P9.2 **AIRBORNE RADAR OBSERVATIONS OF A WARM FRONT DURING FASTEX**

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1. INTRODUCTION

The evolution of fronts within an extratropical cyclone has been the focus of a considerable amount of research since the pioneering work by the Bergen School in Norway. Understanding the structure and dynamics of these fronts is important since a majority of the cyclone's precipitation is concentrated within these regions. Observational and numerical studies on cold fronts have dominated the literature largely as a result of its well-defined structure, often manifested as abrupt windshifts and temperature discontinuities, and its frequent association with severe convective weather. In comparison, there have been relatively few studies on warm fronts leading to a less complete conceptualization of its structure. The dearth of observational analyses on the warm front is, in part, owing to the weakness of the associated surface discontinuity and general absence of severe convective activity. The warm front can often be difficult to locate on a surface map and is of limited horizontal extent compared to the cold front.

One of the first detailed kinematic studies of a warm front was presented by Heymsfield (1979). He composited numerous dual-Doppler volume scans over a three-hour period to produce vertical cross sections through a warm front over the Midwest. Only minimal sounding data were shown for his case. A landfalling warm front was examined by compositing information for nearly 24 hours using single- (Locatelli and Hobbs 1987) and dual-Doppler (Hertzman et al. 1988) techniques as it passed over the radar sites. In addition, several soundings and *in situ* aircraft measurements during the period provided thermodynamic information on the frontal surface. This paper presents a unique combination of airborne Doppler radar syntheses and dropsonde data that provides an unprecedented view of an oceanic warm front that developed during the Fronts and Atlantic Storm Track Experiment (FASTEX).

An intense surface low moved into the FASTEX domain on 5-6 February 1997 (Fig. 1). The low was associated with an intense warm front of limited horizontal extent. Based on the predicted movement and orientation of the warm front, flight tracks were created so that ELDORA could fly through the precipitation shield at low levels and execute perpendicular penetrations through the frontal surface (tracks shown in Fig. 1). The two positions along the warm front were separated by a distance of ~130 km. The flight plans for the UK C-130 were designed such that dropsondes could be deployed along a path that was parallel to the Electra tracks.

2. VERTICAL STRUCTURE

A thermodynamic analysis of dropsonde data is presented is shown in Fig. 2. Also plotted on the figure are select mean dual-Doppler winds. Note the close agreement between the wind speed and direction between the dropsonde and Doppler derived winds in the figure.

The warm frontal zone aloft is well-defined by the veering winds and by the sloping isopleths of virtual potential temperature (θ_v) in Fig. 2. The intersection of the front with the ocean surface, however, is more difficult to identify. While it is well known that the surface warm front is nominally weaker than the cold front, the increase in the intensity of the warm-frontal discontinuity at higher levels is an important observation in the present case. Indeed

6 February 1997 0000 UTC

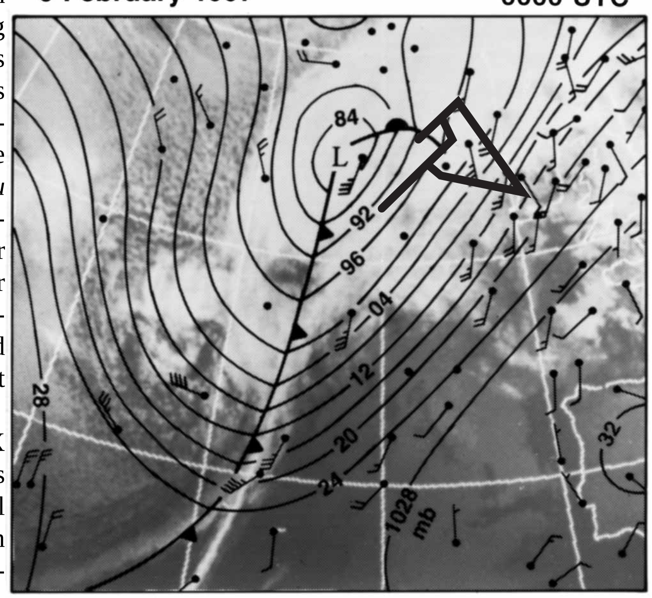


Fig. 1. Infrared satellite image at 00 UTC 6 February 1997. Surface analyses and Electra flight tracks are drawn.

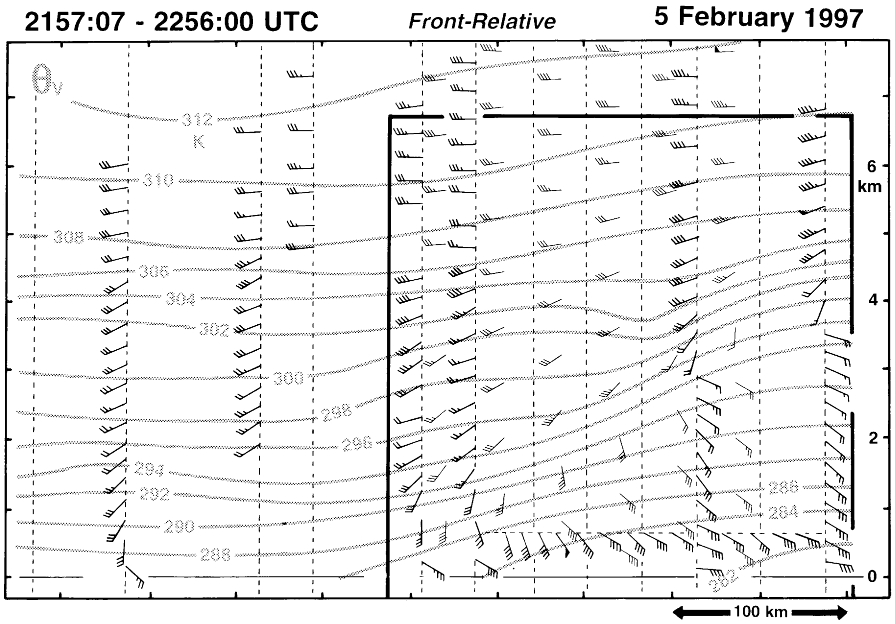


Fig. 2. Vertical cross section of dropsonde data from 2157:07 - 2256:00 UTC on 5 February. Front-relative winds are superimposed onto the virtual potential temperature (gray lines). The black box is the primary dual-Doppler analysis region. The dropsonde locations are shown by the vertical dashed lines. The Electra flight track and flight-level data are shown by the horizontal dashed line.

Bluestein (1993) has proposed that a surface front should be defined as a front whose intensity is strongest near the ground. The present case appears to be an exception to this rule.

The region which encompasses the Electra's flight track is enclosed by the black box in Fig. 2 and is enlarged in Fig. 3. A region of enhanced radar reflectivity associated with the precipitation shield within the cold sector north of the front can be seen in Fig. 3a. The horizontal gradient of θ_v in the direction perpendicular to the front is shown in Fig. 3b. Although thresholds of horizontal temperature gradients to define frontal zones have been somewhat arbitrary, -5°C/100 km has been chosen in the present case.

The vertical structure of the frontal zone has disparate dimensions in the horizontal (50-60 km) and vertical (1-2 km). More importantly, the warm front aloft in Fig. 3b is associated with a temperature gradient that is nearly four times greater than near the surface. A zone of strong ζ is located in a region of intense vertical shear of the front-parallel component of the wind in Fig. 3c. The vorticity maximum is located aloft and not at the surface in contrast to numerous studies documenting the structure of cold fronts.

3. FUTURE WORK

Future work includes calculating the terms in the frontogenesis equation. There have been previous at-

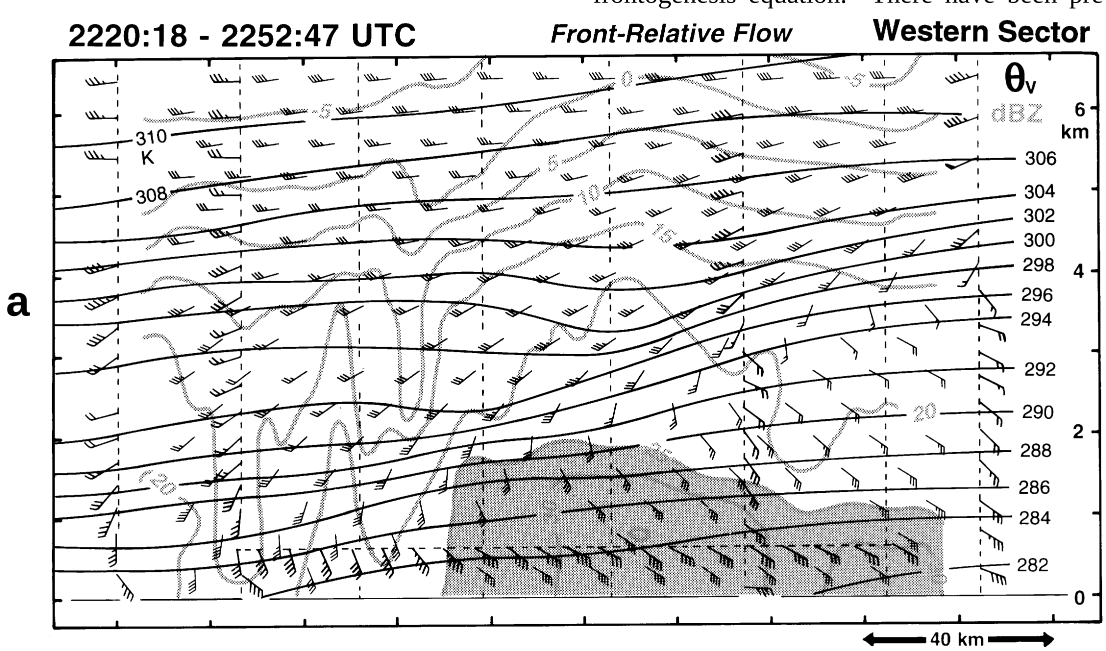
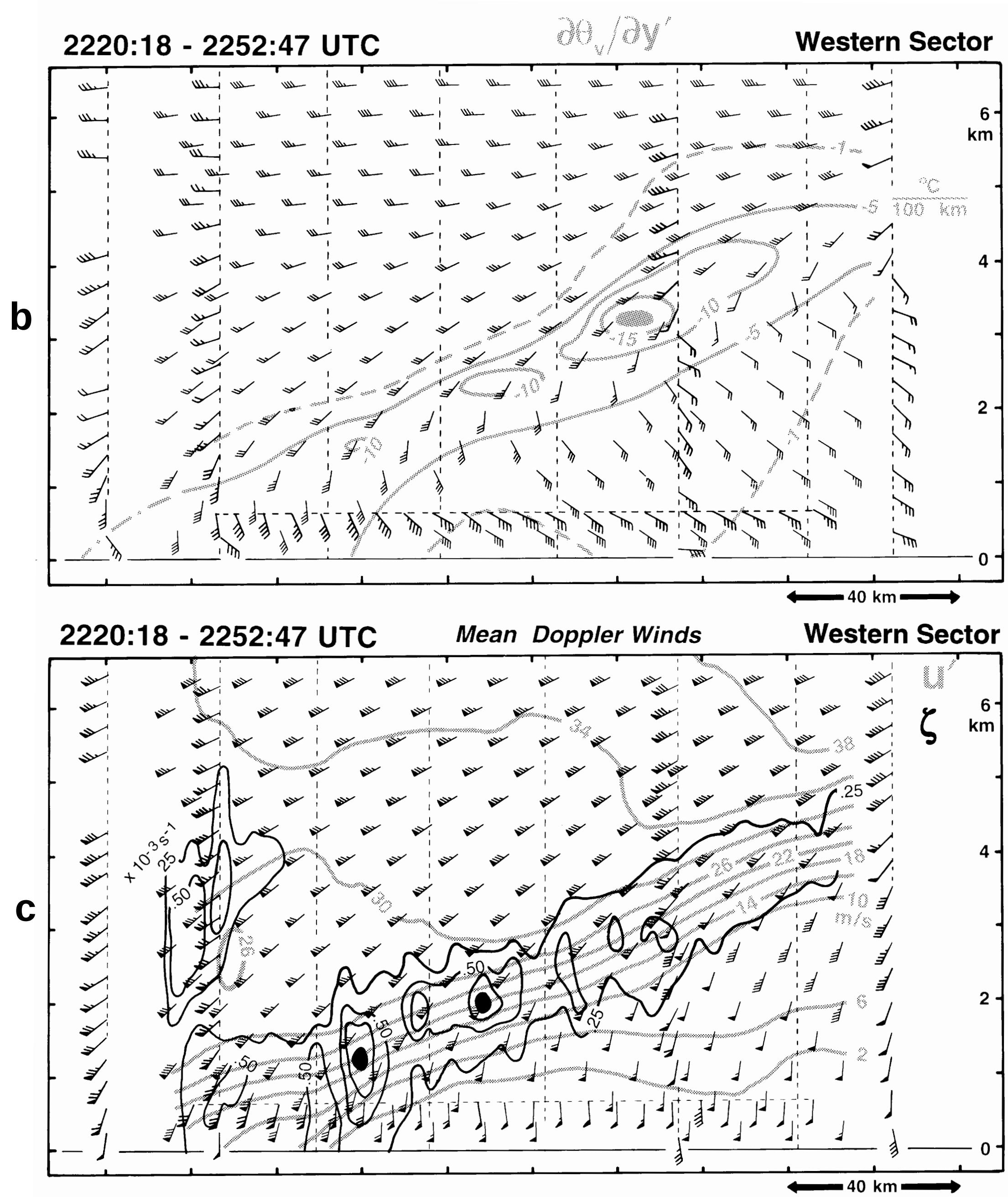


Fig. 3. Mean vertical cross sections perpendicular to the warm front. a) Virtual potential temperature superimposed onto radar-reflectivity. b) Horizontal gradient of virtual potential temperature. c) Vertical vorticity superimposed on the component of flow parallel to the warm front.



tempts to estimate the degree of geostrophic balance within cold fronts by quantifying the difference between the observed vertical wind shear and the geostrophic shear based on thermal wind balance. This difference, referred to as the Thermal Wind Imbalance has not been previously applied to warm fronts

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