

Introduction to Using the VIC Model with NASA Earth Observations

Amita Mehta & Kel Markert (SERVIR Global)

February 15, 22, and March 1, 2018



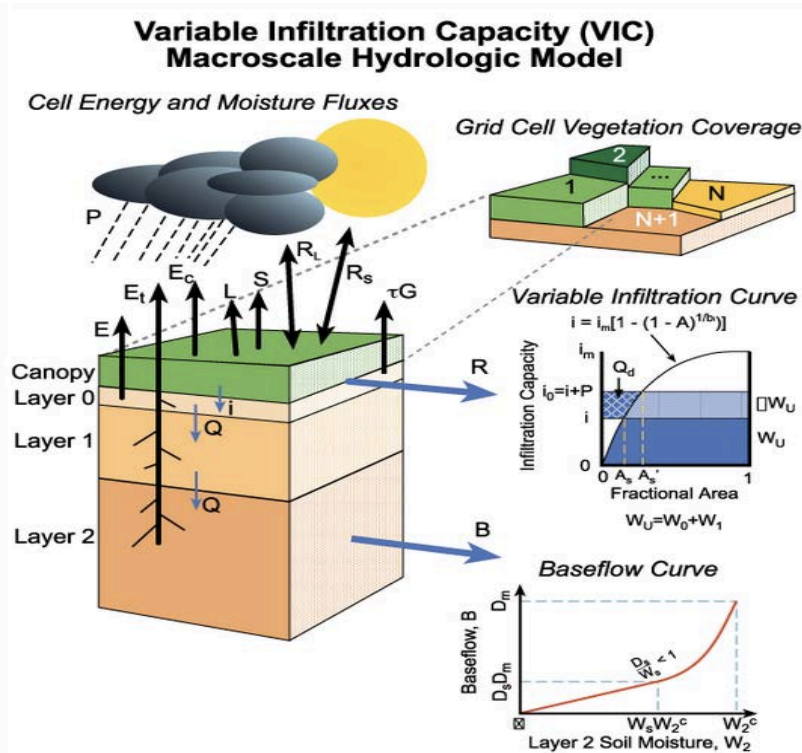
Training Outline

Three Sessions, 09:00-10:00 or 18:00-19:00 EST (UTC-5)

Session 1: Feb 15, 2018

Session 2: Feb 22, 2018

Session 3: Mar 1, 2018



Introduction to the VIC Hydrological Model



Overview of Remote Sensing-Based Input Data for VIC

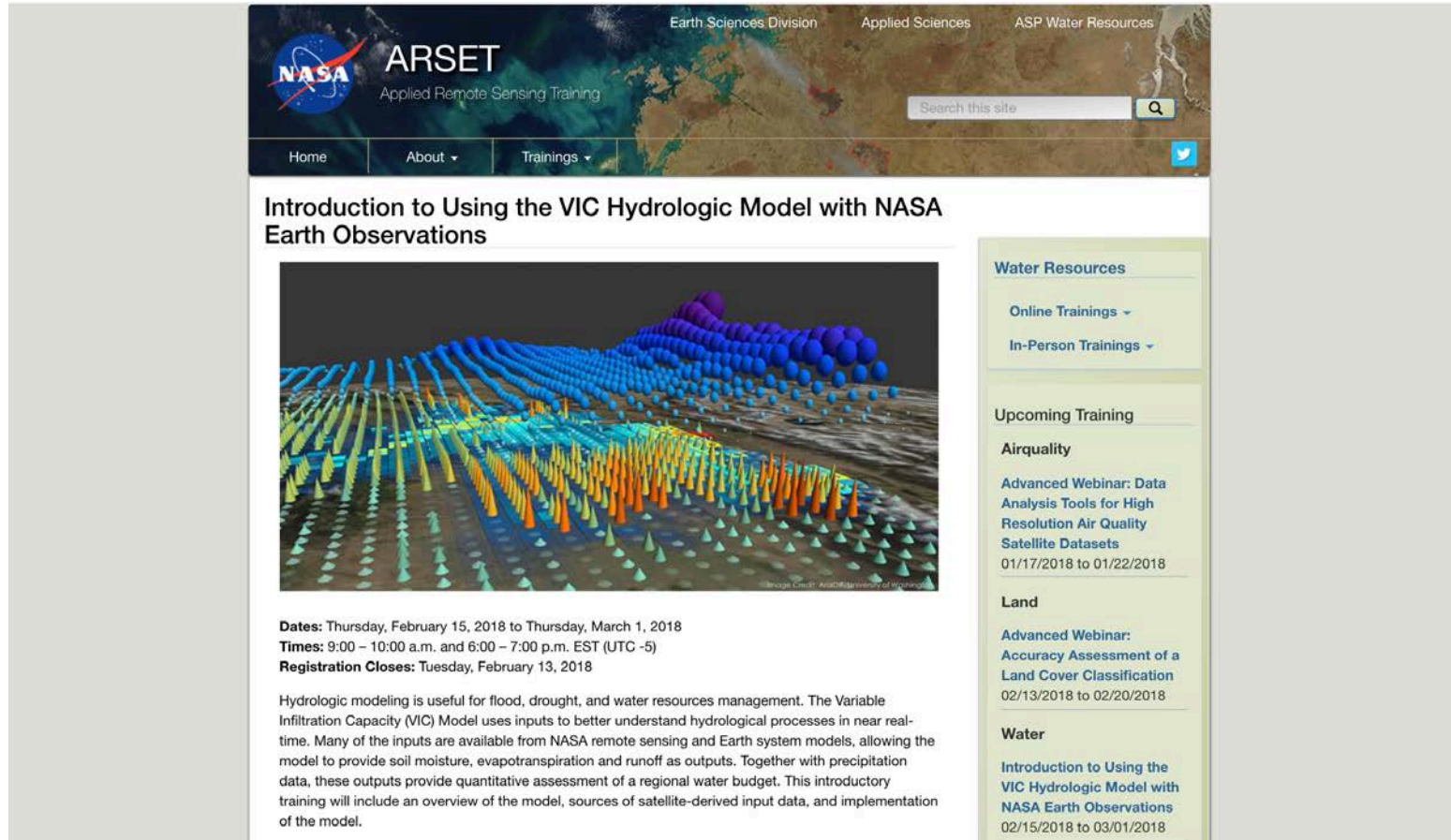


Overview of VIC Implementation for a River Basin



Course Material

Webinar presentations and recording are available at:
<https://arset.gsfc.nasa.gov/water/webinars/VIC18>



The screenshot shows the ARSET (Applied Remote Sensing Training) website. The header includes the NASA logo, the text 'ARSET Applied Remote Sensing Training', and navigation links for 'Earth Sciences Division', 'Applied Sciences', and 'ASP Water Resources'. A search bar is present with the text 'Search this site'. Below the header is a navigation menu with 'Home', 'About', and 'Trainings'. The main content area features a large 3D visualization of a hydrologic model with colorful arrows and terrain. The title of the webinar is 'Introduction to Using the VIC Hydrologic Model with NASA Earth Observations'. Below the image, the dates, times, and registration close date are listed. A sidebar on the right contains sections for 'Water Resources', 'Upcoming Training', 'Airquality', 'Land', and 'Water', each with a list of training events.

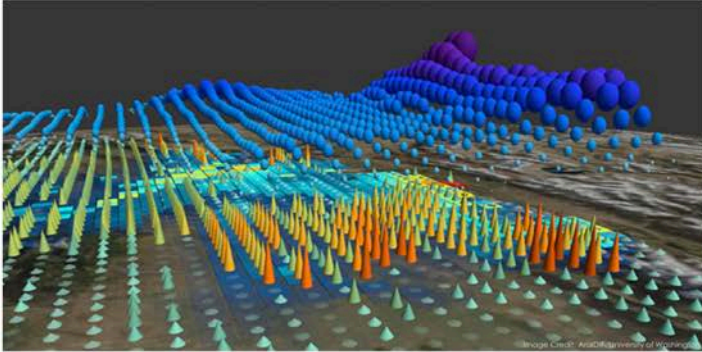
ARSET
Applied Remote Sensing Training

Earth Sciences Division Applied Sciences ASP Water Resources

Search this site

Home About Trainings

Introduction to Using the VIC Hydrologic Model with NASA Earth Observations



Dates: Thursday, February 15, 2018 to Thursday, March 1, 2018
Times: 9:00 – 10:00 a.m. and 6:00 – 7:00 p.m. EST (UTC -5)
Registration Closes: Tuesday, February 13, 2018

Hydrologic modeling is useful for flood, drought, and water resources management. The Variable Infiltration Capacity (VIC) Model uses inputs to better understand hydrological processes in near real-time. Many of the inputs are available from NASA remote sensing and Earth system models, allowing the model to provide soil moisture, evapotranspiration and runoff as outputs. Together with precipitation data, these outputs provide quantitative assessment of a regional water budget. This introductory training will include an overview of the model, sources of satellite-derived input data, and implementation of the model.

Water Resources

- Online Trainings
- In-Person Trainings

Upcoming Training

Airquality

- Advanced Webinar: Data Analysis Tools for High Resolution Air Quality Satellite Datasets
01/17/2018 to 01/22/2018

Land

- Advanced Webinar: Accuracy Assessment of a Land Cover Classification
02/13/2018 to 02/20/2018

Water

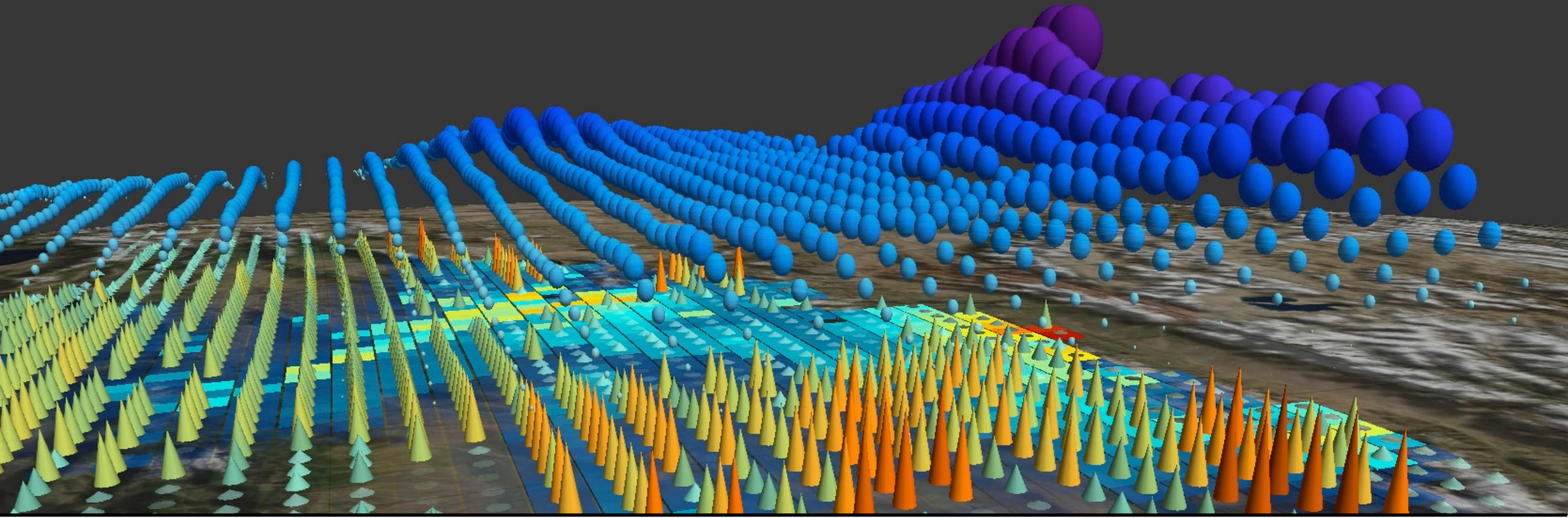
- Introduction to Using the VIC Hydrologic Model with NASA Earth Observations
02/15/2018 to 03/01/2018



Homework and Certificates

- Homework will be available after Session 3 from <https://arset.gsfc.nasa.gov/water/webinars/VIC18>
 - **Answers must be submitted via Google Form**
- Certificate of Completion:
 - Attend all webinars
 - Complete homework assignment by the deadline (March 16, 2018)
 - You will receive certificates approx. two months after the completion of the course from: marines.martins@ssaihq.com

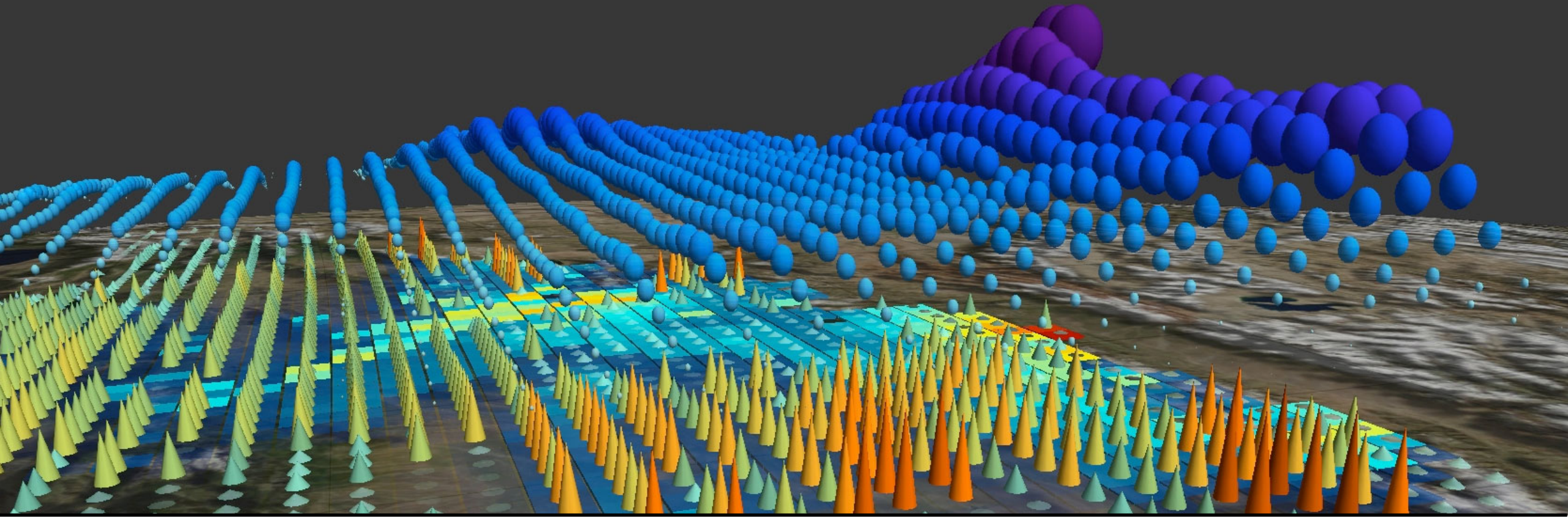




Overview of Remote Sensing-Based Input Data for VIC

Session 2 Outline

- VIC Input Data
- VIC Input Data From NASA Earth Observations
- Demonstration of Data Access for a VIC Simulation of the Mekong Basin



VIC Input Data

VIC Input Information and Source Code

- Detailed information about VIC input data can be found at:
 - <http://www.hydro.washington.edu/Lettenmaier/Models/VIC/Documentation/Inputs.shtml>
 - <http://vic.readthedocs.io/en/vic.4.2.c/Documentation/Inputs/>
- VIC model source code modules are available at:
 - <https://github.com/UW-Hydro/VIC/tree/master/vic/drivers/classic/src>

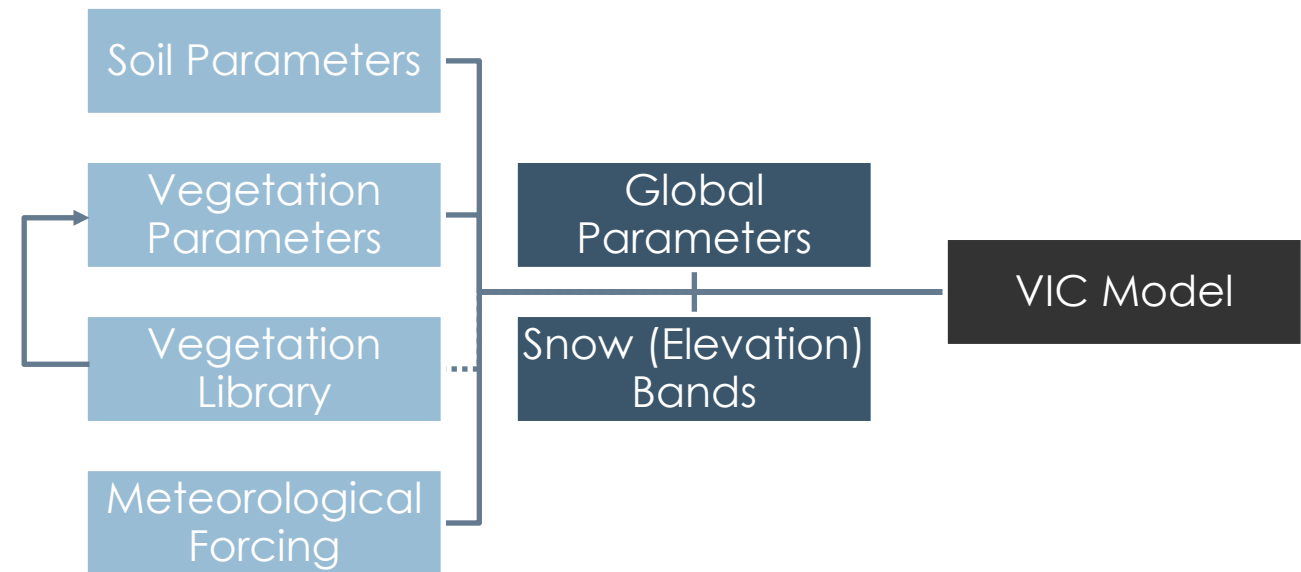


Input Requirements

<http://vic.readthedocs.io/en/vic.4.2.c/Documentation/Inputs/>

- Global Parameter File
- Meteorological Forcing
- Soil Parameters
- Vegetation Parameters
- Vegetation Library
- Elevation Data

Most parameters are available from NASA satellite observations of Earth system models



Global Parameters

<http://vic.readthedocs.io/en/vic.4.2.c/Documentation/GlobalParam/>

The main input file specifies

- Locations of input and output files
- Start and end dates for the model simulation
- Parameters that govern the simulation
- Model mode and physical process options

➔ Definition of File Parameters

Define Simulation Parameters

The following options determine the type of simulation that will be performed.

Main Simulation Parameters

Name	Type	Units	Description
NLAYER	integer	N/A	Number of moisture layers used by the model
NODES	integer	N/A	Number of thermal solution nodes in the soil column
TIME_STEP	integer	hours	Simulation time step length (must divide 24 evenly). NOTE: TIME_STEP should be < 24 for FULL_ENERGY=TRUE or FROZEN_SOIL=TRUE.
SNOW_STEP	integer	hours	Length of time step used to solve the snow model (must divide 24 evenly; if TIME_STEP < 24, SNOW_STEP should = TIME_STEP)
STARTYEAR	integer	year	Year model simulation starts
STARTMONTH	integer	month	Month model simulation starts
STARTDAY	integer	day	Day model simulation starts
STARTHOUR	integer	hour	Hour model simulation starts



Global Parameters

<https://vic.readthedocs.io/en/vic.4.2.c/Documentation/GlobalParam/#example-global-parameter-file>

Example Global Parameter File:

```
#####
# VIC Model Parameters - 4.2
#####
# $Id$
#####
# Simulation Parameters
#####
NLAYER      3 # number of soil layers
NODES       10 # number of soil thermal nodes
TIME_STEP   3 # model time step in hours (set to 24 if FULL_ENERGY = FALSE, set to < 24 if FULL_ENERGY = TRUE)
SNOW_STEP   3 # time step in hours for which to solve the snow model (should = TIME_STEP if TIME_STEP < 24)
STARTYEAR   2000 # year model simulation starts
STARTMONTH  01 # month model simulation starts
STARTDAY    01 # day model simulation starts
STARTRHOUR  00 # hour model simulation starts
ENDYEAR     2000 # year model simulation ends
ENDDAY      31 # day model simulation ends

#####
# Energy Balance Parameters
#####
FULL_ENERGY FALSE # TRUE = calculate full energy balance; FALSE = compute water balance only. Default = FALSE.
#CLOSE_ENERGY FALSE # TRUE = all energy balance calculations (canopy air, canopy snow, ground snow,
# and ground surface) are iterated to minimize the total column error. Default = FALSE.

#####
# Soil Temperature Parameters
# VIC will choose appropriate value for QUICK_FLUX depending on values of FULL_ENERGY and FROZEN_SOIL; the user should
# The other options in this section are only applicable when FROZEN_SOIL is TRUE and their values depend on the applic
#####
```

Sections of the Global Parameter File

- Define Simulation Parameters
- Main Simulation Parameters
- Energy Balance Parameters
- Soil Temperature Parameters
- Precipitation Parameters
- Turbulent Flux Parameters
- Met. Forcing Disaggregation Parameters
- Define Carbon Parameters
- Miscellaneous Parameters
- Define State Files
- Define Meteorological Forcing Files
- Define Parameter Files
- Define Lake Parameters
- Define Output Files



Soil Parameters

<https://vic.readthedocs.io/en/vic.4.2.c/Documentation/SoilParam/>

- Assign ID to each grid cell, along with latitude and longitude information
- Define soil hydrologic and thermal parameters for each grid cell
- Define initial soil moisture conditions

To help in understanding this file, an example file has been attached at the bottom of this page.

Column	Variable Name	Units	Number of Values	Description
1	run_cell	N/A	1	1 = Run Grid Cell, 0 = Do Not Run
2	gridcel	N/A	1	Grid cell number
3	lat	degrees	1	Latitude of grid cell
4	lon	degrees	1	Longitude of grid cell
5	infil	N/A	1	Variable infiltration curve parameter (binfil)
6	Ds	fraction	1	Fraction of D _{max} where non-linear baseflow begins
7	D _{max}	mm/day	1	Maximum velocity of baseflow
8	Ws	fraction	1	Fraction of maximum soil moisture where non-linear baseflow occurs
9	c	N/A	1	Exponent used in baseflow curve, normally set to 2
10 : (N _{layer} +9)	expt	N/A	N _{layer}	Exponent n ($=3+2/\text{Lambda}$) in Campbell's eqn for hydraulic conductivity, HBH 5.6 (where lambda = soil pore size distribution parameter). Values should be > 3.0.
(N _{layer} +10): (2*N _{layer} +9)	K _{sat}	mm/day	N _{layer}	Saturated hydrologic conductivity
(2*N _{layer} +10): (3*N _{layer} +9)	phi_s	mm/mm	N _{layer}	Soil moisture diffusion parameter
(3*N _{layer} +10): (4*N _{layer} +9)	init_moist	mm	N _{layer}	Initial layer moisture content
(4*N _{layer} +10)	elev	m	1	Average elevation of grid cell
(4*N _{layer} +11): (5*N _{layer} +10)	depth	m	N _{layer}	Thickness of each soil moisture layer



Soil Data

<http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/>

- Available from Harmonized World Soil Database (HWSD)
- Worldwide characterization of soil parameters
 - organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, salinity, textural class and granulometry
- Over 15000 different soil mapping units from combined regional and national soil information to form worldwide soil information
- Can also be downloaded in raster form from:
http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/HWSD_Data.html?sb=4



The screenshot shows the FAO Soils Portal website. The header includes the FAO logo and the text "Food and Agriculture Organization of the United Nations". A search bar is located in the top right corner. Below the header, there is a navigation menu with options: Home, Survey, Assessment, Biodiversity, Management, Degradation/Restoration, Policies/Governance, and Publications. The main content area is titled "FAO SOILS PORTAL" and features a sidebar on the left with categories: Soil properties, Soil classification, Sampling and laboratory techniques, and Soil Maps and Databases. The main content area displays "Harmonized World Soil Database v 1.2" with a world map and descriptive text. The text explains that the database is a 30 arc-second raster database with over 15,000 different soil mapping units, combining regional and national updates of soil information worldwide (SOTER, ESD, Soil Map of China, 1971-1981). It also mentions that the resulting raster database consists of 21,600 rows and 43,200 columns, linked to harmonized soil property data. A "Download" section at the bottom provides links for "Download viewer & data" and "Download data".

Resolution: 30 arc-second (~1 km)
raster

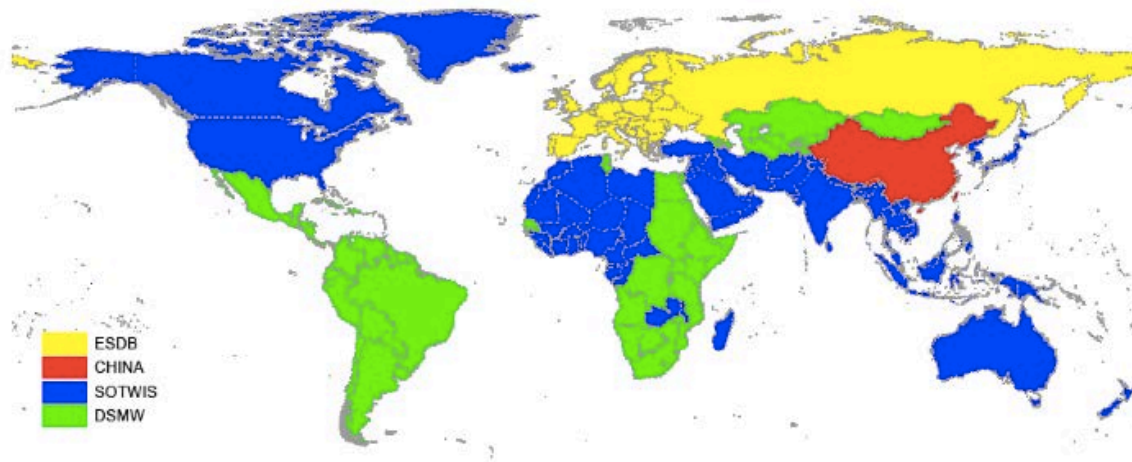


Soil Data

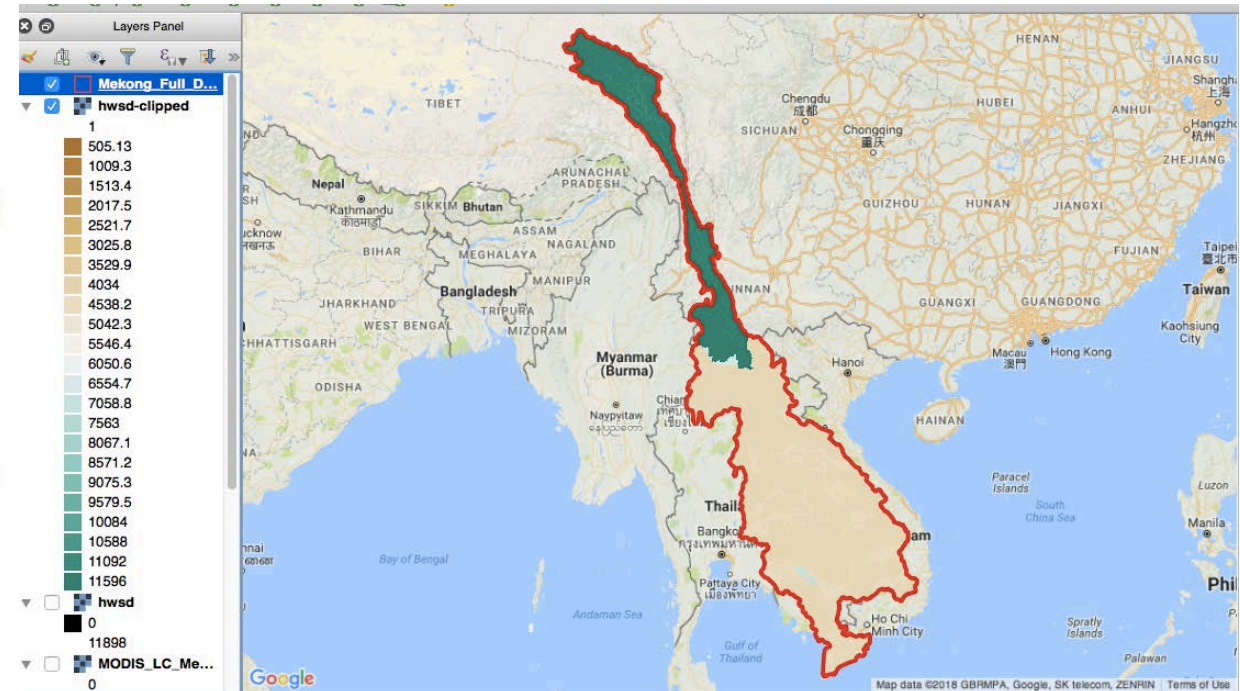
<http://www.fao.org/soils-portal/soil-survey/soil-maps-and-databases/harmonized-world-soil-database-v12/en/>

- For details and data descriptions:
 - http://www.fao.org/fileadmin/templates/nr/documents/HWSD/HWSD_Documentation.pdf

Data sources for the Harmonized World Soil Database (HWSD)



- The global HWSD data are clipped to the Mekong Basin using QGIS



Meteorological Forcing Parameters

<https://vic.readthedocs.io/en/vic.4.2.c/Documentation/ForcingData/>

- Daily data required for VIC simulation in water balance mode:
 - minimum surface air temperature
 - maximum surface air temperature
 - precipitation
 - surface wind speed
- Annual mean precipitation (for specifying initial soil moisture condition)
- Sub-Daily data necessary for VIC simulations in energy balance mode



Vegetation Parameters

<http://vic.readthedocs.io/en/vic.4.2.c/Documentation/VegParam/>

Defines

- Land Cover
- Vegetation Class
- Fraction of a Grid Covered by Vegetation (optional)
- Leaf Area Index (LAI)
- Shortwave Albedo
- Root Zone Depth and Distribution
- Height of Surface Wind
- Vegetation Roughness

Not from remote sensing



Vegetation Parameter File Format

Variable Name	Units	Description
gridcel	N/A	Grid cell number
Nveg	N/A	Number of vegetation tiles in the grid cell

Repeats for each vegetation tile in the grid cell:

Variable Name	Units	Description
		Vegetation class identification number (reference index to vegetation library) <i>NOTE 1:</i> it is common practice to define only one tile for each vegetation class in the grid cell. But this is not strictly necessary. It is OK to define multiple tiles having the same vegetation class.
veg_class	N/A	<i>NOTE 2:</i> As of VIC 4.1.1, if you are simulating lakes, you MUST designate one of the tiles from each grid cell as the tile that contains the lake(s). This designation happens in the lake parameter file . You can either choose an existing tile to host the lakes, or insert a new tile (just make sure that the sum of the tile areas in the grid cell = 1.0). This extra lake/wetland tile may have the same vegetation class as one of the other existing tiles (see NOTE 1). For advice on how to prepare your vegparam and lakeparam files, click here .
Cv	fraction	Fraction of grid cell covered by vegetation tile



Vegetation Library

<http://vic.readthedocs.io/en/vic.4.2.c/Documentation/VegLib/>

Supplements the Vegetation Parameters file

Defines

- Parameterization for all land and vegetation classes



VIC Vegetation Library File

Vegetation parameters needed for each vegetation type used in the VIC model are provided in a column format ASCII file as described in this document. Parameters are given for different vegetation types, and are referenced by the [vegetation parameter file](#), which provides information about the number of vegetation types per grid cell, and their fractional coverage. A header may be added to the top of the file if the first column contains a '#'. Comments can also be added to the end of each line in the vegetation library file.

Vegetation Library File Format

Variable Name	Units	Number of Values	Description
veg_class	N/A	1	Vegetation class identification number (reference index for library table)
overstory	N/A	1	Flag to indicate whether or not the current vegetation type has an overstory (TRUE for overstory present [e.g. trees], FALSE for overstory not present [e.g. grass])
rarc	s/m	1	Architectural resistance of vegetation type (~2 s/m)
rmin	s/m	1	Minimum stomatal resistance of vegetation type (~100 s/m)
LAI	fraction	12	Leaf-area index of vegetation type
VEGLIB_VEGCOVER (Only present if VEGLIB_VEGCOVER=TRUE in global parameter file)	fraction	12	Partial vegetation cover fraction



Elevation Data

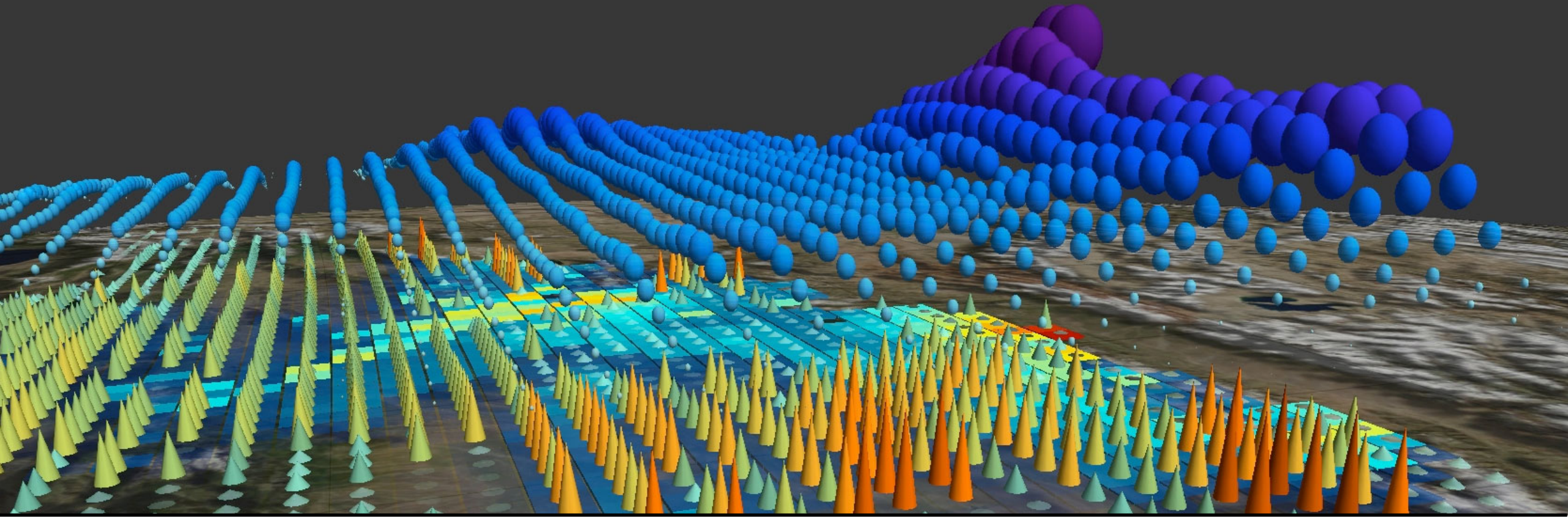
<http://vic.readthedocs.io/en/vic.4.2.c/Documentation/SnowBand/>

- Optional but important data
- Each VIC model grid is divided into a user-specified number of elevation bands (also referred to as snow bands)
- Each elevation band is simulated separately
- The elevation data are useful in snow models to improve model performance representing snow accumulation in mountainous regions

Elevation Band File Format

Column	Variable Name	Units	Number of Values	Description
1	cellnum	N/A	1	Grid cell number (should match numbers assigned in soil parameter file)
2 : (SNOW_BAND+1)	AreaFract	fraction	SNOW_BAND	Fraction of grid cell covered by each elevation band. Sum of the fractions must equal 1.
(SNOW_BAND+2) : (2*SNOW_BAND+1)	elevation	m	SNOW_BAND	Mean (or median) elevation of elevation band. This is used to compute the change in air temperature from the grid cell mean elevation.
(2*SNOW_BAND+2) : (3*SNOW_BAND+1)	Pfactor	fraction	SNOW_BAND	Fraction of cell precipitation that falls on each elevation band. Total must equal 1. To ignore effects of elevation on precipitation, set these fractions equal to the area fractions.





VIC Input Data From NASA Earth Observations

Input Data and Sources

Meteorological
Forcing

Data Parameter	Source
Minimum & Maximum Temperatures Surface Winds	MERRA-2 Model With Assimilated Satellite Observations
Precipitation	Global Precipitation Measurement (GPM) Mission - IMERG
Land Cover, LAI and Albedo	Terra and Aqua MODIS
Elevation	Shuttle Radar Topography Mission (SRTM)

MERRA: Modern-Era Retrospective analysis for Research and Application

IMERG: Integrated Multi-satellite Retrievals for GPM

MODIS: Moderate Resolution Imaging Spectroradiometer

LAI: Leaf Area Index

See [Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management](#) for more information



Input Data and Sources

	Data Parameter	Source
Meteorological Forcing	Minimum & Maximum Temperatures Surface Winds	MERRA-2 Model With Assimilated Satellite Observations
	Precipitation	Global Precipitation Measurement (GPM) mission - IMERG
	Land Cover, LAI and Albedo	Terra and Aqua MODIS
	Elevation	Shuttle Radar Topography Mission (SRTM)

MERRA: Modern-Era Retrospective analysis for Research and Application

IMERG: Integrated Multi-satellitE Retrievals for GPM

MODIS: MOderate Resolution Imaging Specroradiometer

LAI: Leaf Area Index

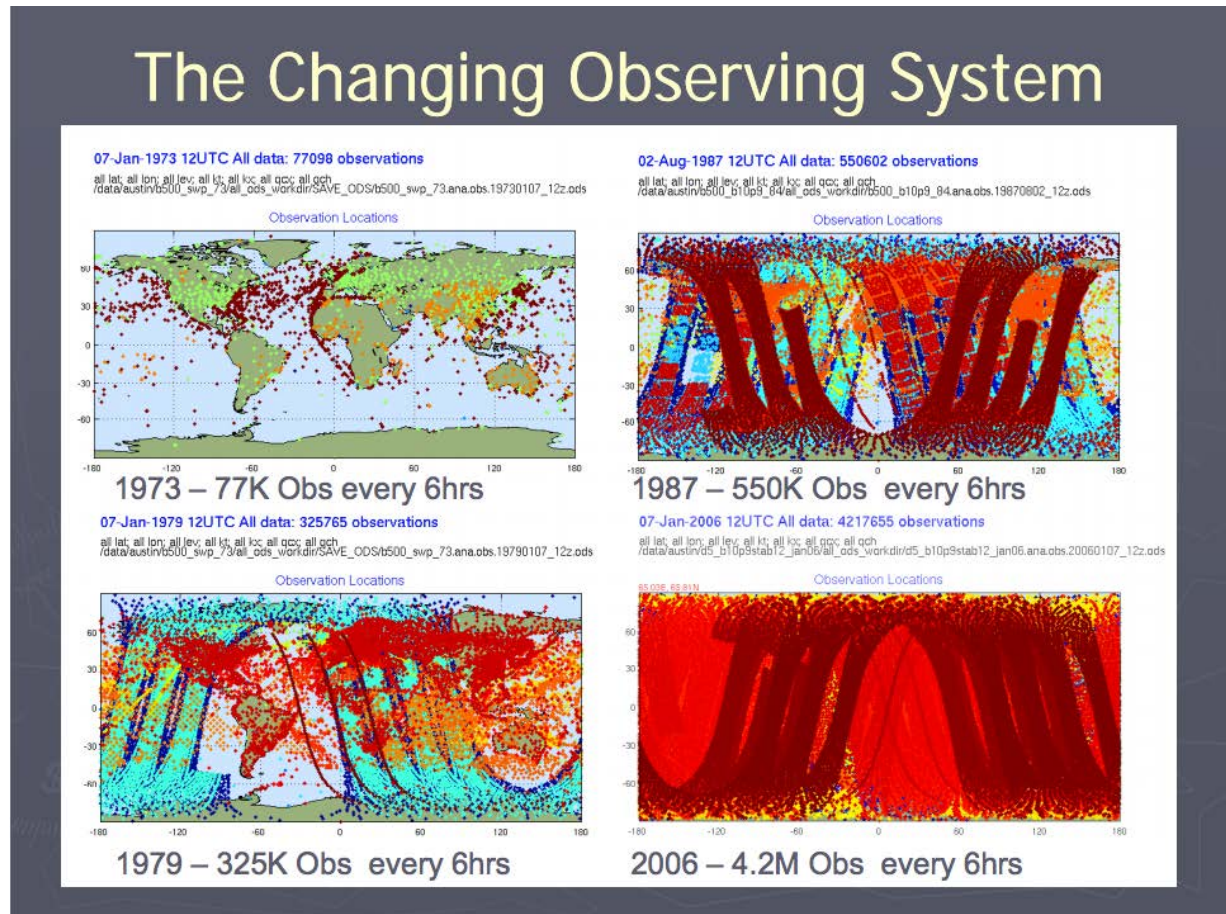
See [Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management](#) for more information



About MERRA-2

<https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/>

- Blends the vast quantities of observational data with output data of the Goddard Earth Observing System (GEOS) model (1979 – present)
- Provides state-of-the-art global analyses on weather to climate time scales
- Focuses on improvement in the hydrological cycle



Coverage of satellite data assimilated in MERRA

Reference: Bosilovich, M., 2009. https://gmao.gsfc.nasa.gov/pubs/docs/MERRA_Purdue_Sep09.pdf



MERRA-2 Data Access

https://gmao.gsfc.nasa.gov/reanalysis/MERRA-2/data_access/

- Data Search, Sub-Setting, and Bulk Data Download:

<https://disc.sci.gsfc.nasa.gov/datasets?page=1&keywords=MERRA-2>

GES DISC Data Collections **MERRA-2** Feedback Help Login

Atmospheric Composition, Water & Energy Cycles and Climate Variability

Data Collections Showing 1 - 32 of 107 datasets associated with MERRA-2

Refine By

Subject Sort ▾

- Altitude (9)
- Atmospheric Chemistry (10)
- Atmospheric Pressure (8)
- Atmospheric Radiation (74)
- Atmospheric Temperature (90)

[More...](#)





Measurement Sort ▾

- Cloud Properties (68)
- Evapotranspiration (12)
- Geopotential Height (9)
- Heat Flux (74)
- Humidity (74)

[More...](#)

Source Sort ▾

- Models/Analyses MERRA-2 (95)
- Models/Analyses Noah-LSM (9)
- Models/Analyses VIC-LSM (3)

Image	Dataset	Source	Temporal Resolution	Spatial Resolution	Process Level	Begin Date	End Date
 Hover	MERRA-2 const_2d_asm_Nx: 2d, constants V5.12.4 (M2C0NXASM.5.12.4) - Clouds, Atmospheric Radiation, Atmospheric Water Vapor ▾ Subset / Get Data	Models/Analyses MERRA-2	1 constant	0.5 ° x 0.625 °	4	1980-01-01	2018-01-19
 Hover	MERRA-2 inst1_2d_asm_Nx: 2d,1-Hourly,Instantaneous,Single-Level,Assimilation,Single-Level Diagnostics V5.12.4 (M2I1NXASM.5.12.4) - Clouds, Atmospheric Radiation, Atmospheric Water Vapor ▾ Subset / Get Data	Models/Analyses MERRA-2	1 hour	0.5 ° x 0.625 °	4	1980-01-01	2018-01-19
 Hover	MERRA-2 inst1_2d_int_Nx: 2d,1-Hourly,Instantaneous,Single-Level,Assimilation,Vertically Integrated Diagnostics V5.12.4 (M2I1NXINT.5.12.4) - Atmospheric Chemistry Subset / Get Data	Models/Analyses MERRA-2	1 hour	0.5 ° x 0.625 °	4	1980-01-01	2018-01-19
 Hover	MERRA-2 inst1_2d_ifo_Nx: 2d,1-Hourly,Instantaneous,Single-Level,Assimilation,Land Subset / Get Data	Models/Analyses MERRA-2	1 hour	0.5 ° x 0.625 °	4	1980-01-01	2018-01-19



MERRA-2 Data Filename Convention

<https://gmao.gsfc.nasa.gov/pubs/docs/Bosilovich785.pdf>

Filename convention: **Runid.Collection.Dims.group.HV.Timestamp**

- **Collection:**

- cnst- time independent
- instF- instantaneous
- tavgF- time average
- statF- statistics
- F- frequency of averaging interval
 - 1,3,6,D (daily), M(monthly), U (monthly-diurnal), 0 (N/A)

- **Dims:**

- 2 or 3 dimensional

- **HV:**

- H is for horizontal grid
 - N for native resolution $5/8 \times 1/2$ degree
- V is for vertical grid
 - x: horizontal-only data (surface, single level)
 - p: pressure-level data
 - v: model layer centers
 - e: model layer edges

- **Timestamp:**

- YYYYMMDD



MERRA-2 Data Filename Convention

<https://gmao.gsfc.nasa.gov/pubs/docs/Bosilovich785.pdf>

Filename convention: **Runid.Collection.Dims.group.HV.Timestamp**

Group:

ANA = direct analysis products

+**ASM = assimilated state variables**

AER = aerosol mixing ration

ADG = aerosol extended diagnostics

TDT = tendencies of temperature

UDT = tendencies of eastward and northward wind components

QDT = tendencies of specific humidity

ODT = tendencies of ozone

GAS = aerosol optical depth

GLC = land ice surface

LND = land surface variables

LFO = land surface forcing output

FLX = surface turbulent fluxes and related quantities

MST = moist processes

CLD = clouds

RAD = radiation

CSP = COSP satellite simulator

TRB = turbulence

***SLV = single level**

INT = vertical integrals

CHM = chemistry forcing

OCN = ocean

NAV = vertical coordinates



Input Data and Sources

	Data Parameter	Source
Meteorological Forcing	Minimum & Maximum Temperatures Surface Winds	MERRA-2 Model With Assimilated Satellite Observations
	Precipitation	Global Precipitation Measurement (GPM) mission - IMERG
	Land Cover, LAI and Albedo	Terra and Aqua MODIS
	Elevation	Shuttle Radar Topography Mission (SRTM)

MERRA: Modern-Era Retrospective analysis for Research and Application

IMERG: Integrated Multi-satellite Retrievals for GPM

MODIS: Moderate Resolution Imaging Spectroradiometer

LAI: Leaf Area Index

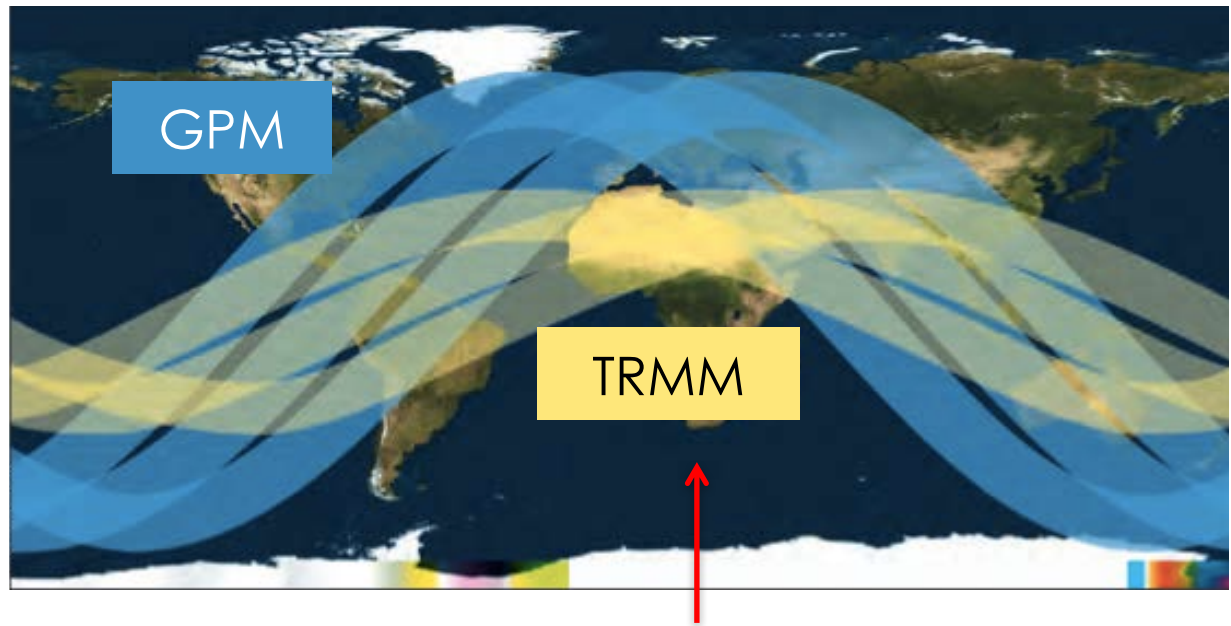
See [Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management](#) for more information



Global Precipitation Measurement (GPM) Mission

<http://pmm.nasa.gov/GPM/>

- Core satellite launched Feb 27, 2014
 - non-polar, low-inclination orbit
 - Altitude: 407 km
- Spatial Coverage
 - 16 day orbits a day, covering global area between 65°S – 65°N
- Along with constellation of satellites, GPM has a revisit time of 2-4 hrs over land
- Sensors:
 - GMI (GPM Microwave Imager)
 - DPR (Dual Precipitation Radar)



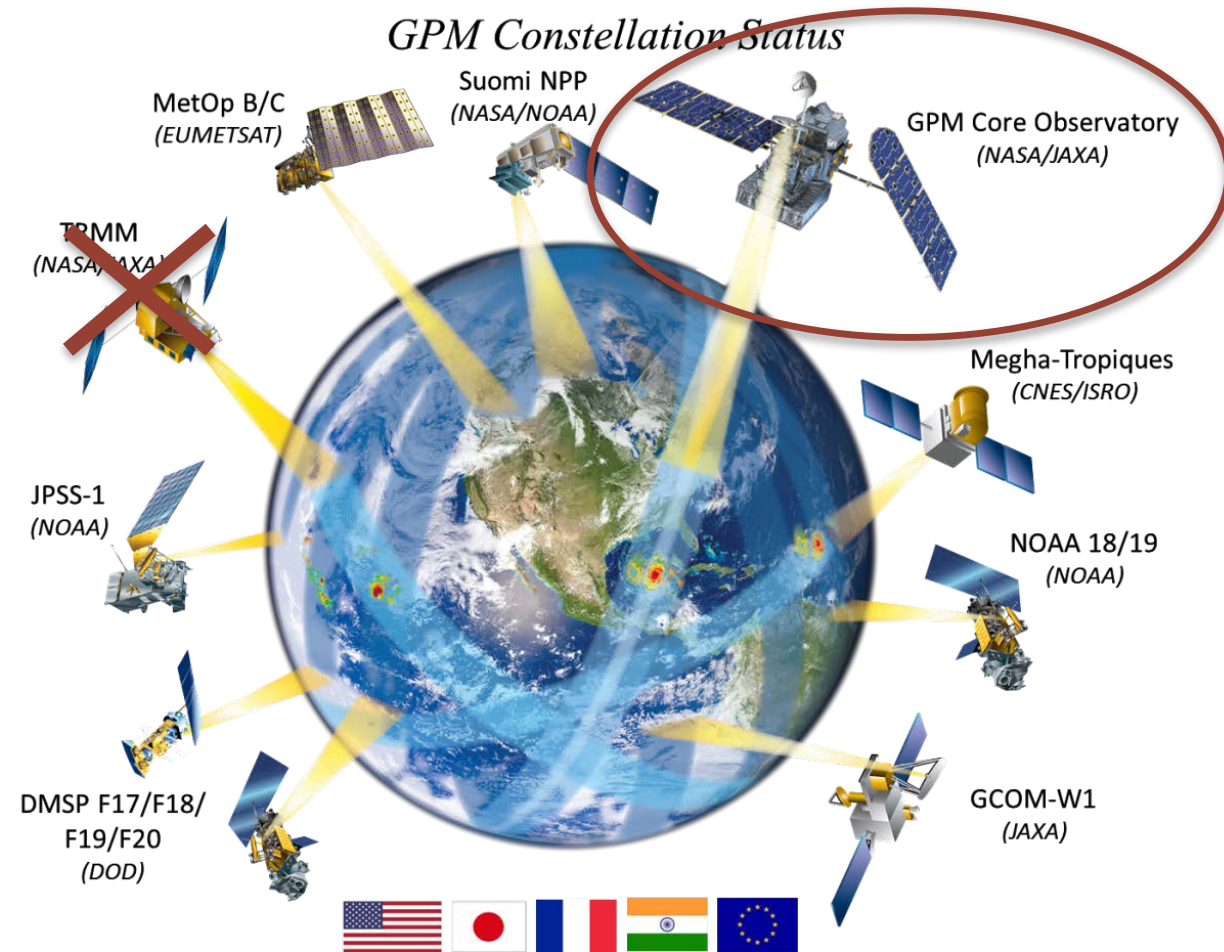
Tropical Rainfall Measurement Mission



Integrated Multi-satellite Retrievals for GPM (IMERG)

http://pmm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V4.5.pdf

- GPM Core satellite data (GMI & DPR) are used to calibrate and combine microwave data from GPM constellation satellites
- GPM constellation satellites include:
 - GCOM-W
 - DMSP
 - Megha-Tropiques
 - MetOp-B
 - NOAA-N'
 - NPP
 - NPOESS
- Final rain product is calibrated with rain gauge analyses on monthly time scale



Integrated Multi-satellite Retrievals for GPM (IMERG)

http://pmm.nasa.gov/sites/default/files/document_files/IMERG_ATBD_V4.5.pdf

- Multiple runs accommodate different user requirements for latency and accuracy
 - “Early” – now 5 hours (flash flooding) – will be 4 hours
 - “Late” – now 15 hours (crop forecasting) – will be 12 hours
 - “Final” – 3 months (research data)
- Native time intervals are half-hourly and monthly (final only)
 - Value-added products at 3 hrs, 1, 3, and 7 days are available
 - Initial release covers 60°N-60°S – will be 90°N-90°S



GPM IMERG Data Access

<https://pmm.nasa.gov/data-access>

Data Access

- Extreme Weather News
- ▼ Data Downloads & Documentation
 - TRMM
 - GPM
 - Ground Validation
- Data Sources
- Data Recipes
- Data News
- Google Earth
- NASA Worldview
- Using the PPS FTP
- Training
- Data FAQ

Connect With Us

- Twitter
- Facebook
- Youtube

Need Help?

- View Frequently Asked Questions
- View the PMM Glossary

How to Access TRMM & GPM Precipitation Data

Precipitation data from the GPM and TRMM missions is made available free to the public in a variety of formats from several sources at [NASA](#) Goddard Space Flight Center. This section outlines the different types of data available, the levels of processing, the sources to download the data, and some helpful tips for utilizing precipitation data in your research.

- **GPM Data Downloads & Documentation**
- TRMM Data Downloads & Documentation
- Explanation of GPM & TRMM Data Sources
- Data Processing "Recipes"
- Precipitation Data in Google Earth
- Frequency Asked Questions (FAQ)

GET DATA
GLOBAL PRECIPITATION MEASUREMENT
New Users Start Here

Use of the PPS FTP and STORM requires you to first register your email address. Click here to register.

- All about GPM data
 - Including updates, news, and FAQ
- Quick data access links and user registration
- For more information about GPM and about data access visit:

<https://pmm.nasa.gov/training>



IMERG Data Access

<https://pmm.nasa.gov/data-access/downloads/gpm/>

Data Access

- Training
- Data Tutorials
- Extreme Weather News
- Data Downloads & Documentation
- GPM**
- TRMM
- Ground Validation
- Data Visualization
- Global Viewer
- Precipitation and Applications Viewer
- NASA Worldview
- Data Sources
- Using the PPS FTP
- Data News
- Data FAQ

Connect With Us

- Twitter
- Facebook
- Youtube

Need Help?

- View Frequently Asked Questions
- View the PMM Glossary
- Contact Us

GPM Data Downloads

* Use of the PPS FTP and STORM requires you to first register your email address. Click here to register.

Level 3 | Level 2 | Level 1 | Related Datasets

Geophysical parameters that have been spatially and/or temporally resampled from Level 1 or Level 2 data.

IMERG: Rainfall estimates combining data from all passive-microwave instruments in the GPM Constellation

This algorithm is intended to intercalibrate, merge, and interpolate "all" satellite microwave precipitation estimates, together with microwave-calibrated infrared (IR) satellite estimates, precipitation gauge analyses, and potentially other precipitation estimators at fine time and space scales for the TRMM and GPM eras over the entire globe. The system is run several times for each observation time, first giving a quick estimate and successively providing better estimates as more data arrive. The final step uses monthly gauge data to create research-level products.

* As of IMERG V05B, full coverage is provided for the latitudes of 60°N-60°S, while the remaining upper and lower latitudes extending to 90° are considered "partial coverage". Learn more.

Documentation:

- IMERG Technical Documentation
- IMERG Algorithm Theoretical Basis Document (ATBD)
- IMERG Quality Index
- IMERG v05B Early and Late Run Release Notes
- IMERG V05B Final Run Release Notes
- IMERG GIS TIFF + Wordfile Documentation
- Transitioning from TMPA (3B42x) to IMERG and Dataset Comparison

Resolution	Regions - Dates	Latency	Format	Source	DL
0.1° - 30 minute	Gridded, 90°N-90°S (* 60°N-60°S full), March 2014 to present	6 hours (NRT / early run)	HDF5	NRT: FTP (PPS)*	↓
			GIS TIFF + Wordfile	NRT: FTP (PPS)*	↓
			Giovanni	Giovanni	↓
			HDF5	OpenDAP	↓
			HDF5	Mirador	↓
			GDS	GrADS Data Server (GDS)	↓
			NETCDF	Simple Subset Wizard	↓

GES DISC

Atmospheric Composition, Water & Energy Cycles and Climate Variability

Data Collections - IMERG

Data Collections Showing 1 - 14 of 14 datasets associated with IMERG

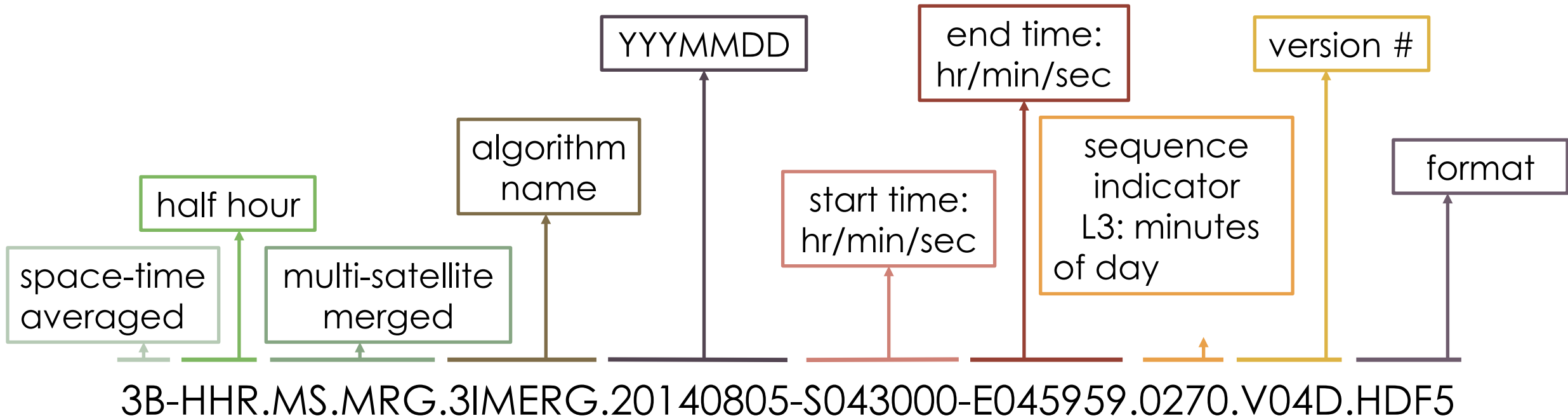
Image	Dataset	Source	Temporal Resolution	Spatial Resolution	Process Level	Begin Date	End Date
	GPM IMERG Early Precipitation L3 1 day 0.1 degree x 0.1 degree V04 (GPM_3IMERGDE.04) - Atmospheric Phenomena, Precipitation	Models/Analyses IMERG	1 day	0.1° x 0.1°	3	2014-03-12	2017-11-30
	GPM IMERG Final Precipitation L3 1 day 0.1 degree x 0.1 degree V04 (GPM_3IMERGDF.04) - Atmospheric Phenomena, Precipitation	Models/Analyses IMERG	1 day	0.1° x 0.1°	3	2014-03-12	2017-02-28
	GPM IMERG Early Precipitation L3 1 day 0.1 degree x 0.1 degree V05 (GPM_3IMERGDE.05) - Atmospheric Phenomena, Precipitation	Models/Analyses IMERG	1 day	0.1° x 0.1°	3	2014-03-12	2018-01-19
	GPM IMERG Final Precipitation L3 1 day 0.1 degree x 0.1 degree V05 (GPM_3IMERGDF.05) - Atmospheric Phenomena, Precipitation	Models/Analyses IMERG	1 day	0.1° x 0.1°	3	2014-03-12	2018-01-19

<https://disc.sci.gsfc.nasa.gov/datasets?page=1&keywords=IMERG>



IMERG File Name Convention

Learn More: <https://go.nasa.gov/2y7AouZ>



Input Data and Sources

Meteorological Forcing

Data Parameter	Source
Minimum & Maximum Temperatures Surface Winds	MERRA-2 Model With Assimilated Satellite Observations
Precipitation	Global Precipitation Measurement (GPM) mission - IMERG
Land Cover, LAI and Albedo	Terra and Aqua MODIS
Elevation	Shuttle Radar Topography Mission (SRTM)

MERRA: Modern-Era Retrospective analysis for Research and Application

IMERG: Integrated Multi-satellitE Retrievals for GPM

MODIS: MOderate Resolution Imaging Specroradiometer

LAI: Leaf Area Index

See [Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management](#) for more information



Terra and Aqua Satellites and MODIS Sensor

Terra

<http://terra.nasa.gov>

- Polar orbit, 10:30 a.m. equator crossing time
- Global Coverage
- December 18, 1999 – Present
- 1-2 observations per day

Aqua

<http://aqua.nasa.gov/>

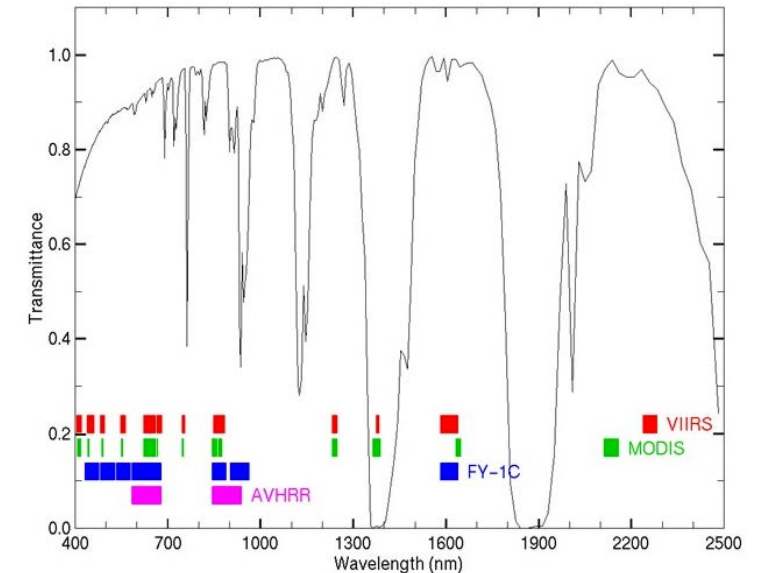
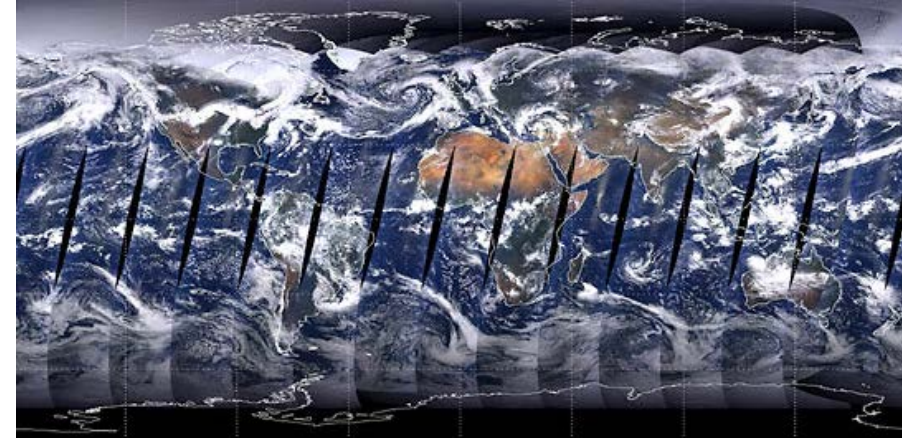
- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day



MODerate Resolution Imaging Spectroradiometer (MODIS)

<http://modis.gsfc.nasa.gov/>

- Spatial Resolution
 - Global, swath: 2,330 km
 - 250 m, 500 m, 1 km
- Temporal Resolution
 - Daily, 8 day, 16 day, monthly, quarterly, yearly
 - 2000 – present
- Data Format
 - Hierarchical data format – Earth Observing System Format (HDF-EO8)



Vegetation Inputs from MODIS

https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table

Data Parameter	MODIS Product Name	Resolution	VIC Requirement
Land Cover	MCD12Q1	500 m, monthly	annual
Leaf Area Index	MCD15A2	1 km, 8 day	monthly
Shortwave Albedo	MCDA3A3	500 m, 16 day	monthly

Note

- MCD stands for MODIS Combined Data (from Terra & Aqua)
- MCD12Q1 contains multiple land cover schemes. We will use the International Geosphere-Biosphere Program classification
- Leaf Area Index & Shortwave Albedo require mean annual cycle (12 months)



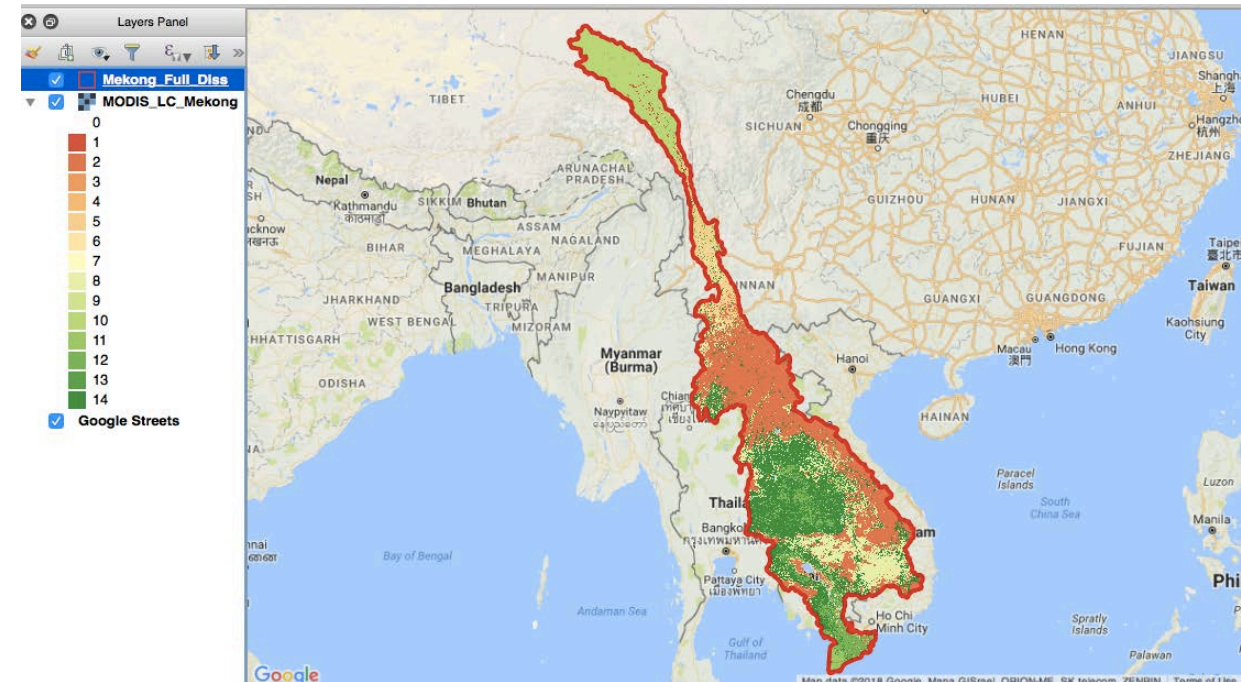
MODIS Land Cover

<https://modis.gsfc.nasa.gov/data/dataproduct/mod12.php>

MODIS IGBP Land Cover Classes

Class	IGBP (Type 1)	Class	IGBP (Type 1)
0	Water	8	Woody savannas
1	Evergreen Needleleaf forest	9	Savannas
2	Evergreen Broadleaf forest	10	Grasslands
3	Deciduous Needleleaf forest	11	Permanent wetlands
4	Deciduous Broadleaf forest	12	Croplands
5	Mixed forest	13	Urban and built-up
6	Closed shrublands	14	Cropland/Natural vegetation mosaic
7	Open shrublands	15	Snow and ice
		16	Barren or sparsely vegetated

MODIS IGBP Land Cover in the Mekong Basin

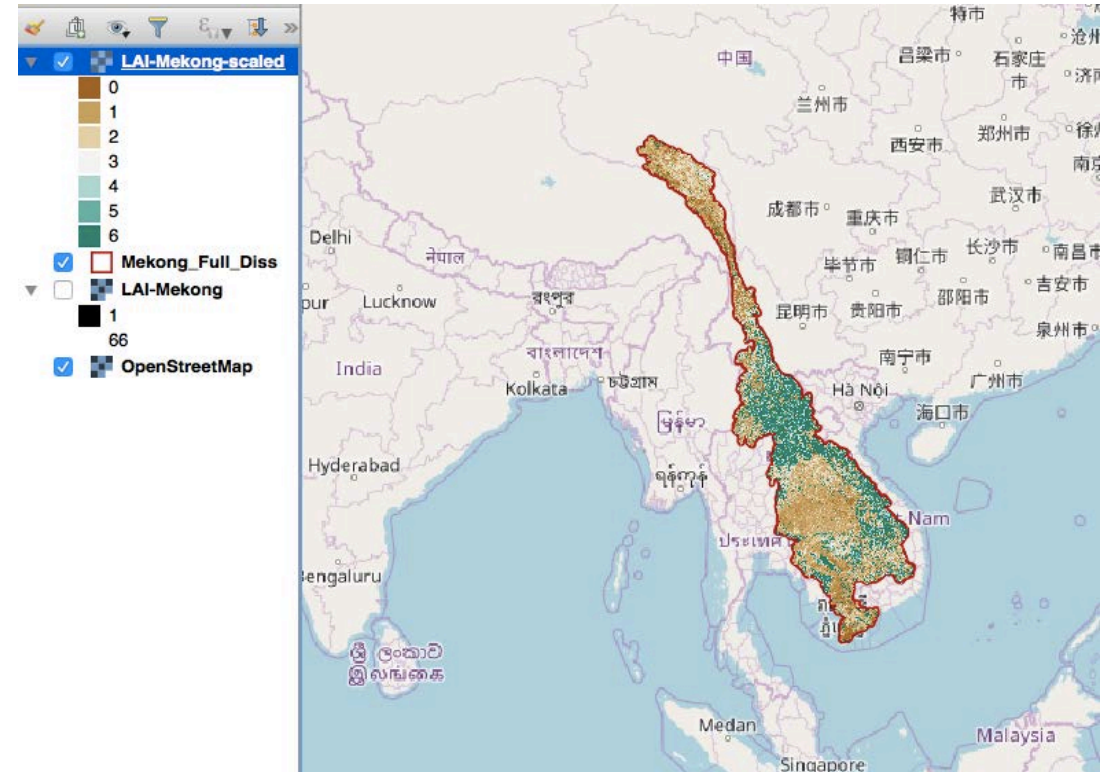


MODIS LAI

https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mod15a2

Science Data Sets (HDF Layers) (6)	UNITS	BIT TYPE	FILL	VALID RANGE	MULTIPLY BY SCALE FACTOR
Fpar_1km	Percent	8-bit unsigned integer	249-255	0-100	0.01
Lai_1km	m2plant/m2ground	8-bit unsigned integer	249-255	0-100	0.1

Value	Description
255	Fillvalue, assigned when: <ul style="list-style-type: none"> * the MODAGAGG surface reflectance for channel VIS, NIR was assigned its _Fillvalue, or * land cover pixel itself was assigned _Fillvalue 255 or 254
254	land cover assigned as perennial salt or inland fresh water
253	land cover assigned as barren, sparse vegetation (rock, tundra, desert.)
252	land cover assigned as perennial snow, ice
251	land cover assigned as "permanent" wetlands/inundated marshlands
250	land cover assigned as urban/built-up
249	land cover assigned as "unclassified" or not able to determine



MODIS LAI July 18, 2016

Also available from <https://earthengine.google.com/>

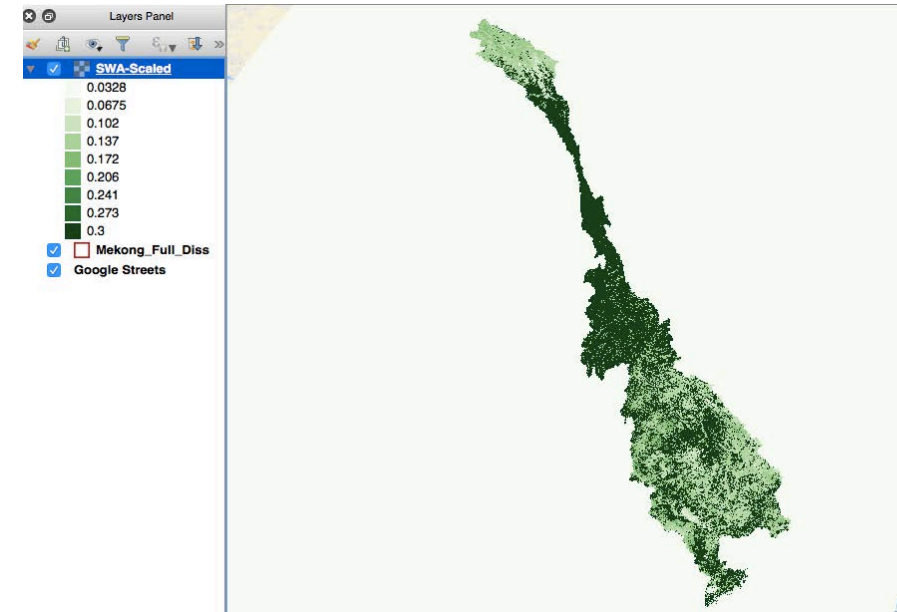


MODIS Albedo

https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd43a3

Science Data Sets for MODIS Terra+Aqua BRDF/Albedo 16-Day L3 Global 500m SIN Grid V005 (MCD43A3):

Science Data Sets (HDF Layers) 20	UNITS	BIT TYPE	FILL	VALID RANGE	MULTIPLY BY SCALE FACTOR
Albedo_BSA_Band_1 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_2 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_3 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_4 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_5 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_6 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_7 (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer 6	32767	0-32766	0.0010
Albedo_BSA_Band_vis (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_nir (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010
Albedo_BSA_Band_shortwave (Black Sky Albedo)	Albedo, no units	16-bit unsigned integer	32767	0-32766	0.0010



MODIS Shortwave Albedo
July 18, 2016



MODIS Data Access Using NASA Earthdata

<https://search.earthdata.nasa.gov/>

Search data by using MODIS Product name

The screenshot displays the NASA Earthdata Search website. At the top, there is a search bar with the placeholder text "Type any topic, collection, or place name". To the right of the search bar are buttons for "Show Tour" and "Earthdata Login". Below the search bar, a map of the Middle East and surrounding regions is visible. On the left side, there is a sidebar menu with categories: "Browse Collections", "Features", "Platforms", "Instruments", "Organizations", "Projects", and "Processing levels". Below the search bar, the results section shows "5502 Matching Collections". There are two checkboxes: "Only include collections with granules" (checked) and "Include non-EOSDIS collections" (checked). A tip says: "Tip: Add + collections to your project to compare and download their data. Learn More". Below this, there are two collection entries:

- Global Maps of Atmospheric Nitrogen Deposition, 1860, 1993, and 2050**
27 Granules • 1860-01-01 to 2050-12-31 • This data set provides global gridded estimates of atmospheric deposition of total inorganic nitrogen (N), NHx (NH3 and NH4+), and NOy (all oxidized forms of nitrogen other than N2O), in mg N/m2/year, for the years 1860 and 1993 and projections for the year 2050. The data set was...
1860_1993_2050_NITROGEN_630 v1 - ORNL_DAAC
- NRT AMSR2 DAILY L3 GLOBAL SNOW WATER EQUIVALENT EASE-GRIDS V0**
29 Granules • 2017-05-22 ongoing • The Advanced Microwave Scanning Radiometer 2 (AMSR2) instrument on the Global Change Observation Mission - Water 1



MODIS Reprojection Tool

https://lpdaac.usgs.gov/tools/modis_reprojection_tool

- MODIS data are available in sinusoidal grids (10°x10° tile) in HDF file format
- To get MODIS data into geographical (WGS84) GeoTIFF format:
 - MODIS Reprojection Tool (MRT)
 - Available from LPDAAC
- NASA Earthdata portal provides reprojection and reformatting for MODIS LAI and albedo
 - land cover data have to be processed using MRT
- A new tool is also available:
<https://newsroom.gsfc.nasa.gov/sdptoolkit/HEG/HEGHome.html>

LP DAAC
LAND PROCESSES DISTRIBUTED ACTIVE ARCHIVE CENTER

Home About Dataset Discovery Citing Our Data **Tools** User Resources User Services Site Search Login with Earthdata

Home > Tools > MODIS Reprojection Tool

MODIS Reprojection Tool

The MODIS tiled Land products are generated by the MODIS Adaptive Processing System (MODAPS), located at the NASA Goddard Space Flight Center, as gridded output in the Sinusoidal (SIN) projection. These data products are then sent to the LP DAAC for archive and distribution.

MRT enables users to read data files in HDF-EOS format (MODIS Level-2G, Level-3, and Level-4 land data products), specify a geographic subset or specific science data sets as input to processing, perform geographic transformation to a different coordinate system/cartographic projection, and write the output to file formats other than HDF-EOS.

The MODIS Reprojection Tool is available for use by all registered users. The MODIS Tool will undergo further development to correct problems as they are detected, incorporate additional functionality, and be modified to enhance computational performance. The funding support for this work comes from the NASA Earth Science Data and Information Systems (ESDIS) Project.

Download
Please log in to download files.

- Linux 32-bit
- Linux 64-bit
- Macintosh OS X (Intel)
- Windows NT+32-bit

Manuals

- MRT User Manual
- MRT Release Notes

Download and Installation
Required



Input Data and Sources

Meteorological
Forcing

Data Parameter	Source
Minimum & Maximum Temperatures Surface Winds	MERRA-2 Model With Assimilated Satellite Observations
Precipitation	Global Precipitation Measurement (GPM) mission - IMERG
Land Cover, LAI and Albedo	Terra and Aqua MODIS
Elevation	Shuttle Radar Topography Mission (SRTM)

MERRA: Modern-Era Retrospective analysis for Research and Application

IMERG: Integrated Multi-satellite Retrievals for GPM

MODIS: Moderate Resolution Imaging Spectroradiometer

See [Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management](#) for more information

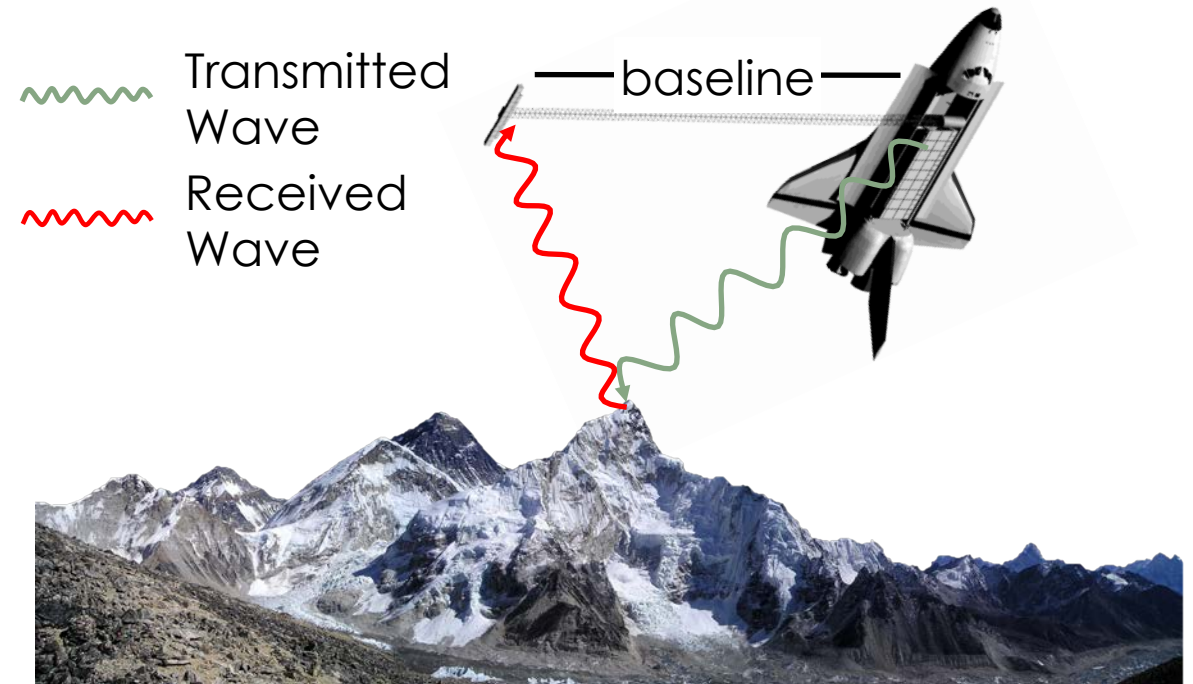


Shuttle Radar Topography Mission (SRTM)

<https://www2.jpl.nasa.gov/srtm/mission.htm>

- A C-band (5.6 cm) radar mission
- On NASA Space Shuttle Endeavour
- Completed February 2000
- 176 orbits around Earth in 11 days
- Acquired digital terrain elevation data of all land between 60°N- 56°S latitude
- ~80% of Earth's total land mass
- SRTM used interferometry to gather topographic (elevation) data
- For detailed information see:
https://arset.gsfc.nasa.gov/sites/default/files/water/Brazil_2017/Day3/S6P2.pdf

Radar signals being transmitted and received on the SRTM mission (not to scale)



Spatial Resolution: 30 m



SRTM Elevation Data Access From Global Data Explorer (GDEx)

<http://gdex.cr.usgs.gov/>

The screenshot displays the Global Data Explorer (GDEx) interface. At the top, there are navigation menus for 'EARTHDATA', 'Data Discovery', 'DAACs', 'Community', and 'Science Disciplines'. The main header features the USGS logo and 'LP DAAC'. A search bar on the right contains 'USGS Home', 'Contact USGS', and 'Search USGS'. The central map shows the United States with a bounding box over the central region. A toolbar at the top of the map includes icons for zooming, panning, and defining regions. Three callout boxes with arrows point to specific icons: 'Zoom' points to the zoom-in icon, 'Define region of interest by bounding box, state, country, or lat/long' points to the bounding box icon, and 'Refresh' points to the refresh icon. A 'Download' callout box points to the download icon. On the right side, the 'Map Layers' panel is visible, showing a list of data layers including 'ASTER Global DEM', 'NASA Blue Marble', 'Data Coverage', 'ASTER Global DEM V2', 'NGA SRTM 1 arcsec', 'NGA SRTM 3 arcsec', 'NASA SRTM 1 arcsec', and 'NASA SRTM 3 arcsec'. The 'Legend' panel at the bottom right shows a map of the United States with a red dashed bounding box.

[Accessibility](#) [FOIA](#) [Privacy](#) [Policies and Notices](#)

U.S. Department of the Interior | U.S. Geological Survey
URL: <https://gdex.cr.usgs.gov/gdex/>
Page Contact Information: LPDAAC@usgs.gov
Page Last Modified: 01/27/2017

[User Guide](#) | [GMU](#) | [CSISS](#) | [About GeoBrain](#) | [Contact](#)



SRTM Elevation Data from CGIAR-CSI

http://csi.cgiar.org/WhtisCGIAR_CSI.asp

CGIAR-CSI: Consultative Group for International Agricultural Research Consortium of Spatial Information

The CGIAR Consortium for Spatial Information (CGIAR-CSI)
Applying GeoSpatial Science for a Sustainable Future...

CGIAR-CSI HOME | SRTM 90m DATABASE HOME | DISCLAIMER | HELP

CGIAR-CSI Content

- Who are CGIAR-CSI ?
- CGIAR-CSI Representatives
- CGIAR-CSI Blog
- CRU Climate Data

SRTM Content

- SRTM Data Search and Download**
- SRTM Data Processing Methodology
- SRTM FAQ
- SRTM Quality Assessment (PDF File - 2.55 Mb)
- About SRTM Imagery
- CIAT Landuse Project
- How to Search for Data?
- Disclaimer
- Contact Us

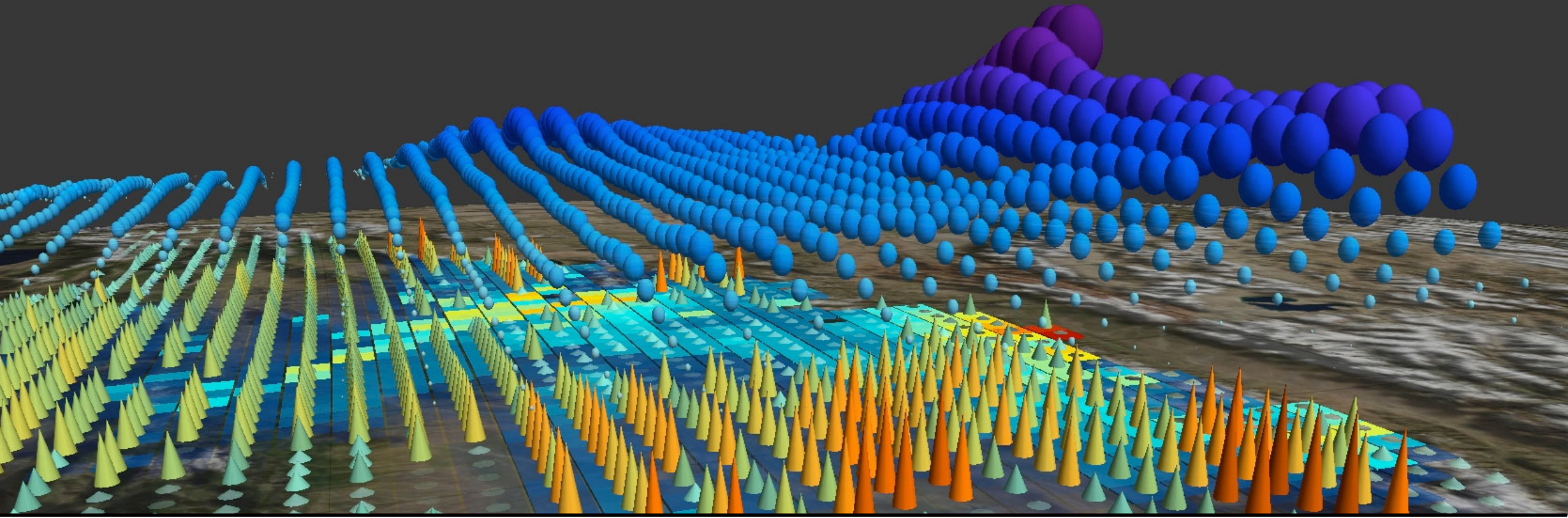
SRTM 90m Digital Elevation Data

Hot Resampled SRTM data to 250m resolutions for the entire globe are available ([Click here](#))

Logos: CGIAR, CIAT, KING'S College LONDON, EUROPEAN COMMISSION Joint Research Centre, ies

A new 250 m composite elevation data from SRTM





Demonstration of Data Access for VIC Simulation for the Mekong Basin

Movie Clips

1. MERRA-2 and IMERG data from GES DISC
2. MODIS Data from Earthdata
3. SRTM from CGIAR



VIC Input: Challenges in Using NASA Earth Observations

- The various input data come from different sources and locations, with different spatial resolutions and formats
 - VIC requires data on the same grids
 - all the data have to be re-gridded at the same resolution
 - VIC requires data at specific temporal resolutions (e.g., meteorological forcing on daily or sub-daily time, land cover on annual time, annual mean precipitation)
 - VIC requires minimum 1-year of spin-up time
 - Data have to be rearranged in VIC-compatible format so that at each grid point, the entire time series of all the inputs are available (Week-3)
- ➔ Extensive pre-processing and computer programming scripts are required for data handling and formatting



VIC Inputs: Advantaged In Using NASA Earth Observations

- Provide spatially continuous data coverage, important for estimating accurate water budget components
- Provide data where no other surface-based data are available
- Data are available from direct satellite observations and also from satellite-assimilated Earth system models
- Open source data are available on historical (> 15 years) and near real-time scales
- Web-based tools available for
 - spatial and temporal sub-setting
 - format conversion
- Trainings about data and data access are available from ARSET and other NASA Data Centers





Thank you!

Next Week: Overview of VIC Implementation
for a River Basin [Mekong Basin Case Study]