Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Snow Depth Monitoring System OLYMPEX

Introduction

The GPM Ground Validation Snow Depth Monitoring System OLYMPEX dataset consists of snow depth, temperature, and relative humidity measurements which were collected using snow depth poles, time lapse cameras, temperature/relative humidity sensors, and manual snow surveys. This dataset was collected during the GPM Ground Validation Olympic Mountain Experiment (OLYMPEX) held on the Olympic Peninsula in the Pacific Northwest of the United States. The analyzed data files are available in netCDF-3 data format. The dataset includes the individual camera photos of snow poles taken hourly during the field campaign, provided as JPG images. There are up to 3 cameras/poles per study site location. In addition, a Microsoft Excel data file contains results of a manual snow survey taken on the specific days of the Airborne Snow Observatory OLYMPEX overflights. In total, measurements contained in this dataset extend from September 5, 2014 through August 20, 2016, but the primary field campaign data were collected during the fall 2015 to spring 2016 time period.

Citation

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Keywords:

NASA, GHRC, GPM, OLYMPEX, Olympic Mountains, Washington, Snow Depth Monitoring System, snow depth, temperature, relative humidity, snow density, time lapse camera, snow survey

Campaign

The Global Precipitation Measurement (GPM) mission Ground Validation 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 at 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 https://pmm.nasa.gov/GPM/.

One of the GPM Ground Validation field campaigns was the Olympic Mountains Experiment (OLYMPEX) which was held in the Pacific Northwest. The goal of OLYMPEX was to validate rain and snow measurements in mid-latitude frontal systems as they move from ocean to coast to mountains and to determine how remotely sensed measurements of precipitation by GPM can be applied to a range of hydrologic, weather forecasting, and climate data. The campaign consisted of a wide variety of ground instrumentation, radars, and airborne instrumentation monitoring oceanic storm systems as they approached and traversed the Peninsula and the Olympic Mountains. The OLYMPEX campaign was part of the development, evaluation, and improvement of GPM remote sensing precipitation algorithms. More information is available from the NASA GPM Ground Validation web site https://pmm.nasa.gov/olympex, and the University of Washington OLYMPEX web site http://olympex.atmos.washington.edu/.

Figure 1: OLYMPEX Domain
(Image Source: https://pmm.nasa.gov/OLYMPEX)

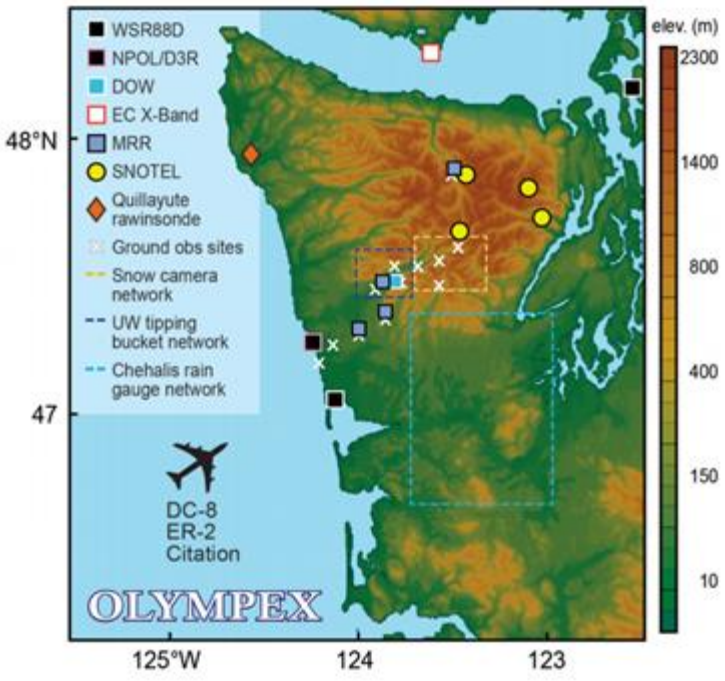

Figure 2: OLYMPEX Field Locations
(Image Source: https://pmm.nasa.gov/OLYMPEX)

Instrument Description

Snow monitoring sites were set up within the Olympic National Park for the OLYMPEX field campaign to provide snow depth, temperature, and relative humidity measurements at the site locations listed in Table 1. Two to three Wingcape time lapse cameras were deployed at each site positioned about 2.8 to 6.8 m above the ground (Wingcape TimelapseCam Model # WCT-00122 were used). These time lapse cameras took pictures of snow poles every hour during the daylight hours (09:00 - 16:00 PDT).

In addition to snow poles and time lapse cameras, most sites had HOBO U23 Pro-v2 temperature/relative humidity sensors and data loggers contained within plastic radiation shields. The sensors used for temperature are reported to have an uncertainty of ±0.21 degrees Celsius at 0 degree Celsius, with the uncertainty increasing to about ±0.75 degrees Celsius at -40 degrees Celsius. If there is no relative humidity data provided for a given site, the HOBO UA-001-08 sensor was used instead. More information about the instruments used for this dataset is available in Currier et al., 2017 and Currier, 2016.

This dataset also contains results from manual snow surveys completed by a collection team dropped at each site by helicopter on February 8, 2016 (mid-season winter) and April 7, 2016 (max snow of season). The surveys coincide with two overflights of the Airborne Snow Observatory (DOI: http://dx.doi.org/10.5067/GPMGV/OLYMPEX/LIDAR/DATA101). A standard snow core tube was used to collect the snow samples at specific sites, as noted in Table 2. Some survey sites are near the time lapse camera locations as noted in Table 1. The snow survey data are provided in the Microsoft Excel file, *Olympex_Snow_Survey.xlsx*

Table 1: Site names, elevations, and locations for each sample site. Only those sites marked with an asterisk * have snow depth data.

Site Name	Elevation (m)	Latitude	Longitude	Comments
Trail Head	183	47.5860	-123.6453	
Halfway House	294	47.6139	-123.6193	
ONeil Creek	403	47.6177	-123.4737	No WY2016 T/RH data
Black and White Transitional - Big Log	496	47.5677	-123.3746	Nearby snow survey
Twelve Mile	568	47.6792	-123.5962	
Enchanted Valley	625	47.6642	-123.3965	Nearby snow survey
Nine Stream	628	47.6138	-123.3405	
Footlog Ford	649	47.7419	-123.4921	
Camp Chicago	671	47.7374	-123.5279	
Big Log	688	47.5693	-123.3695	
Black and White Transitional	918	47.5718	-123.3644	
Halfway to First Divide	977	47.6220	-123.3315	Nearby snow survey
Wynoochee Pass*	997	47.5347	-123.5402	No WY2015 snow depths
White Creek Junction	1009	47.6883	-123.3440	
Dosewallips Basin	1067	47.7093	-123.3105	
Lake Sundown	1162	47.5342	-123.5142	No WY2016 T/RH data
Mount Christie*	1185	47.7195	-123.5422	
Lake Connie*	1262	47.5008	-123.5923	No WY2015 snow depths
Black and White Lake West*	1265	47.5745	-123.3497	No WY2015 snow depths
Mount Seattle East*	1301	47.7188	-123.5783	Nearby snow survey
Mount Steel*	1360	47.6347	-123.3193	
Mount Seattle West*	1368	47.7150	-123.5898	
Black and White Lake East*	1380	47.5730	-123.3435	
Anderson Pass East*	1402	47.6977	-123.1602	Nearby snow survey
Anderson Pass Glacier*	1404	47.6959	-123.1578	
Marmot Lake	1413	47.6462	-123.0347	
West of Lake LaCrosse*	1423	47.6741	-123.0329	No WY2015 snow depths
Mount Hopper*	1447	47.6337	-123.3100	
ONeil Pass	1507	47.6363	-123.3729	No 2016 T/RH data

Table 2: Snow survey locations

Location Name	Number of surveys	General Elevation (ft)

Mt Seattle	2	4489
Anderson Pass	2	4637
Hart Lake	1	4864
Enchanted Valley	2	2100
First Divide	2	4605
Black & White	2	4533
Cox Valley	2	4489
Eel Glacier	2	6080
Mt. Olympus	2	6762

Investigators

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Data Characteristics

The GPM Ground Validation Snow Depth Monitoring System OLYMPEX data files are available in netCDF-3 and Microsoft Excel formats, as well as JPG images of snow poles taken by each camera at each study site. These data are considered to be at a Level 2 and Level 3 processing levels. More information about the NASA data processing levels are available on the NASA Data Processing Level website.

Table 3: Data Characteristics

Characteristic	Description
Platform	Ground station
Instrument	Wingcape TimelapseCam Model # WCT-00122 HOBO U23 Pro-v2 temperature/relative humidity sensors Snow depth poles Snow survey tubes
Projection	WGS 1984 datum
Spatial Coverage	N: 47.822, S:47.501, E: -123.033, W: -123.707 (Washington)
Spatial Resolution	Snow Depth: ~1 m^2 , Camera Image: 10 m^2
Temporal Coverage	September 5, 2014 - August 20, 2016

Temporal Resolution	Per water year for 2015 and 2016
Sampling Frequency	Temperature: hourly Relative humidity: hourly Time-lapse camera photos: every two hours during daylight Snow survey: daily (on Feb 8, 2016 and Apr 7, 2016)
Parameter	Snow depth, temperature, relative humidity
Version	1
Processing Level	Snow survey, temperature, relative humidity: Level 2 Snow depth: Level 4

File Naming Convention

The GPM Ground Validation Snow Depth Monitoring System OLYMPEX dataset has data files with file naming conventions as indicated below. The data files are available in netCDF-3 and Microsoft Excel formats, as well as JPG images for each camera at each study site.

Data files: Olympex_[Snow_Depth|Temperature_RH]_Data_[WY|Sites]_YYYY.[nc|xlsx]
Olympex_Snow_Surveys.xlsx
Browse files: olympex_tlcam_YYYYMMDD_hhmmss_site_camera#.jpg

Table 4: File naming convention variables

Variable	Description
[Snow_Depth|Temperature_RH]	Snow_Depth: data files that contain snow depth estimates by site over time Temperature_RH: data files that contain temperature and relative humidity measurements by site over time
[WY|Sites]	WY: all data summarized in files throughout the OLYMPEX study area for the whole water year Sites: list of sites where temperature and relative humidity were measured
YYYY	Four-digit year
[nc|xlsx]	nc: netCDF-3 format xlsx: Microsoft Excel format
MM	Two-digit month
DD	Two-digit day
hh	Two-digit hour in UTC
mm	Two-digit minute in UTC
ss	Two-digit second in UTC
site	Site name picture was taken at. List of these sites are shown in Table 1 above.

camera#	Camera number at each site
.jpg	Joint Photographic Experts Group (JPEG) format

Data Format and Parameters

The GPM Ground Validation Snow Depth Monitoring System OLYMPEX dataset consists of snow depth, temperature, and relative humidity measurements provided in netCDF-3 and Microsoft Excel formatted files. Snow pole pictures from each camera are provided as JPG browse image files. Table 5 and Table 6 describe the data fields within the netCDF-3 data files. It is important to note that all time measurements are in Pacific Standard Time.

Table 5: Data Fields in Olympex_Snow_Depth_Data_WY_YYYY.nc files

Field Name	Description	Data Type	Unit
Air_Temperature	Air temperature measured following methods of Lundquist and Huggett (2008) with a HOBO U23 Pro v2 temperature/RH sensor. Measured at heights > 4 m and < 7 m.	double	Degrees C
Elevation	Elevation of the site	double	m
Latitude	Latitude of site	double	Decimal degrees
Longitude	Longitude of site	double	Decimal degrees
Relative_Humidity	Relative humidity measured following methods of Lundquist and Huggett (2008) with a HOBO U23 Pro v2 temperature/RH sensor. Measured at heights > 4 m and < 7 m.	double	%
Snow_Depth	Hourly snow depth observations that were averaged to daily snow depth observations	double	cm
Snow_Depth_Lower_Bound	Lower confidence bound for snow depth data.	double	cm
Snow_Depth_Upper_Bound	Upper confidence bound for the snow depth data.	double	cm
Time	Time values in the following order: Year, month, day, hour, minute, second, Julian Day, Matlab serial date.	Time	PST

Table 6: Data Fields in Olympex_Temperature_RH_Data_WY_YYYY.nc files

Field Name	Description	Data Type	Unit

Elevation	Elevation of the site	double	m
Latitude	Latitude of site	double	Decimal degrees
Longitude	Longitude of site	double	Decimal degrees
Relative_Humidity	Relative humidity	double	%
Temperature	Air temperature at each site. If the site has relative humidity data then the data comes from a HOBO U23 Pro v2 temperature/RH sensor, if there is no relative humidity data the data comes from a HOBO UA-001-08.	double	Degrees Celsius
Time	Time values in the following order: Year, month, day, hour, minute, second, Julian Day, Matlab serial date.	Time	PST

Data files are summarized below:
Olympex_Temperature_RH_Data_WY_2015.nc contains temperature and relative humidity measurements for 29 sites starting on September 4, 2014 at 16:00 and runs through May 31, 2015 at 16:00. These files contain hourly time-steps in PST (UTC-8). This is noted within the netCDF-3 file. The Microsoft Excel list of stations is needed to identify the station order in the file

Olympex_Temperature_RH_Data_WY2016.nc contains the temperature and relative humidity measurements for 26 sites (3 were not operating) starting on October 1, 2015 at midnight (00:00) and continuing until July 26, 2016 at midnight (00:00). These times are also at an hourly time-step and in PST (UTC-8). This is also noted within the netCDF-3 file. The Microsoft Excel list of stations is needed to identify the station order within the file.

The file *Olympex_Temperature_RH_Data_Sites.xlsx* contains the list of sites in the order they are provided in the temperature and RH netCDF-3 data files. There is no indication of the site names in the netCDF-3 files and, therefore, one needs to obtain this Microsoft Excel file for site names and locations.

Olympex_Snow_Depth_Data_WY_2015.nc contains snow depth measurements for 7 stations starting on October 1, 2014 at midnight (00:00) and continuing until September 29, 2015 (23:00). These times are hourly time-steps and in Pacific Standard Time UTC-8 as noted in the netCDF-3 file. Note that while these data are at hourly time-steps, the snow depth values and the uncertainties associated with them are daily averages. For instance, the 1:00 value on February 1, 2015 is the same as the 19:00 or 20:00 value on the same day because

it's the daily average. This was done because of uncertainty with interpreting the reading of the snow depth poles.

Olympex_Snow_Depth_Data_WY2016.nc contains snow depth measurements for 11 stations starting on October 1, 2015 at midnight (00:00) and continuing until July 26, 2016 at 00:00. These times are at hourly time-steps and in PST UTC-8. As noted above, the snow depth values are daily averages. This is noted in both netCDF-3 files.

The *Olympex_Snow_Survey.xlsx* data file consists of the snow survey data at select locations at two time periods, February 8-9, 2016 and April 7-8, 2016. Snow depth and density are determined using a snow collection tube. These data can be used for validation of the Airborne Snow Observatory LiDAR data.

Quality Assessment

Snow depth measurements with uncertainty values greater than 5 cm were not used for evaluation, but were shown with uncertainty bounds to provide guidance in the evolution of the snowpack. These uncertainty values were based on experiments where poles were bent at various angles to the camera viewing direction.

For the temperature measurements, if the site has both temperature and relative humidity data then the sensor used was the HOBO U23 Pro v2 temperature/relative humidity sensor. If there is no relative humidity data for a given site, the sensor used was the HOBO UA-001-08, which has slightly less accurate. All temperature sensors were carefully evaluated to ensure they were working correctly before deployment.

The sensors used to record the temperature at each site were reported to have an uncertainty of ±0.21 degrees Celsius at 0 degree Celsius, with the uncertainty increasing to about ±0.75 degrees Celsius at -40 degrees Celsius. The accuracy for the relative humidity sensors used was within ±2.5% between 10% and 90% relative humidity. The uncertainty below 10% and above 90% relative humidity increases to ±3.5%. More information about the instruments and their accuracy is available in Currier et al., 2017 and Currier, 2016.

Software

These data are available in netCDF-3 and Microsoft Excel formats, so no software is required to view these data. However, Panoply can be used to easily plot the netCDF-3 data.

Known Issues or Missing Data

Data with values of -9999 are considered to be missing or no data. Not all sites have continuous data due to camera failures, bending snow poles, temperature or instrument failures, etc. In WY2015, there were 29 sites. The WY2016 data file contains 29 sites, however -9999 is used for 3 of these sites as the data are missing for various reasons:

O'Neill Creek, Lake Sundown, and O'Neill Pass. Snow depth data are provided for only 7 (WY2015) and 12 (WY2016) stations.

An example of snow depth measurements for sites in WY2016 is provided below showing periods of missing data.

Table 7: Example of snow depth measurements showing periods of missing data

Feb 8th Survey							
Sample #	Depth of Snow Inches	Lenth of Core Inches	Weight of Tube and core	Weight of Empty Tube	Water Content Inches	Density Percent	Notes
1	68	65	72	46	26	0.38	
2	73	69.5	72	46	26	0.36	
3	71.5	68.5	75	46	29	0.41	
4	63.5	59	70	46	24	0.38	
5	51	49.5	64	46	18	0.35	
6	52	51.5	68	46	22	0.42	
7	55	51.5	66	46	20	0.36	
8	65.5	63	72	46	26	0.40	
9							Fallen log at this location
10	65	63	70	46	24	0.37	
Mean	**62.7**				**23.9**	**0.38**	

References

Currier, W. R. (2016): An independent evaluation of frozen precipitation from the WRF model and PRISM in the Olympic Mountains for WY 2015 and 2016. Master's thesis, Department of Civil and Environmental Engineering, University of Washington, 58 pp., https://digital.lib.washington.edu/researchworks/handle/1773/38604.

Currier, William Ryan, Theodore Thorson, and Jessica D. Lundquist (2017): Independent Evaluation of Frozen Precipitation from WRF and PRISM in the Olympic Mountains. *Journal of Hydrometeorology*, 18, 2681-2703. doi: https://doi.org/10.1175/JHM-D-17-0026.1

Lundquist, Jessica D. and Brian Huggett (2008): Evergreen trees as inexpensive radiation shields for temperature sensors. *Water Resources Research*, 44:4, W00D04. doi: https://doi.org/10.1029/2008WR006979

Related Data

The Airborne Snow Observatory dataset is related to this snow monitoring dataset as the snow survey data was collected around the time of the ASO overflights and can serve as ground validation for the ASO measurements (DOI: http://dx.doi.org/10.5067/GPMGV/OLYMPEX/LIDAR/DATA101)

All other datasets collected during the OLYMPEX field campaign can be considered related to this dataset. Other OLYMPEX campaign data can be located using the GHRC HyDRO 2.0 search tool.

Contact Information

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

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