3.3 INVESTIGATION OF FLOWS WITHIN COMPLEX TERRAIN AND ALONG COASTLINES USING AN AIRBORNE DOPPLER WIND LIDAR: OBSERVATIONS AND MODEL COMPARISONS

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1. Introduction

As described in further detail by Emmitt et al., 2005 (these proceedings), the Navy's Center for Interdisciplinary Remotely-Piloted Aircraft Studies (CIRPAS) has installed a coherent 2 micron Doppler lidar in a Navy Twin Otter aircraft. The lidar includes a bi-axis scanner mounted on the side door of the aircraft that allows vertical soundings of the wind profile above and below the aircraft as well as taking data with horizontal or vertical perspectives.

The TODWL (Twin Otter Doppler Wind Lidar) instrument is described in Table 1.

Wavelength	2 microns
Energy per pulse	5-7 mJ
Pulse repetition rate	80 hz
Pulse length (FWHM)	90 meters
Telescope diameter	10 cm
Scanner	2 axis forward (240 deg.) and starboard (60 deg.)
Total System Efficiency	7-10 %
Power	1.5 KW
Weight	250 lb

Table 1. TODWL System Description

The one feature that distinguishes this airborne Doppler lidar from most others is the side mounted two-axis scanner which allows for conical scans above, ahead and below the aircraft. In most instances, a complete 8 point step-stare conical scan takes approximately 15 seconds.

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At the nominal cruise speed of 50 m/s (IAS), a wind profile is obtained every 750-800 meters. The scanner can also be pointed directly nadir (adjusted for aircraft pitch and roll). In the nadir setup, vertical motions of the surface and atmosphere can be observed to within 10 cm/sec accuracy. The range resolution depends upon the backscatter structure. Using a sliding range gate in the processing we are able to achieve 25-50 meter vertical resolution. In the case of the water or earth surface, the height resolution is better than 10 meters.

2. Experiments

The TODWL has been flown for ~50 hours in two series of field experiments based out of Monterey, CA in 2002 and 2003.. The primary objectives of the flights were to measure wind profiles above and below aircraft as part of the development of a calibration/validation program for all wind profiling technologies, as well as to develop an understanding of how to interpret DWL returns from the lower troposphere, in particular, within the marine boundary layer where the surface returns from the water could be problematic. However, it was also made possible to expand the flight objectives to, among other activities, include MM5 numerical model validation.

Prior to analyzing the data for weather features and conducting intercomparisons with other observations and model runs, the information from TODWL was processed using an algorithm called Lidar Attitude and Height Determination and Signal Search Algorithm (LAHDSSA) (example provided in Figure 1) that includes:

- Correcting for aircraft induced pointing errors
- Correcting for lidar beam pointing errors

- Employing spectral peak threading near ground
- Accounting for varying terrain heights within a VAD

3. Observations

During the 2002 and 2003 field campaigns, several missions were planned to overfly locations where winds were routinely measured by automated towers, ocean buoys, rawinsondes, microwave sounders, and ground-based lidars (in a single Colorado based flight). Two examples of a comparison between the wind profiles measure by TODWL and by the Microwave wind sounder at Fort Ord, CA are presented in Figures 2 and 3. Both the magnitudes and vertical structure of the two independent wind profiles are very similar. This high degree of similarity between the TODWL profiles and those obtained from the automated and more conventional ground-based sounder provides encouraging validation of the TODWL measurements.

Part of the flight path of one TODWL mission (21 February 2003) is shown below in Figure 4. During this mission, 12-point step-stare scans were conducted each 1-1.5 km along the flight path These profiles were also used to compare with MM5 analyses to be discussed below. The vertical profiles of horizontal speed and direction, as well as vertical velocity for both off shore and on shore soundings are displayed in Figure 5a and 5b. As shown in Figure 5, the low level (below 500m) jet off the central California coast was indeed captured by the TODWL measurements. The breakdown of this jet over land was also identified, as are the more turbulent motions and slightly higher winds aloft (1000 – 2000m) over the terrain. This was also seen during several other missions.

4. Comparison with Model Analyses (MM5)

During the 2003 flight series, Miller and Nuss of the Naval Postgraduate School (NPS) collaborated with the investigators to provide MM5 runs to coincide with the TODWL field missions. The NPS MM5 model was run twice daily, with a warm start and a MRF PBL scheme. The model contained 30 vertical levels with 12 levels at or below 850 mb. The NPS MM5 typically had a triple nested grid of 108, 36 and 12 km, but a 4 km nested grid was run special for this time period.

During an individual mission, the TODWL could collect up to ~3000 profiles over a period of 4 hours with 50 m vertical resolution, ~ 600 m horizontal resolution and ~ .10 m/s accuracy. During the Post-field campaign research, the output from NPS MM5 fine scale grid analyses were compared with the nearest TODWL soundings taken over the water and complex terrain near Monterey (Emmitt, et al., 2003; Emmitt,2003; Emmitt, et al., 2004) during the same time period. Some examples of those profiles are shown in Figure 3. The resolution of the model was 4 km and the DWL soundings were spaced ~ 1km apart.

On February 21 2003, the conditions were suitable for taking a long series of profiles that could be used to test algorithms for aircraft motion removal and validate the NPS MM5 analyses for that day. The TODWL was flown in the pattern shown in Figure 4.. The scanner was in the 12 point step-stare mode and provided a complete profile every 25 seconds (~ 1.2 – 1.3 km of flight path). A sample of the profiles below the aircraft were shown in Figures 5a and b

In figure 4, several locations were noted where comparisons were made between the TODWL profiles and the MM5 model output at 4 km resolution. Examples of these comparisons are shown in Figure 6a-b while Figure 7 displays the MM5-TODWL wind comparison across a horizontal domain, both inland and offshore from Monterey, at both 1500m and 500m. Depending upon ones expectations, this comparison is rather acceptable or may illustrates a major shortcoming of the MM5 on this day and at this location over the ocean just west of Monterey, particularly in the lower levels.

5. Summary

As show by the investigations described above, the TODWL can provide accurate, high space and time resolution wind profiles over open waters and complex terrain and provide a new perspective on marine boundary layer research. TODWL soundings of the wind field have been processed to obtain accuracies of <.10 m/s in each component (u,v,w). Comparisons with other sounders show very similar and encouraging results but must be interpreted with caution since integration times and sample volumes are different. The same holds true regarding comparisons with models. Although the comparisons are encouraging and perhaps suggest that TODWL measurements may be helpful in tuning parameterization schemes of models like the MM5, they also suggest that a significant effort is needed to understand the differences.

6. References

Emmitt, G.D., C. O'Handley, S.A. Wood, R. Bluth and H. Jonsson, 2005: TODWL: An airborne Doppler wind lidar for atmospheric research. Annual Amer. Met. Soc. Conference, 2nd Symposium on Lidar Atmospheric Applications, San Diego, CA, January.

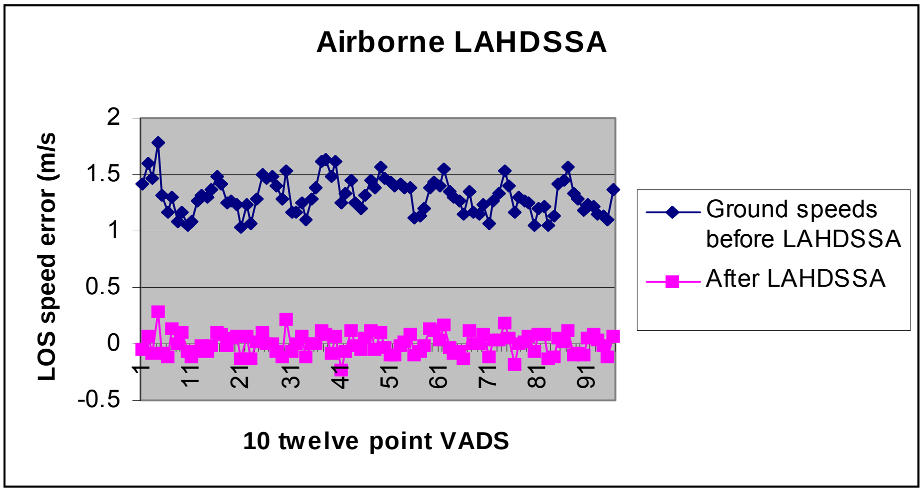


Figure 1. LAHDSSA wind speed correction of TODWL data

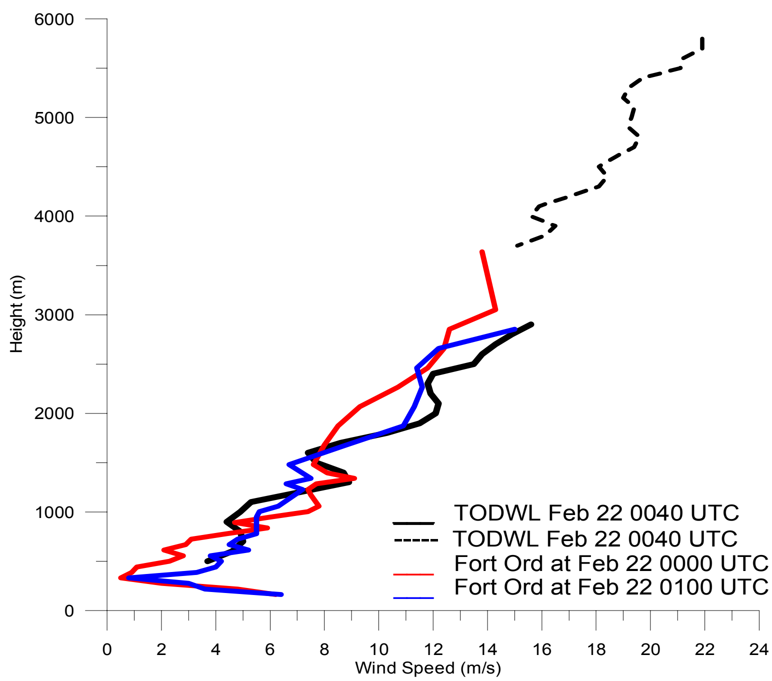


Figure 2. Comparison of one TODWL sounding (up and down portions) with two soundings from the Ft Ord microwave sounder taken one hour apart on February 22, 2003.

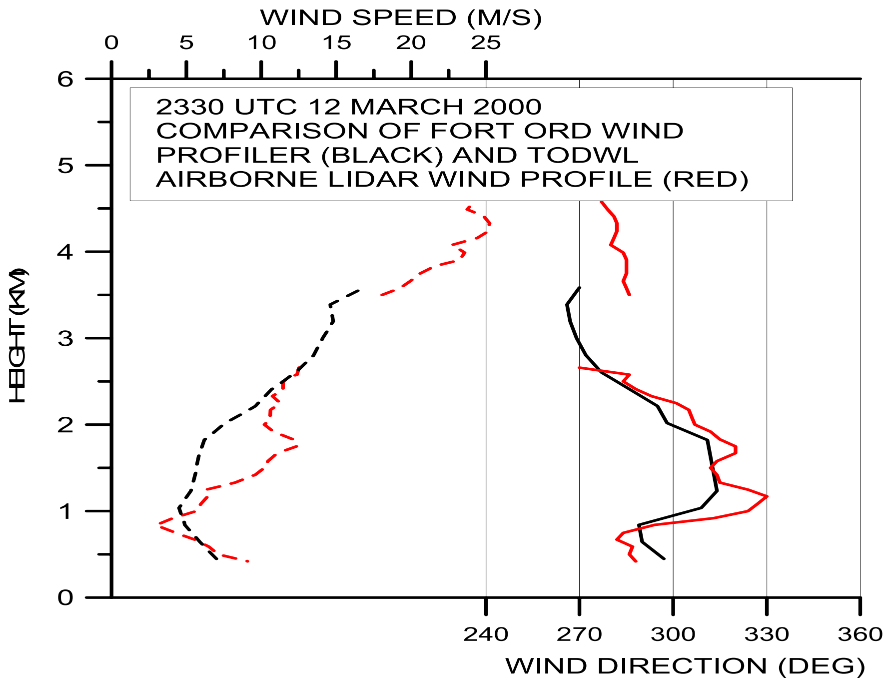


Figure 3. Comparison of one TODWL sounding (red) with a sounding from the Ft Ord microwave sounder taken one hour apart on March 12, 2003.

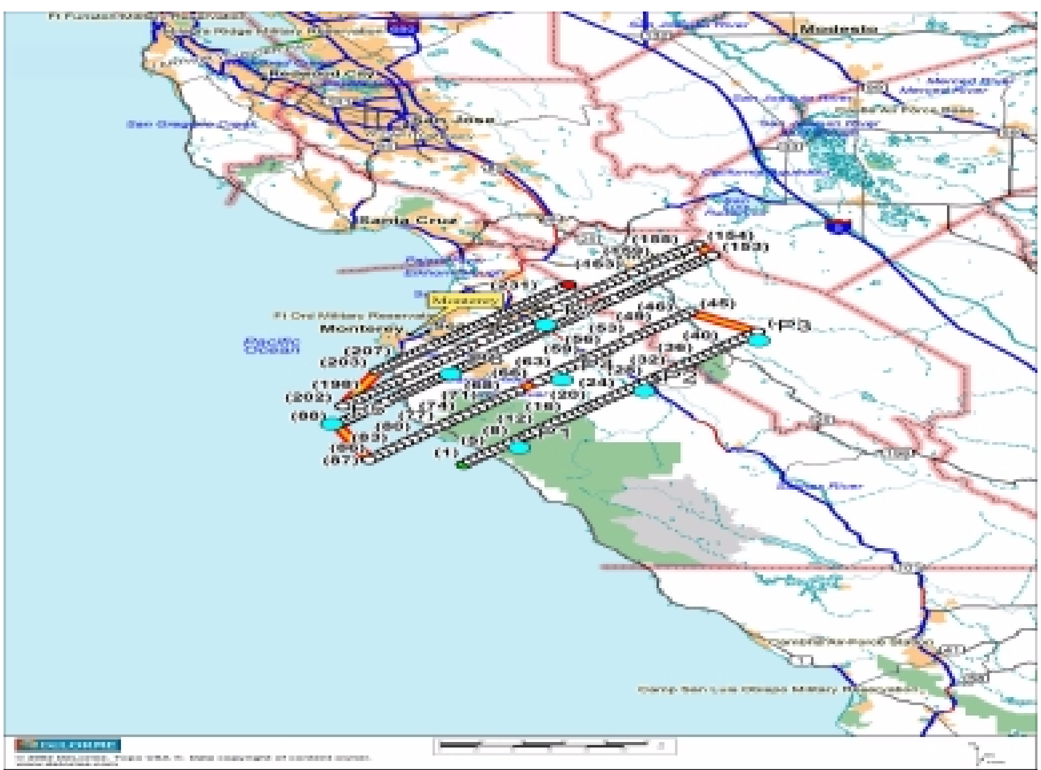


Figure 4. Flight segment of profiles taken on February 21, 2003. Blue circles are the locations of MM5 soundings used in comparison with TODWL soundings. Each white dot is a TODWL sounding.

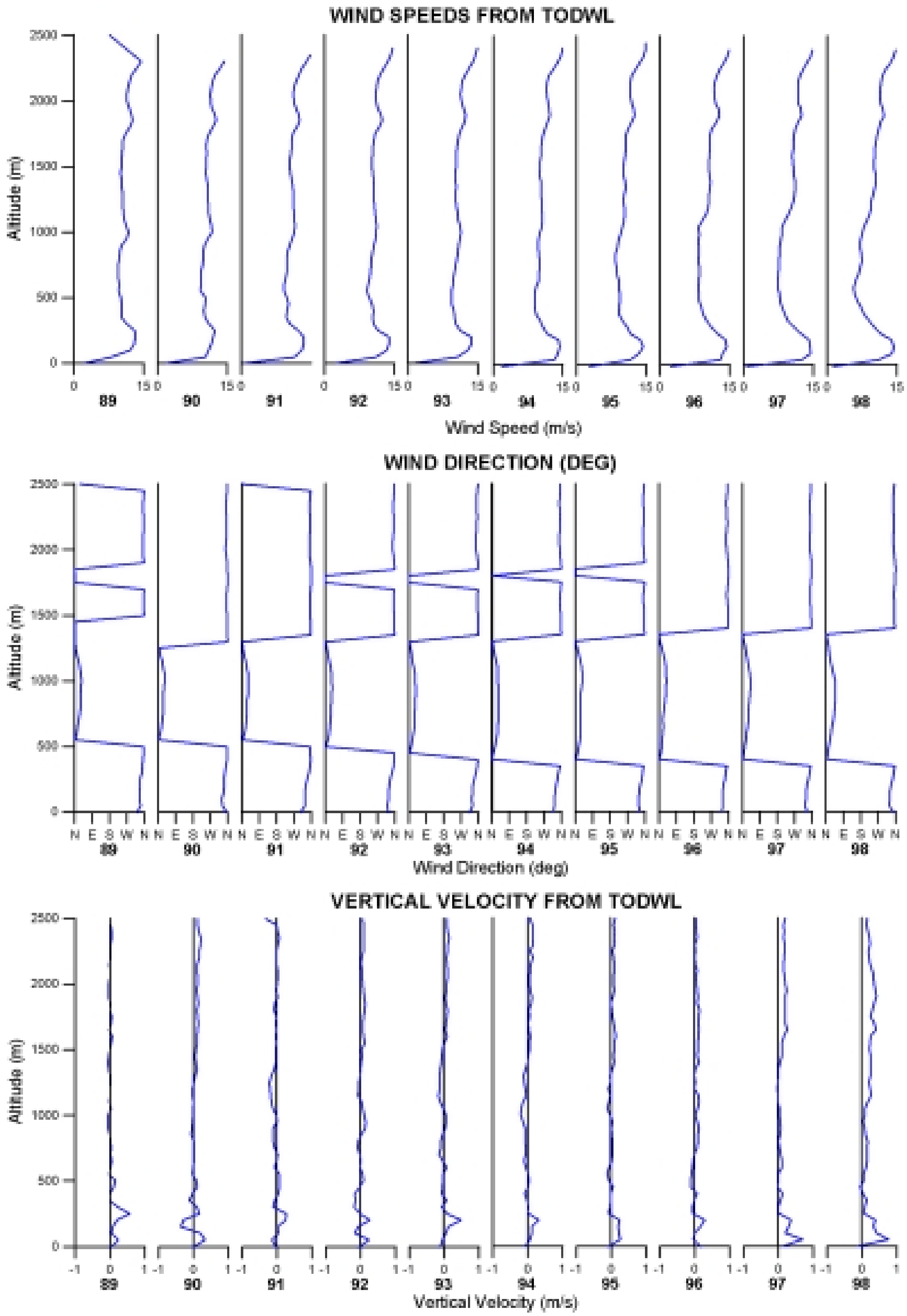


Figure 5a. Series of TODWL soundings obtained over the water just west of Monterey on 2/21/2003. The soundings on the left are farther from the shore than those on the right.

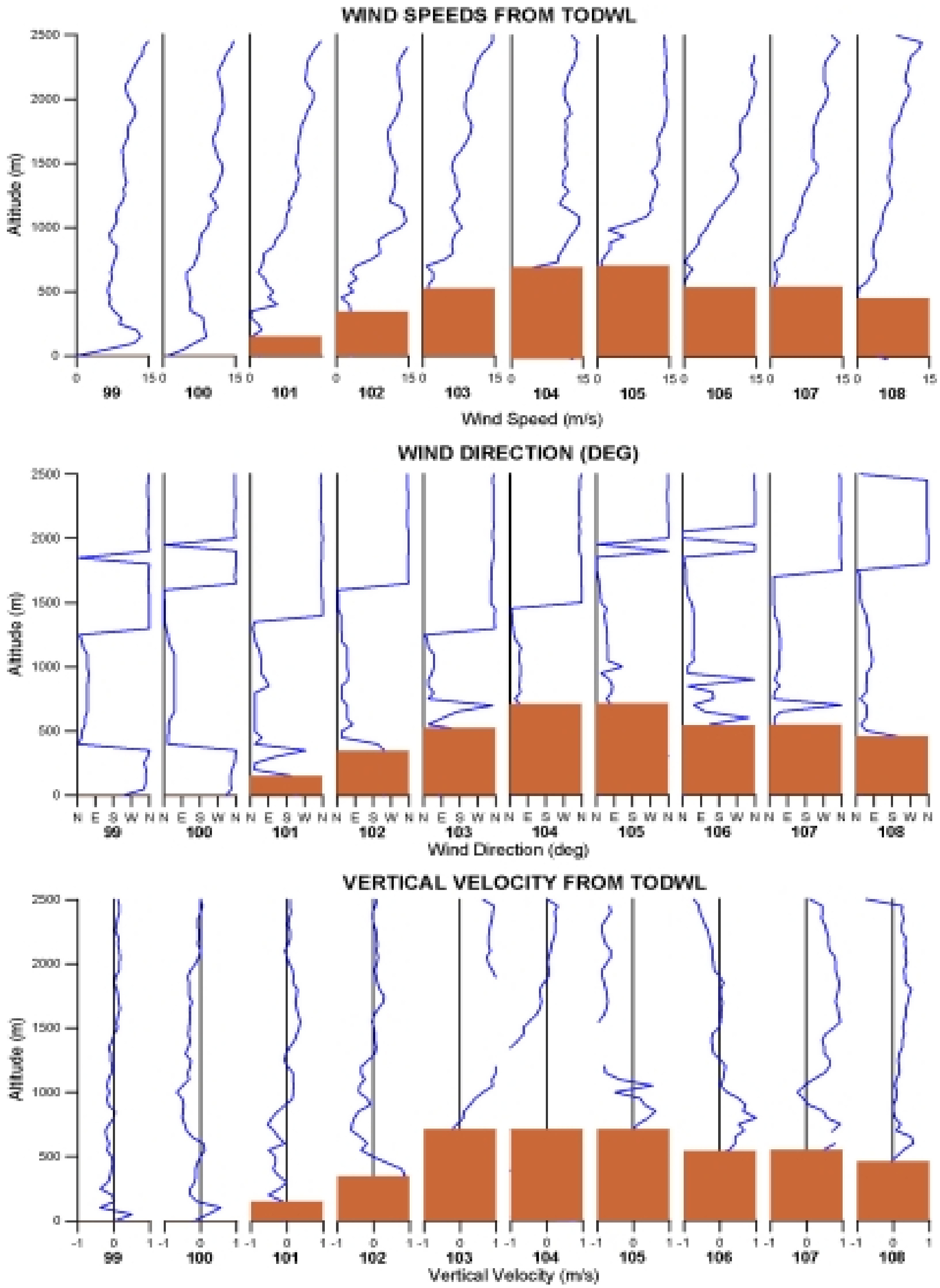


Figure 5b. Series of TODWL soundings mainly inland and just east of Monterey on 2/21/2003..

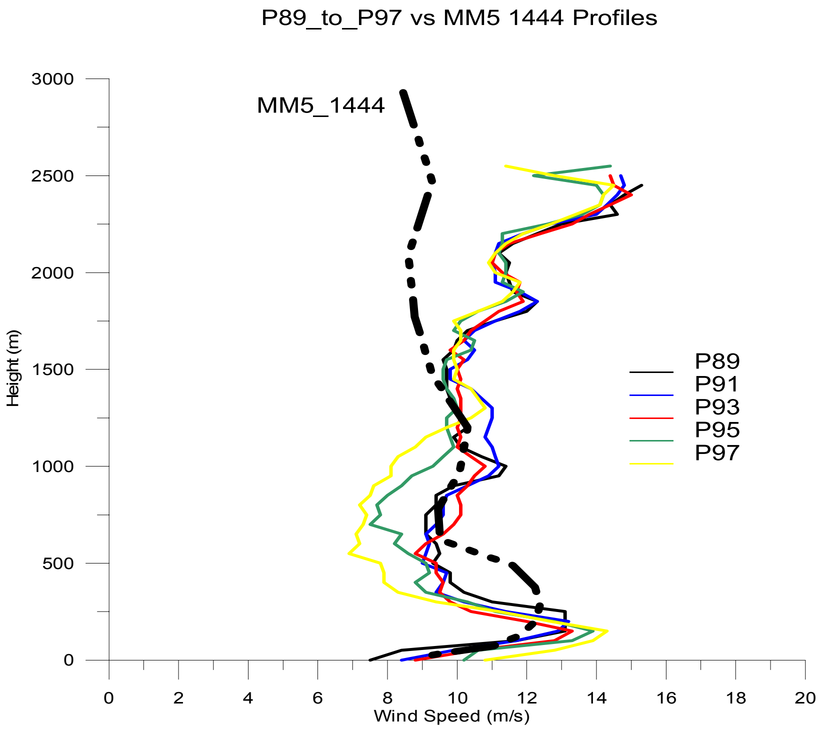


Figure 6a: Comparison of selected TODWL vertical profiles with closest (in time and space) MM5 model analyses profiles.

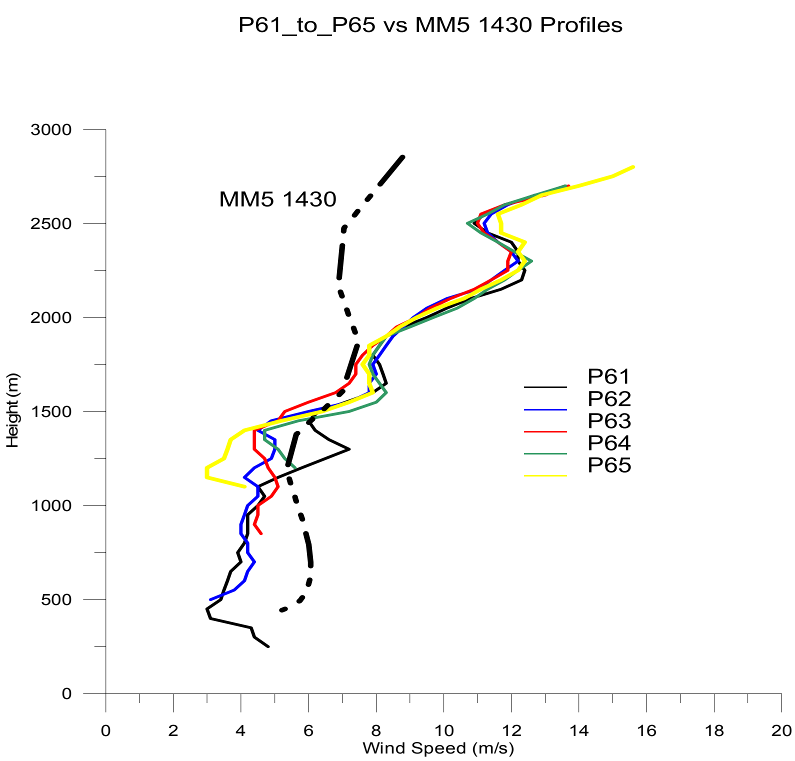
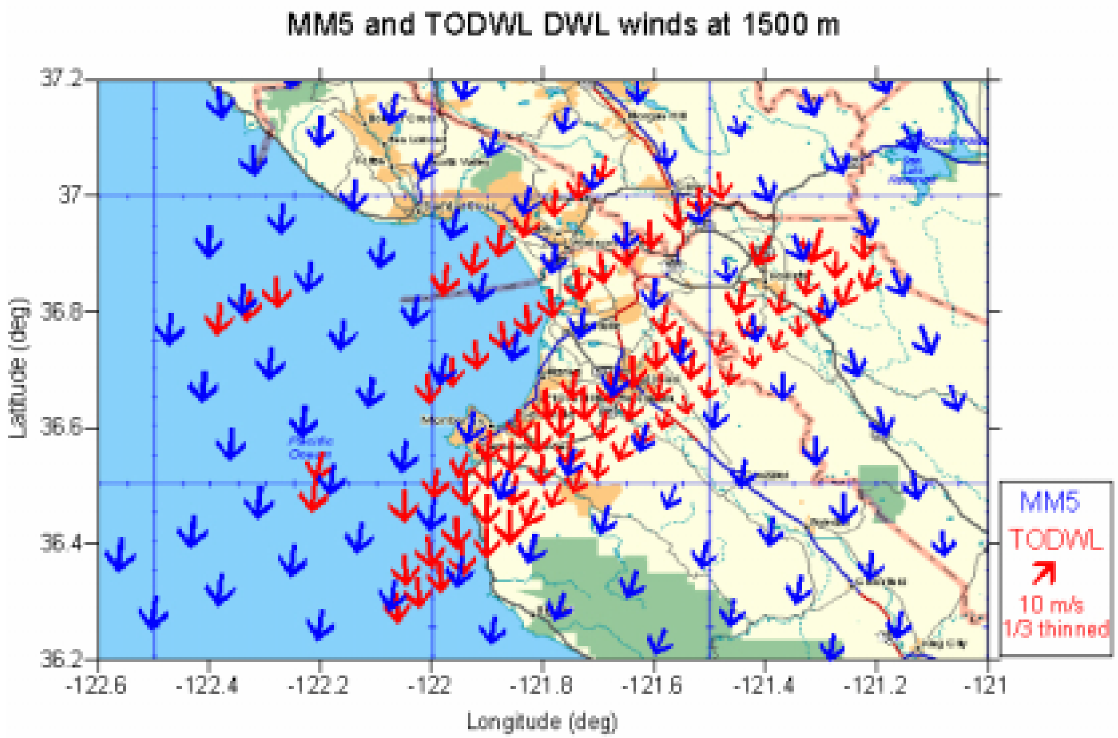


Figure 6b: Same as Figure 6a.



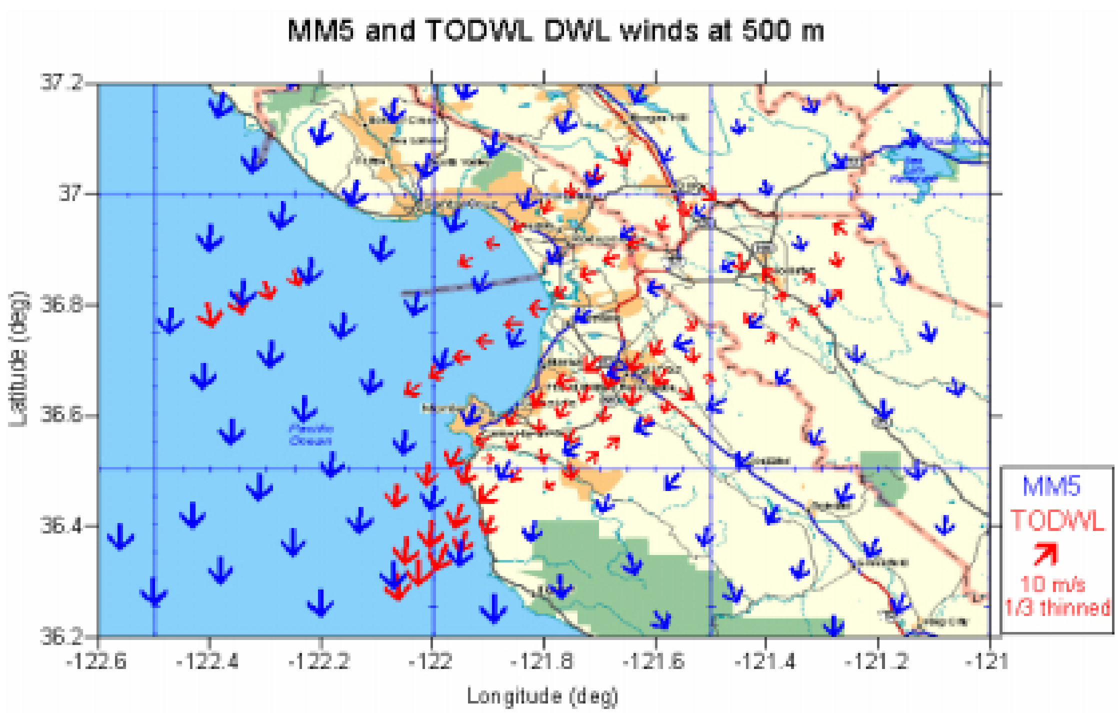


Figure 7: Intercomparison of wind speeds determined by model analyses (MM5) and measured by TODWL along and near the central California coast. Two vertical levels were selected: 1500m (top) and 500m (bottom).