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Daniel H. Schaubert Stephen J. Frasier					
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<p>Post-processing and analysis of TEP data collected during CASES'99 continued through this year. Our work focused first on phase synchronization of the receiving array (necessary for beamforming) using convective boundary layer return and targets of opportunity, namely ascending GLASS sounding balloons. Data from all the IOPs has been reviewed. Unfortunately, very little of it is of science quality. We are, however, using available convective BL to compare horizontal wind estimates using Doppler beam swinging and spaced antenna techniques. Following numerous failures of the transmitter, we have initiated the purchase of a solid-state replacement from Kalmus, Inc.</p>					
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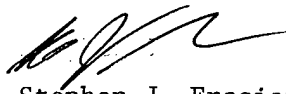
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REPORT TITLE: Use of Turbulent Eddy Profiler in Making Atmospheric  
Boundary Layer Measurements

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SUBMITTED FOR PUBLICATION TO (applicable only if report is manuscript):

Sincerely,



Stephen J. Frasier  
Principal Investigator

ARO Grant DAAG-55-98-1-0480:  
“Use of Turbulent Eddy Profiler in Making Atmospheric  
Turbulence Measurements”

Third Interim Report: CY 2000

## 1 List of Manuscripts

1. Pollard, B.D., S. Khanna, S.J. Frasier, J.C. Wyngaard, D.W. Thomson, R.E. McIntosh, 2000: “Local Structure of the Convective Boundary Layer from a Volume Imaging Radar”, *J. Atmos. Sci.*, **57**, 2281–2296.
2. J. Li, F.J. Lopez-Dekker, T. Ince, S.J. Frasier, 2000: “Volume-Imaging UHF Radar Measurement of Atmospheric Turbulence”, *Proceeding of 2000 International Geoscience and Remote Sensing Symposium (IGARSS'2000)*, Honolulu, HI, July, 2000, IEEE.
3. F.J. Lopez-Dekker, S.J. Frasier, 2000: “Radar Acoustic Measurement of Temperature using a Volume-Imaging UHF Wind Profiler”, *Proceeding of 2000 International Geoscience and Remote Sensing Symposium (IGARSS'2000)*, Honolulu, HI, July, 2000, IEEE.

## 2 Scientific Personnel

1. Daniel H. Schaubert, PI
2. Stephen J. Frasier, Co-PI
3. James R. Carswell, Co-PI
4. Jie Li, Graduate Student
5. Francisco Lopez-Dekker, Graduate Student

## 3 Report of Inventions

None.

## **4 Scientific Progress and Accomplishments**

### **4.1 Scientific Objectives**

The overall objective of our research program is to obtain better understanding of the fine-scale structure of the ABL through the use of high-resolution volume-imaging radar techniques.

### **4.2 Approach**

UMass has developed the Turbulent Eddy Profiler (TEP), a 915-MHz volume-imaging radar that images refractive index fluctuations and their radial velocity structure within a 25° cone about zenith. A 6 m diameter receiving array is used to capture magnitude and phase of the radar echoes on up to 90 receivers. In post-processing, these data are combined to steer a narrow (4°) beam within the 25° field of view. TEP recently underwent a rebuild of the receiver/data acquisition system which was used for the first time during the CASES'99 Nocturnal Boundary Layer experiment.

### **4.3 Tasks Completed**

UMass took delivery of the new VXI-based TEP receiver/data acquisition system during summer 1999. Concurrently, we developed new operating software to control the radar system. In October, the system was deployed for the CASES'99 nocturnal boundary layer experiment held near Leon, KS. There, the radar operated alongside the UMass S-band FMCW radar and numerous other remote and in-situ sensors observing a variety of nocturnal boundary layer features.

Post-processing and analysis of the data began upon return from the field experiment and continued through this year. Our work focused first on phase synchronization of the receiving array (necessary for beamforming) using convective boundary layer return and targets of opportunity, namely ascending GLASS sounding balloons. The latter technique proved more reliable in this case, as the signal-to-noise ratio was higher.

Data from all the IOPs has been reviewed. Unfortunately, very little of it is of science quality. A variety of factors have contributed to this including some intermittent data acquisition bugs, the failure of the transmitter (during IOP 6), and intermittent radio-frequency interference from wireless modems that were operated on-site. While we were aware of one modem on the main tower (NCAR/ATD) which operated with a 10 MHz notch filter about 915 MHz, other modems may have contributed to the problem. Luckily, the S-band FMCW radar operated successfully throughout the experiment with few problems. In many cases there was little, if anything, that

would have been detectable by TEP.

TEP operated during the Dept. of Energy's VTMX experiment in Salt Lake City during October 2000. The system functioned more reliably there, though conditions were much drier yielding few episodes of significant echo. Following additional transmitter failures in spring/summer 2000 leading up to (and during) the VTMX experiment, we have initiated the purchase of a solid-state transmitter replacement from Kalmus, Inc. who has designed a 4 kW, 10% duty-cycle amplifier for NCAR's Multiple Antenna Profiler (MAPR). Our primary objective for the coming year is to integrate the new transmitter and to exercise TEP at Amherst over the summer to obtain the quality of boundary layer observations needed by our collaborators.

#### 4.4 Scientific Results

Figure 1 shows sample vertical plane cuts through the TEP volume collected during afternoon convection. The left hand image shows radar echo power (arbitrary units), while the right hand shows Doppler (radial) velocity. Animation of a sequence of such slices indicates that the bright ascending feature appears to be part of an ascending plume of warm, moist air that is advected through the volume by the mean wind.

Figure 2 shows a 18-min long height versus time profile of backscattered power expressed in terms of the refractive index structure function parameter,  $C_n^2$ , as sensed by a single element of the receiver array. For comparison, observation by the S-band (2.7 GHz) FM-CW radar is also shown. Although the FM-CW has much finer range resolution, it is evident that the 915 MHz TEP is less sensitive to particle targets (insects) that produce Rayleigh backscatter.

While much of the data obtained is anecdotal, graduate student Jie Li is using a small amount of decaying CBL data obtained during IOP 3 to compare horizontal wind estimates using the "Doppler beam swinging" technique common to most wind profilers and the spaced antenna technique, as is used by NCAR's MAPR profiler.

In the DBS technique, vector wind is obtained by combining the wind components measured from the radar beams pointed alternately in several directions. This requires that the wind field be relatively uniform over the horizontal extent of the beam positions and over the time needed to cycle through several beam directions. Since the beamformed TEP image provides simultaneous beams within the field-of-view, the acquisition time can be reduced.

The spaced antenna technique estimates the horizontal wind by calculating the cross-correlation and autocorrelation functions of signals in spaced receiver antennas. The intercept of the autocorrelation and cross-correlation corresponds to a common time lag irrespective of the amount of turbulence. Therefore, the wind component along the baseline can be obtained without explicitly computing the intensity of turbulence, noise, or wind orthogonal to the baseline. Since turbulence

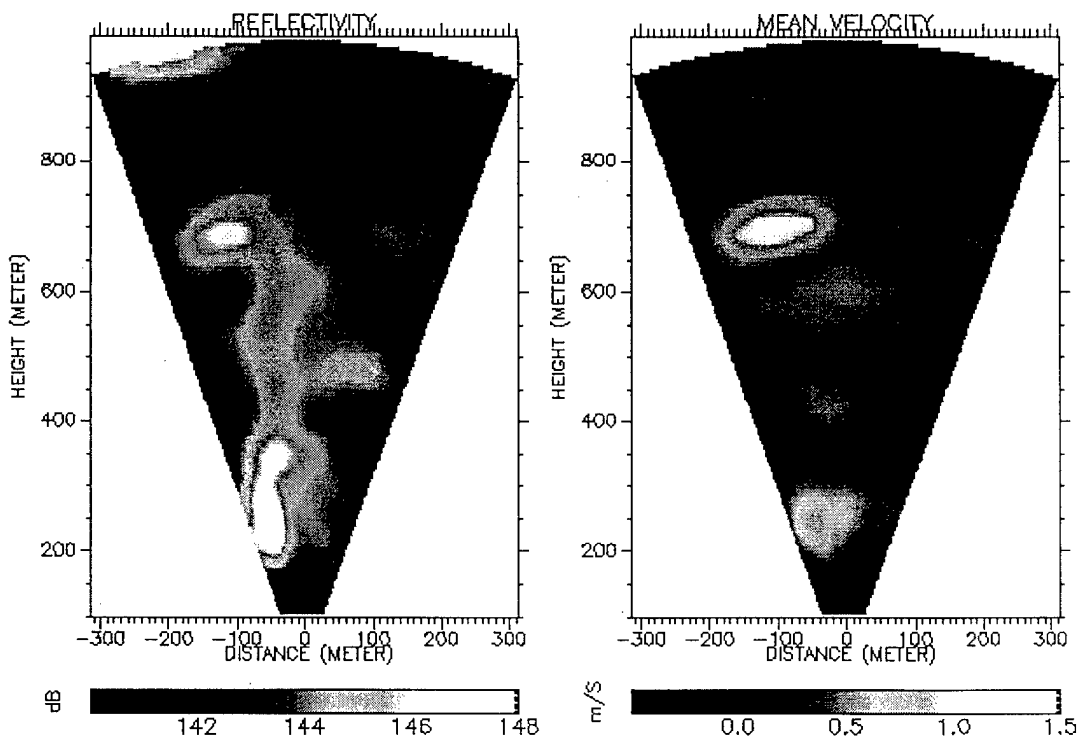
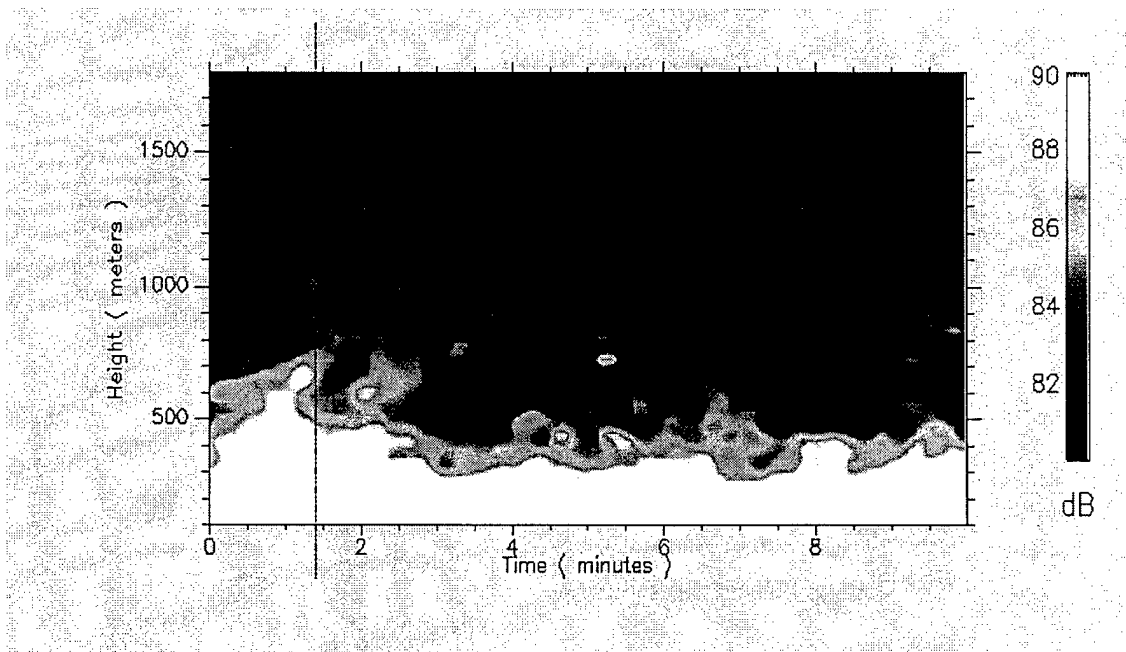


Figure 1: Upper: Time-height sequence of radar echo power from midday convection. The Vertical line corresponds to the time of the vertical plane cuts through the TEP volume shown below. Left: relative power (0<sup>th</sup> spectral moment), Right: radial velocity (1<sup>st</sup> spectral moment).

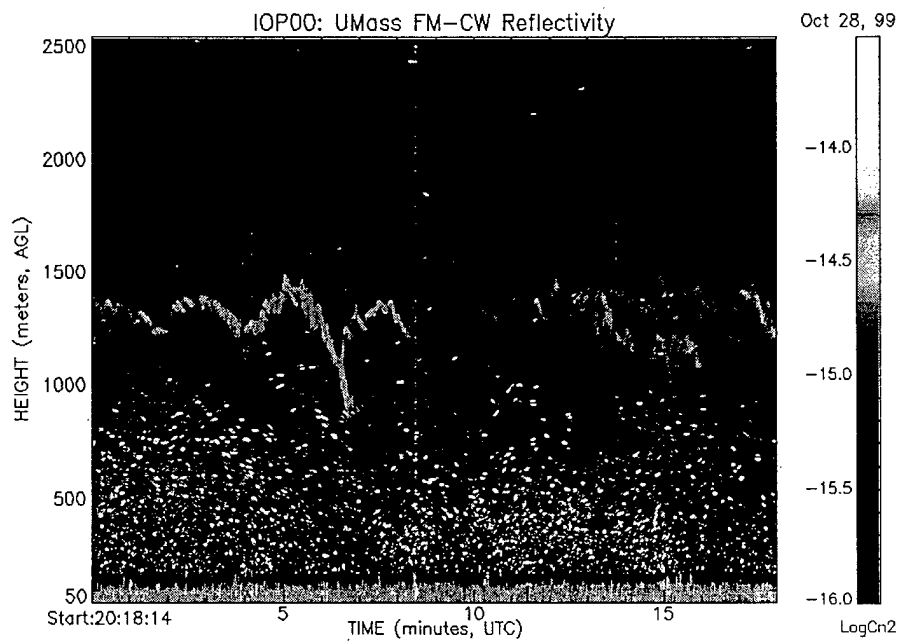
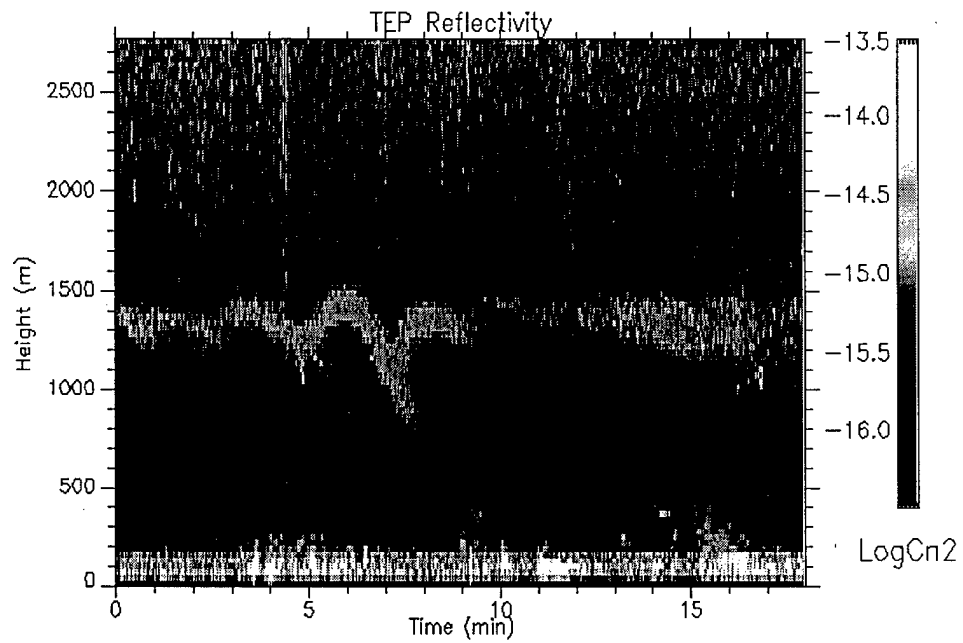


Figure 2: TEP single-element (upper) and S-band FMCW (lower) time-height profiles of the capping inversion. FMCW shows more detail within the inversion layer, while TEP shows more tolerance of Rayleigh scatter from insects in the boundary layer.

will increase the decorrelation between the two antennas, it narrows the correlation functions, lowers the magnitude of the cross-correlation peak, and shifts the peak toward zero time lag. Increasing the correlation between antennas may improve estimates of wind speed. In the TEP antenna array, it is possible to overlap groups of antennas thereby increasing their correlation.

## **5 Technology Transfer**

None.