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**Advances towards accurate general coordinate ocean models:**

# REMAPPING, REGRIDDING AND CONTINUOUS ISOPYCNAL COORDINATES

White & Adcroft, JCP 2008

White, Adcroft & Hallberg, JCP 2009





# Spurious diapycnal diffusion

- A common justification for isopycnal models:
  - “z-coordinates exhibit spurious *diapycnal* diffusion”  
DYNAMO; Legg et al., 2006 (GCE-CPT)
- Attempts to quantify “spurious” diffusion  
Griffies et al, 2000; Maqueda & Holloway, 2006;  
Rennau & Burchard, 2009; **PO45A-03 Getzlaff et al.**
- Motivation for hybrid/general coordinate models
  - use most appropriate coordinate for region e.g. HyCOM
- Will general coordinate models be adiabatic enough?
  - i.e. How much spurious mixing is there in a general coordinate model with active regridding-remapping to isopycnals?

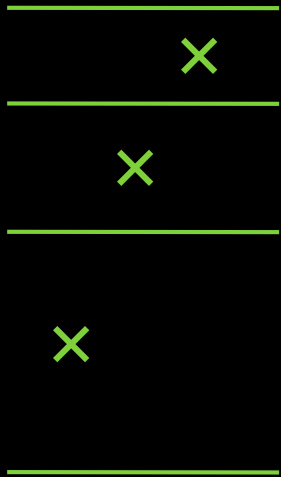


How do you build a coordinate free model?

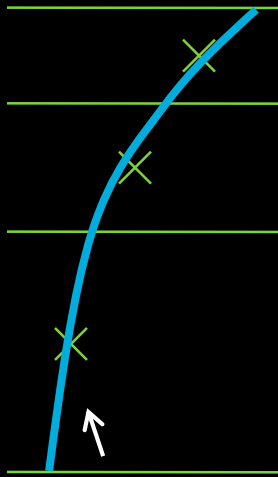


# Coordinate free algorithm

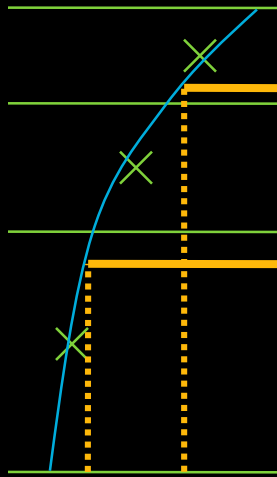
Starting grid/data



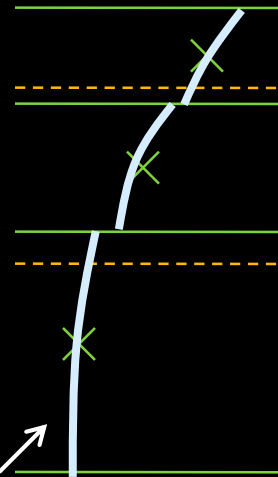
Fit profile



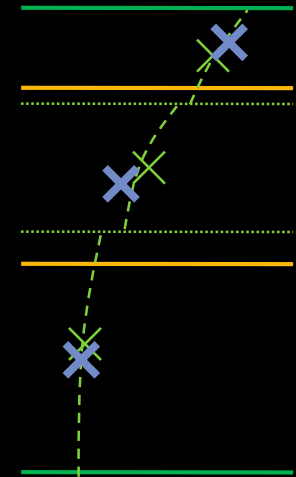
Find new grid



Fit profiles



New cell averages



*Not necessarily the same*

## ■ Re-gridding

## ■ Re-mapping

### □ Re-construct **global** profile

- Single valued (monotonic)
- (continuous or not)
- (conservative or not)

### □ Find position of new grid

### □ Re-construct **local** profiles

- Conservative
- Limited (monotonic)
- Discontinuous (exclusive!)

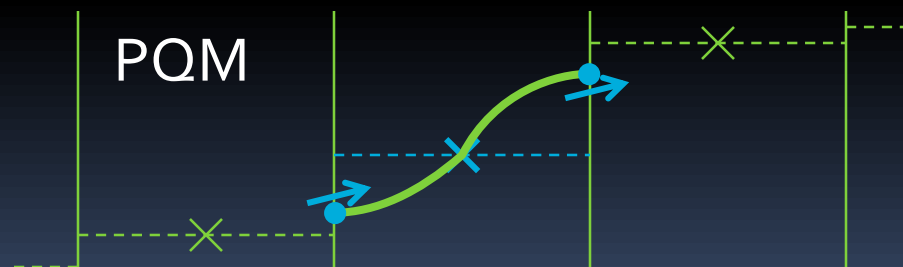
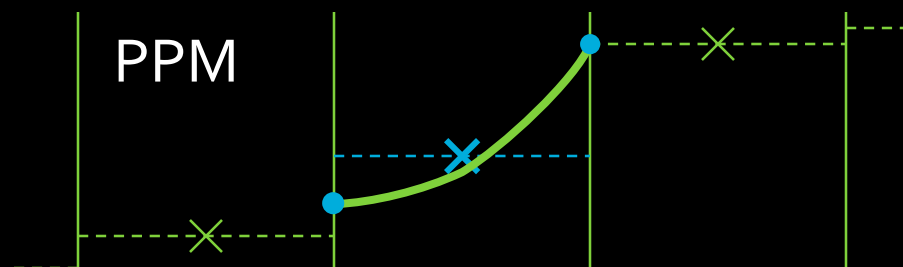
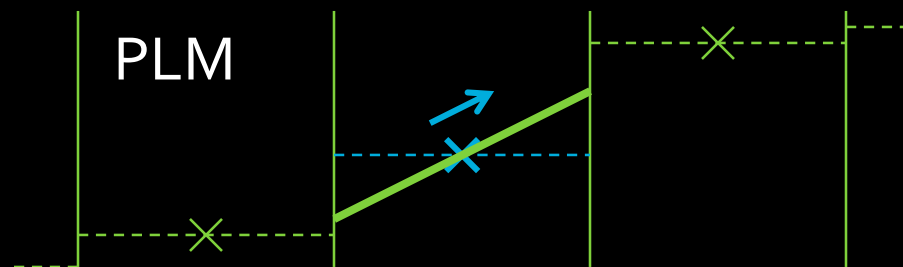
### □ Integrate for new cell averages

- This is not how traditional layered isopycnal models work
- The accuracy of the reconstructions are the key!



# Piecewise \* Method (\* = C, L, P or Q)

- PLM: two degrees of freedom
  - Cell mean + slope
- PPM: three degrees of freedom
  - Very widely used
  - Cell mean + two edge values
- PQM: five degrees of freedom
  - Cell mean + two edge values + two edge slopes

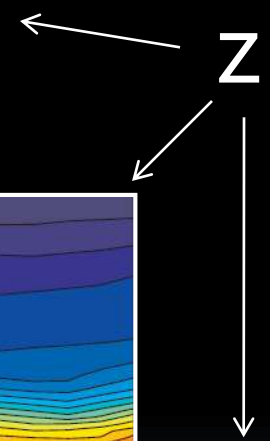
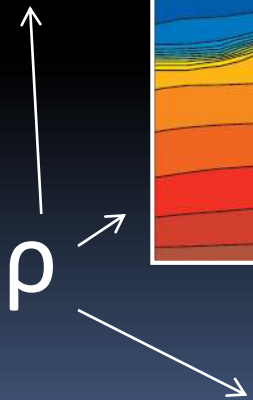
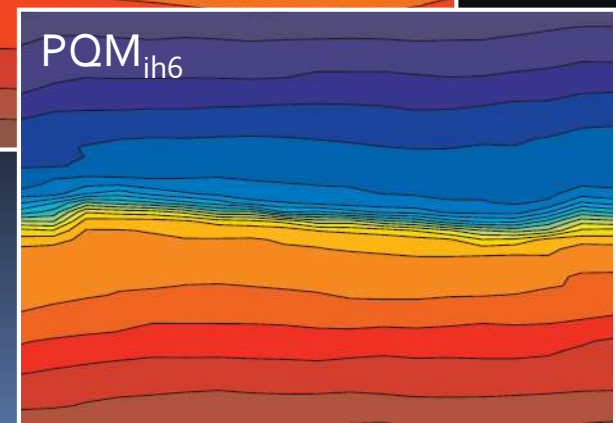
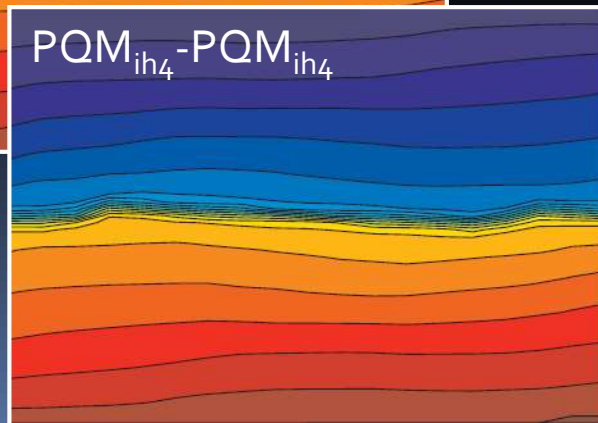
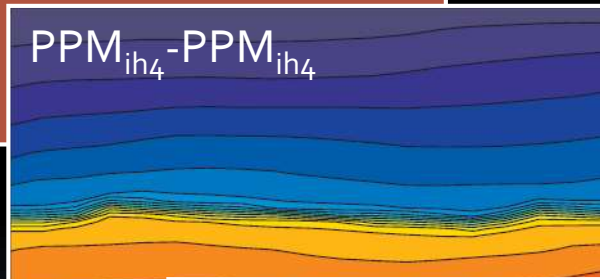
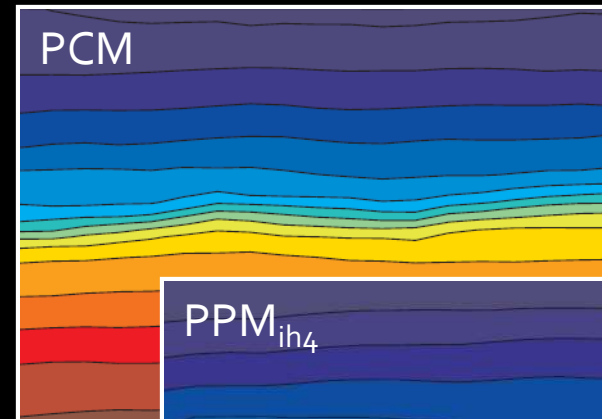
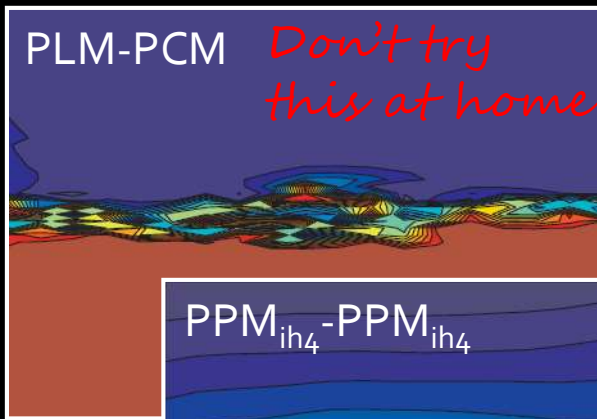
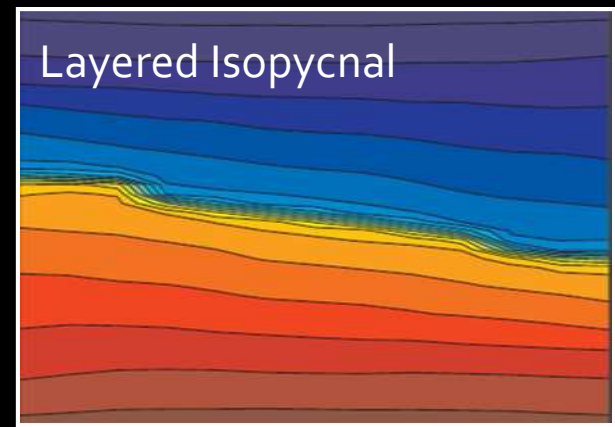


Successive schemes provide more flexibility to represent structures → more accurate



# Sloshing test case

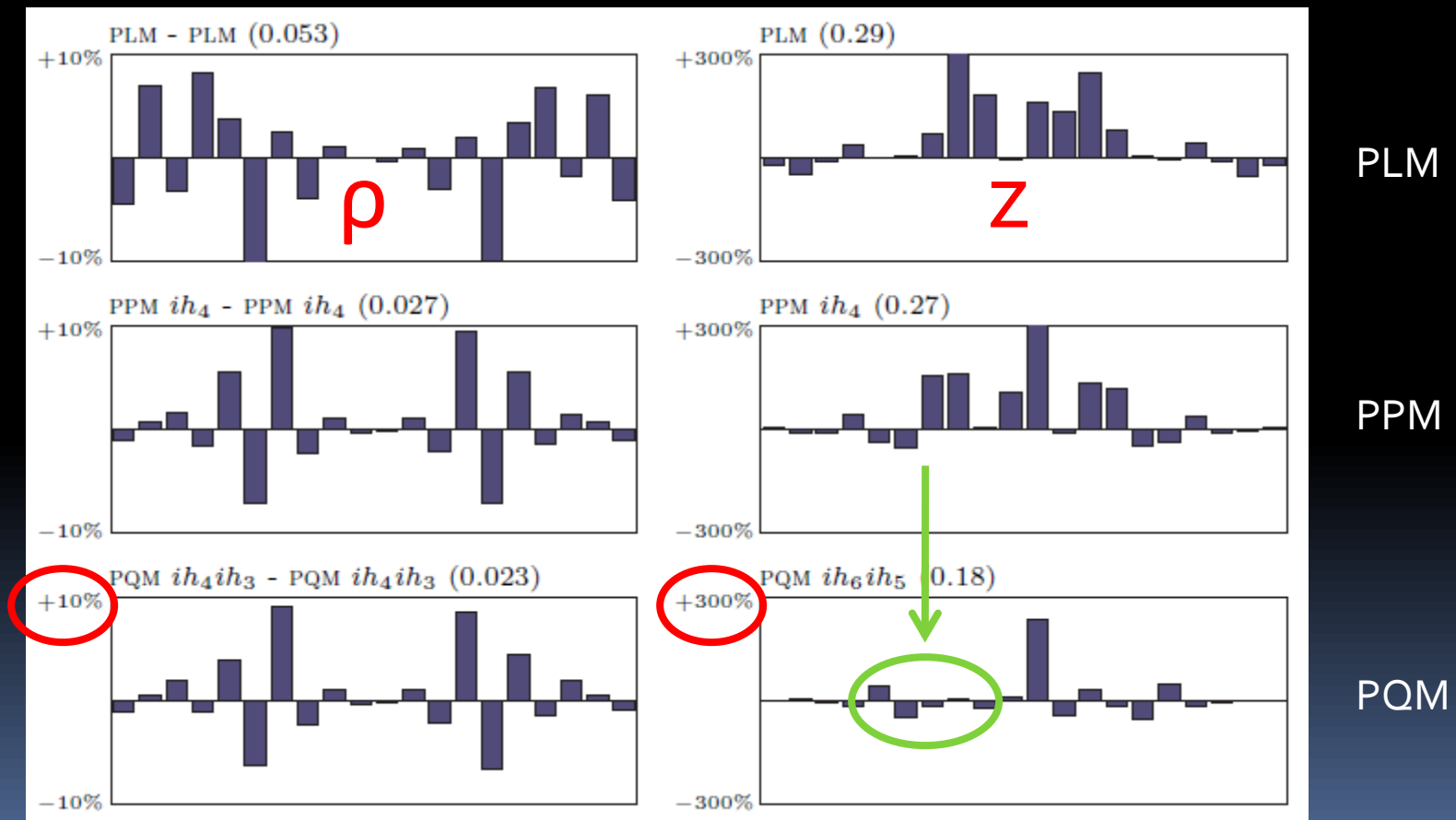
- Continuous isopycnals work
  - PPM too diffuse in z-coordinates
  - PQM-PQM as good as layered





# Sloshing test case

- Internal wave displacing a thermocline (tanh)
  - Simple problem but hard[er] for z-coordinates



% volume change in each density class

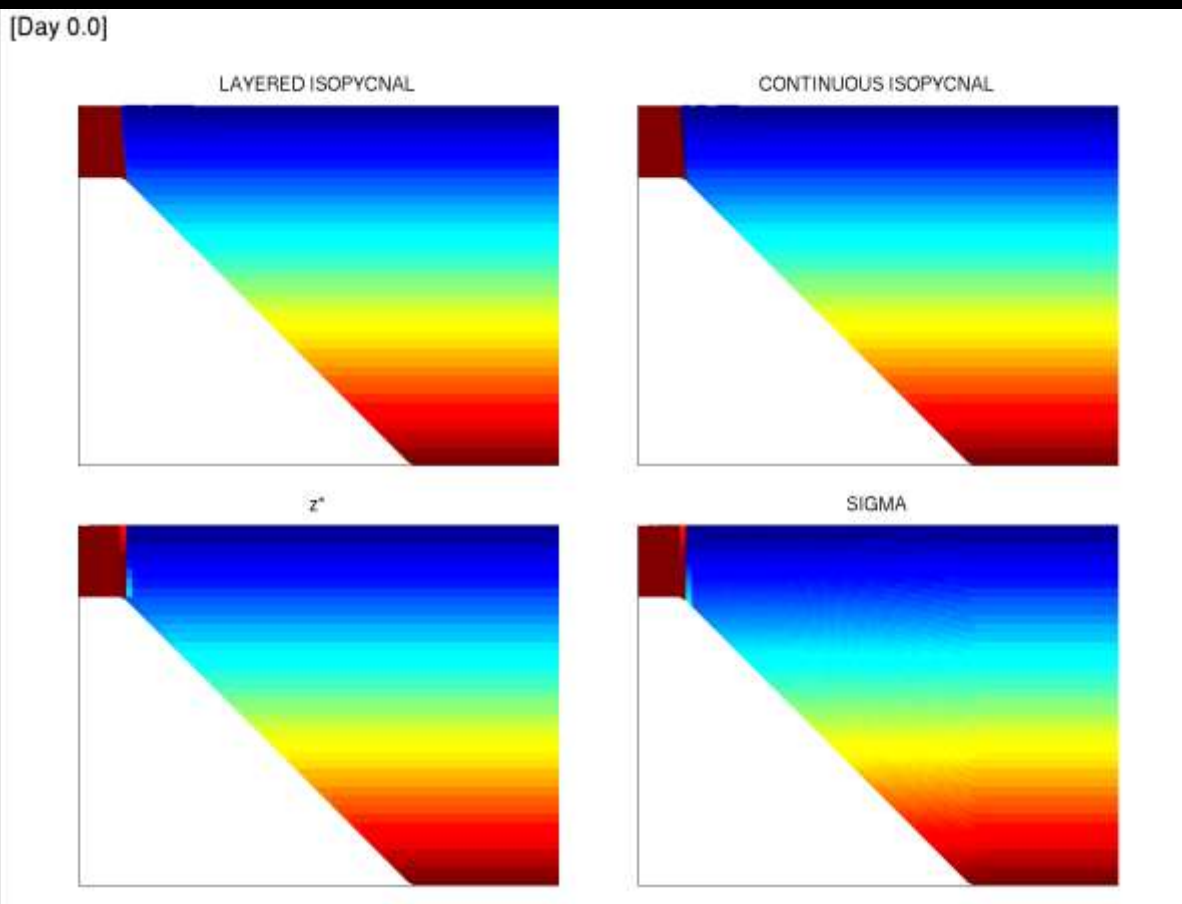




# Gravity current (2D)

- Spurious diffusion significantly dilutes gravity current
- Continuous isopycnals do as well (look better) than layered
- Re-mapping to non-isopycnal clearly diffusive

*“True” soln  
(adiabatic)*



*Better soln :-)*

*$z^*$  and  $\sigma$   
dillute  
buoyancy  
anomaly*

*Same  
numerics for  
non-layered  
models*





# Final thoughts

- GOLD uses same method throughout water column whether isopycnal or not
  - **Continuous isopycnal approach works (as well as layered)**
  - Not tied to pot. density, more flexible than layered isopycnal
- Spurious diffusion can be minimized when remapping to isopycnals
  - ... using PQM
  - PLM is too diffusive; PPM may be too diffusive
- Verdict on non-isopycnal coordinates
  - Jury is out ... but not looking good
  - PQM or even higher order approaches could come to rescue
  - About to evaluate schemes in eddying simulations
- Ready to explore new [hybrid] coordinates
- Consolidate "physics", e.g. bulk mixed layer vs. KPP

Need to quantify in context of global application (measure  $\kappa$ )

