NOAA/Joint Hurricane Testbed

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Guidance on Observational Undersampling over the Tropical Cyclone Lifecycle

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Annual Report

Final Annual Report: No

1. ACCOMPLISHMENTS

a. Project Goals and Planned Activities

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.

b. Activities

In the first half of Year 1, 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.

Sets of 8 figure four penetrations were simulated every 3 hours, rather than every 6 hours, simply to obtain more results.

Analyses and comparisons of these results found considerable inconsistencies. The undersampling estimates based on HNR1 and HNR2 tended to be very large, from 10-20%. The underestimates from the two idealized simulations were lower, 7-10%, and for the Bill simulation they were lower still, around 4%.

Based on these preliminary results, we decided it was necessary that all the simulations should have nearly identical resolutions, vertical levels, and model physics. This contingency was discussed and planned for in the original proposal. The Hurricane Bill simulation was repeated using the same model setup and parameters as HNR1 and HNR2, and in addition, two new idealized simulations were also generated. These two idealized simulations were designed to be different in terms of size and intensity, with one producing a very small and intense hurricane (category 5), and the other producing a broader and weaker cyclone (category 2). These simulations were completed during the second half of Year 1. All of the SFMR undersampling calculations were repeated for the updated simulations.

Also in accordance with the proposed activities, we also investigated the phenomenon of pressure undersampling in the eye. Currently, minimum surface pressure in a hurricane is frequently estimated from the final reported surface pressure made by dropsondes before they land in the ocean. Since it cannot be known if that pressure is the minimum value, NHC uses a correction based on the reported surface wind speed, reducing the estimate by 1 hPa per 10 knots of wind speed at “splashdown.” We set up a framework to assess this practice, by simulating thousands of reported dropsonde surface wind speeds and pressures by sampling model gridpoints at the surface over many model output times.

c. Results

Typical undersampling analyses are shown in Figure 1. The black and red curves show the peak 1-min surface wind and its 6-hour running mean, respectively. The blue dots show the mean of the peak surface wind observed by the SFMR on 8 simulated reconnaissance flights, where error bars represent the 95% confidence interval.

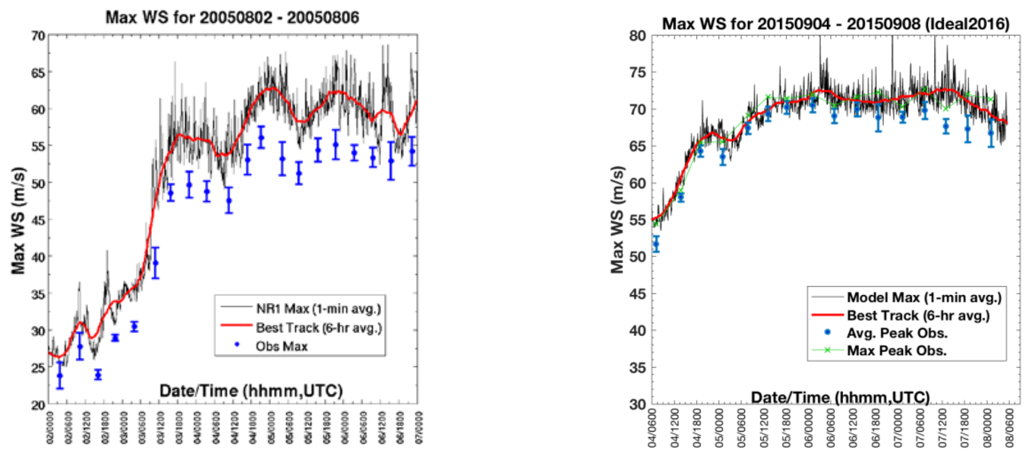

Figure 1: Undersampling results for HNR1 (left) and the new idealized simulation of an intense hurricane (right). Black curve shows peak 1-min mean wind every 6 or 5 min, respectively. Red curve shows running 6-hour mean. Dates for the idealized storm are fictional but used for comparison.

The cumulative results so far are summarized in Table 1. These show the mean values of the underestimate of the peak 1-min surface wind averaged during the approximately 1 hour for the aircraft to complete a figure 4 pattern, and also to the average over the coincident 6-hr synoptic perod, each in terms of actual wind speed (m/s) and in percentages. The original Isabel (2003) case is included from the original model output with 1.33 km grid spacing and simpler model physics.

Preliminary results from the study of undersampling for surface pressure values are shown in Figure 2. The *x* and *y* axes show the surface (10 m) wind speed and the difference between the pressure at that location and the lowest pressure value near the center of the storm, respectively (thus excluding any localized minima that might occur in the eyewall). The colors show the normalized frequency or likelihood that the two values will be observed together, and the black curve shows the mean pressure difference for each wind range. These results show that the rule of 1 hPa per 10 knots of wind is actually pretty good for large wind speeds, but for small wind speeds there should still be some reduction in pressure, because the chance of hitting the true pressure minimum is still very small.

	Avg. 1-hr (%)	Avg. 1-hr (m s^{-1})	Avg. 6-hr (%)	Avg. 6-hr (m s^{-1})
Isabel (2003)	7.3 ± 1.0	4.6 ± 0.6	7.3 ± 1.0	4.6 ± 0.6
Bill (2009)	4.8 ± 0.5	3.0 ± 0.3	4.9 ± 0.6	3.1 ± 0.4
Ideal (Category 2)	7.8 ± 1.5	3.7 ± 0.7	8.1 ± 0.7	3.9 ± 0.3
Ideal (Category 5)	7.9 ± 1.7	5.8 ± 1.4	7.5 ± 1.0	5.5 ± 0.7
Ideal (SST = 29 C)	8.6 ± 1.8	3.4 ± 0.4	9.1 ± 1.7	3.7 ± 0.4
Ideal (SST = 27 C)	12.7 ± 1.2	5.0 ± 0.4	12.9 ± 1.2	5.1 ± 0.4
HNR1	10.9 ± 0.6	5.5 ± 0.4	11.4 ± 0.8	5.7 ± 0.4
HNR2	16.1 ± 1.6	6.3 ± 0.7	16.5 ± 1.9	6.4± 0.7
HNR1 (TS)	11.7 ± 4.5	3.2 ± 1.4	12.7 ± 6.2	4.0 ± 2.5
HNR1 (RI)	14.0 ± 2.4	6.4 ± 2.1	13.3 ± 5.7	5.5 ± 3.5
HNR1 (Small)	11.5 ± 1.5	6.2 ± 0.9	12.4 ± 1.8	7.0 ± 1.2
HNR1 (Mature)	10.7 ± 1.2	6.5 ± 0.8	10.8 ± 1.1	6.7 ± 0.6
HNR1 (Recurving)	11.1 ± 1.8	5.3 ± 0.8	11.5 ± 2.0	5.4 ± 0.9

Table 1. Average underestimations of maximum surface winds for various tropical cyclone simulations are provided based on 1-hr and 6-hour mean model maxima of 1-min surface wind. Average values are presented in m/s and as a percentage of the respective model maxima with 95% confidence intervals also indicated.

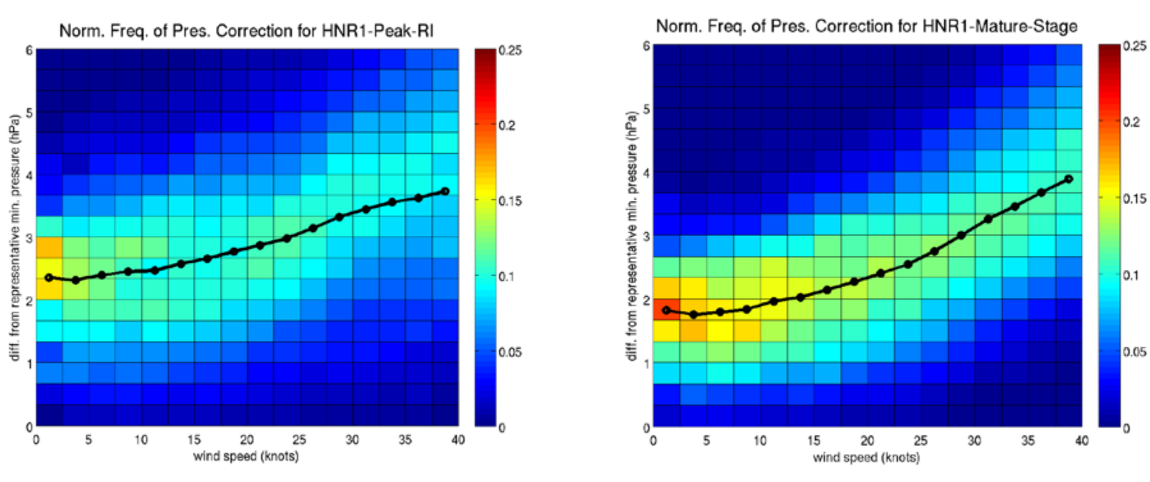

Figure 2: Frequency of surface pressure overestimates as a function of surface wind speed for two different stages of the TC life cycle as simulations in HNR1: First peak intensity after RI (left), and mature stage (right). Black dots show mean overestimate for each wind speed category.

Returning to the issue of wind speed undersampling, we have proposed that SFMR undersampling depends on storm intensity, storm size, and storm asymmetry. To test this hypothesis, we computed correlations between the undersampling value and measures of the above-mentioned descriptors: storm intensity based on the maximum azimuthal mean surface wind; storm size based on the radius of maximum azimuthal surface wind; and storm asymmetry based on the relative amplitudes of the wavenumber 1 and 2 surface wind asymmetries to the maximum azimuthal mean surface wind. These metrics were designed to be similar to what NHC forecasters might be able to ascertain in real time. Figure 3 shows the combined results of these correlations for the two idealized hurricane simulations, the two nature run simulations, and the Bill simulation. Clearly, the undersampling percentage depends strongly on all three parameters, although surprisingly, the asymmetry parameter shows the least correlation.

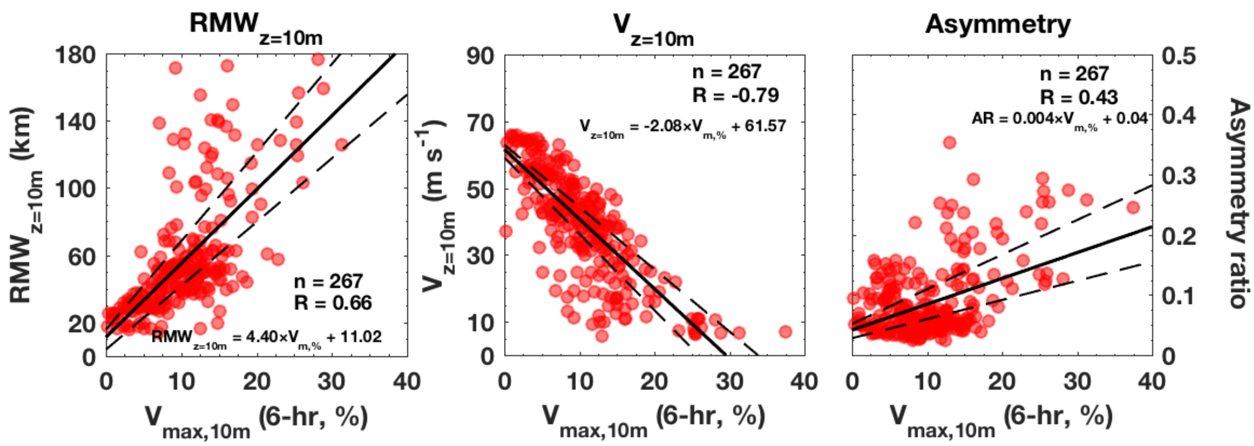

Figure 3: Scatterplots and linear fits of undersampling rate (in percentage) of the 6-hour mean peak intensity as a function of the RMW at the surface (left), azimuthal mean wind speed at the surface (middle) and the asymmetry parameter.

d. Plans for the next reporting period

In the next 6 months, we will continue to refine the results above and to develop a strategy to make them accessible and useful to NHC forecasters in real time. We will also start work on the final goal of our project, which is to compute undersampling estimates for scatterometer overpasses. We will simulate scatterometer overpasses by smoothing the data from the native 1 km model resolution onto grids with appropriate resolutions, such as 50 km (e.g., ASCAT) or 25 km (e.g., future instruments). Peak winds on these grids will be compared to the actual peak winds, and we will explore ways to predict the underestimate purely from the scatterometer wind field itself.

2. PRODUCTS

No major products or deliverables were planned for Year 1. We gave a presentation at the IHC and we presented a poster at the AMS Conference on Hurricanes and Tropical Meteorology:

Klotz, B. W., D. S. Nolan, and E. W. Uhlhorn, 2016: Further studies in observational undersampling in flight-level and SFMR observations. Available from http://ams.confex.com.ams/32Hurr/webprogram/Paper293604.html

3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

The PI, Dr. David Nolan, and Mr. Bradley Klotz of NOAA/HRD/CIMAS, have worked on this project.

Originally, Dr. Eric Uhlhorn of NOAA/HRD was also a PI for this project. However, he departed NOAA for private industry in November 2015. Mr. Klotz was assigned to replace him and to perform much of the analyses originally intended for Dr. Uhlhorn.

Other than UM/RSMAS/CIMAS and NOAA/HRD, no other organizations have been involved.

4. IMPACT

No impact at this time.

5. CHANGES/PROBLEMS

There have been no significant changes to the project plan or activities.

6. SPECIAL REPORTING REQUIREMENTS

At the present time, the results from this project can be characterized by readiness levels RL3 and RL4.

7. BUDGETARY INFORMATION

With the departure of Dr. Uhlhorn, the funds originally intended for his salary were redirected to increase support at CIMAS for Mr. Klotz. No other changes were made to the budgets, and budget expenditures are on track.

8. PROJECT OUTCOMES

As of yet there are no project outcomes.

9. REFERENCES

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Nolan, D. S., J. A. Zhang, and E. W. Uhlhorn, 2014: On the limits of estimating the maximum wind speed in hurricanes. *Mon. Wea. Rev*., **142**, 2814-2837.

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