Improving SFMR Surface Wind Measurements in Intense Rain Conditions

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Background

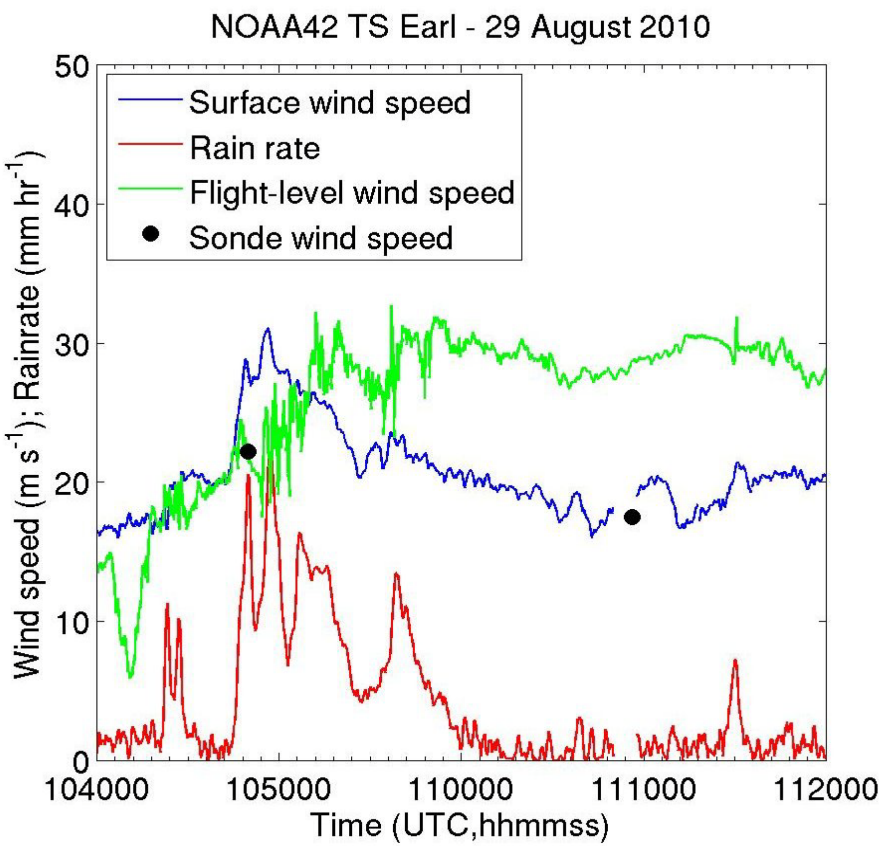
- The airborne stepped frequency microwave radiometer (SFMR) is useful for measuring surface wind speed and rain rate in tropical cyclones

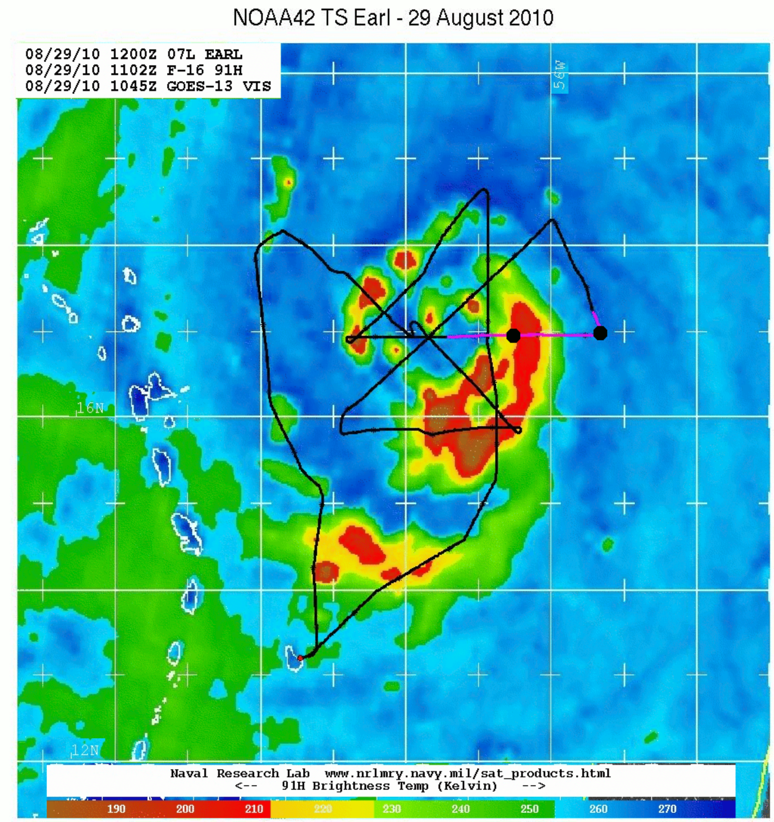
- The SFMR measures wind speeds in all-conditions, but is especially known for accurate measurements of hurricane force winds

- In rainy conditions, the SFMR tends to overestimate the wind speeds in wind regimes less than hurricane strength

- Two reasons for this overestimation:
  - Current Geophysical Model Function (GMF) tuned to weak precipitation conditions
  - Current rain absorption model over-predicts the absorption due to rain

Overestimation of SFMR wind speed





- Example from T.S. Earl shows overestimation of SFMR wind speed in comparison with GPS dropwindsonde surface-adjusted wind speed;
  - $\Delta U \sim 5$ m s^{-1}, $R = 20$ mm hr^{-1} ; $\Delta U < 1$ m s^{-1}, $R < 5$ mm hr^{-1}
- Correlation (r) between wind speed (SFMR and FL) and rain rate
  - Overall (33 flights): $r_{SFMR\_v\_RR} = 0.48$; $r_{FL\_v\_RR} = 0.18$
  - T.S. Earl flight: $r_{SFMR\_v\_RR} = 0.49$; $r_{FL\_v\_RR} = 0.03$

JHT Plan and Goals

- Proposed year 1 plan to address SFMR wind speed overestimation:
  - Quantify the errors of SFMR wind speed, especially in weak wind, heavy rain conditions
  - Develop an empirically derived wind speed correction to be utilized in real time during the 2012 hurricane season

Goals and Objectives:

- Expand the SFMR vs. GPS dropwindsonde database
  - Pre-JHT database (2005-2010) contains paired samples of SFMR wind speed and rain rate and GPS dropwindsonde surface adjusted wind speeds
  - Expanded version contains 2011 pairs as well as synthetically developed dropwindsonde wind speeds (NOAA only)
- Use expanded database to create wind speed correction model
- Apply this correction model to independent data for validation

Database expansion

- Pre-JHT version of database contains very few pairs within the weak wind speeds and moderate-high rain rate regimes ($U < 33$ m s^{-1}, $R > 10$ mm hr^{-1})

- During the 2011 hurricane season, collected pairs in the desired range and increased the representation by 20%
  - Increased from 103 to 124, but still viewed as under-sampled data

- To add more samples to database, created synthetic dropwindsonde wind speeds based on flight-level wind speed reduction
  - Relationship with WL150 wind speed
  - Flight-level winds reduced outside 2 RMW to remove eyewall tilt effects (Dunion et al. 2003)
  - Flight-level wind from ~700 mb height
  - Only considered data with SFMR rain rate > 10 mm hr^{-1}

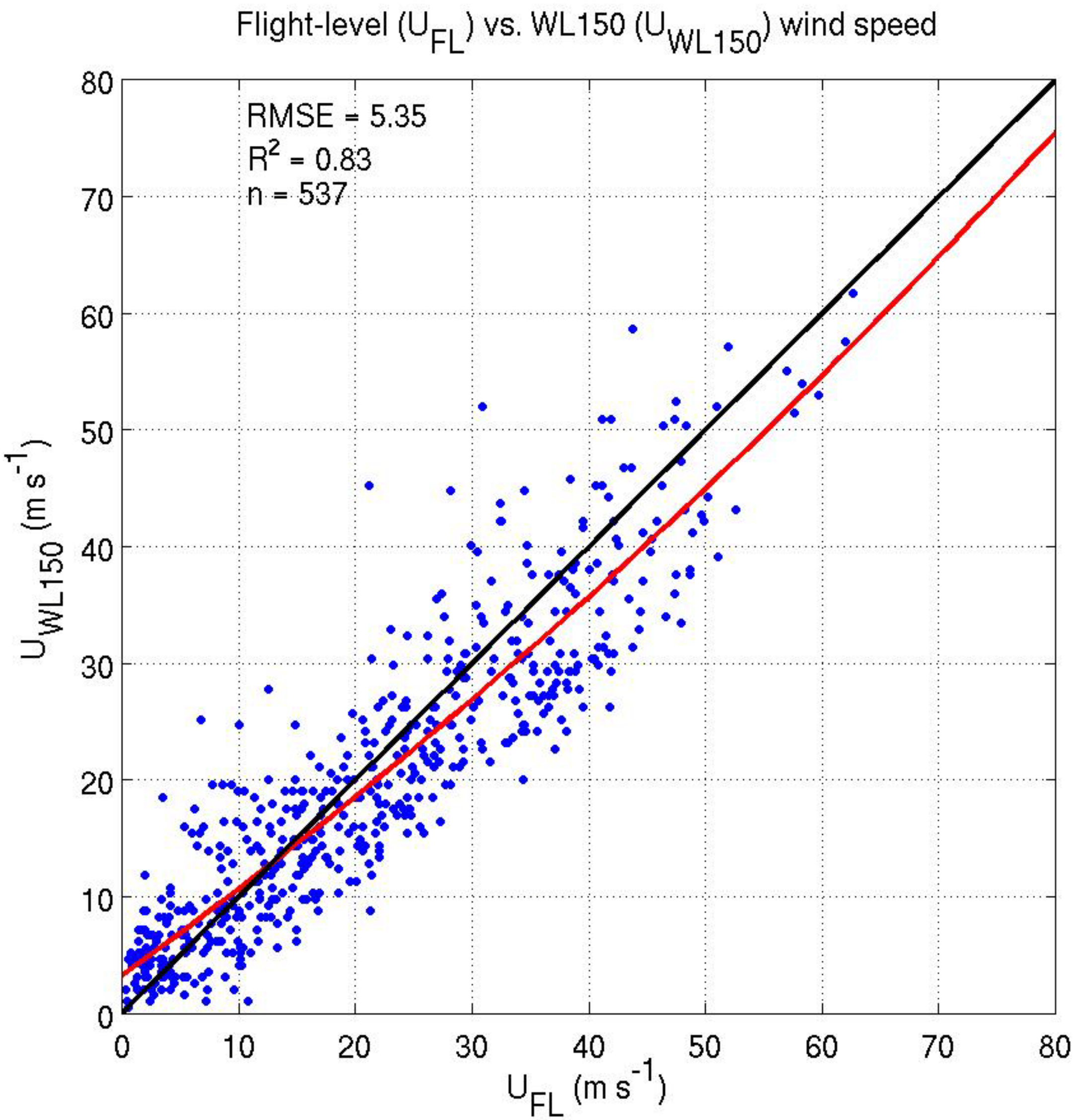
Synthetic dropwindsondes

- Relationship between flight-level wind speed and WL150 from dropwindsonde

- Developed from 2010-2011 NOAA dropwindsonde data

- Regression fit used to calculate expected WL150 wind speeds

- Adjust these wind speeds to surface as discussed in Franklin et al. (2003) and Uhlhorn et al. (2007)



$$U_{WL150} = 2.30\times10^{-3}U_{FL}^{2} + 0.72U_{FL} + 3.21$$

Final database expansion

- With addition of 2011 data and synthetic dropwindsondes, database expanded from 1581 to 2628 total dropwindsondes
- Within wind speeds < 33 m s^{-1} and rain rates >= 20 mm hr^{-1}, increased from 33 to 198 dropwindsondes (over 75% of these are synthetic)
- Overall: RMSE = 4.5 m s^{-1}, mean bias = +2.0 m s^{-1}

	U_{SFMR} (m/s)	<17	17 – 25	25 – 33	33 – 50	> 50
R_{SFMR} (mm/hr)						
< 10		767 – 918 – 918	347 – 418 – 418	154 – 200 – 200	90 – 101 – 101	7 – 7- 7
10 – 20		7 – 7 – 41	27 – 31 – 217	36 – 42 – 178	51 – 57 – 145	6 – 6 – 10
20 – 30		2 – 2 – 19	7 – 9 – 80	17 – 21 – 64	17 – 21 – 80	8 – 8 – 19
> 30		0 – 0 – 5	3 – 5 – 14	4 – 7 – 16	21 – 24 – 60	10 – 10 – 43

SFMR bias correction

- A random sample of 80% of the expanded database was used to develop a bias correction model

- The remaining 20% used as an independent sample for validation of the bias correction model

- Weighted mean biases and several other statistical parameters calculated within 4 rain rate bins and 5 SFMR wind speed bins
    - Real data given highest weight and synthetic data are weighted according to the least-squares fit of the SFMR wind speed and real dropwindsonde surface-adjusted wind speed

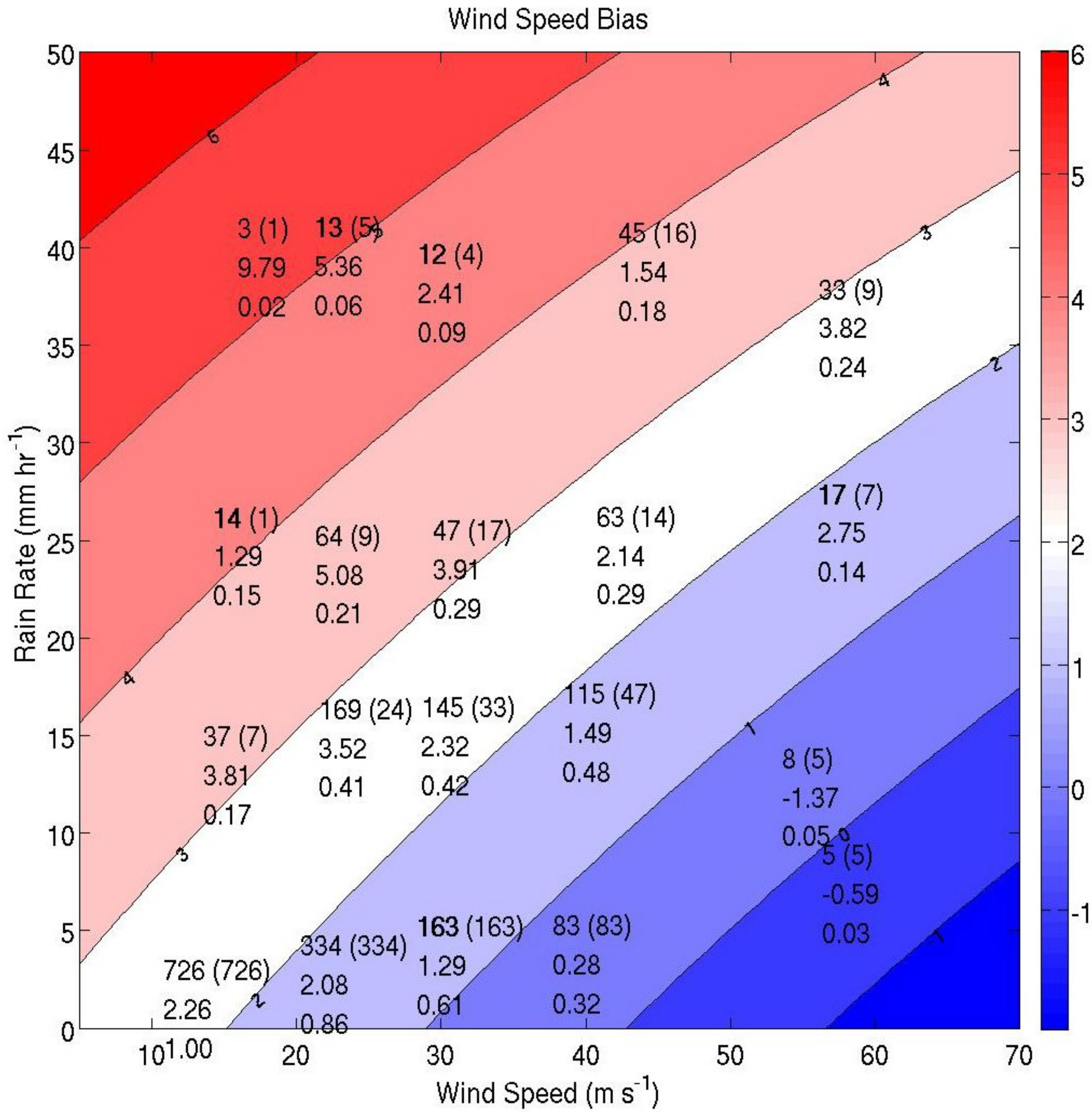
- Polynomial function fit based on these binned data, indicating that weak wind and high rain rate conditions require the largest bias correction

SFMR bias correction (cont.)

- Bias correction model created from the binned data

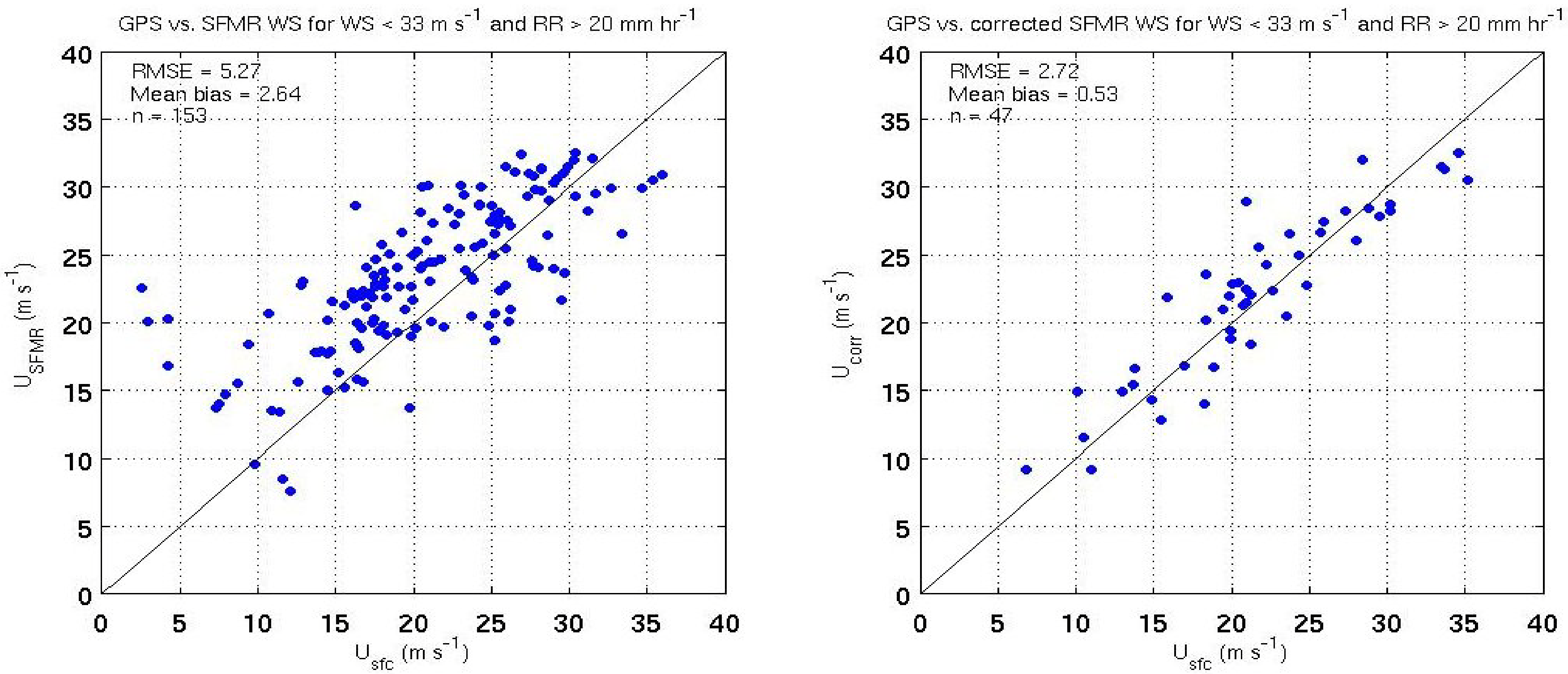
- Weights associated with this function fit are based on the inverse of the standard deviation

- Example: for a wind speed ~17 $m\ s^{-1}$ and rain rate > 30 $mm\ hr^{-1}$, the expected bias would be >= 4.5 $m\ s^{-1}$



$$\Delta U = 3.096 - 0.072 U_{SFMR} + 0.079 R + 4.938 \times 10^{-4} (U_{SFMR} \cdot R)$$

Correction model validation



- Correction model applied to the SFMR wind speeds in the remaining independent sample
- Over all wind speeds and rain rates:
  - RMSE decreases from 4.5 m s^{-1} to 2.9 m s^{-1} **(36% improvement in accuracy)**
  - Mean bias decreases from +2.0 m s^{-1} to +1.0 m s^{-1} **(50% improvement)**
- For U < 33 m s^{-1} and R > 20 mm hr^{-1}
  - RMSE decreases from 5.3 m s^{-1} to 2.7 m s^{-1} **(49% improvement in accuracy)**
  - Mean bias decreases from +2.6 m s^{-1} to +0.5 m s^{-1} **(81% improvement)**

Summary and remaining work for year 1

- To correct the overestimation of SFMR wind speeds in the presence of moderate to heavy rain:
  - Expanded SFMR vs. dropwindsonde database through use of real and synthetic dropwindsonde data
  - Calculated statistics for binned data and developed polynomial function fit to these data
  - Validation from independent sample shows significant improvement in accuracy and in bias correction for the overall data and for the weak wind, heavy rain conditions
  - Correlation between corrected SFMR wind speed and rain rate is reduced from 0.48 to 0.39 – SFMR wind speed is less coupled with trends in rain rate

Remaining tasks for JHT year 1:

- Implement correction software into JHT testing environment for parallel SFMR wind speed product – prior to 2012 hurricane season

- Perform real-time testing of corrected SFMR winds during 2012 season

- Begin development of updated GMF accounting for the corrected wind speeds

References

1. Dunion, J. P., C. W. Landsea, S. H. Houston, M. D. Powell, 2003: A reanalysis of the surface winds for Hurricane Donna of 1960. *Mon. Wea. Rev.*, **131**, 1992 – 2011.

2. Franklin, J. L., M. L. Black, K. Valde, 2003: GPS dropwindsonde profiles in hurricanes and their operational implications. *Wea. Forecasting.*, **18**, 32 – 44.

3. Uhlhorn, E. W., P. G. Black, J. L. Franklin, M. Goodberlet, J. Carswell, A. S. Goldstein, 2007: Hurricane surface wind measurements from an operational stepped frequency microwave radiometer. *Mon. Wea. Rev.*, **135**, 3070 – 3085.

Questions?