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PQM, CONTINUOUS ISOPYCNAL COORDS & IMPLICATIONS FOR HYBRID COORDS

White & Adcroft, JCP 2008
White, Adcroft & Hallberg, JCP subm.

From isopycnal to generalized

Layered model

- Piecewise constant
  - in interior
- Entrainment-detrainment
  - to adjust layer density back to target
- Can be strictly adiabatic

Coordinate free model

- Re-gridding/re-mapping
  - Independent of state
  - Higher order
  - Consistent w. *-models
  - Target interfaces
- Challenge: avoid damage from re-mapping

- Objective: move away from piecewise constant representation in vertical (layered) to a [more] continuous representation

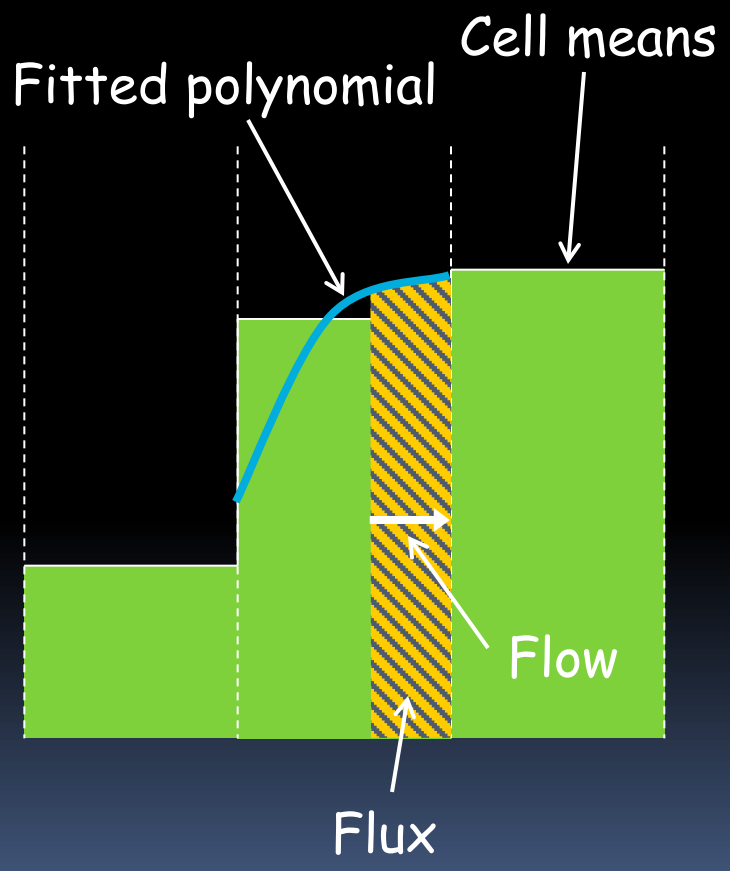
Finite Volume Advection

e.g. R-A-E method

- Reconstruct
  - Fit curve to data

    (cell means)
- Average
  - Integrate under curve
    - that part will be "swept" out of cell
- Evolve
  - Update cell means

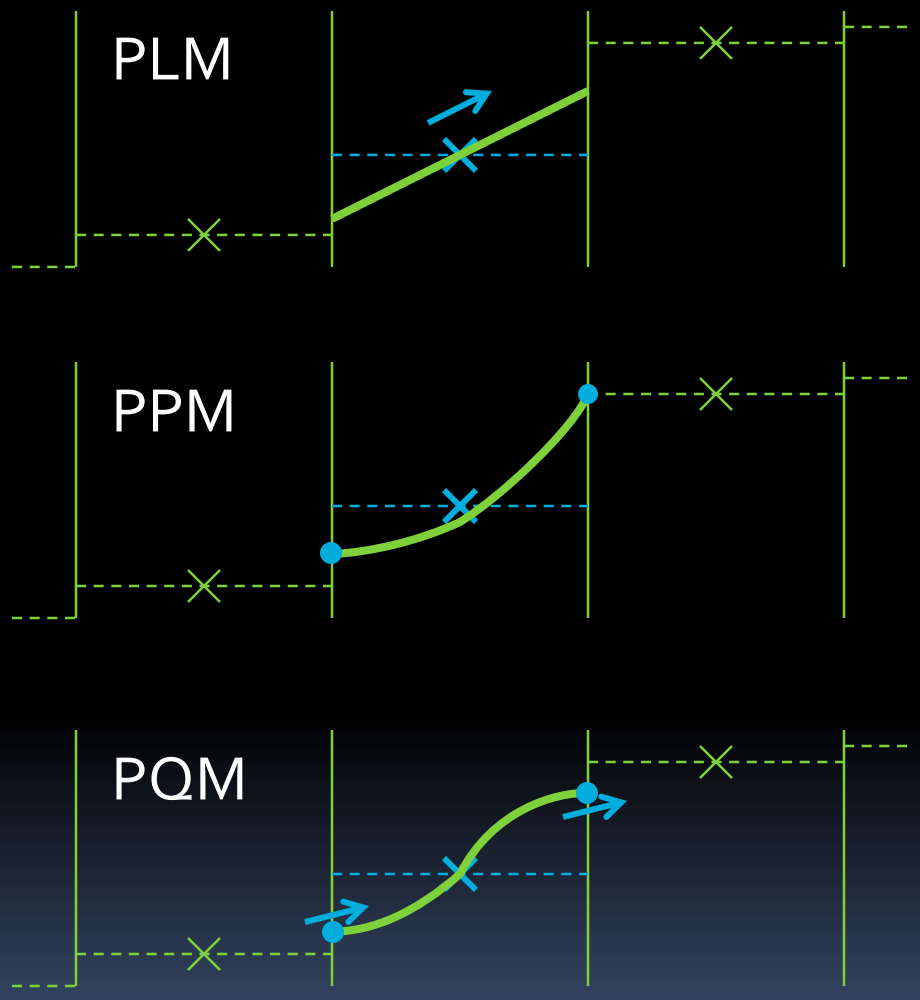
    (sum the integrated parts)



Inspired by Daru & Tenaud, JCP 2004 – introduced OS_i i=1..7

Piecewise * Method (P*M)

- 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

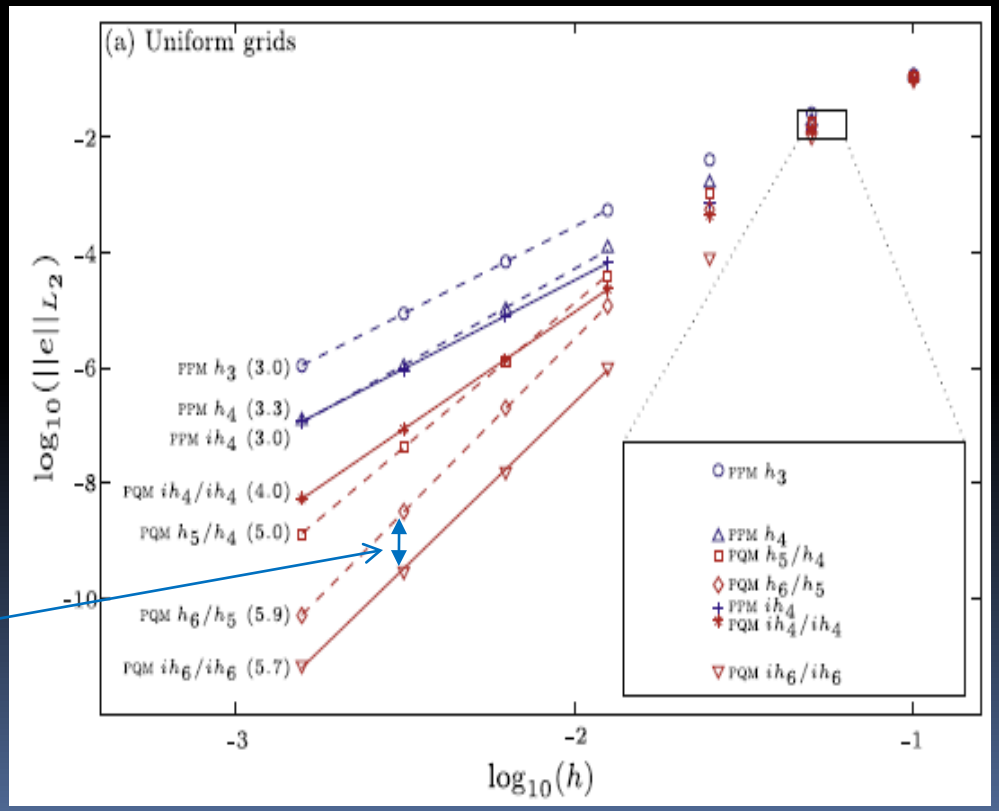


Successive schemes provide more flexibility to represent structures → more accurate

PQM: edge values & slopes

- Explicit interpolation
  - F.V. fit curves to N neighbours
  - Order of interpolation ≥ order of representation
- Implicit interpolation (compact differencing)
  - Possible/affordable in vertical direcition
  - Significantly more accurate than explicit

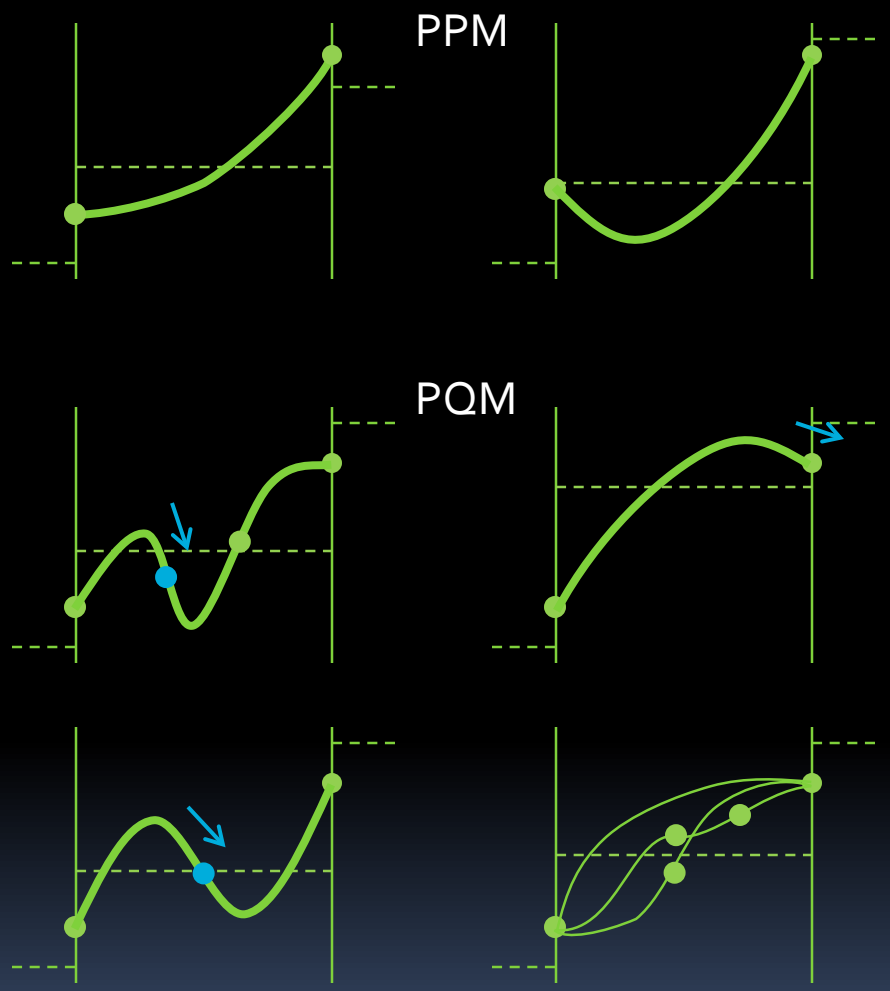
- PQM O(h^6) using either explicit or implicit interpolation



White & Adcroft, JCP 2008

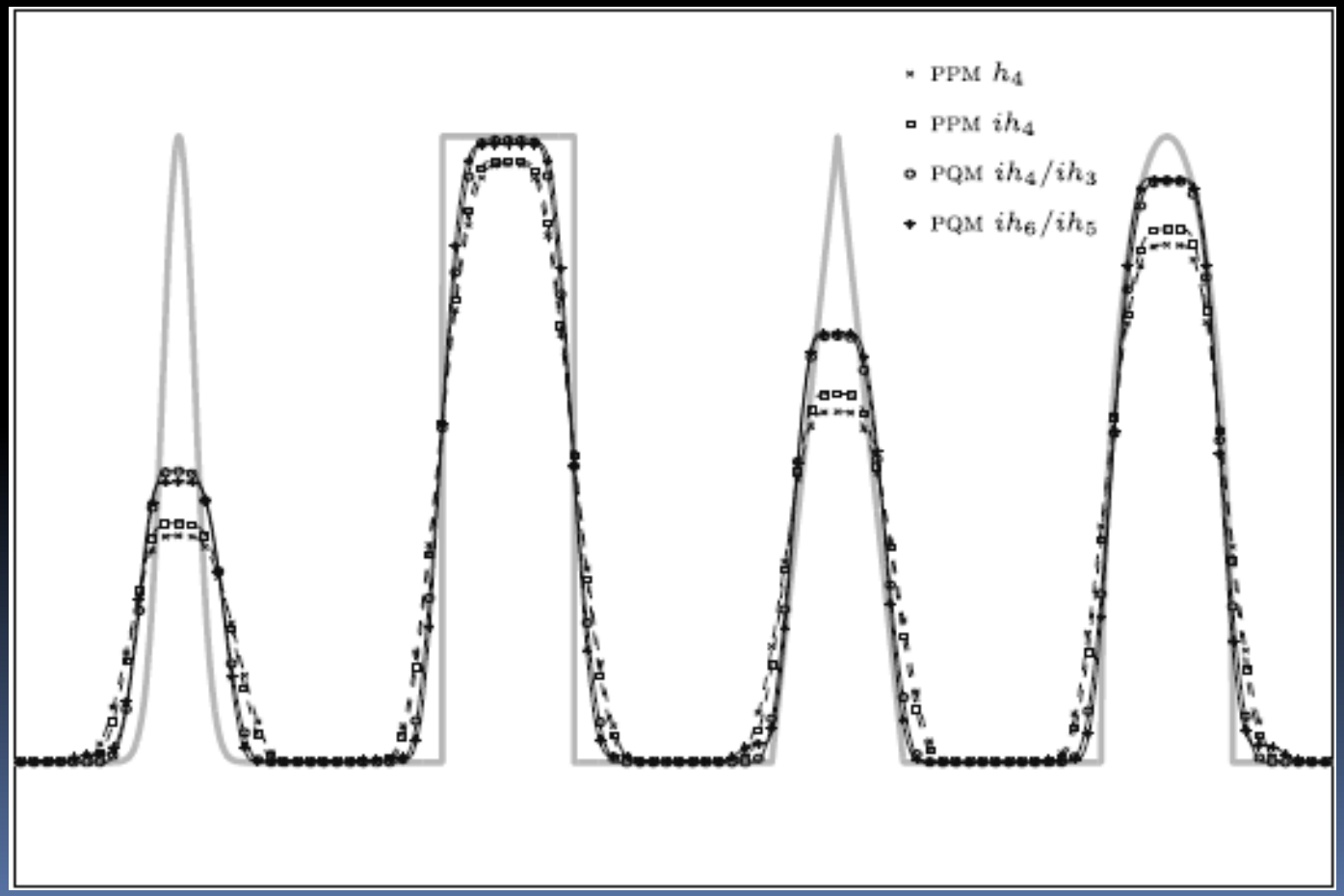
PQM: limiting

- PPM limiting
  - bound edge values
  - extrema outside cell
- PQM limiting
  - bound edge values
  - inflexion points
    - slope in same sense as E.V.
    - or outside cell
    - or joined
  - edge slopes
    - same sense as E.V.



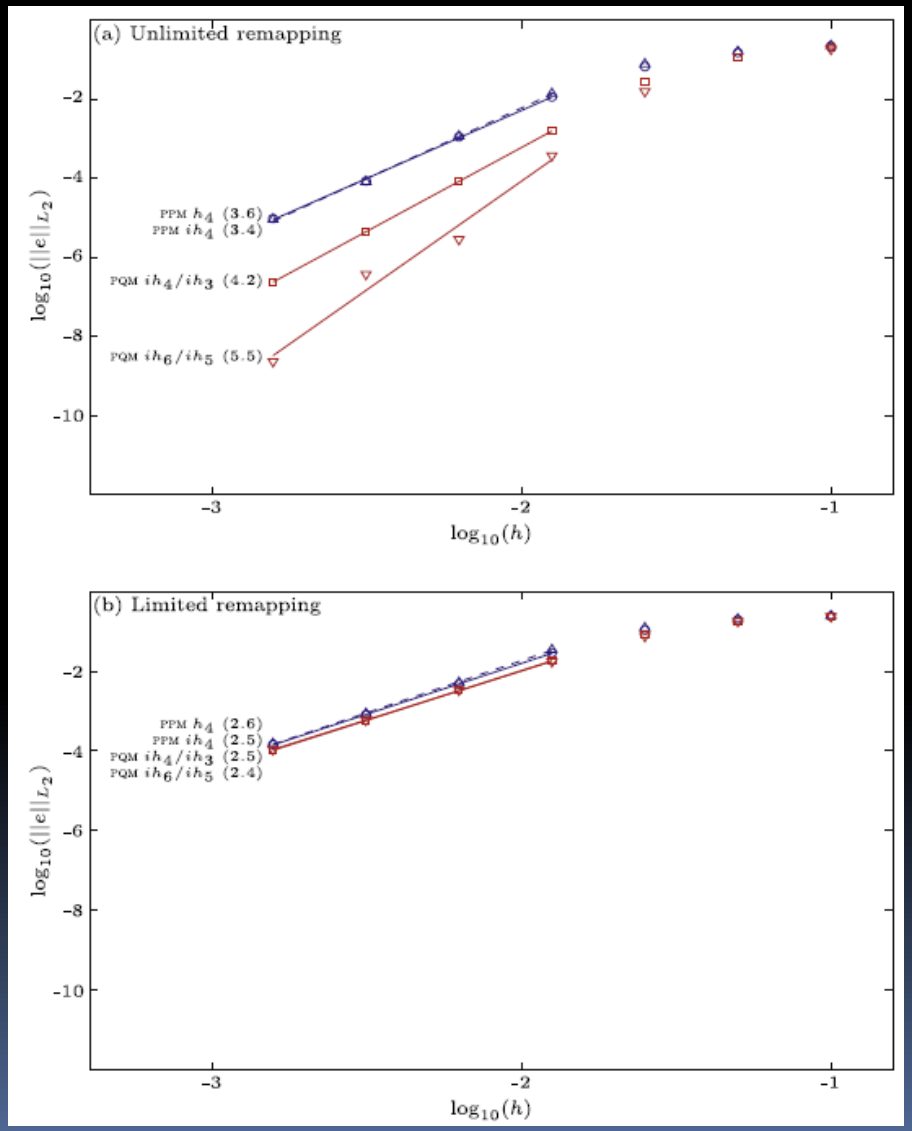
PQM: a non-standard test

- Remap between uniform and <u>random grids</u>
- Limiting <u>always</u> does damage to extrema

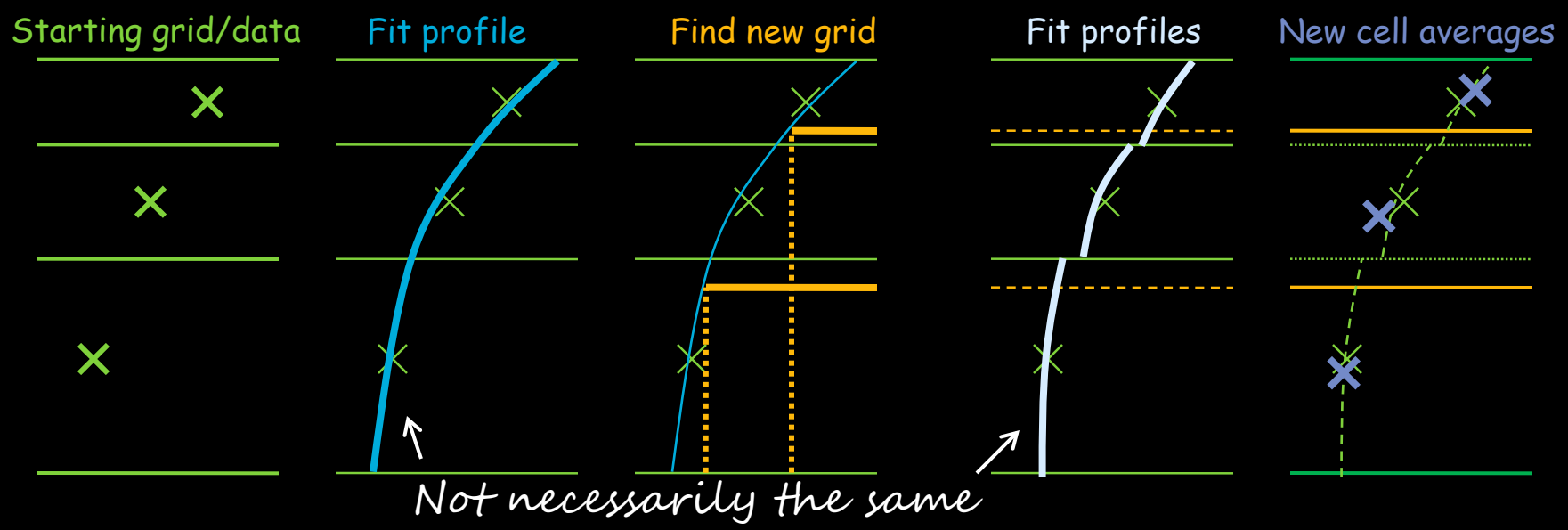


PQM: "limited performance"

- Limiting reduces formal accuracy
  - From $O(h^{5.5})$ to $O(h^{2.5})$
- Even though physically more "accurate"
- Limiters are important area of opportunity…



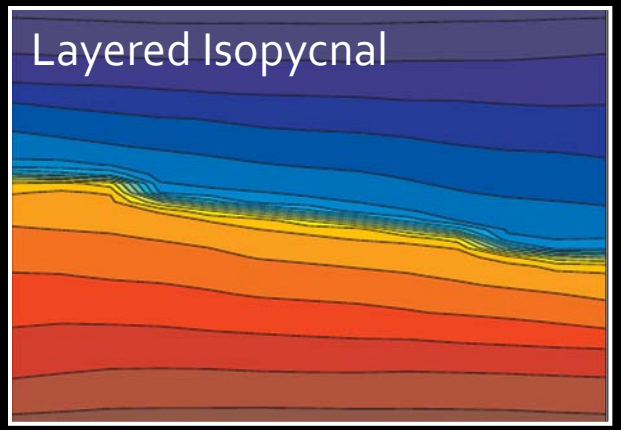
Re-gridding & re-mapping

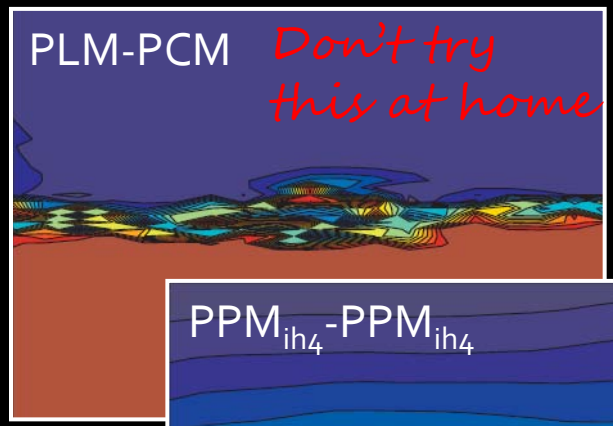


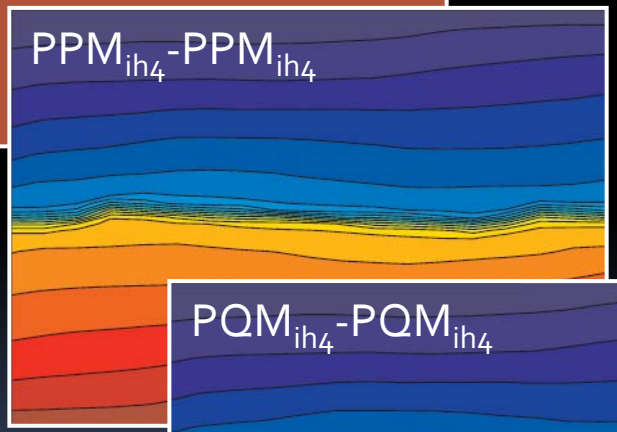
- Re-gridding
  - Re-construct **global** profile
    - Single valued (monotonic)
    - (continuous or not)
    - (conservative or not)
  - Find position of new grid
- Re-mapping
  - Re-construct **local** profiles
    - Conservative
    - Limited (monotonic)
    - Discontinuous (exclusive!)
  - Integrate to find new cell averages

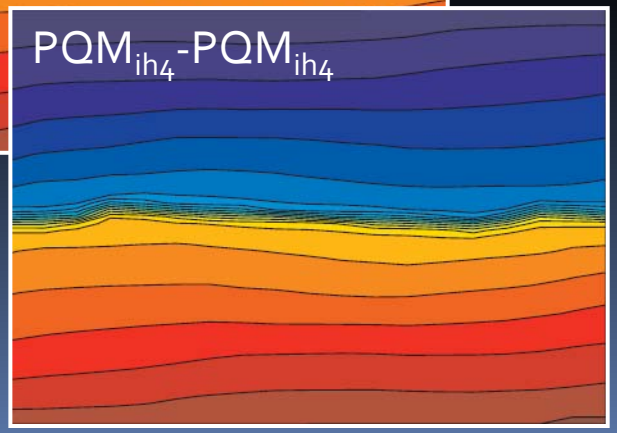
Sloshing test case

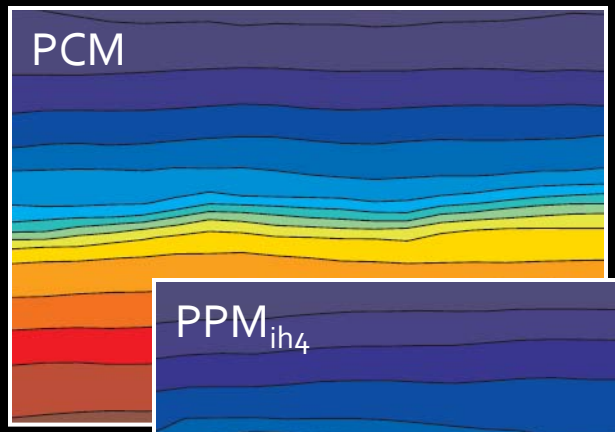
- Non-layered isopycnals <u>work</u>
  - Using PPM/PQM equally useful
  - PQM > PPM for z-coordinates

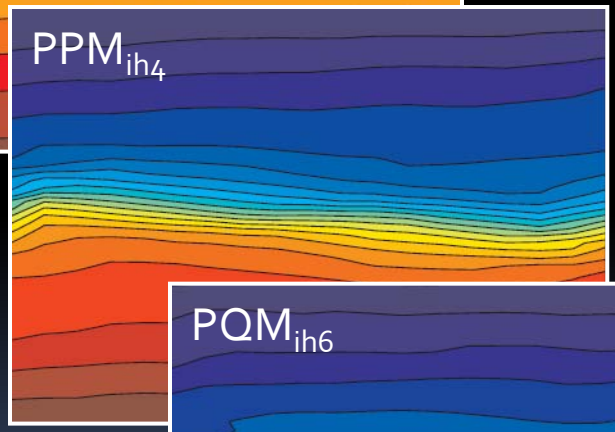


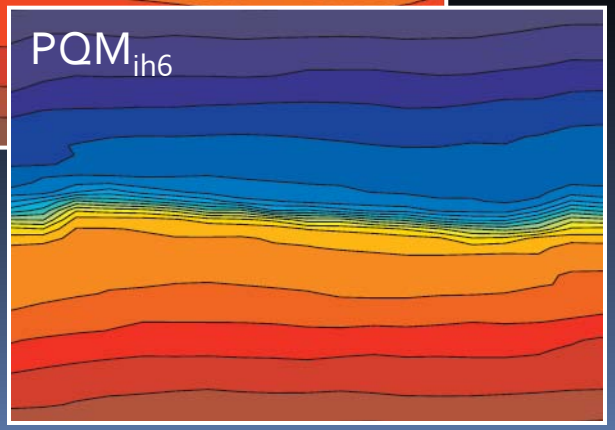










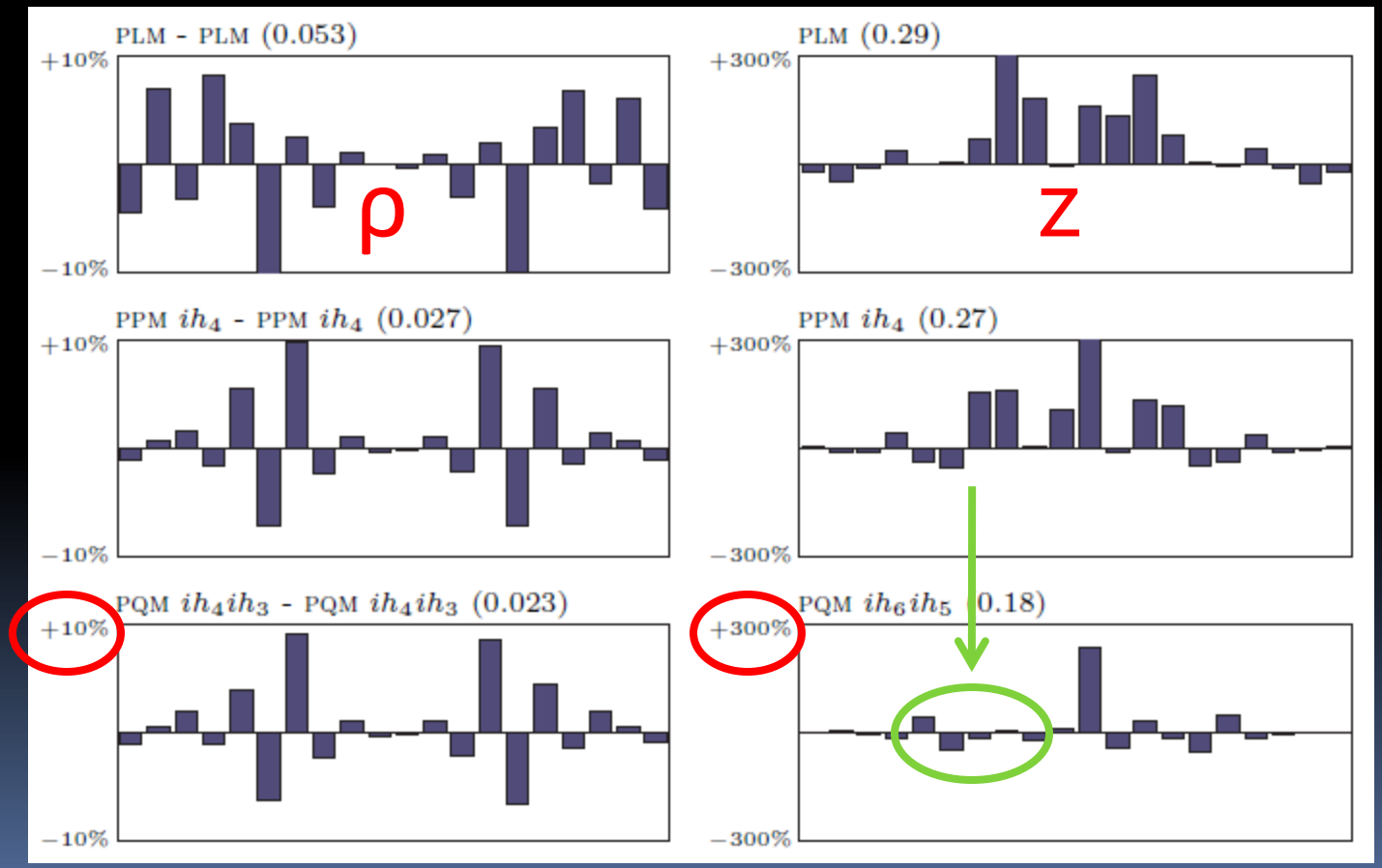


z

ρ

Sloshing test case

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



PLM

PPM

PQM

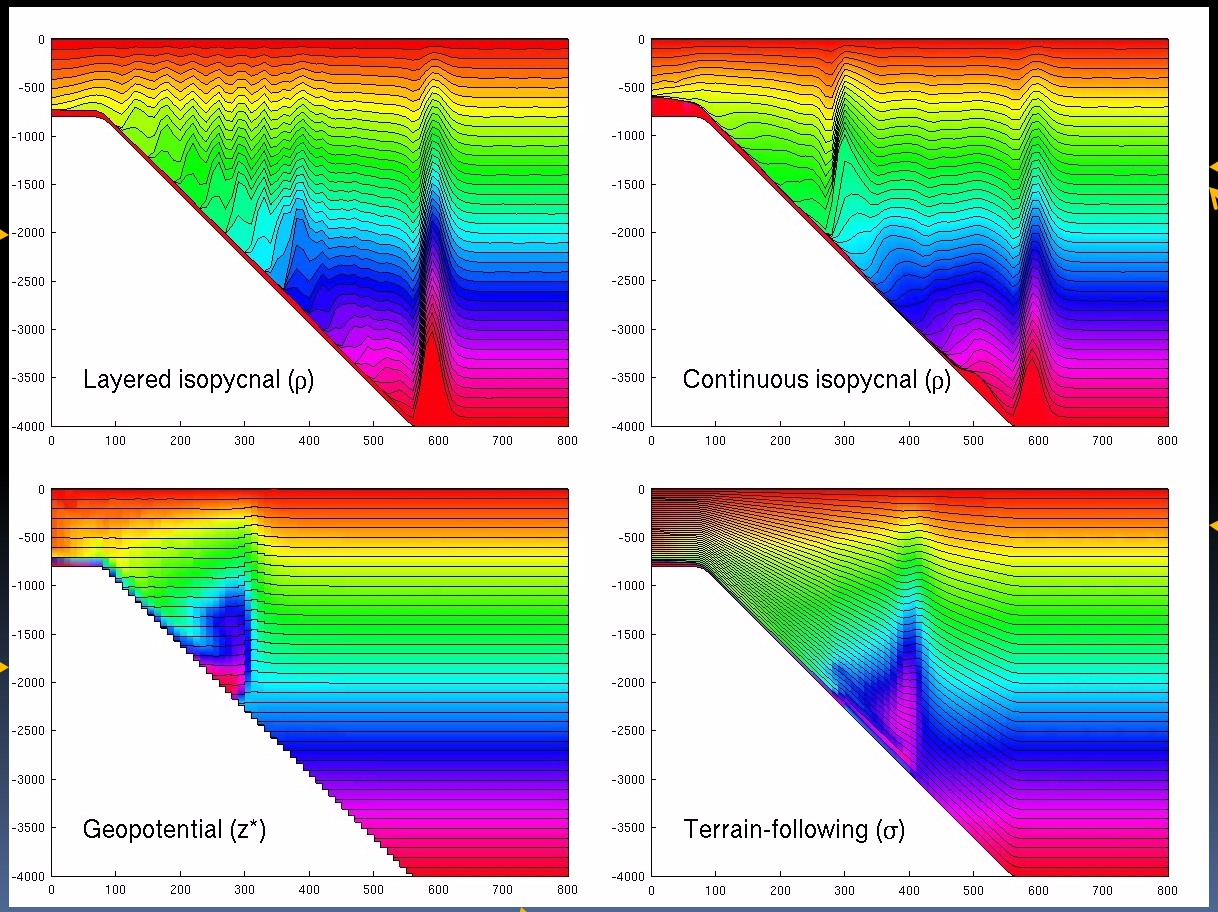
% volume change in each class

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" sol^n (adiabatic)

Better sol^n :-)



Z* and σ dillute buoyancy anomaly

Same numerics for non-layered models

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Final thoughts

- Continuous approach uses same method throughout water column
  - It works
  - Not tied to potential density
  - Consistency across model important
    - FV-PGF, initialization,…
- Spurious diffusion in thermocline has to be minimized
  - Continuous isopycnals seem to be good enough
  - PQM for z-coords *might* also be good enough
    - If not, then need to be even more accurate (P∞M?)
  - Either way,
    - PLM is too diffusive
    - PPM is likely too diffusive

← Need to quantify in context of global application (measure κ)

- Ready to explore new [hybrid] coordinates
- Bulk mixed layer v's KPP (and other "physics")