The Ocean-Land-Atmosphere Model (OLAM)

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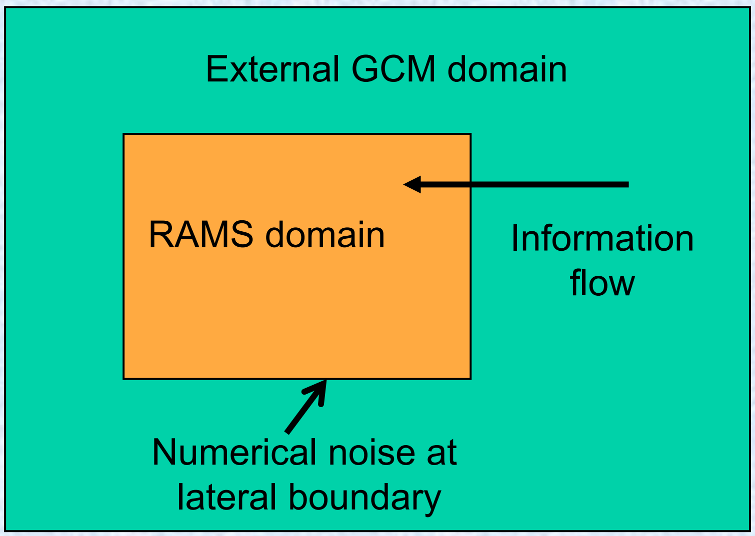
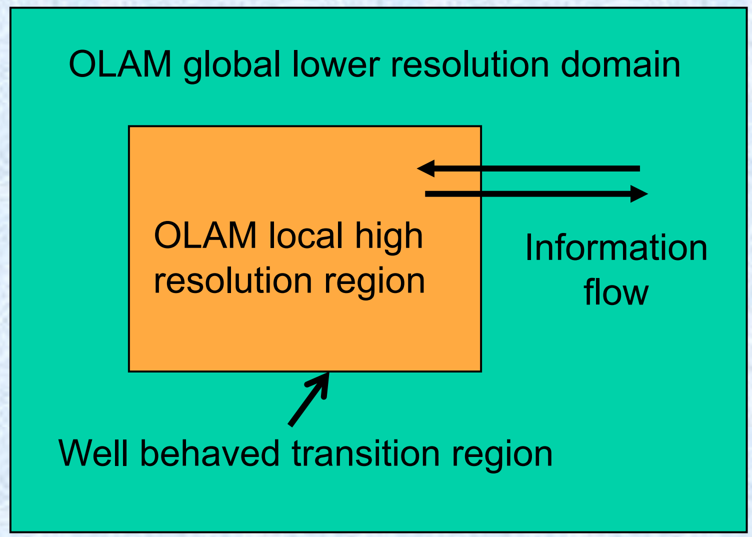
Motivation for OLAM originated in our work with the Regional Atmospheric Modeling System (RAMS)

RAMS, begun in 1986, is a limited-area model similar to WRF and MM5

Features include 2-way interactive grid nesting, microphysics and other physics parameterizations designed for mesoscale & microscale simulations

But, there are significant disadvantages to limited-area models



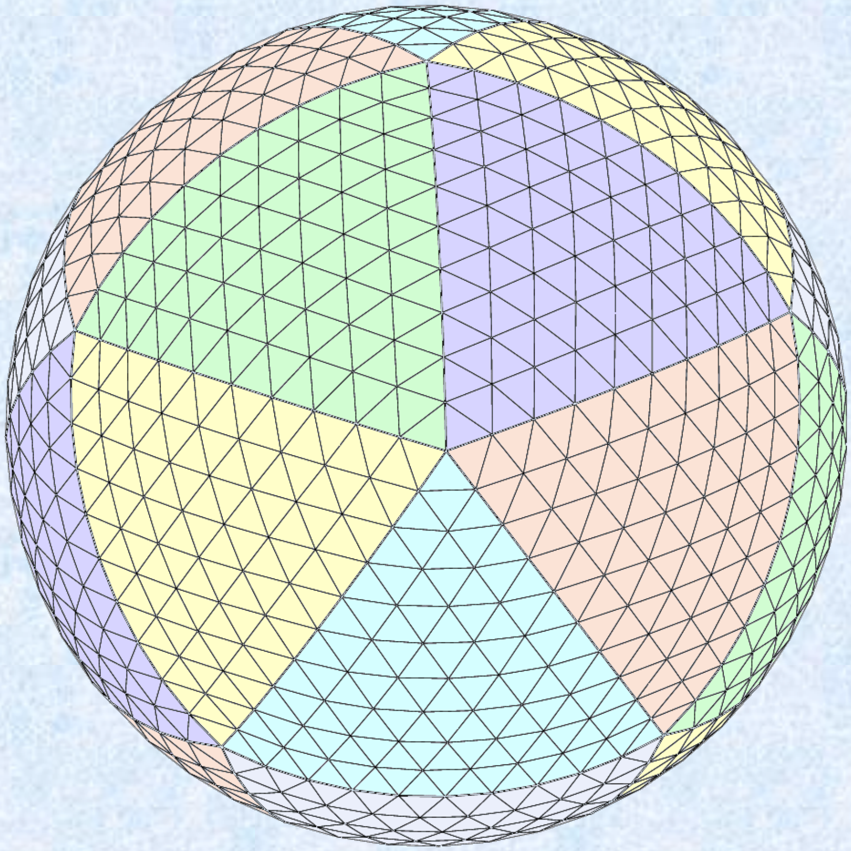


So, OLAM was originally planned as a global version of RAMS.

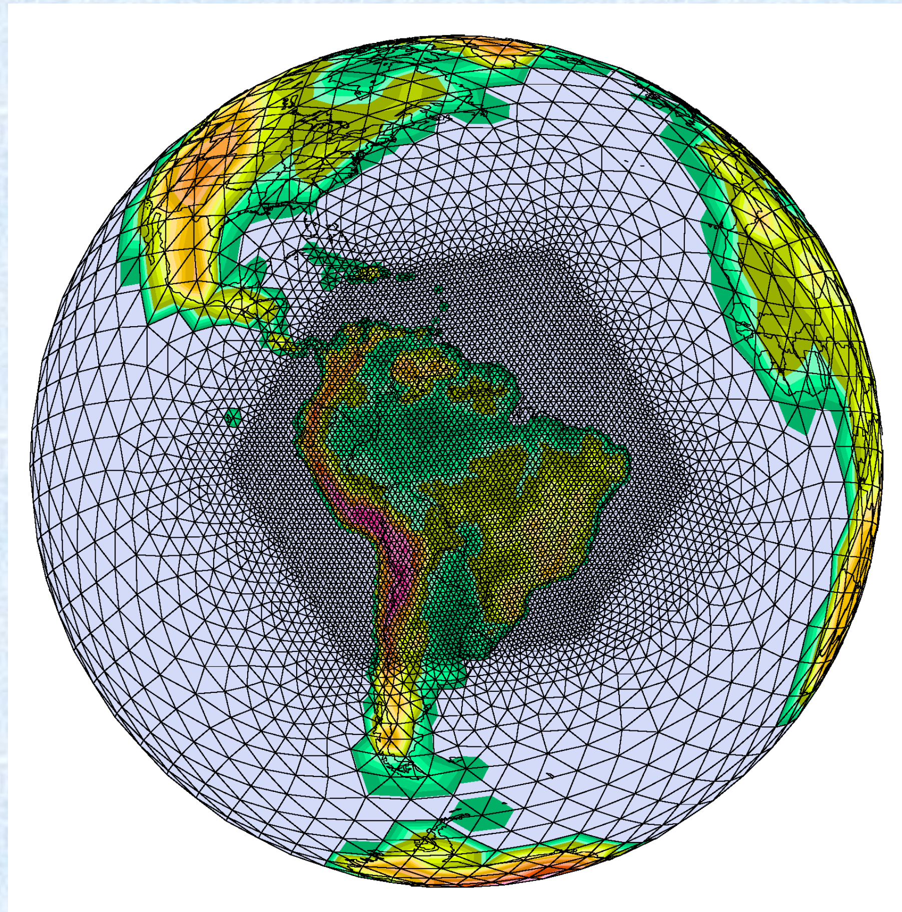
OLAM began with all of RAMS' physics parameterizations in place.

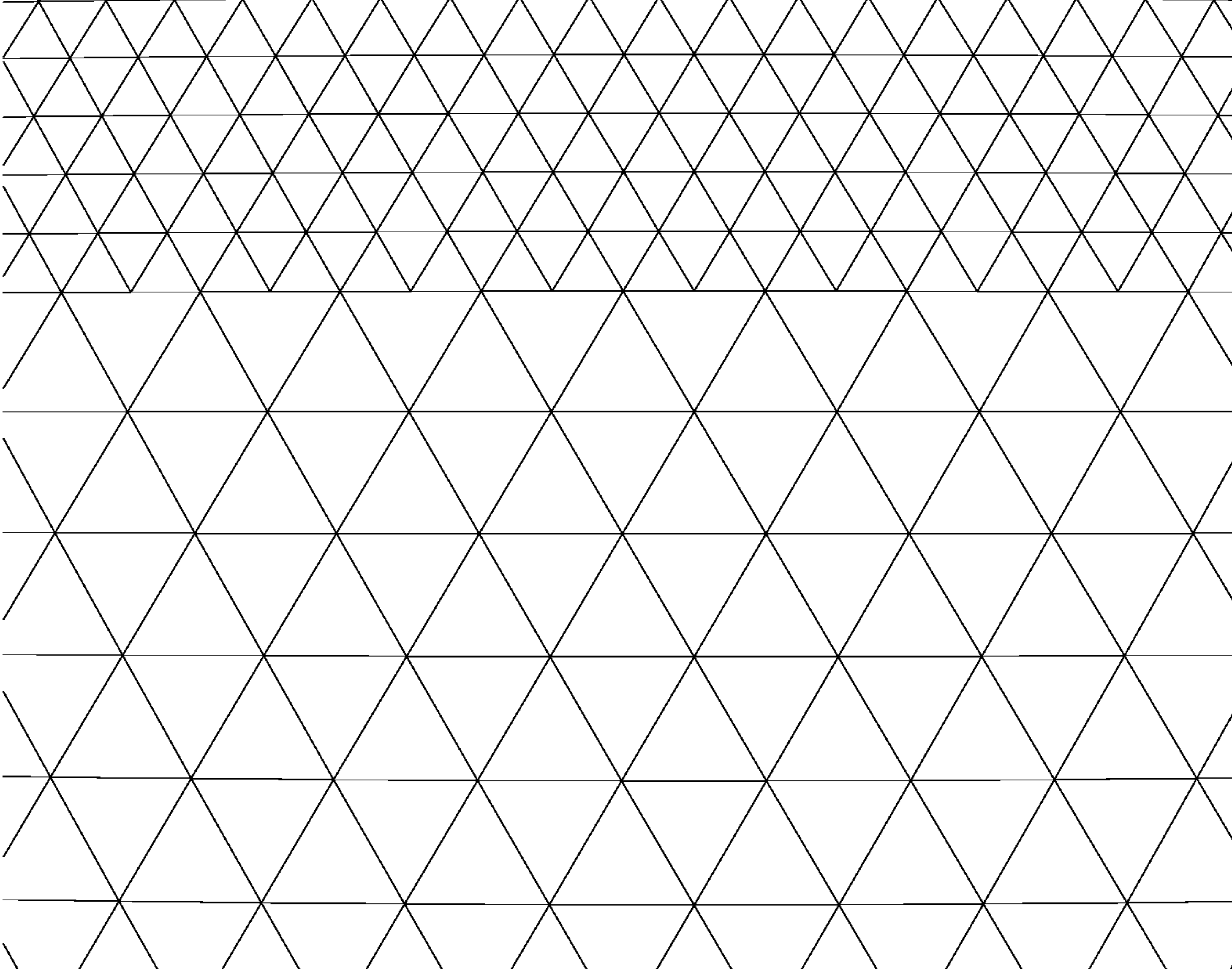
OLAM dynamic core is a complete replacement from RAMS

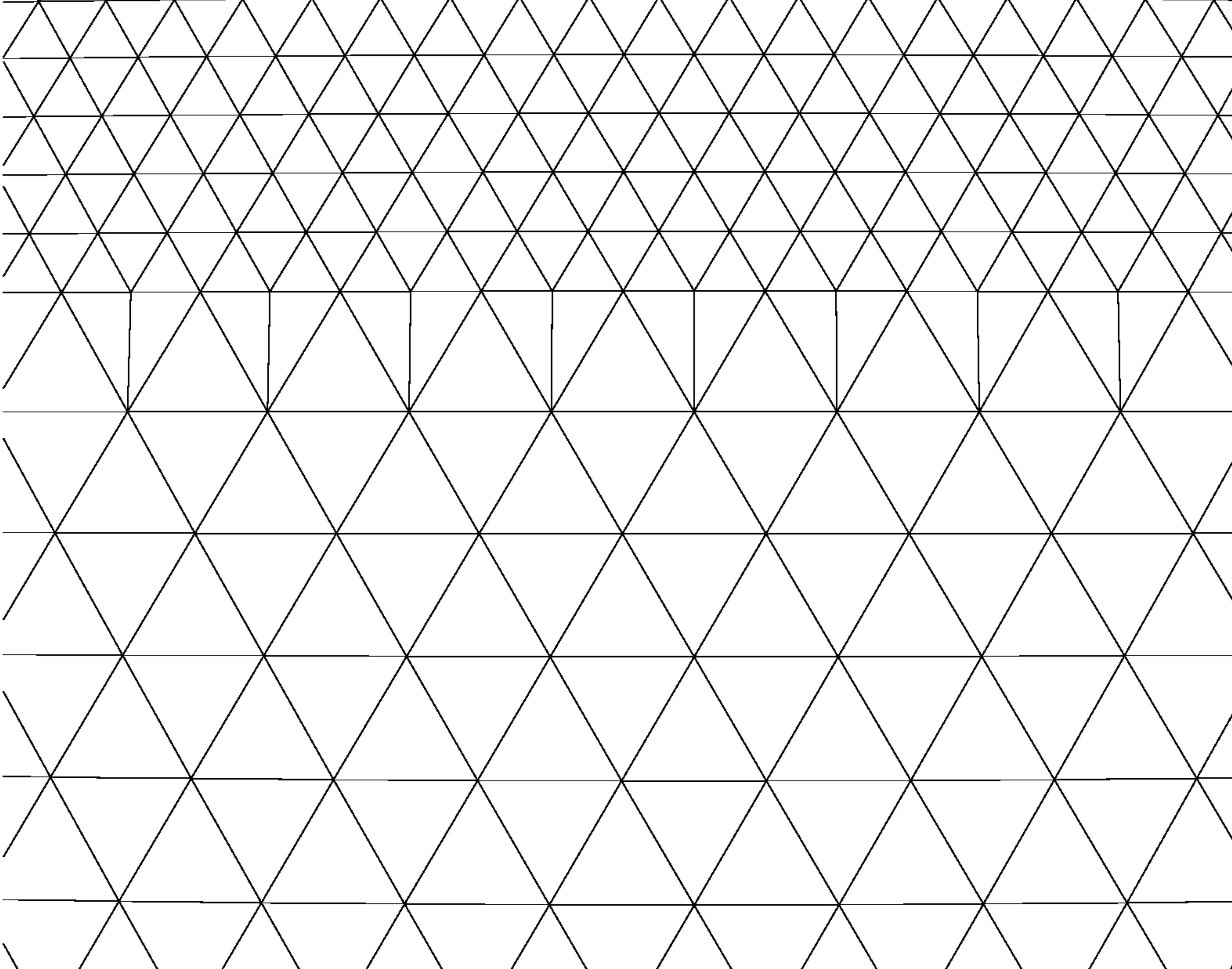
Based on icosahedral grid

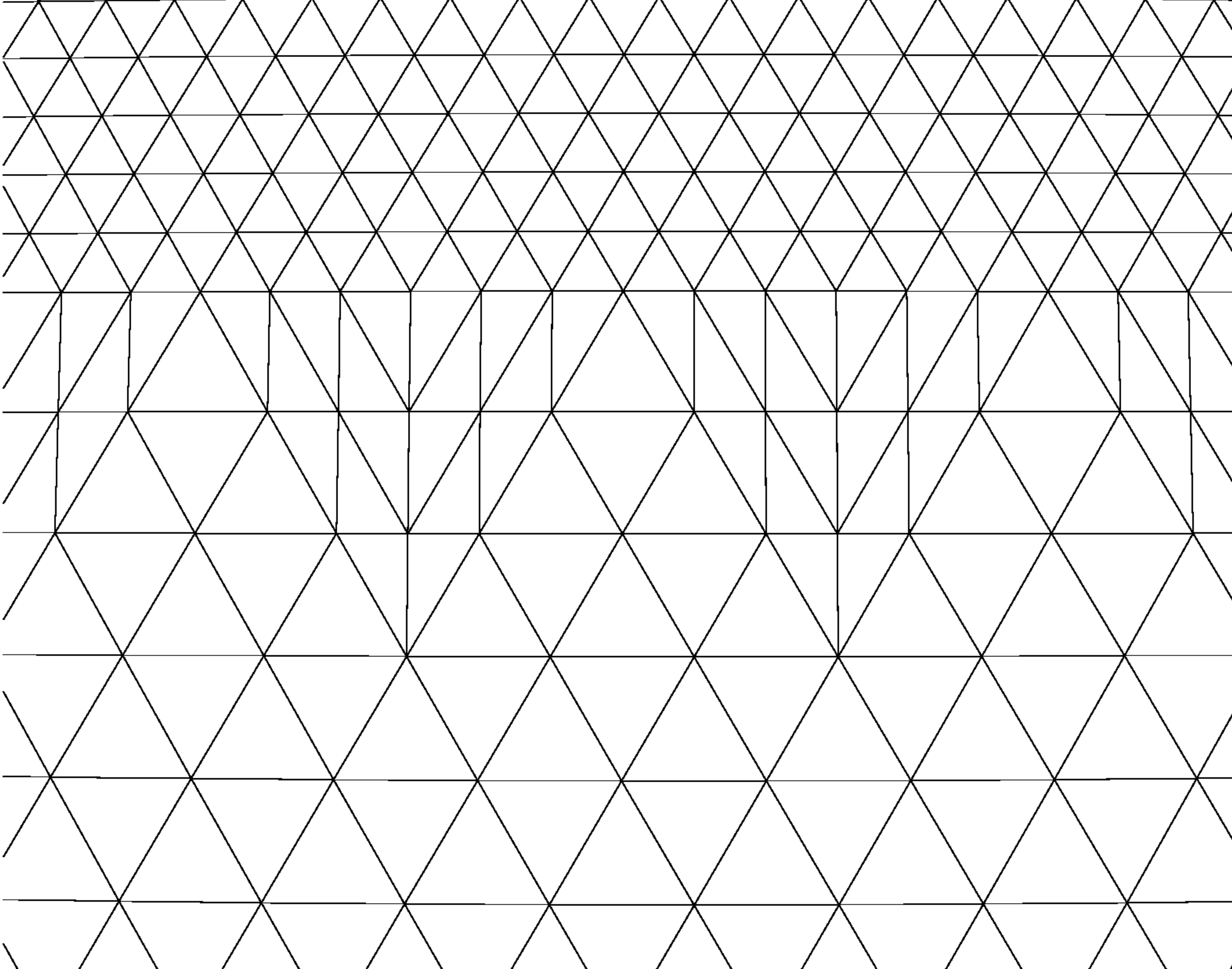


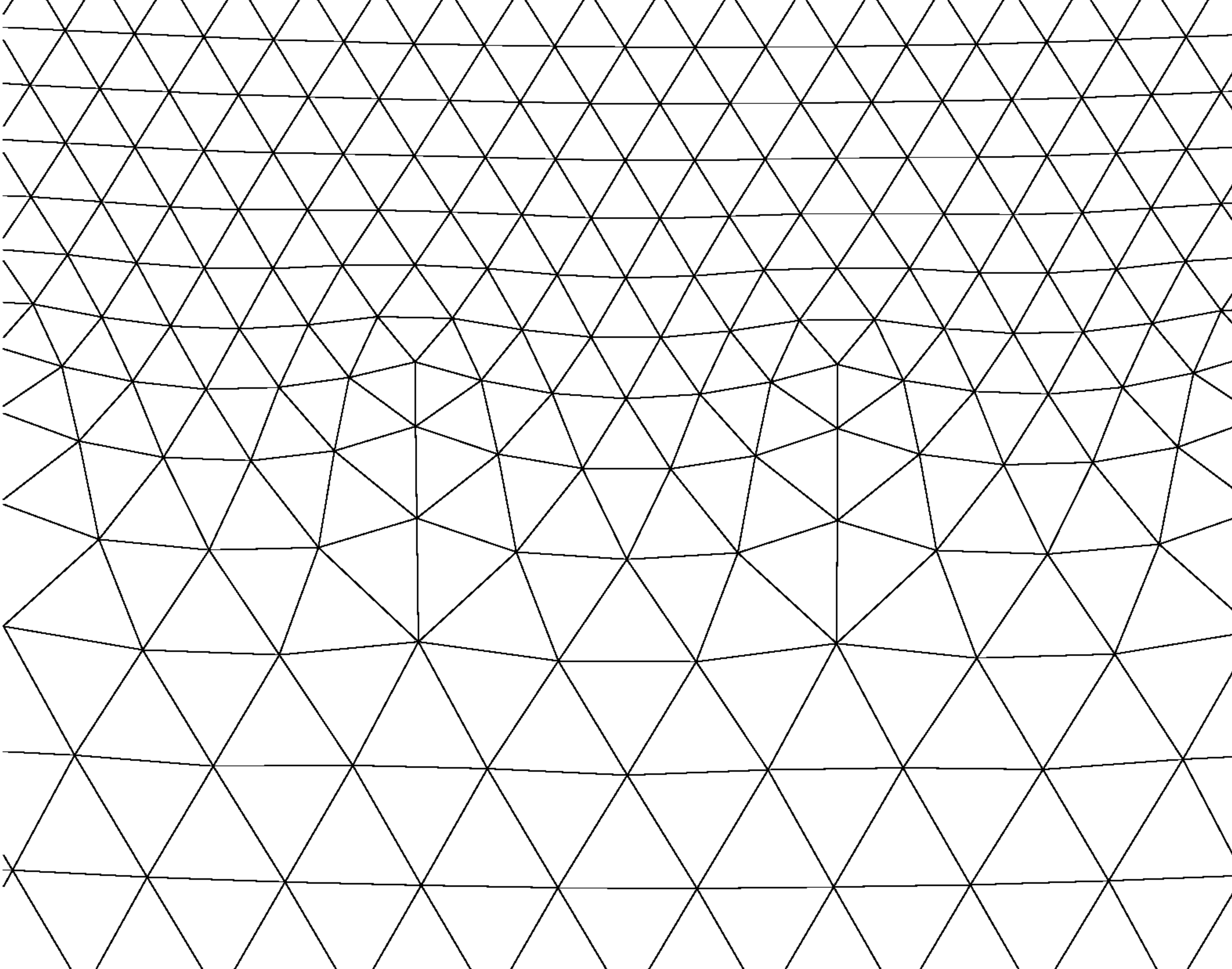
Seamless local mesh refinement



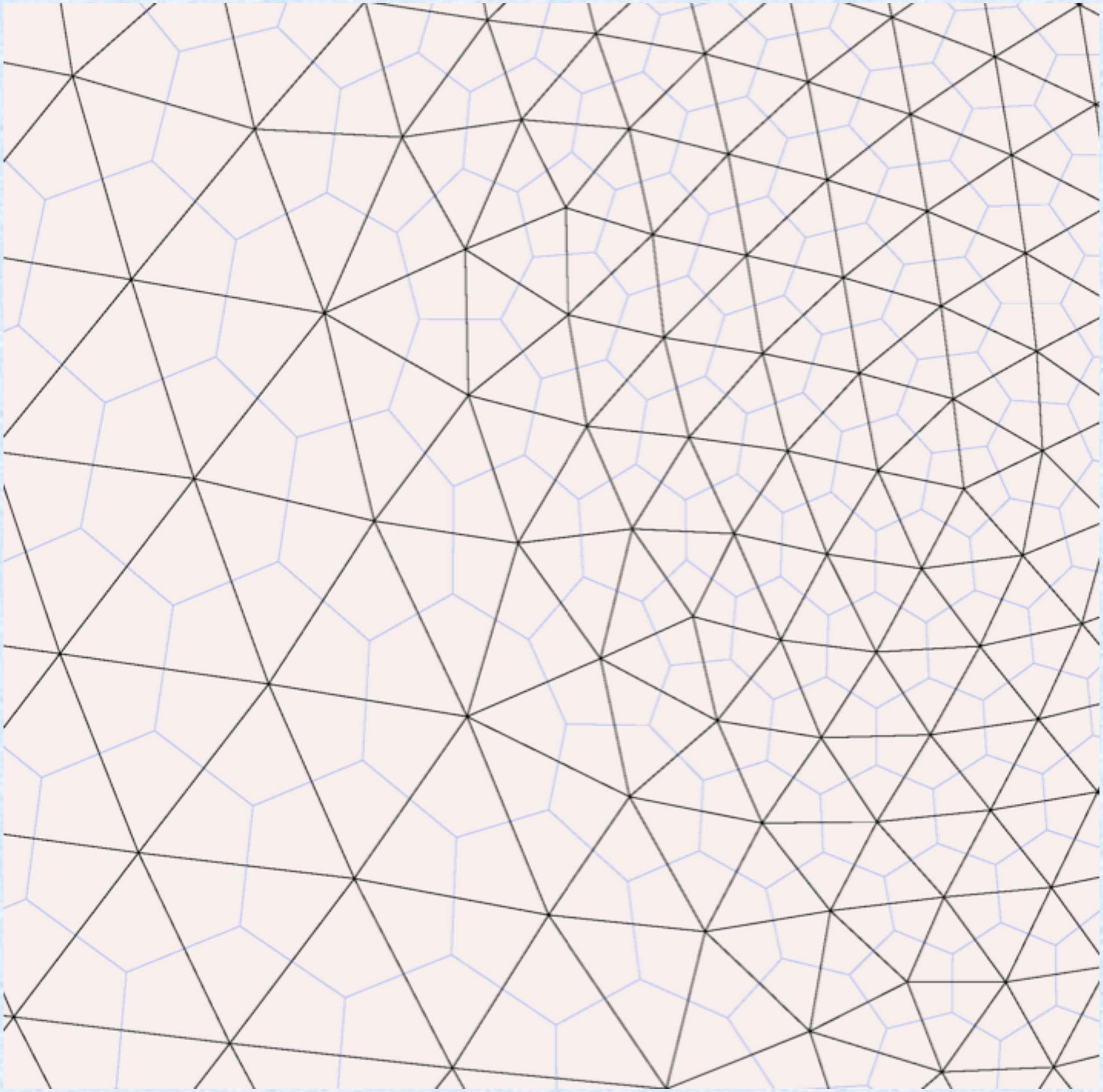




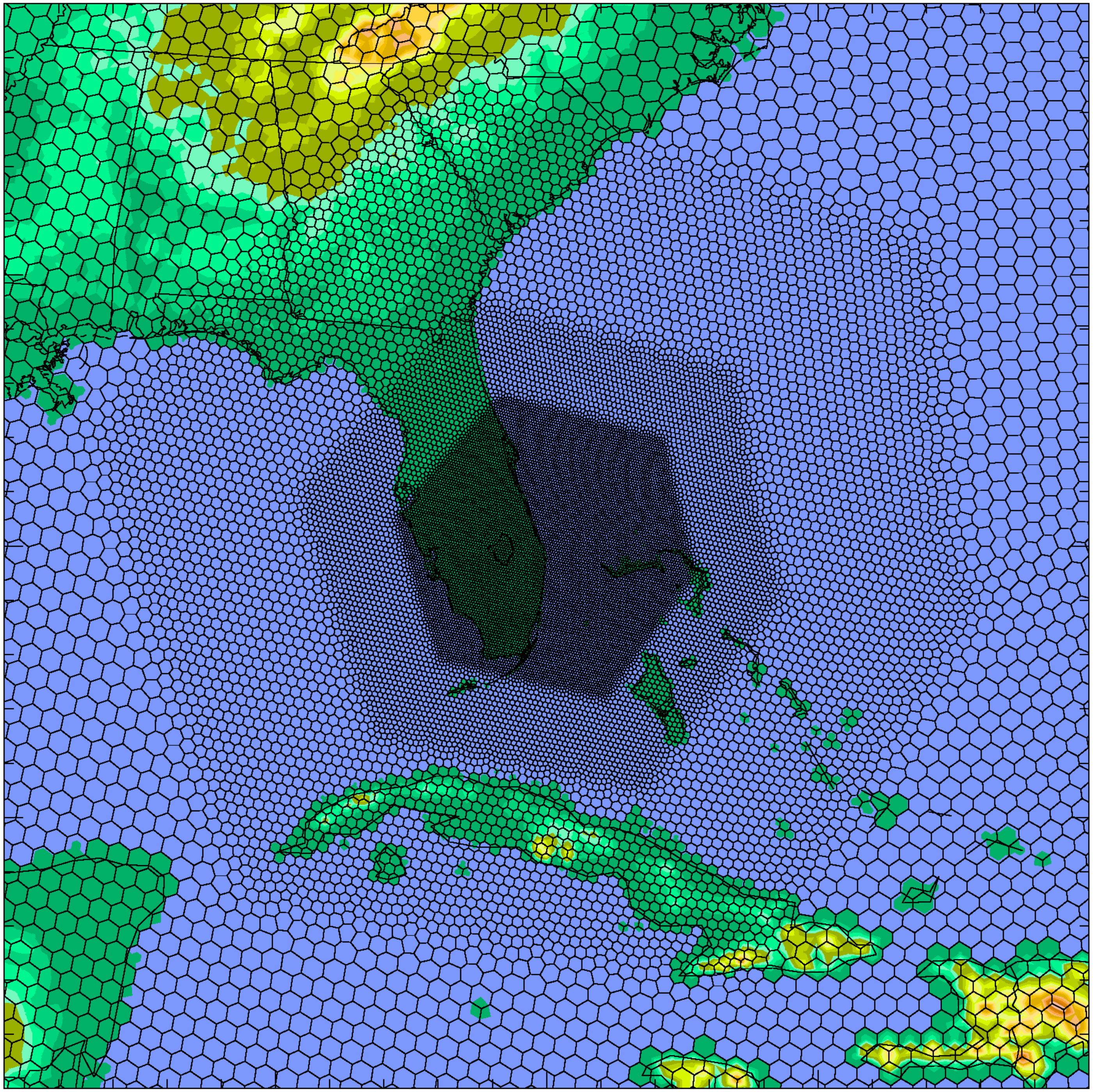


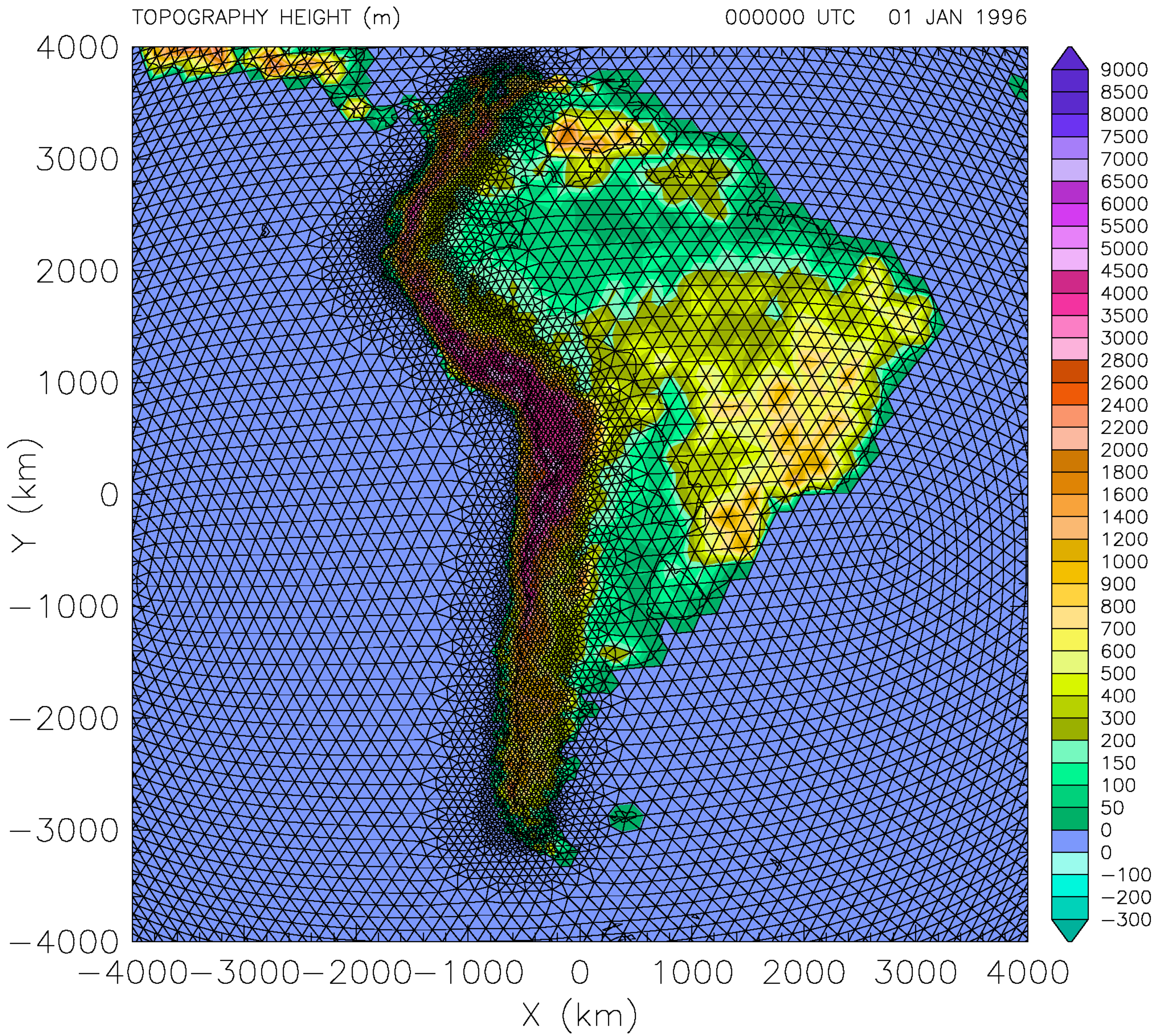


OLAM: Relationship between triangular and hexagonal cells (either choice uses Arakawa-C grid stagger)

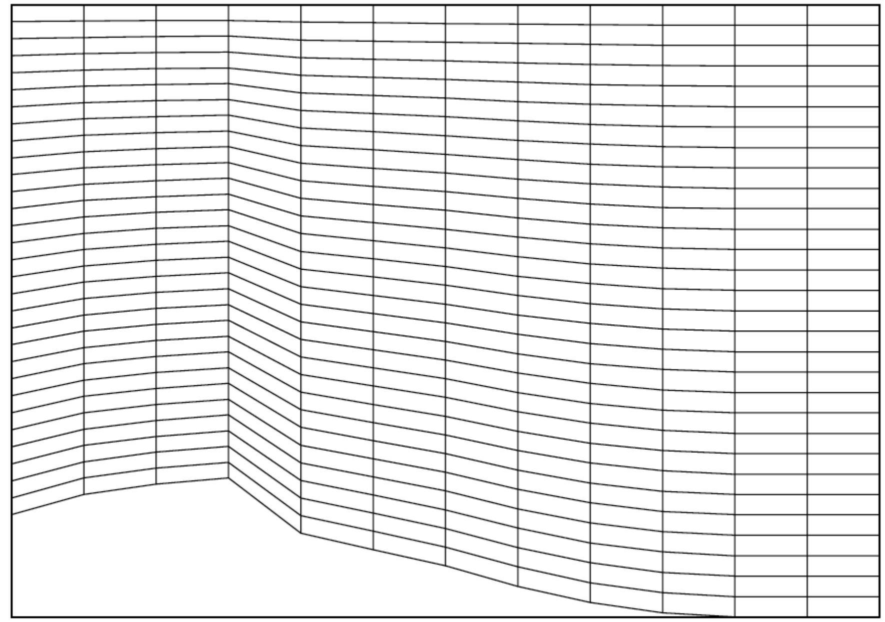


OLAM:
Hexagonal grid cells

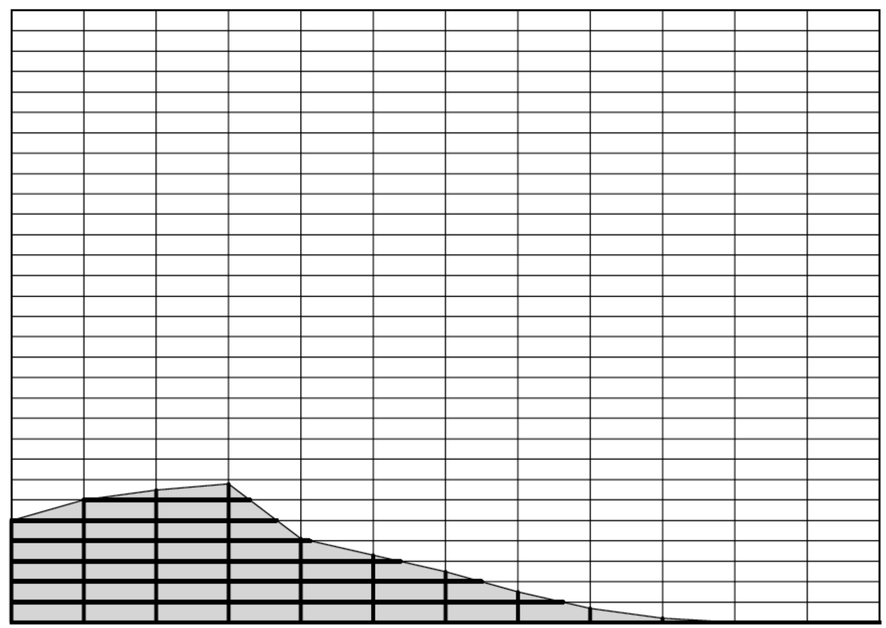



TOPOGRAPHY HEIGHT (m)
000000 UTC 01 JAN 1996
Y (km)
X (km)
4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
9000
8500
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
900
800
700
600
500
400
300
200
150
100
50
0
0
−100
−200
−300

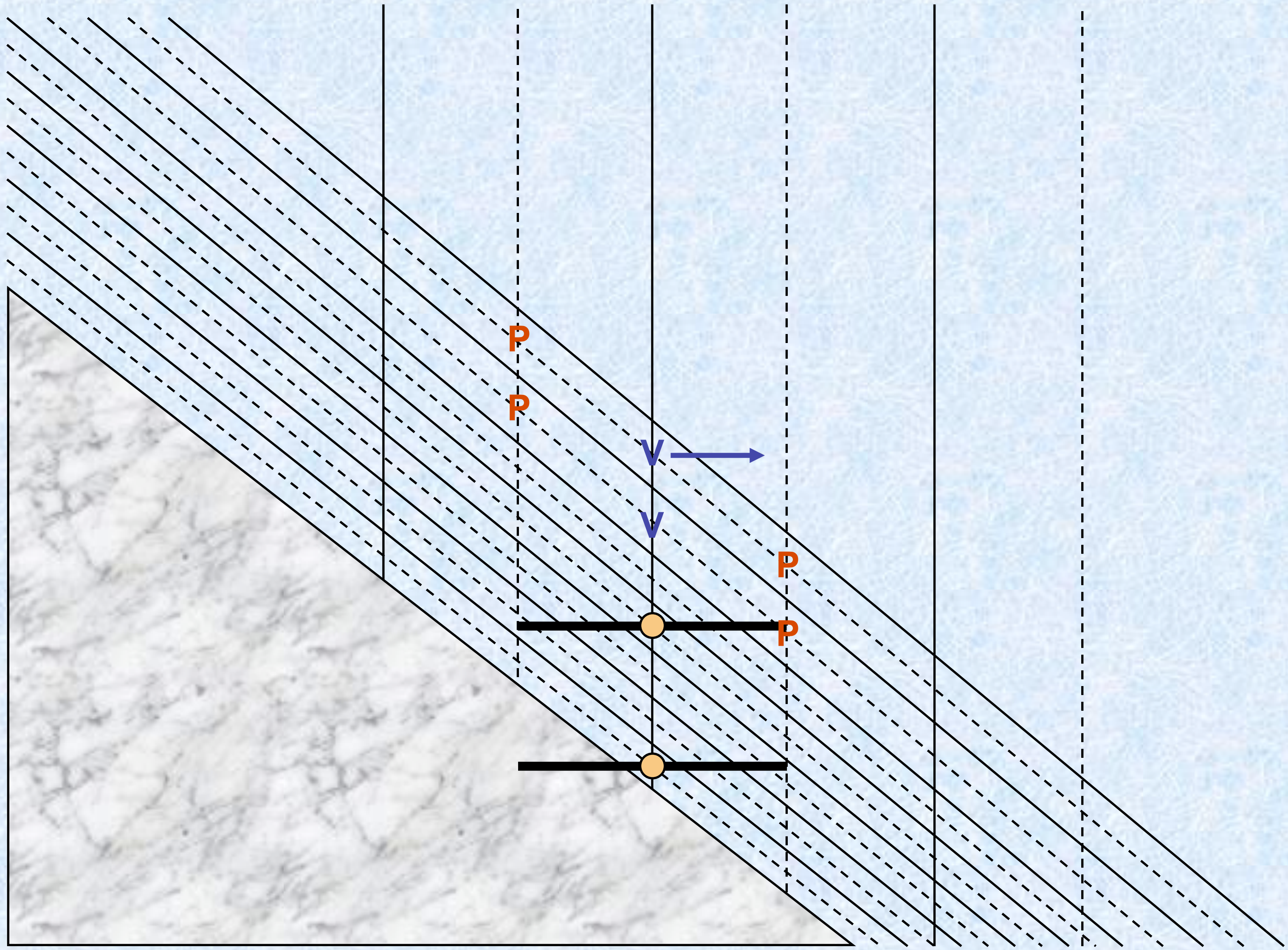
Terrain-following coordinates used in most models



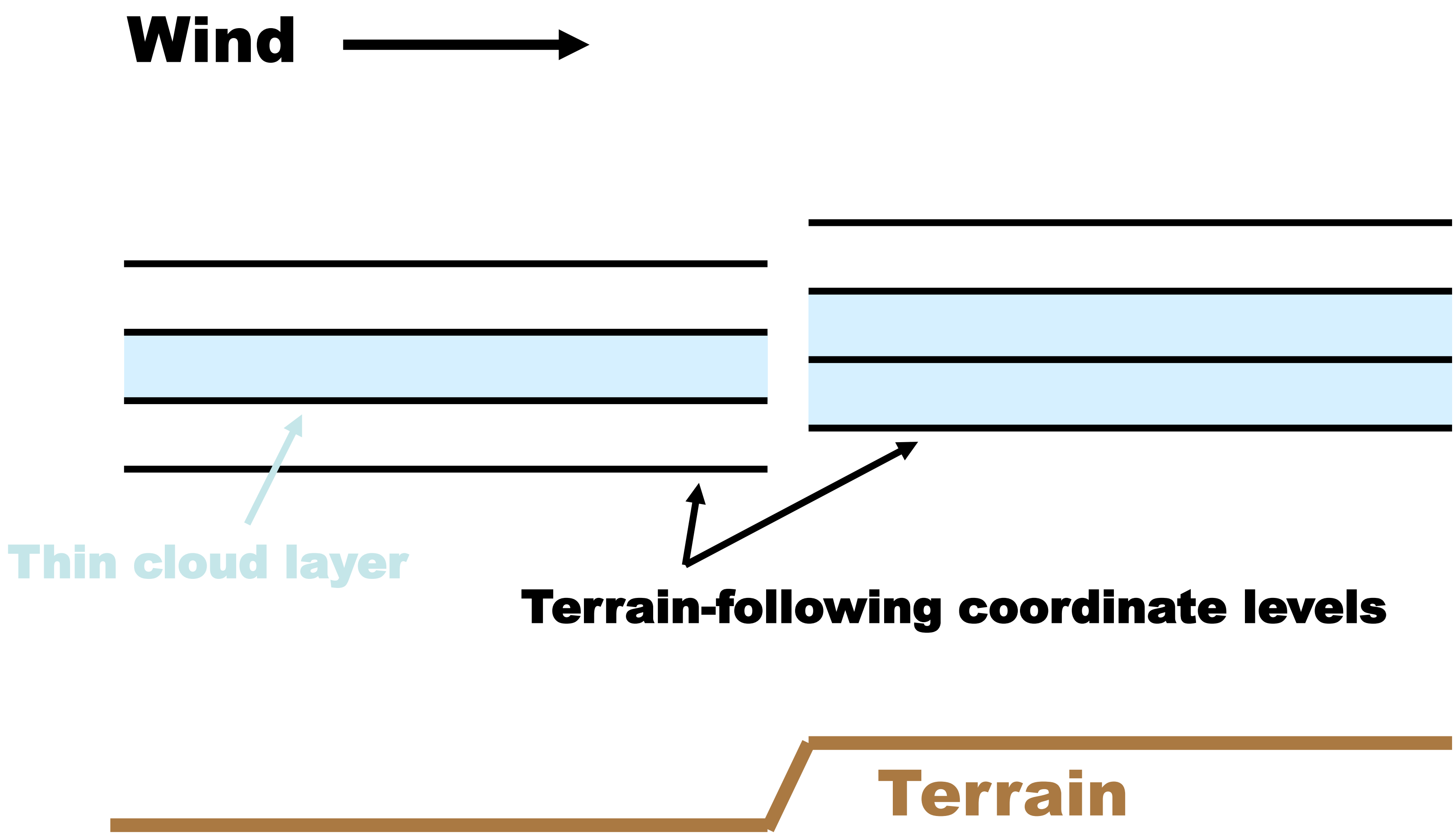
OLAM uses cut cell method



One reason to avoid terrain-following grids:
Error in horizontal gradient computation (especially for pressure)



Another reason:
Anomalous vertical dispersion



Continuous equations in conservation form

$$\frac{\partial V_i}{\partial t} = -\nabla \bullet \left(v_i \vec{V}\right) - \left(\nabla p\right)_i - \left(2\rho\,\vec{\Omega} \times \vec{v}\right)_i + \rho\, g_i + F_i$$

Momentum conservation (component i)

$$\frac{\partial \rho}{\partial t} = -\nabla \bullet \vec{V} + M$$

Total mass conservation

$$\frac{\partial(\rho\,\Theta)}{\partial t} = -\nabla \bullet \left(\Theta \vec{V}\right) + H$$

Θ conservation

$$p = \left[\left(\rho_d R_d + \rho_v R_v\right)\theta\right]^{\frac{C_P}{C_V}} \left(\frac{1}{p_0}\right)^{\frac{R_d}{C_V}}$$

Equation of State

$$\frac{\partial(\rho\, s)}{\partial t} = -\nabla \bullet \left(s\,\vec{V}\right) + Q$$

Scalar conservation (e.g. $s_v = \rho_v / \rho$)

$$\rho = \rho_d + \rho_v + \rho_c$$

Total density

$$\vec{V} \equiv \rho\,\vec{v}$$

Momentum density

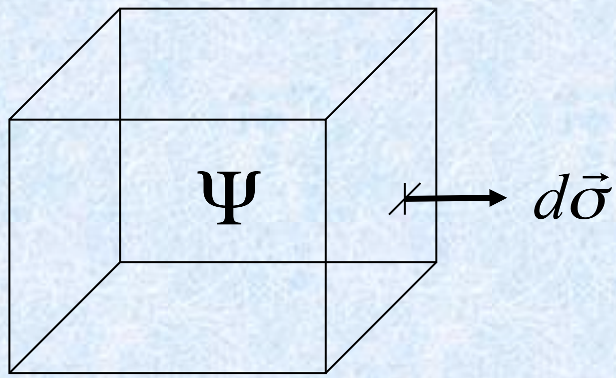
$$\theta = \Theta\left[1 + \frac{q_{lat}}{C_p \max(T,253)}\right]$$

θ = potential temperature

Θ = ice-liquid potential temperature

Finite-volume formulation:
Integrate over finite volumes and apply Gauss Divergence Theorem

$$\int_{\Psi} \nabla \bullet \vec{\Phi}\; d\Psi = \oint_{\sigma} \vec{\Phi} \bullet d\vec{\sigma}$$



Discretized equations:

$$\frac{\partial}{\partial t}\int V_i\, d\Psi = -\oint \left(v_i \vec{V}\right) \bullet d\vec{\sigma} - \int \frac{\partial p}{\partial x_i} d\Psi - \int \left(2\rho\, \vec{\Omega} \times \vec{v}\right)_i d\Psi + \int \rho\, g_i\, d\Psi + \int F_i\, d\Psi$$

$$\frac{\partial}{\partial t}\int \rho\, d\Psi = -\oint \vec{V} \bullet d\vec{\sigma} + \int F_m\, d\Psi$$

$$\frac{\partial}{\partial t}\int \rho\, \Theta\, d\Psi = -\oint \left(\Theta \vec{V}\right) \bullet d\vec{\sigma} + \int F_\theta\, d\Psi$$

$$\frac{\partial}{\partial t}\int \rho\, s\, d\Psi = -\oint \left(s \vec{V}\right) \bullet d\vec{\sigma} + \int F_s\, d\Psi$$

Conservation equations in discretized finite-volume form

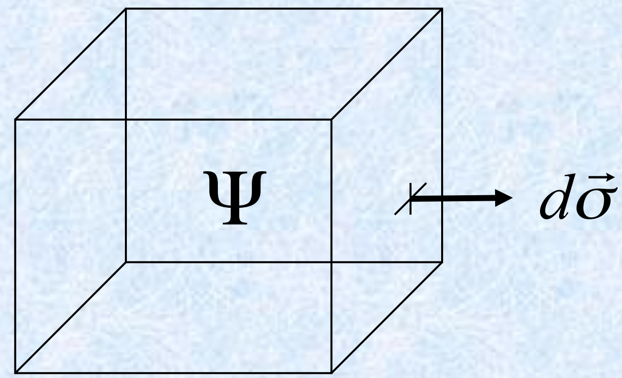
(SGS = “subgrid-scale eddy correlation”)

$$\frac{\partial \overline{V}_i}{\partial t} = -\Psi^{-1}\sum_j \left[\left(\overline{v}_{ij}\overline{V}_j + SGS\{v_{ij}, V_j\}\right)\sigma_j\right] - \frac{\Delta \overline{p}}{\Delta x_i} - \left(2\overline{\rho}\,\vec{\Omega}\times\vec{\overline{v}}\right)_i + \overline{\rho}\,g_i + \overline{F}_i$$

cell volume

cell face area

$$\frac{\partial \overline{\rho}}{\partial t} = -\Psi^{-1}\sum_j \left[\overline{V}_j \sigma_j\right]$$



$$\frac{\partial \left(\overline{\rho\,\Theta}\right)}{\partial t} = -\Psi^{-1}\sum_j \left[\left(\overline{\Theta}_j\overline{V}_j + SGS\{\Theta_j, V_j\}\right)\sigma_j\right] + \overline{H}$$

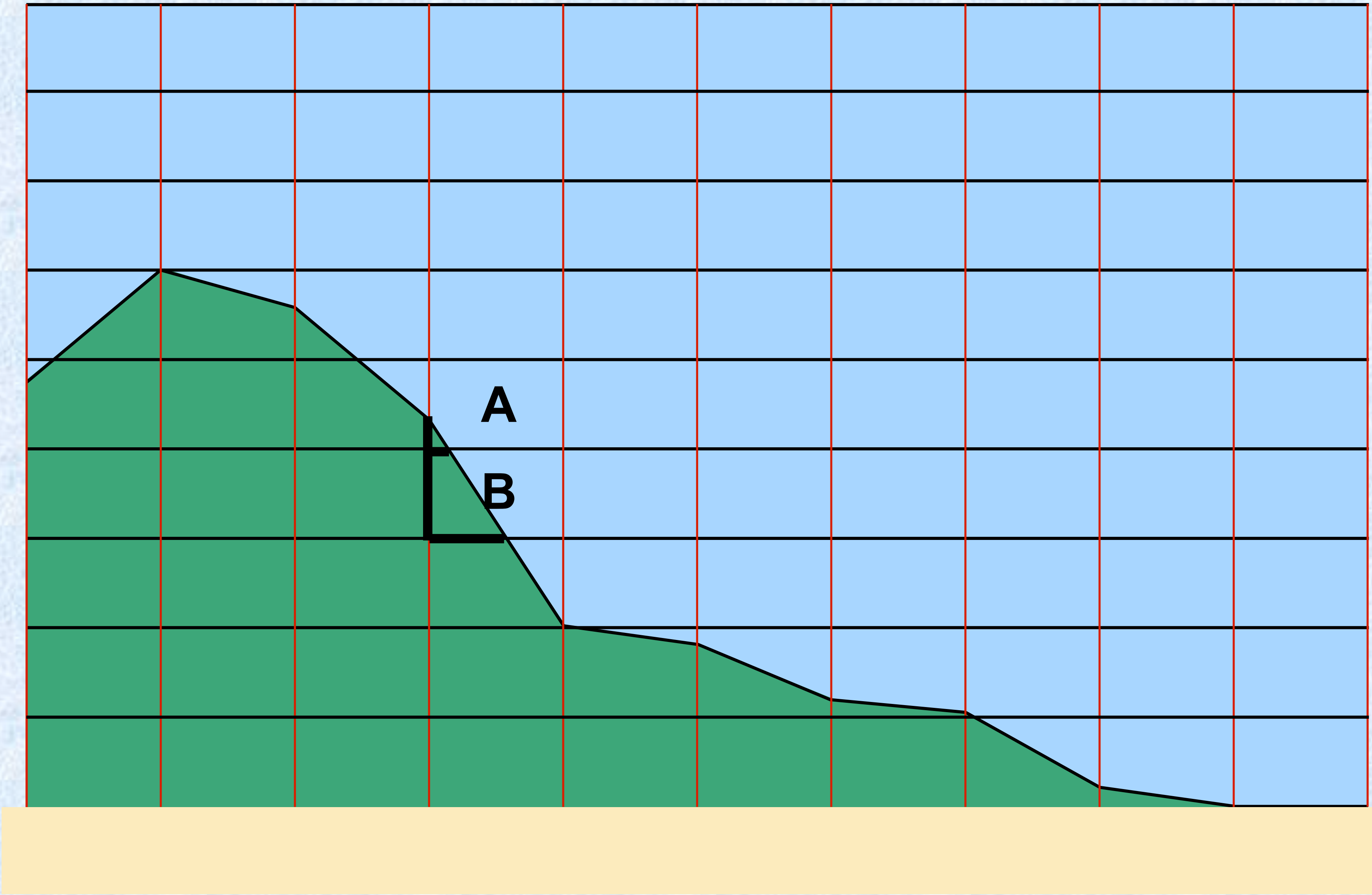
$$\frac{\partial \left(\overline{\rho\, s}\right)}{\partial t} = -\Psi^{-1}\sum_j \left[\left(\overline{s}_j\overline{V}_j + SGS\{s_j, V_j\}\right)\sigma_j\right] + \overline{Q}$$

$$\overline{p} = \left[\left(\overline{s}_d R_d + \overline{s}_v R_v\right)\overline{\rho\,\theta}\right]^{\frac{C_P}{C_V}}\left(\frac{1}{p_0}\right)^{\frac{R_d}{C_V}}$$

Discretized momentum density is consistent between all conservation equations

Grid cells A and B have reduced volume and surface area

Fully-underground cells have zero surface area



C-staggered momentum advection method of Perot (JCP 2002)