P1.2 IN-SITU MEASUREMENTS OF AEROSOL PRODUCTION FROM INDIVIDUAL WHITECAPS DURING SEASAW

Sarah J. Norris*[1], Ian M. Brooks[1], Michael H. Smith[1], Martin K. Hill[1], Barbara J. Brooks[1], Gerrit de Leeuw[2]

[1]University of Leeds, Leeds, UK
[2]University of Helsinki, Helsinki, Finland

1. INTRODUCTION

The production of sea salt aerosol particles is intimately linked to the process of whitecapping on ocean waves and bubble bursting. We present aerosol measurements from two CLASP aerosol probes located on a tethered buoy (Figure 1) and sampling at approximately 0.7 and 1.0 m above the sea surface under a range of wind speeds and whitecap conditions. The tethered-buoy was deployed from the RRS Discovery during the Sea Spray, Gas Flux, and Whitecap (SEASAW) project, part of the Surface Ocean Lower Atmosphere Study (SOLAS) programme. Cruises were undertaken in the North Atlantic off the west coasts of Scotland and Ireland during the periods November 7 to December 2 2006 (D313) and March 21 to April 12 2007 (D317). (Brooks et al. 2007a)

Figure 1. The tether-buoy instrumented with two CLASP units with inlet funnels; motion pack and digital bubble imager.

* *Corresponding Author address*: Dr Sarah J. Norris, Institute for Atmospheric Science, School of Earth and Environment, University of Leeds, Leeds, LS2 9JT, UK; e-mail: s.norris@see.leeds.ac.uk

A bubble imaging camera made simultaneous measurements of the bubble population at approximately 0.5 m below the surface. A motion package mounted on the buoy allows the measurements to be related to the buoy's position on passing waves, and the inlet altitudes relative to mean sea level to be determined. The aerosol spectra recorded from the buoy under different wind and wave conditions as well as whitecap coverage are discussed. A comparison of the buoy aerosol spectra to another CLASP unit located at the top of the foremast allows the changes in aerosol spectra over the lowest 20m of the boundary layer to be assessed.

2. SCIENTIFIC BACKGROUND

Sea spray is an especially important aerosol because, with the exception of dust, it is the largest single source of aerosol mass injected into the atmosphere (Hoppel et al., 2001). When sea spray is produced at the ocean's surface, heat and water mass, plus associated chemicals, bacteria and viruses are transferred from the ocean to the atmosphere. The transfer of heat, water vapour and momentum across the air–sea interface is crucial because of their influence on the intensity of tropical cyclones. Sea salt aerosol are the dominant scatterer of incoming solar radiation (Haywood et al. 1999) and can modify marine stratocumulus clouds which are one of the largest uncertainties in climate predictions. Sea salt plays a significant role in marine stratocumulus microphysics and chemistry (O'Dowd et al. 1999), and can also provide a substantial sink for atmospheric trace gases, both natural and man made (O'Dowd et al. 2000).

There are two production mechanisms of sea spray particles: bubble bursting and mechanical agitation. Bubbles form predominantly from breaking waves; these entrain air into the ocean surface producing a plume of bubbles (Blanchard and Woodcock, 1957). As the bubbles rise and reach the ocean surface, white foam areas form which are called whitecaps.

To understand the production of sea spray, particle number concentration measurements need to be undertaken very close to the ocean surface; however sea spray particle number concentrations available in the literature, from both laboratory and field measurements, have generally been obtained at heights of at least several metres above the wave surface. This is because most particle counters are heavy, bulky

instruments, which are difficult to locate near the ocean surface. Monahan (1968) and Wu et al. (1984) both studied droplet size distributions in the lowest few metres of the atmosphere from floating platforms.
Monahan used a photographic system at a single elevation 13 cm above the sea surface to sample particles greater then 45 μm radius, along with wires to collect the total salt load at several elevations in the lowest 1.2 m of the atmosphere. Wu et al. took measurements at varying heights below 1.3 m using an optical droplet sensor mounted on an arm raised and lowered for each measurement height.

De Leeuw (1986 and 1987) measured low level vertical profiles of sea spray number concentrations of particles greater than 10 μm diameter using a Rotorod inertial impactor in the North Atlantic from 0.2 m up to 11 m and in the North Sea from 0.2m to 18 m. The sizing of the collected particles was completed using ten random microscope images taken from the rods to form one sample.

The methods used by Monahan (1986) and De Leeuw (1986, 1987) are both very labour intensive with long post-measurement data processing. The Wu et al., (1984) method had better temporal resolution but measurements at differing heights could not be made simultaneously. Wu et al. state that locating the droplet source patch along the wave profile would be worthwhile for low to intermediate wind speeds (u <15 ms^{-1}) and secondly, That refining instruments to measure the smaller size particles at these distances above the ocean surface is also required in otder to further increase knowledge of the production mechanisms of sea spray particles.

3. MEASUREMENTS

To study the production of sea spray from individual wave breaking events a CLASP unit was mounted on a small buoy in a fashion similar to the rotorod measurements of de Leeuw, (1986). The CLASP units produce a 16 channel aerosol spectra between 0.05 and 3.5 μm radius at a sample frequency of 10 Hz (Brooks et al. 2007).

The tethered-buoy system deployed during cruises D313 and D317 from the RSS Discovery consisted of two CLASP units positioned between 0.7 and 1 m above the ocean surface as shown in Figure 1; a bubble imaging system recording the bubble spectra at an approximate depth of 0.5 m below the ocean surface; a motion pack on the buoy; and 1 second resolution digital images recorded from a webcam on the ship. The buoy is free floating but held in a fixed location by weighted cable suspended from the RRS Discovery by the aft crane. The wire is passed through the centre of the buoy's central column allowing it to ride freely up and down the cable. The weight is held at a depth of roughly 25 meters below the ocean surface beneath the immediate effect of wave motions to help restrict the sideways movement of the buoy. The bubble system captures images of individual bubbles, like the examples in figure 2, and sizes then into a size spectrum.

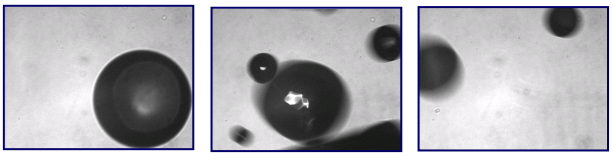

Figure 2. Examples of bubble imagery captured by the TNO camera at 20 frames per second.

A motion pack recorded buoy attitude and movement allowing both its location on the waves and the wave heights to be determined. The motion pack consists of a pitch, roll, and electronic compass module (model TCM2 from PNI Corporation), coupled to a custom built control and communications board incorporating a set of 3-axis accelerometers with a resolution of 1 milli-g. The motion pack provides pitch, roll, heading, and linear accelerations along the x, y, and z axes at 20 Hz (see Brooks et al. 2007b for more details).

The tethered-buoy system was deployed 4 times during D313 and 10 times during D317 for between 2 and 4 hours at a time. The significant wave heights during the deployments reached up to 4 m while the maximum 10 m wind speed was 12 m s^{-1}.

4. RESULTS

The source footprint of aerosol reaching the CLASP instrument on the tethered buoy is small; thus it is possible to isolate spray produced by individual whitecaps – peaks in the aerosol spectra from individual whitecaps can be seen in the time series of the particle number concentration for the different size particles (Figure 3). Most measurements of sea spray aerosol are made at between 8 – 25 m above the surface and then

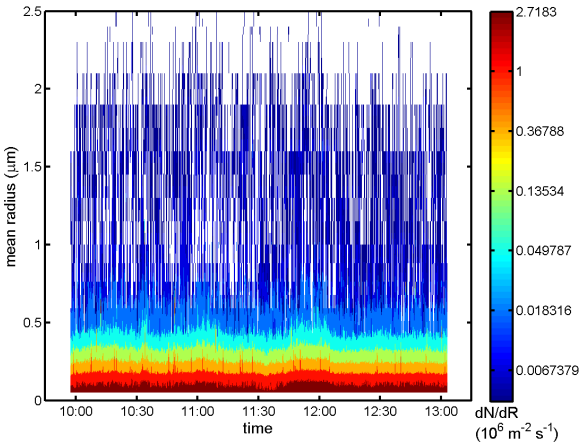

Figure 3. The time series results from the upper CLASP unit from the 4th Deployment on D317.

interpolated down to a reference level (e.g. the sea surface). Large particles tend to fall back to the surface before they reach a substantial altitude, thus the

spectrum of particles will change with height., and surface fluxes derived at different heights will vary significantly and a simple interpolation is not sufficient enough to correct surface fluxes for differences in measurement height. Additionally, an increased wind speed increases turbulent transport from the ocean surface to the measurement level.

A comparison is made between the aerosols spectra recorded at the ocean surface and the aerosol spectra recorded at 21 m above the ocean surface by another CLASP unit mounted on the foremast. Figure 4 shows that many particles large than 0.2 μm in radius are produced near the ocean surface and transported to the 1 m measurement level, but that far fewer are transported up to the top of the foremast. For particles smaller than 0.2 μm radius the concentrations at 1 m

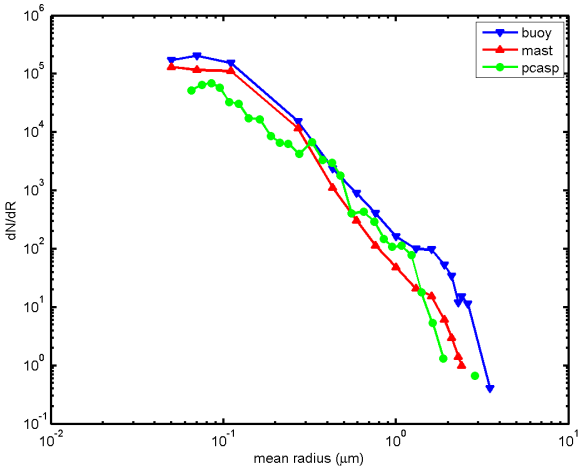

Figure 4. Spectra comparison of aerosol spectra from the buoy to the aerosol spectra recorded by another CLASP unit on the 20m fore mast and the PMI PCASP.

and 21 m are in much closer agreement.

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