Year-3 Report

University of Wisconsin, Space Science and Engineering Center
Scanning-HIS Participation in HS3

NASA Grant NNX10AV08G

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HS3 Year-3 Final Report
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Introduction

This is the Year 3 report for the time period 9/1/2012 - 8/31/2013 of NASA Grant NNX10AV08G to the University of Wisconsin (UW) Space Science and Engineering Center for Scanning High-resolution Interferometer Sounder (S-HIS) instrument participation in the NASA EV-1 Hurricane and Severe Storms Sentinel (HS3) project with the goal of enhancing our understanding of the processes that underlie hurricane intensity change in the Atlantic Ocean basin. Primary activities this year included

(1) Support S-HIS for HS3 range, transit, and science flights (range flight from NASA DFRC, 2012-08-28; science flights from NASA WFF 2012-09-11, 2012-09-14, 2012-09-19, 2012-09-22, 2012-09-25, 2012-09-26, 2012-10-06; transit from DFRC to WFF 2012-09-06 and WFF to DFRC 2012-10-12) and subsequent data analyses;
(2) Verification of optimization of S-HIS interface to Global Hawk zone 25 thermal environment;
(3) Laboratory verification of S-HIS reference blackbody temperature calibration and pre-campaign and post-campaign testing of S-HIS performance;
(4) Follow-up development and optimization of architecture and software to implement real-time, near real-time, and long term data handling, processing, and display for long duration Global Hawk flights;
(5) Development and implementation of improved temperature, water vapor, and cloud retrieval capabilities; and
(6) Support HS3 Science Team teleconferences and the Science Team Meeting May 7-9, 2013.

This report consists of a brief summary of each of these activities.

1. Support S-HIS for HS3 range, transit, and science flights and subsequent data analyses

During the month of August 2012, the UW S-HIS team supported integration and range flight operations of the NASA AV-6 Global Hawk from the NASA Dryden flight facility in Southern California and the NASA Wallops Flight Facility in Virginia. One range flight was completed on 2012-08-28 with the AV-6 HS3 payload (S-HIS hyperspectral infrared sounder, AVAPS dropsonde system, and the Cloud Physics Lidar). The S-HIS instrument successfully collected high quality data from take-off to landing for the range test flight and the optimization of the S-HIS Zone 25 thermal environment was verified.

The DFRC to WFF transit flight and Leslie over-flight was completed 2012-09-06, with return transit from WFF to DFRC on 2012-10-12, and was supported by the UW S-HIS team as required at the DFRC and WFF sites. The S-HIS instrument successfully collected high quality data for the full duration of both flights.

The UW S-HIS team supported the HS3 mission and science flights of the NASA AV-6 Global Hawk from the NASA Wallops Flight Facility 2012-08-30 through 2012-10-11. AV-6 science flights were completed on 2012-09-11, 2012-09-14, 2012-09-19, 2012-09-22, 2012-09-25, 2012-09-26, and 2012-10-06. The S-HIS instrument successfully collected high quality data from takeoff to landing for all flights. Final products and Matlab readers for the data products were delivered via the SSEC ftp server. New users are required to register with an email address for contact information such that a distribution list can be easily maintained for product announcements and updates. A web link to the S-HIS HS3 data product distribution is included at the ESPO HS3 webpage: http://espo.nasa.gov/missions/hs3/data_products. The direct link is http://download.ssec.wisc.edu/sys/login/form/hs3_shis.

Representative examples of S-HIS retrieval products are provided in Figure 1 through Figure 3.

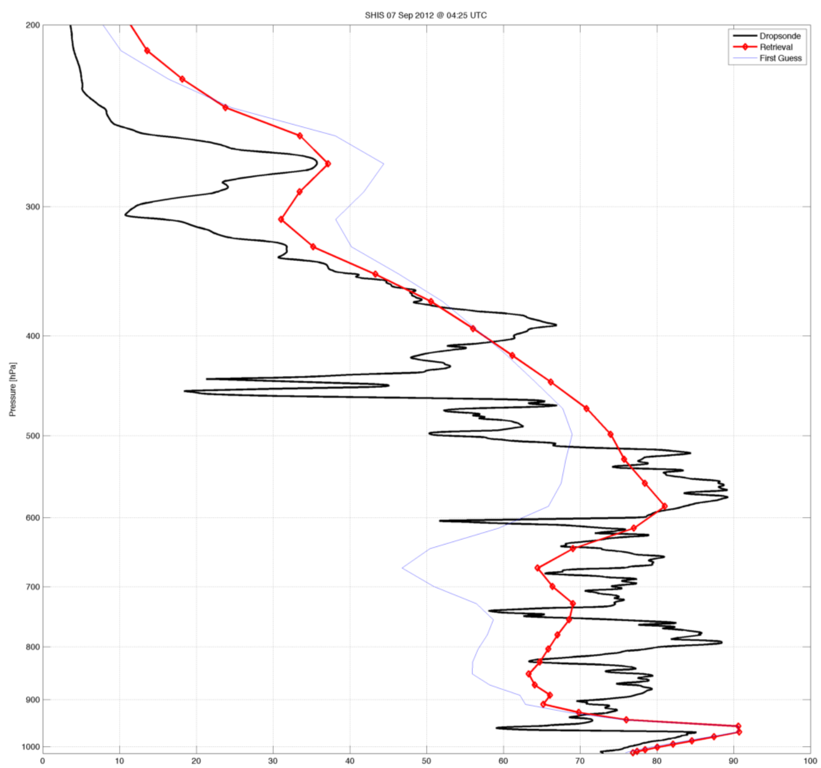

Figure 1: Sample RH Profile from Optimal Estimation with UWPhysRet compared to Dropsonde; 07 Sept 2012, 04:25

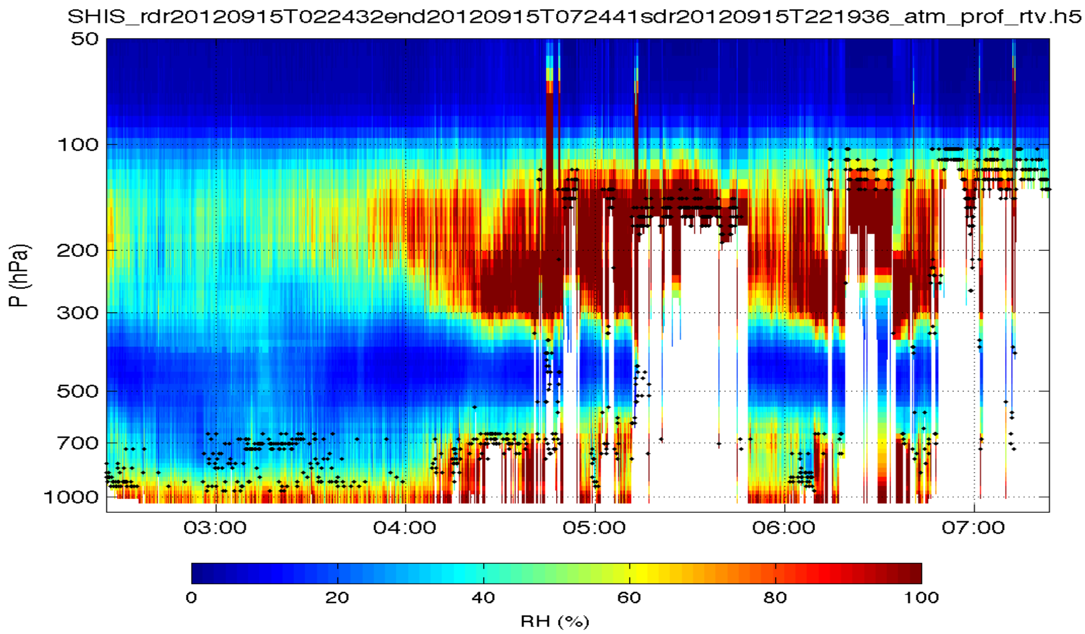

Figure 2: Relative Humidity cross-section; DR retrieval, 2013-09-15. The black dots indicate retrieved cloud tops.

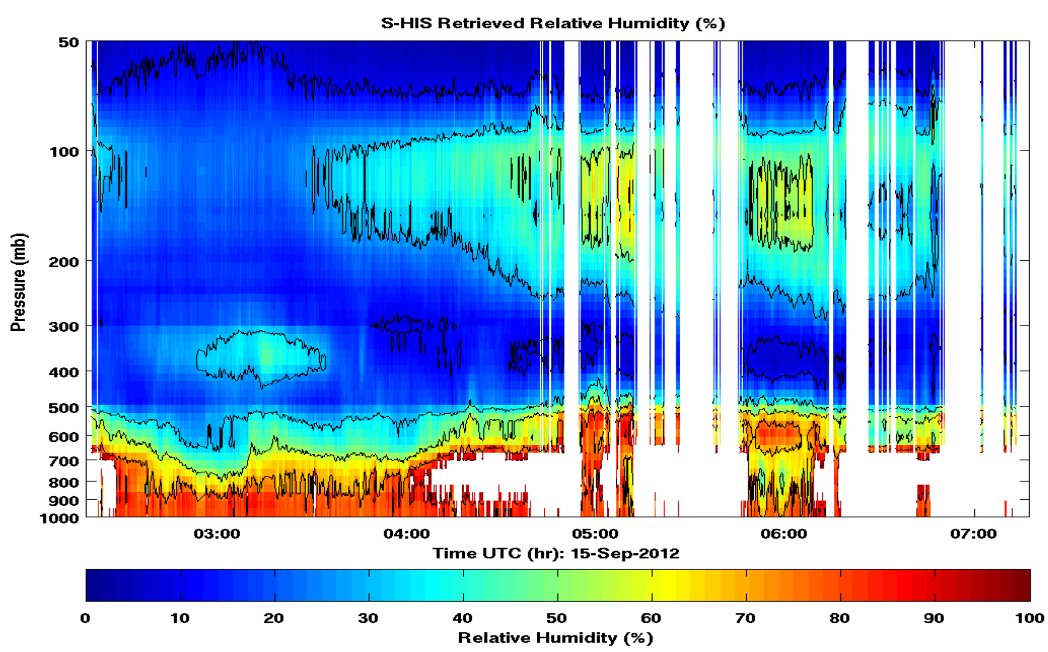

Figure 3: Relative Humidity cross-section; UWPHYSRET retrieval, 2013-09-15.

2. Optimization of S-HIS interface to Global Hawk zone 25 thermal environment

The typical flight environment for the S-HIS is in an aircraft pod exposed to outside ambient pressure and temperature. There are plans on the Global Hawk to provide a wing pod for S-HIS, but this will not be implemented until 2014. Until that time S-HIS will continue to fly in the Global Hawk Zone 25 for HS3. The 2011 flights showed temperatures in this location were warmer than desired – close to the operational limit for some key subsystems. In preparation for the 2012 flights the S-HIS team worked with NASA DFRC to plumb outside air through the zone 25 through a 3” diameter tube. There are 5 different flexible heat straps that couple key areas on the S-HIS instrument to heat exchangers that are thermally coupled to the flow stream. These areas are the ambient blackbody, the Stirling cooler expander and compressor (interferometer box), the electronics box, and the data storage computer box. Each of the unique thermal straps were designed and fabricated by UW SSEC. Table 1 shows key information for each strap and the anticipated flight temperatures that will result from the implementation of the new thermal scheme. The expected performance is based on an ambient instrument environment of -11 °C (based on experience from the 2011 flights), and an effective cooling air tube temperature of -50 °C.

Table 1: Key Thermal Strap Information with Predicted Performance

	ER-2 Source Temp (C)	ER-2 Enclosure Temp (C)	GH Source Temp (C)	GH Enclosure Temp (C)	Power Input (W)	Strap Length (in)	Number of strap wires	Strap wire gage	Wire Area (kcmil)	Strap Thermal R (K/W)	Strap Conducted Power (W)	Predicted GH Source Temp (C)	Predicted GH Enclosure Temp (C)
ABB	-48		-8.8	-8	0	2.5	3	6	26.3	4.2	0.5	-47	--
Compressor	-22	--	12	--	11.5	5	5	4	41.7	3.2	17	-1	--
Expander	-15	--	15	--	5.8	7.1	5	6	26.3	7.1	6.9	4	--
Electronics	0	-16	23	12	52	1.94	5	6	26.3	1.9	26	12	1
Computer	21	12	37	27	52	17.5	6	4	41.7	9.2	6.6	33	23

*Note predicted temps are based on GH pod temp of -11 C and cooling tube air temp of -50 C

Table 2 shows a comparison of relevant measured temperatures for the 2011 flights and the 2012 flights with implementation of the new thermal scheme.

Table 2: Comparison of relevant measured temperatures for the 2011 flights and the 2012 flights with implementation of the new thermal scheme (@~18km altitude, takeoff+12hrs). Note that Zone 25 temperature is approximately unchanged, as desired by DFRC.

Location	2011 Temperature Original Thermal Scheme [K]	2012 Temperature New Thermal Scheme [K]
Zone 25 Temperature	260K	258K
Ambient Blackbody	262K	242K
Cooler Compressor	285K	270K
Cooler Expander	287K	273K
Electronics (Science Processor)	300K	285K
Interferometer Electronics (SEK31, trim heaters with setpoint at 295K)	315K	295K
Data Storage Computer (PCI)	320K	310K

Figure 4 and Figure 5 illustrate the new heat straps and their connection to a tube with internal heat exchangers. The left end of the tube is connected to a new forward inlet port of the Global Hawk (zone 25), and the right end to a new outlet port.

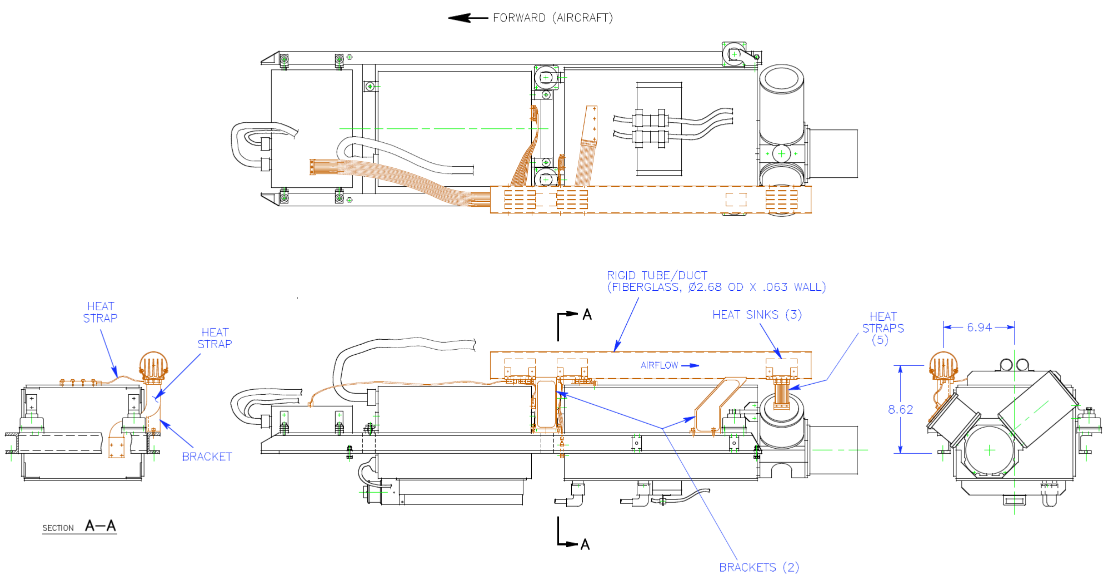

Figure 4: The new flexible heat straps that are connected to heat exchanges within a tube where outside air is forced help reduce key temperatures in the S-HIS. The end-views at lower left and right show the heat exchangers mounted inside the flow tube.

Figure 5: The Scanning HIS integrated to the Global Hawk with the heat straps (4 of 5 are visible) in place and connected to the rigid segment of the outside airflow tube.

3. Laboratory verification of S-HIS reference blackbody temperature calibration and Pre-campaign testing of S-HIS performance

There are four major phases of S-HIS radiometric calibration, outlined below. Step one is typically completed on the order of every 5 years. Steps two and four are completed pre and post mission, respectively, and step 3 describes the in-flight calibration scheme. Steps one and two were completed during the year-2 reporting period and are only summarized briefly here. Please refer to the year-2 report for further details.

1) Pre-Integration at Subsystem Level
The Scanning-HIS thermistor readout electronics are calibrated using a series of 6 fixed resistance standards, that are each calibrated to an accuracy of better than 5 mK (3-sigma) equivalent temperature, using a Fluke 8508A DMM. The Scanning-HIS On-Board Calibration Blackbody thermistors are calibrated at 10 temperatures over the range from -60 °C to 60 °C. These tests are done in a controlled isothermal environment using a NIST traceable temperature probe that is calibrated at Hart Scientific to an accuracy of 5 mK (3-sigma). Following these tests the On-Board Calibration Blackbodies and Readout Electronics are integrated to the Scanning-HIS Instrument.

Results from the blackbody calibration conducted in the spring of 2012 show insignificant change in the key temperature ranges used from the last major blackbody calibration (2004) – less than 25 mK change for the ABB, and less than 5 mK for the HBB. It is noteworthy that the duration between tests (2004 and 2012) in this case exceeds the preferred 5-year interval between tests, but the results confirm insignificant change in blackbody thermometry in this 8-year period.

The overall blackbody temperature uncertainty budget is 53 mK (3-sigma), compared with the requirement of 100 mK. This uncertainty budget reflects the current state of the art for the S-HIS blackbody temperature calibration and captures the best methods, procedures, and techniques developed at UW-SSEC for blackbody calibration.

2) Pre-Deployment Calibration Verification
Prior to each field campaign end-to-end calibration verification is performed using a variable temperate blackbody in the zenith view and an ice blackbody in the nadir view. Similar to the post-campaign tests, the radiances measured by the Scanning HIS instrument are compared to those calculated for the verification blackbodies, using the measured cavity temperature, knowledge of the emissivity, and measurements of the background temperature.

All tests showed agreement within the established instrument uncertainty of 0.2K (3-sigma). This test was conducted in the year-2 reporting period and the detailed results are provided in the year-2 report.

A description and photographs of the end-to-end calibration verification process are included in Step 4 below.

3) Instrument Calibration During Flight Using On-Board Calibration Blackbodies
During flight, the Scanning HIS earth scene radiance measurements are calibrated several times a minute using its two On-Board Calibration Blackbodies: the Ambient Blackbody runs at the pod ambient temperature (between -25 and -55 °C, depending on the local ambient environment); and the Hot Blackbody runs at 27 °C.

4) Post-Deployment Calibration Verification
Following the field campaign end-to-end calibration verification is performed. End-to-end calibration verification is conducted using a variable temperature blackbody in the zenith view and an ice blackbody in the nadir view (Figure 6). Radiances measured by the Scanning HIS instrument are compared to those calculated for the verification blackbodies, based on the measured cavity temperature, knowledge of the emissivity, and measurements of the background temperature.

The variable temperature blackbody used for Scanning-HIS calibration validation has its heritage rooted in the Atmospheric Emitted Radiance Interferometer (AERI) instrument. These blackbodies have had their emissivity measured at NIST using three methods: the Complete hemispherical infrared laser-based reflectometer (CHILR); the Thermal infrared transfer radiometer (TXR); and the Advanced Infrared Radiometry and Imaging Facility (AIRI). The Ice Blackbody is geometrically similar to the AERI Blackbody, and is coated with the same paint.

The Scanning-HIS instrument has undergone a side-by-side radiance intercomparison test with the NIST TXR, using an AERI blackbody as a transfer standard. The mean difference at 10 microns between these instruments was 38 mK - well less than the propagated 3-sigma uncertainties.

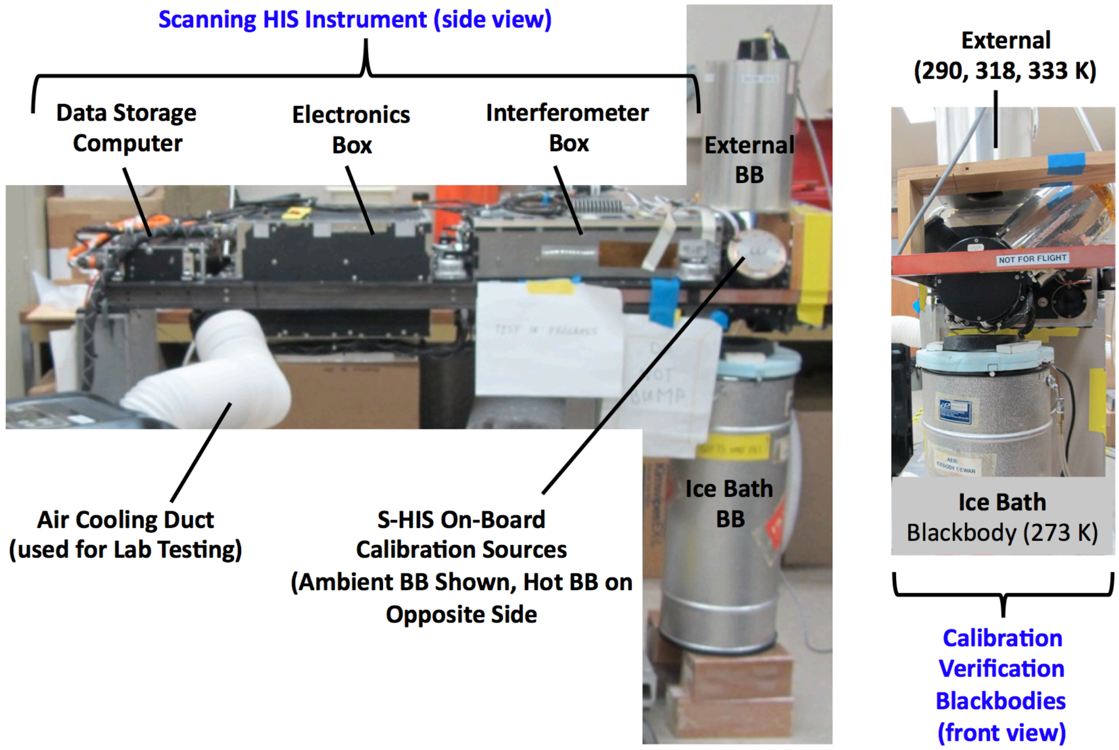

Figure 6: S-HIS radiometric calibration verification configuration.

The results from the S-HIS end-to-end calibration verification that was conducted after the 2012 HS3 field deployment are discussed below. The test configuration is shown in Figure 6.

After instrument and source set up and stabilization was completed and verified, 30 minute datasets were collected at three external blackbody temperatures (Ambient, 318K, 333K). The external blackbody temperature was allowed to stabilize before each data collection, and ice bath blackbody data was collected for the duration of the test (approximately 135 minutes). Ambient, 318K, and 33K tests showed agreement within the established instrument uncertainty of 0.2K (3-sigma). The ice bath blackbody result marginally exceeded the uncertainty estimate for portions of the LW and SW band. The differences between observed and predicted brightness temperature for the ice bath blackbody (in particular, the LW and SW bands), while small and close to our requirement, exceed our expectations and are being explored further.

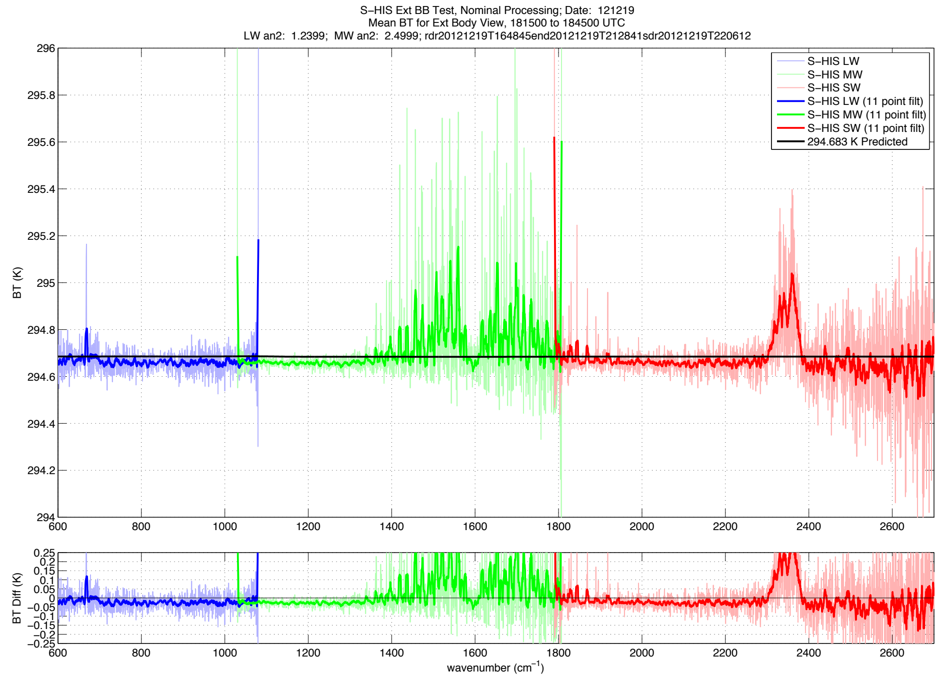

Figure 7: Radiometric calibration verification, external blackbody at ambient.

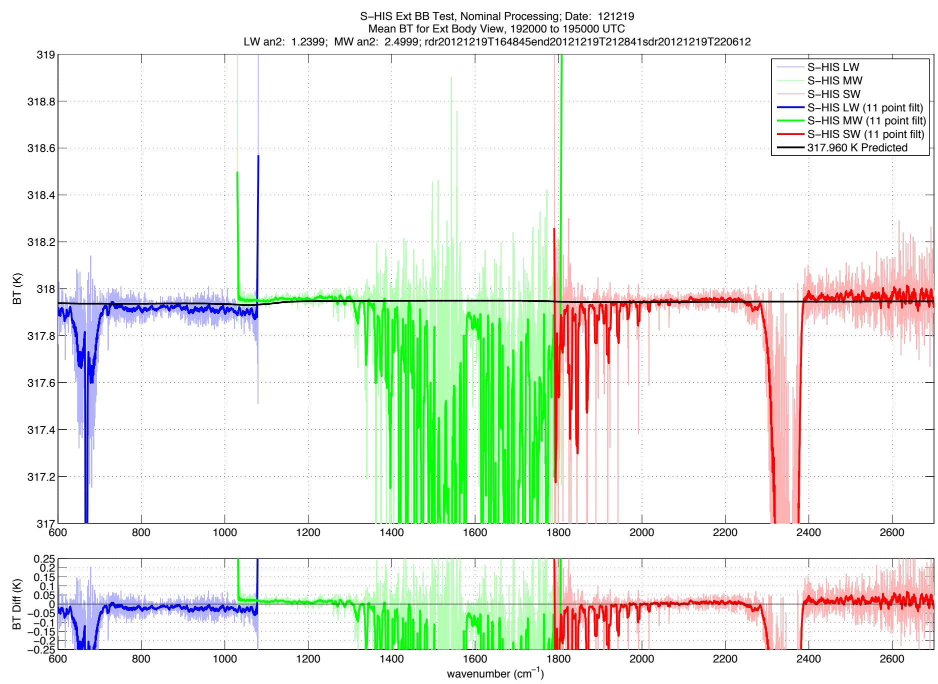

Figure 8: Radiometric calibration verification, external blackbody at 318K.

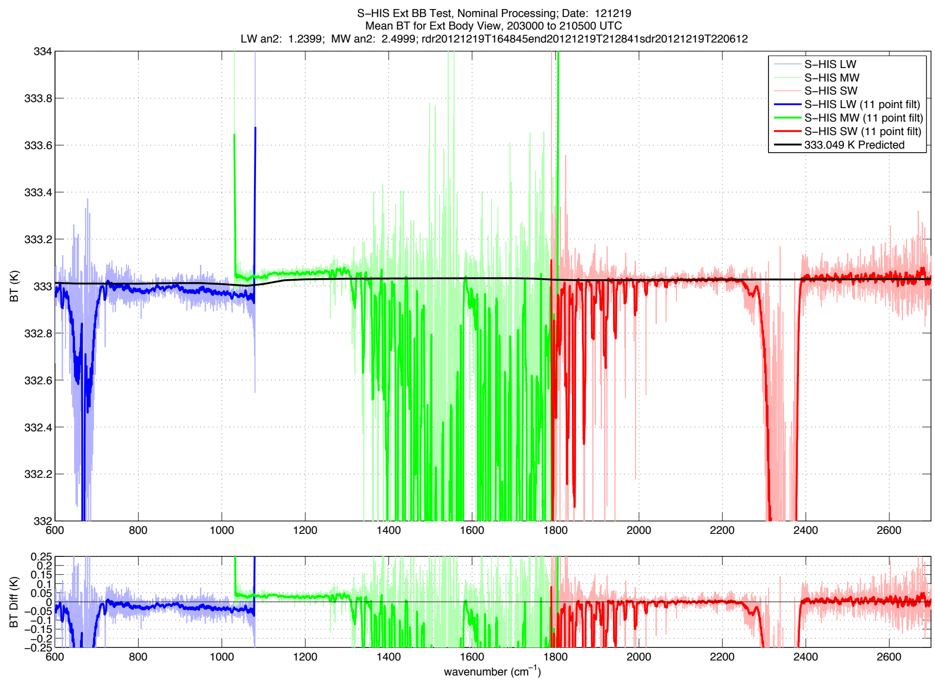

Figure 9: Radiometric calibration verification, external blackbody at 333K.

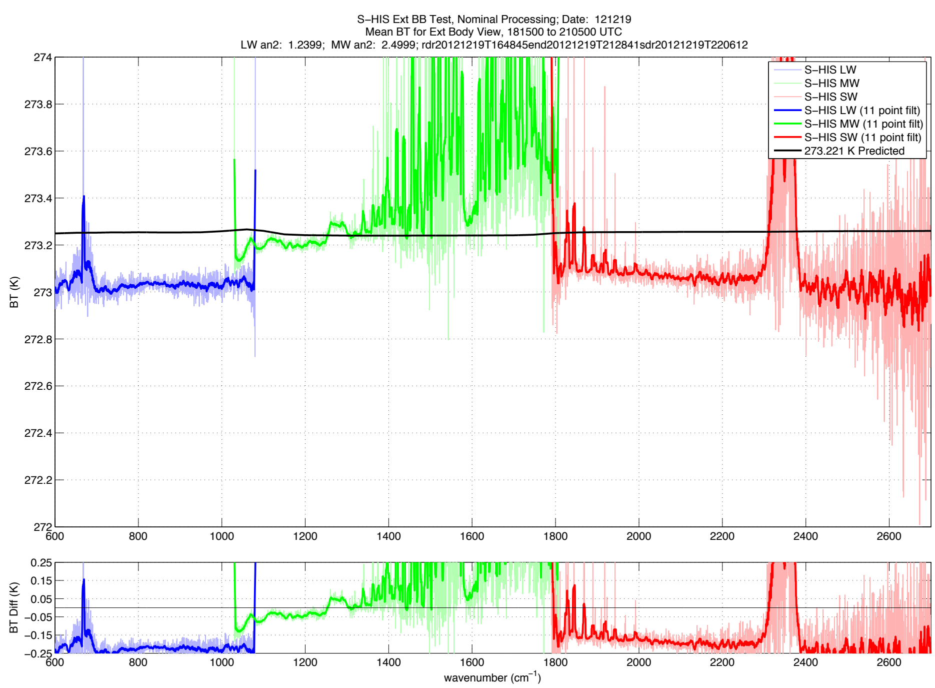

Figure 10: Radiometric calibration verification, ice bath blackbody.

If conditions and timing are sufficient during post-deployment, the Scanning-HIS also undergoes a side-by-side clear sky intercomparison using a well-characterized and calibrated AERI instrument. These two radiance measurements are compared with each other and the radiance calculated from a locally launched radiosonde. This is not a required activity for pre-deployment calibration verification. For the 2012 HS3 post-deployment calibration verification, conditions and timing did not allow for a clear sky intercomparison.

4. Follow-up development and optimization of architecture and software to implement real-time, near real-time, and long term data handling, processing, and display for long duration Global Hawk flights.

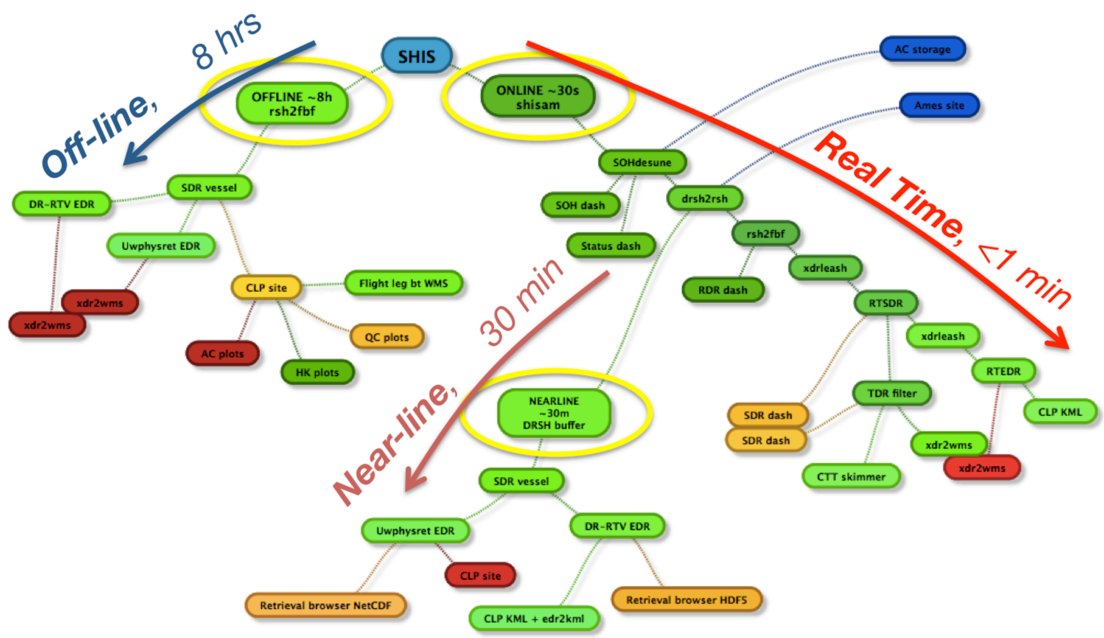

Figure 11: S-HIS HS3 data processing paths.

There are three S-HIS HS3 data processing paths: (1) Offline batch post processing, (2) near-line processing (30 minute latency), and (3) real-time processing (~45 second latency). These data processing paths are illustrated in Figure 11. The batch offline post-processing and real-time processing are summarized in the following sub-sections.

1) Post-processing of Radiance Calibration and Atmospheric Retrieval

Following each flight the UW team downloads the complete raw dataset collected onboard the S-HIS instrument and subsequently uploads the dataset to the SSEC at Wisconsin for post-processing. This post-processing consists of a sequence of batch scripts, which execute custom calibration software for the conversion of interferograms to radiances. A GH flight of 24 hours can be processed in about 4 hours of wall clock time on a dedicated computer at the UW-SSEC. The processing of raw data to radiances is fully tested and automated. Once the radiances are available, the UW team has custom software for the retrieval of temperature and water vapor profiles and cloud heights. Two independent retrieval algorithms have been developed, a Dual Regression algorithm that provides cloud heights for cloudy scenes, and UWPhysRet that is a clear sky algorithm (see Section 5). The retrievals for temperature, water vapor retrieval, and clouds were compared with collocated dropsonde (AVAPS) and lidar (CPL) data for the HS3 2012 flights (examples are provided in Sections 1 and 5). Retrieval algorithms were fully automated during this reporting period. Quick-look product images, comparison plots, and final data products were made available during this reporting period. Final products and Matlab readers for the data products are delivered via the SSEC ftp server. New users are required to register with an email address for contact information such that a distribution list can be easily maintained for product announcements and updates. A web link to the S-HIS HS3 data product distribution is included at the ESPO HS3 webpage: http://espo.nasa.gov/missions/hs3/data_products. The direct link is http://download.ssec.wisc.edu/sys/login/form/hs3_shis.

2) Real-time Radiance Calibration and Atmospheric Retrieval (Hoese et al, 2013)

The S-HIS instrument data downlink methodology has evolved over time with the technology available and over aircraft platforms. Initially, S-HIS data was primarily retrieved from internal storage on the instrument after landing and processed post-flight. In some cases, a small amount of data was provided via status packets or state of health (SOH) packets. These packets hold a minimal amount of information to verify that the instrument is operating as expected and can't be used for high level scientific analysis. For lab or "fly-along" DC-8 airborne lab use, when direct connections to the instrument are possible and not bandwidth limited, a scientist uses a direct TCP network connection to subscribe to data in real-time. A TCP connection is a protocol for communicating over a network in an ordered and reliable way. This TCP connection method was known as an RSH stream (Raw Scanning-HIS). The RSH TCP connection provided data that, in the lab, was used in combination with a graphical user interface to monitor instrument function and calibration.

The HS3 mission on the Global Hawk marks the first time that real-time S-HIS science data is downlinked, processed, and made available to scientists on the ground within 1 minute of observation. The ability to view real-time S-HIS observations allows scientists to quickly analyze the storm formation, and allows real-time mission planning, inclement flight weather avoidance as well as tracking the instrument state of health. For the HS3 mission, a new method was developed named DRSH (Datagram Raw Scanning-HIS). A datagram or UDP connection is an unordered, connectionless protocol for sending data. This means that the software must handle the potential for out of order and even missing data, and also that data connections are unidirectional and use less bandwidth than a RSH TCP connection. A connectionless protocol like UDP is important when operating on the Global Hawk because of the possibility of satellite communication outages for extended periods of time, and to permit security guarantees to the aircraft by operating as an egress-only data relay.

S-HIS data goes through a series of connections to push data from the aircraft to processing machines on the ground. Starting as a DRSH packet sequence from the instrument, the data goes through the aircraft network and is sent over a KU band satellite connection to routing computers on the ground. The routing computers are configured by NASA's IT team to forward S-HIS's DRSH packets from the aircraft payload network to a processing computer in the Payload Mobile Operations Facility (PMOF) at the Wallops

Flight Facility (WFF) and a server at the UW SSEC. The path to the SSEC is made longer by a required detour to Dryden Flight Research Center. Once these machines receive the data, software validates packets and reassembles the RSH data stream, handling any missing or out of order pieces of information. The data is then processed, and radiances and retrieved temperature and water vapor products are made available via GUI software and web services used by the Global Hawk Mission Tool Suite.

S-HIS offers three levels of data products, raw data records (RDR), scientific data records (SDR), and environmental data records (EDR). Raw data records are provided directly from the instrument and include housekeeping temperatures and measurements, blackbody temperatures, and raw observed interferograms. Through radiometric calibration using reference blackbody spectra, RDRs are used to create calibrated absolute radiance spectra SDRs that can in turn be represented as brightness temperature spectra. Through a second, longer, software processing step, SDRs and numerical weather prediction (NWP) data are used to create EDR atmospheric profiles. For purpose of real-time efficiency, a principal component-based dual regression technique was applied to rapidly compute atmospheric profiles. The algorithms used in both SDR and EDR processing are fast enough to produce values within seconds of reception. Real-time processing goes through all of these product levels providing as much useful data to instrument engineers and HS3 scientists as possible.

The state of health of the S-HIS instrument is monitored in real-time in the PMOF at WFF using graphical displays. Once DRSH packets reach the processing machine in the PMOF, RDR processing is performed and then displayed in a graphical user interface known as the S-HIS Dashboard. The Dashboard provides time series of temperatures and spectra for the last 200 measurements (approximately 100 seconds). It also displays the values of various instrument housekeeping sensors, and whether they are within their acceptable operating ranges. Further displays are available for Status and State-of-Health (SOH) packets, for use in the case of a Ku communication outage or if DRSH data is otherwise not available.

Furthermore, collaborating scientists can view the real-time downlinked S-HIS data products through the NASA Mission Tools Suite website or the SSEC S-HIS website, during flight, from anywhere in the world. Data is provided to both of these services via processing on a server at the SSEC. Once a full observational “block” of DRSH packets is received the data is sent to RDR processing software. Once complete, the RDR software then wakes SDR processing, which then wakes EDR processing. For each SDR record that is produced a piece of software called “sdr2wms” adds the brightness temperature data to WMS layers, represented as GeoTIFF image fragments with metadata. WMS layers can be viewed in Mission Tools or Google Earth to see geo-located real-time measurements made by S-HIS. In addition to the WMS software, scripts are run at regular intervals to produce various quick-look images of the SDR brightness temperatures and EDR atmospheric profiles. These scripts make these quick-looks available on the SSEC S-HIS website as geo-located PNG images and as dynamic KML markers that can be viewed in Mission Tools or Google Earth. KML markers are clickable icons on a map that open a separate window for viewing the quick-look images.

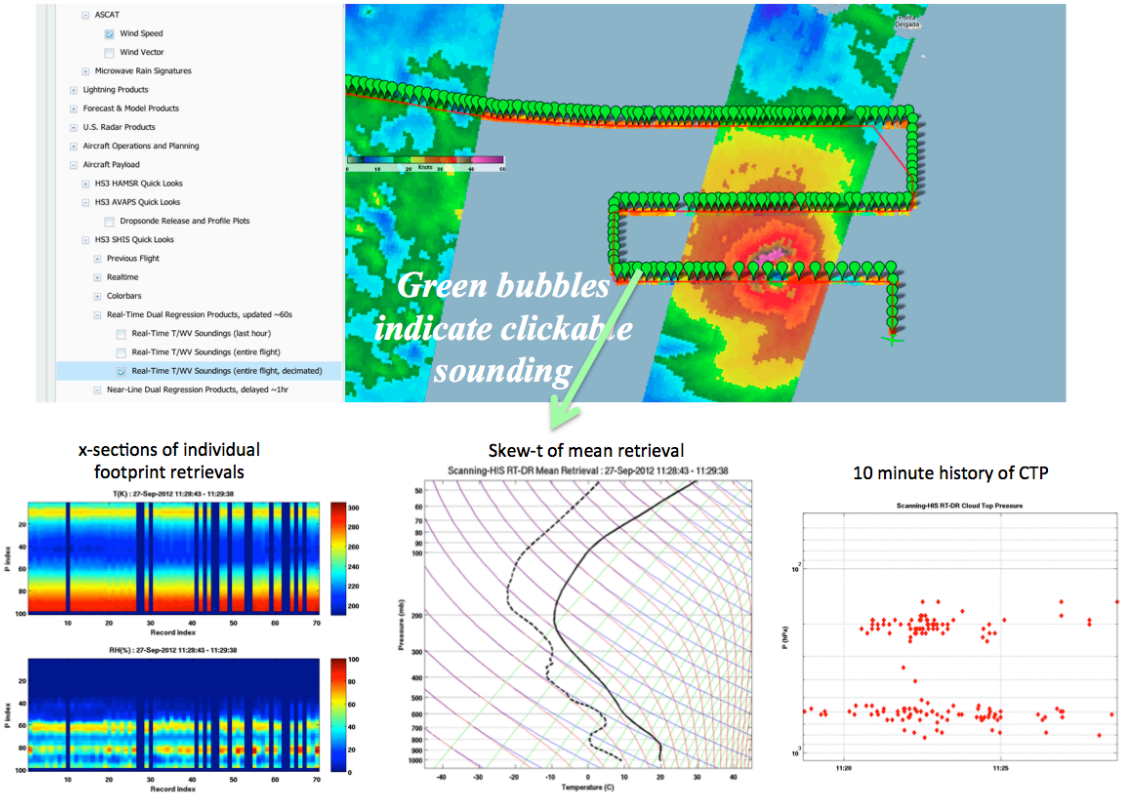

Figure 12: S-HIS Real-time Dual Regression retrieval products.

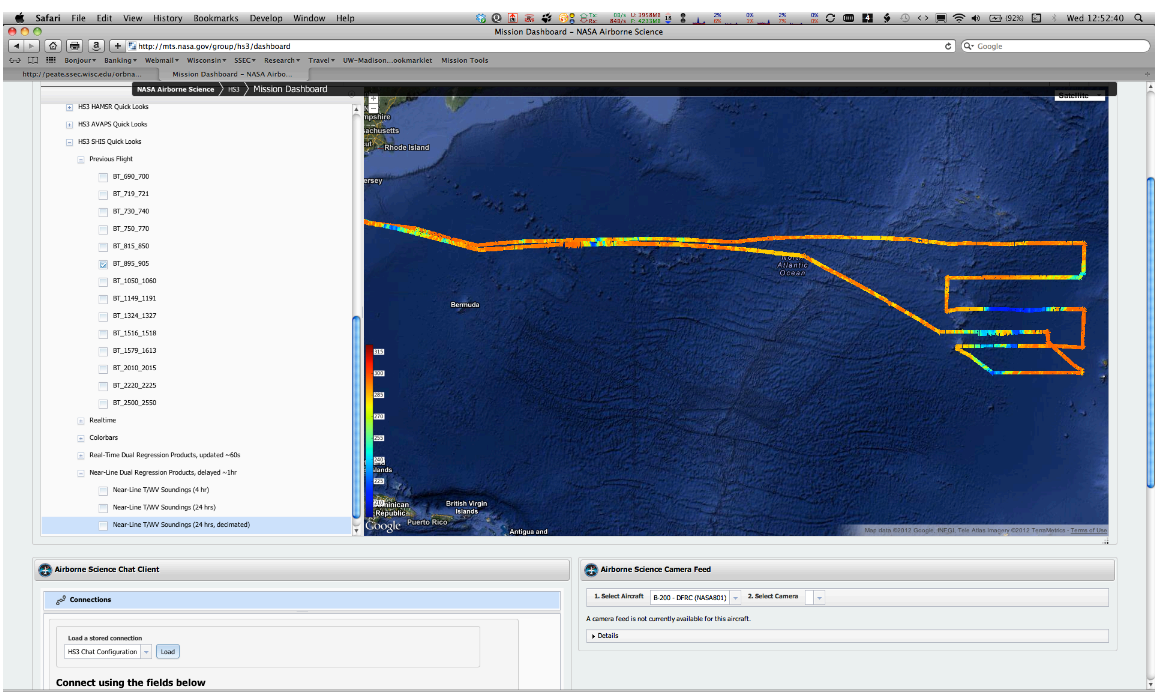

Figure 13: Example S-HIS WMS layer in NASA MTS (S-HIS 900cm^{-1} Brightness Temperature).

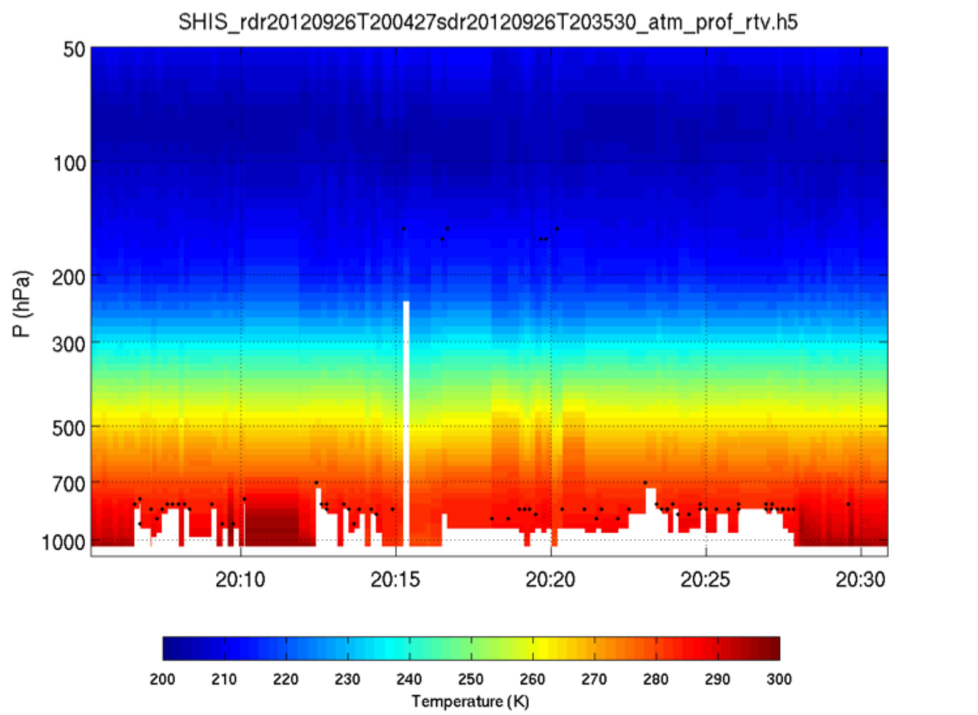

Figure 14: Example real-time temperature profile retrieval delivered via S-HIS website.

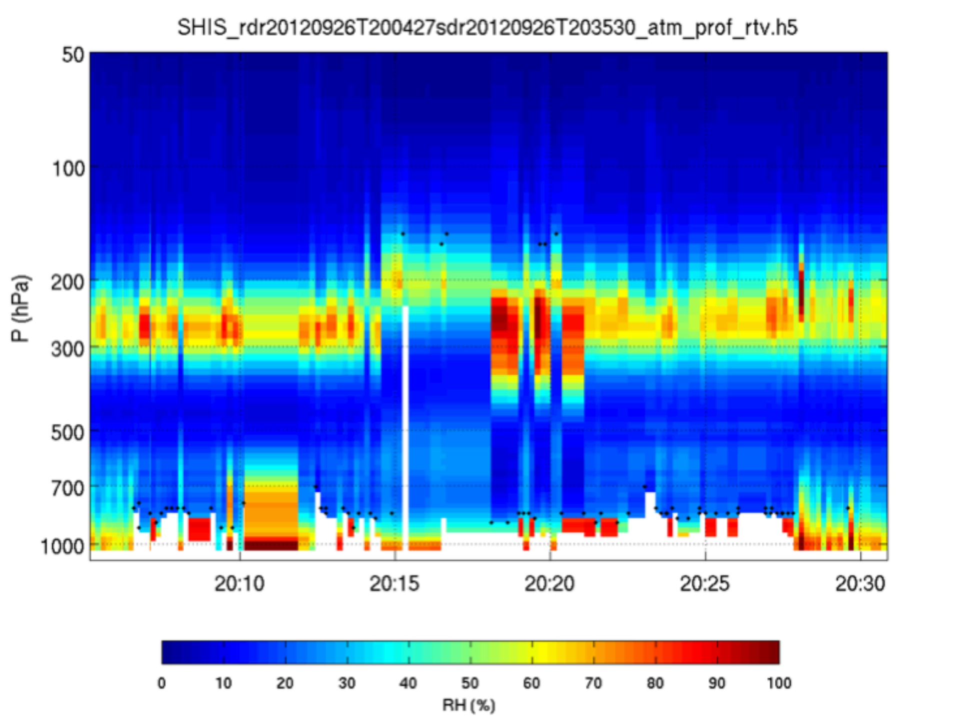

Figure 15: Example real-time relative humidity profile retrieval delivered via S-HIS website.

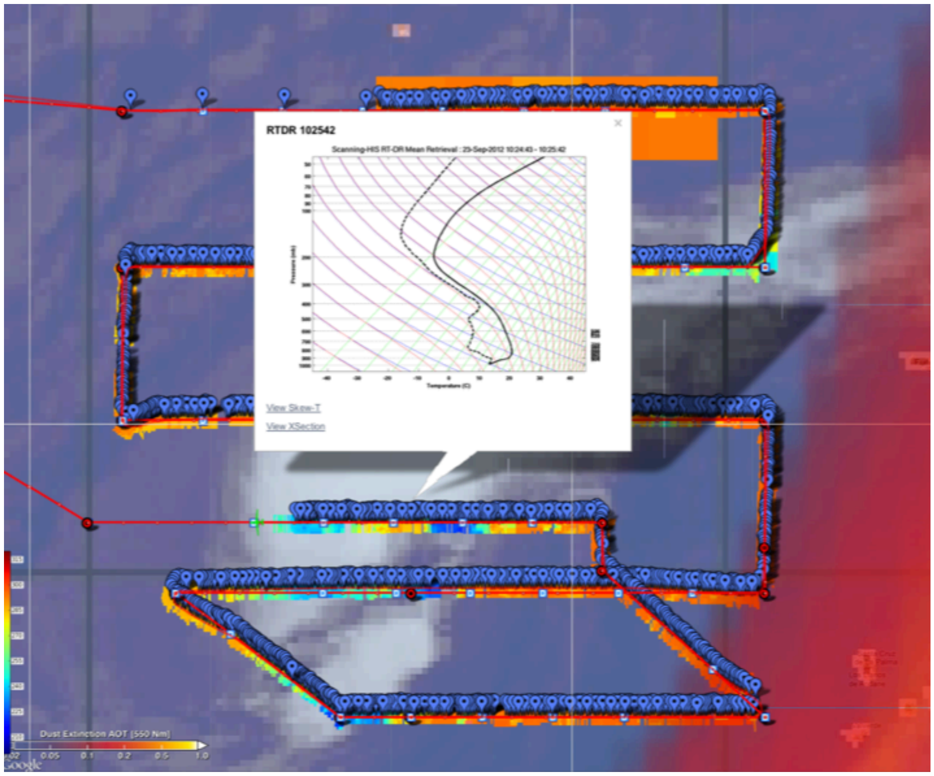

Figure 16: Example Skew T profile delivered in real-time via kml markers in NASA MTS.

*D. Hoese, C. Barnes, F. Best, R. Garcia, J. Gero, R. Knuteson, H. Revercomb, D. Sullivan, J. Taylor, D. Tobin, D. Vangilst, and E. Weisz, "**Real-time Ground Data Processing for the Airborne Scanning High-Resolution Interferometer Sounder**," in Imaging and Applied Optics, J. Christou and D. Miller, eds., OSA Technical Digest (online) (Optical Society of America, 2013), paper FM1D.2*

5. Optimization and implementation of improved temperature, water vapor, and cloud retrieval capabilities

1) Scanning-HIS Dual Regression Retrieval

To provide atmospheric retrievals under all-sky conditions, the "Dual Regression" retrieval algorithm has been adapted for the Scanning-HIS on the Global Hawk. This retrieval approach has been used previously for other high spectral resolution IR satellite sensors including AIRS, IASI, and CrIS, and provides retrievals of temperature and water vapor profiles, various cloud parameters, column ozone and carbon dioxide, and surface pressure and temperature (Smith et al. 2012). This work was performed primarily by Drs. Elisabeth Weisz and William Smith, with coordination provided by Dr. David Tobin.

The S-HIS DR retrieved temperature and water vapor results were compared with collocated AVAPS profiles. A two-minute mean of S-HIS DR temperature and water vapor profiles were plotted on a skew-T diagram for each AVAPS dropsonde during the 2012 HS3 campaign.

An example image from 7-Sept-2012 HS3 sortie is provided in Figure 17. A similar image was created for each AVAPS dropsonde during the campaign. The left panel shows a skew-T diagram that includes the dropsonde (black), S-HIS DR mean retrieval (green) and GDAS model (magenta) profiles; where dashed-lines represent dewpoint temperature and solid lines indicate temperature. The top right image shows the CPL depolarization for a two-minute window centered around the dropsonde time, used to illustrate the nadir cloud conditions for the given dropsonde. This example was for a clear sky measurement, consistent with the DR retrieval shown in the skew-T. A geolocation sanity check is provided in the lower right. This image shows the S-HIS surface projected points (circles; green suggests no cloud while red specifies a positive cloud retrieval) and the dropsonde position during its descent (black x).

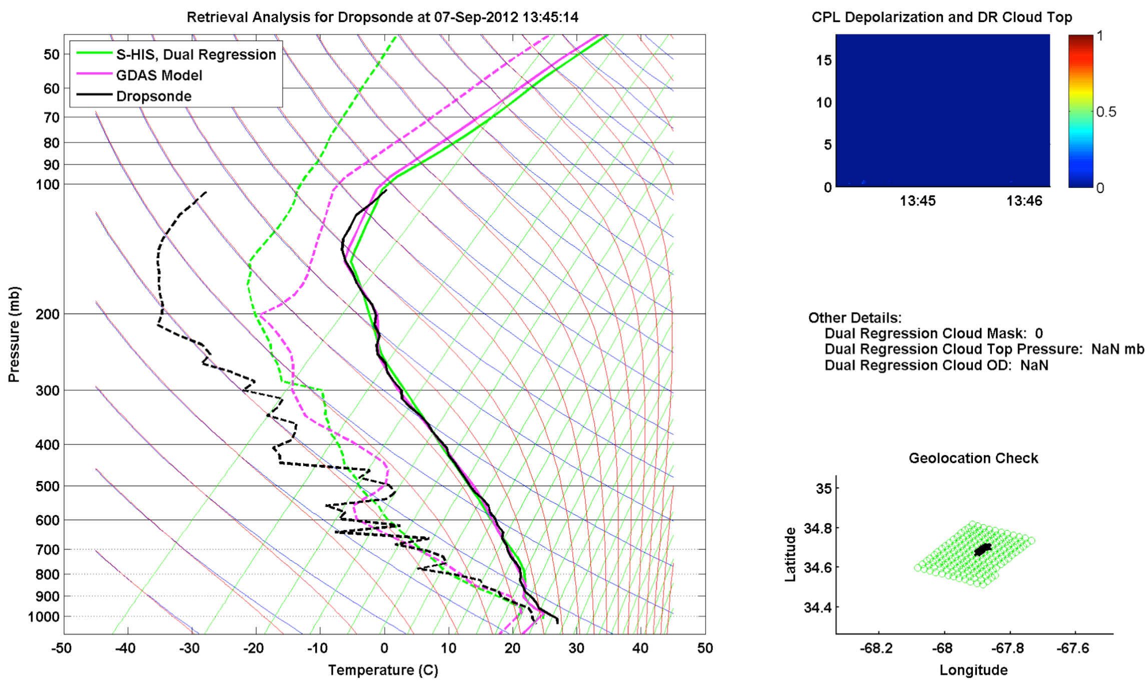

Figure 17: Sample DR Profile comparison to Dropsonde & GDAS; 07 Sept 2012.

Daily-mean, four-panel images representing S-HIS DR retrievals relative to AVAPS dropsondes were also created for each HS3 mission sortie. Data were compiled with respect to relative humidity (RH) and water mass mixing ratio (H2OMMR). Data were also filtered based on DR retrieved cloud top pressure limited to 700 mb. An example four-panel image is provided in Figure 18. The first panel shows the mean daily temperature profile for each dropsonde (black) and corresponding two-minute mean S-HIS DR retrieval (green); panel 2 shows the difference from mean ($T_{DR} - T_{AVAPS}$) and its standard deviation; panel 3 shows the same as panel 1, but for relative humidity (note the significant dry bias in the dropsonde above 400 mb); and panel 4 shows the difference from mean for RH, along with its standard deviation ($RH_{DR} - RH_{AVAPS}$).

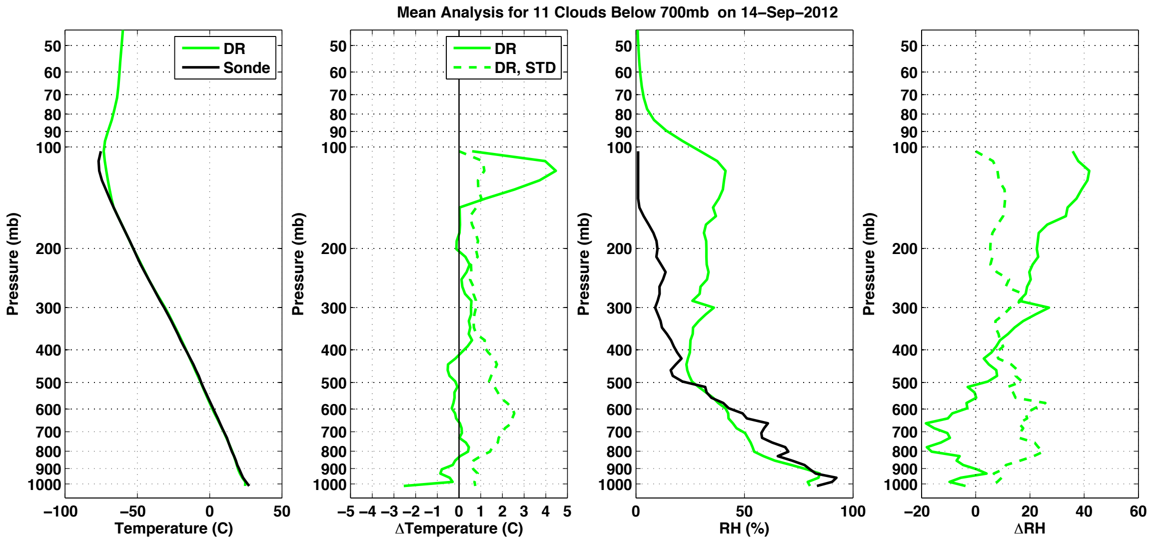

Figure 18: A daily-mean, four-panel image representing S-HIS DR retrievals relative to AVAPS dropsondes was created for each HS3 mission sortie. The dry bias of the dropsonde above 400 mb is a consistent feature.

Nadir S-HIS DR retrieved cloud top pressure and optical depth were also compared to collocated Cloud Physics Lidar (CPL) measurements for all flights. An example of the comparison for the 2012-09-14 flight is shown in Figure 19. The top panel shows the CPL log-extinction as a function of time for the entire flight. The DR cloud top pressure was overlaid upon the CPL image with a black dot for each collocated DR cloud top that was retrieved. The bottom left image shows the collocated flight track for the given sortie, where black indicates high cloud and white indicates low cloud (or clear sky). The adjacent image is a density scatterplot showing the collocated DR cloud top heights relative to CPL. Data are filtered to exclude non-uniform scenes (i.e., CPL Z STD < 2 km). The bottom right-most image provides a summary classification of all collocated S-HIS DR and CPL measurements for the flight, and the neighboring panel to the left shows a histogram of the collocated S-HIS DR – CPL cloud top height differences, applying the same non-uniform scene filter used for the density scatterplot.

The S-HIS team compiled the same statistics for the entire 2012 HS3. The analysis was extended to determine the effects of cloud optical depth for cases where the S-HIS DR did not discern the presence of cloud. Data was further broken down to clouds above (or below) 5 km. Mean collocated CPL data were used for both OD and cloud top height in this analysis. The results of the analysis are presented in Figure 20.

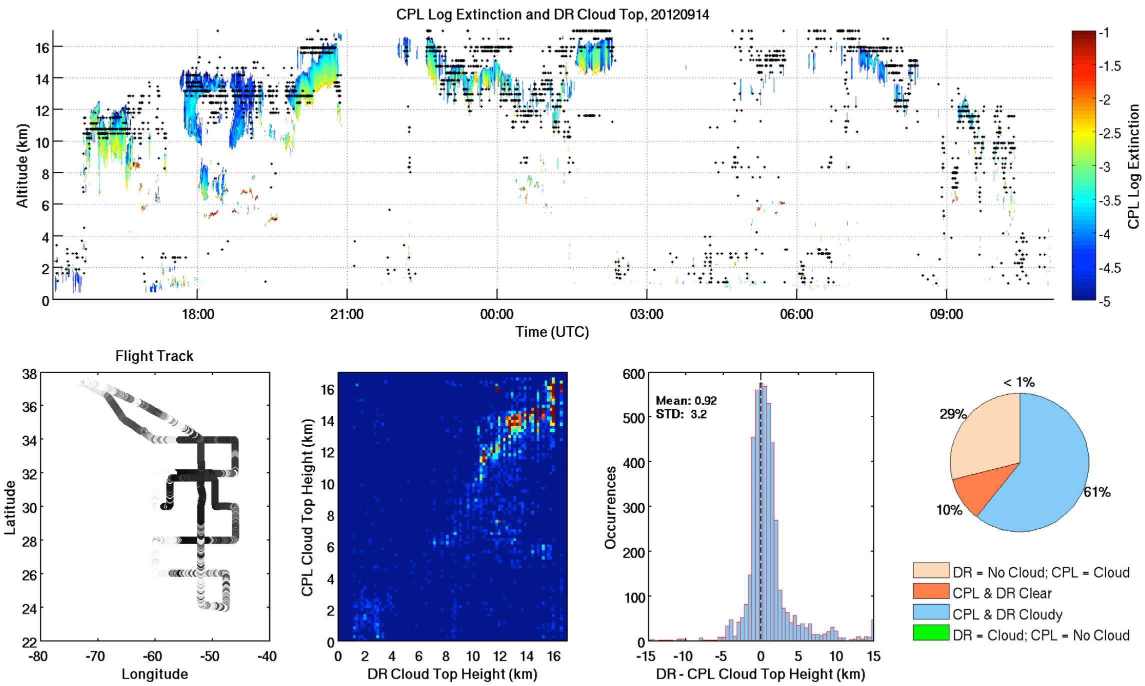

Figure 19: Example comparison of S-HIS DR retrieved cloud top pressure and optical depth and collocated Cloud Physics Lidar (CPL) measurements

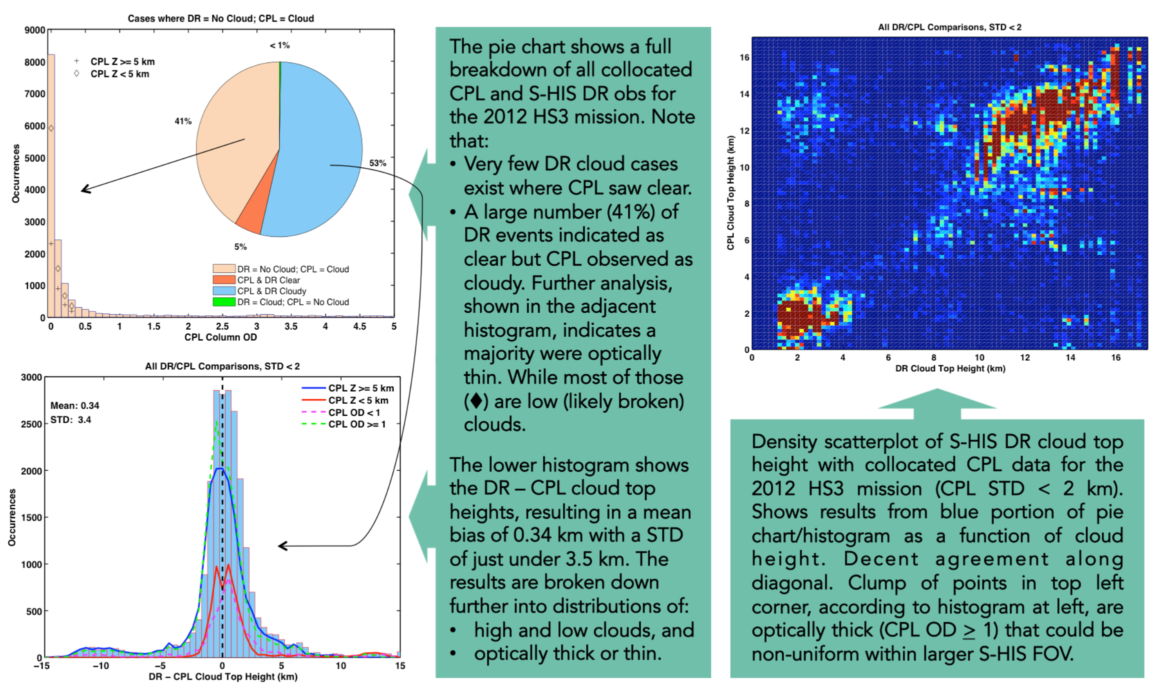

Figure 20: Statistical comparison of S-HIS DR retrieved cloud top pressure and optical depth and collocated CPL measurements for 2012 mission.

Smith, William L. Sr.; Weisz, Elisabeth; Kireev, Stanislav V.; Zhou, Daniel K.; Li, Zhenglong and Borbas, Eva E. ***Dual-regression retrieval algorithm for real-time processing of satellite ultraspectral radiances.*** *Journal of Applied Meteorology and Climatology, Volume 51, Issue 8, 2012, 1455–1476. Reprint #6809.*

2) UWPHYSRET Physical Retrieval Algorithm

A research algorithm developed at the University of Wisconsin for use with satellite data has been implemented for processing Scanning-HIS data during the HS3 mission. This method is based on the Rodgers (2000) methodology of maximum a posteriori probability (MAP) estimation, also known colloquially as Optimal Estimation. The software package developed at the UW-SSEC is called UWPHYSRET. The initial implementation of this algorithm used the LBLRTM line-by-line model from AER, Inc. as the forward operator. This method is very slow, but allows the detailed properties of the retrieval to be accurately evaluated for selected clear case studies. During this reporting period, this retrieval scheme was modified to run much faster by using the OSS forward model that was tuned by AER to accurately agree with LBLRTM. It is now practical to explore a larger set of case studies. UWPHYSRET also provides uncertainty estimates along with the estimate of profile temperature and water vapor values. An example UWPHYSRET derived relative humidity profile is provided in Figure 3 (Section 1).

6. Support of Science Team

The Scanning HIS group supported periodic Science Team telecons during the reporting period in addition to the Science Team meeting on May 7-9, 2013, where PI Henry Revercomb presented a summary of S-HIS status, 2012 real-time data collection and processing, and refined offline processing and results. The following posters were presented by the S-HIS team at the 2013 HS3 Science Team Meeting:

- S-HIS Dual Regression Analysis Relative to AVAPS and CPL Measurements, Dan Deslover et al;
- S-HIS Real-time Processing and Data Transport, David Hoese et al;
- S-HIS Radiometric Calibration and Performance, Joe Taylor et al.

These posters and presentation are available on the HS3 webpage at:
http://espo.nasa.gov/missions/hs3/content/HS3_Science_Presentations

7. UW HS3 Year 3 Summary of Accomplishments

Year 3 activities by our University of Wisconsin Space Science and Engineering Center team supporting Scanning HIS successfully provided real-time, and quality controlled final radiance and retrieval products for the first year of the NASA HS3 mission hurricane flights. Final products have been made available for distribution. Major accomplishments include

- Successful operation of the Scanning HIS on long duration Global Hawk flights has been demonstrated, with greater than 99% up-time from takeoff to landing,
- Accurate radiance spectra from all science flights have been processed and temperature/water vapor profile products show reasonable agreement with dropsonde and HAMSR microwave results,
- Improvements to the aircraft thermal environment to enhance calibration accuracy and reduce operational risks from high electronics temperatures were implemented and verified.

- S-HIS calibration reference accuracy has been verified,
- Data handing and processing for real-time and near real-time processing were operational for all science flights, with products displayed in NASA MTS and via webpage quick-looks,
- Improved retrieval capabilities have been implemented, including a physical retrieval for clear sky (UWPhysRet) and a dual regression capability for cloudy skies, and
- Active participation in the annual science team meeting and in team telecons.
- Quick-look product images, comparison plots, and final data products were made available during this reporting period. Final products and Matlab readers for the data products were delivered via the SSEC ftp server. A web link to the S-HIS HS3 data product distribution is included at the ESPO HS3 webpage: http://espo.nasa.gov/missions/hs3/data_products. The direct link is http://download.ssec.wisc.edu/sys/login/form/hs3_shis.