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

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Background Info

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 <u>decadal and longer time scales</u> (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:

$$PYxy,z = \frac{Yxy - Yxz * Yyz}{\sqrt{(1 - Y^2xz)(1 - Y^2yz)}}$$

PYxy,z is the partial correlation between x and y after control z. Yxy, Yxz,Yyz 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).

Methodology (continue)

4. Partial Regression Coefficient (β): the absolute <u>increase in a dependent variable</u> (PI) <u>associated with one unit of increase in an independent variable</u> (T), <u>the effect of the third variable</u> (AO) <u>on both having been held constant</u> (Johnson 1978)

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

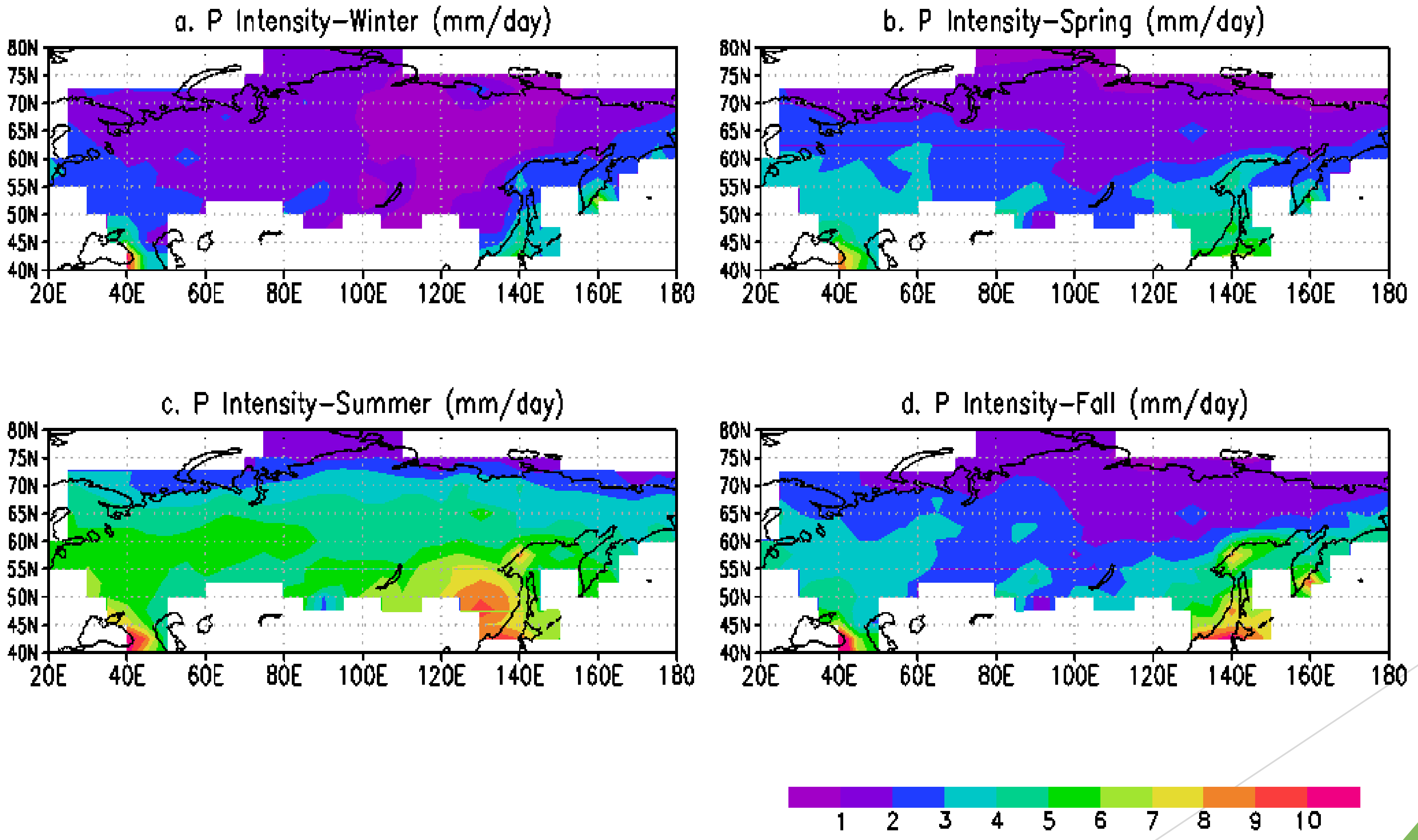
e: residual time series

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

$$T = a_2 + b_2\, AO + e_T$$

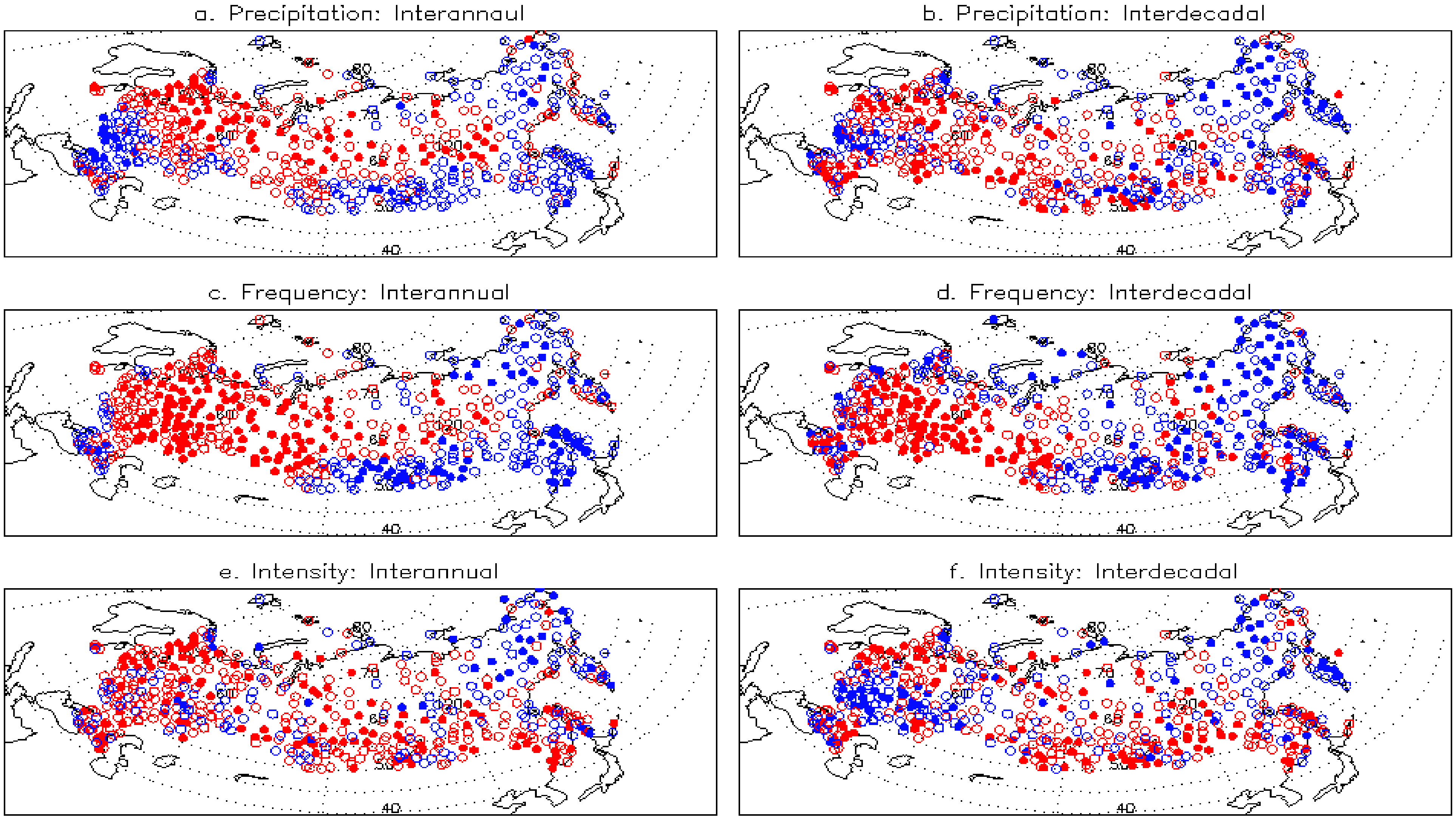
Results:

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)

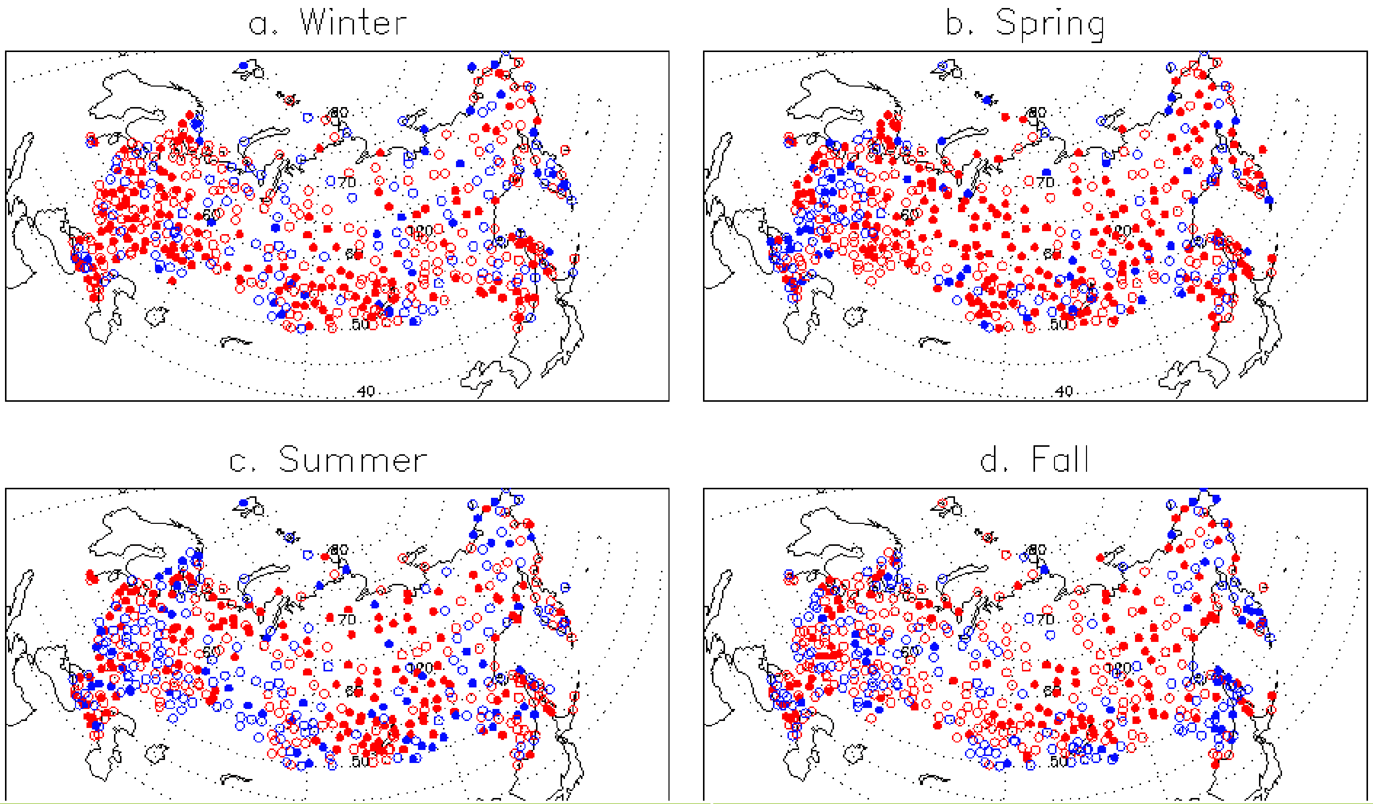


Red: positive correlation; blue: negative correlation; Filled circle: statistically significant; Open circle: not statistically significant.

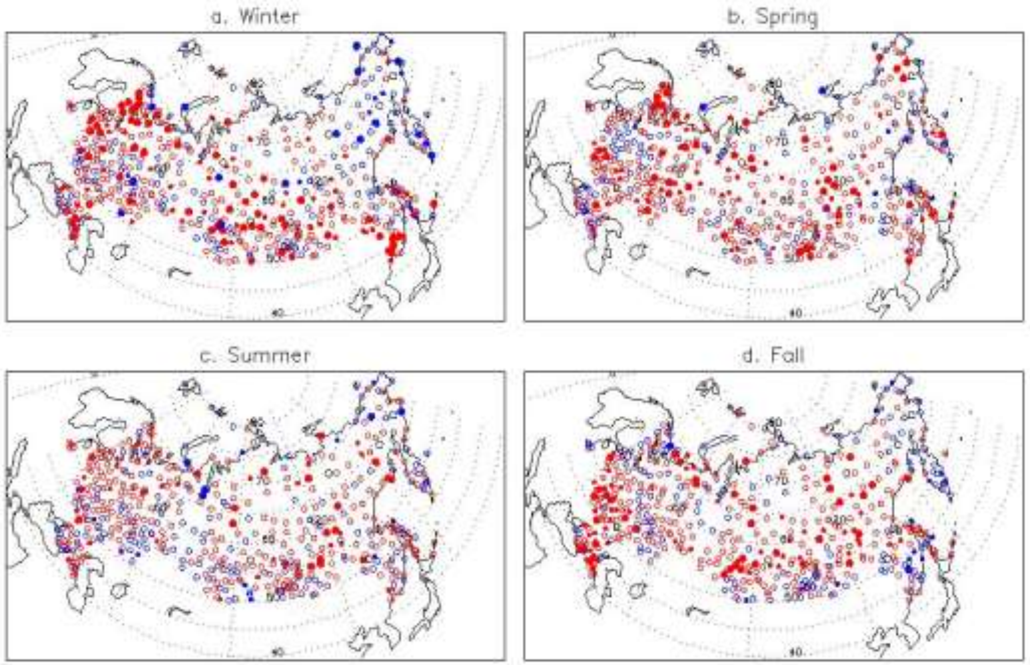
Frequency

Intensity

Results: 3. Partial Correlation Between 11-year Moving Averaged Time Series of Air Temperature and Precipitation Intensity

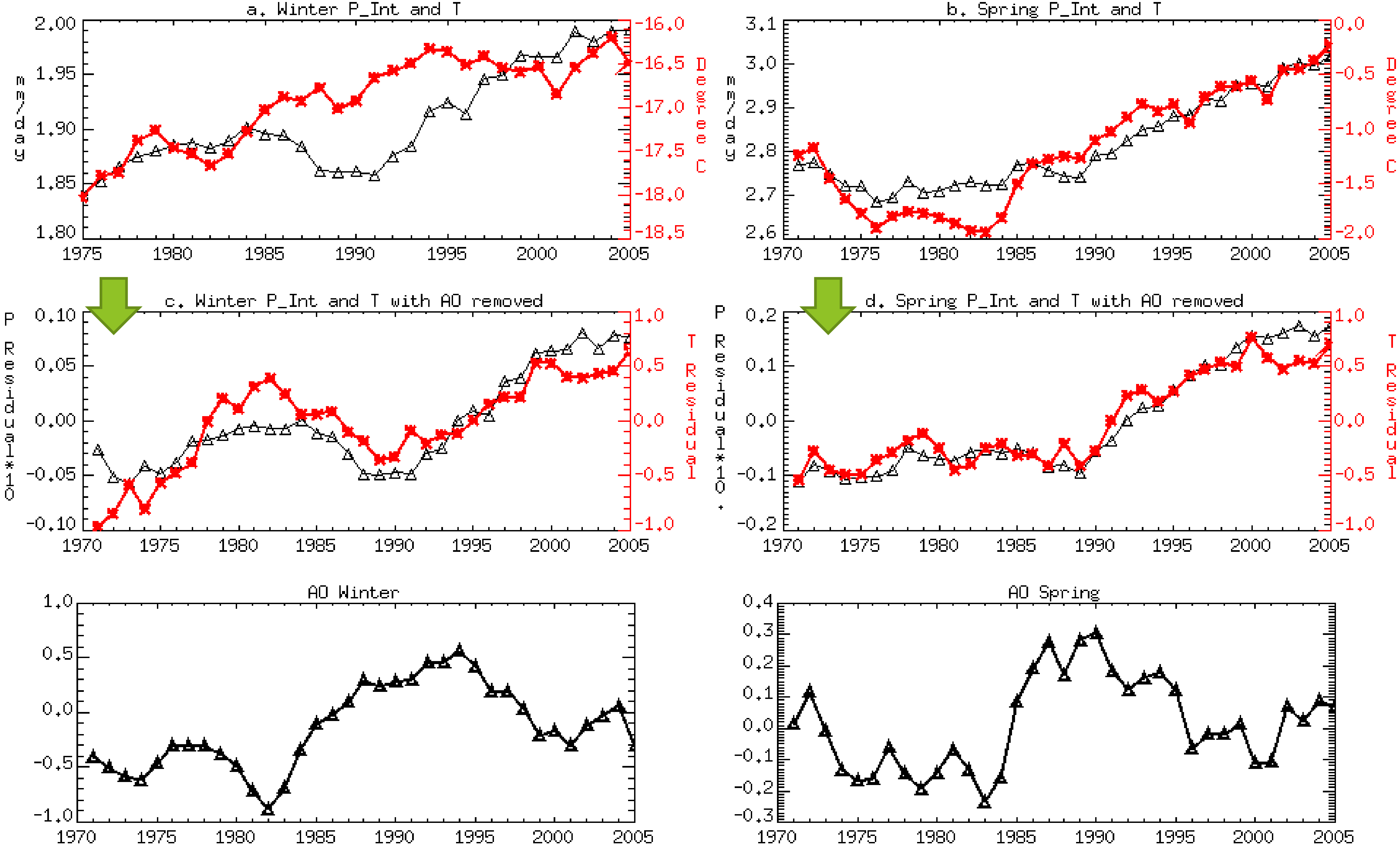


Trend of P intensity 1966-2010



Season	Statistically Significant Positive Stations	Positive Correlation Stations
Winter	31.3% (22.5%-trend)	68.9% (68.8%-trend)
Spring	39.7% (20.8%-trend)	72.3% (75.4% -trend)
Summer	29.4% (9.6%-trend)	60.9% (68.5%-trend)
Fall	23.4% (18.2%-trend)	63.4% (71.4%-trend)

Results: 4. Decadal Time Series of Air Temperature and **Precipitation Intensity** Averaged From All 517 Stations (Winter on the left; Spring on the right)

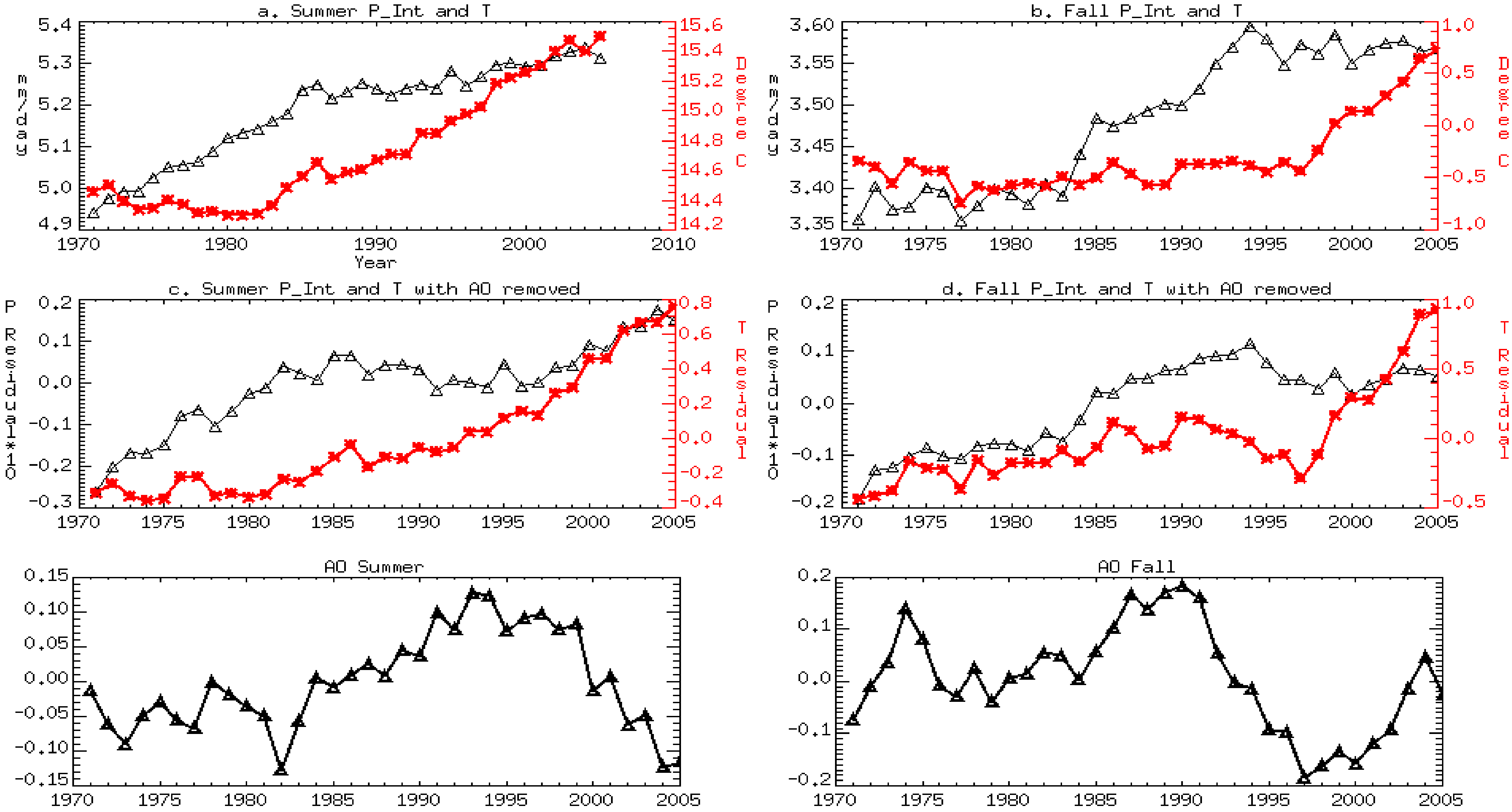


Original

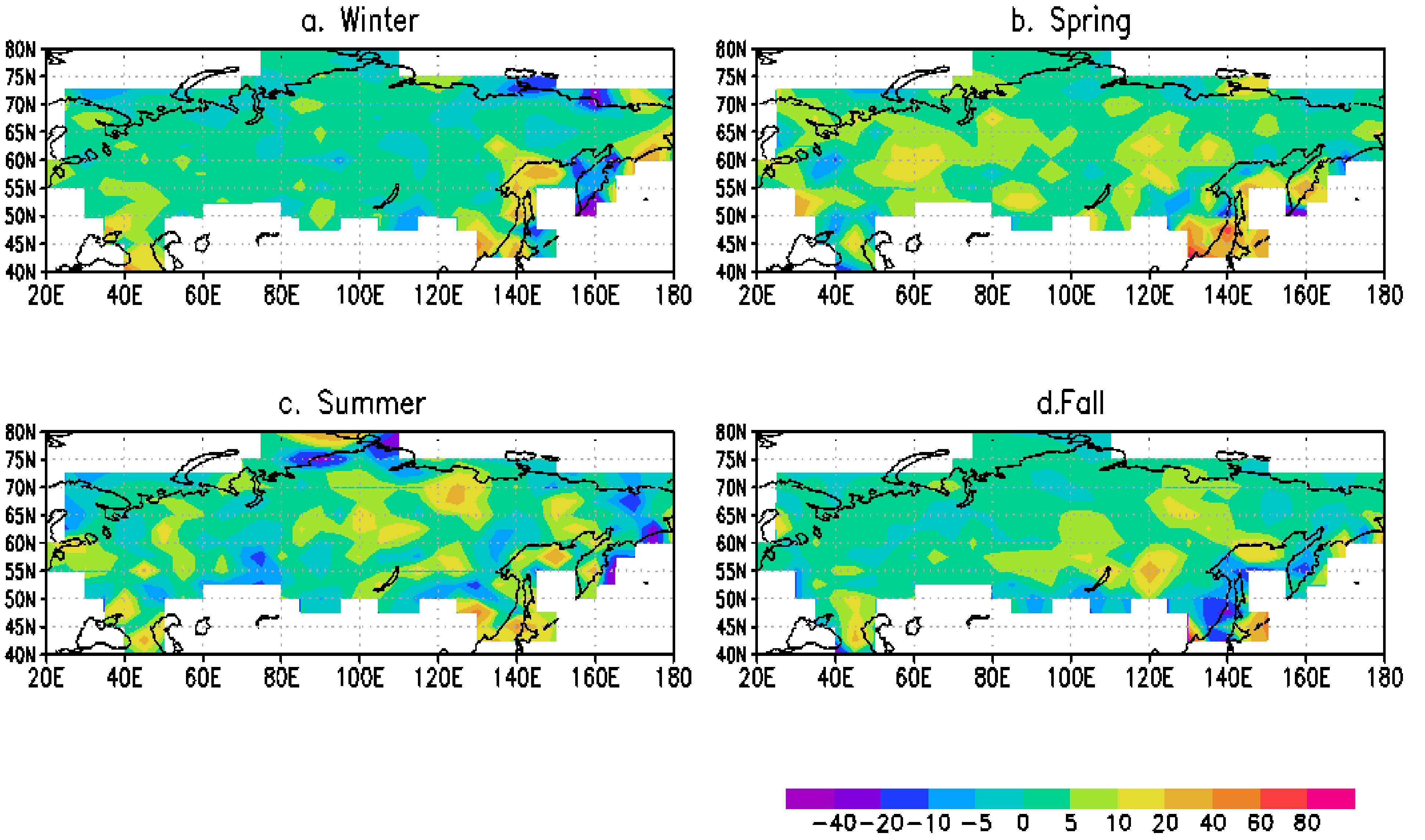
Residual: AO is removed

AO

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!