Science Goal 1: to measure the properties of the condensate transported upwards in the updrafts to determine whether models are handling the various condensate conversion processes properly.

Rationale: In-situ validation of rain rates in mid-column and near-surface are extremely valuable for radar retrievals. Constraints down low from in-situ observations aid the retrievals in the mixed phase region.

Flight Pattern: Penetrations through convection below cloud base and over a range of temperatures (Fig. 1), with the underlying caveat that safety is foremost; lightning, for example, must be avoided[1]. The model for this flight pattern comes from the NAMMA 20 Aug. 2006 case (Fig. 1). It would be very desirable to stack the DC-8 and Global Hawk when possible. Furthermore, during the periods when the WB57 aircraft participates it would be very desirable to stack all three aircraft.

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[1] Richard Blakeslee will provide lightning data during GRIP for real-time analyses. The data will include Vaisala's NLDN (when close to coast), Long Range, and the new GLD360, World Wide Lightning Location Network (WWLLN), and the new Weather Bug Total Lightning Network (WTLN). Together these networks should identify storms that are producing lightning, even if the detection efficiency is low. Both in NAMMA and TC4 when the DC-8 was struck by lightning, RTMM did indicate the presence of lightning in the vicinity of the aircraft prior to the strike to the plane.

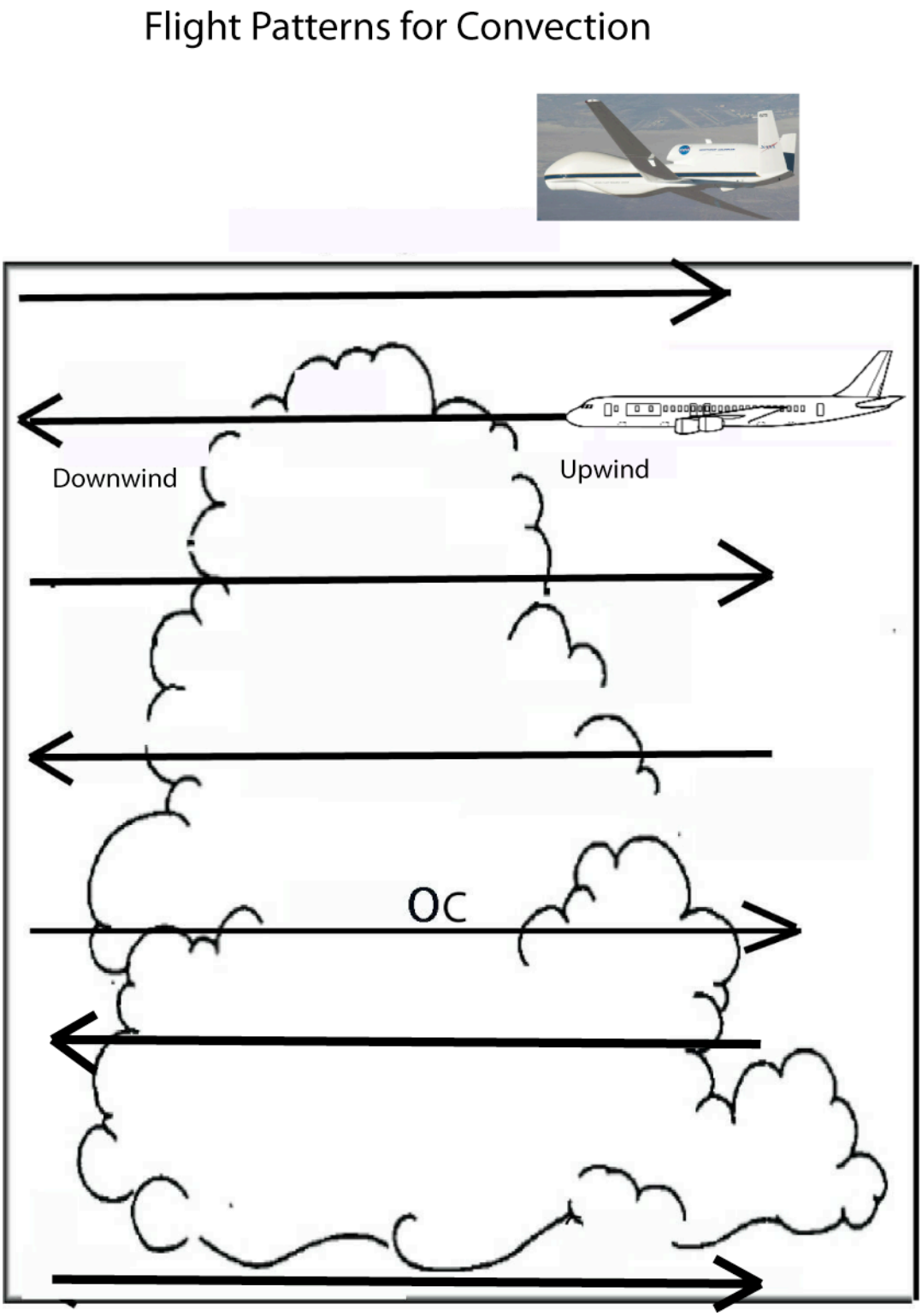


Fig. 1: Flight patterns for Science Goal 1.

Science Goal 2: Characterize the properties of dust layers and examine the influence of dust aerosols on cloud microphysics

Rationale: Rapid intensification of tropical cyclones may be related to the underlying microphysics, which may be influenced by dust acting as cloud condensation nuclei and ice nuclei. Dust outbreaks are commonly found in the western Atlantic during the GRIP time frame. Drawing upon the work of Prospero, Fig. 2 shows a time series of the concentration of dust measured at Barbados during August for the period 1973-2006. There are wide fluctuations in the occurrence of dust, reflecting periodic dust outbreaks at Barbados. We should be able to readily sample dust periodically (1/2 of the time during August) or through horizontal traverses into dust outbreak areas. Satellite imagery and Naval Postgraduate School products can be used to guide us into dust or clean areas.

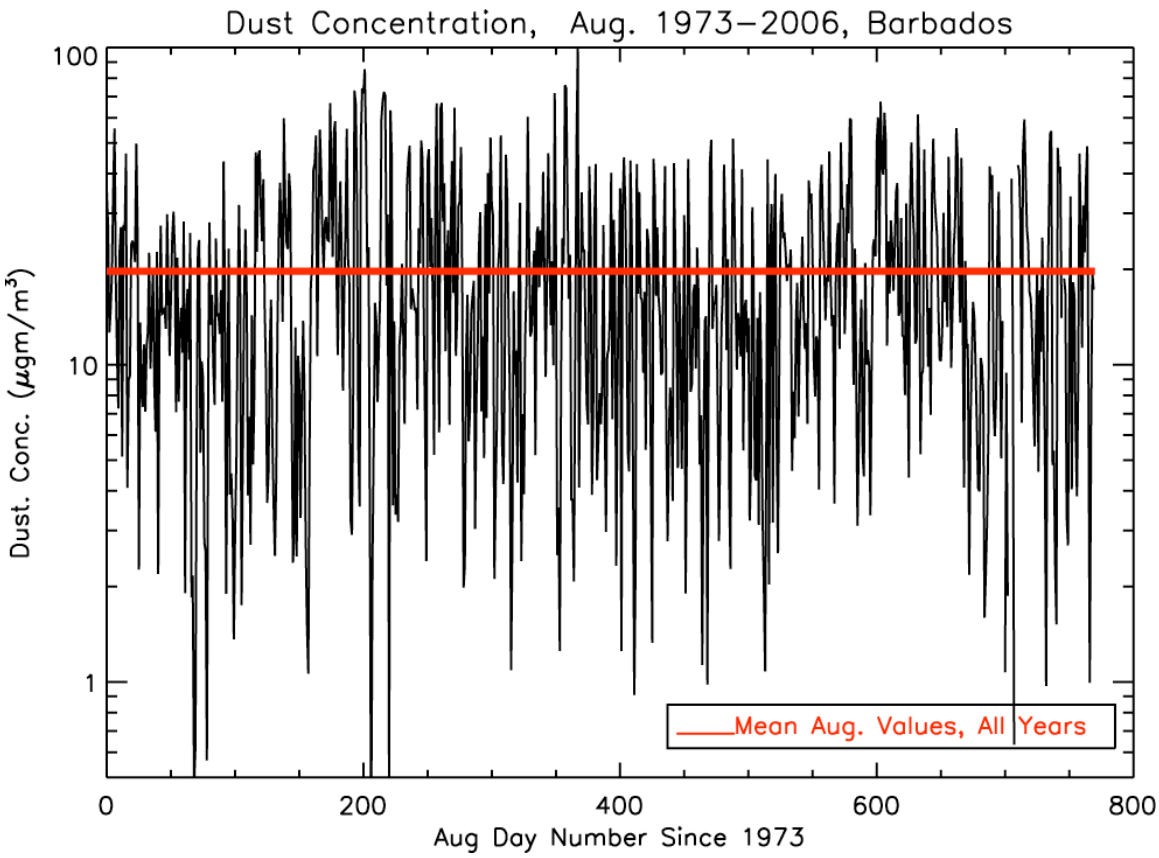


Fig. 2: Concentration of dust measured at Barbados by Prospero on days during August beginning with 1973.The day number refers to the number of August days when data has been collected since 1973. The horizontal line shows the mean value for all days.

Flight Patterns: The flight patterns used to study the influence of dust on cloud microphysics are similar to those given by Fig. 1. To sample dust in clear air conditions, we suggest a spiral flight pattern (Fig. 3), but not Lagrangian (following the horizontal winds) and relatively rapid so as not to consume too much aircraft time.

If time is constrained, we suggest one of two possibilities: straight-legs at two altitudes along and against the wind direction, or porpoising from above to within the dust layer. For the first scenario, begin with an overflight at a high altitude to acquire curtains with lidars, APR-2 and sonde drops. Thereafter, based on the quick-look lidar and radar images (if there is radar echo), identify two penetration altitudes, one within the aerosol layer and one either below or above it. Fly the DC-8 through the aerosol layer, turn while descending through it, then fly either above or below the layer. In the second scenario, determine an approximate height for the dust layer, then porpoise from above to within the layer. Coordinate the DC-8 flight tracks with the Global Hawk and WB-57.

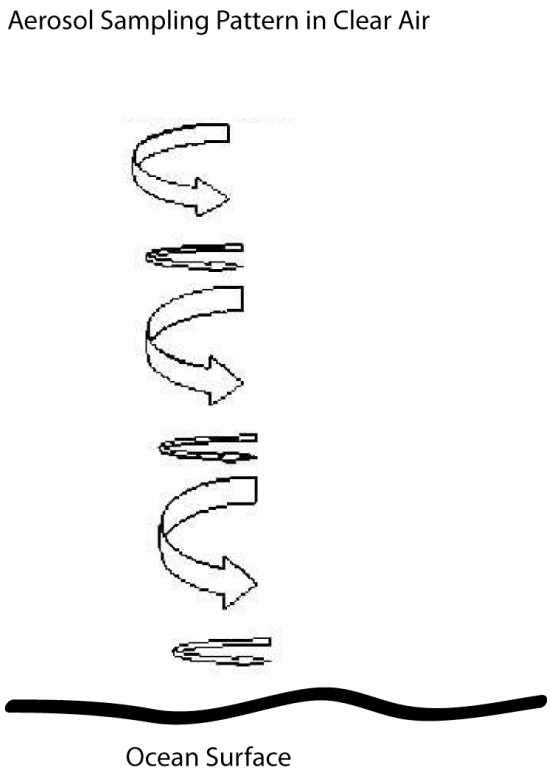


Fig. 3: Profile for characterizing dust layers in clear air.

Science Goal 3: Characterize the cloud microphysics of stratiform regions, especially the ice as it falls through the melting layer.

R**ationale:** Reliable retrievals of ice cloud properties from satellite-borne active and passive remote sensors and accurate modeling of stratiform ice cloud layers produced from the outflow of deep convection and hurricanes using weather forecast/hurricane research models requires reliable measurements which can only be derived from in-situ observations.

Flight Patterns: In horizontally extensive and deep stratiform clouds produced through outflow from deep convection or from hurricanes, conduct Lagrangian spiral descents

from the ice regions through the melting layer. The spirals would drift with the wind, with a Lagrangian spiral conducted as in Fig. 3 but in ice regions. The primary area of interest would be from the -10C to +5C levels to sample ice aggregation and the melting layer microphysics. With an aircraft descent rate of 1 m/s, this pattern would consume approximately 2500-3000 sec. If this takes too long, the descent rate could be increased to 1.5-2 m/s.

If time is not sufficient, use the APR-2 data to define a relatively homogeneous stratiform melting layer. Porpoise up and down through the melting layer, beginning at -5C and ending at +5C. Colocations with the Global Hawk and WB57 would be very desirable.

Science Goal 4: Characterize the cloudy environment during overpasses with active satellite sensors: TRMM, CloudSat/CALIPSO. The goals are two-fold:to validate/evaluate TRMM, CloudSat and CALIPSO microphysical retrievals using the in-situ data and to compare radar reflectivities from the spaceborne sensors to those measured by APR-2 at the same position. Secondly, to augment the GRIP data with active remote sensing observations.

Rationale: In-situ observations of ice, mixed phase and liquid cloud microphysics in conjunction with collocated remote sensing observations in diverse cloud types are necessary to validate/evaluate and improve retrievals from remote sensors.

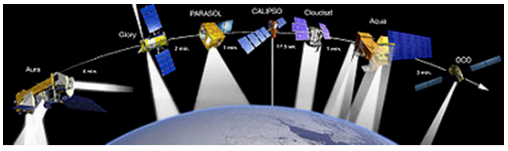
Flight Patterns: Underfly satellite and Global Hawk overflights in a wide range of cloud types.

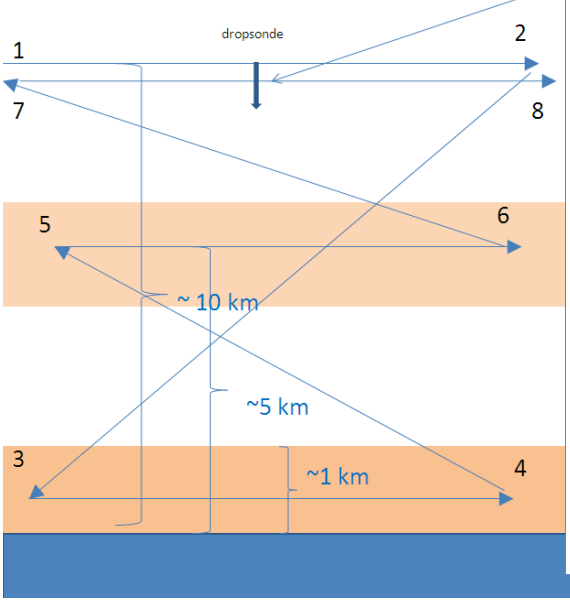
Science Goal 5: Characterize wind, water vapor, and aerosol environment using active airborne, passive and active satellite, and airborne in situ sensors.
Objectives: 1) help assess DAWN wind measurements under a variety of aerosol loading and wind conditions, 2) provide wind and water vapor measurements to help assess models, and depending on aerosol loading, 3) characterize dust layers and impacts on storm development and intensification.

Rationale: To measure winds, DAWN measures backscatter (at 2 micrometer wavelength) from particulates (aerosols) or clouds. Therefore, as this is a new instrument for the DC-8, there is a need to determine the instrument performance as a function of aerosol and cloud backscatter. Based on the draft flight plans, we anticipate that there will be ample opportunities to measure winds using cloud backscatter. Since there will likely be fewer opportunities to acquire data under cloud free conditions with varying levels of aerosols, we propose this module to specifically acquire the data under such conditions. Cloud free conditions at and below the aircraft would enable LASE to quantify the aerosol backscatter levels throughout the profile; these backscatter profiles could then be used to help assess DAWN performance as a function of aerosol loading. Ideally, this would occur for various aerosol loading conditions. (Note: DAWN and LASE cannot acquire useful data flying in thick clouds.)

This module would require cloud-free conditions (or very optically thin clouds) below the aircraft and cloud free conditions at the aircraft altitude. It would also be preferrable to have cloud free conditions above the aircraft to take advantage of satellite (e.g. Terra/Aqua MODIS, Terra MISR, CALIPSO, etc.) measurements of aerosol conditions to help analyze and calibrate the LASE aerosol measurements and to help assess aerosol loading.

The optimal flight pattern would consist of a level leg flight (~10-20 minutes) at mid-high levels (8-12 km) for both LASE and DAWN to acquire data below the aircraft. Ideally, the aircraft would then descend in ramp or spiral to the boundary layer to acquire wind and water vapor measurements throughout the column under the aircraft for DAWN evaluation and LASE analyses. The LARGE aerosol scattering and extinction measurements as a function of wavelength and size distribution measurements made in the boundary layer and in the elevated layer would be useful for translating the LASE measurements (at 815 nm) to the DAWN wavelength (2 micrometers). These measurements would also be made in an elevated aerosol level of interest identified by LASE for more detailed measurements of the aerosol scattering and microphysical characteristic by in situ sensors (i.e. LARGE) on the DC-8. The DC-8 would also perform a level leg within the aerosol layer of interest for optimal measurements by the in situ sensors. The ramp descent (and ascent) between these levels would be preferred as this would allow LASE to continue operations with minimal adverse impacts as well as to better quantify the aerosol transmission with LASE between these levels. The DC-8 in situ measurements of winds acquired during the descent and ascent would also be used to assess the DAWN wind measurements. Alternatively (or in addition) such a pattern could also include a dropsonde release to acquire wind measurements for use in assessing DAWN measurements and LASE water vapor profiles.





Pattern for DAWN evaluation and wind, water vapor, and aerosol sampling

- (1-2) 10 minute leg at 8-12 km to allow LASE and DAWN nadir measurements (dropsonde) during leg to provide winds for DAWN evaluation
- (2-3) ramp descent (~1500 ft/min) to allow sampling of region previously observed
- (3-4) 10 minute leg in BL (~0.5 km) to allow in situ aerosol sampling of BL
- (4-5) ramp ascent to middle of elevated aerosol (dust) layer
- (5-6) 10 min leg in elevated (dust) layer for in situ sampling
- (6-7) ramp ascent to high altitude (8-12 km)
- (7-8) final 10 min leg at high altitude for LASE and DAWN nadir measurements

Time ~ 90 minutes

Requires – cloud free skies at and below high altitude leg

Desire - cloud free skies throughout for satellite coverage

Desire - coincidence with A train

Desire – dropsonde for evaluation and analysis of DAWN (winds) and LASE (RH)

For the GRIP area of operations, we anticipate that the heavier aerosol loading conditions desired for such operations would most likely be in association with dust in the Saharan Air Layer. Examination of several years of satellite imagery indicates that the Caribbean region, between Barbados and Puerto Rico, would have a high probably of achieving a wide range of aerosol loading conditions during August and September. Note that there will be a suite of advanced remote sensing instruments (scanning radar, multiwavelength lidar, DIAL water vapor lidar) based on Barbados that could also provide measurements quite useful for GRIP objectives. This region will also be the approximate location of another NASA aircraft mission designed to remotely measure aerosol (and in particular dust) properties. This other NASA airborne mission will occur for approximate two weeks in the middle of August.

It would also be desirable to conduct this module in the inflow region of the disturbance/storm region. The combination of wind and water vapor measurements provided by these remote sensors would provide a unique dataset to test model sensitivity to high resolution data and assess the impact of these datasets on forecasts of storm intensification. As you may know, Prof. Krishnamurti (FSU) has examined LASE data in such scenarios and found LASE water vapor measurements made a significant positive impact on model forecasts of hurricane track and intensity. It would be quite interesting to perform similar studies during GRIP using the combined LASE+DAWN measurements to study forecast sensitivity to winds, water vapor, and the combination of winds+water vapor. In addition, LASE measurements during NAMMA were quite useful for investigating the impact of the dust and dry air in the SAL on storm/hurricane intensification; we anticipate that the combination of LASE and DAWN measurements could also be useful for somewhat similar studies during GRIP.