W4.1. Extreme events (droughts, wild fire, and downpours) over Northern Asia: Climatology, trends, and possible future changes

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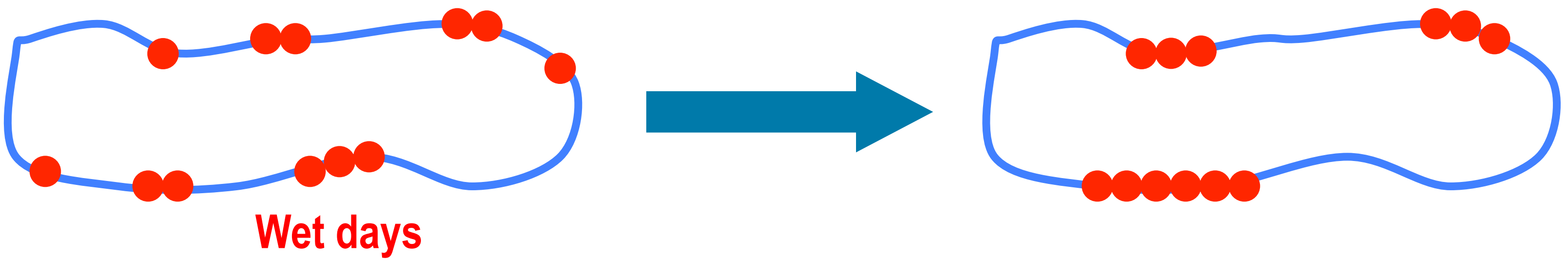
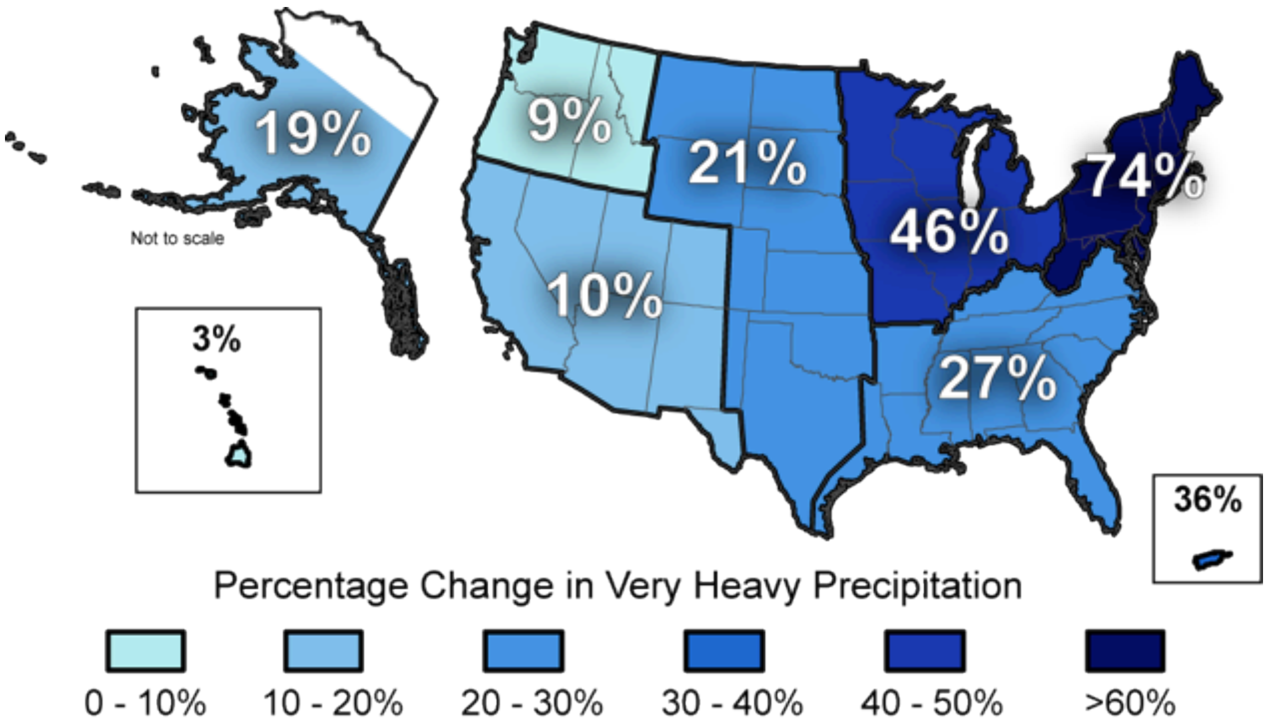
Beads with a fixed number of stones illustrate how we can have in the same region simultaneously increases in prolonged Wet Day and Dry Day Periods even with unchanged precipitation totals (design by O.G. Zolina).



Observed Increases in Very Heavy Precipitation during the 1958 to 2010 period (USGCRP 2009)

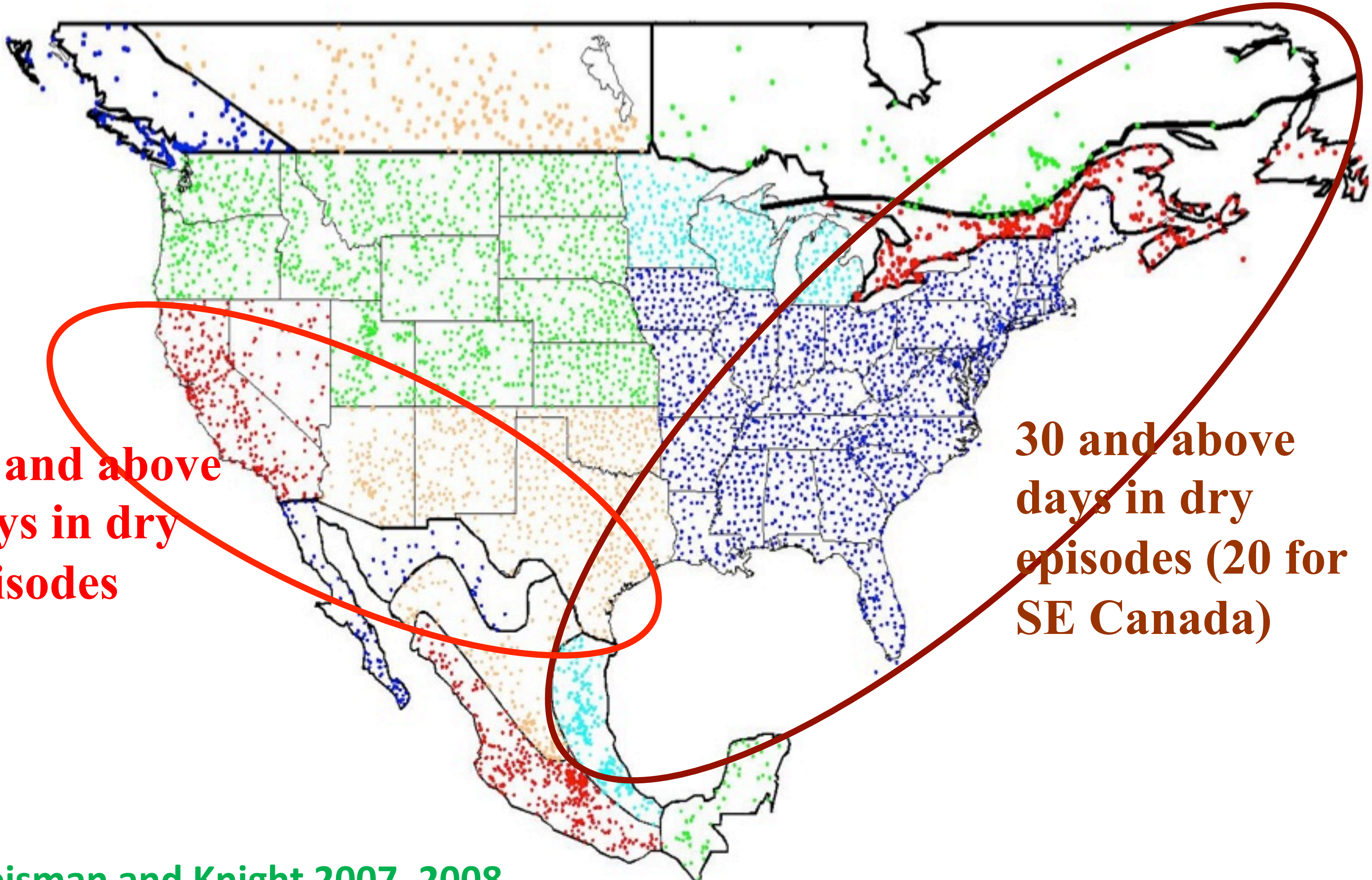
Annual



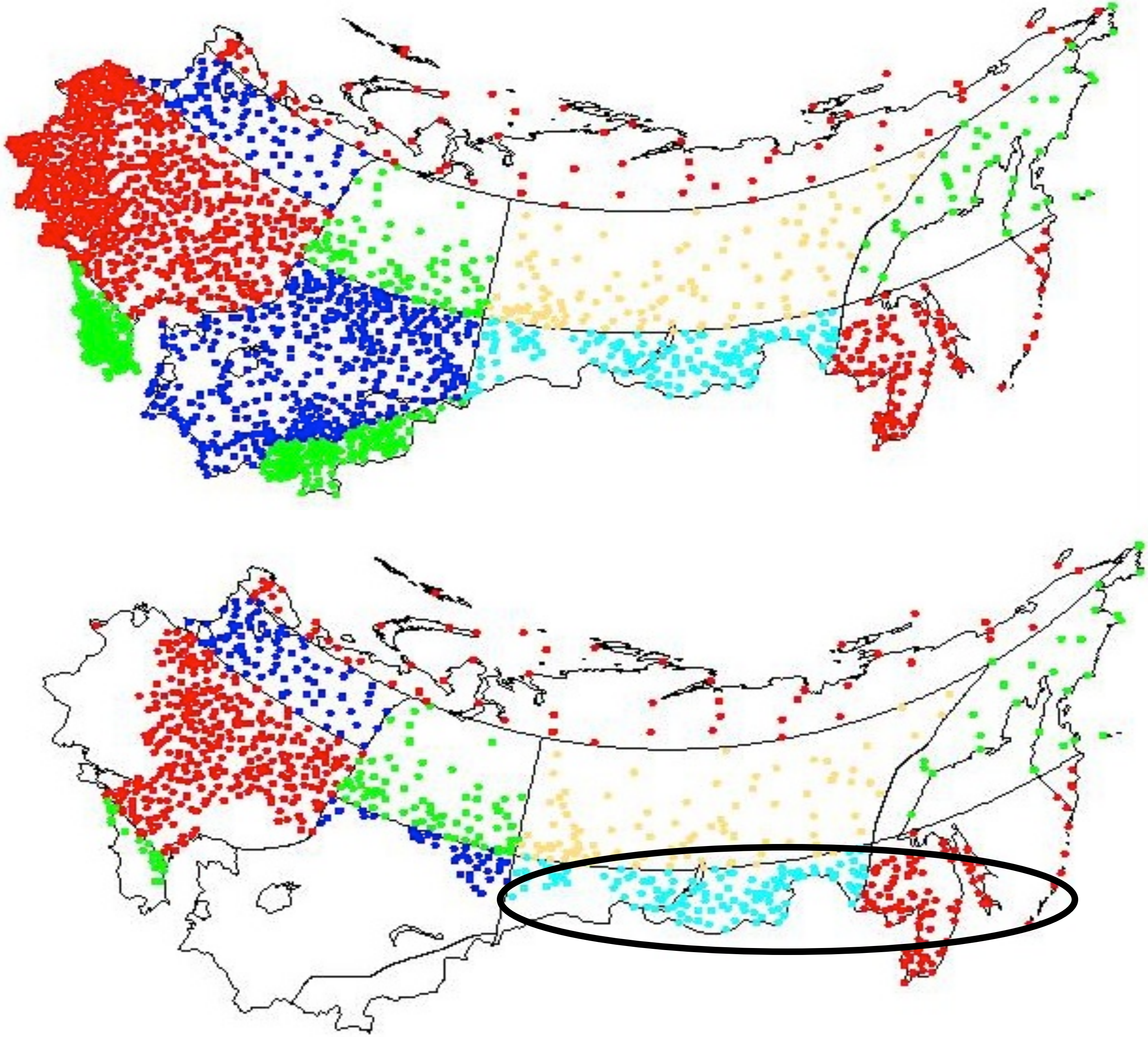
Percent increases in the amount falling in very heavy rain events defined as the heaviest 1 percent of all daily events from 1958 to 2010 for each region

Changes in the Eastern half of the nation are statistically significant at the 0.05 or higher levels and over the Great Plains, at the 0.1 level

Regions where dry episode frequency was increasing during the past 40 years in the warm season



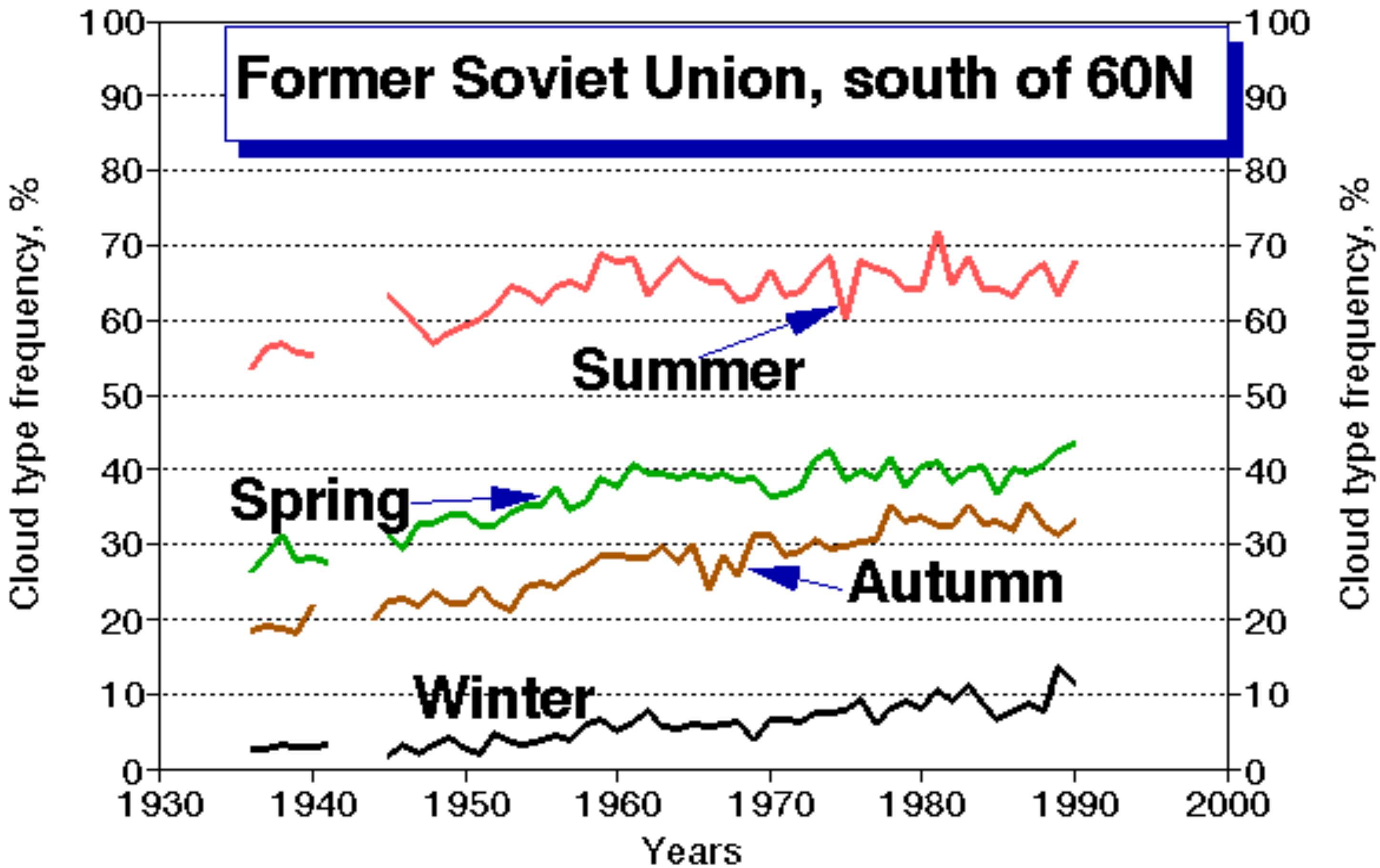
Groisman and Knight 2007, 2008



Station map and regional partition used

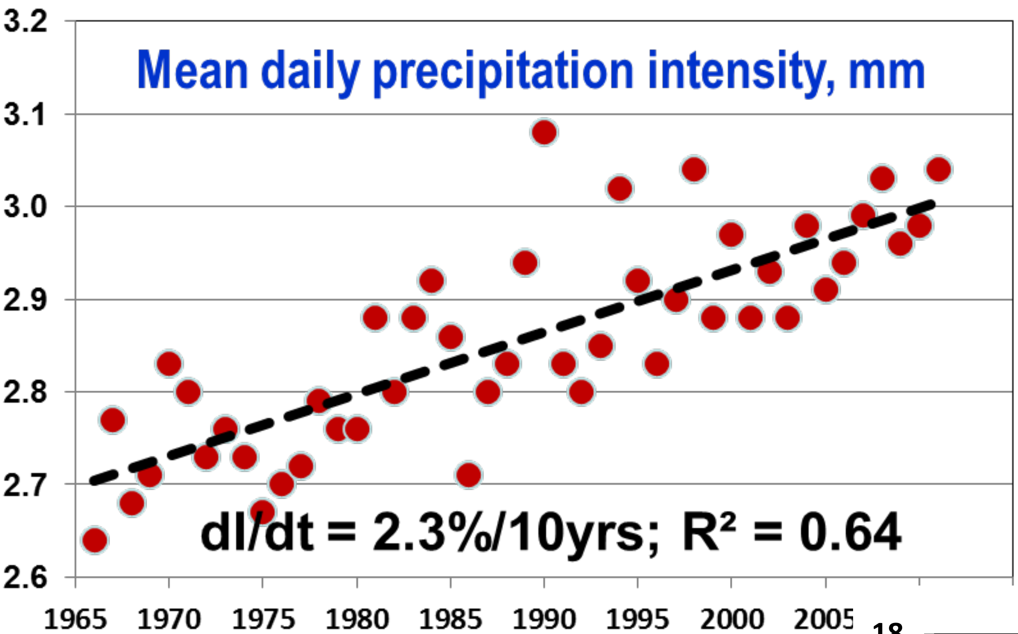
Precipitation Intensity

Seasonal frequency of occurrence of daytime *Cumulonimbus* and *Cumulus*



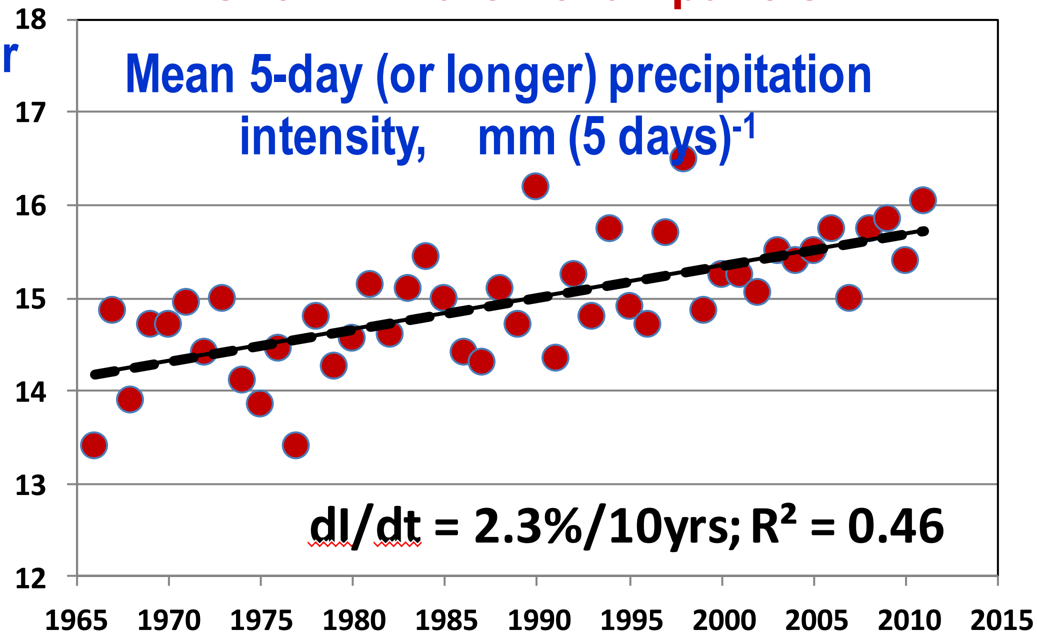
Sun et al (2001, *J. Climate*)

Nationwide precipitation intensity, I, changes over Russia



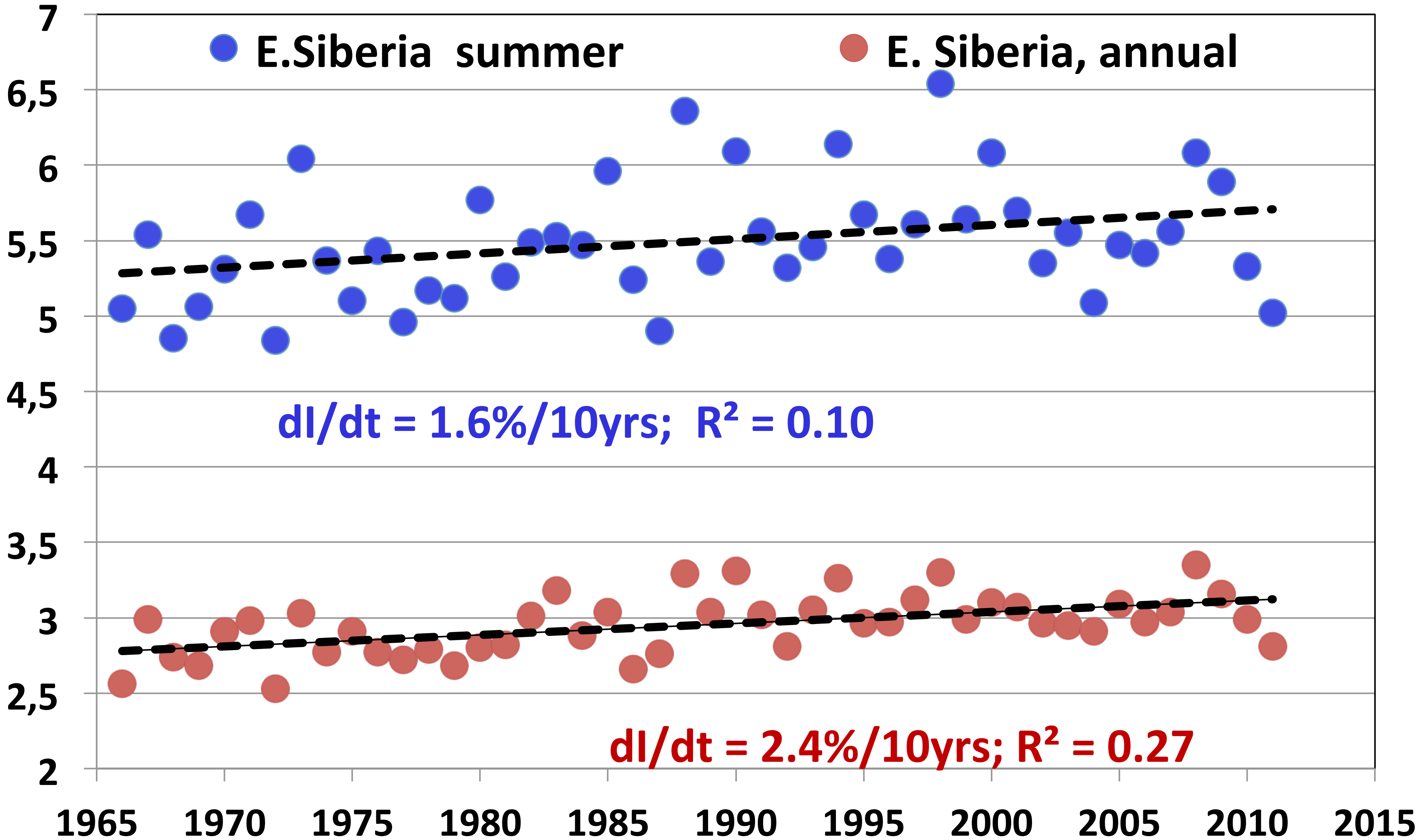
Russian climatological regions:

Pattern of precipitation intensity trends over these regions is shown in the next 2 panels.

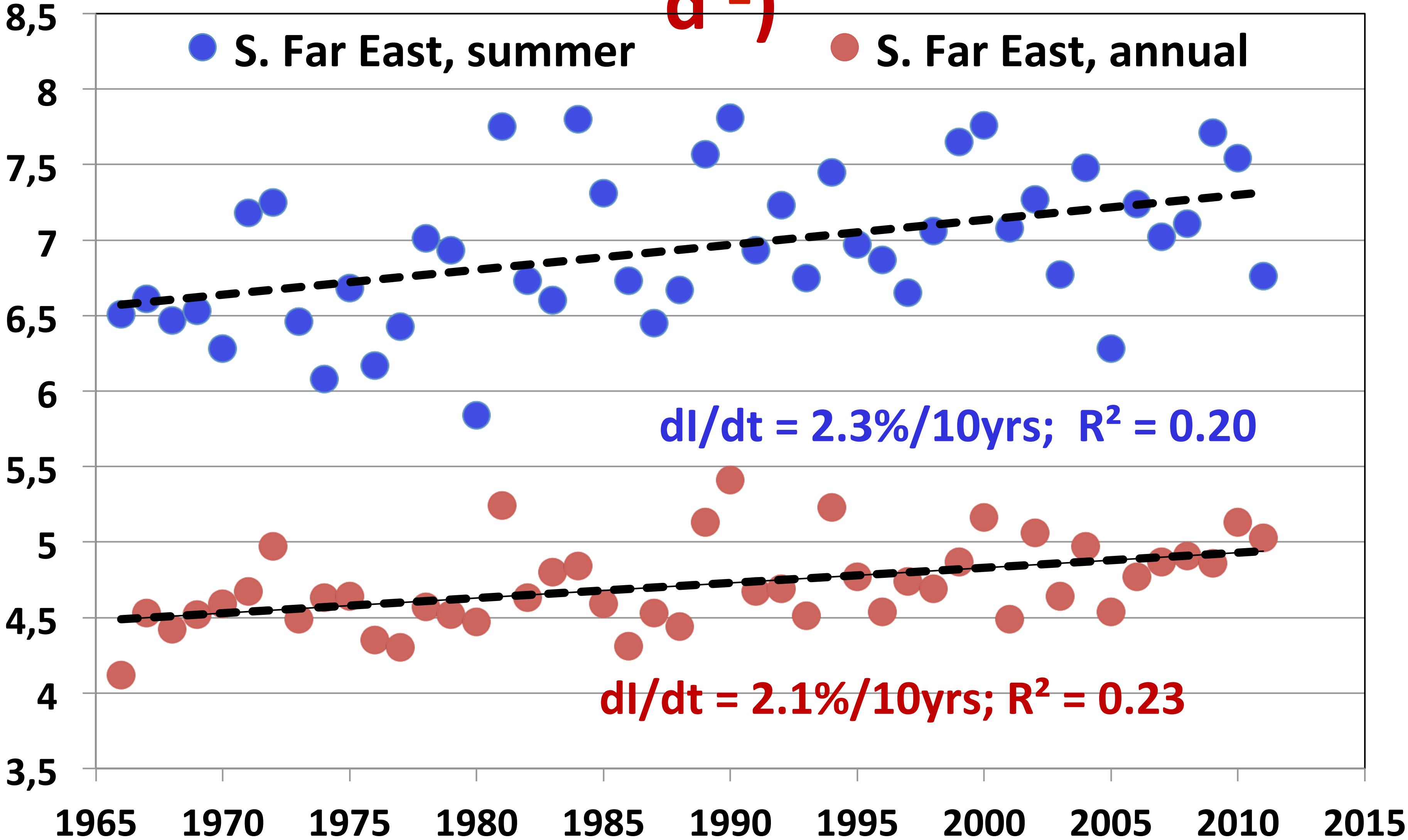


To receive the nationwide time series, for each year and each station mean annual precipitation intensity was calculated as (totals/number of events). Thereafter, point estimates were area-averaged arithmetically within climatological regions shown in the map and, finally, these regional mean values were averaged again with the weights proportional to the areas of the

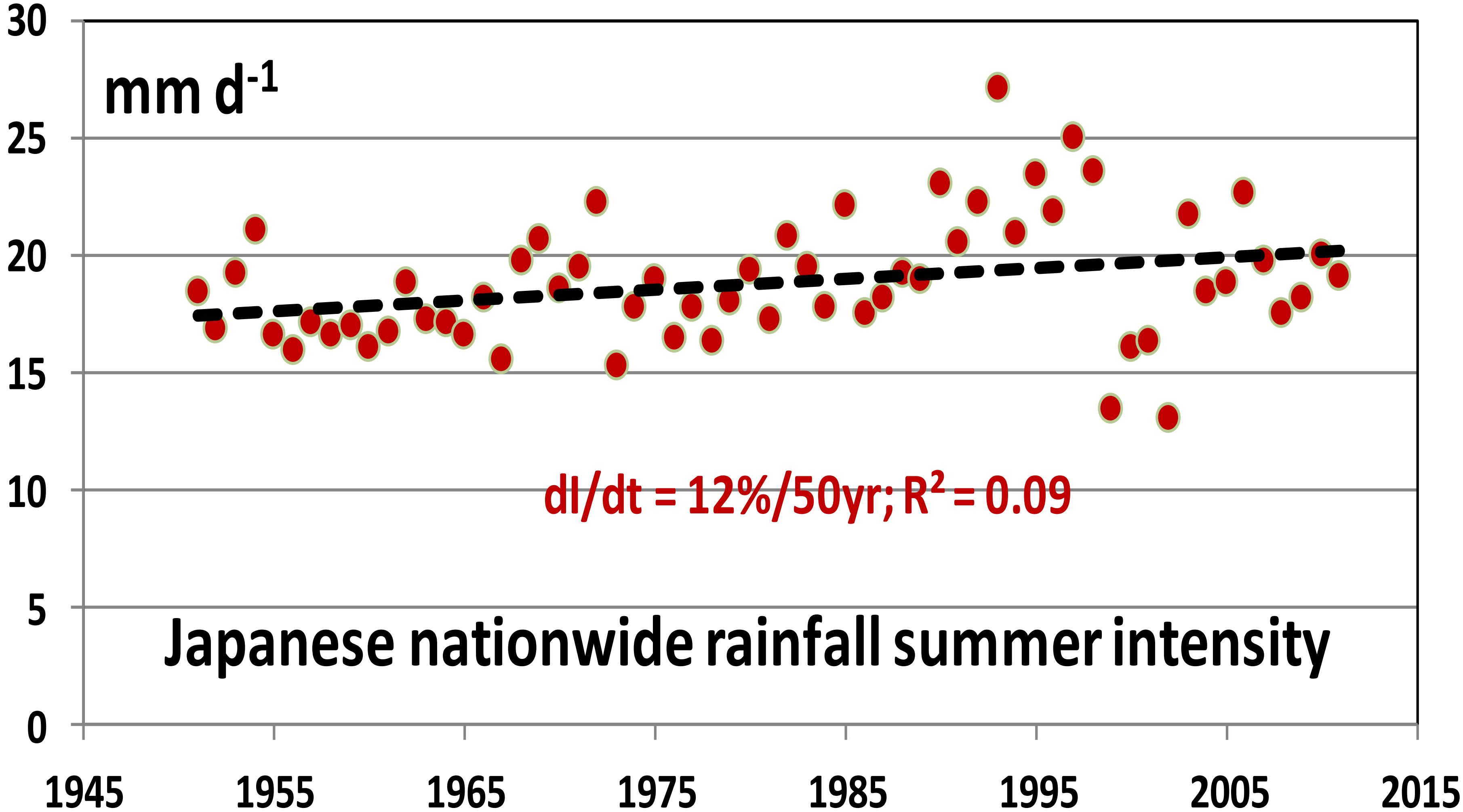
Mean annual and summer precipitation intensity over Eastern Siberia (mm d^{-1})



Mean annual and summer precipitation intensity over S. Russian Far East (mm d^{-1})

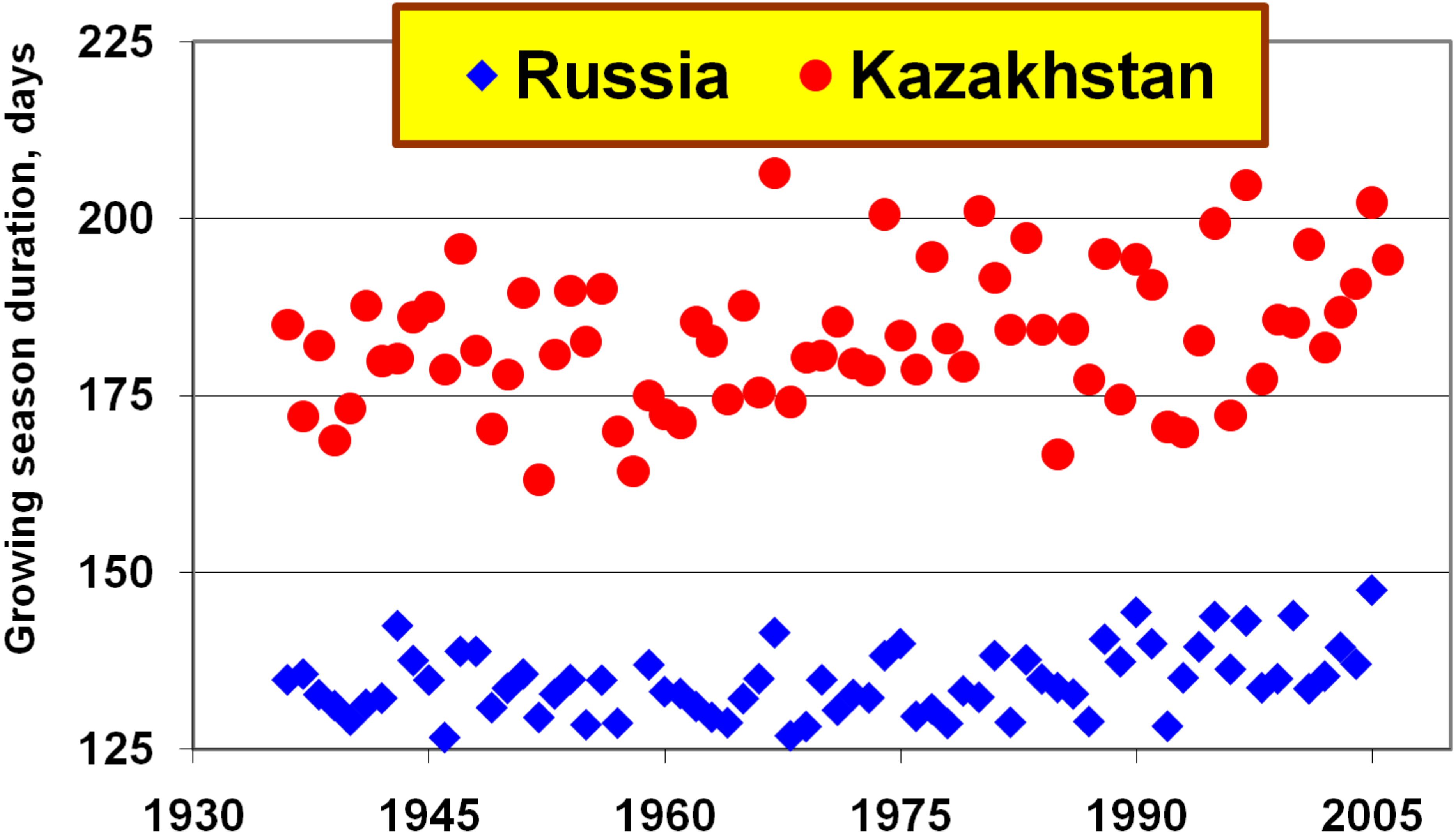


Mean summer (JJA) rainfall intensity, mm d^{-1} over Japan



Warm Season Dryness

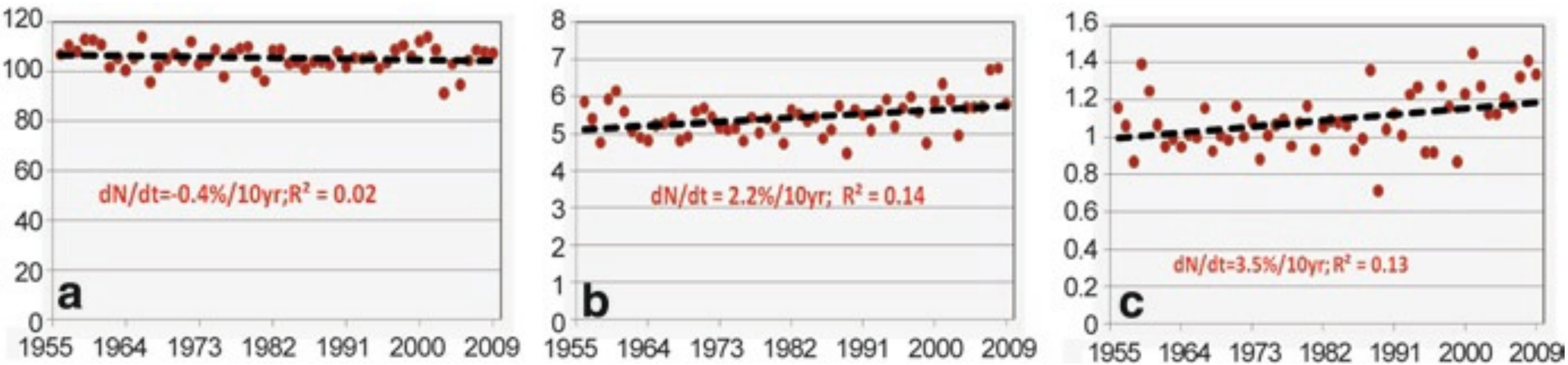
Duration of the growing season area-averaged over Russia and Kazakhstan



During the past 70 years, significant increase by 6 to 11 days (or by 5% to

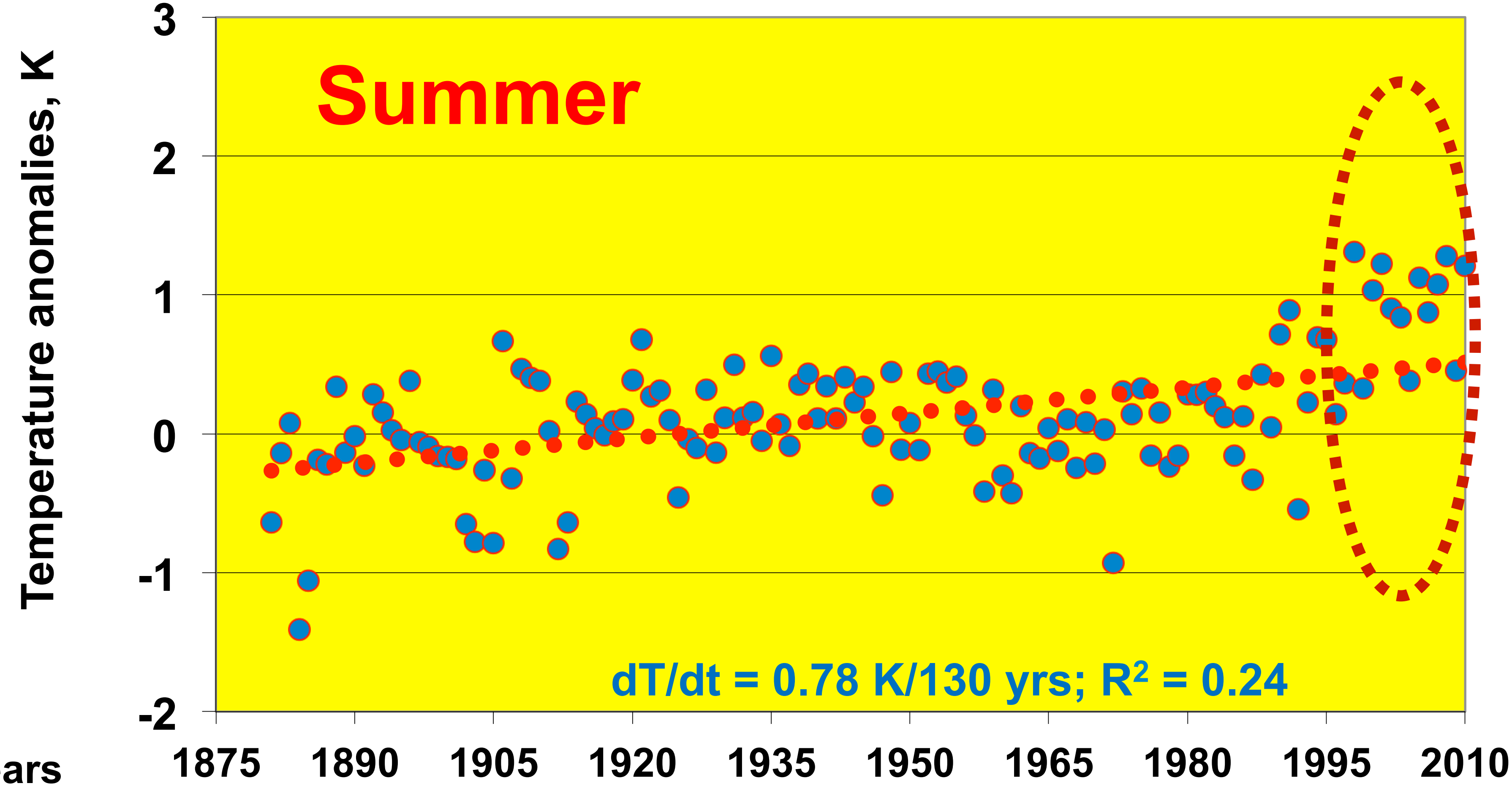
Annual number of days with precipitation over Siberia south of the Arctic Circle

(a) above 0.5 mm **(b) in the upper 5 %** **& (c) 1 % of daily rain events**



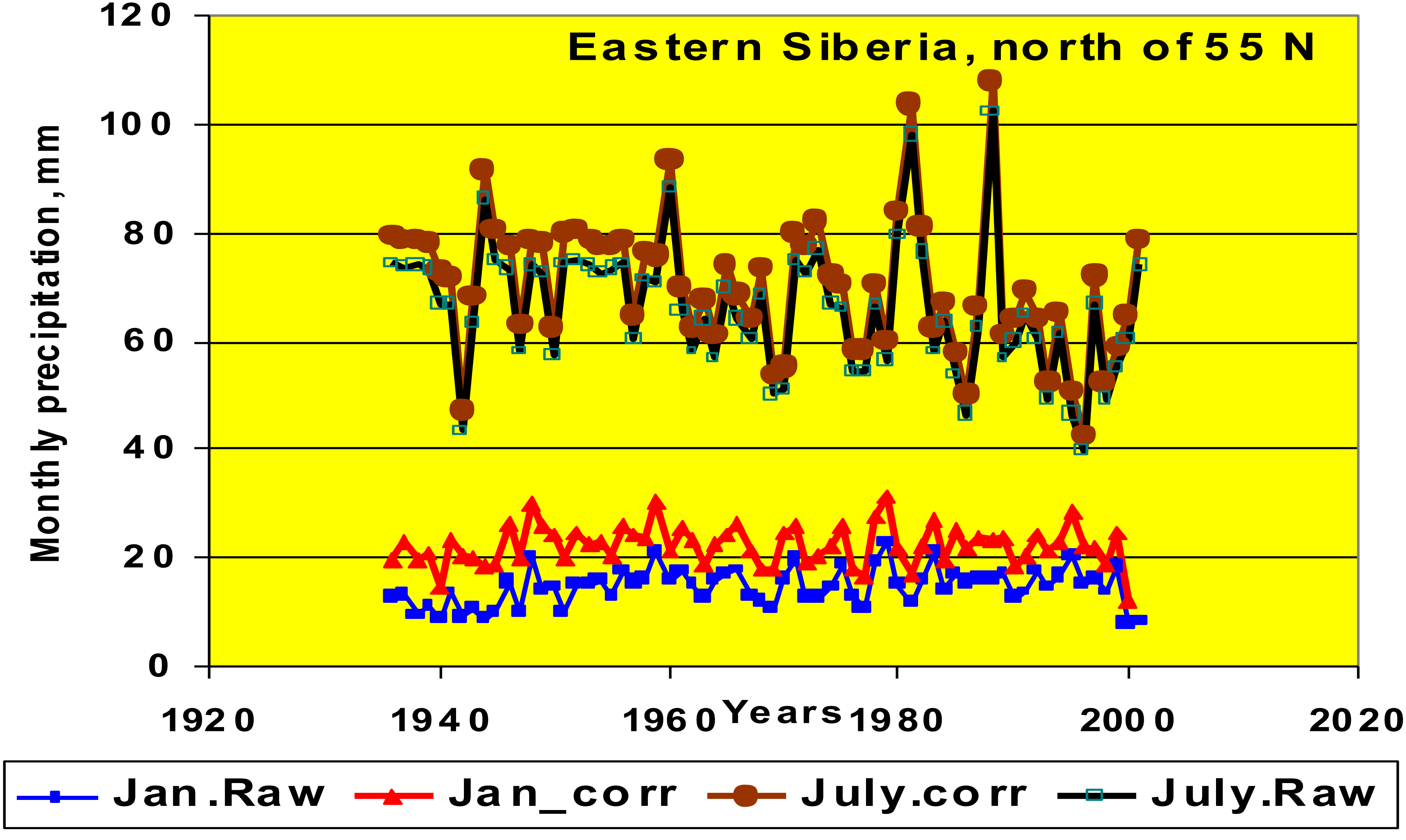
Northern Asia, north of 40°N

Summer temperature anomalies for the past 130 years; 1951-1975 reference period



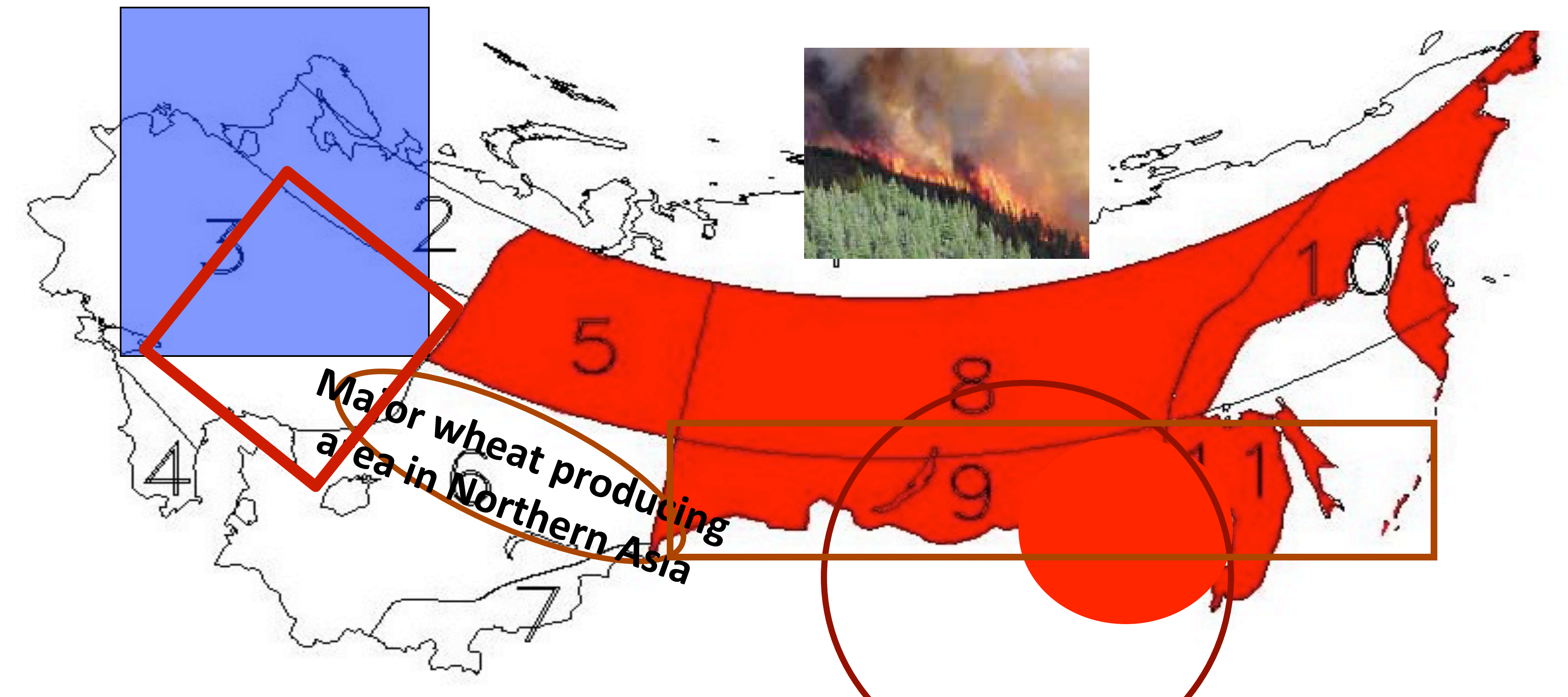
Archive of Lugina et al. 2007, updated

Eastern Siberia. January and July precipitation (prior and after bias correction)



Changes in the surface water cycle over Northern Eurasia that have been statistically significant in the 20th century

More humid conditions (blue),
more dry conditions (red),
more agricultural droughts (circled),
more prolonged dry episodes (rectangled).



Groisman et al 2009 (Bull. Amer. Meteorol. Soc.)

Wild fires and “fire” weather

Three Indices were used to assess the potential forest fire danger

- **Keetch-Byram Drought Index (KBDI)** **(This index uses daily data on maximum temperature and precipitation).**

Index is developed and used in the United States

- **Modified Nesterov and Zhdanko Indices** **(These indices use synoptic daytime data on temperature and humidity and daily precipitation and snow on the ground)**

Indices are developed and used in Russia

Daily KBDI computation

- Begin calculations at the point when soil is close to saturation (e.g., after snowmelt) and KBDI ≈ 0. Then

1. Increase KBDI by **an amount of evapotranspiration, E** (function of the current **KBDI** and **Tmax** values and a mean annual **P**);
2. Reduce it **by the amount of "net" rain**, if any.

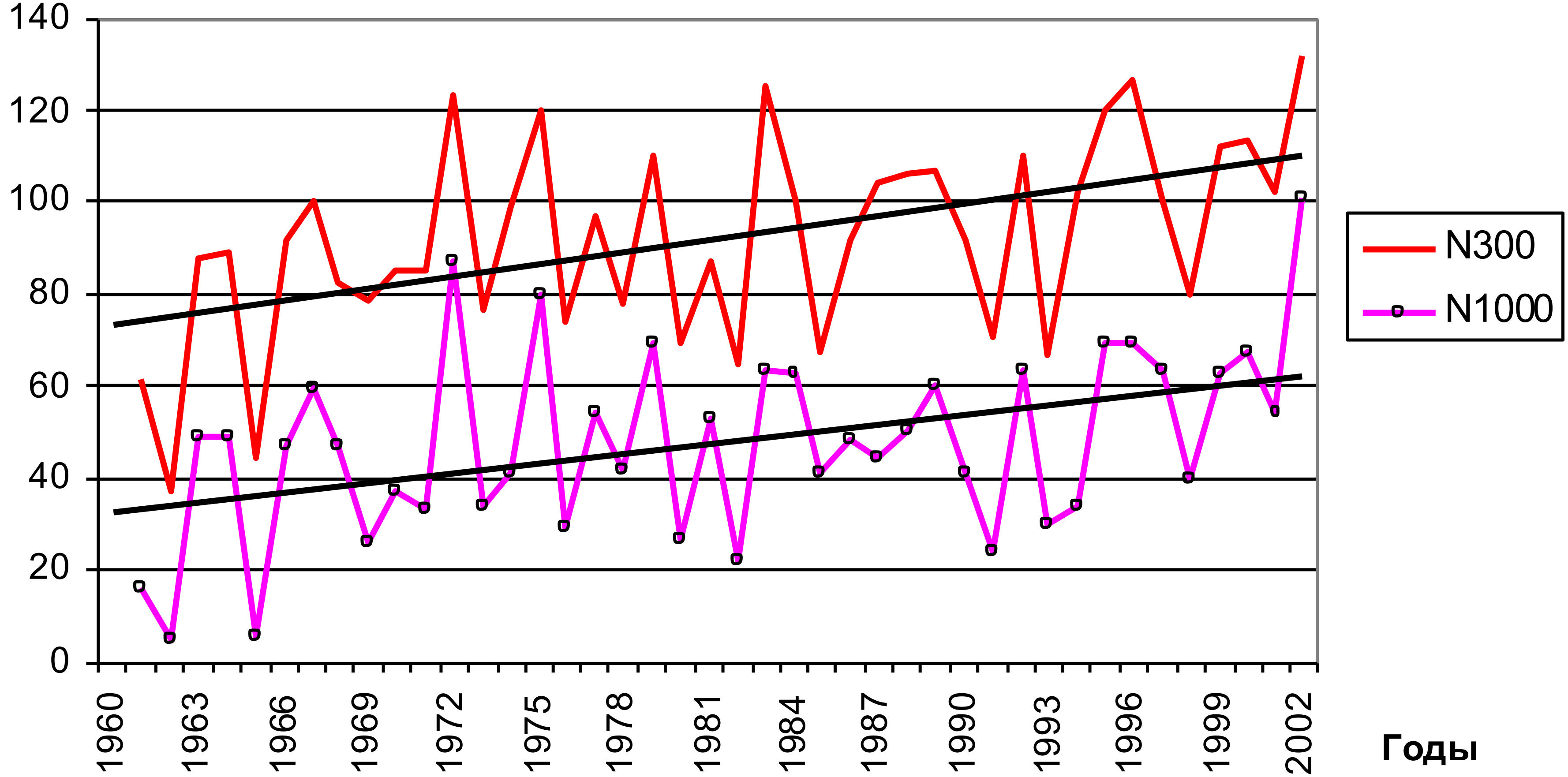
The only regional adjustment in the KBDI computation depends on a long-term annual precipitation, P, that is assumed to be ~ total regional vegetation density (that adjusts itself to **P**) and thus controls **E**.

Surface radiation balance is not used for this control => KBDI should be regionalized.

Nesterov Index (1940)

- $G = \Sigma\ (T^*\ H_{def})$,
  - where T afternoon surface air temperature,
  - H_{def} - humidity deficit ($T - T_d$ with T_d being a dew point at the same observation time)
- Summation occurs for period without rain and T>0 and starts after snowmelt;
- At the day with P > 3 mm, G is set to 0.

Number of days with medium and above (G > 300) and high (G >1000) potential forest fire danger for the Moscow region (Sherstyukov 2002).



Modified Nesterov and Zhdanko Indices

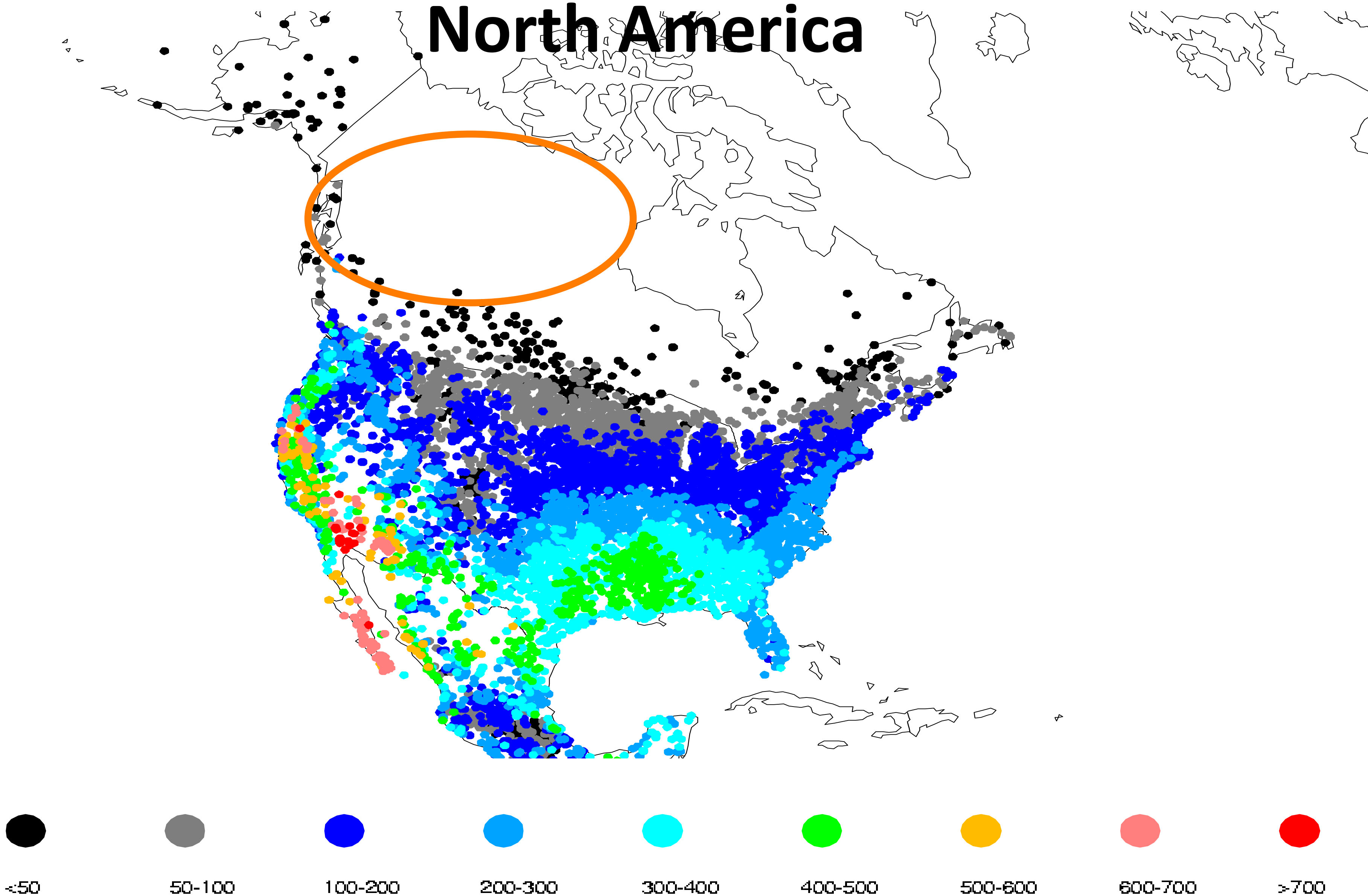
- **These indices use synoptic daytime data on temperature and humidity and daily precipitation**.
- **Nesterov (1940)** assumed that the forest conduciveness to the fire is proportional to the accumulated **daytime** (~1PM local) **product of** [**water vapor (or dew point) deficit**] and [**temperatures above 0°C after snowmelt**]: $\mathbf{G = \Sigma(T \times H_{def})}$,
- Rainfall reduces the index proportionally and the rainfall above 20 mm zeroes it down. Original index used a 3 mm threshold that is now considered an exaggeration.
- Similar index suggested by **Zhdanko (1965)** is the summation of [$T-T_{dew}$] without the multiplication by T with the same rainfall effects. Variations of both indices are well correlated.

Modified Nesterov Index (MNI)

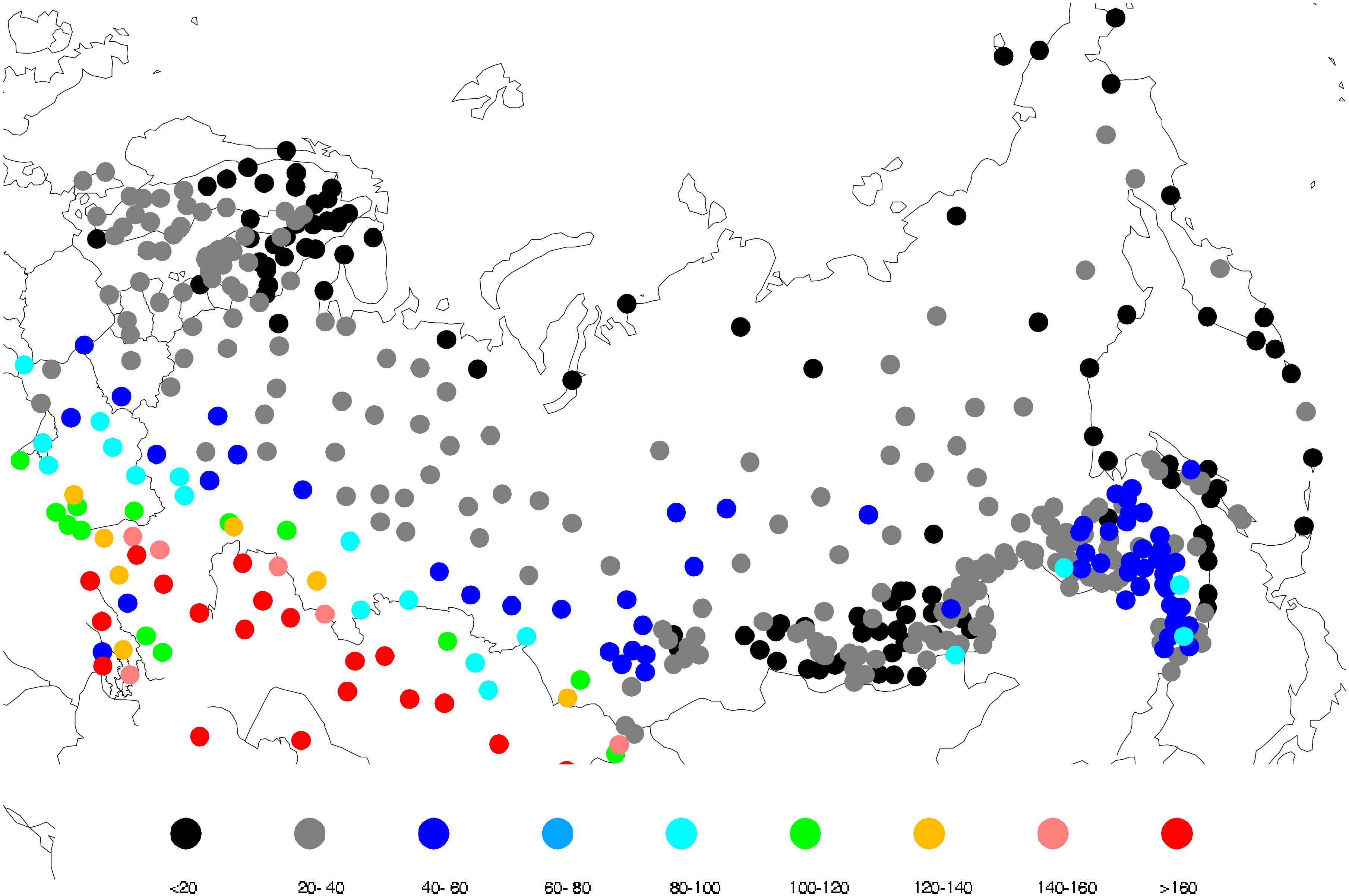
- $G = \sum (T^* H_{def}) \times K$ (rainfall, R)

R, mm	0	0.1 - 0.9	1.0 - 2.9	3.0-5.9
K	1.0	0.8	0.6	0.4
R, mm	6.0 - 14.9		15 - 19	> 20
K	0.2		0.1	0

Climatology of July KBDI values for North America



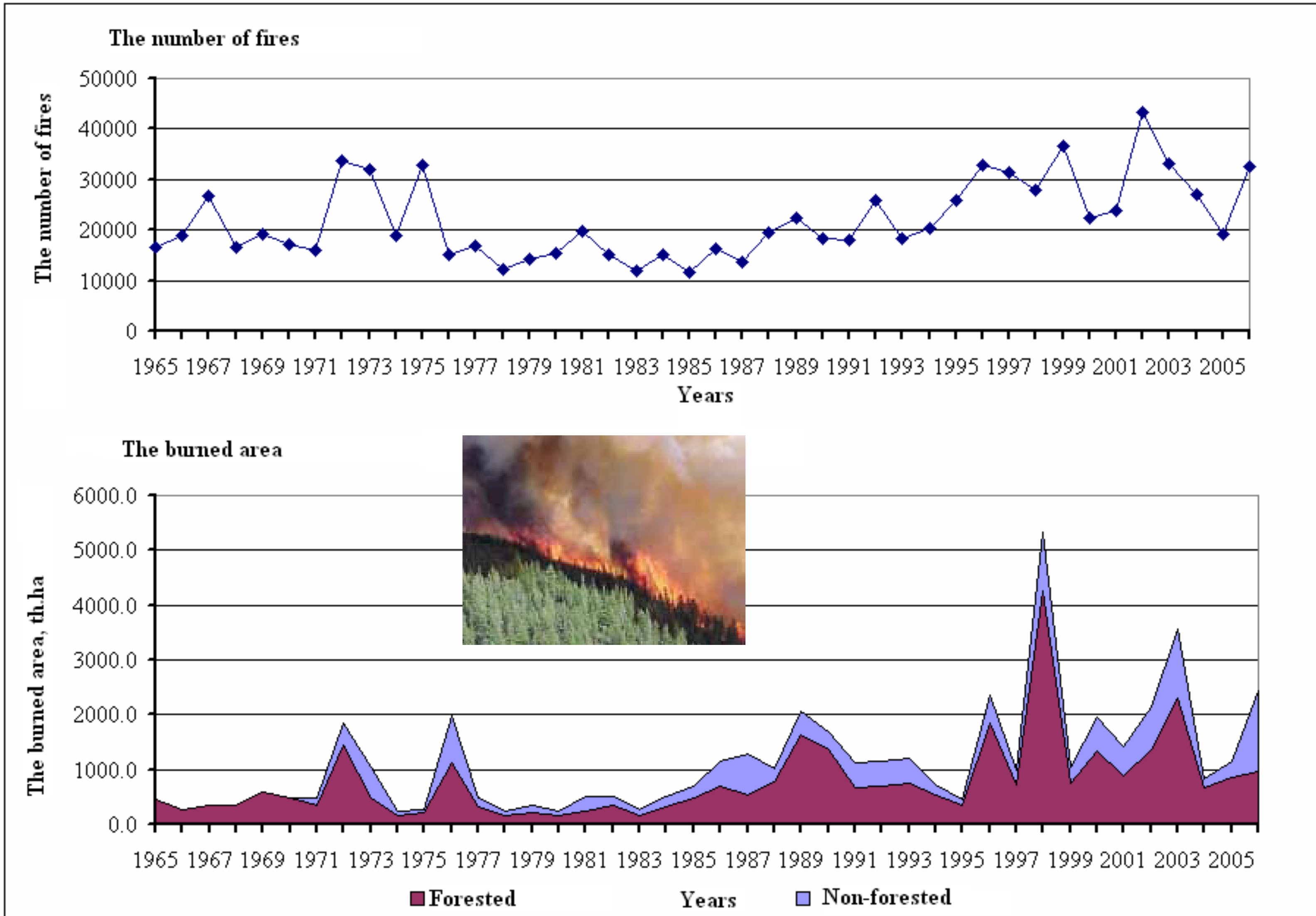
Climatology of July KBDI values for Northern Eurasia



Fires occur in the North and in the South =>

- All these indices were regionalized (normalized) by using the upper frequency part of this scale to select the days with abnormally dry conditions, i.e., the days conducive to forest fire.
- Specifically, for each index at each point and month, we estimated its distribution, defined upper percentiles of this distribution (e.g., upper 10^{th} percentile), and then calculated the number of days above these percentiles.
- After normalization, all potential forest fire indices correlate reasonably well with actual statistics of forest fires…

DYNAMICS OF FIRES NUMBERS AND BURNED AREA (PROTECTED TERRITORY OF RUSSIA)

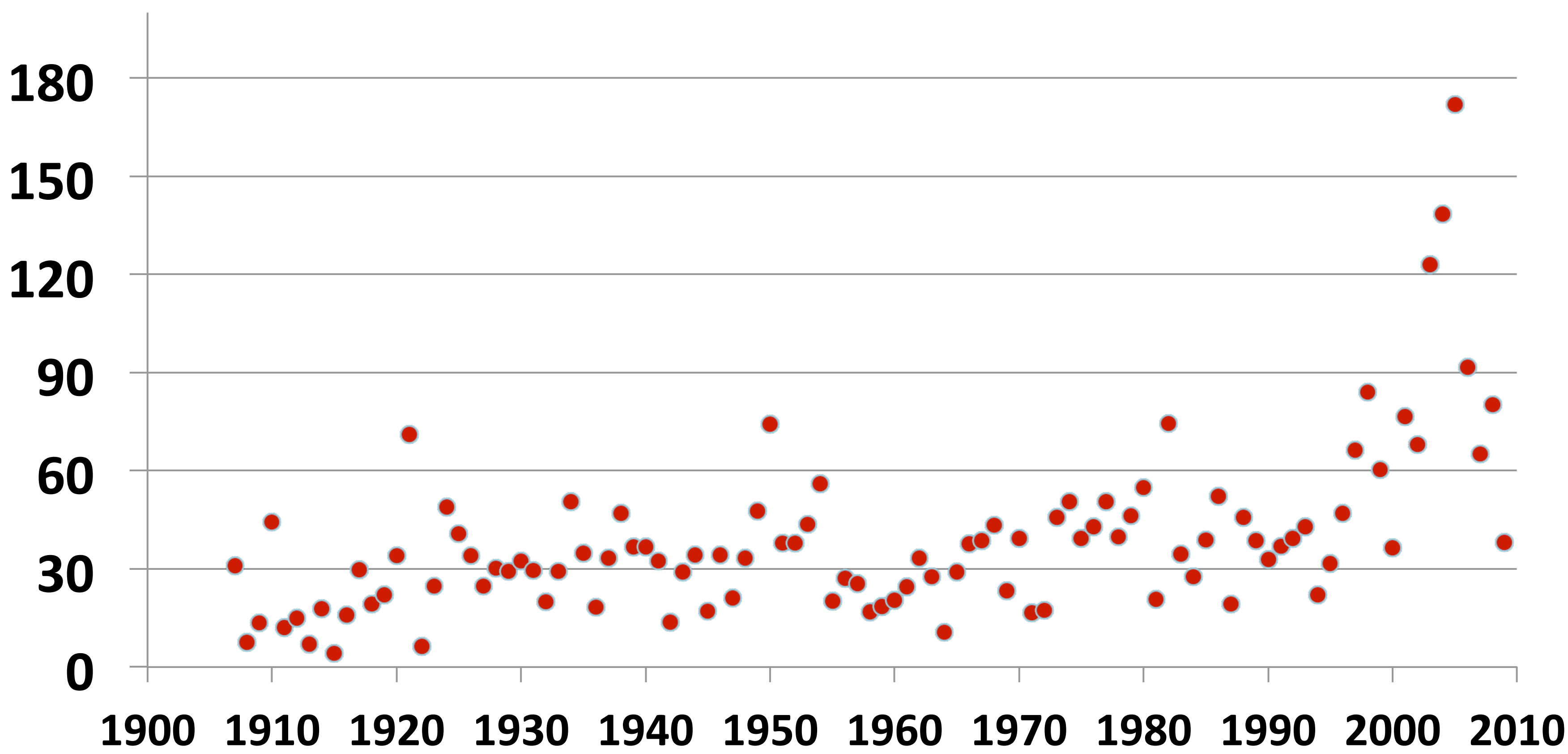


Korovin and Zukkert 2003, updated

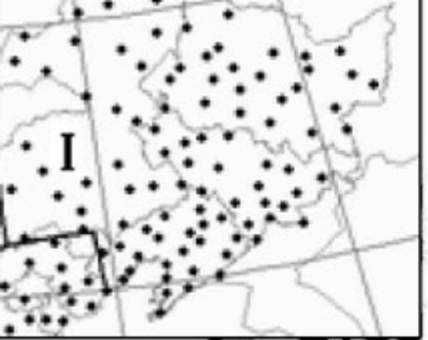
Potential Fire Danger Increase

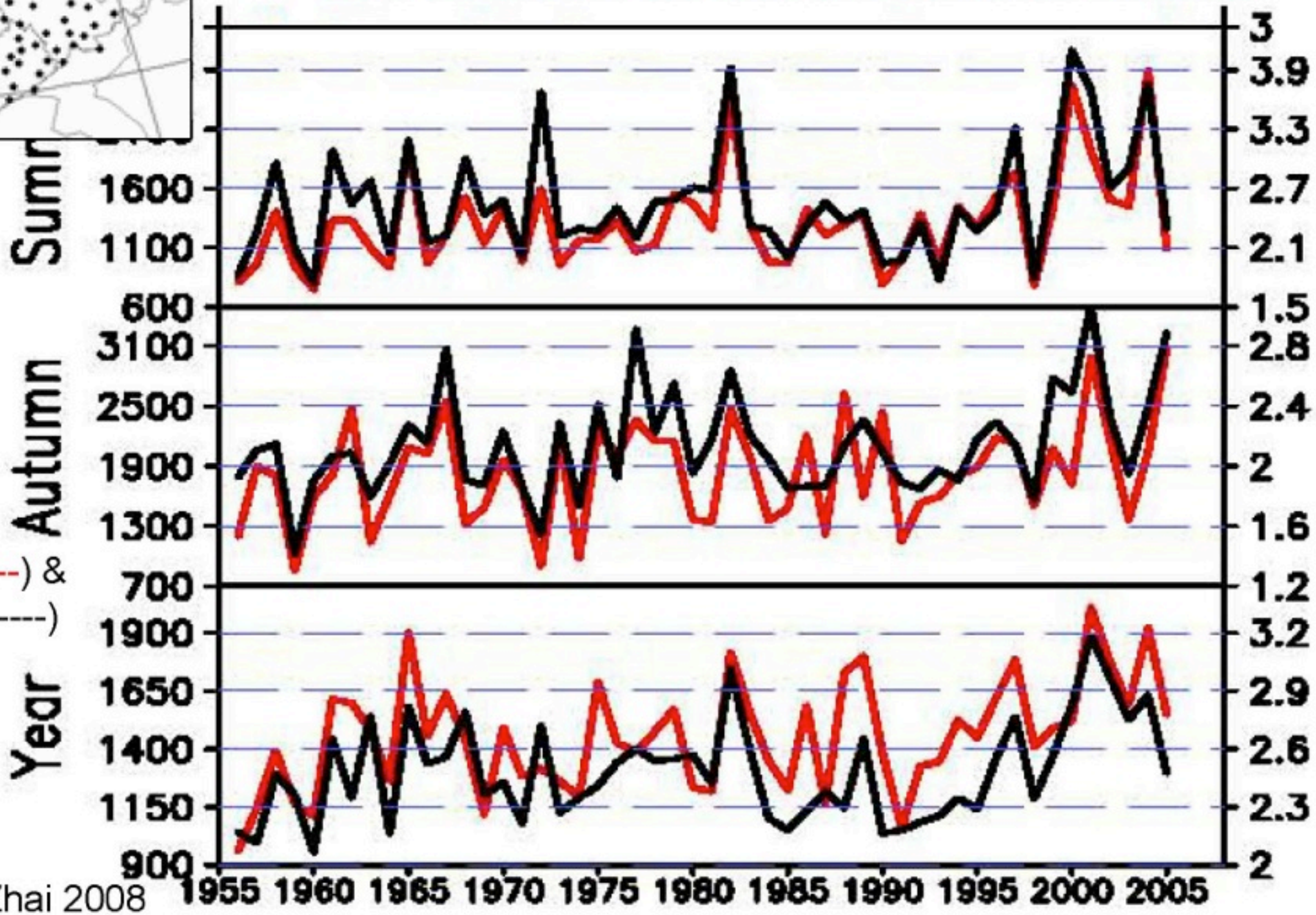
Annual number of days with KBDI > upper 10%-ile

Russian Far East south of 55°N



Seasonal and annual changes in forest fire indices in northeastern China



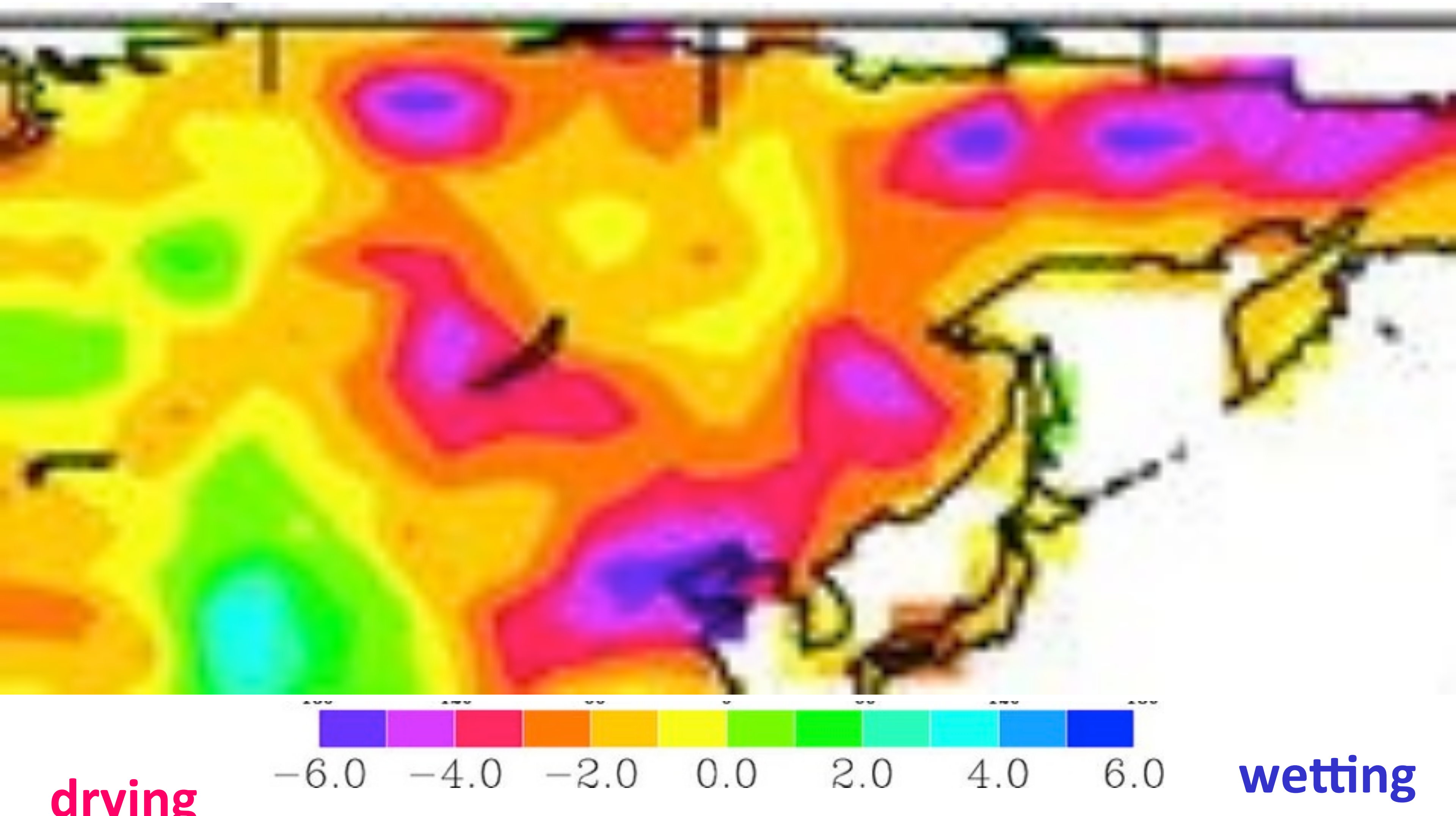


MNI (----) &
FFDI (-----)

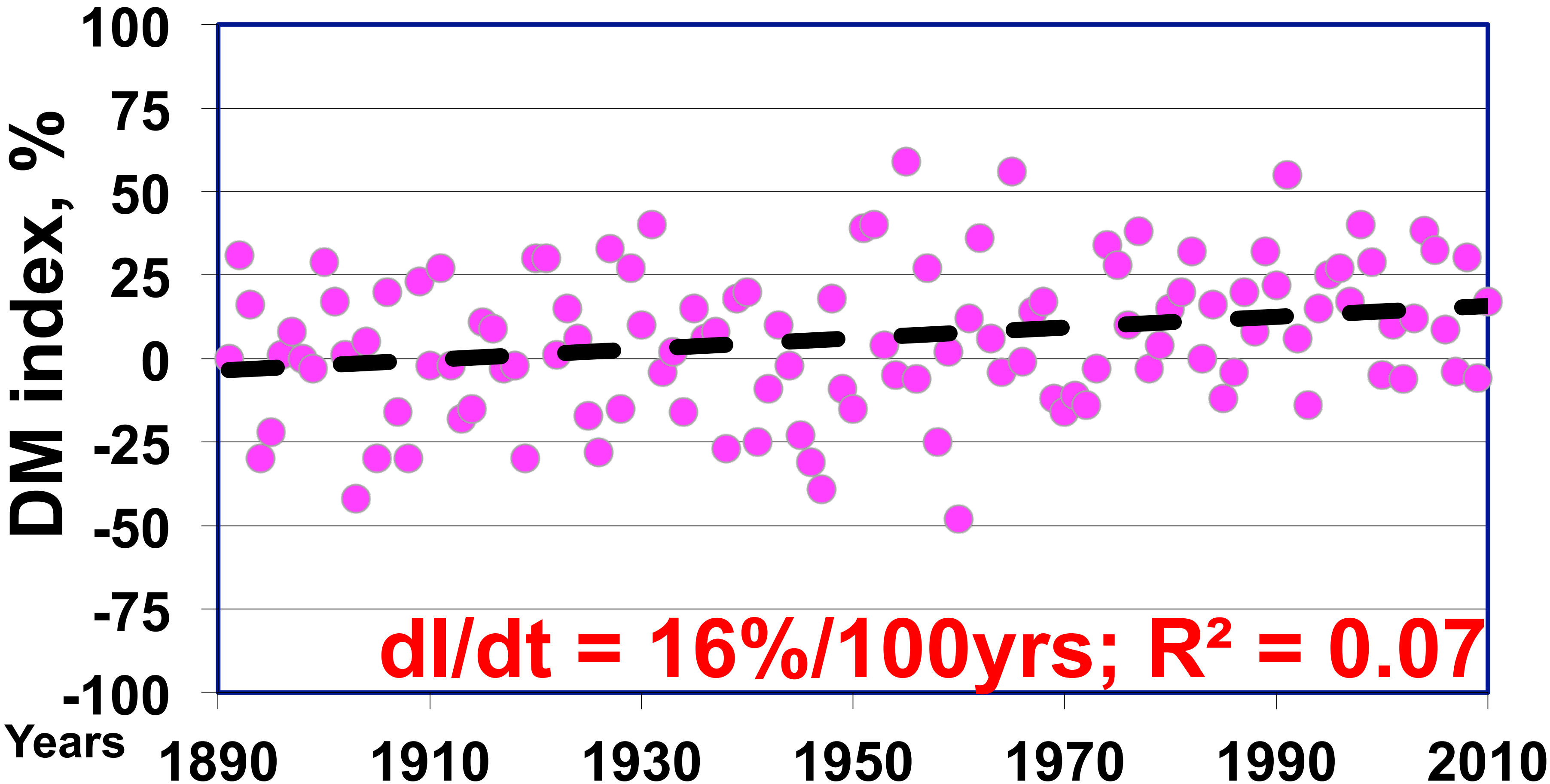
Niu & Zhai 2008

Droughts

Linear trends of PDSI change $(50\ \text{yrs})^{-1}$ based on monthly data [Dai et al. 2004]

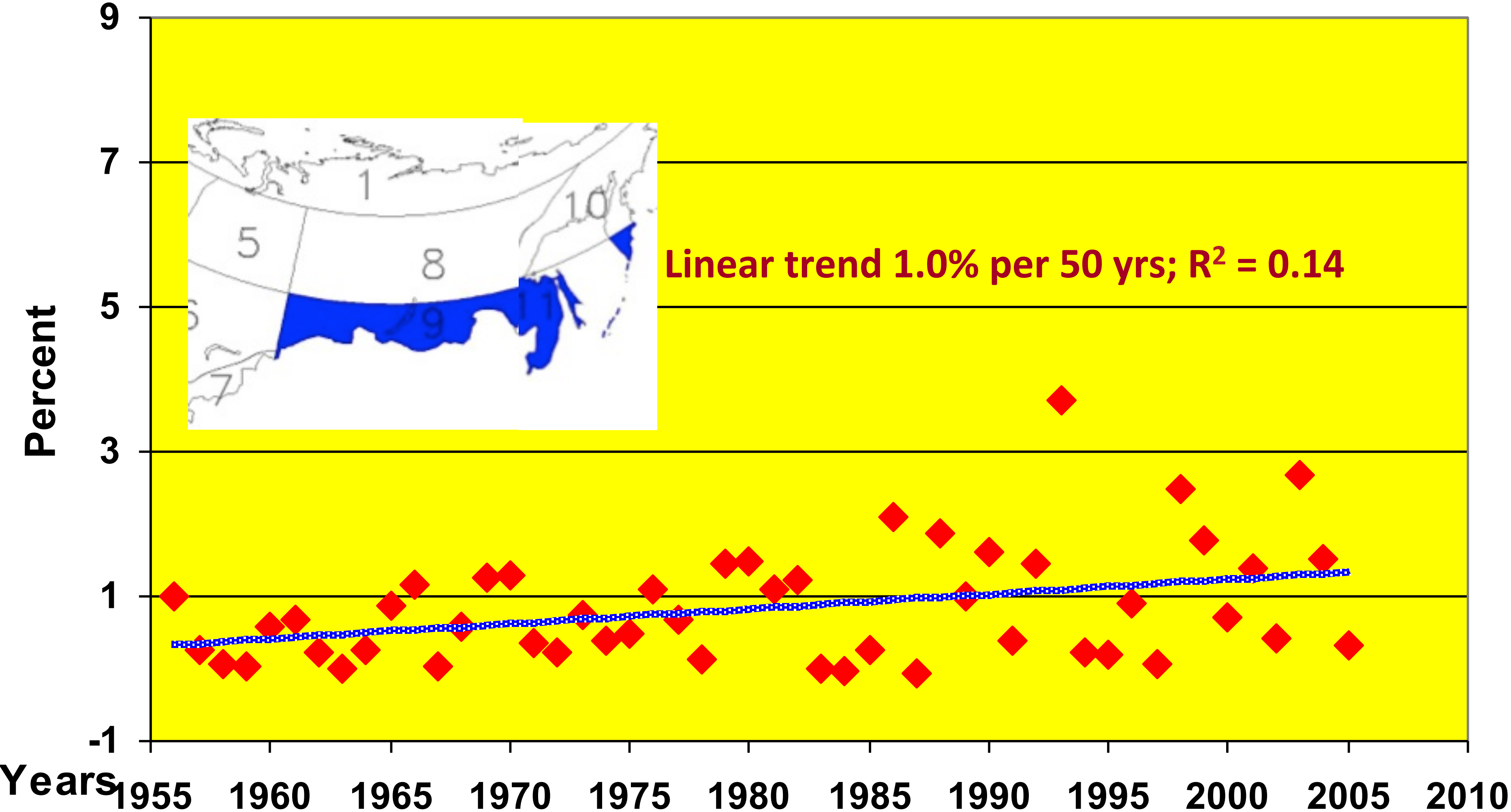


Agricultural regions of West Siberia and Northern Kazakhstan. May – July Drought Index. Meshcherskaya and Blazhevich, 1997, updated to 2010

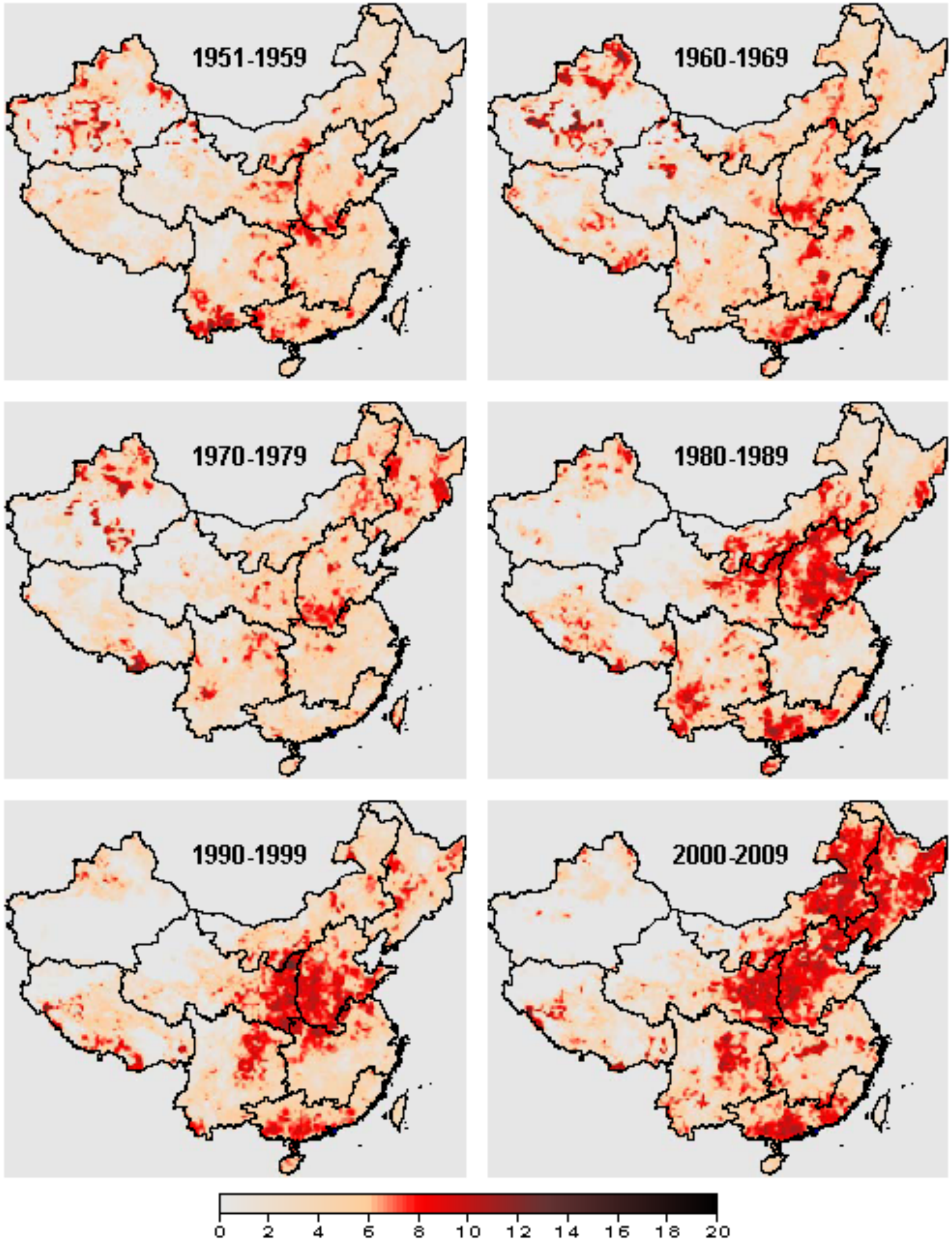


Areas with excessively dry conditions minus areas with excessively wet conditions, (% of total area)

Dry episodes above 30 days during the warm season



Russia east of 85°E, south of 55°N



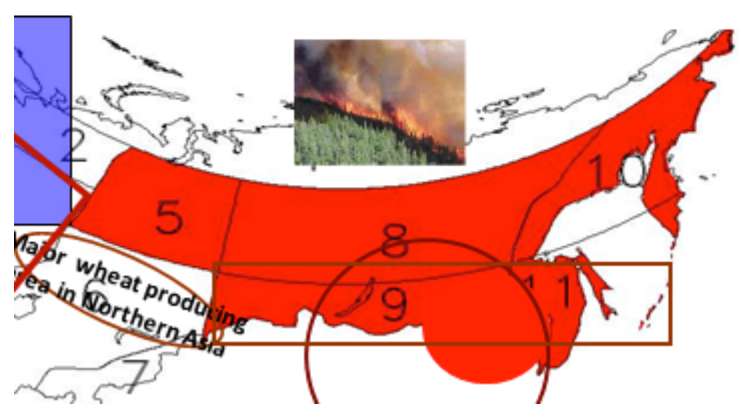
Pattern of drought occurrence over China for the past six decades

Wu et al. 2011

Summary for Northern Asia:

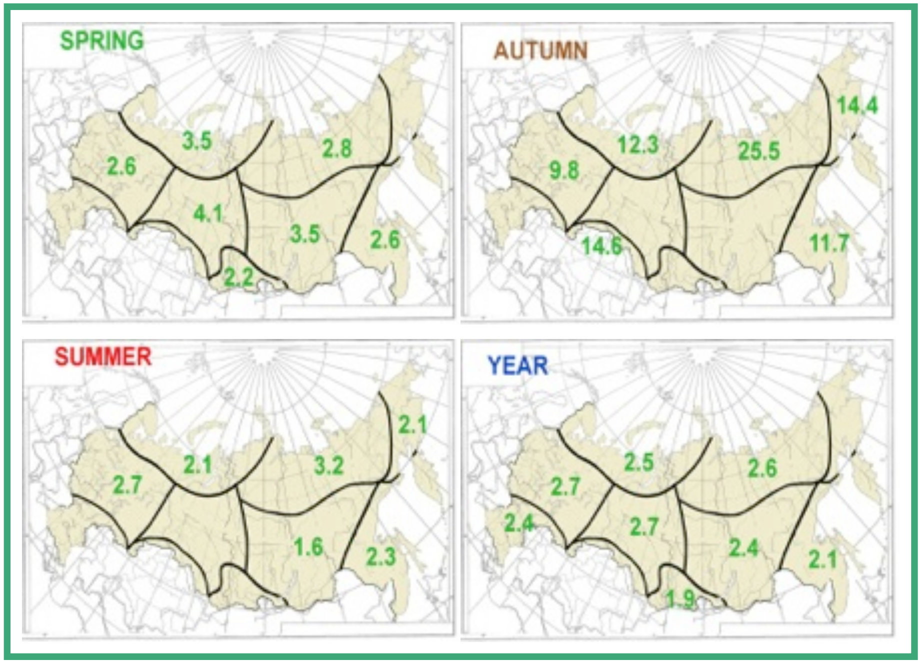
- Warming is stronger than over the globe
- Earlier snowmelt and spring onset
- The “bead rule” is governing in the regional hydrological cycle:

  - More intense rainfall
  - More summer droughts
  - Higher fire danger

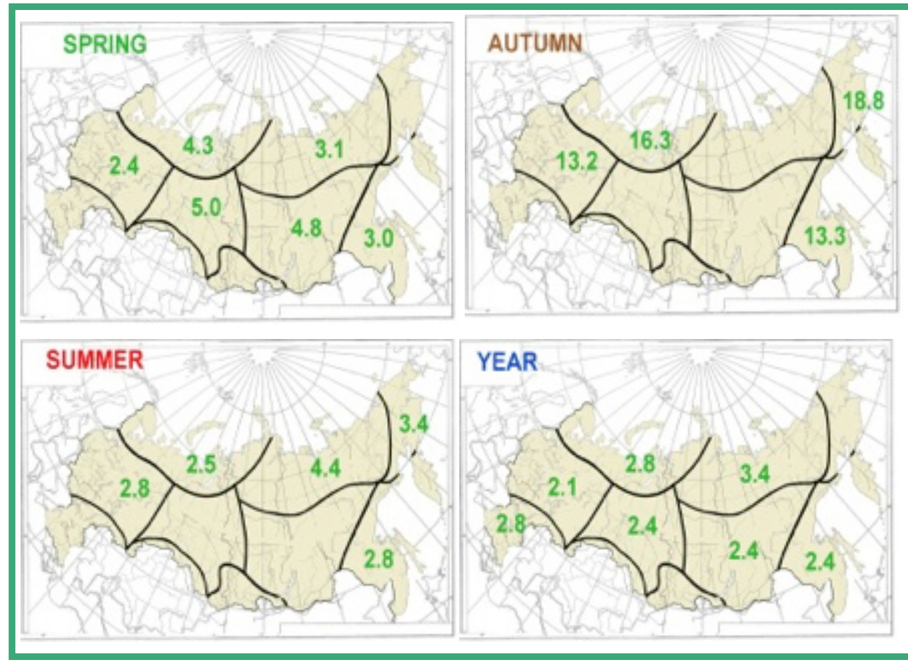


Linear trends (%/10yr) in the mean daily precipitation intensity pattern over Russia during the 1966-2010 period

Changes in intensity during all precipitation days

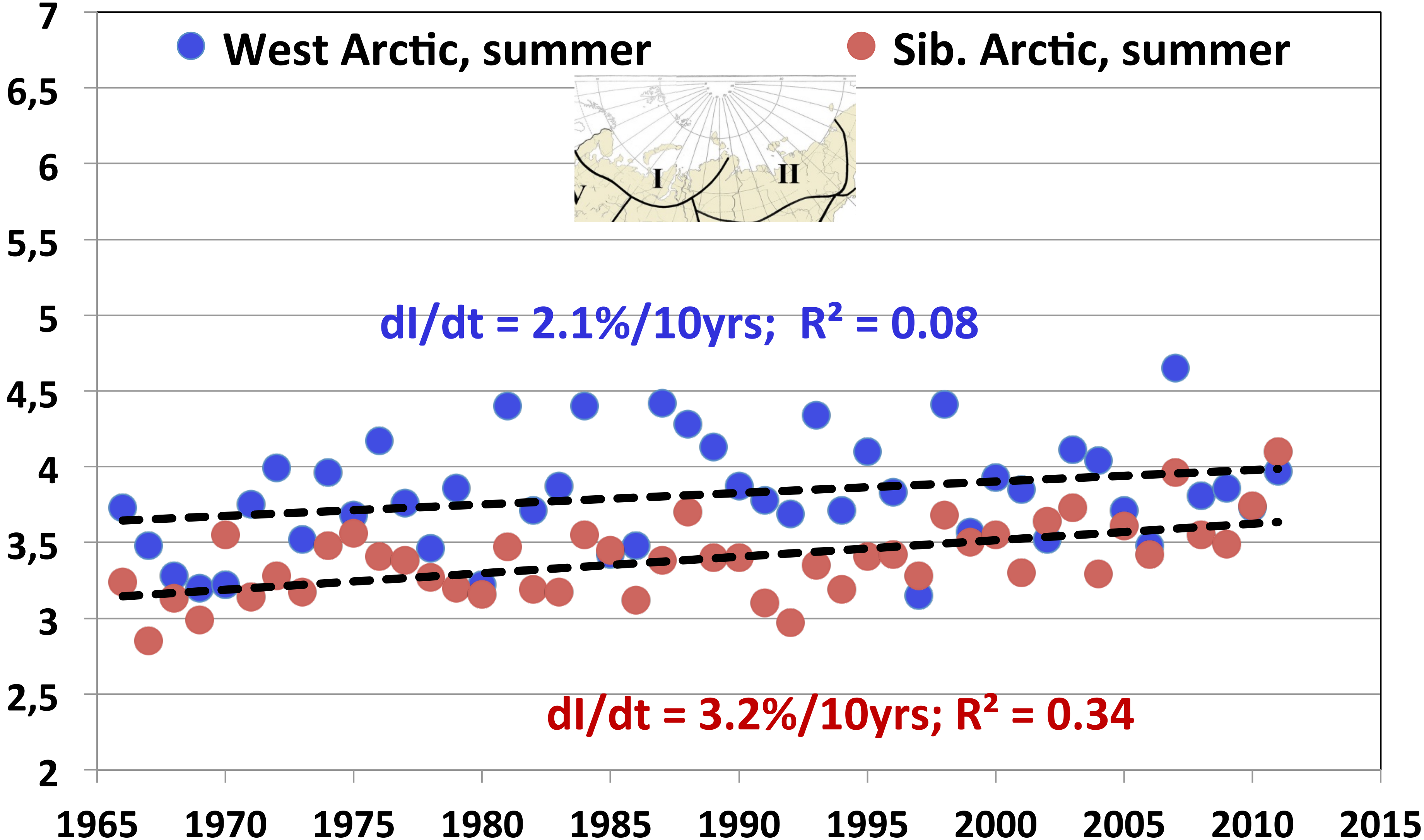


Changes in intensity during prolonged (≥ 5 days) events

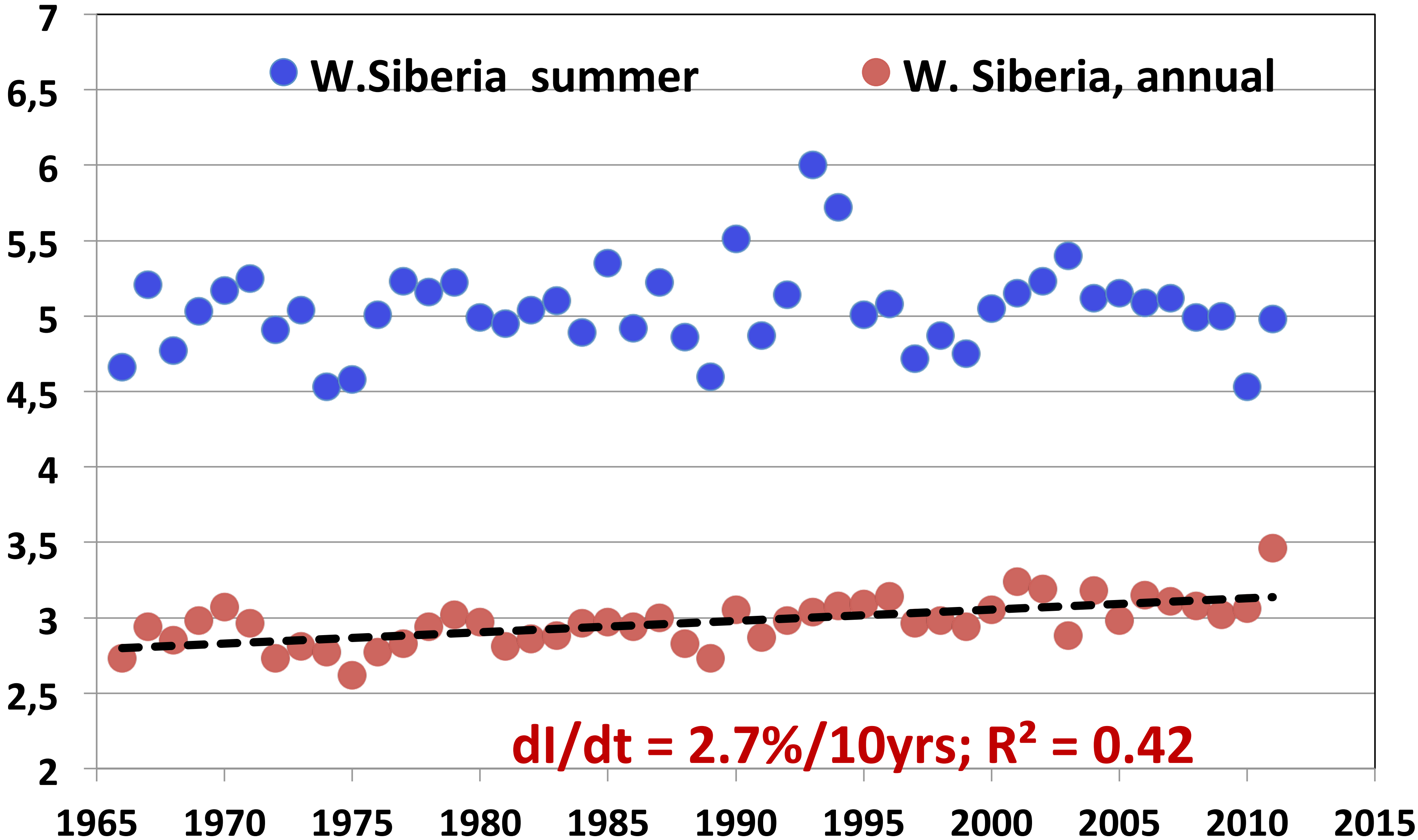


Linear trend estimates are shown only if they are statistically significant at the 0.05 or higher levels

Mean summer precipitation intensity over Russian Arctic (mm d^{-1})



Mean annual and summer precipitation intensity, I, over West Siberia (mm d^{-1})



Mean annual and summer precipitation intensity over Northern Far East (mm d^{-1})