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

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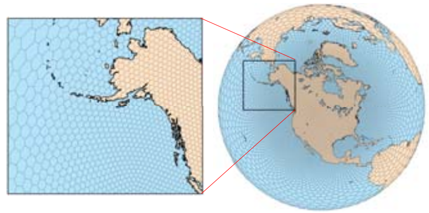
(1) Motivation: variable-resolution meshes in MPAS
(2) Parameterization philosophy and deep convection
(3) Current practice
(4) Preliminary Global MPAS results

(1) Motivation: variable-resolution meshes in MPAS

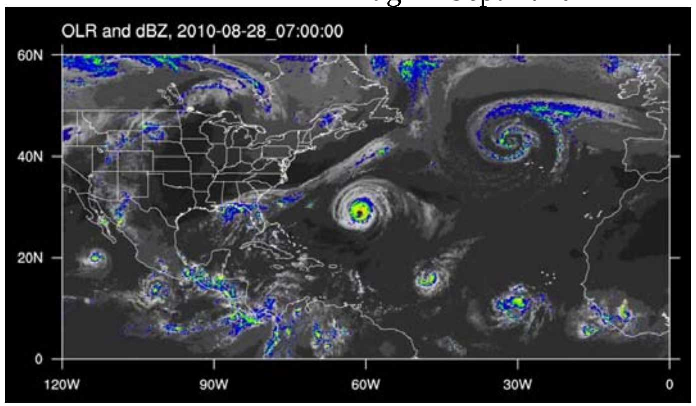


Case-study results using MPAS variable-resolution meshes in hydrostatic regimes ($\Delta x > 10$ km) are good: resolution-appropriate structure, no obvious problems in the mesh transition regions.

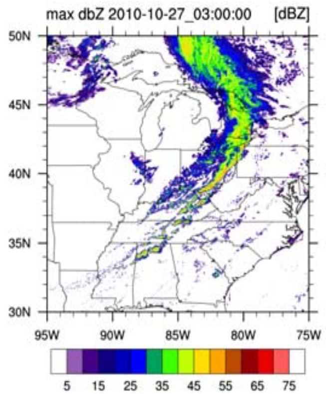
Global MPAS nonhydrostatic-scale simulations ($\Delta x \sim 3$ km) produce structure similar to regional models (WRF) run at the same resolutions.

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

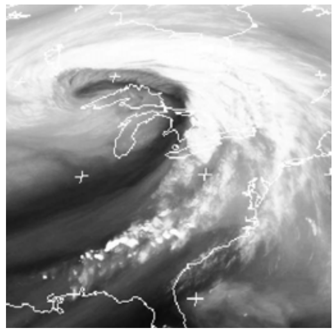
MPAS 3km global simulations, 27 Aug– 2 Sept 2010



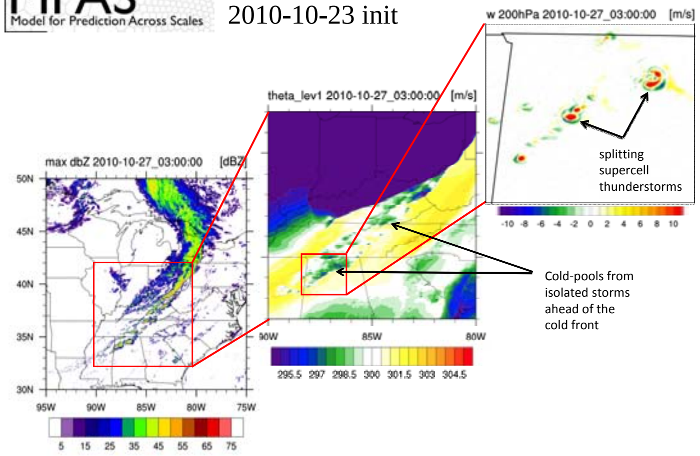
3 km global MPAS-A simulation 2010-10-23 init



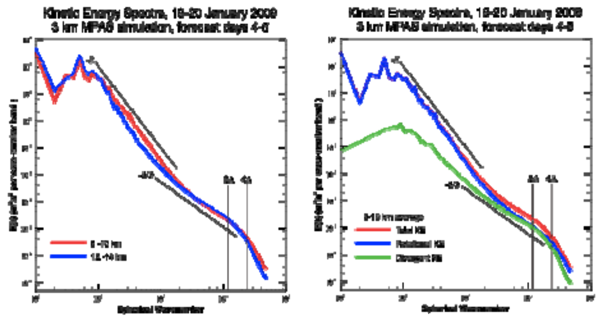
GOES East, 2010-10-27 0 UTC
IR - vapor channel



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



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



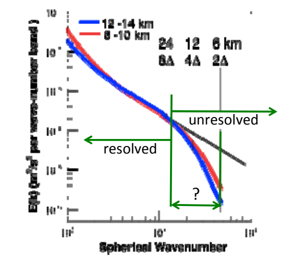
(2) Parameterization philosophy and deep convection

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.



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.

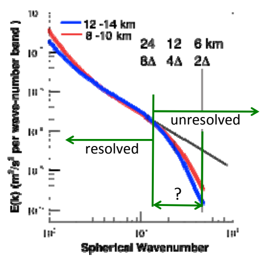
MPAS (3km) uses no formal convective parameterization, but convective cells exist in the 2Δ to 6-8 Δ scales.

(3) Deep convection - current practice

Meshes with Δ ~ a few kilometers

Most models do not use deep convection parameterizations with Δ ~ 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

<u>Meshes with Δ greater than a few kilometers</u>

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

No real consensus exists!
- Mass-flux schemes
- Adjustment schemes
- Use of no deep convection scheme, for example

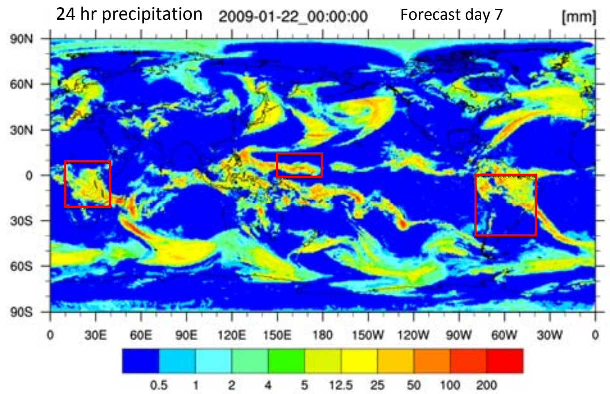
NICAM: 15 and 7.5 km meshes
GFDL: 25 and 50(!) km meshes
UKMO PRACE-UPSCALE project: 12 km meshes
positives: diurnal precip cycle, conv. system propagation (e.g. MJO)
negatives: not generally discussed

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

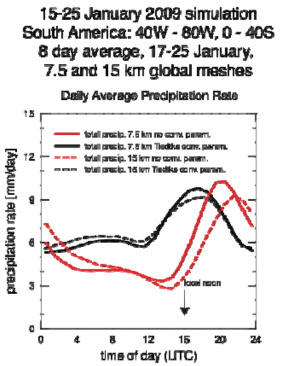
Consensus(?): Explicit deep-convection parameterization should do very little at $\Delta \sim O(few\ km)$ because the "no-parameterization" approach works better than any existing parameterization at that scale.

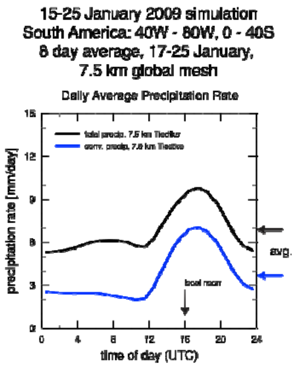
(4) Preliminary Global MPAS results

15 km global MPAS simulation using the Tiedtke convection scheme



(4) Preliminary Global MPAS results





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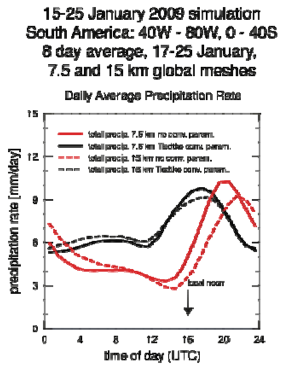

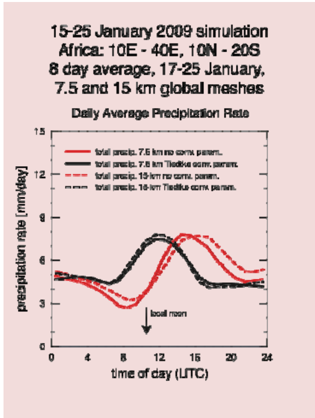

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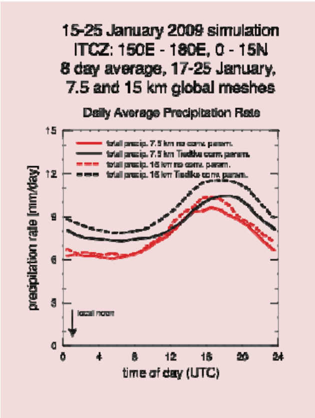

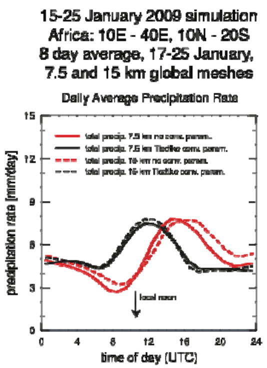

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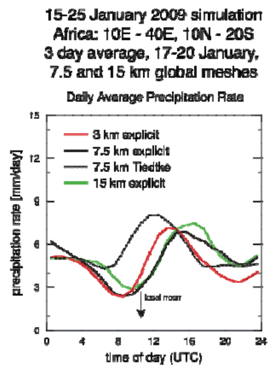

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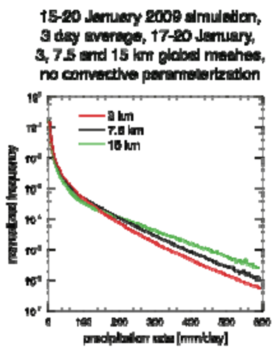
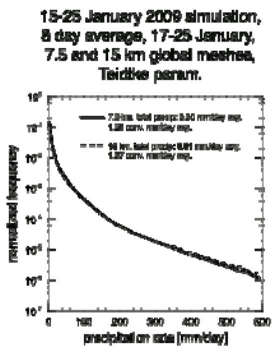
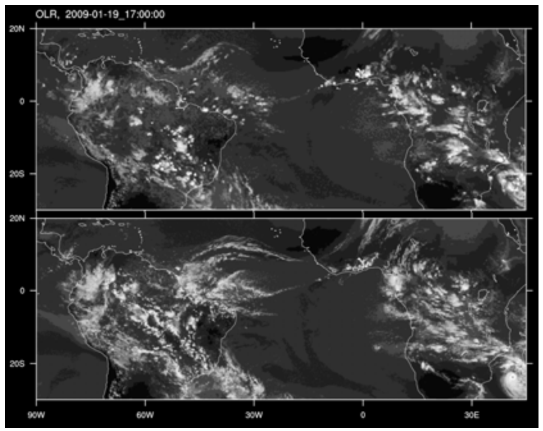




(4) Preliminary Global MPAS results

4 day 17 h forecasts

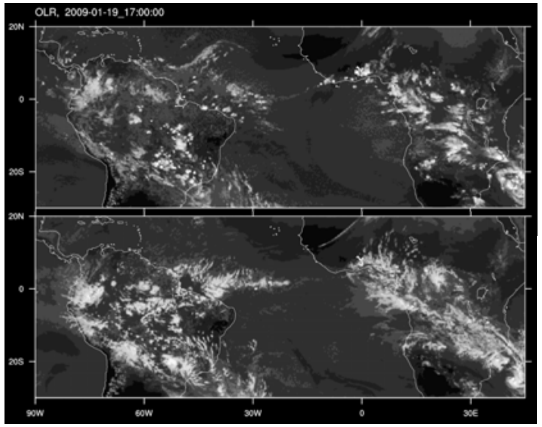


15 km MPAS
explicit convection

3 km MPAS
explicit convection

(4) Preliminary Global MPAS results

4 day 17 h forecasts

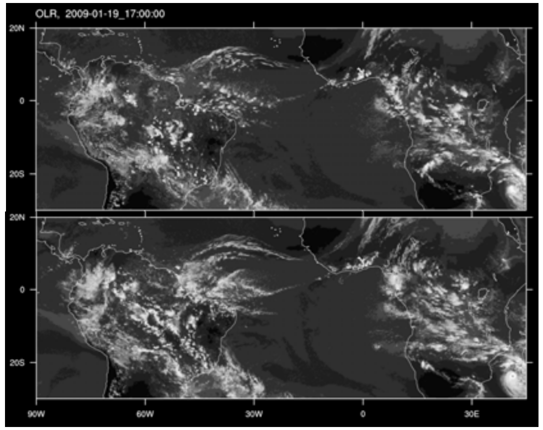


15 km MPAS
explicit convection

15 km MPAS
Tiedtke scheme

(4) Preliminary Global MPAS results

4 day 17 h forecasts



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 $\Delta > 2$-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/