A light blue world map is centered in the background of the slide, showing the continents of North America, South America, Europe, Africa, Asia, and Australia.

Grids for Climate System Modeling

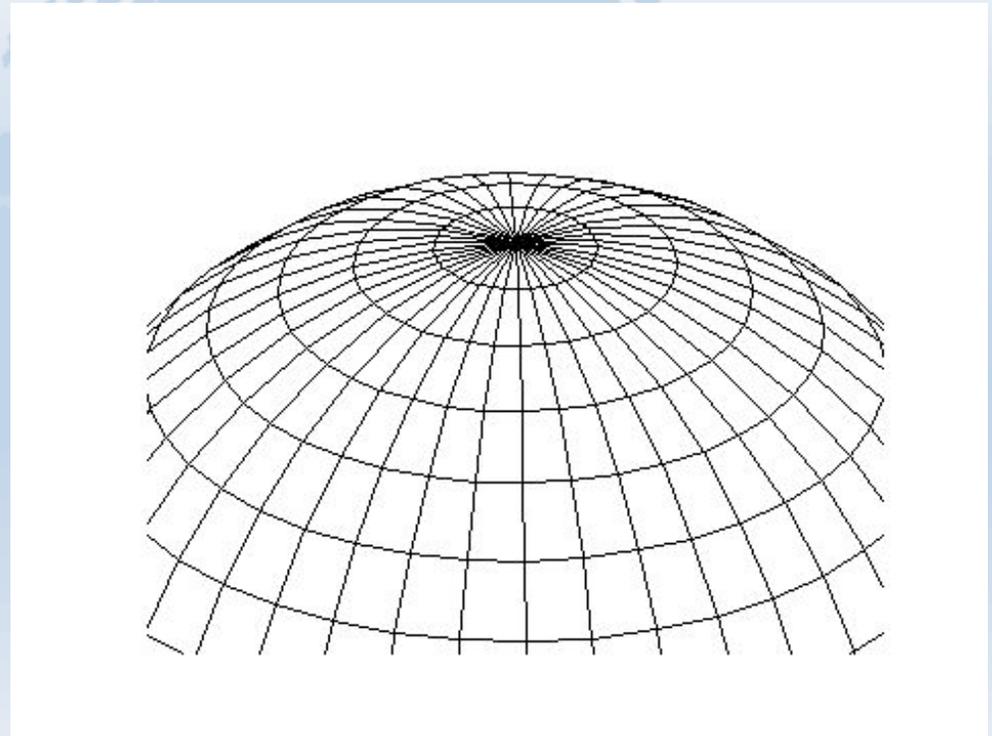
Todd Ringler
Climate, Ocean, Sea-Ice Modeling (COSIM)

Moving beyond the standard model

latitude-longitude have been the standard over the last two decades.

the problems with this grid are obvious and difficult to resolve.

so the question is: why are they the standard?



Early on, alternatives were explored.

The advantages were obvious.

June 1968

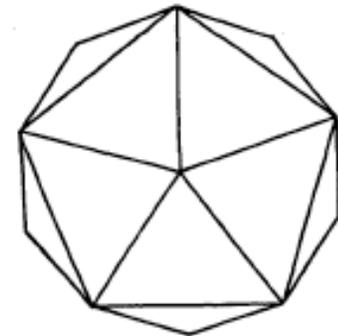
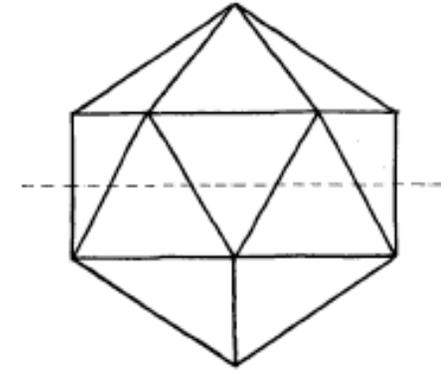
Robert Sadourny, Akio Arakawa, and Yale Mintz

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INTEGRATION OF THE NONDIVERGENT BAROTROPIC VORTICITY EQUATION WITH AN ICOSAHEDRAL-HEXAGONAL GRID FOR THE SPHERE¹

ROBERT SADOURNY,¹ AKIO ARAKAWA, and YALE MINTZ

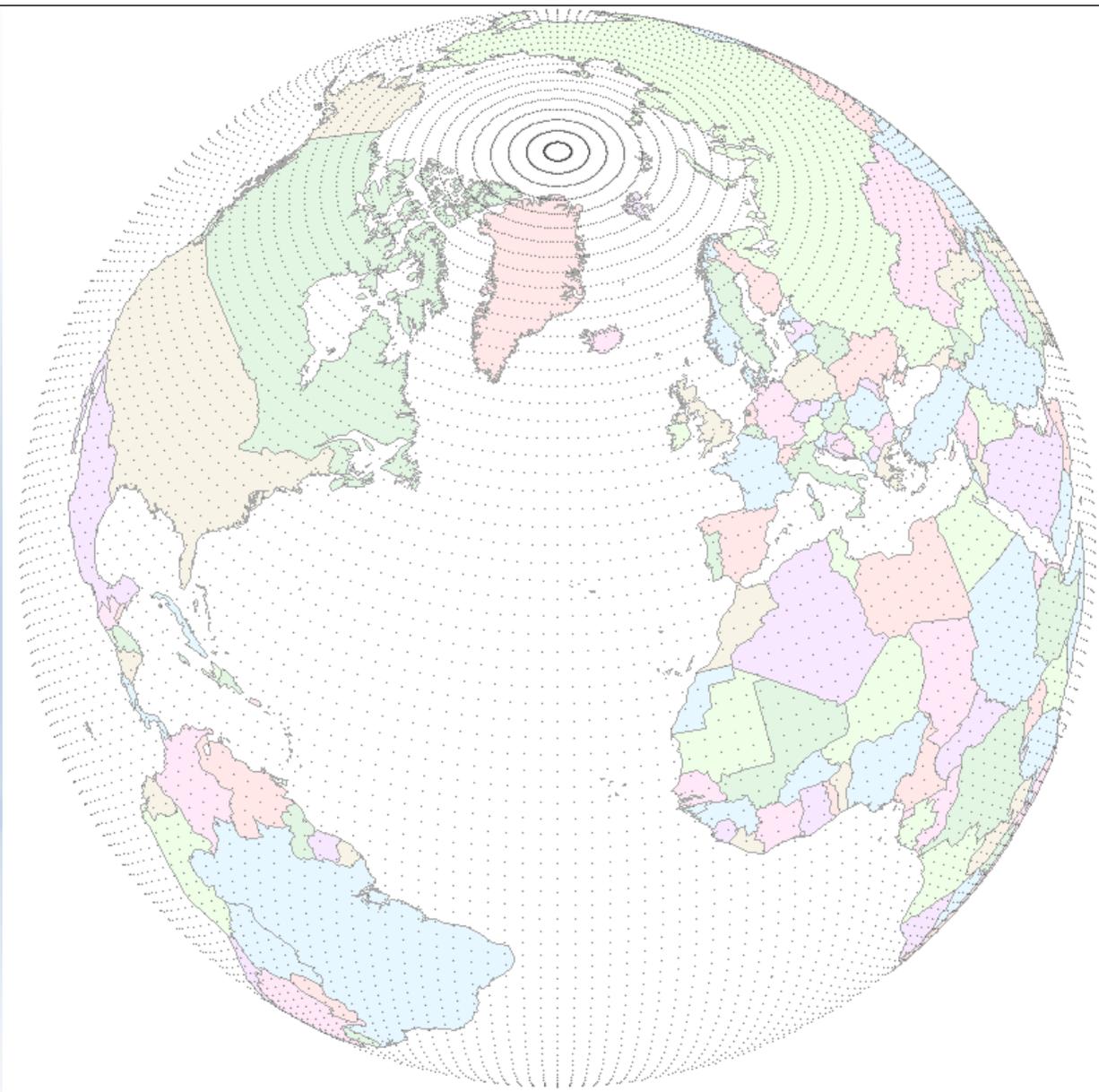
Department of Meteorology, University of California, Los Angeles, Calif.



So what happened?

What happened was the rise of global spectral methods and the accompanying Gaussian Grid.

The entire model is built around the transform grid.

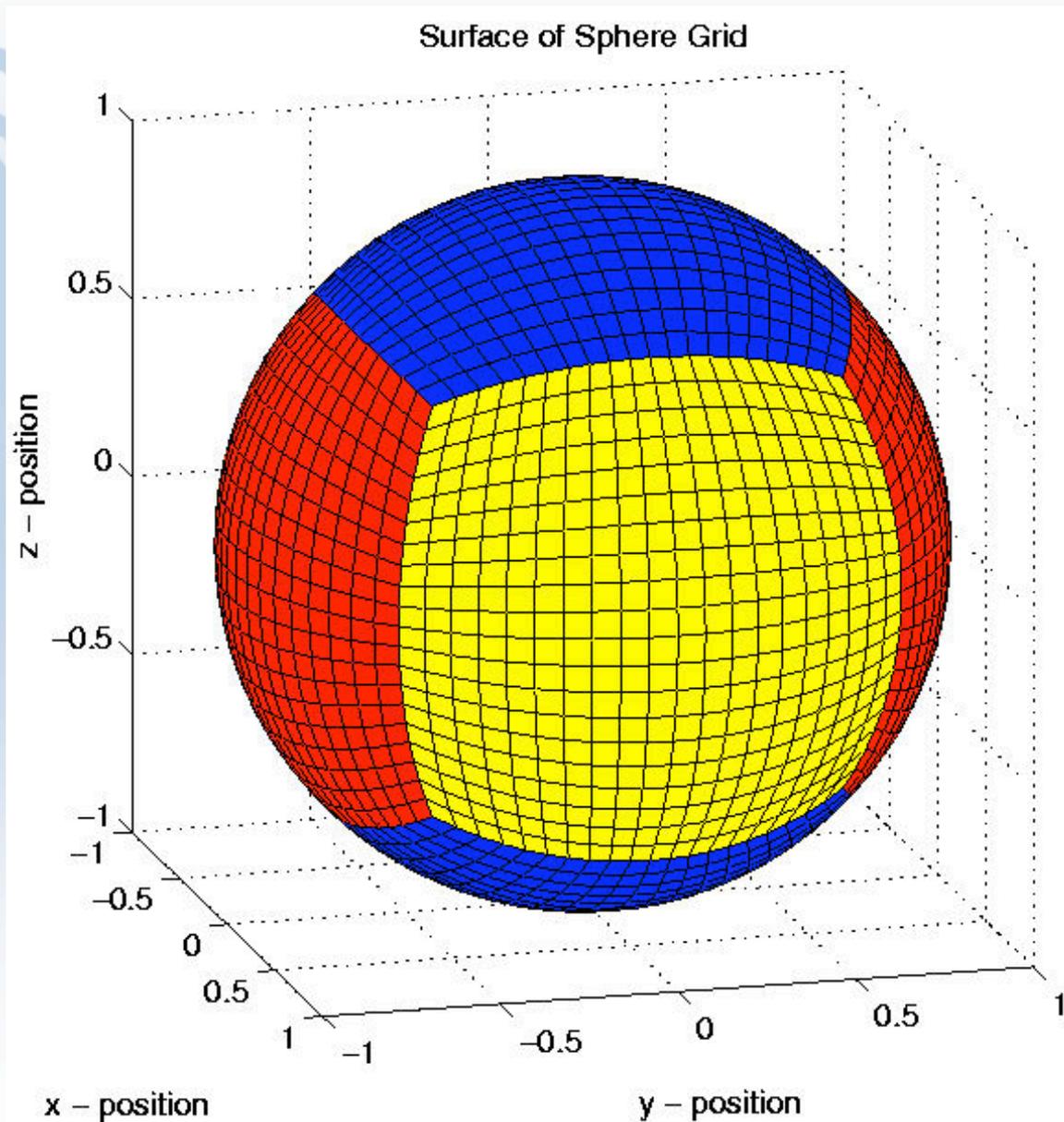




In the mid-nineties there were really three schools of thought on how to move forward:

- 1) stick with the lat/lon grid
- 2) find an alternative with the same topology
- 3) let's rethink this whole process.

One alternative, the cubed-sphere



Another alternative, the stretched-grid A LANL (COSIM) invention



The LANL ocean model (POP) along with this grid is the ocean component of the CCSM

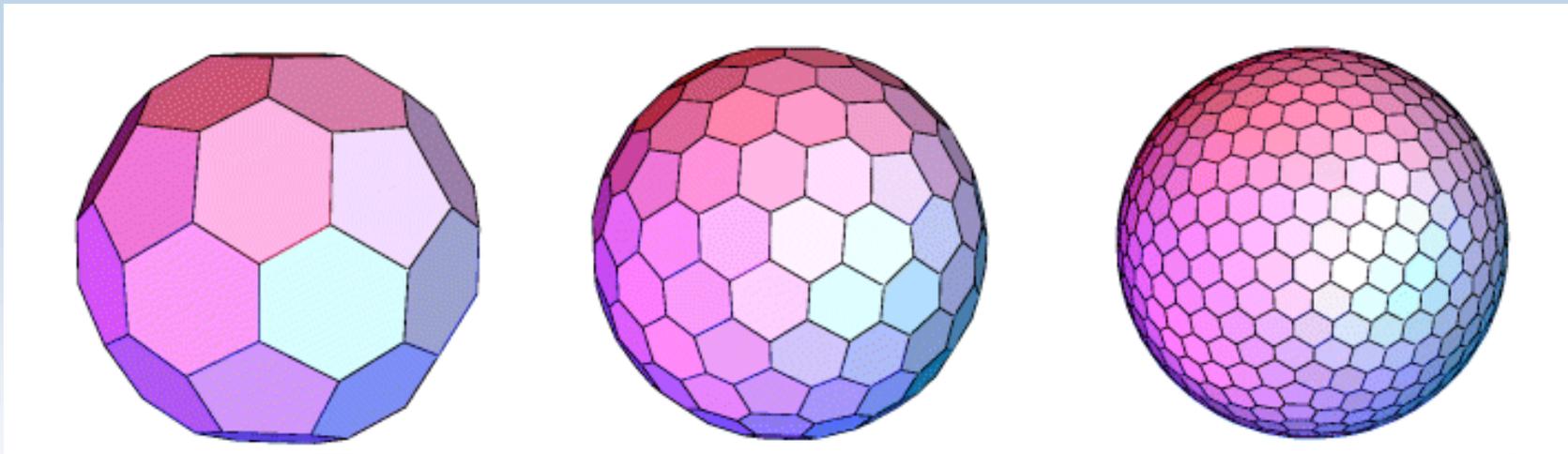
Let's rethink this problem....



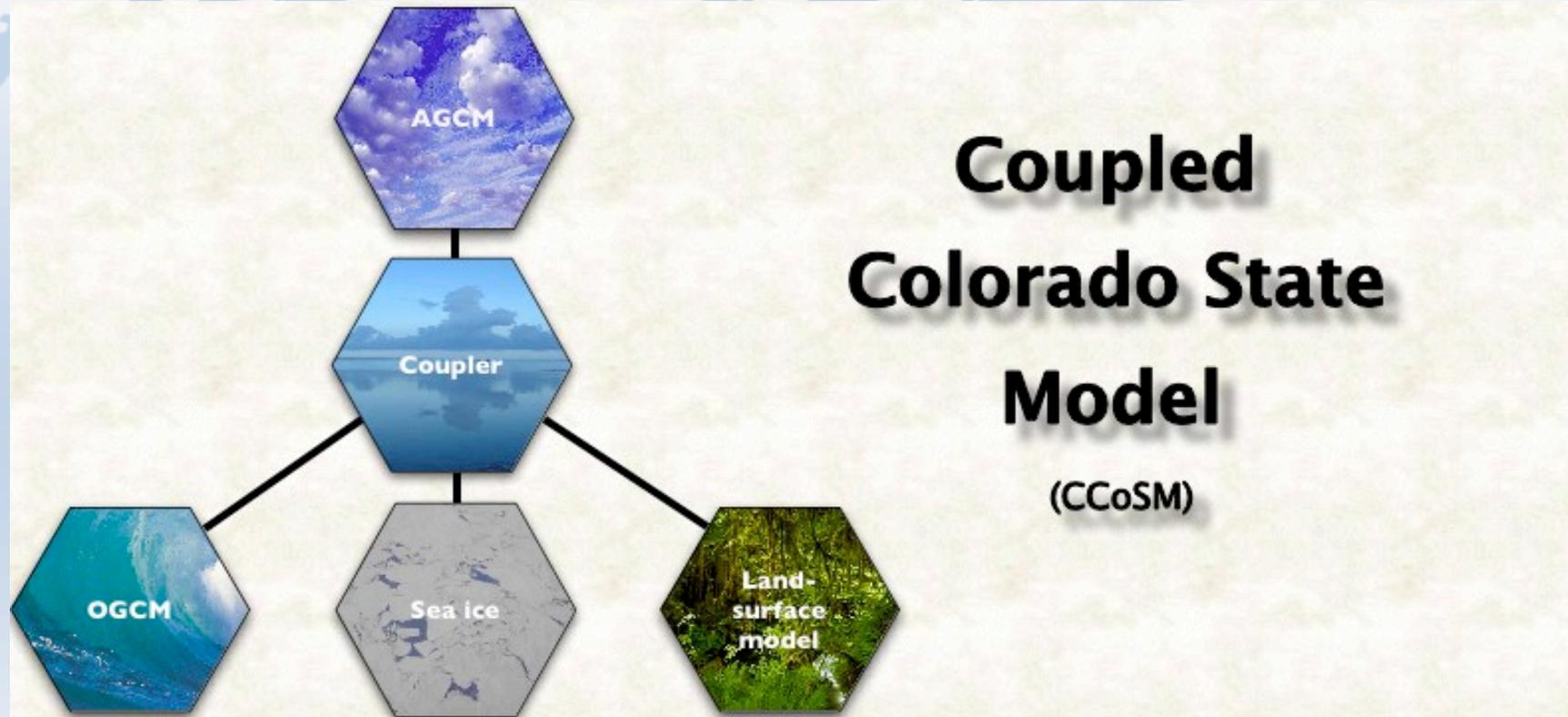
Revisiting the late 60's.

Icosahedral grids lead to quasi-uniform tessellations of the sphere.

The grid is composed of hexagons and twelve pentagons.

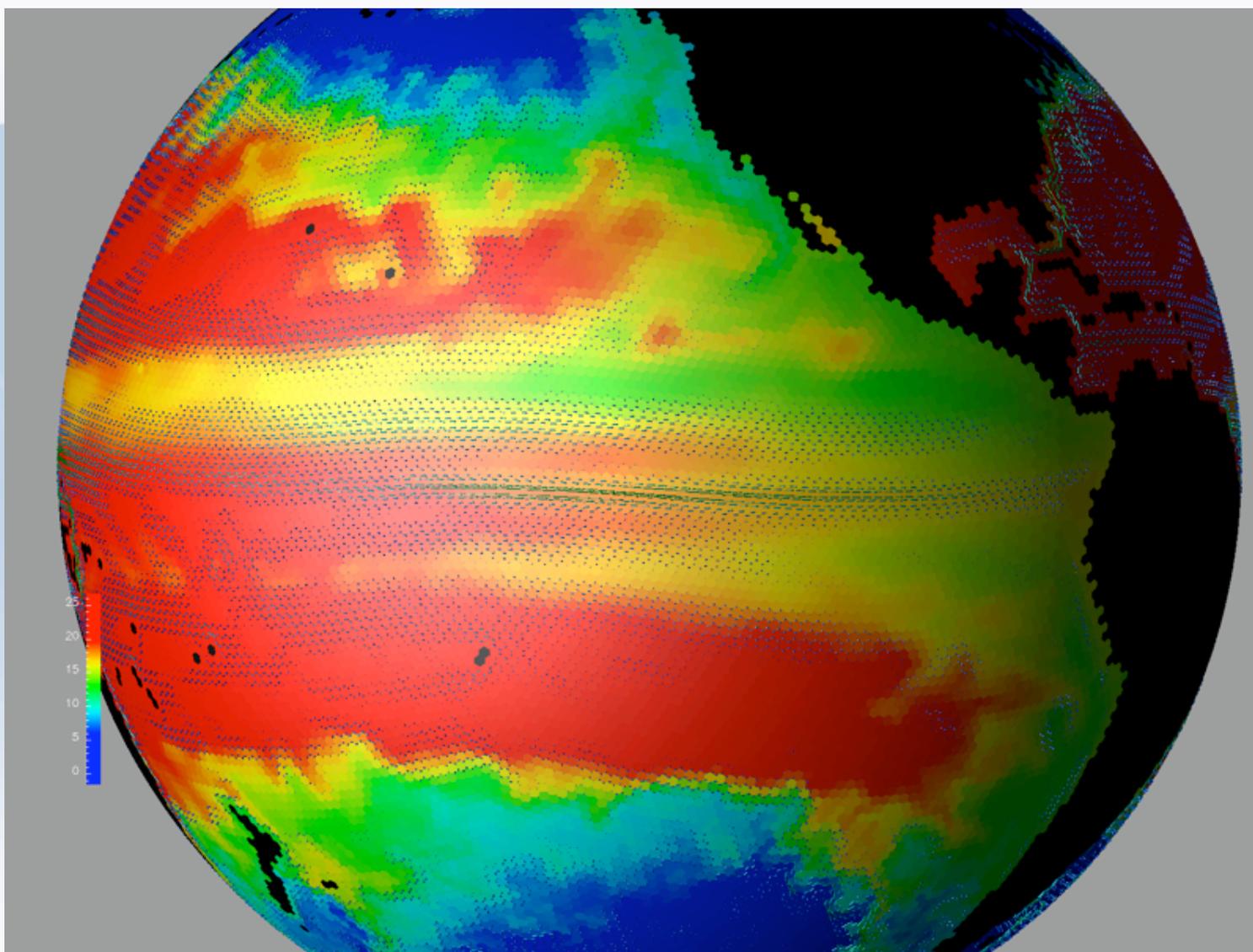


A complete coupled climate using Voronoi tessellations.

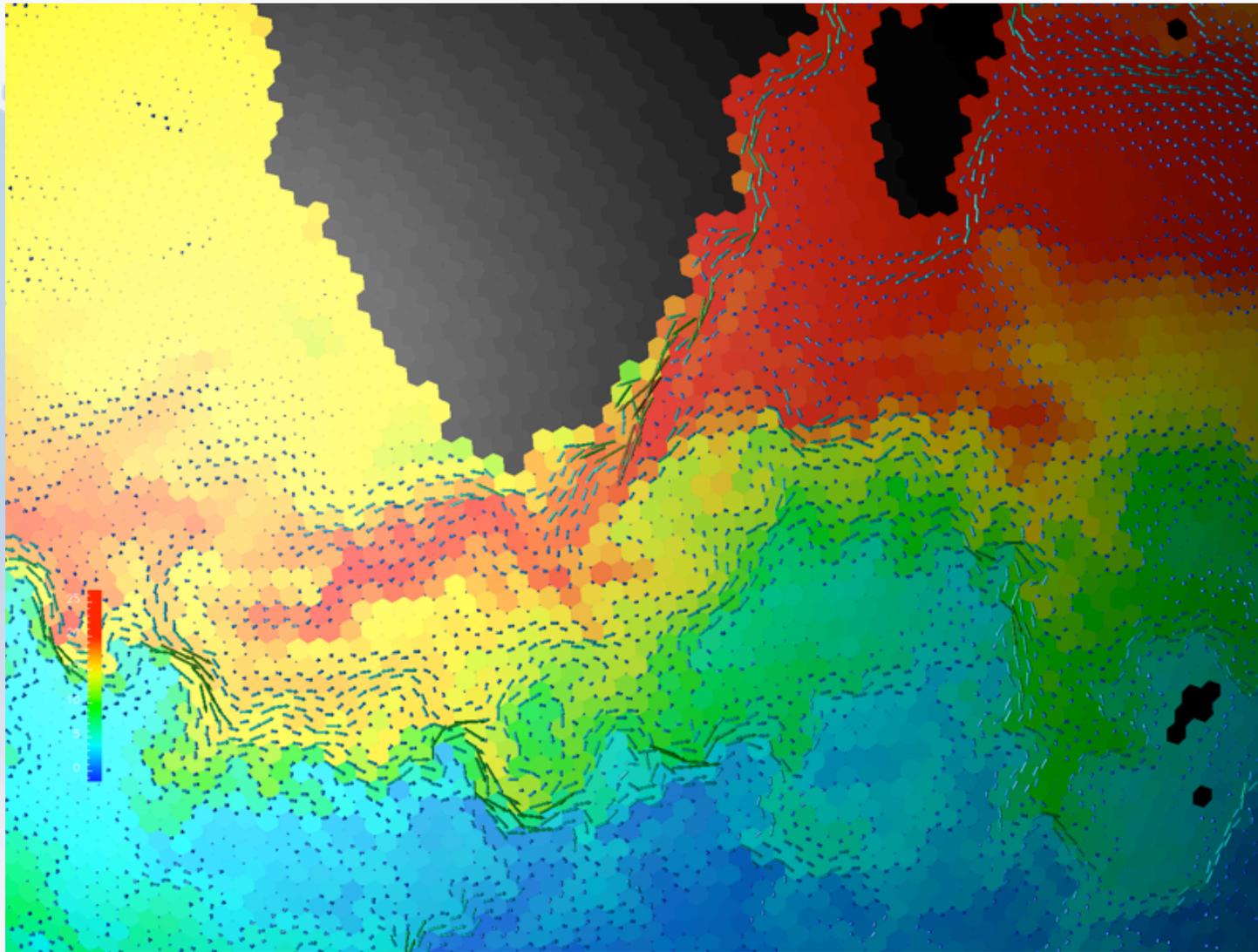


Developed in collaboration with CSU, LANL, UCLA, and NPS

Global Ocean Simulation

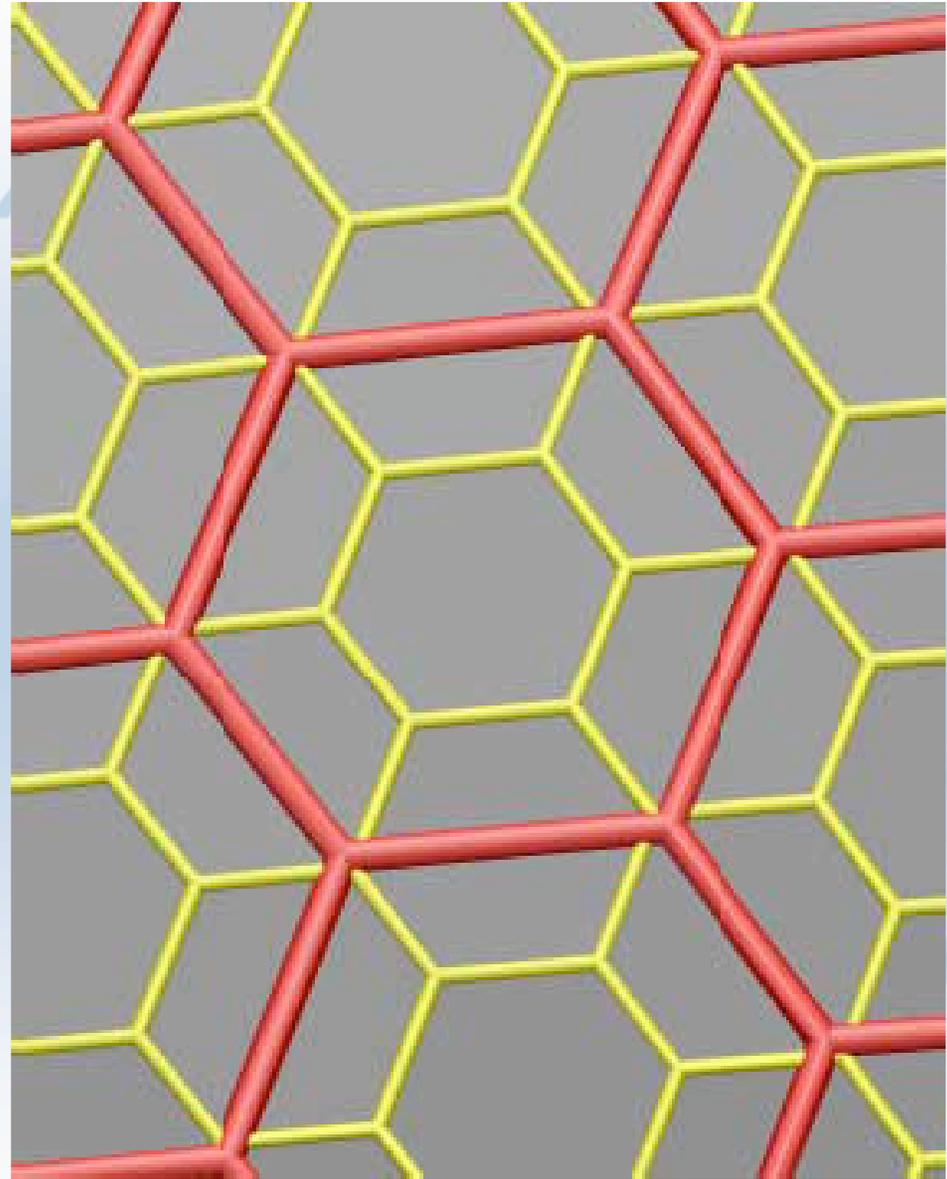


Global Ocean Simulation

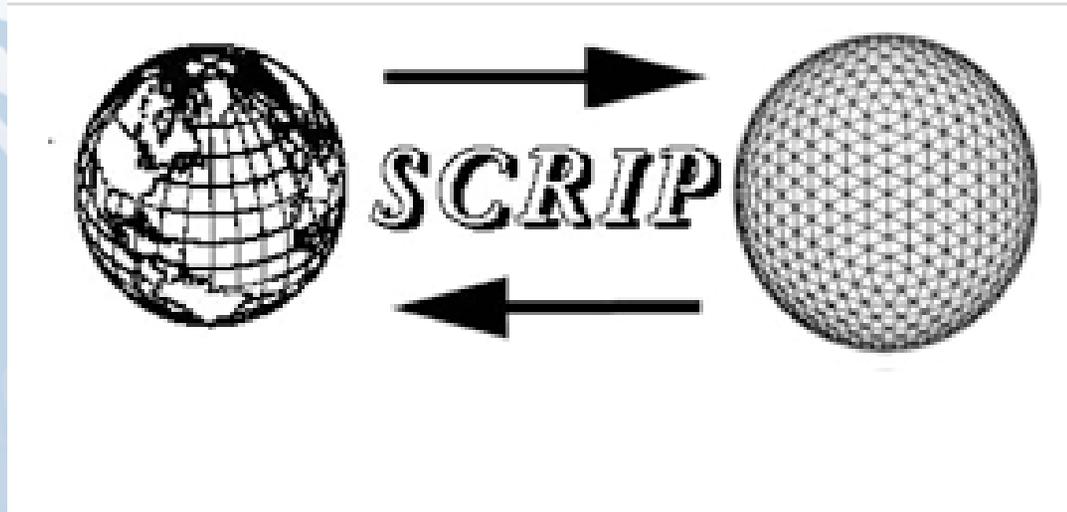


While all components use the same grid type, the grids are not identical.

So we need a robust way to allow the grids to communicate.



Robust coupling of the multiple system components



SCRIP is developed by Phil Jones

Types of remapping:

- Conservative remapping
- Bilinear interpolation
- Bicubic interpolation
- Distance-weighted averaging

Applications:

- Earth System Modeling Framework
- Colorado State University Flux Coupler
- Prism



So that is a summary of the state-of-the-art.

Where is all of this heading?

Unstructured Grids

All of the grids I have shown so far are structured grids in the sense that neighbors are local in memory.

Unstructured grids offer the chance for variable resolution simulations (e.g. enhanced resolution in Gulf Stream).

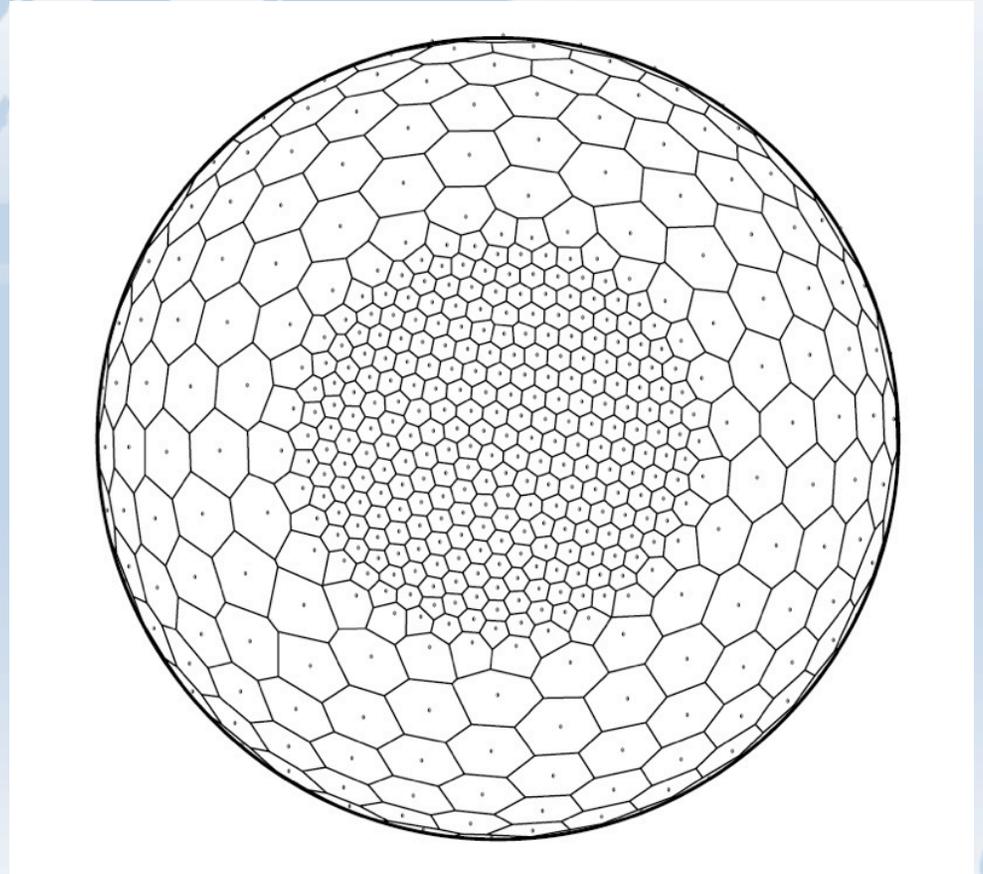
Unstructured grids offer the opportunity to support numerous grid topologies inside the same model.

My personal favorite: Spherical Centroidal Voronoi Tessellations

These are Voronoi point sets.

The Voronoi generator is also the center of mass wrt to a user defined density function.

High density corresponds to increased resolution.

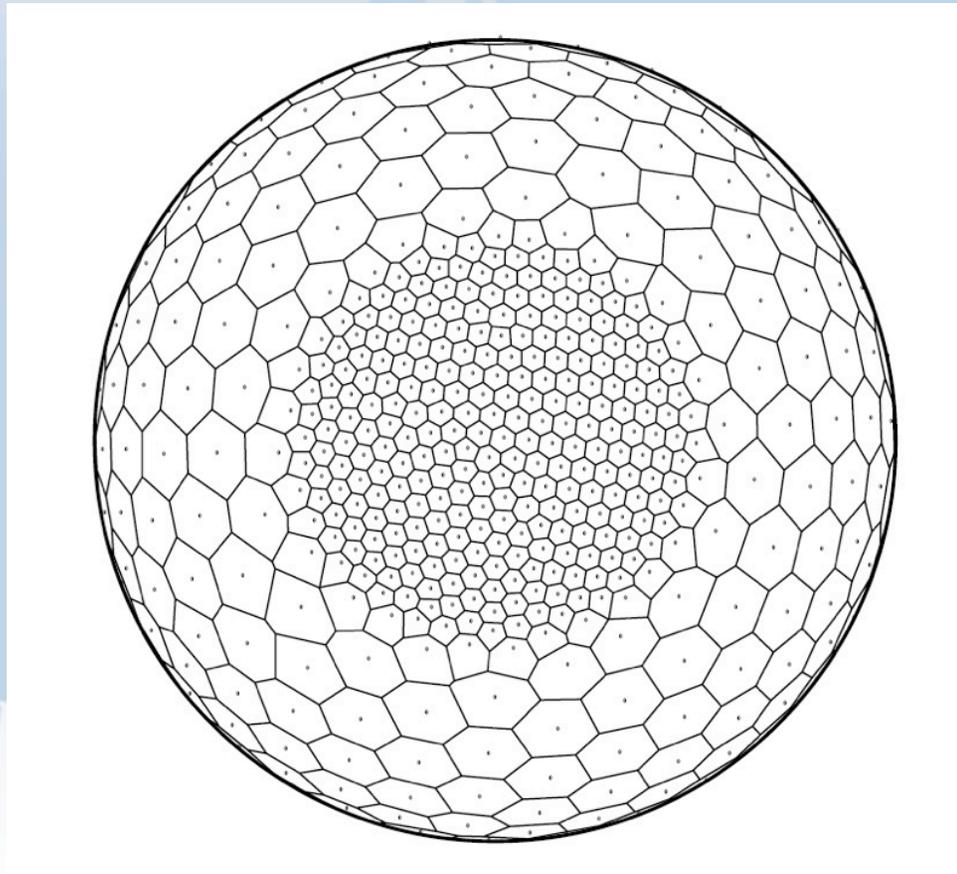


Du and Gunzburger

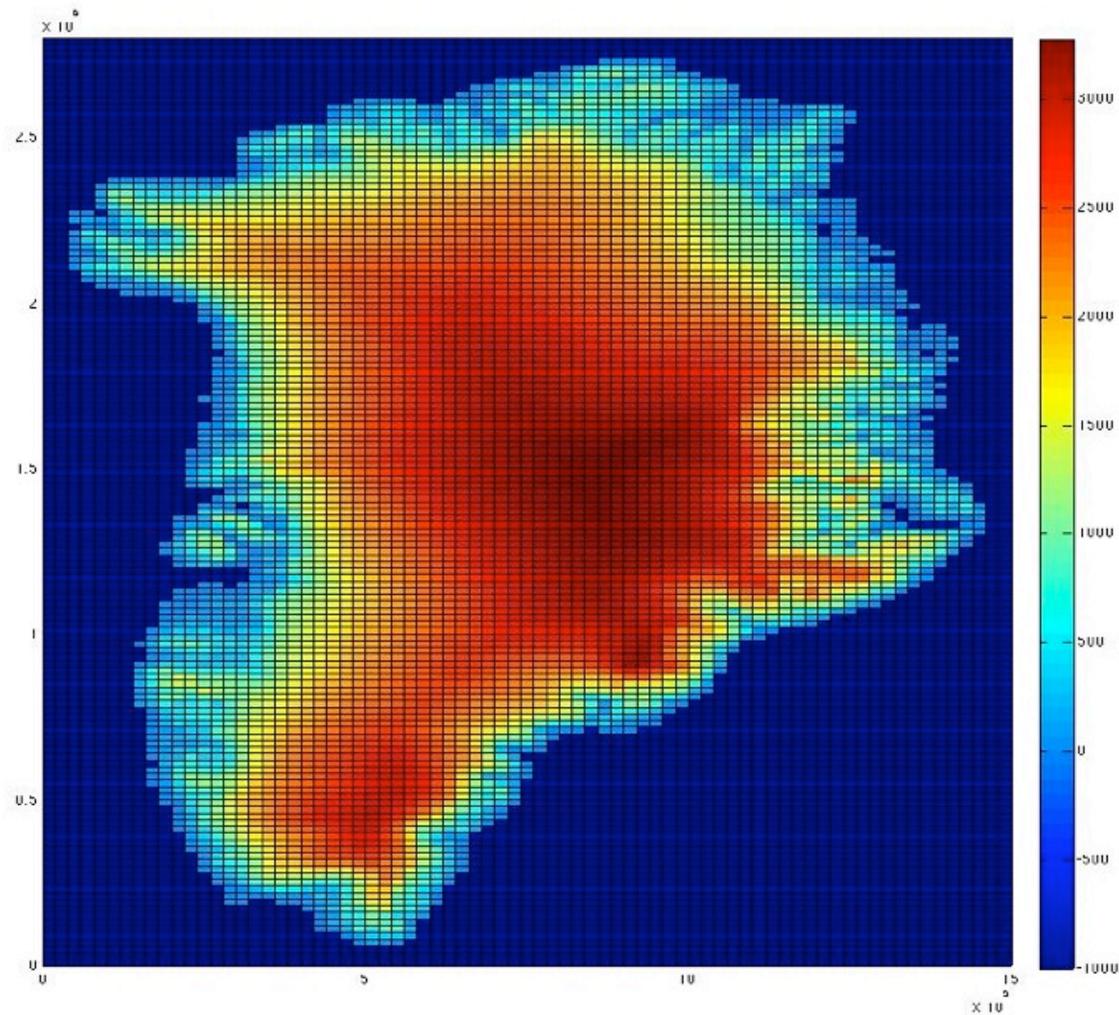
Gershó's Conjecture (proven in 2D on a plane)

In 2D, Voronoi regions are always locally congruent regular hexagons.

The dual Delaunay CVT grid is always locally congruent equilateral triangles



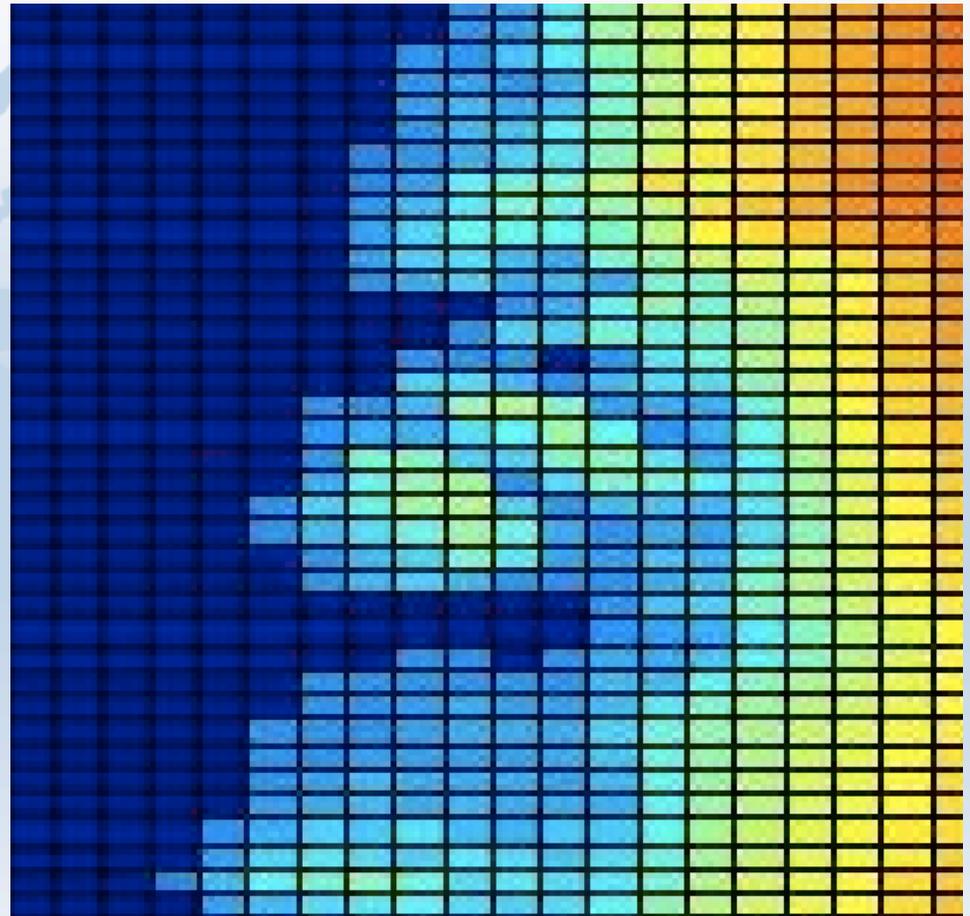
Methods for grid generation: Deterministic Lloyd's Algorithm Probabilistic sampling algorithm



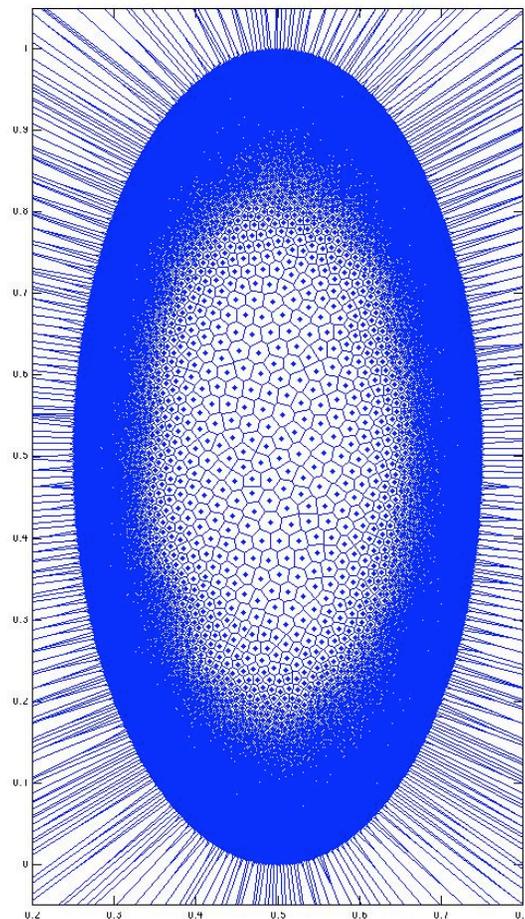
A section of the previous plot

Presently, the boundary position changes with resolution.

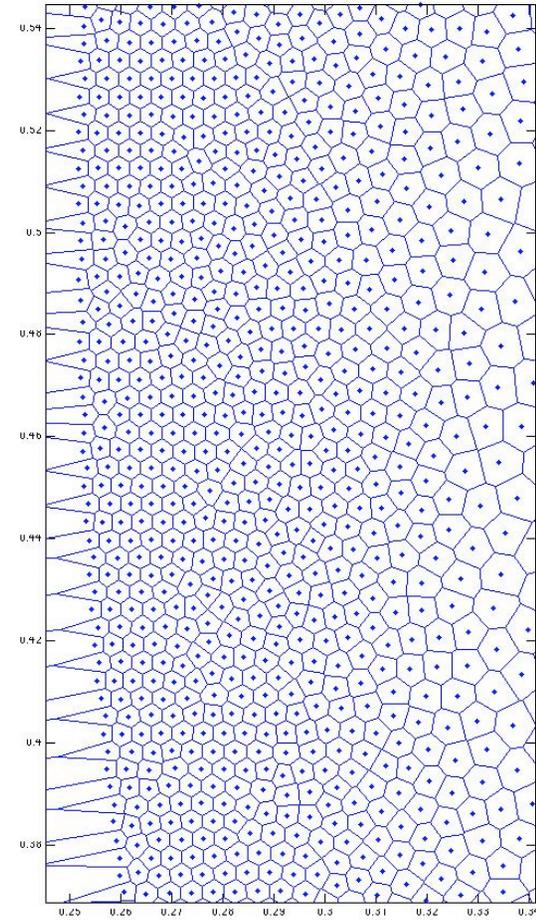
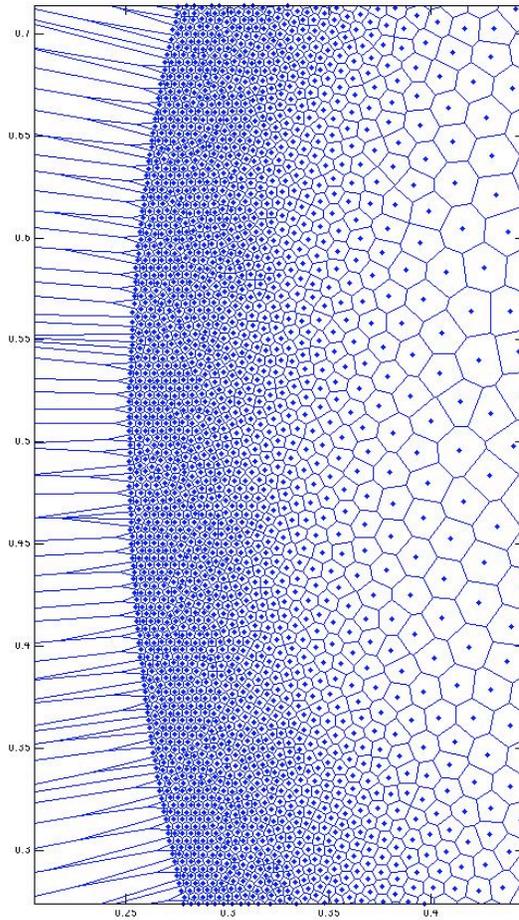
SCVT allows us to specify the boundary (either at the pixel level or as a continuous function) and make the grid conform to that surface.



A starting model of Greenland



A closer look



COSIM needs related to grids

(Derived) data structures to describe the unstructured grids.

Tools to manage and query the data structures.

Understanding the relative merits of adaptive mesh refinement (AMR) and slowly-varying resolution.

Someone to re-write many thousands of lines of source code!

