Global Mapping of Near-inertial and Tidal Internal Wave Propagation

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LONG-TERM GOALS

To understand the magnitude and distribution of internal-wave propagation and internal-wave-induced mixing.

OBJECTIVES

To use detect energy-flux associated with low-mode near-inertial and tidal propagation in moored current meter data at as many locations as possible.

To determine the degree to which energy-flux divergences (and therefore sites of enhanced dissipation) can be determined from this analysis.

To compute time-averaged spatial maps of near-inertial, internal-tidal and mesoscale energy from TOPEX/ POSEIDON altimetry, drifters, current meters and ADCP tracks.

To determine, within the context of Peter Muller's Internal Wave Action Model (IWAM, also supported by ONR), the extent to which these findings are consistent with existing internal-wave propagation theories.

To use large-scale and regional atmospheric models to examine the high-latitude and small-scale reliability, interannual variability, and convergences/divergences in the wind energy flux maps computed by Alford (2001, 2003).

APPROACH

To accomplish the long-term goal stated above, one could measure microstructure at every location on the planet (impossible). The alternate approach taken here is to map the sources of internal waves already begun by Egbert and Ray (2000) for tidal input, and by Alford (2001, 2003) and Watanabe and Hibiya (2002) for near-inertial input), and follow their subsequent propagation. Divergences in the internal-wave energy flux field must then correspond to energy sinks; i.e., regions of enhanced mixing.

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I have computed the energy flux in the near-inertial and tidal bands using historical moored records of velocity and temperature. Hundreds of records have been collected over the years. Kunze et al (2002) showed that energy-flux could be computed from full-depth records of velocity and isopycnal displacement. The approach taken here is first to band-pass moored records of velocity and temperature to either near-inertial or tidal frequencies. Isopycnal displacement is then estimated from temperature records via □=T'/(□T/□z). Time series of velocity and displacement for the first two baroclinic modes are estimated from the moored records using a least-squares fit. The pressure anomaly, p', is then estimated from the full-depth modal profiles of □ according to the methods of Kunze et al (2002), and the vector energy-flux computed from **F**=<**u**'p'>, where <> indicate averaging over a wave period.

WORK COMPLETED

I first improved upon the near-inertial flux maps of Alford (2001), extending them to higher latitude (Alford, 2003) and improving the underlying model. Then, global maps of energy flux in the near-inertial and tidal bands were computed from the 60 usable moorings. These findings were published in the journal Nature this spring (Alford, 2003b). Much has been learned along the way about the subtleties of the flux calculation, which will be submitted soon (Nash, J., MHA, and E. Kunze, in prep).

RESULTS

The results for both the near-inertial and tidal bands are shown in Figure 1. Several observations are immediately apparent:

1. Predominant near-inertial propagation is toward the equator, consistent with generation by wind at the local inertial frequency and subsequent propagation to regions of lower f. This has profound implications for our understanding of the global internal-wave field, and is in contrast with the model of Fu (1981), which attempted to explain the inertial peak by *poleward* propagation of super-inertial internal waves.
2. The magnitudes are of order 1 kWm^{-1}; the same order of magnitude as measured tidal fluxes (e.g. Ray and Cartwright, 2001, and lower panel). Therefore, near-inertial waves appear as important as the tides in transporting energy horizontally.
3. The fluxes in both bands are of sufficient magnitude to radiate substantial percentages (15-50%) of energy away from respective source regions (shown in color). Therefore, assuming that all energy input is dissipated at the source is not justified. Propagation is, in general, away from source regions, as expected.

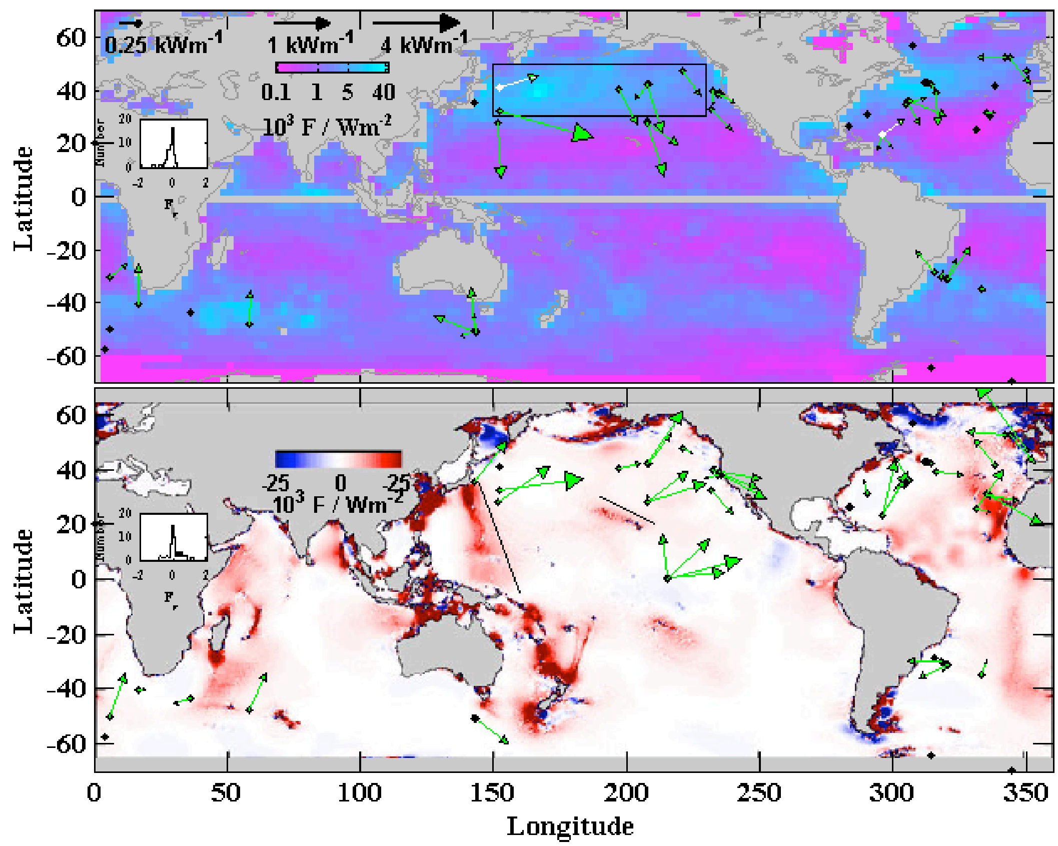

Figure 1: (a) Depth-integrated, annual-mean near-inertial energy-flux vectors for modes 1 and 2 from 60 historical moored records. The arrow lengths are logarithmic, with references indicated at upper left. Moorings with |F|< 0.1 kW m^{-1} appear as a black dot without an arrow. The few instances of poleward propagation are plotted in white. Colormap indicates annual-mean energy input from the wind to near-inertial mixed-layer motions. The color scale is logarithmic and is indicated at upper left. (b) As in (a) but for the semidiurnal band. Colormap denotes internal-tide conversion using the TPXO.5 model, courtesy of G. D. Egbert. (Insets) Histogram of the poleward flux component for all moorings. Flux uncertainties are ±▯50% (magnitude) and ± 30° (direction). For latitudes |▯| > 50° (e.g. northern European shelf), the frequency bands in (a) and (b) overlap, preventing their separation.

IMPACT/APPLICATIONS

The observed tendency for near-inertial energy flux to be directed toward the equator is extremely important, confirming idea of wind as a major source of internal waves. The observation of substantial fluxes in the near-inertial band is a major step toward understanding internal-wave-generated mixing. The tidal fluxes are already being used for comparison to altimetric and model estimates (Harper Simmons, pers. comm). As the database of observations grows, divergences in the energy flux maps should point to regions of high dissipation, guiding future observational efforts.

TRANSITIONS

Maya Whitmont's Ph.D. thesis will continue these analyses, attempting to form a global view of the energy fluxes to, through and out of the internal-wave field.

Peter Muller is enthusiastic about incorporation of these data into his ONR-funded Internal Wave Action Model (IWAM). As the reliability of this model grows, it may be useful in filling in data gaps evident in Figure 1.

RELATED PROJECTS

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