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mountain lee waves at White Sands Missile Range

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1. Introduction

The need for knowledge of wind effect and its variability is well known to all who have worked in the field of unguided missiles. Often the wind is the critical factor which determines whether a scheduled launch actually occurs. At inland sites, the trajectories and impacts are more restricted than at seacoast sites, and wind effect is even more critical. In the past, emphasis has been more on horizontal than on vertical components of the wind, and in general has concentrated on the layers near the ground, since the wind in these layers produces the largest effect. As our expanding technology and our interest in even greater payloads, heights, and distances continue, we are faced with a need for detailed knowledge of the dynamics of the vertical as well as the horizontal wind. To meet this need, a study of mountain lee waves is now being conducted at White Sands Missile Range. [See also Cover Photo of lee wave clouds over the Sierra Nevadas.]

2. Geography of White Sands Missile Range

Most of White Sands Missile Range lies in the Tularosa Basin, a nearly flat valley about 40 miles wide and 100 miles long. On the west, the San Andres Mountains (Fig. 1), just within the range, have numerous craggy peaks reaching from 7000 to 9000 ft mean sea level. The west side of this range rises moderately but the east side drops abruptly to the valley floor at about 4000 ft mean sea level. To the east, the Sacramento Mountains are situated about 10 miles outside the range and have numerous peaks reaching 8000 to 10,000 ft, and one peak of 12,000 ft.

The San Andres Mountains are ideally oriented for the production of lee waves, since they are nearly normal to the prevailing wind during most of the year. Moreover, the terrain to the west consists of a series of other ranges spaced at distances of approximately 30 miles and similarly oriented. This terrain is conducive to harmonic reinforcement of waves of appropriate length.

The dryness of the air prevents formation of typical lee wave clouds on most occasions, but impressive decks are seen several times annually.

3. Data collection

The basic observational technique consists of releasing superpressure balloons, with radar targets and radio-

FIG. 1. Southern extremity of San Andres Mountains viewed from the missile launch complexes to the east.

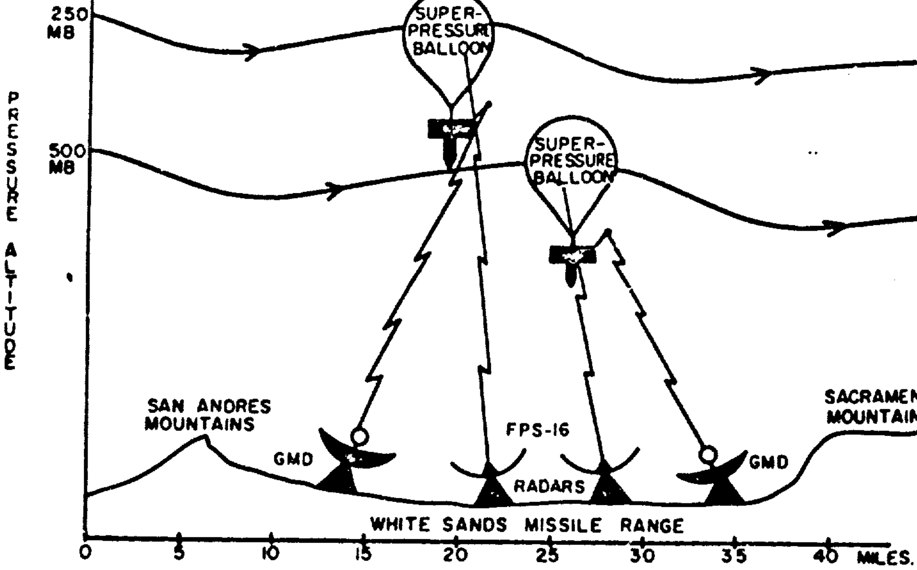

FIG. 2. Sketch of data collecting techniques.

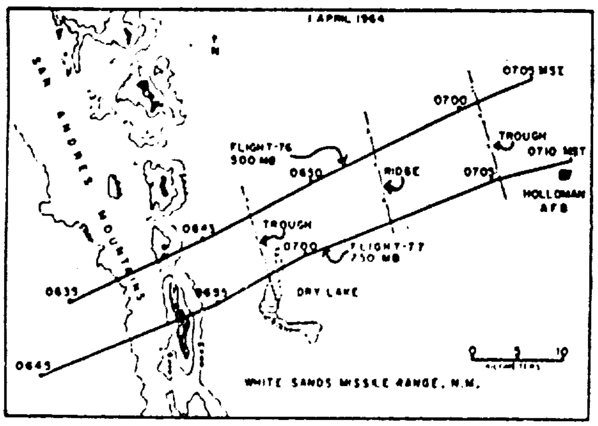

FIG. 3. Trajectories of balloon flights number 76 and 77 over White Sands Missile Range.

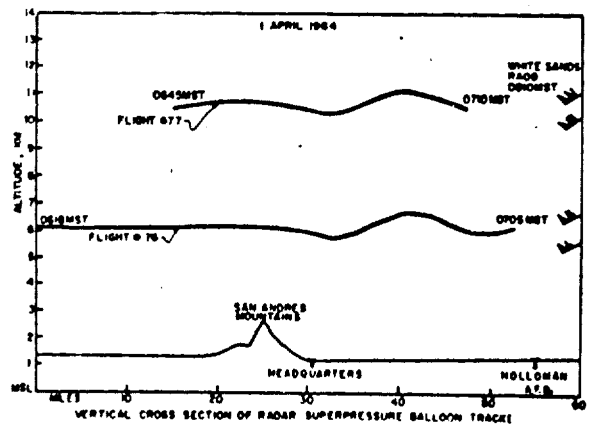

FIG. 4. Vertical cross section of radar superpressure balloon tracks.

sondes attached, at points west of the range and following their trajectories with radars while simultaneously recording temperatures on the GMD's (Fig. 2). The balloons are assumed to follow isopycnic surfaces as they float across the range and to trace out the shape of the lee wave. Two balloons are usually released to float simultaneously over the range at two heights and yield a vertical profile of the wave.

FPS-16 radars were used to track the balloons and their attached spherical targets. Their output was position data in x, y, and z components; data points were recorded on magnetic tape at the rate of one per second.

Early flights with the AMT-15 and AMT-4B radiosondes produced erroneous temperatures, usually too high, resulting from loss of ventilation when floating. This problem was overcome by use of techniques which will be the subject of another publication.

Balloons were obtained for pressure altitudes of 600, 500, 250, 100, and 30 mb and combinations of these were flown during the winter of 1963 and the spring of 1964. During the 1965 season combinations are being flown at 9, 14, and 19 thousand feet msl.

Fifty missions, using 96 balloons, were completed during the 1963–64 season. Most missions had to be scheduled at random, but during one three-day period, three flights were made each day, about six hours apart. About 70 per cent of the missions produced partially complete data and about 20 per cent were completely successful. The balloons were tracked for about 30 minutes on the average.

4. Data analysis

Balloon position data recorded on magnetic tape from the range radars are being processed on the 7094 computer. The computer output lists the x, y, and z components for 30-second averaged intervals, in both meters and feet, and the x, y, and z velocities in meters per second. Hollerith cards are punched for all data.

5. Preliminary results

The data so far processed show mean balloon vertical velocities of near 1 meter per second; some are as high as 6 meters per second. The vertical oscillations extend through an average of 260 meters; a few reached 800 meters in extent. The wavelengths averaged 18.6 kilometers (12 miles); the longest wave was 37 kilometers (23 miles).

One of the most interesting wave situations observed occurred on 1 April 1964 when two balloons were released simultaneously from Deming, New Mexico, just ahead of an approaching cold front which was accompanied by a vigorous trough aloft. Fig. 3 shows the trajectories of these balloons as they were tracked from the western boundary of the missile range, across the San Andres Mountains and the Tularosa Basin, to the eastern range boundary at Holloman Air Force Base. Operational priorities prevented tracking any farther east. The successive positions of the ridges and troughs within the wave are marked on the trajectories.

Fig. 4 shows the vertical motion of the lee wave as these two balloons floated over the White Sands Missile Range. The vertical cross section is shown normal to the wind, which was from 250 degrees; the vertical exaggeration is 4.8 to 1. The length of this wave was about 17 miles; the vertical velocities of the balloons, as shown from the computer output, reached 6 meters per second.

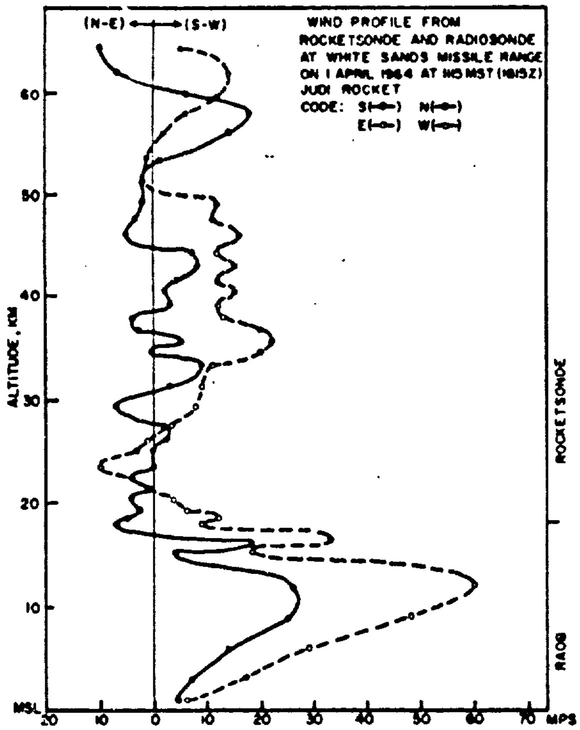

Fig. 5. Rocketsonde winds for 1 April 1964 at White Sands Missile Range.

A final report will contain comprehensive data for each balloon flight, including radiosonde temperatures, data from our 500-ft meteorological research tower, when available, and in many cases rocketsonde data such as is shown in Fig. 5 for the wave occurrence shown in Figs. 3 and 4.