Changes in Intense Precipitation over the Conterminous U.S.

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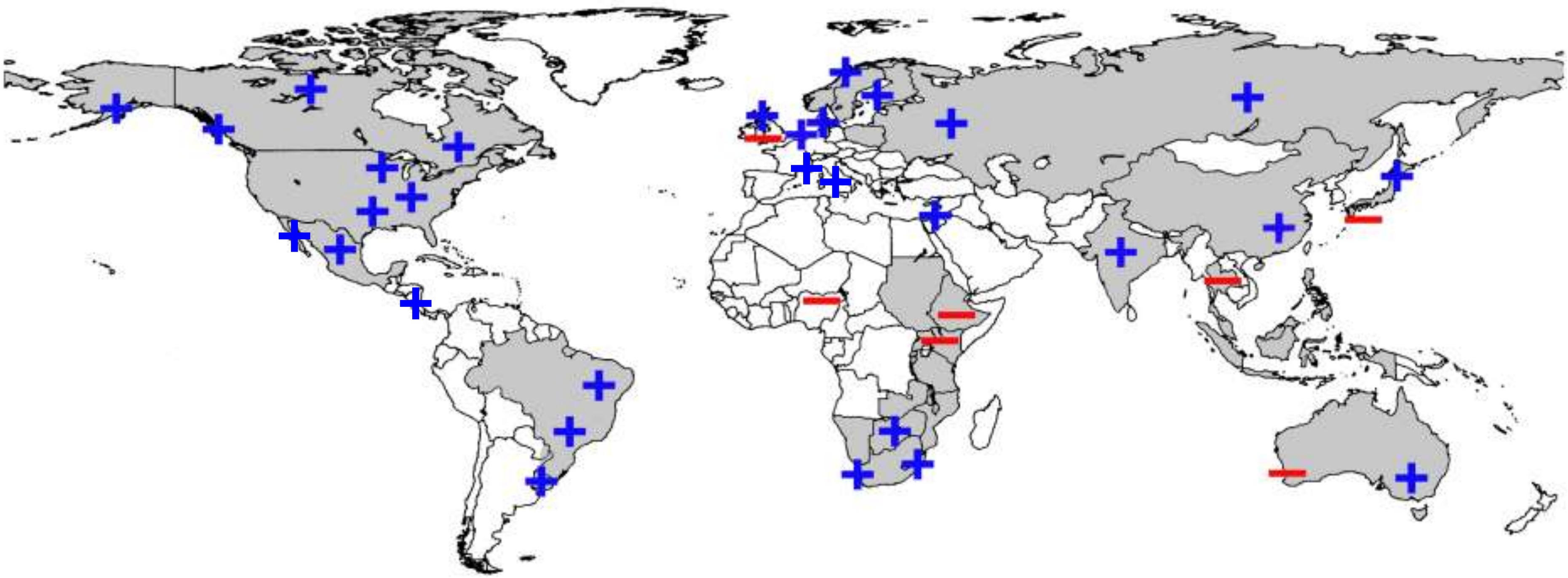
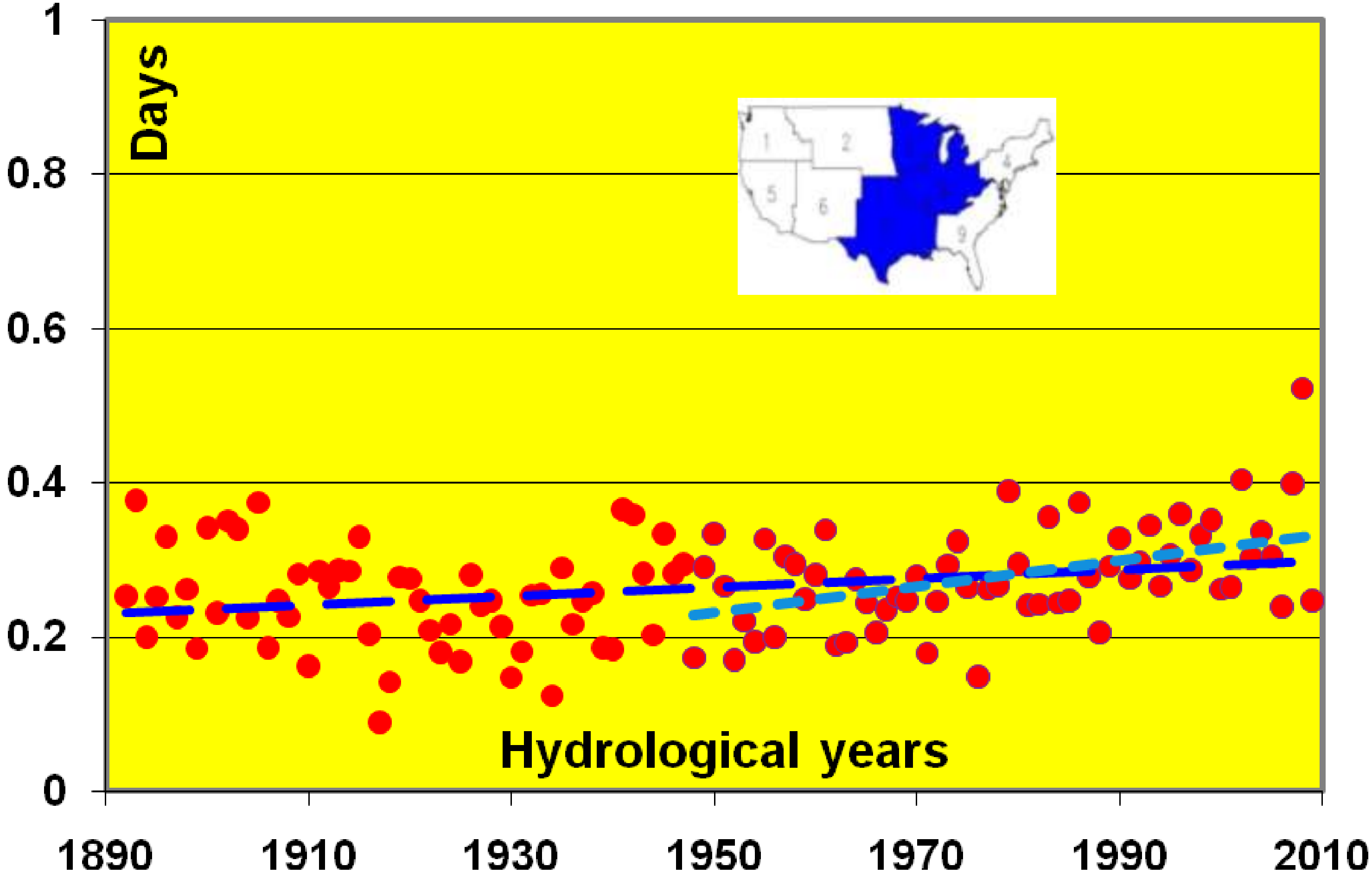
Regions with disproportionate changes in intense precipitation during the past decades compared to the change in the annual and/or seasonal precipitation



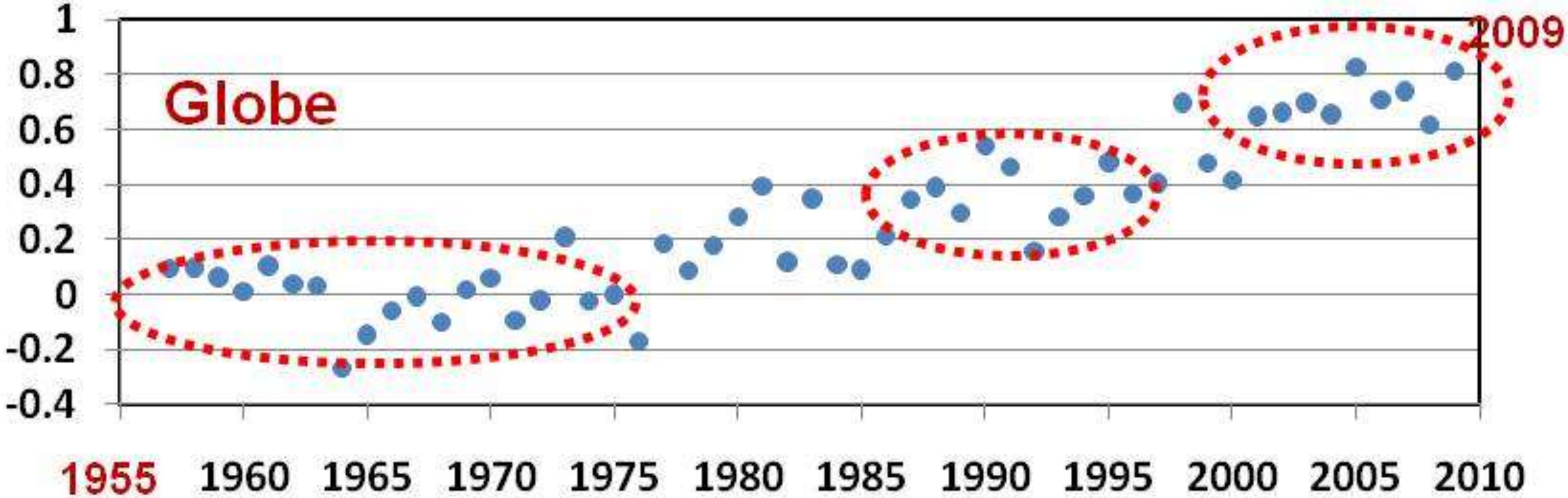
Easterling et al. 2000, substantially updated from Groisman et al. 2005, Zhai et al. 2005, Roy and Balling 2004, Aguilar et al. 2005, Brunetti et al. 2004, and Cavazos 2008, Zolina et al. 2010. Thresholds used to define "heavy" and "very heavy" precipitation vary by season and region.

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 1893–2009 and 1948–2009 periods. are equal to 2.3% (10 yr)$^{-1}$ and 6.4% (10 yr)$^{-1}$, respectively, and are statistically significant at the 0.01 level or higher (Groisman et al. 2005, updated).

Annual Surface Air Temperature Anomalies, °C

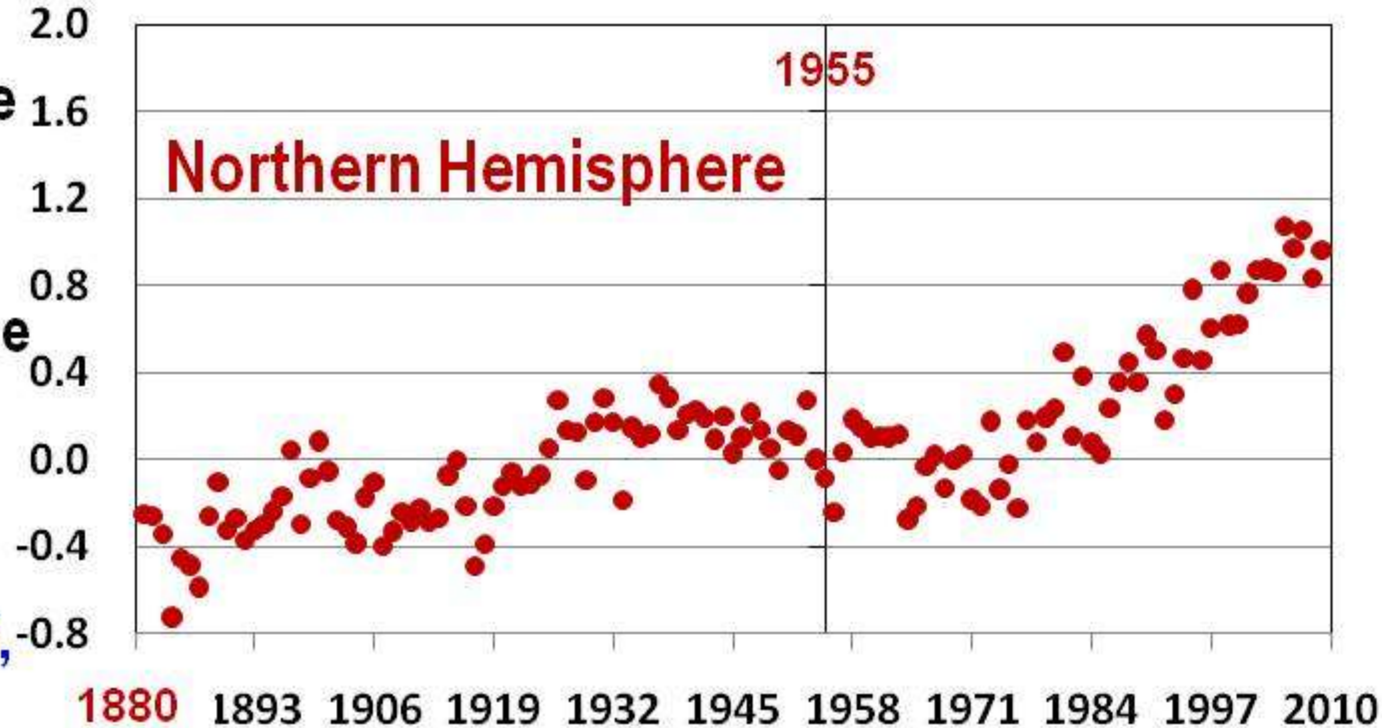


Mean centenary rate of increase of the annual surface air temperature over the Hemisphere is:

0.99°C/129 yr;

$R^2 = 0.63$

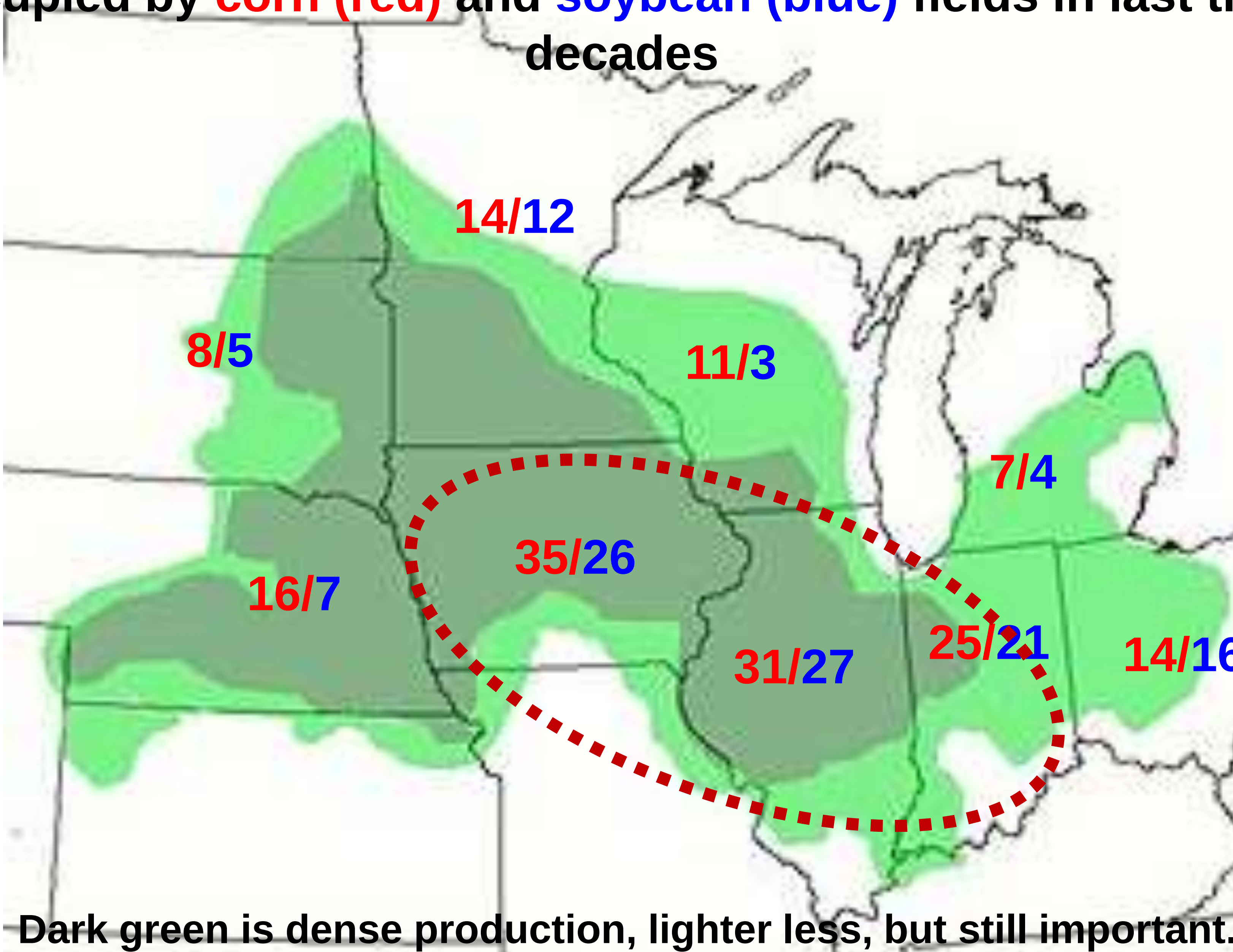
(Lugina *et al.* 2007, updated).



Global warming manifests itself at least at the continental scale →

- There is a reason to look for large scale changes in extremes → we are looking for changes in area-averaged characteristics of extreme events
- Another option would be to search for smaller-scale changes in extremes related to regional and local factors (e.g., land use change and/or water withdrawal)

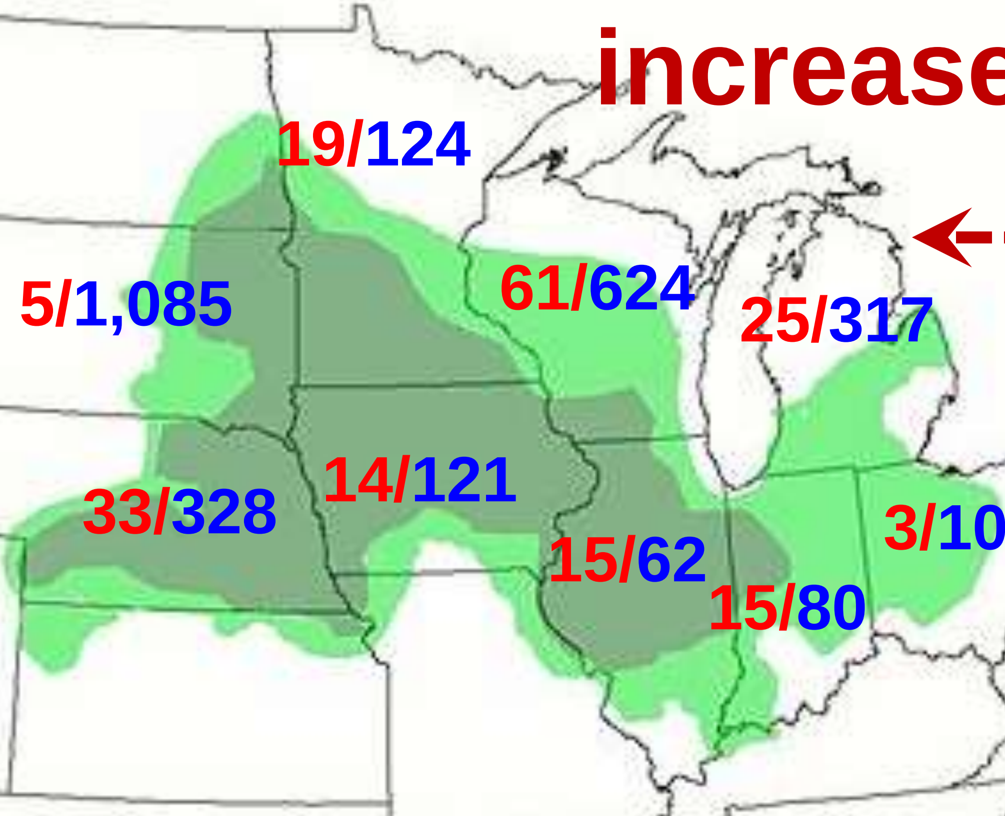
U.S. Corn Belt States with the areas (% of total land area) occupied by corn (red) and soybean (blue) fields in last three decades



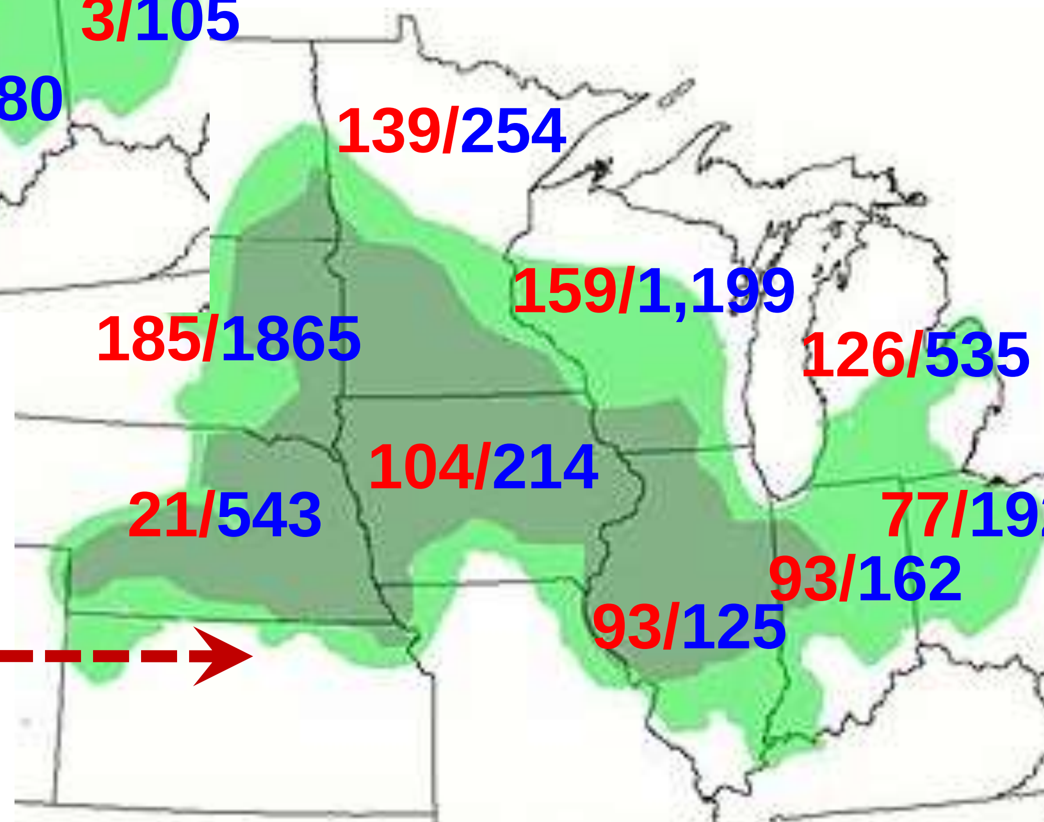
Dark green is dense production, lighter less, but still important.

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

Changes between 1979-2009 and 1948-1978 periods, increase by, %



Area of harvested corn for grain (red) and soybeans (blue)



Total yield of corn (red) and soybeans (blue)

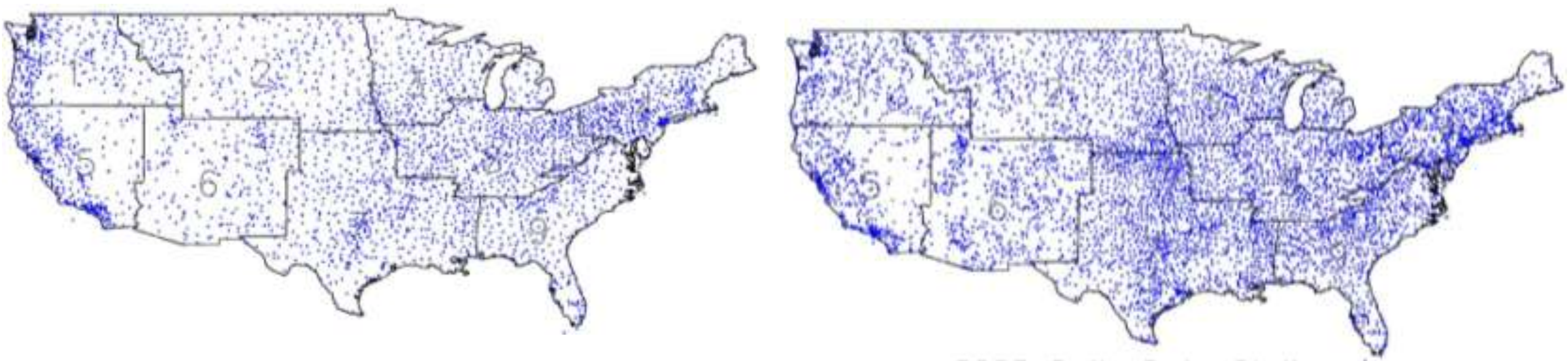
Total amount of rainfall per hurricane season (hs) over the southeastern U.S. during the 1985-2005 period from tropical cyclones (TC) events

41 "cold" TC events	41 km^3 hs^{-1}
41 "warm" TC events	45 km^3 hs^{-1}

Partition cold/warm is made by SST during the few days before the landfall; SST{"warm"} -SST{"cold"} = 1.6°C

Intense precipitation climatology

Our analyses are based upon hourly and daily precipitation data over the conterminous United States



Two station networks used in our analyses of hourly and daily precipitation.
Blue dots on the maps show distribution of 3076 long-term hourly (HPD; left) and 5885 daily stations (COOP; right)

Terminology used in presentation

Day with intense precipitation $P>12.7$ mm d^{-1}

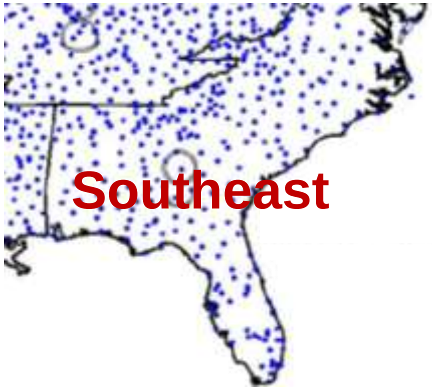
Multi-day intense event is constructed from consequent intense precipitation days

Moderately heavy precipitation $12.7<P \leq 25.4$ mm d^{-1}

Heavy precipitation $25.4 < P \leq 76.2$ mm d^{-1} or mm $(\text{event})^{-1}$

Very heavy precipitation $76.2 < P \leq 154.9$ "-"-"-"-"-"-"

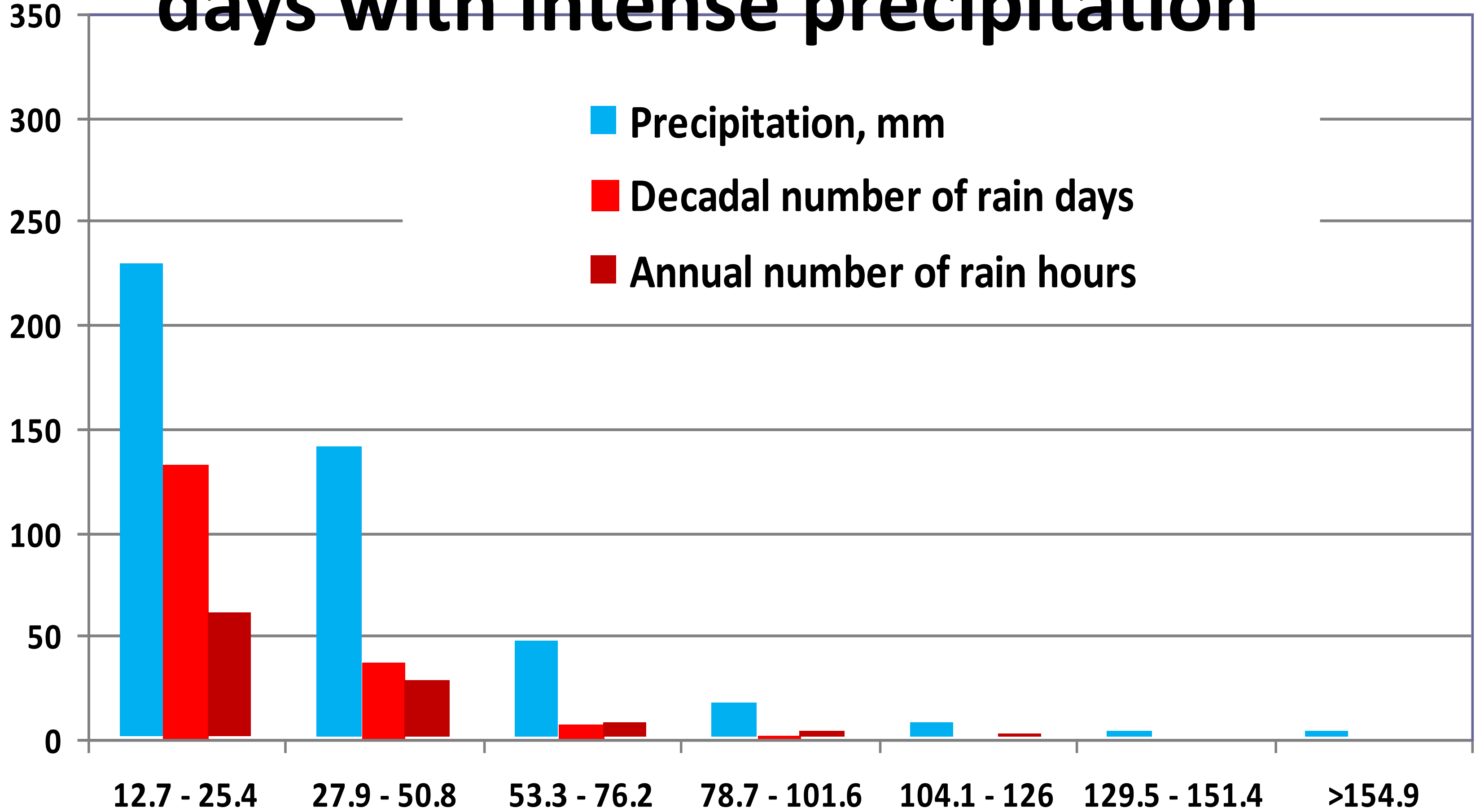
Extreme precipitation $P > 154.9$ mm d^{-1} or mm $(\text{event})^{-1}$



Example of intense precipitation statistics for Southeast for 1948-2007 based on 220 HPD gauges, per station

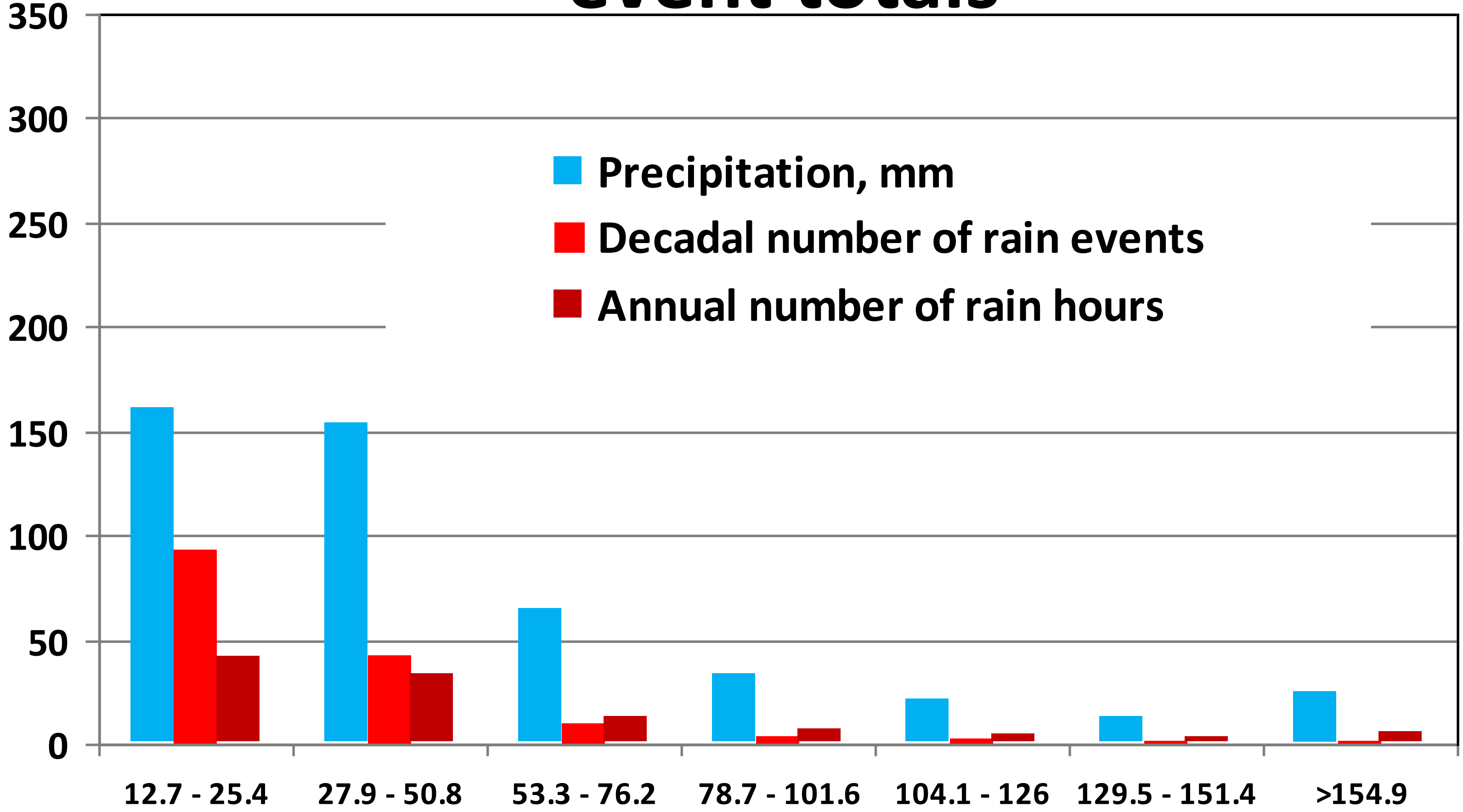
Precipitation event range, mm	Annual rainfall, mm	Decadal number of rain days	Annual number of rain hours	Average intensity, mm/ h.	Duration, hours	Peak intensity, mm/h.
12.7 - 25.4	329	187	73	4.6	3.9	8.9
27.9 - 50.8	250	66	40	6.1	6.1	16.8
53.3 - 76.2	93.5	15	12	7.9	8.1	25.2
78.7 - 101.6	36	4	4	9.1	9.9	30.7
104.1 - 126	16.5	1.4	1.6	10.2	11.2	35. 6
129.5 - 151.4	7	0.5	0.6	11.2	12.6	39.9
>154.9 mm	8.3	0.4	0.6	13.8	14.5	48.0

Nationwide climatology of various characteristics of hourly intense precipitation as a function of daily precipitation totals in the days with intense precipitation



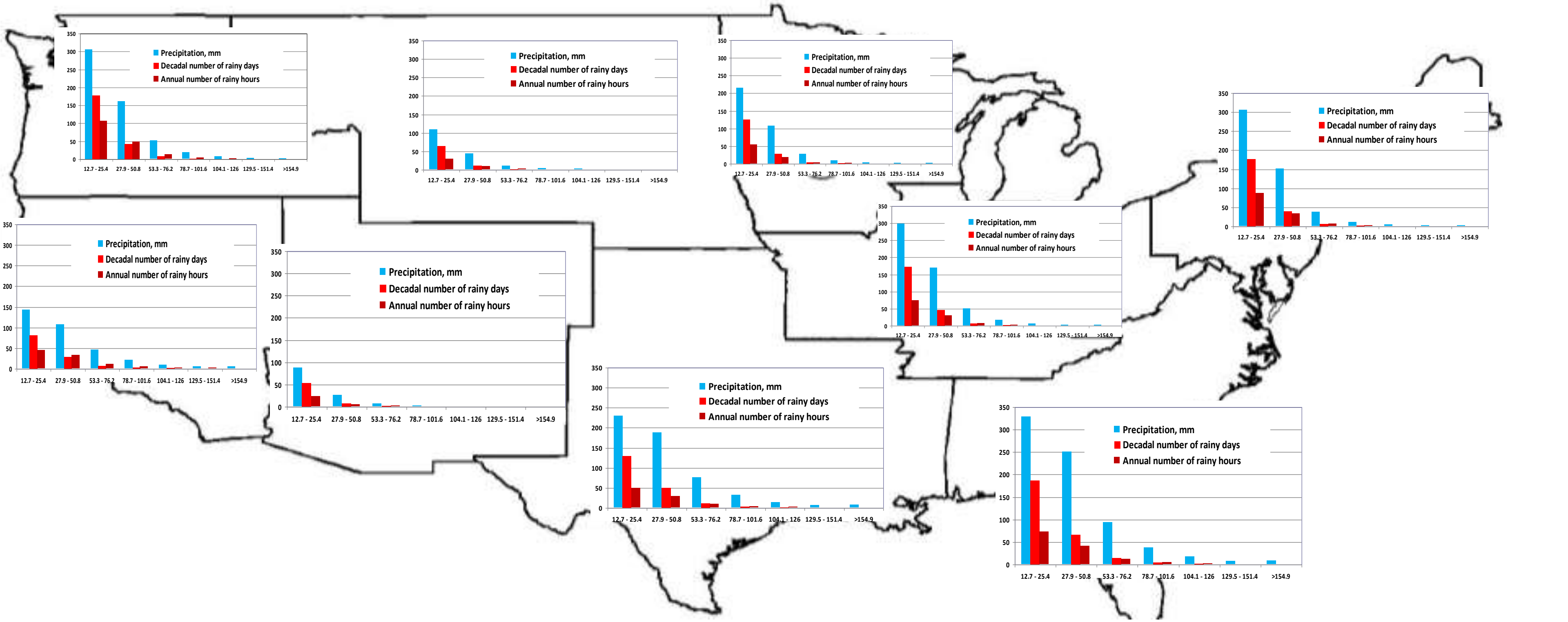
Mean point annual intense precipitation, mm; mean point decadal number of days and mean point annual number of hours with intense precipitation

Nationwide climatology of various characteristics of hourly intense precipitation as a function of multi-day intense precipitation event totals



Mean point annual intense precipitation, mm; mean point decadal number of events and mean point annual number of hours with intense precip.

Regional climatology of various characteristics of hourly intense precipitation as a function of daily precipitation totals in the days with intense precipitation



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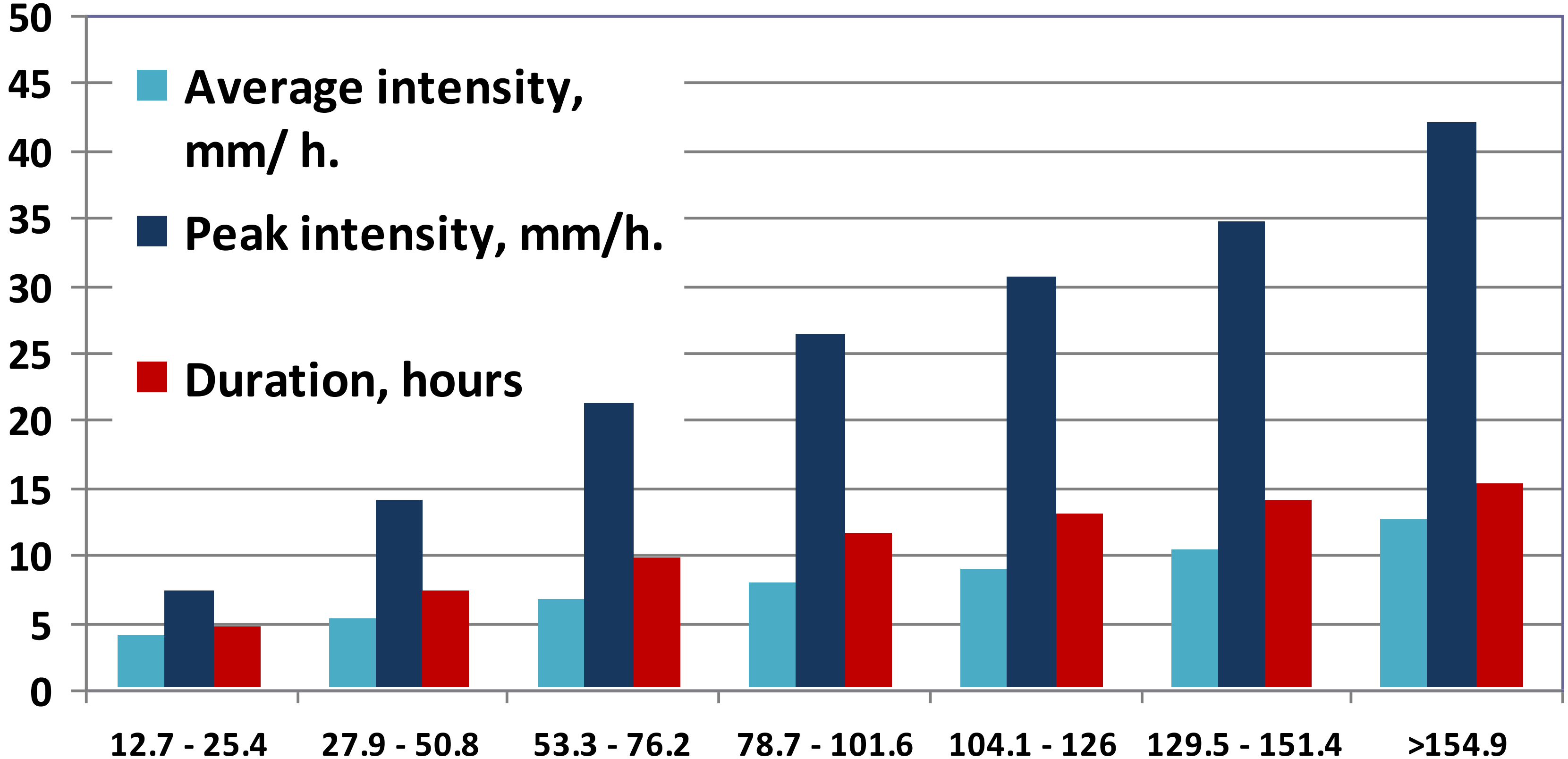
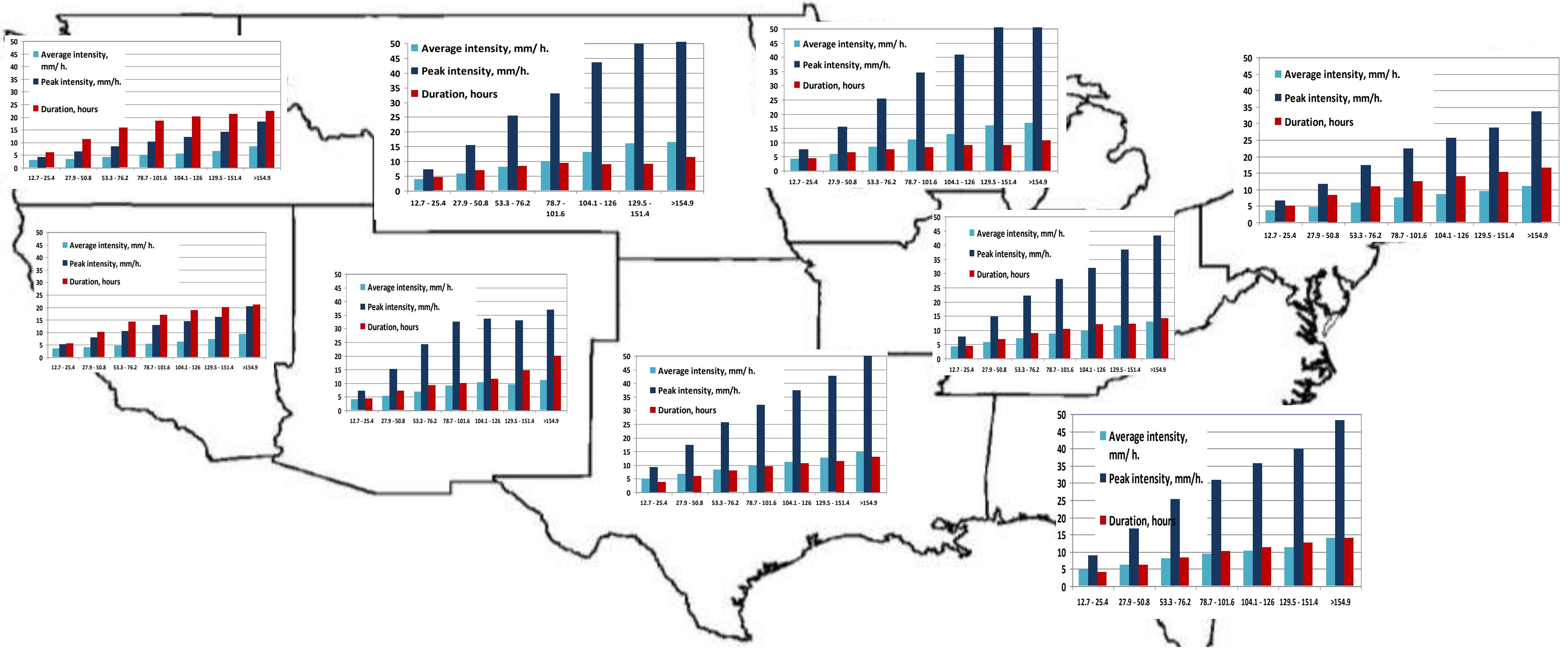


Mean daily and peak precipitation intensity mm h^{-1}; and mean duration of daily precipitation events, hours.

Regional climatology of various characteristics of hourly intense precipitation as a function of daily precipitation totals in the days with intense precipitation



Mean daily and peak precipitation intensity mm h^{-1}; and mean duration of daily precipitation events, hours.

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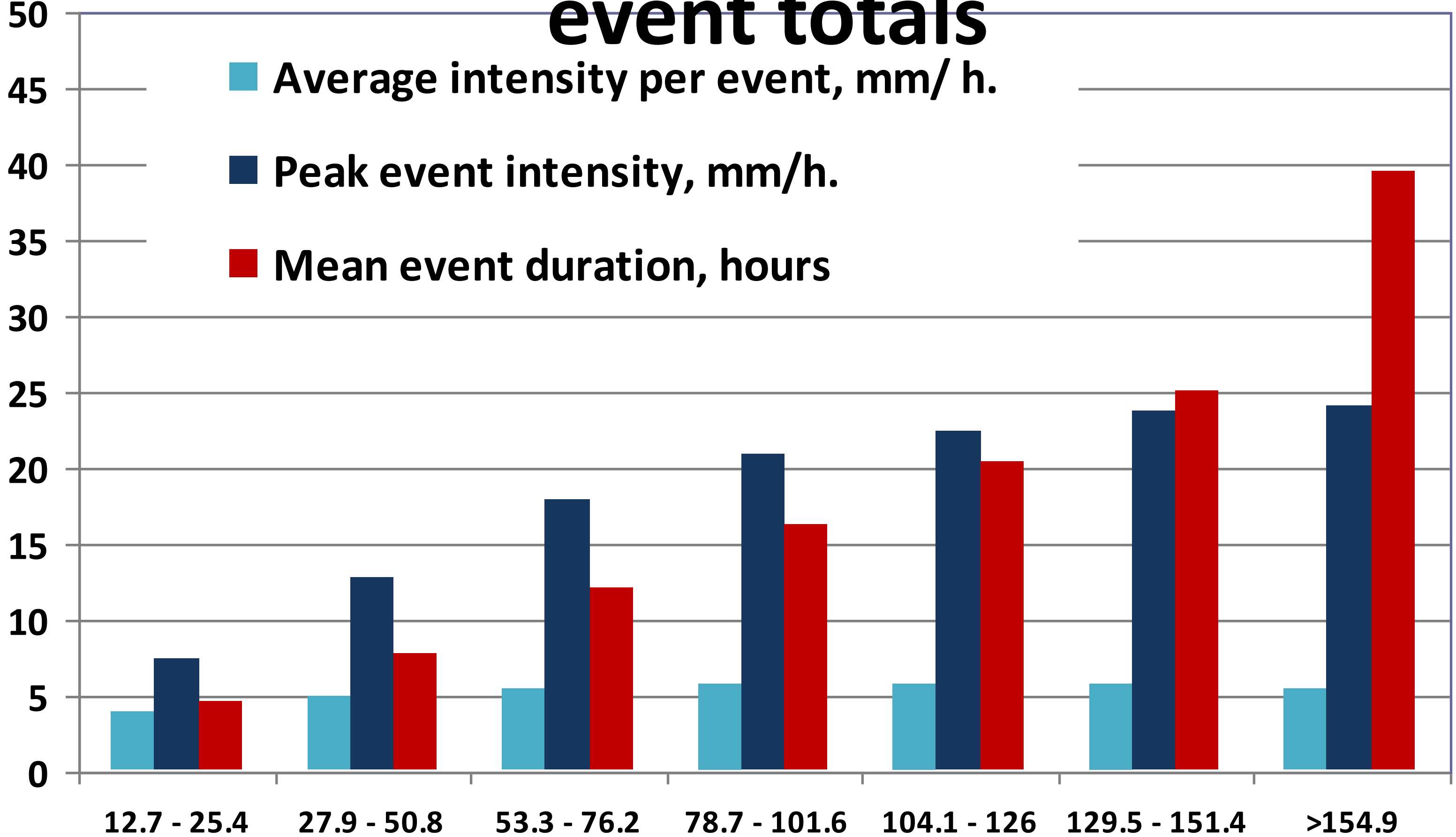


Mean daily and peak precipitation intensity mm h^{-1}; and mean duration of daily precipitation events, hours.

Central United States

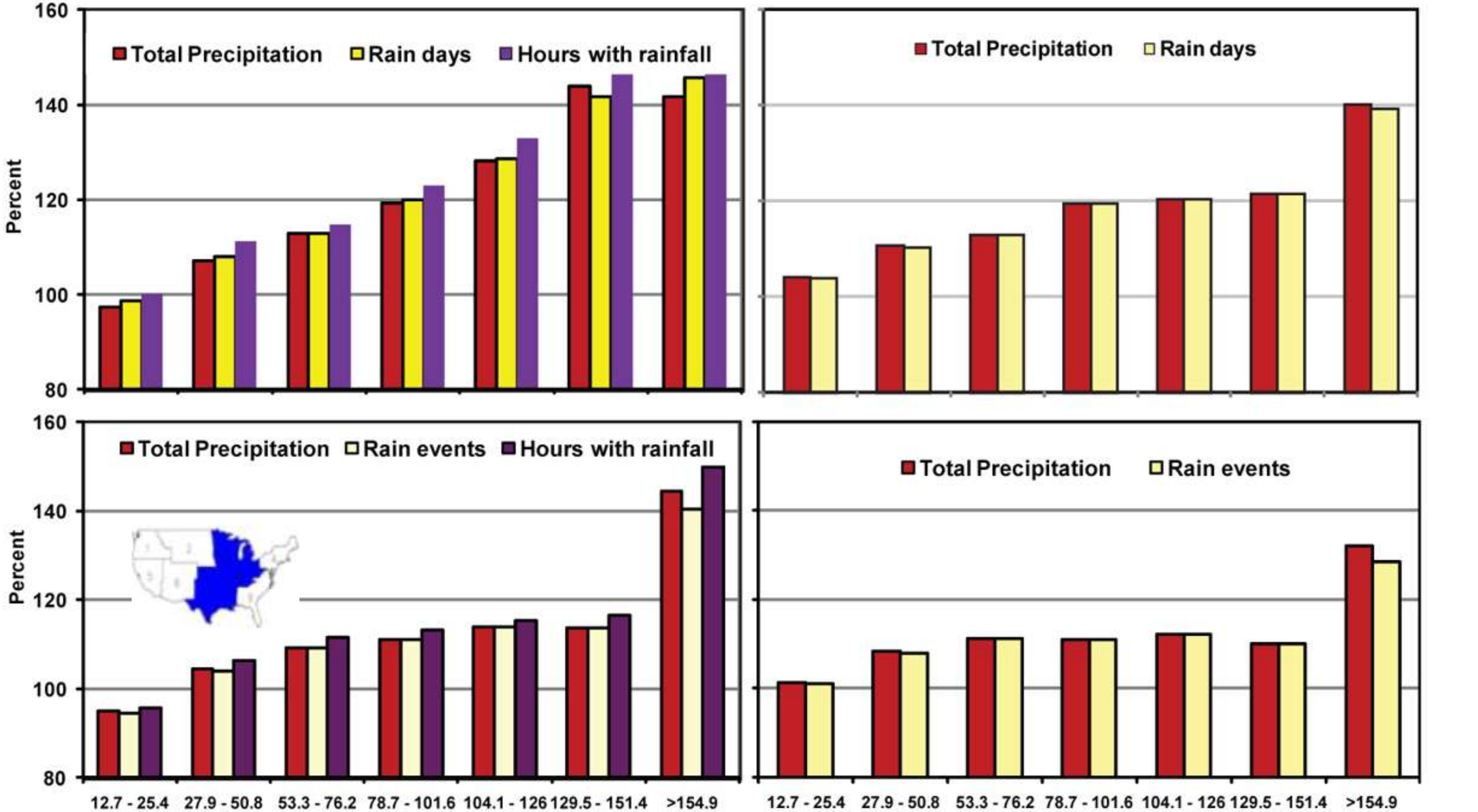
- On average, more than 70% of annual precipitation falls during ~25% of days with intense precipitation
- About half of intense precipitation totals comes from moderately heavy events that comprise more than 70% of all days with intense precipitation
- In the last three decades. only 0.1% of intense rain days were 6-inchers and they brought ~0.8% of intense precipitation in the last decades (but 40 years ago they brought only ~0.6%)
- All trends in very heavy precipitation during the past 118 years are ascribed to the 1948–2009 period and the second half of this period is responsible for most of them

Changes in intense precipitation

Assessing the 1948–2009 period, we compared

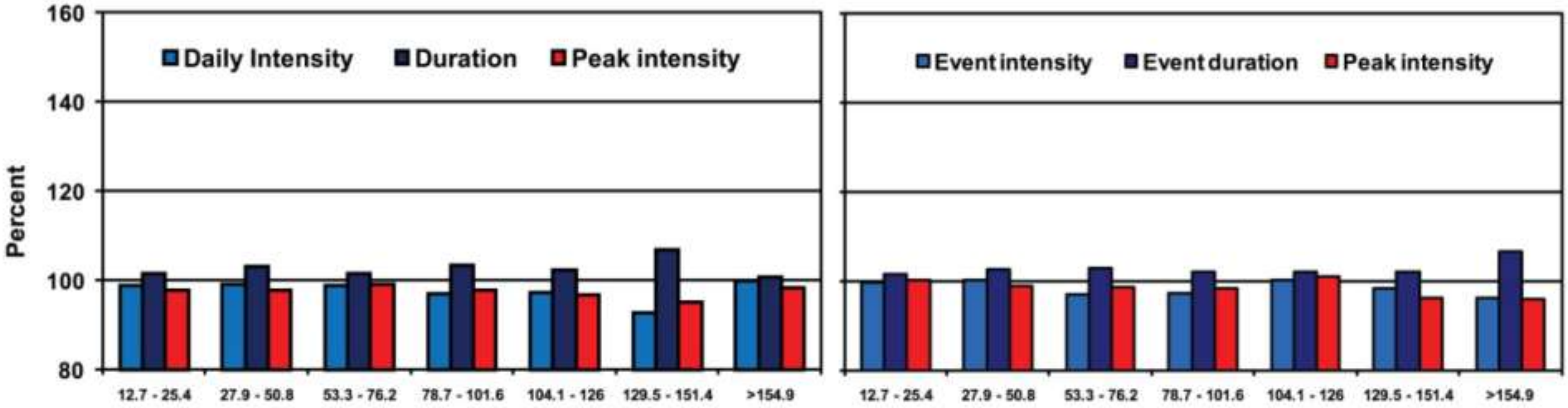
- the first 31 years and the last 31 years of our sample from HPD and COOP networks
- the warmest 31 years and the coolest 31 years using the mean annual surface air temperature of the Northern Hemisphere (TNH) and of the CONUS as guidance
- intense precipitation derived from tropical cyclones (TC) in the hurricane season (June through November) and intense precipitation that originated without direct TC impact, and
- various other combinations.

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)



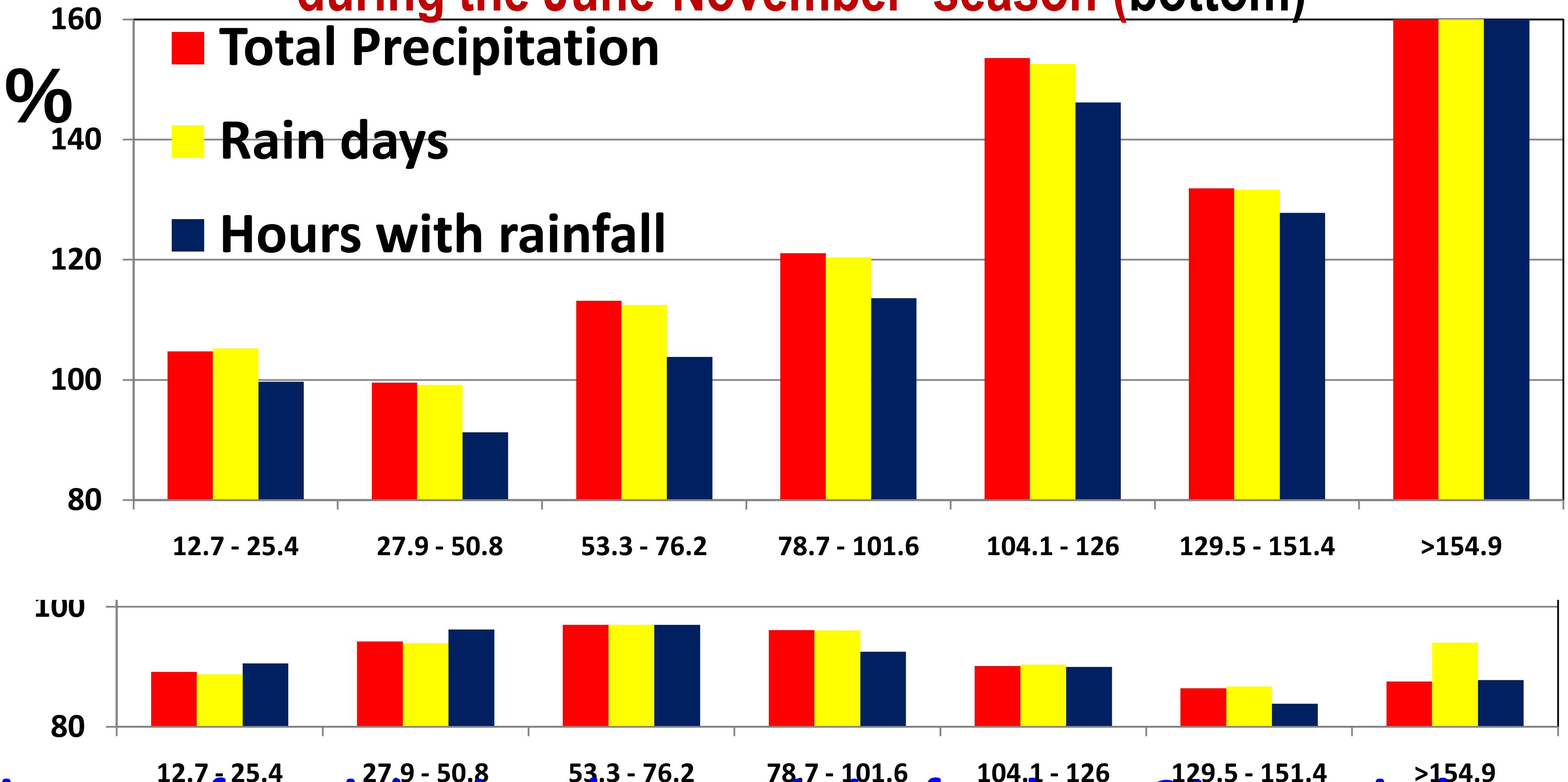
Estimates of precipitation characteristics for these 31-yr periods were averaged and their ratios (in percent per station) are shown for HPD (left) and COOP (right) networks.

Comparison of mean and peak intensity and duration of hourly precipitation for intense precipitation days (left) and multi-day intense precipitation events (right) over the Central U.S. for 1979-2009 and 1948-1978 periods sorted by day/event intensities (in mm)



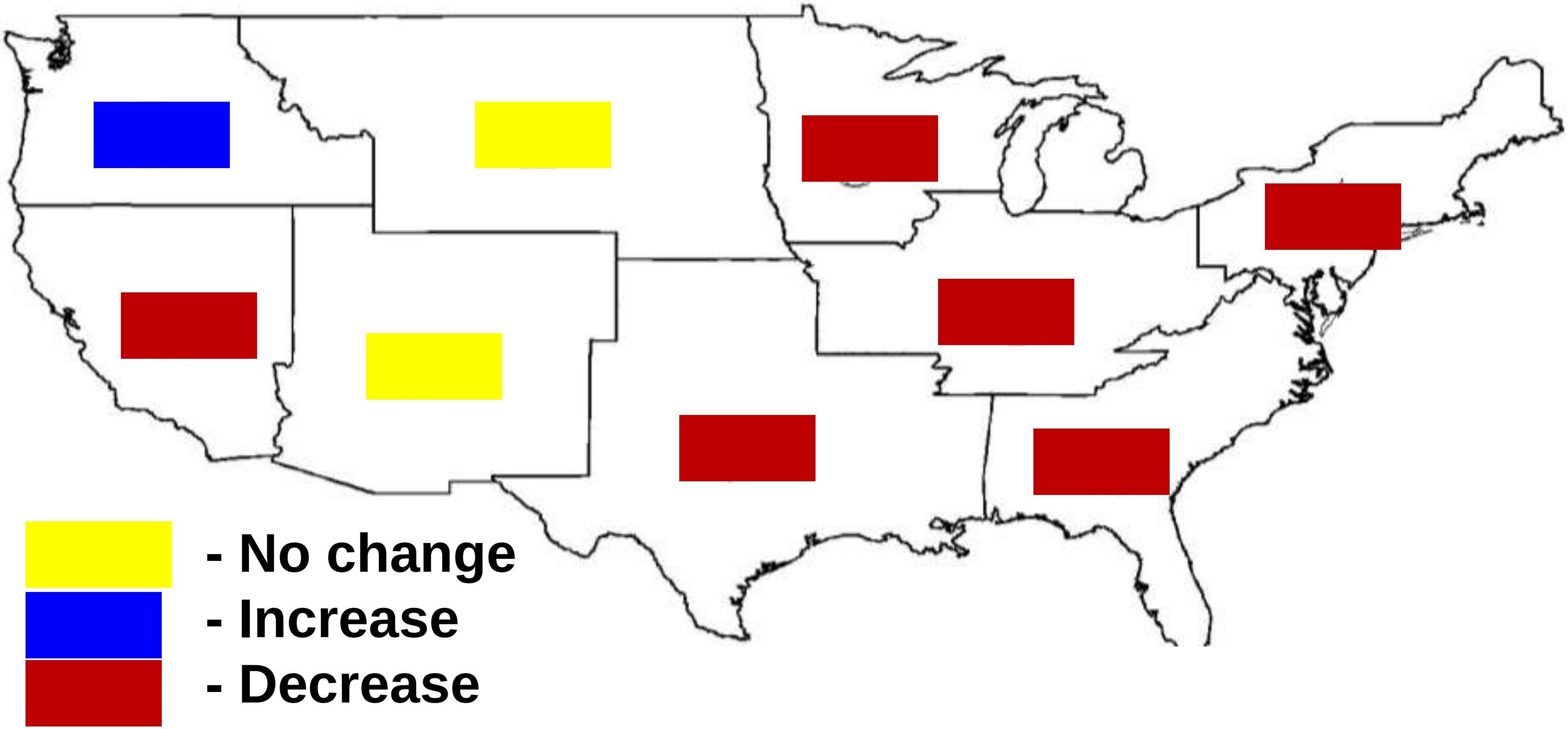
Estimates of precipitation characteristics for these 31-yr periods were averaged and their ratios (in percent per station) are shown

Comparison of intense precipitation characteristics 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 during the June-November season (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 (in mm, x - axes)

. Changes of the fraction of moderately heavy precipitation 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.

Regions of concern in the United States

More heavy, very heavy, and extreme rainfall:

- Central United States
- Southern Alaska

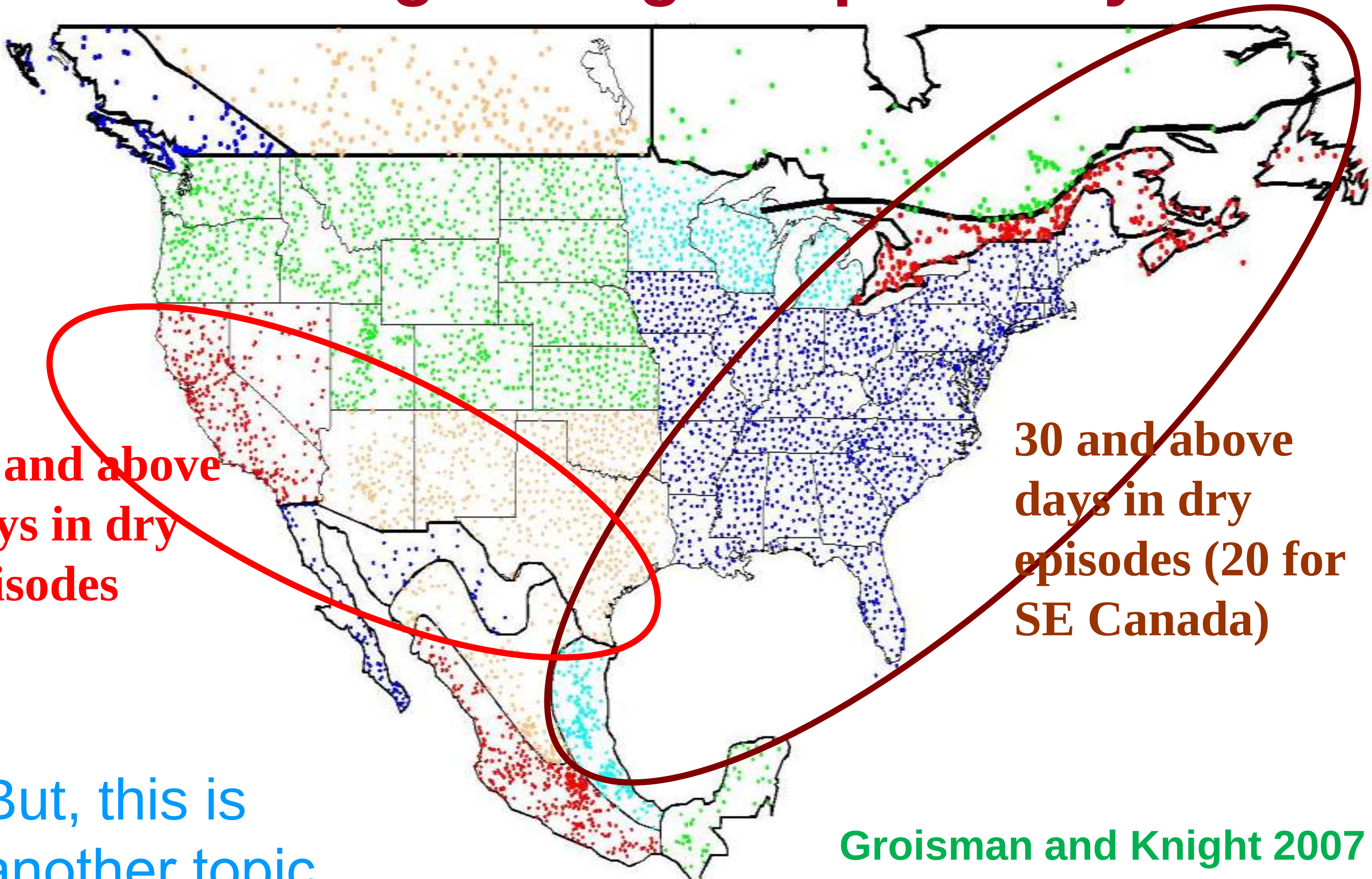
Unfavorable development with atmospheric water supply:

- Southwestern United States
- Southeastern United States

Conclusions

- We documented a significant increase in very heavy and extreme precipitation during the past several decades over the Central U.S. (which comprises more than 35% of the contiguous U.S.)
- Prior to planning for adaptation and mitigation measures for detrimental consequences of these observed changes, the causes of this increase should be carefully investigated using a suite of models
- Projections of future changes critically depend upon correct partitioning of impact and feedbacks of global and/or regional factors responsible for ongoing changes
- Maybe it is time to revitalize the First GEWEX Experiment studies with foci on changes in terrestrial and atmospheric processes over the Mississippi River Basin.
- There are important invariants in the current intense precipitation changes (e.g., maximum rainfall intensity)

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



Groisman and Knight 2007

But, this is another topic…

Thank you!