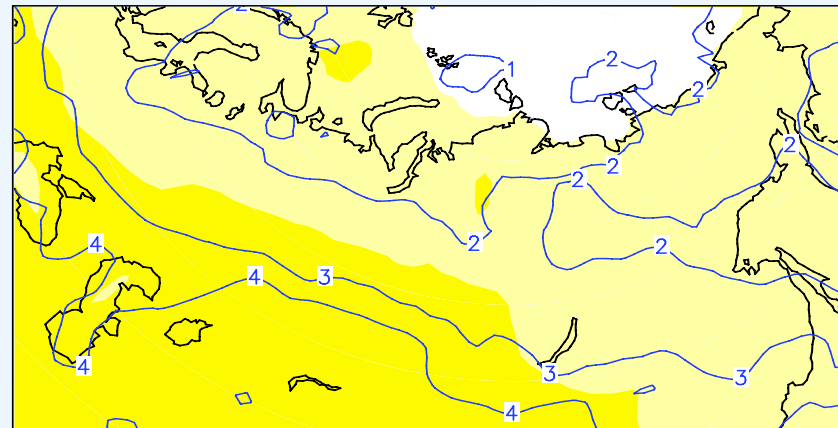
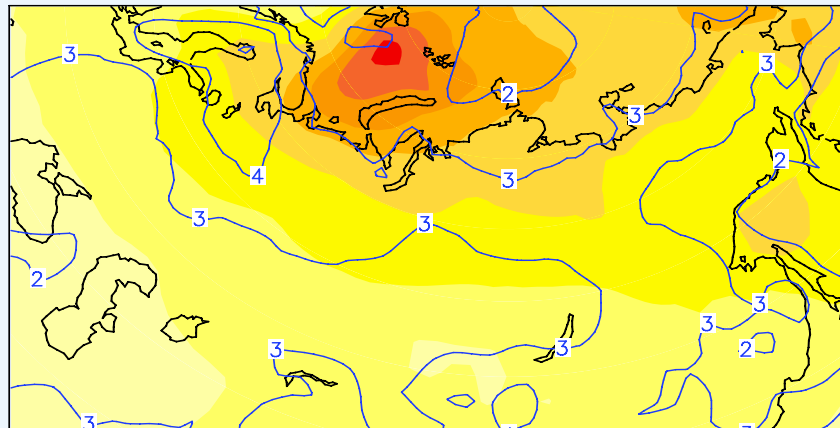
Surface air temperature change in 21st century scenario A2



Winter

2041-2060

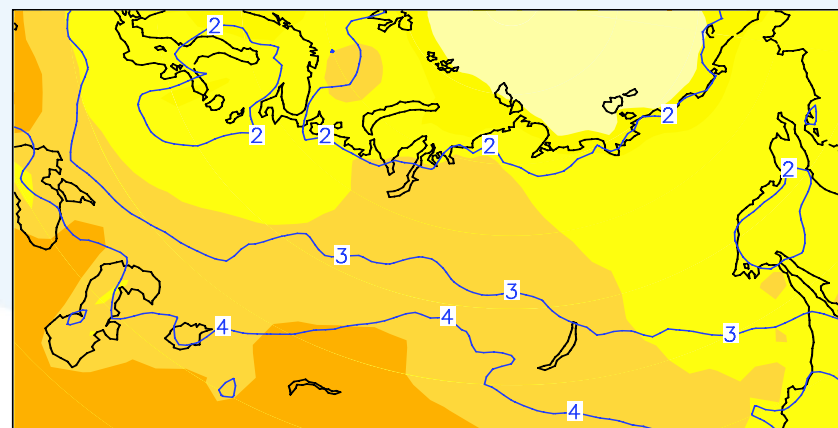
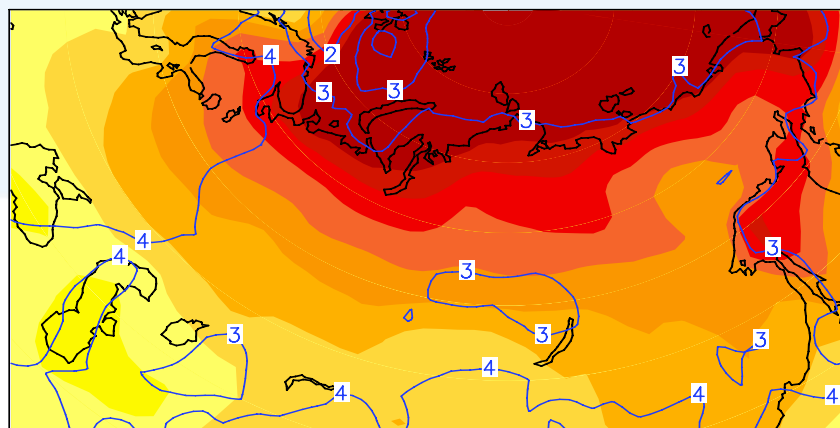
Summer



Winter

2080-2099

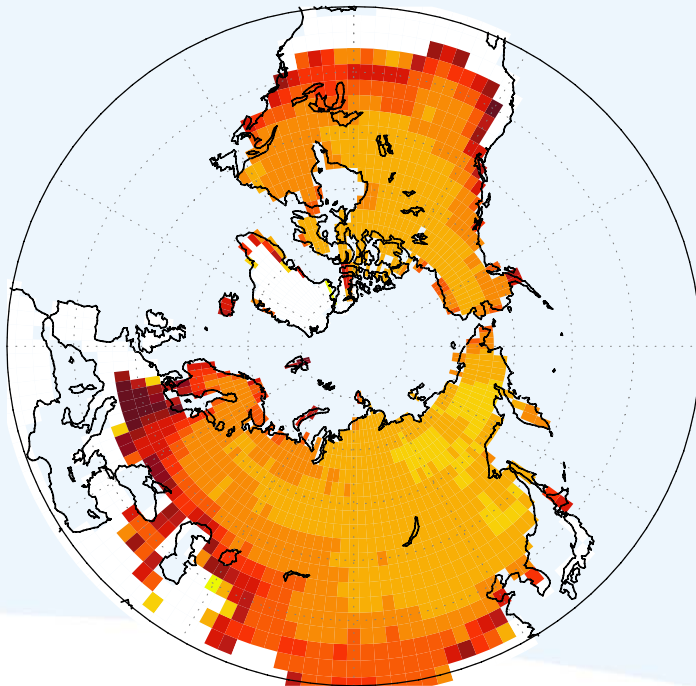
Summer



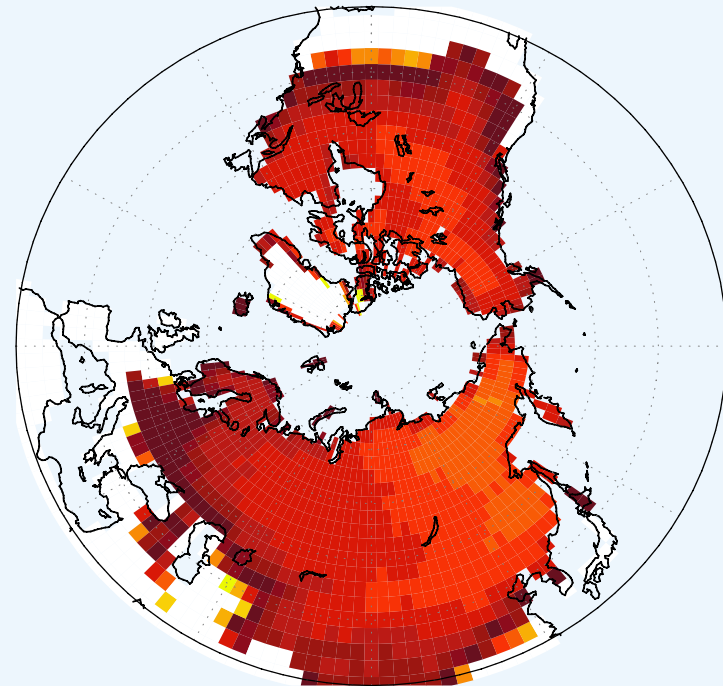


Increased number of non-frosty days in 21st century in Northern Hemisphere as computed from ensemble of IPCC AR4 models. Scenario A2.

2041-2060

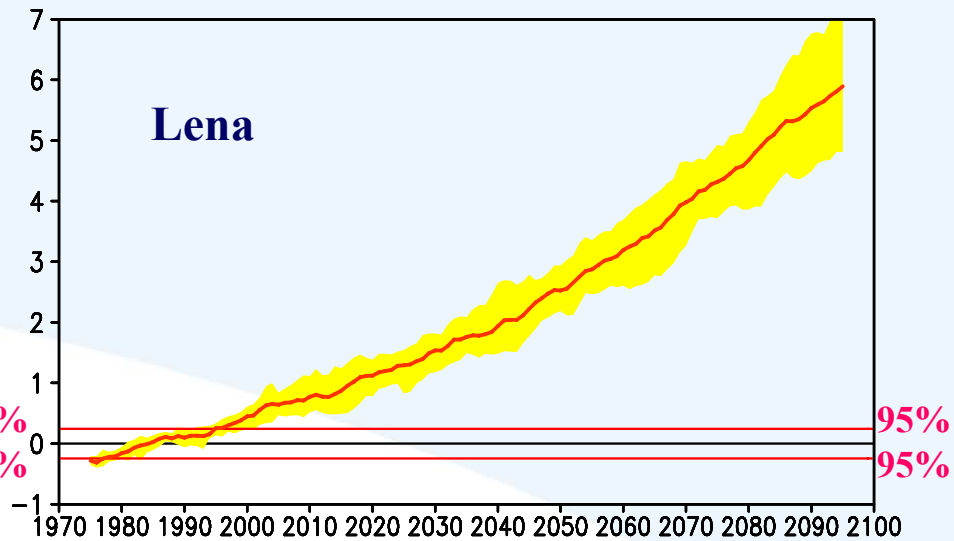
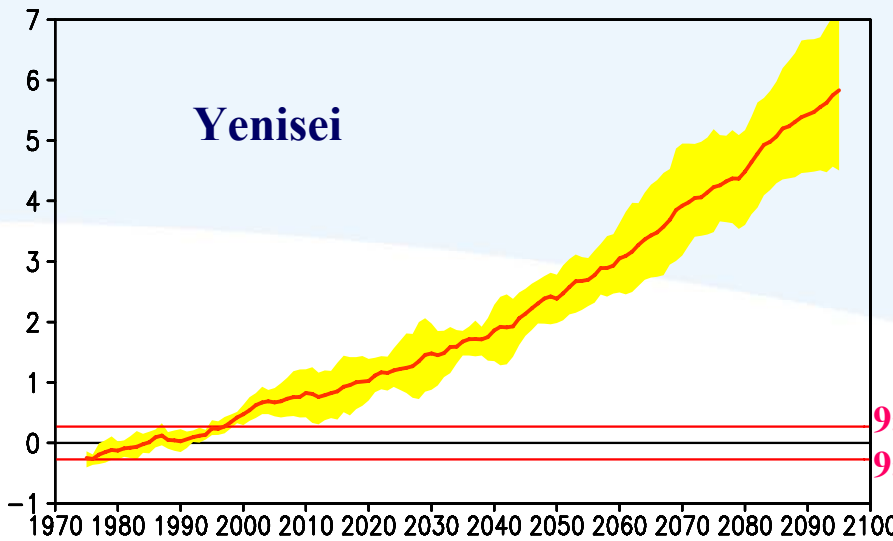
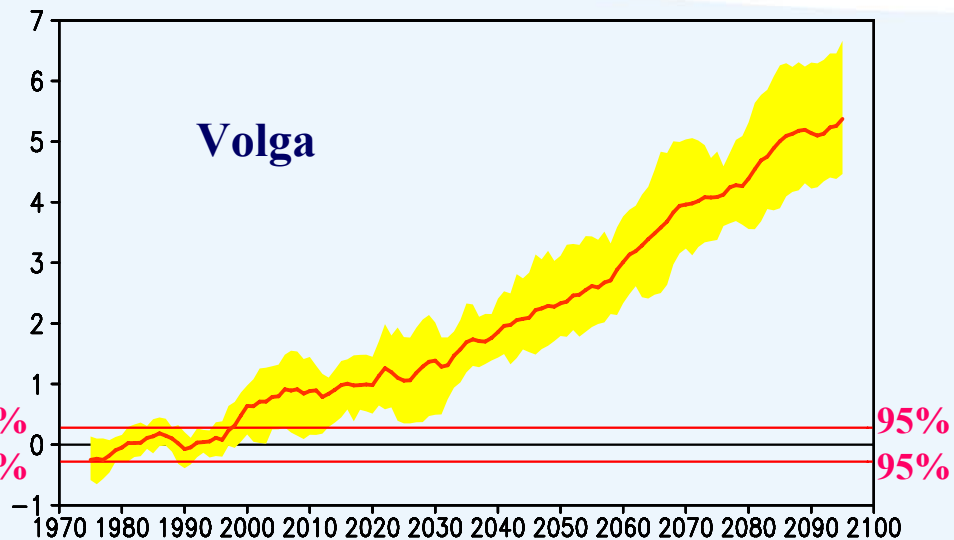
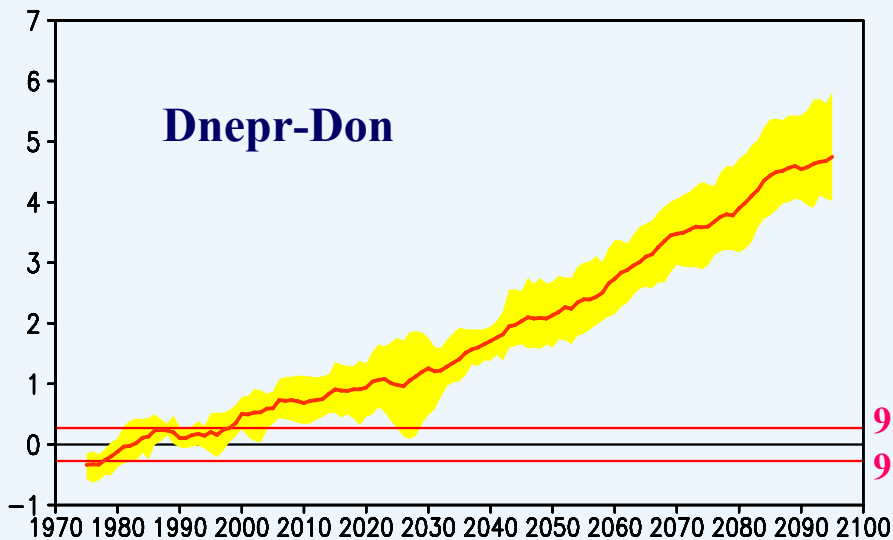


2080-2099





Annual change of surface air temperature over major catchments (deg C) in 21st century relative to current climate (1975-2000). Scenario A2

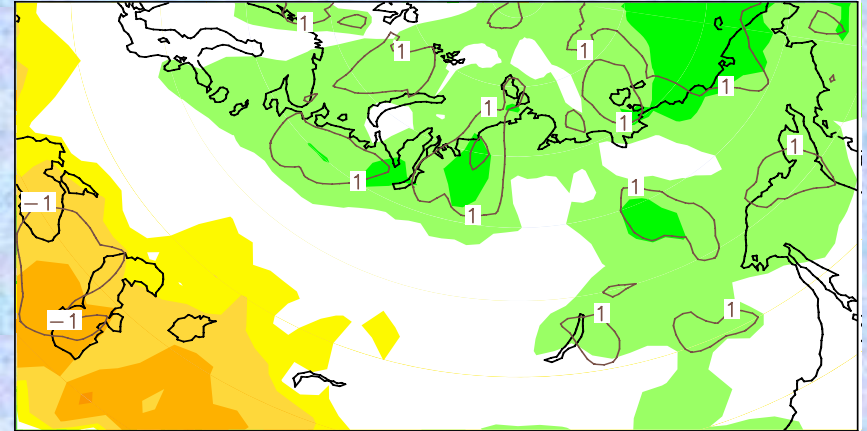
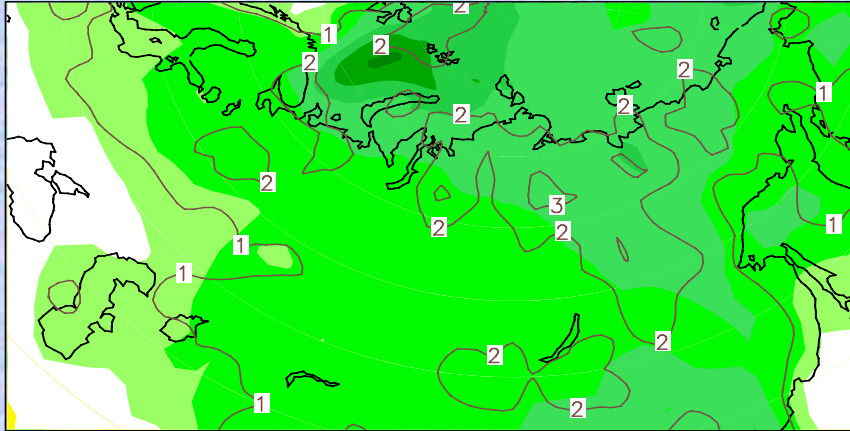


Change of total precipitation (in %) in 21st century relative to precipitation for current climate (1981-2000) in winter, scenario A2

Winter

2041-2060

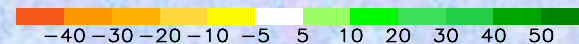
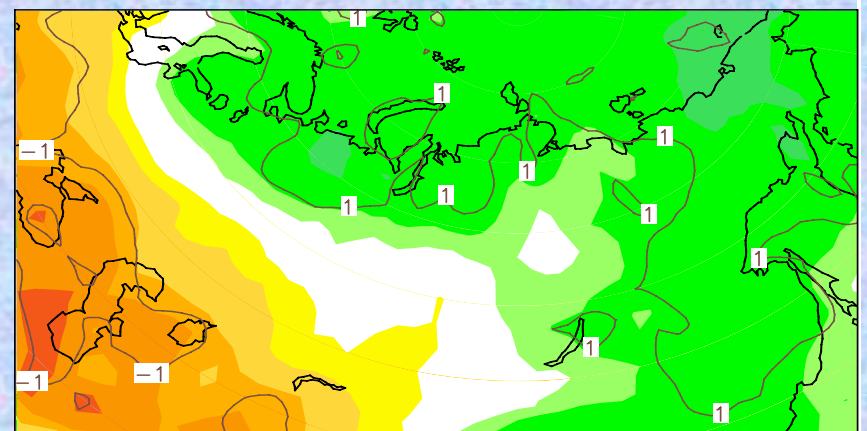
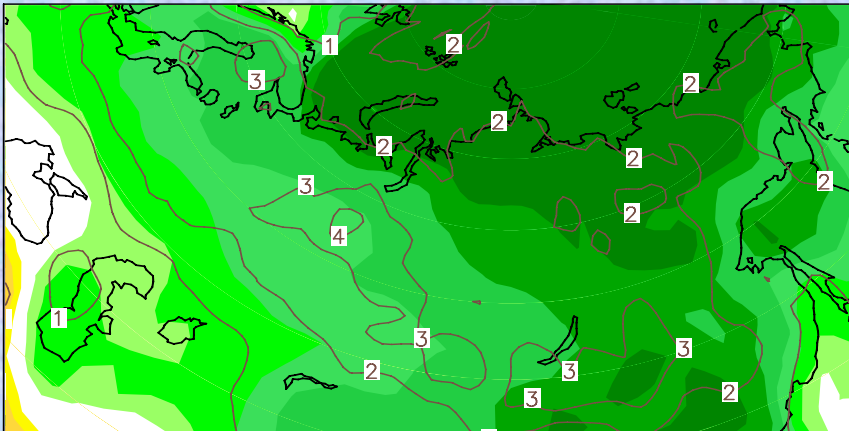
Summer



Winter

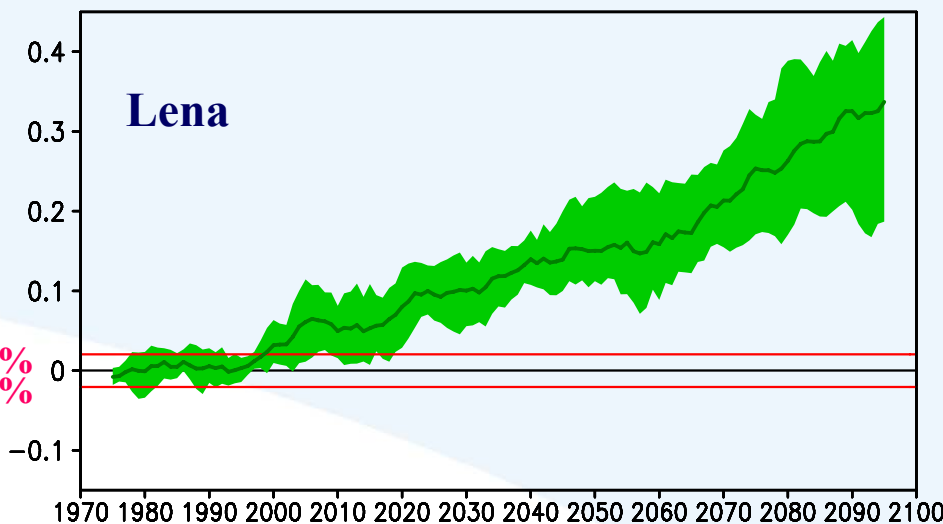
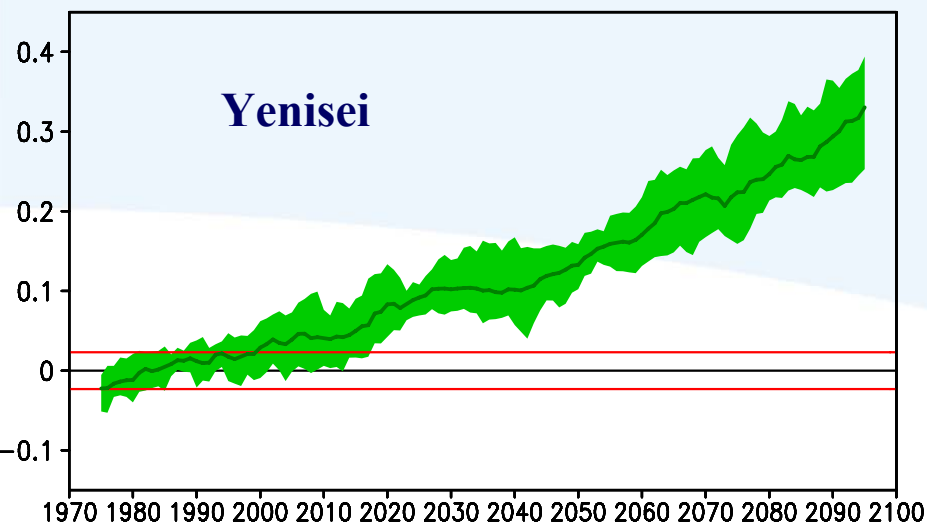
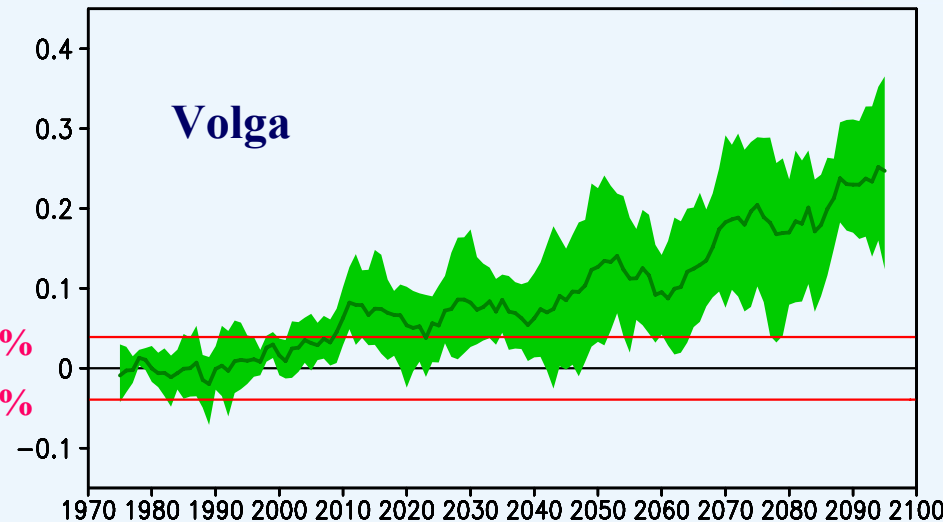
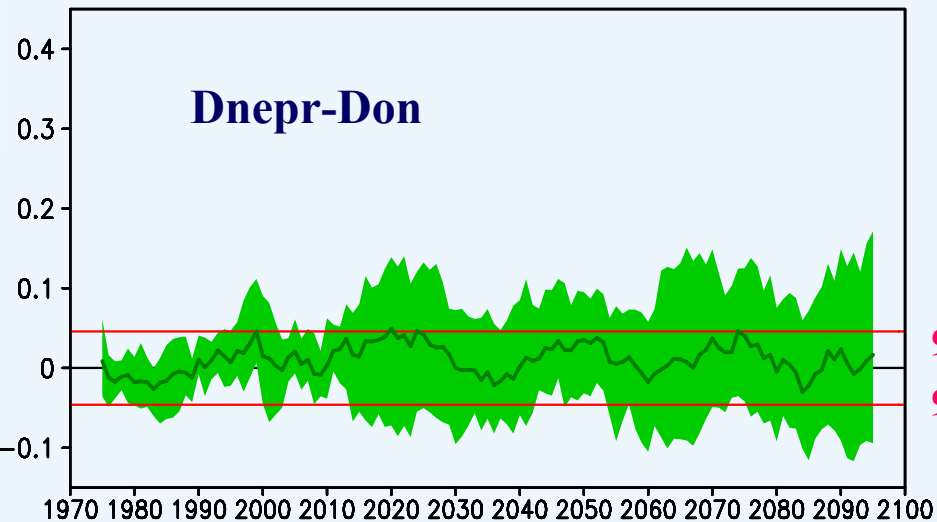
2080-2099

Summer



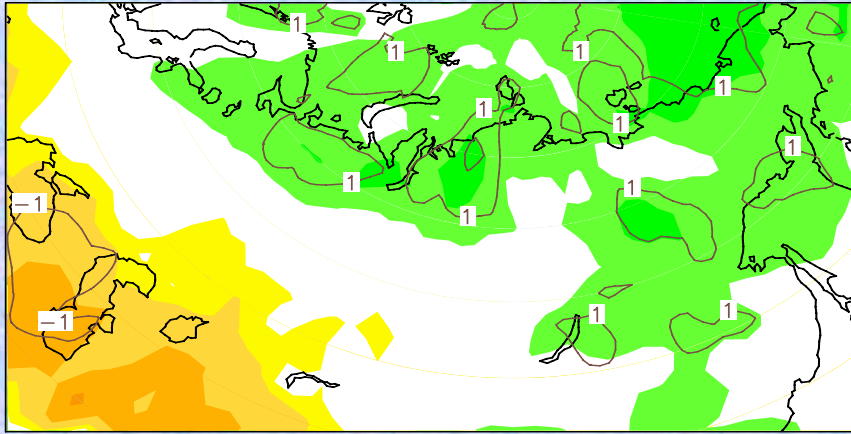


Annual change of precipitation (mm/day) over major catchments in 21st century relative to current climate (1975-2000). Scenario A2

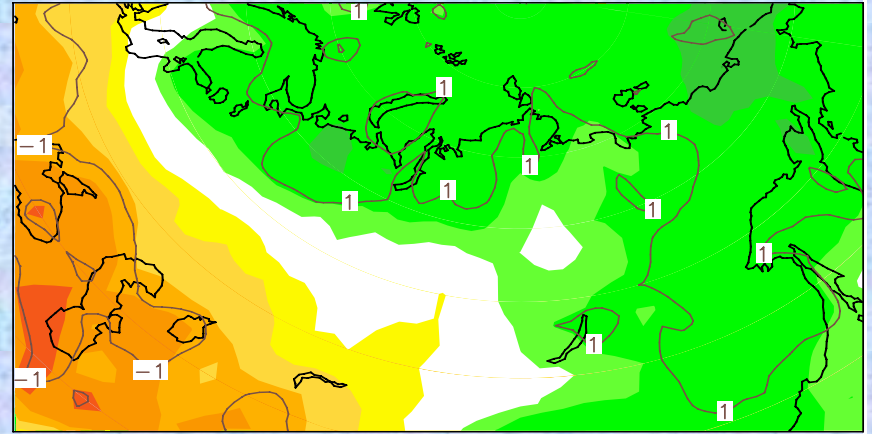


Change of total and convective precipitation (in %) in 21st century relative to total precipitation for current climate (1981-2000) in summer, scenario A2

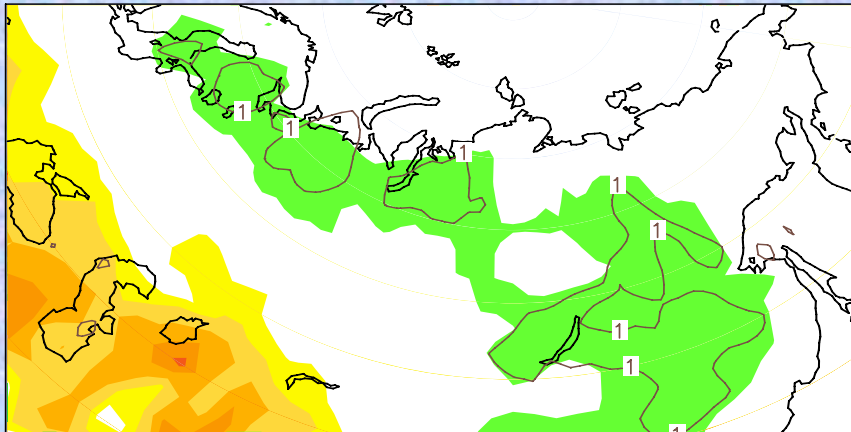
Total precipitation 2041-2060



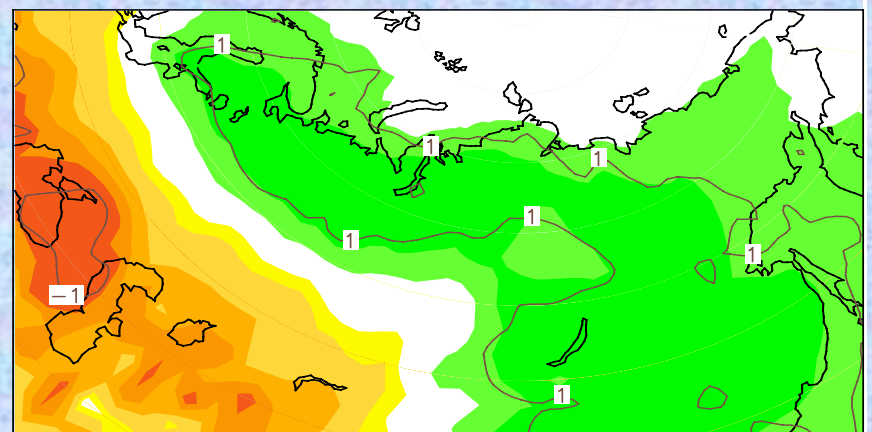
Total precipitation 2080-2099



Convective precipitation 2041-2060

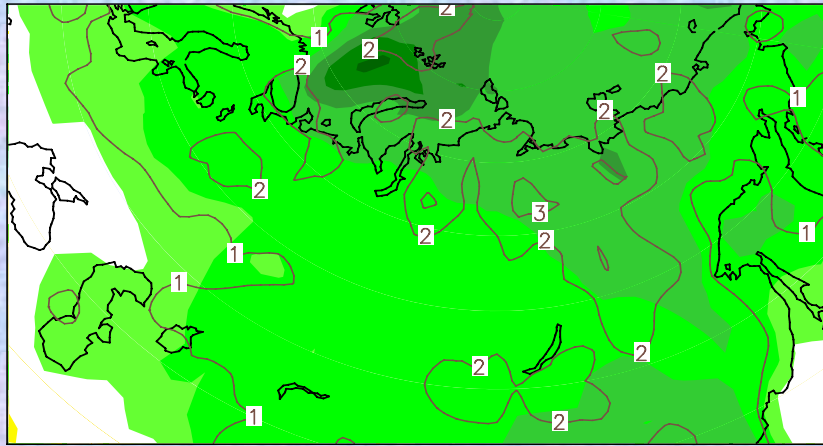


Convective precipitation 2080-2099

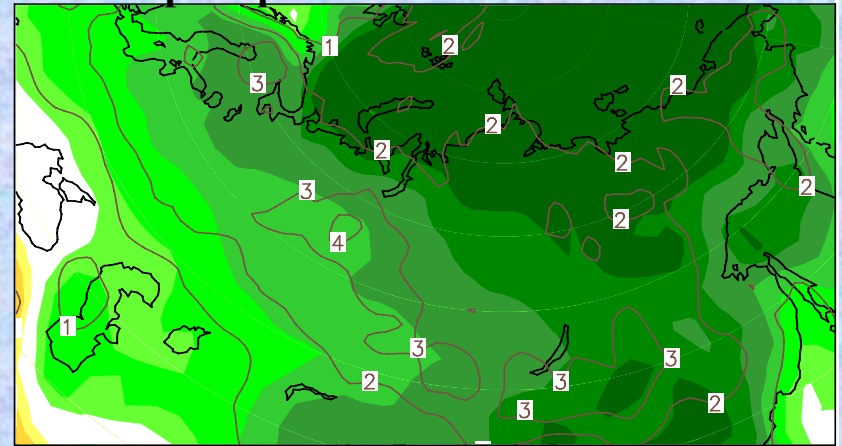


Change of total and solid precipitation (in %) in 21st century relative to total precipitation for current climate (1981-2000) in winter, scenario A2

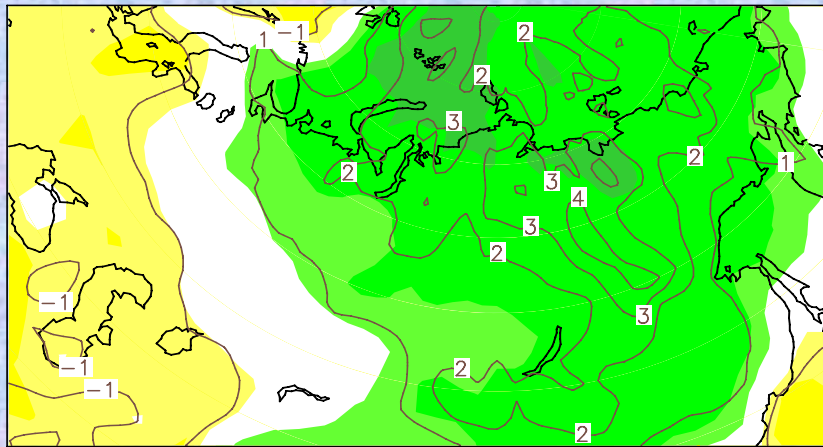
Total precipitation 2041-2060



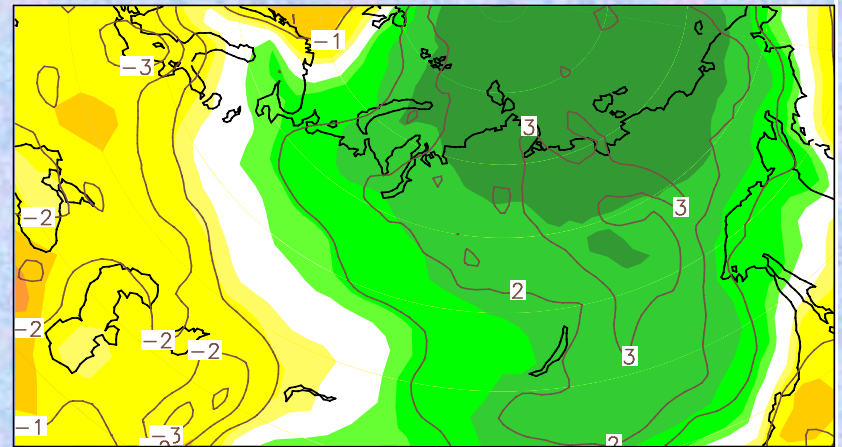
Total precipitation 2080-2099



Snow 2041-2060



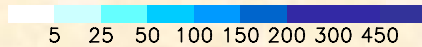
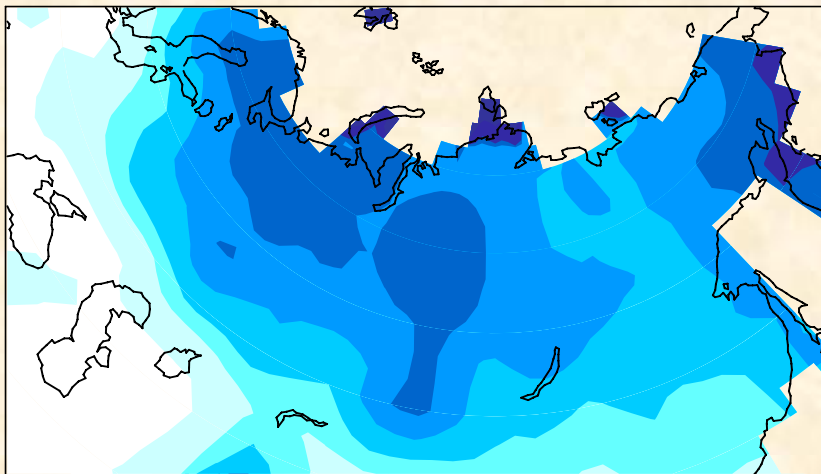
Snow 2080-2099



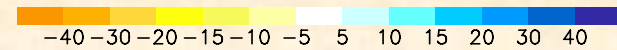
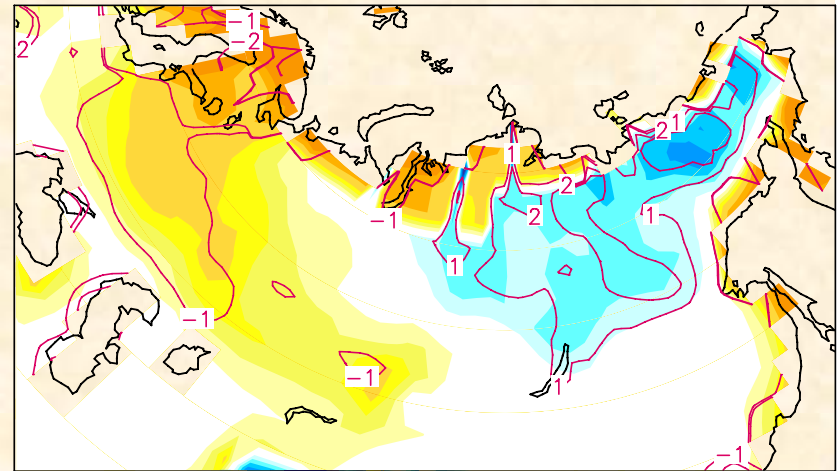
Change of snow mass distribution (kg/m^2) in March relative to current climate

Distribution of snow mass (kg/m^2) in March

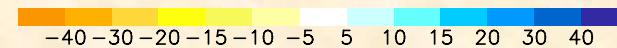
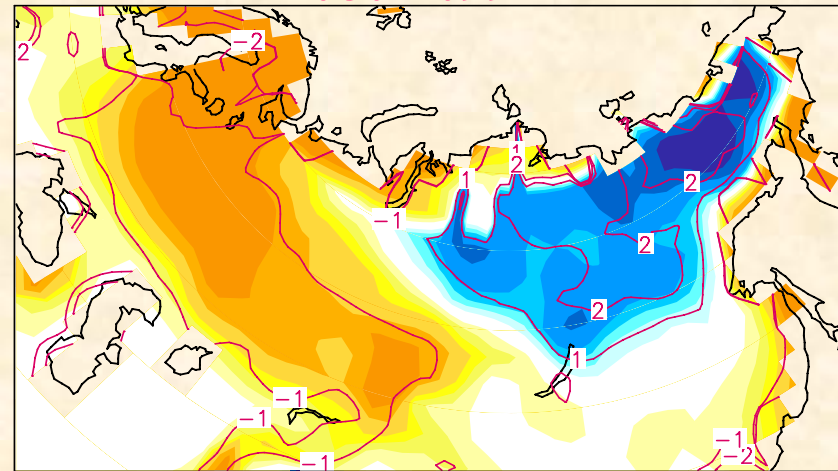
1981-2000



2041-2060

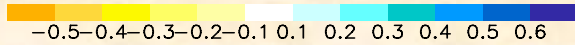
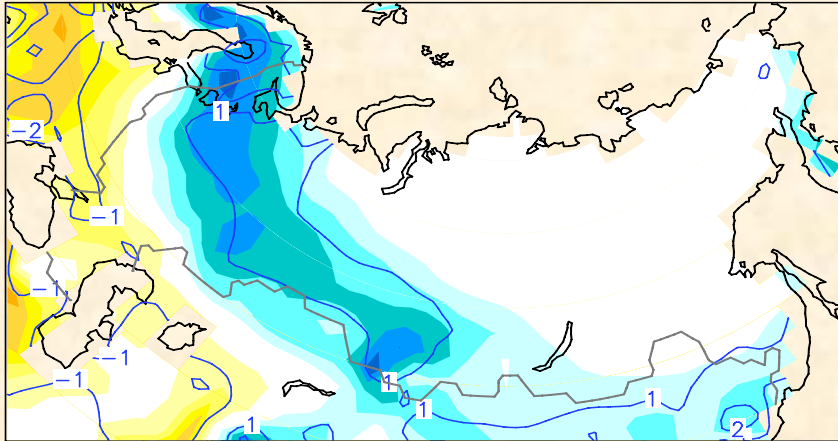


2080-2099

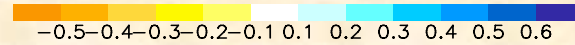
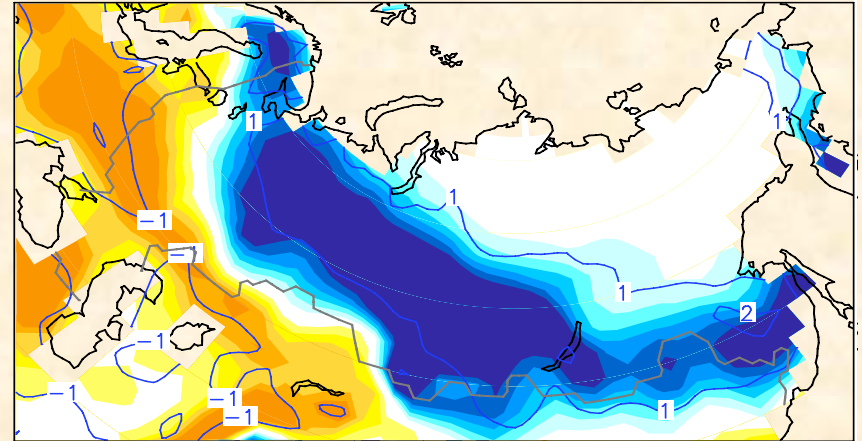


Change of melting rate of snow (mm/day) during spring in the end of 21st century (2080-2099), scenario A2

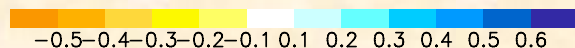
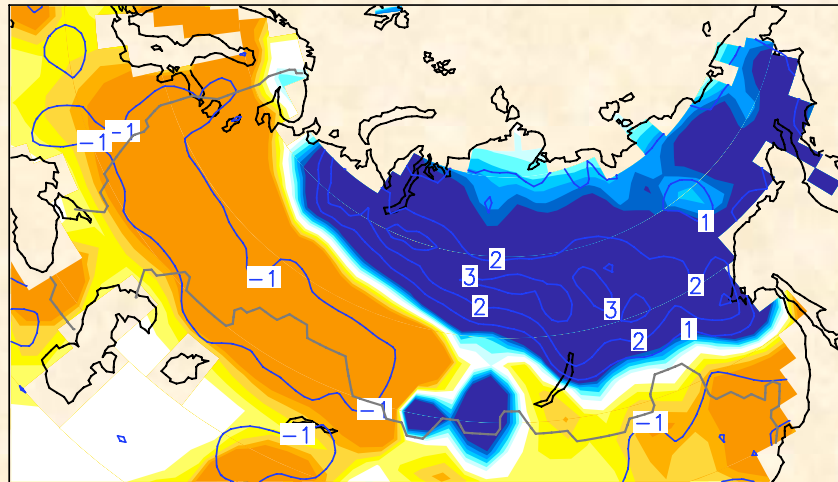
February



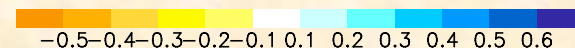
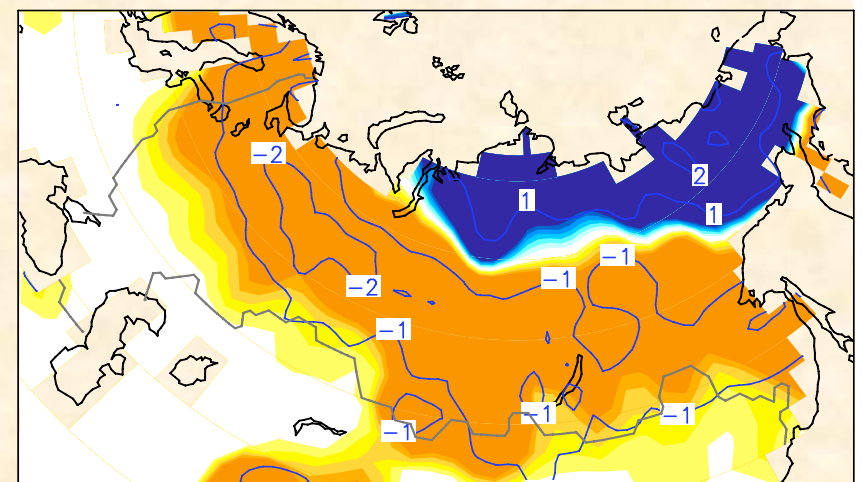
March



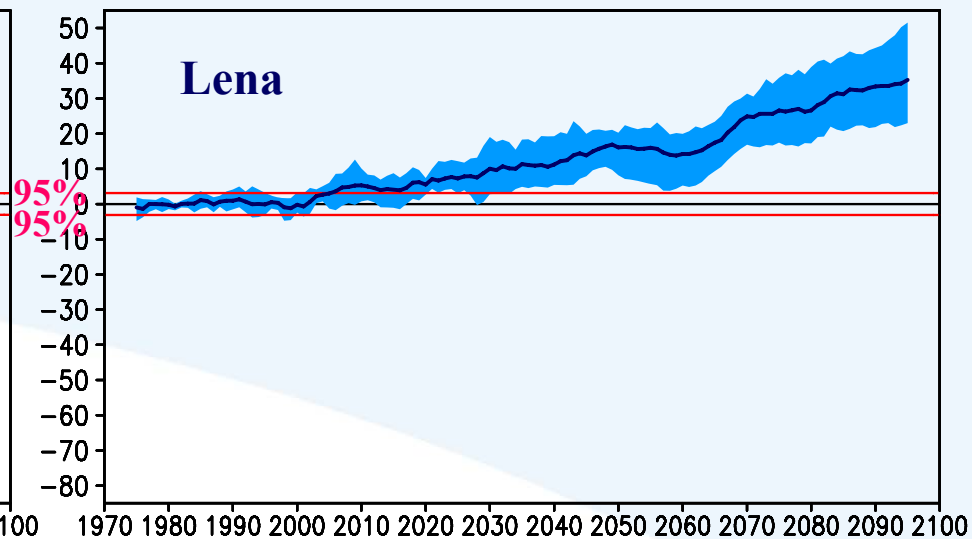
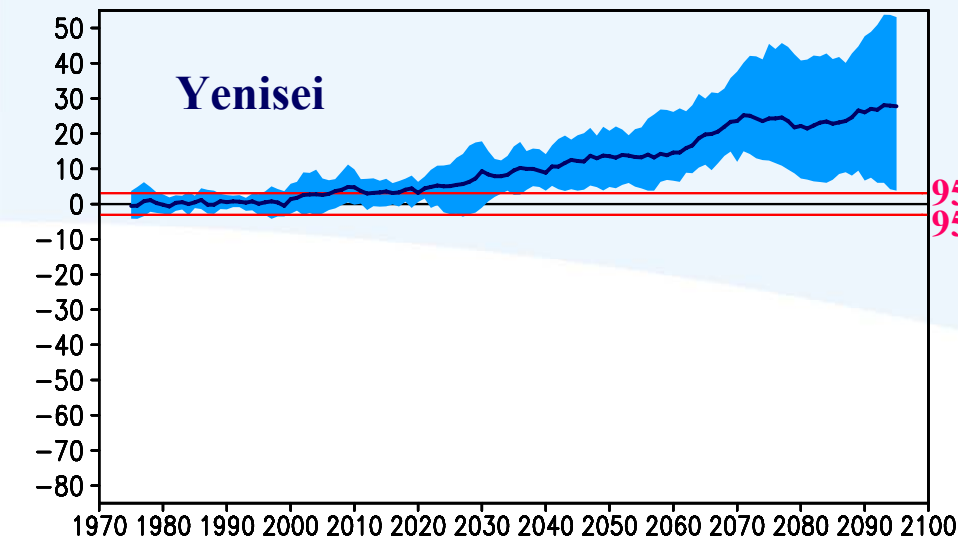
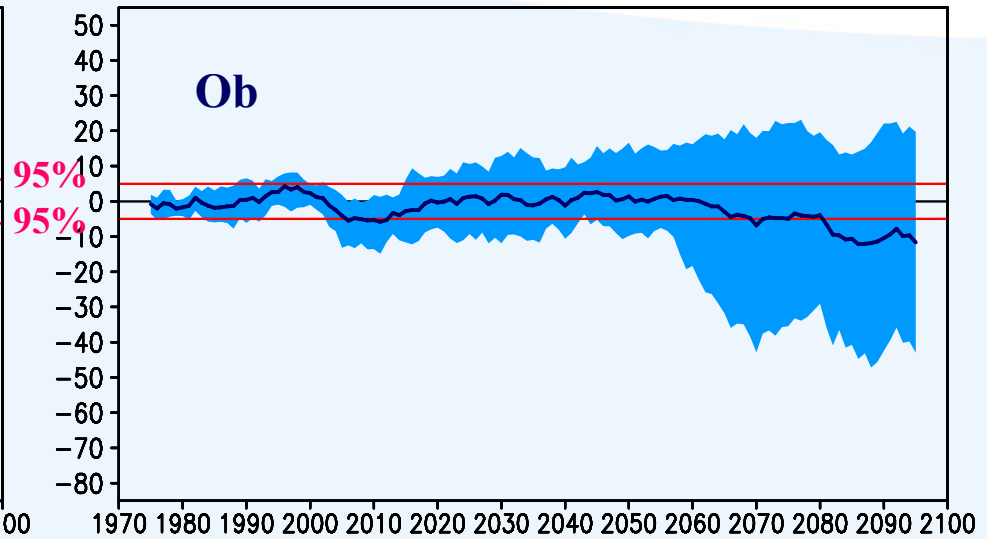
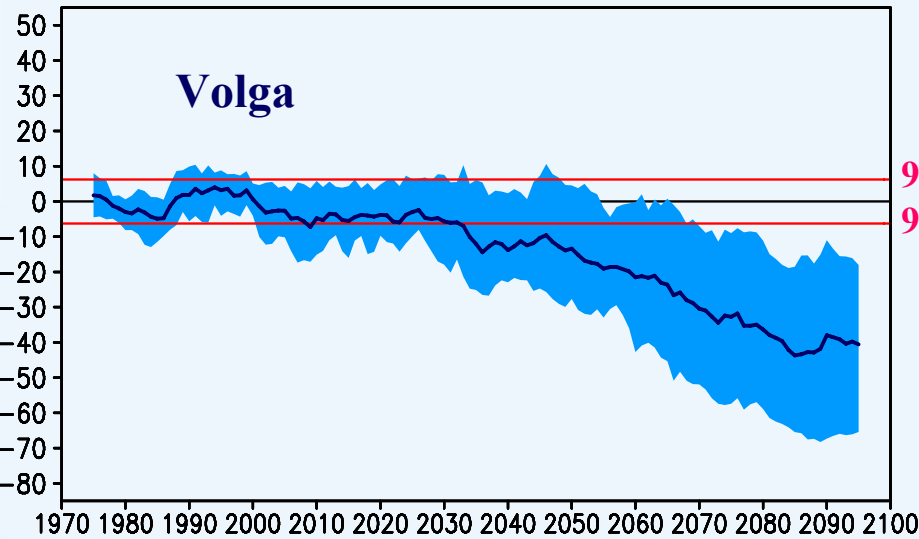
April



May



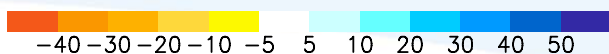
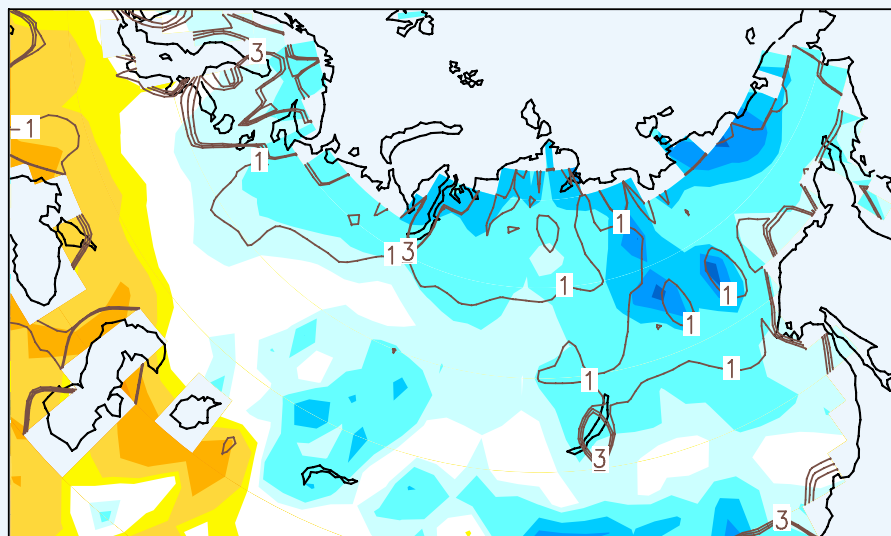
Annual change of melted snow mass (km³/year) over major catchments in spring (March-May) of 21st century relative to current climate (1975-2000). Scenario A2



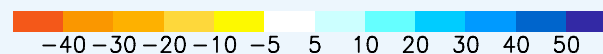
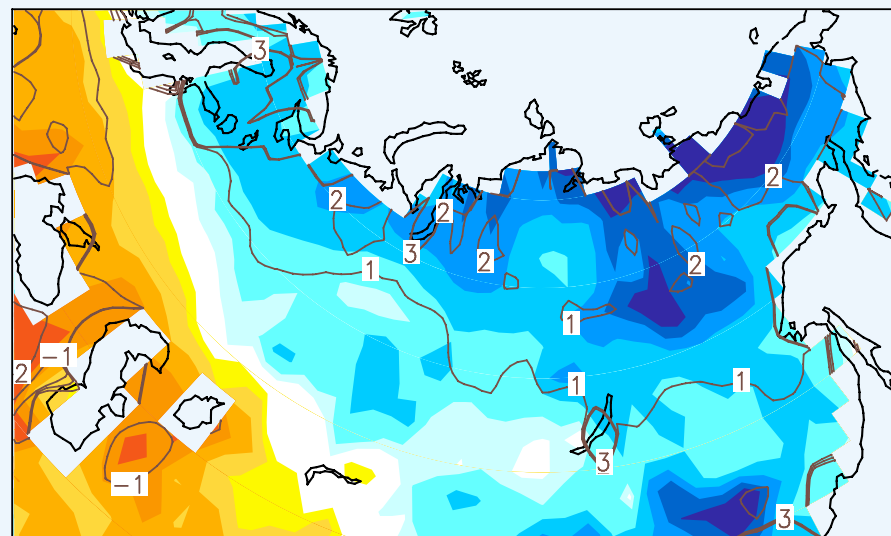


Change of annual runoff in 21st century relative to current climate (1981-2000). Scenario A2

2041-2060

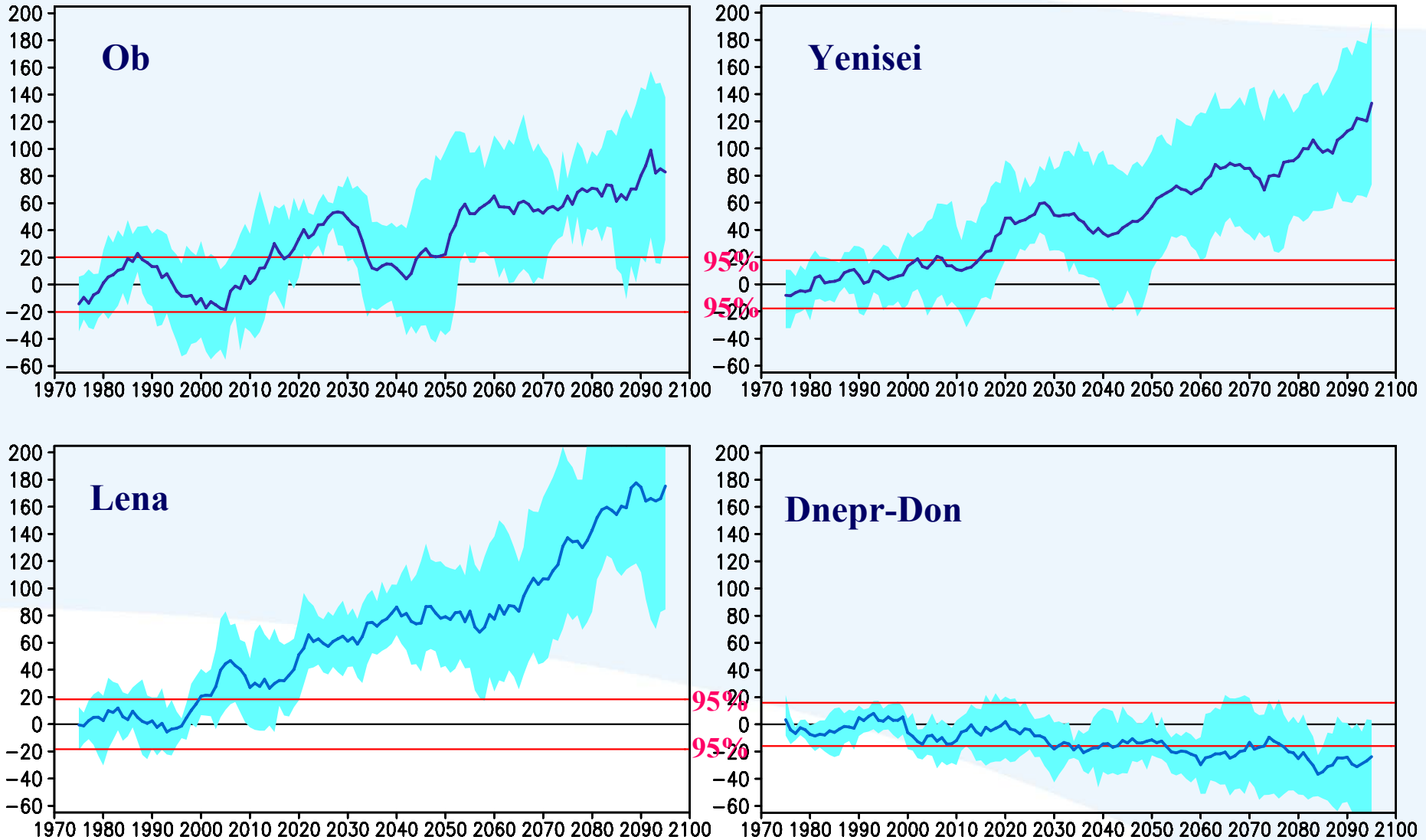


2080-2099



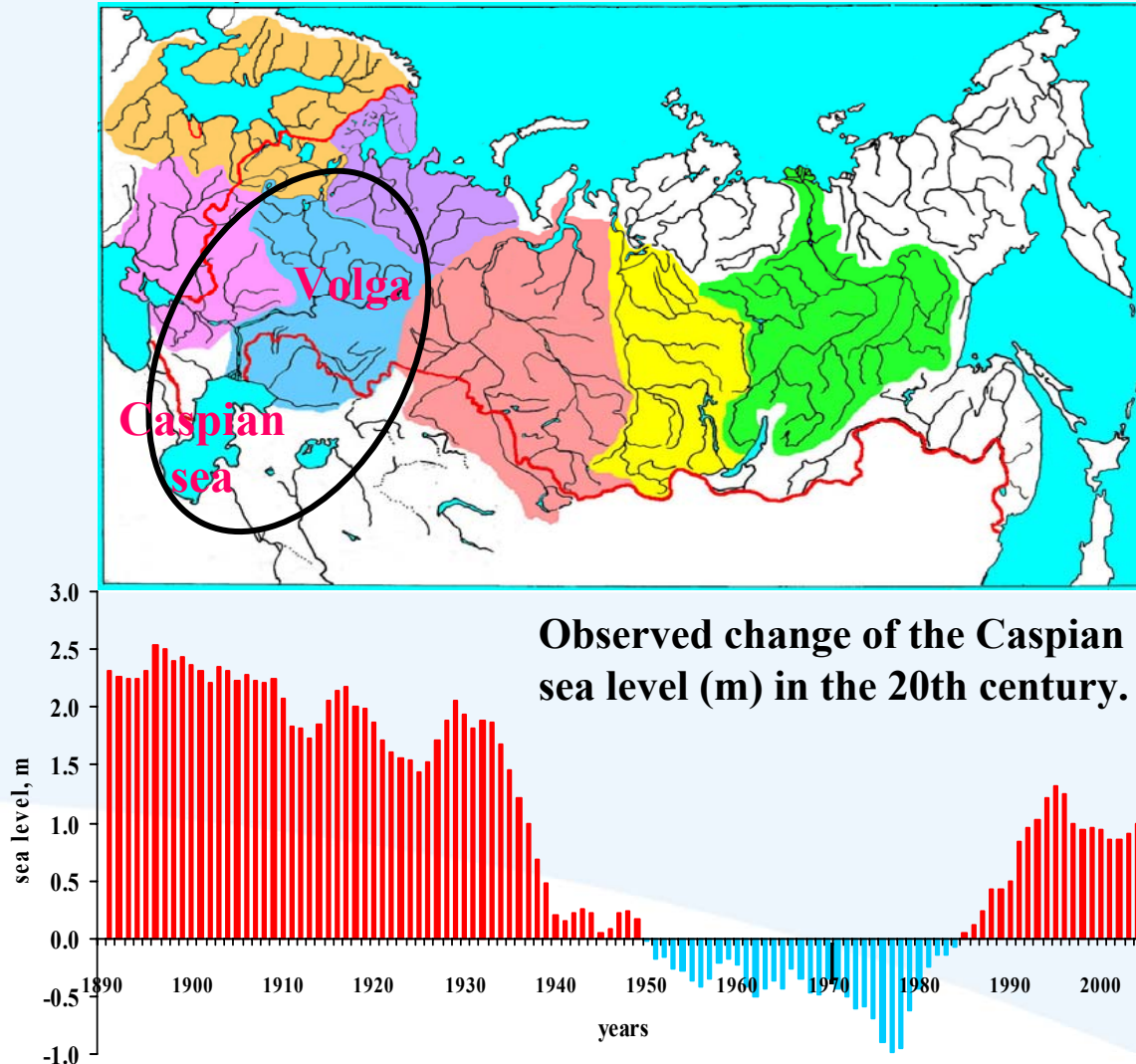


Annual change of runoff in major catchments (km³/year) in 21st century relative to current climate (1975-2000). Scenario A2





Water balance over Volga-Caspian basin and sea level change

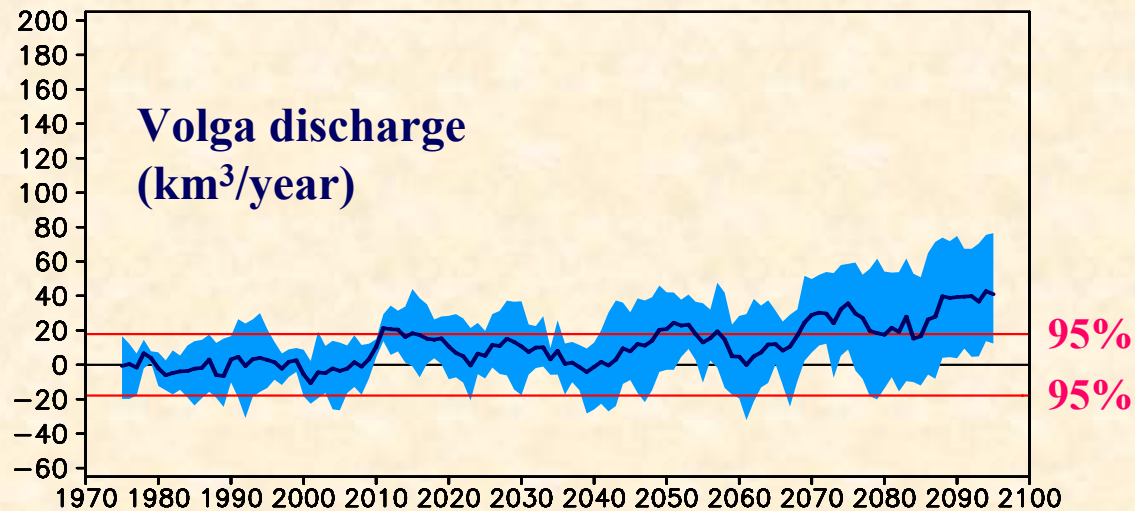
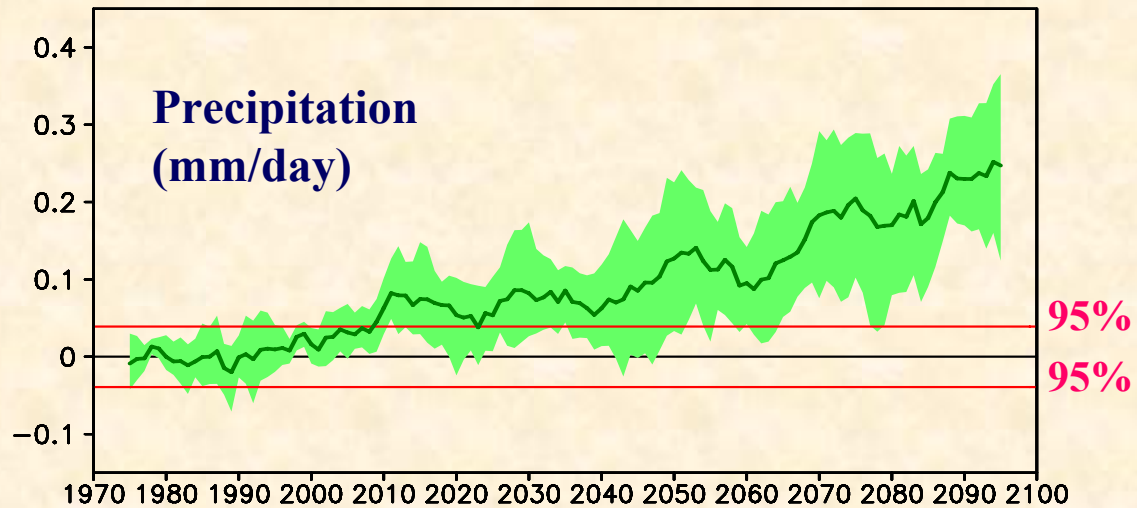




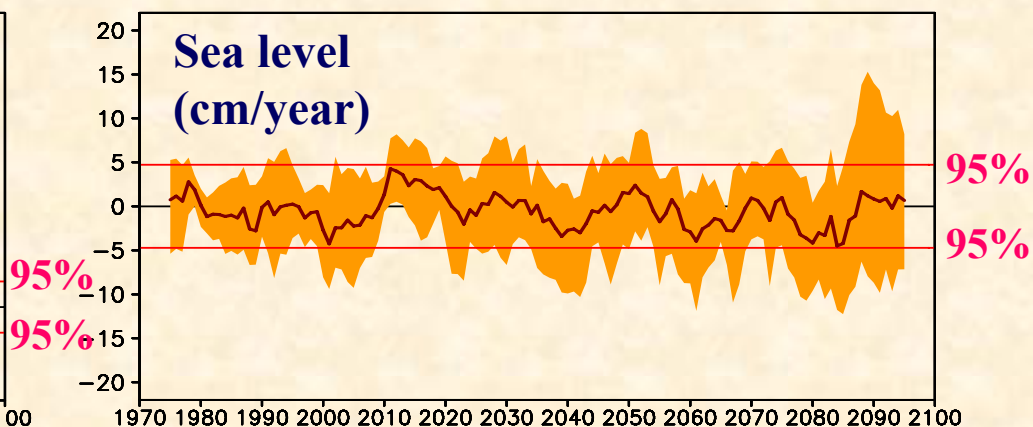
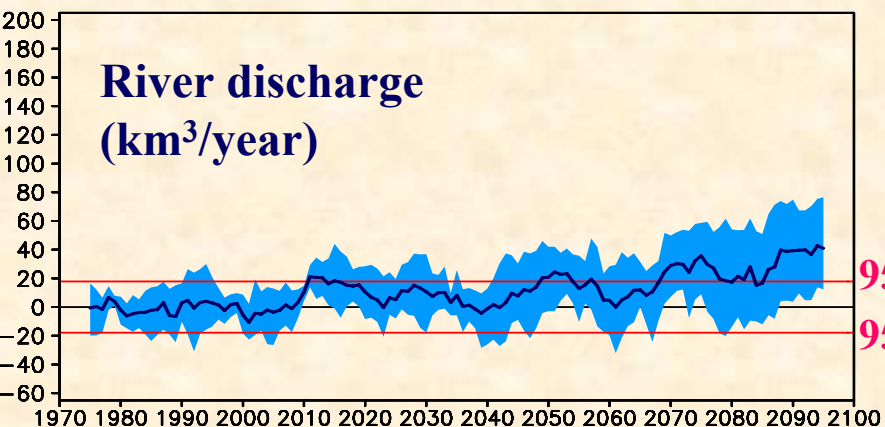
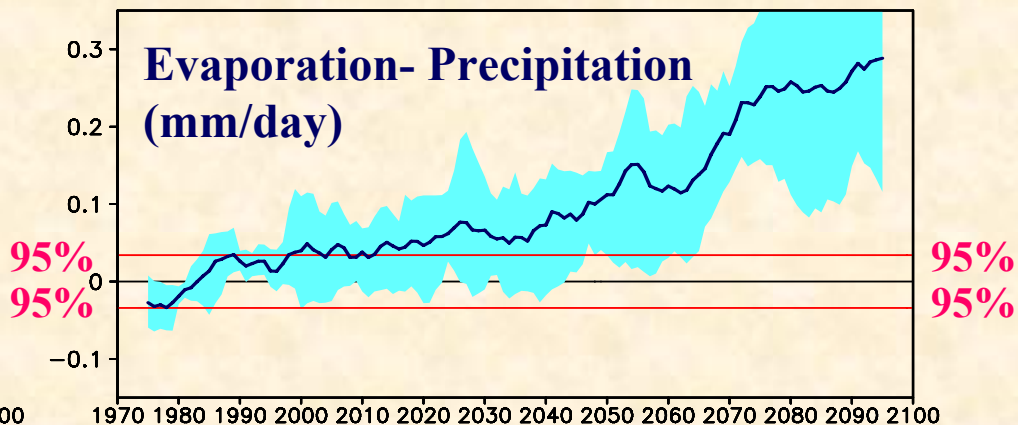
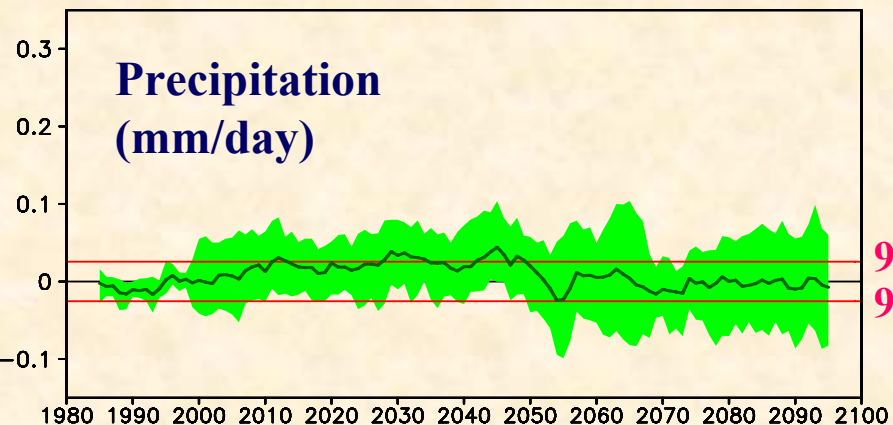
IPCC AR4 coupled climate models used in assessment of water balance change over Volga-Caspian sea

| | Modelling groups | IPCC ID | Atmosphere Resolution | Number of Caspian sea grid points |
|---|---|---------------------------|-------------------------|-----------------------------------|
| 1 | Center for Climate System Research, Japan. | CCSR_ME MIROC3.2 (MED) | Spectral T42L20 | 8 |
| 2 | Meteo-France/Centre National de recherches Meteorologique | CNRM | Spectral T63L18 | 6 |
| 3 | Max Plank Institute for Meteorology, Germany | ECHAM5/ MPI-OM | Spectral T63L31 | 11 |
| 4 | CSIRO Atmospheric Research, Australia | CSIRO-Mk3.0 | Specral T63L18 | 15 |
| 5 | Hadley Centre for Climate Prediction and Research/Met Office UK | HADCM3 | Grid point 96x73xL19 | 4 |

Annual change of water balance over Volga catchments in 21st century relative to current climate (1981-2000). Scenario A2



Annual change of water balance components over Caspian sea (mm/day) in 21st century relative to current climate (1981-2000). Scenario A2



CONCLUSIONS

- **Climate change is expected to manifest through variety of climatic patterns in Northern Eurasia in 21st century due to its large geographical extension.**
- **The ensemble mean warming is significantly higher than the inter-model scatter. Surface air temperature trends become statistically significant in all watersheds from the first half of the 21st century.**
- **Sign of precipitation change depends on the region considered and spread of trends among individual models is larger than that of air temperature.**
- **Hydrological cycle and cryospheric processes undergoes significant regional change during the year and this will impact different areas of human activity.**
- **There are still large number of uncertainties in evaluation of some important climate variables (precipitation, water balance in soil, runoff, extreme events etc.) on regional scales.**

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