3. Doppler Wind Lidar (DWL) Experiment

Principal Investigators: Lisa Bucci (HRD), Kelly Ryan (HRD), Jun Zhang (HRD), G. David Emmitt (SWA), Jason Dunion (HRD), and Robert Atlas (AOML)

Links to IFEX:

This experiment supports the following NOAA IFEX goals:

Goal 1: Collect observations that span the TC lifecycle 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 our understanding of the physical processes important in intensity change for a TC at all stages of its lifecycle;

Program Significance:

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 2016 hurricane season onboard NOAA-43. P3DWL can collect wind profiles through the detection of aerosol scatters in areas of optically thin or broken clouds or where aerosols are ~1 micron or larger. It 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.

This instrument 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 a TC forecast. The main goal of this experiment is to build upon those results and collect both near storm and inner core observations. The observations will be used in Observing System Experiments (OSEs) to assess the impact of P3DWL data on TC track and intensity forecasts. 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 in and around the TC. Each module describes the observations the P3DWL should collect given the location of the plane and the structure of the TC. The P3DWL will require an onboard operator during each mission.

Objectives:

- Collect P3DWL observations in a variety of regions both in and near different types of TCs;
- Validate P3DWL observations against dropsonde and Tail Doppler Radar data;
- Evaluate P3DWL measurements on numerical analyses and forecasts for TC track, intensity and structure;
- Observe and characterize various features in the TC near environment and inner core (listed below):
  - The Saharan Air Layer (SAL) and mid-level easterly jet (~600-800 hPa)
  - Boundary layer (BL) heights and rolls

o Kinematic structure in region between two concentric eyewalls or the moat region between two rainbands

Model Evaluation Component:

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.

OSSE Component:

Observing System Simulation Experiments (OSSEs) can provide useful information regarding the potential impact of P3DWL observations on TC structure, track, and intensity forecasts. OSSEs will be performed during the 2016 Atlantic hurricane season to investigate the suggested flight pattern and P3DWL observing plans for each module. Results from the OSSEs will be compared to averaged result from the OSEs (described in the previous section) after the conclusion of the season. Analysis work will include comparisons of 1) simulated to real observations, 2) track and intensity errors, and 3) impact of P3DWL on TC structure. Calibration of the OSSE system may occur after the analysis work is complete. The latest hurricane OSSE framework will be used in both the OSSEs and OSEs.

Mission Description:

While this experiment is presented as a standalone activity, the following modules may be performed during any of the following HRD research missions: TC Genesis, TC Shear Experiment, Rapid Intensity Experiment, or as part of operational NHC-EMC-HRD Tail Doppler Radar (TDR) missions. This experiment includes 4 types of modules: 1) asymmetric TC module, 2) SAL/Transit module, 3) boundary layer module, and 4) rainband moat module. Each module describes what region(s) of the TC to target with the P3DWL in different types of TCs.

Module 1- Asymmetric TC

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.

This module can be combined with other experiments such as TC Shear or TDR missions. The only pattern requirement is a symmetric coverage of an asymmetric TC (either a rotated Figure-4 or butterfly pattern). The preferred flight-level altitude is 8,000-10,00 feet and GPS dropsondes should be deployed at the end, mid, RMW, and center points of the flight pattern. Dropsonde data will be used to validate and develop quality control measures for the P3DWL vector wind product. Dropsonde observations will also be used to provide information in the boundary layer of the low/no precipitation portion of the TC.

In the regions of higher convection/precipitation, the P3DWL should be operated in the downward looking direction. The scanning mode should repeat a 20° conical pattern followed by a 1 second nadir stare. In the regions of the TC where there is low/no precipitation, the P3DWL should be placed in an upward looking direction. The scanning mode should be a 20° conical pattern, with a 1 second vertical stare after completing the pattern. Sufficient signal strength with the upward scan is important. If signal strength is poor due to lack of aerosols/high cirrus clouds, then return the P3DWL to the downward scanning mode. The scanning mode should not be switched from upward to downward often. Ideally this module should be chosen if half the storm is covered with convection, while the other half lacks precipitation.

Module 2- SAL/Transit Module

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. There are no minimum leg lengths required. The aircraft should fly at the maximum allowable flight-level (~19,000 feet).

The P3DWL should be placed in a downward looking scanning mode. The preferred scanning mode is a conical pattern with an elevation angle of 10°. If that pattern is not collecting the necessary observations, a down and forward sweeping pattern can be used (elevation 20°, sweep -10° to +10° with 5° intervals). GPS dropsonde sampling along the transect will be used to observe the SAL's thermodynamics and winds as well as to validate the P3DWL's wind retrievals. Drop points should be spaced at ~25-50 nm increments near the region where the SAL is impinging on the storm/AEW and spaced at 50-75 nm increments farther from the storm (Fig. 3-1). GPS dropsonde spacing will be determined on a case by case basis at the lead project scientist's (LPS's) discretion.

If no SAL is present, the P3DWL should still collect observations during the transit to/from the TC. It should be placed in the downward scanning mode, with the preferred scanning mode being a 10° conical pattern. The operator should ensure the P3DWL is returning a signal from the surface. No GPS dropsondes are necessary, however, one may be dropped for the purpose of validating the P3DWL observations.

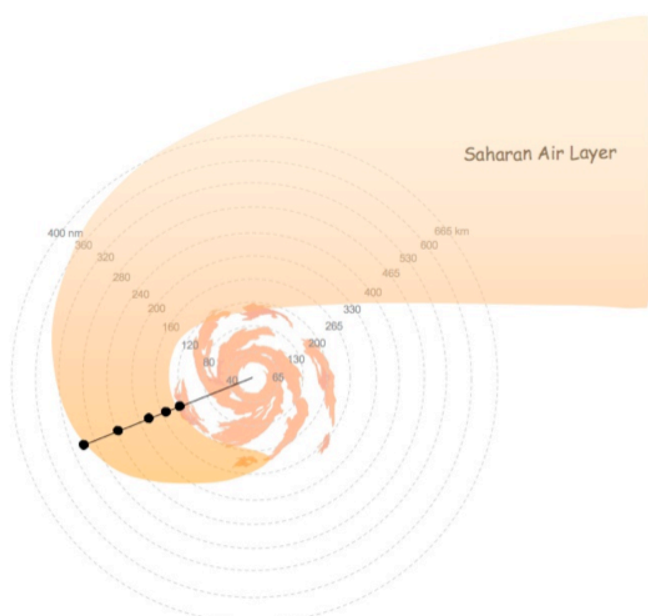

Fig. 3-1: Sample WP-3D flight track during the ferry to/from the storm and GPS dropsonde points for the P-3DWL SAL module.

Module 3- Boundary Layer Module

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.

This module can be combined with other experiments and modules as it does not require a specific flight track. A symmetric coverage of the TC is preferred and TCs of all intensities should be sampled. The P3DWL should be placed in a downward scanning pattern. The preferred scanning mode is conical with an elevation angle of 10° and a 1 second stare at nadir. If that pattern is not collecting the necessary data, a down and forward sweeping pattern can be used (elevation 20°, sweep -10° to +10° with 5° intervals). It is important optically thick convective be avoided as often as possible and the operator should ensure the P3DWL is returning a signal from the sea surface.

Module 4- Eyewall Replacement/Rainband Moat Module

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.

This module does require a circumnavigation flight pattern, which will take ~1 hour to perform (depending on the size of the TC). It can be flown in conjunction with other experiments, such as TDR missions, as was done in Hurricane Arthur (2014). The aircraft should fly in an octagon pattern within the moat region, avoiding the optically thick deep convection in the eyewall and rainbands (Fig. 3-2; also see the SEF/ERC Experiment write-up). The P3DWL should be placed in an upward scanning pattern. The preferred scanning mode is a repeating conical pattern with an elevation angle 20° off vertical and a 1 second stare in the vertical. Sufficient signal strength with the upward scan is important. If signal strength is poor due to lack of aerosols/high cirrus clouds, then the P3DWL should be placed in the downward scanning mode. A GPS dropsonde should be deployed in each quadrant of the storm during the pattern. Quadrants should be defined based on the storm motion vector, and drops should be centered with the quadrant.

If there is opportunity to do a second circumnavigation, the P3DWL should be placed in a downward scanning pattern. GPS dropsondes may again be deployed for validation purposes of the P3DWL observation, however, they should be staggered 45° relative to the storm center from the previous deployed dropsondes.

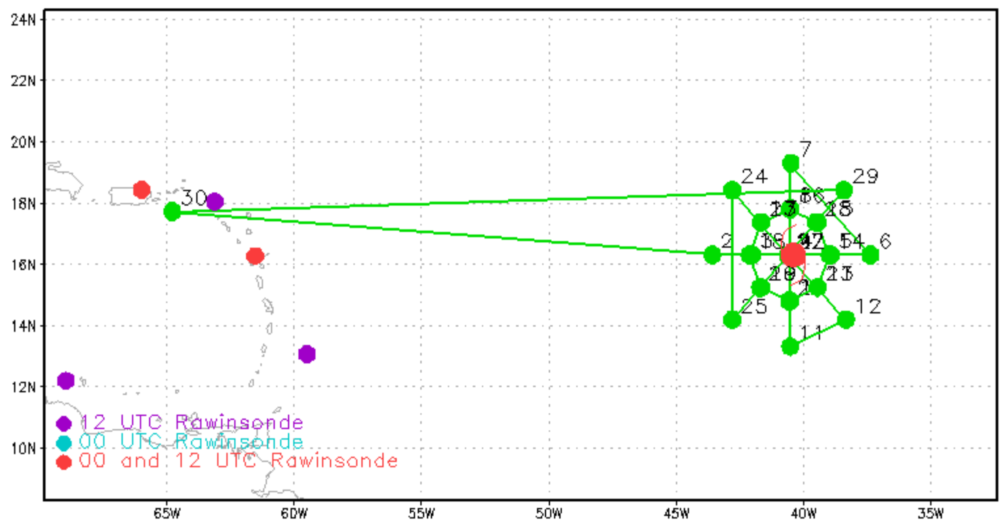

Fig. 3-2: Sample WP-3D flight track during a Moat Module. Pattern shows an initial Figure-4 pattern, followed by a circumnavigation that leads in a second Figure-4.