Measurement of the Sea Spray Droplet Size Distributions at High Winds

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LONG-TERM GOALS

Our long-term goals are to develop phase-Doppler anemometry for measuring size-segregated droplet concentrations and fluxes at high wind speeds in the atmospheric boundary layer (ABL) in order to understand the dynamics of droplets at high wind speeds.

OBJECTIVES

Our objectives for FY 2003 were to measure spray droplets and their velocities during the Spray Production and Dynamics Experiment (SPANDEX) at the Water Research Laboratory at the University of New South Wales and complete the engineering required to mount a TSI Inc. phase-Doppler anemometer on the NOAA P-3 N43RF.

APPROACH

At high wind speeds, droplets are injected upwards into the ABL by bursting bubbles and by shearing off of wave crests. These processes generate drops with radii that vary from a few tenths of a micrometer up to several hundred micrometers [*Andreas et al.*, 1995; *Resch and Afeti*, 1992; *Rossodivita and Andreussi*, 1999; *Spiel*, 1998; *Wu*, 1973]. Over this range, it is the droplets with sizes from a few tens of micrometers and larger that are believed to be important in the air-sea momentum and heat flux [*Kepert et al.*, 1999]. The fundamental parameter required for characterizing these fluxes is the droplet source function, or number of droplets of a given size produced at the ocean surface per unit area and unit time. However, current instrumental techniques are unable to measure the source function directly, and it must be inferred from height-dependent droplet concentrations and a model for turbulent mixing in the atmosphere. Therefore, the droplet concentrations in the ABL required to estimate the source function implies measurement of particle concentrations over at least two orders of magnitude in size.

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14. ABSTRACT
Our long-term goals are to develop phase-Doppler anemometry for measuring size-segregated droplet concentrations and fluxes at high wind speeds in the atmospheric boundary layer (ABL) in order to understand the dynamics of droplets at high wind speeds.

15. SUBJECT TERMS

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It has been only recently that instrumentation has become available with both the dynamic range in particle size and ability to measure relatively large particle concentrations required to measure droplet concentrations in the ABL. In order to provide two independent data sets for the droplet concentrations, we are deploying both a cloud/precipitation droplet probe (CPDP) (which measures size and concentration by imaging droplets) and a phase-Doppler anemometer (PDA) (which relies on detecting light scattered from individual droplets to measure size and concentration). Both instruments can be mounted in aircraft or other field platforms such as towers or ships and can be used in laboratory studies conducted in wind-wave tunnels.

Aircraft-based measurements with the PDA will be made in collaboration with the main CBLAST hurricane research experiments in 2004. We will coordinate our aircraft installations through Dr. Peter Black of the NOAA Atlantic Oceanographic and Meteorological Laboratory. The PDA will provide size-segregated droplet concentrations as a function of aircraft altitude. The PDA data will be compared to droplet concentrations measured from the same aircraft by the CPDP. Data from both instruments can be used in a droplet boundary layer model such as formulated by *Kepert et al.* [1999] to determine the droplet source function. Details on this approach can be found in *Kepert et al.* [1999] or *Pattison and Belcher* [1999]. Once the source function is accurately known, it will be possible to model the contribution of droplets to surface exchange processes.

We also plan to continue joint experiments with Dr. Fairall in wind/wave tunnels to further compare the droplet concentrations measured by the two instruments and provide data for modeling the production of droplets by breaking waves. These experiments will be conducted in collaboration with Profs. Michael Banner and William Pierson at the University of New South Wales (UNSW) in Sydney, Australia.

WORK COMPLETED

We participated in the Spray Production and Dynamics Experiment (SPANDEX) at the Water Research Laboratory at the University of New South Wales (UNSW). The data set from this experiment was used to intercompare the performance of the PDA relative to the CDP currently installed on the NOAA P-3. It was also used to investigate the dynamics of droplets produced through breaking waves and spray at high wind speeds.

The engineering design, fabrication, and assembly of the mounting components required to install the PDA on the NOAA P-3 is complete. Currently we are waiting on final installation to be completed by the NOAA Aircraft Operations Center personnel in order to begin testing the system. Unfortunately, delays in design of the optical mounts prevented data collection with the PDA during the 2003 field season.

RESULTS

On of the main benefits of the PDA is that it provides two orthogonal components of the droplet velocity in addition to the droplet size. This allows the correlation of droplet size and velocity to be studied. These correlations are important in understanding how wave breaking generates the airborne droplets. Figure 1 is data from SPANDEX showing the correlation between droplet diameter and velocity for both the vertical velocity component and the downwind velocity component. In both cases there is little correlation of particle size with velocity. Figure 2 shows the vertical velocity of each drop plotted versus that drop's downwind horizontal velocity. The vertical and horizontal downwind velocities are anti-correlated, with droplets having larger downwind velocities also having larger downward velocities (or smaller upward velocities). Although a definitive explanation for this is unavailable at present, one hypothesis is that the correlation observed in Figure 2 is related to the airflow over the waves. Support for this hypothesis is presented in Figure 3, which shows the correlation of the vertical velocity with wave height measured 3 cm upstream of the PDA measurement volume. In this case, the vertical velocities are correlated with wave height, with higher upward velocities occurring near wave crests. The SPANDEX data set will be useful for verifying models predicting the trajectories and velocities of spray drops produced by breaking waves.

IMPACT/IMPLICATION

The installation of the PDA on the P-3 will provide an additional spray droplet data set for intercomparison with the droplet data provided by the CDP deployed by Chris Fairall.

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PUBLICATIONS

none to date

FIGURES

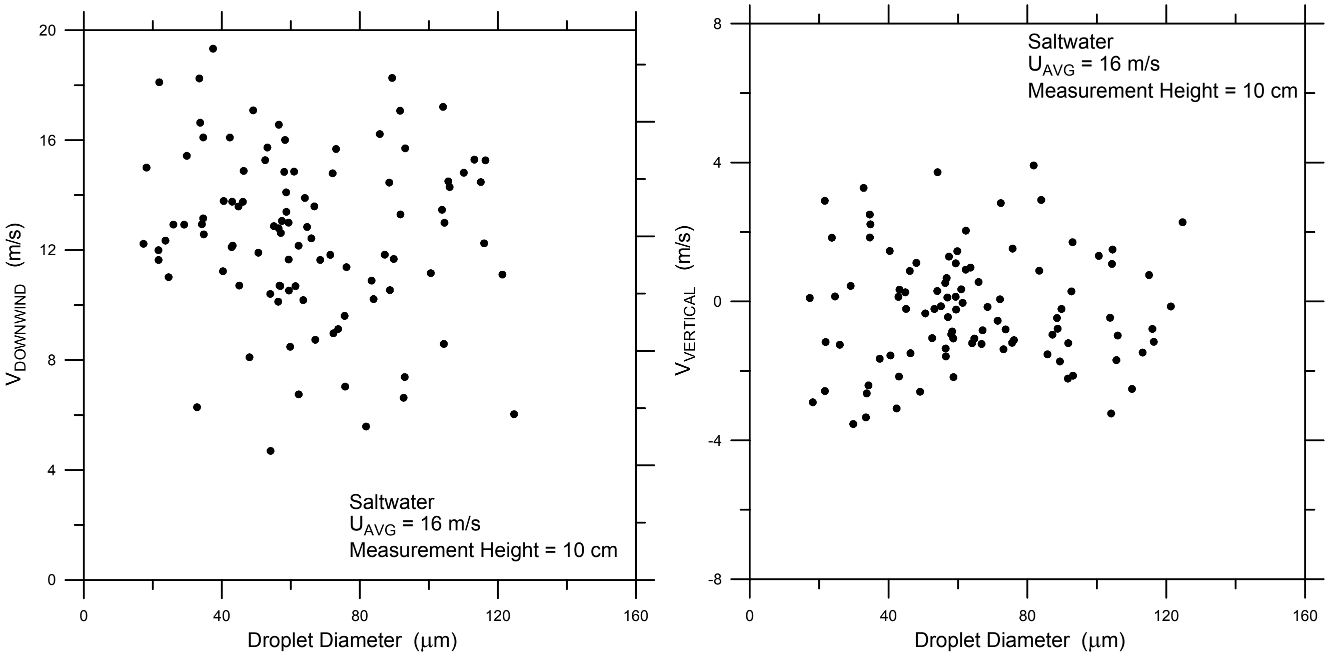

Figure 1: Plot of droplet velocity (m/s) versus droplet diameter in micrometers from the Spray Production and Dynamics Experiment data set. The left hand panel shows the horizontal downstream velocity plotted versus droplet diameter and the right-hand panel shows the vertical velocity plotted versus droplet diameter.

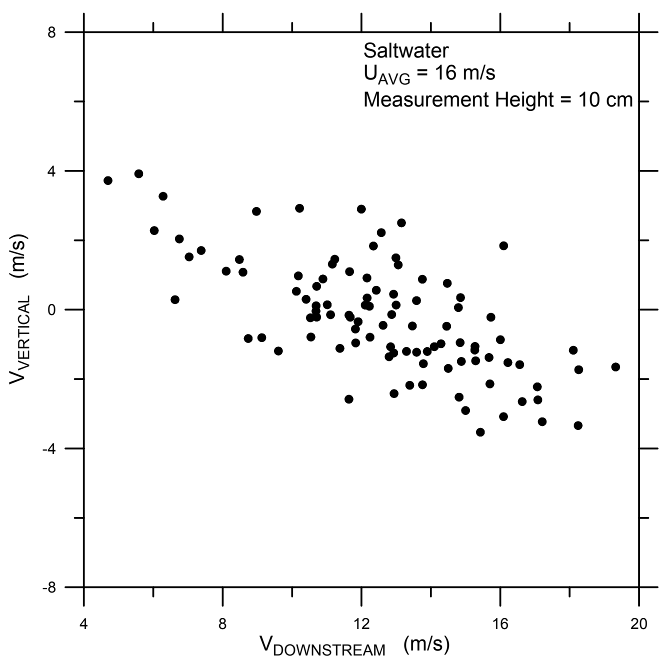

Figure 2: Plot of the vertical droplet velocity (m/s) versus the horizontal downstream droplet velocity from the Spray Production and Dynamics Experiment data set.

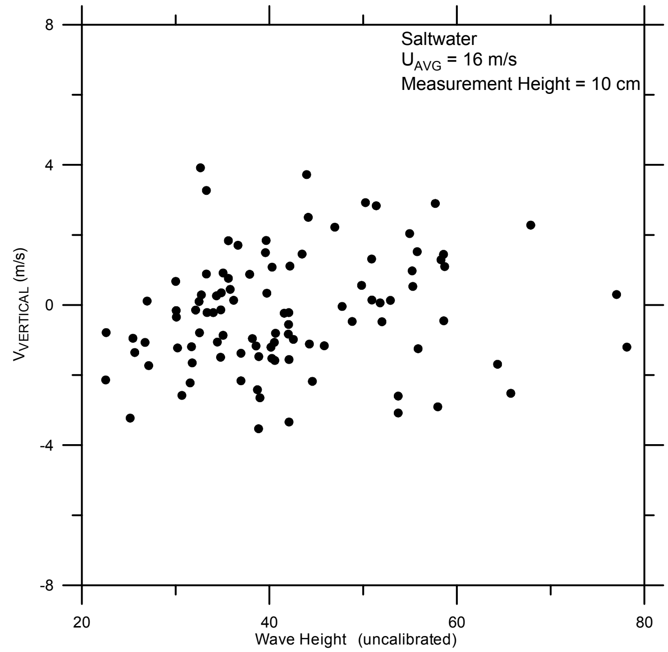

Figure 3: Plot of the vertical droplet velocity (m/s) versus wave height measured 3 cm upstream of the PDA measurement location from the Spray Production and Dynamics Experiment data set.