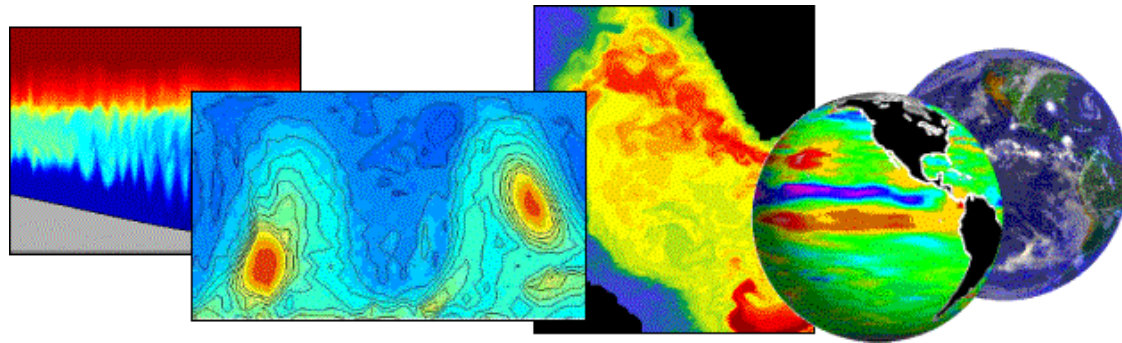




# ***MITgcm Model Development***

ECCO Meeting

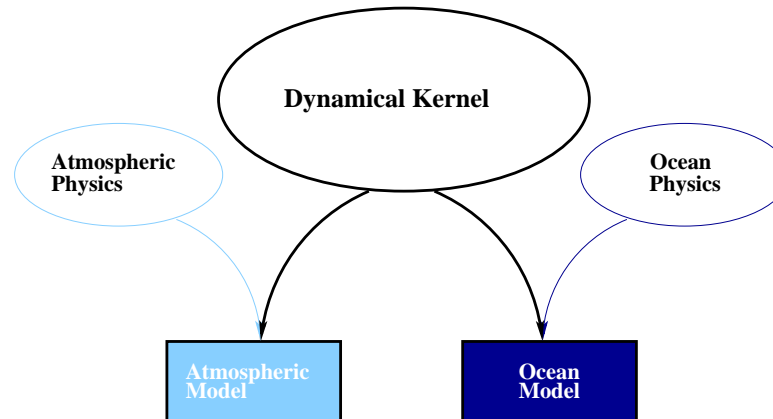
# MITgcm development



- Non Boussinesq ( $\rightarrow$  p-coordinate)
- Real fresh water flux (& sea-ice)
- Time stepping ( $\rightarrow$  longer time-step)
- Adiabatic interior (Alistair)
- Gridding (Ed)

# *Non boussinesq Ocean Model*

- use pressure coordinate
- p-coordinate z-coordinate isomorphism



- OGCM: Martin Loch et al, JPO, p306-309, 2004.

# Equations (1)

Ocean in pressure coordinate:  $\phi = gZ$

$$\frac{D\vec{v}_h}{Dt} + f\hat{\mathbf{k}} \times \vec{v}_h + \nabla_p \phi = \vec{F}$$

$$\frac{\partial \phi}{\partial p} + \alpha = 0$$

$$\nabla_p \cdot \vec{v}_h + \frac{\partial \omega}{\partial p} = 0$$

$$\frac{1}{\alpha} = \rho = \rho(\theta, S, p)$$

$$\frac{D\theta}{Dt} = Q_\theta \quad \frac{DS}{Dt} = Q_s$$

## Equations (2)

upper and lower B.C.:

$$\text{at the top: } p = 0, \quad \omega = \frac{Dp}{Dt} = 0$$

$$\text{at the bottom: } p = p_b, \quad \phi = \phi_{topo} = g Z_{topo}$$

$$\text{free surface (@ bottom): } \frac{\partial p_b}{\partial t} = -\nabla_p \cdot \int \vec{v}_h dp$$

# ***Ocean in pressure***

- “Real Fresh-Water”: at the top ( $p = 0$ ):

$$\omega = g \rho_{fw} (P - E)$$

- Non-Linear free-surface with “p\* ” coordinate:  $p^* = p \frac{P_b^o}{P_b}$

- Atmospheric loading: top boundary condition at

$$p = P_{atm}^{SL}$$

Physical parametrization:

- GM
- KPP

# Fresh Water Flux

Dynamics:

$$\frac{\partial \eta}{\partial t} = P - E$$

Thermodynamics:

“Real Fresh Water”

$$\frac{\partial h}{\partial t} = P - E$$

$$\frac{\partial(hS)}{\partial t} = 0$$

$$\frac{\partial(h\theta)}{\partial t} = \frac{Q}{\rho C_p} + P\theta_{rain} - E\theta_{ev}$$

“Virtual Salt Flux”

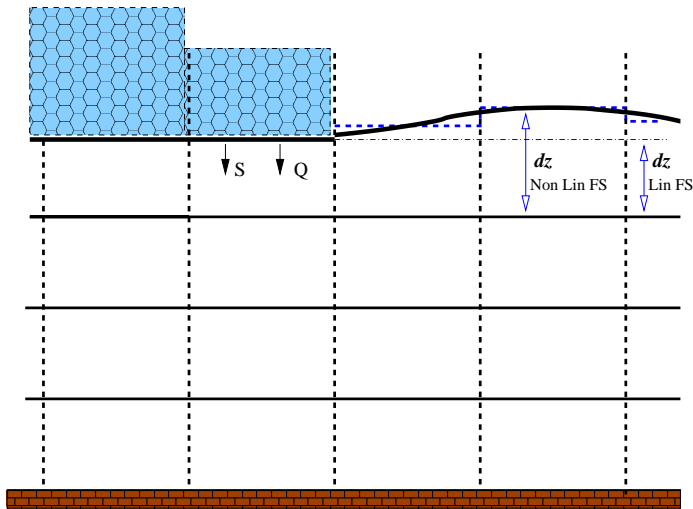
$$\frac{\partial h}{\partial t} = 0$$

$$h \frac{\partial S}{\partial t} = -S^o(P - E)$$

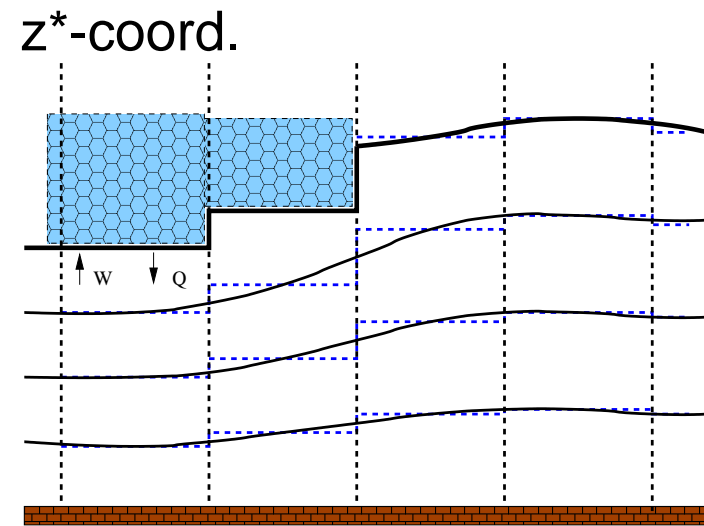
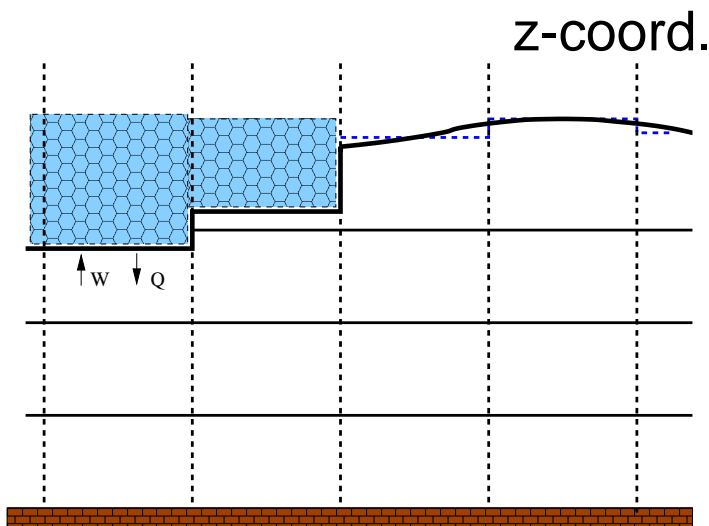
$$h \frac{\partial \theta}{\partial t} = \frac{Q}{\rho C_p}$$

# Sea-Ice & Real Fresh Water flux

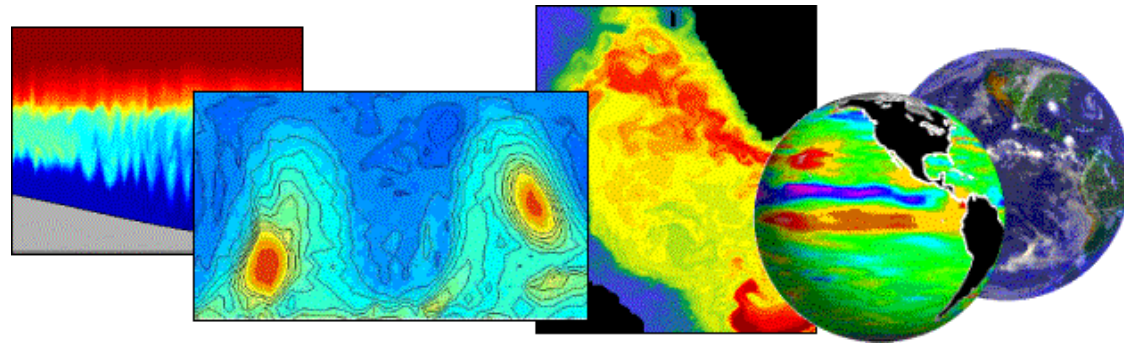
Salt Flux formulation (Linear or Non-Linear FS)



Real Fresh Water formulation (Non-Linear FS)



# *MITgcm development*



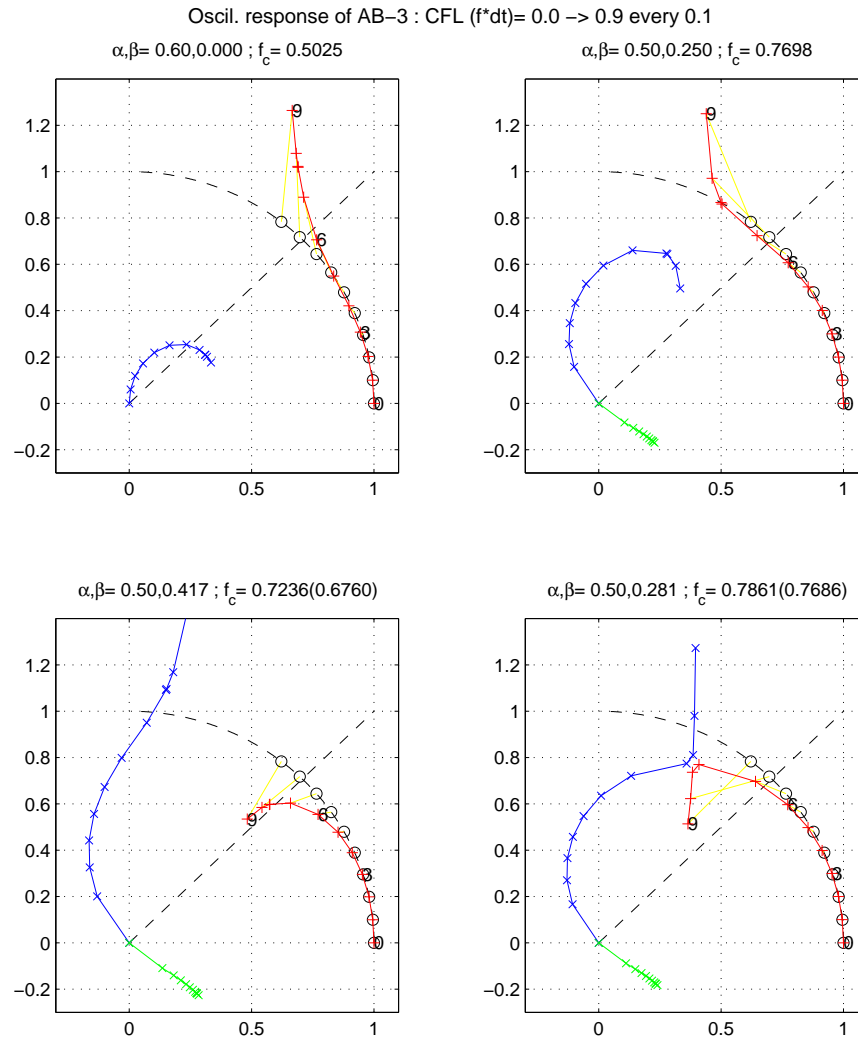
- Non Boussinesq
- Real fresh water flux
- **Time stepping**
- Adiabatic interior
- Gridding

# *Time Stepping*

- Adams-Bashforth 3
- Implicit internal gravity wave
  - reference stratification (horizontally uniform)
  - in situ stratification
- Implicit vertical advection

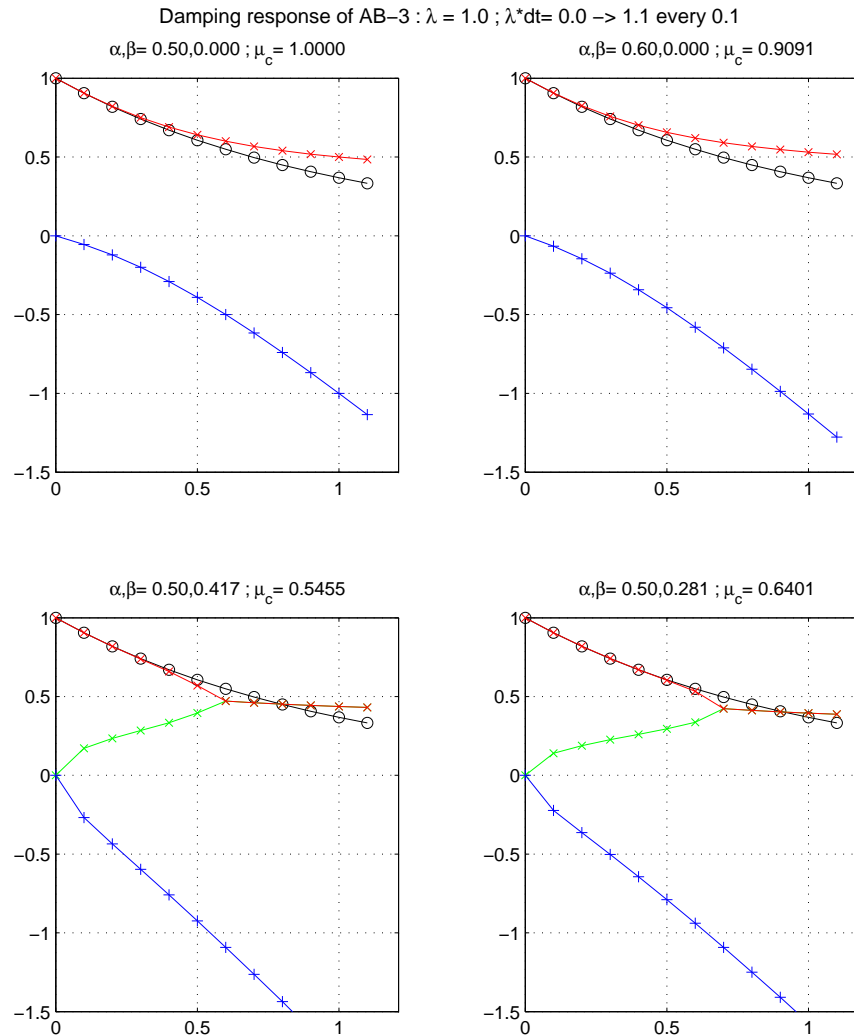
# Adams-Bashforth

## Oscillatory Response



# Adams-Bashforth

## Damping Response



# Implicit IGW

using a reference density profile:  $\rho_{\text{ref}}(z)$  with  $\rho' = \rho - \rho_{\text{ref}}$

$$\frac{\partial \vec{v}_h}{\partial t} + \nabla_h \Phi'_h = 0$$

$$\frac{\partial \Phi'_h}{\partial z} + g \frac{\rho'}{\rho_c} = 0$$

$$\nabla_h \cdot \vec{v}_h + \frac{\partial w}{\partial z} = 0$$

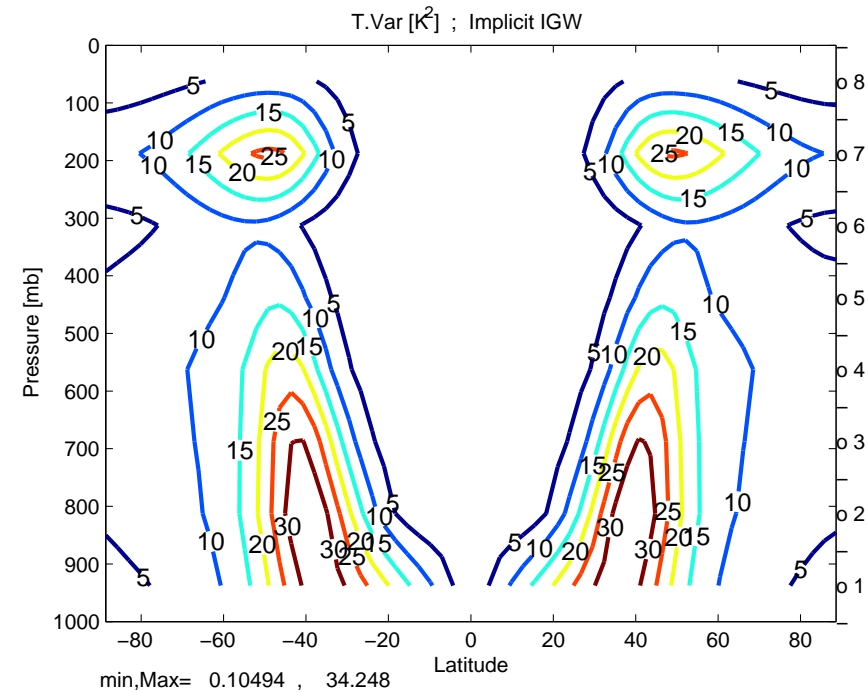
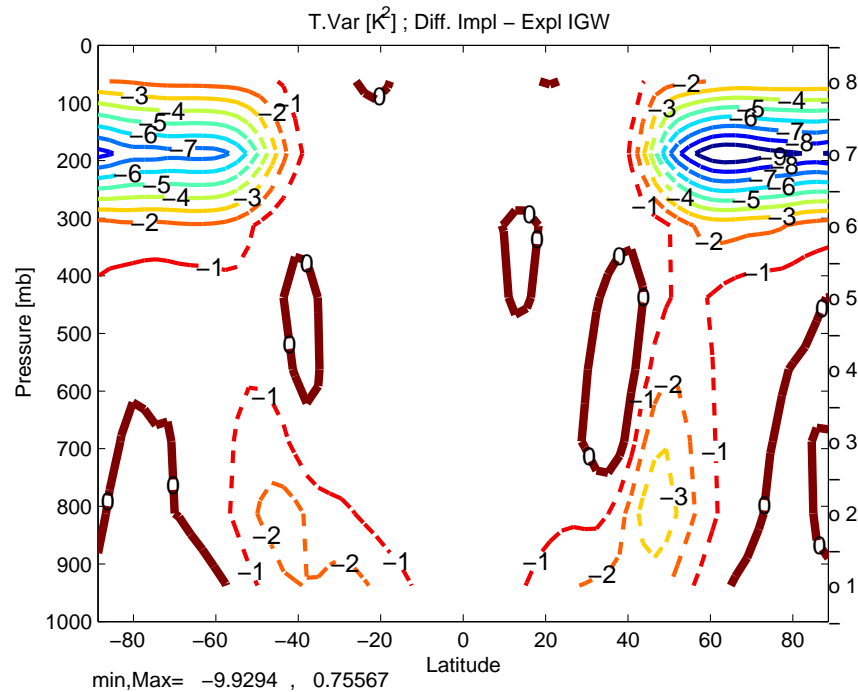
$$\frac{\partial \rho'}{\partial t} + \vec{v} \cdot \nabla (\rho_{\text{ref}} + \rho') = 0$$

leads to the wave equation (with  $N^2 = -g(\partial \rho_{\text{ref}} / \partial z) / \rho_c$ ):

$$\nabla_h \cdot \nabla_h \Phi'_h + \frac{\partial^2}{\partial t \partial z} \left( \frac{1}{N^2} \frac{\partial^2}{\partial t \partial z} \Phi'_h \right) = 0$$

# IGW Results

## Held & Suarez atmospheric benchmark: Comparison Implicit / Explicit IGW



# IGW Summary

- Atmosphere
  - longer time-step (  $> \times 2$  )
  - save time (  $-1/3$  ) despite more computation (3.D solver)
  - preserve mean circulation and variability
- ocean: depending on the set-up:
  - IGW are likely to limit the time-step
  - uniform reference stratification might not be suitable
  - 2nd version: using  $\rho^n$  instead of  $\rho_{\text{ref}}$
  - Non-Hydrostatic with no additional cost