Geodesic Grids for Modeling and Data Analysis

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EOS Investigators Working Group
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A Geodesic Climate Model with Quasi-Lagrangian Vertical Coordinates

DOE Cooperative Agreement

This is a multi-institutional effort:

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Scott Fulton, Clarkson
John Baumgardner, LANL
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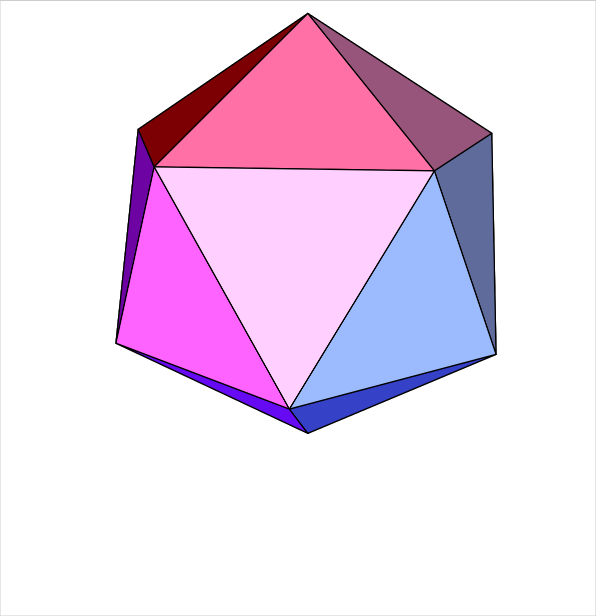
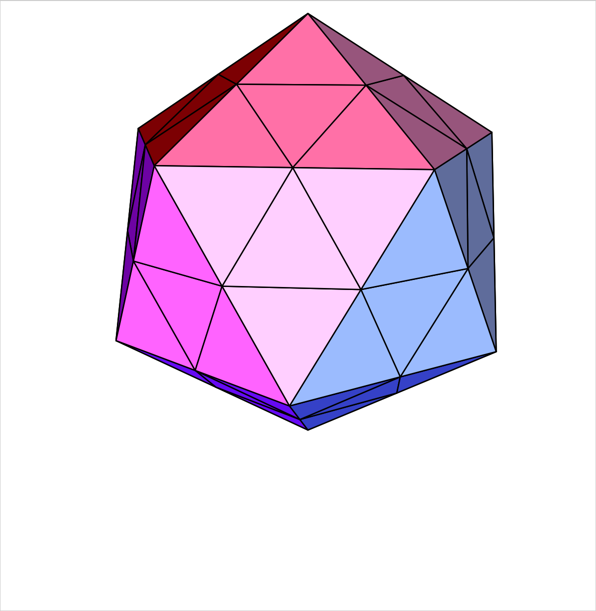
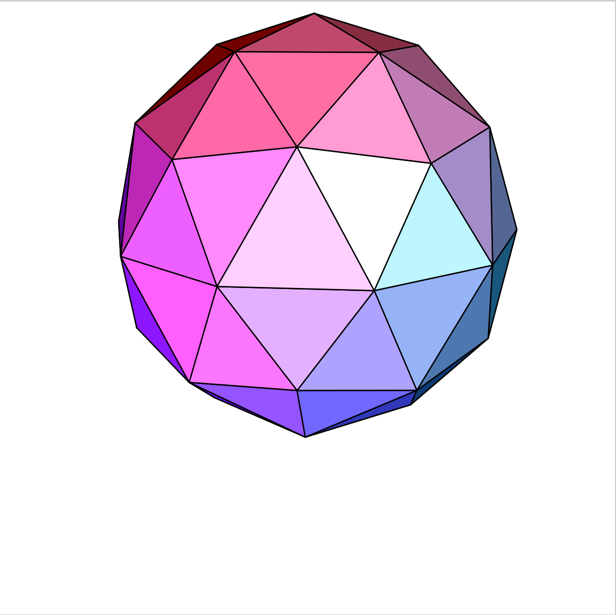
Mission Statement:

“To construct an architecturally unified modeling framework based on geodesic grids and quasi-Lagrangian vertical coordinates that will allow for the creation of a comprehensive, conservative, accurate, portable, and highly scalable coupled climate model.”

Grid Generation:

defining grid cell centers

Each vertex will be a grid point

Icosahedron	Bisect each edge and connect	Project new vertices to the sphere
		

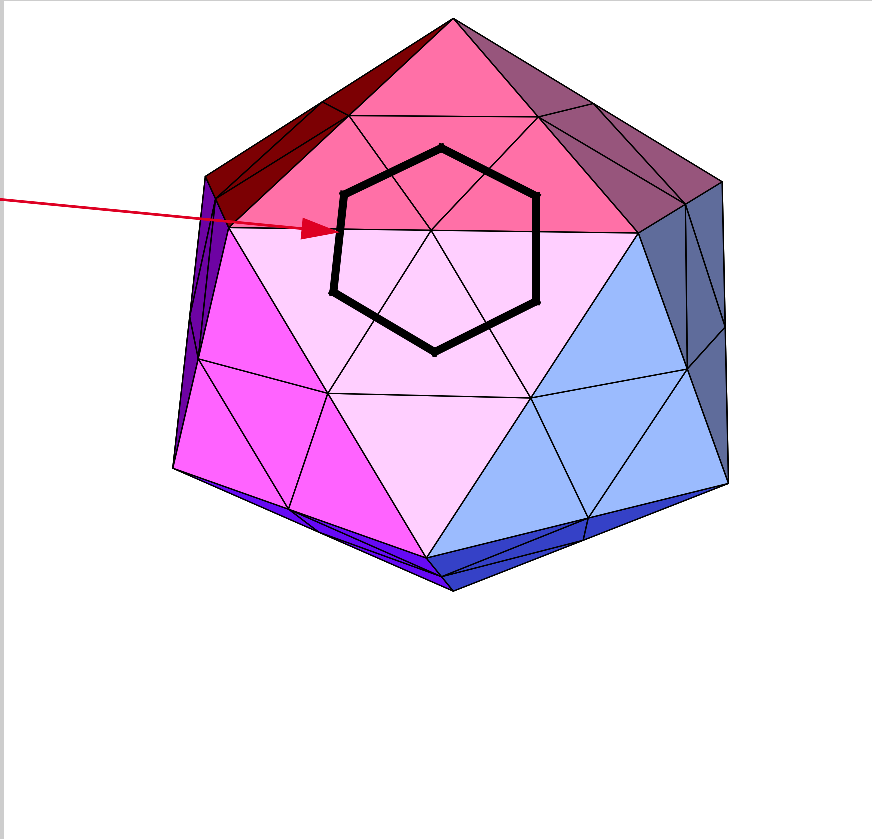
Grid Generation:

defining grid cell areas

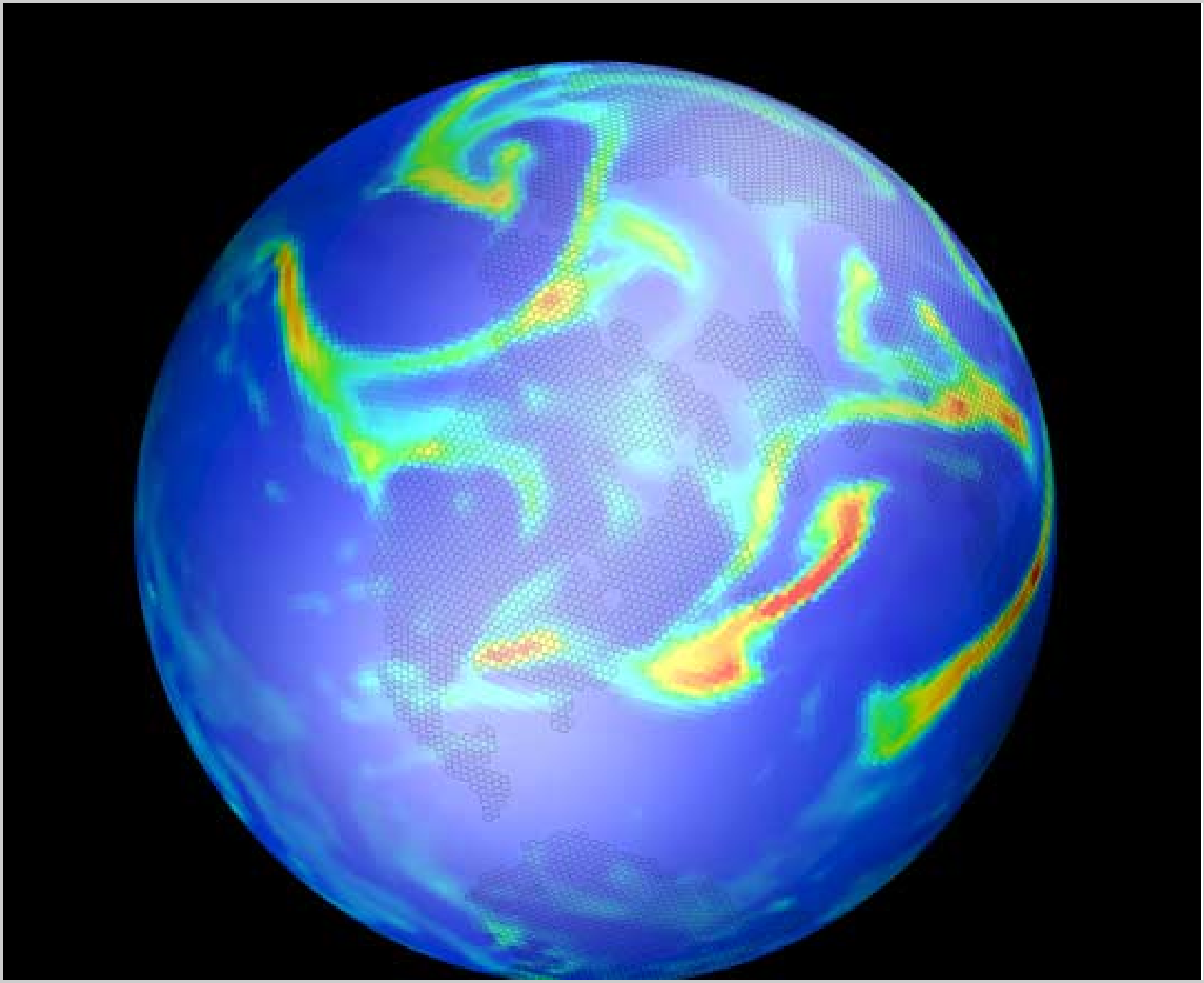
Each grid center owns all the points that are closer to it than any other grid center

All grid cells are hexagons, except for 12 pentagons.

The 12 pentagons correspond to the vertices of the initial icosahedron



...and what we end up with



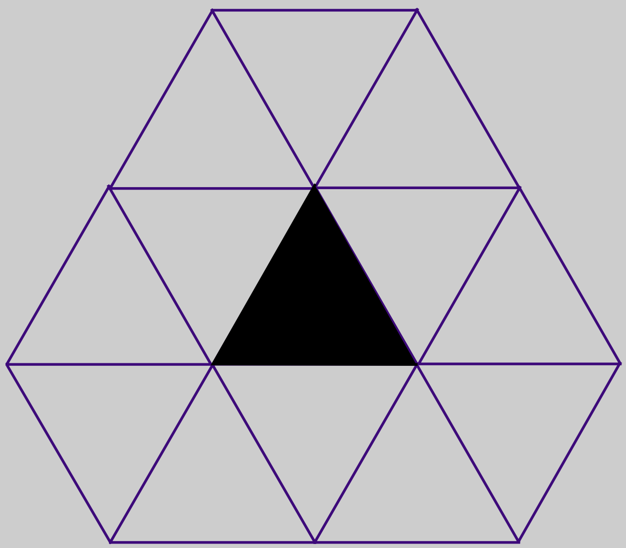
Geometric Properties

R	Number of cells	Number of cells along equator	Average cell area in km^2	Ratio of smallest cell to largest cell	Average distance between cell centers in km	Ratio of smallest to largest distance btn cell centers
0	42	10	1.21e7	0.885	3717.4	0.881
1	162	20	3.14e6	0.916	1909.5	0.820
2	642	40	7.94e5	0.942	961.6	0.799
3	2562	80	1.99e5	0.948	481.6	0.790
4	10242	160	4.98e4	0.951	240.9	0.789
5	40962	320	1.24e4	0.952	120.5	0.788

If we trisect the edges of the initial icosahedron (instead of bisect), we can generate grids in between these resolutions.

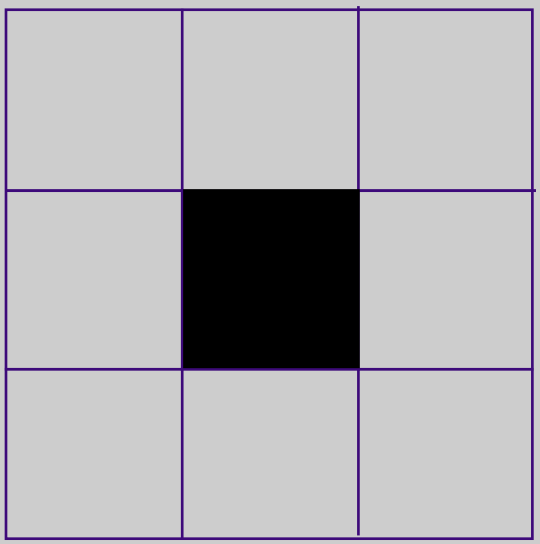
The surface of the sphere is isotropic.

The discretization of the sphere's surface should reflect this isotropy.



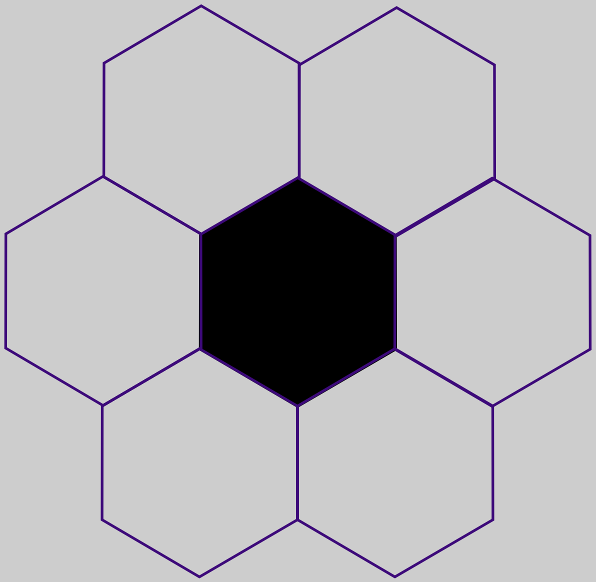
12 neighbors

3 neighbors across walls
3 neighbors across vertices
6 neighbors across vertices on diag



8 neighbors

4 neighbors across walls
4 neighbors across vertices



6 neighbors

6 neighbors across walls

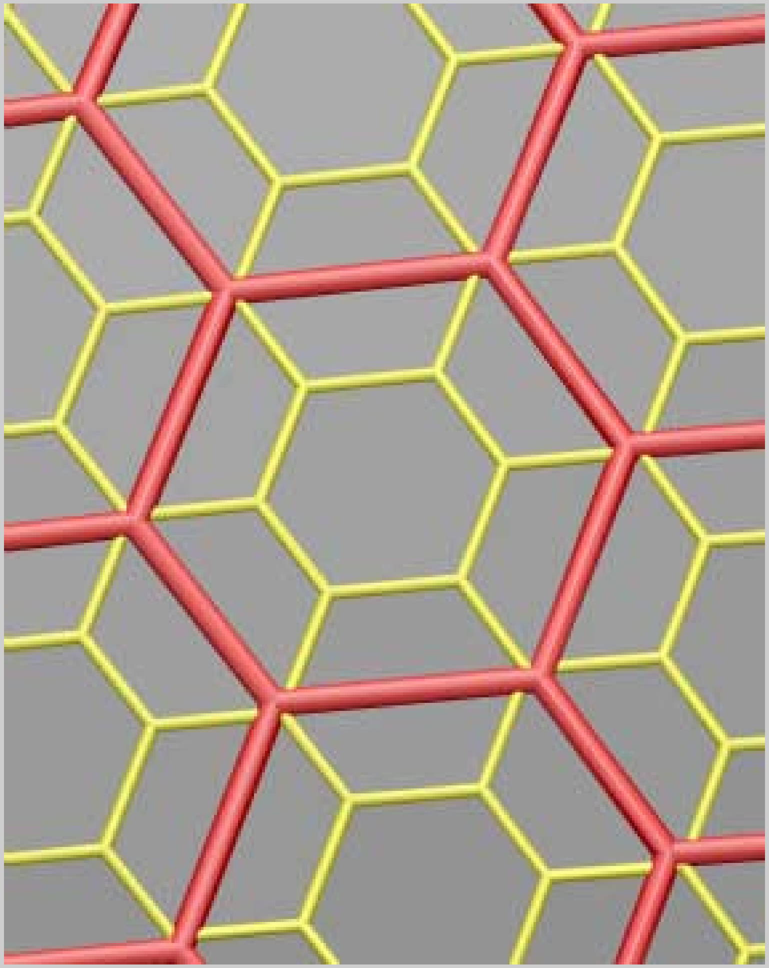
Using geodesic grids throughout a climate model leads to even more benefits.

Climate sub-models generally use different resolutions

These sub-models must communicate.

The high level of conformity between geodesic grids of different resolutions leads to balanced loading and communication.

For MPP architectures, balanced loading and communication is a must.



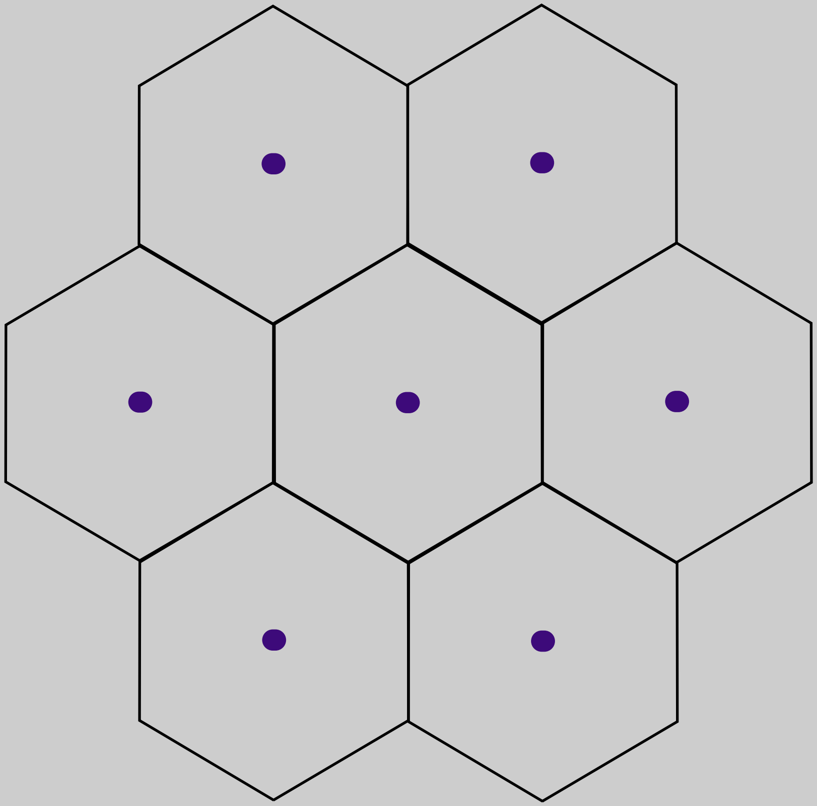
The CSU AGCM uses the Z-grid

[Masuda and Ohnishi (1986), Randall (1994), Heikes and Randall (1995), Ringler et al. (2000)]

This is a scalar formulation, therefore no coordinate system is needed.

Vorticity and divergence are prognosed, instead of the velocity vector.

All variables, both prognostic and diagnostic, are defined at the grid centers.

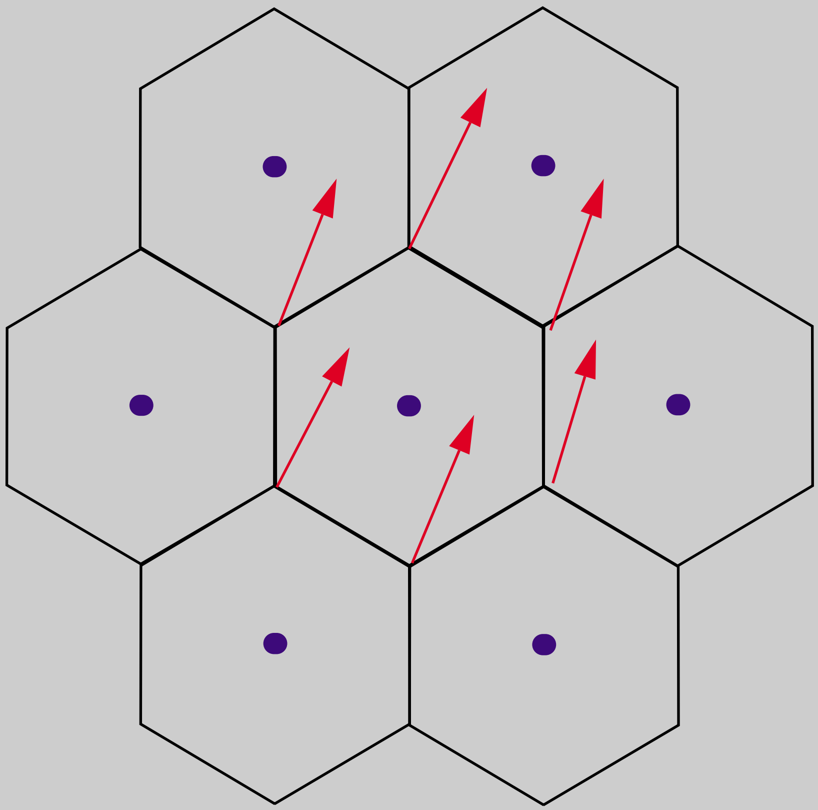


Further improving the Z-grid discretization

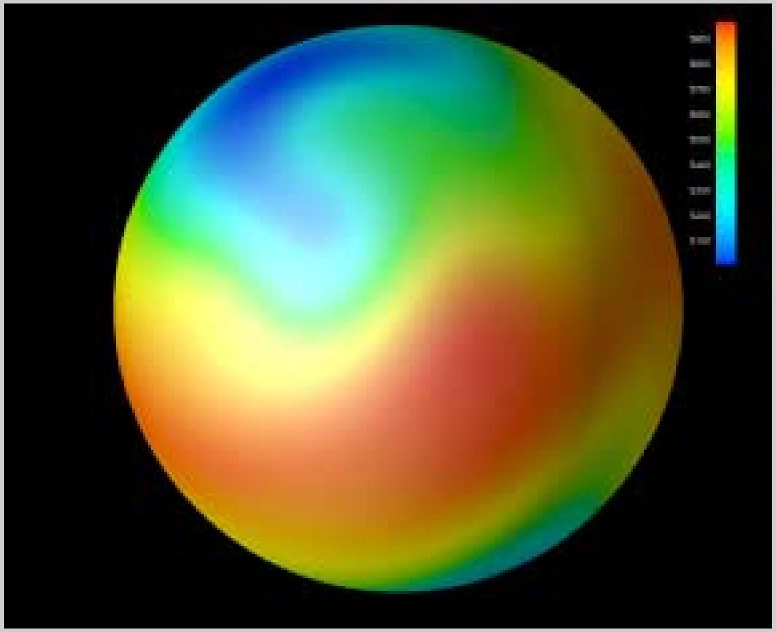
[Ringler and Randall (2001a,b), in review]

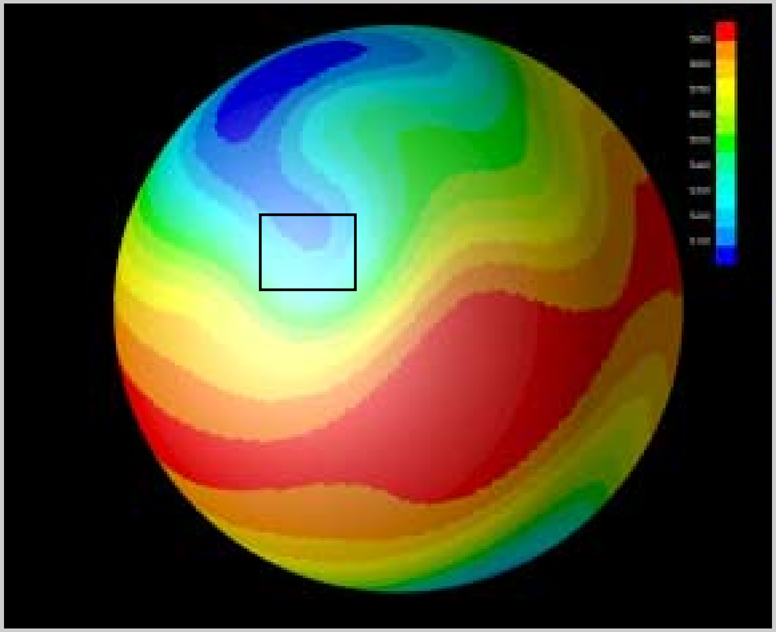
Identified a momentum analog to the Z-grid: the ZM-grid

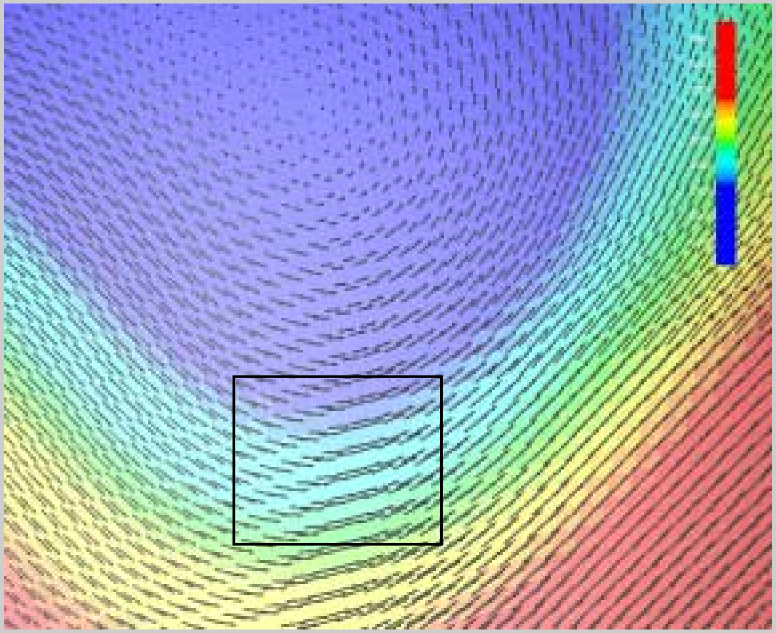
New scheme conserves total energy and potential enstrophy.

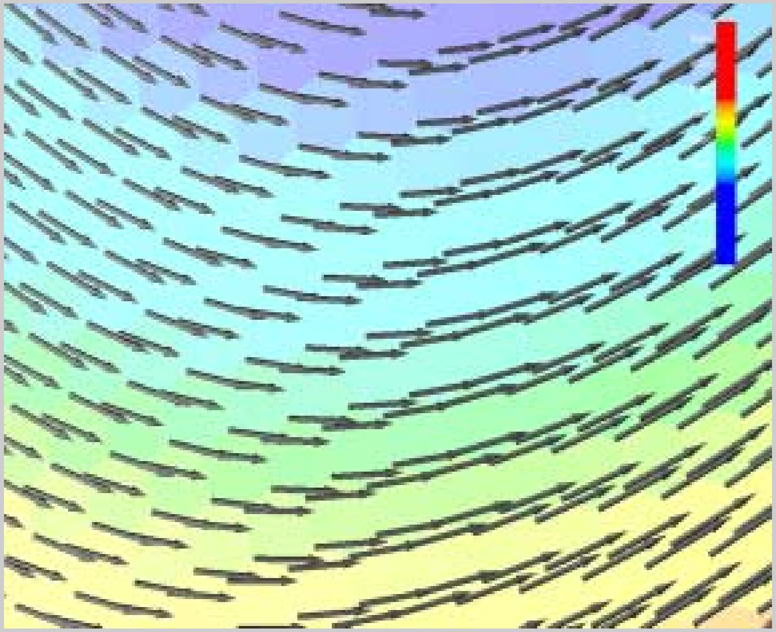


Various views of the surface height and velocity fields at day 10



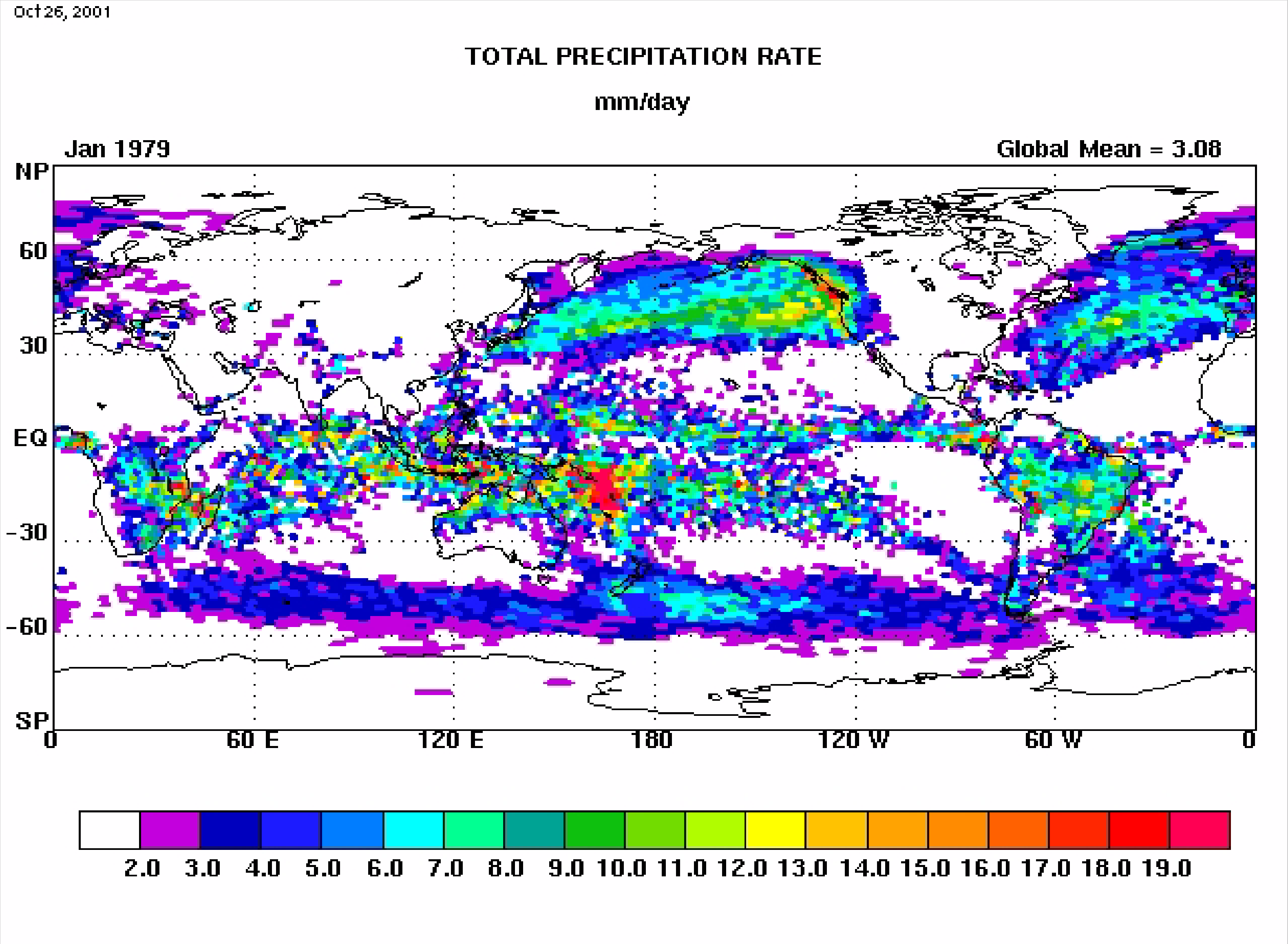




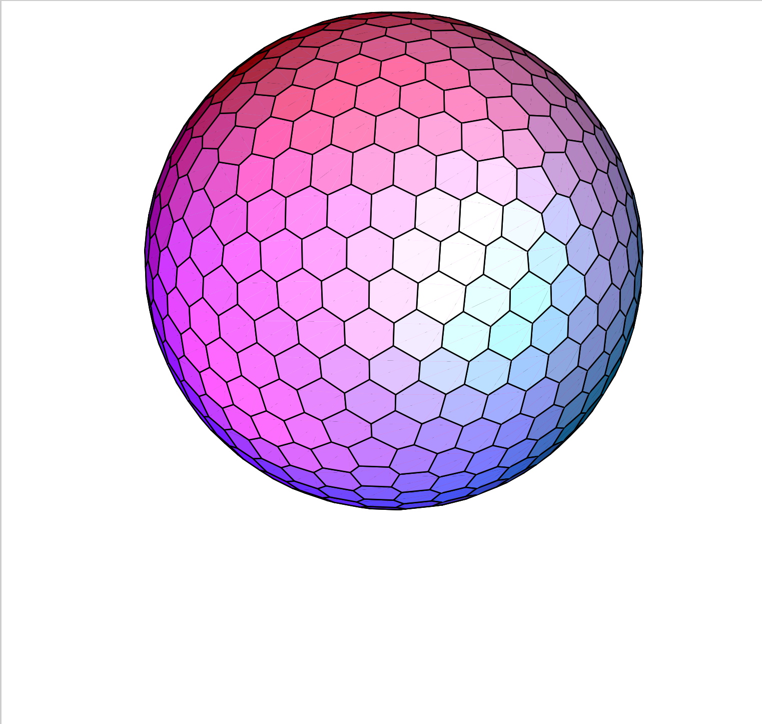


Results for an on-going AMIPII integration

Resolution = 10242, Field = Total Precipitation (mm/day), Month = July



The properties of a geodesic grid that make it attractive for numerical modeling also make it attractive for data analysis.



A homogenous and highly isotropic grid leads to the following:

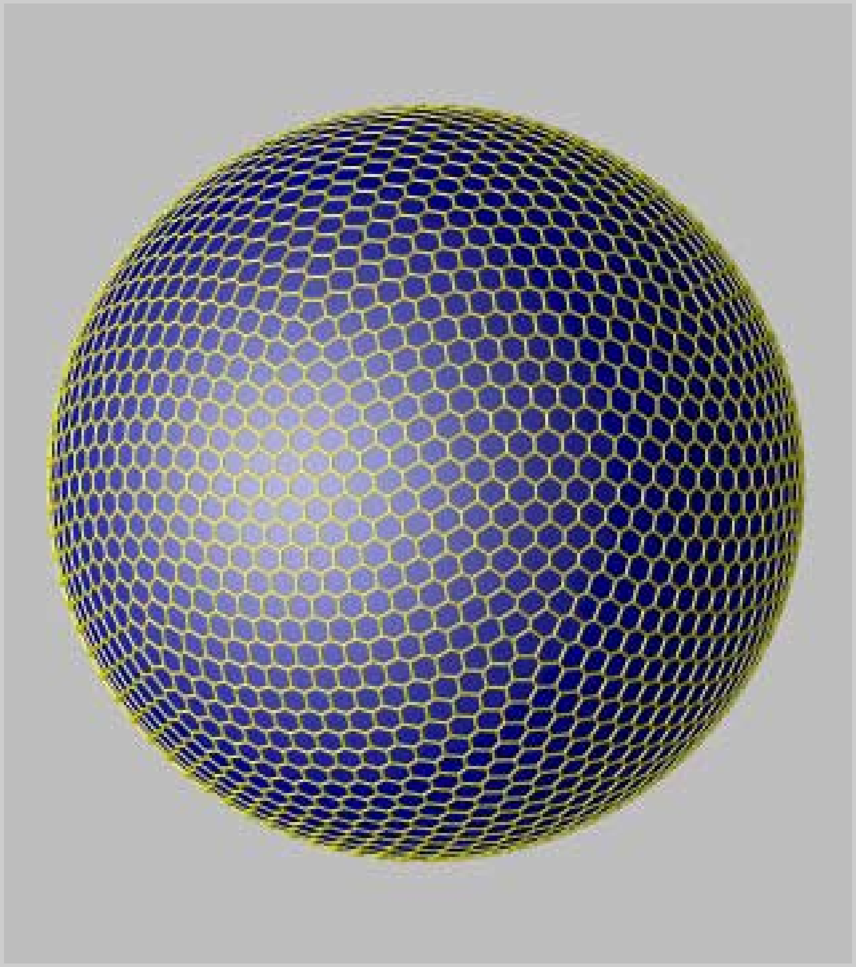
A single grid for analysis of any part of the Earth

Efficient archival of retrieved and derived data sets

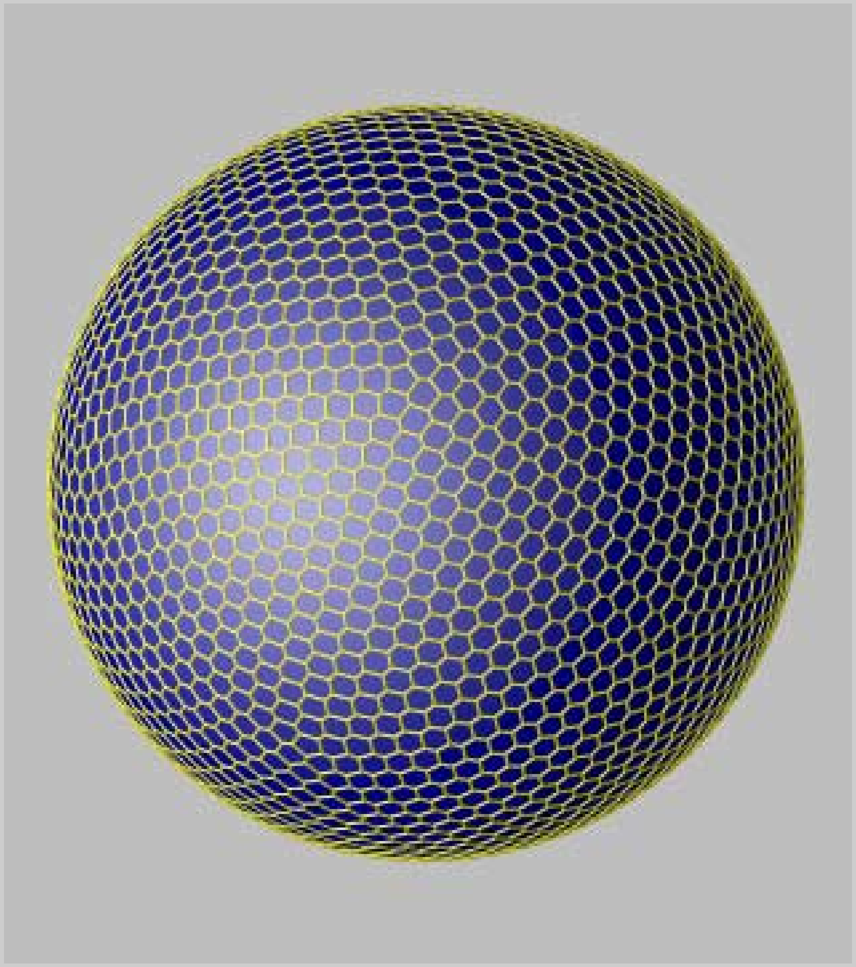
Efficient remapping to and from other grid structures

A Single Grid....

A Satellite View above
the Equator

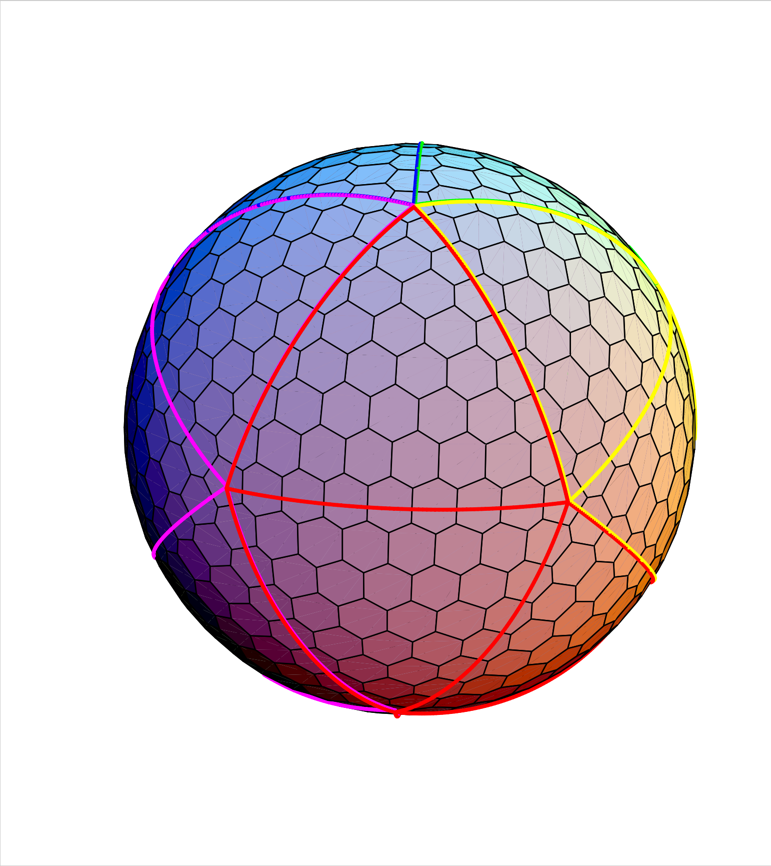


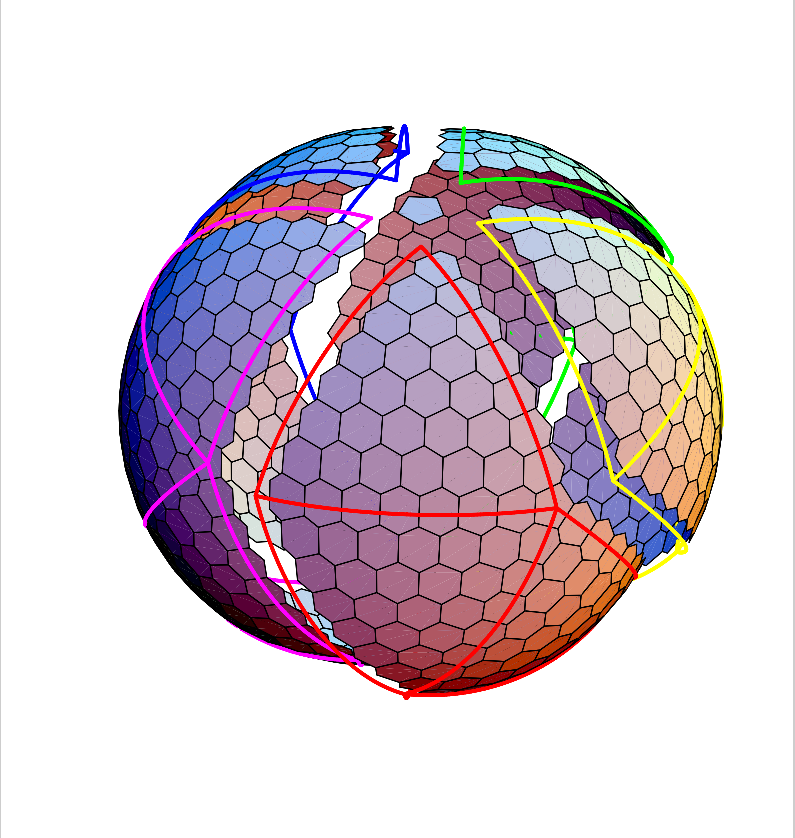
A Satellite View above
the North Pole

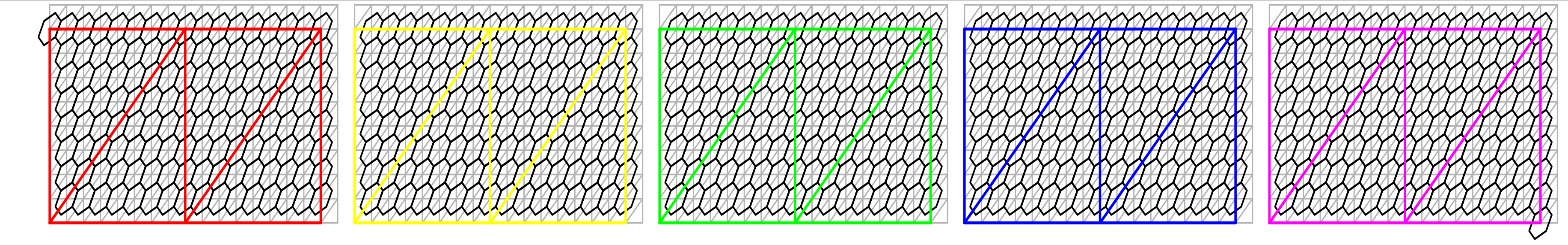


Data Archival

Geodesic grids can be mapped to both 2-d and 1-d data structures



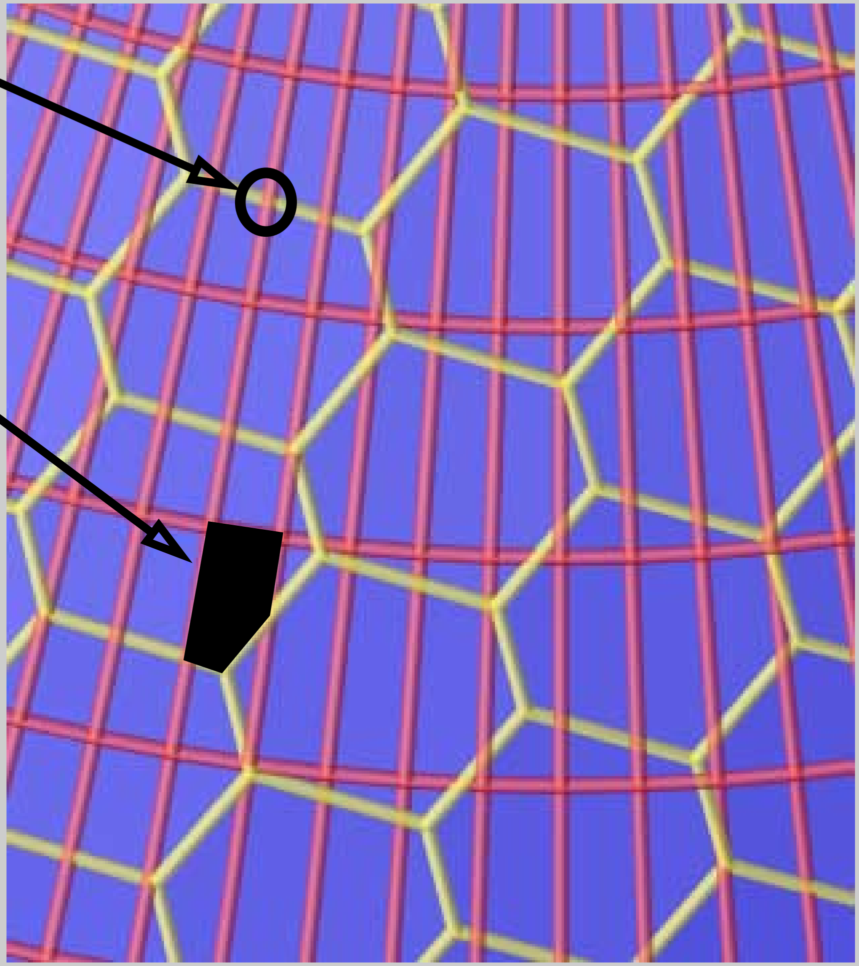




Remapping using SCRIP

SCRIP: Spherical Conservative Remapping and Interpolation Package
[Jones (1999)]

Geodesic - LatLon



SCRIP determines the intersection locations of the **any two grids**.

SCRIP then finds the areas of overlap.

The remapping can be 1st- or 2nd-order accurate.

The remapping is reduced to a set of pre-computed weights.

We use SCRIP everyday for **geodesic-to-geodesic** and **geodesic-to-latlon** remappings

Many of these grid utilities can be downloaded off of our web site

http://kiwi.atmos.colostate.edu/BUGS/projects/geodesic

An Introduction to Geodesic Grids (slide show presentation)

Paper and Technical Reports (pdf format)

Interpolating To and From Geodesic Grids (source code)

Data Structures (html and pdf format)

Domain Decomposition: Using Massively Parallel Platforms (source code)

A Geodesic Shallow Water Model (source code)

Summary

Spherical geodesic grids tile the sphere
in both a homogenous and isotropic fashion.

These properties are beneficial in the
numerical modeling of the climate.

These same properties make geodesic grids
an attractive grid structure for data analysis.

Where to from here?

We are currently developing an ocean GCM, sea-ice model,
and flux-coupler based on geodesic grids.