The Kain-Fritsch Scheme: Science Updates and Revisiting Gray–Scale Issues from the NWP and Regional Climate Perspectives

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United States Environmental Protection Agency

What: Many CP schemes (e.g., KF) do not work properly at gray-scales. i.e., dx >1 km to <10 km

Why: Many assumptions tied to scales around *dx* = ~25 km

How to fix: Relax some of the key assumptions towards achieving scale independence

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Before we jump in, let's see what basic KF cloud process is missing?

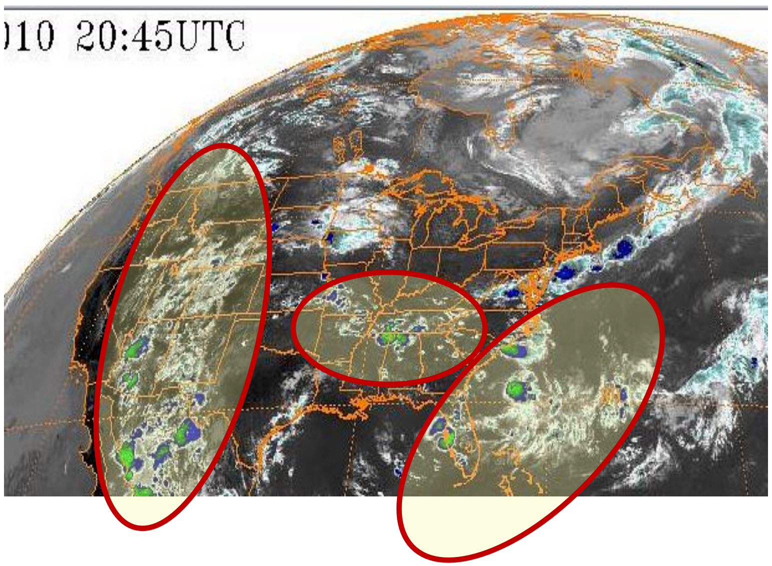
KF cloud-radiation interactions!

Adding Radiative Feedbacks from Subgrid Convective Clouds: 36 km grids

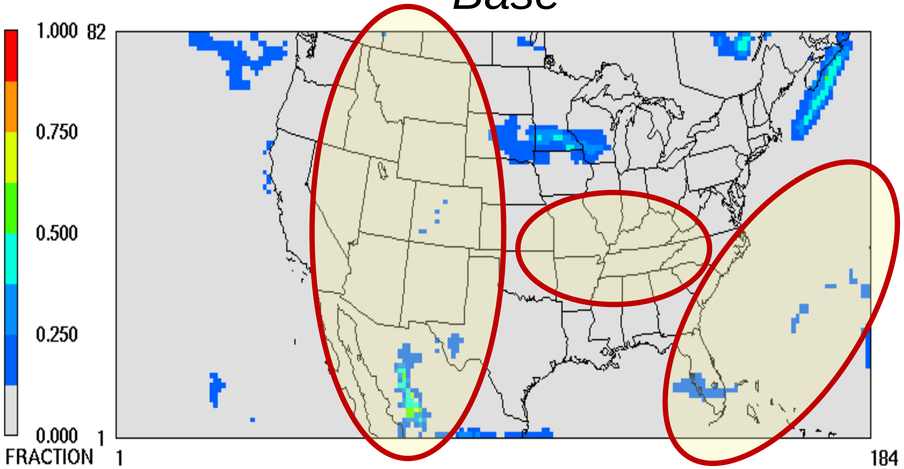
Alapaty et al., *Geophys. Res. Lett.*, 2012

Column Total Cloudiness
5 p.m. EDT
29 July 2010
(5 days into forecast)

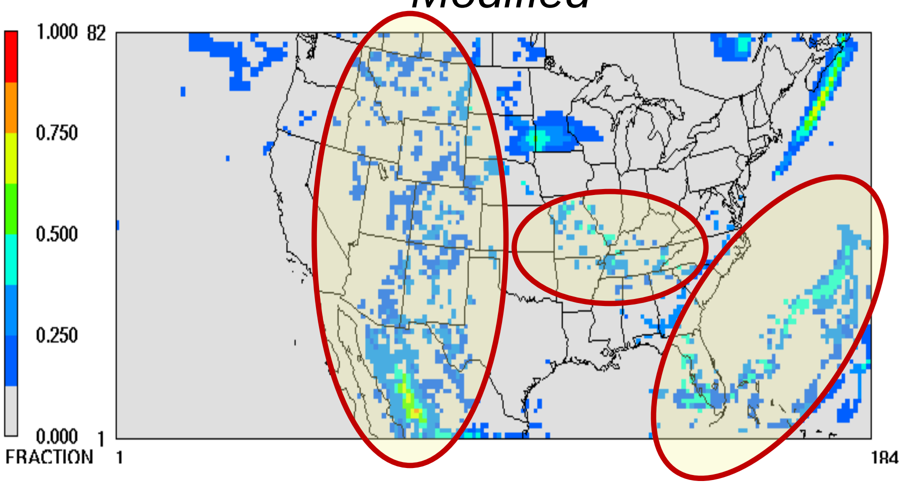
GOES-13 Satellite



Base



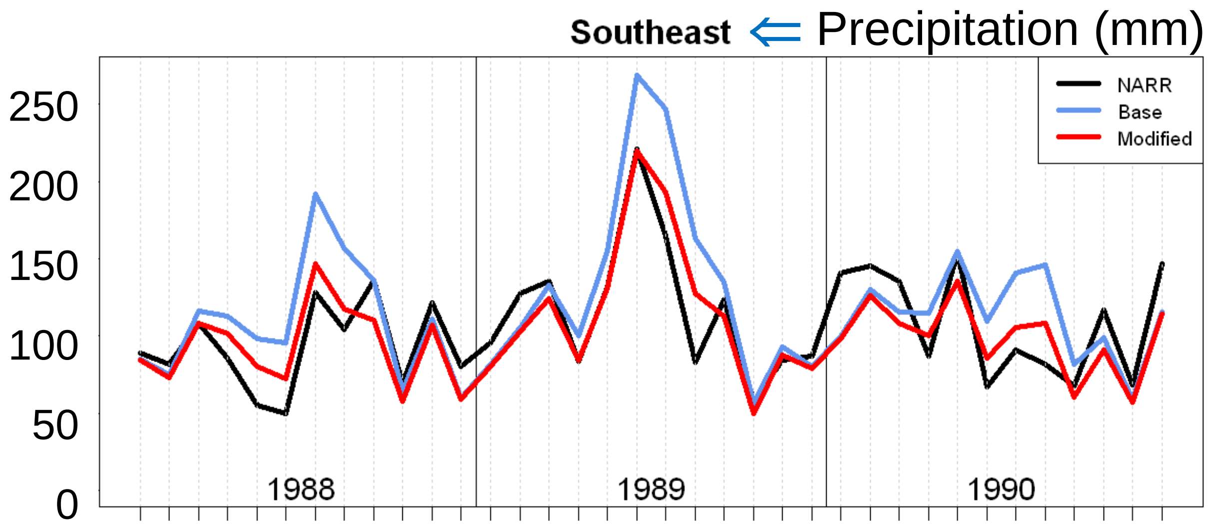
Modified

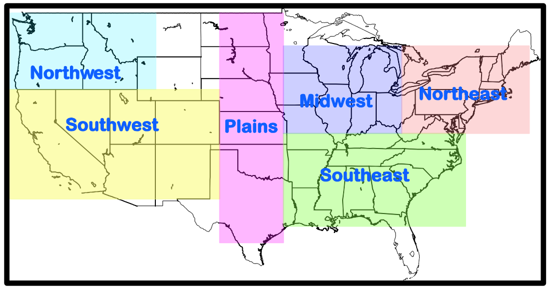


Codes are submitted to NCAR for the next release

Adding Radiative Feedbacks from Subgrid Convective Clouds 36 km grids

EPA United States





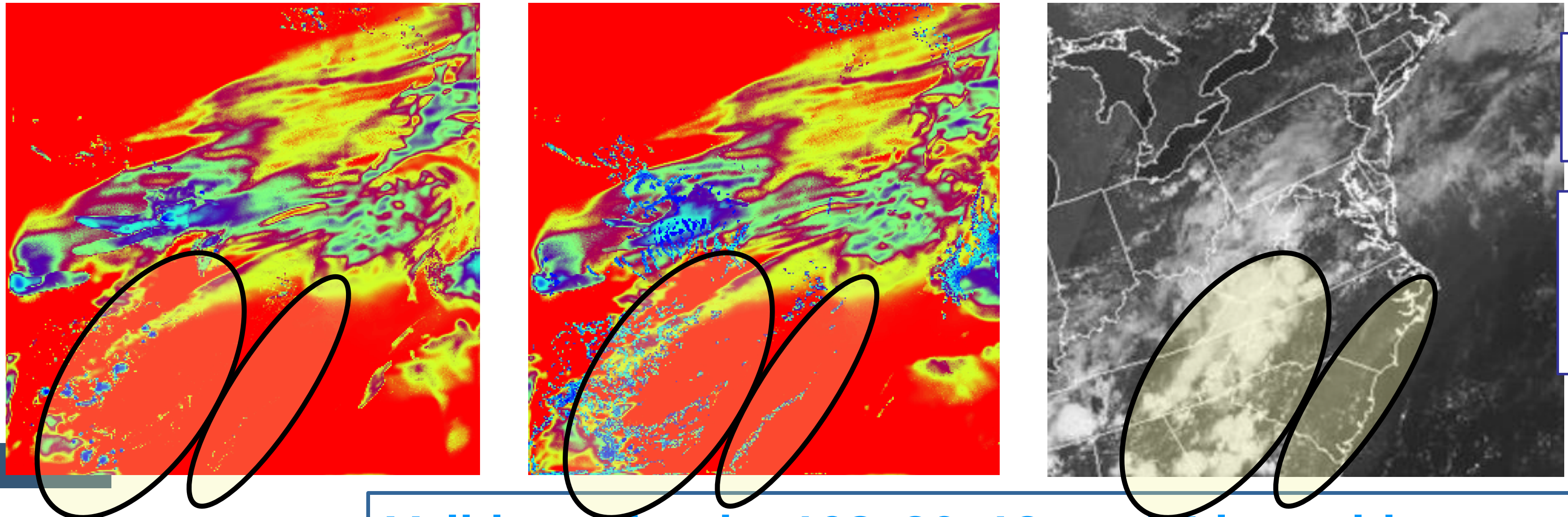
Wet bias in KF is largely eliminated

Herwehe et al., *in preparation: 2013*

Surface SWR: ***KF Base***

KF Rad

Satellite



4 km grids

20 UTC July 4 2011

Validated for dx=108, 36, 12, and 4 km grids

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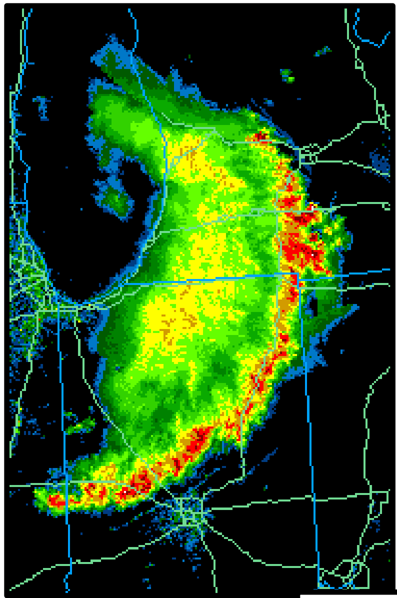
Now, back to the business of scale independence for KF scheme:



Lake Michigan area

Old Thinking: A CP Scheme should avoid grid-scale saturation!
→ It squeezes too much water when applied at high resolution grids

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NEW thinking from resolution perspective → A CP scheme should help moisten the atmosphere:

Which moist physics should restore stability to the atmosphere?

Summer & Winter:

KF & E schemes

KF scheme SHOULD gradually drop out

Summer & Winter:

E scheme

Grid Resolution

~36 km ……… ……… ~1 km

One way to *gradually* dropout the KF is to **control** its ability to stabilize atmosphere and help to moisten the atmosphere

Adapting KF to Transition Across Grid Spacing

- Probable KF parameters that control surface precipitation & depend on grid resolution:

  (1) Adjustment timescale (τ)

  (2) Entrainment

  (3) Convective cloud microphysics

- Goal: Make KF seamless across spatial scales (including gray scales!)

Adapting KF to Transition Across Grid Spacing: <u>(1) Adjustment Timescale</u>

In KF:

$$\left.\frac{\partial\theta}{\partial t}\right|_{conv} = \frac{\theta_{final} - \theta_{initial}}{\tau}$$

Here τ is the time over which CAPE is "removed" to stabilize the atmosphere.

τ is arbitrary in most CPS:

- KF: 0.5 – 1 h
- G3: ~0.75 h
- ZM: ~1 h
- AS: ~2 – 12 h

Timescale not connected to cloud dynamics

No scale dependency

In KF, τ decreases as resolution increases!

But, τ should increase as resolution increases such that <u>KF drops out gradually !!</u>

Adjustment Timescale…

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Bechtold (2008): (ECMWF GCM)

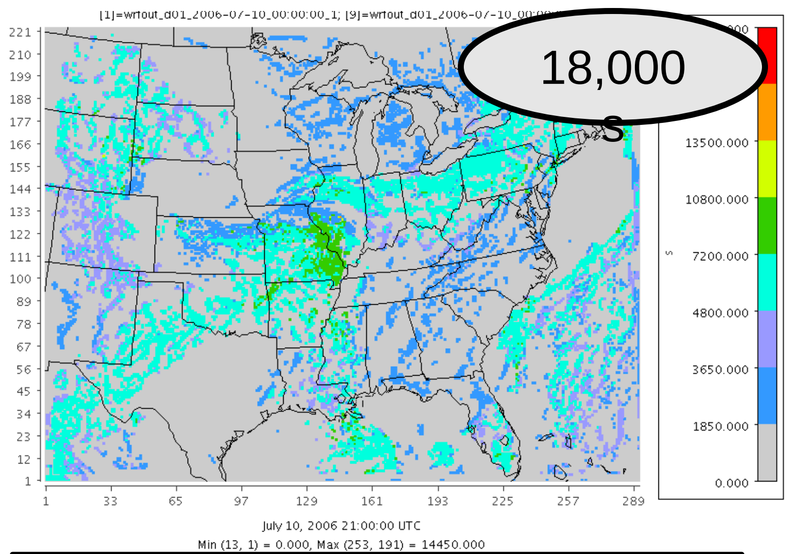
$$\tau = \frac{H}{W}\delta = \frac{Depth\,Scale}{V.Velocity\,Scale} Fn(\Delta X)$$

Our New dynamic formulation

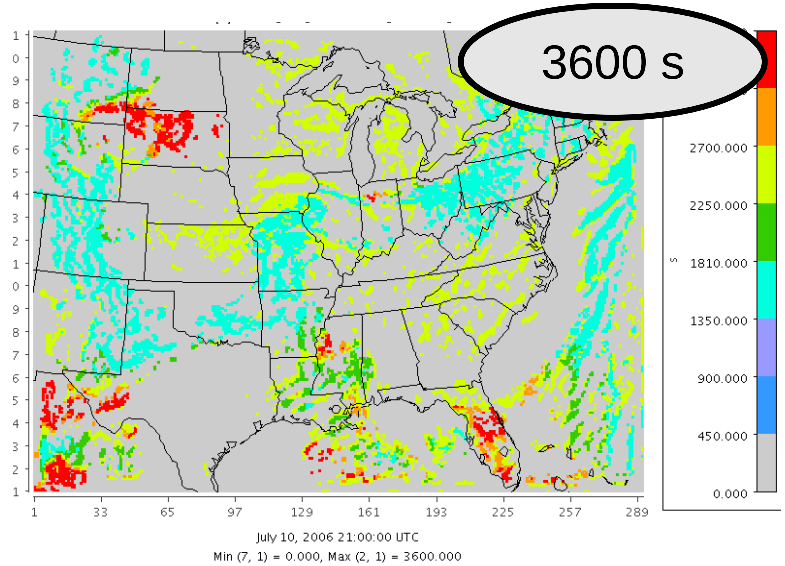
$$\tau = \frac{H}{(m_b A_e)^{1/3}}\delta$$

From Grant & Lock (2004) → LES studies and BOMEX observations: $W = (m_b A_e)^{1/3}$

For now we keep $\delta = 1$ for 12 km grids



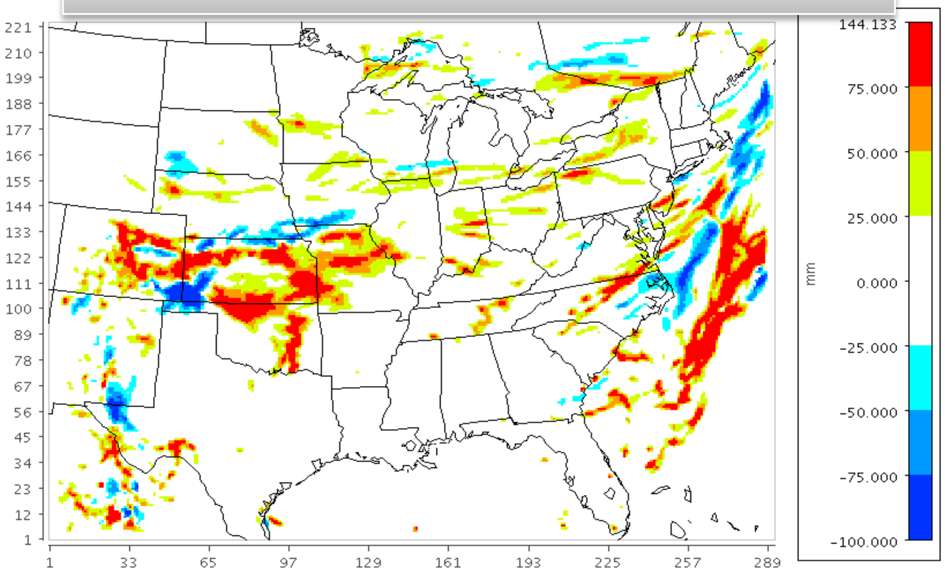
at 21 UTC 10th day of simulation starting July 1, 2006



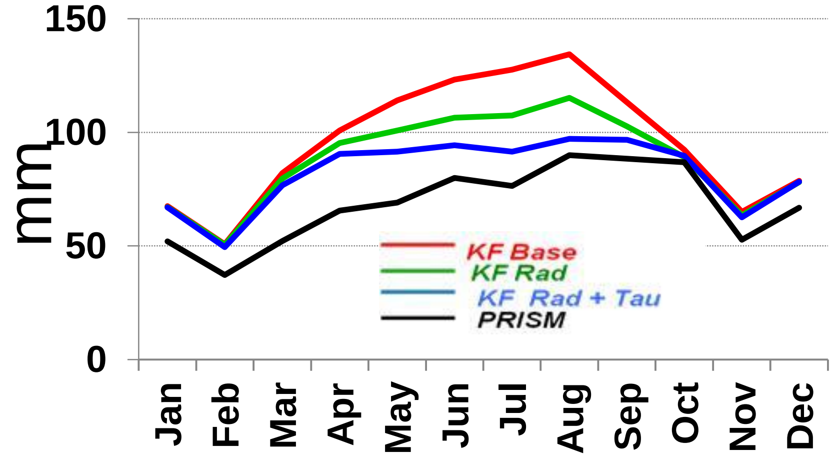
New Tau varies from about 1850 to 10,800 s (0.5h to 3h)

at 21 UTC 10th day of simulation starting July 1, 2006

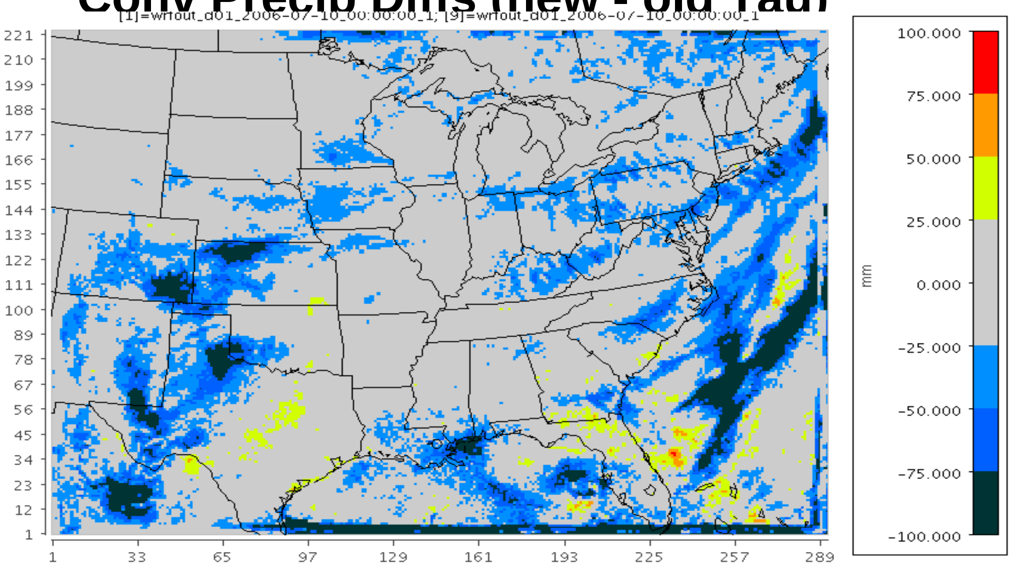
Grid-scale Precip Diffs (new-old Tau)

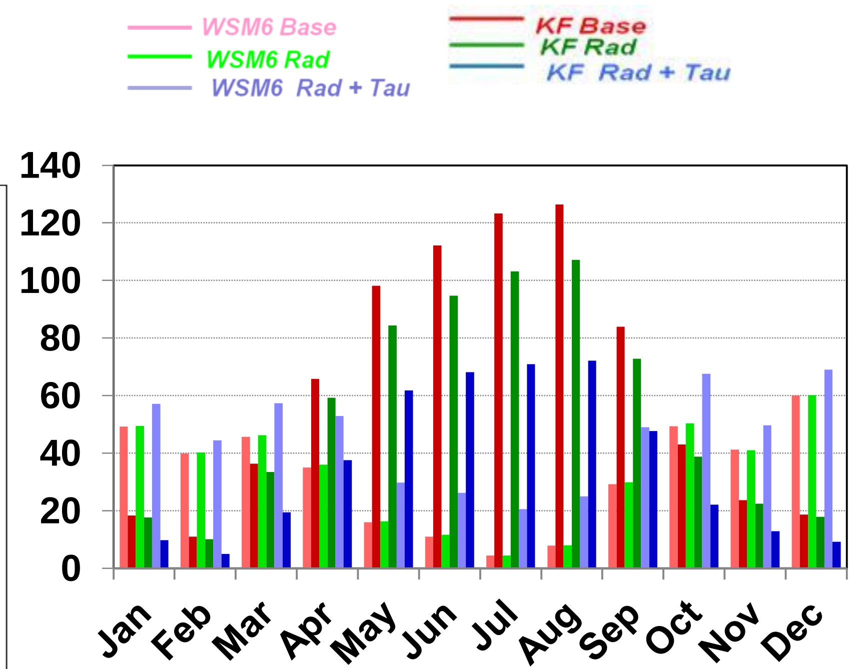


Avg Monthly Precip (mm) "*CONUS*" 12 km grids 2006

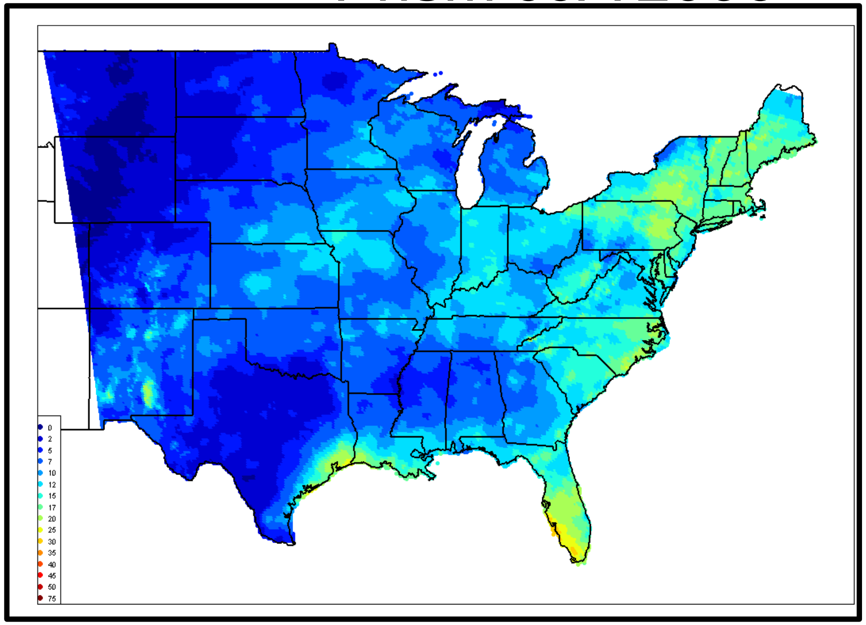


Conv Precip Diffs (new - old Tau)

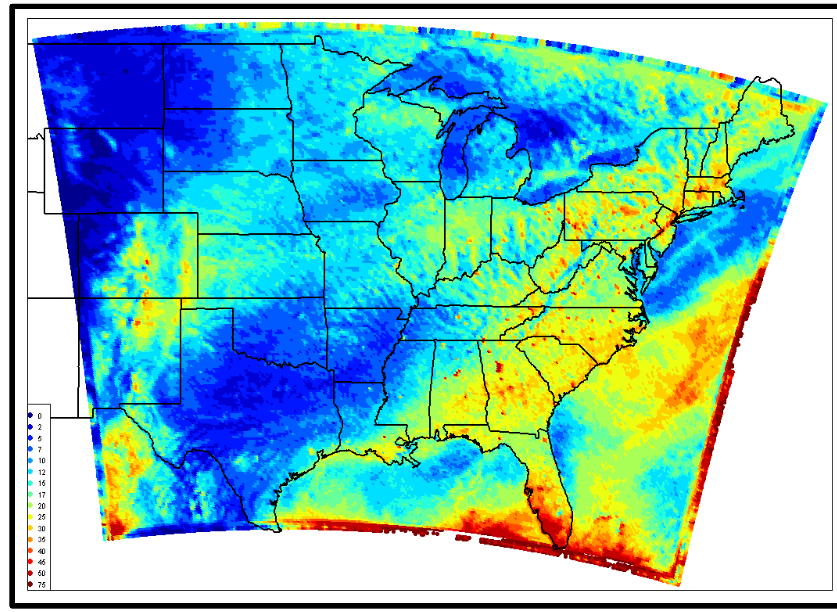




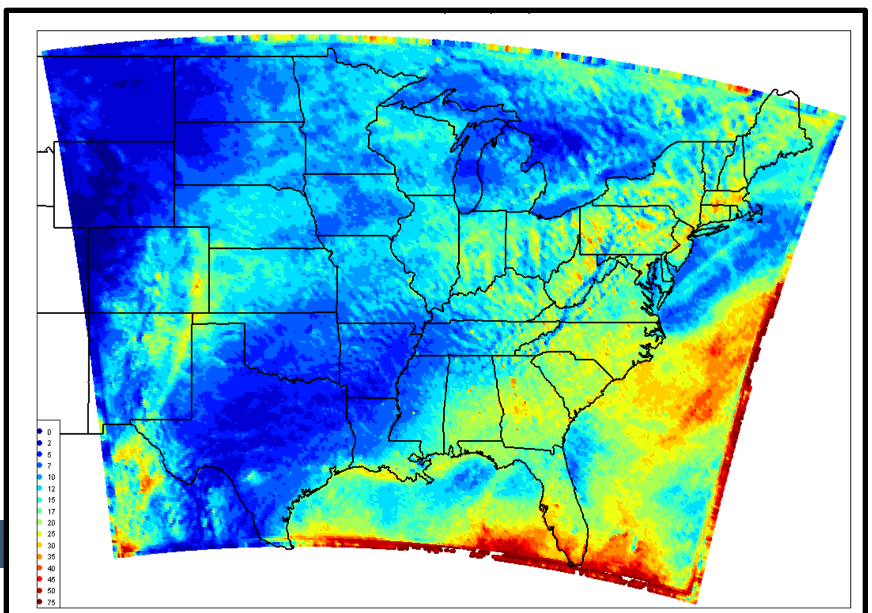
Prism JJA 2006



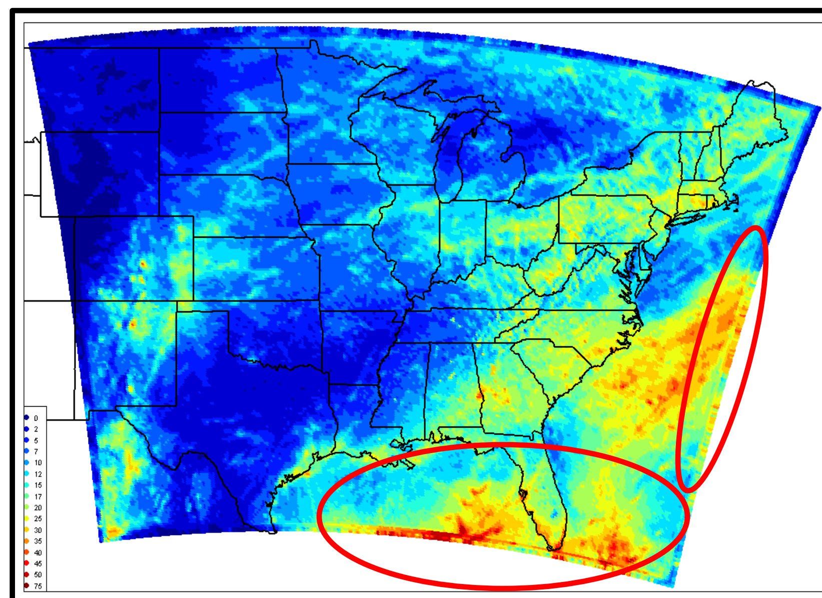
KF Base



KF Rad



KF Rad + Tau



Adapting KF to Transition Across Grid Spacing:

(2) Entrainment

$$\delta M_e = M_b \frac{\alpha}{R} \delta p$$

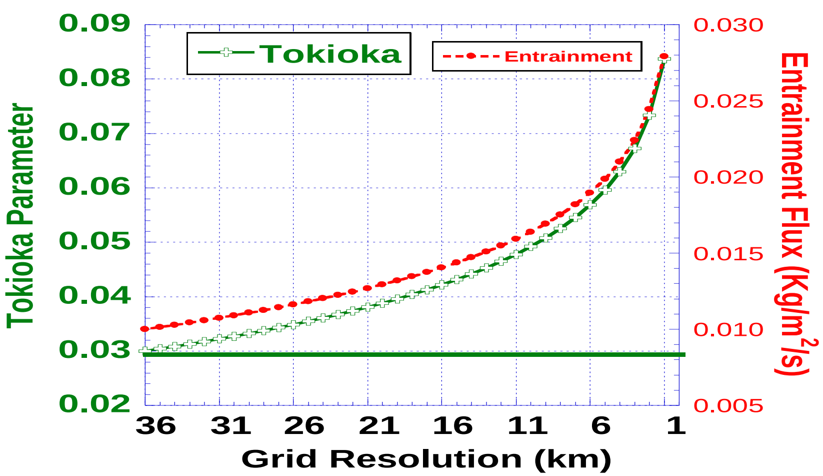
- Efficiency (α = *Tokioka* parameter = 0.03)
  (actually 0.025, *Tokioka 1988*)

GCM studies: Kang et al. (2009); Kim et al. (2011):

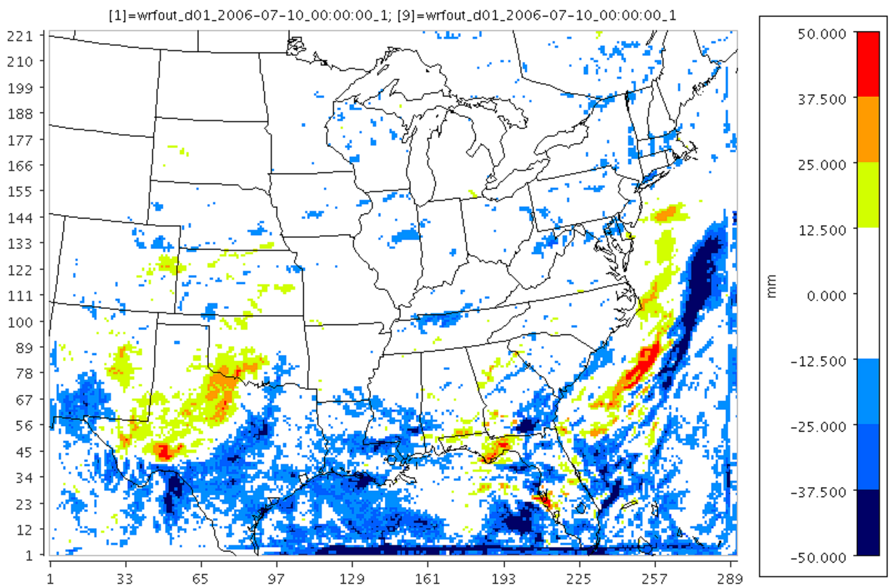
Larger α *(Tokioka)* → Gridscale Precip ⬆ CPS precip ⬇

Then, α needs to increase as resolution increases

Min and Max numbers for Tokioka are based on GCM studies

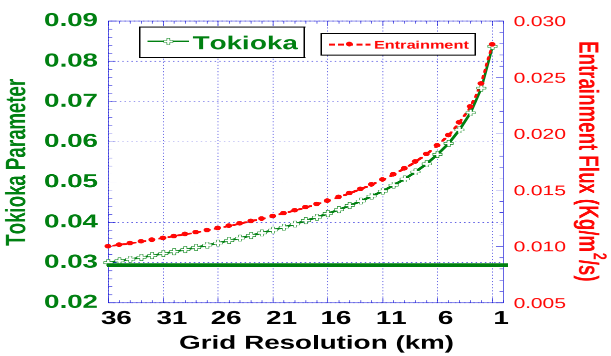


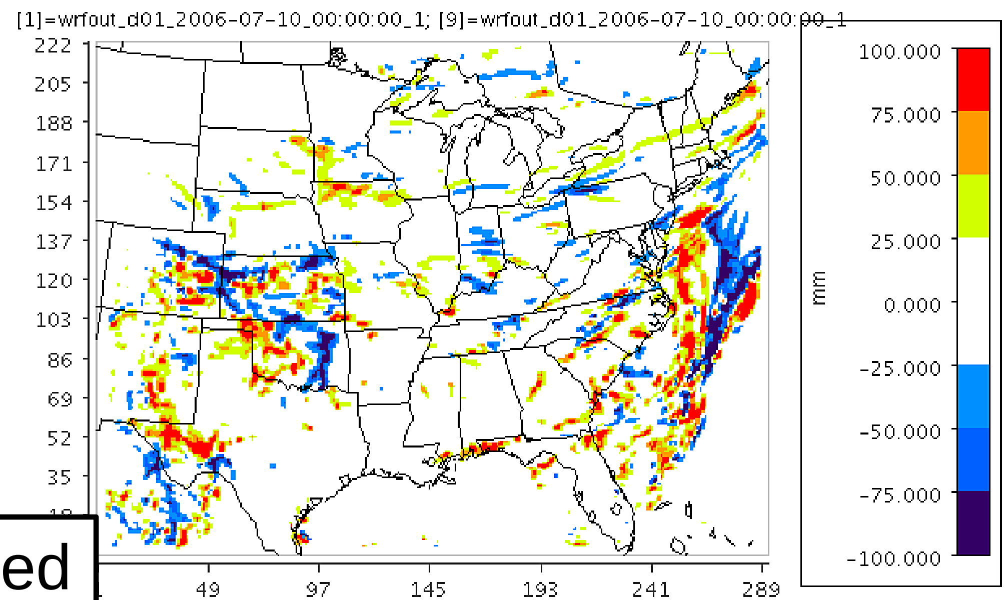
Conv and Non-conv precip differences: end of 10th day simulation starting July 1, 2006



Conv: New - OLD

Grid-scale: NEW - OLD

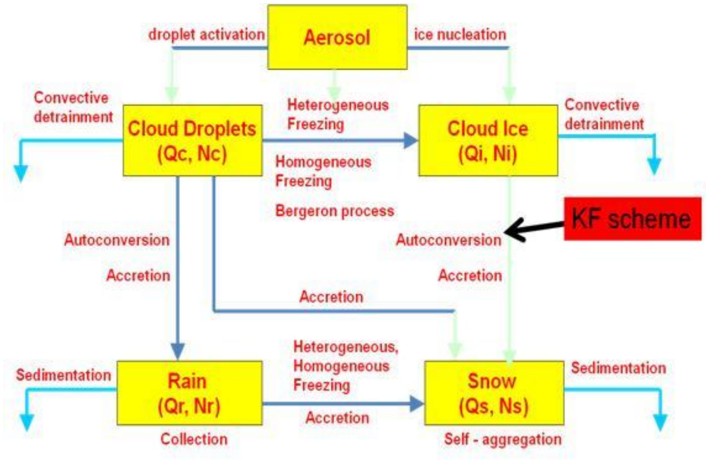




Tone down of α may be needed

Adapting KF to Transition Across Grid Spacing: (3). Convective Cloud Microphysics

ON GOING WORK….
Two-moment microphysics scheme for convective clouds



Song and Zhang, 2011, *J. Geophys. Res.*

Opens up doors to

(1) Avoid DOUBLE COUNTING of precipitation

(2) Establish communication between Grid-scale and Sub-grid scale microphysics

(3) Possibility of linking convection across columns

Down the road: Good News to the MPAS model also !!!