Mission Summary
20060920N Aircraft 49RF
SALEX Flight 2006

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Mission Plan:
NOAA 49RF will participate in a 2-plane (1 P-3, G-IV) Saharan Air Layer Experiment (SALEX) around Hurricane Helene as part of IFEX. The G-IV will leave Barbados at 1445 UTC and will recover back at Barbados at 2140 UTC. The flight track will take the G-IV on a clockwise circumnavigation of the TC and 23 GPS dropwindsondes will be deployed (Fig. 1).

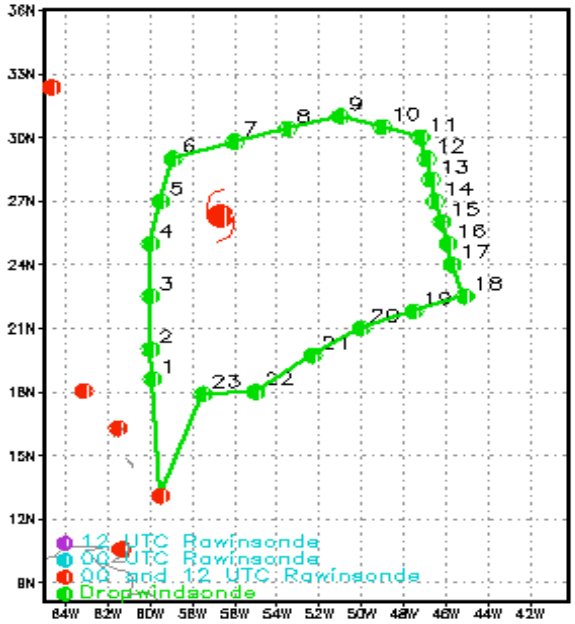

Fig. 1: Flight track (green line) for SALEX mission 060920n. The GPS dropsonde points (23 total) are indicated by green circles.

Mission Summary:

a) Synoptic Situation

Pre-Hurricane Helene emerged from the coast of North Africa as a vigorous AEW on 12 September (Fig. 2). Figure 2 also shows that a very large Saharan Air Layer (SAL) outbreak was located to the north and west of this system at this time. The NASA DC-8 flew a single mission into Tropical Depression 8 (pre-Hurricane Helene) on 12 August from Sal, Cape Verde. This mission was part of the NAMMA field program and the main objectives included cyclogenesis, Saharan Air Layer/dust, and microphysics studies. The disturbance subsequently tracked to the west-northwest around the southeast periphery of a deep layer ridge over the next several days (Fig. 3, left), which brought it into the suppressive influence of SAL and within range of NOAA G-IV and P-3 SALEX missions.

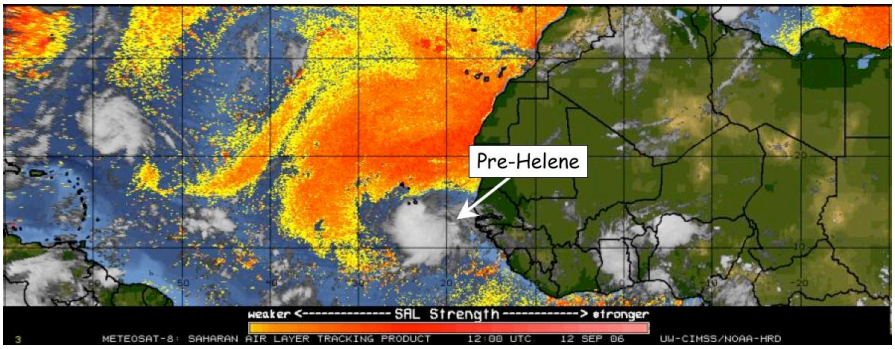

Fig. 2: SAL imagery (12 September 1200 UTC) showing a large SAL outbreak (yellow to red shading) north and west of the AEW that eventually developed into Hurricane Helene.

The G-IV flew a set of back-to-back one-plane SALEX missions from Barbados on 15 and 16 September while Helene was still out of range of the P-3. The P-3 (NOAA-42) was deployed to Barbados on 16 September when it became clear that the storm would be in range to conduct P-3 SALEX missions from Barbados. A first-ever G-IV/P-3 coordinated hurricane research mission (SALEX) was completed on 18 September. Although Helene continued moving northwest through the now bifurcated subtropical ridge to its north (Fig. 3, right), it had tracked far enough to the west to remain within range of a follow on coordinated set of P-3/G-IV SALEX missions from Barbados. At 1800 UTC during the day of the 060920n mission, Hurricane Helene was a 90 kt Category 2 hurricane and located at ~26.3 N 56.7 W. Vertical wind shear analyses from UW-CIMSS suggested that the shear over Helene was increasing north of the storm and was now ~10-20 kt (Fig. 4, left). This shear was likely being enhanced by the remnants of an upper-level cold low to its west that was located at ~27 N 67 W [Fig. 4].

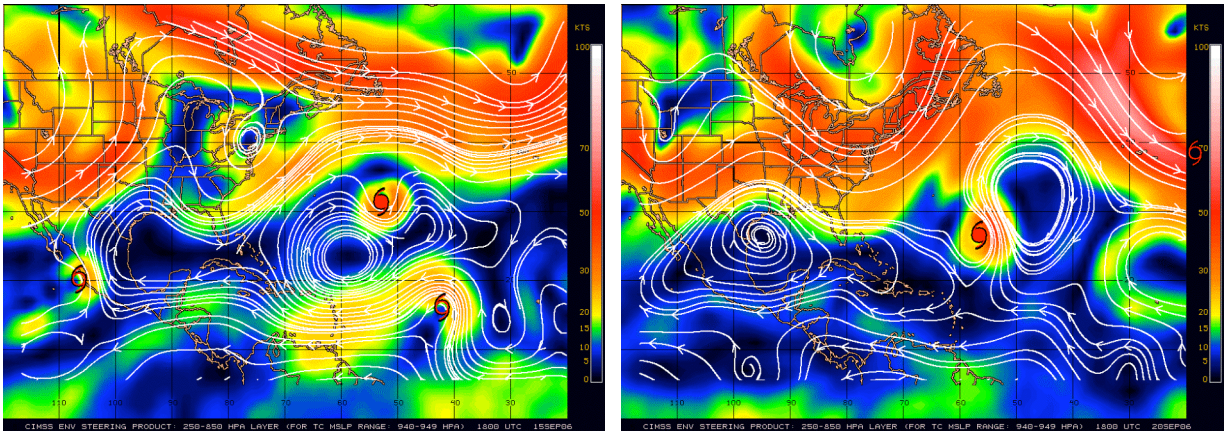

Fig. 3: Plots of 250-850 hPa deep layer mean steering [magnitude (direction) of the steering flow is indicated by colored shading (white streamlines)] for (left) 15 Sep 1800 UTC and (right) 20 Sep 1800 UTC. Helene was located at ~26.3N 56.7W during the 060820n mission. Images courtesy of UW/CIMSS.

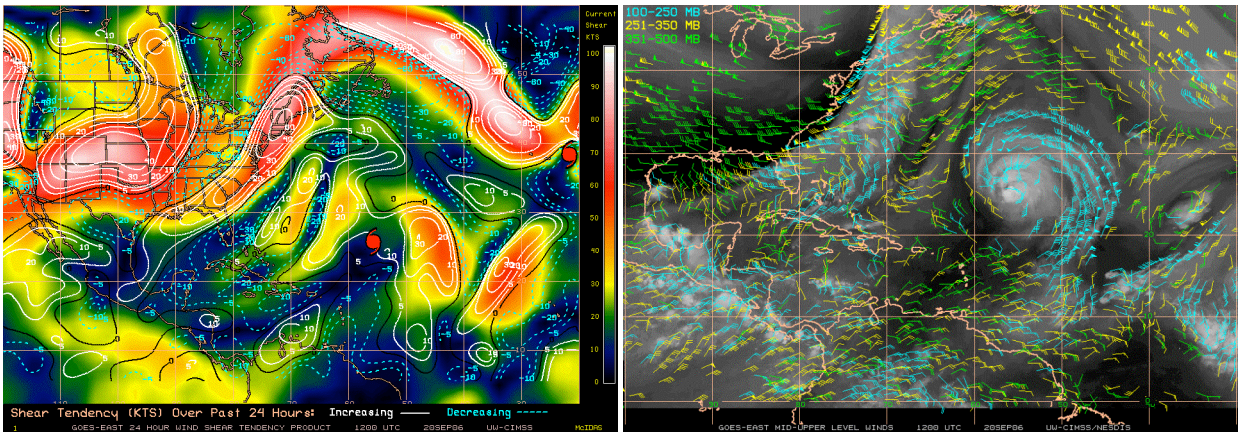

Fig. 4: Plots of (left) vertical wind shear [magnitude (direction) of the wind shear is indicated by yellow contours (orange streamlines)] and (right) mid to upper-level GOES-12 water vapor winds for 20 August 1200 UTC. Hurricane Helene was located at ~26.3N 56.7W at this time. Images courtesy of UW/CIMSS.

b) Mission Specifics

The flight plan was designed to initially sample west and north of the storm at an optimal flight level of 41,000-45,000 ft. Subsequent legs around the east and south sides of the storm investigated a large SAL outbreak east of Helene (Fig. 5, *SAL 2*; drops 8-19) and a dry SAL intrusion that was wrapping in around the southwest and southeast quadrants of the storm [Figs. 5 (*SAL 1*) & 6 (left), drops 20-23]. A SSE-NNW GPS dropsonde sequence was also coordinated with overpasses (within 90-150 min) by NASA's CloudSat ands Calipso satellites (Fig. 6, right; drops 11-18). This coordination provided an opportunity to compare satellite retrievals of precipitation (CloudSat) and Saharan dust (Calipso) with GPS dropsonde data across an extended segment of the *SAL 2* outbreak (Figs. 5 & 6). Although a delay in the G-IV takeoff time resulted in a fairly large time gap between the GPS dropsonde sequence and the satellite overpasses, the relatively static environment of the SAL (Fig. 5, *SAL 2*) should still make for fairly robust comparisons between the platforms. All GPS dropsondes were transmitted in real-time, so that data from the sondes could be assimilated into the NOAA GFS model.

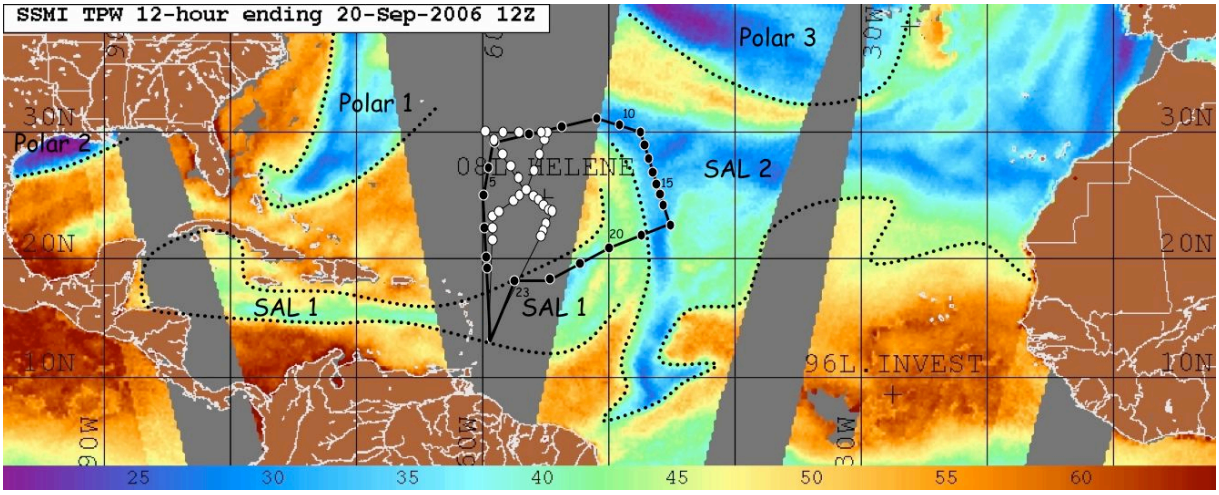

Fig. 5: Mosaic of total precipitable water (TPW) from the constellation of SSM/I satellites (1800 UTC 20 September 2006). Regions where TPW values of <45 mm (dotted lines) indicate dry air in the low to mid-levels of the atmosphere (~600-925 hPa). Two distinct areas of dry SAL air (*SAL 1, & 2*), three areas of dry polar air (*Polar 1, 2, & 3*), a tropical disturbance (*96L. INVEST*), and Hurricane Helene are indicated in the imagery. The P-3 (G-IV) flight tracks [thin (thick) black curves] and dropsonde points [white (black) circles] are overlaid on the imagery. Imagery courtesy of NRL-Monterey.

Takeoff was at 1445 UTC from Barbados. Zoomed SSMIS TPW imagery from the F-16 DMSP satellite from 1139 UTC suggested that dry SAL air [Fig. 6 (left), <45 mm TPW; green to blue shading] was surrounding Helene in what appeared to be band-like patterns around the storm (Fig. 6, left). This was also noted in TPW imagery from the prior day. Four extended legs comprised this G-IV SALEX flight pattern around Hurricane Helene:

- Leg 1 (630 nm N-S leg; drops 1-6): These GPS dropsondes sampled the SAL along the west side of Helene and indicated extremely dry air (~5-40% RH) in the middle levels (~600-800 hPa), as well as a 30-45 kt mid-level jet from the northwest. The collocation of the dry air and strong mid-level jet was likely advecting dry air in toward the western semicircle of the storm and may partly explain why the convection in this region was fairly asymmetric (Fig. 7, left).
- Leg 2 (635 nm W-E leg; drops 7-10): These GPS dropsondes sampled dry SAL air on the north side of Helene (Fig. 5, *SAL 2*). GPS dropsondes along this leg indicated 5-20% RH in a deep layer from ~300-850 hPa and temperature inversions at the SAL base (~800 hPa) of as much as ~2ºC (drop #9). Additionally, a strong (40-50 kt) mid to upper-level southeasterly jet was indicated at ~375-425 hPa (drops 7-8).
- Leg 3 (465 nm NNW-SSE leg; drops 11-18): These GPS dropsondes targeted the leading edge of the SAL outbreak east of Helene and were coordinated with overpasses by NASA's CloudSat and Calipso satellites. This dropsonde sequence indicated a deep layer of dry air (~5-20% RH) from ~300-850 hPa, a 30-35 kt jet near 700 hPa, and temperature inversions at the base of the SAL (800-825 hPa) of generally 1-2ºC and as strong as 4.5ºC (drop #11).
- Leg 4 (765 nm ENE-WSW leg; drops 19-23): This final GPS dropsonde sequence south of Helene sampled the large SAL outbreak that had been wrapping around the southwest and southeast quadrants of Helene for the previous several days and was currently spanning across the entire Caribbean Sea (Fig. 5, *SAL 1*). All of the GPS dropsondes along the final leg of the mission indicated generally light winds (10-20 kt) in the lower to middle levels and a deep layer of dry (5-30%) SAL air from ~300-800 hPa.

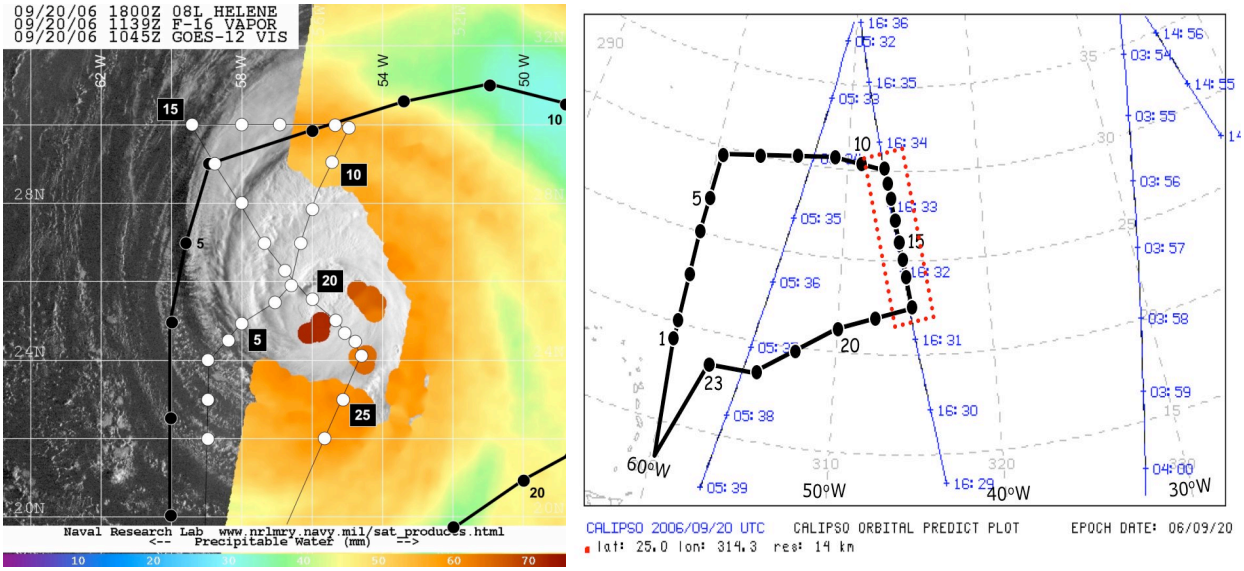

Fig. 6: (Left) SSMIS TPW imagery showing Hurricane Helene on 20 September 1139 UTC. The SAL's dry air is indicated by values of <45 mm (green to blue shading) in the TPW image. (Right) The CloudSat and Calipso ascending satellite overpasses (blue line, 1631-1634 UTC). The dashed red box outlines the overlap between the satellite overpasses and the G-IV GPS dropsonde sequence. The P-3 (G-IV) flight tracks [thin (thick) black curves] and dropsonde points [white (black) circles] are overlaid on both figures. Imagery courtesy of NRL-Monterey.

Figure 7 shows GOES-12 infrared imagery of Hurricane Helene in the morning and evening of day of the mission. The convection associated with the storm became relatively shallow and asymmetric throughout the day and was likely being affected by the combination of strong mid-level winds and dry SAL air that were noted during the mission. Figure 8 shows the 060920n flight track overlaid on the 20 September 1800 UTC GFS model analysis of 700 hPa RH. The GFS model analysis appeared to accurately depict the spatial extent of the SAL that was surrounding Helene (Fig. 5, *SAL 1 & 2*; Fig. 8, 700 hPa RH of <50%). However, it appears that the model was significantly overestimating the 700 hPa moisture around the storm, particularly in Helene's western, northern, and southern semicircles.

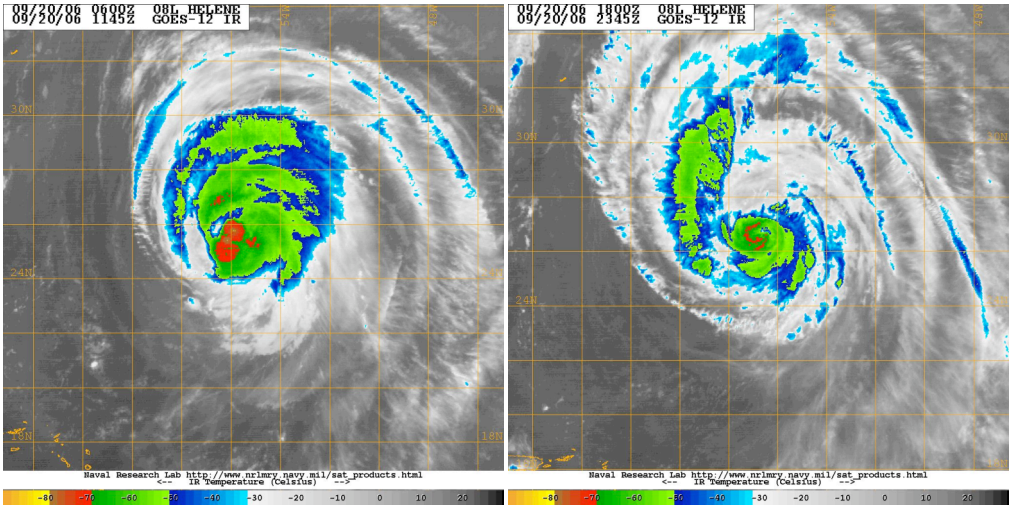

Fig. 7: GOES-12 infrared imagery showing Hurricane Helene on 20 September 2006 at (left) 1145 UTC and (right) 2345 UTC. Imagery courtesy of NRL-Monterey.

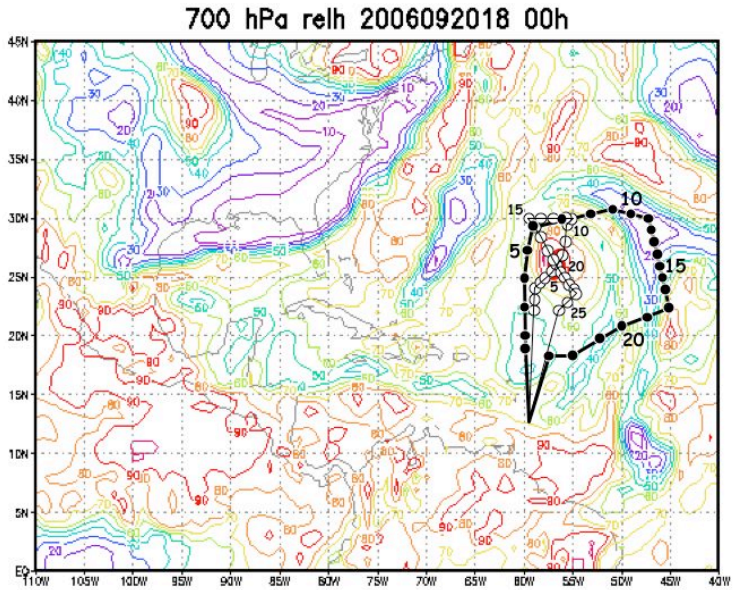

Fig. 8: Analysis of GFS 700 hPa relative humidly (%) for 20 September 1800 UTC. The P-3 (G-IV) flight tracks [thin (thick) black curves], GPS dropsonde points [white (black) circles], and location of Hurricane Helene are overlaid on the analysis.

Problems:

There were no major problems related to this flight. Although "codeless" GPS dropsondes mainly from 2000-2004 were used, only two dropsondes failed out of the 23 that were dropped.