AESOP Internal Tides and Mixing

Final Report—ONR Physical Oceanography

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LONG-TERM GOALS

This project, with Eric Kunze at the University of Victoria (now at APL-UW), was undertaken as part of a Departmental Research Initiative (DRI) of the Office of Naval Research (ONR) entitled AESOP (Assessing the Effectiveness of Submesoscale Ocean Parameterizations). The principal goals of AESOP were to (a) increase the understanding of ocean dynamics—particularly processes that are not included or not resolved in numerical models—and (b) improve forecasts of ocean conditions. Our (Girton and Kunze) component of the experiment was focused on internal tides and mixing, both in terms of constraining the dominant mechanisms supplying energy for mixing in the ocean and for the purposes of explaining tidal and internal wave velocity variance in the coastal ocean.

OBJECTIVES

The principal tasks of AESOP were a set of ocean observations designed to evaluate submesoscale processes (including internal tides and small-scale fronts and eddies) in a suite of models of the coastal ocean around Monterey Bay. These observations formed metrics that could be used to test the representation of the processes in the models. In addition, model studies were undertaken to study the impact of those processes on the larger-scale fields.

The particular objectives targeted by our component of the experiment included:

- The characterization and understanding of the horizontal and vertical structure of the internal wave field in a region of coherent but weak internal tides, rough topography, and elevated internal wave continuum.
- The development of techniques for broad-scale characterization of internal tides in the ocean, using both in-situ (ship-lowered, expendable, or moored) and remote sensing (satellite, HF RADAR) technologies.

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- The testing of numerical predictions of internal tide generation, propagation, and dissipation.
- The estimation of rates of internal wave spectral energy transfer through critical reflection, topographic generation, and boundary and internal dissipation.
- The comparison of mixing estimates with diffusivities and turbulent fluxes from regional numerical models with a view toward determining the impact of internal waves on simulated distributions of temperature and salinity.
- The use of this information to guide improvements in mixing parameterizations, leading to improved predictions of oceanic properties and air-sea fluxes.

APPROACH

Our approach included a set of targeted observations over the continental slope south of Monterey Bay in September 2006, coupled with analysis of other tide-resolving data from the region (Fig. 1). The location for the field work was selected on the basis of numerical model results suggesting that the internal tides in Monterey Canyon seen by Kunze et al. (2002) originated from the submarine ridge west of Point Sur (Jachec et al., 2006).

Profiling instruments used in the 2006 survey on the R/V *Point Sur* included the XCP (expendable current profiler), a rapid-surveying tool providing a full water column (up to 2000 m) profile of temperature and instantaneous horizontal water velocity; VMP (vertical microstructure profiler) a loosely-tethered profiler capable of making hourly profiles of T, S and turbulent dissipation to 1000 m, depending on wind and sea state; EM-POGO, a low-cost free-falling, recoverable, full-water column velocity and temperature profiler; CTD/LADCP (a single 300 KHz Workhorse ADCP mounted on the ship's CTD package), providing full water column measurements of T, S and water velocity, as well as dissolved oxygen, chlorophyll fluorescence, and light transmission; and finally the vessel-mounted 75 KHz and 300 KHz ADCP (acoustic Doppler current profiler), returning profiles of water velocity to 400 m and 100 m, respectively (typically in 5-min averages). In addition the R/P *FLIP* was moored for 16 days near the center of our survey pattern after the survey was completed, providing highly-resolved timeseries of velocity, T and S variability over 80% of the water column.

Graduate student Samantha Terker (née Brody) conducted a large part of the analysis of the profiling survey and *FLIP* measurements as part of her Ph.D. research (Terker et al., 2012; Terker, 2012).

A complementary portion of our effort involved the use of wide-area and long-duration measurements of internal tides by satellite altimetry, HF RADAR (HFR), and moorings. APL Oceanographer Zhongxiang Zhao was primarily responsible for this work, which meshed well with his ongoing development of techniques for extracting internal tides from remotely-sensed and mooring data (Zhao and Alford, 2009; Zhao et al., 2010). The work on this project included both developing refinements of the altimetric techniques and regional compilation of data from HFR sites (Paduan and Rosenfeld, 1996; Paduan and Cook, 1997) and multi-month moorings (Ramp et al., 1997; Tisch and Ramp, 1997) shown in Figure 1.

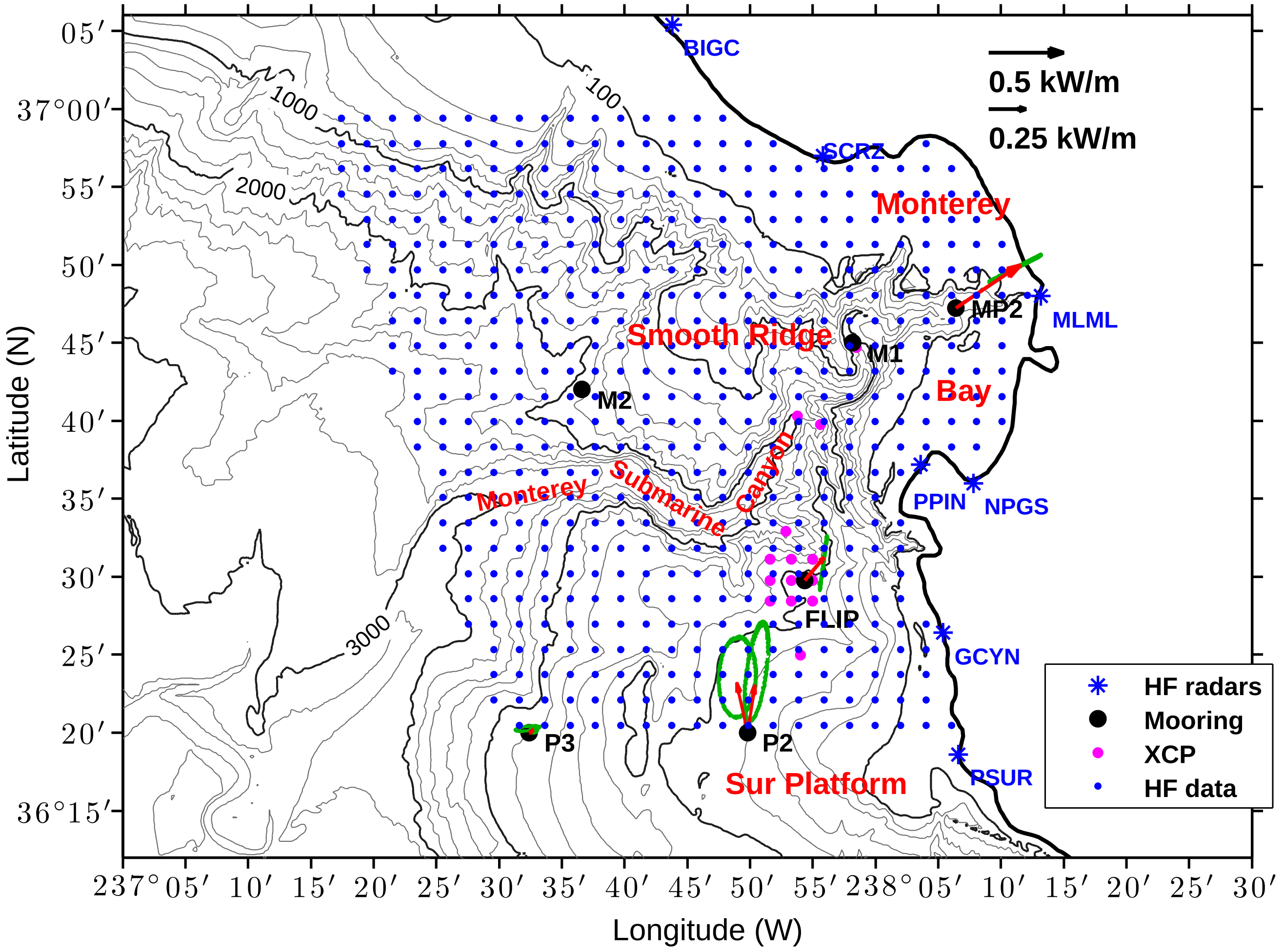

Figure 1: Chart showing the bathymetry of the Monterey Bay region and locations of internal tide observations used in this report, including moorings (black dots), HF RADAR (HFR; antennas at blue stars; measurements at blue dots), and the 2006 AESOP XCP survey (pink dots). Moorings P2 and P3 were multi-year current-meter deployments by the Naval Postgraduate School (Ramp et al., 1997; Tisch and Ramp, 1997). M1 and M2 are ongoing upper-ocean ADCP and current-meter moorings maintained by MBARI. MP2 was a 4-week moored-profiler deployment as part of a process study in Monterey Canyon (Wain et al., 2012). FLIP was moored near the center of the XCP box for 2 weeks as part of AESOP, beginning several days after the XCP survey. In addition, first-mode semidiurnal (M_2+S_2) internal tide energy fluxes are shown for selected mooring locations (with red arrows showing time-mean flux, and green ellipses indicating the 14-day spring-neap cycle).

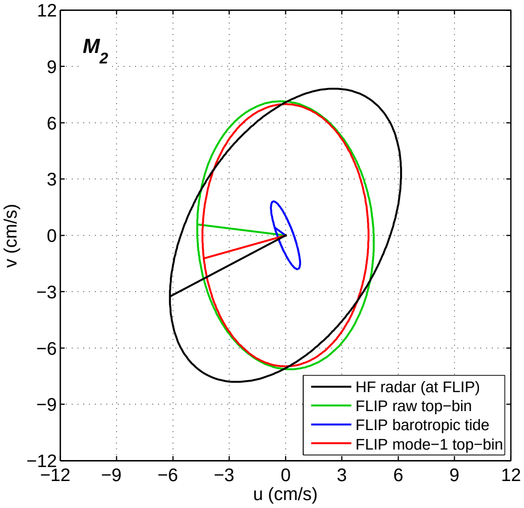

Figure 2: Comparison between M_2 (12.4-hour period) tidal currents observed by HFR and FLIP. Amplitude and polarization are indicated by the ellipses, and phase is indicated by the radial lines. The FLIP surface current (green) is significantly larger than the barotropic tide (blue, which closely matches the TPXO prediction—not shown) and is essentially identical to the surface value of the first-mode baroclinic (internal) tide (red). At this location, then, the HFR surface current (black) agrees well in both amplitude and phase with the first-mode internal tide.

WORK COMPLETED

The field experiment was conducted during a 10-day cruise on the R/V *Point Sur* (10–19 August 2006) concurrent with several other cruises making up the AESOP field experiment in Monterey Bay. A full description of the activities can be found in the cruise report, available online at `http://charybdis.apl.washington.edu/aesop/cruisereport.pdf`. A brief summary is as follows:

- A 3x3 grid (box) of XCP profiles (magenta dots in Fig. 1), occupied 5 times over semidiurnal tidal cycles on two consecutive days, sampled the full range of tidal phase, allowing a 3-D picture of the internal wavefield to be constructed;
- an additional high-resolution (half-hourly) XCP timeseries was made at one of the box stations on the following day. Fig. 5a and b illustrate the resulting sampling patterns at the box and timeseries stations, respectively;
- CTD/LADCP and EM-POGO timeseries were collected at sites bracketing the box to the north and south, as well as in a few stations at the mouth and interior of Monterey Canyon;
- 12-hour VMP timeseries were collected each night; and
- under-way meteorological and near-surface oceanographic data were collected along the entire cruise track.

In addition, a regional compilation of mooring and HFR data, together with the *FLIP* timeseries was used to explore the imprint of internal tides in the surface currents. Figures 2 and 3 show the agreement of tidal constituents in the moorings and HFR to be quite good, with the surface velocity dominated by

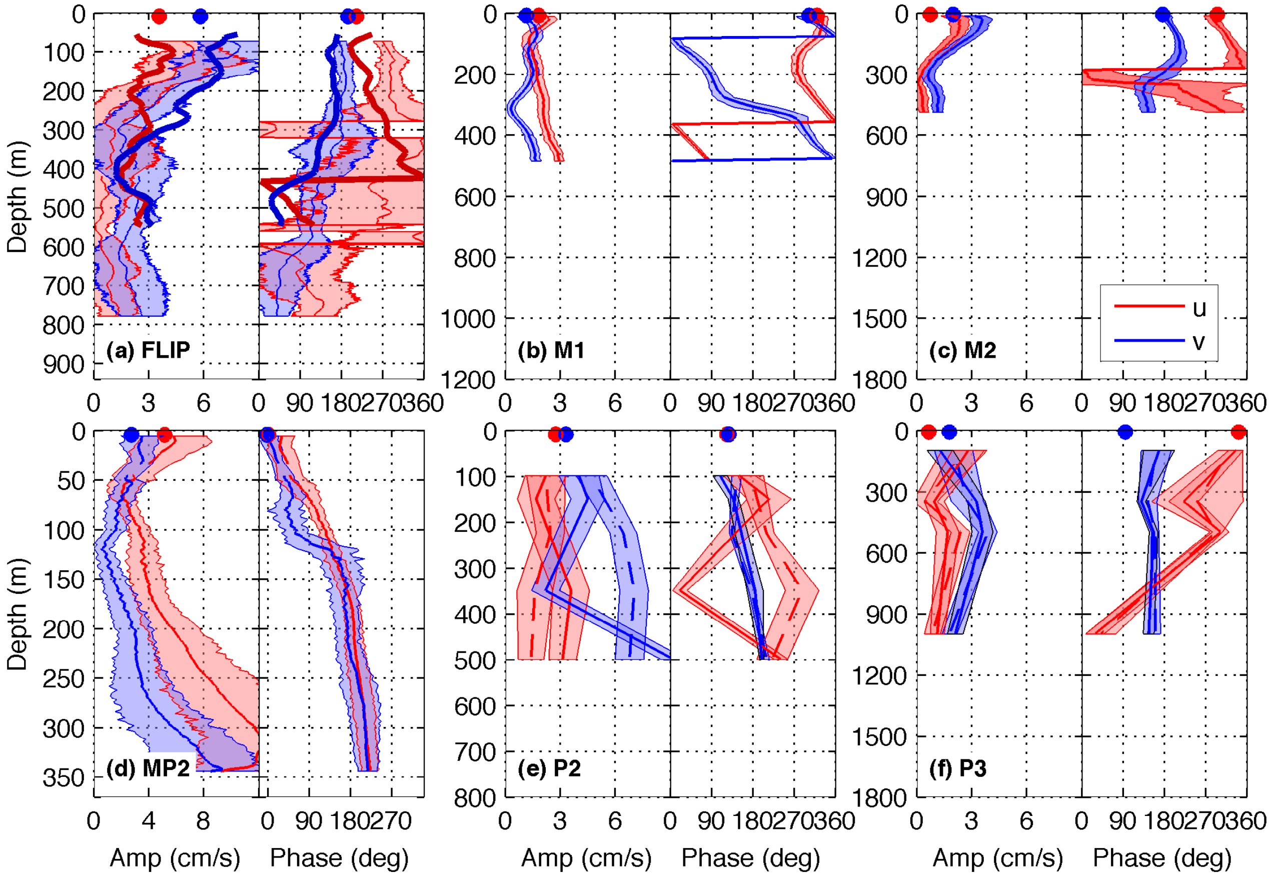

Figure 3: Additional comparisons between tidal currents observed by subsurface moorings (locations shown in Fig. 1) and nearby surface HFR points. Subsurface amplitude and phase of M_2-frequency east (red) and north (blue) velocity components are shown as profiles with 95% confidence interval shading. HFR values are shown as dots at the surface in each panel and, in general, agree quite well with the shallowest mooring values.

the low-mode internal tide. This enables the continued use of HFR data to investigate the structure of the internal tide in the region.

Analysis of internal wave signals in the *Point Sur* in-situ survey data focused on characterizing the semidiurnal tide. A complicating factor in this was the existence of diurnal baroclinic signals (related to sub-inertial coastally-trapped waves rather than freely-propagating internal waves) that were not well resolved by the sampling strategy and which added considerable uncertainty to the semidiurnal results. By sub-sampling the *FLIP* data it was nevertheless possible to develop appropriate uncertainty estimates for the semidiurnal flux estimates (Figures 4 and 5).

RESULTS

The major results of this work include the following:

- Measurements in the internal tide beam from the Sur Ridge (Fig. 4, south of Monterey Bay) are

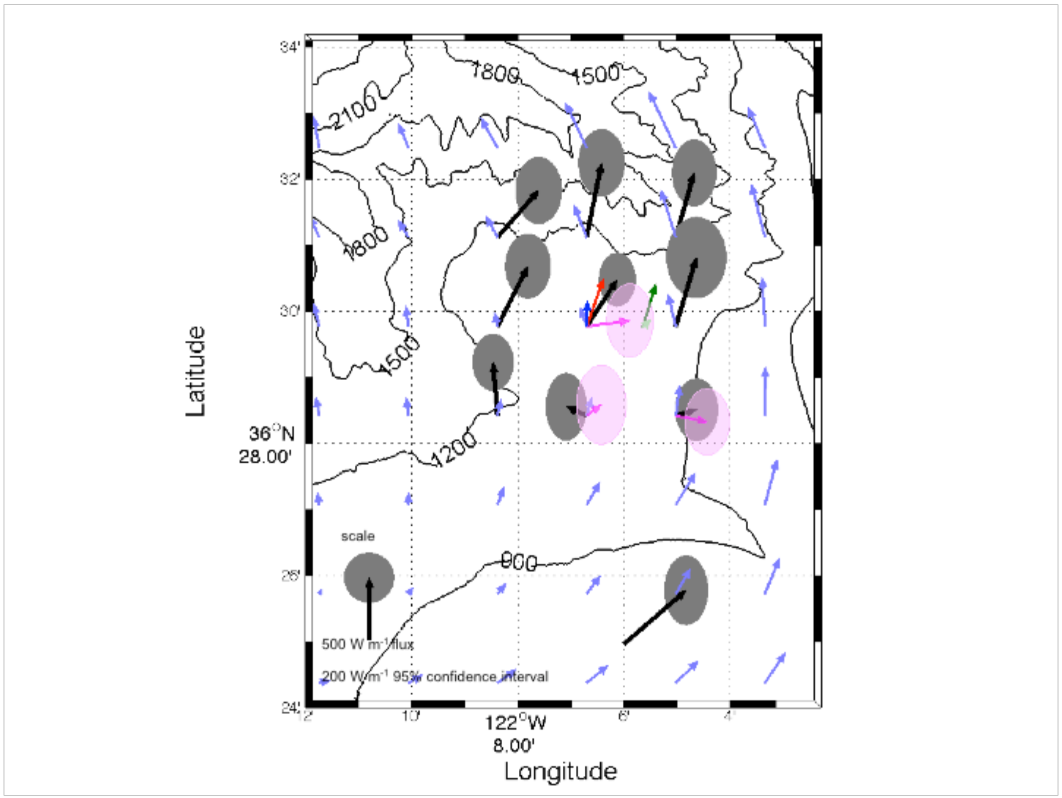

Figure 4: Depth-integrated semidiurnal internal tide energy flux from the AESOP XCP survey with uncertainty ellipses (Terker et al., 2012). Black arrows with gray ellipses indicate the best-possible flux estimates at all stations, including three more heavily-sampled stations (as shown in Fig. 5b). Magenta arrows with pink ellipses are the results at these three stations using only the sparsely-sampled first two days of the box survey (as in Fig. 5a, and, therefore, more directly comparable to the results at the other stations). The red arrow is the mean over all 9 stations in the 3x3 box. The light green and dark green arrows, respectively, are the time-mean and maximum (spring-tide) semidiurnal fluxes observed by **FLIP**. ***Blue arrows are from the Carter (2010)*** M_2***-only numerical model (with the dark blue arrow at the center of the box indicating the mean over the box).***

consistent with model results suggesting that this is the major source for the internal tide energy in Monterey Canyon.

- Measured internal tide energy fluxes can be influenced by coastally-trapped propagating waves below the local inertial frequency (as shown by the energy flux of diurnal motions in the *FLIP* measurements and accompanying errors in the 12-hour sampled XCP survey, Fig. 5).
- Even within a coherent internal tide beam, interference among multiple sources can produce variability over relatively short (relative to the mode-1 wavelength) spatial scales. A plausible explanation for the weak northward energy fluxes observed in the southeast portion of the box is interference between waves from the Sur Platform and Sur Ridge, as illustrated by Figure 6 (Terker et al., 2012).
- Tides in HFR surface currents are compatible with subsurface mooring observations and tend to be dominated by internal (baroclinic) tides rather than the barotropic tide (Figs. 2 and 3).

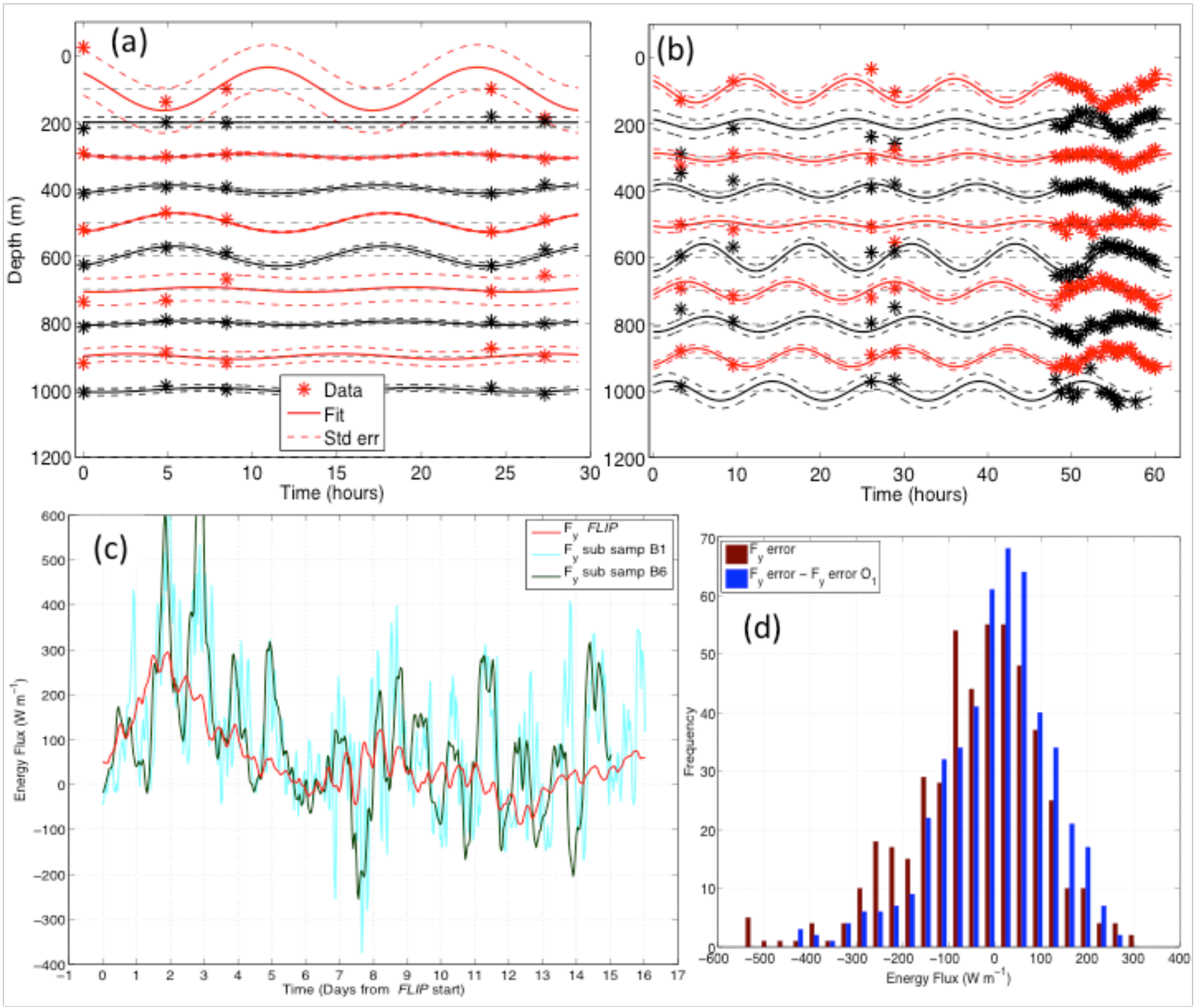

Figure 5: Illustration of the technique used for computing uncertainty ellipses in Fig. 4. The FLIP data were subsampled using the temporal sampling pattern at each XCP station (generally two 12-hour periods separated by a 12-hour gap, as for station B1 shown in panel a, but more at a few stations, as for station B6 shown in panel b). Energy flux is computed by fitting a semidiurnal (M_2) cycle to the subsampled velocity and pressure at each depth, then averaging $v'p'$ in time. Panel c: Timeseries of depth-integrated energy flux from the subsampling (cyan and black curves) are compared with the "true" semidiurnal energy flux timeseries using a 48-hour (fully-sampled) sliding window (red). Panel d: Histogram of the resulting error in northward flux (magenta) and the minor modification resulting from removing the deterministic O_1 diurnal cycle of the error (blue). From Terker et al. (2012).

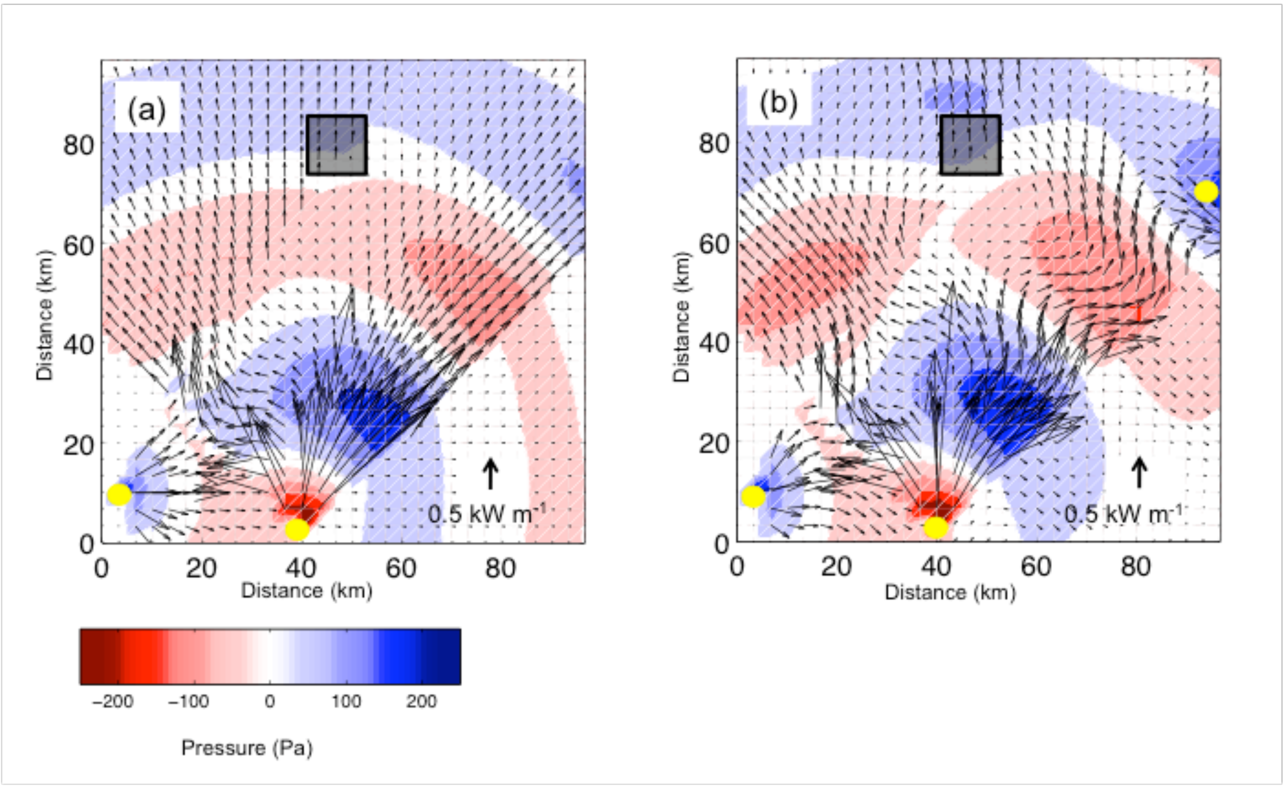

Figure 6: Example 2 and 3-wave interference patterns that could explain the small-scale variability in the Fig. 4 fluxes. Azimuthally-limited radially-spreading first-mode internal tide sources (yellow dots) are superimposed and the resulting time-averaged energy fluxes computed, following Rainville et al. (2010). The sources are meant to represent the locations of the Sur Platform and Sur Ridge, as well as a possible third source at the Monterey shelf-break. Pressure (colors) and energy fluxes (vectors) are shown, illustrating regions of both positive and negative interference as well as sharp changes at the edges of beams. Despite the large variability in flux magnitude and direction, it can be shown analytically that the divergence resulting from this interference pattern is identically zero. From Terker et al. (2012).

Although the baroclinic modal content and barotropic-to-baroclinic ratio are quite spatially variable, the dominance of the internal tide is supported by the similarity of tidal patterns in HFR and satellite altimetry (Fig. 7).

- The surface signature of internal tides in at least the first 3 baroclinic modes can be clearly identified in satellite altimetry in the deep ocean (Fig. 8). A similar situation is expected for HFR in the coastal ocean.
- Internal tide energy flux patterns can be clarified and enhanced by fitting multiple waves to spatial data (Fig. 9 and 10). This method has been developed with satellite altimetry, including multiple altimeter satellites and track patterns, and transitioned to use with HFR. It is also being explored for application to NASA's upcoming wide-swath altimeter mission (SWOT) to enable removal of internal tides for the better study of non-tidal submesoscale phenomena.
- The isolation of the first-mode internal tide in HFR requires the identification of statistically-significant gradients in tidal *phase* matching the modal phase speed. In the HFR case

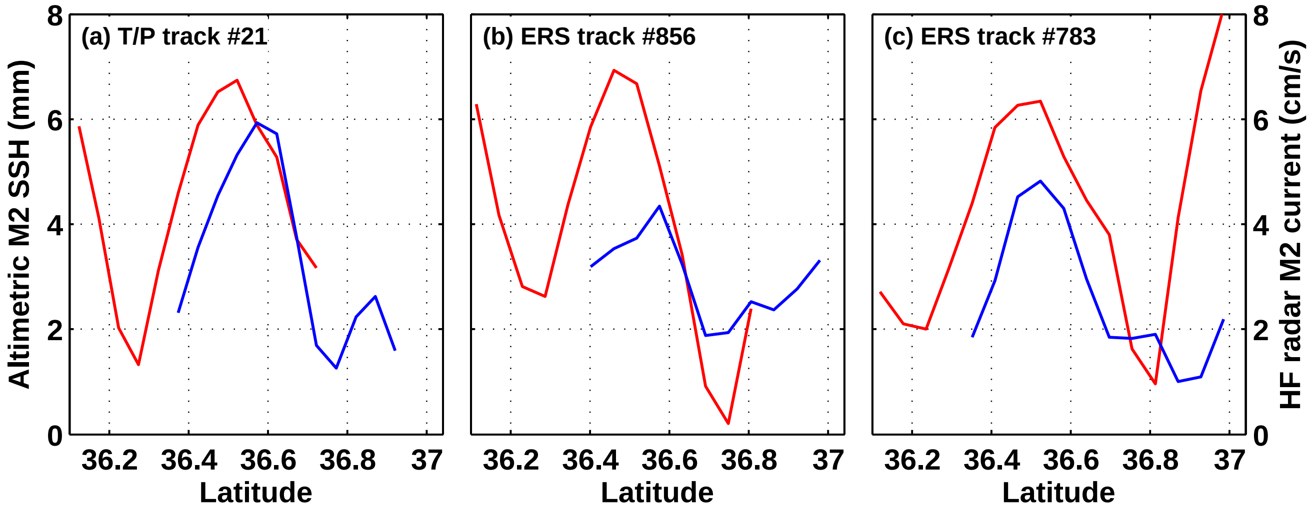

Figure 7: Comparison between M_2 tide amplitudes estimated from satellite altimetry (SSH, red) and HFR (velocity major axis, blue), sampled along particular altimeter tracks.

of well-constrained phase estimates and closely-spaced measurements, this allows for significantly finer resolution than the internal tide wavelength and much potential improvement over the altimeter maps (Fig. 11).

- The internal tide in the Monterey Bay region has identifiable sources and beams but also complex regions of interference among multiple waves (Fig. 12a). Figure 12b shows the coherent phase propagation along the beam from the Sur Ridge, while Figure 6 illustrates the types of patterns achievable by internal wave interference.
- Within the simpler "beam-like" regions, low-frequency variations in the internal tide can be identified and tied to seasonal or fortnightly cycles in stratification or forcing (Fig. 13).

IMPACT/APPLICATIONS

This work has led to improved appreciation of the complexities of the internal wave field and its interaction with topography on undersampled continental margin environments. While it has been suggested that continental margins might be hotspots for turbulent mixing based on sparse sampling, the microstructure data collected during AESOP indicate that this is not true everywhere. Nevertheless, the continental margins are an important transition space between the deep oceans, where long-range internal wave propagation is typical, and the shelf, where internal tides become even more complex and linear waves are less-easily identifiable. Since much of continental slope contains rough topography suitable for internal tide generation, as well as canyons where energy is often dissipated (Kunze et al., 2012), the experience understanding the Monterey slope is a valuable guide to both the identification of tidal signals within the Bay and Canyon and to future study.

In order to explore these applications, P.I. Girton organized a special session on "Boundary Mixing and Interior Exchange" along with colleague Erika McPhee-Shaw at the 2010 Ocean Sciences meeting in Portland, OR.

And, finally, the AESOP project formed a major part of APL-UW student Samantha Terker's Ph.D.

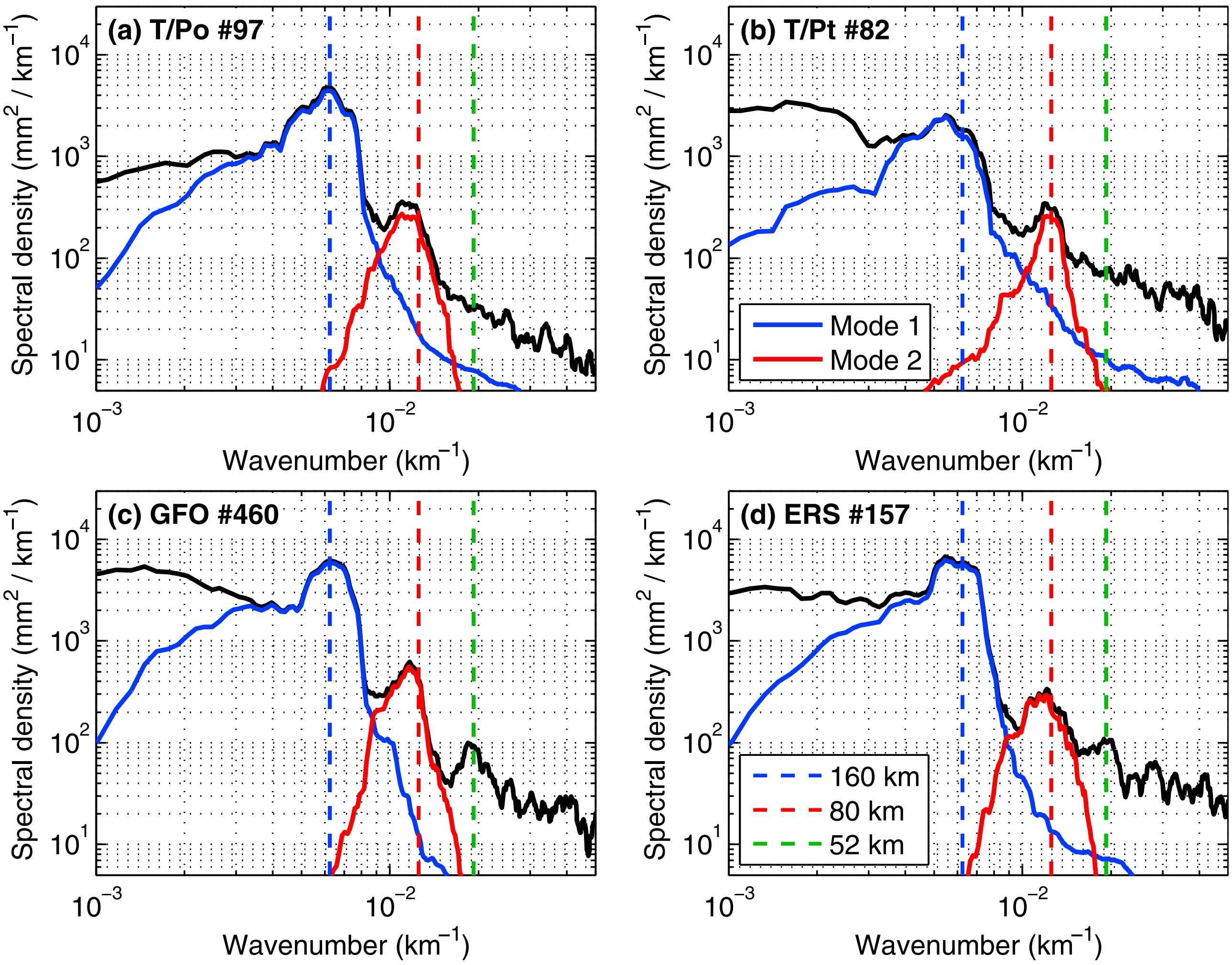

Figure 8: Along-track wavenumber spectra of the M_2 tidal harmonic of SSH from satellite altimetry, demonstrating the presence of internal tides in the first (blue), second (red), and third (green) baroclinic modes. Dashed lines indicate modal wavelengths, and solid curves are band-passed spectra. From Zhao et al. (2011).

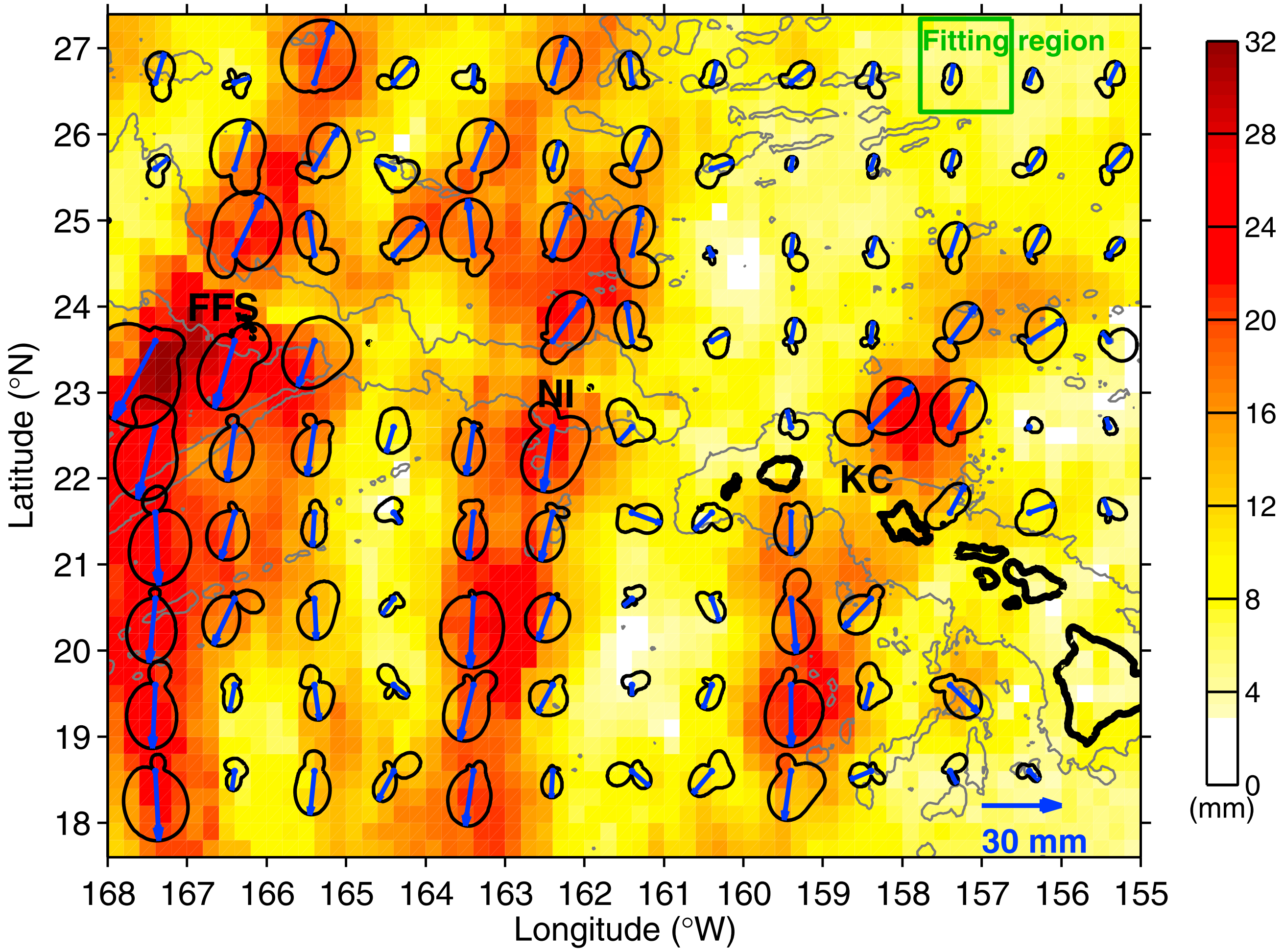

Figure 9: Beam patterns around the Hawaiian Ridge, derived from plane-wave fitting within a sliding window (green box). These beam patterns are used to generate energy flux maps as shown in Fig. 10 as well as to qualitatively evaluate the dominant internal tide source locations and interference patterns. From Zhao et al. (2011).

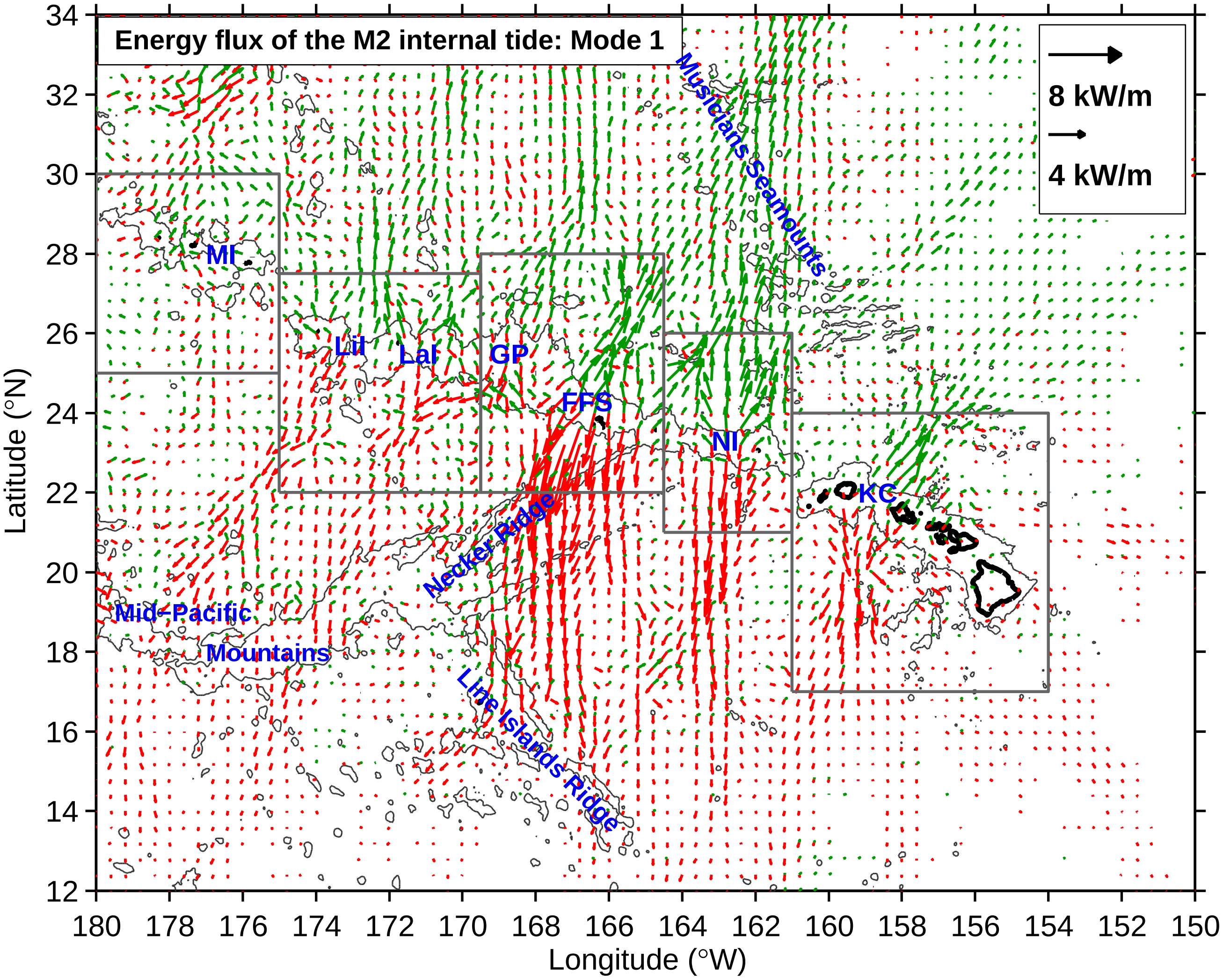

Figure 10: Hawaiian Ridge first-mode internal tide energy-flux estimated from multi-satellite altimetry. From Zhao et al. (2011).

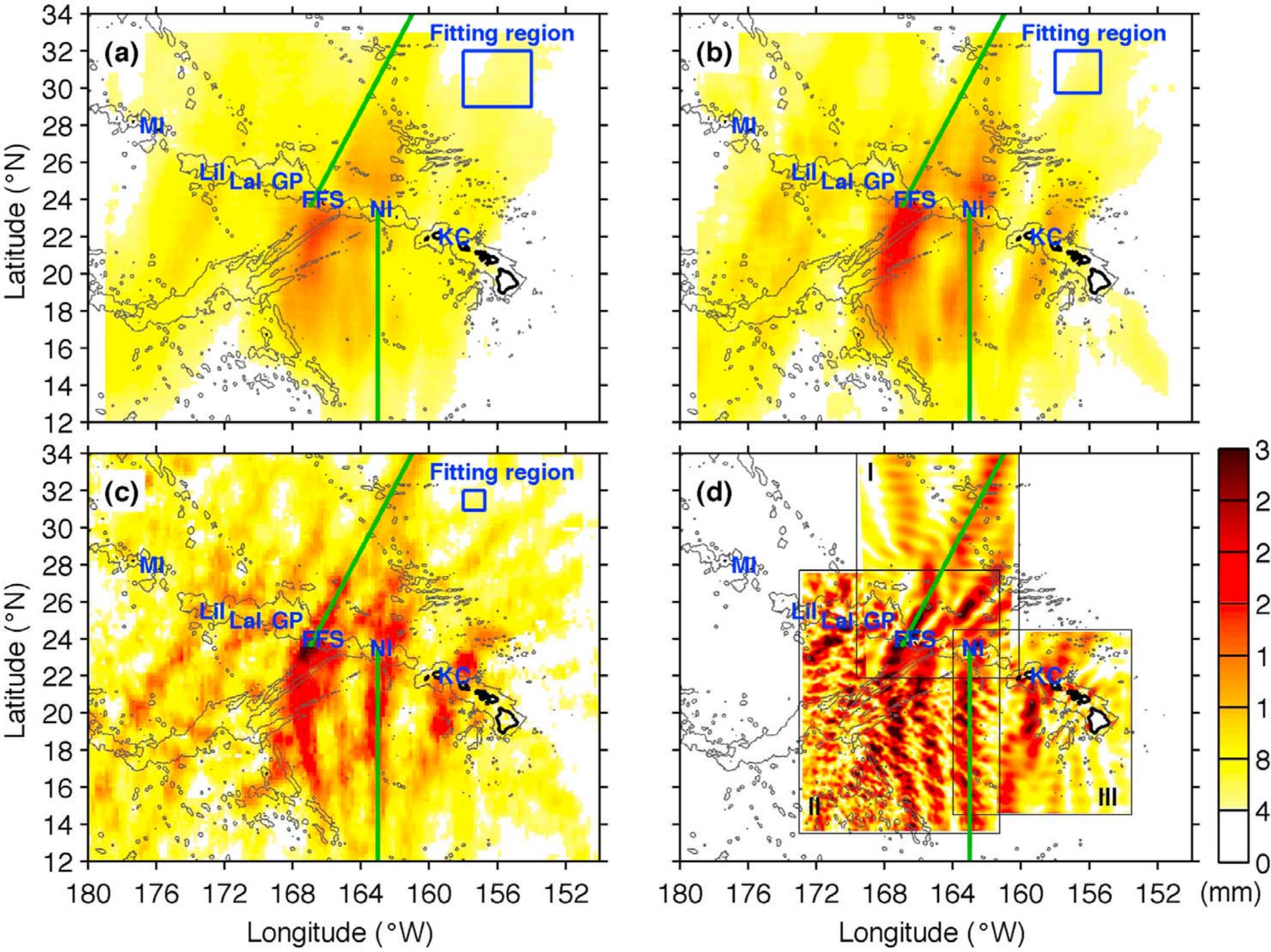

Figure 11: Influence of window size on altimetric internal tide maps. Panels a–c illustrate the first-mode M_2 internal tide surface height amplitude estimated using progressively smaller plane-wave fitting windows. Smaller window sizes lead to greater detail in the beam patterns (apparently converging toward the model-based estimate shown in panel d) and a larger net flux (because of the dependence of energy flux on the square of the amplitude). From Zhao et al. (2011).

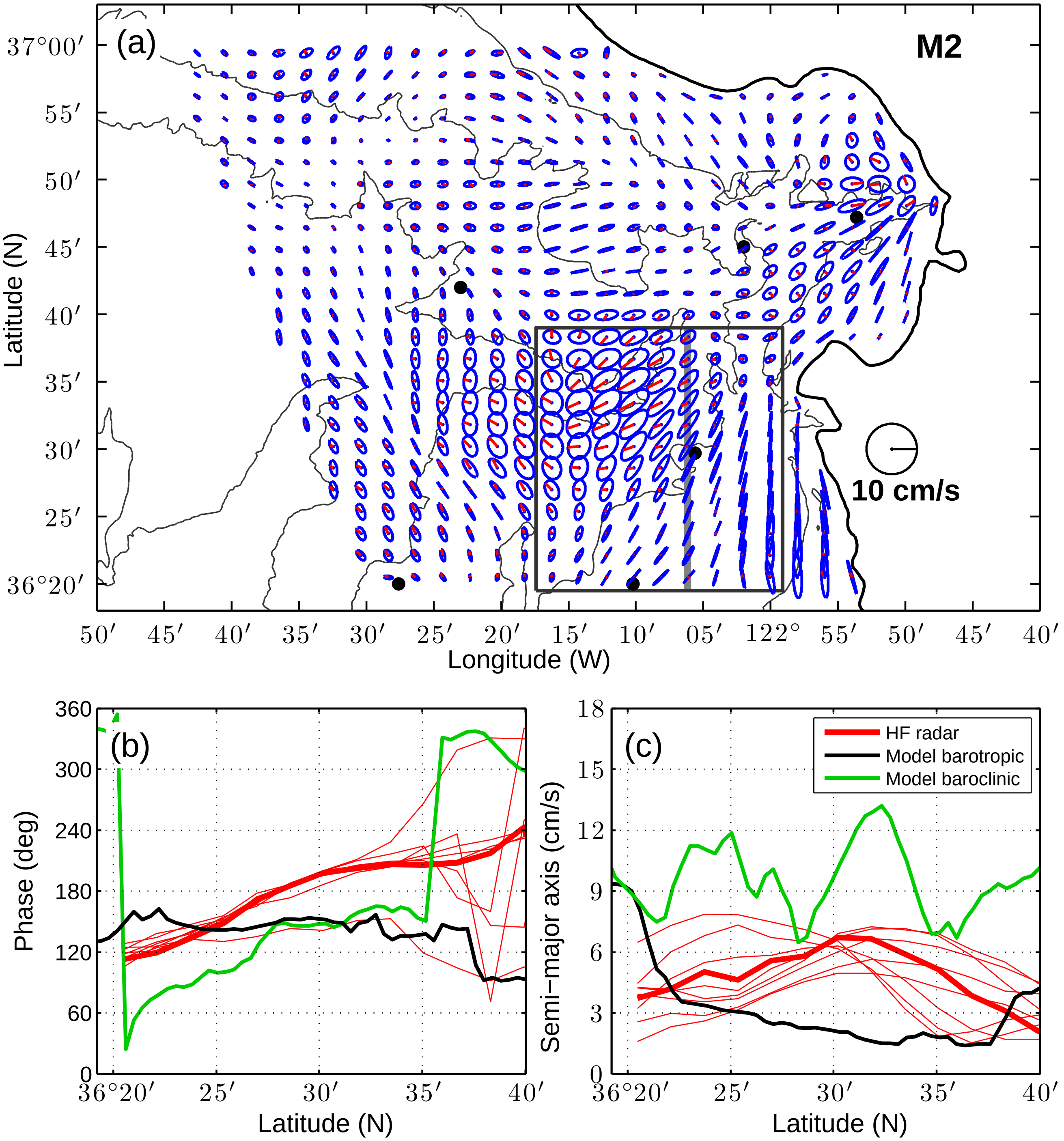

Figure 12: M_2 amplitude and phase in HFR surface currents around Monterey Bay, focusing on the region around the AESOP XCP survey and FLIP deployment. The northward increase in phase shown in panel b indicates that the HFR is observing the internal tide beam from the Sur Platform. Green and black lines in panels b and c show the baroclinic and barotropic tide constituents in the Carter (2010) model.

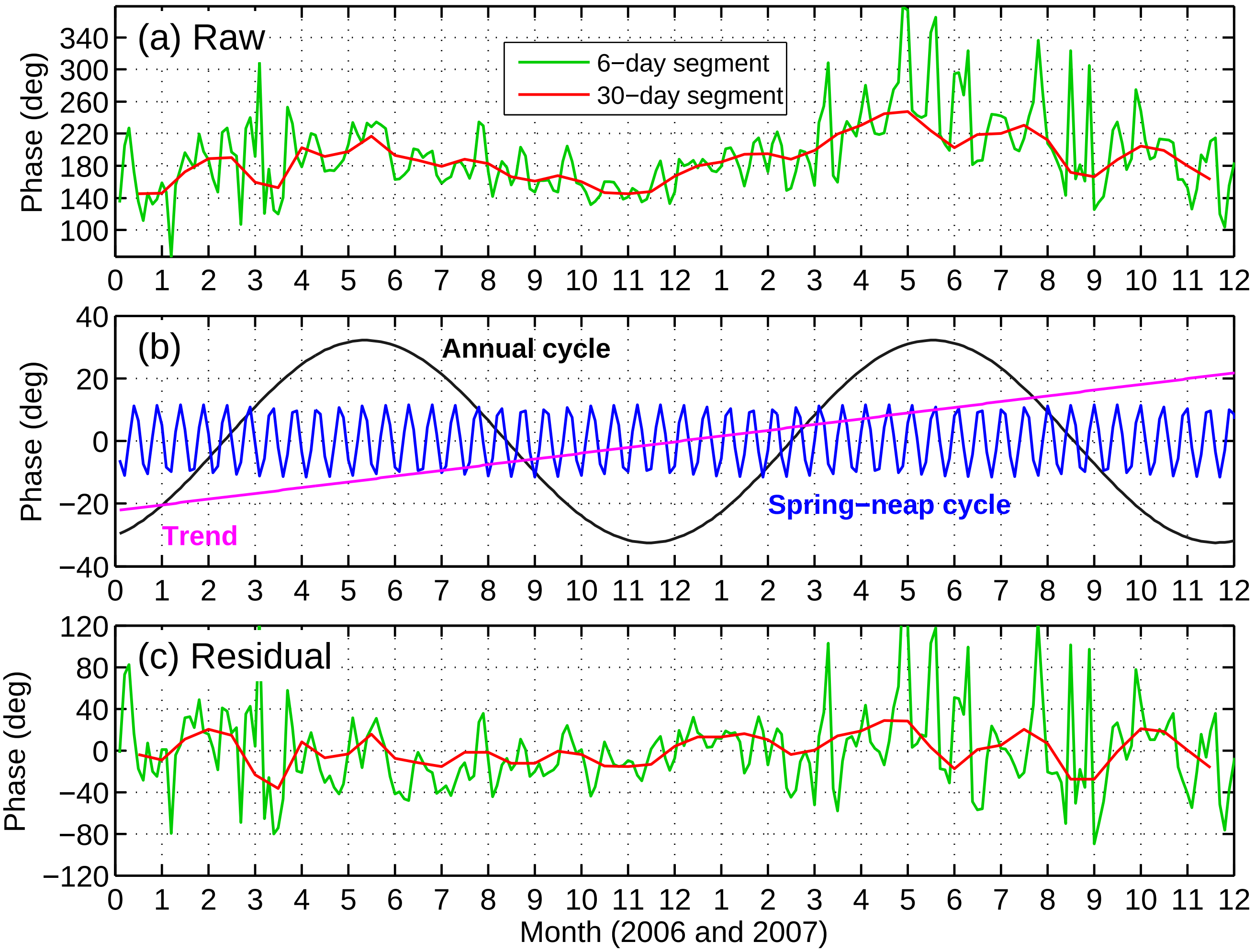

Figure 13: Phase of the HFR M_2 harmonic at the FLIP/XCP site along the northward beam from the Sur Platform, illustrating low-frequency modulations at annual and shorter periods. Causes of the variations may include changes along the propagation path (such as the impact of seasonal stratification variations on internal tide phase velocity), changes at the generation site (including the modulation of semidiurnal phase caused by the spring-neap cycle), or time-varying interference among multiple generation sites.

thesis. Additional portions of Dr. Terker's thesis include closely-related related work on the internal tide in Monterey Submarine Canyon (Terker, 2012) and a description of an electromagnetic profiler, the EM-POGO, used during the 2006 AESOP cruise on the R/V *Point Sur* (Terker et al., 2011).

TRANSITIONS

Although this basic research project is not expected to lead directly into commercial or military applications, the knowledge gained on coastal internal tides is contributing to further research and development of parameterizations for numerical models. In particular, a new project by graduate student Brian Chinn at APL-UW (co-advised by Girton and M. Alford) is exploring the properties of internal wave wavenumber–frequency spectra in a variety of regions, including Monterey Bay. Results from several recent internal tide experiments by Girton, Alford, and Kunze have influenced his choice of strategies. In addition, internal wave related parameterizations for large-scale climate models are under development by a Climate Process Team led by Jennifer MacKinnon at Scripps Institution of Oceanography. Girton and Kunze are both involved in an advisory sense.

RELATED PROJECTS

Through the course of planning the AESOP DRI, this project was closely-coordinated with companion projects by R. Pinkel and J. Klymak (R/P *FLIP* measurements) and D. Rudnick and S. Johnston (R/V *Wecoma* measurements using SeaSoar, described by Johnston et al. (2011)), as well as with the modeling efforts led by O. Fringer (Stanford), I. Shulman (NRL), and Y. Chao (JPL). Post-cruise collaboration was most closely carried out with the *FLIP* team and the Stanford modeling group, as well as subsequent modeling by Glenn Carter and Rob Hall (Univ. Hawaii).

Subsequent work on internal tides in Monterey Submarine Canyon has been undertaken through two NSF-sponsored studies by APL-UW investigators. Field work in these projects took place in August 2008 (Girton, McPhee-Shaw, and Kunze) and in 2009 (Gregg, Carter, Alford, and Lien). In addition, Z. Zhao's work on mapping of global internal tides with satellite altimeter data is continuing through an NSF grant.

PUBLICATIONS

Publications specifically arising from this work include Terker et al. (2012), Terker (2012), Zhao et al. (2011), Rousseau et al. (2010), and a manuscript in prep (Zhao and Girton, "Coastal internal tides observed with high-frequency RADARs").

REFERENCES

Carter, G. S. (2010). Barotropic and baroclinic M_2 tides in the Monterey Bay region. *J. Phys. Oceanogr.*, 40(8):1766–1783.

Jachec, S. M., Fringer, O. B., Gerritsen, M. G., and Street, R. L. (2006). Numerical simulation of internal tides and the resulting energetics within Monterey Bay and the surrounding area. *Geophys. Res. Lett.*, 33:L12605.

Johnston, T. M. S., Rudnick, D. L., Carter, G. S., Todd, R. E., and Cole, S. T. (2011). Internal tidal beams and mixing near Monterey Bay. *J. Geophys. Res.*, 116(C3).

Kunze, E., MacKay, C., McPhee-Shaw, E. E., Morrice, K., Girton, J. B., and Terker, S. R. (2012). On turbulent mixing and exchange with interior waters on sloping boundaries. *J. Phys. Oceanogr.*, in press.

Kunze, E., Rosenfeld, L. K., Carter, G. S., and Gregg, M. C. (2002). Internal Waves in Monterey Submarine Canyon. *J. Phys. Oceanogr.*, 32:1890–1913.

Paduan, J. D. and Cook, M. S. (1997). Mapping surface currents in Monterey Bay with CODAR-type HF radar. *Oceanography*, 10(2):49–52.

Paduan, J. D. and Rosenfeld, L. K. (1996). Remotely sensed surface currents in Monterey Bay from shore-based HF radar (coastal ocean dynamics application radar). *J. Geophys. Res.*, 101(C9):20669–20686.

Rainville, L., Johnston, T. M. S., Carter, G. S., Merrifield, M. A., Pinkel, R., Worcester, P. F., and Dushaw, B. D. (2010). Interference pattern and propagation of the M2 internal tide south of the Hawaiian Ridge. *J. Phys. Oceanogr.*, 40(2):311–325.

Ramp, S. R., Rosenfeld, L. K., Tisch, T. D., and Hicks, M. R. (1997). Moored observations of the current and temperature structure over the continental slope off central California 1. A basic description of the variability. *J. Geophys. Res.*, 102(C10):22,877–22,902.

Rousseau, S., Kunze, E., Dewey, R., Bartlett, K., and Dower, J. (2010). On turbulence production by swimming marine organisms in the open ocean and coastal waters. *J. Phys. Oceanogr.*, 40(9):2107–2121.

Terker, S. R. (2012). *Measurements and analysis of the internal tide in the Monterey Bay region*. PhD thesis, University of Washington.

Terker, S. R., Girton, J. B., Kunze, E., Klymak, J. M., and Pinkel, R. (2012). Observations of the internal tide on the California continental margin near Monterey Bay. *Cont. Shelf Res.*, accepted.

Terker, S. R., Sanford, T. B., Dunlap, J. H., and Girton, J. B. (2011). The EM-POGO: A simple, absolute velocity profiler. *Deep-Sea Res. II*, submitted.

Tisch, T. D. and Ramp, S. R. (1997). Moored observations of the current and temperature structure over the continental slope off central California 2. The energetics of the flow off point sur. *J. Geophys. Res.*, 102(C10):22,903–22,920.

Wain, D., Gregg, M. C., Alford, M. H., Carter, G. S., and Hall, R. (2012). SWIMS survey of internal tide in Monterey Submarine Canyon. *J. Geophys. Res.*, submitted.

Zhao, Z. and Alford, M. H. (2009). New Altimetric Estimates of Mode-1 M2 Internal Tides in the Central North Pacific Ocean. *J. Phys. Oceanogr.*, 39(7):1669–1684.

Zhao, Z., Alford, M. H., Girton, J. B., Johnston, T. M. S., and Carter, G. (2011). Internal tides around the Hawaiian Ridge estimated from multisatellite altimetry. *J. Geophys. Res.*, 116(C12039).

Zhao, Z., Alford, M. H., MacKinnon, J. A., and Pinkel, R. (2010). Long-range propagation of the semidiurnal internal tide from the Hawaiian Ridge. *J. Phys. Oceanogr.*, 40(4):713–736.

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The principal tasks of AESOP were a set of ocean observations designed to evaluate submesoscale processes (including internal tides and small-scale fronts and eddies) in a suite of models of the coastal ocean around Monterey Bay. These observations formed metrics that could be used to test the representation of the processes in the models. In addition, model studies were undertaken to study the impact of those processes on the larger-scale fields.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
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