Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Duke Soil Moisture IPHEx

Introduction

The GPM Ground Validation Duke Soil Moisture dataset consists of a collection of various data obtained during the Integrated Precipitation and Hydrology Experiment (IPHEx) which occurred in the Southern Appalachians, spanning into the Piedmont and Coastal Plain regions of North Carolina from February 27, 2014 through October 17, 2014. The various instruments used included Theta Probes, Infrared Thermometers, 200-A Soil Core Samplers, a Global Positioning System (GPS), Soil Thermometers with Scanning L-band Active Passive (SLAP) flight concurrent survey data, and CS6161 Water Reflectometers. Data are available in a variety of formats based on instrument, including shapefiles, Excel files, Word document files, and ASCII formats. Browse images of site locations and data are available in JPG format.

Citation

Barros, Ana P., Edward Kim, and Walter A. Petersen. 2018. GPM Ground Validation Duke Soil Moisture IPHEx [indicate subset used]. Dataset available online from the NASA EOSDIS Global Hydrology Resource Center Distributed Active Archive Center, Huntsville, Alabama, U.S.A. doi: http://dx.doi.org/10.5067/GPMGV/IPHEX/GAUGES/DATA102

Keywords:

NASA, GHRC, IPHEx, North Carolina, Duke, soil moisture, soil samples, theta-probe, infrared thermometer, soil thermometer, water reflectometer, volumetric soil moisture, gravimetric soil moisture, soil density, soil texture, surface roughness, soil porosity

Campaign

The Global Precipitation Measurement (GPM) mission Ground Validation (GV) campaign used a variety of methods for validation of GPM satellite constellation measurements prior to and after launch of 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). Surface rainfall was measured by very dense rain gauge and disdrometer networks a various field campaign sites. These field campaigns accounted for the majority of the effort and resources expended by GPM GV. More information about the GPM mission is available at http://pmm.nasa.gov/GPM.

One of the GPM-GV field campaigns was the GPM Integrated Precipitation and Hydrology Experiment (IPHEx) which was held in North Carolina during 2013 and 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 NASA GPM-GV field campaign (IPHEX_GVFC) and the evaluation of Quantitative Precipitation Estimation (QPE) products for hydrologic 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 http://gpm.nsstc.nasa.gov/iphex/.

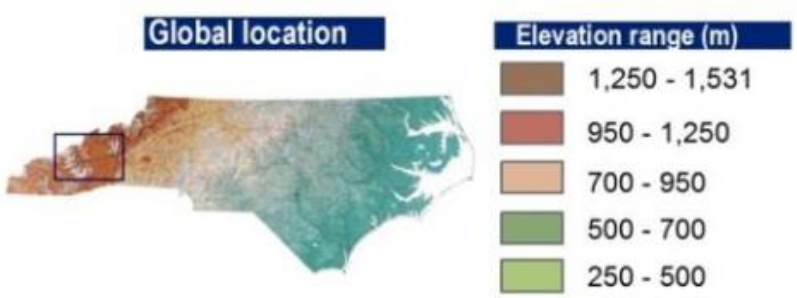

Figure 1: Region of North Carolina IPHEx campaign ground validation (image source: http://gpm-gv.gsfc.nasa.gov/Gauge/)

Dataset Description

The GPM Ground Validation Duke Soil Moisture dataset consists of soil moisture measurements in support of the field campaign:

1. Data collected at 5 locations (site #s 16, 21, 22, 23, 26) only during flyovers of the Scanning L-band Active Passive (SLAP) instrument onboard the NASA Langley King Air aircraft. SLAP flyovers occured on May 2, 5, 9, and 21, 2014. The data provide validation data for SLAP and ultimately SMAP (Soil Moisture Active Passive) satellite radiometer. Measurements made include manually collected soil samples in addition to soil and surface temperatures. Data are located in shape files by site and the Calibrated_SoilMeasurements.xlsx excel file. Photographs of each data collection area, designed to cover an area roughly the size of a SLAP measurement, are included in the

document directory for reference.

2. Soil temperature and soil moisture collected by 7 automated stations in the mountainous regions of the IPHEx study area that collected data throughout the campaign study period from March - October 2014. These are referred to as NASA soil measurement locations (site #s 29, 31, 33, 37, 39, 40, 41) and were collocated with rain gauge and parsivel instruments. The data are provided in excel files by site PMM-NASA####-PROCESSED-<start date>-<end date>.xlsx

IPHEx-IOP In Situ Sampling Sites (in Piedmont region) - Measurements taken concurrently along with SLAP overflight Measurements: soil moisture (0~6cm); soil temperature at 1, 5, and 10cm; surface temperature (IRT); soil bulk density; sampling point GPS locations; soil roughness; vegetation properties			
Site	Lat/Lon	Land Cover Description	Sample Dates
Site 16	[35.800076, -82.042432]	Nursery field with many different fields including tilled surface, grassland, nursery trees and scattered large trees	May 2nd, 5th, 9th and 21st, 2014
Site 21	[36.216691, -81.583917]	Grassland with scattered forest (on small hillslopes)	
Site 22	[36.230431, -81.547296]	Grassland with scattered forest (on small hillslopes)	
Site 23	[36.036190, -81.707537]	Nursery field with many different small/short trees and a small area of tilled surface (in a valley)	
Site 26	[35.793058, -82.027969]	Nursery field with many different fields including tilled surface, grassland and nursery trees	
IPHEx Soil Moisture Stations (in mountains) - Measurements automatically recorded every 15 minutes during IPHEx (measurements: 5cm soil moisture, 5cm soil temperature, soil bulk density)			
Station	Lat/Lon	Land Cover Description	Measure Period
NASA0029 (P-14)	[35.373104, -83.506194]	Next to a building at foothill (Southwestern Community College)	Mar. 06 - Oct. 13, 2014
NASA0031 (P-1)	[35.885678, -82.584475]	Grassland, at the top of a mountain (Marshall Ridge)	Feb. 27 - Oct. 13, 2014
NASA0033 (P-15)	[35.441441, -83.074138]	a small area of grassland at foothill (NC Wildlife Maintenance Yard)	Apr. 02 - Oct. 17, 2014
NASA0037 (GladMtn)	[35.613561, -82.847097]	Grassland, at the top of a mountain	Mar. 11 - Oct. 14, 2014
NASA0039 (P-7)	[35.778928 -83.214276]	Forest (Cosby, right on the edge of the GSMNP)	Apr. 13 - Oct. 15, 2014
NASA0040 (P-6)	[35.664333 -83.590458]	a small area of grassland, surrounded by forest (Elkmont - GSMNP)	May 01 - Oct. 15, 2014

NASA0041 (P-5)	[35.686193 -83.500831]	a small area of grassland at foothill (Twin Creek Cherokee - GSMNP)	May 01 - Oct. 15, 2014

Soil Measurements

Measurements of soil temperature, density, texture, moisture, and surface roughness were collected by students in the field concurrently as SLAP instrument overflights. Instruments used to make measurements included theta probes, infrared thermometers, and soil thermometers. The two groups of data are handled differently. Samples at sites were also only collected during SLAP flight dates and on days of no rain or severe weather. The dates of overflight were May 2, 5, 9 and 21, 2014.

The Theta Probes (Figure 2) used in the study were Type ML2 manually-operated impedance instruments manufactured by Delta-T Devices, Ltd. Theta probes measure the volumetric soil moisture content. The soil temperature was determined using a soil thermometer (Figure 3) and an infrared thermometer (Figure 4) was used to measure the air temperature of the surface.

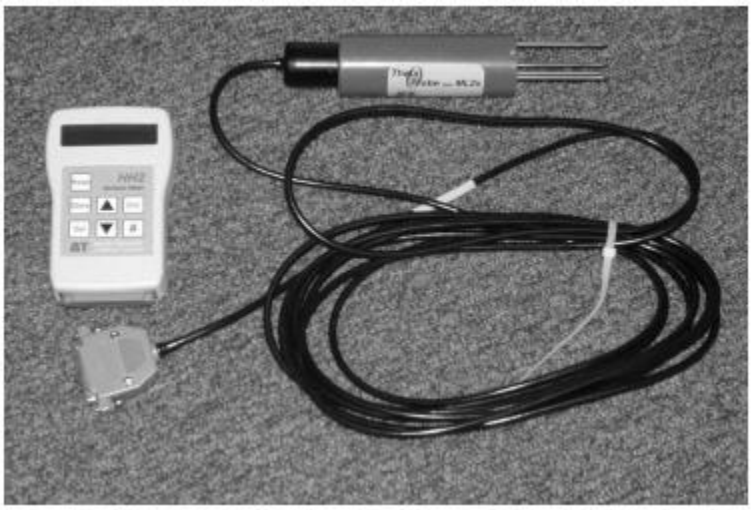

Figure 2: Theta Probe (HH2 is white controller to the left in the image)
(Image source: Soil Moisture Experimental Plan for IPHEx-2014)

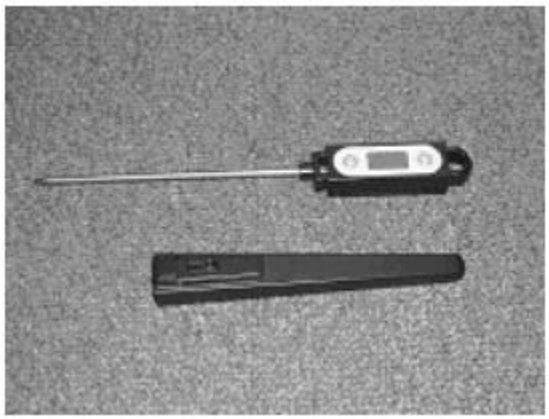

Figure 3: Soil thermometer
(Image source: Soil Moisture Experimental Plan for IPHEx-2014)

Figure 4: Infrared thermometer
(Image source: Soil Moisture Experimental Plan for IPHEx-2014)

Soil samples were collected and taken to a lab where the samples were weighed, dried, and reweighed to determine the soil moisture of each sample. Photos of sample locations were taken to show surface vegetation and roughness. All photos are located online in the documents directory. All sites involved in gravimetric soil moisture sampling were characterized for soil bulk density. The method used was a volume extraction technique that has been employed in most of the previous experiments and is especially appropriate for the surface layer using a tool called a 200-A soil core sampler. Four replications were made for each site. A Trimble Juno series GPS was used to obtain the coordinates of each site location where soil measurements instruments were placed. In addition, a CS616 Water Content Reflectometer was used to measure the volumetric water content of soils. More information about the CS616 Water Content Reflectometer can be found in the CS616 and CS625 Water Content Reflectometers Instruction Manual.

SLAP

The SLAP instrument, with both passive (radiometer) and active (radar) microwave L-band imaging capabilities, can detect soil moisture from the NASA Langley King Air aircraft. SLAP is an aircraft scale simulator of NASA's Soil Moisture Active Passive (SMAP) radiometer. The SLAP radiometer has a 1.4 GHz channel similar hardware to the SMAP satellite radiometer and includes the same type of digital backend development unit used for SMAP. The digital backend provides 4-Stokes polarization capability. The real-aperture radar operates in the 1215-1300 MHz band with quad-pol capability. The radar and radiometer share one antenna via diplexers that are spare units from the Aquarius satellite instrument. As the SLAP instrument flew over the study area, soil samples were

concurrently taken on the ground using temperature and soil moisture probes. Figure 5 shows the flight lines of SLAP when taking measurements with concurrent soil sample locations.

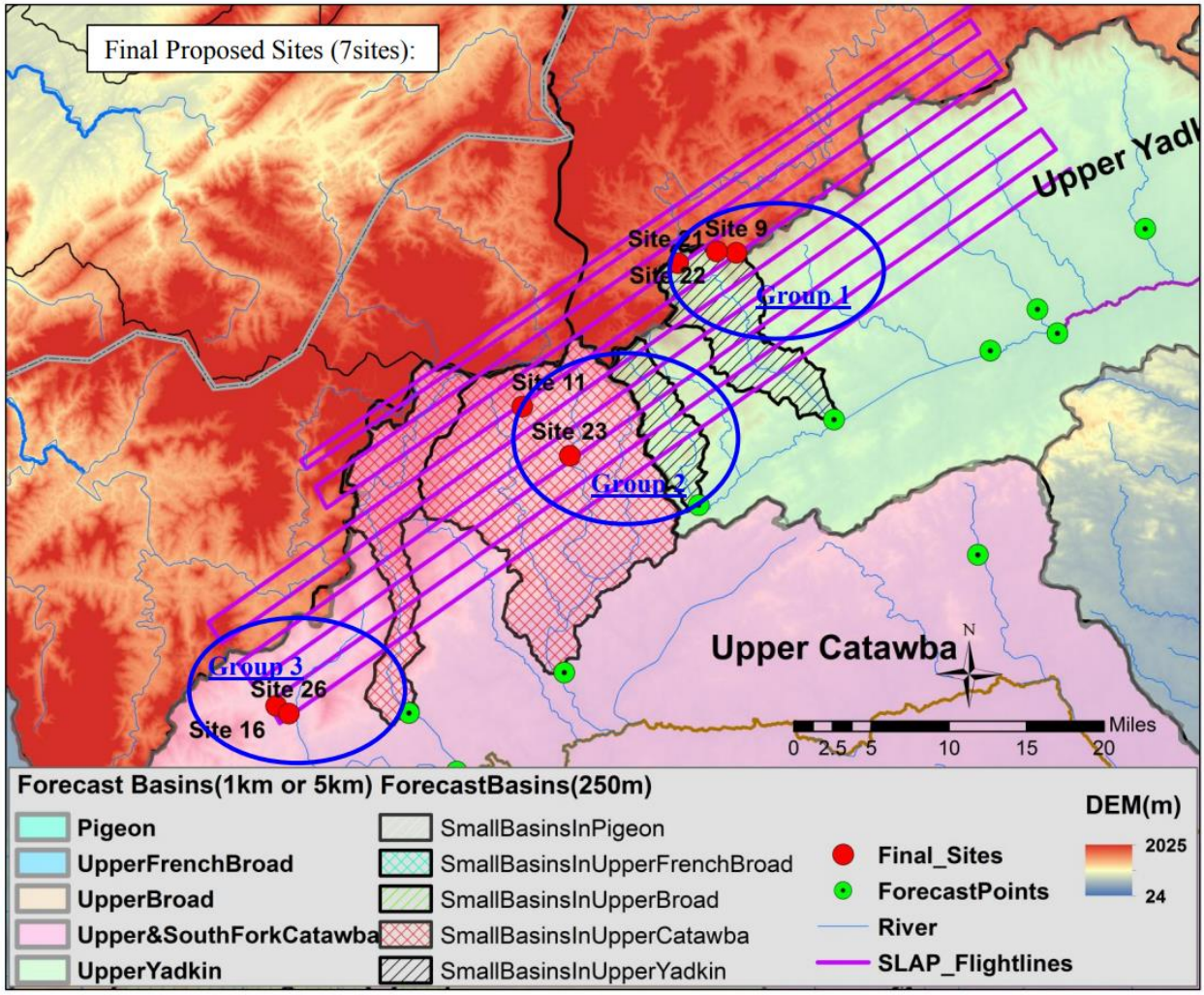

Figure 5: Flight lines of SLAP with concurrent soil sample locations

More detailed information about the instrumentation used in the IPHEx field campaign and this dataset in particular can be found in the Soil Moisture Experimental Plan for IPHEx-2014.

Investigators

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Data Characteristics

The GPM Ground Validation Duke Soil Moisture IPHEx datasets consists of shapefiles, Excel files, Word document files, and ASCII format files. The data are a Level 2 data processing level. More information about the NASA data processing levels are available on the NASA Data Processing Levels website. Browse images of the data collection sites are available in JPG format. These site photos are important as they show the soil roughness and vegetation characteristics of each collection site. A list of site locations can be found on pages 6 through 11 in the Soil Moisture Experimental Plan for IPHEx-2014.

Table 1: Data Characteristics

Characteristic	Description
Platforms	Ground stations
Instruments	Theta-Probes Infrared Thermometers 200-A Soil Core Samplers Global Positioning System (GPS) Soil Thermometers CS6161 Water Reflectometers
Projection	n/a
Spatial Coverage	N: 36.519 , S: 35.373, E: -81.132, W: -83.590 (North Carolina)
Spatial Resolution	Point
Temporal Coverage	February 27, 2014 - October 17, 2014
Temporal Resolution	2 hours
Sampling Frequency	Varies: <1 minute
Parameter	Vegetation roughness, soil water content, soil density, soil porosity, soil temperature, surface temperature, soil moisture, dielectric constant
Version	1
Processing Level	2

File Naming Convention

The GPM Ground Validation Duke Soil Moisture IPHEx dataset has the file naming convention shown below. The data files are available as shapefiles, Excel files, Word document files, and ASCII format files. Browse images are available in JPG format.

Data files:

Calibrated_SoilMeasurements.xlsx
IPHExIOP-SMExpData_[Calibrated|Raw].xlsx
PMM-NASA####-PROCESSED-<start date>-<end date>.xlsx
SLAPExperimentCalTests.docx
SLAP_Cal_YYYYMMDD.docx
AllSites_BDLocations.[dbf|prj|sbn|sbx|shp|shp.xml|shx]
AllSite_Sampling.[dbf|prj|sbn|sbx|shp|shp.xml|shx]
Site**_[GoodSampling|VegRough].[dbf|prj|sbn|sbx|shp|shp.xml|shx]
Site**_GoodSampling_BDLocations.[dbf|prj|sbn|sbx|shp|shp.xml|shx]
NASA0040_Resets_YYYYMMDD.txt

Browse files:

NASA####_Temp_Graphs.pdf
Site**_YYYYMMDD_hhmmss.jpg

Table 2: File naming convention variables

Variable	Description
[Calibrated|Raw]	Calibrated: Calibrated instrument data Raw: Raw data
NASA####	NASA station number
<start date>	Date when measurements began in YYYYMMMDD format, where: YYYY: Four-digit year MMM: Four-letter month DD: Two-digit day
<end date>	Date when measurements ended in YYYYMMMDD format, where: YYYY: Four-digit year MMM: Four-letter month DD: Two-digit day
.xlsx	Excel document
YYYY	Four-digit year
MM	Two-digit month
DD	Two-digit day
.docx	Word document
.[dbf|prj|sbn|sbx|shp|shp.xml|shx]	Formats needed to pull in a single shapefile into an ArcGIS software
Site**	Site number. Some files may include multiple sites in the file naming convention
.txt	ASCII file format
.pdf	Portable Document Format
.jpg	Lossy compression for digital images format

Data Format and Parameters

The GPM Ground Validation Duke Soil Moisture IPHEx dataset consists of shapefiles, Excel files, Word documents, and ASCII format files. JPG browse images are also provided of site locations. The data files contain vegetation roughness, soil water content, soil density, soil porosity, and other aircraft and GPS information. Table 3 describes the parameters collected in the Calibrated_SoilMeasurements.xlsx file. Table 4 describes the parameters collected in the IPHExIOP-SMExpData_[Calibrated|Raw].xlsx file. Table 5 describes the parameters collected in the PMM-NASA####-PROCESSED-<start date>-<end date>.xlsx data files. The SLAPExperimentCalTests.docx file shows measurements from the temperature probes when calibrating the instruments prior to use in field, and the SLAP_cal_YYYYMMDD.docx files show measurements from Jordan Lake when the SLAP radiometer flew over and data were used for instrument calibration. Documentation of when the site NASA0040 instrument had to be reset is in the NASA0040_Resets_YYYYMMDD.txt file. It should be noted that there is only one station with reset data. No other stations required reset.

Table 3: Parameters collected in Calibrated_SoilMeasurements.xlsx files

Field Name	Unit
Day	mm/dd/yyyy
Time	hh:mm
Container Weight (CW)	g
CW + wet soil	g
CW + dry soil	g
Wet Soil Weight	g
Dry Soil Weight	g
Bulk Density	g/cm^3
Grav. Water Content	g/g
Vol. Water Content	cm^3/cm^3
Soil Porosity	milliseconds

Table 4: Parameters collected in IPHExIOP-SMExpData_[Calibrated|Raw].xlsx files

Field Name	Description	Unit
Site	Site number	-
Mon	Month	-
Day	Day of the month	-
Hour	Hour	UTC
Minute	Minute	UTC
Point	Sampling point ID	-
Lat	Latitude	Degrees North
Lon	Longitude	Degrees East
IRT(°C) (Infrared Thermometer)	SG = Shaded Ground Temperature	Degrees C
	EG = Exposed Ground Temperature	
	SV = Shaded Vegetation Temperature	
	EV = Exposed Vegetation Temperature	

Soil Temperature(°C)	1cm: Soil temperature at 1 cm soil depth	Degrees C
	5cm: Soil temperature at 5 cm soil depth	
	10cm: Soil temperature at 10 cm soil depth	
Theta Probe (%)	Theta Probe measurement at Sample A	%
	Theta Probe measurement at Sample B	
	Theta Probe measurement at Sample C	
Avg. TP(%)	Average Theta Probe value of 3 samples	%
Voltage(mV)	Theta Probe voltage reading	mV
VSM Calibr. M1(%)	Volumetric Soil Moisture calibration measurement 1	%
VSM Calibr. M2(%)	Volumetric Soil Moisture calibration measurement 2	%
Can ID	Identification number of the can used for sample	-
Can Weight (g)	Weight of can	g
Wet Weight (g)	Weight of sample when wet	g
Dry Weight(g)	Weight of sample after drying	g
SM(g)	Soil moisture (found be subtraction, Wet - dry weight)	g
GSM(%)	Gravimetric Soil Moisture	%
Bulk Density	Bulk density of soil	-
VSM=GSM*BD	Volumetric soil moisture: output of multiplying gravimetric soil moisture and bulk density of soil together. This is considered as the true VSM observation corresponding to each Theta Probe reading	-
Field Operator	Name or ID of student collecting data	-

Table 5: Parameters collected in PMM-NASA####-PROCESSED-<start date>-<end date>.xlsx files

Field Name	Description	Unit
Date	Date of measurement in mm/dd/yyyy	-
Time (UTC)	Time of measurement in hh:mm:ss:fff	UTC
DateTime (UTC)	Date and Time of measurement in mm/dd/yyyy hh:mm	UTC
Period	Time period	millisecond
Temp	Temperature of soil at 2-inch depth	Degrees C
Period (Temp corrected)	Temp corrected time period	millisecond
Corrected Period VWC	Volumetric water content	cm^3/cm^3
Non-Corrected Period VWC	Volumetric water content	cm^3/cm^3

Quality Assessment

The various instruments used at ground sites were calibrated before placement for the IPHEx campaign. More information about these calibration methods are available in the NASA GPM-Ground Validation Integrated Precipitation and Hydrology Experiment 2014 Science Plan.

Calibration of the SLAP instrument is conducted during each flight using a conductivity/ temperature probe to measure ground temperature, salinity, and conductivity of a nearby lake before, during, and after the plane carrying the SLAP instrument passed overhead. Then, these measurements are used to calibrate the instrument. The accuracy ±0.4°C for temperature and ± (1% of reading + 0.2 µS/cm) for conductivity, and the resolution is 0.1°C and 0.1 µS/cm, respectively.

Before receiving the probe at Duke University, Edward Kim at NASA calibrated the uncompensated conductivity measurements, a proxy for salinity, to laboratory-grade standards of 0 µS/cm, 103 µS/cm, and 104 µS/cm. Before taking measurements in the field, the temperature sensor on the probe is tested against ice water (~0°C) and water at room temperature (~21°C). Careful measurements are made by placing the probe 1 cm below the water surface; this ensures that the measurements made by the probe are similar to those made by the SLAP instrument. Before taking measurements in the field, the conductivity sensor on the probe is tested against new distilled water (~0 µS/cm), and calibration standard liquids of 0 µS/cm, 103 µS/cm, and 104 µS/cm.

There are two methods for calibrating VSM readings from the Theta Probe. The first method is a conventional calibration approach based on the calibration equation from Cosh et al., 2005. The second calibration method seeks the linear relationship between the VSM readings from the Theta Probe and the VSM measurements at locations that soil samples and bulk density were collected. Then, a linear regression equation is used to calibrate each VSM reading during the campaign to obtain the true VSM measurement. Although the two methods use completely different approaches, they result in very identical results. More information about the calibration of the Theta Probe is available in the Summary of Calibration for Theta Probe (TP) document.

Features of the CS616 Water Content Reflectometer include high accuracy and high precision, fast response time, it's designed for long-term unattended water content monitoring, and the probe rods can be inserted from the surface or buried at any orientation to the surface. The Probe-to-Probe Variability is ±0.5% VWC in dry soil, ±1.5% VWC in typical saturated soil. The resolution is better than 0.1% volumetric water content. Water content accuracy is ±2.5% VWC using standard calibration with bulk electrical conductivity ≤0.5 deciSiemen per meter (dS m^{-1}) and bulk density ≤ 1.55 g cm^{-3} in measurement range 0-50% VWC. The reflectometer precision is better than 0.1% volumetric water content. More information can be found in the CS616 and CS625 Water Content Reflectometers Instruction Manual.

Software

No software is required to view the Excel files, Word document files, and ASCII data; however, ESRI's ArcGIS Software is required to view the shapefiles.

References

Barros, Ana P., Edward Kim, Walter A. Petersen, et al. (2014): Soil Moisture Experimental Plan for IPHEx-2014. https://ghrc.nsstc.nasa.gov/pub/fieldCampaigns/gpmValidation/iphex/Duke_soil_moisture/doc/IPHEx2014_SM_ExperimentalPlan.pdf

Barros, Ana P., Walt Petersen, Mathew Schwaller, et al. (2014): NASA GPM-Ground Validation Integrated Precipitation and Hydrology Experiment 2014 Science Plan. https://ghrc.nsstc.nasa.gov/pub/fieldCampaigns/gpmValidation/iphex/Duke_soil_moisture/doc/IPHEX_SciencePlan.pdf

Cosh, Michael H., Thomas J. Jackson, Rajat Bindlish, et al. (2005): Calibration of an impedance probe for estimation of surface soil water content over large regions. *Journal of Hydrology*, 311, 49-58. doi: https://doi.org/10.1016/j.jhydrol.2005.01.003

Tao, Jing, Di Wu, Jonathan Gourley, Sara Q. Zhang, et al. (2016): Operational Hydrological Forecasting during the IPHEx-IOP Campaign - Meet the Challenge. https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170002552.pdf

Related Data

All data from other instruments collected during the IPHEx field campaign are related to this dataset. Other IPHEx campaign data can be located using the GHRC HyDRO 2.0 search tool.

In addition, there are other soil moisture data in previous GPM Ground Validation and AMSR2 field campaigns. The following datasets contain soil moisture data:

GPM Ground Validation USDA ARS Soil Moisture IFloodS (http://dx.doi.org/10.5067/GPMGV/IFLOODS/PROBES/DATA301)

GPM Ground Validation Environment Canada (EC) Passive Microwave Radiometer and Soil Moisture-Temperature Data GCPEx (http://dx.doi.org/10.5067/GPMGV/GCPEX/RADIOMETER/DATA101)

NRT AMSR2 Unified L2B Half-Orbit 25 km Ease-Grid Surface Soil Moisture Beta V1 (http://dx.doi.org/10.5067/AMSRU/AU_Land_NRT_R01)

NRT AMSR2 Unified L2B Half-Orbit 25 km Ease-Grid Surface Soil Moisture Preliminary V0 (http://dx.doi.org/10.5067/AMSR2/A2_Land_NRT)

Contact Information

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

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320 Sparkman Drive
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