

## Hurricane and Severe Storm Sentinel (HS3) Mission

### HS3 2014 18-19 Sept Flight Report: GLOBAL HAWK AV-6 Edouard Flight

Flight Scientists:

Shift 1 (0400-1300 EDT): Anthony Didlake, Pete Colarco, Scott Braun

Shift 2 (1200-2100 EDT): Deanna Hence, Paul Neuman, Rob Rogers

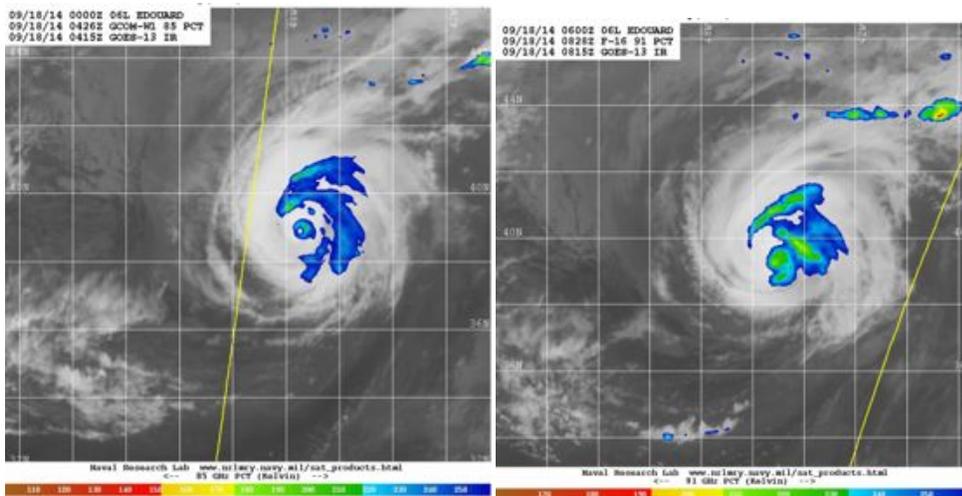
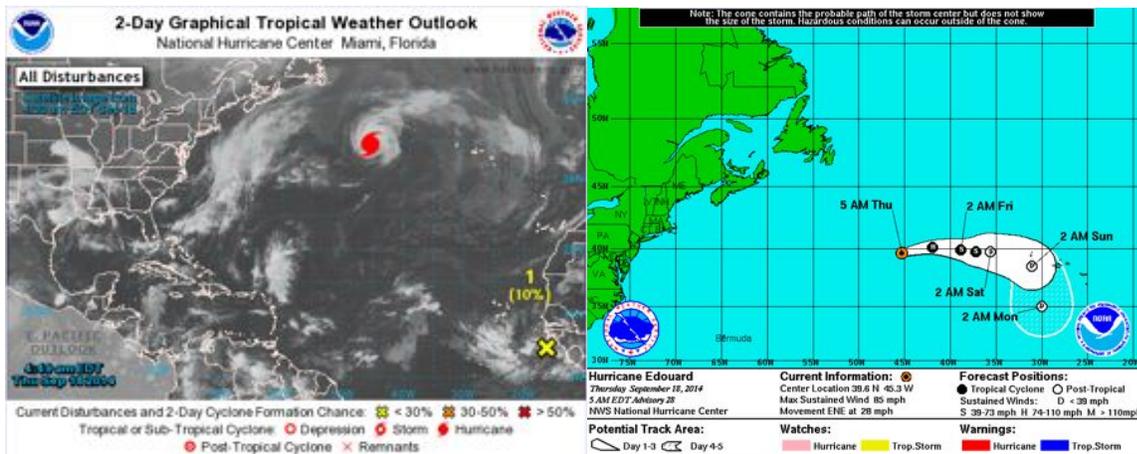
Shift 3 (2000-0500 EDT): Jon Zawislak, Jason Sippel, Mike Montgomery

Shift 4 (0400-2100 EDT): Anthony Didlake, Pete Colarco

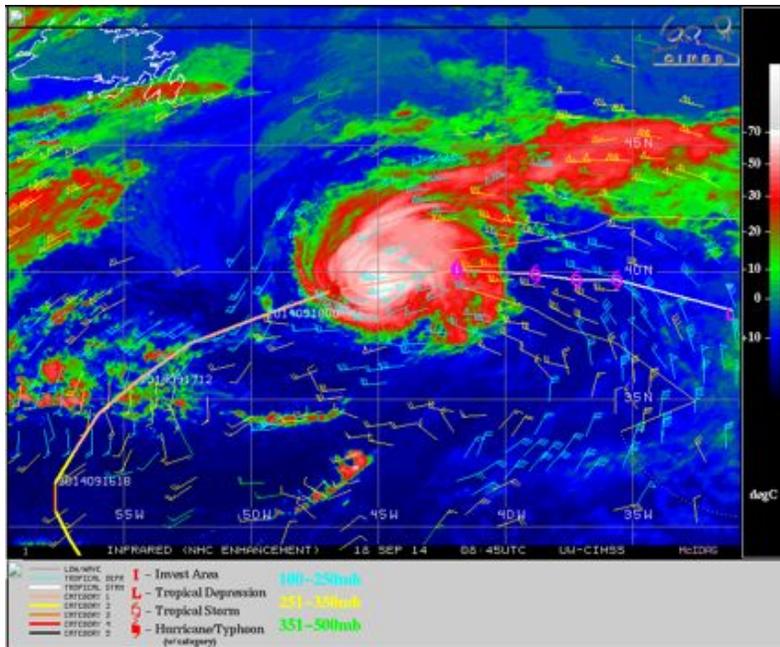
Takeoff: 16/1100Z

Landing: 17/

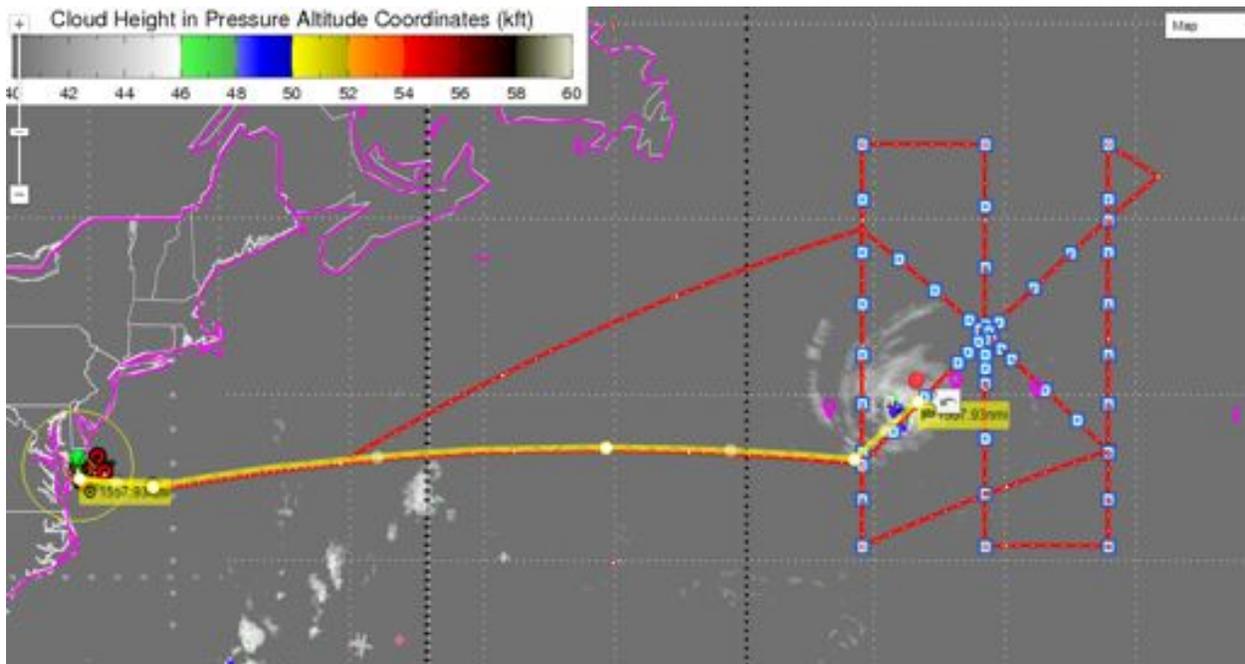
Mission goal: Science flight to investigate Hurricane Edouard during its weakening phase in northern Atlantic and transition to an extratropical storm.



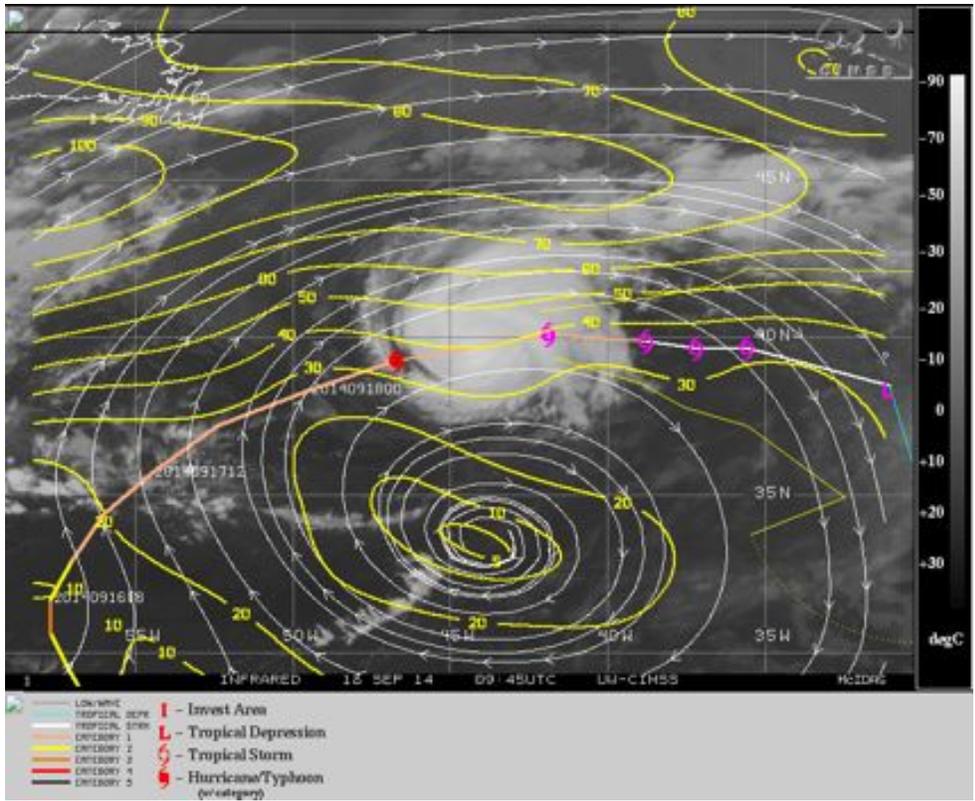
NHC 5am advisory has Edouard at 75 kts central pressure 965 hPa moving at 065/24kts. Forecast is to weaken later today as instability decreases and westerly vertical shear increasing, slowing down in translation. Expected to lose all deep convection in 36-48 hours. AMSR2 (0426z) shows good eye structure, but dissipated in later SSMIS (0828z) and bands smearing out.



GOES 0845z IR and upper level winds shows broad system and outflow to east. Track guidance is for storm to track east at about 40 N.



Initial flight track plan has storm center crossing somewhat north and east of current track predictions (see purple markers moving west to east as 06z 9/18, 18z 9/18, and 06 9/19 track positions from NHC).

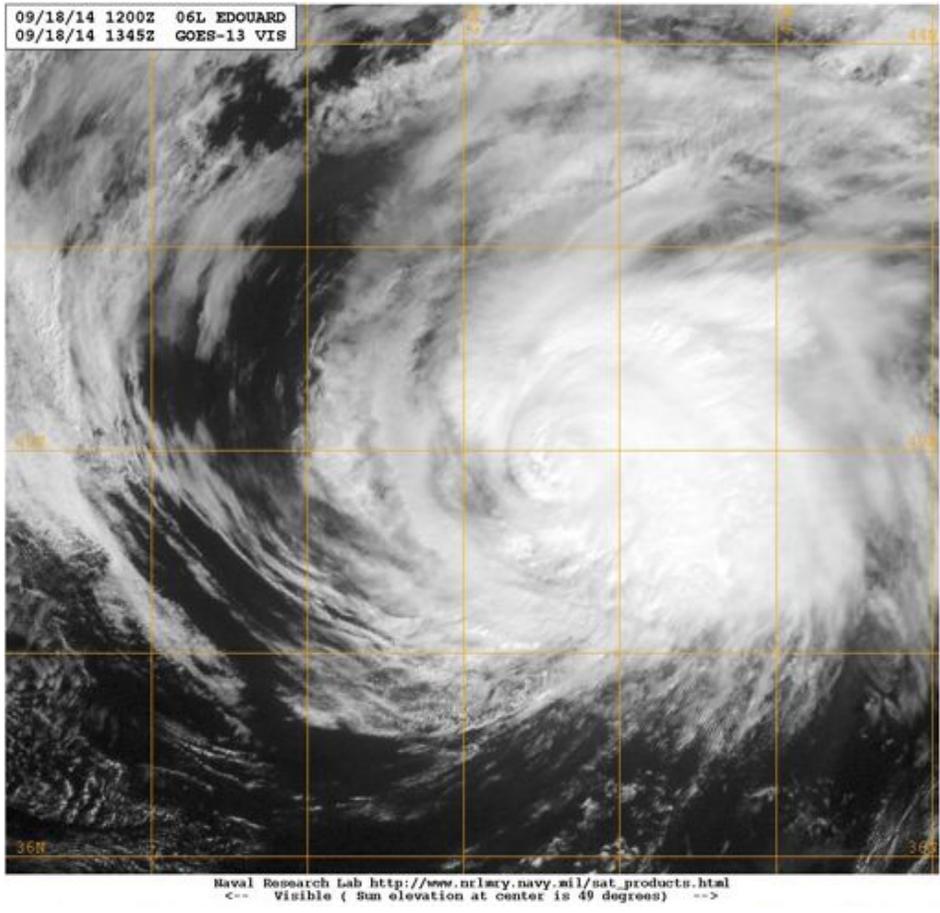


System moving east along contours of modestly high 40 kts shear.

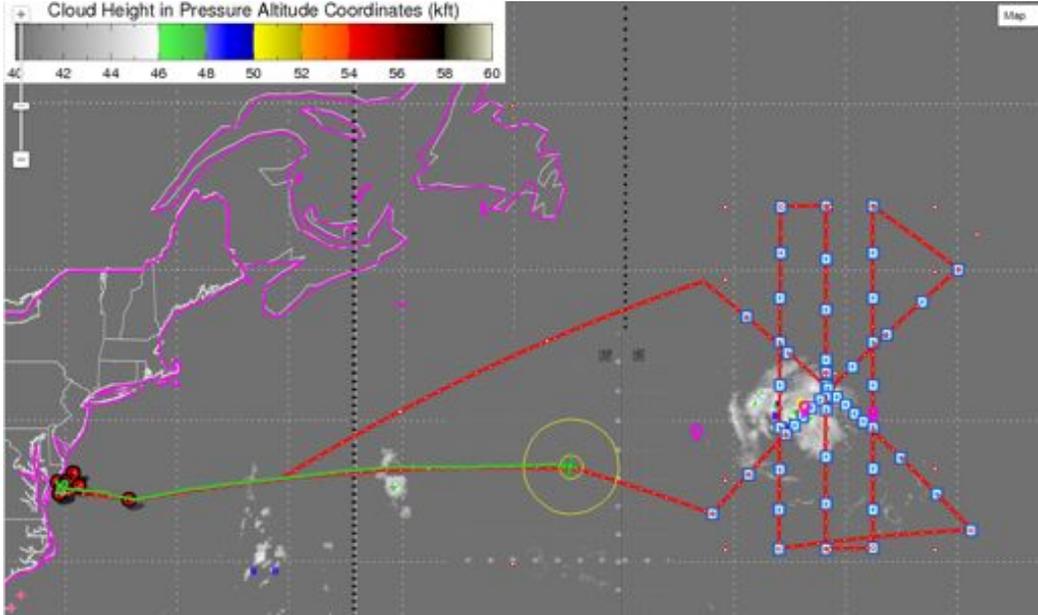
1052 We had an engine fault earlier, forcing engine shutdown and restart. Fault did not reappear on restart, good to go, so we are just delayed a bit on take off. Expected take off at 1110.

1115 Take off

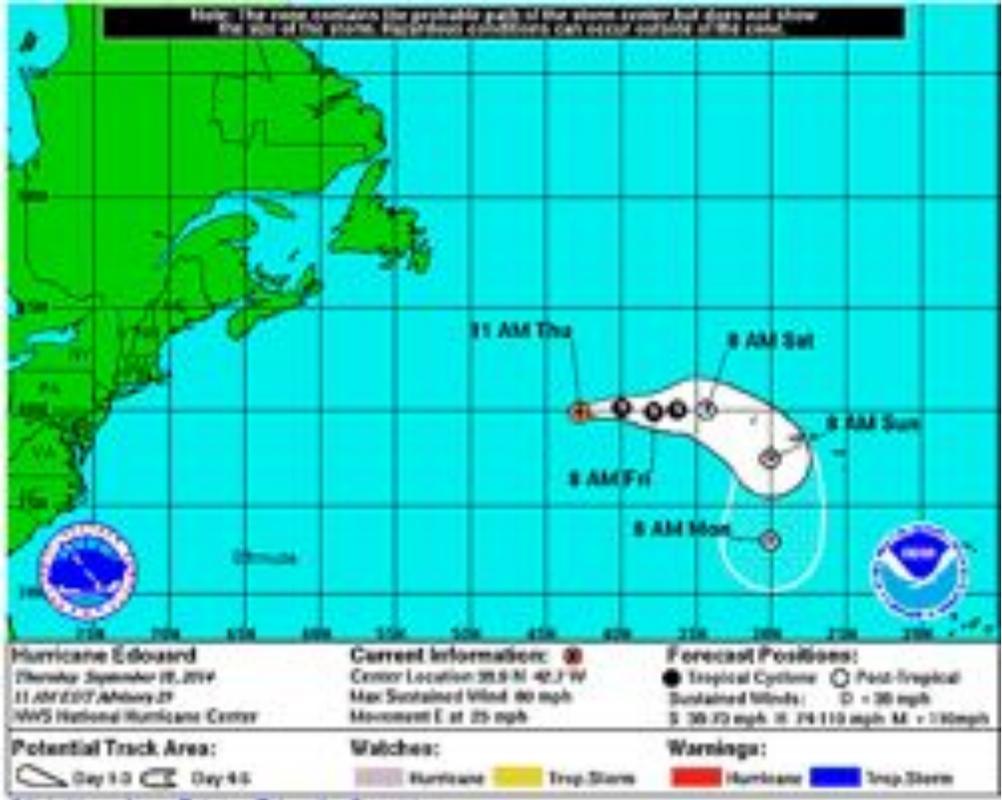
1305 All's quiet. Working on new flight pattern based on actual storm movement.



1400 Here's latest GOES vis image of system. Center about 43 W 40N



1445 New flight plan uploaded to MTS to catch storm position. Move entry point to system further south and orient sonde drops further south.



1453 NHC 11EDT advisory is released. Max sustained winds 70 kts, 970 hPa, movement east at 085/22 kts.

1533 Forecasters recommend position of storm at 1615z of 40 N, 42 W

1546 D01 first drop away

1604 D02

1609 Question now is about tilt of storm, with low level center displaced perhaps two degrees west of upper level center, so how to retarget plane and plan drop pattern?

1621 D03

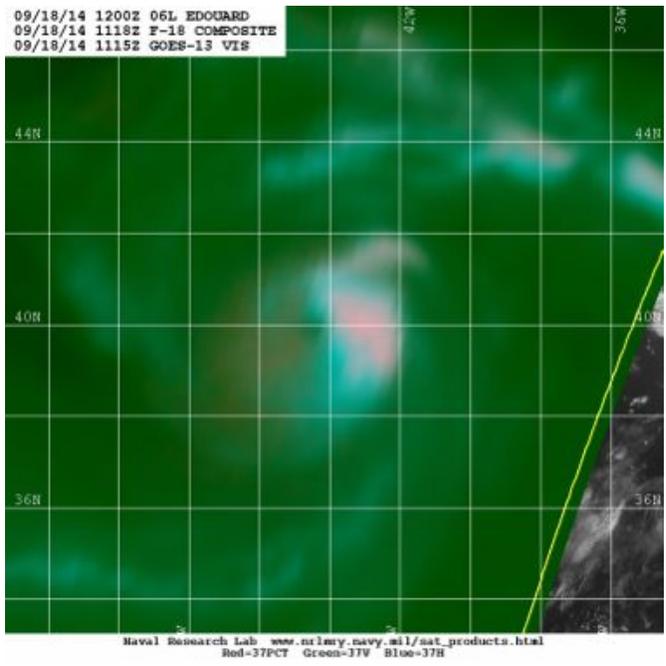
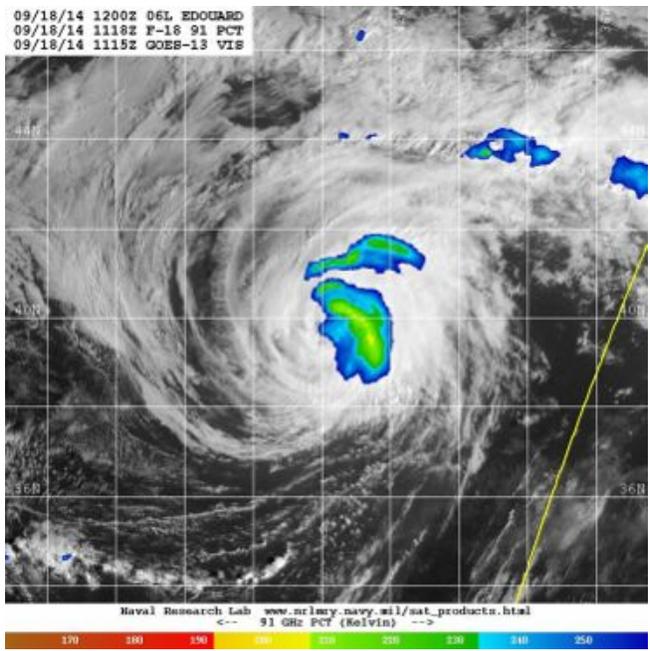
1625 D04

1630 D05

1634 D06

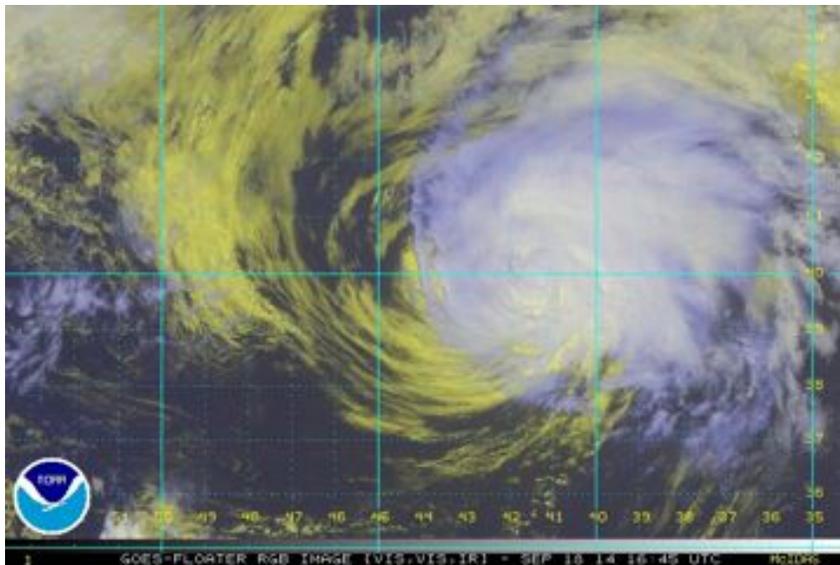
1639 D07

1643 Modification to flight pattern – on the final center pass, will modify it so that it aligns along the expected tilt vector (west-east with increasing height). Will adjust the orientation of this pattern if the tilt direction is different. Also, will target the low-level center on all center passes. We are timing the N-S passes such that there is a 90-nm east-west spacing between legs in a storm-relative framework.



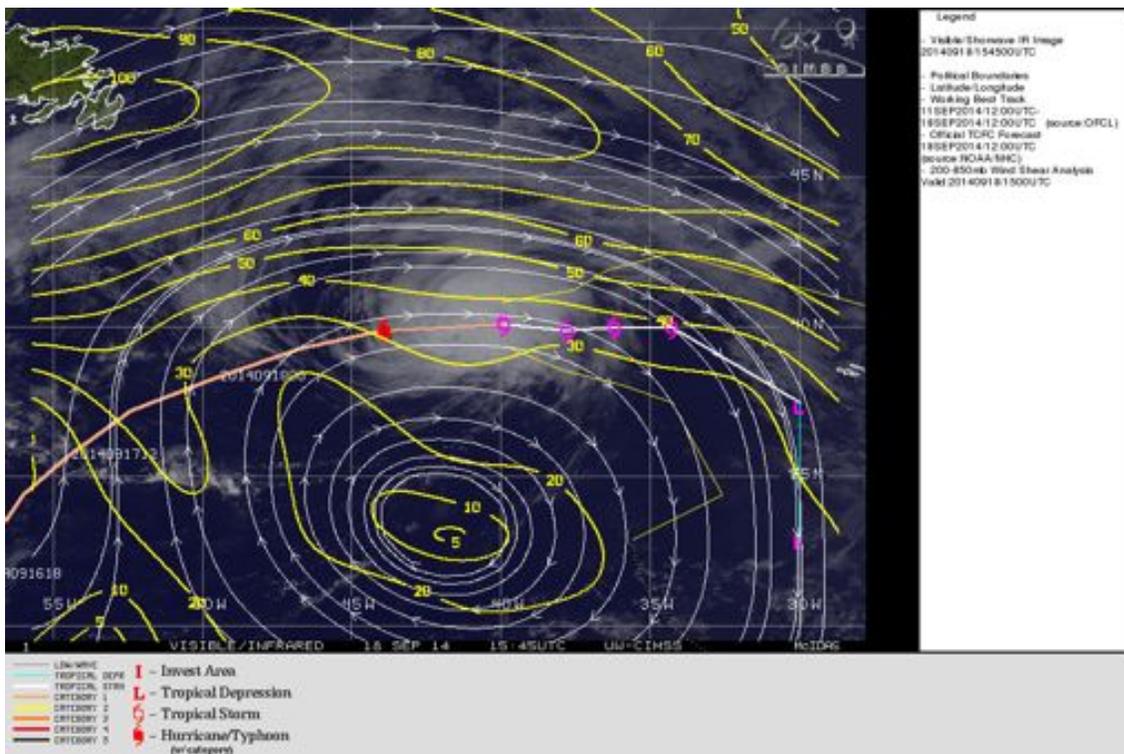
1650 Comparison of 85 and 37 GHz imagery from 1118 UTC (5 h previous to current time) suggests a tilt of ~40-50 nm toward the east-southeast at this time

1659 D08 – Fast Fall



1707 Latest Vis/IR combined image shows clear decoupling between low- and mid-level centers of about 100 nm toward the east.

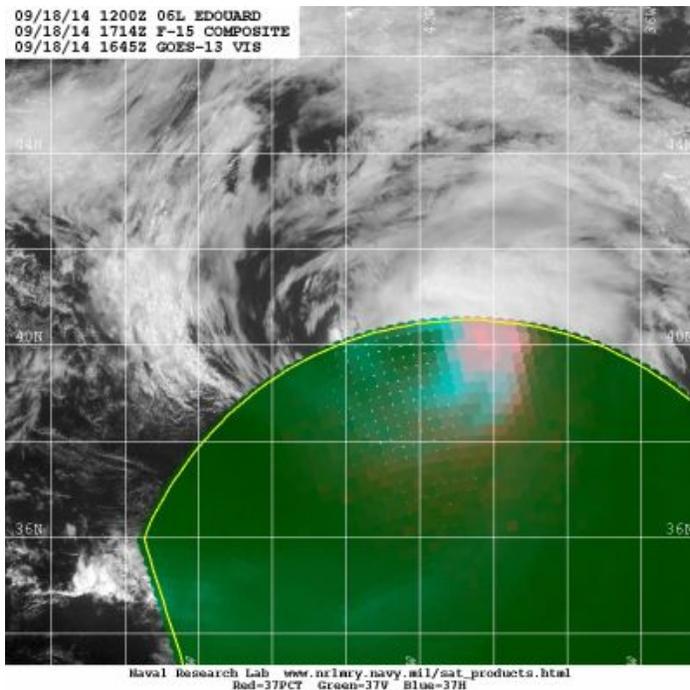
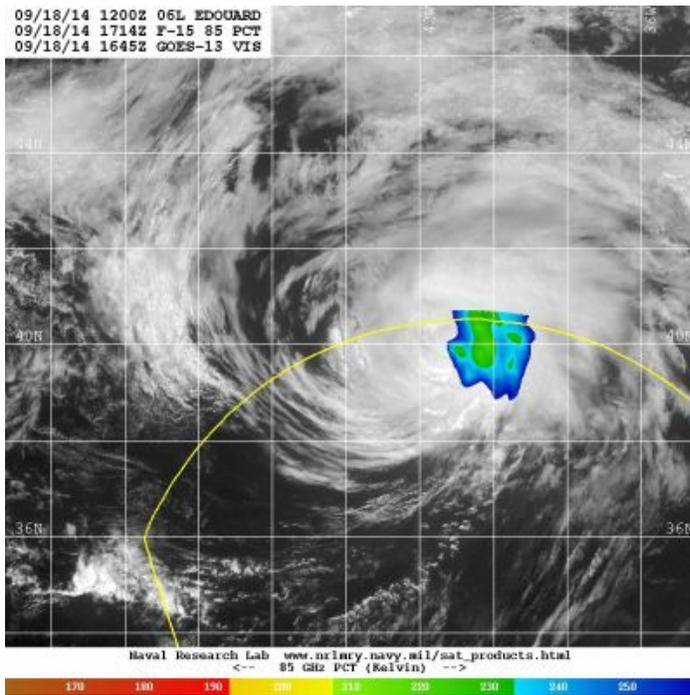
1714 D09



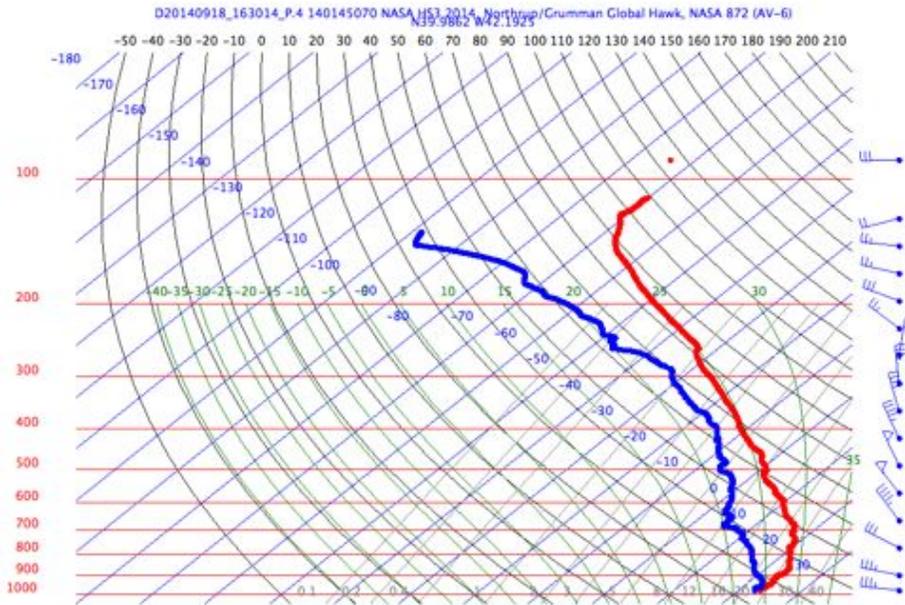
1722 CIMSS analysis at 1545 UTC shows ~30-40 kt of westerly shear over storm, decoupling between low and midlevel centers apparent

1730 D10

1748 D11

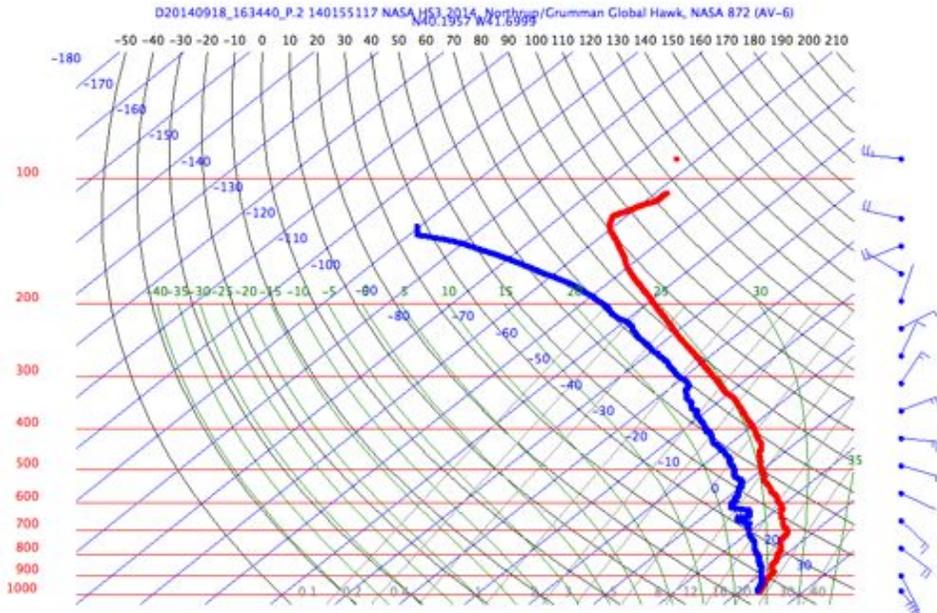


1804 Recent microwave overpasses continue to show a highly tilted system, ~100-120 nm displacement between lower and middle troposphere toward the east



Aspen 3.1, 18 Sep 2014 17:41 UTC

1809 Dropsonde at presumed center point (D05 at 1630 UTC) shows drop was actually on the west and southwest side of actual storm center



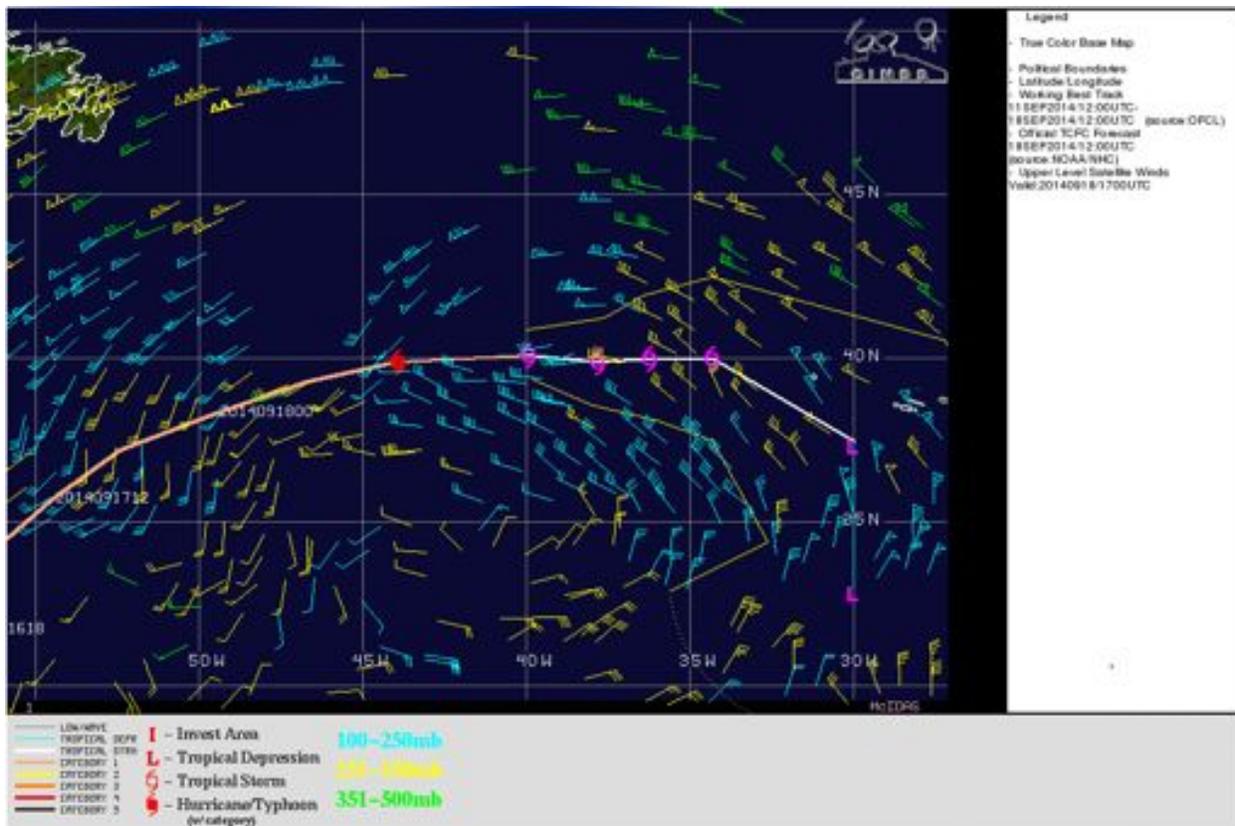
Aspen 3.1, 18 Sep 2014 17:49 UTC

1810 Next drop to the northeast (D06 at 1634 UTC) was closer to the actual center over much of troposphere

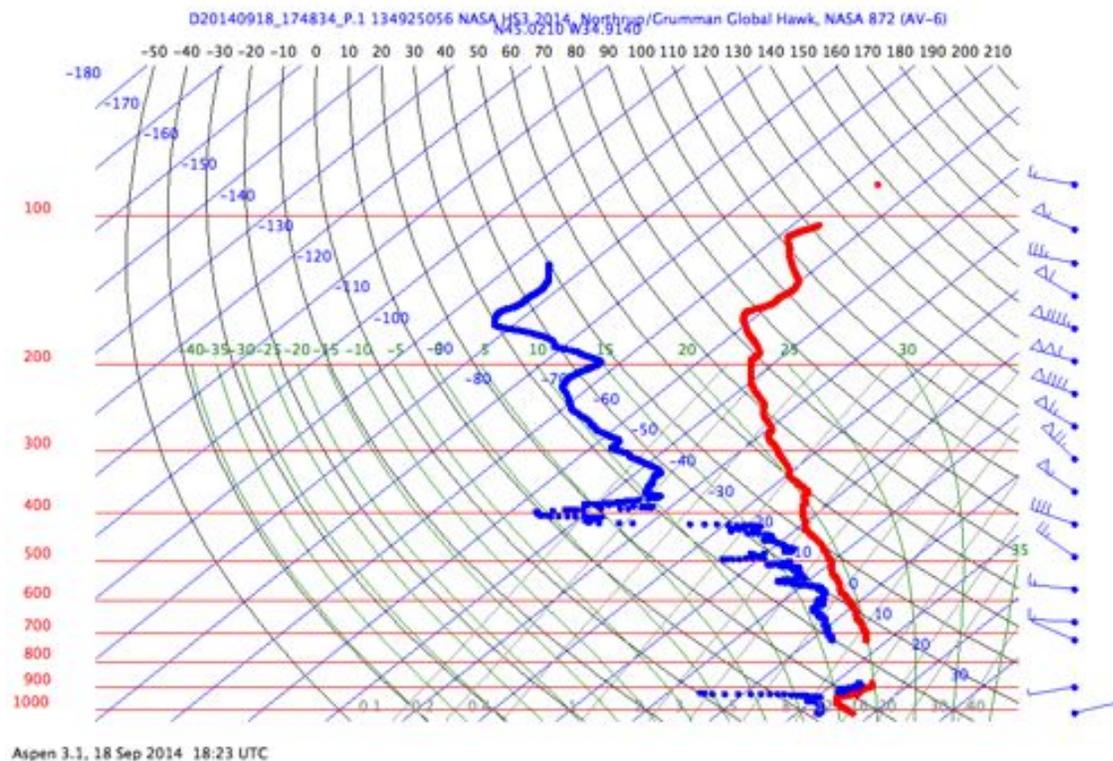
1828 D12

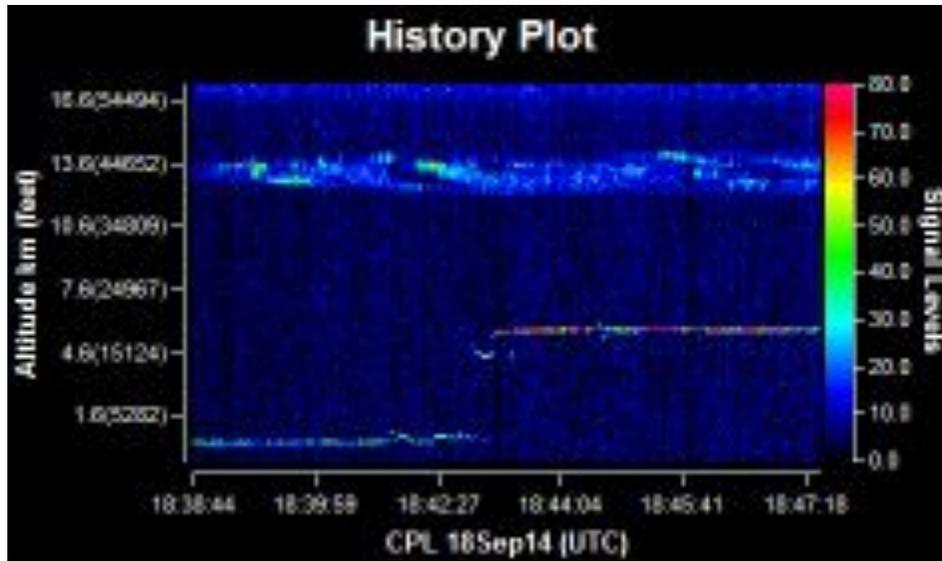
1828 Turn to begin first lawnmower leg; N-S leg

1842 D13



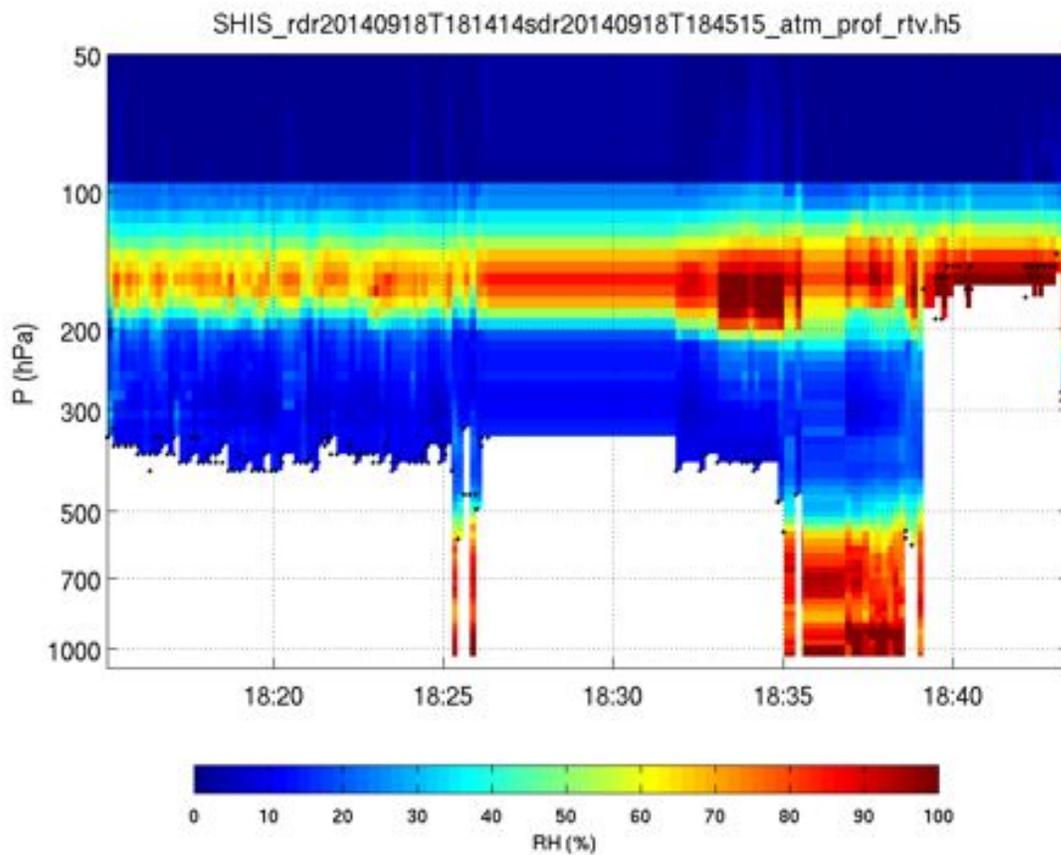
1845 Satellite-derived upper level winds show 80+ kt of westerly wind on north side of storm. Dropsonde from northeast corner (D11) showed 110 kt at 200 hPa.





1853 CPL shows cirrus outflow on NE side of storm (GH currently at 43.3 N, 39.35 W)

1857 D14



1858 D14

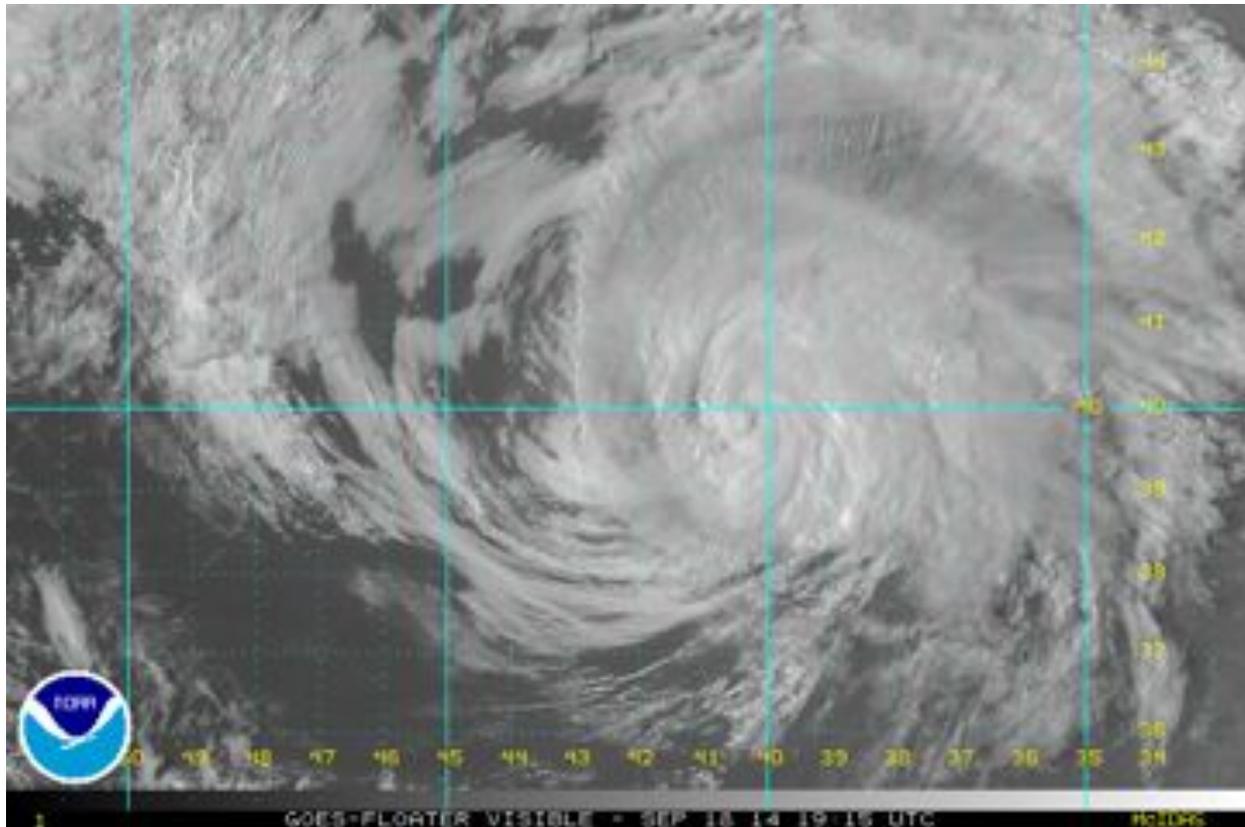
1907 SHIS RH profile shows cirrus shield on NE side of storm, on leg setting up for first N-S pass.

1914 D15

1928 D16

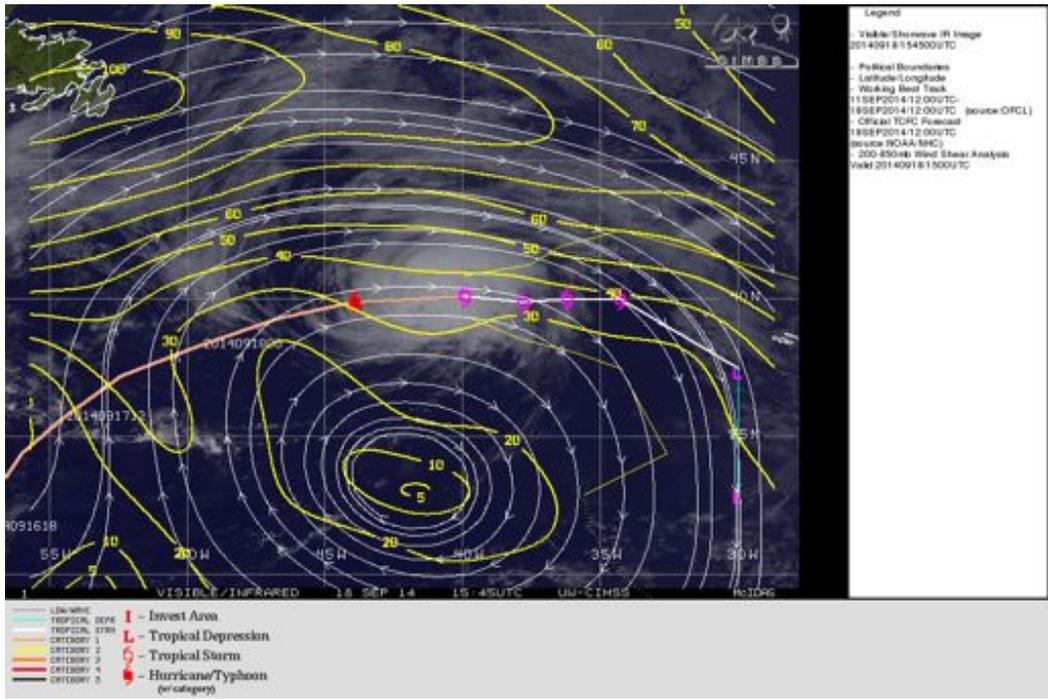
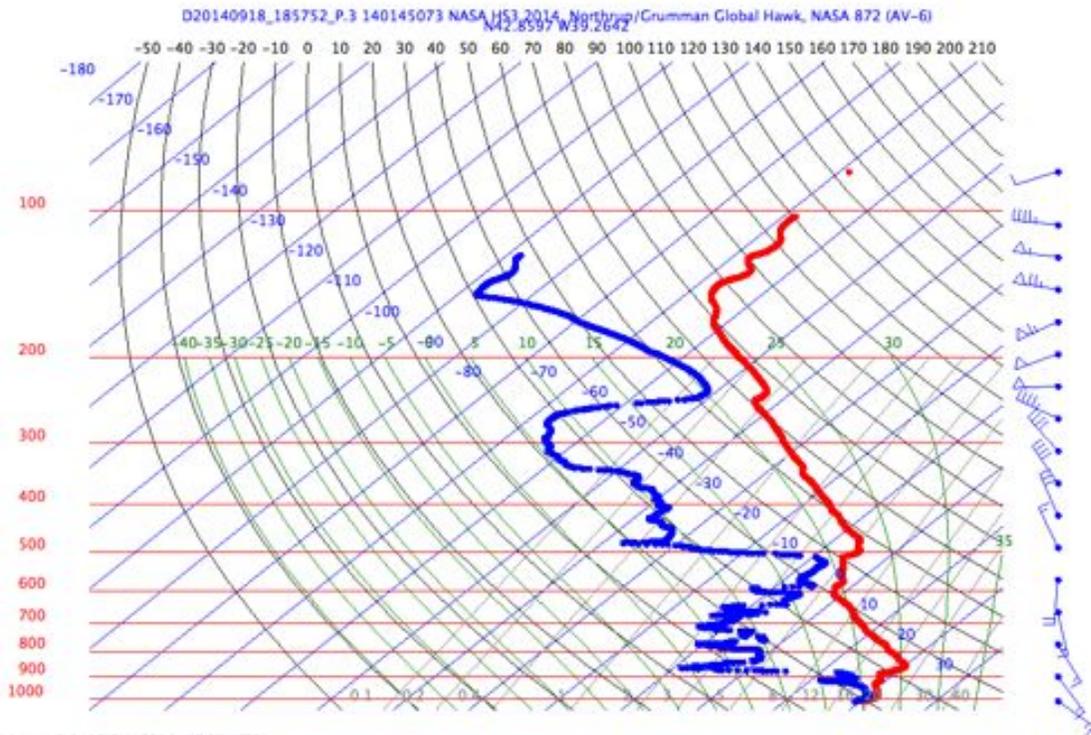
1944 D17

1956 Visible image (below) shows transverse banding in outflow on north side, will be good to examine shear values from dropsondes. Continued zonal displacement of upper- and low-level centers also evident.



2000 D18 release

2014 Sonde on northern section of first lawnmower leg (D14) shows clear area of vertical shear between lower troposphere and above 500 hPa. This is generally consistent with CIMSS analysis in similar area showing shear values on the order of 50-60 kt.



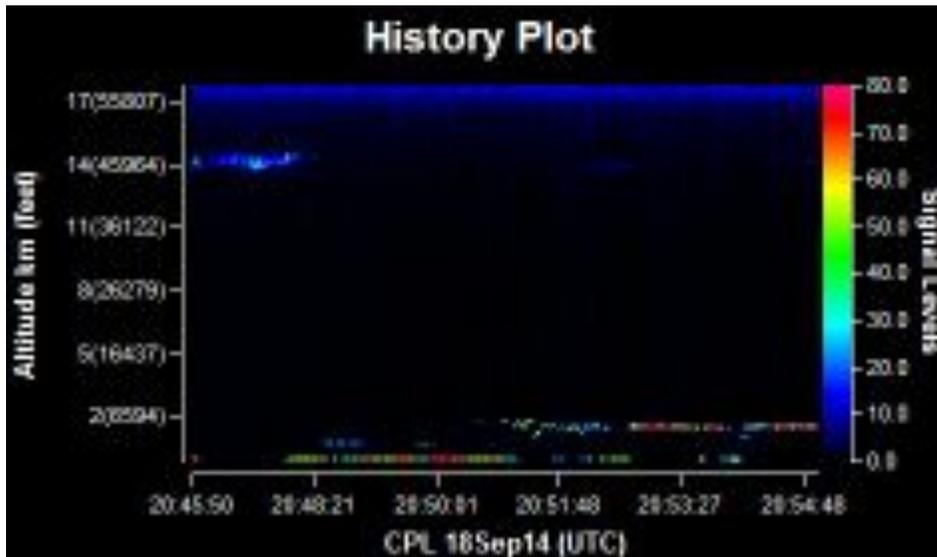
2014 D19 release

2031 D20 release

2047 5PM NHC advisory downgrades Edouard to a tropical storm... “Over the past 6 hours, visible and microwave satellite imagery indicate that the upper-level and low-level circulations have started to decouple due to strong westerly vertical wind shear, with the upper-level center having become displaced more than 60 nm east of the low-level center....” Winds from NHC estimated at 60 kt, storm motion is 090/14.

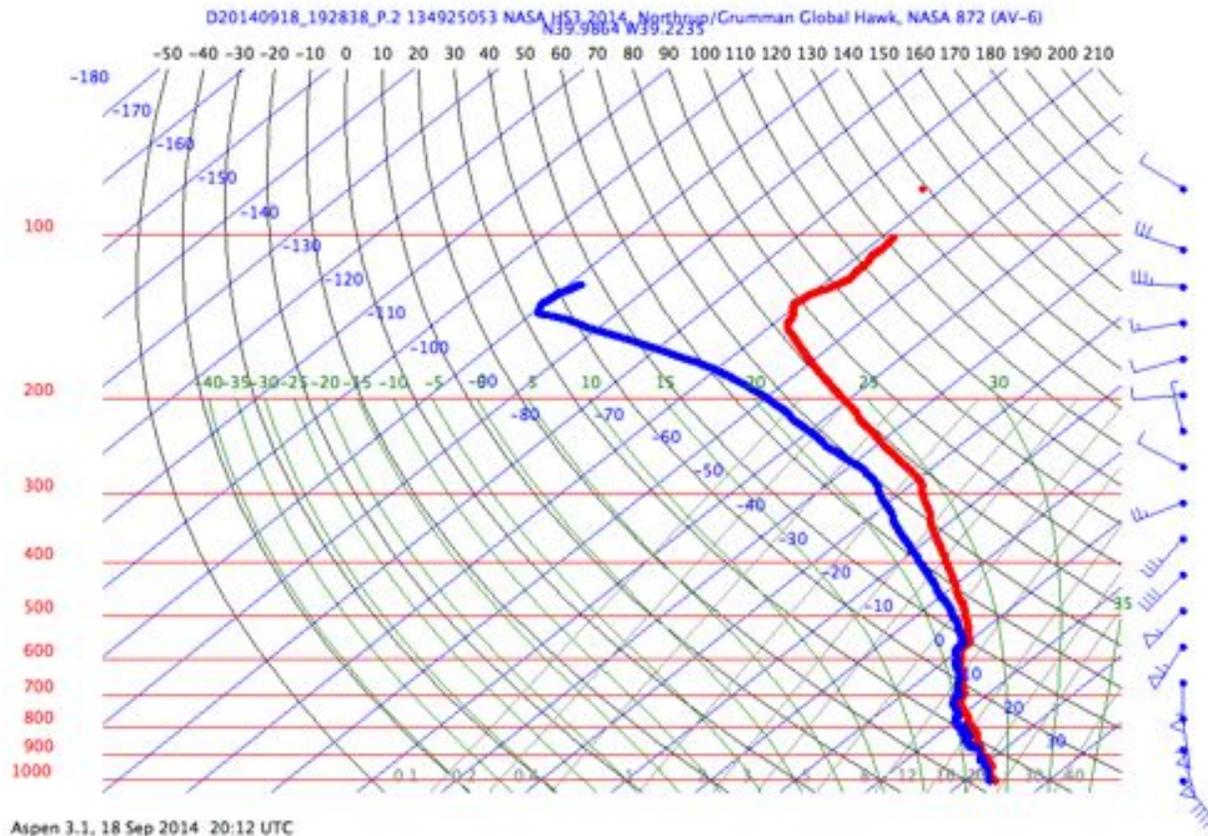
2049 D21 release

2102 CPL on south side of storm shows mostly clear skies

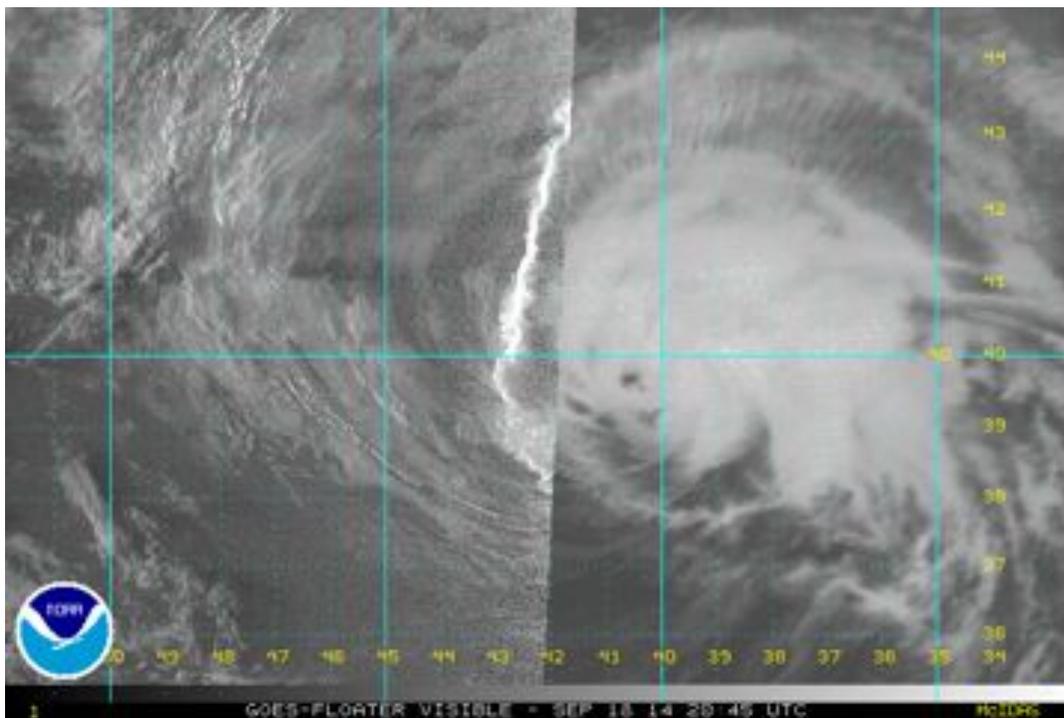


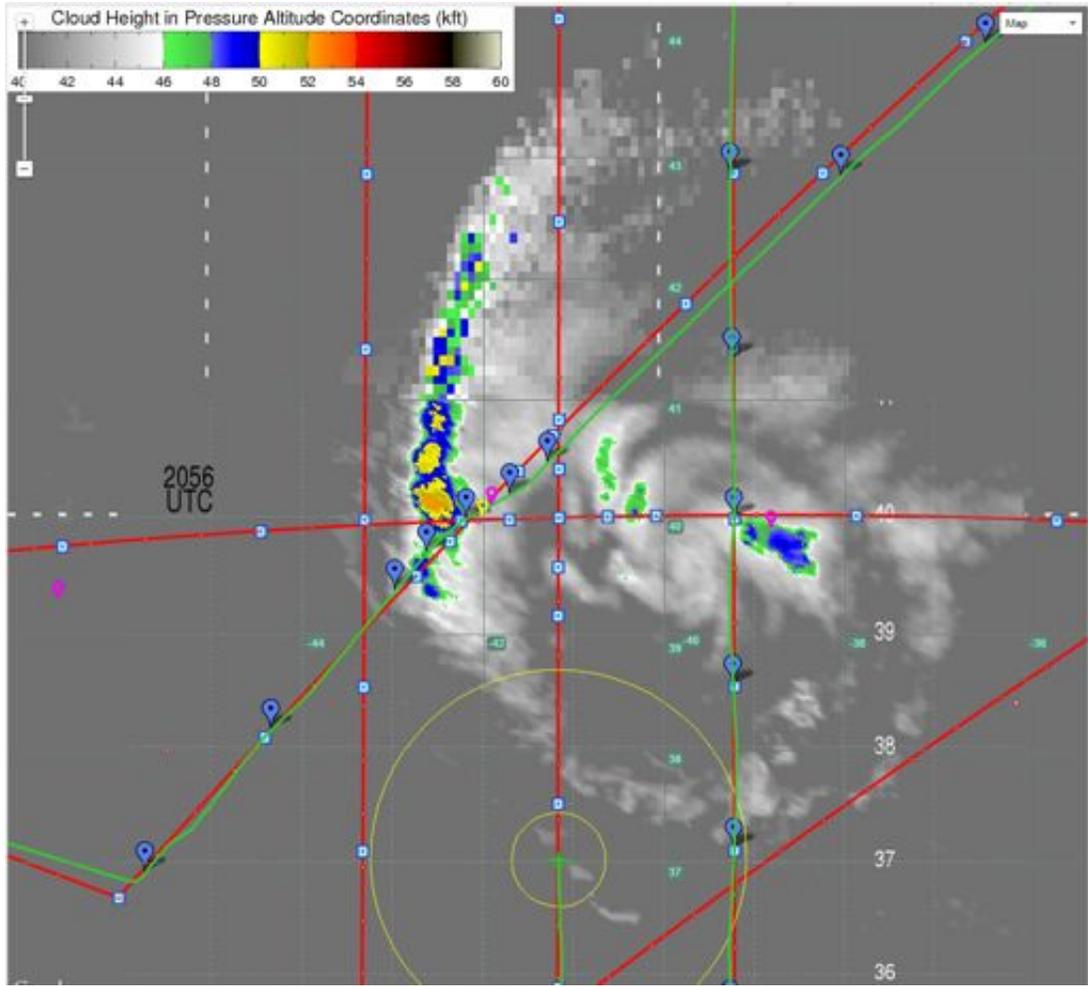
2105 D22 release

2108 Sonde along the first lawnmower leg just to the east of the center (D16) shows winds below 600 hPa are southerly at about 50-60 kt. Above 600 hPa the winds shift to southwesterly flow, suggesting that the low-level vortex is due west of the drop location, while the upper-level vortex is to the northwest. This suggests a tilt of the vortex toward the northeast with height (i.e. a downshear-left tilt orientation).

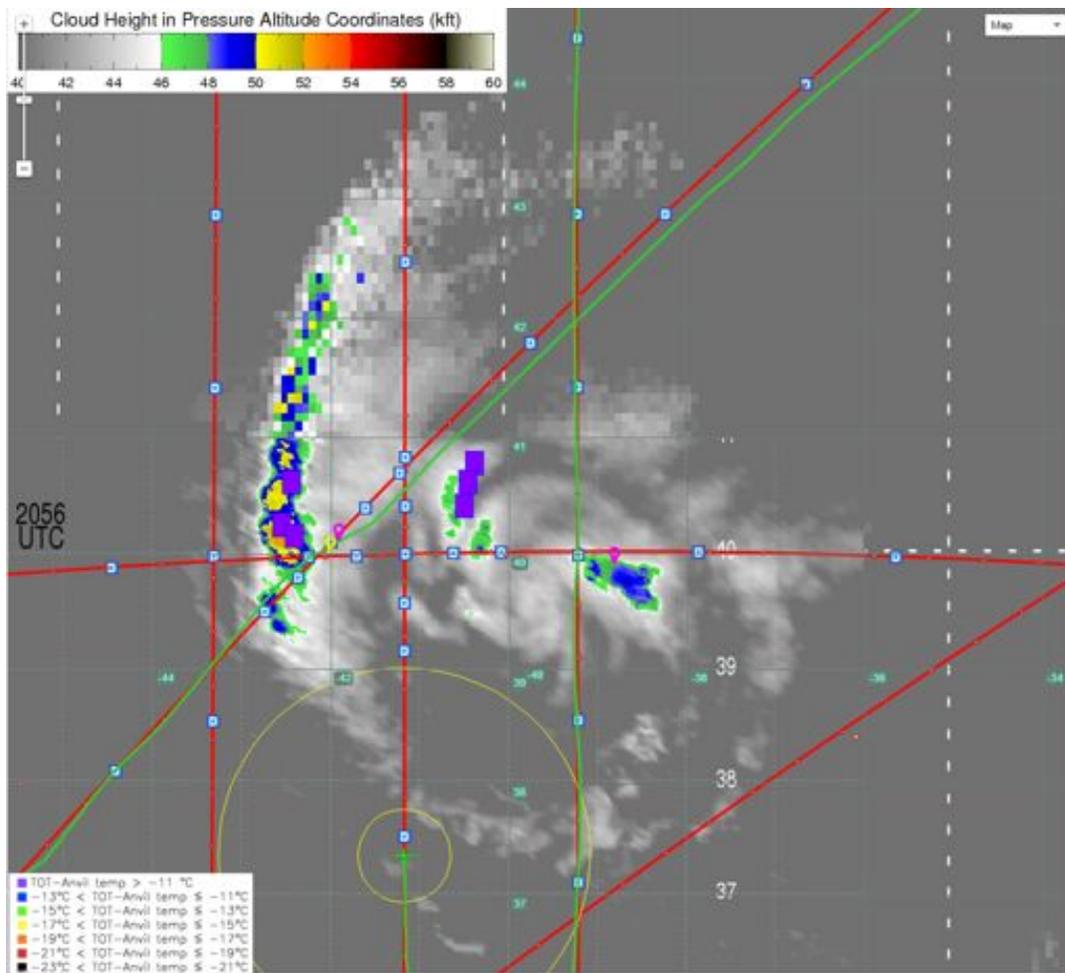


2112 Visible (shortwave IR) image shows a sharp boundary in the outflow on the west side of the storm along 42.5 W. This is coincident with a band of relatively high cloud tops from MTS.





Some overshooting tops ( $\Delta T < -11$  C) are seen at the upstream edge of this banded feature (below).



2121 D23 release

2138 D24 release, beginning of rapid sonde sequence, 50 nm south of expected low-level center.

2143 D25 release, 25 nm south of expected low-level center.

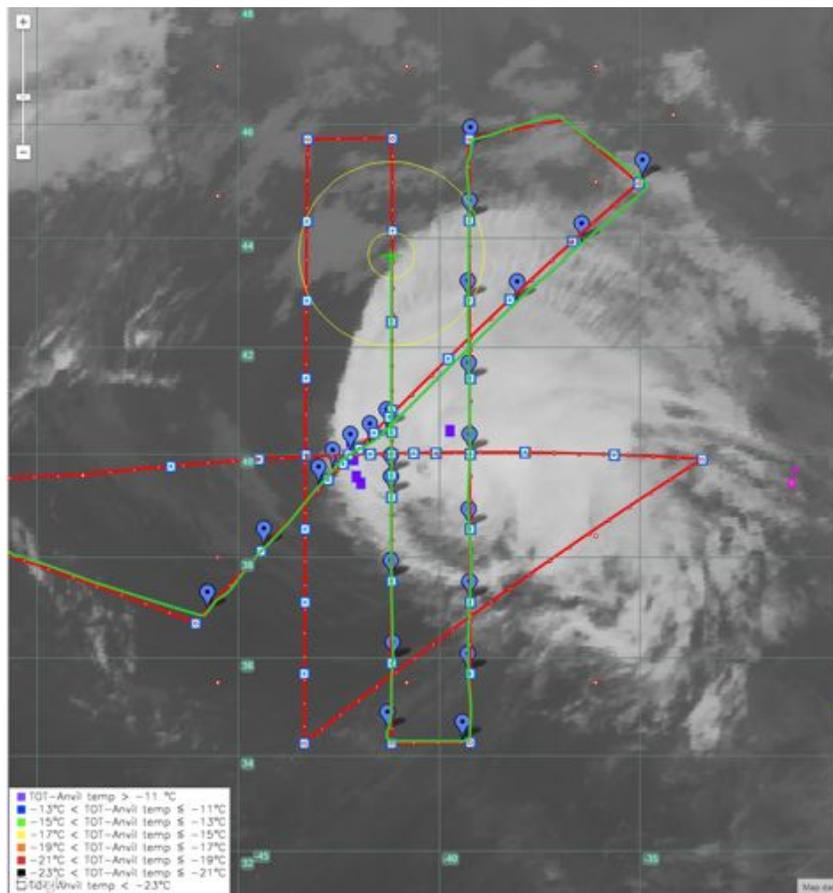
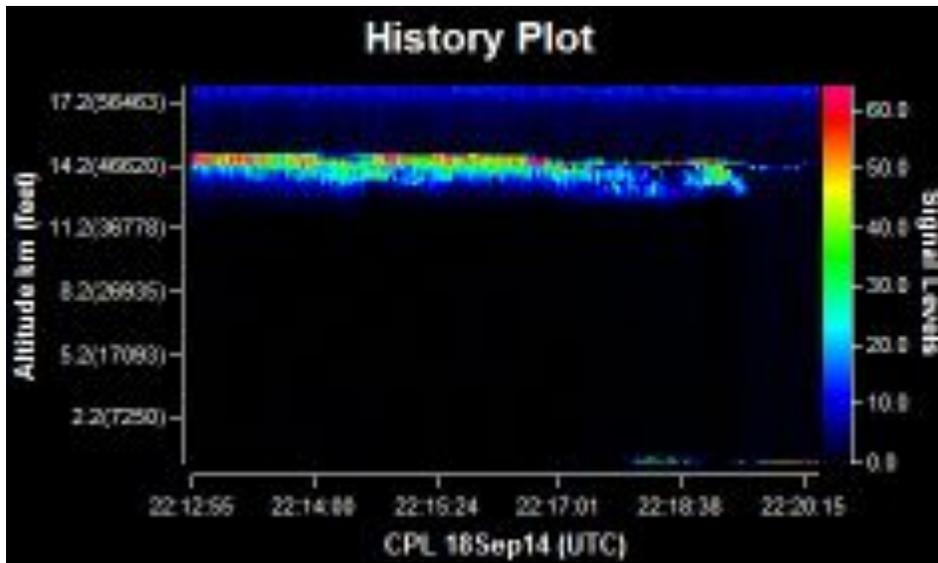
2147 D26 release, at expected low-level center.

2152 D27 release, 25 nm north of expected low-level center.

2156 D28 release, 50 nm north of expected low-level center.

2213 D29 release

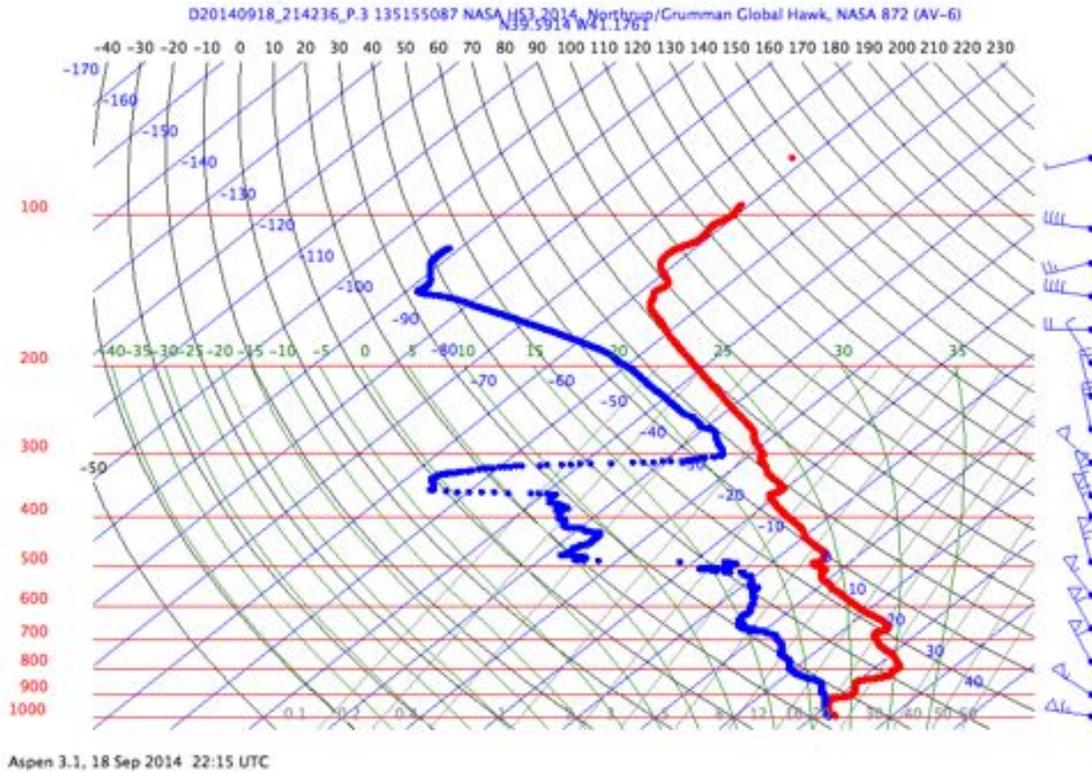
2225 Just popped out of clouds on north side of storm, will be in clear air for ~3 more hours.



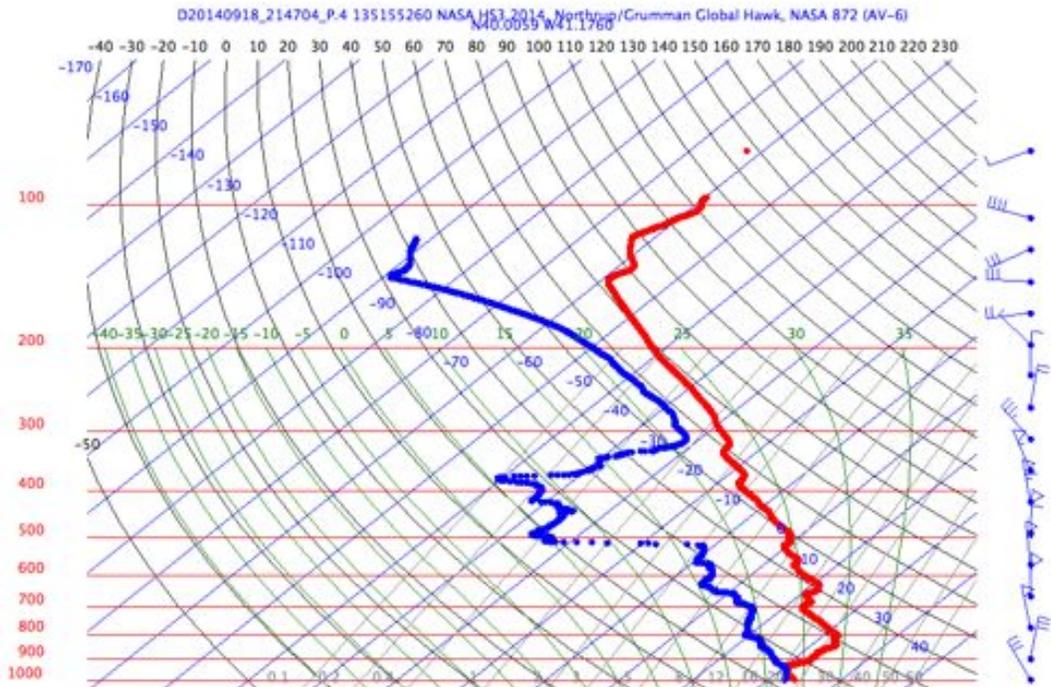
2228 Sonde D24 (at 2138 UTC) had bad GPS tracking, no data below 225 hPa

2231 D30 release

2234 Drop at 25 nm south of expected low-level center (D25; at 2143; see below) shows winds in lowest 50 hPa of about 65 kt from nearly due west. Looks like it captured the low-level center pretty well. You can also see that between 800 and 200 hPa, the winds are NNW, indicating that the circulation in these levels is displaced to the east and east-northeast from the circulation below 800 hPa (again consistent with a downshear-left orientation). Very dry air also seen below 300 hPa, including down to 800 hPa. Below that altitude is a different air mass, moist, and associated with the low-level vortex.

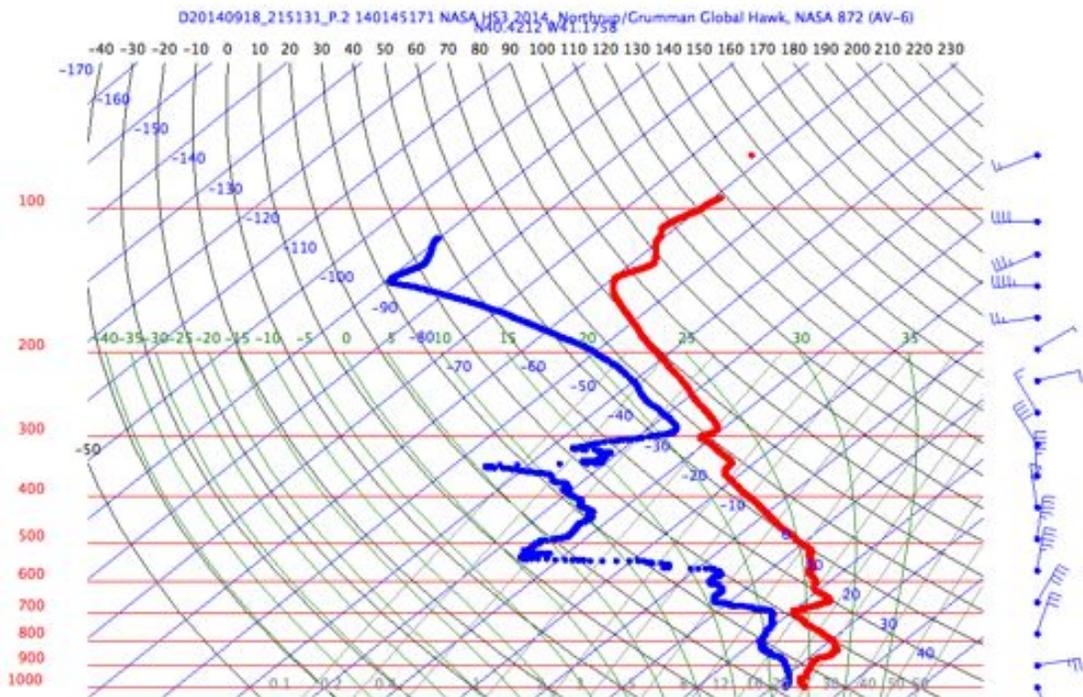


2243 Drop at expected low-level center (D26, at ???; see below) shows that we missed the low-level center on the west side, as there are northerly winds of ~30 kt in the lowest 50 hPa. Otherwise the structure is similar to the sonde 25 nm to the south – dry air between 900 hPa and 300 hPa, moist environment in the PBL.



Aspen 3.1, 18 Sep 2014 22:20 UTC

2249 D31 released



Aspen 3.1, 18 Sep 2014 22:28 UTC

2250 Drop at 25 nm on north of LLC (above) shows a sharp asymmetry in the PBL wind speeds; about 65 kt on the south side of storm 25 nm from center, 20 kt on north side 25 nm from center. From both sondes the midlevel circulation is to the east of the drop locations.

2305 D32 released

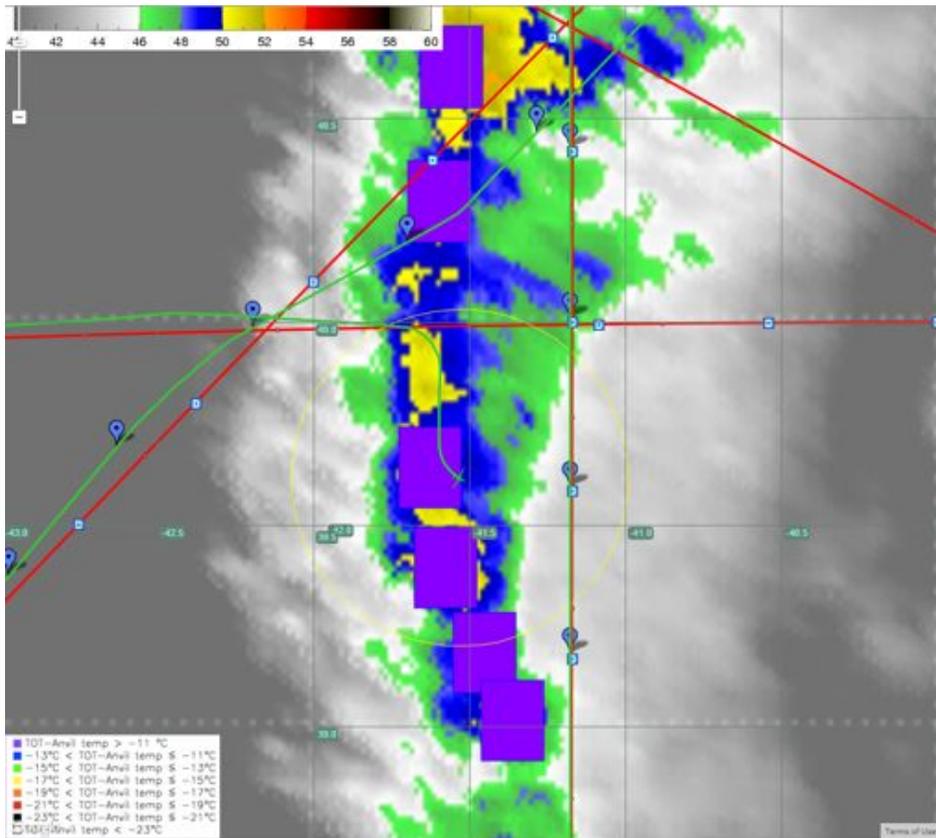
2320 D33 released

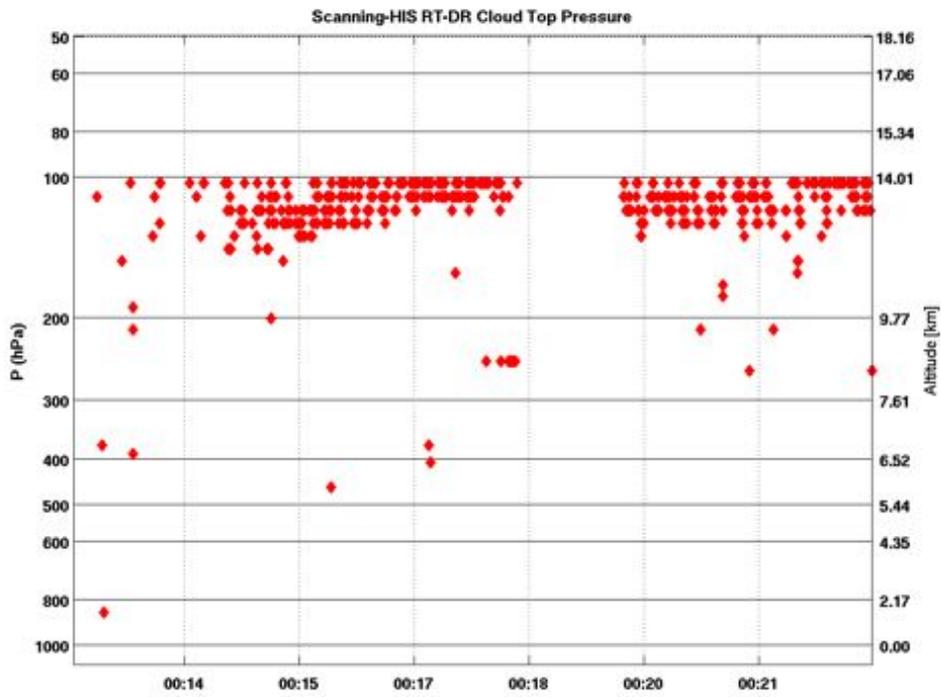
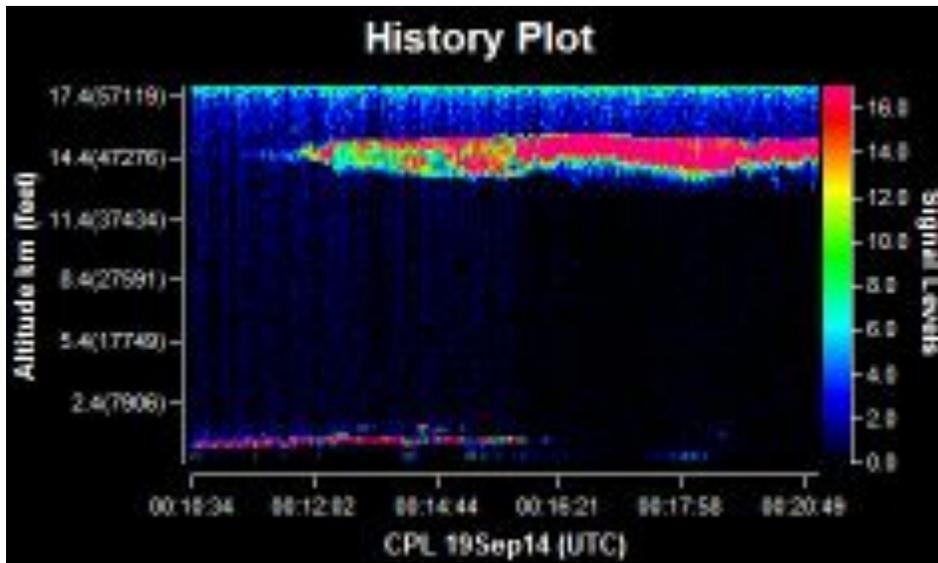
2323 Modified flight track. Cutting westernmost N-S leg of survey pattern short at latitude of LLC, turning back inbound toward east. Continuing outbound to point 300 nm east, then turn toward a point 300 nm southeast of center, head inbound toward the northwest for a final pass from SE-NW.

2335 D34 released

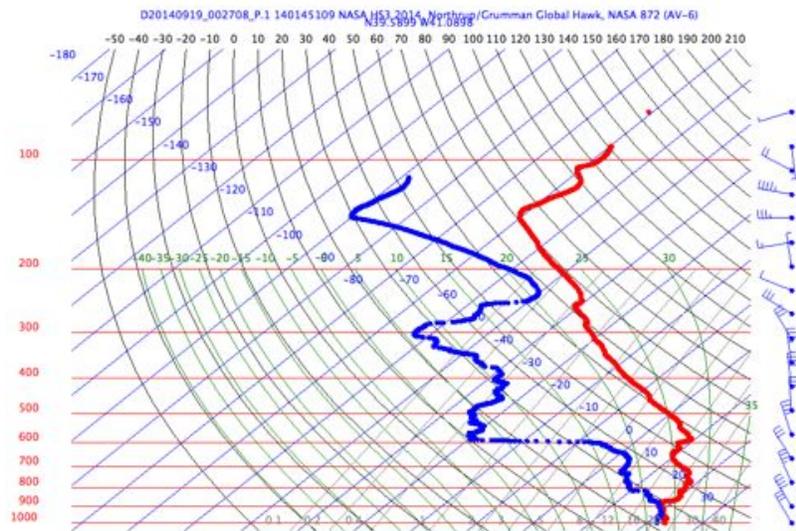
2356 Cancelled drop on the west side before we turn inbound

0022 On inbound leg from W-E, deviated to south a bit to better align with low level center. During this deviation we're tracking southbound right along the axis of the high cloud tops. CPL shows thick cirrus shield. SHI-S also shows saturation at 100 hPa.

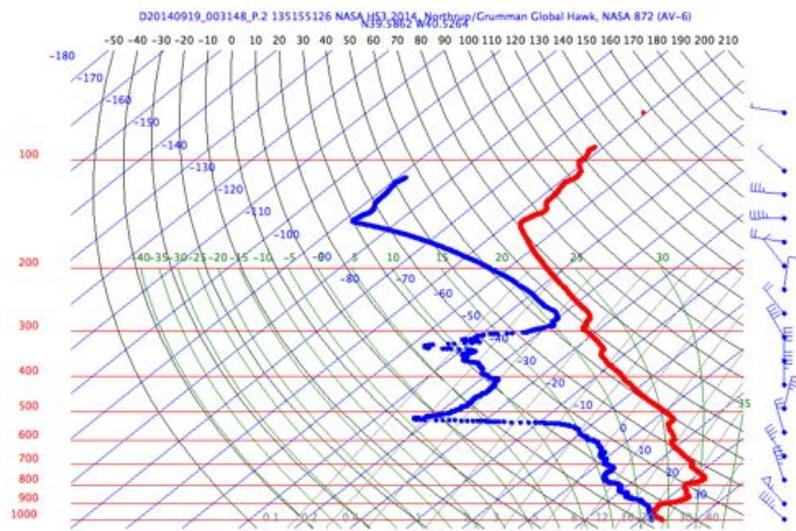




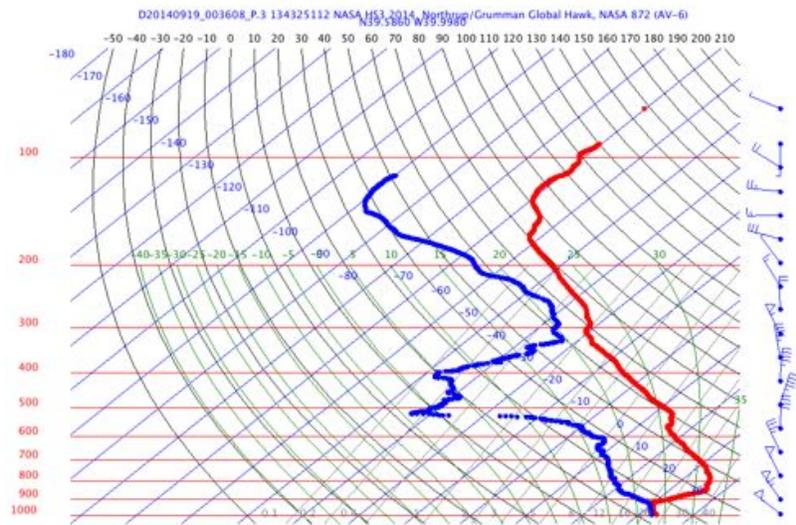
0027 D35 released



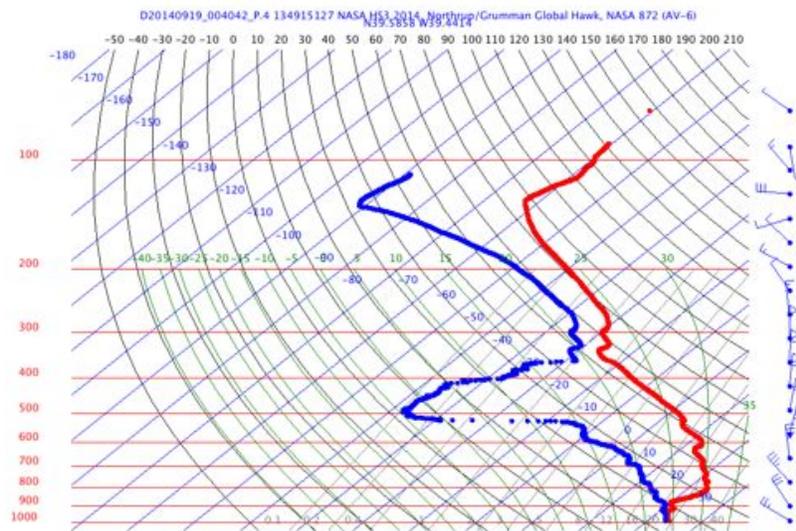
Aspen 3.1, 19 Sep 2014 01:18 UTC



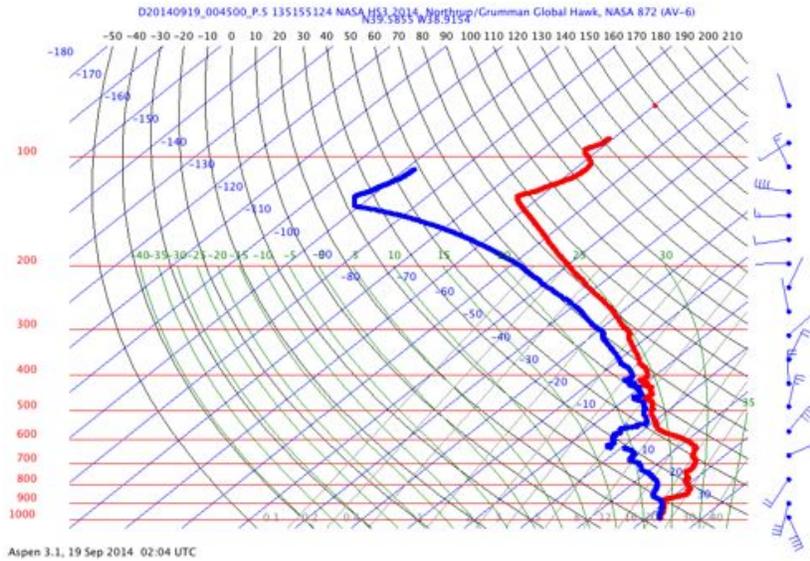
Aspen 3.1, 19 Sep 2014 01:02 UTC



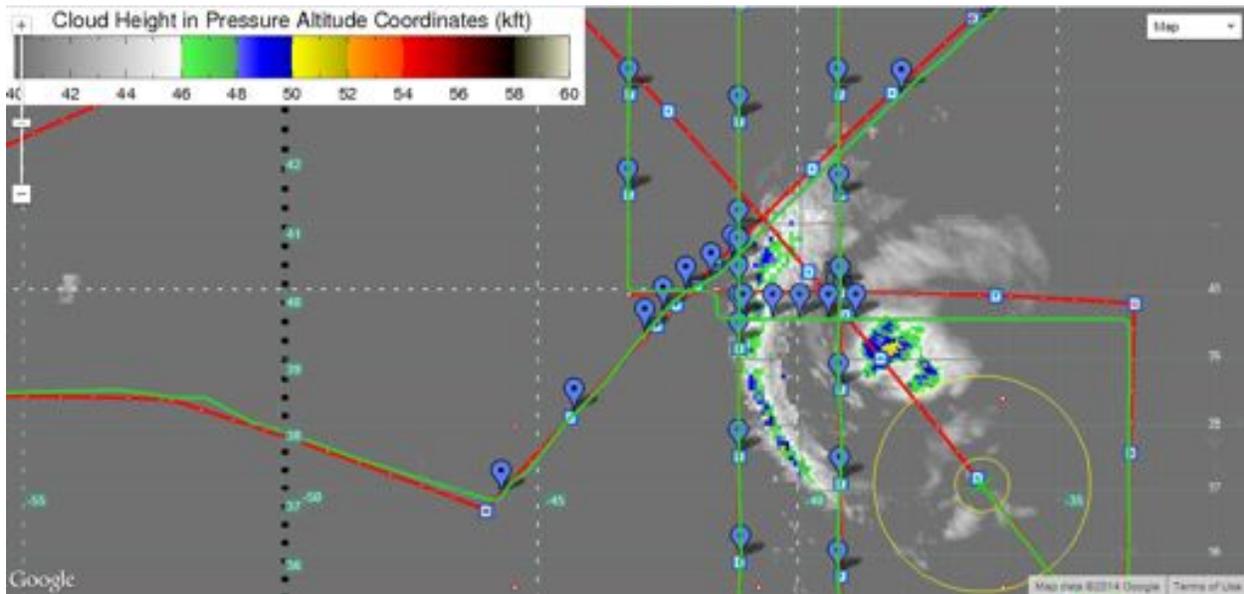
Aspen 3.1, 19 Sep 2014 01:43 UTC



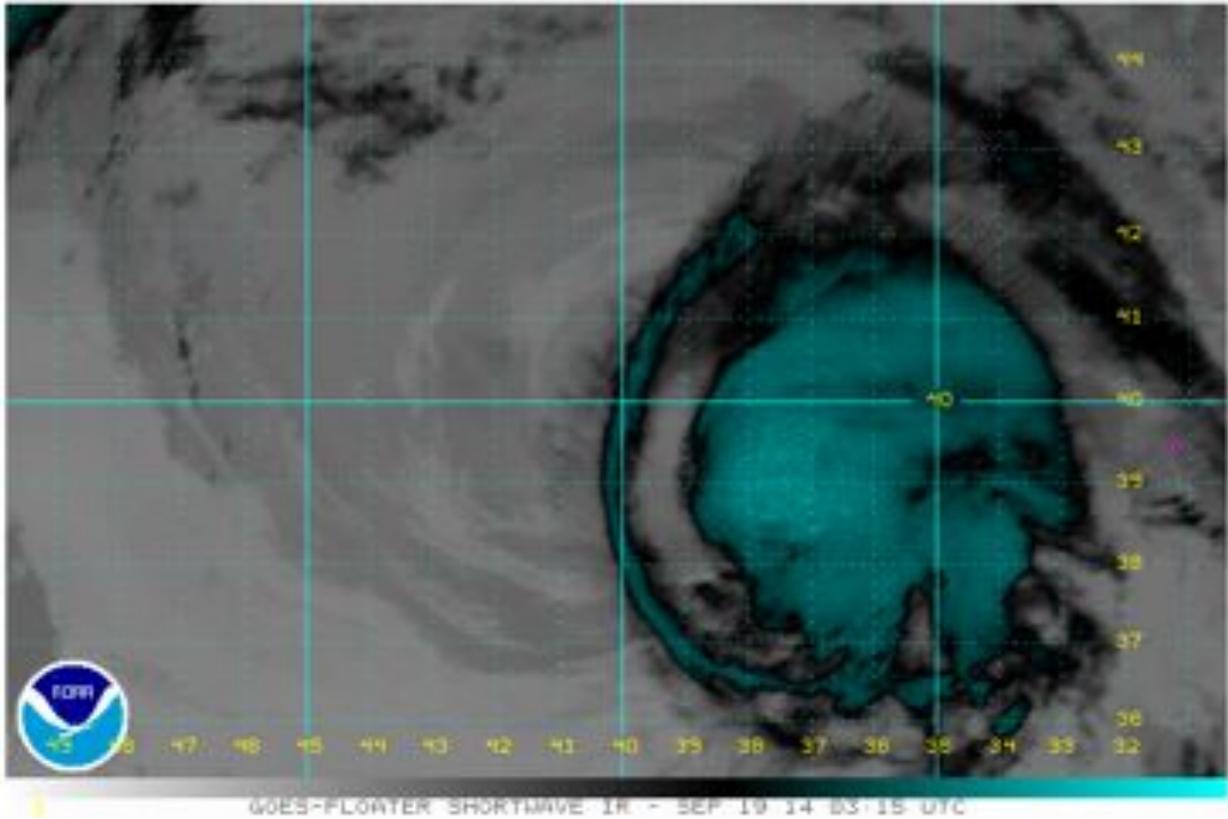
Aspen 3.1, 19 Sep 2014 01:59 UTC



These five sondes were dropped on the west to east leg between 0000 and 0100 UTC (see updated flight track below). An examination of the above sondes suggests that the fourth sonde was just west of the LLC, and the fifth sonde was just east of the LLC. In particular, the surface winds in the fifth sonde suggest that the center is to the west or southwest of the sonde location near the surface; at higher levels the wind structure suggests that the center is east of this sonde in the middle levels. Such a wind structure is consistent with a cyclonic vortex that is tilted to the northeast. This structure is not permanent however. The satellite data 2 h later strongly suggests a southeasterly tilt. Note the strong signature of subsidence in the first four soundings – consistent with subsidence on the upshear side.



0244 UTC



The low-level center can now be seen almost completely decoupled from the mid- to upper-level centers.

Yet the storm shows signs of continued deep convection near the center despite a sea-surface temperature of approximately 24 C. The inner-core circulation seems to be approximately holding its intensity near this time.

(Question: How is this possible?)

11 PM (03 Z) NHC Forecast Discussion:

## Tropical Storm EDOUARD Forecast Discussion

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 WTNT41 KNHC 190236  
 TCDAT1

TROPICAL STORM EDOUARD DISCUSSION NUMBER 31  
 NWS NATIONAL HURRICANE CENTER MIAMI FL AL062014  
 1100 PM AST THU SEP 18 2014

Edouard has not changed much during the past several hours.

Microwave images indicate that the low-level center is located on the western side of the main area of deep convection due to about 30 kt of westerly shear. Despite being in a strong shear environment and over cool waters, an ASCAT pass just before 0000 UTC indicated that Edouard has not weakened significantly. Maximum reliable winds seen in the ASCAT data are in the 55 to 60 kt range, and dropsonde wind reports from the NASA Global Hawk suggest a similar intensity. Therefore, the initial wind speed is held at 60 kt for this advisory. The storm is expected to remain in hostile conditions, therefore, steady weakening is anticipated and Edouard is forecast to become post-tropical in about 24 hours. The global models show the post-tropical cyclone degenerating into a trough by 96 hours, and this is reflected in the official forecast.

Satellite fixes suggest that Edouard is moving eastward at about 15 kt on the north side of a subtropical high. A continued eastward motion with a decrease in forward speed is predicted for the next day or so, followed by a turn to the southeast when the cyclone becomes embedded in the flow between the subtropical high and a deep layer low over the northeast Atlantic Ocean. The NHC track forecast is nudged a little to the north of the previous one, and lies very close to the multi-model consensus, TVCA.

The 34- and 50-kt wind radii were updated based on the ASCAT pass and the NASA Global Hawk dropsonde data.

FORECAST POSITIONS AND MAX WINDS

INIT	19/0300Z	39.9N	39.2W	60 KT	70 MPH
12H	19/1200Z	39.9N	37.8W	50 KT	60 MPH
24H	20/0000Z	39.9N	36.1W	40 KT	45 MPH...POST-TROPICAL
36H	20/1200Z	40.0N	34.0W	35 KT	40 MPH...POST-TROPICAL
48H	21/0000Z	39.5N	31.5W	35 KT	40 MPH...POST-TROPICAL
72H	22/0000Z	36.0N	29.5W	30 KT	35 MPH...POST-TROP/REMNT LOW
96H	23/0000Z	...DISSIPATED			

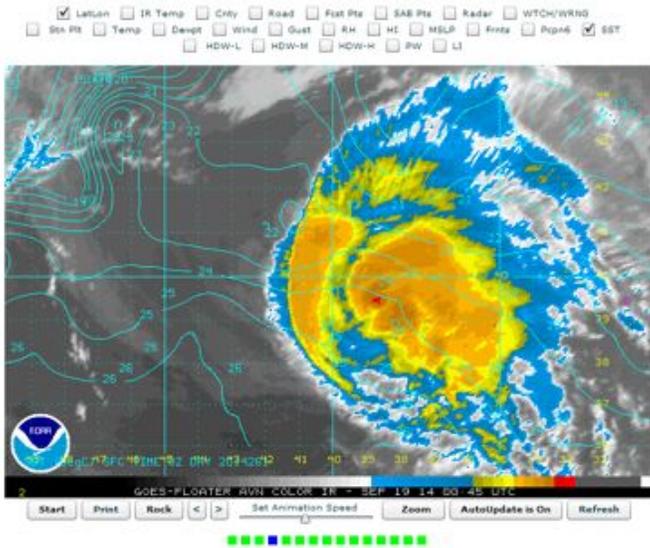
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Forecaster Cangialosi

Straddling this time period, the cold cloud top region of TS Edouard appears to be moving in the southeast direction, moving approximately parallel to the 24 C isotherm.

0045 Z

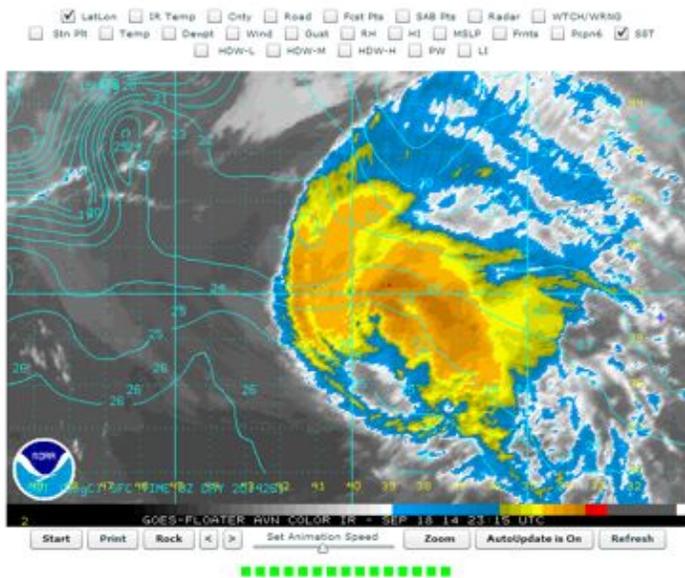
### Edouard Long Floater - AVN Color Imagery Loop



This loop intended for informational purposes only!  
For Emergency situations and/or decisions, please refer to your local Emergency Management Office.  
[Additional Flash Information](#)

0345 Z

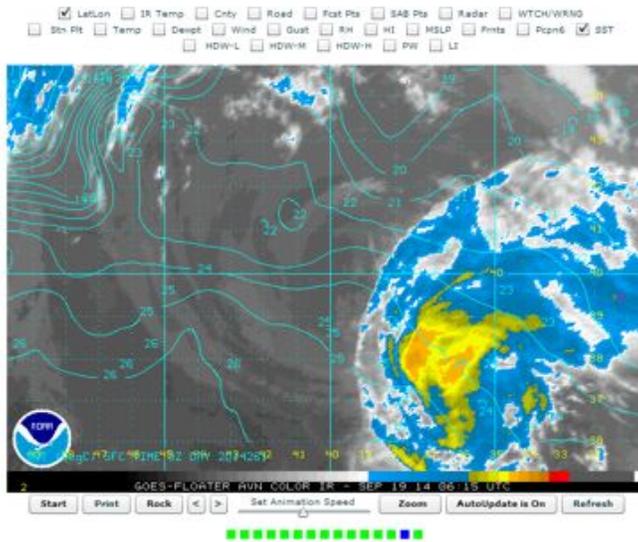
### Edouard Long Floater - AVN Color Imagery Loop



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For Emergency situations and/or decisions, please refer to your local Emergency Management Office.  
[Additional Flash Information](#)

0615 Z

### Edouard Long Floater - AVN Color Imagery Loop



This loop intended for informational purposes only!  
For Emergency situations and/or decisions, please refer to your local Emergency Management Office.  
[Additional Flash Information](#)

The low-level circulation appears to be heading eastward, decoupled from the middle and upper-level circulation moving southeastward (as inferred from IR cloud top temperatures) shown above.

The storm is undergoing a dramatic separation between the lower and upper levels!

Last Drop released at 0434 Z.

(50 dropsondes released)

AV6 returning to base.

0829 Powering down instruments for landing

1020 Waiting for chase before landing

1024 Weather brief on Edouard from NHC

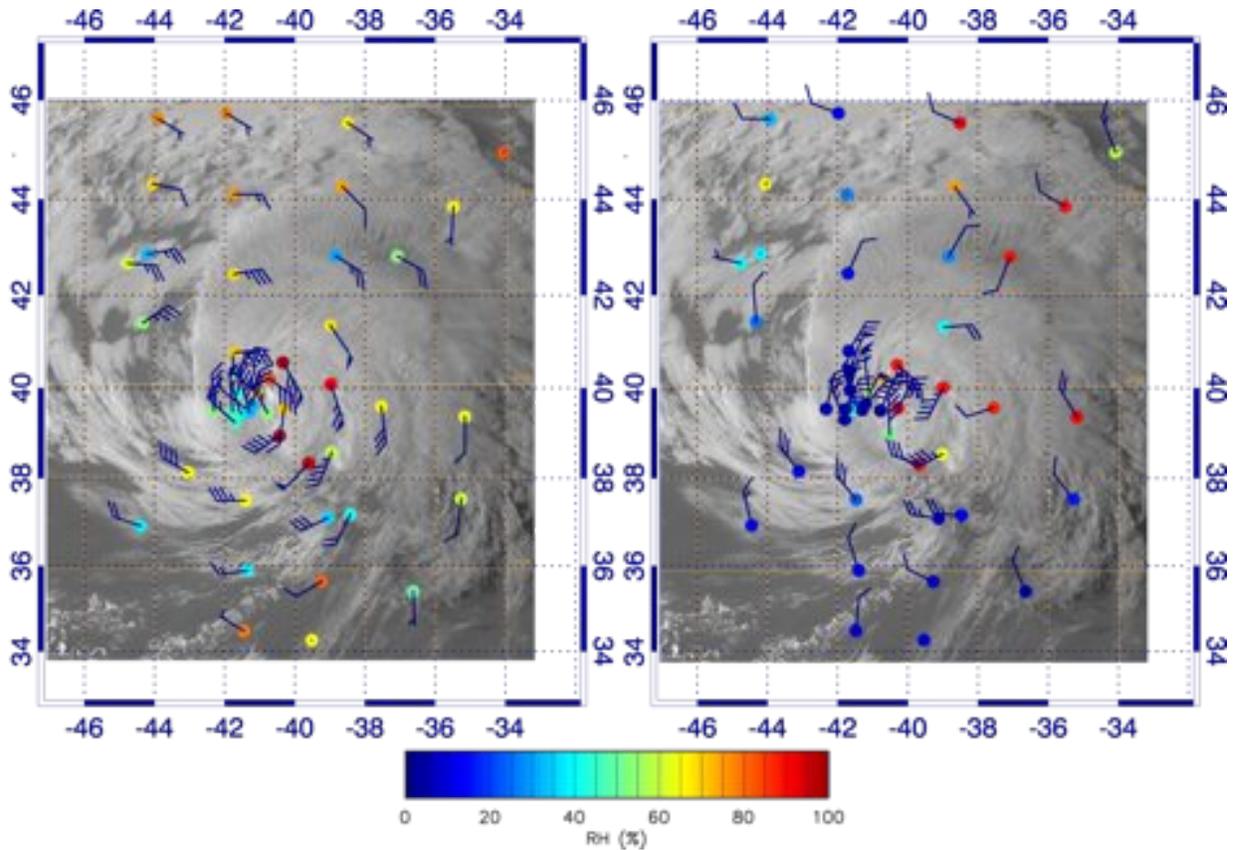
TROPICAL STORM EDOUARD DISCUSSION NUMBER 32  
NWS NATIONAL HURRICANE CENTER MIAMI FL AL062014  
500 AM AST FRI SEP 19 2014

Satellite images indicate that Edouard has become much less organized during the past several hours. The low-level center is now exposed with no associated deep convection, with the old mid-level circulation decoupled well to the southeast. With the absence of deep convection, Edouard is probably losing strength quickly, so the initial wind speed is lowered to 50 kt, a little higher than the average of the satellite estimates in consideration

of the earlier Global Hawk/ASCAT data. Edouard is unlikely to redevelop organized deep convection since it is over 23C water with strong shear. Thus, the storm should continue to weaken and will likely become post-tropical in about 12 hours. Extratropical transition is indicated in a couple of days since most of the global models are now showing the former tropical cyclone developing frontal features by that time.

Edouard has slowed down considerably during the past few hours, with initial motion estimate of 090/6 kt. A continued eastward motion is predicted for the next day or so, followed by a turn to the southeast when the cyclone becomes embedded in the flow between the subtropical high and a deep-layer low over the northeast Atlantic Ocean. The latest NHC forecast is blend of the previous NHC prediction and the latest dynamical model consensus, which results in a small westward shift in the 48-72 hour time frame.

1058 Landing



The above figures show the sonde distribution in a storm-relative reference frame. Wind barbs show storm-relative winds. Color filled circles show relative humidity at 800 and 500 hPa.

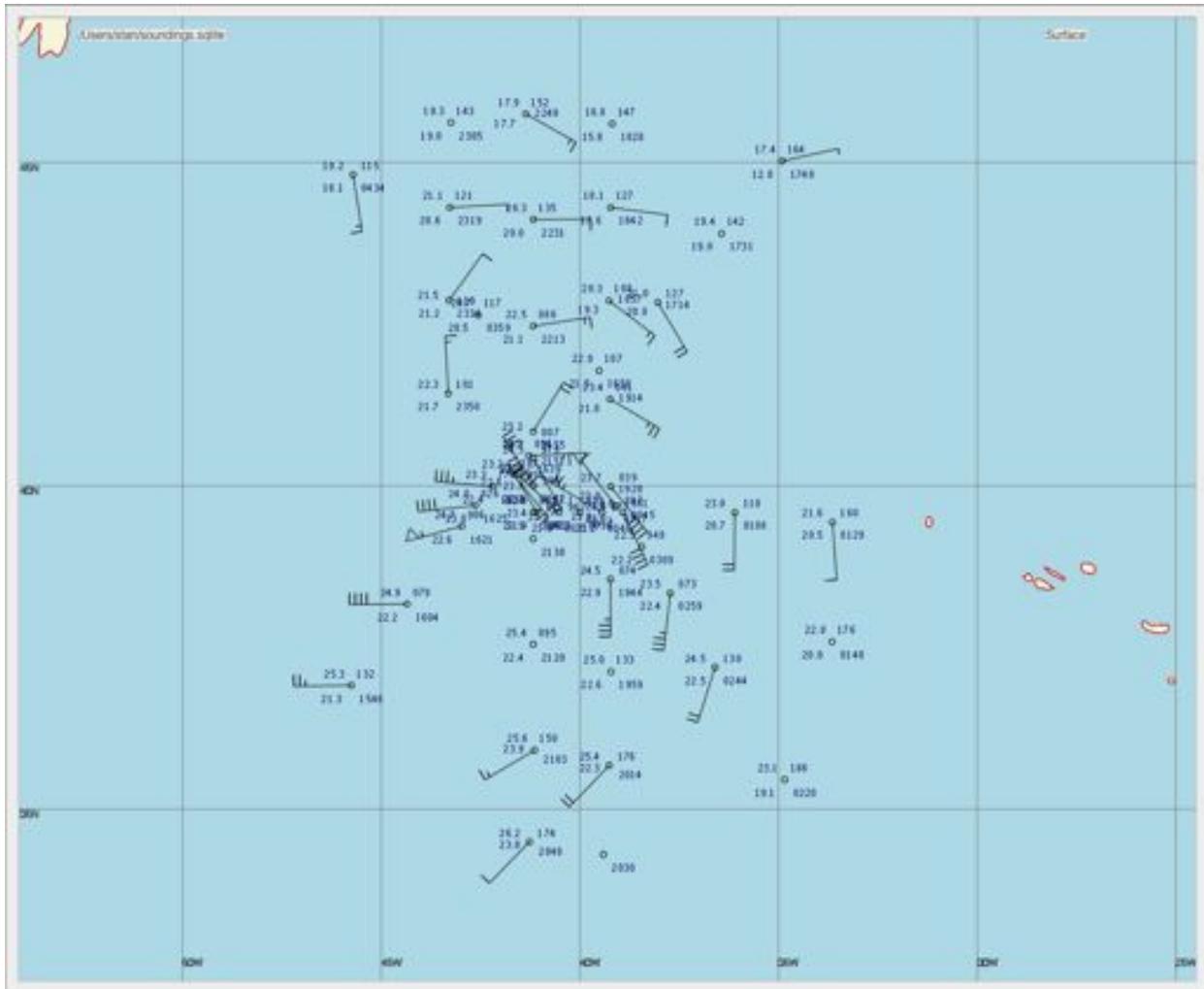
## Instrument summaries

## AVAPS

AVAPS loaded and deployed 50 sondes during RF08 into the weakening Hurricane Edouard. Overall, AVAPS operations were very routine and data quality appeared quite good. We did experience one fast fall (drop 8) which has been very rare this year with the current set of production sondes. Two sondes experienced data gaps above 900 mb associated with periods of enhanced RFI. One sounding (drop 20) terminated early at 828 mb for a yet-to-be-determined reason. Inspection of corresponding binary data files indicates data will not be recoverable. One additional sounding (drop 24) had no GPS/wind data. The real time data terminated at 225 mb, but the binary data file suggests the PTU data were obtained down to the surface and will be recoverable in post processing. Data from 49 of the soundings (all but the fast fall) were processed in real-time and made available. The resulting surface synoptic map is shown below.

While no system faults were observed during the flight, post-flight inspection did reveal failure of a screw connecting the launch plunger to its drive chain. The launcher component was removed from the aircraft and repaired. Further testing showed the launcher to be working nominally again and the system is ready for the next desired flight.

<b>Sondes Allocated</b>		<b>750</b>	
<b>Remaining</b>		<b>214</b>	<b>28.5%</b>
<b>Released</b>		<b>536</b>	<b>71.5%</b>
<b>Flight</b>	<b>Take off Date</b>	<b>Sonde Usage</b>	<b>Sondes Left</b>
RF01	8/26/2014	75	675
RF02	8/28/2014	70	605
RF03	9/3/2014	50	555
RF04	9/5/2014	59	496
RF05	9/11/2014	64	432
RF06	9/14/2014	80	352
RF07	9/16/2014	88	264
RF08	9/18/2014	50	214



## S-HIS Summary

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Science Flight #8 was a combination of 'lawnmower' patterns and diagonal transects of Edouard, which began the flight as a hurricane but was downgraded to a tropical storm by 2100 UTC. Fifty dropsondes were launched. By the time AV-6 intercepted Edouard, the eye had become less distinct and became less identifiable in S-HIS brightness temperature (Figure 1) and T/RH retrievals (Figure 3). Also visible in Figure 2, the upper and lower level cyclonic patterns had become sheered apart.



Figure 1. AV-6 flight path depicted by 900 cm<sup>-1</sup>S-HIS brightness temperatures.

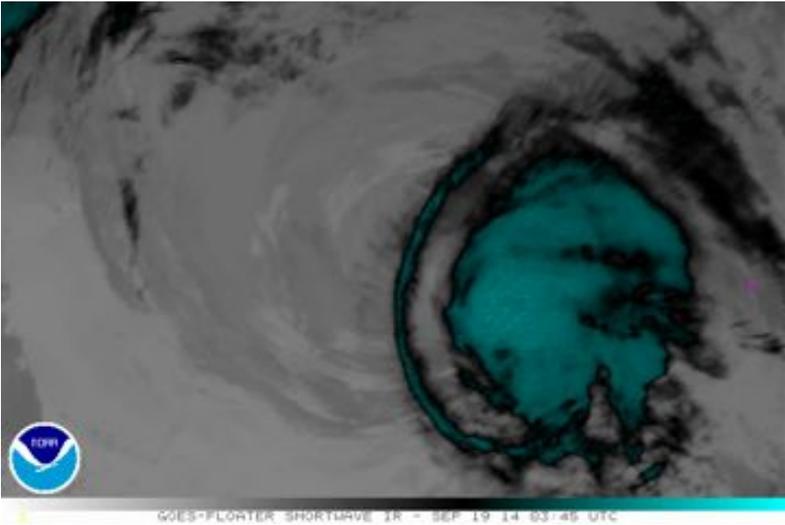
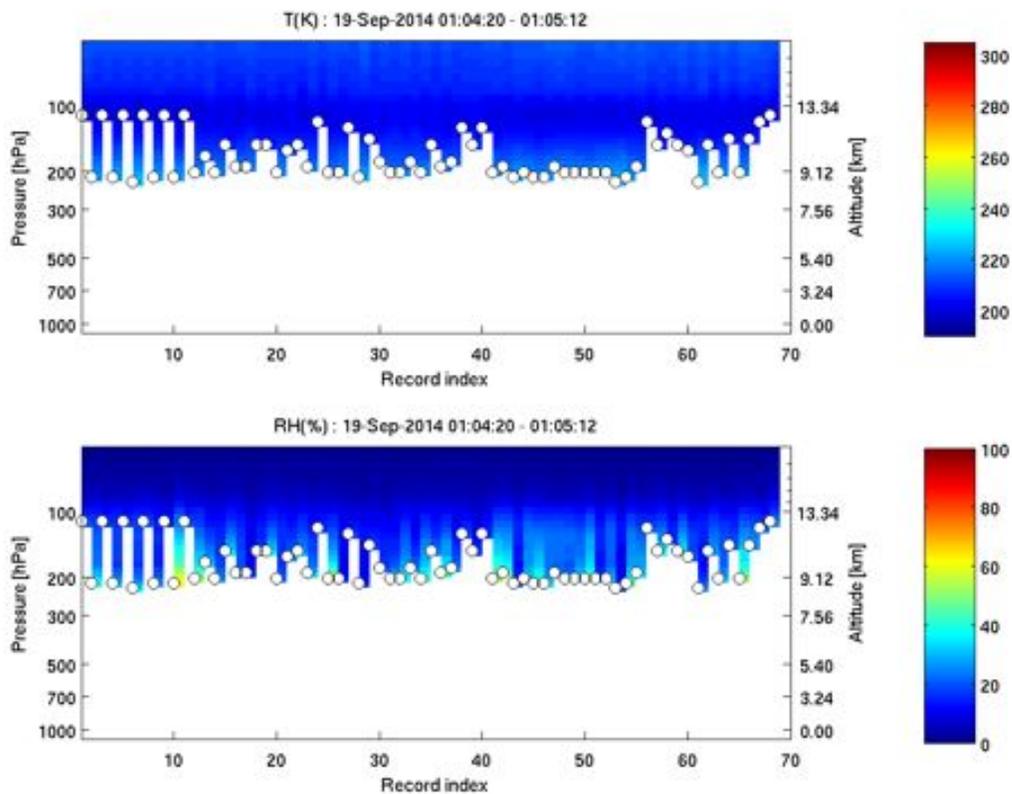


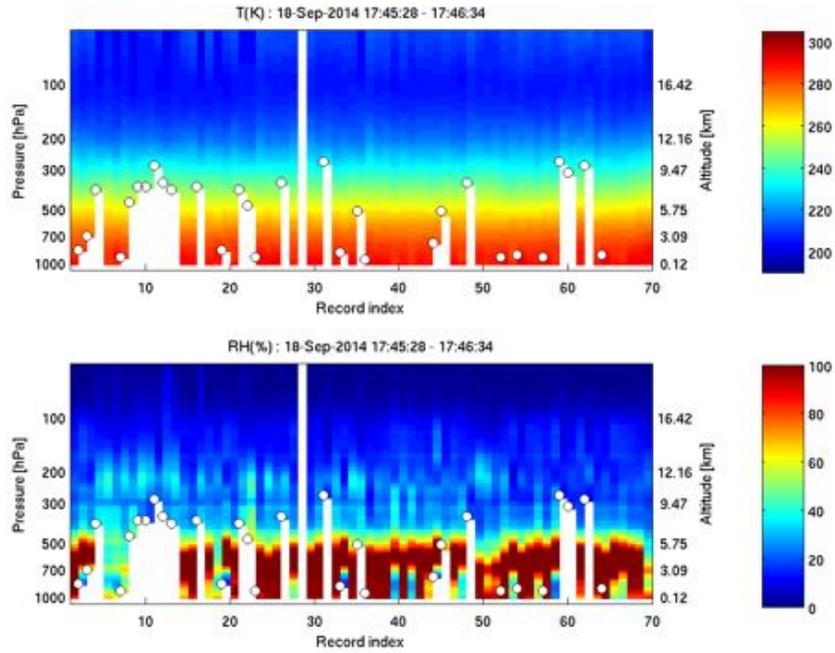
Figure 2. GOES-IR imagery of tropical storm Edoard at 0345 UTC 19 September.



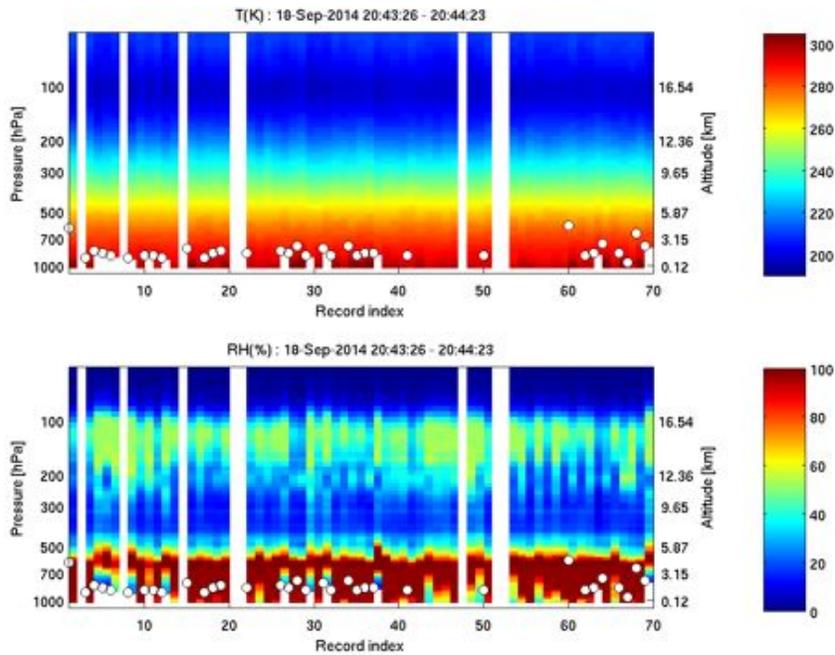
**Figure 3.** Temperature and Relative Humidity cross-sections near eye transect (01:04:20 – 01:05:12 UTC) of tropical storm Edouard.

Edouard was far enough north that only a small portion of the Saharan Air Layer was forecast to be interacting with the eastern portion of the storm. Retrievals over the storm itself were limited in depth, with few getting below 250 hPa. Even the eye lacked sufficient definition to be appreciably penetrated as seen in Figure 3 during the W-E transect. Cloud top pressures differed by storm region and temporally, with the western portions reaching ~100 hPa and the eastern ~250 hPa.

The moisture profiles varied outside of the storm. Figures 4 and 5 show the profiles to the northeast and south of the storm, respectively. Both show a moist surface layer extending to slightly above 500 hPa to the NE, and just shy of it to the south. The southern profile also captures upper level moisture potentially associated with Edouard outflow.



**Figure 4.** Temperature and Relative Humidity cross-sections in the region northeast and outside of the storm.



**Figure 4.** Temperature and Relative Humidity cross-sections in the region south and outside of the storm.

## Instrument Summary

S-HIS performed nominally for the duration of the flight. No cooler cycling was performed.

### Timeline (All times UTC)

- 1011 GH engine start
- 1023 GH engine problem. They're going to try a restart.
- 1040 Second GH engine start
- 1049 DC41 ON (BusA)
- 1049 DC42 ON (BusB)
- 1053 Pin pulled
- 1056 Ku ON and transmitting
- 1101 Flight plan problem
- 1112 Taxi
- 1113 IL41 ON (SHIS Power)
- 1115 Takeoff
- 1130 Detectors cooled, cooler current signature is nominal
- 2100 Edouard downgraded to tropical storm
- 0045 Eye transect
- 0315 Eye transect
- 0807 IL42 ON (Descent heaters)
- 0828 Instrument power OFF before descent (IL42, IL41, DC42, DC41)
- 0850 Instrument power ON (DC41, DC42, IL41, IL42)
- 1040 Instrument power OFF (DC41, DC42, IL41, IL42) est L-0:20
- 1058 Landing

## CPL

CPL performed acceptably for this flight and all data were captured to the disk. We had turned down the laser energy further to see if we could get rid of the ringing in the 1064 channel. However, the data still show the problem. With lower energy, the 532 data is somewhat more noisy during the day, but is fine at night. The attached image from 18:24 UTC shows the noise day vs night. This image is from the first two passes over the now decaying Edouard. The second image from 22:26 UTC shows two later passes over the storm and eye region of Edouard. The first eye crossing occurred at about 00:38 UTC 9/19. The 1064 depolarization showed a region of lower depol possibly associated with a convective turret near the eye. These data can be seen on the CPL web site. Data spans 12:23 9/18 to 08:19 9/19 UTC.