Further Studies of Observational Undersampling in Flight-Level and SFMR Observations

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Introduction

Tropical cyclone (TC) intensity is an operational requirement of the National Hurricane Center (NHC) and is based on determining a maximum sustained surface wind (i.e. 1-minute, 10 m). Aircraft reconnaissance missions provide the best opportunity to provide this estimate, but due to limitations of timing and flight patterns, it is almost impossible to observe the maximum surface wind speed in a TC. Therefore, forecasters at NHC often expect that the true maximum wind speed is higher than observed (Landsea et al. 2004).

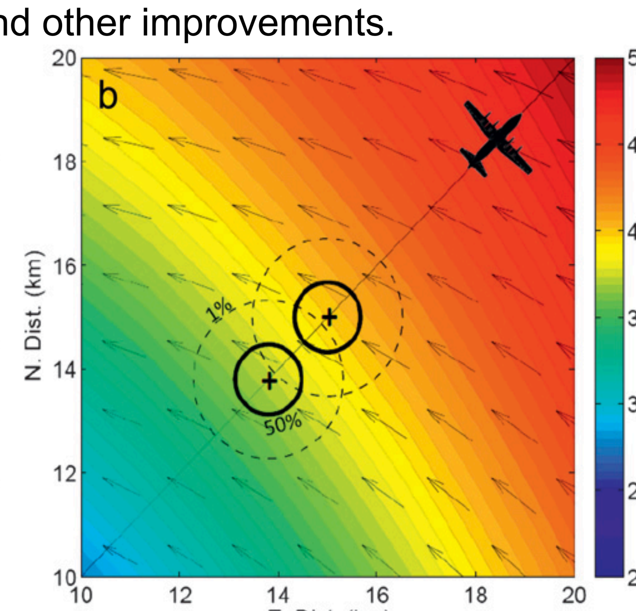
To quantify the undersampling by aircraft reconnaissance, Uhlhorn and Nolan (2012) utilized a high resolution simulation of Hurricane Isabel (2003) from Nolan et al. (2009), simulated stepped frequency microwave radiometer (SFMR, Uhlhorn et al. 2007) flight tracks, and compared the highest observed surface wind speed along the track to the maximum 1-minute sustained surface wind speed at any location in the surface wind field. Their results revealed an average underestimate of 7.8 ± 1.2%. Isabel was an intense, symmetric, and mature hurricane during the simulation window and model output were only provided hourly. A follow-on study (Nolan et al. 2014) found that the underestimation is also dependent on the size, structure, and intensity of the wind field.

Because SFMR measurements are the standard for TC surface wind observations, this project expands on the work from Uhlhorn and Nolan (2012) to examine how the variations in storm size, intensity, asymmetric structure, and model improvements impact the underestimate of maximum surface wind speed.

Data and Methods

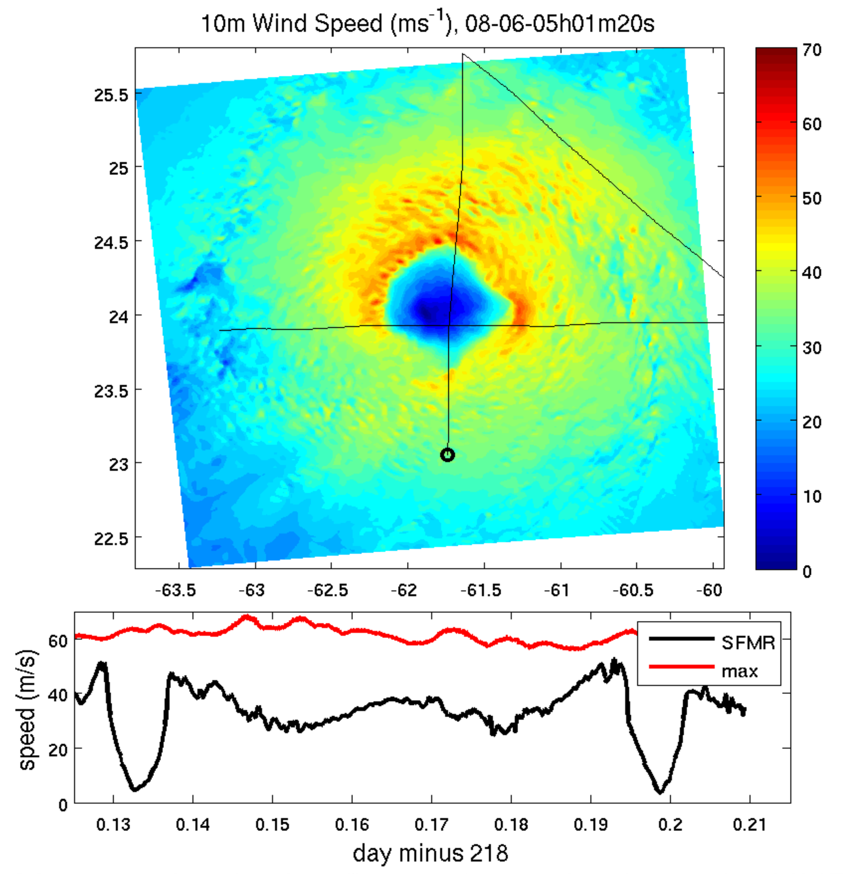
SFMR flight tracks are simulated in the single figure-4 pattern at 8 initial incidence angles within each specified time window of a simulation. In this study, for example, flight times are initiated every 3 hours instead of the 6 used previously. Because each figure-4 is completed in ~2.5 hours, sampling periods without a simulated aircraft in storm are reduced significantly (minutes instead of hours). This reduction can help better address specific changes that occur over short periods of time, such as rapid intensification or weakening.

To obtain the underestimation through the TC lifecycle, we use the high resolution Nature Run (HNR1, Nolan et al. 2013), which includes periods of genesis, rapid intensification, an eyewall replacement cycle, and recurvature. A variant of this simulation, HNR2 (Nolan and Mattocks 2014), provides a simulation that is impacted by land. Several other simulations, including intense Hurricane Bill (2009, Moon and Nolan 2015) and Idealized simulations at Category 2 and 5 strength are used to address differences in intensity and structure, model configuration, resolution and other improvements.

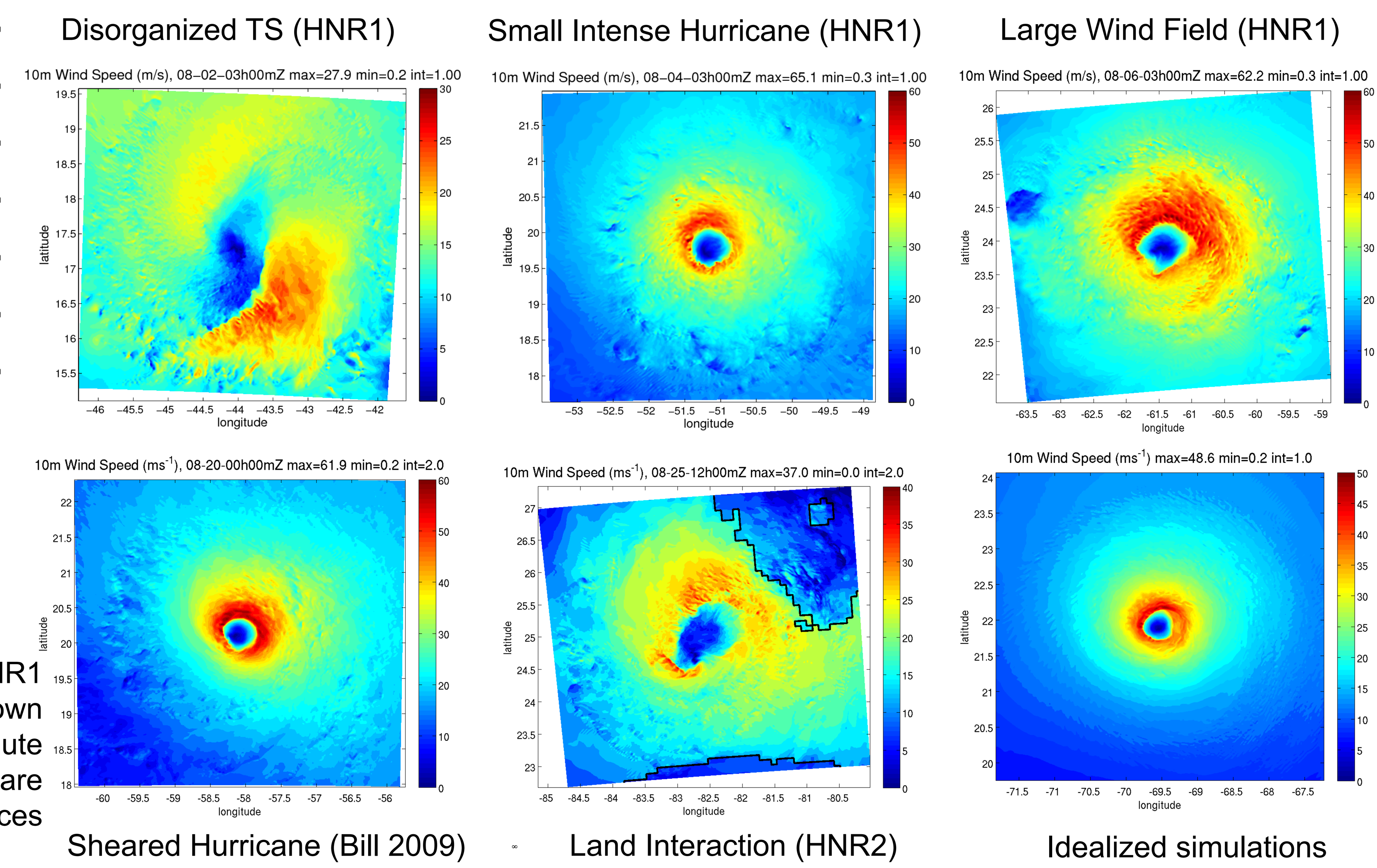


Right: This figure (7b from Uhlhorn and Nolan 2012) shows a simulated SFMR footprint overlaid on the model output. The footprints are separated by 10-s of flight time, which corresponds to the SFMR averaging time.

Sampling Various TC Intensities, Sizes, and Structures in Simulations



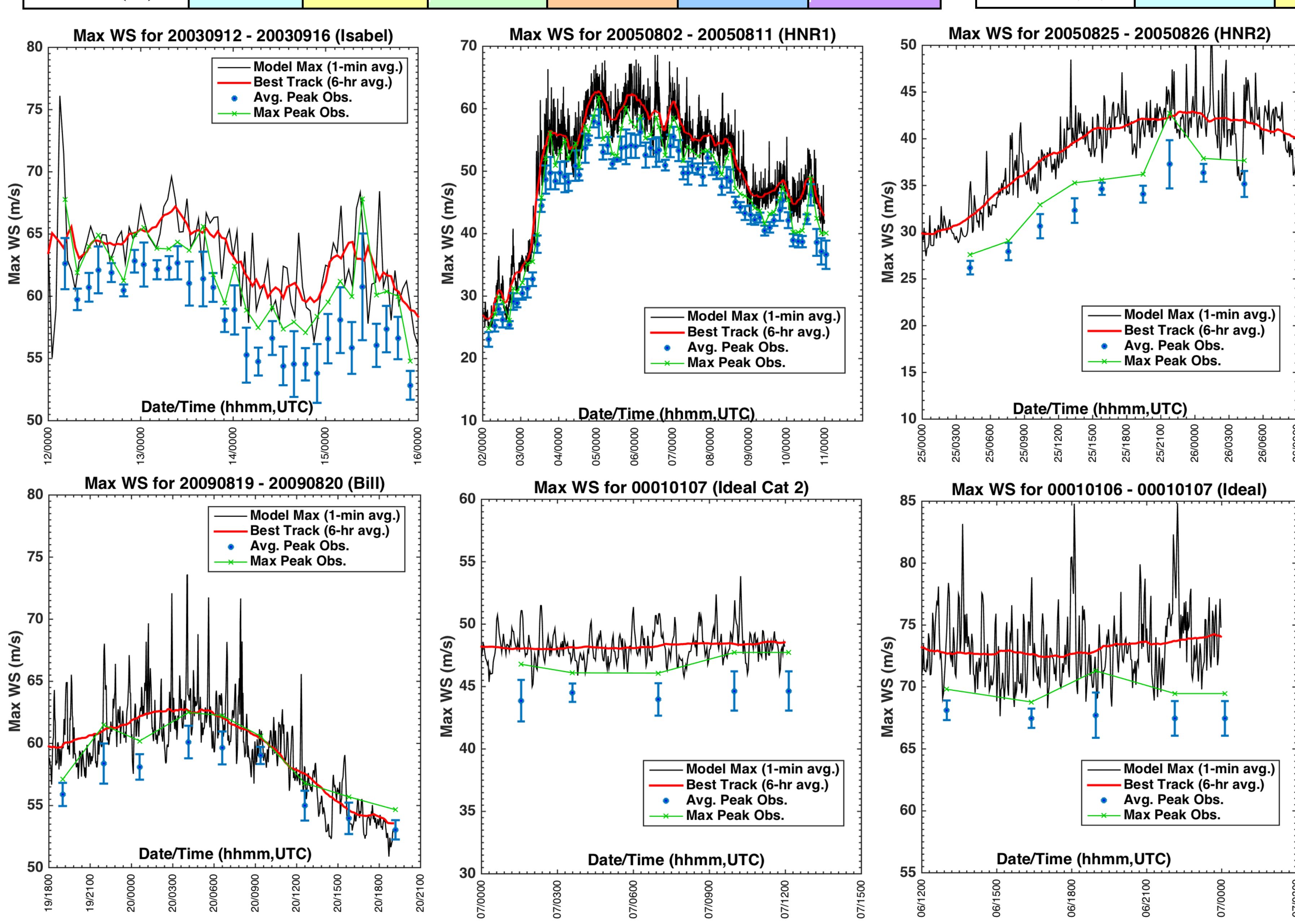
Above: A single figure-4 track through HNR1 during the mature phase of development is shown along with the SFMR observation and 1-minute maximum wind. **Right:** These six panels are examples of the various structural differences found in the simulations.



Undersampling Results

	HNR1	HNR2	Bill	Isabel	Ideal (Cat 5)	Ideal (Cat 2)
Dates (mm/dd)	08/02-11	08/25-26	08/19-20	09/12-16	12-hr period	12-hr period
Avg 1-min (%)	10.9 ± 0.6	16.1 ± 1.6	3.8 ± 1.9	7.3 ± 1.0	7.9 ± 1.7	7.8 ± 1.5
Min 1-min(%)	5.7 ± 0.8	10.5 ± 2.8	0.4 ± 2.0	2.7 ± 1.0	5.0 ± 2.2	2.5 ± 2.3
Avg 6-hr (%)	11.4 ± 0.8	16.0 ± 1.9	4.1 ± 1.2	7.3 ± 1.0	7.5 ± 1.0	8.1 ± 0.7
Min 6-hr (%)	6.2 ± 0.8	10.4 ± 3.4	0.7 ± 1.5	2.6 ± 1.2	4.6 ± 2.0	2.8 ± 1.6

	HNR1 – TS	HNR1 - RI	HNR1 - Small	HNR1 - Mature	HNR1 - Recurve
Times (dd/hh)	02/00-12Z	03/00-18Z	03/18-04/06Z	05/00–07/00Z	09/00-11/00Z
Avg 1-min (%)	11.7 ± 4.5	14.0 ± 2.4	11.5 ± 1.5	10.7 ± 1.2	11.1 ± 1.8
Min 1-min(%)	5.0 ± 4.4	8.1 ± 5.1	3.4 ± 5.5	5.8 ± 1.6	6.6 ± 2.0
Avg 6-hr (%)	12.7 ± 6.2	13.3 ± 5.7	12.4 ± 1.8	10.8 ± 1.1	11.5 ± 2.0
Min 6-hr (%)	6.0 ± 6.3	7.4 ± 5.9	4.3 ± 5.9	5.8 ± 1.8	7.0 ± 1.9



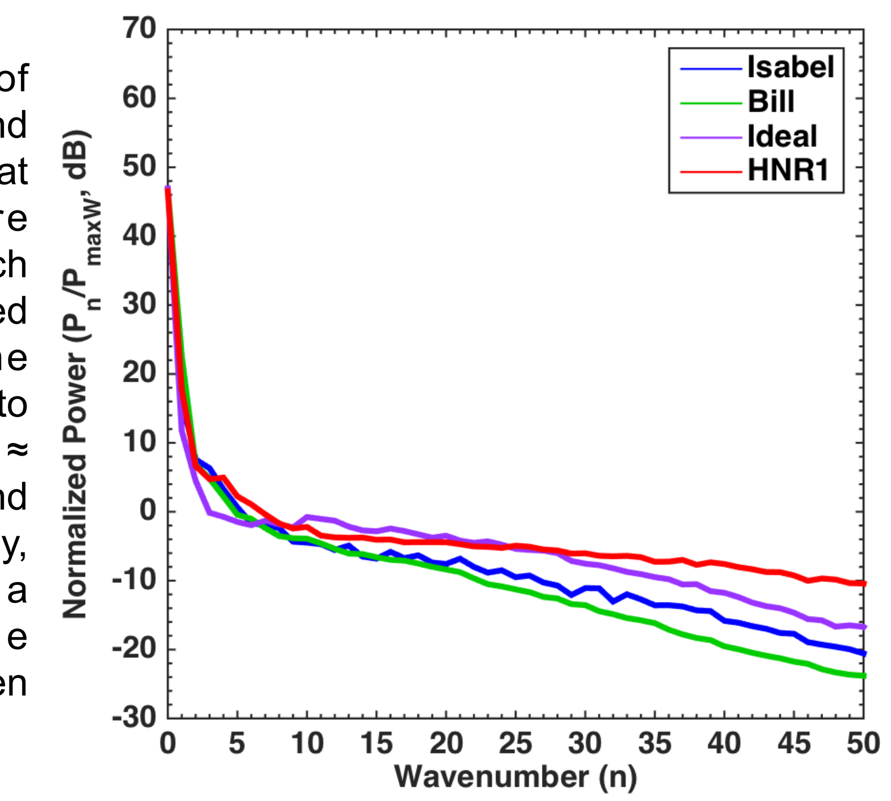
To quantify the underestimation of the 1-minute maximum, the average of the 8 observed maxima within each 3 hour sampling window is calculated. The six panels to the **right** display the resulting average values (blue markers) and 95% confidence intervals (error bars) along with the maximum of the 8 maxima (green line, i.e. minumum underestimate). The black line is the 1-minute model maximum and the red line is the 6 hour 'best track' running mean estimate.

In the top-left table, the average underestimate for Isabel is ~0.5% better using the 3 hour sampling. Bill gets the closest to the 1-minute winds and HNR2 has the largest underestimate due to the asymmetric structure and interaction with land. A 3.5% increase using HNR1 compared to Isabel is indicative of model differences.

HNR1 is separated into the various stages of the TC lifecycle from weak TS, RI, changing storm size, and recurvature. The 1-minute underestimates tend to be similar for all periods except RI. Because the storm is intensifying quickly, the observation strategy has more difficulty observing the maximum wind.

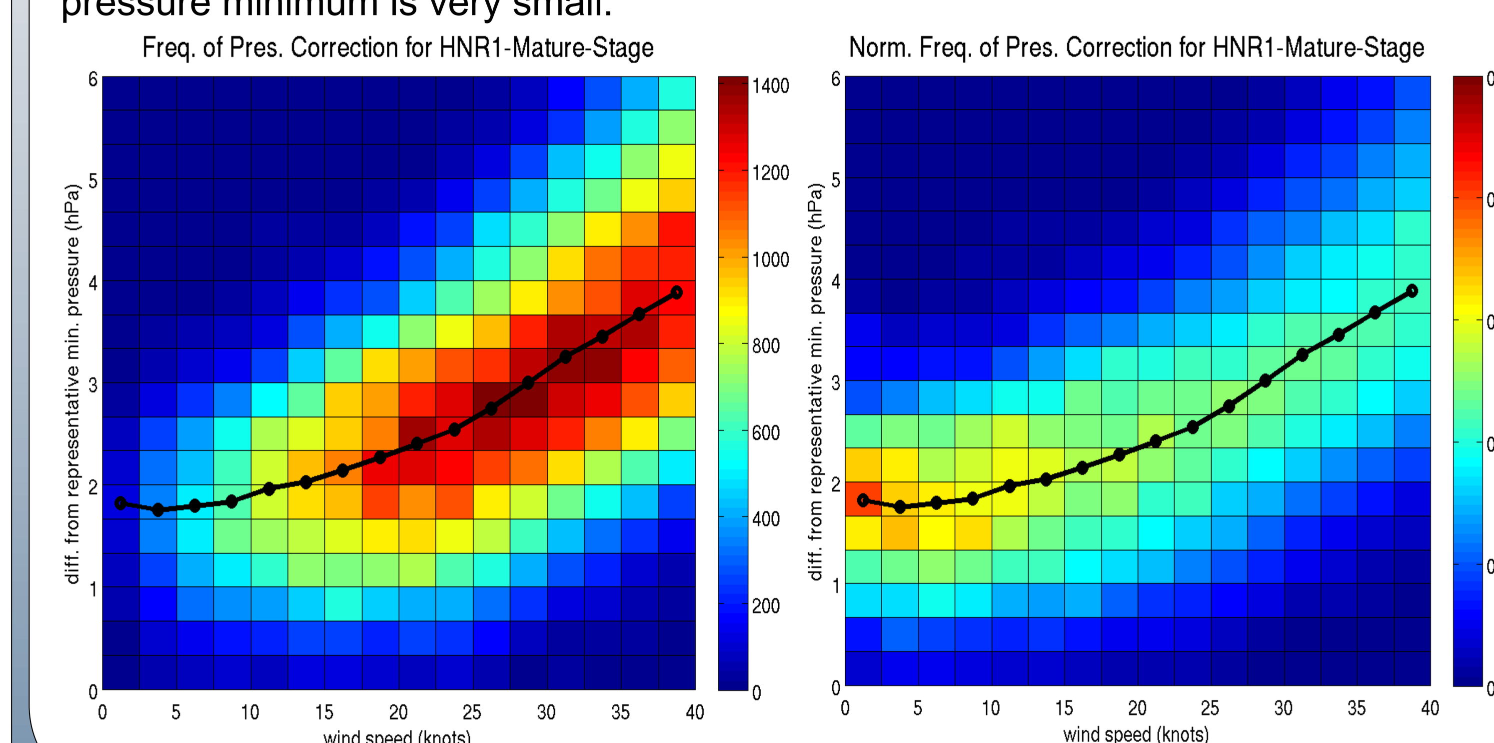
Impact of Model Differences

Right: For the simulations of Isabel, Bill, Ideal(ized) (Cat 5), and HNR1, Fourier decompositions at each normalized radius are calculated. The power at each wavenumber is then normalized based on the power of the maximum wind. HNR1 is able to obtain useful information past n ≈ 30 while simulations of Bill and Isabel only to n ≈ 15-20. Clearly, model differences can play a significant role in the underestimation statistics as seen in the previous tables.



Wind Pressure Centers

As a secondary goal of this work, the authors seek to improve the central pressure correction based on dropsonde observations. Typically, the surface pressure estimate is reduced 1 hPa for every 10 kt of wind at "splash." To evaluate this rule, we compute the surface wind speed and difference from the true minimum pressure at every grid point within 40 km of the center over a 6 hour period. These data points are binned into a joint histogram (**below left**). Normalizing each column by its total number of events shows a PDF of pressure correction for each wind speed (**below right**). At wind speeds of 25-40 kt, 1 hPa per 10 kt is about right. At very low wind speeds, a correction is still needed because the chance of hitting the true pressure minimum is very small.



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