2020 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 and G-IV 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 pulse repetition frequency is about 3000 Hz, and a long compressed pulse is used to produce sensitivity on the order of -10 dBZ at 10 km. For the P-3 TDR, a short pulse is 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 (2.7) degrees for the P-3 (G-IV).

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

The Multi-Mode Radar (MMR) is an X-band, horizontally-scanning 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 is the Hurricane Weather mode (HWX) with turbulence identification. HWX mode shows nine colors referenced to reflectivity (dBZ) on the aircraft display, with the ninth color (white) being designated for turbulence detection when the range is set to less than or equal to 40 n mi. The pulse repetition frequency is about 1000 Hz, but varies according to maximum recording range, and the horizontal and vertical beam widths are 1.4 and 5 degrees, respectively.

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 4.7 and 7.1 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, as well as the relationship between rain emissivity and frequency (using a geophysical model function, GMF, and inversion algorithm) to retrieve surface wind and rain rate 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. Improve SFMR wind speed estimates at high wind speeds (wind speed $\geq$100 kt) by collecting collocated SFMR and dropsonde surface observations.
2. Develop corrections in the SFMR algorithm to obtain measurements of wind speed when the aircraft pitch and roll angle exceeds ±10°, which are currently not reported.

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.

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 probes). NOAA Hurricane Underwater Glider (autonomous underwater vehicle) deployments are also planned that will measure profiles of temperature, salinity, oxygen, and chlorophyll).

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 will include

1. 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}. The CCP includes 2 droplet instruments:
    a. **Cloud Droplet Probe (CDP)** for hydrometeor sizes between 3 - 50 µm)
    b. **Cloud Imaging Probe (CIP)** for hydrometeor sizes between 25 µm - 1.6 mm, including the **CIP Grayscale (CIP GS)** particle imaging module
2. **Precipitation Imaging Probe (PIP)** for hydrometeor sizes between 100 µm and 6.4 mm

3. **Cloud and Aerosol Spectrometer (CAS)** for aerosol and cloud hydrometeor size between 0.5 and 50 µm). The CAS forward resolution is 0.63 - 50 µm, while the backward resolution is 1.6 - 100 µm.

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. This season, the dedicated WSRA experiment goal is to collect WSRA data in the TC environment to help improve NHC/TAFB's High Seas analyses and forecasts and NOAA's Wavewatch III ocean model.

9. Compact rotational Raman Lidar (CRL) [P-3 (N42RF or N43RF)]

The CRL is powered by a Nd:YAG laser with 50 mJ pulse energy running at 30 Hz. The normal ocular hazard distance of CRL is less than 200 m, which allows eye-safe operation during aircraft normal operation away from airport. It uses a compact, lightweight transmitting- receiving system, which can be easily mounted to the P-3 nadir port. The CRL was initially developed to obtain 2-D distributions of water vapor, aerosols, and clouds and was first deployed on the University of Wyoming King Air (UWKA) in 2010 (Liu et al. 2014). The successful demonstration of CRL led the development of MARLi. In early 2015, low-J and high-J pure rotational Raman channels (J is the rotational quantum number) were added to provide temperature measurements (Wu et al. 2016).

Although the 50-mJ laser limits water vapor measurement to short range under high solar background conditions, the CRL still can provide excellent data for characterizing the spatial variability of aerosol, water vapor, and temperature during night or under normal solar background conditions. CRL signals are sampled with an A/D card at 250 MHz, which corresponds to a 0.6 m vertical resolution. The temporal/horizontal resolution will be set depending on the application. The data acquisition system is capable of saving individual profiles, which correspond to about

3.6 m horizontal resolution at a typical P-3 cruise speed of 108 m s^{-1}. The highest resolution data is important for studying ocean surface wave characteristics, fine-scale sea spray structure, and ABL height variation. Different post-averaging can be done to improve signal-to-noise ratio as necessary for different atmospheric features. CRL will collect data continuously during P-3 research and operational missions to provide real-time fine-scale environment variations in TC, which are hard to detect with satellite measurements or airborne passive sensors alone. With the current small laser, we expect CRL water vapor and temperature measurements to be limited within 2 km below aircraft altitude without extensive spatial averaging. The instrument can obtain surface aerosol measurements and surface wave structure when the P-3 flies within 3-4 km altitude and is clear of clouds. Such measurements are still valuable to characterize thermodynamics structure and aerosol variations within TC. For example, flights between the eyewall and rainbands can measure the inflow structure within the inner core. CRL also provides aerosol depolarization measurements, which can be used to effectively identify dust aerosols associated with the Saharan air layer (SAL).

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