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# 9.17A MEASUREMENTS OF VERTICAL VELOCITY OVER FLAT TERRAIN BY ST RADAR AND OTHER RELATED USES OF THE RADAR DATA SET

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## INTRODUCTION

The first part of this communication points out the need to study vertical velocity measurements from an ST radar located on the plains, far from the mountains. As all presently available clear-air radars are located in or near mountains, the second part discusses the construction and operation of a VHF Doppler (ST) radar in the midwestern part of the United States to make meteorological measurements. While our primary interest is in measuring the synoptic-scale vertical velocities in the troposphere and lower stratosphere, it should be stressed, however, that the radar data set generated during the radar experiment would have many other valuable uses of interest to us and others some of whom are listed below. The required radar parameters, approximate costs, and recommended mode of operation are also detailed.

## SCIENTIFIC ISSUE

The vertical velocity is the atmospheric variable most closely linked with weather, except perhaps moisture, yet it has been almost impossible to measure directly. Clear-air, or ST radars offer an opportunity to measure the vertical velocity directly and continuously. In a recent study we found that the time-average vertical motion over the Platteville, Colorado ST radar compared favorably with the computed synoptic-scale vertical velocity under certain synoptic conditions: when the prevailing winds were light or from the east and the synoptic-scale vertical velocity was over one or two centimeters per secone. When the prevailing winds were from the west, across the Rocky Mountains, the meteorological noise was too large to permit computing a mean vertical velocity with sufficiently small statistical uncertainty, or else standing lee waves made the radar site unrepresentative of the large geographical area of the synoptic-scale system. In either case, it is a meteorological signal-to-noise problem induced by the mountains. We have found a similar situation in the ALPEX data from Southern France, i.e., when the winds were off the sea the measured and computed vertical velocities agreed favorably but when the winds were across the mountains the agreement was poor or uncertain. Thus, we can conclude that at ST radar stations near mountains the synoptic-scale vertical velocity can be measured only under restricted conditions. These statistics strongly suggest that it may be possible to measure the large-scale vertical velocity under general conditions at a radar site located in the plains. This question should be addressed by using radar data from a site on the plains. The only MST radar located in the central plains at this time is at the University of Illinois; it does not measure the vertical velocity and according to Prof. S. A. Bowhill, it could not easily be adapted for that purpose.

Thus we propose installing an ST radar at a site in the central plains, and operating continuously for at least a year, taking measurements of the vertical velocity in the troposphere and lower stratosphere, and comparing the radar w's with computed values and with proxy indicators of the large-scale vertical motion such as weather-radar echoes and satellite pictures. We expect these "Flatlands" data would be of interest for other purposes as well, both meteorological and radar engineering, and we would, of course, make it available to other scientists. If the ability to measure the synoptic-scale vertical velocity can be demonstrated, this technique should impact a wide meteorological community. For example, research programs such as the upcoming

STORM project may be enhanced by adding vertical velocity measurements to their data base.

This radar could be constructed to point just vertically or be made to point its antenna beam sequentially to the vertical and four oblique directions. A practical data rate is one complete sequence of antenna directions in 500 s. This technique has already been tested at the Sunset radar; it offers the advantage of horizontal wind measurement to aid interpretation and provides, by the continuity equation, a kinematic check on the vertically pointed beam's measurements. This capability would permit us to resolve any lingering questions regarding the interpretation of the vertical velocity measurements from a vertically directed radar beam. For example, a primary reflecting mechanism for the vertical beam is specular reflections from specular layers. If the stable layers are moving vertically at a rate different from the air velocity, say at some phase velocity, the radar could give misleading results. By using the steering capability we can address this and any other issues of interpretation. Additionally, the slant antenna beam reflectivity would provide a measure of the intensity of turbulence versus altitude (the variable $C_n 2$). Studies of the specular reflection phenomenon and tropopause detection would be enhanced by the comparison of the vertical beam with the off-vertical beams. Spectra from the time series of the slant as well as the vertical velocity measurements are of interest. The use of the u' w' from the various beams would allow the computation of the vertical momentum flux due to gravity waves.

The antenna configuration and design required for accurate vertical velocities will give this radar a useful mesospheric capability and will frequently obtain echoes in the 65-85 km altitude region. Recording this additional data will add only about 2 K/yr to the cost of the operation.

## THE EXPERIMENT

### (a) Site Selection

Since we already have data in or near mountains, the site should be at the other orographic extreme -- smooth terrain. Midwestern states, especially Indiana and Illinois, are flat and relatively far from mountains. We have already contacted the Base Commanders at Grissom Air Force Base, IN, Whiteman Air Force Base, MO, and Chanute Air Force Base, IL, and find that they have space available and technicians (who would change tapes and check dials) on duty even during holiday periods. Purdue University, Lafayette, IN, has space available and has expressed interest in a cooperative experiment. We have arranged to personally inspect these and perhaps other prospective sites in late May of this year.

### (b) Frequency

Although a frequency allocation must be obtained when the site is selected, a frequency near 49 MHz is likely (wavelength = 5 m). We have had experience with the proposed measurement in this frequency band.

### (c) Equipment

A phased dipole antenna would be purchased or built at the Aeronomy Laboratory. A 100-kW transmitter and the necessary data-processing equipment would be purchased. The individual components would be checked out at the Sunset Radar in combination with an existing radar before shipment and assembly at the new radar site. It should be noted that the checkout of the new radar at Sunset would provide a unique comparison of operation at 7.4 m and 6 m wavelengths.

The multiposition antenna configuration would require a second antenna colocated with the first but at a right angle to it. Steering would be by remote controlled phase shifters developed for use at the Sunset Radar.

(d) Operation

The proposed "Flatland" radar would operate continuously at a range resolution of 1 km with a minimum of interruption. If the steerable option is implemented with its wide range of experimental possibilities, the mode of operation would be optimized for the vertical velocity measurement. It is proposed that this mode of operation be changed infrequently, if at all, during the first year of operation. As it turns out, this is also the optimum measurement technique for most of the additional scientific uses of data listed above, since they require a consistent data set of long duration.

(e) On-Line Procesing and Data Collection

A variety of methods are available: One mode is to hire a technician to change the tapes at the radar site (estimated at $30 K per year) or asking an Air Force Base to assign someone to do it. The mode of collection that we favor is to bring the radar output back to Boulder, CO, by a leased telephone line. As shown this would cost about $15,000 per year and would allow experienced people at the Aeronomy Laboratory to monitor the quality of the data. The cost of changing tapes would of course be eliminated. In principle, telephone access could be provided for those experimenters requiring real-time data.

CHARACTERISTICS OF "FLATLAND" RADAR

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|---|---|
| Location | Somewhere in Missouri, Illinois or Indiana |
| Wavelength | probably 6 m |
| Antenna | |
| Type | Two colocated arrays of coaxial-colinear dipoles |
| Feed | Tapered to reduce sidelobes |
| Size | 50 - 100 m square |
| Steerability | Five preset positions |
| Transmitter | Vert, 15° (E, W, N, S) |
| Peak power | 100 kW |
| Average power | 3 - 5 kW |
| Range resolution | 1 km (will have capabilities for 150 m - 2.4 km) |
| Operation | Fixed mode (continuously sequenced through 5 antenna positions) |