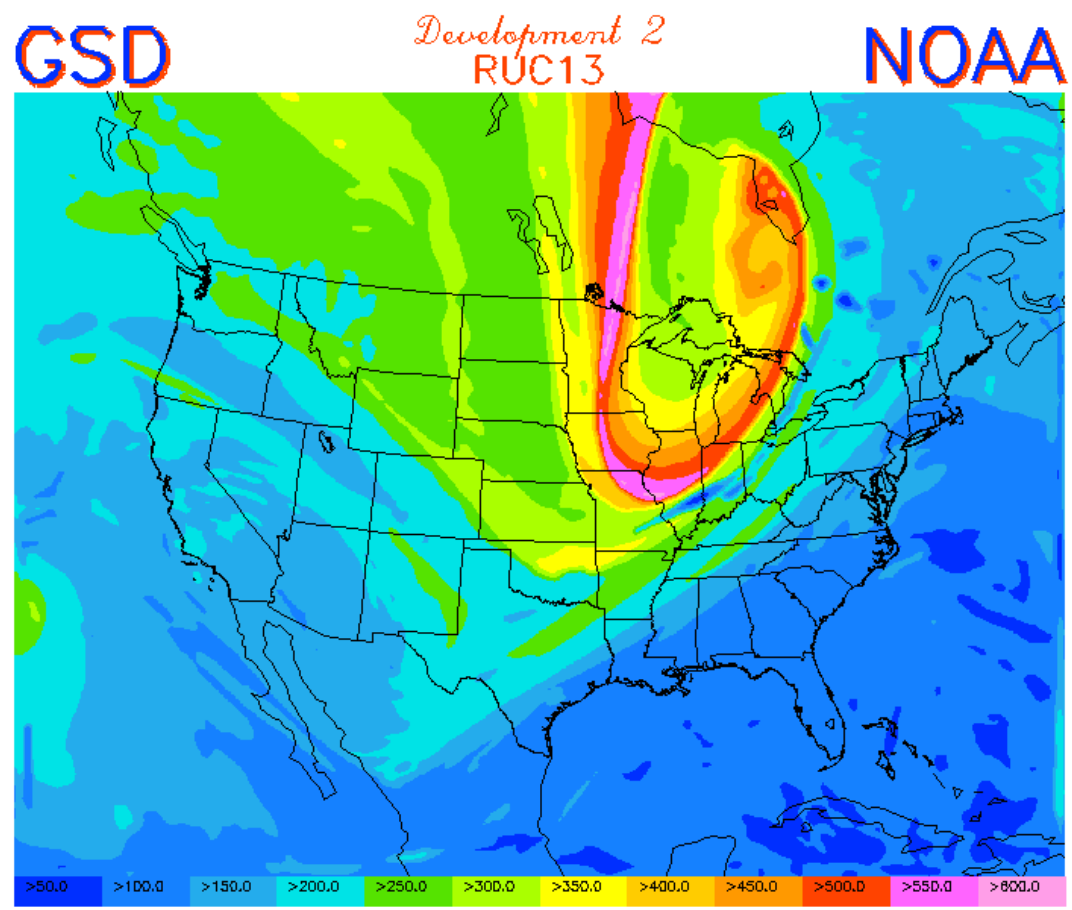
Progress Toward a NOAA-ESRL earth system model: coupling an atmosphere to an ocean

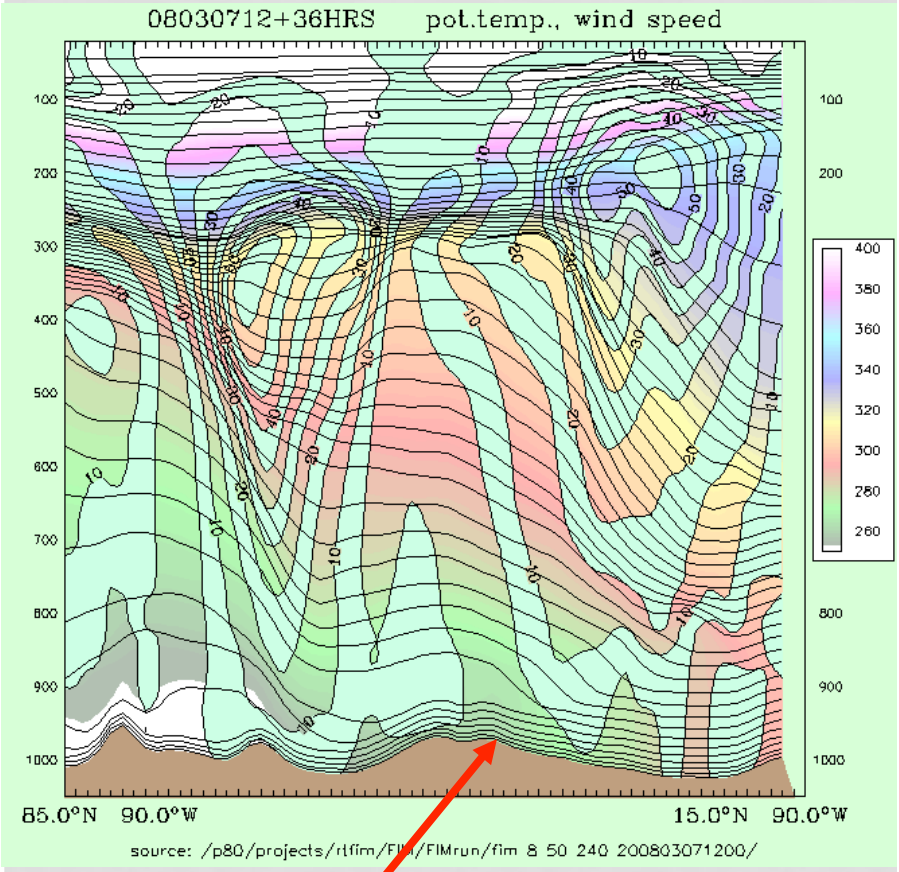
Shan Sun NOAA/ESRL
Rainer Bleck NASA/GISS & NOAA/ESRL

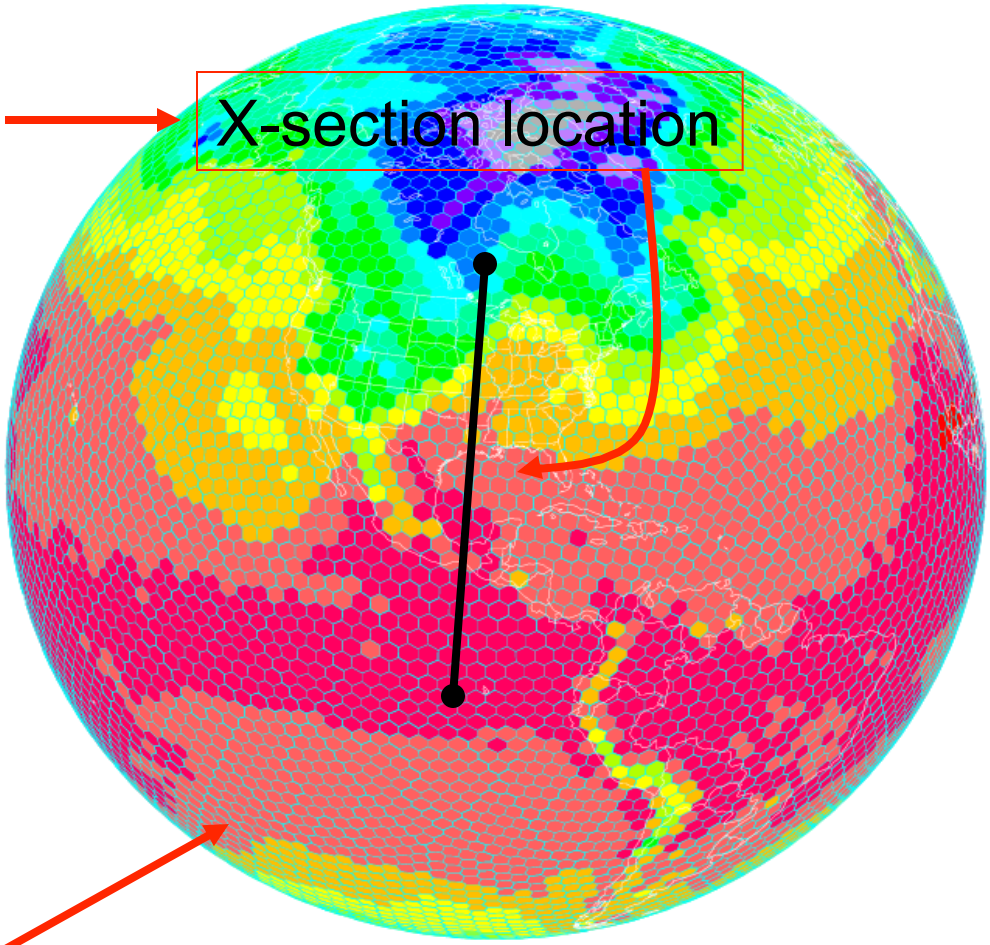
NOAA Earth System Research Laboratory

Global Systems Division

GSD's mission: "to conduct research and development to provide NOAA and the Nation with systems that deliver global environmental information and forecast products ranging from short-term weather predictions to longer-term climate forecasts."







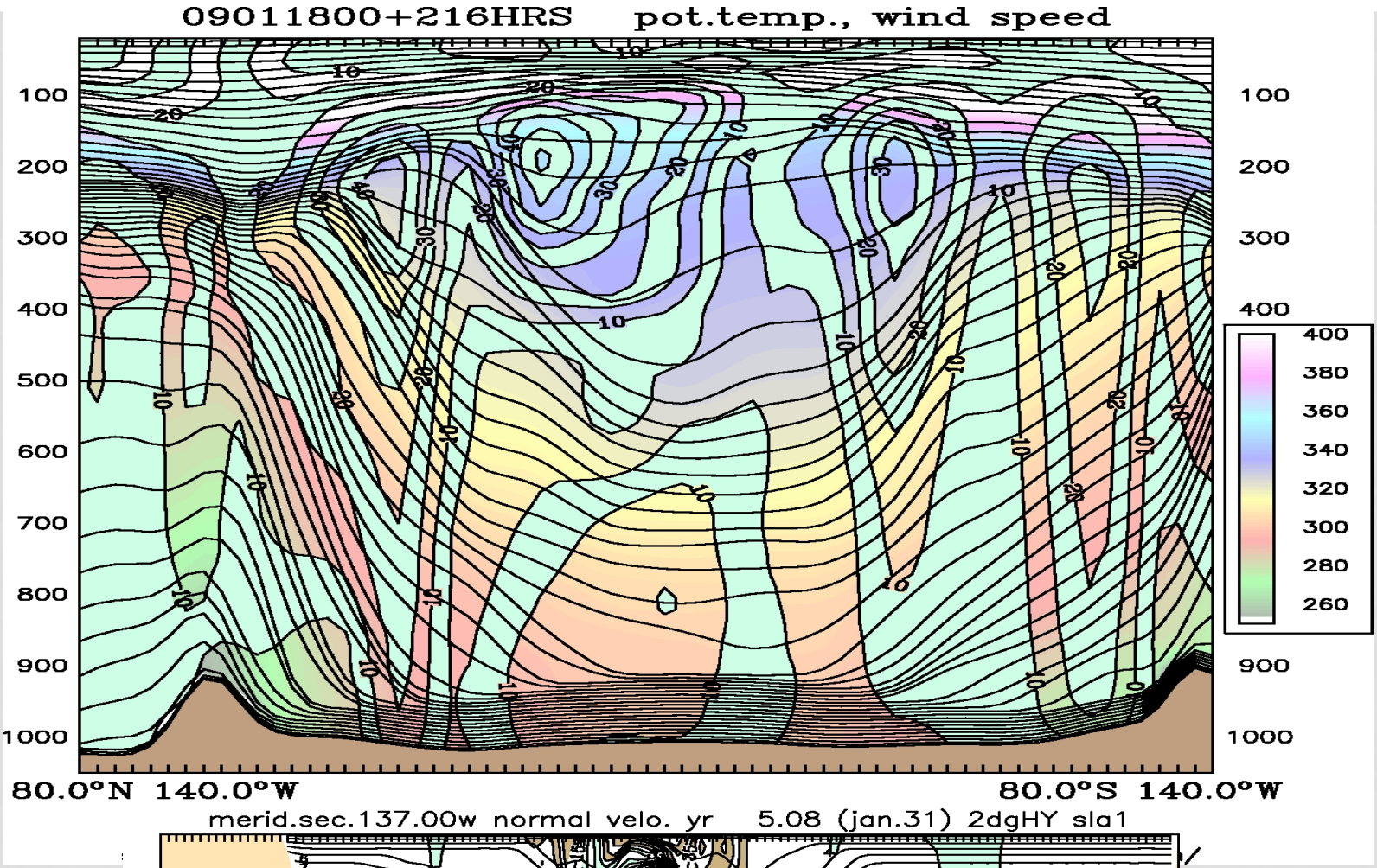
Temp at lowest level

Flow-following- finite volume Icosahedral Model FIM

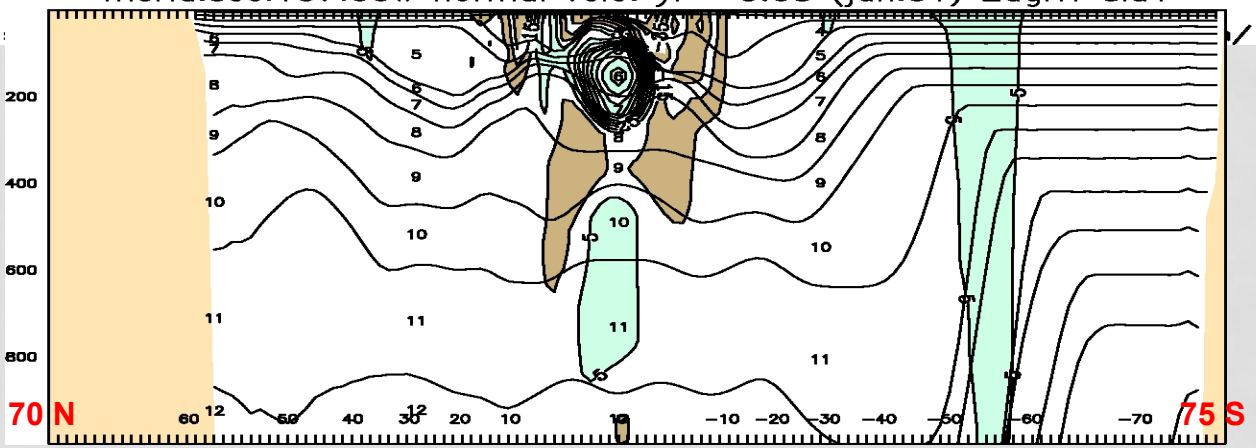
HISTORY OF OCEAN-ATMOSPHERE COUPLING

- Early coupled models required matching horizontal grids in ocean and atmosphere.
- Later, sophisticated “flux couplers” were developed to accommodate independently developed component models.
- Flux couplers rely on spatial interpolation. This degrades accuracy in the location of greatest interest where accuracy matters most.
- **Our plan is to “turn back the clock” and use identical grids (icosahedral in this case) in both sub-models**.
- At 15 km FIM resolution, ocean eddies are resolved (crudely at least). This eliminates one historic reason for using higher horizontal resolution in the ocean than in the atmosphere.

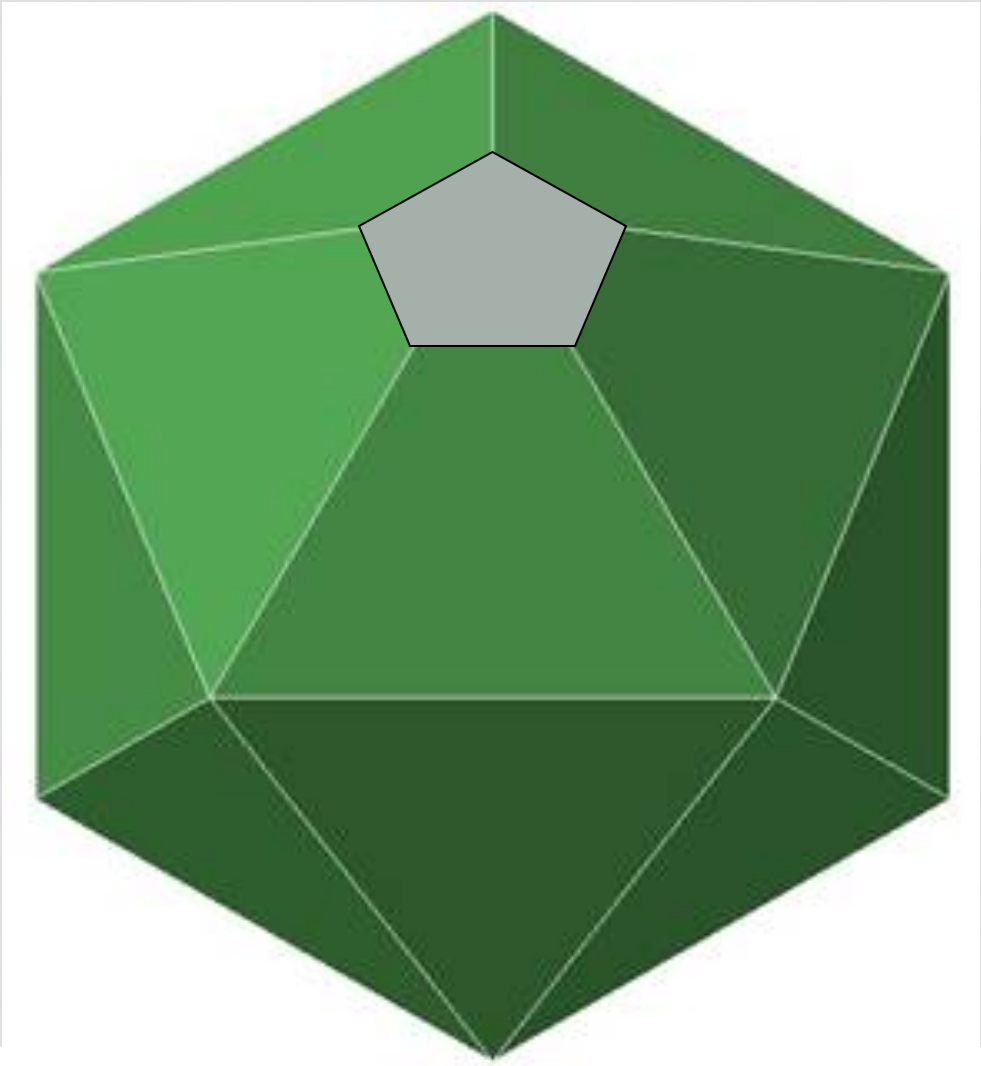
FIM



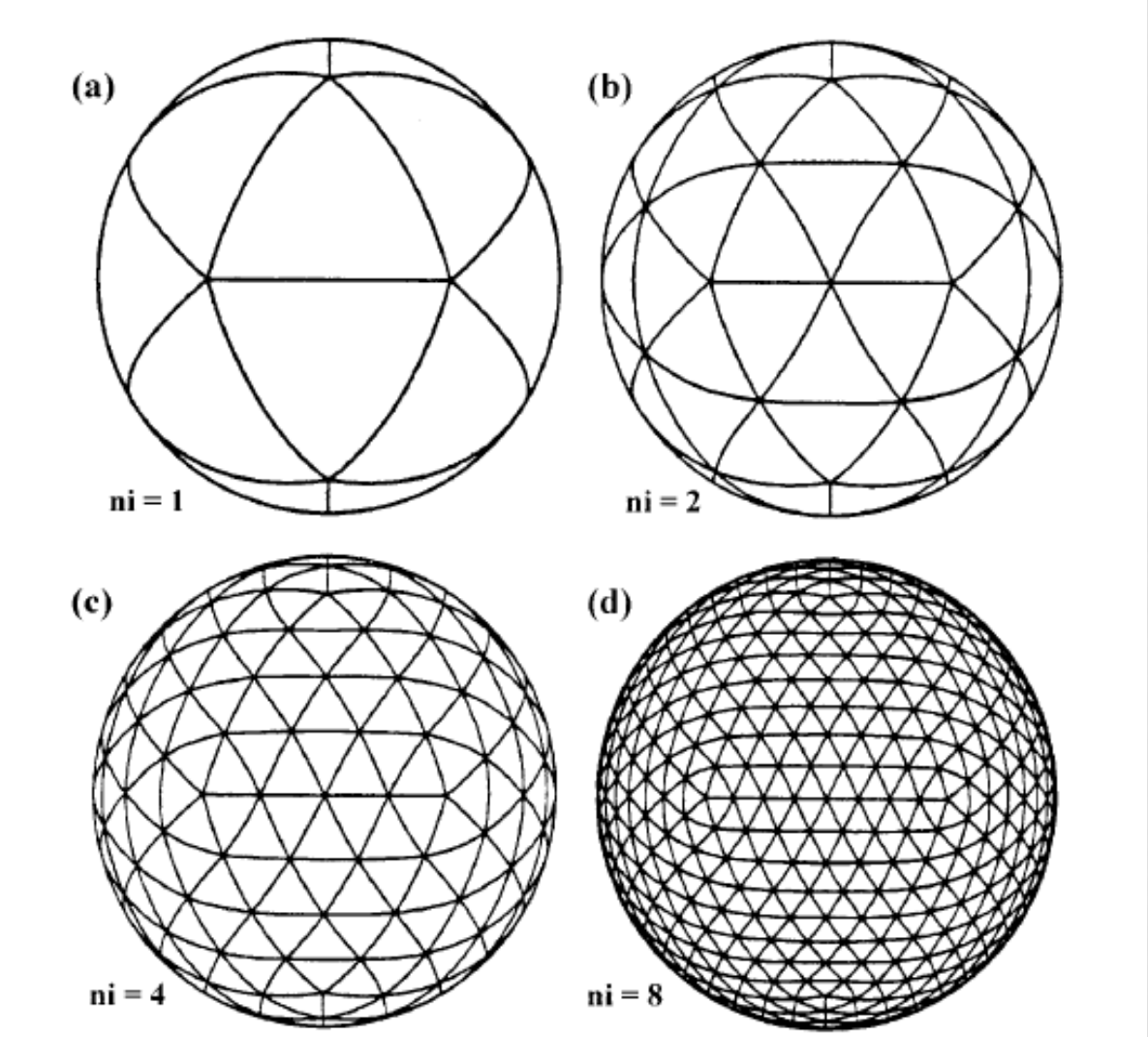
HYCOM => OFIM



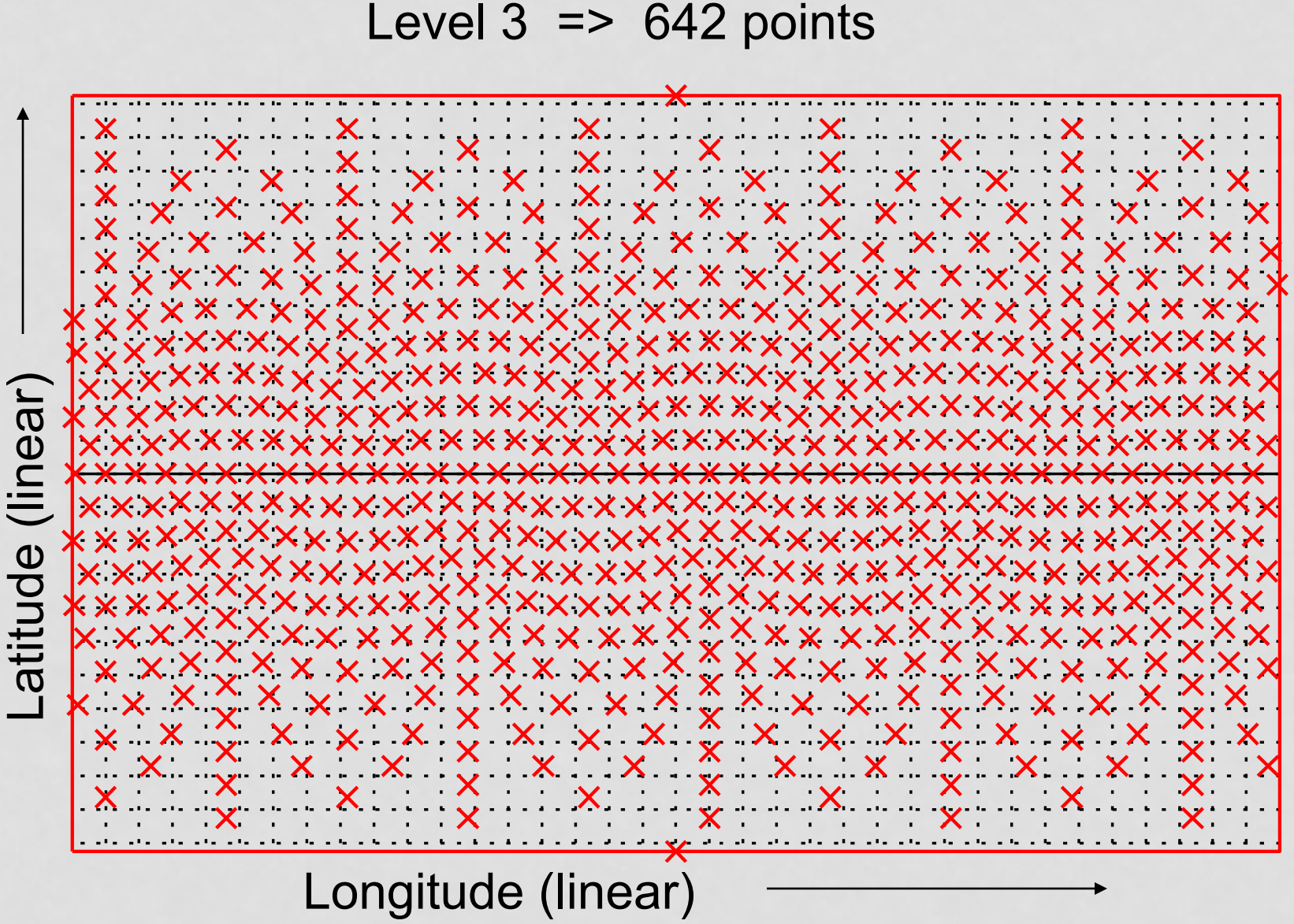
THE ICOSAHEDRON

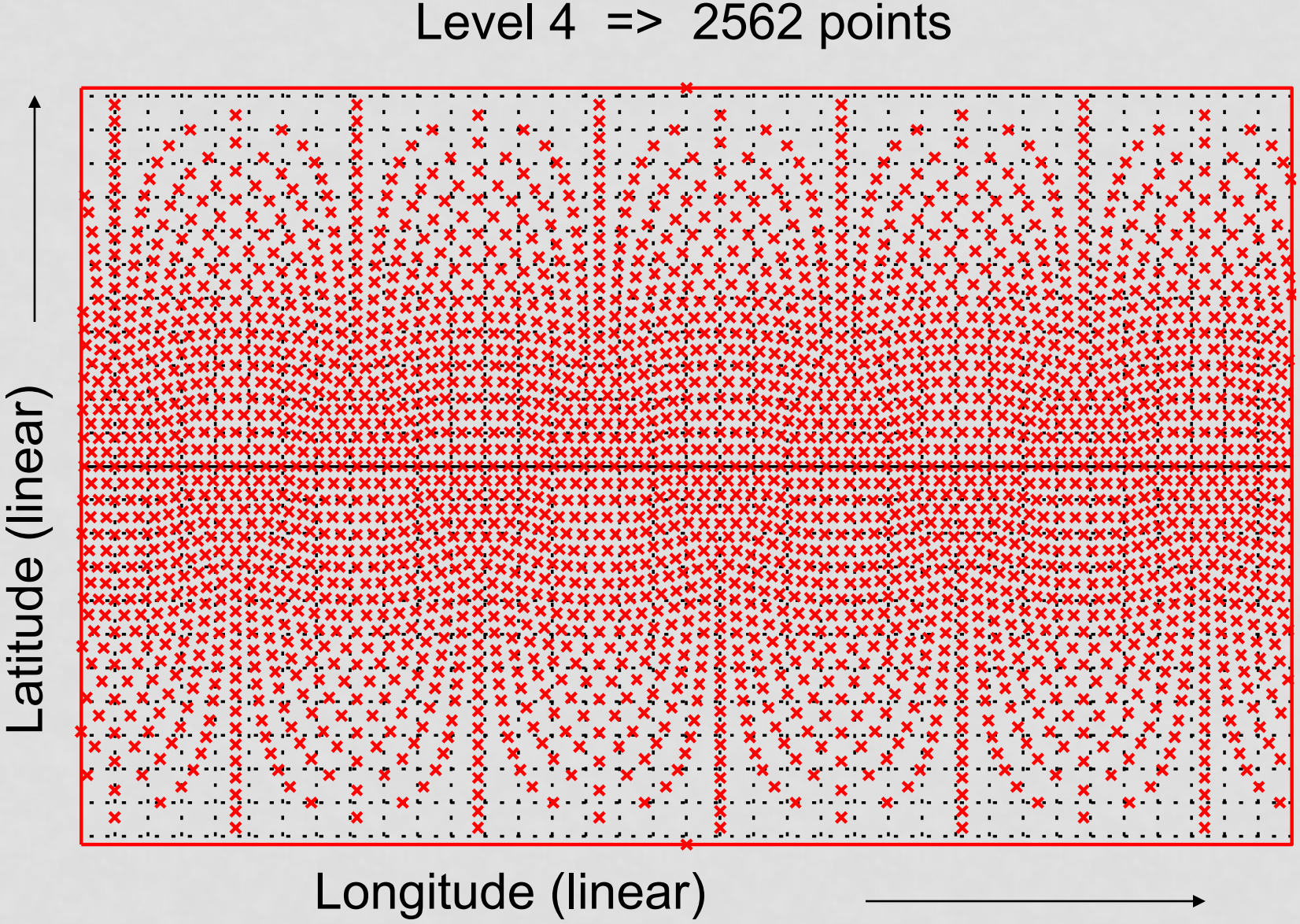


Icosahedral Grid Generation

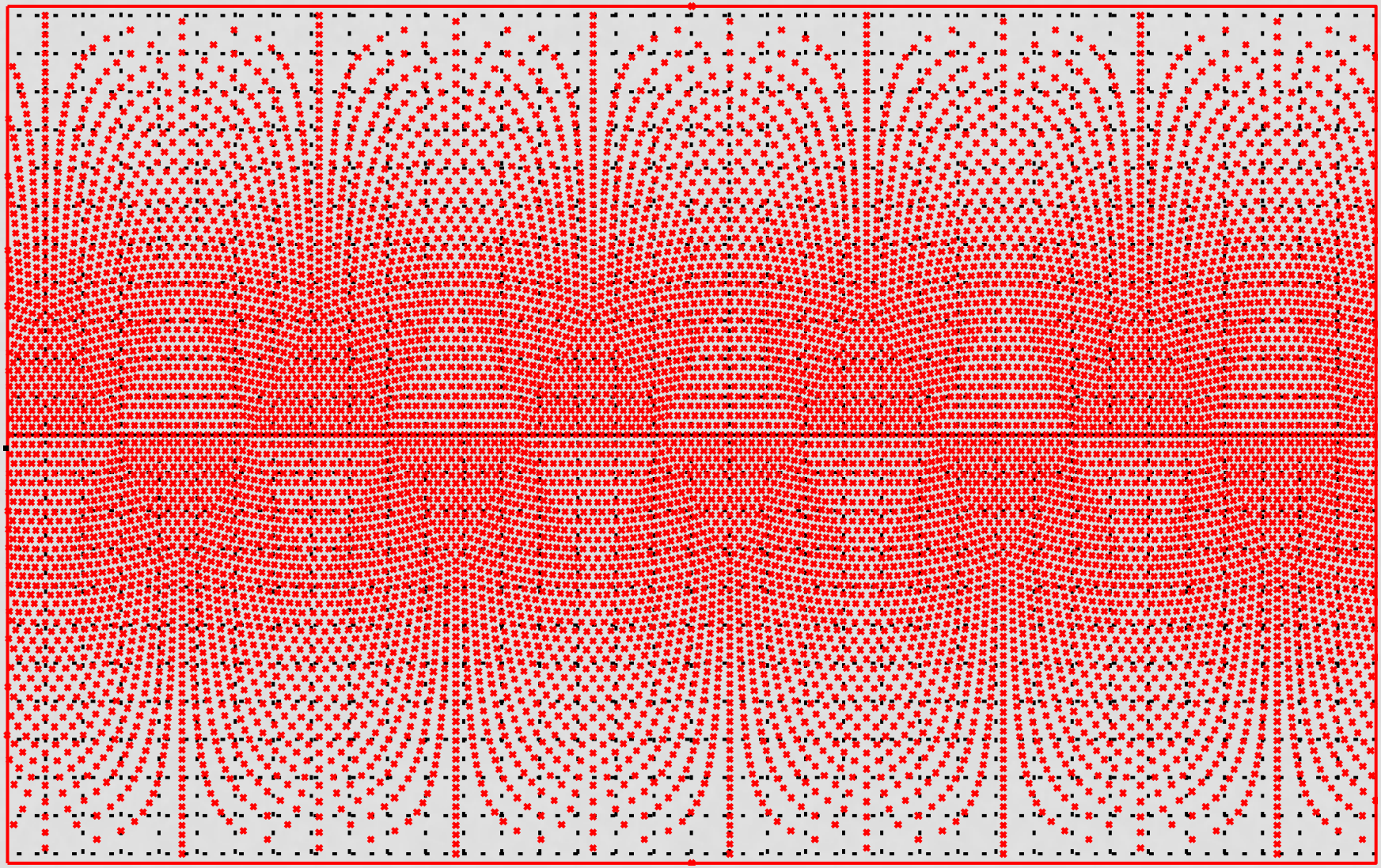


$N=((2^n)^2)x10 + 2$; 5th level: n=5 → N=10242; d~240km; max(d)/min(d)~1.2
6th level: n=6 → N= 40,962 ~120km; 7th level: n=7 →N= 163,842 ~60km
8th level: n=8 → N=655,362 ~30km; 9th level: n=9 →N=2,621,442 ~15km


Level 3 => 642 points
Latitude (linear)
Longitude (linear)

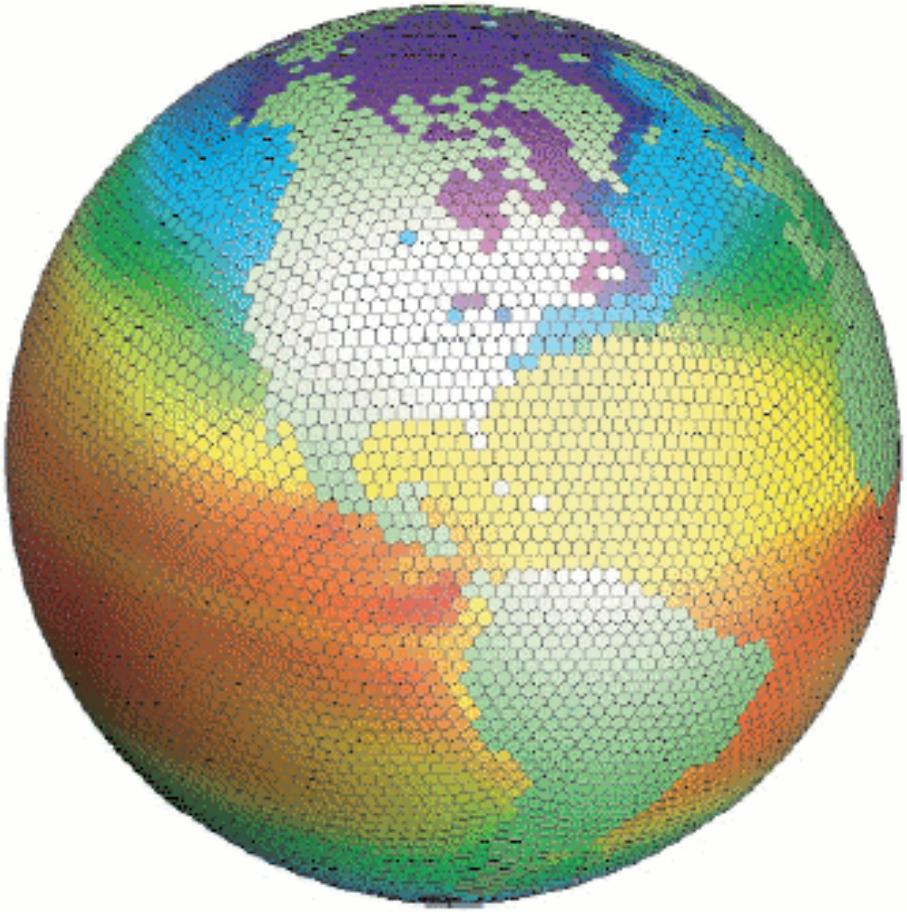

Level 4 => 2562 points
Latitude (linear)
Longitude (linear)

Level 5 => 10,242 points



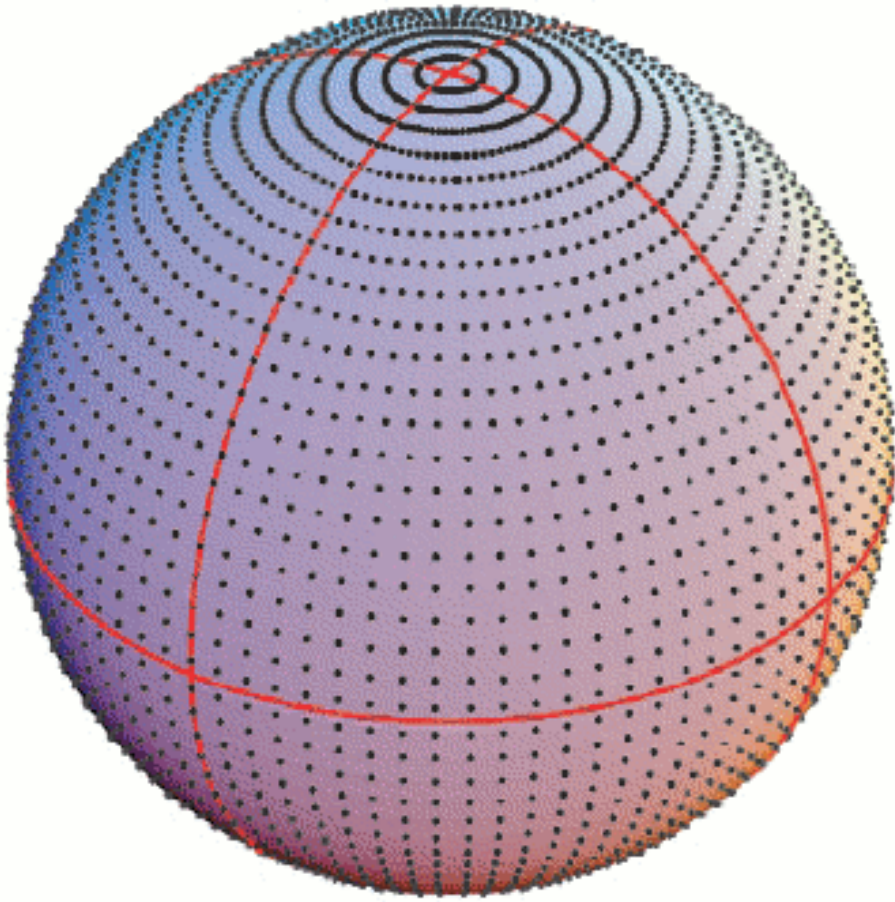
Global discretization for models

Icosahedral grid

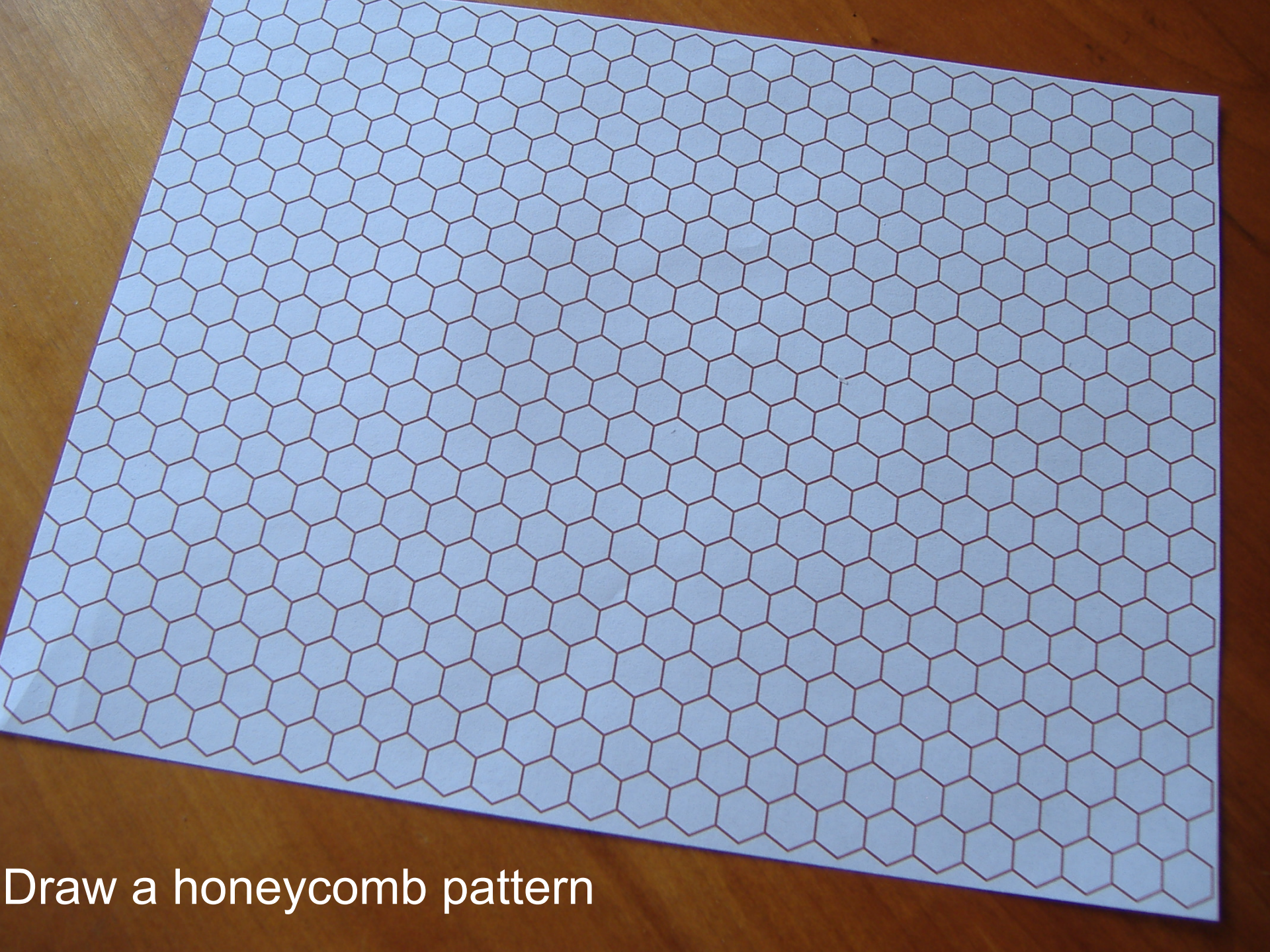


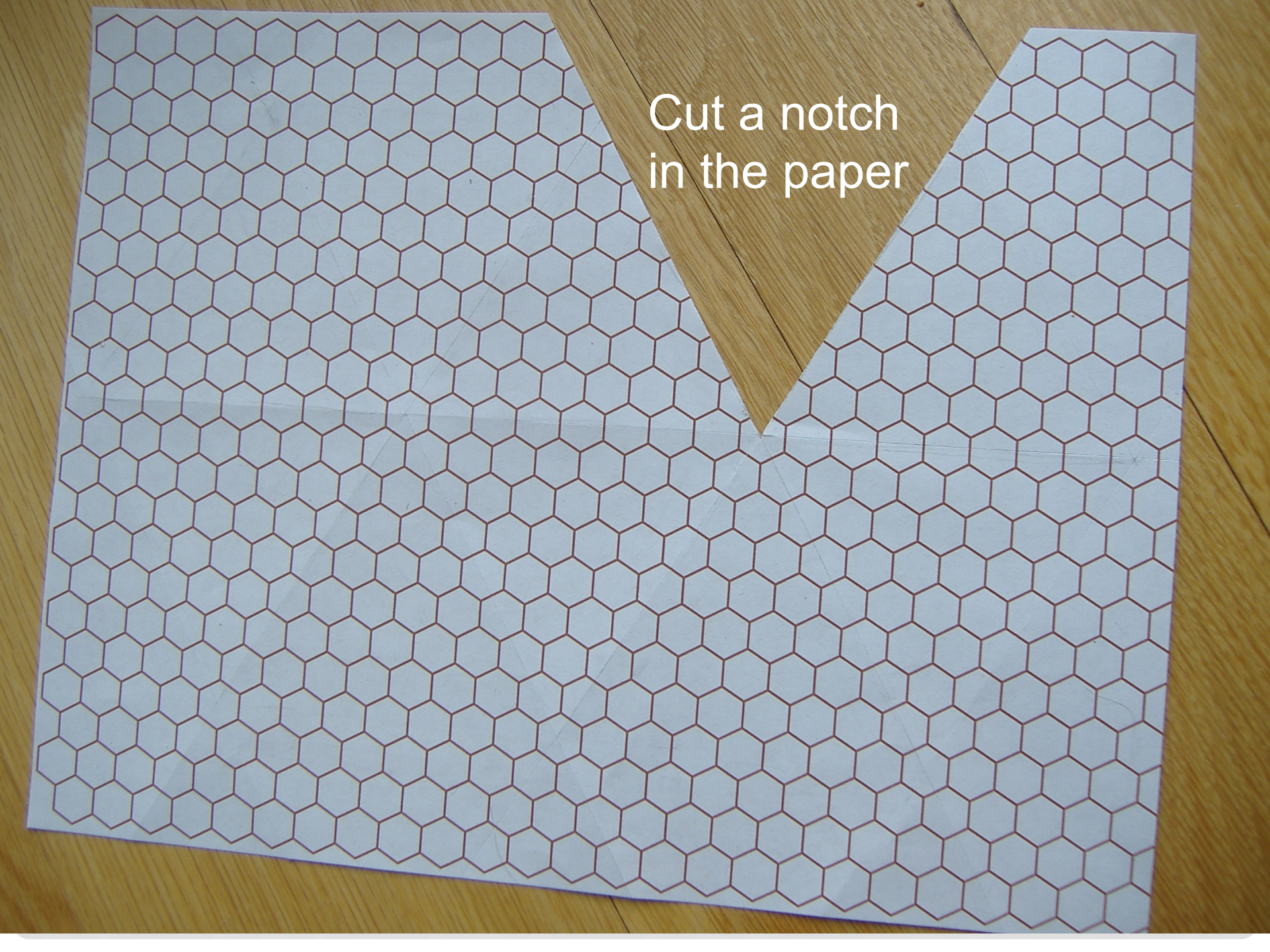
Nearly uniform grid size, including near poles

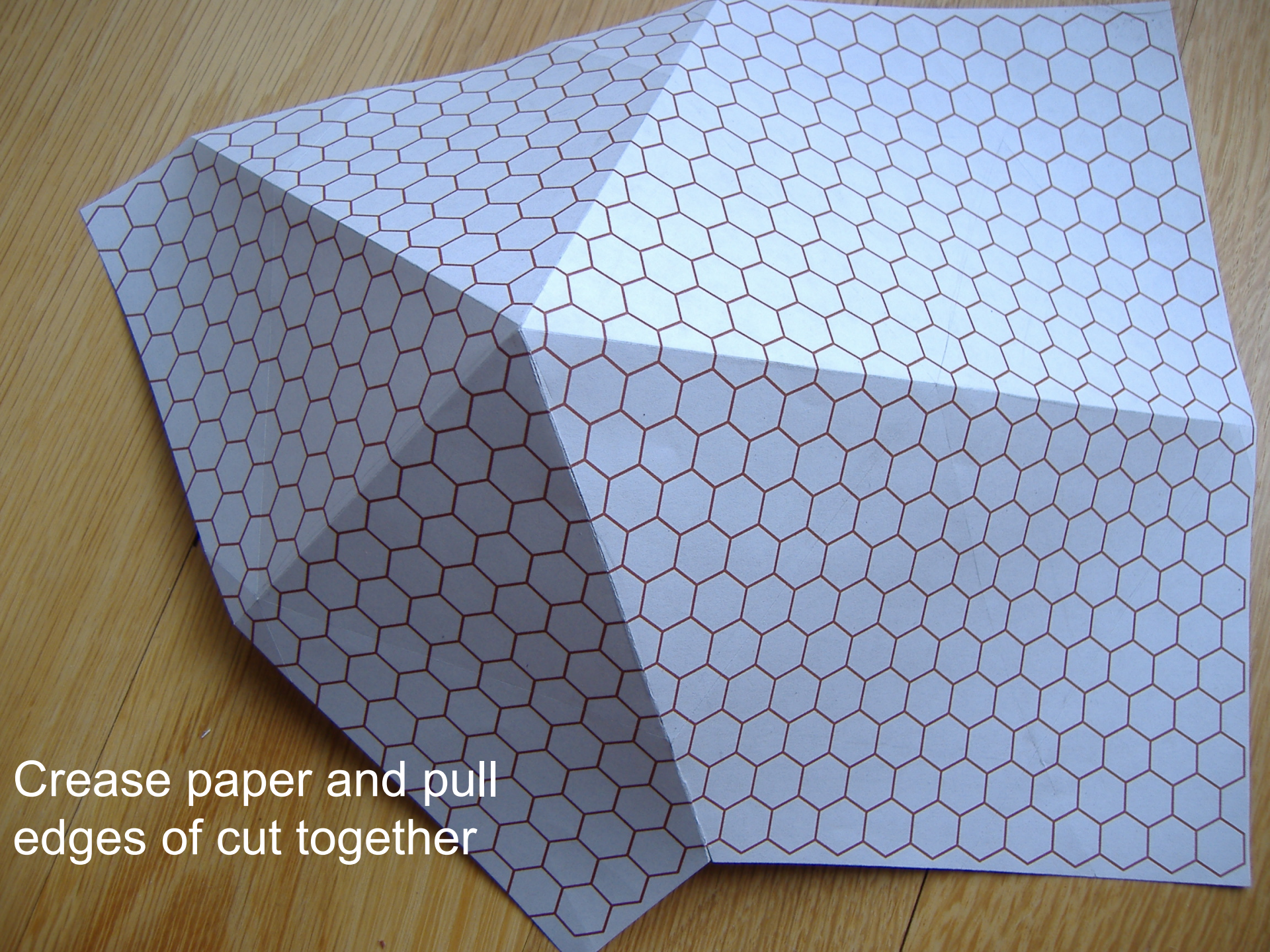
Lat-lon representation

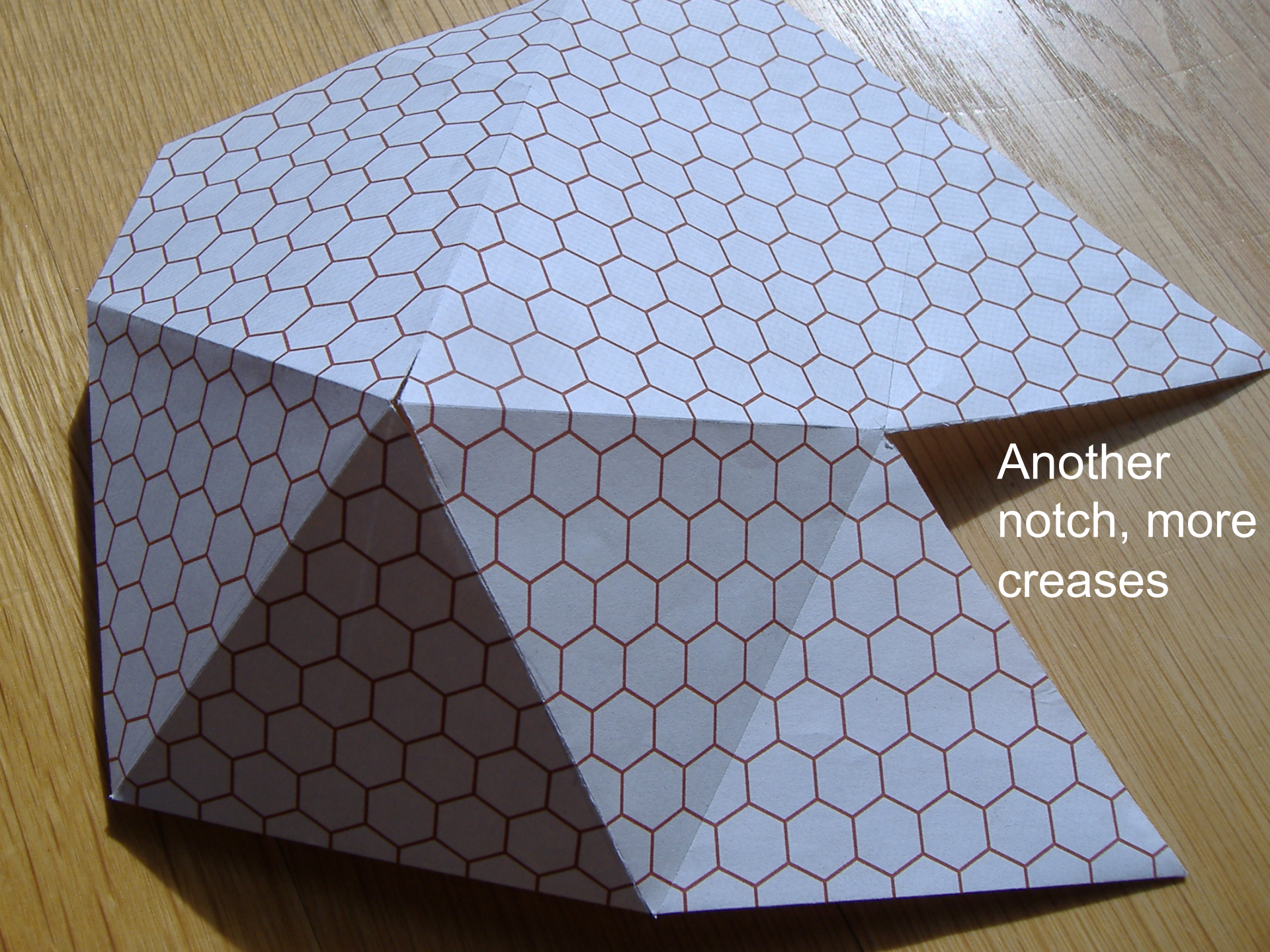


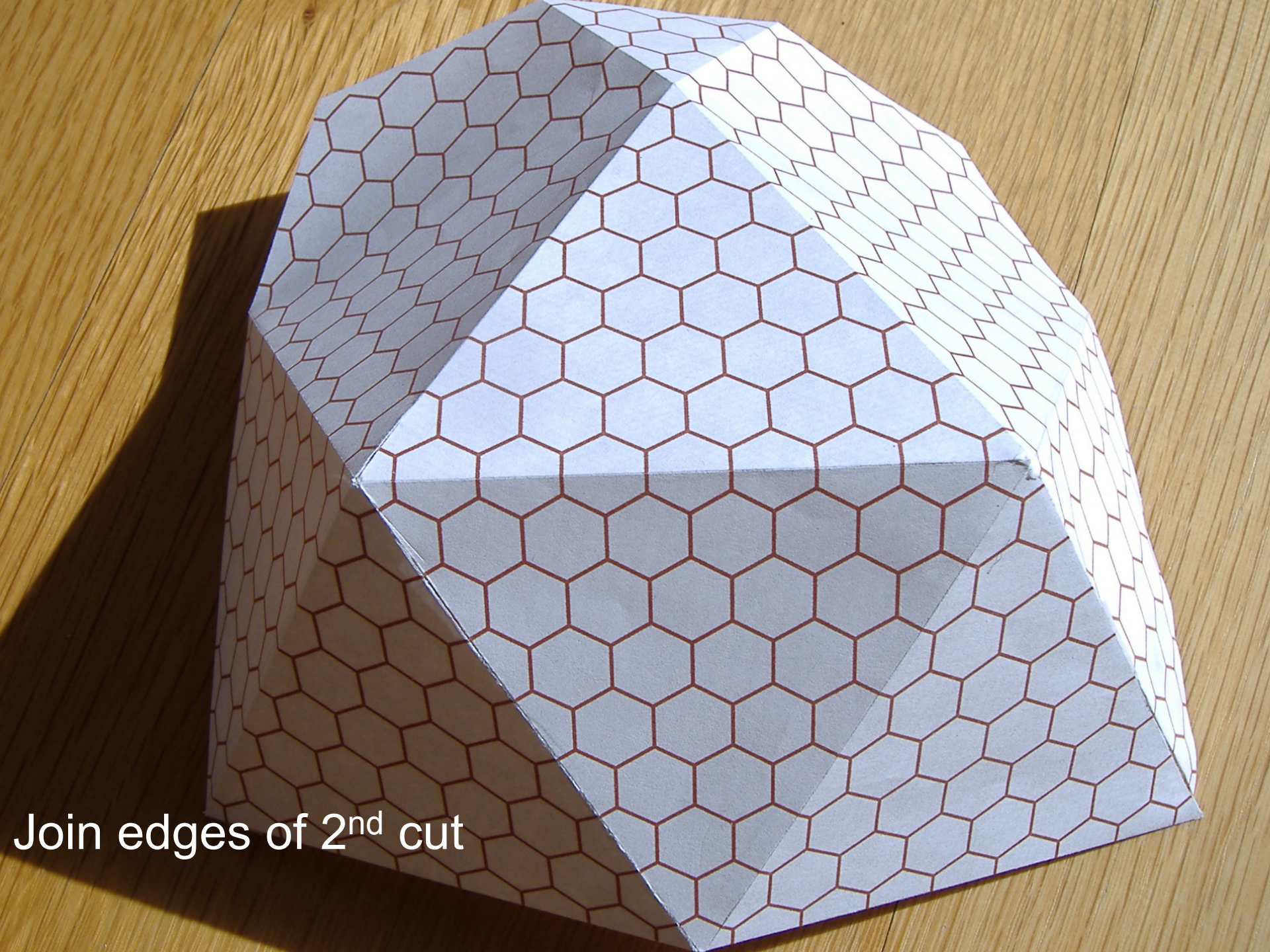
Issues near poles


Draw a honeycomb pattern


Cut a notch
in the paper


Crease paper and pull
edges of cut together

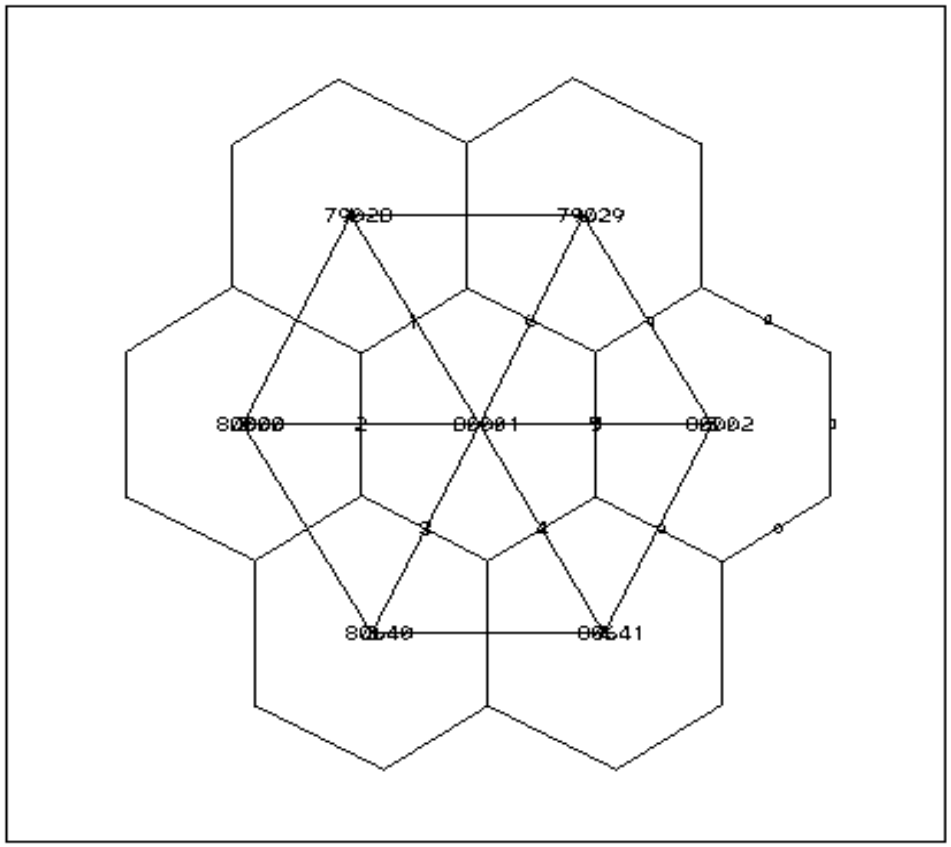

Another
notch, more
creases


Join edges of 2nd cut

NUMERICS ON THE ICOSAHEDRAL GRID

- Finite-Volume line-integrals including
  (i) Vorticity operator based on Stokes' theorem,
  (ii) Divergence operator based on Gauss' theorem,
  (iii) Gradient operator based on Green's theorem.

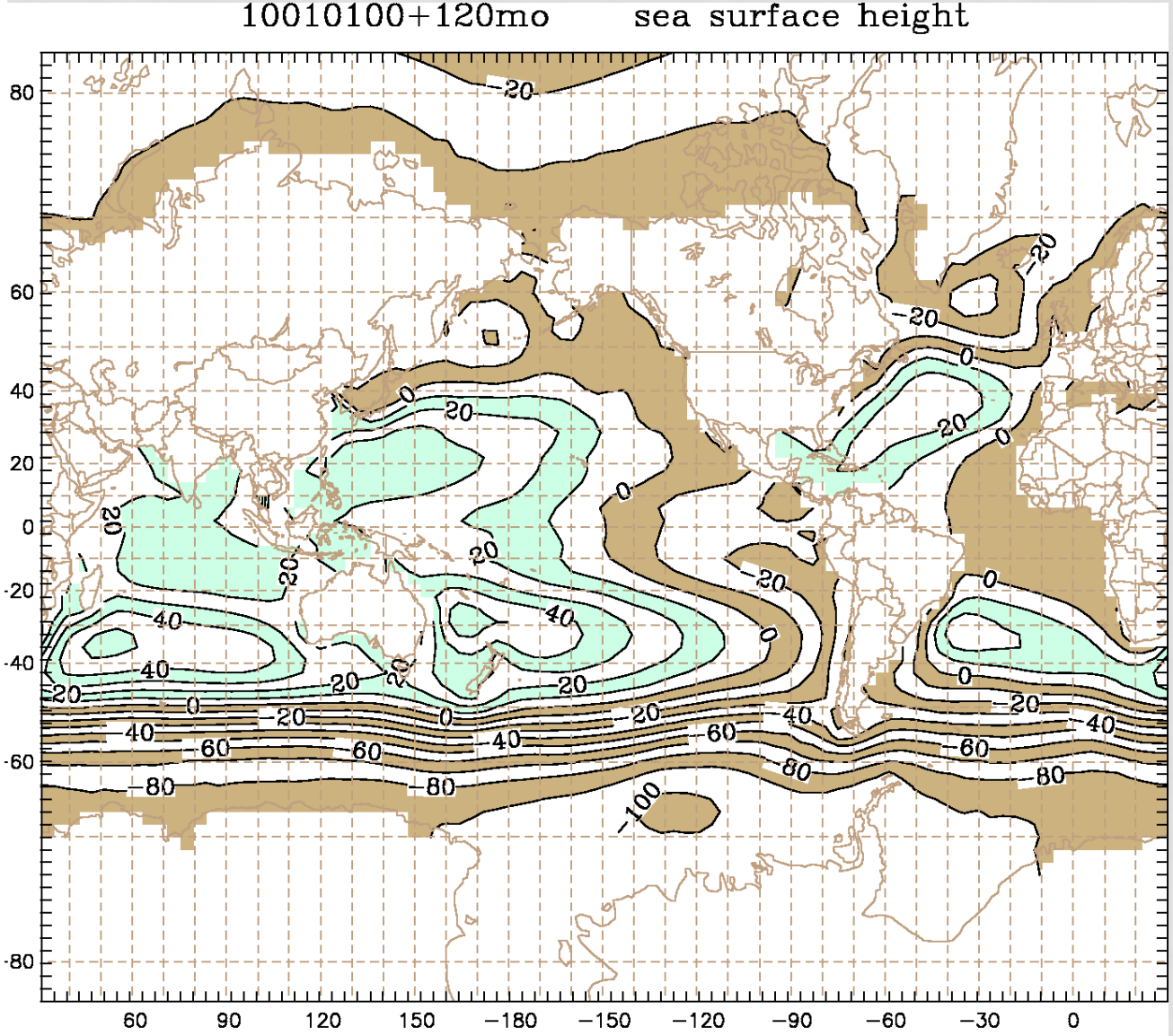
- No horizontal staggering (Arakawa A Grid)



Finite volume flux computation:
- flux into each cell from surrounding donor cells

CURRENT STATUS OF FIM/OFIM COUPLING

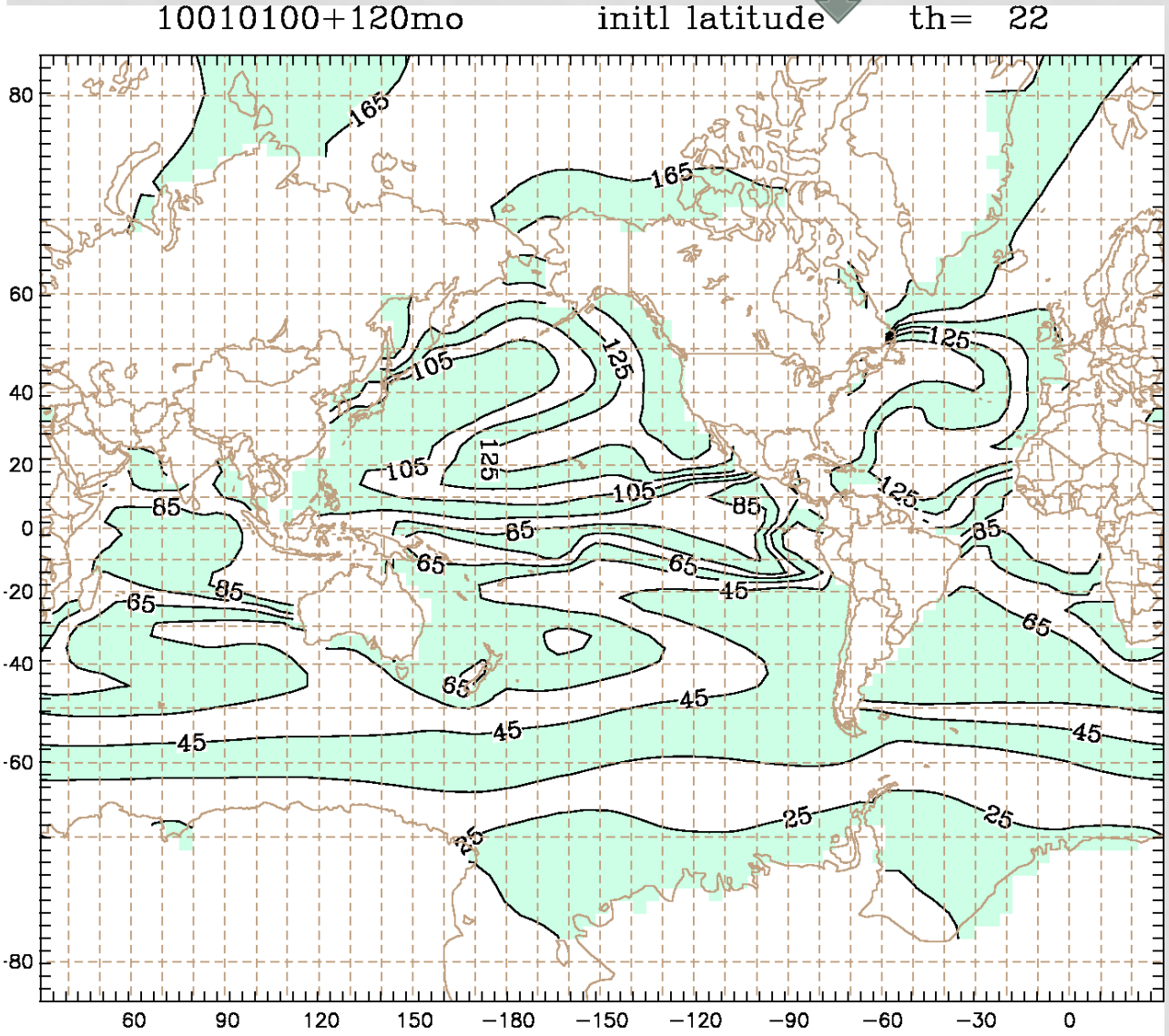
- A team of ~~two~~-scientists
  1.3
- One-way coupling of FIM to OFIM
- Wind driven only
- Capability to advect multiple tracers (precursor to T/S advection)



Sea surface height (cm) at year 10. OFIM receives wind stress from FIM every 6 min.

source: /lfs0/projects/fim/sun/ocean trunk/FIMrun/400m tc/fim5 10 40/fim/

+90



Passive tracer in layer 1, representing initial latitude (+90) of each water parcel, advected for 10 years.

source: /lfs0/projects/fim/sun/ocean trunk/FIMrun/400m tc/fim5 10 40/fim/

- Potential complications:
  - HYCOM-inspired split-explicit treatment of the barotropic mode presently fails on an icosahedral grid with “A”-type staggering.
  - FIM remains numerically stable without explicit lateral mixing terms. Don't know yet whether such terms will be needed in OFIM (ocean is less stratified and hence more temperamental).