Design and Testing of a Global Cloud Resolving Model (GCRM)

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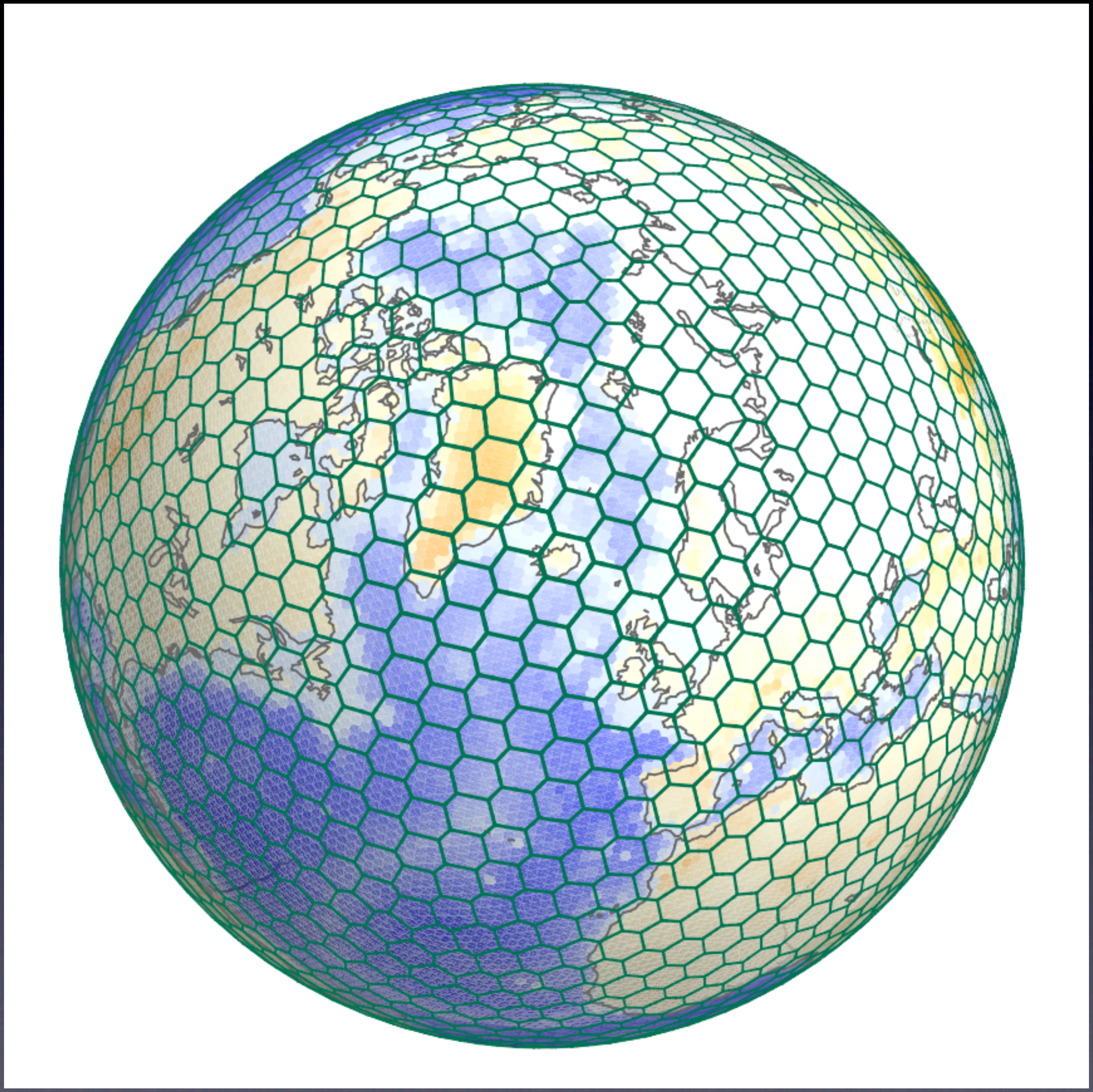
CScADS Workshop on Scientific Data Analysis and Visualization for Petascale Computing, 3-6 August 2009.

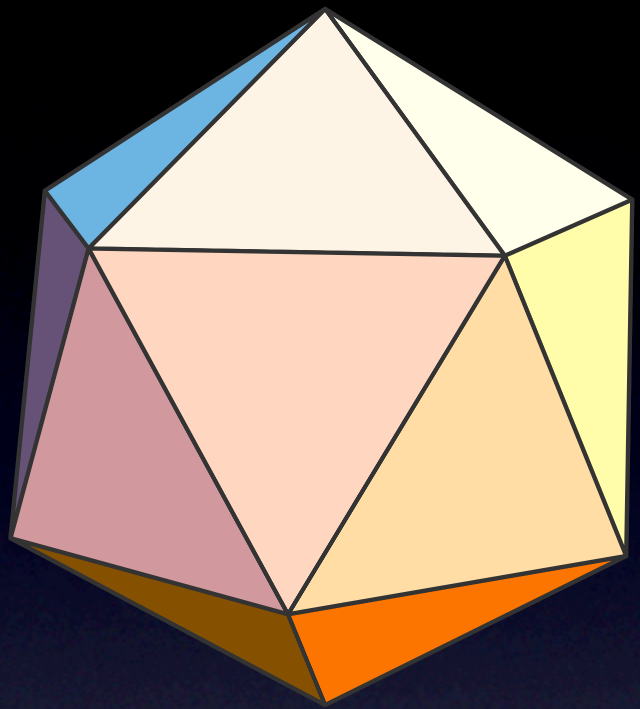
What is a global cloud resolving model (GCRM)?

- Most of the current global models do not resolve the clouds, but the effect of clouds are represented.

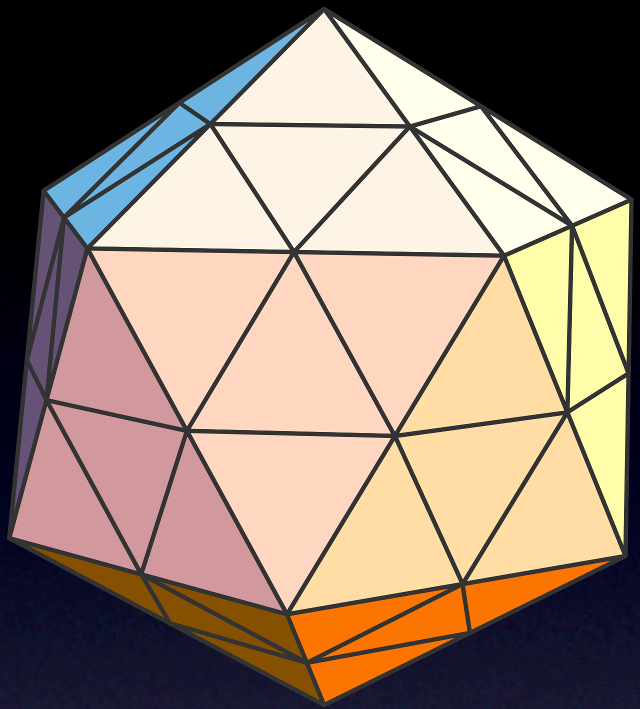
- GCRM is a global model that has 4 km or less grid resolution to directly resolve large clouds.



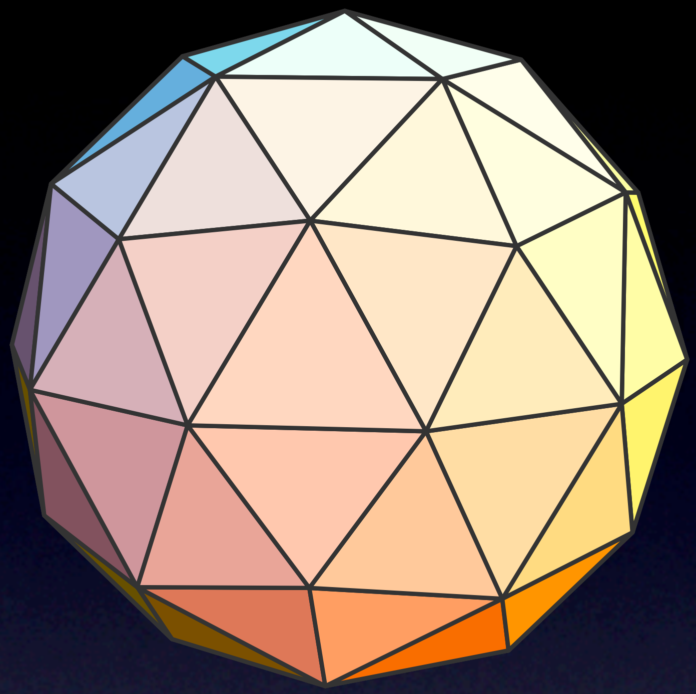
Horizontal grid: Icosahedral grid basics



Consider the icosahedron



Bisect each edge to form new faces



Project new vertices

- The vertices are the model grid points.
- Numerous algorithms exist to adjust grid point positions to optimize grid properties.
- Each grid point on a coarser resolution can be associated with four grid points after the bisection.

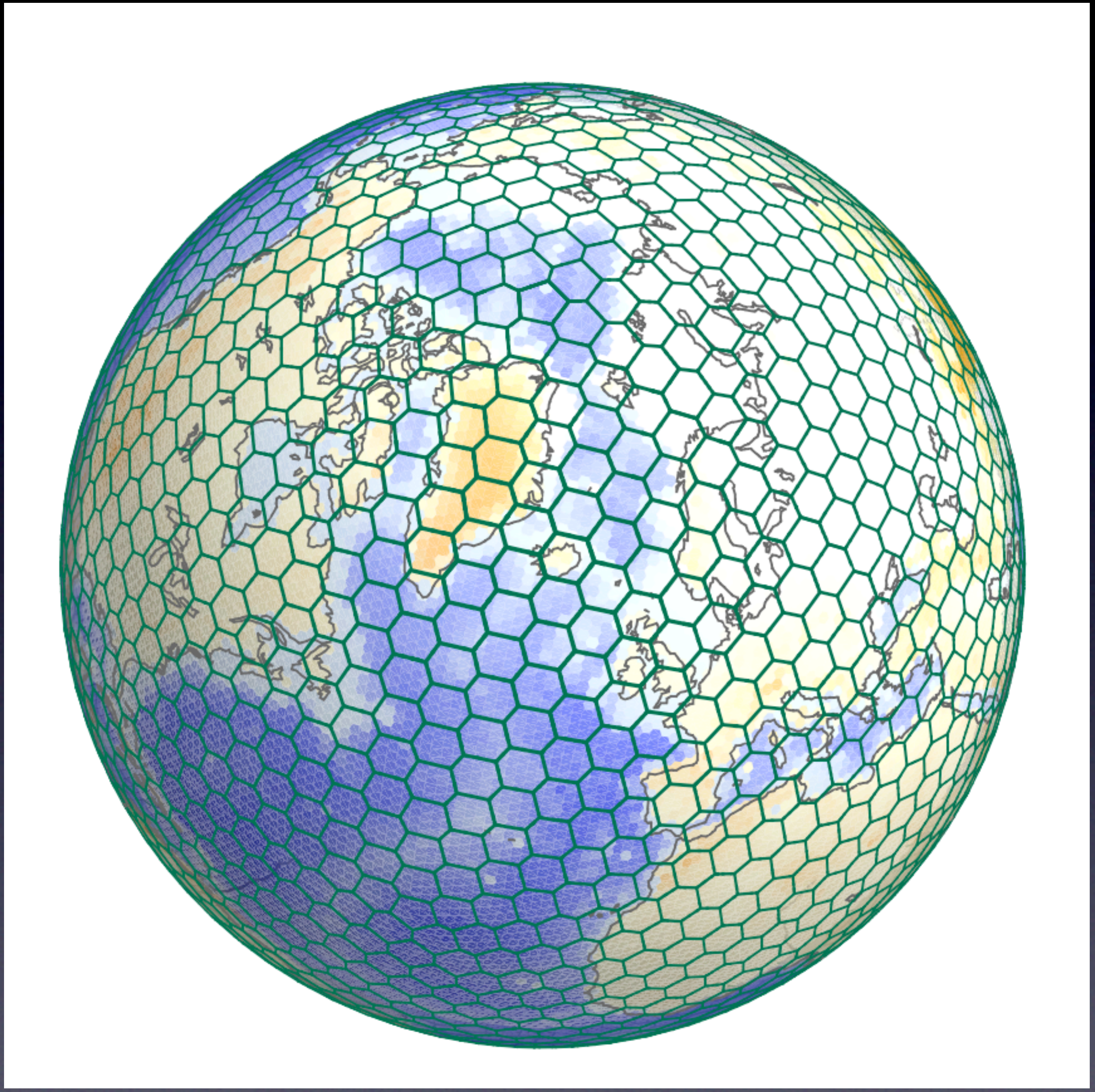
Horizontal Grid

- The global number of grid points is given by

$$N = 2 + 10 \times 2^{2r}$$

- There are 12 pentagons and N-12 hexagonal cells
- Cells as a function of resolution:

resolution (r)	number of cells (N)	global grid point spacing (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
13	671,088,642	0.997



GCRM memory requirements for I/O

- Assume a single *snapshot* in time of model output will include the following fields:

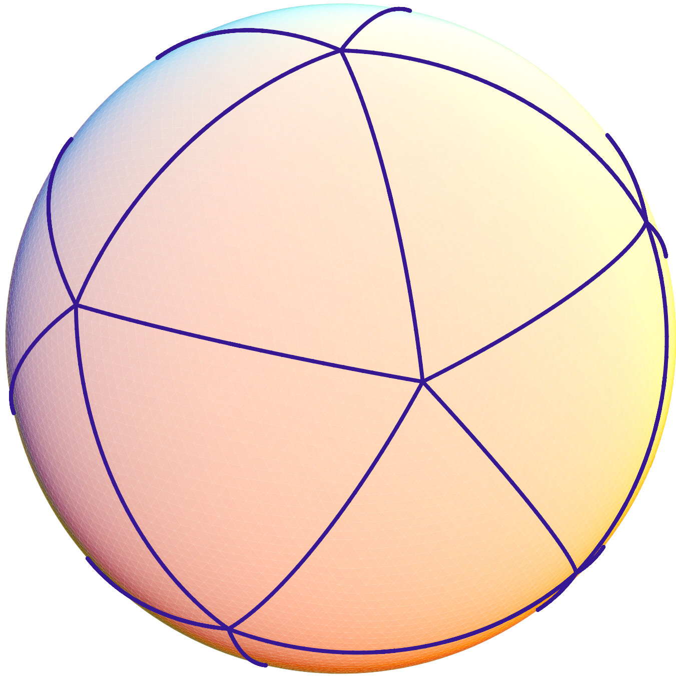
  1. Pressure
  2. Temperature
  3. 5 species of water
  4. Horizontal velocity **v** (×3 for edges)
  5. Vertical velocity w

- Total of above gives 11 numbers per grid point per snapshot.
- With 4 bytes per number (single precision) gives 44 bytes per grid point per snapshot.
- Assume 96 vertical layers.

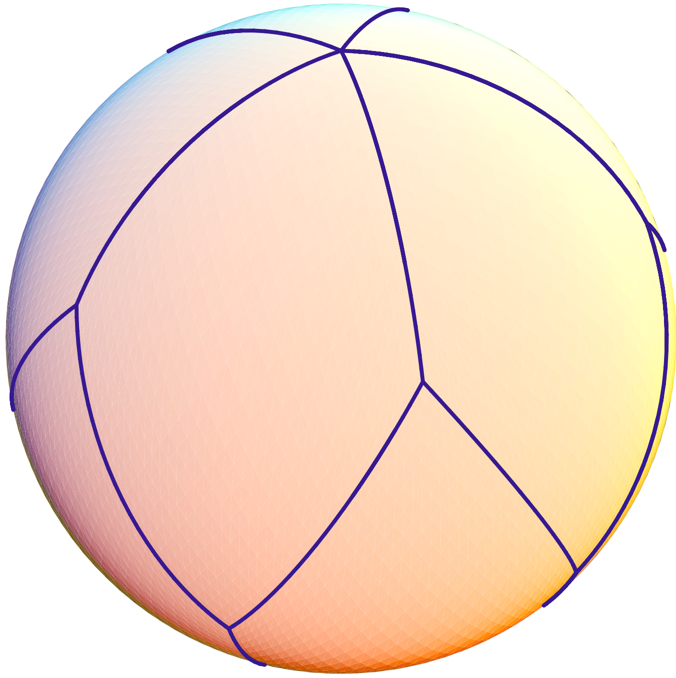
(grid) Resolution (km) (global number of grid points)	disk space per snapshot (TB)
(10) 7.819 km (10,485,762)	0.044
(11) 3.909 km (41,943,042)	0.177
(12) 1.955 km (167,772,162)	0.709
(13) 0.977 km (671,088,642)	2.83
(14) 0.487 km (2,684,354,562)	11.3

Parallel domain decomposition

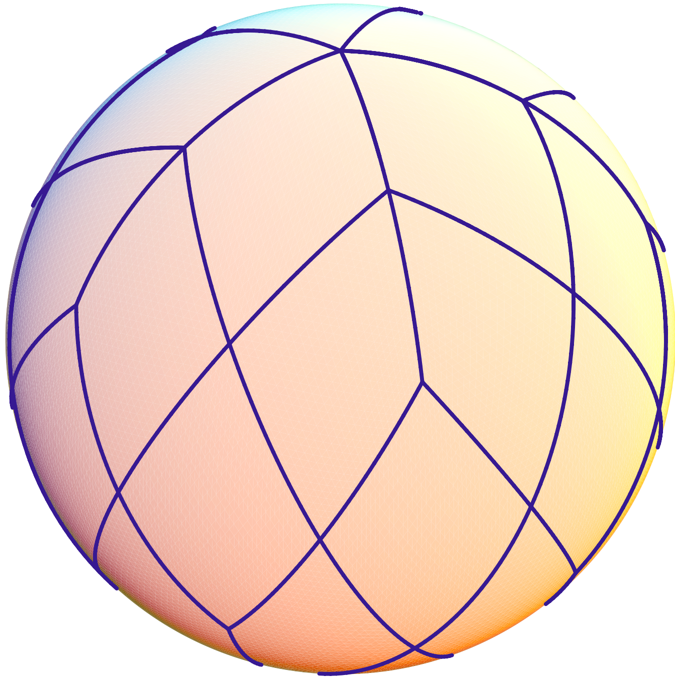
- Concatenating the faces of the icosahedron allows the sphere to be partitioned into 10 quadrilateral regions (subdomains).



Icosahedron projected to sphere



10 quadrilateral regions

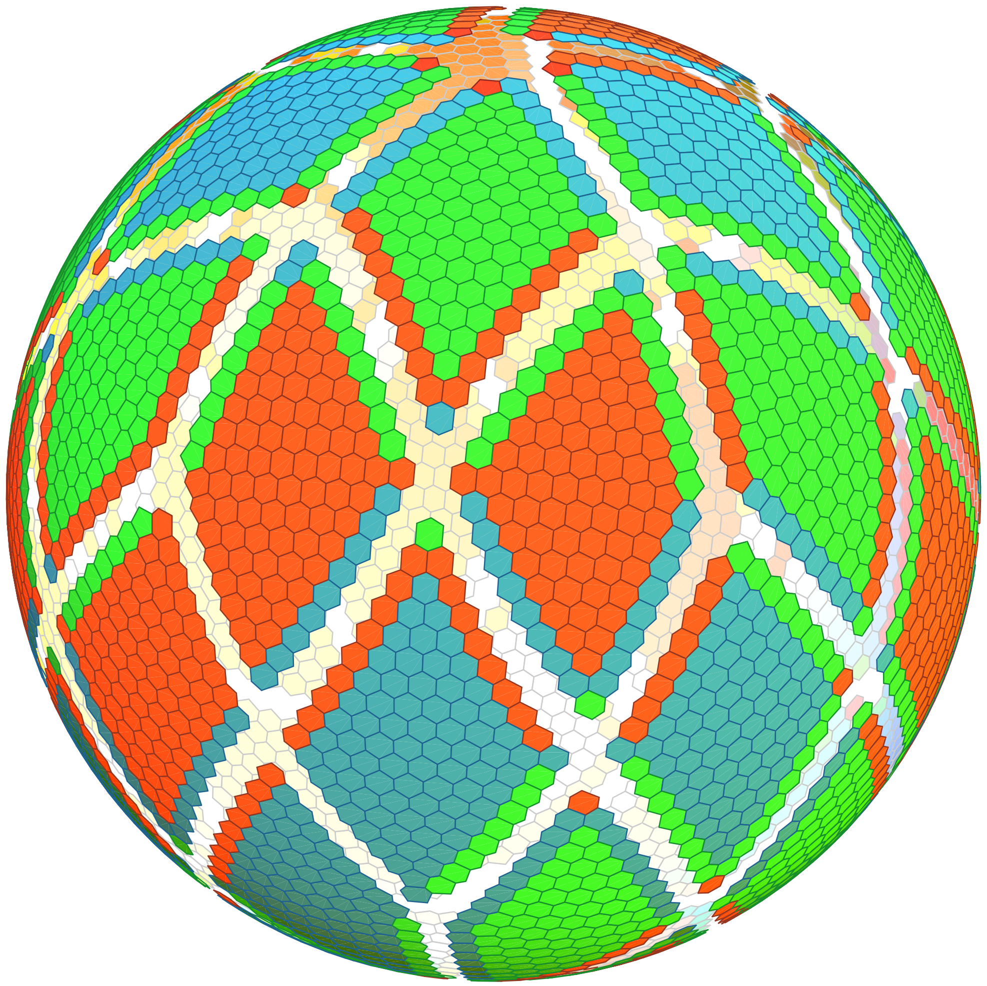


40 quadrilateral regions

- All the cells within a given subdomain are assigned to a process.
- Any subset of the global number of subdomain can be assigned to a process.

Parallel communication

- Ghost cell values are communicated between processes
- Nonblocking MPI (MPI_ISEND, MPI_IRECV and MPI_WAITALL) is used for communication between subdomain blocks.
- Future plans include use of
  - RMA MPI2 communication (MPI_PUT or MPI_GET)
  - PGAS languages such as Berkeley UPC
- The processes can exchange arbitrarily wide ghost cell regions.



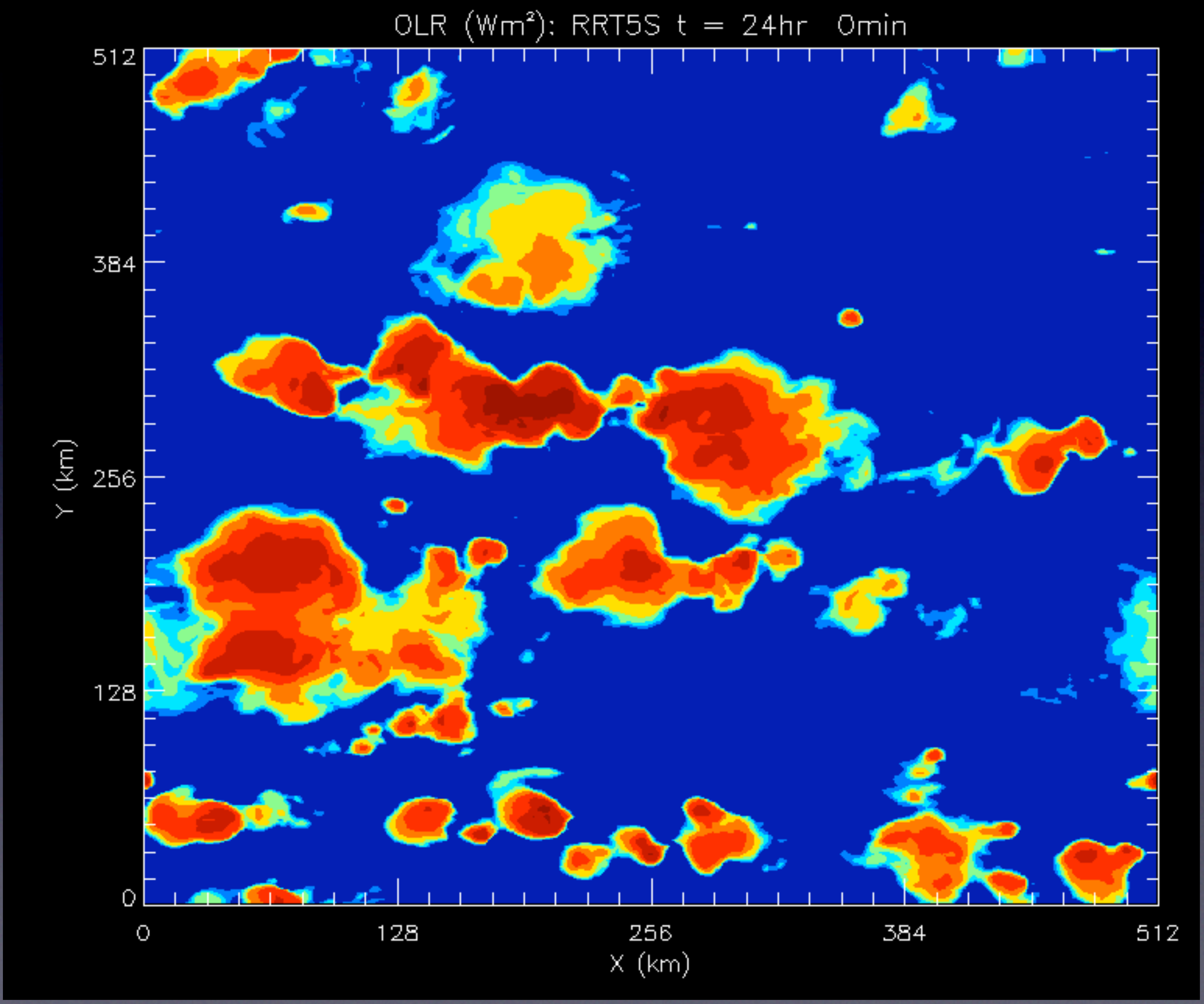
- There is an option to separate send/recv from wait to allow for overlap of communication and computation.

Model design

- We cannot obtain a GCRM by simply increasing the resolution of current global models.
- These models should be designed from scratch inspired by the cloud resolving models currently used over small domains for shorter integration times.

- Our GCRM is an application of the Vector-Vorticity Model (VVM) developed for a Cartesian grid on a rectangular domain to a globe.
- My work involves testing the VVM in simulating realistic atmospheric conditions.
- My future work may involve analysis and visualization of the GCRM results

Animation of Outgoing Longwave Radiation (W/m^2) from the VVM



Our goal: make a numerical weather prediction run of 4-5 days.

Challenges:

- Large number of processors will be required (~80,000)
- Tsunami of data (Karen Schuchardt and Bruce Palmer, PNNL)
- Storage of data: where, data transfer, access
- General analysis and visualization of data, including quick look

Computers to be used for simulations

- Jaguar: Cray XT5 at Oakridge
- Intrepid: IBM Blue Gene/P at Argonne
- Franklin: Cray XT4 at NERSC (current use)

What we'd like to do

- VisIt is applied to the icosahedral geodesic grid (Prabhat, Lawrence Berkeley National Laboratory)
- Interface between model datasets and Visit visualization (Bruce Palmer and Karen Schuchardt, PNNL)
- We are open to ideas regarding the best way to visualize our data