Hurricane and Severe Storms Sentinel (HS3) Data Management Plan

Earth Science Division
NASA Science Mission Directorate

National Aeronautics and Space Administration

Hurricane and Severe Storm Sentinel (HS3)
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1.0 Introduction

The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission that will investigate hurricane intensity change in the Atlantic Ocean basin. This Earth Venture mission (EV-1) will be executed in three phases with deployment of two instrumented Global Hawk unmanned aircraft in the summers of 2012, 2013 and 2014. In preparation for the first deployment, test flights focused on instrument integration and intercomparisons were conducted in 2011. This data management plan identifies the data products that will be generated from the mission and describes the procedures and processes that will ensure the transition of the data from the field to the Global Hydrology Resource Center (GHRC) where it will be archived and made available to the research community, educators, and the general public. HS3 has completed required reviews (Investigation Concept and Design reviews, and Key Decision Point-C) and will conduct its first deployment in August-September 2012.

1.1 DMP Development, Maintenance, and Management Responsibility

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1.2 Change Control

It is not expected that this document will change frequently. However, when significant changes occur such as changes to operations plans, hardware capabilities or the science data product suite, this document will be modified to reflect those changes. The change dates and a short description will be recorded in the table below and updated versions will be posted to the project website.

Document Change Log		
Version	Date	Description
V1.0	07-31-2012	Initial Version
V2.0	02-26-2013	Revised Version

1.3 Relevant Documents

The information in this DMP is supported by a number of other external documents which together fully describe the HS3 mission. These include the original science proposal, Project Plan, mission operations concepts and plans, and relevant documents for each instrument. The following table lists and provides links to those resources.

List of Relevant Supporting Documents	
Title	Location
HS3 Proposal	PI, GSFC
HS3 Project Implementation Plan	ESSPO, LARC
HS3 Program-Level Requirements	ESSPO, LARC

2.0 Project Overview

The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission funded as part of the Earth Venture–1 program and specifically targeted to investigate the processes that underlie hurricane intensity change in the Atlantic Ocean basin. The major limitations in predicting intensity change in hurricanes are a poor understanding of the processes that cause it, inadequate representation of those processes in models, and a general lack of adequate observations of the storm environment and internal processes. These are the problems that HS3 will address.

HS3 will consist of two Global Hawks with separate payloads, one geared toward sampling the storm environment and the other toward sampling inner-core (primarily precipitation and wind) structure. The environmental payload will be aboard the Global Hawk AV-6 (tail number 872) and measurements include:

- Continuous sampling of temperature and relative humidity in the clear-air environment from the scanning High-resolution Interferometer Sounder (S-HIS).
- Continuous wind profiles in clear air from the Tropospheric Wind Lidar Technology Experiment (TWiLiTE) instrument. TWiLiTE is a direct detection Doppler lidar capable of measuring the motion of air molecules in clear air environments [Delayed to last deployment in 2014].
- Full tropospheric wind, temperature, and humidity profiles from the Airborne Vertical Atmospheric Profiling System (AVAPS) dropsonde system, which is capable of releasing up to 100 dropsondes in a single flight.
- Aerosol and cloud layer vertical structure from Cloud Physics Lidar (CPL).

The over-storm payload will be aboard the Global Hawk AV-1 (tail number 871) and measurements will include:

- Three-dimensional wind and precipitation fields from the High-Altitude Imaging Wind and Rain Airborne Profiler (HIWRAP) conically scanning Doppler radar.
- Surface winds and rainfall from the Hurricane Imaging Radiometer (HIRAD) multi-frequency interferometric radiometer.
- Measurements of temperature, water vapor, and liquid water profiles, total precipitable water, sea-surface temperature, rain rates, and vertical precipitation profiles from High-Altitude MMIC Sounding Radiometer (HAMSR).

Addressing HS3's science questions requires sustained measurements over several years due to the limited sampling opportunities in any given hurricane season. Past NASA hurricane field campaigns have all faced the same limitation: a relatively small sample (3-4) of storms forming under a variety of scenarios and undergoing widely varying evolutions. The small sample is not just a function of tropical storm activity in any given year, but also the distance of storms from the base of operations.

HS3 will build upon results from previous NASA field campaigns [Convection and Moisture Experiments 3 (1998) and 4 (2001), Tropical Cloud Systems and Processes experiment (2005), Genesis and Rapid Intensification Processes experiment (2010)] where some of the same types of instruments were flown. In particular the HIRAD, HIWRAP, and HAMSR instruments were flown during the GRIP mission conducted in the summer of 2010 while the dropsonde system (AVAPS) was flown a few months later in a limited campaign called Winter Storms and Atmospheric Rivers (WISPAR). GRIP was conducted to better understand how tropical storms form and develop into major hurricanes. In addition to the Global Hawk, NASA employed the DC-8 and WB-57 aircraft. For GRIP, the Global Hawk instrument payload included HAMSR and HIWRAP. HIRAD was flown aboard the WB-57. As will be for HS3, the GRIP flights were over the Atlantic Ocean.

Many of the HS3 instruments have a legacy that extends back for a decade. HAMSR was flown on the NASA African Monsoon Multidisciplinary Analyses (NAMMA) campaign in 2006 and in the fourth Convection and Moisture Experiment (CAMEX-4) in September 2001. The Cloud Physics Lidar (CPL) was first employed in the Southern African Regional Science Initiative (SAFARI) campaign in southern Africa during August-September 2000 and most recently the Multiple Altimeter Beam Experimental Lidar (MABEL) flights – as a demonstrator instrument for the ICESat-2 mission. S-HIS has flown in numerous Aqua validation and NPOESS testbed campaigns. The only truly new instrument is the TWiLiTE wind lidar.

Early years of the HS3 project (2010-2011) have focused on integration of instruments and test flights designed to ensure maximum capability and productivity during the major deployment periods. The test flights were carried out in September 2011. HS3 flew two instrument configurations. The first was a range flight of the 2012 instrument suite - S-HIS, CPL and AVAPS (dropsondes). This flight was completed Sept. 1. CPL was replaced with HAMSR for the second configuration on AV-6 (AV-1 was not yet configured for science flights). AV-6 flew one test flight over the Pacific to compare S-HIS, HAMSR and AVAPS on Sept 8-9. This was an important comparison opportunity because during actual HS3 hurricane flights over the next 3 years, HAMSR will fly on Global Hawk AV-1 and S-HIS and AVAPS on AV-6. The final 2011 HS3 test flight was to the Gulf of Mexico on Sept 13-14. Its focus was a dropsonde comparison with NOAA's G-IV dropsonde system. A total of 35 dropsondes were released, 26 of which were coordinated with the NOAA G-IV. Although, the Ku communications system didn't work for any of the 3 flights, the instruments all functioned well and collected data.

During the 2012 deployment, a number of factors led to AV-1 not participating in the Wallops deployment. As a result, data in 2012 is only available for the environmental GH AV-6.

2.1 Project Objectives

The HS3 objectives are to obtain critical measurements in the hurricane environment in order to identify the role of key factors such as large-scale wind systems (troughs, jet streams), Saharan air masses, African Easterly Waves and their embedded critical layers (that help to isolate tropical disturbances from hostile environments) and to observe and understand the three-dimensional mesoscale and convective-scale internal structures of tropical disturbances and cyclones and their role in intensity change.

HS3 addresses the key NASA Earth Science Enterprise (ESE) Science Goal to study Earth to advance scientific understanding and meet societal needs and NASA's research objective to "enable improved predictive capability for weather and extreme weather events." In particular, HS3 will reduce the considerable uncertainty that exists about the factors that influence hurricane intensity change including whether it is primarily a function of the storm environment or storm internal processes. HS3 will obtain the measurements needed to improve scientific understanding and serve as a driver behind the transfer of that understanding into improved intensity prediction.

2.2 Science Objectives

HS3 comprises a set of aircraft and payloads ideally suited for the study of hurricanes and other severe weather systems. The HS3 goal is to better understand the physical processes that control hurricane intensity change. HS3 is a five-year mission specifically targeted to enhance our understanding of the processes that underlie hurricane intensity change in the Atlantic Ocean basin. We define intensity change broadly, including the intensification of a tropical disturbance into a tropical cyclone, further intensification into a hurricane (including the more specific case of rapid intensification), and significant decreases in intensity. Important science questions that HS3 will answer include:

1. What impact does the large-scale environment, particularly the Saharan Air Layer (SAL), have on intensity change?
2. What is the role of storm internal processes such as deep convective towers?
3. To what extent are these intensification processes predictable?

We know that certain necessary conditions must exist for storms to develop such as warm ocean temperatures, weak vertical wind shear, and high humidity. However, competing hypotheses abound about the factors that determine whether a storm will intensify or weaken, including hypotheses related to inertial instability of the upper troposphere, favorable upper-level eddy fluxes of angular momentum associated with nearby large-scale troughs, protection of convective disturbances by a protective wave “pouch”, convective hot towers, and the Saharan Air Layer (SAL). These different hypotheses can be distilled down to the extent to which either the environment or processes internal to the storm are key to intensity change.

- Is the likelihood of intensification after formation mainly a result of characteristics of the large-scale environment?
- Are internal processes driven by large-scale forcing or do internal processes act independently of this forcing?

Data analysis will be geared toward utilization of the observations in conjunction with satellite data and numerical models to better understand the relationships between observed environmental and in-storm characteristics and processes important to hurricane formation and intensity change. HS3 will advance our knowledge about the structure and evolution of the SAL with respect to developing and non-developing tropical disturbances, the interaction of storms with large-scale wind systems in their environment, and the evolution of wind structure changes in the inner-core region in relation to deep convective bursts within and near the eyewall. HS3 will also demonstrate the utility of some of the data sets for improved model initialization (specifically HIWRAP and HIRAD), evaluation, and improvement.

The primary data users are the HS3 science team and the NASA Hurricane Science Research Program (HSRP) funded under ROSES. Additional users will include NOAA funded researchers under the Hurricane Forecasting Improvement Project (HFIP), with which the HS3 team is collaborating, and operational users at the National Hurricane Center (to the extent data can be provided in real time). However, we anticipate that the larger hurricane science community will have great interest in HS3 data so that it is critical to maintain a long-term and publically available data archive. While we expect to significantly improve our understanding of the roles of the environment and inner-core processes by the end of HS3 in 2015, particularly the roles of the SAL and deep convective clouds, it will be several years later before the full benefit of the data collected is realized.

2.3 Mission Summary

The NASA Global Hawk UASs are ideal platforms for investigations of hurricanes, capable of flight altitudes between 55,000 and 65,000 ft and flight durations of up to 30 h (see the HS3 Investigation Project Plan for more details). HS3 will utilize two Global Hawks, one with an instrument suite geared toward measurement of the environment and the other with instruments suited to inner-core structure and processes. HS3 will be deployed from the Wallops Flight Facility in Virginia, providing access to unrestricted air space and unprecedented access to hurricanes over the Atlantic ocean. The nominal deployment dates are September 1-October 5 in 2012 and approximately August 20-September 24 in 2013-2014. During 2012-2014, a total of up to eleven 26-h flights during each of three one-month deployments will be conducted. While the exact division of the flight hours between the two aircraft is uncertain, we anticipate that flight hours will be divided close to evenly between them.

HS3's suite of advanced instruments will measure key characteristics of the storm environment and its internal structures. The environmental payload on AV-6 will consist of the S-HIS interferometer sounder, the Cloud Physics Lidar, the AVAPS dropsonde system, and by 2014, the TWiLiTE wind lidar. The over-storm payload on AV-1 consists of the HIWRAP Doppler radar, the HAMSR microwave sounder, and the HIRAD microwave radiometer. See Figs. 1-1 and 1-2 for the configurations.

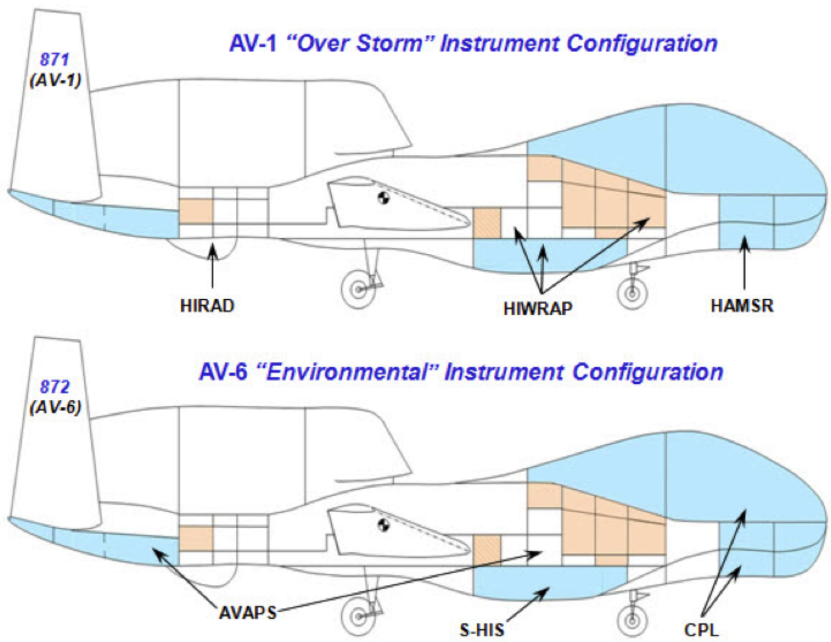

Figure 1-1 shows the baseline instrument configurations on the two GHs (Air Vehicle or AV-1 and AV-6, respectively) for 2012 and 2013.

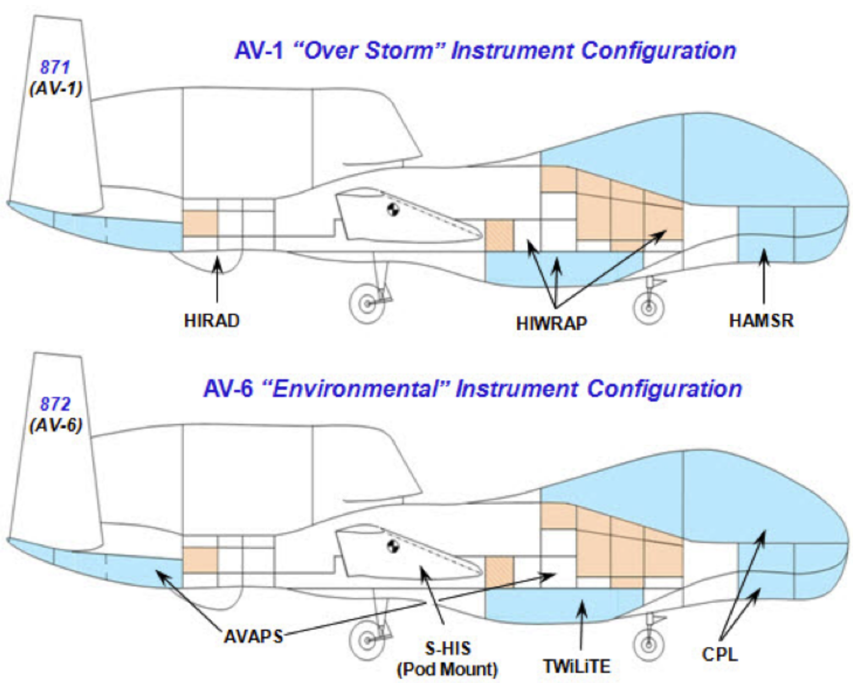

Figure 1-2 shows the baseline instrument configurations on the two GHs for 2014.

2.4 Instrument Overview

The following subsections provide an overview of each of the instruments and links, as appropriate, to more detailed information about the instruments and the datasets generated from them.

2.4.1 HIRAD

HIRAD (Hurricane Imaging Radiometer, see Table 2-1) is a passive microwave sensor that operates in the C-band frequencies (4, 5, 6, and 6.6 GHz) to measure strong winds and rain over the ocean surface. Using a synthetic aperture technique with no moving parts, the instrument provides both along-track and cross track resolution of better than 2 km at nadir (~5 km near swath edges), with a swath width of approximately 60 km when flown on a high-altitude airborne platform. The remote sensing principles are the same as that of the operational Stepped Frequency Microwave Radiometer (Uhlhorn and Black 2003, Uhlhorn et al. 2007) that flies on NOAA and USAF reconnaissance aircraft. SFMR consists of a single nadir-viewing antenna and receiver capable of making measurements of radio emission from the sea surface at six selectable frequencies between 4 and 7 GHz. The broad spectral coverage and signal processing algorithm enable the simultaneous retrieval of both hurricane surface wind speeds and rain rates. HIRAD adds the capability for cross-track wind retrievals by using a synthetic thinned array planar antenna. HIRAD will be mounted forward of zone 61, beneath the tail of AV-1.

http://hirad.nsstc.nasa.gov/
http://ghrc.nsstc.nasa.gov/uso/ds_docs/grip/griphirad/griphirad_dataset.html

2.4.2 HAMSR

The High Altitude monolithic microwave integrated Circuit (MMIC) Sounding Radiometer (HAMSR, see Table 2-1) is a microwave atmospheric sounder developed by JPL under the NASA Instrument Incubator Program. HAMSR has 8 channels near the 60 GHz oxygen line complex, 10 channels near the 118.75 GHz oxygen line and 7 channels near the 183.31 GHz water vapor line. HAMSR scans cross track below the GH and has a 45° field of view. HAMSR provides measurements that can be used to infer the 3-D distribution of temperature, water vapor, and cloud liquid water in the atmosphere, even in the presence of clouds. The new UAS-HAMSR reduces noise to less than 0.1K, improving observations of small-scale water vapor. HAMSR is mounted in payload zone 3 near the nose of the Global Hawk.
http://ghrc.nsstc.nasa.gov/uso/ds_docs/grip/griphamsr/griphamsr_dataset.html
http://microwavescience.jpl.nasa.gov/instruments/hamsr/

2.4.3 HIWRAP

The High-altitude Imaging Wind & Rain Airborne Profiler (HIWRAP, see Table 2-1) is a dual-frequency (Ku- and Ka-band, or ~14 and 35 GHz), dual-beam (30° and 40° incidence angle), conically scanning radar that has been designed for the GH (Heymsfield et al. 2008). HIWRAP uses solid state transmitters along with a novel pulse compression scheme that results in a system that is considerably more compact and requires less power than typical radars used for precipitation and wind measurements. By conically scanning at 10-20 rpm, its beams will sweep below the GH collecting Doppler velocity/reflectivity profiles, yielding the 3 wind components. The unique HIWRAP sampling and phase correction strategy implemented (frequency diversity

Doppler processing technique) will be used to de-alias Doppler measurements. HIWRAP's dual-wavelength operation enables it to map full tropospheric winds from cloud and precipitation volume backscatter measurements, derive information about precipitation drop-size distributions, and estimate the ocean surface winds using scatterometry techniques similar to NASA's QuikScat. Winds will be retrieved using a gridding approach similar to well-established ground-based multi-Doppler radar wind analyses. HIWRAP will be mounted in zone 25, in the 'belly' of AV-1.
http://har.gsfc.nasa.gov/index.php?section=13

2.4.4 CPL

CPL (details in Table 2-1) is a multi-wavelength backscatter lidar originally built for use on the ER-2 aircraft and was first deployed in 2000 (McGill et al., 2002; 2003). CPL provides information on the radiative and optical properties of cirrus and subvisual cirrus clouds and aerosols. A duplicate CPL has been constructed for the GH, and has been integrated flown during the GloPac mission in 2010 and during HS3 test flights in 2011.

CPL utilizes a high repetition rate, low pulse energy transmitter and photon-counting detectors. It is designed specifically for three-wavelength operation and maximum receiver efficiency. An off-axis parabola is used for the telescope, allowing 100% of the laser energy to reach the atmosphere. CPL measures the total (aerosol plus Rayleigh) attenuated backscatter as a function of altitude at each wavelength. For transmissive cloud/aerosol layers, using optical depth measurements determined from attenuation of Rayleigh and aerosol scattering, and using the integrated backscatter, the extinction-to-backscatter parameter (S-ratio) can be directly derived. This permits unambiguous analysis of cloud optical depth since only the lidar data is required. Using the derived extinction-to-backscatter ratio, the internal cloud extinction profile can then be obtained. This approach to directly solving the lidar equation without assumption of aerosol climatology is a standard analysis approach for backscatter lidar (McGill et al 2003). CPL uses 355, 532 and 1064 nm channels and a small field of view, which eliminates multiple scattering. It offers 30 m vertical resolution and 200 m horizontal resolution.

http://cpl.gsfc.nasa.gov/

2.4.5 S-HIS

The S-HIS interferometer (details in Table 2-1) is an advanced version of the HIS ER-2 instrument (Revercomb et al. 2003). It was developed between 1996 and 1998 with the combined support of the DOE, NASA, and the NPOESS Integrated Program Office. It has flown in numerous field campaigns and on multiple platforms (ER-2, DC-8, Proteus, and WB-57f) beginning in 1998 and has proven to be very dependable and effective. It recently completed successful test flights on the GH in September 2011. Its noise levels are sufficiently low to allow cloud and surface properties to be derived from each individual field of view. Temperature and water vapor profiling can be performed on individual field of views after taking advantage of Principal Component Analysis to reduce noise levels (Antonelli et al, 2004). The optical design is very efficient, providing useful signal-to-noise performance from a single 0.5 s dwell time. This allows imaging to be accomplished by cross-track scanning. Onboard reference blackbodies are viewed via a rotating 45° scene mirror as part of each cross-track scan, providing updated calibration information every 20-30 s.

The measured emitted radiance is used to obtain temperature and water vapor profiles of the Earth's atmosphere in clear-sky conditions. S-HIS produces sounding data with 2 kilometer resolution (at nadir) across a 40 kilometer ground swath from a nominal altitude of 20 kilometers onboard a NASA ER-2 or Global Hawk.

http://deluge.ssec.wisc.edu/~shis/

2.4.6 TWiLiTE (Tropospheric Wind Lidar Technology Experiment)

TWiLiTE (details in Table 2-1) is a scanning direct-detection Doppler lidar that measures range-resolved profiles of wind by transmitting a laser pulse to the atmosphere and detecting the laser light backscattered by the air molecules (Gentry et al. 2007). Because the primary scattering target is the molecular backscattered signal, TWiLiTE is the first true clear-air airborne Doppler lidar. Developed under NASA IIP, TWiLiTE is modular by design and was designed for autonomous ER-2 or WB-57 flights. The TWiLiTE lidar transmits a short (15 ns) laser pulse at a 45_o from nadir angle to measure the component of the horizontal wind field projected along the line-of-sight. The laser signal backscattered from the atmosphere by molecules and aerosols is collected and analyzed interferometrically for Doppler frequency shifts to produce profiles of radial wind speed versus range. The beam can be scanned in azimuth in a step-stare conical scanning pattern to increase cross track coverage and also to derive u, v vector wind information from the radial wind data. For HS3, TWiLiTE will collect full profiles of the vertical structure of the horizontal wind field in clear-air conditions from the lower stratosphere to the surface.

http://twilite.gsfc.nasa.gov/

2.4.7 AVAPS (Dropsonde)

The Airborne Vertical Atmospheric Profiling System (AVAPS) is the dropsonde system for the Global Hawk. The Global Hawk dropsonde is a miniaturized version of standard RD-93 dropsondes based largely on recent MIST driftsondes deployed from balloons. The dropsonde provides vertical profiles of pressure, temperature, humidity, and winds. Data from these sondes are transmitted in near real-time via Iridium or Ku-band satellite to the ground-station, where additional processing will be performed for transmission of the data via the Global Telecommunications System (GTS) for research and operational use. The dispenser is located in zone 61 in the Global Hawk tail and is capable of releasing up to 89 sondes in a single flight.

http://www.esrl.noaa.gov/psd/psd2/coastal/satres/ghawk_dropsonde.html

Table 2-1. Instrument performance characteristics.

Instrument	Spectral Bands	Spatial Resolution (FOV), Profile resolution	Sample/ Profile Frequency	Raw Measurement Precision	Retrieved Parameter Precision	Calibration Requirements
Environmental						
CPL	355, 532, and 1,064 nm, with depolarization at 1,064 nm	100 mr, 30 m	0.1 s	Backscatter coeff 10-15%	Optical depth 15-25%,	N/A
Dropsondes	N/A	N/A, 0.5 s	N/A	pressure ± 1.0 hPa temperature ± 0.2° C wind ± 0.1 ms^{-1} humidity ± 7%	N/A	N/A
S-HIS	continuous spectral coverage 3.3 to 16.7 µm @ 0.5 cm^{-1}	0.1 radians (11 samples cross-track), 1-3 km vertical	0.5 s / FOV	NEdN ~0.5 RU LW (MW/m^2 sr $cm^{-1)}$, 0.3 RU MW, 0.07 RU SW	Profiles below A/C T <1K water vapor <15%	Self calibrating to Tb <0.2 K (3-sigma for Tb > 240K)
TWiLiTE	355 nm	200 mr, 250 m vertical	10 s integration	velocity ± 1 ms^{-1}	u, v winds <2ms^{-1}	N/A
Over Storm						
HAMSR	50-60 GHz, 113-118 GHz, 166-183 GHz	2 km horizontal, 1-3 km vertical	8 ms, 320 samples/scan	TB ~ 0.1 - 0.6 K precision, < 1 K accuracy	2 K for temperature, 15% for water vapor, and 25% for liquid water	None, self calibrating
HIRAD	4, 5, 6, 6.6 GHz	1.6 km (6.6 GHz), 2.5 km (4 GHz) @ nadir from 20 km	1.2 s integration	NEDT 0.19K - 0.27K brightness temperature	wind speed 1-5 ms^{-1}	calm, rain-free ocean surface
HIWRAP	13.35, 13.91, 33.72, 35.56 GHz	0.42 km (Ka), 1.0 km (Ku), 60 m	30 ms (2° azimuth intervals)	velocity ± 0.3 ms^{-1} reflectivity ± 1 dBZ	horiz. Wind <2 ms^{-1}, <15° @ 1km resolution	ocean surface used

3.0 HS3 Project Data Flow

Figure 3-1 shows the flow of data from its collection during a deployment to its eventual archival at the GHRC. Immediately following each mission in 2012, 2013 and 2014, the data will transition to the respective instrument team's institution. The instrument team leads will be primarily responsible for operating research-grade instruments, processing data, and submitting data according to project schedules and format requirements. The HS3 investigation data processing will occur in three phases: 1) real-time or near real-time products (not quality controlled or calibrated), 2) Level-1 (calibrated) data generated during or shortly after the field deployment, and 3) final Level-2 data resulting from post-deployment processing and analysis. The HS3 airborne data will be recorded during each 4-5 week field deployment period. Preliminary real-time (or near real-time) airborne data will be submitted to the instrument-specific data repositories typically within 120 hours after each flight. Exceptions will be granted upon request of the instrument investigators, particularly during intensive operations periods when consecutive flights may occur. The real-time data will be generated using preliminary (or in-field) calibrations (if available) with minimal time allowed for QA/QC processing. The timely submission is required because the real-time data will be used by the PI, PM, and mission scientists to monitor project progress, to formulate plans for follow-up flights, and to report on important events. Exceptions may be granted when flights are scheduled for consecutive days or if there are instrument problems. In these cases, the HS3 PI and PM must be notified. In addition, instrument PIs may seek prior approval from both the HS3 PI and PM for an exception if it is determined that the data submission period is too stringent in consideration of labor intensive data processing procedures. The distribution and use of real-time data will generally be limited to the HS3 science team and collaborators since they are used primarily for the field activities and are not required deliverables for the mission. These data are not suitable for research or for public release, having not been adequately calibrated and quality controlled. Distribution beyond the science team is at the discretion of the instrument teams and will likely depend on the level of maturity/quality of the products.

Calibrated level-1 data will be archived at the instrument-specific repositories and will also be transferred to the GHRC within 3 months of the end of each field deployment and made available for public use. Final level-2 data will be similarly archived 6-9 months after each deployment. **Once available, links to the respective final products will be made available to the public on the HS3 web page (espo.nasa.gov/missions/hs3).** Each instrument team PI will be responsible for managing the data during the 9 month Science Operations Period when reprocessing, final calibrations and full QA/QC processes are carried out. In addition, the instrument PIs will be responsible for maintaining an archive of their data through the end of the mission in 2015, at which point the GHRC archive will be the primary site for data distribution. The final level-1 and level 2 data products are expected to be scientifically defendable and suitable for publication in peer-reviewed journals. The instrument PIs will assure that the data products conform to standard data formats and that the metadata are consistent with NASA ESD requirements. HS3 final data will be made available to the public in compliance with NASA science data policy. The final investigation data will be submitted to the GHRC within 9 months after the end of the final field deployment in 2014. Initial level-1 and level-2 data should arrive at the GHRC beginning in March 2013. This early archival of data is being funded by the HS3 investigation and includes data storage and a simple ftp interface only. A more complete archive of all data and related documentation, along with a web-based interface for data retrieval, will be developed in 2014 with dedicated funding from HQ.

The instrument PIs will provide to the GHRC all information relevant to the respective instrument including all ancillary data, aircraft navigation, browse or quick-look imagery, as well as any supporting written reports and documentation generated during the mission.

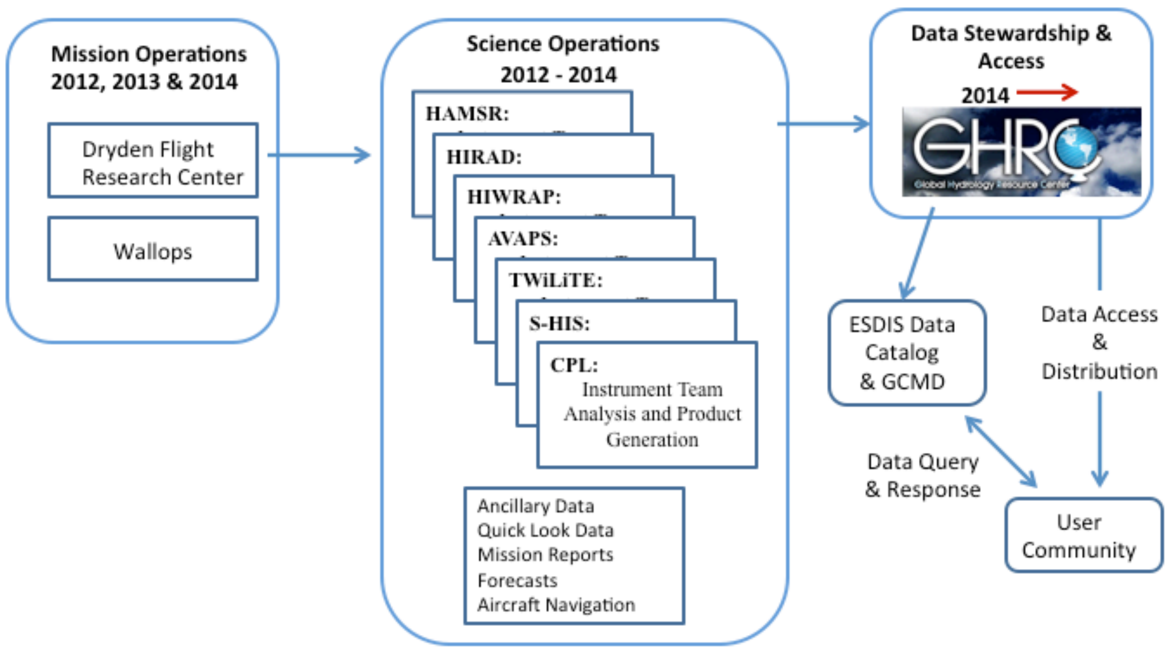

Figure 3-1. Flow of data from collection to archive.

3.1 Science Data Set Generation and Documentation Requirements

As described earlier, the instrument PIs are assigned the responsibility of data processing for their respective instruments. The data processing procedure will convert the primary instrument outputs to data products quantitatively describing atmospheric properties including temperature, relatively humidity, winds, radar reflectivity, and aerosol profiles. The data processing algorithms will be refined through detailed instrument characterization and calibration (if applicable) to ensure data quality in terms of accuracy and precision. This reflects the fact that most in-situ and remote sensing instruments selected for the HS3 investigation have successfully been deployed in previous airborne studies. Most of these instruments and measurement techniques have been published in peer-reviewed scientific journals.

For the dropsonde system, the processing algorithms are mathematically straightforward. Remote-sensing data reduction uses algorithms similar in many ways to satellite retrievals. As part of the HS3 proposal, each instrument PI has budgeted sufficient financial, computational, and staffing resources necessary to process their instrument data and generate science data products.

To comply with the NASA data policy, the HS3 instrument PIs will be required to archive or reference sufficient documentation for each of the funded measurements at GHRC. The primary goals of the documentation requirement are: 1) to maintain data reprocessing capability, 2) to maintain transparency of the data processing, and 3) to facilitate users' understanding and use of data. This documentation should consist of an instrument description as well as primary instrument output data and ancillary data sets that are needed for reprocessing. The instrument description document should include the measurement principle, instrument description, calibration procedures and standards (if applicable), data processing procedure (including software if necessary), data validation (if applicable), data revision records, and uncertainties/detection limits. Since much of the information can often be found in peer-reviewed publications, relevant publications can be used as references. The document itself should primarily be focused on the details or modifications specific to the instrument operation for each of the HS3 field deployments. The program scientist, PI, and PM, in consultation with the instrument PIs and an assigned representative from the GHRC, will determine the appropriate documentation requirements for each instrument on a case-by-case basis. As defined in Section 3.3, documentation materials will be submitted to the GHRC along with the final data within 9 months of the end of the 2014 deployment.

3.2 Project Data Storage and Distribution

During the project life cycle, HS3 science data products (see Section 4) will be archived at the instrument PI institutions. A public data archive for HS3 will be set up at http://espo.nasa.gov/hs3 to provide links to airborne preliminary and final data. Also archived are scientifically relevant satellite images and other analysis products.

Table 3-1 summarizes the submission schedule and access control along the HS3 science data flow illustrated in Figure 3-1. Also given is the data archive location. The HS3 final data along with documentation materials will be transferred to the GHRC no later than 9 months after the completion of the 2014 deployment.

Table 3-1. Summary of HS3 data submission and flow.

Data Products	Data Provider	Submission Schedule	Data Access/Location
Real-time data	Instrument PI	Within 120 h after flight	Science team and partners/Instrument PI archive
Level-1 calibrated data	Instrument PI	3 months after each deployment	Public/Instrument PI archive (transfer to GHRC at 6-9 months)
Level-2 data products	Instrument PI	6-9 months after each deployment	Public/PI archive and GHRC ftp server
Final data following investigation	GHRC	No later than 9 months after the 2014 deployment	Public/GHRC mission data archive web site

The instrument PIs are required to submit their data in the standard formats defined in section

3.3.3 Password-based access control will be established by the instrument PIs to limit data sharing to appropriate HS3 participants for data processing purposes during the first 6-9 months after each field deployment. This time period allows instrument PIs to process final research quality data. In addition to the archive function, instrument PIs will be responsible for transferring data to the GHRC. The HS3 PI will be responsible for establishing data sharing agreements with partner organizations and providing web links/access to members of the HS3 science team and the public.

3.3 Post-Mission Stewardship and Access

In order to provide continuity of data archival during and after the investigation, the HS3 project is funding the early establishment of a data archive at the GHRC–the NASA earth science data center assigned to provide long-term data archival for HS3. All data products, along with scientific software, coefficients, and ancillary data required for researchers to use these products will be transferred before the end of the project. This will ensure post-mission access to the products.

3.3.1 Transition of HS3 Data to GHRC

The GHRC will provide data stewardship for all HS3 science data products and ancillary information. The GHRC staff will work with the HS3 team to ensure that all data are accurately and securely transitioned, and made available to the research community in a timely manner. The transition of data to the GHRC will be facilitated due to the experience that the GHRC staff have with HS3 PIs who have been involved with previous NASA field campaigns. Specifically the GHRC worked with Instrument Scientists Dr. Bjorn Lambrigtsen (HAMSR), Dr. Gerald Heymsfield (HIWRAP), Dr. Timothy Miller (HIRAD), and Dr. Jeff Halverson (DC-8 AVAPS dropsondes) during the GRIP mission in 2010. As a result, the GHRC already has a data transition procedure for HIRAD, HAMSR, HIWRAP, and AVAPS. It is expected that the same or slightly modified procedure can be employed for HS3 data transition from other instruments. Likewise the GHRC already has an inventory of data from those instruments. Thus, there already exist metadata, instrument documentation and dataset guides for data collected by HIRAD, HAMSR, HIWRAP, and AVAPS during GRIP. As above, there will likely be some changes to the metadata and documentation, but the GHRC is well prepared to make any required modifications for new instruments.

The GHRC will work with Instrument Scientists for the remaining three instruments, Drs. Matthew McGill (CPL), Bruce Gentry (TWiLiTE) and Hank Revercomb (S-HIS), to develop a transition plan for their data. This will involve the specification of metadata for each data product, collection of instrument documentation, development of data set guides and most importantly providing a mechanism for the transition of the data files. Typically the transition of data to the GHRC is accomplished by FTP. An incoming directory is set up for each Instrument Scientist or their designee to upload the data. Once the transition is complete it is checked for accuracy and, if there are no errors, the data are moved to the GHRC FTP server. There the data remain as the database is populated and the documentation is finalized. When all data and documentation are on hand, the data are made available to the public through the GHRC. Data distribution metrics are automatically collected by the ESDIS Metrics System (EMS).

Preliminary data volumes are shown in Table 3-2.

Table 3-2. HS3 data rates and parameters.

Instrument	Raw Data (MB/hour)	Data Rates (kbps)	Downlink Data Parameter	Data Products
CPL	~500	1.726 per profile, one profile every 0.1 s	Single wavelength profiles of attenuated backscatter	Profiles of calibrated attenuated backscatter (3 wavelengths); cloud/aerosol layer boundaries; cloud/aerosol optical depth, extinction, and depolarization; color ratio
Dropsondes	1.5 (@ 5 drops/hr)	0.1	P, T, RH, and winds	Quality controlled vertical profiles of P, T, RH and GPS-derived u- and v- winds,
HAMSR	34	75	Raw power	Calibrated, geo-located brightness temperature, vertical profiles of temperature, water vapor and liquid water; precipitation structure
HIRAD	7,200	2000	Brightness temperatures	Surface wind speed, rain rate, and temperature; brightness temperature fields at 4 C-band frequencies
HIWRAP	Raw (infrequent) 576,000; processed 17,000	20	Raw power, Doppler velocity	Calibrated reflectivity, platform-corrected Doppler velocity, Surf. return, 3-D reflectivity fields and horizontal winds, ocean surface winds.
S-HIS	320	9.6	Interferogram ZPD Magnitude (Broadband Calibrated Radiance)	Infrared Brightness Temperature Spectra, IR Cloud Top Temperature, Cloud Top Height, Cloud OD, Cloud EffR, Water Skin Temperature Atmospheric Temperature and Water Vapor Profiles in Clear Sky Conditions Collocated CPL/S-HIS Observations
		38	Reduced Resolution Unfiltered Interferograms	
TWiLiTE	40	5	Profiles of backscattered signal radial velocity	Profiles of backscatter intensity, backscatter ratio, Doppler velocity, horizontal winds

3.3.2 Directories and Catalogs

All data products are published through the GHRC data catalog, the NASA EOS Clearing House (ECHO), and the Global Change Master Directory (GCMD). Users will be able to search for HS3 data through either the GHRC data search and order system (HyDRO) or the ESDIS data search and order system (Reverb).

3.3.3 Standards and Policies

The HS3 data products will conform to industry standards. Five of the seven instrument teams already provide data products using either the HDF or NetCDF standard data formats. The AVAPS system produces data in ASCII which is not currently one of the accepted formats for NASA data. The AVAPS data can easily be transitioned into NetCDF and GHRC will work with AVAPS team to implement a method for conversion if desired.

The CPL data historically have used extended data records (XDR) as the format of choice. However, XDR is also not one of the NASA approved data formats for Earth science data. GHRC will work with the CPL team to establish a procedure for producing their data in a standard format – preferably NetCDF.

3.3.4 Networking Requirements

All data transfer will be accomplished using standard internet connections. The volume and number of files to be transitioned are such that no special connectivity or bandwidth above typical T1 connections is required. Alternately, the GHRC can accept data on media such as DVD, flash drives or large external hard drives if the scientist prefers those methods. All computing resources of the GHRC reside on the NASA network and are under control of NASA/MSFC security. All systems have a security plan on file and strict procedures will be used to ensure accurate safe transfer of data.

4.0 Products

4.1 Science Data Product Summary

4.1.1 HIRAD

It is anticipated that four primary data products will be released upon final calibration of HIRAD observations during flights associated with the 2012 HS3 mission. In addition to the primary products, ancillary information associated with georeferencing and data quality will be provided. Table 4-1 details the list of products and their spatial and temporal resolution. A discussion of the methodology to produce the parameters follows.

Table 4-1. List of data products to be provided based on calibrated HIRAD observations during HS3.

Parameter	Description	Spatial Resolution†	Temporal Resolution††
Brightness temperature	Calibrated brightness temperature @ 4, 5, 6, 6.6 GHz for level flight legs over storm	***Along-Track x Cross-Track (km)***	
Excess brightness temperature	Observed brightness temperatures @ 4, 5, 6, 6.6 GHz in excess of that based on a model using observed sea surface temperatures and assumptions of no rain and calm winds at ocean surface	*Angle* *Res.* 0° 1.9x1.2 15° 2.0x1.4 30° 2.2x1.8 45° 2.7x3.1 60° 3.8x9.6	1 second
Wind speed	Wind speed determined from application of inverse model to observed brightness temperatures		
Rain rate	Rain rate determined from application of inverse model to observed brightness temperatures		
Georeferencing information	Latitudes, longitudes, and times of observed brightness temperature in both absolute and storm-relative coordinates		
Aircraft navigation	Aircraft attitude (i.e. pitch, roll, heading), altitude, and ground speed		
Data Quality Flag	Flags indicating potential interference from RFI or land		

†The spatial resolution estimate is based on a nominal flight altitude of 18km and an aircraft ground speed of 200m/s. Spatial resolution are based on the 4 GHz footprint size.
††HIRAD observations are oversampled. The current product will be provided at evenly sampled times.

Low-Level Processed Data

Brightness Temperature:
Raw instrument counts are converted to intermediate antenna temperatures and calibrated non-zero visibilities (Ruf et al., 1988) based on calibration coefficients determined from environmental chamber experiments and sky-viewing test runs. An inversion process follows the general procedure described in Tanner and Swift (1993) to produce the brightness temperature from these measured visibilities. This inversion technique is based on the production of a calibration matrix using data generated from testing in an anechoic chamber. A final antenna pattern calibration is performed to produce the calibrated brightness temperature scenes. Brightness temperatures are produced at C-band frequencies of 4, 5, 6, and 6.6 GHz.

Excess Brightness Temperature:
The brightness temperature scenes show a limb darkening due to decreases in the horizontal polarization brightness with increasing incidence angle. For quick look imagery, the excess brightness temperature is provided to emphasize geophysical features through removal of the background scene brightness that would be observed at the given sea surface temperature and incidence angle under the assumption of no rain and no wind at the ocean surface. The resulting excess brightness temperature reflects observed geophysical structure primarily due to the combinatorial effects of rain and wind.

Georeferencing Information and Aircraft Navigation:
HIRAD operates as a synthetic aperture microwave radiometer. The inversion procedure results in a cross-track scan width of approximately 60km. The scan pixels are geolocated based on aircraft attitude and altitude information. The time stamp, pixel latitude, pixel longitude, and aircraft navigation information are provided to users.

High-Level Processed Data

Wind Speed and Rain Rate:
An empirical algorithm developed through use of radiative transfer simulations relates the observed brightness temperatures with incidence angle to estimated wind speed and rain rates. The expected valid range of sensitivity for HIRAD measurements are 10 – 85 m/s for wind speed and 5 – 100 mm/hr for rain rate. A description of the forward modeling and retrieval algorithm development can be found in Amarin et al. (2012).

Data Quality Flag:
During operation, radio frequency interference (RFI) and land scenes are potential sources of contamination to HIRAD measurements in the C-band frequency range. Kurtosis-based and median filter detection routines are used to identify RFI and flags are provided to identify such circumstances. Any scenes with potential land contamination are also flagged.

References:

Amarin, R. A., W. L. Jones, S. F. El-Nimri, J. W. Johnson, C. S. Ruf, T. L. Miller, and E. Uhlhorn, 2012: Hurricane wind speed measurements in rainy conditions using the Airborne

Hurricane Imaging Radiometer (HIRAD). *IEEE Transactions on Geoscience and Remote Sensing*, **50**, 180–192, doi:10.1109/TGRS.2011.2161637.

Ruf, C. S., C. T. Swift, A. B. Tanner, and D. M. Le Vine, 1988: Interferometric synthetic aperture microwave radiometry for the remote sensing of the earth. *IEEE Transactions on Geoscience and Remote Sensing,* **26**, 597–611.

Tanner, A. B., and C. T. Swift, 1993: Calibration of a synthetic aperture radiometer. *IEEE Transactions on Geoscience and Remote Sensing*, **31**, 257–267.

4.1.2 HAMSR

The High Altitude MMIC Sounding Radiometer (HAMSR) produces two data products, the Level 1B product and the Level 2 product. The Level 1 product contains the raw instrument telemetry (e.g. voltages, counts), but is not released publically. The Level1B product contains time-ordered and geo-located brightness temperatures for the Earth scan for each of the 25 HAMSR channels. The Level 2 product contains geophysical variables retrieved from the HAMSR Level1B brightness temperatures.

The HAMSR Level 1B and Level 2 data files are in netCDF format. The processing from Level1 to Level 1B involves conversion of the raw counts to brightness temperature using the two blackbody calibration targets that are viewed through the main reflector each scan. The Level 1B data are produced at the sensor resolution and no along-track or cross-track averaging is performed. The HAMSR beam width is 5.7^o (1.8km resolution from the Global Hawk) and the Earth scene is sampled every 0.84^o in the along-track direction and 1.7^o in the along-track direction, meaning the data are over-sampled significantly. The Earth scan consists of observations from +/ 60^o about nadir, though users are cautioned about using edge-of-scan data (greater than 45^o) for applications requiring high accuracy since edge of scan errors approach 2K. See Brown et al. 2011 for more details.

The processing from Level 1B to Level 2 involves a re-sampling of the brightness temperatures to a uniform posting and then these re-sampled TBs are input to a retrieval algorithm to produce geophysical retrievals.

Low-Level Processed Data—Level 1B Product

The contents of the Level 1B files are shown in the following table. The variables in the netCDF file are also fully attributed and self-describing. The nominal channel dimension is 25 and the nominal cross-track dimension is 127 pixels. The along-track dimension varies from flight-to-flight.

Table 4-2. List of parameters to be provided in HAMSR Level-1 products.

Parameter	Description	Dimensions
HAMSR time	seconds since 2000-01-01 00:00:00.0	along track
pixel latitude	Latitude for each HAMSR pixel [-90:90]	cross track x along track
pixel longitude	Longitude for each HAMSR pixel [-180:180]	cross track x along track
altitude	Aircraft altitude from GPS in meters	along track
brightness temperature	Calibrated Brightness Temperature for the Earth scene. Default value is -1.	channel x cross track x along track
pixel Earth incidence angle	Earth incidence angle for each HAMSR pixel [0:89.9]	cross track x along track
aircraft latitude	Aircraft Latitude [-90:90]	along track
aircraft longitude	Aircraft Longitude [-180:180]	along track
aircraft roll	Aircraft Roll [-180:180]	along track
aircraft pitch	Aircraft Pitch [-180:180]	along track
aircraft heading	Aircraft Heading [-180:180]	along track
Brightness temperature Quality Flag for the entire scan	0 – good 1 – data may be noisier than normal, exclude for high-accuracy applications 2 – not recommended for use	along track

High-Level Processed Data—Level 2 Product

The contents of the Level 2 files are shown in the following table. The variables in the netCDF file are also fully attributed and self describing. The cross track dimension is 42 and the along track dimension varies from flight to flight.

Table 4-3. List of parameters to be provided in HAMSR Level-2 products.

Parameter	Description	Dimensions
HAMSR time	seconds since 2000-01-01 00:00:00.0	along track
pixel latitude	Latitude for each HAMSR pixel [-90:90]	cross track x along track
pixel longitude	Longitude for each HAMSR pixel [-180:180]	cross track x along track
altitude	Aircraft altitude from GPS in meters	along track
Re-sampled brightness temperature	Calibrated Brightness Temperature for the Earth scene resampled to a uniform posting. Default value is -1.	channel x cross track x along track
pixel Earth incidence angle	Earth incidence angle for each HAMSR pixel [0:89.9]	cross track x along track
aircraft latitude	Aircraft Latitude [-90:90]	along track
aircraft longitude	Aircraft Longitude [-180:180]	along track
aircraft roll	Aircraft Roll [-180:180]	along track
aircraft pitch	Aircraft Pitch [-180:180]	along track

aircraft heading	Aircraft Heading [-180:180]	along track
Land flag	0 – ocean >0- not ocean (retrievals currently not valid over land)	cross track x along track
Sea Ice Flag derived from NCEP	0 – no sea ice 1- sea ice present (retrievals not valid)	along track
Ancillary surface temperature	Surface temperature from NCEP (K)	along track
Ancillary surface elevation	Surface elevation from NCEP (m)	along track
Ancillary surface pressure	Surface pressure from NCEP (mb)	along track
Ancillary surface wind speed	Surface wind speed from NCEP (m/s)	along track
HAMSR precipitable water vapor –regression algorithm	Integrated water vapor in cm	cross track x along track
HAMSR cloud liquid water –regression algorithm	Integrated cloud liquid water in mm	cross track x along track
HAMSR Air Temperature Profile	Vertical air temperature from HAMSR at 33 levels [K]	cross track x along track x vertical
HAMSR Absolute Humidity Profile	Vertical Absolute Humidity from HAMSR at 33 levels [g/m^3]	cross track x along track x vertical
HAMSR Cloud Liquid Water Profile	Vertical cloud liquid water density from HAMSR at 33 levels [g/m^3]	cross track x along track x vertical
HAMSR Relative Humidity Profile	Vertical relative humidity from HAMSR at 33 levels [%]	cross track x along track x vertical
HAMSR Potential Temperature Profile	Vertical potential temperature derived from HAMSR profiles at 33 levels [K]	cross track x along track x vertical
HAMSR Equivalent Potential Temperature Profile	Vertical equivalent potential temperature derived from HAMSR profiles at 33 levels [K]	cross track x along track x vertical
HAMSR Lifting Condensation Level	Lifting condensation level derived from HAMSR profiles [mb]	cross track x along track
HAMSR Level of Free Convection	Level of free convection derived from HAMSR profiles [mb]	cross track x along track
HAMSR precipitable water vapor from profile	Integrated water vapor derived from HAMSR absolute humidity profile in cm	cross track x along track
HAMSR cloud liquid water from profile	Integrated cloud liquid water derived from HAMSR cloud water profile in cm	cross track x along track
HAMSR air temperature at the surface	Air temperature at surface retrieved from HAMSR [K]	cross track x along track
HAMSR relative	Relative humidity at surface retrieved	cross track x along track

humidity at the surface	from HAMSR [%]	
HAMSR absolute humidity at the surface	Absolute humidity at surface retrieved from HAMSR [K]	cross track x along track
HAMSR air temperature at the flight altitude	Air temperature at flight altitude retrieved from HAMSR [K]	cross track x along track
HAMSR relative humidity at the flight altitude	Relative humidity at flight altitude retrieved from HAMSR [%]	cross track x along track
HAMSR absolute humidity at the flight altitude	Absolute humidity at flight altitude retrieved from HAMSR [K]	cross track x along track
HAMSR Profile Retrieval Quality Flag	0-good convergence and low residual error 1-converged with higher residual error (use with caution) 2-did not converge (use not recommended)	cross track x along track
HAMSR Profile Pressure Levels	Pressure at each of the 33 levels for the HAMSR vertical profiles [mb]	33 levels
HAMSR Height of Pressure Levels	Height at each of the 33 pressure levels for the HAMSR vertical thermodynamic profiles [m]	33 levels
HAMSR derived radar reflectivity profile	X-band reflectivity derived from HAMSR TBs at 15 levels [dBZ]	cross track x along track x vertical
HAMSR Height of Reflectivity Profile Levels	Height at each of the 15 levels where reflectivity is retrieved from HAMSR [m]	15 levels

References

Brown, S., Lambrigtsen, B., Tanner, A., Oswald, J., Dawson, D., Denning, R., 2007: Observations of tropical cyclones with a 60, 118 and 183 GHz microwave sounder. *Geoscience and Remote Sensing Symposium*, IGARSS 2007. IEEE International 23-28 July 2007, 3317 – 3320.

Brown, S. T.; Lambrigtsen, B.; Denning, R. F.; Gaier, T.; Kangaslahti, P.; Lim, B. H.; Tanabe, J. M.; Tanner, A. B., 2011: The High-Altitude MMIC Sounding Radiometer for the Global Hawk Unmanned Aerial Vehicle: Instrument Description and Performance. IEEE Trans. Geosci. Remote Sens., **49**, 3291-3301. doi: 10.1109/TGRS.2011.2125973

4.1.3 HIWRAP

Low Level Processed Data

HIWRAP conical scan data is processed into a sequence of profiles, or radial data, covering the 360^o scan. Each profile derives reflectivity and Doppler information from 64 pulses, and with the 16 rpm scan rate and 5000 Hz pulse repetition frequency, the typical azimuthal spacing of profiles is 1.25 degrees. This spacing was not achieved during GRIP but it is the goal for HS3. HIWRAP radial data files are as follows:

- The data files are in NetCDF (Network Common Data Form), and are named as the GRIP example below:

  hs3_hiwrap_subc_yymmdd_hhmmss_hhmmss.nc

  subc – indicate radar frequency (Ku or Ka), inner or outer beam, and pulse sequence (chirp or pulse).

  yymmdd_hhmmss_hhmmss – indicate the GPS (note that GPS time is ahead of UTC by 15 sec) start and end time of the data (year, month, day and hours, minutes, seconds)
- The gate spacing is 150 meters.
- Measurements included within the data files are chirp radar reflectivity and Doppler velocity profiles for given radar frequency and antenna pointing angle (inner or outer beam).
- The Doppler velocity has been corrected for folding and aircraft motion.
- Other information associated with data positions is also included. These data can be read with most any NetCDF reader, thus no sample read software is provided by the data producer. More information about NetCDF may be found at http://www.unidata.ucar.edu/software/netcdf/
- An example of metadata is given at the end of this document.

The following quantities are provided for each frequency (Ku- and Ka-band) and each beam (inner and outer):

Table 4-4. List of parameters to be provided in HIWRAP low-level processed products.

Parameter	Description	Dimensions
Tgps	GPS time (seconds from last Sunday at 12am)	[nbeam]
Lat	Latitude (deg)	[nbeam]
Lon	Longitude (deg)	[nbeam]
rota	Antenna rotation angle	[nbeam]
ht	Altitude of the aircraft (m)	[nbeam]
head	Aircraft heading (deg)	[nbeam]
track	Aircraft track (deg)	[nbeam]
evel	East Aircraft speed (deg)	[nbeam]
nvel	North Aircraft speed (deg)	[nbeam]
wvel	Vertical Aircraft speed (deg)	[nbeam]
roll	Aircraft roll angel (deg)	[nbeam]
pitch	Aircraft pitch (deg)	[nbeam]
calpulse	Magnitude (dB) of calibration beam	[nchan,nbeam]
surfpwr	Power for surface return	[nchan,nbeam]
sgate	surface gate index	[nchan,nbeam]
surfvel	surface velocity	[nchan,nbeam]

vacft	velocity contribution from aircraft	[nbeam]
incid	incidence angle of beam [nchan,nbeam]	[nchan,nbeam]
sigma0	normalized surface backscattering cross-section [nchan, nbeam]	[nchan,nbeam]
dopcorr	Doppler velocity corrected for aircraft motion	[nchan,nbeam,ngate]
pwr	returned power [nchan,nbeam,ngate]	[nchan,nbeam,ngate]
dopl	Doppler – low PRF estimate [nchan,nbeam,ngate]	[nchan,nbeam,ngate]
doph	Doppler – high PRF estimate	[nchan,nbeam,ngate]
doplh	Doppler – dual-PRF estimate	[nchan,nbeam,ngate]
doplu	Unfolded Doppler – low PRF estimate	[nchan,nbeam,ngate]
dophu	Unfolded Doppler – high PRF estimate	[nchan,nbeam,ngate]
doplhu	Unfolded Doppler – dual-PRF estimate	[nchan,nbeam,ngate]
ref	Reflectivity	[nchan,nbeam,ngate]

These parameters require that the radar reflectivities are calibrated and the noise has been removed from the power, and that the Doppler velocities are unfolded.
[xx] is a 1-D array, and [xx,xx,xx] is a 3-D array.
Nchan = number of channels, ngate = number of gates, nbeam = number of beams

The delivery schedule will be less than 4– 6 months for the low level data, with emphasis and first delivery on the highest priority cases.

High Level Processed Data

Nadir "Curtain" Cross Sections

The HIWRAP conical scan data will be used to produce vertical cross sections of along-track horizontal wind and vertical hydrometeor motion (vertical air motion + fallspeed). Vertical air motion can be derived with an appropriate empirically-based fallspeed relation [2]. The basics for the algorithm using forward and rearward looking Doppler data for the wind retrieval are given in [3]. This data will be provided in a netCDF file and the parameters are:

Table 4-5. List of parameters to be provided in HIWRAP high-level processed curtain products.

Parameter	Description	Dimensions
dx	horizontal grid spacing	1
dz	vertical grid spacing	1
ref2d	reflectivity	[dx, dz]

u2D	horizontal wind in cross section	[dx, dz]
W2D	vertical hydrometeor motion	[dx, dz]

[dx, dz] is a 2-D array.
dx = horizontal grid spacing (4.0 km); dz = vertical grid spacing (1.0 km)

The delivery schedule will be less than 9 months for the 2D gridded data, with emphasis and first delivery on the highest priority cases. All straight and level flight lines will be processed.

3D Gridded Parameters
The HIWRAP data will also be used to produce 3D gridded data sets. As HIWRAP moves over a region, the conical scans from two tilt angles provide Doppler measurements at different look angles allowing least squares and variational optimization retrievals of the horizontal wind vector and vertical hydrometeor motion. Vertical air motion can be derived with an appropriate empirically-based fallspeed relation. This data will be provided in a netCDF file and the parameters are:

Table 4-6. List of parameters to be provided in HIWRAP high-level processed gridded products.

Parameter	Description	Dimensions
dx/dy	horizontal grid spacing	1
dz	vertical grid spacing	1
ref3d	reflectivity	[dx, dy, dz]
u3D	zonal component of wind over HIWRAP swath	[dx, dy, dz]
v3D	meridional component of wind over HIWRAP swath	[dx, dy, dz]
W3D	vertical hydrometeor motion over HIWRAP swath	[dx, dy, dz]

[dx, dy, dz] is a 3-D array.
dx = east-west horizontal grid spacing (4.0 km); dy = north-south horizontal grid-spacing (4.0 km), dz = vertical grid spacing (1.0 km)

The delivery schedule will be less than 9 months for the 3D gridded data, with emphasis on the selected high priority cases since this product is more laborious than other products. Only straight and level flight lines will be processed.

Ocean Surface Winds
Ocean surface winds can be derived from the normalized radar cross section (s^o) that is obtained from HIWRAP. Ocean scatterometry has a long history at Ku-band [3], but has generally not been used at Ka-band due to contamination. HIWRAP's scatterometry is currently under development. The Ku-band Geophysical Model Function (GMF) has been around for a long

while but it is continually being improved; the Ka-band GMF has to be developed. Algorithm development will continue past the first HS3 deployment in 2012.

References

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4.1.4 CPL

Table 4-7. List of products to be provided by the Cloud Physics Lidar (CPL).

Category	Data Product Name	Parameters	Format Type	Est. File Size	Data use	Time Res.	Spatial Res.
Meta Data							
	map_*sortie_date*.gif	Flight track map with time stamps	GIF image	0.03 Mb	General	n/a	n/a
Low-Level Processing							
	cal_*sortie_date*.final	Calibration coefficients to apply to NRB file to create atten. backscatter profiles for flight segment	text	0.02 Mb	Only appl. to lidar attenuated backscatter profile creation	n/a	n/a
	imgsum_*sortie_date*_wl.gif	Summary curtain image of atten. backscatter per wavelength for flight segment	GIF image	0.25 Mb	General use showing signal strength inside particulate layers	10 sec	30 m vert. 1800 m horiz.
	imgseg*nn*_*sortie_date*.gif	A series of 30-min curtain images of 355, 532, & 1064 nm atten. backscatter plus depolarization ratio	GIF image	0.17 Mb	General use showing signal strength inside particulate layers	1 sec	30 m vert. 180 m horiz.

	layers_*sortie_date*.txt	Time, latitude, longitude, plane height, roll, no. of layers, top, bottom, & type of all layers, height of earth's surface	text	1.10 Mb	General use showing layer location	1 sec	30 m vert. 180 m horiz.
	cipbl_*sortie_date*.txt	Layer location, lidar ratio & optical depth for cirrus "zone" and cloud-cleared PBL only	text	3.50 Mb	First look optical properties of cirrus & PBL	1 sec	180 m horiz.
	ciod_*sortie_date*.gif	Summary plot displaying cirrus zone optical depth	GIF image	0.02 Mb	First look optical depth of cirrus	1 sec	. 180 m horiz.
	pblod_*sortie_date*.gif	Summary plot displaying PBL optical depth	GIF image	0.01 Mb	First look optical depth of PBL	1 sec	180 m horiz.
High-Level Processing							
	NRB_*sortie_date*.xdr	Normalized non-calibrated backscatter profiles per wl & depolarization ratio profiles after instrument corrections plus navigation data & layer info for flight segment	Binary	461.23 Mb	Final processed lidar. backscatter profiles when calibration applied	1 sec	30 m vert. 180 m horiz.
	OP_*sortie_date*.xdr	optical properties of every layer sensed, including optical depth, lidar ratio, and extinction profiles per wl	Binary	417.58 Mb	Final processed optical properties	1 sec	30 m vert. 180 m horiz.
	EXTSEG*nn_sortie_date*.gif	A series of 30-min plots displaying layer type and loc., 532, 1064 extinction, and column optical depth per wl	GIF image	0.05 Mb	General use showing extinction results	1 sec	30 m vert. 180 m horiz.
	cod_*sortie_date*.gif	Summary plot displaying column total cloud optical	GIF image	0.02 Mb	General use showing total cloud OD	1 sec	180 m horiz.

		depth per wl for flight seg.					
	aod_*sortie_date*.gif	Summary plot displaying column total aerosol optical depth per wl for flight seg.	GIF image	0.02 Mb	General use showing total aerosol OD	1 sec	180 m horiz.
	tod_*sortie_date*.gif	Summary plot displaying column total optical depth per wl for flight seg.	GIF image	0.02 Mb	General use showing total OD	1 sec	180 m horiz.

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4.1.5 S-HIS

Table 4-8. List of products to be provided by S-HIS.

	Data Type	File Type	Product Description	Creation	Archive
Low-Level Processed Data					
	Raw (L0)	RSH file	Numerically Filtered Interfereograms	On instrument in real-time	48 hours
	Radiance (L1B)	netCDF	Calibrated and geo-located radiance spectra	At ground station within 48 hours	6 months
High-Level Processed Data					
	Profiles (L2)	netCDF	Vertical profiles of atmospheric temperature and water vapor	At home institution within 48 hours	6 months
	Browse	Image files	2D and 3D graphical images	Within 48 hours	6 months
Ancilliary Information					
	Source Code	Zip or Tar	Source code used in processing L1 and L2 data	Within 6 months	9 months
	ATBD	DOC	Algorithm description document	Within 6 months	9 months
	Data Quality	DOC	Summary of product data quality for users.	Within 6 months	9 months

4.1.6 TWiLiTE

Low Level Processed Data

TWiLiTE is a clear air Doppler lidar system that derives wind profile information by measuring the Doppler shift of the molecular backscattered laser signal. The backscattered laser signal is collected in three channels each with several photomultiplier detectors operating in photon counting mode sampling the signal. One channel is an energy monitor and there are two edge filter channels. The edge filter channels are filtered with a high spectral resolution Fabry Perot etalon and are used for the Doppler wind measurement. The energy monitor channel contains unfiltered backscattered signal information that can be used for signal normalization and to obtain cloud and aerosol information. The lidar operates with a 45 deg nadir angle and the telescope steps through a sequence of discrete azimuth angles, dwelling at each position to collect sufficient signal for a radial Doppler shift measurement at that azimuth angle. The conical step stare scan data is processed into a sequence of profiles, or radial data, covering the 360^{o} scan cycle. Lidar signal data for each detector is sampled in range every 30 meters and stored every 1 second. Each radial wind profile derives lidar SNR and Doppler information from accumulating 2000 pulses, a 10 sec dwell at a 200 Hz pulse repetition frequency. The typical step stare pattern proposed for HS3 will have 4 to 8 azimuthal angles to produce the wind profiles.

TWiLiTE lidar signal data and radial wind files are as follows:

- The low level files are in NetCDF (Network Common Data Form), and are named as the examples for TWiLiTE signal and radial Doppler files respectively:

  hs3_twilite_signal_yymmdd_hhmmss_hhmmss.nc
  hs3_twilite_radial_yymmdd_hhmmss_hhmmss.nc

  where yymmdd_hhmmss_hhmmss – indicate the GPS start and end time of the data (year, month, day and hours, minutes, seconds)
- The base range gate spacing for the lidar signal data is 30 meters and is recorded at 1 second intervals. The radial Doppler retrievals will be averaged in range and in time. The averaging will be integer multiples of the base values given by parameters Range_avg and Dwell.
- Measurements included within the lidar signal data files are measured signal counts for each detector. The data are corrected for solar background and corrected for detector deadtime effects.
-
- Doppler radial velocity profiles for given HOE telescope azimuth angle.
- The Doppler radial velocity has been corrected for aircraft motion.
- Other information associated with aircraft and instrument positions and orientation is also included. These data can be read with most any NetCDF reader, thus no sample read software is provided by the data producer. More information about NetCDF may be found at
  http://www.unidata.ucar.edu/software/netcdf/

The following quantities are provided for each azimuthal angle and each detector channel, edge or energy monitor:

Table 4-9. List of parameters to be provided in TWiLiTE low-level sigal products.

Parameter	Description	Dimensions
Tgps	GPS time (seconds from previous Sunday at 00 UT)	[nazim]
Lat	Latitude (deg)	[nazim]
Lon	Longitude (deg)	[nazim]
HOE_az	HOE rotation angle (deg)	[nazim]
Alt	Altitude of the aircraft (m)	[nazim]
Head	Aircraft heading (deg)	[nazim]

Track	Aircraft track (deg)	[nazim]
Evel	East Aircraft speed (deg)	[nazim]
Nvel	North Aircraft speed (deg)	[nazim]
Wvel	Vertical Aircraft speed (deg)	[nazim]
Roll	Aircraft roll angle (deg)	[nazim]
Pitch	Aircraft pitch angle (deg)	[nazim]
LaserEM	Outgoing laser pulse energy (200 shot avg)	[nchan,nazim]
Nadir	nadir angle of beam	[nchan,nazim]
Signalcts_avg	detected signal cts	[nchan,nazim,ngate]

These parameters require that the detected signal counts are calibrated and the background noise has been removed.
[xx] is a 1-D array, and [xx,xx,xx] is a 3-D array.
Nchan = number of channels, ngate = number of gates, nazim = number of azimuth positions,

Table 4-10. List of parameters to be provided in TWiLiTE low-level processed radial wind products.

Parameter	Description	Dimensions
Tgps_avg	GPS time (seconds from previous Sunday at 00 UT)	[nazim]
Lat_avg	Latitude (deg)	[nazim]
Lon_avg	Longitude (deg)	[nazim]
HOE_az	HOE rotation angle (deg)	[nazim]
Alt_avg	Altitude of the aircraft (m)	[nazim]
Head_avg	Aircraft heading (deg)	[nazim]
Track_avg	Aircraft track (deg)	[nazim]
Uvel_avg	U component Aircraft speed (m/s)	[nazim]
Vvel_avg	V component Aircraft speed (m/s)	[nazim]
Wvel_avg	Vertical Aircraft speed	[nazim]
Roll_avg	Aircraft roll angle (deg)	[nazim]
Pitch_avg	Aircraft pitch angle (deg)	[nazim]
LaserEM_avg	Outgoing laser pulse energy (mJ)	[nazim]
Dwell	Dwell time at Azimuth position (sec)	
Range_avg	Range gates averaged	[nazim]
Etalpos_	Etalon lock position	[nazim]
Sgate	surface gate index	[nazim]
Nadir	nadir angle of beam	[nchan,nazim]
Radialv_corr	Doppler velocity corrected for aircraft motion	[nchan,nazim,ngate]
Signalcts_avg	Detected signal counts	[nchan,nazim,ngate]

EdgeSens	Edge filter sensitivty	[nchan,nazim,ngate]
Shot_error	Signal shot noise limited error estimate	[nchan,nazim,ngate]

These parameters require that the detected signal counts are calibrated and the background noise has been removed.
[xx] is a 1-D array, and [xx,xx,xx] is a 3-D array.
Nchan = number of detector channels, ngate = number of range gates, nazim = number of beams, Quantities with _avg suffix have been averaged over time spent at each HOE azimuth positions denoted by quantity Dwell

The delivery schedule will be less than 3– 6 months for the low level data, with emphasis and first delivery on the highest priority cases. All straight and level flight lines will be processed first.

High Level Processed Data

3D Gridded Parameters

The TWiLiTE data will also be used to produce 3D gridded data sets. As TWiLiTE moves over a region, the repetitive step stare azimuth scans provide radial Doppler measurements at different look angles allowing variational optimization retrievals of the horizontal (u,v components) wind vectors. This data will be provided in a netCDF file and the parameters are:

Table 4-11. List of parameters to be provided in TWiLiTE high-level processed gridded products.

Parameter	**Description**	**Dimensions**
dx/dy	horizontal grid spacing	1
Dz	vertical grid spacing	1
Sig3d	Average signal counts	[dx, dy, dz]
u3D	zonal component of wind over TWiLiTE swath	[dx, dy, dz]
v3D	meridional component of wind over TWiLiTE swath	[dx, dy, dz]

[dx, dy, dz] is a 3-D array.
dx = east-west horizontal grid spacing (4.0 km); dy = north-south horizontal grid-spacing (4.0 km), dz = vertical grid spacing (1.0 km)

The delivery schedule will be less than 9 months for the 3D gridded data, with emphasis on the selected high priority case. Only straight and level flight lines will be processed.

4.1.7 AVAPS
The science data product from AVAPS will be high vertical resolution soundings of pressure, temperature, and humidity variables along with wind speed and direction. The data will be

provided, following quality control by scientists on the instrument team, in the Earth Observing Laboratory (EOL) sounding file format that has commonly been used for AVAPS deployments in past field campaigns.

The EOL format is an ASCII text format that includes a header (Table 4-12), with detailed project and sounding information, and seventeen columns of high-resolution data (Table 4-13). The "QC.eol" files are quarter-second resolution data files with appropriate corrections and quality control measures applied. Note that the thermodynamic data (pressure, temperature and humidity) are only available at half-second resolution and wind data is available at quarter-second resolution. The naming convention for these files is "D", followed by "yyyymmdd_hhmmss_PQC.eol" where yyyy = year, mm = month, hh = hour of the day UTC, mm = minute of the hour, ss = second of the hour (which refer to the launch time of the sonde), and "QC.eol" refers to the EOL file format type.

Table 4-12. EOL Sounding File Format

```
Data Type/Direction:                    AVAPS SOUNDING DATA, Channel 3/Descending
File Format/Version:                    EOL Sounding Format/1.1
Project Name/Platform:                  NASA HS3 2011, Science Flight 1/Global Hawk, NASA 872 (AV-6)
Launch Site:
Launch Location (lon,lat,alt):          154 26.51'W -154.441874, 27 00.48'N 27.007975, 18420.10
UTC Launch Time (y,m,d,h,m,s):          2011, 09, 09, 14:10:07
Sonde Id/Sonde Type:                    094355195/
Reference Launch Data Source/Time:      IWGADTS Format (IWG1)/14:10:07
System Operator/Comments:               Remote Operator/none, none
Post Processing Comments:               Aspen Version 3.1; Created on 14 Oct 2011 20:12 UTC; Configuration GHdropsonde
/
  Time   -- UTC  --   Press    Temp   Dewpt     RH    Uwind   Vwind    Wspd     Dir      dZ  GeoPoAlt         Lon         Lat   GPSAlt
   sec   hh mm   ss      mb       C       C      %      m/s     m/s     m/s     deg     m/s         m         deg         deg        m
-------- -- -- ----- ------- ------- ------- ------- ------- ------- ------- ------- ------- -------- ----------- ----------- --------
  -1.0   14 10  6.00   74.80  -67.60 -999.00 -999.00    7.73    2.41    8.10  252.70 -999.00 18355.81 -154.441874   27.007975 18420.10
   0.0   14 10  7.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
   0.2   14 10  7.25 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
   0.5   14 10  7.50 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
   0.8   14 10  7.75 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
   1.0   14 10  8.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
   1.2   14 10  8.25 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
   1.5   14 10  8.50 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00 -999.00  -999.00 -999.000000 -999.000000  -999.00
```

The header contains information including data type, project name, site location, actual release time, and other specialized information. The first seven header lines contain information identifying the sounding. The release location is given as: lon (deg min), lon (dec. deg), lat (deg min), lat (dec. deg), altitude (meters). Longitude in deg min is in the format: ddd mm.mm'W where ddd is the number of degrees from True North (with leading zeros if necessary), mm.mm is the decimal number of minutes, and W represents W or E for west or east longitude, respectively. Latitude has the same format as longitude, except there are only two digits for degrees and N or S for north/south latitude. The following three header lines contain information about the data system and auxiliary information and comments about the sounding. The last 3 header lines contain header information for the data columns. Line 12 holds the field names, line 13 the field units, and line 14 contains dashes (--- characters) signifying the end of the header. Data fields are listed below in Table 4-13.

The variables pressure, temperature, and relative humidity are calibrated values from measurements made by the dropsonde. The dew point is calculated from the relative humidity and temperature. The geopotential altitude is calculated from the hydrostatic equation, typically from the ocean's surface upward. For dropsondes that failed to transmit useful data to the surface, we integrate geopotential altitude from flight level down. The descent rate of the sonde is computed using the time-differentiated hydrostatic equation. The position (lat, lon) and wind data come directly from the GPS sensor.

Table 4-13. Data Fields Provided in the EOL Format ASCII Soundings

Field No.	Parameter	Units	Measured/Calculated
1	Time	Seconds	---------------
2	UTC Hour	Hours	---------------
3	UTC Minute	Minutes	---------------
4	UTC Second	Seconds	---------------
5	Pressure	Millibars	Measured
6	Dry-bulb Temperature	Degrees C	Measured
7	Dewpoint Temperature	Degrees C	Calculated
8	Relative Humidity	Percent	Measured
9	U Wind Component	Meters/Second	Calculated
10	V Wind Component	Meters/Second	Calculated
11	Wind Speed	Meters/Second	Measured
12	Wind Direction	Degrees	Measured
13	Descent Rate	Meters/Second	Calculated
14	Geopotential Altitude	Meters	Calculated
15	Longitude	Degrees	Measured
16	Latitude	Degrees	Measured
17	GPS Altitude	Meters	Measured

While preliminary sounding data will be available to appropriate HS3 participants upon request shortly after flight completion, the formal science product will be made available only after detailed quality control in the months following the science flights. The detailed steps in the data quality control process are as follows:

1. Profiles of pressure, temperature, RH, wind speed and descent rate from the raw D-files are first examined to determine if all of the files contain data, and to ensure that nothing looks suspicious. Doing this allows us to determine if a sounding was started up, but not launched, or if the data contains any features that warrant further investigation.

2. The raw soundings files are then processed through the Atmospheric Sounding Processing ENvironment (ASPEN) software, which analyzes the data, performs smoothing, sensor time response corrections, and removes suspect data points.

3. Time series plots of quality controlled temperature, RH, wind speed, and fall rate, are used to examine the consistency of soundings launched during each flight, and to show the variability of soundings from different missions. These plots are also used to determine if the sounding did not transmit data to the surface, or if there was a "fast fall" caused by failure of the parachute to properly deploy.

4. Profiles of temperature, RH and winds from the quality controlled soundings are visually evaluated for outliers, or any other obvious issues.

5. Finally, histograms of pressure, temperature, relative humidity, wind speed and wind direction are created to examine the distribution, range, and characteristics of each parameter.

4.2 Associated Archive Products

4.2.1 Aircraft flight reports

After each flight, the GH mission management team will submit a flight report through the Airborne Science Program (ASP) Website on-line system. This is a requirement of the ASP management for all SMD aircraft flights. The report will be automatically linked to the HS3 website and can be accessed through the calendar by clicking on the icon shown on the flight day.

4.2.2 Mission scientist reports

Two types of reports will be produced by the mission scientists. Daily reports will provide high-level summaries of daily weather conditions and forecasts and the flight tasking decisions and options for each Global Hawk for the current and next several days. This will be posted and archived in the ASP Mission Tool Suite site and available to all HS3 participants. Science flight summary reports by the mission scientists will be produced after each flight. This report will provide a description of significant events that occurred during each flight including problems related to the aircraft or instruments, weather conditions during flight and key observations related to the mission science objectives. This will also be submitted through the ASP Website on-line system and will be combined with the flight report to create one document accessible through the HS3 website calendar.

4.2.3 Forecaster reports

Weather discussions and forecasts will be prepared on a daily basis to aid flight planning. The discussions and forecasts will cover the next 3-5 days and will include information on local conditions at Wallops, current conditions in the tropics, the likelihood of tropical storm formation, and track and intensity forecasts for existing storms. While the discussions will be conducted primarily through WebEx and web browsing software, forecasters will prepare forecast summaries each day, usually in the form of PowerPoint presentations. These summaries will be archived. This will be posted and archived in the ASP Mission Tool Suite site and available to all HS3 participants.

4.2.4 GH navigation data

Navigation data from all Global Hawk flights will be archived at Ames Research Center.

4.2.5 2011 Test flight data

During September 2011, two test flights were conducted with AV-6 with HAMSR, S-HIS, and AVAPS onboard. The first flight occurred in the Pacific Ocean region flying a north-to-south leg from 50°N to 10°N along the longitude of Hawaii. The goal of the flight was to intercompare measurements from the three instruments. The second flight was in the Gulf of Mexico. The primary goal of this flight was a comparison of measurements from the Global Hawk and NOAA G-IV dropsonde systems. Data from these test flights for HS3 will be archived with data from the hurricane season deployments.

5.0 Acronyms

ASCII	American Standard Code for Information Interchange
ASPEN	Atmospheric Sounding Processing ENvironment
ATBD	Algorithm Theoretical Basis Documents
AV	Air Vehicle
AVAPS	Airborne Vertical Atmospheric Profiling System
CAMEX	Convection and Moisture Experiment
CPL	Cloud Physics Lidar
DMP	Data Management Plan
DOE	Department of Energy
DVD	Digital Video Disc
ECHO	EOS Clearing House
EMS	ESDIS Metrics System
EOL	Earth Observing Laboratory
EOS	Earth Observing System
ESD	Earth Science Division
ESDIS	Earth Science Data & Information System
ESSPO	Earth Science Systems Program Office
EV	Earth Venture
FTP	File Transfer Protocol
GCMD	Global Change Master Directory
GH	Global Hawk
GHRC	Global Hydrology Resource Center
GMF	Geophysical Model Function
GPS	Global Positioning System
GRIP	Genesis and Rapid Intensification Processes
GSFC	Goddard Space Flight Center
GTS	Global Telecommunications System
HAMSR	High-Altitude MMIC Sounding Radiometer
HFIP	Hurricane Forecast Improvement Project
HIRAD	Hurricane Imaging Radiometer
HIWRAP	High-altitude Imaging Wind and Rain Airborne Profiler
HS3	Hurricane and Severe Storm Sentinel
HSRP	Hurricane Science Research Program
IIP	Instrument Incubator Program
IR	Infrared
JPL	Jet Propulsion Laboratory
LRC	Langley Research Center
MABEL	Multiple Altimeter Beam Experimental Lidar
MIST	Miniature In-situ Sounding Technology
MMIC	Monolithic Microwave Integrated Circuit
NAMMA	NASA African Monsoon Multidisciplinary Activities
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System

OD	Optical Depth
P	Pressure
PI	Principal Investigator
PM	Project Manager
QA	Quality Assurance
QC	Quality Control
RFI	Radio Frequency Interference
RH	Relative Humidity
ROSES	Research Opportunities in Space and Earth Science
SAFARI	Southern African Regional Science Initiative
SAL	Saharan Air Layer
SFMR	Stepped Frequency Microwave Radiometer
S-HIS	Scanning High-resolution Interferometer Sounder
T	Temperature
TB	Brightness Temperature
TWiLiTE	Tropospheric Wind Lidar Technology Experiment
UAS	Unmanned Airborne System
USAF	U. S. Air Force
UTC	Coordinated Universal Time
WISPAR	Winter Storms and Atmospheric Rivers
XDR	Extended Data Records