HS3 Genesis Missions (DRAFT 3)

June 12, 2012

1 Hypotheses regarding TC genesis

There appear to be three current hypotheses regarding TC genesis:

1. Montgomery-Dunkerton pouch hypothesis: The TC forms in a pre-existing wave at the intersection of the wave axis and the latitude where the wave propagation velocity matches the zonal wind velocity of the environment. The wave-relative winds are weakest at this point, resulting in a pouch region protected from the environment.

2. Elsberry hypothesis: The TC forms in the low-shear, deep moisture region generally on the south side of the wave in westerly winds. This location is generally to the south of the Montgomery-Dunkerton pouch.

3. Raymond hypothesis: The low-level circulation signaling the formation of a TC develops underneath a pre-existing mid-level circulation that provides the thermodynamic environment needed for the development of the bottom-heavy convective mass flux profiles required for low level spinup.

These hypotheses aren't necessarily mutually exclusive. However, we need to design patterns which test all three of the above hypotheses simultaneously.

2 Platforms and instruments

Two Global Hawk (GH) unmanned aircraft will be available for the project. NOAA and Air Force Reserve aircraft will be working in coordination with the GHs when interests overlap. Points of interest:

- Flights will operate from Wallops Flight Facility near Chincoteague, VA for approximately the month of September in 2012, 2013, and 2014.

- Flights will be up to 26 hr with operating altitudes between 55,000 and 60,000 ft.

- Almost any point in the Atlantic basin including the Caribbean and Gulf of Mexico where TCs occur can be reached, with 6-16 hr on station, depending on location.

- Time for turnaround of a GH aircraft is 48 hr, though this may be reduced in the future.
- One aircraft will be flown at a time, with the launch of a second aircraft occurring a minimum of 2 hr after the return of the first. Launch of a second aircraft 4 hr before the return of the first may be possible in the future.
- Takeoff and landing must occur during daylight hours. Morning is preferred, due to cooler conditions (important, as fuel is used to cool electronics). However, takeoff and landing around 2 PM would allow better 00Z/12Z coordination with NOAA G-IV and P-3 tasked missions.

The GH aircraft and instrumentation now available are briefly described below.

2.1 AV-6 (environmental payload)

- AVAPS: This is the dropsonde system. 88 sondes are available for each flight.
- S-HIS: This is a passive infrared sounder used to obtain profiles of temperature and humidity in clear air.
- CPL: This is the cloud physics lidar, used to profile cloudiness and aerosols.

2.2 AV-1 (over-storm payload)

- HIRAD: This is a passive microwave sensor to measure ocean surface wind conditions and rainfall. It operates on the same principle as NOAA's stepped frequency radiometer.
- HIWRAP: This is a Doppler radar which makes downward-looking conical scans using Ku (1.7 - 2.5 cm) and Ka (0.75 - 1.13 cm) wavelengths. It also measures surface wind using scatterometry.
- HAMSR: This is a passive microwave sounder used to obtain temperature and humidity profiles. Its resolution and accuracy are less than those of S-HIS, but it works in cloudy conditions.

Note that AV-1 does not carry a dropsonde system at this point. However, there was strong sentiment at the May 2012 meeting at Wallops to install such a system in time for the 2013 field program.

3 Thoughts on strategy

Before getting down to the business of drawing flight patterns, we outline strategies for testing the above hypotheses. Additions/corrections welcome.

- Though collaborative operations with NOAA will be welcome, we must realize that NOAA has its own priorities. Our view is that we need to plan flights that will yield useful information in the absence of NOAA collaboration, but that will be enhanced if such collaboration occurs.

- Russ's idea about dropping a fairly broad pattern of dropsondes in the first flight with one goal of getting the drops into the global operational models is excellent. This should help in model predictions at least for the following 24 hr or so. Thus, AV-6, with its dropsonde capability, should generally launch first.

- The scale of the pattern we fly should contract as the system's scale contracts during development. Ed Zipser's idea of trying to fly a pattern twice in one flight is a good one primarily in the later stages of development, e.g., as a system is intensifying from tropical depression to tropical storm. The scale is smaller, giving time for repeated measurements; the time scale for development is shorter in this case, making such measurements productive.

- The best geographical scenarios for studying genesis are the western Atlantic and the Gulf of Mexico. The eastern Caribbean is heavily constrained by land and politics, with the western Caribbean being only marginally better. The eastern Atlantic has long ferry times. Given the variability in cyclogenesis patterns, we need to plan for east-central Atlantic observations as well as in more favorable areas. Eastern Caribbean operations are likely to be the most frustrating. It may be possible to address both the SAL and genesis objectives in the same flight.

- Repeated observations over time are generally needed for genesis observations due to the uncertainty in genesis time. Given the long turnaround time of the GHs, the best we can hope for (independent of NOAA flights) in the early stages of genesis is a 1-2 punch with a broad-scale pre-genesis flight of AV-6 centered on a disturbance of interest, followed by a flight on the next day of AV-1, in which hot spots within the broad disturbance are investigated. Hot spots are defined here as large, persistent convective regions either in or near the pouch (Montgomery) or east to southeast of the pouch in the inflow of moist, low-shear air which often exists there (Elsberry).

- Previous to tropical storm formation, AV-6 should employ a pattern which provides uniform spatial resolution over the entire region of interest, as there is no well-defined center at this stage. The pouch position is the predicted center according to the Montgomery-Dunkerton hypothesis, and this is a reasonable point on which to center flight patterns, but the regions peripheral to this point need to be well-resolved as well. In particular, the region south and east of the pouch needs to be documented to test the Elsberry hypothesis and the extent of the mid-level vortex should be covered to test the Raymond hypothesis. Given the projected time on station, this should be possible for all areas except the far eastern Atlantic.

- A suggestion is to use lawn mower patterns for the earliest stages and progress to square spirals as the system becomes better defined. Square spirals are better for the type of repeated patterns advocated by Ed Zipser, as restarting the pattern requires a ferry of

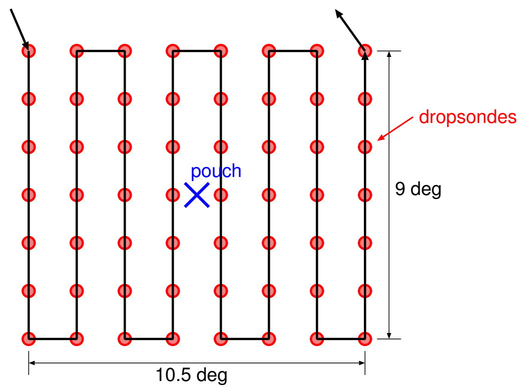

Figure 1: Broad flight pattern for AV-6. The 56 dropsondes (red circles) are spaced by 1.5°.

half the pattern diameter, whereas the lawn mower would require a ferry equal to the full diameter of the pattern.

- Measuring vertical mass fluxes as well as temperature and moisture patterns is important for the Raymond hypothesis, and probably for the others as well. Regularly spaced dropsonde array patterns serve this function. We need to determine how useful the HIWRAP radar on AV-1 is in providing horizontal winds suitable for computing vertical mass fluxes. We also need to think through the design of patterns needed to provide this information using HIWRAP.

- Ed Zipser suggests that the first flight have two plans, one with broad coverage, the second with finer resolution coverage within the box defined by the broad coverage in case the target system develops and shrinks in scale in the 48 hr or so between the initial filing of a flight plan and the actual flight. Hopefully, the finer resolution plan could be implemented on short notice, if it is within the confines of the initial pattern.

4 Sample flight patterns for AV-6

Sample flight patterns are sketched out below. In both cases the flight plan should be drifted with the motion of the system under study. A flight velocity for the GH of 6° per hour is assumed.

4.1 Broad pattern

This pattern is to be flown once. The objective is to sample a large area of a wave disturbance at about 1.5° resolution, using dropsondes. Figure 1 shows a possible pattern. A 3D-VAR analysis can be used to obtain wind and thermodynamic fields, and from these, the vorticity, divergence, and thermodynamic fields can be obtained. This pattern addresses all three of the above-discussed hypotheses. The wind pattern plus the disturbance propagation speed (obtainable from satellite observations) can be used to define the pouch, the winds plus mixing ratio give us the flow of moisture in from the south and the possible flow of dry Saharan air in from the north, and the full vorticity budget can be used to determine the

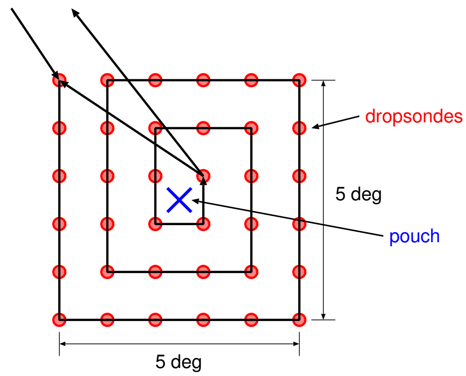

Figure 2: As in figure 2 except a focused pattern for AV-6. This pattern would be executed twice if possible resulting in $2 \times 36 = 72$ dropsondes.

vorticity tendency pattern. In addition, the winds plus thermodynamic data can be used to derive the moist entropy tendency, which is crucial for determining whether the atmosphere is moistening or drying.

The pattern as outlined would take about 14 hr to execute, exclusive of ferry time, and would require 56 dropsondes. If less on-station time were available, the pattern could be reduced in size in the longitudinal direction. Eliminating two north-south legs would result in an approximate 10 hr execution time, using 42 dropsondes. The pattern should be centered on the predicted pouch position and drifted with the disturbance. The entry and exit points of the pattern are taken on the north side, thus minimizing ferry time. The pattern can be flown either west to east or east to west, depending on circumstances.

4.2 Focused pattern

Given a better defined disturbance, e.g., a tropical depression, a smaller pattern can be flown. This might allow the pattern to be flown twice, as suggested by Ed Zipser. A square spiral is chosen, as this minimizes the ferry time between ending the first pass and beginning the second pass. The square spiral pattern shown in figure 2 shows the proposed pattern, which covers an area $5^\circ \times 5^\circ$ at 1° resolution. Each traversal of the pattern requires about 5.7 hr with a 0.6 hr ferry between traversals, resulting in a total of 12 hr, exclusive of ferry to and from Wallops. A total of 72 dropsondes would be used. The interval between the two traversals is 5.3 hr.

This pattern has much the same goals as the broad pattern, but at higher spatial resolution and with a repeat, allowing system evolution to be observed. As with the above case, the pattern should be drifted with the disturbance of interest.

5 Sample flight patterns for AV-1

The most useful instrument on AV-1 is likely to be the the HIWRAP Doppler radar. This radar can obtain horizontal wind profiles in the presence of clouds and precipitation using downward-looking conical scans. However, for at least 2012, there will be no dropsondes.

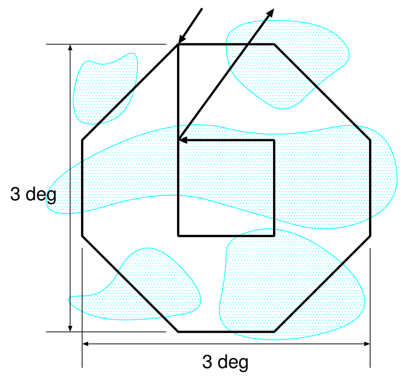

Figure 3: Alternative 1 pattern for AV-1 in which the HIWRAP Doppler radar is used to measure the wind field. The scale would change with the size of the targeted disturbance.

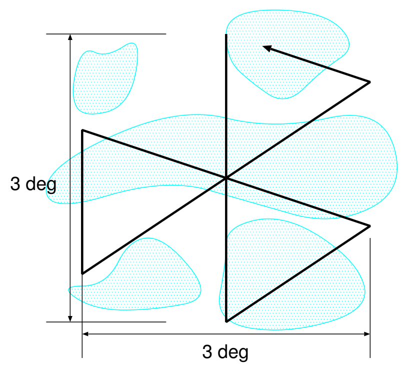

Figure 4: Alternative 2 AV-1 convective flight plan which maintains straight flight paths in the center of the pattern. Best for well organized, isolated convection.

It therefore makes sense to target convective regions. The wind profiles can in principle be used in a 3D-VAR analysis to map wind fields. These can be used in turn in an analysis of the vorticity budget. As this has not been done previously, 2012 must be viewed partly as an experiment testing the feasibility of this mode of operation. Two issues are likely to be important: (1) finding sufficient cloudiness to fill the radar beam; and (2) attenuation in heavy precipitation.

As the the convective field is hard to predict two hours, much less two days in advance, the only feasible mode of operation for AV-1 is to block out an area of interest with Air Traffic Control, with freedom to define patterns in near-real time within this block. The most important thing is to obtain adequate coverage to produce a 3D-VAR (or other) analysis, with the goal of analyzing the vorticity budget of the convective region. Modified square spiral patterns are probably best for this, as illustrated in figure 3, though this sacrifices radar data in the frequent turns.

The pattern in figure 3 should take about 2.5 hr. If multiple convective regions are to be studied, or if the same region is to be studied multiple times, between two and five patterns like this can be flown, depending on the available time on station ($6 - 16$ hr) and the ferry time between patterns.

An alternate pattern that takes about the same time as the pattern in figure 3, but

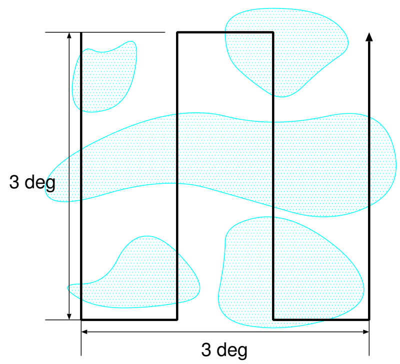

Figure 5: Alternative 3 AV-1 convective flight plan which maintains straight flight paths in the center of the pattern, but which would be better for highly disorganized convection.

maintains straight flight segments in the central regions of the pattern is a butterfly, as seen in figure 4. This would be useful if convection were focused in a somewhat circular pattern. However, it sacrifices spatial resolution in the outer regions.

A third alternative would be a scaled down lawnmower pattern (figure 5). This would probably be better when the convection has no discernable organization, or alternatively, linear organization. The pattern could be rotated so that the long tracks are normal to any linear structure.

All of these flight plans can be scaled in size, depending on the size of the convective cluster being studied. As with the AV-6 patterns, these patterns should be drifted with the motion of the system being studied.

The HAMSR passive microwave sounder is available on AV-1 to obtain low-resolution profiles of temperature and humidity. In principle the output of this instrument could be used to develop moisture budgets, but given the accuracy and resolution limitations of the instrument, this may or may not be a useful exercise.