Increasing Daily Precipitation Intensity Associated with Warmer Air Temperatures Over Northern Eurasia

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Increasing air temperature is associated with increasing atmospheric water vapor

- Extreme precipitation events will become more frequent (e.g. Allan and Soden 2008; Groisman et al. 2005; Shiu et al. 2012)
- Observations in Europe: daily precipitation intensity increases in winter but decreases in summer (Berg et al. 2009)

Precipitation has a larger spatial and temporal variability compared to air temperature; the long term trend is weaker

One way to understand potential changes in precipitation characteristics under a background of warming climate

- Is to examine relationships between precipitation and temperature at **decadal and longer time scales** (filter out noisy shorter term variability)
Questions

How does precipitation intensity change under a warming climate for each season over Northern Eurasia?

What is the role of atmospheric circulation (Arctic Oscillation) to the relationships between seasonal precipitation intensity and air temperature at inter-annual, decadal and longer time scales?
Data

Precipitation and Air Temperature: the Daily Temperature and Precipitation Data for 518 Russian Meteorological Stations from the Carbon Dioxide Information Analysis Center (CDIAC) (Bulygina and Razuvaev 2012).

Arctic Oscillation Index: Climate Predication Center

Daily Precipitation Intensity: the monthly precipitation total divided by the number of precipitation days per month

Time period: 1966-2010
Methodology

1. Seasonal time series of Precipitation Intensity, Air Temperature, and AO for each station

2. 11-year moving average is applied to all time series to examine relationships at decadal and longer time scales

3. Partial correlation analyses to remove the influence of third inter-related variable:

\[ p_{Yxy, z} = \frac{Y_{xy} - Y_{xz} \cdot Y_{yz}}{\sqrt{(1 - Y^2_{xz})(1 - Y^2_{yz})}} \]

\( p_{Yxy, z} \) is the partial correlation between x and y after control z. \( Y_{xy}, Y_{xz}, Y_{yz} \) are the correlations between x and y, x and z, and y and z respectively. The number of degrees of freedom is \( N-3 \) (\( N \) is the sample size or the actual sample size for the 11-moving time series-to remove autocorrelation).
4. Partial Regression Coefficient ($\beta$): the absolute increase in a dependent variable ($PI$) associated with one unit of increase in an independent variable ($T$), the effect of the third variable ($AO$) on both having been held constant (Johnson 1978)

$$e_{PI} = \alpha + \beta e_T + \varepsilon$$

$e$: residual time series

$$PI = a_1 + b_1 AO + e_{PI}$$

$$T = a_2 + b_2 AO + e_T$$
Results:

1. Geographical Distribution of Mean Seasonal Precipitation Intensity (mm/day)
Results:

2. Correlation Between the AO and Precipitation Total (a and b), Frequency (c and d), and Intensity (e and f) in Winter Season. (Interannual-left, interdecadal-right)

Red: positive correlation; blue: negative correlation; Filled circle: statistically significant; Open circle: not statistically significant.
Results: 3. Partial Correlation Between 11-year Moving Averaged Time Series of Air Temperature and Precipitation Intensity

<table>
<thead>
<tr>
<th>Season</th>
<th>Statistically Significant Positive Stations</th>
<th>Positive Correlation Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Winter</td>
<td>31.3% (22.5%-trend)</td>
<td>68.9% (68.8%-trend)</td>
</tr>
<tr>
<td>Spring</td>
<td>39.7% (20.8%-trend)</td>
<td>72.3% (75.4% -trend)</td>
</tr>
<tr>
<td>Summer</td>
<td>29.4% (9.6%-trend)</td>
<td>60.9% (68.5%-trend)</td>
</tr>
<tr>
<td>Fall</td>
<td>23.4% (18.2%-trend)</td>
<td>63.4% (71.4%-trend)</td>
</tr>
</tbody>
</table>
Results: 4. Decadal Time Series of Air Temperature and Precipitation Intensity Averaged From All 517 Stations (Winter on the left; Spring on the right)
For Summer (left) and Fall (right)
Results: 5. Percentage Rate of Change in Precipitation Intensity for Each Degree of Air Temperature Increase (AO’s influence has been removed)
Conclusions

- Increasing precipitation intensity is significantly correlated with increasing air temperature for all seasons.
- The relationship between precipitation intensity and air temperature is strongest at decadal and longer time scales and in cold seasons.
- The average rate of increase for each degree of air temperature increase is 6.2% for spring and 3.1-3.5% for other seasons.
- The relationship is insensitive to AO variability.

Precipitation intensity has been increasing over Northern Eurasia under a background of a warming climate!