Extreme Precipitation Regimes in Northern Eurasia in the 20th Century and Their Possible Changes in the 21st Century

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This communication is devoted to the analysis and potential revision of variations in precipitation characteristics—its quantity, intensity, and the probability of days with precipitation and their extreme regimes—in some regions of northern Eurasia based on daily meteorological observations during the 20th century. The ability of climatic models to simulate these regimes and their variations is demonstrated by way of an assessment of probable changes in Siberian river basins, the Volga River basin, the Caspian Sea region, and the Caucasus in the 21st century.

The last century was characterized by significant regional variations in characteristics of the hydrological cycle in northern Eurasia and elsewhere. The analysis of relevant data indicates a trend of the enhancement of extreme precipitation regimes in different regions, particularly over land regions in middle and high latitudes of the Northern Hemisphere [1]. According to [1], the enhancement of this trend should be expected in many regions under conditions of global warming in the 21st century [see also 2, 3].

We analyzed daily data on precipitation obtained in numerical experiments with different climatic models (ECHAM4/OPYC3 [4, 5] and ECHAM5/MPI-OM1 [6, 7]). For the subperiod of 1860–1990, the concentration of atmospheric greenhouse gases (CAGG) in calculations with model ECHAM4/OPYC3 was assigned using observation data. For the subperiod of 1991–2000, we used the IS92a scenario [8] that approximately corresponds to CAGG doubling or trebling in the middle and terminal 21st century, respectively. The results of calculations with model ECHAM5/MPI-OM1 were also checked for the period of 500 yr (with preindustrial CAGG levels and lack of additional external impact on the climatic system) and for 80 yr (with the 1% growth of the CAGG relative to its preindustrial level).

For comparison with model calculations, ORNL/CDIAC [9] and CRU [10] precipitation characteristics based on daily observations in the 20th century, as well as revised ESMWF (ERA-40) data [11] for the period of 1958–2001, were analyzed. Quantitative values of regional precipitation from [12] were also used. As a whole, models ECHAM4/OPYC3 and ECHAM5/MPI-OM1 simulate sufficiently well the quantity of precipitation in basins of various Russian rivers.

The table presents data on trends in regional precipitation characteristics during the 20th century based on the CRU data and ECHAM4/OPYC3 calculations for the Volga, Ob, Yenisei, and Lena river basins. According to ORNL/CDIAC and revised ERA-40 data, the central European part of Russia (e.g., Moscow and Nizhni Novgorod regions) shows a general increase in precipitation quantity, its probability, average intensity, and extreme values for all seasons (except spring) during the second half of the past century. For the spring season, this trend is revealed from all the analyzed data only for the probability of days with precipitation. According to ORNL/CDIAC data, trends of other precipitation parameters are different in the springtime at different meteorological stations of this region.

The ORNL/CDIAC data also demonstrate substantially different seasonal trends in precipitation characteristics for the Caspian Sea region during the second

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half of the 20th century. For instance, the general increase in precipitation, its average intensity, and extreme values in Kalmykia (Elista, in particular) can be explained by corresponding trends for intermediate seasons (spring and autumn). In terms of these characteristics, opposite or notably weaker trends are recorded for summer and winter (for instance, in the total quantity of winter precipitation and average intensity of summer rains). Seasonal distribution of trends is different for the probability of days with precipitation: decrease in winter (insignificant decrease in spring) and increase in summer and autumn.

Based on both observation data and model calculations, precipitation characteristics for the 20th century revealed a general trend of growth of intensity in the Volga, Ob, Yenisei, and Lena river basins. One can also see a general increase in precipitation quantity in all these basins, except for summer precipitation in the Yenisei basin (based on the CRU data) and the Lena basin (inferred from model calculations). According to the CRU data, regional trends of changes in precipitation probability are similar to corresponding trends noted for the total precipitation (general growth except for the summer in the Yenisei River basin). Model calculations reveal a notable decrease in precipitation in the Yenisei and, particularly, Lena river basins during the summer season against the background of a general increase in precipitation probability for all the basins in winter.

All the river basins under consideration (Volga, Ob, Yenisei, and Lena) show a general trend of increase in the intensity of winter and summer precipitation during the 20th century with the simultaneous growth of variations in the intensity of winter precipitation during the 21st century relative to the 20th century.

Figure 1 demonstrates trends of different characteristics of winter and summer precipitation in the 21st century calculated for the Volga, Ob, Yenisei, and Lena river basins and the Caucasian region using the climatic models ECHAM4/OPYC3 and ECHAM5/MPI-OM1. As follows from Fig. 1a, winter precipitation intensity and its extreme values increases in all regions under consideration. A similar trend is noted for the total precipitation and probability of regional precipitation, except for the Caucasian region as a whole. According to Fig. 1b, the probability of summer precipitation decreases in all the regions, while its intensity and extreme values should grow in the Volga, Ob, Yenisei, and Lena river basins during the 21st century. The assessment of regional variations in extreme precipitation and its average intensity in the Caucasian region revealed substantial differences between the values obtained for the summer season using models ECHAM4/OPYC3 and ECHAM5/MPI-OM1.

On the whole, model estimates of probable changes in the 21st century suggest a general increase in precipitation intensity and its extreme values for different regions of northern Eurasia. According to the ORNL/CDIAC, CRU, and ERA-40 data, this trend had already become evident in the 20th century. At the same time, trends in the variations of precipitation characteristics for different regions are substantially different. The Caucasus and some other regions are characterized by ambiguous trends.

Variations in the precipitation characteristics of river basins are reflected in corresponding changes in the river runoff. For instance, model assessments suggest a substantial increase in extreme runoff values for the Siberian rivers (particularly, the Lena River) [3, 13]. According to ECHAM4/OPYC3 calculations, the maximal values of annual Lena River runoff in the 21st century might be one-third higher as compared to the 20th century [14]. The corresponding parameter is estimated to be one and half times lower for the Yenisei River and

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Basin</th>
<th>CRU</th>
<th></th>
<th>ECHAM4/OPYC3</th>
<th></th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Winter</td>
<td>Summer</td>
<td>Year</td>
<td>Winter</td>
<td>Summer</td>
</tr>
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<td>Volga</td>
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<td>8.8</td>
<td>5.0</td>
<td>6.8</td>
</tr>
<tr>
<td></td>
<td>Ob</td>
<td>8.8</td>
<td>4.0</td>
<td>6.0</td>
<td>8.2</td>
</tr>
<tr>
<td></td>
<td>Yenisei</td>
<td>15.4</td>
<td>–0.6</td>
<td>5.7</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>Lena</td>
<td>15.3</td>
<td>6.5</td>
<td>8.1</td>
<td>11.2</td>
</tr>
<tr>
<td>Precipitation intensity</td>
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<td>4.4</td>
<td>3.1</td>
<td>3.1</td>
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<tr>
<td></td>
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<td>2.1</td>
<td>2.9</td>
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<tr>
<td></td>
<td>Yenisei</td>
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<td>0.1</td>
<td>1.8</td>
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<td></td>
<td>Lena</td>
<td>8.7</td>
<td>3.5</td>
<td>3.4</td>
<td>6.3</td>
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<tr>
<td>Precipitation probability</td>
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<td>4.6</td>
<td>2.3</td>
<td>3.8</td>
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<tr>
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<td>Ob</td>
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<td>2.3</td>
<td>4.4</td>
<td>5.3</td>
</tr>
</tbody>
</table>
is expected to remain unchanged for the Ob River. Calculations based on the global climatic model IFA RAN yielded even higher growth in the maximal values of annual Lena River runoff and lower values for the Yenisei River as compared with model ECHAM4/OPYC3 [14, 15]. In contrast to the latter model, calculations based on model IFA RAN predict a substantial increase in the maximal values of annual runoff for the Lena River as well [14].

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