

Running MPAS Part 3: Preparing limited-area meshes and lateral boundary conditions

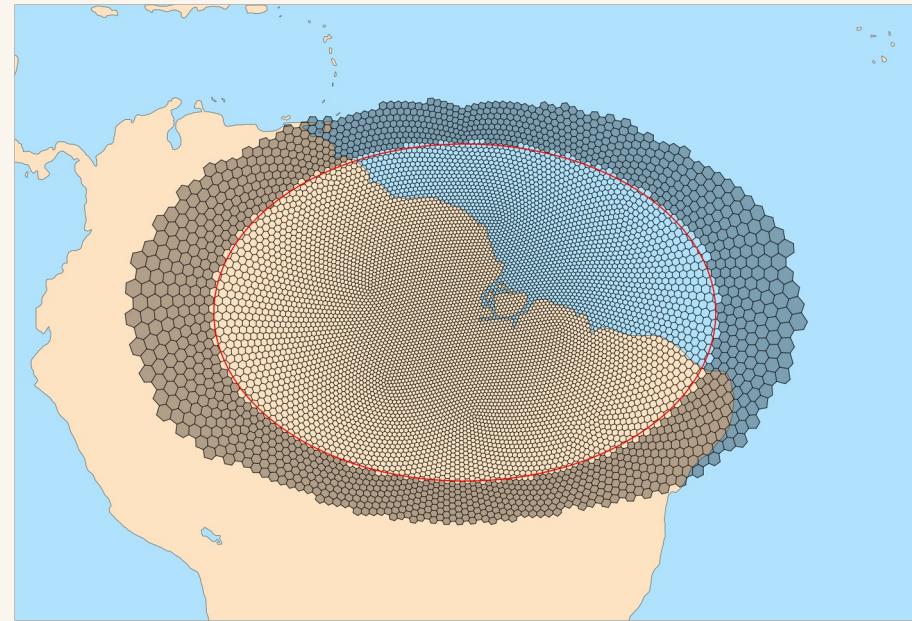
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Overview

Running limited-area simulations with MPAS-Atmosphere involves only small variations on the process of running global simulations:

- 1) A limited area domain must be defined, and a mesh must be created for that domain
- 2) In addition to ICs, lateral boundary conditions (LBCs) must be generated with the *init_atmosphere* core
- 3) LBCs must be enabled when running the *atmosphere* core



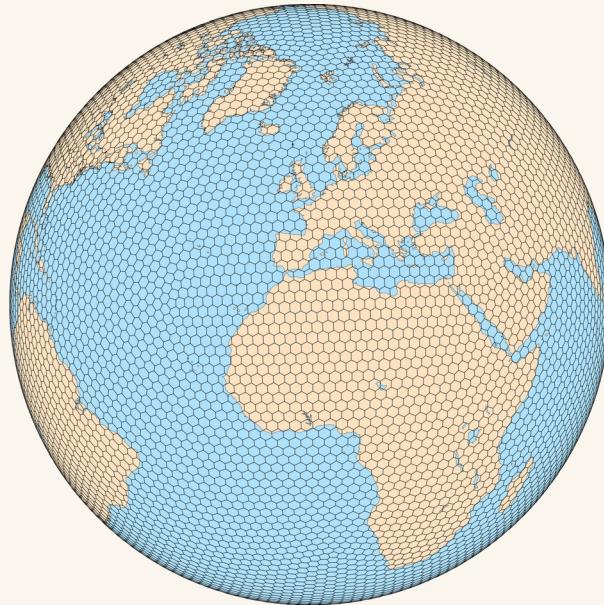
Above: A variable-resolution, limited-area MPAS mesh. Relaxation zone and specified zone cells are shaded gray.

See Sections 4.3 and 8.2 in the User's Guide

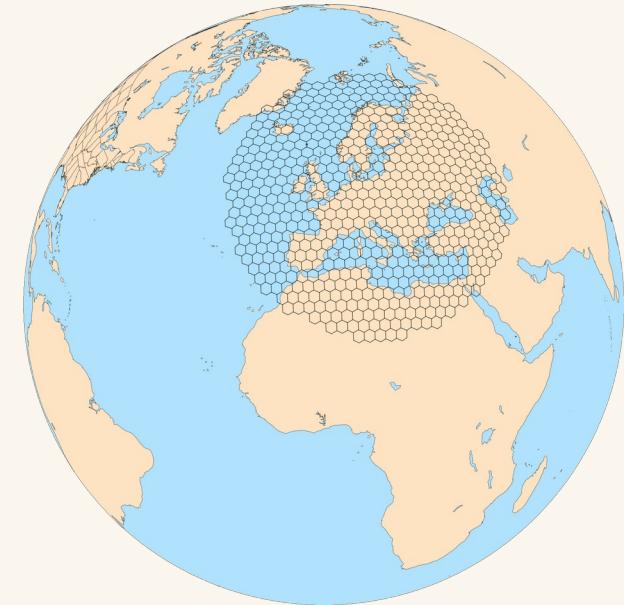
Creating limited-area meshes

As mentioned elsewhere, generating new CVT meshes can be quite time consuming

- At present, limited-area meshes are created by subsetting existing meshes with the MPAS-Limited-Area tool



Each cell in the limited-area mesh is exactly coincident with a cell in the "parent" mesh

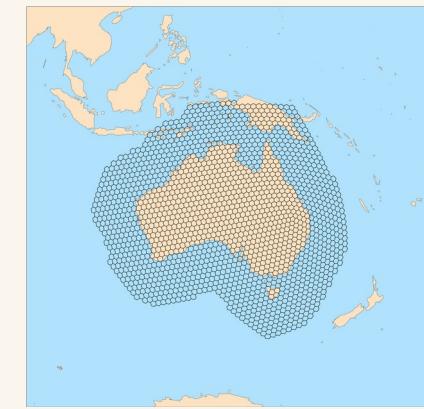
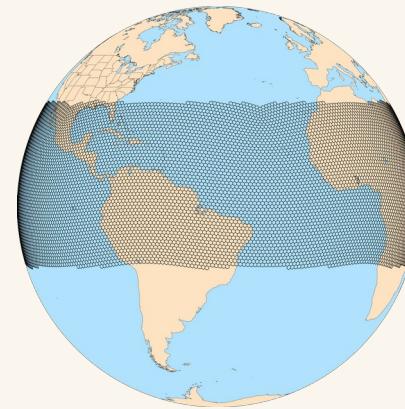
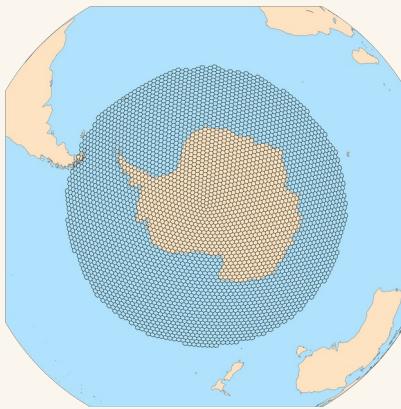


- The key point is that subsetting mesh is computational trivial, while generating a new mesh is not!

Creating limited-area meshes

MPAS-Limited-Area is a simple (~1300 lines) Python tool

- The Python NumPy, and NetCDF4 modules are required
- A “parent” mesh and a region definition file are the only inputs



Various region types are supported for defining regions: circles, ellipses, channels, and general polygons

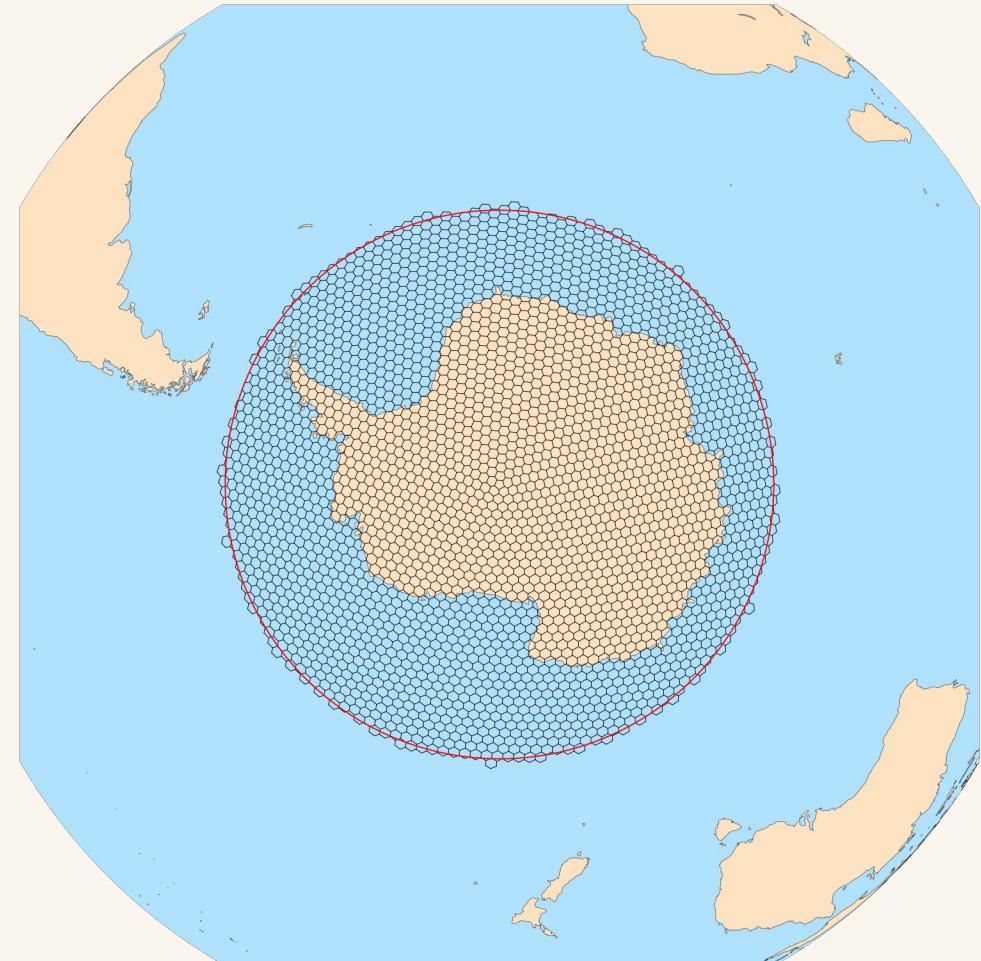
- With some Python knowledge, adding new region types should be easy

<https://github.com/MPAS-Dev/MPAS-Limited-Area>

Creating limited-area meshes: circular region

For circular regions, the region definition looks like the following

```
Name: Antarctic  
Type: circle  
Point: -90.0, 0.0  
radius: 3300
```

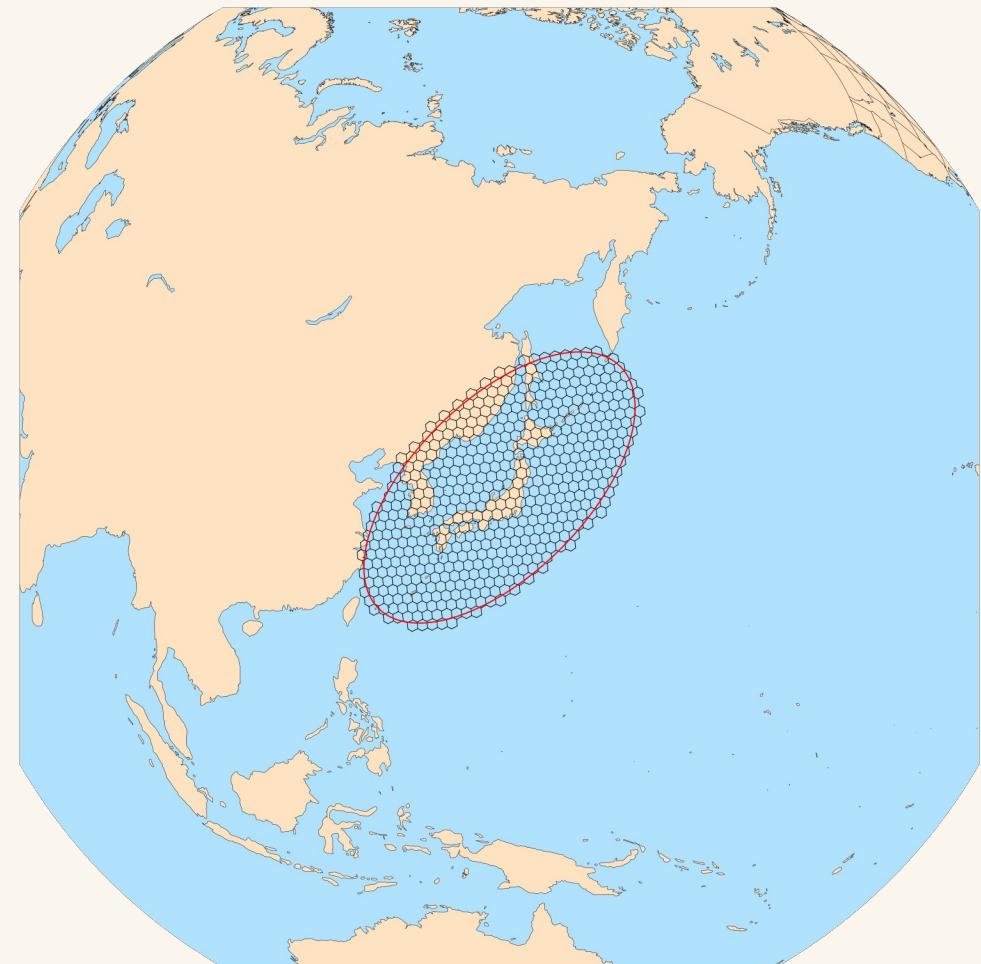


"Point" gives the latitude and longitude at the center of the circle, and "radius" gives the radius in km

Creating limited-area meshes: elliptical region

For elliptical regions, the region definition looks like the following

```
Name: Japan  
Type: ellipse  
Point: 38.0, 138.0  
Semi-major-axis: 2000000  
Semi-minor-axis: 1000000  
Orientation-angle: 45
```

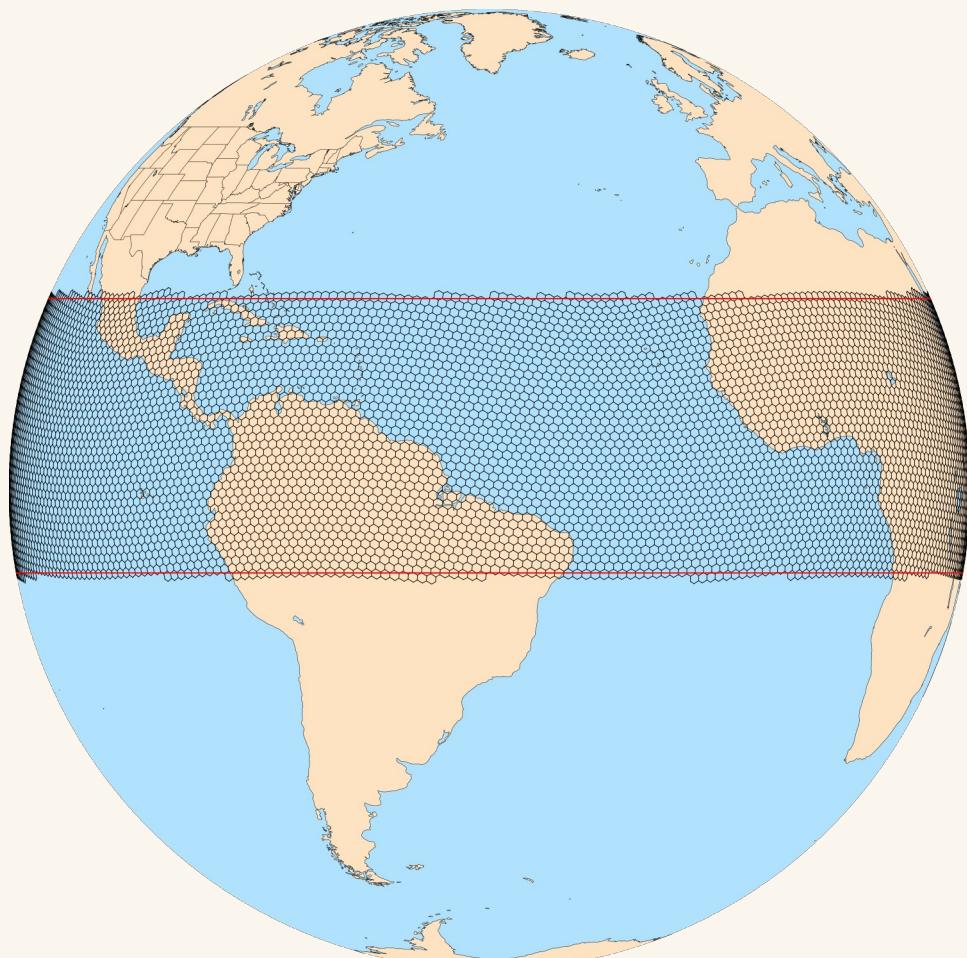


"Point" gives the latitude and longitude at the center of the ellipse, "Semi-major-axis" and "Semi-minor-axis" are in meters, and "Orientation-angle" gives the rotation of the axes of the ellipse

Creating limited-area meshes: channel region

For channel regions, the region definition looks like the following

```
Name: Tropics  
Type: channel  
ulat: 23.4  
llat: -10.0
```

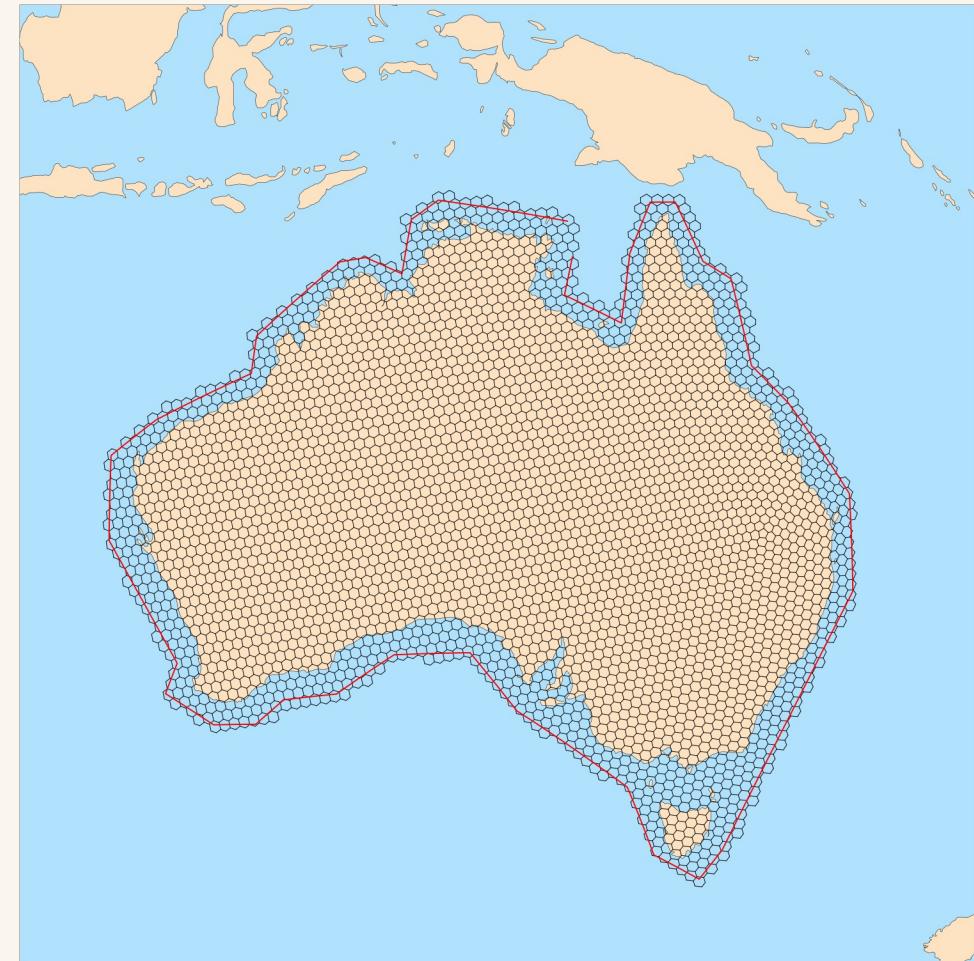


"ulat" gives the upper latitude of the channel, and "llat" gives the lower latitude of the channel

Creating limited-area meshes: polygon region

For polygon regions, the region definition looks like the following

```
Name: Australia  
Type: Custom  
Point: -24.0, 134.0  
-11.36, 137.50  
-10.27, 130.85  
-11.24, 129.46  
...  
-15.17, 137.40  
-13.20, 137.78
```

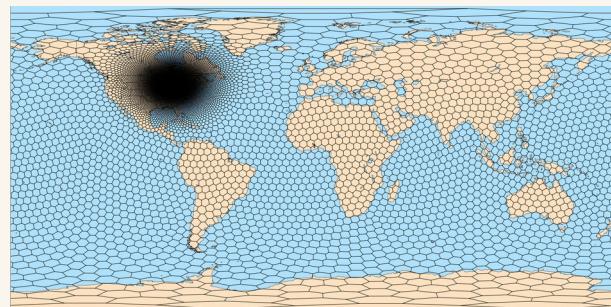
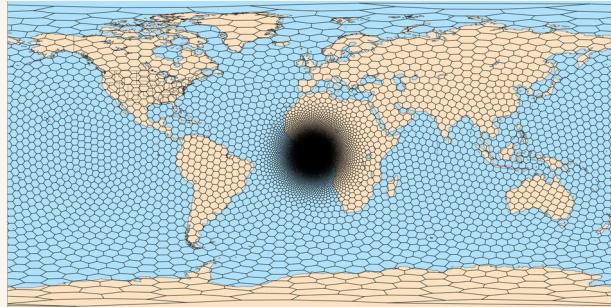


"Point" gives the latitude and longitude of a point that is interior to the polygon, and it is followed by a list of latitude, longitude boundary points

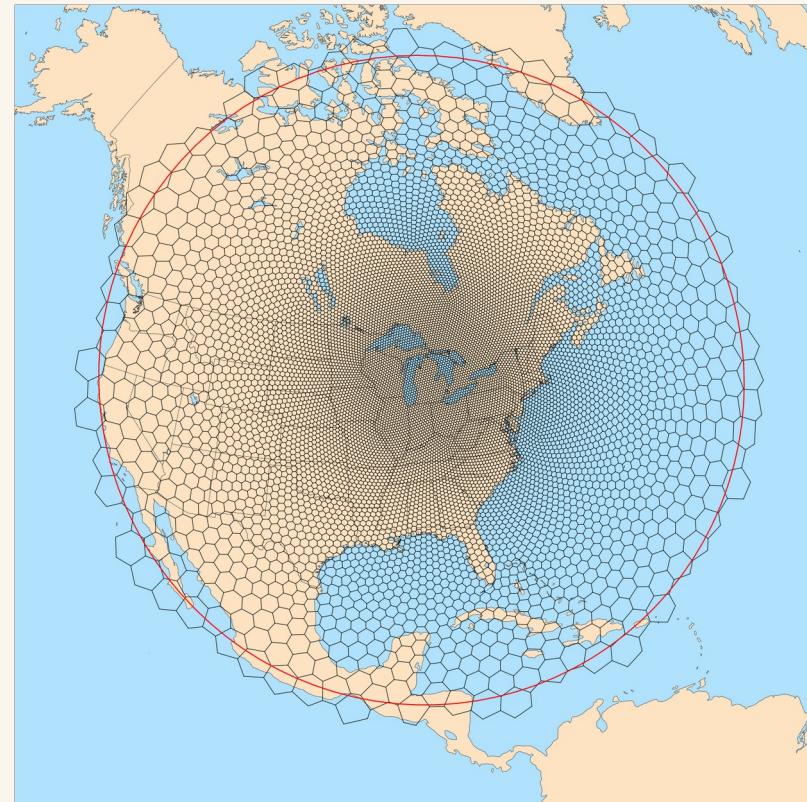
Creating limited-area meshes: refinement

Creating limited-area meshes from variable-resolution “parent” meshes works equally well...

- 1) Rotate the refinement to a region of interest using the *grid_rotate* tool described earlier

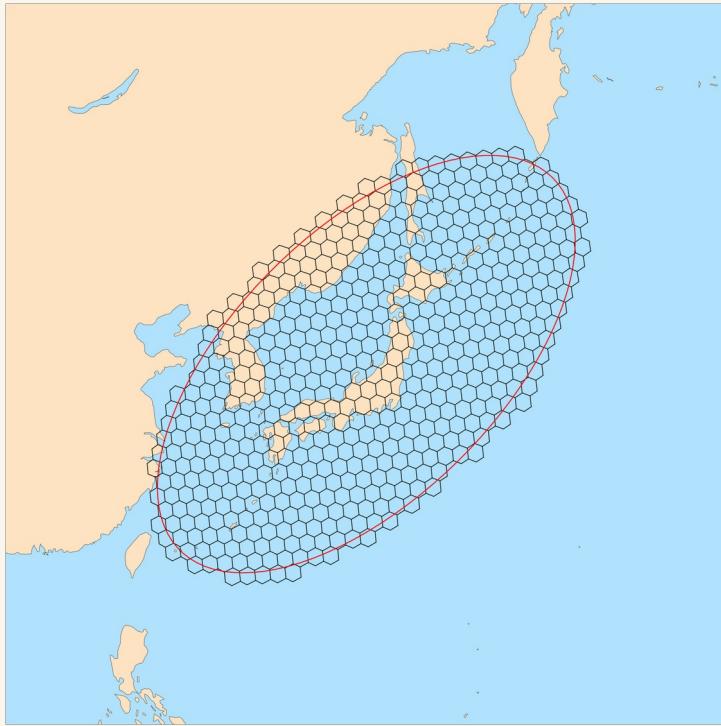


- 2) Extract a limited-area mesh using MPAS-Limited-Area

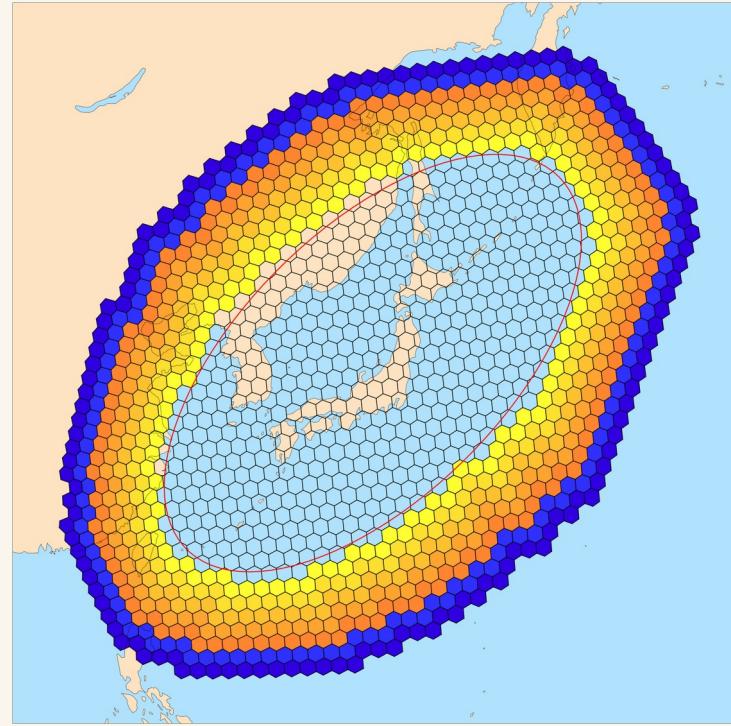


Creating limited-area meshes: boundary cells

After cells inside the region have been identified, layers of *relaxation* and *specified* cells are added



Above: An elliptical region (red) with cells identified as being in the region



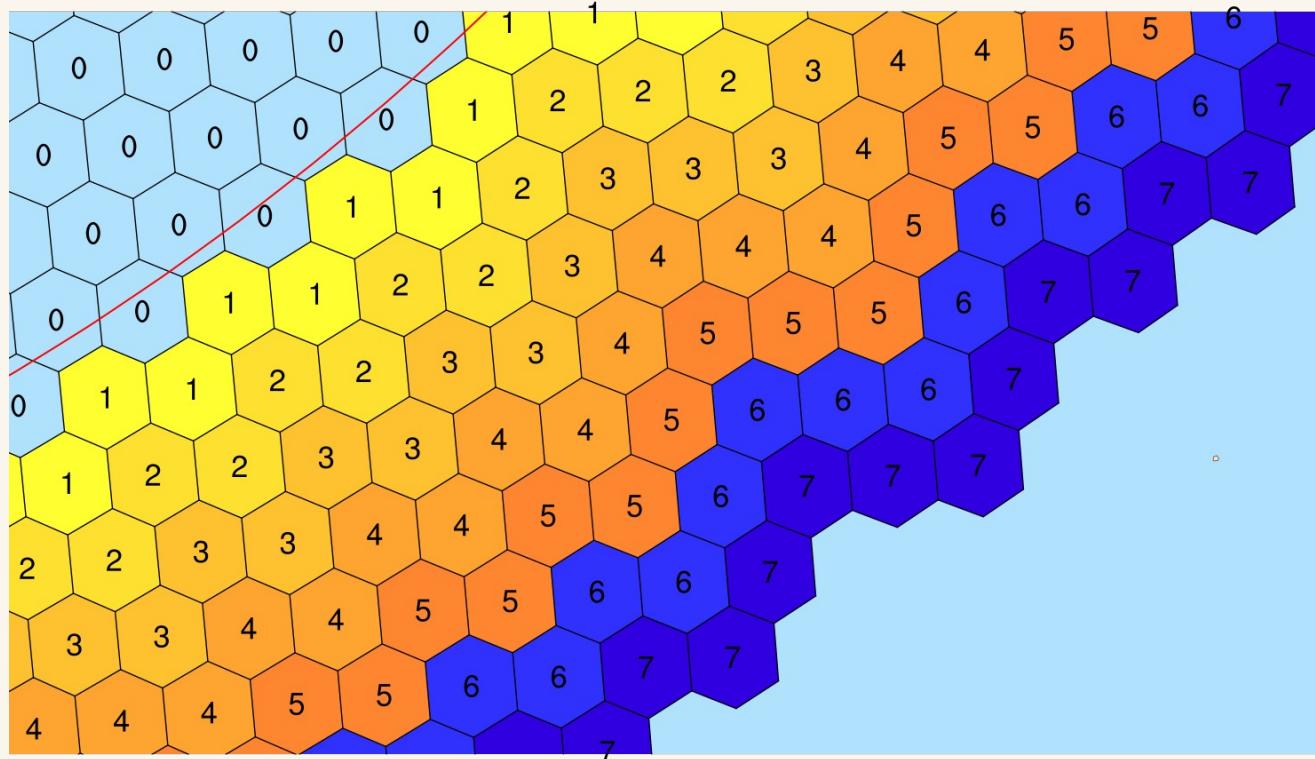
Above: Layers of relaxation zone cells (yellow-orange) and layers of specified zone cells (blue-purple) are added

Creating limited-area meshes: boundary cells

In MPAS v8.2, we have

- Five layers of relaxation-zone cells
 - Two layers of specified-zone cells

An integer field, `bdyMaskCell`, identifies boundary cell types in the regional mesh file

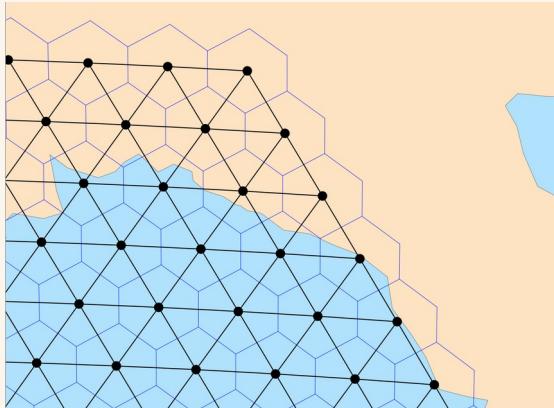


*Left: Values of the
bdyMaskCell field at
the lateral boundary*

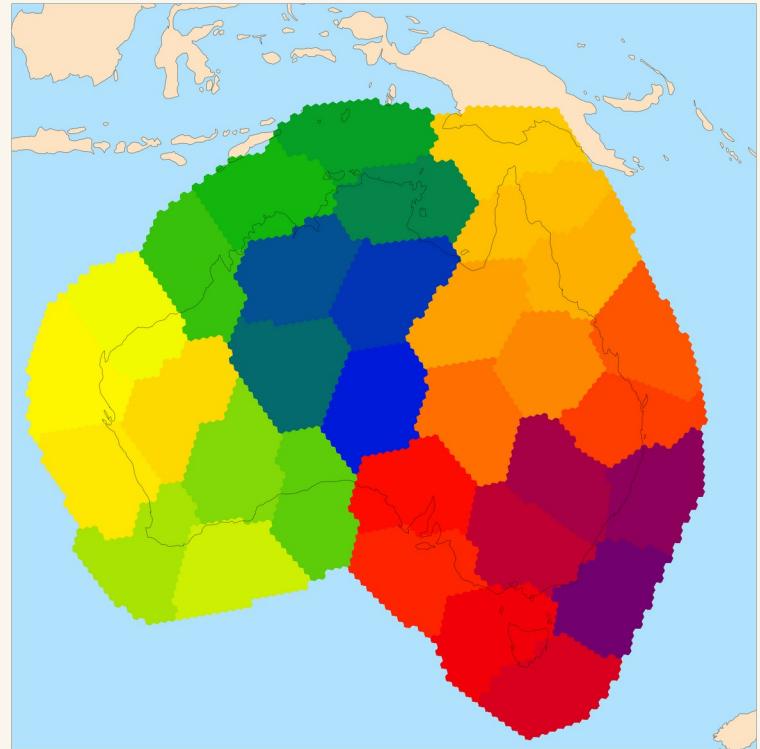
Creating limited-area meshes: partitioning

For newly created limited-area meshes, one must partition the mesh for parallel execution

MPAS-Limited-Area writes not only the netCDF mesh file, but also a *graph.info* file



Above: An illustration of the mesh connectivity information contained in a graph.info file



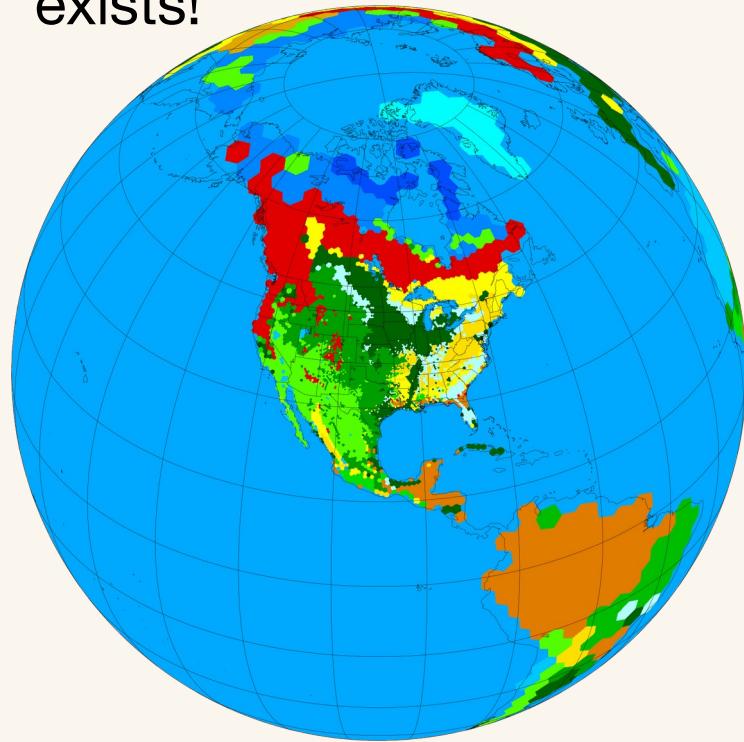
Above: Cells in a regional mesh colored according to their partition

See Section 4.1 in the User's Guide

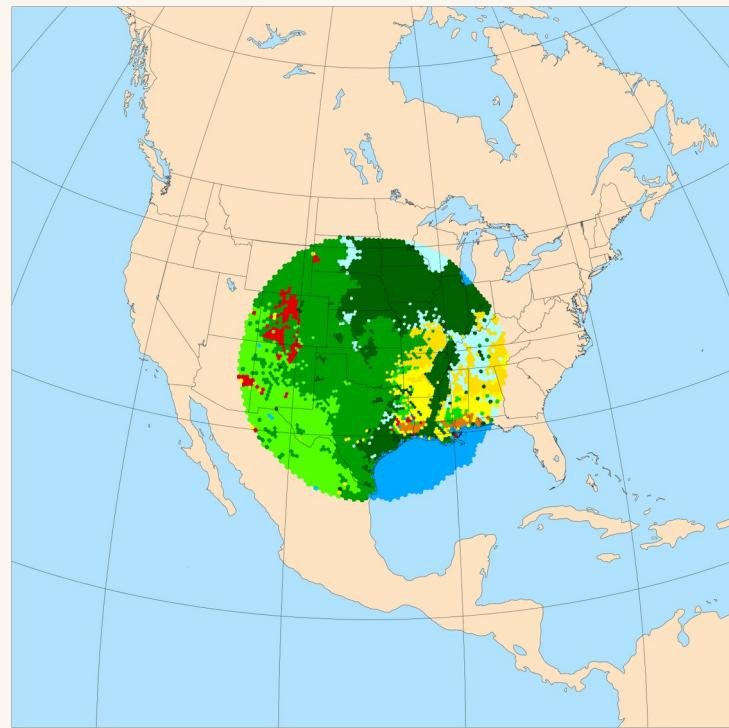
Creating limited-area meshes: static fields

If no rotation needs to be applied, the MPAS-Limited-Area tool can also subset “static” files

- This can save time, e.g., if a global, uniform static file already exists!



Above: A global, variable-resolution static file that took ~34 minutes to produce



Above: A limited-area subset of the static file that took <5 seconds to subset

Regional ICs

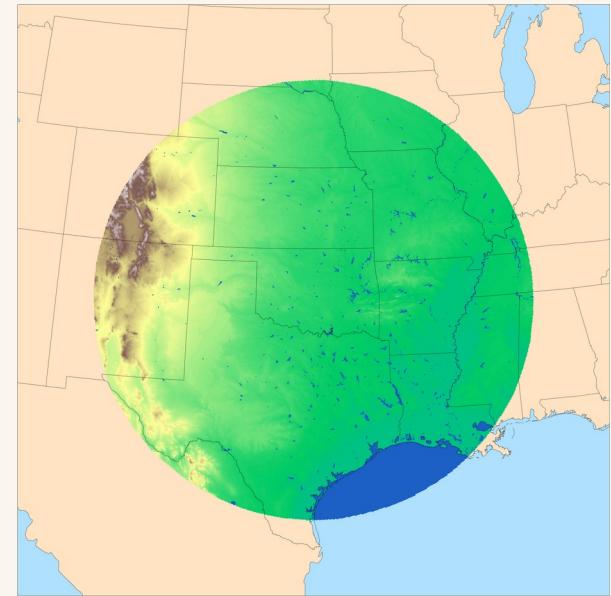
Generating limited-area initial conditions works exactly as for global initial conditions, with one exception:

The terrain height in boundary cells is generally averaged with the terrain height from the first-guess dataset

```
&vertical_grid
    config_ztop = 30000.0
    config_nsmtterrain = 1
    config_smooth_surfaces = true
    config_dzmin = 0.3
    config_nsm = 30
    config_tc_vertical_grid = true
    config_blend_bdy_terrain = true
/

```

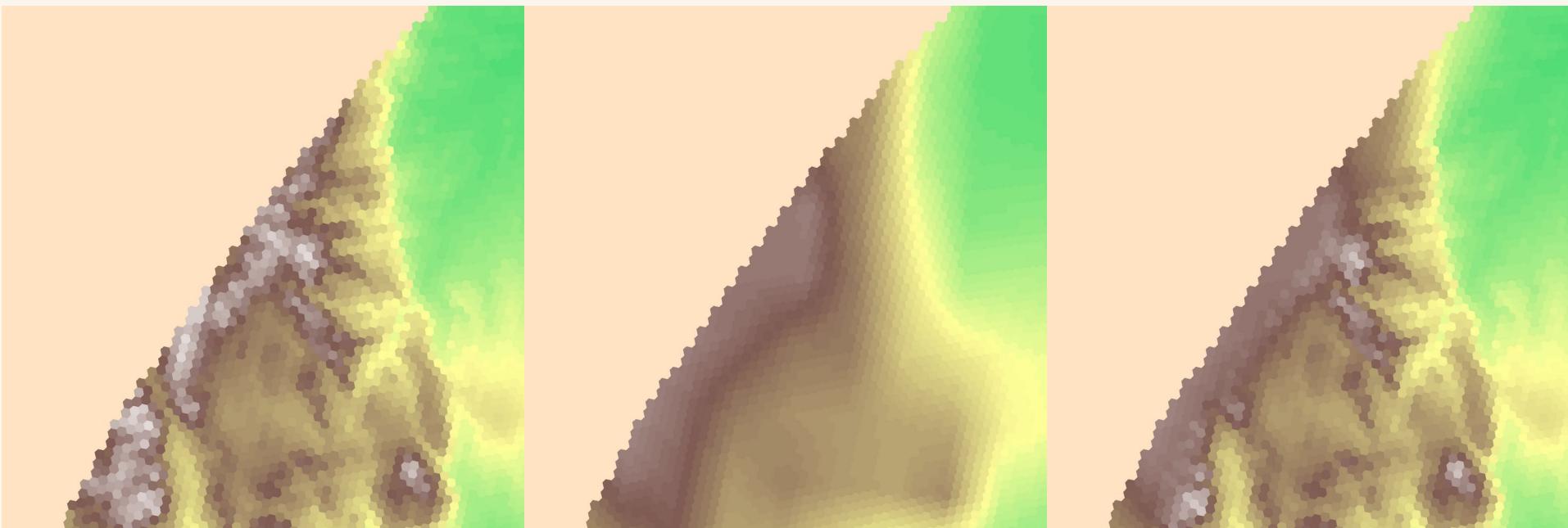
Above: When `config_vertical_grid=true`,
`config_blend_bdy_terrain` should be ‘true’ as well



Above: The terrain field in a ~3-km regional mesh

Regional ICs: blending boundary terrain

The `config_blend_bdy_terrain` option only affects terrain in the boundary cells (where `bdyMaskCell > 0`)



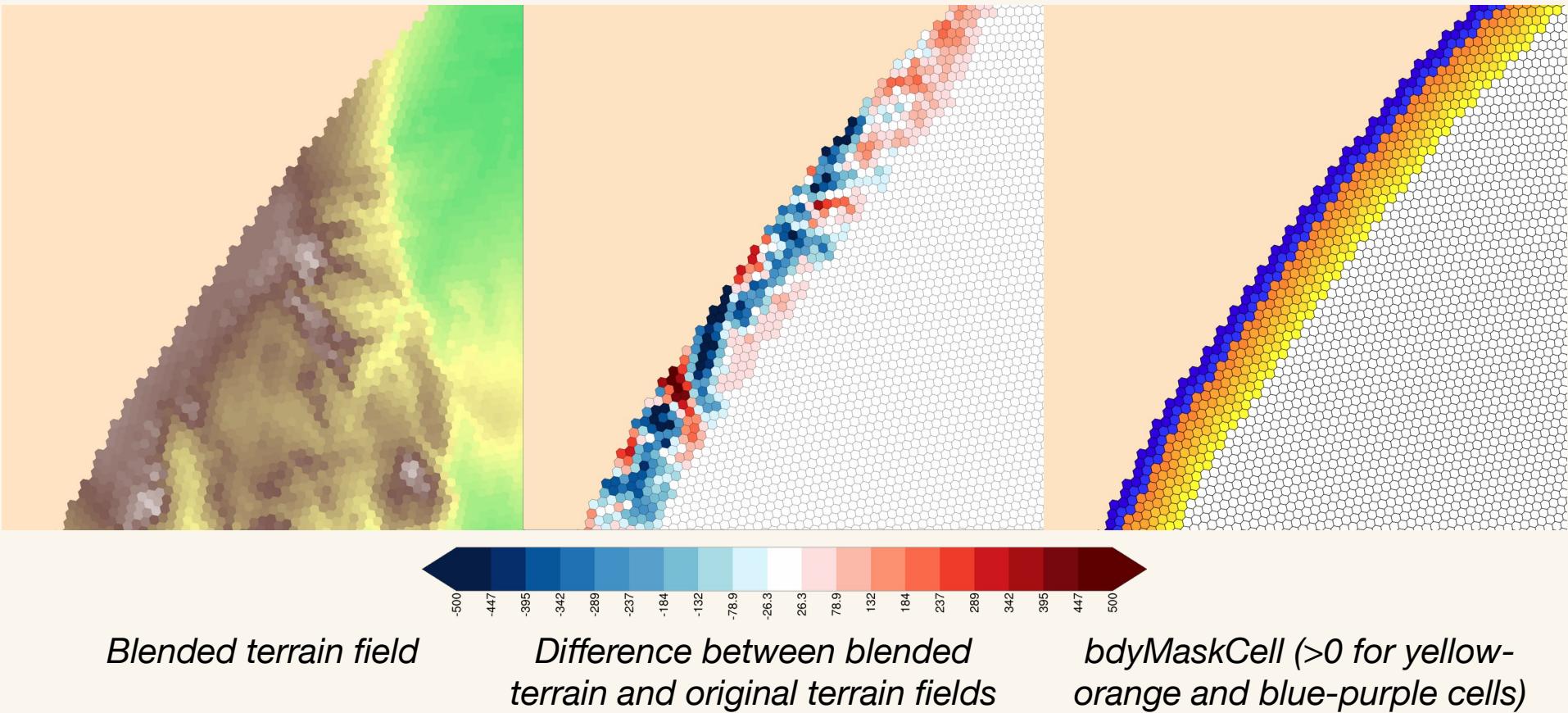
Terrain field from 3-km static file, interpolated directly from GMTED2010

0.25-deg GFS terrain field interpolated to 3-km mesh

Blended terrain field used in the generation of vertical coordinate surfaces

Regional ICs: blending boundary terrain

The `config_blend_bdy_terrain` option only affects terrain in the boundary cells (where `bdyMaskCell > 0`)



Generating regional LBCs

Lateral Boundary Conditions (LBCs) for limited-area simulations are created by the *init_atmosphere* core with “init case” 9:

```
&nhyd_model
    config_init_case = 9
    config_start_time = '2019-08-31_00:00:00'
    config_stop_time = '2019-09-03_00:00:00'
/
&data_sources
    config_met_prefix = 'GFS'
    config_fg_interval = 10800
    config_use_specchumd = false
/
&interpolation_control
    config_extrap_airtemp = 'lapse-rate'
/
```

Left: The key namelist options to be set when generating lateral boundary conditions with the init_atmosphere core

See Section 8.2 in the User’s Guide

Generating regional LBCs

The “input” stream must be set up to read from a file with vertical grid information

- Typically, this done by setting the `filename_template` to the name of the initial conditions file

```
<immutable_stream name="input"  
                  type="input"  
                  filename_template="CONUS.init.nc"  
                  input_interval="initial_only" />
```

Generating regional LBCs

The “output_interval” for the “lbc” stream must also be set in the `streams.init_atmosphere` file

- This interval must match “config_fg_interval” from the `namelist.init_atmosphere` file

```
<immutable_stream name="lbc"  
                  type="output"  
                  filename_template="lbc.$Y-$M-$D_$h.$m.$s.nc"  
                  filename_interval="output_interval"  
                  packages="lbcs"  
                  output_interval="3:00:00" />
```

Above: A typical “lbc” stream definition for the `init_atmosphere` core. Besides the `output_interval`, one may also change the `filename_template`.

What's in an LBC file?

The individual LBC netCDF files contain *full, uncoupled fields* of:

- Potential temperature (`lbc_theta`)
- Dry density (`lbc_rho`)
- Normal component of horizontal winds on edges (`lbc_u`)
- Vertical velocity on vertical cell interfaces (`lbc_w`)
- Scalars (`lbc_qv`, `lbc_qc`, `lbc_qr`, etc.)
- Valid time of fields (`xtime`)

Applying LBCs during the simulation

When running the atmosphere core (i.e., the model itself), enable the enforcement of LBCs in the `namelist.atmosphere` file:

```
&limited_area
    config_apply_lbccs = true
/
```

Above: The only namelist option needed to “activate” a regional simulation in MPAS v8.2

If `config_apply_lbccs` is not set to true for a regional simulation, the model will stop with the following error:

```
ERROR: Boundary cells found in the bdyMaskCell field, but config_apply_lbccs =
false.
ERROR: Please ensure that config_apply_lbccs = true for limited-area simulations.
ERROR: Please correct issues with the model input fields and/or namelist.
```

Applying LBCs during the simulation

Additionally, set the “input_interval” for the “lbc_in” stream in the streams.atmosphere file

- The interval *must not be higher in frequency* than the interval at which LBC files were produced!

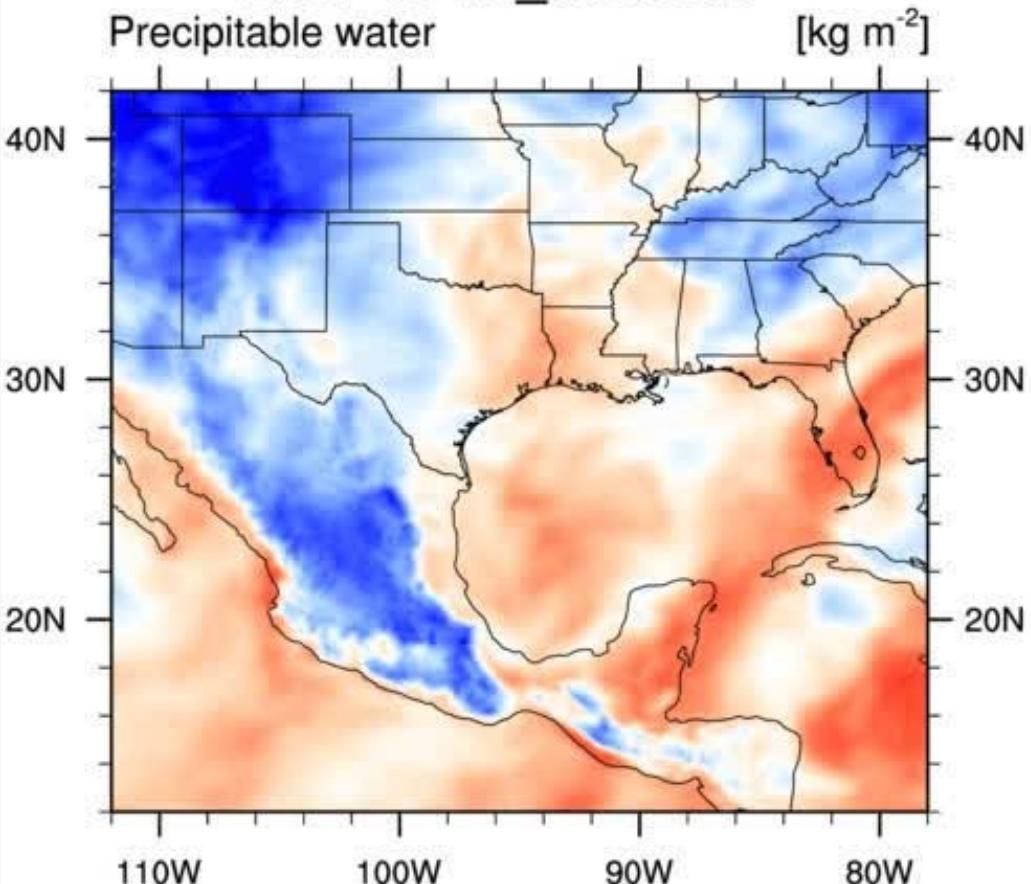
```
<immutable_stream name="lbc_in"
                  type="input"
                  filename_template="lbc.$Y-$M-$D_$h.$m.$s.nc"
                  filename_interval="input_interval"
                  packages="limited_area"
                  input_interval="3:00:00" />
```

If the “input_interval” is smaller than the interval of LBC files, the model will stop with an error like:

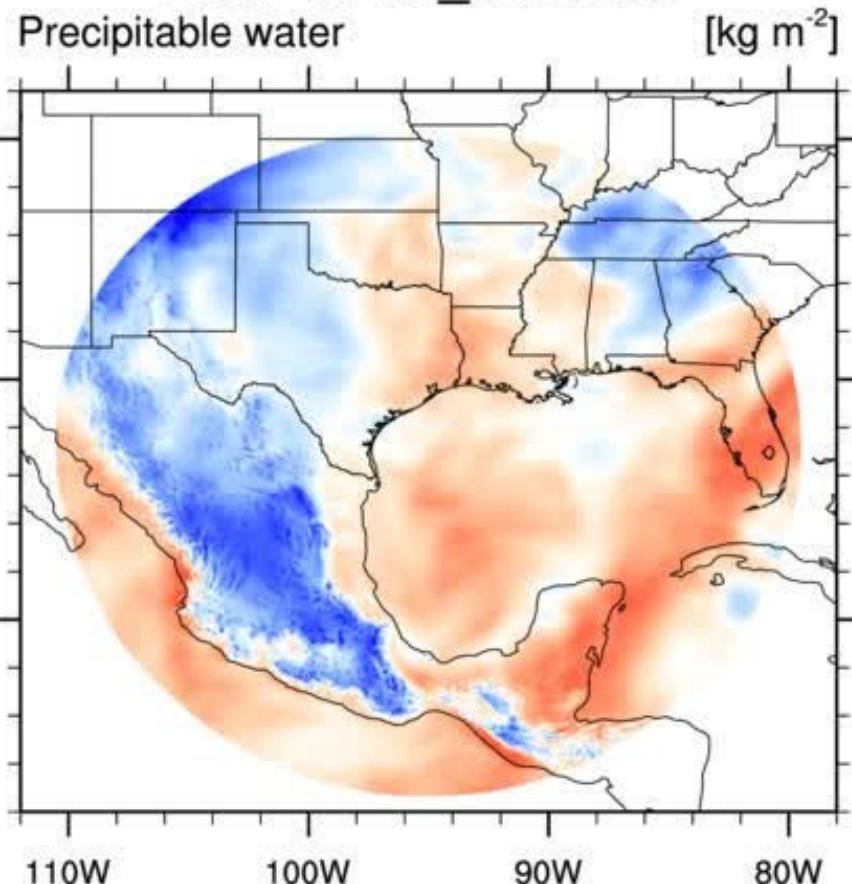
```
ERROR: Could not read from 'lbc_in' stream after the current date to update lateral
boundary tendencies
ERROR: Failed to process LBC data at next time after 2019-08-31_00:00:00
```

Example simulation: Hurricane Harvey

MPAS 60-15km global
2017-08-21_00:00:00



MPAS 3-km regional
2017-08-21_00:00:00



Above: Animation of the precipitable water field from a 6-day variable-resolution, global simulation alongside a 6-day regional simulation

Post-processing concerns

Along the lateral boundaries of meshes cells, edges, and vertices will be missing “neighbors”

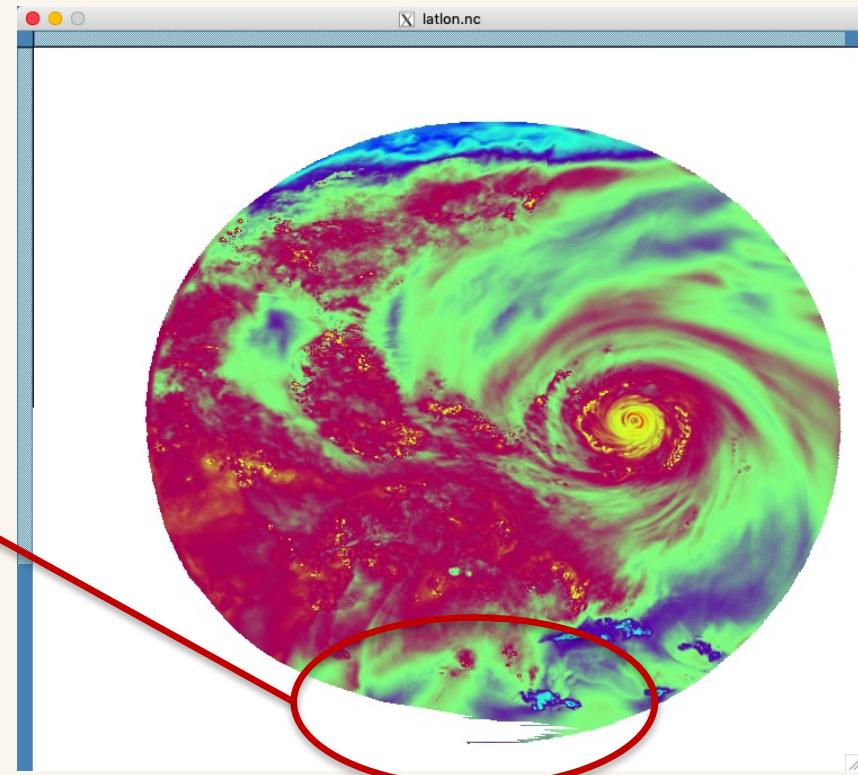
- If using the `cellsOnCell`, `edgesOnVertex`, `cellsOnEdge`, or `edgesOnEdge` fields, remember that a neighbor index of 0 indicates a non-existent neighbor
- This may be important particularly when applying horizontal operators (e.g., smoothing) to model input or output fields

Post-processing concerns

As of today, the `convert_mpas` program doesn't handle limited-area meshes very well...

- “Smearing” or “streaking” is almost certainly an interpolation artifact and not a problem in your model fields
- We expect to fix this soon!

These are interpolation artifacts produced by the `convert_mpas` program as of this tutorial...



Summary

Running limited-area simulations is only slightly more difficult than running a global simulation!

- 1) Create a subset of an existing mesh with the MPAS-Limited-Area tool
- 2) Generate initial conditions using “init case” 7 as usual, but set

```
&vertical_grid
    config_blend_bdy_terrain = true
/
```

- 3) Generate LBCs using “init case” 9
- 4) Run the model as usual, but set

```
&lbc
    config_apply_lbc = true
/
```

and set the input interval for the “lbc_in” stream in the streams.atmosphere file