2023 NOAA/AOML/HRD Hurricane Field Program - APHEX

SATELLITE VALIDATION EXPERIMENT
Science Description

Experiment/Module: Evaluation of the tropical transition environment using satellite soundings

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Requirements: No requirements: flown at any stage of the TC lifecycle

Plain Language Description: This module will collocate radiosondes with real-time satellite sounding products to understand the near and surrounding environment of pre-Tropical Cyclones and/or Tropical Cyclones. The focus of this year's flights is extratropical transition, tropical transitions, and invests, if useful cases arise. This module will also explore the value of satellite soundings for Tropical Cyclone monitoring and forecasting using newly developed web-based and local software tools.

Satellite Validation Science Objective(s) Addressed:

Test new (or improved) satellite technologies with the potential to fill gaps, both spatially and temporally, in the existing suite of airborne measurements in TCs. These measurements include improved three-dimensional representation of the hurricane wind field and thermodynamic structure and more accurate measurements of ocean surface winds and underlying ocean conditions [*APHEX Goal 2*]

Motivation: NUCAPS (Barnet et al., 2021) atmospheric soundings (temperature, moisture, and trace gasses) produced from polar orbiting satellites provide global coverage and have been extensively validated using ground-based and ship-launched rawinsondes (Nalli et al., 2013). More recently, the performance of NUCAPS in tropical environments with strong horizontal and vertical gradients in temperature and moisture [e.g., the Saharan Air Layer and the environments of tropical disturbances (e.g., African easterly waves (AEWs), invests, and TCs)] was accessed through JPSS participation and collaboration in APHEX (Esmaili et al., 2022; Esmaili and Barnet, 2022). We found that 1) NUCAPS meets latency requirements and 2) NUCAPS temperature and moisture profiles had good agreement with dropsondes. This is promising because NUCAPS can provide thousands of atmospheric soundings in the environments of TCs globally. Furthermore, thermodynamics can be an important factor governing the intensity and structure of AEWs, invests, TCs, low pressures undergoing tropical transition (TT), and TCs undergoing extratropical transition (ET). In this module, we are building on this work to study the tropical cyclone environment and potentially improve forecasting of challenging tropical cyclone scenarios. For instance, ET is well-characterized in operational meteorology, but there have been recent examples of storms transitioning back into the tropical phase (TT) and posing hazards to marine vessels. This module can potentially improve definitions of tropical transition (TT) and evaluate satellite sounding value for operational forecasters.

Background: The NOAA Unique Combined Atmospheric Processing System (NUCAPS) provides atmospheric soundings of temperature, water vapor, cloud fraction, cloud top pressure, trace gasses, dust, and volcanic emissions. NUCAPS is a heritage algorithm based upon the Atmospheric Infrared Sounder (AIRS) Science Team algorithm (Susskind et al. 2003), implemented operationally at NOAA since 2002. These soundings are derived from the CrIS (1,305 IR channels; 3.9-15 μm) and ATMS (22 microwave channels; 23-183 GHz) instruments flying onboard the NOAA-20 polar orbiting satellite. NUCAPS provides ~324,000 soundings per day with 20-30 min latency and is also now available in a gridded format in AWIPS. NUCAPS grids are geolocated and provide two-dimensional views of temperature, moisture, and trace gases. NUCAPS has been extensively evaluated for pre-convective forecasting (Esmaili et al., 2020) but is also feasible for TC applications (Kalluri et al., 2022). In addition to temperature and moisture retrievals, stability metrics that are useful for monitoring TC intensification and possible transitions, such as CAPE, can be derived from profiles and are available in gridded form.

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Goal(s): Use GPS dropsondes launched from the NOAA P-3 and G-IV aircraft to validate NUCAPS three-dimensional temperature and moisture profiles produced from the NOAA-20 and NOAA-21 polar orbiting satellites. Use GPS dropsonde data to assess the skill of NUCAPS soundings for monitoring the tropical and extratropical cyclone environment.

Hypotheses:

1. NUCAPS soundings may show good agreement with dropsondes in the clear to partly cloudy environment outside the TC, invest, or storm inner core [R≥80 n mi (150 km)].
2. NUCAPS soundings may be useful for anticipating extratropical and tropical transition by examining the atmospheric column composition and thermodynamics.
3. NUCAPS may help tropical cyclone researchers better define characteristics of tropical transition.
4. NUCAPS may be useful to examining the vertical structure of a Saharan Air Layer (SAL) event, which can impact air quality in the Caribbean and southeastern United States.

Objectives:

1. Coordinate P-3 and G-IV GPS dropsonde observations and overpasses by the NOAA-20 or NOAA-21 satellites that are coincident in time (preferably ≤1 hr) and space [preferably ≤27 n mi (≤50 km)].

2. Collect GPS dropsonde thermodynamic observations in the near environment [R~80-160 n mi (150-300 km)] of TCs or invests where the atmospheric profile contains a mixture of clear/subsiding air, outer rainbands, and the outer edges of the cirrus canopy. Use those soundings to validate coincident NUCAPS atmospheric profiles.

3. Collect GPS dropsonde thermodynamic observations in environments where a TC is undergoing extratropical or tropical transition to validate coincident NUCAPS atmospheric profiles.

Aircraft Pattern/Module Descriptions (see *Flight Pattern* document for more detailed information):

P-3 Pattern 1/Module 1: This can be a stand-alone pattern or a break-away module that samples the environment of the SAL. Targets will include sampling the SAL's thermodynamics (warmth and low to mid-level dry air) for satellite validation, as well as the SAL's mid-level easterly jet. Although not a requirement, the SAL would preferably be interacting with a tropical disturbance (e.g., AEW, invest, or TC). For SAL-only sampling, a standard (or modified) Lawnmower pattern will be flown. For tropical disturbances interacting with the SAL, the following standard patterns can be flown: Figure-4, Rotated Figure-4, Butterfly, Lawnmower, Square Spiral, and P-3 Circumnavigation. For TC/invest targets, circumnavigations will be flown as close to the inner core as safety permits [e.g., R~60-90 n mi (110-165 km)] and legs should extend out to the (near) cloud free region in the periphery of the storm [e.g., R=80-215+ n mi (150-400+ km)] to sample regions where NUCAPS soundings will experience less cloud contamination and therefore likely to be more robust. Take-off times will be adjusted to maximize temporal and spatial overlap with the NOAA-20/-21 satellite overpass. Targets of interest can also be sampled during ferries to/from the storm.

P-3 Pattern 2/Module 2: This can be a stand-alone pattern or a break-away module that samples the peripheral environment (e.g., R~90-215 n mi/165-400 km) of a tropical disturbance (e.g., AEW, invest, or

TC) or the environment of a TC undergoing ET. Depending on the intensity of the target of interest, the following standard patterns can be flown: Figure-4, Rotated Figure-4, Butterfly, Lawnmower, Square Spiral, and P-3 Circumnavigation. For TC targets, circumnavigations will be flown as close to the inner core as safety permits [e.g., R≥60−90 n mi (110-165km)]. Take-off times will be adjusted to maximize temporal and spatial overlap with the NOAA-20/-21 satellite overpass. Targets of interest can also be sampled during ferries to/from the storm.

G-IV Pattern 1/Module 1: This can be a stand-alone pattern or a break-away module that samples the environment of the SAL. Targets will include sampling the SAL's thermodynamics (warmth and low to mid-level dry air) for satellite validation, as well as the SAL's mid-level easterly jet. Although not a requirement, the SAL would preferably be interacting with a tropical disturbance (e.g., AEW, invest, or TC). For SAL-only sampling, a standard (or modified) Lawnmower pattern will be flown. For tropical disturbances interacting with the SAL, the following standard patterns can be flown: Figure-4, Rotated Figure-4, Butterfly, Lawnmower, Square Spiral, G-IV Circumnavigation, G-IV Star, or G-IV Star with Circumnavigation. For TC/invest targets, circumnavigations will be flown as close to the inner core as safety permits [e.g., R~60-90 n mi (110-165 km)] and legs should extend out to the (near) cloud free region in the periphery of the storm [e.g., R=80-215+ n mi (150-400+ km)] to sample regions where NUCAPS soundings will experience less cloud contamination and therefore likely to be more robust. Take-off times will be adjusted to maximize temporal and spatial overlap with the NOAA-20/-21 satellite overpass. Targets of interest can also be sampled during ferries to/from the storm.

G-IV Pattern 2/Module 2: This can be a stand-alone pattern or a break-away module that samples the peripheral environment (e.g., R~90-215 n mi/165-400 km) of a tropical disturbance (e.g., AEW, invest, or TC) or the environment of a TC undergoing ET. Depending on the intensity of the target of interest, the following standard patterns can be flown: Figure-4, Rotated Figure-4, Butterfly, Lawnmower, Square Spiral, G-IV Circumnavigation, G-IV Star, or G-IV Star with Circumnavigation. For TC targets, circumnavigations will be flown as close to the inner core as safety permits [e.g., R≥60−90 n mi (110-165km)]. For TCs undergoing ET at higher latitudes (e.g., north of 35ºN), the lower climatological altitude of the tropopause may allow the G-IV to overfly the storm center more easily and will be assessed on a case-by-case basis. Take-off times will be adjusted to maximize temporal and spatial overlap with the NOAA-20 satellite overpass. Targets of interest can also be sampled during ferries to/from the storm.

Links to Other Experiments/Modules: This module can generally be flown in conjunction with another campaign or module if there is significant TC environmental sampling and significant coincidence with a NOAA-20/-21 satellite overpass.

Analysis Strategy: Guidance for P-3 and G-IV take-off times will be determined by the timing and location of NOAA-20/-21 satellite overpasses in the target(s) of interest. The GPS dropsonde sampling strategy will be determined by the tropical cyclone, invest, transitioning storm, and/or SAL outbreak locations relative to the satellite overpass times and locations. Retrospective analyses will be conducted to assess how well NUCAPS represent the environments that are sampled by GPS dropsondes.

References:

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