University of Wisconsin-Madison (UW)

S-HIS Dual-Regression Retrievals, V1.2

Data User's Guide, 2016-06-03

Revision History				
Rev	**Description**	**Date**	**Revised/ Resolved By**	**Approved By**
1.0	Original document		DCT	
1.1	Updated to represent 2015Q1 processing chain and products	2015-04-21	DH/RKG/JKT	JKT
1.2	Updated for CF-convention NetCDF output revisions 2015-2016	2016-06-03	DH	JKT
1.3	Minor revisions resolved	2017-01-10	DH/RKG/JKT	JKT

This document describes the algorithm and retrieval product of the UW hyperspectral (HS) retrieval software that takes Scanning-HIS Level 1 calibrated radiances and produces geophysical retrievals of atmospheric, surface, and cloud parameters in NetCDF file format.

This is version V1.1 of this file, which corresponds to V1.3 of the S-HIS Dual Regression algorithm and corresponding output files provided along with this file.

This algorithm and product files are very similar to that provided in the UW Community Software Processing Package (CSPP) that provides retrievals for the three operational polar-orbiting infrared sounders (Atmospheric InfraRed Sounder (AIRS) on Aqua, Infrared Atmospheric Sounding Interferometer (IASI) on Metop-A, (3) Cross-track Infrared Sounder (CrIS) on NPP), which is available at http://cimss.ssec.wisc.edu/cspp/.

For questions and feedback regarding the HS-3 SHIS DR retrievals, the main point of contact is shis-data@ssec.wisc.edu.

The Scanning-High Resolution Interferometer Sounder (S-HIS)

The S-HIS is a high spectral resolution Fourier Transform Spectrometer (FTS), providing observations of upwelling infrared radiance spectra from the Global Hawk during HS-3. The basic components of the S-HIS include a scene mirror module, telescope, Michelson plane mirror interferometer, aft optics, detector module with mechanical cooler, laser metrology, calibration blackbodies, and on-board signal processing and solid state storage. It has a 100 μrad spatial field of view, producing 2 km diameter nadir footprints from an altitude of 20 km. Earth and internal calibration bodies are viewed by rotation of the scan mirror. The scan mirror sequence is programmable; the sequence used during HS-3 provided 14 views of Earth and several calibration views per cross-track scan. The scan speed of the interferometer is 4 cm/s and the maximum optical path difference is ±1.037 cm, resulting in the collection of an interferogram with spectral resolution of 0.48 1/cm (FWHM = 0.58 1/cm) every ~0.5 seconds.

Dual Regression Algorithm Description

The hyperspectral retrieval algorithm is based on the concept of 'Dual Regression' (DR) that is a statistical eigenvector regression method. It uses a large training dataset (SeeBorV5.0_2003_July2006.bin) of globally representative atmospheric profiles, surface and cloud parameters with their associated simulated radiances (using forward model version 3.3 of PCRTM developed by Xu Liu et. al., 2006). To simulate the cloudy radiances, a fast radiative transfer model developed in collaboration with Texas A & M University (Ping Yang, Heli Wei) has been used. A

set of selected channels with wavenumbers below 2400 cm^{-1} are used. Clear sky regression coefficients have been calculated for 6 classes of brightness temperatures (average of 11 wavenumbers around at 920 cm-1). Cloudy regression coefficients have been calculated for 8 overlapping cloud classes (from 100 to 900 hPa in 200 hPa increments). In addition, coefficients for both cases (clear and cloudy) have been calculated for 11 classes of scanning angles(between 0 and 49 deg) and 5 classes of mean annual CO2 concentrations (average of 4 years from 2002 to 2013).

The two sets of regression coefficients (clear and cloudy) are then separately applied to real observations at a single-field-of view (SFOV) basis to obtain a clear-trained and cloudy-trained solution. A cloud top is set at the level where the two temperature profiles start to deviate from each other at the level closest to the central pressure of the cloud layer class from which it was derived. Only cloud classes in which the departure level falls within the cloud layer for the class from which it was produced are considered as possible solutions. If the differences between clear and cloudy profiles remain negligible at all the levels below the cloud top the FOV is considered clear and the clear-trained solution makes up the final result. On the other hand, if there is large deviation between clear and cloudy solutions the latter is retained as the solution below the cloud as long as certain thresholds, dependent on the fraction and optical depth of the cloud are met. Note, surface skin temperature and surface emissivity is retrieved under clear conditions only. Parameters like total ozone, total precipitable water, precipitable water 1-3,lifted index and convective available potential energy are retrieved under clear sky conditions and under optically thin cloud and broken cloud conditions as long as the cloud threshold conditions mentioned above are satisfied.

Note, the algorithm is applied to every SFOV. No cloud clearing is performed. The algorithm determines if a pixel can be considered clear or cloudy. Values below thick opaque clouds are replaced by fill values (i.e., -9999). It should also be noted that the retrievals below the surface are replaced with fill values. This information is important to know especially in regions of higher terrain.

The input fields required by the algorithm are the L1 radiance and associated solar zenith angle products for the S-HIS, together with an estimate of the surface pressure, the skin temperature ,the atmospheric temperature profile, and the humidity profile (e.g. from NCEP GDAS).

Bias corrections:

The current (2014) software incorporates a statistical bias correction . At a 50 km interval, simulated radiances are computed by applying PCRTM to the co-located GDAS profile; then a retrieval is performed on that simulated spectrum. The bias is

then calculated from GDAS minus GDAS_retrieved (for temperature and humidity), and applied to the original retrieved profiles.

In prior years' datasets the bias corrected retrievals were a supplemental product marked with 'bc' in the filename. Note that the bias correction is now integrated into the main dual regression retrieval algorithm. Prior years' datasets will be made available using the improved algorithm during mid-2015.

For more information about the retrieval algorithm, please see these references:

- Smith,W.L.Sr., Weisz,E., Kireev,S.V., Zhou,D.K., Li,Z., Borbas,E.E. (2011), Dual-regression retrieval algorithm for real-time processing of satellite ultraspectral radiances, Journal of Applied Meteorology and Climatology, Volume 51, Issue 8, 1455-1476.
- Weisz, E, W. L. Smith, J. Li, W. P. Menzel, N. Smith, 2011: Improved profile and cloud top retrievals by using dual-regression on high-spectral resolution measurements. Proc. Hyperspectral Imaging and Sounding of the Environment (HISE), Toronto, Canada, OSA, Paper HWA4.
- Weisz, E, J. Li, W. P. Menzel, A. K. Heidinger, B. H. Kahn, C.-Y. Liu (2007): Comparison of AIRS, MODIS, CloudSat and CALIPSO cloud top retrievals. Geophys. Res. Lett., 34, L17811.
- Weisz, E., Huang, H.-L., Li,J., Borbas,E., Baggett,K., Thapliyal,P., Guan,L. (2007), International MODIS and AIRS processing package: AIRS products and applications, Journal of Applied Remote Sensing, 1, doi:10.1117/1.2766867
- Huang,H. -L, Gumley,L. E., Strabala,K., Li,J., Weisz,E., Rink,T., Baggett,K. C., Davies,J. E., Smith,W. L., Dodge,J. C. (2004), International MODIS and AIRS processing package (IMAPP), Bulletin of the American Meteorological Society, 85, 159-161. doi: 10.1175/BAMS-85-2-159
- Liu, Xu; Smith, William L.; Zhou, Daniel K. and Larar, Allen. Principal component-based radiative transfer model for hyperspectral sensors: Theoretical concept. Applied Optics, Volume: 45, Issue: 1, 2006, pp.201-209.
- Yang, P., B. C. Gao, B. A. Baum, Y. X. Hu, W. J. Wiscombe, S. C. Tsay, D. M. Winker, and S. L. Nasiri, 2001: Radiative properties of cirrus clouds in the infrared (8–13 mm) spectral region. J. Quant. Spectrosc. Radiat. Transfer, 70, 473–504.
- Yang, P., B. C. Gao, B. A. Baum, A. J. Heymsfield, Y. X. Hu, H.-L. Huang, S. C. Tsay, and S. Ackerman, 2003: Single-scattering properties of droxtal

DR SFOV Unfiltered Output Files

Format: The data files are CF-compliant NetCDF files (http://www.unidata.ucar.edu/software/netcdf/).

File naming convention: The output file naming convention of the DR SFOV files is:

SHIS_rdr<START_TIME>end<END_TIME>sdr<SDR_TIME>.atm_prof_rtv.nc

where START_TIME and END_TIME are ISO8601 *YYYYMMDD*"T"*HHMMSS* format Date/Times for the start and end time of the data, and SDR_TIME is the Date/Time of the SDR (aka L1B) processing.

These files contain dual regression retrieval records for observations during level flight and where high quality retrievals were computed. Each data file contains a maximum of approximately 6 hours of data. Data for a given flight is therefore spread over multiple files.

The "Flight_Segment" variable is provided to identify straight and level flight legs/segments within the flight/file. Non-zero integer values denote records of the same leg/segment. Records with Flight_Segment = 0 are records corresponding to steep turns and/or ascents/descents, internal calibration views, or other conditions where retrievals are not performed, and as stated above these records are removed from both of the DR SFOV NetCDF files and radiance NetCDF files. Each flight segment also contains a consistent number of cross track FOVs per scan line.

Note that there is not a one to one correspondence of records in the DR NetCDF files with records in the radiance NetCDF files. The DR SFOV NetCDF files only include records where computed retrievals were considered “high quality” (Qflag1 == 0).

Three quality flags (Qflag1,2,3) are also provided:

(1) The first Qflag refers to the success of the retrieval run. Values can be 0, 1 or 2, describing, respectively, a successful retrieval, a bad retrieval (output=fill values) due to bad radiances, and a bad retrieval (output=fill values) due to non-convergence of the cloud class iteration.

(2) The second Qflag (certainty quality flag) describes the uncertainty associated with the decision made in the codes whether the FOV should be considered clear or cloudy. This decision is based on certain thresholds. If the actual value is close to that threshold the decision is regarded as uncertain (Value=1), otherwise it is certain (Value=0).

(3) The third Qflag (accuracy quality flag) can assume values 0 (=very good), 1 (=good),2 (=acceptable) or 3 (=not acceptable) based on the overall (tropopause to surface) level mean root-mean-square-error (RMSE) (or retrieved profile temperature error) derived from the difference between retrieved temperature minus GDAS temperature. Value = 0 if RMSE <= 1.5 K, Value=1 if 1.5<=RMSE<3 K, Value=2 if 3<=RMSE<4.5 K, Value=3 if RMSE>=4.5 K. If there are not enough levels (i.e. less than 5) to compute the 'GDAS vs.retrieval' level mean RMSE then the value of this quality flag will be set to the fill-value. Please note that in this case the retrievals themselves might still be good, i.e.contain values other than fill values.

Additionally, retrievals are valid only where the aircraft altitude (variable Aircraft_Altitude) is above ~16 km.

DR SFOV Filtered Output Files

Format: The data files are CF-compliant NetCDF files (http://www.unidata.ucar.edu/software/netcdf/).

File naming convention: The output file naming convention of the DR SFOV files is: SHIS_rdr<START_TIME>end<END_TIME>sdr<SDR_TIME>.atm_prof_rtv_avg.nc

where START_TIME and END_TIME are ISO8601 YYYYMMDD"T"HHMMSS format Date/Times for the start and end time of the data, and SDR_TIME is the Date/Time of the SDR (aka L1B) processing.

In addition to the invalid record filtering of the unfiltered files, these filtered files contain S-HIS retrievals in which “nearest neighbor” retrievals are filtered and averaged to remove a cold bias caused by undetected cloud attenuation. For each valid retrieval, the "nearest neighbor" retrievals within a great circle distance of 0.05 degrees (i.e., 5.55km) are collected and averaged. The nearest neighbors greater than or equal to the area mean value are then averaged to produce the final value for the air temperature retrieval. The means of all other retrieval quantities associated with the "warmest" neighbors are also averaged to form the final values for each of the retrieved variables listed below.

DR SFOV Data File Contents

The following parameters are retrieved and provided in the NetCDF files. Further information on the units, sizes, fill values, etc of these variables is provided below.

- atmospheric temperature [K] at 101 pressure levels
- atmospheric humidity [g/kg] at 101 pressure levels
- atmospheric ozone [ppmv] at 101 pressure levels
- atmospheric relative humidity [%] at 101 pressure levels
- atmospheric dew point temperature [K] at 101 pressure levels
- surface skin temperature [K]
- surface emissivity at instrument spectral resolution [cm-1]

- total precipitable water (vertically integrated from 100 hPa to surface) [cm]
- precipitable water 1 (vertically integrated from 900 hPa to surface) [cm]
- precipitable water 2 (vertically integrated from 700 to 900 hPa) [cm]
- precipitable water 3 (vertically integrated from 300 to 700 hPa) [cm]
- total ozone amount (vertically integrated) [dobson units]
- lifted index [deg celsius]
- convective available potential energy [J/kg]
- CO2 amount [ppmv]
- cloud top pressure [hPa]
- cloud top temperature [K]
- cloud optical thickness
- effective cloud emissivity
- cloud mask (values: 0 clear, 1 cloud)

In addition to the parameters above the output file contains:

- latitude [degrees]
- longitude [degrees]
- pressure levels [hPa]
- surface emissivity wavenumbers [cm^-1]
- channel index (indices of good channels used in retrieval)
- 3 quality flags
- GDAS surface pressure (gdas values interpolated to sounder grid) [hPa]
- GDAS temperature (gdas values interpolated to sounder grid) [K]
- GDAS relative humidity (gdas values interpolated to sounder grid) [%]
- aircraft altitude
- flight segment (integer index to straight/level legs within the flight)
- date (in YYMMDD)

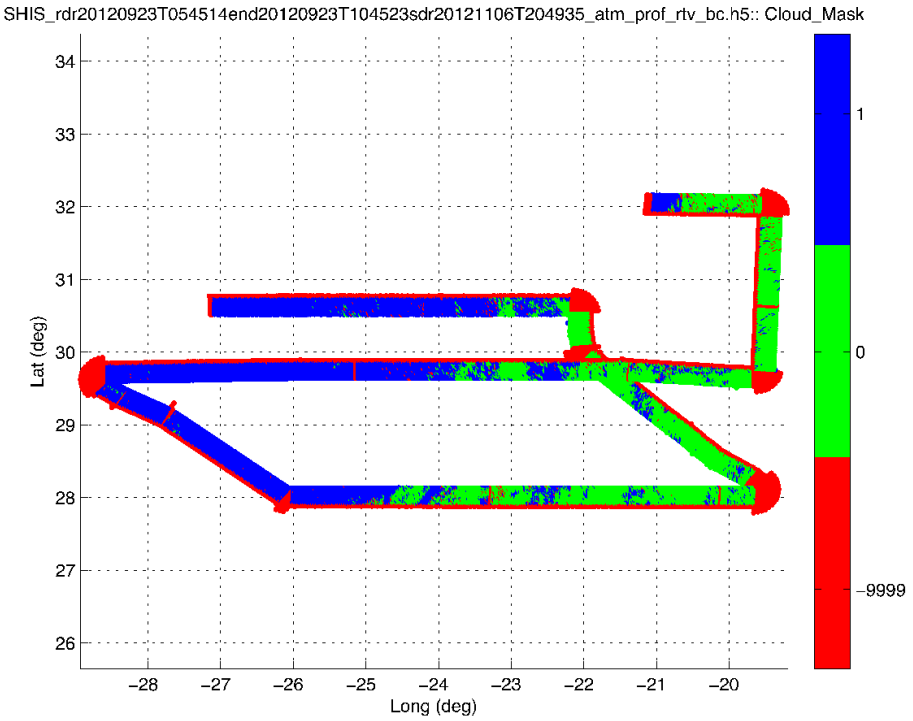
- time (in HHMMSS)
- aircraft time (fractional hours)
- FOVangle (scan angle)

Quicklook images

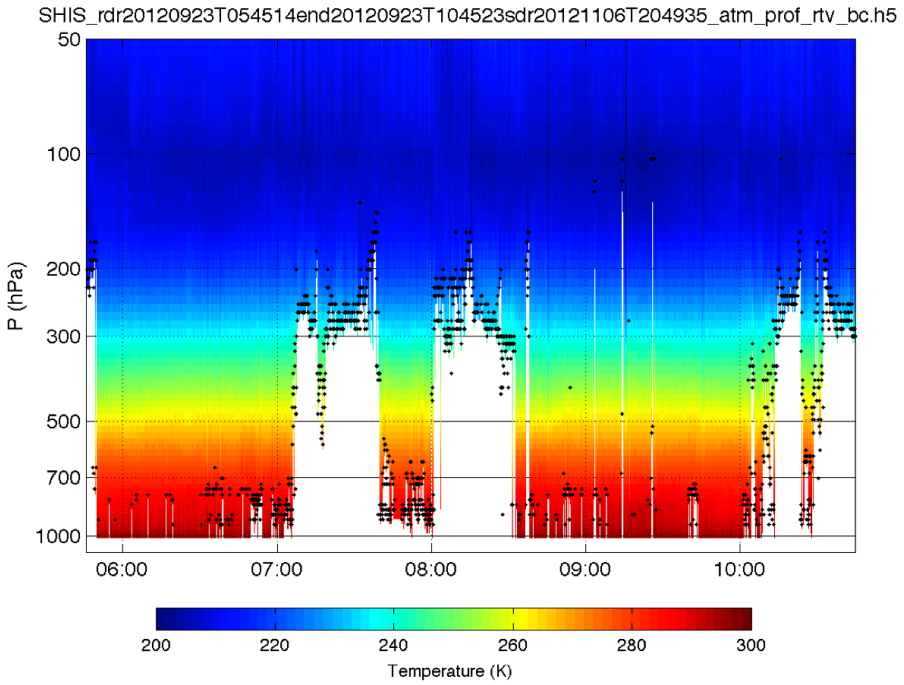
For each SFOV data file, several quicklook images are provided.

- Lat/Lon map of Cloud Mask (fig1)
- Nadir view cross section of retrieved Temperature and Cloud Top Pressure (fig2)
- Nadir view cross section of retrieved Relative Humidity and Cloud Top Pressure (fig3)
- Nadir view cross section of model (GDAS) Temperature (fig4)
- Nadir view cross section of model (GDAS) Relative Humidity (fig5)

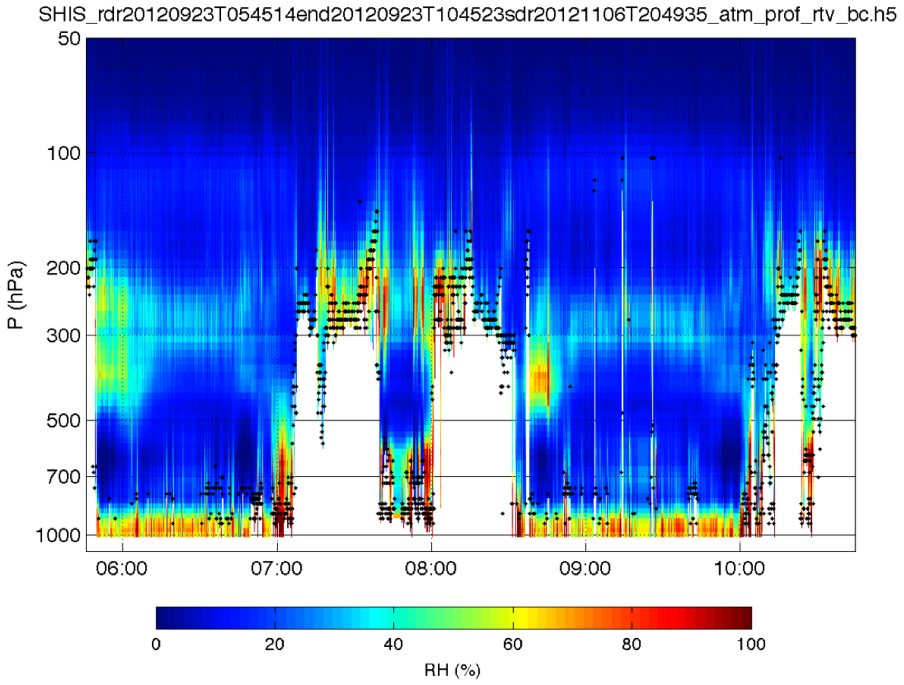
Sample quicklook plots are shown below.



DR Cloud Mask values (1=cloudy, 0=clear,-9999=fill) for a flight segment on 23 Sep 2012 from 05:45:14 to 10:45:23 UTC.



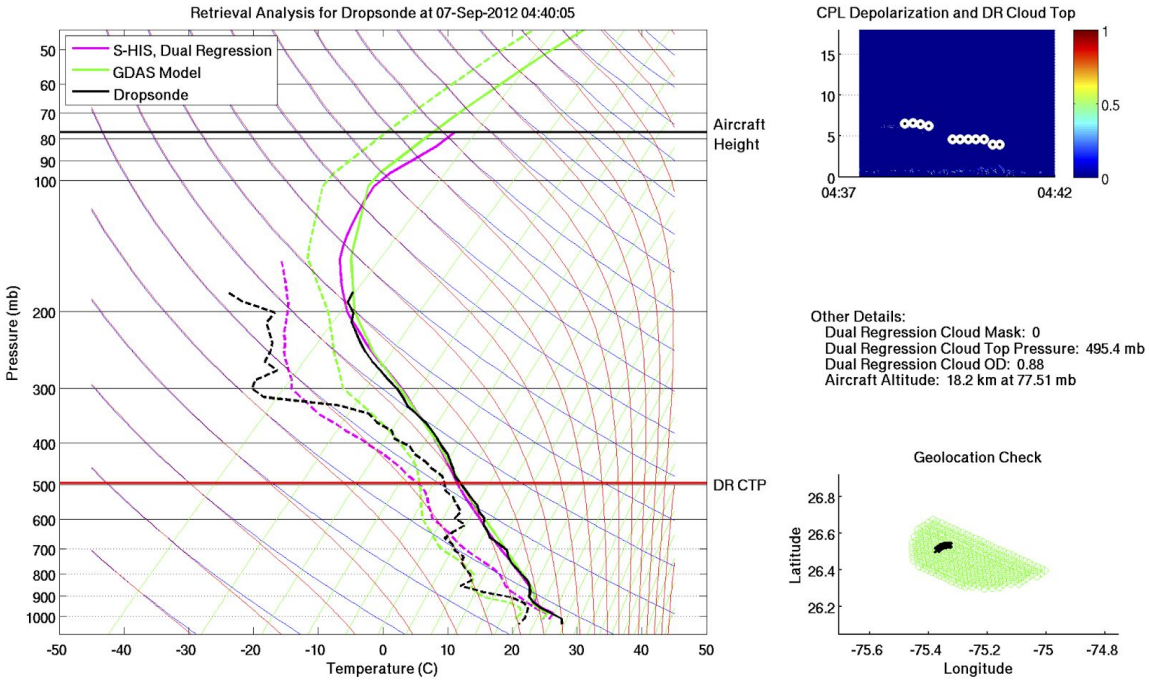
Nadir DR Air Temperature cross section for a flight segment on 23 Sep 2012 from 05:45:14 to 10:45:23 UTC.



Nadir DR Relative Humidity cross section for a flight segment on 23 Sep 2012 from 05:45:14 to 10:45:23 UTC.

Dropsonde/CPL/DR comparison plots

Comparisons of HS3 dropsondes, CPL, and DR products are provided for a subset of the flights where such data is available. These plots/files include comparisons of the Scanning-HIS DR and dropsonde temperature and dewpoint profiles, and a quicklook of the Scanning-HIS DR cloud top height retrieval at the dropsonde time overlaid with the CPL depolarization. A sample result for the 07-Sep-2012 054:40 dropsonde is shown below. Other plots showing statistical comparisons of the DR and dropsonde profiles and the DR and CPL cloud heights are also provided.



Example comparison of S-HIS DR and dropsonde temperature and relative humidity profiles and CPL depolarization and S-HIS DR cloud top height for the 07-Sep-2012 04:40 dropsonde.

Errata: Missing Files

Due to instrument calibration quality checks, not all sections of flights have radiances or dual regression retrieval products. Typically such sections occur during the descent or ascent phases of flight.

Appendix A: NetCDF File Content Description for a sample DR SFOV file

```
netcdf SHIS_rdr20140930T203727end20140930T224712sdr20160322T185948_atm_prof_rtv {
dimensions:
    SurfEmis_Wavenumbers = 4366 ;
    record = UNLIMITED ; // (4214 currently)
    Channel_Index = 3142 ;
    Plevs = 101 ;
variables:
    float CTT(record) ;
        CTT:_FillValue = -9999.f ;
        CTT:units = "K" ;
        CTT:long_name = "Cloud Top Temperature" ;
        CTT:missing_value = -9999.f ;
        CTT:description = "cloud top temperature" ;
    float Dewpnt(record, Plevs) ;
        Dewpnt:_FillValue = -9999.f ;
        Dewpnt:units = "K" ;
        Dewpnt:long_name = "Dewpoint Temperature Profile" ;
        Dewpnt:missing_value = -9999.f ;
        Dewpnt:description = "dew point temperature profile" ;
    float COT(record) ;
        COT:_FillValue = -9999.f ;
        COT:units = "1" ;
        COT:long_name = "Cloud Optical Thickness" ;
        COT:missing_value = -9999.f ;
        COT:description = "retrieved cloud optical thickness" ;
    float Aircraft_Altitude(record) ;
        Aircraft_Altitude:_FillValue = -9999.f ;
        Aircraft_Altitude:units = "km" ;
        Aircraft_Altitude:long_name = "Aircraft Altitude" ;
        Aircraft_Altitude:standard_name = "altitude" ;
        Aircraft_Altitude:missing_value = -9999.f ;
        Aircraft_Altitude:description = "Aircraft Altitude" ;
    float H2Olow(record) ;
        H2Olow:_FillValue = -9999.f ;
        H2Olow:units = "cm" ;
        H2Olow:long_name = "Low-Level Precipitable Water Vapor" ;
        H2Olow:missing_value = -9999.f ;
        H2Olow:description = "vertically integrated water vapor from 900 hPa to surface" ;
    float TAir(record, Plevs) ;
        TAir:_FillValue = -9999.f ;
        TAir:units = "K" ;
        TAir:long_name = "Temperature Profile" ;
        TAir:missing_value = -9999.f ;
        TAir:description = "retrieved temperature profile at 101 levels" ;
    float CldEmis(record) ;
        CldEmis:_FillValue = -9999.f ;
        CldEmis:units = "1" ;
        CldEmis:long_name = "Effective Cloud Emissivity" ;
        CldEmis:missing_value = -9999.f ;
        CldEmis:description = "effective cloud emissivity" ;
    float H2OMMR(record, Plevs) ;
        H2OMMR:_FillValue = -9999.f ;
        H2OMMR:units = "g/kg" ;
        H2OMMR:long_name = "Humidity Profile" ;
        H2OMMR:missing_value = -9999.f ;
        H2OMMR:description = "retrieved humidity (water vapor mixing ratio) profile at 101 levels" ;
    int Cmask(record) ;
        Cmask:_FillValue = -9999 ;
        Cmask:units = "1" ;
        Cmask:long_name = "Cloud Mask" ;
        Cmask:standard_name = "cloud_binary_mask" ;
        Cmask:missing_value = -9999 ;
        Cmask:description = "cloud mask: 0 = clear, 1 = cloud" ;
    float totH2O(record) ;
        totH2O:_FillValue = -9999.f ;
```

totH2O:units = "cm" ;
totH2O:long_name = "Total Precipitable Water Vapor" ;
totH2O:missing_value = -9999.f ;
totH2O:description = "vertically integrated water vapor from 100 hPa to surface" ;
float Plevs(Plevs) ;
Plevs:units = "hPa" ;
Plevs:long_name = "Atmospheric Pressure Levels" ;
Plevs:standard_name = "air_pressure" ;
Plevs:description = "vertical coordinate axis (101 pressure levels)" ;
float Latitude(record) ;
Latitude:_FillValue = -9999.f ;
Latitude:units = "degrees_north" ;
Latitude:long_name = "Latitudes" ;
Latitude:standard_name = "latitude" ;
Latitude:missing_value = -9999.f ;
Latitude:valid_range = -90., 90. ;
float CTP(record) ;
CTP:_FillValue = -9999.f ;
CTP:units = "hPa" ;
CTP:long_name = "Cloud Top Pressure" ;
CTP:missing_value = -9999.f ;
CTP:description = "cloud top pressure" ;
float H2Omid(record) ;
H2Omid:_FillValue = -9999.f ;
H2Omid:units = "cm" ;
H2Omid:long_name = "Mid-Level Precipitable Water Vapor" ;
H2Omid:missing_value = -9999.f ;
H2Omid:description = "vertically integrated water vapor from 700 hPa to 900 hPa" ;
float FOVangle(record) ;
FOVangle:_FillValue = -9999.f ;
FOVangle:units = "degrees" ;
FOVangle:long_name = "FOVangle" ;
FOVangle:missing_value = -9999.f ;
FOVangle:description = "FOV Angle" ;
float aircraftTime(record) ;
aircraftTime:_FillValue = -9999.f ;
aircraftTime:units = "seconds since 2014-09-30 20:37:20" ;
aircraftTime:long_name = "aircraftTime" ;
aircraftTime:standard_name = "time" ;
aircraftTime:missing_value = -9999.f ;
aircraftTime:description = "Aircraft Time (fractional hours)" ;
float GDAS_RelHum(record, Plevs) ;
GDAS_RelHum:_FillValue = -9999.f ;
GDAS_RelHum:units = "%" ;
GDAS_RelHum:long_name = "GDAS Relative Humidity Profile" ;
GDAS_RelHum:missing_value = -9999.f ;
GDAS_RelHum:description = "Interpolated from gdas1.PGrbF00.140930.18z" ;
float Lifted_Index(record) ;
Lifted_Index:_FillValue = -9999.f ;
Lifted_Index:units = "degC" ;
Lifted_Index:long_name = "Lifted Index" ;
Lifted_Index:missing_value = -9999.f ;
Lifted_Index:description = "lifted index (LI) stability index" ;
float O3VMR(record, Plevs) ;
O3VMR:_FillValue = -9999.f ;
O3VMR:units = "1e-6" ;
O3VMR:long_name = "Ozone Profile" ;
O3VMR:missing_value = -9999.f ;
O3VMR:description = "retrieved ozone profile at 101 levels" ;
float totO3(record) ;
totO3:_FillValue = -9999.f ;
totO3:units = "Dobson" ;
totO3:long_name = "Total Ozone Amount" ;
totO3:missing_value = -9999.f ;
totO3:description = "vertically integrated ozone" ;
float GDAS_TAir(record, Plevs) ;

GDAS_TAir:_FillValue = -9999.f ;
GDAS_TAir:units = "K" ;
GDAS_TAir:long_name = "GDAS Temperature Profile" ;
GDAS_TAir:missing_value = -9999.f ;
GDAS_TAir:description = "Interpolated from gdas1.PGrbF00.140930.18z" ;
float SurfPres(record) ;
SurfPres:_FillValue = -9999.f ;
SurfPres:units = "hPa" ;
SurfPres:long_name = "GDAS Surface Pressure" ;
SurfPres:missing_value = -9999.f ;
SurfPres:description = "Interpolated from gdas1.PGrbF00.140930.18z" ;
int Qflag3(record) ;
Qflag3:_FillValue = -9999 ;
Qflag3:long_name = "Quality Flag 3" ;
Qflag3:missing_value = -9999 ;
Qflag3:description = "Temperature profile retrieval error with respect to GDAS temperature. 0=very good, 1=good, 2=acceptable, 3=not acceptable" ;
int Qflag2(record) ;
Qflag2:_FillValue = -9999 ;
Qflag2:long_name = "Quality Flag 2" ;
Qflag2:missing_value = -9999 ;
Qflag2:description = "Describes uncertainty associated with clear/cldy decision. 0=certain,1=uncertain" ;
int Qflag1(record) ;
Qflag1:_FillValue = -9999 ;
Qflag1:long_name = "Quality Flag 1" ;
Qflag1:missing_value = -9999 ;
Qflag1:description = "Reflects quality of input. 0=successful, 1=no retrieval due to bad radiances, 2=no retrieval due to non-convergence of cloud class iteration" ;
float dateYYMMDD(record) ;
dateYYMMDD:_FillValue = -9999.f ;
dateYYMMDD:long_name = "dateYYMMDD" ;
dateYYMMDD:missing_value = -9999.f ;
dateYYMMDD:description = "Date in YYMMDD" ;
int Flight_Segment(record) ;
Flight_Segment:_FillValue = -9999 ;
Flight_Segment:long_name = "Flight Segment" ;
Flight_Segment:missing_value = -9999 ;
Flight_Segment:description = "Flight Segment Numbers" ;
float Longitude(record) ;
Longitude:_FillValue = -9999.f ;
Longitude:units = "degrees_east" ;
Longitude:long_name = "Longitudes" ;
Longitude:standard_name = "longitude" ;
Longitude:missing_value = -9999.f ;
Longitude:valid_range = -180., 180. ;
float CO2_Amount(record) ;
CO2_Amount:_FillValue = -9999.f ;
CO2_Amount:units = "1e-6" ;
CO2_Amount:long_name = "Carbon Dioxide Amount" ;
CO2_Amount:missing_value = -9999.f ;
CO2_Amount:description = "retrieved carbon dioxide (CO2) amount" ;
float Time(record) ;
Time:_FillValue = -9999.f ;
Time:units = "seconds since 1970-01-01 00:00:00" ;
Time:standard_name = "time" ;
float CAPE(record) ;
CAPE:_FillValue = -9999.f ;
CAPE:units = "J/kg" ;
CAPE:long_name = "Convective Available Potential Energy" ;
CAPE:missing_value = -9999.f ;
CAPE:description = "convective available potential energy (CAPE) stability index" ;
float barometricAltitude(record) ;
barometricAltitude:_FillValue = -9999.f ;
barometricAltitude:units = "meter" ;
barometricAltitude:long_name = "barometricAltitude" ;
barometricAltitude:standard_name = "barometric_altitude" ;

```
        barometricAltitude:missing_value = -9999.f ;
        barometricAltitude:description = "Barometric Altitude" ;
    float RelHum(record, Plevs) ;
        RelHum:_FillValue = -9999.f ;
        RelHum:units = "%" ;
        RelHum:long_name = "Relative Humidity Profile" ;
        RelHum:missing_value = -9999.f ;
        RelHum:description = "retrieved relative humidity at 101 levels" ;
    float aircraftExtPressure(record) ;
        aircraftExtPressure:_FillValue = -9999.f ;
        aircraftExtPressure:units = "hPa" ;
        aircraftExtPressure:long_name = "aircraftExtPressure" ;
        aircraftExtPressure:standard_name = "air_pressure" ;
        aircraftExtPressure:missing_value = -9999.f ;
        aircraftExtPressure:description = "Aircraft External Pressure" ;
    float SurfEmis_Wavenumbers(SurfEmis_Wavenumbers) ;
        SurfEmis_Wavenumbers:units = "cm^-1" ;
        SurfEmis_Wavenumbers:long_name = "Surface Emissivity Wavenumbers" ;
        SurfEmis_Wavenumbers:standard_name = "sensor_band_central_radiation_wavenumber" ;
        SurfEmis_Wavenumbers:description = "wavenumbers at which emissivities are retrieved (full spectrum)" ;
    float H2Ohigh(record) ;
        H2Ohigh:_FillValue = -9999.f ;
        H2Ohigh:units = "cm" ;
        H2Ohigh:long_name = "High-Level Precipitable Water Vapor" ;
        H2Ohigh:missing_value = -9999.f ;
        H2Ohigh:description = "vertically integrated water vapor from 300 hPa to 700 hPa" ;
    float TSurf(record) ;
        TSurf:_FillValue = -9999.f ;
        TSurf:units = "K" ;
        TSurf:long_name = "Surface Skin Temperature" ;
        TSurf:missing_value = -9999.f ;
        TSurf:description = "retrieved surface skin temperature" ;
    float timeHHMMSS(record) ;
        timeHHMMSS:_FillValue = -9999.f ;
        timeHHMMSS:long_name = "timeHHMMSS" ;
        timeHHMMSS:missing_value = -9999.f ;
        timeHHMMSS:description = "Time in HHMMSS" ;
        timeHHMMSS:valid_range = 0., 240000. ;
    int Channel_Index(Channel_Index) ;
        Channel_Index:units = "1" ;
        Channel_Index:long_name = "Selected Channel Index" ;
        Channel_Index:description = "indices of channels used in retrieval (out of full spectrum)" ;
    float SurfEmis(record, SurfEmis_Wavenumbers) ;
        SurfEmis:_FillValue = -9999.f ;
        SurfEmis:units = "1" ;
        SurfEmis:long_name = "Retrieved Surface Emissivity" ;
        SurfEmis:missing_value = -9999.f ;
        SurfEmis:description = "retrieved surface emissivitiy at full spectrum" ;

// global attributes:
        :Number_of_Levels = "101" ;
        :DRRTV_coeffs_type = "HS3" ;
        :Number_of_Samples = "12614" ;
        :Software_Version = "SHIS_DR_RTV_V1.32" ;
        :bias_corrected = "1" ;
        :DRRTV_version = "201502" ;
        :Instrument_Name = "S-HIS" ;
        :Mission_Name = "AIRCRAFT" ;
        :SDR_uuid = "f0109ac6-0056-4c25-84be-b49314eb6c8e" ;
        :QC_filter_level = "1" ;
        :Number_of_Channels = "4366" ;
        :Creation_Date = "2016-03-22T19:24:17Z" ;
        :Averaged = 0L ;
        :Description = "This file contains S-HIS retrievals that are filtered to only include high quality retrievals (Qflag1 ==
0)." ;
        :Conventions = "CF-1.6" ;
```

```
}

END
```