The effect of a giant wind farm on precipitation in a regional climate model

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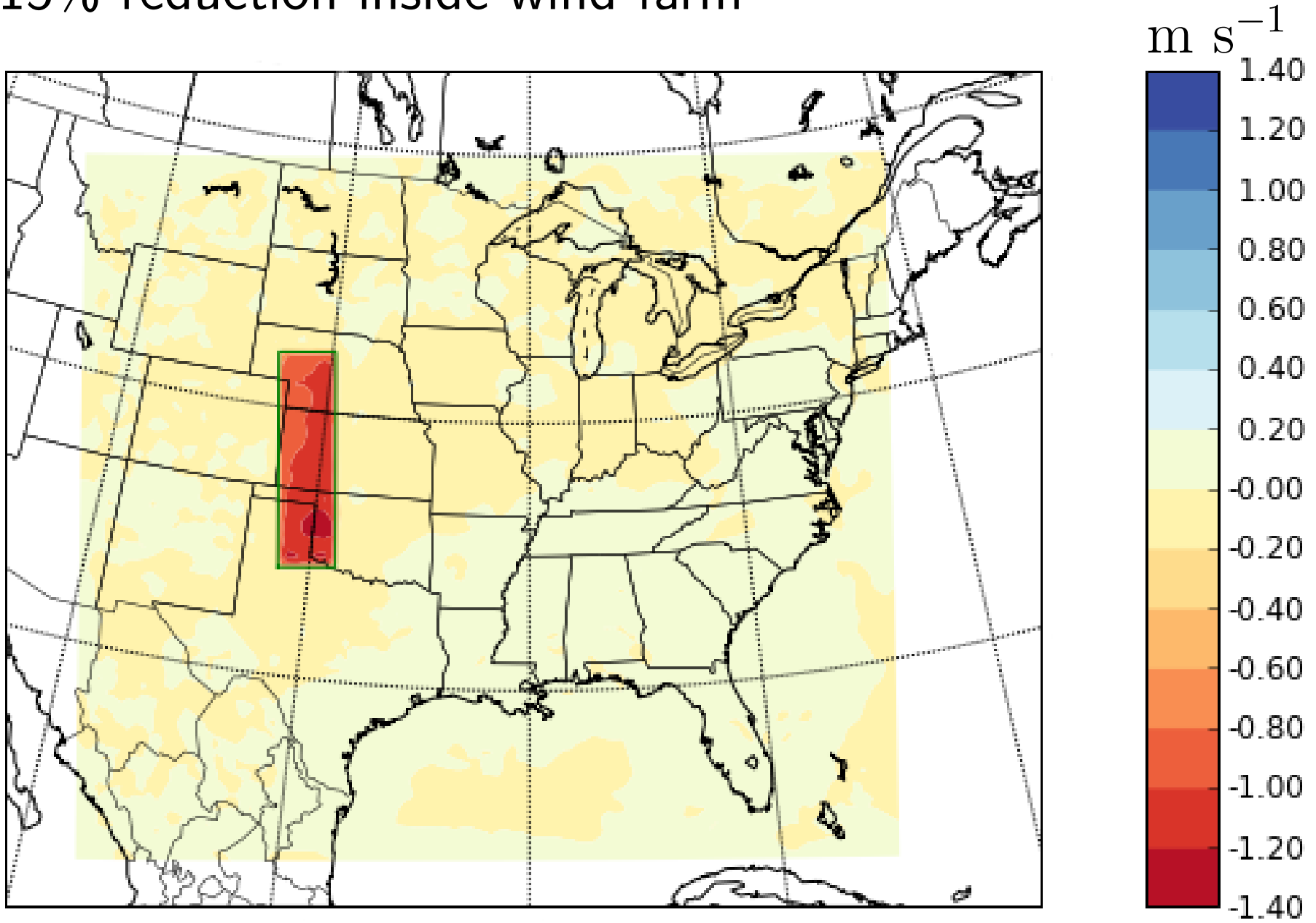
1948-2009 average wind speed change at 100 m

15% reduction inside wind farm

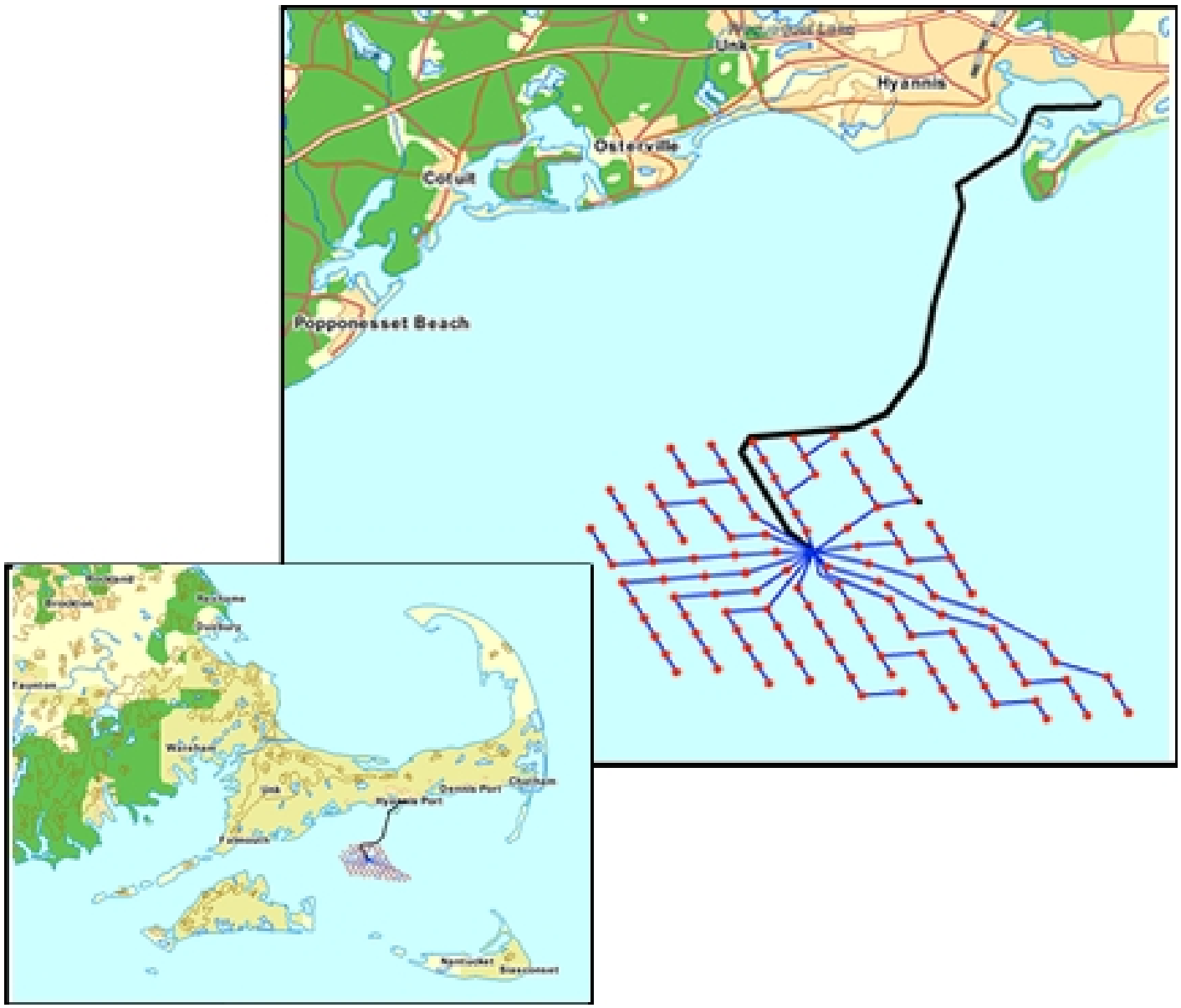


- Bukovsky & Karoly WRF configuration, identical to what they used for 2x CO2
- Nested in May-June-July-August Reanalysis Data for 1948-2009

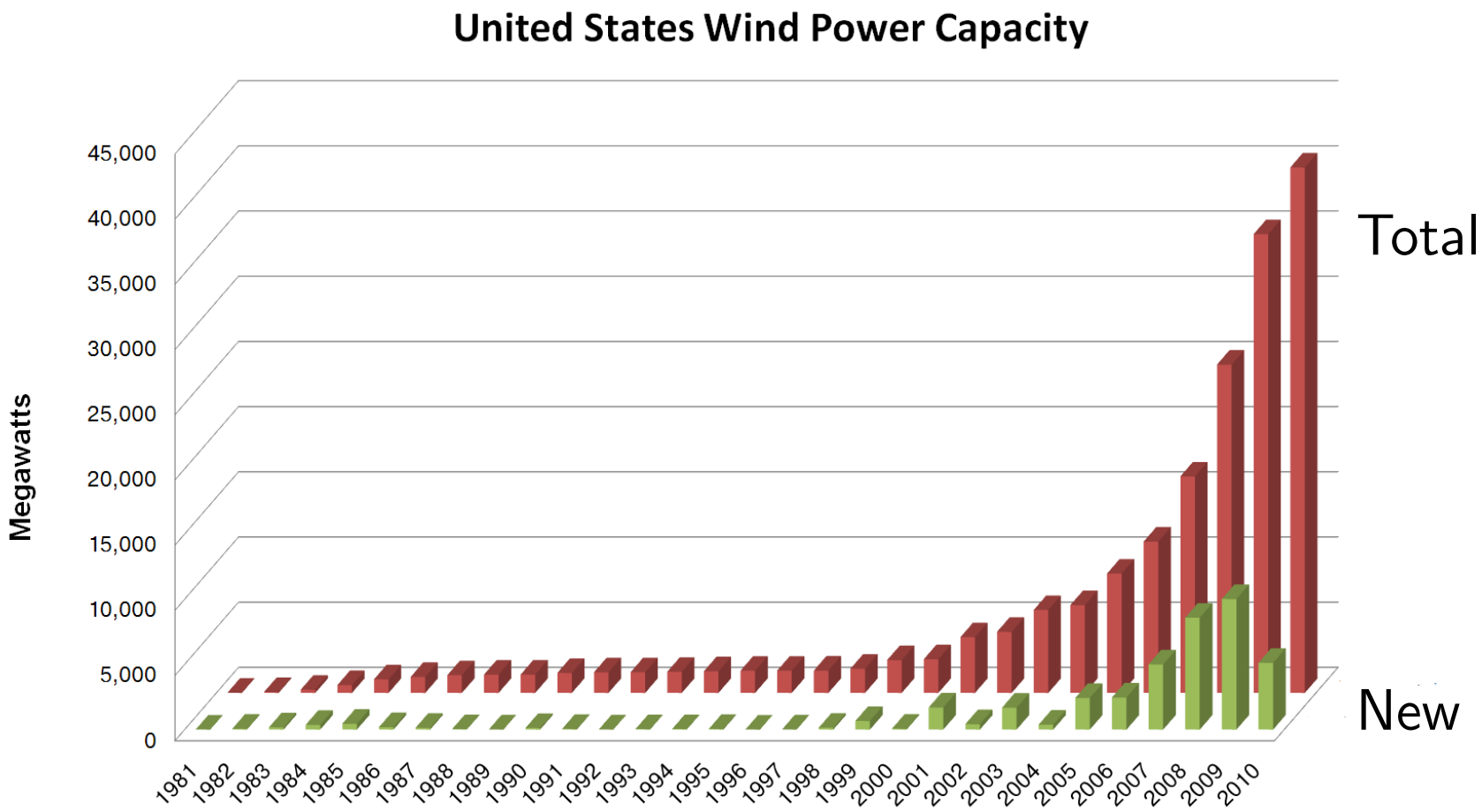
- WRF 30 km resolution, Kain-Fritsch convection, MYJ boundary layer
- Adams & Keith wind farm parameterization, for elevated drag of rotors

- 228,375 2.0 MW turbines $=$ 457 GW capacity
- 1.25 turbines per km^2
- expected production 457 GW $\times$ 20% $=$ 91 GW
- would supply 0.6% of the world's power of 15,000 GW
- at optimistic \$3 per Watt, total cost is 1.3 trillion dollars

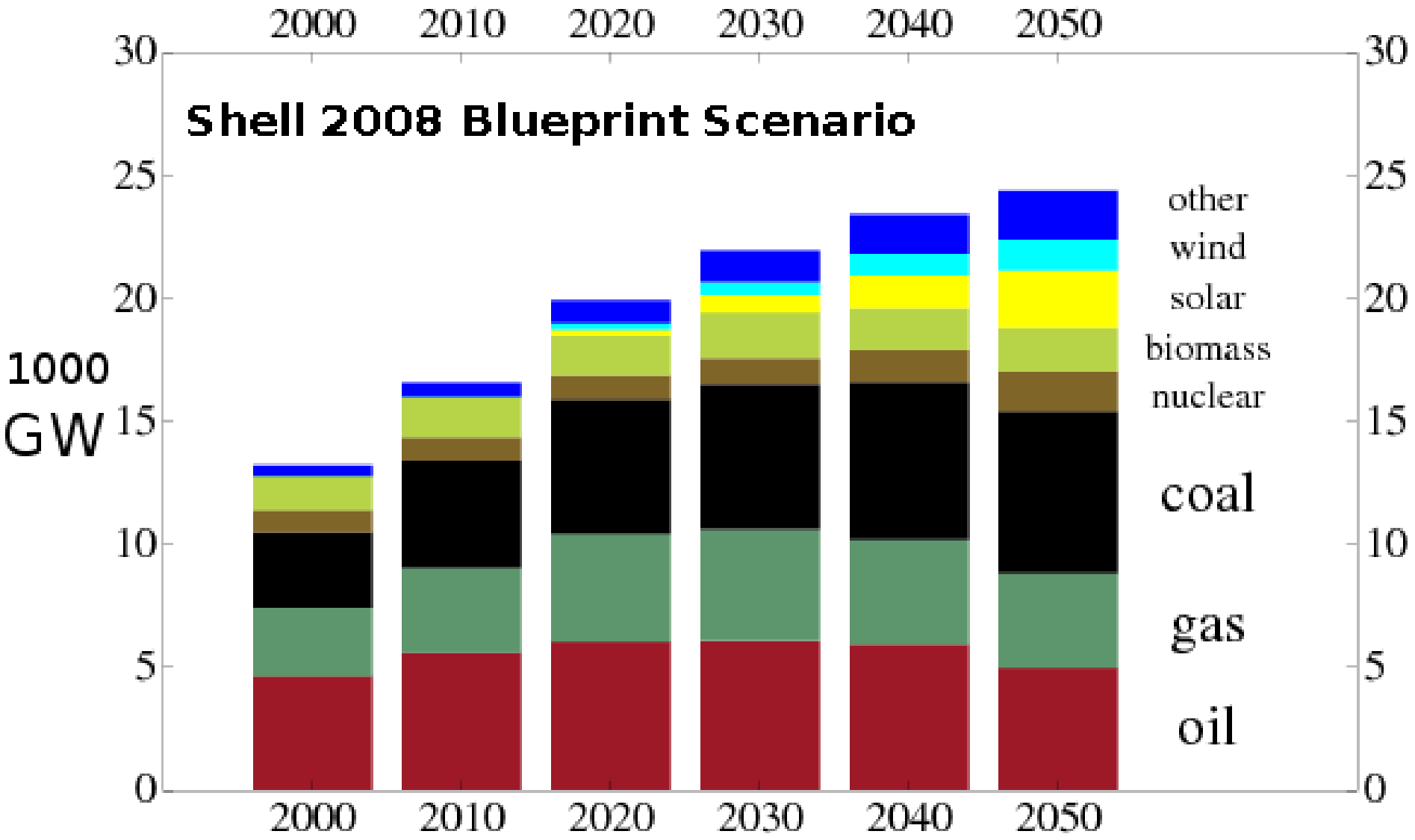
Equivalent to 1000 Cape Wind:



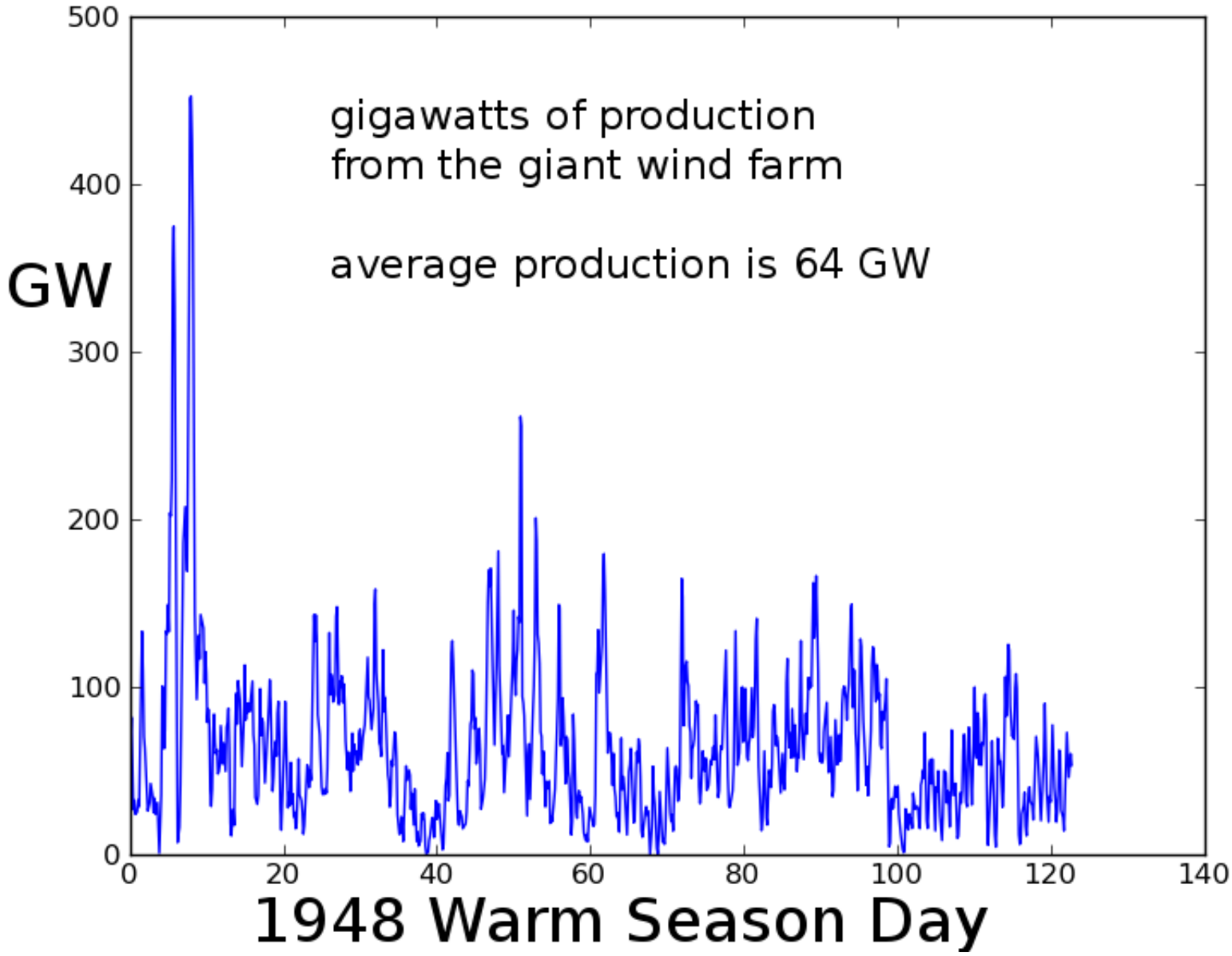
Equivalent to 10 times current US capacity:



Need ~ 10 giant wind farms by 2030 to meet Shell's projection:

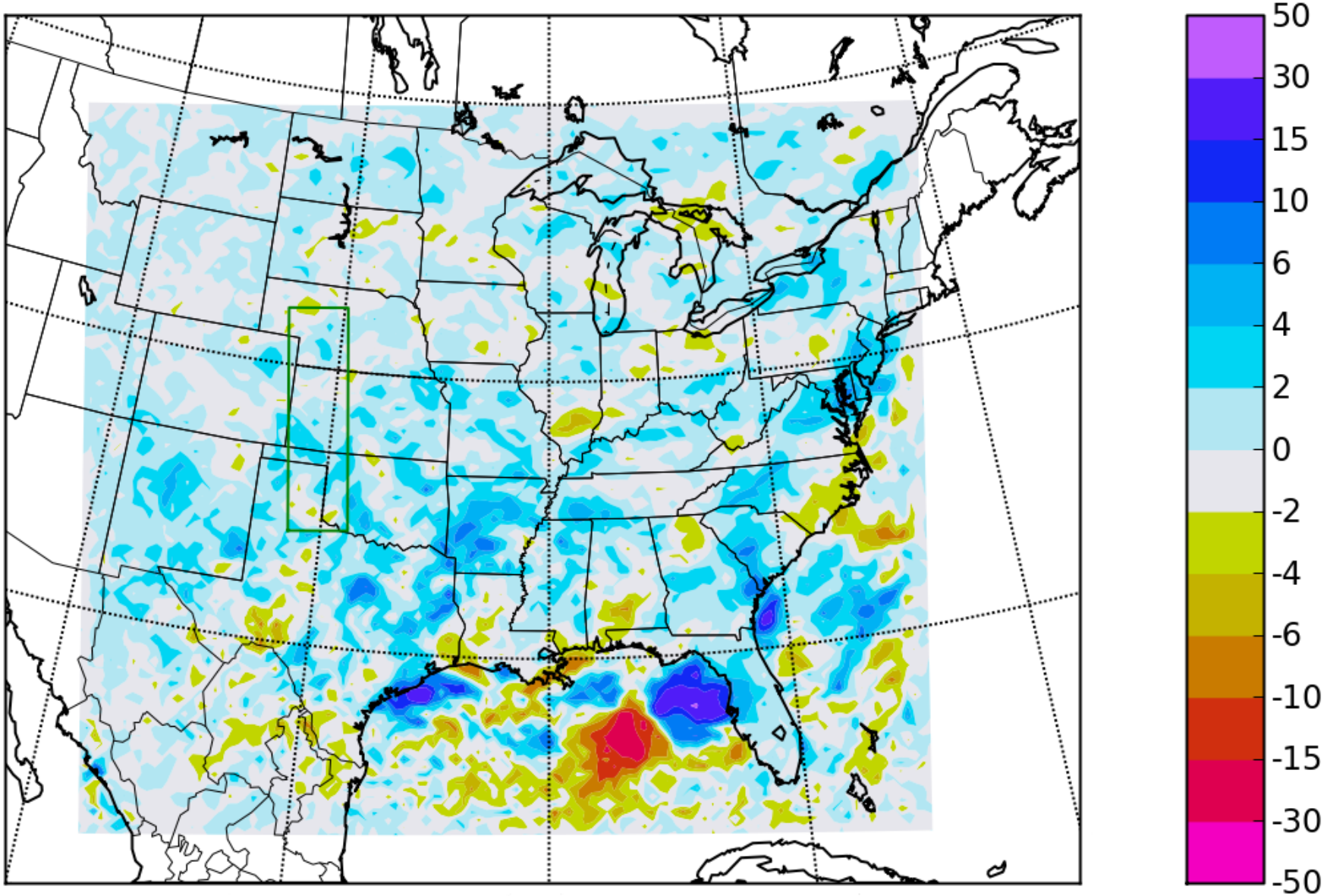


poor performance in summer months, $0.35\ \mathrm{W\ m^{-2}}$:



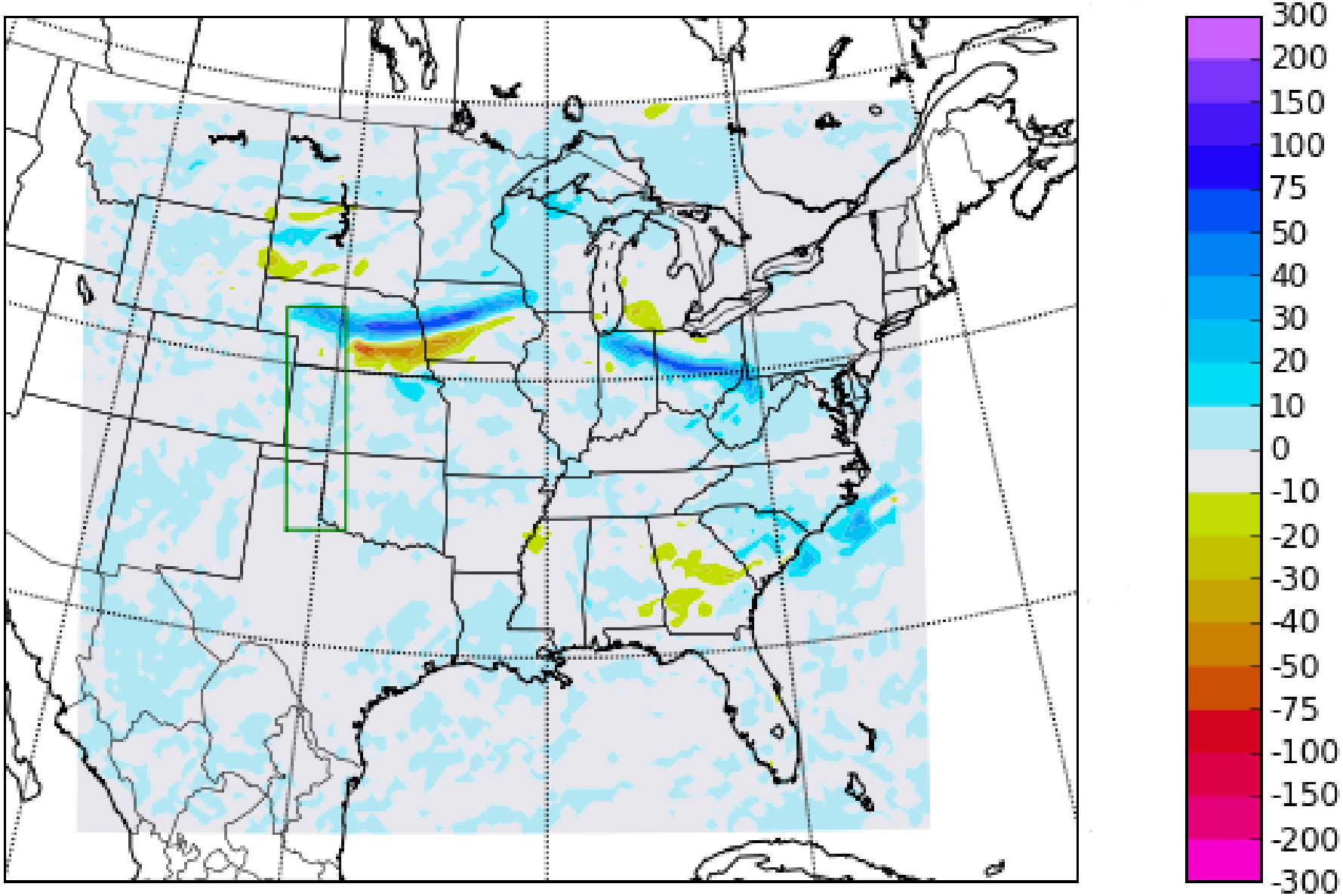
62 seasons: May-August 1948-2009 rainfall

WITH minus NO, percent difference



One day: 16 July 1948 rainfall

WITH minus NO, millimeter difference



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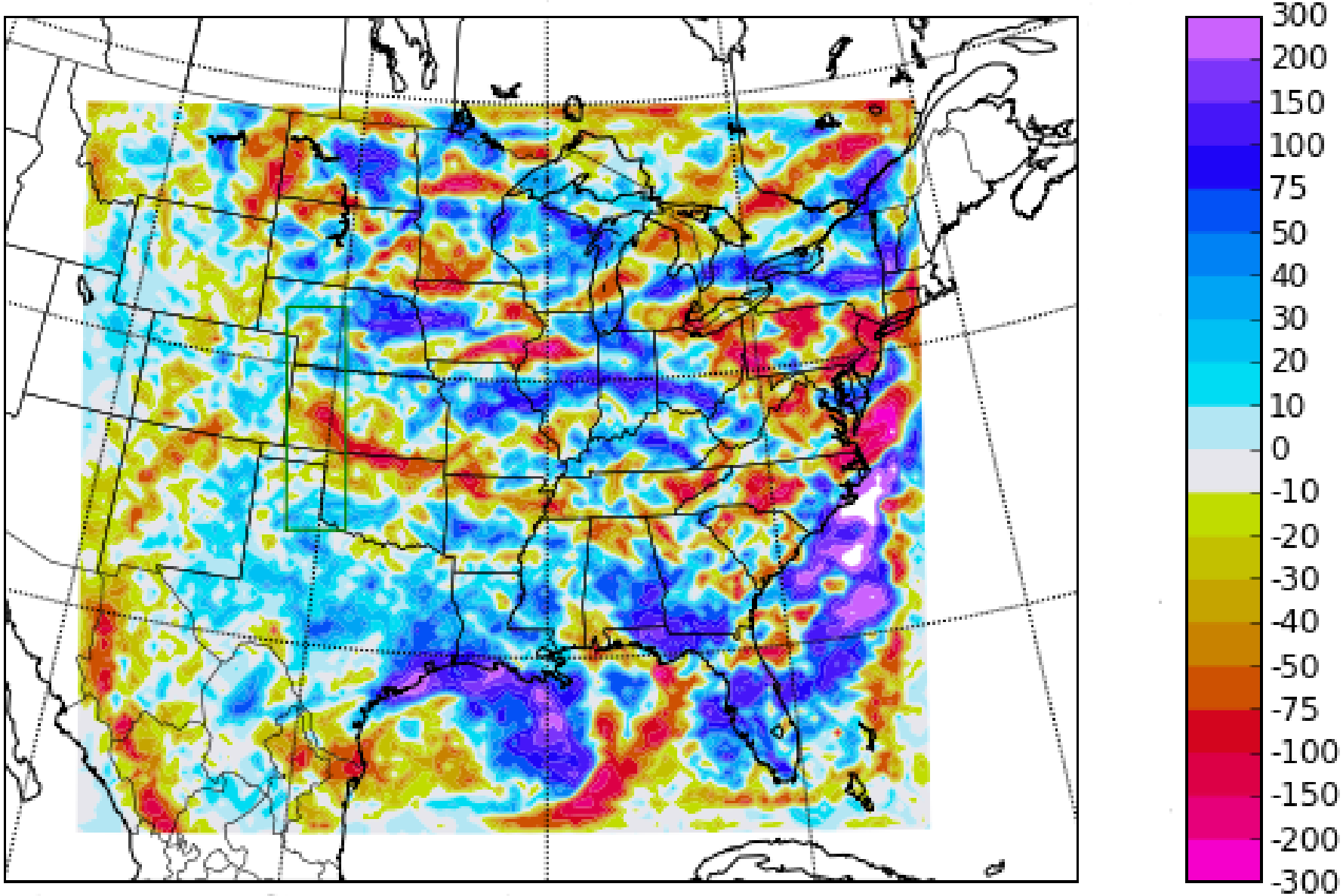

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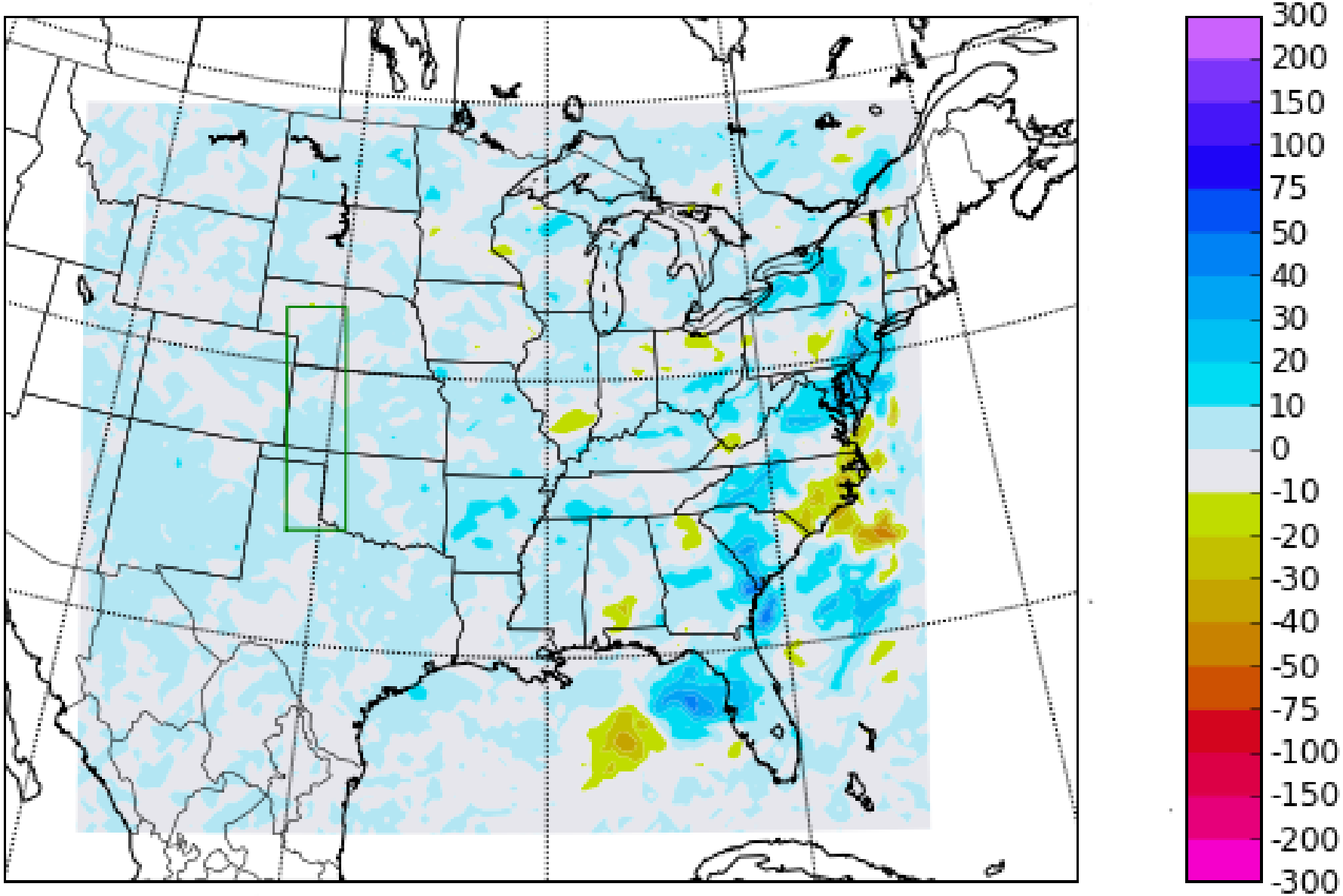

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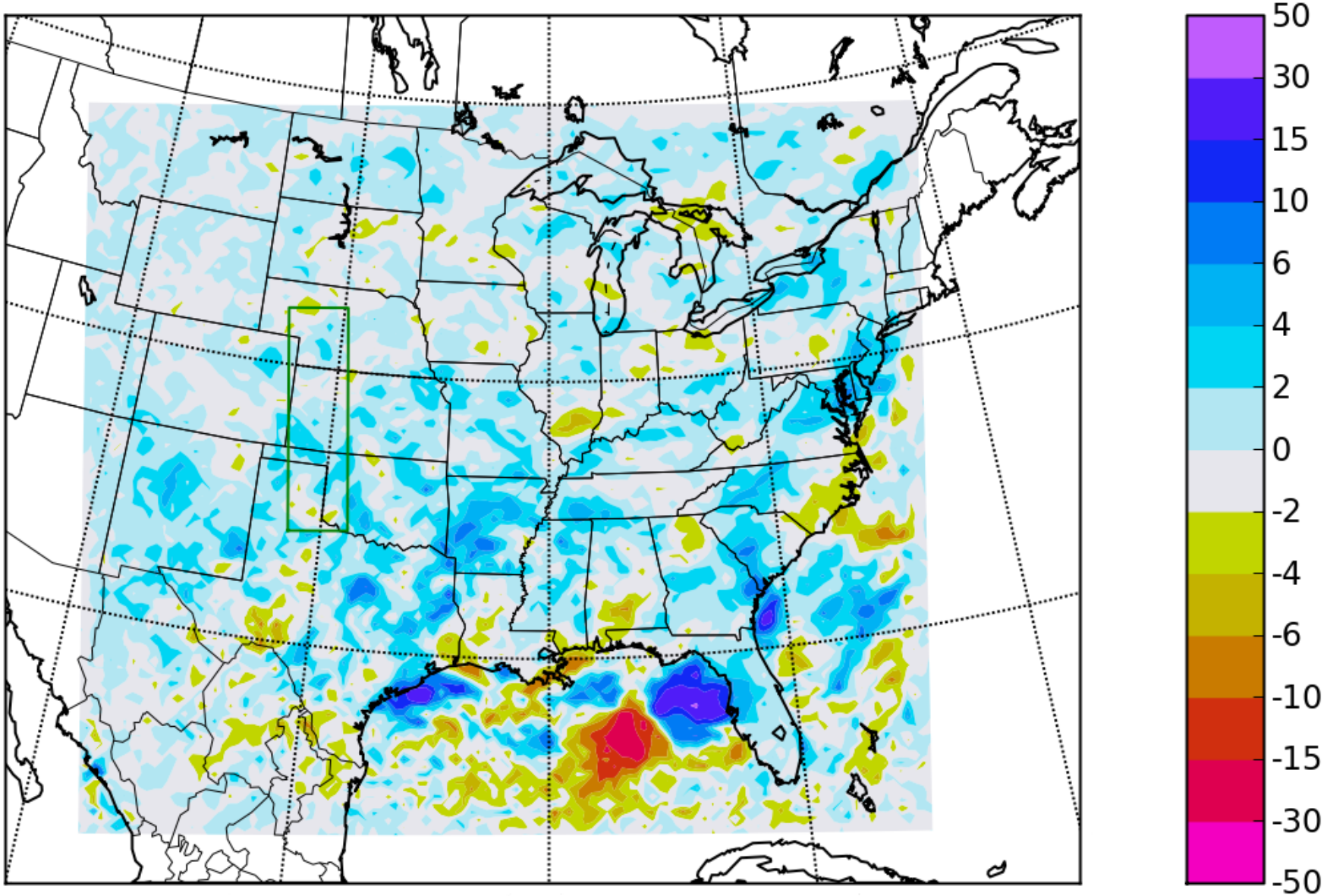


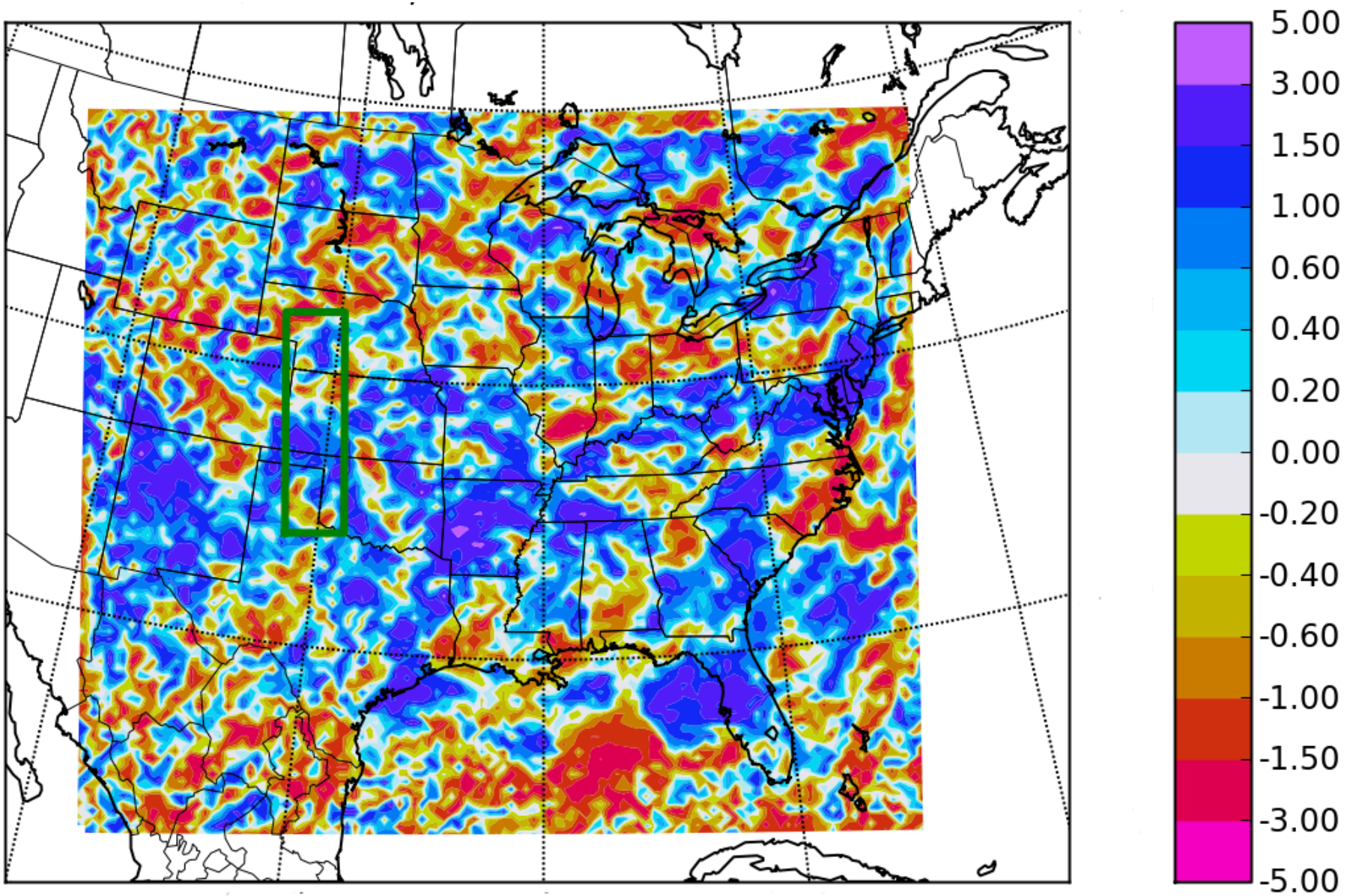
The difference pattern is for $N = 62$ seasons.

What is the pattern for $N \to \infty$? Do we have confidence that anything in the pattern for $N = 62$ represents the pattern for $N \to \infty$?

To make the statistical inference, we must use knowledge about the variance in the time series.

$$t = \sqrt{N}\frac{\bar{r}}{\sigma_r} \qquad N = 62$$

r is precipitation difference



In the following slides:

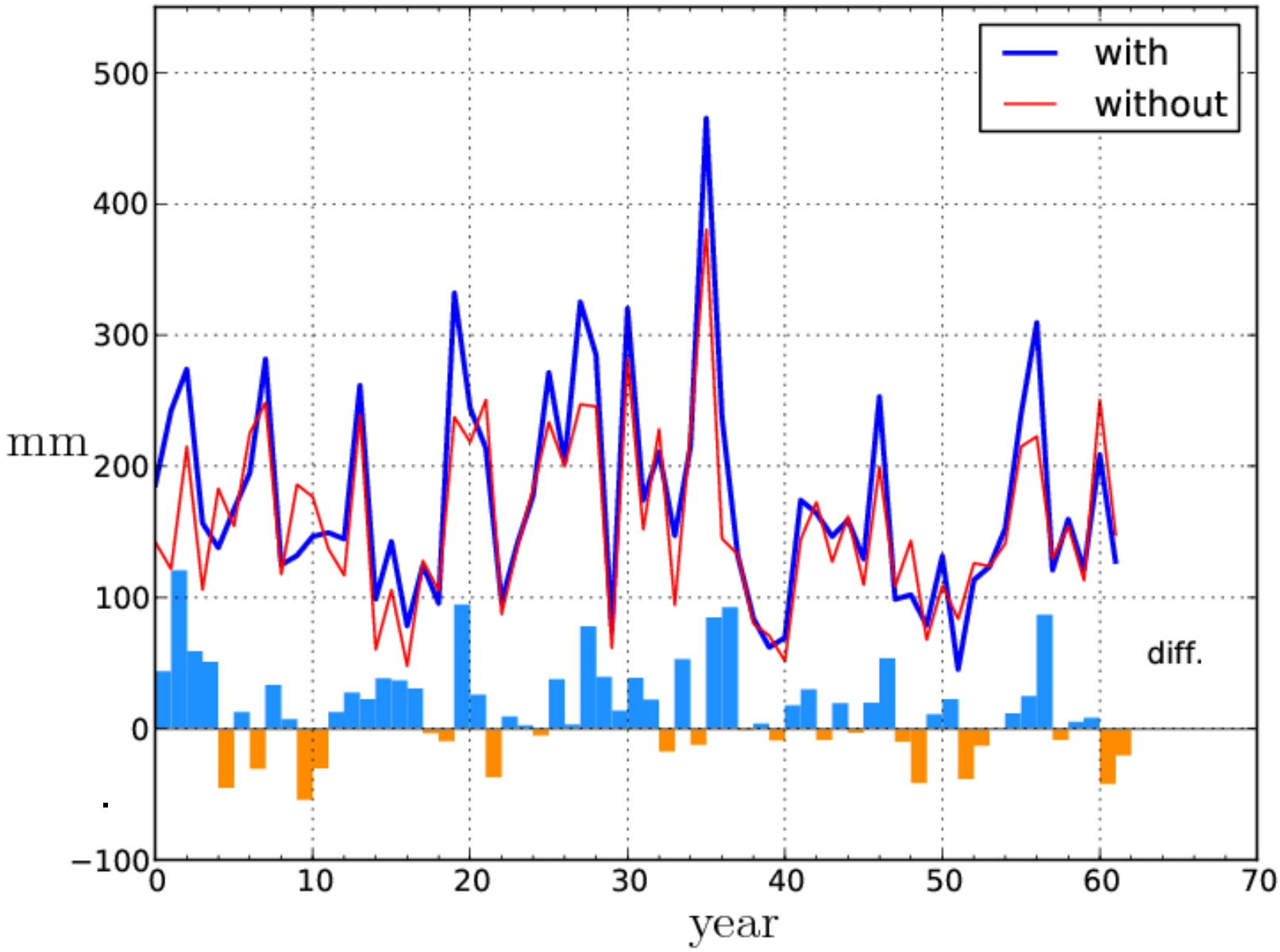
- f is the fraction of the domain
- t is the t-value from the Student's t-test
- p is Student's t-test probability that the true mean is opposite in sign from the observed mean

red p is resampling-with-replacement p-value

Require $p < \frac{1}{20} f$ for
"statistical significance"

Arkansas point: *not significant*

$t = 3.35,\ p = .00070,\ p = .00023,\ f = .00009$



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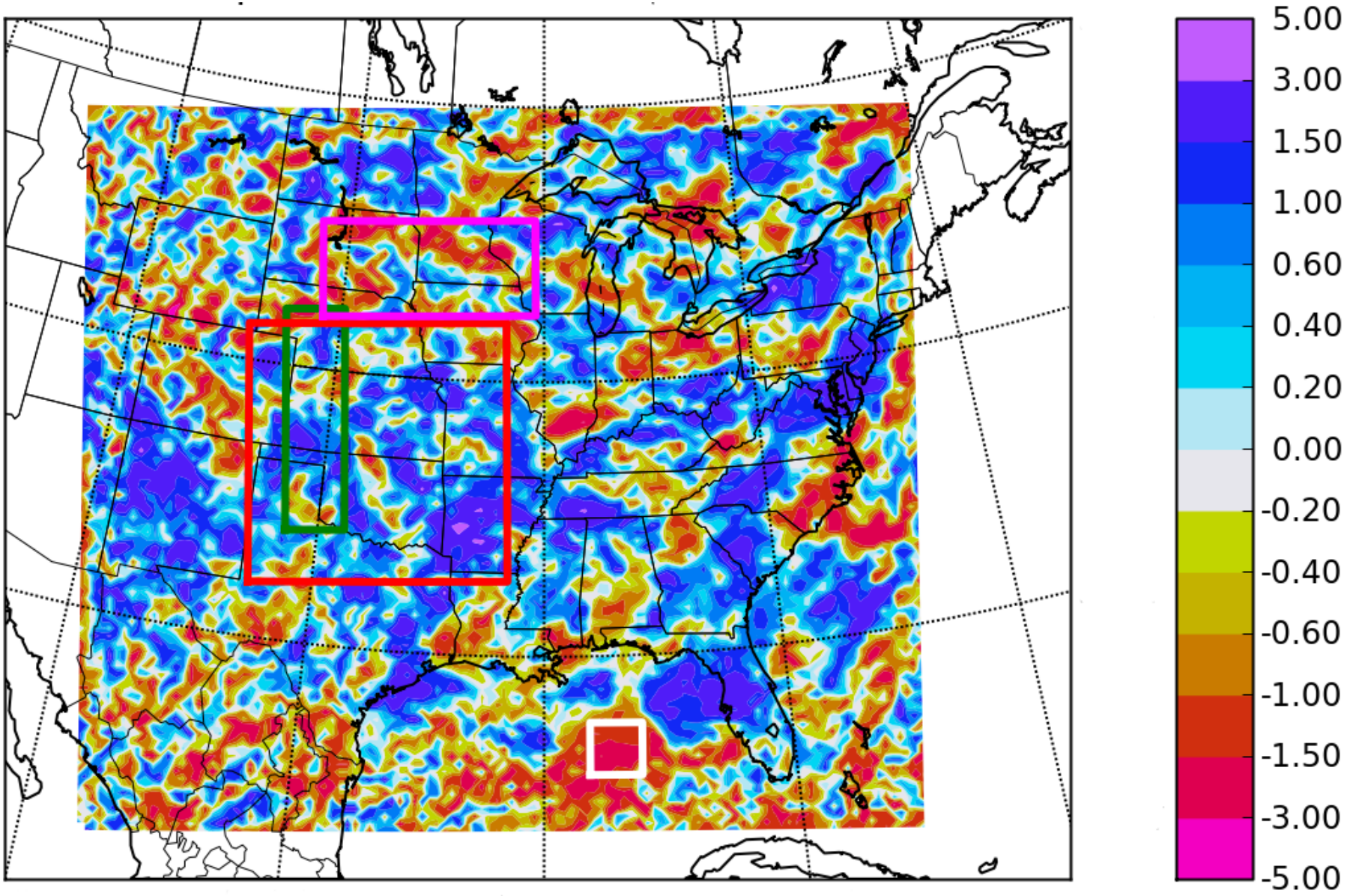

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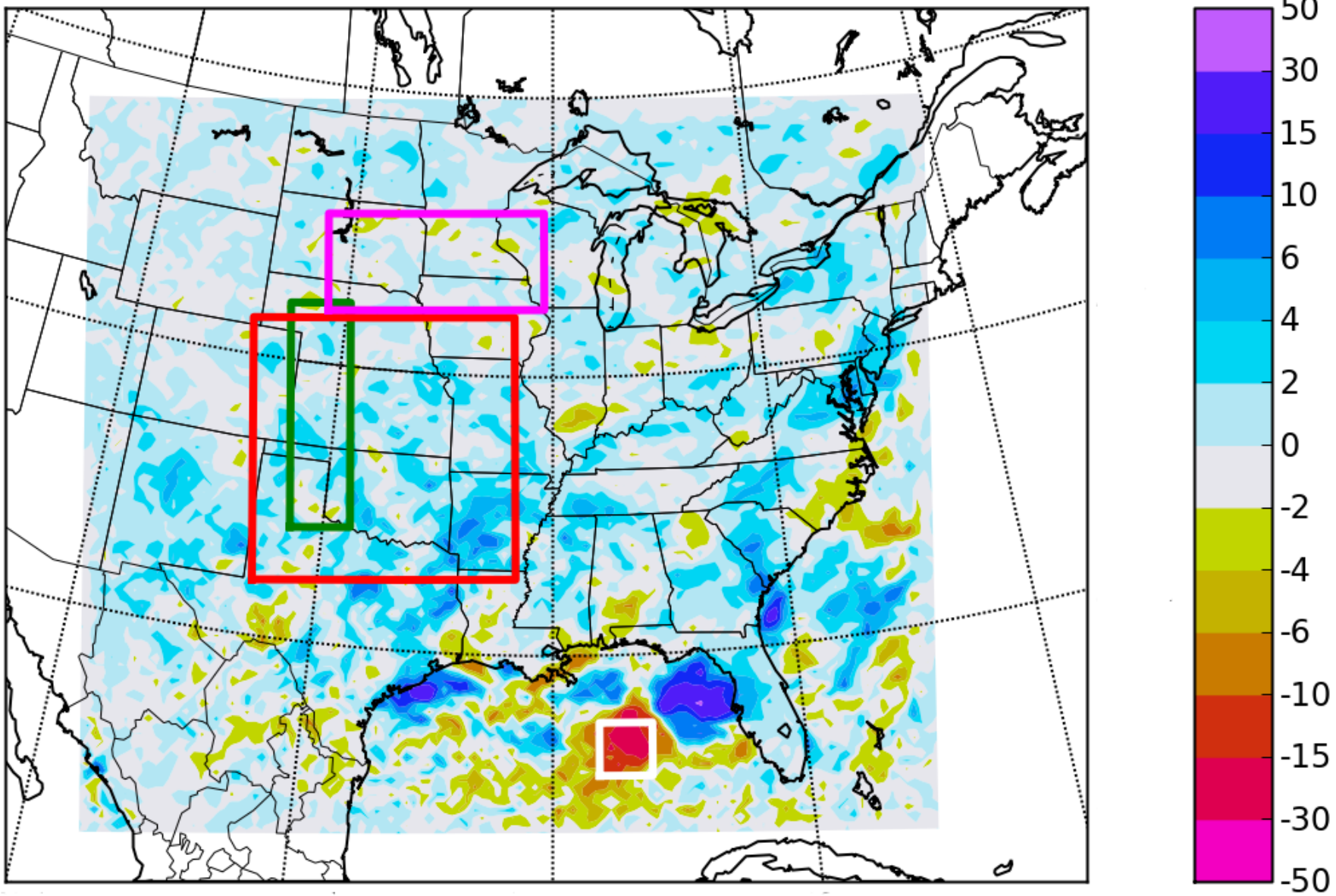


t of the average

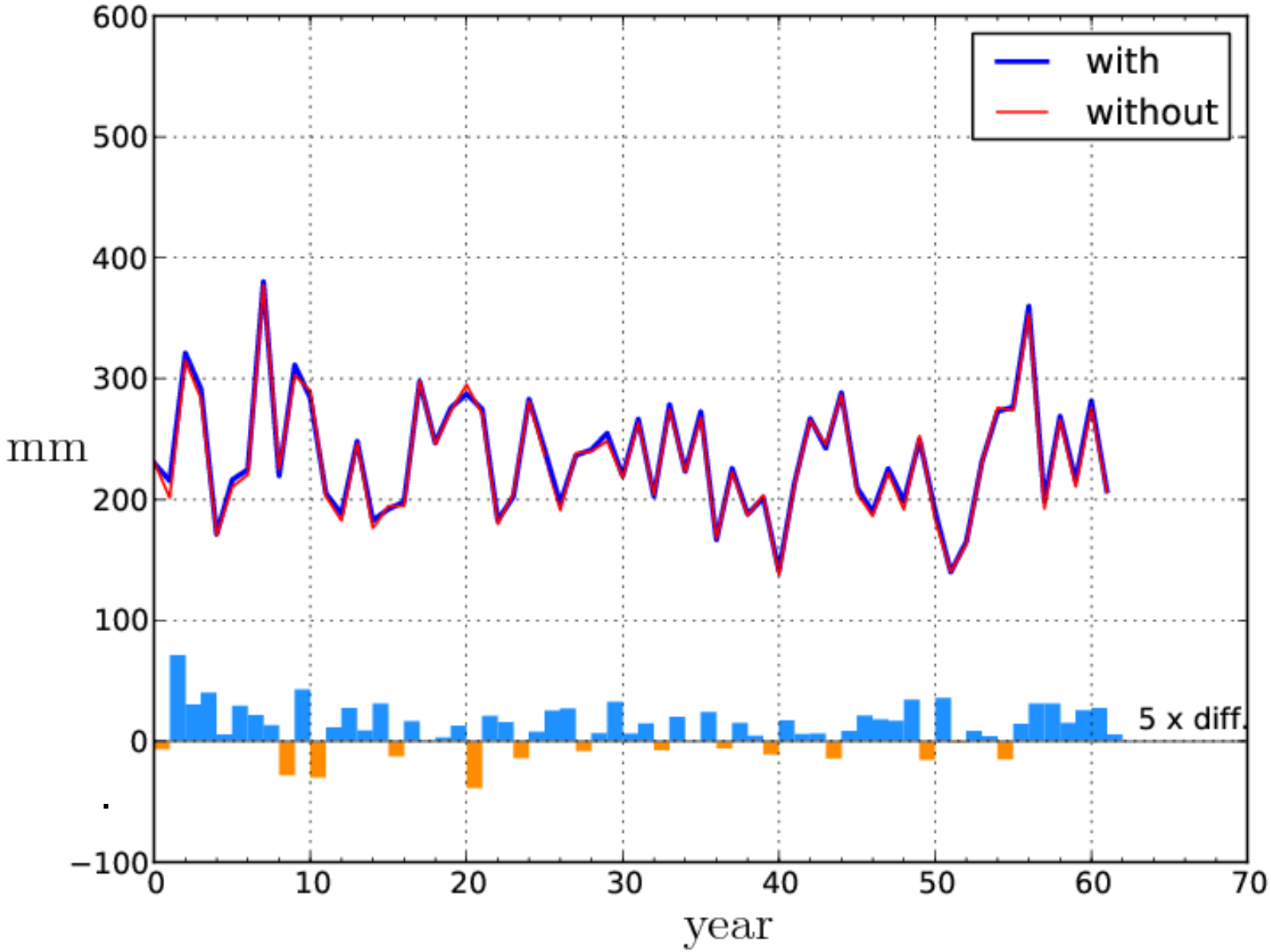
is greater than

the average of t

The rainfall difference over large areas is more certain than at individual grid points.

Red box: *significant*

$t = 4.71,\ p = .000008,\ p = .000002,\ f = .11$

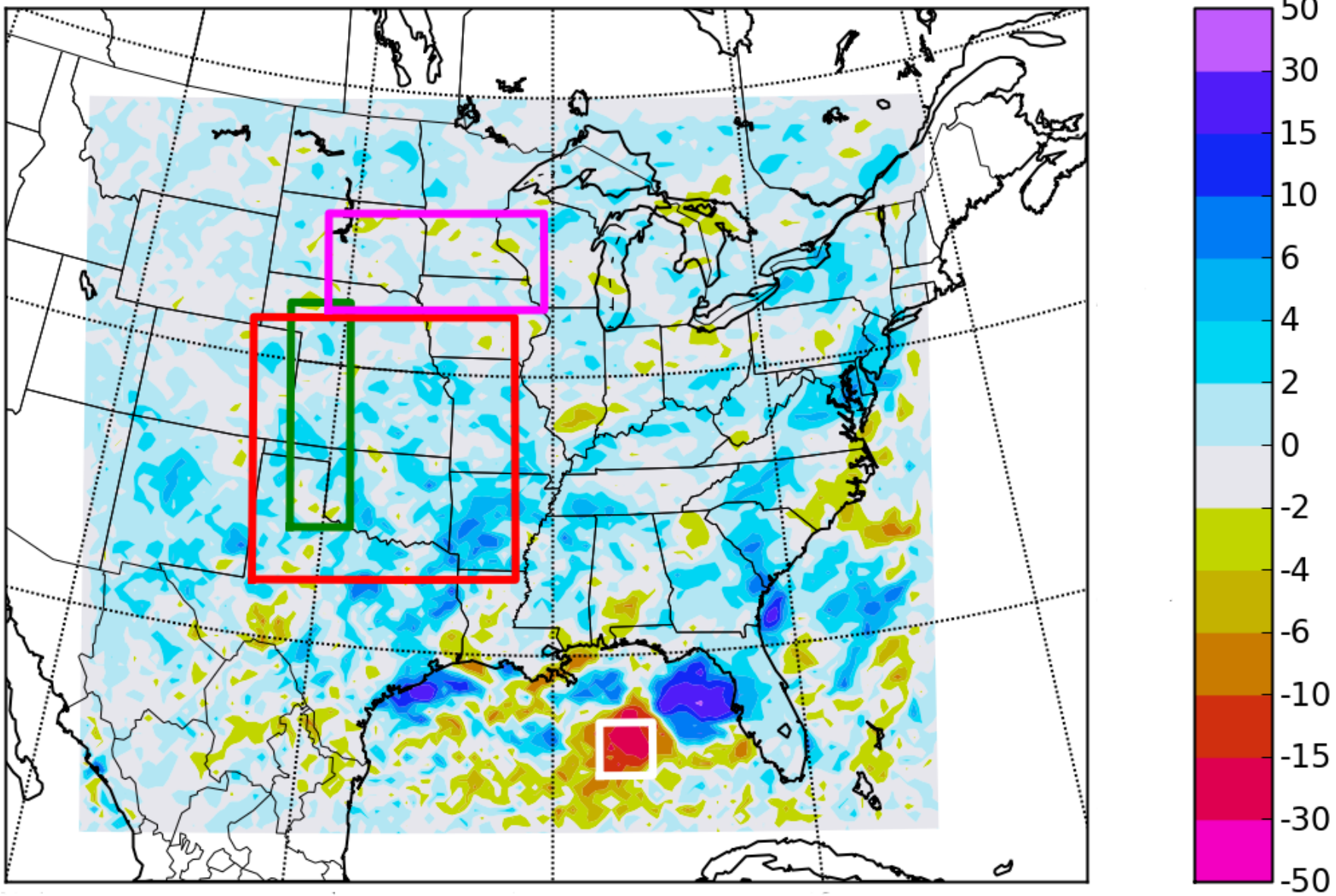


90% confidence that the model wind farm causes the true mean of precipitation to be between 0.64% and 1.33% enhancement within the red box.

A resampling-with-replacement method produces the identical 90% confidence interval.

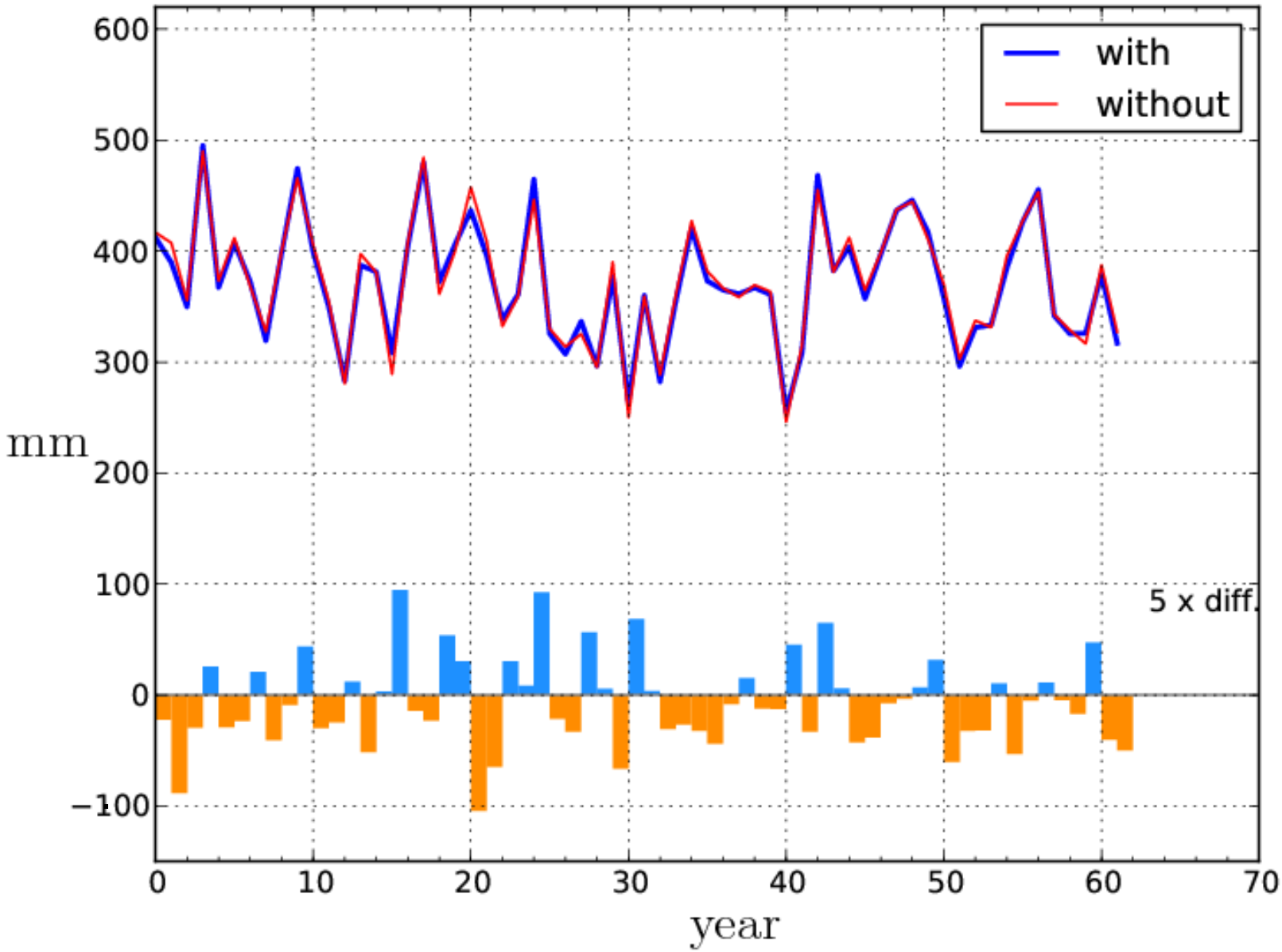
62 seasons: May-August 1948-2009 rainfall

WITH minus NO, percent difference



Magenta box: *not significant*

$t = -1.5,\ p = .07,\ p = .07,\ f = .033$



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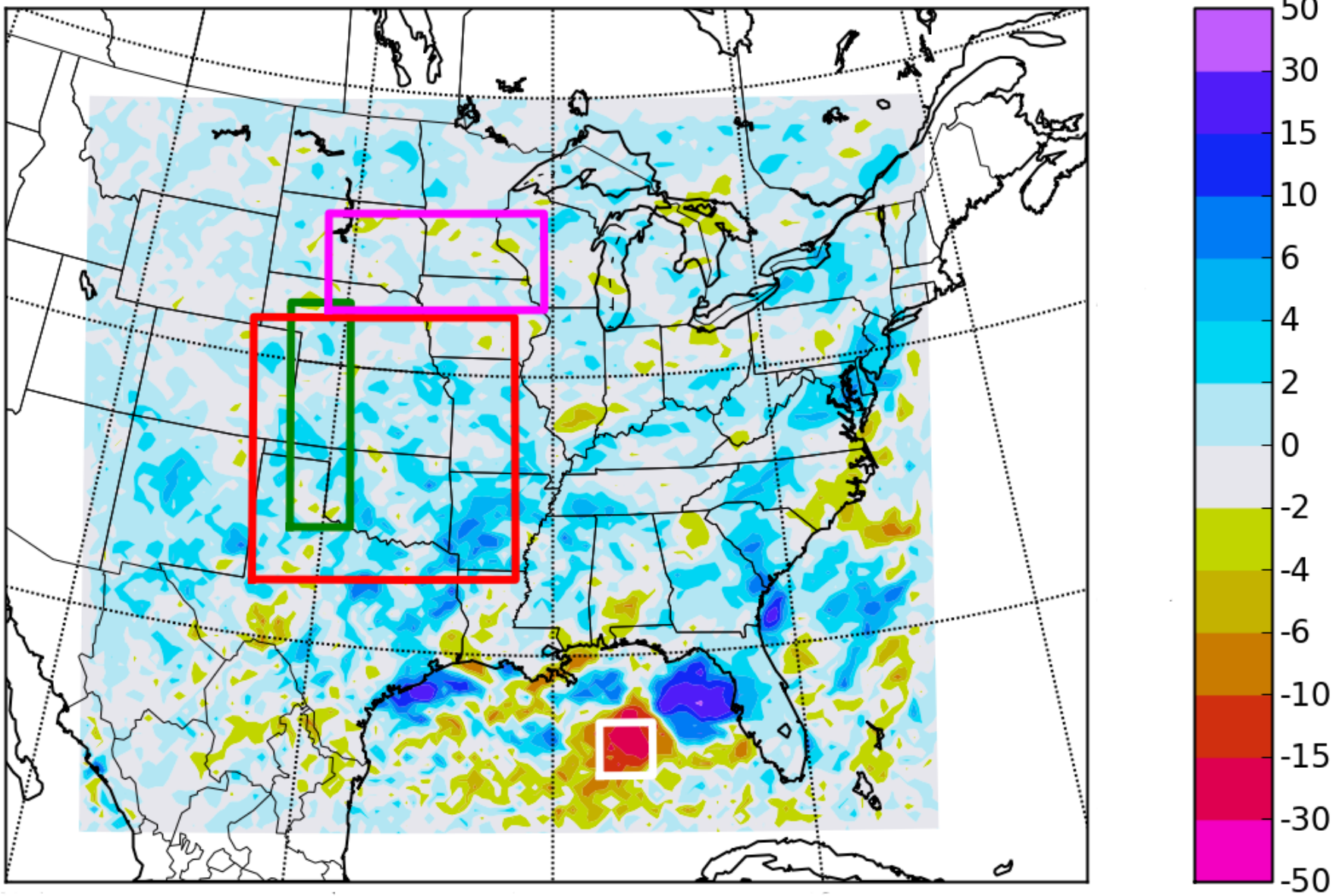
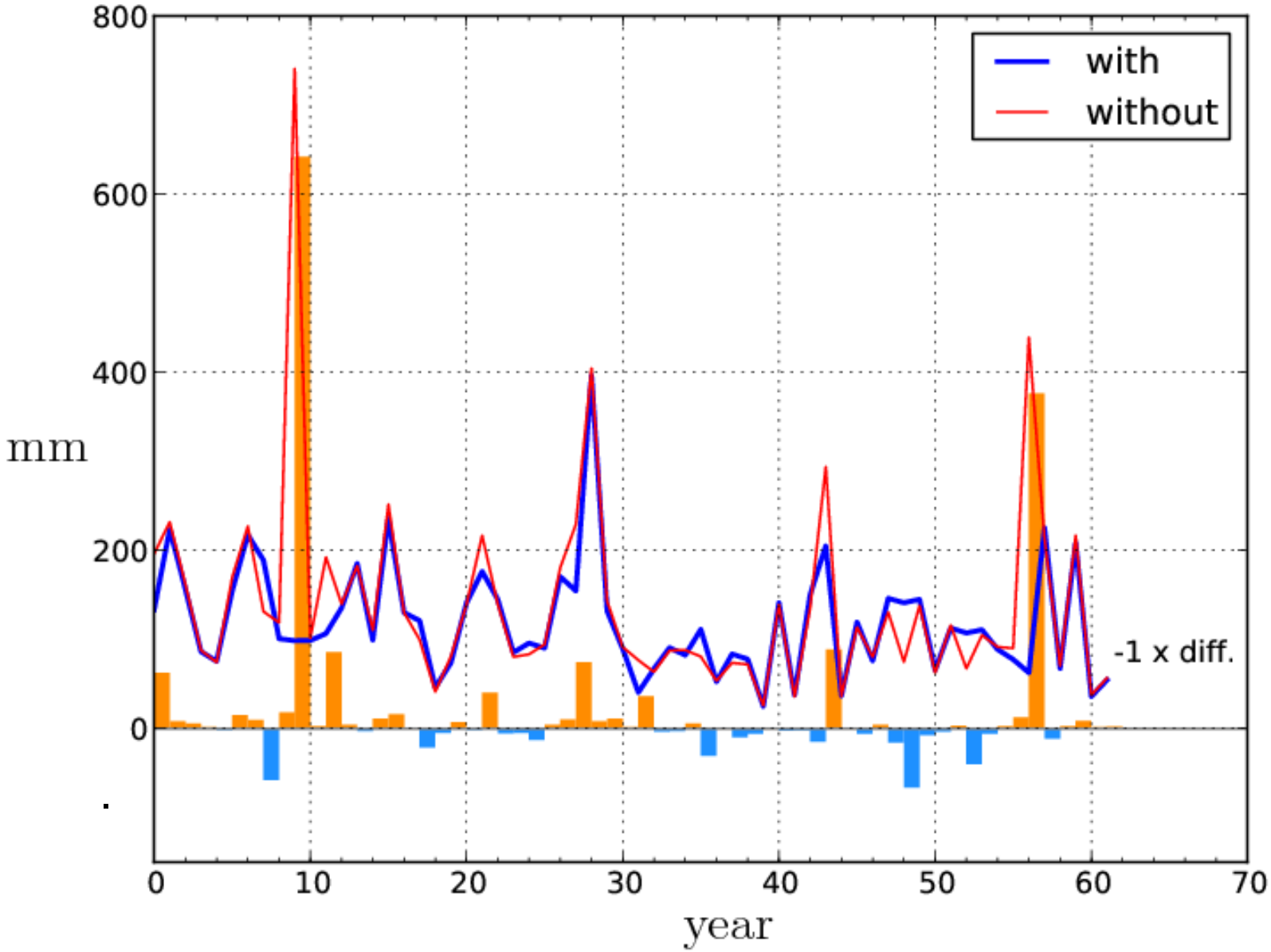


White box: *not significant*

$t = -1.64,\ p = .053,\ p = .016,\ f = .0043$



Conclusions:

- Wind farms have a big effect on WRF weather
  . . . so do butterflies.
- *Skillful* forecast of the effect on real weather
  — by the giant wind farm or any wind farm —
  has *not* been demonstrated and was *not*
  investigated in this research.

- Effect on WRF climate is small: 1% increase in precipitation in a broad area around the wind farm.

Project completed on two Lenovo desktops with a duo-processor I3, in about four months.

"RIKEN and Fujitsu have taken first place on the 37th TOP500 list announced today..."

Achieves world's best performance of 8.162 petaflops to lead TOP500 list

A weather investigation to consider:

- A wind economy would require 200 giant wind farms. Sometime this century it will be accepted that weather forecast skill requires a wind farm parameterization. On the day in history that this acceptance occurs, something else happens. . .
- Thus, inevitably, in a wind economy, wind farms become an instrument of *planned* weather modification, because wind farms can be turned off. Wind farm operators will become liable for decisions to furl the blades or not.

Our quest for perfect weather prediction becomes a wicked Faustian bargain.

A climate question for future investigation:

- What would happen at $1\ \mathrm{km}$ resolution?

Tornado Tracks 1950-2010