Representing internal-wave driven mixing in global ocean models

A US CLIVAR Climate Process Team

k: use what we collectively know about internal wave physics
a dynamic parameterization of diapycnal mixing that captures
s and can evolve in a changing climate.

PIs

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rbic (U Michigan)

k Bryan (NCAR)

hassignet (FSU)

anabasoglu (NCAR)

er Gent (NCAR)

Griffies (GFDL)

Hallberg (GFDL)

e Jayne (WHOI)

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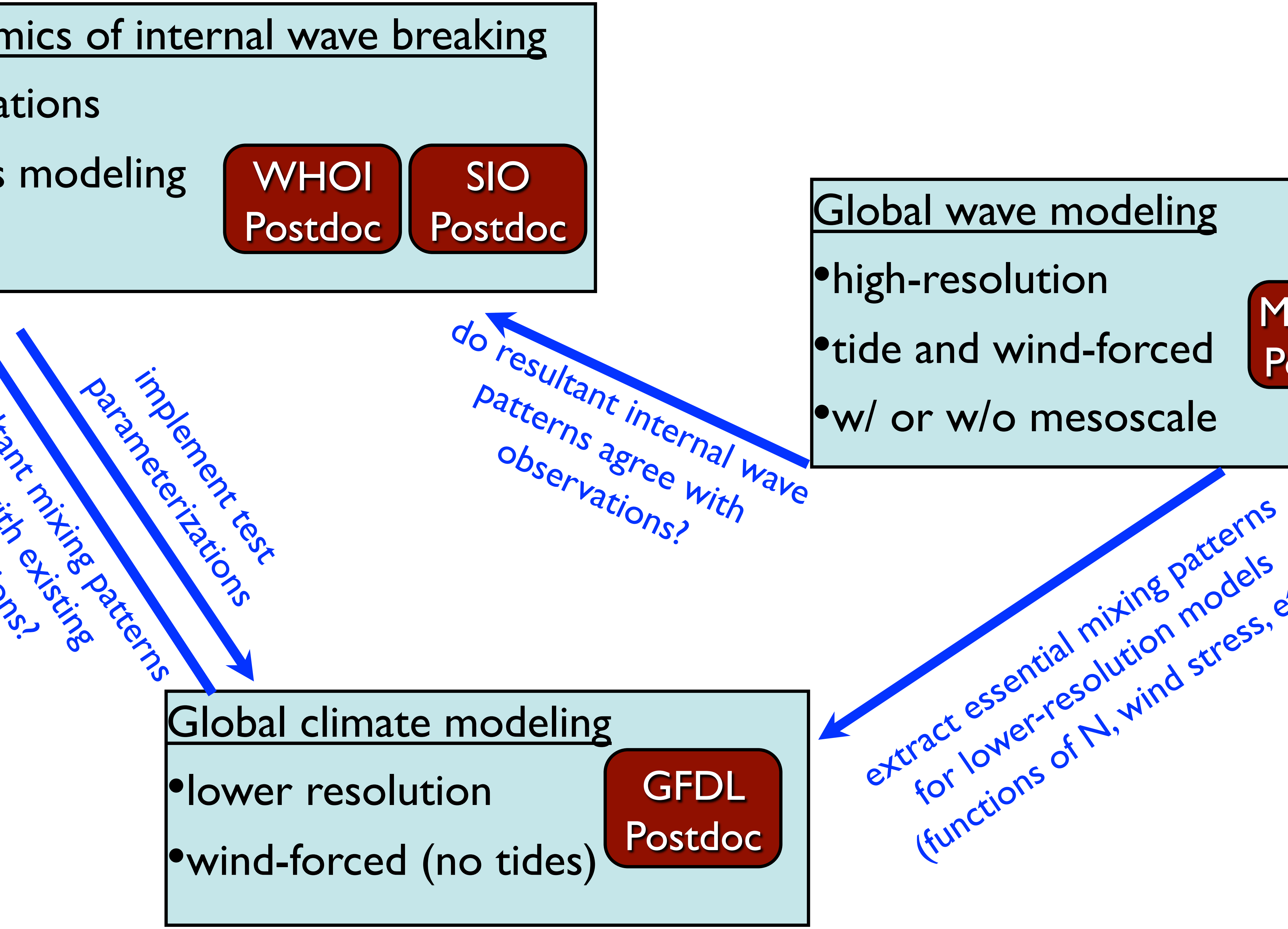
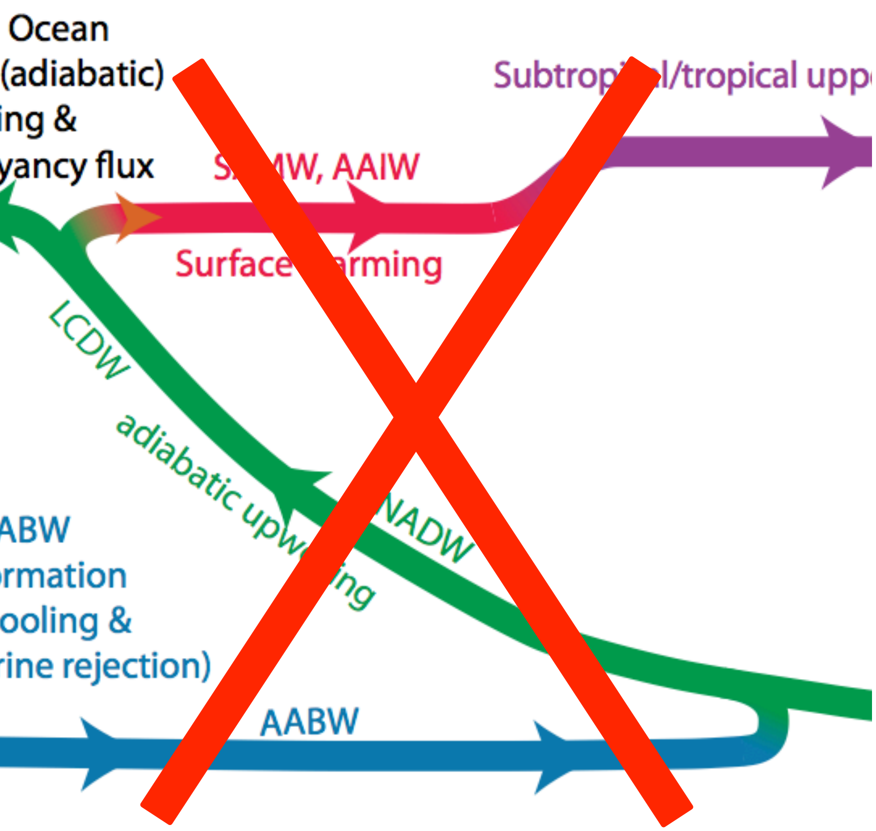
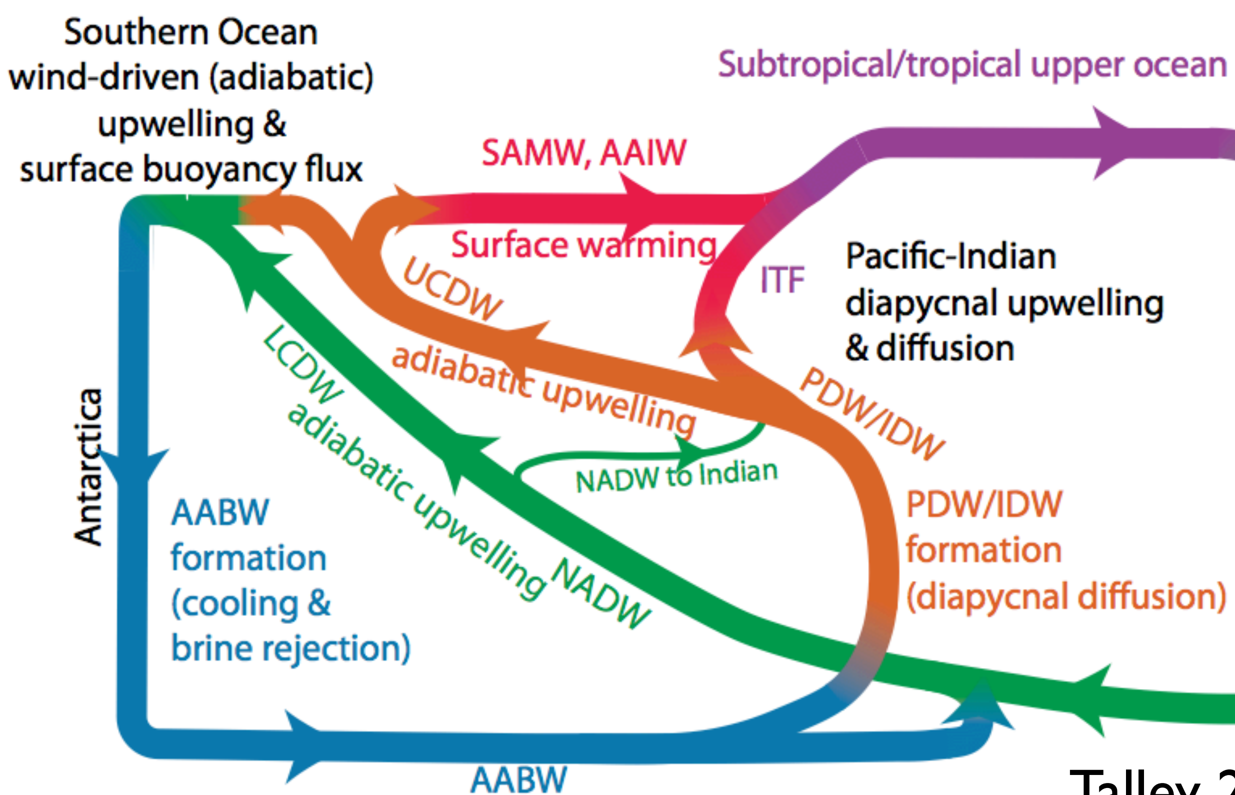


mics of internal wave breaking
ations
modeling
WHOI Postdoc
SIO Postdoc
Global wave modeling
•high-resolution
•tide and wind-forced
•w/ or w/o mesoscale
do resultant internal wave patterns agree with observations?
implement test parameterizations
extract essential mixing patterns for lower-resolution models
Global climate modeling
•lower resolution
•wind-forced (no tides)
GFDL Postdoc

overall goal of this CPT is to refine, develop and implement dynamically appropriate parameterizat
liapycnal mixing in the *ocean interior* for use in global climate models.
e ocean interior, the internal wave field is the conduit through which energy moves from the scale
ng to the dissipative scale of turbulence.
articular, internal-wave-induced mixing drives the diabatic evolution of the ocean's stratification on
time scales of central interest to the climate prediction problem.
are not charged with examining mixing parameterizations in the surface layer or bottom-boundary
.

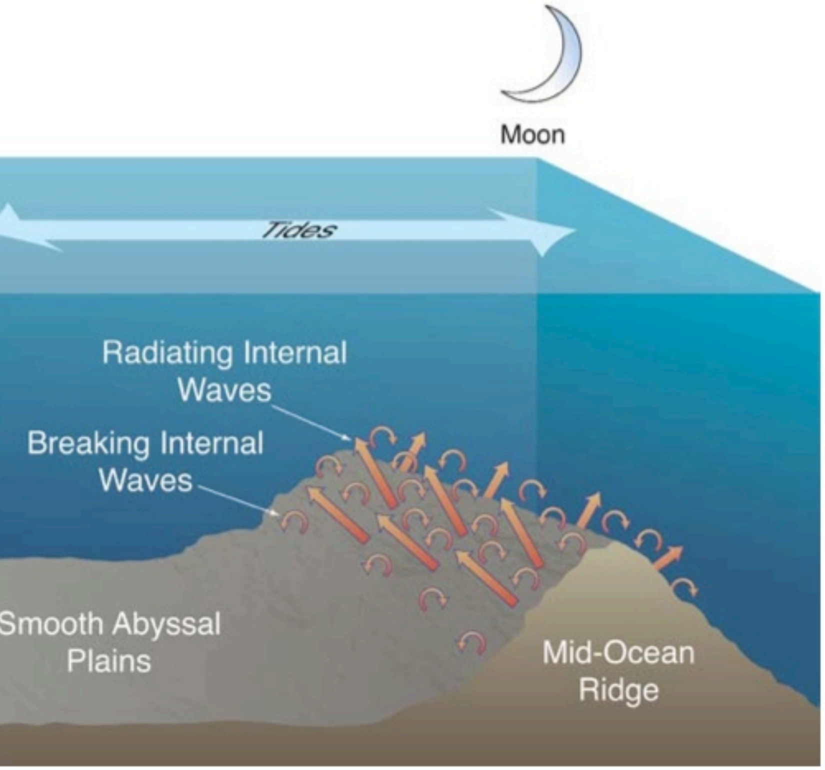


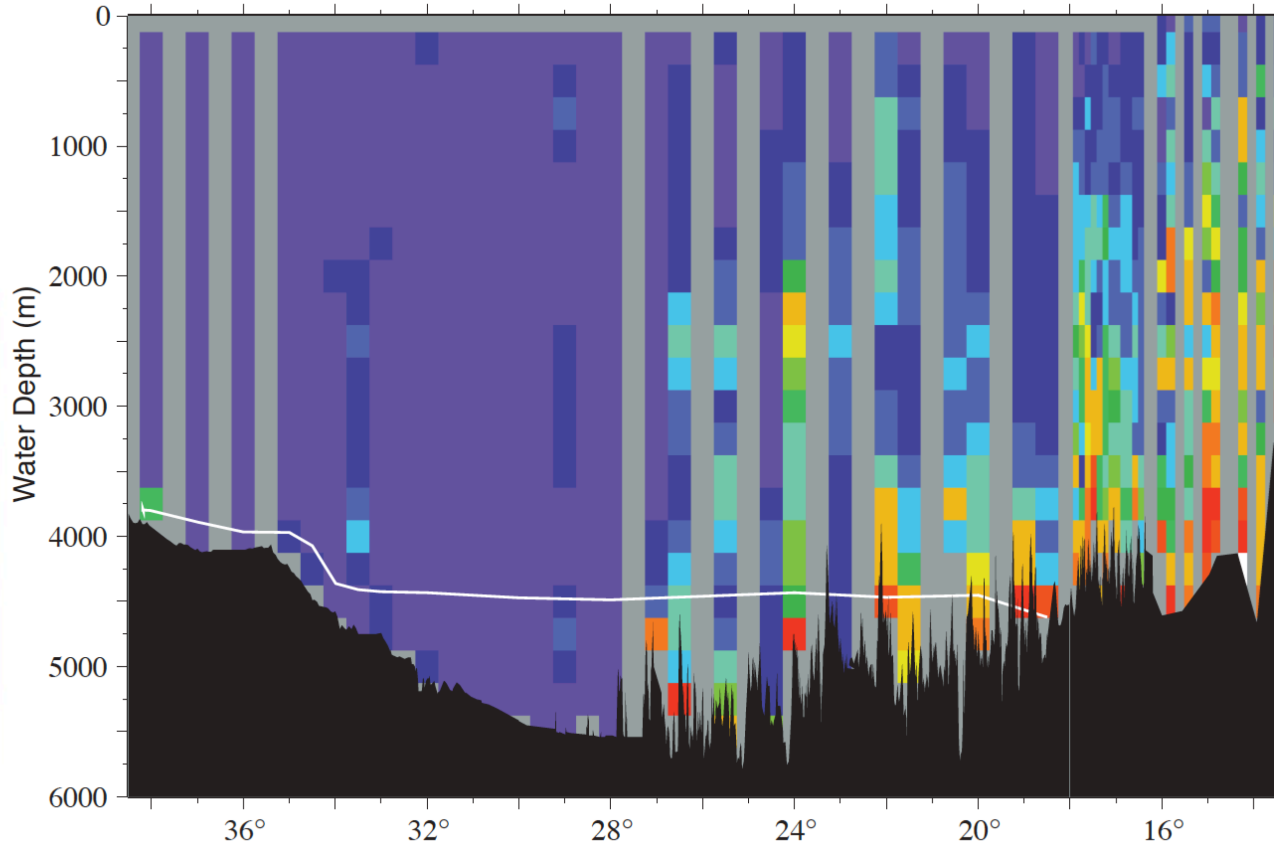
en used cartoon of the MOC



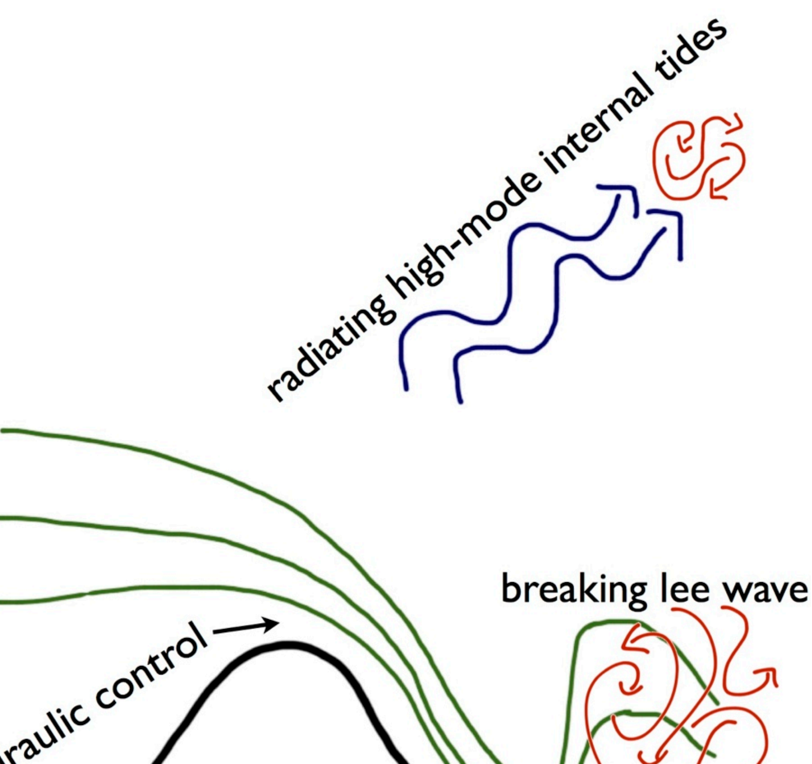
Talley 2

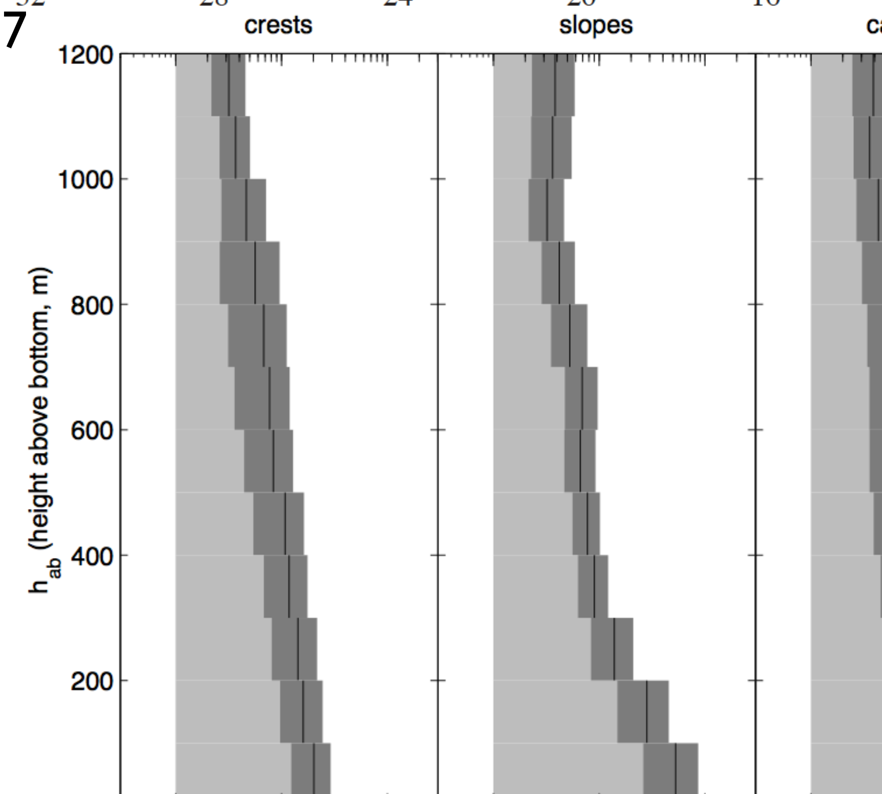
More realistic cartoon of the MOC





Toole et al. 1997





Laurent, Simmons and Jayne (2002) scheme:

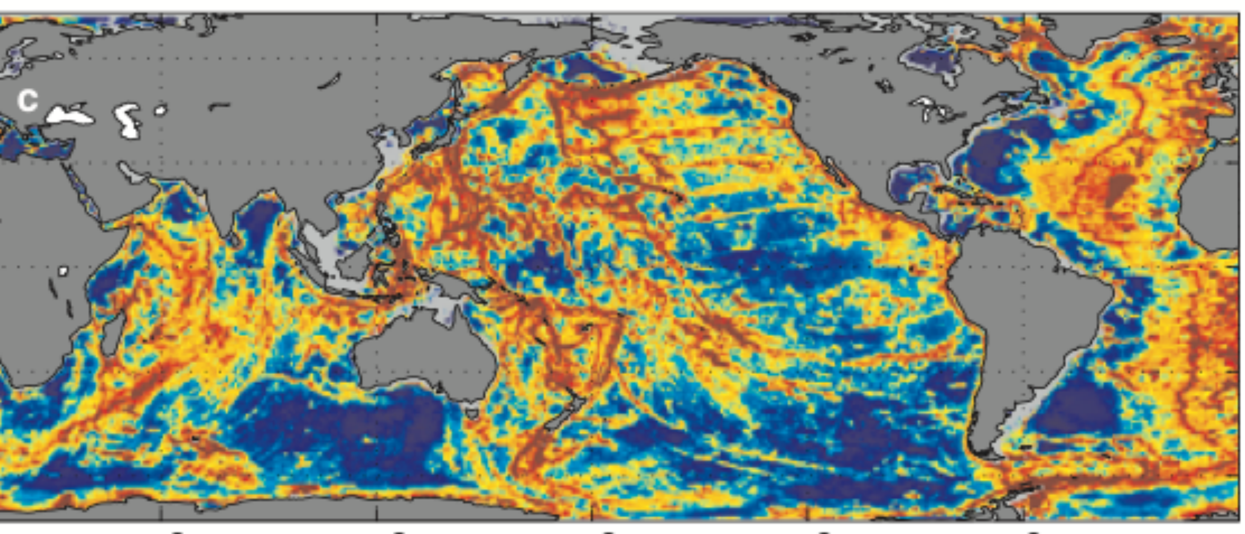
ternal
y flux
n Jayne
urent
el

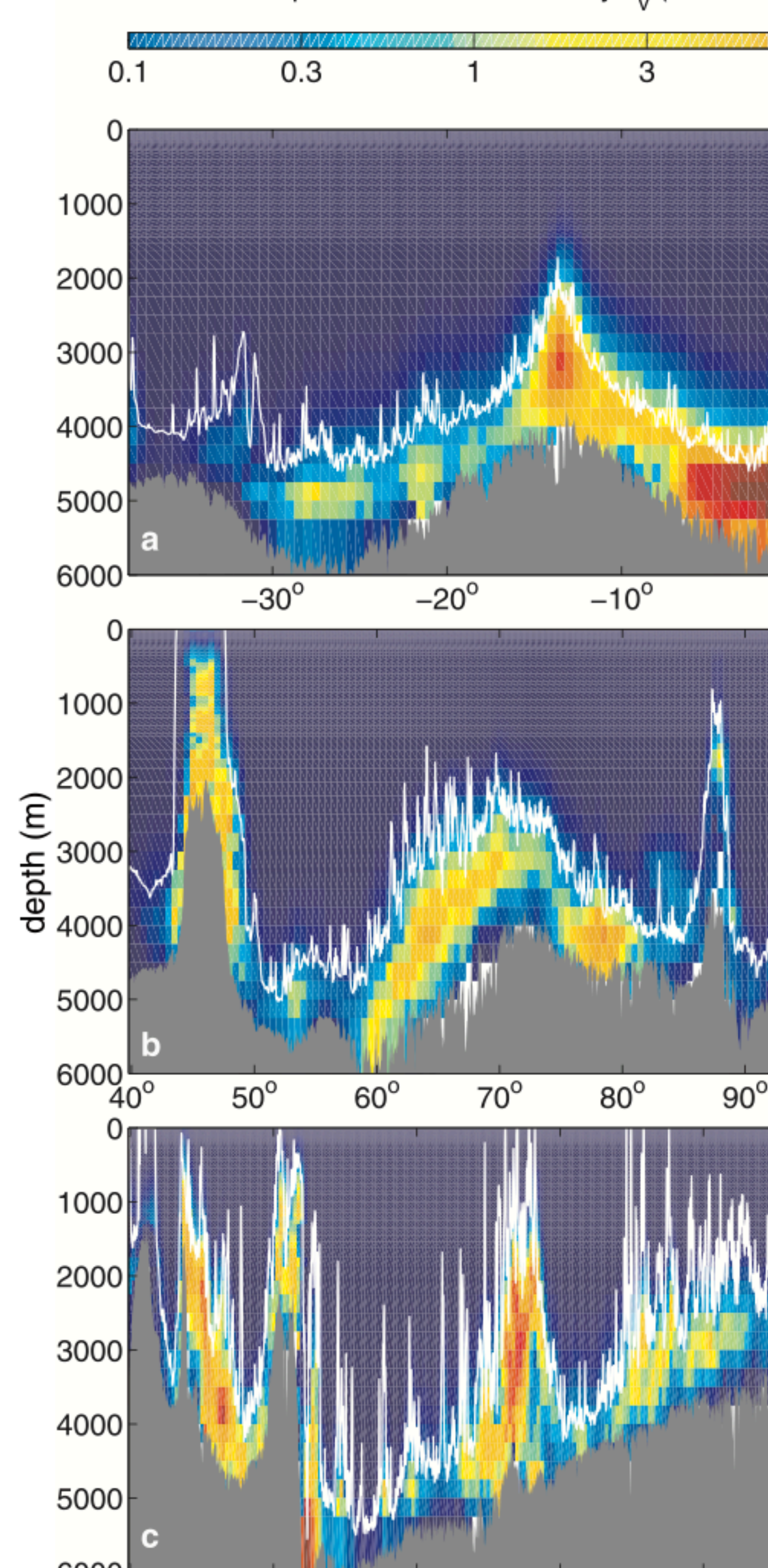
vertical structure based on empirical fit to data:

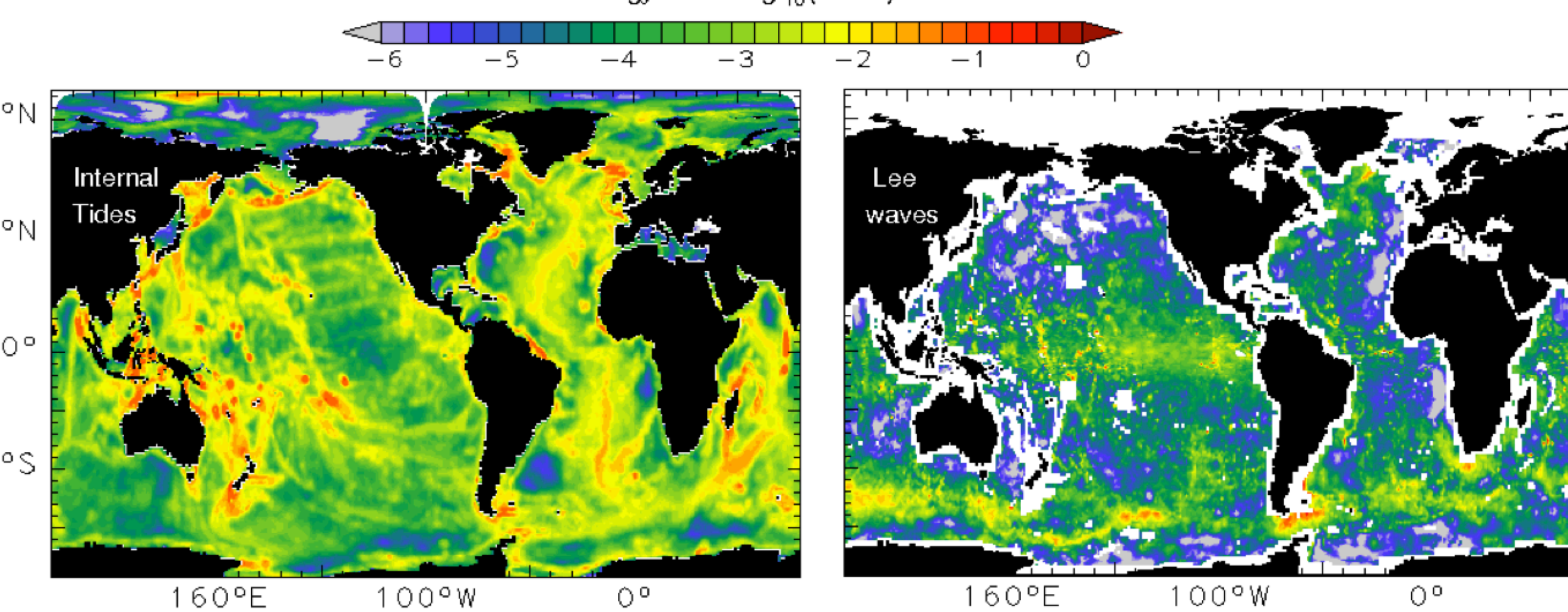
$$\varepsilon = \varepsilon_0 e^{-(H+z)/\zeta}, \quad F(z) = \frac{e^{-(H+z)/\zeta}}{\zeta\left(1 - e^{-H/\zeta}\right)}$$

$$\frac{E(x,y)F(z)}{\rho}$$

energy that
locally taken as
analysis of data





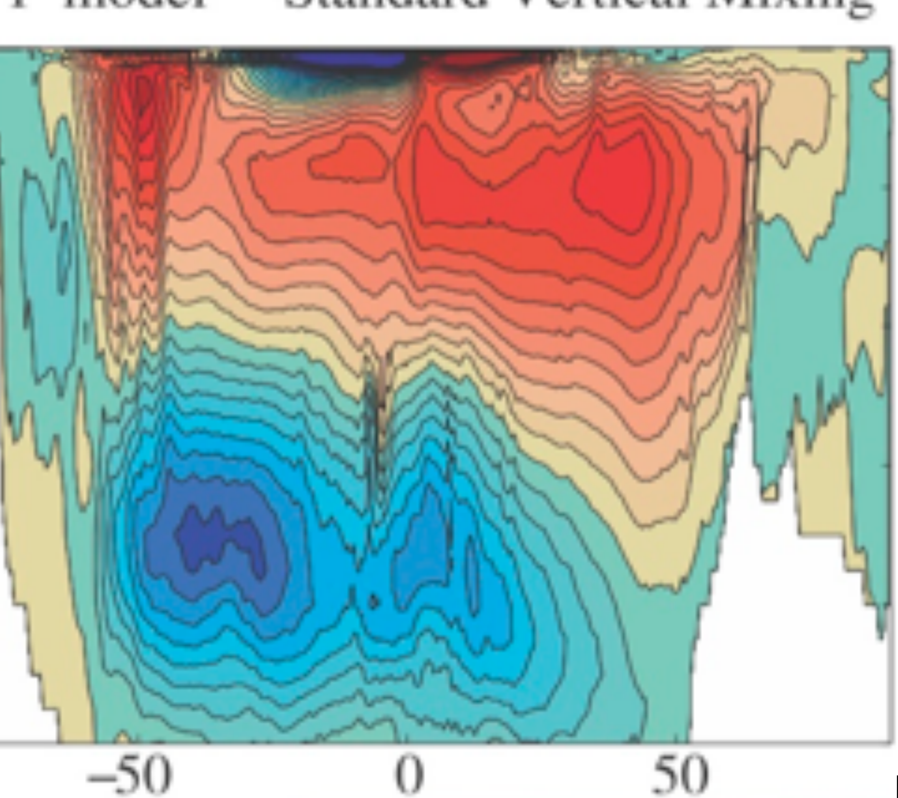


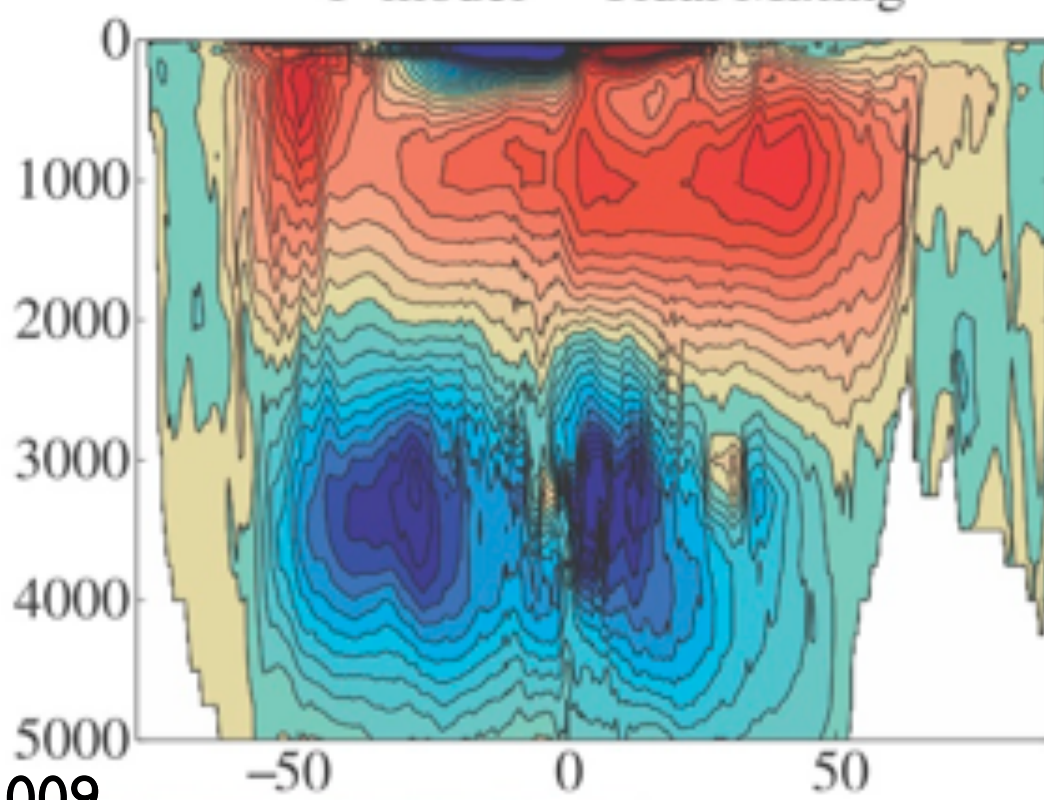
map of internal tide and lee wave energy flux, from multiple simulations of the global internal wave field

vertical structure based on wave-wave interaction physics Polzin 09, Melet et al. 13)

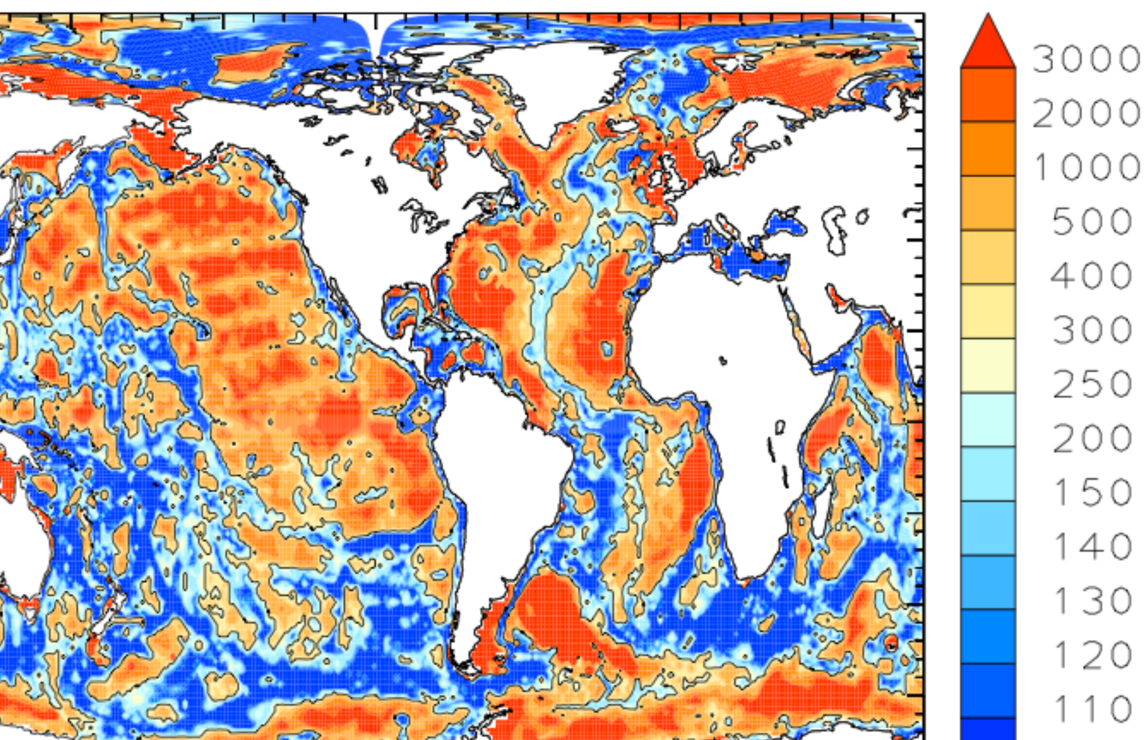
rate (related
vity through
efficiency)

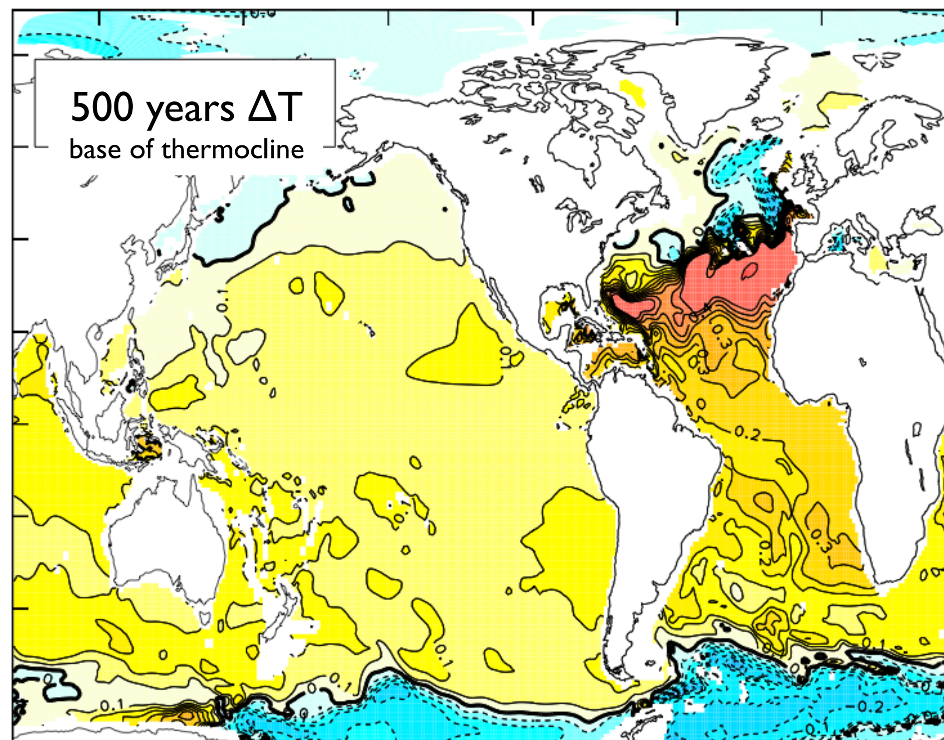
$$\varepsilon = \frac{qE(x,y,t)F(x,y,z,t)}{\rho}$$

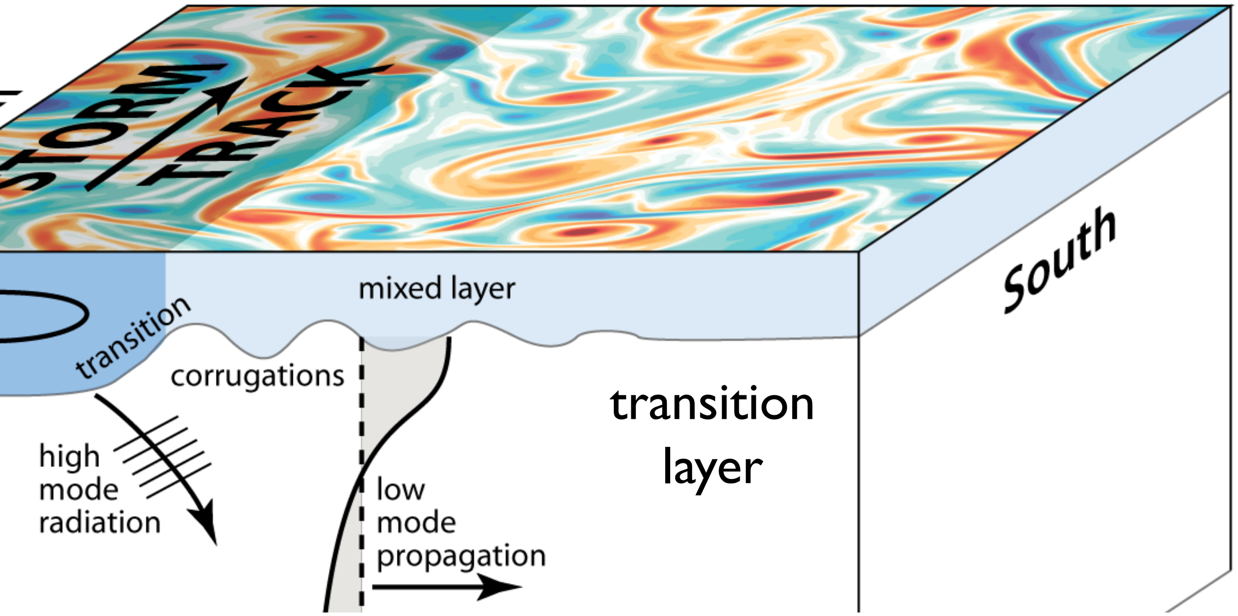

–50
0
50

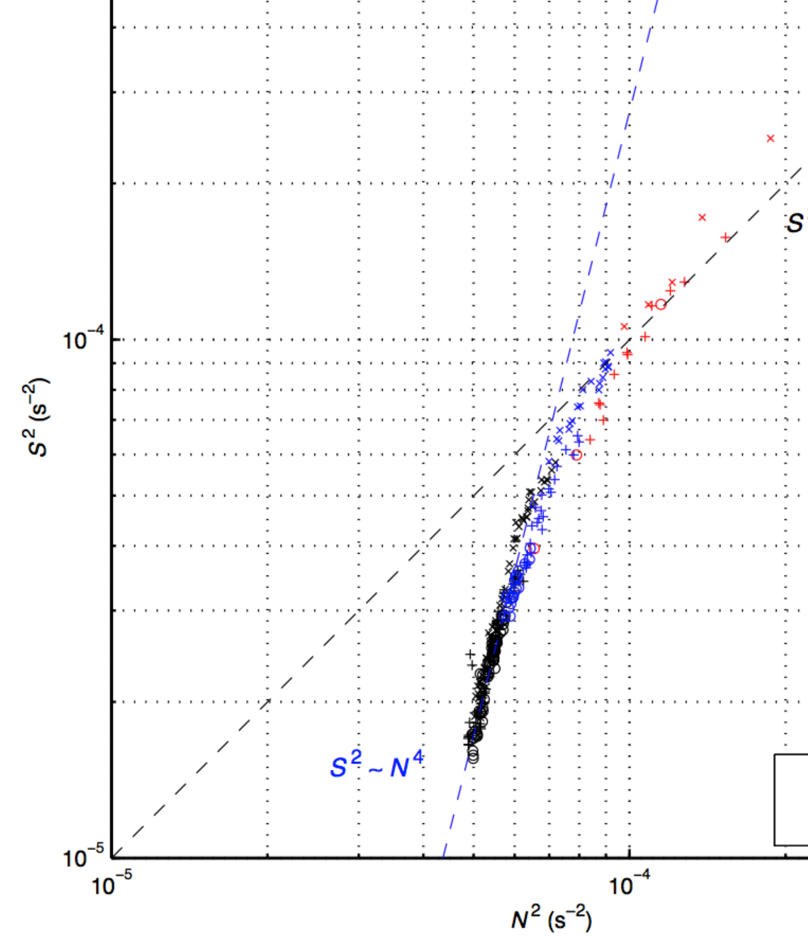

0
1000
2000
3000
4000
5000
–50
0
50

Jayne 2009

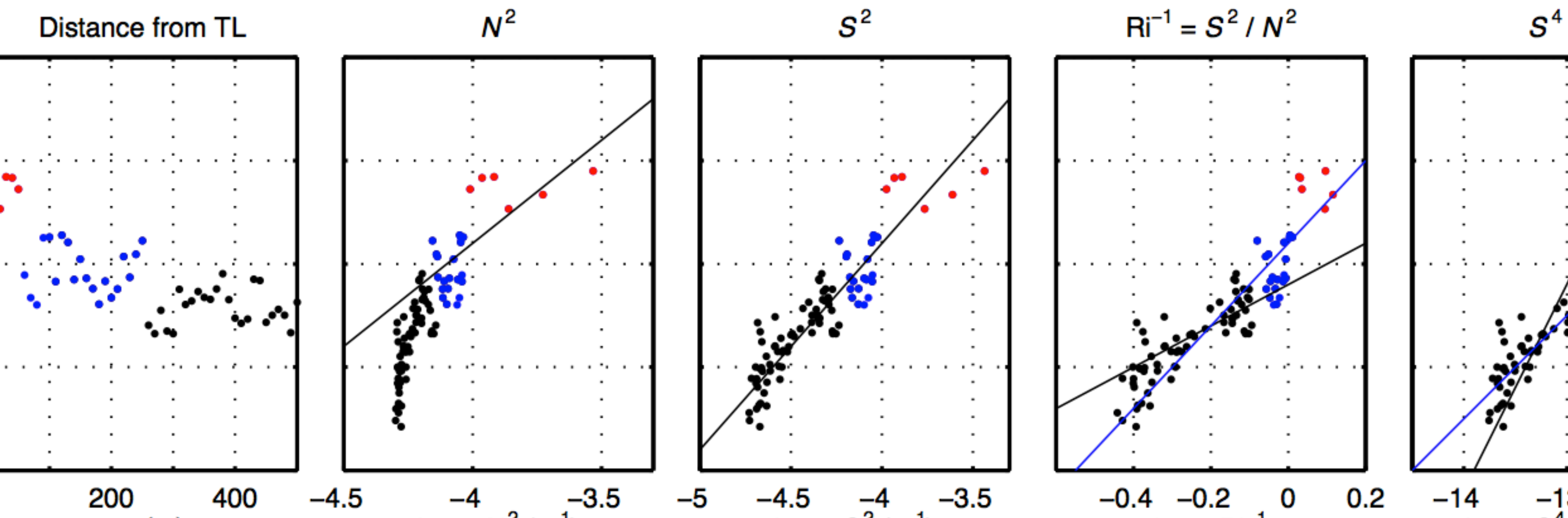

3000
2000
1000
500
400
300
250
200
150
140
130
120
110


500 years ΔT
base of thermocline





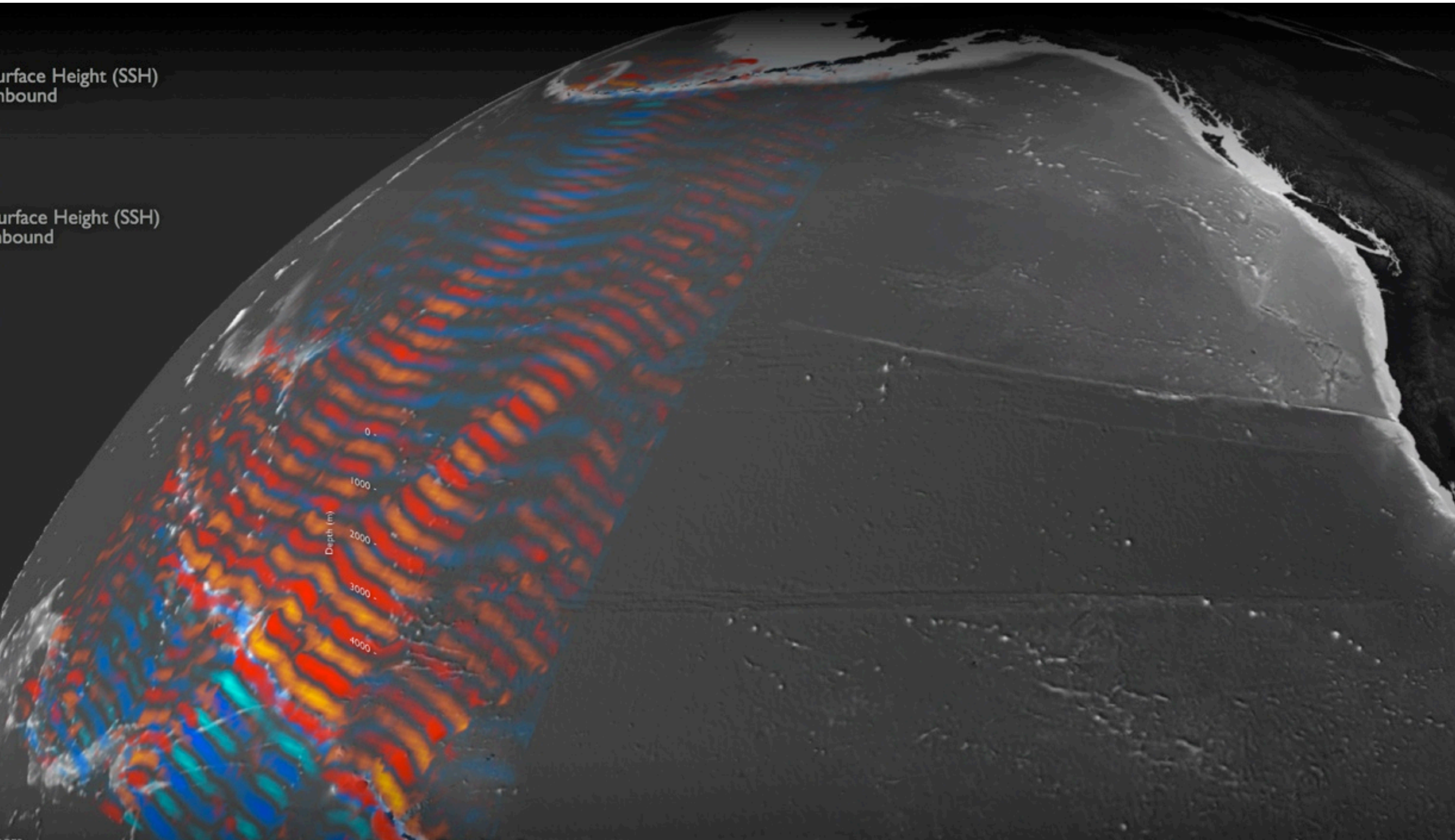
n, Rahter, Polzin, Jayne, St. Laurent (2013)

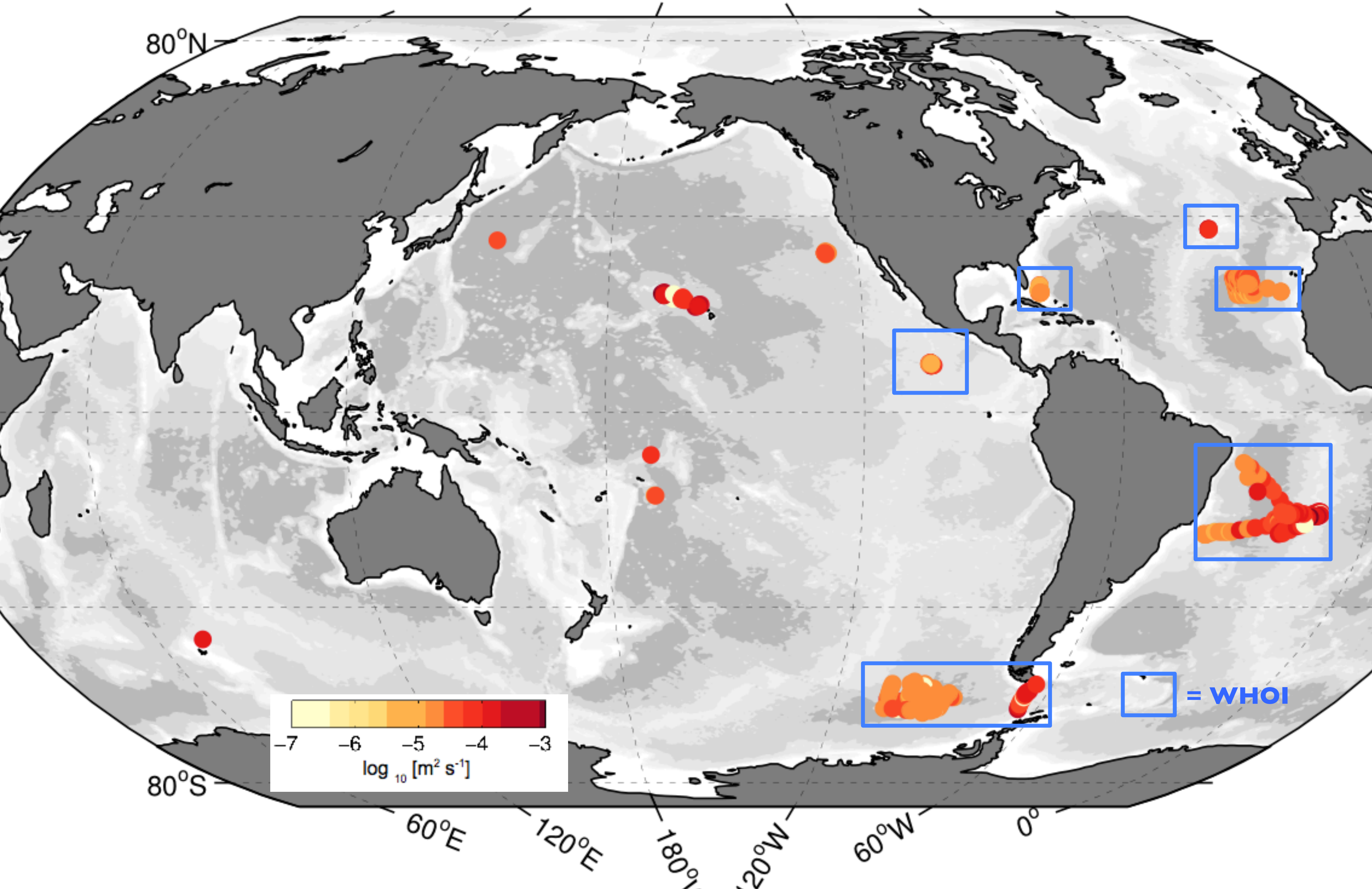


(0-90%) internal tide energy escapes to propagate thousands of km a

do these waves break? [St. Laurent and Nash 04]

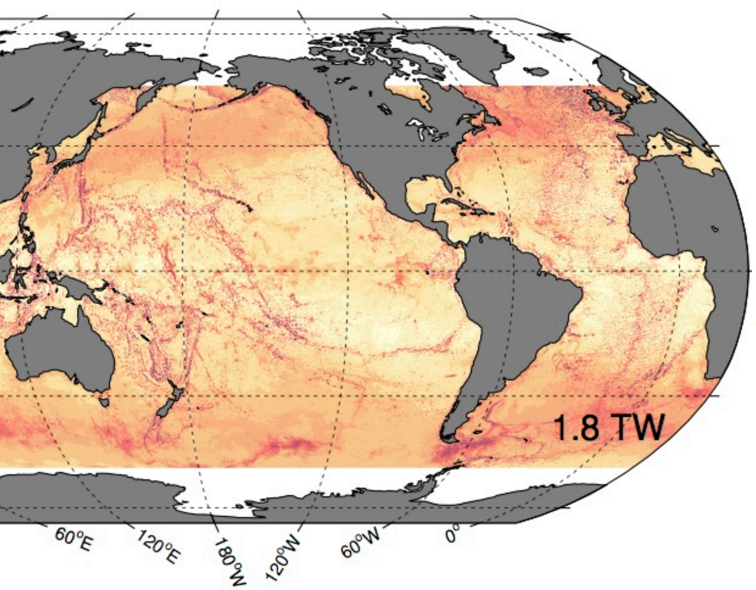
Altimetric measurements of internal tide energy flux Zhao an



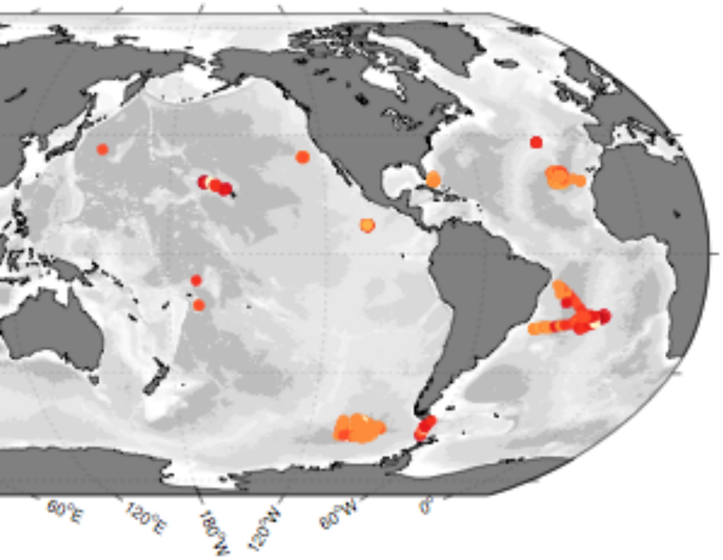


Full-depth microstructure at deep ocean sites, courtesy of numerous PIs
All data is being contributed to an open archive (NODC)

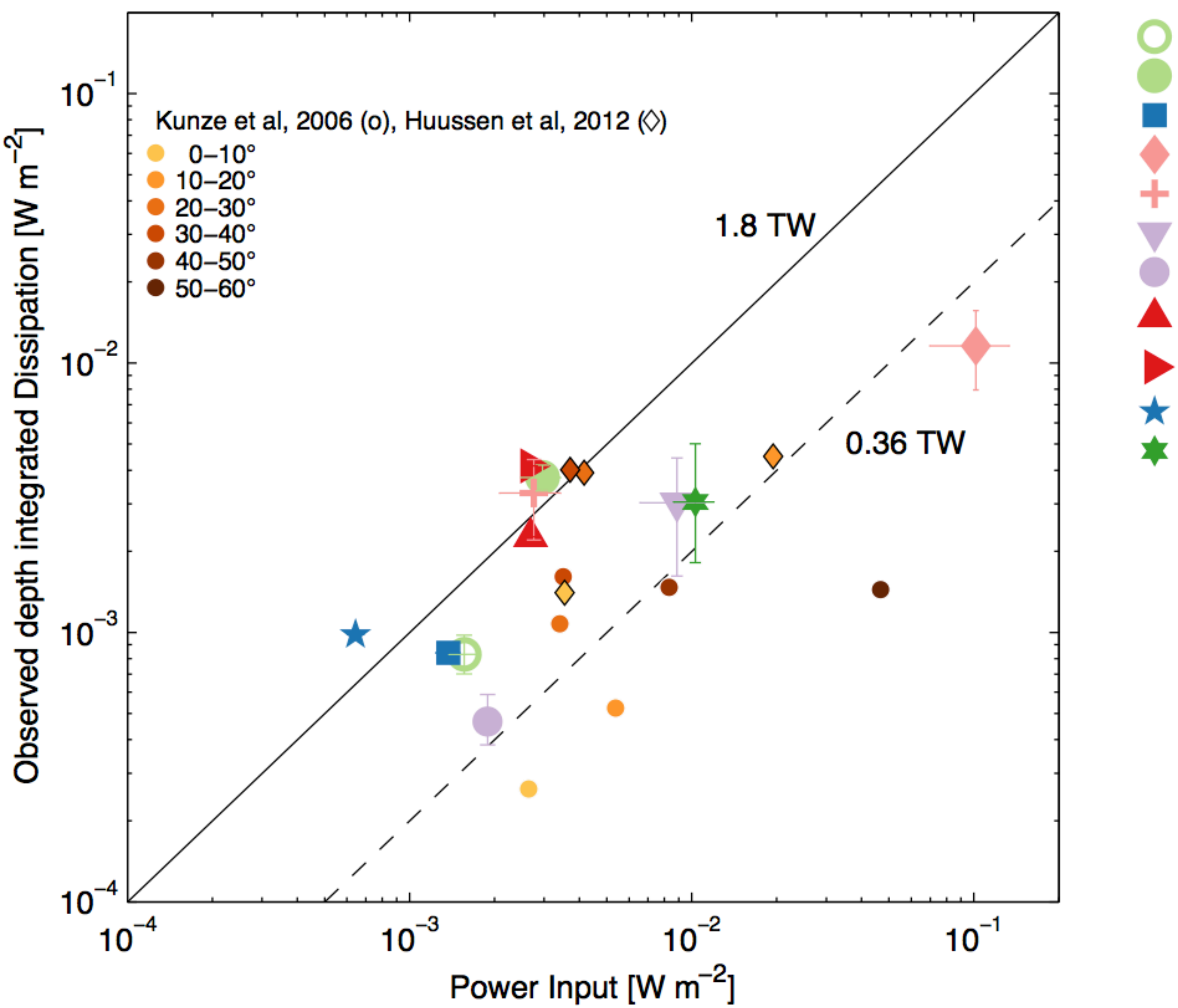
on of total internal wave generation power input (Simmon's model) at
th microstructure measurements versus depth-integrated dissipation



VS



(Waterhouse et al 13)



ocesses and geography of how propagating internal wa
te are open questions. Hypotheses include:

dy dissipation as they go through nonlinear wave-wave interactions
uding PSI = parametric subharmonic instability, which may be enhanc
N/S). Depth range: any. [MacKinnon et al 13] Current work by J. Anso

anced dissipation (again) where waves scatter over rough mid-ocean
ography. Depth range: deep. [St. Laurent and Garrett 02, Johnston an
rifield 03, EXITS study]. Current work by O. Sun.

ess studies show elevated mixing on continental slopes, especially ne
ed canyons. Some of this due to local energy sources, some due to
tering of incoming low-mode internal waves. If the resultant mixed v
orted into the interior, mixing at the margins could contribute a sign
ion of basin-wide av[Eriksen 82, Legg and Adcroft 03, Nash et al 04, , K
n 10, Klymak et al 11, Martini et al 11, Lucas et al 11, Kunze et al 12,

ervations of turbulence and models accounting d and tidal mechanical power input give consist lts for average mixing rates of 1 cm^2/s.

specific patterns are important in setting wate s properties and flow on the basin and sub-bas es.

re developing GCM parameterizations for some of these rns, mostly related to mixing near internal wave generatio h topography, storm tracks)

esting emerging conclusion that there may be significant pation at the boundaries, unclear what the effect on circula

and regional circulation patterns and fluxes sensitive to the
ed geography of diapycnal mixing rates

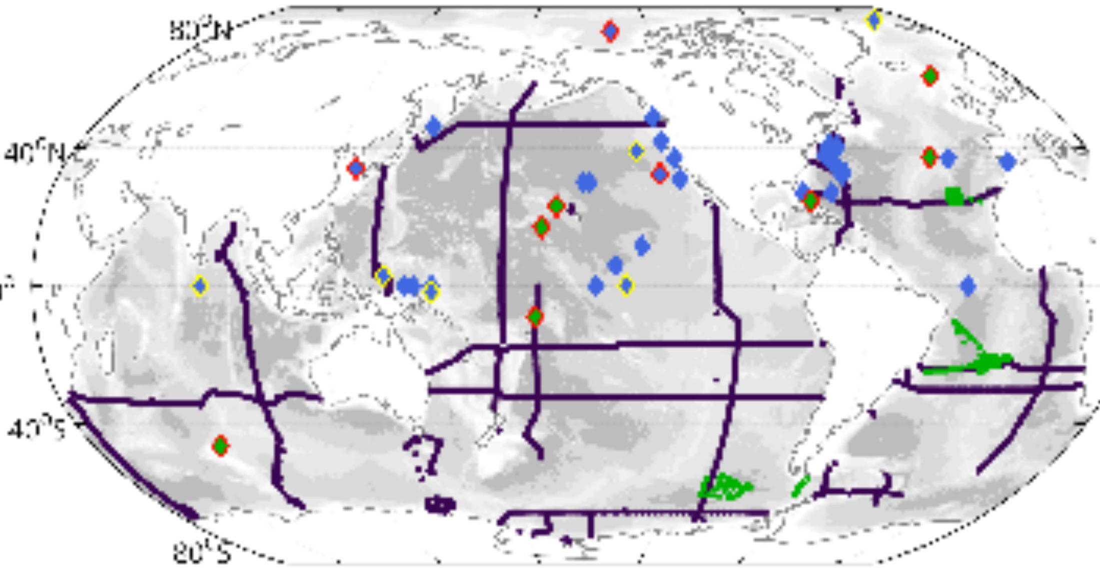
parameterizations are being developed and implemented tha
ent elevated mixing near sites of internal tide and near-inert
ation

of the energy in the internal wave field (1-q) propagates awa
te elsewhere, possibly at the margins. New parameterizatio
considered.

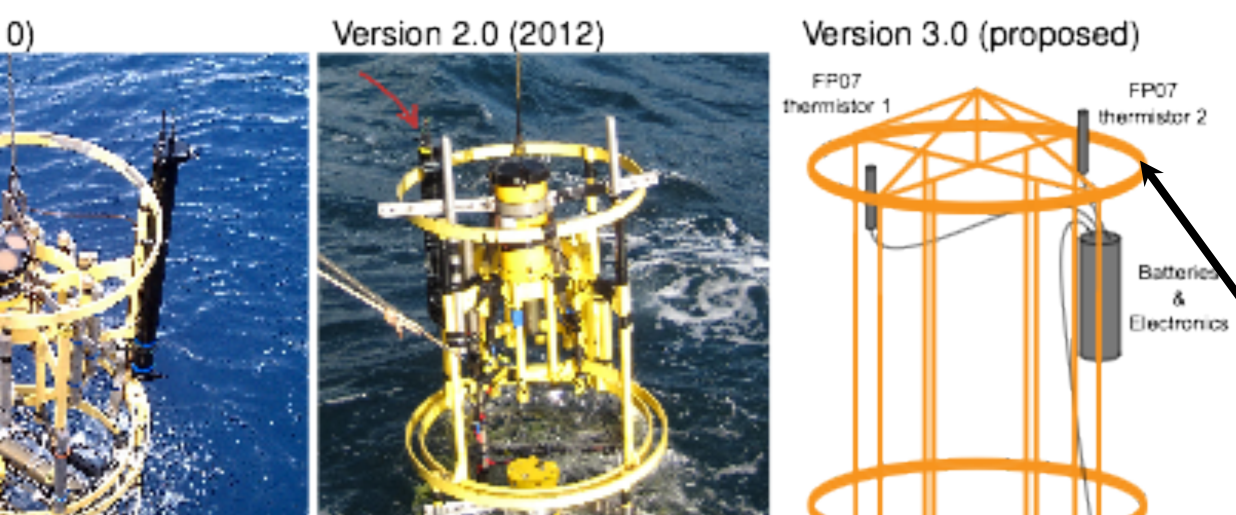
cant power potentially also available from the mesoscale, dis
of which are unknown. One example is lee waves, but othe
al wave pathways are likely.

hydrography cruises: (Nash, Moum and MacKinnon)

ng full-depth microstructure
s are EXTREMELY sparse
(green dots)



l add “chi-pods” (mixing meters) to standard CTD casts, giving fu
f turbulent mixing rates at every station. Our newly NSF-funded
be for a PILOT experiment for two cruises in 2014/15.



If successful, this could b
regular part of the re
hydrography progra