National Aeronautics and Space Administration

NASA Earth Observations for Reservoir and Water Utility Management

Part 1: Data Requirements for Reservoir Management

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August 04, 2026

About ARSET

About ARSET

- **The Applied Remote Sensing Training (ARSET) program provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**
- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

AGRICULTURE
DISASTERS
ECOLOGICAL CONSERVATION
HEALTH & AIR QUALITY
WATER RESOURCES
WILDLAND FIRES

About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.

Training Learning Objectives

By the end of this training, participants will be able to:

- Recognize the importance and availability of Earth observations (EO) and modeled data for hydropower reservoir management.
- Identify NASA EO products applicable to reservoir management, focusing on key hydrological parameters such as precipitation, soil moisture, snow cover and Snow Water Equivalent (SWE), runoff, water surface elevations for reservoirs and tributaries, and simulated streamflow in inflow rivers from a global hydrology model.
- Access and visualize the EO parameters using relevant web tools (e.g. Worldview, Global Water Measurements, SWOTViz) and Google Earth Engine to monitor critical watershed conditions upstream of reservoir inflows, and water levels in reservoirs.
- Apply the GEOGLOWS River Forecast System (RFS) hydrology model output to query historical river data and construct predictive streamflow hydrographs for inflow rivers using the GEOGLOWS RFS model.
- Analyze time series of the EO parameters for a given river basin boundaries and reservoirs of interest.

Prerequisites

- Fundamentals of Remote Sensing
- Introduction to NASA Snow and Ice Data Products and Applications for Water Resources Management
- ARSET: Monitoring Global Terrestrial Surface Water Using Remote Sensing
- ARSET: Monitoring and Predicting Floods Using Earth Observations for Planning and Preparedness

Training Outline

Part 1
Data Requirements for Reservoir Management
August 4, 2026

Part 2
Accessing NASA Earth Observations for Reservoir Management
August 6, 2026

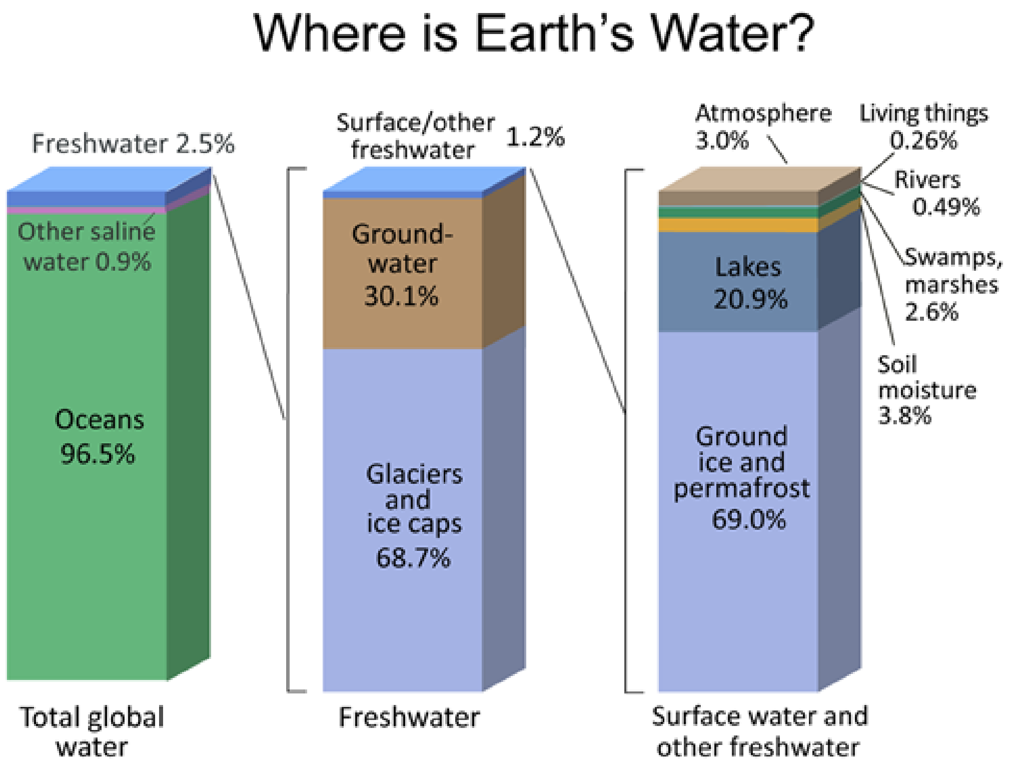
Part 3
Applying NASA Earth Observations to Hydropower Reservoir Management
August 11, 2026

Homework
Opens August 11– **Due August 25** – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Review of Prior Knowledge

- Water is critical for drinking, agriculture, industries, hydroelectric power generation, public health, and transportation among other usage.
- Despite the vast amount of water on Earth, only 2.5% is freshwater. The remaining 97% is locked away as saltwater in our oceans (USGS, 2019).
- Satellite remote sensing measures emitted, backscattered, and reflected radiation (optical, infrared, and microwave) for water measurement.
- The mass or volume of snow is expressed as an equivalent volume of water: Snow Water Equivalent (SWE)



Credit: U.S. Geological Survey, Water Science School. https://www.usgs.gov/special-topic/water-science-school
Data source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

Part 1 – Trainers

Dr. Amita Mehta

Research Scientist/Trainer

(NASA/UMBC)

Sean McCartney

Scientific Analyst/Trainer

(NASA/STC)

Part 1 Objectives

By the end of Part 1, participants will be able to:

- Identify the key challenges, operational factors, and data requirements associated with reservoir management.
- Determine the relevant NASA Earth observation datasets that can support management efforts.

How to Ask Questions

- To ensure we see your question, please locate the three dots (...) at the bottom right of your training window.
- You will see a Slido/Q&A option. You may also see a standalone Slido tab or app.
- We will address **all questions relevant to the training topic** at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

NASA Earth Observations for Reservoir and Water Utility Management
Overview

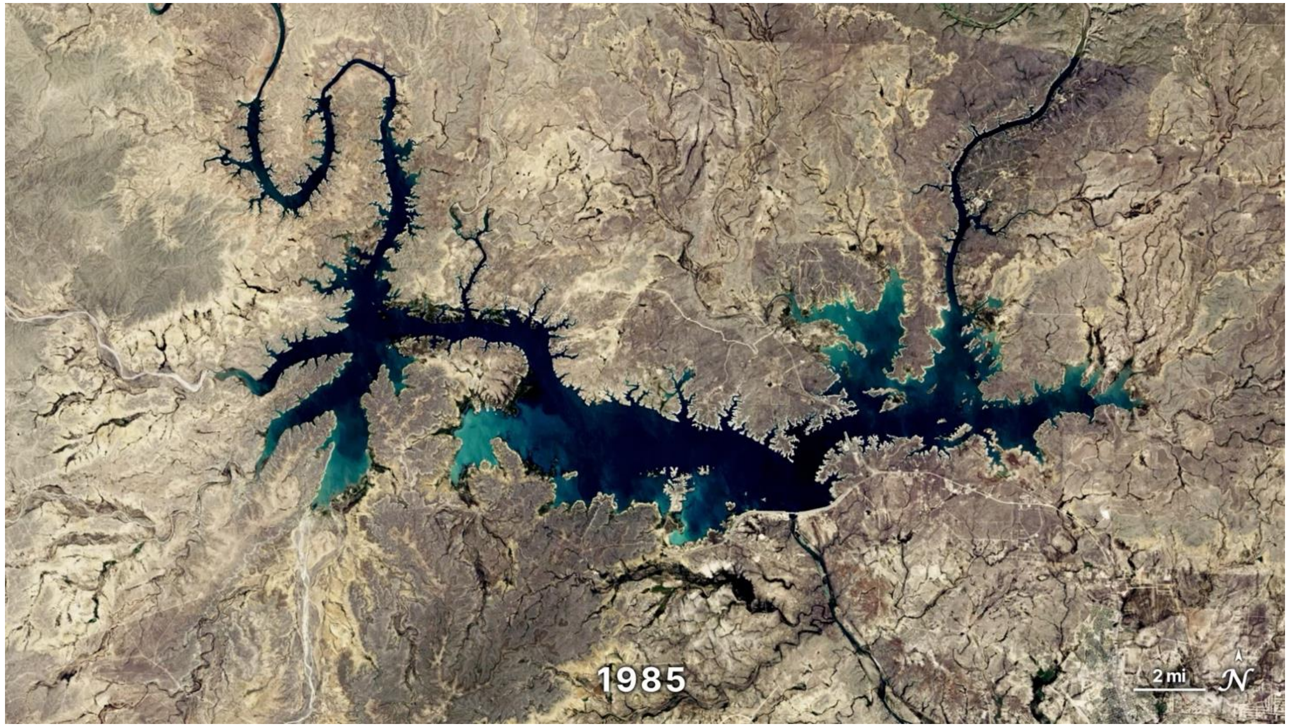
What is a Water Reservoir?

- A reservoir is a **man-made lake** where water is stored.
- Most reservoirs are created by **damming** a river, which traps the natural flow to form a storage basin (USGS).
- A World Bank review in 2023 of global and regional datasets estimated the number of "large" dams & reservoirs at 35,000 to 62,000.
  - The Global Dams and Reservoirs Database in ArcGIS
- The U.S. National Inventory of Dams reports 90,000+ dams.
  - National Inventory of Dams in US Dept. of Transportation

Credit: Ecoticias

The Evolution of Water Management

- One of the world's oldest known dams, the Jawa Dam in modern-day Jordan, was built around 3000 B.C. for irrigation.
- Most of the world's existing dams were constructed after World War II, driven by the push for global economic development (Schmutz & Moog, 2018).
- Modern reservoirs are multi-purpose infrastructure systems, used for:
  - Water Supplies
  - Agricultural Irrigation
  - Mitigating Flood Risks
  - Hydroelectric Power
  - Public Recreational Spaces.



A natural-color Landsat time series of the Amistad Reservoir on the U.S.-Mexico border from 1985 to 2025. Credit: NASA Goddard Space Flight Center

Types of Reservoirs

- **On-Stream Reservoirs:** Built directly on a river using a dam to capture natural flow.
  - Used for large-scale hydropower, flood mitigation, and downstream flow regulation due to their massive storage capacity.
- **Off-Stream Reservoirs:** Built away from the main river channel, filled by diverting or pumping water into a storage basin.
  - Commonly used for municipal drinking water supplies, specialized agricultural irrigation, and pumped-storage hydropower.

Landsat 7 image of the San Luis Reservoir in Merced County, California. The reservoir stores water taken from the San Joaquin-Sacramento River Delta and is an example of an off-stream reservoir.
Credit: NASA

Reservoir Management: Importance

- **Water Supply:** Secures drinking water for municipalities and sustains agricultural irrigation.
- **Flood Mitigation:** Protects downstream communities by capturing and regulating extreme runoff.
- **Energy Generation:** Provides reliable, renewable hydroelectric power to the grid (run-of-river, base-load storage, peak-load.)
- **Recreation:** Supports economies through public access for boating, sport fishing, and water sports.

Credit: Matthew Binebrink

Reservoir Management: Challenges

- **Competing Timescales**:
  - Short-Term (Hours to Days): Rapid decision-making for peak hydropower generation, daily market demands, and immediate flood mitigation.
  - Long-Term (12–18 Months): Strategic planning based on predicted runoff volumes, snowpack assessments, and seasonal water supply forecasts.
- **Data Blind Spots:** Monitoring un-gauged mountain basins and low-elevation snowpack.
- **Water Quality:** Managing dropping elevations and rising temperatures that trigger Harmful Algal Blooms (HABs).
- **Transboundary Coordination**: Synchronizing operations across state or international borders.

NASA Earth Observations and Earth System Models to Monitor Reservoir Watershed Conditions

Data Parameters Relevant for Reservoir Management

- Required data for monitoring water availability and storage changes across current, short-term (hourly/daily), and long-term (seasonal) timescales include:
- **Watershed Hydrology and Meteorology Parameters**
  - Land Cover
  - Precipitation
  - Runoff
  - Snow Cover
  - Snow Melt (SWE: Snow Water Equivalent)
  - Soil Moisture
  - Topography and Stream Network
  - Wind Speed, Temperature, Humidity, and Solar Radiation, Vegetation
- **Reservoir Parameters**
  - Bathymetry
  - Reservoir Water Level
  - Sedimentation
  - Seepage & Evaporation
  - Water Inflow: Streamflow from upstream rivers
  - Water Outflow: Scheduled release for downstream supply/usage, power generation

Earth Observations for Reservoir Management: Watershed Parameters

Parameter	Satellite/Sensor & Earth System Model
Land Cover	Terra and Aqua/MODIS; SNPP, NOAA 20 and 21/VIIRS; Landsat 8 & 9/OLI; Sentinel-2/MSI
Precipitation	GPM and international constellation of satellites/microwave radar, radiometers, imagers
Runoff	GLDAS, NLDAS
Snow Cover	Terra and Aqua/MODIS, SNPP, NOAA 20 and 21/VIIRS
Snow Water Equivalent	GLDAS, NLDAS
Soil Moisture	SMAP
Topography and Stream Network	HydroSHEDS
Wind speed, Temperature, Humidity, Solar Radiation	GEOS-5, MERRA-2

Earth Observations for Reservoir Management: Reservoir Parameters

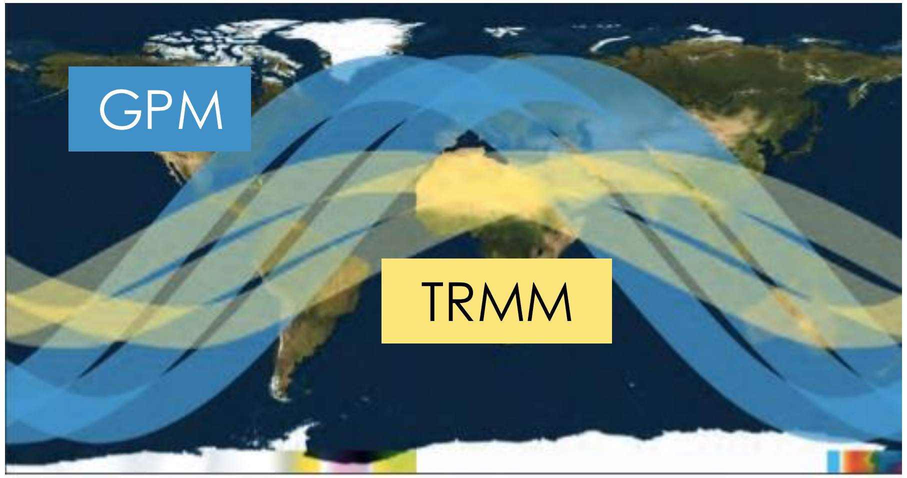
Parameter	Satellite/Sensor & Earth System Model
Bathymetry	ICESat-2/LiDAR
Reservoir Water Level Height	SWOT, Sentinel-6, Jason 2 & 3/Radar Altimeters
Sedimentation	Landsat 8 & 9/OLI, Sentinel-2/MSI
Seepage	Water Height and Model-Based
Water Inflow	GEOGLOWS Streamflow
Water Outflow	GEOGLOWS Streamflow, In Situ Data for Water Usage


IMERG Precipitation Data

GPM and TRMM – Precipitation Measurement Missions

- Dedicated precipitation measurement missions (PMM) to measure precipitation from active and passive microwave observations.
- Collaborative missions between NASA and Japanese Space Agency (JAXA).
- **TRMM:** November 1997 to April 2015
- **GPM:** February 2014 to Present
- **Combined, TRMM and GPM provide 25+ years of precipitation data.**

TRMM: Tropical Rainfall Measuring Mission
GPM: Global Precipitation Measurement



- TRMM measurements were limited to the tropics (35° north/south latitude).
- GPM measurements span middle and high latitudes (65° north/south latitude).

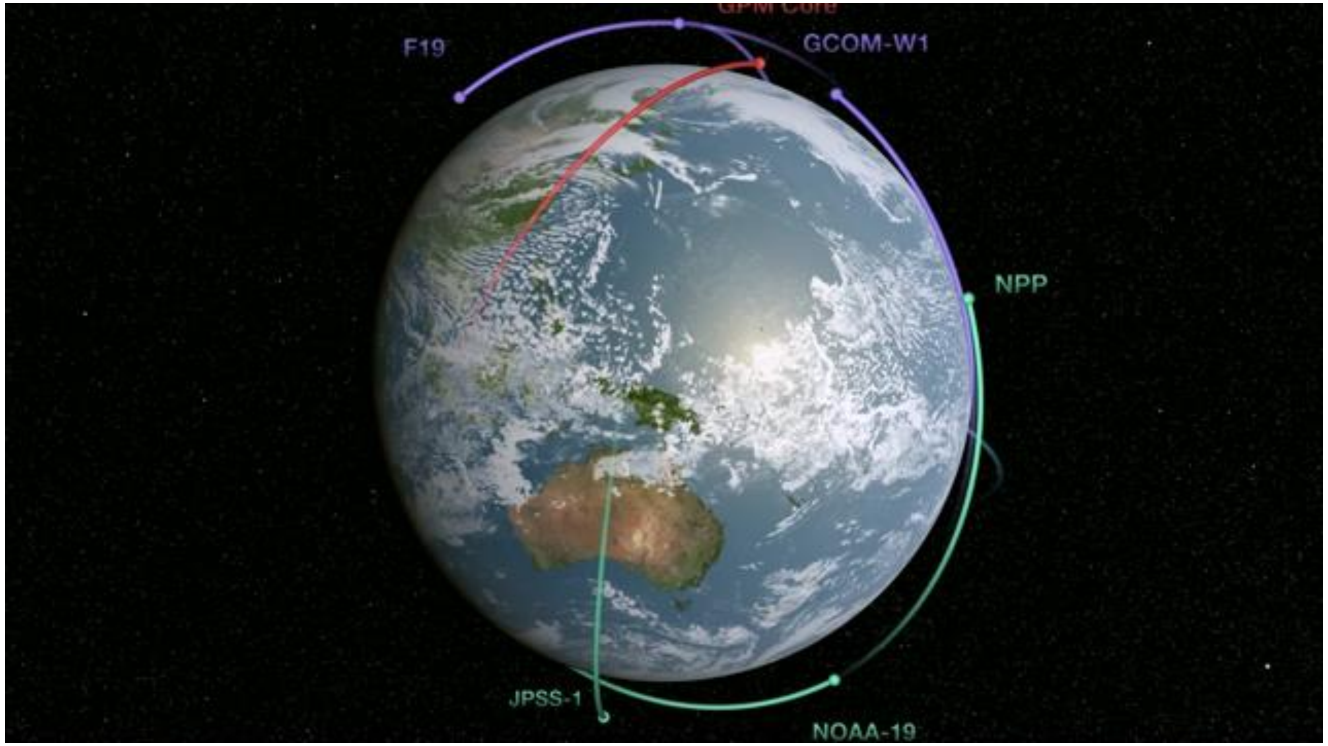
http://pmm.nasa.gov/

Multi-Satellite Algorithms for TRMM and GPM

- TRMM & GPM core satellites are used to calibrate microwave observations from a constellation of national and international satellites.
- TRMM Multi-satellite Precipitation Analysis (**TMPA**)
- Integrated Multi-satellitE Retrievals for GPM (**IMERG**)
- IMERG is calibrated with TMPA to provide long-term precipitation record.
- Lean more about the precipitation algorithms.

GPM Satellite Constellation

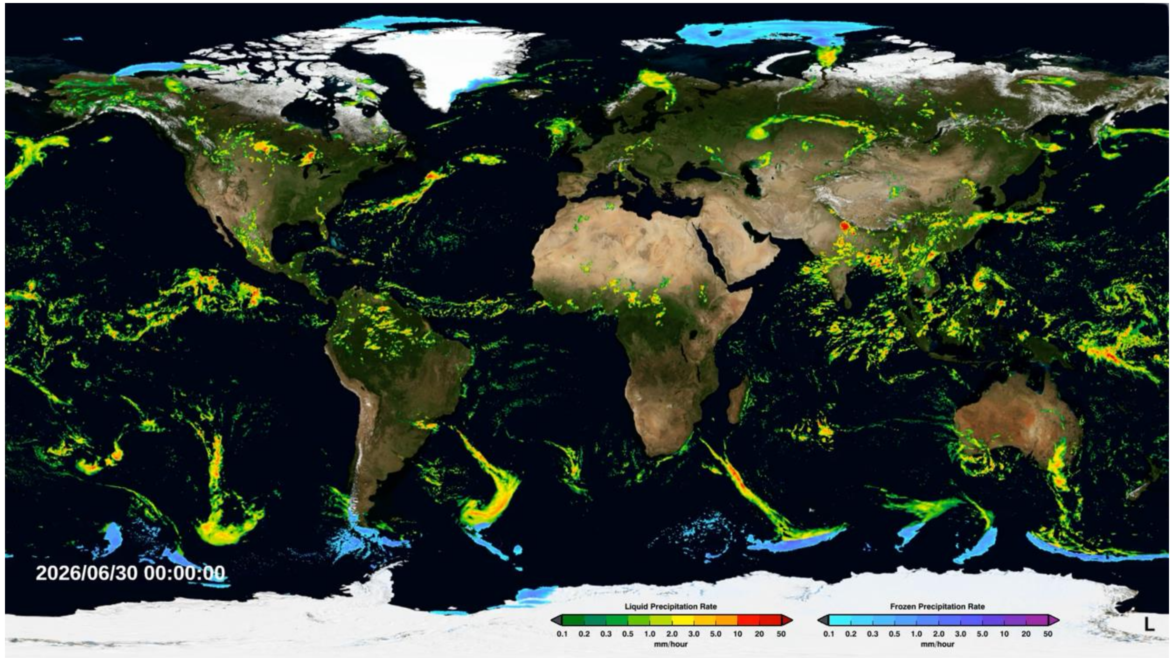
Allows improved spatial and temporal coverage of precipitation data



Credit: NASA Science Visualization Studio

Global Precipitation Product – IMERG

- Integrated Multi-satellitE Retrievals for GPM (IMERG) is a single integrated code system for near real-time and production precipitation data.
- Multiple runs accommodate different user requirements for latency and accuracy:
  - “Early” – 4 hr. (flash flooding)
  - “Late” – 14 hr. (crop forecasting)
  - “Final” – 3 months (research)
- Spatial Resolution: 0.1° global grid
- Spatial Coverage: 90° N/S (global product from version 7)
- Temporal Resolution: 30-min., 1-day, and monthly (final run only)
- Temporal Coverage: 1998–Present



Credit: NASA

IMERG Applications for Monitoring Reservoir Watershed Conditions

- IMERG measures how much water is falling across the entire watershed, even in remote areas where ground gauges don't exist.
- Fills critical observation gaps in un-gauged or mountainous sub-basins.
- Tracks extreme weather and atmospheric rivers in near real-time to guide short-term water release decisions.
- Helps assess basin saturation and runoff efficiency prior to major storm events.
- Tracks long-term precipitation anomalies to manage droughts and long-term water supply.

Integrated Multi-satellitE Retrievals for GPM (IMERG) Technical Documentation. Huffman et al. (2019)

IMERG Data Visualization – Worldview

https://worldview.earthdata.nasa.gov/

SMAP Soil Moisture Data

Soil Moisture – SMAP

- The soil acts like a giant **sponge**, knowing exactly how wet or frozen that "sponge" is across the entire watershed is the key to predicting how much rain or snowmelt will flow into the reservoir versus soaking into the ground.
- Soil Moisture Active Passive (**SMAP**) – Mission launched Jan 31, 2015 (still active)
- Objective: Measure the moisture in the top 5 cm of the soil globally every 2–3 days.
- Microwaves can penetrate through clouds and vegetation, operate day and night, and are highly sensitive to the water in the soil due to the change in the soil microwave dielectric properties.

SMAP – Instrument and Spacecraft

Radiometer

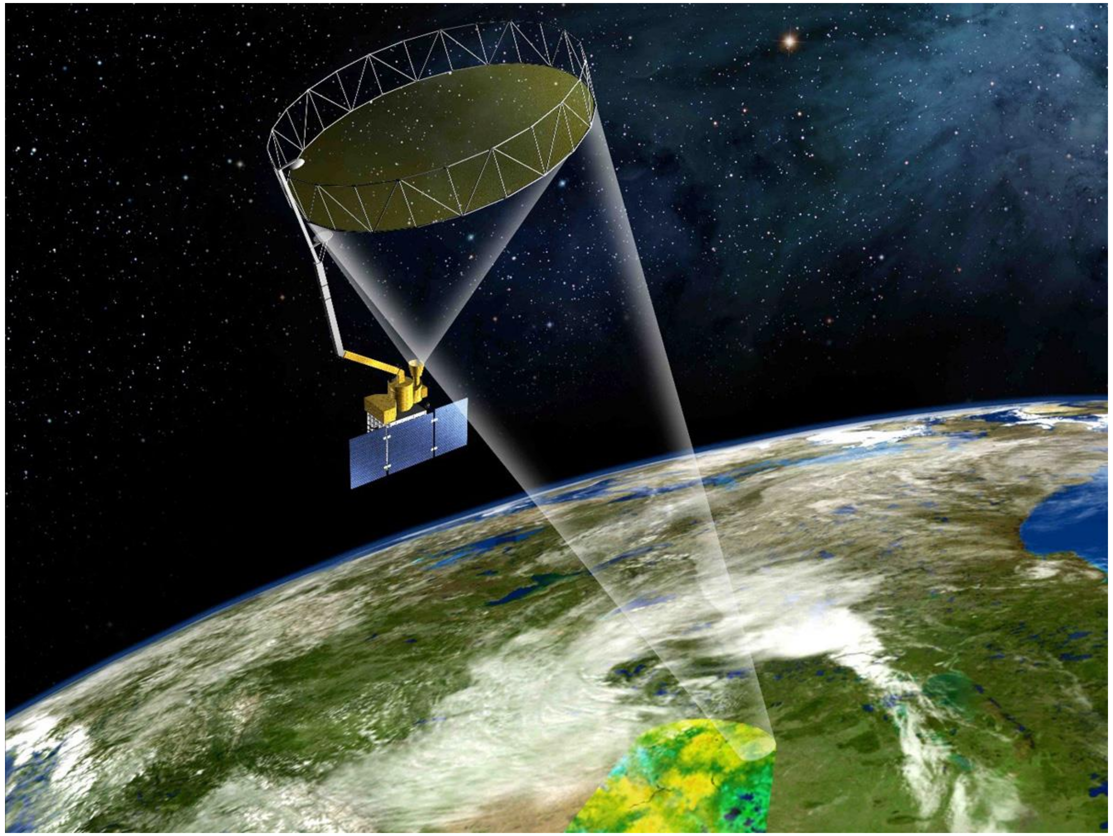
- Frequency: 1.41 GHz
- Polarization: H, V
- Resolution: 40km

Antenna

- 6 m diameter
- Constant Incidence Angle: 40 deg
- Swath: 1,000 km wide

Orbit

- Sun-synchronous, 6 am/pm orbit
- 685 km altitude
- Orbit/swath enables 2–3-day global coverage



Credit: NASA JPL

SMAP Mission Products

- SMAP Data – National Snow and Ice Data Center (NSIDC)
- **Level 1: Instrument Measurements**
  - Contains raw or calibrated/geolocated data from the radar and radiometer.
- **Level 2: Soil Moisture Retrievals**
  - Derived from Level 1 products combined with ancillary data files.
- **Level 3: Daily Composites**
  - Daily composite maps of Level 2 soil moisture and freeze/thaw state data.
- **Level 4: Modeled Products**
  - Provides model-derived root-zone soil moisture.
- Spatial Resolution: 3 km, 9 km, 36 km
- Spatial Coverage: Global
- Temporal Resolution: 1–2 days
- Temporal Coverage: 2015–Present

SMAP Applications for Monitoring Reservoir Watershed Conditions

Applications:

- **Antecedent Soil Moisture:** Measures how saturated the basin is before a storm to predict if rain will soak in or cause rapid flood runoff.
- **Enhanced Runoff Modeling:** Feeds critical surface and root-zone moisture data into hydrologic models to improve reservoir inflow forecasts.
- **Freeze/Thaw Tracking:** Detects when frozen ground thaws, signaling the onset of seasonal snowmelt and spring runoff.
- **Drought Monitoring:** Assesses deep soil dryness to guide long-term water conservation and hydropower release decisions.
- **Hazard Mitigation:** Identifies highly saturated, unstable slopes at risk of landslides that could threaten dam infrastructure or water quality.

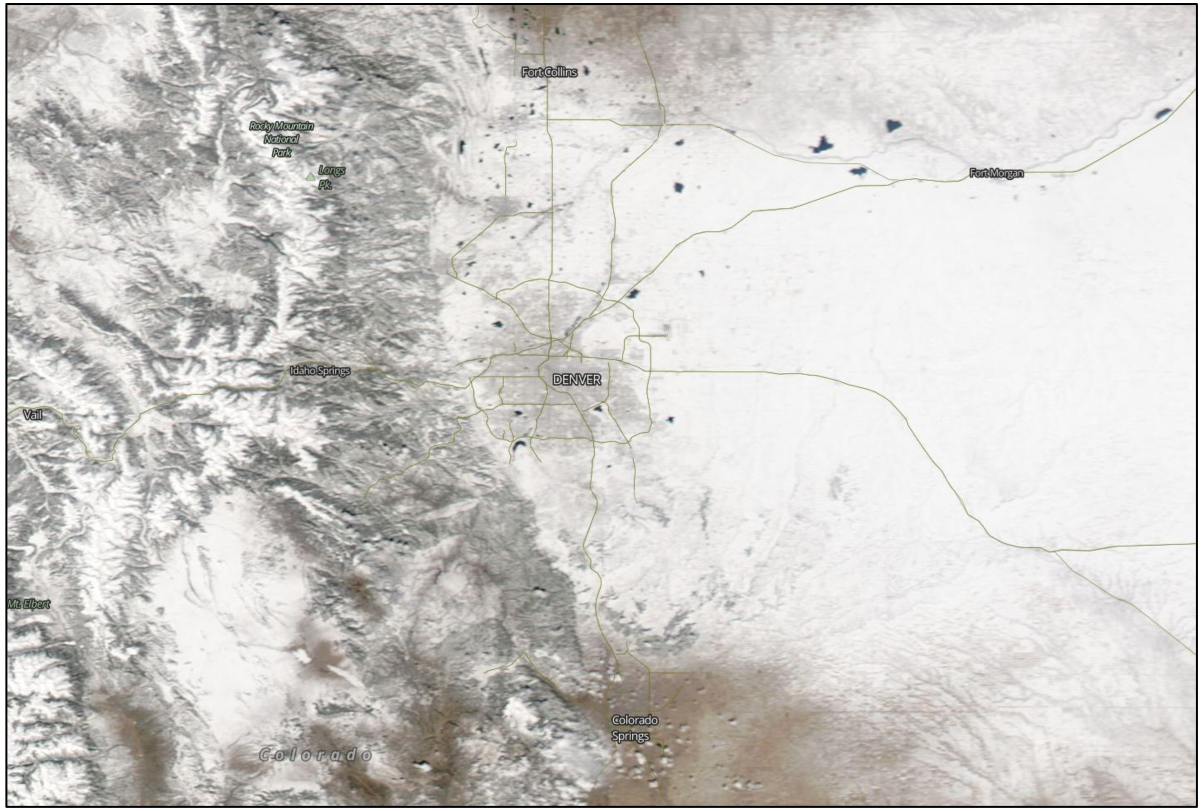
 

SMAP Data Visualization – Worldview
https://worldview.earthdata.nasa.gov/

Snow Cover Data

Snow and Ice as Storage Reservoirs

- When snow accumulates at high latitudes or high elevations, water is stored for days to months.
- Glaciers (the result of snow accumulating over years) store water for hundreds to tens of thousands of years.
- Meltwater from snow and ice is an important contribution to runoff, especially in basins that have less precipitation in spring and summer.



MODIS True Color image from NASA Worldview. Denver, Colorado (USA) March 25, 2013

Observing Snow with Remote Sensing Instruments

- **Passive Microwave Emission:** Emission from the ground is scattered by snow cover, so change in emission received by sensor.
- **Visible Wavelengths:** Snow is white, so reflectance/albedo can be used to identify snow-covered vs. bare ground.
- **LiDAR:** Altimeter measures distance from sensor to surface; difference in height of bare surface and snow-covered surface yields snow depth.
- **Radar (SAR):** Active microwave sensor also potentially useful: backscatter from surface affected by snow and snow properties.

Photo from NASA SnowEx

Snow in Visible and Infrared (IR)

- Snow has high and consistent reflectance in visible wavelengths → snow is white!
- Snow has low reflectance in Short-wave infrared (SWIR) and Thermal infrared (TIR).

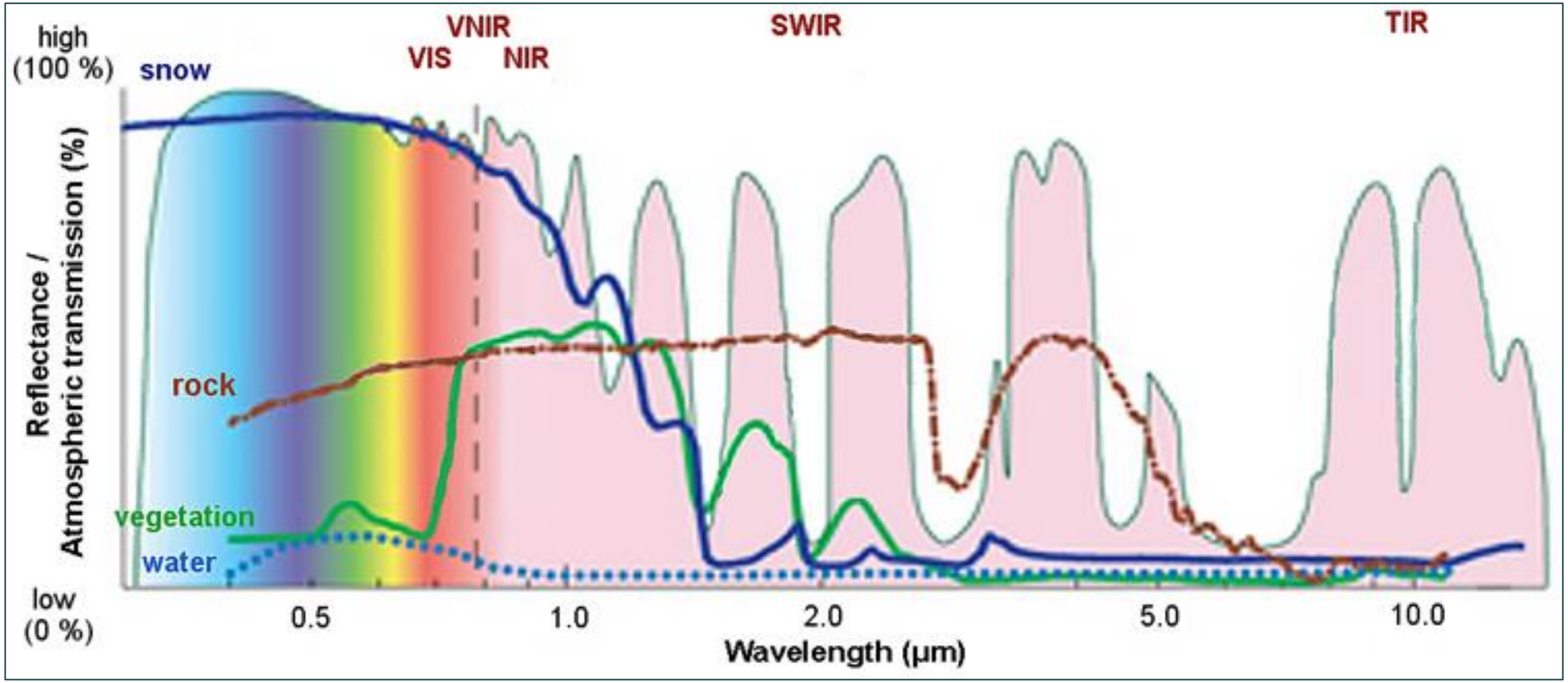
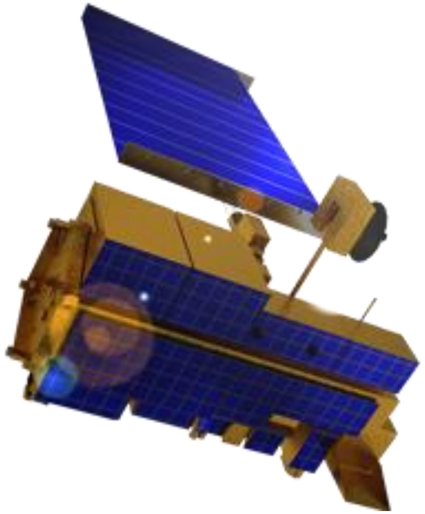


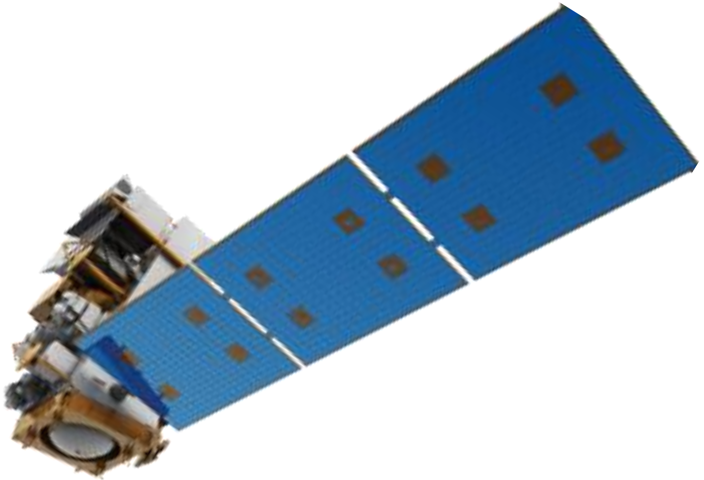
Image by Andreas Kaab, Univ. Oslo, from EUMeTrain

Multispectral Sensors used for Satellite Snow Retrievals

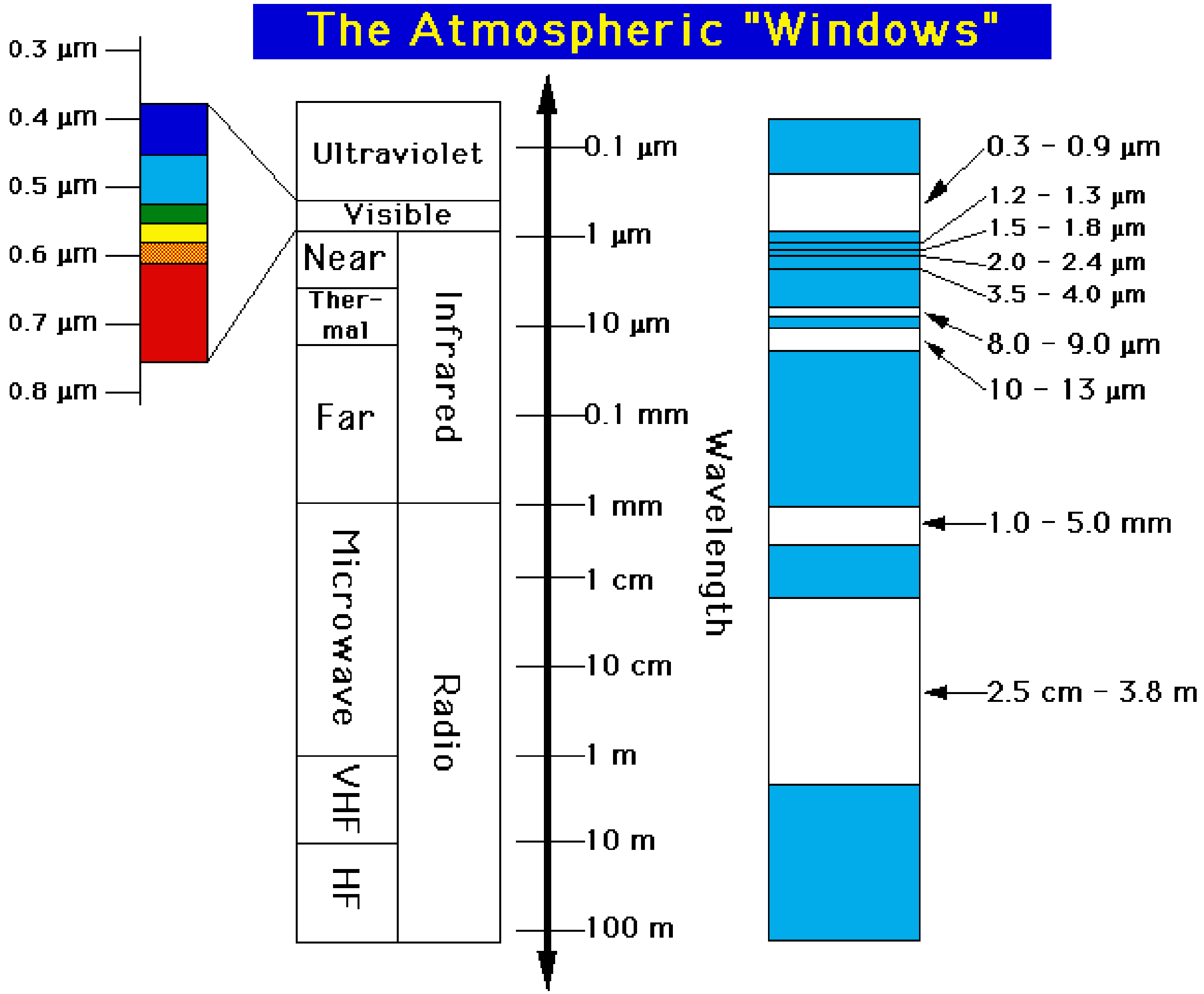
- **MODIS:** MODerate-resolution Imaging Spectroradiometer on NASA EOS Terra (1999–present) and Aqua (2002–present) satellites



- **VIIRS:** Visible Infrared Imaging Radiometer Suite on Suomi NPP (2011–present), NOAA-20 (2017–present), and NOAA-21 (2022–present)



MODIS and VIIRS Wavelengths

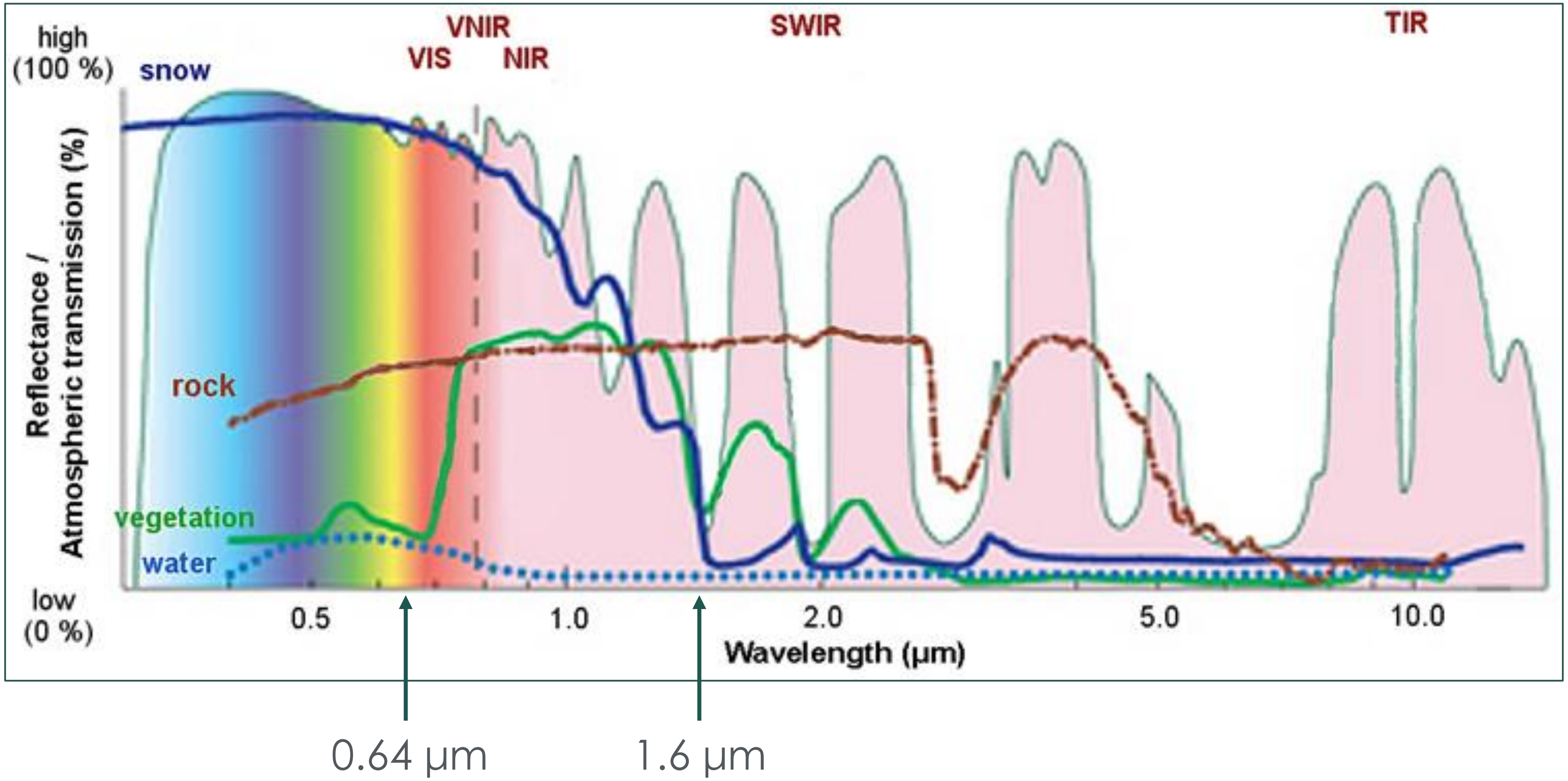


Channel	MODIS	VIIRS
Red	0.645	0.672
Green	0.555	0.555
Blue	0.469,…	0.488,…
Near/SW IR	0.905,…	0.865
SWIR	1.64	1.61
Thermal/Mid	3.75,…	3.70,…
Thermal IR	11.0,…	10.763,…
Thermal IR	12.0,…	12.013,…
Total Chan.	**36**	**22**

Wavelengths in μm

While the specific wavelengths listed are central values, sensors actually capture energy over a broader range, which is called the bandwidth.

Deriving Snow Cover from MODIS and VIIRS



Snow reflectance is high at ~0.64 µm and low at 1.6 µm.

Image by Andreas Kaab, Univ. Oslo, from EUMeTrain

Normalized Difference Snow Index (NDSI) for VIIRS

$$\mathrm{NDSI} = \frac{(\mathrm{Vis} - \mathrm{SWIR})}{(\mathrm{Vis} + \mathrm{SWIR})} = \frac{(\mathrm{R}_{0.64} - \mathrm{R}_{1.6})}{(\mathrm{R}_{0.64} + \mathrm{R}_{1.6})}$$

NDSI < 0, Definitely Not Snow

NDSI > 0, Possibly Snow

NDSI > 0.4, Likely Snow

Snow always has an NDSI > 0, but not all surfaces with an NDSI > 0 are snow!

*MODIS uses slightly different wavelengths.

MODIS Snow Products

Product	Parameter	Spatial Res.	Level/Grid	Sampling
MOD10_L2	NDSI	500 m	Swath (L2)	5-minute
MOD10A1	Snow Cover, Albedo	500 m	Sinusoidal Gridded Tiles (L3)	Daily
MOD10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
MOD10A2	Snow Extent	500 m	Sinusoidal Gridded Tiles (L3)	8-day
MOD10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
MOD10C2	% Snow Cover	0.05 deg	Climate Model Grid (L3)	8-day
MOD10CM	Monthly Mean Snow Cover	0.05 deg	Climate Model Grid (L4)	1-month

The product ID above refers to MODIS on Terra product. The same products are also produced from Aqua MODIS.

”MOD” refers to MODIS on Terra.

“MYD” refers to MODIS on Aqua.

Currently, Version 61/Collection 6.1 is available at the NSIDC DAAC, HDF-EOS2 format.

VIIRS Snow Products

Product	Parameter	Spatial Res.	Level/Grid	Sampling
VNP10	NDSI	375 m	Swath (L2)	6-minute
VNP10A1	NDSI	375 m	Sinusoidal Gridded Tiles (L3)	Daily
VNP10C1	% Snow Cover	0.05 deg	Climate Model Grid (L3)	Daily
VNP10A1F	Cloud Gap-Filled Snow	375 m	Sinusoidal Gridded Tiles (L3)	Daily

The product ID above refers to VIIRS on Suomi NPP. The same products are also available from JPSS-1/NOAA-20.

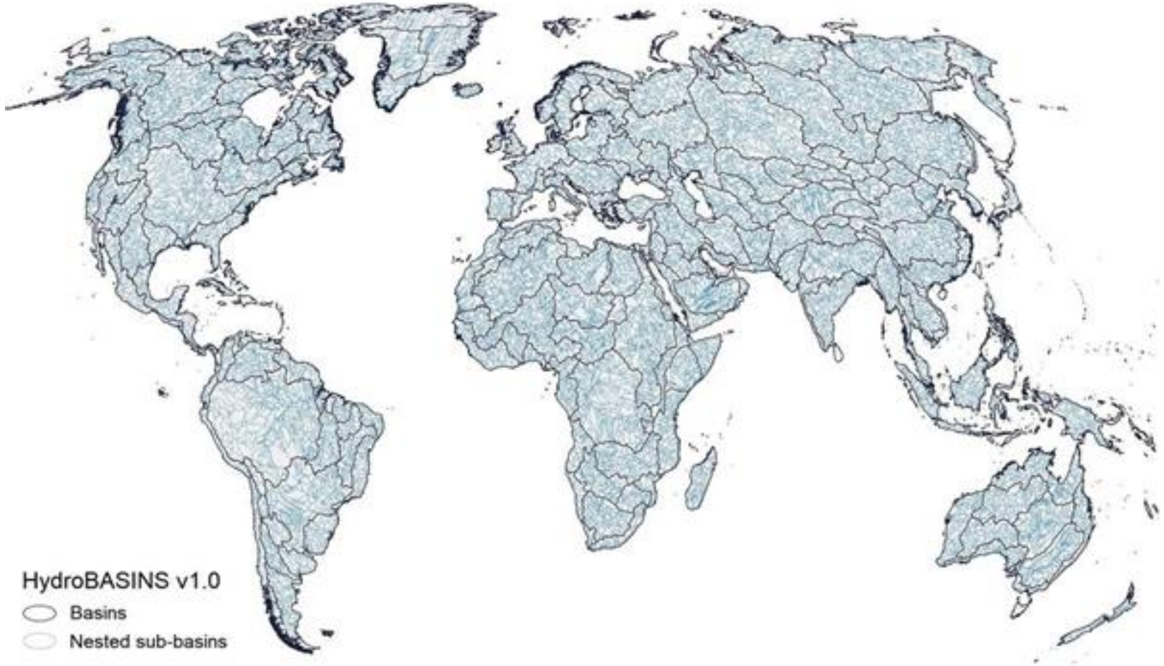
"VNP" refers to VIIRS on Suomi NPP.

"VJ1" refers to VIIRS on JPSS-1/NOAA-20.

Currently, Version 2 is available at the NSIDC DAAC, HDF-EOS5 format.

Watershed Boundaries – Limiting Snow Data to Your Region of Interest

- Hydrobasins (Global)
  - Nested scaled watersheds by continent



- National Hydrography Dataset (U.S.)
  - Smaller watershed boundaries available

Watershed Boundary Data on Colorado's Continental Divide

Snow Cover Data Visualization – Worldview
https://worldview.earthdata.nasa.gov/

Snow Water Equivalent and Runoff from Land Data Assimilation Systems (LDAS)

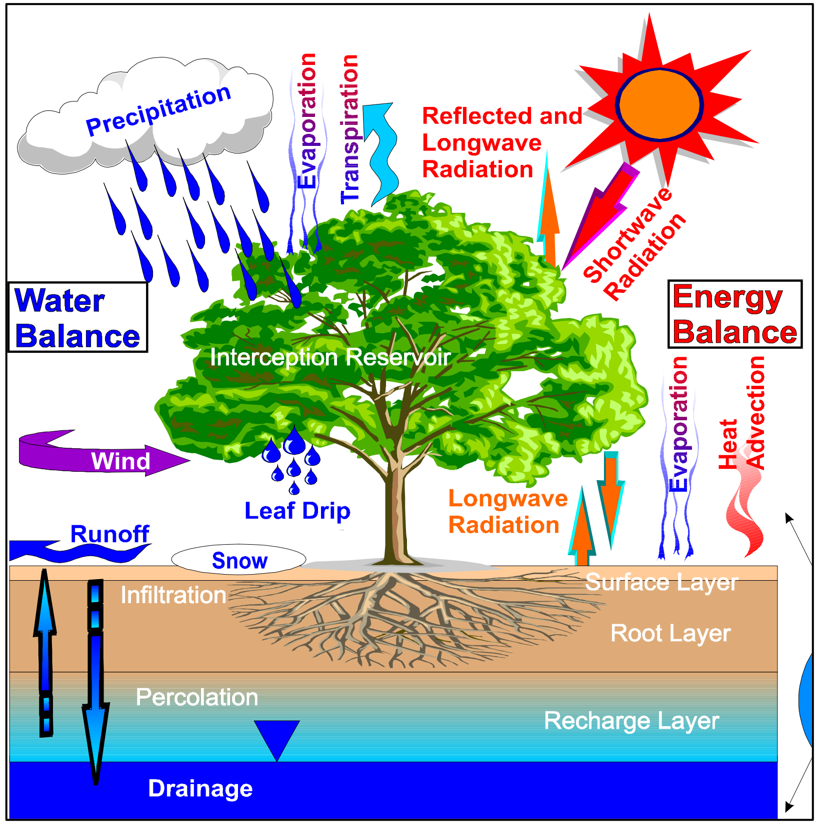
Snow Water Equivalent and Runoff for Reservoir Management

- **Runoff** is the water that flows over the land surface into streams, rivers, and lakes, resulting from rain or melting snow.
- **Snow Water Equivalent (SWE)** is the amount of liquid water stored in a snowpack. As snow accumulates during the winter season, SWE serves as a measure of potential future water availability.
- When spring and summer snowpack melts, SWE is released as runoff. In mountainous watersheds, winter snow cover and SWE accumulation determine the total volume of seasonal streamflow. This snowmelt runoff is a primary water inflow source for many global reservoirs.
- Not all SWE becomes available as runoff or reservoir inflow. The total amount of runoff is affected by the rate of snowmelt, sublimation and evaporation rates, soil moisture, and ground conditions (whether frozen or thawed).
- Peak winter SWE is measured to forecast spring and summer runoff, which is critical for reservoir operations managing:
  - Drinking Water Supplies
  - Agricultural Irrigation Planning
  - Flood Risk Assessments
  - Hydroelectric Power Generation

Land Data Assimilation System (LDAS)

- NASA Land Data Assimilation System (LDAS) integrates satellite and ground-based observational data in water and energy balance land surface models.
- Land Surface Models solve for the interaction of energy, momentum, and mass between the surface and the atmosphere in each model element.
- The LDAS projects (NLDAS, GLDAS, FLDAS, WLDAS, and NCA-LDAS) are based on the Land Information System (LIS) land surface modeling software that have been configured for specific domains and applications.

GLDAS	Global Land Data Assimilation System
NLDAS	North American Land Data Assimilation System
WLDAS	Western Land Data Assimilation System
NCA-LDAS	National Climate Assessment Land Data Assimilation System



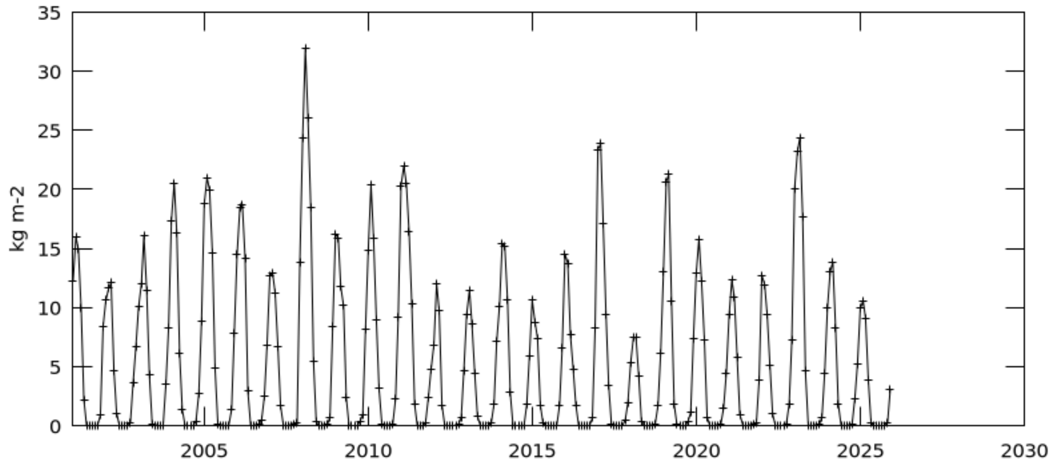
Atmosphere, Land Surface, Vegetation Interactions. (Figure Credit: Matthew Rodell, NASA-GSFC)

LDAS Data and Applications

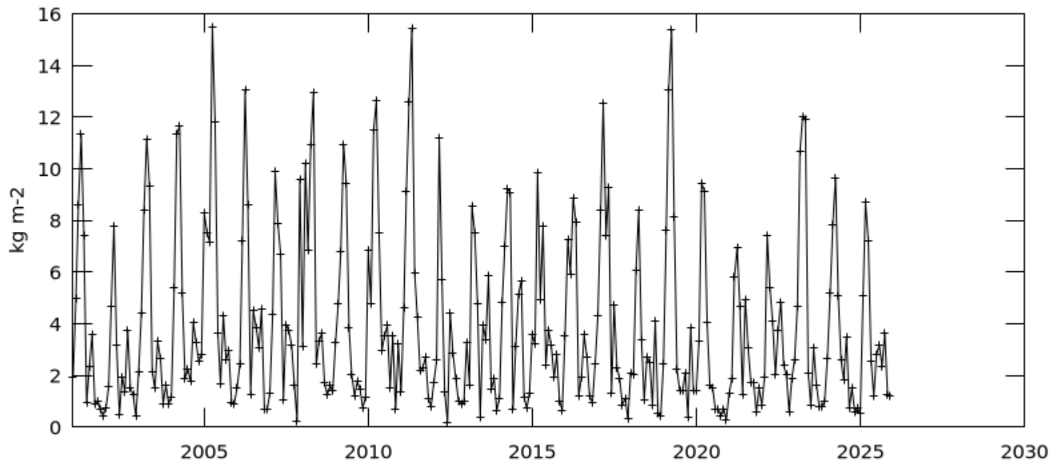
- We will use GLDAS and NLDAS data in this training for reservoir management applications.
- GLDAS data from NOAH, VIC, CLM, and Mosaic models are available globally and NLDAS data from NOAH, VIC, and Mosaic models are available for North America.
- GLDAS and NLDAS are widely used for:
  - Water Resources Applications
  - Drought and Wetness Monitoring
  - Numerical Weather Prediction Studies
  - Water and Energy Cycle Research

VIC	Variable Infiltration Capacity
CLM	Catchment Land Surface Model

Area-Averaged NLDAS NOAH Snow Water Equivalent (kg m-2)
Monthly Mean over the Colorado River Watershed



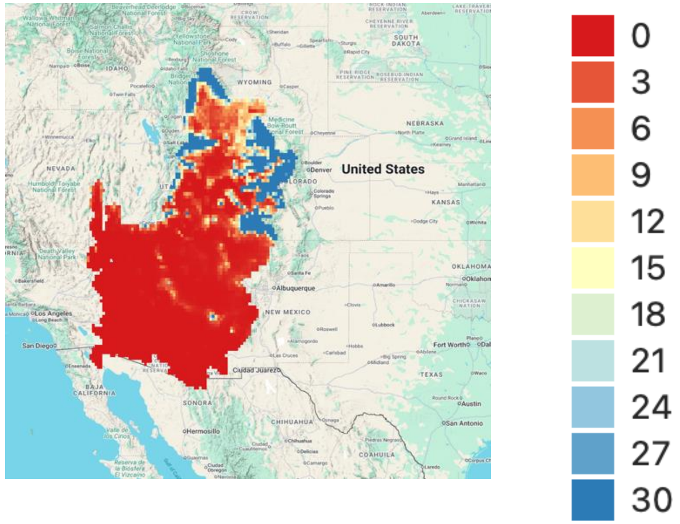
Area-Averaged NLDAS NOAH Runoff (kg m-2)
Monthly Mean over the Colorado River Watershed



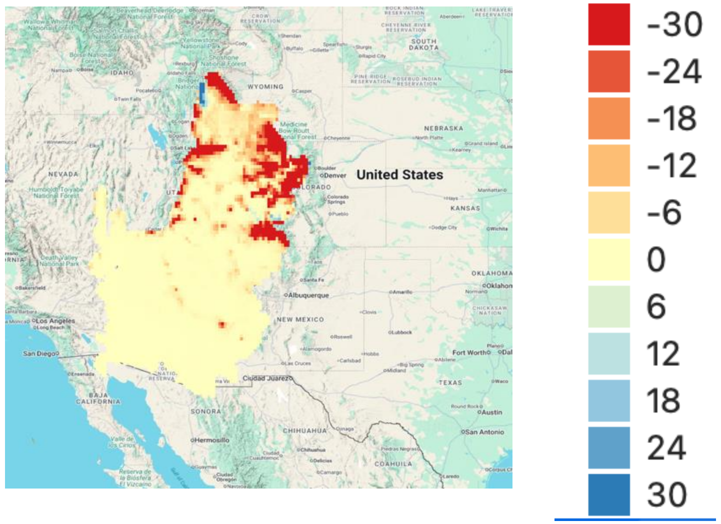
LDAS Snow Water Equivalent and Runoff

- The latest version of **GLDAS-2.2** assimilates groundwater information from GRACE/GRACE-FO satellites, provides SWE and Runoff data at **0.25x0.25-degree** resolution on **hourly** and **monthly** time scales, from **2003 to present**.
- **NLDAS-2** provides SWE and Runoff at **0.125x0.125-degree** resolution at hourly and monthly time scales, from **1979 to present**.
- LDAS data are available from [NASA Earthdata Search]() and can be accessed, analyzed, visualized, and downloaded from [Giovanni]().

NLDAS SWE 11/2000 to 2/2001 (Kgm^{-2})



SWE Difference
[11/2025 to 2/2026] and [11/2000 to 02/2001 (Kgm^{-2})



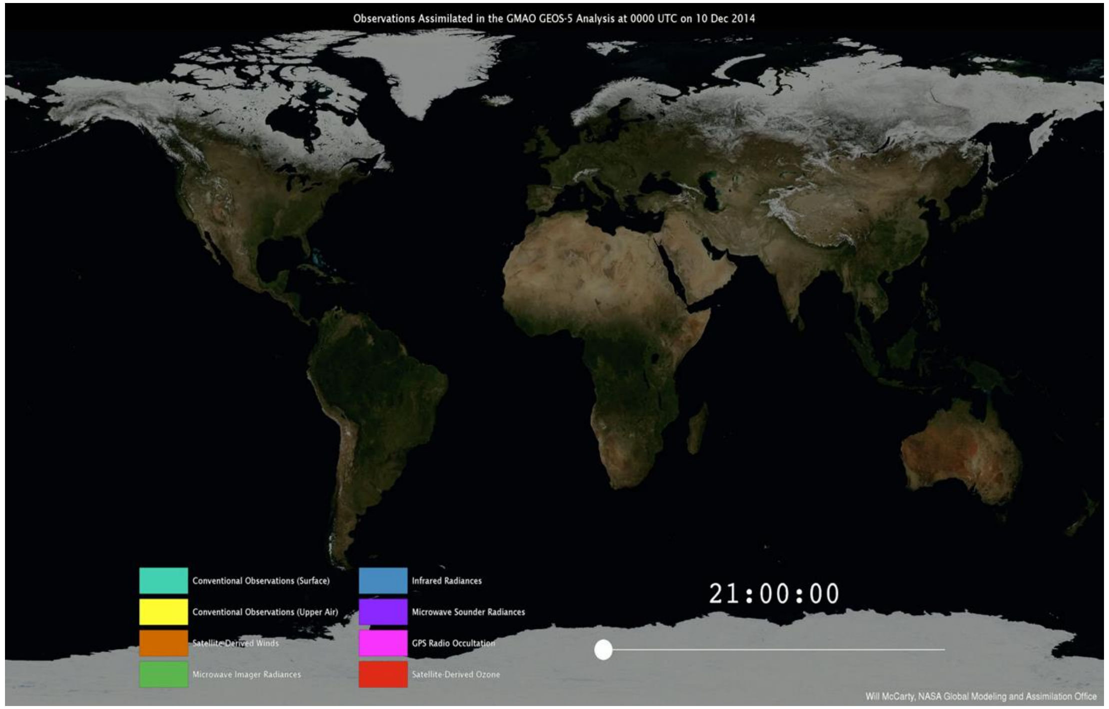
Demonstration: Examine LDAS Snow Water Equivalent and Runoff using Giovanni webtool


Weather and Hydrology Analysis and Forecast Data

NASA Earth System Models

- NASA has developed Earth system models, including atmosphere, ocean, and land components, to monitor and predict weather and hydrology parameters.
- The Goddard Earth Observing System Version 5 (GEOS-5), assimilates a vast amount of satellite and ground-based data to analyze weather and hydrology in near-real time (Modern-Era Retrospective analysis for Research and Applications, Version 2; or MERRA-2).
- GEOS-5 also generates 5-day forecast products (GEOS-FP) and long-term predictions on sub-seasonal to seasonal (S2S) timescales.

From Observations to Model



Credit: NASA/GSFC Global Modeling and Assimilation Office

GEOS-5 Data Information

- GEOS-5 data products include precipitation (rain and snow), temperature, wind, humidity, snowmelt, runoff, and surface radiation.
- MERRA-2 data are available in near-real time at
- GEOS-FP 5-day forecast data are available at 0.25° latitude by 0.3125° longitude resolution on hourly to 3-hourly basis.
- S2S (Version 3) data are available as weeks to to 9 month, 6-hourly predictions.

Product	Brief Description	Links
GEOS-S2S-3	Atmosphere Ocean coupled assimilation and seamless forecasts spanning from weeks to 9 months.	Seasonal-Decadal Analysis & Prediction Products
GEOS FP	Analyses and forecasts produced in real-time using the most recently validated GEOS system	GEOS NRT Product Information GEOS FP Weather Analyses & Forecasts
MERRA-2	A reanalysis of the period 1979 to the present, including aerosols	MERRA-2 data archive at the GES-DISC GMAO Reanalysis Products

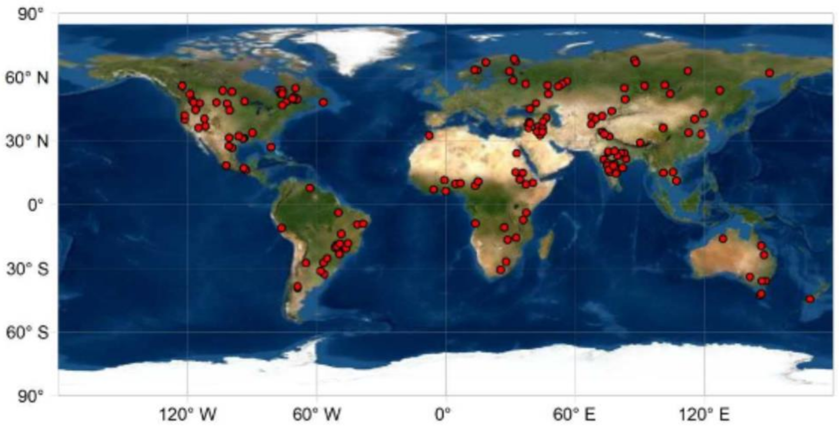
Weather Forecast Data for Reservoir Management

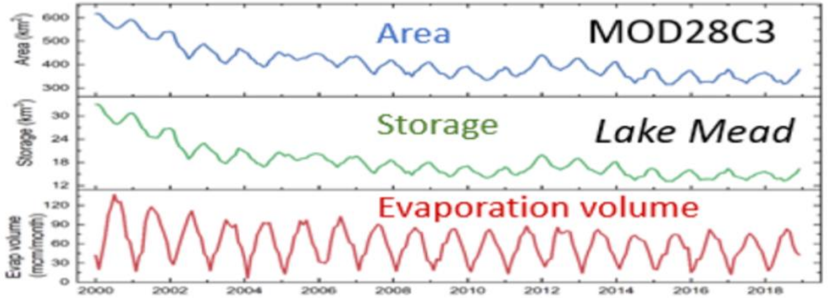
- Traditional reservoir management uses climatological data to restrict reservoir water levels.
- Recently, water managers have adopted Forecast-Informed Reservoir Operations (FIRO). This approach uses high-resolution weather forecasts to establish dynamic water-level thresholds, allowing operators to proactively release or retain water based on impending storm or drought conditions.
  - For example, short-term predictive capability (3–5 days) allows reservoir managers to track how much water will reach the basin in case of rapid snow melt runoff and prepare accordingly to prevent downstream damage.
- We will focus on FIRO in our future training using GEOS-5 short- to long-term predictions.

NASA Earth Observations and Earth System Models for Monitoring Reservoirs and Tributaries

MODIS Reservoir Product (MOD28)

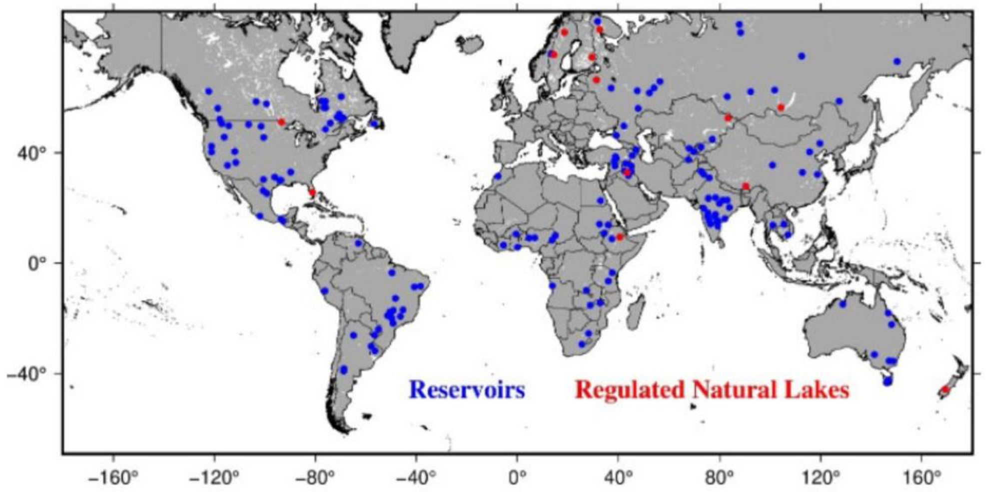
- MODIS Water Reservoir Product
- Measures: Surface area, elevation, storage, and evaporation for 164 global reservoirs (~46% of global man-made capacity).
  - Resolution: 8-day and monthly data (tabular HDF format).
- Methodology:
  - Area: Near-Infrared (NIR) classifications from Terra/Aqua.
  - Elevation & Storage: Calculated using Area-Volume-Elevation (AVE) curves.
- Access & Use: Features an interactive web tool for quick plotting and downloads to support water management and hydrologic modeling.
- Webtool – NASA LDOPE Water Reservoir Time Series
- MODIS Global Reservoir Product User's Guide





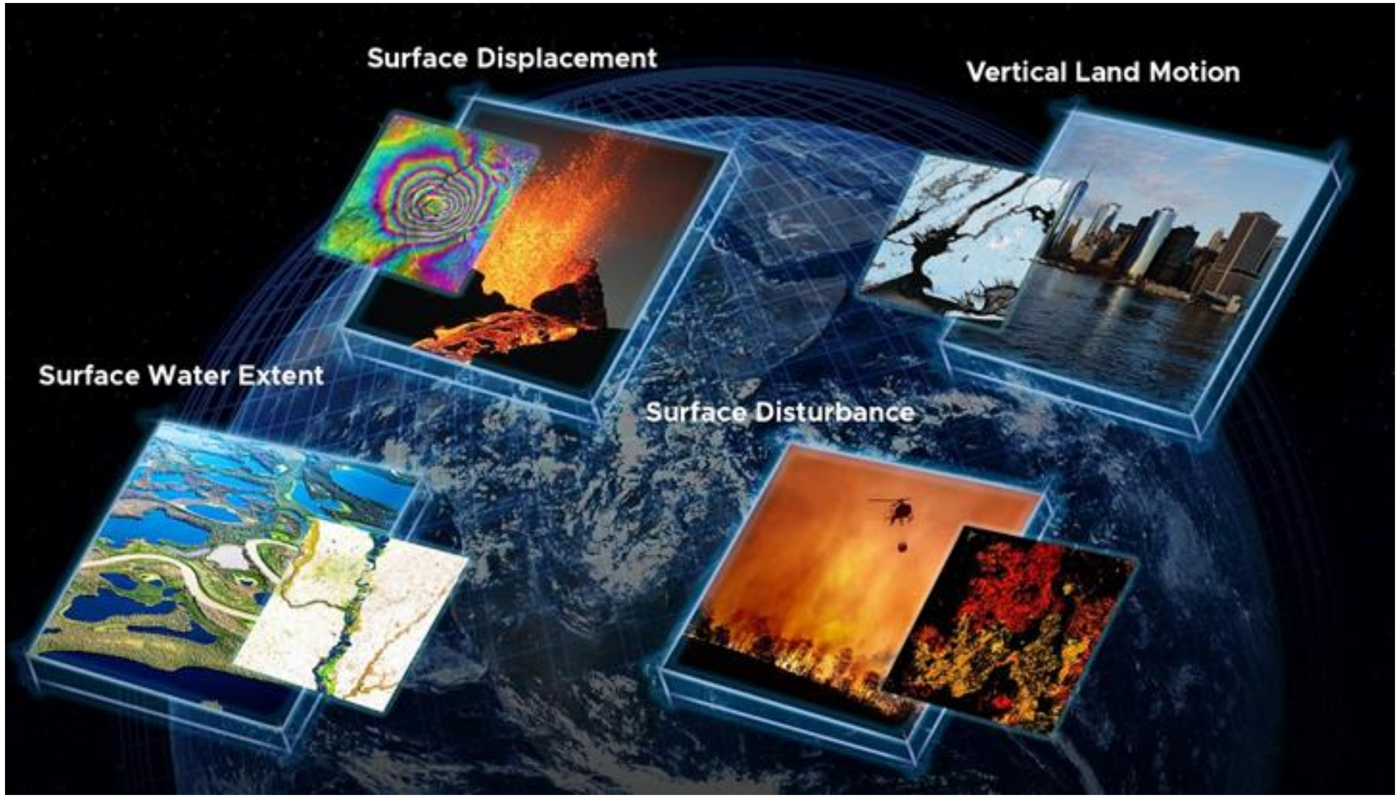
VIIRS Reservoir Product (VNP28)

- VIIRS Water Reservoir Product
- Measures: Area, elevation, storage (8-day/monthly), and evaporation (monthly) for 164 major reservoirs (~46% global capacity).
- **Advancements over MODIS (MOD28):** Refined algorithms address terrain shadows, improve classification, and enhance data quality assessments.
- Methodology:
  – Area: SNPP and NOAA-20 Near-Infrared (NIR) classifications
  – Elevation & Storage: Area-Volume-Elevation (AVE)
- **Access:** Shared interactive web tool with MODIS for easy plotting, downloads, and hydrologic modeling.
- Webtool – NASA LDOPE Water Reservoir Time Series
- VIIRS Global Reservoir Product User's Guide



Observation Products for End-users from Remote Sensing Analysis (OPERA)

- OPERA Datasets:
  - Funded by the **Satellite Needs Working Group**, responding to well-defined end-user needs.
  - Free and open, low-latency, ready-to-use data to support disaster response, recovery, damage assessments, and others.
  - Provides life/property-saving data and actionable intelligence for resilience and prosperity of our nation.



OPERA Products

Level 3

- DSWx – Surface Water Extent
- DIST – Surface Disturbance
- DISP – Surface Displacement
- VLM – Vertical Land Motion

Level 2

- RTC – Radiometric Terrain Corrected
- CSLC – Coregistered Single-Look Complex

OPERA Level 3 Products

DSWx
Surface Water Extent

- **Description:** Maps surface water using optical (HLS) and SAR imagery (S1, NISAR)
- **Coverage:** Near-global
- **Temporal Resolution:** Every few days
- **Spatial Resolution:** 30m
- **Product Record Begins:** Apr. 2023 (HLS), Sep. 2024 (S1), soon in 2026 (NISAR)

Available now!

DIST
Surface Disturbance

- **Description:** Maps vegetation disturbance using optical (HLS) and SAR imagery (S1)
- **Coverage:** Near-global
- **Temporal Resolution:** Every few days
- **Spatial Resolution:** 30m
- **Product Record Begins:** Feb. 2023 (HLS), Mar. 2026 (S1)

Available now!

DISP
Surface Displacement

- **Description:** Maps surface displacements in LOS (S1 and NISAR)
- **Coverage:** North America*
- **Temporal Resolution:** 6, 12, or 24 days
- **Spatial Resolution:** ≤ 30m
- **Product Record Begins:** Apr. 2014 (S1), NISAR validated record.
- **Production Begins:** Dec. 2024 (S1), soon in 2026 (NISAR)

Available now!

VLM
Vertical Land Motion

- **Description:** Maps surface displacements in vertical + horiz. (S1 and NISAR)
- **Coverage:** North America*
- **Temporal Resolution:** 6, 12, or 24 days
- **Spatial Resolution:** ≤ 30 m
- **Product Record Begins:** Apr. 2014 (S1), NISAR validated record.
- **Production Begins:** Apr. 2028 (S1 + NISAR)

Available in 2028

OPERA data is available through EarthData Search.

OPERA Level 2 Products

RTC
Radiometric Terrain Corrected

- **Description:** S1 radar backscatter corrected for the topography. Basis for the DSWx-S1 products.
- **Coverage:** Near-global
- **Spatial Resolution:** 30m
- **Product Record Begins:** Oct. 2023

Available now!

CSLC
Coregistered Single-Look Complex

- **Description:** Geocoded and coreg. SLC (S1, NISAR). Basis for all the DISP products.
- **Coverage:** North America*
- **Spatial Resolution:** ≤ 10m
- **Product Record Begins:** Jul. 2016 (S1) and TBD (NISAR)
- **Production Begins:** Oct. 2023 (S1), TBD (NISAR)

Available now!

OPERA data is available through [EarthData Search]

The Dynamic Surface Water Extent – Harmonized Landsat/Sentinel-2

DSWx
Surface Water Extent

- **Description:** Maps surface water using optical (HLS) and SAR imagery (S1, NISAR)
- **Coverage:** Near-global
- **Temporal Resolution:** Every few days
- **Spatial Resolution:** 30m
- **Product Record Begins**: Apr. 2023 (HLS), Sep. 2024 (S1), soon in 2026 (NISAR)

Available now!

Sample DSWx-HLS Granule

Download Files | AWS S3 Access

OPERA_L3_DSWx-HLS_T56LPN_20260517T235741Z_20260519T134553Z_S2C_30_v1.1_B01_WTR.tif

DSWx-HLS

- File Name:
  - OPERA_L3_DSWx-HLS
  - **T56LPN**: **M**ilitary **G**rid **R**eference **S**ystem (MGRS) Tile ID
  - **20260517T235741Z**: **acquisition** date and time
  - **20260519T134553Z**: production time
  - **S2C**: produced with Sentinel 2C imagery. Other values: L8, L9, S2A, S2B
  - **30**: spatial resolution in meters
  - **B01** through **B10**: product layers
  - We will cover B01 WTR (basic water occurrence layer)

DSWx direct link
DSWx documentation

The Dynamic Surface Water Extent – Sentinel-1

DIST
Surface Disturbance

- **Description:** Maps vegetation disturbance using optical (HLS) and SAR imagery (S1)
- **Coverage:** Near-global
- **Temporal Resolution:** Every few days
- **Spatial Resolution:** 30m
- **Product Record Begins:** Feb. 2023 (HLS), Mar. 2026 (S1)

Available now!

Sample DSWx-S1 Granule

Download Files | AWS S3 Access

OPERA_L3_DSWx-S1_T36JXT_20260519T030158Z_20260520T060722Z_S1A_30_v1.0_B01_WTR.tif

DSWx-S1

- File Name:
  - OPERA_L3_DSWx-S1
  - **T36JXT**: MGRS Tile ID
  - **20260519T030158Z: acquisition** date and time
  - **20260520T060722Z**: production time
  - **S1A**: produced with Sentinel 1 radar imagery. Other value: S1C
  - **30 m**: spatial resolution
  - **B01** through **B04**: product layers
  - We will cover B01 WTR (basic water occurrence layer)

DSWx [direct link]
DSWx [documentation]

The Dynamic Surface Water Extent (DSWx) WTR Layer

DSWx
Surface Water Extent

- **Description:** Maps surface water using optical (HLS) and SAR imagery (S1, NISAR)
- **Coverage:** Near-global
- **Temporal Resolution:** every few days
- **Spatial Resolution:** 30m
- **Product Record Begins:** Apr. 2023 (HLS), Sep. 2024 (S1), soon in 2026 (NISAR)

Available now!

DSWx-HLS

- Based on **optical** data collected by **Landsat** 8, 9 and **Sentinel**-2 A, B, C.
- Classification algorithm is open.

- Main Classes:
  - **0: not water**
  - **1: open water** (100% inundated)
  - **2: partial water** (50%<Inundated fraction<100%)
  - **252: snow**, **ice**, or high sediment content
  - **253: cloud** or cloud shadow
  - **255: no data**

DSWx-S1

- Based on **synthetic aperture radar** data collected by **Sentinel**-1 A and C.
- Classification algorithm is open.

- Main Classes:
  - **0: not water**
  - **1: open water** (100% inundated)
  - **3: inundated vegetation**
  - **250: H**eight **A**bove the **N**earest **D**rainage **M**asked (area with elevation higher than HAND threshold)
  - **251: layover** or shadow **masked**
  - **255: no data**

DSWx direct link
DSWx documentation

Which product is more appropriate for my application?

Currently two options (DSWx-HLS or DSWx-S1) with DSWx-NI to be added. Which one should I use:

1. **Data Availability**
2. Data Quality Considerations:
   - **Cloud Cover**
     - Persistent cloud cover favors Radar platforms, e.g., Sentinel-1.
   - **Landcover and Soil Type**
     - Water detection in arid environments often favor optical data. Desert may appear as water in radar-derived DSWx-S1.
     - Old lava flows can trick optical sensors. Radar may be more reliable.
     - Thick vegetation may favor Radar platforms.
   - **Feature Size and Sensitivity Requirements**
     - DSWx-HLS is often more sensitive to water and has lower incidence of false detection.
   - **Duration of the Event**
     - Long lasting or events with slow dynamics may enable temporal mosaicking for cloud removal.

DSWx Data Visualization – Worldview

https://worldview.earthdata.nasa.gov/

Reservoir Water Level Height –
Surface Water Ocean Topography (SWOT) Altimeter

What is an Altimeter?

- Altimetry is a technique for measuring height. A radar used for altimetry is called an altimeter.
- The time taken by a radar pulse to travel from the satellite antenna to the surface and back (radar echo), combined with precise satellite location data, is measured in altimetry.

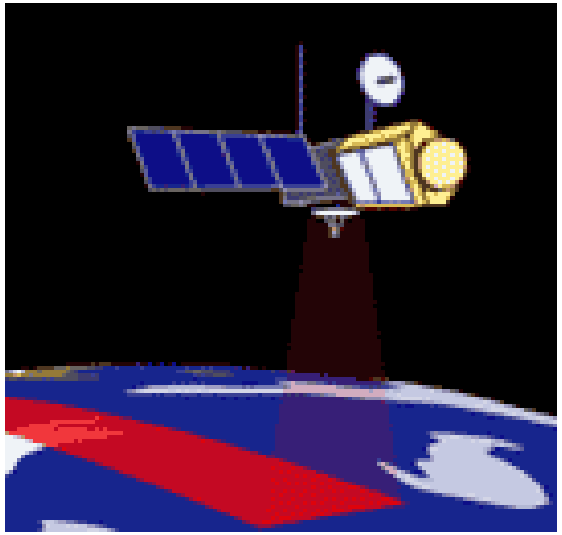


Image Source: JPL

Historical and Current Missions with Radar Altimeter

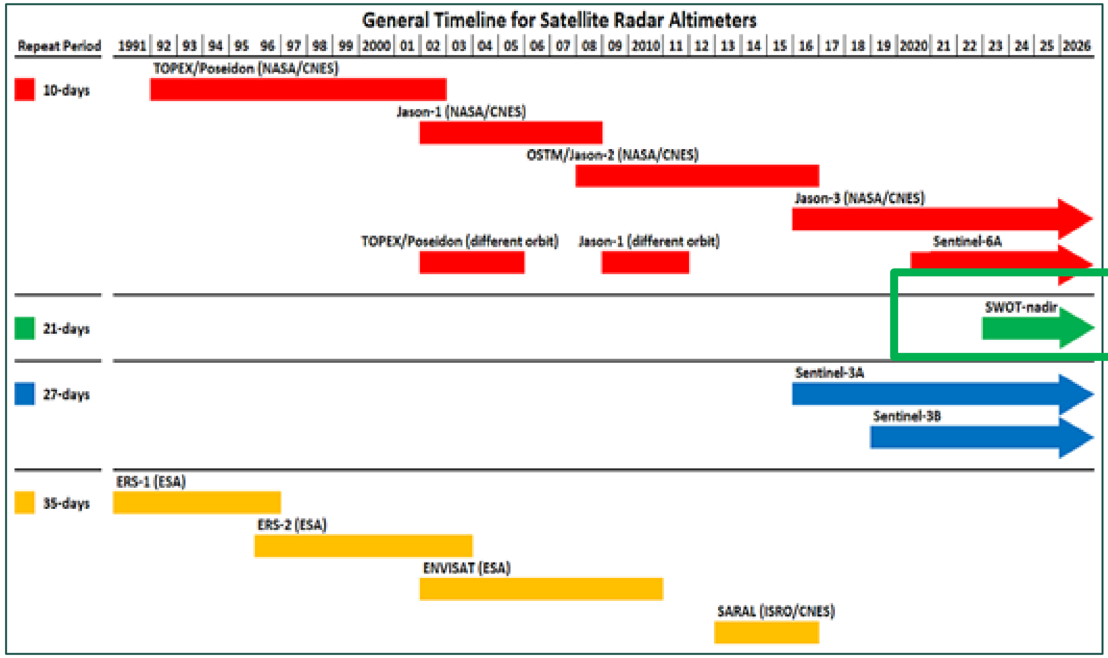


Image Source: USDA-FAS

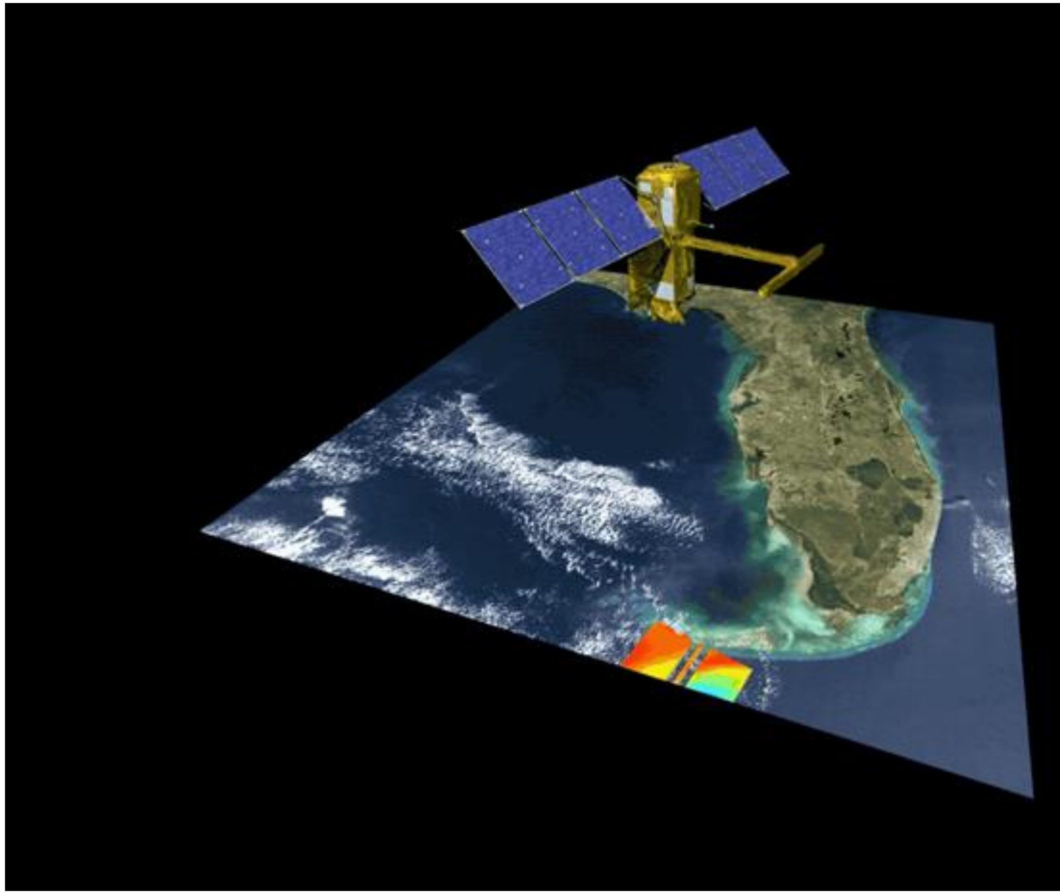
SWOT: Overview

- SWOT is Joint Mission developed by NASA and Centre National D'Etudes Spatiales (CNES) with contributions from the Canadian Space Agency (CSA) and United Kingdom Space Agency.
- Launched on 16 December 2022, SWOT is in a near-circular, non-sun-synchronous orbit with 2-day repeat cycle with coverage between 78 ° N/S.
- SWOT Sensors Include:
  - Ka-band Radar Interferometer (KaRIn): Uses dual antennas on a 10-meter boom to map 2D water elevations across two 50-km-wide swaths.
  - Nadir Altimeter: Measures exact water distance in the gap between KaRIn swaths to calibrate the data.
  - Microwave Radiometer: Measures atmospheric water vapor to correct KaRIn and altimeter readings.
- SWOT conducts the first-ever global survey of Earth's surface water, capturing water levels across millions of lakes, rivers, and oceans at an unprecedented resolution. This highly detailed elevation data is then used to calculate river slopes worldwide.

SWOT Data

SWOT Provides:

- Global **ocean** surface topography
- Land surface water extents
- Highly accurate water elevation using interferometry
- River slope



SWOT Launched Dec 2022!

21-Day Orbit Cycle (Average 2 observations per cycle)

78° N/S Latitudinal Coverage

Credit: JPL

SWOT Measurements Simplified

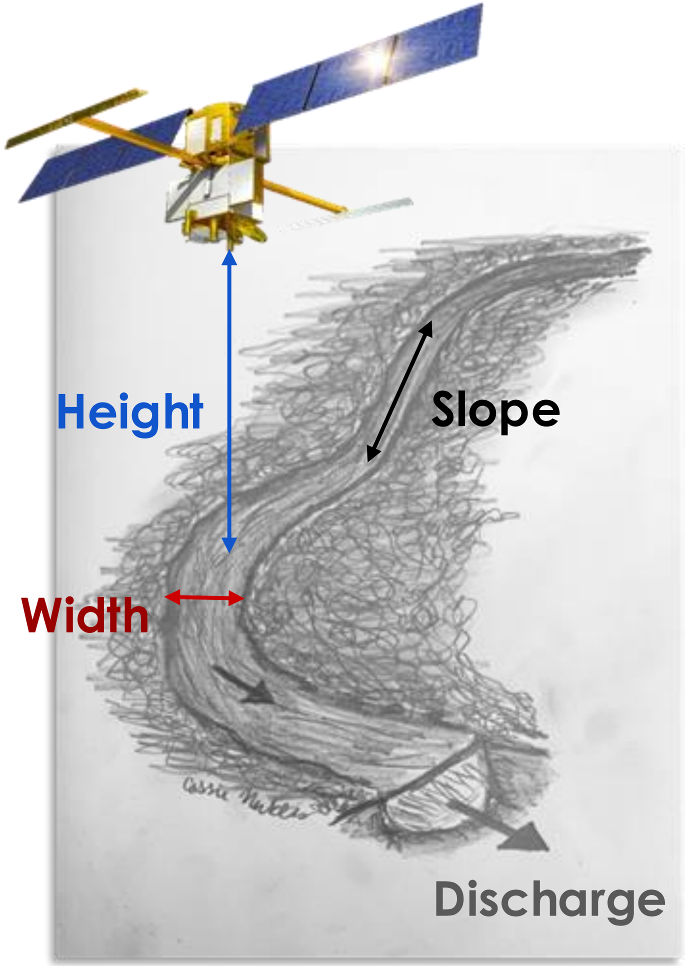
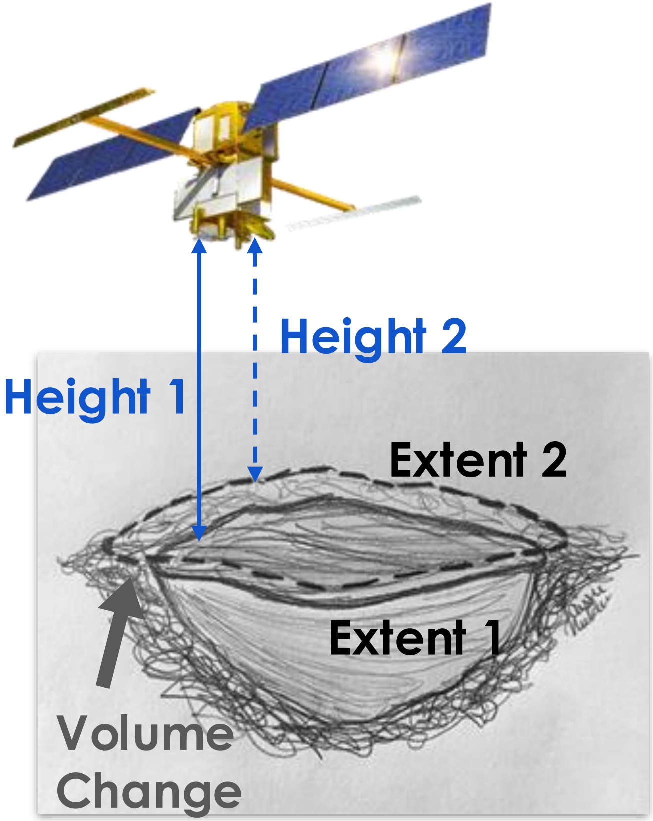


Image Credit: C. Nickles



Requirements:
Rivers > 100 m wide
Lakes > 250 m^2

SWOT Level-2 Data Products:

- Water Mask Pixel Cloud
- Pixel Cloud Vector Attribute
- **River Vector Shapefile**
- **Water surface elevation**
- **Lake Vector Shapefile**
- Cycle Average River Vector Shapefile
- Cycle Average Lake Vector Shapefile
- Floodplain Digital Elevation Model

Future Derived Products:

- River Flow (i.e., Discharge)
- Lake/Reservoir Volume Change

SWOT: Water Elevation Data

Data: Geographically fixed rasterized water surface elevation and inundation extent.

Spatial Extent: Scene (128x128 km^2), Resolves streams (> 100 m wide)and lakes (> 250 m^2 area)

Variables: Water Surface Elevation, Area, Water Fraction, Backscatter, Geophysical Information

Level-2 Product Subcollections:

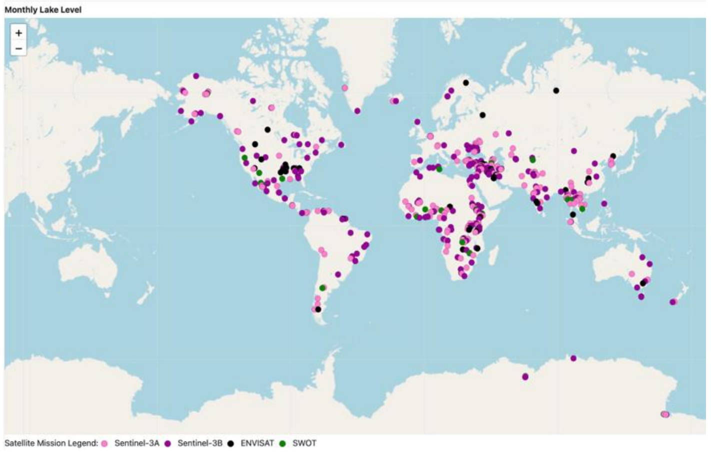
- SWOT_L2_Raster_100m
- SWOT_L2_Raster_250m

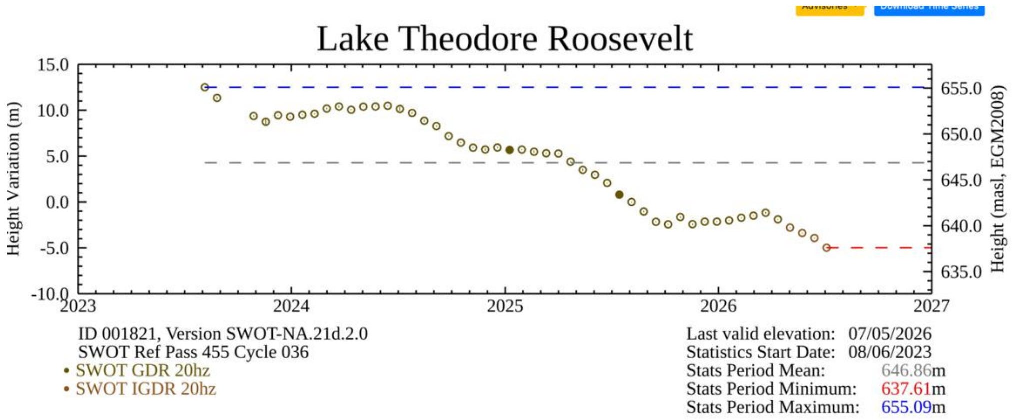
Data Access: NASA Earthdata Search

Data Viewers: SWOTVIZ (rivers and lakes/reservoirs)

Global Water Measurements (lakes/reservoirs)

Global Water Measurements: Monthly Lake Level





SWOT Reservoir Elevation and River Slope/Elevation Data for Reservoir Management

- SWOT reservoir elevation combined with reservoir surface area observed over time can help estimate changes in reservoir water storage volume.
- Accurate elevation data allows dam operators to know exactly how much space is left in a reservoir – helping flood control (higher than normal elevation) and water conservation (lower than normal elevation).
- For hydroelectric plants, the elevation of the water relative to the turbines can help assess power generation potential.
- River slope together with its width and elevation river discharge can be estimated for rivers feeding into or draining out of a reservoir.
- The river slope and discharge indicate river flow speed, which affect sediments carried to a reservoir at inflow.

Demonstration: Explore Global Water Measurement Portal for Reservoir Water Height

River Discharge from Group of Earth Observations Global Water Sustainability (GEOGLOWS)

GEOGLOWS: Overview

- A partnership initiative among 100+ national government and organizations to deliver accurate, open, and accessible hydrological predictions on a global scale.
- Based on the ECMWF ERA5 and Integrated Forecast System (IFS) data. The ERA5 models include in situ and multiple satellite data assimilation.
- Uses a hydrologic model with inputs from models, gauges, and satellites to calculate runoff, distributed vertically.
- Uses a river routing model to get river discharge.
- Provides retrospective and forecast hydrographs for global river segments.
- Provides return periods, monthly and annual averages and maximums, and flow duration curves from the retrospective data.
- Data visualization through HYDROVIEWER webtool and ArcGIS web map, and query and download from Amazon Web Service.

Case Study: Water Release from Lake Sherburne, Montana

"High water releases from Lake Sherburne continue as flooding impacts Many Glacier area"

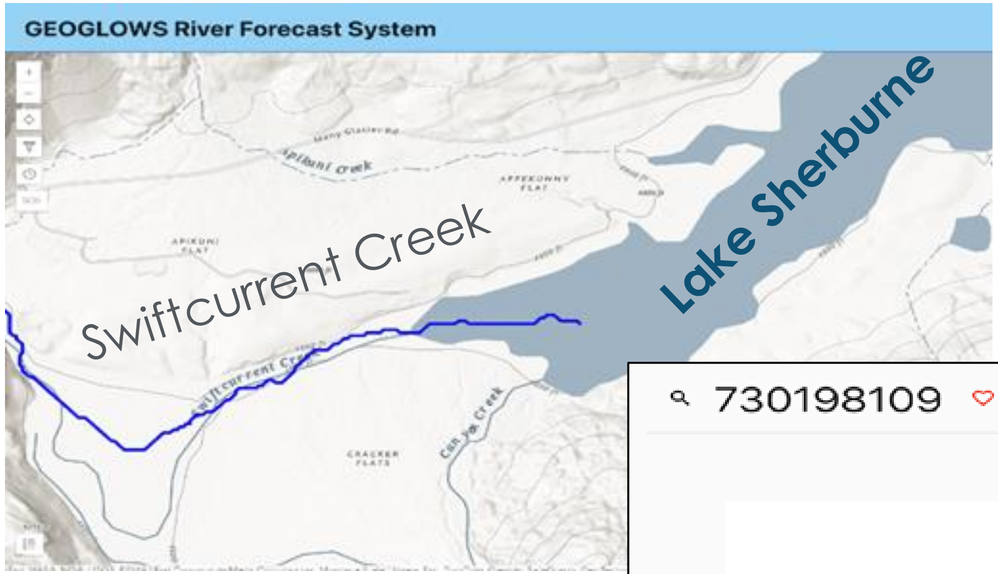
- Heavy rains in late June (29-30 June 2026) near Many Glacier in Glacier National Park.
- Inflow from Swiftcurrent Creek to Lake Sherburne increased rapidly prompting reservoir operators to release the maximum amount of water from Lake Sherburne.
- Operators opened the dam's gates to their maximum release of approximately 2,000 cubic feet per second (CFS) to keep the reservoir below its spillway. Typical releases during June and July are around 600 CFS.

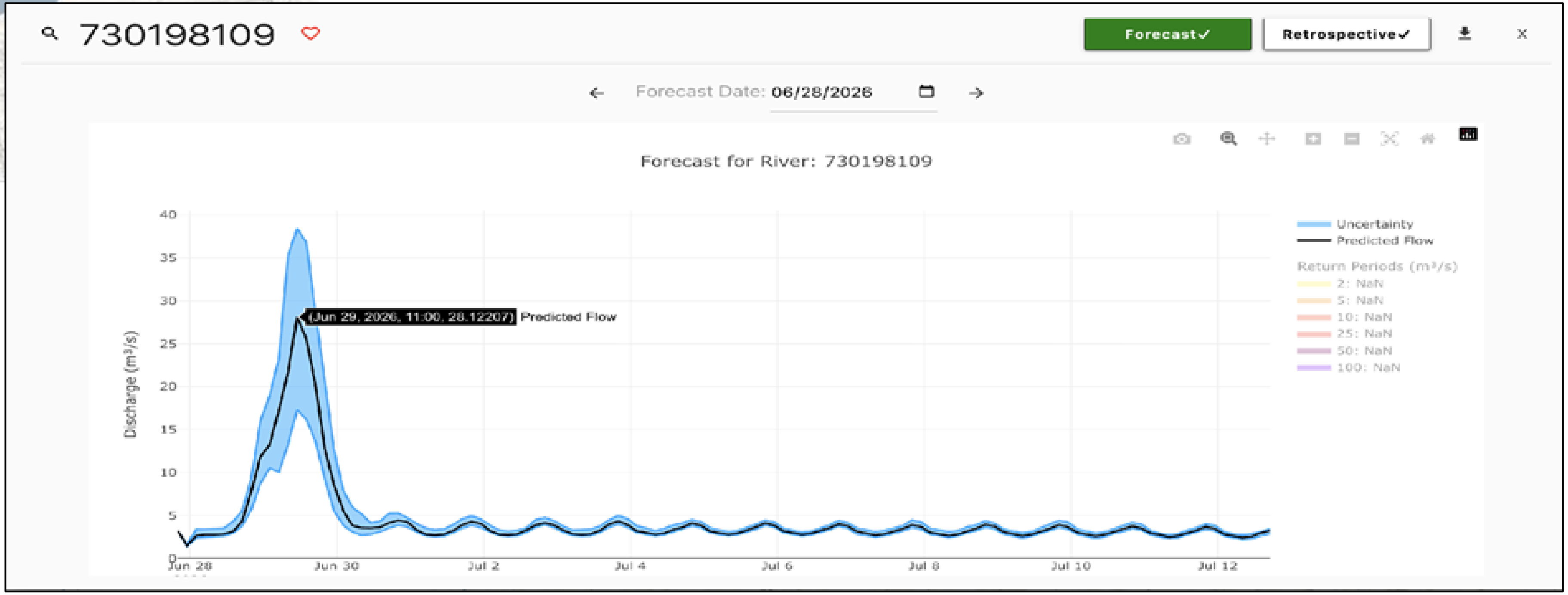
Source: Google Earth

Dam on Lake Sherburne

Case Study: GEOGLOWS Discharge from HYDROVIEWER

Swiftcurrent Creek to Lake Sherburne on 29 June





Summary

Summary

- Reservoirs are man-made lakes built directly on a river (on-stream) or filled via diversion (off-stream).
- They are critical infrastructure for municipal water, flood mitigation, hydroelectric power, and public recreation.
- Managers balance short-term operational decisions with long-term planning, coordinate across borders, and mitigate water quality threats like Harmful Algal Blooms (HABs).
- Effective forecasting requires monitoring watershed conditions (precipitation, snow, soil moisture) and reservoir parameters (water level, bathymetry, inflow/outflow).
- GPM IMERG fills observation gaps in un-gauged basins, tracking near real-time extreme weather, basin saturation, and long-term droughts.
- SMAP measures antecedent soil moisture to predict whether precipitation will absorb or become rapid flood runoff, while tracking freeze/thaw states.
- Measuring peak winter SWE is critical for forecasting spring/summer snowmelt and seasonal reservoir inflows.
- MODIS and VIIRS Global Water Reservoir products provide time-series data on surface area, elevation, storage, and evaporation for 164 large reservoirs.
- SWOT provides high-resolution elevation and area measurements to estimate reservoir storage volume, hydropower potential, and river discharge.
- Tools like LDAS integrate these satellite observations into hydrologic models, while OPERA datasets track dynamic surface water extent using Landsat and Sentinel data.

Looking Ahead to Part 2

Accessing NASA Earth Observations data for Reservoir Management

- Access and monitor watershed parameters, reservoir water levels, and inflow rivers using NASA Earth observations and web tools.
- Navigate Earthdata as the primary repository for finding and accessing NASA satellite datasets.
- Use Google Earth Engine to map basins via Hydrosheds and extract time-series data for precipitation, soil moisture, runoff, and snow water equivalent.
- Visualize regional precipitation and snow cover dynamics using NASA Worldview.
- Explore specific reservoir datasets utilizing the MODIS and VIIRS Global Water Reservoir Products.
- Monitor reservoir water levels using the Global Water Measurements tool and SWOTviz.
- Track river streamflow using the GEOGLOWS Hydroviewer and explore global dam information via the Global Dam Watch database.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 11/8/2026
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 25/8/2026**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

- Amita Mehta
  - amita.v.mehta@nasa.gov
- Sean McCartney
  - sean.mccartney@nasa.gov

- ARSET Website
- ARSET YouTube

For questions, comments, or to share how you have applied our trainings to your work or studies, email nasa.arset@gmail.com.

Join our mailing list to stay up-to-date on our latest trainings. Visit our Contact page to subscribe.

Resources

- Applied Remote Sensing Training Program (ARSET). Introduction to NASA Snow and Ice Data and Applications for Water Resources Management. (2025)
- Huffman et al. Integrated Multi-satellitE Retrievals for GPM (IMERG) Technical Documentation. (2019)
- Hydrosheds – Seamless hydrographic data for global and regional applications
- Li et al. NASA's MODIS/VIIRS Global Water Reservoir Product Suite from Moderate Resolution Remote Sensing Data (2021)
- Lyon, Wishart, & Sohns. What's the deal with dam data? (2024)
- NASA's Earthdata Search
- NSIDC Datasets – Repository of cryospheric data and more
- Python Tutorial – Snow Depth and Snow Cover Data Exploration
- Schmutz & Moog. Dams: Ecological Impacts and Management. (2018)
- The National Hydrography Dataset (NHD) – Includes the watershed boundary dataset (WBD)
- Water Wise School. The distribution of water on, in, and above the Earth. (2019)

Thank You!