EARLY STAGE EXPERIMENT
Flight Pattern Description

Experiment/Module: Vortex Alignment Module (VAM)

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Requirements: TD, TS, Category 1

Early Stage Science Objective(s) Addressed:

1) Collect datasets that can be used to improve the understanding of intensity change processes, as well as the initialization and evaluation of 3-D numerical models, particularly for TCs experiencing moderate vertical wind shear [*APHEX Goals 1, 3*].
2) Obtain a quantitative description of the kinematic and thermodynamic structure and evolution of intense convective systems (convective bursts) and the nearby environment to examine their role in TC intensity change [*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 early stage TCs. These measurements include improved three-dimensional representation of the TC wind field, more spatially dense thermodynamic sampling of the boundary layer, and more accurate measurements of ocean surface winds [*APHEX Goal 2*].

Rotations to standard P-3 Patterns for VAM

P-3: Standard Figure-4

What to Target: Sample the inner core region of a TC.

When to Target: Every 6–12 h, possibly in coordination with a corresponding G-IV mission (G-IV Pattern #1), depending on the VAM *Scenario* chosen.

Pattern: A standard Figure-4 pattern centered on the estimated low-level or, preferably, mid-level center, oriented such that the radial passes are aligned along and perpendicular to the direction of vertical tilt of the circulation center. In the absence of previous TDR analyses, the mid-level center can be estimated by the region of coldest infrared brightness temperatures from geostationary satellite imagery. If possible, the first inbound-outbound center pass should be oriented (to the best it can be determined) along the direction of the low-level to mid-level center tilt. After completion of the Figure-4 pattern, it is preferred that P-3 Module #1 ("*Vortex Alignment Module*") be flown.

Flight altitude: 10–12 kft, either radar or pressure altitude; potentially up to 20 kft, safety permitting if aircraft icing is not an issue.

Leg length or radii: 105 n mi (195 km), although legs can be abbreviated to 100 km from TC center if no obvious scatterers are noted on TDR display.

Estimated in-pattern flight duration: ~2 h for the Fig. 4, but up to ~4.5 h if P-3 module #1 is flown afterward.

Expendable distribution: Standard dropsonde pattern for Fig. 4, with drops at turn points, midpoints, and center (10 sondes total).

Instrumentation Notes: Use TDR defaults. Use straight flight legs as safety permits. Inbound-outbound passes should be uninterrupted.

P-3: Standard Butterfly

What to Target: Sample the inner core region of a TC.

When to Target: Every 6–12 h, possibly in coordination with a corresponding G-IV mission (G-IV Pattern #1), depending on the VAM *Scenario* chosen.

Pattern: A standard butterfly pattern centered on the estimated low-level or, preferably, mid-level center. If centered on the low-level center, legs in the downtilt direction may also be extended (and uptilt legs shortened to compensate) to account for misalignment and precipitation symmetry. The butterfly should be oriented such that the downshear / downtilt portion of the storm contains the most radial legs. In the absence of previous TDR analyses, the mid-level center can be estimated by the region of coldest infrared brightness temperatures from geostationary satellite imagery. If possible, the first inbound-outbound center pass should be oriented (to the best it can be determined) along the direction of the low-level to mid-level center tilt. After completion of this pattern, it is preferred that P-3 Module #1 ("*Vortex Alignment Module*") be flown.

Flight altitude: 10–12 kft, either radar or pressure altitude; potentially up to 20 kft, safety permitting if aircraft icing is not an issue.

Leg length or radii: 105 n mi (195 km), although legs can be abbreviated to 100 km from TC center if no obvious scatterers are noted on TDR display.

Estimated in-pattern flight duration: ~3.25 h for the butterfly, but up to ~4.5 h if P-3 module #1 is flown afterward.

Expendable distribution: Standard dropsonde pattern for Fig. 4, with drops at turn points, midpoints, and center (15 sondes total).

Instrumentation Notes: Use TDR defaults. Use straight flight legs as safety permits. Inbound-outbound passes should be uninterrupted.

P-3 Pattern #1: Vortex Alignment Module

What to Target: The vortex and precipitation structure associated with a vertically misaligned (i.e., tilted) TC vortex. The vortex tilt structure can be identified from the most recent TDR analysis generated from a given mission. Ideally, the 2–7-km tilt magnitude is on the order of 50–125 km and convective activity has been observed near the mid-level or low-level TC center.

When to Target: Every 6–12 h, possibly in coordination with a corresponding G-IV mission (G-IV Pattern #1), depending on the VAM *Scenario* chosen.

Pattern: Fly straight legs beginning 25 n mi (~45 km) up-tilt of the low-level TC center (at a height of 2 km) to 25 n mi (~45 km) down-tilt of the mid-level TC center (at a height of 6–7 km). TC respective centers can be identified from the previously flown legs from either P-3 Pattern #1 or #2. Then the aircraft samples the same transect, following the opposite heading, from up-tilt of the mid-level TC center to down-tilt of the low-level TC center. This pattern is repeated for an additional 1–4 times, with potential changes in orientation of the legs as needed to account for evolution in the tilt magnitude and direction. In the event convection is too intense to permit straight and level legs directly between the two TC centers, it is preferred that a box pattern be flown as close as possible to the respective low- and mid-level centers as safety considerations permit.

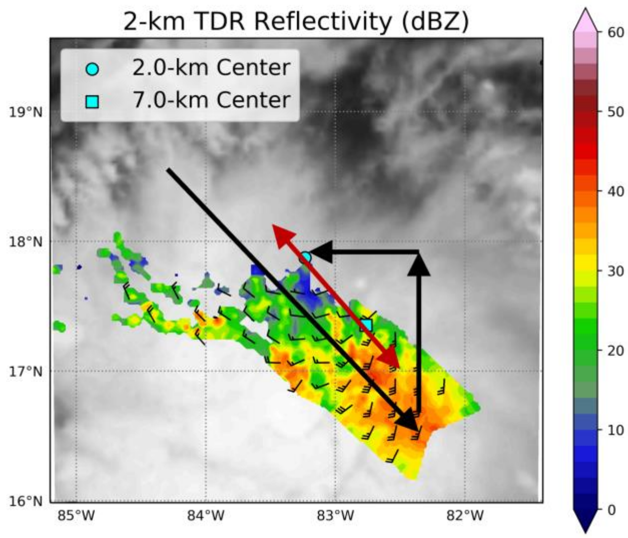

Figure VAM1: Example of one possible Vortex Alignment Module to be flown. IR brightness temperatures are shown in grayscale shading and 2-km TDR reflectivity is shown in color shading and wind in black barbs. The vortex tilt structure is identified from an initial Figure-4 pattern, shown by the black arrows, while the Vortex Alignment Module flight track would follow the red arrows, flying in straight lines back and forth between the low-level center (shown here by the cyan circle) and the mid-level center (shown here by the cyan square).

Flight altitude: 10–12 kft within precipitation regions (red line)

Leg length or radii: Dependent upon vortex tilt magnitude as described above

Estimated in-pattern flight duration: 45 min to 2 hr, depending on tilt magnitude, such that at least two complete transects (four radial legs) between the low-level and mid-level TC centers are conducted.

Expendable distribution: Release dropsondes each-time the low-level TC center is transected.

Instrumentation Notes: TDR analyses should be generated for each radial leg (e.g., each leg between either the low-level to mid-level TC center or vice versa). Use straight flight legs as safety permits. Inbound-outbound passes should be uninterrupted.

G-IV Pattern #1:

What to Target: Sample the inner core, near environment, and environment of a TC

When to Target: Every 6–12 h, possibly in coordination with a corresponding P-3 mission, depending on the VAM *Scenario* chosen.

Pattern: Standard single Figure-4 with Double Circumnavigation; if time is not available to complete the full pattern, the Fig. 4 is prioritized with either the inner or outer circumnavigation (preference to the inner circumnavigation). If ongoing convection prevents the G-IV from flying the initial Fig. 4 pattern passing over the TC center, the Fig. 4 can be substituted with a box pattern about the TC center. Ideally, this substitute box pattern would have legs that pass within 30 n mi of the TC center location to maximize TDR coverage.

Flight altitude: 40–45 kft

Leg length or radii: Up to 150 n mi (275 km) for the Fig. 4; 90 n mi (165 km) and 210 n mi (390 km) for the inner and outer circumnavigation, respectively.

Estimated in-pattern flight duration: ~6.5 h

Expendable distribution: Dropsonde at each turn point, midpoint, and center on each pass, and another at the midpoint of downwind leg; dropsonde at each turnpoint of the circumnavigations; 11 total for Fig. 4, 13 total for circumnavigations, and 24 total for pattern. Optionally, can increase the density of sondes in Fig. 4 and/or circumnavigations, potentially doubling the total dropsondes released in the pattern.

Instrumentation Notes: Use TDR defaults. Use straight flight legs as safety permits.