Measurement of the Sea Spray Droplet Size Distributions at High Winds

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LONG-TERM GOALS

Improved understanding of fundamental processes of turbulence and sea-spray interactions under very strong wind conditions.

OBJECTIVES

This project will develop cloud droplet probes and phase-Doppler anemometry for measuring size-segregated droplet concentrations at high wind speeds in the ABL. The data will be used for investigating droplet dynamics in the marine atmospheric boundary layer, characterizing the droplet surface flux source function, and determining the effect spray drops have on air-water surface exchange processes. A physically-based parameterization of droplet production in terms of wind/wave variables will be developed.

APPROACH

The fundamental parameter required for representing the effect of sea spray on air-sea exchange processes is the size dependent *source function* for droplets, or number of droplets of a given size produced at the sea surface per unit surface area per unit time as a function of wind speed. Because the source function cannot be measured directly at present, it must be estimated from the height-dependent number-size distribution of droplets, $n(r, z)$ (i.e., the number of droplets of given radius, r, per unit volume of air per increment of radius at height z) and a model for the atmospheric boundary layer that incorporates droplet dynamics. However, progress in determining the source function has been frustrated due to the difficulty of measuring $n(r, z)$. The present droplet source function parameterizations are based on droplet concentrations determined on a beach [*Smith et al.*, 1993], 10 hours of data at a wind speed of 21 m/s from the HEXOS program [*de Leeuw*, 1990], and inferences from various laboratory studies. The data from *Smith et al*. [1993] were recorded for U up to 30 m/s but, besides not being representative of the open ocean, contain no measurements of the larger size

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(r>20 μm) droplets believed to be important in air-sea exchange processes. In this project two different aircraft-mounted particle-sizing instruments will be used to measure droplet concentrations at high wind speeds (including hurricanes), and this data will be used in droplet dynamics models (Kepert et al., 1999] to estimate droplet source functions at very high wind speeds.

Because droplet measuring instruments often yield conflicting results, we plan to pursue at least two measurement technologies with an emphasis on understanding the measurements and reconciling their disagreements. The first technique is a cloud/precipitation droplet probe (CPDP) based on optical droplet imaging methods. The second droplet measurement method will be based on a phase-Doppler anemometer (PDA). Both cloud droplet probes and PDA's are commercially available and can be deployed from an airplane to measure droplet concentrations. We will conduct these aircraft measurements as part of the intensive field experiments associated with the hurricane science team of the ONR Coupled Boundary Layer/Air-Sea Transfer (CBLAST) DRI. In addition to the aircraft measurements, we will also conduct additional field experiments in the surf zone and laboratory measurements in a wind-wave tunnels.

Dr. Chris W. Fairall from NOAA Environmental Technology Laboratory and Dr. William E. Asher from the University of Washington Applied Physics Laboratory will collaborate on this joint proposal to evaluate both instruments. Dr. Fairall will be direct the measurements made with the CPDP and Dr. Asher will direct the research conducted with the PDA. Drs. Fairall and Asher will collaborate with Dr. Mike Banner (UNSW - University of New South Wales, Australia) on developing a parameterization of droplet production in terms of breaking-wave properties as diagnosed in numerical wave models. The aircraft work will be done in collaboration with Drs. Pete and Robert A. Black, NOAA AOML.

WORK COMPLETED

Funding for this project was received near the end of FY01 so the reporting period only covers a few months. The two main accomplishments were (1) placing an order for a commercially available droplet probe [Model CIP airborne cloud imaging probe from Droplet Measurement Technologies (DMT)], (2) a visit by C. Fairall in July, 2001, to UNSW to meet with Mike Banner and initiate collaboration on linking sea spray production and numerical modeling of oceanic surface wave growth and breaking.

RESULTS

A market survey was done to determine the best droplet technology for this project and an order for the CIP was placed with DMT in mid-July after the usual lengthy federal purchase process. To evaluate the candidate probes, a simple scaling model of droplet concentration profiles was developed based on the data of de Leeuw [1990].

The wind tunnel at UNSW was set up and tested for possible simulation of spume droplet production mechanisms at high winds. A preliminary run was made and high speed photographs showed direct production of large sea spray droplets at tunnel wind speeds of 20 m/s. The tunnel can be run at much higher wind speeds. Discussions with Mike Banner and associates lead to the first steps in the development of a new parameterization of sea spray production. The breakdown of the air-sea interface is characterized as a balance of the free energy of droplet formation versus the spectral transfer of TKE which is proportional to the input to wave dissipation by breaking. The introduction of the droplets into the atmosphere is a balance of the slope of their trajectory due to their fall velocity and the distribution of horizontal wind gusts versus the local wave slope. This approach can produce a droplet production size spectral shape similar to existing empirical formulations. An example for HEXOS type conditions is shown in Figure 1. A paper on this model is in preparation.

IMPACT/APPLICATIONS

This work will lead to improved treatment of air-sea fluxes for wind speeds exceeding 20 m/s. Primary application will be in numerical forecasting models in conditions with mid-latitude and tropical cyclones.

TRANSITIONS

None

RELATED PROJECTS

"Mid-Oceanic Wintertime Surface Fluxes and Atmospheric Boundary Layer Structure: Relationship to Cyclone Development and Evolution", NSF. O. Persson, P.I.

SUMMARY

We have taken preliminary steps in formulating a new physical model of sea spray droplet formation and initiated contact with UNSW for laboratory simulations of the processes. Next summer we anticipate acquiring long-needed measurements of sea spray concentrations over the oceans in near hurricane force winds. If successful, we can make progress on a parameterization of spray production and an evaluation of spray thermodynamic effects on hurricanes.

REFERENCES

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Kepert, J., C. W. Fairall, and J. W. Bao, 1999: Modeling the interaction between the atmospheric boundary layer and evaporating sea spray droplets. In *Air-Sea Fluxes of Momentum, Heat, and Chemicals*, Ed. G. L. Geernaert, Kluwer, Dordrecht, Holland, 363-409.

Smith, M. H., P. M. Park, and I. E. Consterdine, 1993: Marine aerosol concentrations and estimated fluxes over the sea. *Quart. J. Roy. Met. Soc.*, **119**, 809-824.

PUBLICATIONS

None