The MIT General Circulation Model

- Cubed Sphere Grid
- ‘Modified pressure’ (eta) vertical coordinate
- ‘Partial cell’ handling of topography
- Dynamical Core which runs Ocean or Atmosphere based on Fluid Isomorphisms
- GEOS-3 Atmospheric Physics

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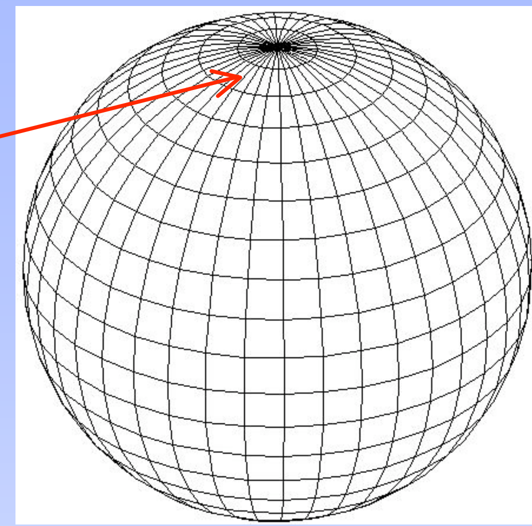
Gridding the sphere

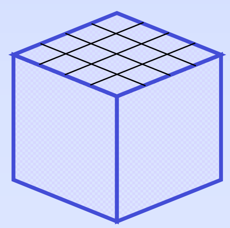
- Latitude-longitude grid
  - converging meridians
  - prohibitive scaling

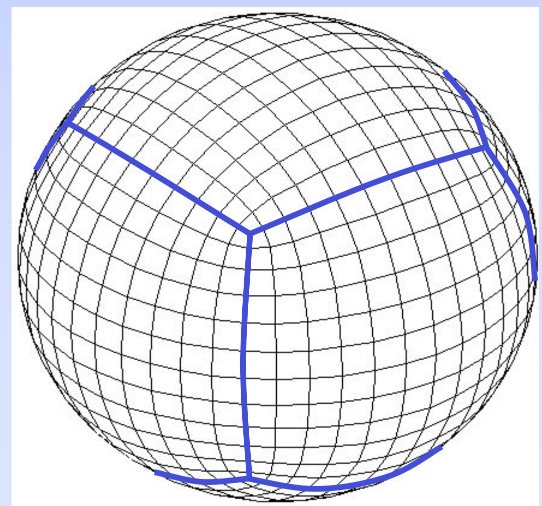
$$\Delta x_{min} \sim N^{-2}$$



- Expanded spherical cube
  - near uniform resolution
  - much improved scaling

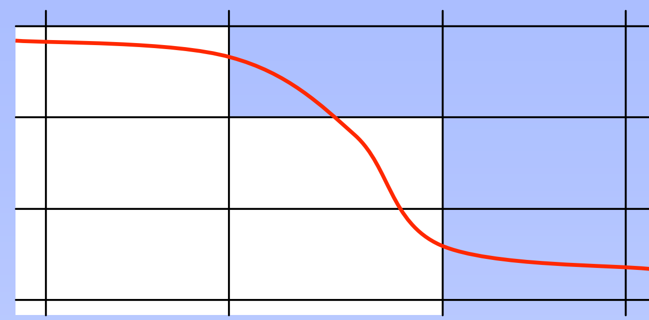
$$\Delta x_{min} \sim N^{-4/3}$$



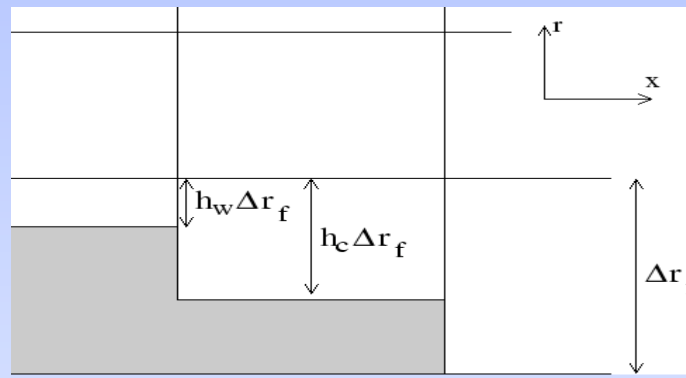


‘Partial Cell’ topography

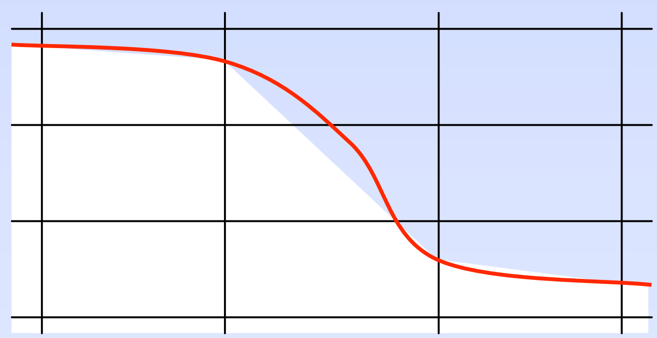
Conventional block-wise topography/orography



Partial cell topography (finite volume)

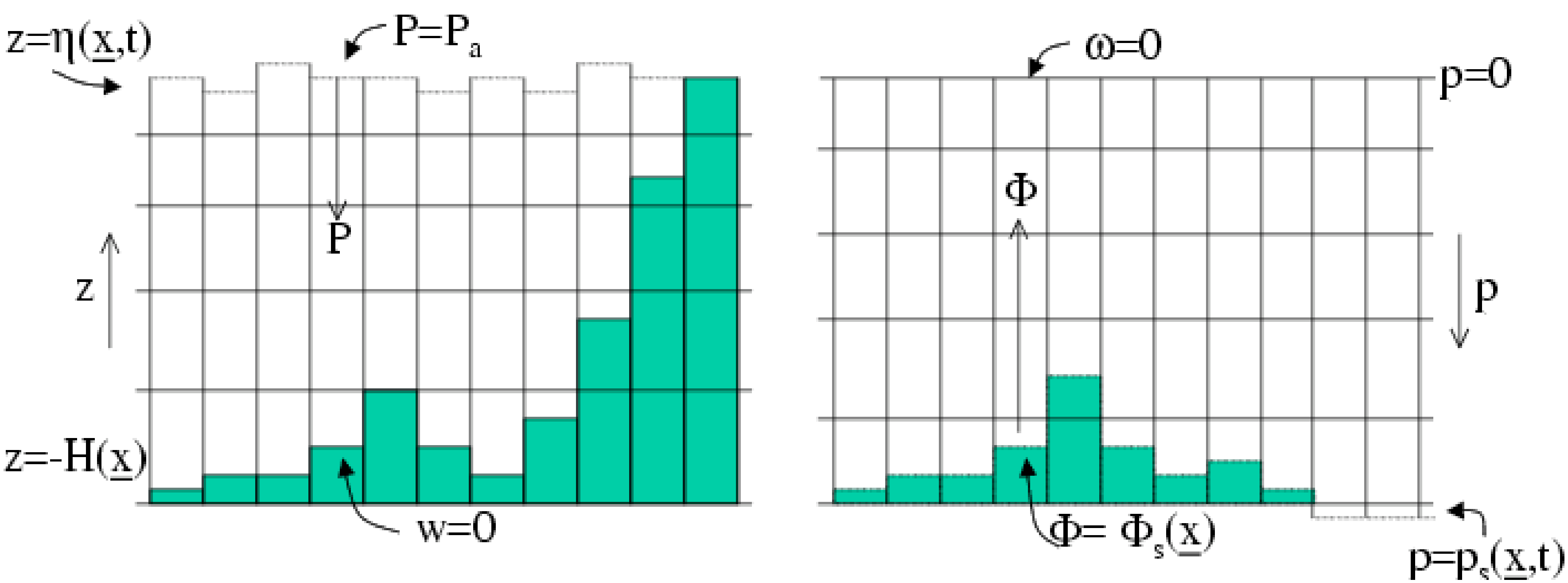


Peicewise linear arbitrary topography (finite volume)



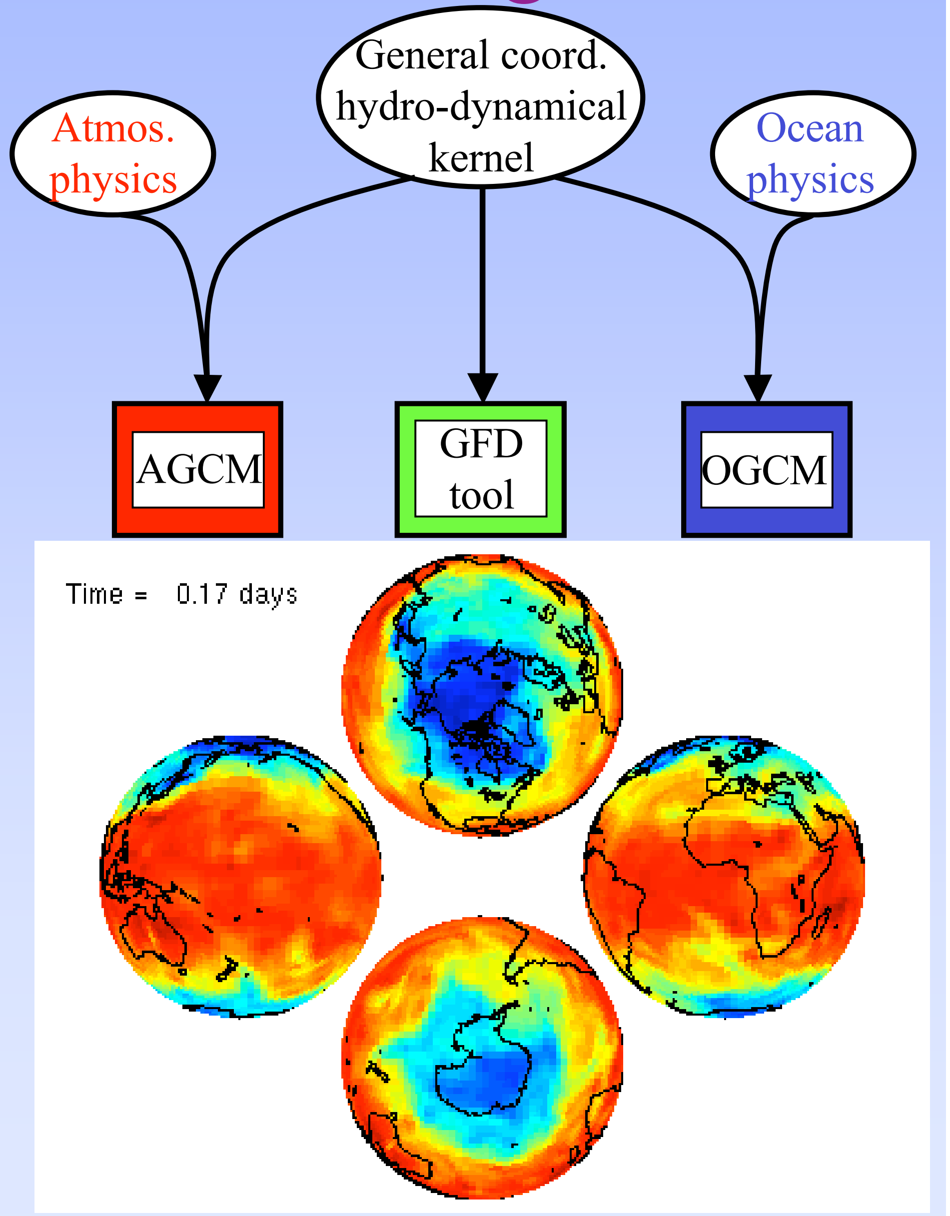
z-P Isomorphism

Ocean (z coordinates) (Boussinesq)	$z \leftrightarrow p$	Atmosphere (p coordinates) (non-Boussinesq)
$d_t\underline{v} + f \times \underline{v} + \underline{\nabla}_z P = \underline{F}$	$P \leftrightarrow \Phi$	$d_t\underline{v} + f \times \underline{v} + \underline{\nabla}_p \Phi = \underline{F}$
$g\rho + \partial_z P = 0$	$\rho \leftrightarrow \alpha$	$\alpha + \partial_p \Phi = 0$
$\underline{\nabla}_h \cdot \underline{v} + \partial_z w = 0$	$w \leftrightarrow \omega$	$\underline{\nabla}_p \cdot \underline{v} + \partial_p \omega = 0$
$d_t\theta = Q$	θ	$d_t\theta = Q$
$d_t s = S$	$s \leftrightarrow q$	$d_t q = S$
$\partial_t \eta + \underline{\nabla}\cdot(\eta + H)\underline{v} = P\text{-}E$	$\eta + H \leftrightarrow p_s$	$\partial_t p_s + \underline{\nabla}\cdot p_s \underline{v} = 0$



Unified approach to Ocean/Atmosphere modeling

- The z-p isomorphism
  – allows same dynamical core to model either ocean or atmosphere
- Discriminate between fluids with "plug-in" physics
- Leverage developments
  – Developments for one application immediately available in the other
    - e.g. "cubed sphere", vertical coordinate, finite volume method, automatic adjoint, etc…



GEOS-3 Atmospheric Physics

- Moist Convection - RAS Scheme of Moorthi&Suarez

Linearized Arakawa Schubert type scheme. Cloud model is a rising plume model with linear entrainment, closure is with the quasi-equillibrium assumption. Convective and large-scale cloud fractions are determined diagnostically in proportion to the detrained liquid water amount, and separate values are used for cloud ice particles and water droplets.

- Atmospheric Turbulence - Mellor-Yamada Level 2.5 of Helfand & Labraga

Second-order (1.5) closure to the Reynolds' equations; assumes that turbulence is *nearly* isotropic; contains a prognostic equation for turbulent kinetic energy and diagnostic equations for the other second moments; models turbulence as a diffusion process. Includes a 'moist' boundary layer - conservative thermodynamic variable is liquid water potential temperature.

- Radiation - Chou (SW), Chou&Suarez (LW)

The shortwave radiation scheme computes radiative heating due to the absoption by water vapor, ozone, carbon dioxide, oxygen, clouds, and aerosols and due to the scattering by clouds, aerosols, and gases. Infrared fluxes are computed due to absorption by water vapor, carbon dioxide, and ozone. Clouds are grouped into low ($p>700$), middle ($700 > p > 400$), and high ($p < 400$) cloud regions.

- Land Surface Characteristics - Koster-Suarez LSM (SVAT)

LSM links the physical description of canopy processes with detail descriptions of soil moisture and temperature (moisture and energy balance equations). The vegetation acts to determine surface roughness, reflectance and canopy resistance to the flow of moisture and heat. 3 soil levels, 2 temperature levels.