2024 NOAA/AOML/HRD Hurricane Field Program - APHEX

OCEAN OBSERVING EXPERIMENT

Flight Pattern Description

Experiment/Module: CHAOS (Coordinated Hurricane Atmosphere-Ocean Sampling)

PIs: Jun Zhang, Lev Looney (NOAA/U Miami), Cheyenne Stienbarger (NOAA GOMO),

Investigator(s): Kathy Bailey (U.S. IOOS), Michael Bell (CSU), Luca Centurioni (Scripps), Paul Chang (NOAA NESDIS), Joe Cione, Gregory Foltz (NOAA AOML), Alex Gonzalez (WHOI), Stephan Howden (USM), Steven Jayne (WHOI), Zorana Jelenak (NOAA NESDIS), Hyun-Sook Kim (NOAA AOML), Matthieu Le Henaff (CIMAS/PhOD), Kevin Martin (USM), Edoardo Mazza (NOAA PMEL), Travis Miles (Rutgers), Theresa Paluszkiewicz (OOC, LLC),
David Richter (UND), Pelle Robbins (WHOI), Johna Rudzin (Mississippi State), Joe Sapp (NOAA NESDIS), Martha Schonau (Scripps), Nick Shay (UMiami), Joshua Wadler (ERAU), Chidong Zhang (NOAA PMEL), Dongxiao Zhang (UW-PMEL)

Collaborators: Dave Jones, StormCenter Communications | GeoCollaborate

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

Ocean Observing Science Objective(s) Addressed

1) Collect observations targeted at better understanding air-sea interaction processes contributing to hurricane structure and intensity change. [*APHEX Goals 1, 3*]

2) Collect observations targeted at better understanding the response of hurricanes to changes in underlying ocean conditions, including changes in sea surface temperature, ocean mixed layer depth, turbulent mixing and ocean heat content [*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 and surface measurements in TCs. 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 ocean conditions [*APHEX Goal 2*]

Note: With limited numbers of assets, the expendables described in the flight patterns below are proposed on an *if-available* basis. Further, there are no specific requirements for regular GPS dropwindsondes over StreamSondes across all flight patterns.

See here for the accompanying 2024 Science Description.

P-3/G-IV Pattern #1: Ocean Observing Platform Overflight

What to Target: Pre-existing ocean observing platform (saildrone, glider, mooring, drifter, profiling float, etc.), with preference to those within the region of TS-force winds or higher

When to Target: Must be within 25 nautical miles (NM) of the ocean observing platform, preferred would be directly overhead the platform, but 25 NM is the maximum distance. The closer, the better (significantly). *Can be during operational or research-based flights.*

Pattern: No constraint. *Ideally the pre-existing flight pattern would be adjusted to include direct flyover* (as in CHAOS-1)

Flight altitude: No constraint

Leg length or radii: No constraint

Estimated in-pattern flight duration: < 5 minutes (pending pre-existing flight pattern)

Expendable distribution: No constraint, preference for at least 1 atmospheric and oceanic expendables as available

Notes: The goal here is to get as close to the ocean observing platform as possible. The pre-existing ocean observing platform may have been deployed from a previous flight. If multiple ocean platforms present, see pattern #2. If pattern #2 cannot be conducted, please conduct pattern #1 multiple times to best fit all platforms present. Direction the pattern is flown and storm-relative position is not a constraint.

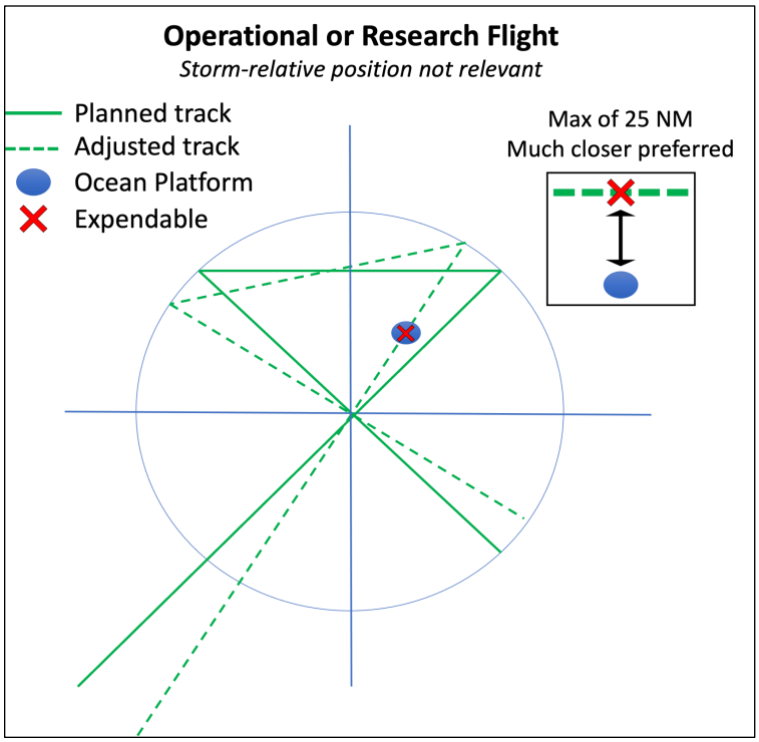

Figure CHAOS-1: *No specific pattern expected. Here, we illustrate a pre-existing Figure 4 pattern adjusted to fly near/over the ocean observing platform along with the expendable location.*

P-3/G-IV Pattern #2: Multi-Platform Overflight

What to Target: Multiple pre-existing ocean observing platforms (including saildrones, gliders, moorings, drifters, profiling floats, etc.) within TS-force conditions or higher and a *maximum separation of 25 NM* between ocean observing platforms

When to Target: No constraint, preferably the estimated time of strongest conditions for the pair during flight

Pattern: Straight line (as in CHAOS-2)

Flight altitude: No constraint

Leg length or radii: Maximum of 25 n mi (45 km)

Estimated in-pattern flight duration: < 10 min (straight line)

Expendable distribution: No constraint, preference for at least 2 atmospheric and oceanic expendables as available

Notes: If expendables are limited, the primary expendable deployment should be directly overhead the higher priority platform (i.e., platforms with met-ocean sensors). Direction the pattern is flown and storm-relative position is not a constraint. If flying over both platforms is not possible or they are more than 25 NM apart, defer to doing Pattern #1 for each platform.

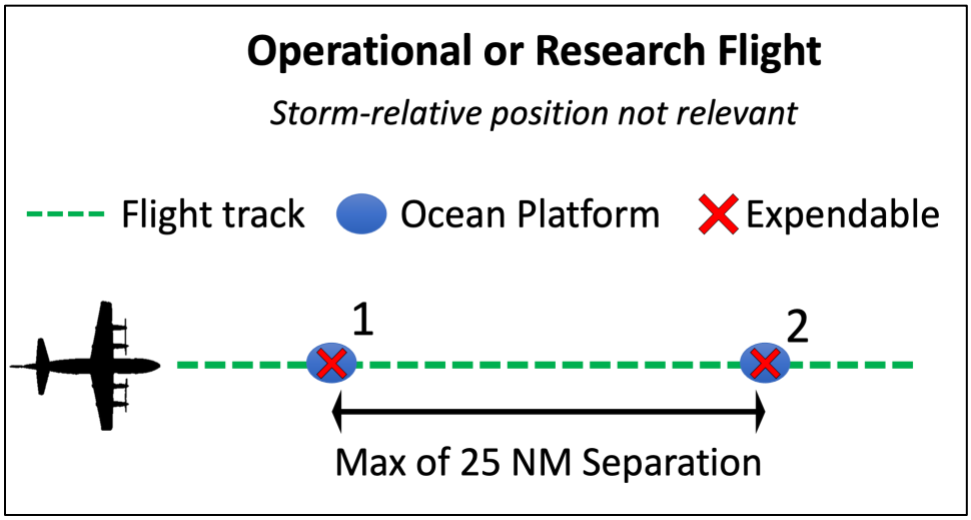

Figure CHAOS-2: *Typical pattern flown is expected to be a straight line overhead both ocean observing platforms with the expendable location.*

P-3/G-IV Pattern #3: Minimum Saildrone Gradient

What to Target: Saildrone within region of TS-force winds or higher

When to Target: Centered over saildrone, preferably the estimated time of strongest conditions for the saildrone during flight

Pattern: Straight line (as in CHAOS-3)

Flight altitude: No constraint

Leg length or radii: 5 - 25 n mi (10-45 km)

Estimated in-pattern flight duration: ~5-15 min (pending distance, straight line)

Expendable distribution: At least 3 atmospheric expendables and 1 oceanic expendable as available

Notes: Preferred distance between deployment location '1' and '2' is 5 NM. However, up to 25 NM is acceptable. Direction the pattern is flown and storm-relative position is not a constraint. Preferred leg is tangential to the winds, however, perpendicular to the winds would be second preference.

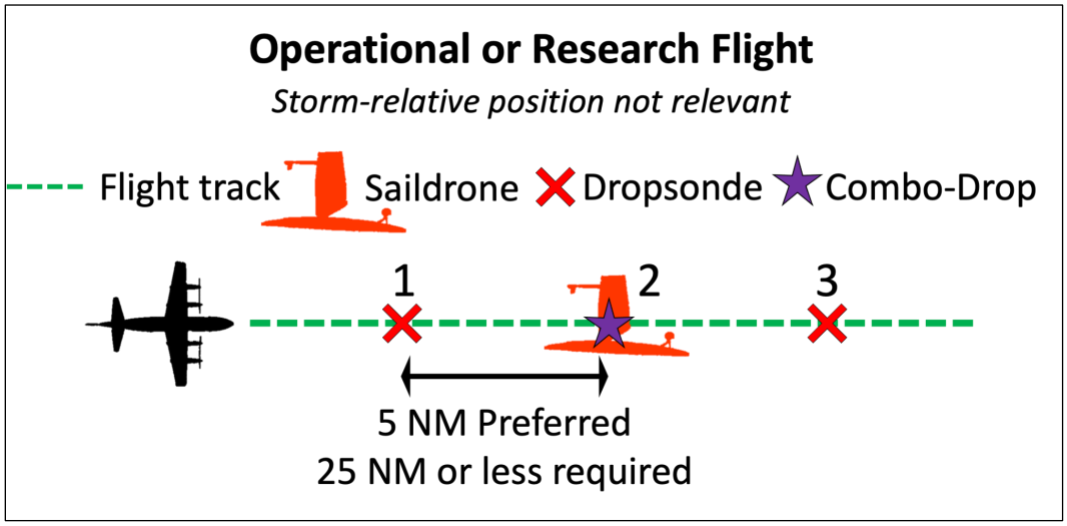

Figure CHAOS-3: *Typical pattern flown is expected to be a straight line overhead the saildrone with the expendable locations. If 1 or more ocean expendables are available, priority deployment is at location '2' (combo-drop).*

P-3 Pattern #4: A-DWSD Wave Drifter Deployment and Fly Over

What to Target: Area ahead of and slightly to the right of TC center

When to Target: On-flight KaIA or WSRA must be working and running

Pattern: Figure 4 (as in CHAOS-4 A) or specially designed pattern (as in CHAOS-4 B)

Flight altitude: 10k ft or lower for drifter deployment

Leg length or radii: ≥ 20 NM

Estimated in-pattern flight duration: ~10 min (Figure 4); ~15 minutes (specially designed)

Expendable distribution: Priority: 2 wave drifters; if available: 2 atmospheric expendables

Notes: (A/Operational Flights) The A-sized Directional Wave Spectra Drifters (A-DWSD) should be deployed ahead of the storm in the front-right quadrant with at least 10 NM spacing ahead of the eyewall and 15-20 NM spacing between drifters. (B/Research Flights) A-DWSD can be deployed in locations around the eye wall with repeat radial flights across the eyewall. In both research and operational flights, preference would be to return back to overfly the drifters and deploy atmospheric expendables. However, if overflight is not possible, atmospheric expendables would be co-deployed with the initial drifter deployment.

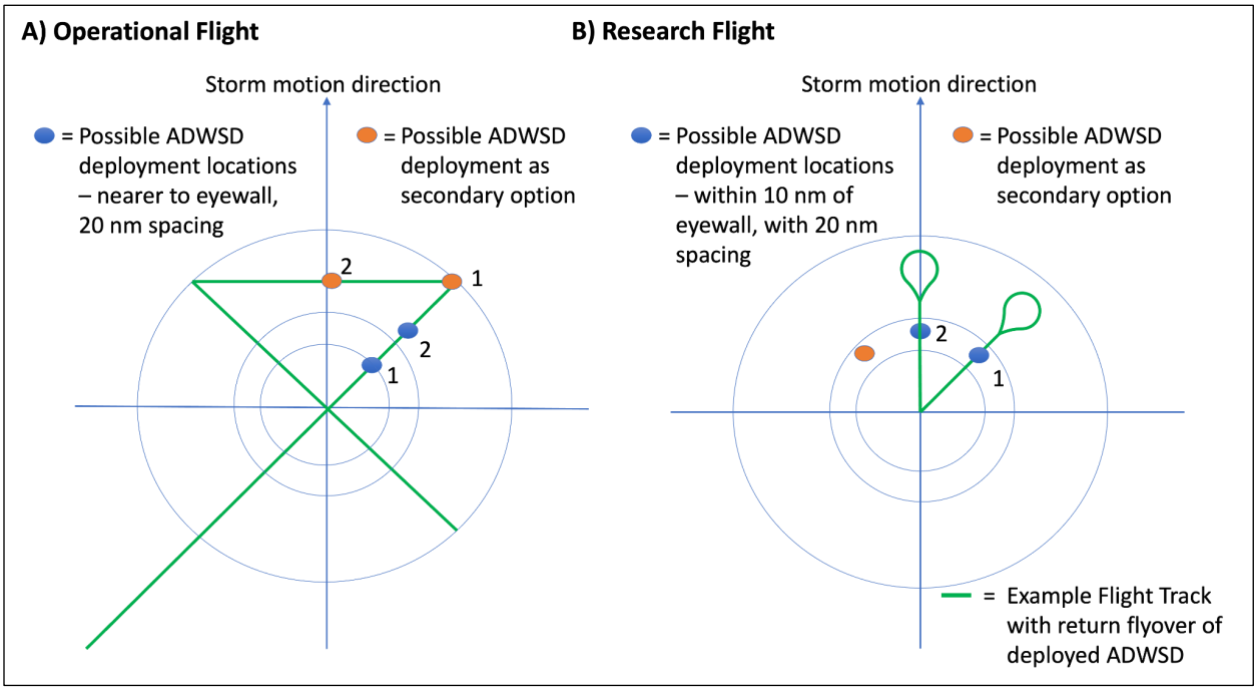

Figure CHAOS-4: *Typical pattern is expected to be a Figure 4 or other standard patterns in HFP Appendix A, with deployment locations. For research missions, other specially designed P-3 patterns may be used.*

P-3 Pattern #5: Full Saildrone Gradient

What to Target: Saildrone within region of TS-force winds or higher

When to Target: Centered over saildrone, preferably the estimated time of strongest conditions for the saildrone during flight

Pattern: Figure 4 (as in CHAOS-5)

Flight altitude: No constraint

Leg length or radii: 5-25+ NM

Estimated in-pattern flight duration: ~10-40 min (Figure 4)

Expendable distribution: At least 6 atmospheric expendables and 1 oceanic expendable as available

Notes: If oceanic expendables are limited, the deployment should be directly overhead the saildrone at the combo-drop location. Direction the pattern is flown and storm-relative position is not a constraint. Preferred to have one leg tangential to the winds, while the other leg is preferred to be perpendicular to the winds. The reduced pattern (A) is when expendables are more limited. For both patterns, the lowest priority expendable deployment is the cross-leg location.

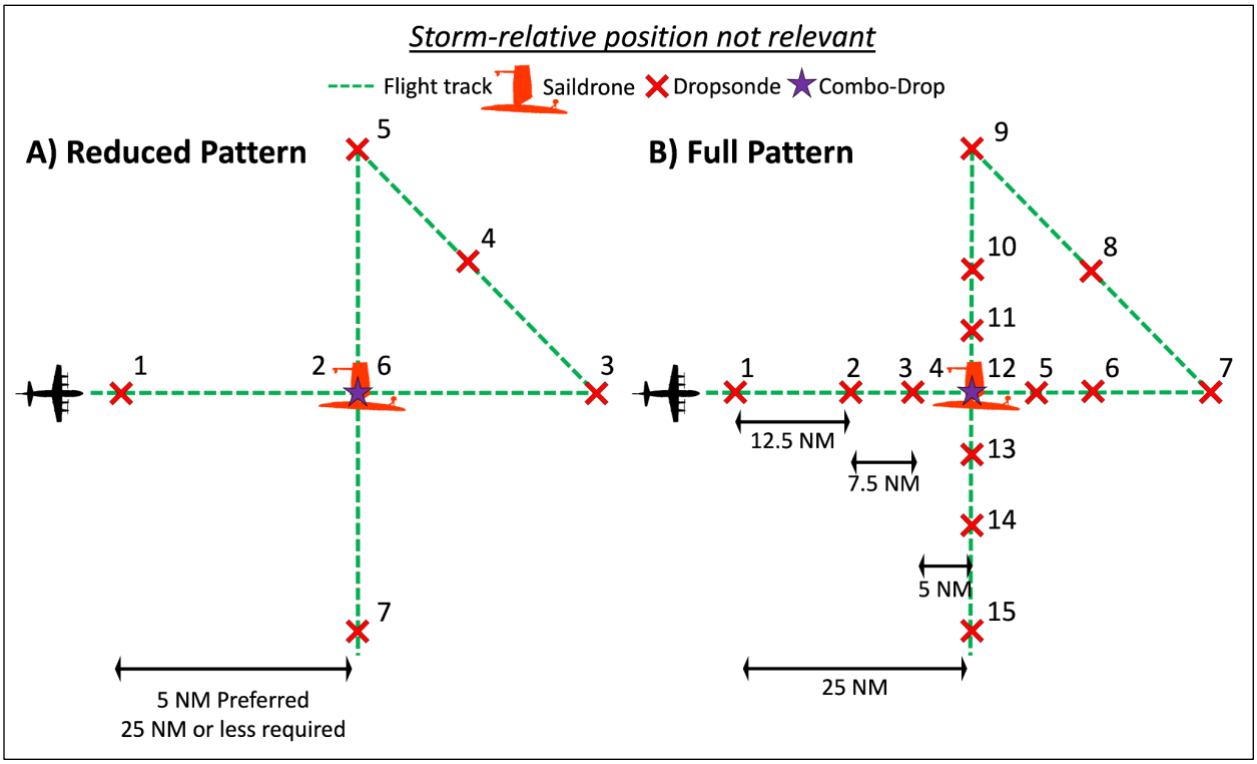

Figure CHAOS-5: *Typical pattern flown is expected to be a Figure 4 centered over the saildrone with the expendable locations. The reduced pattern (A) is when expendables are more limited, whereas the full pattern (B) is the full amount requested. If 1 or more ocean expendables are available, priority deployment is at combo-drop location.*

P-3 Pattern #6: sUAS/P-3 Saildrone Overflight

***NOTE:** The detailed version of this pattern is described in the "Research In Coordination with Operations Small Uncrewed Air Vehicle Experiment (RICO SUAVE)" Pattern #6.

What to Target: Saildrone within region of TS-force winds

When to Target: Preferably the estimated time of strongest conditions for the saildrone during TC intercept

Pattern: Pending conditions, possibly Figure-4 (as in CHAOS-6 P-3 Flight Path Orange)

Flight altitude: 10 kft for sUAS deployment, then no constraint

Leg length or radii: Pending conditions, minimum of 10 NM

Estimated in-pattern flight duration: 30+ min (Figure 4)

Expendable distribution: N/A (see RICO SUAVE)

Flight Pattern Description

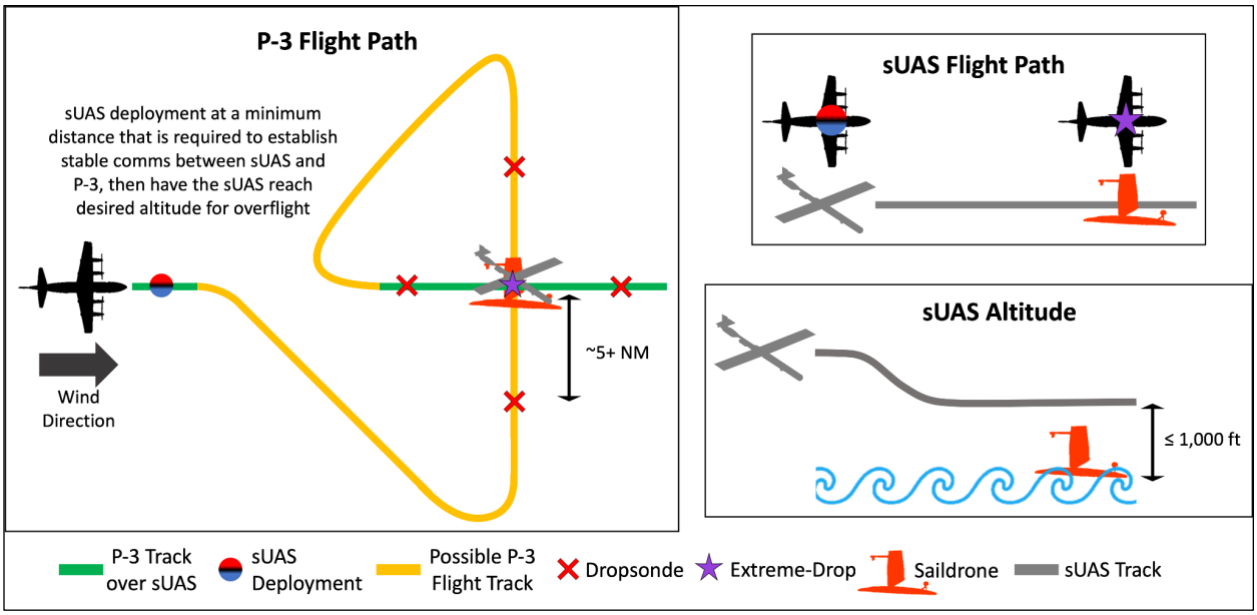

Figure CHAOS-6: *P-3 and sUAS flight patterns for the saildrone overflight module. The sUAS is deployed far upwind (distance pending other variables) of the saildrone at the red/black/blue circle. The following goal would be to have the P-3 fly overhead the saildrone at the nearest time possible as the sUAS overflies the saildrone (depicted in green). The P-3 will (pending safety) deploy expendables ~5 NM either side of the saildrone and a deployment of all available types of expendables directly overhead the saildrone. During the time between the deployment of the sUAS and the overfly, the P-3 pattern depends on conditions, with the orange path depicting what would be preferred. The sUAS flight path (top right; gray) should be downwind directly to the saildrone. During this time, the sUAS will drop to ≤ 1,000 ft (pending conditions) for the overflight. If battery and conditions permit the sUAS to circumnavigate the TC and overfly the saildrone again, then the final leg of the pattern is repeated (final green line).*