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

8/10/2015: Oct 15, 16 and 17, 2014 Hurricane Gonzalo overflight data is released with wind speed retrieval for selected legs.

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.

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

- The content of each file is:

Name	Long Name	Type
HIRAD_data_20141015T202704_20141015T2043...	HIRAD_data_20141015T202704_20141015T204303_leg05.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
flagHWS	Validity Flag for HIRAD Wind Speed	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

- HIRAD instrument cannot sense low wind speeds i.e. below ~10-15 m/s. Wind Speed retrievals are performed only for the legs which are over the storm. The leg numbers are noted in the "README.txt" file provided with the data.

- The "Excess Brightness Temperature" data field is derived by subtracting the modeled ocean surface emission (at 0 wind speed) from the observed brightness temperatures. JPL MUR sea surface temperature data used to compute this surface emission is also included.

- Aircraft navigation data is also included.

- 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 NASA HS3 mission.   Access to HIRAD data is not restricted. However, we do ask that data users respect the 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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Appendix I Example of metadata

File "HIRAD_data_20141015T202704_20141015T204303_leg05.nc"

File type: NetCDF-3/CDM

```
netcdf file:/C:/Users/sbiswas/Desktop/HIRAD_data_20141015T202704_20141015T204303_leg05.nc {
  dimensions:
    time = 960;
    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=960);
      :units = "seconds since 2001-01-01 00:00:00";
      :standard_name = "time";
      :long_name = "UTC Time";

    float ACLON(time=960);
      :units = "degrees_east";
      :valid_range = -180.0f, 180.0f; // float
      :long_name = "Aircraft Longitude";

    float ACLAT(time=960);
      :units = "degrees_north";
      :valid_range = -90.0f, 90.0f; // float
      :long_name = "Aircraft Latitude";

    float ACALT(time=960);
      :units = "meters";
      :valid_range = 0.0f, 20000.0f; // float
      :long_name = "Aircraft Altitude";
      :standard_name = "altitude";

    float RANG(time=960);
      :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=960);
      :units = "degree";
      :valid_range = -30.0f, 30.0f; // float
      :long_name = "Aircraft Pitch Angle";
      :standard_name = "platform_pitch_angle";
      :coordinates = "ACLON ACLAT ACALT";

    float THDG(time=960);
      :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=960);
      :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=960, azimuth=321);
  :units = "degrees_east";
  :valid_range = -180.0f, 180.0f; // float
  :long_name = "Pixel Longitude";

float PLAT(time=960, azimuth=321);
  :units = "degrees_north";
  :valid_range = -90.0f, 90.0f; // float
  :long_name = "Pixel Latitude";

float PEIA(time=960, 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=960, 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=960, 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=960, azimuth=321);
  :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=960, 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=960, 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=960, 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=960, 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=960, 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";

float HWS(time=960, azimuth=321);
  :units = "meters per second";
  :valid_range = 0.0f, 80.0f; // float
  :used_channels = "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 JSST(time=960, 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=960, 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=960, 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=960, 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=960, azimuth=321);
  :flag_values = 0, 1, 2; // int
  :flag_meanings = "0_valid_data 1_questionable_data 2_invalid_data";
  :long_name = "Validity Flag for 6.0 GHz Observations";
  :standard_name = "brightness_temperature status_flag";
  :coordinates = "PLON PLAT";

int flag7(time=960, 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=960, 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";

  // global attributes:
  :FileName = "HIRAD_data_20141015T202704_20141015T204303_leg05.nc";
  :FlightDate = "2014/10/15";
  :Leg = 5; // int
  :TimeInterval = "2014/10/15 20:27:04   -   2014/10/15 20:43:03 UTC";
  :Source = "NASA/MSFC/ZP11";
  :Project = "Hurricane Imaging Radiometer";
  :Contact = "sayak.k.biswas@nasa.gov";
  :Campaign = "HS3";
  :Aircraft = "NASA WB57";
  :StormName = "Gonzalo";
  :Conventions = "CF-1.6";
}
```