Ocean climate process teams: successes and lessons learned

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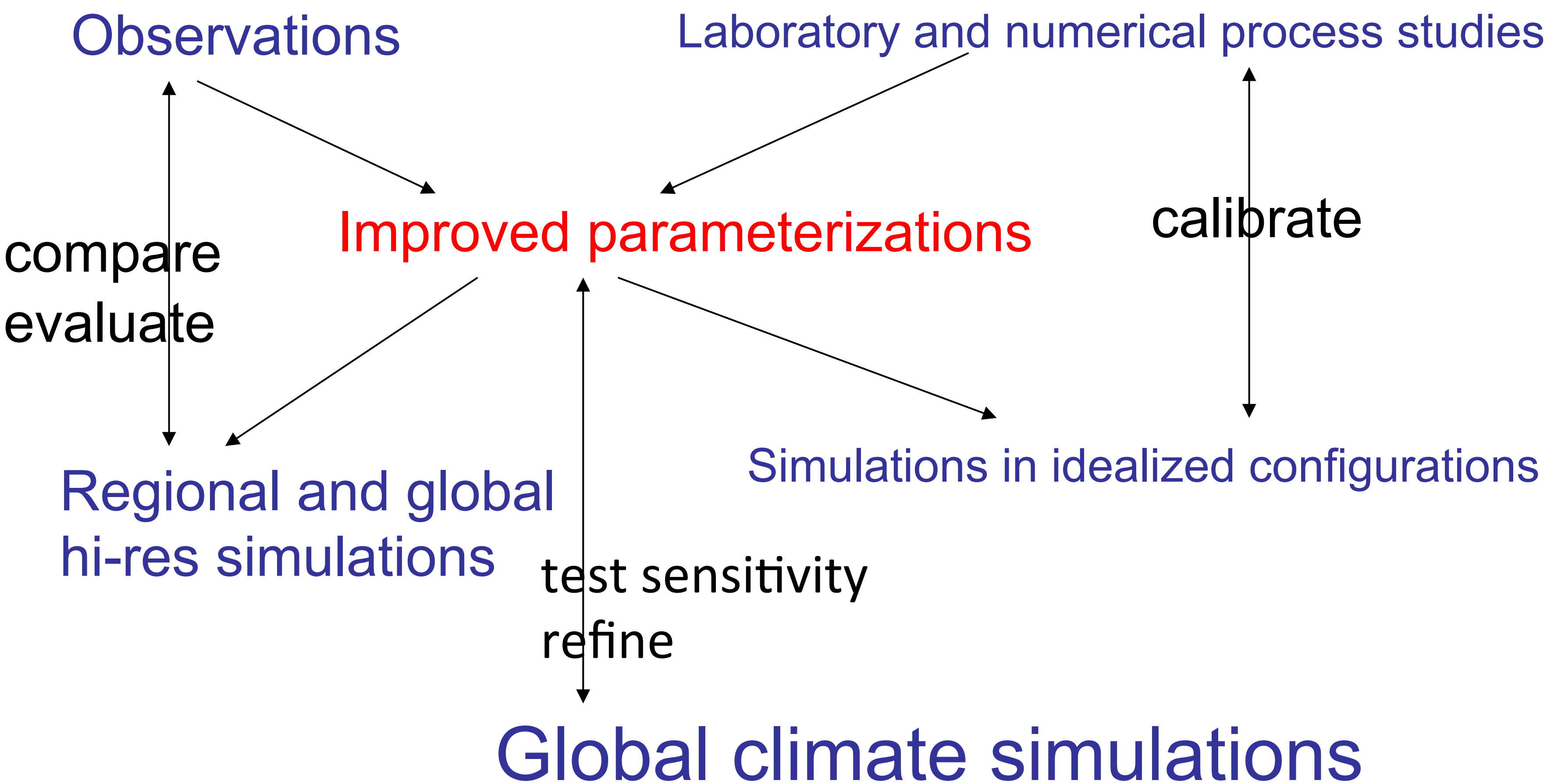
How do we improve process representation in ocean climate models?

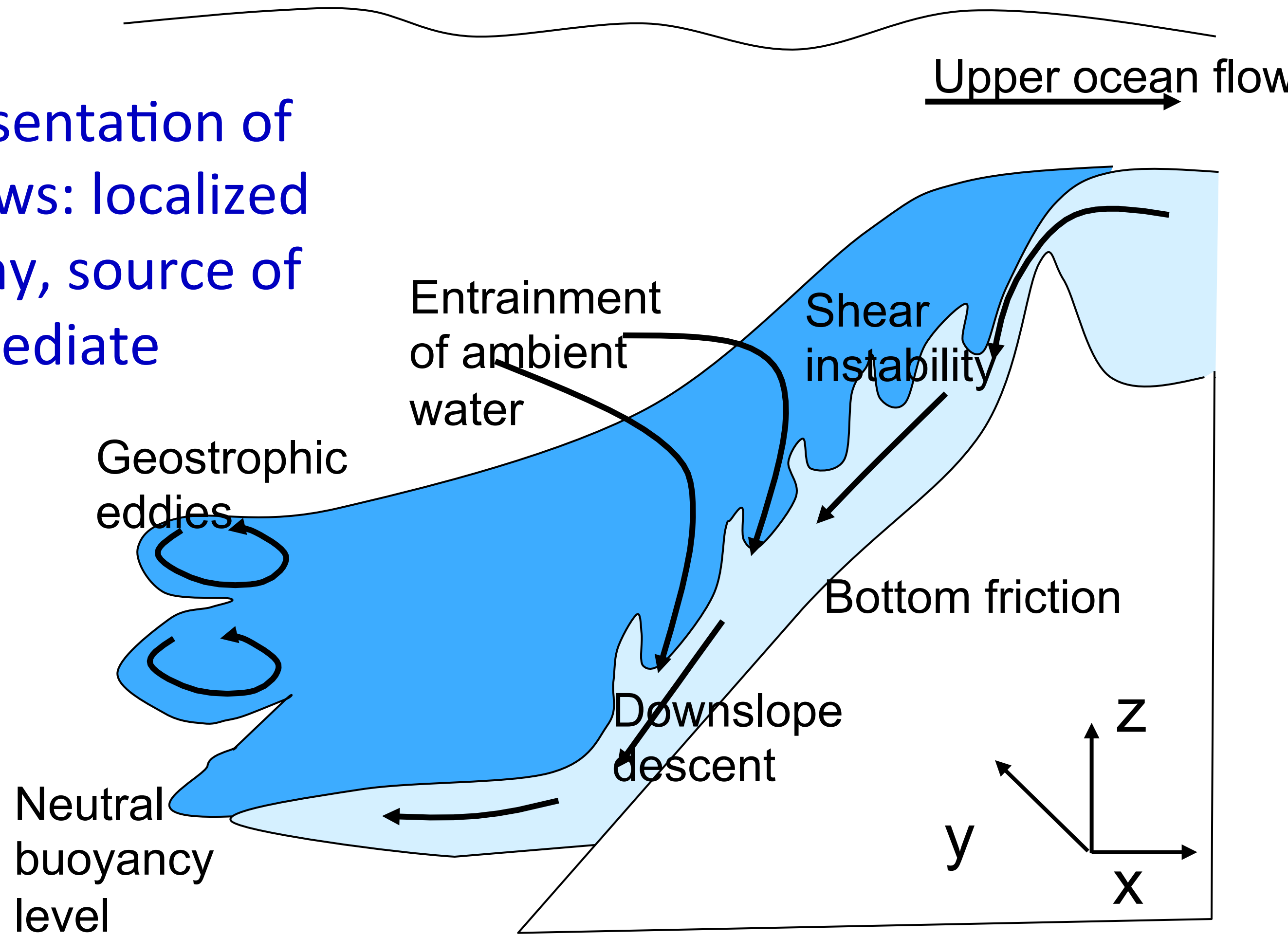
Climate process teams: multi-institutional collaborations between PIs involved in observational and numerical process studies and building and running climate models.



The Gravity Current Entrainment Climate Process Team

Goals: Improve representation of dense oceanic overflows: localized flows down topography, source of most deep and intermediate water.

Key issues: Too much or too little mixing; under-resolved topographic gaps

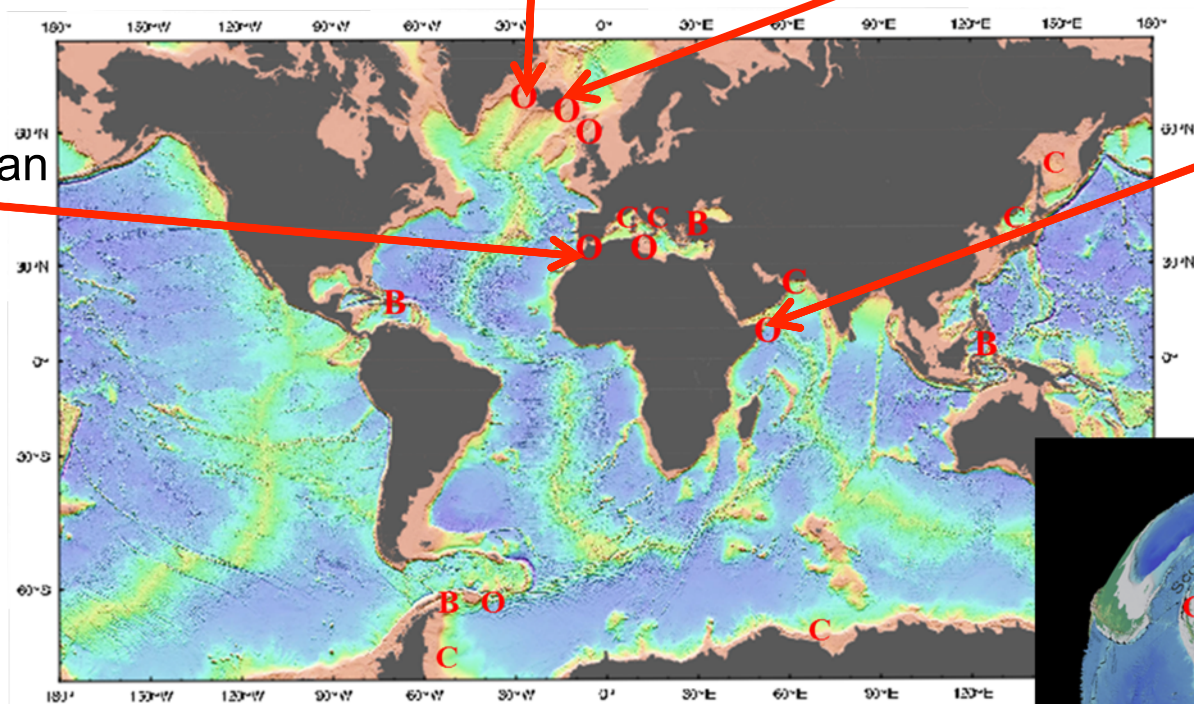


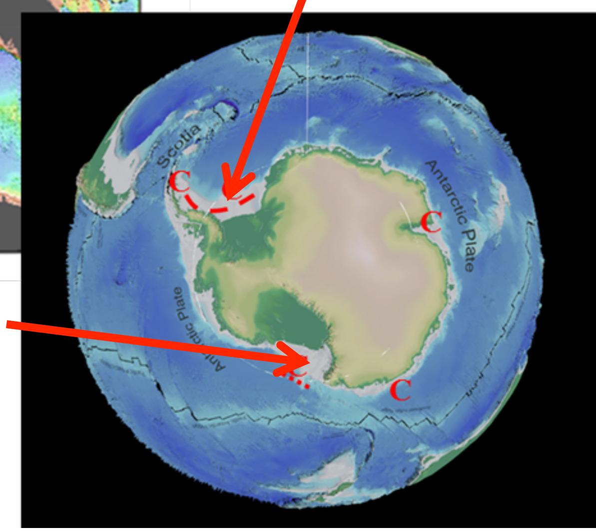
A US CLIVAR project funded by NSF and NOAA, 2003-2008.

3 postdocs at GFDL, WHOI, Miami; 1 NCAR staff scientist
Annual workshops

Gravity current entrainment CPT products

i. Synthesis of observations

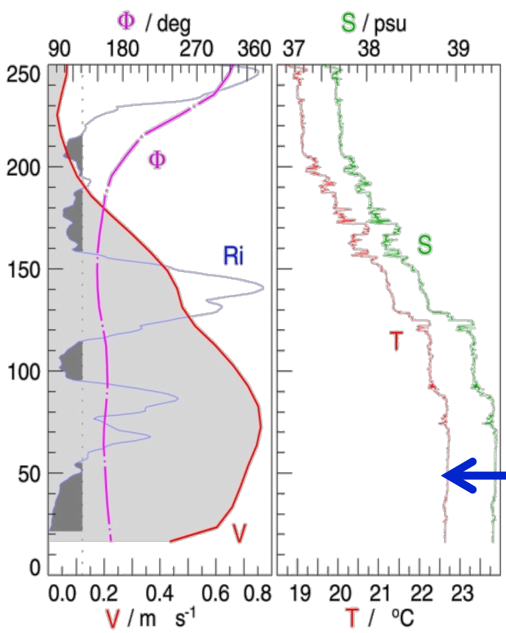




"Table of observations" : easy-to-reference parameters of major overflows.
(Legg et al, 2009, BAMS)

Gravity current entrainment CPT products
ii. New mixing parameterizations

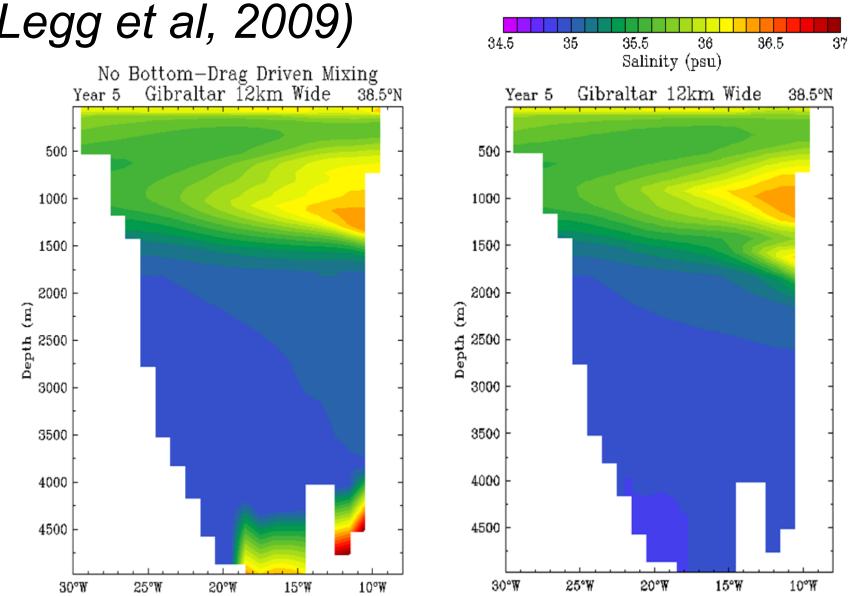
- Shear-driven mixing: *Xu et al, 2006* (HyCOM), *Jackson et al, 2008* (GOLD, MOM6)
- Bottom boundary mixing: *Legg et al, 2006* (GOLD, MOM6)
  Combines insights from observations and process simulations to improve parameterization of near boundary mixing.



Red Sea Overflow observations *(Peters et al, 2005)*

Well-mixed Bottom Boundary Layer Mixing driven by bottom stresses

GOLD simulations of Med outflow salinity *(Legg et al, 2009)*



Without bbl mixing

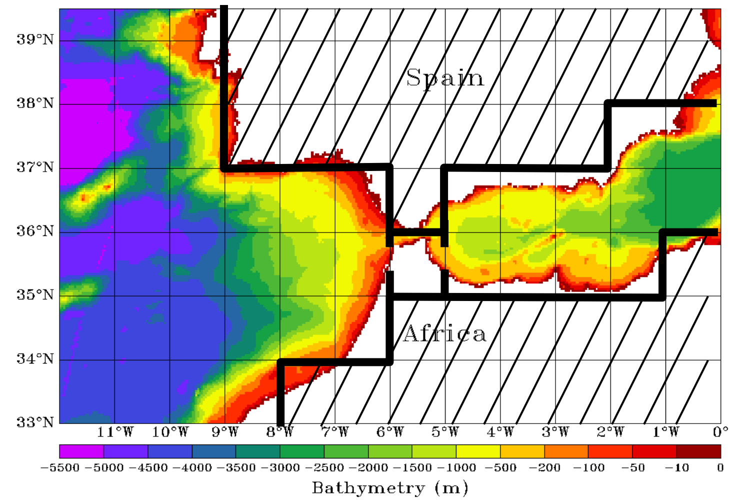
With new bbl mixing parameterization

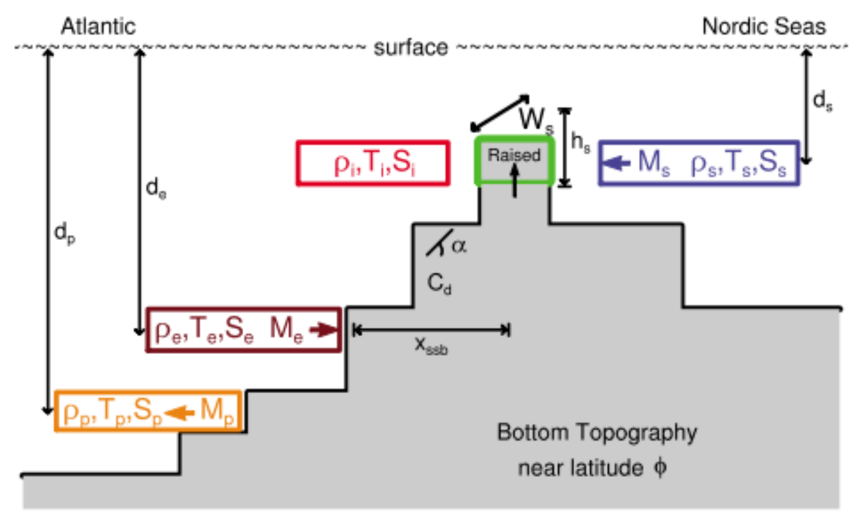
Gravity current entrainment CPT products
iii. New representations of flow through narrow straits

- Partially open barriers for sub-grid-scale straits *(Legg et al 2009, Adcroft 2014)*

- Marginal Sea Boundary Condition: (Price and Yang 1998) adapted for CCSM *Danabasoglu et al 2010*
- Includes parameters from Table of Observations
- Reduces spurious mixing in z-coordinate models

- MSBC implemented in HYCOM *(Bozec et al, 2011)*



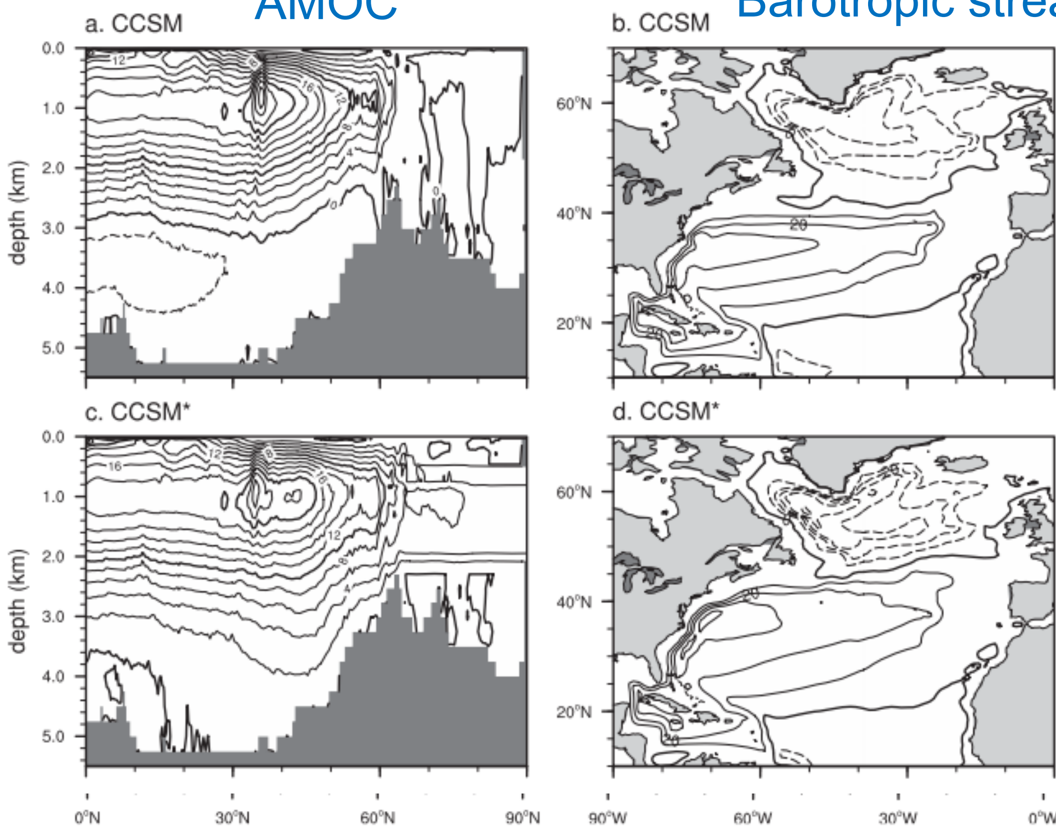


Legacies and impacts of GCE-CPT

- CCSM and ESM2G IPCC AR5 models and MOM6 include new CPT parameterizations
- New parameterizations impact AMOC, AABW, surface Atlantic climate

AMOC

Barotropic streamfn



Without overflow parameterization

With overflow parameterization

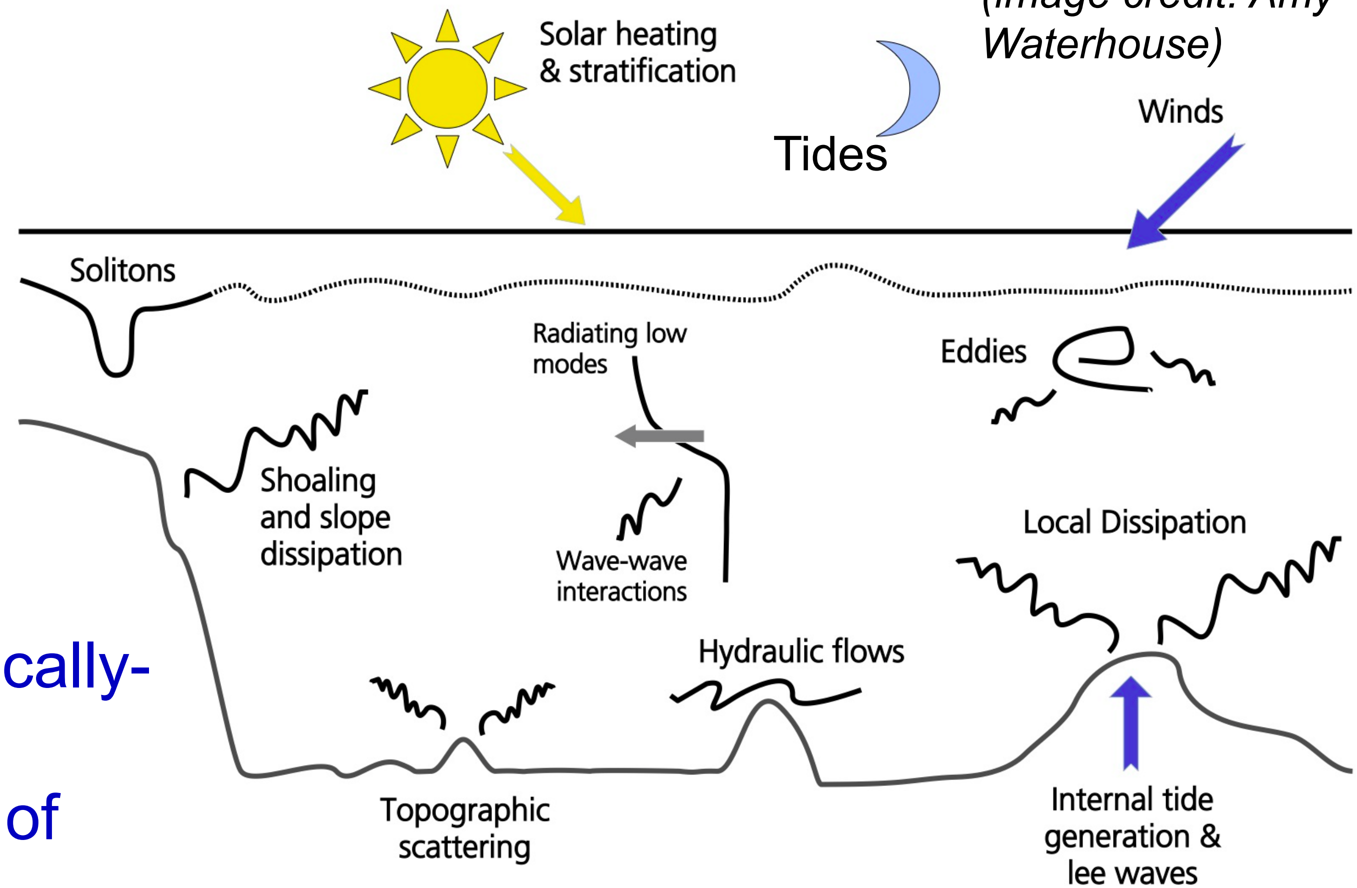
Yeager and Danabasoglu, 2012

The Internal-wave driven mixing CPT

Lead PI: Jen MacKinnon
20 PIs
4 postdocs at WHOI, GFDL, UMich, and UCSD-SIO.
Annual workshops.

Goal: an energetically-consistent parameterization of spatially- and temporally-varying diapycnal mixing due to internal waves.

(image credit: Amy Waterhouse)

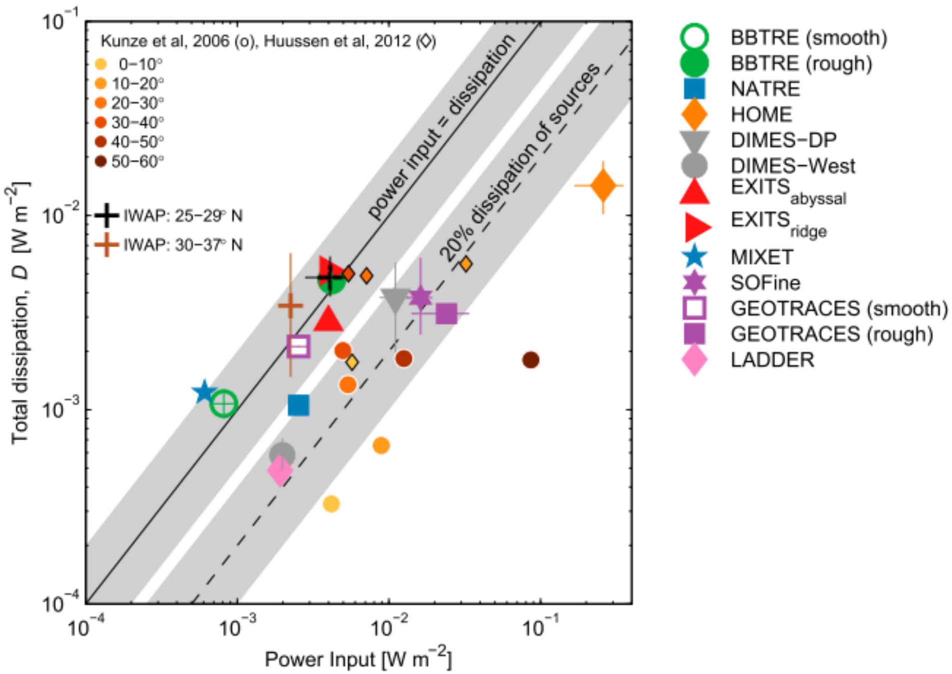


Pre-existing parameterization template
(St Laurent et al 2002)

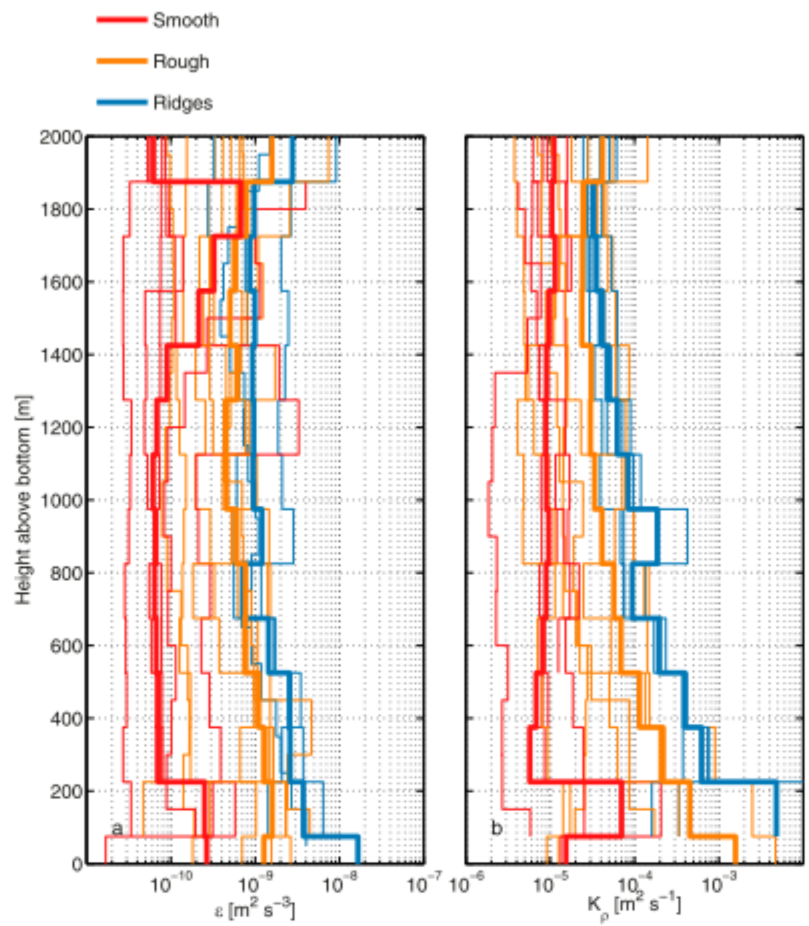
$$\kappa = \Gamma E(x,y) q F(z) / \rho N^2$$

Iwave mixing CPT products
i. Synthesis of observations

Waterhouse et al, 2014



Local dissipation is 20-100% of local energy input (tides/winds)

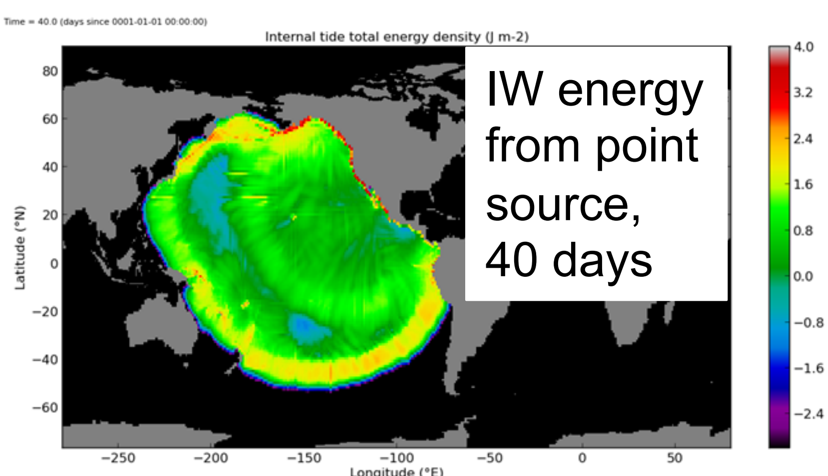


Vertical profile of dissipation depends on bottom topography

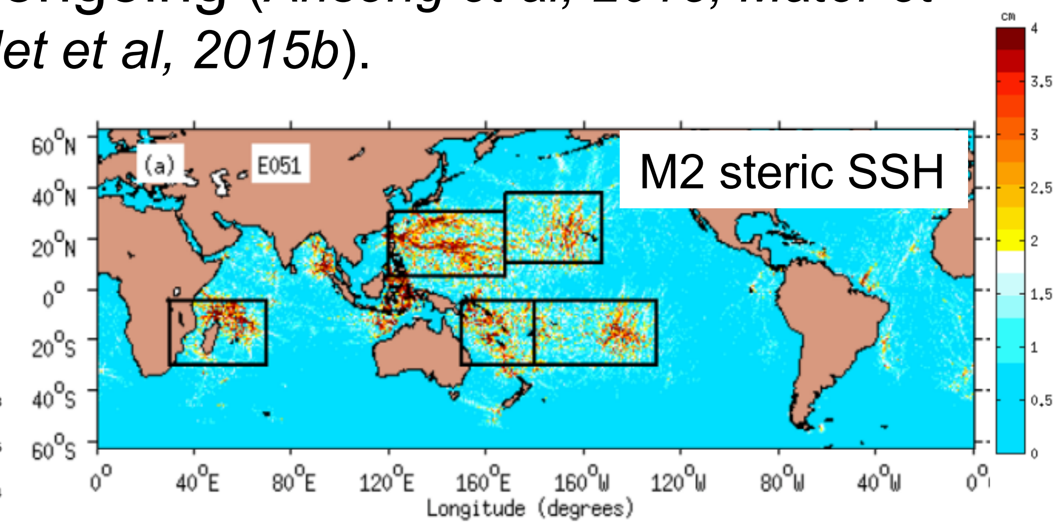
Observations provide constraints on GCM parameterizations

Iwave mixing CPT products
ii. New parameterizations

- Near-inertial wave-driven mixing in thermocline (CCSM: *Jochum et al, 2013*)
- New vertical profile for local internal tide dissipation (MOM6: *Melet et al, 2013*; and CCSM)
- Lee-wave-driven mixing (MOM6: *Melet et al, 2014,2015a*)
- Estimates of local fraction of dissipation, wave propagation and far-field dissipation: ongoing (*Ansong et al, 2015; Mater et al, 2015; Sun et al, 2015, Melet et al, 2015b*).



Ray-tracing model predicts Iwave propagation *(Ben Mater, in prep)*



Global internal tide models help constrain location of farfield iwave dissipation *(Ansong et al, 2015)*

Thoughts for discussion

- Ocean CPTs have led to improved representation of physical processes in multiple IPCC-class climate models which would not have happened without involvement of process study scientists.
- Synthesis of existing observations is a vital component to guide parameterization development; results motivate follow-on observations (e.g. Samoan Passage, Ttide)
- End results cannot always be foreseen at proposal-writing time.
- “Shovel-ready” parameterizations lead to early progress.
- 5 year timeline: 3 years to demonstrate potential, 2 years to work out details
  - too short to bring ideas to fruition, including testing in climate models?
  - too long to keep everyone fully engaged?
- How to maintain engagement between annual workshops?