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THE STATE EXPERIMENT — MESOSPHERIC DYNAMICS

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ABSTRACT

The STructure and Atmospheric Turbulence Environment (STATE) experiment was conducted during the second week of June 1983 at Poker Flat Research Range, Alaska. The measurements focus on a study of the middle atmosphere dynamics by comparison between in-situ probe measurements and MST radar measurements. Rocket launchings were conducted at three periods which were selected by monitoring the doppler velocity spectra of the MST radar.

The STATE program has included the efforts of several scientists in planning and carrying out the ground-based and rocket measurements. An overview of the program is given together with some preliminary results. The regions in intense backscatter signals detected by the MST radar are shown to correlate with large irregularities in the electron profiles measured.

INTRODUCTION

The use of coherent backscatter radars has been recognized as an important way to monitor atmospheric conditions /1/. In the troposphere and lower stratosphere, the radar backscatter signal depends upon aerosols and water vapor. In the mesosphere, the radar signature depends upon irregularities in the electron concentration Major efforts have been made in the FRG /2/ and in the USA /3,4/ to measure the properties of the mesosphere using coherent backscatter radar at VHF wavelengths. The STATE program was planned to provide the in-situ measurements of atmospheric properties together with the radar measurements so that the signatures may be properly interpreted. The MST radar at Poker Flat Research Range, Alaska, is situated to allow comparison between rocket-borne sensors and the radar. Measurements performed at PFRR /4/ have shown that the backscatter signal is much stronger in the summer months and thus the summer comparison was chosen.

The MST (Mesosphere, Stratosphere, Troposphere) Radar at PFRR and its counterparts (Sunset Radar, CO /5/; Sousy Radar, FRG /2/) are intended to be a primary research tool for obtaining measurements on the dynamical properties of the middle atmosphere and the upper atmosphere during the time period of the 1980's. The intercomparison of in-situ rocket techniques with the radar data is necessary to develop the foundation for the interpretation of the atmospheric dynamical properties. The information that could be obtained from the MST Radar on an almost continuous basis includes the vertical and horizontal wind components and an estimate of the turbulent diffusivity. The focus of this effort has been to make use of the best currently available techniques to measure the dynamical properties in conjunction with the coherent backscatter radar so that the radar capabilities can be established for long term synoptic measurements. The MST radar at PFRR is located such that an intercomparison can be made. However, the results should be applicable to the interpretation of the other coherent backscatter radars.

MEASUREMENT TECHNIQUES

Accelerometer. The triaxial piezoelectric accelerometer /6/ has the unique capability for measuring the small scale structure, with a resolution of about 100 meters, through the upper stratosphere, mesosphere and lower thermosphere (i.e. approximately 40 to 150 km). The instrument measures the structure in the density, temperature, and wind profiles with a high degree of linearity over a very wide dynamic range (5 m/sec^2 to 10^{-6}m/sec^2). In addition, a prototype of a high frequency accelerometer has been recently constructed which should be able to measure the microscale structure down to about 2 meter scale size. This instrument has been successfully integrated into the same 25 cm diameter falling sphere with the triaxial accelerometer, telemetry encoder, transmitter, tracking system and power control unit. The spectrum analysis of the small scale structure measurements is used to derive the eddy dissipation rate, eddy diffusion coefficient and check the extent of the inertial subrange, also, it may be possible to identify the limit of the viscous subrange at several altitudes where turbulent layers exist at the time of the experiment. In addition, the accelerometer data can be used to define those regions that should be statically unstable /7/ based on the criteria, $\partial (\ln \rho)/ \partial z < g/C^2$ where the negative logarithmic density gradient is smaller than the density adiabat, g/C^2 (C is the speed of sound). From the accelerometer data it is is also possible to indicate the regions of dynamic instability based on the Richardson number,

$$R_i = g/T (\partial T/ \partial z + \Gamma) (\partial V/ \partial z)^{-2}$$

where the temperature profile is obtained from integration of the density measurement, the wind velocity is obtained from the accelerometer data, and Γ is the adiabatic temperature gradient.

Electron probe. The high measurement rate that is possible with the plasma frequency probe and the DC probes make them useful for measuring the small scale irregularities in the D- and E-regions. For altitudes below about 100 km the motion of the electrons and ions is controlled by the neutral gas due to the high collision frequency. The structure in the profile can thus be used to derive the spectral scales of the turbulent motion. This electron structure is directly related to the MST Radar backscatter measurements. The in-situ probe measurements should be capable of measuring the spectrum of the turbulent structure whereas the radar is sensitive to scales of about the half-wavelength of the EM wave (i.e. about 3 m).

MST radar. The radar measurements are used to directly derive the wind velocity as a function of altitude from the Doppler shift when the beam is directed toward the north (334° Az) and toward the east (64° Az) at a 15° angle from the zenith. The zenith measurements are used to derive vertical velocities while those from beams directed north and east can be vectorially combined to derive the wind vector as a function of altitude. The mean backscatter power can be related to the refractivity turbulence structure constant, C_n^2. Estimates of the turbulent energy dissipation rate can then be obtained. The comparison of the in-situ measurements with the radar data will make it possible to derive those estimates and then use them to obtain values for the turbulent diffusivity.

SUMMARY OF RESULTS

The rocket field program efforts began on 6 June 1983 at PFRR and the preparation phase of the effort was completed 11 June 1983. Also, starting on 6 June, the high resolution tests using 2 and 4 μ sec data were begun and high resolution, 300 meter (2 μ sec), data was obtained for the following two week period. This data set will provide not only the direct comparison with the rocket measurements, but will form the basis for understanding some of the mesospheric variations as part of the STATE program. The radar data for the period was collected at 70 range gates of 300 meters each and for each antenna direction (vertical, 15° off zenith on azimuth 64°, 15° off zenith on azimuth 334°) centered in the mesosphere.

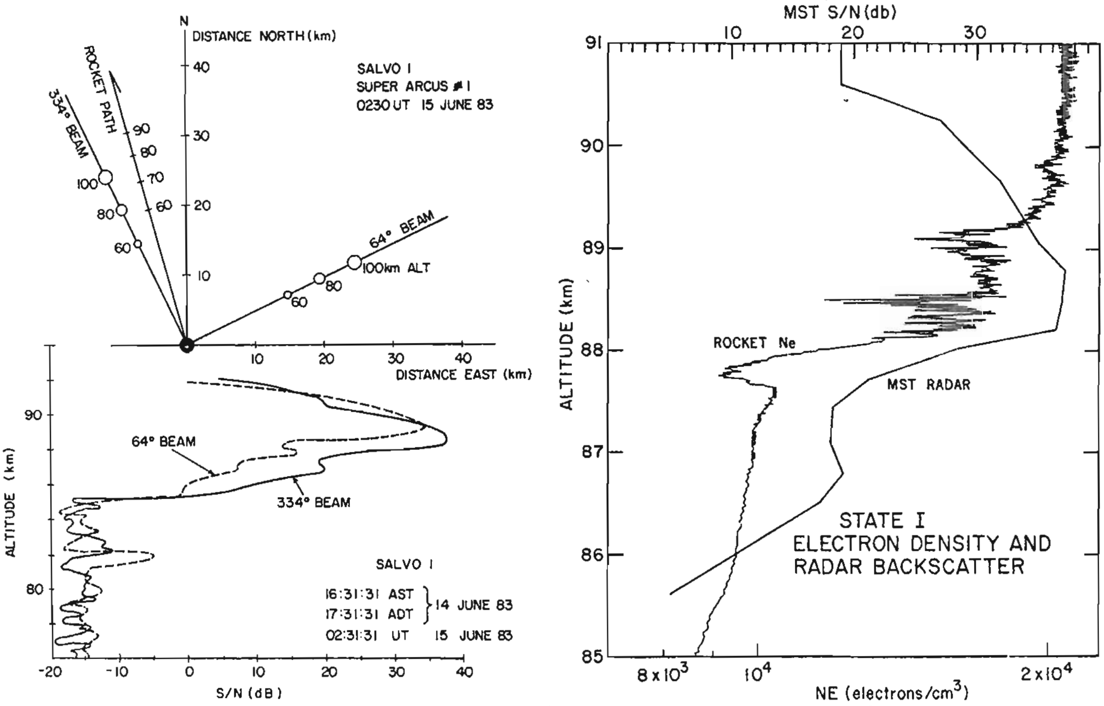

Fig. 1. The relationship between the rocket flight path and the radar beams is shown with a comparison between the radar signal and the measured electron density profile.

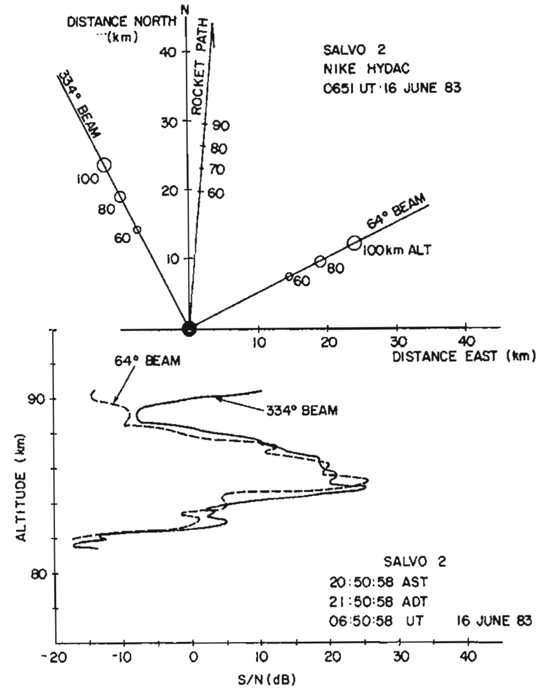

Fig. 2. Relationship between the rocket flight path and radar beams for Salvo 2.

TABLE 1 Science Working Group for STATE

Program Scientist - C.R. Philbrick *
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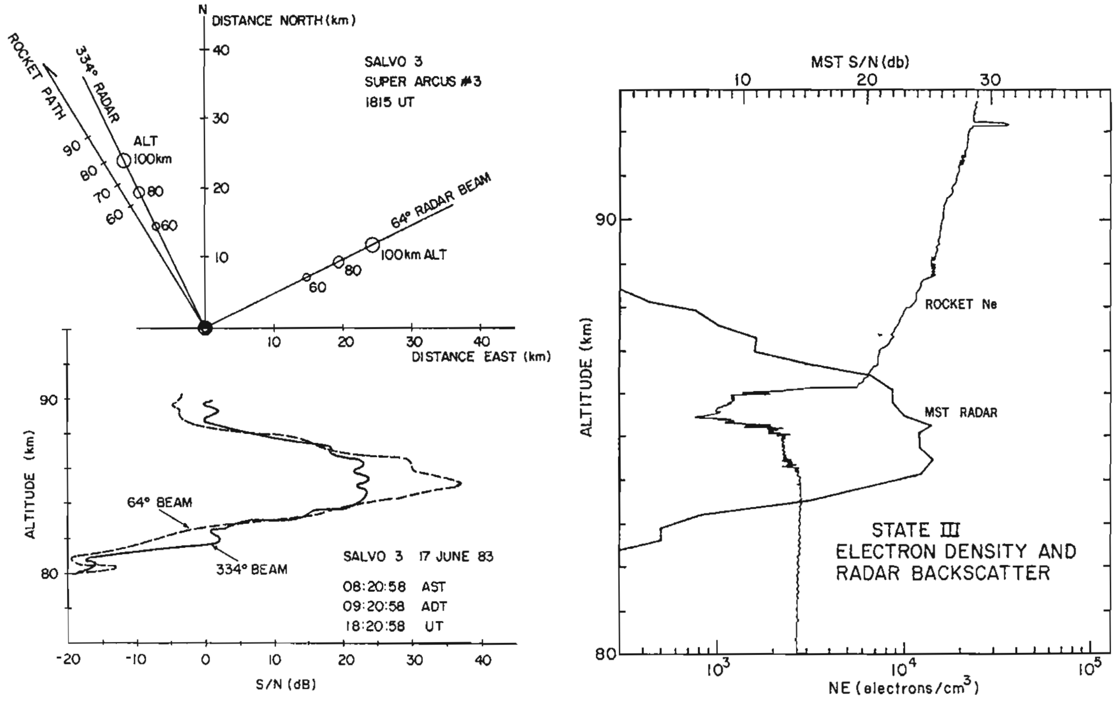

Fig. 3. The rocket flight path relative to the radar beams is shown together with a comparison of the radar echo signal with the electron density.

Salvo 1. The Super Arcus launched at 1730 ADT, 14 June, provided high resolution (8,000 samples per second) measurements of electron density. In Figure 1 the relationship between the regions of measurement for the rocket and radar experiments is shown together with a comparison between the radar signal and measured electron density. The Super Arcus motors had their paint removed in order to provide a large return current area and the electron measurements which were made by applying a +3 volt potential on the tip probe. The electron density was observed to increase from 52 km to a relatively sharp ledge near 82 km which corresponds to a region of enhanced echo in the MST return. In the region around 87 km the variations in electron density indicate an onset of strong irregularities. There exist two regions in the electron density profiles with very strong irregularities near 88 and 89 km. Above 92 km large irregularities with a different character begin to appear and continue to apogee. These These higher altitude irregularities are most likely associated with plasma instability. The regions of electron irregularities between 88 and 89 km are observed again on down leg at the same altitudes and show a similar character. The echo signal strength for Salvo 1 shows the maximum echo intensity occurs near the irregularity in the electron data.

Salvo 2. Salvo 2 was launched on 15 June beginning around 2150 ADT. The Nike-Hydac vehicle was launched into a condition of moderately strong MST echoes but with good spatial uniformity between the different antennas. In addition, significant wind velocity and wind shear regions were observed. The profile of the echoes measured by radar was more typical of the nominal summer condition with the echo peak intensity near 86 km. Good results from the multiply-instrumented Hydac payload were obtained for the accelerometer sphere, electron probe, plasma frequency probe, and photometers measuring minor species. Figure 2 shows the relationship of the rocket flight path to the radar beams and the amplitude of the radar echos for the two beam directions is shown.

Salvo 3. Based on an examination of the results obtained in the earlier salvos, the launch condition was chosen for a large spread in the velocity spectrum of the radar. Salvo 3 was launched on Friday morning, 17 June, in a condition of very strong echoes with regions of large spread on the doppler velocity spectrum and a region of strong wind shear. The configuration of the experiment for Salvo 3 and the results for the electron measurements in the region of the strong radar echo are shown in Figure 3. Three successful Super Loki passive sphere measurements were made which provide wind, density, and temperature data as a basis of evaluating atmospheric stability during the salvo. The Super Arcus payload provided a good data set which shows a region of irregularity near 83 km followed by a decrease of a factor of about 3 in electron density near 84 km and a strong ledge with irregularities near 86 km. The regions of strong electron irregularities again appear to correlate well with the regions of strong echoes in the MST Radar.

The results obtained from the STATE program will provide a better understanding of the dynamical processes in the middle atmosphere and a better interpretation of the radar signature. A scientific working group composed of experimental and theoretical investigators who are developing the analysis and interpretation of the results is shown in Table 1. This description provides an overview of the effort which will be described in detail in the near future.

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