LIMITED-AREA MODELING WITH MPAS-ATMOSPHERE

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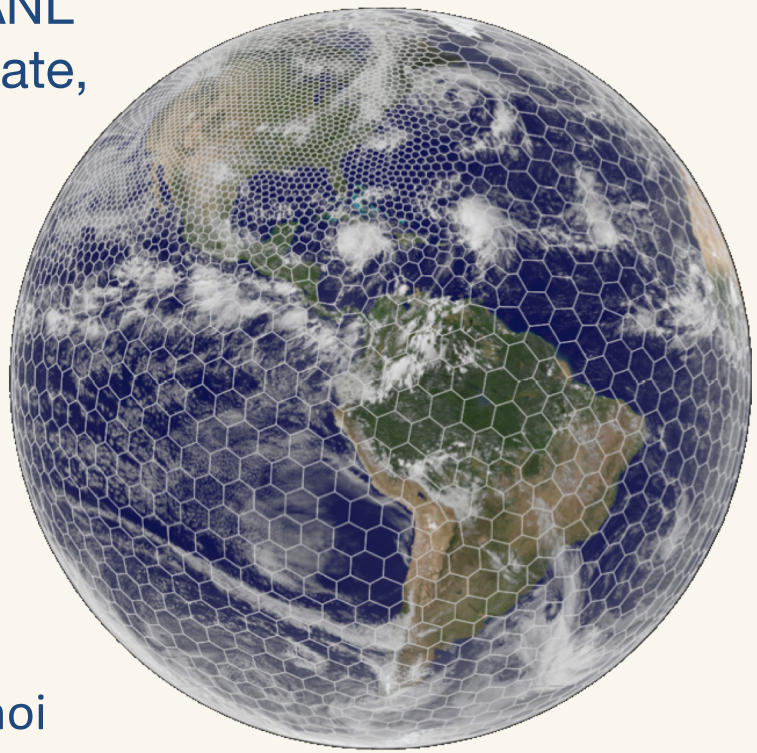
WHAT IS THE MODEL FOR PREDICTION ACROSS SCALES (MPAS)?

A collaboration between NCAR and DoE/LANL to develop models for climate, regional climate, and NWP applications:

- MPAS-Atmosphere (NCAR)
- MPAS-Ocean (LANL)
- MPAS-Land Ice (LANL)
- MPAS-Sea Ice (LANL)
- MPAS framework and infrastructure (NCAR, LANL)



MPAS models are based on the centroidal Voronoi tessellation (CVT) with a C-grid staggering

https://mpas-dev.github.io/

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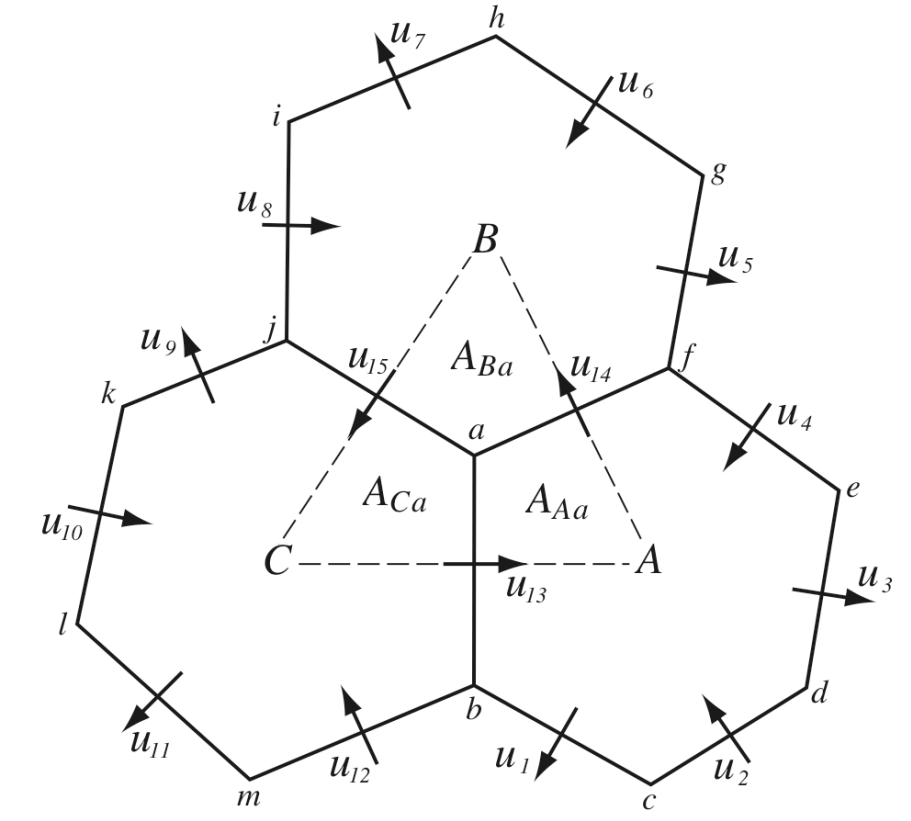
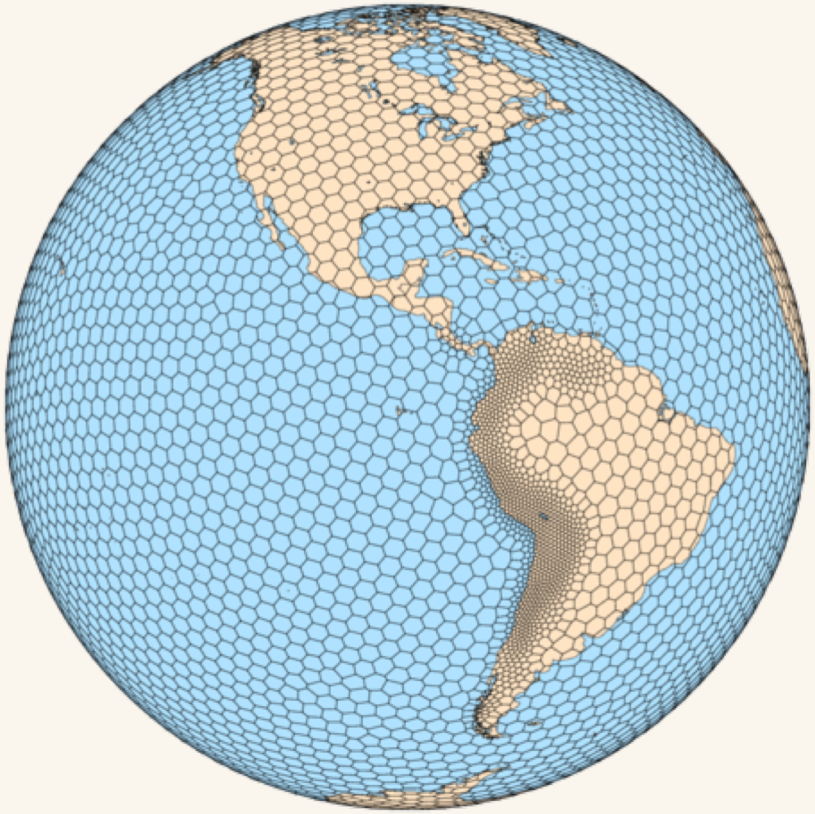


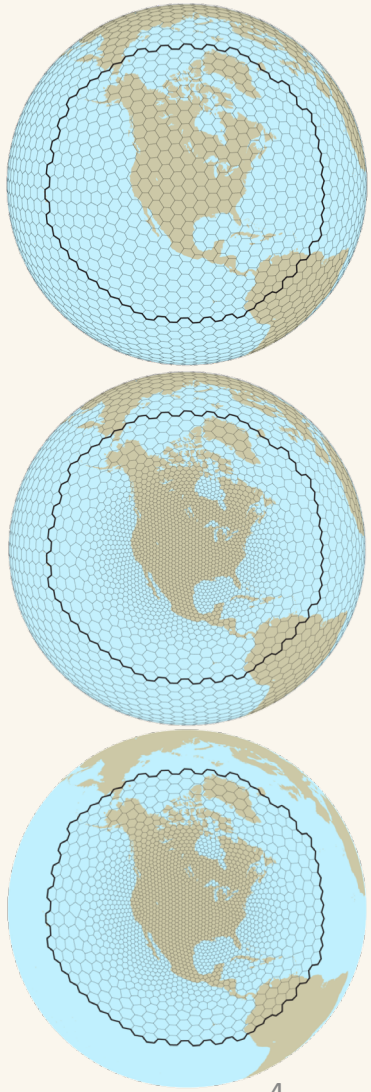


The CVT meshes employed by MPAS are fully unstructured and permit gradual refinement of the mesh around regions of interest

MOTIVATION

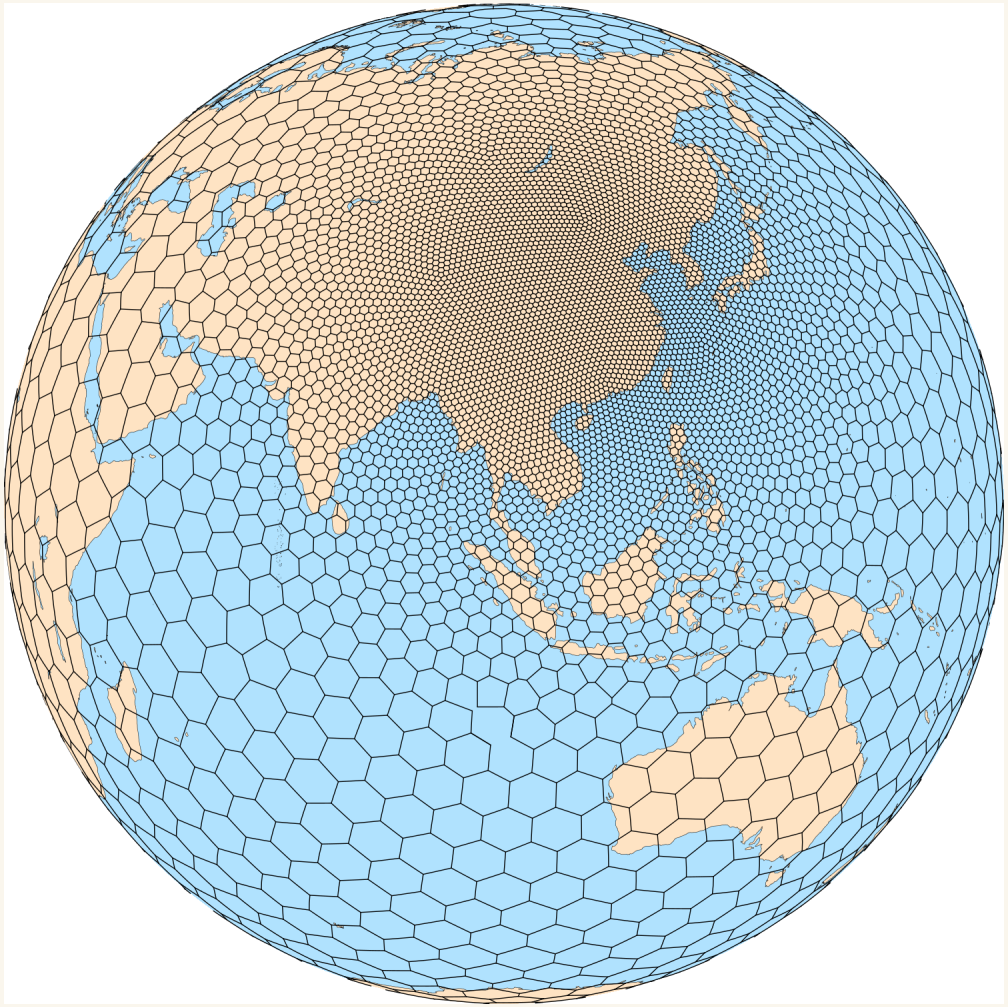
We already have WRF; why do we need a regional MPAS capability?

1. Allow less costly testing of MPAS at high resolutions
2. Leverage MPAS development for next-generation architectures for regional applications
3. Enable regional atmospheric applications within MPAS-enabled coupled modeling systems (e.g., CESM)
4. Employ variable resolution in regional applications to reduce LBC errors
5. Provide a consistent (equations, mesh) regional solver to complement global MPAS
6. Groups external to NCAR have asked for a regional capability in MPAS and are supporting its development (KISTI)



CREATING LIMITED-AREA MESHES

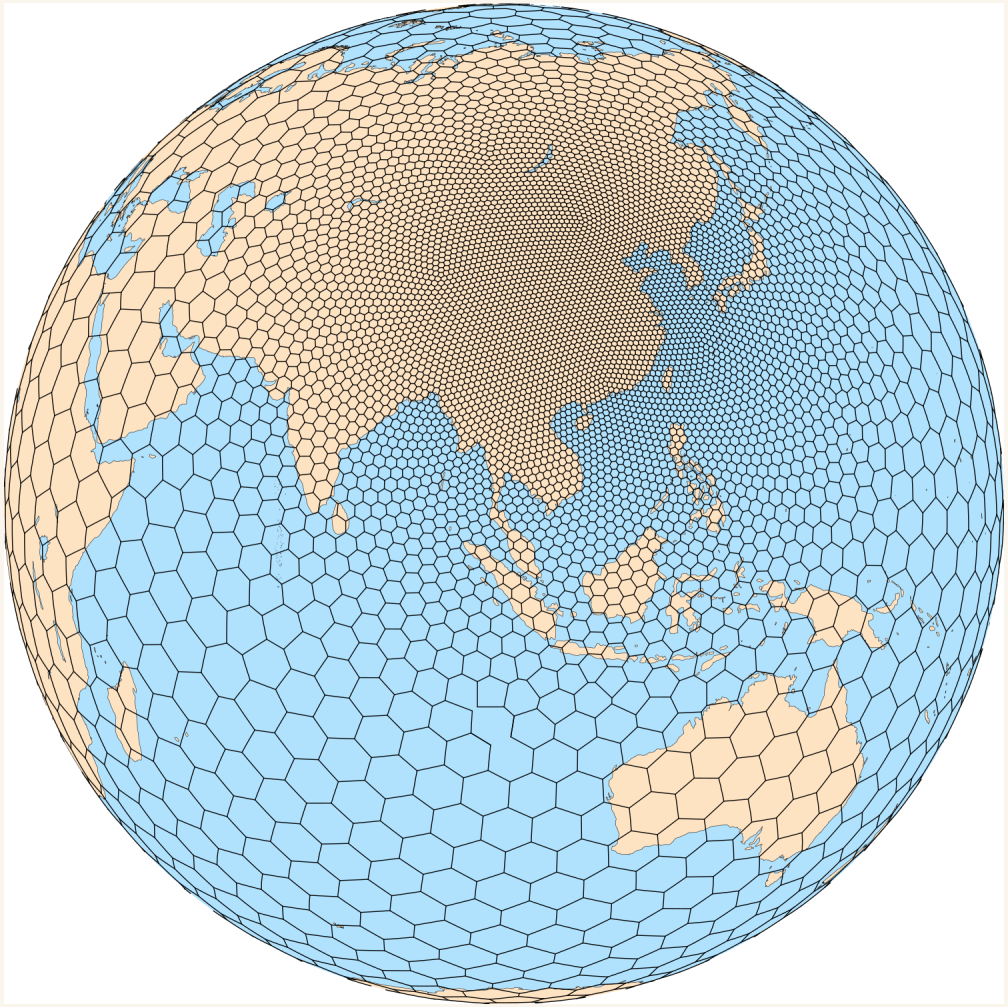
Rather than constructing regional centroidal Voronoi tesselations from scratch, regional domains are defined as subsets of existing MPAS meshes



CREATING LIMITED-AREA MESHES

Six easy steps:

1. Take any existing (global) mesh, rotate the refinement as needed



CREATING LIMITED-AREA MESHES

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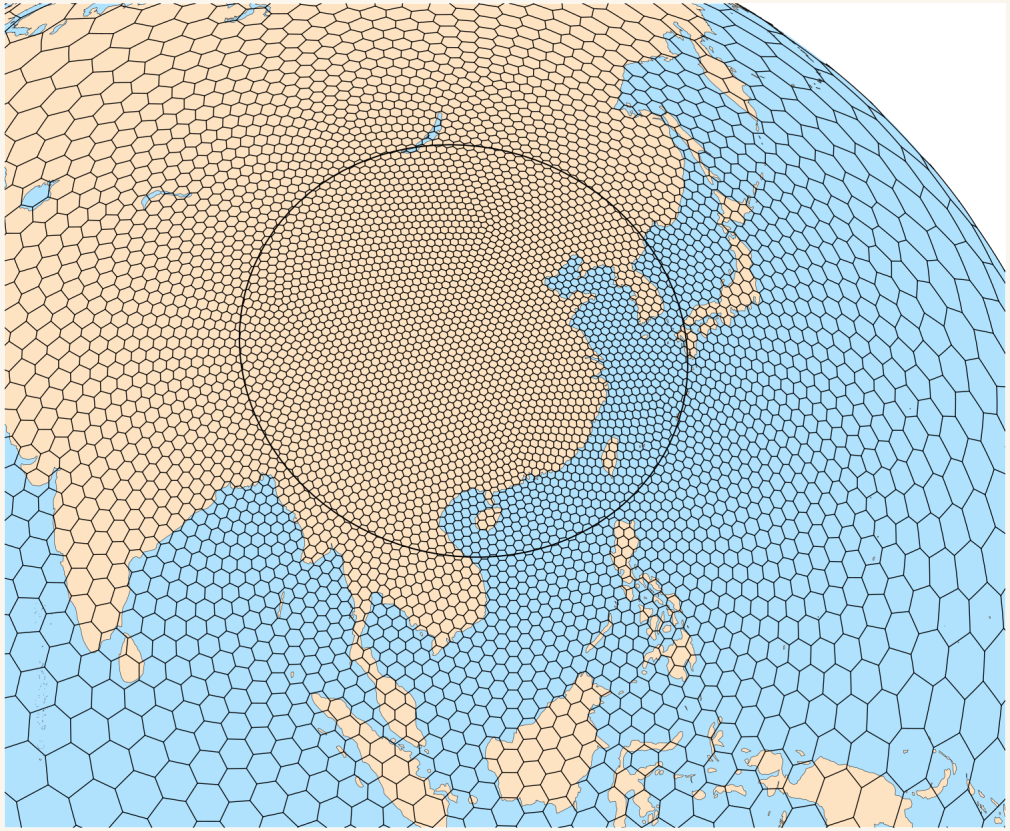
2. Identify a region of interest



CREATING LIMITED-AREA MESHES

Six easy steps:

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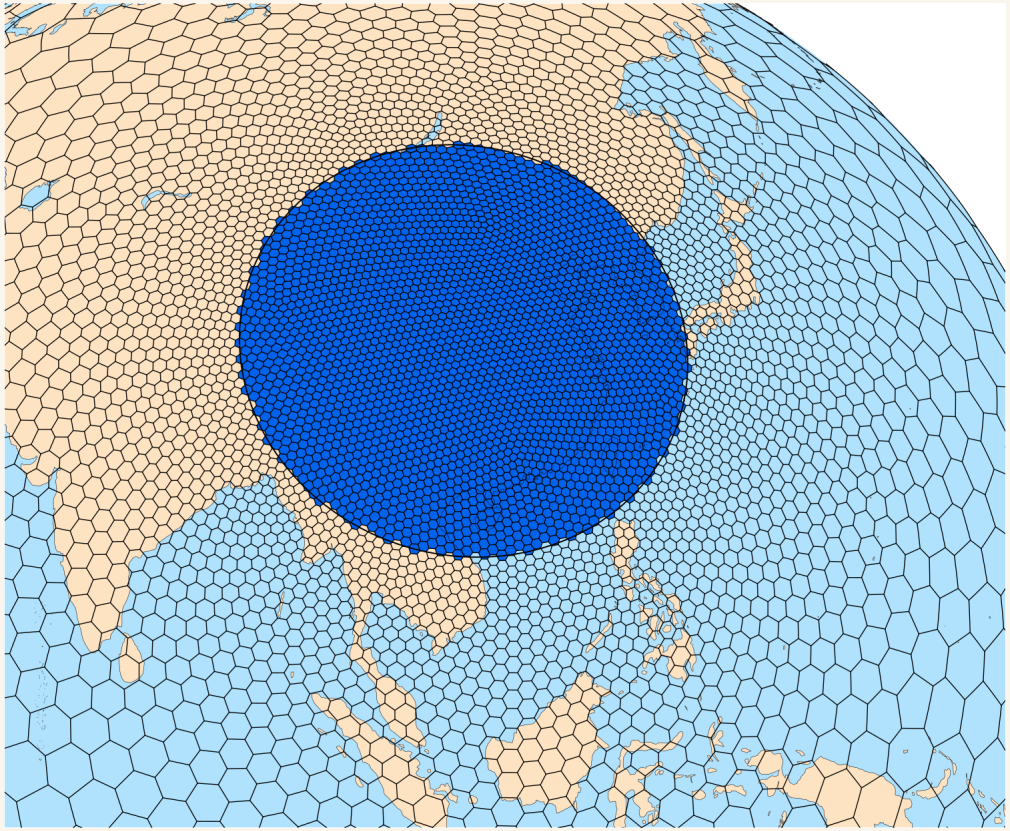
3. Let the regional domain consist of all cells whose generating point (center, roughly) lies within the region



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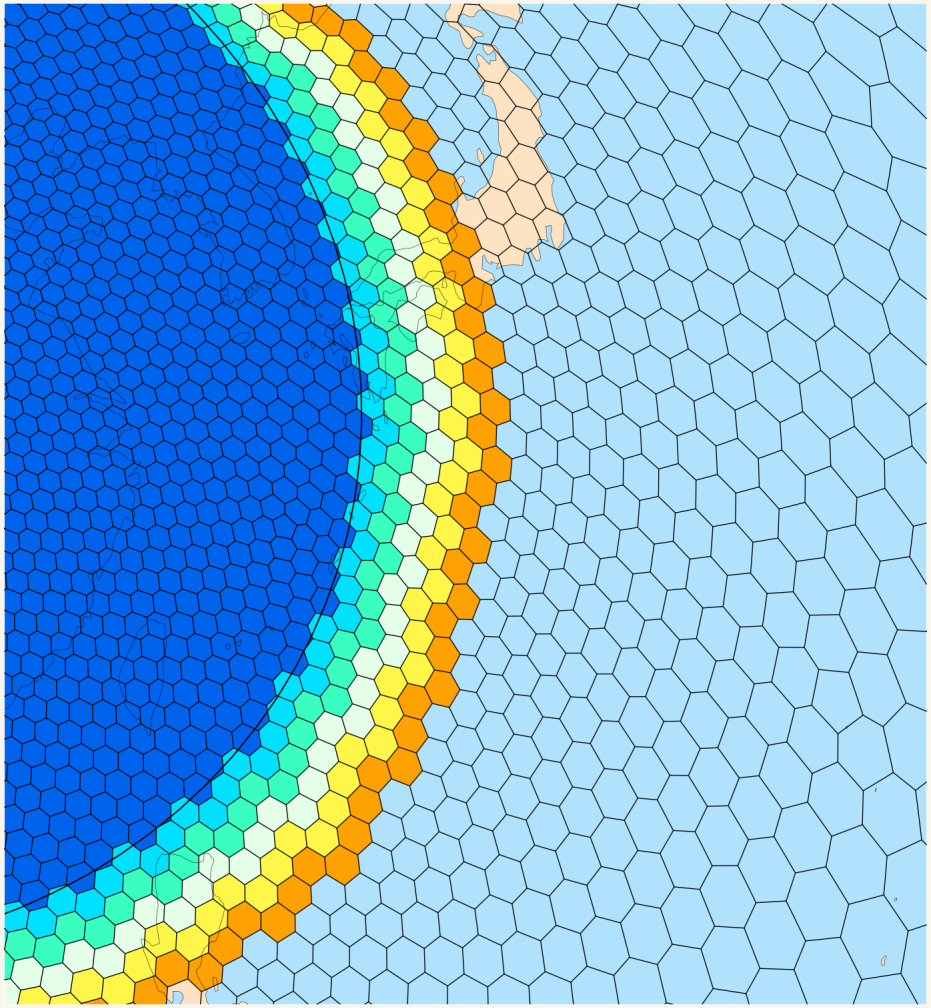
4. Build layers of “relaxation zone” cells (we’ve been testing with 5)



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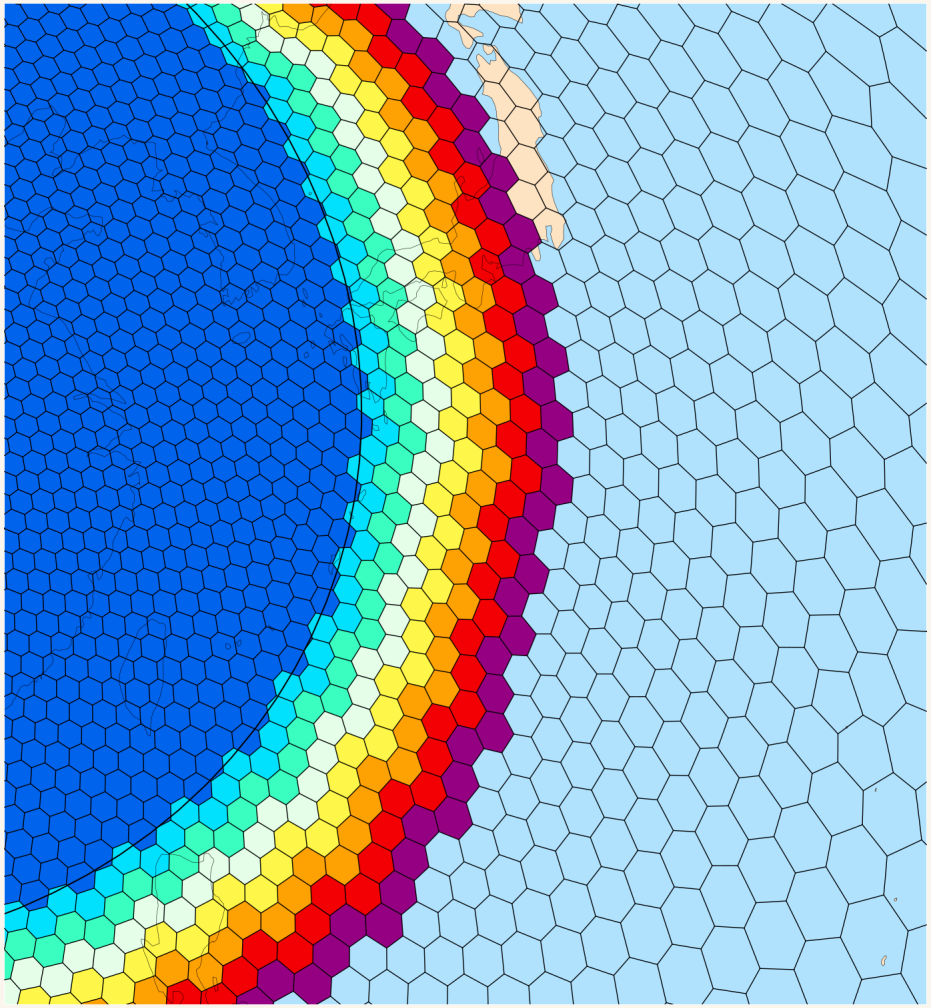

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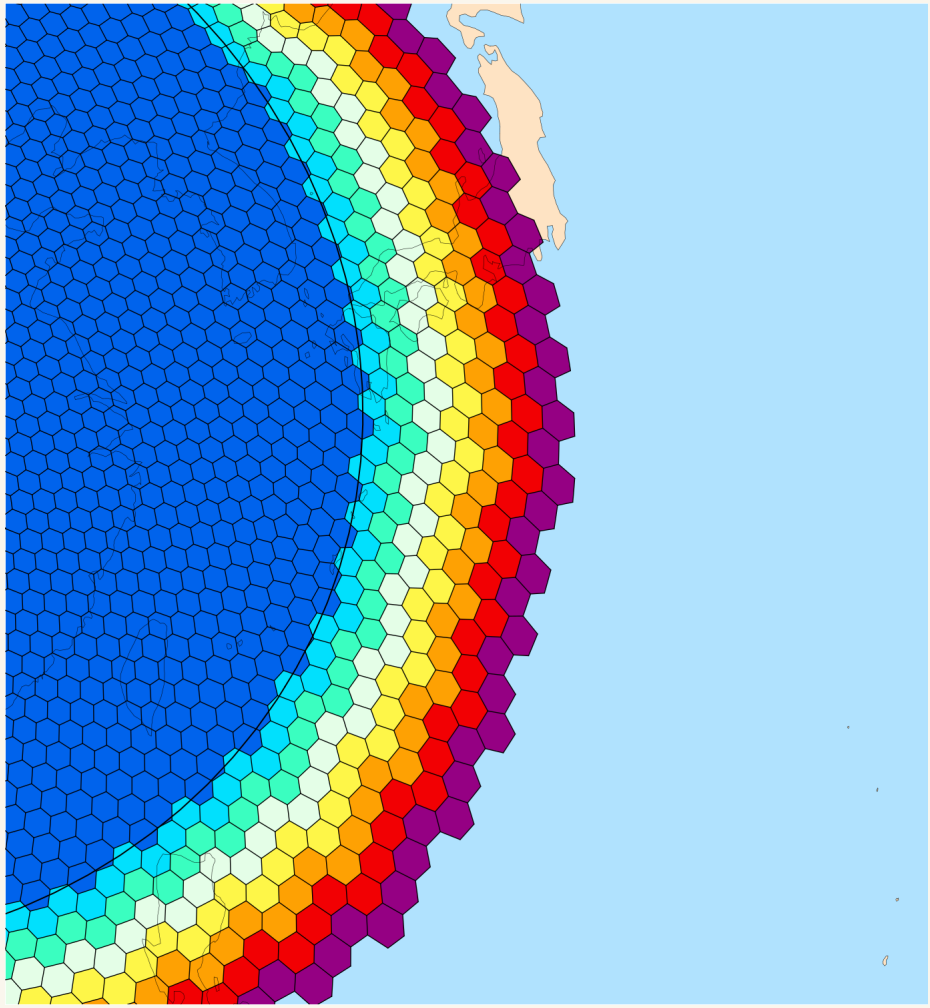
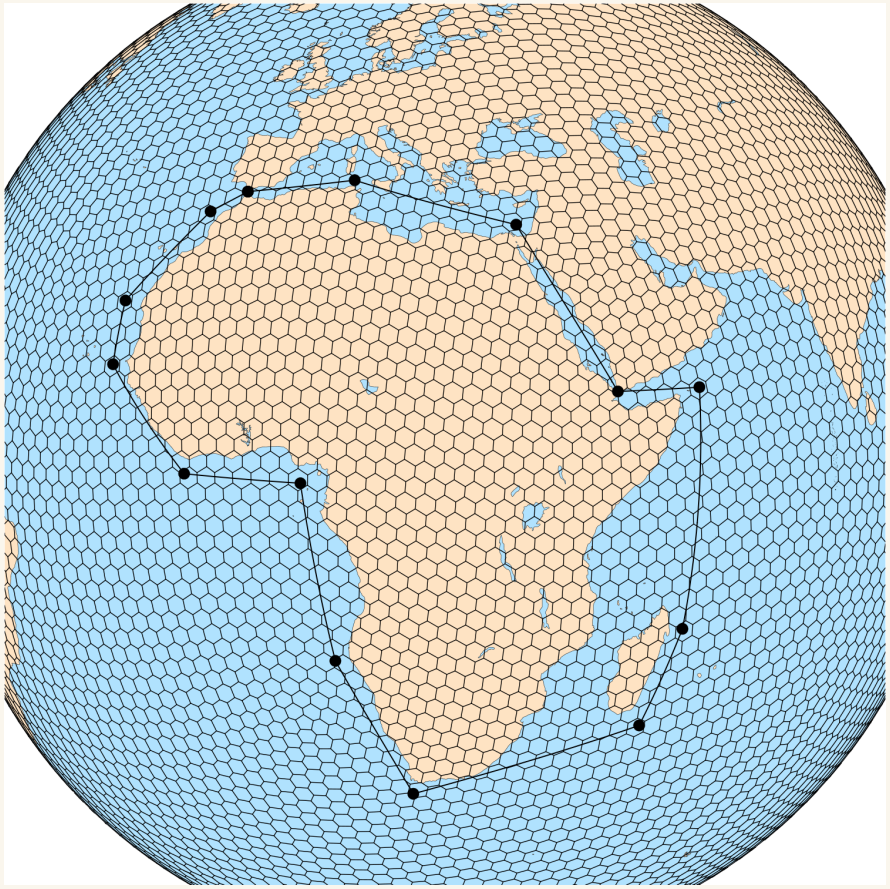
6. Cull any remaining cells and re-index cells/edges/vertices to a contiguous range of indices



CREATING LIMITED-AREA MESHES

The same method works for regions defined by a set of connected points



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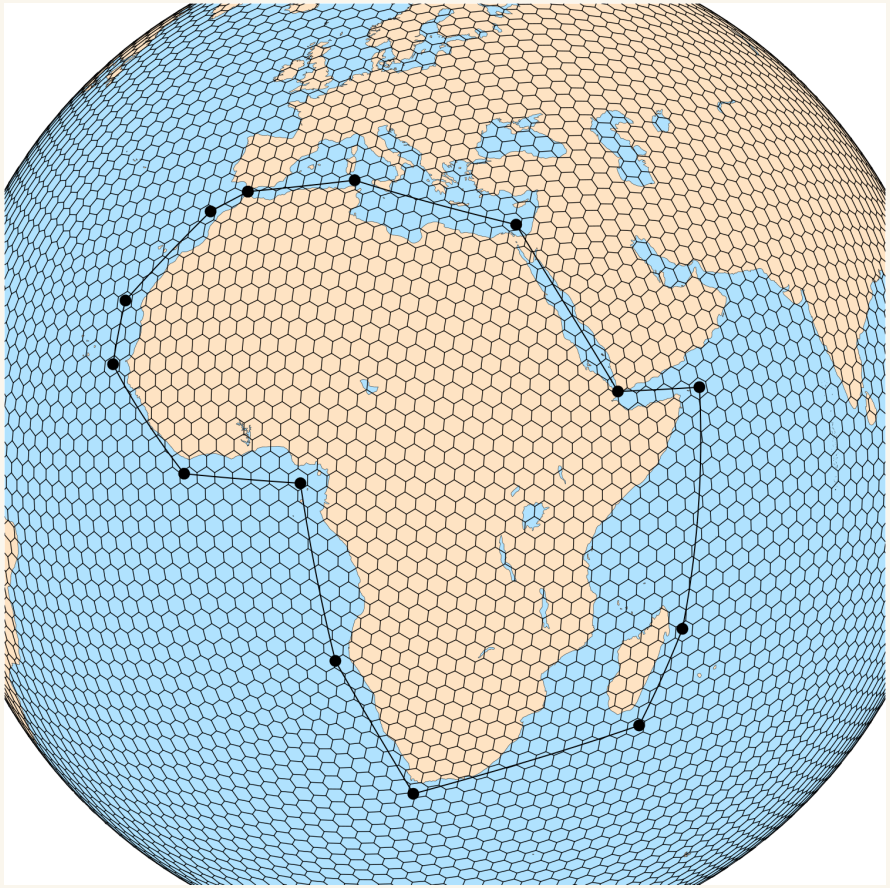
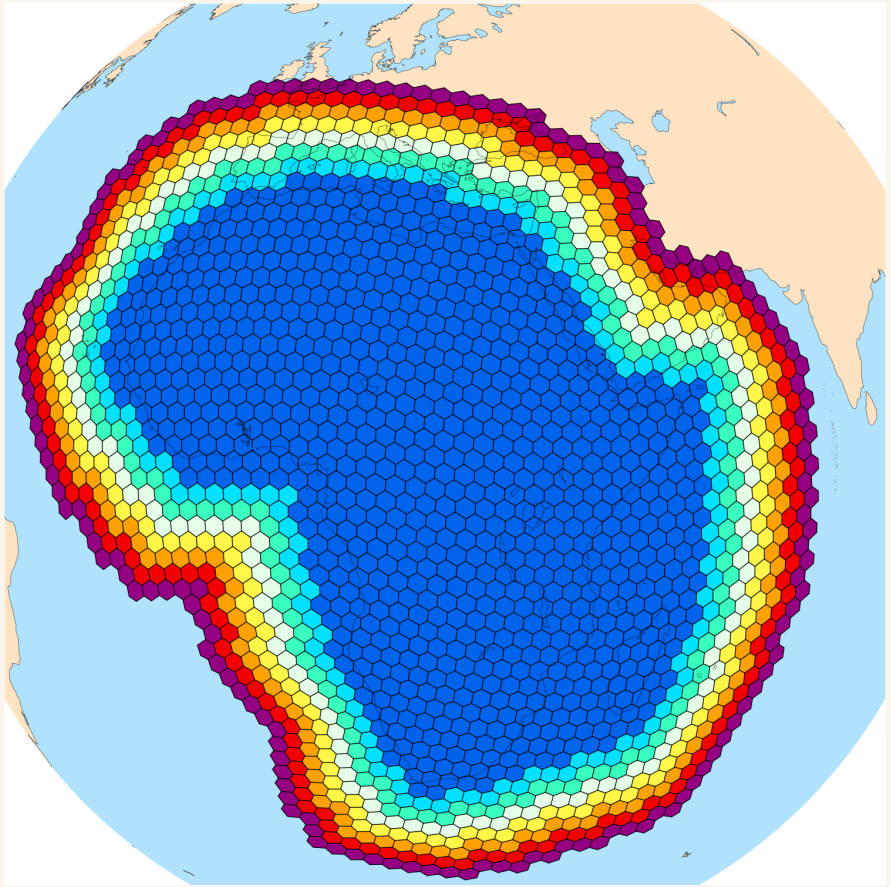
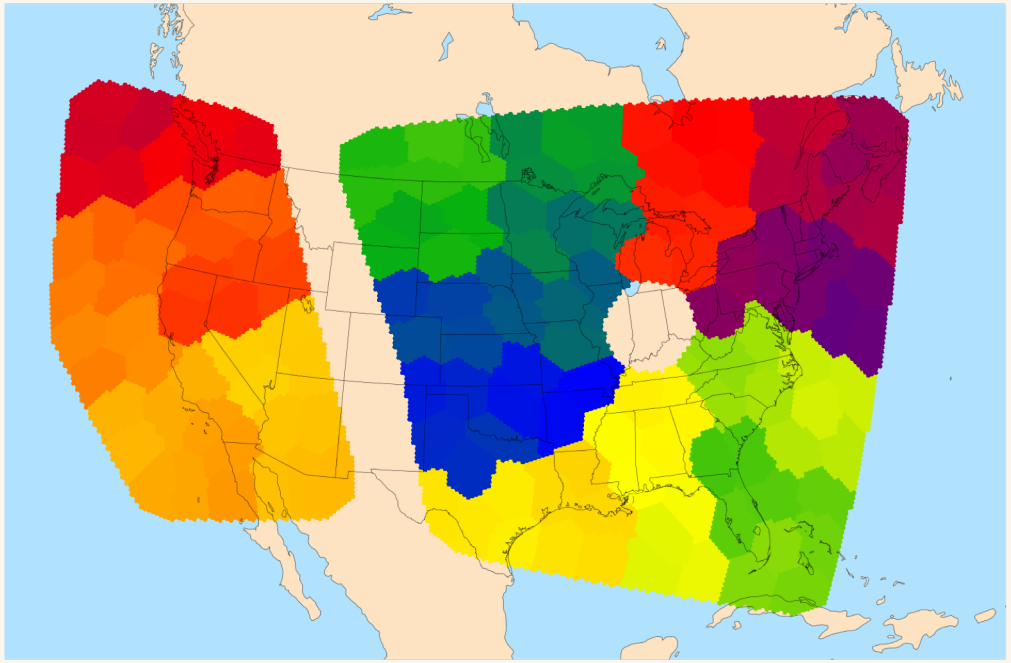




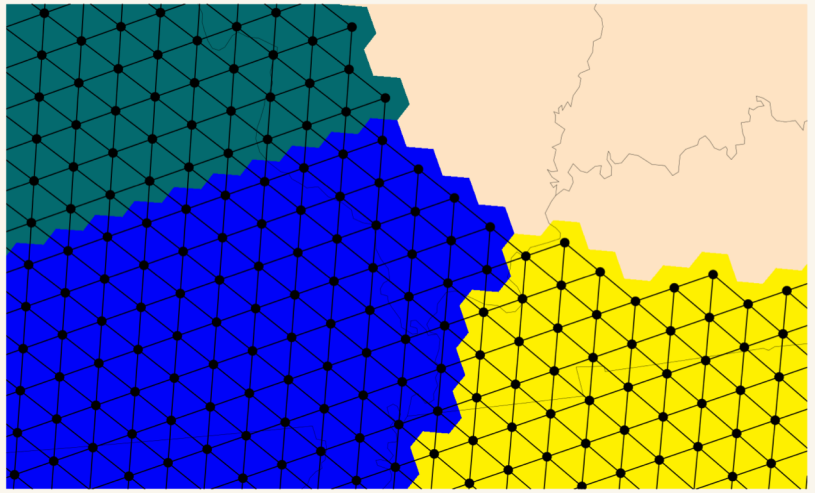
PARTITIONING OF REGIONAL MESHES

Partitioning limited-area meshes works the same as for global meshes

- Consider the connectivity graph of the cells in the mesh
- Divide the nodes in the graph into *k* partitions while minimizing the *edge cut* of the partitioning

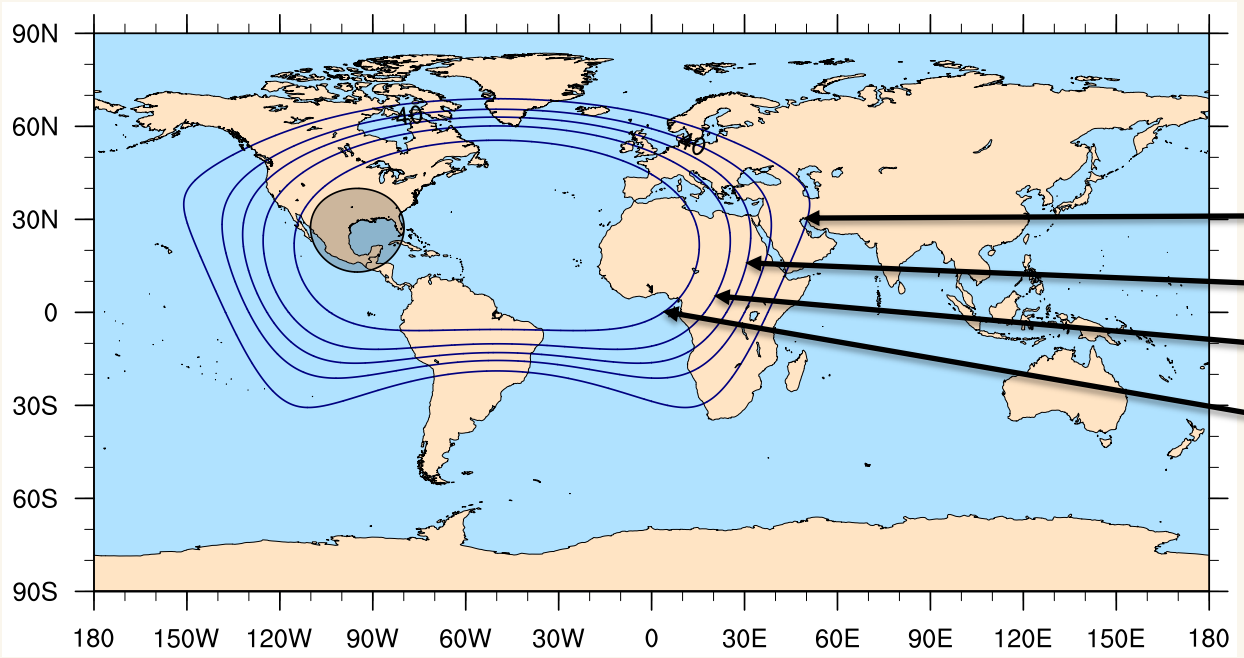


Partitioning of a regional MPAS mesh by Metis into 144 partitions.



The connectivity graph of cells near the south-west of Indiana.

EXAMPLE: HURRICANE HARVEY



Approximate grid size:

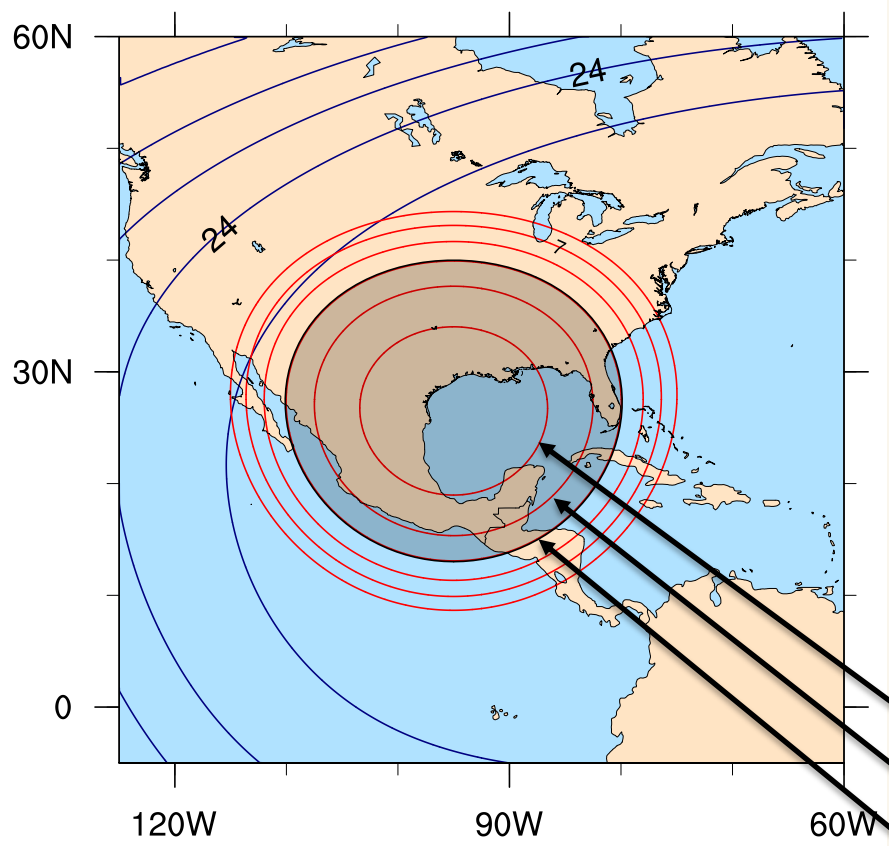
- 48 km
- 32 km
- 24 km
- 16 km

Global MPAS simulation

- 21 – 27 August 2017
- Variable-resolution, 60-15 km mesh
  - Refinement over Atlantic
- GFS initial conditions
- Output for regional LBCs saved every 3 h

- 535554 grid columns
- 55 vertical layers
- “Mesoscale reference” physics suite

EXAMPLE: HURRICANE HARVEY



Regional MPAS simulation:

- Domain (shaded) extracted from high-resolution part of a 60 – 3 km mesh
- Boundaries of domain have grid size of approximately 5 km
- 21 – 27 August 2017
- 501718 grid columns
- 55 vertical layers
- “Mesoscale reference” physics suite

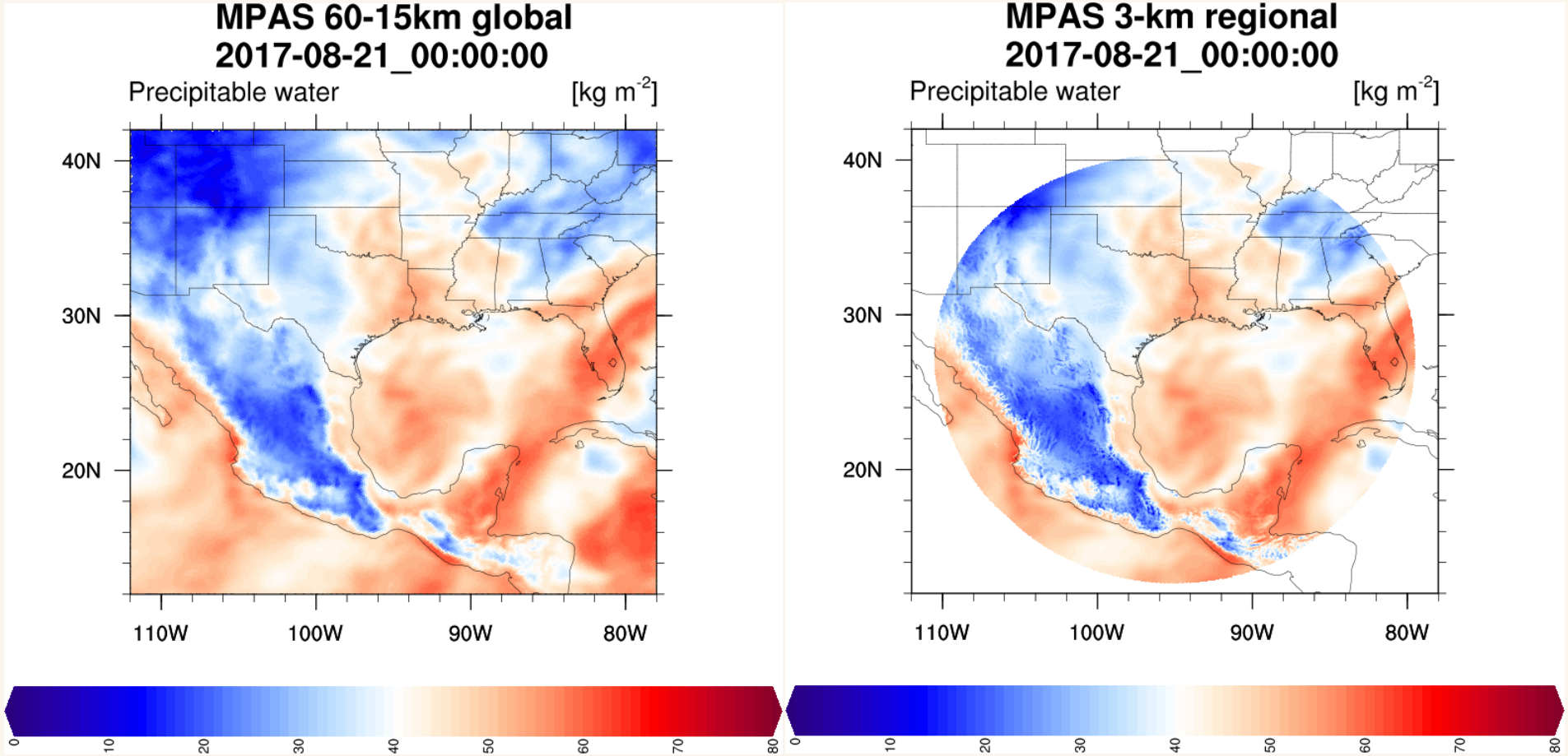
Approximate grid size:

3 km

4 km

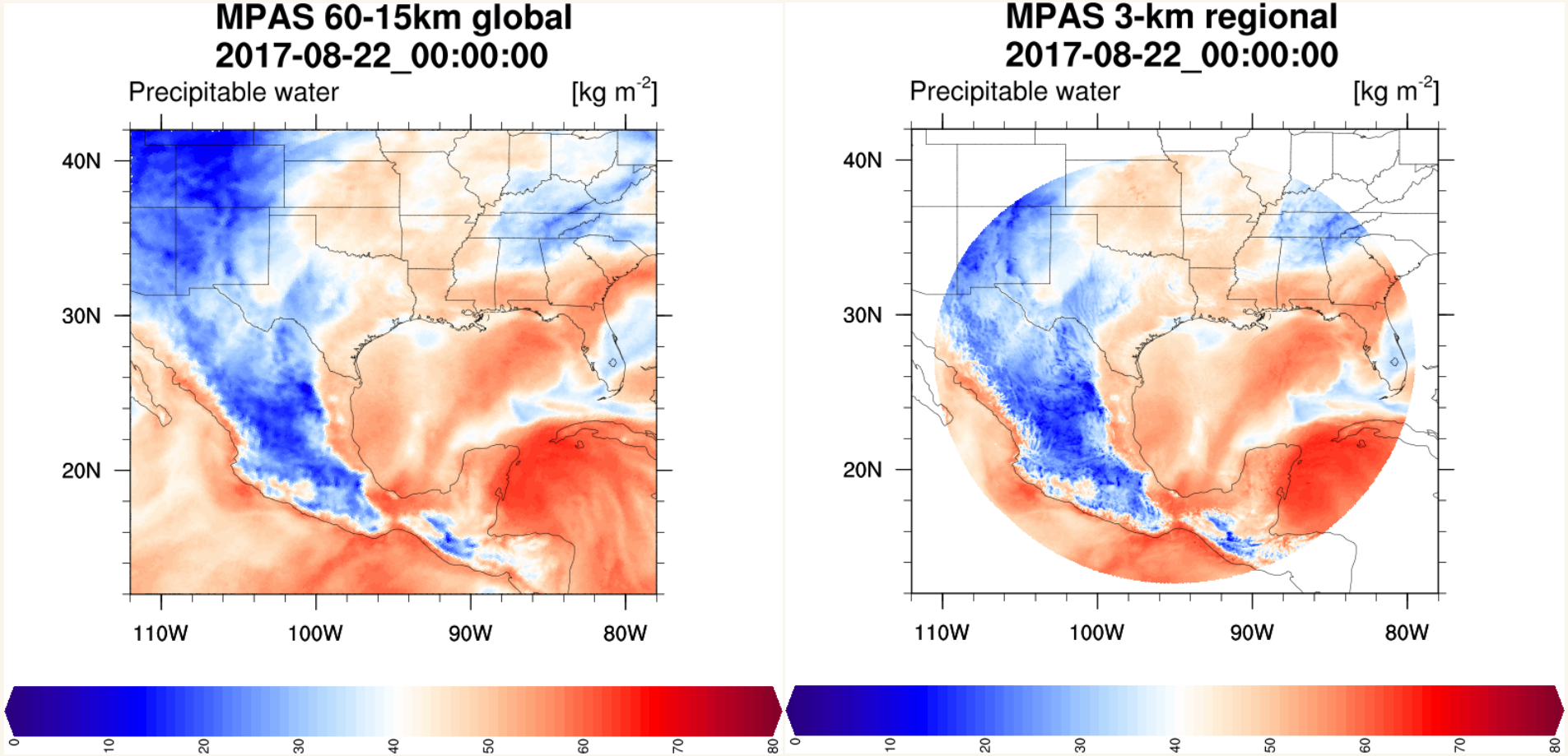
5 km

EXAMPLE: HURRICANE HARVEY +00H



Above: Precipitable water from a global, 60-15 km MPAS simulation (left) and from a regional, 5-3 km MPAS simulation (right).

EXAMPLE: HURRICANE HARVEY +24H



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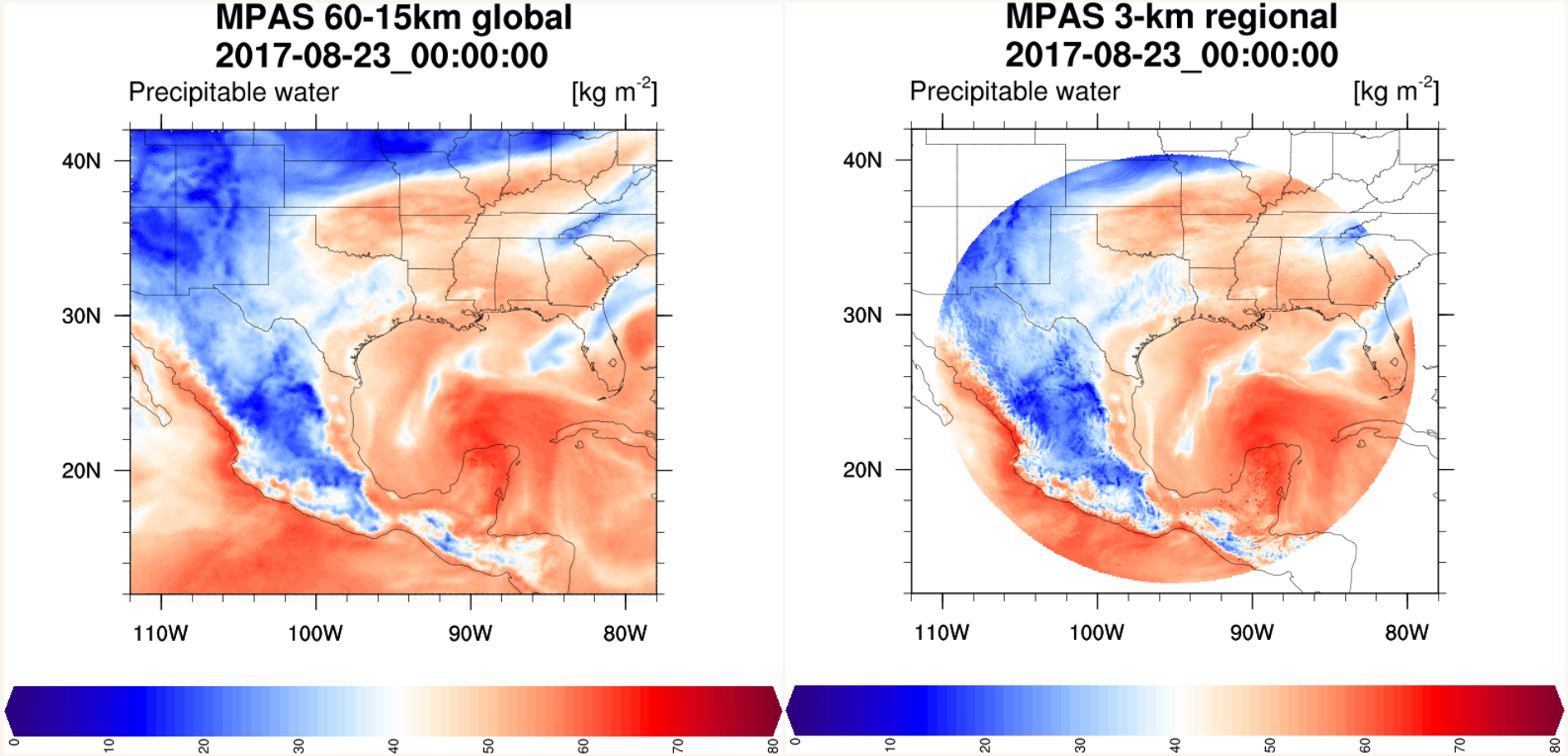
EXAMPLE: HURRICANE HARVEY +48H



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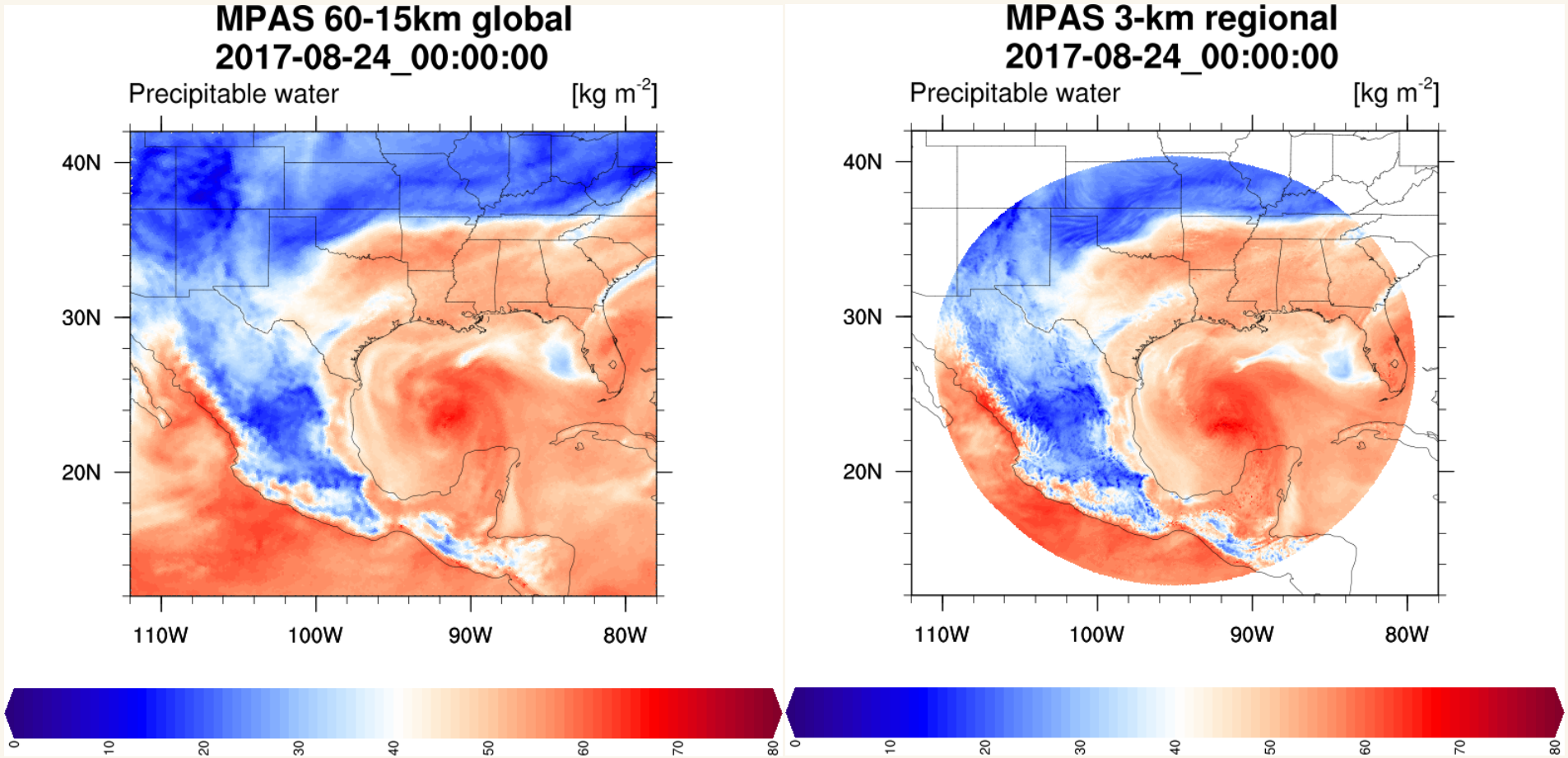
EXAMPLE: HURRICANE HARVEY +72H



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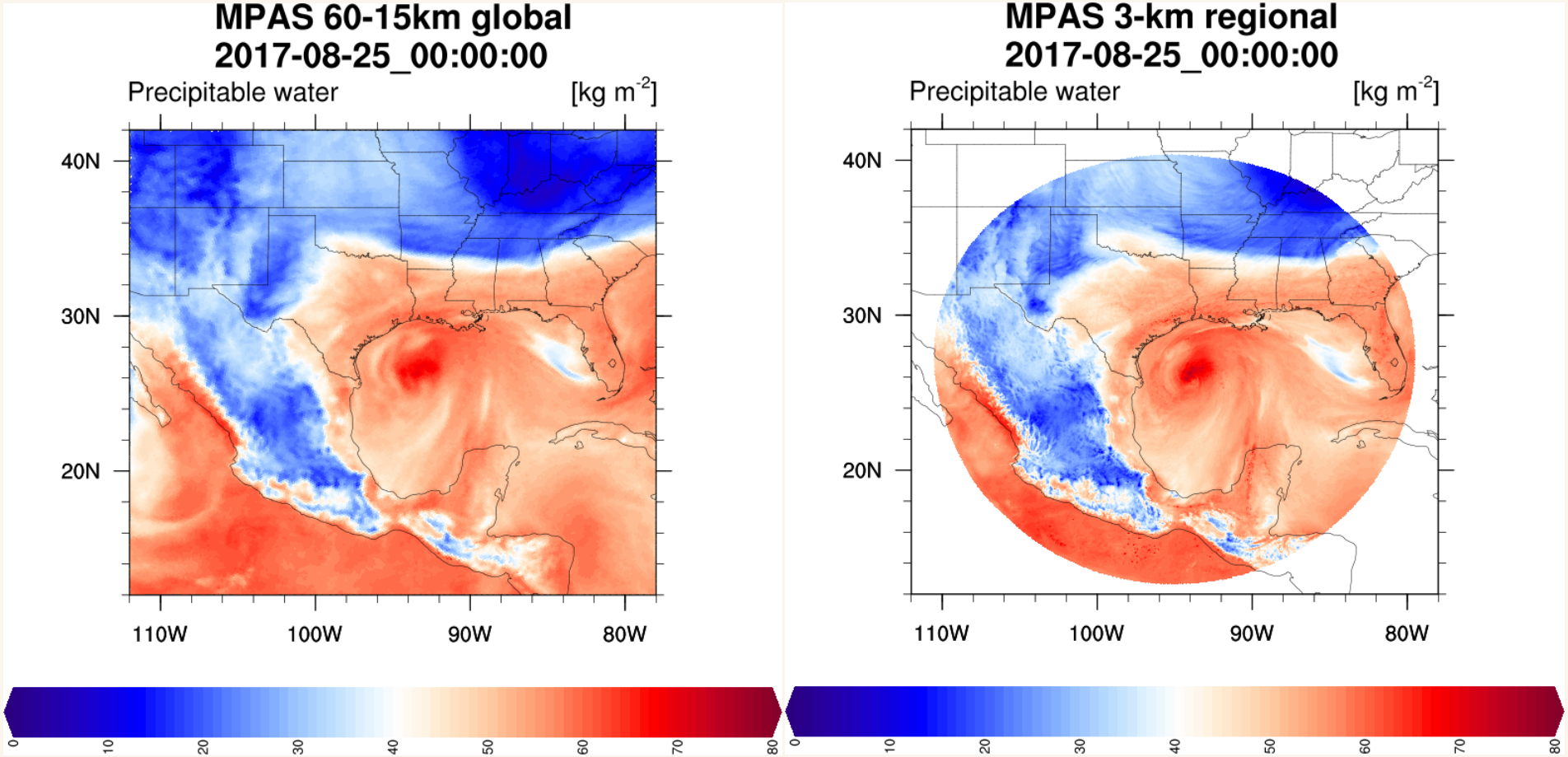
EXAMPLE: HURRICANE HARVEY +96H



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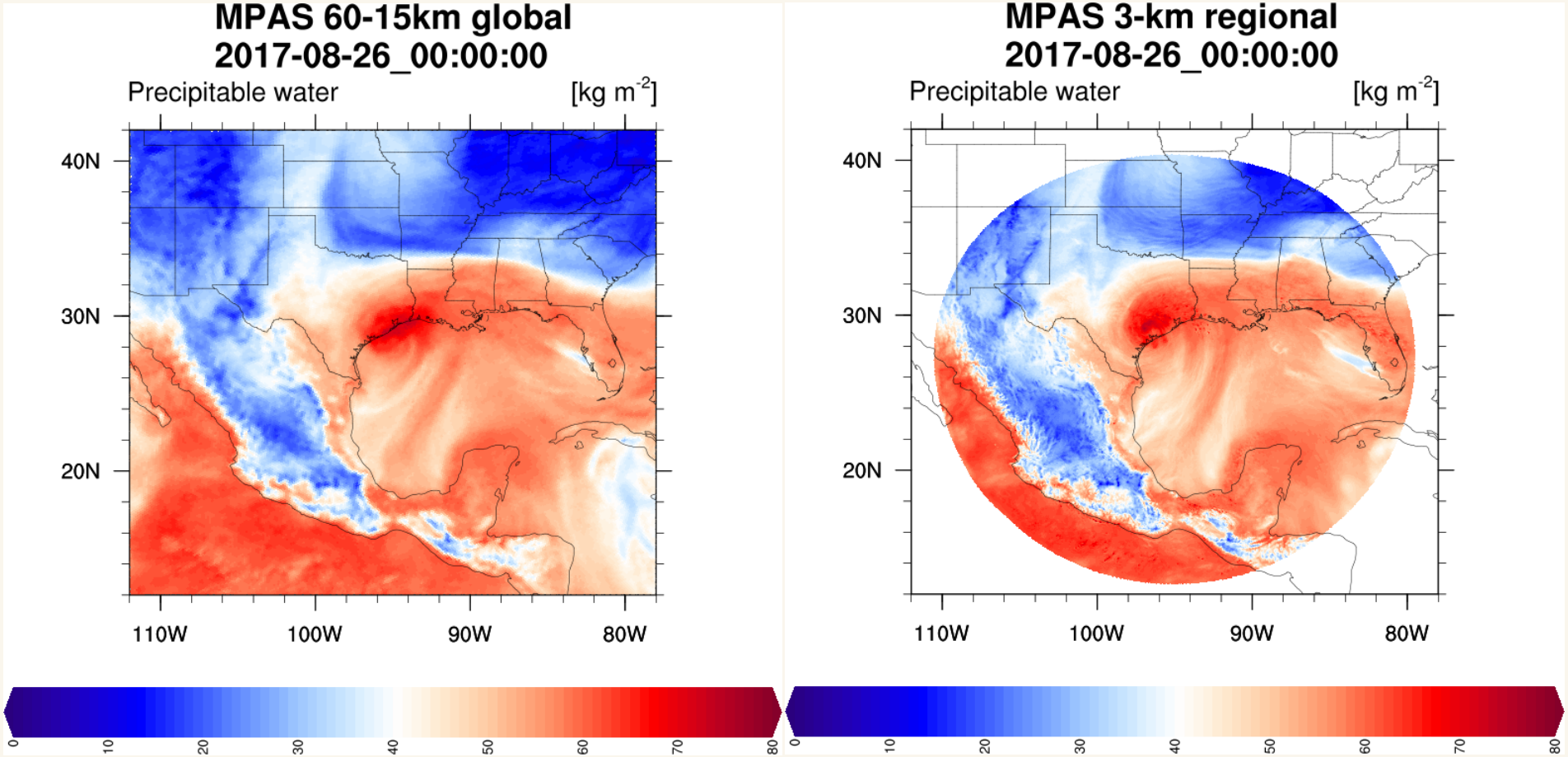
EXAMPLE: HURRICANE HARVEY +120H



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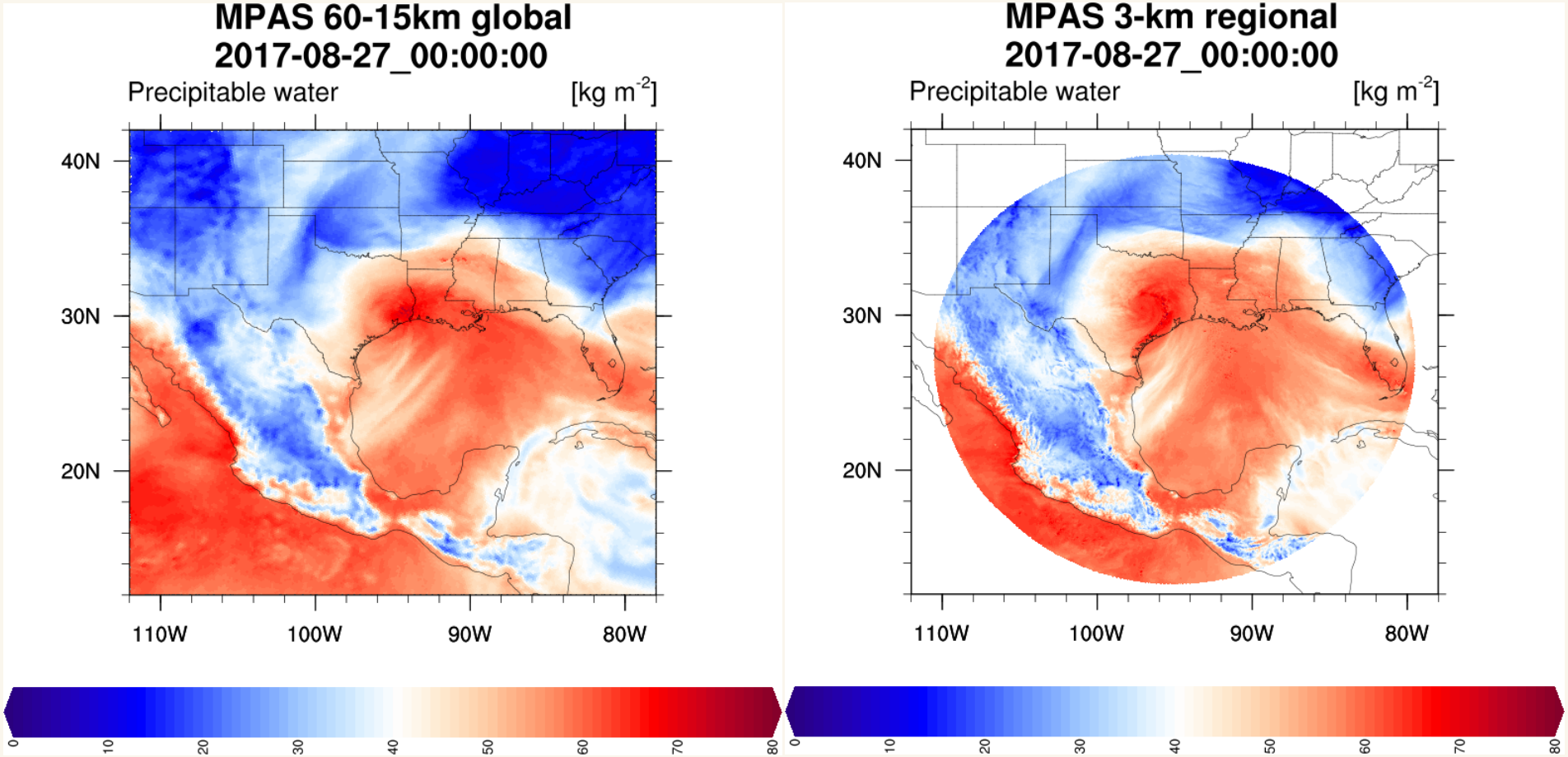
EXAMPLE: HURRICANE HARVEY +144H



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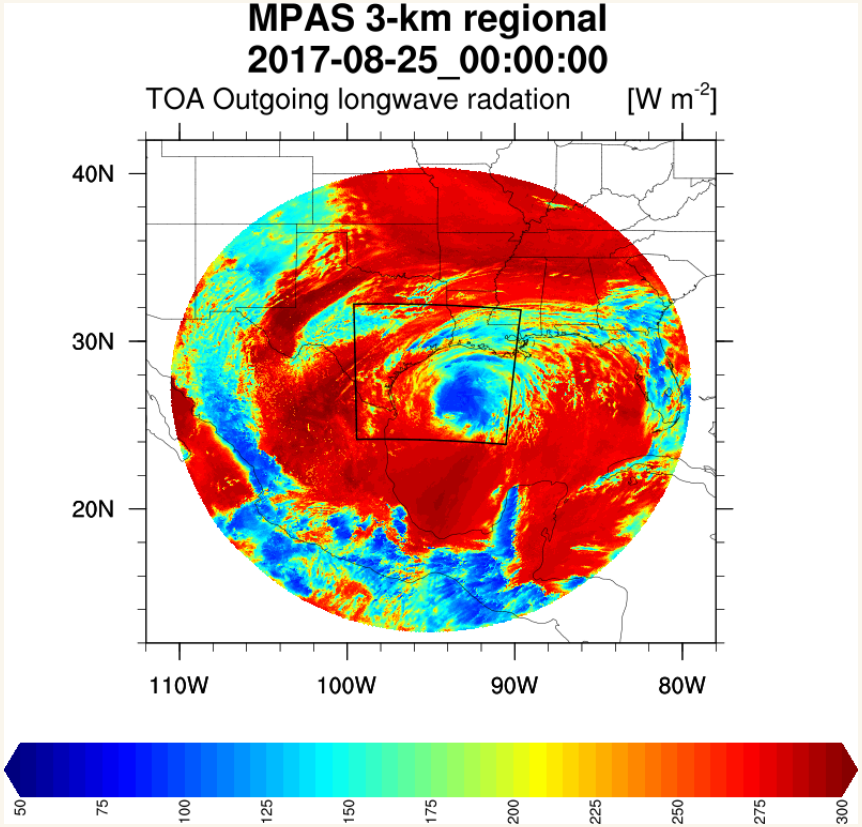
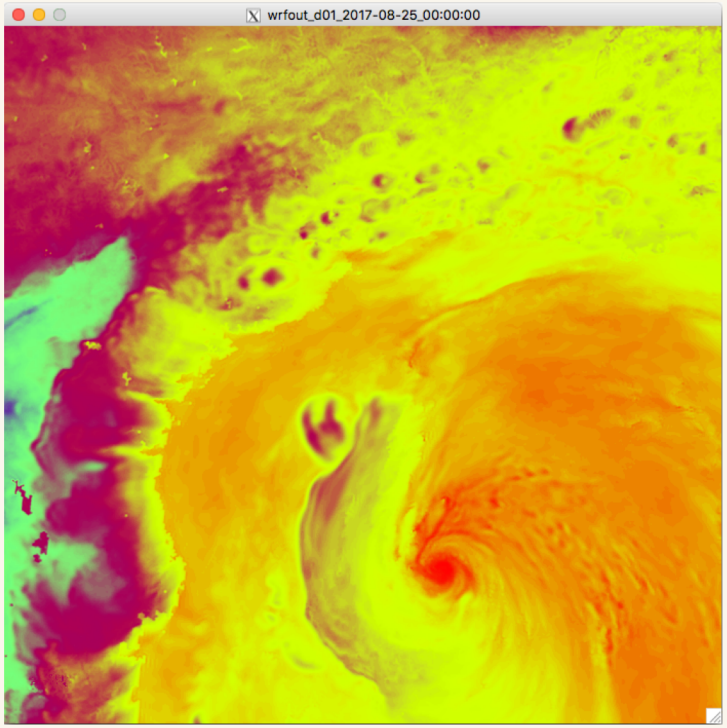
USING MPAS FOR WRF ICS AND BCS

Beginning with the WPS v3.9 release, native MPAS-Atmosphere output may be used for initial and boundary conditions in WRF!



The output from the 3-km regional MPAS simulation was used to provide ICs and LBCs for a 1.33 km WRF domain (black rectangle).



The lowest model level QVAPOR field in the WRF initial conditions on 2017-08-25_00:00:00 .

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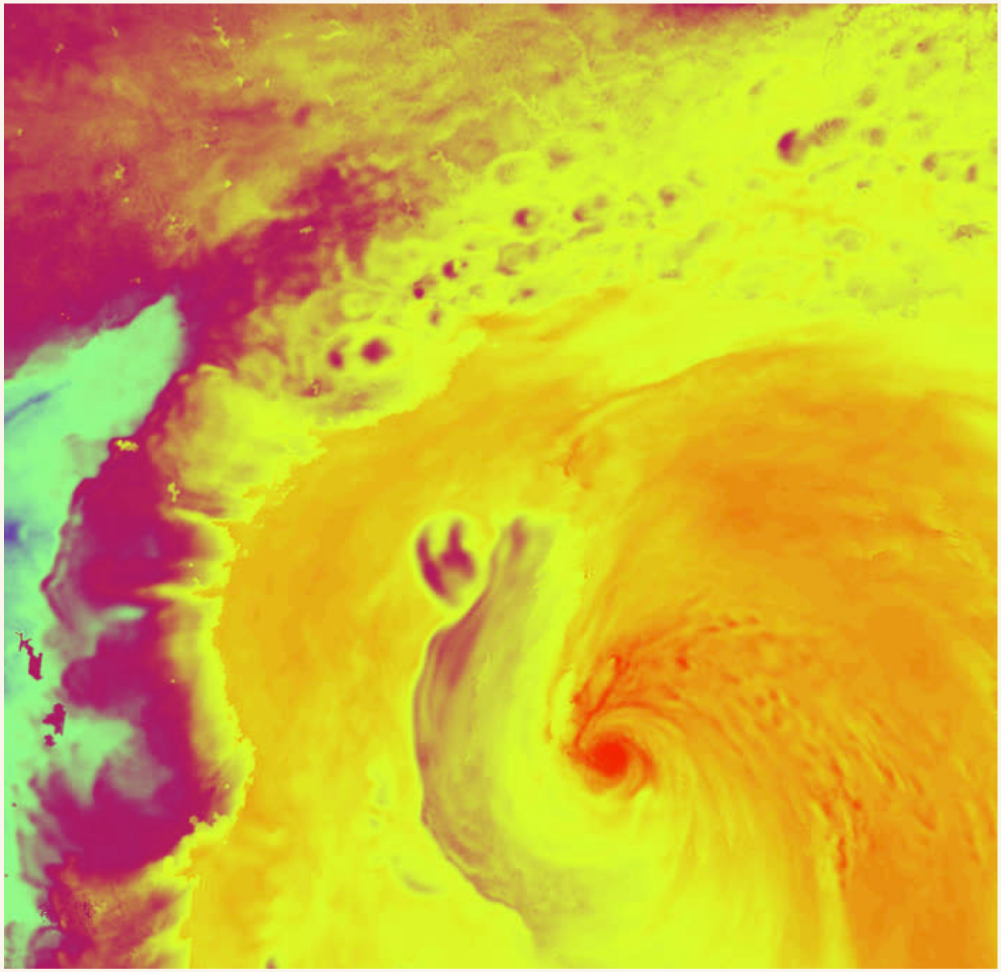

Left: Lowest model level QVAPOR from a 24-h WRF simulation initialized 2017-08-25_00:00:00 using MPAS 3-km initial and boundary conditions. Frames are every 10 simulated minutes (145 frames total).

<u>WRF configuration:</u>

- WRF v3.9.1.1
- 'tropical' physics suite
- dx = 1.33 km
- 41 levels, ptop = 50 hPa
- LBC update interval = 3600 s

SUMMARY AND FUTURE WORK

Key points:

- Regional MPAS offers a tremendous amount of flexibility
- Cost of regional MPAS can be competitive with WRF (not shown here)
- MPAS (regional or global) can provide ICs and LBCs for WRF
- At this point, mostly code clean-up, documentation, and restructuring of pre-processing tools

- **We expect to make a publicly supported release of MPAS with a limited-area capability by summer 2019**

Skamarock, W. C., M. G. Duda, S. Ha, and S-H. Park, 2018: Limited-Area Atmospheric Modeling Using an Unstructured Mesh. *Mon. Wea. Rev.*, 146, 3445-3460.

doi: 10.1175/MWR-D-18-0155.1