Implementation and use of a global nonhydrostatic model (MPAS) for extended prediction

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Six-day forecast for convective storms, with focus on the C-3-4 corridor.
“Convection-allowing” prediction with a global model (MPAS)

• What/why “convection-allowing”?
  – horizontal gridpoint spacings ~4 km
    • precludes the need to parameterize the effects of cumulus convection
      – improved convective precipitation
    • allows explicit representation of thunderstorm morphology, e.g., *supercell thunderstorm*
      – allows quantification of morphological attributes like updraft rotation
Supercell Thunderstorm

Quantify supercell existence using *updraft helicity* (UH)

\[ UH = \int w\zeta \, dz \]

and *radar reflectivity*

Courtesy J. Frame, UIUC
“Convection-allowing” prediction with a global model (MPAS)

• Why global?
  – the atmosphere is a global fluid
  – the alternative to global modeling is regional modeling, which requires initial/boundary conditions ... from a global model
    • places a constraint on evolution of processes within the regional domain...
regional domain

boundary conditions from global model

initial condition from global model

restricts range of internally generated processes/feedbacks
“Convection-allowing” prediction with a global model (MPAS)

• Why global?
  – the atmosphere is a global fluid
  – regional-modeling require initial/boundary conditions from a global model
    • places a constraint on evolution of processes within the regional domain...
  – thus, a global model is better suited longer time integrations, & thus for extended range predictions
“Convection-allowing” prediction with a global model (MPAS)

• Limitations of global modeling …
  – often *hydrostatic*
    • i.e., no $A$ in $F = mA$ for vertical direction … but vertical $A$ is at heart of our interest
  – the large number of global gridpoints has made it more difficult to enable convection-allowing resolution
    • compromise: grid refinement!
MPAS: Model for the Prediction Across Scales

- Both limitations are addressed by MPAS:
  - nonhydrostatic and fully compressible global model, with capability for regional grid refinement (Skamarock et al. 2012, MWR)
equations are discretized/solved on centroidal Voronoi (quasi-uniform, nominally hexagonal) meshes
MPAS application: Operational support for RELAMPAGO operations

- The RELAMPAGO Remote sensing of Electrification, Lightning, And Mesoscale/microscale Processes with Adaptive Ground Observations field campaign, was conducted in November and December 2018 in Argentina
  - key objective of RELAMPAGO is to understand why some of most intense thunderstorms on the planet form in southeastern South America
MPAS setup

- Horizontal grid spacing: 15 km (globe) – 3 km (South America)
MPAS setup

• Horizontal grid spacing: 15 km (globe) – 3 km (South America); 41 levels
  – total 6488066 grid points

• Daily integrations from 00 UTC Day 0 to 00 UTC Day 4 (18-s time step, hourly output)

• “Convection-permitting”–suite of physical parameterizations
  – Grell-Freitas “scale-aware” convection scheme

• MPAS-Atmosphere only
  – thus, need we lower bc updates ... which we derive from the GFS model
Logistics/details of MPAS implementation

Initiate pre-proc (get GFS ic/SST bc, interp)

Begin model execution

0730 UTC

4-day fcst completed

1730 UTC

Post-proc, push to server

1930 UTC

Daily planning meeting

2100 UTC

... thankfully, all done on a reservation
Why the need for extended range forecasts?

• to avoid missing a favorable event ...
  – ground crews: human resource limitations (~4 consecutive days); expendables (weather balloons, etc.); competing objectives
  – also, two domains, with 1-day transit
Potential success of extended range forecasts in Argentina?

- **Hypothesis**: multi-scale atmospheric processes are strongly controlled by terrain (Andes, Sierras de Córdoba Mountains), thus contributing to higher predictability
Why Blue Waters?

• stable, reliable platform
• sufficient resources for this project to run at high resolution
  – MPAS execution: 192 nodes, ~10 hr wallclock, but daily for 45+ days
• sufficient resources on machine, such that this project was not too burdensome
coarse resolution global models indicated vigorous pressure trough by 10 November, which appeared supportive of supercell thunderstorms, but necessary granular details not provided by such models
92-hr forecast
(valid 20 UTC 10 Nov)

simulated radar reflectivity

“swath” of UH indicating supercell track

Updraft Helicity
Cordoba radar
2020 UTC
68-hr forecast
(valid 20 UTC 10 Nov)

change in evolution?
44-hr forecast
(valid 20 UTC 10 Nov)

less organized storms...
20-hr forecast
(valid 20 UTC 10 Nov)

still different evolution
140-hr forecast
(valid 20 UTC 10 Nov)

return to a more accurate evolution!
Preliminary thoughts…

• useful extended range guidance (even out to 6 days) for many, but certainly not all events
  – planned objective evaluation

• degradation of guidance with time?
  – for shorter-range forecasts, less spinup time from coarse ic from global model?
  – counter to recent finding by Schwartz (2019, *MWR*) in U.S.

• still need comparison with regional model forecasts to determine if MPAS/global modeling adds value
Questions/comments?
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RELAMPAGO is sponsored by the National Science Foundation
Brief digression: Building MPAS on Blue Waters...

• It took a while ...
• MPAS uses the Parallel IO (PIO) library (as used in CESM), and with help from NCAR team (Michael Duda) and NCSA’s Ryan Mokos, we determined that PIO did not install properly with PGI compilers
MPAS@Blue Waters 116h fcst
Init: 2018110600 UTC Valid: 2018-11-10 20:00:00 UTC

more favorable...

116-hr forecast
(valid 20 UTC 10 Nov)
grid refinement is not a new concept, but is fundamental to the success here