



10/18/2016



HURRICANE IMAGING RADIOMETER (HIRAD)

Summary

The Hurricane Imaging Radiometer (HIRAD) is a multi-band passive microwave radiometer operating between 4-6.6 GHz. It uses novel interferometric aperture synthesis technique to produce high resolution wide swath observation without any mechanical scanning of the antenna. The instrument was designed to measure ocean surface wind speed in tropical storms and hurricanes. Developed in collaboration between scientists and engineers at NASA MSFC, University of Central Florida & University of Michigan, the instrument was first flown on NASA high altitude aircraft in the Genesis and Rapid Intensification Processes (GRIP) Experiment in 2010 and Hurricane and Severe Storm Sentinel (HS3) in 2012-2014.

Instrument Description

| | |
|-----------------------|--------------------------|
| Measurement Frequency | 4.0,5.0, 6.0 and 6.6 GHz |
| Bandwidth | 75 MHz |
| Swath Width | ~60 km |
| Resolution | ~1-5 km |
| Retrieved Wind Speed | ~10-85 m/s |
| Retrieved Rain Rate | ~5-100mm/hr |

Data Release History

10/17/2016: This release include HIRAD data (v2.1) collected during Tropical Cyclone Intensity (TCI) Experiment (July 15 – October 31, 2015) over Hurricanes: Erika (08/30), Marty (09/27, 09/28), Joaquin (10/02 – 10/05) and Patricia (10/21 – 10/23).

File Naming Convention and Data Format

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

HIRAD_data_yyyymmddTHHMMSS_yyyymmddTHHMMSS_legNN.nc

NN – leg number. Data is divided into a number of flight legs.

yyymmddTHHMMSS – UTC time for the start and end of each file with ‘T’ being a separator between date and time fields.



10/18/2016



- The content of each file is:

| Name | Long Name | Type |
|-----------------------------------------------------|------------------------------------------------------------------------------|------------|
| HIRAD_data_20151022T185440_20151022T192440_leg09.nc | HIRAD_data_20151022T185440_20151022T192440_leg09.nc | Local File |
| ACALT | Aircraft Altitude | 1D |
| ACGS | Aircraft Ground Speed | 1D |
| ACLAT | Aircraft Latitude | 1D |
| ACLON | Aircraft Longitude | 1D |
| EXTB4 | Excess Brightness Temperature @ 4.0 GHz | Geo2D |
| EXTB5 | Excess Brightness Temperature @ 5.0 GHz | Geo2D |
| EXTB6 | Excess Brightness Temperature @ 6.0 GHz | Geo2D |
| EXTB7 | Excess Brightness Temperature @ 6.6 GHz | Geo2D |
| flag4 | Validity Flag for 4.0 GHz Observations | Geo2D |
| flag5 | Validity Flag for 5.0 GHz Observations | Geo2D |
| flag6 | Validity Flag for 6.0 GHz Observations | Geo2D |
| flag7 | Validity Flag for 6.6 GHz Observations | Geo2D |
| flagHRR | Validity Flag for HIRAD Rain Rate | Geo2D |
| flagHWS | Validity Flag for HIRAD Wind Speed | Geo2D |
| HRR | HIRAD Rain Rate | Geo2D |
| HWS | HIRAD Wind Speed | Geo2D |
| JSST | JPL MUR Sea Surface Temperature | Geo2D |
| MWS | MERRA 2m Wind Speed | Geo2D |
| PANG | Aircraft Pitch Angle | 1D |
| PAZ | View Angle of Each Antenna Beam Relative to Sensor (+ve is starboard side) | 1D |
| PEIA | Pixel Earth Incidence Angle | Geo2D |
| PLAT | Pixel Latitude | 2D |
| PLON | Pixel Longitude | 2D |
| RANG | Aircraft Roll Angle | 1D |
| TB4 | Brightness Temperature @ 4.0 GHz | Geo2D |
| TB5 | Brightness Temperature @ 5.0 GHz | Geo2D |
| TB6 | Brightness Temperature @ 6.0 GHz | Geo2D |
| TB7 | Brightness Temperature @ 6.6 GHz | Geo2D |
| THDG | Aircraft True Heading (Clockwise from North) | 1D |
| TIME | UTC Time | 1D |

- For each data file a corresponding *.png image is included which contains geo-referenced images of some key variables (TB*, EXTB*, HWS and HRR).
- The “Excess Brightness Temperature” data field is derived by subtracting the modeled top of the atmosphere brightness temperature (at 0 surface wind speed) from the observed brightness temperatures. This method intends to compensate for the incidence angle dependence of the observed H-pol brightness temperature. A fixed atmospheric profile (Temperature, Pressure, Humidity) is assumed and JPL MUR sea surface temperature data (included JSST variable) used for this computation.
- Aircraft navigation data is also included (AC* variables).
- These data can be read with 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.

Data Policy

The HIRAD data collection was funded by the ONR TCI mission. Access to HIRAD data is not restricted. However, we do ask that data users respect the



10/18/2016



experiment PIs and others with rights to the data. Acknowledgement or an offer of co-authorship on any publications, presentation, etc., should be made to the PI and his/her team if images and/or data are used (even if they are freely accessed).

Contact Information

Users are welcome to address questions and provide feedback to

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10/18/2016



Appendix I Example of metadata

File "HIRAD_data_20151022T185440_20151022T192440_leg09.nc "

File type: NetCDF-3/CDM

```
netcdf file: HIRAD_data_20151022T185440_20151022T192440_leg09.nc {
  dimensions:
    time = 1801;
    azimuth = 321;
  variables:
    float PAZ(azimuth=321);
      :units = "degree";
      :valid_range = -80.0f, 80.0f; // float
      :long_name = "View Angle of Each Antenna Beam Relative to Sensor ( +ve
is starboard side )";

    double TIME(time=1801);
      :units = "seconds since 2001-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "UTC Time";

    float ACLON(time=1801);
      :units = "degrees_east";
      :valid_range = -180.0f, 180.0f; // float
      :long_name = "Aircraft Longitude";

    float ACLAT(time=1801);
      :units = "degrees_north";
      :valid_range = -90.0f, 90.0f; // float
      :long_name = "Aircraft Latitude";

    float ACALT(time=1801);
      :units = "meters";
      :valid_range = 0.0f, 20000.0f; // float
      :long_name = "Aircraft Altitude";
      :standard_name = "altitude";

    float RANG(time=1801);
      :units = "degree";
      :valid_range = -30.0f, 30.0f; // float
      :long_name = "Aircraft Roll Angle";
      :standard_name = "platform_roll_angle";
      :coordinates = "ACLON ACLAT ACALT";

    float PANG(time=1801);
      :units = "degree";
      :valid_range = -30.0f, 30.0f; // float
      :long_name = "Aircraft Pitch Angle";
      :standard_name = "platform_pitch_angle";
```



10/18/2016



```
:coordinates = "ACLON ACLAT ACALT";

float THDG(time=1801);
:units = "degree";
:valid_range = 0.0f, 360.0f; // float
:long_name = "Aircraft True Heading (Clockwise from North)";
:standard_name = "platform_yaw_angle";
:coordinates = "ACLON ACLAT ACALT";

float ACGS(time=1801);
:units = "meters per second";
:valid_range = 0.0f, 999.0f; // float
:long_name = "Aircraft Ground Speed";
:standard_name = "platform_speed_wrt_ground";
:coordinates = "ACLON ACLAT ACALT";

float PLON(time=1801, azimuth=321);
:units = "degrees_east";
:valid_range = -180.0f, 180.0f; // float
:long_name = "Pixel Longitude";

float PLAT(time=1801, azimuth=321);
:units = "degrees_north";
:valid_range = -90.0f, 90.0f; // float
:long_name = "Pixel Latitude";

float PEIA(time=1801, azimuth=321);
:units = "degree";
:valid_range = 0.0f, 90.0f; // float
:missing_value = -999.9f; // float
:long_name = "Pixel Earth Incidence Angle";
:standard_name = "angle_of_incidence";
:coordinates = "PLON PLAT";

float TB4(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Brightness Temperature @ 4.0 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag4";

float TB5(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Brightness Temperature @ 5.0 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag5";

float TB6(time=1801, azimuth=321);
```



10/18/2016



```
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Brightness Temperature @ 6.0 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag6";

float TB7(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Brightness Temperature @ 6.6 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag7";

float EXTB4(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Excess Brightness Temperature @ 4.0 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag4";

float EXTB5(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Excess Brightness Temperature @ 5.0 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag5";

float EXTB6(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Excess Brightness Temperature @ 6.0 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag6";

float EXTB7(time=1801, azimuth=321);
:units = "Kelvin";
:valid_range = 0.0f, 400.0f; // float
:missing_value = -999.9f; // float
:long_name = "Excess Brightness Temperature @ 6.6 GHz";
:standard_name = "brightness_temperature";
:coordinates = "PLON PLAT";
:ancillary_variables = "flag7";
```



10/18/2016



```
float HWS(time=1801, azimuth=321);
:units = "meters per second";
:valid_range = 10.0f, 90.0f; // float
:used_channels = "4.0,5.0,6.0 and 6.6GHz";
:missing_value = -999.9f; // float
:long_name = "HIRAD Wind Speed";
:standard_name = "wind_speed";
:coordinates = "PLON PLAT";
:ancillary_variables = "flagHWS";

float HRR(time=1801, azimuth=321);
:units = "millimeters per hour";
:valid_range = 0.0f, 110.0f; // float
:used_channels = "4.0,5.0,6.0 and 6.6GHz";
:missing_value = -999.9f; // float
:long_name = "HIRAD Rain Rate";
:standard_name = "rain_rate";
:coordinates = "PLON PLAT";
:ancillary_variables = "flagHRR";

float JSST(time=1801, azimuth=321);
:units = "Celsius";
:valid_range = 0.0f, 100.0f; // float
:missing_value = -999.9f; // float
:long_name = "JPL MUR Sea Surface Temperature";
:standard_name = "sea_surface_temperature";
:coordinates = "PLON PLAT";

float MWS(time=1801, azimuth=321);
:units = "meters per second";
:valid_range = 0.0f, 100.0f; // float
:missing_value = -999.9f; // float
:long_name = "MERRA 2m Wind Speed";
:standard_name = "wind_speed";
:coordinates = "PLON PLAT";

int flag4(time=1801, azimuth=321);
:flag_values = 0, 1, 2; // int
:flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
:long_name = "Validity Flag for 4.0 GHz Observations";
:standard_name = "brightness_temperature_status_flag";
:coordinates = "PLON PLAT";

int flag5(time=1801, azimuth=321);
:flag_values = 0, 1, 2; // int
:flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
:long_name = "Validity Flag for 5.0 GHz Observations";
:standard_name = "brightness_temperature_status_flag";
:coordinates = "PLON PLAT";

int flag6(time=1801, azimuth=321);
:flag_values = 0, 1, 2; // int
:flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
```



10/18/2016



```
:long_name = "Validity Flag for 6.0 GHz Observations";
:standard_name = "brightness_temperature_status_flag";
:coordinates = "PLON PLAT";

int flag7(time=1801, azimuth=321);
:flag_values = 0, 1, 2; // int
:flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
:long_name = "Validity Flag for 6.6 GHz Observations";
:standard_name = "brightness_temperature_status_flag";
:coordinates = "PLON PLAT";

int flagHWS(time=1801, azimuth=321);
:flag_values = 0, 1, 2; // int
:flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
:long_name = "Validity Flag for HIRAD Wind Speed";
:standard_name = "wind_speed_status_flag";
:coordinates = "PLON PLAT";

int flagHRR(time=1801, azimuth=321);
:flag_values = 0, 1, 2; // int
:flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
:long_name = "Validity Flag for HIRAD Rain Rate";
:standard_name = "rain_rate_status_flag";
:coordinates = "PLON PLAT";

// global attributes:
:FileName = "HIRAD_data_20151022T185440_20151022T192440_leg09.nc";
:Version = "2.1";
:FlightDate = "2015/10/22";
:Leg = 9; // int
:TimeInterval = "2015/10/22 18:54:40 - 2015/10/22 19:24:40 UTC";
:Source = "NASA/MSFC/ZP11";
:Project = "Hurricane Imaging Radiometer";
>Contact = "sayak.k.biswas@nasa.gov";
:Campaign = "Tropical Cyclone Intensity (TCI) Experiment, 2015";
:Aircraft = "NASA WB57";
:StormName = "Patricia";
:Conventions = "CF-1.6";
}
```