Simulations of Global Climate With a High-Resolution Atmospheric Model

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With help from
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Thanks to Dave Bader & Jerry Elwood for their support

My talk:

- Motivations
- High-resolution global climate simulations we've done
- Results:
  - Two quick Taylor diagrams
  - Precipitation in continental U.S.
    - Spatial patterns of seasonal-mean precip
    - Statistics of daily precip amounts
- Concluding remarks
- Animations

Goals of this work

- Increase horizontal resolution as much as possible and “see what happens:”
  - Assess computer science issues
  - Evaluate simulated climate
    - What happens to parameterized physics?
- Use results to improve understanding of regional climate change and its societal impacts.

Problems when increasing resolution:

- Model goes slowly
- Hydrostatic limit
- Parameterizations
  - Do they “misbehave?”
  - Effects need to be reduced because more scales are resolved

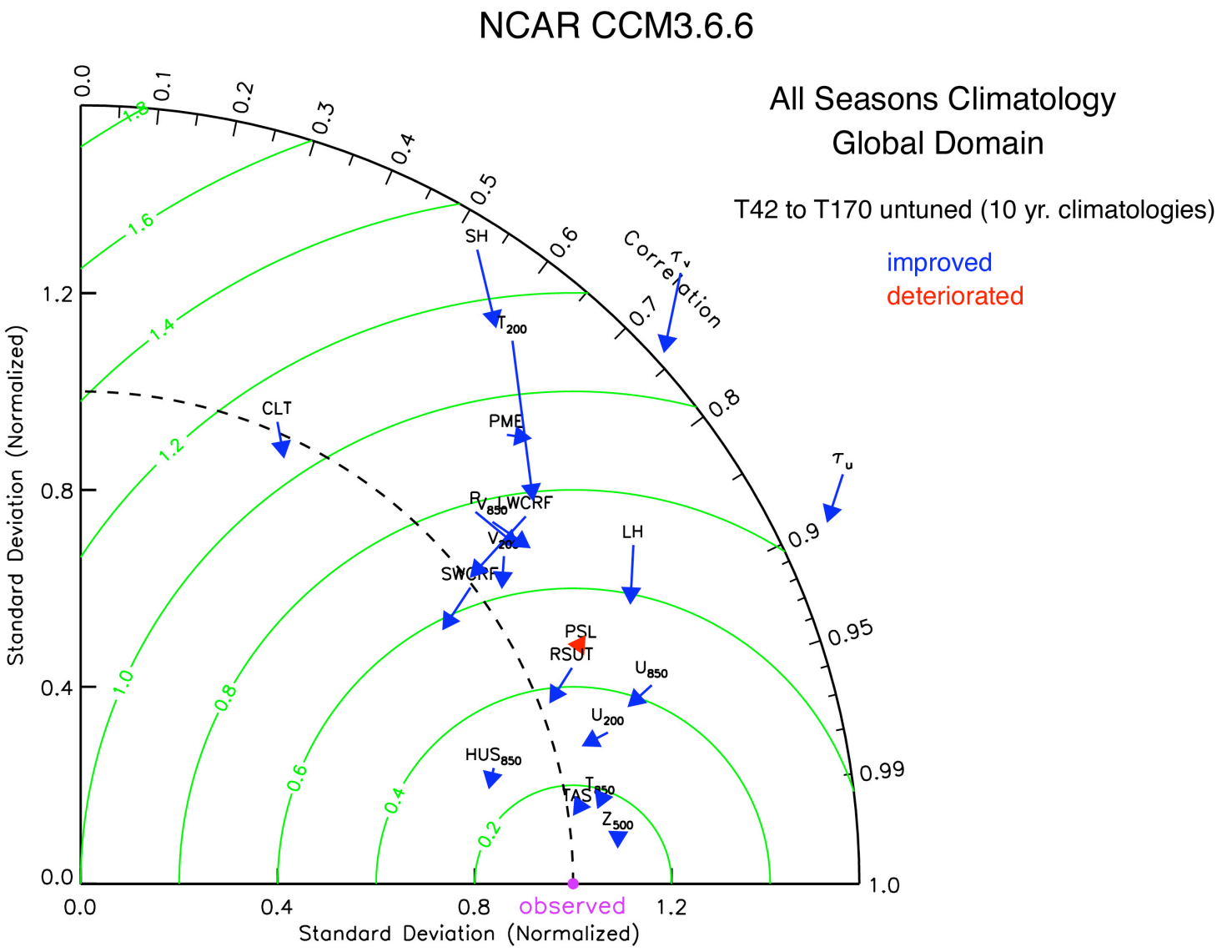
Simulations with CCM3:

- We have performed simulations at T21, T31, T42, T63, T85, T170, and T239.
- All these simulations use prescribed SSTs
- Mostly we compare results at T42, T170, and T239 to observations.
- At T42, T170, and T239 we have simulated
  - The present climate
  - Effects of increased greenhouse gases
- With help from J.J. Hack, we partly returned parameterizations at T170.
- We have simulated present and 2xCO_2 climates at T170 saving 6-hourly boundary data to drive nested regional climate models

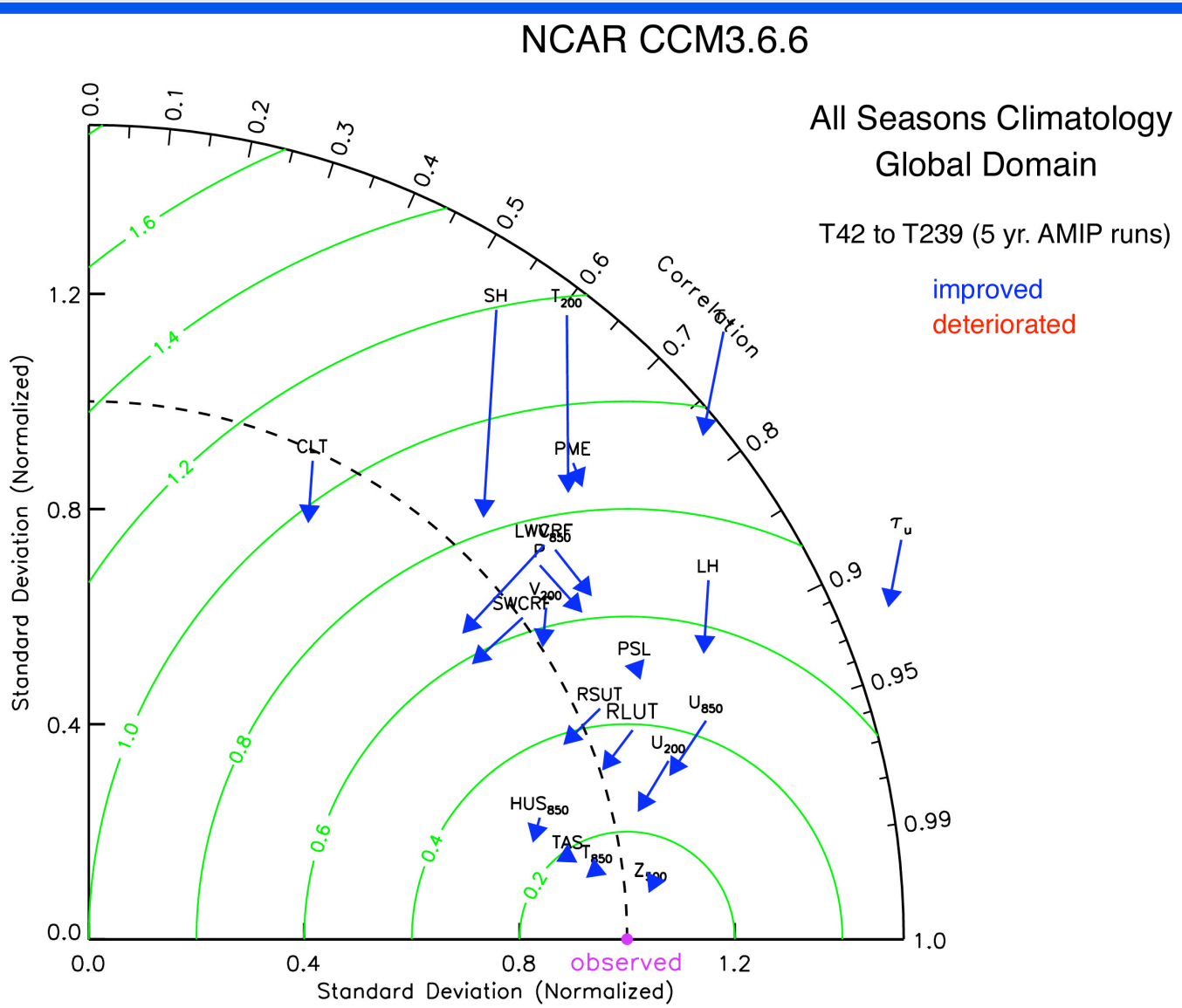
Simulations with CAM2 and FVGCM

- With CAM2, simulations at T170 and 0.4° X 0.5 ° (FV dycore) are under way.
- With FVGCM, a simulation at 0.5 ° x 0.625 ° is under way.
- With FVGCM, a simulation at 0.25 ° x 0.3125 ° is planned.

300 km -> 75 km “untuned” All Seasons, Global Domain

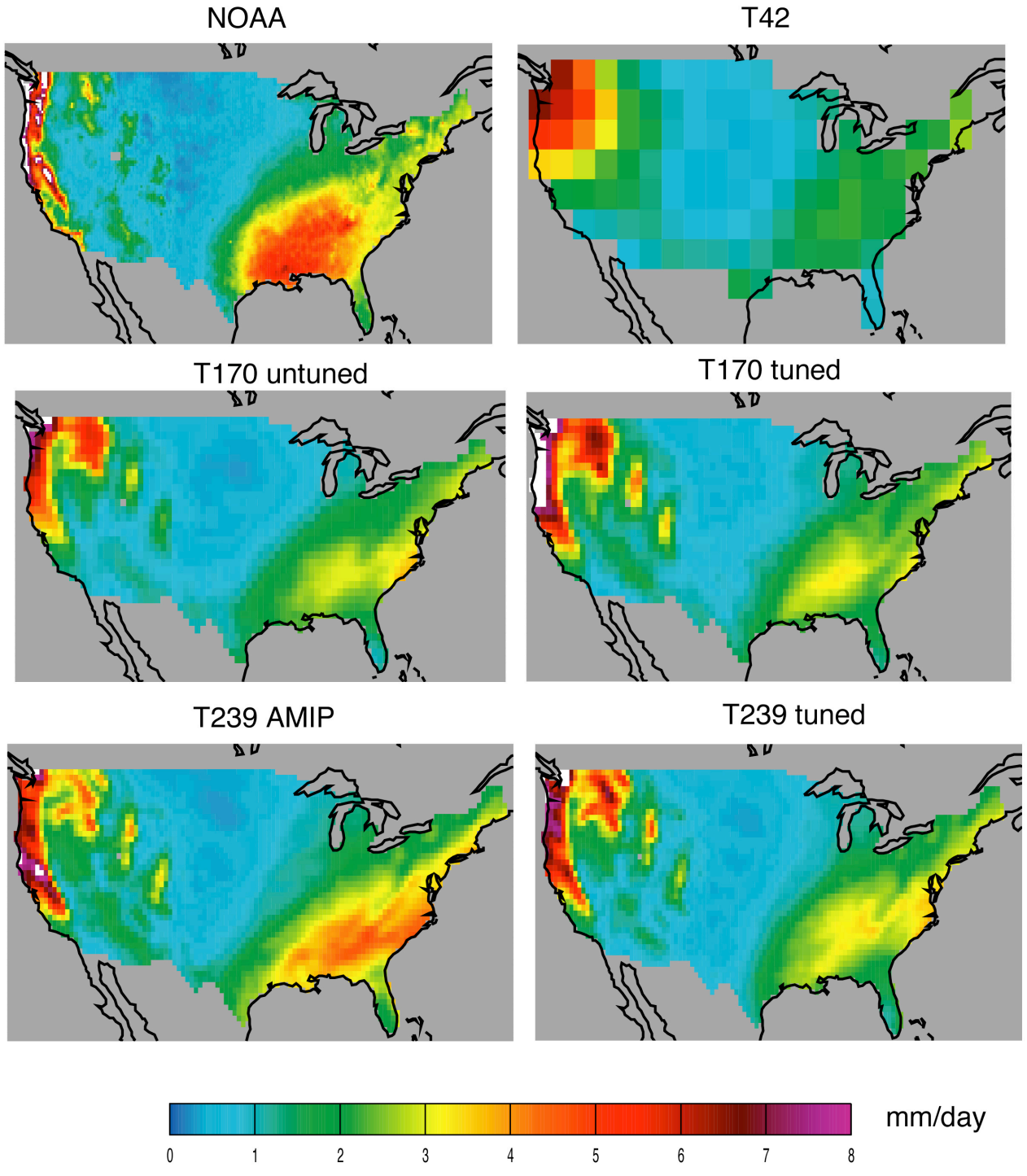


300 km -> 50 km “untuned”, All Seasons, Global Domain

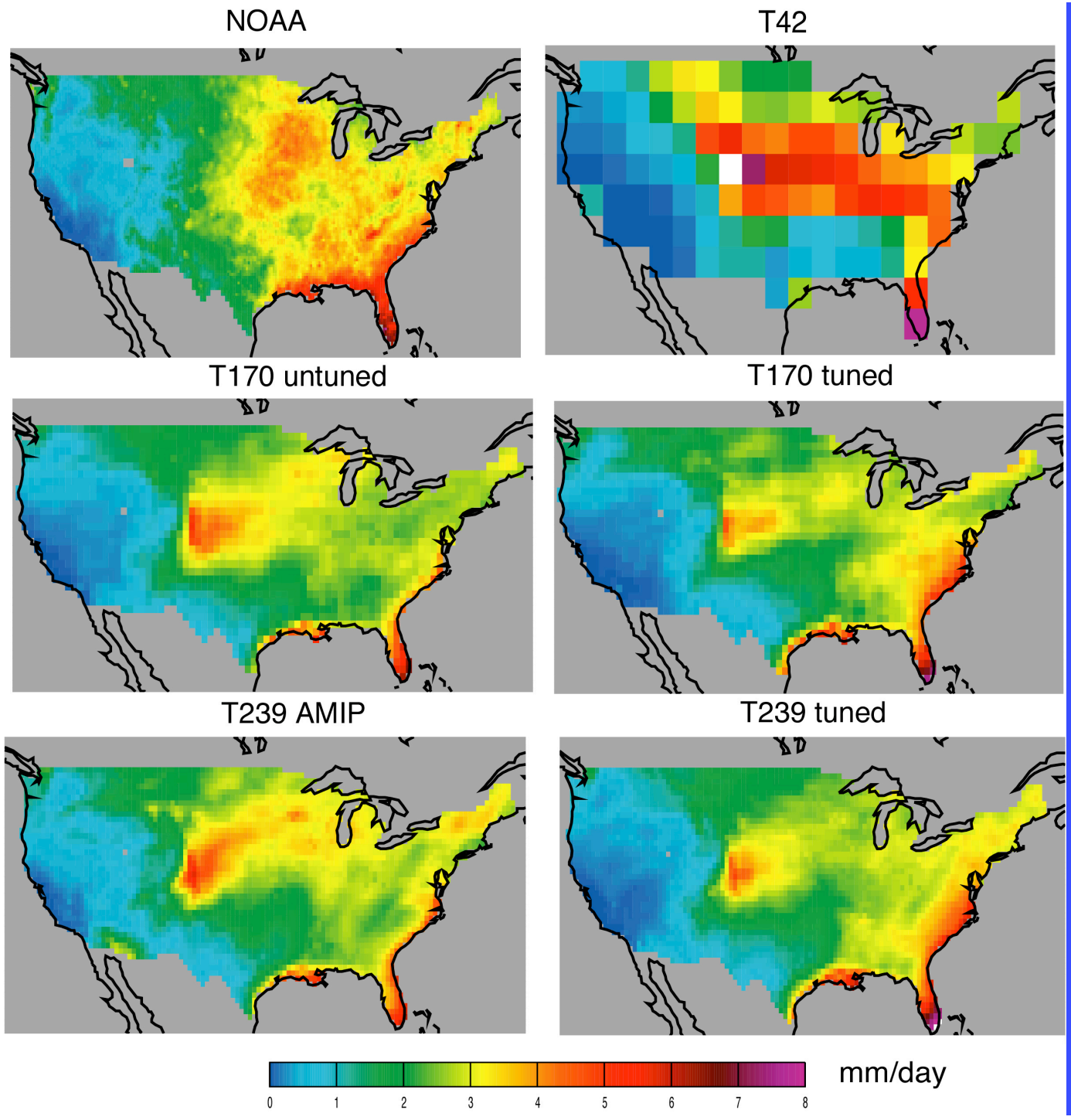


Precipitation in USA*

* With observations about behavior of parameterized precipitation at high resolution



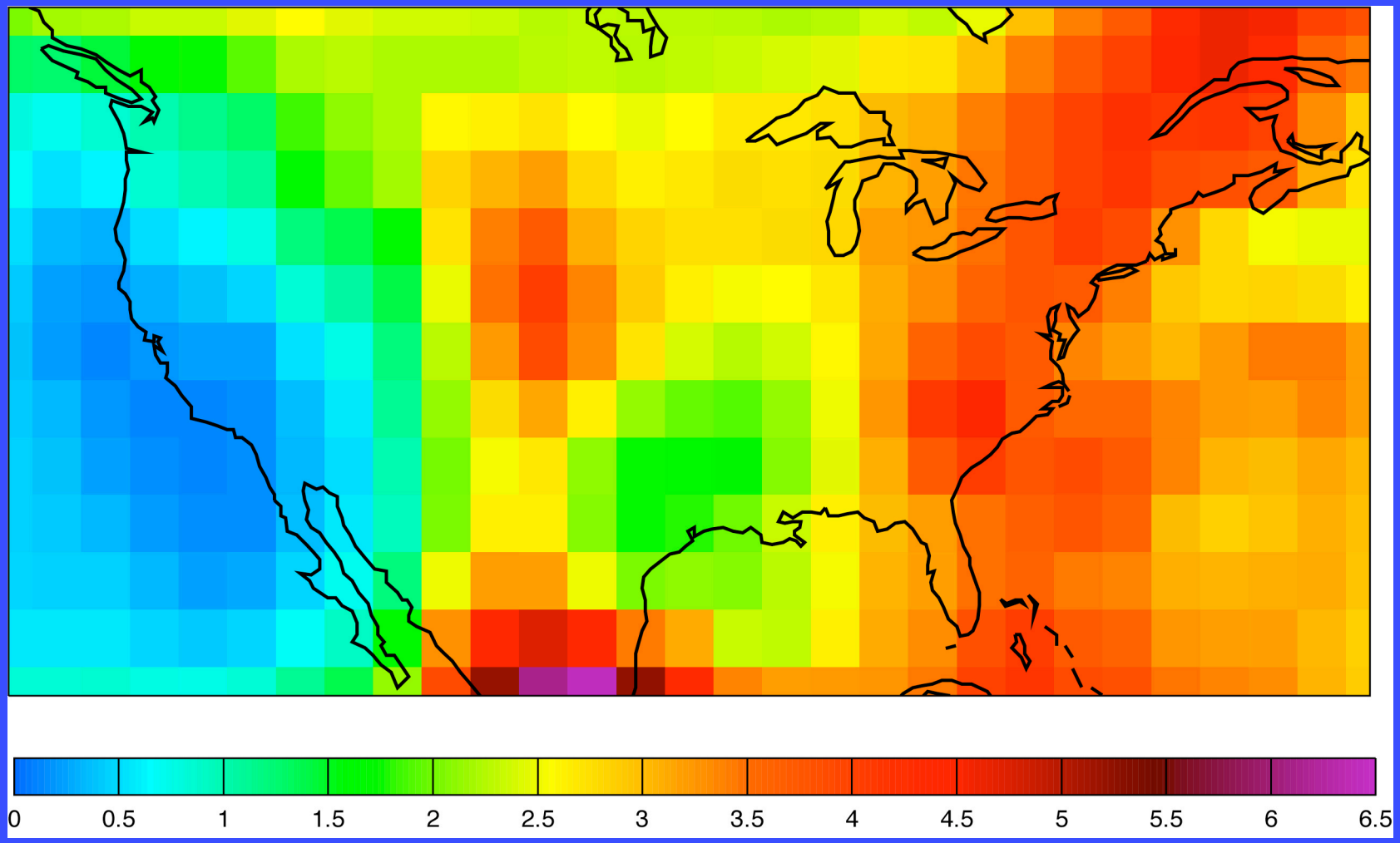
DJF Precipitation



JJA Precipitation

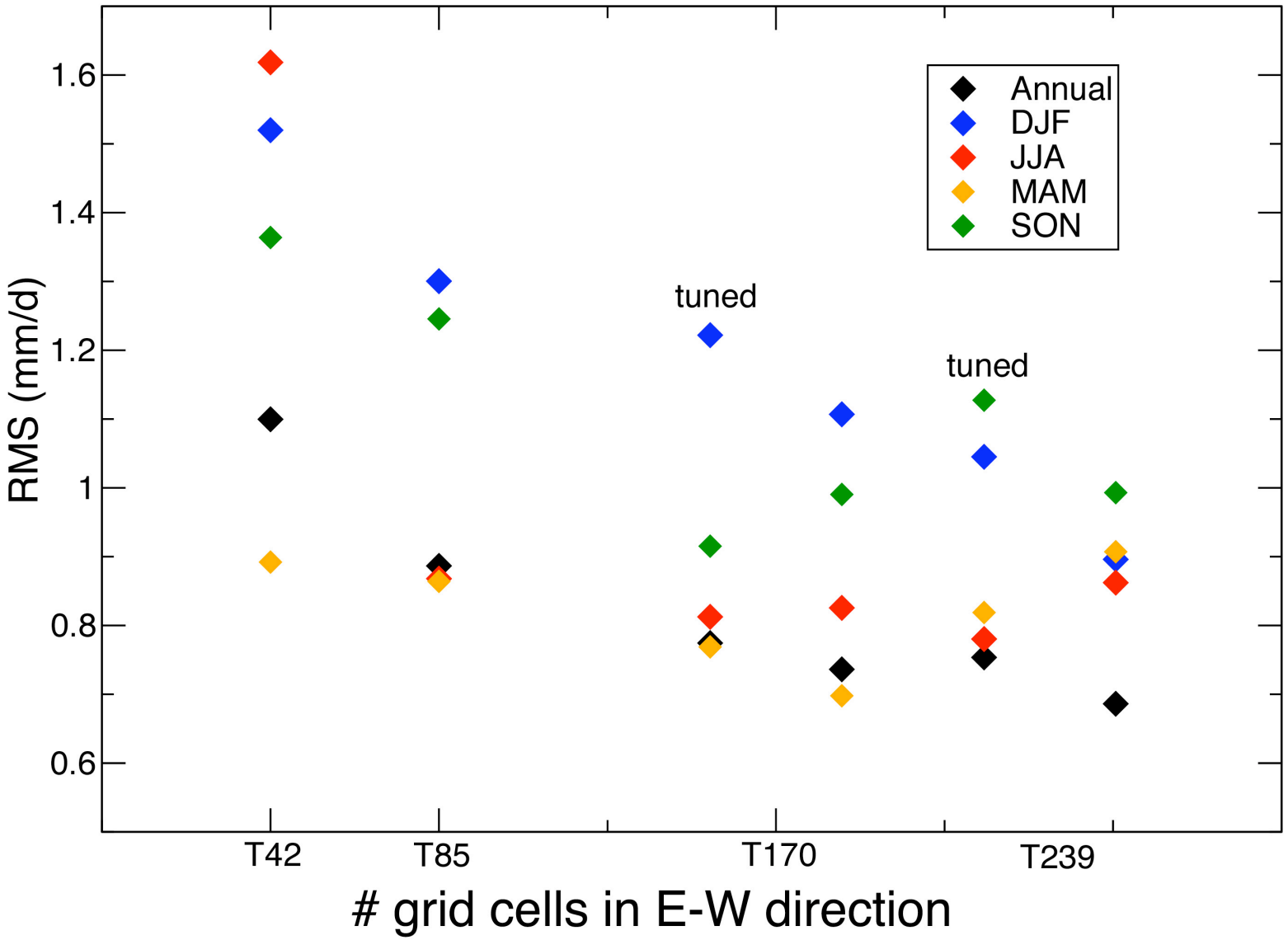
False summertime precipitation maximum in central US appears in many models

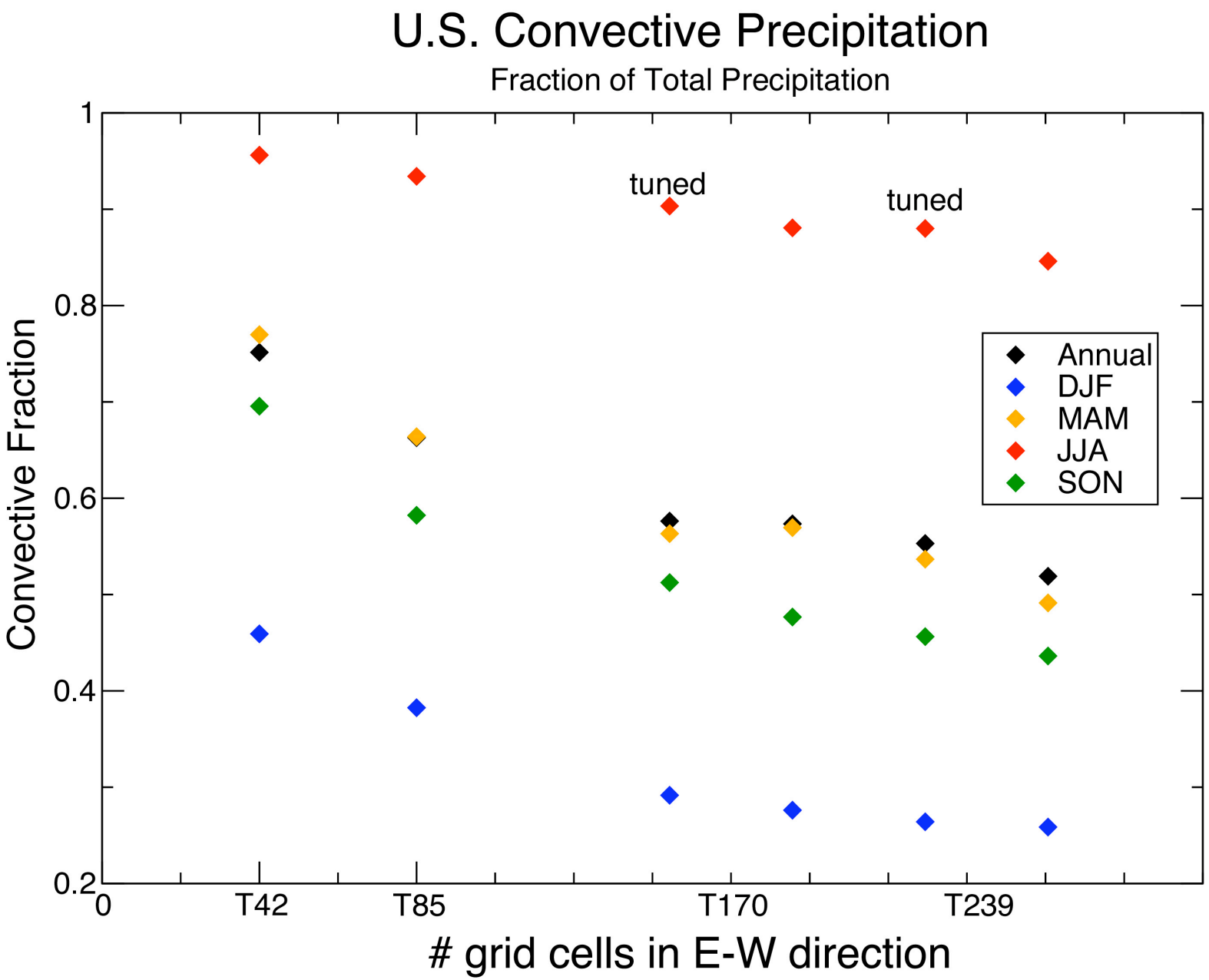
Average JJA precipitation in 16 CMIP climate models



RMS errors in seasonal-mean precipitation

vs. NOAA (0.25)

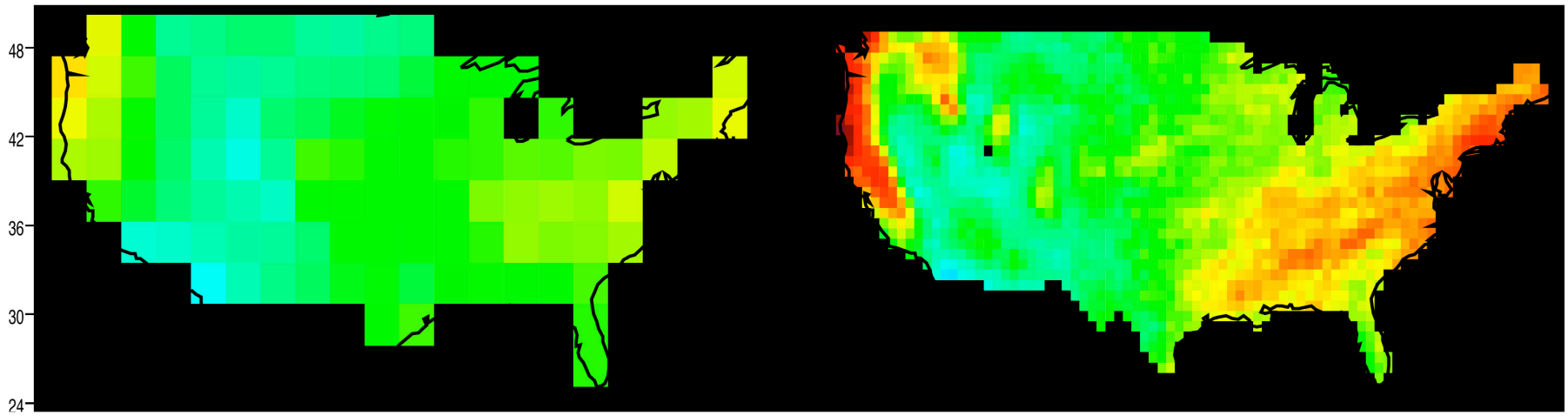



U.S. Convective Precipitation
Fraction of Total Precipitation
Convective Fraction
1
0.8
0.6
0.4
0.2
0
T42
T85
T170
T239
tuned
tuned
Annual
DJF
MAM
JJA
SON
grid cells in E-W direction

Findings:

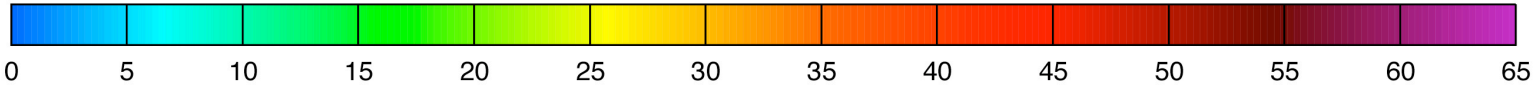
In DJF and SON, precip is mostly “large-scale,” and simulated spatial pattern of seasonal-mean precip improves as resolution is increased.

In MAM and JJA, precip is mostly convective, and simulated spatial pattern of seasonal-mean precip does NOT improve as resolution is increased.

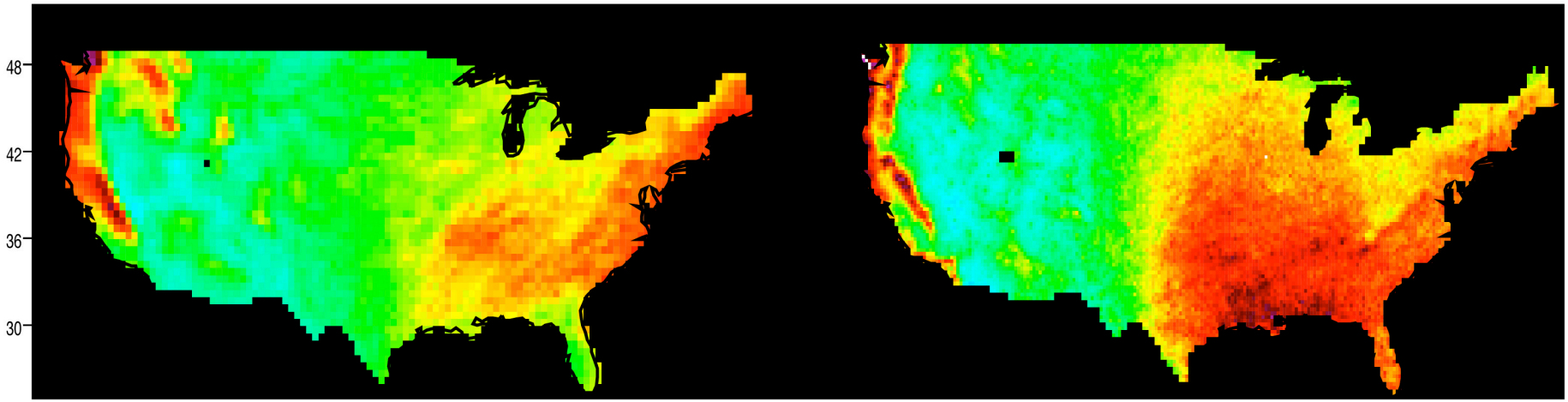


CCM3 at T42

CCM3 at T170

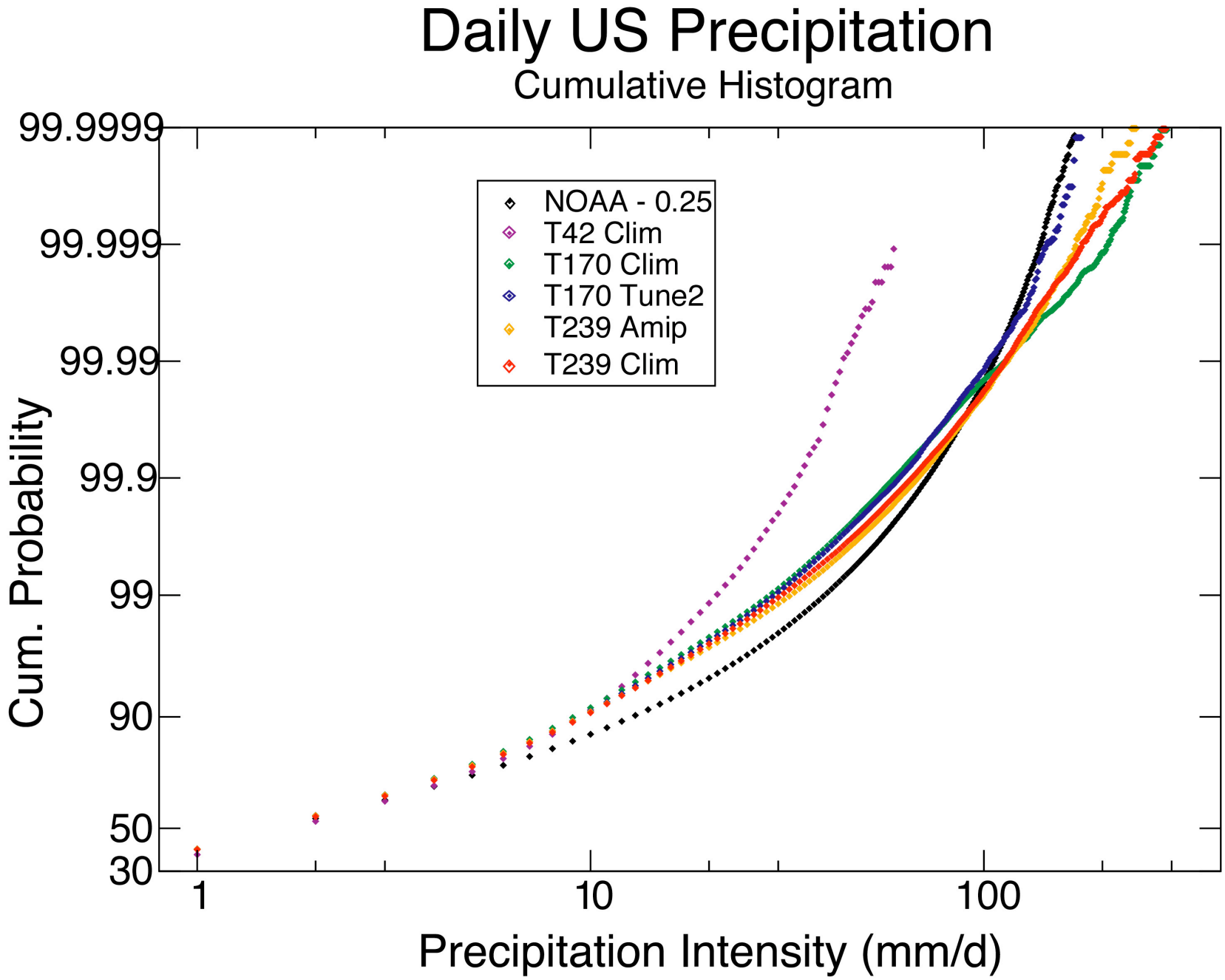


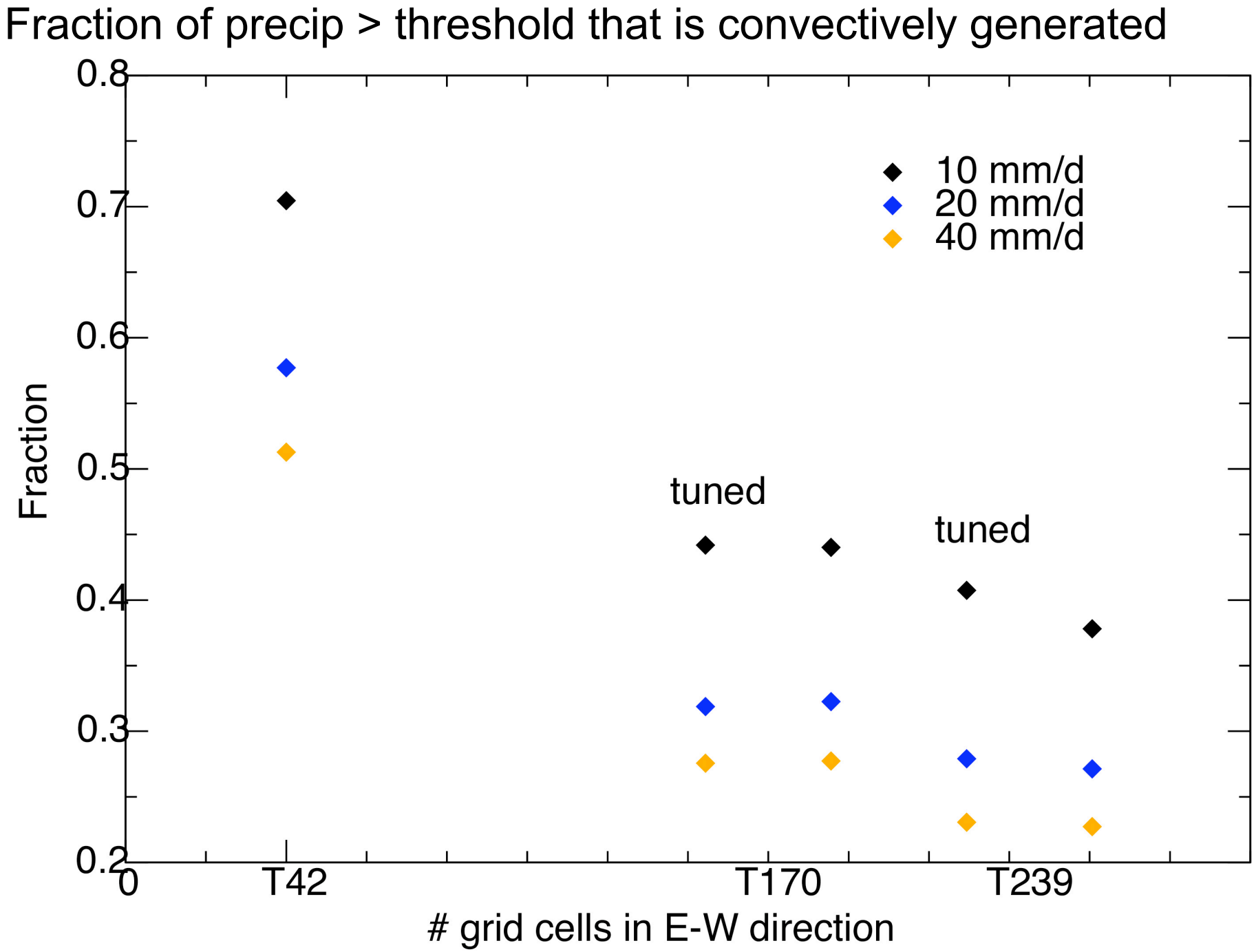
99th %-ile Daily Precipitation Rate (mm/day)



CCM3 at T239

Observations (NOAA)


Daily US Precipitation
Cumulative Histogram
NOAA - 0.25
T42 Clim
T170 Clim
T170 Tune2
T239 Amip
T239 Clim
Cum. Probability
99.9999
99.999
99.99
99.9
99
90
50
30
1
10
100
Precipitation Intensity (mm/d)


Fraction of precip > threshold that is convectively generated
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Fraction
10 mm/d
20 mm/d
40 mm/d
tuned
tuned
0
T42
T170
T239
grid cells in E-W direction

Findings:

Higher-resolution simulations predict more realistic intensities of rare daily precipitation events;

These strong daily precip events are mainly large-scale, not convective

Concluding Remarks

Preliminary conclusions:

- As spatial resolution is increased in CCM3, both spatial pattern of precip and statistics of daily precip amounts in CCM3 become more realistic.
- Improvements in simulated precip that occur with increasing resolution are NOT mainly due to improved results from parameterizations;
- Rather, they seem to be mainly due to less reliance on parameterizations.
- On the other hand, we see no evidence from looking at US precip that parameterizations are going haywire*

  * but we know there are problems in e.g. CRF

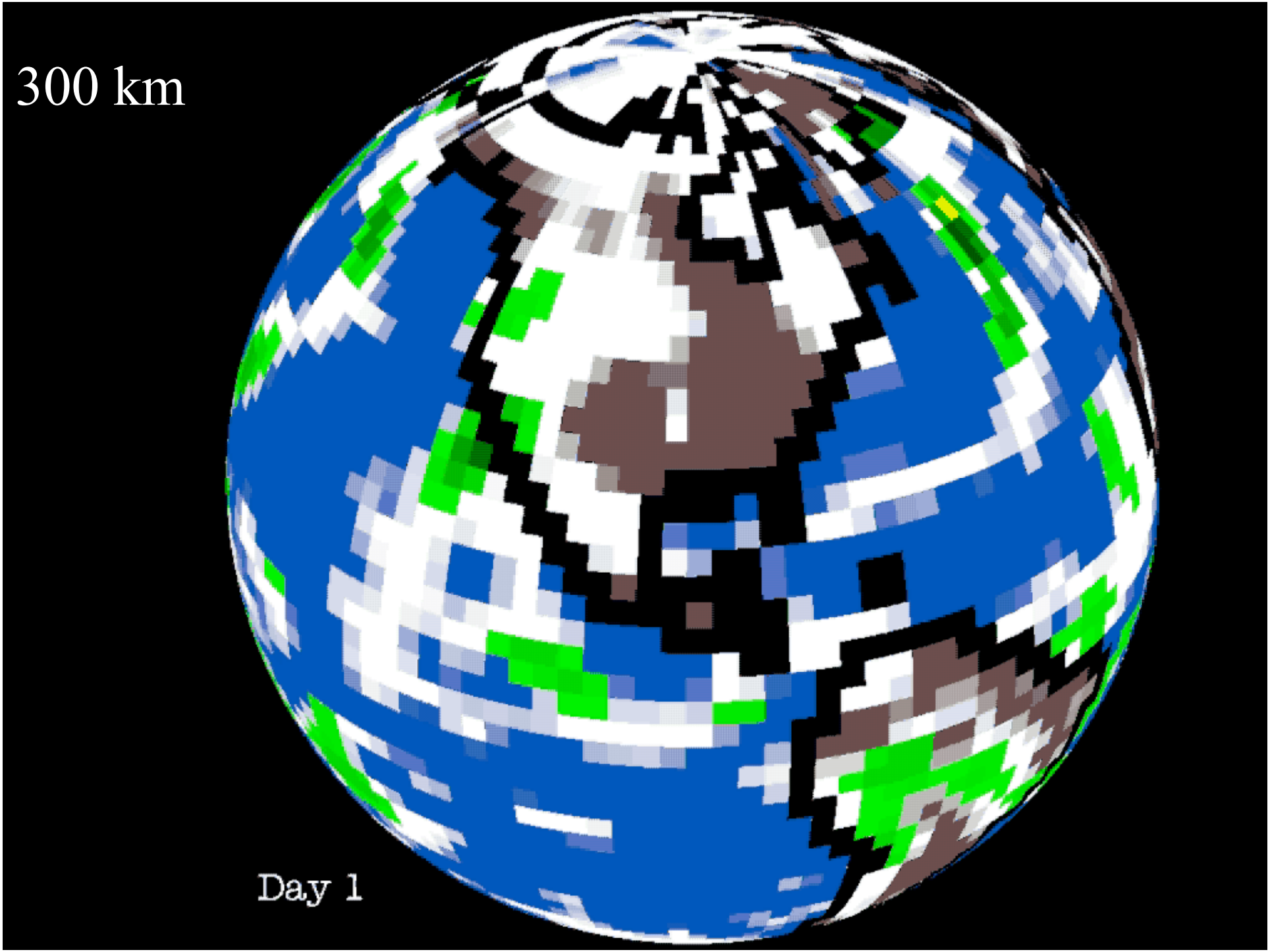
Groups Using Our Model Output:

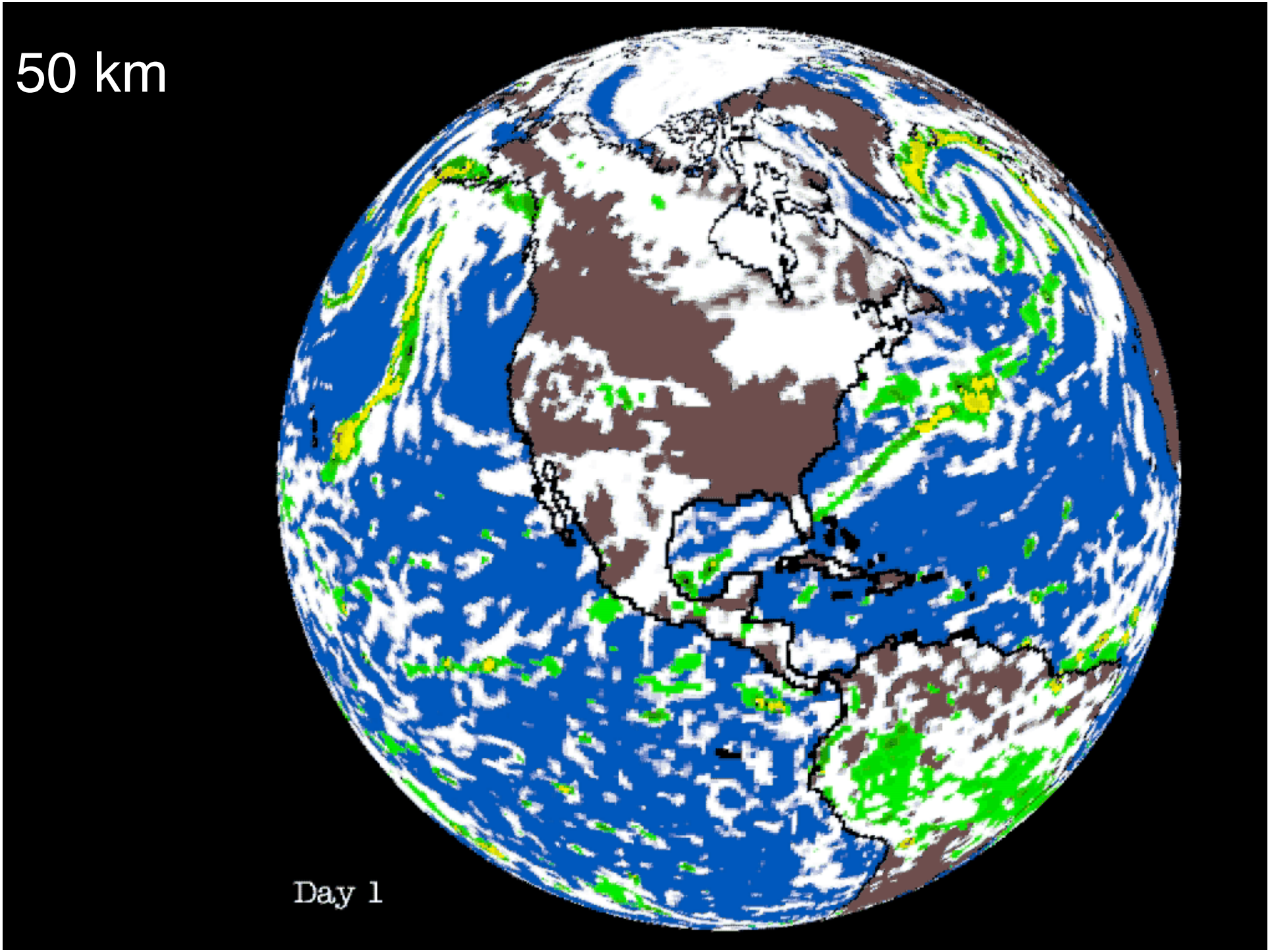
- W. Gutowski (Iowa State) Regional precipitation
- L. Sloan (UCSC) high resolution regional model
- J. Norris (UCSD) cloud properties
- Eric Wilcox (UCSD) cloud properties
- J. Orr (CEA, France) atmospheric CO_2 transport
- C. Bitz (U.Wash.) Arctic climate
- R. Doherty (NCAR) N. Slope of Alaska
- C. Bonfils (UCB) crop diseases
- L. Mearns (NCAR) societal impacts
- B. Haddad (UCSC) urban water supplies
- J. Brunkard (UCSC) vector-borne diseases
- Richard Grotjahn (UC Davis)
- John Walsh (Univ. of Illinois) Arctic climate change
- S. Ghan (PNNL) subgrid parameterization of precipitation
- C. Bretherton, (U. Washington)
- S. Cameron (University of Texas) biodiversity in Ecuador
- Ping Liu (U. of Hawaii) precipitation in Tibetan Plateau

What's Next? We will…

- … look more thoroughly at parameterized physics in CAM at high resolution
- … run SP-CAM with CAM at high resolution (T170?)
- … run the NCAR/NASA Finite Volume GCM at 25 km resolution
- …evaluate the effect of higher-resolution driving boundary data on the solution of the PNNL regional climate model.

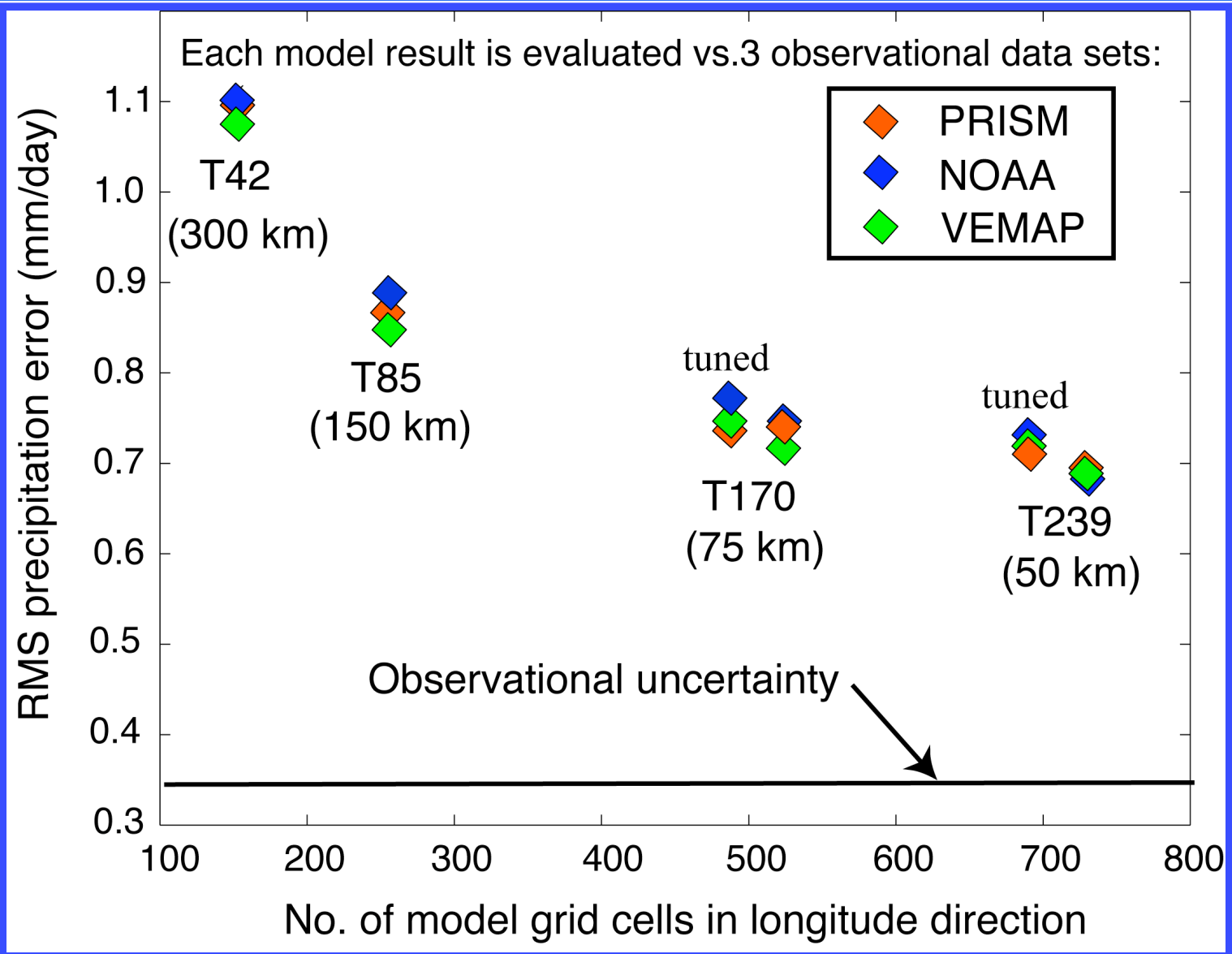
Animations


300 km
Day 1

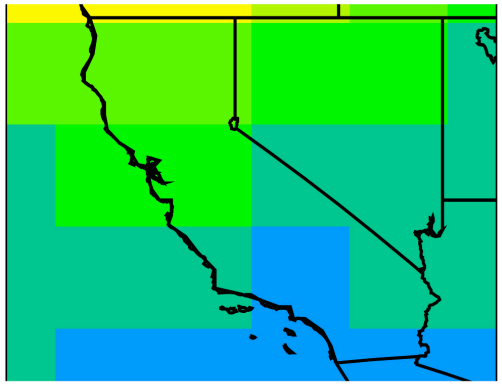

50 km
Day 1

The End

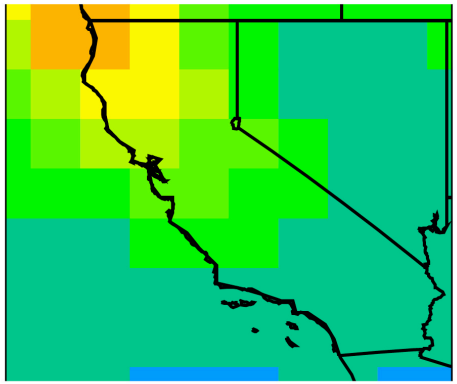
RMS errors in U.S. annual mean precipitation



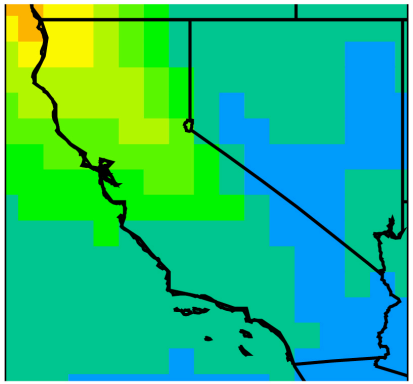
DJF precipitation in California and environs



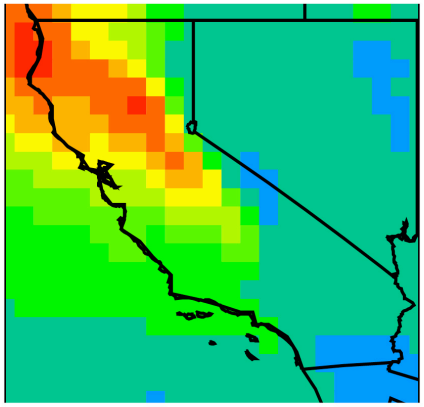
T42 (300 km)



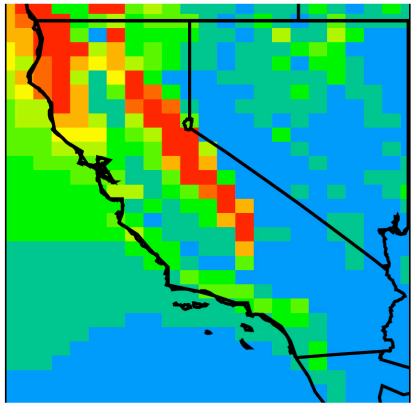
T85 (150 km)



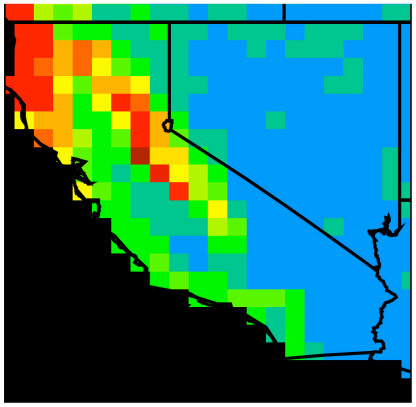
T170 (75 km)



T239 (50 km)



0.4^{o} x 0.5^{o} (40 x 50 km)



Observations (VEMAP)

Less reliance on parameterization as resolution increases

Quantity	Observed	T42	T170 untuned	T239 untuned	T170 tuned	T239 tuned
Total Precip	2.69	3.09	3.27	3.35	3.13	3.12
Large-Scale Precip	—	0.480	.885	1.08	0.840	1.00
Convective Precip	—	2.61	2.39	2.27	2.29	2.12