

Post-processing and visualizing MPAS-Atmosphere output

Michael G. Duda
NCAR/MMM



Post-processing overview

Now that you've run MPAS-Atmosphere, how can you take a graphical look at 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 or Python

What's in these output files, anyway?

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)

In the "Computing new diagnostics" lecture, we'll say more about the framework for adding new diagnostics to MPAS-A.

What's in these output files, anyway?

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

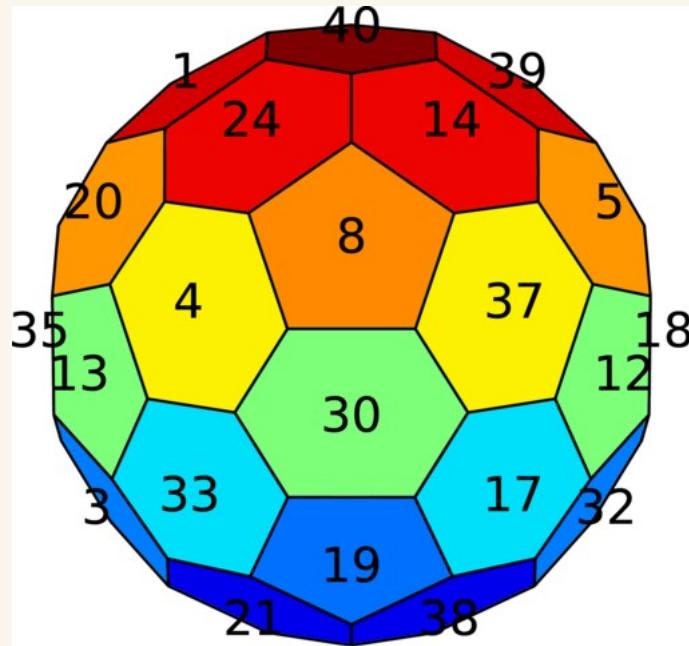
(various other fields)

Full mesh information (horizontal and vertical)

In the "Running MPAS, part 2" talk, we discussed how to modify the set of fields written to model output files using *streams*

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)`.

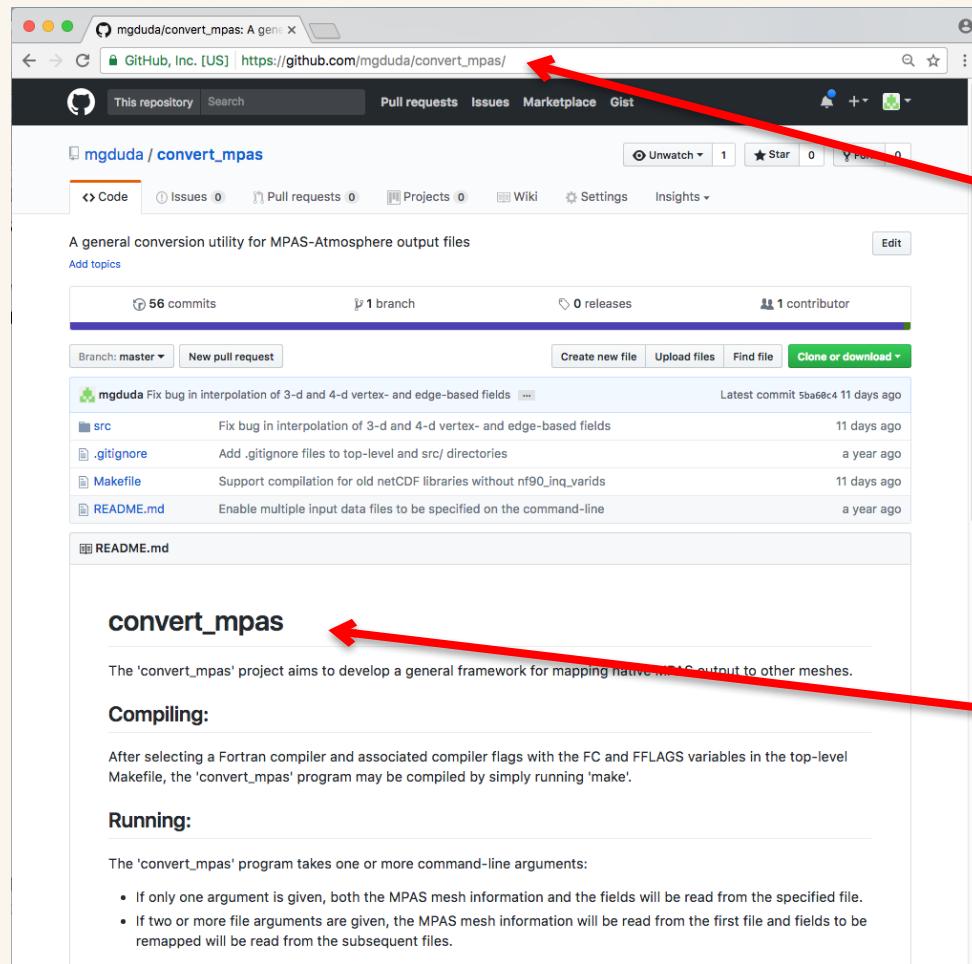


Left: Can you spot Hurricane Matthew in the MPAS 'qv' field seen in ncview?

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



A screenshot of a web browser displaying the GitHub repository page for `mgduda/convert_mpas`. A red arrow points from the text above to the repository URL in the browser's address bar. Another red arrow points from the text below to the title of the `README.md` file in the repository.

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

convert_mpas

The ‘convert_mpas’ project aims to develop a general framework for mapping native MPAS output to other meshes.

Compiling:

After selecting a Fortran compiler and associated compiler flags with the FC and FFLAGS variables in the top-level Makefile, the ‘convert_mpas’ program may be compiled by simply running ‘make’.

Running:

The ‘convert_mpas’ program takes one or more command-line arguments:

- If only one argument is given, both the MPAS mesh information and the fields will be read from the specified file.
- If two or more file arguments are given, the MPAS mesh information will be read from the first file and fields to be remapped will be read from the subsequent files.

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

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

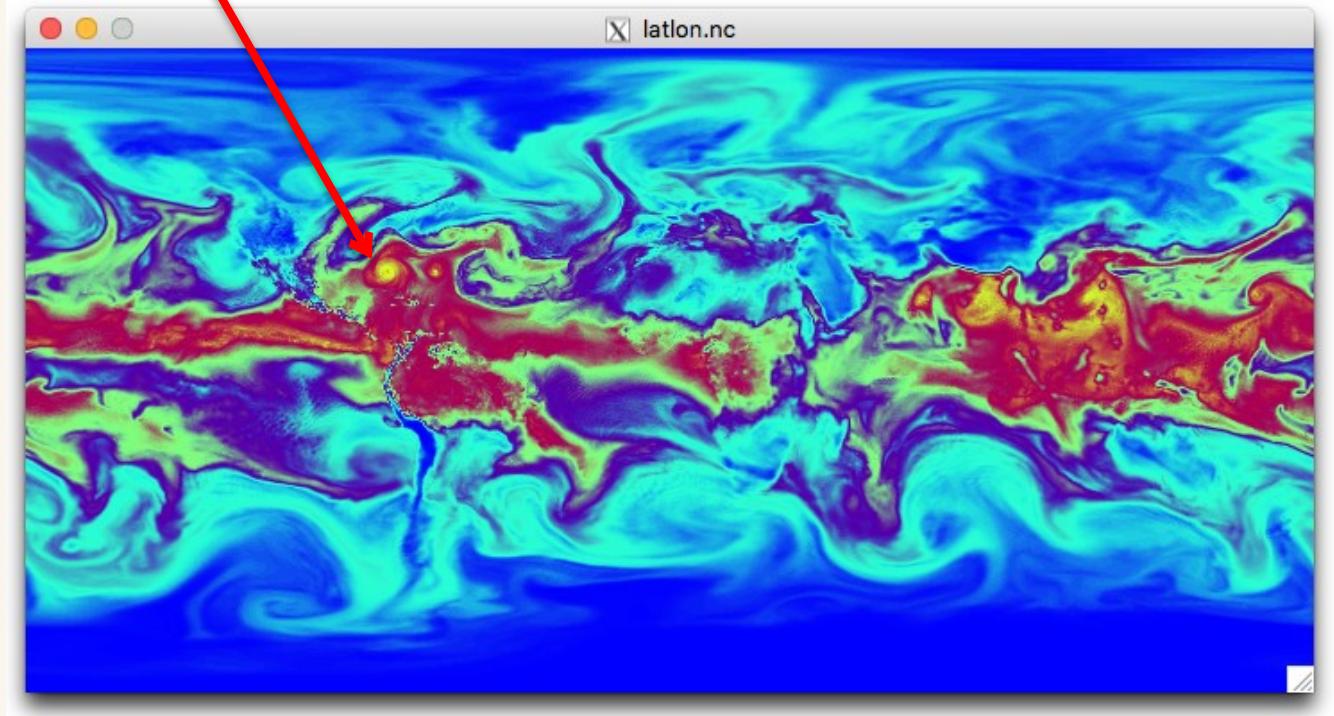
The *convert_mpas* utility

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
 - E.g.: `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
 - E.g.: `convert_mpas x1.40962.grid.nc diag*nc`
 - E.g.: `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

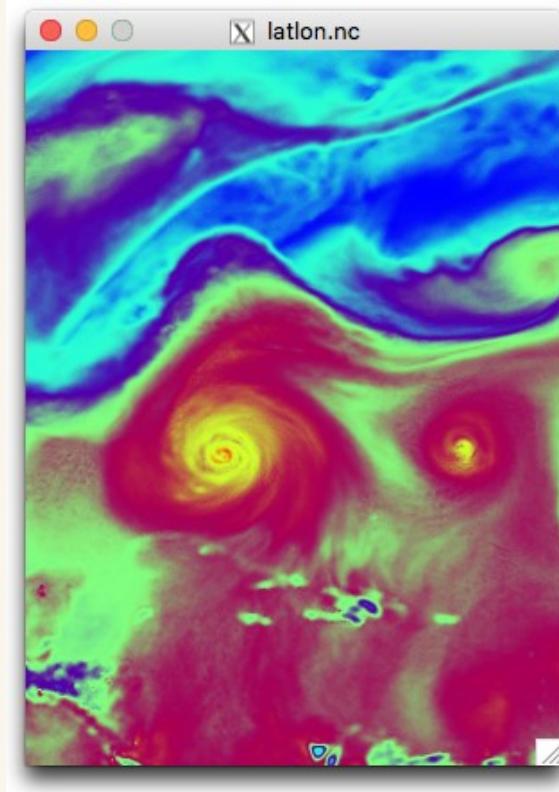


How can we interpolate to just the region of interest and at higher resolution?

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 or Python

To plot fields directly from the native MPAS mesh, try NCL or Python



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MPAS Atmosphere Public Releases

MPAS Atmosphere 8.2.0 was released on 27 June 2024.

For information on the GPU-enabled MPAS-Atmosphere model, please refer to [this documentation](#)

[MPAS Atmosphere 8.2.0 release notes](#)

Source code downloads:

- [MPAS v8.2.0](#)
- [GPU-enabled MPAS-Atmosphere v6.x](#)

[MPAS-Atmosphere Users' Guide](#)

[MPAS-Atmosphere tutorial](#)

[MPAS-Atmosphere meshes](#)

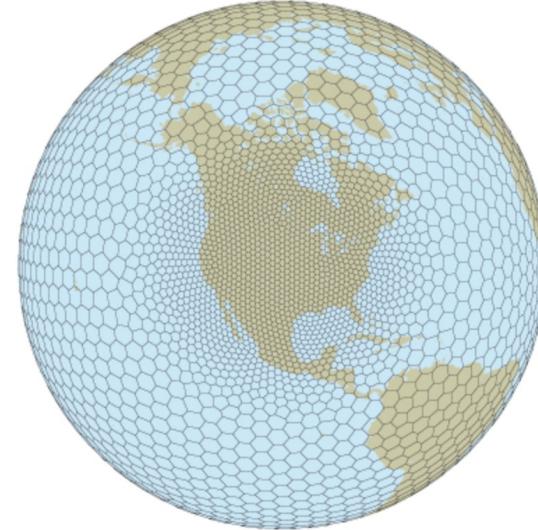
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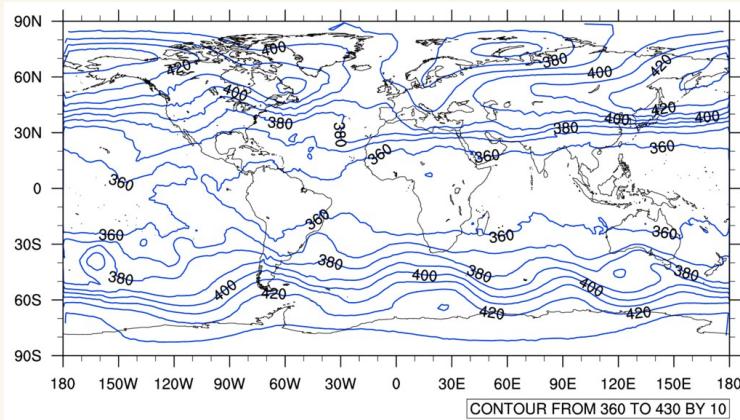


A variable resolution MPAS Voronoi mesh

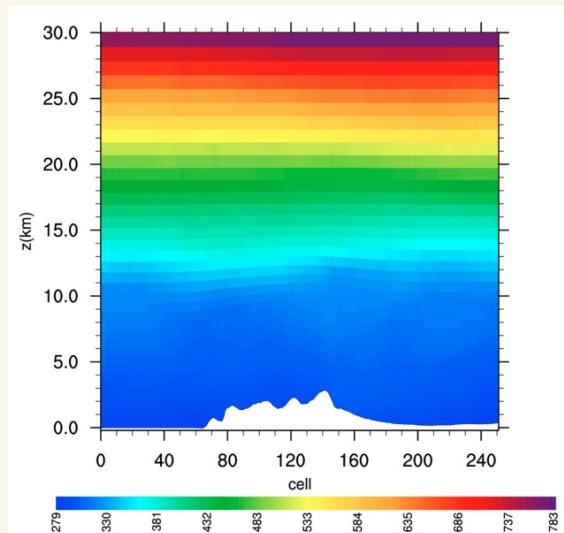
The MPAS-Atmosphere download page contains a collection of example NCL scripts

Python examples are coming soon!

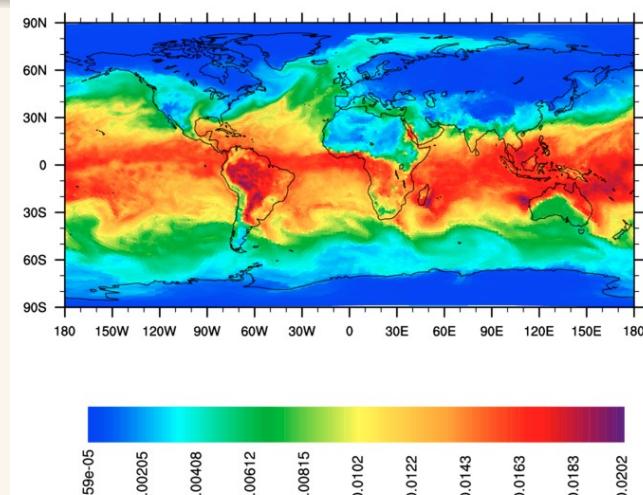
Example NCL scripts from the MPAS-Atmosphere downloads page



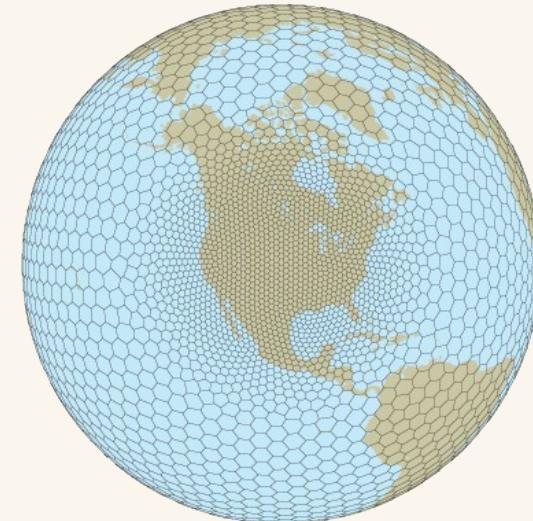
Contours – simple or color-filled



Vertical cross-sections with specified endpoints



Individual grid cells as a color-filled polygons

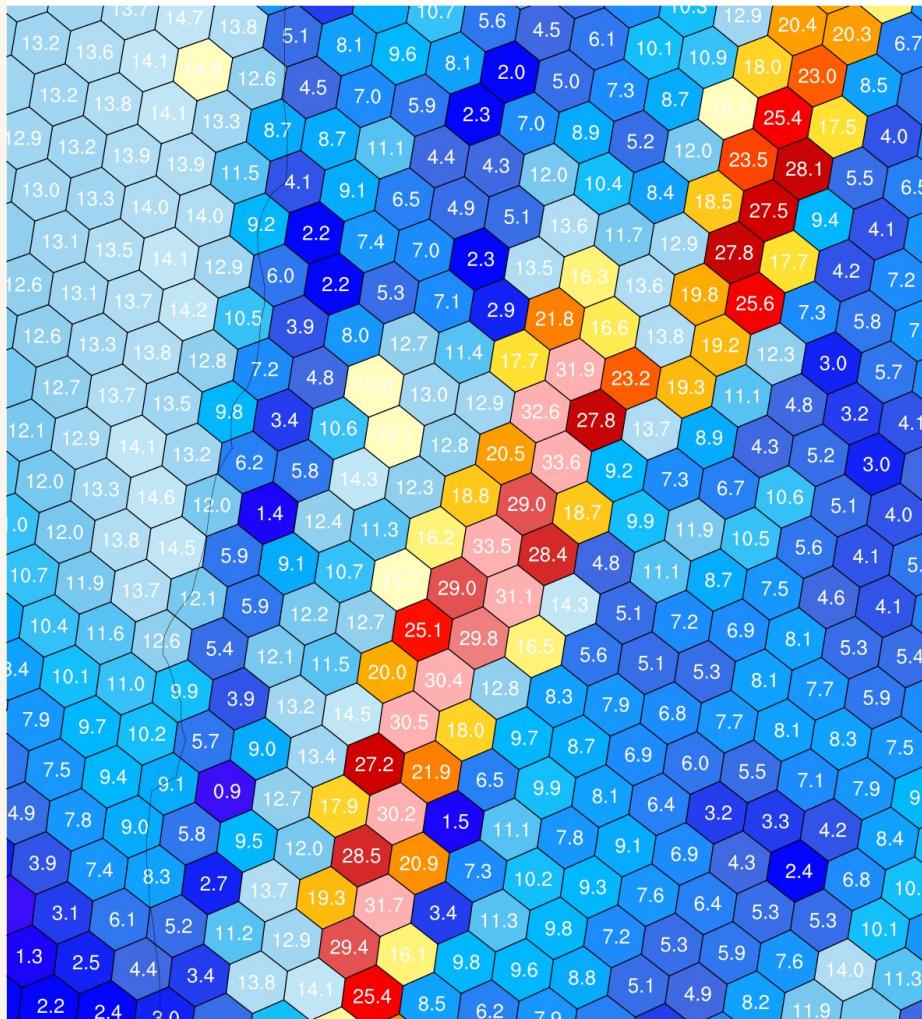


Voronoi mesh against a map background

Plotting values on cells is also possible

wind speed @ $k=1$

[m s^{-1}]



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

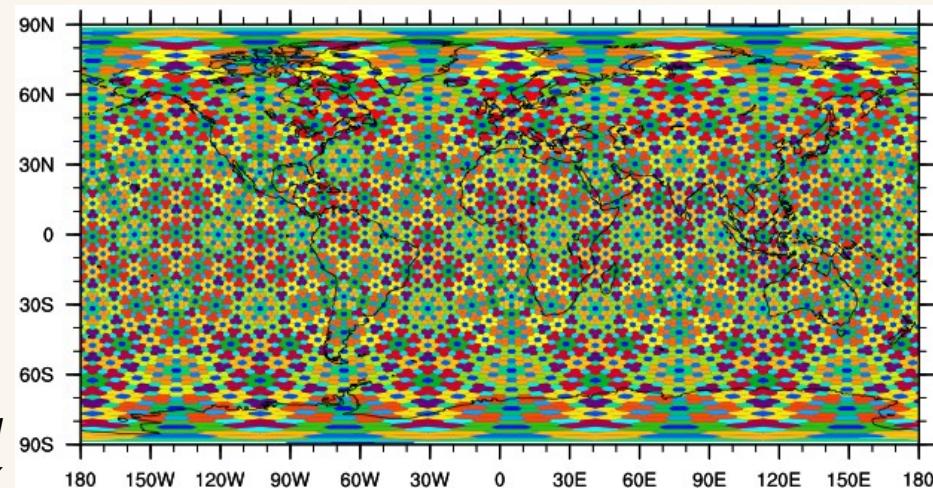
In many limited-area models, finding the nearest grid cell to a given (lat,lon) location is a constant-time operation:

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...

Right: 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

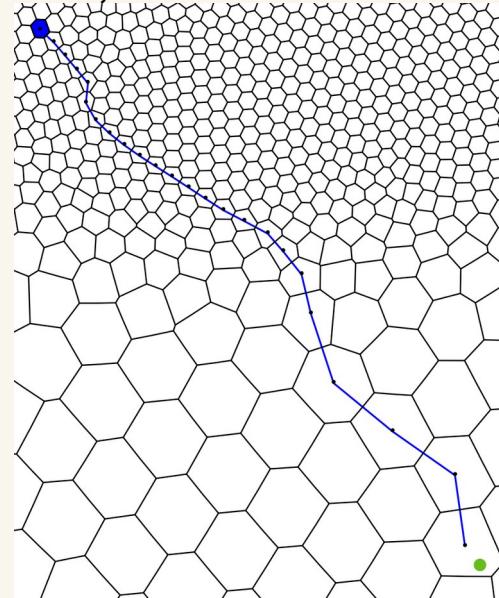
One solution would be to use search trees – perhaps a *kd*-tree – to store the cells in a mesh

- $O(n \log n)$ 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, $O(n^{1/2})$ cost per search (depending on mesh geometry...)
- For repeated searches of “nearby” locations, almost constant cost!

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



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

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

Problem: Scan all cells within a specified radius of a given (lat,lon) location

Option 1: We could check all cells in the mesh (very inefficient!)

Option 2: We could make use of the connectivity arrays (efficient!)

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)

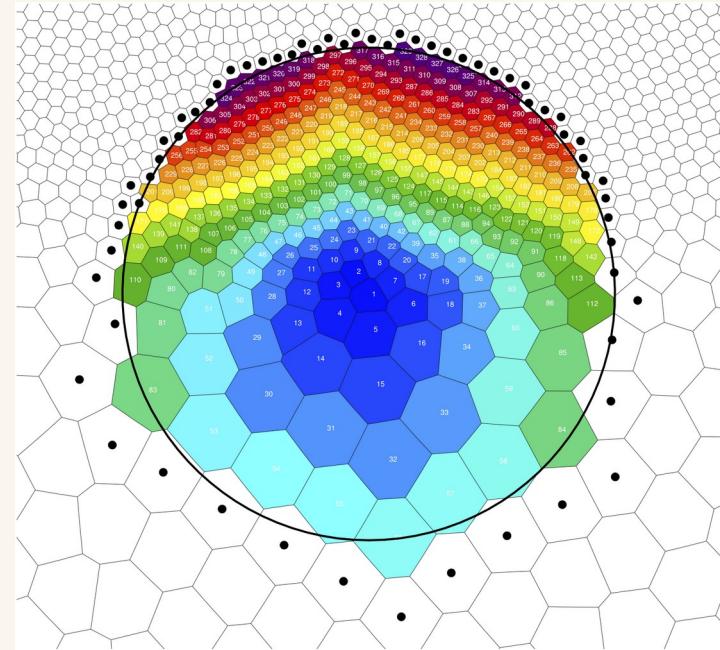
 k = cellsOnCell(i,C)

 if (k not already considered)

 mark k as considered

 if (k within search radius)

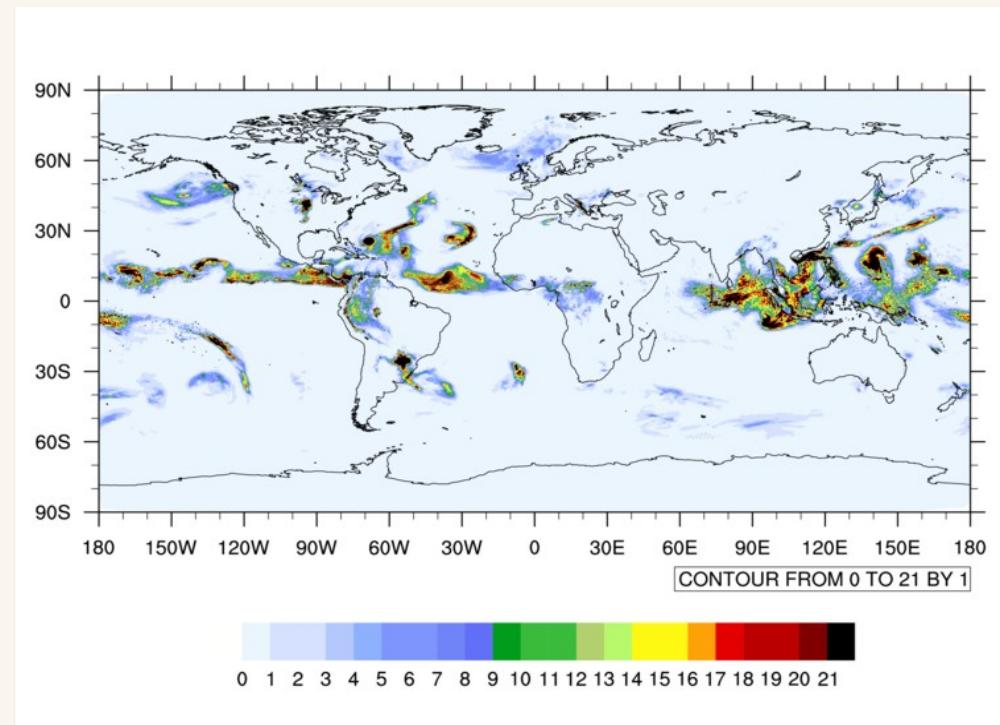
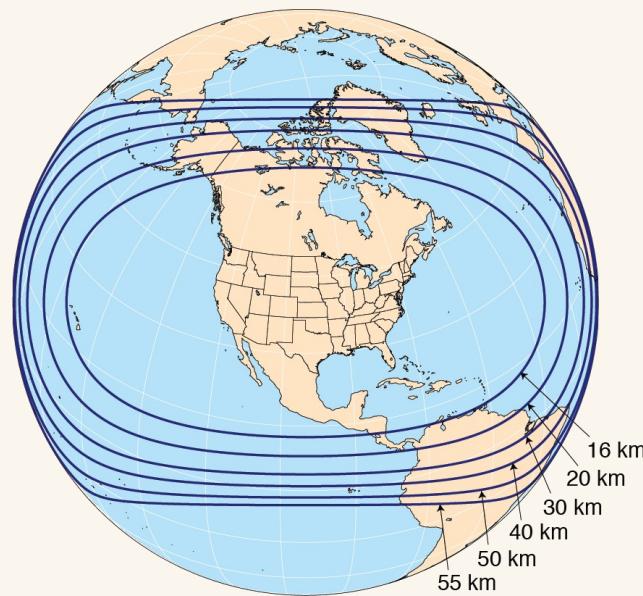
 insert k into the queue



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 mean precipitation rate on a variable-resolution MPAS mesh:



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

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

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

In an MPAS simulation with a variable-resolution mesh with a refinement factor of N (e.g., $N=4$ for a 60-15 km mesh), the cell area ratio between the largest and smallest cells in the mesh is $N^2!$

```
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**