SYNOPTIC FLOW EXPERIMENT
Science Description

Experiment/Module: Synoptic Flow Experiment

Investigator(s): Jason Dunion (Co-PI), Sim Aberson (Co-PI), Kelly Ryan, Jason Sippel, Rob Rogers, Ryan Torn (SUNY Albany), Eric Blake (NWS/NHC), Mike Brennan (NWS/NHC), Chris Landsea (NWS/TAFB) (Co-Is)

Requirements: No requirements: flown at any stage of the TC lifecycle

Science Objective(s):

1) Investigate new strategies for optimizing the use of aircraft observations to improve numerical forecasts of TC track, intensity, and structure [*IFEX Goal 1*]

Motivation: Operational G-IV Synoptic Surveillance missions have resulted in average GFS track-forecast improvements of 5–10% and statistically significant intensity improvements through 72 h (Aberson 2010). However, the basic G-IV flight-track design and observational sampling strategies have remained largely unchanged for the past decade while the model, ensemble and data-assimilation systems have been upgraded considerably. The Synoptic Flow Experiment is designed to investigate new strategies for optimizing the use of aircraft observations to improve numerical forecasts of TC track, intensity, and structure.

Background: Accurate numerical TC forecasts require the representation of meteorological fields on a variety of scales, and the assimilation of the data into realistic models. Based on this requisite, HRD re-designed synoptic surveillance in 1998 to improve track predictions of TCs during the watch and warning period by targeting GPS dropsonde observations in the storm environment and assimilating those data into numerical models. Optimal sampling was attained using a fully nonlinear technique that employed the breeding method, the operational NCEP ensemble-perturbation technique at the time, in which initially random perturbations in the model were repeatedly evolved and rescaled. This technique helped define the fastest growing modes of the system, where changes to initial conditions due to additional data grow (decay) in regions of large (small) perturbation in the operational NCEP Ensemble Forecasting System. Although this approach provided a good estimate of the locations in which supplemental observations are likely to have the most impact by identifying locations of probable error growth in the model, it did not distinguish those locations which impact the particular TC forecast of interest from those which do not. The G-IV flight track designs and targeting techniques developed from the series of 1996–2006 HRD Synoptic Flow Experiments were transitioned to operations at NOAA NHC and AOC in 2007 and have continued to be an integral part of operations since then. These operational missions resulted in average GFS track-forecast improvements of 5–10% and statistically significant intensity improvements through 72 h (Aberson 2010).

Recently, an ensemble-based targeting method has emerged that can provide an a priori estimate of the impact of hypothetical observations on forecast metrics, including TC track and intensity (e.g., Ancell and Hakim 2007, Torn and Hakim 2008, Torn 2014). This technique is advantageous because it can compute target locations for metrics directly tied to TCs, combines the data assimilation system with forecast sensitivity analysis, and is inexpensive. It also combines sensitivity information with forecast uncertainty, which makes it more likely that assimilating observations in a target region will reduce forecast uncertainty for the particular metric of interest (e.g., 72-hr track uncertainty). During the 2015-2016 NOAA SHOUT and 2017 NOAA UAS field campaigns, the ensemble-based sensitivity method was applied to real-time ensemble forecasts to determine optimal locations for Global Hawk-deployed GPS dropsonde observations (Dunion et al. 2018). These analyses were derived from 80-member HWRF and 52-member ECMWF model ensembles.

Hypotheses:

1. New, more advanced targeting techniques that optimize aircraft sampling of the TC environment can improve numerical forecasts of TC track, intensity, and structure, and could potentially be transitioned to operations.

Aircraft Pattern/Module Descriptions (see *Flight Pattern* document for more detailed information):

P-3 Pattern 1: When ensemble prediction systems suggest sensitivity of TC-related forecast metrics (e.g., track, intensity, and structure) in/near the inner core (i.e., R≤105 n mi/R≤195 km), fly any standard pattern that provides symmetric coverage (e.g., Figure-4, Rotated Figure-4, Butterfly, P-3 Circumnavigation).

G-IV Pattern 1: When ensemble prediction systems suggest sensitivity of TC-related forecast metrics (e.g., track, intensity, and structure), fly a non-standard pattern that will vary from storm to storm and be defined by regions that are identified using model targeting techniques. These patterns will typically resemble a Lawnmower pattern and can be flown at any time during the mission, including during the ferries to/from the storm. The over storm or near storm portion of the pattern could incorporate the following standard patterns: Figure-4, Rotated Figure-4, Butterfly, Lawnmower, Square Spiral, G-IV Circumnavigation, G-IV Star, or G-IV Star with Circumnavigation. In order to maintain consistency with NOAA NHC operational Synoptic Surveillance missions, an outer circumnavigation at R=180 n mi (335 km) should be flown. If time and conditions permit, a second inner circumnavigation at R=60-90 n mi (110-165 km) is also desirable.

G-IV Pattern 2: When 2 or more TCs (or invests) are interacting with each other, fly a multi-part pattern in addition to G-IV Pattern 1 which focuses on the non-priority TC in the interaction. This pattern must be flown in coordination with P-3 and G-IV sampling for the priority TC. The plans will vary depending on the interacting TCs, their distance apart, and mission turn-around time. The two parts include symmetric, storm-centered sampling of the near-TC/outer-core conditions (R≥90-105 n mi/165-195 km), and sampling in the joint environment through which the TCs are interacting.

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Links to Other Mature Stage Experiments/Modules: This experiment can be flown in conjunction with nearly all HFP *Genesis*, *Early*, and *Mature Stage* experiments. P-3 and/or G-IV GPS dropsonde targeting can also be performed during ferries to/from targets of interest (e.g., African easterly wave, invest or TC).

Analysis Strategy: Guidance from ensemble prediction systems (e.g., ECMWF and HWRF) will be used to compute the sensitivity of TC-related forecast metrics (e.g., track, intensity and structure) and will be used to guide GPS dropsonde sampling of the TC and its environment. Retrospective data denial experiments will be conducted post mission to assess the impact of the GPS dropsonde, TDR, and HDob data on model forecasts of TC track, intensity and structure.

References:

Aberson, S.D., 2010: 10 years of hurricane synoptic surveillance (1997–2006). *Mon. Wea. Rev.*, **138**, 1536–1549.

Ancell, B., and G.J. Hakim, 2007: Comparing adjoint and ensemble-sensitivity analysis with applications to observation targeting. *Mon. Wea. Rev.*, **135**, 4117-4134.

Dunion, J.P., G. Wick, P. Black, and J. Walker, 2018: Sensing Hazards with Operational Unmanned Technology: 2015–2016 Campaign Summary, Final Report. NOAA Tech Memo. OAR-UAS-001, 39 pp.

Torn, R.D., and G.J. Hakim, 2008: Ensemble-based sensitivity analysis. *Mon. Wea. Rev.*, **136**, 663-677.

Torn, R. D., 2014: The impact of targeted dropwindsonde observations on tropical cyclone intensity forecasts of four weak systems during PREDICT. *Mon. Wea. Rev.*, **142**, 2860– 2878.