

# Surface Fluxes and Wind-Wave Interactions in Weak Wind Conditions

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## LONG-TERM GOALS

We will investigate a number of factors on air-sea transfer of momentum, heat, and moisture under weak wind conditions. We will focus on important impacts of swell amplitude and propagation direction and influences of large atmospheric eddies on turbulence transfer. Improved understanding of the various influences on surface fluxes under weak wind conditions will be used to modify the existing bulk aerodynamic formula.

## OBJECTIVES

Our objectives for 2003 is to finalize the wavelet analysis method for derivation of two-dimensional directional wave spectra from three-laser altimeters on board the LongEZ aircraft, and participate in the CBLAST-Low main field campaign off coast of Martha's Vineyard, MA during July-August 2003. The scientific objectives for our participation in the CBLAST-Low main field campaign is to understand air-sea interactions under weak wind conditions by mainly focusing on aircraft observations, especially in 1) spatial variation of fluxes and vertical structure of the atmospheric boundary layer; 2) development and structure of internal boundary layers; 3) characteristics of air-sea interactions over heterogeneous sea surfaces; 4) characteristics of stable boundary layer associated with weak wind conditions.

## APPROACH

We designed some simple waves with known wave characters to test sensitivity of the wavelet analysis method for derivation of two-dimensional directional wave spectra. Based on the sensitivity test, the laser altimeter data collected by the LongEZ aircraft during SHOWEX and CLBAST-Low 2001 pilot experiment were used to derive two-dimensional directional wave spectra. The derived directional wave spectra were compared with buoy wave directional spectra.

For the CBLAST-Low main field campaign, the CIRPAS Pelican aircraft was deployed to replace the LongEZ aircraft. Our involvement during the field campaign was to design flight plans to meet scientific objectives, to evaluate instrument performance and data quality, and to monitor aircraft data for interesting air-sea interaction phenomena. During the field experiment, we examined the aircraft data whenever the aircraft data were available. Preliminary analysis has been performed based on the data delivered to the CBLAST-Low community during the field campaign.

## Report Documentation Page

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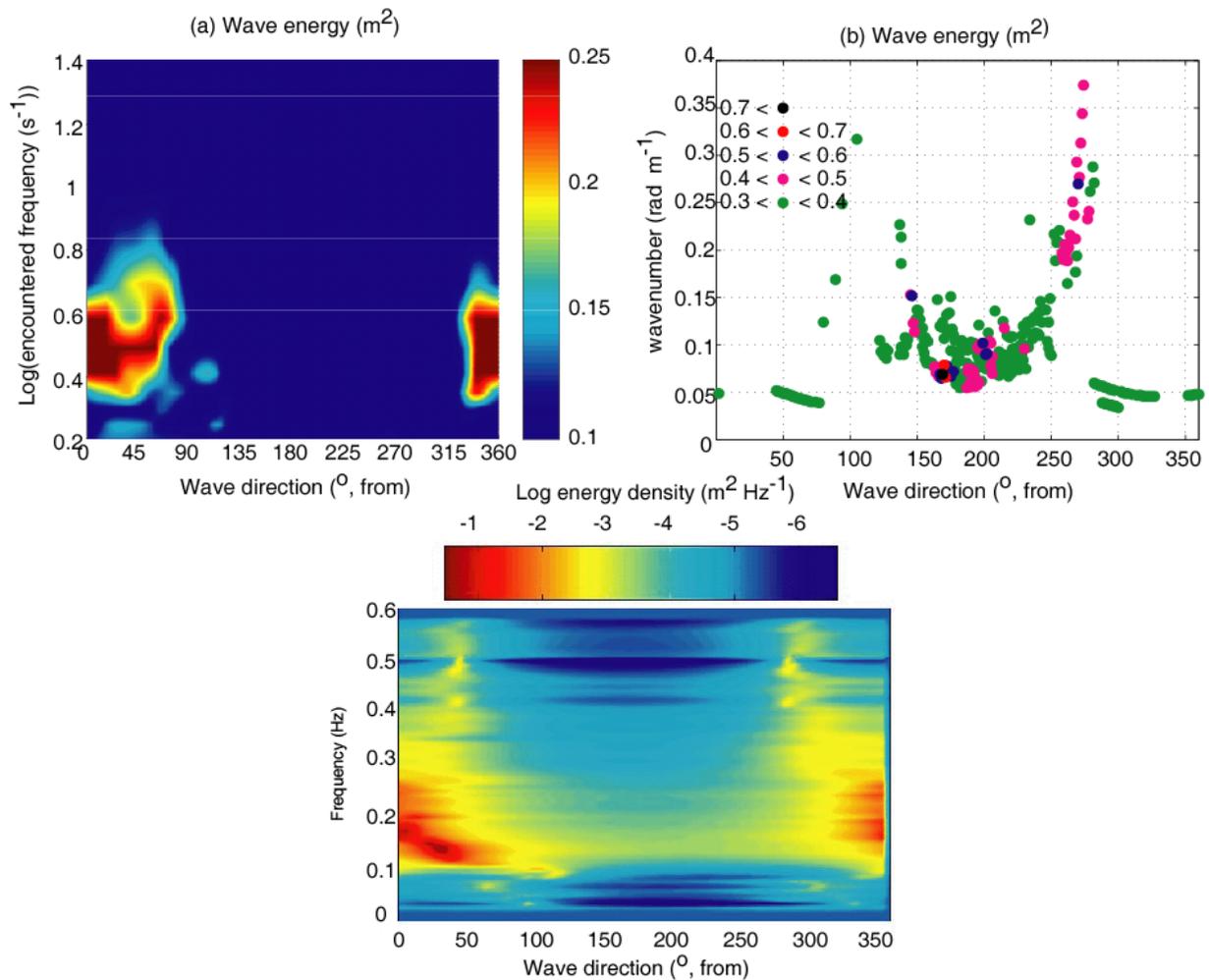
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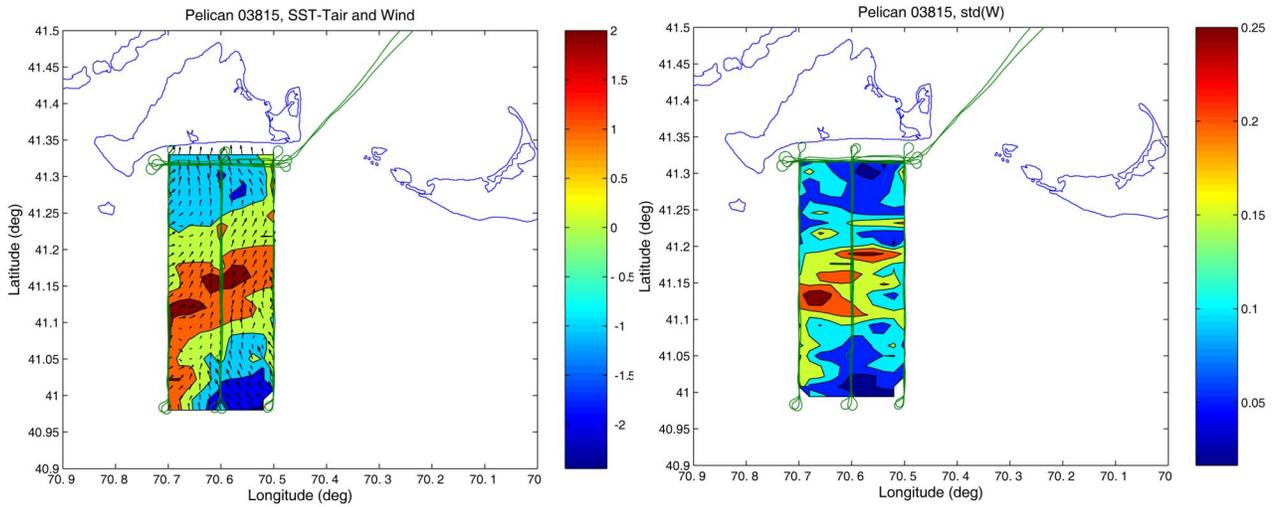
## WORK COMPLETED

The wavelet analysis method for derivation of two-dimensional directional wave spectra using three laser altimeters on board the LongEZ aircraft has been finalized and is proved to be able to capture two-dimensional directional wave spectra (Figure 1). The wavelet analysis method could fail for derivation of the directional wave spectra if the aircraft flies along wave crests or troughs, or waves with different wavelengths and phase speeds have the same encountered wavelength from the aircraft (i.e. aircraft observations could not distinguish one from the others). The detailed description of the wavelet analysis method and intercomparison between the aircraft derived and buoy directional wave spectra are documented in a manuscript submitted to Journal of Atmospheric and Oceanic Technology, the SHOWEX (Shoaling Waves Experiment) special issue (see Publications below).

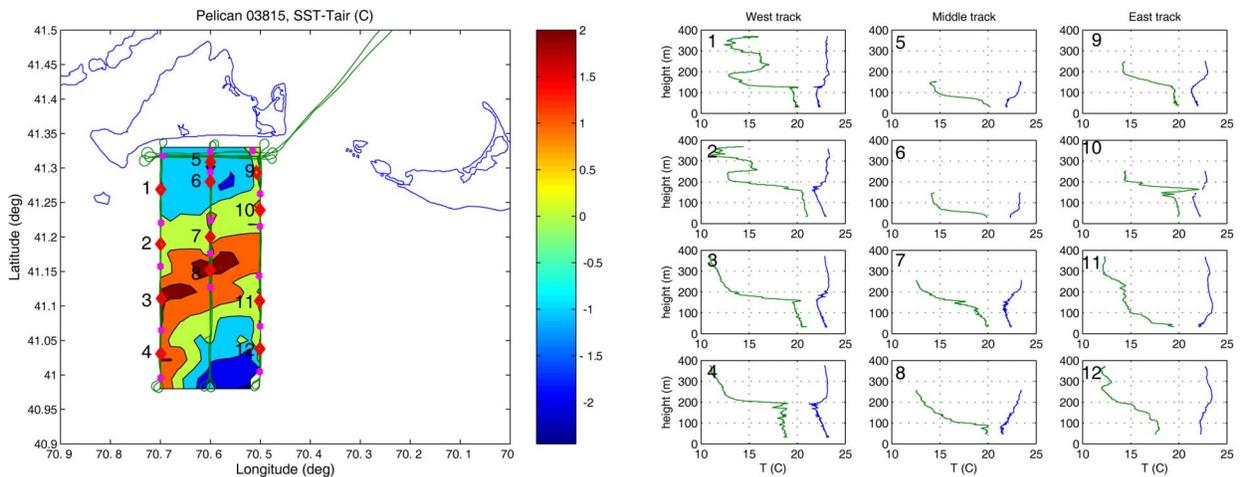
## RESULTS



**Figure 1. Intercomparison between aircraft-observed and buoy-observed directional wave spectra for 15 November 1999 during SHOWEX. Derived wave energy as a function of wave propagation direction and aircraft encountered wave frequency and as a function of wave propagation and wavenumber are on the top left and right, respectively. The bottom panel is two-dimensional directional wave spectra at the time of the flight derived from the Datawell Directional Waverider.**



**Figure 2. Air-sea temperature difference and wind vectors (left) and standard deviation of vertical velocity for every 250 m horizontal distance (right) on 15 August 2003.**



**Figure 3. Air-sea temperature difference and slant sounding locations (centered at diamonds and between magenta crosses) and temperature (blue) and dew point (green) profiles on 15 August 2003. The sounding numbers correspond to the location numbers on the left panel.**

All the flight data during the CBLAST-Low main field campaign are plotted for both level and sounding runs. Preliminary analysis has been done to investigate main air-sea interaction features observed during the main field campaign. Our preliminary analysis of the CBLAST-Low main field campaign data show that the observation area was dominated by spatial and temporal variations of sea surface temperature (SST). Structure of the atmospheric turbulence responded to wind cross various SST fronts. For example, on 15 August 2003, the air temperature was higher than SST in the northern and southern observation area and lower than SST in the middle (Figure 2, left). Standard deviation of vertical velocity, which represents the strength of the turbulence, showed relatively large values in the middle and small values in the northern and southern areas, in response to the unstable boundary layer

in the middle and stable boundary layer at the northern and southern areas (Figure 2, right). In addition, we found that the boundary layer height is also sensitive to air transport across SST fronts. On 15 August 2003, the atmospheric boundary layer was relatively deep and about 200 m at the southwest corner of the observation area, and shallow at southeast, although the slant soundings could mix horizontal with vertical variations of air temperature and humidity (Figure 3).

## **IMPACT/APPLICATIONS**

Using laser altimeters on board an aircraft to remotely measure directional wave spectra offers us a new capability for investigating sea surface wave characters. With the laser altimeters on board an aircraft, atmospheric turbulence and directional wave spectra can be measured simultaneously along flight tracks. Success of this technique leads to efficient and economical investigation of air-sea interactions over heterogeneous surfaces (Sun et al. 2001).

Based on our preliminary analysis of the CBLAST-Low main data, spatial variations of air-sea temperature is dominated by spatial variations of SST, which implies that monitoring and modeling SST changes over coastal zones can be one of the crucial factors for correctly modeling air-sea interactions.

## **REFERENCES**

Sun, J., D. Vandemark, L. Mahrt, D. Vickers, T. Crawford, and C. Vogel, 2001: Momentum transfer over the coastal zone. *Journal of Geophysical Research*, **106**, 12,437-12,448.

## **PUBLICATIONS**

Sun, J., S. P. Burns, D. Vandemark, M.A. Donelan, L. Mahrt, T. L. Crawford, G.H. Crescenti, J.R. Frech, 2003: Measurement of directional wave spectra using aircraft laser altimeters. *Submitted to J. Atmos. Oceanic Technol.*