6. SFMR High-Incidence Angle Measurements

Principal Investigator(s): Heather Holbach (FSU/HRD), Brad Klotz (HRD), and Dr. Mark Bourassa (FSU)

Primary IFEX Goal: 2 - Develop and refine measurement technologies that provide improved real-time monitoring of TC intensity, structure, and environment

Motivation: Surface winds in a tropical cyclone are essential for determining its intensity. Currently, the Stepped-Frequency Microwave Radiometer (SFMR) is used for obtaining surface wind measurements. Due to poor knowledge about sea surface microwave emission at large incidence angles and high wind speeds, SFMR winds are only retrieved when the antenna is pointed directly downward from the aircraft. Understanding the relationship between the SFMR measured brightness temperatures, which are used to obtain a surface wind speed, wind direction, and the ocean surface wave field at off-nadir incidence angles would potentially allow for the retrieval of wind speed measurements when the aircraft is in turns. It is hypothesized that at off-nadir incidence angles the distribution of foam on the ocean surface from breaking waves impacts the SFMR measurements differently than at nadir. Therefore, by analyzing the excess brightness temperature at various wind speeds and locations within the tropical cyclone environment at off-nadir incidence angles, the relationship between the ocean surface characteristics and the SFMR measurements will be quantified as a function of wind direction relative to the look angle.

Objective: Determine the relationship between the SFMR measured surface brightness temperature and the ocean surface wave field characteristics.

Module overview: These modules are designed to obtain SFMR measurements in various locations of the tropical cyclone environment for several different wind speeds during constant banked aircraft turns at several different roll angles, specified below. A full pattern for each module consists of three complete circles for each specified roll angle (Figure 6-1). It is important to maintain a constant roll angle. A dropwindsonde and AXBT pair should be released at the beginning of the pattern. The wide swath radar altimeter (WSRA) should also be obtaining measurements during the pattern for analysis of the ocean surface characteristics. The wave spectra obtained by the WSRA will allow for a more accurate investigation of the sensitivity of the SFMR to the surface wave characteristics. It is ideal to fly these modules in rain-free areas as to reduce the impact of the atmospheric emission on the SFMR measurements and to obtain measurements in regions of moderate to heavy precipitation, as deemed safe by the aircraft pilots, in order to understand the impact of varying the path length of the precipitation. Coordinating measurements with HIRad overpasses would also be ideal if possible.

Modules:

1. Zero wind, high incidence angle response
   - This module is designed to determine the antenna pattern corrections and possible impacts of sun glint
   - Fly circles at roll angles of 15, 30, 45, and 60 degrees

2. Moderate wind response (~15 m/s, 30 kts)
   - This module is designed to understand the mixed "phase" (i.e., foam vs roughness contributions to

brightness temperature)
- o Fly circles at roll angles of 15, 30, and 45 degrees

3. Moderate winds (~15 m/s, 30 kts) and substantial swell or varying fetch length response
   - o This module is designed to determine the sensitivity to stress
   - o This can be performed on the way to the storm or in different sectors of the storm
   - o Fly circles at roll angles of 15, 30, and 45 degrees
   - o It would be ideal to coincide with a WindSat overpass if cloud free

4. Strong wind response (>30 m/s, 60 kts)
   - o This module should be flown in multiple storm quadrants (motion relative)
   - o Fly circles at roll angles of 15, 30, and 45 degrees

- Other things to consider
  - o Possibility for V-pol measurements (i.e., rotate SFMR antenna 90 deg)

Data Analysis: The SFMR data from these flights will be analyzed to determine if a double harmonic oscillation is evident in the excess brightness temperatures as was found in data collected from Hurricane Gustav (2008). The WSRA data will then be used to analyze the differences in the ocean surface characteristics to reveal any possible relationships between the double harmonic oscillation found in the SFMR measurements and the ocean surface characteristics. Wind speed and direction from the dropwindsondes will be used to verify the SFMR wind speed. SST from the AXBTs will be used as input to the brightness temperature algorithm. If coinciding measurements are retrieved from HIRad it will be possible to do a comparison with the SFMR measurements to gain a further understanding of the SFMR data.

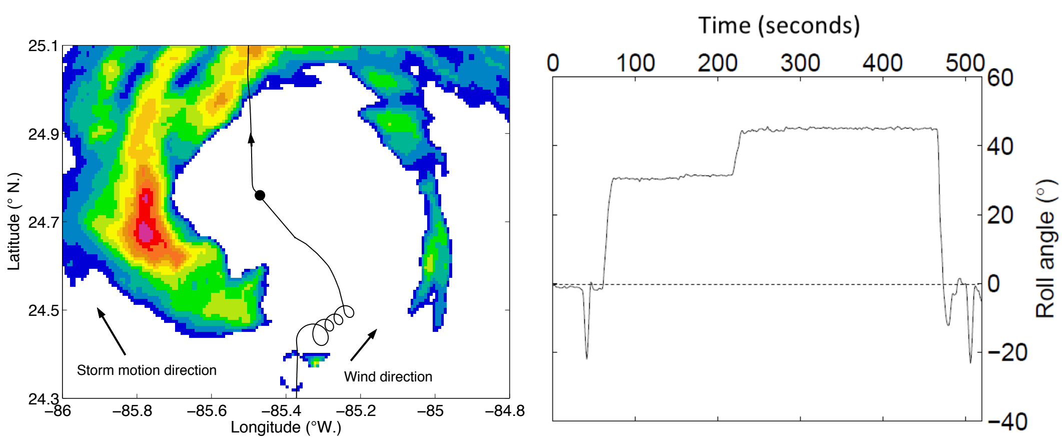

Figure 6-1: Flight pattern for module flown in Hurricane Gustav (2008) in a rain-free portion of the eyewall experiencing approximately 35 ms^{-1} surface winds (left panel). Time series of P-3 roll angle during period of turns in Gustav (right panel).

Thus far, measurements have been obtained primarily on the right side of storms (Figure 6-2). To develop a more complete composite picture, we are particularly interested in obtaining measurements on the left side of storms (motion relative) this season. We would also like to focus on regions with wind speeds greater than 20 m/s.

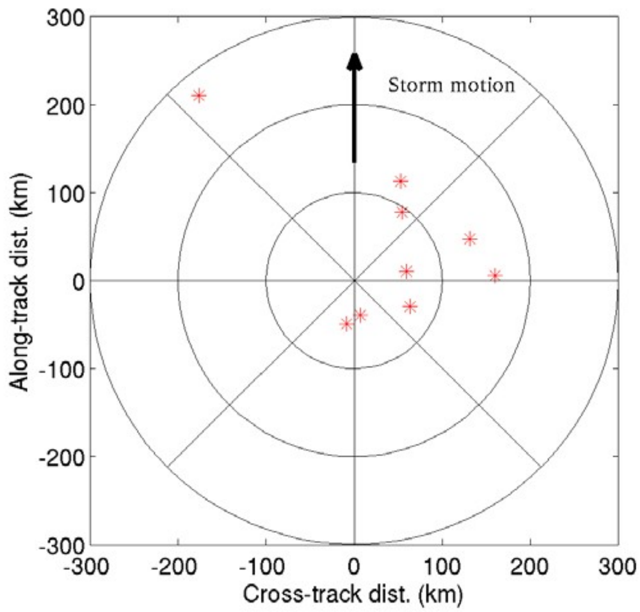

Figure 6-2: Storm-relative locations of high-incidence SFMR observations obtained to date.