C.1.2. Recent Trends in Regional and Global Intense Precipitation Patterns

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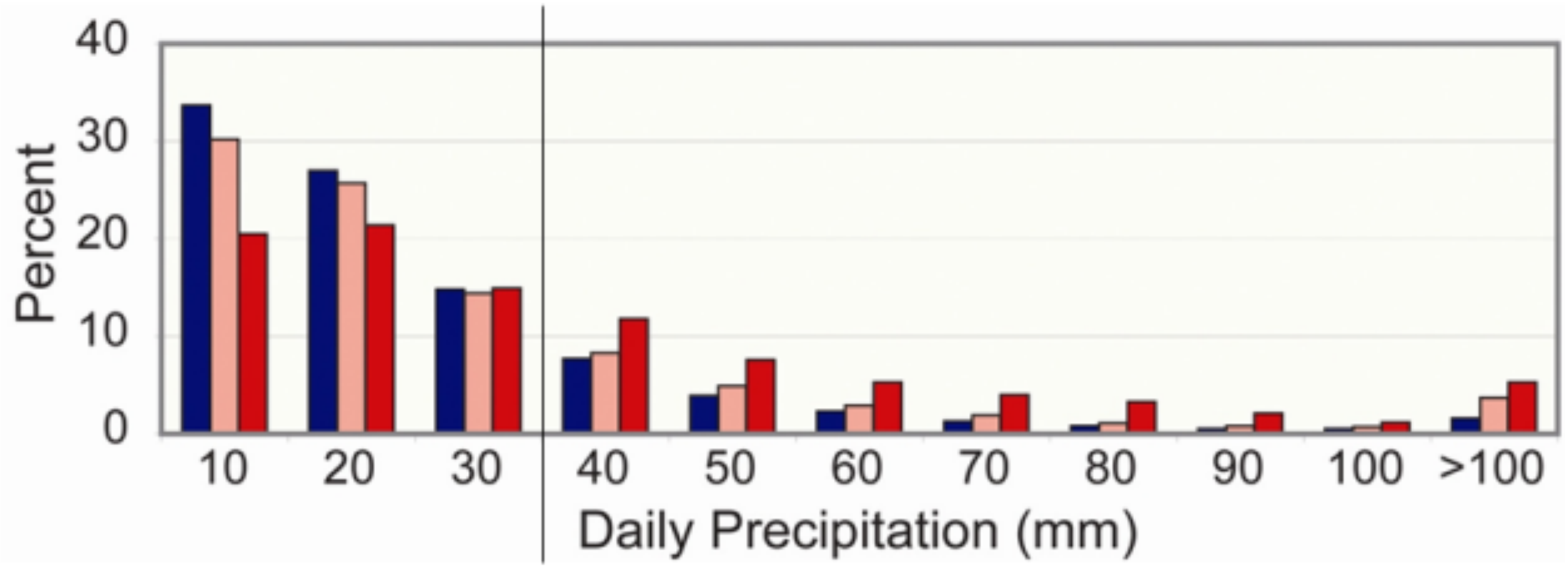
Higher temperatures => increase in precipitation intensity

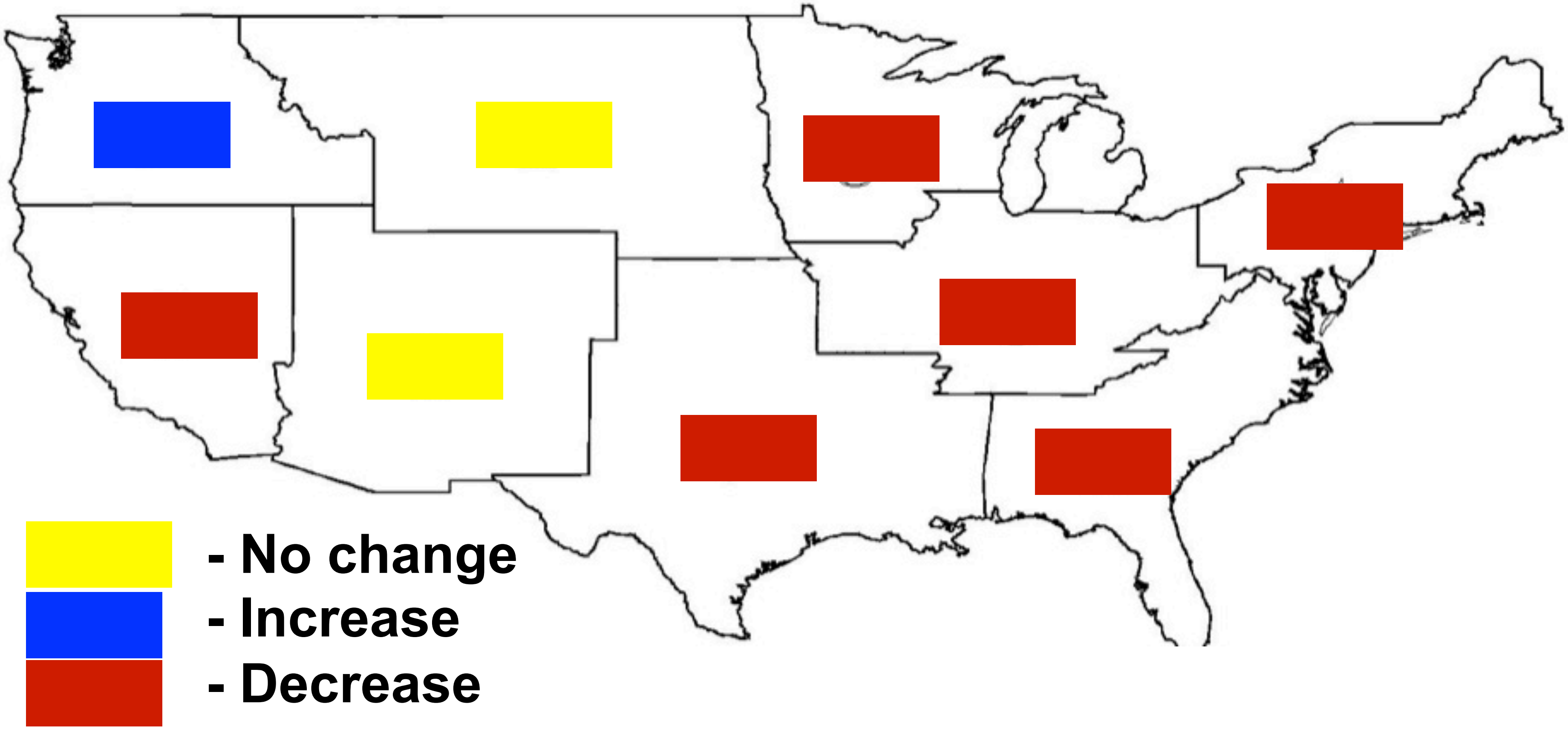


- Climatology of the intensity of daily precipitation in 10 mm/day categories for stations with the same mean seasonal precipitation (~230 mm) and different temperature regimes (<19°C, blue bars; between 19°C and 29°C, pink bars; and > 29°C, red bars)

[Karl and Trenberth 2003, Science]

… and (by implication) a possible reduction of the frequency of rainy days

Changes of the fraction of moderately heavy precipitation (from 13 to 25 mm) with time, past three decades versus previous period



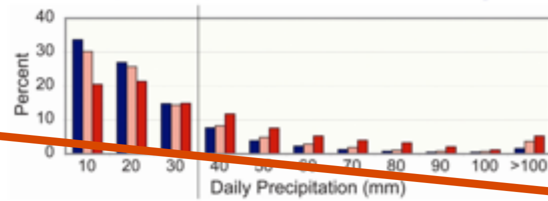
Fraction of "moderately intense" precipitation within the intense precipitation spectra is decreasing over most of the contiguous U.S.

Changes in rainfall intensity

Why do we expect changes?

- *Climatology*
- *Models*
- *Models + Observations*

Higher temperatures => increase in precipitation intensity



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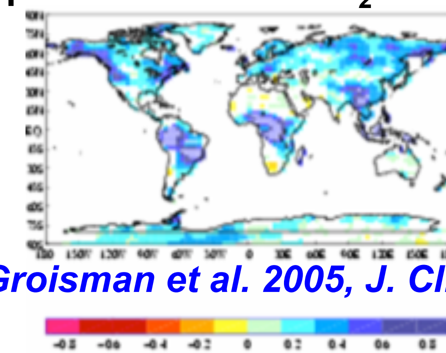
[Karl and Trenberth 2003, Science]

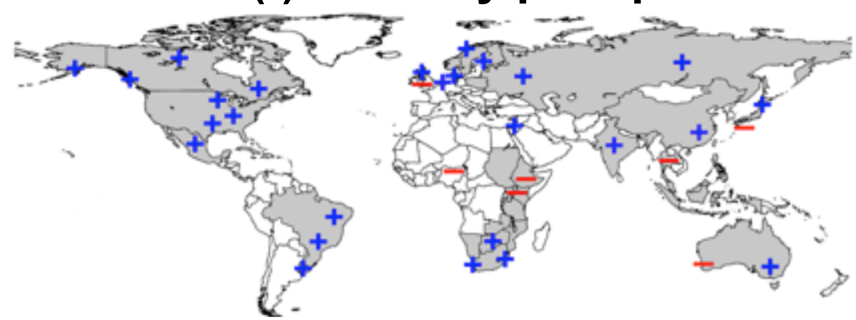
Projected changes in "very heavy" precipitation with the CO_2 doubling



Groisman et al. 2005, J. Climate

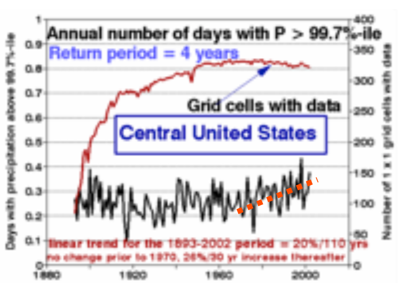
Frequency of the upper 10% of rainy days over the northeastern quadrant of the contiguous United States.

Regions with disproportional increase (+) and decrease (-) in heavy precipitation

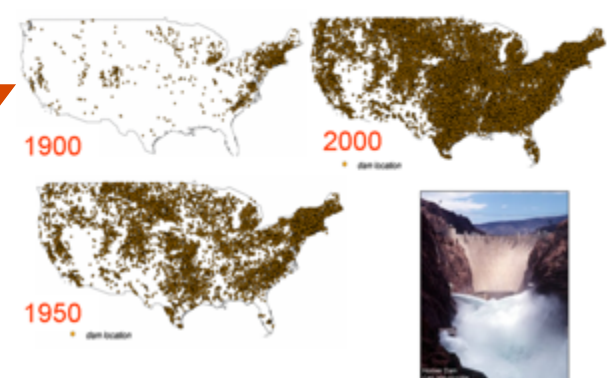


What have we already observed?

Regions with statistically significant annual increases in "very heavy" precipitation over the United States

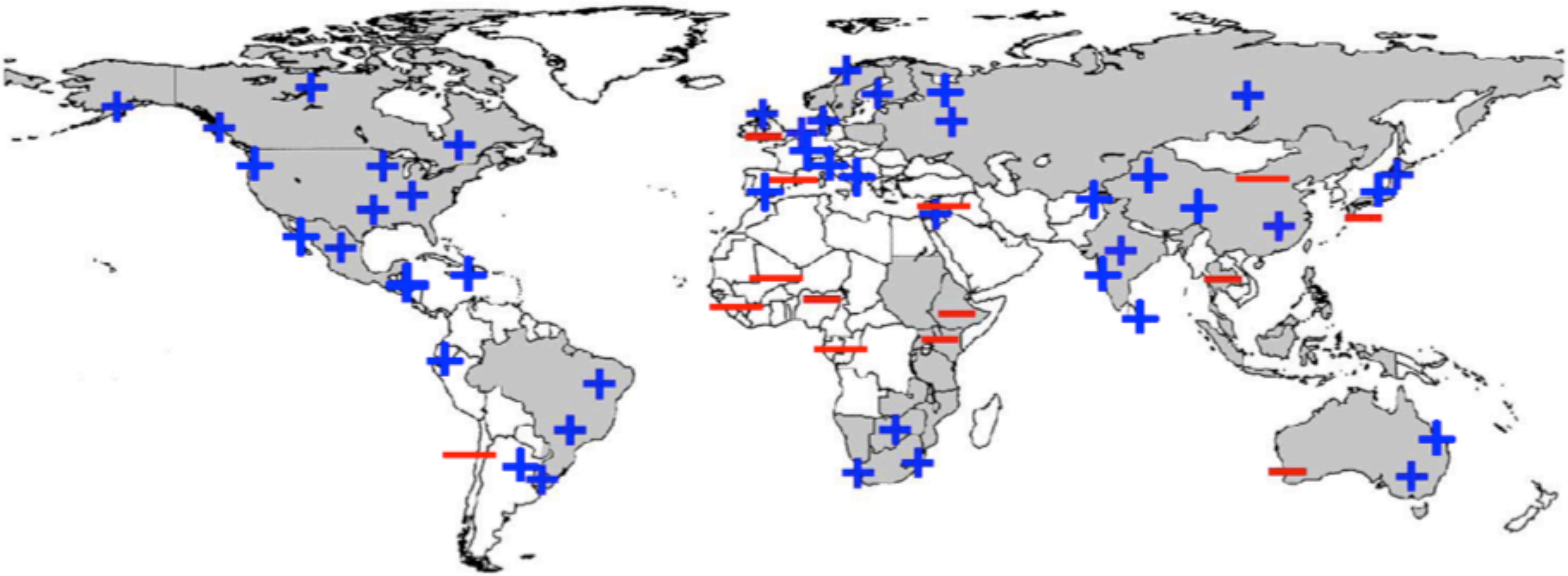


U.S. National Inventory of Dams (Vórósmarty 2004)



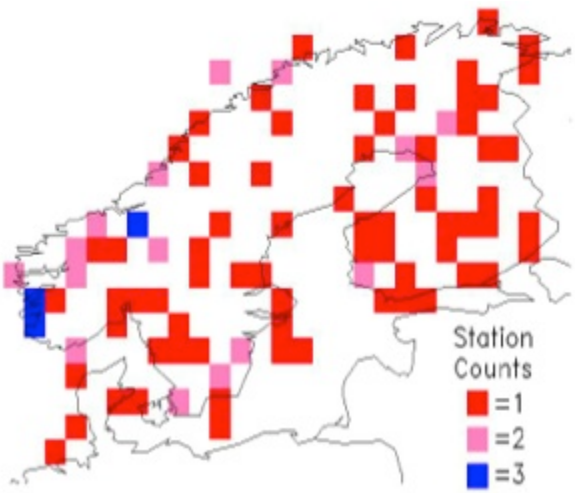
Why are changes in the rainfall intensity not so visible in changes in flood events?

Regions with disproportionate changes in intense precipitation during the past decades compared to the change in the annual and/or seasonal precipitation

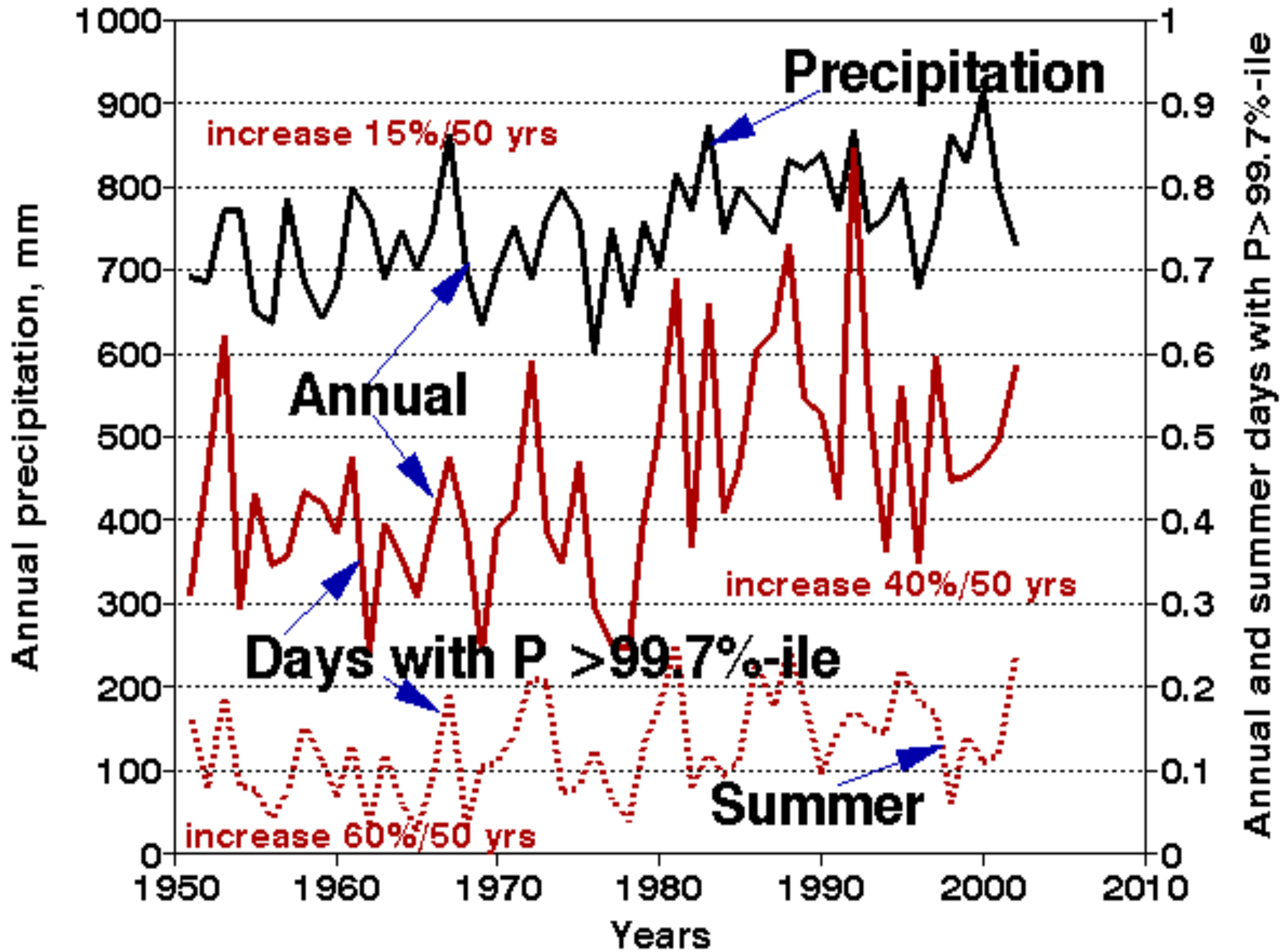


Easterling et al. 2000, substantially updated from Groisman et al. 2005, Zhai et al. 2005, Roy and Balling 2004, Aguilar et al. 2005, Brunetti et al. 2004, Cavazos 2008, Zolina et al. 2010; and finalized in Groisman and Knight 2012. Thresholds used to define "heavy" and "very heavy" precipitation vary by season and region.

Precipitation and “very heavy” precipitation in Fennoscandia



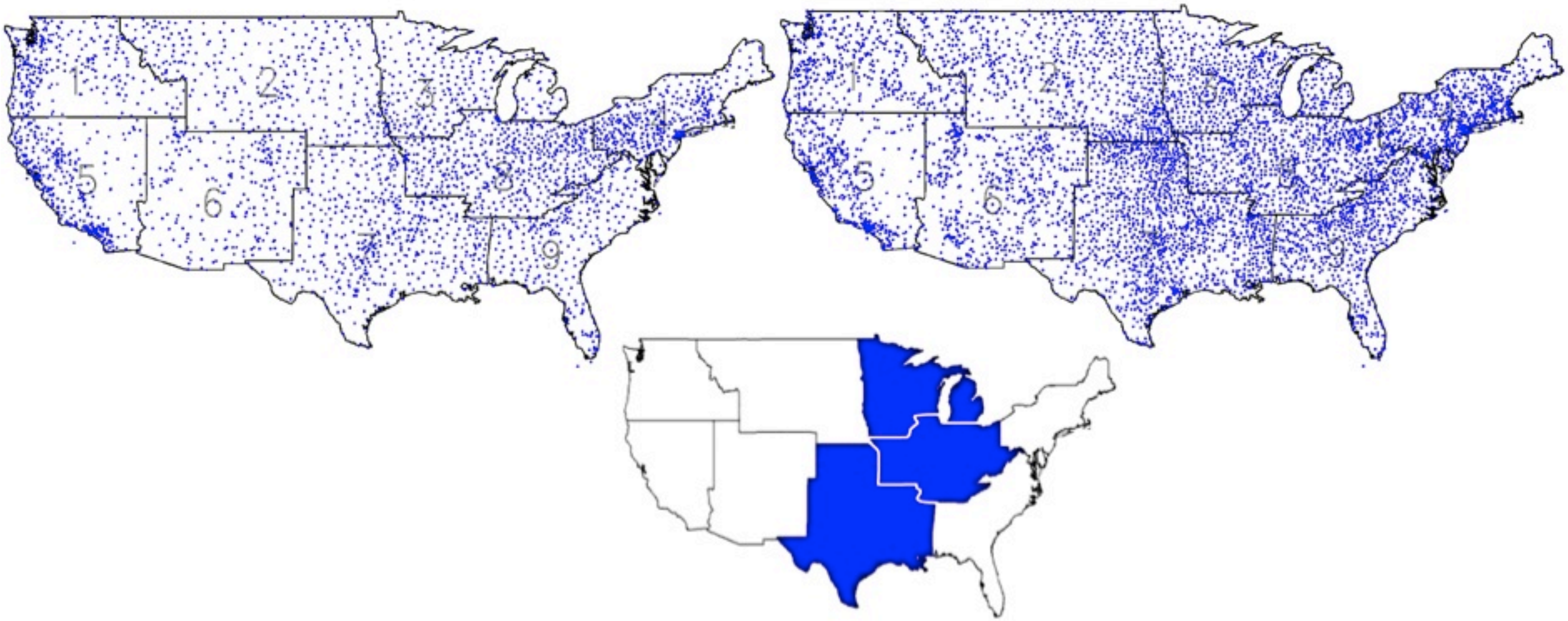
All increases in the second half of the 20th century have occurred in the past 25 yrs



Case Study:

Intense precipitation over the Contiguous United States (CONUS)

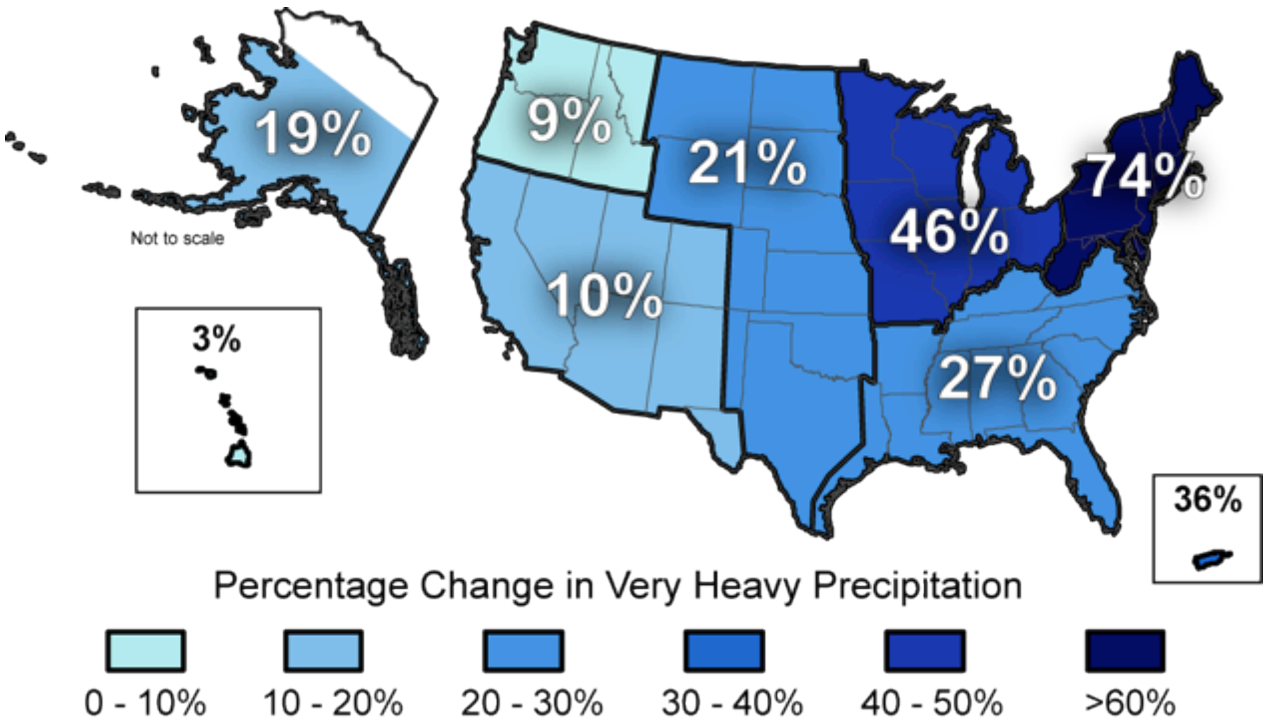
Two station networks with long-term precipitation time series of hourly and daily precipitation available for the past 60 years over the contiguous United States.



Blue dots on the maps show distribution of 3076 stations with hourly precipitation data stations (HPD, left) and 5885 long-term daily cooperative observer (COOP) stations (right).

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

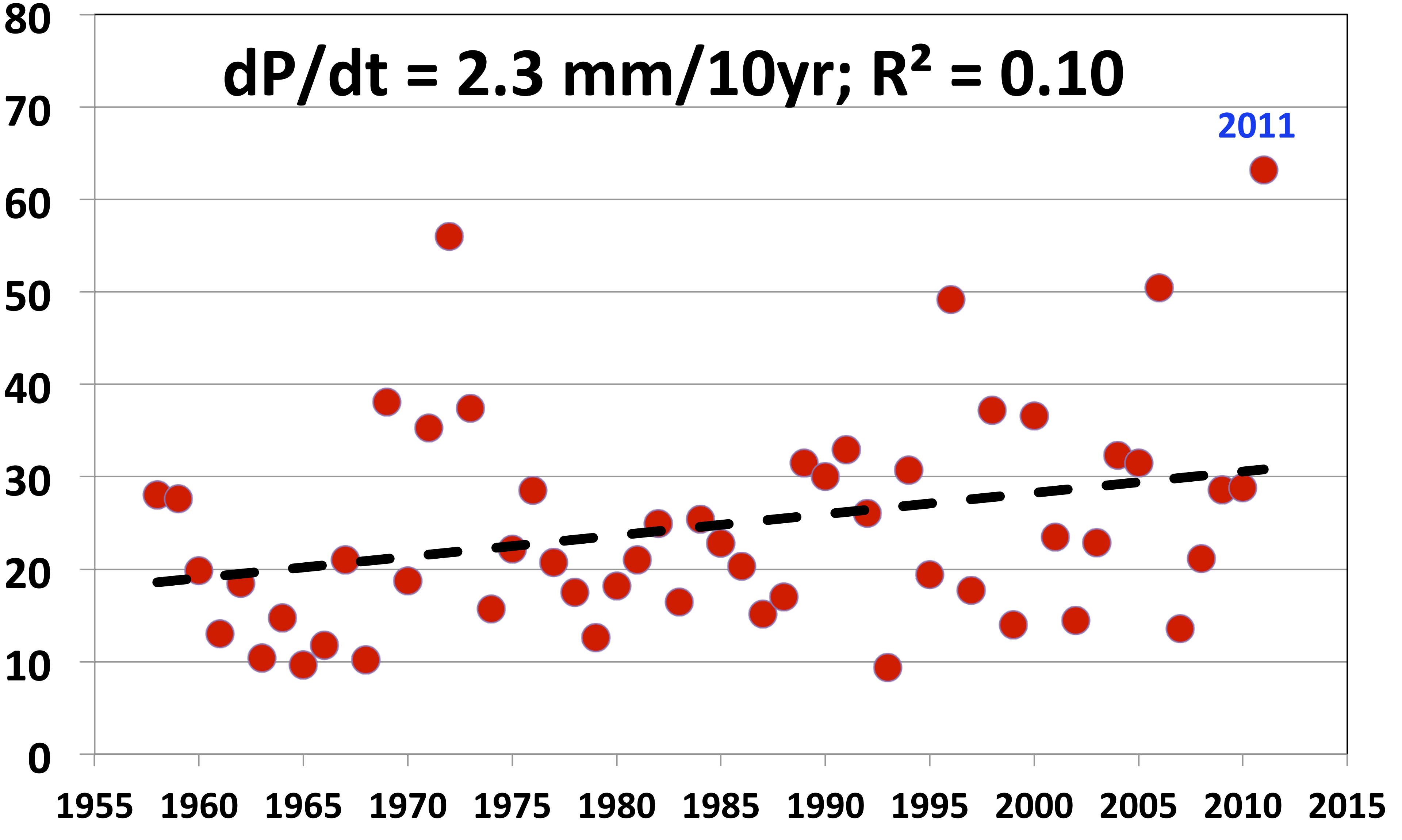
Annual

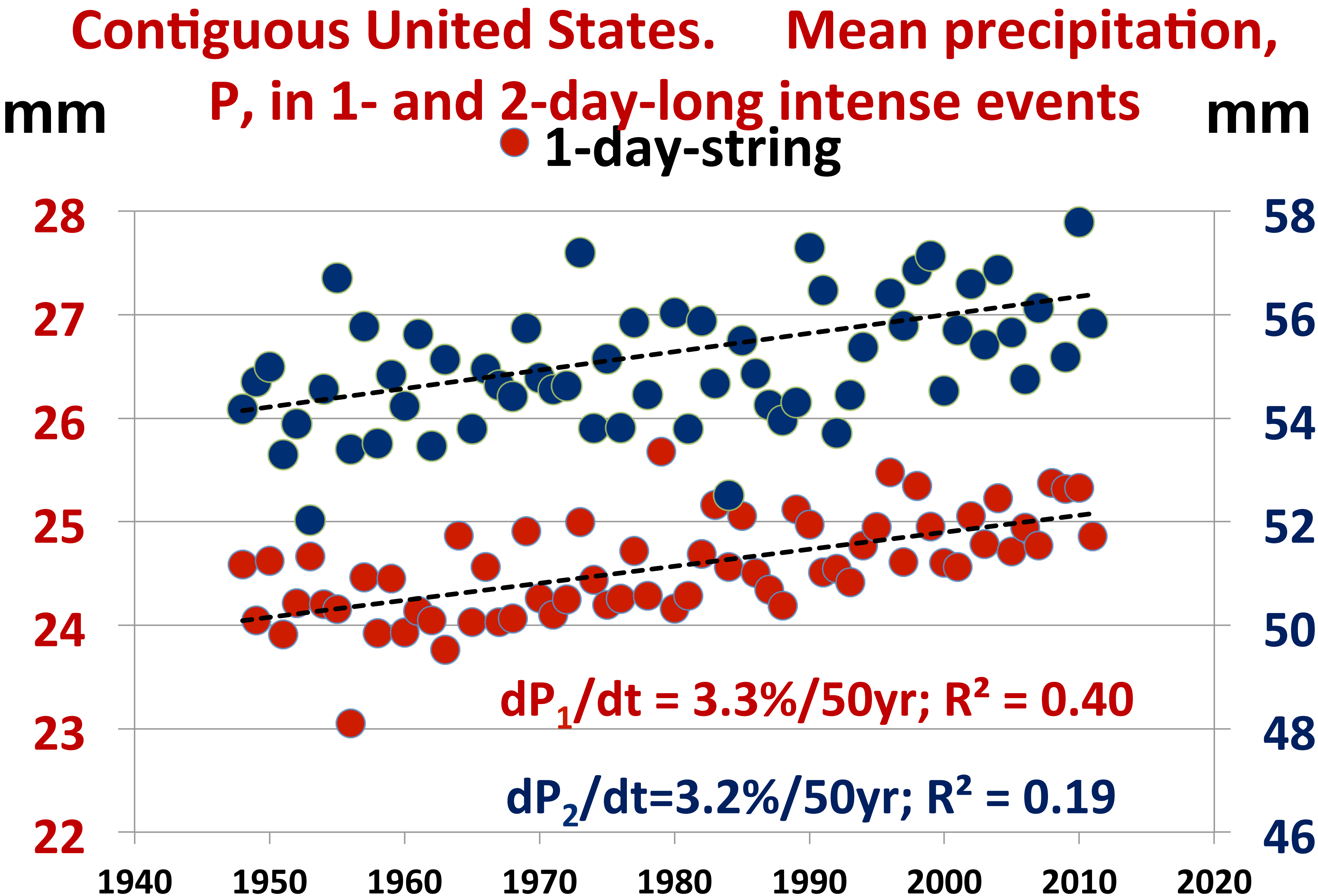


Percent increases in the amount falling in very heavy rain events defined as the heaviest 1 percent of all daily events from 1958 to 2010 for each region

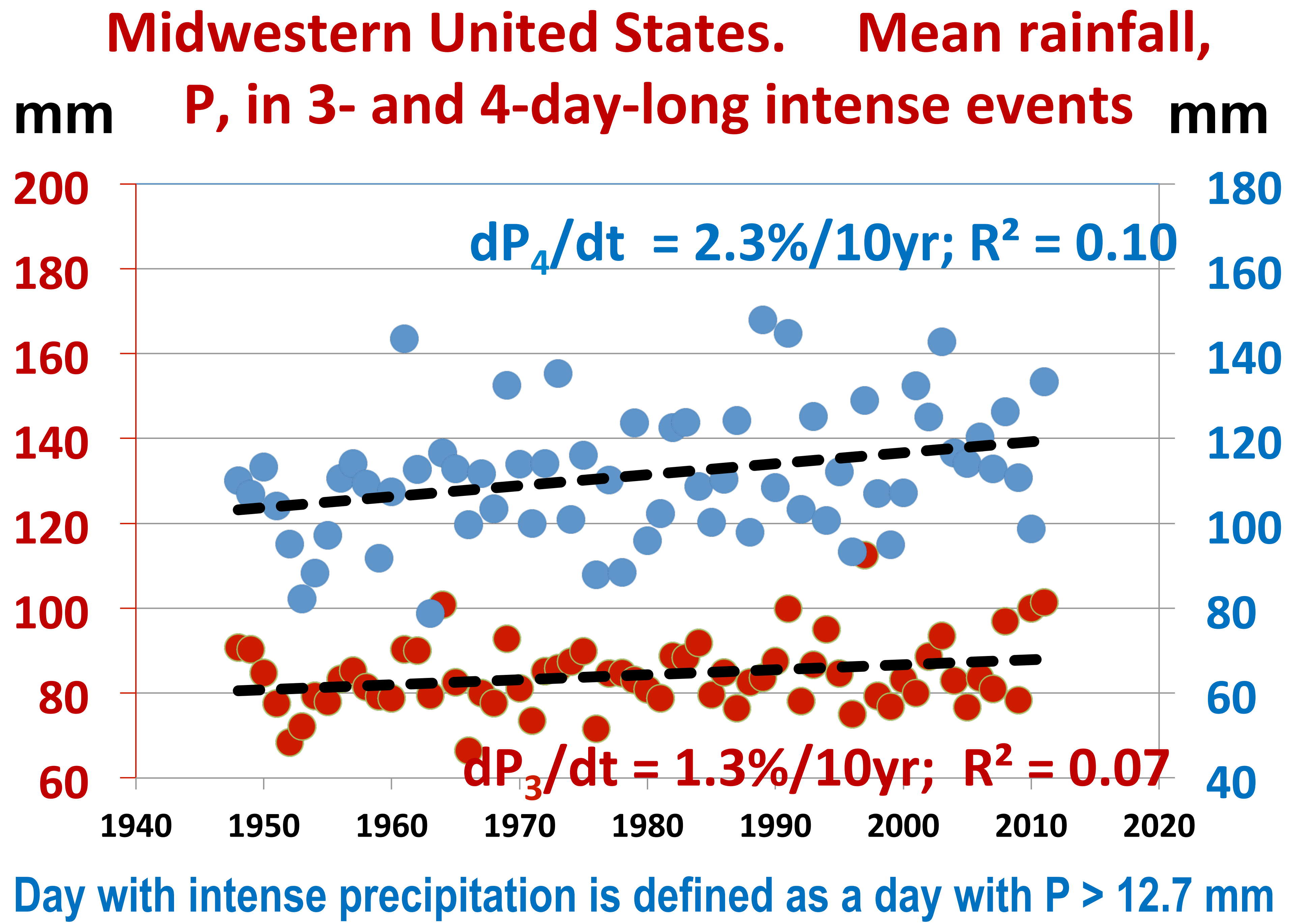
Changes in the Eastern half of the nation are statistically significant at the 0.05 or higher levels and over the Great Plains, at the 0.1 level

Upper 1% of the summer rainfall totals, mm. Northeastern U.S.

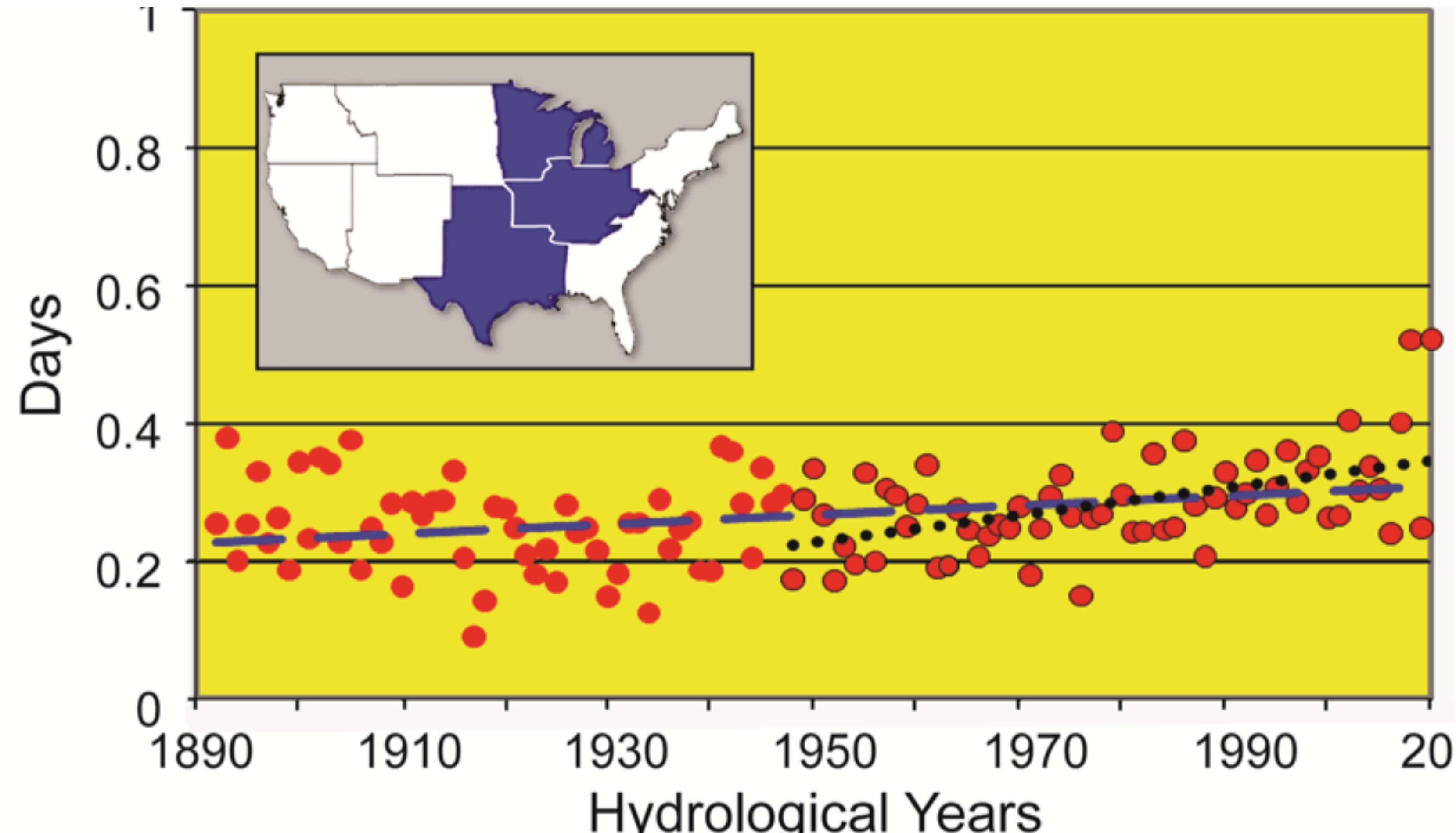




Day with intense precipitation is defined as a day with P > 12.7 mm


Midwestern United States. Mean rainfall,
P, in 3- and 4-day-long intense events
mm
mm
200
180
160
140
120
100
80
60
180
160
140
120
100
80
60
40
$dP_4/dt = 2.3\%/10yr; R^2 = 0.10$
$dP_3/dt = 1.3\%/10yr; R^2 = 0.07$
1940
1950
1960
1970
1980
1990
2000
2010
2020
Day with intense precipitation is defined as a day with P > 12.7 mm

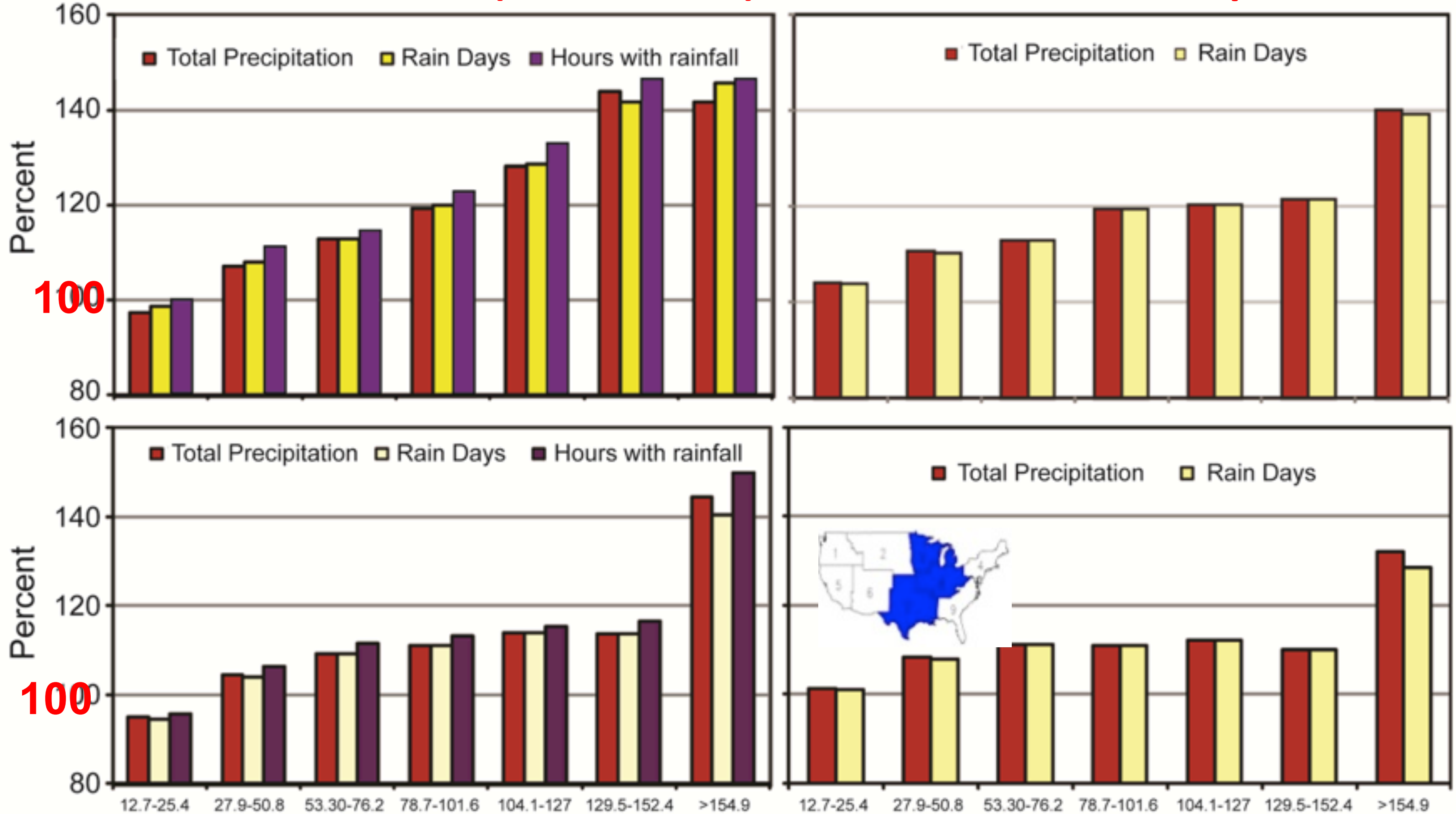
Annual number of days with very heavy precipitation defined as an upper 0.3% of daily precipitation events over the central U.S. (dark blue in the insert)



Linear trend estimates for the 1893–2010 and 1948–2010 periods. are equal to 2.6% (10 yr)$^{-1}$ and 7.4% (10 yr)$^{-1}$, respectively, and are statistically significant at the 0.01 level or higher (Groisman et al. 2012*, J. Hydrometeorol*.).

Comparison of intense precipitation days (upper line of plots) and multi-day intense precipitation events (lower plots) over the Central U.S. for 1979-2009 and 1948-1978 periods sorted by day/event intensities (in mm).

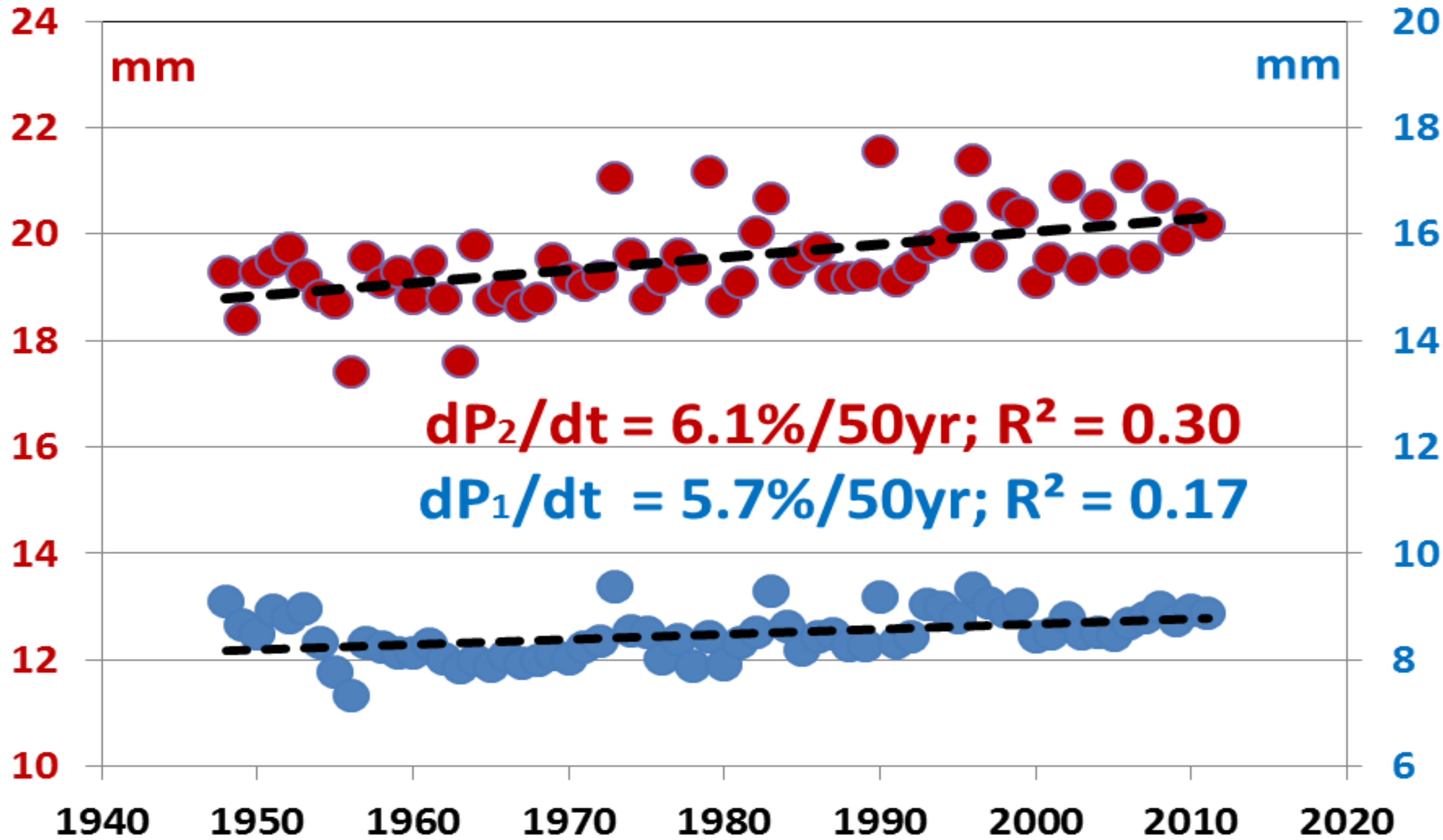
Extreme rain events (P > 155 mm) became 40% more frequent.



Estimates of precipitation characteristics for these 31-yr periods were averaged and their ratios (in percent per station for the past 31 years to those for the previous 31-yr-long period) are shown for hourly (left) and daily (right) networks.

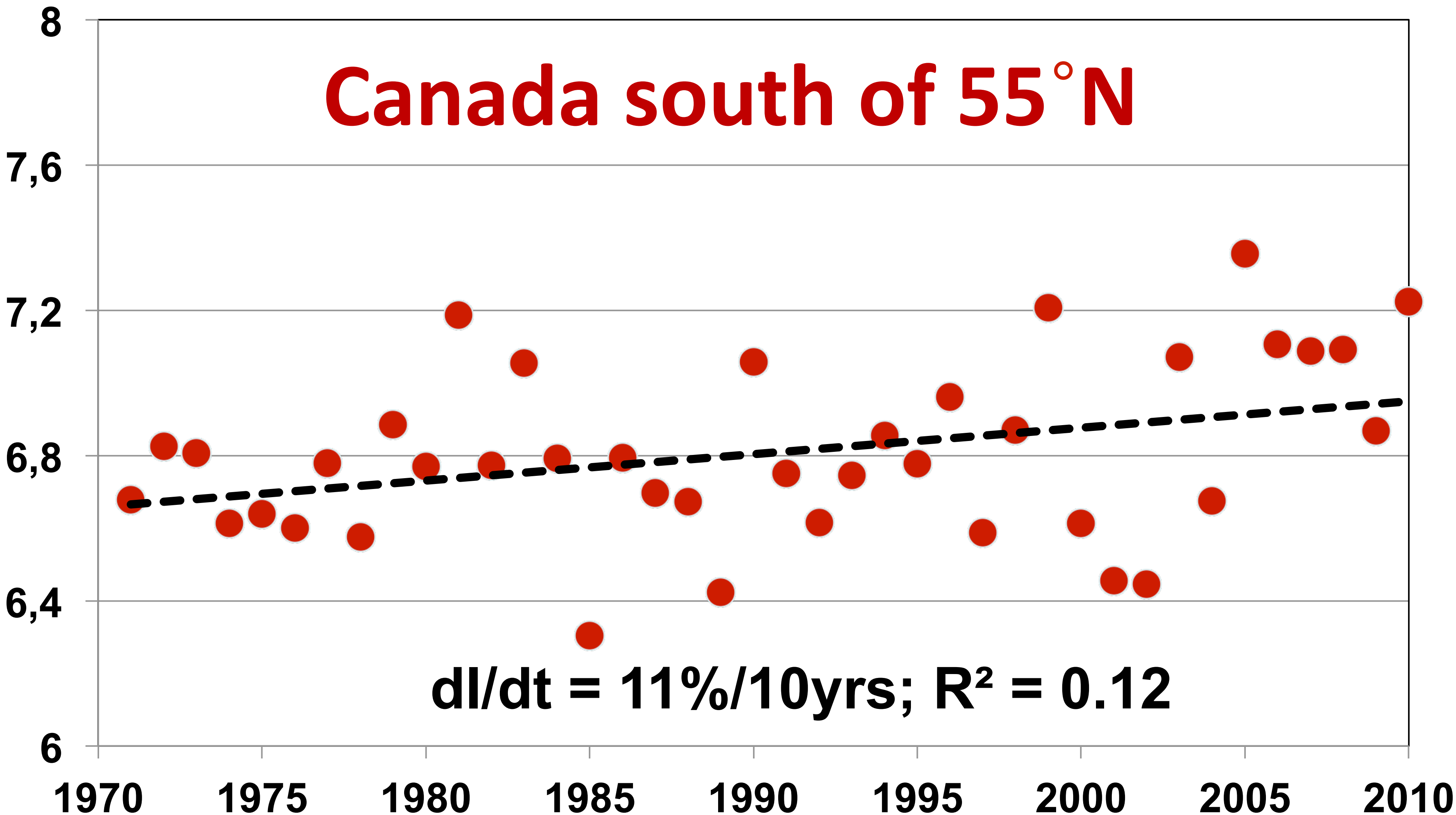
Precipitation Intensity

Mean precipitation per event that comes with 1-day- and 2-day-long events over the contiguous United States

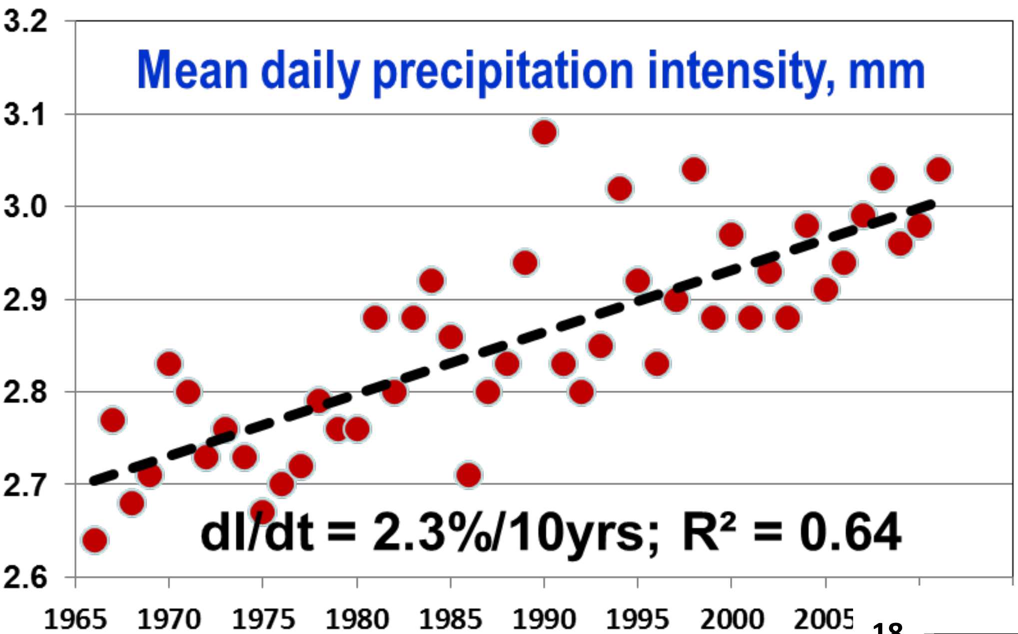


The estimates of precipitation intensity in 1-day-long (P_1, mm day^{-1}) and two-day-long (P_2, mm (2 days)$^{-1}$) are based upon all precipitation events above 0.5 mm at ~6,000 long-term U.S. cooperative stations during the 1948-2011 period (Updated archive of Groisman et al. 2012).

Mean annual precipitation intensity, mm d^{-1} over Canada south of 55°N



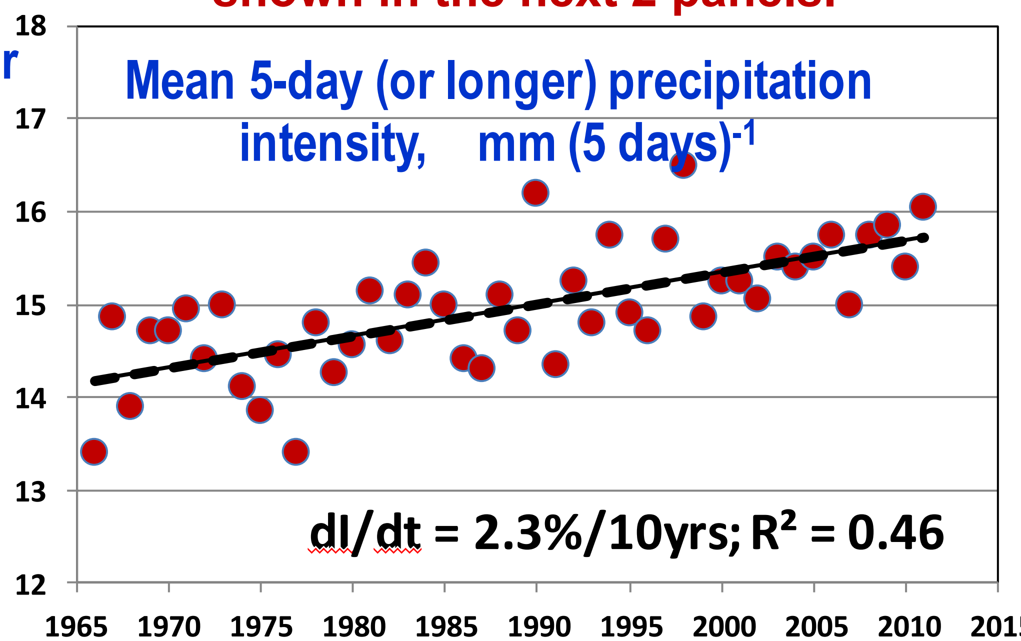
Nationwide precipitation intensity, I, changes over Russia



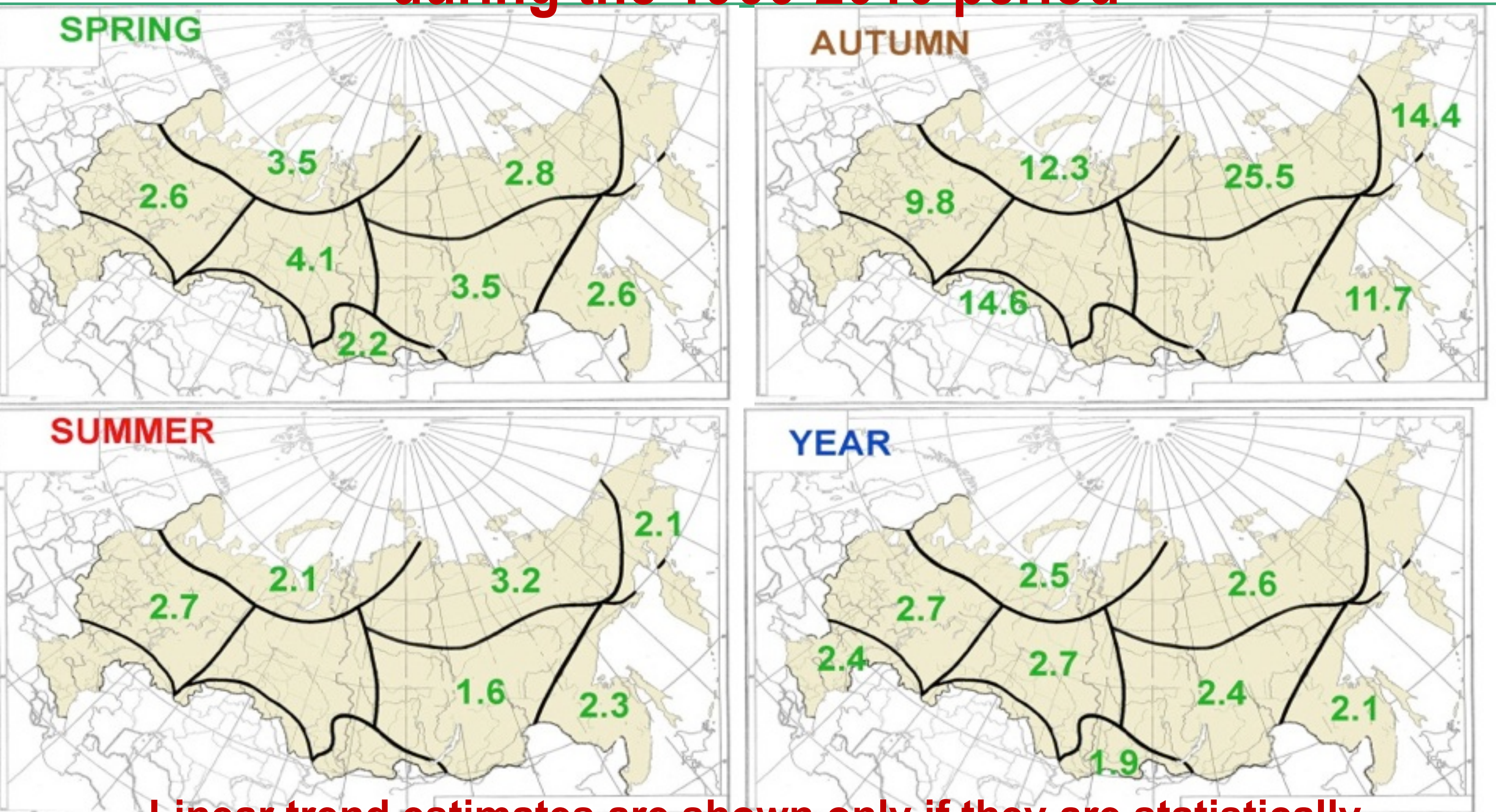
Russian climatological regions:

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

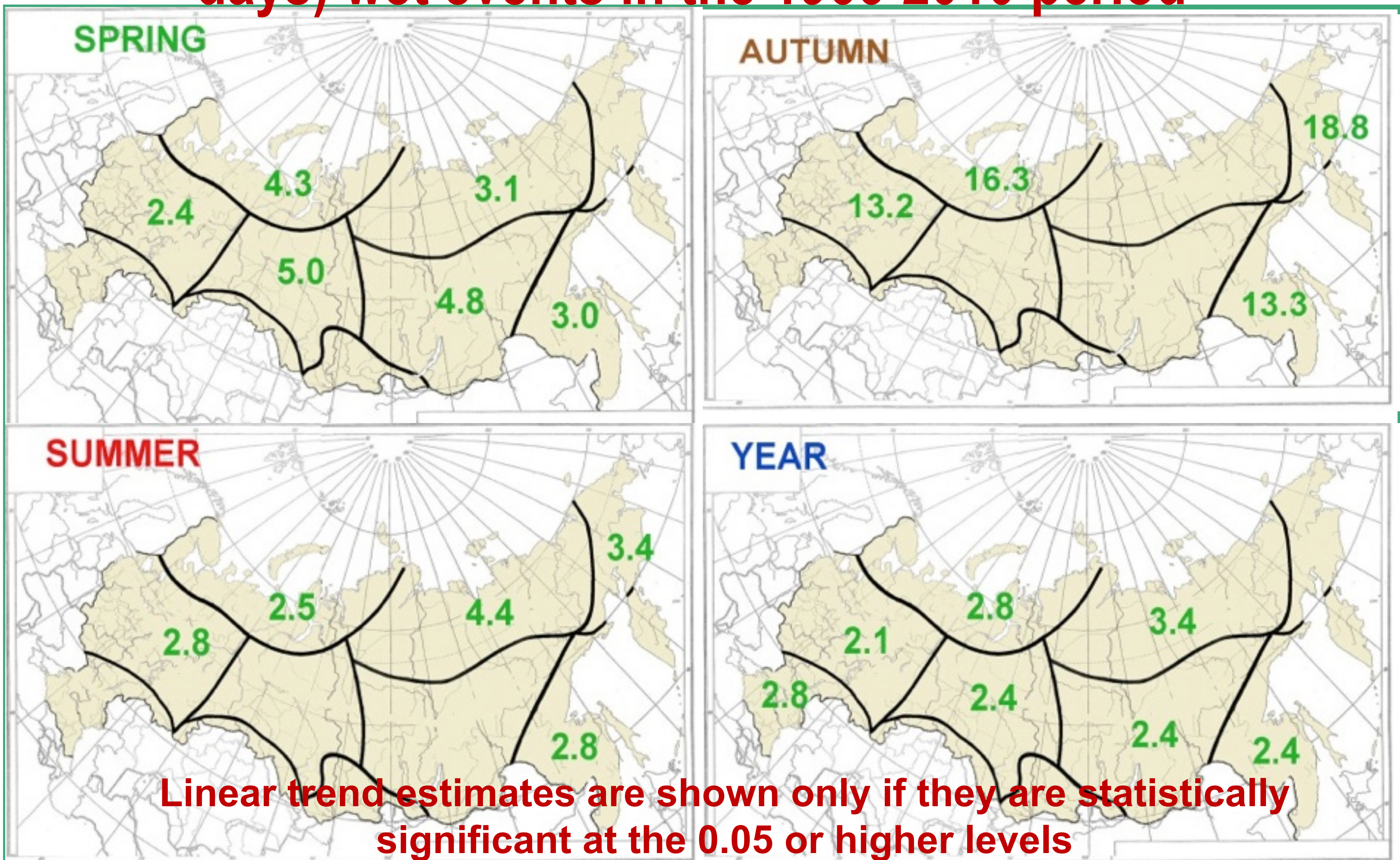


Linear trends (%/10yr) in the mean daily precipitation intensity pattern over Russia during the 1966-2010 period



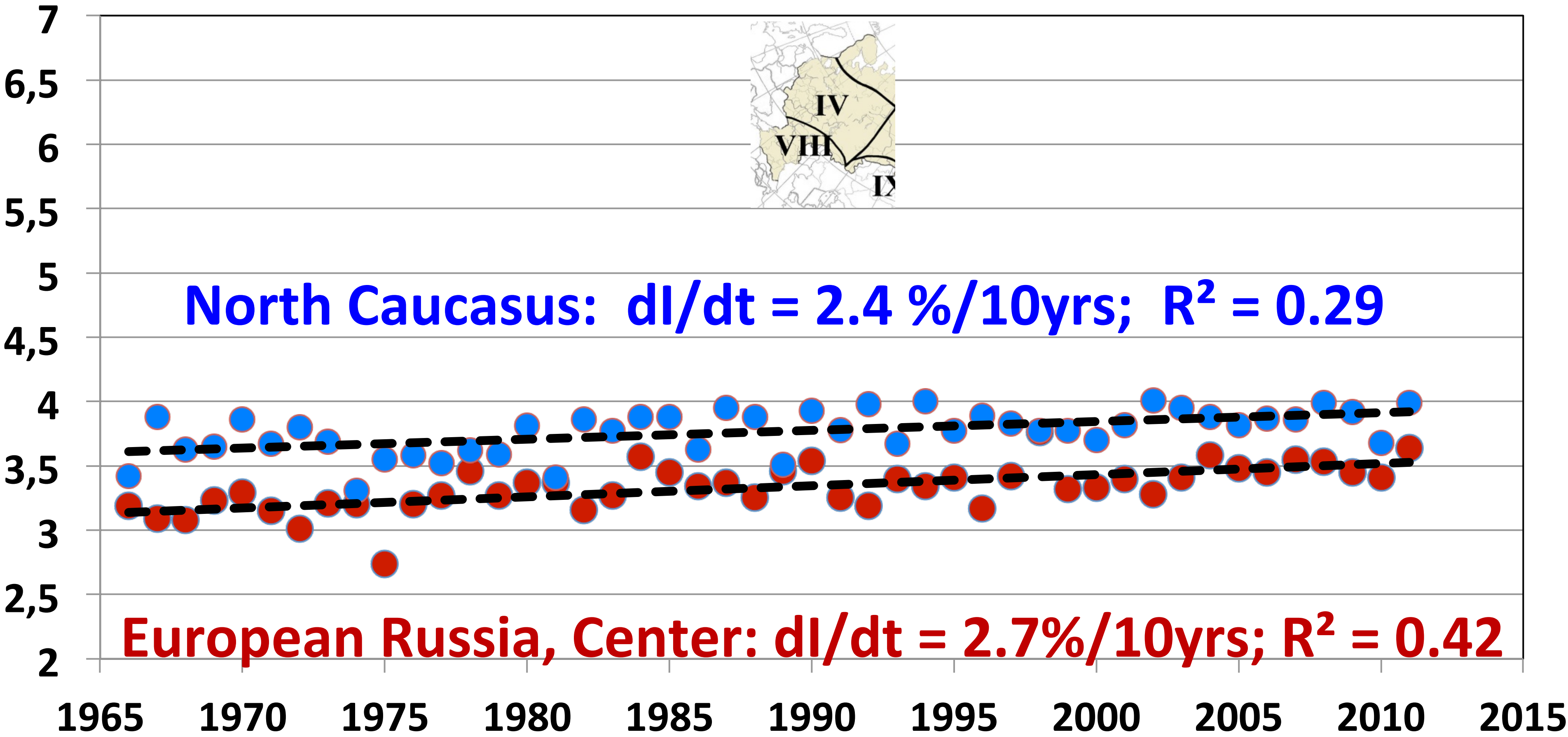
Linear trend estimates are shown only if they are statistically significant at the 0.05 or higher levels

Linear trends (%/10yr) in the mean daily precipitation intensity pattern over Russia during prolonged (≥ 5 days) wet events in the 1966-2010 period



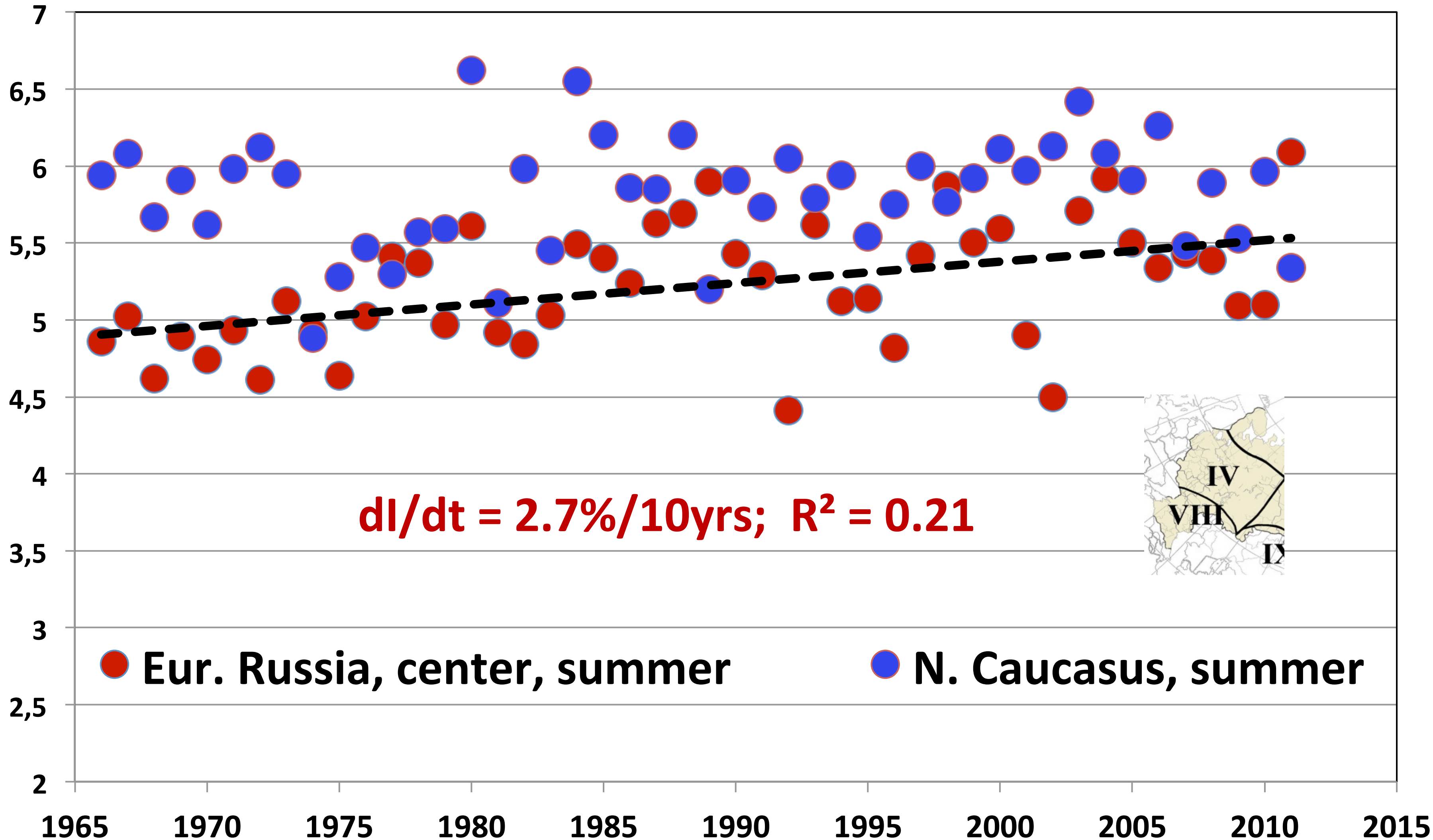
Linear trend estimates are shown only if they are statistically significant at the 0.05 or higher levels

Mean annual precipitation intensity over European Russia south of 63°N (mm d^{-1})

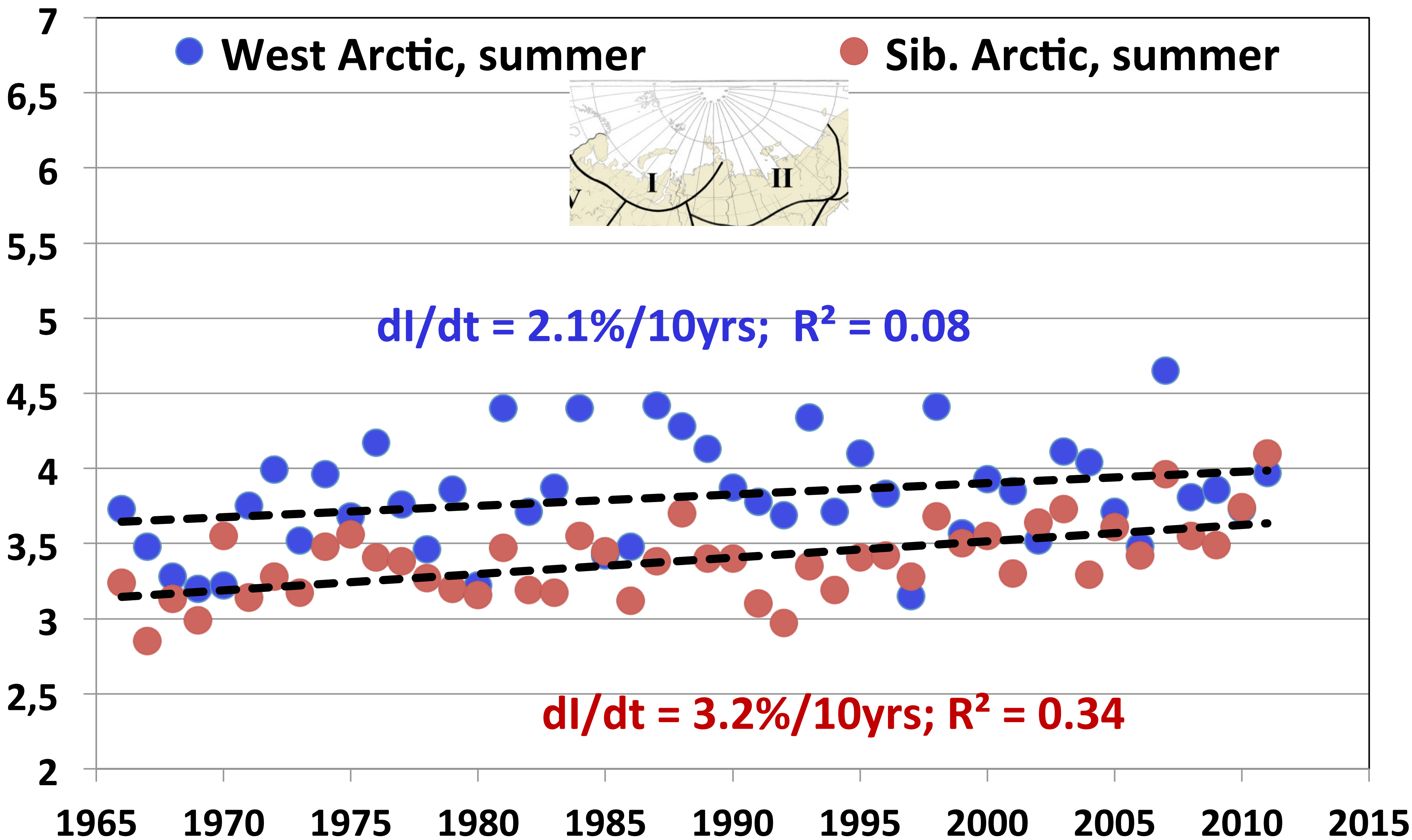


O.N. Bulygina 2012

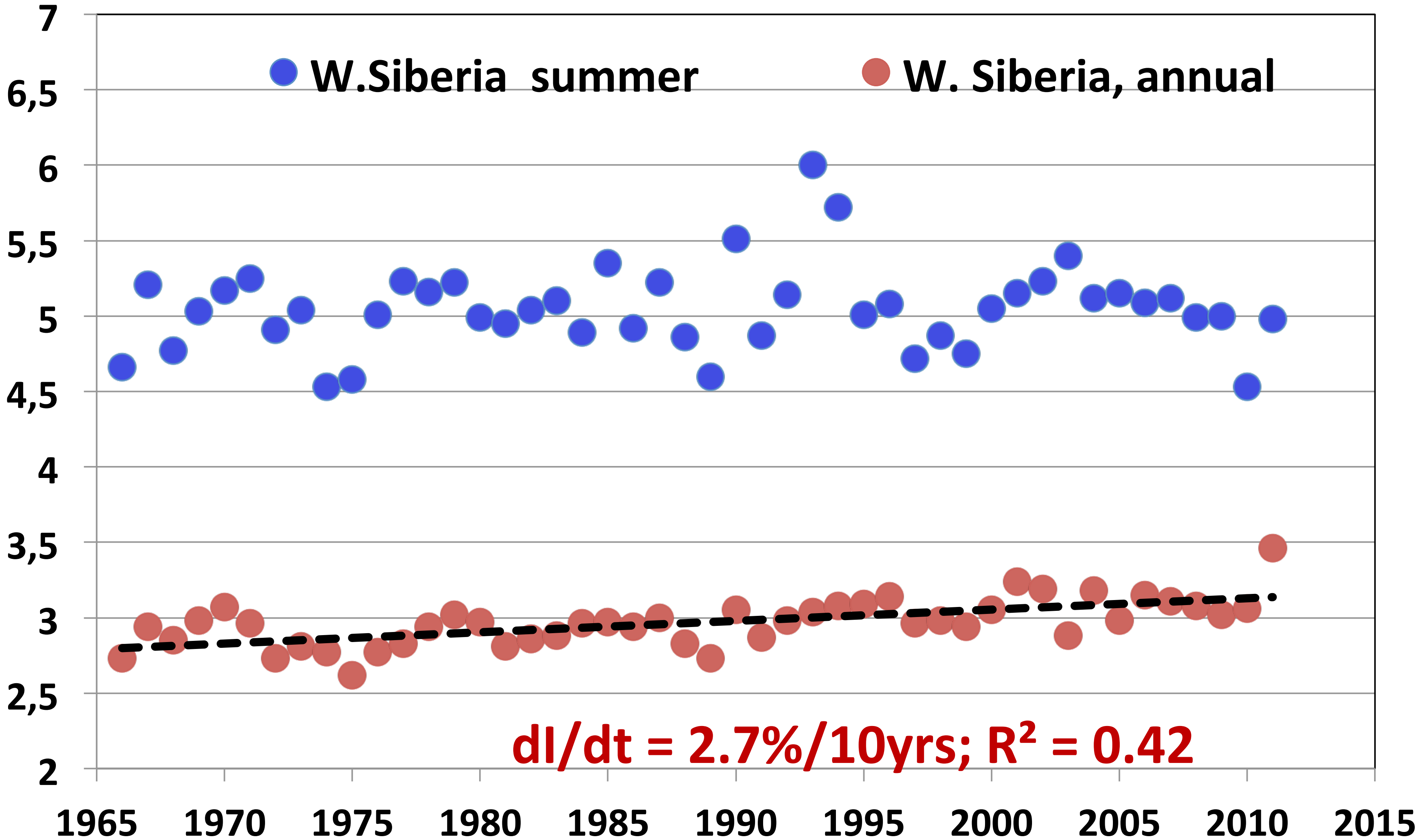
Mean summer precipitation intensity over European Russia south of 63°N (mm d^{-1})



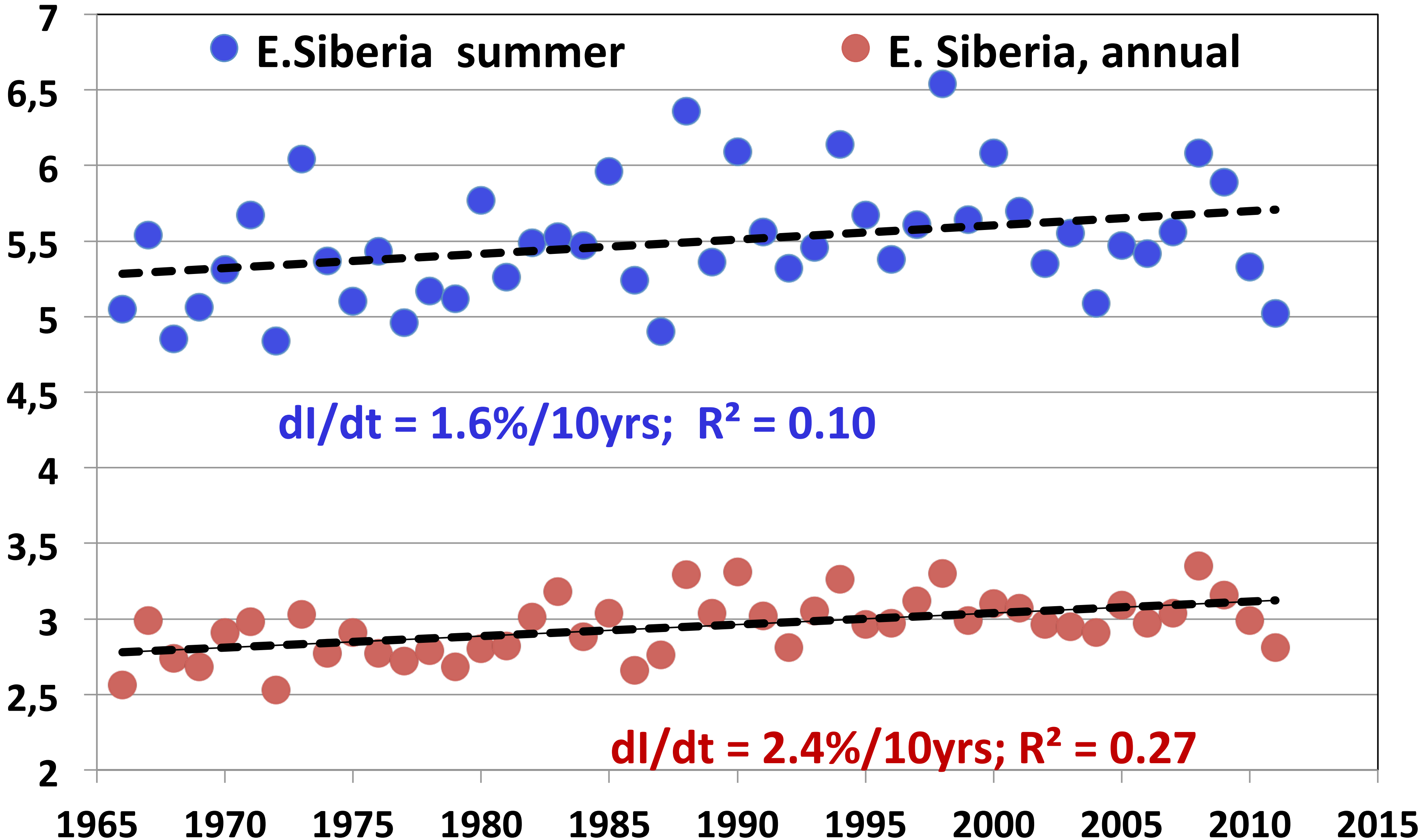
Mean summer precipitation intensity over Russian Arctic (mm d^{-1})



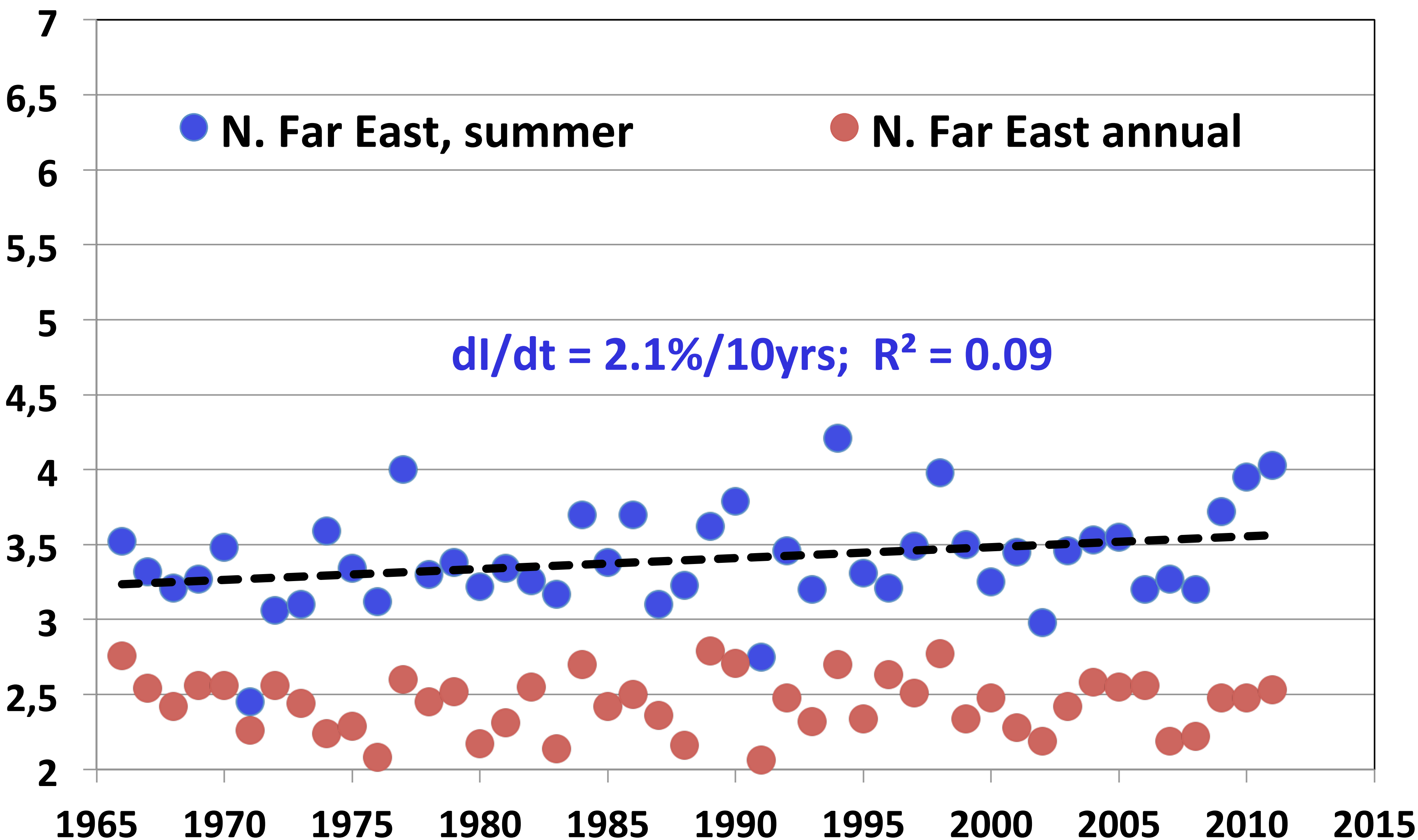
Mean annual and summer precipitation intensity, I, over West Siberia (mm d^{-1})



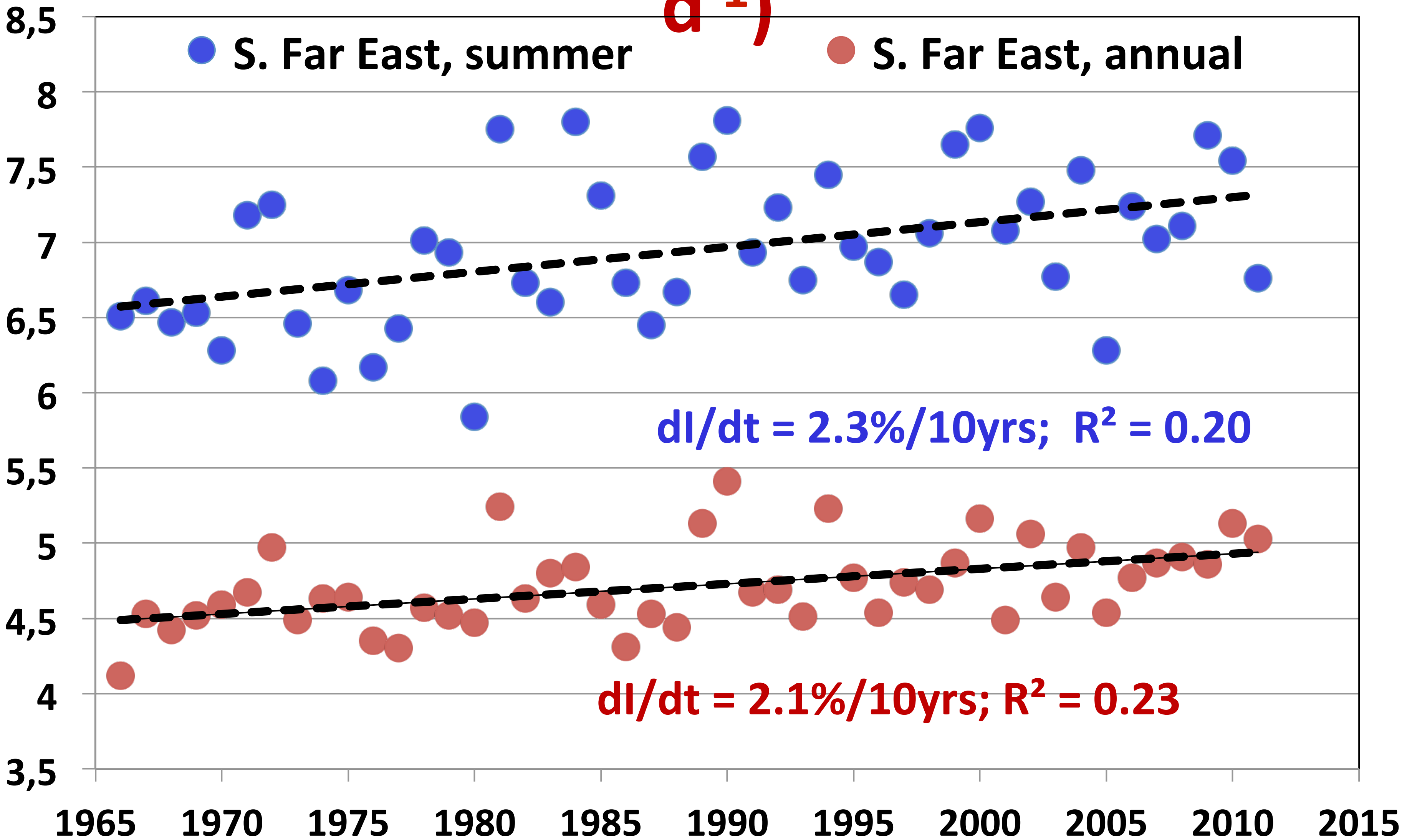
Mean annual and summer precipitation intensity over Eastern Siberia (mm d^{-1})



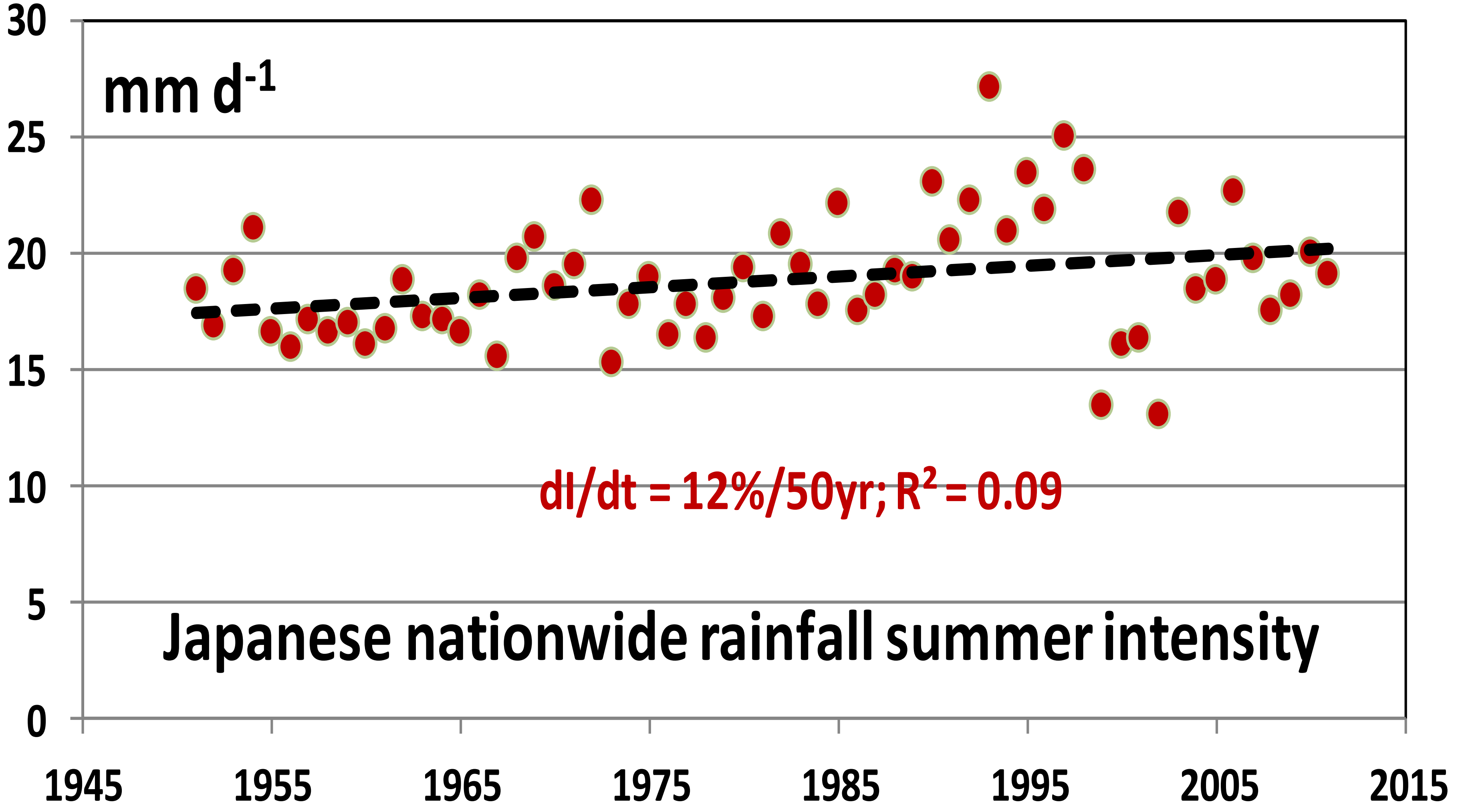
Mean annual and summer precipitation intensity over Northern Far East (mm d^{-1})



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

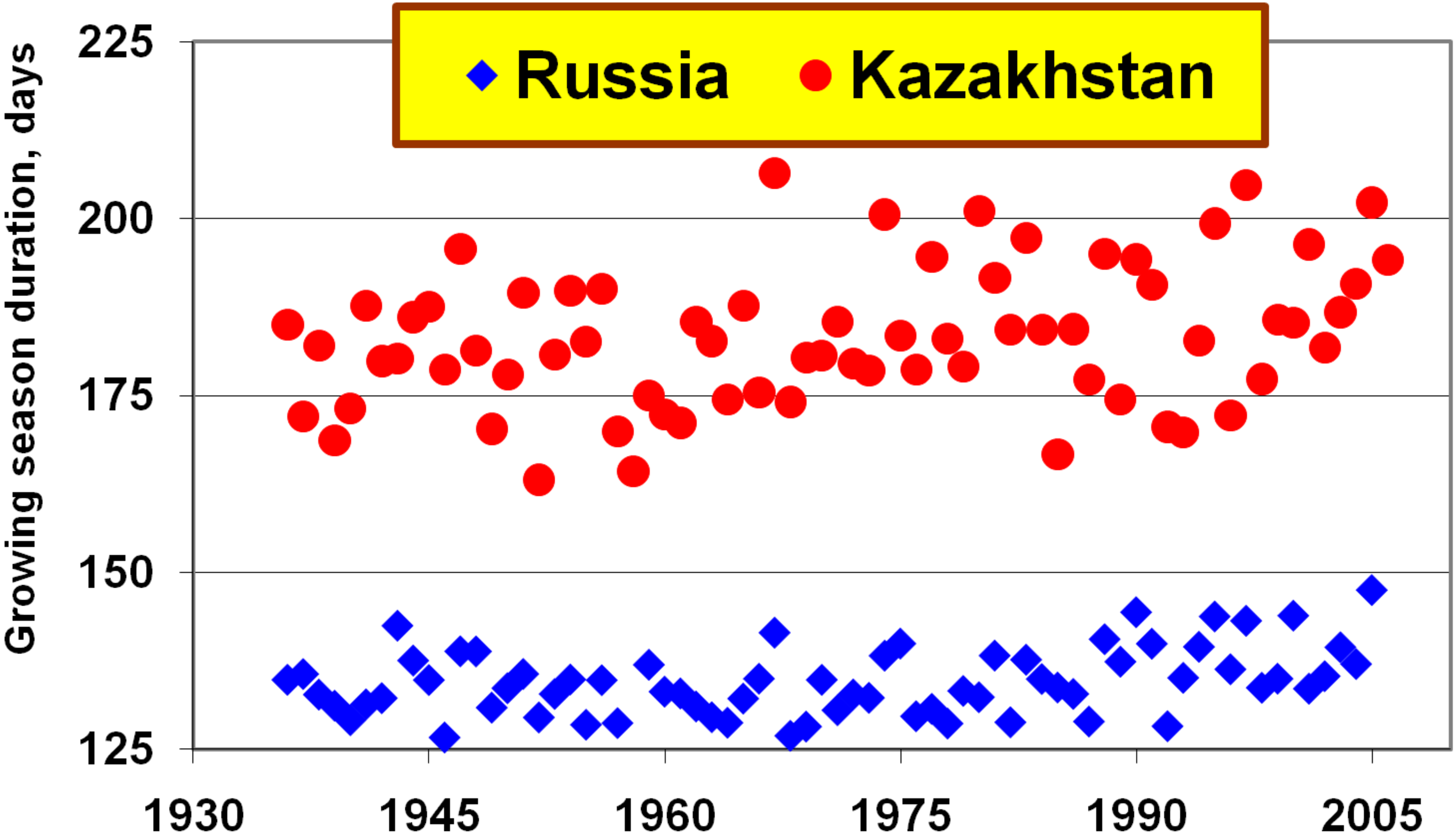


Mean summer (JJA) rainfall intensity, mm d^{-1} over Japan



Warm Season Dryness

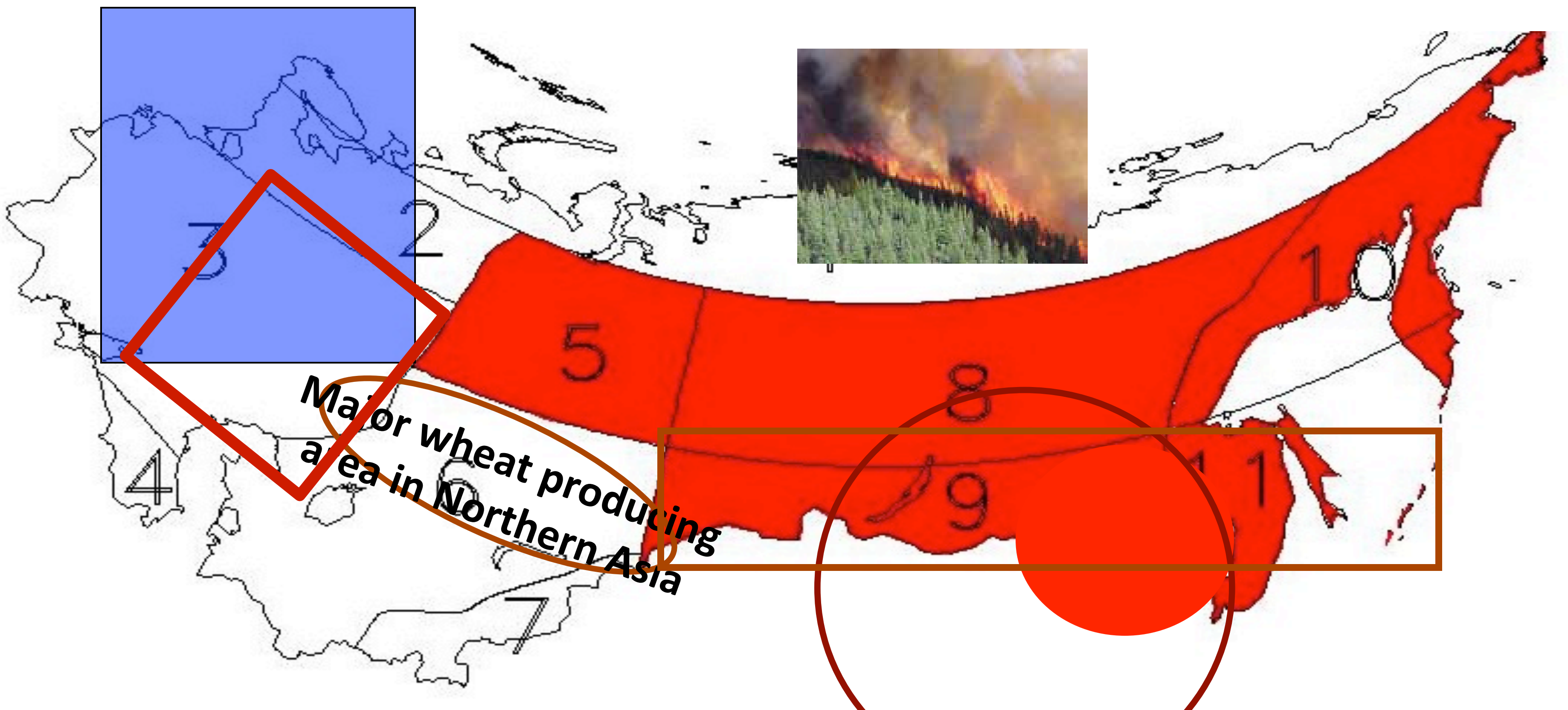
Duration of the growing season area-averaged over Russia and Kazakhstan



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

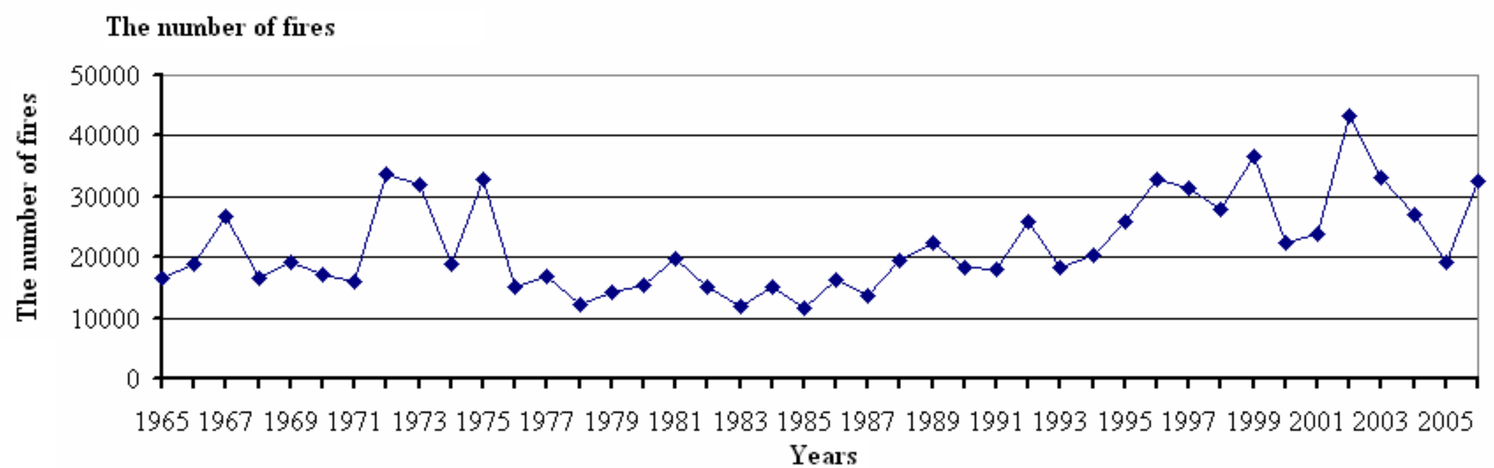
Changes in the surface water cycle over Northern Eurasia that have been statistically significant in the 20th century

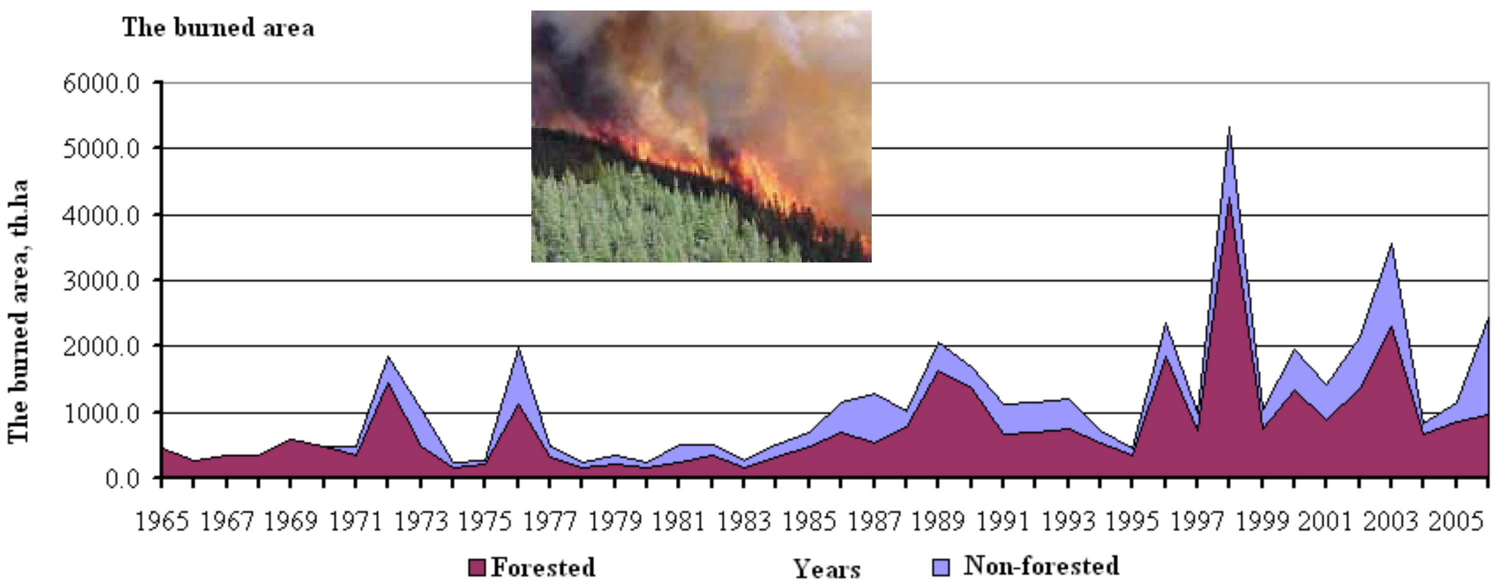
More humid conditions (blue),
more dry conditions (red),
more agricultural droughts (circled),
more prolonged dry episodes (rectangled).



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

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

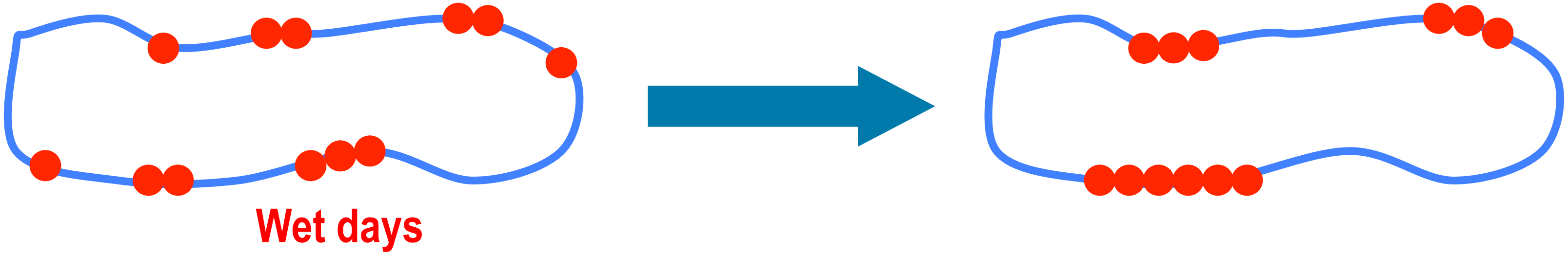




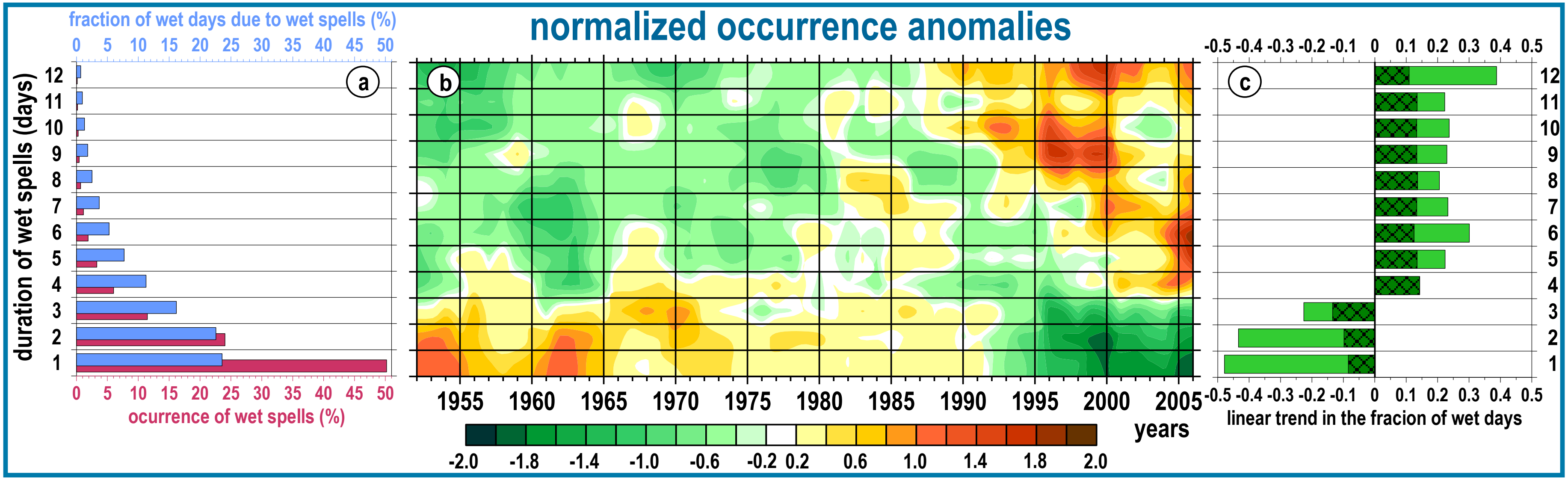
Korovin and Zukkert 2003, updated

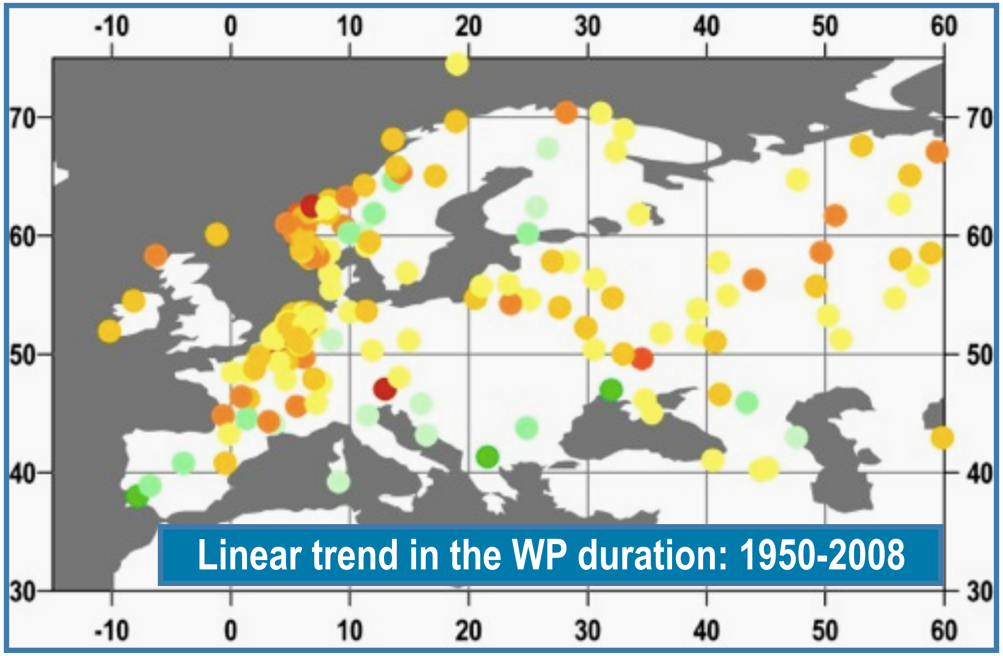
NON-LINEARITIES

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).

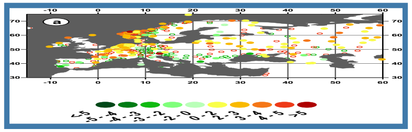


Changes in the duration of European wet periods





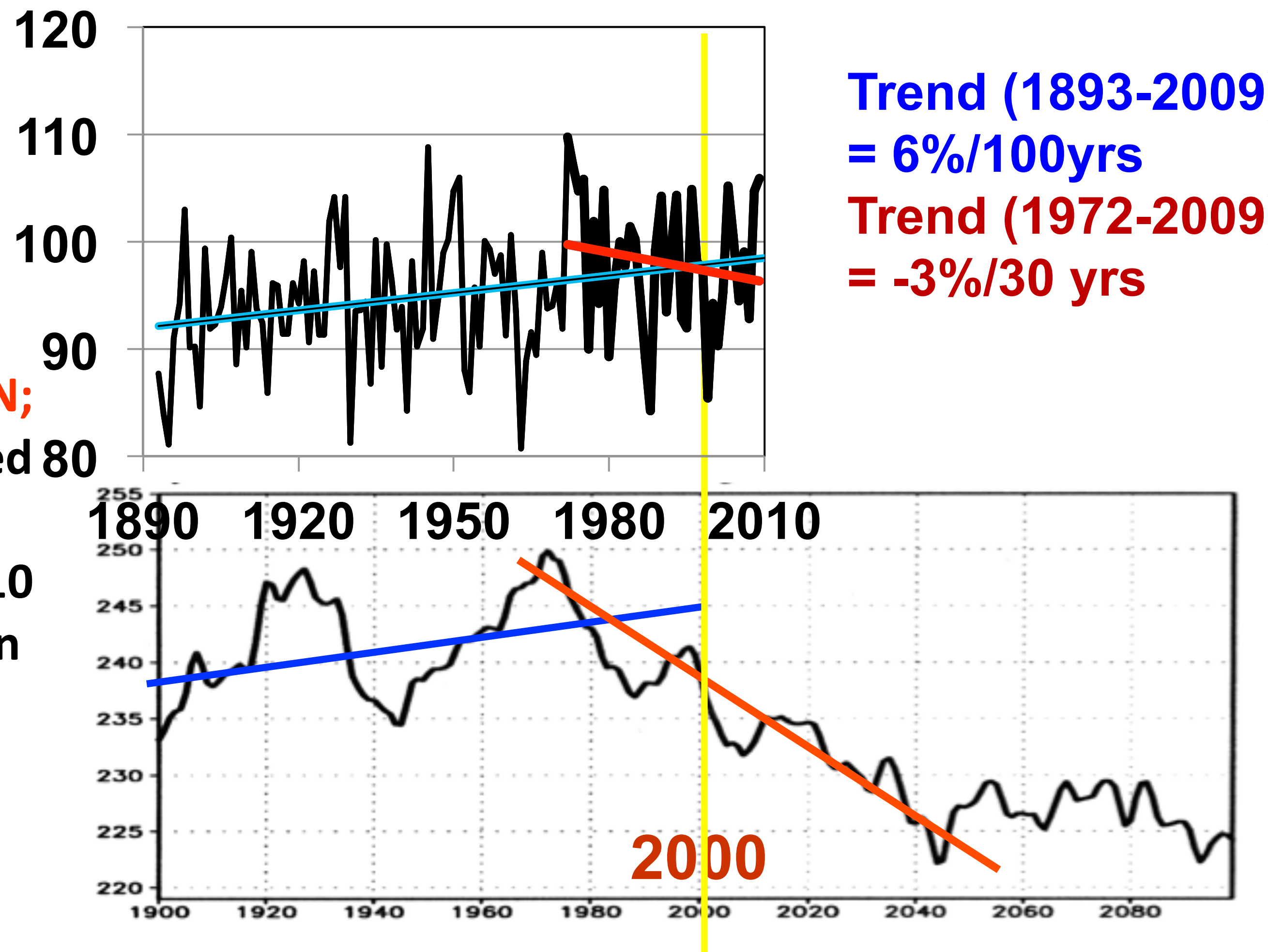
It is not the effect of changing number of wet days!!!



Zolina et al. 2010, Geophys. Res. Lett.

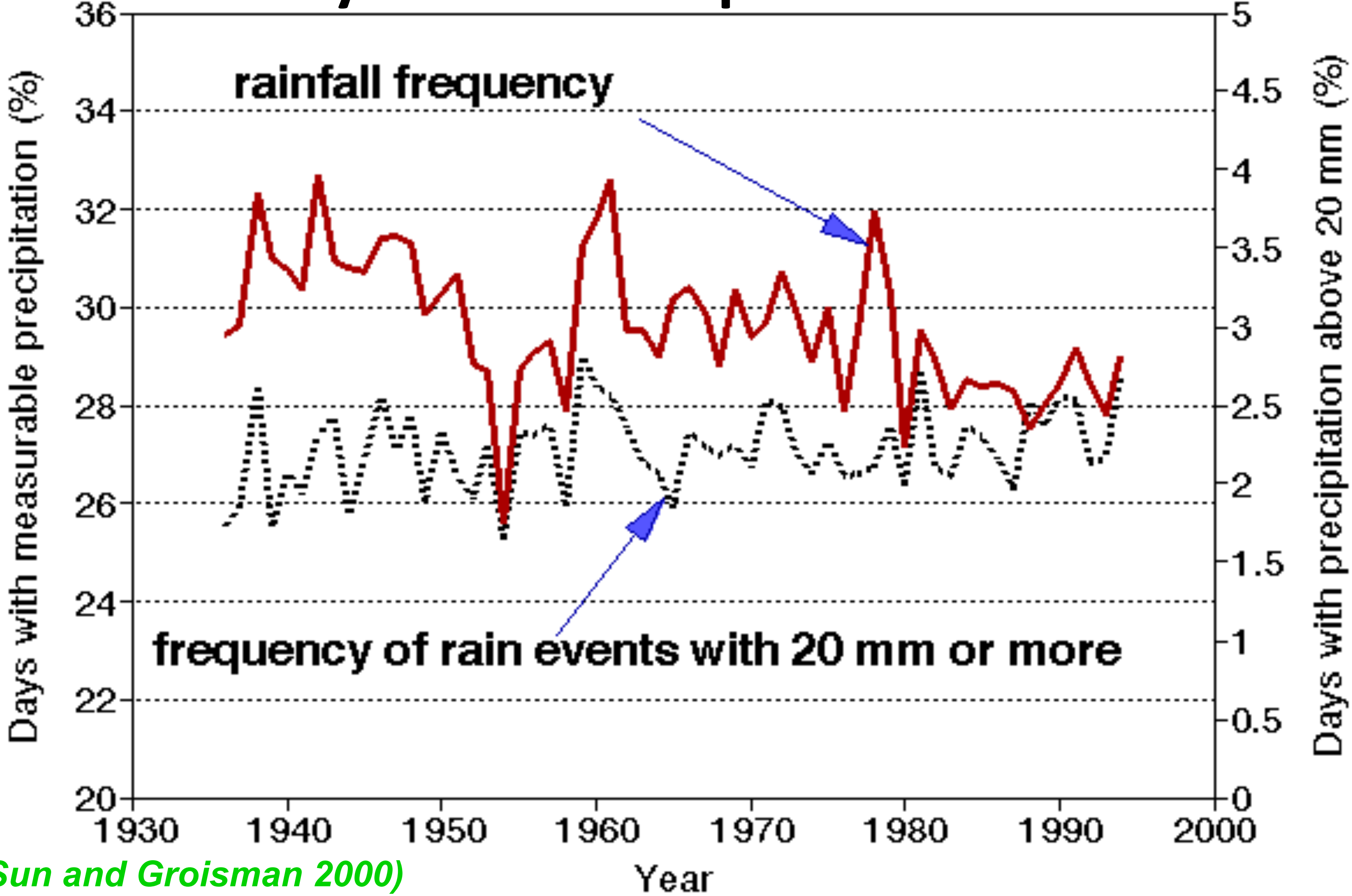
Frequency of rainy days over the northeastern quadrant of the contiguous United States (*both show a decrease during the past 30 years*).

- **Observations** (Northeast and Midwest regions) for 1893-2009.
- **ECHAM4 (35N-45N; 75W-85W;** adapted from Semenov & Bengtsson 2002) 10 year running mean values for 1900-2090.



(Groisman et al. 2005, updated to 2009)

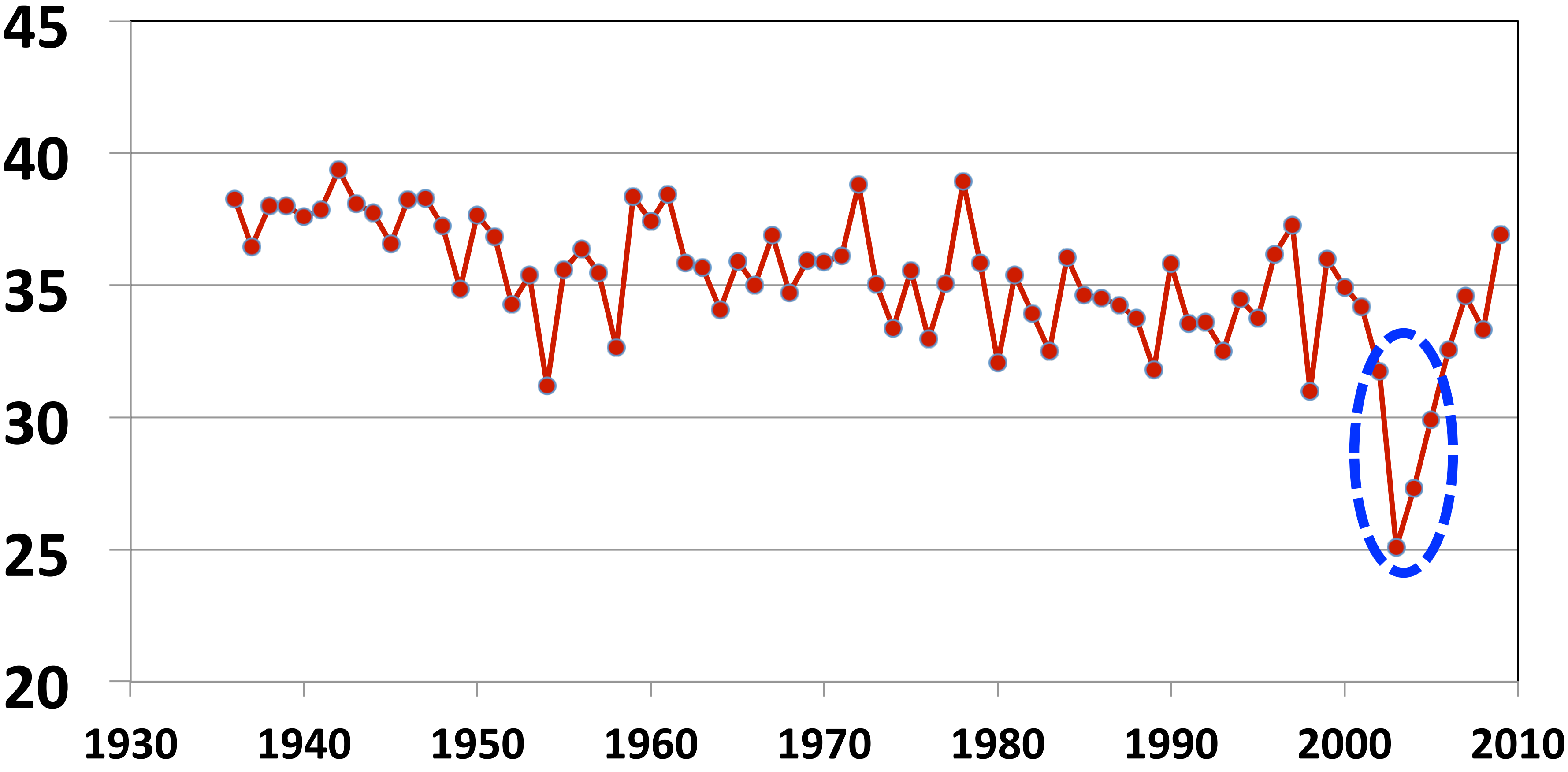
Summer frequency of rainy days and days with heavy rains. Asian part of Russia



(*Sun and Groisman 2000*)

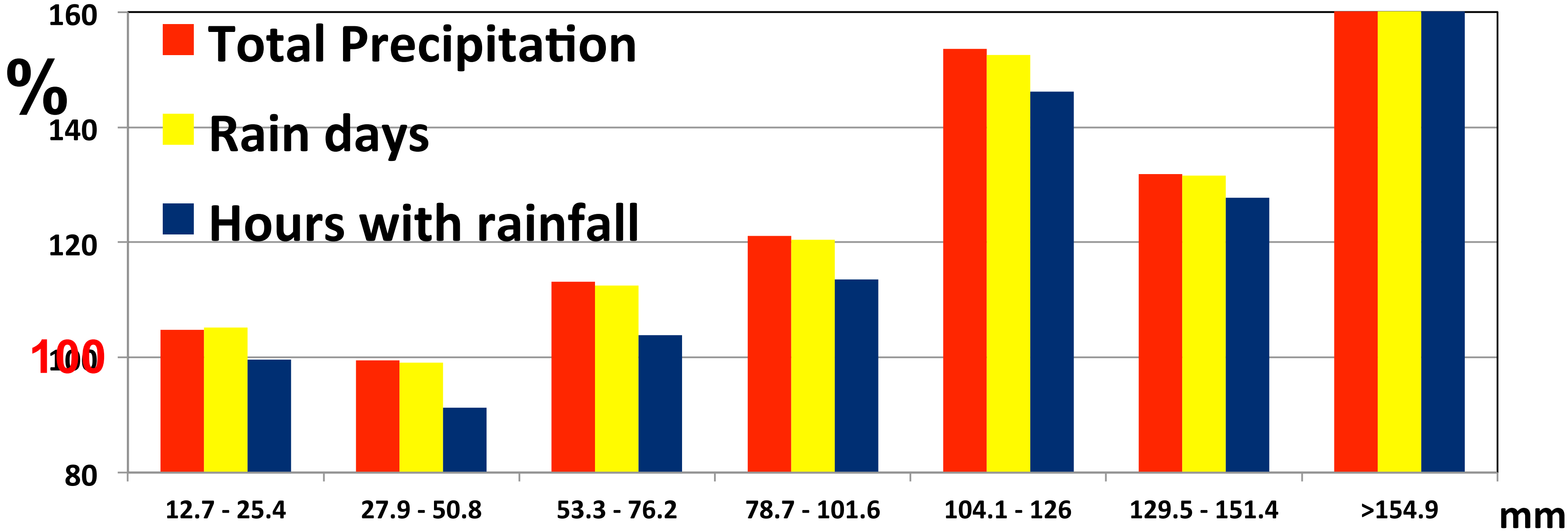
Summer frequency of rainy days over Asian Russia

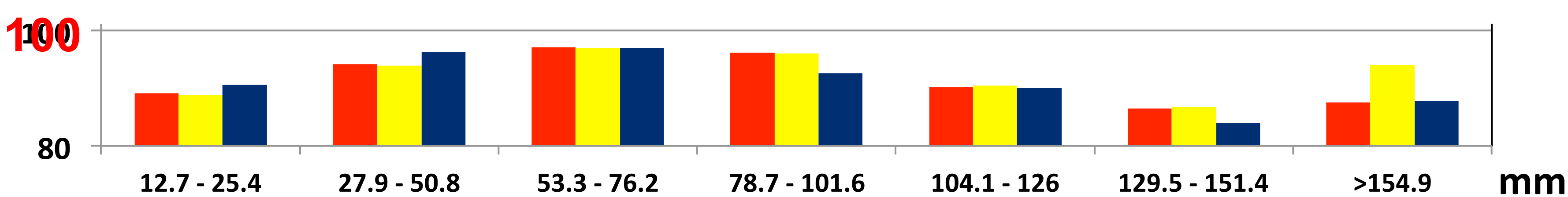
Summer days with P>0.5 mm, %



(Sun and Groisman 2000, updated)

Comparison of intense precipitation characteristics during the June-November season over the Southeastern U.S. associated with tropical cyclones (TC) for the 31 years of warmest and coldest Northern Hemisphere temperatures during the 1948-2009 period (top) and other not-associated with TC intense rainfall (bottom)

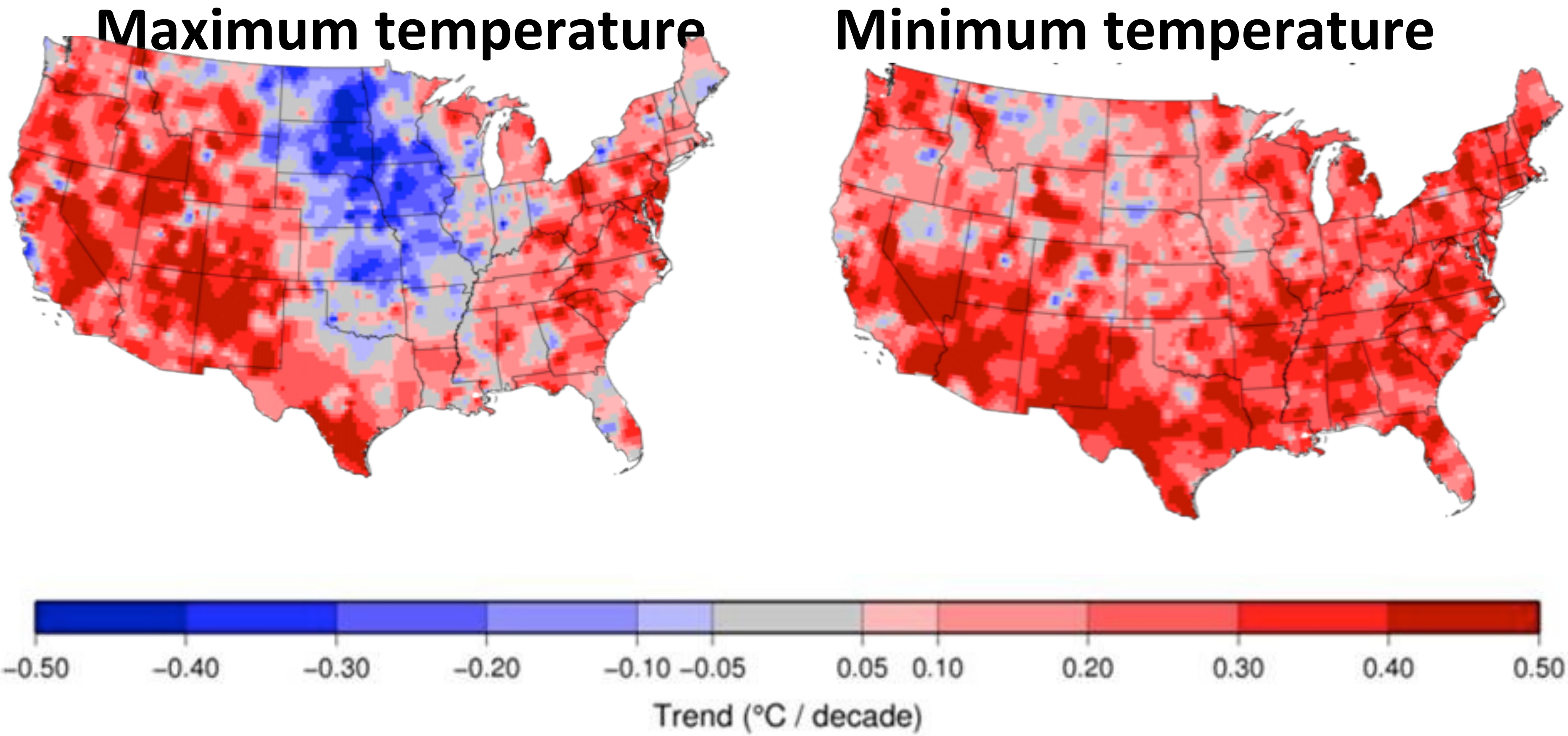




Estimates of precipitation characteristics for these 31-yr periods were averaged and their ratios (in percent per station) are shown sorted by day rainfall intensity ranges

Intensification of land use

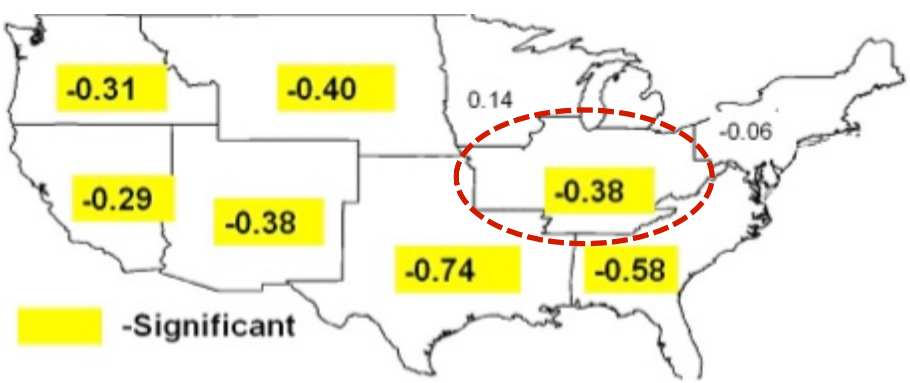
Summer (JJA) surface air temperature linear trends, 1970-2010



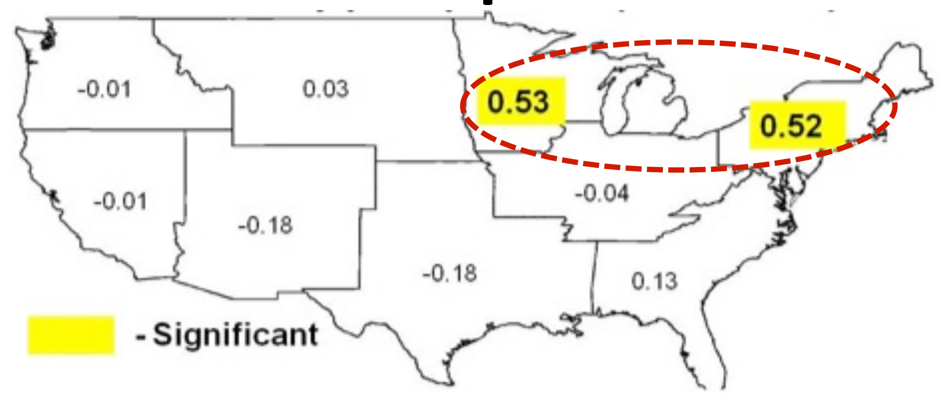
Temperature data were bias-adjusted (Menne et al. 2009)

Correlation of the warm season temperatures with D, the number of days with heavy precipitation >25.4 mm.

Maximum temperature

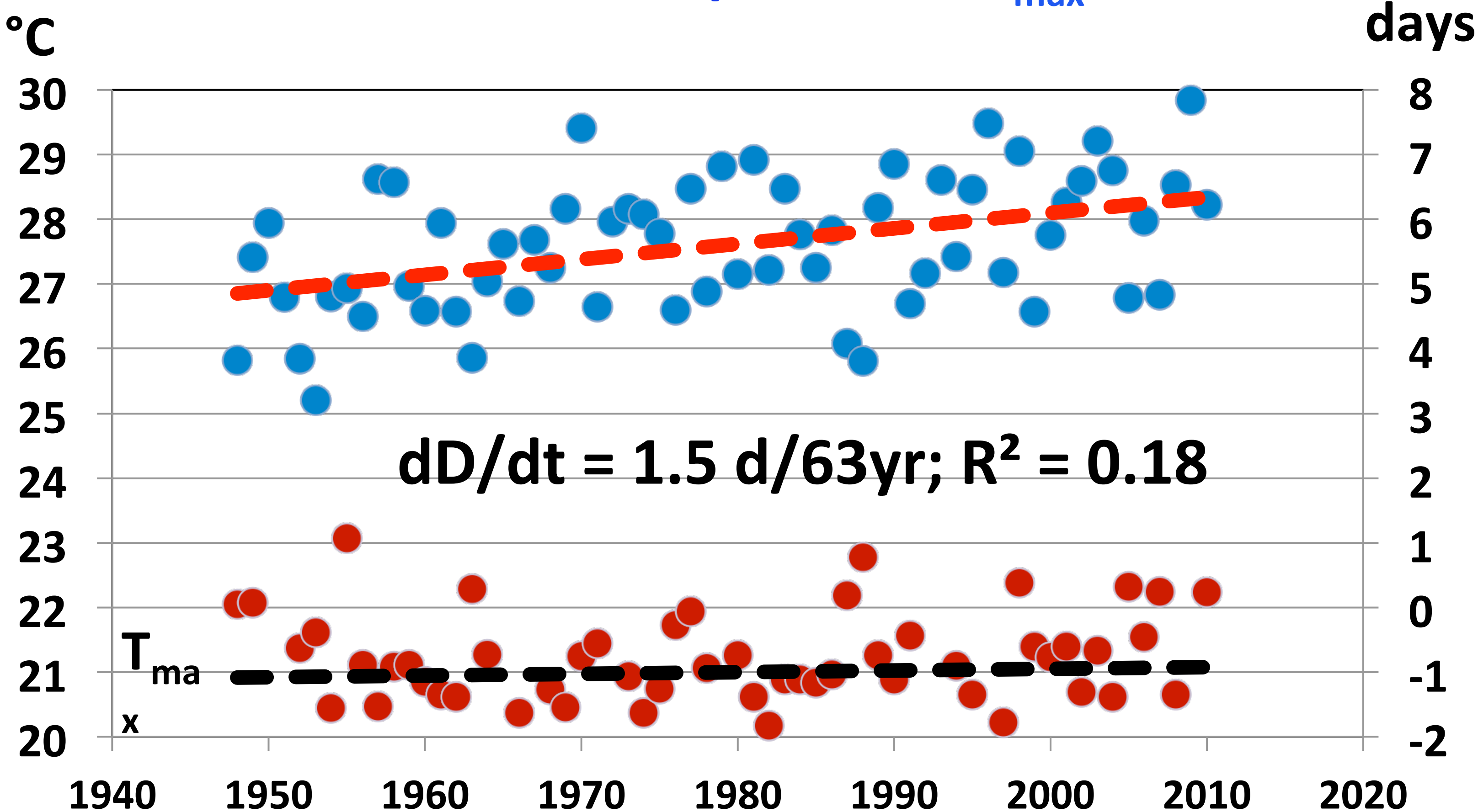


Minimum temperature



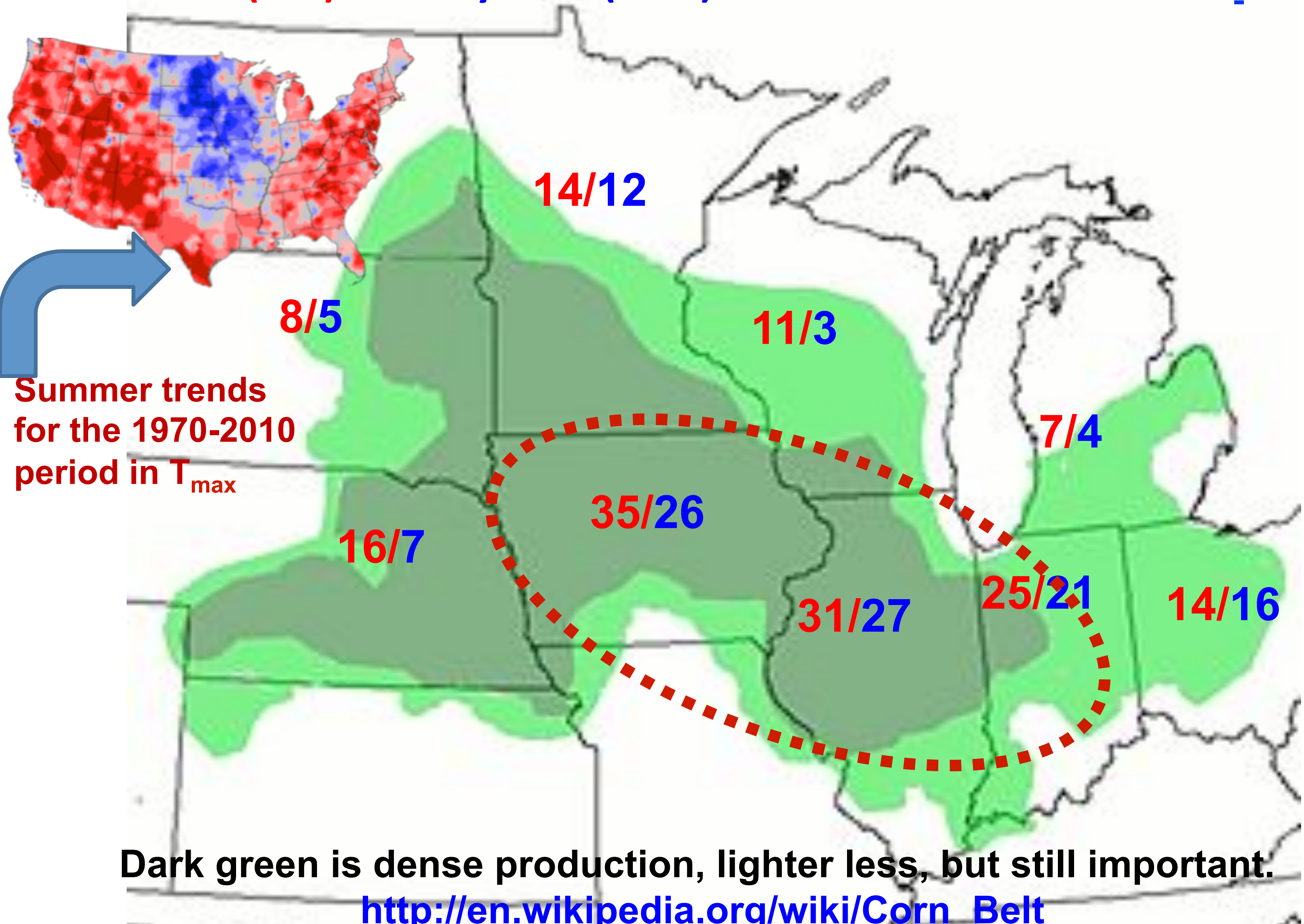
On the interannual time scale, D is negatively correlated with T_{max} over most of the contiguous U.S. except the Great Lakes and Northeast where it is positively correlated with T_{min} (and these correlations remain intact after detrending).

Changes of the number of days with heavy rainfall in the warm season regionally averaged over Midwest, D, and mean seasonal maximum temperatures, T_{max}



After accounting for effect of D on T_{max}, the T_{max} residual time series shows an increase by 0.62°C/63yr. Rate of change in D is 1.5 days or 27% per 63 years.

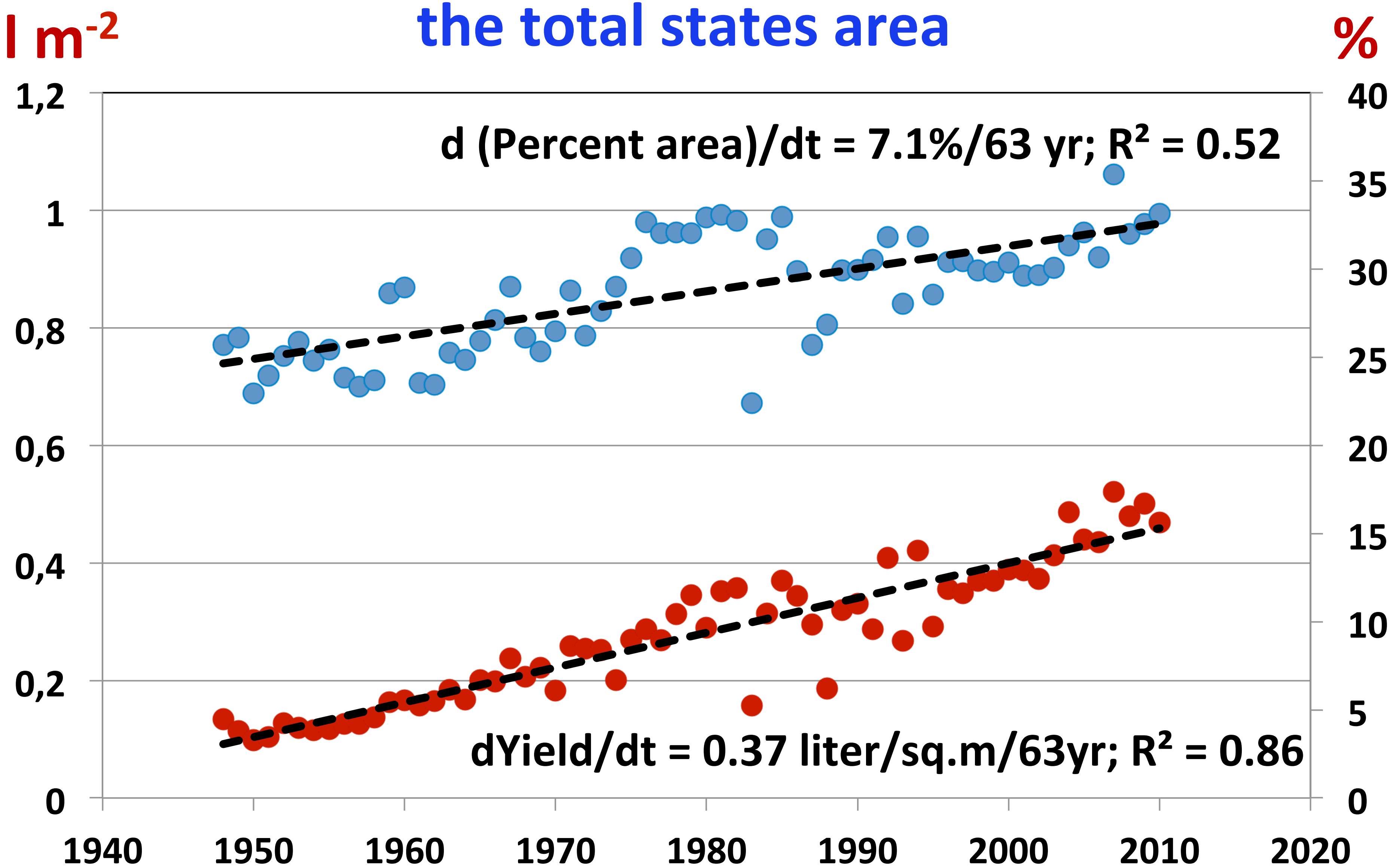
U.S. Corn Belt States with the areas (% of total land area) occupied by corn (red) and soybean (blue) fields in last three decades



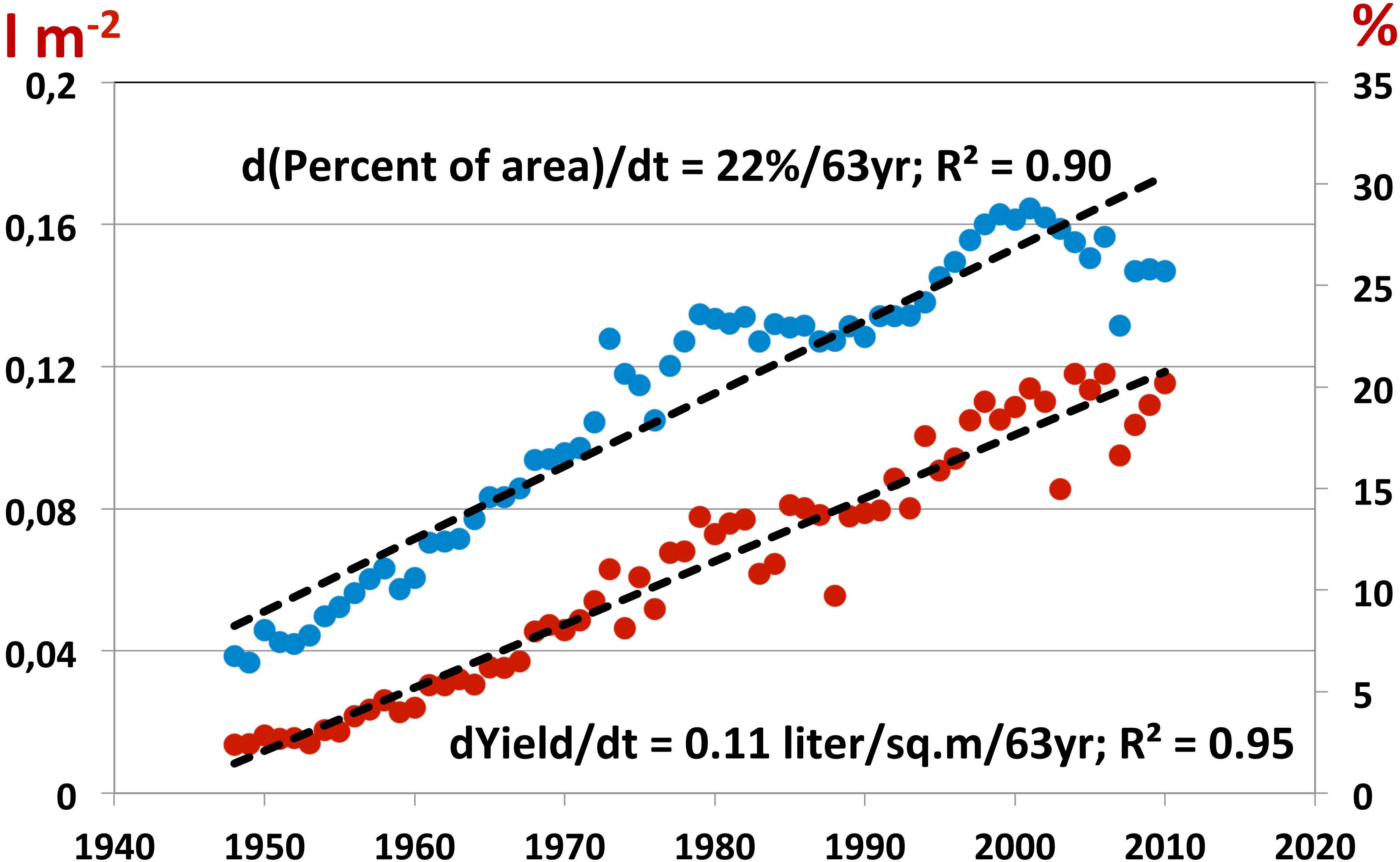
Dark green is dense production, lighter less, but still important.

http://en.wikipedia.org/wiki/Corn_Belt

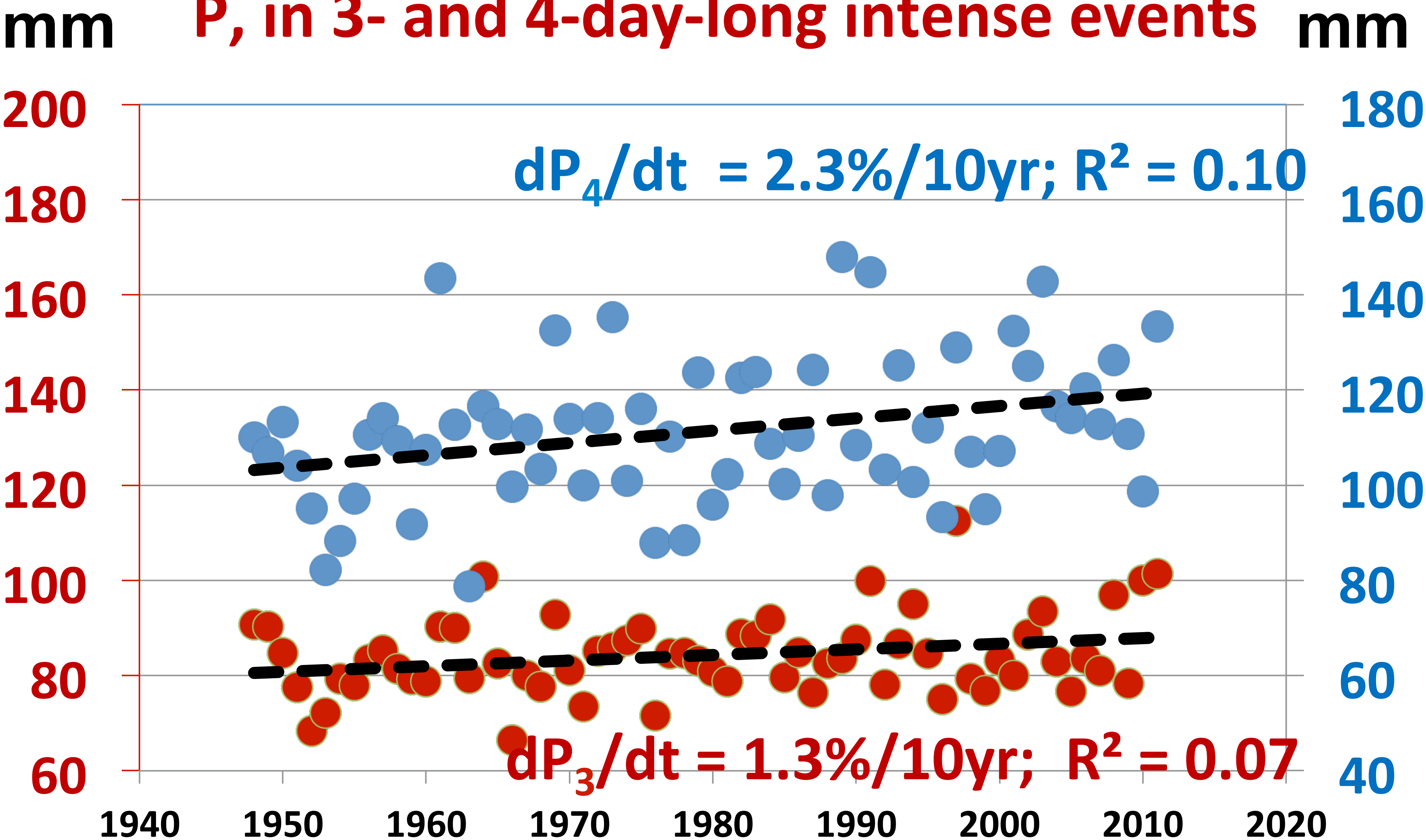
Core Midwest (IA, IL, and IN) States. Areas with corn harvested, %, and yield (liter m^{-2}) related to the total states area



Core Midwest (IA, IL, and IN) States. Areas with soybeans harvested, %, and yield (liter m^{-2}) related to the total states' area



Midwestern United States. Mean rainfall, P, in 3- and 4-day-long intense events



Day with intense precipitation is defined as a day with P > 12.7 mm

General Statement

- Numerous observational studies show that in the past several decades precipitation has become more intense over most of the extra-tropics
- At the same time, (and often in the same regions) precipitation events may occur less frequently or come in sequences of prolonged no-rain and wet periods
- European Russia and most of the contiguous U.S. are among these regions