Wind Input, Surface Dissipation and Directional Properties in Shoaling Waves

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LONG-TERM GOAL

We wish to improve our understanding of the physics and interactions which govern the spatial and temporal evolution of surface waves in finite depth water.

SCIENTIFIC OBJECTIVES

1) To measure the direct wind forcing of waves as they advance into shallow water.

2) To measure the evolution of the wavenumber spectrum as the waves shoal.

3) To estimate the kinetic energy dissipation in the surface waters.

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4) To determine the dependence of the energy and momentum input into shoaling waves on the wavenumber spectrum and the wind.

5) To determine the dependence of wave dissipation on the wavenumber spectrum and the rate of shoaling.

6) To determine the directional response of the wavenumber spectrum on surface current shears and variable bottom bathymetry.

APPROACH

An extensive field program, SHOWEX (Shoaling Waves Experiment) was carried out to study the spectral balance of shoaling ocean waves in September – December 1999. Three air-sea interaction spar (ASIS) buoys were deployed at the inner and outer shelf off Duck, NC and acquired continuous timeseries of directional wave spectra using a nested wave wire gauge array, observations of meteorological variables (wind stress, atmospheric stability and pressure, and humidity), and near-surface oceanographic variables (near-surface currents, temperature, density and salinity).
An HF Doppler radar measured surface vector currents maps over most of the domain including the ASIS buoys and directional waveriders from other investigators. Raw data was also collected to estimate directly: 1) the directional wave properties and 2) marine surface wind vectors over the domain at high spatial and temporal resolution.

Direct measurements of the wind input to the waves was obtained from a small SWATH ship, the ‘‘*Fredrick G. Creed*‘‘, which was equipped with a special boom to measure pressure, flow and turbulence at four levels following the wavy ocean surface and the directional wave spectrum using a nested array of laser altimeters. These measurements will be used to estimate source terms for wind input and wave dissipation. The transects of the SWATH ship will provide the context of the measured spectral evolution of the wave field among the buoys and will be compared to calculations based on the action balance equation by incorporating the measured source terms.

WORK COMPLETED

1. Three ASIS buoy systems (spar and tether buoy) were deployed during SHOWEX and collected continuous data: *BRAVO*: 29 Oct - 26 Nov; *ROMEO*: 22 Oct - 30 Nov; *YANKEE*: 29 Oct - 13 Dec, 1999.

2. Processing of all data is completed and means of meteorologic and oceanographic variables have been computed. Directional wave spectra using the MLM and wavelet (WDM) techniques are completed to generate frequency-direction and directional wavenumber spectra. These spectra are now evaluated to estimate Doppler shifts and depth dependent current velocities from the dispersion relation.

3. Intercomparison of mean wave parameters with other buoys and instrumentations is in progress („Intercomparison of Directional Wave Spectra during SHOWEX“, Graber et al., in preparation for JTECH special issue).

4. The SWATH ship was operated during SHOWEX from 12 Nov - 07 Dec. Pressure and wave elevation data were collected on a boom at several levels above the ocean surface. These

measurements were made coincident with water elevation (nested set of lasers) and wind velocity (sonic anemometers) relative to the ship, boom motion and ship motion. The initial preparation and calibration of the laser wave height gauge data has been completed. A number of ancillary measurements (wind and water stress, air stability, etc.), measured from a mast at the bow of the ship are also available in the data set. These will be used to relate and scale the wave-supported energy and momentum fluxes. The entire analysis of the air pressure and Pitot-derived winds will be carried out in parallel by Dr. Fred Dobson by a separate project. The measured pressures will be corrected for several types of disturbance.

5. Second SHOWEX workshop was held at University of Miami to provide inventory of data collected by all investigators, facilitate data exchanges and begin collaborations with other investigators.

6. The SHOWEX web site is continuously updated to reflect the current status of the pre- and post-experimental activities as well as new results. The web site will be used to exchange data and information among the investigators of the SHOWEX experiment. The web site is located at http://cheyenne.rsmas.miami.edu/showex.

RESULTS

We have demonstrated (Donelan *et al.* 2001 [paper prepared for the special JAOT issue on SHOWEX instrumentation systems]) that the array of laser elevation gauges provides both adequate resolution for defining the directional properties of ocean waves and adequate slope information for correlation with the actual (static) pressure measurements for calculation of the wind input to the waves. The pressure measurements themselves have been verified and the fidelity of the motion measuring systems shown to be reliable. The data set consists of about 50 hour-long runs in which most instruments functioned according to specifications. We are exploring the directional characteristics of the wind input. Vector slope measurements were made directly beneath the pressure transducers with a triplet of laser elevation sensors – the pressure-slope correlation in any direction relative to the wind may thus be determined. Initial calculations show a directional response in keeping with $[U \cos \theta / c - 1]^2$ (see Figure 1).

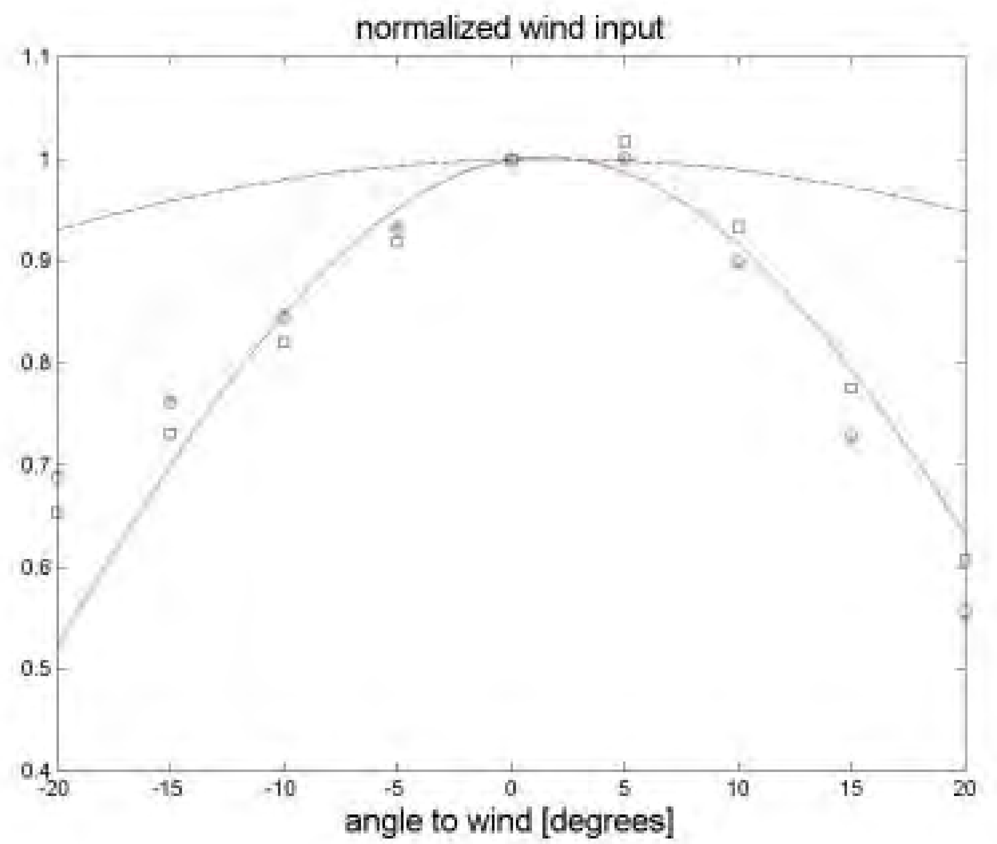

Figure 1: Measurements of the fall-off of the direct wind input to waves with the off-wind angle. The data are from a single run with the symbols signifying transducers at different heights above the surface. The dashed line is cos θ; the dotted line is $\cos^4 \theta$; while the solid line has the form of $[U \cos \theta / c - 1]^2$. These results are preliminary.

The first results of applying the wavelet technique of Donelan et al. (1999) to the ASIS buoy data are shown below. With this approach of analysis we can now compute directly the wavenumber spectrum needed for remote sensing applications (e.g., SAR, HF radar, COSRAR, etc) for intercomparisons. Furthermore, the combination of directional frequency and wavenumber spectra will allow us to estimate directly the dispersion relation and the Doppler shift currents as a function of depth. These values we will use to validate the HF radar current measurements and determine the effective depth corresponding to the HF radar technique. Figure 2 shows the frequency-direction spectrum and the corresponding directional wavenumber spectrum computed from the wavelet technique for ASIS „ROMEO“ on 23 October 1999, 0202 UTC. The wind was blowing at 12 m/s from 250^{o}T. The swell (f ~ 0.1 Hz) is propagating towards the north at about 320^{o}, while windsea is building in the northeast. Note the directional spreading of the higher frequency waves. This is especially noticable in the wavenumber spectrum (right) with the waves bifurcate at high wavenumbers.

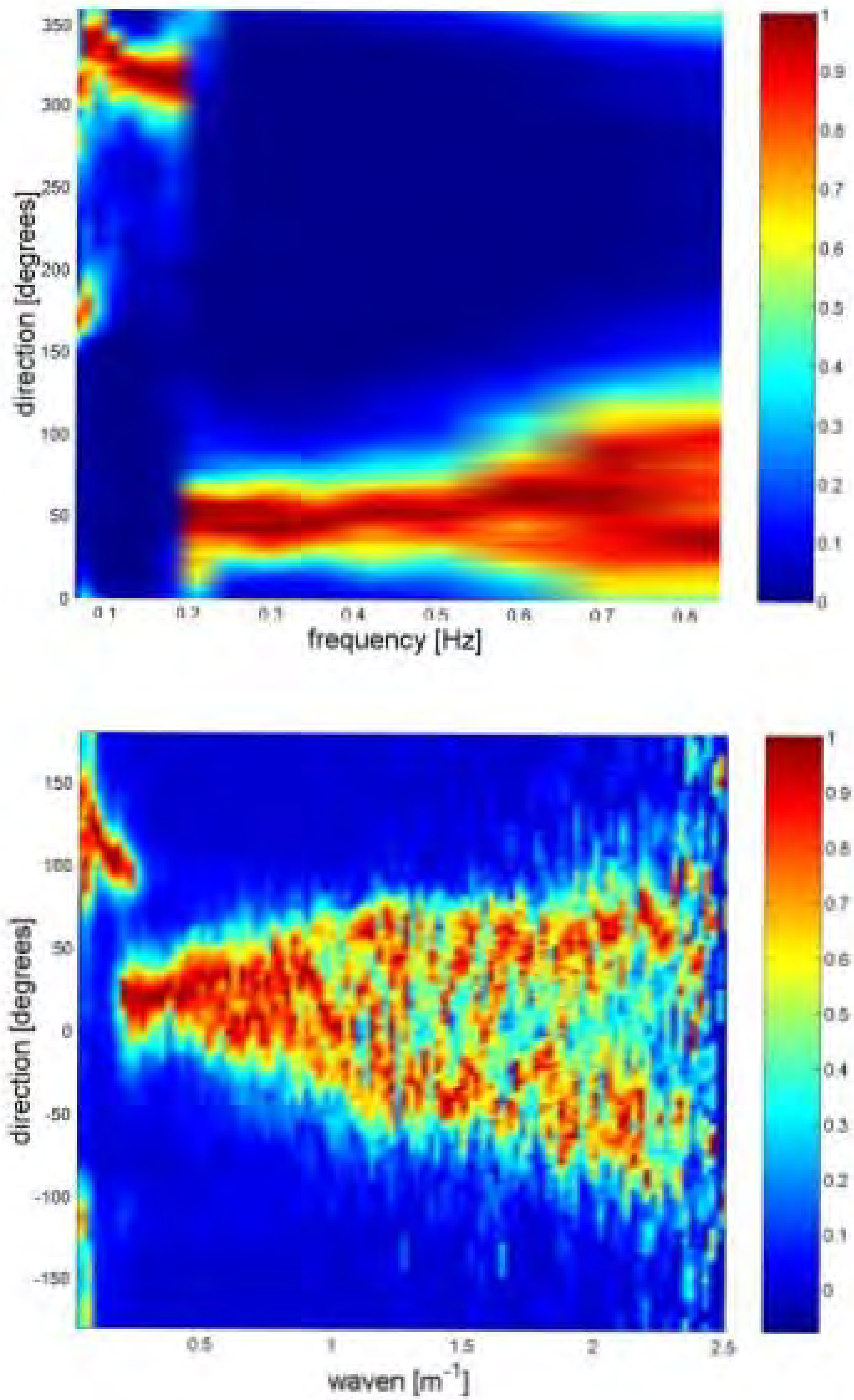

Figure 2: Directional wave spectra at ASIS "ROMEO" computed with the wavelet technique. On the top is the frequency direction spectrum and on the bottom the directional wavenumber spectrum. The latter was shifted in direction around the mean wave direction to enhance the display of the high wavenumber spreading. Both spectra are normalized to the peak value as a function of frequency or wavenumber.

Figure 3 shows the calculated Monin-Obukhov length for „ROMEO" using two methods: i) a bulk method for the heat fluxes and ii) heat fluxes derived from the sonic temperature $\langle w' t_s' \rangle$ with the correction of Dupuis *et al.* (1997). The agreement is excellent except for points where $|T_{air}\text{-}SST|$ is small. Here the two methods sometimes give opposite signs. In these cases we expect the sonic derived fluxes to be correct, as the bulk derived SST may not be representative of the surface temperatures driving the heat flux.

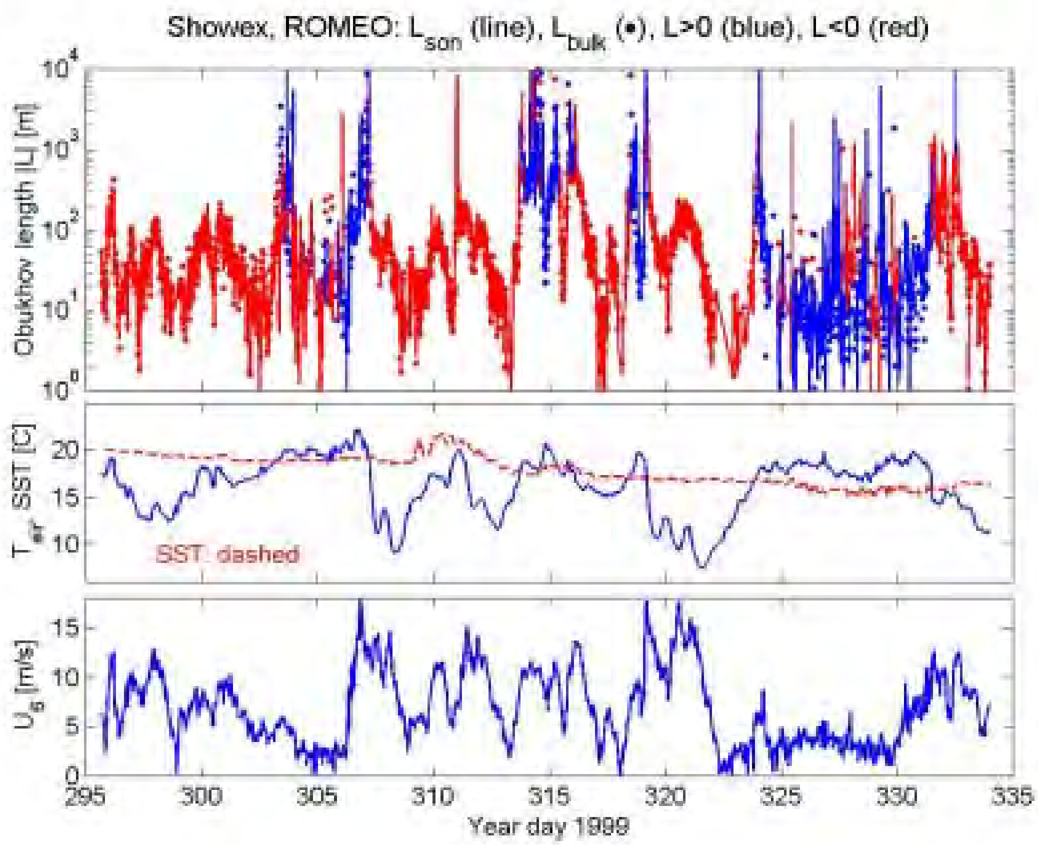

Figure 3: Top panel: Time series of Monin-Obukhov length using two methods: bulk formulation (dots) and flux method with sonic temperatures (solid line). The blue and red colors indicate stable and unstable conditions, respectively. Center panel: Time series of air (blue) and sea surface temperature (red dashed). Bottom panel: Time series of wind speed measured with sonic anemometer.

IMPACT/APPLICATION

The ASIS buoy system has been tested under a variety of conditions in numerous experiments. Its superb stability characteristics (pitch and roll) makes it a suitable platform for high-resolution air-sea interaction, near-surface turbulence and directional wave measurements. Such measurements are critical to understand mixed-layer dynamics, transport of fluxes across the interface and backscatter issues in microwave and acoustic remote sensing.

TRANSITIONS

None yet.

RELATED PROJECTS

The ASIS buoys were recently used in a joint calibration/validation experiment for passive microwave radiometry for the upcoming Navy satellite WindSAT. Additional deployments are planned for calibration and validation of upcoming the DMSP SSMI-S and WindSAT satellite missions.