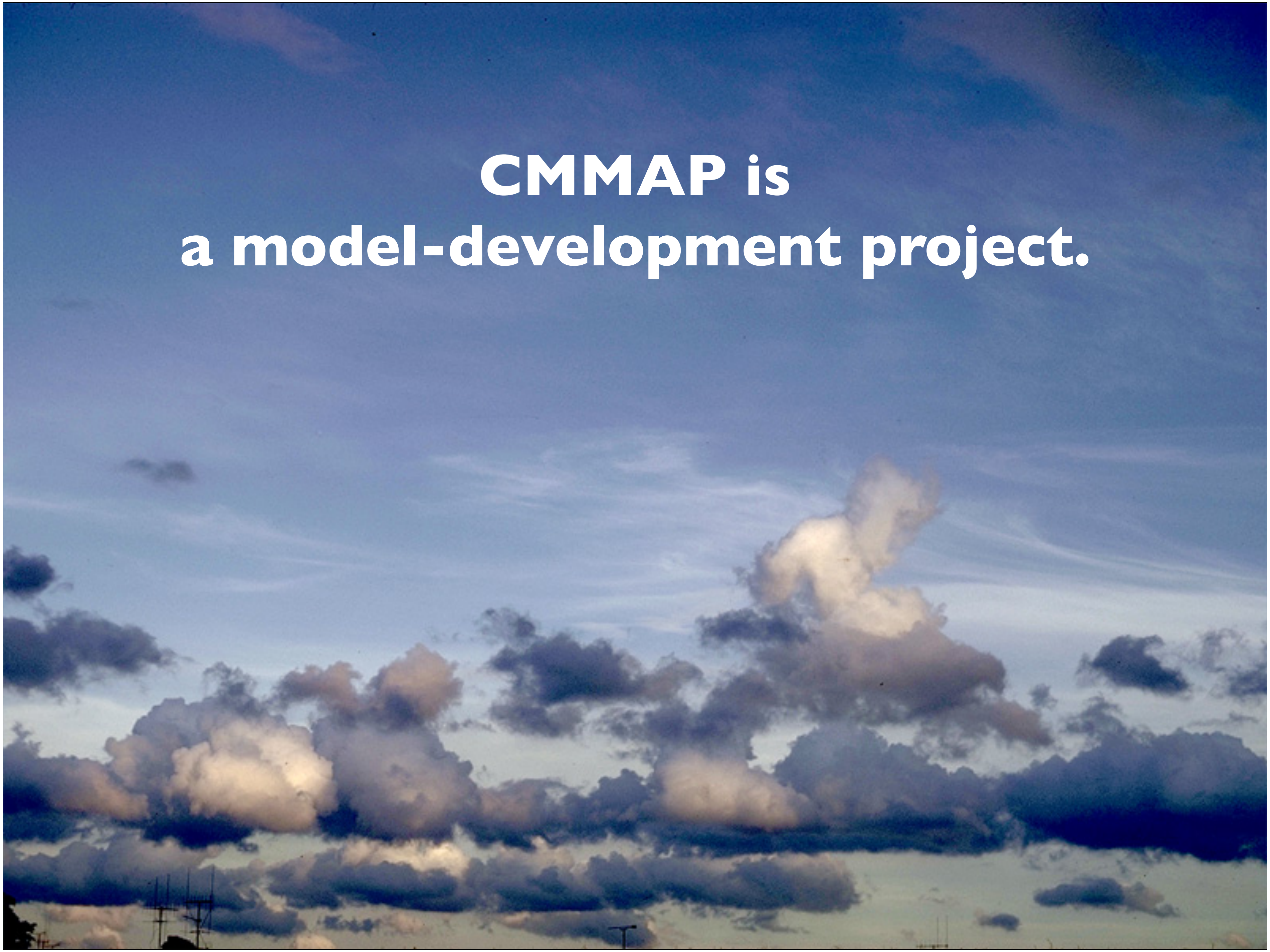
CMMAP Modeling Landscape


CMMAP is
a model-development project.

Research Goals

1. Create a radically new class of models that take advantage of petascale computers to produce dramatically improved simulations of the interactions of clouds with the global circulation of the atmosphere.
2. Identify, analyze, and understand the strengths and weaknesses of the new models using a variety of state-of-the-art observational datasets, derived from in situ observing systems, as well as both ground-based and satellite-borne remote sensors.
3. Apply the new models to develop an improved understanding of the role of clouds in the Earth system.

SAM

- CRM used in Super-CAM
- Developed and supported by Marat, and widely used both inside and outside CMMAP
- Recent work includes:
  - Giga-LES
  - Tests of new turbulence and microphysics parameterizations

CMMAP's Stable of Models

- **Current**
  - **Super-CAM**
  - **SAM**
  - **VVM**
- **Under development**
  - **GCRM**
  - **Q3D MMF**

CMMAP interacts with other modeling activities, but does not support work with other models.

Super-CAM

- **Lots of work has been done already.**
- **Current and planned work includes:**
  - **In-depth analysis of simulated MJO**
  - **Evaluation by U. Washington group**
  - **4xCO_2 runs**
  - **Coupling with POP**
  - **More experiments with a 3D CRM**
  - **Tests with new turbulence and microphysics parameterizations**
  - **New parallelization scheme under development by Marat**
    - **CAM 3.5**
    - **BlueGene**
- **Output is being archived on CMMAP Digital Library**
- **"User-support" is being provided by Mark Branson**

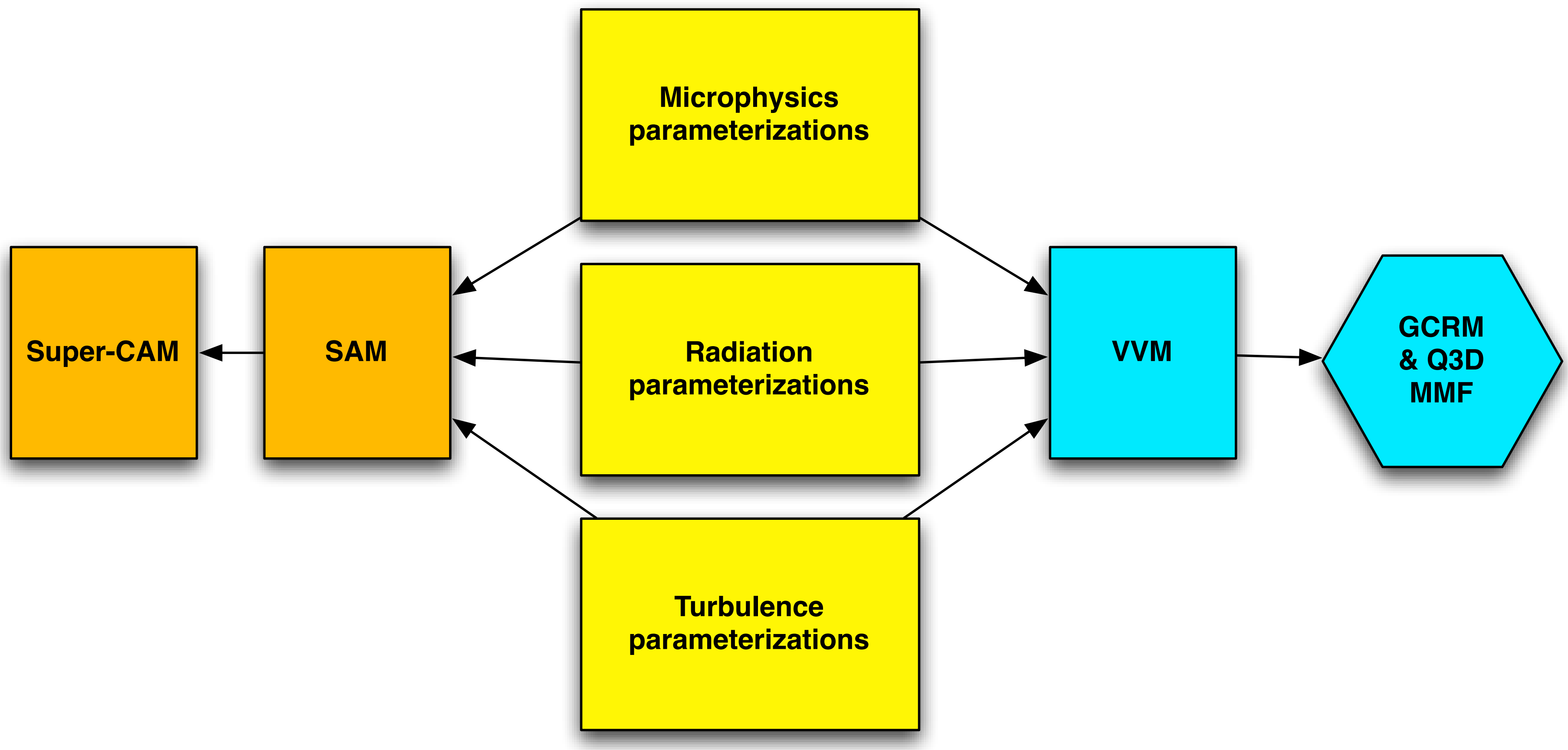
Super-CAM User Support

- In response to popular demand
- No comprehensive hand-holding
- Need to help each other as this ramps up

VVM

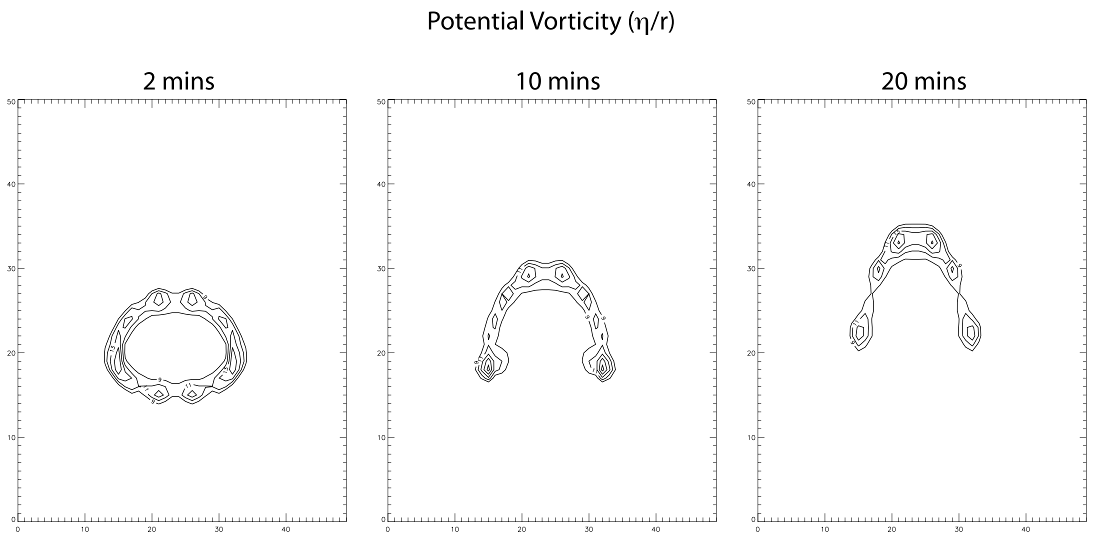
- A very unique model developed by AA & Joon-Hee
  - Conceptual ancestor: Steve K's 2D model
  - Based on vector vorticity equation
  - First version is anelastic
  - Plan to use Unified System™
  - First version uses rectangular & Lorenz grid
  - Hex & CP grid version being tested now by Celal
- Tests & applications by Chin-Hoh, Todd Jones, Grant Firl, and Anning Cheng
- Recently parallelized by Ming-Xuan Chen
- Equatorial beta-plane version under development by Hiroaki Miura
- Basis of Q3D MMF
- Global version (GCRM) under development by Ross & Celal

Testing parameterizations



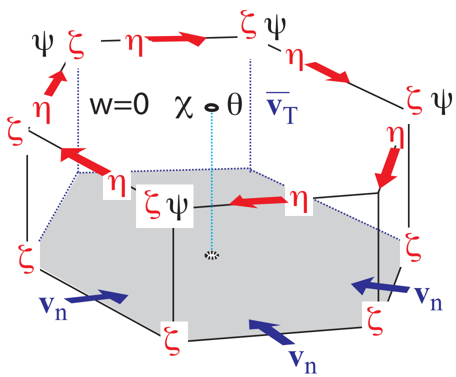
Hex VVM

- An extension of the VVM concept to a planar hexagonal grid
- First version is anelastic, but plan to use Unified System™
- CP grid is used in the vertical
- A parallel code being tested without physics by Celal
- Will be tested with a variety of physical parameterizations
- Is being used as a basis for the GCRM

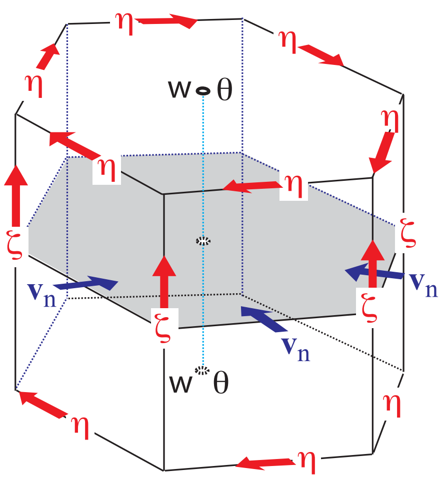


Hex VVM

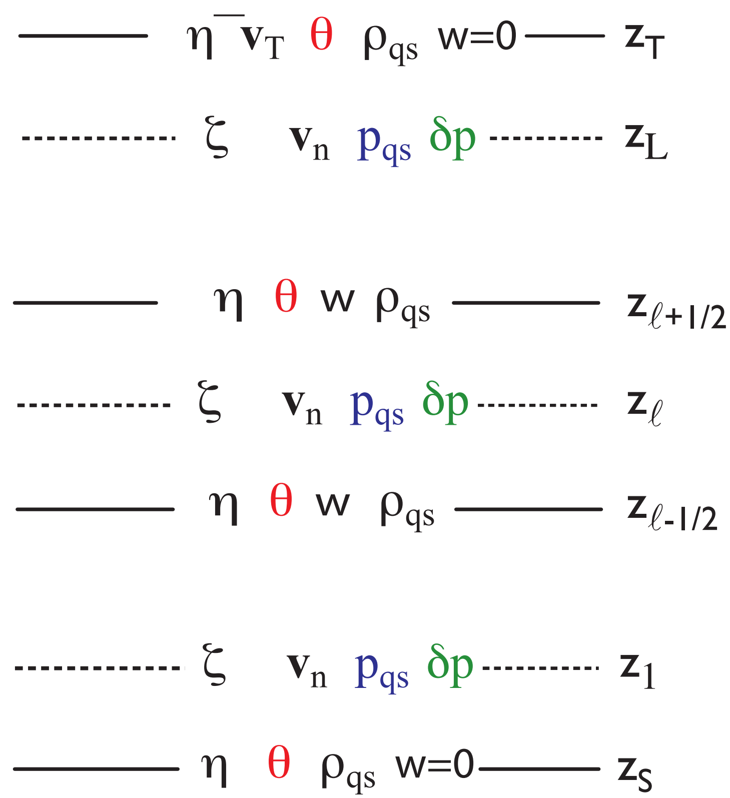
Upper Boundary



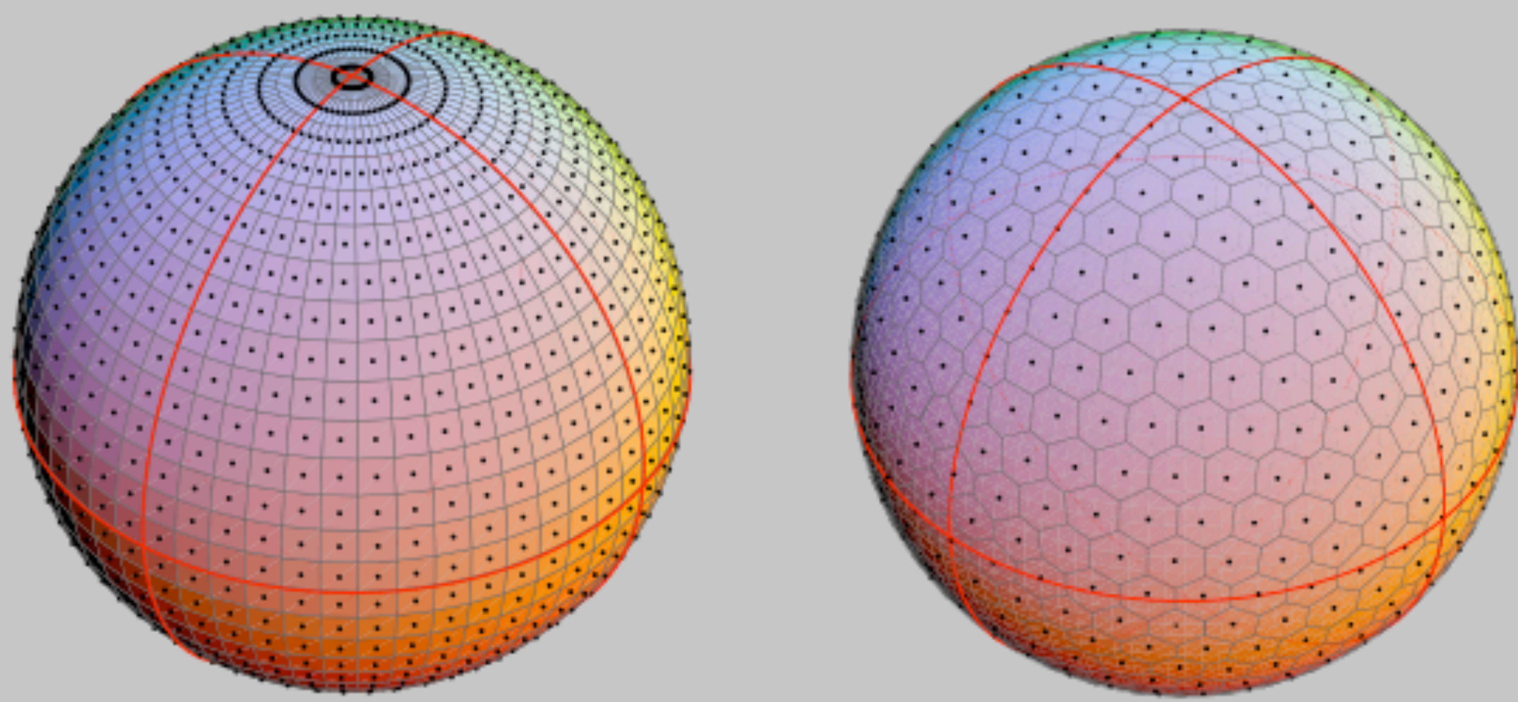
Interior



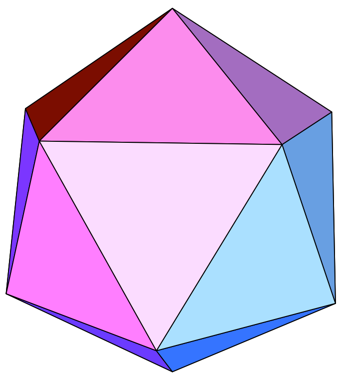
Charney-Phillips Vertical Grid



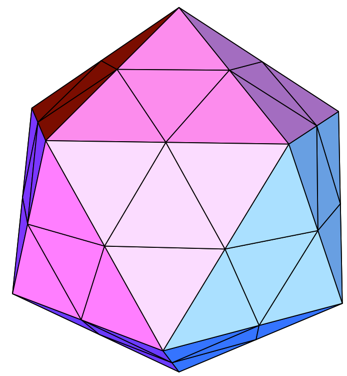
Lat-Lon Versus Geodesic Grids



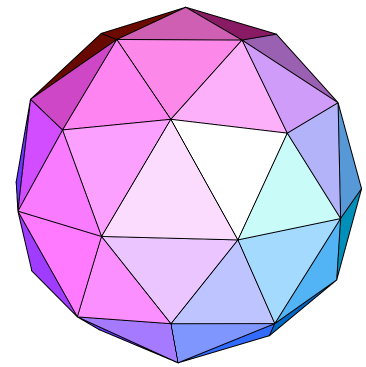
Geodesic Grid



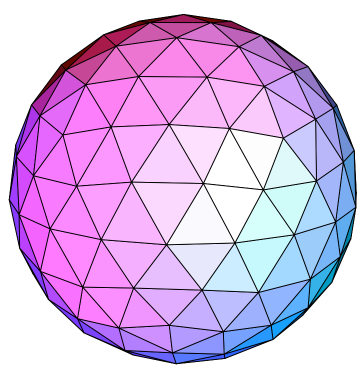
Icosahedron

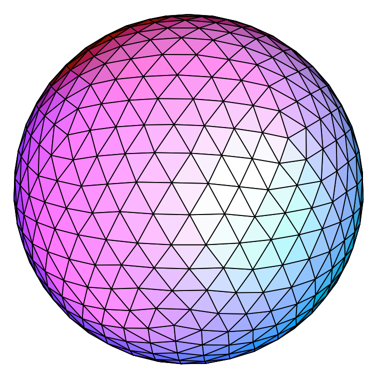


Bisect each edge
and connect the dots



Pop out onto
the unit sphere





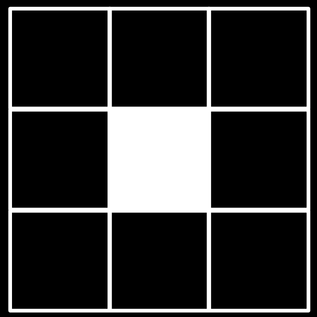
And so on, until we reach our target resolution...

Variationally “tweaked” geodesic grids

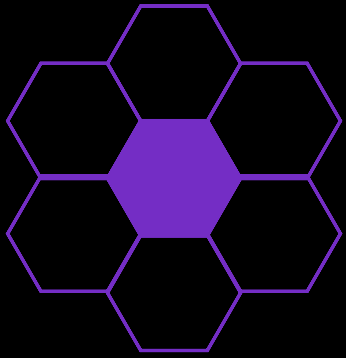
Recursion number	Number of cells	Average distance between cell centers, km	Area ratio (smallest to largest)
0	12	7054	1
1	42	3717	0.885
2	162	1909	0.916
3	642	961	0.942
4	2562	481	0.948
5	10242	240	0.951
6	40962	120	0.952

Tiling the Plane

12 neighbors
3 wall neighbors



8 neighbors
4 wall neighbors



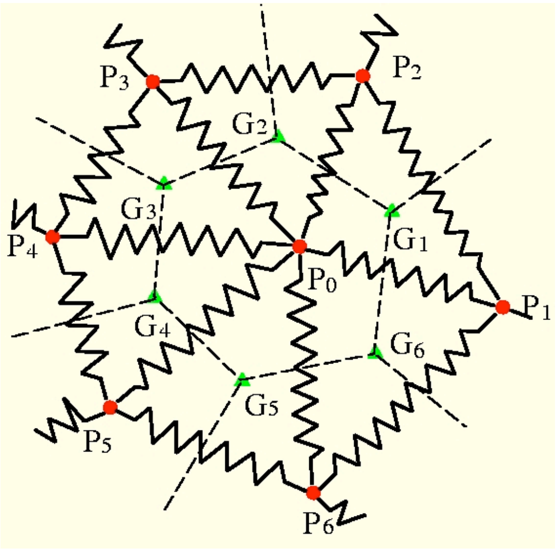
6 neighbors
6 wall neighbors

Triangles
nest.

Squares
nest.

Hexagons
don’t nest.

Springs



Following Tomita et al. (2001), "springs" can be used to vary the grid spacing over the sphere.

Multigrid Scaling

Scaling tests were performed on four platforms:

1. **Seaborg at the National Energy Research Scientific Computing Center (NERSC). IBM SP with 6,080 375 MHz POWER 3 processors.**

2. **Blue Gene/L at Argonne. 1024 dual PowerPC 440 700MHz 512MB nodes.**

3. **Jaguar at the National Center for Computational Sciences (NCCS). Cray XT containing a combination of XT3 and XT4 systems. Each node contains 2.6 GHz dual-core AMD Opteron processors and 4 GB of memory.**

4. **Franklin at the National Energy Research Scientific Computing Center (NERSC). Cray XT4 system with 9,660 compute nodes. Each node has dual processor cores, and the entire system has a total of 19,320 processor cores of a 2.6 GHz dual-core AMD Opteron processors. Each compute node has 4 GBytes of memory.**

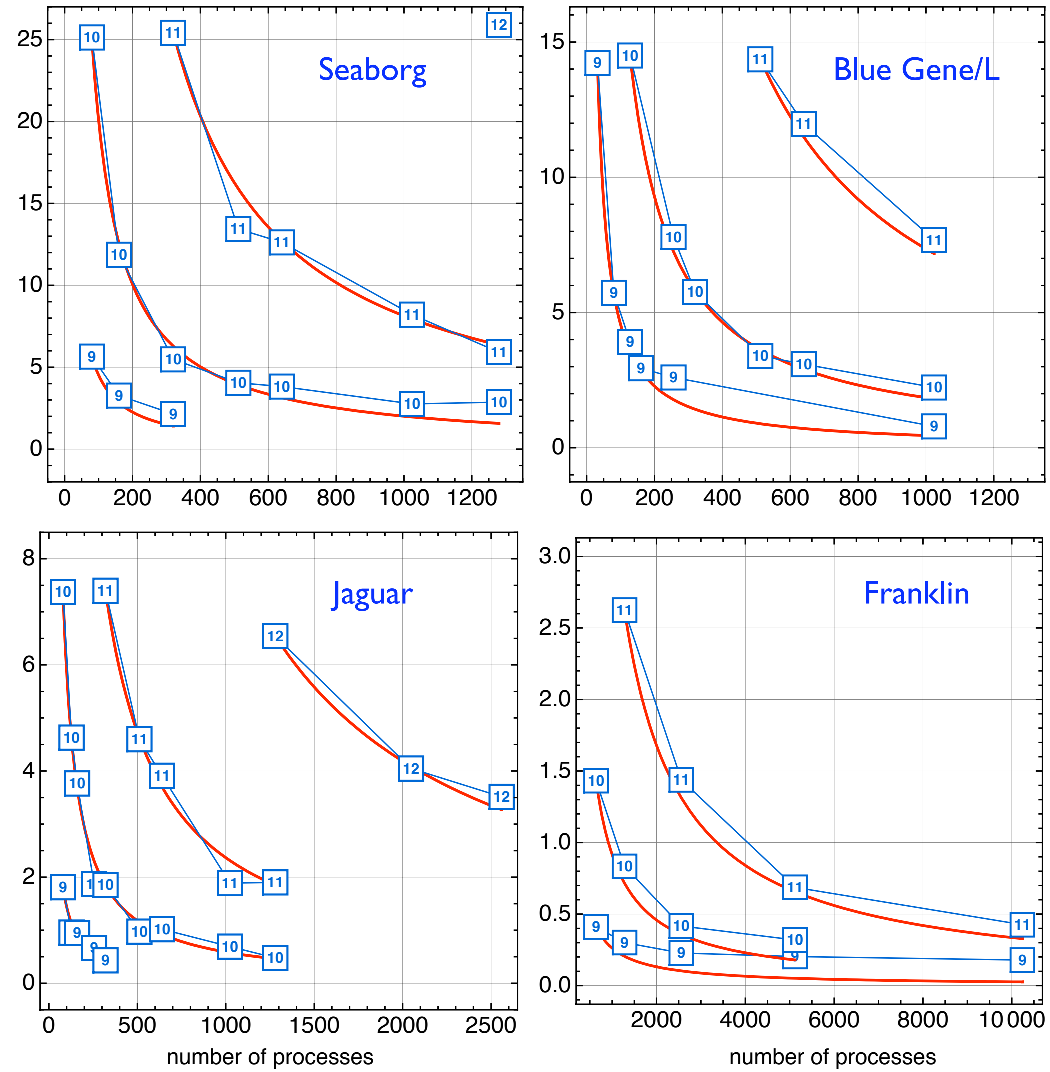
Multigrid Scaling

The x-axis is number of processes and the y-axis is time.

The blue square indicates grid resolution

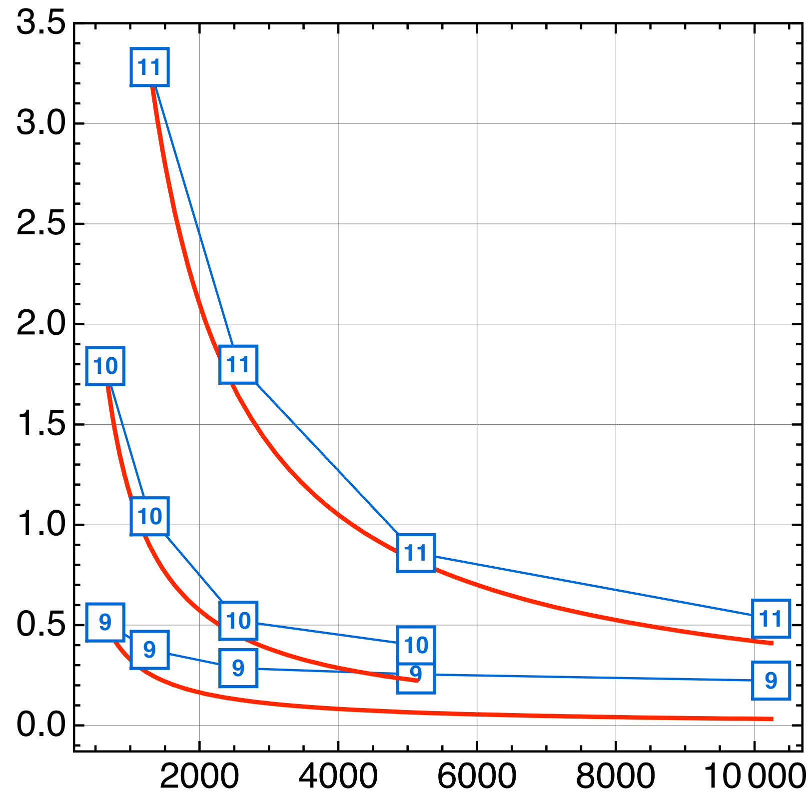
The red line is ideal speed-up

Level of recursion	Number of grid columns	Distance between grid columns, km
9	2,621,442	15.64
10	10,485,762	7.819
11	41,943,042	3.909
12	167,772,162	1.955



GCRM

- Based on Hex VVM (with CP grid), combined with BUGS6
- Major support from SciDAC
  - Model development
  - SAP
- Computationally very demanding
  - Computer time
  - Archival space



Q3D MMF

- **We have worked on four kinds of grid, 3D CRM, Q3D CRM, 3D MMF and Q3D MMF. Using a fully-prognostic and fully-interactive Q3D MMF, we have entered the final phase of testing (as far as application to a small-domain is concerned.)**

- **Q3D prediction tends to shift the spectrum toward horizontally larger scales, producing excessively strong horizontal velocity.**

- **Inclusion of a "selective damping" effectively controls the computational instability associated with this shift.**

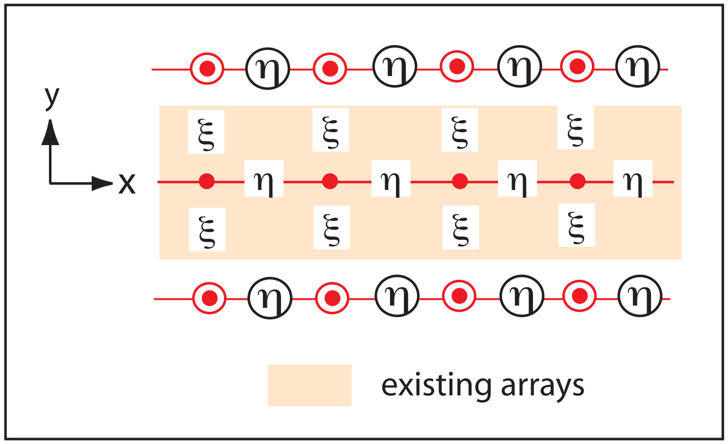
- **Encouraging results are obtained for the overall strengths of cloud-scalle enstrophy and horizontal and vertical kinetic energy, surface precipitation and surface heat fluxes, the vertical profiles of buoyancy and momentum fluxes, and those of the network mean cloud water (except in the PBL) and precipitants.**

- **In spite of those successes, prediction of the mode of convective organization is unsuccessful. Instead of the propagating three-dimensional structure in the benchmark simulation, the Q3D MMF tends to choose a persistent organization along one direction with the largest interval in the other direction.**

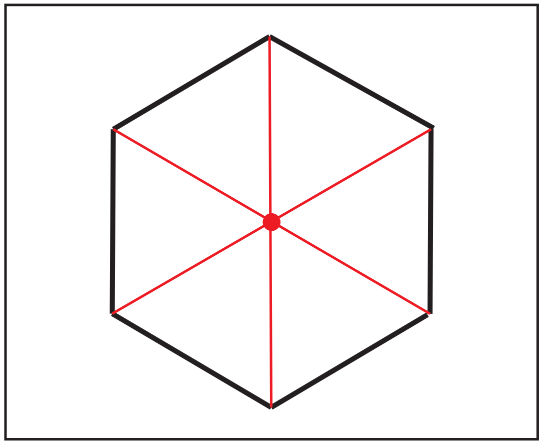
Next steps

- We will continue to assess the strengths and weaknesses of the current Q3D algorithm through more detailed and comprehensive analysis.
- Relatively poor prediction of the water-vapor variance can be attributed to the nudging of water vapor to a reference profile, a feature included even in the benchmark to guarantee a realistic climatology. We will try to find an alternative.
- To predict propagation of organized clouds in the direction normal to a grid-point array, information on the asymmetry across the array is needed. Currently, the asymmetry is inferred using the statiastics of the orientation of cloud organization. To explicitly predict the asymmetry, we look into the possibility of a next-generation Q3D MMF, which may use the grid shown below.

To add a degree of freedom
in the normal direction



To add a degree of freedom
in the orientation



Testing parameterizations