Wind Profiler

Planned Use of Wind Profilers In National Weather Service Operations

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ABSTRACT

The wind Profiler is a Doppler radar oriented vertically which senses turbulent backscatter. It emits pulses of radiation, just like "regular" radars, at a specific frequency. The detected shift in the frequency of the backscattered signal is translated into wind components toward or away from the Profiler radar. Current wind profiling systems operated experimentally by NOAA's Environmental Research Laboratories (ERL) have at least two beams, oriented 15 degrees apart; these provide u- and v- components of the wind. Some systems have a third beam pointing vertically which allows the wind's w-component to be computed. The ERL experimental Profilers transmit on three frequencies: 50 MHz, 405 MHz, and 915 MHz.

At this time, NWS use of wind Profilers in daily operations is limited. WSFO/CWSU Denver have received data in the form of plotted time-height cross sections from the ERL Profilers for several years; and since March 1986, wind data from the ERL Profilers have been sent in raob code on AFOS, primarily for use by NMC and NSSFC. NWS use of Profiler data will receive a tremendous boost by 1989 with the deployment of the Wind Profiler Demonstration Network in the Midwest. ERL will operate this network of 30 405-MHz Profilers during the period October 1989 through September 1992 (FY 1990 through FY 1992), and will make the network data available to NWS field offices and National Centers.

Although Profilers have so far seen little use in NWS operations, there have been a number of potential data applications, for single site data, small configurations (triangular arrays), and larger networks of Profilers. These applications involve either Profiler data alone or integrated with other data sets. They include:

- *time height cross sections (single sites)*
- *vertical profiles of vorticity, divergence, and vertical velocity (triangular array)*
- *vertical "stacks" of winds for each site*
- *constant-level wind plots, integrated with satellites imagery, rawinsonde data, thermodynamic Profiler data, or NWP output*
- *time variation of convergence, vorticity, and vertical velocity*
- *subsynoptic diagnostic and prognostic models (not yet developed; awaiting network data)*

The NWS is developing an assessment plan to evaluate the wind Profiler's technology in an operational setting, from both meteorological and systems-engineering viewpoints. This plan will involve WSFO's, CWSU's, Regional SSD's, NMC, NSSFC, ERL, and NWS Headquarters. It will primarily assess the use of the Wind Profiler Demonstration Network in NWS operations, and it is expected to prepare the way for NOAA to develop a nationwide network of wind Profilers.

1. BACKGROUND

The use of microwave Doppler radar to measure wind was begun in the early 1960s, to investigate the structure of clouds. Later in the 1960s, returns detected from clear air were found to be caused by irregularities in moisture and temperature fields caused by turbulent eddies moving with the mean wind. Since the early 1970s radars have been built that are sensitive enough to translate the backscattered energy from turbulent eddies into vertical profiles of wind velocities. NOAA's Wave Propagation Laboratory (WPL) has operated several experimental wind profiling radars since the late 1970s, mostly in Colorado. These radars are usually known as wind Profilers (or simply Profilers).

2. CURRENT NOAA PROFILERS

The experimental Profilers operated by WPL have different transmission frequencies and structures, but they employ a common principle to detect turbulent eddies. All current systems have at least two orthogonal radiation beams, oriented 15 degrees off the vertical, and pointing towards the north and east; this allows u- and v-components of wind to be calculated. On some systems, an additional beam pointing vertically will yield the component of vertical velocity.

Currently, WPL operates four wind Profilers in various parts of Colorado, as shown in figure 1; this grouping is known as the Colorado Mini-Net. Each Profiler transmits on one of three frequencies: 50 MHz 405 MHz, and 915 MHz, also as shown in figure 1. Each signal frequency allows winds to be calculated over varying vertical ranges, given similar atmospheric conditions at all sites. And each frequency has been chosen after careful consideration of available transmission frequencies.

Profilers use varying pulse-repetition periods (modes) to sense backscattering to a maximum usable height. The Mini-Net Profilers operate in two

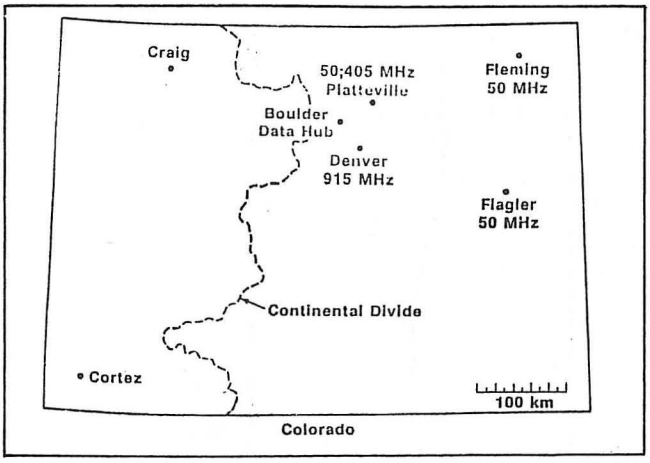

Fig. 1. Locations of Colorado Mini-Net Wind Profilers and Hub. (2)

modes (low and high) with overlapping ranges, except that the 915-MHz Profiler uses three modes. Primarily because of the time needed for transient currents in the antenna to dissipate, Profilers cannot detect energy between the surface and a minimum usable height. The 50-MHz system's useful range is from about 3 km to 18 km AGL; the 405-MHz system's range, about 0.5 km to 16 km AGL; and the 915-MHz system's range is between 2 and 15 km AGL. Winds are detected at discrete levels (range bins) in the vertical. Spacing of the levels depends on mode, which is a function of the pulse energy. The spacing ranges from about 0.25 km in low mode of operation to about 1 km in high mode. (Exception — the 915-MHz Profiler has a minimum spacing of 0.14 km.) Each profiling site produces time-averaged wind values at the range bins every hour for transmission to a central collection point called the hub, located in Boulder, CO. Real-time data are sent to users hourly, but are calculated for non-real-time research purposes every 6 minutes.

From the hub, Profiler wind data are sent hourly in modified RAOB code to Central and Eastern Regions via AFOS. The Denver WSFO and CWSU have also received data from the Stapleton (915-MHz) Profiler via special transmission from the Program for Regional Observing and Forecast Systems (PROFS) for several years. Within the NWS, only the Denver WSFO and CWSU have made operational use of wind Profiler data since most Profilers have operated in Colorado. The National Severe Storms Laboratory (NSSL) at Norman, OK, expects to have a wind Profiler operating soon, whose data may be available to WSFO Oklahoma City.

A small configuration of Profilers like the Colorado Mini-Net would appear to have very limited value when considering the U.S. as a whole; vertical time sequences of Profiler winds in Colorado have no utility to forecasters at Chicago. But the mini-net can show the way to production of useful meteorological quantities that can be applied to future Profiler networks. Figure 2 illustrates vertical profiles of vertical velocity, divergence, and vorticity calculated at the centroid of the triangle of Profilers. Similar plots can be made of horizontal divergence. Time series of divergence at different levels for a site, shown in figure 3, and winds at constant heights, are but two of many fields that can be analyzed in the mesoscale using data points calculated from a network of Profilers.

Comparisons of Profiler and rawinsonde data are difficult in that rawinsondes sample the wind over a one-hour period in an irregular upward path, while Profilers perform instantaneous sampling, averaged in a discrete time period, through a nearly vertical volume. Nonetheless, both kinds of data appear to have about the same accuracy.

3. THE WIND PROFILER DEMONSTRATION PROJECT

This project, led by WPL, focuses on the development and implementation of an experimental wind Profiler network in anticipation of a projected national Profiler network. It uses the Colorado Mini-Net and hub to plan for the establishment of the Wind Profiler Demonstration Network (WPDN). The WPDN will consist of 31 sites as shown in figure 4; the site at White Sands, NM, will be operated by the U.S. Army and will be the only non-NOAA Profiler in the network. The WPDN Profilers will all be 405-MHz systems, possibly with colocated surface sensors that will provide wind, temperature, and pressure measurements. Site surveys are under way at this time. Many factors must be considered in locating wind Profilers, such as: environment (terrain, avoidance of population centers), land availability (about an acre of land per site), and possible radio frequency interference (to/from communications and satellites). Profilers for the WPDN are expected to be installed over a one-year period starting late 1988 (i.e., FY 1989); the WPDN will be operating from about late 1989 to late 1992 (i.e., FY 1990-92). The WPDN will be, strictly speaking, a demonstration; WPL does not guarantee 24-hour operation but will make every effort to run the Profilers without interruption.

4. NWS ASSESSMENT OF PROFILER UTILITY IN OPERATIONS

Data from the WPDN will be made available to the NWS from the network Hub in Boulder, a prototype of which serves the current Colorado Mini-Net. Plans at this time call for three data sets for field sites: hourly winds, averaged over the past hour; 12-minute winds, averaged over the preceding 30 minutes; and unaveraged (instantaneous) data every 6 minutes. The hourly and 12-minute data will, in addition, be quality controlled, with any suspect data flagged before being sent to users. The exact form and method of availability of the data have not been determined; but it is expected that data will be available from single sites, from groups of sites, and from the network as a collective.

By agreement with the Office of Oceanic and Atmospheric Research, the NWS will perform an organized assessment of the utility of wind Profiler technology in its field operations. This assessment, which will be based mostly on the WPDN, will employ a twofold approach — meteorological and systems engineering — to assist NOAA Management

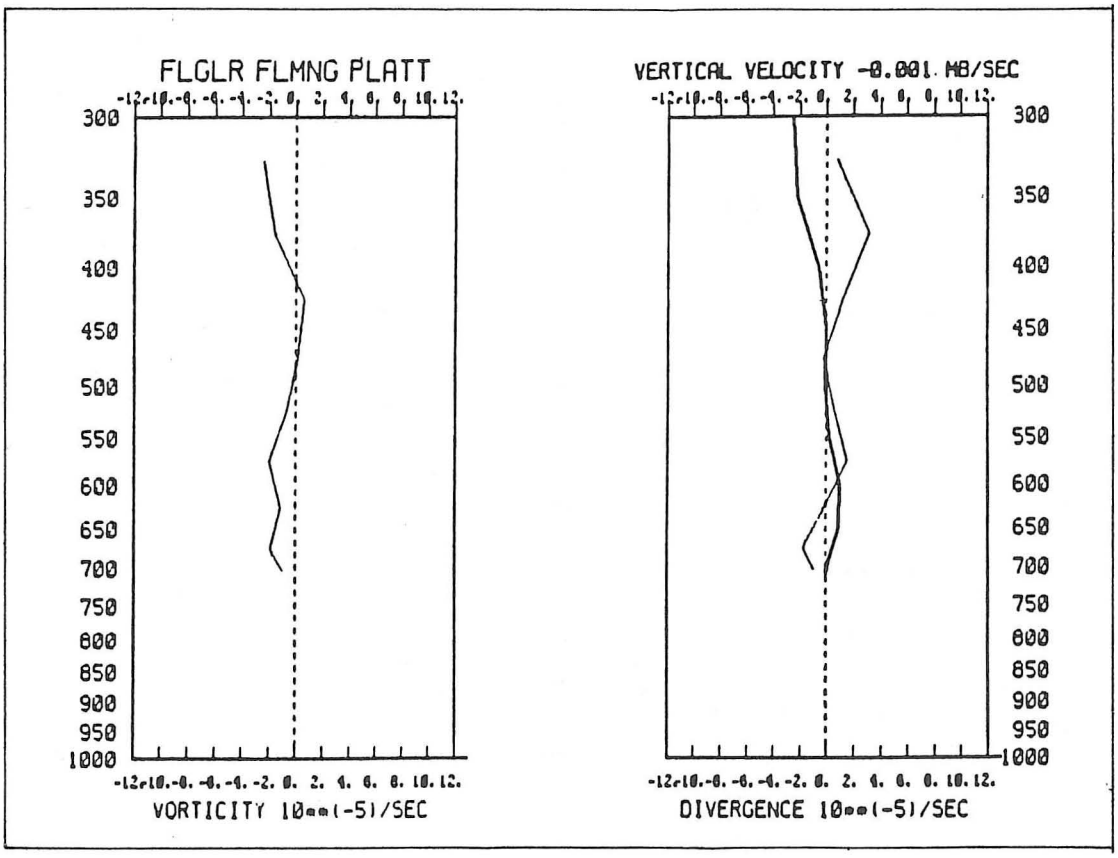

Fig. 2. Vorticity (on left) and divergence and vertical velocity (on right) profiles for the Platteville-Fleming-Flagler triangle at 1820 UTC, July 24, 1985. In the right graph, the lighter curve is for divergence; the heavier curve is for vertical velocity. Values to the right of the zero line indicate positive vorticity or rising motion. (2)

in laying the foundation for a national Profiler network. The NWS assessment of Profiler utility has two goals:

- Use the operational information from the wind Profilers in an operational environment to better understand the ways the data may be used to improve NWS operational forecasts and services, and
- Assess the system characteristics of the wind Profilers, both individually and in networks, to determine those characteristics required for a fully operational national network.

To fulfill these goals, NWS is developing an assessment plan involving field sites, Regions, Techniques Development Laboratory (TDL), National Centers, Environmental Research Laboratories (ERL), and NWS Headquarters. This plan is expected to be implemented by the end of 1986. Some details of the assessment activities of the plan's participants follow.

Field sites: Until the WPDN is established, only WSFO Denver and CWSU Denver can count on having any Profiler data for operational use. Both sites have used the Colorado Mini-Net data for several years. They have built up considerable experience with Profilers and will be expected to provide information on Profiler utility to NWS Headquarters during the pre-WPDN time. The WSFO's and CWSU's whose forecast areas of responsibilities lie in or close to the WPDN domain will, when the network is running, be included as participants in the NWS assessment, to see how Profilers technology can be operationally useful.

Regions: During the time that the WPDN is running, the Scientific Services Divisions of NWS Central and Southern Regions will be involved with the WSFO's and CWSU's in their Region to find ways to use both single-site and network Profiler data. This will include development of applications techniques for local-site use in subsynoptic-scale forecasting. There are many phenomena whose understanding and forecasting may be improved by the use of network Profiler data, such as: structure and movement of fronts, time tendency and structure of the vertical wind field, and frequent analyses of parameters (e.g., vorticity) currently available only every 12 hours.

TDL: During the pre-Network time, TDL will adapt and develop subjective and objective techniques for Profiler data use by local field sites. They will examine techniques that have been developed elsewhere (e.g., by WSFO's) to determine their general applicability. Once the Network is

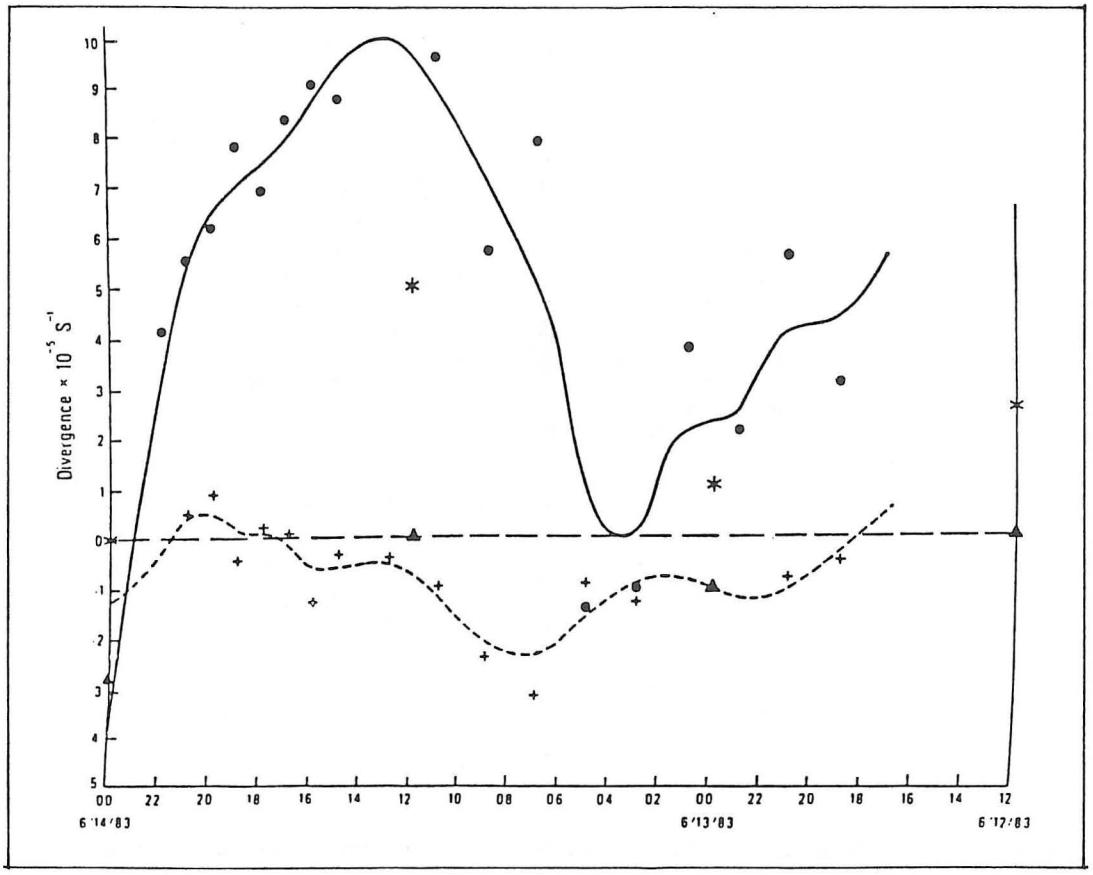

Fig. 3. Time-smoothed variation of divergence, June 12-13, 1983, at 9 km (solid line) and 3 km (dashed line) computed from Profilers in the SW, NW, and SE Colorado. Time increases from left to right. Dots and crosses are unsmoothed values from the Profilers. Triangles and asterisks are valued computed from rawinsonde data.

running, TDL will also develop local-scale forecast models, and will use Profiler and VAS data in frequently calculated thunderstorm probabilities.

National Centers: NMC and NSSFC will participate in the assessment. A summary of their assessment activities follows.

In the pre-WPDN period, NMC is developing a four-dimensional data-assimilation system to effectively use volumes of data such as those produced by a Profiler network. They are also performing time-series analyses of Colorado Mini-Net data to determine time and space scales measured by Profilers and to estimate error rates in the data. Once the WPDN is running, NMC expects to: examine data accuracy; examine scales of observed phenomena; study data rejected by NMC analysis quality control, and determine the effect of WPDN data on current and future numerical weather prediction models. Included in the last task are answers to these questions: Do WPDN data contribute information not found in existing data sets? Can Profiler data be used instead of existing data types? Can time resolution be traded for space resolution?

NSSFC's forecast units — Severe Local Storms (SELS), Convective Sigmet (CS), and National Aviation Weather Advisory Unit (NAWAU) — will receive the same training that field forecasters will get (see ERL/PROFS section below) for familiarization with Profiler data. They will develop analysis and forecast techniques for their missions working with their Techniques Development Unit

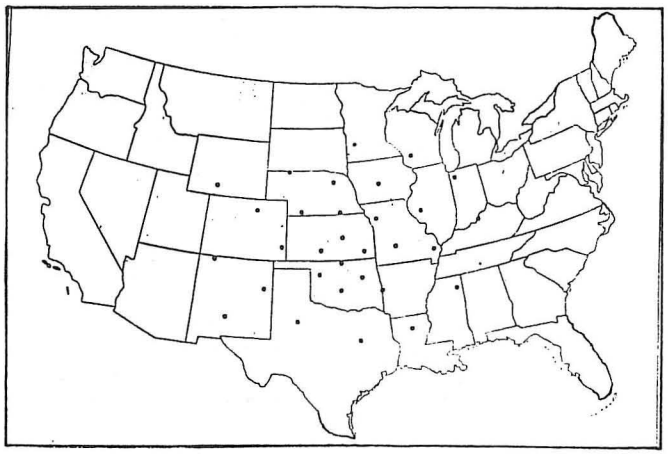

Fig. 4. Sites Profilers in WPL's Wind Profiler Demonstration Network.

(TDU). There are a number of phenomena they consider important in their forecasting missions, such as: triggering mechanisms like troughs, wind shears, jets, and gravity waves. These will be better understood once frequent winds-aloft data permit their detailed examination.

ERL/PROFS: Based on their experience in using Profiler technology, PROFS is developing training material (videotapes and manuals) for NWS forecasters to use when Profiler network data become available. PROFS is also developing quality-control procedures to filter (but not reject) WPDN data sent to users. They will work with NMC to develop techniques and models for NMC's data-assimilation system under development; in fact, PROFS will work with NMC on NMC's assessment tasks already listed during the time that the Profiler network is running.

OM: With help from OSO and OSD for the systems-engineering portion of the NWS wind Profiler assessment, OM will lead the overall assessment effort. OM will chair a working group for wind Profiler assessment, made up of representatives from field sites, Regions, TDL, NSSFC, NMC, OSO, OTS, and PROFS. OM will also: hold annual assessment meetings; require annual assessment reports from all participants; produce an annual assessment summary; develop and administer assessment budgets; and assist NOAA Management in developing a national Profiler network.

During the time of the Network's operation, other major activities will be under way in connection with NWS planned moderization and field restructuring: observational programs (NEXRAD and ASOS), communications programs (e.g., NOAAPORT), and data-integration programs (SWIS and AWIPS-90). Profiler data are expected to be extensively used in an interactive mode as well as by themselves. The NWS assessment scheme just described seems very ambitious, but NWS views it as sufficiently important to be in the same class with the major programs mentioned that will profoundly affect its field operations.

NOTES AND REFERENCES

1. Brian G. Smith is a meteorologist with the Systems Requirements Branch of the Office of Meteorology at National Weather Service Headquarters.

2. Schlatter, Thomas W. Use of ground-based wind profiles in mesoscale forecasting. Proceedings, Symposium and Workshop on Global Wind Measurements. Columbia, MD, 29 July-1 August 1985.

Folklore

by Sue Mroz

"BUSHY FUR COATS AND CAT TAILS HIGH . . . LOOK OUT!"

Winter's just around the corner and those who have made it a custom to try to guess what Old Man Winter has in store for us are busy noting nature's profusion of signs. Among the things to watch for according to country lore are: ears of corn up very high on the stalk....there will be a lot of snow; extremely tall weeds in the summer are also supposed to mean we'll be doing a lot of shoveling. If there are a lot of acorns for hungry squirrels, it's supposed to mean a snowy winter, and if the squirrels take their food supply high up in the trees, rather than burying it in the ground....look for deep snow drifts. Also, I recall speaking to a group of wives of veterinarians a few years ago who told me that their husbands had noted very thick and early coats on the animals they were seeing. That turned out be a very cold winter. Farmers also take note of where the hornets and the wasps are making their homes before winter sets in. Reportedly, if they (mud wasps) try to put their nests in protected areas such as barns and wood sheds, it'll be a very harsh winter. Personally, when I see the monarch butterflies flying south in their large groups by night....I know winter can't be far off, and they probably have the right idea, wintering in Mexico.