14D.5 MESOSCALE AND PRECIPITATION PROCESSES OBSERVED BY DOPPLER PROFILER AND RADAR DURING THE LANDFALL OF TROPICAL STORM GABRIELLE

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1. Introduction

On 14 September 2001 Tropical Storm Gabrielle underwent rapid transformation during landfall on the west Florida coast near Venice. Special observing platforms (associated with CAMEX-4), including the UAH Mobile Integrated Profiling System (MIPS) and the Shared Mobile Atmosphere Research and Teaching Radar (SMART-R), acquired high resolution data sets that documented mesoscale airflow, precipitation and boundary layer (BL) properties very near the point of landfall. The mesoscale and precipitation observations are summarized in this paper

2. Instrumentation

The SMART-R and MIPS acquired measurements from a nearly co-located location (~1 km apart) near the Venice airport (along the Florida west coast). The MIPS site was located ~100 m from the coast line. The SMART-R, located 70 km south of the Tampa Bay WSR-88D radar, scanned primarily full volume (360 deg) scans continuously from 0.8° to 19-42°. In this study, both single and dual Doppler analyses are (or will be) used to determine mesoscale flows and precipitation distribution for a 12 h period during landfall.

3. Mesoscale Properties

Gabrielle was a distinctly unsteady, asymmetric tropical storm exhibiting a period of rapid intensification, followed by rapid weakening, during the 12-h period (0000-1200 UTC) before landfall. A general increase in cyclonic circulation was measured by reconnaissance aircraft between 0600 and 0900 UTC (Molinari et al. 2004), and by the WSR-88D and SMART-R Doppler radars between 0900 and 1100 UTC. A rapid weakening of deep convection occurred during the 1100-1815 UTC period, and by 1815 UTC, deep convection around the circulation center had disappeared.

The evolution of precipitation around the landfall point is depicted by reflectivity factor (Z) presented in Fig. 1. The rapid intensification stage was accompanied by vigorous deep convection downshear of the circulation center, apparent in Fig. 1a as a region exceeding 45 dBZ. A broad stratiform region appears as a separate entity north and northeast of the convective region during the 0600-1000 UTC period, and stratiform precipitation extended over much of central and northern Florida during this period. By 1200 UTC, a dry intrusion had wrapped around the southern and eastern side of the circulation (Fig. 1b).

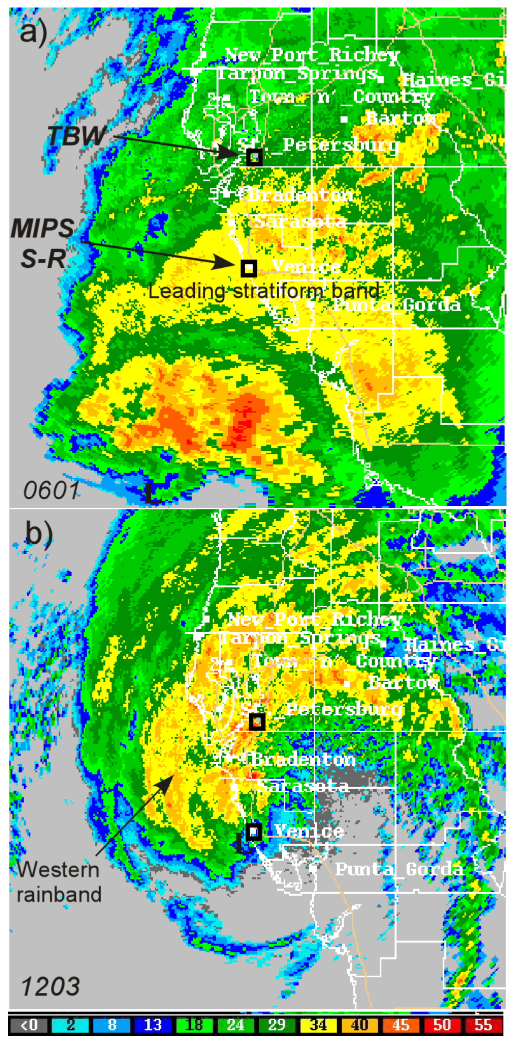

Fig. 1. Reflectivity factor from the Tampa Bay WSR-88D.

The circulation center of Gabrielle passed nearly directly over the MIPS and SMART-R. A time vs. height section of 915 MHz profiler spectral moments is presented in Fig. 2 for the 12 h period 0400-1600 UTC. This time series identifies the following regimes: (a) the mature stage of the leading stratiform precipitation (0500-0700 UTC), (b) a period of convective and mixed convective/stratiform precipitation (0700-1030 UTC); (c) a period of no precipitation during the passage of the circulation center over the MIPS (1030-1230 UTC); and (d) west flank stratiform precipitation and shallow rainbands during 1230-1500 UTC.

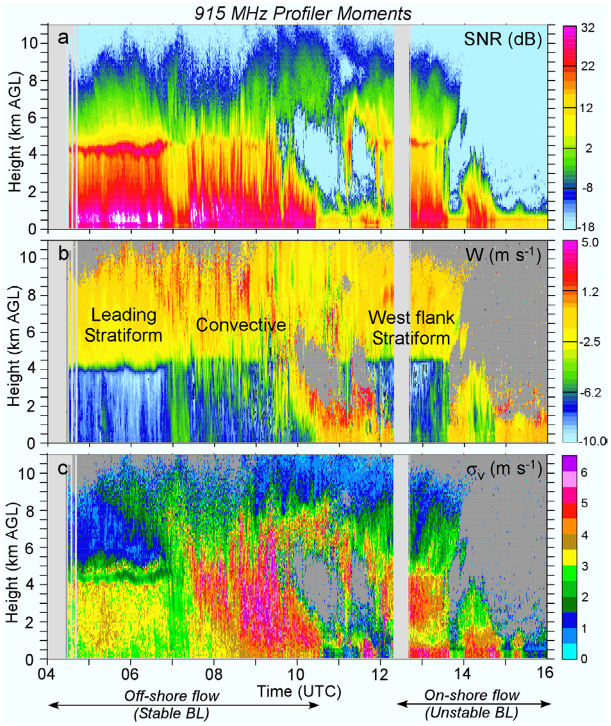

Fig. 2. 915 MHz profiler moments from the vertical beam. Time period is about 1 minute.

3.1 Leading stratiform rain band

Wind profiles (not shown) within the this leading band show a low level easterly flow that veered with height between 0500-1100 UTC, consistent with the warm advection measured in the 0600 and 1200 UTC Tampa Bay (TBW) soundings 70 to the north. Single Doppler EVAD analyses indicate that mesoscale downdrafts, partly supported by evaporational cooling, maintained this mesoscale outflow which at times exhibited a local wind maximum below 500 m AGL. Although the band is stratiform, significant variability in wind profiles and rainfall rate (up to 25 mm hr^{-1}) was observed.

3.2 Development of banded precipitation structures

After about 0900 UTC distinct rainbands formed primarily in the left to front-left portion of Gabrielle. This banded structure is apparent in Fig. 1b, and a major band that was associated with a wind maximum (northerly component over water) within the left quadrant (during the 1030-1100 period) is identified. A series of dual Doppler analyses will explore the kinematic structure of this major band.

3.3 Dry intrusion

Dry air wrapped around the south side of Gabrielle as a mid-latitude trough interacted with Gabrielle during the landfall process. The middle stages of this intrusion event are shown in Fig. 1b. A dual Doppler analysis combined with single Doppler TREC winds will examine mesoscale aspects of this process.

3.4 Fronts and boundaries

In the companion paper 14D.4, the development of warm and cold fronts was related to prolonged cooling from the leading stratiform precipitation, enhanced surface heat flux off the west Florida coast, and convergence within the core of Gabrielle. Although confined to the boundary layer, such fronts were mesoscale in character and produced variable wind profiles, enhanced storm-relative helicity, and played a key role in production of tornadoes within the warm frontal zone.

3.5 Core region upper tropospheric waves

As the core of Gabrielle pass over the MIPS during landfall, a series of waves, most prominent with in the 8-10 km AGL layer, were recorded. A time series of vertical particle motion at 8.5 km AGL is shown in Fig. 3. At the time of this writing, the origin of the waves is unknown, and their dynamical forcing is unclear. They may have been forced by asymmetries associated with variations in BL friction during landfall.

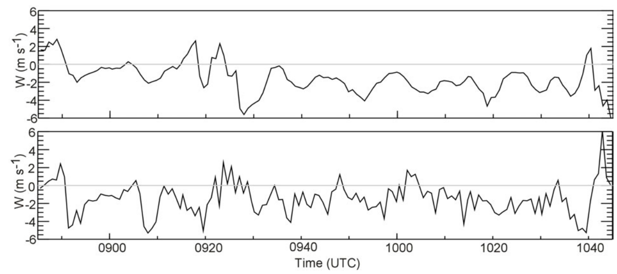

Fig. 3. Vertical particle motion ($W=w+V_T$) from the 915 MHz profiler at heights of 7 (top) and 8 (bottom) km AGL.

4. Microphysical Properties

Microphysical properties are being examined through analyses of Doppler spectra from the 915 MHz vertical beam, and EVAD analyses applied to the SMART-R observations. The following items are currently being explored in some detail:

a) The bright band structure differs appreciably from the leading stratiform to the western flank rainband stratiform. These are apparent as variations in spectral moments between the two regions, shown in Fig. 2. We hypothesize that ice phase microphysics above the bright and differ between the two regions, and will quantify this difference though retrieval of mesoscale motion, terminal fall speeds and analysis of Doppler spectra to retrieve particle size distributions.

b) Profiles of 915 MHz spectral moments suggest a much different microphysical process in the convective region, one in which raindrop growth took place below 5 km, as opposed to raindrop breakup that was especially prominent in the western rainband.

c) A rapid decrease in cloud top occurred after 1100 UTC as cold BL air generated over the Florida peninsula was entrained into the core of Gabrielle. Interestingly, moderate to heavy rain persisted around the Tampa Bay region in the presence of cloud tops to about 4 km AGL, suggesting that virtually all the precipitation was generated by the warm rain process at this time.

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