# Prolonged Dry Episodes Over Northern Eurasia and North America: New Tendencies Emerging during the Last 40 Years

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**NEESPI/LCLUC Science Team Meeting with focus on the dry land area of Northern Eurasia, Urumqi, China, 16-21 Sept., 2007**

# Plan of the talk

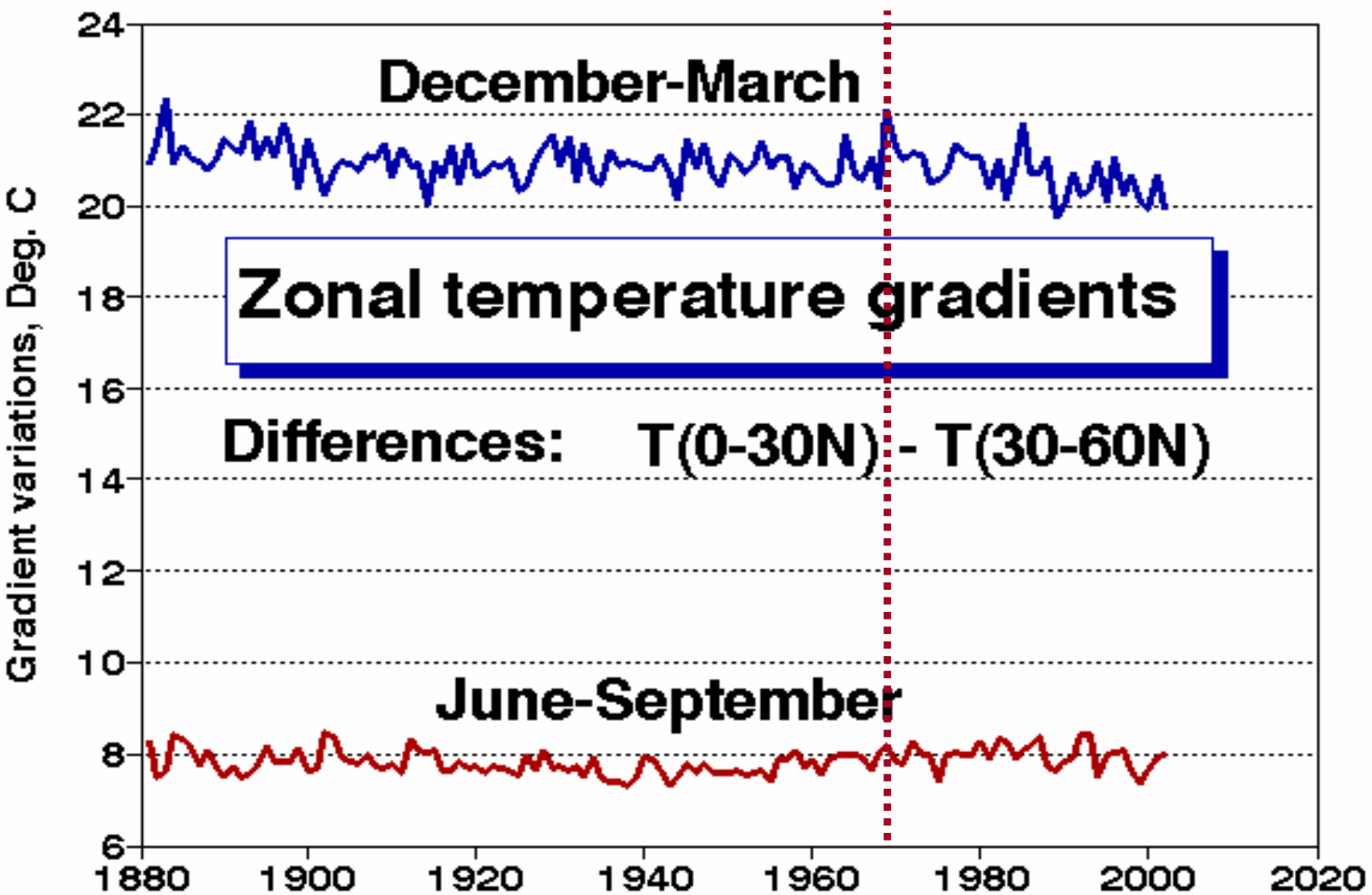
1. Summer dryness, obsevational evidence
2. Prolonged dry episodes across Northern Eurasia and North America

# Summer Dryness. Theoretical expectations

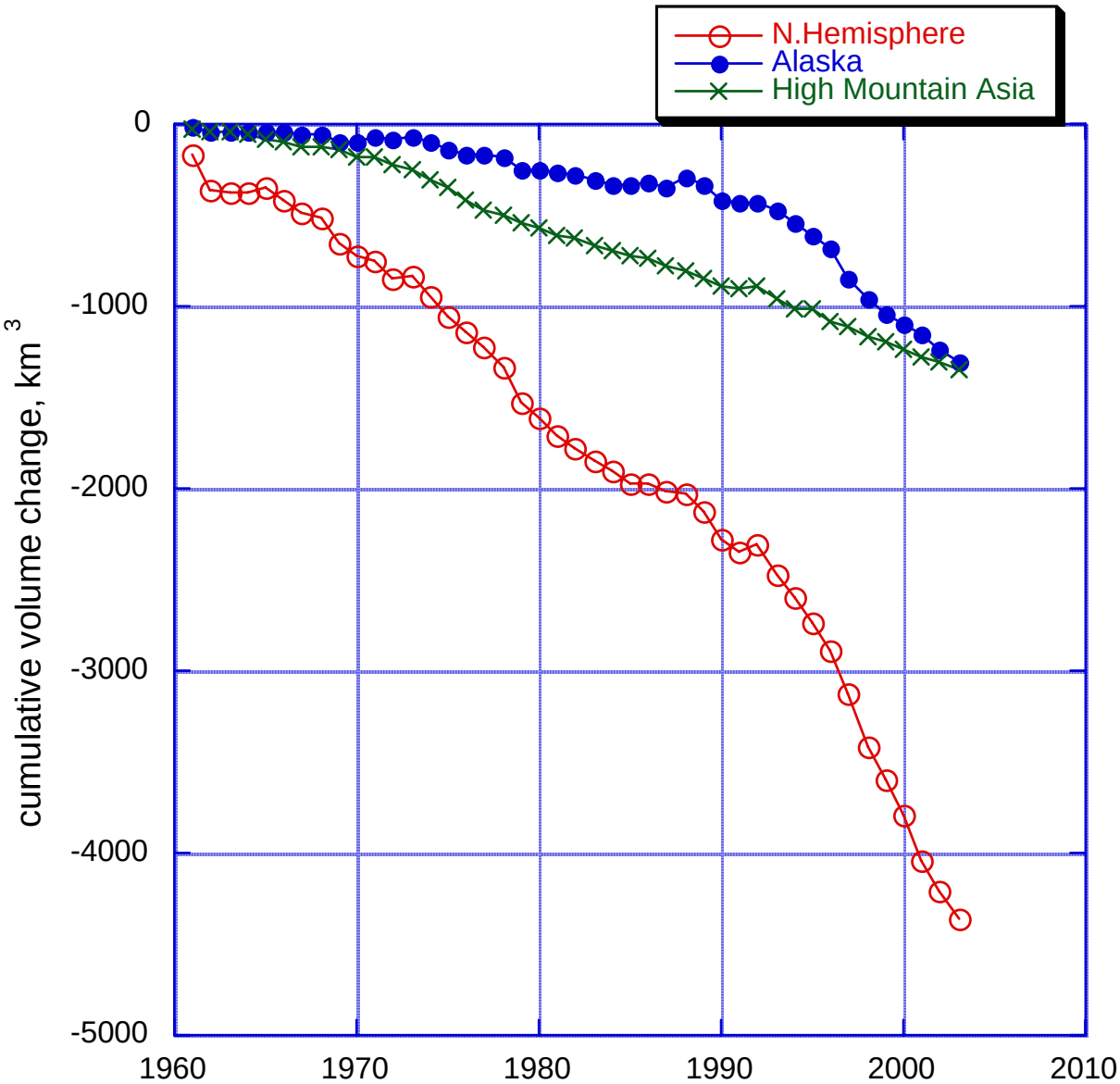
- **Manabe, S., R.T. Wetherald, and R.J. Stouffer**, 1981: Summer dryness due to an increase of atmospheric $CO_2$ concentration. *Climatic Change*, **3**, 347-386
- **Manabe, S., R. T. Wetherald, P. C. D. Milly, T. L. Delworth, R. J. Stouffer,** 2004: Century-scale change in water availability: $CO_2$ quadrupling experiment. *Climatic Change*, **64**, 59-76.

**Everything else will be empirical evidence**

# Seasonal changes in zonal temperature differences between tropics and mid-latitudes

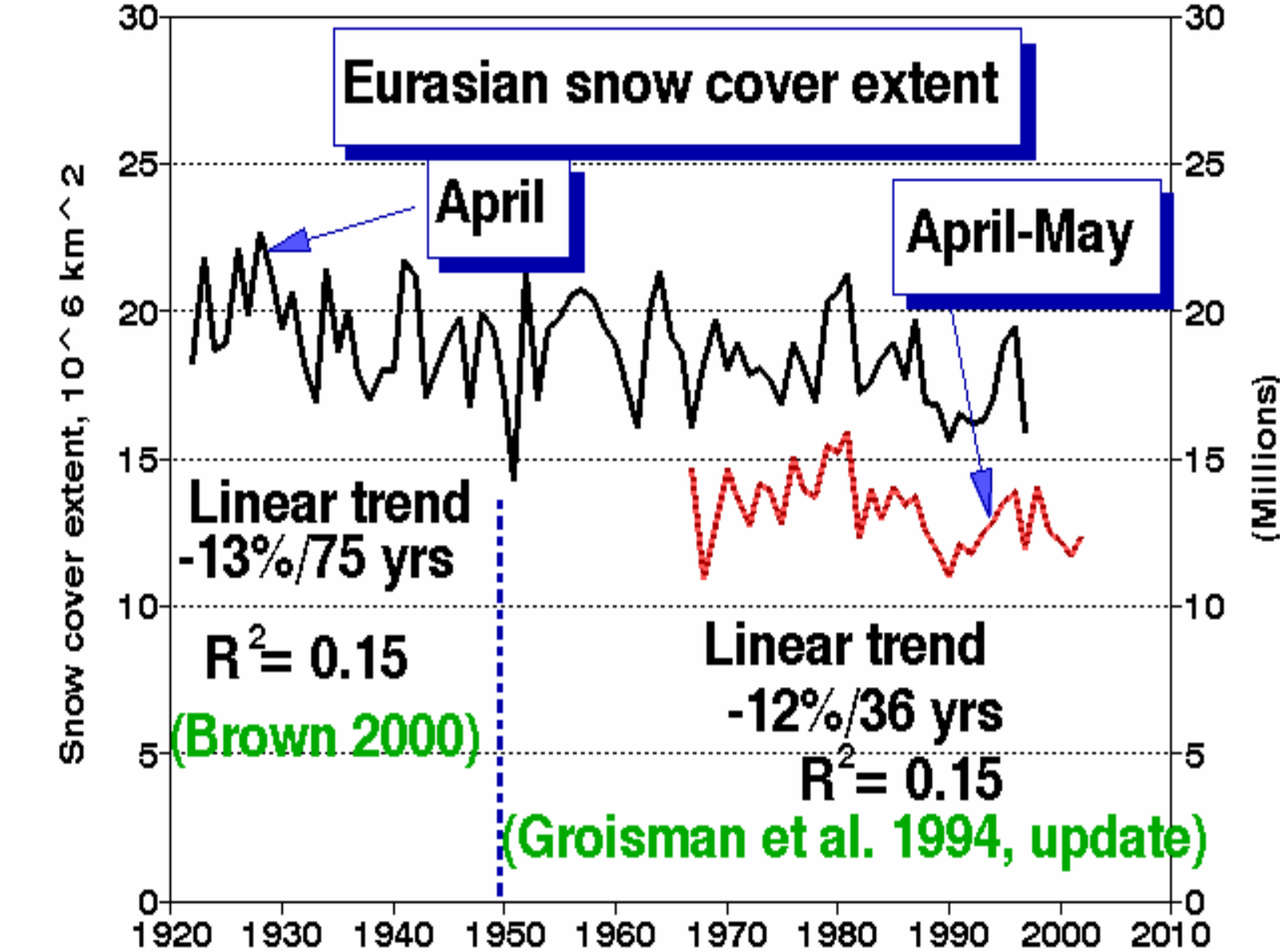


# Changes in glacier volume ($km^3$) since 1960



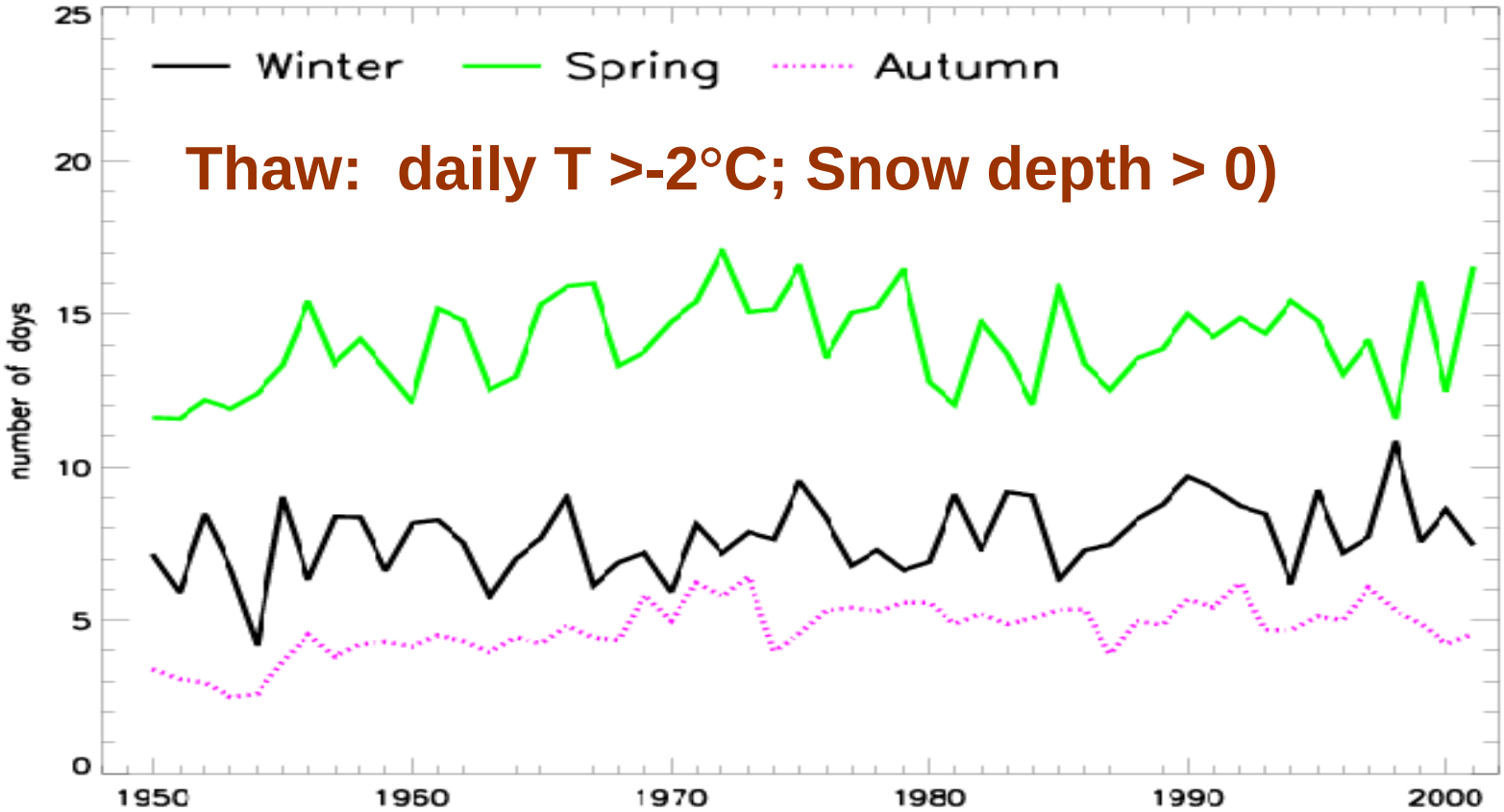

**Source: http://www.nsidc.org**

# Spring snow cover over Eurasia



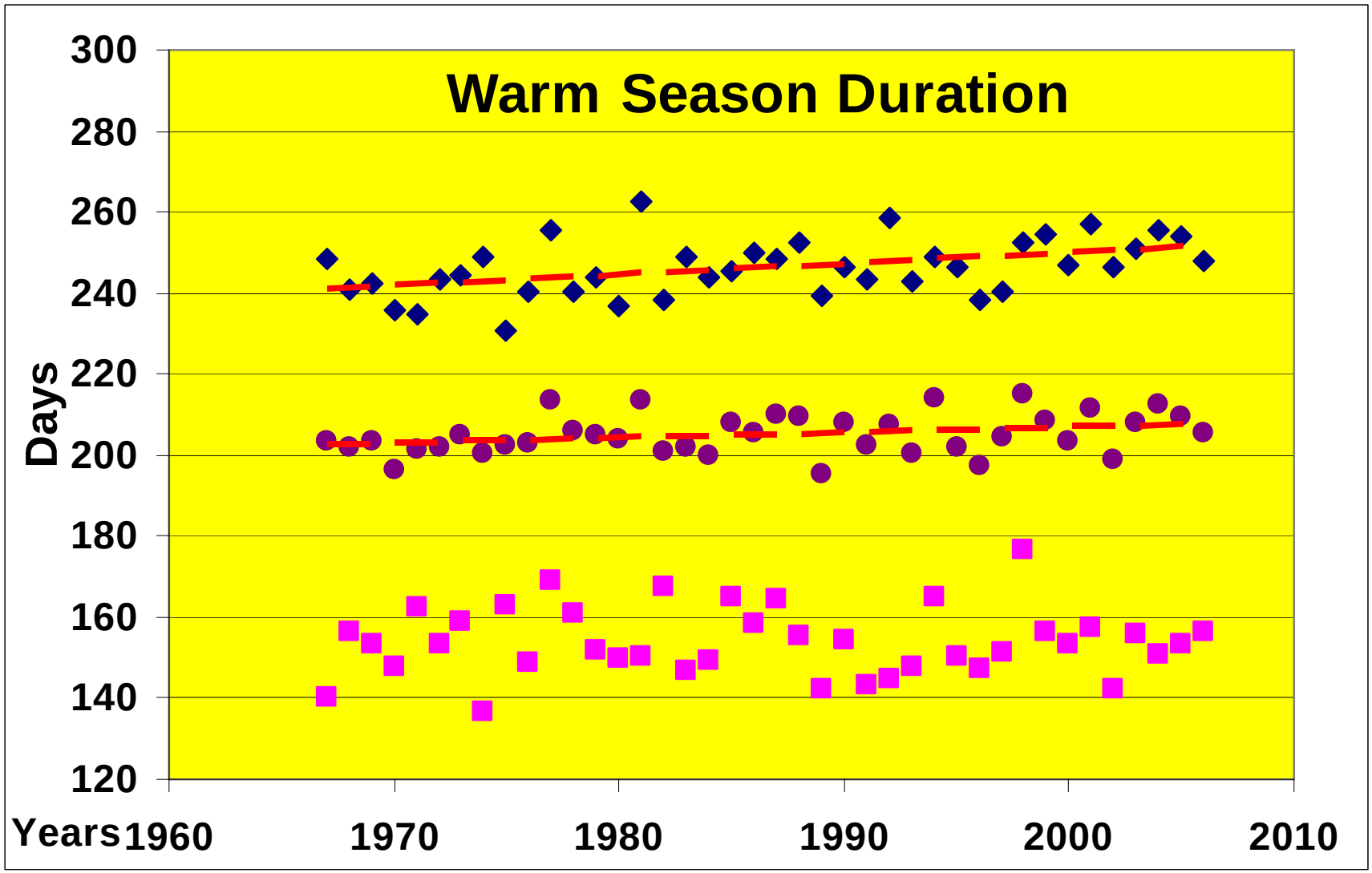
# Frequency of days with thaw

## over Alaska, Canada, and the fUSSR north of 50°N




**a 20% (winter) to 40% (autumn) increase during the second half of the 20th century**

# Warm season duration (T > 5°C) over the conterminous US (dots), southwestern US, (rhombs), and northwestern U.S. (squares)

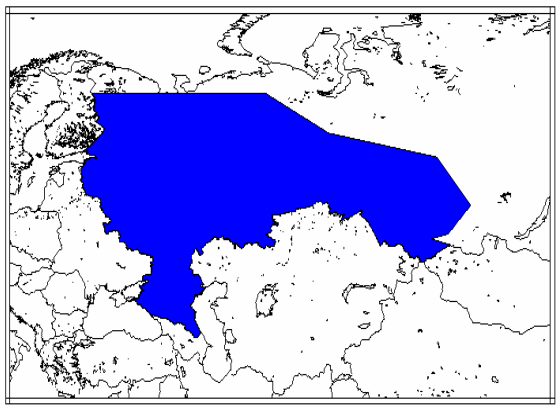


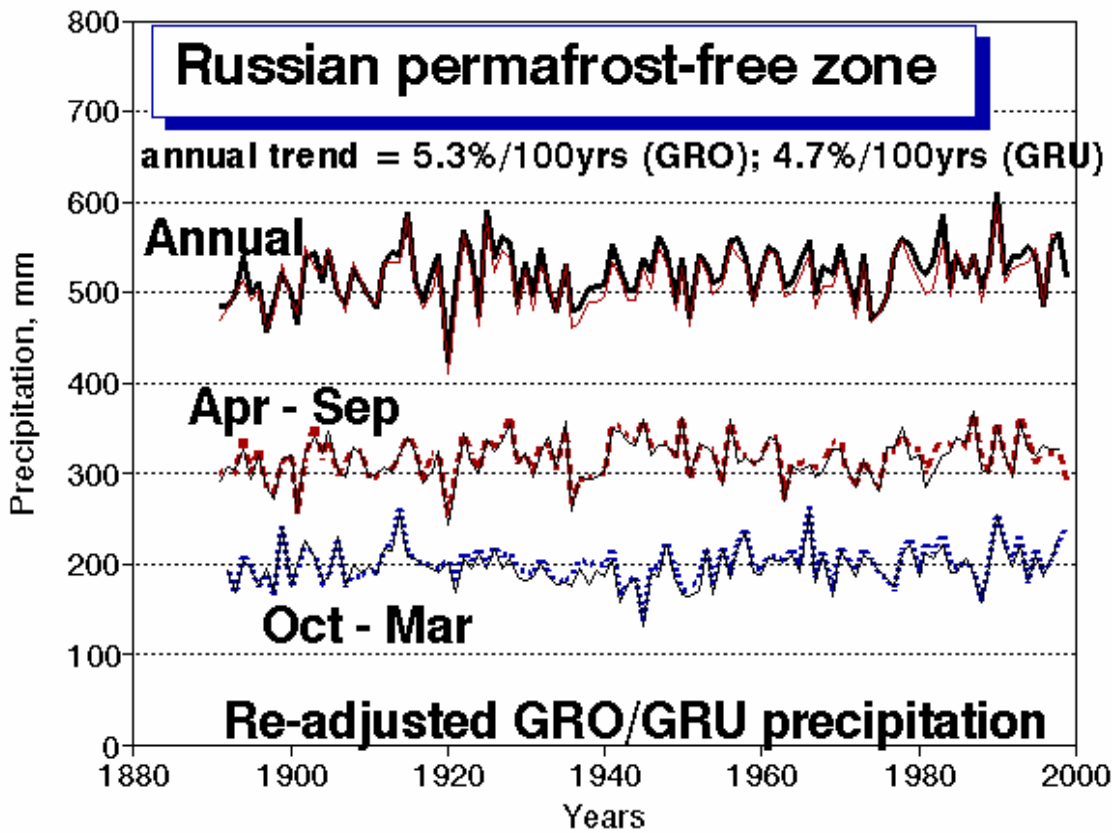
# Changes in derived-temperature characteristics over Northern Eurasia during the past 54 years (within the former USSR boundaries; period 1951-2004)

| Characteristic | Trend estimates, %/54 yrs | |
|---|---|---|
| | Former USSR | Siberia & Russian Far East south of 66.7°N |
| Heating-degree days | -7 | -7 |
| Degree-days below 0ºC | -15 | -14 |
| Degree-days above 15ºC | 11 | 20 |
| Duration of the growing season | | |
| T> 10ºC | 9 | 14 |
| T> 5 ºC | 8 | 12 |
| Duration of the frost-free period | 8 | 11 |

All trend estimates are statistically significant at 0.01 or higher levels

# Major permafrost-free zone of the Russian Federation and its precipitation changes

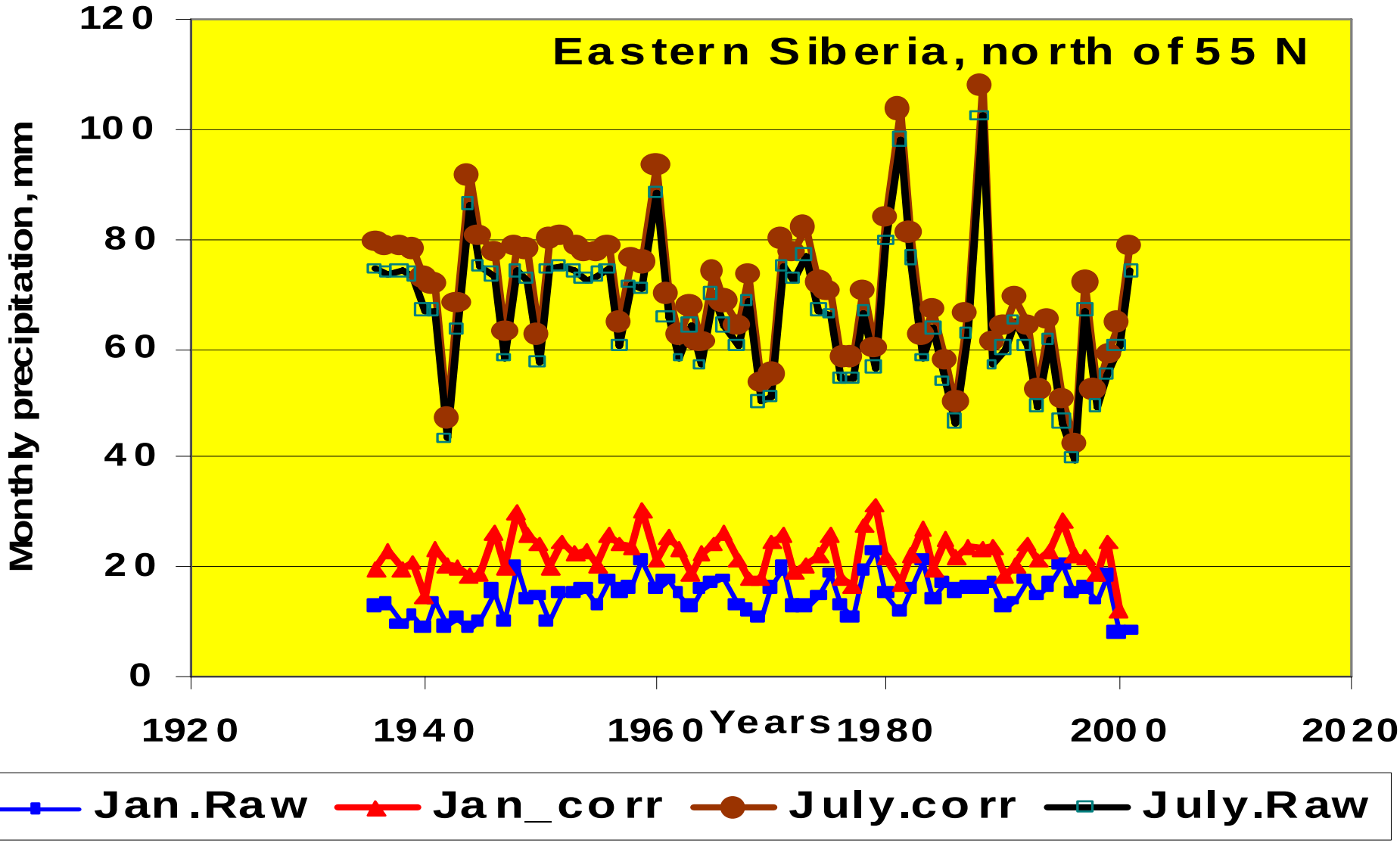




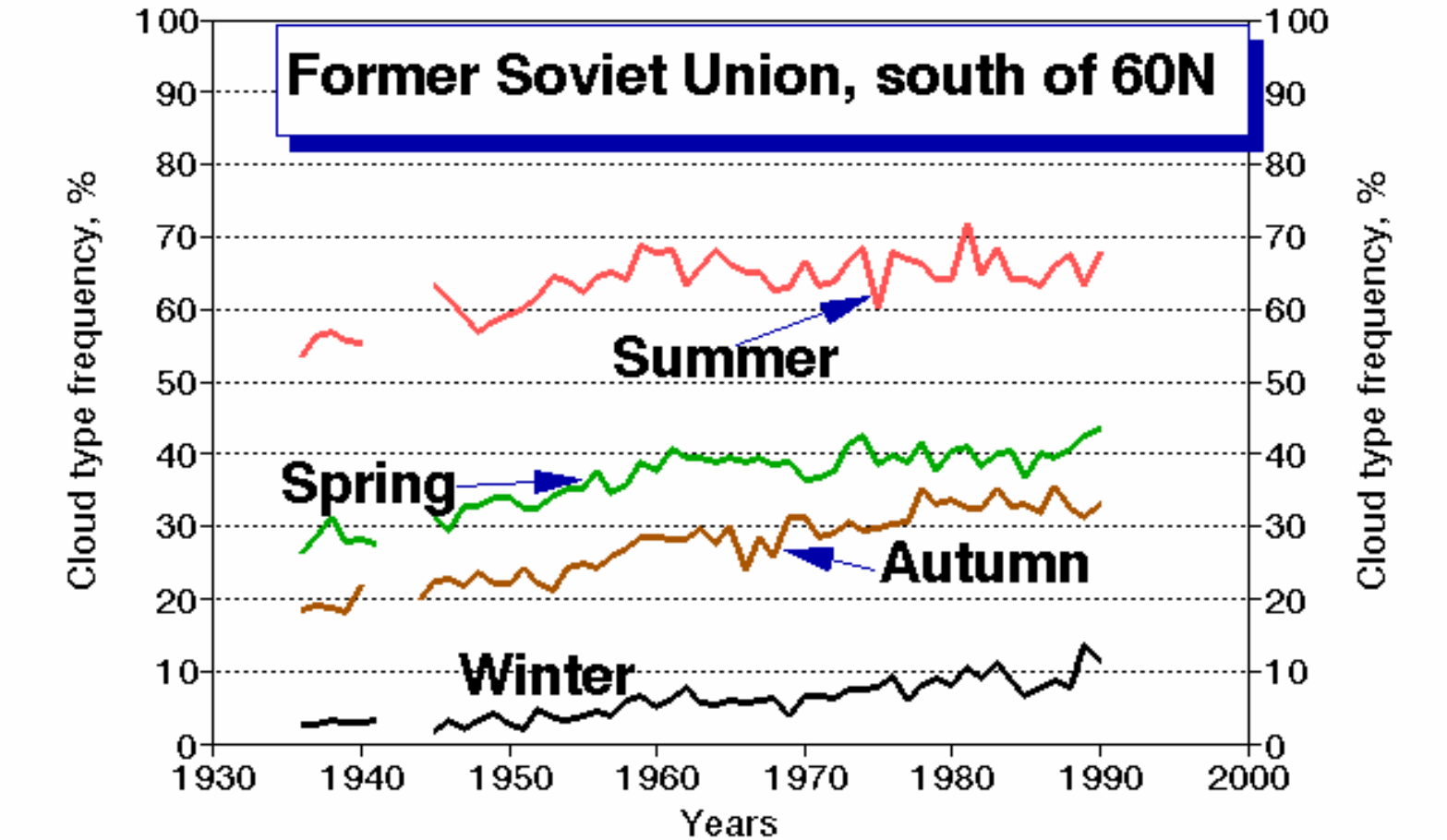

*Groisman and Rankova 2001*

# Eastern Siberia.

## Regionally averaged January and July precipitation prior and after bias correction



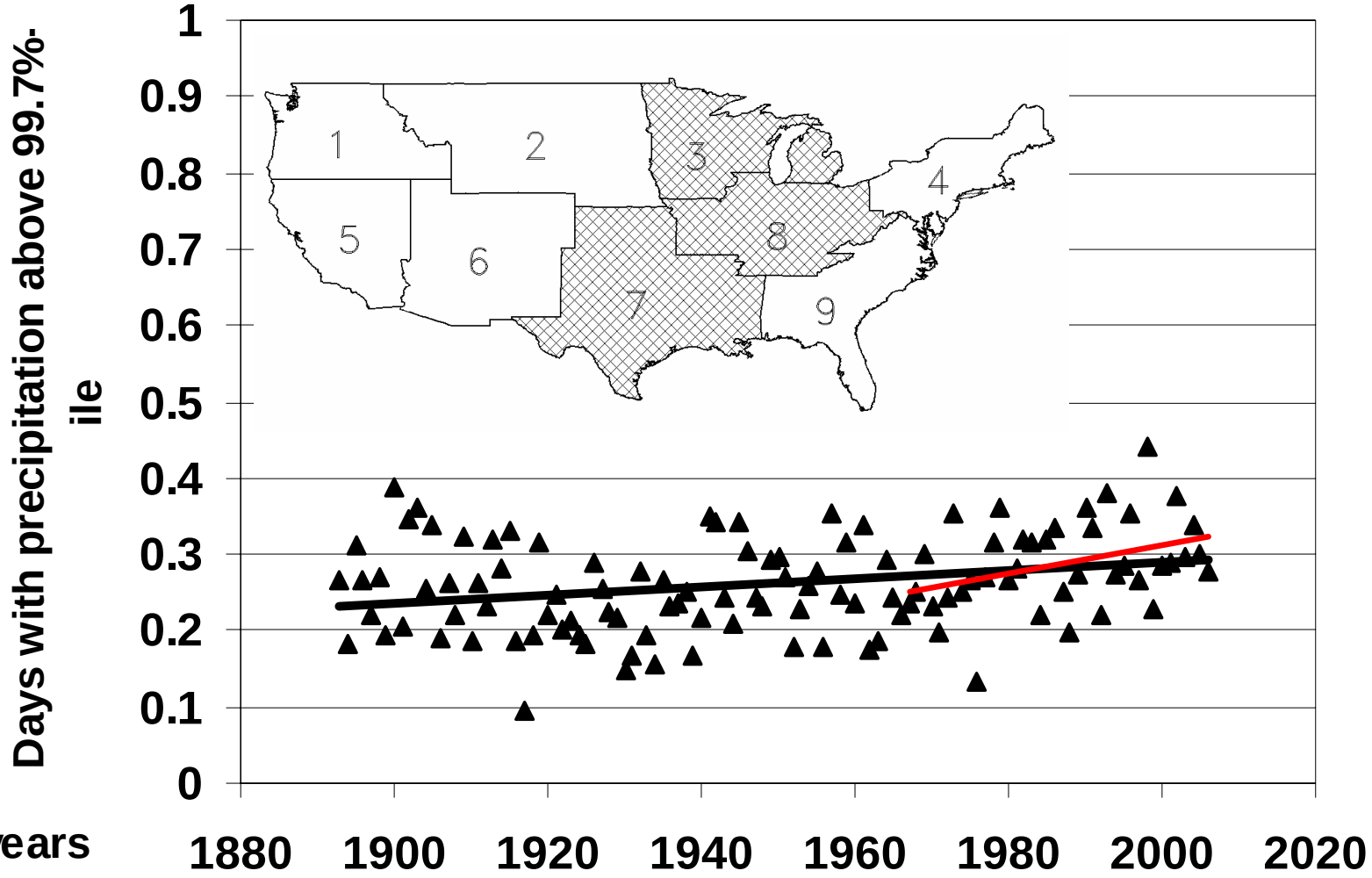
# Seasonal frequency of occurrence of daytime *Cumulonimbus* and *Cumulus*




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

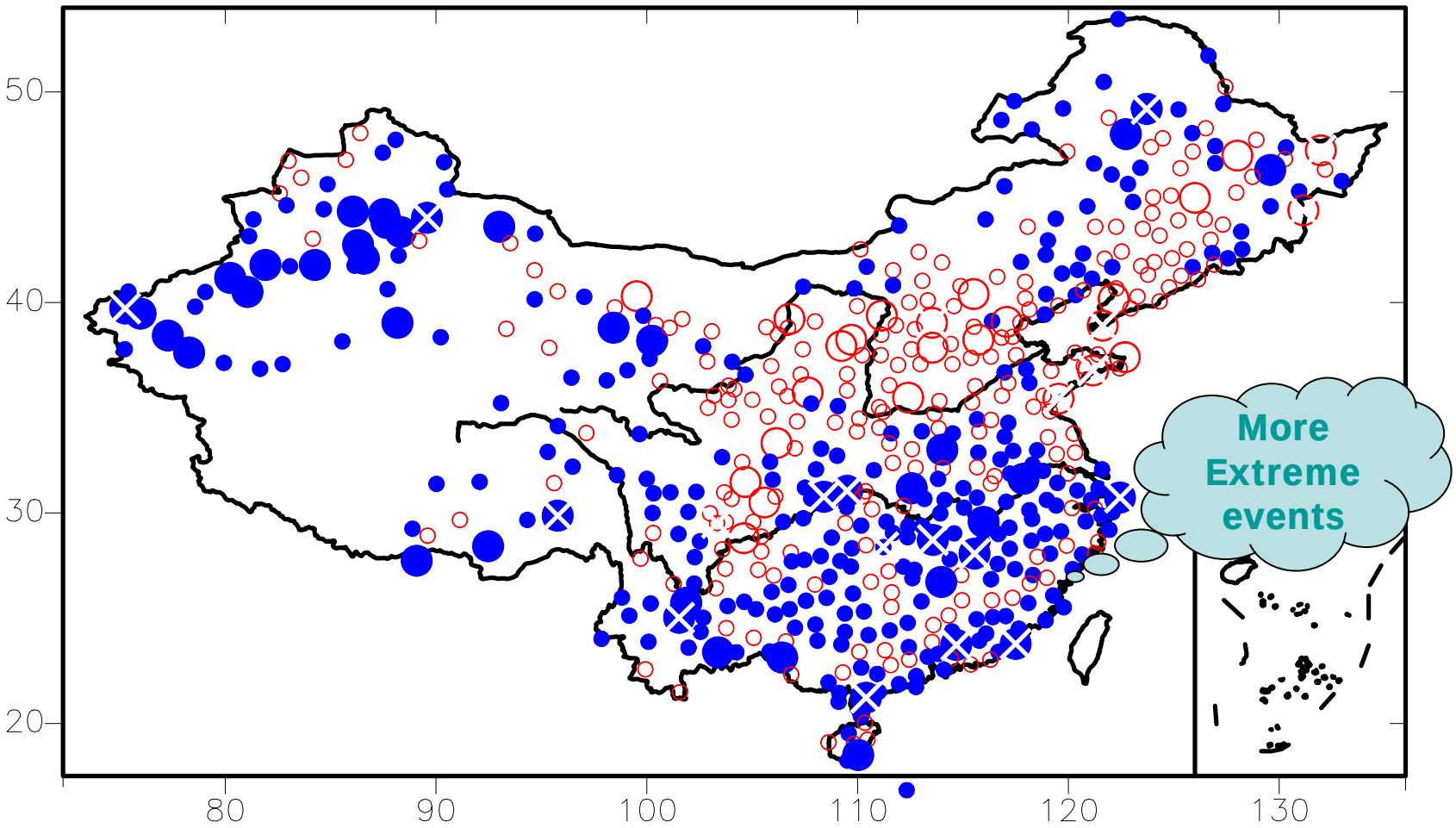
Regions in the Central U.S. where statistically significant annual **increases in very heavy precipitation** were reported and counts of the upper 0.3% of daily rain events (with return period of 4 years)

Linear trends (1893-2006 and 1967-2006) are 22%/114yrs and 27%/40yrs respectively




**Update of Groisman et al. 2005**

# Trends in number of extreme precipitation days derived from 95th percentile

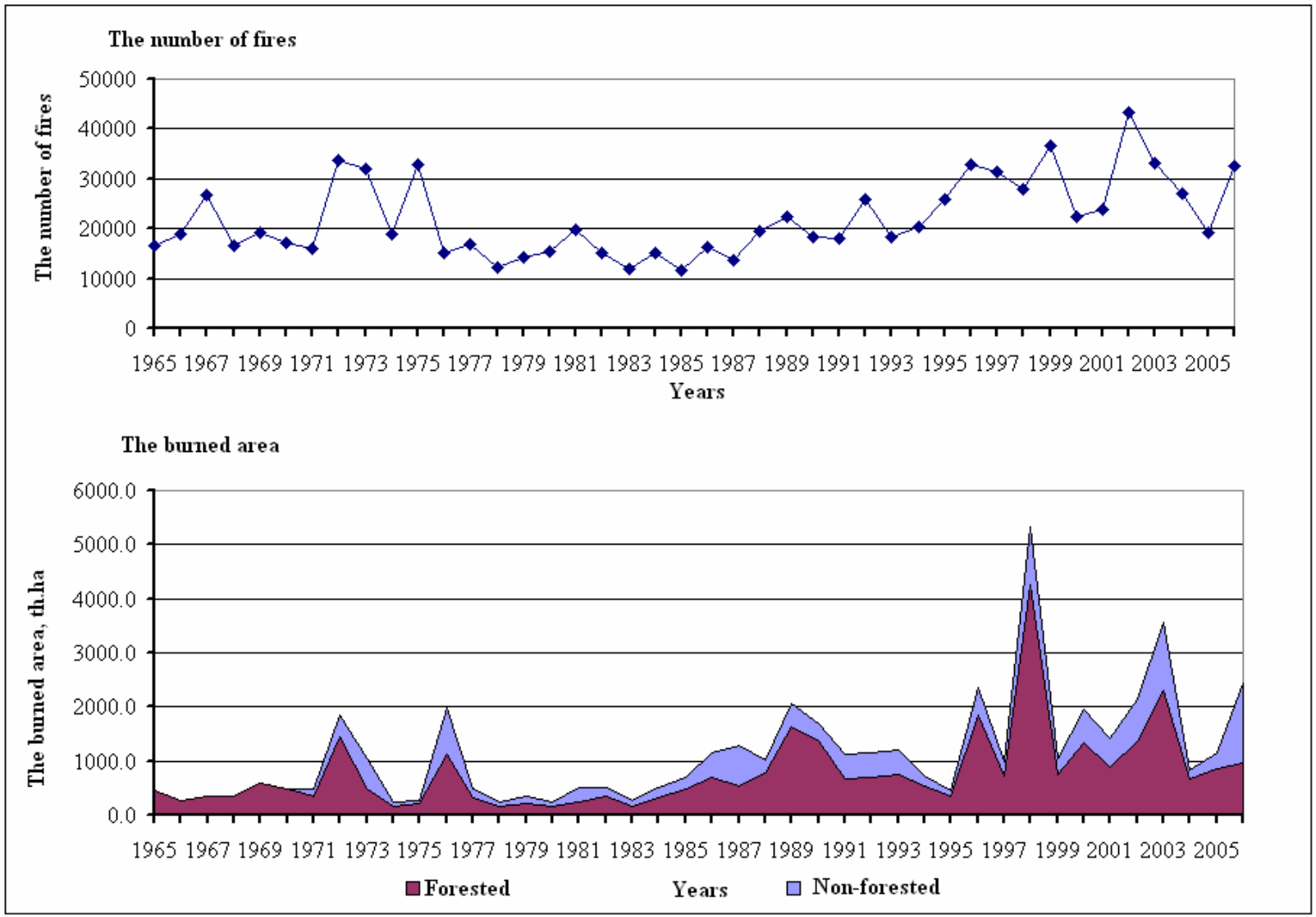



**(Zhai et al. 2007)**

# Thus, in high&mid latitudes we have:

- Up to two-digit (%) increase in temperature derivatives ➔ evapotranspiration may ↑ ;
- Earlier snowmelt & more frequent thaws ➔ more cold season precipitation become unavailable in the warm season;
- Only moderate increase in precipitation but increase in thunderstorm activity ➔ more warm season precipitation goes into runoff;
- All the above ➔ possibility of drier summer conditions ➔ increase in forest fire danger.

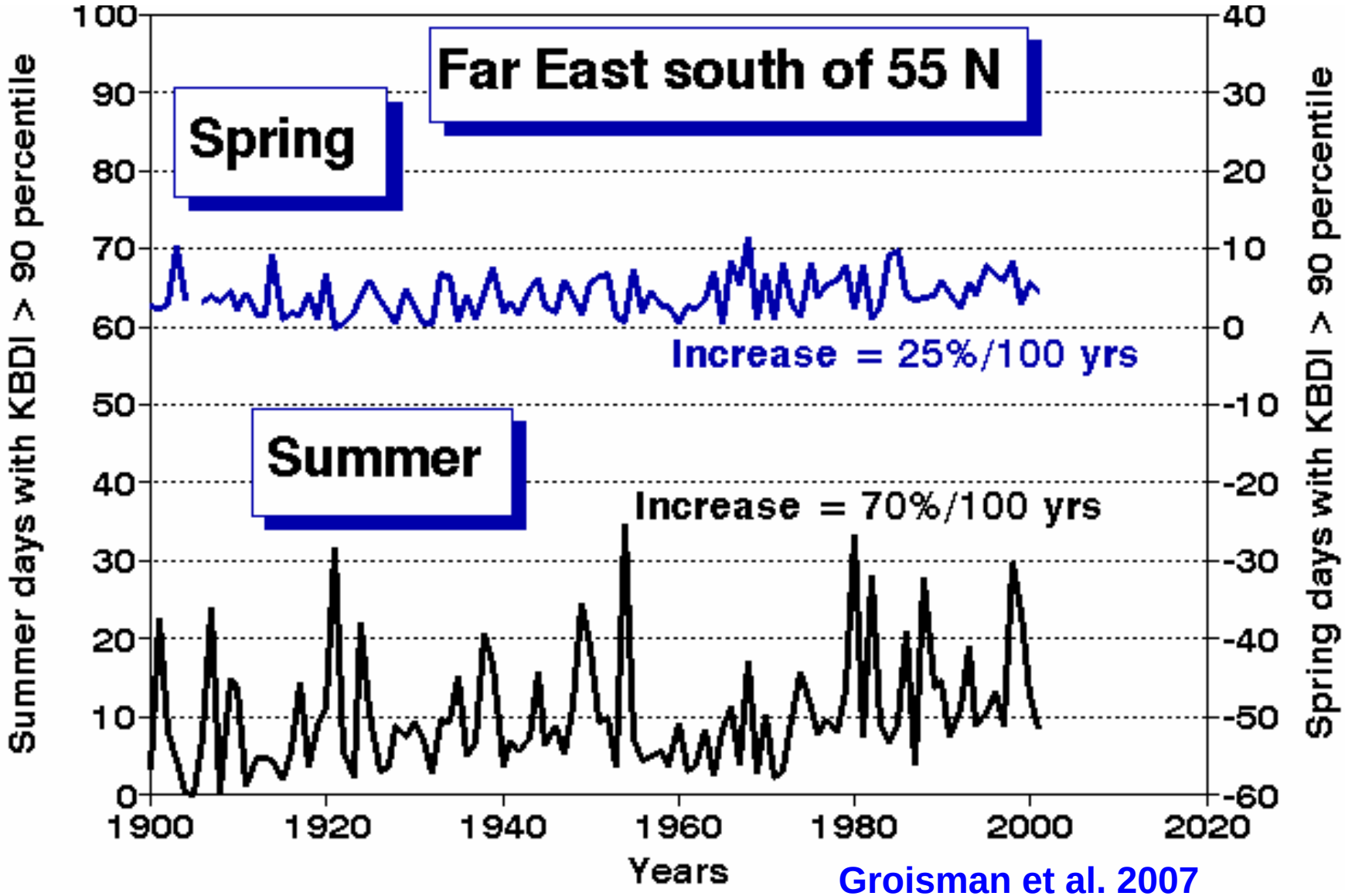
# DYNAMICS OF FIRES NUMBERS AND BURNED AREA (PROTECTED TERRITORY OF RUSSIA)




Korovin and Zukkert 2003, updated

# Potential Forest Fire Danger Increase.

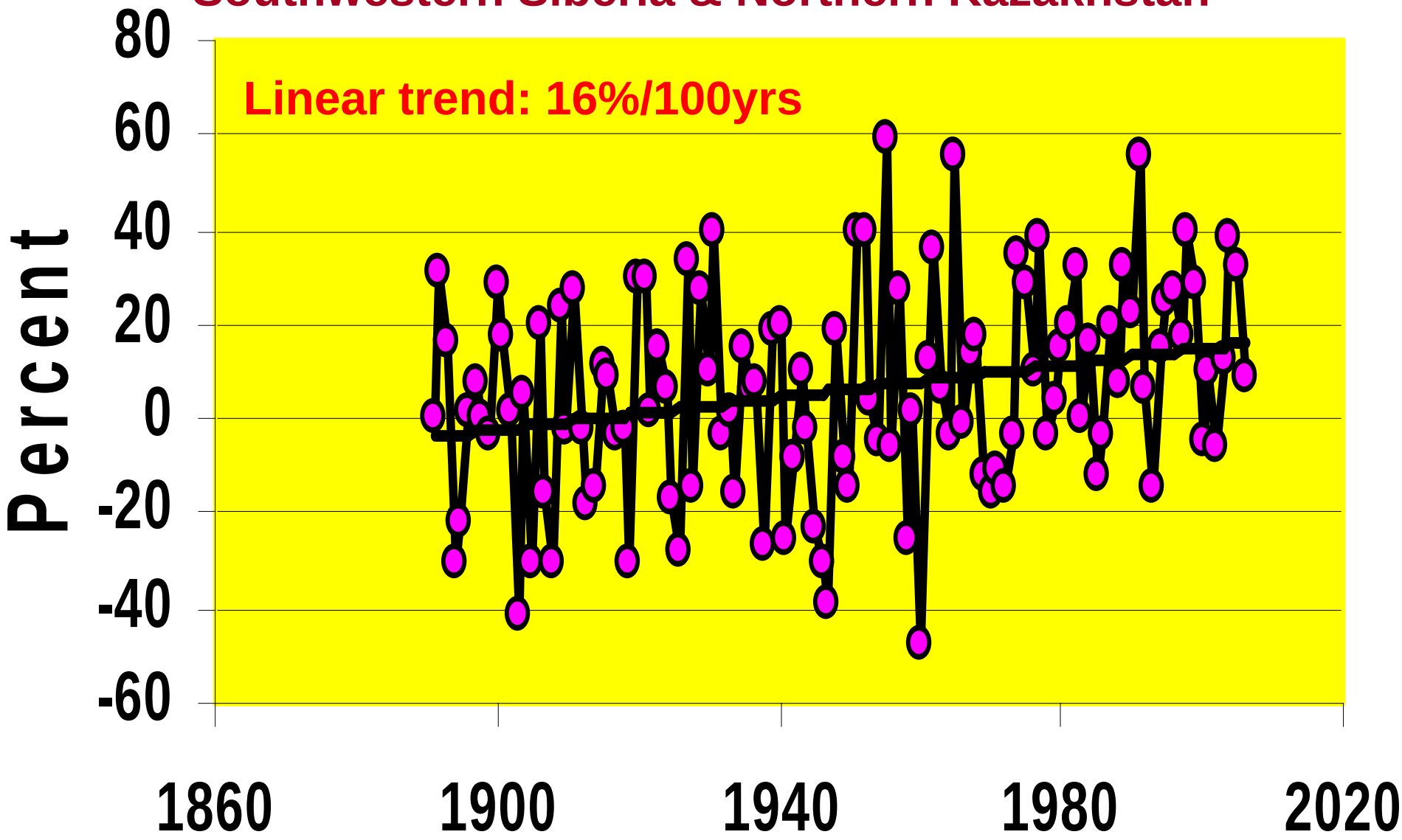
## Russian Far East south of 55°N




Groisman et al. 2007

# May-July drought index for the major cereal-producing region

## Southwestern Siberia & Northern Kazakhstan



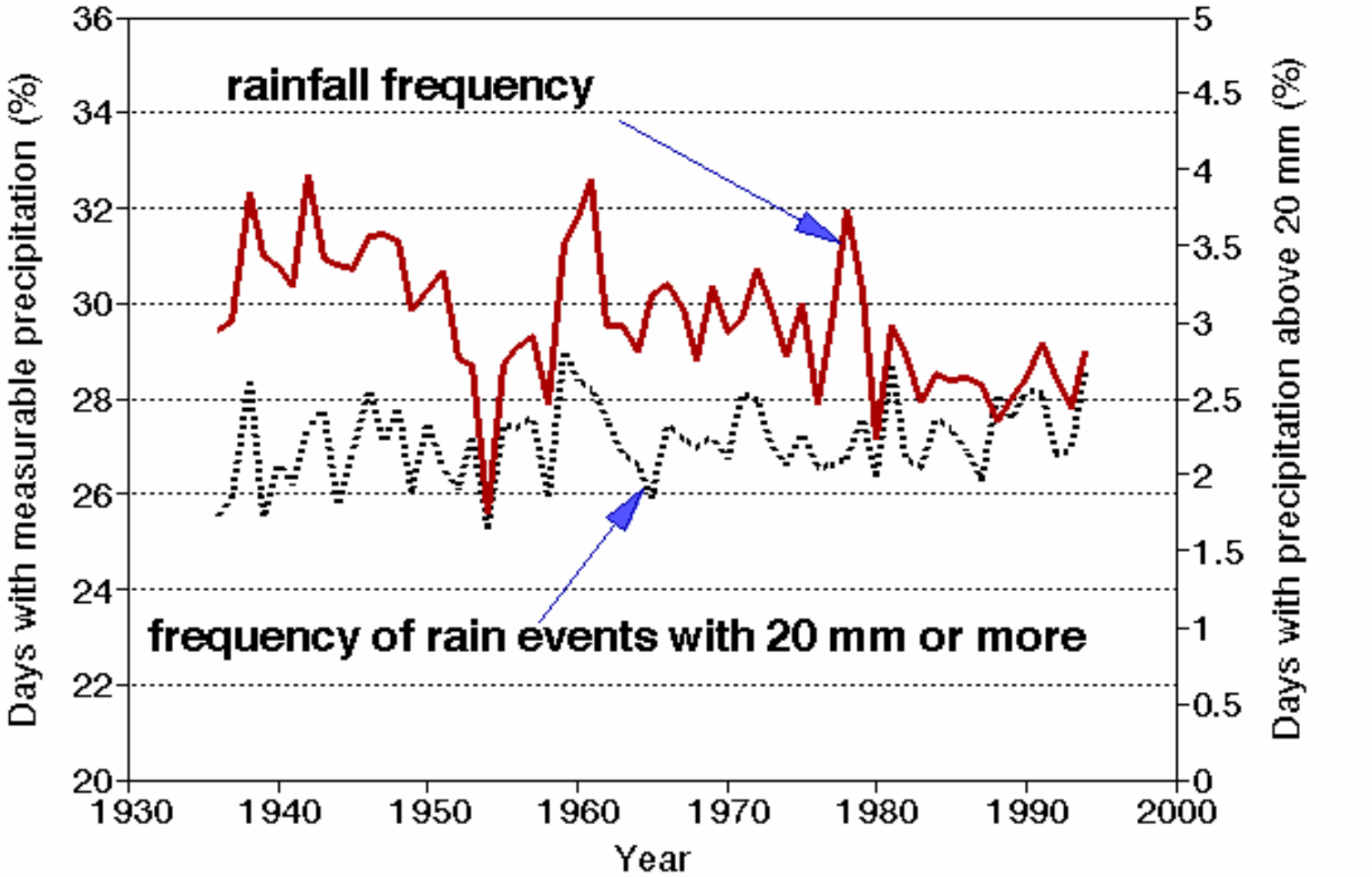

(Mescherskaya & Blazhevich, 1997, updated to 2006)

# Rationale to look on the last 4 decades

- a disproportional increase in precipitation coming from intense rain events
- an extension of the vegetation period with intensive transpiration
- an insignificant change in total precipitation

**All the above could lead to prolonged periods without precipitation (even when seasonal rainfall totals increase)**

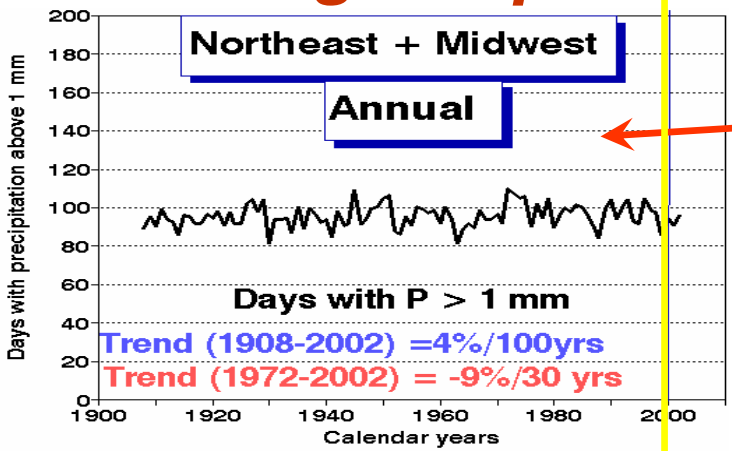
# Summer frequency of wet days and days with heavy rains. Asian part of Russia




*Sun and Groisman 2000*

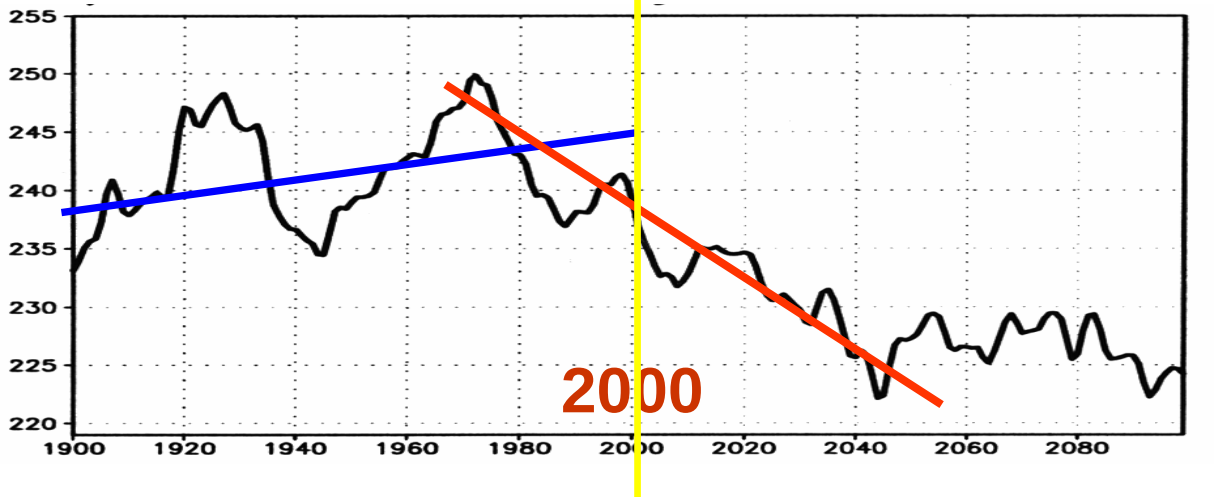
# Frequency of rainy days over the northeastern quadrant of the contiguous United States (*both show a decrease during the past 30 years*).

- **Observations** (Northeast and Midwest regions) for 1908-2002.



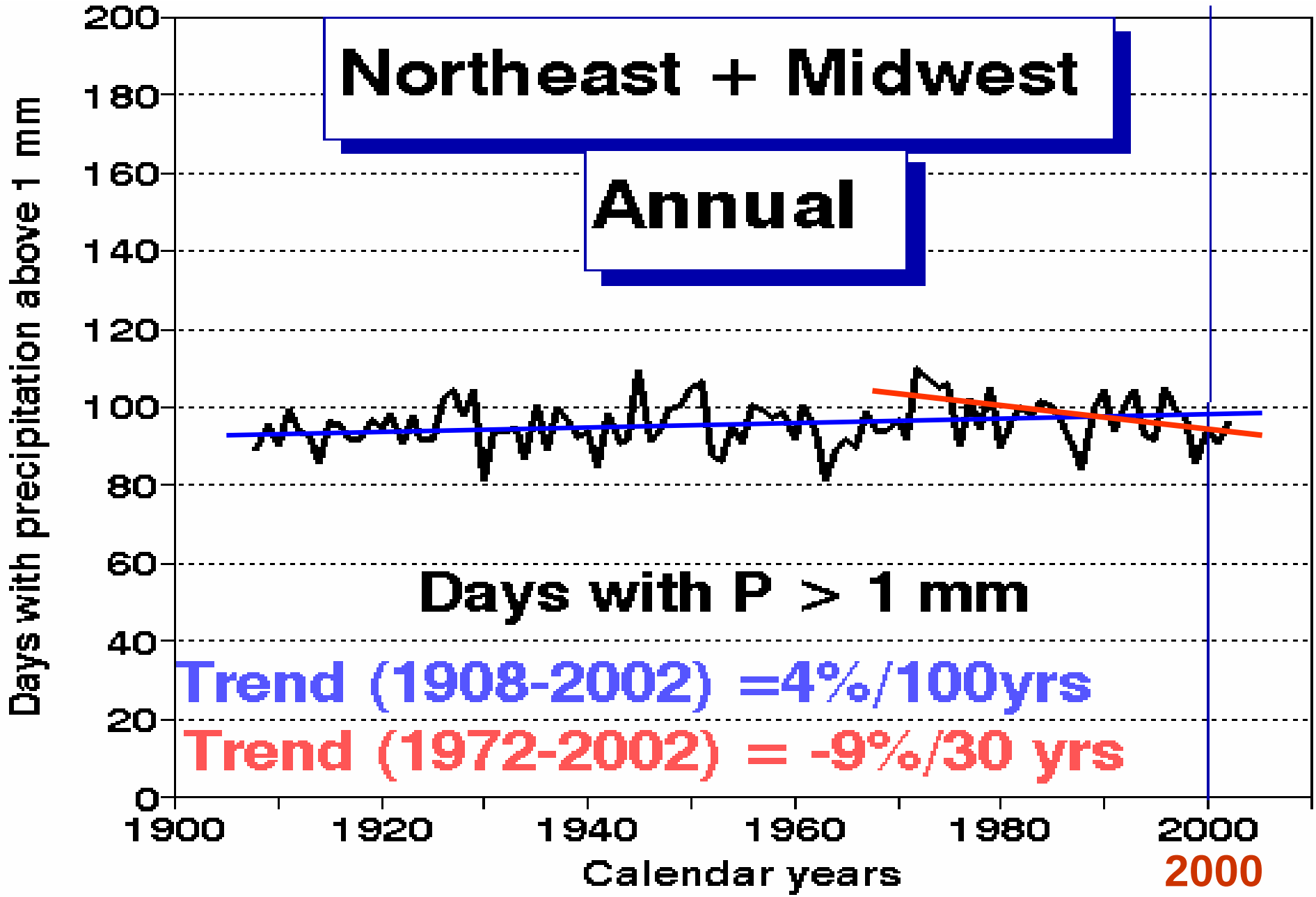

This picture is enlarged in the next slide.

- **ECHAM4 (35N-45N; 75W-85W**; adapted from Semenov & Bengtsson 2002) 10 year running mean values for 1900-2090.




Groisman et al. 2005

# Rainy days over the northeastern quadrant of the U.S.




2000

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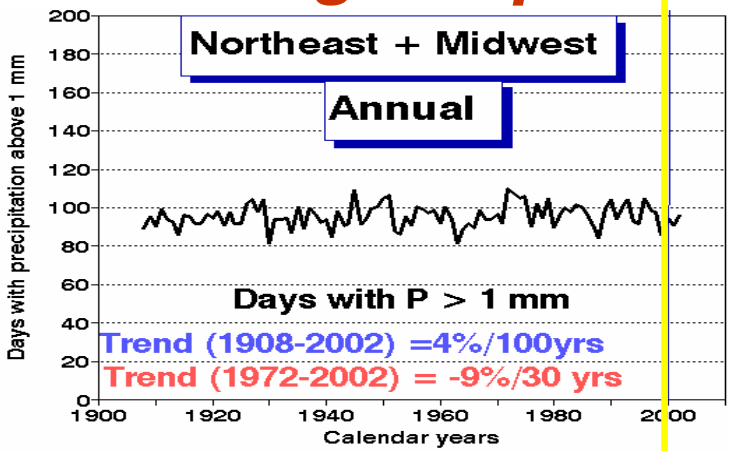


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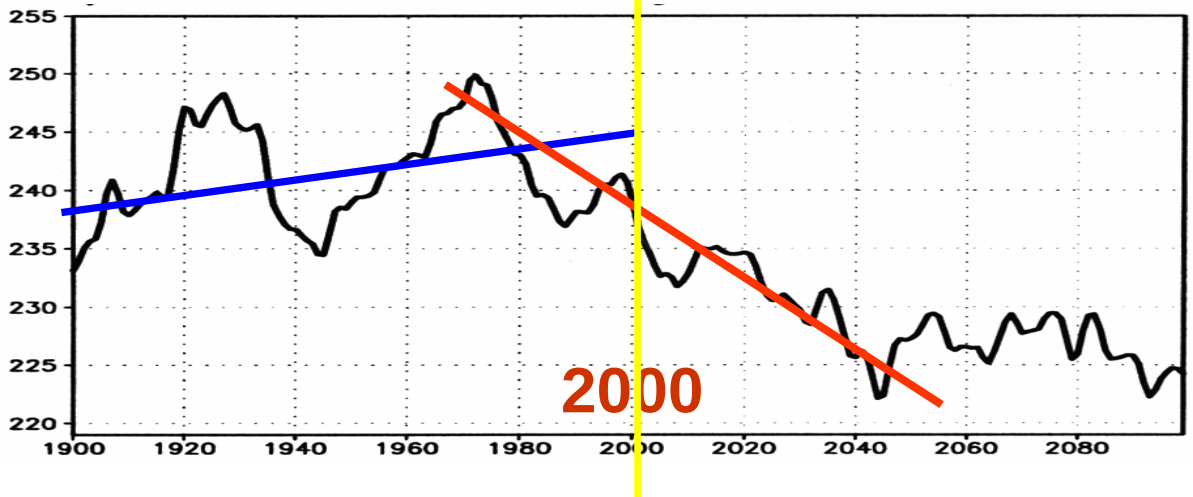


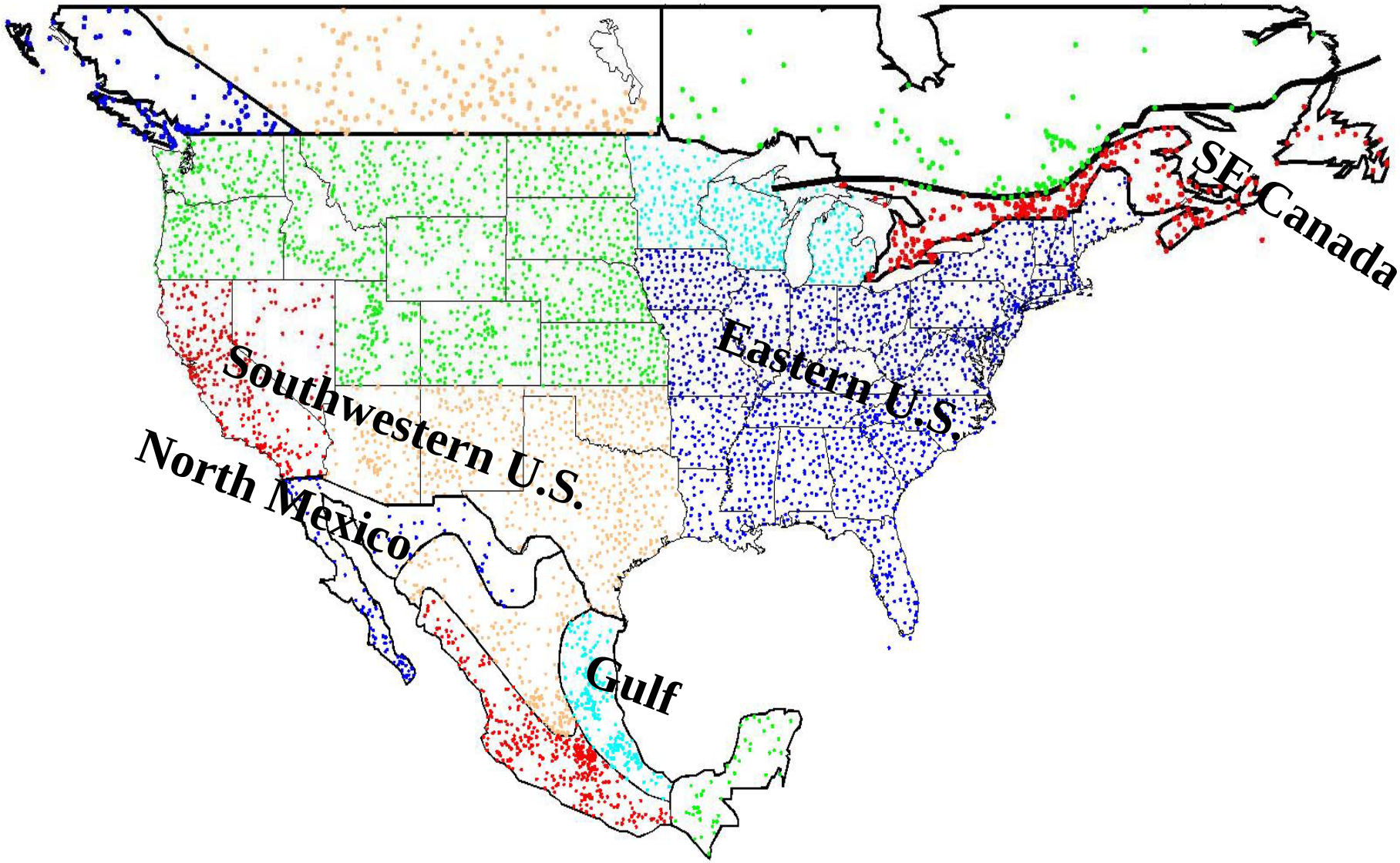

Groisman et al. 2005

# Lengthy intervals of “dry” days without sizeable rain during the warm season (when daily T > 5°C)

**We assess the following quantities:**

- Fraction of the warm season (%) with dry day intervals above 20, 30, 60, 90 days, etc.
- Number of days within these dry intervals during the warm season

# Station map and regional partition used



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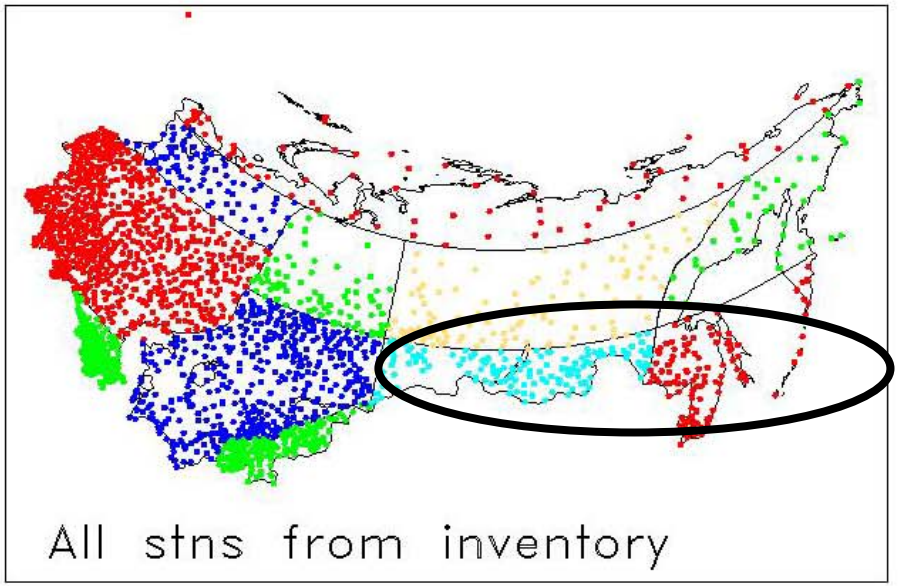
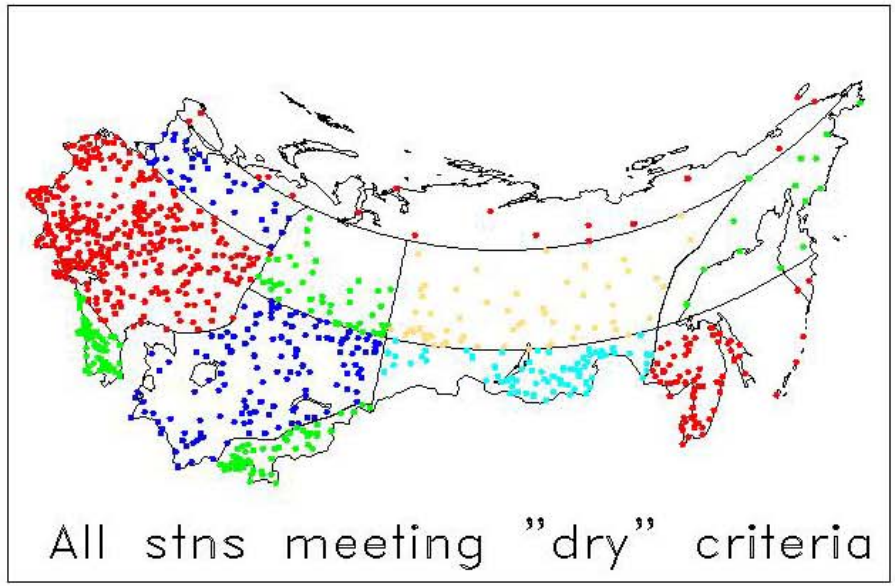
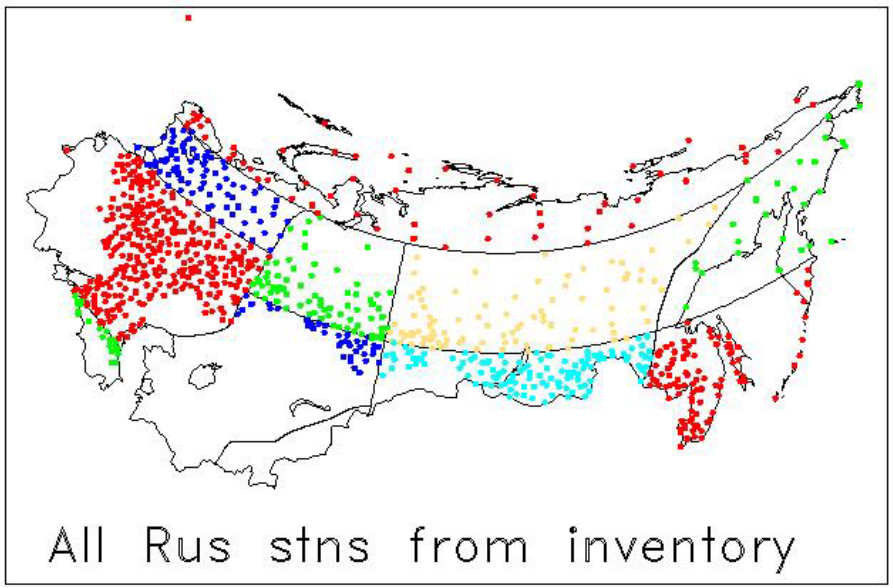
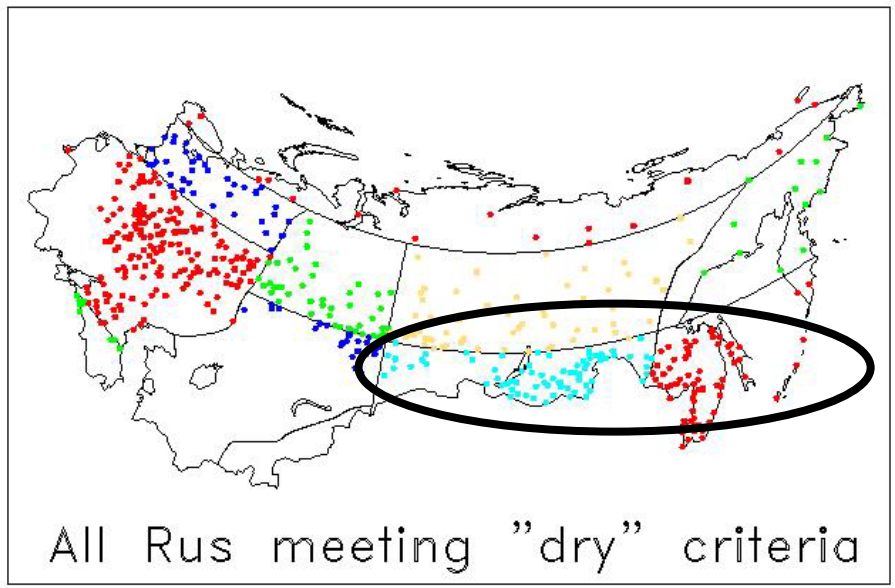


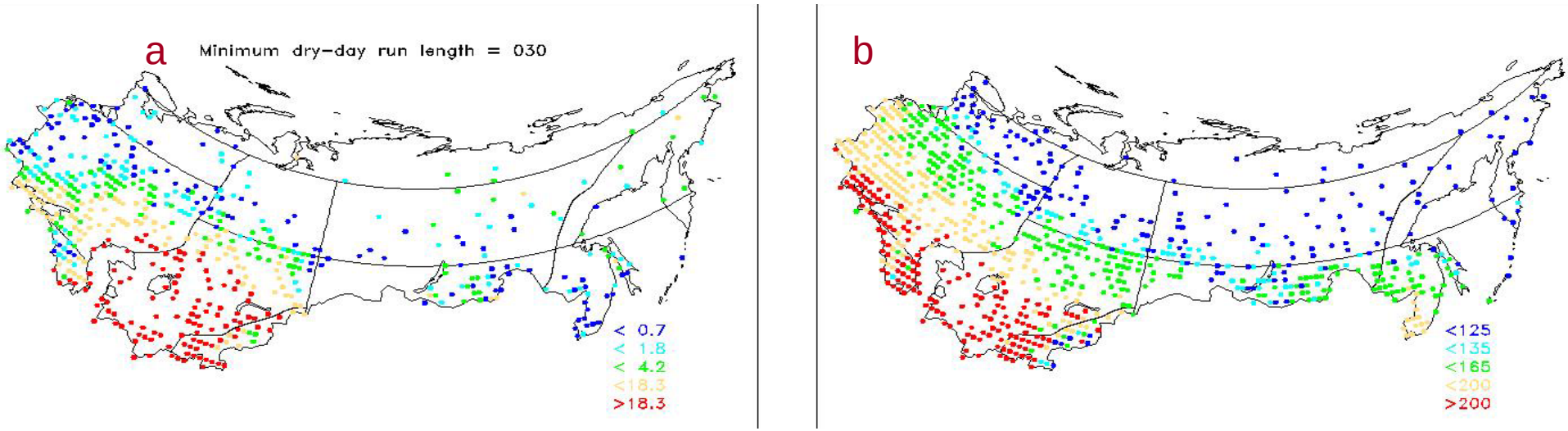



# Climatology.

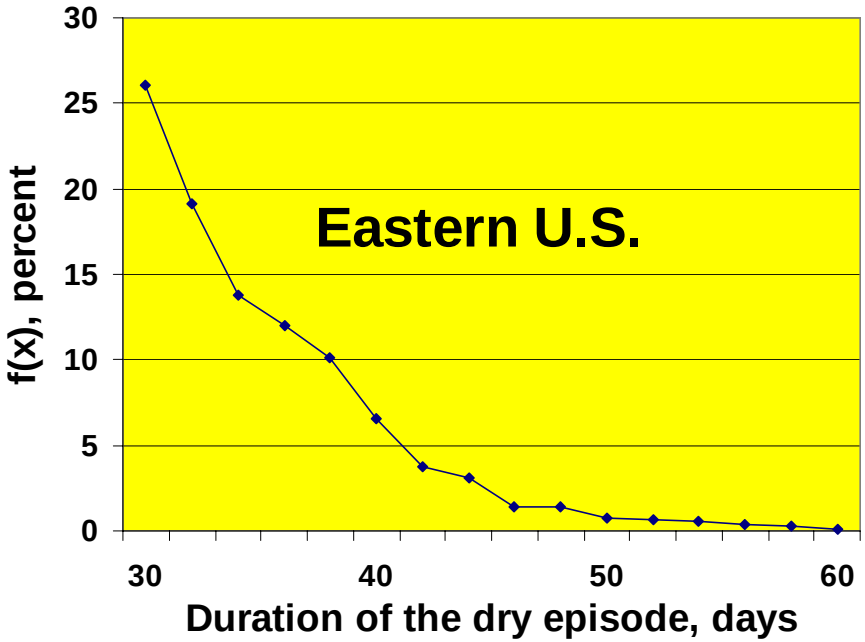
**Percentage** of the warm season included in the prolonged dry days episodes of (a) 30 and more days; (b) the warm season duration (days with mean daily T > 5°C).

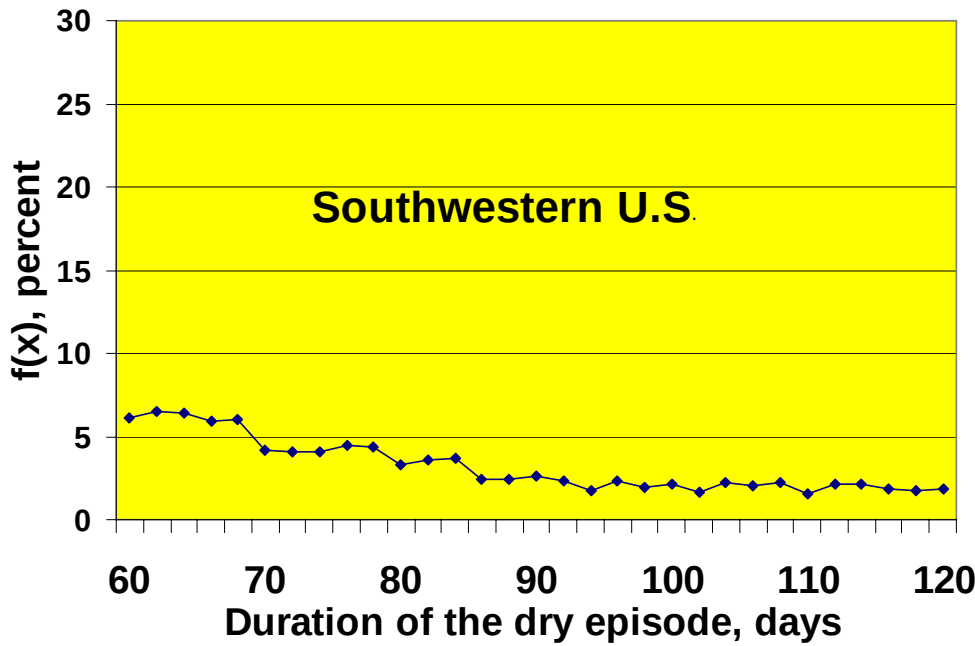


# What does it mean, when 2% of the warm season is occupied by dry episodes that are 30 or more days long?

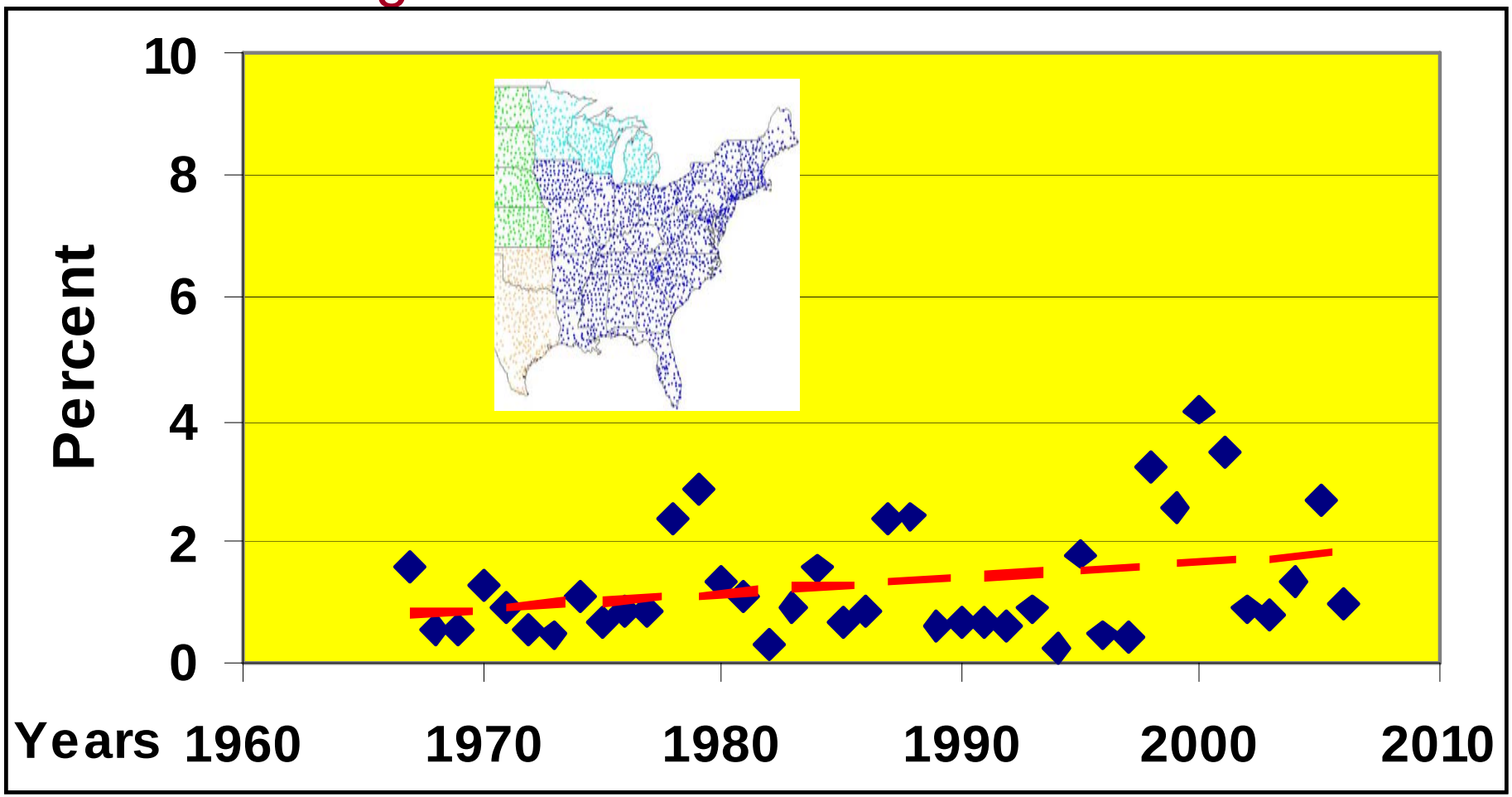
- Example: warm season = 200 days
  therefore during the past 55 years, we observed: 200 x 55 x 0.02 = 220 such days or maximum 7 such dry episodes during the past 55 years with return period of ~ 8 years ([220/30] = 7).

# Distribution function of the prolonged dry interval durations above 30 (Eastern U.S.) and 60 days (Southwestern U.S.).



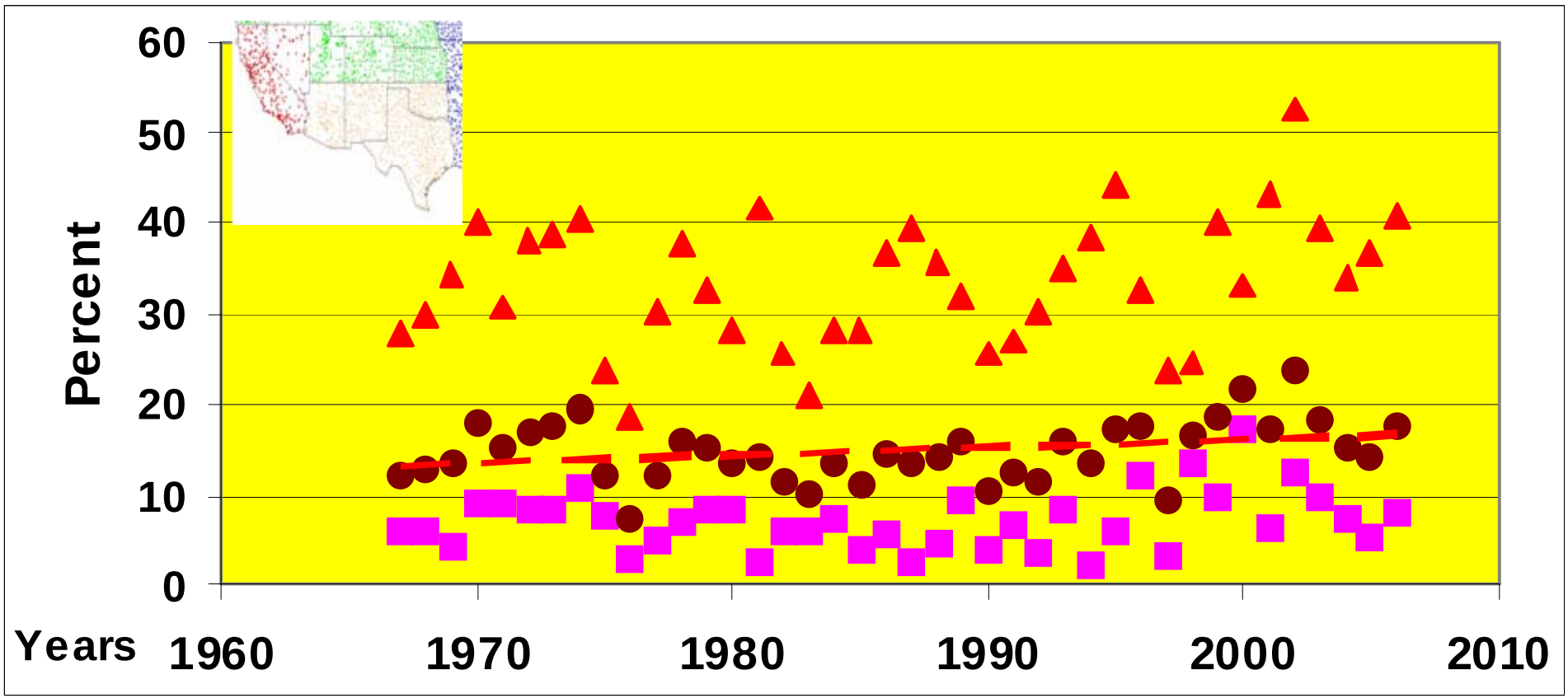



# Fraction of the dry day episodes with 1-month or more length during the warm season during the past 40 years area-averaged over the Eastern United States



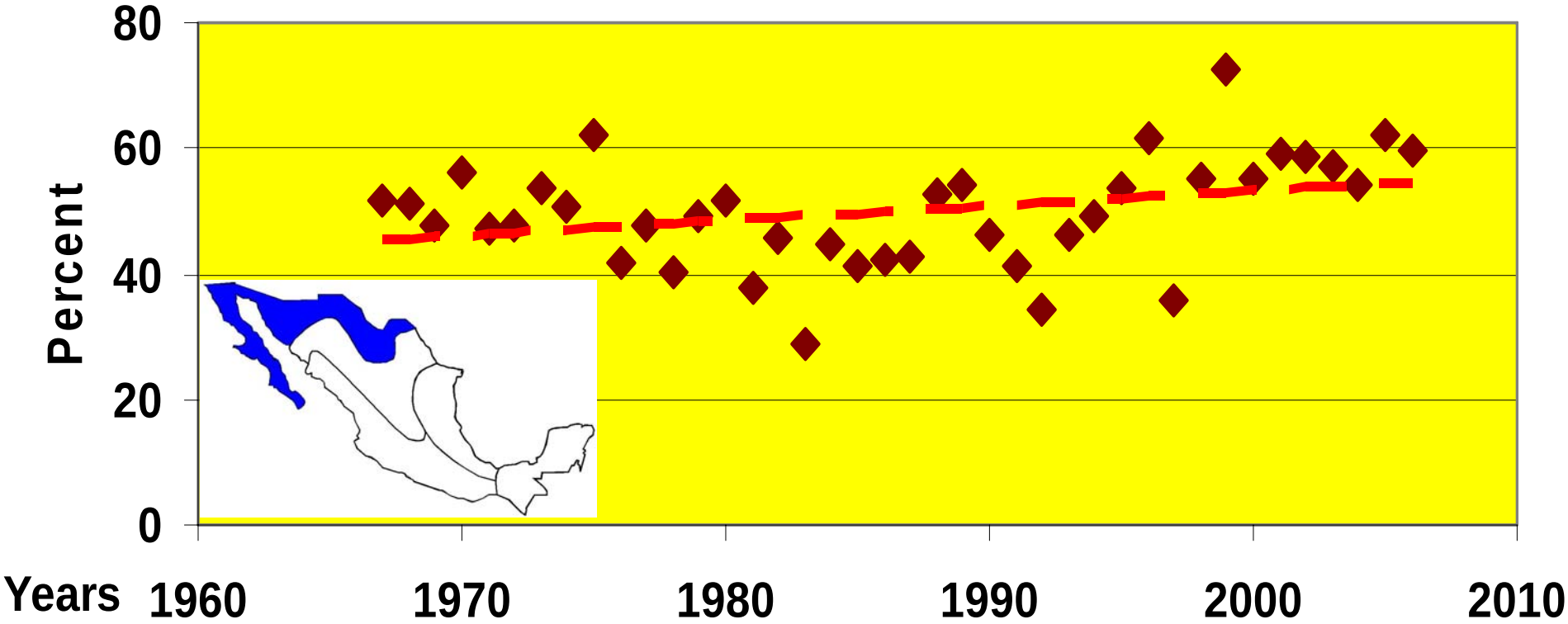

**Red dashed line: linear trend (1.1 % per 40 years)**

# Fraction of the dry day episodes with 2-month or more length during the warm season during the past 40 years area-averaged over the southwestern United States (dots), CA and NV (triangles), and TX, OK, NM, and AZ (squares)



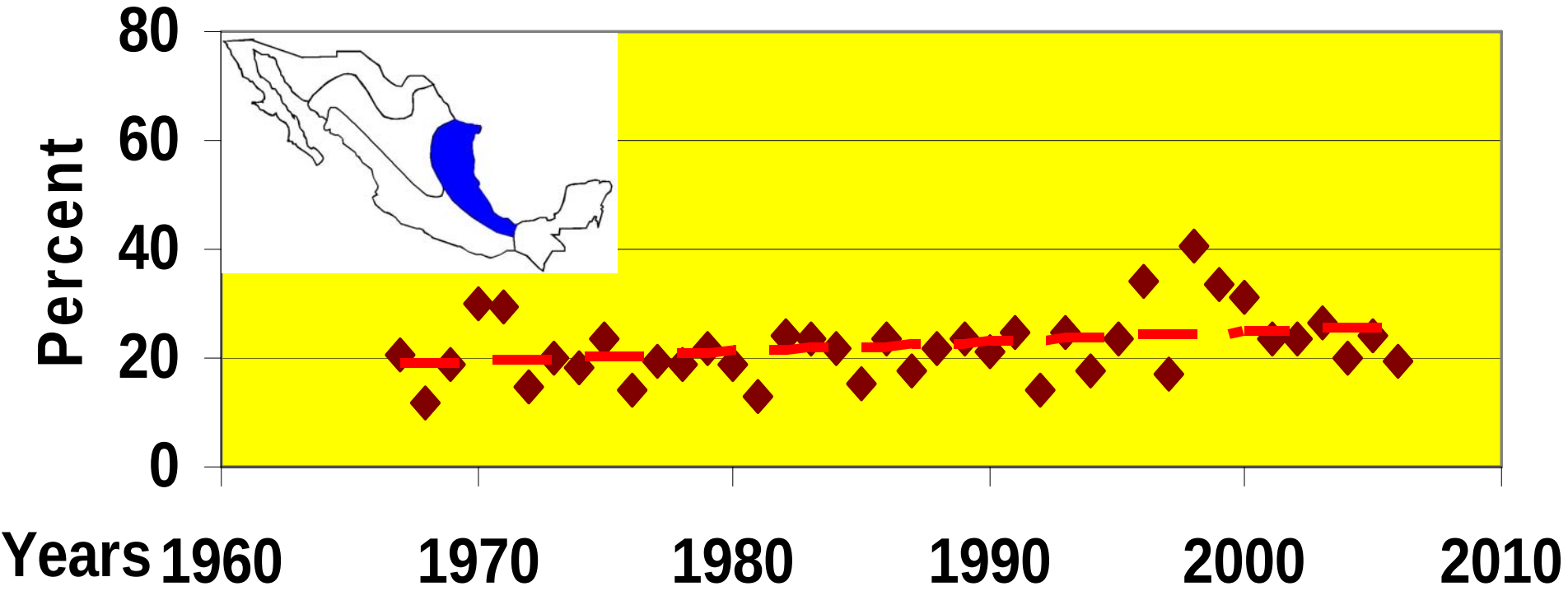

**Red dashed line: linear trend (4.3 % per 40 years)**

# Northern Mexico, fraction of strings of dry days longer than 60 days



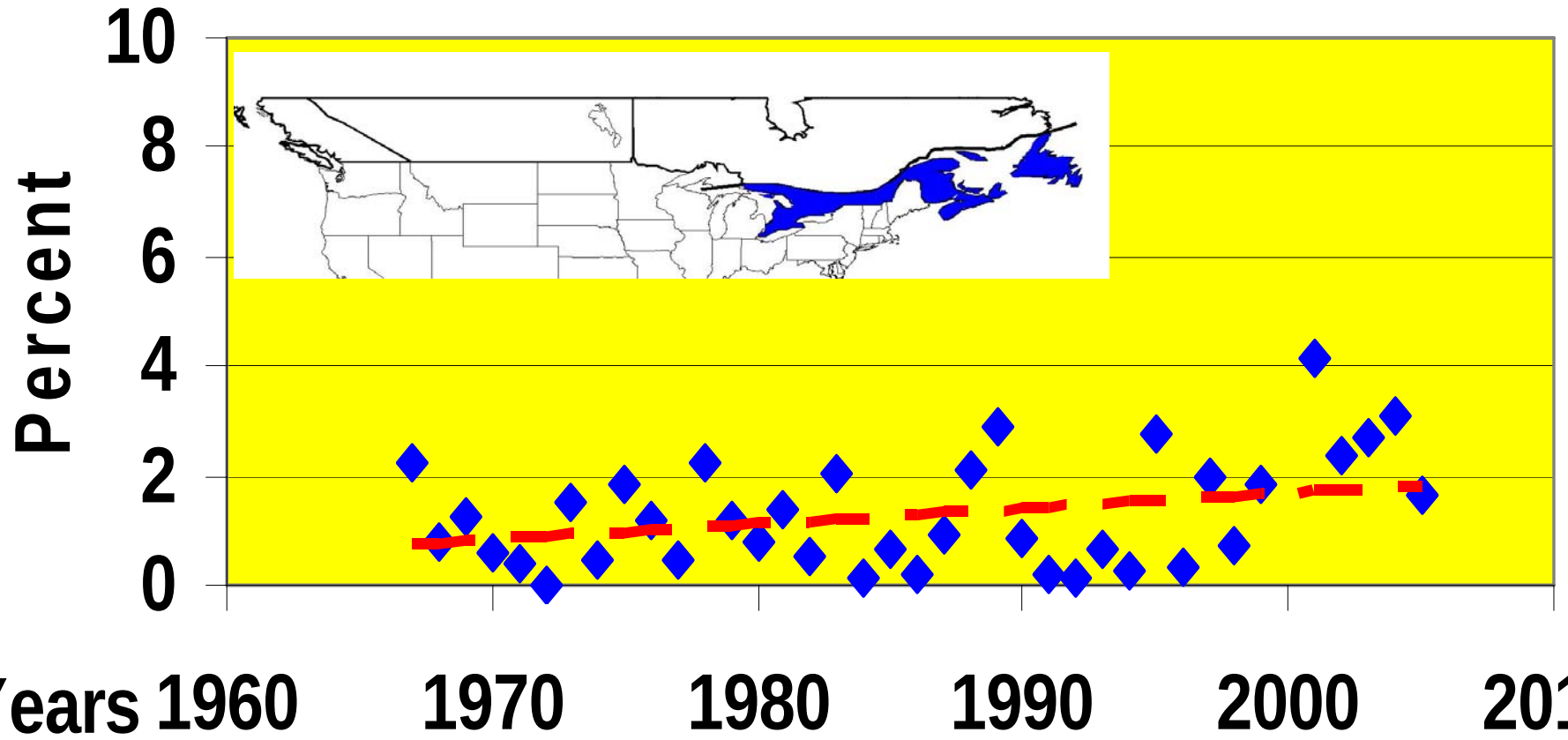

**Red dashed line: linear trend (9.4% per 40 years)**

# Gulf coast of Mexico, fraction of strings of dry days longer than 30 days



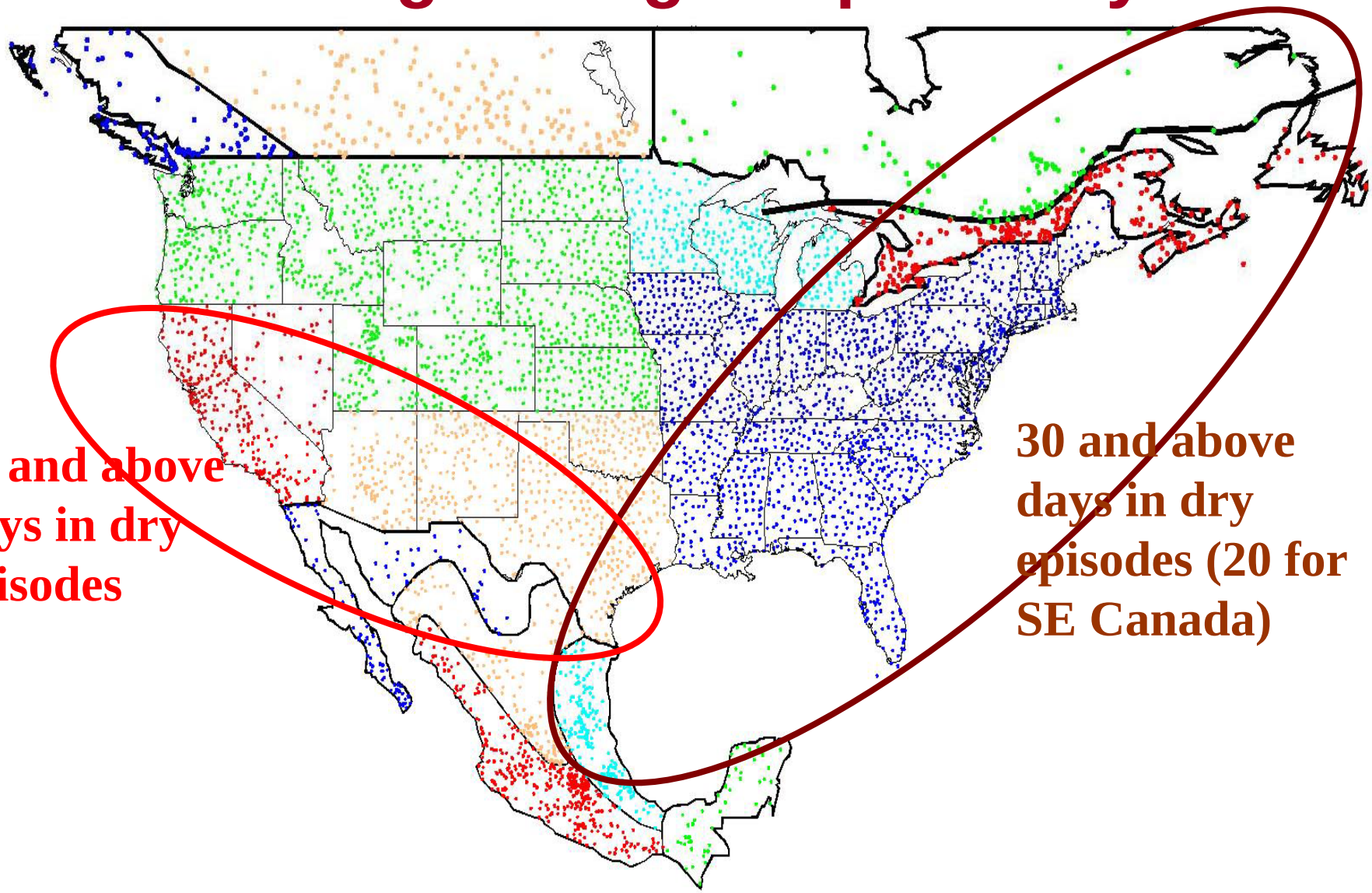

**Red dashed line: linear trend (7.3% per 40 years)**

# Southeastern Canada, fraction of strings of dry days longer than 20 days

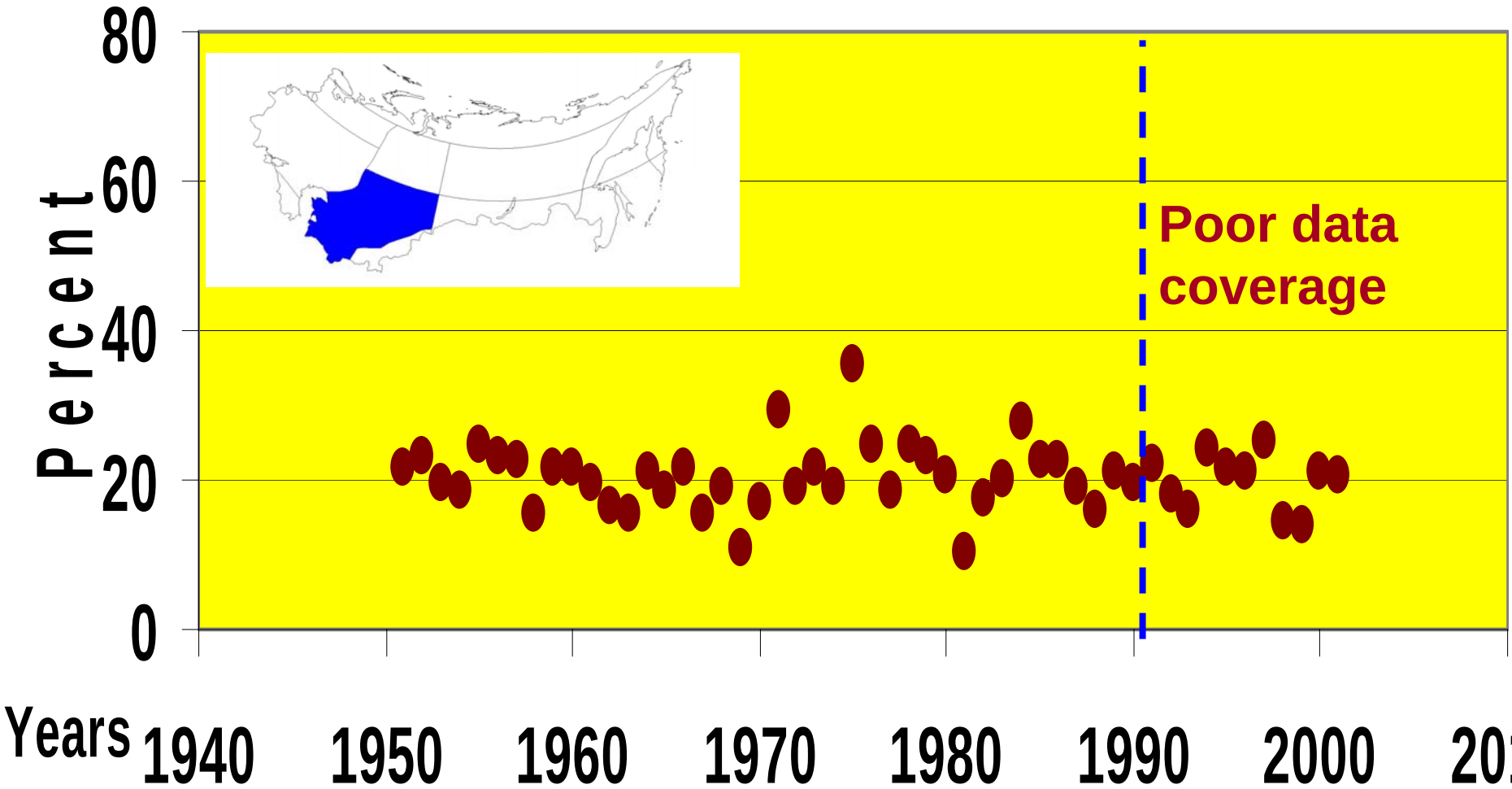



**Red dashed line: linear trend (1.3% per 40 years)**

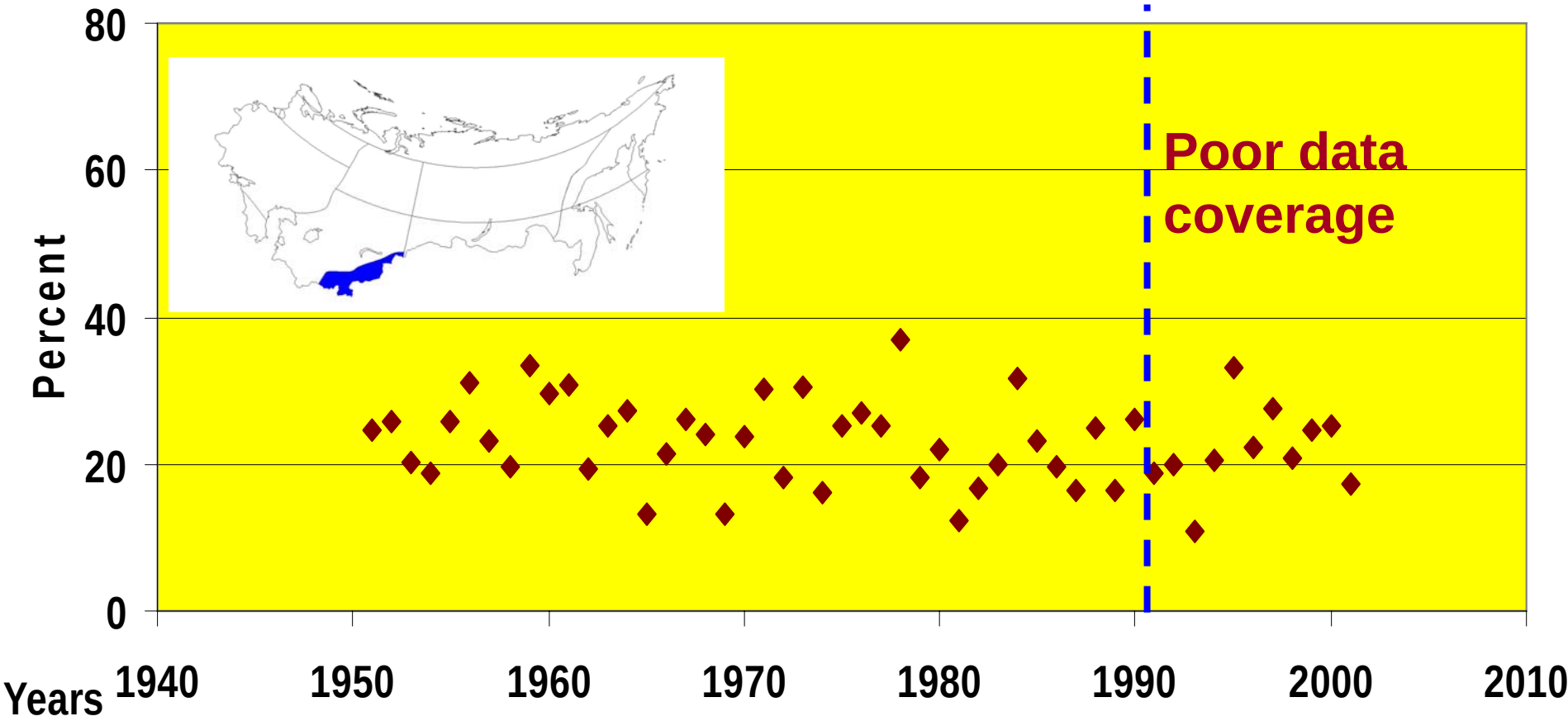
# Regions where dry episode frequency is increasing during the past 40 years



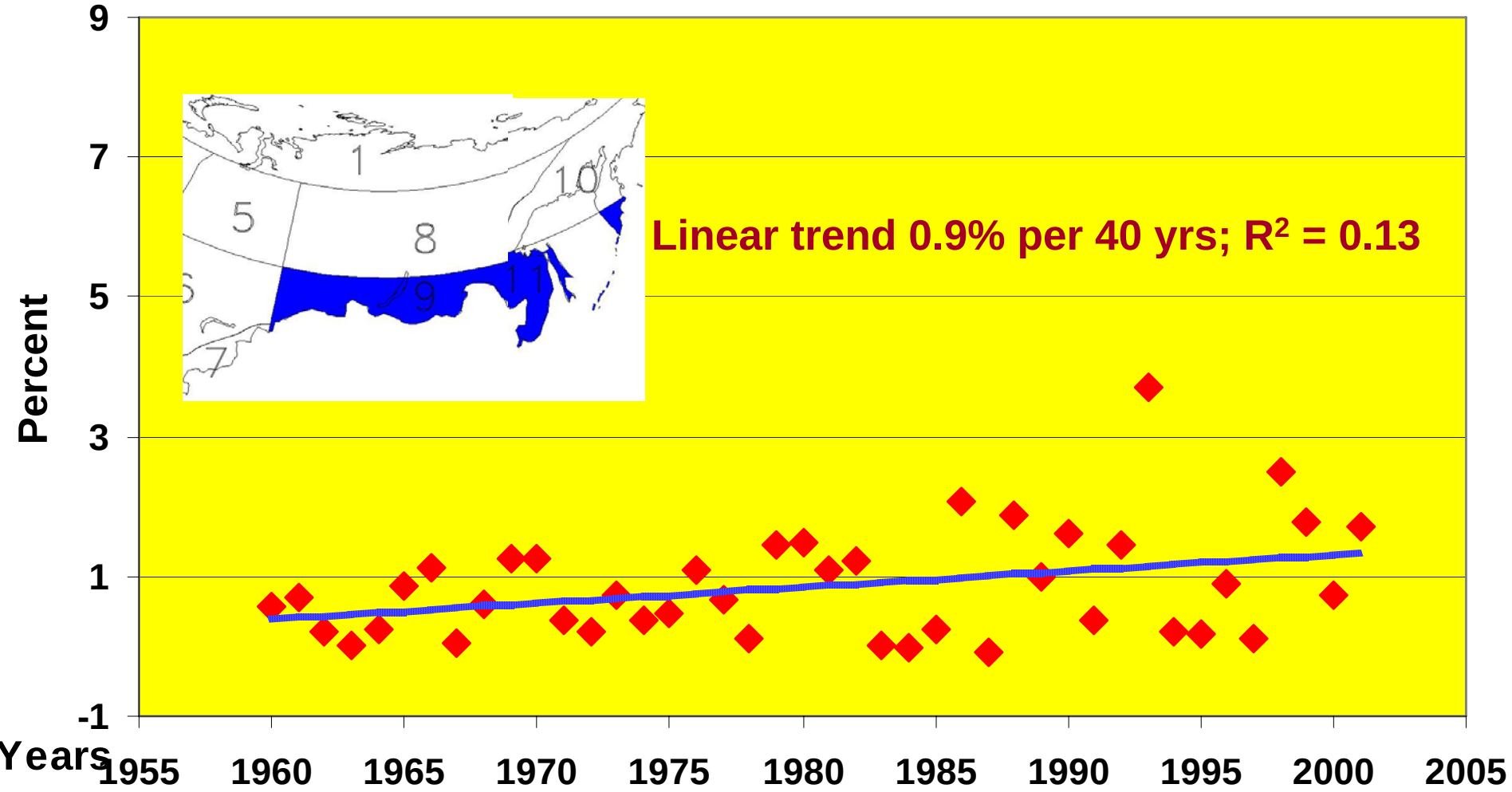
# Lowland Central Asia, fraction of strings of dry days longer than 50 days



# Mountainous Central Asia, fraction of strings of dry days longer than 50 days



# Russia east of 85°E, south of 55°N

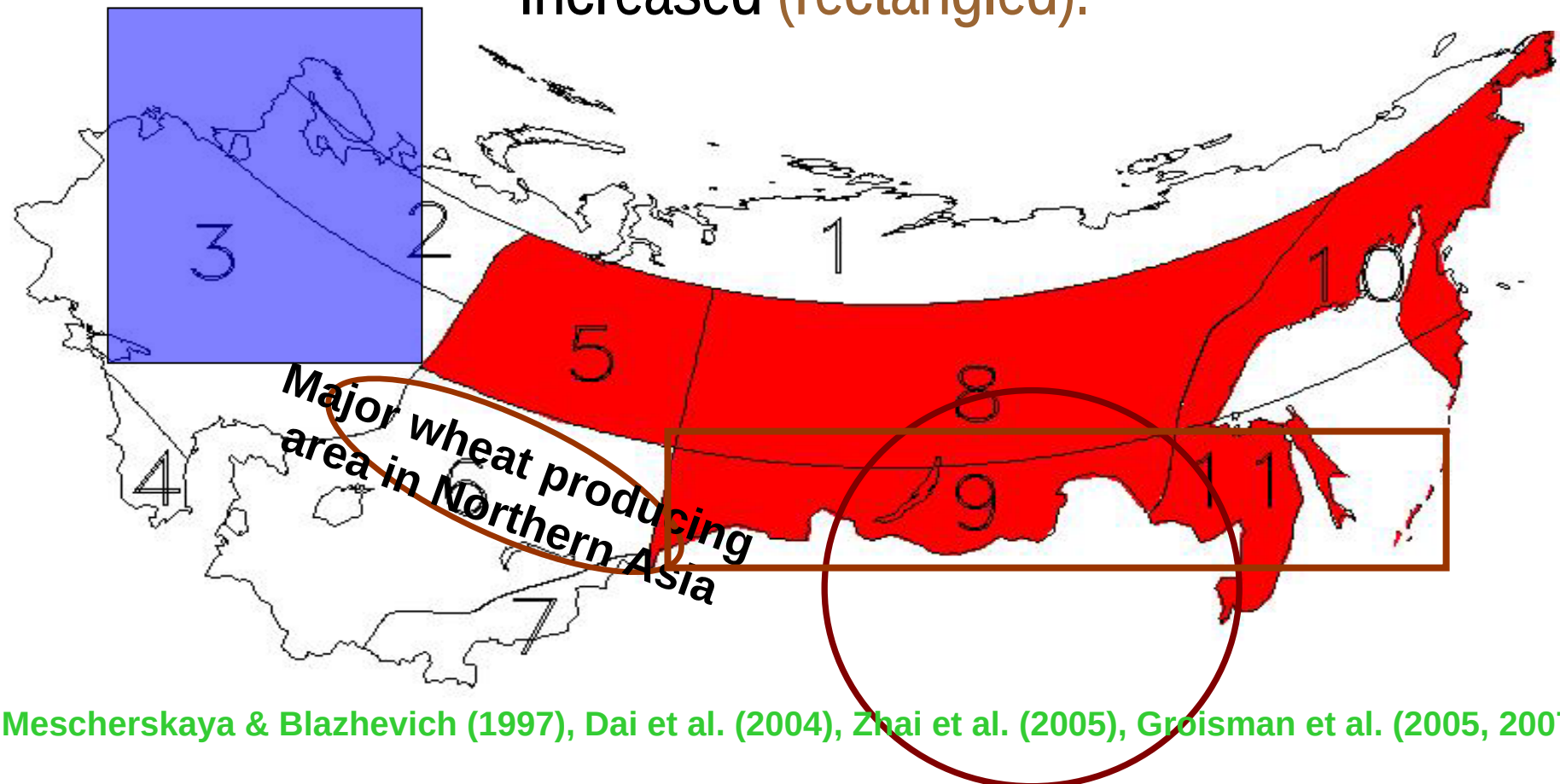



## Dry episodes above 30 days during the warm season

Plus several droughts (severe fire weather conditions in the 2000s)

## Changes in the surface water cycle listed below have been statistically significant in the 20th century

Regions with more humid conditions (blue), regions where potential forest fire danger has increased in the 20th century (red), the region where agricultural droughts have increased (circled), and the region where prolonged dry episodes have increased (rectangled).




Mescherskaya & Blazhevich (1997), Dai et al. (2004), Zhai et al. (2005), Groisman et al. (2005, 2007),

# Summary

During the past four decades **over the contiguous US**:

- **the duration of prolonged dry episodes has significantly increased over the Eastern and Southwestern United States.**

- For the same period, the increase in the frequency of prolonged dry episodes has expanded to **neighboring regions of Mexico and Canada**
- **Over the southern part of Asian Russia prolonged 1-month-or-longer dry episodes has significantly increased.**
- The changes are a new phenomenon, are observed on the background of the relatively “wet” period, and is consistent with the notable change in rainfall rate distribution (increase in intense rainfall frequencies while mean precipitation grows slower or does not increase at all (e.g., Southern Siberia).
- **Studies of this type are possible only in the regions with a dense daily precipitation network**.