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Rain Rate Measurement with an Airborne Scanning Radar Altimeter

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I. Introduction

The NASA Scanning Radar Altimeter (SRA) sweeps a radar beam of 1° half-power width (two-way) across the aircraft ground track within ±22° of nadir, simultaneously measuring the backscattered power at its 36 GHz (8.3 mm) operating frequency and the range to the sea surface at 64 points spaced across the swath at 0.7° incidence angle intervals. The measurement geometry is shown in Fig. 1 with the specific numbers referring to the flights made into Hurricane Humberto on 23 and 24 September 2001, aboard a WP-3D hurricane research aircraft of the NOAA Aircraft Operations Center. The ranges produce raster lines of sea surface topography at a 10 Hz rate. The SRA was primarily designed to produce sea surface directional wave spectra, but the backscattered power measurements can be used to determine path integrated rain rate below the aircraft.

II. Hurricane Humberto

Hurricane Humberto strengthened to Category 2 during the first flight, then diminished to Category 1 for the second flight. The SRA aircraft flight pattern, shown in Fig. 2 for 24 September 2001, was the same on both days. It featured three radial passes through the eye, connected by downwind legs, and was coordinated with three other aircraft in the Coordinated Observations of Vortex Evolution and Structure (COVES) experiment.

The surface wind speed measured by the NOAA AOML Hurricane Research Division (HRD) Stepped Frequency Microwave Radiometer (SFMR) along the flight track is shown in top panel of Fig. 3. The closest approach to the center of the eye on the three radial passes is indicated by the wind speed minimums at 2124 and 2254 UTC on 24 September and 0032 UTC on 25 September 2001. Rain rate measured by the SFMR along the aircraft ground track is shown in the bottom panel.

III. SRA Rain Measurement Technique

Calculations based on the Marshall-Palmer distribution indicate that the attenuation (dB/km) of a 36 GHz radar signal is approximately linearly related to rain rate [1]. At 1.8 km height, the SRA signal suffers a 1dBattenuation for each mm/hr of rain rate. If the sea surface radar backscatter coefficient is constant as one transitions into a region of rain, the loss of signal will determine the rain rate to an accuracy of a fraction of a mm/hr. In general, changes in the backscatter coefficient at nadir are small compared to the rain absorption in the hurricane high wind environment and can be differentiated from changes in rain absorption by examining the variation of backscattered power with incidence angle.

Figure 4 shows the variation of the backscattered power at (a) 37.43°N, 66.69°W, near the beginning of the southeast pass through the eye, and at (b) 37.04°N, 65.71°W. The first observation was during a SFMR data gap, but the SRA data

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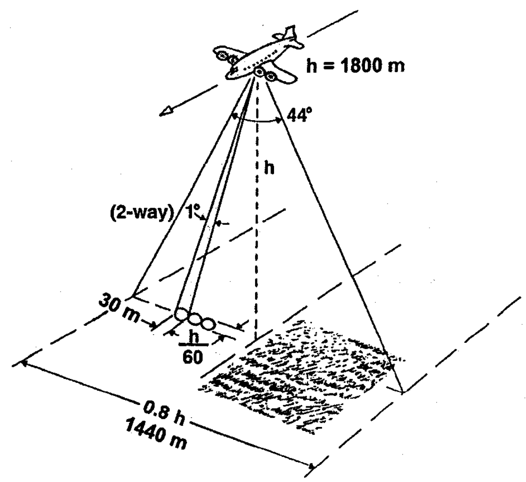

Fig. 1. Scanning Radar Altimeter measurement geometry.

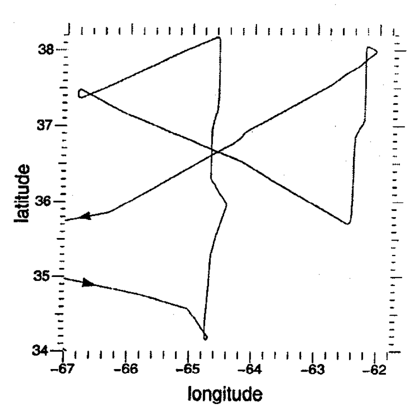

Fig. 2. NOAA aircraft flight track on 24 September 2001.