# Improved SFMR Surface Wind Measurements in Intense Rain Conditions

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**Funded Project Period:** September 2011-August 2013

**Overview:**

The airborne stepped frequency microwave radiometer (SFMR) estimates surface winds and rain rate in most weather conditions, particularly in tropical cyclones. However, retrieval accuracy has been suspected to be biased high in weak-to-moderate winds coupled with strong precipitation. The objective of this two-year project was to quantify the wind speed errors in such situations and propose a solution that may be implemented for real-time operations.

A main motivating point for conducting this work, it was stipulated that the SFMR wind speeds were biased high in the presence of heavy precipitation. In order to verify this bias, the PIs developed a database of coincident dropsonde and SFMR winds between 1995 and 2012. While there were numerous dropsondes available within this time period, it was determined that there were too few data in the presence of moderate to heavy rain because the research and reconnaissance flights were not specifically designed to target precipitating regions with dropsondes. Therefore, a synthetic wind speed was developed from a relationship between flight-level winds and the WL150 dropsonde reported wind speed. These winds were used to supplement precipitation regions of the database that were lacking a robust sample size.

Based on the SFMR wind speed and GPS dropsonde surface-adjusted wind speed pairs (both actual and synthetically-derived), a wind speed bias correction model was developed. A working version was available at the National Hurricane Center (NHC) during the 2012 and 2013 seasons. This correction model indicates that the largest bias is typically found for weak wind speeds and heavy precipitation but also a small high bias exists at weak winds without the influence of precipitation. The correction, however, only partially reduced the high wind bias observed to occur in the weak winds/heavy precipitation regime.

In the second year of the project, an updated geophysical model function (GMF) that reduces the rain contamination problem was developed. For the wind-absorption component of the GMF, the wind versus emissivity relationship was evaluated for wind speeds less than 35 m/s and precipitation rate of less than 2 mm/hr in order to remove any impact from rain on the emissivity within weaker wind regimes. Also, emissivity values for comparison were only taken from the lowest SFMR frequency (4.74 GHz) because this channel is expected to be the least affected by rain and is therefore the best option for obtaining a rain free relationship between wind and emissivity. The new wind-absorption component obtained was somewhat surprisingly quite similar to the version currently used in operations, despite that the new version had ten times as many data points to perform the calibration on. With the wind portion of the GMF updated, the rain-absorption portion of the algorithm needed to be addressed. This took into account new understanding of the reflectivity-rainfall rate relationship, based upon recent Orion P-3 aircraft missions into several hurricanes. The rain-absorption component, unlike the wind portion, did make for substantial changes to the GMF, which now will able to indicate substantially higher rain rates in the SFMR than previously. In all rain conditions for wind speeds greater than hurricane force, the revised SFMR based upon the new GMF revealed no statistically significant biases. Additionally, a significant reduction in mean bias (from +5.1 m/s to +3.7 m/s for wind speeds less than hurricane force was found by applying the revised algorithm, although a significant bias remained.

Because there still remained some high bias in the heaviest precipitation at weak wind speeds, the PIs developed a second bias correction model that used the updated algorithm. This bias correction model is applied to wind speeds less than hurricane strength and in heavy rain rates as this is the region where the updated algorithm still produces a moderate high bias that is not within the SFMR noise constraints. The application of the bias correction along with the revised GMF provides the best – most accurate and least biased – methodology for obtained SFMR surface winds.

**Four criteria used in consideration for operational implementation:**

**1. Forecast or Analysis Benefit -** expected improvement in operational forecast and/or analysis accuracy:

The substantial revisions made to the SFMR methodology have allowed for the development of more accurate and much smaller biased surface wind estimates, based upon a more robust calibration and more physically-based GMF. It appears unclear, however, if the new SFMR surface winds are now completely unbiased, though this does not seem likely. Changes that are being introduced into the SFMR winds from the existing operational output can be generalized as the following:

1) Low wind (20-45 kt), low rain (< 5 mm/hr) regime: SFMR winds decreased ~ 5 kt;
2) Low wind (20-45 kt), moderate to high rain (≥ 5 mm/hr): SFMR winds decreased ~10 kt;
3) Moderate wind (50-70 kt), any rain condition: SFMR winds negligible decrease;
4) Strong wind (75-95 kt), any rain condition: SFMR winds ~ no change;
5) Extreme wind (≥ 100 kt), any rain condition: SFMR winds negligible increase.

(It is worth noting, however, frustration amongst the Hurricane Specialists that after seven or so years of "operational" SFMR data, we are still making substantial changes to the calibration, including some unfortunate windshield-wipering around the important tropical storm/hurricane threshold. [As an example, SFMR data for Isaac on September 28th, 2012 was operationally transmitted as 64 kt, which if believed would argue for a hurricane upgrade. According to the PIs' best advice at the time, this was adjusted down to 58 kt based upon the wind speed bias correction used at that time, arguing against a hurricane upgrade. Now with the final version of the SFMR algorithm it is assessed to be 62 kt, which makes it certainly a reasonable upgrade call.] Changes like these on what seems to be an annual basis undermines forecaster confidence in the data, and in user confidence in final best track analysis.)

These SFMR changes are to be most relevant for determination of the intensity (especially for the threshold from tropical depression to tropical storm at 34 kt) and the 34 kt wind radii. Improved intensity and wind radii analysis has a direct connection toward better predictions of these capabilities.

Additionally, the SFMR rainfall rates have been modified to provide substantially values higher and are likely to be much more realistic. Except for helping to interpret whether some rain contamination may be occurring with the winds being retrieved, the rainfall rates are not being substantially used at NHC.

**Overall Forecast or Analysis Benefit: Neutral-Favorable**

**2. Efficiency Assessment** - adherence to forecaster time constraints and ease of use needs:

The PIs, in coordination with Mike Brennan, were able to provide the first version of the SFMR bias correction, which was seen in operations during the 2012 and 2013 seasons. This allowed the Hurricane Specialists to become acquainted with the draft revisions of the new SFMR and become more accustomed to the downward changes in the provided values in the low wind/high rain regime.

If fully transitioned to operations (see below), then the new SFMR values would become the standard surface winds (and rainfall rates) for the Hurricane Specialists to interpret. Thus the new SFMR values would be available in the high density observations (HDOB) text files, the intranet-based time series figures provided by Mike Brennan, and within NCEP Advanced Weather Interactive Processing System (N-AWIPS). Thus the new SFMR would, like the current SFMR, be efficient to assess by Hurricane Specialists in our operational environment.

**Overall Efficiency Assessment: Favorable**

**3. Compatibility -** IT compatibility with operational hardware, software, data, communications, etc.:

Implement of the revised algorithm for real-time SFMR retrievals will require a modification to the SFMR processor software code. Coordination among all relevant groups (AFRC/53rd WRS, NOAA/AOC, Prosensing Inc.) would be conducted, with the PIs providing code revisions where necessary. The final corrected SFMR wind and rain retrievals would then be transmitted as usual in the HDOB messages for real-time operations and access. Thus the new SFMR methodology should be fully compatible with existing hardware, software, and communications needs.

**Overall Compatibility Assessment: Favorable**

**4. Sustainability -** availability of resources to operate, upgrade and/or provide support:

Once implemented, no additional resources would be needed to operate and provide support for the running of the new SFRM algorithm. The PIs do mention the possibility of periodically revisiting the statistical bias correction as new data become available. Such work could be undertaken by the PIs or internally within the Technology and Science Branch of NHC. However, it is anticipated that such revisions would generally be quite minor tweaks to the new substantially revised calibrations.

**Overall Sustainability Assessment: Favorable**

**NHC Director Decision for Operational Implementation:**

_**X**_ Accept ___Defer ___Do not accept

Rick Knabb
NHC Director
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