SFMR Performance During the 2005 Hurricane Season

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Flown in 9 storms, 7 landfall situations
- Arlene Cindy Dennis
- Emily Irene Katrina
- Ophelia Rita Wilma

34 total SFMR missions, 23 tasked
- 16 total, 8 tasked for NOAA42
- 18 total, 14 tasked for NOAA43
SFMR used in 23 advisories, prompted 2 special advisories

All cases played decisive role in an important decision on current intensity or estimates of intensity change

Especially crucial for landfall intensity estimates for Dennis, Katrina, Rita and Wilma

Mentioned prominently in Katrina, Rita and Ophelia NHC storm reports
Difficult for forecasters to transition from routine AFRC flight level reco data to SFMR surface data, especially in landfall situations like Katrina.

Extensive use of SFMR in 2004-2005 illustrates the urgent need for SFMR installation on WC-130J aircraft as soon as possible—especially critical in current era of enhanced TC activity.
SFMR Updates

- From HRD projects:

- From NHC storm reports:
Key SFMR Issues

- Calibration vs. Model Development
- Averaging Considerations
- Real-Time Quality Control
- Future Interpretation Issues
SFMR Calibration Procedure

- Single “pre-season” laboratory calibration by ProSensing

\[ T_B = a_0 + a_1 \gamma + \ldots \]

- Single “pre-season” airborne ‘calibration adjustment’ of \( a_0 \) for in-flight configuration
  - Flight in weak winds over known surface conditions (U10, SST) from redundant surface observation sources: buoy, GPS sonde, AXBT’s
  - Adjustment to theoretically-based \( T_B \)
  - In practice, should be performed annually
Empirically-based wind/emissivity ($T_B$) model function

Statistical correlation of surface wind estimates with calibrated SFMR measurements
- Early model function related emissivity to surface adjusted flight-level winds
- Since 2003, related to GPS sonde near-surface winds
- Updated 2005 function based on larger data base of GPS near-surface winds

New model function corrects previously observed biases (e.g. moderate wind “high bias” & extreme wind “low bias” noted in 2004 data)
2004 HRD SFMR -- Old Model (SWEMOD-1.1)

n = 194
rmsd = 9.5 kts.
bias = +5.7 kts.
Corrects moderate wind
High bias

Corrects extreme wind
Low bias

Old Model (SWEMOD-1.1)
New Model (SWEMOD-2.0)
Katrina
Rita
Katrina 08/29

Sfc. Adj. (JF) WL150-Based SFMR Wind/Emissivity Model (SWEMOD)
New SFMR Wind/Emissivity Model

Function

\[ \Delta e_w = c_0 + c_1 (w - w_b) + c_2 (w - w_b)^2, \quad w \leq w_b \]
\[ = c_0 + c_1 (w - w_b), \quad w > w_b \]

\[ w_b = 33.2 \text{ m/s} \]
\[ c_0 = 5.3058 \cdot 10^{-2} \]
\[ c_1 = 3.3313 \cdot 10^{-3} \]
\[ c_2 = 5.22101 \cdot 10^{-5} \]
SFMR/GPS 2004/2005 Comparisons -- SWEMOD-2.0

n = 374

rsmd = 8.3 kts.

bias = +0.4 kts.
SFMR/GPS 2004/2005 Comparisons -- SWEMOD-2.0

n = 239
rsmd = 10.3 kts.
bias = -2.6 kts.
Ocean Surface Whitecaps and Foam Streaks in a Hurricane
SFMR measures C-band microwave emission from foam (air bubbles in the ocean)

First guess pre-2005: Emissivity a quadratic function of wind speed for all winds.

2005 new knowledge: Emissivity a quadratic function of wind up to hurricane force only- a linear function for hurricane winds
Hurricane Katrina - SFMR
29 Aug
Flat profile: $V_{maxsfc} = 100$ kt

28 Aug - Sharply peaked profile
$V_{maxsfc} = 142$ kt
Averaging Considerations

- Model function
  - All SFMR channels update several times (~3s) over a 10s period
  - Correlate surface-adjusted WL150 wind speed (avg time = ??) with 10-s average SFMR (frequency-independent) emissivity
  - Cross-track footprint (22 deg) vs along-track footprint for 10, 30, 60 s avg time @ 110 m/s (220 kt) GS:
    - RA = 330m (1500’): 0.2x1.3 km, 0.2x3.9 km, 0.2x7.8 km
    - RA = 1500m (5000’): 0.6x1.7 km, 0.6x5.1 km, 0.6x10.2 km
    - RA = 3000m (10000’): 1.3x2.4 km, 1.3x7.2 km, 1.3x14.4 km
  - Reference: Swell wavelength ~ 200m; local sea ~ 75m
  - Issue: time required for air parcel at different wind speed to travel across one beamwidth on the surface
  - OR: time required for foam coverage to respond to changes in the wind
  - Consideration: since all waves from cm-scale capillaries up to the peak are likely breaking in hurricane conditions, time scale likely small~ minutes??
Averaging Considerations (Cont’d)

- Real time wind retrieval
  - Transmitted retrieval averaging tied to data rate in past
  - Need to be made consistent across all aircraft, i.e. IHC06 Agenda item proposal for 30-s average
Quality Control

- Basic QC checks
  - Outlier TB measurements
  - Aircraft pitch, rolls (> 6 deg)
  - Over-land measurements (Tb> 270K)

- External QC
  - Landmasking
  - Bathymetry
  - Improved SST

- NOAA flight director’s discretion (yes/no decision on data transmission)

- Many issues are to be addressed by JHT
Other SFMR Issues (for SFMR JHT, YR 2)

- **Bathymetry**
  - SFMR issues in shallow water are still merely anecdotal, theory suggests that winds may be overestimated in ‘surf zone’ where swell breaking in shallow conditions
  - ‘Sheltered’ shallow water (offshore flow, Bahama Banks, Lake Ponchartrain) wind retrievals ‘look good’
  - To be addressed by excluding near-coastline “shallow-water” retrievals; extensive shallow-water dropsonde obs
  - Similar issue with wind/current interactions (no quantitative info), i.e. Gulf Stream, Loop Current boundaries

- **Rain**
  - Has little effect on results at high (> 50 kt) winds, even in extreme rainrates (~ 50 mm/hr)
  - Weaker winds have tendency to be overestimated in heavy rain (e.g. in an outer rainband) – Issue is due to emissivity-rain model bias
WC-130J SFMR Installation Status

- Dec., 2004- $10.5M supplemental to DoD for SFMR on AFRC WC-130J’s
- 26 July, 2005- first Technical Interchange Meeting (TIM) at Wright-Paterson to define project scope- delivery of first SFMR set for Sept, 2006
- Oct., 2005- Lockheed (LM) under contract
- 17 Nov., 2005- Second TIM at LM/Dobbins
- Feb, 2006- Air Force purchasing office announces slippage in delivery to Jan, 2007
- Mar, 2006- ProSensing under subcontract
- Mar, 2006- With NOAA concurrence, G-IV SFMR to LM moves delivery to Nov, 2006
- Mar, 2006- still no contract for delivery of remaining 9 SFMR units to operational WC-130J’s.