NOAA Joint Hurricane Testbed (JHT)
Mid-Year Project Progress Report, Year 1

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Project Title:	Guidance on Observational Undersampling over the Tropical Cyclone Lifecycle
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1. Long-term Objectives and Specific Plans to Achieve Them

The intensity of a hurricane is defined by the maximum one-minute average wind speed that is associated with the storm. Recent studies using high-resolution hurricane simulations with very frequent output have explored the relationship between the highest directly observed wind speed and the contemporaneous maximum 1-minute wind. These studies, one using SFMR data from simulated reconnaissance flights (Uhlhorn and Nolan 2012, hereafter UH2012), and another for simulated surface observations (Nolan et al. 2014), both show that the peak reported winds generally underestimate the actual peak winds. For the SFMR winds, the inherent undersampling of the highly variable hurricane wind field causes the highest observed wind to underestimate the actual intensity by 7-10%. This is generally supportive of the National Hurricane Center practice that assumes it is unlikely the maximum 1-minute wind is observed. However, these results were drawn from a single high-resolution simulation of Hurricane Isabel (2003), using only the period when the storm was intense, highly symmetric, and in fairly steady state. Given the significant asymmetries in the wind fields of most tropical cyclones, the underestimates for more complex systems could be considerably larger. Indeed, the aforementioned study that simulated surface observations found that the underestimates depended also on the size and asymmetry of the storm. These more diverse structures were sampled from a high-resolution simulation of the complete life cycle of an Atlantic hurricane.

The goal of this study is to compute systematic underestimates of hurricane intensity as measured by airborne SFMR instruments, surface observations (such as ships or buoys), and satellite-borne scatterometers. The underlying data sets will be very high-resolution, high-quality simulations, the realisms of which have already been well documented. As needed, additional simulations will be generated that are representative of storm structures that are not available from the first two cases. The deliverable product will be guidance for forecasters and for post-season analysts as to how to interpret SFMR, scatterometer, and point measurements of surface winds and pressure for differing classes of tropical storms and hurricanes.

2. Mid-year Accomplishments:

a. Application of the simulated aircraft flights to new storms and calibration

The same procedures and codes used to produce the results published in UH2012 have been applied to model output from 5 additional simulations: Hurricane Nature Run 1 (HNR1, Nolan et al. 2013), Hurricane Nature Run 2 (HNR2, Nolan and Mattocks 2014), the Hurricane Bill (2009) simulation of Moon and Nolan (2015a,b), and two new idealized simulations using the idealized modeling system described in Nolan (2011). Along with being newer simulations with higher resolution (1 km versus 1.33 km) and more sophisticated parameterizations, all of these simulations provide model output every 6 minutes or less. The results in UH2012 used wind fields that were linearly interpolated from hourly model output. Also, sets of 8 figure four penetrations were simulated every 3 hours, rather than every 6 hours, simply to obtain more results. The flights were also repeated for the original Hurricane Isabel (2003) simulation.

The calibration procedure discussed in UH2012 was also repeated, which evaluates the extent to which the model simulations correctly reproduce wind asymmetries with sufficient amplitudes in comparison to the azimuthal mean wind. We found that most of the new simulations had even more realistic asymmetries than before, so the calibration step was actually not necessary.

b. Results for wind observations

As an example, Figure 1 shows the results of simulated flights into HNR1 every 3 hours from the tropical storm stage to the recurving stage. The black curve shows the peak surface wind, corrected to 1-minute means, every 6 min. The red curve is the running 6-h average which is equivalent to a 6-h representative “best track” intensity. The blue dots with error bars are the means and 95% confidence intervals produced from SFMR observations from 8 simulated figure-4 flights every 3 hours. The green curve is the maximum wind observed at any time by any of those 8 flights.

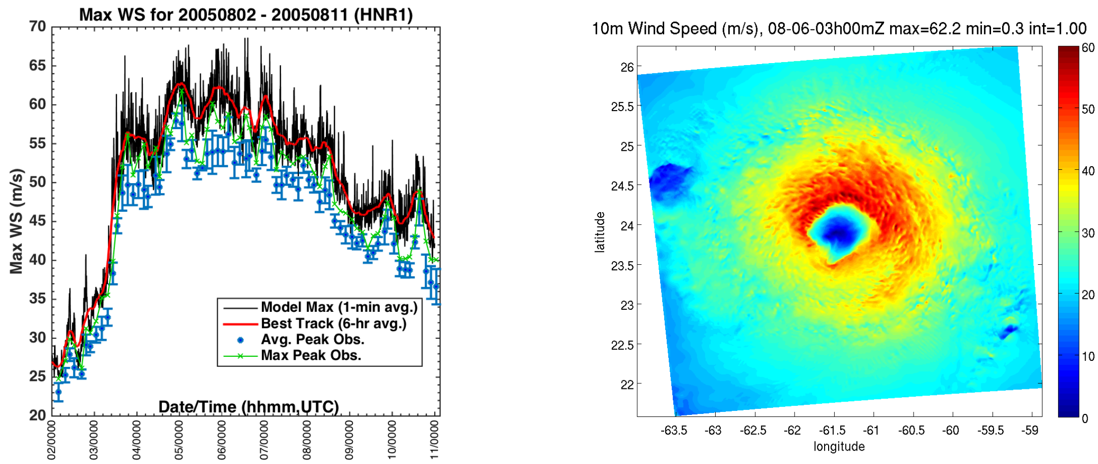

Figure 1: Results of SFMR measurements for simulated flights in HNR1 (left) and a sample surface wind field (right).

Figure 1 suggests that a typical SFMR-based analysis of the hurricane wind field will significantly underestimate the actual representative intensity. The mean underestimate shown in Fig. 1 is 11%. During the rapid intensification period, it is 14%. We believe the higher underestimate values, as compared to the previous results of 7-8%, are due to several factors: the increased horizontal and vertical resolution of the model, the more sophisticated radiation and microphysics schemes, and the larger size of the storm, which allows more mesoscale vortex features to exist at any one time.

However, some contradictory results have been found. The same analysis applied to a 24 hour period of the Hurricane Bill (2009) simulation (a period when 2-min output is available) found very low underestimates of intensity, about 4%, as shown in Figure 2. On the other hand, simulated flights into an idealized simulation of a category 5 hurricane produce underestimates of 7.5% (Figure 3), very similar to the original results of UN2012.

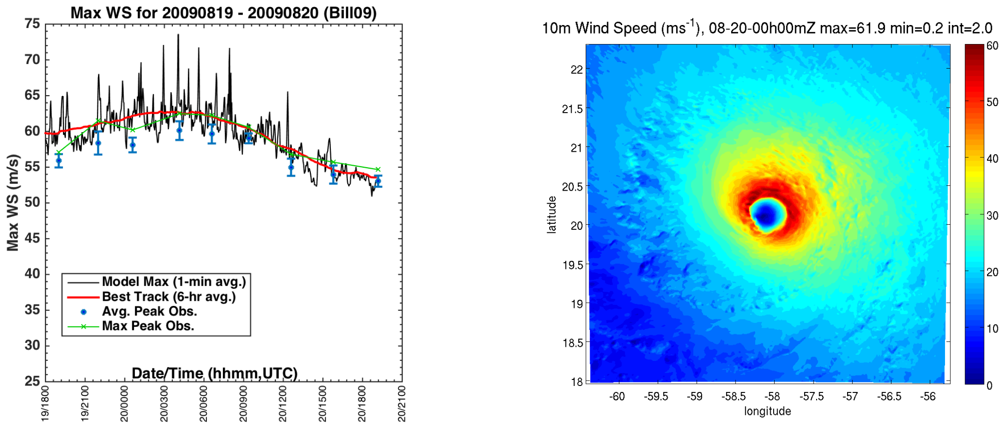

Figure 2: As in Figure 1, but for the simulation of Hurricane Bill (2009).

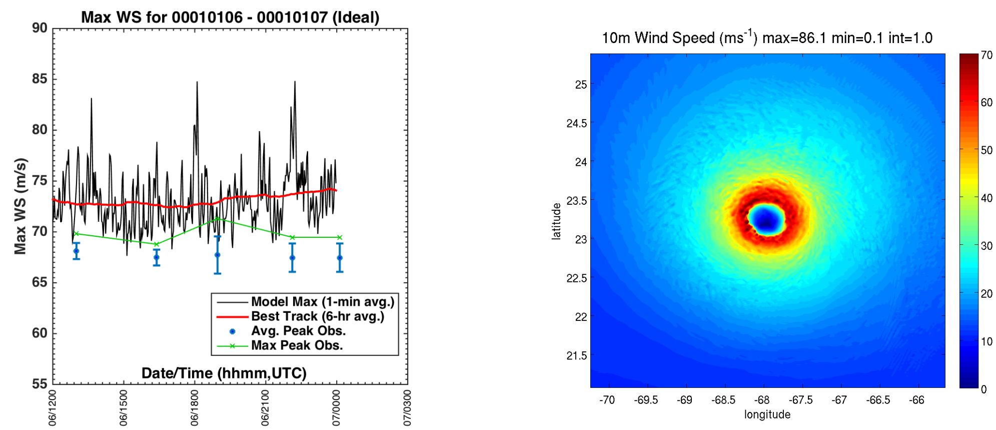

Figure 3: As in Figure 1, but for an idealized simulation of a category 5 hurricane.

Our results so far are summarized in Table 1 below. The two "nature run" simulations, which are high resolution simulations over entire TC life cycles, suggest higher undersampling rates of 10-14%. The idealized simulations suggest 7-8%. The Bill simulation is very low, at 4%.

To better understand these differences, we computed the power for each azimuthal wavenumber of the wind speed along the radius of maximum wind (RMW) as a function of azimuth around the storm. The resulting curves are shown in Figure 4. Consistent with the above results, the simulated hurricane in HNR1 has by far the most power at high wavenumbers (n > 30), meaning the small-scale features along the RMW have greater amplitudes as compared to the other storms, and thus an aircraft passing through the eye is less likely to observe the fastest winds. The idealized storm (category 5 version shown here) is next, followed by Isabel, and then Bill. If we attempt to generalize the results, they appear to show that simulated undersampling rates are larger for storms with more physics, smaller grid spacing, and larger eyewalls. The Bill results, on the other hand, seem to be anomalous.

	HNR1	HNR2	Bill	Isabel	Ideal (Cat 5)	Ideal (Cat 2)
Avg. 6-hr (m/s)	5.7 ± 0.4	6.3 ± 0.8	2.4 ± 0.8	4.6 ± 0.6	5.5 ± 0.7	3.9 ± 0.3
Min. 6-hr (m/s)	3.1± 0.4	4.0 ± 1.3	0.4 ± 0.9	1.7 ± 0.8	3.4 ± 1.5	1.3 ± 0.7
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

Table 1. Average underestimations of maximum surface winds for various tropical cyclone simulations are provided based on 6-hour mean model maxima. Additionally, the average minimum underestimate values (i.e. closest maximum wind speed to the model maximum) are provided for the same conditions. Average values are presented in m/s and as a percentage of the respective model maxima with 95% confidence intervals also indicated.

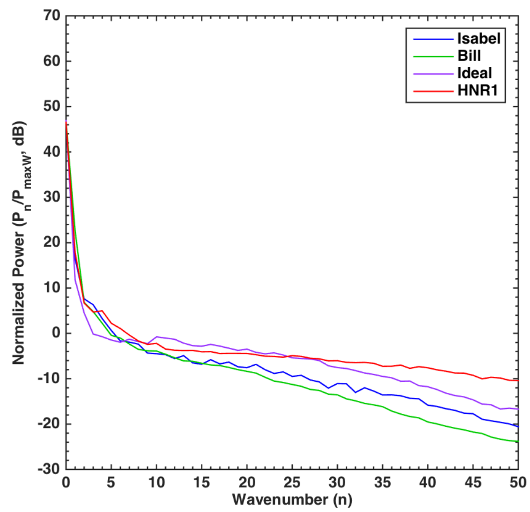

Figure 4: Normalized power for each azimuthal wavenumber of the total wind speed along the radius of maximum winds (RMW) as a function of azimuth around the storm.

c. New simulations

The result above indicate a strong dependence on model framework. Extensive experience validating research-quality hurricane simulations against observations (e.g., Nolan et al. 2009a,b; Nolan et al. 2013; Nolan and Mattocks 2014) lead us to believe that simulations with higher resolution, more advanced physics, and some accounting for air-sea interaction will produce more realistic hurricane wind fields. For this reason, we will re-run the Hurricane Bill simulation and the idealized simulations to have model physics as similar as possible to those of the two nature runs. The idealized simulations will also use the simple ocean cooling model, more realistic environmental wind shear, and fully interactive radiation with the diurnal cycle. Data for these cases will also be stored over most of the storms' lifecycles.

d. Other goals of the project

Our project has two other goals: a) to use a similar strategy to estimate corrections to near-surface pressures reported by dropsondes that land near the center but with significant wind speeds; b) to simulate peak wind undersampling by scatterometer overpasses. Preliminary results for goal (a) have shown that the current "rule of thumb" of reducing the observed minimum pressure by 1 hPa for every 10 knots of wind actually does quite well on average. More comprehensive results are being prepared at this time. Goal (b) will be taken on in earnest once the new hurricane simulations have been completed.

3. Current and Future Year 1 Efforts:

April 2014:	Systematic assessment of differences between surface wind speed surface pressures in the hurricane eye with application to correcting dropsonde "splash" pressures. Preparation of undersampling results for presentation at the 32nd AMS Conference on Hurricanes and Tropical Meteorology.
May-June 2014:	Hurricane Bill and idealized simulations will be repeated using the same physical parameterizations as used in the Hurricane Nature Runs.
July-August 2014:	Reevaluation of SFMR undersampling results with new simulations; further studies of surface wind and pressure differences near the centers of tropical cyclones.

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