P1.54 FORECASTING THE IMPACT OF A STATICALLY STABLE LAYER IN THE LOWER ATMOSPHERE ON SURFACE WIND CONDITIONS DURING HURRICANE ISABEL

Patrick F. Maloit* and John A. Billet
NOAA/National Weather Service, Wakefield, Virginia

1. INTRODUCTION

Hurricane Isabel came ashore 18 September 2003 (18 SEPT) as a category 2 hurricane (83-95kt sustained winds) near Ocracoke Inlet, North Carolina (NC), then tracked north-northwest. Isabel was steered by a large high pressure system centered over northern New England, with its ridge axis extending back into the Ohio Valley. The impact of cool, stable air present in the lower atmosphere ahead of Isabel limited the amount of wind being mixed down to the surface. The purpose of this paper is to show how the use of WSR-88D 8-bit data, LAPS soundings, and cross-sections of frontogenesis can be used as a tool to aid forecasters in giving advanced warning of localized wind gusts in situations where a statically stable layer inhibits the mix down of stronger winds from aloft.

2. ENVIRONMENT AND RADAR

An analysis of mean sea-level pressure (MSLP) showed ridging down the eastern side of the Appalachian Mountains into Virginia. Most of Virginia (VA) was on the cool side of a coastal front, shown by the surface theta-e gradient (Fig. 1). This ridging has been shown by Bailey et al. (2003) to be a signature of cold air damming. Further evidence of damming was indicated by the dry and stable air mass found over much of VA and NC in morning on 18 SEPT (Fig. 2a).
This stability was noted in RAOB, LAPS, and model soundings by an inversion or isothermal layer between 950 and 900hPa (exact depth varied by location across eastern VA and northeast NC). This stably stratified layer in the lower atmosphere prevented most of the stronger winds measured above the layer in Isabel from mixing down to the surface, except for brief gusts associated with convective rainbands, which were not as strong as one would have expected.

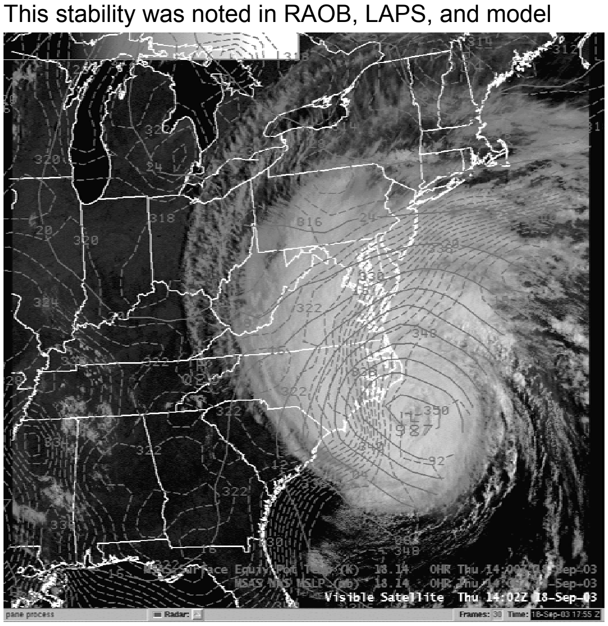

Fig. 1. Visible satellite picture of Hurricane Isabel, with MSLP (solid every 2hPa) and theta-e (dashed every 2K) at 14 UTC 18 SEPT 2003.

LAPS provided detailed analysis of the local area as Isabel approached. The detailed soundings showed a low level inversion in areas from Newport News, VA west, while areas to the east showed a much weaker inversion at 15 UTC (not shown). LAPS soundings for Roanoke Rapids showed the low level inversion dissipated by 21 UTC.

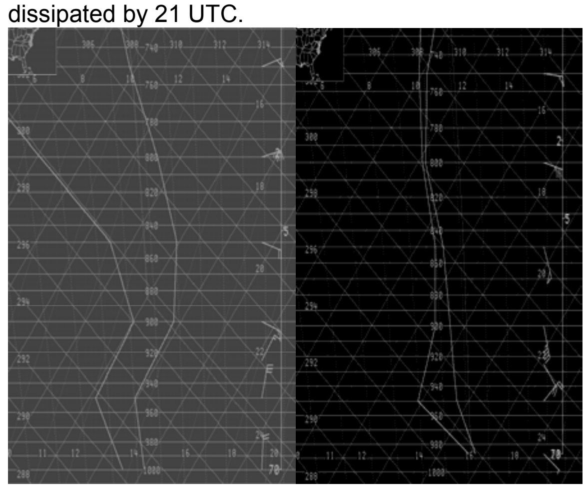

Fig. 2a (left) and 2b (right). The 15 UTC and 21 UTC 18 SEPT LAPS soundings for Roanoke Rapids, NC (KRZZ) respectively. An inversion is evident in Fig. 2a from 950 to 900hPa, while Fig. 2b features an unstable layer from the surface to 900mb.

An examination of Peterson 2D frontogenesis on a cross-section perpendicular to the circulation, revealed a strong axis of low-level frontogenesis, centered from Williamsburg, VA south through central Suffolk, VA at 15 UTC (Fig. 3). This axis represented a coastal front that was moving through the area ahead of Isabel. The passage of the coastal front served to overcome the static stability present in the low level damming environment, thus allowing stronger winds to mix down from aloft. This is shown in Fig. 3 by the 30kt contour nearly intersecting the ground at the leading (inland) edge of the coastal front. By tracking this axis, plots of 925-850hPa frontogenesis, which depicted the coastal front, it was possible to forecast when stronger wind gusts would affect an area. At 15 UTC surface winds to

* *Corresponding author address:* Patrick F. Maloit
NOAA/National Weather Service Office, 10009 General Mahone Hwy., Wakefield, VA 23888-2742

the east of this front are generally northeast 25 knots (kt) sustained with gusts to 40kt, while west of this axis winds are from the northwest with average sustained winds near 20kt and gusts to around 30kt.

The decrease in low-level atmospheric stability allowed for an increase in momentum transport to the surface by the mixing down of stronger winds from the upper boundary layer, especially as convective bands passed. Observations showed that as the coastal front continued to move west, reflected on the surface by an accompanying wind shift (not shown), passing through Richmond, VA around 20 UTC, the wind gusts increased from 37kt at 20 UTC to 47kt by 21UTC. The same holds at Roanoke Rapids, NC, where gusts to 36kt at 20 UTC increased to 56kt by 22 UTC after the coastal front axis passed.

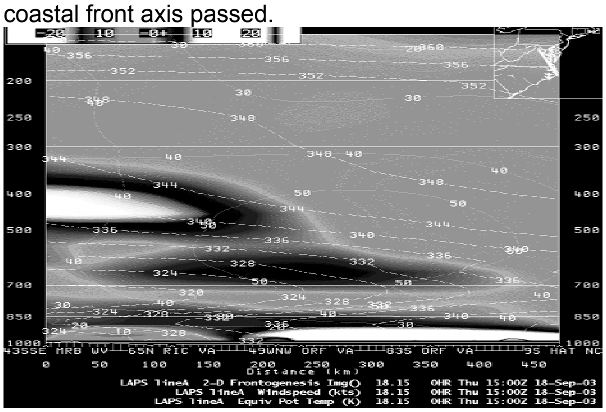

Fig. 3. Cross-section of 2-D frontogenesis (image, higher values in white), theta-e (dashed, every 4K) and wind speed (dotted, every 10kt) at 15 UTC 18 SEPT.

Figure 3 shows an area of strong frontogenesis existed between Roanoke Rapids, NC (KRZZ) and Norfolk, VA (KORF) at 15 UTC. LAPS soundings (Fig. 2) shows an isothermal layer reducing the amount of wind mixed down from low levels at KRZZ. A convective band crossed KRZZ from 1437 to 1452 UTC with radar derived winds (not shown) at 3800 feet at 70kt, with a peak wind gust recorded on the ground of only 34kt at 1442 UTC. Meanwhile, a band crossed KORF between 1417 and 1437 UTC with a maximum wind speed of 72kt at 3200 ft. This produced a gust on the ground of 52kt at 1438 UTC. Isabel at this time was about equal distance between KORF and KRZZ, so the elevation sampled by the Wakefield, VA WSR-88D was similar, and showed the impact of the statically stable layer in reducing the wind speed reaching the ground.

The WSR-88D 8-bit data was useful in depicting the hurricane's spiral bands and wind field. When the convective bands, primarily oriented perpendicular to the wind, intercepted regions of high low-level wind speed, surface wind gusts occurred (Fig. 4). The convective downdrafts provided a means of estimating when maximum gusts may occur. When combined with knowledge of the environment, a gross estimate can be made of the extent to which low level wind speeds might mix to the ground. Figure 4 shows where the 18 UTC observation for KPHF (taken at 1754 UTC) reported a wind gust of 45kt, then at 1756 UTC KPHF reported its highest gust (65kt) with Isabel (note the leading edge of a convective band at KPHF).

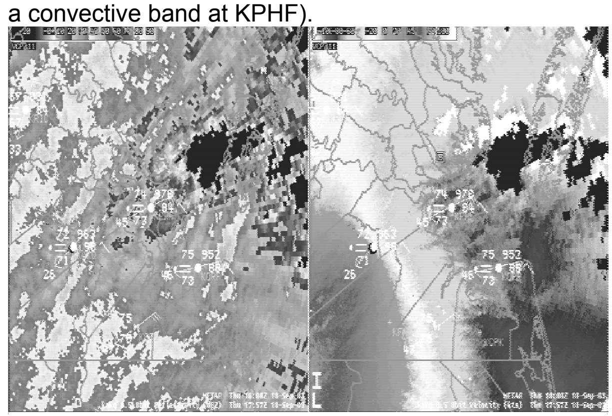

Fig. 4. Wakefield, VA WSR-88D 0.5 degree 8-bit reflectivity (left) and 8-bit velocity (right) at 1757 UTC with 18 UTC observations overlaid. KPHF is the northern most observation.

A wave pattern is noted in the velocity data. The convective nature of Isabel (Nicholls and Pielke 2000), and the presence of a low-level inversion and upper level wind maximum (Uccellini and Koch 1987) suggest an environment could support gravity waves, but further investigation is needed.

3. CONCLUSION

The cold air damming preceding Isabel over VA and NC, created a stably stratified lower atmosphere that prevented the full mixing down of strong winds to the surface. Knowledge of when the stably stratified lower atmosphere would destabilize, provided an understanding of when more momentum could be transferred to the surface. WSR-88D 8-bit reflectivity and velocity data, showed detailed convective band and velocity structure associated with Isabel, and possible gravity waves, a study of the exact nature and impact of this wave structure needs further research. Where the convective bands intercepted wind maxima, peak wind gusts were found to occur. Use of WSR-88D 8 bit data, coupled with knowledge of the local atmospheric conditions, can enable forecasters to increase lead times in providing short term forecasts of localized high winds before they occur.

REFERENCES

Bailey, Christopher M., G. Hartfield, G. Lackmann, K. Keeter, S. Sharp, 2003: An Objective Climatology, Classification Scheme, and Assessment of Sensible Weather Impacts for Appalachian Cold-Air Damming. *Wea. Forecasting*, **18**, 641–661.

Uccellini, Louis W., S. Koch, 1987: The Synoptic Setting and Possible Energy Sources for Mesoscale Wave Disturbances, *Mon. Wea. Rev.*, **115**, pp. 721-729.

Nicholls, Melville E., R. Pielke, 2000: Thermally Induced Compression Waves and Gravity Waves Generated by Convective Storms. *J. Atmos. Sci.*, **57**, 3251–3271.