Scaling of Langmuir Circulation:
Field Work of Opportunity

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LONG-TERM GOALS

The goal is to understand and parameterize the impact of air-sea interactions on mixed layer dynamics. There are also links to understanding the interactions between the mixed layer “turbulence” (e.g., Langmuir circulation) and internal waves or fronts, and to acoustic properties in the wavy, bubbly medium near the ocean surface.

OBJECTIVES

The objective of this work is to obtain a data set adequate to test the relation between (measured) response of Langmuir circulation (figure 1) and the surface mixed layer to the known and hypothesized forcing. The known forcing terms include wind, waves, heat-flux, and shear across the thermocline. Newly hypothesized candidates include bubble-density, wave-induced viscosity, and a reduction of the wave-current interaction due to thinness of the surface layer.

APPROACH

To specify the forcing of Langmuir circulation, the following are needed:

- Wind and windstress.
- Waves. Height and direction at minimum, full 3D spectrum if possible. Also very useful to have wave height and slope at the anemometer site for direct correlation analysis.
- Heat flux: (a) Sensible, (b) latent (moisture flux), (c) radiative.
- Stratification. Initial and final at minimum, continuous sampling strongly recommended.
- Velocity structure. Initial for model initiation, continuous for response.
- Bubble distribution: (a) in the horizontal, depth-averaged, (b) in the vertical.
- Wave breaking or the resulting turbulence levels in the mixed layer.

Report Documentation Page

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14. ABSTRACT
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To specify the response, the following are needed:

- Time-series of the spatial pattern of near-surface velocities. Order 10 m resolution to observe the smaller structures, and "long-range" (~1.5 km) to resolve hypothesized modulations or large-scale variations in Langmuir circulation strength.
- Time-series of density profiles and overturns, to track the deepening and bulk mixing rates.
- Time-series of the velocity profile, to track strength of inertial oscillations.

This is a formidable list, but most of these are available in the ongoing HOME experiment. Weak points are: (a) bulk-estimates of heat flux, (b) no vertical bubble distributions (though horizontal are well covered), (c) independent wave breaking measurements (visual and sonar observations of the waves and backscatter intensities will provide semi-quantitative estimates), (d) the radiative fluxes are not well measured. On the positive side, the parameters measured form as complete a list as has been achieved previously.

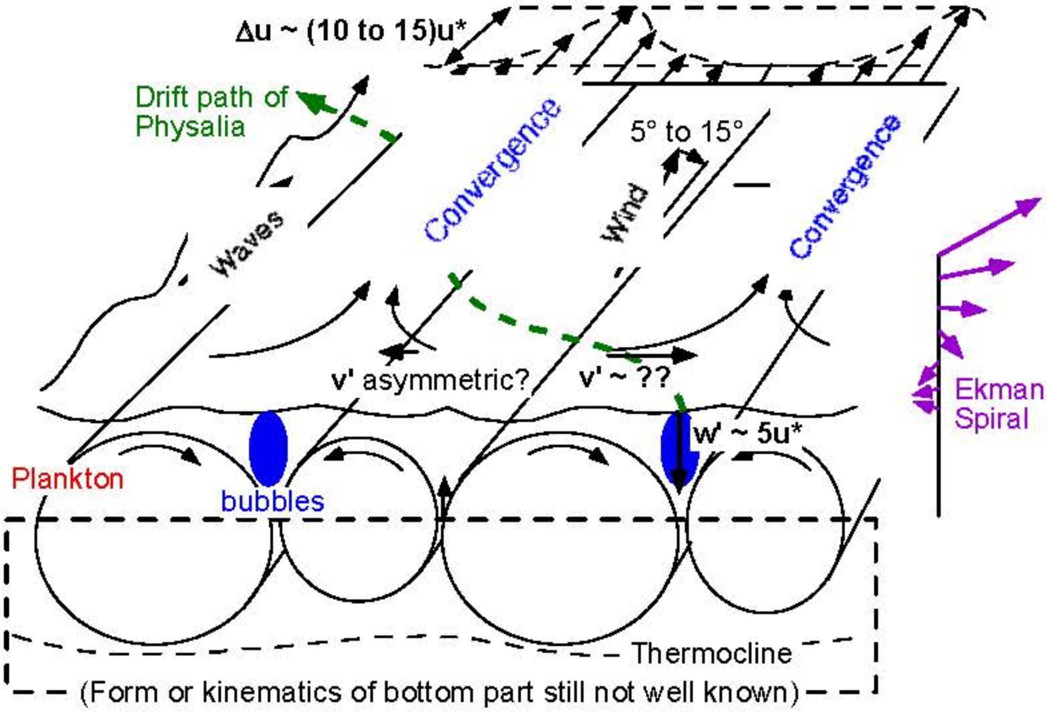

Figure 1. Schematic diagram of Langmuir circulation, illustrating the basic form, how plankton and bubbles get concentrated in lines, and some rough scaling estimates. (From [Smith, 2001].)

To obtain the measurements the following are deployed at the site of HOME-II (off Oahu, Hawaii):

- Sonic anemometers. Provides wind, stress, and sensible heat flux.
- Wave wires. Provides elevation and general wave statistics.

- LRPADS ("Long-Range Phased-Array Doppler Sonar"). This provides detailed directional spectra of the waves, near-surface mean velocity (helpful in determining the inertial current shear), and the spatial patterns of velocity and intensity that form the heart of the Langmuir circulation response characterization. The LRPADS has the range to see larger scale patterns and to resolve wave group evolution (which may be related to the level of wave breaking).
- Rapid-profiling CTD system. Provides the time-space resolution to see mixing as it happens, and to unambiguously resolve the overall deepening rates.
- Up/down-looking "deep-8" Doppler sonar. Provides velocity profiles continuously from a few meters below the surface down well below the thermocline.

The site is characterized by large internal tides, strong currents and winds, and fronts. It should prove interesting to see how these interact with each other and with such Langmuir circulation as occurs.

The analysis plan is to follow the template of previous work: (1) simulate and correct for instrument response; (2) derive time-series of strength, spacing, orientation, and the various forcing parameters; (3) compare and correlate to test the various hypotheses; and finally (4) look for the best explanation (and, if appropriate, parameterization) of the observations (e.g., see [*Smith*, 1998]).

The analysis and display of the data is taken to two distinct levels initially:

Movies. Movies of the intensity and velocity fields over the domain played at about 30 times real-time (e.g., a snapshot every 2.5 s replayed at 15 frames per second) are effective in revealing wave propagation and groupiness, providing dynamic insight into how and where waves are breaking or interacting. Movies of 1-minute averages of intensity, velocity, and velocity variance (replayed at 10 to 20 fps, or about 600 to 1000 times faster than real time) provide similar insight into motions associated with Langmuir circulation. In particular, links between wave variance and (say) the convergence zones (indicated by high-intensity backscatter) may be seen, indicating that it would be useful to pursue correlations between the variables. Movies of 10 to 30 minute averages permit focusing attention on time-scales appropriate to variations in wind or straining by internal waves. In each case, the movies provide vital data quality checks: before taking correlations and spectra seriously, it is vital to see that the data are sensible. In essence, the data are broken into frequency bands, and the 2D-space + time behavior is examined in each band. This approach (at least the two higher-frequency bands) will be performed and displayed at least partially in real time to help tune and modify the experimental plan.

Spectra. 3D spectra (2-space and time) provide details of the surface wave field directly, since in deep water the components are very nearly independent (velocity at a fixed level just below the wave troughs, which is the nearest equivalent to the PADS-style data, displays much smaller harmonics than, say, surface elevation). Similarly, 3D spectra of the Langmuir-circulation frequency band reveals the orientation, mean spacing, and degree of organization of the flow field (see [*Smith*, 1998] for an example of how this information can be used). Since the spectra take longer to form, these appear only in near-real-time.

WORK COMPLETED

Work began in late July, 2002. The LRPADS, developed under PasSAS, was deployed as part of that program over the last two weeks of July 2002, and has performed technologically as or better than anticipated. The LRPADS is now deployed and operating from R/P FLIP off the North shore of Oahu, in collaboration with the HOME experiment ongoing there. FLIP is scheduled to be on site there from 9 September to 21 October (on site as this is written). At this point all systems are operational.

RESULTS

The instrument is now operating off Oahu. Results will follow the experiment.

IMPACT/APPLICATIONS

We anticipate that the LRPADS will prove useful in many future investigations, both in the open ocean and, perhaps, nearshore.

TRANSITIONS

None

RELATED PROJECTS

PasSAS ("Passive Synthetic Aperture Sonar" experiment, ONR acoustics; W Kuperman, lead PI, JA Smith among the co-PI's)- A multi-PI project to characterize the ocean environment sufficiently to assess the performance of passive synthetic aperture sonar. The Pinkel/Smith section focuses on characterizing waves, internal waves, and Langmuir circulation over an $O(1.5\text{ km})^2$ area of the ocean surface. A 16 channel 45 kHz PADS was deemed adequate to describe the large-scale features and satisfy our objectives in PasSAS.

HOME ("Hawaii Ocean-Mixing Experiment," primarily NSF funded project). A multi-institution, multi-investigator field program investigating ocean mixing resulting from the conversion of barotropic to baroclinic (internal wave) tidal energy at a mid-ocean ridge. More information is available at http://chowder.ucsd.edu/home/

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