MATURE STAGE EXPERIMENT
Science Description

Experiment/Module: NESDIS Ocean Winds

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Requirements: Categories 2–5

Plain Language Description: To improve our understanding of microwave retrievals of the ocean surface and atmospheric wind fields, and to evaluate new remote sensing techniques/technologies. To help validate satellite-based sensors of the ocean surface in extreme conditions and reduce risk for future satellite missions.

Mature Stage Science Objective(s) Addressed:

1) Collect observations targeted at better understanding internal processes contributing to mature hurricane structure and intensity change [*APHEX Goals 1, 3*].
2) Collect observations targeted at better understanding the response of mature hurricanes to their changing environment, including changes in vertical wind shear, moisture and underlying oceanic conditions [*APHEX Goals 1, 3*].
3) Test new (or improved) technologies with the potential to fill gaps, both spatially and temporally, in the existing suite of airborne measurements in mature hurricanes. These measurements include improved three-dimensional representation of the hurricane wind field, more spatially dense thermodynamic sampling of the boundary layer, and more accurate measurements of ocean surface winds and underlying oceanic conditions [*APHEX Goal 2*]

Motivation: This effort aims to improve our understanding of microwave scatterometer retrievals of the ocean surface wind field and to evaluate new remote sensing techniques/technologies. The Ocean Winds experiment is part of an ongoing field program whose goal is to further our understanding of microwave scatterometer and radiometer retrievals of the ocean surface winds in high wind speed conditions and in the presence of rain for all wind speeds. This knowledge is used to help improve and interpret operational wind retrievals from current and future satellite-based sensors. The hurricane environment provides the adverse atmospheric and ocean surface conditions required.

Background: The NOAA/NESDIS/Center for Satellite Applications and Research in conjunction with the University of Massachusetts (UMASS) Microwave Remote Sensing Laboratory, Remote Sensing Solutions (RSS), the NOAA/AOML/Hurricane Research Division, and the NOAA/OMAO/Aircraft Operations Center have been conducting flight experiments during the hurricane season for the past several years. The Imaging Wind and Rain Airborne Profiler (IWRAP), which is also known as the Advanced Wind and Rain Airborne Profiler (AWRAP), was designed and built by the University of Massachusetts and is the critical sensor for these experiments. IWRAP/AWRAP consists of two dual-polarized, dual-incidence angle radar profilers operating at Ku-band and at C-band, which measure profiles of volume reflectivity and Doppler velocity of precipitation in addition to the ocean surface backscatter. Since 2015 the C-band portion of IWRAP has been installed with the prototype antenna for EUMETSAT's ASCAT follow-on satellite sensor that will be launched on EPS-SG. This antenna, on loan from ESA, is a dual-polarized slotted waveguide antenna and has allowed us to measure the cross-polarized response of the ocean surface, which is a new capability being implemented for the ASCAT follow-on sensor. This season we aim to reinstall the scanning antenna. The Stepped-Frequency Microwave Radiometer (SFMR) and GPS dropsonde system are also essential instrumentation on the NOAA-P3 aircraft for this effort. A Ka- and Ku-band interferometric altimeter radar system (KaIA) will be installed again to enable finer resolution measurements at the air-sea boundary to help decouple what is happening at the interface in the storm environment.

Goal(s): The Ocean Winds P-3 flight experiment program has several objectives:

- Calibration and validation of satellite-based ocean surface vector wind (OSVW) sensors such as ASCAT, AMSR-2, and the CYGNSS mission that uses GNSS-R techniques to infer the ocean wind speed.
- Product improvement and development for current and planned satellite-based sensors (ASCAT, OceanSat-3, CYGNSS and SCA)
- Testing of new remote sensing technologies for possible future satellite missions (risk reduction) such as the dual-frequency scatterometer concept.
- Testing of new real-time airborne remote sensing technologies and transmission to forecasters.
- Advancing our understanding of broader scientific questions such as:
    - Rain processes in tropical cyclones and severe ocean storms: the coincident dual-polarized, dual-frequency, dual-incidence angle measurements would enable us to improve our understanding of precipitation processes in these moderate to extreme rainfall rate events.
    - Atmospheric boundary layer (ABL) wind fields: the conical scanning sampling geometry and the Doppler capabilities of this system provide a unique source of measurements from which the ABL winds can be derived. The advanced digital receivers and data acquisition system recently implemented will enable retrieval of the wind and reflectivity profiles essentially to the surface.
    - Analysis of boundary layer rolls: linearly organized coherent structures are prevalent in tropical cyclone boundary layers, consisting of an overturning "roll" circulation in the plane roughly perpendicular to the mean flow direction. The instruments used by this team have been shown to resolve the kilometer-scale roll features, and the vast quantity of data this instrument has already collected offers a unique opportunity to study them.

- Drag coefficient, Cd: extending the range of wind speeds for which the drag coefficient is known is of paramount importance to further our understanding of the coupling between the wind and surface waves under strong wind forcing, and has many important implications for hurricane and climate modeling. The advanced digital receivers and data acquisition capability allows us to retrieve wind and reflectivity profiles closer to the ocean surface, which can also be exploited to derive drag coefficients by extrapolating the derived wind profiles down to 0 m altitude.

Hypotheses:

1. We don't fully understand what is happening at the air-sea interface in extreme storm conditions, but it should be possible to characterize this with the proper instrumentation and data collection methodologies.
2. Stepped Frequency Microwave Radiometer brightness temperatures represent geophysical phenomena different from those sampled by the sources of ground truth used for developing the wind speed and rain rate retrieval processes (specifically, dropsondes and TDR). These differences are due to the significant location difference of the surface and atmospheric winds encountered by the SFMR and the dropsonde and the non-uniform distribution of wind and rain in a hurricane.

Objectives:

1. Sample the atmosphere and ocean surface in hurricane-force wind conditions with varying degrees of rain with IWRAP, KaIA, SFMR, and GPS dropsondes.
2. Perform near-real-time significant wave height (SWH) retrievals with KaIA in hurricane conditions and transmit to the ground.
3. Perform near-real-time ocean surface vector wind (OSVW) retrievals with IWRAP in hurricane conditions and transmit to the ground.

Aircraft Pattern/Module Descriptions (see *Flight Pattern* document for more detailed information): The sensitivity of the IWRAP/AWRAP system defines the preferred flight altitude to be below 10,000 ft to enable the system to still measure the ocean surface in the presence of rain conditions typical of tropical systems. With the Air Force Reserve typically flying at 10,000 ft pressure altitude, we have typically ended up with an operating altitude of 7,000 ft radar. Operating at a constant radar altitude is desired to minimize changes in range and thus measurement footprint on the ground. Higher altitudes would limit the ability of IWRAP/AWRAP to consistently see the surface during intense precipitation, but these altitudes would still provide useful data, such as measurements through the melting layer, to study some of the broader scientific questions.

Links to Other Mature Stage Experiments/Modules: NESDIS Ocean Winds can be flown in conjunction with following *Mature Stage* experiments and modules: Eye-Eyewall Mixing, Gravity Wave, Rainband Complex Survey, RICO SUAVE, Surface Wind Speed and Significant Height Validation, and TC Diurnal Cycle Experiment.

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Analysis Strategy: The analysis depends on the scientific question under investigation, but it usually involves comparing the normalized radar cross-section (NRCS) or Doppler-derived winds measured by IWRAP to another sensor on a storm-relative grid. Computing the NRCS involves compensating for the illuminated area on the surface, so keeping a consistent altitude from the ocean surface removes uncertainty associated with this calculation. Instruments used in the past include SFMR, dropsondes, and satellite observations (Sapp et al. 2013, 2016b,a, 2018; Guimond et al. 2018). Improvements to satellite geophysical model functions have also been developed from SFMR wind speed collocation with satellite observations (Soisuvarn et al. 2013). High-resolution 3D wind field structures in the hurricane boundary layer is also included in the analysis (Guimond et al. 2018). The behavior of cross-polarized NRCS has been studied recently at C-band in extremely strong wind conditions (Sapp et al. 2018, 2016a) using SFMR, dropsondes, and a storm-relative gridding scheme. Cross-polarized NRCS at Ku-band at hurricane-force wind speeds have only been measured by IWRAP in the 2018 hurricane season, and that will continue. New elements will include: collocation of wave height measurements from an on-board Ka-band interferometric altimeter to analyze the dependence of NRCS on wave height and sea spray.

References:

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