WESTERN REGION TECHNICAL ATTACHMENT
NO. 97-04
JANUARY 28, 1997

USE OF AN ACOUSTIC WIND PROFILER (SODAR) AT THE FORK FIRE FOR CONTINUOUS UPPER LEVEL WIND PROFILE AND STABILITY MEASUREMENTS

Fred Svetz - Interagency Fire Weather Unit - Redding, CA
Alexander N. Barnett, - AeroVironment Environmental Services Inc. - Monrovia, CA

[Editor's Note: The use of corporation names and/or their products is for the information and convenience of the reader and should not be misconstrued as an official endorsement by the National Weather Service.]

Introduction

An acoustic wind profiler or SODAR (SOund Detection and Ranging) was deployed at the Fork Fire that occurred in the Mendocino National Forest in August 1996. The SODAR is a remote sensing instrument that measures wind speed, wind direction and atmospheric stability data at approximately 100 (30 meter) intervals up to a maximum altitude of 2000 (750 meters) to 3000 (1050 meters) above ground level using sound. It emits a sound pulse at a known frequency and monitors the return echoes that are scattered back by small temperature fluctuations associated with atmospheric turbulence. By measuring the Doppler shift of these return echoes, the wind speed and direction at various altitudes can be calculated. The SODAR can provide averaged wind data in time intervals from five minutes to one hour. For this deployment, the SODAR was set to provide data every 10 minutes.

The SODAR was requested by the Incident Meteorologist (IMET) in anticipation of a frontal passage that was expected to create erratic fire behavior. It was felt that the SODAR's capability to measure low-level winds on a continuous basis would improve the reliability of weather and fire behavior forecasts and provide a means to monitor expected environmental changes.

SODAR Description

The SODAR was an AeroVironment Inc. Model 2000 (AV2000). It consists of the following:

- Three parabolic dish antennas mounted on a 30 long trailer (Figure 1).
- A controller unit which houses the control electronics, a power amplifier, and a power supply assembly (Figure 2).
- A 486 IBM compatible computer that runs the interface software that provides data logging and processing, and a means to display the data in either tabular or graphical (Figures 3a & 3b) formats.

Each antenna consists of a parabolic dish that faces upward and an acoustic driver that is mounted above each dish pointing downward (Figure 4). The drivers serve two functions. First, they produce the output pulses that are reflected by the parabolic dishes upward, and second, they serve as microphones to pick up the pulse echoes scattered by small scale temperature fluctuations in the atmosphere. Surrounding each dish and driver are eight foot tall foam and lead lined wooden enclosures. The enclosures serve to dampen the sound pulses produced by the SODAR to the surrounding environment and to increase the sensitivity of the measurements by reducing the impact of background noise when the system is in the listen mode. The horizontal wind speed and wind direction measurements are provided by the two antennas that are tilted 16° from the vertical. The tilt provides the measurements of the x and y component horizontal wind speeds (along the orientation of these antennas) that are used in calculating the resultant wind speeds and wind directions.

Set Up and Operations

The SODAR unit was deployed in the extreme northwestern corner of the fire zone, just below the ridge defined in Figure 5. The site was 3,200 feet (1,050 meters) above sea level in a picnic area on a hillside overlooking the fire zone (Figures 6a & 6b). The site was selected because:

- Background noise levels were low (below 50 dB).
- There were no physical obstructions in the SODAR beam paths.
- Elevation was adequate to ensure that beam coverage would be representative of the low-level wind flow pattern above the fire.
- It was upwind of the fire zone (for operator safety considerations and to detect changes before they reached the fire zone - minimizing burnovers).
- It contained a road adequate for maneuvering a 30 foot trailer.

The IMET wanted the SODAR to collect data for 24 to 48 hours prior to the arrival of the weather front so the SODAR began its measurements at 0900 PDT on August 16. Deploying the SODAR unit well before the front arrived meant that the IMET could easily compare baseline weather conditions with changes brought about by the frontal passage. Operationally, it was decided that the communications between the SODAR operator and the IMET would be conducted primarily by cellular phone. Each hour the SODAR operator called the IMET and verbally read wind speed and wind direction data in miles per hour and degrees, for the ten minute period from ten minutes before each hour to the hour. The IMET made up forms for the data transfer and transcribed the wind speed and wind direction data. As a backup, the SODAR operator was given a command radio but was instructed to use the radio only in cases when the cellular communications were not available or when changes in the wind patterns or trends were noted between the hourly cellular contacts.

The IMET used this data to develop a "blueprint" of the wind patterns and stable layer development and dissipation that occurred during a normal daily cycle in the fire zone. When fire crew weather observations were reported from the field, the IMET compared those observations with corresponding SODAR wind and stability data to verify the SODAR readings. The excellent comparisons between SODAR data and field observations gave the IMET confidence to use the SODAR data in the preparation of the twice daily weather forecasts and to encourage the Fire Behavior Analysts (FBA) to use the data in their forecasts as well.

The weather and fire behavior forecasts correlated well with the actual conditions in the fire zone during this period, which increased the incident command staff's confidence in the information being provided by the IMET and the FBAs. On the day of the expected frontal passage (August 17), the forecast of morning winds south to west, 4 - 8 mph with gusts to 14 mph changing in the afternoon to west to northwest, 10 - 20 mph with gust to 30 mph, was taken seriously by the command staff. As a result, it was decided to defer assigning crews in the expected path of the fire until the predicted changes had taken place. All fire crews and equipment, with the exception of a limited number of crews that were assigned to hold the flanks and bulldozers that were constructing fire breaks in front of communities that were in the path of the expected runs, were held back from the fire lines. One hour prior to the arrival of the weather front, the SODAR was able to detect increasing wind speeds at the level of the ridge tops (approximately 1000 above the average elevation of the fire). This one-hour warning gave the command staff time to move the remaining fire crews and equipment out of the way of the expected runs. Within the next six hours, an explosively developing firestorm consumed 40,000 acres. During this period there were no burnovers, no equipment losses, and no injuries attributed to fire behavior.

Conclusions

The SODAR proved to be a valuable tool for characterizing wind and stability patterns that influenced the fire behavior on the Fork Fire. It provided the IMET with a rare opportunity to gather quantitative low-level wind data on a near real-time basis. The consistency and reliability of these data from an area immediately adjacent to the wildfire (compared to occasional surface observations from spotters in the field) made it possible to verify wind forecasts for the fire area, which in turn increased the IMET's confidence in the accuracy of his forecasts and prevented mis-analysis of the low-level wind field. The incident command staff also gained confidence in the forecasts and as a result placed greater emphasis on its inclusion in planning the strategy for the fire suppression efforts. With respect to the expected erratic fire behavior related to the frontal passage, the SODAR data provided an objective basis for the strategy employed in fighting the fire during this period, as well as providing an additional margin for fire fighter safety.

For the future, it is hoped that the success of the SODAR operations at the Fork Fire will open discussions with incident command staff personnel nationwide on how the SODAR can be incorporated into wildland fire suppression strategies. As with the Fork Fire experience, the SODAR should be looked upon as a resource for assisting IMETs with their forecasting tasks and in turn incident commands staffs with their decision-making process with respect to fire suppression efforts when erratic fire behavior is occurring or is expected. When erratic fire behavior is not expected, the SODAR can also be considered for temporary (24 to 48 hour) deployments to characterize the daily wind and stability patterns in the fire area in order to provide actual data upon which the IMET can base the forecasts.

It is anticipated that technical improvements that will make the SODAR more effective in providing wind and stability data to the IMET will center on data transfer, portability, and the ability to rapidly deploy the SODAR to the field. With respect to data transfer, the most difficult part of the SODAR operations at the Fork Fire was the transfer of the wind and stability information from the measurement site to the IMET in a time and labor-efficient manner. As mentioned above, data transfer was effected by voice communications using cellular phones. The IMET then had to transcribe the data to a form before it could be interpreted and used. To eliminate unnecessary intermediary steps and to provide the IMET with the continuously updated graphical displays of the data, the use of radios coupled to modems and a repeater system is being investigated as a way to move the SODAR's computer from the measurement site to where the IMET and FBA are preparing their forecasts, so that they would have continuously updated graphical displays. Given that most wildland fires occur in remote locations where cellular communications are spotty at best, the radio/modem/repeater system would ensure that the SODAR antennas could be set up in accordance with the necessary siting criteria and that the data collected would be received continuously by the IMET.

In terms of portability and rapidity of deployment, SODARs are available in various sizes. For example, two other SODAR models are available (Figures 7 & 8) which are less than 1/3 the size of the SODAR used at the Fork Fire. These SODARs have one antenna which is made up of an array of small speakers or tweeters (Figure 9). By sequencing the output of the individual tweeters, the beam can be tilted in a predetermined direction and at a predetermined angle. In this manner, the one antenna can produce the three beams needed to gather the data needed for the wind and stability calculations. The physical size of these phased-array SODARs makes it possible to air freight the units to an incident in the same way that the IMET's Air Transportable Mobile (weather) Unit (ATMU) can be shipped. Once at the incident, the SODAR can be quickly assembled, mounted in the back of a pickup truck, and operated from this platform. The differences between the three models reside in the operating or output frequencies, which determines the maximum altitude and data intervals (in the vertical), and the physical size of the units. The selection of one unit over another will depend on the requirements of the deployment which would include the altitude of the measurements, space availability for setting up the SODAR, and the accessibility of the area where the SODAR would be set up and operated. Table 1 summaries key specifications of the three SODAR models.

SODAR Model	**Output Frequency (Hz)**	**Maximum Altitude (m)**	**Data Intervals (M)**	**Antenna Size (ft)**
AV2000	1500	1500	30	30 x 8 x 8
AV3000	2400	600	10	6 x 6 x 6
AV4000	4800	200	5	4 x 4 x 4

TABLE 1. Key specifications of three SODARs.

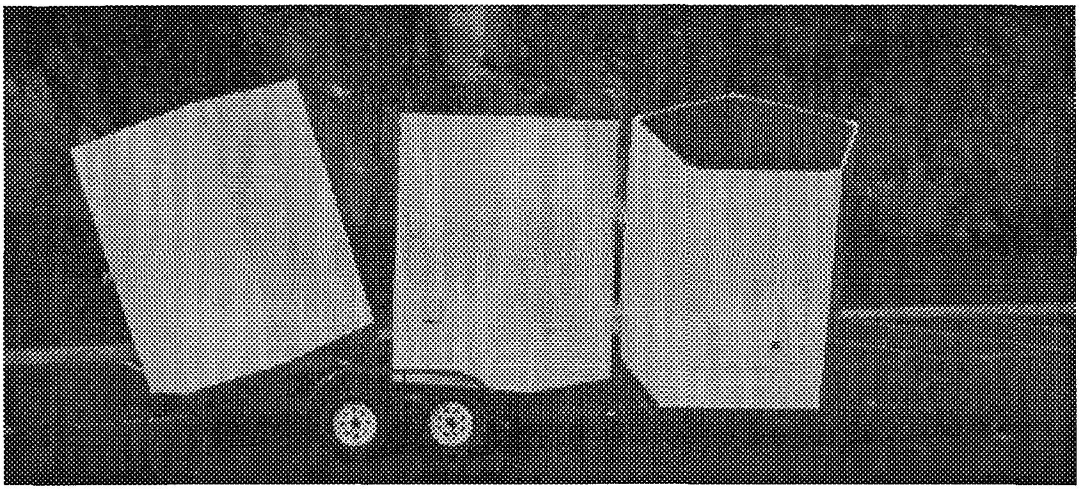

Figure 1

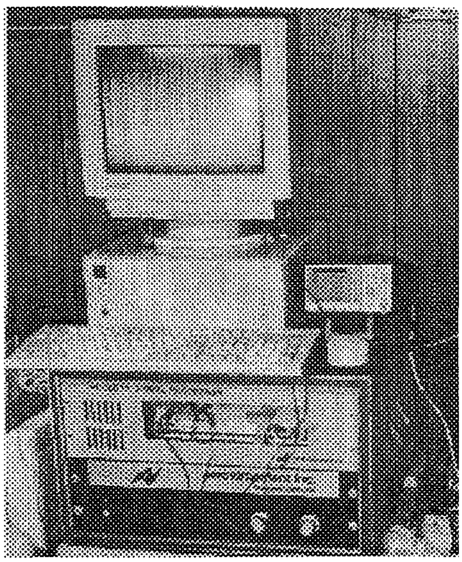

Figure 2

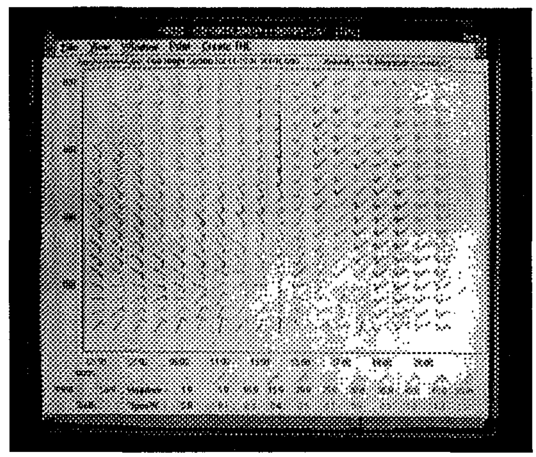

Figure 3a

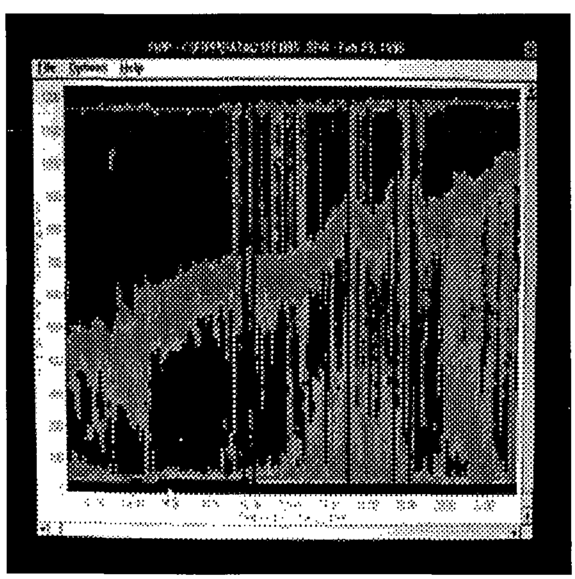

Figure 3b

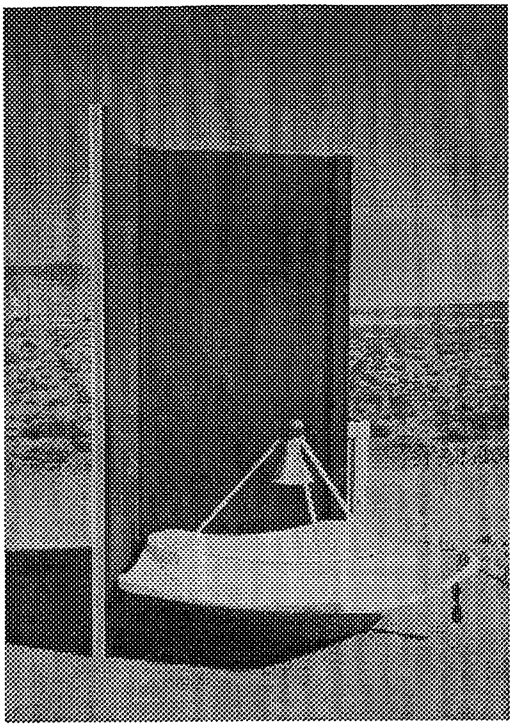

Figure 4

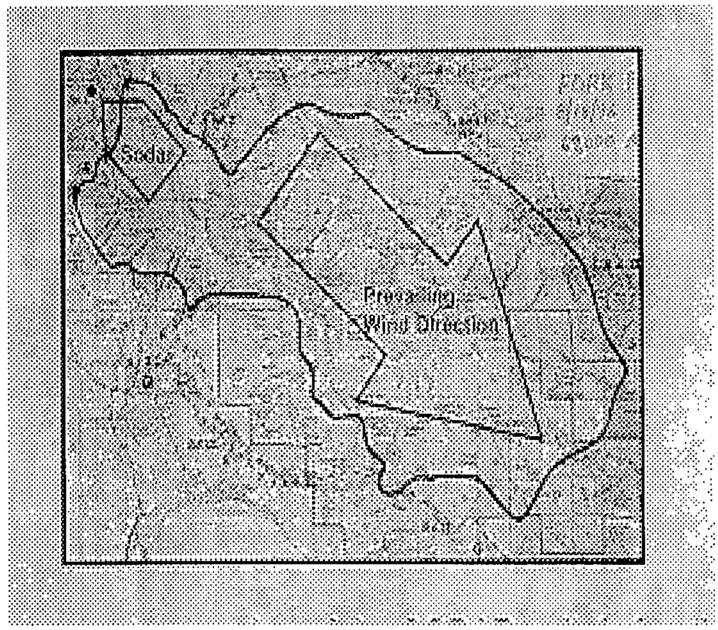

Figure 5

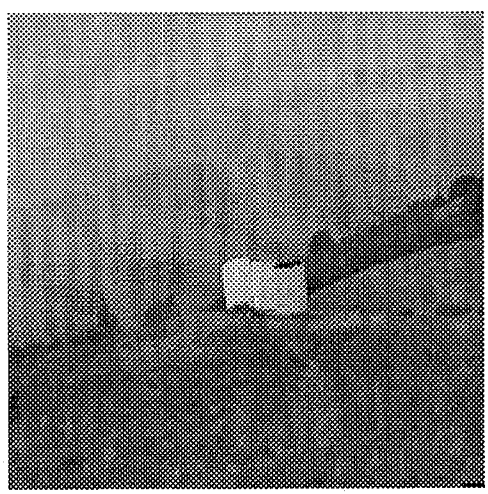

Figure 6a

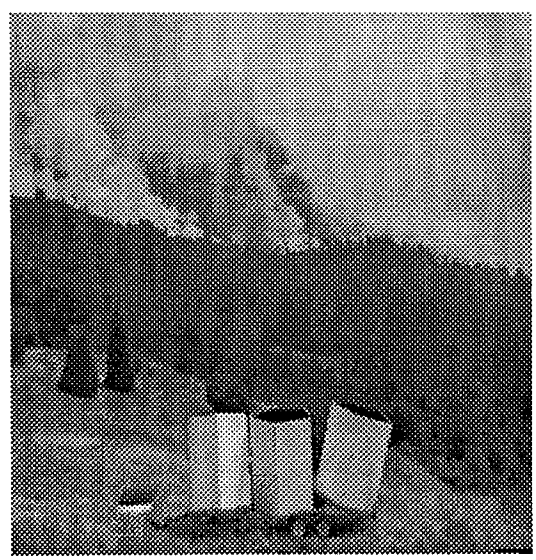

Figure 6b

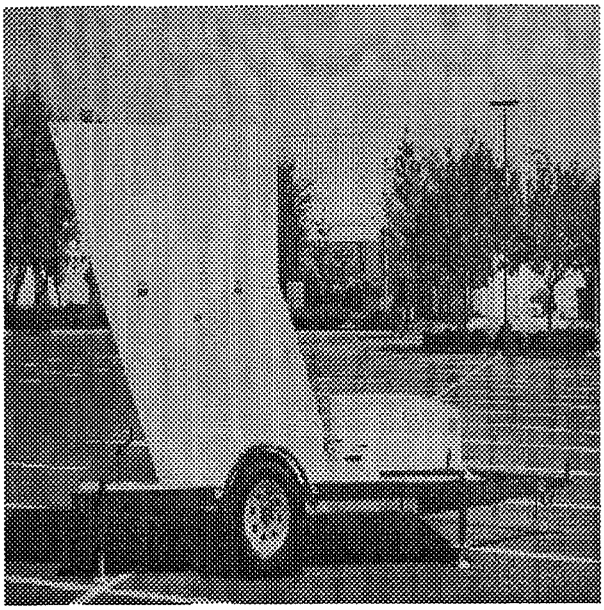
Figure 7

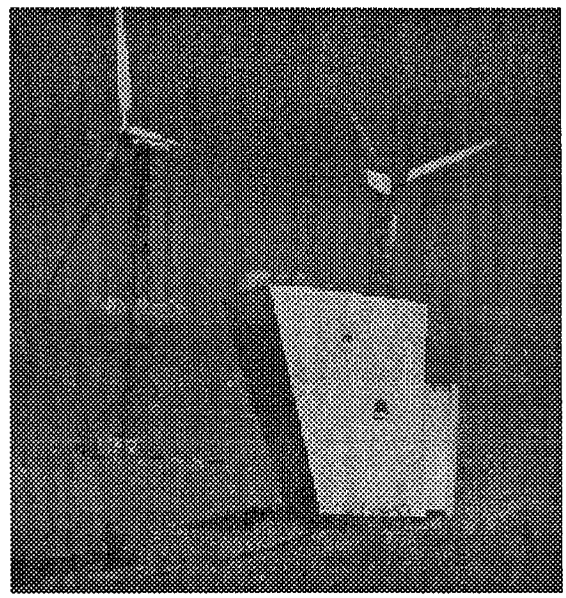
Figure 8

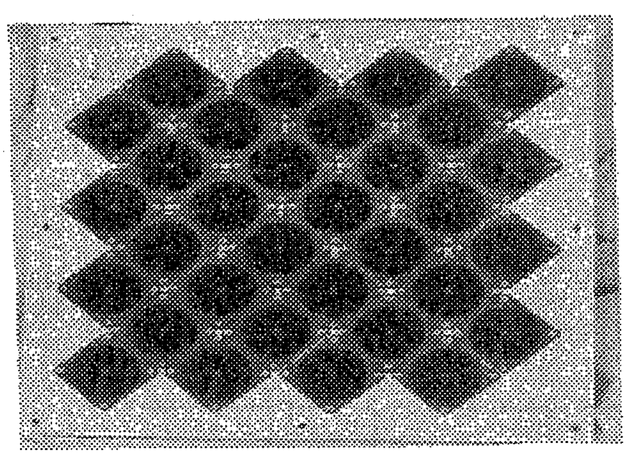

Figure 9