ACME
Accelerated Climate Modeling for Energy

The ocean surface boundary layer: its representation and importance in Earth System Models

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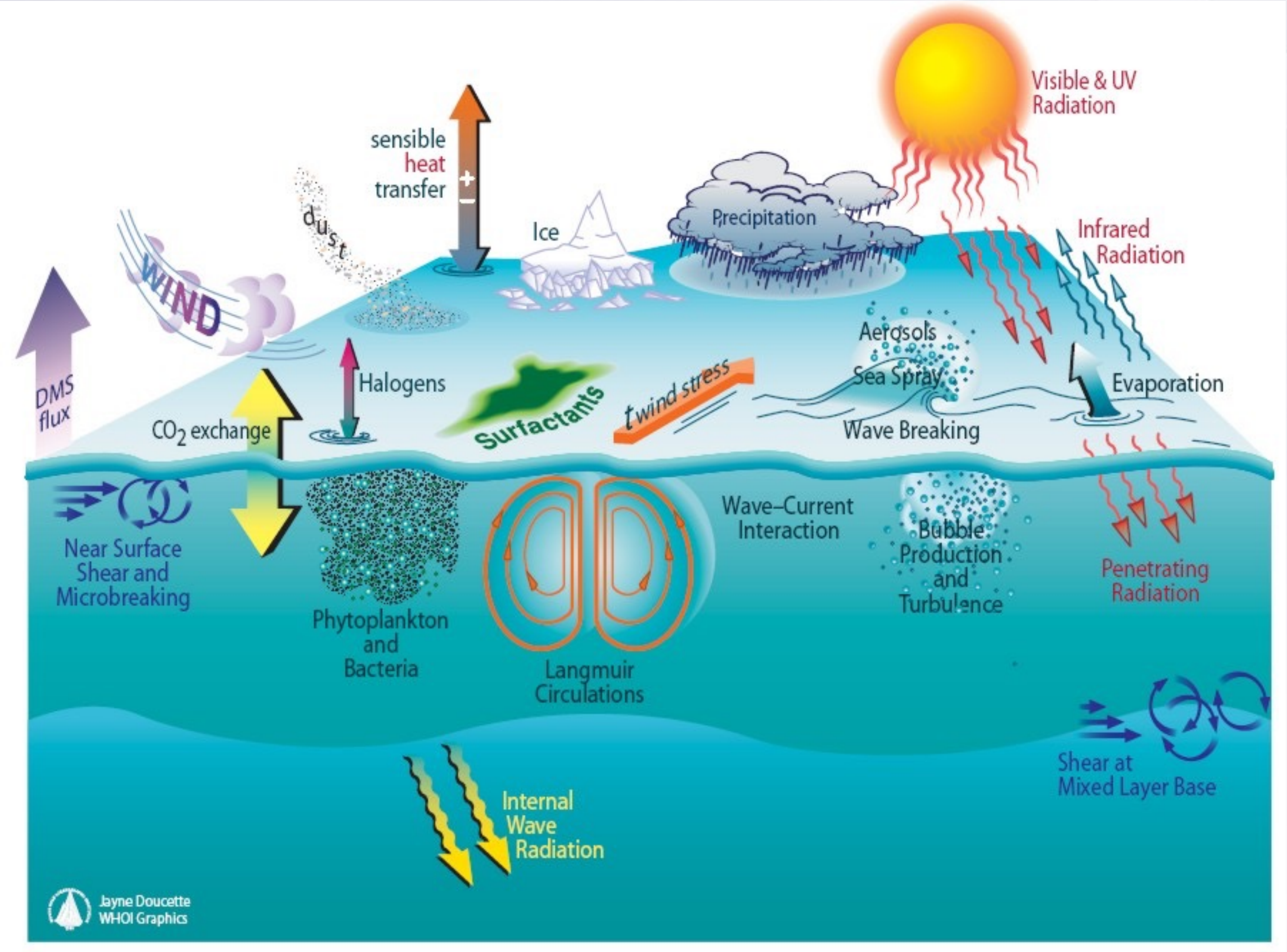
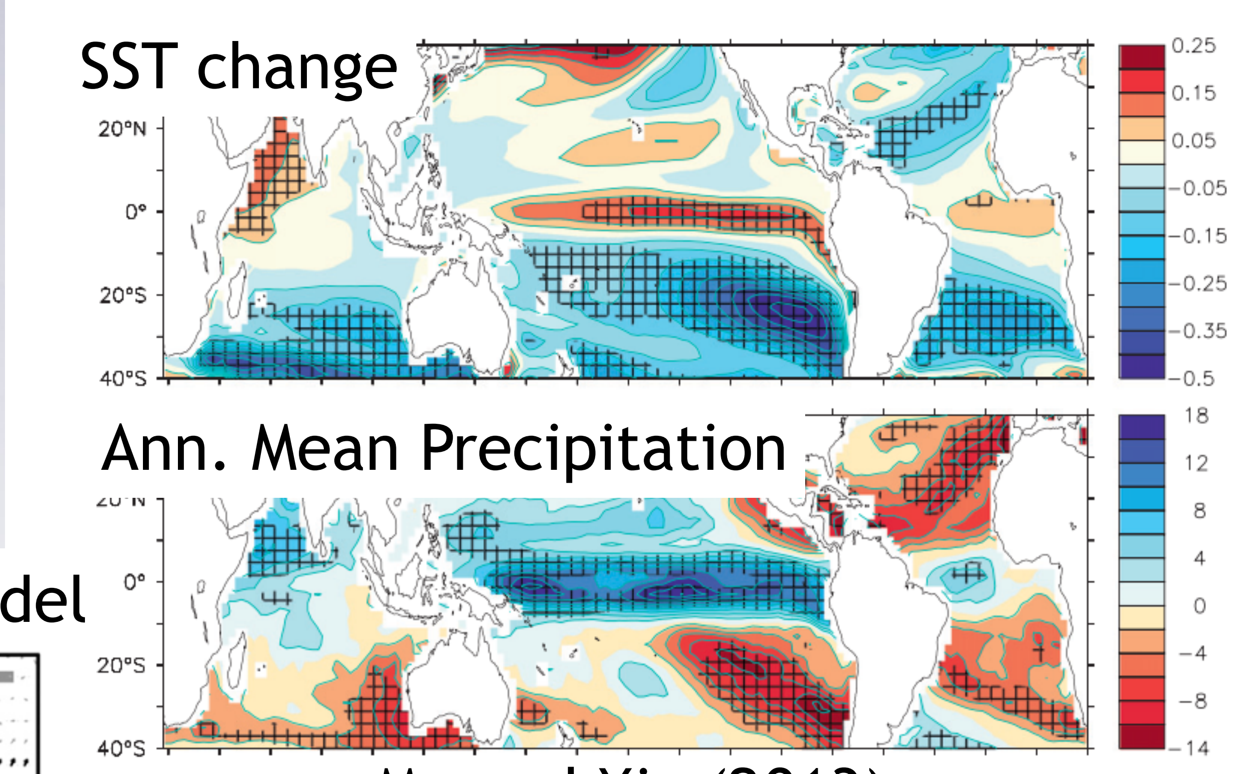
Ocean Surface Boundary Layer (OSBL)

- O(0.1 - 1 km) deep
- Mediates fluxes between atmosphere and deep ocean
- Many important physical properties
  - Most missing from ocean models

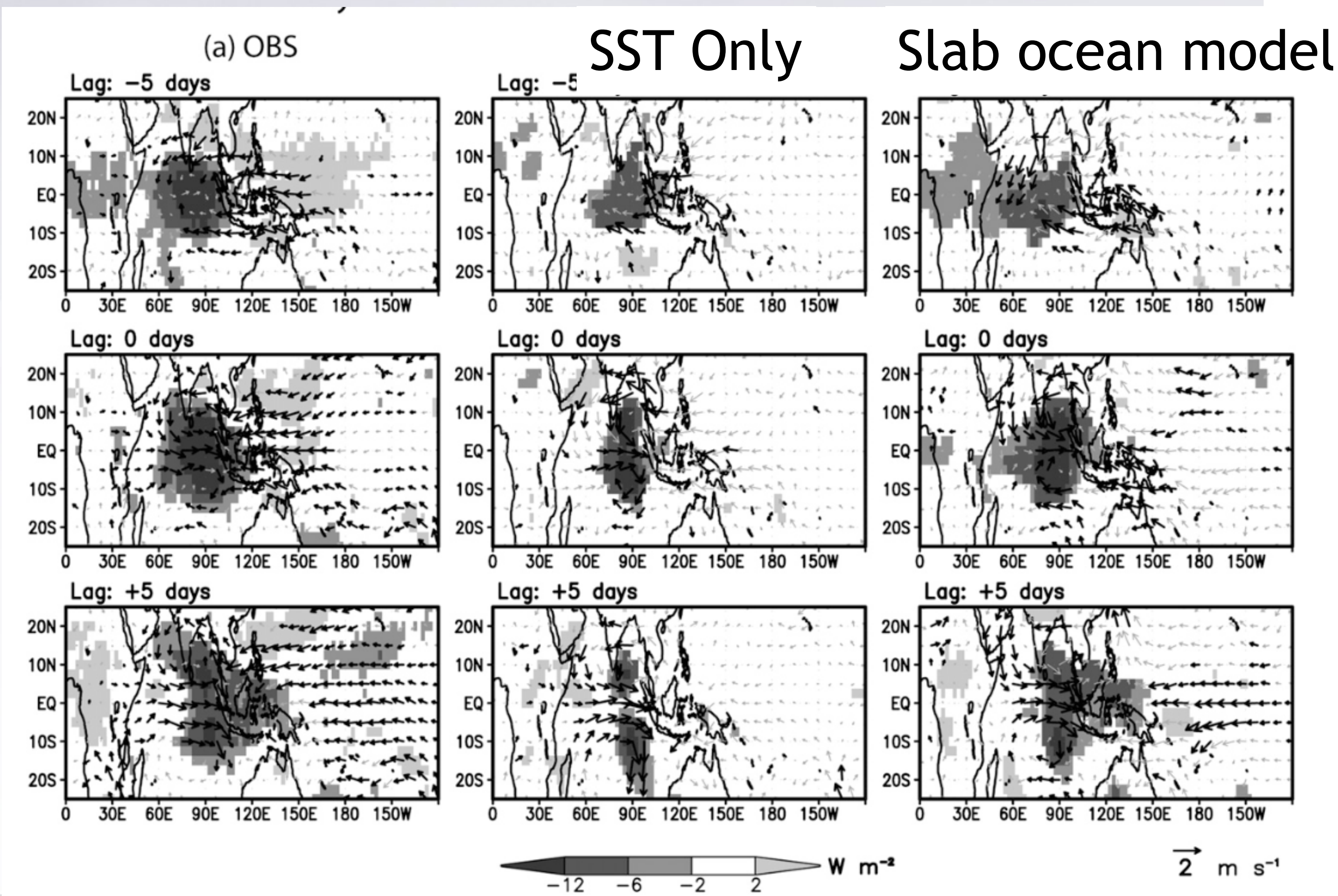


OSBL influences

- Regional precipitation dependent on sea surface temperature (SST)



Ma and Xie (2013)



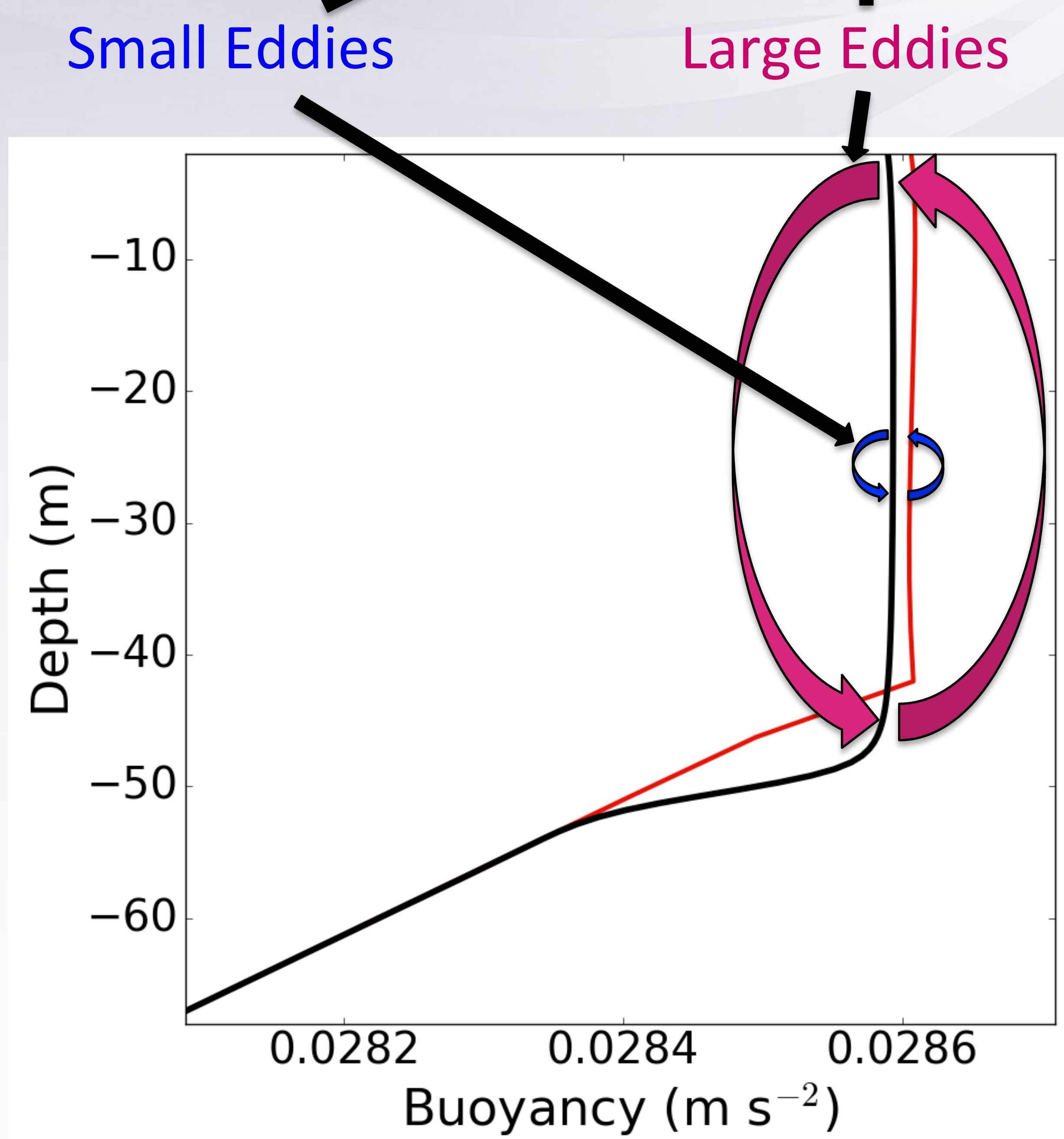
- Boundary layer depth (i.e., heat content) influences convective structure of the MJO

Benedict and Randall (2011)

OSBL models

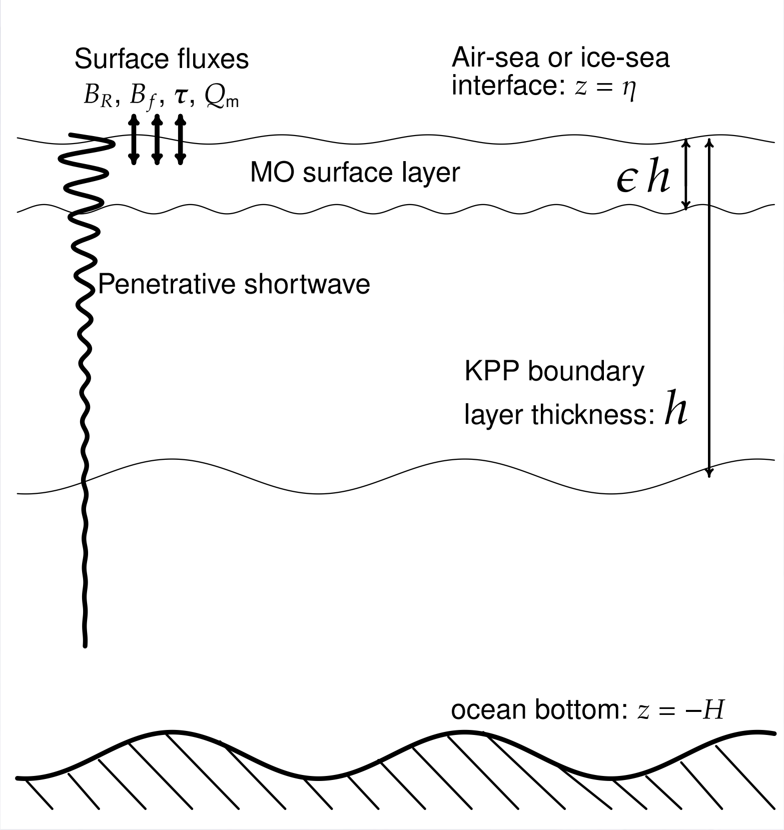
$$\overline{w'T'} \approx \underbrace{-\kappa \frac{\partial T}{\partial z}}_{\text{Local}} + \underbrace{\kappa \gamma_T}_{\text{Non-Local}}$$

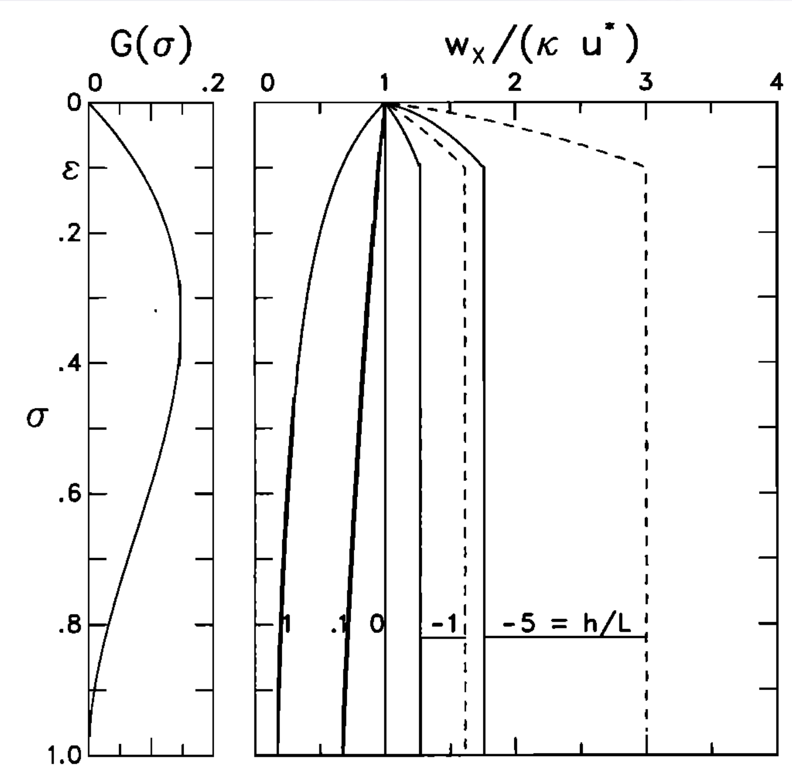
- Need to predict vertical turbulent fluxes (e.g., $\overline{w'T'}$)
- Could use turbulence closure (e.g. Mellor and Yamada 1982)
  - Computationally expensive
  - Missing physics (e.g., non-local)
- Integrated turbulence kinetic energy (Kraus and Turner 1967)
  - No OSBL vertical structure



K-Profile Parameterization

- Allows structure in the OSBL by assuming diffusivity follows a specified shape $(G(\sigma);\, \sigma \equiv -z/h)$
  - $G(\sigma)$ magnitude determined by
    - Surface fluxes
      - Deep ocean influence via diffusivity matching across OSBL
    - Boundary layer depth
- Non-local transport is a redistribution of any destabilizing surface flux
  - No non-local momentum transport.
- No prediction equations



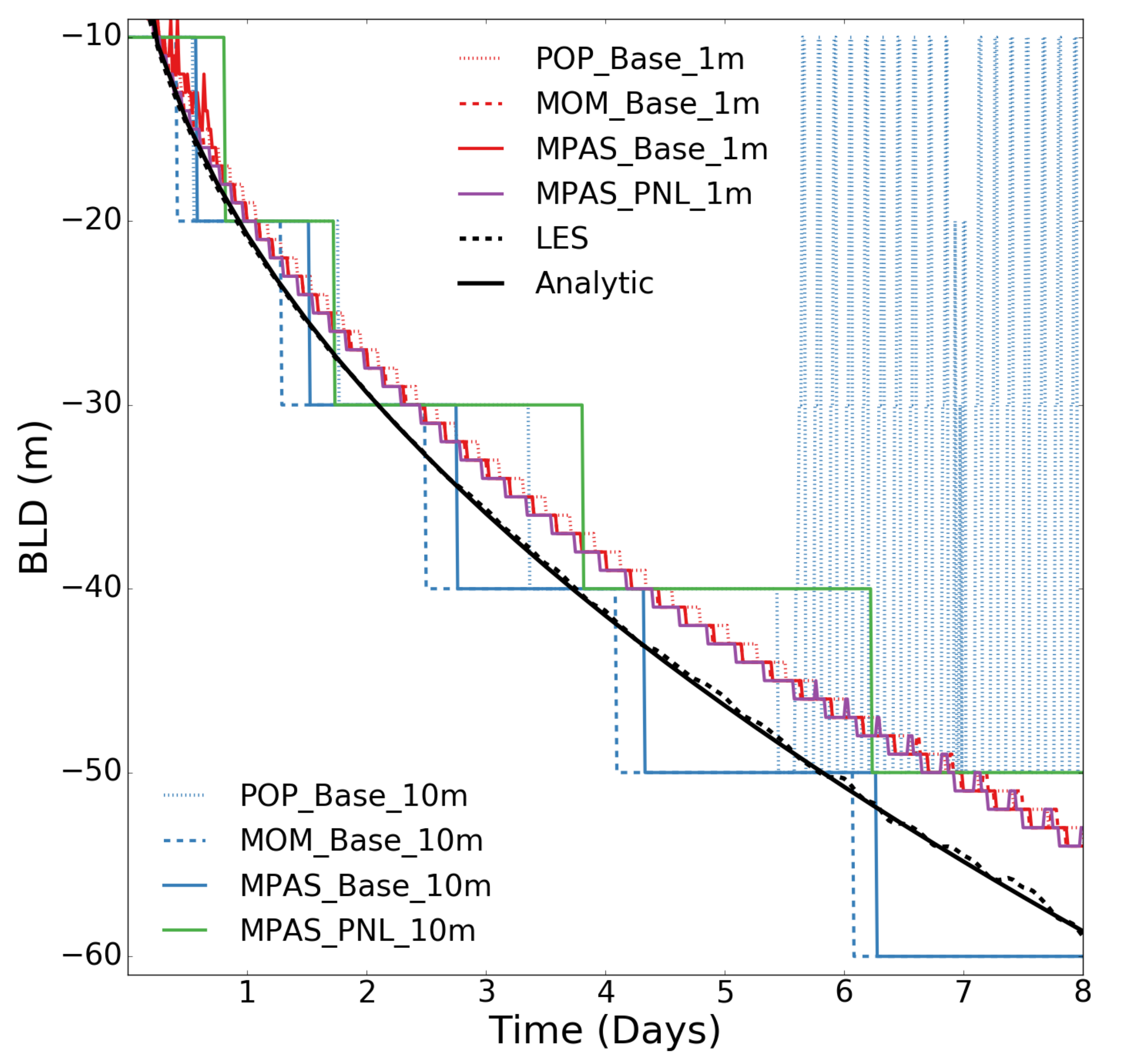


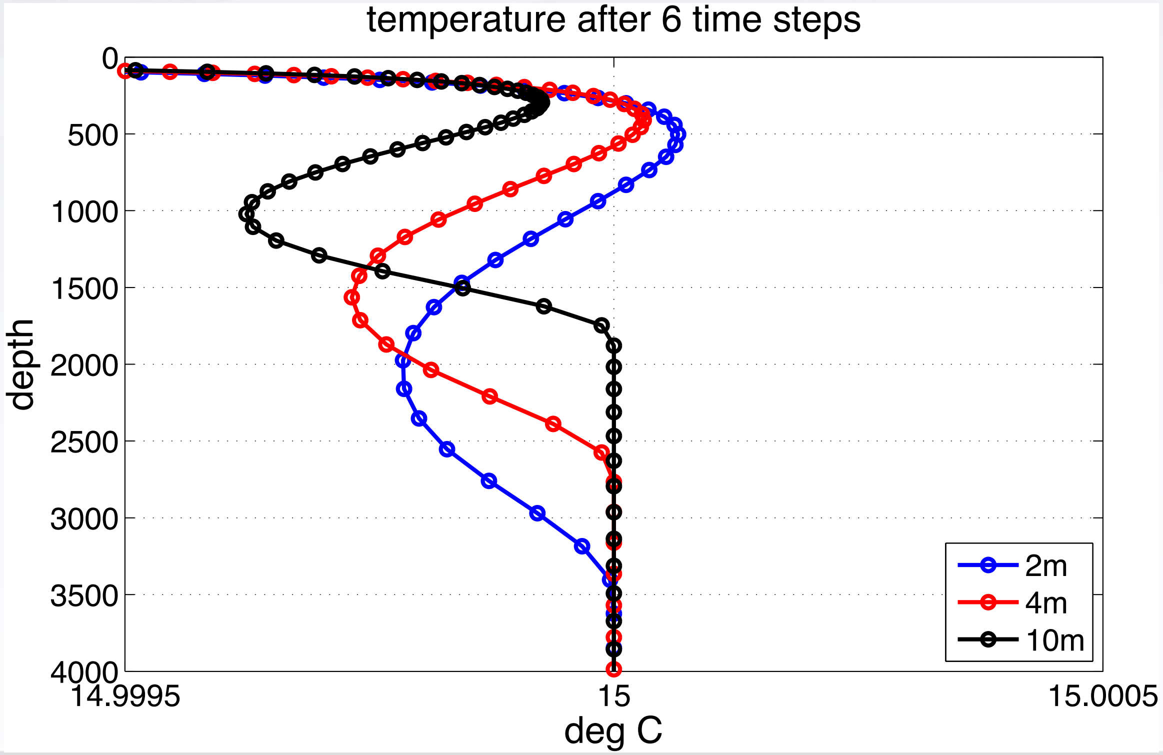
Testing

- Use large eddy simulation (LES) model as control
  - Can correctly minimize horizontal tendencies
  - Can ensure consistent forcing with KPP
- LES includes salinity and solar radiation.
- Experiments test a few key physical assumptions in KPP
  - Non-local transport
    - Is a cubic shape function appropriate?
    - Should shortwave radiation be included?
  - OSBL diffusivity matching to other mixing schemes
  - Not subject to energetic constraints

Cooling Test

- No internal mixing
  - Matching does not matter
  - Artificially enhanced diffusivity at OSBL base does!
- OSBL deepening is dependent on resolution

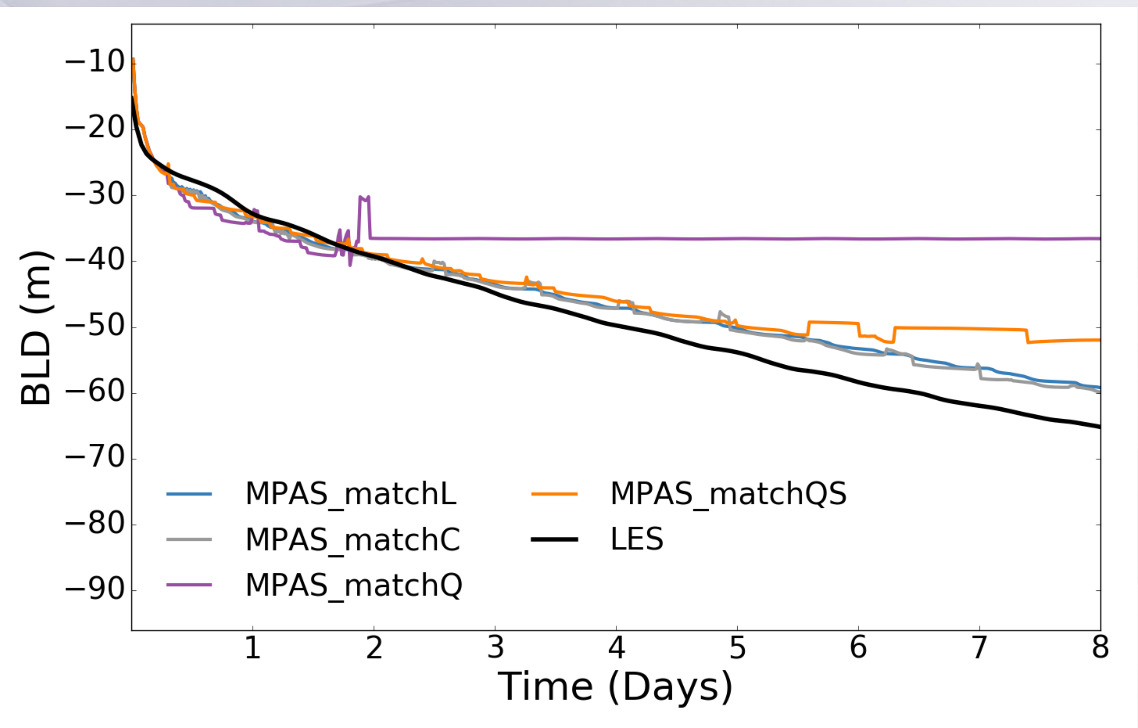


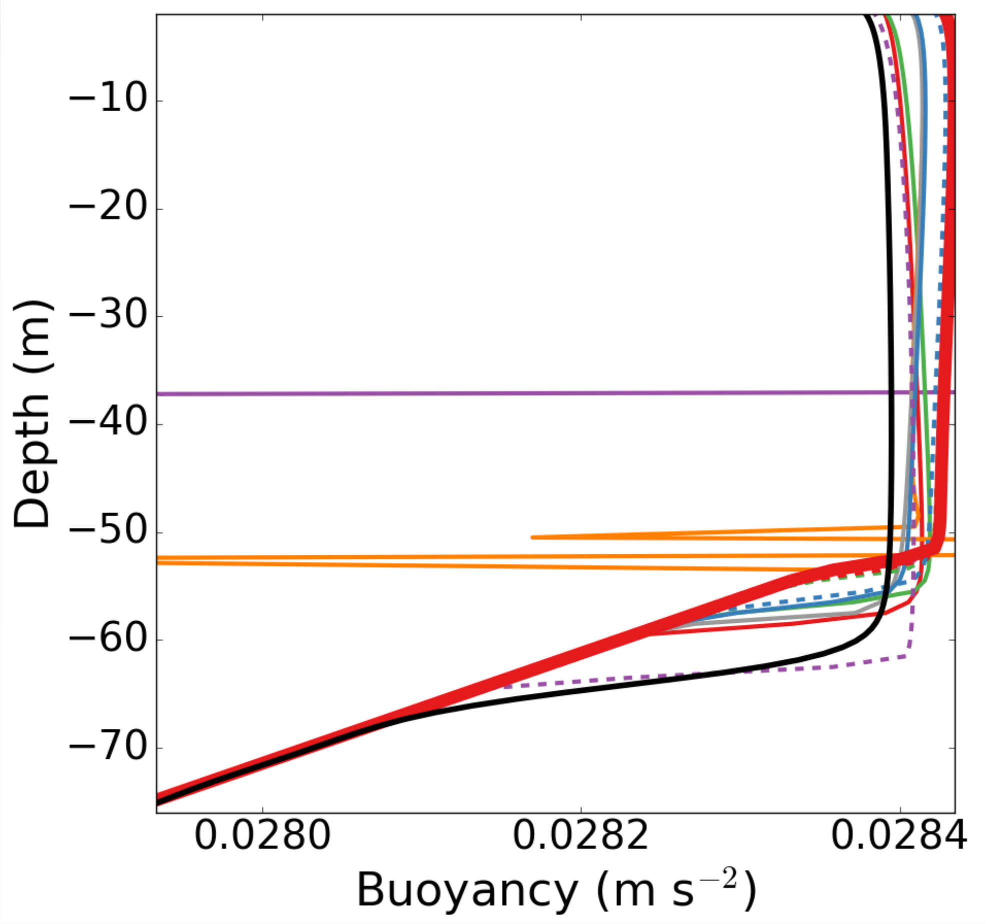


- Noise above is due to non-local shape function.
- With a halocline and uniform T(z), KPP non-local flux produces warming in the presence of cooling

Cooling with Wind

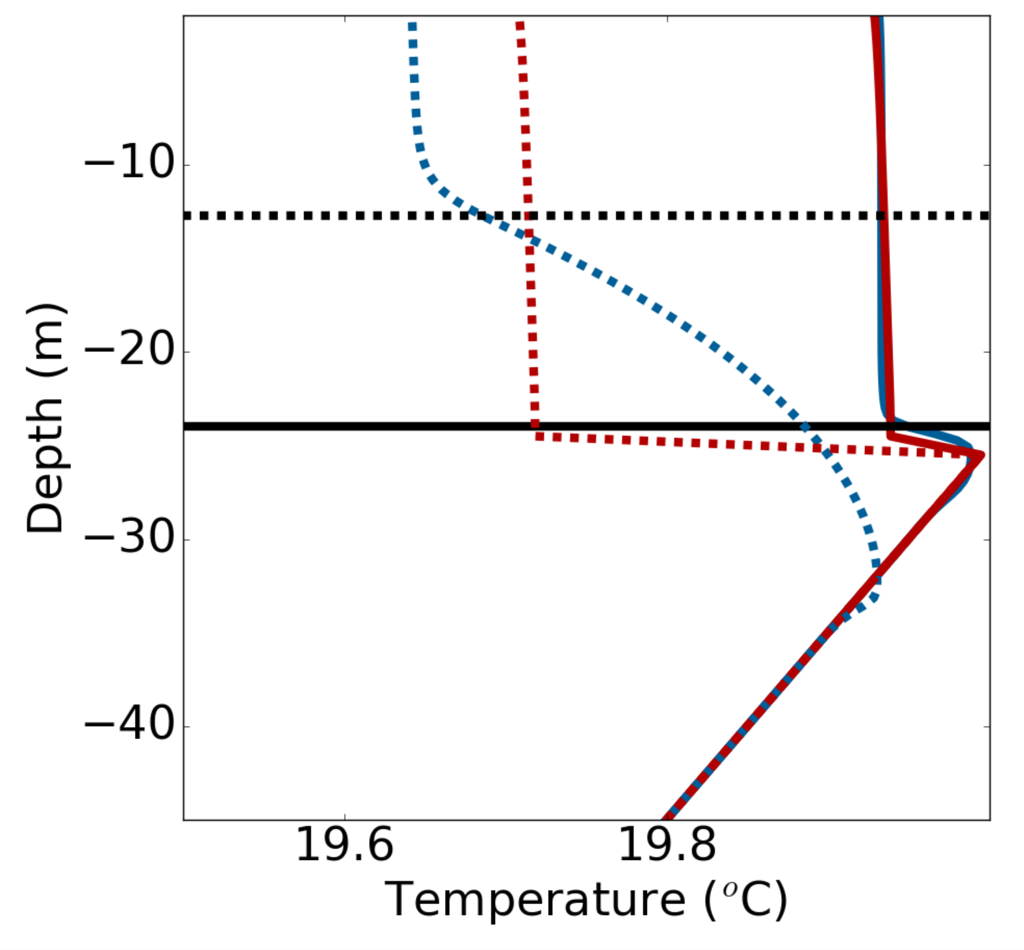
- Large internal diffusivity gradients across OSBL base cause serious issues.
  - Large OSBL biases
  - Negative diffusivities.
- Using diffusive interpolation (linear) weakens internal gradient
- Smoothing internal diffusivities does not solve all issues





Summary

- Changes in ACME v1
  - Diffusivity matching abandoned
  - Diffusivity from internal schemes extended into the OSBL
- Remaining issues:
  - Entrainment (OSBL deepening) dependent on vertical resolution
  - Non-local term in KPP can cause many issues.
    - Negative BGC concentrations
    - Biases are very large near river outflow



The path forward

- Fixing KPP
  - Shape function issues
    - "Best" shape function for non-local transport changes with forcing
  - OSBL structure depends on assumed internal mixing
  - Not subject to energetic constraints
- Abandon KPP
  - Based on assumed distributions (ADHOC, CLUBB)
  - More details at poster