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 SFMR, UH2012 found that the inherent undersampling of the highly variable hurricane wind field causes the highest observed wind to underestimate the actual intensity by 7-10%. 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 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 Nolan et al. (2014) 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, satellite-borne scatterometers, and dropsonde estimates of minimum central pressure. The underlying data sets are very high-resolution, high-quality simulations, the realisms of which have already been well documented: Hurricane Nature Run 1 (HNR1) and Hurricane Nature Run 2 (HNR2). In Year 1, three additional simulations were generated that are representative of storm structures that are not available from the first two cases: these include a simulation of Hurricane Bill (2009) and two idealized hurricanes that achieve Category 2 and Category 5 intensity.

The deliverable product from this project is 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. Year 2 Activities and Results*

The work done in Year 2 has culminated in the completion of the primary stated goal of the project, which is the production of a short document that has been delivered to the NHC staff which provides guidance as to how to adjust wind observations in tropical storms and hurricanes to account for the effect of undersampling (Nolan and Klotz 2017). The form of the document was modeled after an earlier document that provides guidance for how to convert flight-level winds, and low-level wind speeds reported by dropsondes as they fall through the hurricane boundary layer, into surface wind speeds (Franklin 2001). This new document provides guidance for 4 kinds of observations: 1) SFMR measurements of surface wind speed; 2) surface wind estimates from satellite scatterometers; 3) surface winds reported by fixed instruments; 4) minimum surface pressure estimates from dropsondes or surface instruments. Where possible, the document provides different undersampling corrections for storms of different intensities and different size.

The guidance is provided in terms of the *undersampling correction* ($C_U$) which has units of percentage. This is the amount that a particular peak wind speed should be increased so as to most likely provide the "best track" wind speed, which is the mean peak wind speed during the synoptic period of interest, such as the 6 hours around 00Z on a given day. Two tables from the guidance document are reproduced below.

The first draft of the document was provided to our NHC contacts on June 13, 2017. After two rounds of revisions, a final version was accepted on September 20, 2017.

| Undersampling Corrections for a Single Figure-4 | | | |
|---|---|---|---|
| Size/Category | Tropical Storm | Category 1-2 | Category 3-5 |
| Small<br>RMW < 15 nm | 10% | 5% | 2% |
| Medium<br>15 nm < RMW < 30 nm | 15% | 9% | 5% |
| Large<br>RMW > 30 nm | 19% | 11% | 8% |

Table 1: Undersampling corrections ($C_U$) that should be made to peak winds that result from a single, complete "figure-4" survey of a tropical storm or hurricane with an aircraft-borne SFMR. RMW refers to the radius of maximum surface winds.

| Undersampling Corrections for Scatterometer Winds (Category 1 and less only) | | |
|---|---|---|
| Resolution | Ignore Rain Flag | Respect Rain Flag |
| 12.5 km | 17% | 20% |

Table 5: Undersampling corrections ($C_U$) for scatterometers, for up to category 1 winds, and assuming complete coverage of the TC core.

*c. Plans for the next reporting period*

A one-year no-cost extension has been granted for this project. The guidance document will not be used operationally in the 2017 hurricane season. After the season, Drs. Nolan and Klotz will continue to work with NHC to evaluate the document and its potential utility, and to make any improvements that are needed. The remaining funds will be used to support travel to conferences, such as the Interdepartmental Hurricane Conference or the AMS Conference on Hurricanes and Tropical Meteorology.

Please see the end of this document for the requested “Test Plan Outline.” This has been updated since the mid-year report.

## 2. PRODUCTS

In 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

Presentations with more results were presented by the PI at the 2016 AGU meeting in San Francisco and at the 2017 AMS Meeting in Seattle. The latter is recorded and available online:

Nolan, D. S., and B. W. Klotz, 2017: Further studies of observational undersampling of the surface wind and pressure fields in the hurricane core. 97th Annual Meeting of the American Meteorological Society, Seattle, WA. Recorded presentation available from: https://ams.confex.com/ams/97Annual/webprogram/Paper306107.html

A report has been produced that provides guidance on how to convert surface wind measurements into likely best-track wind speeds, account for the effects of undersampling – see Nolan and Klotz (2017) in the references.

## 3. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

The PI, Dr. David Nolan, and Dr. 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 Dr. Klotz. No other changes were made to the budgets, and budget expenditures are on track.

## 8. PROJECT OUTCOMES

A report has been produced that provides guidance on how to convert surface wind measurements into likely best-track wind speeds, account for the effects of undersampling – see Nolan and Klotz (2017).

## 9. REFERENCES


Franklin, J. L., 2001: Guidance for reduction of flight-level observations and interpretation of GPS dropwindsonde measurements.

Moon, Yumin, and David S. Nolan, 2015: Spiral rainbands in a numerical simulation of Hurricane Bill (2009). Part I: Structures and comparisons to observations. *J. Atmos. Sci*., **72**, 164-190.

Nolan, D. S., 2011: Evaluating environmental favorableness for tropical cyclone development with the method of point-downscaling. *J. Adv. Model. Earth. Syst*., **3**, Art. M08001.

Nolan, D. S., R. Atlas, K. T. Bhatia, and L. R. Bucci, 2013: Development and validation of a hurricane nature run using the joint OSSE nature run and the WRF model. *J. Adv. Model. Earth. Syst*., **5**, 1-24.

Nolan, D. S., and B. W. Klotz: Guidance for adjustments to in-situ observations of wind and pressure over the tropical cyclone life cycle. Submitted for consideration to the National Hurricane Center.

Nolan, D. S., and C. Mattocks (2014): Development and evaluation of the second hurricane nature run using the joint OSSE nature run and the WRF model. *Preprints, AMS 31st Conference on Hurricanes and Tropical Meteorology,* San Diego.

Nolan, David S., Daniel P. Stern, and Jun A. Zhang, 2009: Evaluation of planetary boundary layer parameterizations in tropical cyclones by comparison of in-situ data and high-resolution simulations of Hurricane Isabel (2003). Part II: Inner-core boundary layer and eyewall structure. *Mon. Wea. Rev.*, **137**, 3675-3698.

Nolan, D. S., J. A. Zhang, and D. P. Stern, 2009: Evaluation of Planetary Boundary Layer Parameterizations in Tropical Cyclones by Comparison of In Situ Observations and High-Resolution Simulations of Hurricane Isabel (2003). Part I: Initialization, Maximum Winds, and the Outer-Core Boundary Layer. *Mon. Wea. Rev*., **137**, 3651-3674.

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.

Uhlhorn, E. W. and D. S. Nolan, 2012: Observational undersampling in tropical cyclones and implications for estimated intensity. *Mon. Wea. Rev*., **140**, 825-840.

# TEST PLAN OUTLINE

I. What **concepts/techniques** will be tested? What is the scope of testing (what will be tested, what won't be tested)?

*What will be tested is quantitative guidance for how to interpret and adjust in-situ measurements of wind speeds and pressures in tropical storms and hurricanes so as to provide the best estimate of "best-track" intensity (maximum 1-minute sustained wind speed averaged over a 6 hour period).*

II. **How** will they be tested? What **tasks** (processes and procedures) and activities will be performed, what preparatory work has to happen to make it ready for testing, and what will occur during the experimental testing?

*Our project results have been delivered in the form of contingency tables or similar simple guidelines. They will not be used by forecasters during the 2017 hurricane season. Our expectation is that the guidance will be used in the off-season during the development of the best-track analyses and the tropical cyclone reports, with comparisons to results that do not use the guidance.*

III. **When** will it be tested? What are **schedules and milestones** for all tasks described in section II that need to occur leading up to testing, during testing, and after testing?

*During the 2017-2018 hurricane off-season, and during the 2018 hurricane season.*

IV. **Where** will it be tested? Will it be done at the PI location or a NOAA location?

*Testing will occur at NHC.*

V. Who are the key **stakeholders** involved in testing (PIs, testbed support staff, testbed manager, forecasters, etc.)? Briefly what are their **roles and responsibilities**?

*The stakeholders are the PI, NHC, and its forecasters. The PI's role is to provide the most accurate undersampling estimates possible, and to provide them in a manner that is useful in real-time forecasting. The NHC role is to use the guidance and to assess its accuracy and utility.*

VI. What **testing resources** will be needed from each participant (hardware, software, data flow, internet connectivity, office space, video teleconferencing, etc.), and who will provide them?

*No resources are required.*

VII. What are the **test goals, performance measures, and success criteria** that will need to be achieved at the end of testing to measure and demonstrate success and to advance Readiness Levels?

*There will be two aspects of success: first, in post-season analysis, if it appears that the guidance would have had a positive impact in improving real-time analyses of tropical cyclone intensity; and second, whether NHC forecasters will actually use the guidance in real-time in the future.*

VIII. How will testing **results** be documented? Describe what information will be included in the **test results final report**.

*In spring of 2018 we will work with NHC hurricane specialists to learn how the guidance influenced the post-season best track analyses. These findings will be put in the final report.*