"To parameterize or not to parameterize" deep convection in O(10) - O(1) km mesh forecasts

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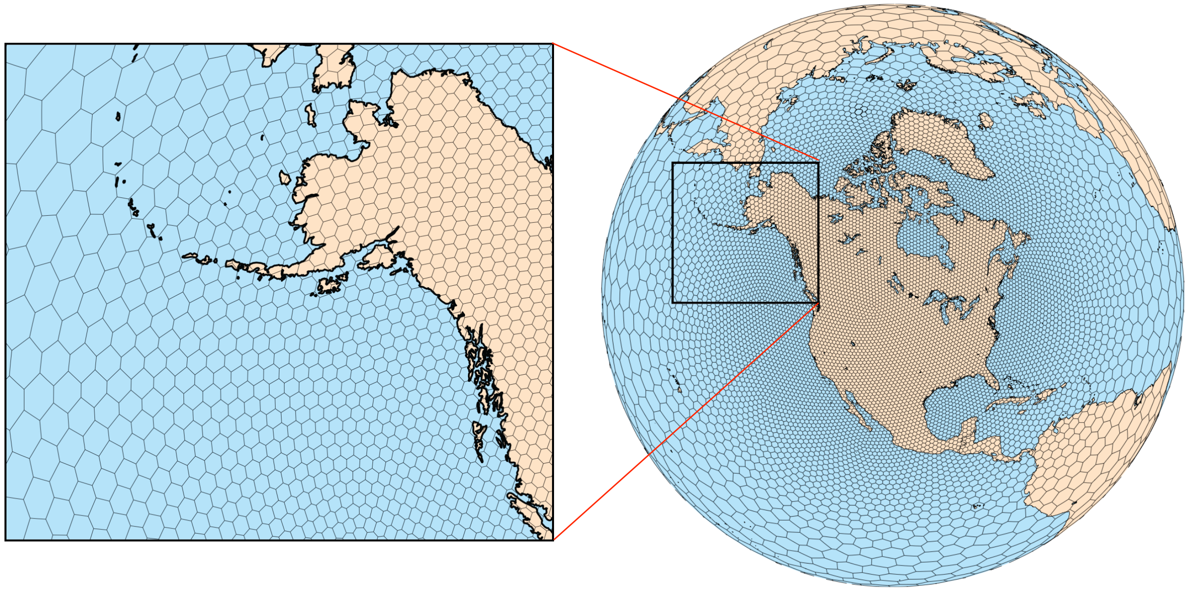
(1) Motivation: variable-resolution meshes in MPAS
(2) Parameterization philosophy and deep convection
(3) Current practice
(4) Preliminary Global MPAS results

(1) Motivation: variable-resolution meshes in MPAS

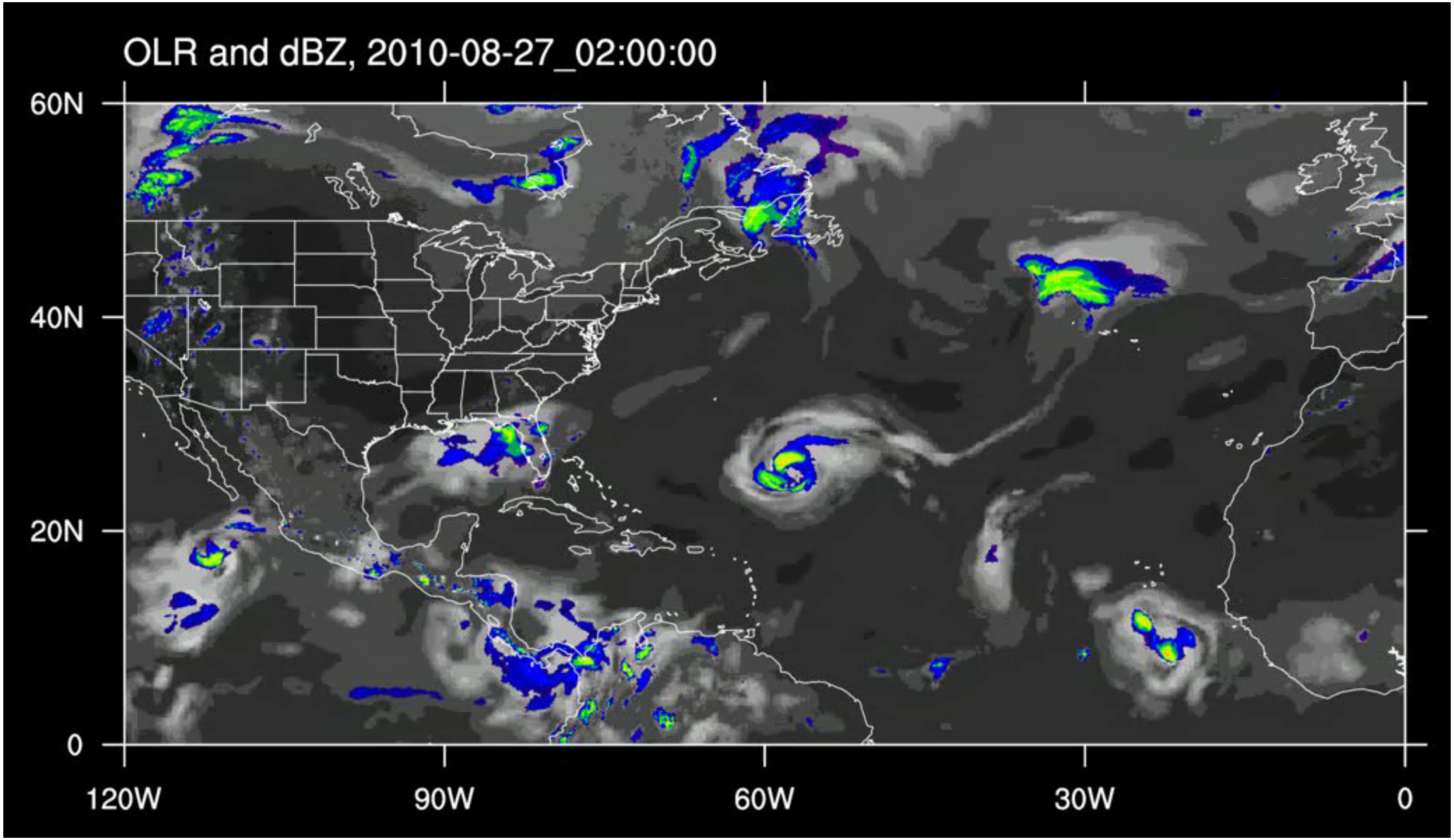


Case-study results using MPAS variable-resolution meshes in hydrostatic regimes ($\Delta x > 10$ km) are good: resolution-appropriate structure, no obvious problems in the mesh transition regions.

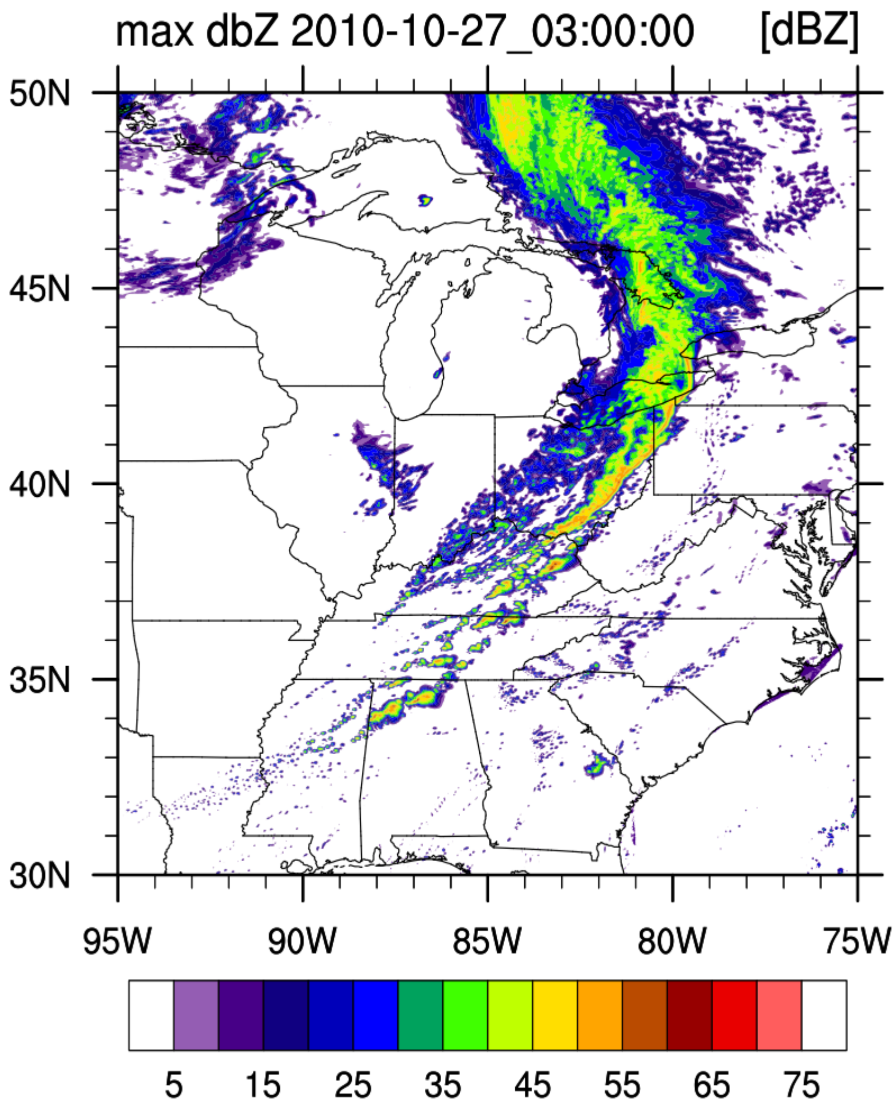
Global MPAS nonhydrostatic-scale simulations ($\Delta x \sim 3$ km) produce structure similar to regional models (WRF) run at the same resolutions.

Question: How do we configure MPAS to run on variable-resolution meshes that span nonhydrostatic [$\Delta x \sim O(1\text{ km})$] to hydrostatic [$\Delta x > O(10\text{ km})$] scales?

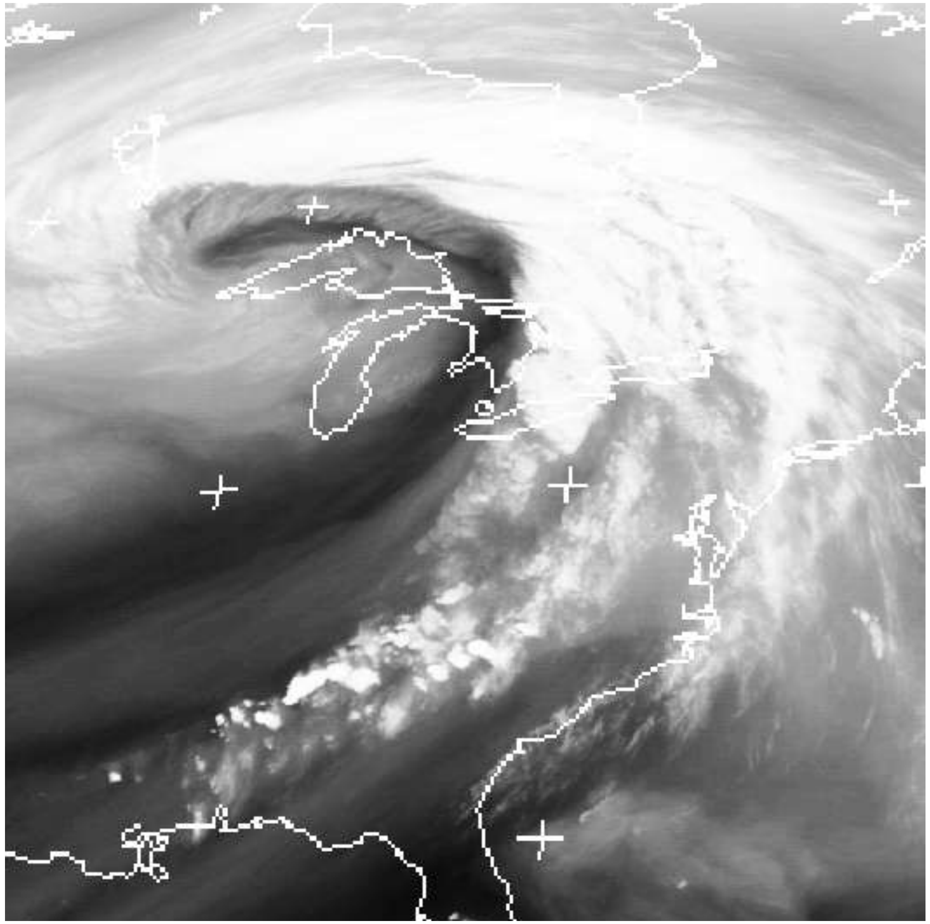
MPAS 3km global simulations, 27 Aug– 2 Sept 2010



3 km global MPAS-A simulation
2010-10-23 init



GOES East, 2010-10-27 0 UTC
IR - vapor channel



3 km global MPAS-A simulation
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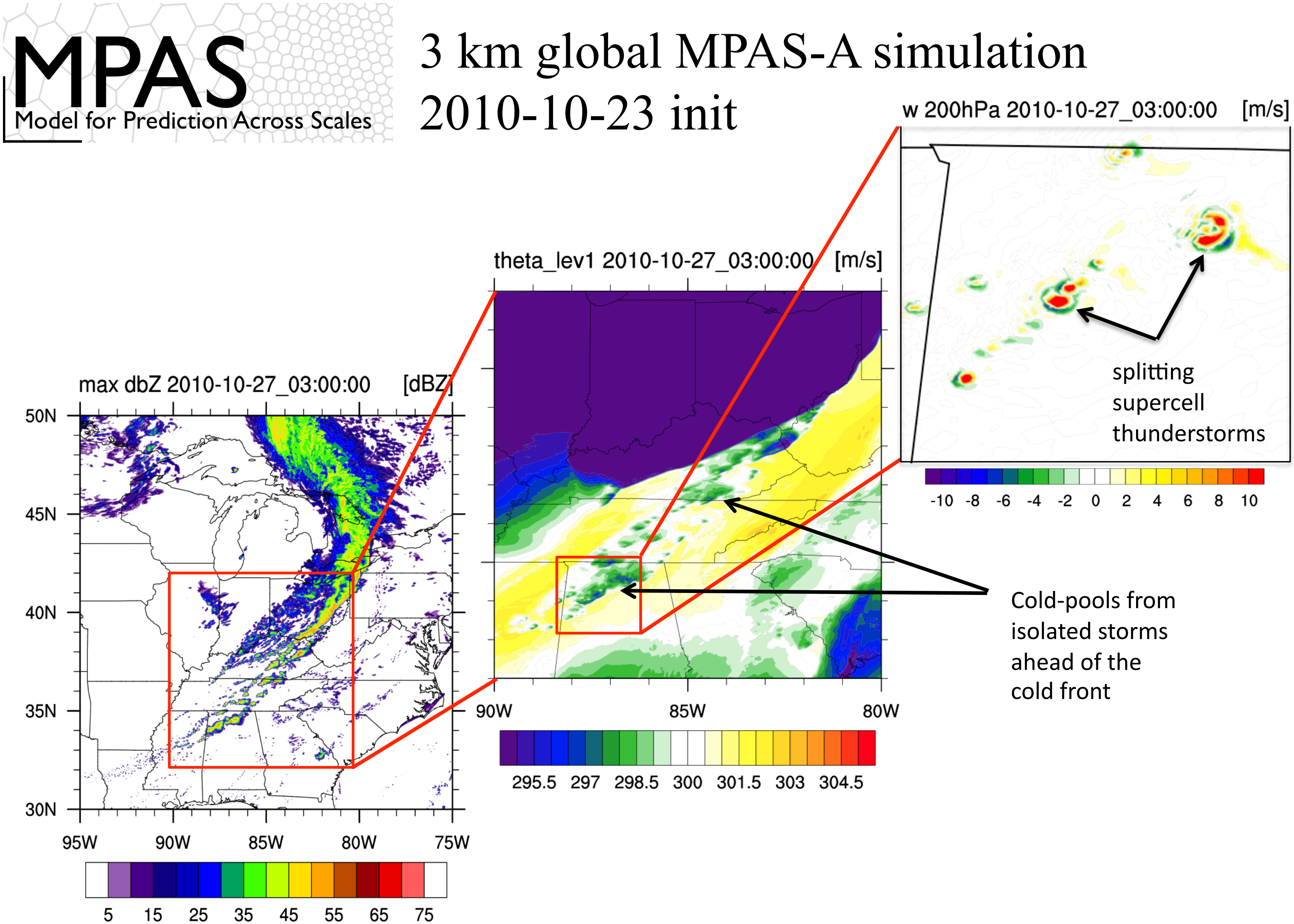
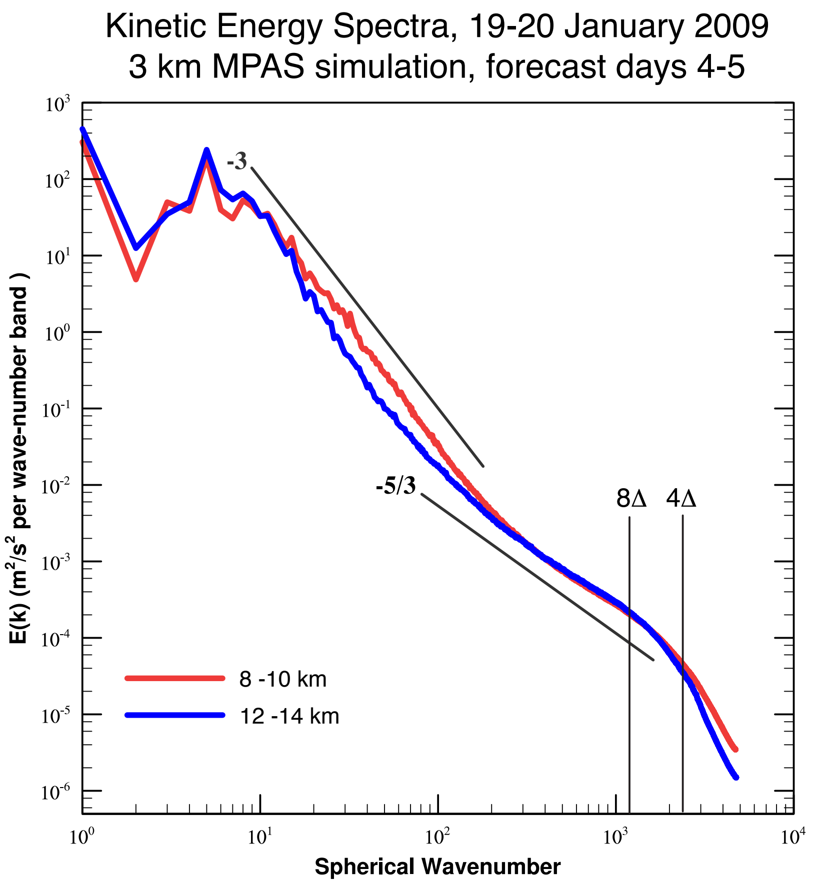
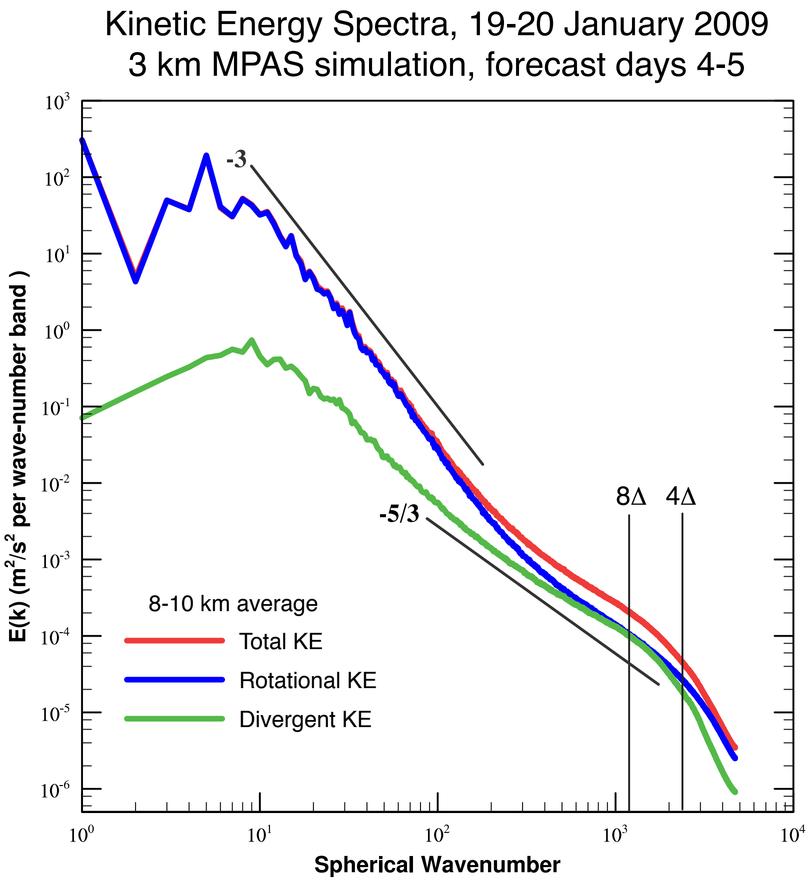


3 km global MPAS-A simulation 2009-01-15 init





(2) Parameterization philosophy and deep convection

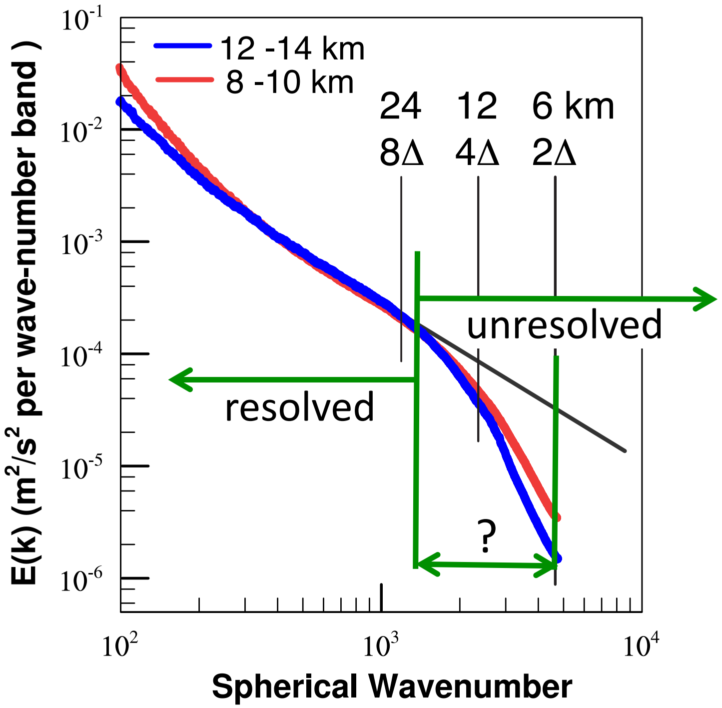
Resolved-scale effects of any unresolved structures need to be parameterized.

Resolved: Accurately represented by the model in its time-space discretization.

Deep convection: Cell updraft diameters are O(1) km (largest supercells d < 10 km).

Deep convection: entraining eddies in updrafts are O(100) m.

Kinetic Energy Spectra, 19-20 January 2009
3 km MPAS simulation, forecast days 4-5



Example: MPAS

Resolved scales > 6-8 Δ; cutoff 2Δ

Strict parameterization: All convective cells must be completely parameterized on meshes with Δ >= O(km)

MPAS (Δ >= 10km) uses a formal convective parameterization.

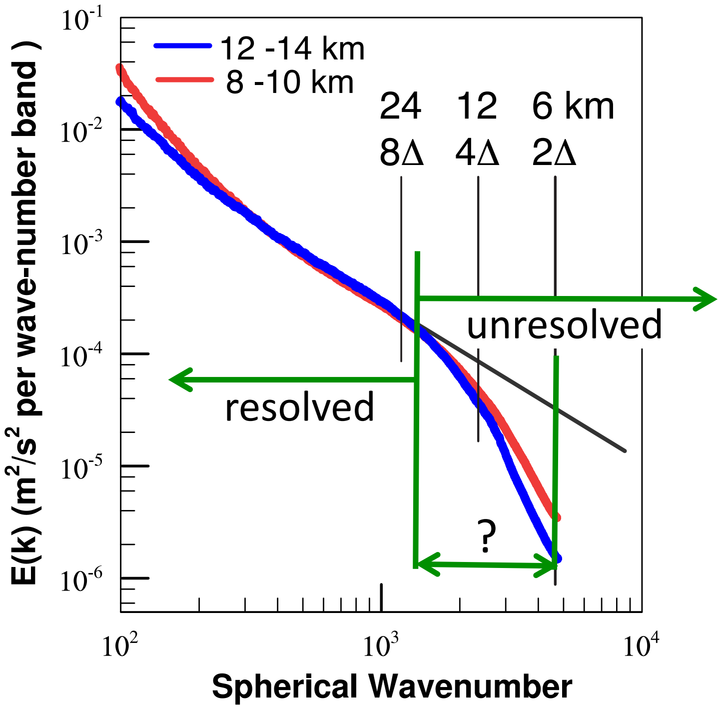
MPAS (3km) uses no formal convective parameterization, but convective cells exist in the 2Δ to 6-8 Δ scales.

(3) Deep convection - current practice

Meshes with $\Delta \sim$ a few kilometers

Most models do not use deep convection parameterizations with $\Delta \sim$ a few kms

Weisman et al (1997): Without convection parameterization, mesh spacings *"of 4 km are sufficient to reproduce much of the mesoscale structure and evolution of the squall-line-type convective systems ..."*



Using no parameterization is a parameterization:
Allowing explicitly-simulated unphysically-large laminar plumes to accomplish the effects of unresolved deep convection on the resolved-scale flow is our parameterization.

This is not a theoretically justifiable parameterization approach.

It generally works better than other deep convection parameterizations.

(3) Deep convection - current practice

Meshes with Δ greater than a few kilometers

Hydrostatic regime: $\Delta > O(10\ \text{km})$

No real consensus exists!

- Mass-flux schemes
- Adjustment schemes
- Use of no deep convection scheme, for example

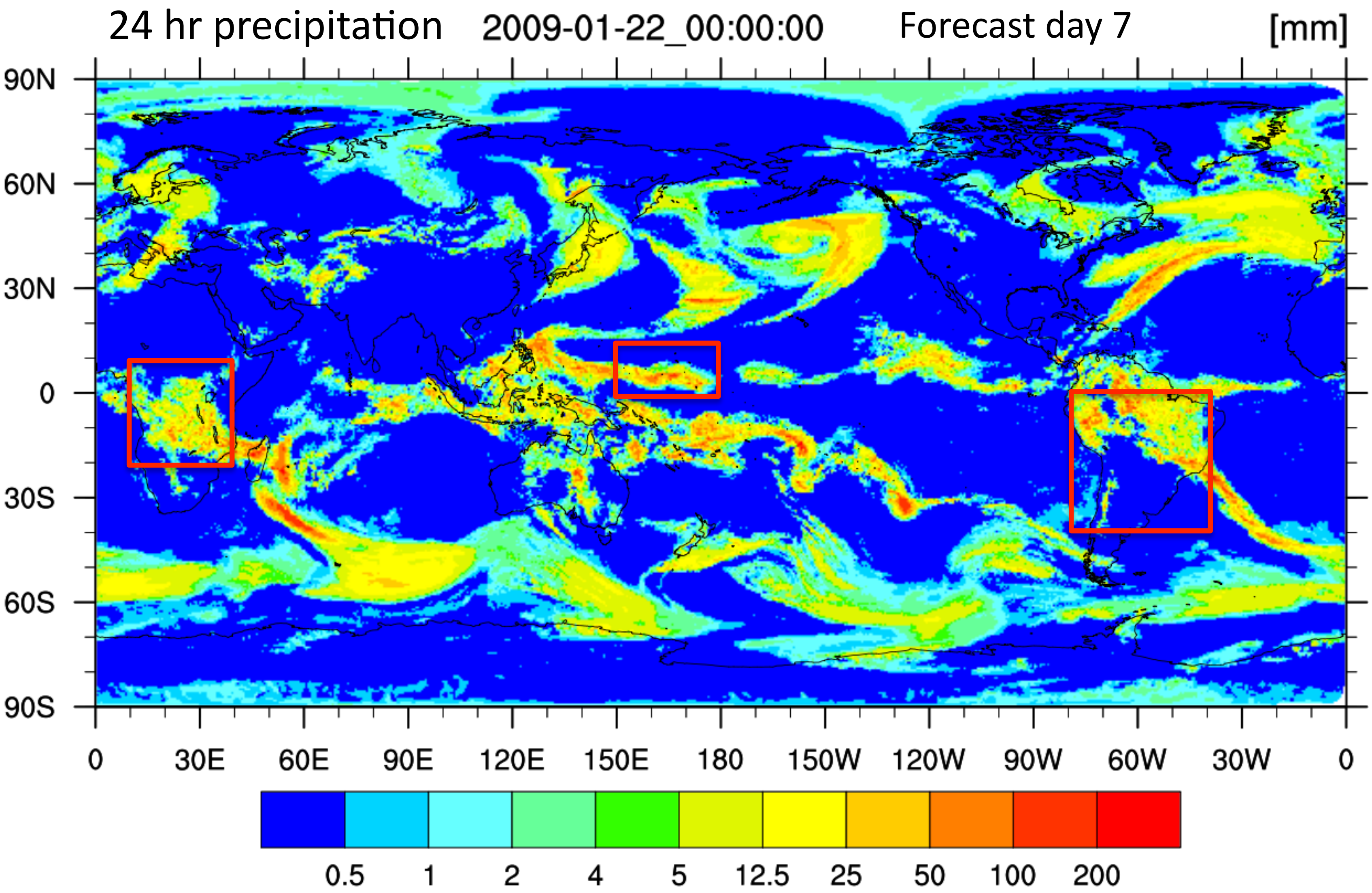
NICAM: 15 and 7.5 km meshes
GFDL: 25 and 50(!) km meshes
UKMO PRACE-UPSCALE project: 12 km meshes
positives: diurnal precip cycle, conv. system propagation (e.g. MJO)
negatives: not generally discussed

Hydrostatic-nonhydrostatic transition: $O(10\ \text{km}) > \Delta > O(\text{few km})$

Consensus(?): Explicit deep-convection parameterization should do very little at $\Delta \sim O(\text{few km})$ because the "no-parameterization" approach works better than any existing parameterization at that scale.

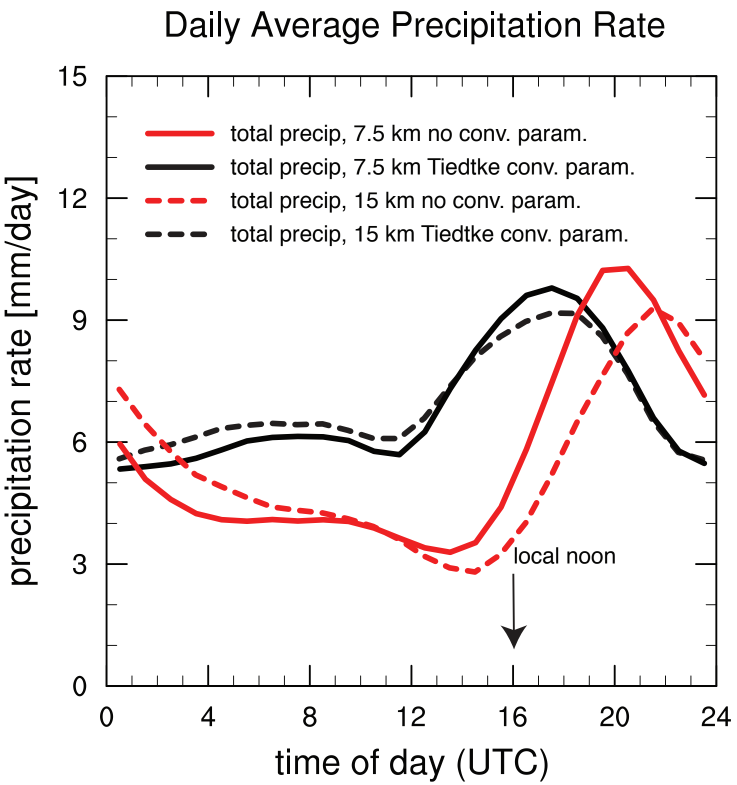
(4) Preliminary Global MPAS results

15 km global MPAS simulation using the Tiedtke convection scheme



(4) Preliminary Global MPAS results

15-25 January 2009 simulation
South America: 40W - 80W, 0 - 40S
8 day average, 17-25 January,
7.5 and 15 km global meshes



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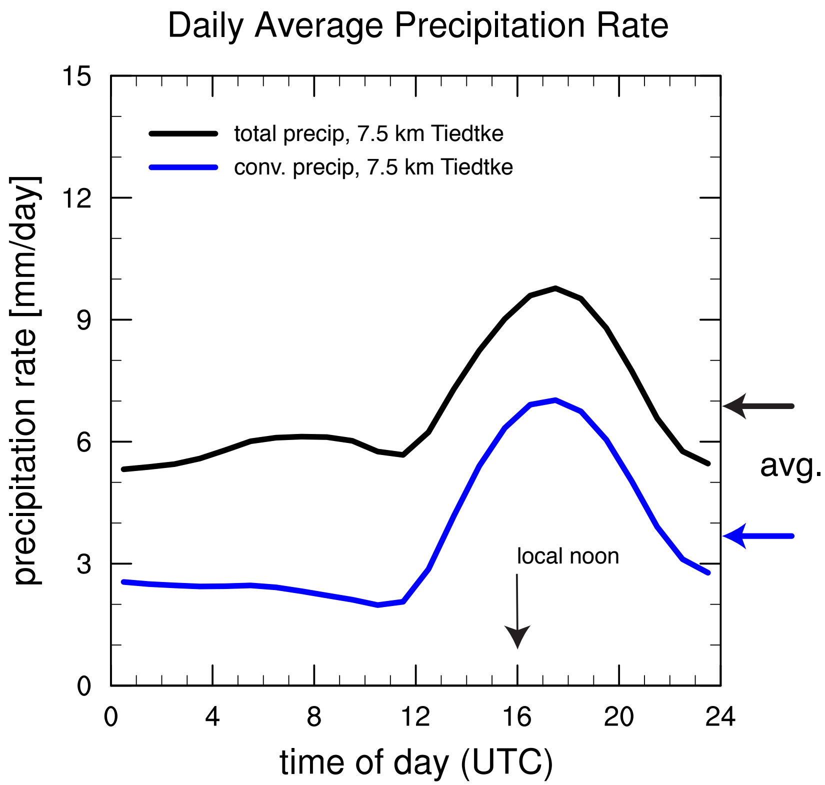

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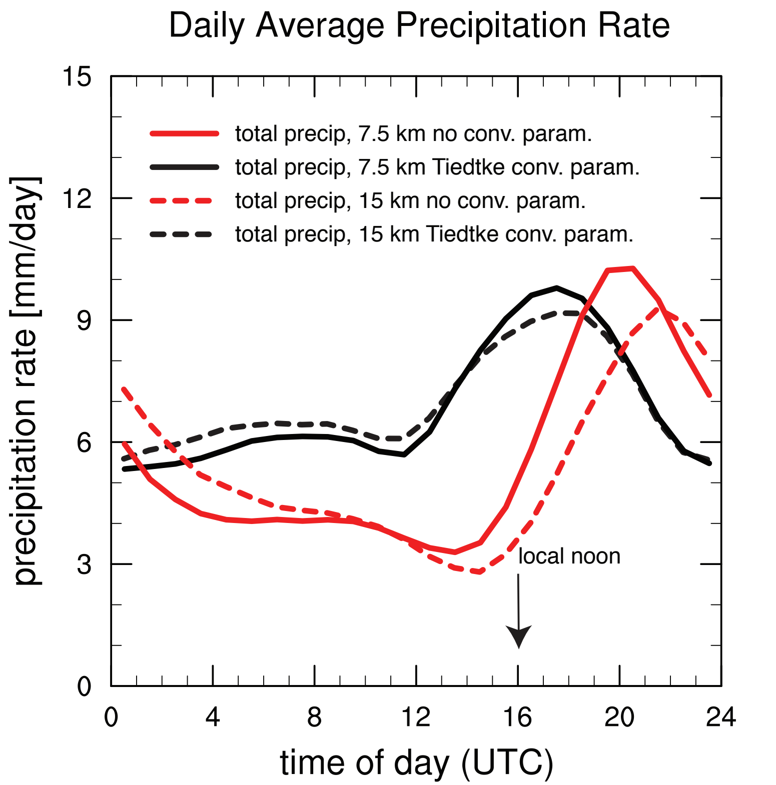

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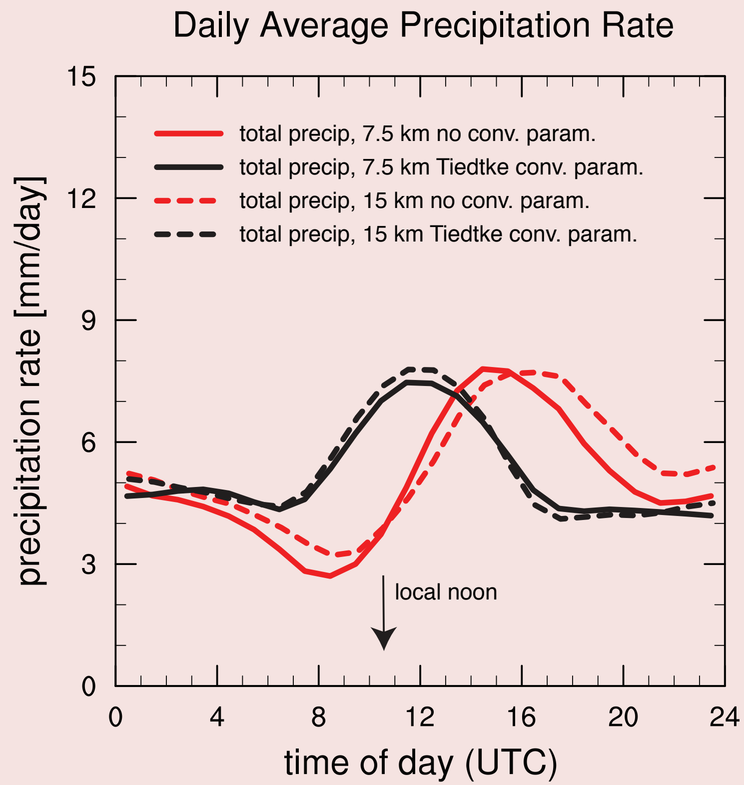

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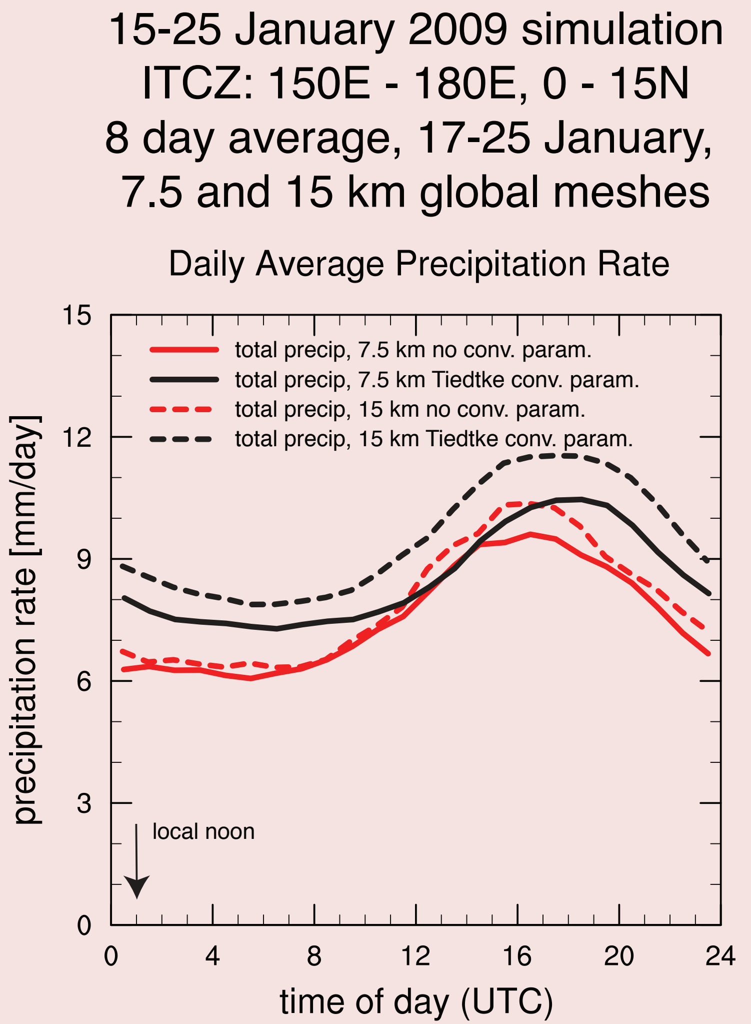

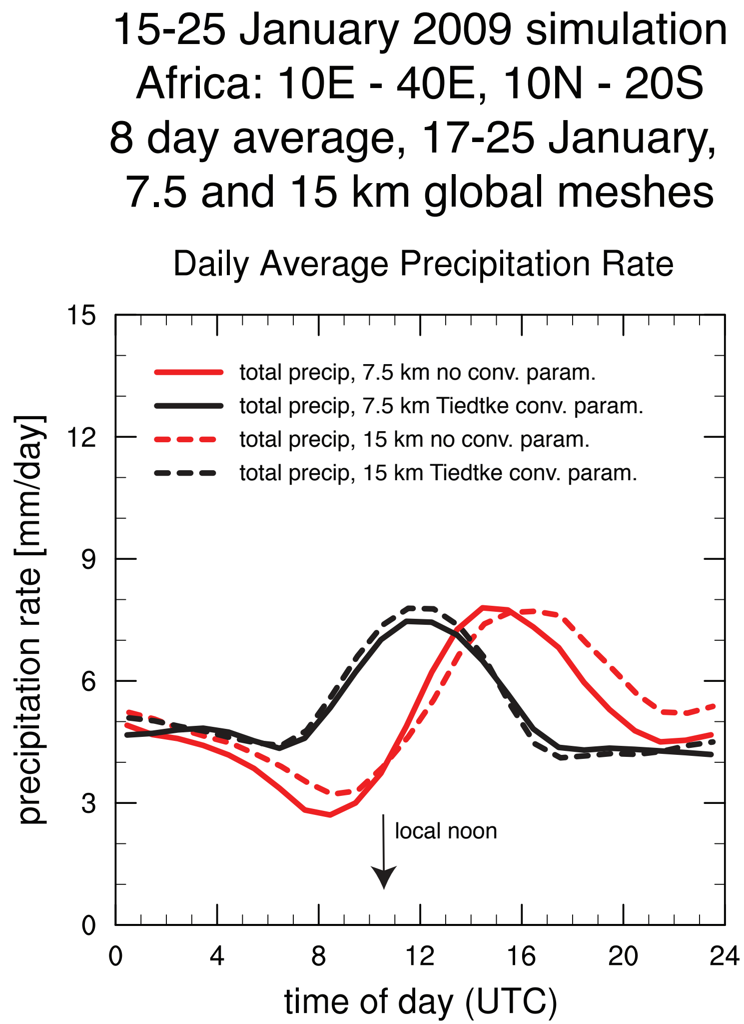

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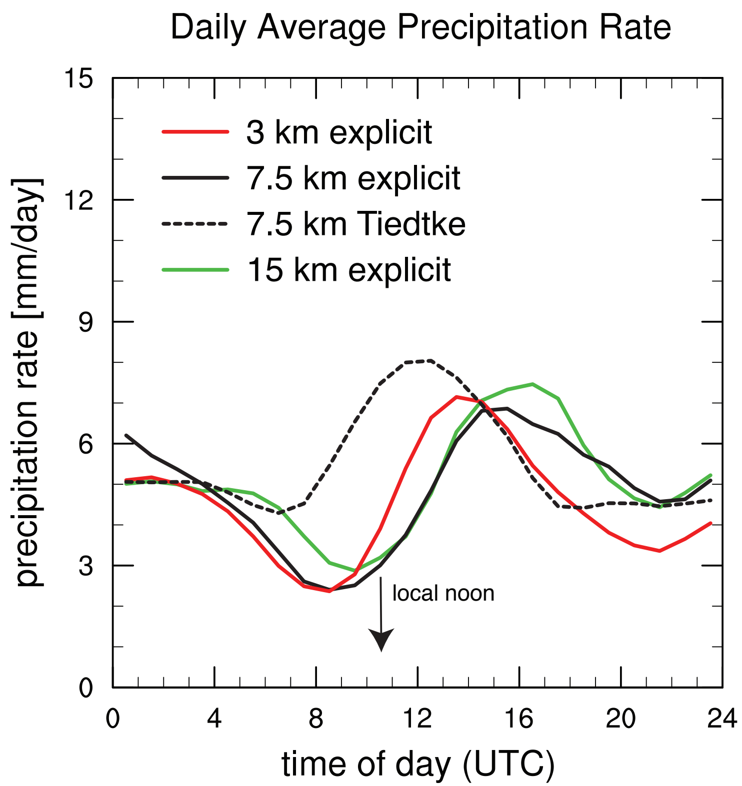

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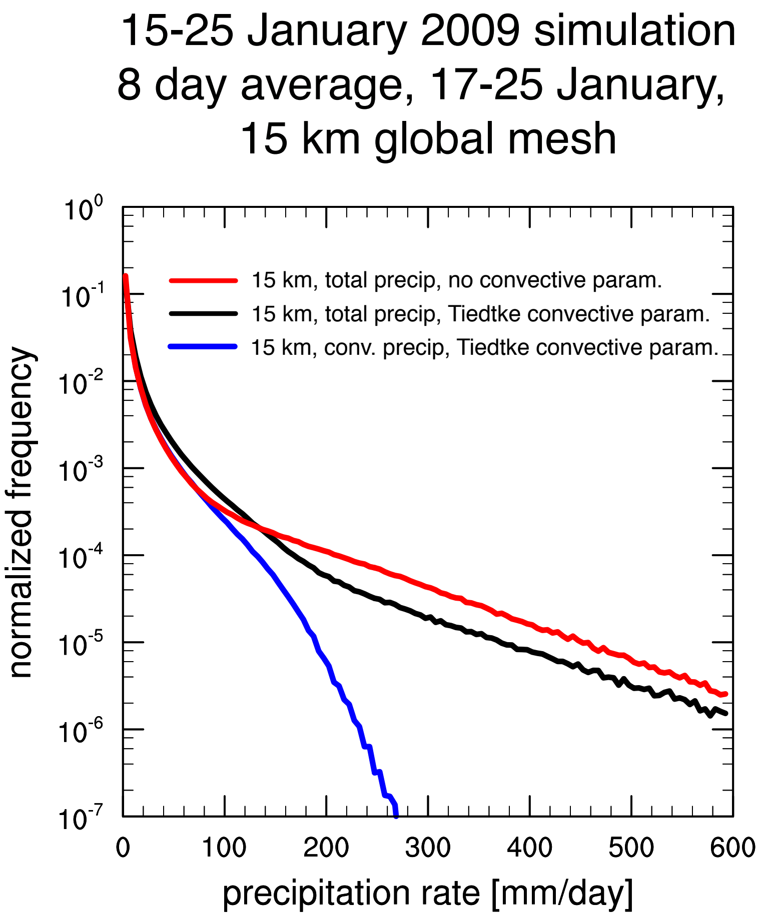
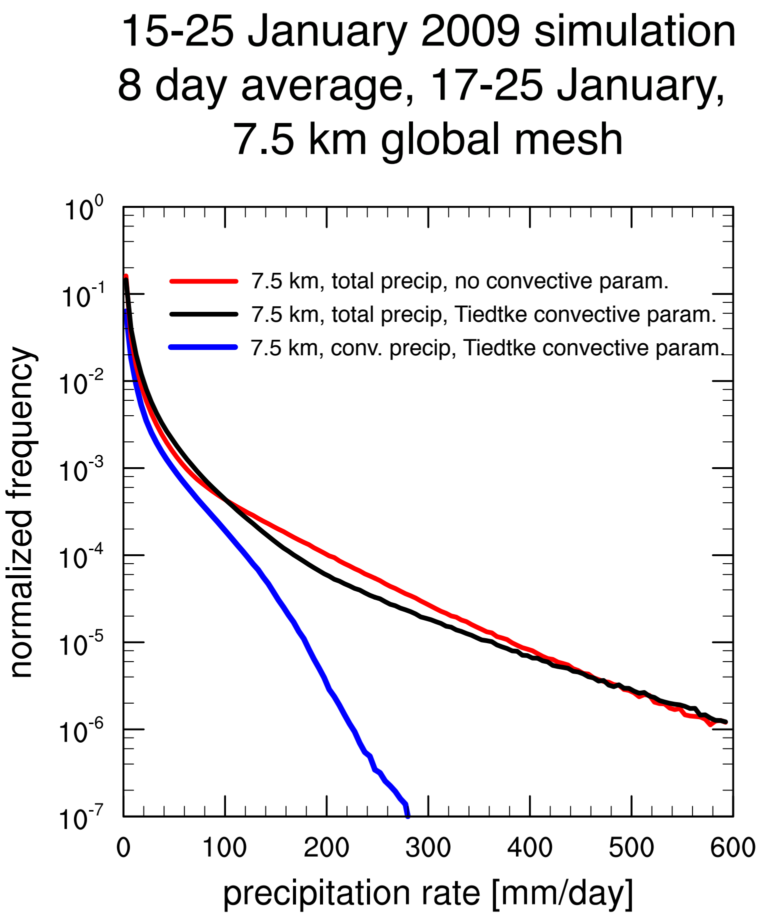
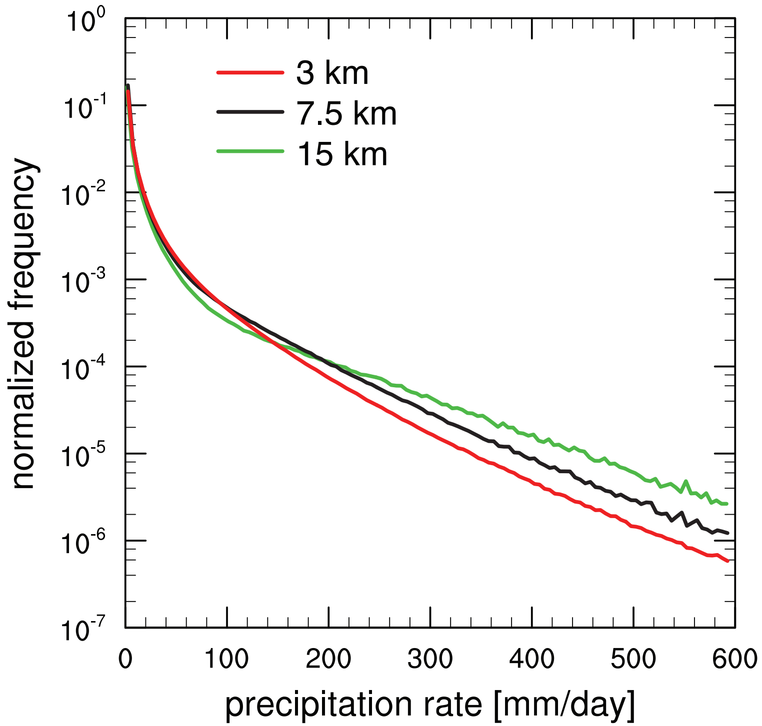




(4) Preliminary Global MPAS results

15-20 January 2009 simulation,
3 day average, 17-20 January,
3, 7.5 and 15 km global meshes,
no convective parameterization



15-25 January 2009 simulation,
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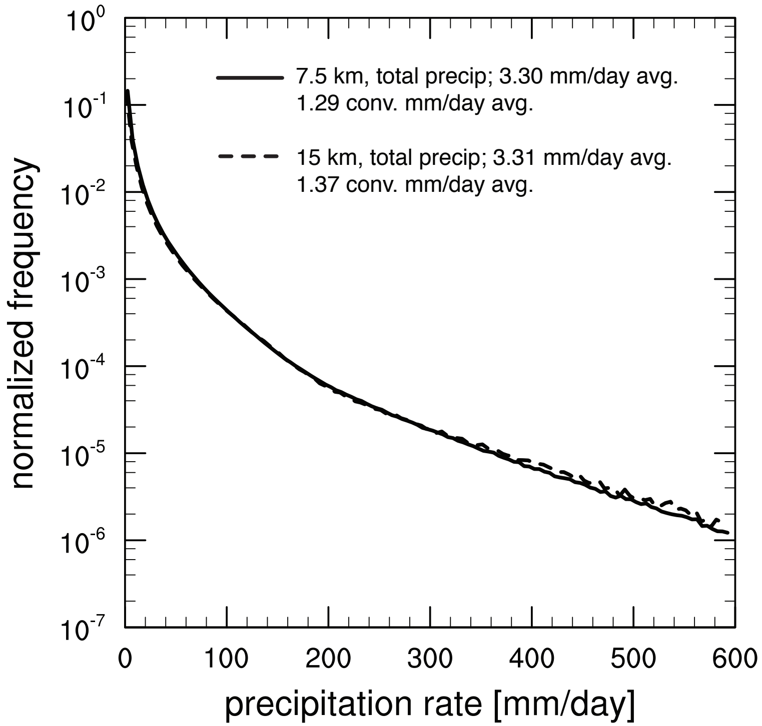
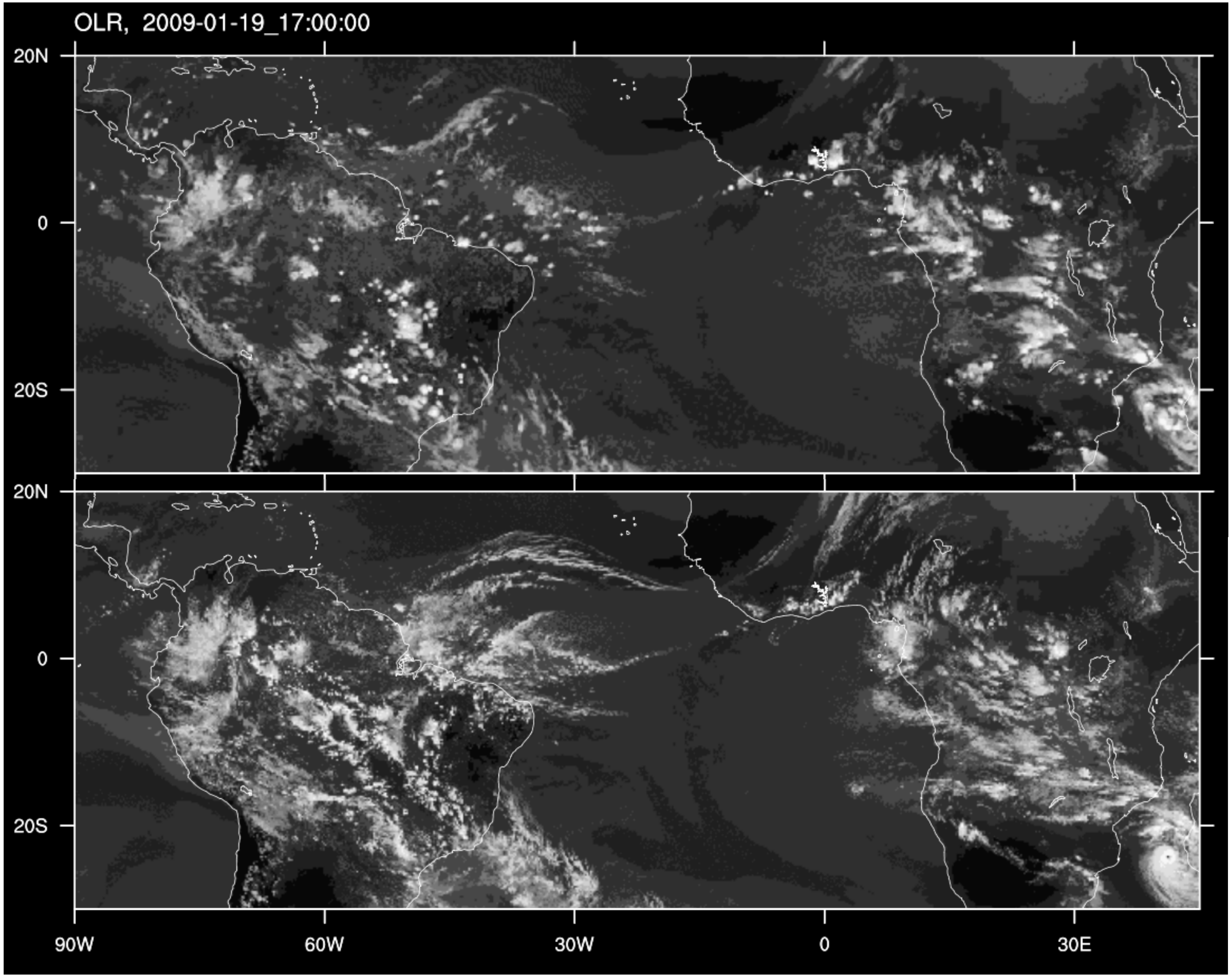
Teidtke param.



(4) Preliminary Global MPAS results

4 day 17 h forecasts



15 km MPAS
explicit convection

3 km MPAS
explicit convection

(4) Preliminary Global MPAS results

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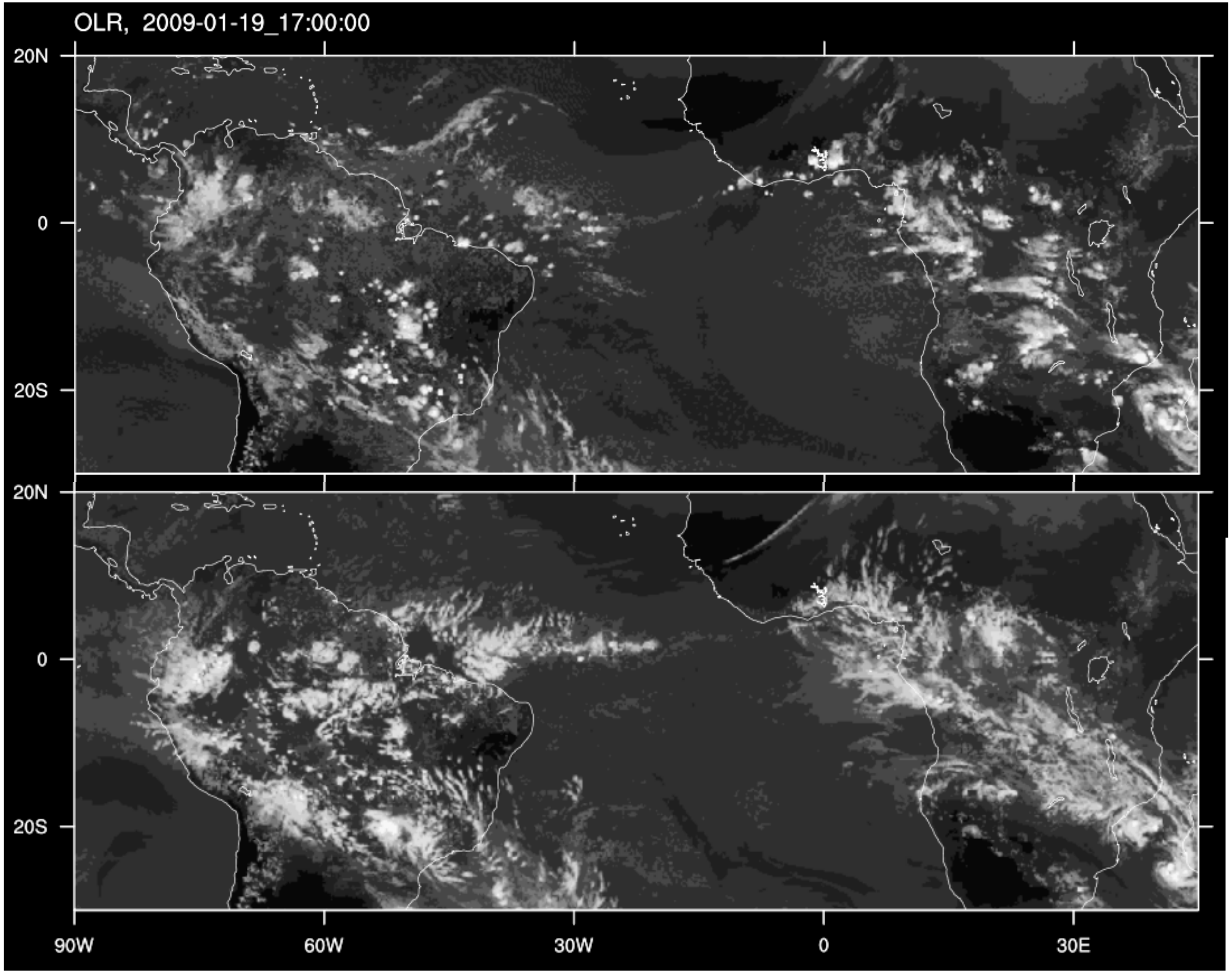

15 km MPAS
explicit convection

15 km MPAS
Tiedtke scheme

(4) Preliminary Global MPAS results

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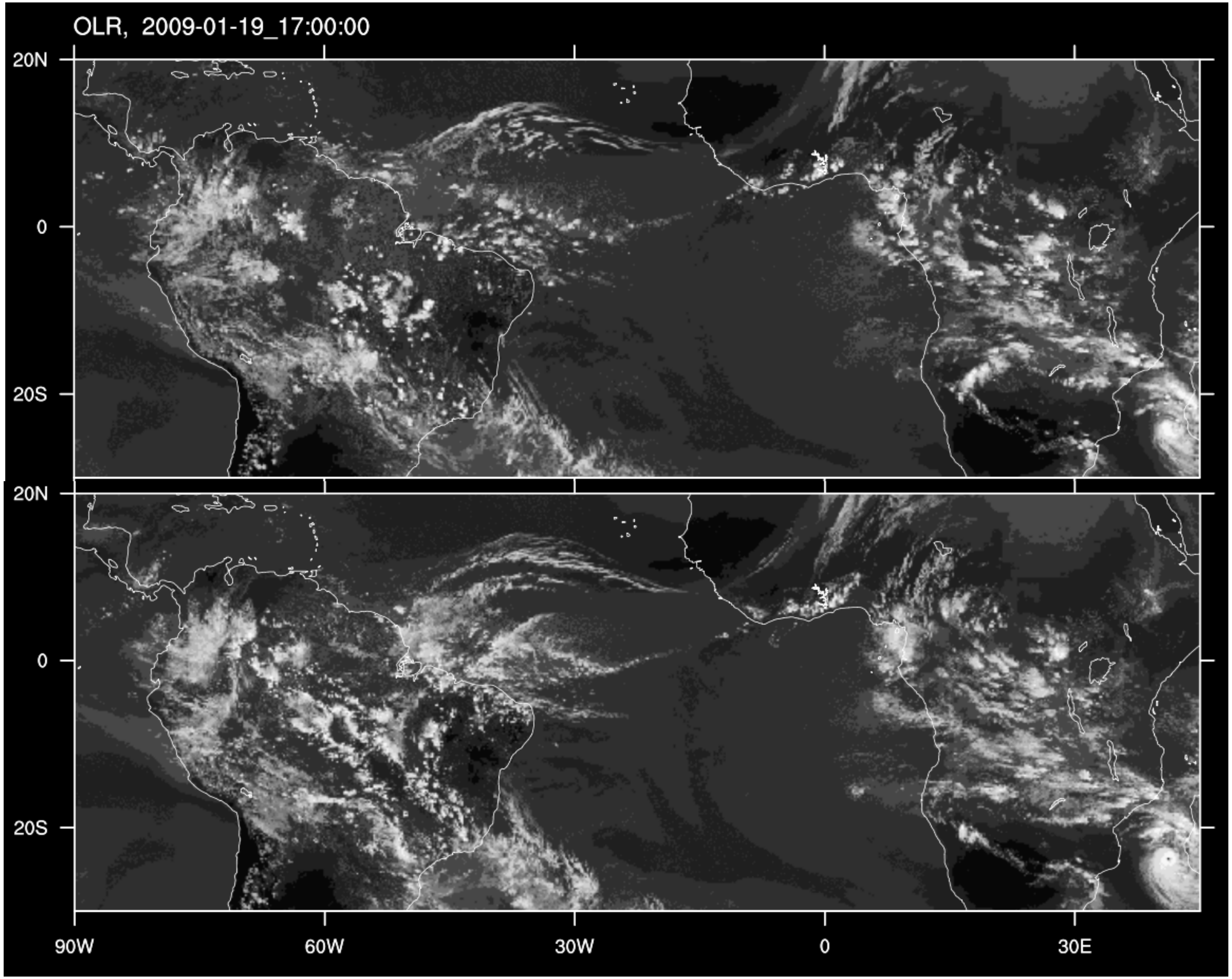


7.5 km MPAS
explicit convection

3 km MPAS
explicit convection

Summary

Initial experiments with global MPAS at meshes spanning nonhydrostatic-hydrostatic scales confirms:

- All approaches to treating convection have problems.
- Explicit convection at hydrostatic scales is too slow/late to develop.
- Parameterized convection peaks too early, close to local noon (maximum heating).
- Explicit tropical convective-system structure is poor on meshes with $\Delta > 2\text{-}4$ km.
- MPAS results are similar to regional nonhydrostatic models (e.g. WRF) at all resolutions.

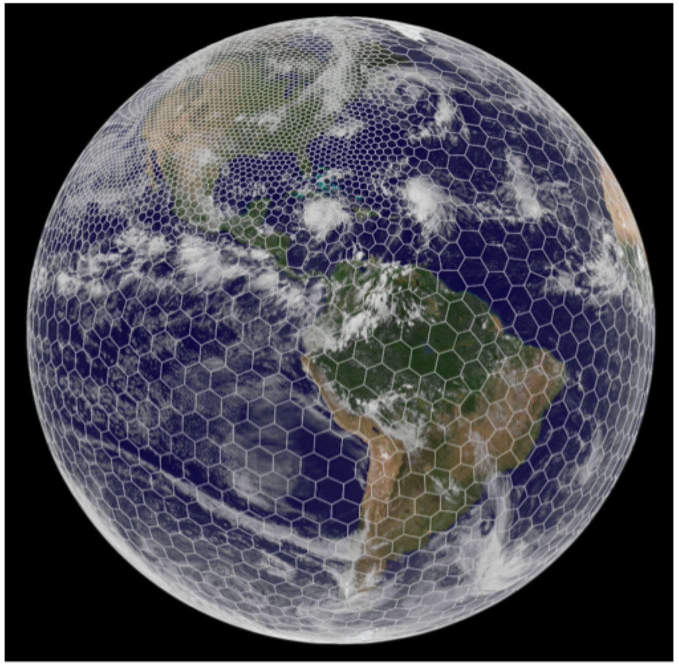
Additionally:

- MPAS (WRF) versions of Tiedtke and KF schemes remain active at high mesh density (e.g. 7.5 and 3 km).

Future:

- Test various approaches to reducing the convective scheme forcing at nonhydrostatic-scale resolutions.

Initial MPAS release next month (June 2013)
see http://mpas-dev.github.io/



Reflectivity (dBZ) valid 2010-10-26 3 UTC