**4. Doppler Wind Lidar (DWL) Experiment**

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**Links to IFEX:**

* **Goal 1:** Collect observations that span the TC life cycle in a variety of environments for model initialization and evaluation.
* **Goal 2:** Develop and refine measurement technologies that provide improved real-time monitoring of TC intensity, structure, and environment.
* **Goal 3:** Improve understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle.

**Motivation:** Currently there are limited continuous high-resolution wind observations in the TC boundary layer and in regions of low or no precipitation. A coherent-detection Doppler wind profile (P3DWL) system will be available for the 2017 hurricane season onboard NOAA-43. P3DWL can collect wind profiles through the detection of aerosol scatters motion in areas of optically thin or broken clouds or where aerosols are ~1 micron or larger. A secondary goal is to use the data to understand physical processes in data sparse regions such as in the boundary layer, Saharan Air Layer (SAL), regions in-between rainbands, and in the ambient tropical environment around the TC.

**Background:** The P3DWL was previously used in the West Pacific field campaign THORPEX in 2008 for typhoon research (Pu et al. 2010). The study showed P3DWL data collected in the near storm environment improved both the track and intensity of one TC forecast. However, no in storm measurements were presented. NASA’s DAWN lidar was the first coherent lidar flown in an Atlantic tropical cyclone (Hurricane Earl, 2010) during the GRIP field campaign. Due to mechanical difficulties, only a very limited set of observations were collected. The P3DWL was flown with limited success in the 2015 Atlantic hurricane season. It collected continuous observations during one flight into Tropical Storm Erika. After some mechanical issues were resolved, the P3DWL was successfully flown in the 2016 season into two TCs for a total of 5 flights.

The DWL is capable of performing a variety of scanning patterns, both above and below the aircraft. Depending on the scanning pattern, the vertical resolution of the wind profiles is 25-50m and the horizontal resolution is 1-2km. Below the aircraft, the instrument can observe winds at or near the surface (~25m). When sampling above the aircraft, it can observe as high as ~14km (in the presence of high cirrus). However, in the presence of optically thick convection or within ~400m of the instrument, P3DWL is unable to collect measurements. The P3DWL will require an onboard operator during each mission.

**Hypotheses:**

* Hypothesis 1: Providing more continuous wind observations in data sparse regions to a data assimilation system will lead to a better analysis and forecast of a TC.
* Hypothesis 2: Collecting wind profiles in the TC boundary layer, inner core and environment will lead to identify key physical processes governing TC intensity change.
* Hypothesis 3: The P3DWL is capable of capturing accurate observations in regions with hurricane force winds.

**Asymmetric Tropical Cyclone Module Description:** The objective of this module is to provide symmetric coverage of the kinematic field in an asymmetric storm. The P3DWL will provide observations in low/no precipitation regions of a TC to complement the observations collected by the TDR. The combination of observations from these two platforms will be used to improve the initial structure of the TC in model analyses.

**Secondary Eye Wall/Moat Region Module Description:** This module will characterize the upper level subsidence and boundary layer kinematics within the region between two concentric eyewalls and/or within a rainband moat. It should only be performed in a stronger, more organized TC that contains either classic rainband structures (including a moat) or during an eyewall replacement cycle. The P3DWL should target the moat region and collect observations to complement data from the TDR.

**Transit/Saharan Air Layer (SAL) Module Description:** The objective of this module is to characterize the suspended Saharan dust and mid-level (~600-800 hPa) easterly jet that are associated with the SAL with a particular focus on SAL-TC interactions. Observations should target the possible impingement of the SAL mid-level jet and suspended dust along the edges of the storm inner core region. It can be conducted between the edges of the storm’s (African Easterly Wave’s (AEW)) inner core convection (deep convection) to points well outside (several hundred kilometers) of the TC environment during the commute to/from the storm.

**Boundary Layer Module Description:** This module will target sampling of the kinematic structure of the boundary layer with focus on investigating the characteristics of the boundary layer height and coherent structures. The purpose of this data will be to improve the initial state of the HWRF model and validate the boundary layer structures represented in the model.

**High Winds Module Description:** This module will target areas of high winds (above 35 m/s) below flight level with fewer optically thick clouds obstructing the P3DWL. The purpose is to expand the existing dataset and characterize how the P3DWL performs in a high wind regime. It will be necessary to deploy dropsondes for the validation process.

**Mass Flux Budget Module Description:** This module is to be performed on the ferry to/form a TC. A box will be flown in an area with winds 20 m/s or less and few optically thick clouds. The purpose of this module is to determine whether the P3DWL is a good tool to "close the box" and perform line integrals around a quiescent region where the flow is not apparently complex. Results will set a baseline for other future potentially boxes in more complicated flow regimes. This is also a module on NASA’s DC8 to be performed by the DAWN observing system.

**Analysis Strategy:**

The basic analysis of the DWL wind data follows that presented in recent observational studies of TC structure (e.g., Dunion and Velden 2004; Zhang and Uhlhorn 2012; Zhang et al. 2011; 2013; Montgomery et al. 2014; Rogers et al. 2015; Abarca et al. 2016). The analysis includes: the height of the maximum tangential wind speed, the inflow layer depth, the strength of the peak inflow, inflow angle, low-wavenumber kinematic structure of the boundary layer, a gradient wind in the secondary eyewall, and easterly jet in the SAL.

Observing System Experiments (OSEs) will be performed using both the line of sight (LOS) data and the post-processed vector wind data product to determine the impact of P3DWL observations on the analyses of TC structures, track, and intensity forecasts. Observations collected from the P3DWL in conjunction with other observing platforms will be used to evaluate the model representation of different aspects of a TC, such as the boundary layer, SAL intrusions, and sheared TCs. Multiple modeling frameworks are expected to be used. Options include the operational HWRF model, the latest Observing System Simulation Experiment (OSSE) system, and the HEDAS-HWRF setup.

**References:**

Abarca, S. F., M. T. Montgomery, S. A. Braun, J. Dunion, 2016: On the secondary eyewall formation of Hurricane Edouard (2014). *Mon. Wea. Rev*., **144**, 3321–3331.

Dunion, J. and C. S. Velden, 2004: The impact of the Saharan air layer on atlantic tropical cyclone activity. *Bull. Amer. Meteor. Soc.*, **85**, 353–365.

Kavaya, M. J. et al., 2014: The Doppler aerosol wind (DAWN) airborne, wind-profiling coherent-detection Lidar system: overview and preliminary flight results. *J. Atmos. Oceanic Technol.*, **31**, 826 –842. 0739-0572

Montgomery, M. T., J. A. Zhang, and R. K. Smith, 2014: An analysis of the observed low-level structure of rapidly intensifying and mature Hurricane Earl, 2010: *Quart. Jour. Roy. Met. Soc*., **140**, 2132-2146.

Pu, Z., L. Zhang, and G. D. Emmitt, 2010: Impact of airborne Doppler wind lidar data on numerical simulation of a tropical cyclone. *Geophys. Res. Lett.*, **37**, L05801, doi:10.1029/2009GL041765.

Rogers, R. F., P. D. Reasor, and J. A. Zhang, 2015: Multiscale structure and evolution of Hurricane Earl (2010) during rapid intensification. *Mon. Wea. Rev*., **143**, 536–562.

Zhang, J. A., and E. Uhlhorn, 2012: Hurricane sea surface inflow angle and an observation-based parametric model. *Mon. Wea. Rev*., **140**, 3587-3605.

Zhang, J. A., R. F. Rogers, D. S. Nolan, and F. D. Marks, 2011: On the characteristic height scales of the hurricane boundary layer, *Mon. Wea. Rev*., **139**, 2523-2535.

Zhang, J. A., R. F. Rogers, P. D. Reasor, E. W. Uhlhorn, and F. D. Marks Jr., 2013: Asymmetric hurricane boundary layer structure in relation to the environmental vertical wind shear from dropsonde composites. *Mon. Wea. Rev.*, **141**, 3968–3984.