TOWARDS ULTRA-HIGH RESOLUTION CLIMATE SIMULATION USING A TWO-WAY NESTED MODEL: PRECIPITATION AND EXTREME EVENTS

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HIGH-RESOLUTION MODELING: LIMITED-AREA VS GLOBAL MODELS

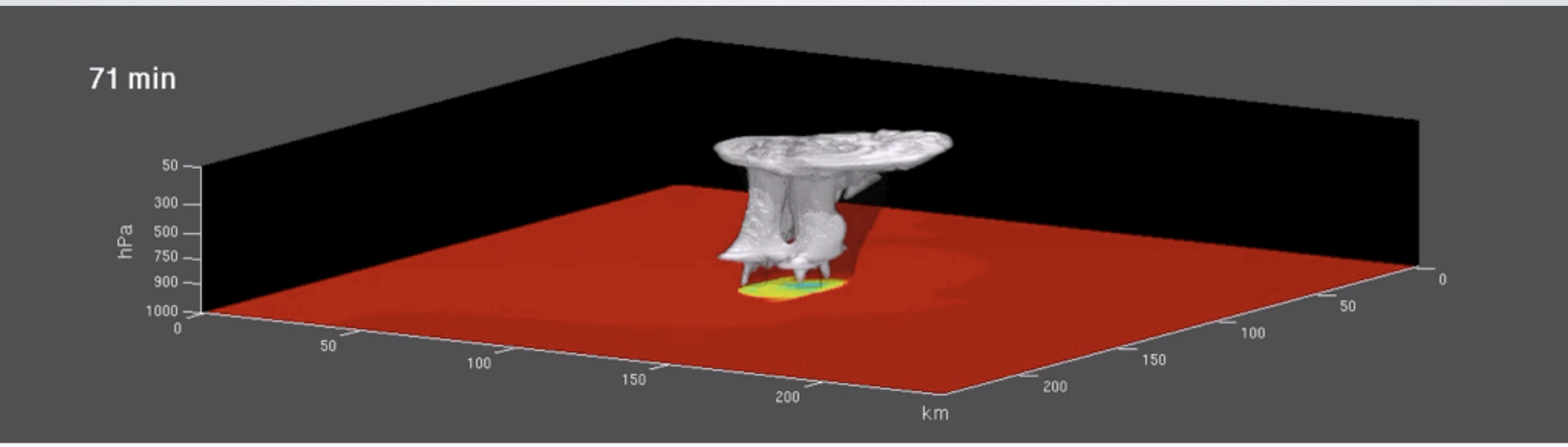
- Boundary conditions of limited-area models become a problem for simulations longer than a few days
  - Require BCs supplied from a possibly-inconsistent global model, can cause boundary errors
  - No feedback onto large-scale
- Global models have no boundaries and provide a consistent solution everywhere, but global high resolution can be impractical
- Solution: grid refinement of a global model!

THE GFDL FV^3 CORE

- Finite-volume D-grid model solving the vector-invariant (vorticity-KE form) hydrostatic primitive equations
  - Variables are cell- (or face-) averages, not point values
  - Flux-form scheme, so mass conserving
  - Vertically-Lagrangian hybrid-pressure coordinate
- Cubed-sphere grid in more recent versions
  - Non-hydrostatic version in late development

A message from our sponsor

- Nonhydrostatic core
- 2 km: c256 stretched by 20 (global model!!)
- Solo core with warm-rain microphysics

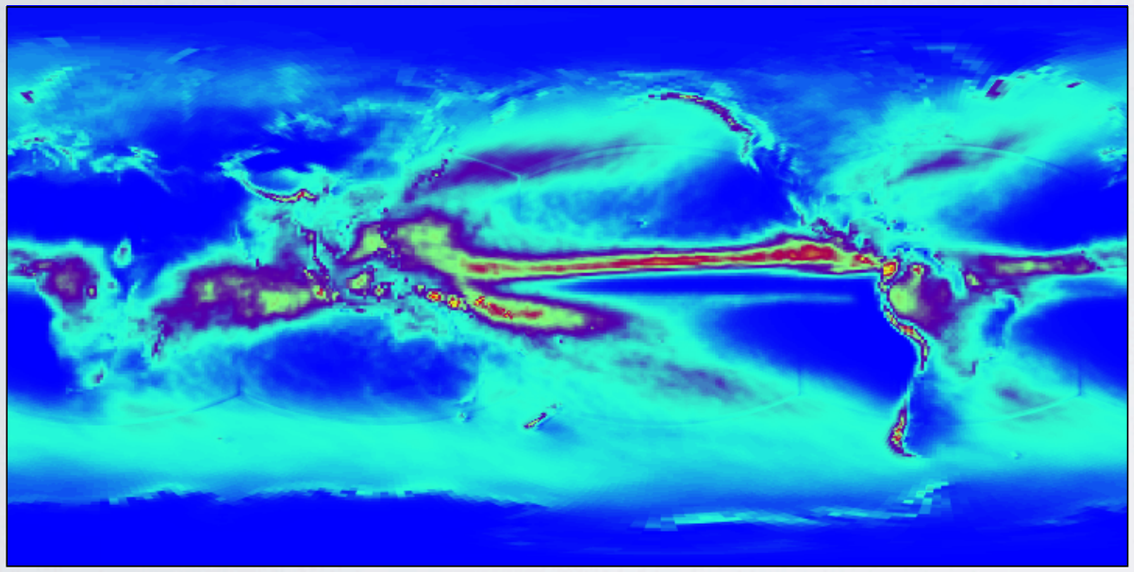


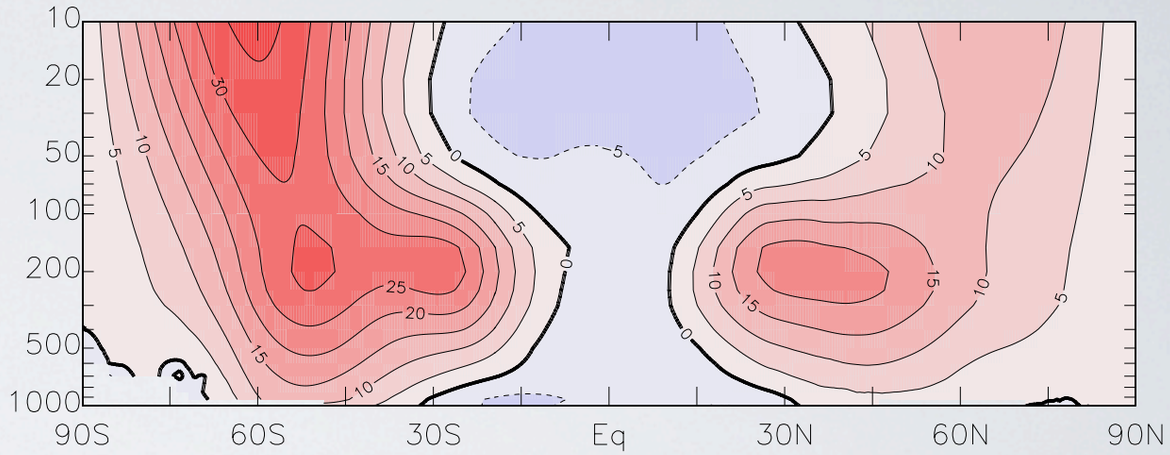
http://www.gfdl.noaa.gov/visualizations-mesoscale-dynamics

NESTING METHODOLOGY

- BCs: All variables linearly interpolated in space into nested grid halo
  - Concurrent nesting: extrapolation in time so nest and coarse grids can run simultaneously
- Two-way update:
  - Averaging-update for temperature
  - Vorticity-conserving for winds
  - **No** update for air and tracer mass: ensures mass conservation!!

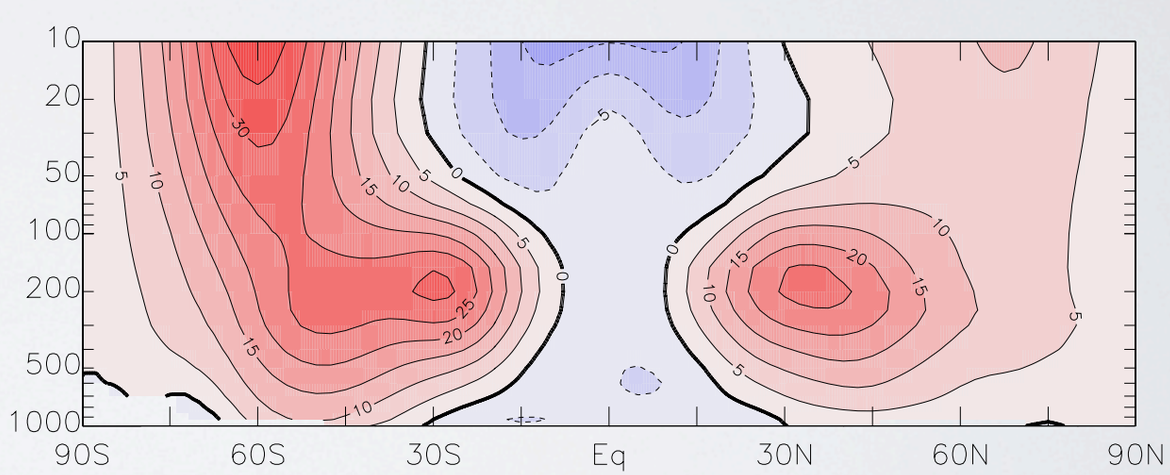
WHY CLIMATE SIMULATION?
(ONE POINT OF VIEW)





mean: 8.133
std dev: 10.8323

c192–1g–AMIP



mean: 7.296
std dev: 11.0019

Reanalysis

- Initial condition less important
- Running a climate simulation tests *every* resolved phenomenon repeatedly
- Errors have nowhere to hide!
  - But cause and effect of errors hard to diagnose–literally can be (thousands of) miles apart

PNAS

Link between the double-Intertropical Convergence Zone problem and cloud biases over the Southern Ocean

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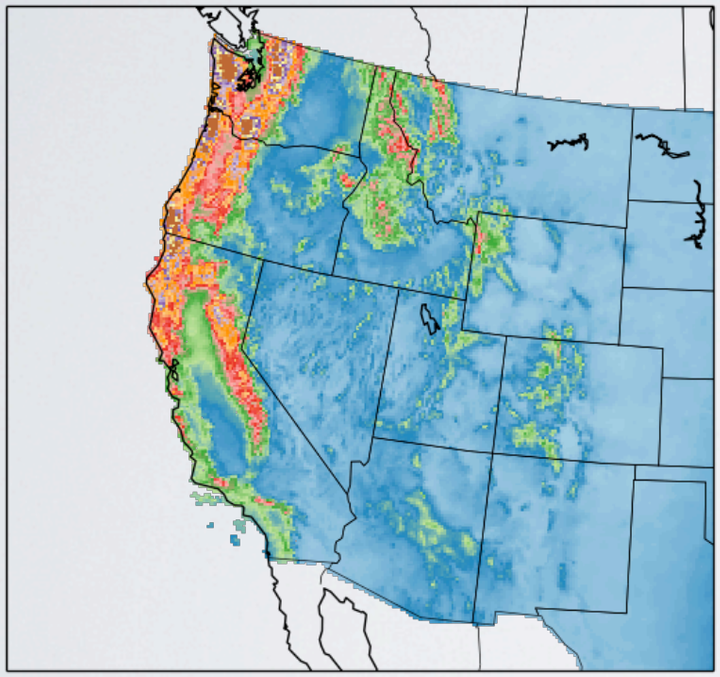
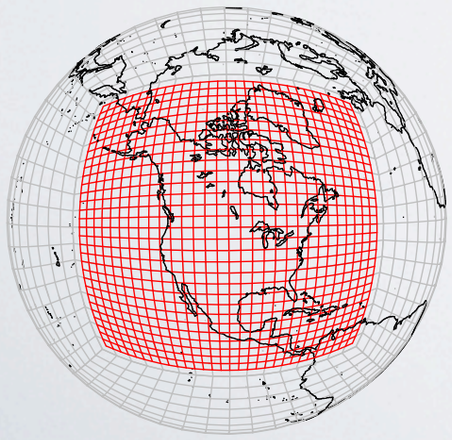
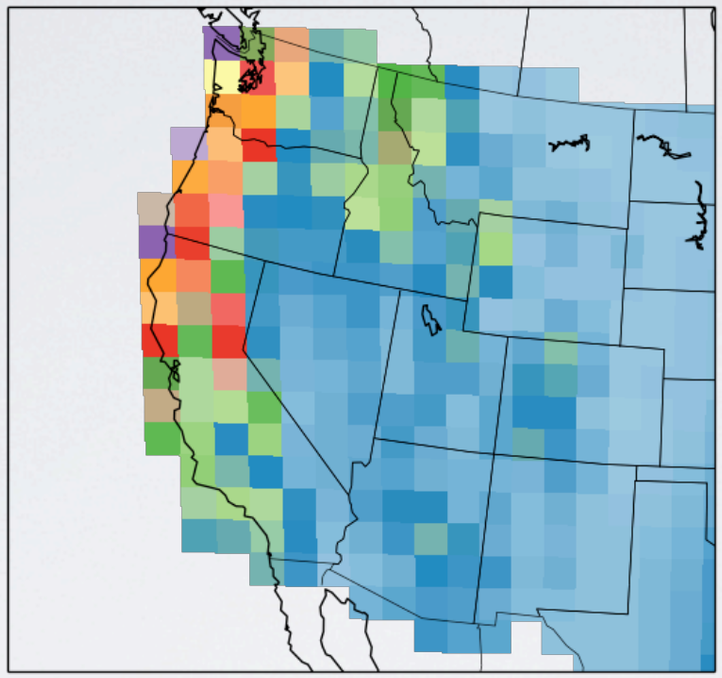
WESTERN US DJF PRECIPITATION

PRISM Observations

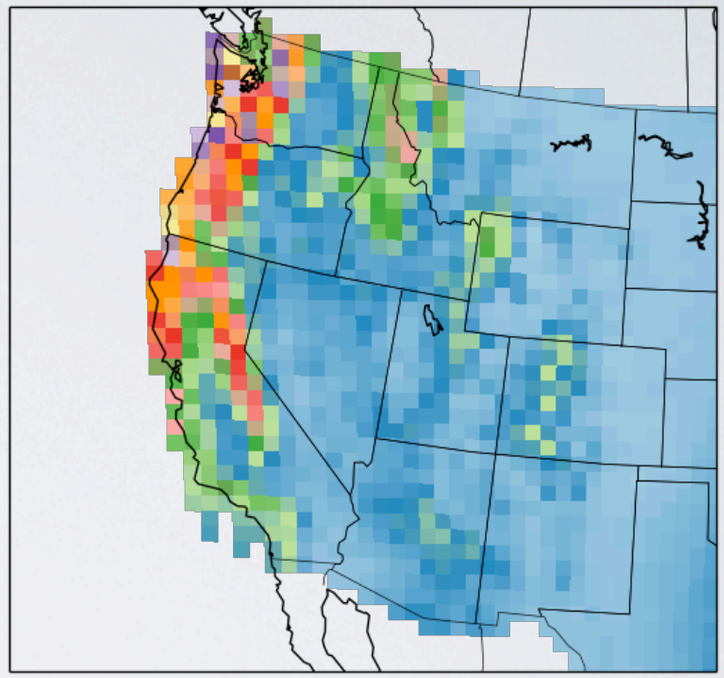




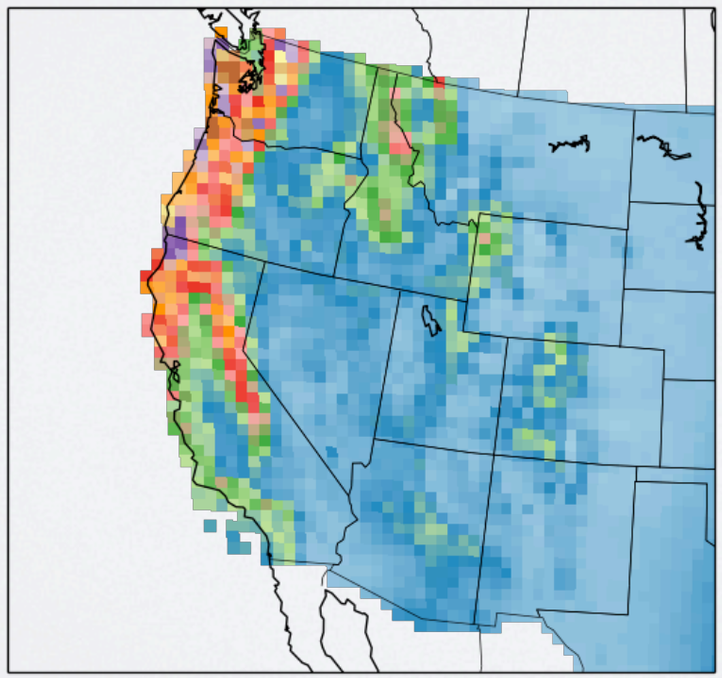
c90 (110 km) single-grid



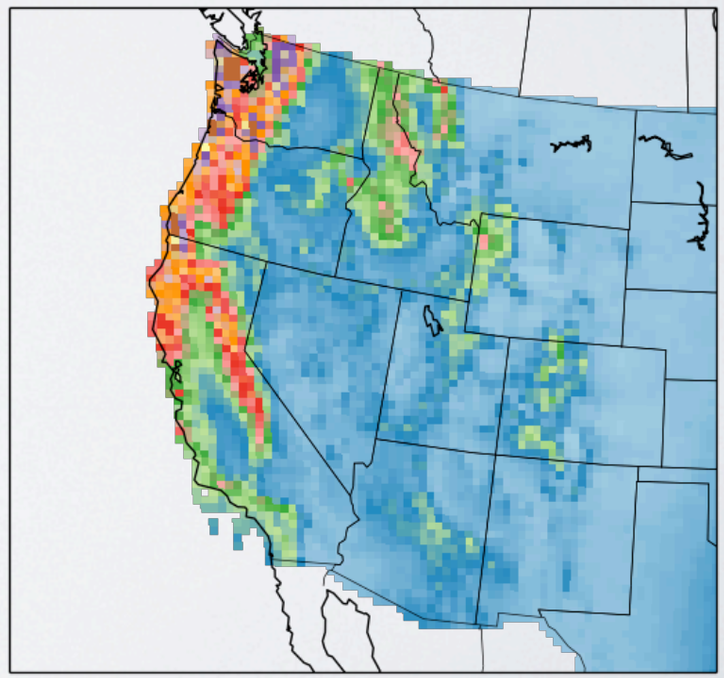
c192 (50 km) single-grid

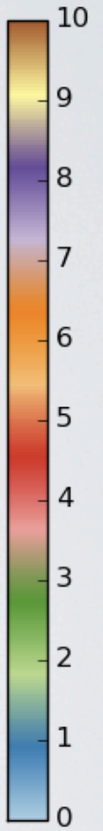


c90n3 (40 km) nest



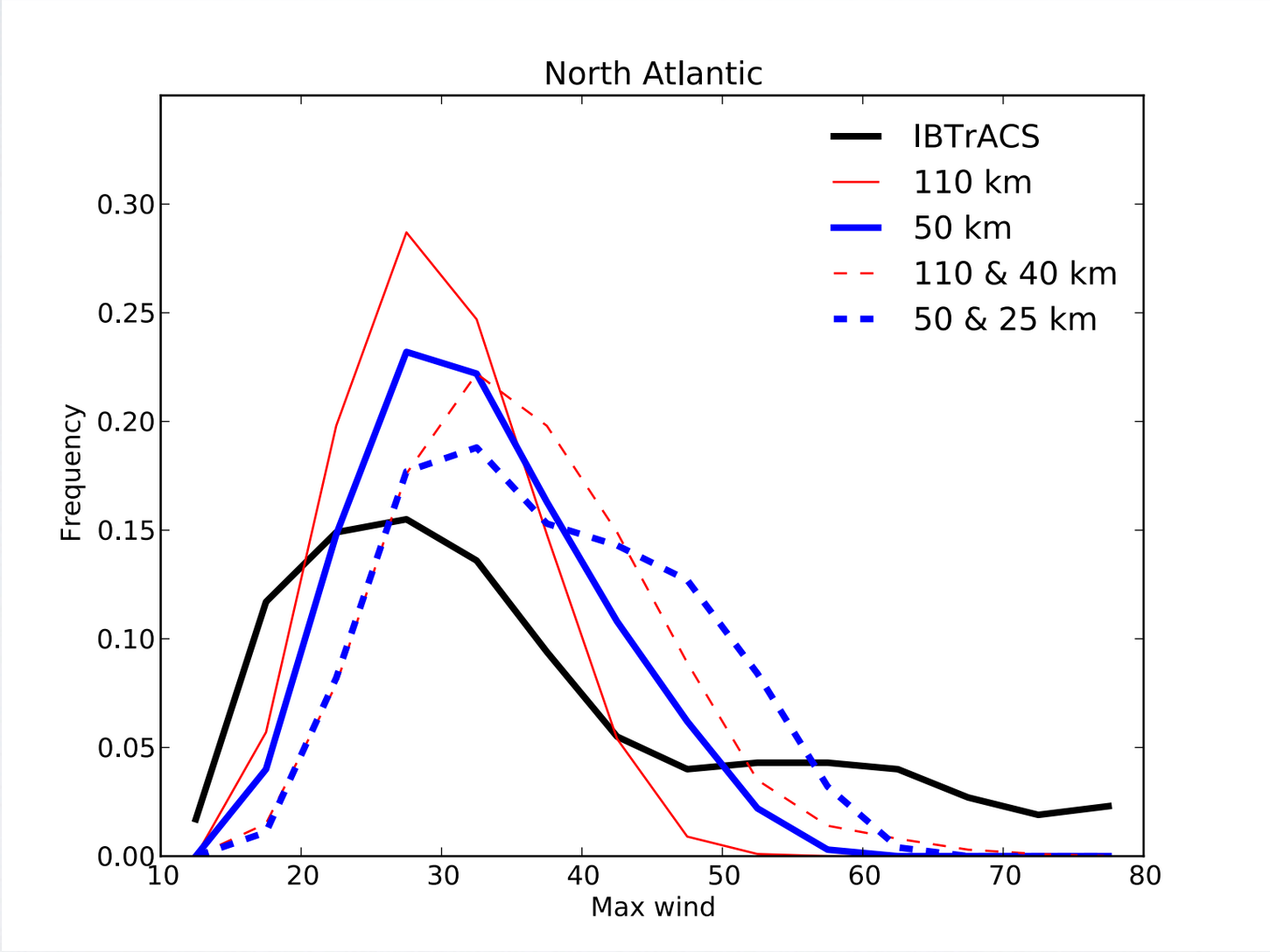
c192n2 (25 km) nest





mm/d

HURRICANE INTENSITY



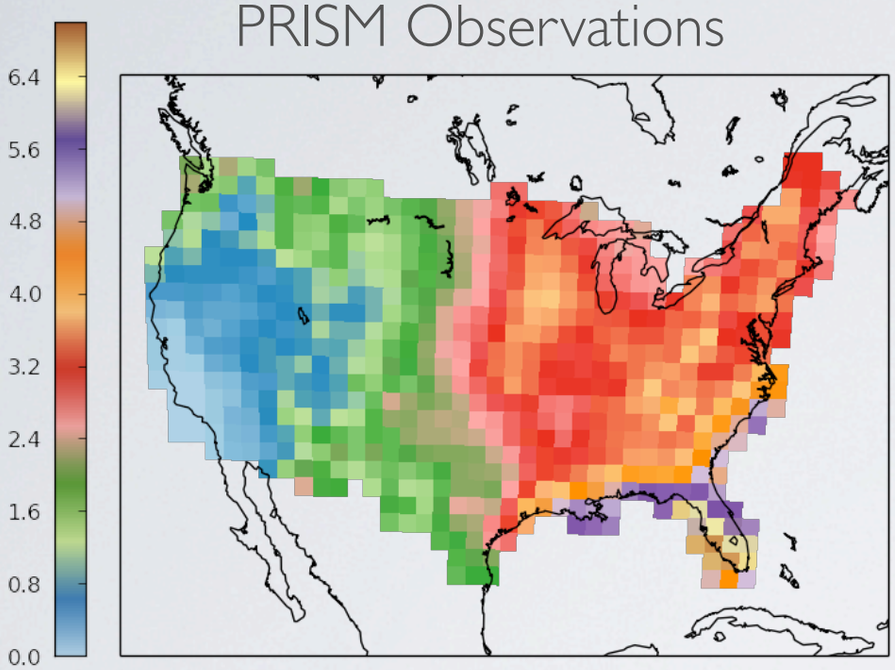
Nested-grid max intensity

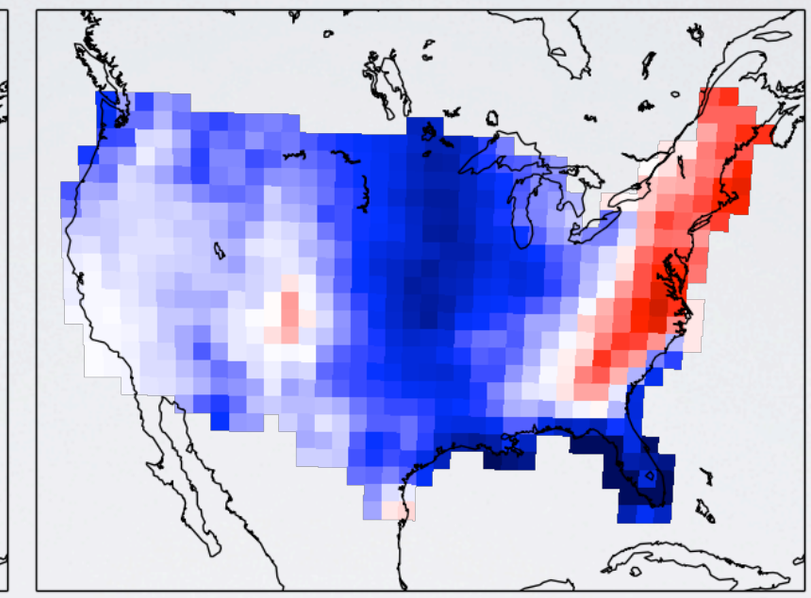
JJA PRECIPITATION

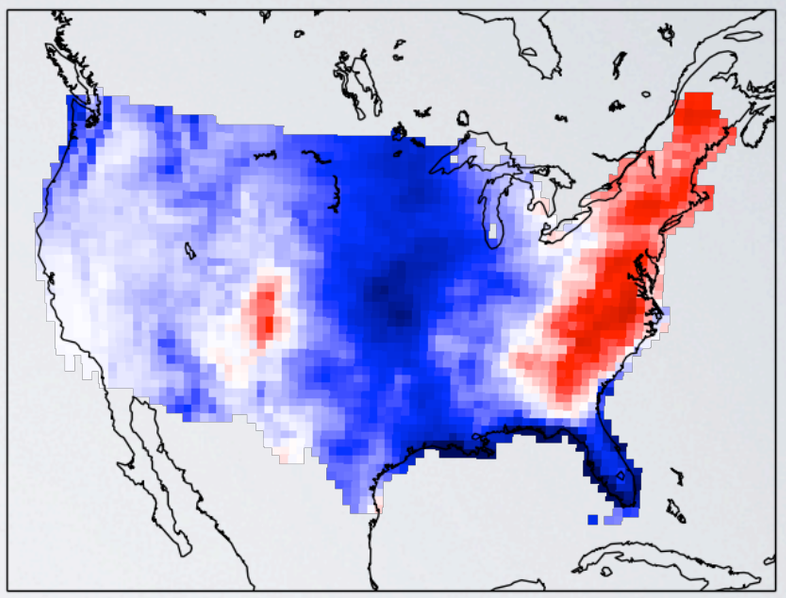
PRISM Observations

c90 (110 km) single-grid

c192 (50 km) single-grid



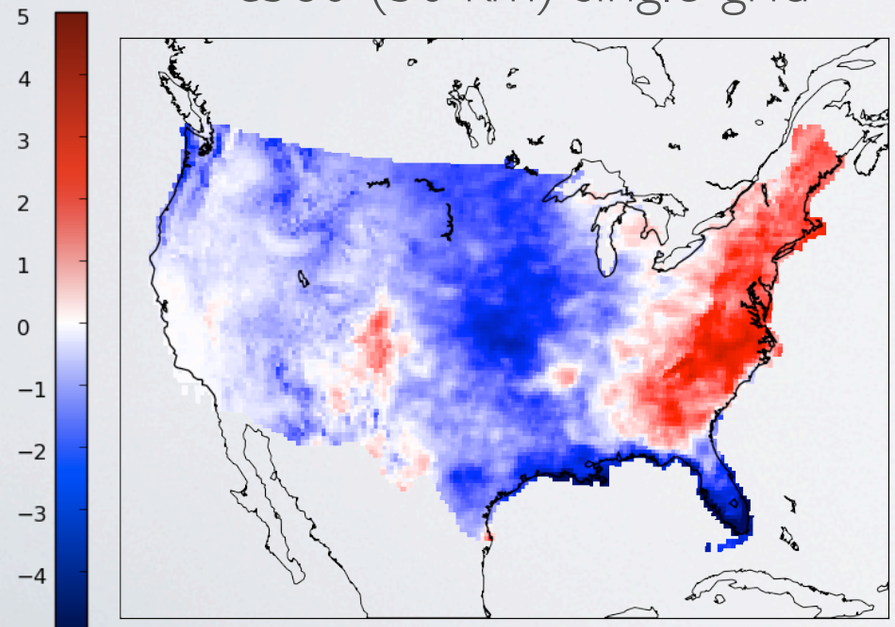


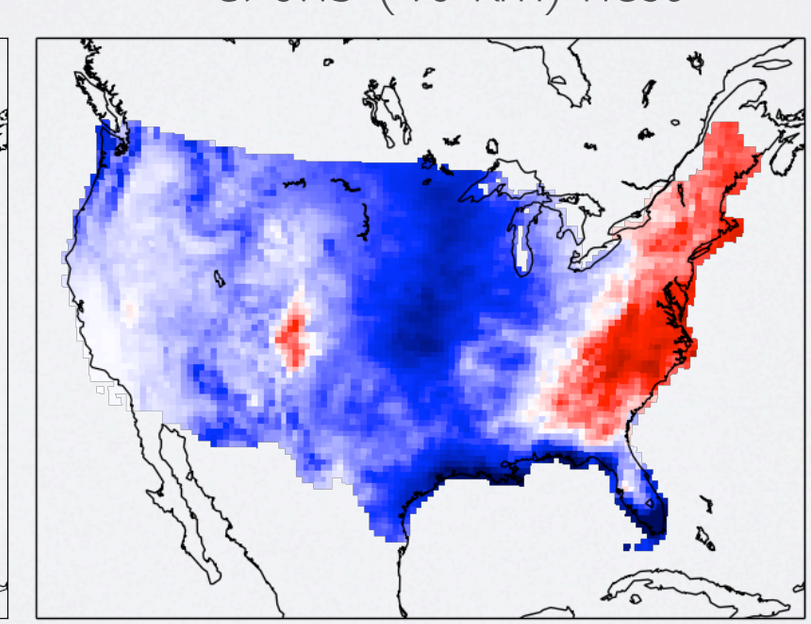


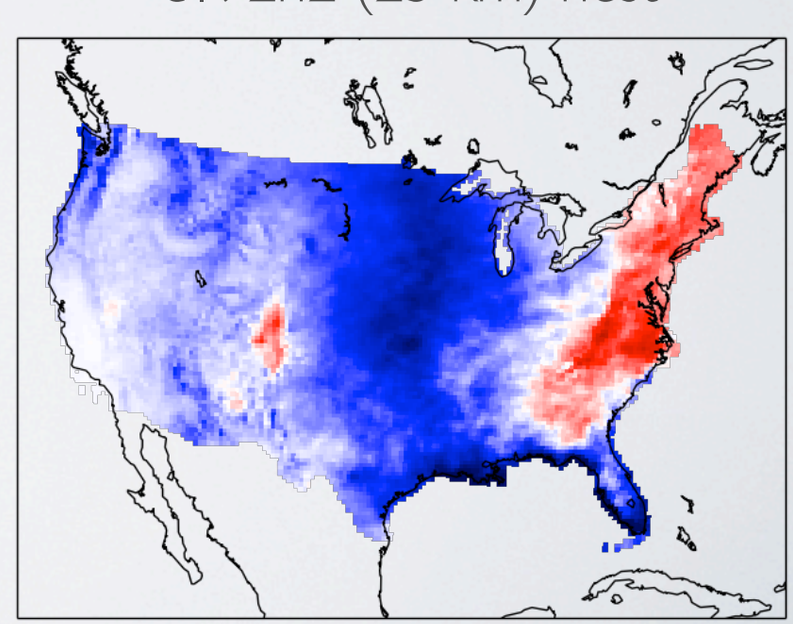
c360 (30 km) single-grid

c90n3 (40 km) nest

c192n2 (25 km) nest

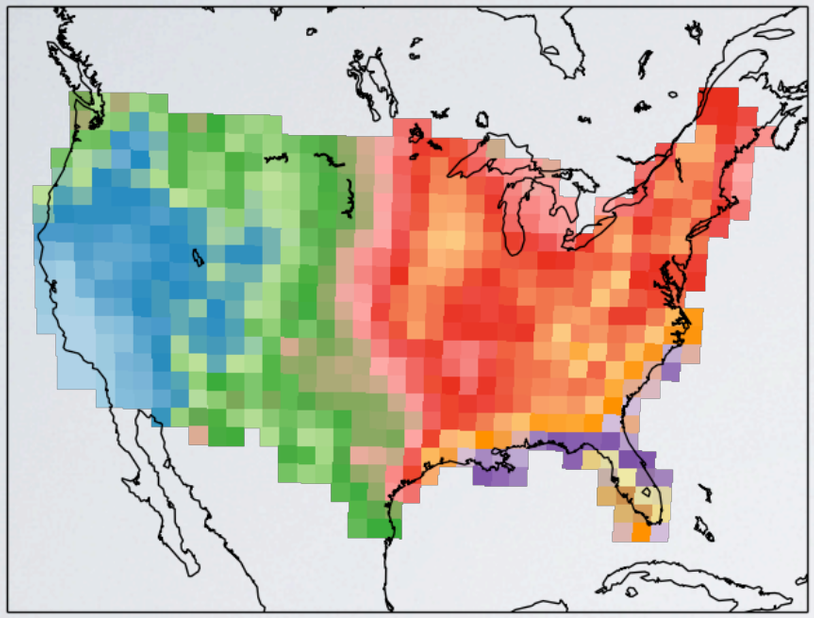




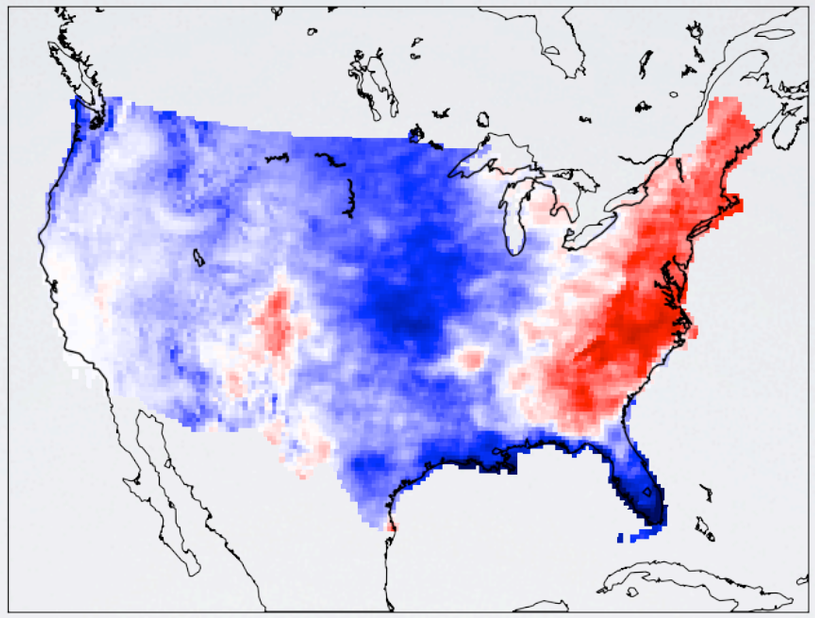


C384 SINGLE-GRID RESULTS

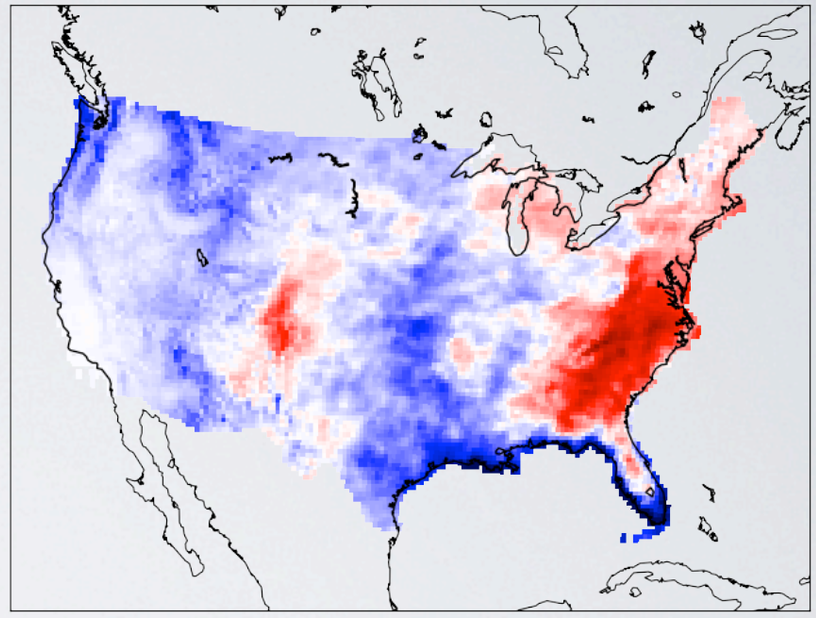
PRISM Observations

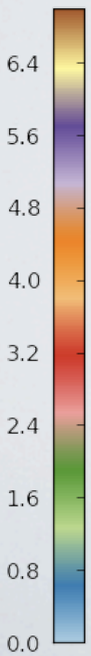


c360 (30 km) single-grid



c384 (25 km) single-grid

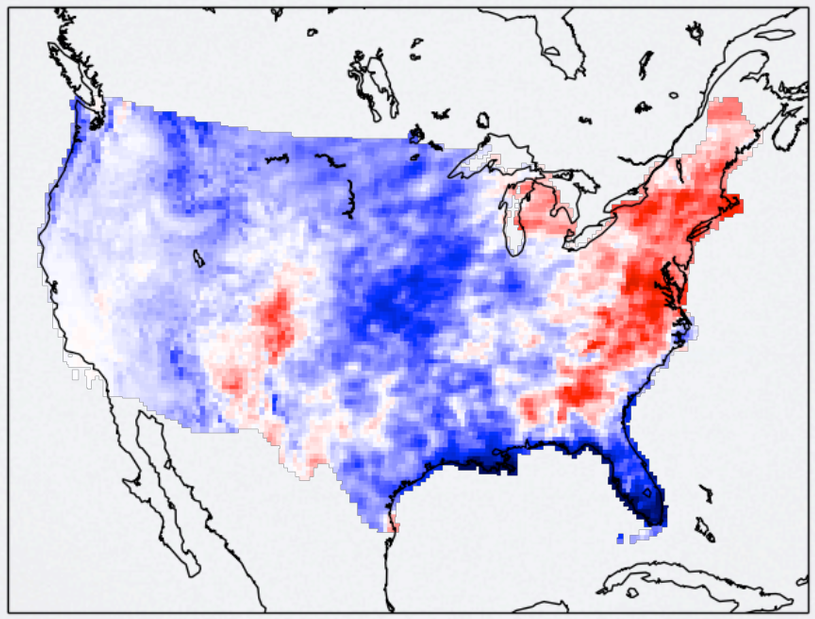




mm/d

mm/d

c384 Alternative configuration

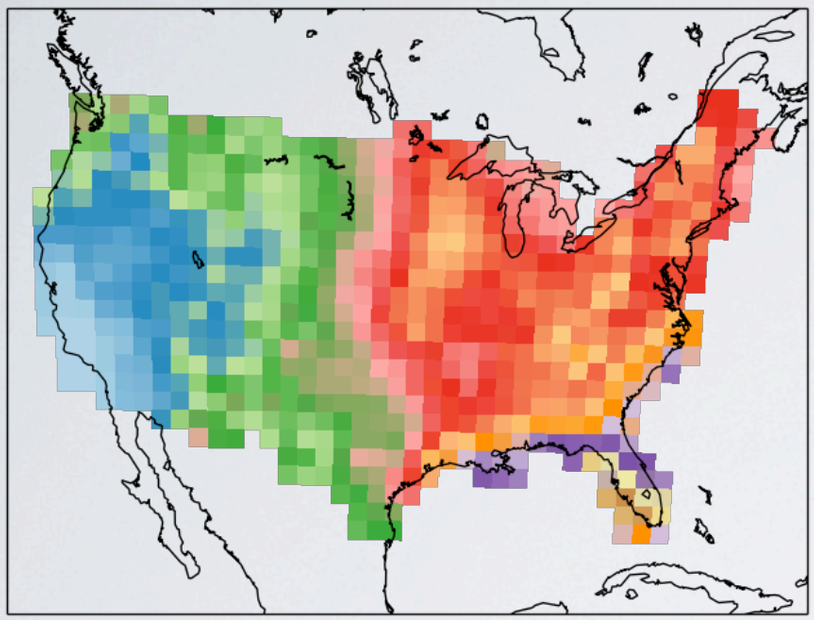


New nest: c384n3

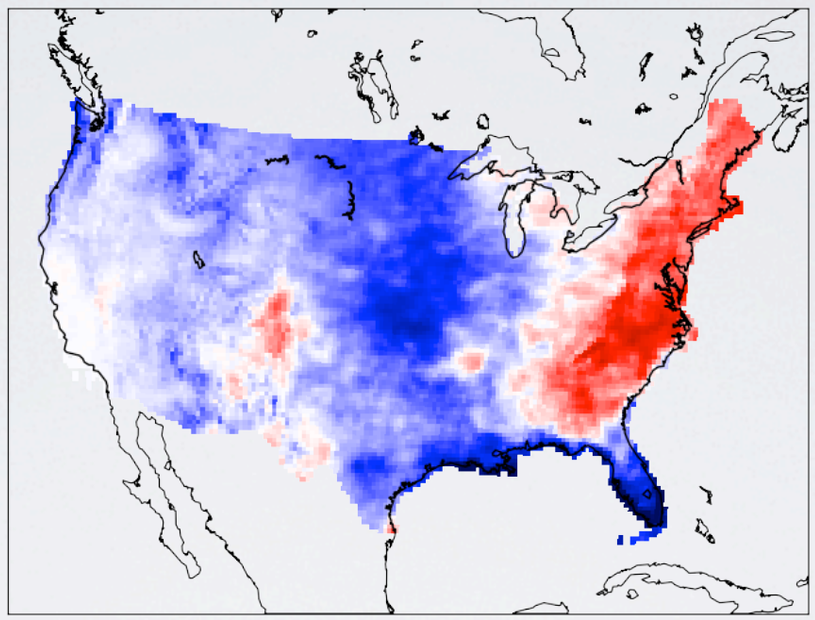
- c384 global grid (25 km)
- Factor-of-three nest (8 km) over CONUS
- 8 mo/day with 4248 cores (c384 single-grid: 19 mo/day with 3456 cores)

C384 AND C384n3

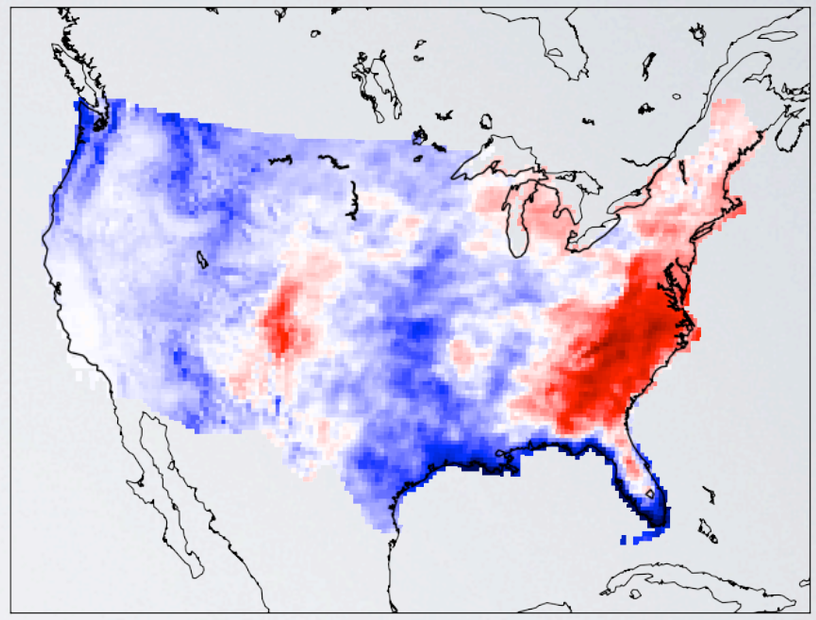
PRISM Observations

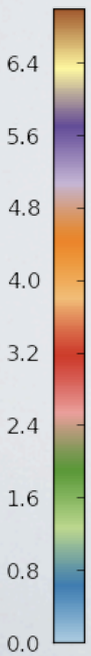


c360 (30 km) single-grid



c384 (25 km) single-grid

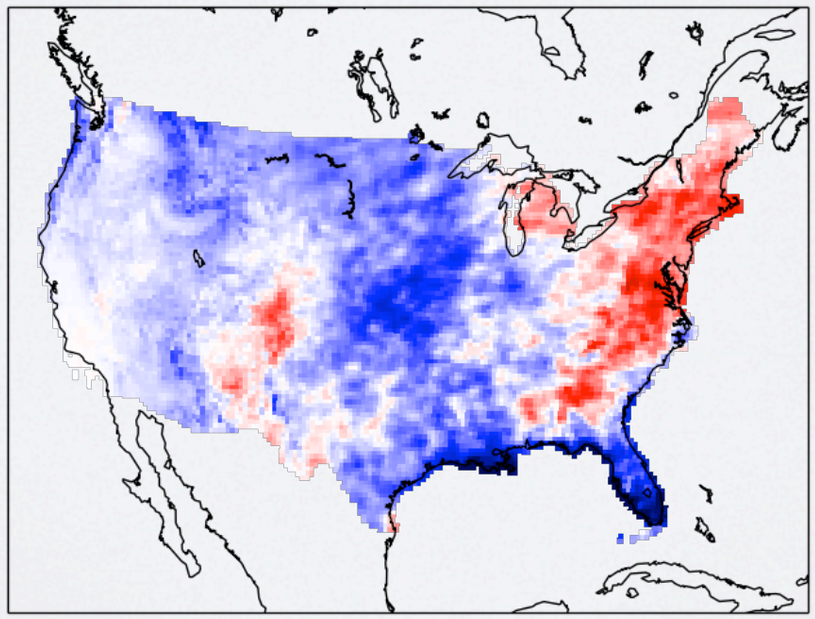




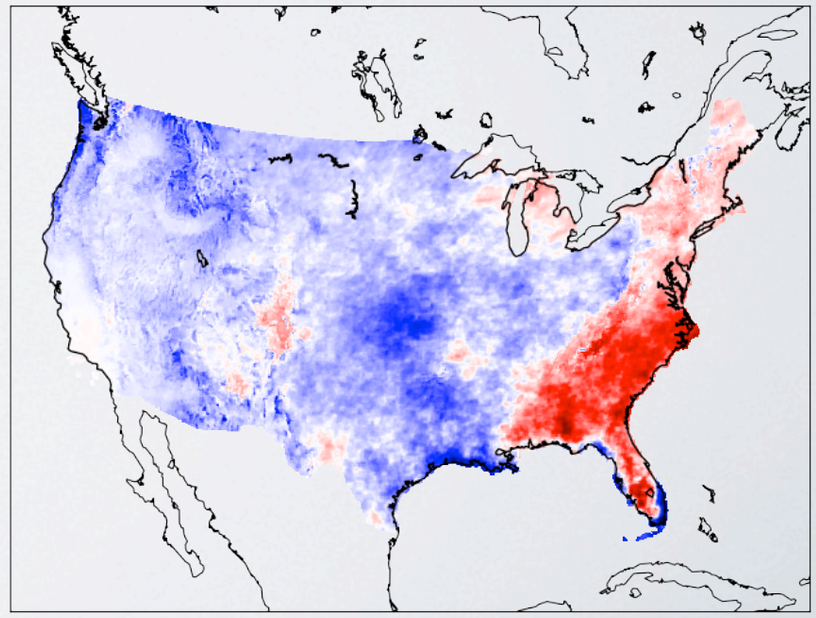
mm/d

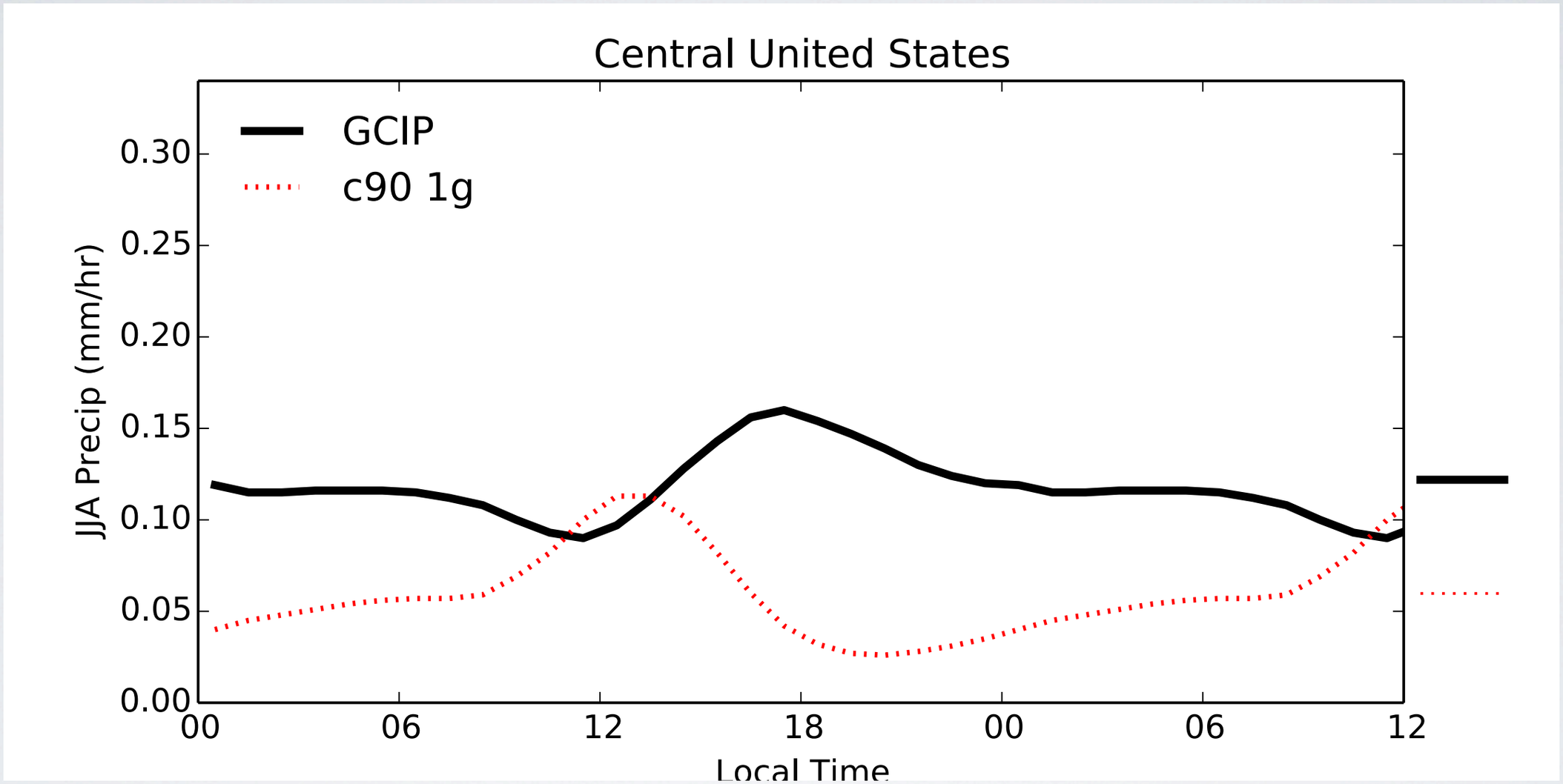
mm/d

c384 Alternative configuration



c384n3 (8 km) nested




Central United States
GCIP
c90 1g
JJA Precip (mm/hr)
0.30
0.25
0.20
0.15
0.10
0.05
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00
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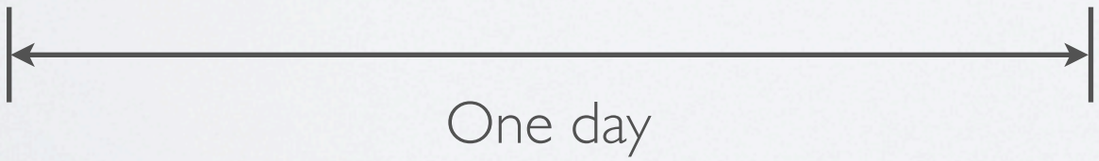
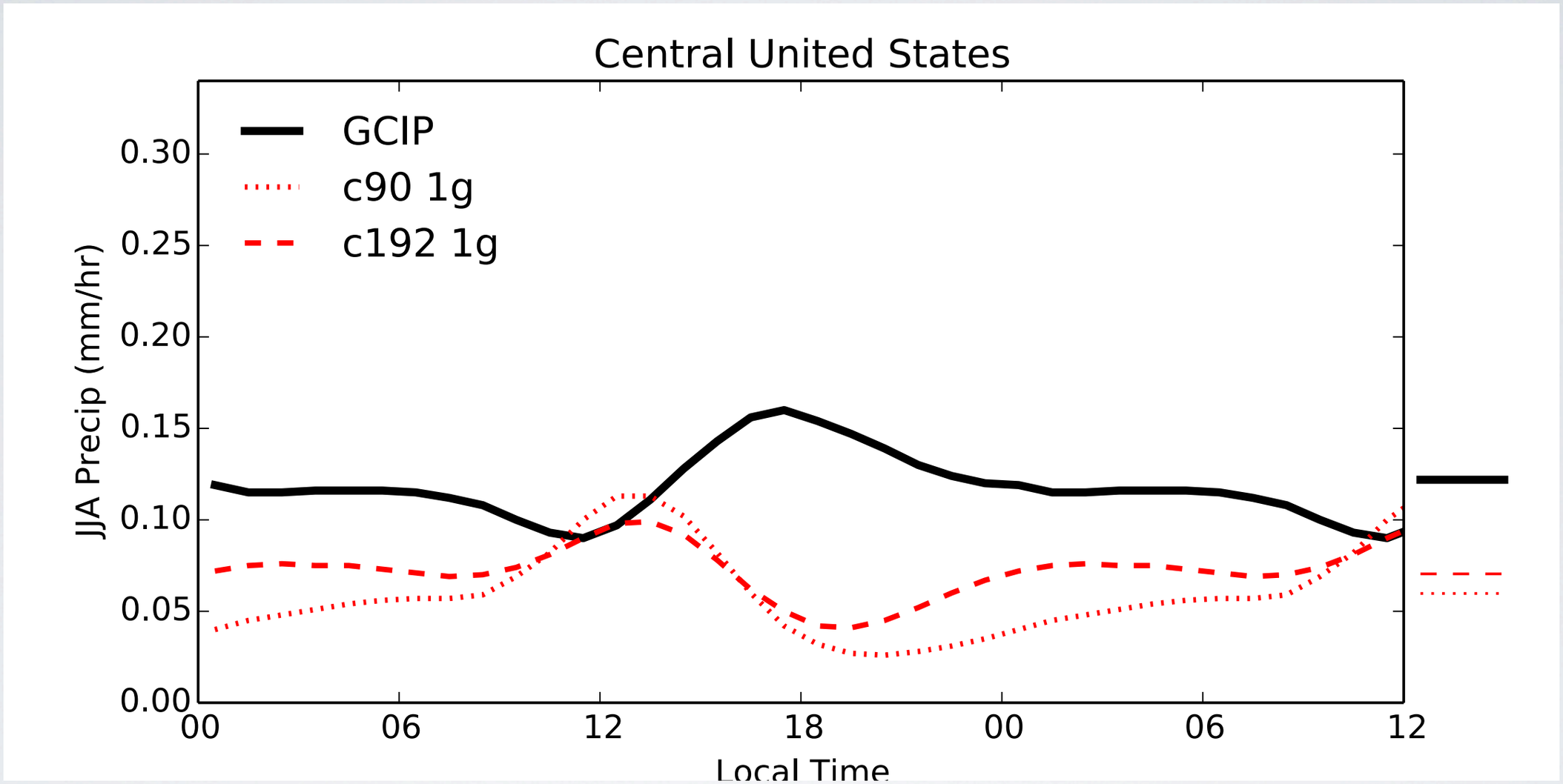
12
18
00
06
12
Local Time


One day


Central United States
GCIP
c90 1g
c192 1g
JJA Precip (mm/hr)
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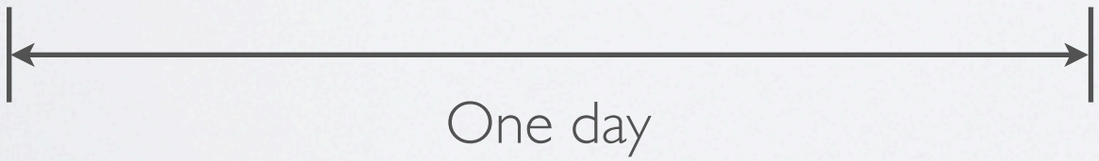
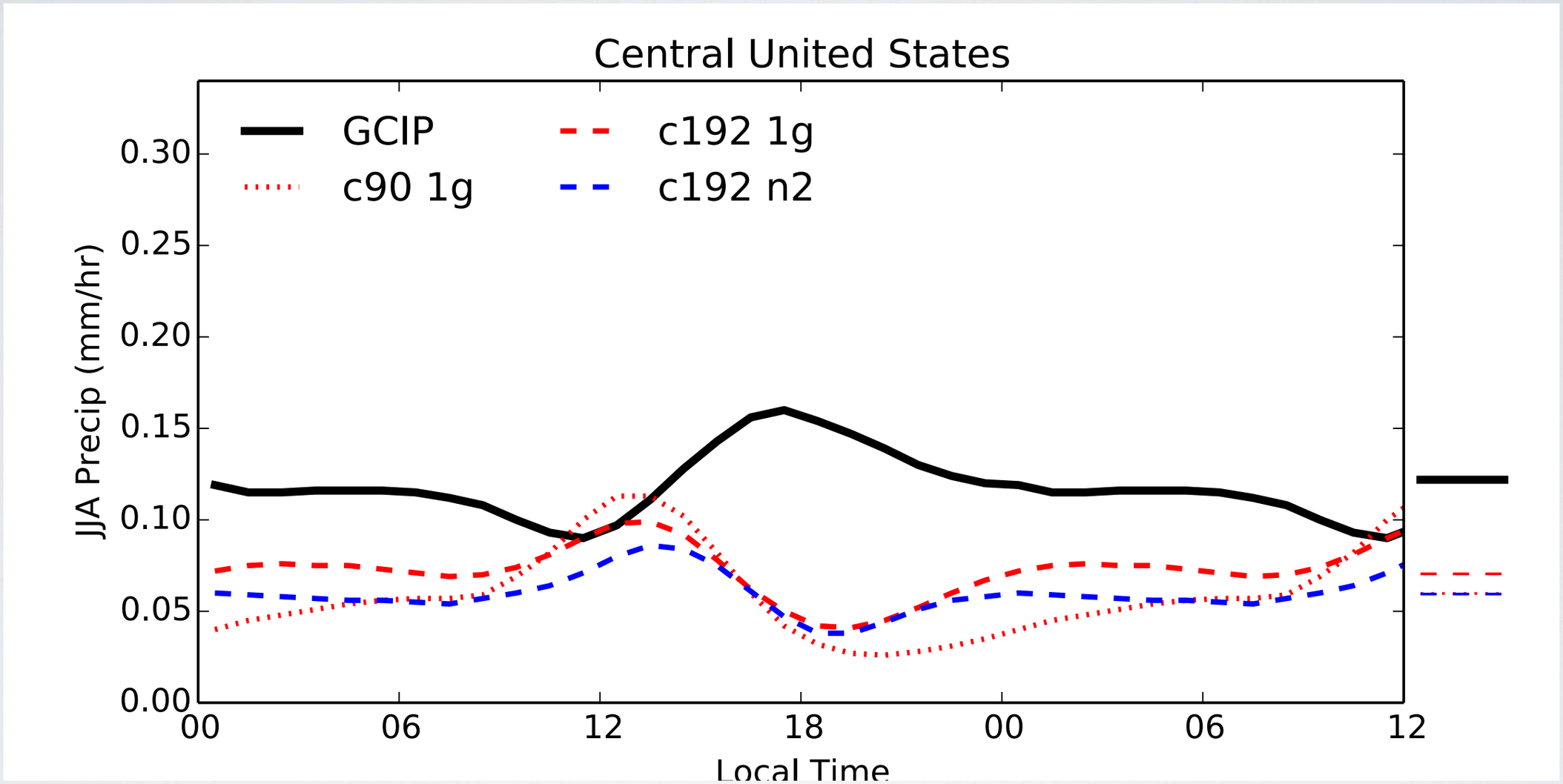
Local Time


One day


Central United States
GCIP
c90 1g
c192 1g
c192 n2
JJA Precip (mm/hr)
0.30
0.25
0.20
0.15
0.10
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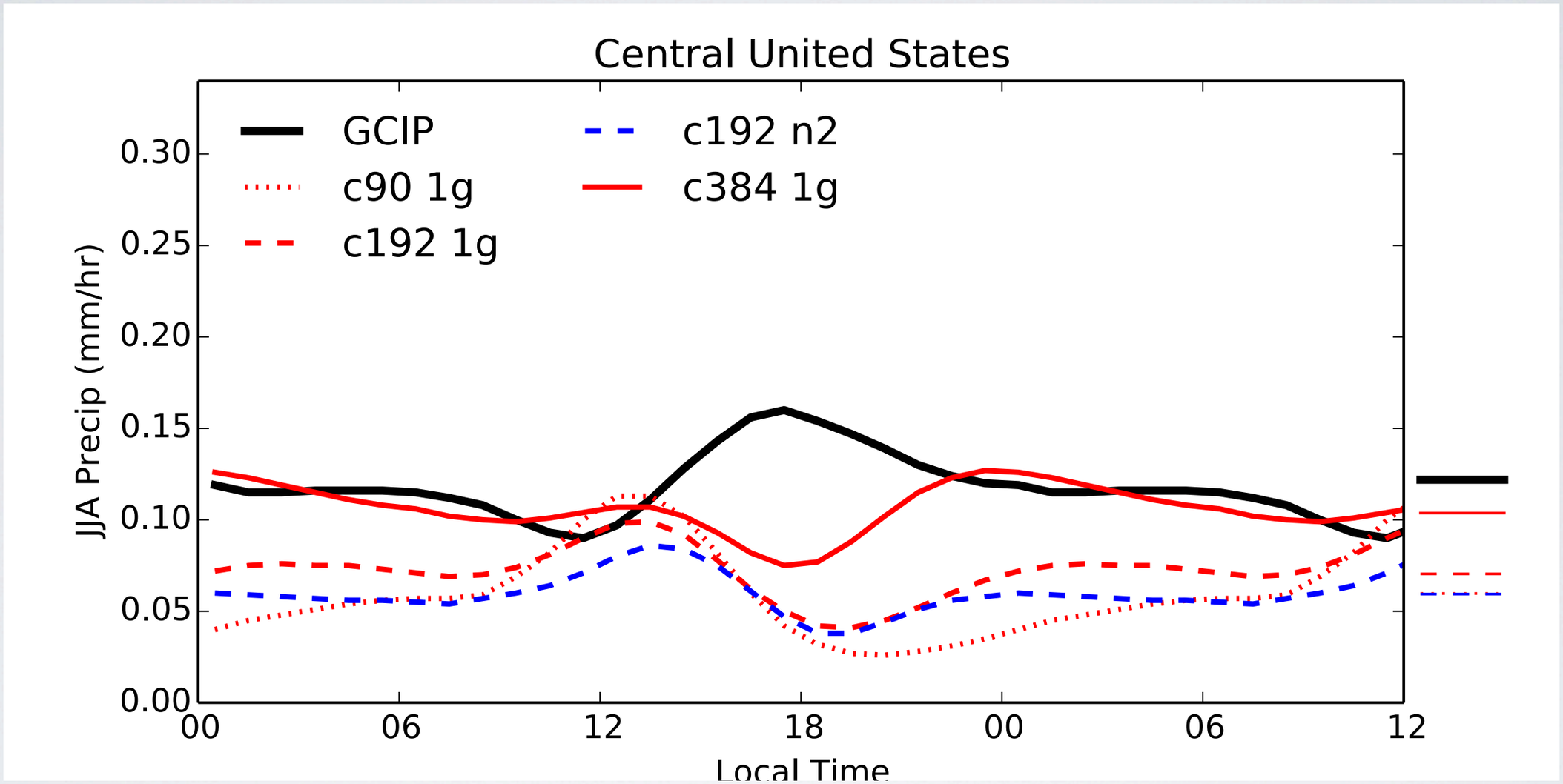
Local Time

One day


Central United States
GCIP
c90 1g
c192 1g
c192 n2
c384 1g
JJA Precip (mm/hr)
0.30
0.25
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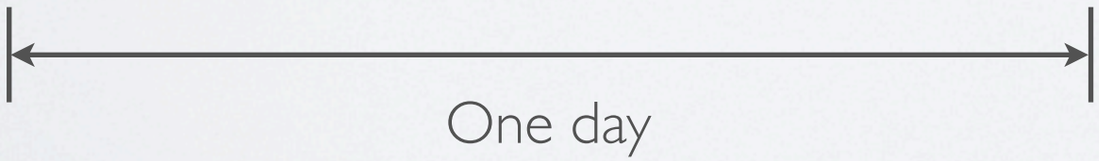
Local Time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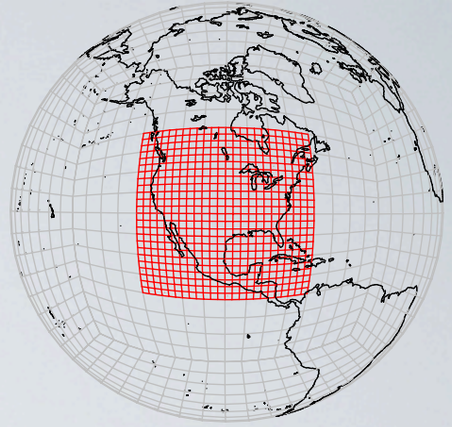

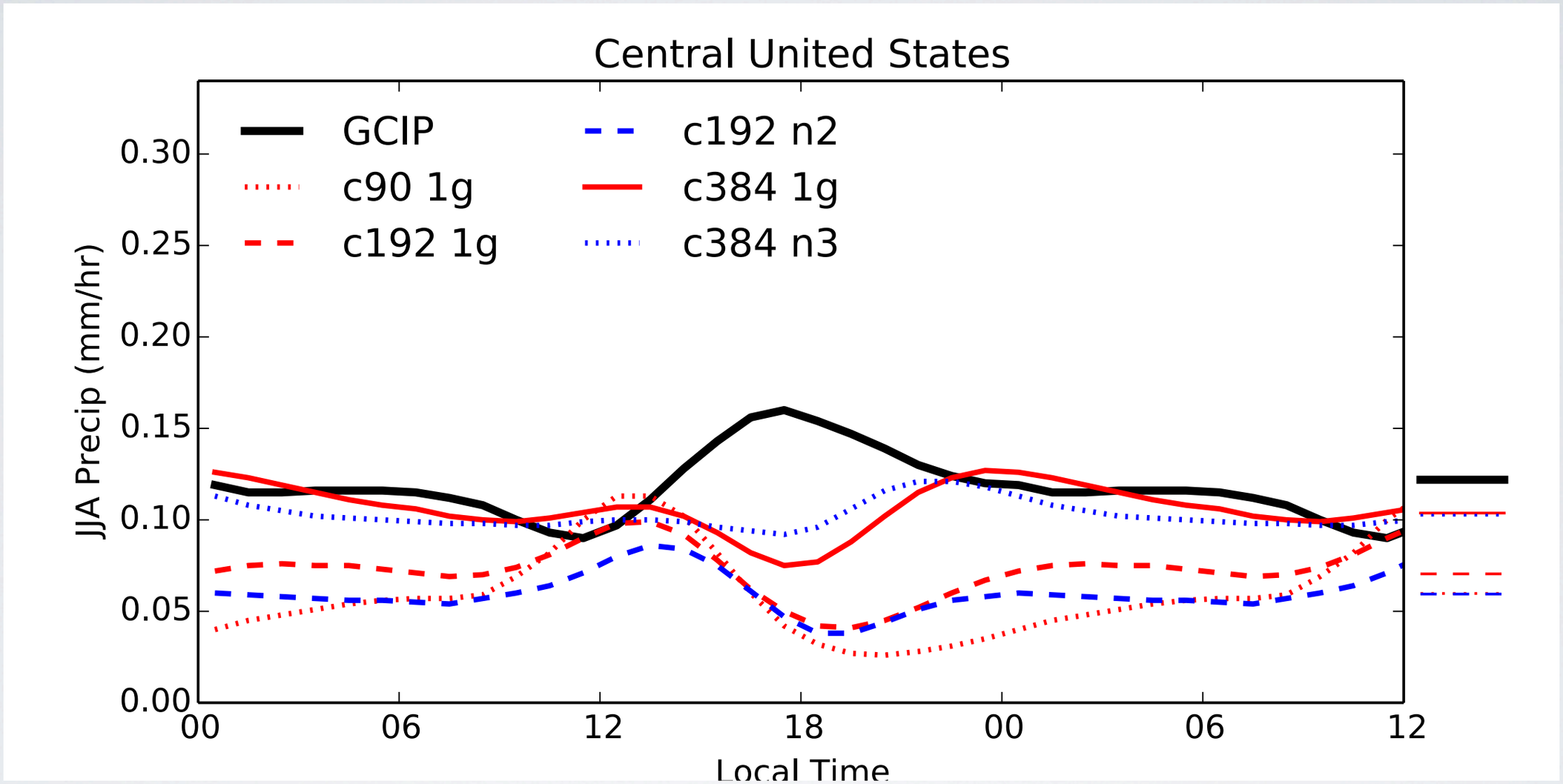
Central United States
GCIP
c90 1g
c192 1g
c192 n2
c384 1g
c384 n3
JJA Precip (mm/hr)
0.30
0.25
0.20
0.15
0.10
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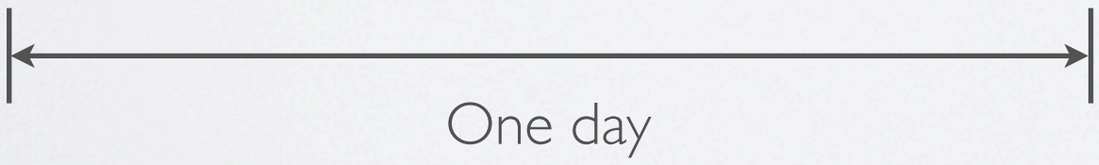
Local Time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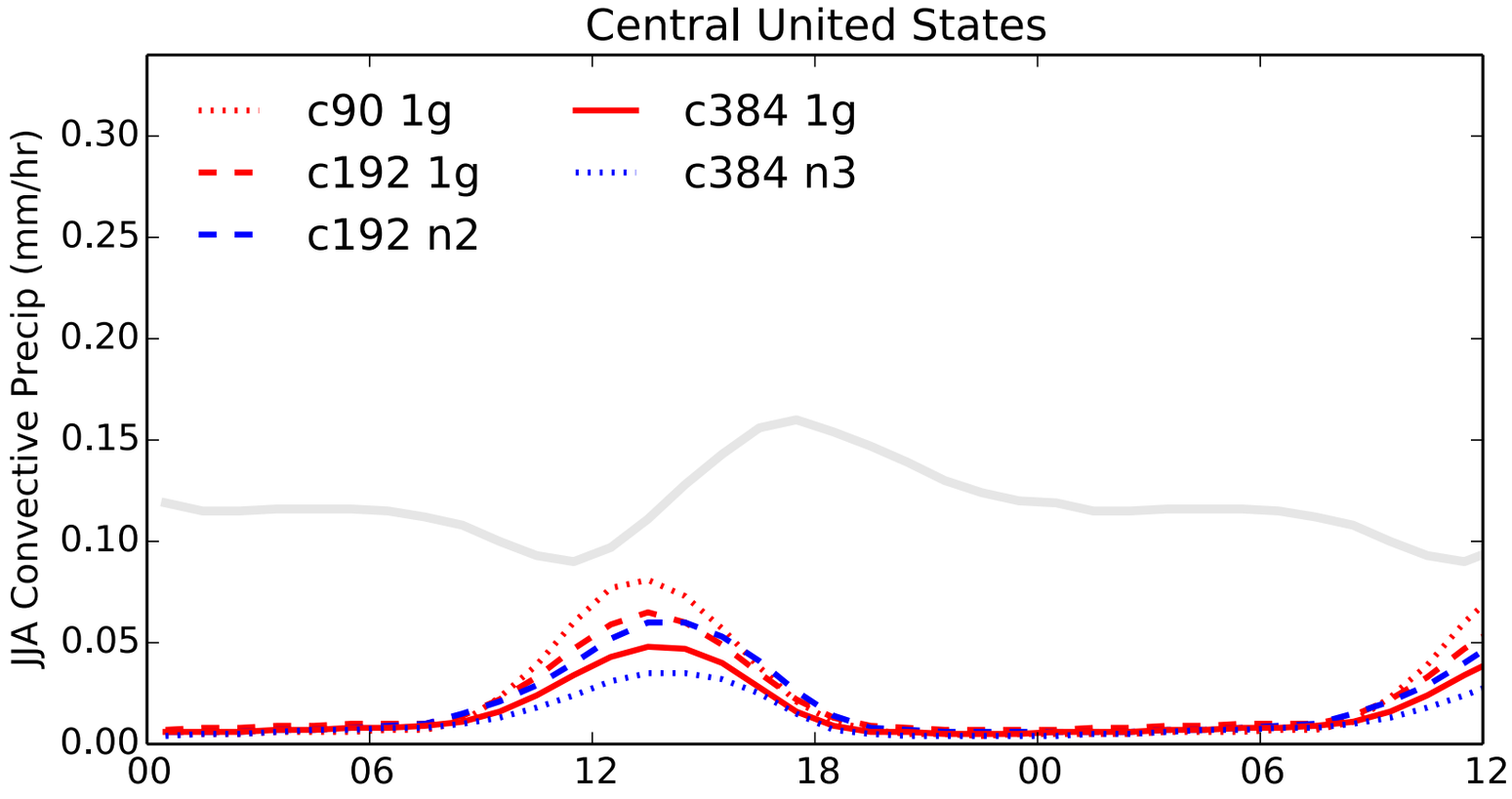
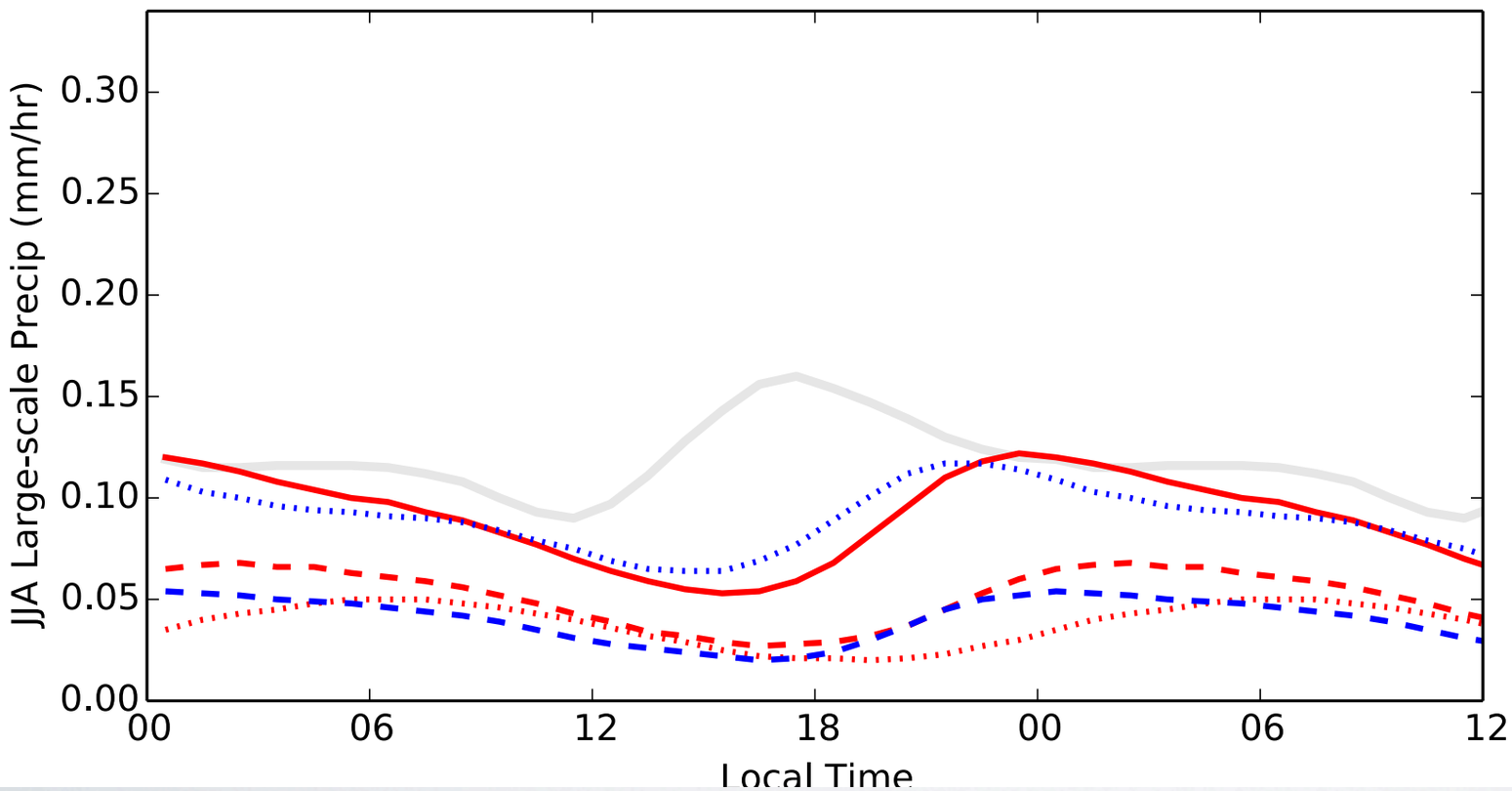
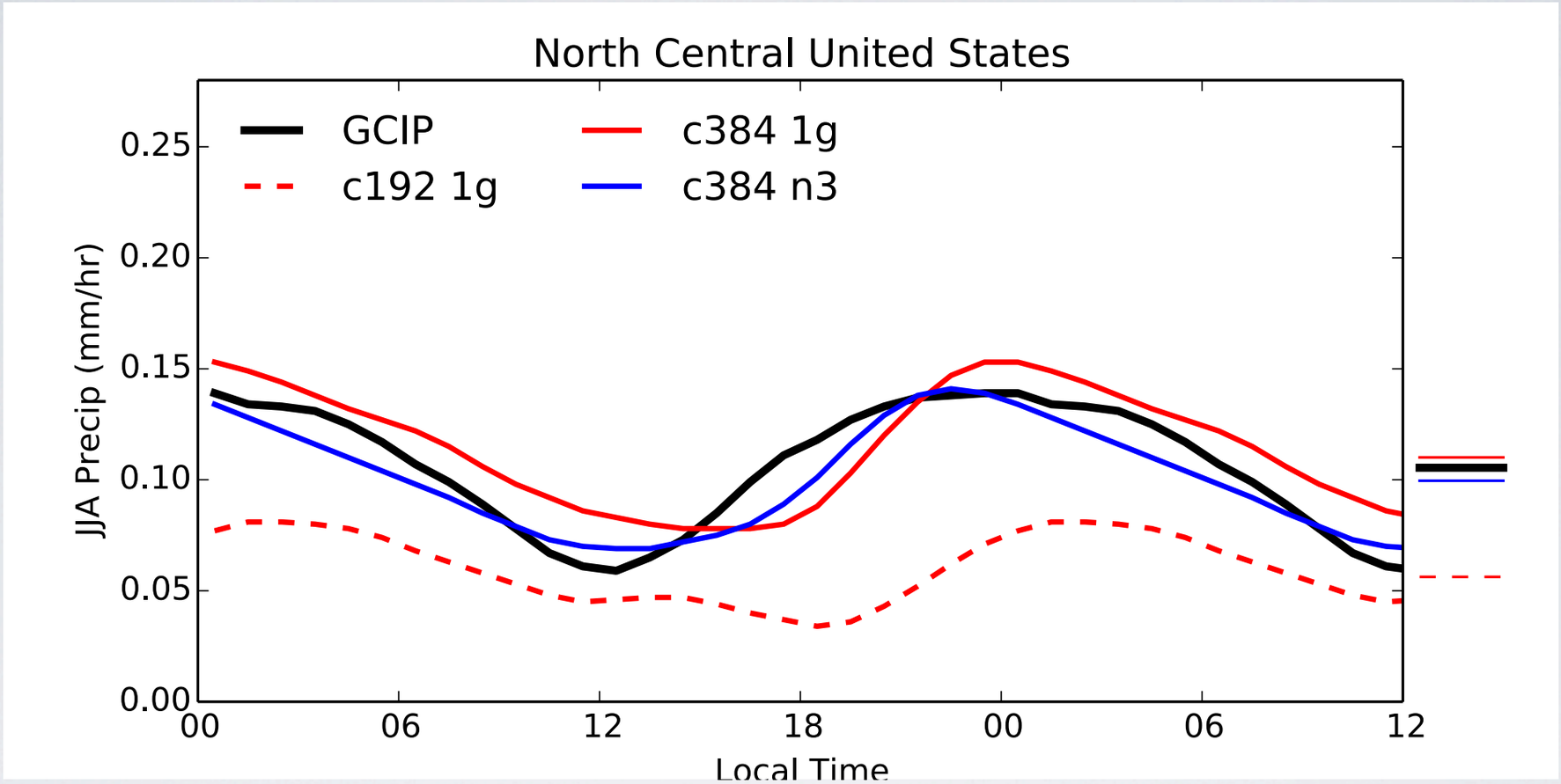
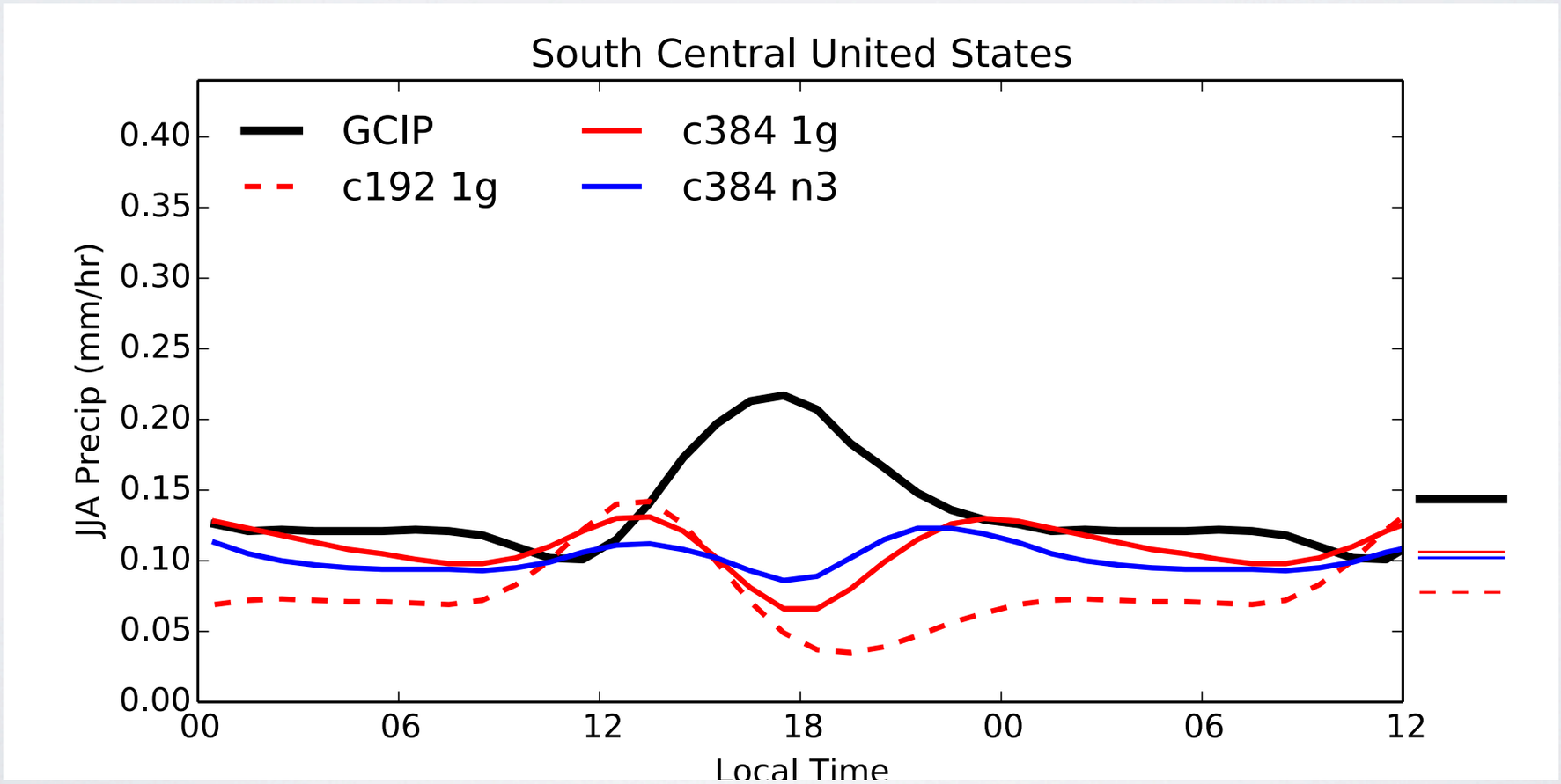


Parameterized Precipitation



Resolved Precipitation


North Central United States
GCIP
c192 1g
c384 1g
c384 n3
JJA Precip (mm/hr)
0.00
0.05
0.10
0.15
0.20
0.25
00
06
12
18
00
06
12
Local Time


South Central United States
GCIP
c192 1g
c384 1g
c384 n3
JJA Precip (mm/hr)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
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06
12
18
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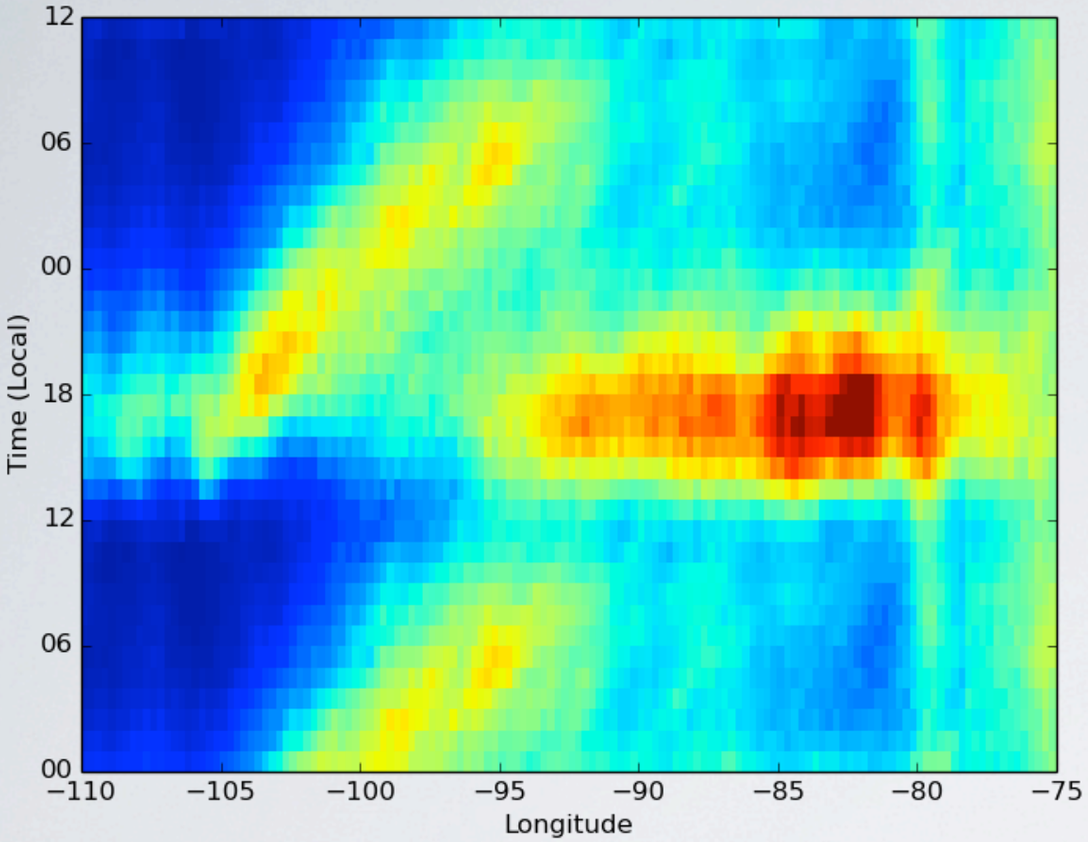
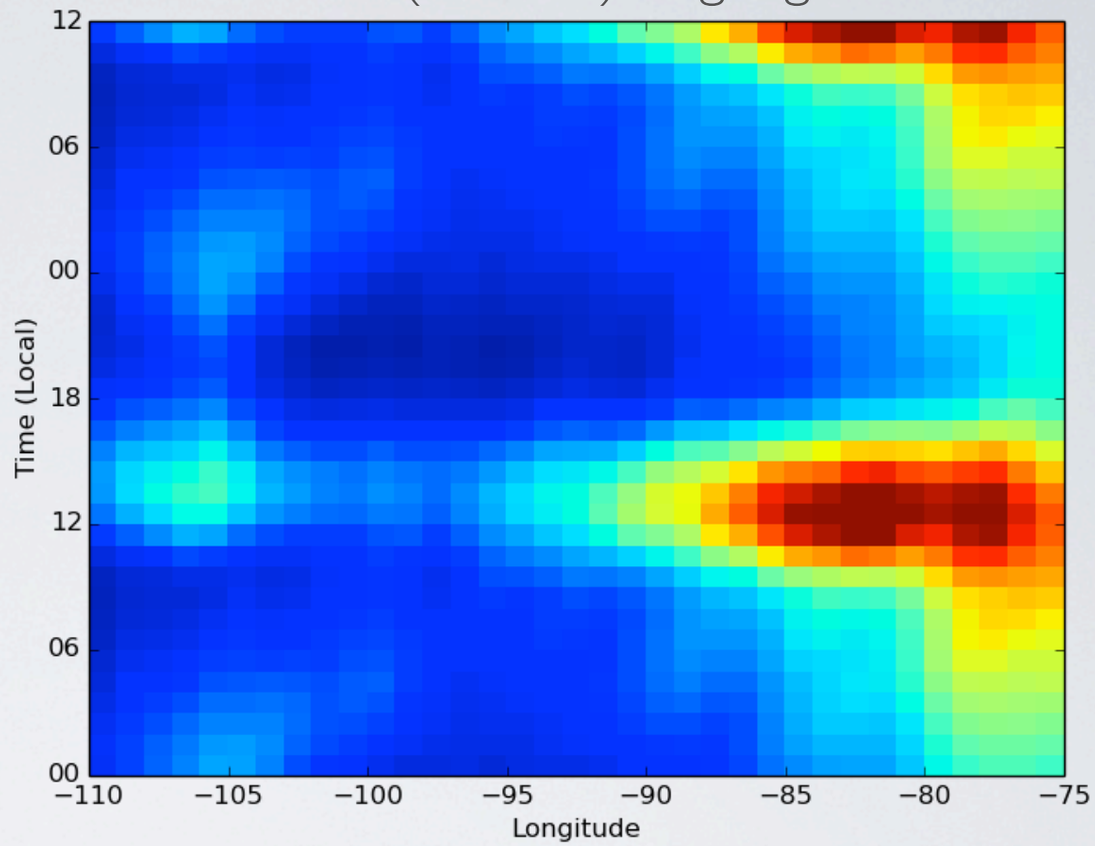
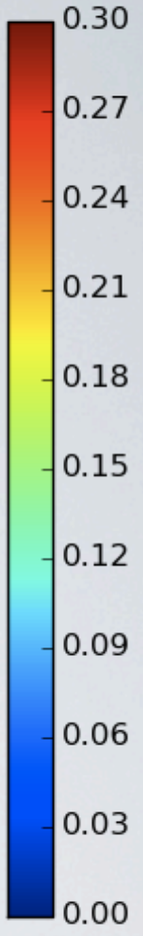
06
12
Local Time

GCIP Observations



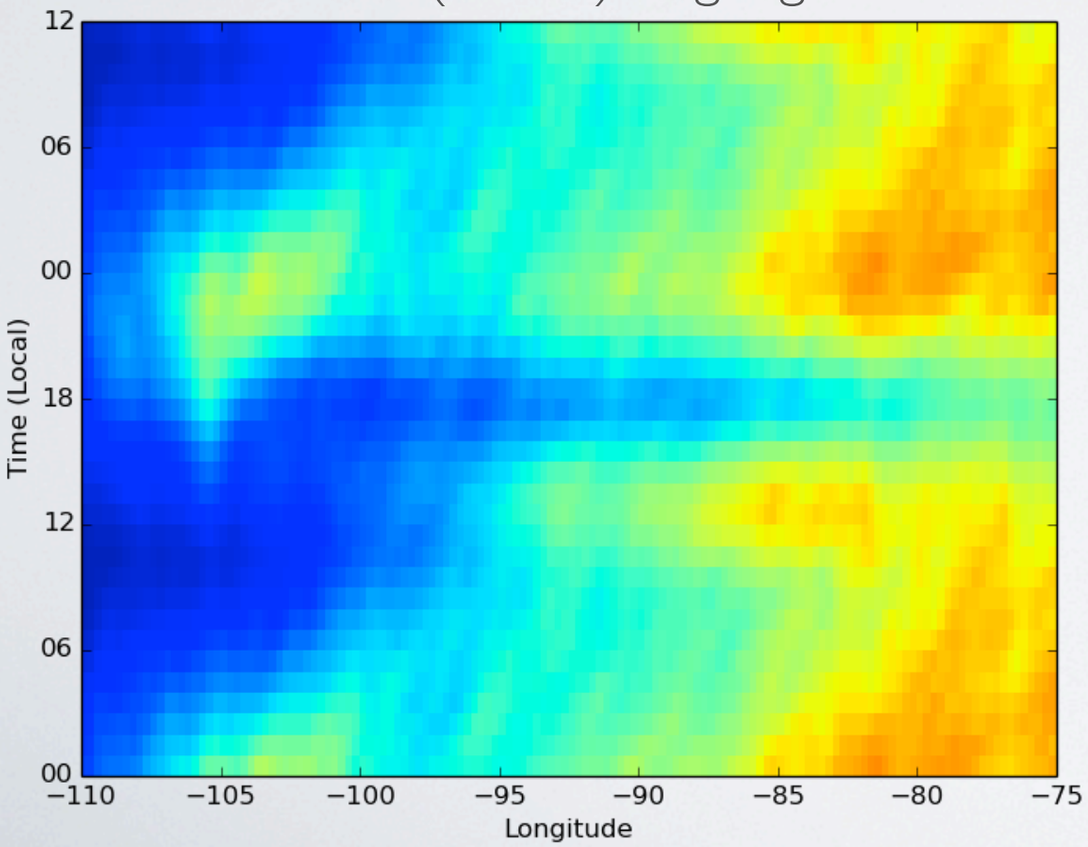
c90 (110 km) single-grid



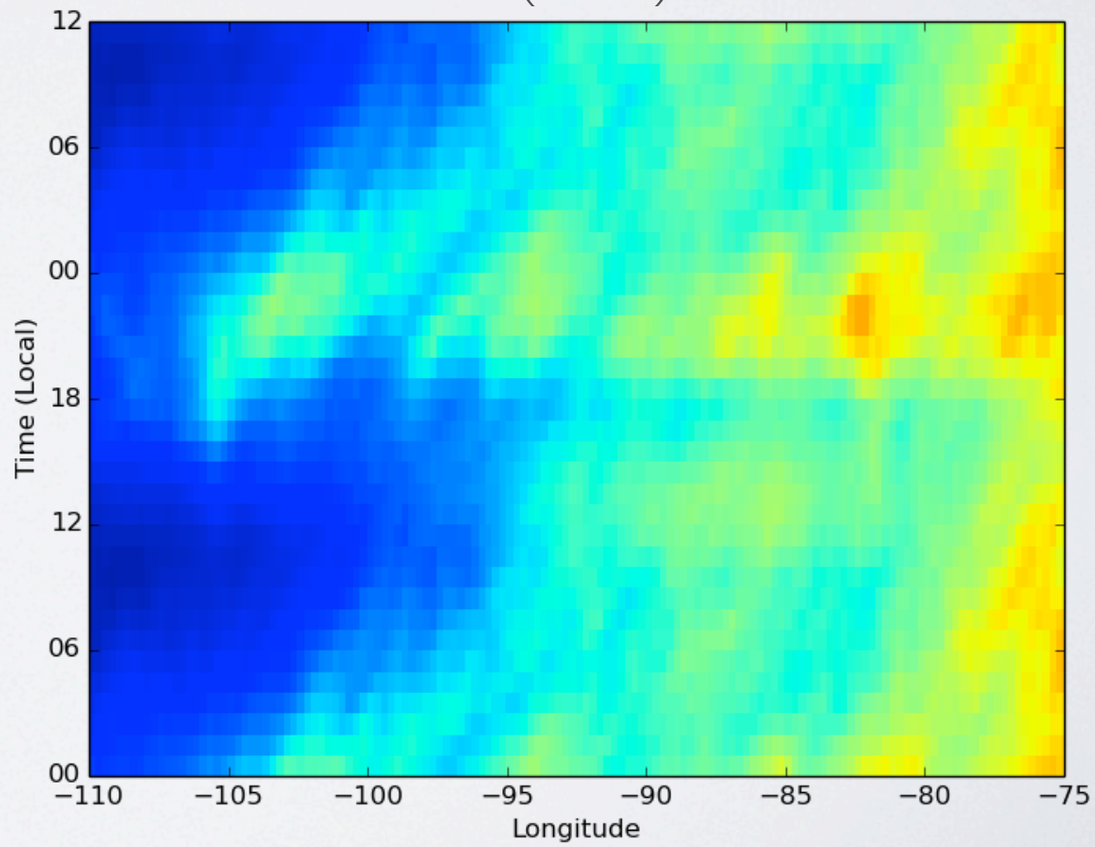


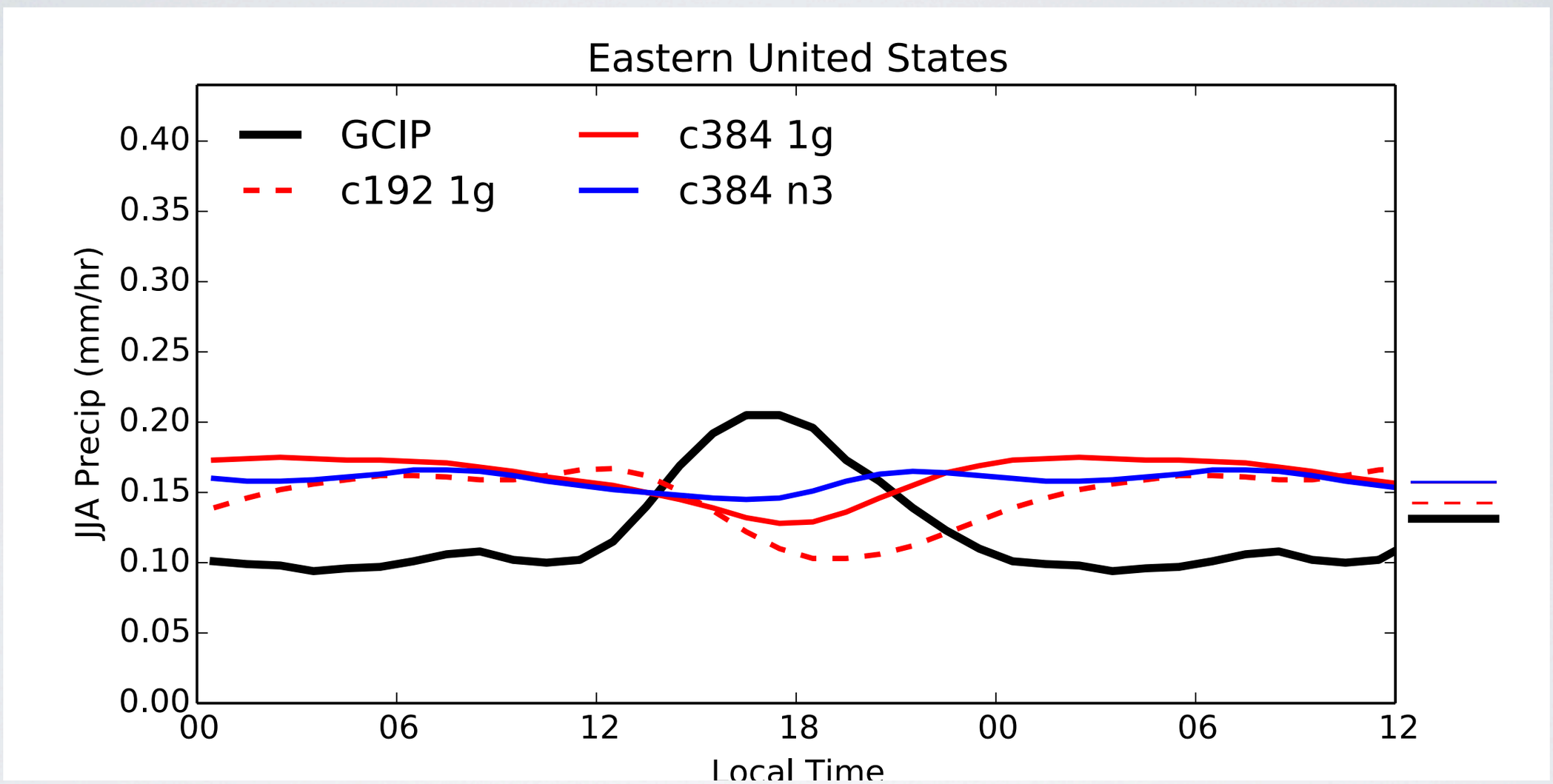
mm/hr

c384 (25 km) single-grid



c384n3 (8 km) nested




Eastern United States
GCIP
c192 1g
c384 1g
c384 n3
JJA Precip (mm/hr)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
00
06
12
18
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12
Local Time

CONCLUSIONS

- Enhanced resolution readily improves representation of orographic precipitation and hurricane intensity
- Great Plains precipitation only improves weakly with increasing resolution
- Nesting to 8 km gets the best results, especially in representing propagating features in the Northern Plains
- Want to avoid parameterization as much as possible to get the diurnal cycle right!!