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Ocean Science Discussions

Interactive comment on "Field measurements of aerosol production from whitecaps in the open ocean" *by* S. J. Norris et al.

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The purpose of this paper is to estimate aerosol fluxes per unit area of whitecap using measurements of near-surface aerosol concentration and bubble spectra. The study was carried out in the North Atlantic Ocean as part of two cruises during the SEASAW project. The cruises occurred during the periods 7 November to 2 December 2006, and 21 March to 12 April 2008. A compact Lightweight Aerosol Spectrometer Probe (CLASP) attached to a small buoy with an inlet 1 m above the surface was deployed during each cruise. CLASP provides a 16-channel size spectrum at ambient relative humidity, covering the size range 0.12 < Ramb < 9.25 μm at a sample rate of 10 Hz. Size spectra were adjusted to 80% relative humidity for sea-salt. Measurements of bubble size spectra in the range 13-620 μm was done by a video-based measuring

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system, mounted underside the buoy at 0.4 m below the surface. An accelerometer allowed the movement of the buoy over the waves to be determined, along with estimates of individual wave heights. Finally, two Nikon Coolpix 8800 digital SLR cameras were installed on the port side of the bridge, with images taken every 30 s during daylight hours to estimate the whitecap fraction of breaking waves at the surface. The authors compare their mean bubble spectra with laboratory studies at different water temperatures, three open ocean studies, and two surf zone studies. The authors have given a good summary of their experiment and present valuable results. Conclusions of this paper contribute to the current field of marine aerosol production, and therefore I would like to see paper published. However, the manuscript requires significant restructuring and clarifications. One of the main findings of the paper is that the aerosol production flux per unit area of whitecap derived from mean particle spectra increases with the wind speed for particles with R80 below approximately 1–2 μm, while there is no clear relationship between the production flux of larger particles and wind speed. Paper also shows that production flux for larger particles decreased more rapidly with bubble size compared to production flux of the earlier studies.

The reviewer has mis-read the paper, we do NOT state that aerosol production drops off more quickly with bubble size than previous studies, but that the aerosol production as a function of aerosol particle size decreases more rapidly than for previous studies (ie the spectral slope is steeper)

To explain these differences the authors name multiple different factors, often without clear rational. For example, when talking about the effect of bubbles the logic does not seem to work. Fig. 4 shows much higher concentration for the lab generated and surf zone bubbles compared to the open ocean. The differences are particularly pronounced for bubbles with diameter larger than 200 μm. Now, considering that "jet droplets, between about 1 and 10 μm radius, are produced by the smallest (< 200 μm diameter) bubbles (Blanchard, 1983)," shouldn't there be lower production flux of film drops for the open ocean measurements? Is that due to normalization by whitecaps?

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The effect of measurement height? (as noticed in the paper the majority of the field measurements of sea spray particle number concentrations have been made between 5–25 m above the surface, compared to 1 m used in the current study.) Could the entire notation of large bubbles producing sub-micron sized film drops while small bubbles producing super-micron sized jet drops be flawed? If this is the case, which may very well be true, I would recommend authors to remove the discussion of the bubble spectra.

This discussion has been largely rewritten. We more clearly state where it is possible to infer relationships between the aerosol flux and bubble properties, and where too little information is available to do so. We further emphasis the different nature of the bubble measurements in the open ocean and surf zone, which makes direct comparisons difficult. We provide a plausible explanation for the difference in behavior of the production flux with wind speed for small and large particles: essentially the large aerosol, derived from jet drops, result from small bubbles, which have a low rise velocity, so a larger volume of entrained air does not necessarily result in an increase of the flux of such bubbles to the surface, but does increase the number of large bubbles bursting.

The discussion for the potential dependence of sub-micron in situ flux estimates with wind history is also confusing. Were there corresponding differences (i.e., with increasing, decreasing and steady wind speeds) in the bubble spectra recorded? Can change in the bubble spectra or variability in whitecap coverage support these source flux estimates?

Yes, there is some evidence of increased bubble concentrations with rising winds compared to steady winds – now noted in the revised discussion. Note however, that the source flux depends on both bubble properties and total whitecap fraction, but with the limited data available a full assessment of the behavior is not possible. We are only able to point out where the observations are consistent with proposed mechanisms.

Specific comments: Please include the mean aerosol spectra for each buoy deploy-

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ment. The knowledge of number of particles in each CLASP channel size is important for interpretation of the production flux data.

A figure has been included in the paper as Figure 3 showing the mean aerosol concentration for each deployment. All other figure numbers have been updated to account for this addition and a reference to the figure has been included on at the beginning of section 3.1.

Pg. 3366. While Horst and Weil (1992) model formulation defines flux footprint, I believe concentration footprint should be used in the manuscript. Compared to flux footprint, concentration footprint can be 10–100 times further upwind (Ceburnis et al. 2008; Vesala et al., 2008).

This and the following question suggest the reviewer misunderstands exactly what is being done here. We isolate the freshly produced aerosol from a single whitecap by finding the difference between the sharply defined, and very short ($\sim$1 second) peaks in concentration and the background concentration. We do NOT explicitly require either the flux or concentration footprints in our calculations, but determine the flux footprint only to demonstrate that it is of the same order as the width of the whitecaps and thus that the peak in aerosol concentration measured from the buoy should be representative of that produced by the local whitecap. On page 3367 lines 1 to 8 we already discuss how we isolate the aerosol spectrum produced from individual whitecaps from the mean background spectrum and the time scales we are considering in this work.

Pg. 3370. Please explain how the production flux was derived, include references.

The method by which the production flux is derived is already given on p3370 lines 14 to 24. As Ed Andreas suggested in point 9 of his review we have included some additional history and references to previous use of this method.

Pg. 3390. Please correct the legend in Figure 6.

This has been corrected as suggested.

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Interactive comment on Ocean Sci. Discuss., 9, 3359, 2012.