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6.7 AIRBORNE DUAL-DOPPLER OBSERVATIONS OF A COASTAL WIND MAXIMUM ASSOCIATED WITH A LANDFALLING COLD FRONT

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1. INTRODUCTION

The Pacific Northwest coast of the U.S. is a geographical location where extratropical cyclones frequently make landfall. The dynamic interactions of these landfalling systems with the coastal terrain often produce a variety of mesoscale phenomena (e.g., orographically-enhanced rain bands and barrier jets, etc.) and cause locally strong winds and other severe weather near the coastal zone (Bond et al., 1997; Braun et al, 1997; Overland and Bond, 1995). Unfortunately, the present observational network is unable to resolve these coastal phenomena due to lack of adequate observational coverage in this region (especially off-shore), although some features accompanying these coastal interactions have been well simulated by recent modeling studies (e.g. Colle and Mass, 1996; Doyle, 1997).

During the COAST experiment (Coastal Observations And Simulations with Topography; Bond et al.,1997), a cold frontal system that encountered steep coastal terrain near the border of Oregon and California on 1 December 1995 was investigated by the NOAA P-3 aircraft. A distinct aspect of this event near the coastal zone was a significant enhancement of the along-shore flow component (i.e. the development of a coastal jet) as the cold front approached the steeply rising coastal mountains. A modeling study of this event is being undertaken by Yang et. al. (1997).

Owing to the successful collection of consecutive aircraft measurements over a ~5 h period within ~50 km of the shore during the landfall of the synoptic cold front, this case provides an excellent opportunity to document this coastal wind maximum and to explore further how a frontal system interacts with the coastal topography. The primary objective of this study is to use airborne Doppler radar data to show the existence of a coastal prefrontal jet and further to investigate processes forming the jet and the dynamic interactions leading to an associated zone of enhanced precipitation as well as more familiar frontal rainbands.

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2. WIND PROFILER OBSERVATIONS OF FRONTAL LANDFALL

The time sequence of hourly-averaged observations from the 915 MHz wind profiler at Crescent City (cf. location in Fig. 1) operated by NOAA/ETL during this period is shown in Fig. 2. There was a notable wind shift from southerlies to westerlies between 08 UTC and 09 UTC, indicating passage of the cold front. The strength of along-shore flow continuously increased as the frontal system approached, and reached its maximum value (~25 ms^{-1}) in the lowest 600 m between 06 UTC and 07 UTC. The strong winds ahead of the front extended to upper levels where they were primarily maintained by the pronounced pressure gradient associated with a deepening upper-level low (not shown).

3. DUAL-DOPPLER OBSERVATIONS

While providing desirable time continuity, profiler observations are not adequate to describe the horizontal

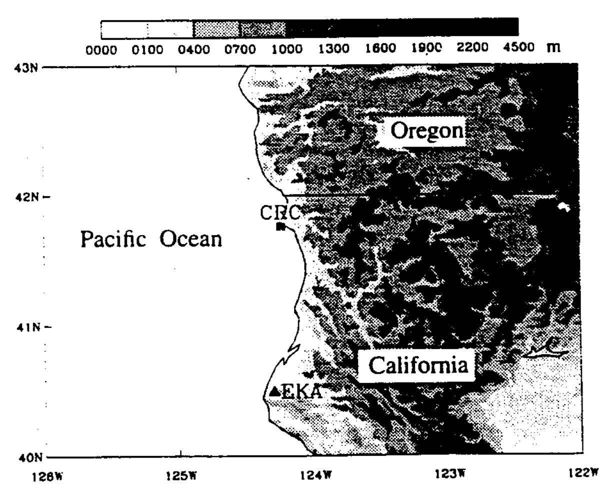

Fig. 1: Coastal topography near the Oregon-California border of the western U.S. Terrain heights (m, MSL) are shaded with interval 300 m beginning at 100 m. Locations of the 915 MHz research wind profiler site at Crescent City and operational NEXRAD WSR-88D radar are indicated by CRC and EKA, respectively.

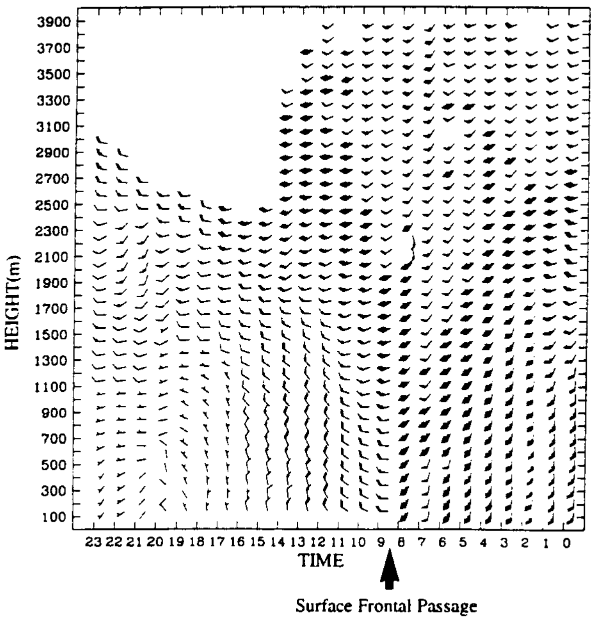

Fig. 2: Time-height cross section of hourly-averaged winds observed by the wind profiler at Crescent City from 00 UTC to 23 UTC on 1 December 1995. Full barbs and flags represent speeds of 5 ms^{-1} and 25 ms^{-1}, respectively.

variability of the coastal jet and its relation to mesoscale precipitation features. Thus, airborne Doppler radar measurements collected during this event provide important information with respect to the finescale structure and evolution of the coastal jet. The centerpiece of the COAST field experiment was a NOAA P-3 aircraft equipped with a tail-mounted Doppler radar employing a highly efficient scanning strategy (referred to as the Fore/Aft Scanning Technique, FAST), which allowed retrieval of the three-dimensional wind and precipitation fields via a pseudo dual-Doppler synthesis technique (Jorgensen and Smull, 1993). In this case, fourteen dual-Doppler volumes were systematically collected during the period of frontal landfall.

Figure 3 shows horizontal structure of winds and precipitation near the coast at 0.75 km (MSL) for the interval 0515-0543 UTC during which the surface front was initially observed ~70 km north of the Oregon-California border (near x=30 km, y=110 km in Fig. 3). At this level, the prefrontal region was dominated by strong south-southwest flow. Airflow more parallel to the coast (i.e., with an enhanced along-shore component) was found below this level (not shown). The maximum wind speeds (20-22 ms^{-1}) tended to be collocated with the region of heavy precipitation and organized into a narrow zone (~30 km in width) whose long axis lay parallel to the barrier and coincident with the coastline (Fig. 3). In general, the magnitude of the peak Doppler derived winds near the coast is comparable to that observed by the Crescent City wind profiler during this period (Fig. 2).

As the cold front progressed southeastward its associated convergence zone appeared to both sharpen and deepen, with a concomitant intensification of the southwest-northeast oriented narrow cold frontal rainband, leading to an even clearer depiction of the front by the P-3's airborne Doppler radar near the coast as shown in Fig. 4. Relatively weak westerly flow (~10-12 ms^{-1}) characterized the post-frontal air mass, in contrast to strong southwesterly prefrontal flow adjacent to the steep coastal terrain. The maximum winds (~24-26 ms^{-1}, cf. isotachs in Fig. 4b) were still found along the coast. Similar to earlier observations, the zone of maximum winds possessed an orientation parallel to the coastline. Unlike most kinematic features referred to as "jets", the flow in this coastal wind maximum was oriented at a large angle to the axis of the elongated isotach maximum. Nonetheless, because of its perceived dynamical importance, we refer to this feature as a "coastal jet".

During this period, the mesoscale precipitation pattern exhibited two distinct bands within the coverage of Doppler analysis domain. One was nearly parallel to the orientation of the front. This precipitation band coincided with the low level wind shift zone and was thus likely produced by the low level frontal lifting. The other was parallel to the coastline (e.g., two precipitation cores near x=60, y=50 km). The existence of this band may relate to the dynamic forcing of coastal terrain. Careful inspection of Fig. 4a indicates this band was associated with a deflection of the prefrontal flow from southwesterly off-shore to south-southwesterly near the coast, with a pronounced deceleration of cross-shore flow within ~15 km of the shore. Therefore, it is suggested that partial blocking of the prefrontal flow by the coastal terrain resulted in the generation of low level convergence and thus contributed to the generation of this coastal rainband. Nevertheless, due to the inherent complexity in flow response to the topography near the coastal zone, a more comprehensive analysis will be required to clarify the role of other effects (e.g. upslope forcing, microphysics) in producing this localized precipitation enhancement.

4. CONCLUSIONS

By exploiting an unique set of airborne Doppler radar measurements, the detailed precipitation and airflow structure accompanying a cold front making landfall onto steep coastal terrain have been documented and analyzed. Results show that a low-level wind speed maximum developed ahead of the front, with the zone of strongest wind speeds (dominated by the along-shore component) being organized into an elongated zone parallel to the coast.

Precipitation also tended to be enhanced immediately inland from the coast in this zone. Preliminary analysis suggests that low-level convergence accompanying blocking of the prefrontal flow contributed to precipitation enhancement near the coast, well upstream of the steepest slopes of the mountain barrier.

Acknowledgments

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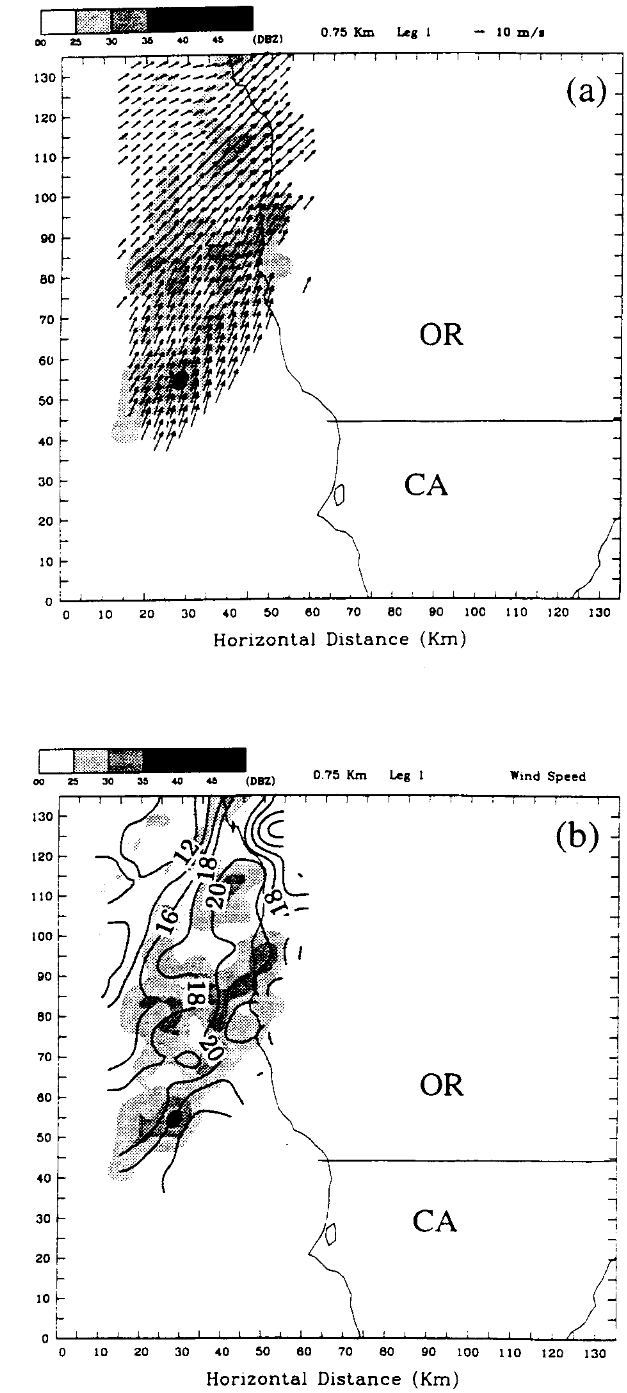

Fig. 3: The 0.75 km ground-relative winds and radar reflectivity (shading, dBZ) derived from the airborne Doppler analysis at 0515-0543 UTC 1 December 1995. (a) Wind vectors (key at upper right); (b) Corresponding wind speeds; the isotach interval is 2 ms^{-1}.

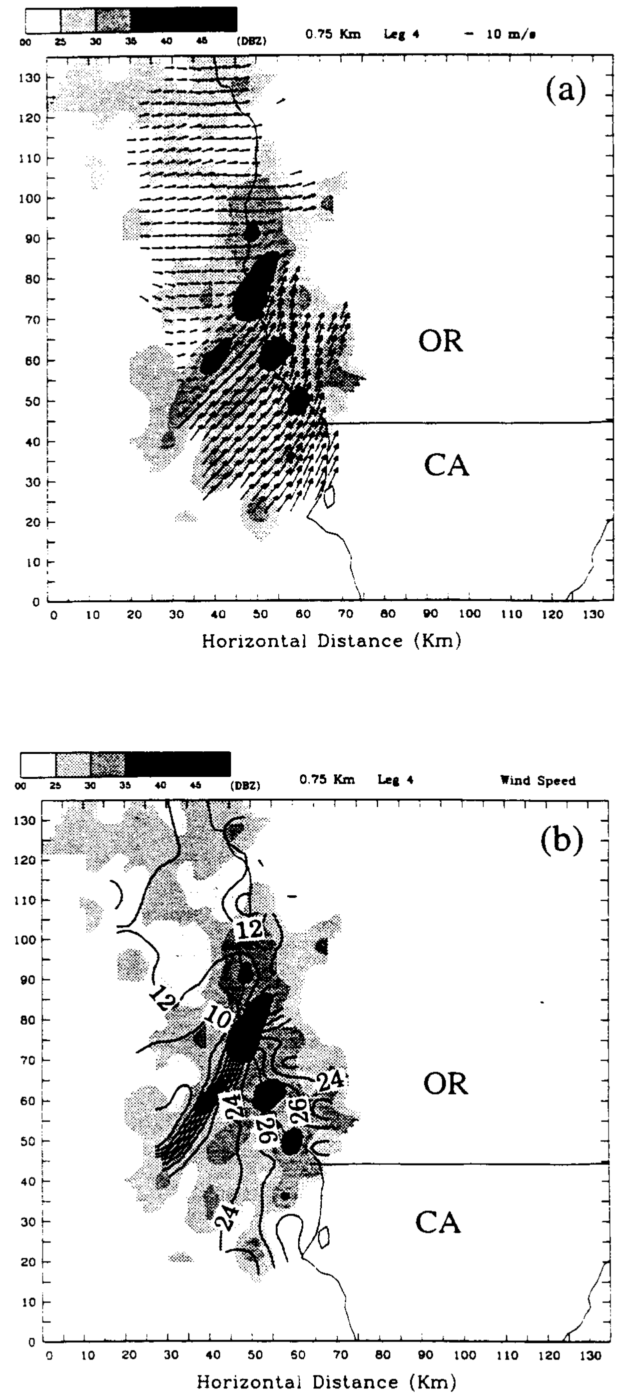

Fig. 4: As in Fig. 3 except for analysis time 0641-0657 UTC.