Year-4 Report

University of Wisconsin, Space Science and Engineering Center
Scanning High-resolution Interferometer Sounder (S-HIS) Participation in HS3

NASA Grant NNX10AV08G

Hank Revercomb, PI

05 August 2014

HS3 Year-4 Final Report
University of Wisconsin, Space Science and Engineering Center
Hank Revercomb, PI

Introduction

This is the Year 4 report for the time period 9/1/2013 - 8/31/2014 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 include:

(1) Support of S-HIS for flights conducted in the reporting period (range, transit, and science) and subsequent data analyses;
(2) Pre-campaign and post-campaign testing of S-HIS performance;
(3) Ongoing 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;
(4) Development and implementation of improved temperature, water vapor, and cloud retrieval capabilities; and
(5) Support HS3 Science Team teleconferences and the Science Team Meeting April 29 – May 1, 2014.

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

The UW S-HIS team supported instrument integration onto NASA Global Hawk AV-6, as well as range, transit and science flight operations. Activities formally within this reporting period include:

(1) Science flight support:
  - 2013-09-04: Tropical Storm Gabrielle
  - 2013-09-07: Tropical Storm Gabrielle
  - 2013-09-16: Tropical Storm Humberto
  - 2013-09-19: Pouch 37, Invest 95

(2) Transit flight support:
  - 2013-09-26: Transit flight from NASA Wallops Flight Facility (WFF) to NASA AFRC

(3) De-integration of S-HIS from AV-6 at NASA AFRC

Activities completed in the 2013 HS3 flight season, but formally within the prior reporting period include:

(1) Integration of S-HIS onto AV-6 at NASA AFRC, including support of the range flight conducted on 2013-08-01.
(2) Transit flight support:

- 2013-08-16: Transit flight from NASA AFRC to NASA WFF

(3) Science flight support:
- 2013-08-20: Former Tropical Storm Erin, Saharan Air Layer
- 2013-08-24: Saharan Air Layer
- 2013-08-29: Pre-Gabrielle, Saharan Air Layer

The S-HIS instrument successfully collected high quality data from takeoff to landing for the range test flight. The AFRC to WFF transit flight was completed 2013-08-16, with return transit from WFF to AFRC on 2013-09-26. Transit flights were supported by the UW S-HIS team at the AFRC 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 2013-08-20 through 2013-10-01. The S-HIS instrument successfully collected high quality data from takeoff to landing for all science flights, with the exception of a instrument power cycle during the 2013-09-04 flight. The power cycle resulted in a loss of S-HIS data for approximately 40 minutes, and the on-duty Mission Scientist was consulted such that the timing of the power cycle did not impact critical science data.

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 and brightness temperature products are provided in Figure 1 through Figure 5

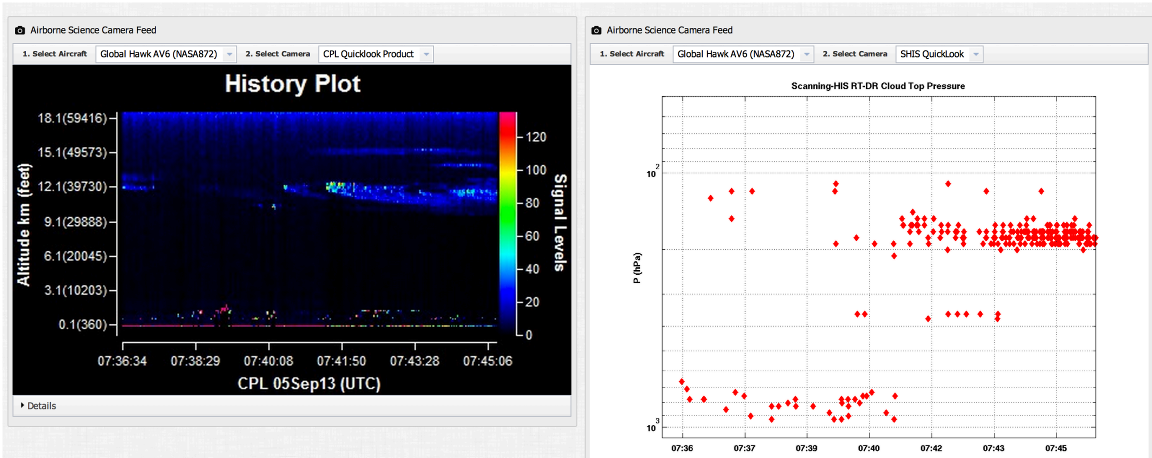

Figure 1: Comparison of CPL and S-HIS cloud top height real-time products (2014-09-04).

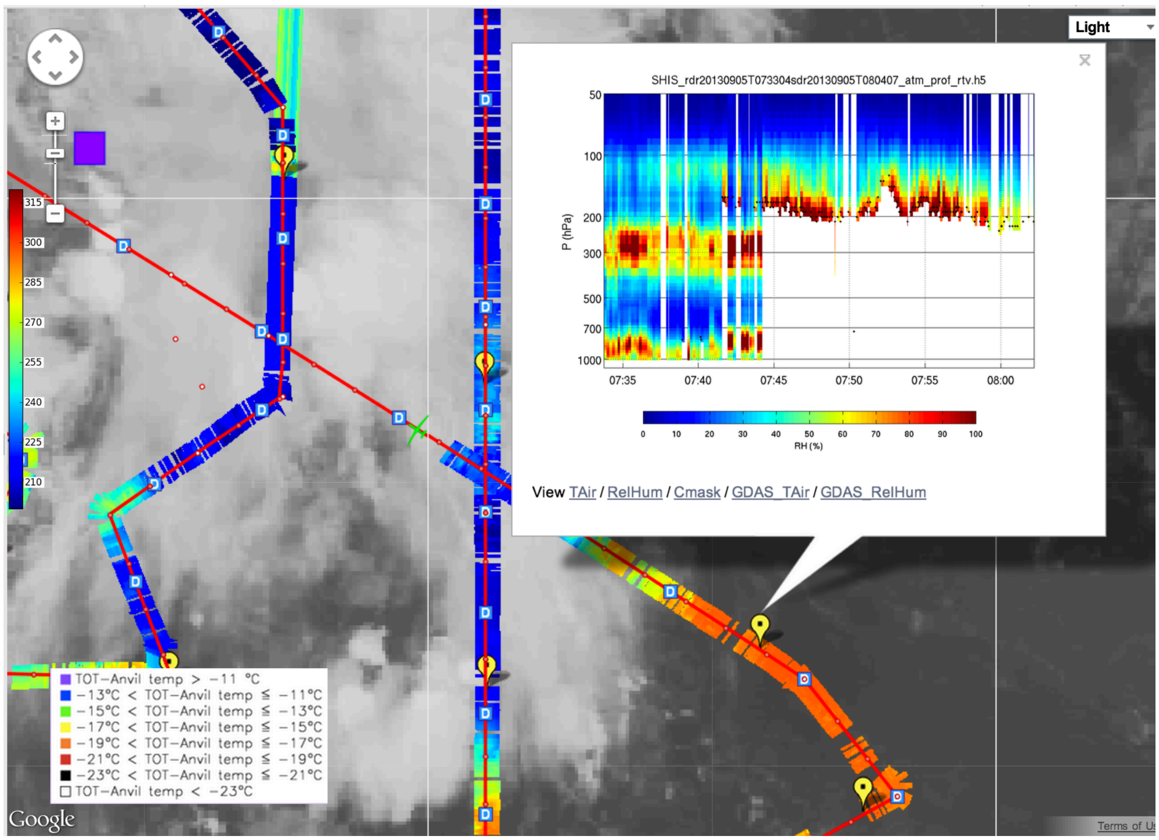

Figure 2: Corresponding 30 minute DR retrieval RH summary plot (2014-09-04).

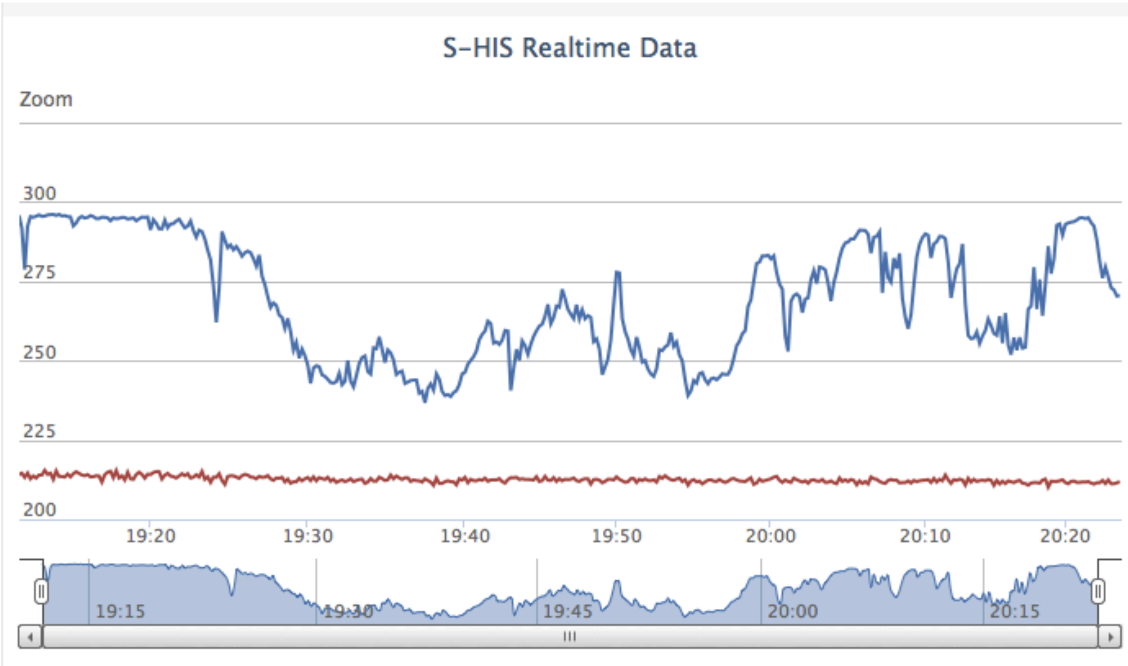

Figure 3: A new data display showing time series of realtime S-HIS brightness temperatures was tested. 895-905 cm^{-1} (blue) and 690-700 cm^{-1} (red) channels are shown above (2013-09-16).

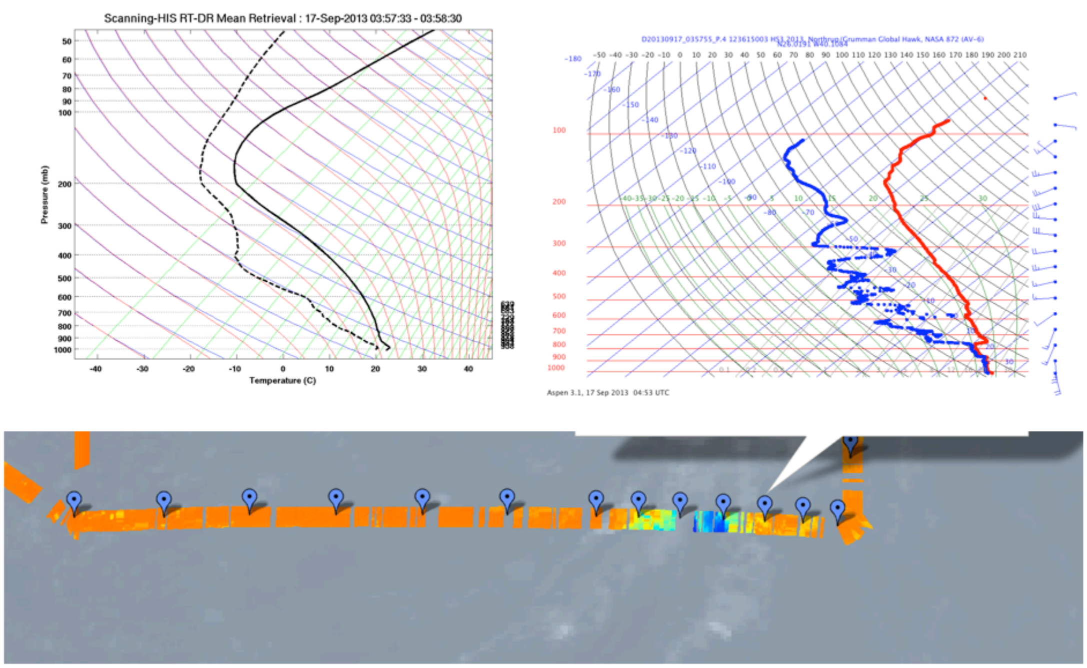

Figure 4: Relatively good agreement between SHIS temperature and moisture structure (left) with the dropsonde profiles (right). This comparison is in the SE corner of the flight where the SAL was encountered (2013-09-16).

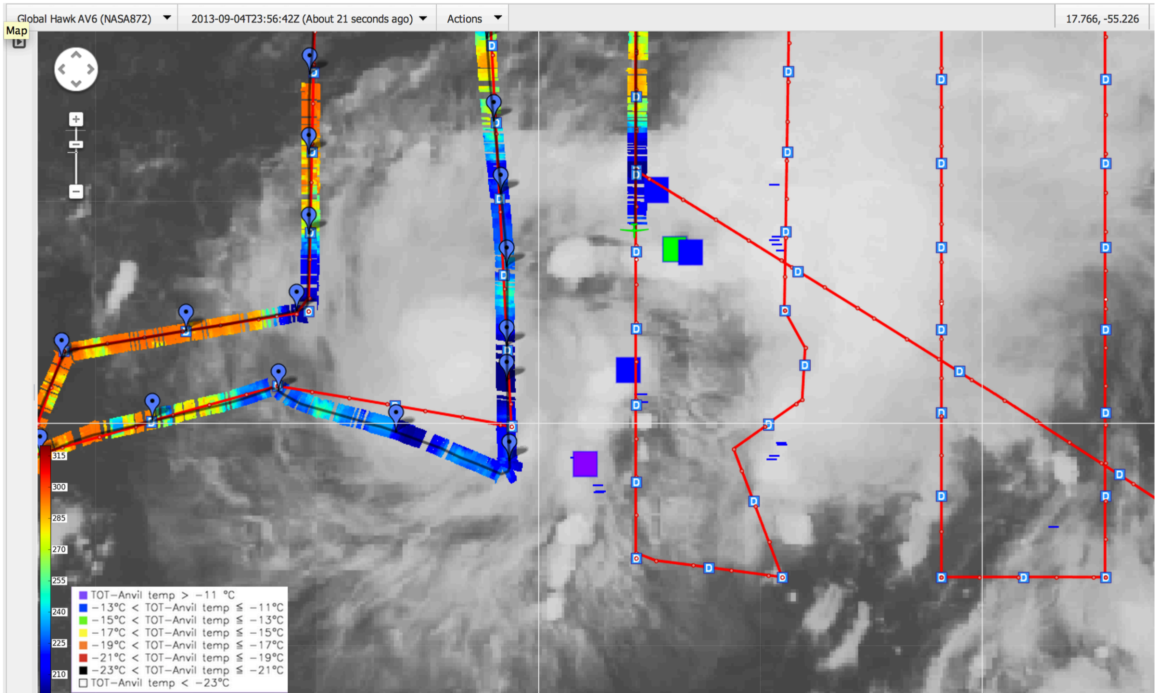

Figure 5: S-HIS 895-900 cm^{-1} Brightness Temperature image overlaid on GOES IR in MTS (2013-09-04). Overshooting tops and lightning are also indicated.

2. Pre-campaign and post-campaign testing of S-HIS performance

There are four major phases of S-HIS radiometric calibration:

1. Pre-Integration at Subsystem Level
2. Pre-Deployment Calibration Verification
3. Instrument Calibration During Flight Using On-Board Calibration Blackbodies
4. Post-Deployment Calibration Verification

Step one is typically completed on the order of every 5 years and was completed in 2012 (details provided in year-2 report). Steps two and four are completed pre and post mission, respectively, and step 3 describes the in-flight calibration scheme.

2.1. Pre-Integration at Subsystem Level

The S-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 S-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 S-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. Details of the blackbody calibration are included in the 2012 report.

2.2. 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-bath blackbody in the nadir view. Similar to the post-campaign tests, the radiances measured by the S-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 calibration and validation uncertainty (3-sigma). This test was conducted in the previous reporting period and details of the test are not included within this report.

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

2.3. Instrument Calibration During Flight Using On-Board Calibration Blackbodies

During flight, the S-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.

2.4. 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-bath blackbody in the nadir view (Figure 6). Radiances measured by the S-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 S-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-bath blackbody is geometrically similar to the AERI Blackbody, and is coated with the same paint.

The S-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.

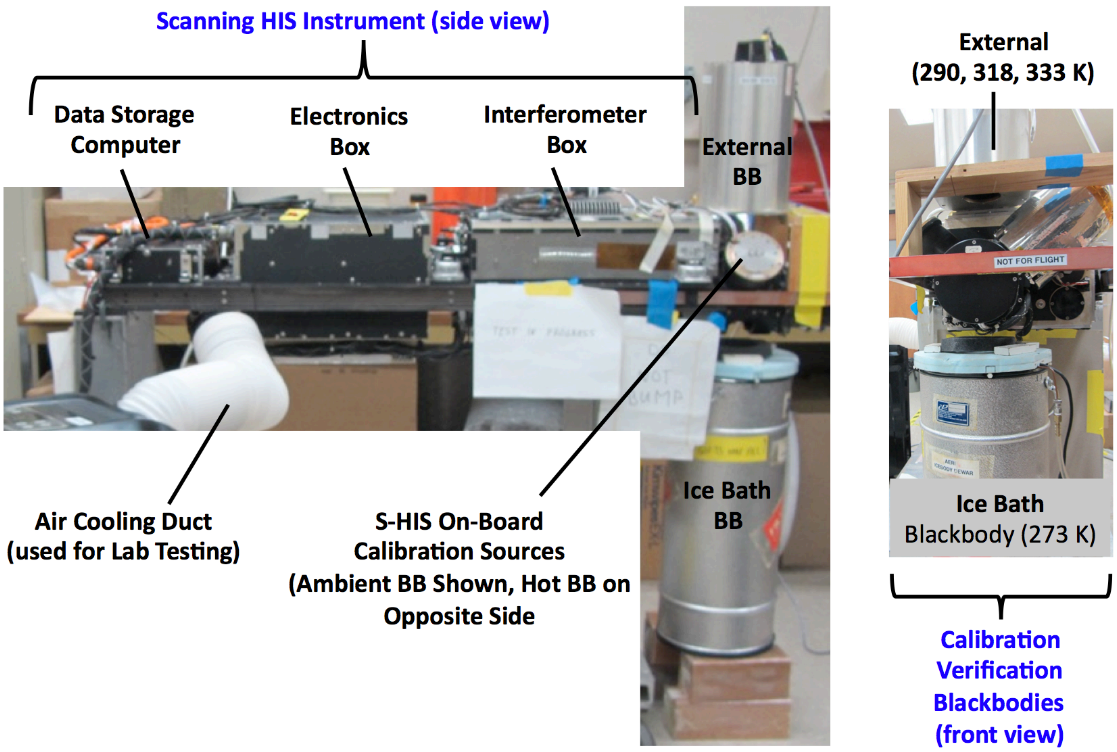

Figure 6: S-HIS radiometric calibration verification configuration.

The results from the S-HIS end-to-end calibration verification that was conducted after the 2013 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, 333K, and ice-bath blackbody tests showed agreement within the established calibration and validation uncertainty (3-sigma). Results are shown in Figure 7 through Figure 10. While the results are within the established uncertainties, the mid-wave band result for the ice-bath blackbody is not ideal. This behavior is consistent with historical results for ice-bath blackbody tests conducted in the laboratory environment. The nonlinearity correction parameters for the long-wave and mid-wave band are optimized for flight conditions, and the mid-wave result is likely due to non-optimal nonlinearity correction in the laboratory thermal environment.

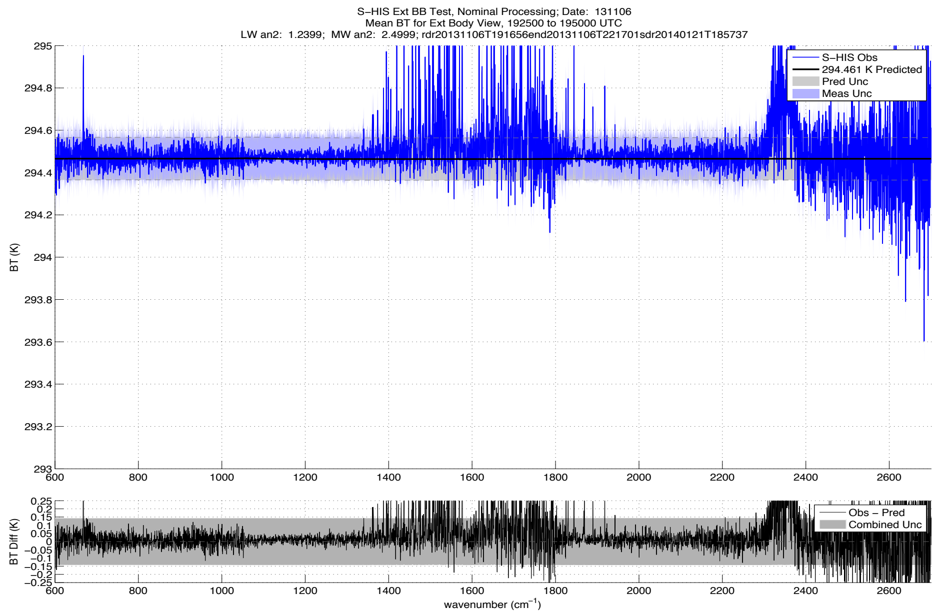

Figure 7: Radiometric calibration verification, external blackbody at ambient. The top panel indicates the predicted brightness temperature in black (uncertainty in gray), and the measured brightness temperature in blue (uncertainty in light blue). The bottom panel shows the measured – predicted difference, with combined uncertainty. All uncertainties are 3-sigma.

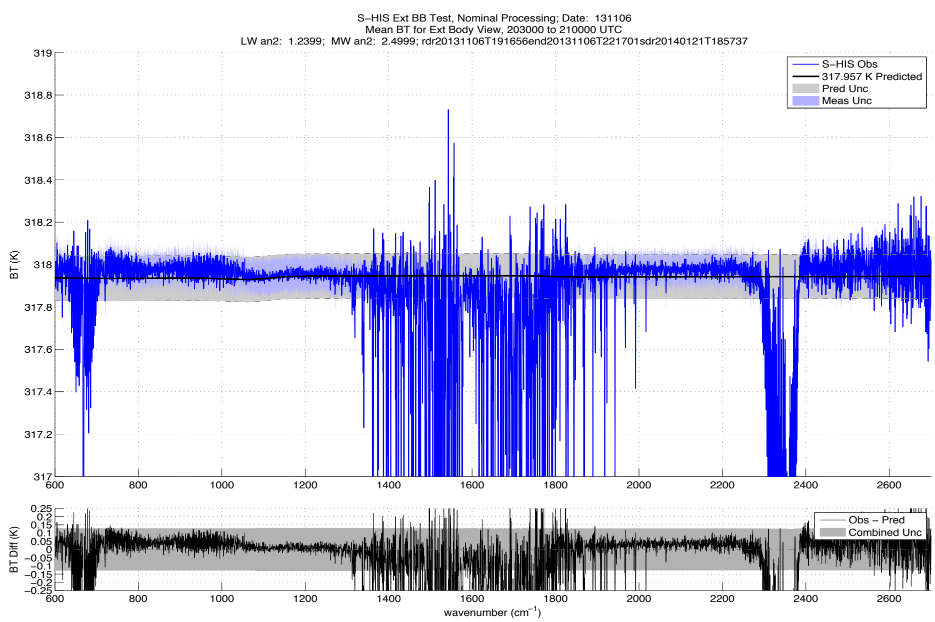

Figure 8: Radiometric calibration verification, external blackbody at 318K. The top panel indicates the predicted brightness temperature in black (uncertainty in gray), and the measured brightness temperature in blue (uncertainty in light blue). The bottom panel shows the measured – predicted difference, with combined uncertainty. All uncertainties are 3-sigma.

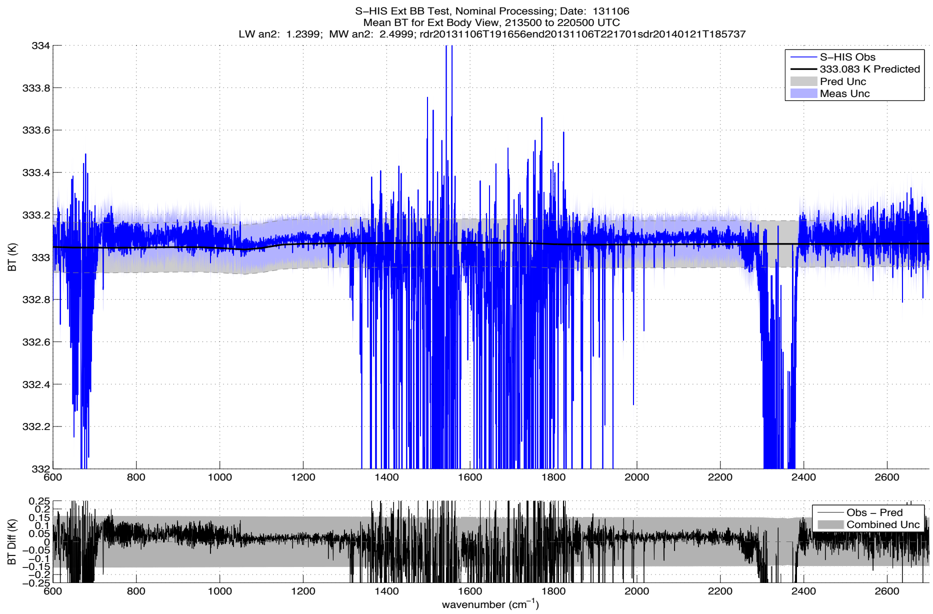

Figure 9: Radiometric calibration verification, external blackbody at 333K. The top panel indicates the predicted brightness temperature in black (uncertainty in gray), and the measured brightness temperature in blue (uncertainty in light blue). The bottom panel shows the measured – predicted difference, with combined uncertainty. All uncertainties are 3-sigma.

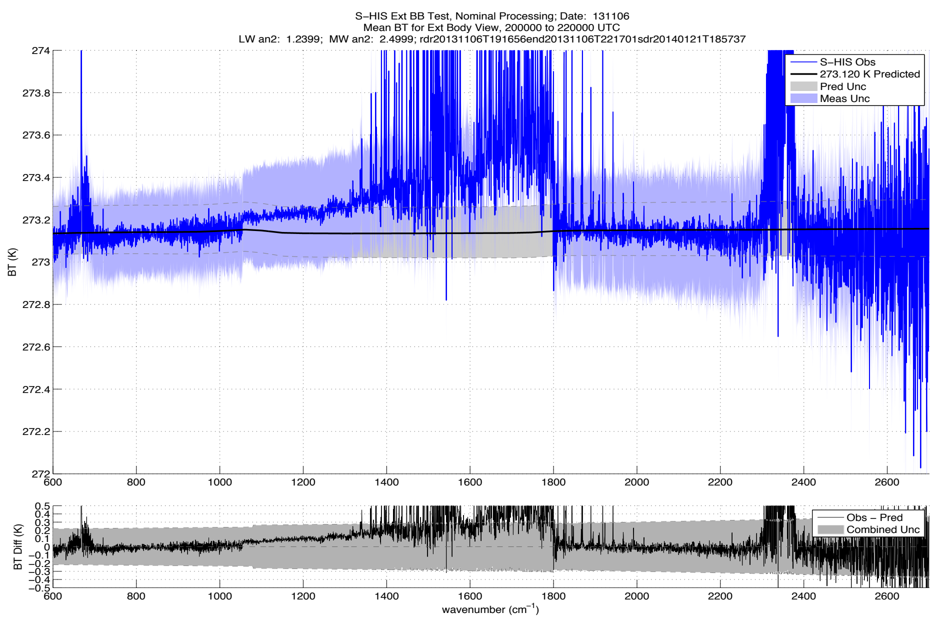

Figure 10: Radiometric calibration verification, ice-bath blackbody. The top panel indicates the predicted brightness temperature in black (uncertainty in gray), and the measured brightness temperature in blue (uncertainty in light blue). The bottom panel shows the measured – predicted difference, with combined uncertainty. All uncertainties are 3-sigma.

3. **Ongoing 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.**

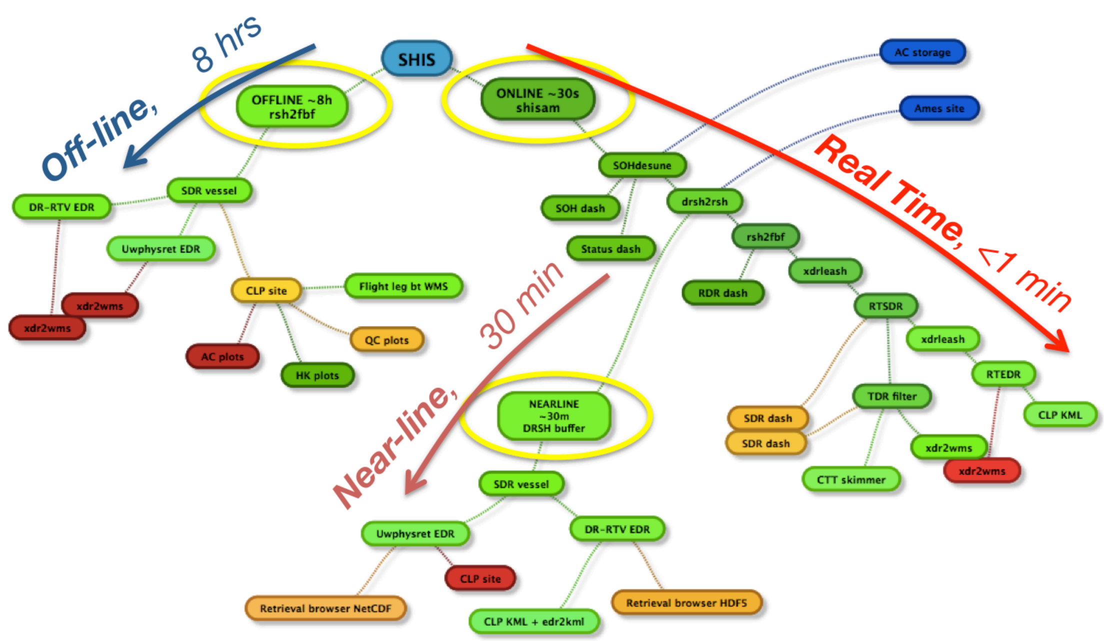

Figure 11: S-HIS HS3 data processing paths.

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 are used to create EDR atmospheric profiles. The SDR and EDR data are operationally produced and distributed.

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 and are summarized in the following sub-sections.

3.1. 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 (DR) algorithm that is a statistical eigenvector regression method, and provides retrievals under clear and cloudy conditions; 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 2013 flights (examples are provided in Sections 1 and 5). Retrieval algorithms are fully automated. 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 to the data is:

http://download.ssec.wisc.edu/sys/login/form/hs3_shis.

3.2. Real-time and Near-line Radiance Calibration and Atmospheric Retrieval

The S-HIS instrument data downlink methodology has evolved over time with the technology available and new 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.

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.
The algorithms used in the real-time SDR and EDR processing are fast enough to produce values within seconds of reception. Near-line processing utilizes the full batch processing including quality control, applied to KU downlinked data separated into 30

minute data segments. For the 2013 season, near-line processed 30-minute segment products were also delivered via MTS with a latency of approximately 30 minutes. Examples of the real-time and near-line product displays are provided in Figure 12 through Figure 16.

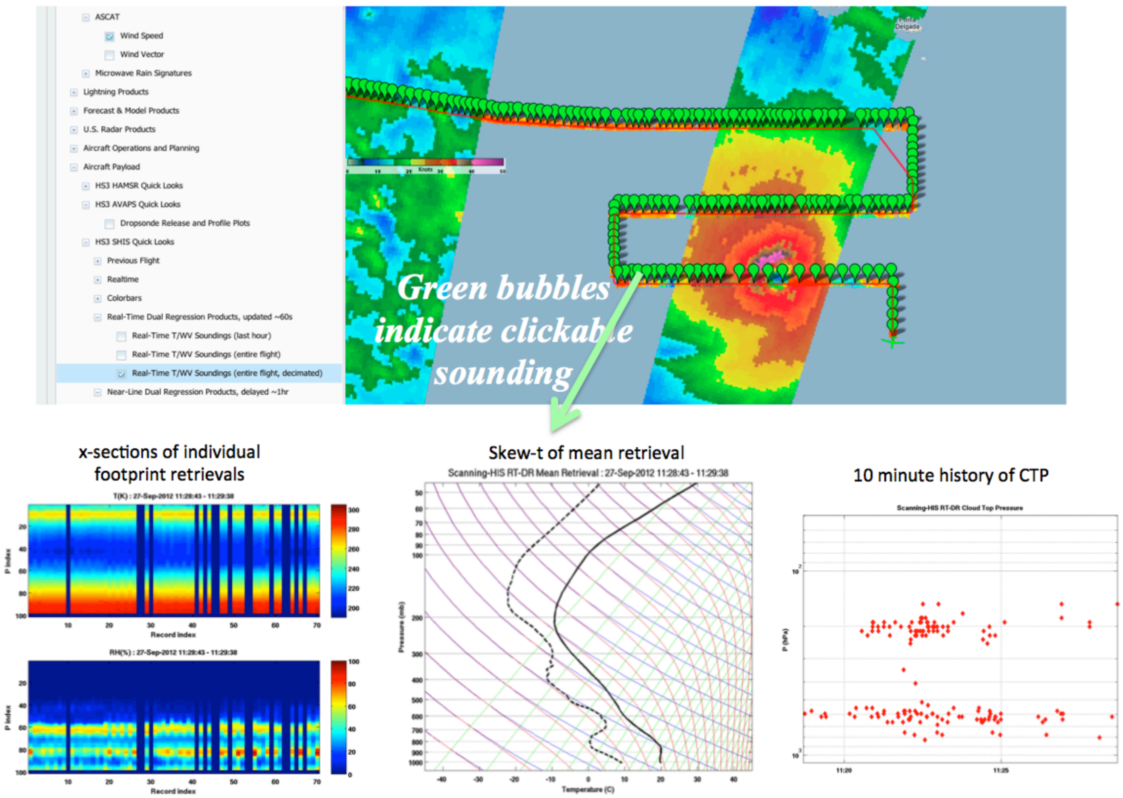

Figure 12: S-HIS Real-time Dual Regression retrieval products.

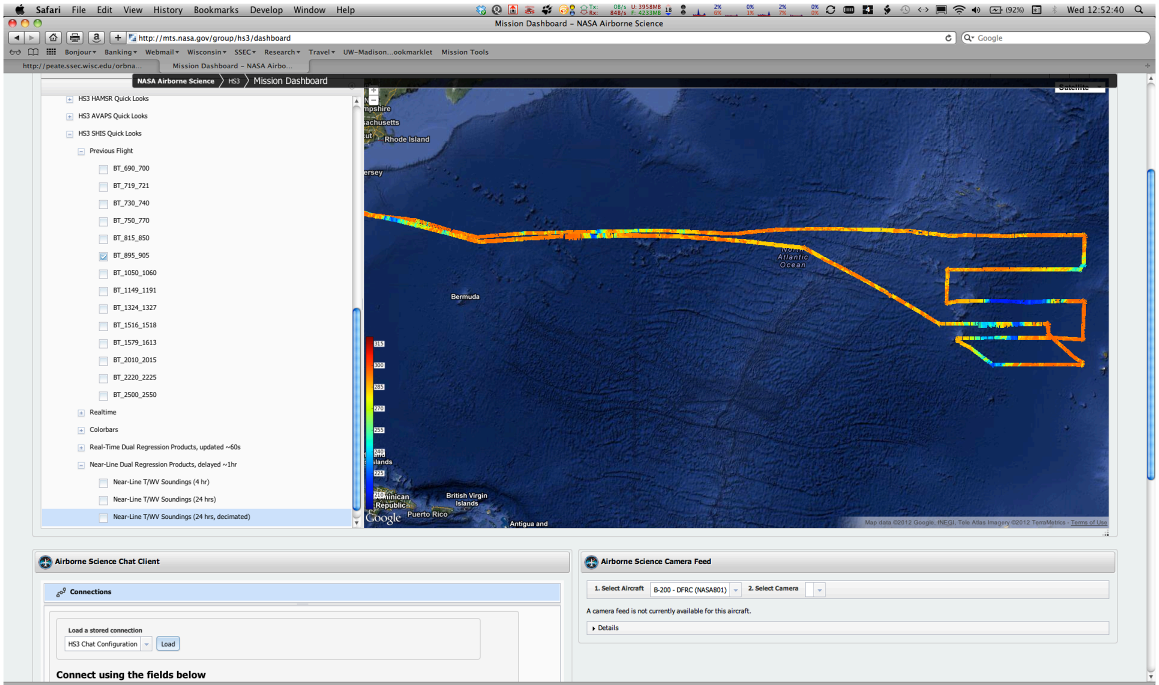

Figure 13: Example S-HIS WMS layer in NASA MTS (S-HIS 900cm^{-1} Brightness Temperature).

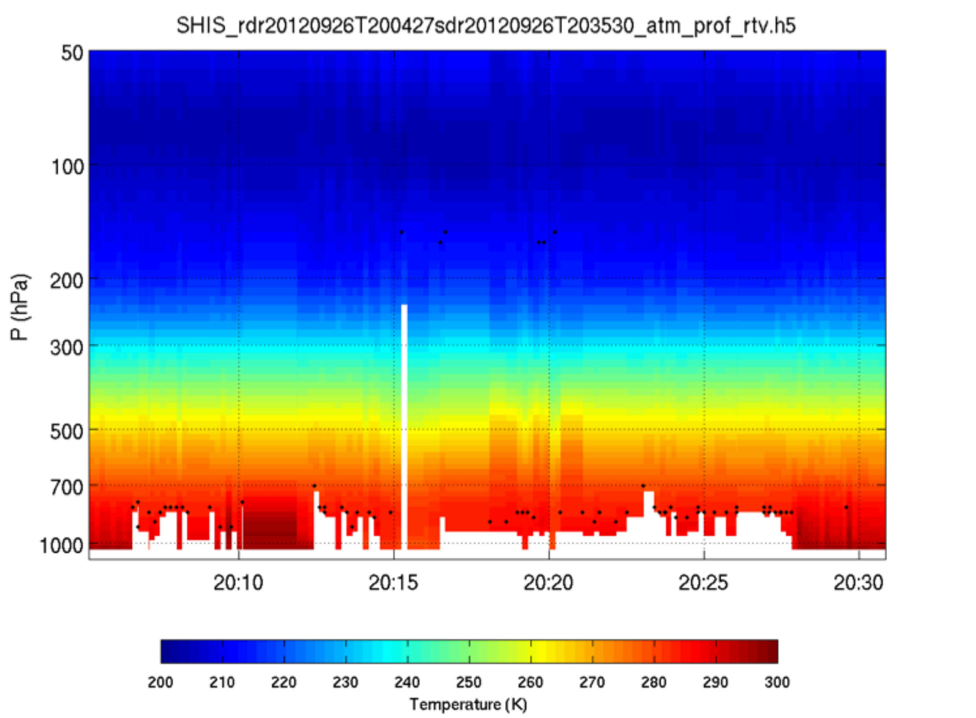

Figure 14: Example real-time temperature profile retrieval delivered via S-HIS website.

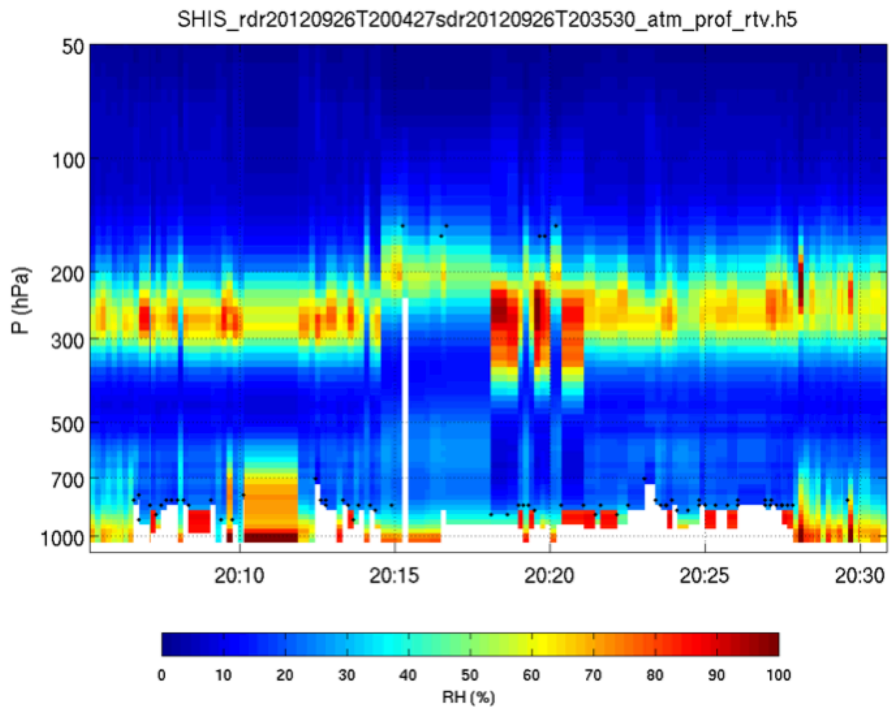

Figure 15: Example real-time relative humidity profile retrieval delivered via S-HIS website. Discontinuities are non-physical, and artifacts of cloud contamination in the real-time product. The near-line and final processing provide a refined interpretation of the results and include a thorough quality control algorithm.

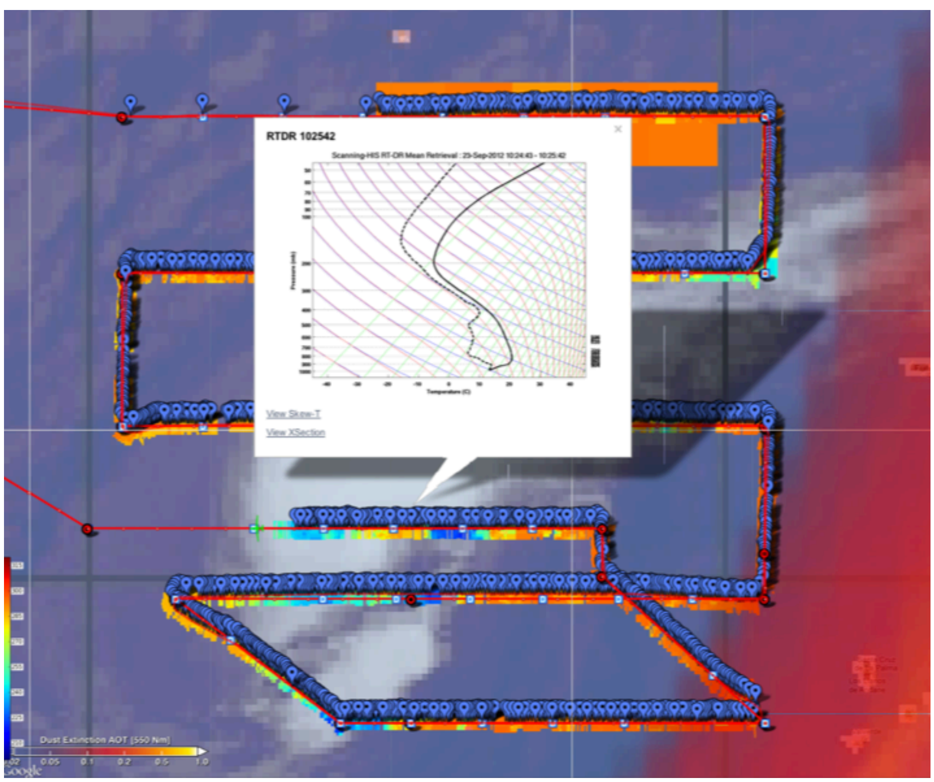

Figure 16: Example Skew T profile delivered in real-time via kml markers in NASA MTS.

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

4.1. S-HIS Dual Regression Retrieval

Development and optimization of the S-HIS Dual Regression Retrieval algorithm continued in 2013, and all HS3 datasets (2011, 2012, 2013) were reprocessed using the updated algorithm.

To provide atmospheric retrievals under all-sky conditions, the "Dual Regression" retrieval algorithm has been adapted for the S-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 2013 HS3 campaign.

An example image from 24-August-2013 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 on the dropsonde time, used to illustrate the nadir cloud conditions for the given dropsonde. 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).

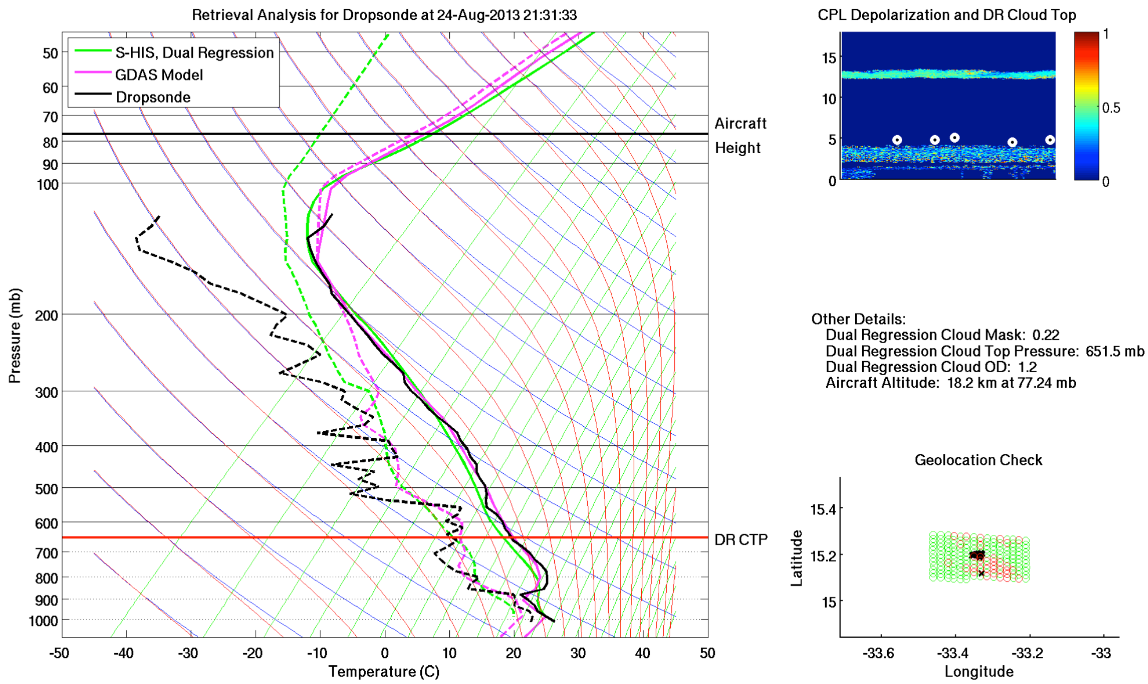

Figure 17: Sample DR Profile comparison to Dropsonde & GDAS; 24 August 2013. This example shows a good retrieval quality, despite upper level thin cirrus and lower level aerosol layers.

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 ($RH_{DR} - RH_{AVAPS}$).

A radiative closure study was also completed to further characterize and confirm the observed AVAPS dry bias. Once again, data were compiled with respect to relative humidity (RH) and water mass mixing ratio (H2OMMR), and were filtered based on DR retrieved cloud top pressure limited to 700 mb. The AVAPS and dual-regression retrieved profiles were used to compute upwelling radiance at the Global Hawk altitude and compared to the S-HIS measured radiances. The resulting comparisons, in brightness temperature units, are shown in Figure 19 for the 24 August flight. The strong negative bias for AVAPS between 1200 and 2000 cm^{-1} is indicative of an upper tropospheric water vapor deficiency (dry bias). The S-HIS measured radiances are expected to be accurate to approximately 0.25K or better for this wavenumber region and brightness temperature.

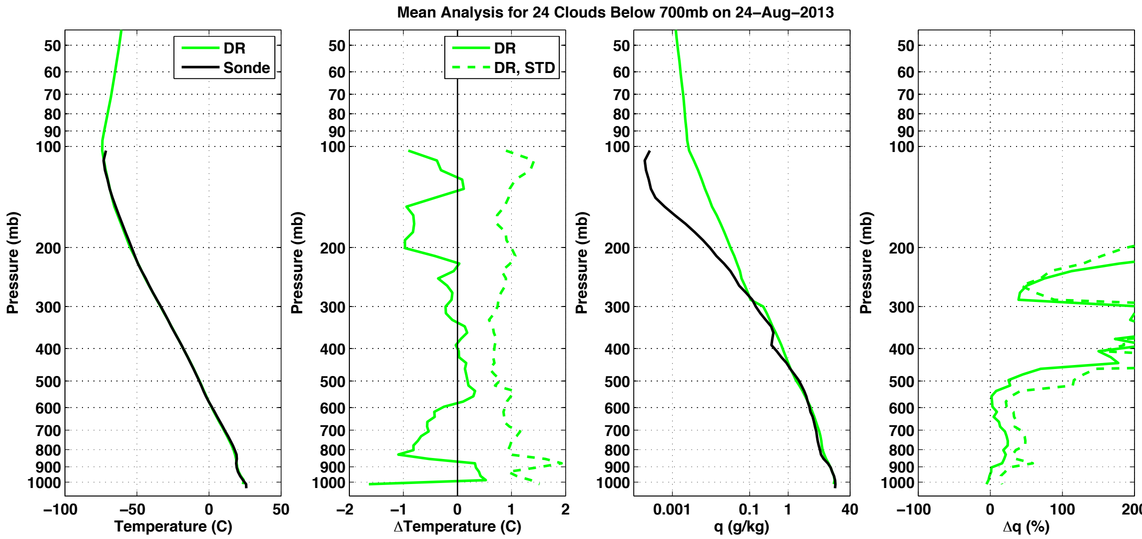

Figure 18: A daily-mean, four-panel image representing S-HIS DR retrievals relative to AVAPS dropsondes was created for each HS3 mission sortie. The dry bias of the dropsonde above 400 mb is a consistent feature.

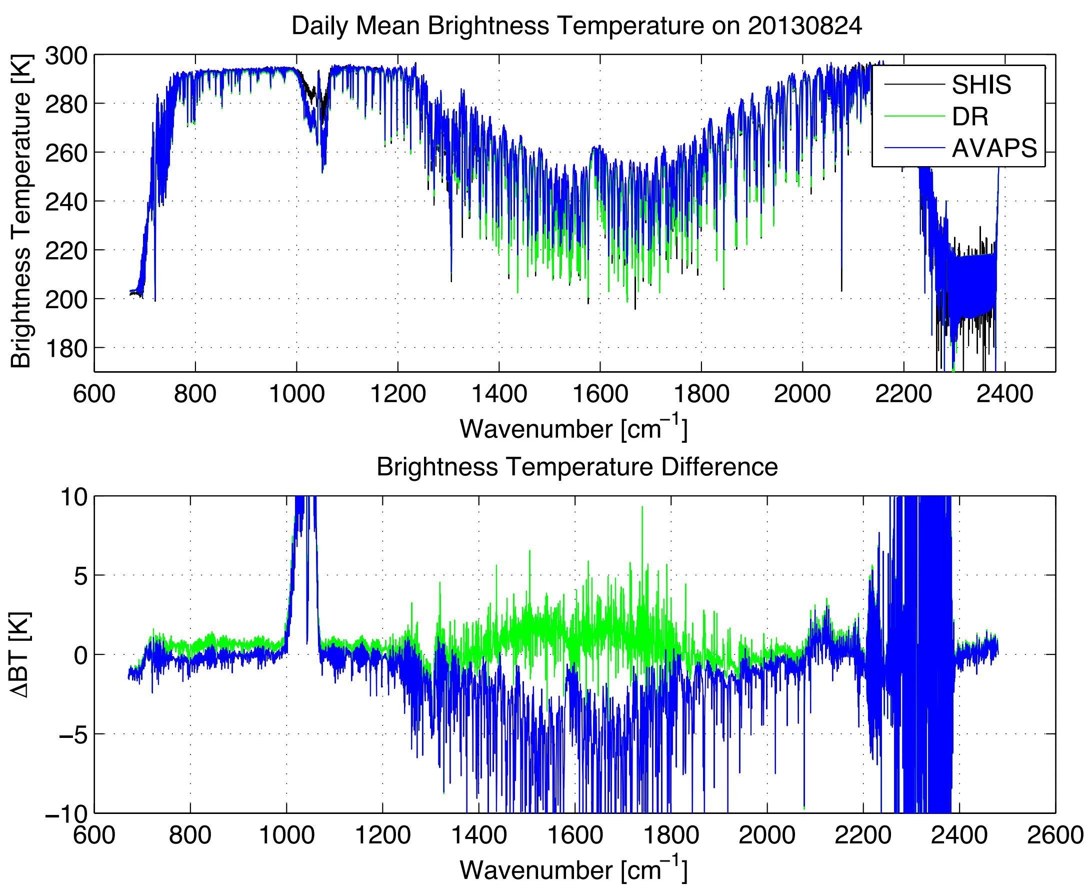

Figure 19: Radiance closure study results for 24 August 2013 flight. The AVAPS and dual regression profiles were used to compute upwelling radiance at the Global Hawk altitude and compared to the S-HIS measured radiance. Results are indicated in brightness temperature units. The strong negative bias for AVAPS between 1200 and 2000 cm^{-1} is indicative of an upper tropospheric water vapor deficiency (dry bias).

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 2013-08-28 flight is shown in Figure 20. 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 2013 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 21. The statistical analysis was also re-applied to the 2012 data after re-processing with the improved 2013 algorithm (Figure 22).

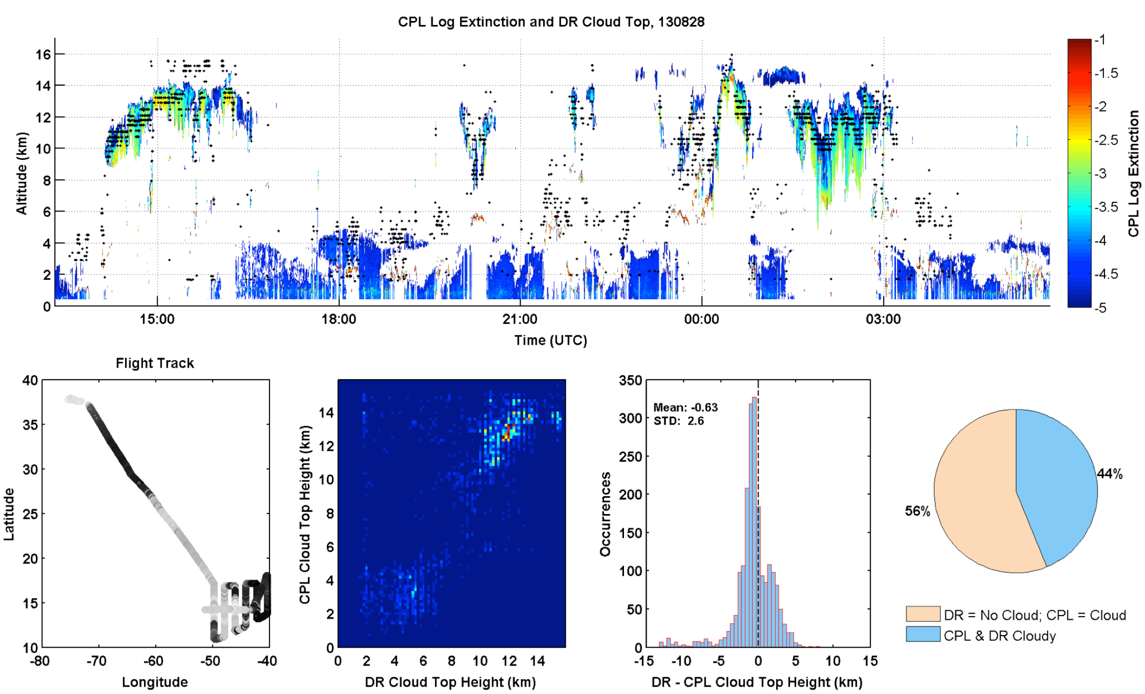

Figure 20: Example comparison of S-HIS DR retrieved cloud top pressure and optical depth and collocated Cloud Physics Lidar (CPL) measurements

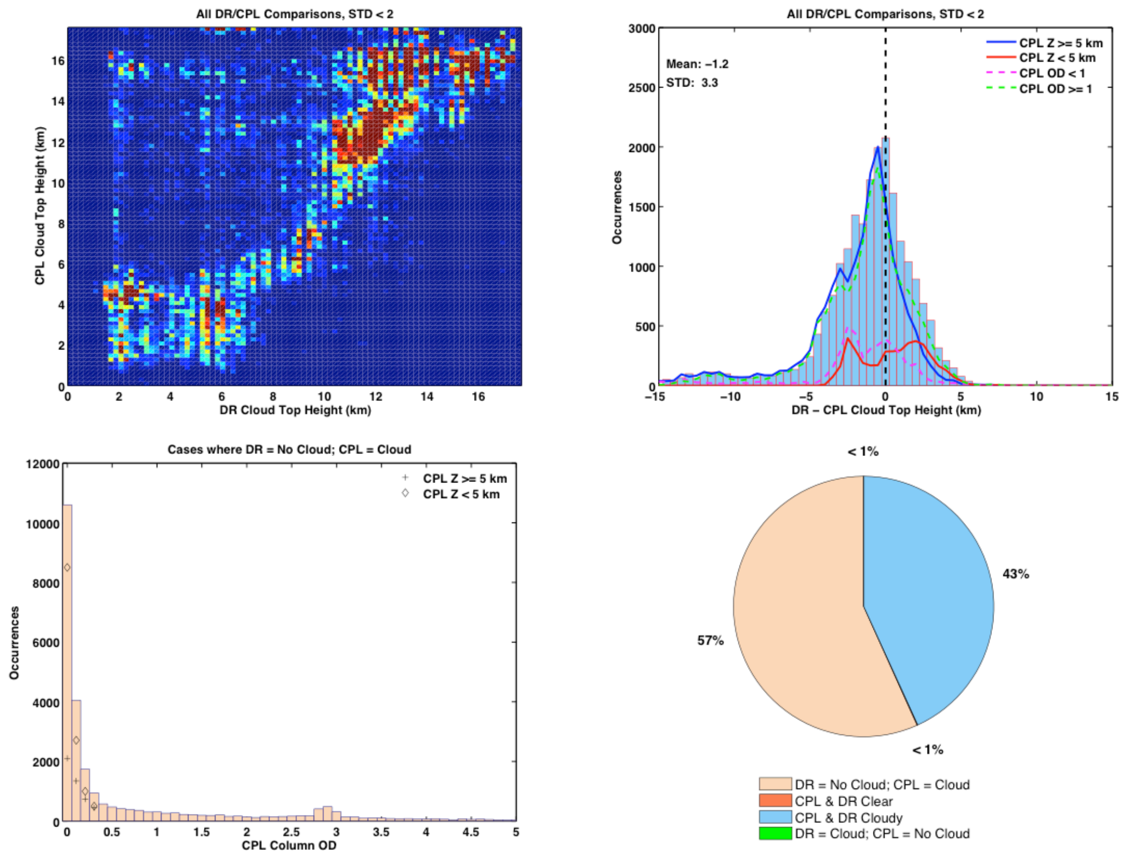

Figure 21: Statistical comparison of S-HIS DR retrieved cloud top pressure and optical depth and collocated CPL measurements for 2013 mission.

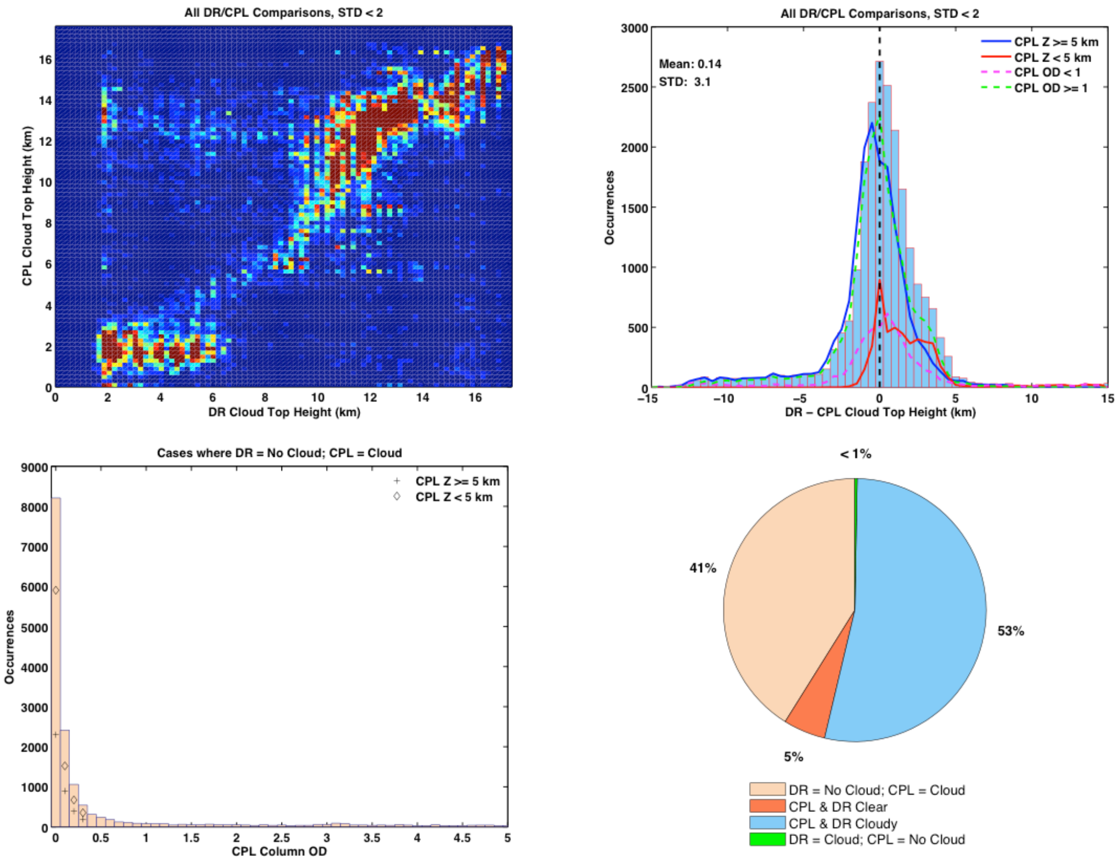

Figure 22: Statistical comparison of S-HIS DR retrieved cloud top pressure and optical depth and collocated CPL measurements for 2012 mission.

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.*

4.2. UWPHYSRET Physical Retrieval Algorithm

A research algorithm developed at the University of Wisconsin for use with satellite data has been implemented for processing S-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.

5. Support of Science Team

The S-HIS group supported periodic Science Team telecons during the reporting period in addition to the Science Team meeting on Meeting April 29 – May 1, 2014. Henry Revercomb (S-HIS Principal Investigator), Joe Taylor (S-HIS Project Manager and Instrument Engineer), and Dan Deslover (Researcher) attended the meeting. Dan Deslover presented a summary of S-HIS status, real-time data collection and processing, and refined offline processing and results. The following posters were presented by the S-HIS team at the 2014 HS3 Science Team Meeting:

- S-HIS dual regression analysis for the 2012 and 2013 campaigns relative to AVAPS and CPL measurements, Dan Deslover et al;
- Scanning High-resolution Interferometer Sounder (S-HIS) radiometric calibration and performance summary (HS3 2013), Joe Taylor et al.

6. UW HS3 Year 4 Summary of Accomplishments

Year 4 activities by our University of Wisconsin Space Science and Engineering Center team supporting S-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 S-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 results,
- 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,
- 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. Prior datasets were reprocessed using the 2013 data processing algorithms, and re-distributed. A web link to the S-HIS HS3 data product distribution is included at the ESPO HS3 webpage.
    - ESPO link: http://espo.nasa.gov/missions/hs3/data_products
    - Direct link: http://download.ssec.wisc.edu/sys/login/form/hs3_shis