3.13 AIRBORNE DOPPLER WIND LIDAR INVESTIGATIONS OF OLEs OVER THE EASTERN PACIFIC AND THE IMPLICATIONS FOR FLUX PARAMATERIZATIONS

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1. Introduction

Real data always reveal more texture, more variability in time and space than we can replicate in models. One challenge is to determine how to parameterize average properties or net fluxes on scales appropriate for the models being used. A second challenge is to understand how to use routinely available data (such as satellite, surface networks, and models) as input to the parameterizations. One area that is a special challenge to the coupled model (e.g. COAMPS) parameterizations is the momentum flux across the air/sea interface. Field programs have revealed significant variability in winds and fluxes in the atmosphere as well as variability in sea surface temperature (SST), waves and currents (Rogers, et al., 1998; Edwards et al., 2001). Understanding the coupling between these sub-grid scale features and the implications these relationships have to current bulk flux parameterization schemes (Fairall et al., 2003) is a major challenge. If much or all of this variability results in linear cross correlations, then simple averaging could work. However, it is thought that non-linearity is the rule in these processes and that, in the presence of organized large eddies (OLE), the implications to flux parameterizations are significant and put a limit on the expected level of success with bulk flux approaches for coupled ocean/atmospheric models. One very important feature of OLE dominance is the nearly stationary (or moving with 5-10% of the mean MBL wind speed) nature of the wind anomalies. Consequently, a buoy or other point sensor may not, with time averaging, obtain good estimates of the spatial average. In addition, a space-based sensor with a larger spatial footprint may appear to offer a better areal average but in fact may not because of biased sampling from sub- pixel variations in the wind.

The Navy's Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) and the Naval Postgraduate School (NPS) has developed an airborne capability to collect data within the lower troposphere related to aerosols and turbulent fluxes. The Navy Twin Otter aircraft is equipped with a variety of particle probes and wind sensors. As also described in Emmitt et al., 2005 (these proceedings) and Greco et al., 2005 (these proceedings), CIRPAS, together with the IPO (Integrated Program Office of NPOESS), recently (2002) added a scanning Doppler wind lidar that provides range resolved winds, turbulence and aerosols (inferred from backscatter).

Doppler lidars obtain range resolved line-of-sight (LOS) winds from aerosol and/or molecular backscatter. As with scanning radar, the lidar can be scanned to obtain vertical profiles of the full wind vector, including vertical motion (w). The range of observations depends upon the lidar size and signal integration time. Given today's technology affordable for atmospheric research, the ranges are usually less than 20 – 25 kms (with the exception of long integration with molecular systems). Accuracy of the LOS measurements is usually < 1m/s RMSE. The TODWL (Twin Otter Doppler Wind Lidar) has the capability of pointing in most directions viewable from the right side of the aircraft and forward of the wing. As described in further

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detail in Emmitt et al., 2005 and Greco et al., 2005, the TODWL is a coherent 2 micron system with a bi-axis scanner mounted on the side of the door. The measurement accuracy is on the order of a few cm/sec in speed and a degree or two in direction. The footprint of the lidar beam is < 10 cm and the full wind profiles are normally constructed with wind observations over ~ 500 – 1000 meter flight segment. The vertical resolution is usually ~50 meters. The TODWL provides vertical profiles (surface to 5 km) of the wind in clear air along the aircraft's flight path, profiles of aerosol concentrations, depth of the MBL and estimates of turbulence within its field of regard.

2. Experiments

In 2002 and 2003 the IPO funded TODWL flights to identify confounders for using lidar returns from and near the ocean surface for a future space-based wind lidar. Out of ~ 50 hours of airborne data, approximately 20 hours were collected with the purpose of investigating OLEs and gravity waves over the Pacific Ocean and Monterey Bay. This includes flight legs at different heights above the water with the DWL pointed straight ahead and flight legs at or above 3km with the DWL pointed straight down. For the IPO, the focus was upon the degree of correlation between the winds and the Marine Boundary Layer (MBL) aerosols and the size of the correlated structures.

The analyses of data from the TODWL flights reveals the presence of OLEs over Monterey Bay as also described in Emmitt et al., (2002) and Bowdle et al., (2004). As shown in Figure 1 for a flight in March 2002, the OLEs were easily detectable and were characterized by a strong correlation between aerosols and wind speed.

In the 2003 experiments, we were able to further sample the OLEs from several perspectives, including cross wind, along wind and from a nadir view. Although the DWL is usually configured to scan for vertical profiles of the wind, considerable flight time was spent at 30 meters above the water with the lidar beam pointed straight ahead (Bowdle et al., 2004). The goal was to collect data on the correlations between horizontal (and vertical) wind variation and aerosol backscatter variation. On some flights, the objective was to investigate the 3D flow patterns beneath subtle indications of organization such as that shown in Figure 2. Quantifying such correlations was needed to design data processing algorithms for space based lidars. As expected, there was considerable correlation found as evidenced by the Hovmuller plots (Figure 3 and 4). The DWL is an excellent tool for observing and quantifying the spatial and temporal variations in such organized structures which have significant non-linear impacts on the net air/sea fluxes on the submesoscale. Figure 5 shows the wind and aerosol structure of the boundary layer in which the OLEs of Figures 3 and 4 were found. Note the strong shear in both speed and direction at 350-375 meters above the water and the low level jet at 200 meters.

3. Other investigations

In collaboration with Foster (Foster et al., 2004), the TODWL data has been used with his non-linear roll model (Foster, 1996) to compare its predictions of roll size and velocities. The preliminary results are extremely encouraging. The key inputs for running the model are the depth of the MBL, the wind profile within the entire layer and the SST. Although the surface winds from radar or buoys can be used with the model, the DWL winds (Emmitt and O'Handley, 2003) are extremely valuable for both running the model and validating its representation of the flux variations over the ocean surface.

In addition, during the IPO's 2002 and 2003 TODWL flights, there were several opportunities to underfly RadarSat, which was turned on over Monterey Bay especially for the DWL comparisons, and QuikScat. Those comparisons are still in process at the University of Washington (Foster and Brown, personal communication).

4. Summary

In addition to horizontal and vertical winds, an airborne Doppler lidar can be used to study water surface motions and their correlations with aerosols. These correlations have significance in the interpretation of data obtained with space based lidars and also the parameterization of fluxes over water surfaces at wind speeds above those that produce whitecaps. The investigation of OLEs will continue to be among the objectives of future TODWL flights.

5. References

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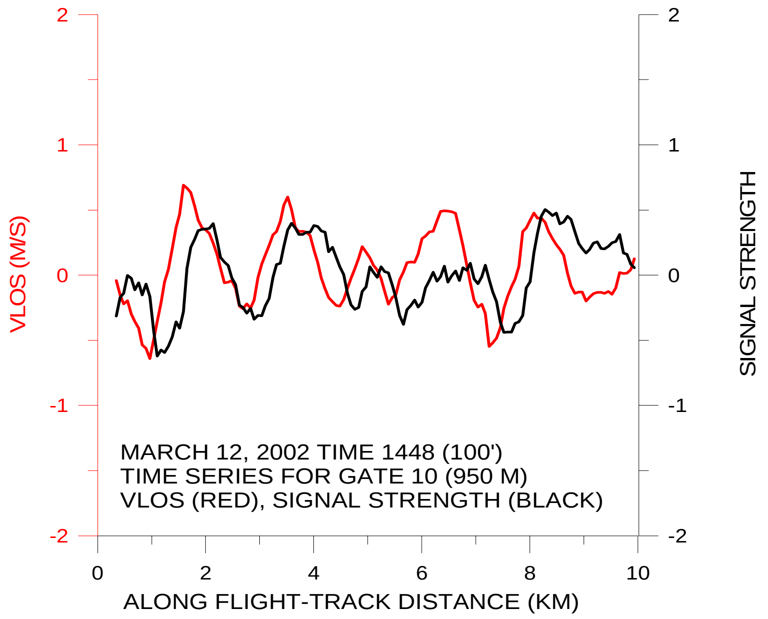

Figure 1: Co-plot of signal return strength from a fixed range from aircraft vs. LOS velocity at the same range gate.

Figure 2: Picture taken from CIRPAS Twin Otter of organized aerosol or incipient cloud streets.

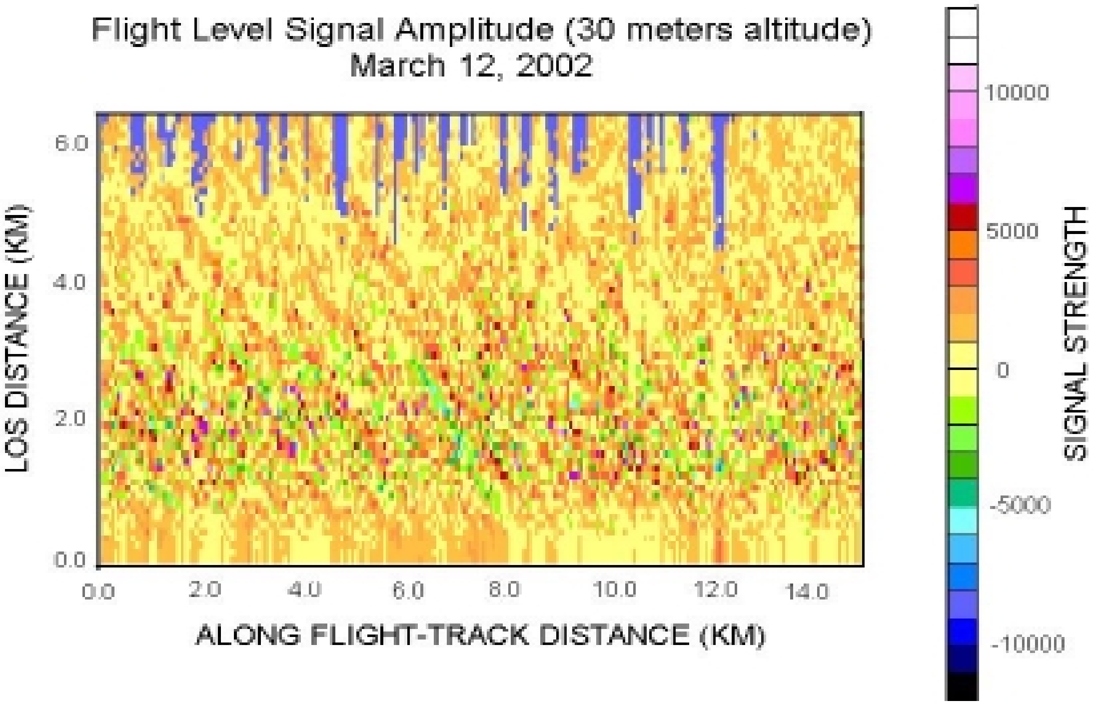

Figure 3: Hovmuller plot of aerosol signal using data collected from DWL flying at 30 meters above Monterey Bay with lidar beam pointed straight ahead.

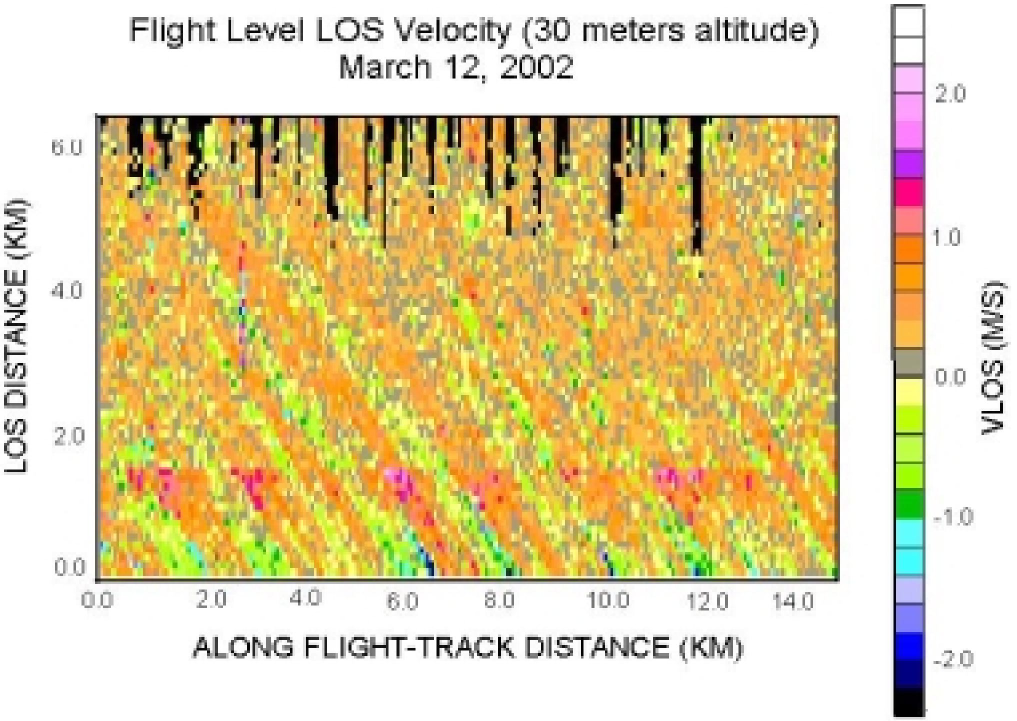

Figure 4: Hovmuller plot of LOS wind using data collected from DWL flying at 30 meters above Monterey Bay with lidar beam pointed straight ahead.

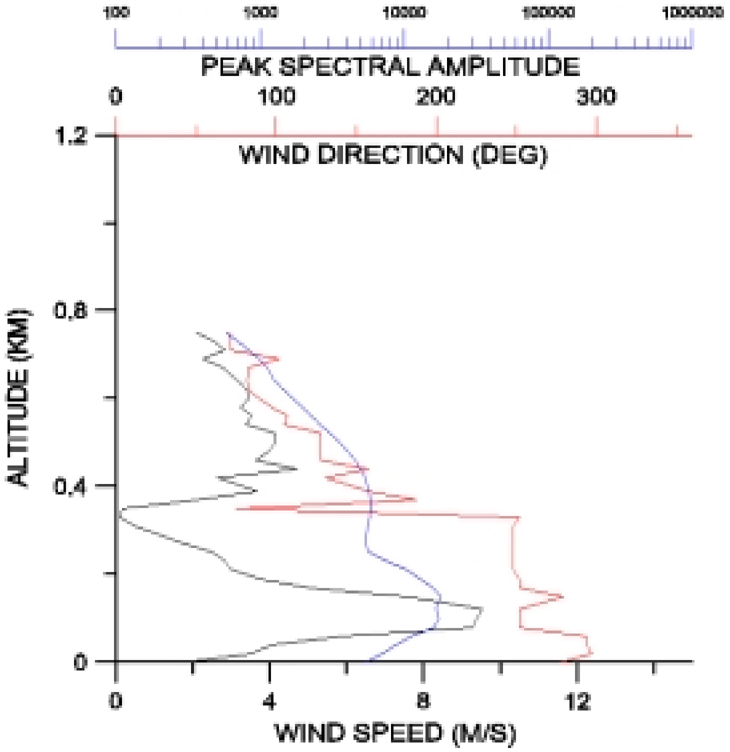

Figure 5: A TODWL profile taken over Monterey Bay, March 2002. TODWL was flown at a 1 km altitude with the scanner programmed for a downward conical pattern