Weather and Climatic Extremes:
Data, Analysis and Impact

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Климатические и погодные экстремальные явления:
данные, анализ и воздействие

Extreme atmospheric precipitation in Western Siberia based on different databases

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The aim of the work is to study changes in extreme precipitation in Western Siberia (50-70N, 60-90E) from 1979 to 2019 based on various databases, and to carry out their comparative analysis.

The following databases were used: observational data at 57 meteorological stations (RIHMI-WDC, 1979-2019), GPCC (1979-2016), APHRODITE-2 (1979-2007), and ERA5 (1979-2019) and NCEP (1979-2019) reanalysis data. To identify the dynamics in extreme precipitation, a comparison of estimates for two time intervals was made: 1979-1998 and 1999-2019 (until 2007 for APHRODITE-2 and until 2016 for GPCC). The median of the sample probability distribution function was derived as the average characteristic for the territory. The extreme values of climate values were determined by its threshold quantiles (1% and 5% and 95% and 99%) for warm and cold seasons of the year.

To provide comparative analysis several types of data interpolation into station coordinates were applied. In addition, to eliminate the influence of spatial heterogeneity of meteorological stations location spatial interpolation of calculated monthly and annual average precipitation values on a 1°x1° grid was carried out based on observational data using the kriging algorithm. The magnitude of the relationship between values was determined using linear correlation coefficient.

The spatial distribution analysis revealed a significant discrepancy between reanalysis and observational data in the southern part of Western Siberia (Kosh-Agach station and Neozhidannyy), which is due to the mountainous landscape. It was found that, in general, the time variability of average annual precipitation according to all databases is similar. However, values are overestimated in the ERA5 and NCEP reanalysis data. Correlation analysis showed that the greatest agreement with the observational data was revealed with GPCC data ($r>0.95$), and the least - for the NCEP reanalysis data ($r=0.65$-0.77). A sufficiently high degree of relationship was derived for ERA5 and APHRODITE – $r=0.79$-0.90.

Based on analysis of extreme precipitation from observational data, it was found that more precipitation occurred at the southern stations than at the northern ones in the XXI century. Correlation analysis showed that the greatest agreement between extreme values was revealed with GPCC and the least - for the NCEP reanalysis data.

Thus, the precipitation data presented in the reanalysis databases depend on data assimilation method used and on the grid resolution. It was found that, the average estimates of precipitation obtained from observational and reanalysis data are in better agreement with each other than their extreme values.

An empirical method for predicting extreme low winter sea ice extent in the Russian Arctic in the 21st century under global warming (on the example of the Barents Sea)

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The late decades of the 20th century and early 21st century were characterized by significant global warming. The most dramatic changes occurred in the northern high latitudes in a wintertime. Higher rates of warming in the Arctic relative to temperature changes in the middle and low latitudes, called Arctic amplification (e.g., [Bekryaev et al., 2010]), can lead to a transformation of atmospheric circulation regimes with an increased probability of stationary weather regimes [Francis et al., 2012; Semenov and Latif, 2015] leading to weather extremes. Along with the increase in global temperature, there was a rapid reduction of the Arctic sea ice extent, which accelerated at the beginning of the 21st century [Ivanov et al., 2013; Semenov et al., 2015]. The strongest sea ice retreat is observed in September, whereas winter sea ice decrease is about three time slower. However, winter sea ice changes result, due to huge temperature and humidity contrasts and stronger wind speed, in much large ocean-atmosphere heat flux anomalies that strongly impact atmosphere circulation [Petoukhov and Semenov, 2010]. The greatest loss of winter ice extent was observed in the Barents Sea [Matveeva et al., 2020; Onarheim et al., 2015]. The extrapolation the current ice trends in the Barents Sea into the future implies the ice-free conditions already in 2023 and 2036 for quadratic and linear trends, respectively [Onarheim and Årthun, 2017].

The sea ice in numerical experiments with climatic models is linked to the sea surface temperature. At the same time, climate models do not always realistically reproduce processes in the ocean and, in particular, the multidecadal variability of sea surface temperature in the North Atlantic [Ba et al., 2014]. In addition, the uncertainty in the results of model estimates of the ice coverage is due to significant intermodel spread. For example, ice-free conditions in the Barents Sea "are projected to occur for the first time in 2028 in GFDL CM3, 2061 in MPI-ESM-MR, and 2063 in NorESM1-M" [Onarheim and Arthun, 2017]. Researchers have noted that "the Barents Sea is currently almost ice free in summer, while the models in average simulate such conditions by the end of the 21st century or around 2050 in the CMIP3 and CMIP5 ensembles, respectively" [Semenov et al., 2015]. The overestimation of sea ice can be associated with an underestimation of the ocean heat transport to the Barents Sea in CMIP5 models [Li et al., 2017]. The importance of the prediction of the sea ice cover extent in the Barents Sea is rising because it is one of the major regions of the offshore oil and gas exploration and an important part of the marine sea routes.

The purpose of this study is to predict the timing of the ice free conditions in the Russian Arctic seas using statistical methods based on the observed relationship between sea ice concentration and surface air temperature over vast part of the Northern Hemisphere.

The method of linear singular decomposition of covariance matrices (SVD, Singular Value Decomposition) [Bretherton, 1992] was used to determine the areas of the most significant correlation between the leading modes of joint variability of the sea ice concentration (SIC) in January-March and the surface air temperature (SAT) of the Northern hemisphere north to 30N in the autumn, winter and spring months in the 1979-2019 period. An analysis of the structure of this linkage showed its robustness for SIC in the Barents Sea. The system of the relationships between the studied parameters changed in the late 1990s in other Seas of the Russian Arctic. It was revealed that average January-March SIC in the north of the Barents Sea was strongly corelated with average November-January SAT in Scandinavia and over the Barents Sea (correlation coefficient is -0.8). Thus, an increase/decrease in November-January SAT in Scandinavia and over the Barents Sea in 70% of the study period resulted in a subsequent decrease/increase in January-March SIC in the north of the Barents Sea in the period 1979-2019. Using the link between SIC and SAT in key areas, independent SIC estimates have been obtained in the shelf zone in the north of the Barents Sea in the 21st century according to an ensemble of 30 CMIP5 GCMs. It was found that the RCP 4.5 scenario results in a reduction of the ice coverage in the north of the Barents Sea by 2041-2050 to values where year-round navigation is possible in the region. At the same time, the complete disappearance of sea ice is not expected until the end of the century. According to the aggressive scenario RCP 8.5, year-round navigation in the region will already be possible in 2031–2040, and almost free-ice Barents Sea should be expected by the middle of the 21st century.

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