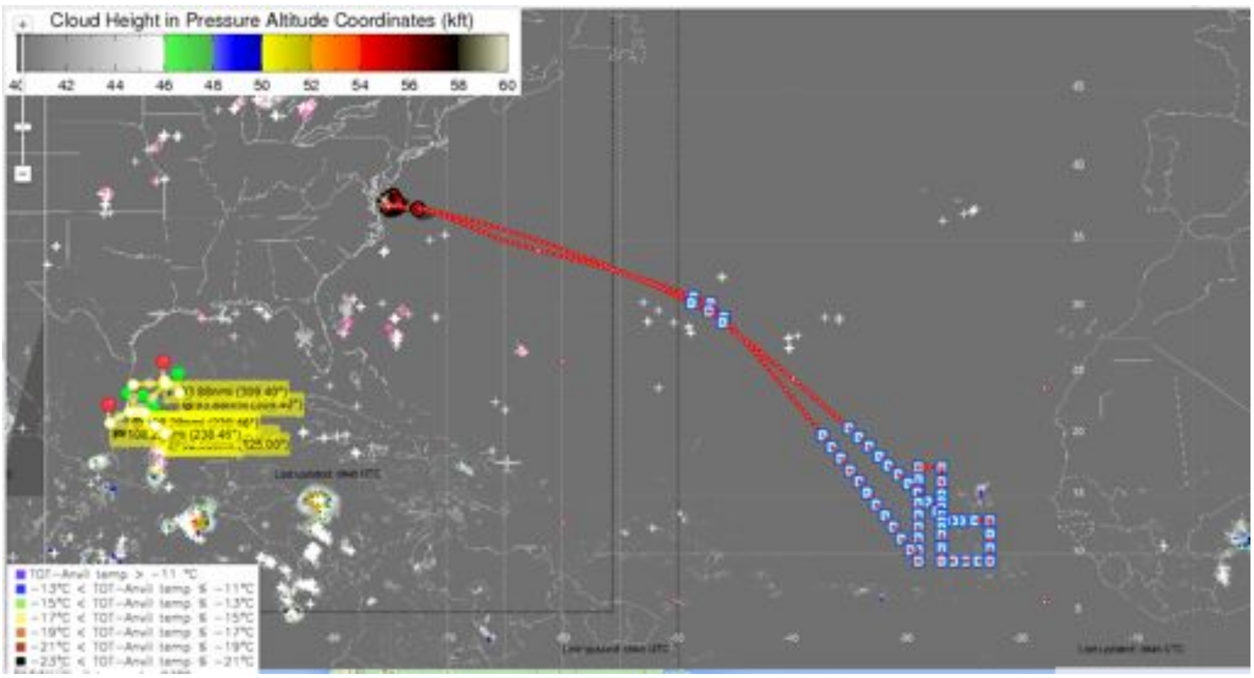
Hurricane and Severe Storm Sentinel (HS3) Mission

HS3 2014-09-05 Flight Report: GLOBALHAWK AV-6 90L Flight

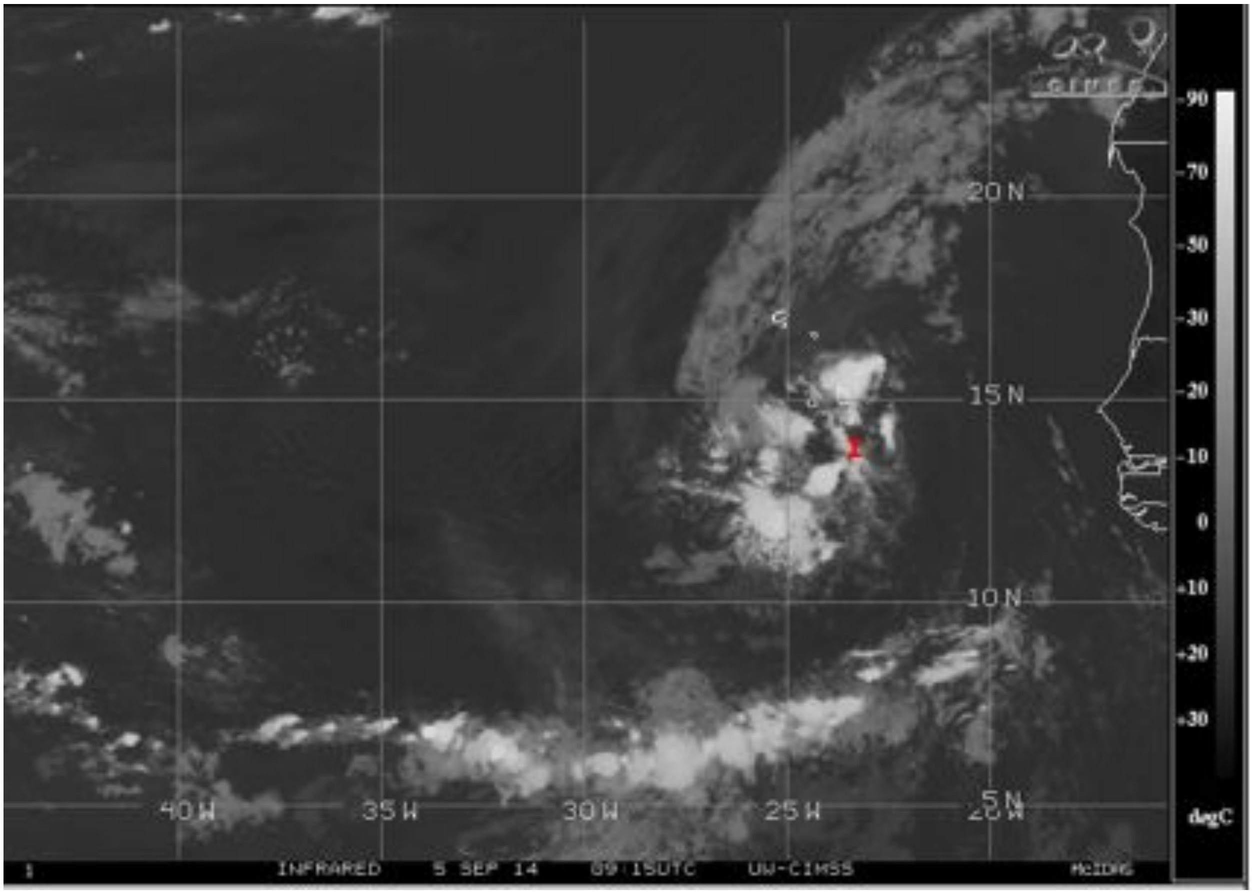
Flight Scientists:
Shift 1 (0400-1300 EDT): James Doyle, Pete Black, Amber Emory, Jon Moskaitis
Shift 2 (1200-2100 EDT): Paul Newman, Chris Velden, Ed Zipser
Shift 3 (2000-0500 EDT): Mike Montgomery, Mike Black, Jason Sippel
Shift 4 (0400-1300 EDT): James Doyle, Pete Black, Amber Emory, Jon Moskaitis

Takeoff: 1111 UTC (0711 LT)
Landing: 1115 UTC (0715 LT)

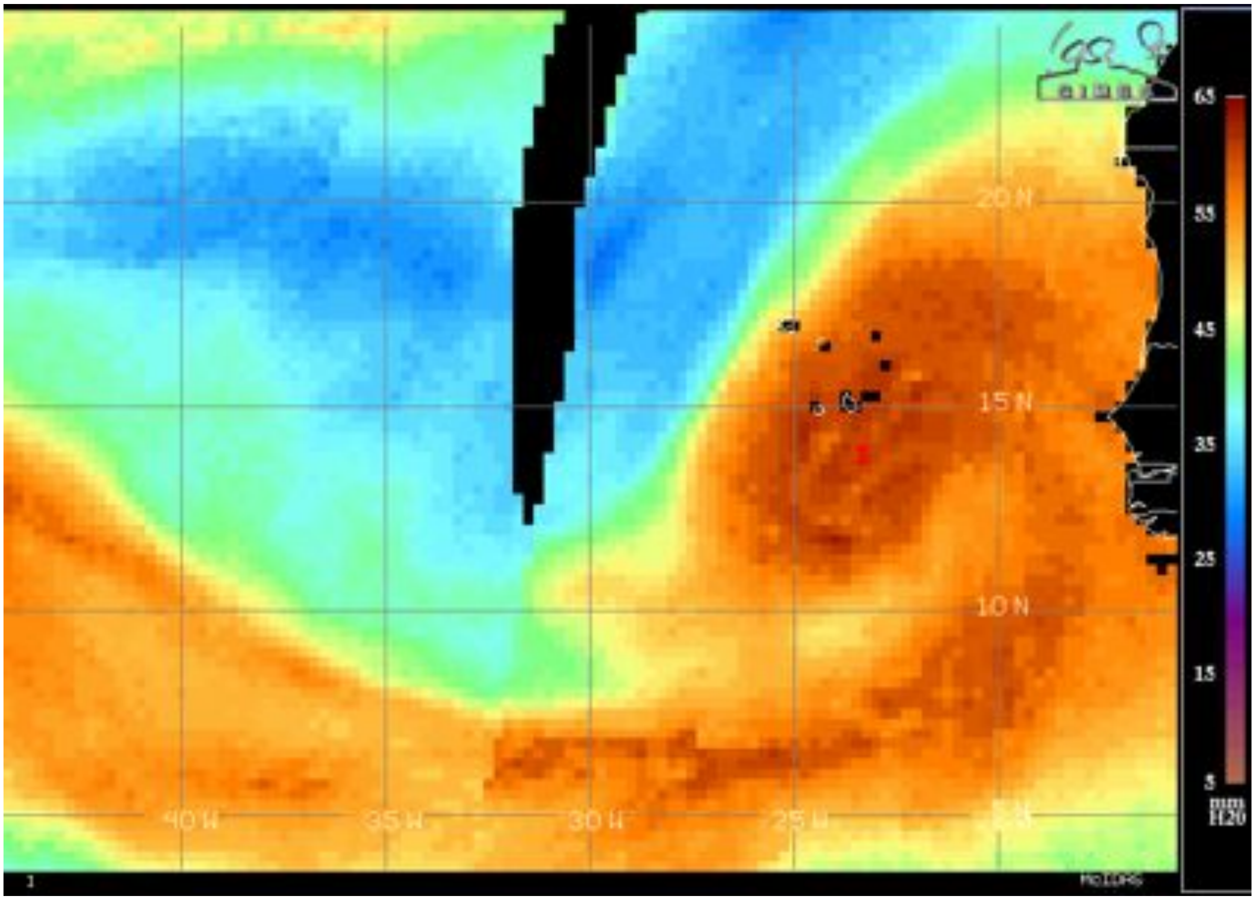
Mission goal: Science flight to investigate 90L and interaction with SAL.



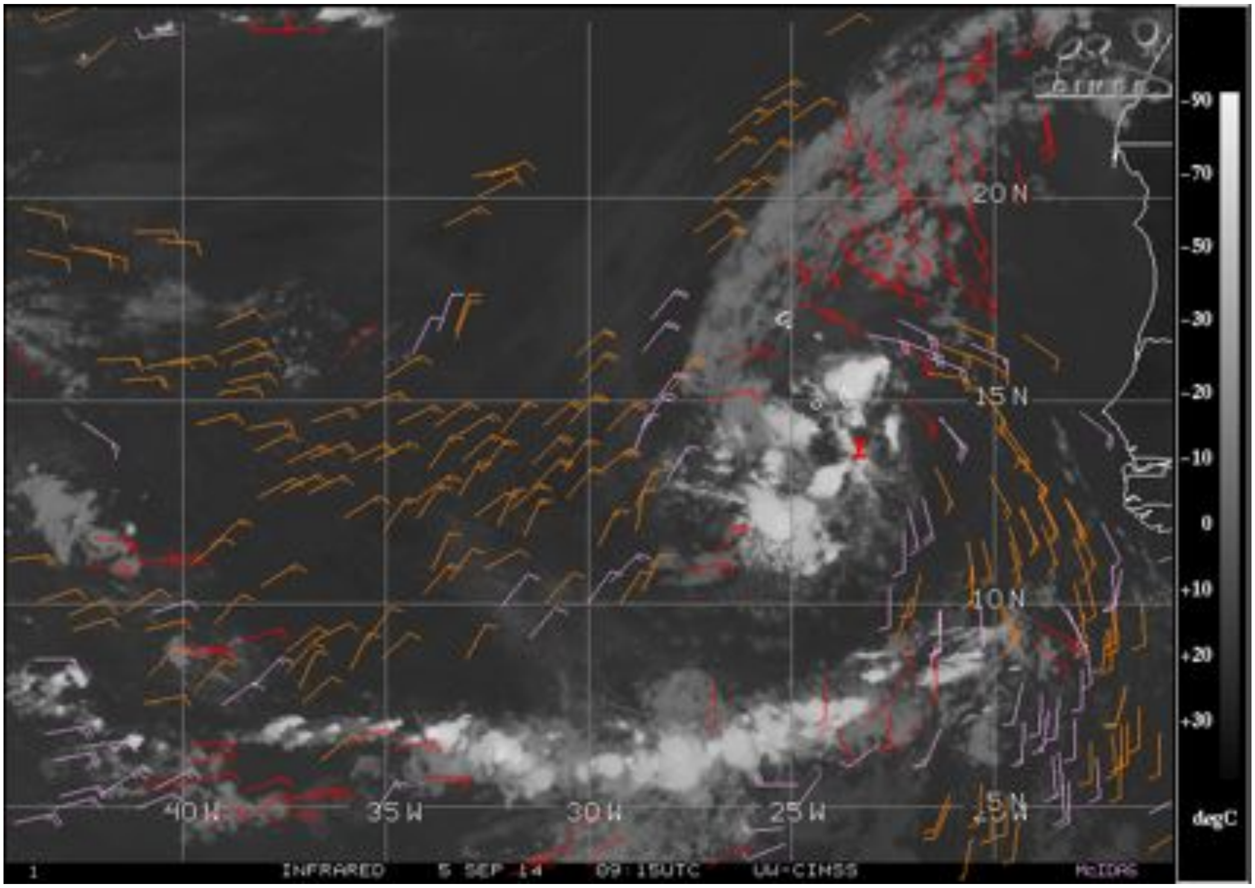
Planned flight track and dropsonde deployment plan to observe 90L.



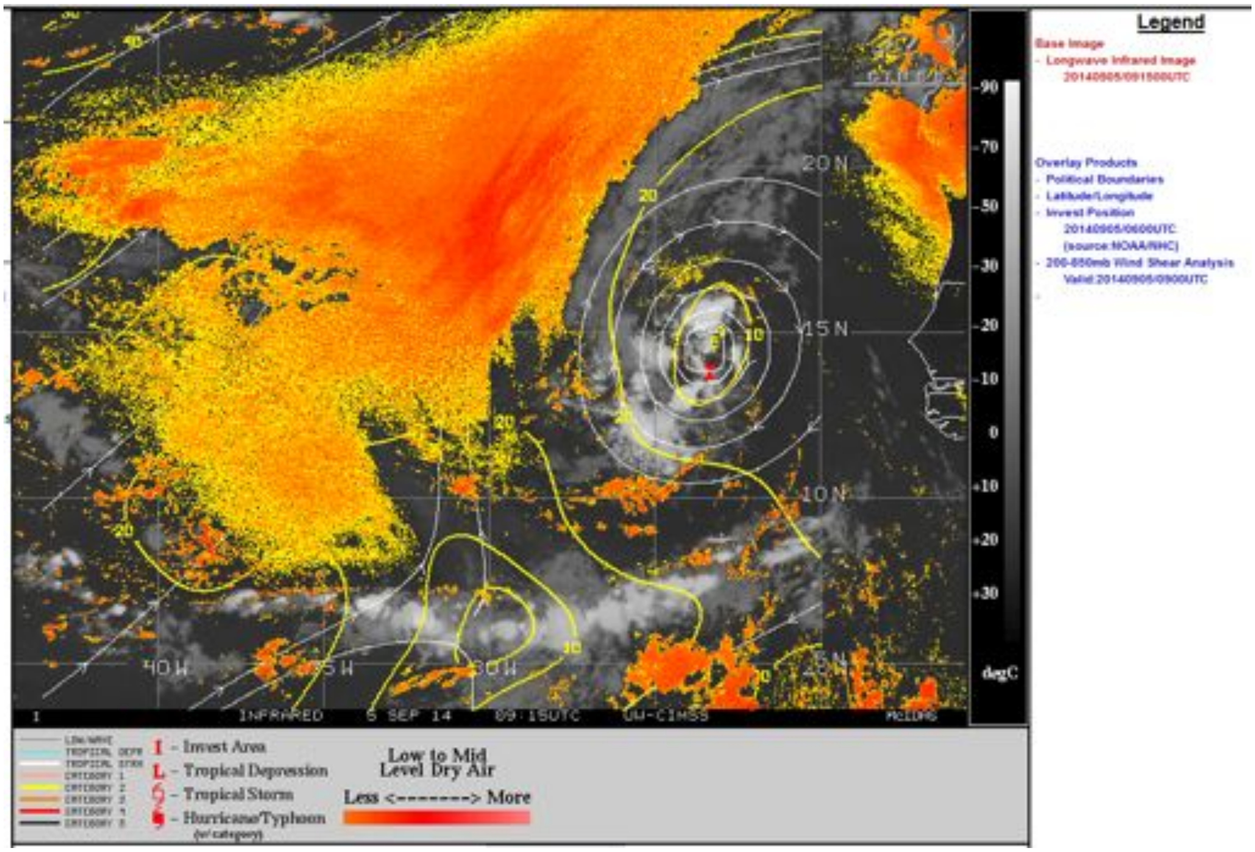
0915 UTC IR shows disorganized convection around 90L.

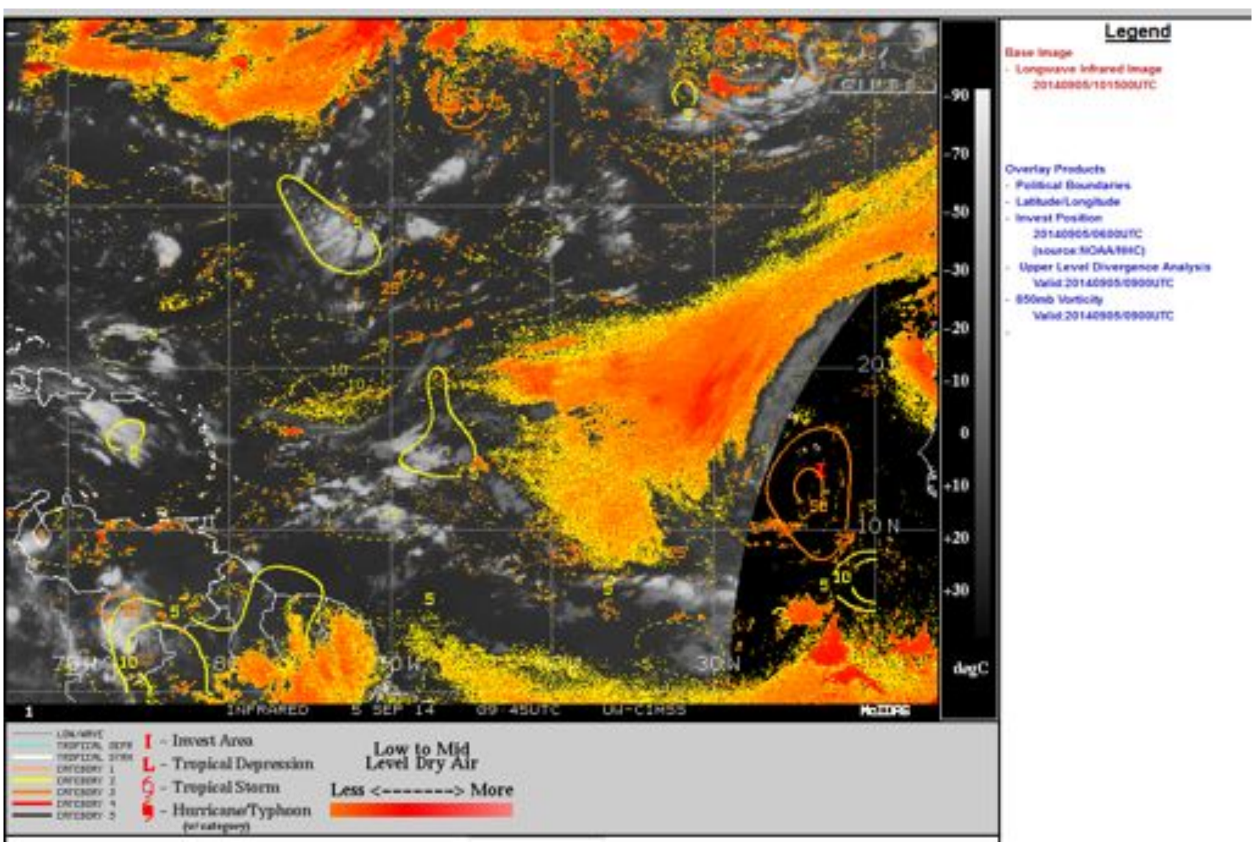


TPW product from CIMSS at 0200 UTC shows dry air wrapping around the west side of 90L. Moist conditions in the center of the circulation.

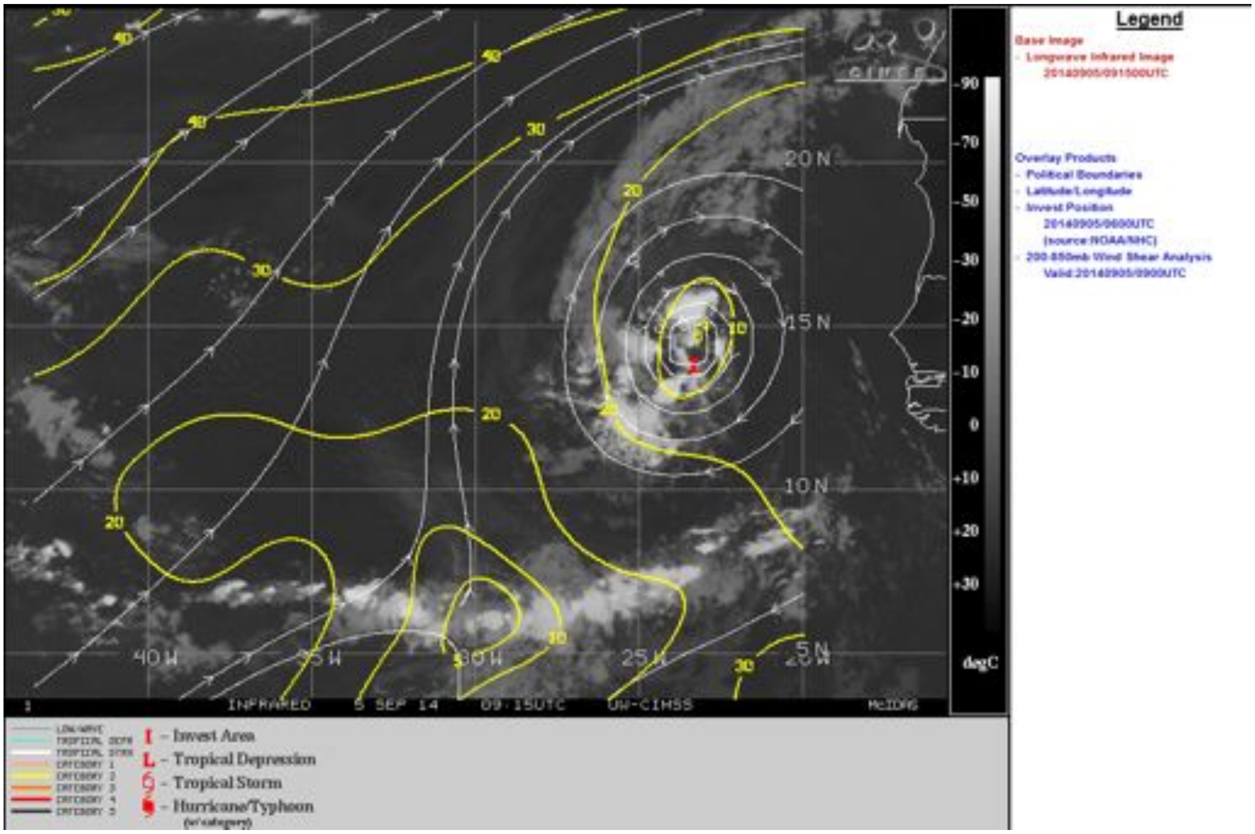


Lower-level satellite winds (AMVs) show the low-level circulation around 90L.

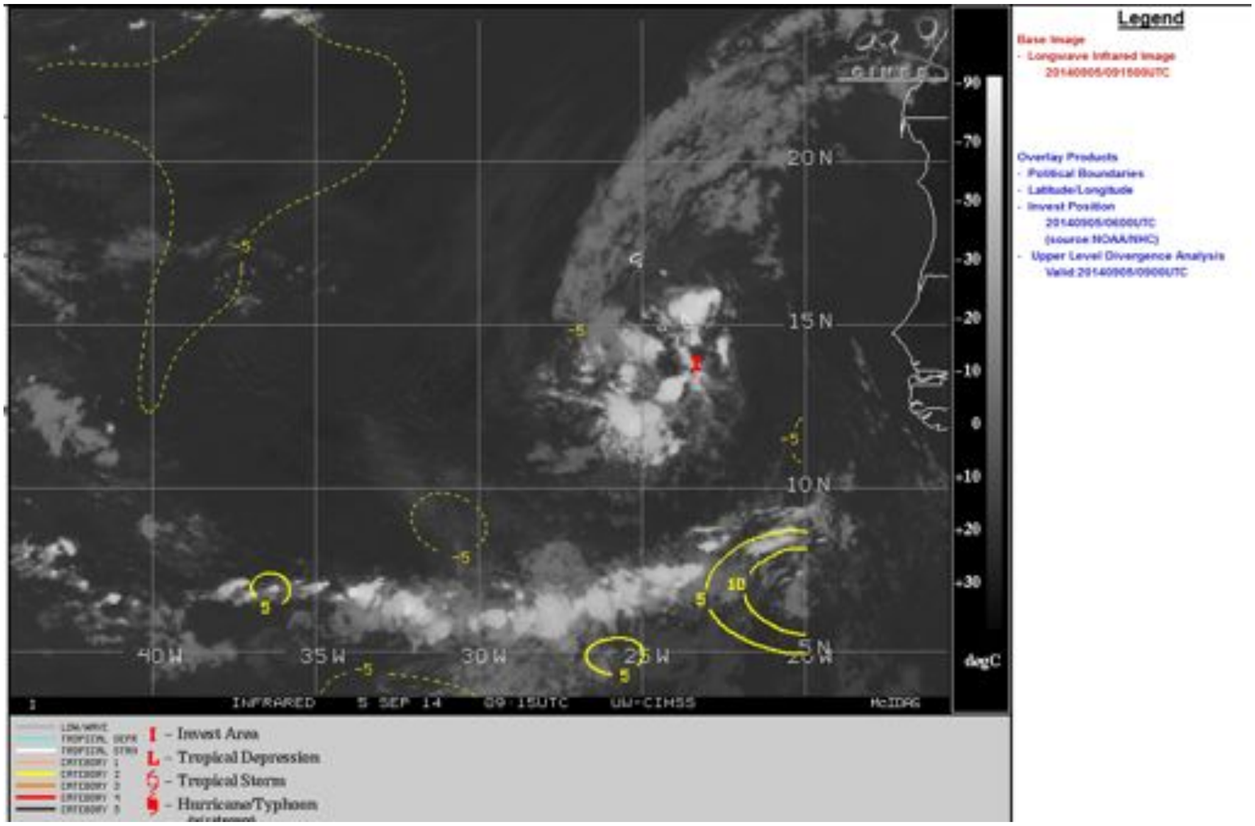

INFRARED 5 SEP 14 09:15UTC UW-CIMSS
20N
15N
10N
40W
35W
30W
25W
-90
-70
-50
-30
-20
-10
0
+10
+20
+30
degC
I - Invest Area
L - Tropical Depression
Tropical Storm
Hurricane/Typhoon
(w/ category)
Low to Mid Level Dry Air
Less <--------> More
Legend
Base Image
- Longwave Infrared Image
20140905/091500UTC
Overlay Products
- Political Boundaries
- Latitude/Longitude
- Invest Position
20140905/0600UTC
(source:NOAA/NHC)
- 200-850mb Wind Shear Analysis
Valid:20140905/0900UTC


INFRARED 5 SEP 14 09:45UTC UW-CIMSS
McIDAS
20N
10N
30W
-90
-70
-50
-30
-20
-10
0
+10
+20
+30
degC
I - Invest Area
L - Tropical Depression
Tropical Storm
Hurricane/Typhoon
(w/ category)
Low to Mid Level Dry Air
Less <--------> More
Legend
Base Image
- Longwave Infrared Image
20140905/101500UTC
Overlay Products
- Political Boundaries
- Latitude/Longitude
- Invest Position
20140905/0600UTC
(source:NOAA/NHC)
- Upper Level Divergence Analysis
Valid:20140905/0900UTC
- 850mb Vorticity
Valid:20140905/0900UTC

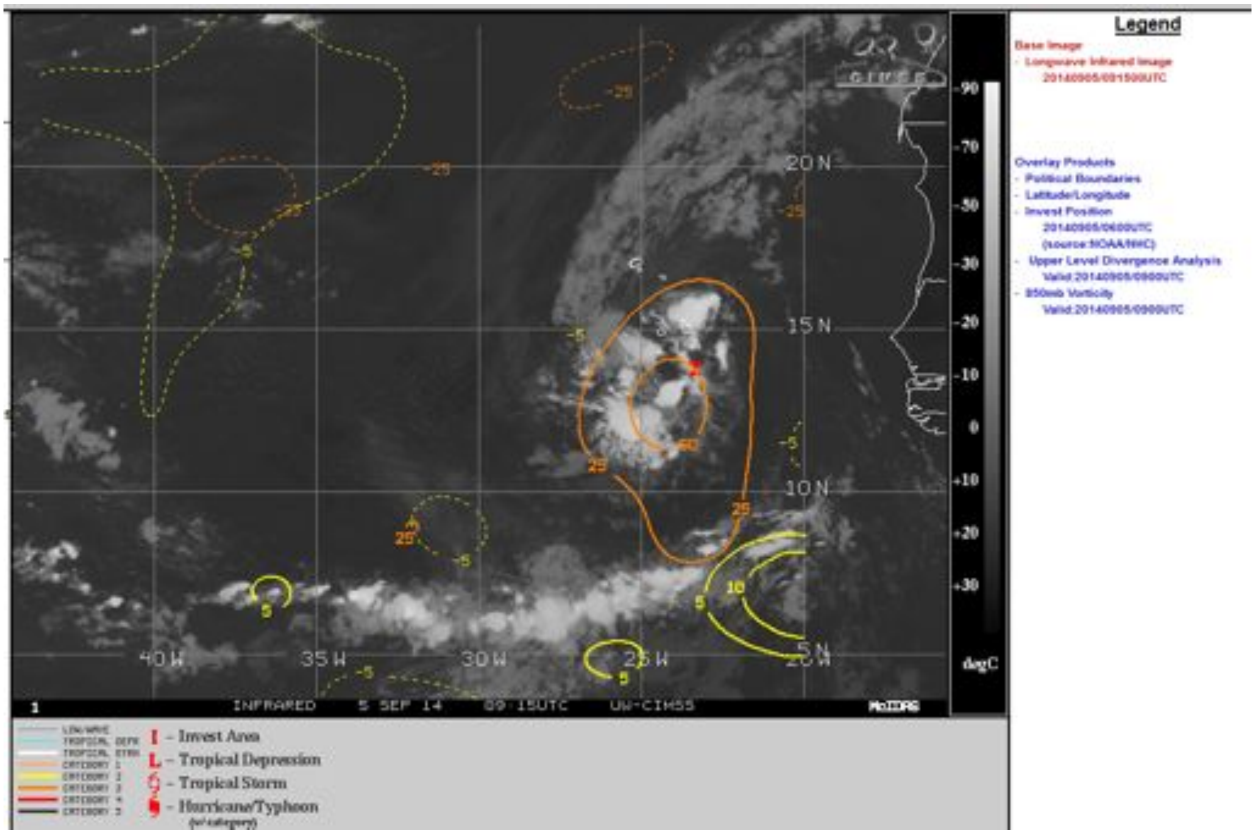
Dry air is evident along the west side of 90L.



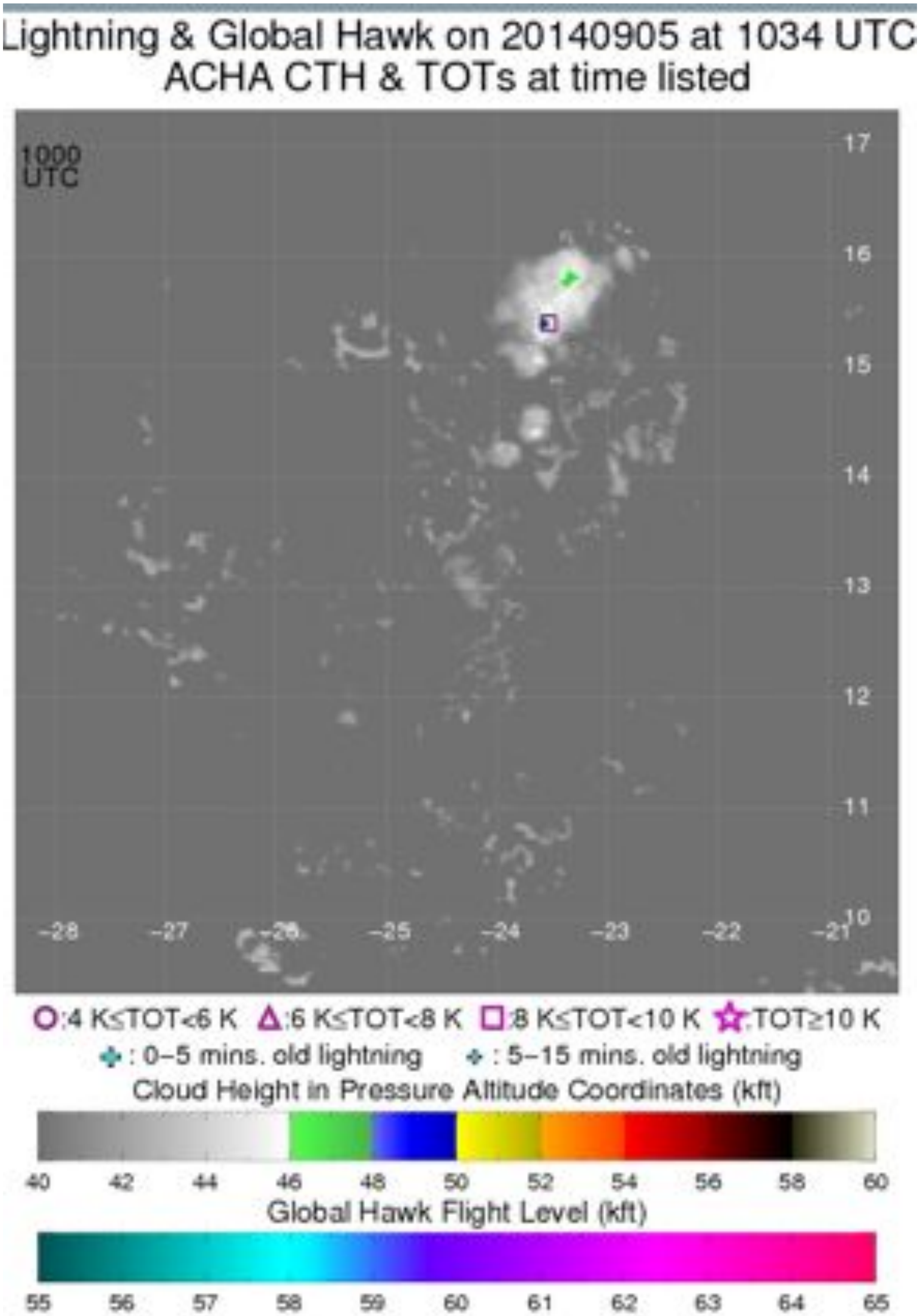
Shear product from CIMSS shows 90L should move into an area with greater shear during the flight.



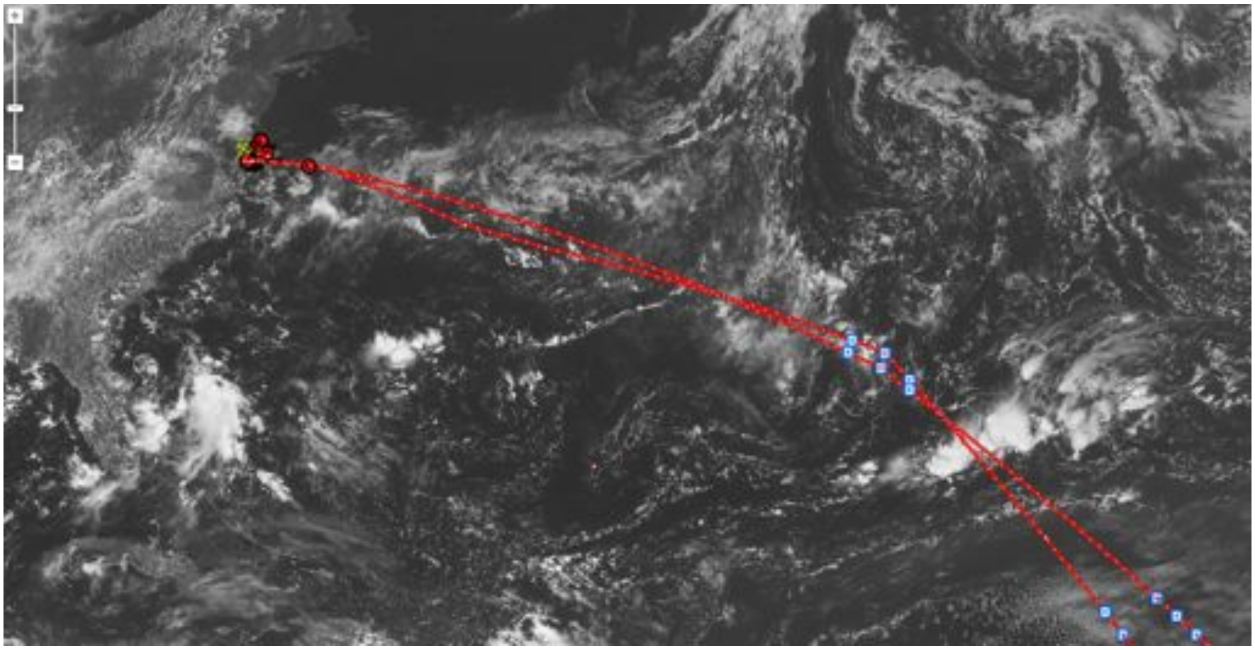
Upper-level divergence does not show especially favorable conditions aloft for development.

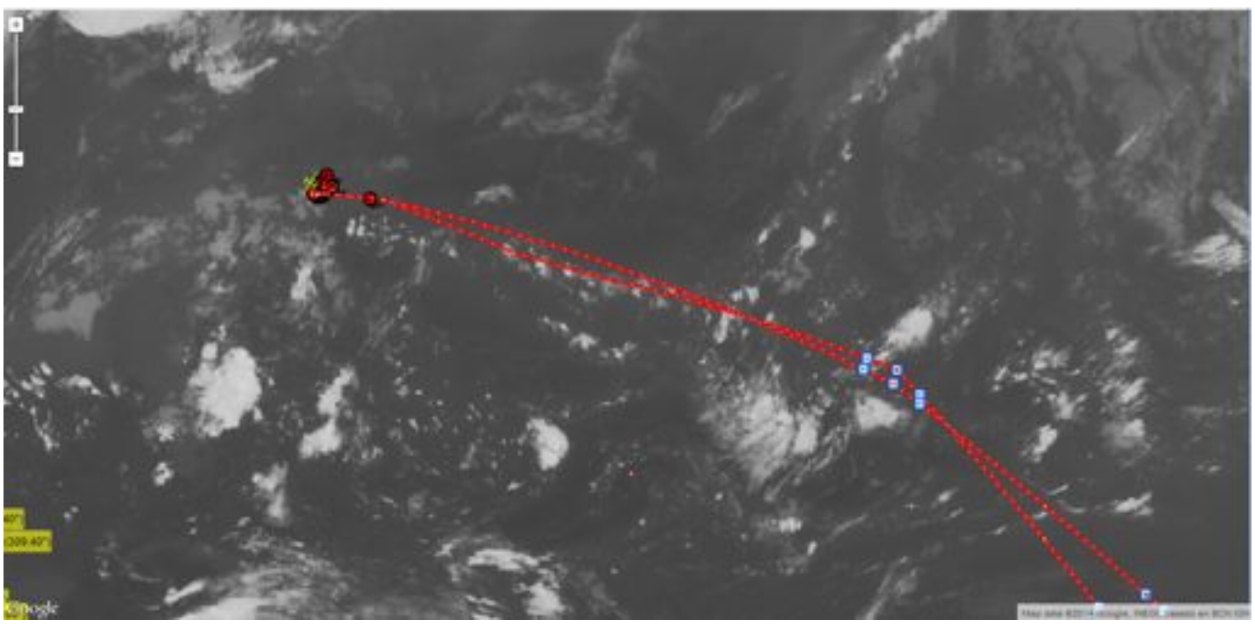


Vorticty product from CIMSS.

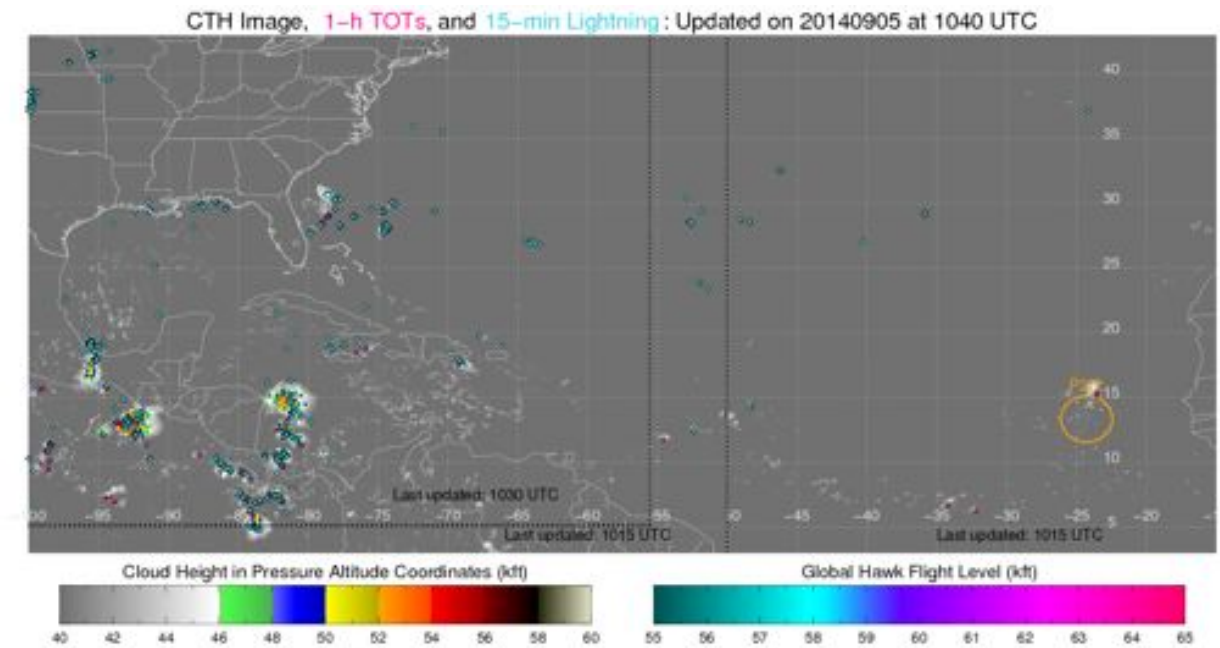


Overshooting cloud top and lightnight product shows 90L is going through a cycle that is not as active.

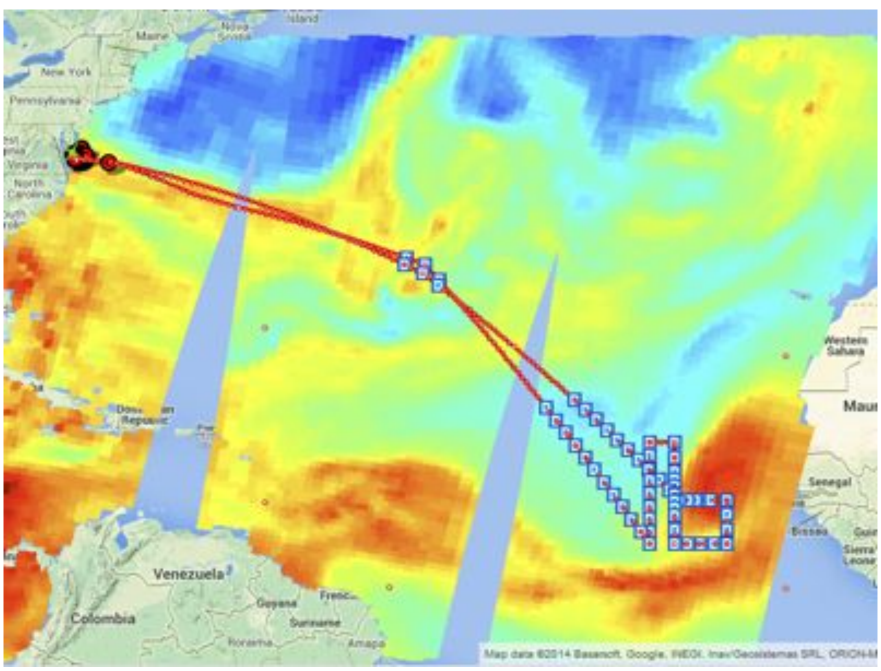




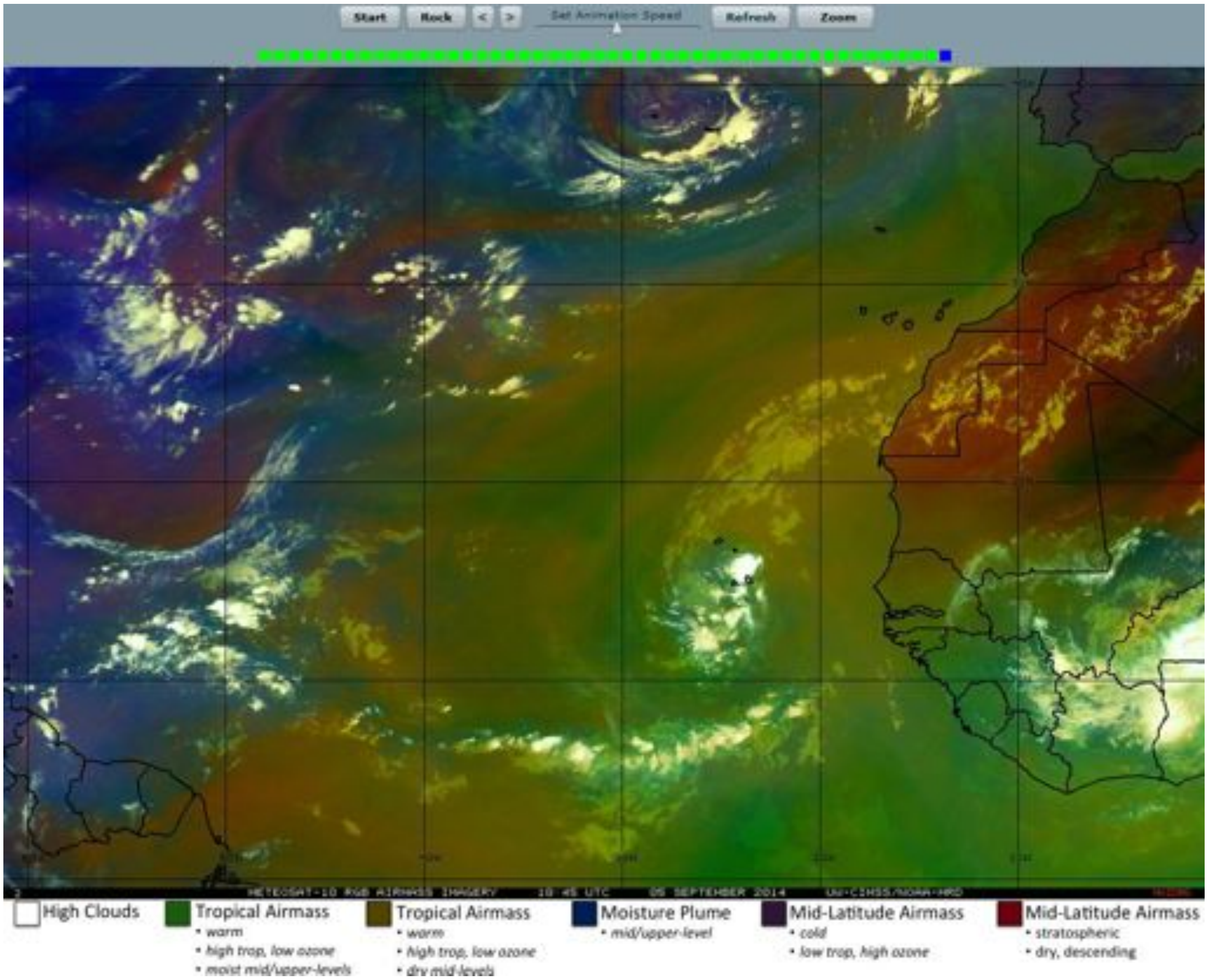
Goes visible and IR showing first part of ferry including the mid-Atlantic system. 3 drops are planned into the mid-Atlantic system.



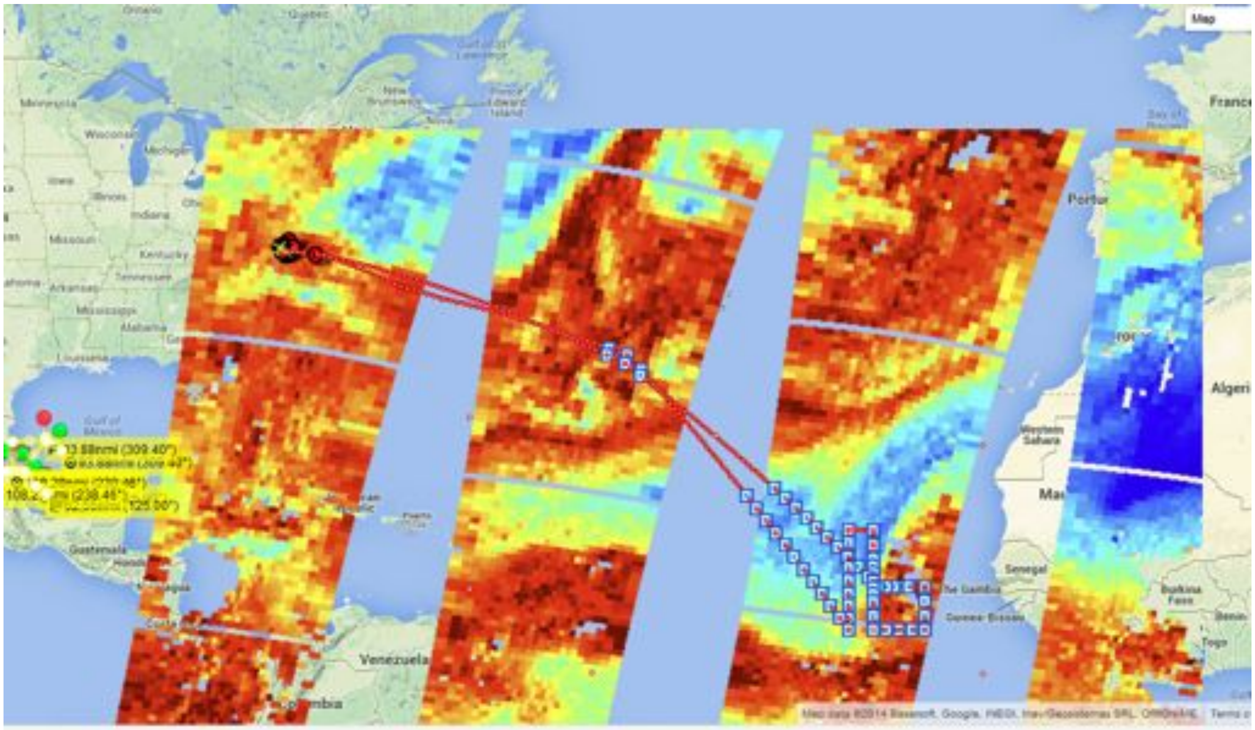
Full Atlantic view of the cloud top heights and and lightning at 1040UTC on 5 September.



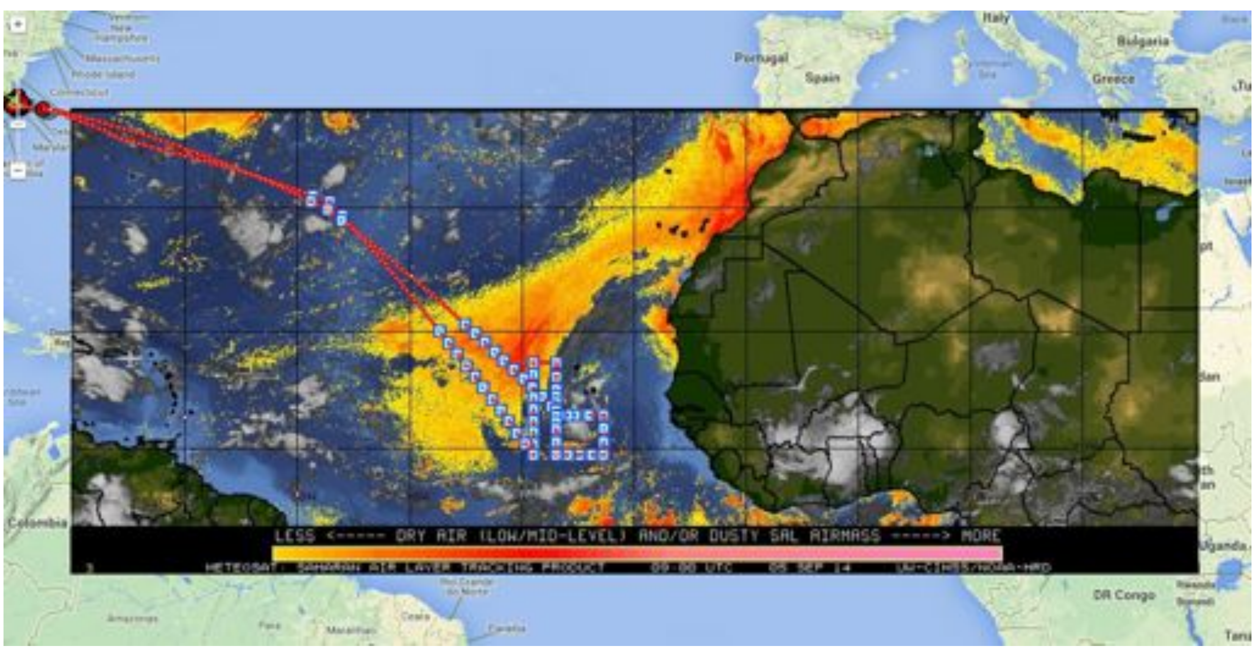
TPW product with the planned flight track overlayed.



Meteosat-10 image of Atlantic and 90L, valid 1045 UTC.

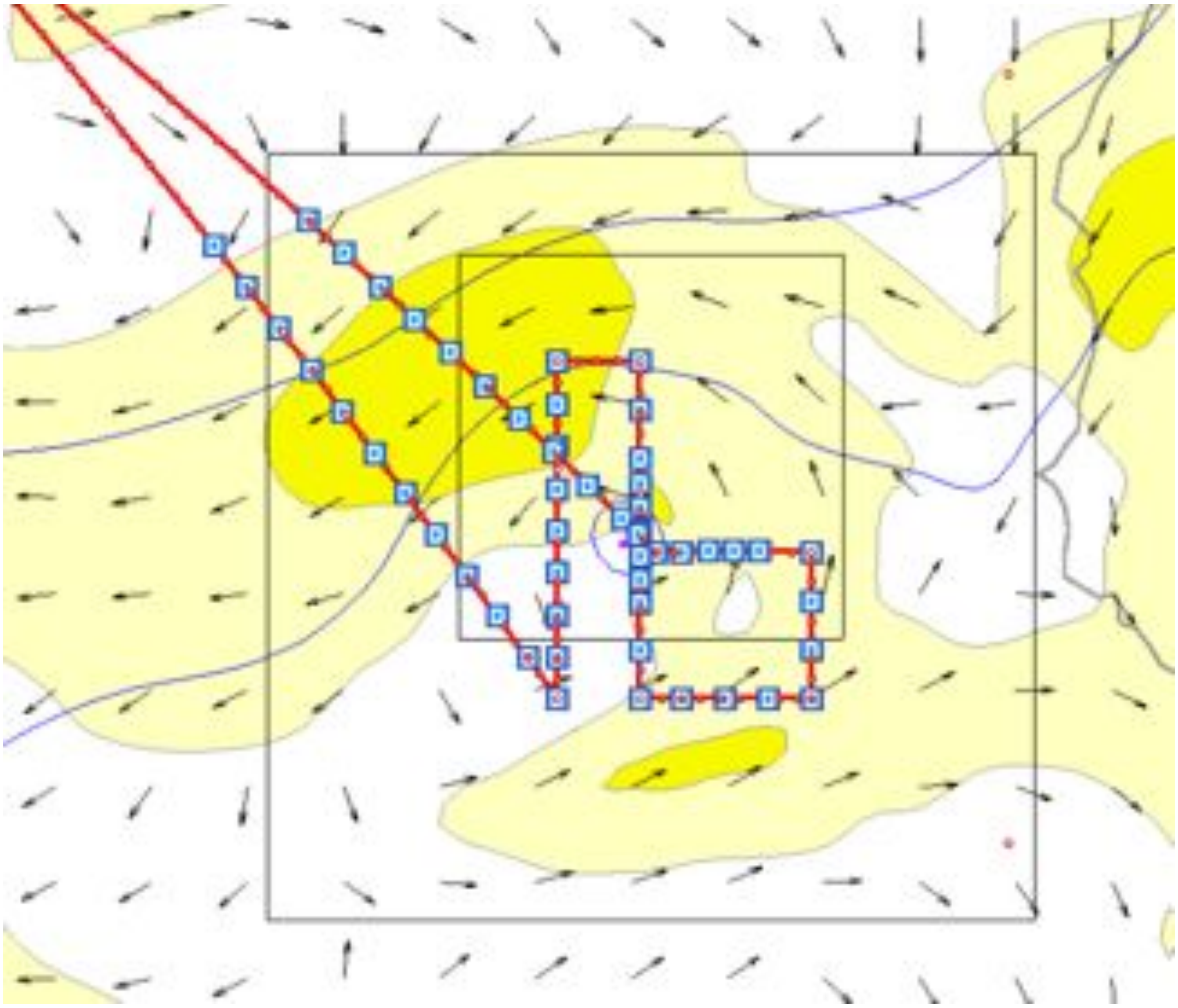


AIRS RH 850-mb product.

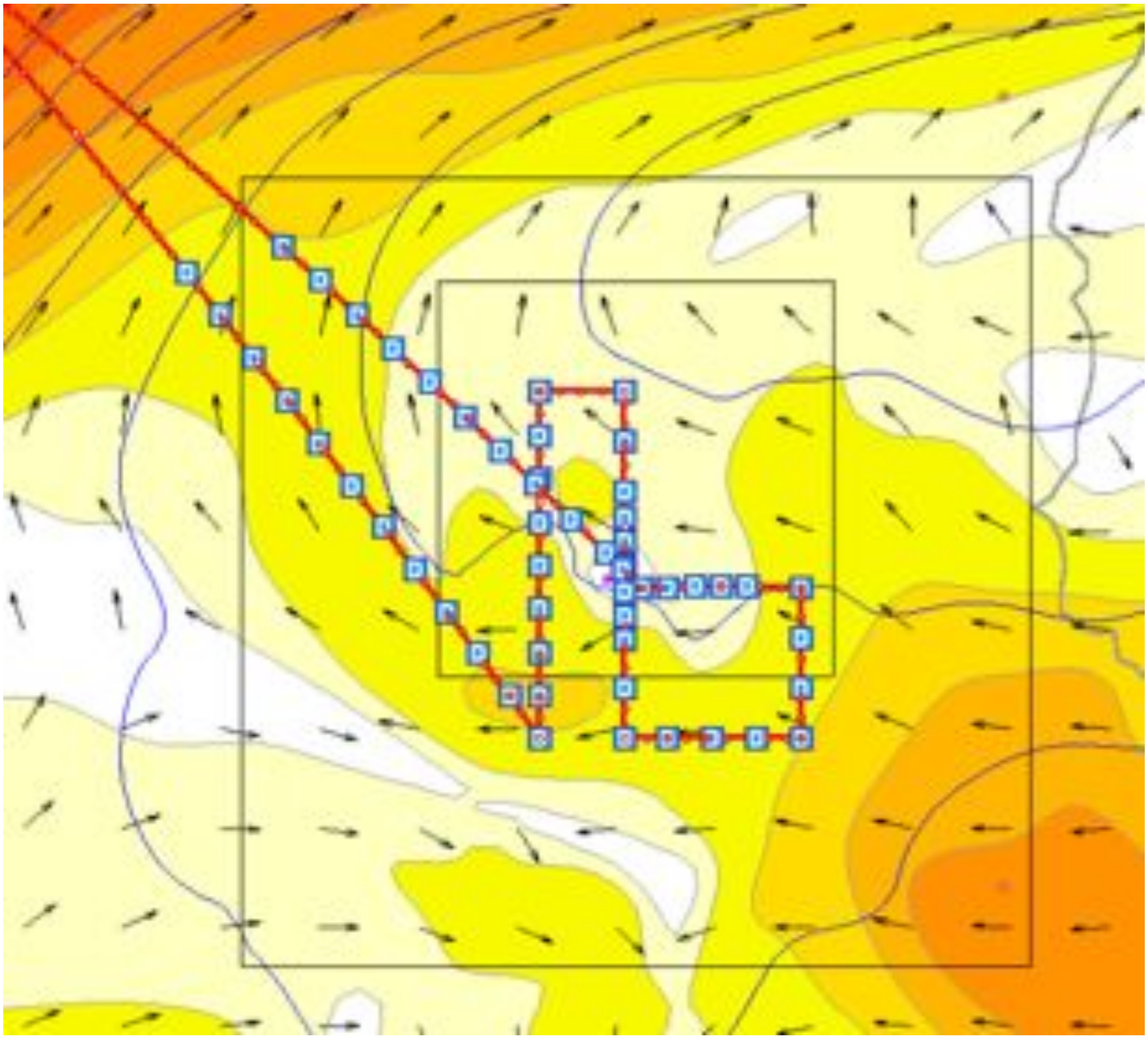


Dry air product 0900 UTC showing SAL.

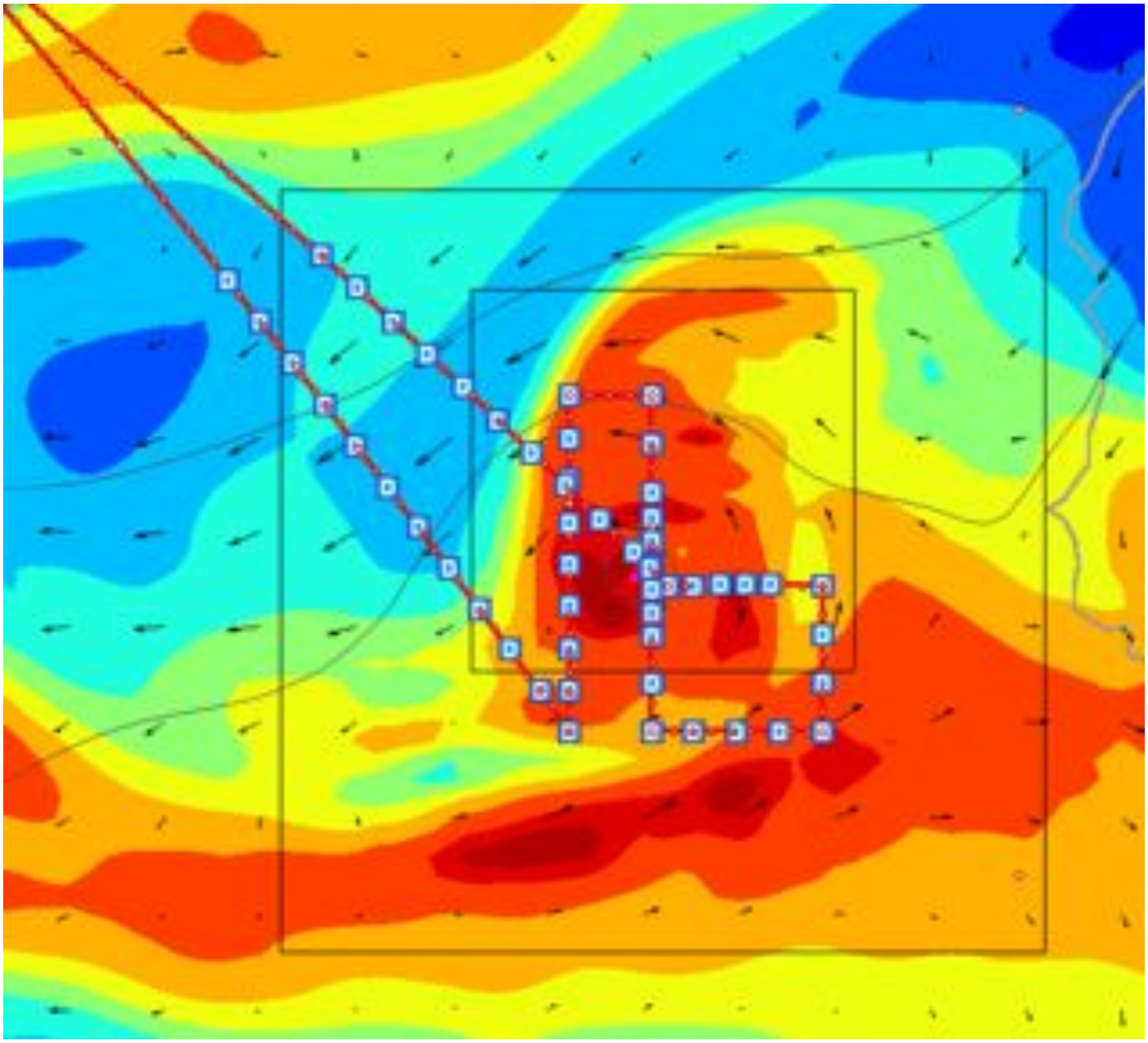
Shallow cumulus from AV6 camera.



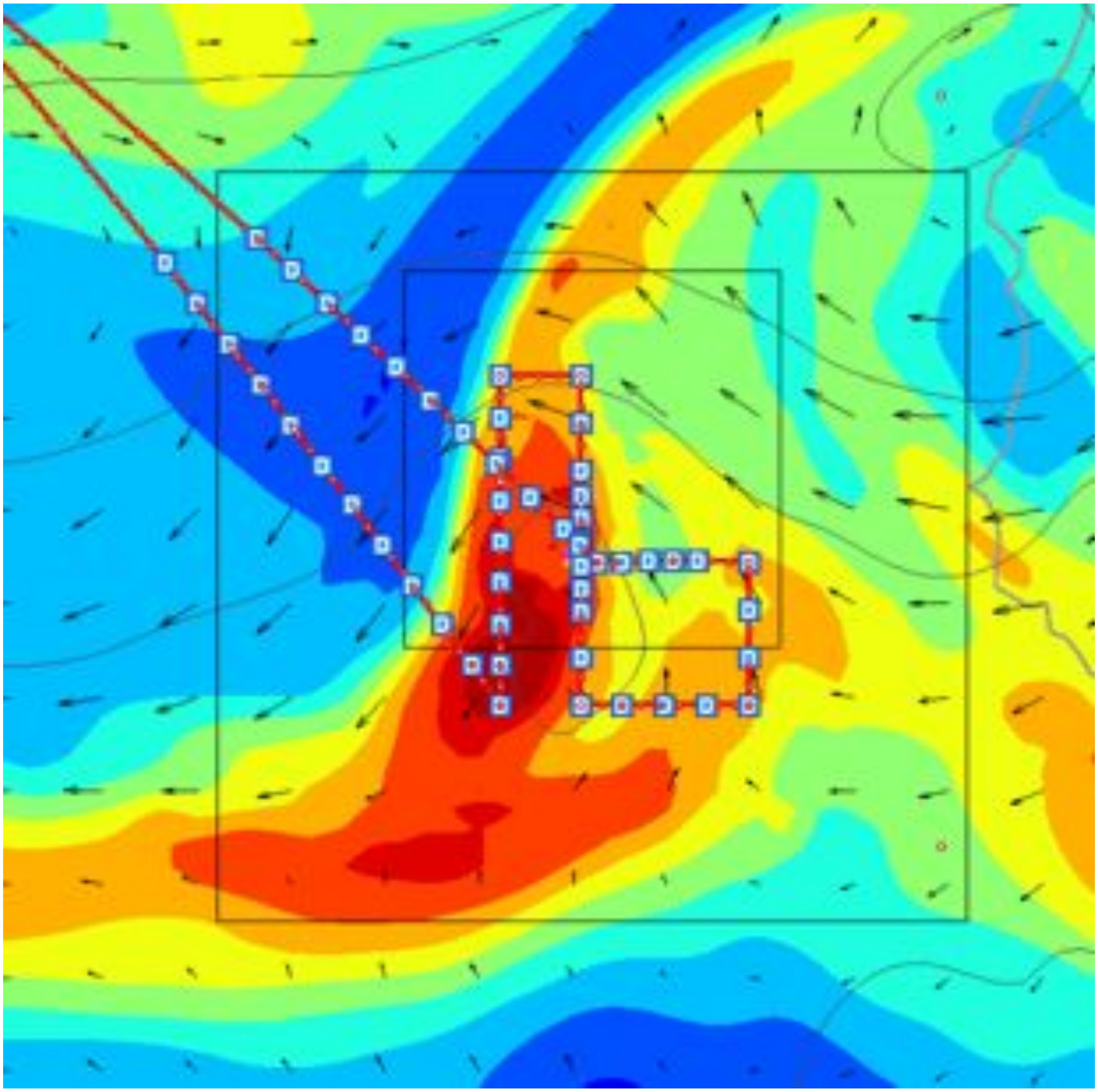
COAMPS-TC forecast of 850 mb wind speed (color contours every 5 m/s), wind direction, and geopotential height (contours every 20 m) valid at 06/00z with planned flight track overlay. 18h forecast from 05/06z. Broad circulation.



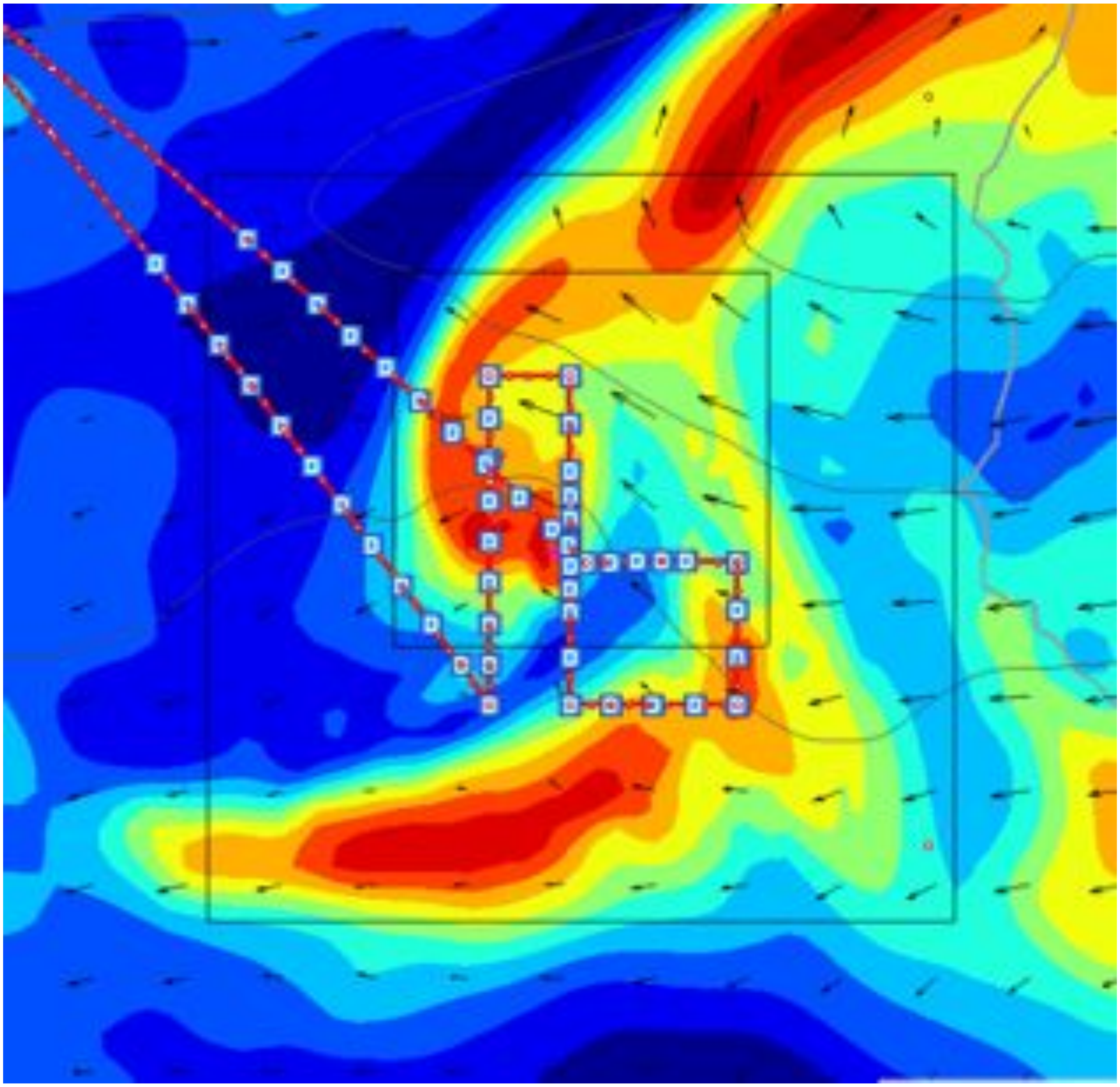
COAMPS-TC forecast of 200 mb wind speed (color contours every 5 m/s), wind direction, and geopotential height (contours every 20 m) valid at 06/00z with planned flight track overlay. 18h forecast from 05/06z. Broad circulation.



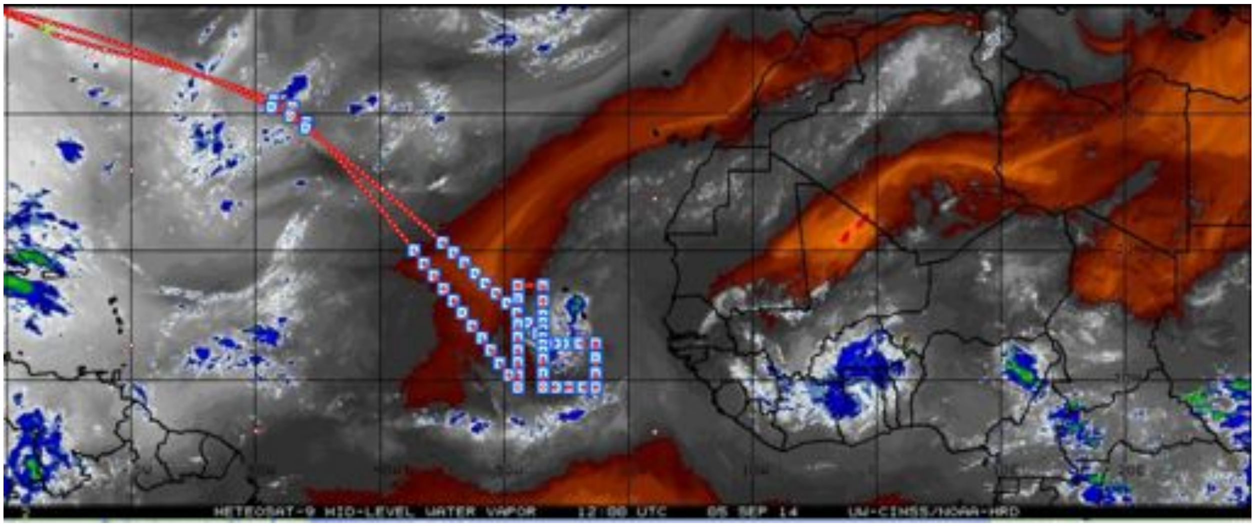
COAMPS-TC forecast of 850 mb wind (vectors), geopotential height (contours every 20 m) and relative humidity valid at 06/00z with planned flight track overlay. 18h forecast from 05/06z.



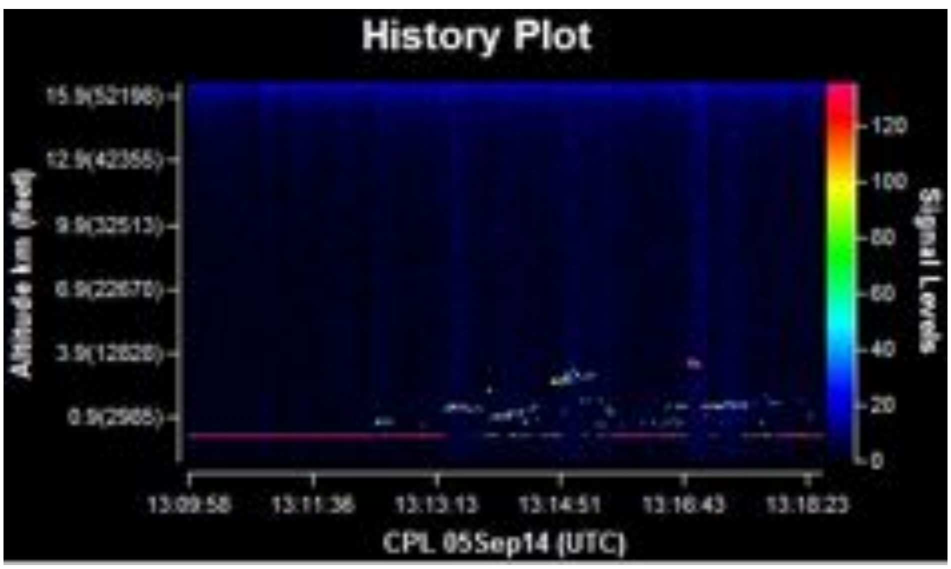
COAMPS-TC forecast of 700 mb wind (vectors), geopotential height (contours every 20 m) and relative humidity valid at 06/00z with planned flight track overlay. 18h forecast from 05/06z.



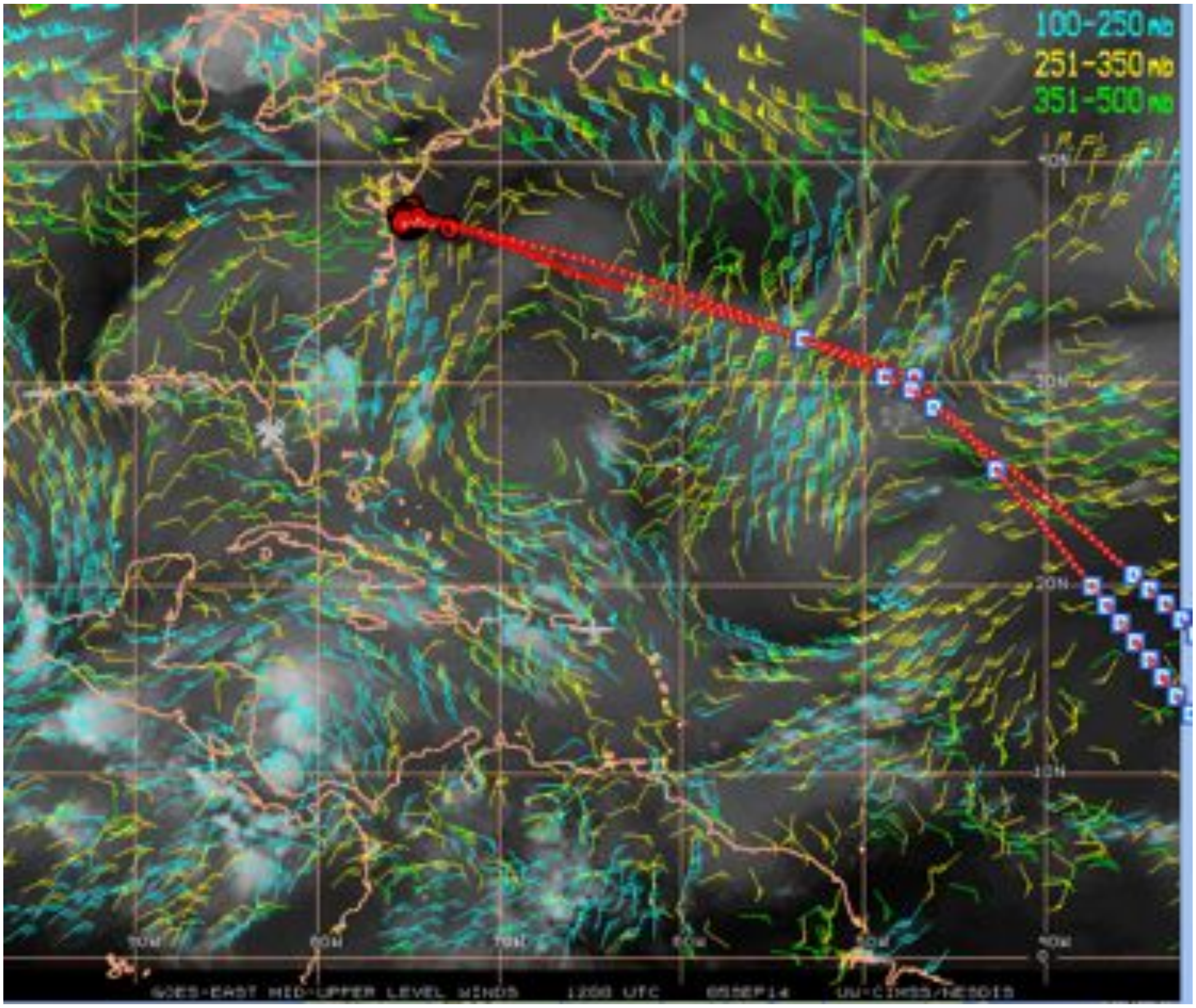
COAMPS-TC forecast of 500 mb wind (vectors), geopotential height (contours every 20 m) and relative humidity valid at 06/00z with planned flight track overlay. 18h forecast from 05/06z.



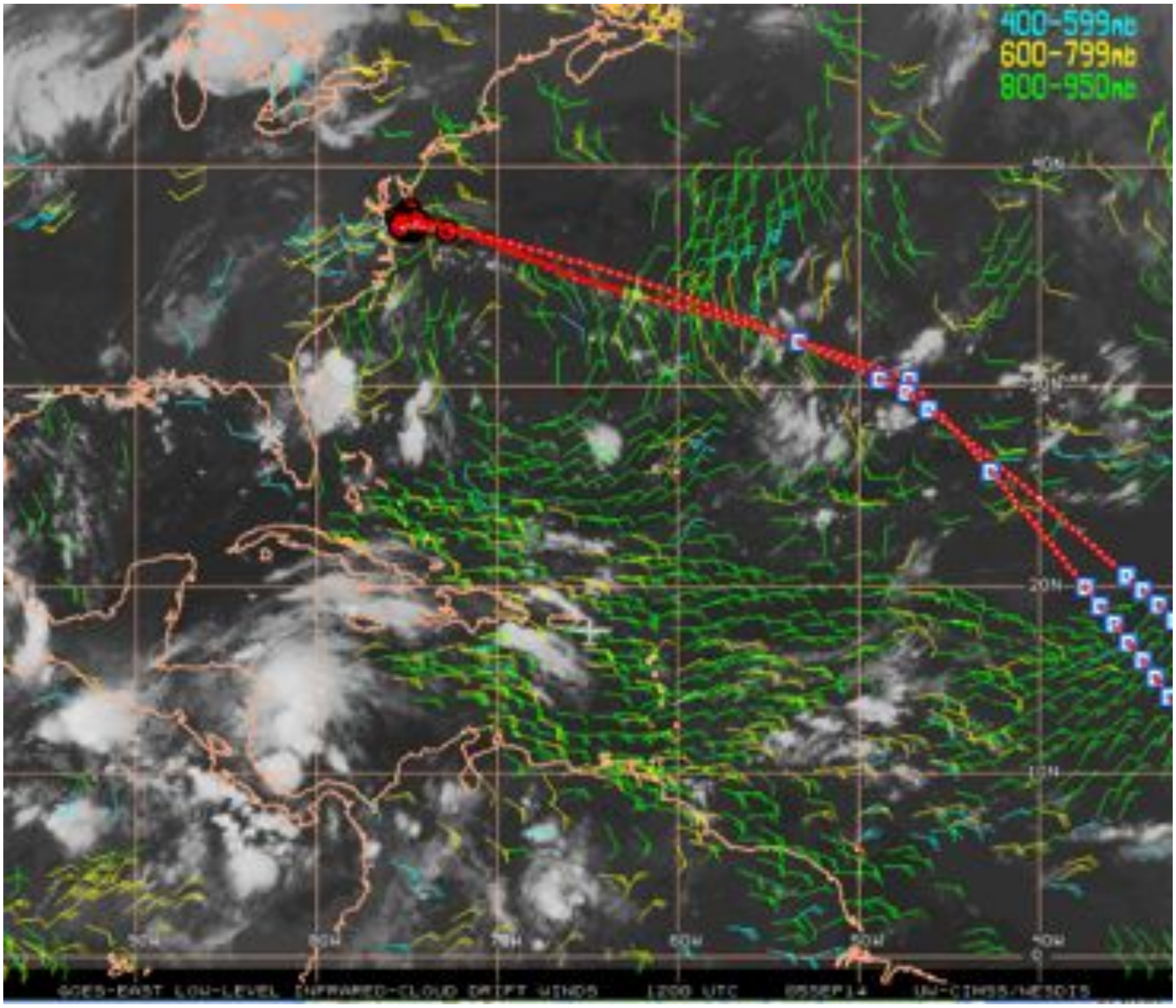
SAL mid-level water vapor product valid at 12UTC showing dry SAL air to the west of 90L.



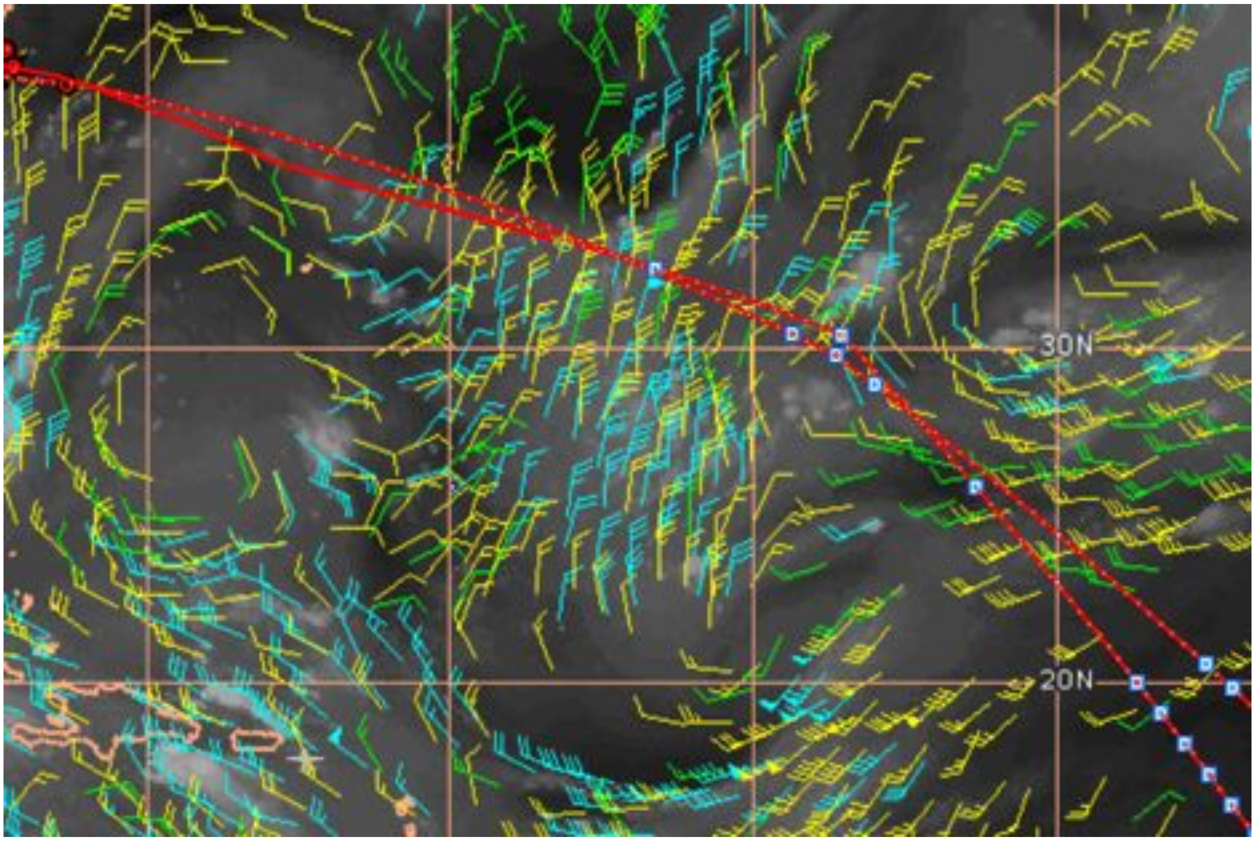
CPL quick look from 1324 UTC.



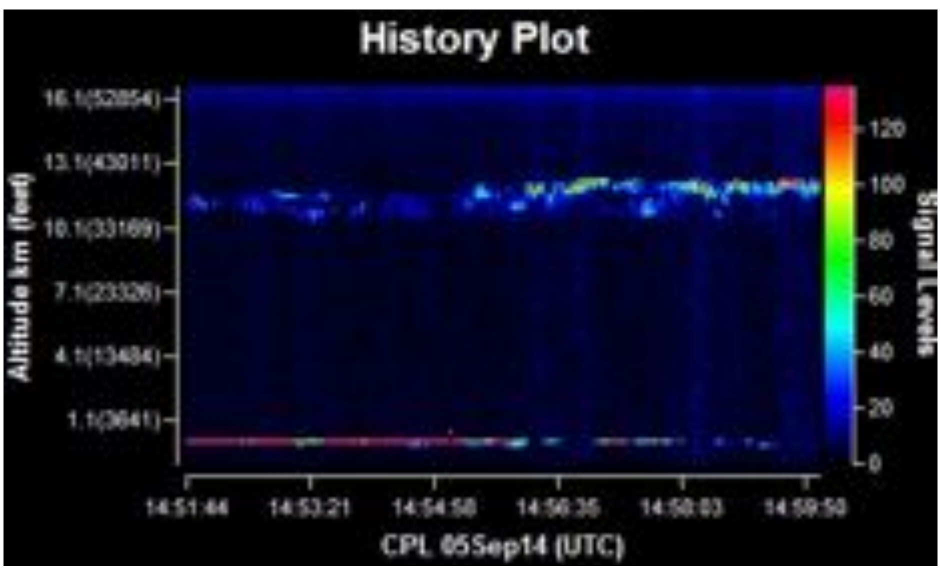
Mid-Upper level AMVs valid at 1200 UTC.



Low-level AMVs valid at 1200 UTC.

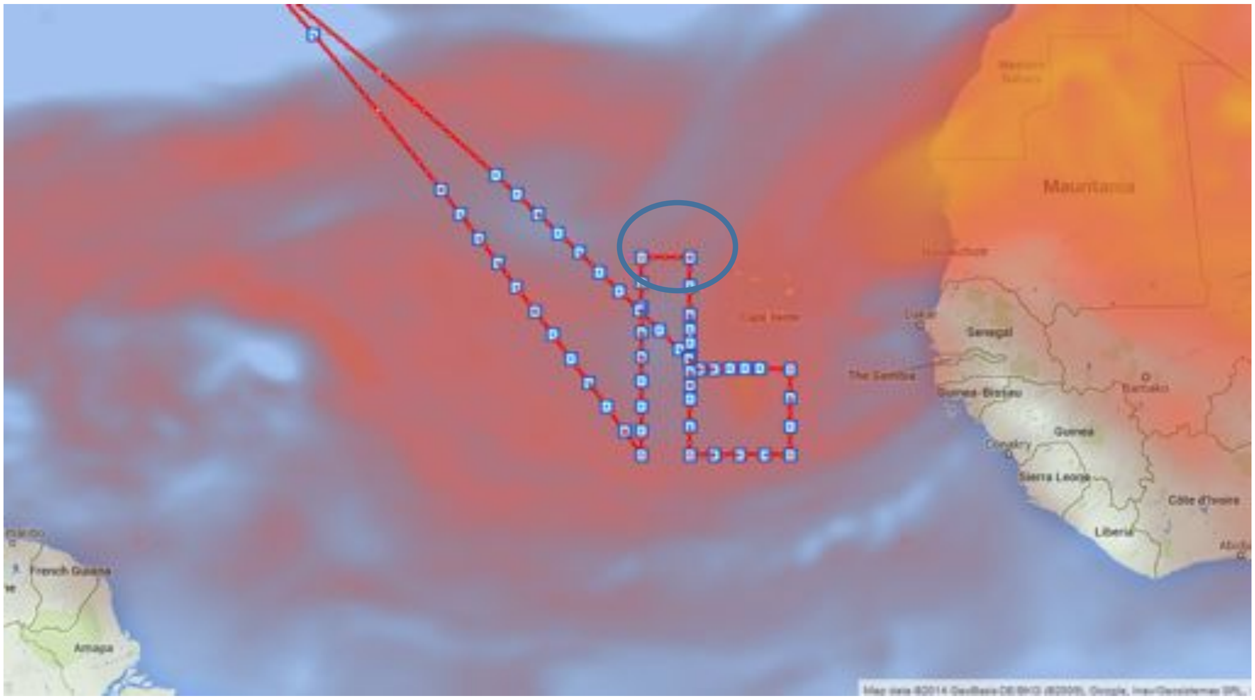


Mid-upper level AMVs at 1200 UTC 5 Sep – zoomed in over mid-level trough.



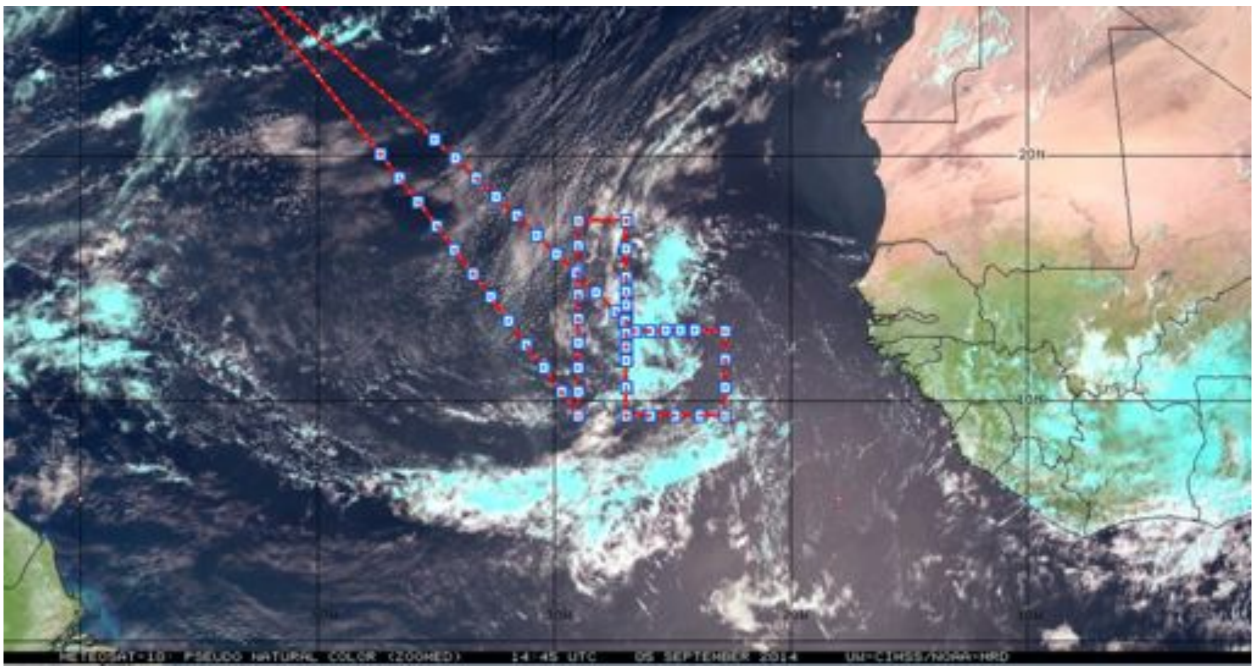
CPL valid at 1500UTC 5 September.

First dropsonde out at 1509 UTC 5 September (good launch, good data).



Planned flight track overlayed on the GOES-5 Dust Extinction AOT (550 Nm) valid at 23Z 5 September. Discussion of possibly extending legs in blue circle by 60 nm and shortening the legs in the SE box at the eastern end. Flight planning is underway to assess modification.

Daylight camera valid at 1517 UTC showing upper- and mid-level cloud layers.



MeteoSAT-10 Pseudo Natural Color image valid at 1445 UTC showing larger-scale structure of 90L.

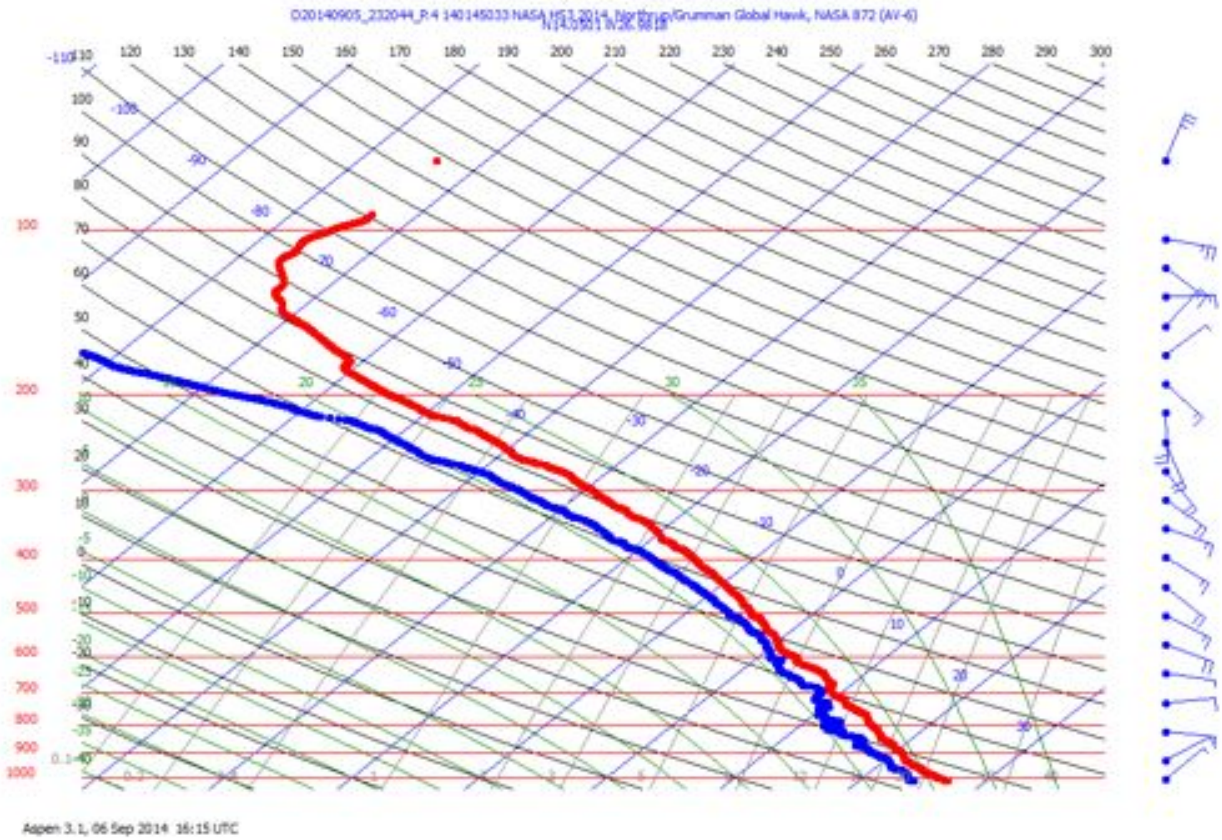
Drop released 1844 UTC

Drop released 1915 UTC

Drop released 1929 UTC

2300 UTC:

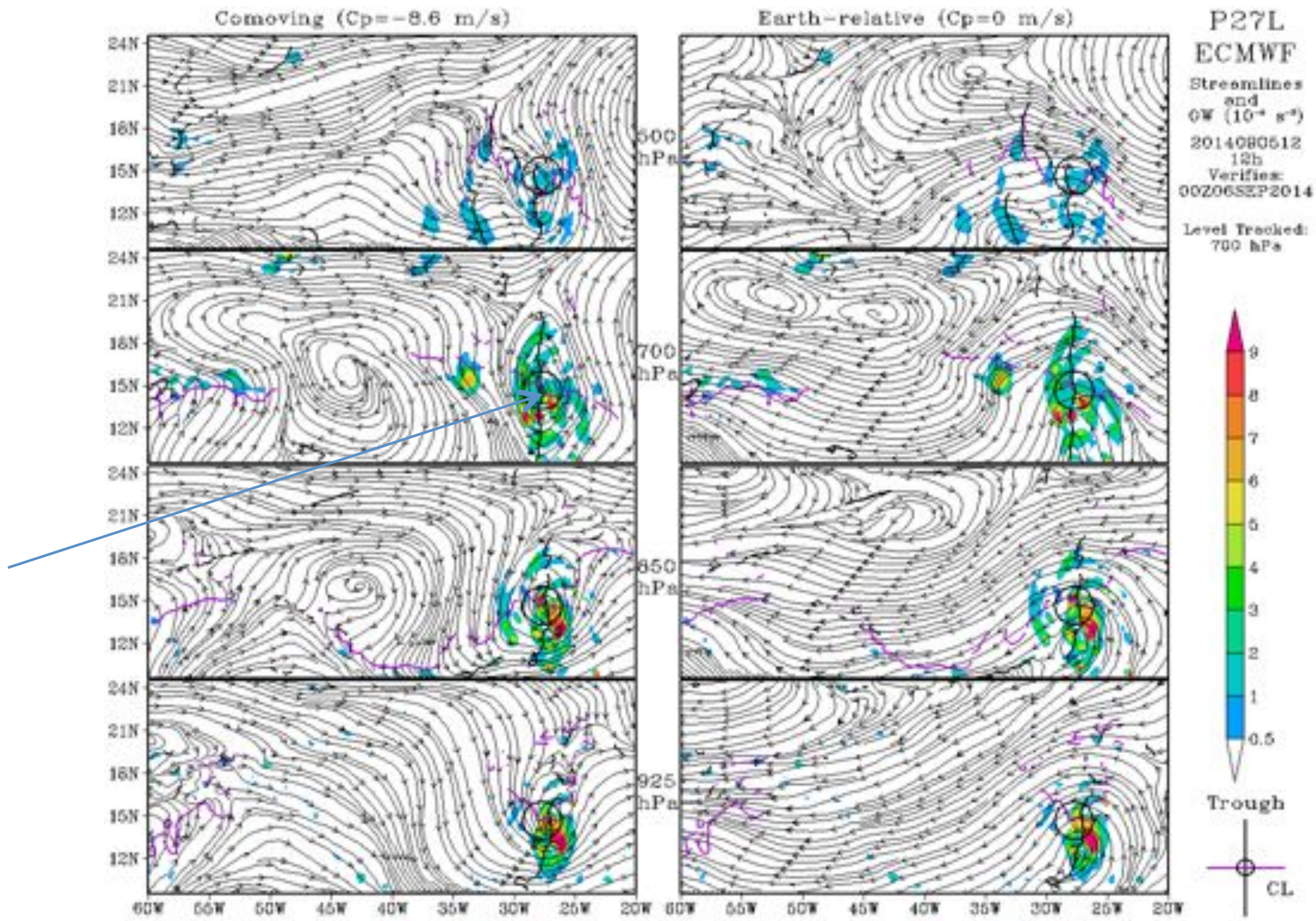
Plane now heading due south along Lon = -27 and within pouch. Shown is an example drop within the pouch at 2320 Z 05 Sept (Drop # 28: Lon = -27 Lat = 14.05) and near the sweet spot. Nearly moist adiabatic up to approx. 400 hPa with only slight dry layer evident around 800 hPa. Some deep convection to 55 kft was evident in overshooting top products around this time (as would be expected for such a sounding), but of course this moist air could be the result of moistening by prior convectve episodes earlier today or yesterday.



To obtain further understanding of the significant of this sounding, see pouch products below from Montgomery Research Group showing. The eight-panel images show the location of this sounding (with blue arrow from left) near this time using ECMWF forecast (progged 12 h from 12 Z 05 Sept). Plotted here in (a) is OW (with cyclonic vorticity shown above threshold); co-moving & earth-relative streamlines; together with sweet spot position (center of circle) at the 700 hPa tracking level for this case. Plotted in (b) is the 12 h forecast relative humidity (in %) with co-moving and earth-relative streamlines as in (a).

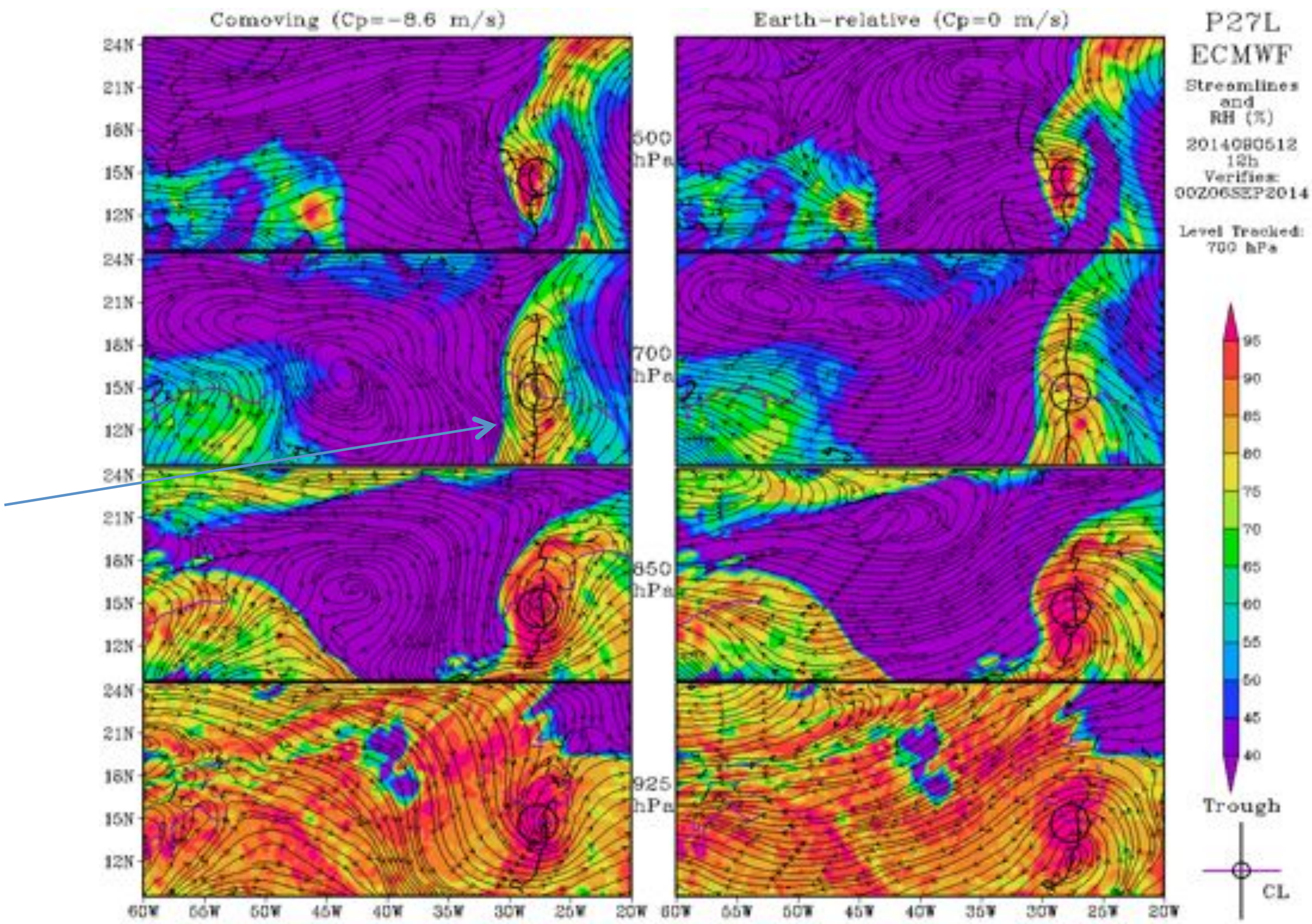
Moist and very dry air in close jusxtaposition confirmed by the pouch theory.

(a)

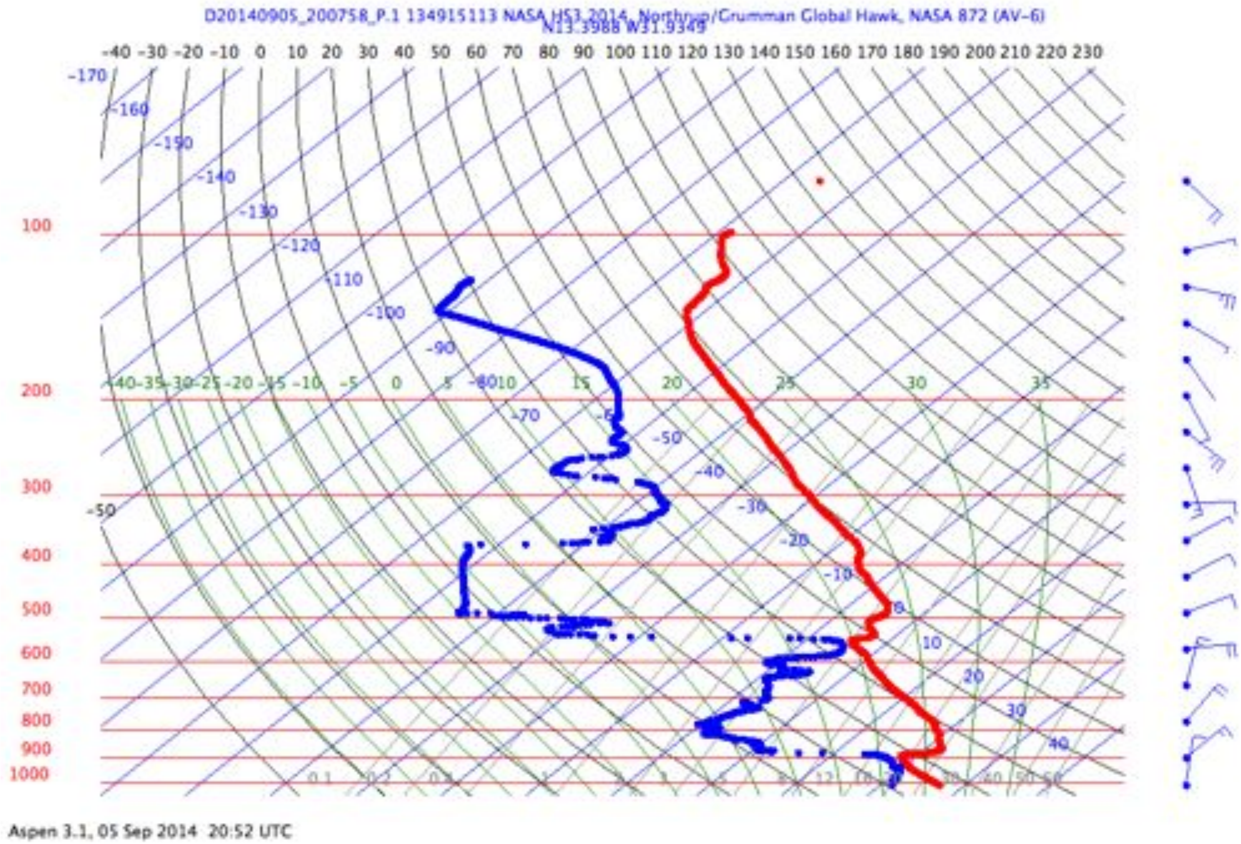


ECMWF Okubo-Weiss OW parameter (only positive regions with cyclonic vorticity above a small threshold are shown in color) overlaid on the co-moving & earth-relative streamlines at the respective pressure levels. Indicated also is the sweet spot position (center of circle) at the 700 hPa tracking level for P27 (Invest 90L). The latitude and longitude position of Drop#28 is indicated with arrow from left.

(b)



ECMWF 12 h forecast relative humidity (in %) with co-moving and earth-relative streamlines. Arrow indicates the lat and lon location of a very different-looking Drop 12 shown below. The model forecast suggests that this drop is just on the outside of the Lagrangian fluid boundary, which is approximately parallel to the curve of maximum tracer gradient (interpreted using RH outside of the pouch). (see Rutherford and Montgomery 2012, Atmos. Chem. Phys. for two other examples from the PREDICT experiment.)

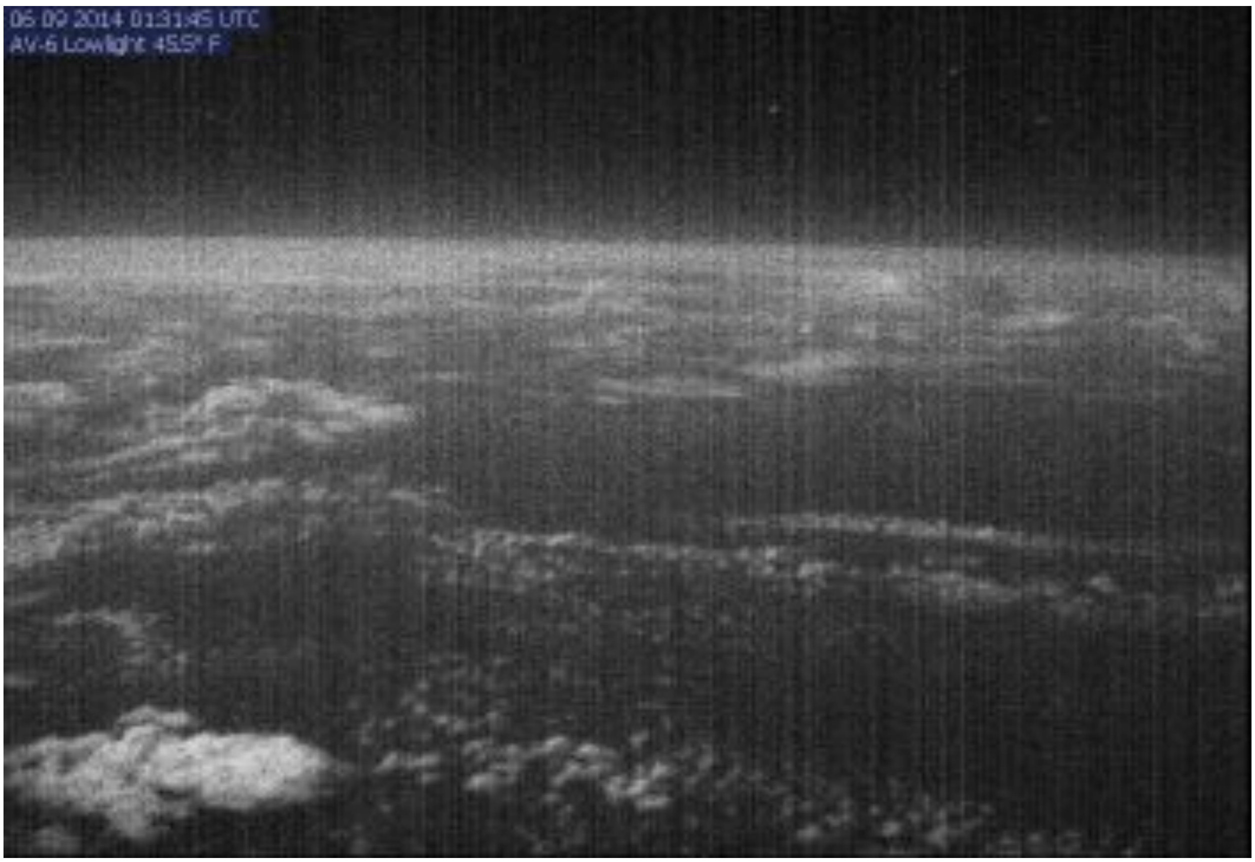


Drop #12: Lon = -31, Lat = 12.43. This sonde is just to the left of the Lagrangian pouch boundary indicated in the 700 hPa and 500 hPa RH fields. When the flow is time dependent even in the co-moving frame, the co-moving streamlines only approximately indicate the layerwise boundaries in the flow. As more accurate estimate of the intrinsic flow boundaries is revealed by the curves of maximum RH gradient.

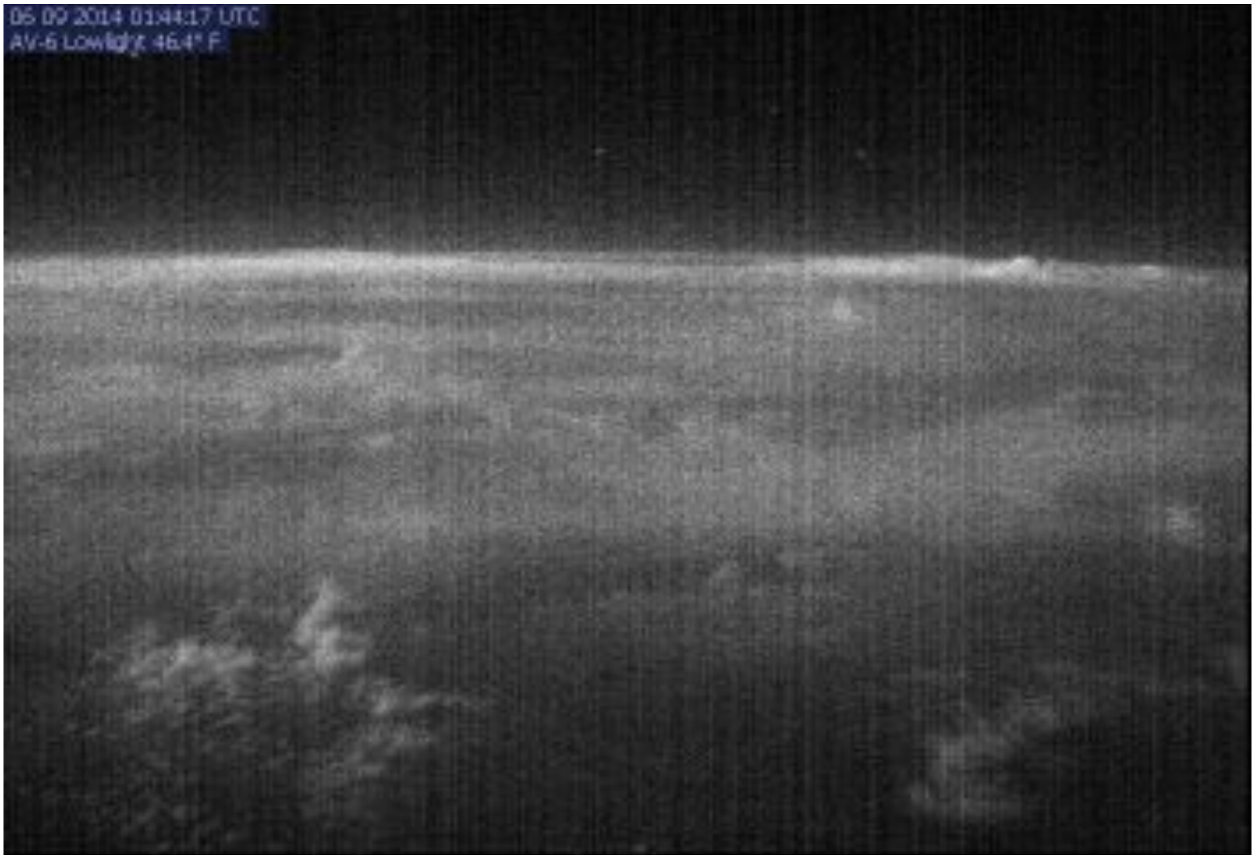
Outside and approaching the pouch boundary from the west, this gradient of RH behaves approximately like a model tracer where convection is largely absent at these levels. In comparison to drop 28 shown above, this figure shows a dramatic change in both vertical profiles of temperature and dew point temperature. In particular, there is a relatively strong inversion at 900 hpa level; a fairly strong dew point depression is evident between 600 hPa and 900 hPa, capped by nearly saturated air at approx. 550 hPa. (One school of argument would suggest that this latter feature is a signature of SAL air at this level and below.) A second inversion is evident between 550 hPa and 500 hPa, with a very strong dew point depression between 500 hPa and 300 hPa.

The moral os the story is clear: The observed close juxtaposition of very moist and dry air below 600 hPa level is confirmed by the pouch theory and related model forecasts. From this observation, along with others like it that originate outside the pouch boundary (not shown), from a moist thermodynamics perspective the exterior air is very unfavorable for initiating and sustaining deep to moderate convection. Deep and moderate convection is needed to converge absolute vorticity substance and counteract the detrimental effect of surface friction that always acts at this early stage to spin the system down (Raymond et al. 1998).

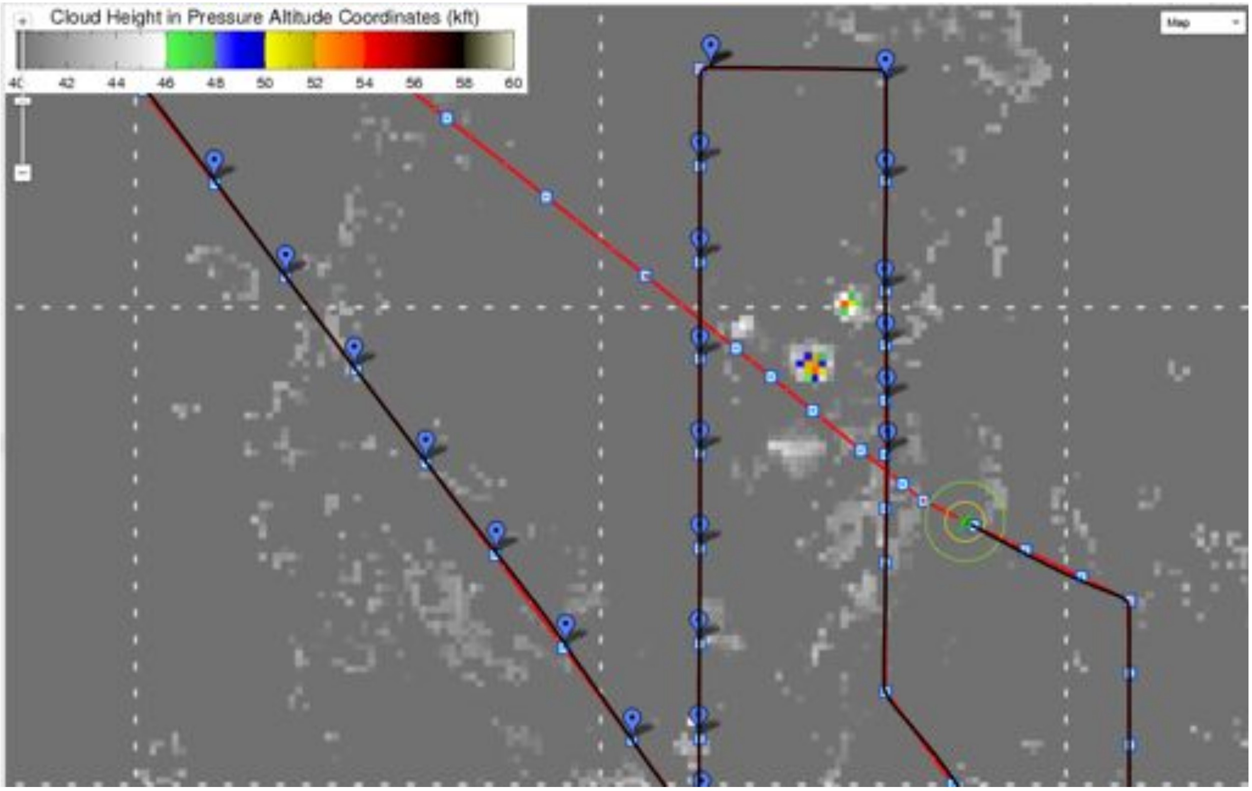
Whether the moisture shown in the observations above can be contained in the face of Lagrangian mixing between the pouch and vertical shear (not considered here) is one of the 64,000 dollar questions going forward into tomorrow and the day after when we migfht be able to fly this system again.



AV6 low-light camera heading back northwest toward center of pouch



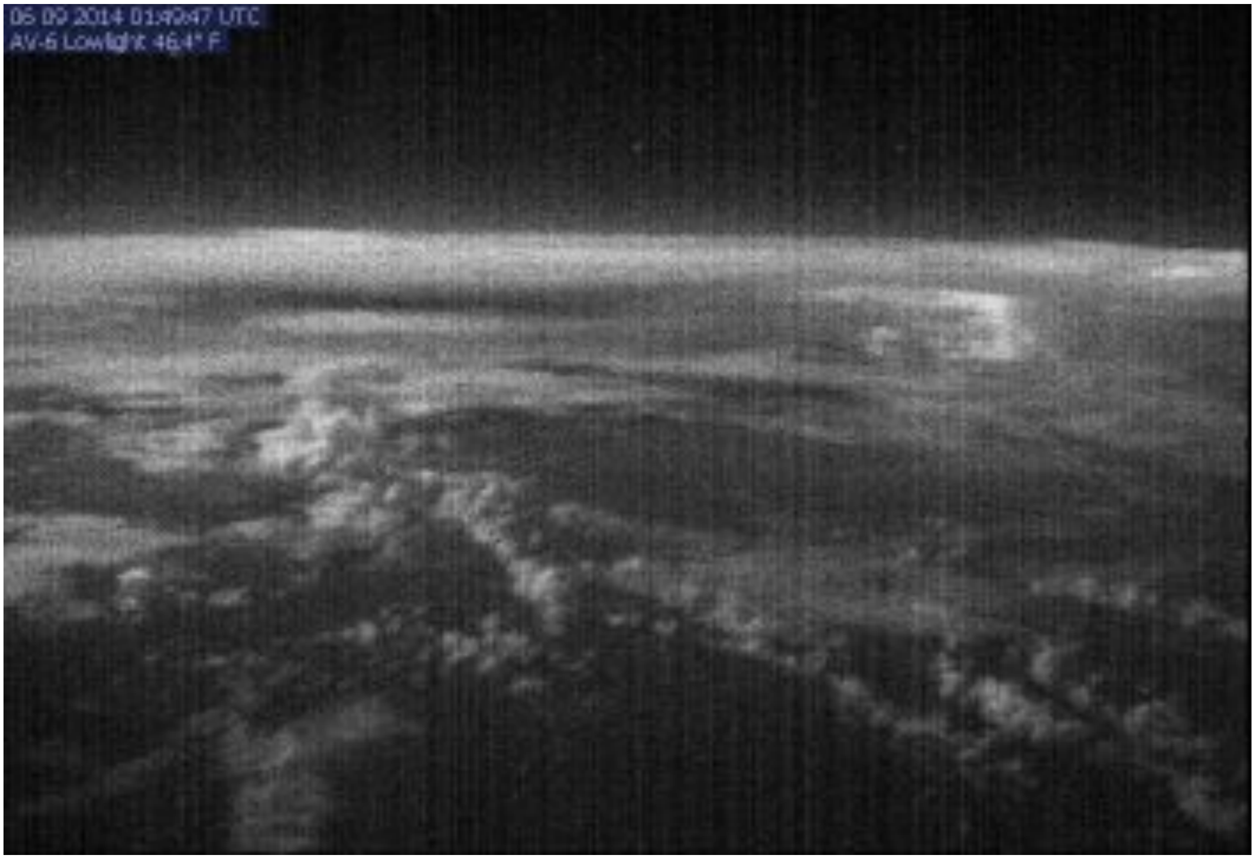
Coming up on some cells near the center of the pouch.

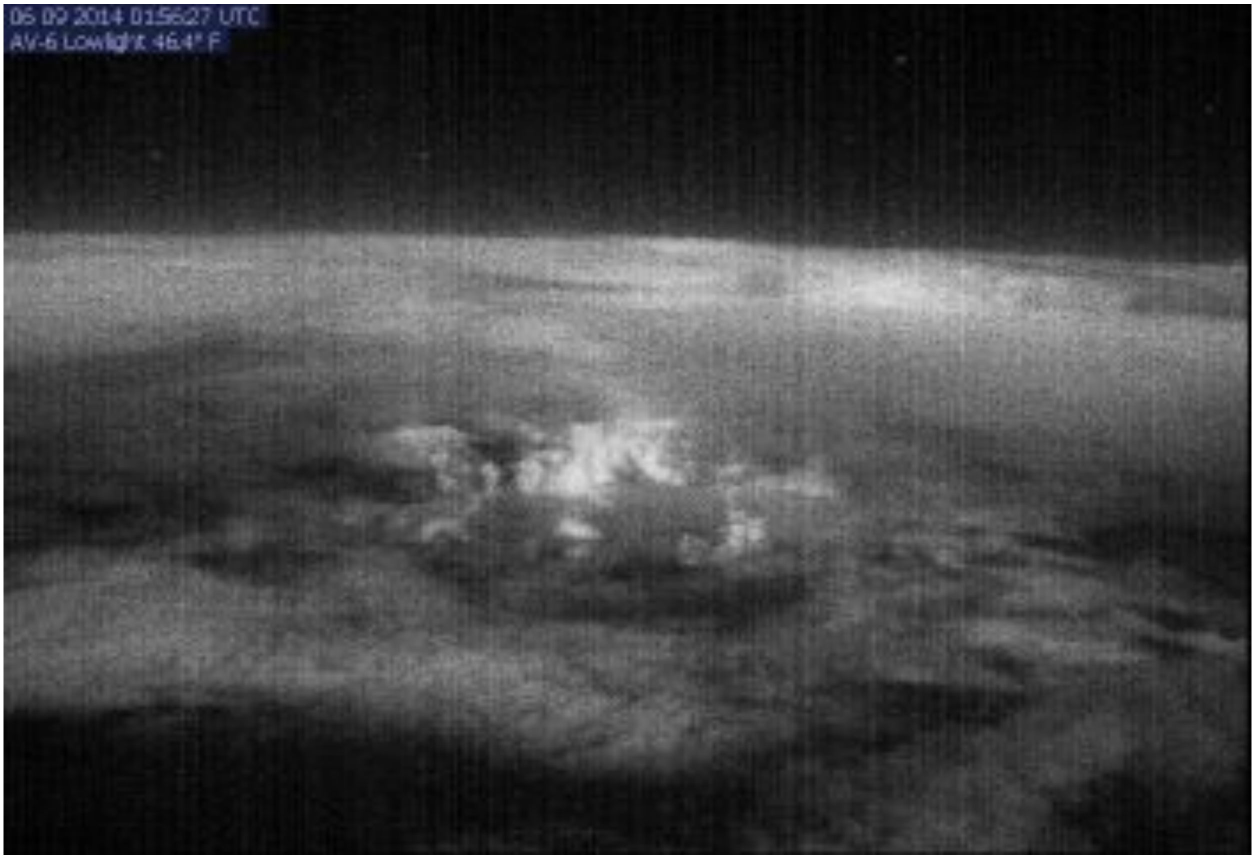


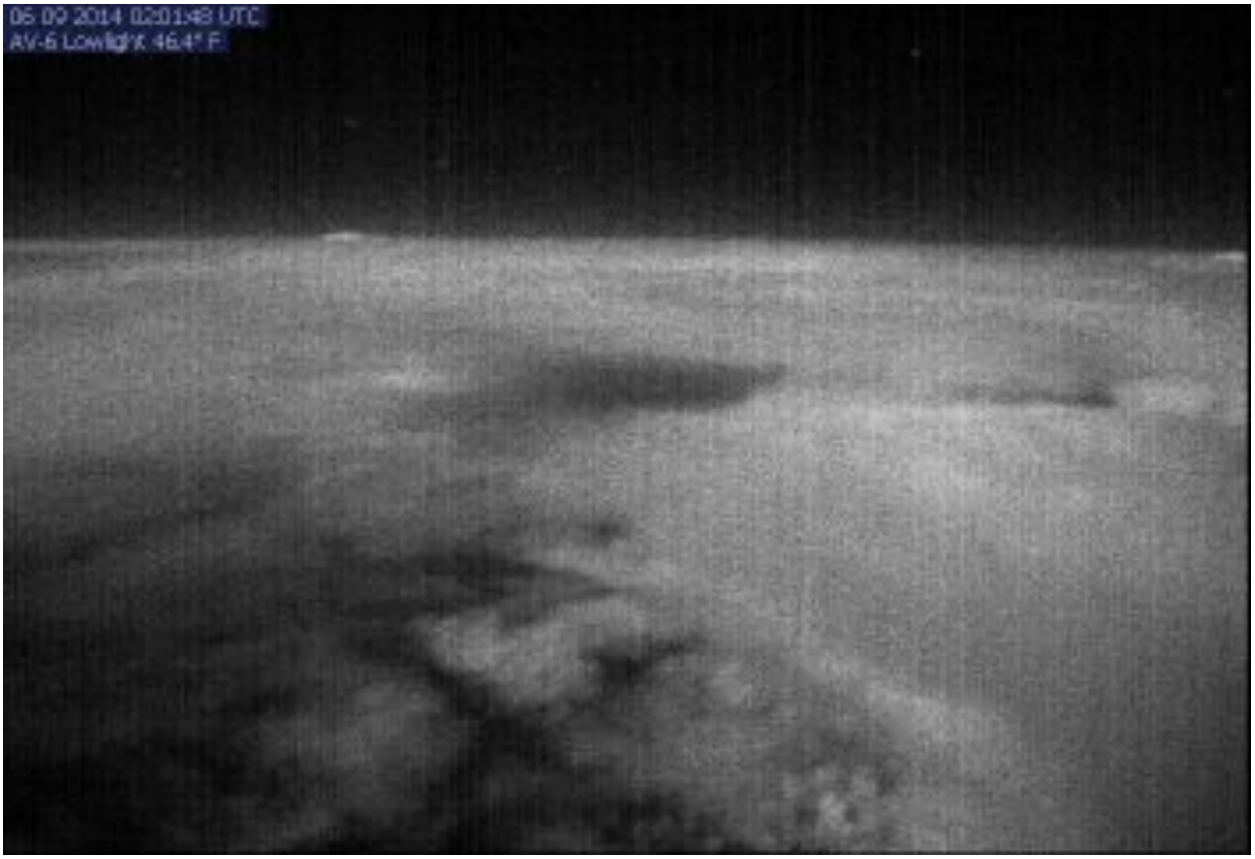
And cloud-top height at the same time.

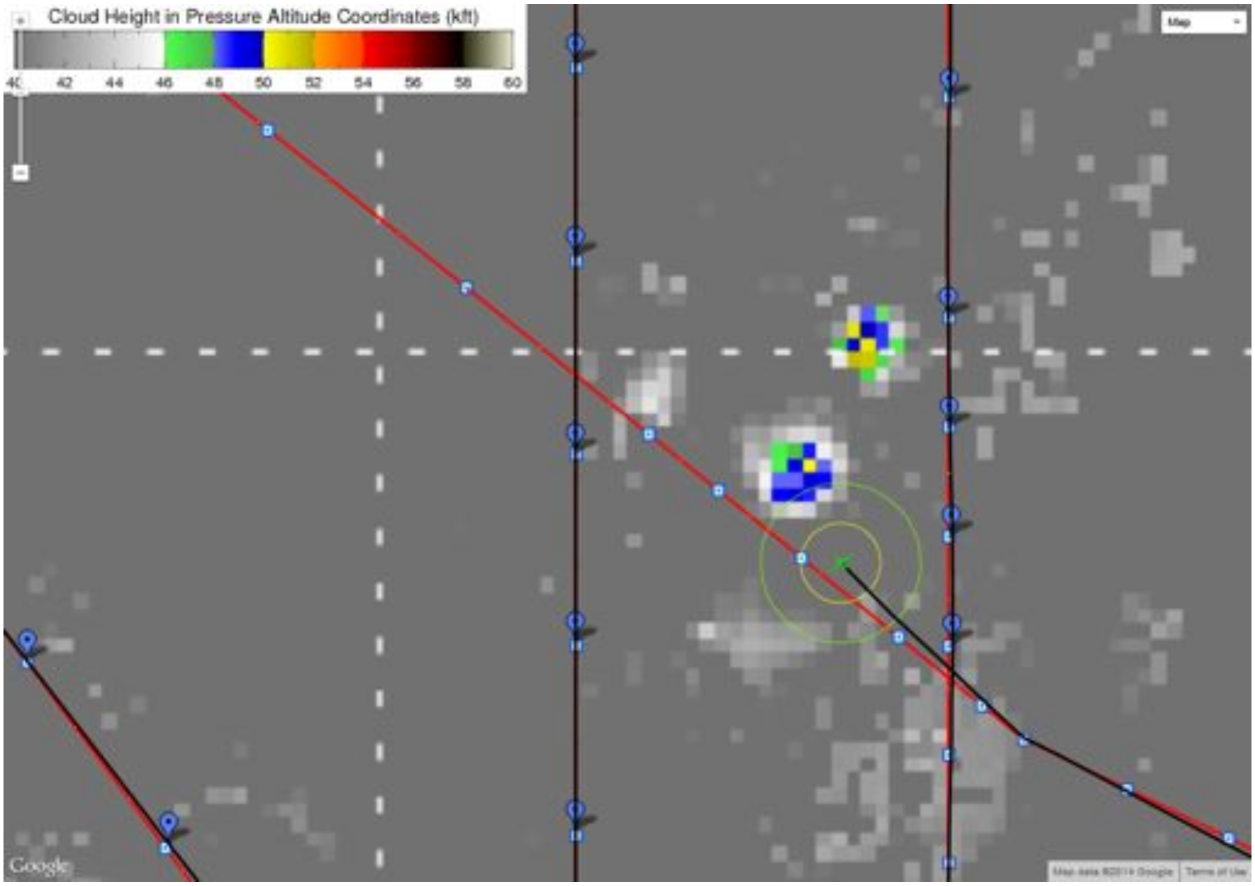
All of the output from this mission's dropsonde analysis (courtesy AVAPS team and Michael is Black) is contained in the folder entitled:

2014-09-05-AV6 90L

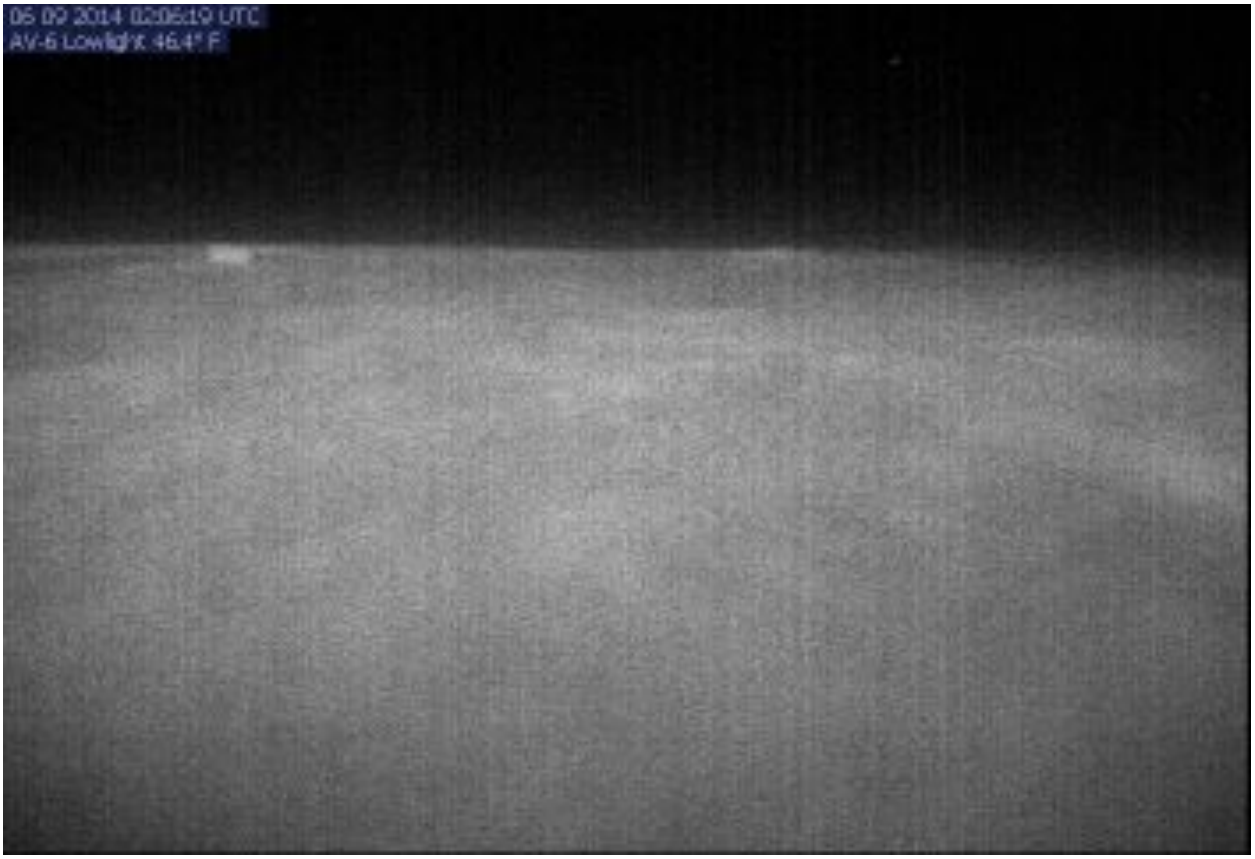

06 09 2014 01:49:47 UTC
AV-6 Lowlight 46.4° F

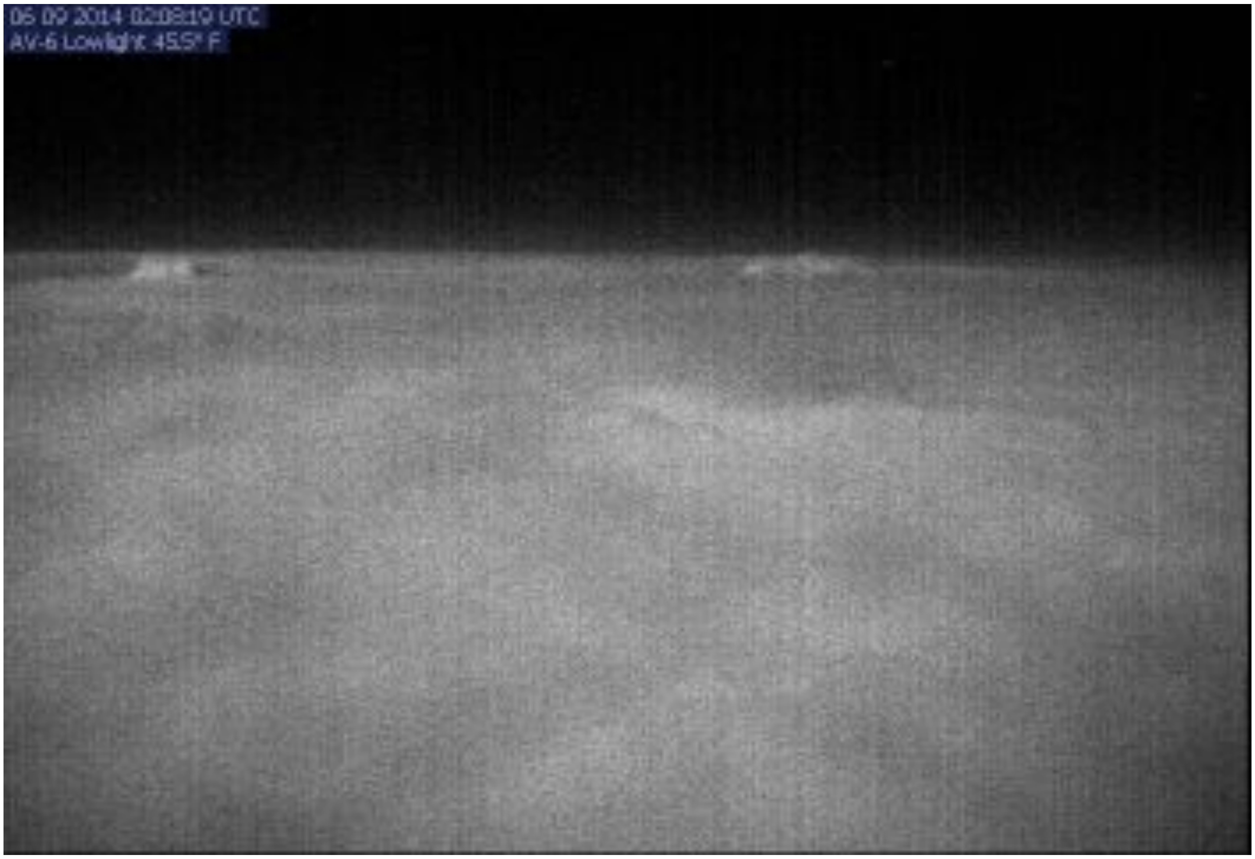

06 09 2014 01:56:27 UTC
AV-6 Lowlight 46.4° F


06 09 2014 02:01:48 UTC
AV-6 Lowlight 46.4° F

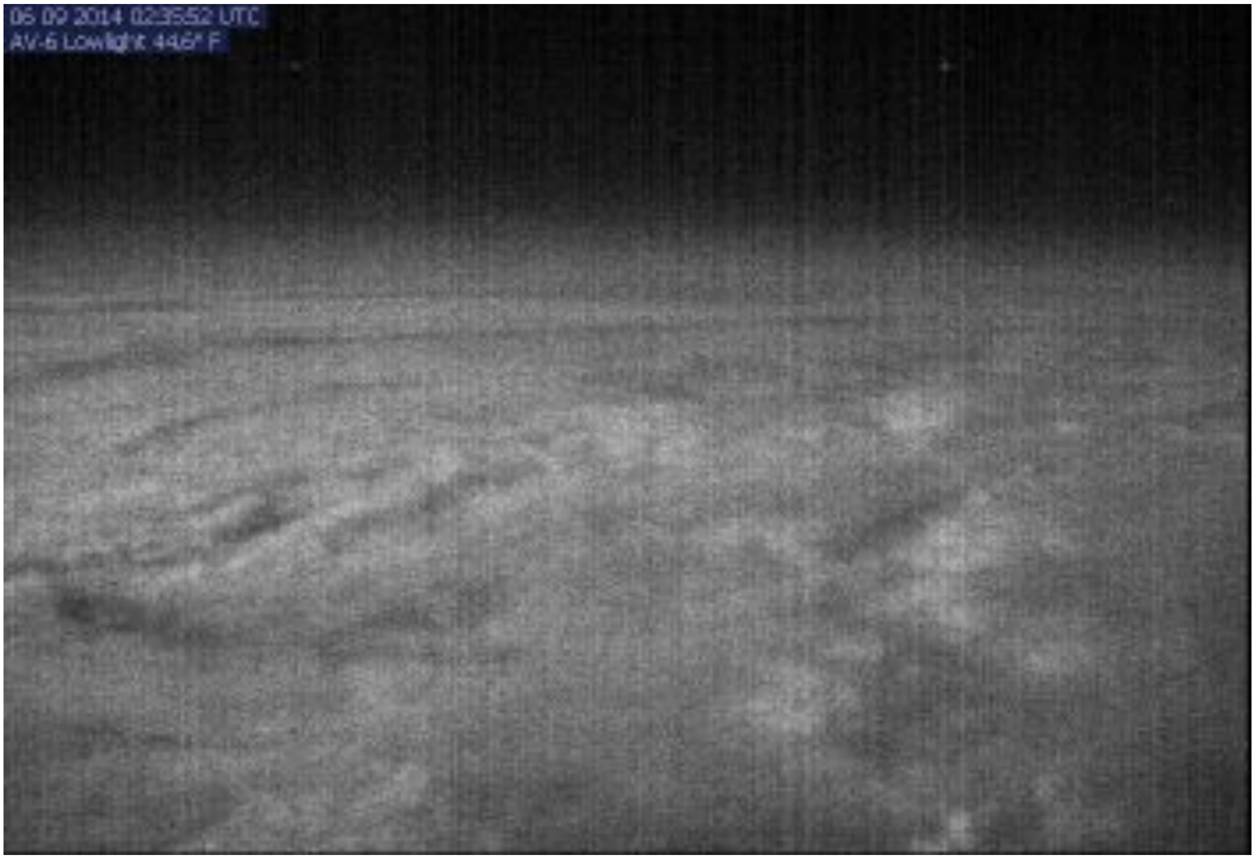


Cloud Height in Pressure Altitude Coordinates (kft)
40
42
44
46
48
50
52
54
56
58
60
Map
Google

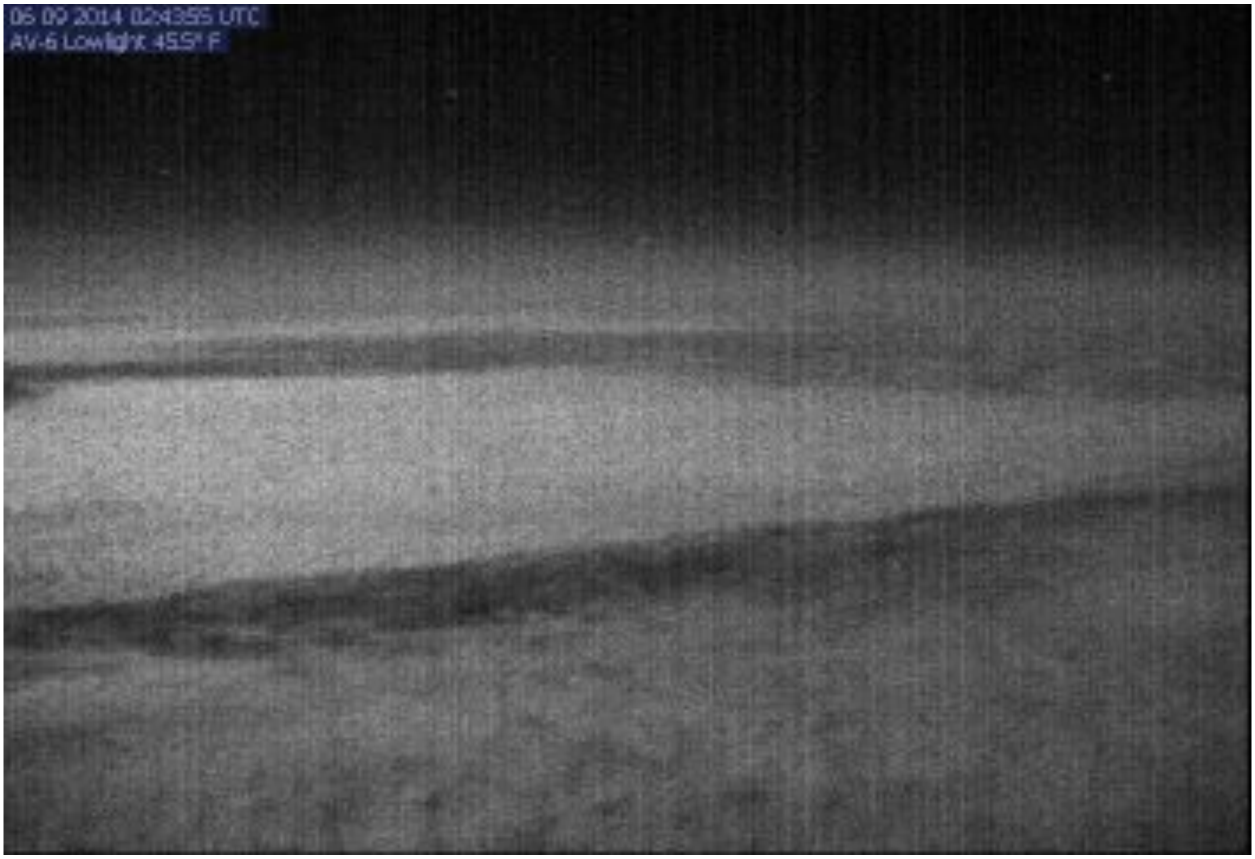

06 09 2014 02:06:19 UTC
AV-6 Lowlight 46.4° F



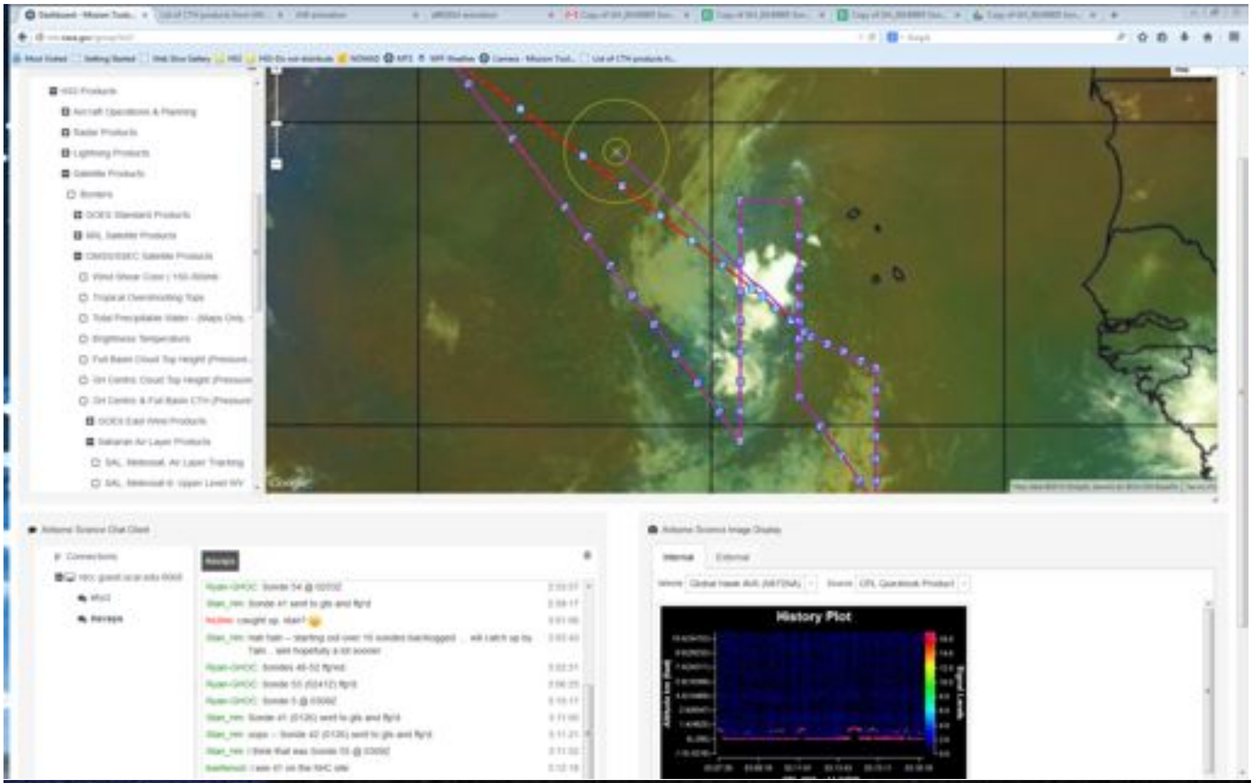
Seeing some overshoots off to our right.



Cloud swirl below flight level – with no overshooting tops evident.



Low-level clouds only in this image.


History Plot

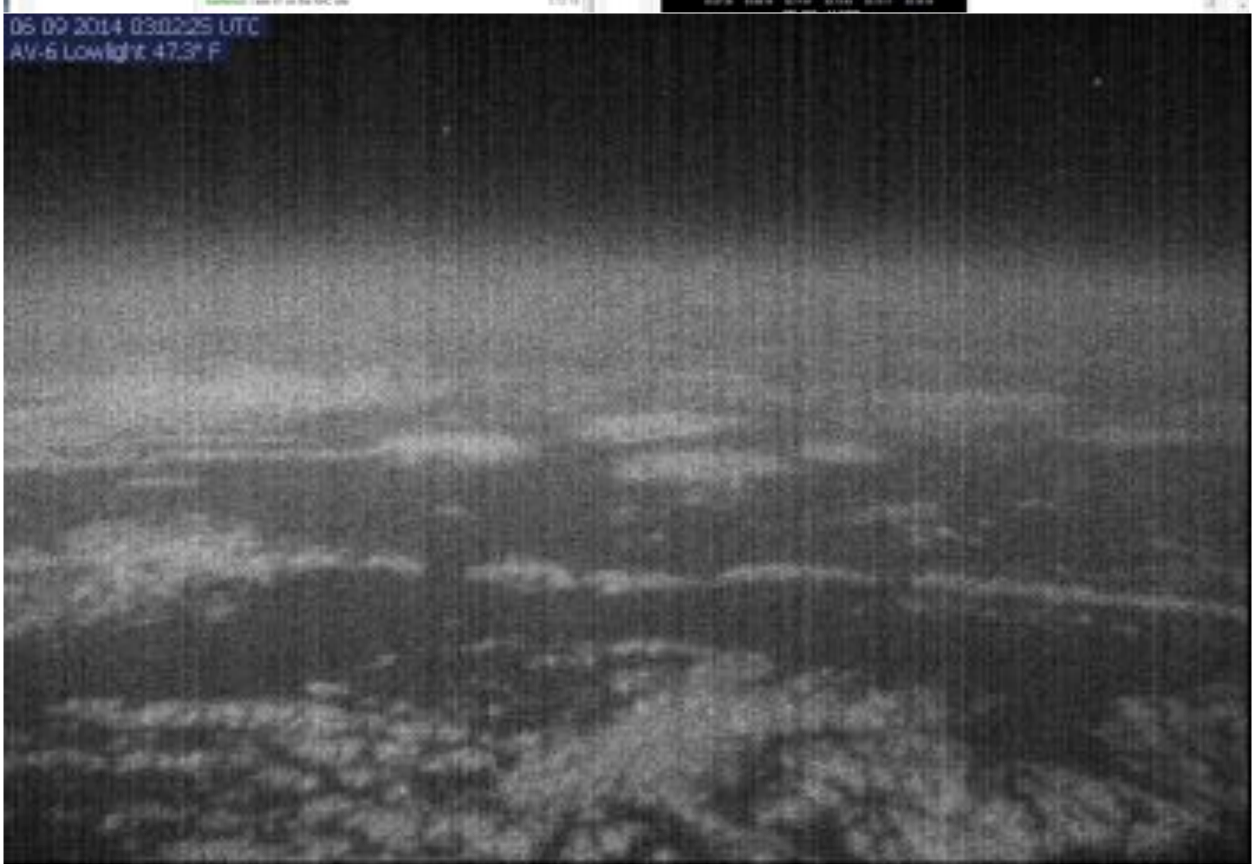
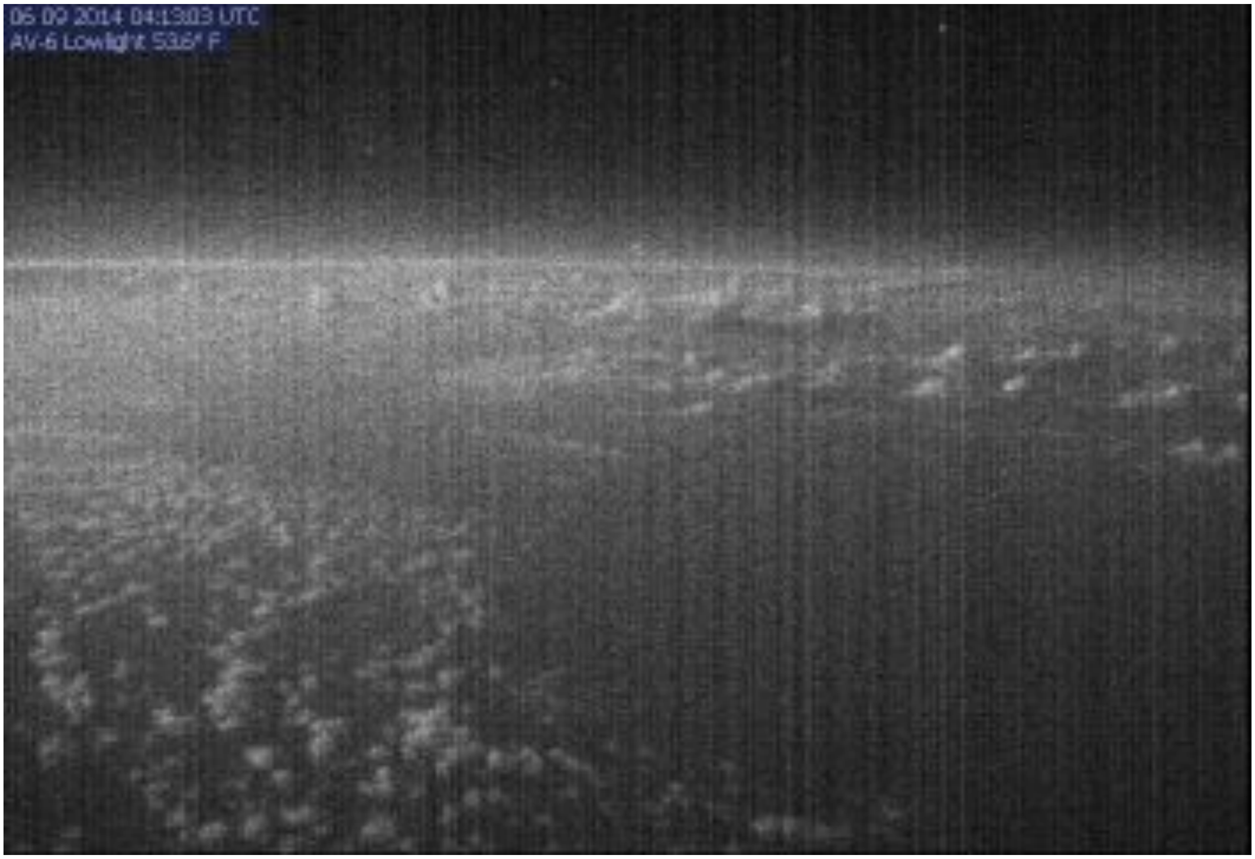
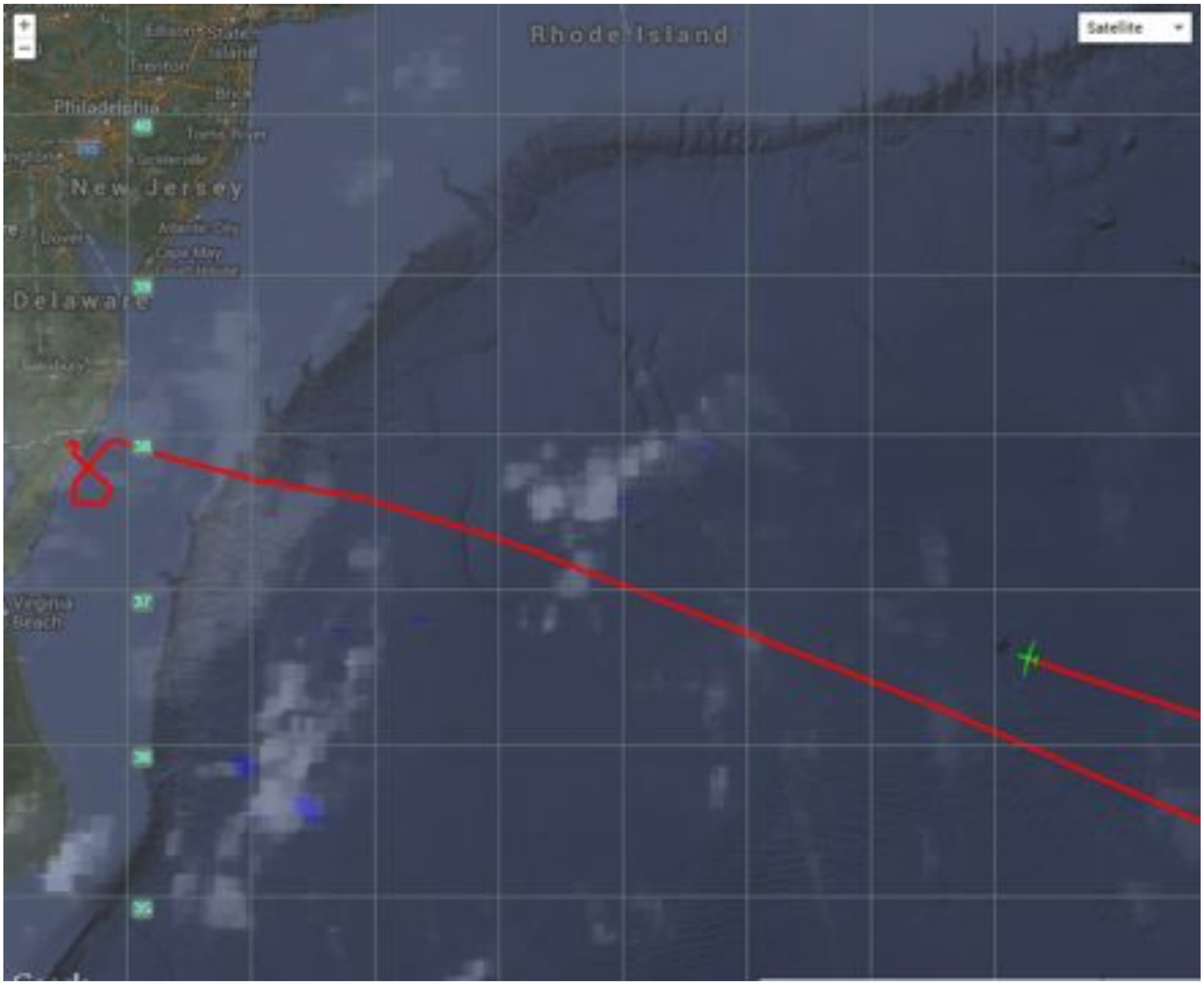

06 09 2014 03:02:25 UTC
AV-6 Lowlight 47.3° F

Figure above: GH AV-6 track with remnant convective signature (a CIMMS satellite product) evident near and around pouch sweet spot. Scanning HIS shown also, together with lowlight camera.

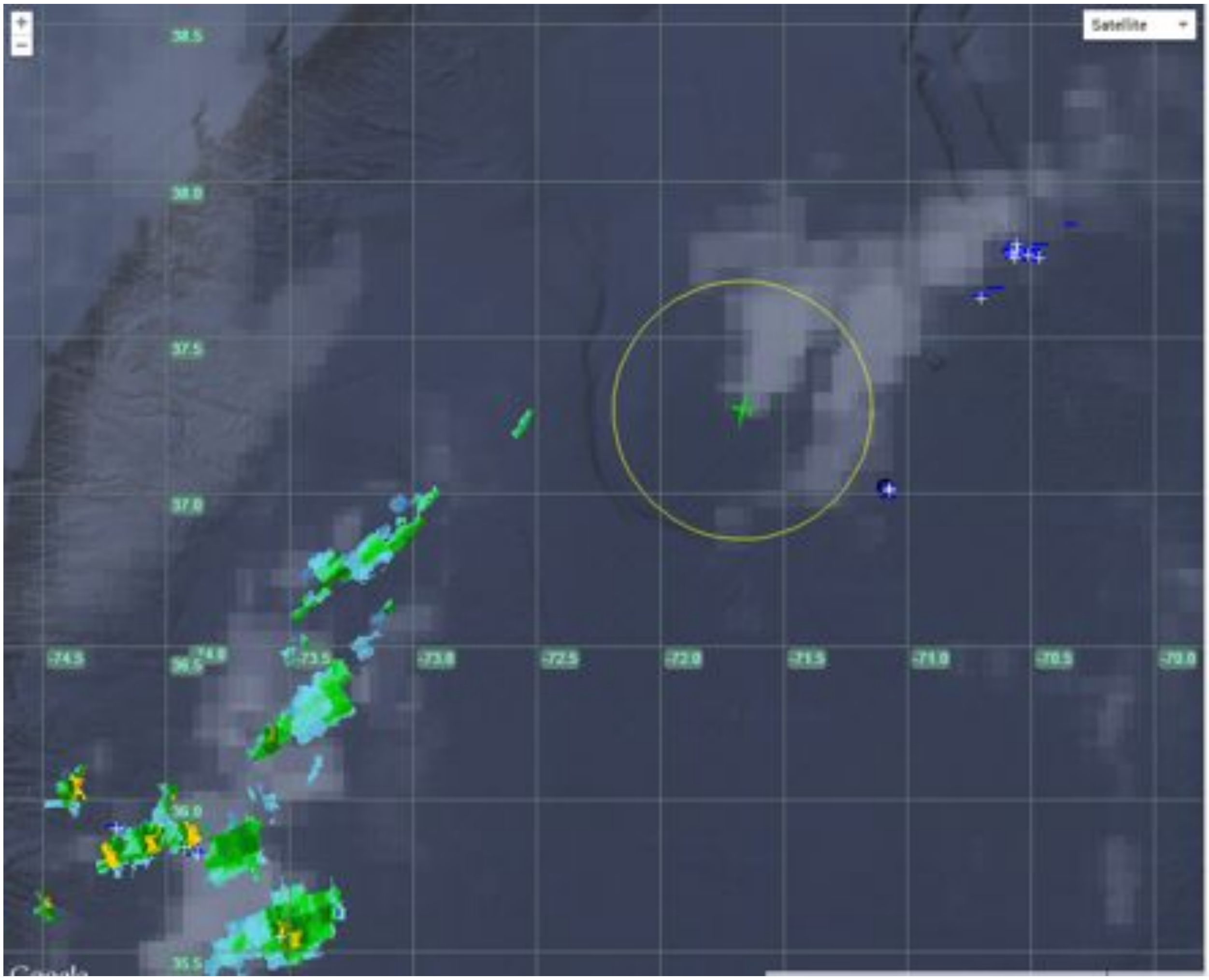
☺



GH AV-6 en route home to Wallops. Shallow cumulus and stratocumulus to north.



Lightning in cloud cluster right of track 06/0910Z and left of track. Convection moving ENE, anvil blowing off to south (northerly flow aloft)

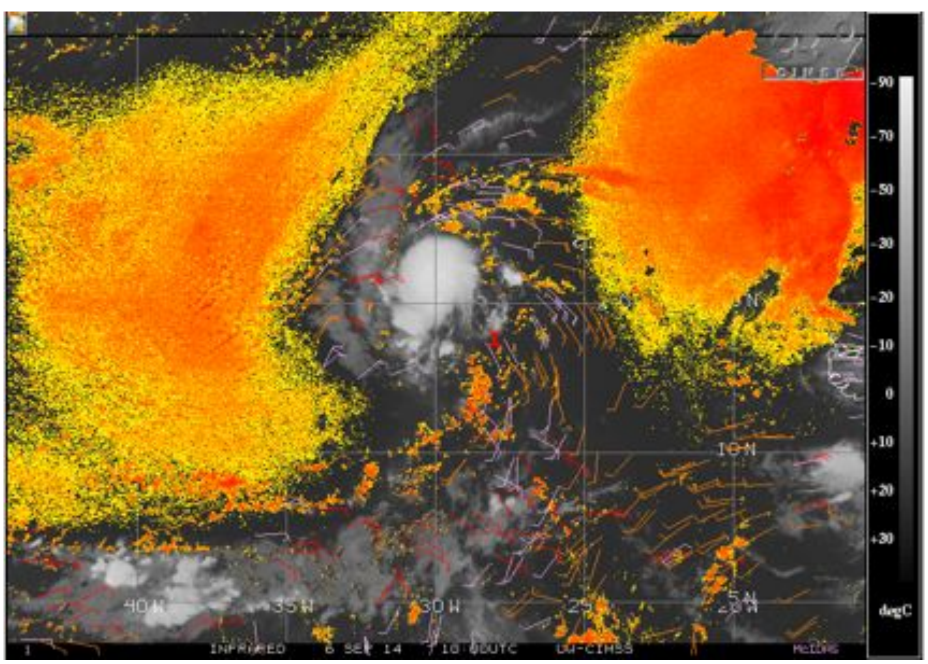


Lightning in cloud cluster right of track 06/0945Z and left of track. Convection moving ENE, anvil blowing off to south (northerly flow aloft)

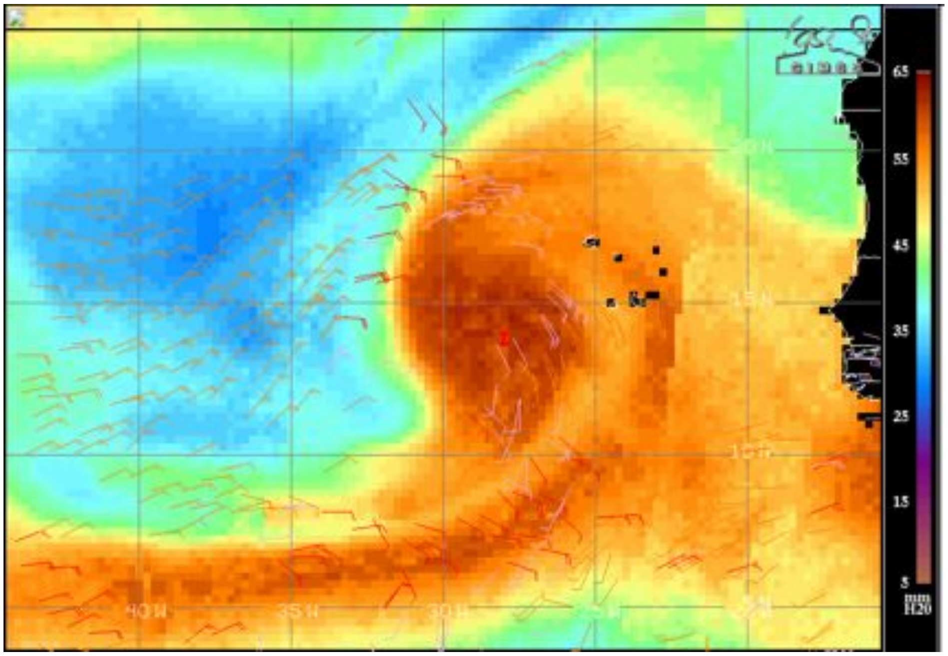
Sunrise prior to landing.

Chase airborne at 1040Z.

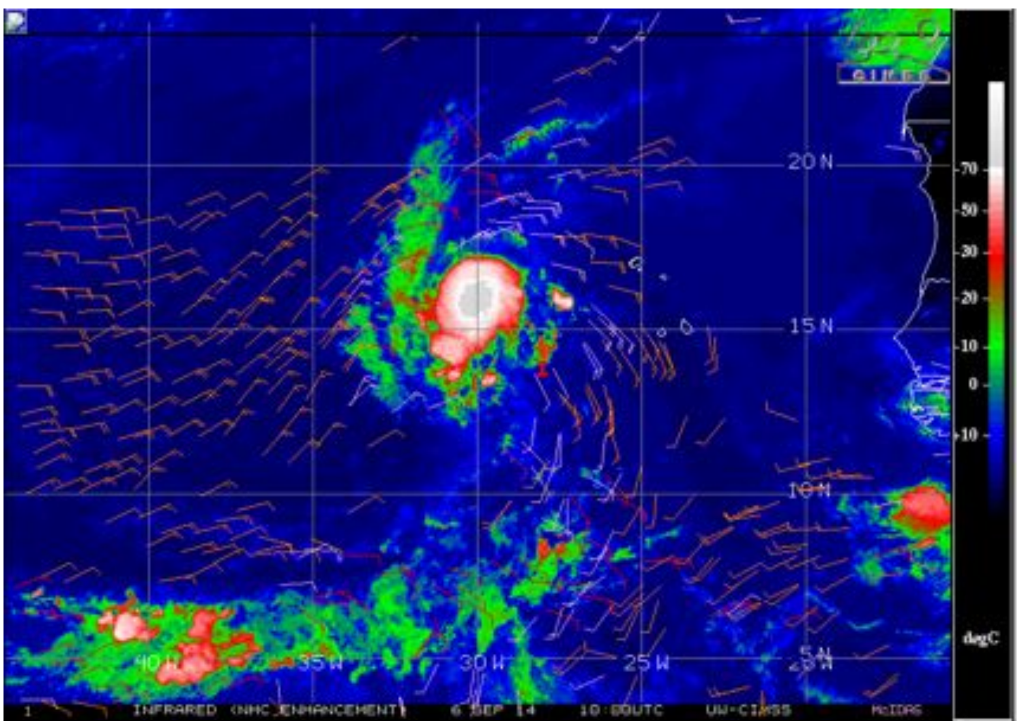
1133 Landing



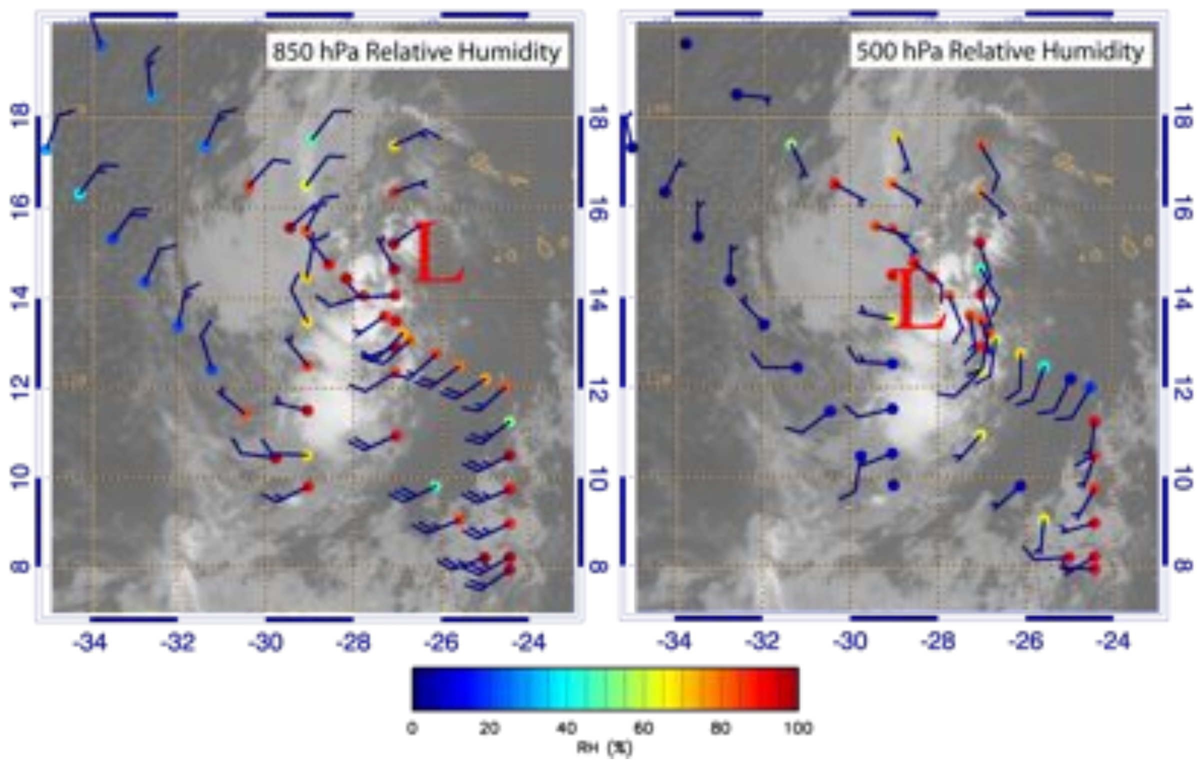
Dust and low level AMVs 06/10Z- well defined (closed) circulation.



TPW and low level AMVs 06/10Z- well defined (closed) circulation.



IR enhanced and low level AMVs 06/10Z- well defined (closed) circulation.



The above figures show the sonde distribtion in a storm-relative reference frame. Wind barbs show storm-relative winds. Color filled circles show relative humidity at 850 and 500 hPa. The L indicates the approximate center of circulation at each level. Dry SAL air is seen to the west and wraps around to the SE (more apparent at 800-700 hPa). At upper levels very dry air clearly wraps around the storm to just NE of the circulation center. The system appears to be tilted toward the west with height.

Instrument summaries

AVAPS

Research Flight 4 (20140905) – Invest 90L SAL Interaction in Tropical Eastern Atlantic

Station 9 (AVAPS Science): Ryan Spackman*, Natalie Gaggini

Station 8 (AVAPS Ops): Dean Lauritsen, Laura Tudor

* Corresponding author

Science flight 4 was a 24 hour flight to Invest 90L (P27L) which had recently exited western Africa and was forecasted to weaken during a SAL interaction over the far eastern tropical Atlantic. AVAPS was loaded with 60 sondes and 59 were deployed at the planned drop locations D1-D59. AV-6 was on station performing drops in a lawnmower pattern for about 8-9 hours with planned drops D4-D57. Six additional drops were planned (and 5 deployed) on the transit to/from the lawnmower pattern into a vorticity max at about 30N, 48W.

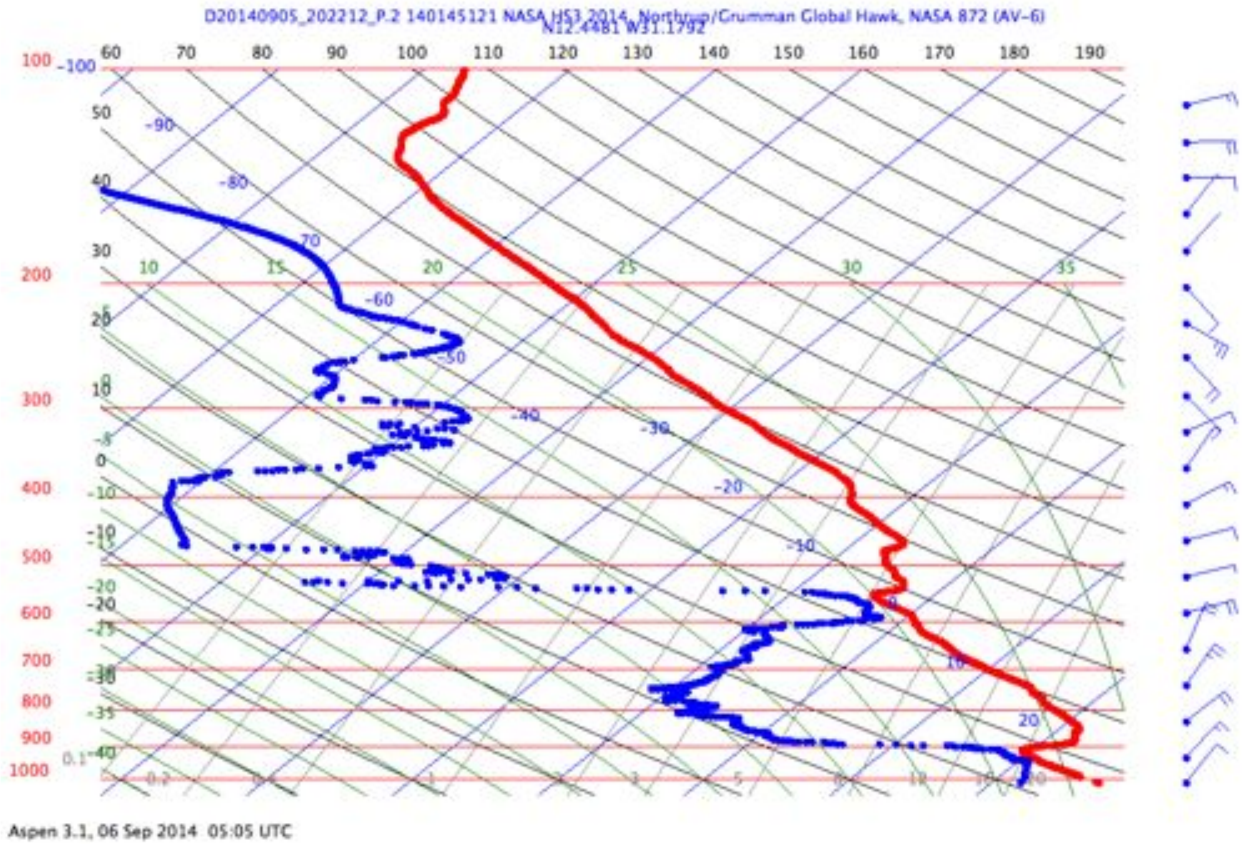
This was a successful flight for AVAPS with data collected from all launched sondes. Data quality and telemetry were excellent with no known fast falls. Operationally, it proved difficult to launch sondes for two sequences along the southern edge (< 10 deg N) of the lawnmower pattern when AV-6 was outside the Ku coverage region for the assigned satellite. AVAPS was command and controlled via iridium communications successfully although there were some delays in launching sondes due to sparse iridium coverage. As a lesson learned, it will be important to consider Ku coverage in the design of flight plans so that dropsondes are spaced far enough apart to allow for successful and timely launches. Also, it is important to keep in mind that the data acquired during Ku outages cannot be retrieved from AV-6 for processing until Ku coverage is restored.

During the post-flight, the remaining sonde was discovered lying in the launcher assembly box below Bins 6-10. Early indications suggest the sonde was likely released (together with another sonde) from Bin 7 (or 6) during a normal load command sequence due to a mechanical fault. Instrument log files confirmed that each load command was immediately followed by a launch command confirming that 2 sondes were *not* inadvertently loaded into the launch tube (as the AGS software is designed to prevent). The cause of the mechanical fault is being further investigated but we do not suspect this is a recurring problem. The instrument is fully operational and prepared for the next flight.

The automation of the D-file download from AV-6 is one step closer to full autonomy with this flight. All the files were automatically transferred from the link server to the science network. Data IT will be working with us to make sure that the key stays in place on the asp-interface-2 server for the transfer to work. We will also be implementing additional scripts during the upcoming flight to automate the transfer from the asp-interface-2 server to the ESRL server making the data available to HRD for ASPEN processing without AVAPS operator handling.

All the data were processed in near real time, transmitted to the GTS, and preliminary data made available to science team members. The Skew-T plots produced from the data acquired during the Ku outages were delayed by up to 2 hours.

Sondes Allocated		**750**	
Remaining		**496**	**66.1%**
Released		**254**	**33.9%**
Flight	**Take off Date**	**Sonde Usage**	**Sondes Left**
RF01	8/26/2014	75	675
RF02	8/28/2014	70	605
RF03	9/3/2014	50	555
RF04	9/5/2014	59	496



S-HIS Flight Summary

B. Smith, A. Merrelli, J. Taylor; SSEC, University of Wisconsin-Madison

Figure 1 shows an image of the SAL as depicted by the split window of the SEVIRI instrument on the MSG satellite. As can be seen the flight track of the Global Hawk crosses over the SAL on its way to the east coast of Africa during its 5 September flight.

Figure 1: An image of the SAL as depicted by the split window of the SEVIRI instrument on the MSG satellite with the flight track of the Global Hawk overlaid.

Figure 2 shows the S-HIS Relative humidity cross-section across the southeast boundary of the SAL. The SAL is depicted by the dry layer of air between 700 and 850 hPa in this image. The boundary of the SAL can be seen to occur at around 20:30 UTC as this dry dust layer gives way to a humid marine boundary layer. This can also be seen in both the dropsonde and S-HIS vertical sounding plots for locations just inside the SAL and outside the SAL as shown in Figure 3.

There is very good qualitative agreement between the dropsonde and S-HIS temperature and dew point profiles both inside and outside the SAL.

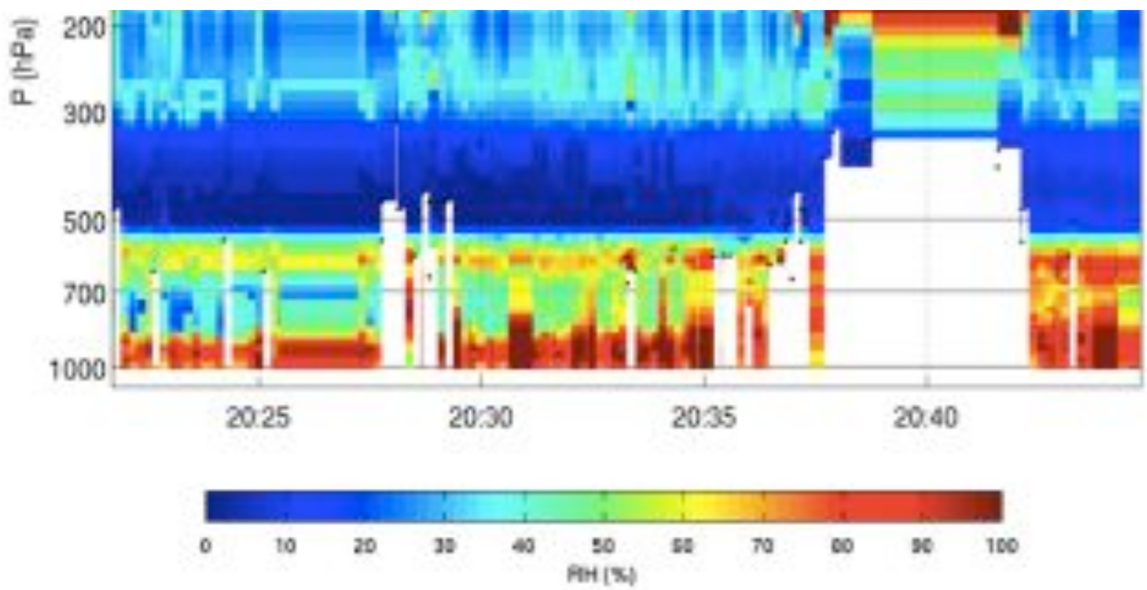


Figure 2: S-HIS Relative humidity cross-section across the southeast boundary of the SAL.

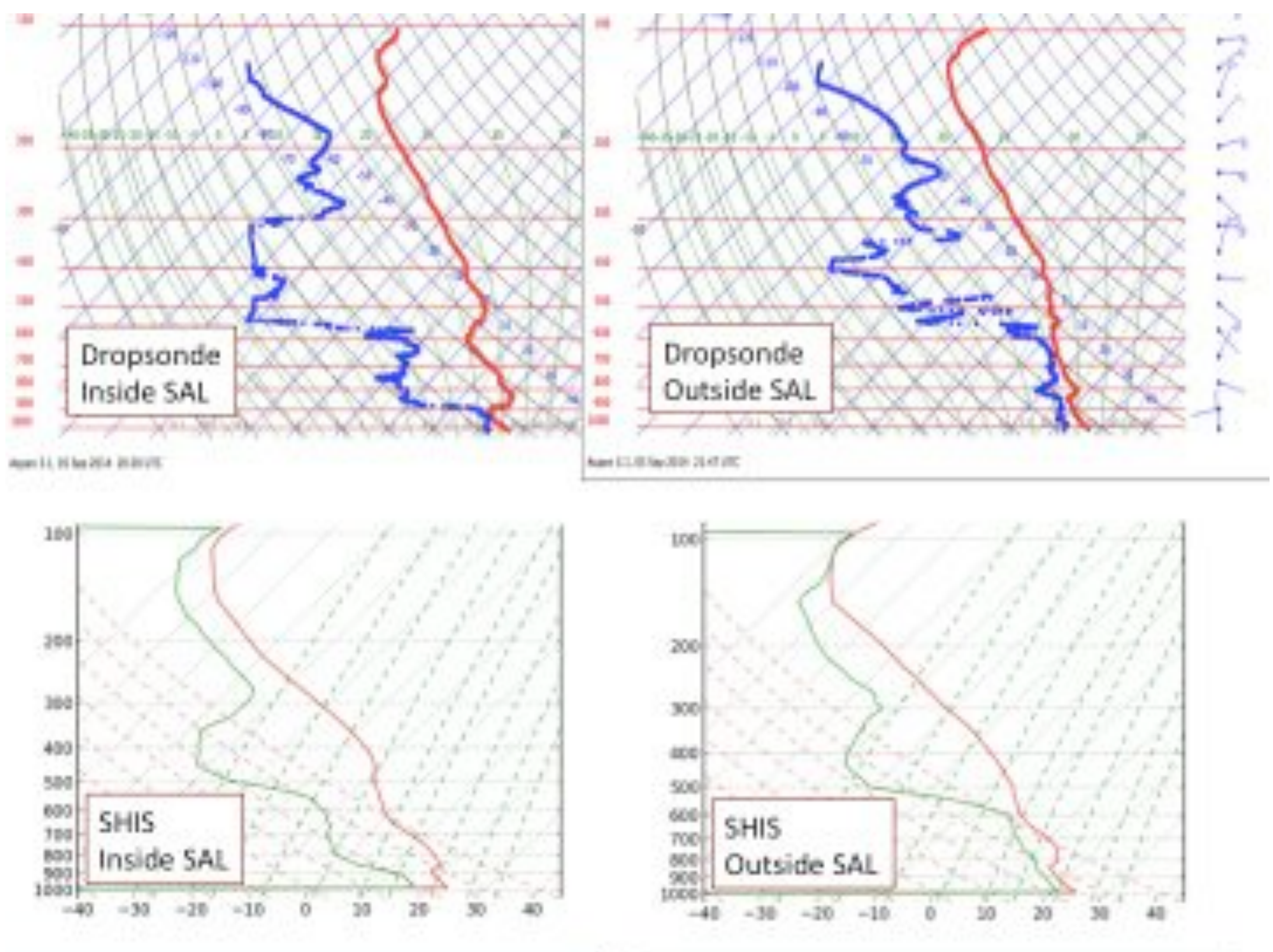


Figure 3: Dropsonde and S-HIS vertical sounding plots for locations just inside the SAL and outside the SAL.

Once the aircraft passed the SAL, the interior of the pouch showed much deeper moist layers. Figure 4 shows some high moisture profiles in between the deep convective clouds, near the middle of the pouch. The RH is over 80% to the 500 hPa in most of the area. Another interesting water vapor structure is shown in Figure 5, which is a comparison the dropsonde with a nearby S-HIS retrieval. The sharp transition from moist to dry at 500 hPa is of course too sharp for the infrared retrieval to fully capture, but the S-HIS retrieval does a nice job of showing the transition altitude from moist to dry.

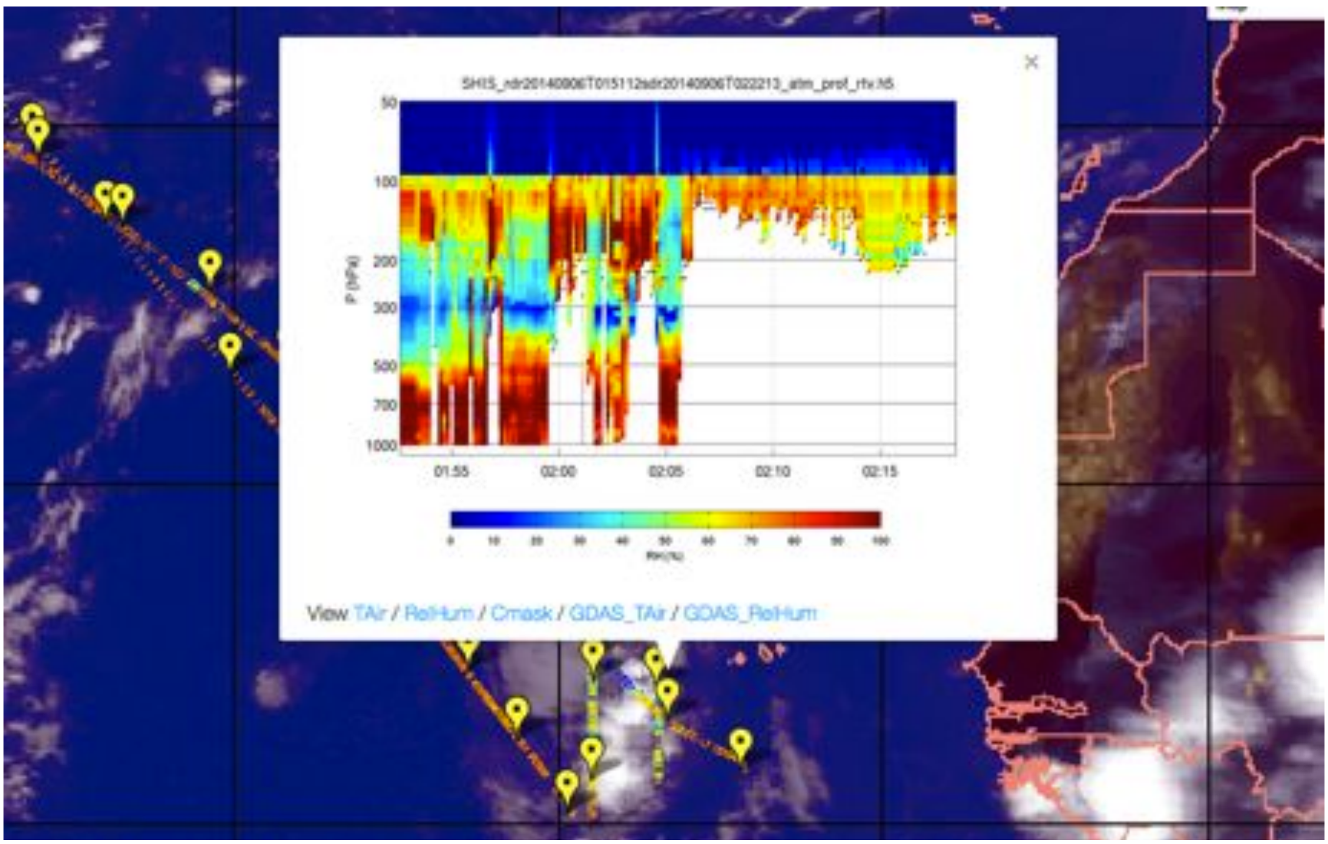


Figure 4: Once the aircraft passed the SAL, the interior of the pouch shows much deeper moist layers. High moisture profiles in between the deep convective clouds, are retrieved near the middle of the pouch.

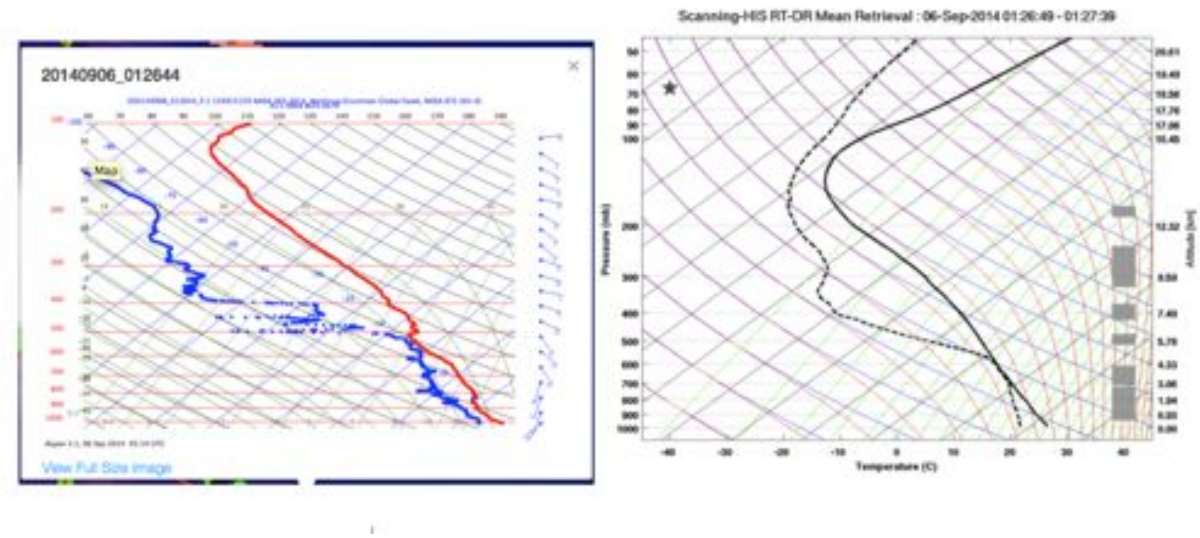


Figure 5: A comparison the dropsonde with a nearby S-HIS retrieval (Sept 6, 0126 UTC).

Instrument Summary

The Scanning-HIS operated nominally throughout the flight. An instrument power cycle (15 minutes off) at 60 minutes prior to the first science waypoint was implemented.

Some improvements were made in the Global Hawk onboard communications and downlink configuration (contact Global Hawk IT for details), which improved the downlink of the S-HIS datagrams. Figure 6 shows the real time cross-track brightness temperature footprints, showing the clear increase in data density after the configuration change.

Timeline (All times are UTC and are only approximate):

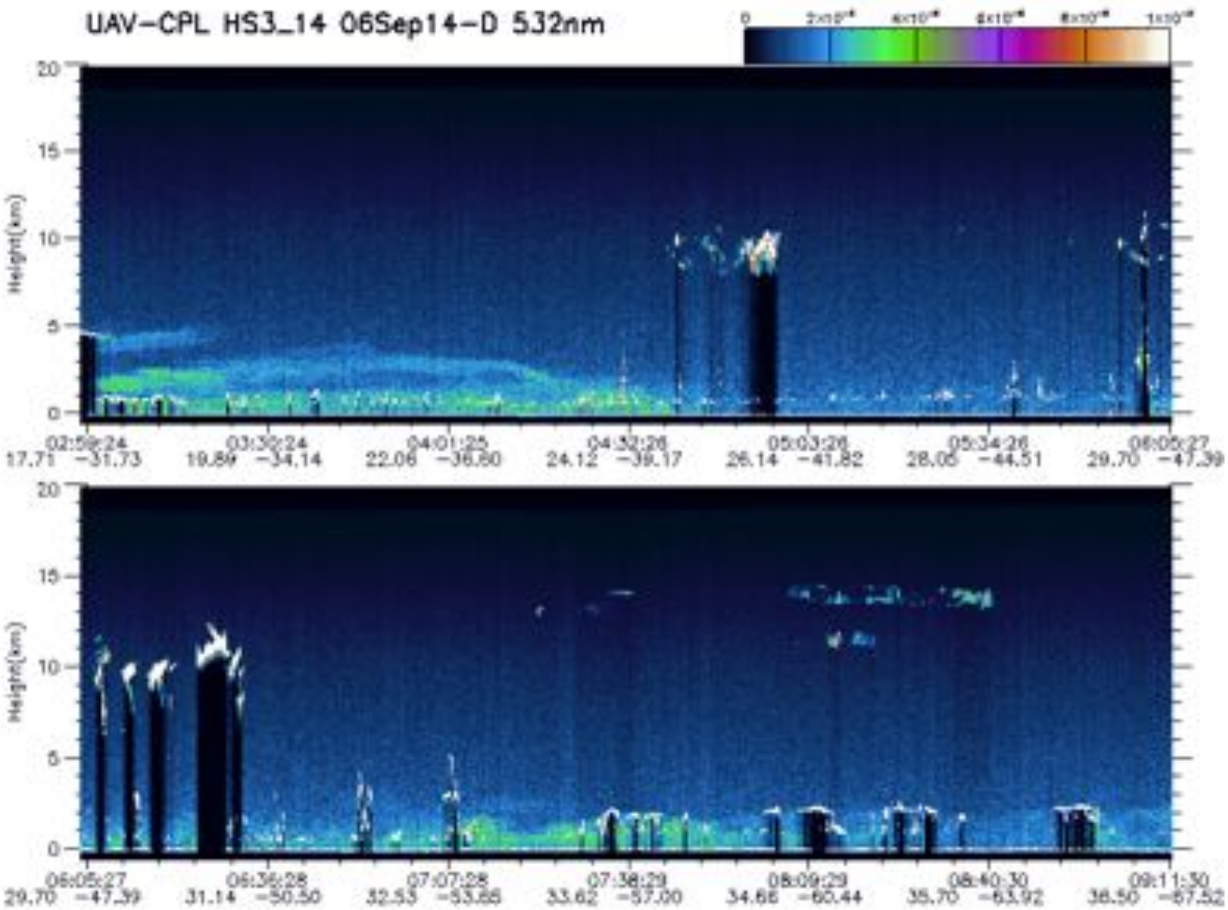
- 20140905T1022 GH engine start
- 20140905T1054 Ku ON and transmitting
- 20140905T1105 S-HIS Power on
- 20140905T1111 Takeoff
- 20140905T1122 S-HIS detectors cooled
- 20140905T1330 S-HIS power cycle; 60 minutes prior to science waypoint 1 (15 minutes off)
- 20140905T1351 S-HIS power cycle complete, IL41 on
- 20140905T1411 S-HIS detectors cooled, cooler current nominal
- 20140905T1745 IT made some tweaks and our Ku transmission yield improved markedly. Don Sullivan turned “auto negotiation” ON between the autolink and Ku modems.
- 20140906T0907 S-HIS descent heaters on
- 20140906T0928 Instrument power OFF before descent (IL42, IL41, DC42, DC41)
- 20140906T0944 Instrument power ON (DC41, DC42, IL41, IL42)
- 20140906T1052 Instrument power OFF (DC41, DC42, IL41, IL42)
- 20140906T1111 Landing

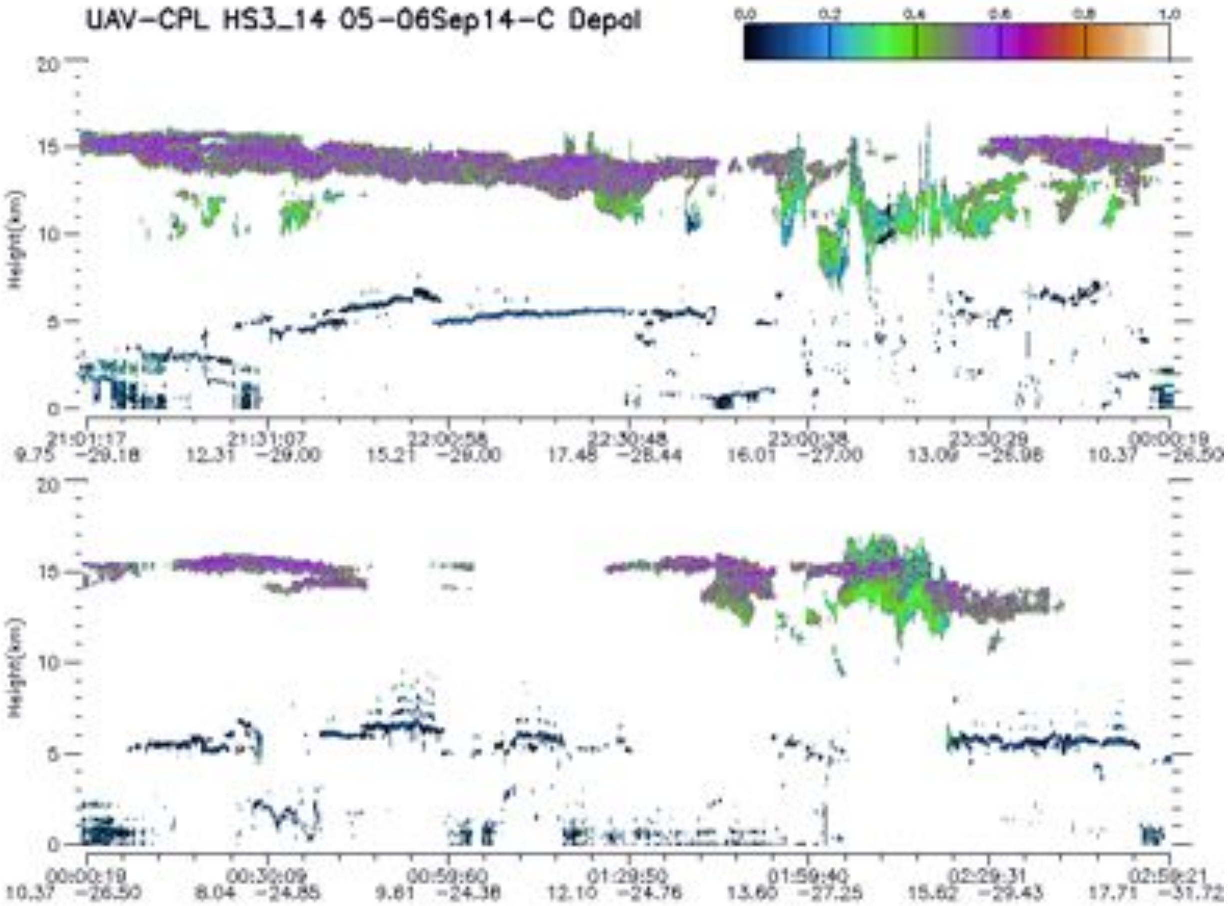
Figure 6: Real time cross-track brightness temperature footprints, lower flight leg shows the clear increase in data density after the Global Hawk onboard communications and downlink configuration change.

CPL Summary

Overall, CPL worked acceptably for the 05-06Sep14 flight, although we are continuing to experience laser pulse issues. The 355 and 532nm channels were noisier than we would like, but produce good products at night with no solar background. The 1064nm channel had strong signals throughout, but the pulse is occasionally multi-pulse, resulting in occasional "ringing" in the 1064 images. The instrument temperatures remained inside thresholds. We had turned the laser power up on this flight to hope to get a better snr with the 532nm channel, but the 1064 issue got worse. We have turned the laser power back down to near normal levels for the next flight. Matt McGill has told me there isn't much we can do in the field to remedy the laser issue. It needs a tune up in the GSFC lab.

CPL started data flow at 12:31 UTC on 05Sep. and ended data flow at 09:11 UTC on 06Sep. Some high values of depolarization ratio were found in the cirrus in Segment C over and around 90L (attached). The SAL was sensed well on the way back home in Segment D (attached).




UAV-CPL HS3_14 05-06Sep14-C Depol
Height(km)
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21:31:07
22:00:58
22:30:48
23:00:38
23:30:29
00:00:19
00:30:09
00:59:60
01:29:50
01:59:40
02:29:31
02:59:21