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1.3.1 THE REAL-TIME USE OF WIND PROFILERS IN NOWCASTING

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I. INTRODUCTION

The Program for Regional Observing and Forecasting Services (PROFS) has been using wind profile data in experimental forecast applications for over two years, mostly in the form of real-time color displays on the PROFS forecast workstation. The most ambitious test of the workstation to date, the 1985 PROFS Real-Time Experiment (RT-85), ran from 15 May-23 August, 1985. This paper describes the use of wind profiler products during this and previous experiments.

Data from the experimental profiler network in Colorado (Figure 1) and from the PRE-STORM profiler in Oklahoma reach PROFS via ERL's Wave Propagation Laboratory, which operates the network. The data are in the form of hourly averages. Arriving data frequently contain errors whose origins range from interference by aircraft in the beams to highway truck traffic. Most of the irregularities are apparent through visual inspection of profiler wind observations plotted on a time-height cross section, but this method of quality control is inadequate if the intended uses of the data involve numerical calculations.

With the advent of the STORM program and plans for the Profiler Hub (a facility for collection, quality control, and archival of all profiler data), PROFS has been assigned responsibility for developing automated quality control procedures for profiler wind observations. At present, the quality control is rudimentary, including only a check for excessive vertical shear. The vertical check is limited in that it can recognize only two consecutive bad data points. Because as many as eight or ten vertically adjacent profiler wind observations have been in error in some cases, a more stringent quality control is needed. PROFS is refining the vertical quality control procedures and adding tests for temporal and horizontal consistency.

II. PROFILER DATA ON THE PROFS WORKSTATION

Several products on the PROFS forecast workstation utilize profiler data. Most popular with the forecasters is the time-height cross section of wind observations from a particular profiler site. This 12-hour time series has time increasing to the left to allow spatial interpretation of the data through the principle of time-space conversion. Different modes of operation (different pulse lengths and pulse repetition intervals) are color-coded on the screen. Longer pulses at longer intervals allow probing higher in the atmosphere, but at decreased vertical resolution. The utility of this display during a PROFS' Spring 1984 forecasting exercise has been discussed by GAGE and SCHLATTER (1984). In particular, with the increased spatial and temporal resolution of tropospheric data over Colorado, forecasters became adept at tracking short waves moving across the state and in detecting short-term changes in their amplitude, including the formation of closed circulations.

Another display, added during RT-85, is a quasi-three-dimensional depiction of wind profiles from all four Colorado sites projected onto a regional map. Winds are color-coded as in the time-height cross section. This is an hourly product that can be animated.

The Profiler Station Plot is a plot of the winds at all profiler stations for one level, developed for overlay on a satellite image.

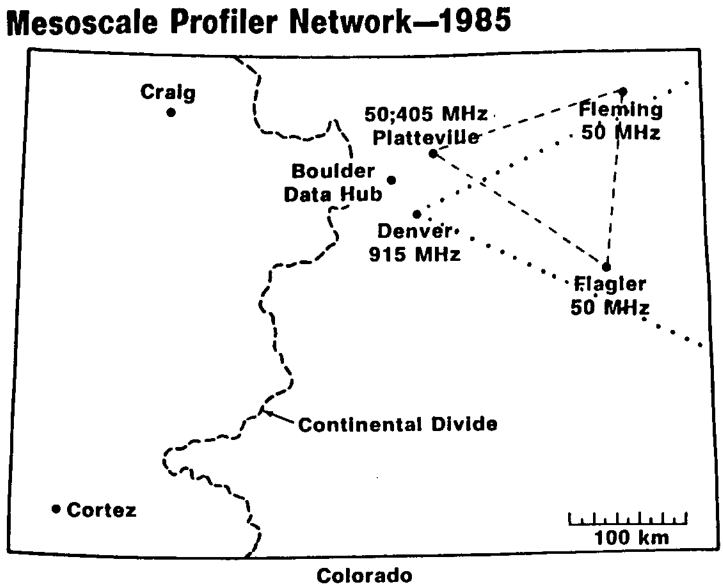

Figure 1. The Colorado profiler network overlayed with the kinematic analysis areas. The profiler triangle is in dashed lines; the RAOB triangle is denoted by dotted lines.

Smooth temperature and moisture profiles derived from a six-channel radiometer (HOGG et al., 1983) supplement measurements by the wind profiler. Accurate estimates of the geopotential height and total precipitable water have been obtained from these profiles, and several color displays are based upon them, but they will not be discussed further here.

Profiler data provide input to the Mesoscale Analysis and Prediction System (MAPS) and the Kinematic Analysis Model (KAM). MAPS is a mesoscale analysis/short-range forecasting system, utilizing data from rawinsondes, VAS soundings, aircraft reports, and wind and temperature profiles (BENJAMIN et al., 1985). MAPS will provide upper-level guidance to PROFS forecasters in the form of frequent analyses and 12-hour wind forecasts over the contiguous United States and adjacent areas.

The Kinematic Analysis Model, which was brought to PROFS from Purdue University, calculates vertical profiles of vorticity, divergence, and vertical velocity. The computer code was originally written for use with RAOB data in prediction of Great Lakes snowstorms (AGEE, 1983). KAM uses data from a triangle formed by three sounding stations. At each station, the u and v components of the wind are expanded in a first-order Taylor's series

$$u_n = u_o + \left(\frac{\partial u}{\partial x}\right)_o (x_n - x_o) + \left(\frac{\partial u}{\partial y}\right)_o (y_n - y_o)$$

$$n = 1,2,3$$

$$v_n = v_o + \left(\frac{\partial v}{\partial x}\right)_o (x_n - x_o) + \left(\frac{\partial v}{\partial y}\right)_o (y_n - y_o)$$

where the zero subscript refers to the middle of the triangle. These are six equations in six unknowns, u_o, v_o, and their partial derivatives. Once the equations are solved, the vertical component of vorticity and the horizontal divergence can be calculated. Pressure data, required to determine the vertical velocities, are unavailable from the profiling system. As an expedient, the pressure/height correspondence for the closest RAOB is calculated and applied to the profiler data heights to get a good approximation of the actual pressure. If the RAOB data are missing, the radiometric profile at Denver is used (HOGG et al., 1983). The vertical velocity can be derived by integrating the boundary conditions. At present, the vertical velocity is assumed to be zero at the lowest level, about 1500 meters above the ground. This is a shortcoming, particularly in summer, because it is known that most of the convergence which initiates thunderstorms occurs in the first kilometer above ground. We will attempt to remedy the situation by using PROFS' surface mesonet data in specification of the lower boundary conditions.

Another liability in the computation of kinematic quantities from three profiler sites is the data availability. If any of the three instruments is inoperative or transmitting unreliable data, then the analysis cannot be run -- an annoying situation which arose on some of the more interesting days last summer. Improved automatic quality control of the data will help to solve this problem.

III. PROFILERS IN USE: AN RT-85 CASE STUDY

The Kinematic Analysis Model was first used extensively with profiler data during RT-85. Two consecutive days, 1 and 2 August, provide an interesting comparison of synoptic vs mesoscale influences. In the following paragraphs, we refer to profiles of convergence and vertical velocity computed from soundings made at the vertices of two triangles. The small triangle (Figure 1) includes the profiling sites at Platteville, Flagler, and Fleming, Colorado. The large triangle (western portion shown in Figure 1) includes the rawinsonde sites at Denver, Colorado, North Platte, Nebraska, and Dodge City, Kansas.

On the afternoon of 1 August, a typical flow pattern existed over the Colorado Rockies. In Figure 2, a broad band of clouds depicts a weak flow of warm and very moist air extending from the Mexican border north-northeastward to Colorado. At 500 mb, a trough of cool air lies to the northwest over Washington and Oregon. Profiles of convergence and vertical velocity from the large and small triangles (Figures 3 and 4, respectively) show similar patterns -- slight divergence and subsidence at all levels. Although very little convective activity occurred inside either triangle, strong convection occurred to the west: the Cheyenne, Wyoming, hailstorm and flash flood caused fatalities between 0200 and 0400 GMT 2 August; another cluster of thunderstorms caused excessive rainfall and hail south of Denver.

By 2 August, the trough aloft had moved east to the northern Rockies (Figure 5), and the flow over Colorado had become more westerly, although still moist. The early evening profiles from the large triangle (Figure 6) show very weak divergence in the lower troposphere and weak convergence above 500 mb. The vertical velocity is correspondingly weak, mostly downward. A much different situation exists within the small triangle (Figure 7), with moderate convergence aloft and rising motion. Thunderstorms developed during the afternoon and moved into the triangle by early evening. They dropped hail both outside the triangle -- on the foothills northwest of Platteville -- and inside. Near the western corner of the triangle, hail up to 2 cm in diameter lay in drifts along the roadside.

The correspondence between profiles of vertical velocity and thunderstorm activity is by no means perfect, in part, because the 50-MHz profilers cannot obtain measurements close to the ground and because surface wind observations are not yet being used. We expect to remedy the latter problem soon.

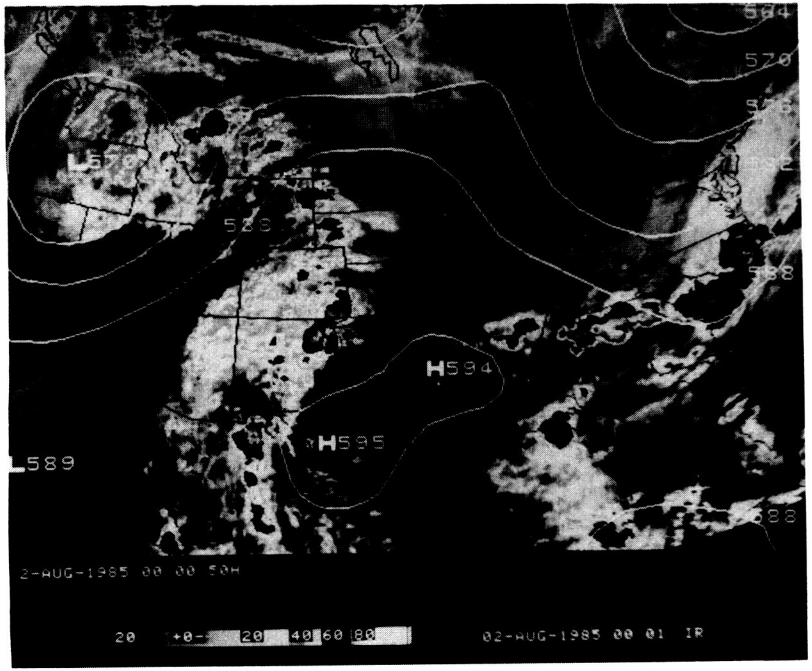

Figure 2. GOES IR image for 00:00Z, 2 August 1985, overlayed with corresponding 500 mb height analysis.

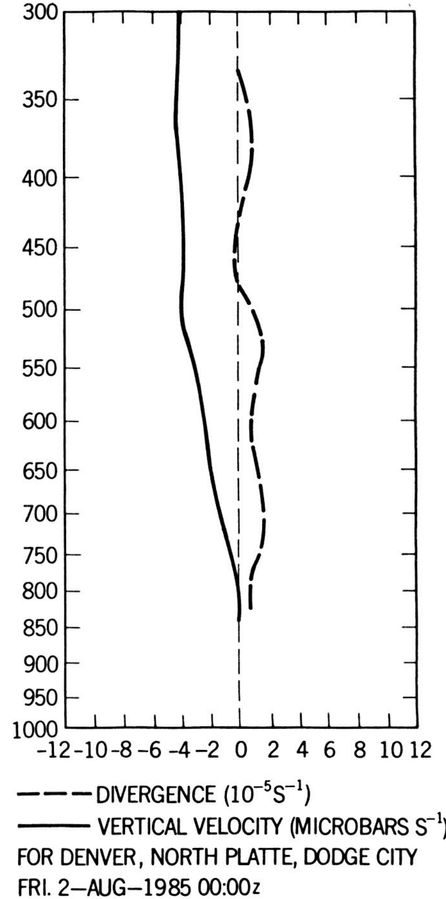

Figure 3. Kinematic Analysis Model output at 00:00Z, 2 August 1985, for the RAOB triangle. Rising motion is denoted by vertical velocity values to the right of the zero line.

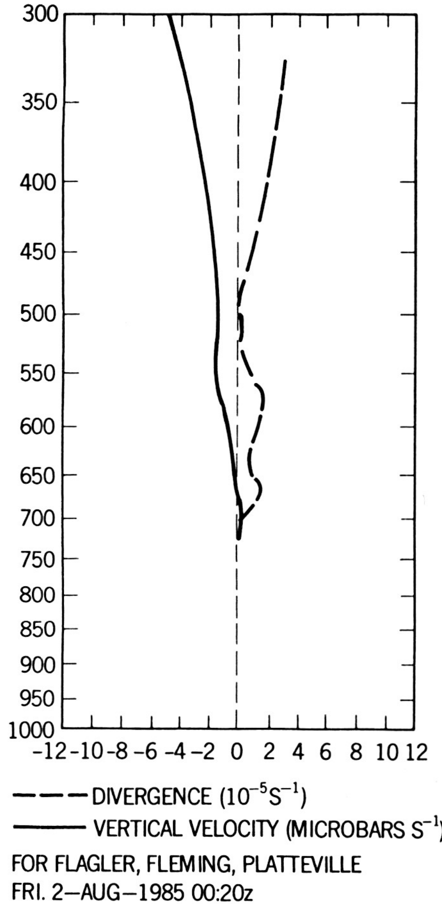

Figure 4. Kinematic Analysis Model output at 00:20Z, 2 August 1985, for the profiler triangle.

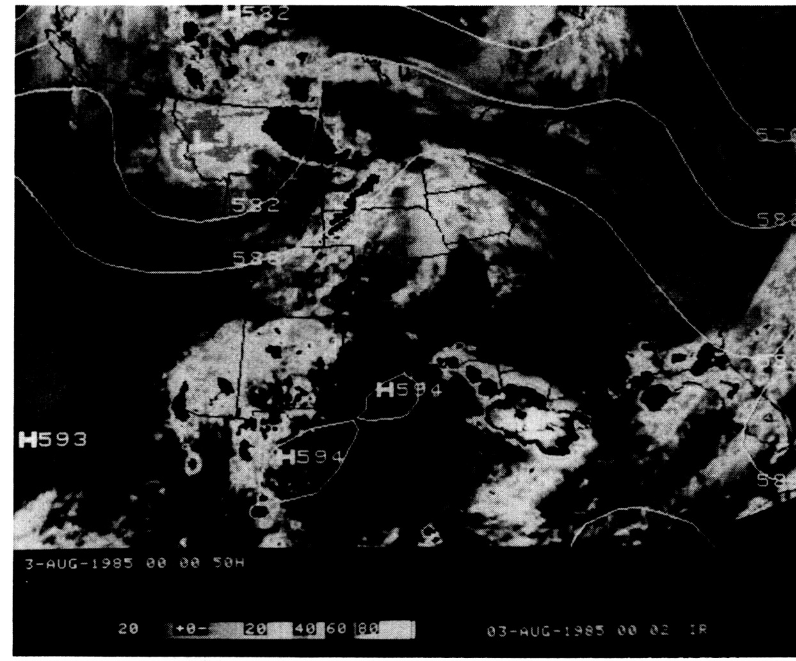

Figure 5. GOES IR image for 00:00Z, 3 August 1985, overlayed with corresponding 500 mb height analysis.

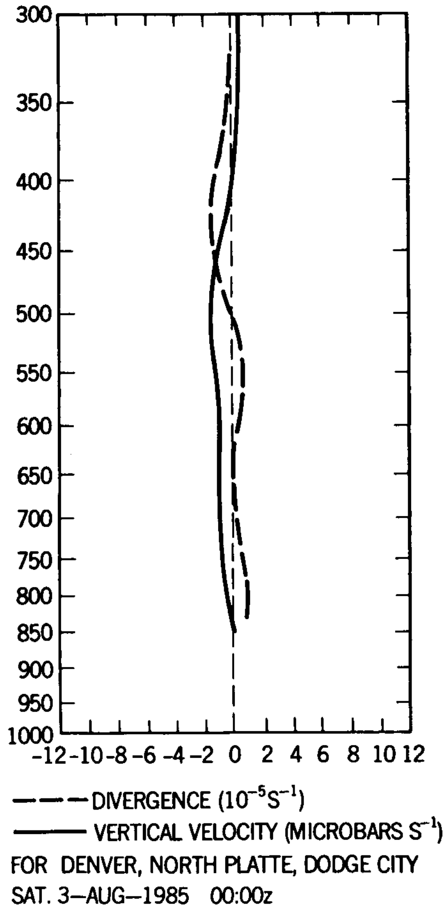

Figure 6. Kinematic Analysis Model output at 00:00Z, 3 August 1985, for the RAOB triangle.

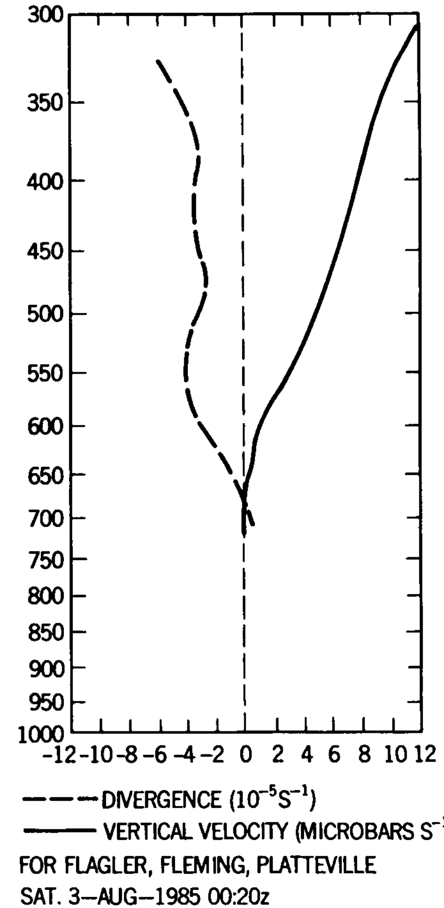

Figure 7. Kinematic Analysis Model output at 00:20Z, 3 August 1985, for the profiler triangle.

IV. FUTURE WORK

Applications of the profiler winds are continuing to be discovered and developed. BLECK et al. (1984) have developed a method for using the profiler winds to put better vertical resolution into the radiometric profiles of temperature. The radiometer is capable only of smooth profiles because the radiation it measures emanates from thick layers. Any sharp kinks in the temperature profile such as a frontal inversion are undetectable. Using variational calculus and the profiler wind data, Bleck and his colleagues expect to build such details back into the temperature profile. In an operational setting, this technique could be used to upgrade the quality of radiometric or satellite soundings.

Visiting forecasters who operate the PROFS workstation often recommend extensions to existing products. One useful suggestion is a time series of divergence, vorticity, and vertical velocity at a given level. We are also adding the capability of making an hourly product of the kinematic fields, so that it can be loaded for animation, to give the observer a dynamic view of the temporal changes.

If we can trust the early indications, profiler data displayed in a great variety of ways will prove to be a boon to very-short-range forecasting. PROFS will be continuing its application of profiler data to the problems of forecasting during its next cool-season exercise in early 1986.

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