Global Hydrology Resource Center

## Data User Guide

# *GPM Ground Validation Advanced Microwave Precipitation Radiometer (AMPR) IPHEx*

## Introduction

The GPM Ground Validation Advanced Microwave Precipitation Radiometer (AMPR) IPHEx dataset was acquired by the AMPR instrument flown aboard the high altitude ER-2 aircraft during the IPHEx field campaign in North Carolina from May 1, 2014 through June 14, 2014. The goal of IPHEx was to evaluate the accuracy of satellite precipitation measurements and use the collected data for hydrology models in the region. These files include the Level 2B calibrated and georeferenced brightness temperature for the four AMPR-observed frequencies (10, 19, 37, 85 GHz). These data are archived in a netCDF-4 format that contains the calibrated brightness temperatures in addition to ER-2 aircraft navigation and instrument scene georectification variables. Corresponding browse imagery are also available in JPG format. A set of Python software has been developed for reading, plotting, and providing some additional analysis capabilities.

## Citation

Lang, Timothy and Jason Brent Roberts. 2015. GPM Ground Validation Advanced Microwave Precipitation Radiometer (AMPR) IPHEx [indicate subset used]. Dataset available online from the NASA Global Hydrology Resource Center DAAC, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/GPMGV/IPHEX/AMPR/DATA202


## Keywords:

*NASA, GHRC, GPM GV, PMM, AMPR, IPHEx, North Carolina, brightness temperature, MODIS, water fraction*


## Campaign

The Global Precipitation Measurement mission Ground Validation (GPM GV) campaign used a variety of methods for validation of GPM satellite constellation measurements prior to and after launch on the GPM Core Satellite, which launched on February 27, 2014. The instrument validation effort included numerous GPM-specific and joint-agency/international external field campaigns, using state of the art cloud and precipitation observational infrastructure (polarimetric radars, profilers, rain gauges, and disdrometers). These field campaigns accounted for the majority of the effort and resources expended by the GPM GV mission. More information about the GPM GV mission is available at the PMM Ground Validation webpage.

One of the GPM GV campaigns was the GPM Integrated Precipitation and Hydrology Experiment (IPHEx), which was held in North Carolina during 2014 with an intense study period from May 1 to June 15, 2014. The goal of IPHEx was to characterize warm season orographic precipitation regimes and the relationship between precipitation regimes and hydrologic processes in regions of complex terrain. The IPHEx campaign was part of the development, evaluation, and improvement of remote sensing precipitation algorithms in support of the GPM mission through the NASA GPM GV field campaign (IPHEX_GVFC) and the evaluation of Quantitative Precipitation Estimation (QPE) products for hydrological forecasting and water resource applications in the Upper Tennessee, Catawba-Santee, Yadkin-Pee Dee, and Savannah river basins (IPHEX-HAP, H4SE). NOAA Hydrometeorology Testbed (HTM) has synergy with this project. More information about IPHEx is available at the IPHEx Field Campaign webpage.

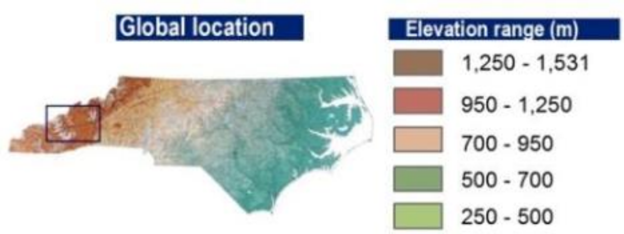


Figure 1: Region of North Carolina IPHEx campaign ground validation (image source: http://gpm-gv.gsfc.nasa.gov/Gauge/)

## Instrument Description

The Advanced Microwave Precipitation Radiometer (AMPR) is a multi-frequency, dual-polarized, cross-track scanning microwave radiometer. The AMPR instrument was flown on NASA's Earth Resources 2 (ER-2) high-altitude airborne science aircraft. The instrument is a low noise system which can provide multi-frequency microwave imagery with high spatial and temporal resolution. AMPR measures brightness temperatures at a combination of four microwave frequencies (10.7, 19.35, 37.1, and 85.5 GHz) with two orientations each (Vpol-to-Hpol and Hpol-to-Vpol) from which cloud, precipitation, water vapor, and surface properties (including ocean winds) can be derived. These frequencies are sensitive to the emission and scattering of precipitation-sized ice, liquid water, and water vapor (Hood et al., 2006). AMPR scans at 90 degrees cross-track, perpendicular to the direction of aircraft motion. The data are geolocated based on scan angle and aircraft position and attitude information. It has a dual-lens antenna to accommodate two separate feed horns. The horn that feeds the three higher frequency channels is a copy of the Special Sensor Microwave/Imager (SSM/I) space borne multi-frequency feed horn currently flying aboard the Defense Meteorological Satellite Program (DMSP) satellites. A separate AMPR feed horn, which was built by the Georgia Technology Research Institute (GTRI), accommodates the 10.7 GHz frequency. Table 1 lists several of the AMPR performance characteristics. More information about the AMPR instrument is available on the NASA AMPR webpage and the NASA MSFC AMPR webpage.

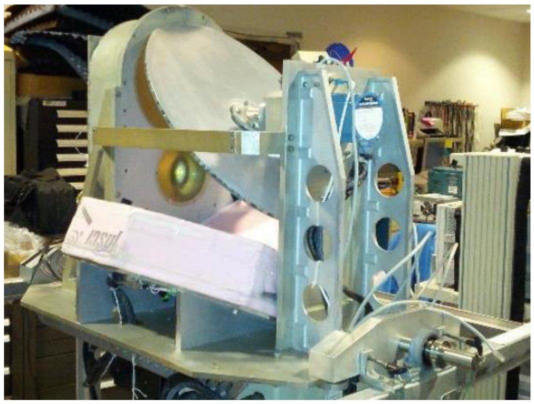

Figure 2: AMPR Instrument at MSFC
(Image Source: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150022943.pdf)

Table 1: AMPR Performance Characteristics

| Characteristic | 85.5GHz | 37.1GHz | 19.35GHz | 10.7GHz |
|---|---|---|---|---|
| Bandwidth (MHz) | 1,400 | 900 | 240 | 100 |
| Integration Time (ms) | 50 | 50 | 50 | 50 |
| Horn Type | SSM/I | SSM/I | SSM/I | GTRI |
| Lens Diameter (inches) | 5.3 | 5.3 | 5.3 | 9.7 |
| Beam width (degrees) | 1.8 | 4.2 | 8.0 | 8.0 |
| Footprint (km) [@20 km ER-2 alt. 500kts] | 0.64 | 1.48 | 2.78 | 2.78 |
| Beam Efficiency (%) | N/A | 98.8 | 98.7 | 97.8 |
| Cross Polarization (%) | N/A | 0.4 | 1.6 | 0.2 |

## Investigators

Timothy Lang
NASA Marshall Space Flight Center
Huntsville, AL

J. Brent Roberts
NASA Marshall Space Flight Center
Huntsville, AL

## Data Characteristics

The GPM Ground Validation AMPR IPHEx dataset consists of brightness temperature, water fraction, and ER-2 aircraft navigation and instrument scene georectification variables in netCDF-4 format, as well as corresponding quicklook browse imagery for each data file in JPG format. These data were collected from May 1, 2014 through June 14, 2014. These data are considered Level 2 processing level. More information about the NASA data processing levels are available on the EOSDIS Data Processing Levels webpage. Table 2 shows the characteristics of the dataset.

Table 2: Data Characteristics

| Characteristic | Description |
|---|---|
| Platform | NASA Earth Resources 2 (ER-2) |
| Instrument | Advanced Microwave Precipitation Radiometer (AMPR) |
| Spatial Coverage | N: 40.00 , S: 26.00, E: -70.00, W: -125.00 (United States of America) |
| Spatial Resolution | 0.5-3 km, varies with flight altitude and scan |
| Temporal Coverage | May 1, 2014 - June 14, 2014 |
| Temporal Resolution | 2-4 hours per ER-2 flight, one flight per data file |
| Sampling Frequency | 3 seconds |
| Parameter | Microwave brightness temperature, water fraction |
| Version | 2 |
| Processing Level | 2 |

## File Naming Convention

The GPM Ground Validation AMPR dataset includes data files in netCDF-4 format with corresponding browse imagery available in JPG format. The files are named with the following convention:

**Data files:** IPHEX_AMPR_YYYYMMDD_level2b_v2.nc
**Browse files:** IPHEX_AMPR_YYYYMMDD_level2b_v2_[bd|pz]_quicklook.jpg
**Quality Control Browse files:**
IPHEX_AMPR_YYYYMMDD_level2b_v2_[bd|pz]_with_qc_quicklook.jpg

Table 3: File naming convention variables

| Variable | Description |
|---|---|
| YYYY | Four-digit year |
| MM | Two-digit month |
| DD | Two-digit day |
| [bd\|pz] | bd: Band frequency<br>pz: Polarization channel |
| .nc | netCDF-4 file format |
| .jpg | JPG file format |

## Data Format and Parameters

The AMPR data files include brightness temperature (TB) measurements, quality control (QC) metrics, flight profile characteristics, and water fraction information in netCDF-4 format. The TB, QC, and water fraction data are available for all four bands (10, 19, 37, and 85 GHz). The TB and QC data are also available from both the A (vertical) and B (horizontal) polarization channels. Table 4 below includes the description, data type, and unit for each variable.

Table 4: Data Fields

| Field Name | Description | Data Type | Unit |
|---|---|---|---|
| airSpeed | Aircraft Air Speed | double | m/s |
| FovWaterFrac10 | Water Fraction in 10 GHz Field Of View [0 - 1] | double | - |
| FovWaterFrac19 | Water Fraction in 19 GHz Field Of View [0 - 1] | double | - |
| FovWaterFrac37 | Water Fraction in 37 GHz Field Of View [0 - 1] | double | - |
| FovWaterFrac85 | Water Fraction in 85 GHz Field Of View [0 - 1] | double | - |
| gAlt | GPS Altitude | double | m |
| gLat | GPS Latitude | double | Degrees North |
| gLon | GPS Longitude | double | Degrees East |
| groundSpeed | Aircraft Ground Speed | double | m/s |
| heading | Aircraft Heading | double | degrees |
| iLat | INS Latitude | double | Degrees North |
| iLon | INS Longitude | double | Degrees East |
| incidence_angle | Incidence Angle | double | degrees |
| iWindDir | Wind direction | double | degrees |
| iWindSpeed | Wind Speed | double | m/s |
| lat | Latitude | double | Degrees North |
| lon | Longitude | double | Degrees East |
| pitch | Aircraft Pitch | double | degrees |
| qcIncidence | Incidence angle quality control | short | - |
| qctb10a | Channel 10A Tb QC flag value [0-8]* | short | - |
| qctb10b | Channel 10B Tb QC flag value [0-8]* | short | - |
| qctb19a | Channel 19A Tb QC flag value [0-8]* | short | - |
| qctb19b | Channel 19B Tb QC flag value [0-8]* | short | - |
| qctb37a | Channel 37A Tb QC flag value [0-8]* | short | - |

| | | | |
|---|---|---|---|
| qctb37b | Channel 37B Tb QC flag value [0-8]* | short | - |
| qctb85a | Channel 85A Tb QC flag value [0-8]* | short | - |
| qctb85b | Channel 85B Tb QC flag value [0-8]* | short | - |
| relative_azimuth | Relative Azimuth | double | degrees |
| roll | Aircraft Roll | double | degrees |
| scan_angle | Scan Angle | double | degrees |
| scan_number | Scan Number | long | - |
| scan_position | Scan Position | long | - |
| staticPressure | Aircraft Static Pressure | double | mbar |
| tbs_10a | 10A Scene Brightness Temperature | double | kelvin |
| tbs_10b | 10B Scene Brightness Temperature | double | kelvin |
| tbs_19a | 19A Scene Brightness Temperature | double | kelvin |
| tbs_19b | 19B Scene Brightness Temperature | double | kelvin |
| tbs_37a | 37A Scene Brightness Temperature | double | kelvin |
| tbs_37b | 37B Scene Brightness Temperature | double | kelvin |
| tbs_85a | 85A Scene Brightness Temperature | double | kelvin |
| tbs_85b | 85B Scene Brightness Temperature | double | kelvin |
| time | Scan Time | double | seconds since 1970-01-01 |
| totalTemp | Aircraft Total Temperature | double | celsius |
| track_angle | Aircraft Track Angle | double | degrees |

*see Quality Assessment section

## Algorithm

As a part of the GPM GV campaign, the AMPR instrument collects brightness temperature measurements to identify atmospheric parameters, such as water vapor and cloud composition.  Certain algorithms are used to convert these brightness temperature measurements into precipitation information. The AMPR uses four different passive frequencies (10, 19, 37, and 85 GHz) that detect different types of precipitation, ranging from raindrops to cloud ice. This multi-frequency data is combined with additional information such as model calculations or active/passive retrievals to determine precipitation characteristics.

Additional information on the PMM precipitation algorithms can be found on the PMM Precipitation Algorithms webpage.

## Quality Assessment

The GPM Ground Validation AMPR IPHEx data files include calibrated and georeferenced brightness temperature measurements and QC flags. The QC flag value is estimated using the brightness temperature difference between the pixel and its neighboring pixels within their 9x9 kernel. This QC flag can be used to determine if the pixel value represents bad data or certain features within the scene. An incidence angle flag is provided to identify the pixels whose incidence angles were highly affected by aircraft roll maneuvers. This allows for pixels with high incidence angles, unsuitable for making accurate observations, to be flagged without eliminating entire scans taken during aircraft roll maneuvers. The pixel field of view (FOV) water fractions are also provided, created using MODIS surface data to estimate the percent FOV containing surface water features that affect AMPR measurements. These quality control field values are listed in Table 5.

Table 5: Quality Control Fields

| Value | Description |
|---|---|
| 0 to >4* | The quality control metric is estimated based on the brightness temperatures of neighboring pixels. |
| 1= 0-45 degree, 2= >45.0 degree incidence angle | The incidence angle flag marks the pixels with high incidence angles, usually edge pixels, that result from aircraft roll maneuvers. A typical observation angle is -45 to 40 degrees. |
| FOV < 0.1 (Mostly land)<br>FOV > 0.9 (Mostly water) | The pixel FOV water fractions provide an estimate of a pixel's percent FOV that contains surface water features. |

*Typically, QC flags less than 2 are good data; values of 3 are more suspect but can arise from sharp transitions related to physical phenomenon; >4 usually indicative of some very noisy scenes (bad data) or local outliers.

Additional information on the quality control fields can be found in the PI documentation.

AMPR data from previous campaigns have been compared to radar precipitation measurements in Vivekanandan et al., 1993.

## Software

The AMPR netCDF-4 files can be viewed using Panoply. A Python toolkit (PyAMPR) has also been developed to allow for reading, plotting, and analysis of the Level 2B AMPR data files. This toolkit is capable of reading both the netCDF-4 Level 2B files as well as the older, not deprecated, ASCII-distributed AMPR data files from previous missions, also archived by the GHRC. PDF files of the Jupyter notebooks used for preliminary analysis of each flight's data are available on the GHRC server in the software directory for IPHEx AMPR. A Word document discussing significant QC issues from each flight is also provided. For Python users, a working Jupyter notebook is provided, demonstrating how to use PyAMPR to ingest and display the data.

Table 6: Software/Tool Information Table

| Name | Type | Access | Software | License |
|---|---|---|---|---|
| PyAMPR | Data visualization and analysis | https://github.com/nasa/PyAMPR | Python 2.7 or 3.4, numpy, matplotlib, Basemap, os, time, simplekml, datetime, calendar, codecs, gzip, netCDF4. | All of this software, including software requirements, are opensource. |

## Known Issues or Missing Data

The quality assessment section gives information on QC values indicating scenes with bad data. The QC metric identifies suspect values typically associated with instrument issues, potential scene contamination, or interference with another instrument. The HIWRAP instrument, also flown on the NASA ER-2, causes a surface reflection near nadir over clear ocean in the AMPR 37 GHz channel. This interference is indicated by a high quality control index of 8.

The QC flag, along with the incidence angle and pixel FOV values, provide the user the information needed to determine whether a pixel value marked as suspect is bad data or was generated by a physical phenomena due to certain features within the scene. Users are advised to read the PI documentation provided on the GHRC server.

## References


Barros, A. P., Petersen, W., Schwaller, M., Cifelli, R., Mahoney, K., Peters-Liddard, C., … Kim, E. (2014). NASA GPM-Ground Validation: Integrated Precipitation and Hydrology Experiment 2014 Science Plan, *12*. https://doi.org/10.7924/G8CC0XMR

Erlingis, J., Gourley, J., Kirstetter, P., Anagnostou, E.N., Kalogiros, J., Anagnostou, M.N., & Peterson, W. (2018). Evaluation of Operational and Experimental Precipitation Algorithms and Microphysical Insights during IPHEx. *Journal of Hydrometeorology*, *19*, 113-125. https://doi.org/10.1175/JHM-D-17-0080.1

Hood, R. E., Cecil, D. J., LaFontaine, F. J., Blakeslee, R. J., Mach, D. M., Heymsfield, G. M., & Goodman, M. (2006). Classification of tropical oceanic precipitation using high-altitude aircraft microwave and electric field measurements. *Journal of the Atmospheric Sciences*, 63(1), 218–233. doi: http://doi.org/http://doi.org/10.1175/jas3606.1

Hood, R. E., Spencer, R. W., LaFontaine, F. J., & Smith, E. A. (1994). Simulation of Future Microwave Satellite Instruments Using High Resolution AMPR Aircraft Data. In Seventh Conference on Satellite Meteorology and Oceanography (Vol. Section 3., pp. 160–163).

Lang, T., Roberts, B., Guillory, A., Cantrell, E., Dietz, K., Simmons, D., . . . LaFontaine, F. (2014). The Advanced Microwave Precipitation Radiometer (AMPR) - Initial Results from the Integrated Precipitation Hydrology Experiment (IPHEx) [PDF file]. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140012894.pdf

Lang, T., Roberts, B., Meyer, P., Cantrell, E., & Wolff, D. (2015). AMPR and radar observations from IPHEx: Data quality control and product generation [PDF file]. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20150022943.pdf

Spencer, R.W., Hood, R.E., Lafontaine, F. J., Smith, E. A., Platt, R., Galliano, J., . . . Lobl, E. (1994). High-Resolution Imaging of Rain Systems with the Advanced Microwave Precipitation Radiometer. *Journal of Atmospheric and Oceanic Technology, 11,* 849-857. https://doi.org/10.1175/1520-0426(1994)011%3C0849:HRIORS%3E2.0.CO;2

Tao, J., Wu, D., Gourley, J., Zhang, S.Q., Crow, W., Peters-Lidard, C., & Barros, A.P. (2016). Operational hydrological forecasting during the IPHEx-IOP campaign - Meet the Challenge. *Journal of Hydrology, 541,* 434-456. https://doi.org/10.1016/j.jhydrol.2016.02.019

Vivekanandan, J., Turk, J., & Bringi, V. N. (1993). Comparisons of Precipitation Measurements by the Advanced Microwave Precipitation Radiometer and Multiparameter Radar. *IEEE Transactions on Geoscience and Remote Sensing*, 31(4), 860–870. doi: http://doi.org/10.1109/36.239909

## Related Data

All data from other instruments collected during the IPHEx field campaign are considered to be related datasets. These data can be located by searching 'IPHEx' in HyDRO 2.0. The complete IPHEx collection can be found here.

Below are datasets from other GPM GV field campaigns that used the AMPR instrument to collect data:

GPM Ground Validation Advanced Microwave Precipitation Radiometer (AMPR) OLYMPEX (http://dx.doi.org/10.5067/GPMGV/OLYMPEX/AMPR/DATA101)

GPM Ground Validation Advanced Microwave Precipitation Radiometer (AMPR) MC3E (http://dx.doi.org/10.5067/GPMGV/MC3E/AMPR/DATA101)

## Contact Information

To order these data or for further information, please contact:

NASA Global Hydrology Resource Center DAAC
User Services
320 Sparkman Drive
Huntsville, AL 35805
Phone: 256-961-7932
E-mail: support-ghrc@earthdata.nasa.gov
Web: https://ghrc.nsstc.nasa.gov/

Created: 7/6/2015
Updated: 2/21/2019