NASA Hurricane and Severe Storm Sentinel (HS3) Observations for Testing Environmental Control of Hurricane Formation and Intensification

Russell L. Elsberry
Department of Meteorology
Naval Postgraduate School
Monterey, CA 93943-5114
phone: (831) 656-2373 fax: (831) 656-3061 e-mail: elsberry@nps.edu

Patrick A. Harr
Department of Meteorology
Naval Postgraduate School
Monterey, CA 93943-5114
phone: (831) 656-3787 fax: (831) 656-3061 e-mail: paharr@nps.edu

Award Number: N0001414WX20029

LONG-TERM GOAL

The long-term goal is to utilize the NASA Global Hawk unmanned aircraft observations to advance understanding of Atlantic tropical cyclone formation and intensification.

OBJECTIVES

Advancement in the understanding and prediction of tropical cyclone formation and intensification requires observational studies of the combined effects of vertical wind shear, evaporational cooling in saturated convective-scale downdrafts, and the physical processes occurring along two air streams: (i) an equatorial source of warm, moist air with maximum winds in the lower troposphere; and (ii) a subtropical source of cool, dry air with maximum winds in the mid-troposphere. Although a mesoscale convective circulation is considered to be an essential element, it is hypothesized that the environmental properties in the two air streams control the timing and location of the formation of the tropical cyclone. Global Hawk observations are required along both air streams flowing into the region of the pre-tropical cyclone seedling. The objectives are to document the environmental conditions and the physical processes that lead to the spinup of the mesoscale vortex that becomes the inner core of the tropical cyclone to the southeast of the synoptic-scale circulation center, but inhibit formation to the northwest. The two long-duration, high altitude NASA Global Hawks devoted to Environmental and Over-Storm missions with various remote sensing instruments are uniquely suited for these required observational studies.

Mission planning for a field experiment observing a relatively rare event such as a mature tropical cyclone can be rather difficult when an expensive and heavily-instrumented platform is only available for a limited amount of time and with a limited number of flight hours. Questions may include: Will a target storm be available within the range of the aircraft in the first (of five) week? If not in the first...
week, in the second week? If a rather marginal storm is available early in the field experiment, should that storm be observed or wait for better storms later? Will there be a 2+ week gap of no storms during the field experiment due to unfavorable phase of the Madden-Julian Oscillation?

Our research team had provided extended-range forecast support for the Impact of Typhoons on the Ocean in the Pacific (ITOP) during August-October 2010 utilizing the 51-member European Center for Medium-range Weather Forecasts (ECMWF) 32-day ensemble predictions. These ensemble predictions made twice a week were able to predict the formation and subsequent tracks of typhoons and many tropical storms and depressions 3-4 weeks in advance. In addition, the ECMWF ensemble was able to predict a three-week period of no tropical cyclones in the western North Pacific during the climatologically active time in the typhoon season. The second objective was to provide such extended-range tropical cyclone forecasts of formation and tracks in support of HS3.

**APPROACH**

We have participated in the 2012, 2013, and 2014 HS3 field experiments to obtain NASA Global Hawk (GH) observations to test two hypotheses related to environmental properties favorable or unfavorable for tropical cyclone formation. Observations were sought along a warm and moist air stream flowing into a convective burst region to the southeast of the pre-tropical seedling circulation center that leads to the spin-up of a mesoscale vortex that then becomes the inner core of the tropical cyclone. Observations were also sought along a cool and dry air stream on the northern side to verify a physically-based hypothesis for why such a lower-level mesoscale vortex does not form to the northwest of the circulation center. Unfortunately, the 2013 field experiment period had few storms and none were sampled in the formation stage. It was particularly discouraging that the AV1 Global Hawk achieved few missions during 2013 and none in 2014.

Because we were proposing to provide extended-range forecast support for HS3, the ECMWF provided in real-time (about synoptic time plus 12 h) the tracks of all tropical cyclone-like vortices in the Atlantic predicted by the 51 members over the 15-day and 32-day forecast intervals. We combined those vortices with similar formation locations and similar tracks into “ensemble storms.” A special aspect of our approach is to not assume equal likelihood to all ensemble vortices; rather, we discard all tracks less than 72 h and give greater (smaller) weight to the 12-h motion vectors of vortices that are close (far from) the position at the end of the prior 12-h period. Although we had no prior experience with extended-range forecasts of Atlantic tropical storms, we also subjectively discarded any ensemble storms that were likely to be false alarms based on our previous experience in the western North Pacific (Tsai et al. 2013).

Beginning in mid-August 2013 and 2014 as HS3 was getting organized, we provided the mission planning team Week 1, Week 2, Week 3, and Week 4 forecasts of tropical cyclones twice a week. During the El Niño-like year in 2014, the focus was the twice-daily ECMWF 15-day ensemble forecasts to provide Atlantic tropical cyclone formation and track guidance. Although these 15-day forecasts are delayed relative to the 5-day deterministic NCEP GFS and ECMWF forecasts used by the HS3 forecast team, the longer-tracks from the ECMWF 15-day ensemble provided useful guidance for mission planning. When AV1 was cancelled, and the possibility was raised that the WB57 with the two instruments from AV1 might be deployed from San Diego into eastern North Pacific tropical cyclones, we made available the 15-day forecasts for that basin.
Special observations from the NOAA Gulfstream 4 and WP3 aircraft and the U. S. Air Force recon aircraft in intensifying Tropical Storm (TS) Arthur during July 2014 may be a unique data set to test our hypotheses regarding intensity and structure changes. With the new tail Doppler radar on the Gulfstream 4, a three-dimensional description from the tropopause to the ocean surface is available. As also indicated from recent simulation studies by Prof. Rob Fovell’s research team, the deep layer of ascent to large radius on the east side of TX Arthur should lead to an expansion of the vortex. This size change is hypothesized to be similar to the Mode 1 outer wind structure changes in Stenger and Elsberry (2014).

RESULTS

During the past year and a half, Professor Pat Harr has been working with NASA and other government agency researchers to explore opportunities for Global Hawk deployment to the western North Pacific following HS3. The experiences gained from the 2012 and 2013 HS3 field experiments have been very helpful in the preparation of the NASA OUTFLOW proposal.

An evaluation of the performance of the ECMWF 32-day ensemble in predicting the formations and tracks of the Atlantic tropical storms and hurricanes from May 31 to December 17, 2012 was published in Weather and Forecasting (Elsberry et al. 2014). The primary focus was the characteristics of the successful forecasts, especially during the HS3 experiment when the formations and subsequent tracks were generally well forecast. However, both the early season and late season storms (including Superstorm Sandy) had more limited success with only the early portions of the tracks being forecast. The most surprising result from the 2012 Atlantic season was that the twice weekly ECMWF 32-day ensemble predictions did not forecast during any of the four weeks three baroclinically-forced storms [Hurricanes Chris (AL03) and Michael (AL13) and Tropical Storm Tony (AL19)] and Tropical Storm Patty, which was a short-lived storm that formed at 25ºN, 74ºW from mesoscale processes. Thus, the overall extended range forecastability of Atlantic tropical cyclones during the 2012 season was considerably less than we have documented in the western North Pacific (Tsai et al. 2013).

Elsberry and Tsai (2014) used the same procedures developed for the extended-range forecasts with the ECMWF seasonal forecasts from 1 May, 1 June, and 1 July 2012. While useful information was provided on the African Easterly Wave (AEW) type of storms that have westward tracks that may threaten the United States. The ECMWF seasonal forecasts for the 2012 Atlantic season essentially had no skill for subtropical formations with northward tracks or the late season tracks that started at low latitudes and moved northward due to strong interaction with the midlatitudes. It is important that these are generally the same storms that the ECMWF extended-range predictions failed to forecast even one week in advance. More importantly, this result suggests an important predictability limitation for Atlantic tropical cyclones. One outcome of the HS3 observational and modeling studies may be to improve understanding and prediction of these difficult-to-forecast tropical cyclones.

IMPACT/APPLICATIONS

This new understanding of the physical processes and the unique data sets will provide the basis for improved numerical model predictions of tropical cyclone formation (and non-formation) and intensification, and ultimately lead to better forecasts and warnings for the Fleet and DoD bases.
RELATED PROJECTS

This research is closely related to the ONR project (N0001414WX210461) entitled “Transition of the 32-day and 15-day forecasts of tropical cyclone events to operations in the western North Pacific and extension to other global basins.”

REFERENCES


PUBLICATIONS

