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DUGWAY PROFILER CAPTURES FIRST LAKE-EFFECT SNOW STORM OF SEASON

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Introduction

In the past, forecasters in northern Utah typically have had to rely on data from rawinsondes released once every 12 hours to determine wind flow patterns aloft. While these data often are sufficient to capture the typical gradual wind changes at the synoptic scale, rapid mesoscale and microscale wind changes often go by undetected. Data collection in the future promises to be different through the use of a radar wind profiler that was installed in the spring of 1990 at Dugway Proving Ground (DPG), Utah, by the U.S. Army. Since the profiler continuously samples the atmosphere for wind motions, the forecaster will be able to have an up-to-date report of wind shifts at any level of the atmosphere below about 300 mb. Subtle wind shifts that often influence lake-effect snow accumulations in the Salt Lake City (SLC) metropolitan area during the late autumn and winter seasons should now be detectable. This Technical Attachment examines the performance of the wind profiler for the first lake-effect snow storm of the 1990 season in northern Utah that occurred on November 5-6.

Storm Synopsis

On November 5, 1990, an intensifying short-wave trough moved southeastward from eastern Oregon into northern Utah. As depicted on the 500 mb chart, valid 1200Z November 5 (Fig. 1), there were two vorticity maxima contained within the trough. While the Oregon vorticity maximum was associated with the initial cold front, it was the second vorticity maximum northwest of Washington that was forecast to track over the Great Salt Lake (GSL) and would help increase the potential for lake-effect snow. However, an upper-level disturbance is just one of several factors that needs to be considered in forecasting true lake-effect snow. The following is a brief synopsis of the criteria necessary for a significant lake-effect snow episode, as proposed by Carpenter (1985); and how these compared to the November 5-6 conditions.

1) For optimum convective activity, the temperature difference between GSL and 700-mb must be between 17 and 23°C. On November 5-6, the SLC 700 mb temperature was -11°C, and the GSL temperature was estimated to be 6 to 8°C.

2) For the most efficient moisture transfer from the lake to the air mass above, the difference between the upstream surface dew-point temperature and the lake temperature must be >5°C. On November 5-6, the upstream surface dew points in southern Idaho were less than 0°C and, as noted above, the GSL was 6 to 8°C.

3) For good vertical development of the instability, the base height of the subsidence inversion following the 700-mb trough must be no lower than 650 to 700 mb. At 0000Z November 6, the subsidence inversion was above 620 mb.

4) For enhanced instability, an upper-level disturbance should generally be present, as indicated by a 700-mb thermal trough or positive vorticity advection (PVA) in the 500-mb analysis. On November 6, a vorticity maximum crossed the GSL.

Storm Evolution

Surface observations from November 5 indicate that the initial cold front moved across SLC at about 1400Z. Between 1400Z and 1800Z, the SLC airport received a water equivalent of 0.38 inches, while other northern Utah reporting stations received lesser amounts such as 0.09 and 0.02 inches at DPG and Tooele South (T62), respectively. The large difference in precipitation amounts suggests that orographic effects or convection may have played important roles in this first phase of the storm. Figure 2 shows the locations of selected observation sites in northern Utah and Fig. 033 gives chronological observations from these sites that depict the evolution of the storm.
During the following 6 to 24 hours (phase 2 of the storm), several disturbances rippled across northern Utah including a disturbance that changed the flow to northerly following its passage and created the "true lake-effect" snow event. Often these somewhat larger disturbances are identifiable through the use of satellite images. In this case, an area of enhanced clouds over central Idaho moving southeastward supported the existence of the vorticity maximum depicted by the NGM. Extrapolation placed it over the GSL between 0300Z and 0500Z November 6. This disturbance was not manifested as much by changes in winds at the surface as it was by occasional lightning to the west of SLC, which was reported at 0452Z. The lightning detection system recorded four cloud-to-ground strikes at the south end of the GSL between 0445Z and 0530Z.

As shown by data from the wind profiler, there are many more perturbations or disturbances in the atmosphere than any computer model can accurately analyze or forecast. In this case study, data retrieved from the profiler and shown in Fig. 4 indicates that at least two disturbances (labeled #2 and #3, Fig. 4) moved through the region after the initial sharp cold front had passed (labeled #1, Fig. 4). These disturbances were indicated by shifts in wind direction; the first, between the surface and 750 mb, occurred between 0100Z and 0200Z, and the second and more easily discernible, between 500 and 700 mb, occurred about 0500Z November 6. This second wind shift correlates well with the passage of the enhanced cloud signature depicted on the satellite images. Light snow occurred in the Salt Lake Valley between 0200Z and 0700Z in association with these disturbances, but more important was the southwestward development of heavier snow into the Tooele Valley at about 0500Z as a result of the wind shift to north following the passage of this upper-level disturbance.

The radar wind profiler has the ability to measure not only the horizontal (u and v) wind components, but also the vertical (w) component. In this case, the majority of the sampled atmosphere revealed upward vertical motion just prior to the passage of the upper-level disturbance and a downward motion after the passage. The fact that the entire sample did not conform to upward motions before and downward motions after the passage raises the question of whether the profiler can identify true vertical motions in all types of conditions. Although the representativeness of the vertical component is questionable, there appears to be at least some promise in the future for using the vertical component as a forecasting tool.

Conclusion

The Dugway wind profiler was able to document the storm history beginning with the initial wind shift associated with the baroclinic boundary and ending with the passage of the upper-level disturbance more than 12 hours later. Despite the fact that the Dugway profiler is located 60 miles southwest of the GSL, winds registered by the profiler have matched favorably with wind data retrieved from SLC rawinsonde flights during the past several months. This comparison indicates that wind shifts measured by the profiler (especially above the planetary boundary layer) are often representative of wind shifts in the Salt Lake Valley. One drawback that forecasters will face is that they will not be able to use profiler data to identify upstream wind shifts during northwest wind flow events. Instead, the profiler's usefulness will be to assist the forecaster by indicating when the wind direction or speed has changed at any level throughout the life cycle of the storm. Therefore, lake-effect timing, i.e., the onset, duration, and ending of the heavier snow, due to shifts in the wind both at the surface and aloft should be more forecastable in the future. This has been just one case study, but the profiler's usefulness already shows a good potential for improved local lake-effect snow forecasting/nowcasting.

References

Carpenter, D.M., 1985: *Great Salt Lake Effect Snowfall: Some Notes and An Example,* NOAA Technical Memorandum NWS WR-190. NWSFO Salt Lake City, Utah. October 1985.

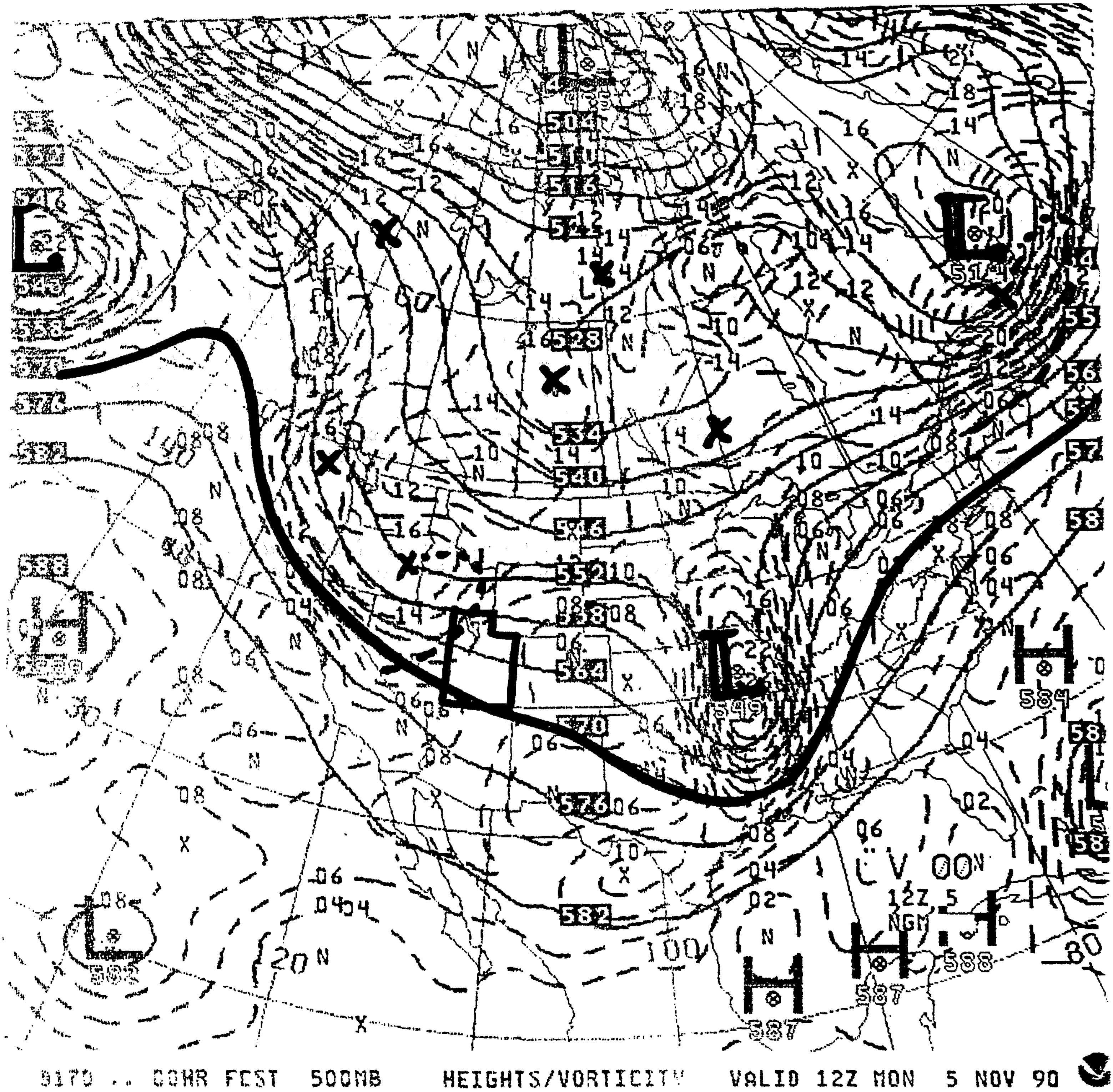

FIGURE 1

Analysis of 500 MB HEIGHTS/VORTICITY Valid 12Z Mon Nov 90.
Note the double vorticity maxima structure to the short-wave trough.

FIGURE 2

M A P O F N O R T H E R N U T A H

CONTOUR - HIGHLIGHTED AREA ABOVE 5500 FT.

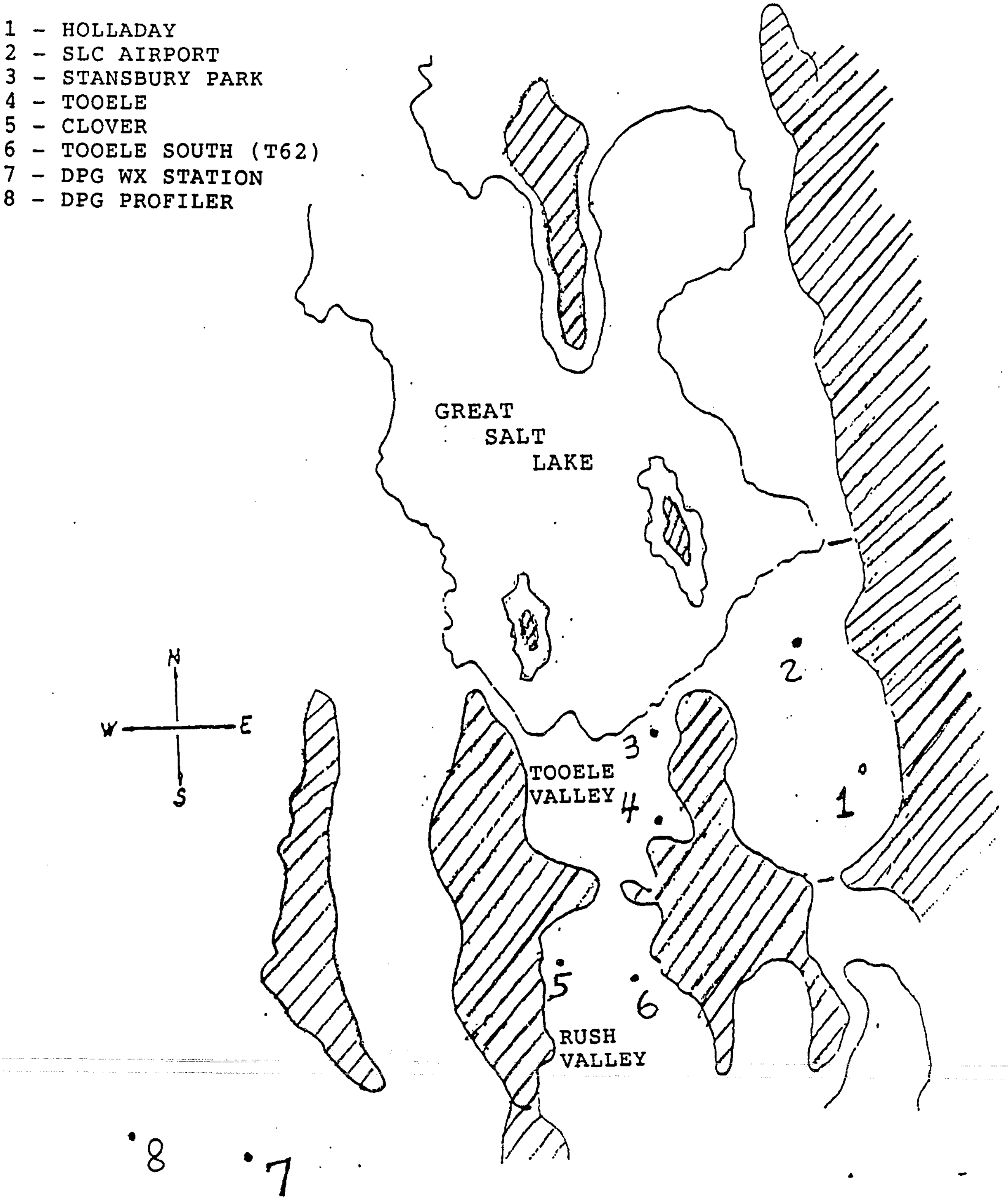

FIGURE 3

STORM EVOLUTION TIME TABLE

TIME (GMT)	DPG PROFILER(8)	DPG(7)	SLC(2)	HOLLADAY(1)	STANSBURY PARK(3)	TOOELE(4)	T62(6)	RUSH VALLEY(5)
PHASE 1 OF THE STORM - INITIAL COLD FRONT								
NOV-5								
1200-1300	Wind shifts at lowest level, indicating FROPA							
1400-1500	Frontal boundary extends vertically to about 700mb		Apparent FROPA with temperature drop and moderate rain showers					
1500-1600			Rain showers mix with snow				Wind shift rain showers	
1400-1800		Reports .09"	Reports 0.38"				ReportS .02"	
PHASE 2 OF THE STORM - SECONDARY DISTURBANCE								
NOV-6								
0100-0300	A small but distinct wind shift in lower 100 mb	Wind shifts to NW and doubles in velocity	Wind shift, snow showers begin and ceiling drops 3000ft	1" of snow				
0430-0530	Noticeable sharp veering of winds between 650 and 500mb		Trace of snow	No measurable snow after 2000	Several flashes of lightning and snow begins			
0600-0700	Winds veer toward north, then to just east of north					Snow begins		
0700-0800	Mid-level winds continue to be north northeast						Snow begins	Snow begins
1000-1200					Accumulating snow ends	Accumulating snow ends		
1600-1700							Accumulating snow ends	Accumulating snow ends
Storm Total		Trace of snow	Trace of snow	1" of snow	1" of snow	2-3" of snow	2" of snow	6-7" of snow

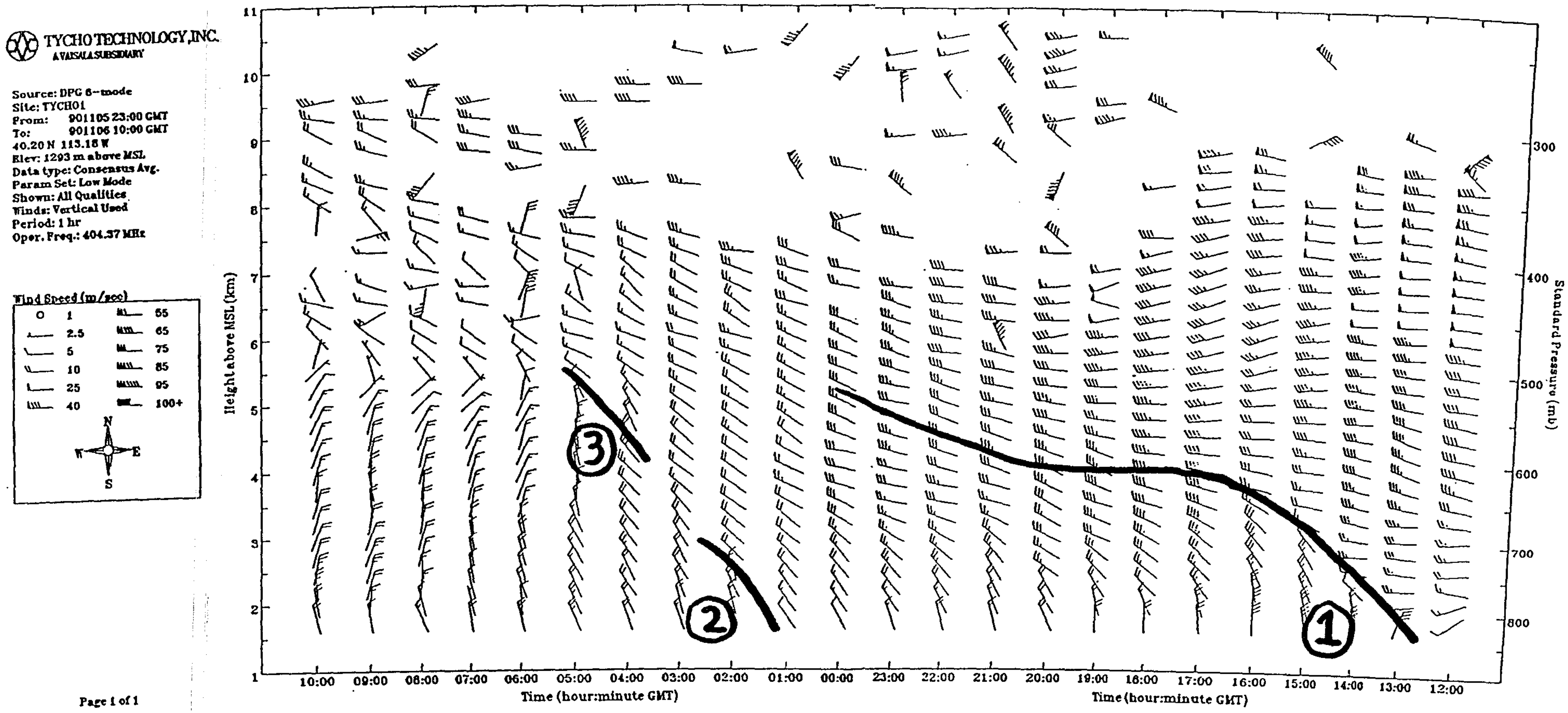

FIGURE 4

Time series of 1-hour averaged wind profiler data beginning at 12Z November 5 and ending at 10Z November 6. Note the time axis reads from right to left. The solid line labled #1 indicates the approximate slope of the cold front inferred from the shift in wind direction. Nearly 12 hours later a weak perturbation at the surface moves across the wind profiler location, as highlighted by the solid line labled #2. Between 04Z and 06Z the profiler indicates a distinct disturbance between the 500 to 650 mb levels (#3). This is likely associated with the vorticity maximum forecast by the NGM. After the passage of this feature, note that the winds between 500 and 800 mb become northerly to slightly east of due north.