Reprocessing the Tropical Cyclone SFMR database: Procedures and Evaluation

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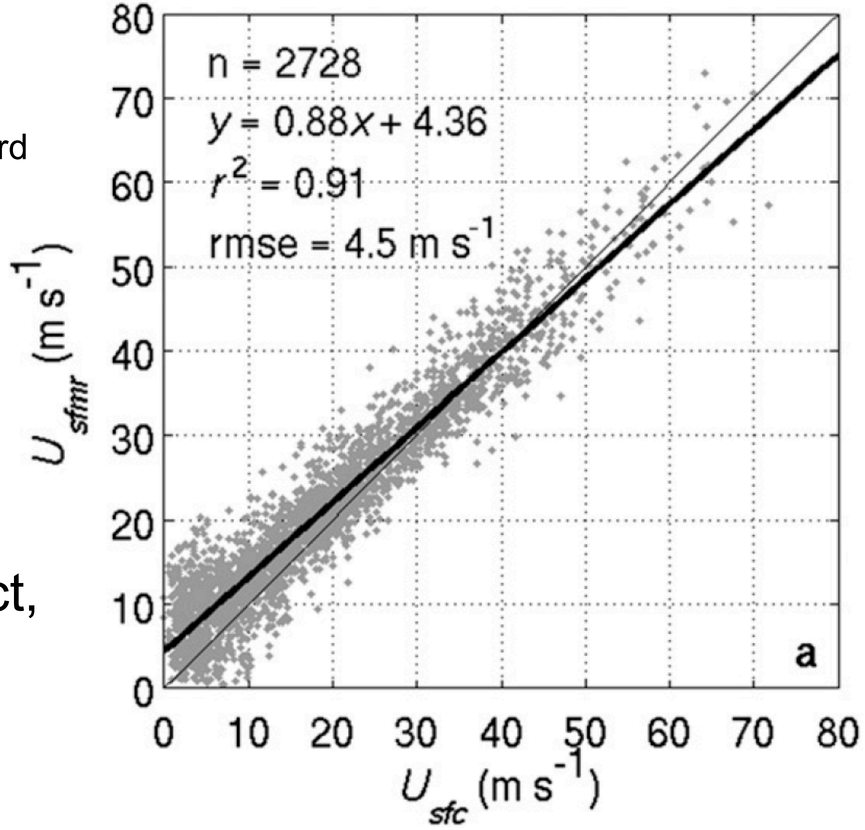
Background

- Historically, the airborne SFMR has provided reliable estimates of surface wind speed and rain rate in tropical cyclones, especially hurricanes
- The instrument is operated on both NOAA P-3 and AFRC 53rd Reconnaissance Squadron C-130s
- For years, there was anecdotal evidence of a bias in the SFMR wind speeds, especially below hurricane strength.
- Through a Joint Hurricane Testbed (2011-2013 series) project, we sought to quantify this bias and were able to improve the SFMR processing algorithm
- This updated algorithm has been operational since 2015



Algorithm Update

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Improved Stepped Frequency Microwave Radiometer Tropical Cyclone Surface Winds in Heavy Precipitation

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Algorithm Update – Wind vs. Emissivity

- The GMF directly relates excess emissivity (ε_w) to wind speed (U_{sfc})
- To calculate ε_w, calculate the smooth surface emissivity (ε_0 = 1-Γ) and then:

$$\varepsilon_w(f, U_{\text{sfc}}) = \varepsilon(f, T_s, S, U_{\text{sfc}}) - \varepsilon_0(f, T_s, S)$$

- Using the 4.74 GHz channel as a reference – least impacted by rain – and a constrained piecewise regression, we obtain:

$$\varepsilon_{w,4.74} = \begin{cases} a_1 U_{\text{sfc}} & 0 \le U_{\text{sfc}} < w_l \\ a_2 + a_3 U_{\text{sfc}} + a_4 U_{\text{sfc}}^2 & w_l \le U_{\text{sfc}} < w_u \\ a_5 + a_6 U_{\text{sfc}} & w_u \le U_{\text{sfc}} \end{cases}$$

	a_1	a_2	a_3	a_4	a_5	a_6	w_u
Previous	4.012×10^{-4}	2.866×10^{-3}	-4.177×10^{-4}	5.849×10^{-5}	-5.666×10^{-2}	3.314×10^{-3}	31.9
Current	1.232×10^{-3}	3.440×10^{-3}	2.492×10^{-4}	7.020×10^{-5}	-9.266×10^{-2}	5.444×10^{-3}	37.0

Algorithm Update – Rain vs. Absorption

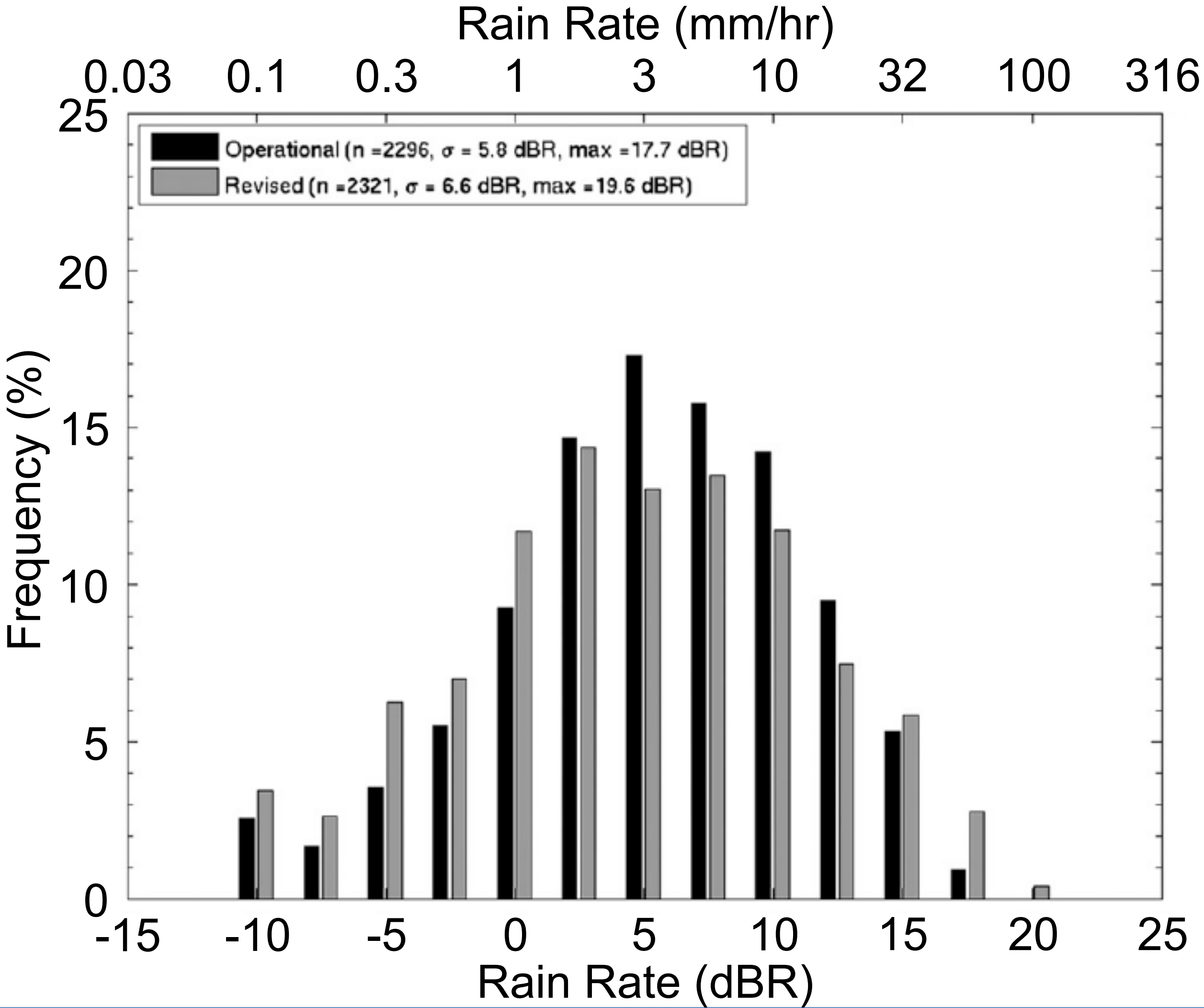
- Rain column height (*H*) has an impact on the rain rate obtained from the algorithm
- Previous algorithm assumes 4 km as the freezing level height
- The revised algorithm incorporates a variable *H*, which is calculated using the flight-level temperature and a typical hurricane T profile

$$H = h + \gamma^{-1} T_{\mathrm{amb}}$$

- h is the aircraft flight-level (m), T_{amb} is ambient flight-level temperature, and γ is 5.22×10^{-3} K m^{-1}

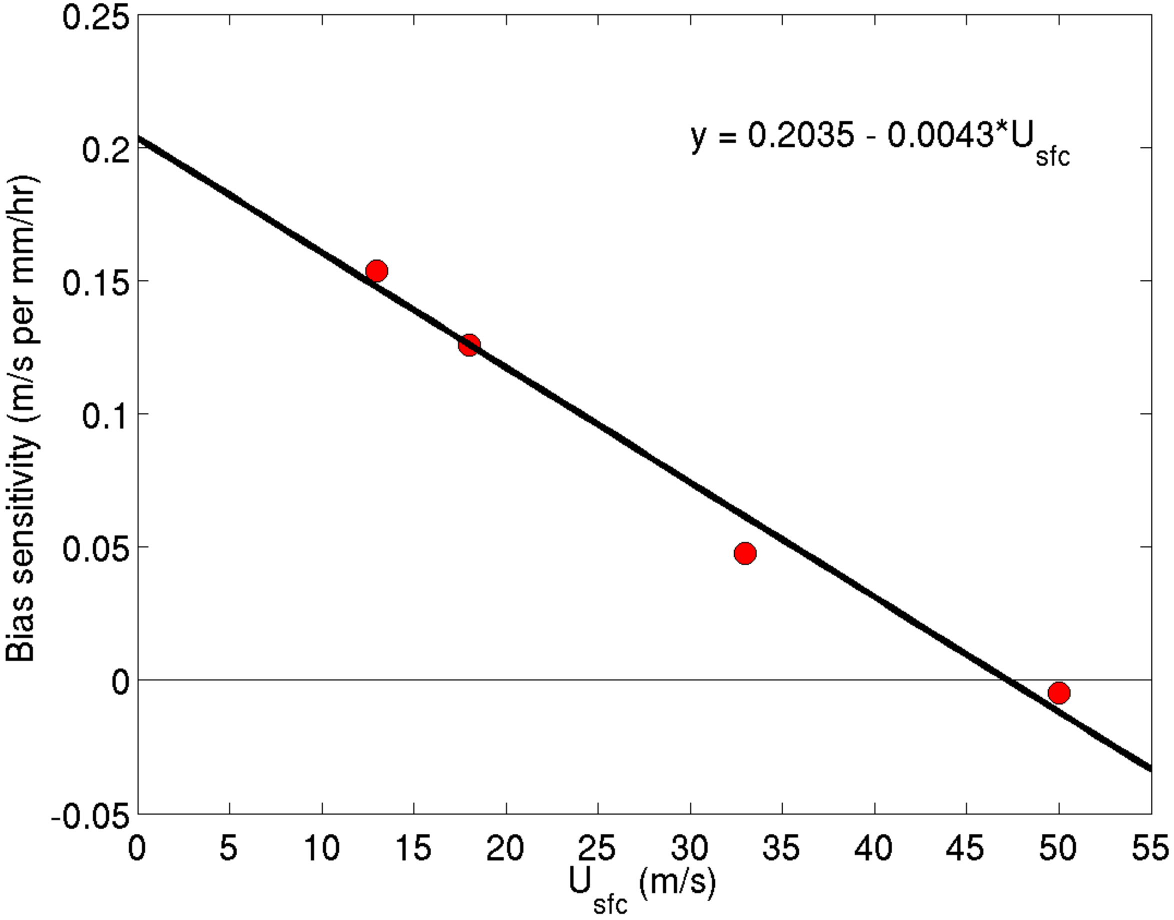
Algorithm Update – Rain rate

- Maximum R now ~100 mm h^{-1} as opposed to ~60 mm h^{-1}



Algorithm Update – Bias Sensitivity

- Because of a remaining high bias at low wind speeds, we also apply this rain-dependent bias sensitivity parameter



$$U_{bc} = \frac{U_{sfmr} - a_0 R_{sfmr}}{1 + a_1 R_{sfmr}}$$

a_0 = 0.035
a_1 = -0.0043

We do not alter the winds if the corrected wind speed is larger than the original

Reprocessing SFMR data

- For consistency within the full SFMR dataset, we decided to reprocess data prior to 2015 using the algorithm updates

- Data are currently available in NetCDF format on the HRD web site (www.aoml.noaa.gov/hrd/data_sub/)

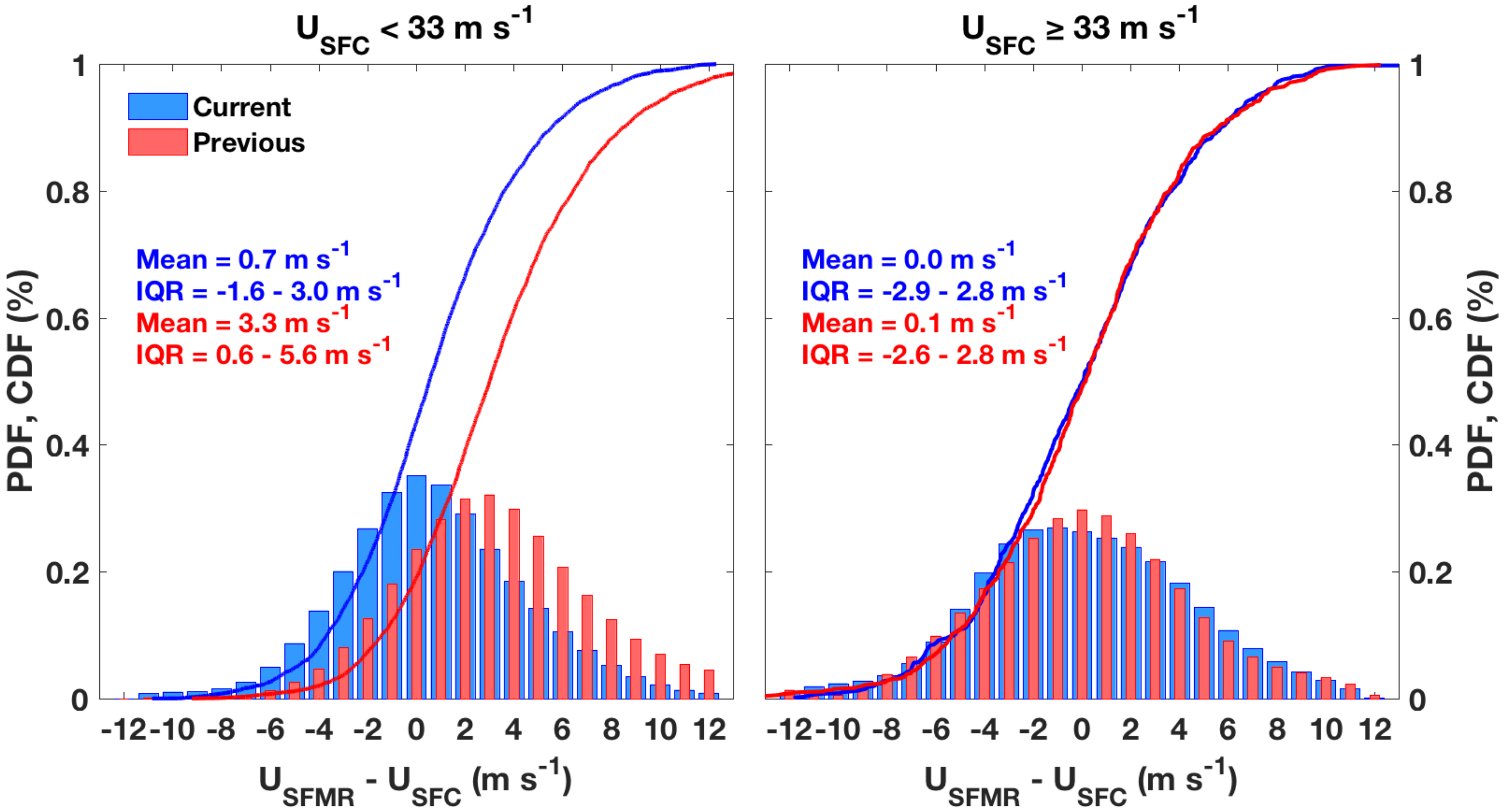
- Necessary to account for:
  - C-band frequency difference prior to 2005 (see Uhlhorn and Black 2003)
  - Flights where the IWRAP was operational – interference on 2nd SFMR channel
  - Accurate SST measurements – occasionally notice inconsistencies

Evaluating the Reprocessed data

- We follow a similar methodology to Klotz and Uhlhorn (2014)
  - Pair the SFMR surface wind speed with a coincident dropsonde surface-adjusted wind speed (U_{sfc})
  - Determine statistical relationships as a function of wind speed and rain rate
  - Establish any remaining bias to consider when using the SFMR wind speeds and compare with the previous algorithm results

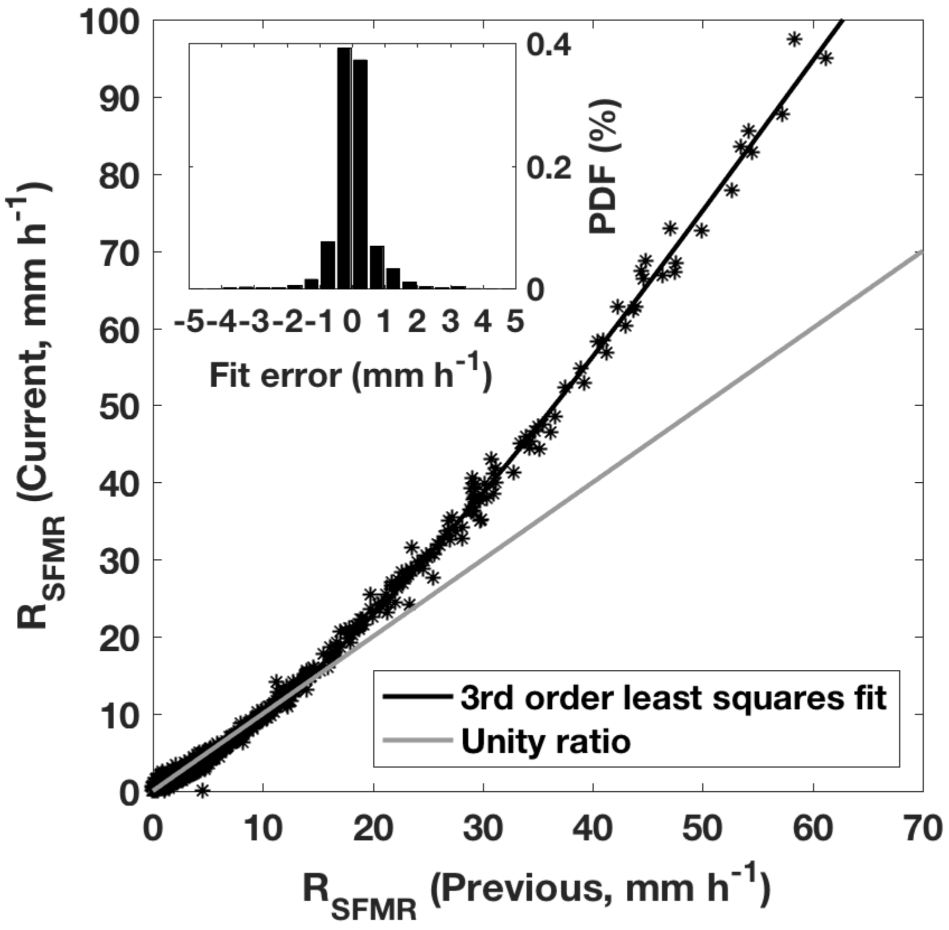
Evaluation – TS vs Hurricane

- Algorithm comparison for TS and hurricane wind speeds (1998-2016)



Evaluation – Rain Rate Conversion

- We apply a rain rate conversion to the previous algorithm to account for the change in the current algorithm



$$R_C = a_1 R_P + a_2 R_P + a_3 R_P + a_4$$

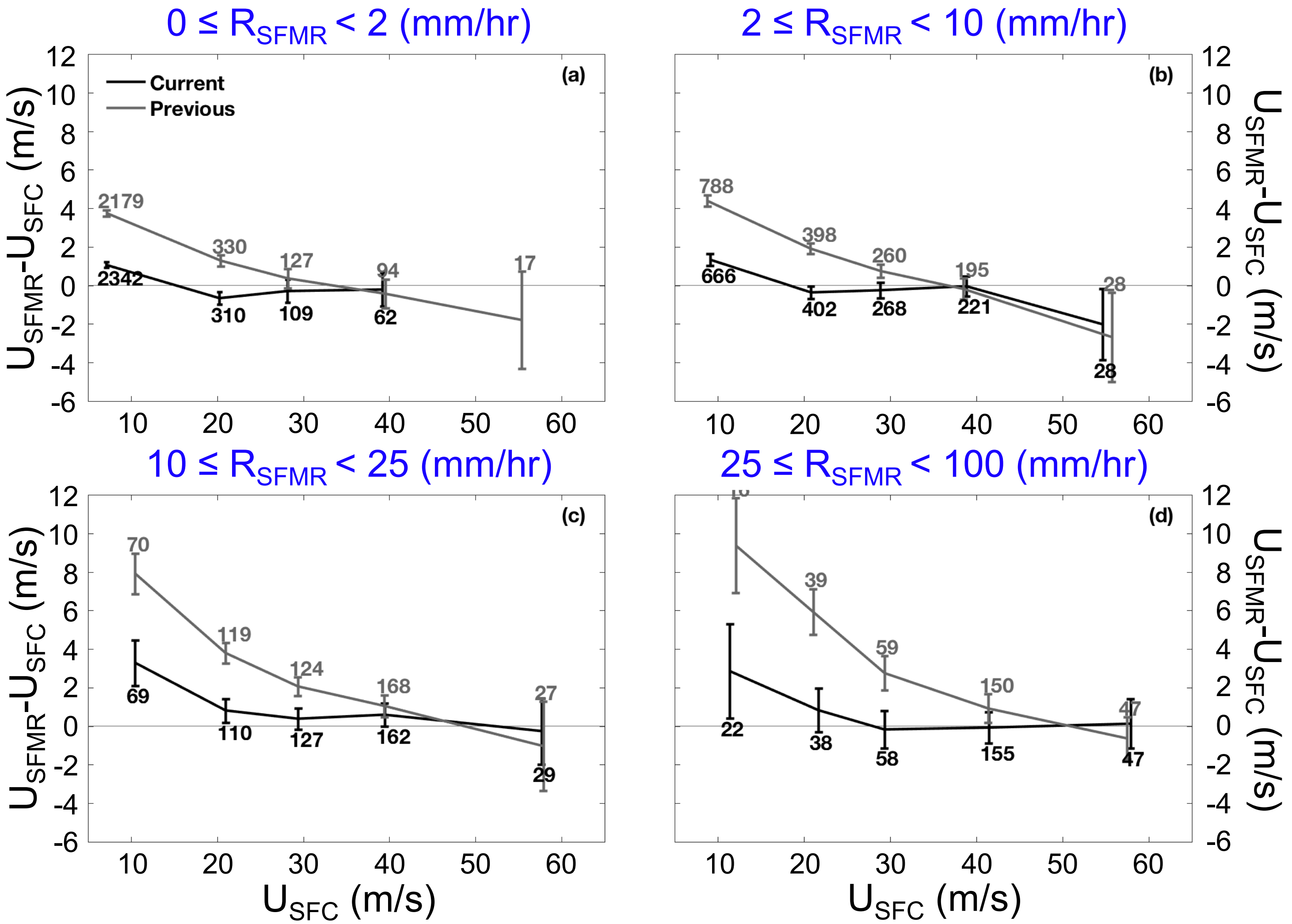
R_C = Current rain rate

R_P = Previous rain rate

$a_1 = -1.1742\times10^{-4}$
$a_2 = 2.0193\times10^{-2}$
$a_3 = 7.9068\times10^{-1}$
$a_4 = -1.1180\times10^{-1}$

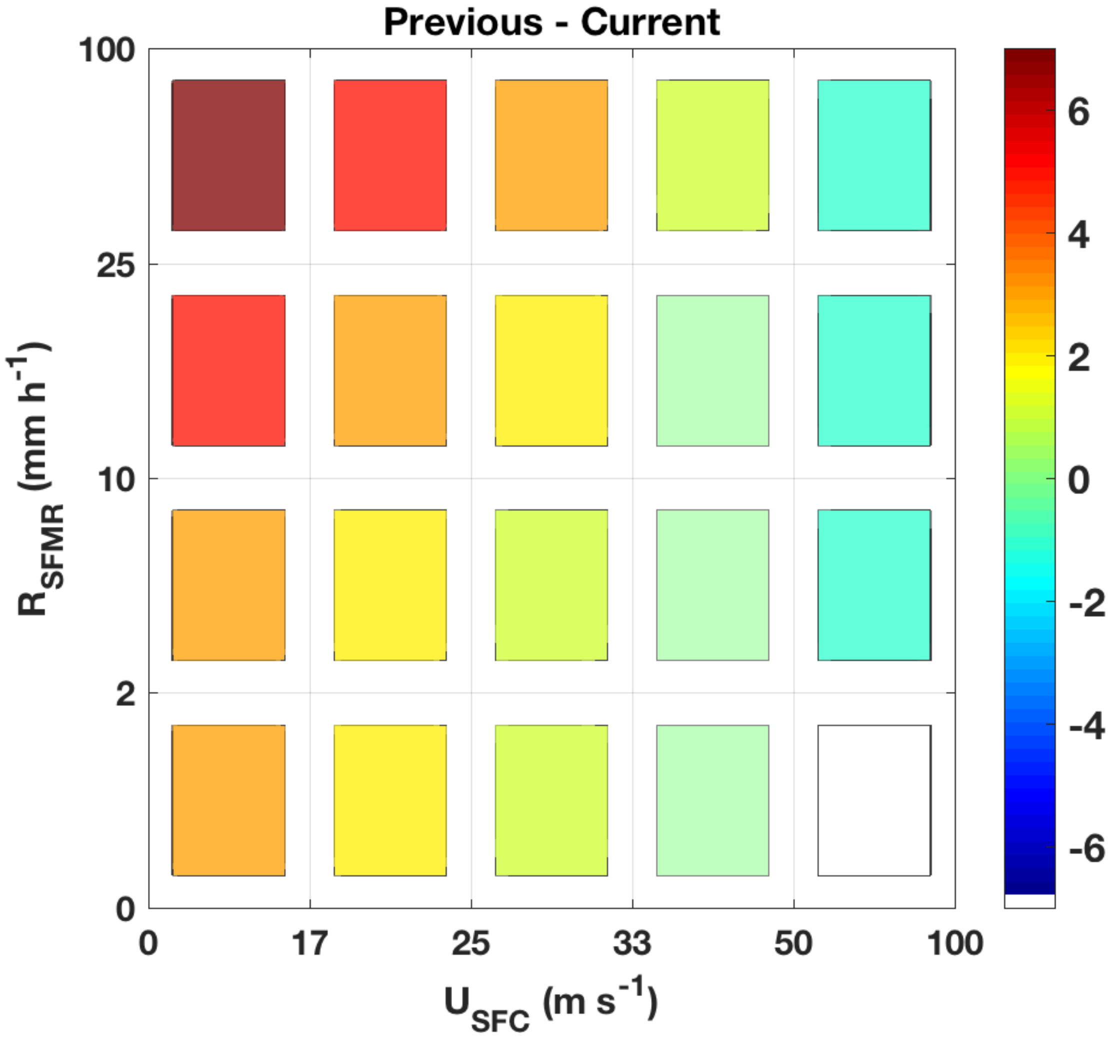
Evaluation – Function of Rain Rate

- Algorithm comparison as a function of rain rate

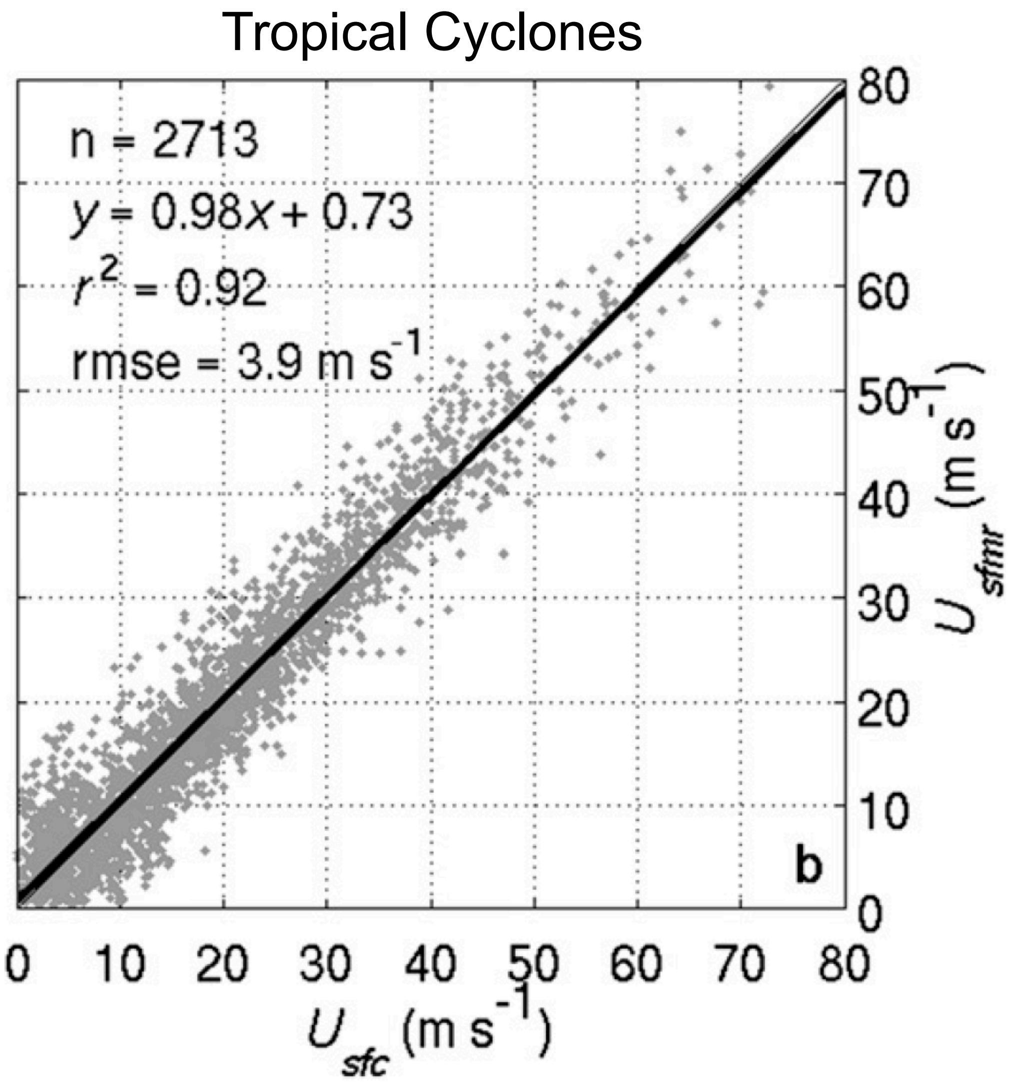


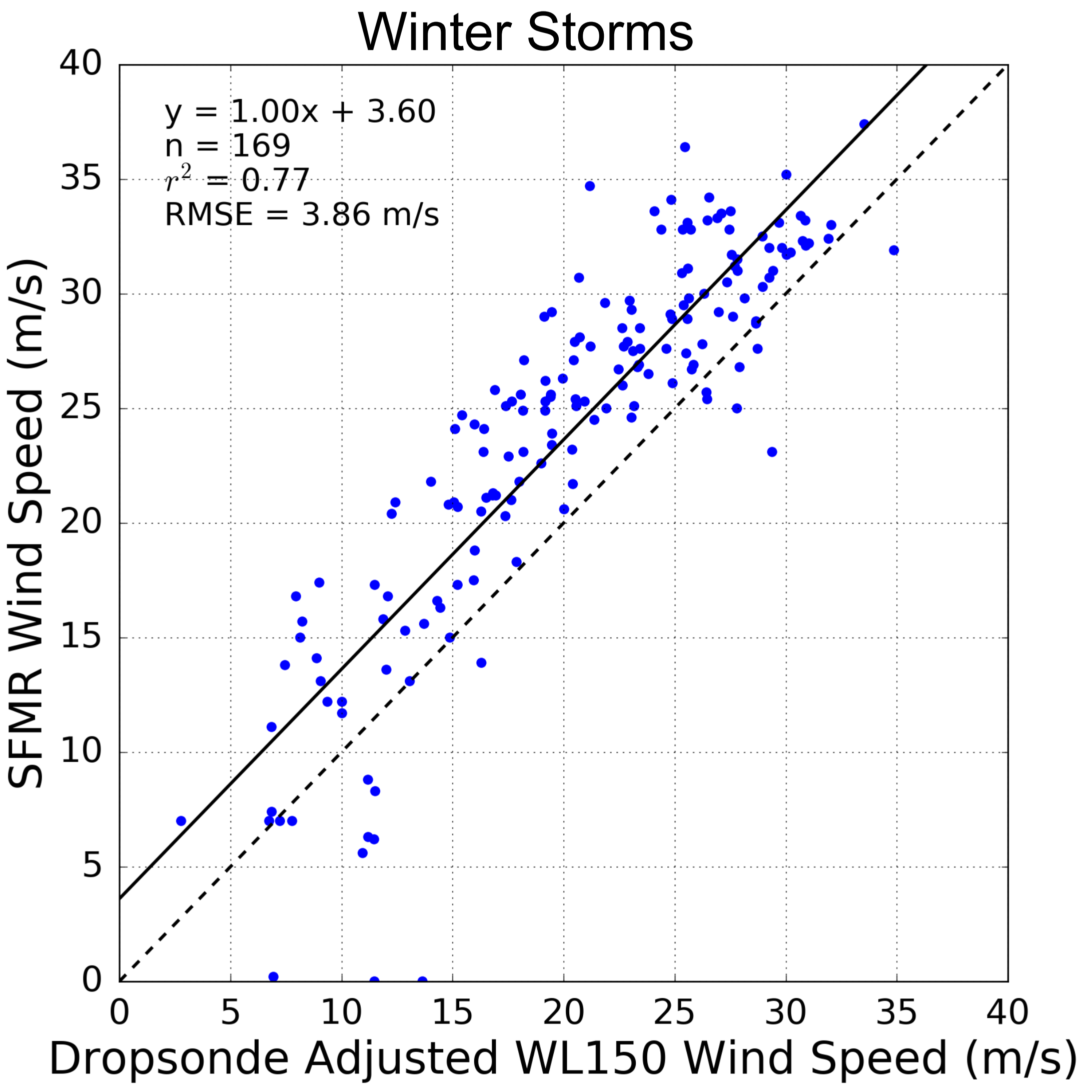
Evaluating the Reprocessed data

- Bias differences between the algorithms (Previous – Current)



Comparison to Winter Storms Data





Final remarks

- After reprocessing the older data and evaluating it relative to the previous algorithm data, we have confirmed that:
    - The high wind speed bias in no rain conditions has been reduced significantly
    - Wind speeds above hurricane strength have largely been unaffected, but the low bias above 100 kt has also been improved
    - A small high bias remains at low wind speeds and moderate to heavy rain

Questions?

Extra slides…

Algorithm Update – Wind vs. Emissivity

- Must also consider the ε_w dependence on frequency:

$$(\varepsilon'_w = d\varepsilon_w/df)$$

- Previous calculation:
- $$\varepsilon'_w = 0.15\varepsilon_w$$
- To verify the previous equation, use a least squares regression to determine new equation:

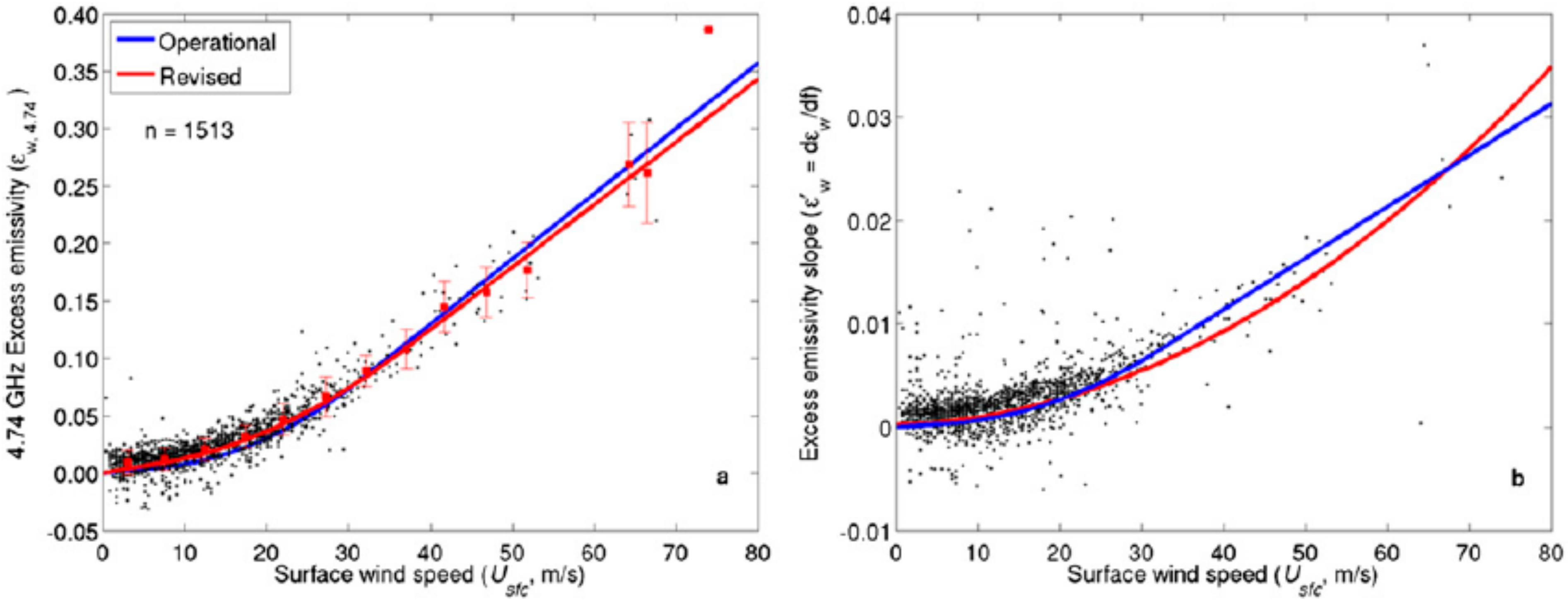
$$\varepsilon'_w = 5.166 \times 10^{-6} U_{sfc}^2 + 1.860 \times 10^{-5} U_{sfc} + 2.788 \times 10^{-4}$$

Algorithm Update – Wind vs. Emissivity

- The final form of the revised wind-emissivity equation is:

$$\varepsilon = \varepsilon_{w,4.74} + \varepsilon'_w \Delta f + \varepsilon_0$$

$\Delta f = f - 4.74$ (GHz)



Impact on max winds in hurricanes

- Some differences in the maximum wind speeds for some extreme or well-known hurricanes in the SFMR database are presented

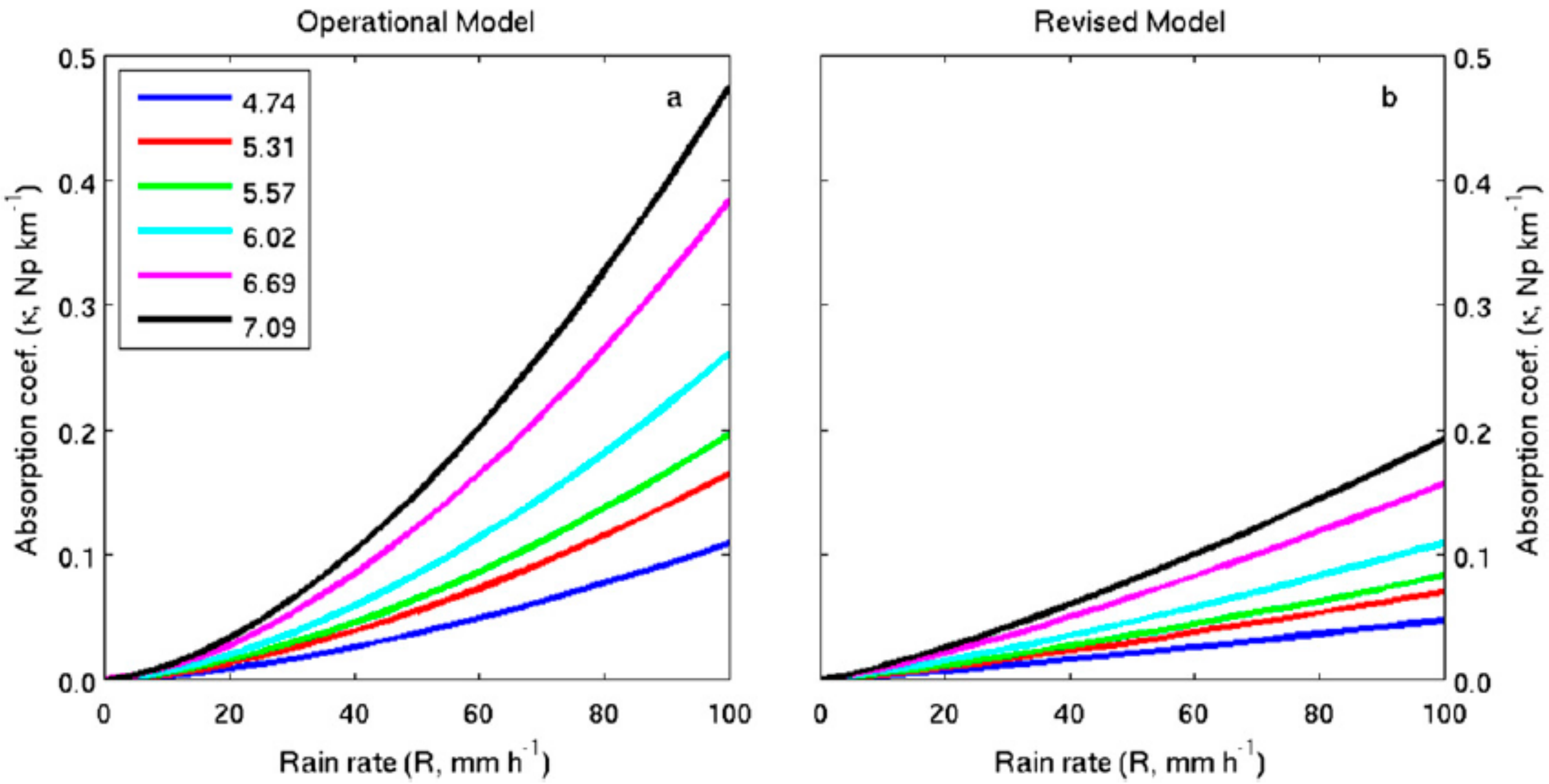
	U_{max} (Previous)	U_{max} (Current)	Best Track V_{max}
Katrina (28 Aug. 2005, 18Z)	70 m s^{-1}	72 m s^{-1}	77 m s^{-1}
Rita (22 Sep. 2005, 18Z)	75 m s^{-1}	78 m s^{-1}	77 m s^{-1}
Felix (3 Sept. 2007, 00Z)	84 m s^{-1}	87 m s^{-1}	77 m s^{-1}
Earl (2 Sept. 2010, 06Z)	60 m s^{-1}	63 m s^{-1}	64 m s^{-1}
Sandy (25 Oct. 2012, 06Z)	49 m s^{-1}	50 m s^{-1}	51 m s^{-1}
Patricia (23 Oct. 2015, 06Z)	96 m s^{-1}	96 m s^{-1}	95 m s^{-1}

Reprocessing SFMR data – Processing

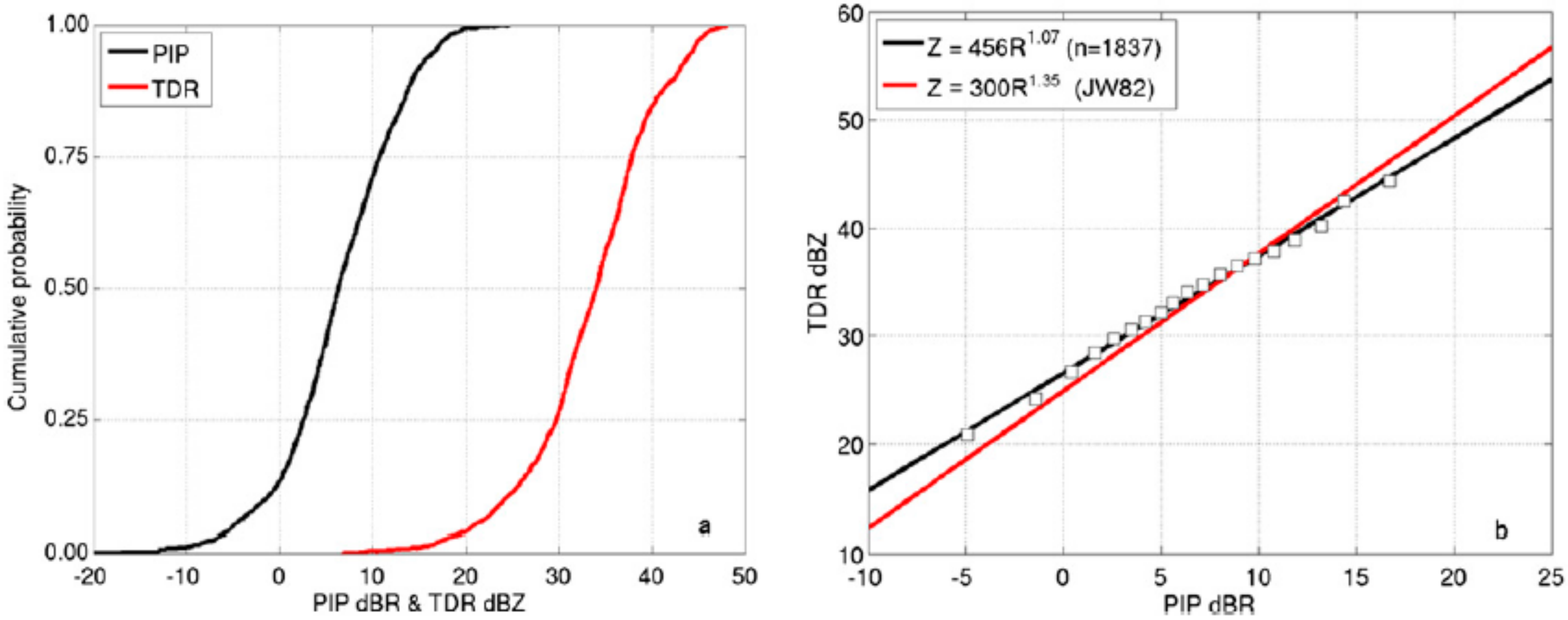
- We first streamlined the processing code to apply more automation
- Verified the brightness temperatures were consistent in each file, especially for flights with known issues
- Completed the processing and quality controlled the data
- Data are currently available in NetCDF format on the HRD web site (www.aoml.noaa.gov/hrd/data_sub/)

Algorithm Update – Rain vs. Absorption

- *κ-R* relationship for the Previous and Current GMF



Algorithm Update – Rain vs. Absorption



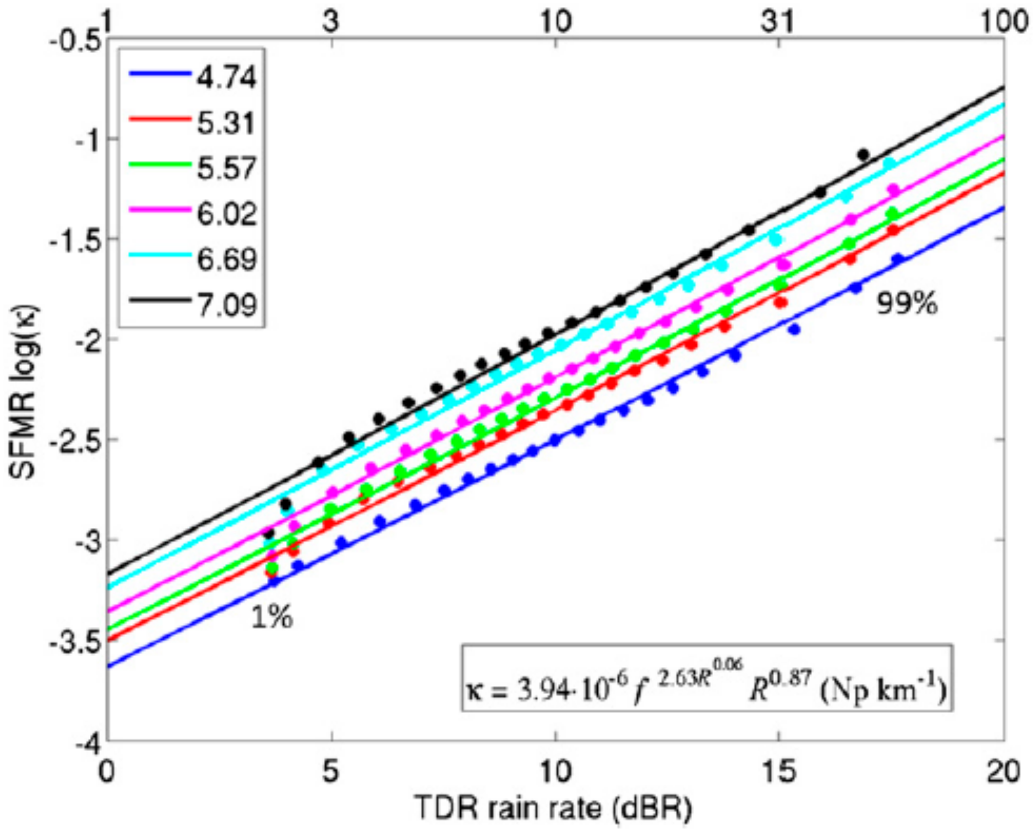
- Independent measurements of rain from PIP and Tail Doppler radar (TDR)
- Probability matching between PIP rain rate and TDR reflectivity produces new Z-R relationship:

$$Z = 456 R_{pip}^{1.07}$$

Algorithm Update – Rain vs. Absorption

- Pairs of κ and R_{tdr} are used to calculate an empirical κ-R relationship:

$$\kappa = aR_{\text{tdr}}^{b} \quad \text{or} \quad \kappa = gf^{n} R_{\text{tdr}}^{b}$$



	g	c	d	b
Previous	1.87×10^{-6}	2.60	0.0736	1.15
Current	3.94×10^{-6}	2.63	0.0600	0.87

Dropsonde Profiles

Mean Hurricane Profiles from Franklin et al. (2003)