P9.4 EVALUATION OF COARSE MODE SEA-SALT FLUX PARAMETERIZATIONS THROUGH SHIPBOARD EDDY-CORRELATION METHODS COUPLED WITH VERTICAL PROFILE DATA

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1. INTRODUCTION

It has been repeatedly shown that measurements of sea salt and sea spray fluxes reported in the literature vary by several orders of magnitude (e.g., Andreas, 1998). To a large degree, these differences can be mitigated in modeling studies if the investigator applies such algorithms in a manor that is consistent with the original assumptions from which the algorithm was generated. In such circumstances the correct particle concentration can be derived even if the flux is grossly in error (e.g., Gong et al., 1998). However, recent studies are increasingly interested in not only particle concentrations but rather in geochemical cycles. In such circumstances these large uncertainties in sea salt fluxes become much more problematic.

In recent years fundamental processes such as sea salt production and dry deposition have come increasingly into question (e.g., Reid et al. 2001, Hoppel et al., 2002). It is unclear to what extent fundamental measurements of sea salt fluxes in wave tanks or dry deposition estimates from theory are valid. As part of the Rough Evaporation Duct (RED) experiment, the R/P FLIP and the CIRPAS Twin Otter research aircraft were deployed to the eastern shore of Oahu, HI to study air-sea fluxes the sub-tropical marine boundary layer. As part of the RED study we wished to study if currently used source and sink functions can adequately explain sea salt particle concentrations at a sub-tropical receptor site.

In this paper, we present preliminary data from the field study. We focus on a comparison of sea salt flux algorithms and flux measurement methods. We demonstrate that data from eddy correlation measurements of sea salt particle generation can be used to estimate particle fluxes.

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2. METHODS AND APPROACH

The RED field campaign took place in the vicinity of Hawaii from August 25 through September 15, 2001. The field study focused around the R/P FLIP, which was moored 10 km offshore of the eastern (windward) side of Oahu, HI. On the port side boom, a 20-meter tower was deployed with a variety of sonic anemometers and hygrometers to measure momentum, sensible and latent heat fluxes. Aerosol particle measurements were focused on the starboard side boom. Located 11 meters off of the ocean surface, and 8meters off the side of the ship, a set of instruments were deployed to measure sea salt particle fluxes through eddy-correlation methods. A mobile trolley was placed on the boom which carried a Campbell CSAT3 sonic anemometer, a LICOR CS7500 open path H_20/CO_2 analyzer, a Forward Scattering Spectrometer Probe(FSSP-100) measuring particle sizes between 1 and 32 μm , and a Passive Cavity Spectrometer Probe(PCASP) measuring particle sizes between 0.1 and 3 μm in diameter. Particle probes were ventilated using a auxiliary pumps. Trade winds were steady out of the east and at no time was the difference between wind direction and the particle inlets in excess of 20 degrees. The sonic anemometer and H_20 analyzer recorded data at 50 Hz. The particle probes sampled data on a 1 hour 10 Hz, 3 hour 1 Hz cycle. From this instrumentation momentum, sensible, latent heat and particle fluxes were calculated.

In addition to the eddy correlation instrumentation, an aerosol shed was deployed on the upper deck of FLIP. Instrumentation in the shed was fed by a 5” inlet pipe that protruded 3 meters above the top of FLIP. Sample air was heated to a relative humidity below 35% before passing into a TSI 3-λ nephelometer (λ=450, 550, 700 nm) and a TSI Aerodynamic Particle Sizer 3320 (APS) measuring particle sizes between 1 and 20 μm. For this instrumentation, comparisons of particle concentration, size, and light scattering, were made to mean meteorological conditions.

The R/P FLIP was supported by the CIRPAS twin otter from August 28-Sept 10, 2000. The twin otter carried a basic meteorological package and a sea surface temperature probe. Particle instruments on-board included FSSP-100, PCASP, CAPS, and APS probes as well as a variety of nephelometric instrumentation. Included in the flight plans were vertical profiles of particle concentrations above FLIP and 100 km upwind.

3. RESULTS AND DISCUSSION

The R/P FLIP collected data from August 29 through September 14. Figure 1 shows a time series of wind speed and particle concentrations taken onboard FLIP as well as bulk particle concentrations measured by the APS. On one occasion (Aug 31-Sept 1) winds increased above 10 m^{-1} and were accompanied by 2 m swells. Precipitation was limited to a few isolated convective cells. As would be expected in the sub-tropical trade winds, air temperatures and air-sea temperature differences were ~26 and –0.75^o C, respectively. A slight (1 m s^{-1}) but consistent diurnal cycle to wind speed was observable with a maximum around 20:00 local time.

For the most part, coarse mode particle concentrations did not correlate with particle wind speed. A particle maximum did correspond to the Aug 31 wind event. However, the three most distinctive coarse mode particle events (Aug 28 and Sept 10&14) were not associated with local production. For example, back trajectories place the Sept 10&14 particle events to the remnants of Hurricane Gill off of Baja California. Similarly, the August 28 can be traced to higher winds associated with an upwind easterly wave. Based on twin otter particle soundings, particles were dominant in the 500 m thick MBL with an exponential decrease through the convective boundary layer to the trade inversion.

The eddy correlation instrumentation onboard FLIP was not deployed until August 30. The instrumentation ran without incident with the exception of a FSSP outage from Sept 6-9. Momentum, sensible heat and latent heat fluxes were easily derivable and near expected values. Eddy correlation measurements of sea salt particle generation were visible and statistically significant for the Aug. 31-Sept 1 wind event when whitecaps were prevalent. Figure 2 shows an example of momentum flux for a 30-minute period during the high wind event when winds average 11 m s^{-1}.

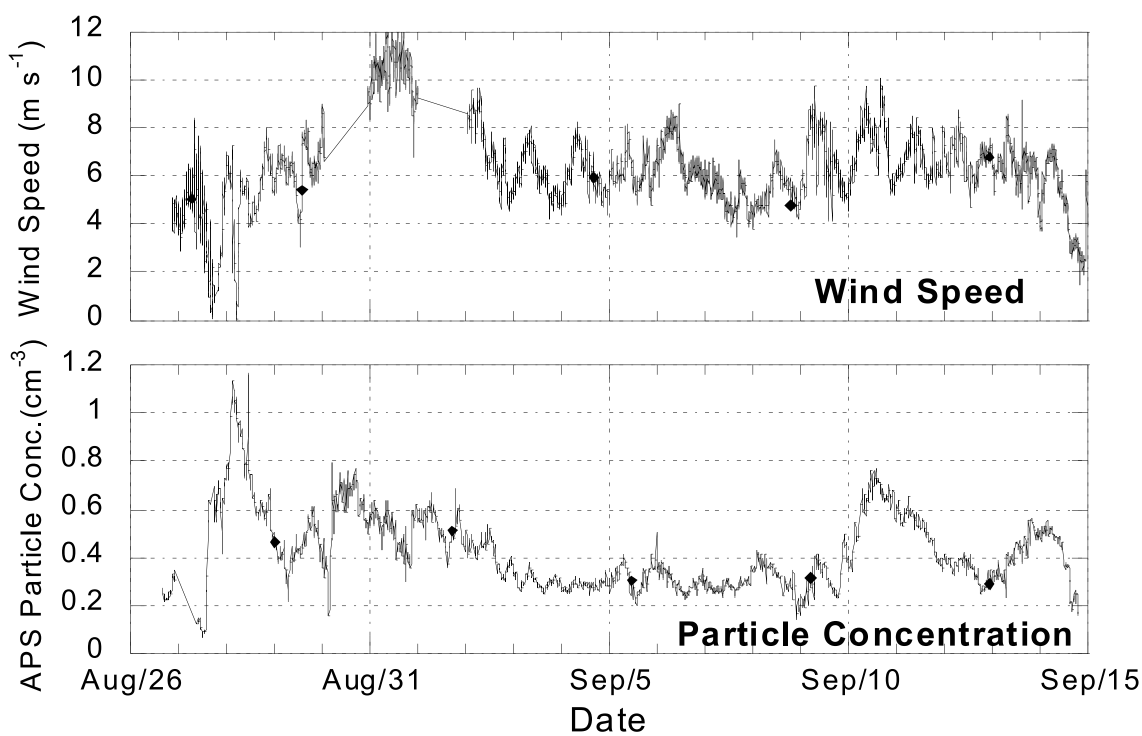

Figure 1. Time series of wind speed and coarse mode particle concentration on the R/P FLIP during the RED campaign.

The upper plot shows all of the raw data sampled at 1 Hz. The lower plot shows average values and standard errors for data binned by w'. Correlation coefficients are reasonable at 0.44.

Figure 3 shows the eddy correlation between the variation from the mean of the raw number of counts from the FSSP compared to w'. During this time period, the FSSP counted on average 30 particles per second, enough counting statistics to perform the regression (To derive the particle concentration, divide this value by 15 cm^3). Mean particle concentrations for this period at the FSSP was ~1 cm^{-2}. Hence, the variance about the mean is only about 10%. Correlations between particle concentration and w' are considerably lower than the momentum flux (r=0.18). This is not surprising as unlike the momentum flux which is more or less continuous over the ocean surface. Particle ejection events from the ocean surface by whitecaps are very sporadic, covering only 5% of the ocean surface during this period. At 11 m s^{-1}, we retrieved a net particle flux of 30,000 m^{-2} s^{-1} for particles greater than 2 μm. This is almost half the value derived by Reid et al. (2001) who used a box model approach and 30% more than the values derived by more commonly used parameterization of Smith et al. (1993). This is also a factor of two lower than the parameterization derived by Andreas (1998).

For other time periods with high particle concentration and lower wind speeds, such as the event on Sept 10, fluxes were not statistically

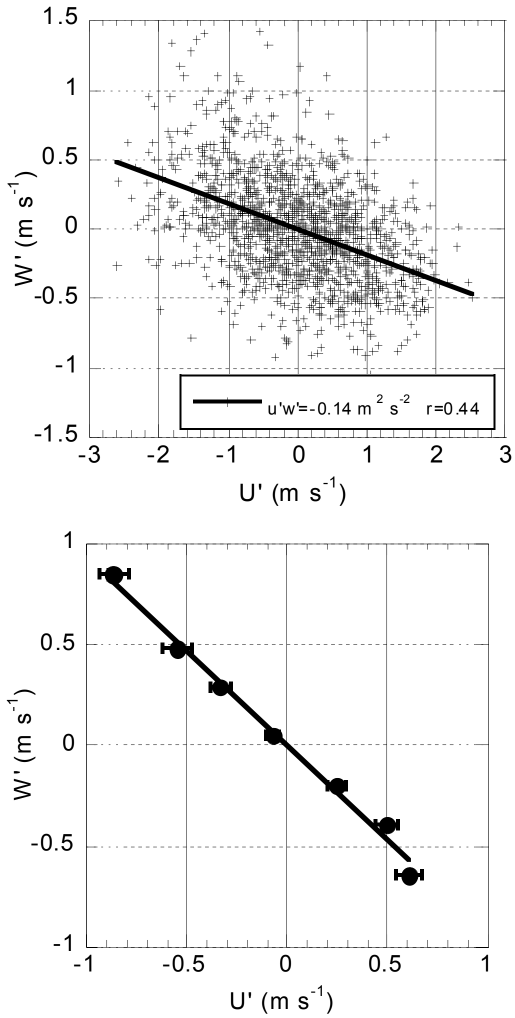

Figure 2 Eddy correlation regression of the momentum flux for a 30 minute period on Sept. 1, 2001 when the mean wind was 11 m s^{-1}.

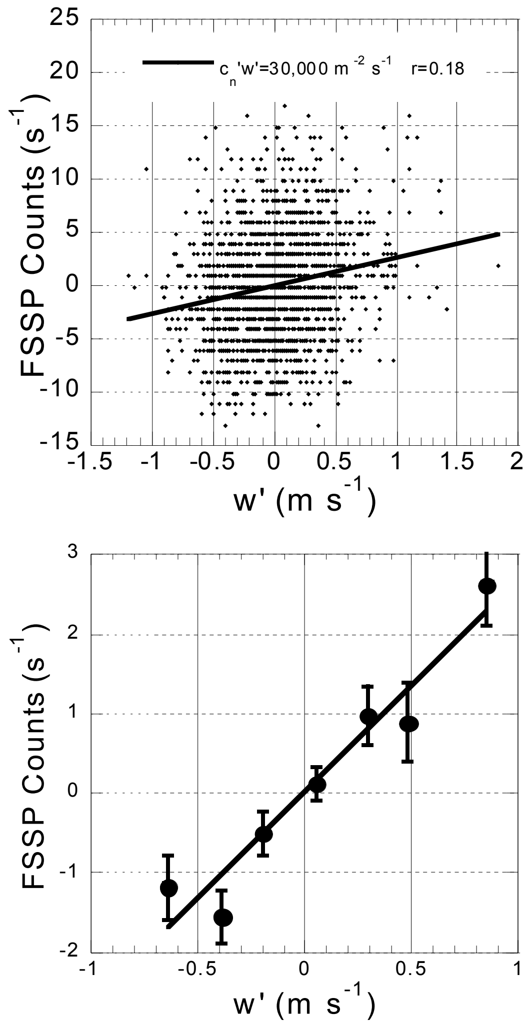

Figure 3. Same as Figure 2 but for eddy correlation regression of the coarse mode particle concentration (prime) versus w'.

different from zero (although a very slight downward flux was visible, but cannot be differentiated from noise). At 6.5 m s^{-1} wind speeds, there is little salt production and we derived a value of 3500 m^{-2} s^{-1} for particles greater than 2 μm. For winds less than 6 m s^{-1} expect that the net flux of particles is out of the atmosphere at FLIP by way of dry deposition. For particles less than ~5 μm in diameter, we expect wet deposition to dominate atmospheric removal and dry deposition to be very low. Hence a clear dry deposition (e.g., negative flux) could not be measured at FLIP. Examination of Tropical Rainfall Measuring Mission (TRMM) records show there was little precipitation in the sub-tropical Pacific Ocean during the RED study. Thus, for particles less than ~5 μm in diameter there was not a significant sink available.

The differences in the flux measurements found in this study and those of other studies highlights the point that the true uncertainty in sea salt fluxes is still about a factor of two. While Hoppel et al. (2002) as shown that the method of Smith et al., (1993) is highly uncertain, these new measurements place fluxes near Smith's original values and away from those of Andreas (1998) and Reid et al., (2001). It is unclear at this time if the actual flux varies from location to location, or if these are simply instrument uncertainties.

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