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During the second year of funding on this DRI we determined that we needed to shift our efforts from the HRDL data evaluation to the more general investigation of the partitioning of boundary layer fluxes into those best estimated by eddy diffusivity formalisms and those better described as mass fluxes. This shift in emphasis was, in part, driven by the recognition that the HRDL data did not have the frequency resolution needed to resolve the vertical velocities required for some of our initially proposed work.

The move to examining the ABL using data taken from the CIRPAS TODWL (Twin Otter Doppler Wind Lidar) remains consistent with this ONR DRI to better understand the relationship between organized structures (OLEs, LLJs, directionally sheared layers, etc) and the efficiency of energy, mass and momentum exchange at the bottom and top of the ABL.

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Investigation of the Air-Wave-Sea Interaction Modes Using an Airborne Doppler Wind Lidar: *Analyses of the HRDL data taken during DYNAMO*

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INTRODUCTION WITH GOALS

During the second year of funding on this DRI we determined that we needed to shift our efforts from the High Resolution Doppler Lidar (HRDL) data evaluation to the more general investigation of the partitioning of boundary layer fluxes into those best estimated by eddy diffusivity formalisms and those better described as mass fluxes. This shift in emphasis was, in part, driven by the recognition that the HRDL data did not have the frequency resolution needed to resolve the vertical velocities required for some of our initially proposed work.

The move to examining the atmospheric boundary layer (ABL) using data taken from the CIRPAS TODWL (Twin Otter Doppler Wind Lidar) remains consistent with this ONR DRI to better understand the relationship between organized structures (OLEs, LLJs, directionally sheared layers, etc) and the efficiency of energy, mass and momentum exchange at the bottom and top of the ABL.

After discussions with ONR, it was agreed that we would focus our 2nd and 3rd year air-sea interaction effort on the more general and more inclusive topic of ABL flux parameterization over the ocean (Monterey Bay, CA) and over land (Dugway, UT). TODWL data plus other data from the CTV and land based flux towers.

OBJECTIVES

As stated in our FY12 report, we added a new research objective which is to investigate dry convection rolls (Organized Large Eddies, OLE) using data from an airborne DWL flown in April 2007 near Monterey, CA. This additional research objective is tightly associated with the research we are doing under another ONR DRI, the Unified Physical Parameterization for Extended Forecasts DRI, where the EDMF flux parameterization is being evaluated for its use in numerical models for seasonal predictions.

Two primary objectives for year 2 were:

1. Study the fluxes at the air-sea interface using the TODWL and CTV instruments flown together near the California coastline.
2. Use the MATERHORN experiment at Dugway, UT in October 2013 as an opportunity to expand the DWL data base to include ABL surveys in complex terrain as a comparison to the ABL over cold water. Note that the MATERHORN was co-funded by ONR.

APPROACH

The work on objective one continues as we examine several cases in 2013 where the CTV was operating adequately and the ABL contained OLEs and LLJs needed for our investigation. The first important step was to navigate the data from the two systems so that their data sets could be joined. This was not as easy as it seemed since the CTV did not fly faithfully directly below the Twin Otter.

The second step was to compute heat moisture and momentum fluxes for both the CTV and Twin Otter flux sensors.

The last step is to determine the correlations between ABL structures and the fluxes.

To meet the second objective, we had to process several thousand wind profiles obtained with TODWL over Granite Mountain at Dugway Proving grounds, UT.

After processing the TODWL data for 7 missions, comparisons of u,v and vertical velocities were compared to those predicted by a WRF model.

WORK COMPLETED

As noted above we have processed more than 50 hours of TODWL data from both the Monterey and DPG areas. We have begun combining the information from the TODWL, CTV and Twin Otter sensors to establish the relationship between the local fluxes and the energetic of LLJs and OLEs. We have also begun to modify the EDMF (Eddy Diffusivity and Mass Flux) parameterization to account for the differences between thermally driven convection and dynamically driven vertical transports.

RESULTS

Here we provide several examples of the cases we are studying related to our DRI goals.

Monterey based study

The figure below was generated with TODWL data taken in April 2007. Cases such as this provided motivation to push forward with investigations using the CTV as well as the TODWL in the study of the MBL in the presence of organized structures. In Figure 1, Organized Large Eddies (OLEs) are seen in both the wind and aerosol fields (on left side). Time slices (on the right) through the lidar data at a single height illustrates the periodicity expected for such organized features. Both the aerosol return and the wind measurement reveal organized circulations. The question is “how do these OLEs change the total BL fluxes over that expected in a purely eddy diffusivity explained exchange?” More than 20 additional cases showing various degrees of organization have been identified including the provocative cases of “stacked OLEs” that appear when there is a Low Level Jet (LLJ) with its maximum below 200 meters.

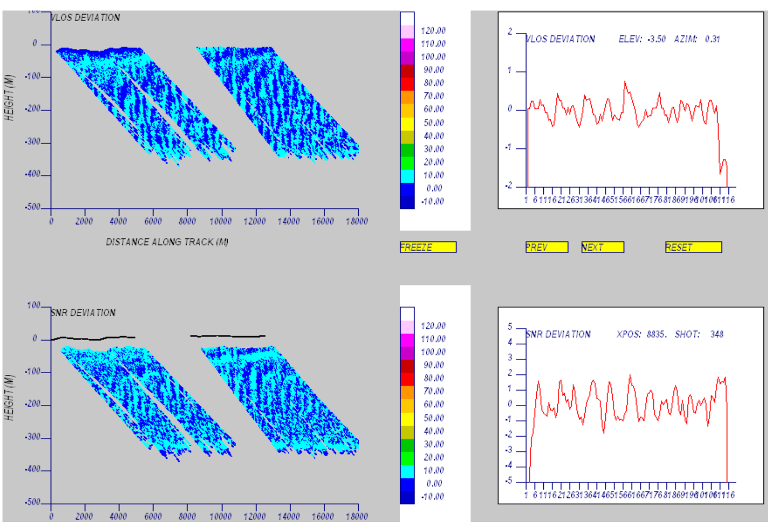


Figure 1. Time series of TODWL data taken with a down elevation angle of ~ 3 degrees pointing forward. The color scale has been chosen to highlight changes of the horizontal wind that exceed 1 m/s (above left panel) or 1 dB of SNR (lower left panel).

During a 1012 flight campaign near Monterey, CA, the TODWL system was used to investigate stable MBLs capped with incipient clouds, in some cases only detectable by the lidar. Using some new signal processing algorithms developed by SWA under this DRI, protected channels of turbulence were detected. A good example of such a feature can be seen in the lower panel of Figure 2. While one amongst many channels, the most obvious one can be seen on the left-hand side extending from the surface to the “incipient” cloud layer. We note that the onboard observer reported cloud free but hazy conditions. These channels are a focus of current theoretical (Emmitt and Foster) and empirical research efforts.

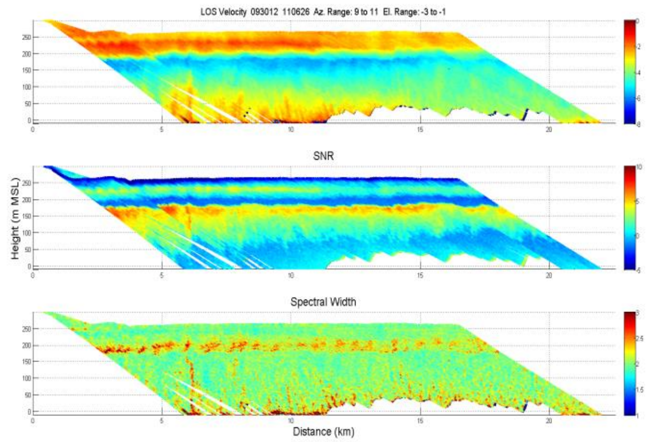


Figure 2. Data obtained with TODWL during UPP flight on 9/30/12. Top: LOS wind speed (m/s) along beam directed straight ahead and down 3 degrees. Middle: Signal to Noise Ration (SNR in dB) mapping the strength of the returns from aerosols and clouds. Lower: Width (m/s) of the velocity peak in the spectrum denoting the amount of turbulence in the illuminated volume.

We are currently working to match up the CTV fluxes and Twin Otter fluxes with the features revealed by the wind lidar during some flight segments on 9/30/12 flown at 300 meters above the water. Examples of the CTV and Twin Otter data are shown in Figure 3. Table 1 summarizes the results of some very preliminary analyses.

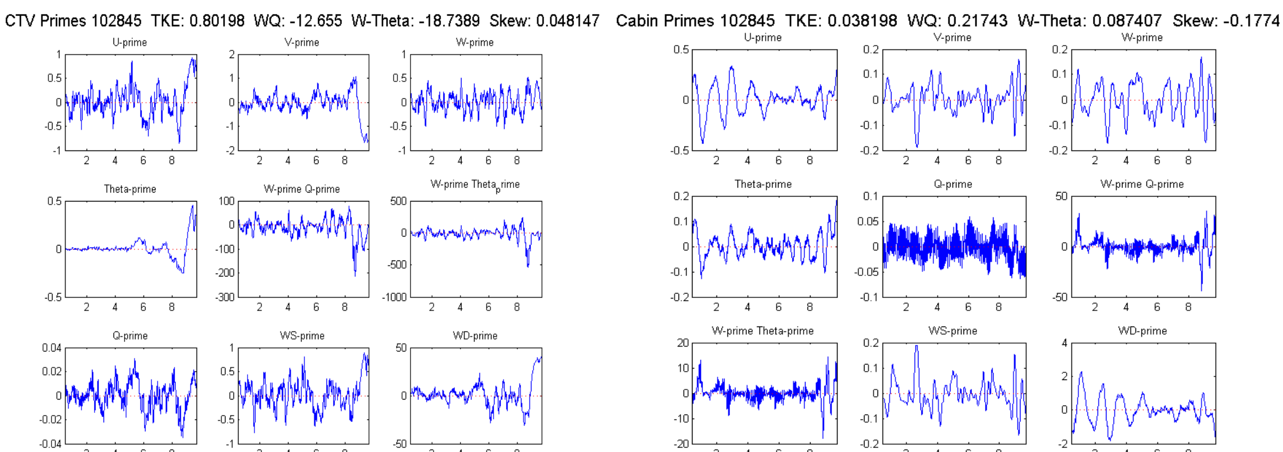


Figure 3. Examples of the data from both the CTV and Twin otter that are used to compute the turbulent fluxes as well as identifying those features associated with mass fluxes.

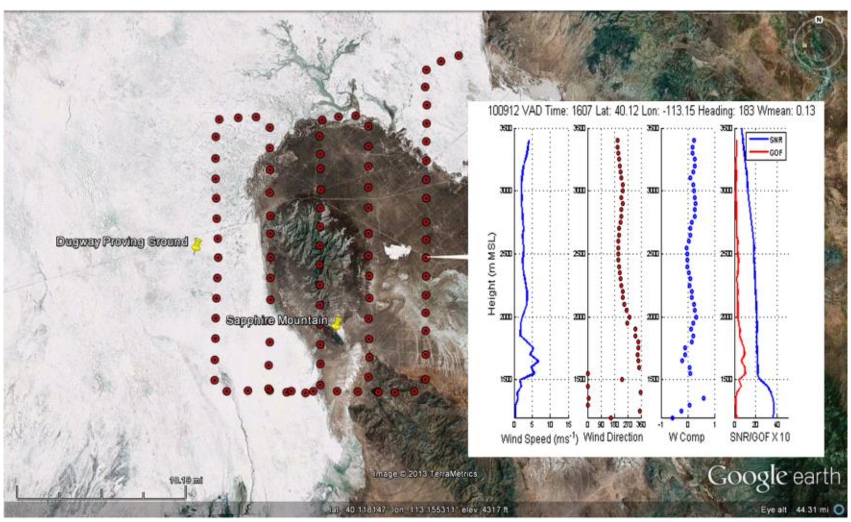
Summary of segment statistics

Flight Segment	TODWL Altitude	CTV Altitude	Heading	TKE	Sensible Heat (W)	Latent Heat (W)	Skewness
1007	284	60	94	.19	8.55	3.43	-.40
				1.92	-1.28	15.15	.90
1028	292	25	98	.04	.22	.09	-.18
				.80	-12.6	-18.7	.05
1106	286	75	294	.05	3.02	1.21	-.51
				1.1	-3.36	-1.19	-.17
1111	290	75	293	.24	1.98	.80	-.37
				.29	-.74	.55	.22
1121	288	climbing	98	.14	-1.11	-.44	.90

Table 1 Very preliminary results of analyses of lidar and flux data obtained during flights on 3/9/12.

During October 2012, we were authorized to participate in the MATERHORN conducted with ONR support. The focus of our participation remained pursuing a better understanding of the role that ABL structures mapped by the wind lidar have in augmenting fluxes within the lower troposphere. The basic data set obtained with the TODWL in MATERHORN was vertical profiles of u,v,w and aerosol backscatter. These profiles were navigated within Google Earth to allow for easy overlaying of the wind fields with the topography (Figure 4).

MATERHORN 2012 TODWL N-S Legs on October 9, 2012
1601 - 1641



*** - Provided by Simpson Weather Associates, NRL, ONR, ARL and ARO**

Figure 4. Example of the TODWL soundings as navigated into Google Earth. By clicking on a red dot, one gets the panel of information as shown in the example.

A particular question we wanted to address was that of how reliable the vertical velocity information was. For each conical scan used to derive the horizontal wind components, we recorded the DC offset in the sine fit and argued that it was related to the vertical speed averaged at the 12 locations where LOS data was recorded during the conical scan. We programmed the scanner to take 5 seconds (~250 meters along flight path) of pure nadir velocity between conical scans. In the left panel in Figure 5, the differences between the two *w* estimates within 300 profiles are shown. The less than .02 m/s suggest there is no bias in the two estimates. We continue exploring the utility of the vertical velocity information since this relates directly to one of the original DYNAMO questions directed to the ship-based DWL (HRDL).

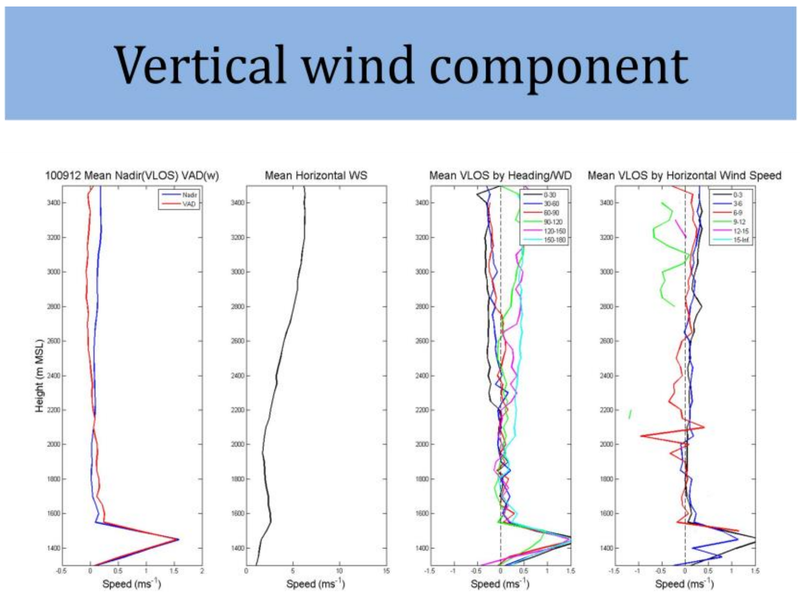


Figure 5. Results of comparing the vertical wind component derived from a conical scan with that measured close by with a nadir sample (vertical velocity only).

RELATED PROJECTS

ONR grant to study the utilization of Doppler wind lidar (DWL) data to quantify the contribution of organized large eddies (OLEs) to the EDMF Unified Physical Parameterization.

PLANS FOR YEAR 3

We have three primary goals for year 3 of this DRI.

1. Finish the development of a methodology for joining airborne DWL data and in situ flux data to achieve an understanding of how the organized ABL structures modulate ABL fluxes.
2. Apply that methodology to the DWL data sets already identified and in some cases analyses.
3. Develop an expression for mass fluxes by OLEs in the MBL that is suitable for use in numerical model parameterizations. This will be derived from flux data measured directly by the CTV (Monterey) and towers (Dugway) and associated with organized ABL structures mapped from the DWL.

We will pursue publishing our results should the findings of this research merit such.