Global Hydrology Resource Center

Data User Guide

GPM Ground Validation Airborne Snow Observatory (ASO) OLYMPEX

Introduction

The GPM Ground Validation Airborne Snow Observatory (ASO) OLYMPEX dataset consists of snow depth, bare earth surface, land surface classification and a Red, Green, Blue (RGB) composite image, provided at 3 m spatial resolution during the GPM Ground Validation Olympic Mountains Experiment (OLYMPEX) field campaign held in the Pacific Northwest. These data were collected by a Riegl Q1560 scanning LiDAR and an ITRES CASI-1500 imaging spectrometer , both part of the NASA Airborne Snow Observatory (ASO), during two separate periods, February 8-9, 2016 and March 29-30, 2016. A previous September 2014 flight was used to obtain no-snow measurements used for deriving snow depth. The data are provided in GeoTIFF format.

Citation

Painter, Thomas and Dennis Lettenmaier. 2018. GPM Ground Validation Airborne Snow Observatory (ASO) OLYMPEX [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/OLYMPEX/LIDAR/DATA101

Keywords:

NASA, GHRC, GPM, OLYMPEX, Washington, snow depth, land surface classification, ASO, LiDAR, CASI, DEM

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)

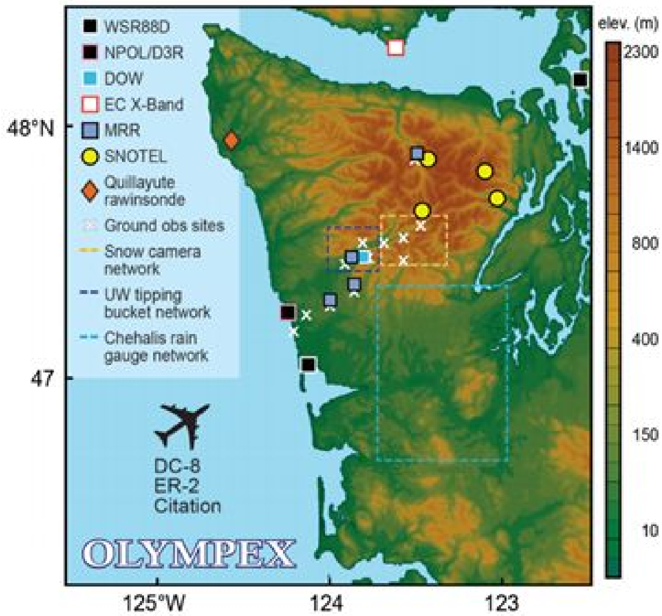

Figure 2: OLYMPEX Field Locations. The image does not contain ASO sampling region. (Image Source: https://pmm.nasa.gov/OLYMPEX)

Instrument Description

This dataset contains measurements obtained by the airborne snow observatory system which consists of a Riegl Q1560 scanning LiDAR coupled with an ITRES CASI-1500 imaging spectrometer (*itres* Research Limited, www.itres.com). The imaging spectrometer is used to quantify spectral albedo, broadband albedo, and radiative forcing by dust and black carbon in snow.

The scanning LiDAR captures the surface topography with better than 10 cm vertical accuracy and is used to determine snow depth by subtracting previous snow-free measurements. Snow water equivalent can be quantified when combined with in-situ constrained modeling of snow density.

The ITRES CASI-1500 imaging spectrometer captures imagery in 72 spectral bands from the visible to the near-Infrared. This provides spectral albedo of the snow surface, which is used to determine the energy absorbed from incoming sunlight. This, combined with energy balanced modeled from meteorological conditions, yields snowmelt rates.

An integrated Applanix Inertial Measurement Unit (IMU) and GPS provide aircraft attitude and position information, and this information is combined with error corrections from an existing network of GPS base stations at fixed locations near the survey area.

More information about the ASO LiDAR and imaging spectrometer is available in [Painter et al., 2016](#).

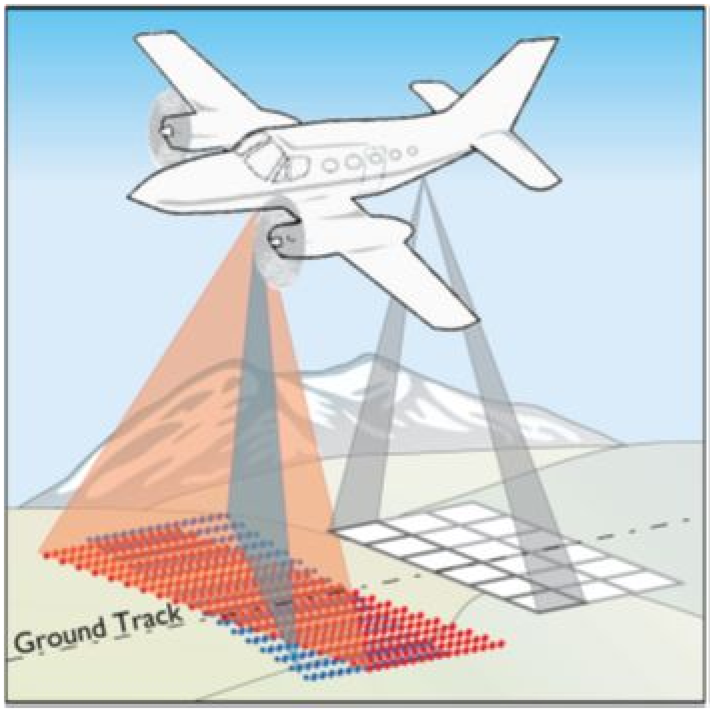

Figure 3: Scan configuration of the ASO scanning lidar (Riegl Q1560) in color and the imaging spectrometer (Itres CASI-1500) in grayscale.
(Image source: Painter et al., 2016)

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Data Characteristics

On 8–9 February and 29–30 March, during winter in the Olympic Mountains, assessments of snowpack accumulation were made by the LiDAR on the Jet Propulsion Laboratory's Airborne Snow Observatory (ASO) aircraft (Painter et al. 2016). The February and March measurements were compared to data obtained during a flight in September 2014, a time with no snow cover on the mountains. The Feb/Mar 2016 measurements minus the Sept 2014 measurements allow for the determination of the snow depth. The February flights occurred at a midseason time before maximum snow cover. The late March flights took place when winter snow cover was near maximum. More information about the field campaign is available in Houze et al. , 2017.

This GPM Ground Validation ASO OLYMPEX dataset files six files, in GEOTIFF format at Level 3 processing level. Note that these GEOTIFF files are quite large. More information about the NASA data processing levels are available on the NASA Data Processing Levels website. Table 1 provides the characteristics of the data files.

Table 1: Data Characteristics

Characteristic	Description
Platform	Aircraft: Airborne Snow Observatory
Instruments	LiDAR, imaging spectrometer
Projection	WGS_1984_UTM_zone_10N
Spatial Coverage	N: 48.091, S: 47.493, E: -123.129, W: -124.185
Spatial Resolution	3 m
Temporal Coverage	Snow measurements on February 8-9, 2016 and March 29-30, 2016. Non-snow measurements on September 4, 2014.
Temporal Resolution	Per file: One day concatenated together from two days for complete spatial coverage
Sampling Frequency	N/A
Parameter	Snow depth, DEM, RGB image, land surface classification
Version	1
Processing Level	Level 3

File Naming Convention

The GPM Ground Validation ASO OLYMPEX dataset consists of six GeoTIFF data files. Some of the file name variables used in the 6 files is listed below.

Data files: olympex_ASO_[US][WA]_[OL]_[CASI]_<date>_[<end>]_<parameter>.tif

Table 2: File naming convention variables

Variable	Description
[US] [WA] [OL]	US: United States WA: Washington OL: Olympics
[CASI]	CASI: imaging spectrometer
<date>	Start date of data collection in YYYYMMDD YYYY: Four-digit year MM: Two-digit month

	DD: Two-digit day
<end>	End day of data collection in DD DD: Two-digit day
<parameter>	Parameter can be those listed below (see next section for more information: SUPERsnow_depth_glacier mega_classifier_3p0m weekly_mosaic_classified_lidargrid weekly_mosaic_rgb_lidargrid f1a1_mcc_bareDEM_3p0m_despiked
.tif	GeoTIFF format

Data Format and Parameters

The GPM Ground Validation ASO OLYMPEX dataset consists of six GeoTIFF data files.

The *olympex_ASO_OL_20160208_09_SUPERsnow_depth_glacier.tif* file and the *olympex_ASO_OL_20160329_30_SUPERsnow_depth_glacier.tif* file contain snow depth in meters as derived from the scanning LiDAR for February 8-9, 2016 (mid-season) and March 29-30, 2016 (typically the max snow period), respectively.

The *olympex_ASO_CASI_20160329_weekly_mosaic_classified_lidargrid.tif* contains land surface classification maps derived from the CASI imaging spectrometer measurements on March 29-30, 2016. Classified pixels are: 1=snow, 2=vegetation, 3=soil/rock, 4=water.

The *olympex_ASO_OL_20160329_30_mega_classifier_3p0m.tif* contains a land surface classification map produced from both the CASI imaging spectrometer data and the intensity of the LiDAR returns measured on March 29-30, 2016. Classified pixels are: 1=snow, 2=vegetation, 3=soil/rock, 4=water.

The *olympex_ASO_CASI_20160329_weekly_mosaic_rgb_lidargrid.tif* contains a red, green, blue (RGB) composite image constructed from the CASI imaging spectrometer measurements on March 29-30, 2016.

The *olympex_ASO_USWA_OL_20140904_f1a1_mcc_bareDEM_3p0m_despiked.tif* contains a bare earth (no-snow) surface map (Units: meter), a secondary raster product derived from LiDAR measurements on September 4, 2014. This data excludes tops of trees and vegetation but includes snow surface and bare ground/rock. Anomalies have been filtered out ("despiked"). DEM stands for Digital Elevation Model. The data in this file are used to determine snow depth from the Feb/Mar 2016 measurements.

Algorithm

Snow depth maps are a core component of the ASO processing. ASO uses LiDAR-derived terrain surfaces for both snow-on (winter) and snow-off (summer) conditions to retrieve spatially distributed snow depths (Figure 4).

For areas of forest cover, as well as extremely rugged topography, snow depth retrievals via simple surface subtraction gets complicated. To minimize the impacts of terrain- and forest-induced errors, the Multiscale Curvature Classification (MCC) algorithm (Evans and Hudak, 2007) is used to identify ground points in forested areas. Snow depth is calculated from snow-on and snow-off gridded surfaces from the MCC-classified point cloud elevation measurements. A final composite snow depth grid is generated from merging the single return differences (bare areas) and the NCC differences (areas with trees).

Spectral radiance is calculated for the CASI 1500 data, giving 72 spectral bands from 380 to 1,050 nm in units of μW cm^{-2} sr^{-1} nm^{-1}.

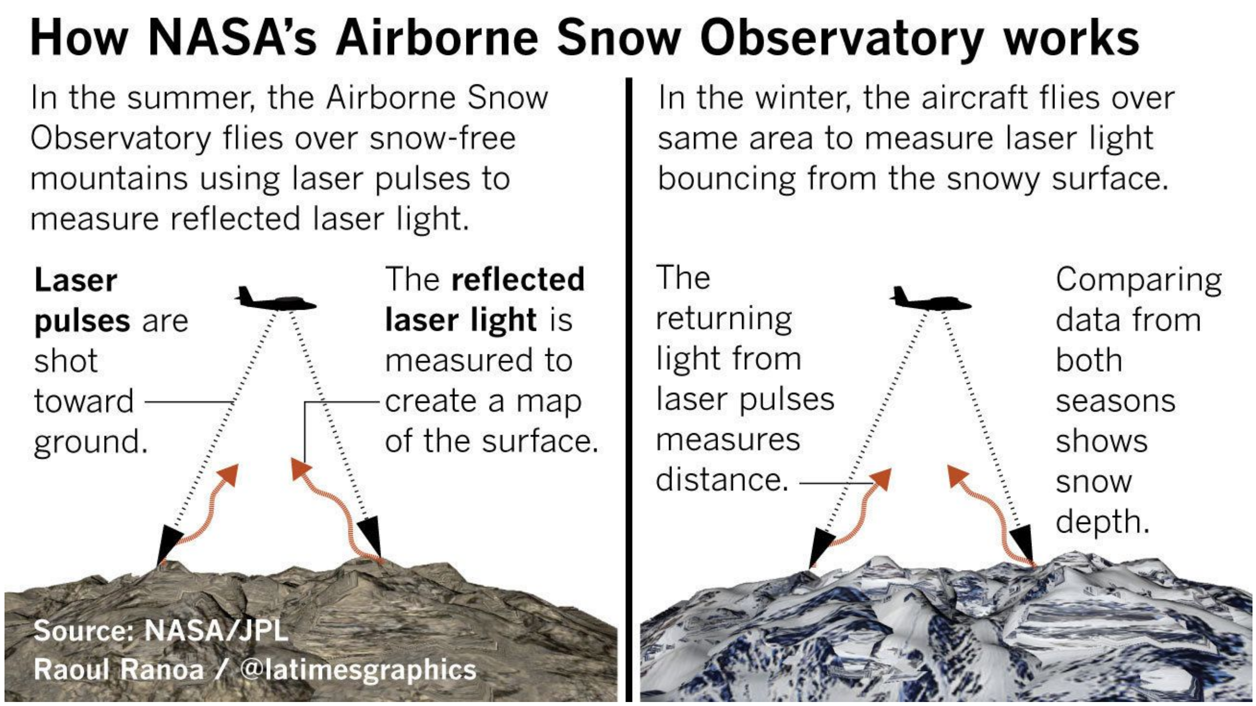

Figure 4: ASO uses LiDAR measures snow depth.
(Image source:
http://www.trbimg.com/img-591dfbe3/turbine/la-g-snowex-graphic-20170518)

Quality Assessment

In addition to ASO measurements, there were crews on the ground carried by helicopter to site locations in the Olympic Mountains, to measure the depth and density of the snowpack. These manual snow surveys were conducted near most of the locations of the snow poles and cameras that are part of the OLYMPEX snow monitoring dataset available from GHRC (DOI: http://dx.doi.org/10.5067/GPMGV/OLYMPEX/SNOWTUBE/DATA101). The ASO snow depth estimates derived generally have mean absolute errors of <8 cm, with bias < 1 cm when compared to the manually measured snow depths at the 15x15 m scale. When coarsened from 3 m spatial resolution to 50 m, the error is reduced to <2 cm.

To minimize the impacts of terrain- and forest-induced errors, the Multiscale Curvature Classification (MCC) algorithm (Evans and Hudak, 2007) is used to identify ground points in forested areas.

It is important to note that shrubs can create cavities in the snow column and as such create a snow depth scenario that the lidar cannot detect.

More information about the quality of the ASO LiDAR data are available in Painter et al., 2016 and Cao et al., 2018.

Software

These data are available in GeoTIFF format and can be read using Python. These data can also be viewed in ESRI's ArcMap. More information can be obtained from http://trac.osgeo.org/geotiff/

Known Issues or Missing Data

Missing data are set as -9999.0.

In the snow depth data, values of -200.0 are present that represent glaciers. These values should not be used.

References

Painter, T. H., D. F. Berisford, J. W. Boardman, K. J. Bormann, et al. (2016): The Airborne Snow Observatory: Fusion of scanning lidar, imaging spectrometer, and physically-based modeling for mapping snow water equivalent and snow albedo. *Remote Sens. Environ*., 184, 139–152. doi: https://doi.org/10.1016/j.rse.2016.06.018

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Related Data

The manual snow surveys collected during the winter ASO overflights (Feb/Mar 2016) are available as an excel file that is part of the OLYMPEX snow monitoring dataset also available from GHRC. DOI for this dataset is http://dx.doi.org/10.5067/GPMGV/OLYMPEX/SNOWTUBE/DATA101

All datasets from OLYMPEX can be considered related to this ASO dataset. Other OLYMPEX campaign data can be located using the GHRC HyDRO 2.0 search tool, by entering the term 'OLYMPEX'.

Contact Information

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

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