Post-processing and visualizing MPAS-Atmosphere output

MPAS
Model for Prediction Across Scales

Post-processing overview

Now that you've run MPAS-Atmosphere, what do you do with the output?

```
diag.2010-10-23_00.00.00.nc   history.2010-10-23_00.00.00.nc
diag.2010-10-23_03.00.00.nc   history.2010-10-23_06.00.00.nc
diag.2010-10-23_06.00.00.nc   history.2010-10-23_12.00.00.nc
diag.2010-10-23_09.00.00.nc   history.2010-10-23_18.00.00.nc
diag.2010-10-23_12.00.00.nc   history.2010-10-24_00.00.00.nc
diag.2010-10-23_15.00.00.nc
diag.2010-10-23_18.00.00.nc   restart.2010-10-24_00.00.00.nc
diag.2010-10-23_21.00.00.nc
diag.2010-10-24_00.00.00.nc
```

Above: Typical output files from an MPAS-Atmosphere simulation

1. Interpolate to a regular lat-lon grid
2. Visualize output directly with NCL

What's in these output files, anyway?

We'll say more in the next talk how to adjust the contents of the standard model output files.

By default, the *history* files contain:

q_v , q_c , q_r , …
theta
zonal, meridional wind
vertical velocity
full pressure
dry density
accumulated rain (cumulus and microphysics)
soil moisture, soil temperature
(various other fields)
Full mesh information (vertical and horizontal)

What's in these output files, anyway?

We'll say more tomorrow about the framework for adding new diagnostics to MPAS-A.

By default, the *diag* files contain:

RH, T, height, winds @ 200, 250, 500, 700, 850, 925 hPa

CAPE, CIN, LCL, LFC, updraft helicity

U10, V10, T2, Q2

Simulated radar reflectivity

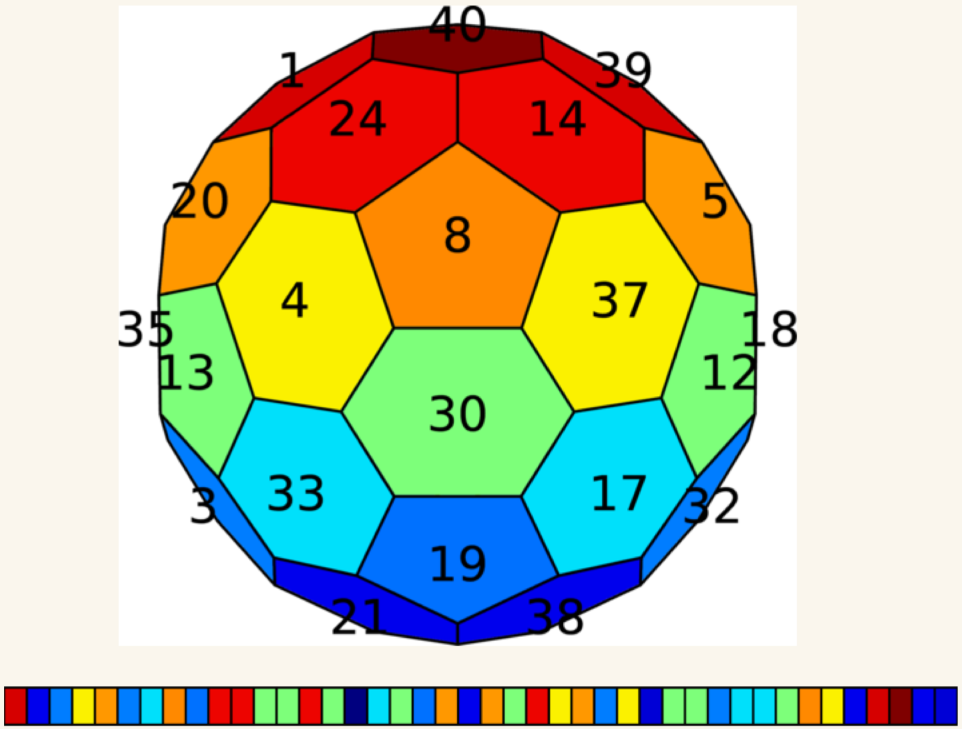
PMSL

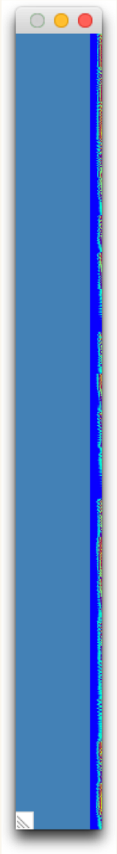
Surface, 1km AGL, 6km AGL winds

(various other 2-d fields)

Interpolating output to a regular lat-lon grid

MPAS stores 2-d horizontal fields in 1-d arrays; 3-d fields are 2-d arrays with the vertical (structured) dimension innermost, e.g., `qv(nVertLevels,nCells)`.



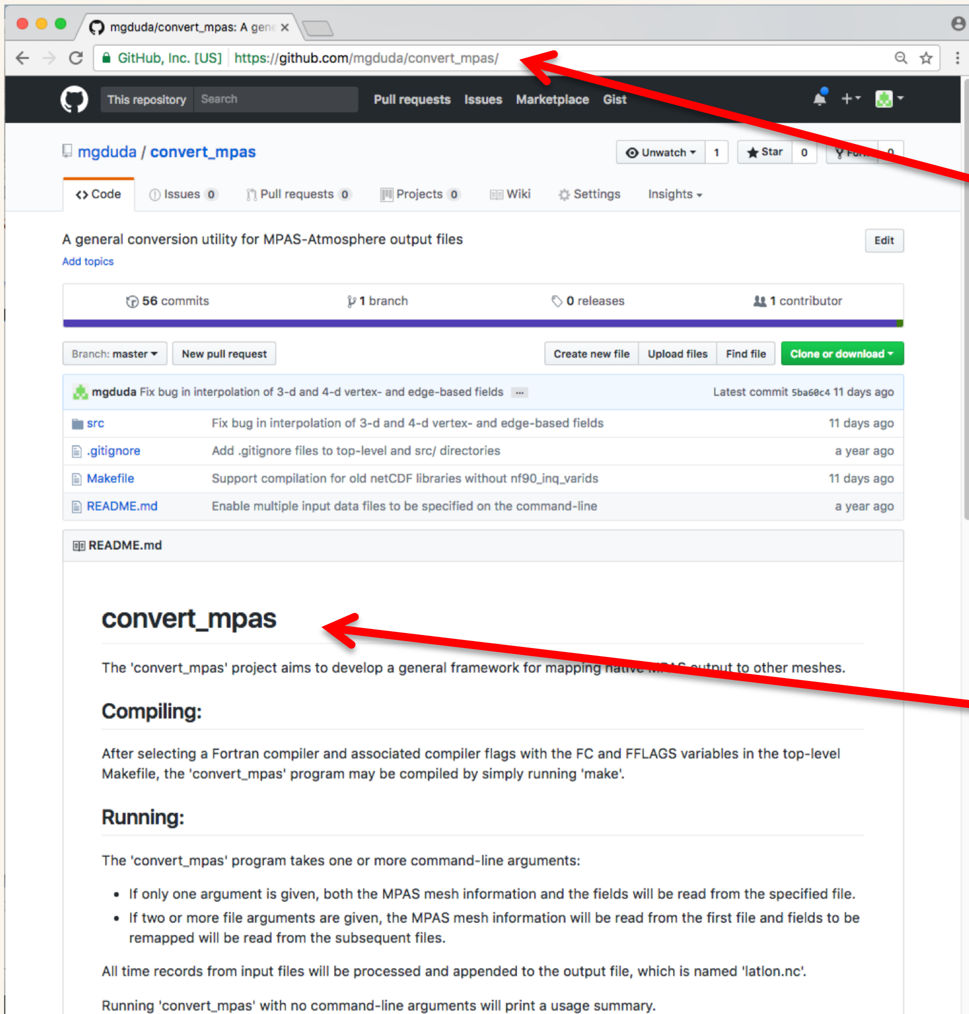


Left: Can you spot Hurricane Matthew in the MPAS 'qv' field seen in ncview?

Using 'ncview' directly on MPAS netCDF files doesn't work well...

Interpolating output to a regular lat-lon grid

The ‘convert_mpas’ tool can quickly interpolate MPAS files to a specified lat-lon grid



Source code can be obtained from https://github.com/mgduda/convert_mpas/

The README.md file summarizes the key details of compiling and running

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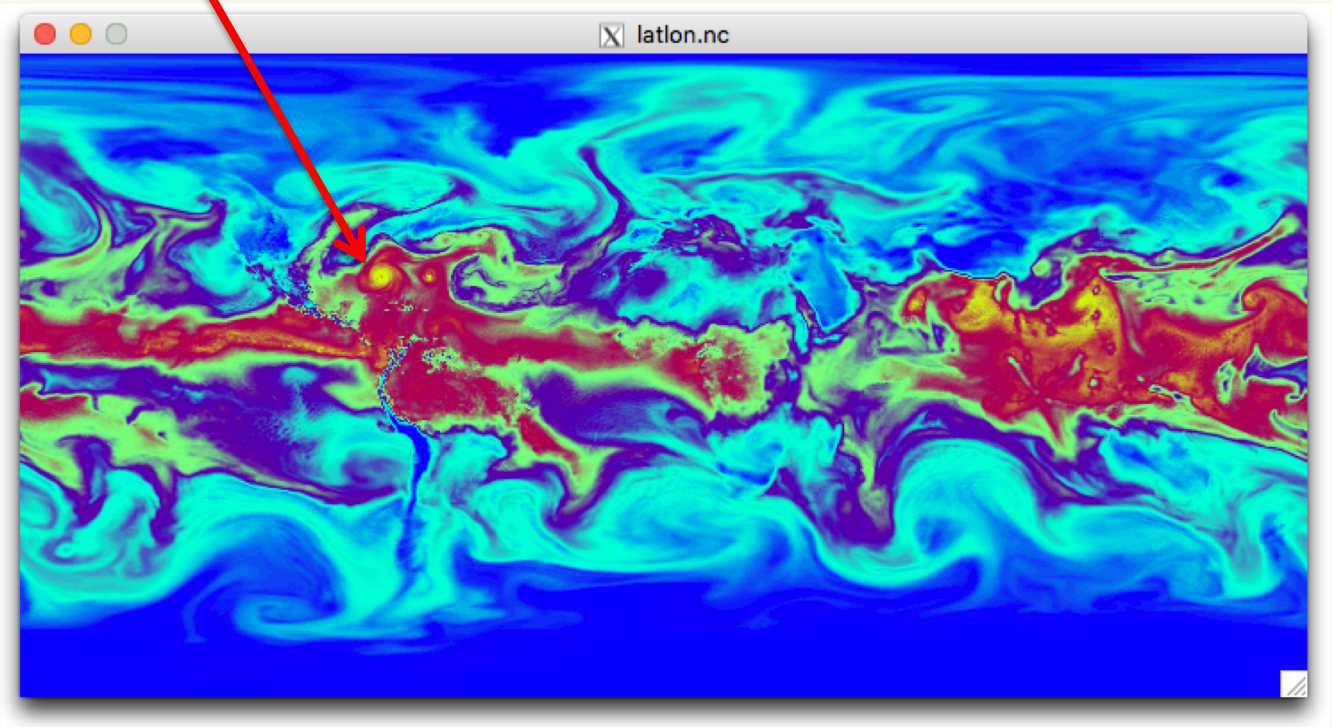
The *convert_mpas* utility

Basic usage of ‘convert_mpas’:

- If just one argument is given, it specifies an MPAS file that has mesh information as well as fields to be interpolated
  - Ex: `convert_mpas x1.40962.init.nc`
- If more than one argument is given:
  - First argument is used *only to obtain mesh information*
  - All remaining arguments contain fields to be interpolated
  - Ex: `convert_mpas x1.40962.grid.nc diag*nc`
  - Ex: `convert_mpas history.2017-06-16_00.nc history*nc`
- Output file is always called `latlon.nc`
  - Probably best to remove this file before re-running ‘convert_mpas’
- Default output grid is 0.5-degree lat-lon grid

The *convert_mpas* utility

Now we can see Hurricane Matthew in our MPAS output

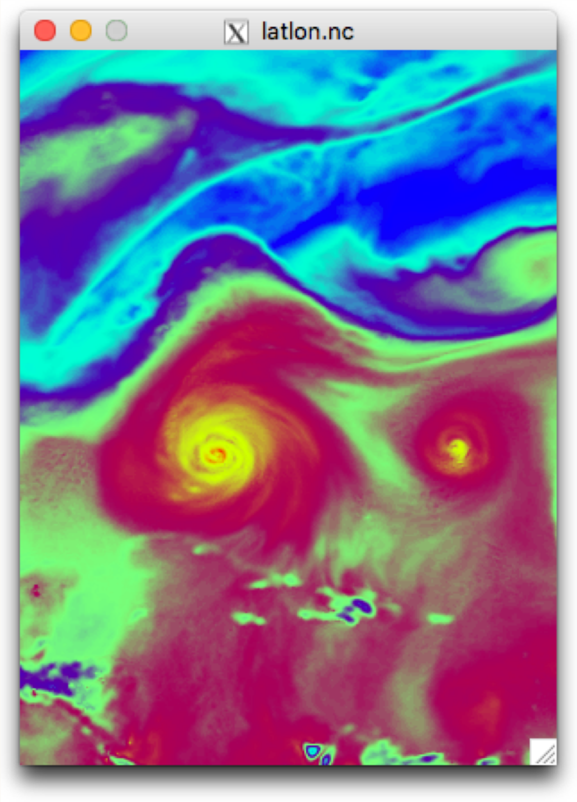


How can we interpolate to just the region of interest and at higher resolution?

The *convert_mpas* utility

A text file named `target_domain` in your working directory may be used to specify parameters of the lat-lon grid:

```
startlat=10.0
endlat=50.0
startlon=-90.0
endlon=-60
nlat=400
nlon=300
```



A text file named `include_fields` in your working directory may also be used to list the fields that should be interpolated

Plotting output directly with NCL

To plot fields directly from the native MPAS mesh, try NCL, Python, Matlab, etc.

MPAS

https://mpas-dev.github.io

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MPAS Atmosphere 7.0 was released on 8 June 2019.

***As of September 2018**, official support for MPAS-Atmosphere has migrated from the Google Groups forum to a web forum hosted by NCAR's Mesoscale and Microscale Meteorology. Users are encouraged to post any questions related to building and running MPAS-Atmosphere to the appropriate sub-topic in the MPAS-Atmosphere forum at http://forum.mmm.ucar.edu/phpBB3/. Posting to the forum requires the creation of an account, but no account is needed to browse the forum.*

A variable resolution MPAS Voronoi mesh

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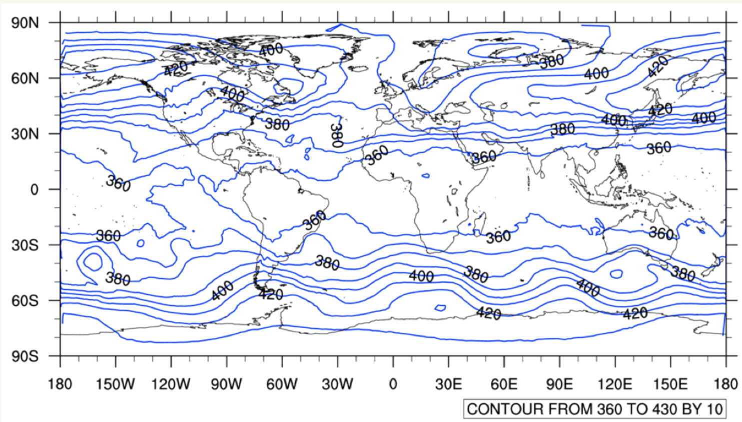
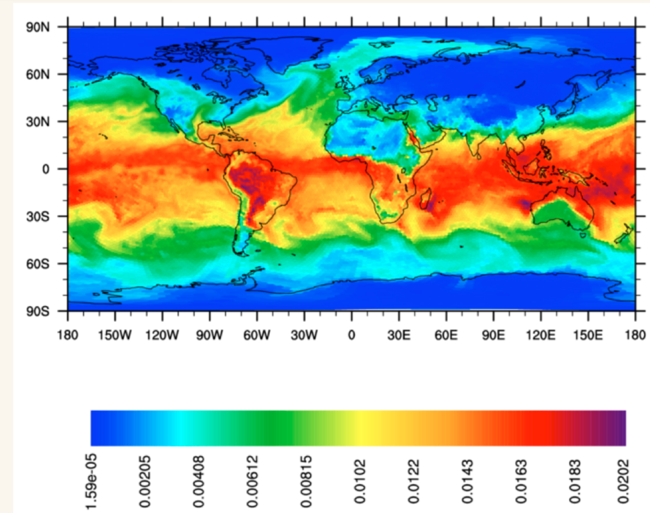
The MPAS-Atmosphere download page contains a collection of example NCL scripts

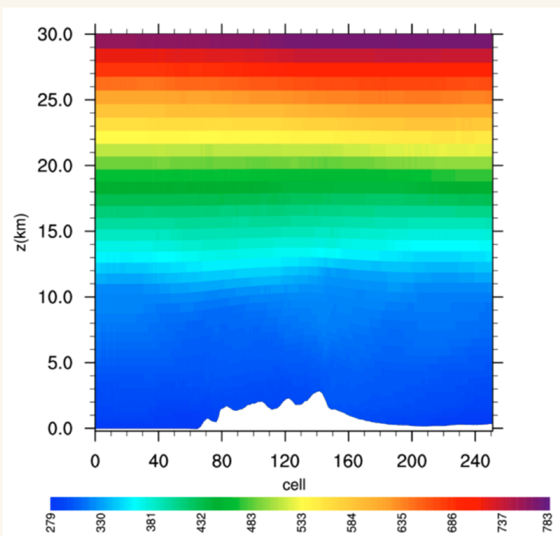
Example NCL scripts from the MPAS-Atmosphere downloads page



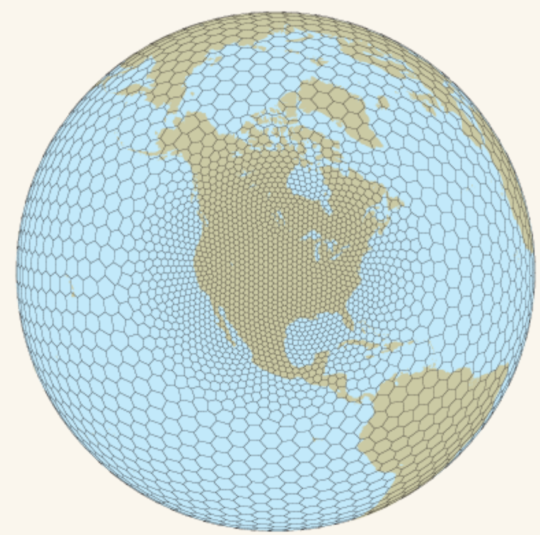
Contours – simple or color-filled



Individual grid cells as a color-filled polygons



Vertical cross-sections with specified endpoints



Voronoi mesh against a map background

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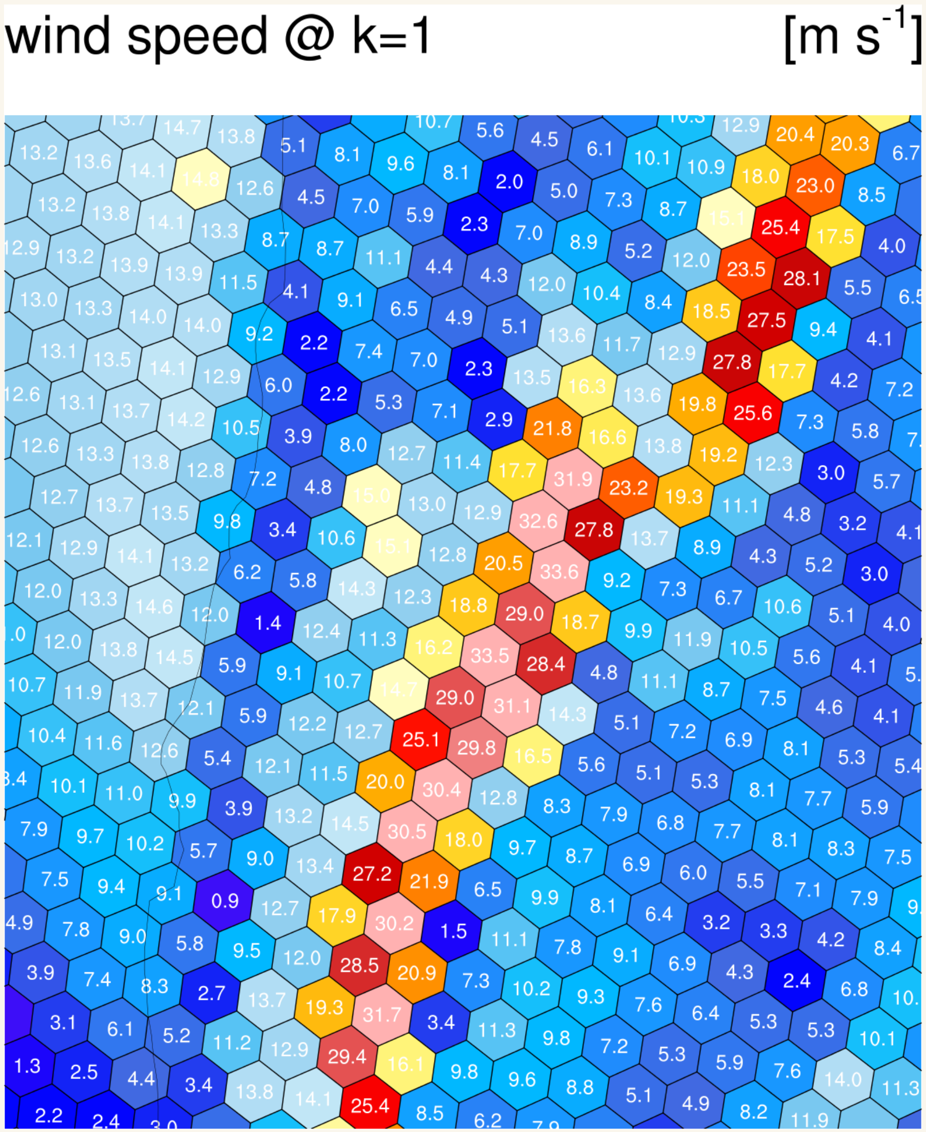
Plotting values on cells is also possible



Given *latVertex*, *lonVertex*, *verticesOnCell*, and *nEdgesOnCell*, we can plot each MPAS Voronoi cell as a color-filled polygon

- Overlaying numeric values can be quite helpful in debugging

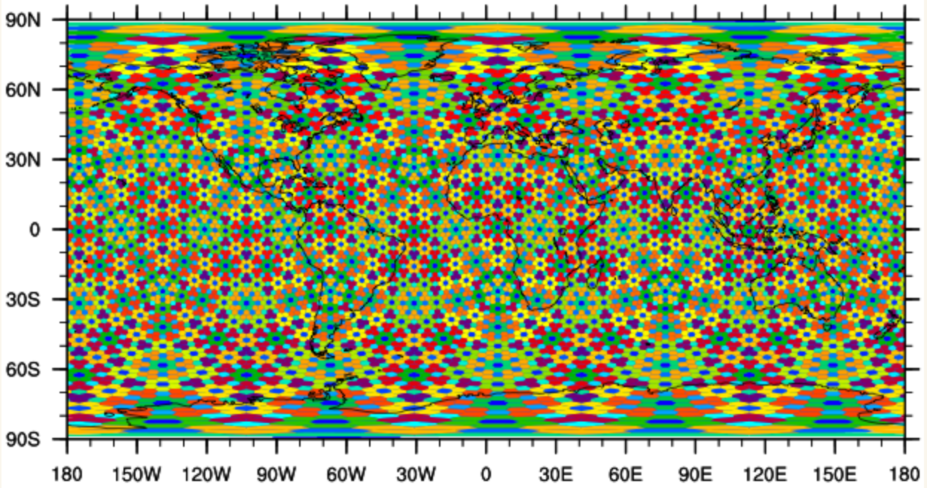
Making use of the MPAS mesh representation to more efficiently work with MPAS output

In many limited-area models, finding the nearest grid cell to a given (lat,lon) location is a constant-time operation:

1. Using the map projection equations for the model grid projection, compute the real-valued (x,y) coordinates of the (lat,lon) location
2. Round the real-valued coordinates to the nearest integer

However, in MPAS, *there is no projection*, and the horizontal cells may be indexed in any order.

- We could just compute the distance from (lat,lon) to every cell center in the mesh and choose the nearest cell, or we could do something more efficient...



Above: Cells in the x1.10242 mesh colored according to their global index

Making use of the MPAS mesh representation to more efficiently work with MPAS output

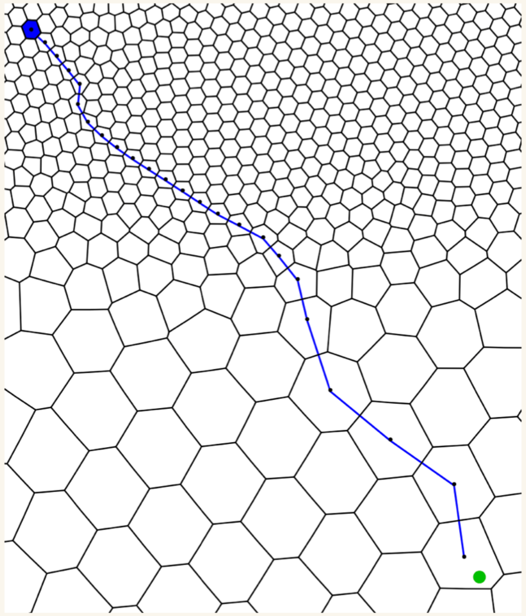
One solution would be to use search trees – perhaps a *kd*-tree – to store the cells in a mesh

- *O*(n log n) setup cost; each search takes O(log n) time, for a mesh with *n* cells

Alternatively, we can make use of the grid connectivity arrays nEdgesOnCell and cellsOnCell to navigate a path of monotonically decreasing distance to the (lat,lon) location

- No setup cost, at most $O(n^{1/2})$ cost* per search
- For repeated searches of "nearby" locations, almost constant cost!

```
C_nearest = any starting cell
C_test = NULL
do while (C_nearest ≠ C_test)
    C_test = C_nearest
    d = distance from C_test to (lat,lon)
    for i = 1 to nEdgesOnCell(C_test)
        k = cellsOnCell(i, C_test)
        d' = distance from k to (lat,lon)
        if ( d' < d )
            d = d'; C_nearest = k
```



Above: Path taken from starting cell (blue) to target location (green circle).

*At least, intuitively...

Making use of the MPAS mesh representation to more efficiently work with MPAS output

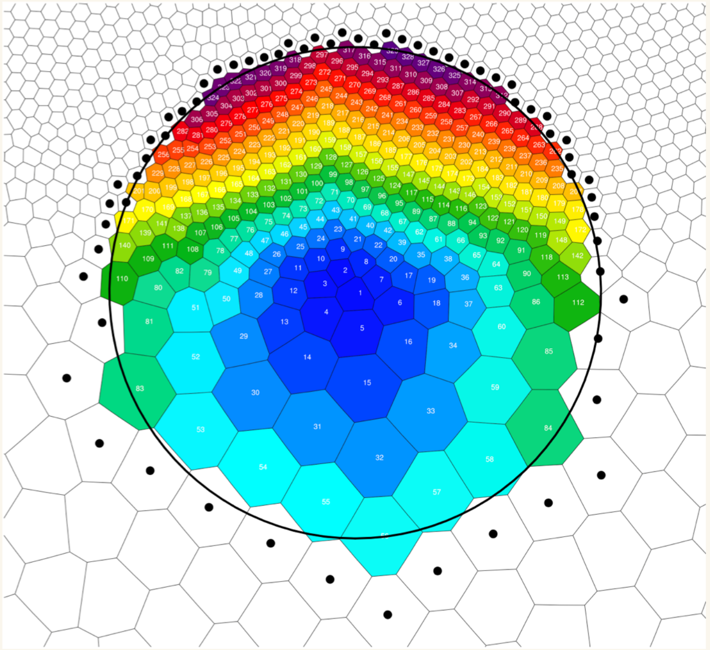
Similar to the problem of nearest grid cell, to scan all cells within a specified radius of a given (lat,lon) location, we could check all cells in the mesh...

... or we could make use of the connectivity arrays.

```
C = origin of the search
mark C as visited
insert C into the queue
do while (queue not empty)
    C = next cell from the queue

    C is within search radius, so process C

    for i = 1 to nEdgesOnCell(C)
        k = cellsOnCell(i,C)
        if ( k not visited )
            mark k as visited
            if (k within search radius)
                insert k into the queue
```

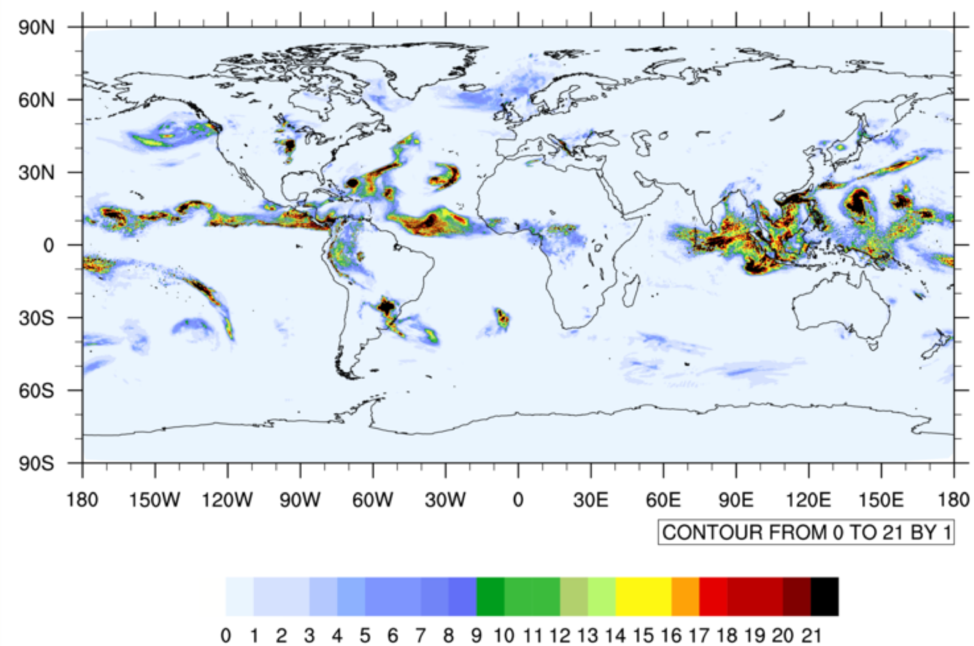


Above: Cells shaded according to the order in which they were visited by a 750-km radius search; dots indicate cells that were considered but found to be at a radius >750 km.

Important considerations for post-processing on variable-resolution meshes

Consider the computation of the daily precipitation rate on a variable-resolution MPAS mesh:

Above: An MPAS 60-15 km variable-resolution mesh with refinement over North America



Above: The accumulated total precipitation between 2016-10-14 00 UTC and 2016-10-15 00 UTC on from MPAS with the 'mesoscale_reference' physics suite.

How much can the way in which we compute the daily precipitation rate affect our results?

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An obvious conclusion, but one that's important...

Taking a simple average of the precipitation rate in all cells gives **3.43 mm/day**

```
f1 = addfile("diag.2016-10-14_00.00.00.nc","r")
f2 = addfile("diag.2016-10-15_00.00.00.nc","r")
fld = (f2->rainc(0,:) + f2->rainnc(0,:)) –
      (f1->rainc(0,:) + f1->rainnc(0,:))
fg = addfile("init.nc","r")
print(sum(fld * fg->areaCell(:)) / sum(fg->areaCell(:)))
```

Weighting the precipitation rate by cell area gives **2.93 mm/day**

In a "typical" WRF simulation with map scale factors between 0.9 and 1.1, the cell area ratio between the largest cell and the smallest is about **1.49**.

In an MPAS simulation with a variable-resolution mesh with a refinement factor of four (e.g., 60-15 km grid distance), the cell area ratio between the largest and smallest cells in the mesh is **16**!