

Spatial Variations of the Wave, Stress and Wind Fields in the Shoaling Zone

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LONG-TERM GOAL

Our long term goals are to improve parameterization of surface fluxes in the coastal zone in the presence of wave growth, shoaling, and internal boundary layer development. These goals include improving the present form of similarity theory used by models to predict surface fluxes and stress over water surfaces and documenting development of internal boundary layers in the coastal zone that are currently not modelled correctly, particularly in cases of flow of warm air over colder water.

OBJECTIVES

The long-term objectives are to improve parameterization of surface fluxes in the coastal zone in the presence of wave growth, shoaling, and internal boundary layer development. These goals include improving the present form of similarity theory used by numerical models to predict surface fluxes and stress over water surfaces, especially over the coastal zone, and to document development of internal boundary layers in the coastal zone which are currently not modeled correctly, particularly in cases of flow of warm air over colder water.

APPROACH

The first approach is to categorize all of the cases to separate effects of atmospheric internal boundary layers and the shoaling waves on the interaction between the atmosphere and the sea. The second approach is to compare the roughness length with the surface roughness detected from the downward looking scatterometer and examine the roughness length behavior with existing formulas to study the interaction between the atmosphere and shoaling waves. The third approach is to explore implementation of the modified roughness length formula in numerical models in cooperation with other groups.

WORK COMPLETED

Data analysis concentrated on the correlation between the spatial variation of the atmospheric momentum flux and the oceanic surface roughness using the dataset from the 1997 pilot experiment (Sun et al. 1999a). This is the first dataset in which both spatial variations of the atmospheric momentum flux and the oceanic waves were simultaneously measured over the coast zone within the first 10 km off-shore.

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The 1999 Shoaling Spring Pilot Experiment was completed in March (Sun et al., 1999b) where the NOAA LongEZ emphasized the off-shore cold-air over warm-water situation near Duck, North Carolina. Due to atypical weather patterns encountered during the period, several new flight strategies were tested to examine the influence of the internal boundary layer on the air-sea interaction. All the instruments on board the LongEZ operated successfully except one of the three laser altimeters and the downward looking scatterometer were damaged and became inoperative for the last half of the experiment, and the infrared temperature sensor did not work properly. The performance of all the instruments on board of the LongEZ is reported in the annual report of Tim Crawford (Contract No. N00014-97-F-0123).

In addition to the LongEZ aircraft measurements, ground measurements over the land tower and on the pier were collected during the same period during the spring pilot experiment. The land tower observations included 10 thermocouples and a 3-D Campbell CSAT 10 cm sonic anemometer. The pier measurements included a 3-D ATI sonic anemometer, a 2-D Handar 20cm sonic anemometer, a 3-D Campbell CSAT 10 cm sonic anemometer, and 10 slow response thermistors. The ground observations reflect upstream land conditions for the off-shore internal boundary layer study. The dataset from this spring pilot experiment was quality-controlled by Oregon State University. The web page is organized by the NCAR group (see web page <http://blg.oce.orst.edu/shoaling/shoaling.html>).

RESULTS

We find that the correlation between the observed momentum flux and the sea surface roughness in the coastal zone is significantly different between the on-shore and off-shore flow cases. With on-shore flow, the spatial variation of the stress in the coastal zone is small, and is influenced partly by the spatial variation of the atmospheric stability and partly by the sea surface roughness caused by shoaling. The sea surface roughness observed by the downward-looking Ka-band radar scatterometer increases with increasing friction velocity, and decreasing wave age.

With off-shore flow, the observed momentum flux significantly decreases with off-shore distance, independent of the atmospheric stability, and the sea surface roughness observed by the on-board laser altimeters and the radar. With off-shore flow, the momentum flux over the coastal zone is strongly influenced by the advection of large momentum flux from the upstream land surface. The correlations between the radar-observed sea surface roughness and the friction velocity and between the radar-observed sea surface roughness and the wave age are not very clear. The influence of the advection of strong turbulence from the land surface in the off-shore case may lead to ambiguous physical interpretation of the correlation between the momentum flux and the derived sea state, such as the wave age, due to self-correlations.

The relationship between the wind stress and the normalized radar cross section from the downward looking scatterometer under situations of roll vortices is investigated by Doug Vandemark and Piere Mourad.

IMPACT/APPLICATION

The results from the November 1997 shoaling experiment suggest that the traditional small values of the wave age parameter for the young waves in the coastal zone may be influenced by turbulence advected from land. The small wave age, which is strongly influenced by the self-correlation between the wave age and the observed momentum flux, may not reflect the true oceanic surface roughness. In order to avoid the ambiguous interpretation of the air-sea interaction due to the turbulence advected from the land surface, on-shore and off-shore cases need to be separately examined.

PUBLICATIONS

Mahrt, L., Dean Vickers, J. Sun, Timothy Crawford, Chris Vogel and Ed Dumas, 1999: Coastal Zone Boundary Layers. 13th Symposium on Boundary Layers and Turbulence. American Meteorological Soc. Dallas.

Sun, J., L. Mahrt, Dean Vickers, John Wong, Tim Crawford, Chris Vogel and E. Dumas, 1999: Air-sea interaction in the coastal shoaling zone. 13th Symposium on Boundary Layers and Turbulence. American Meteorological Soc. Dallas.

Sun, J., Douglas Vandemark, Larry Mahrt, Dean Vickers, Timothy Crawford, Chris Vogel, Edward Dumas, 1999a: Momentum transfer over the coastal zone. To be submitted to JGR.

Sun, J., L. Mahrt, T. Crawford, J. Crescenti, E. Dumas, Pierre Mourad, Douglas Vandemark, W.K. Melville, 1999b: Experiment Plan for the Shoaling Experiment.