2019 NOAA/AOML/HRD Hurricane Field Program - IFEX

INSTRUMENT DESCRIPTIONS

The following are descriptions of instruments being flown on the P-3 and the G-IV aircraft during the season.

1. Flight-level Measurements [P-3s and G-IV]

Data from flight-level measurements are provided at 40 Hz (FAST) and 1 Hz and include: positional information, true air and ground speed, radar and pressure altitude, static and dynamic air pressure, air temperature, dew point temperature, d-value, horizontal and vertical wind, water vapor mixing ratio, and extrapolated surface pressure.

2. Tail Doppler Radar (TDR) [P-3s and G-IV]

The P-3 tail Doppler radar (TDR) systems have two solid-state transceivers that simultaneously transmit through the fore and aft antennas. The antennas are canted approximately 20 degrees fore or aft of the plane normal to the fuselage of the aircraft. The exact functioning of the TDR for the hurricane season is still being developed. It is expected the single pulse repetition frequency will be about 3000/sec, and a long compressed pulse will be used to produce sensitivity on the order of -10 dBZ at 10 km. A short pulse will be added to provide data in the first 3 km from the aircraft. The frequency of the radar is in the X-band, with a wavelength of approximately 3 cm, and the beam width is approximately 2 degrees.

The G-IV tail Doppler radar system has two transceivers that use traveling wave tube amplification. They transmit simultaneously through the fore and aft antennas. The antennas are canted approximately 20 degrees fore or aft of the plane normal to the fuselage of the aircraft. The single pulse repetition frequency will be about 3000/sec and a long compressed pulse provides sensitivity on the order of -10 dBZ at 10 km. There is no short pulse, so there are no data recorded within 3 km range of the radar. The frequency of the radar is in the X-band, with a wavelength of approximately 3 cm. The beam width is approximately 2.7 degrees.

3. Multi-Model Radar (MMR) [P-3s]

In 2018, the Lower Fuselage (LF) radars in the belly radome of the P-3s were replaced with a new radar system, the Multi-Mode Radar (MMR). The MMR is an X-band, pulse Doppler radar system with a range up to 200 n mi, that has multiple operational modes available to the radar operator. Most relevant to hurricane operations are the Hurricane Weather mode (HWX) with turbulence identification. HWX mode displays nine colors (defined within the Navigation and Weather, [NAW] mode, referenced to reflectivity, dBZ), with the ninth color (white) being designated for turbulence detection when the range is set to less than or equal to 40 n mi.

4. Stepped Frequency Microwave Radiometer (SFMR) [P-3s and G-IV]

SFMR is an airborne microwave radiometer that offers retrieved surface wind speed and rain rate by measuring the surface brightness temperature at nadir at six C-band frequencies between 4.6 and 7.2 GHz. The apparent brightness temperature of the ocean surface is sensitive to the sea surface temperature (SST) and surface foam coverage due to wave breaking; as the surface wind speed increases, so does the coverage of sea foam and, subsequently, the brightness temperature (Nordberg et al. 1971; Rosenkranz and Staelin 1972; Klotz and Uhlhorn 2014). Therefore, brightness temperature increases with surface wind speed for a given SST. A retrieval algorithm uses the relationship between the surface emissivity and wind speed (using a geophysical model function, GMF, and inversion algorithm) to retrieve surface wind estimates along the flight track (Uhlhorn et al. 2007). Recently, Klotz and Uhlhorn (2014) corrected a deficiency in the SFMR surface wind speed algorithm for an overestimation of wind speed in weak wind and heavy rain conditions by revising the GMF coefficients for both the rain absorption and wind-induced surface emissivity models. The result was a significantly reduced bias at wind speeds less than hurricane force, and more accurate retrieved rain rates.

This season, dedicated SFMR experiment goals are to: 1) develop corrections in the SFMR algorithm to obtain measurements of wind speed when the aircraft pitch and roll angle exceeds ±5°, which are currently not reported, and 2) verify measurements from the SFMR on the G-IV against those from the operational SFMR on the P-3.

Additionally, a second SFMR (UMASS) will be deployed on N43RF, in support of the NESDIS Ocean Winds data collection. The University of Massachusetts (UMASS) SFMR is a dual-polarization, multi-frequency microwave radiometer that, unlike the operational ProSensing SFMRs, samples each frequency (4.63, 5.50, 5.92, 6.34, 6.60, and 7.05 GHz) simultaneously.

References

Klotz, B. W., and E. W. Uhlhorn, 2014: Improved Stepped Frequency Microwave Radiometer Tropical Cyclone Surface Winds in Heavy Precipitation. *J. Atmos. Oceanic Tech*., **31**, 2392–2408.

Nordberg, W. J., J. Conway, D. B. Ross, and T. Wilheit, 1971: Measurements of microwave emission from a foam-covered, wind-driven sea. *J. Atmos. Sci*., **28**, 429–435.

Rosenkranz, P. W., and D. H. Staelin, 1972: Microwave emissivity of ocean foam and its effect on nadrial radiometric measurements. J. *Geophys. Res*., **77**, 6528–6538.

Uhlhorn, E. W., P. G. Black, J. L. Franklin, M. Goodberlet, J. Carswell, and A. S. Goldstein, 2007: Hurricane Surface Wind Speed Measurements from an Operational Stepped Frequency Microwave Radiomater, *Mon. Wea. Rev*., **135**, 3070–3085.

5. GPS Dropwindsondes [P-3s and G-IV] and Ocean Profilers [P-3s]

The GPS dropwindsonde (dropsonde) is part of the National Center for Atmospheric Research (NCAR) / Earth Observing Laboratory (EOL) AVAPS (Airborne Vertical Atmospheric Profiling System) Dropsonde system that measures vertical profiles of atmospheric temperature, pressure, humidity, and wind speed as it falls from the aircraft to the surface.

Possible ocean profiling probes (to measure ocean temperature and salinity profiles) that could be used this season include: AXBTs (Airborne Expendable BathyThermograph), AXCPs (Airborne

Expendable Current Profilers), and AXCTDs (Airborne Expendable Conductivity, Temperature, and Depth).

6. Cloud Microphysics [P-3s]

The P-3s are equipped with cloud microphysics probes that image cloud and precipitation particles and produce particle size distributions. The probes flown include the Droplet Measurement Technologies, Inc. (DMT) (www.dropletmeasurement.com) Cloud Combination Probe (CCP) (for aerosol and cloud hydrometeor size distributions from 2 to 50 µm; 2-D images and precipitation size distributions between 25 and 1550 µm, liquid water content from 0.05 to 3 g m^{-3}), Precipitation Imaging Probe (PIP) (for hydrometeor sizes between 100 µm and 6.2 mm), and the Cloud and Aerosol Spectrometer (CAS) (for aerosol and cloud hydrometeor size between 0.5 and 50 µm).

7. Doppler Wind LIDAR (DWL) [P-3 (N43RF)]

7.1 Technical Details

Due to operational instrument limitations, only limited continuous high-resolution wind observations exist in the TC boundary layer and in regions of low or no precipitation. A coherent-detection Doppler wind profile (P3DWL) system will be installed on the NOAA P-3 (N43RF) for the season and 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. In addition to potential improvement due to assimilation into numerical weather models, these measurements may shed light on physical processes in data sparse regions such as in the hurricane boundary layer, Saharan Air Layer (SAL), regions in-between rainbands, and in the ambient tropical environment around the TC.

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 25-50 m and the horizontal resolution is 1-2 km. Below the aircraft, the instrument can observe winds at or near the surface (~25 m). When sampling above the aircraft, it can observe as high as ~14 km (in the presence of high cirrus). However, in the presence of optically thick convection or within ~400 m of the instrument, the DWL is unable to collect measurements.

The DWL was used in the West Pacific field campaign THORPEX in 2008 where data collected in the near-TC environment improved both track and intensity forecasts. DWL has successfully retrieved continuous observations in high-wind regimes where few measurements are typically collected. Measurements obtained in the boundary layer provide a means of evaluating near-surface momentum field where surface energy exchange is an important process for hurricane evolution. The DWL provides observations that allow for axisymmetric wind field coverage due to its complementary relationship to TDR. This distribution of measurements is theorized to improve hurricane prediction by capturing asymmetries in the vortex.

7.2 Pattern/Module Requirements

The DWL is usually operated using a conical step-and-stare scan pattern around the vertical axis, 20° off of nadir. It is pointed in 12 different directions (each for 1 s) to collect horizontal winds followed by 5 s at nadir to collect the vertical wind motion. The scanning pattern is varied as follows based on the listed criteria:

- Weak or asymmetric TCs: Repeat four downward scans followed by one upward scan. If signal strength in the up scan is very weak, only scan down.
- Boundary layer/SEF measurements: Only scan in the downward direction.
- SAL: Two scans downward followed by one upward. If signal strength in the up scan is very weak, change to 4 scans down, one scan up. If no signal upward, only scan down.

7.3 Analysis Strategy

An analysis of TC structure will be performed by evaluating boundary layer height, inflow characteristics (layer depth, strength of the peak, angle), and gradient wind in secondary eyewall. An analysis of SAL includes capturing the details of the easterly jet. To evaluate the impact of DWL observations on hurricane forecasts, OSE's will be performed using both line-of-sight and post-processed vector wind data. Observations collected from the DWL 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.

8. Imaging Wind and Rain Airborne Profiler (IWRAP) [P-3 (N42RF)]

IWRAP, which is also known as the Advanced Wind and Rain Airborne Profile (AWRAP), consists of two dual-polarized, dual-incidence angle radar profilers operating at Ku- and C-bands, and measures profiles of volume reflectivity and Doppler velocity of precipitation, as well as ocean surface backscatter. For more information regarding the use of IWRAP during this year's HFP, please refer to the following three NESDIS Ocean Winds Experiment documents in the Mature Stage Experiment: *Science Goals & Observational Applications*, *Science Description*, and *Flight Pattern Descriptions.*

9. Wide Swath Radar Altimeter (WSRA) [P-3 (N43RF)]

The WSRA (developed by ProSensing: http://www.prosensing.com) is an instrument that provides for measurements of sea surface topography and rain rate. The WSRA measures the sea surface topography by determining the range to the sea surface in 80 narrow beams spread over ±30° in the cross-track direction (Walsh et al. 2014). Using measurements of sea surface topography and backscattered power, the WSRA offers real-time information on significant wave height, ocean directional wave spectra, the mean square slope of the ocean surface, and rain rate. The mean square slope (i.e., the sea surface small-scale roughness) responds to changes in wind speed, and can be determined by the variation of the radar-backscattered power with incidence angle. Data collected are transmitted to NHC for operational use.

References

Walsh, E. J., I. PopStefanija, S. Y. Matrosov, E. Uhlhorn, and B. Klotz, 2014: Airborne Rain-rate Measurement with a Wide-Swath Radar Altimeter. *J. Atmos. Oceanic Tech.*, **31**, 860–875.