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CONTAMINATION OF WSR-88D VAD WINDS DUE TO BIRD MIGRATION: A CASE STUDY

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1. INTRODUCTION

The implementation of the Weather Surveillance Radar - 1988 Doppler (WSR-88D) network across the United States has introduced forecasters to an array of new meteorological products (Klazura and Imy 1993). One of the most important characteristics of the radar is its ability to provide real-time wind information from the surrounding atmosphere (Federal Meteorological Handbook No. 11 1990). However, the technology is not totally foolproof. Raindrops and snowflakes aren't the only reflectors in the atmosphere. Swarms of insects and flocks of birds are also excellent reflectors of radar energy. Because birds are not necessarily carried along by the prevailing wind, they can introduce significant errors in the radar algorithms that calculate winds (O'Bannon 1995). This paper presents a case study of bird contamination at the WSR-88D in Buffalo, New York, and suggests ways to alert forecasters to the potential for a bird contaminated Velocity Azimuth Display (VAD) Wind Profile (VWP).

2. RADAR-DERIVED WINDS

The WSR-88D measures Doppler radial velocity within a sample volume and converts the information through a series of algorithms into many derived products. Wind information is processed by the VAD algorithm. The processed information is displayed as wind velocity and direction in the VWP product. The algorithm assumes horizontal uniformity of the wind field and does not account for deformation (e.g., in the vicinity of frontal boundaries). Significant deviations from this uniformity will bias the wind estimate, unless RMS velocity and symmetry thresholds are exceeded, in which case the wind estimates will be discarded by the algorithm altogether (Federal Meteorological Handbook No. 11 1991).

The VWP product displays an estimate of the mean horizontal wind as a series of wind barbs on a time vs. height scale for up to 30 altitudes in the vicinity of the radar. The specific altitudes are adaptable in 1000-ft increments and are plotted at levels for which there is sufficient signal to be processed by the algorithm. VAD winds are used to update the environmental winds table in the WSR-88D which in turn is used by the velocity dealiasing algorithm. Incorrectly dealiased velocities can have a serious impact on subsequent algorithms such as the mesoscale detection algorithm. Furthermore, the VWP provides wind information that is useful for making many types of short-term forecasts. Examples include aviation forecasts for wind sensitive operations such as hot air ballooning and soaring, forecasts for dispersion of airborne pollutants during hazardous materials (HAZMAT) releases, low level wind forecasts to predict the movement of lake effect snow bands (Niziol et al. 1995), and classification of thunderstorm types based on the low level wind shear profiles (Weisman and Klemp 1982). Finally, VWP data has recently been incorporated into the initialization of the newly operational RUC-2 model (Benjamin et al. 1998) and may eventually be applied to other operational numerical forecast models including the ever increasing suite of mesoscale models. It is extremely important, therefore, to be aware of the variables that can influence and directly affect the quality of derived wind data from the radar.

3. BIRD MIGRATION PATTERNS

There is a wealth of published information about the sensitivity that many types of radars have to moving point targets such as birds (Eastwood 1967). Recently, a number of case studies have been presented that show the possible contamination of WSR-88D VAD winds by birds (O'Bannon 1995). In order to gain some understanding of the relationship between weather radar return signals and birds, it is important to know a bit about bird behavior and migration. Wilczak et al. (1995) summarized favored patterns of migration across North America that can be categorized both seasonally and diurnally. Most bird migration occurs at night during the Spring and Fall. Typical air speeds range from 16 to 30 kt and they tend to fly at the level where the winds are most favorable. Maximum heights of migration are generally around 7000 ft MSL but heights to 15 000 ft MSL are possible. In addition, the rate of migration, especially in the Fall, is often related to the passage of synoptic frontal systems. Because birds provide excellent reflectivity cross sections (Federal Meteorological Handbook No. 11 1990), they are easily detected by radar. Birds, however, do not drift with the prevailing wind as insects do. Therefore, birds can introduce large errors into the VAD wind algorithm.

A number of WSR-88D sites have reported instances when radar-derived winds have differed considerably from nearby radiosonde observations (O'Bannon 1995). Often, these anomalies are consistent with the seasonal and diurnal patterns of bird migration, when large flocks of birds are all flying in the same direction. At times, the contaminated winds are very difficult to identify with current algorithms because the erroneous data set provides a of a very coherent signal with relatively small spectrum width values.

Western New York State is located in close proximity to Lakes Erie and Ontario. The shores of both lakes are noted as staging grounds for many species of birds that migrate north and south each Spring and Fall. In addition, the strip of land that separates both lakes, known as the Niagara Peninsula, serves as a "flyway" for many species of birds that prefer over-land migration routes (Rising 1997, personal communication). There are also a number of sites in Western New York, such as the Iroquois and Montezuma Wildlife Refuges, that are notable landing and nesting habitats for many types of waterfowl. Because of these features, Western New York State is considered a prime area for bird migration during the Spring and Fall. It follows that the weather radar at Buffalo is particularly vulnerable to potential contamination of its VAD wind profile. This is especially true under certain conditions such as when superrefraction of the radar beam due to nocturnal inversions exaggerates the depth of the bird echoes (O'Bannon 1995).

4. CASE STUDY

One such case of coherent, erroneous winds in the VWP occurred during early November 1996 in the vicinity of Buffalo, New York. By that time of the year, many of the migratory songbirds have already left for warmer conditions in southern latitudes. However, waterfowl flights are typically in progress (Gathreaux 1980).   During the period of 5-10 November 1996, a pronounced change in the synoptic weather pattern occurred across the Great Lakes region. During 6-8 November, a very strong southerly flow developed over the Great Lakes in advance of a slow moving surface cold front over the Midwest (Fig. 1). The cold front crossed the eastern Great Lakes on 8 November and winds shifted to north that evening (Fig. 2). The evening was also characterized by nearly continuous rain showers. A secondary low and associated cold front crossed the region early on 9 November (Fig. 3). The wind maintained a northerly component during most of 9 November before backing to a weak westerly flow that night.

The vertical wind profile for Buffalo, NY, before and during the migration is displayed in Fig. 4. Of particular note is the extended period of very strong southerly flow during 7-8 November when the winds taken from the Buffalo radiosonde were as high as 60 kt between 2000 and 7000 ft MSL.

During the evening of 9 November, approximately one half hour after sunset, the radar began to display an area of anomalous echoes along the north shore of Lake Ontario, about 60 km north of Buffalo (Fig. 5). The echoes showed a continuous movement due south during the next two hours. At the same time, however, the area well to the south of the Buffalo radar was covered with echoes that looked more like distinct precipitation cells which were moving toward the northeast.

Prior to the appearance of the anomalous echoes north of the radar, the VWP generally indicated a southwest wind at 15 to 20 kt at levels between 2000 and 8000 ft, corresponding to isolated precipitation echoes south of Buffalo (Fig. 6a). As the anomalous echoes appeared, the VWP product began to display north winds at 15 to 25 kt between approximately 2000-5000 ft MSL (Fig. 6b). The winds eventually became well-aligned out of the north at 15 to 25 kt (Fig. 6c). The pattern presented by the reflectivity loop and the VWP product immediately aroused the suspicion of the forecasters who postulated that what they were really seeing north of the radar were flocks of birds migrating south from the north shore of Lake Ontario.

The bird migration scenario seemed quite reasonable. The synoptic scale weather pattern a few days prior to the event produced an extended period of strong southerly winds, accompanied by precipitation, for a number of days before the flight. Lincoln (1939) noted that headwinds of high velocity, as well as periods of rain or snow, can force succeeding flocks of birds down at some point. It would seem reasonable that the north shore of Lake Ontario would make a good staging area for birds to wait for a few days until the weather conditions improved. The foul weather grounded a number of migrating birds until the winds and weather became favorable after the passage of the second cold front. It should be noted that even though the winds became more favorable for migration on the evening of 8 November, nearly continuous rain showers would have discouraged flight (Lincoln 1939).

When conditions finally did improve, the resulting migration on the evening of 9 November was more like a "bird wave", as discussed by Lincoln (1939), that progressed southward across the radar scope. The large flocks of migrating birds produced anomalous VWP winds on the Buffalo WSR-88D. Because there were no precipitation echoes at the same elevation angle and distance from the radar, the reflected energy was dominated by the bird echo returns. Therefore, the VAD data showed only minor RMS errors and minimal asymmetry in the mean radial velocity of the wind, a likely signature for a flock of birds all moving in roughly the same direction.

5. QUALITY CONTROL CHECKS

This event was in progress at the time of the evening radiosonde launch, so it was possible to evaluate the radar-derived winds against those measured directly by the radiosonde. The radiosonde winds were significantly different from the VWP data between 2000 and 5000 ft. The radiosonde indicated weak primarily westerly winds at these levels compared to the stronger north winds indicated by the radar (Fig. 7). The radiosonde data strongly suggested that the north winds on the VWP were actually a signature resulting from the movement of the birds.

It was fortuitous that the bird migration occurred at the time of the radiosonde release and at a location in close proximity to the radiosonde site. At times other than the standard radiosonde release times (i.e., 0000 UTC and 1200 UTC) or in locations far removed from the radiosonde site, another quality control check can be done by comparing the VWP data with hourly forecast soundings from numerical model guidance (Mahoney and Niziol 1997). In Fig. 7, the VWP and radiosonde data from the evening of 9 November were compared to a 12-hr wind forecast for Buffalo, NY, from the 1200 UTC 9 November run of the eta model. The model forecast winds compare very well with the actual radiosonde data and, in this case, were a good quality control check for the VWP winds. Because the model soundings are available on an hourly basis for many locations, this type of data set can be used by forecasters to perform preliminary checks on VWP data at times other than radiosonde release times and for locations that are far removed from the existing radiosonde launching sites.

6. PARAMETERS ASSOCIATED WITH BIRD CONTAMINATION

A check for bird contamination on wind profilers was devised by F. M. Ralph and D. W. Van de Kamp based on work reported in Wilczak et al. (1995). Although the somewhat rigorous set of algorithms developed for the wind profilers cannot be applied to Doppler weather radars, a few of the more generalized rules noted by Wilczak et al. (1995) can be used by forecasters to alert them to the potential for contaminated Doppler wind data. The rules have been compiled in Table 1. Minor changes have been made to correspond to sunset in the eastern U.S.

Table 1. Parameters conducive to bird migration that can be used by forecasters to identify potential scenarios for the contamination of VWP data on the WSR-88D.

Parameter	Spring	Fall
Time of Year	15 February - 15 June	15 August - 30 November
Time of Day	2300 - 1100 UTC	2100 - 1200 UTC
Wind direction	Southerly	Northerly
Height	below 10,000 ft	below 10,000 ft

A similar set of parameters are used to check for bird contamination in VWP data before they are incorporated into the initialization of the RUC-2 model. A solar angle is calculated, and if the sun is down and the temperature is warmer than -2 °C, VAD winds are not used if they have a northerly component between 15 August and 15 November or a southerly component between 15 February and 15 June (Benjamin et al. 1998).

7. CONCLUSIONS

It has been shown that under certain conditions the VWP data from the WSR-88D can be significantly contaminated by biological targets such as birds. In fact, if they go unrecognized, it is possible that the contaminated winds can have an adverse impact on numerical model initializations, and on short-term forecasts for wind-sensitive aviation events, dispersion of airborne hazardous materials, and thunderstorm and lake effect snow morphology. Fortunately, a number of procedures can be employed to cross-check the accuracy of the winds.

If the event occurs near the locations and times of a radiosonde launches, which occur roughly near sunrise and sunset during the Spring and Fall months, the VWP data in question can be checked against actual radiosonde winds. At locations that are some distance from radiosonde sites, or at times other than the standard radiosonde release times, the VWP winds can be checked against hourly forecast soundings from the operational numerical models. Finally, because bird migrations follow identifiable patterns related to the season, time of day, direction of movement, and height above the ground, a number of general rules can be used by forecasters to identify conditions that are favorable for bird migrations that can cause contamination of the WSR-88D VWP.

ACKNOWLEDGMENTS

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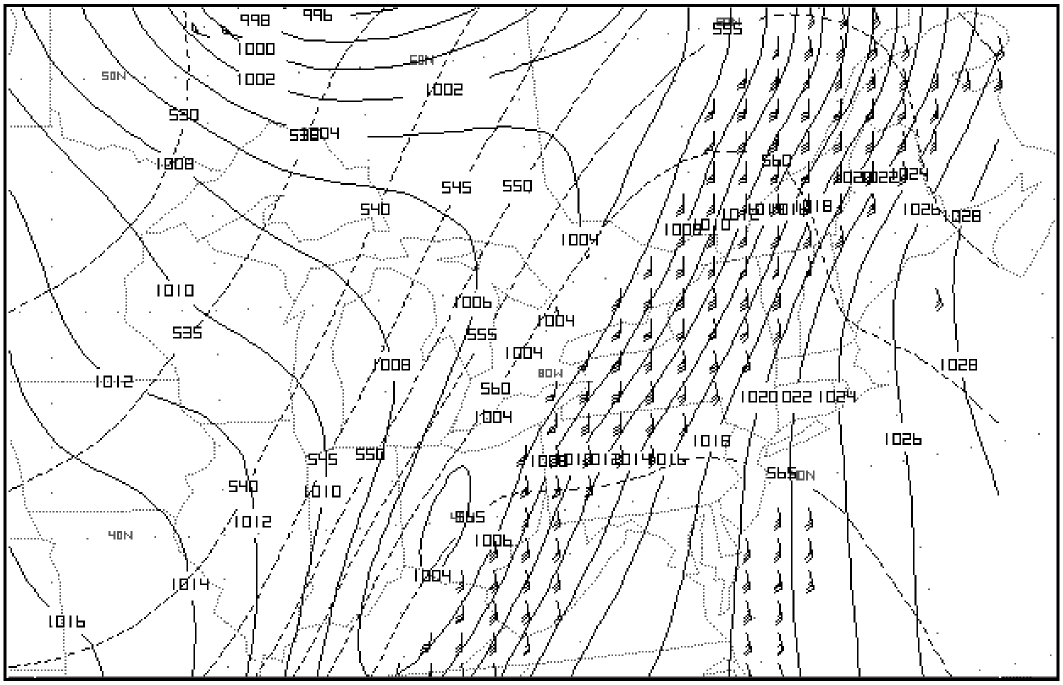


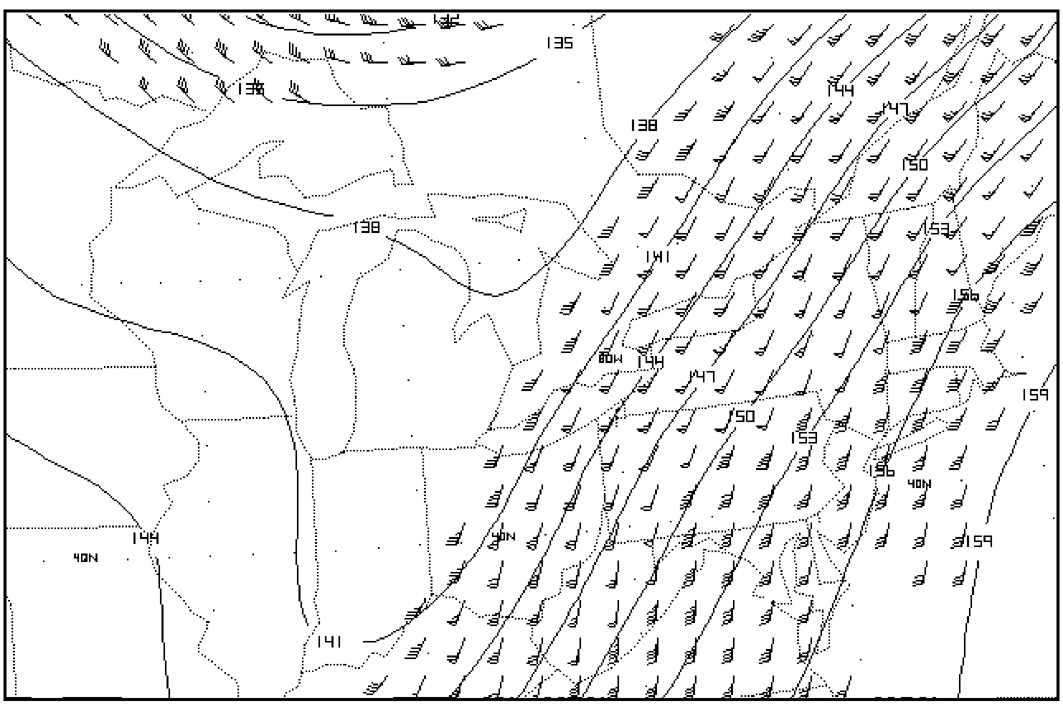
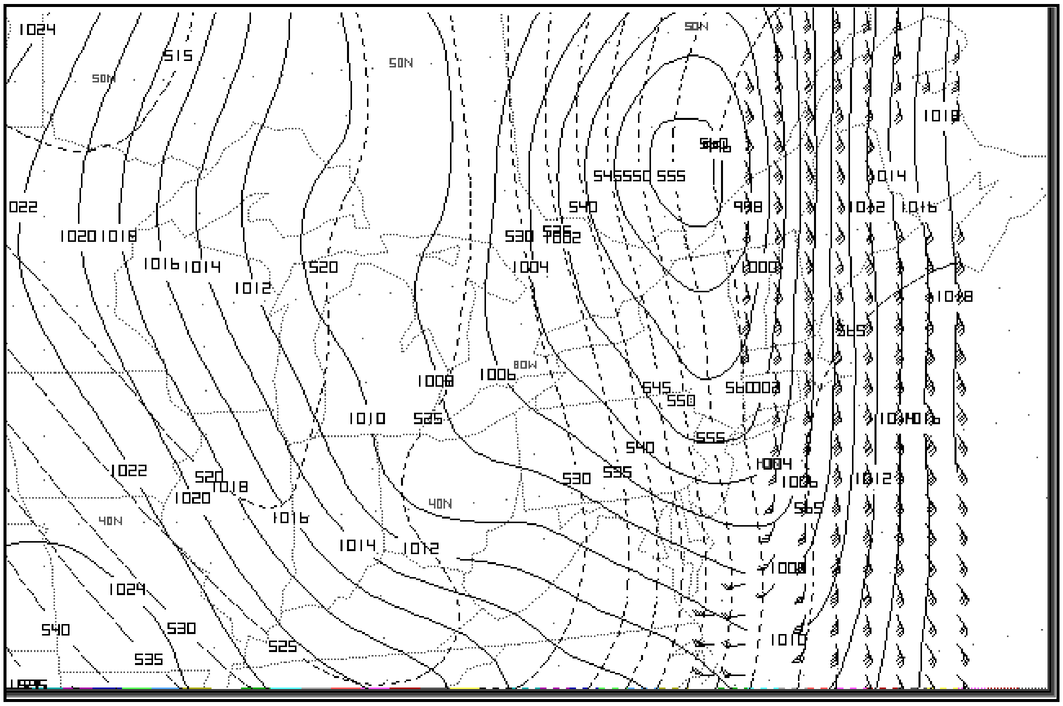


Figure 1. Analyses from the eta model initialized at 1200 UTC 7 November 1996 for a) MSL pressure (contoured every 2 mb), 1000-500 mb thickness (contoured every 5 dam) and winds greater than 25 kt; and b) 850-mb heights (contoured every 30 dam), and winds greater than 30 kt.



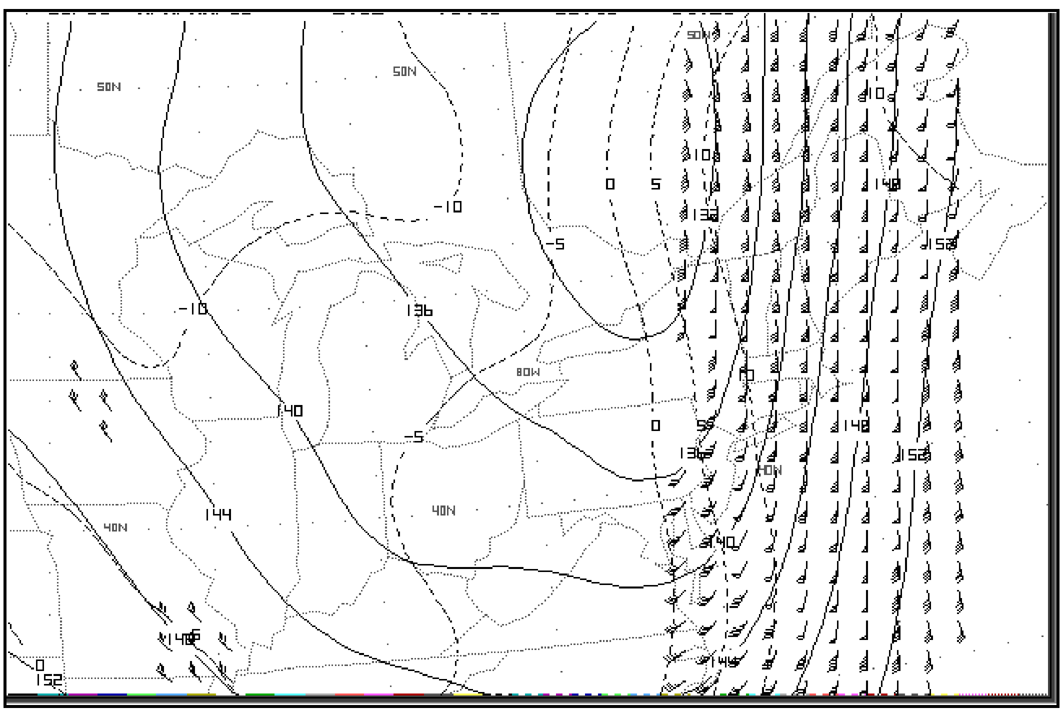


Figure 2. As in Fig. 1, except for 0000 UTC 9 November 1996. Also, the dashed contours in 2b) represent 850-mb temperature contoured every 5 °C**.**

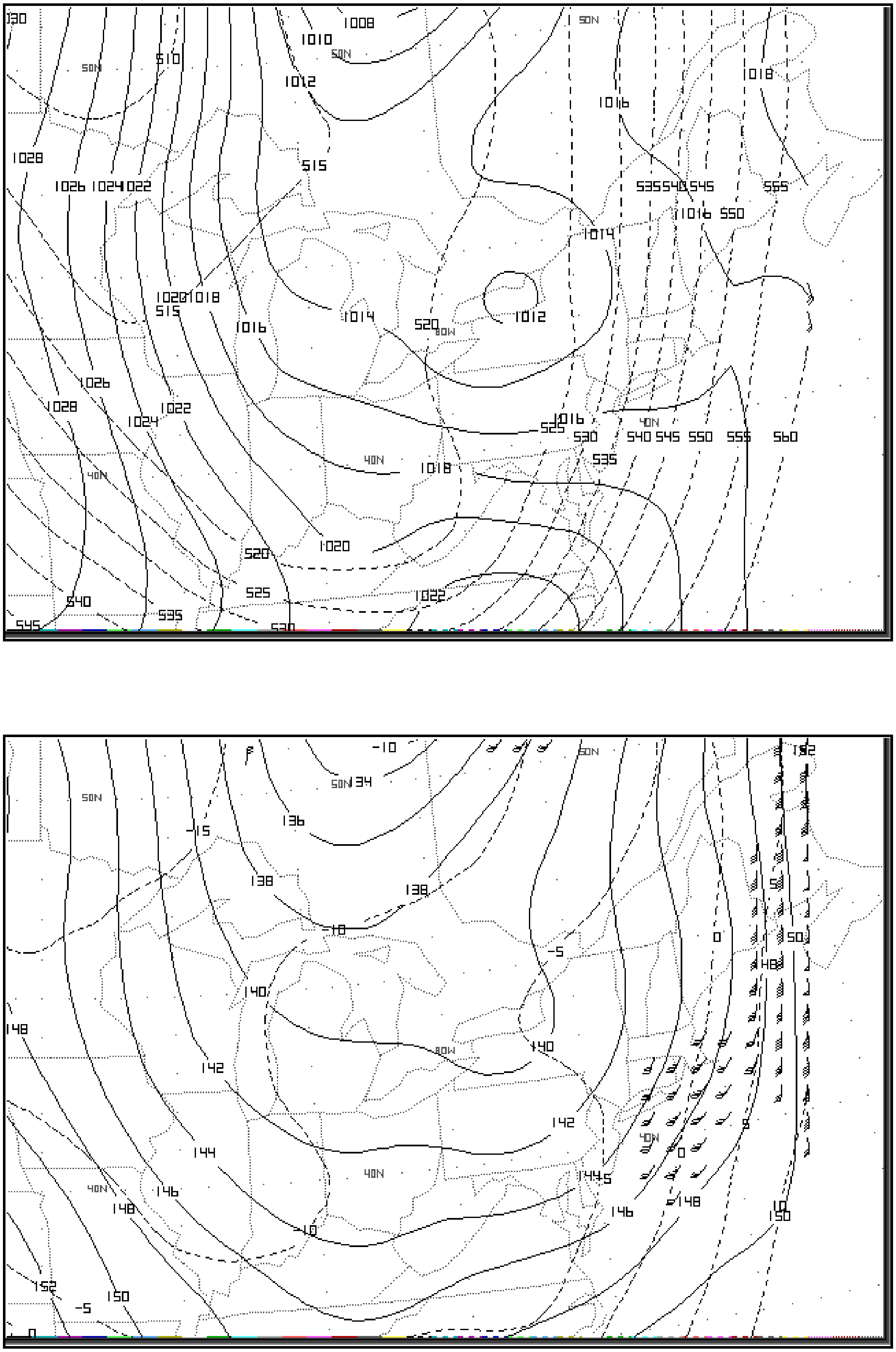


Figure 3. As in Fig. 2, except for 0000 UTC 10 November 1996.

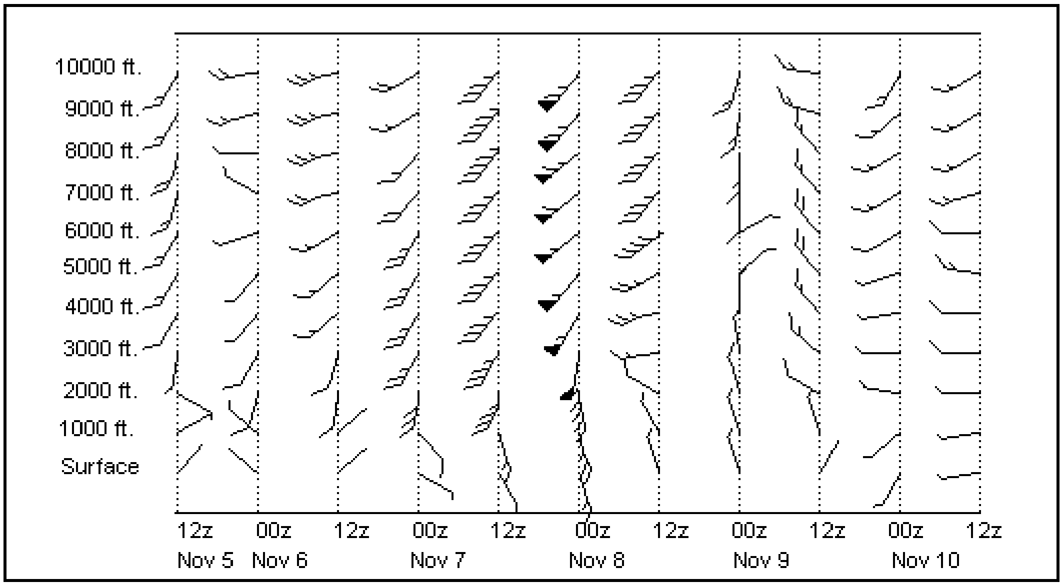


Figure 4. Radiosonde winds at Buffalo, NY, for the period 5-10 November 1996. Heights are AGL and wind barbs are in knots.

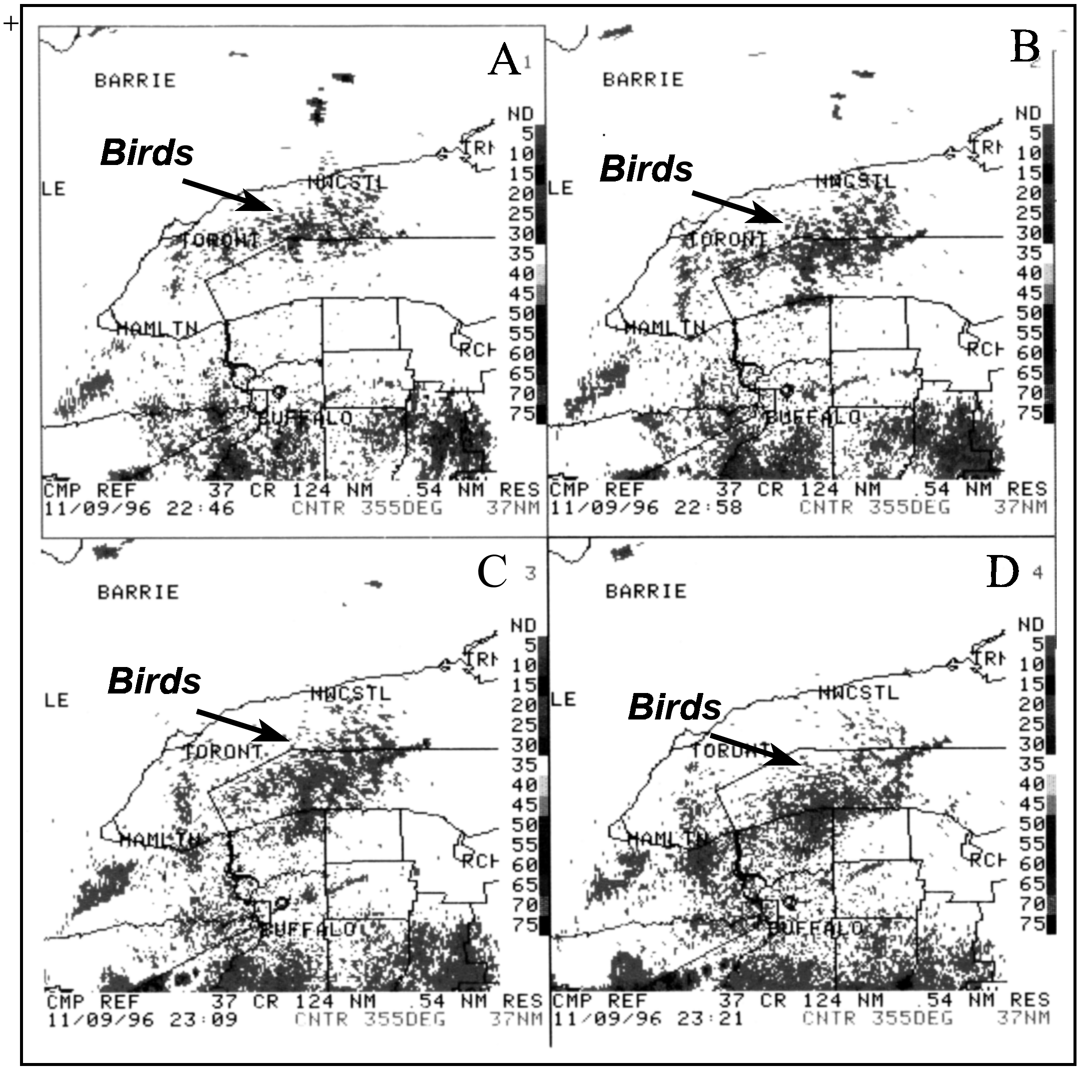


Figure 5. Buffalo, New York, WSR-88D 4-panel base reflectivity for 09 November 1996 at a) 2246 UTC, b) 2258 UTC, c) 2309 UTC, and d) 2321 UTC. The grey scales on the right of each panel depict intervals of reflectivity in units of dBZ. The elevation angle is 0.5°, range of coverage is 248 n mi (460 km), and resolution is 1° x 0.54 n mi (1 km).

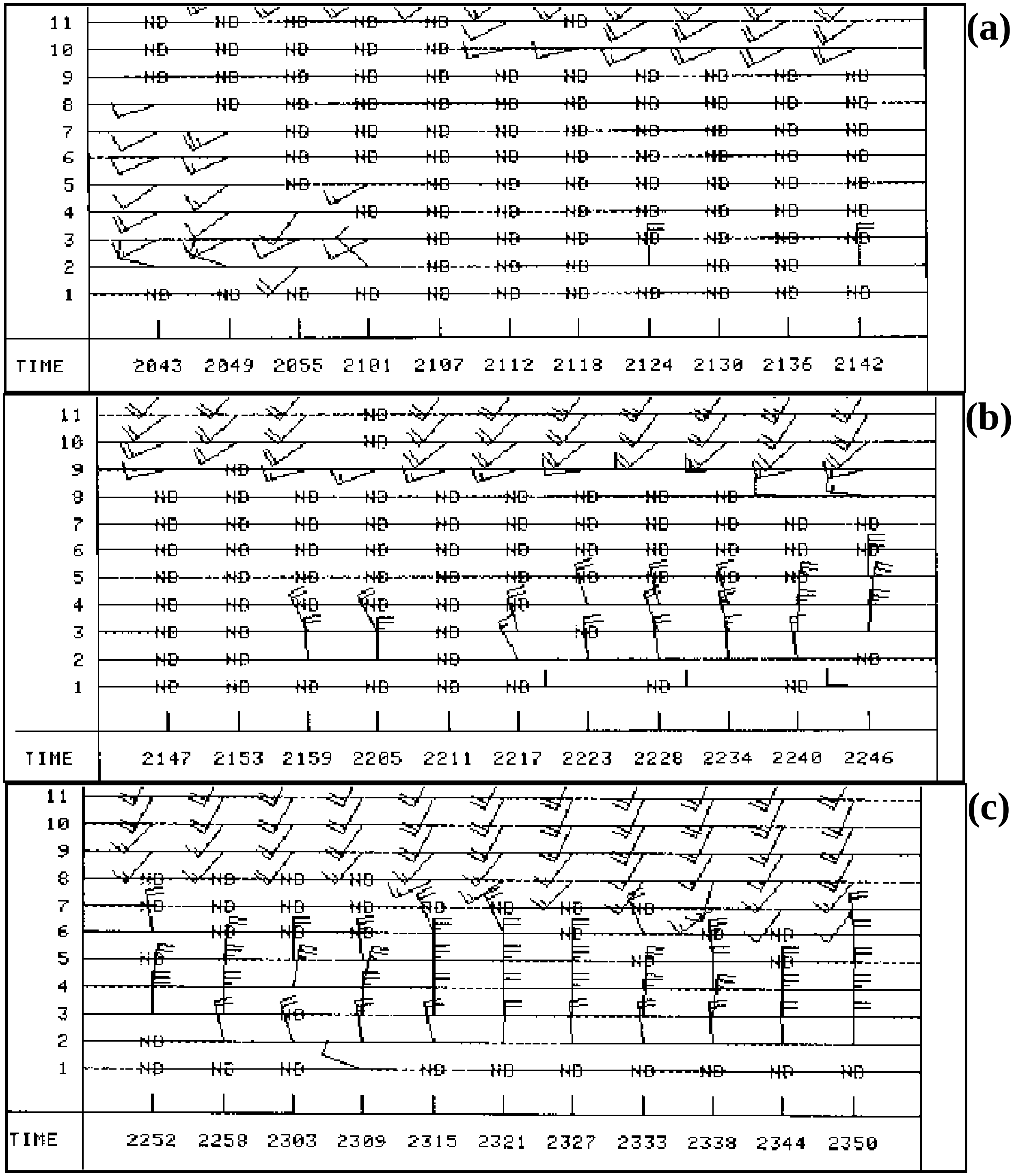


Figure 6. Buffalo, NY WSR-88D velocity azimuth display wind profile (VWP) product for 09 November 1996 between a) 2043-2142 UTC, b) 2147-2246 UTC, and c) 2252-2350 UTC. Vertical axis is altitude in thousands of feet. Here "ND" indicates no data. Notice the evolution from southwest flow to northerly flow in the layer between 2000 and 5000 ft (0.5 and 1.5 km) through the period.

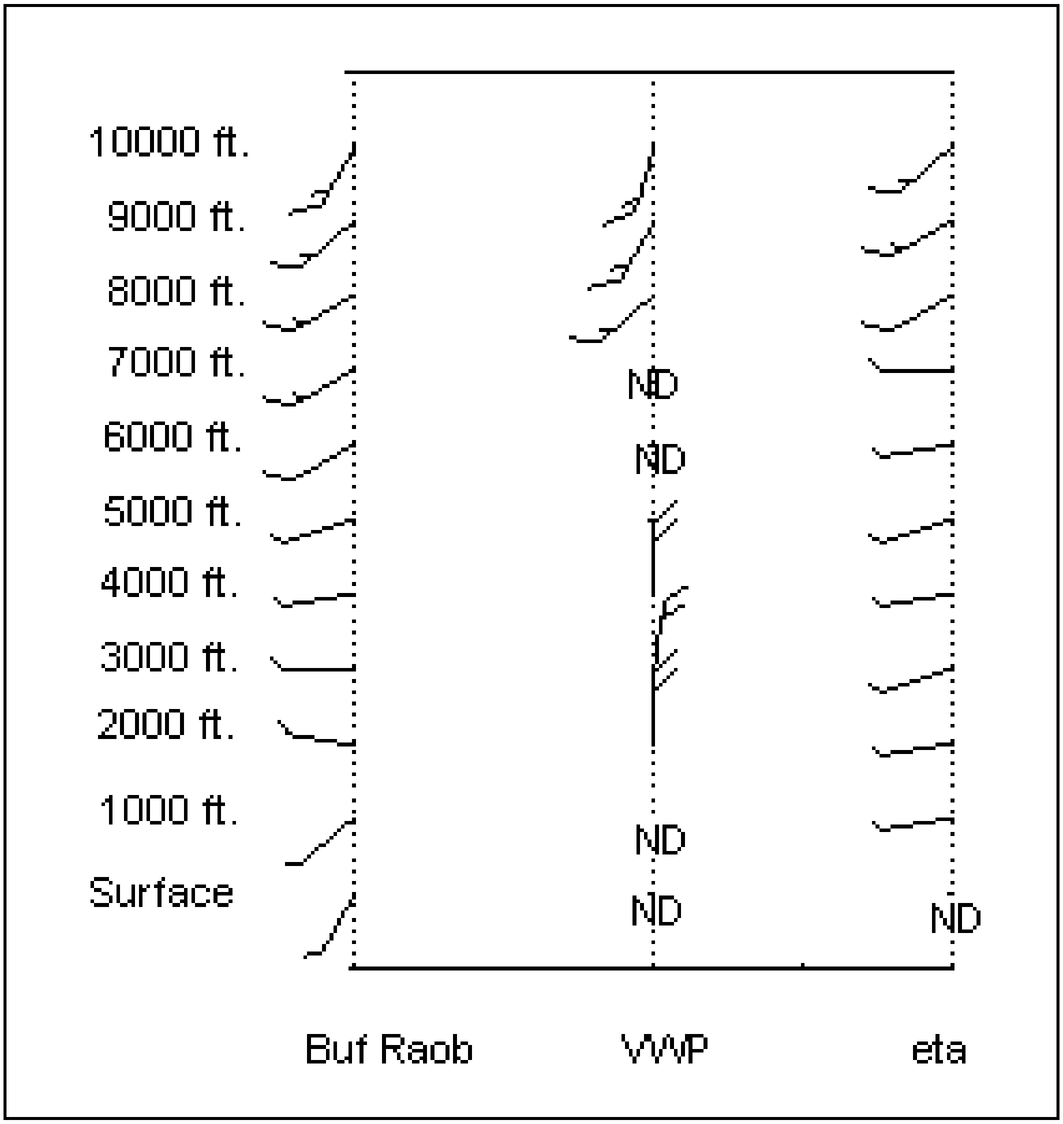


Figure 7. Comparison of the wind profile valid 0000 UTC 10 November 1996 from the Buffalo upper air sounding, the VWP, and the 12-hr forecast sounding from the eta model. “ND” indicates no data.