Observations of deep near-inertial waves interacting with large- and meso-scale currents in the Kuroshio Extension

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Propagation of near-inertial waves (NIWs)

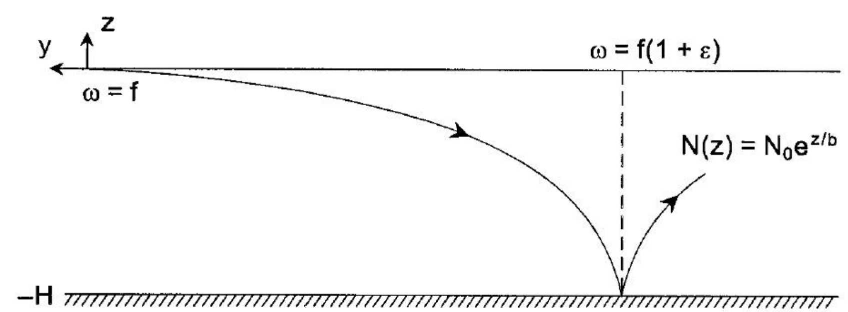
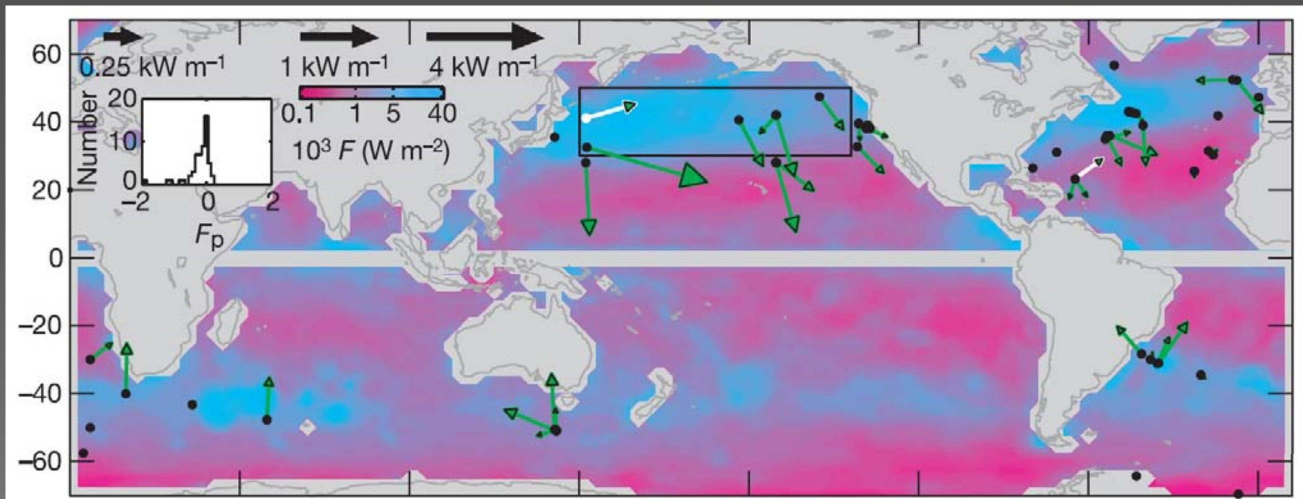


Fig. 1. Schematic of the ray for inertial waves generated at the surface and propagating equatorward and downward. The frequency ω is fixed, but the Coriolis frequency is a function of meridional distance y.

Garrett (2001)

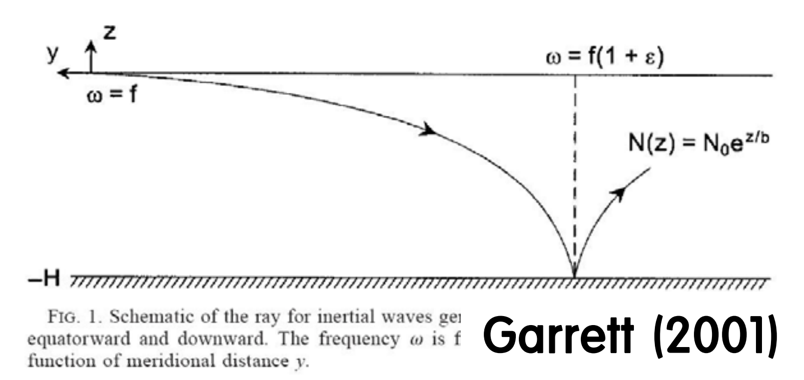
A simple model predicts that NIWs propagate downward and equatorward



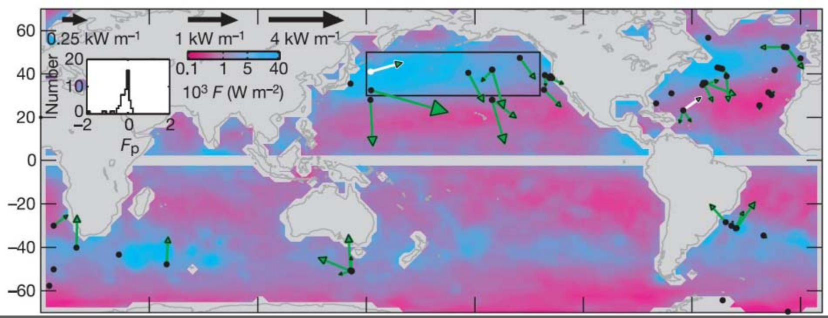
Alford (2003)

Supported by observational evidence

Propagation of near-inertial waves (NIWs)



Garrett (2001)

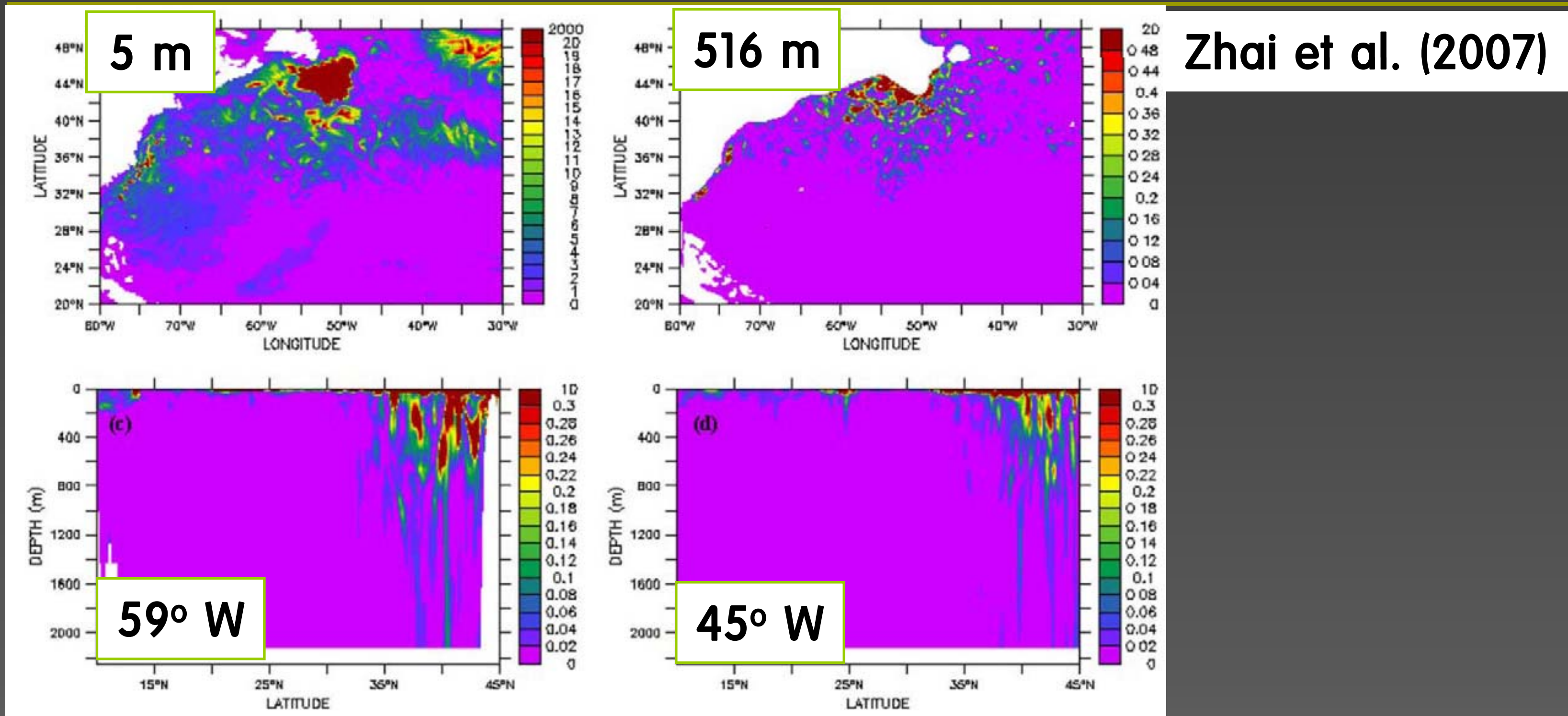


Alford (2003)

However,

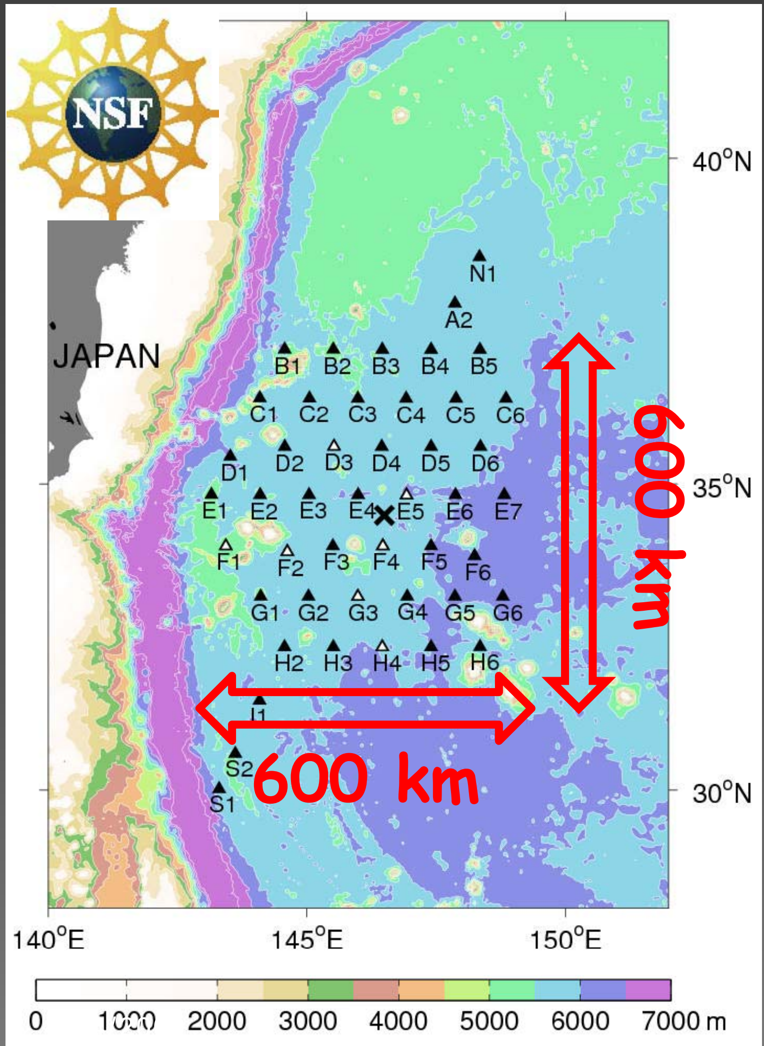
1) Theory ignored the effect of variable background current shear and stratification that can change the propagation path of the NIW energy.
2) Observations have been scarce in regions of strong background shear such as western boundary currents.

Gulf Stream can create a "desert" for NIW energy (from simulation)



Predicting that "inertial chimney" (Lee and Niiler, 1998) associated with anti-cyclonic eddy activities prevents further propagation of NIWs to the south

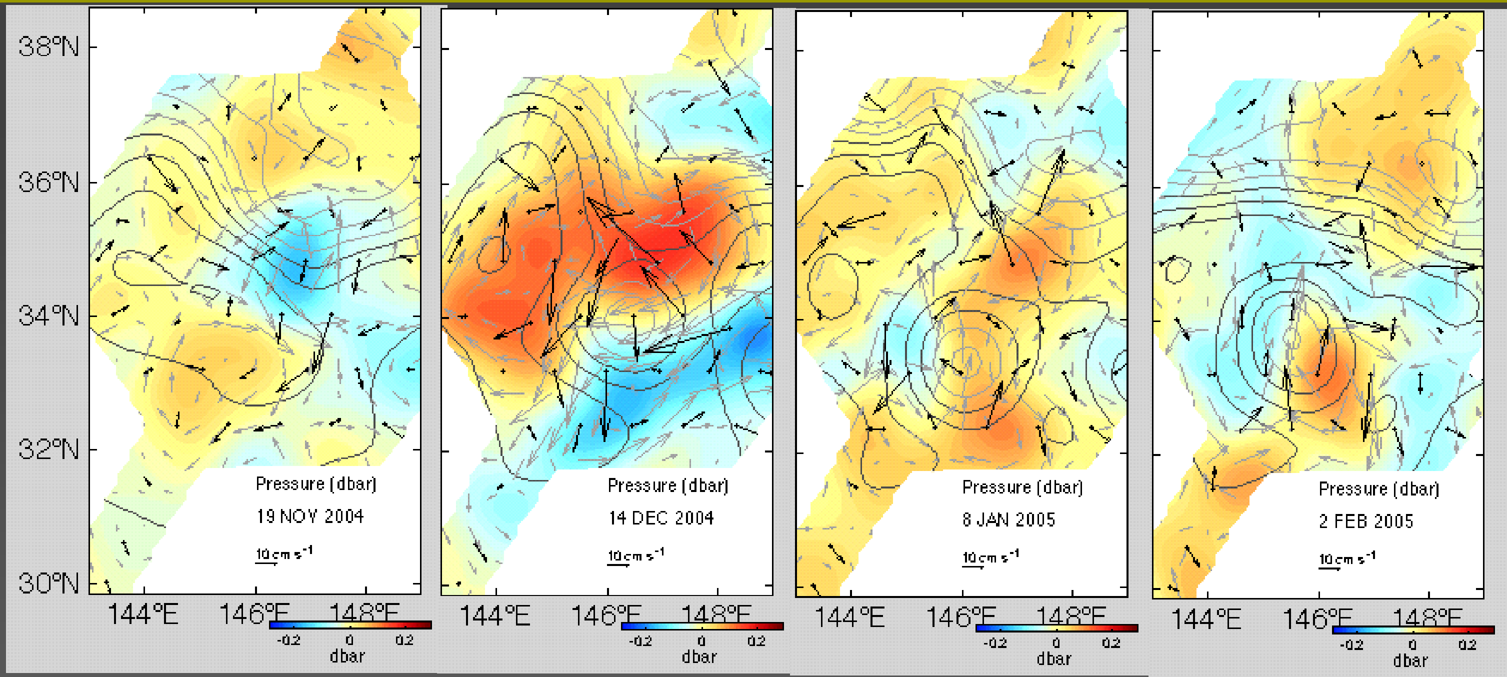
Kuroshio Extension System Study
(KESS, May 2004 - June 2006)
www.uskess.org



- 600 km x 600 km array
- 46 near-bottom current sensors (RCM11)
  (~50 m above the bottom,
  ~90 km spacing,
  5300-6100 m depth)

Park/URI

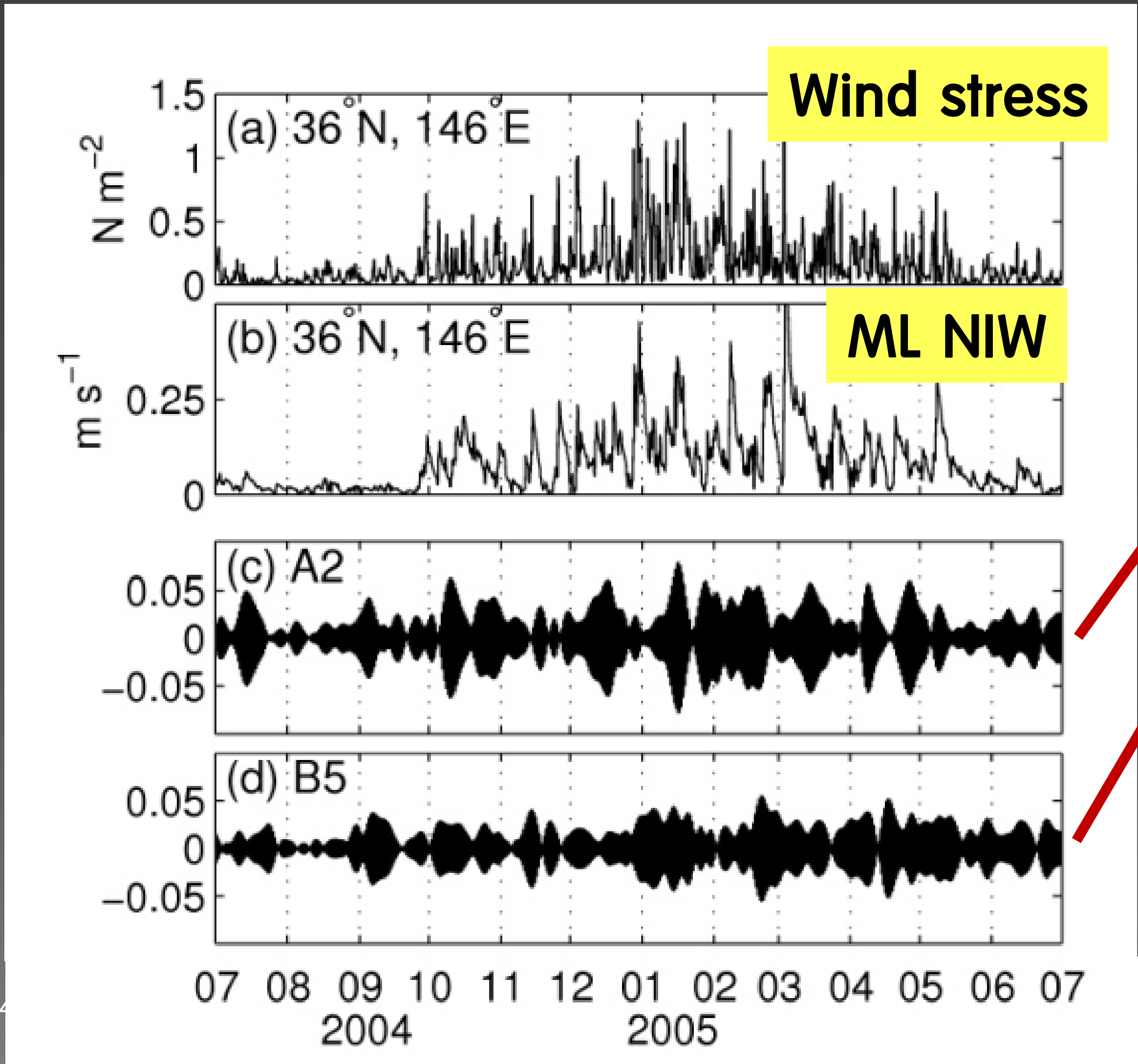
Upper- and deep-flow variabilities in the Kuroshio Extension

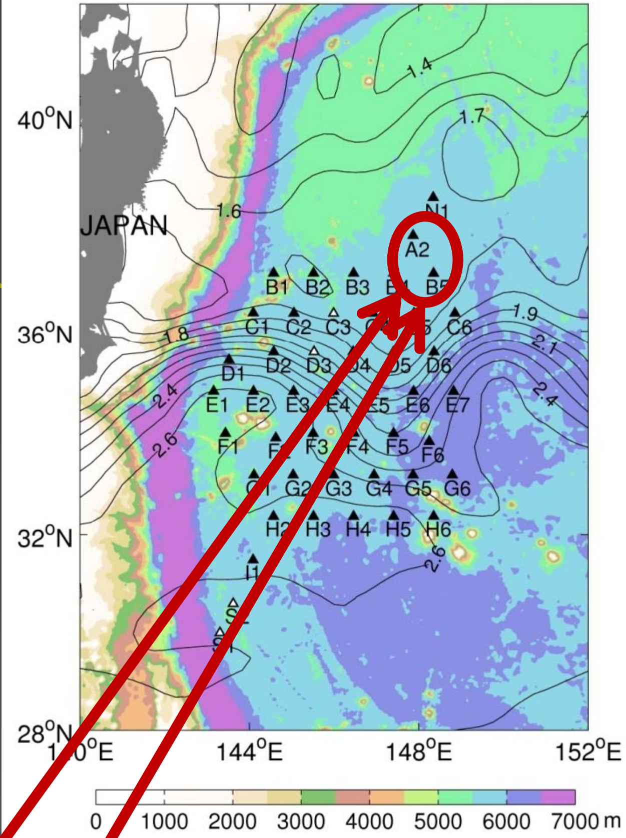


- Colored contours
  :deep pressure fields
- Black and gray contours
  :upper flow fields

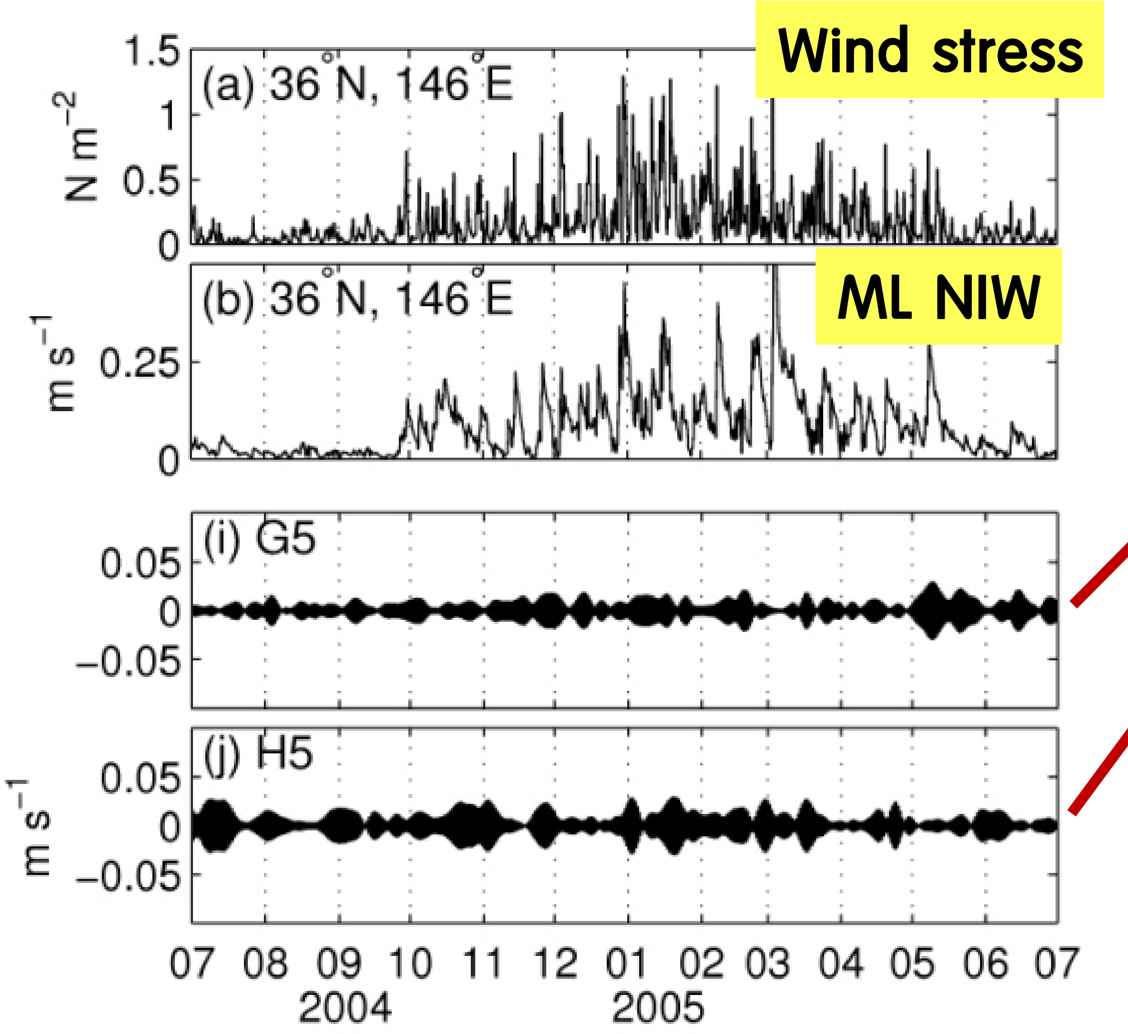
- Black arrows
  :observed deep flows
- Gray arrows
  :OI mapped flows
  using both U and P_{bot}

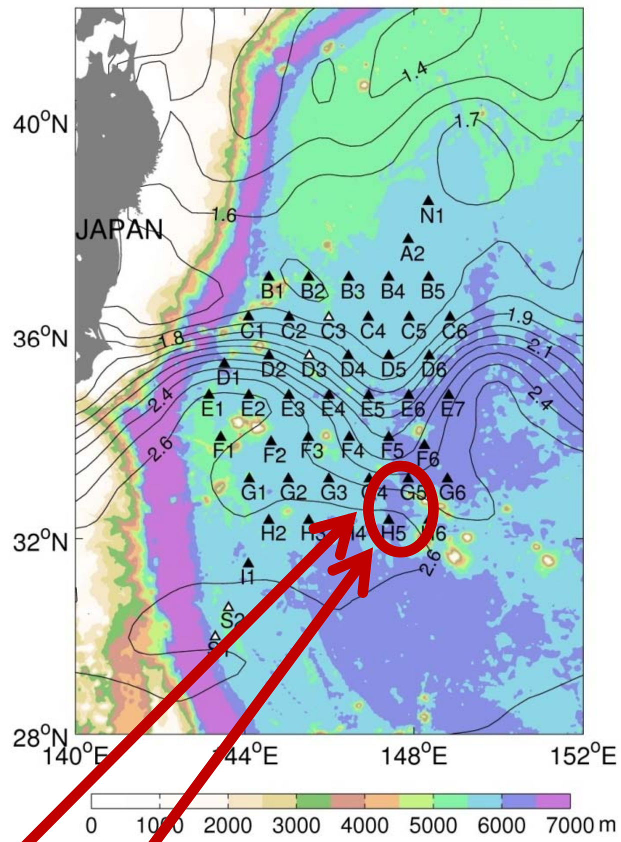
Wind, ML NIW & Deep NIW





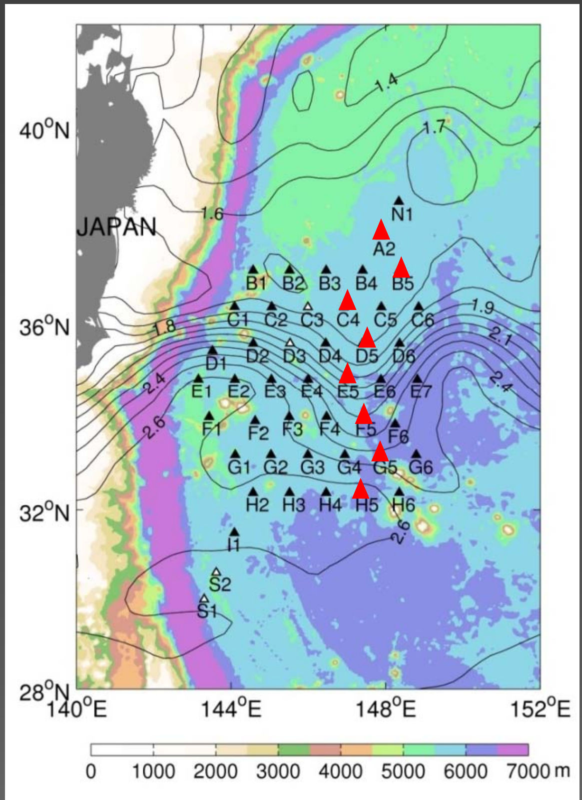
Wind, ML NIW & Deep NIW





Bandpass filterd Inertial current (u)

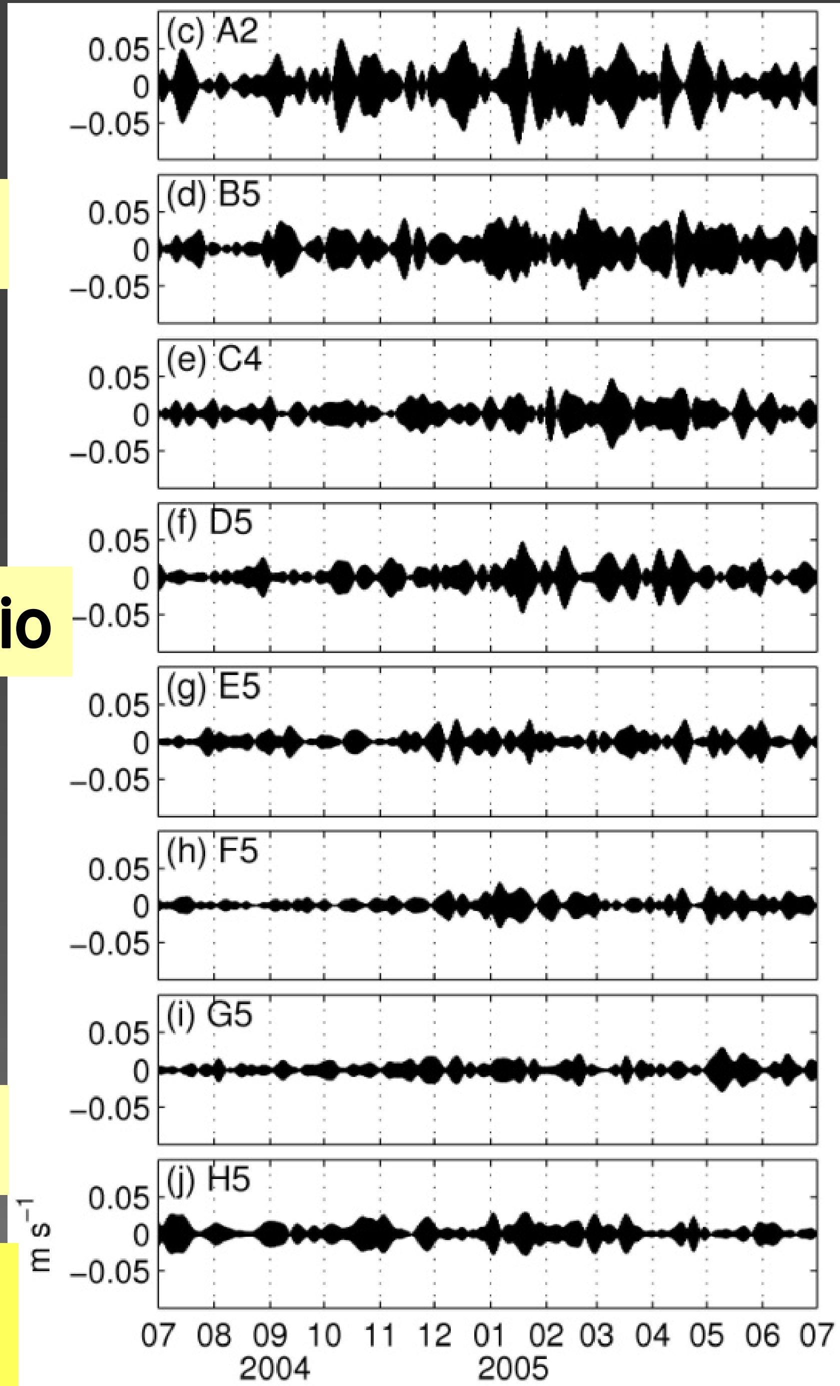
Change of NIWs across the KE



North

Kuroshio

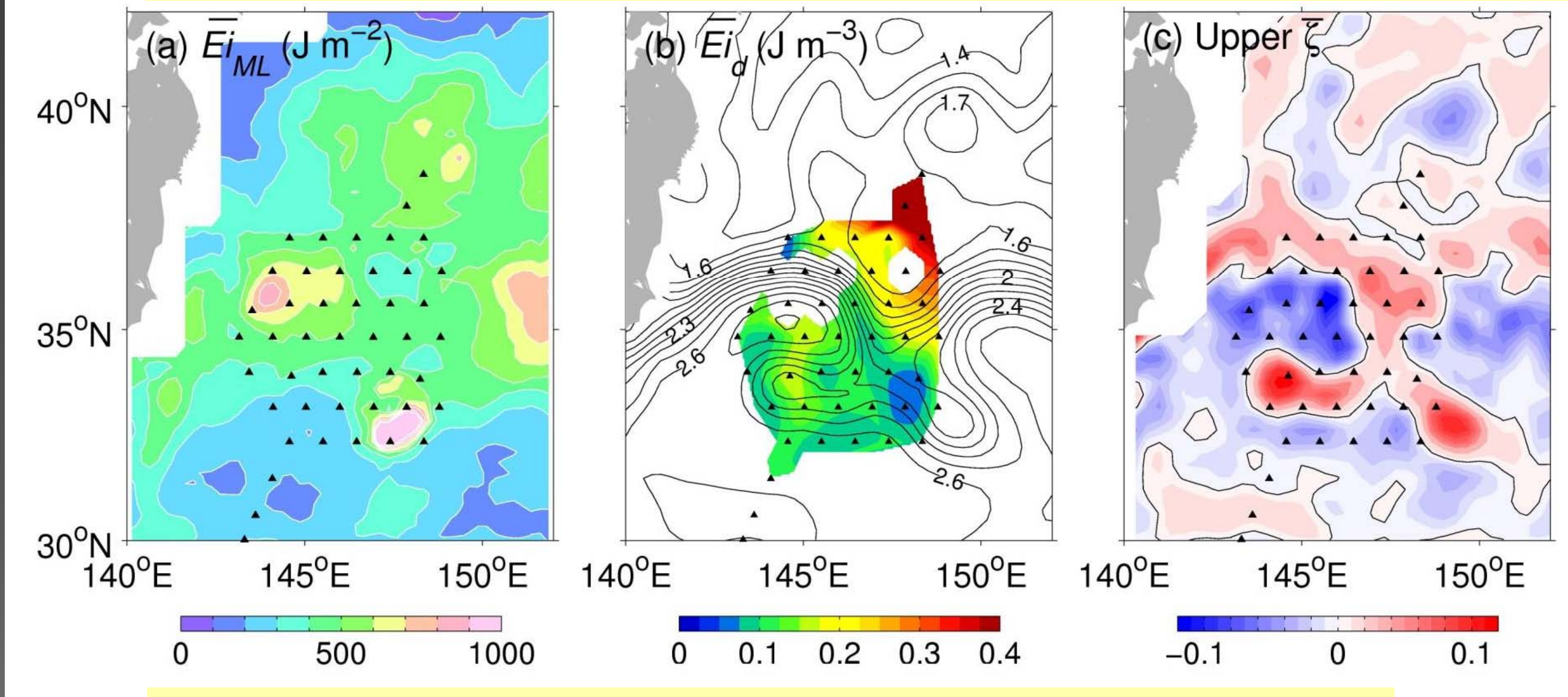
South



Bandpass filterd Inertial current (u)

Wintertime-mean upper and deep maps of NIW energy vs. relative vorticity

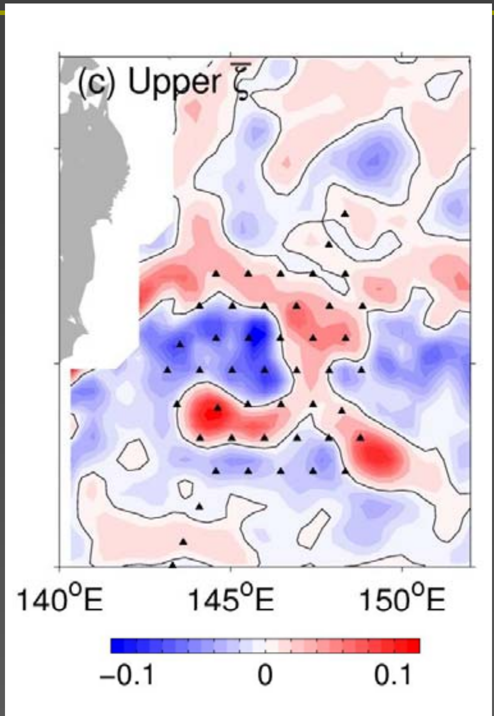
ML NIW   deep NIW   relative vorticity



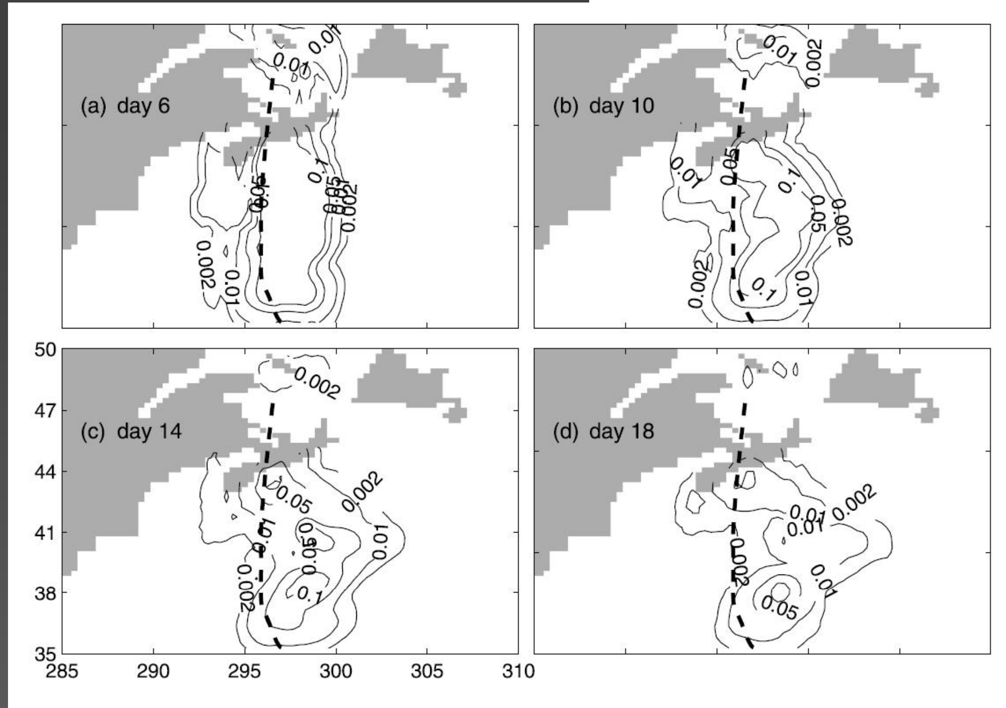
From wind   deep currents   SSH

11/2004-04/2005

What can cause the high NIW energy north of the KE?



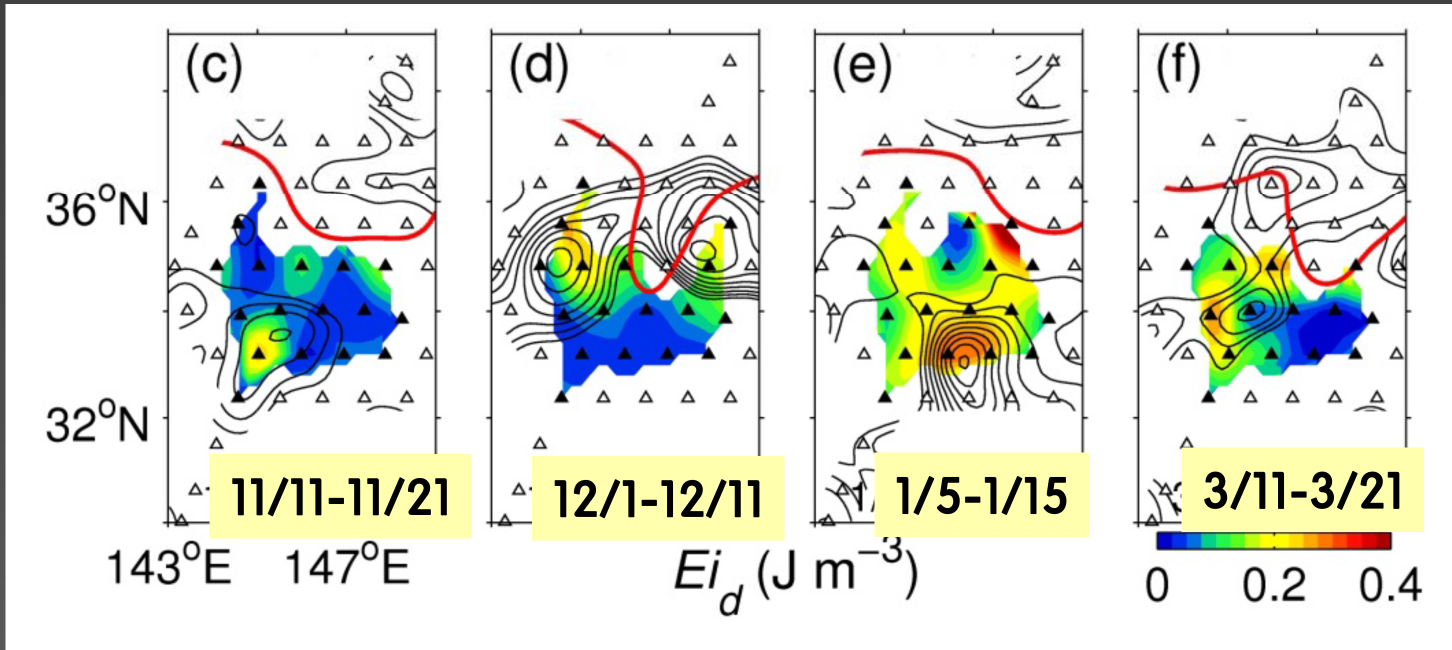
Zhai et al. (2004)



Reflection of NIWs to the North by the positive vorticity barrier of the Kuroshio

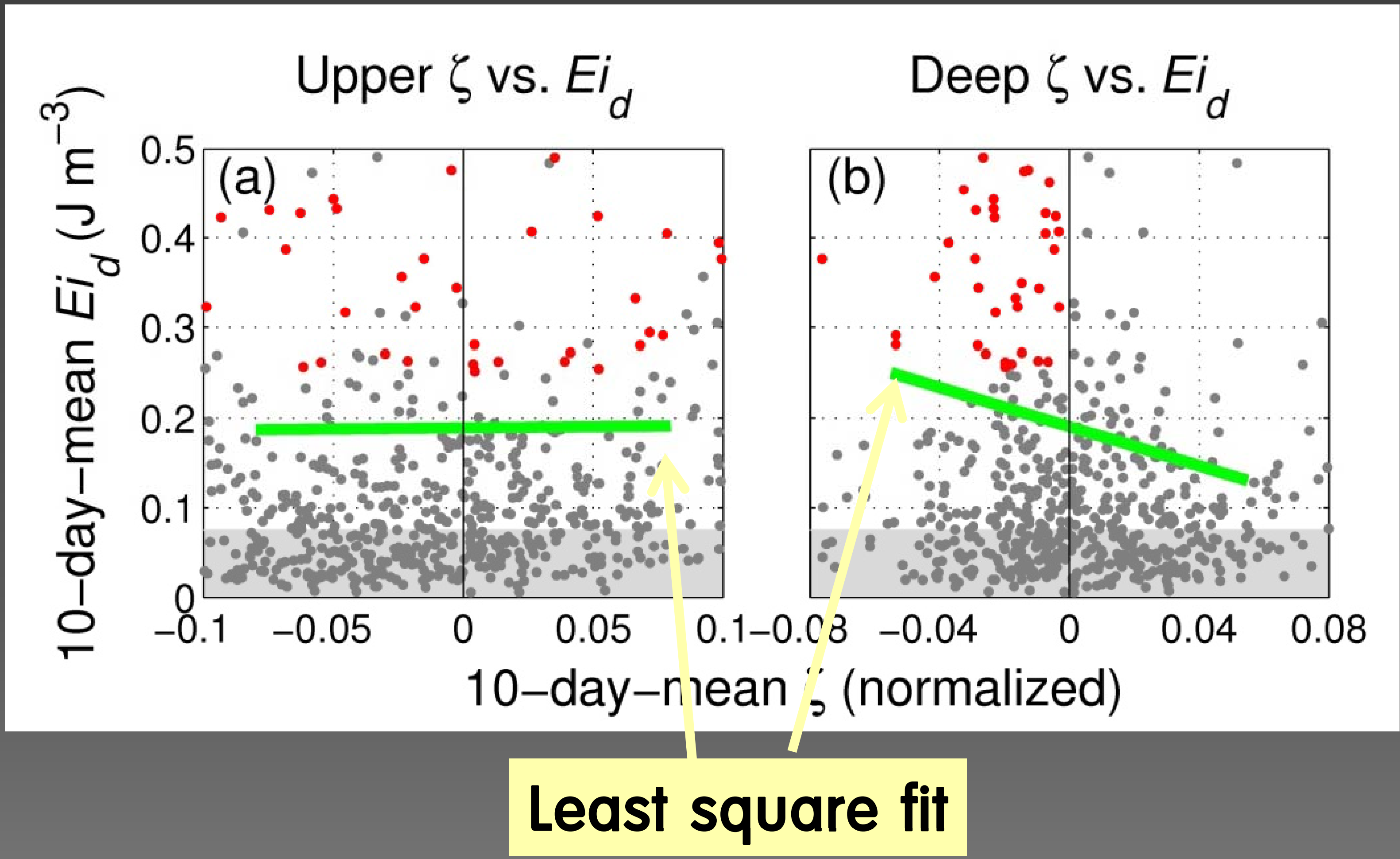
Advection of NIWs to the East

Relationship between deep NIWs and deep mesoscale eddies



- Deep NIW energy maps for four separate 10-day periods
- black contours : 10-day-mean positive bottom pressure fields (i.e., anticyclonic)
- Red contours: 10-day-mean Kuroshio locations

Scatter plots of 10-day-mean deep NIW energy vs. upper and deep relative vorticity

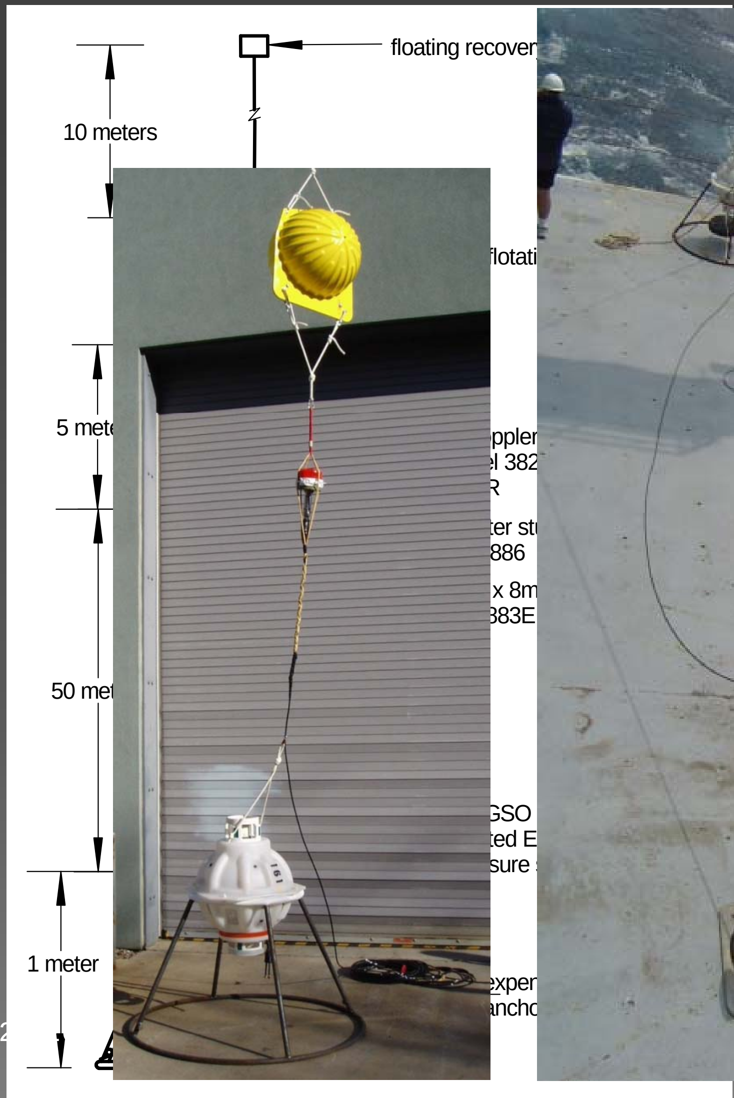


Summary

- We observed a sharp factor-of-5 decrease of wintertime-mean deep NIW energy across the KE with large values on the north side of the KE.
- Blockage of NIW energy by the KE can create areas of relatively little NIW energy such as the NIW energy desert in subtropical gyres.
- Localized episodic high deep near-inertial events are found to be associated with deep anticyclones rather than upper ones.
- Meaningful estimation of NIW energy input to the deep ocean should consider large- and meso-scale flows.

CPIES

(Current-and-Pressure-recording Inverted Echo Sounder)



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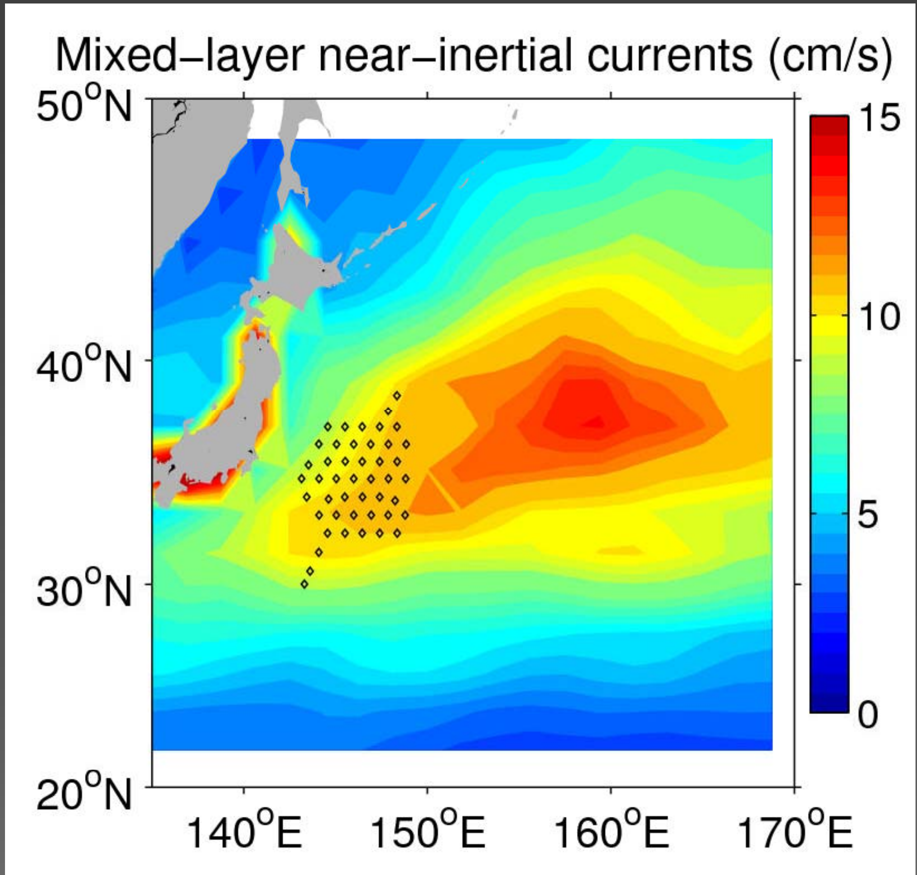
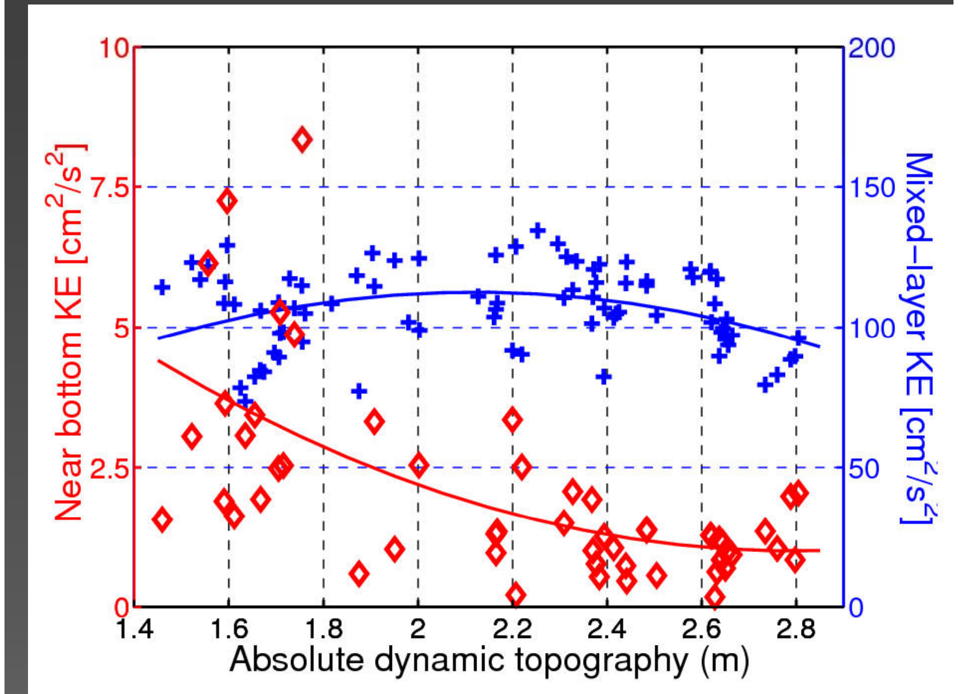
e surface

n pressure
1mm

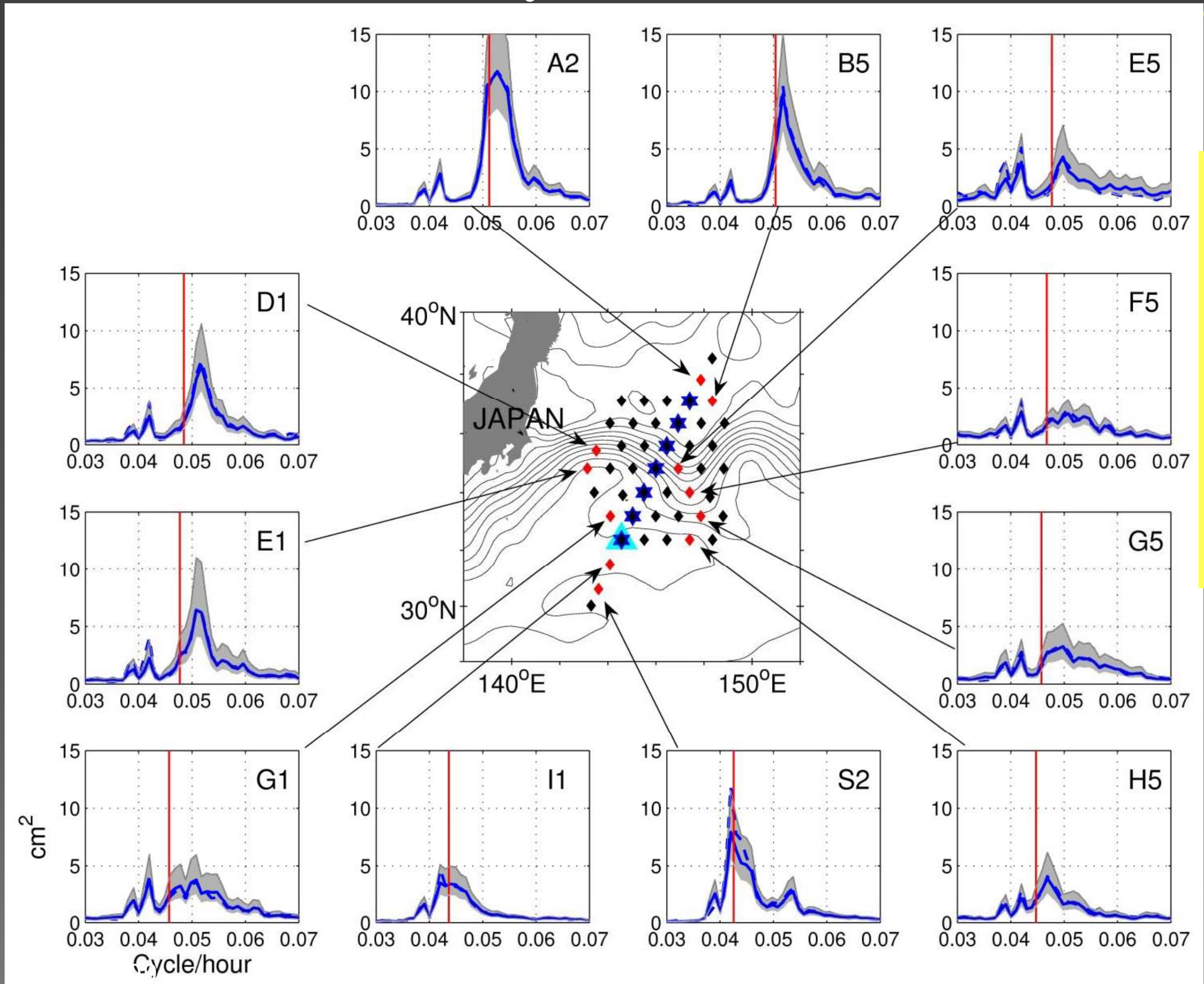
current

ML and Deep NIWs vs. SSH





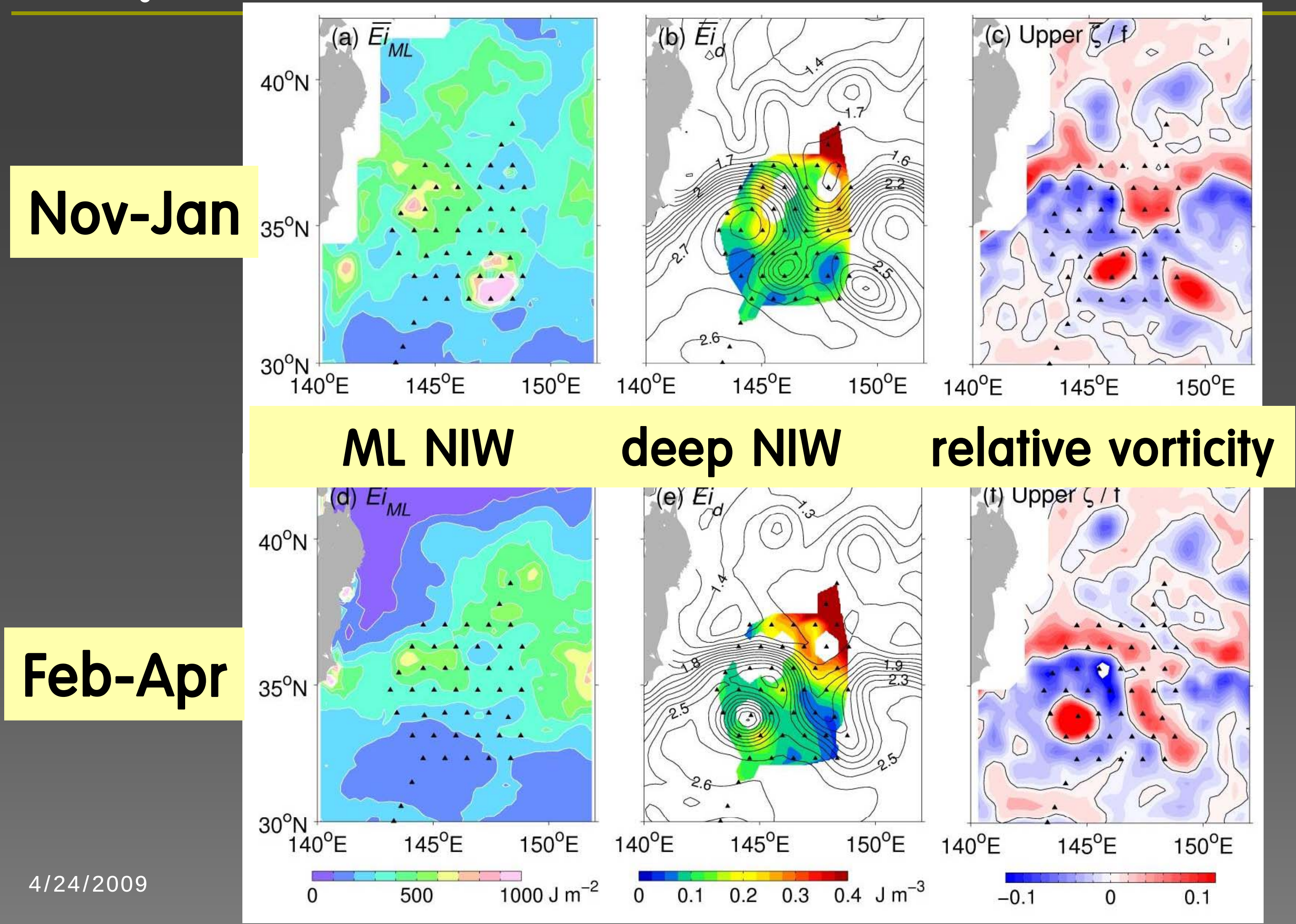
PSD of deep currents



North of the KE
⇒High PSD

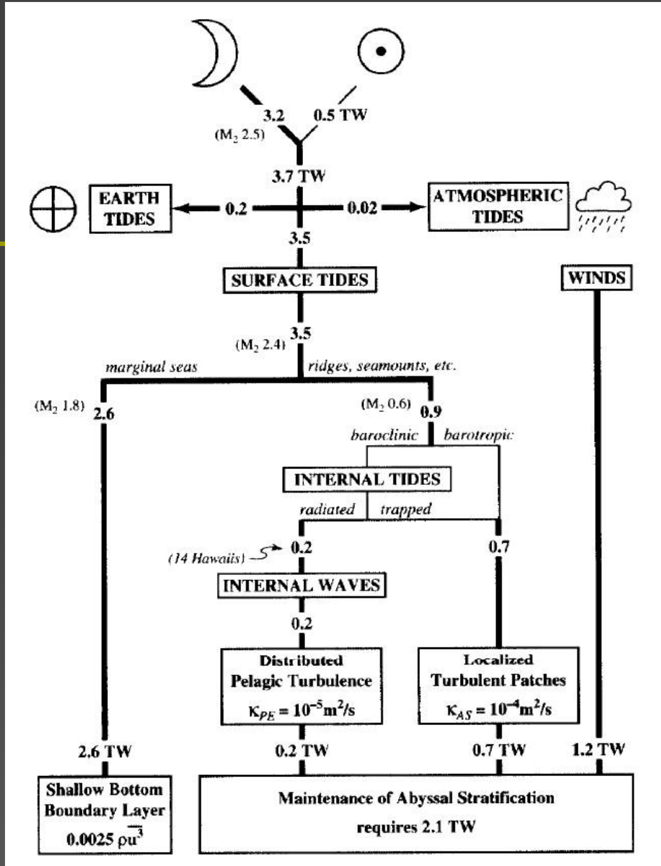
South of the KE
⇒Low PSD

Wintertime-mean upper and deep maps of NIWs vs. relative vorticity



Ocean needs 2.1 TW

- Ocean mixing maintains oceanic stratification and MOC
- Major energy source for mixing
  => Tides (0.9 TW) and
  winds (1.2 TW)
  by Munk and Wunsch (1998)
- Wind-induced near-inertial waves
  => 0.4-0.7 TW
  (e.g., Watanabe and Hibiya, 2002;
  Alford, 2003)



Munk and Wunsch (1998)