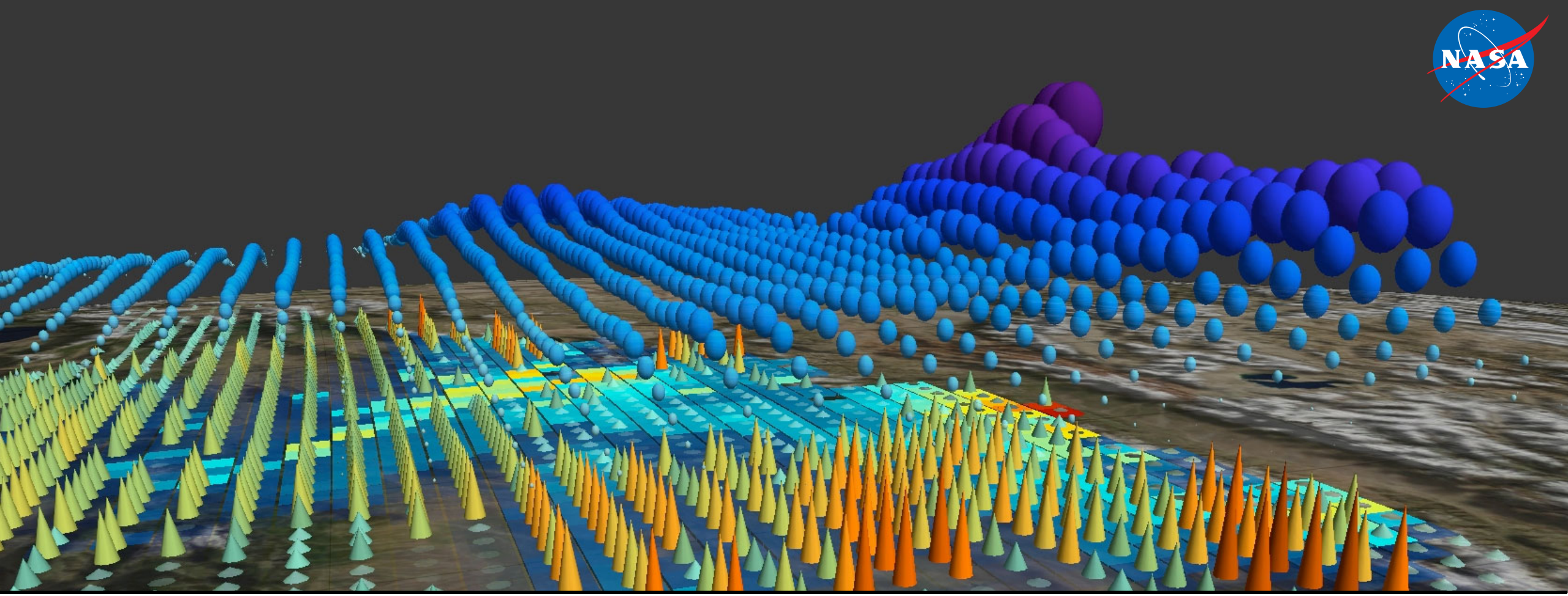


Introduction to Using the VIC Model with NASA Earth Observations

Amita Mehta & Kel Markert (SERVIR Global)

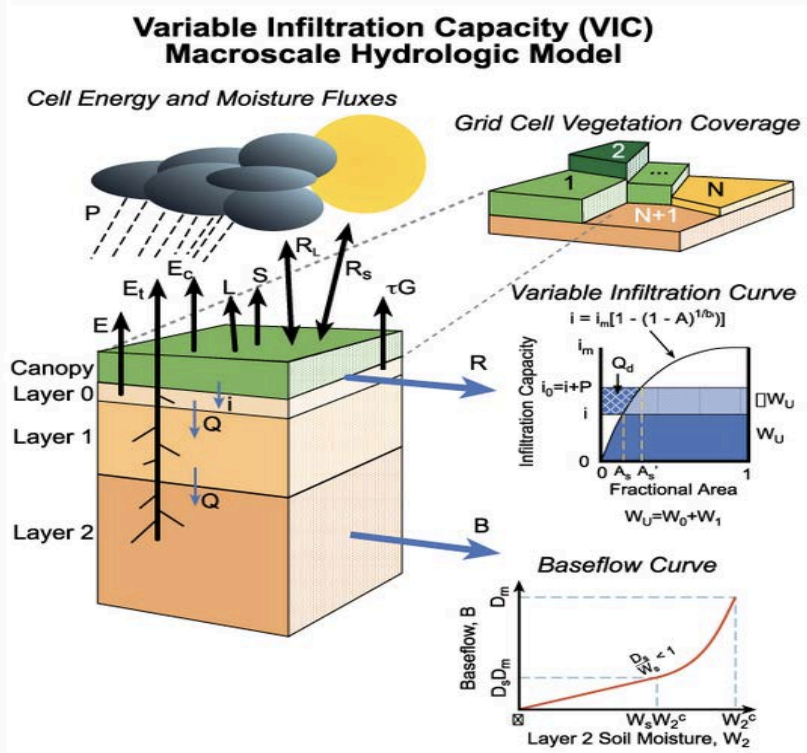
February 15, 22, and March 1, 2018

Image Credit: AralDIF, University of Washington

Training Outline

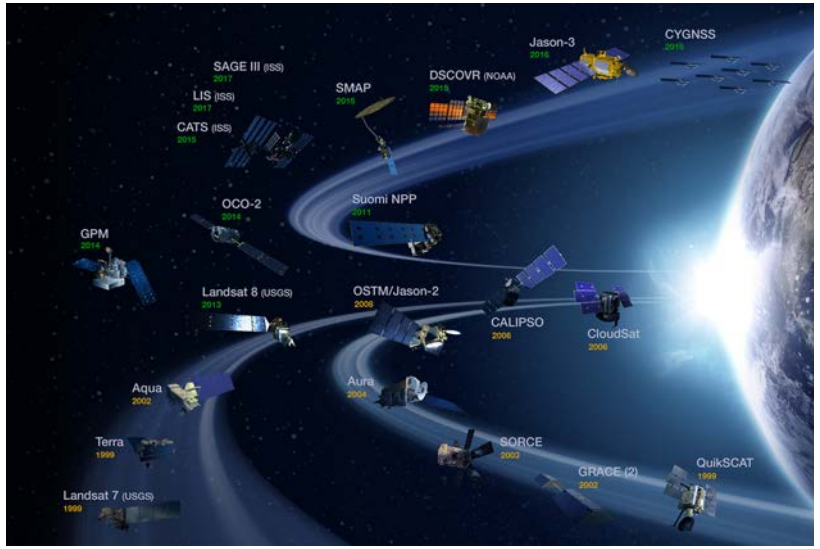
Three Sessions, 09:00-10:00 or 18:00-19:00 EST (UTC-5)

Session 1: Feb 15, 2018



Introduction to the VIC Hydrological Model

Session 2: Feb 22, 2018



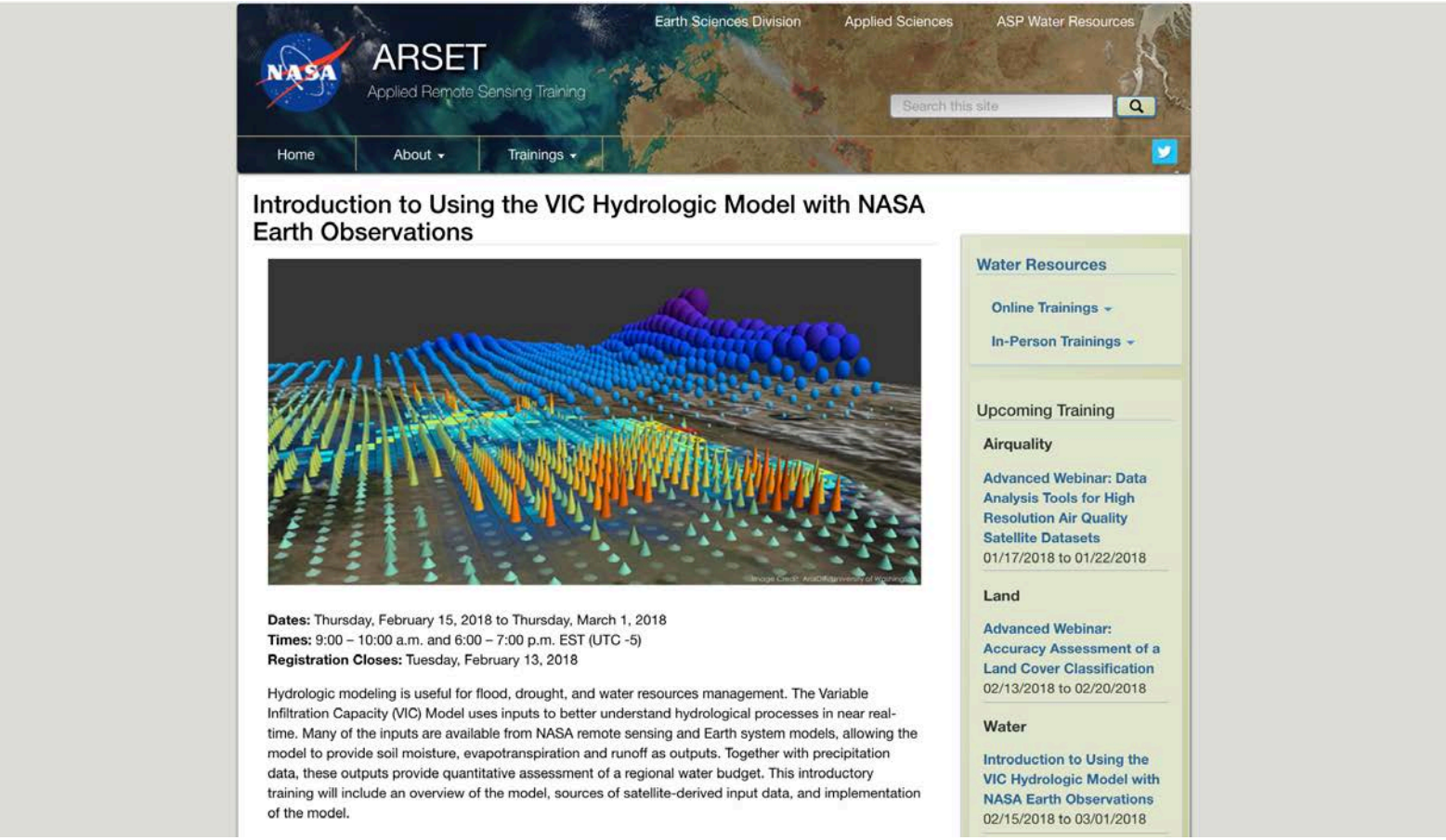
Overview of Remote Sensing-Based Input Data for VIC

Session 3: Mar 1, 2018

Overview of VIC Implementation for a River Basin

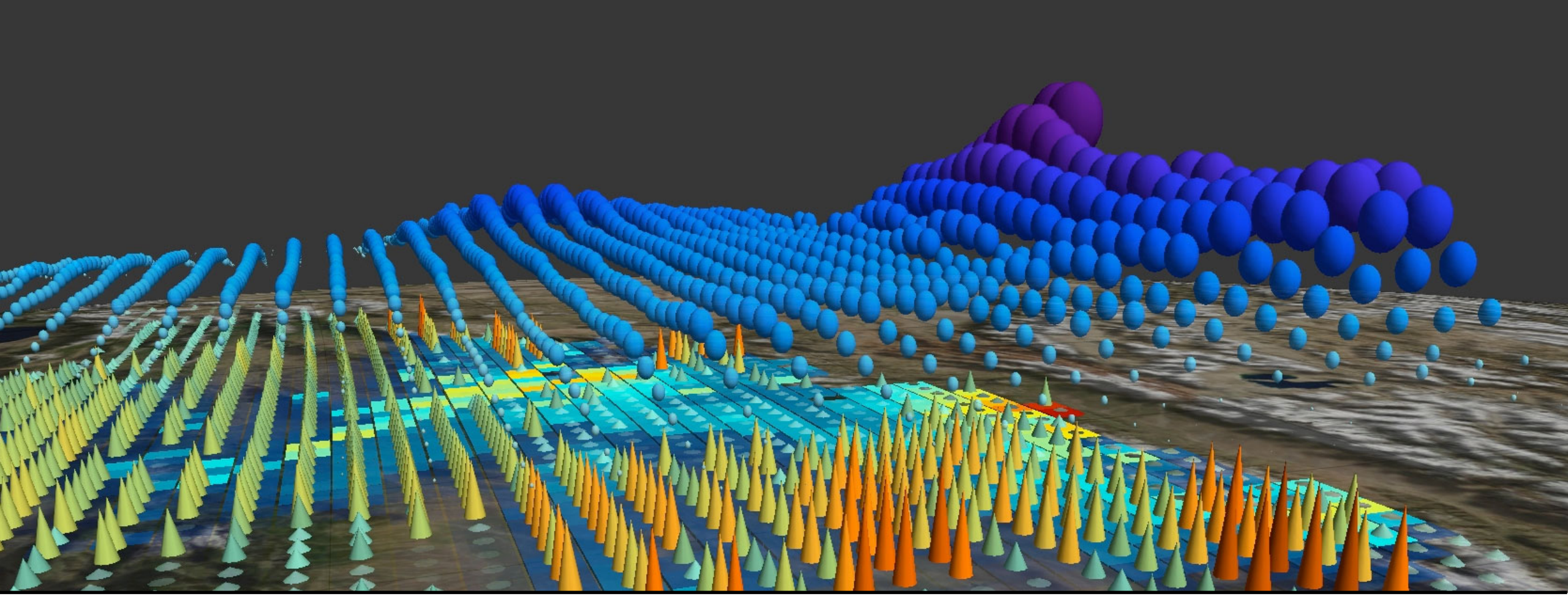
Course Material

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



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

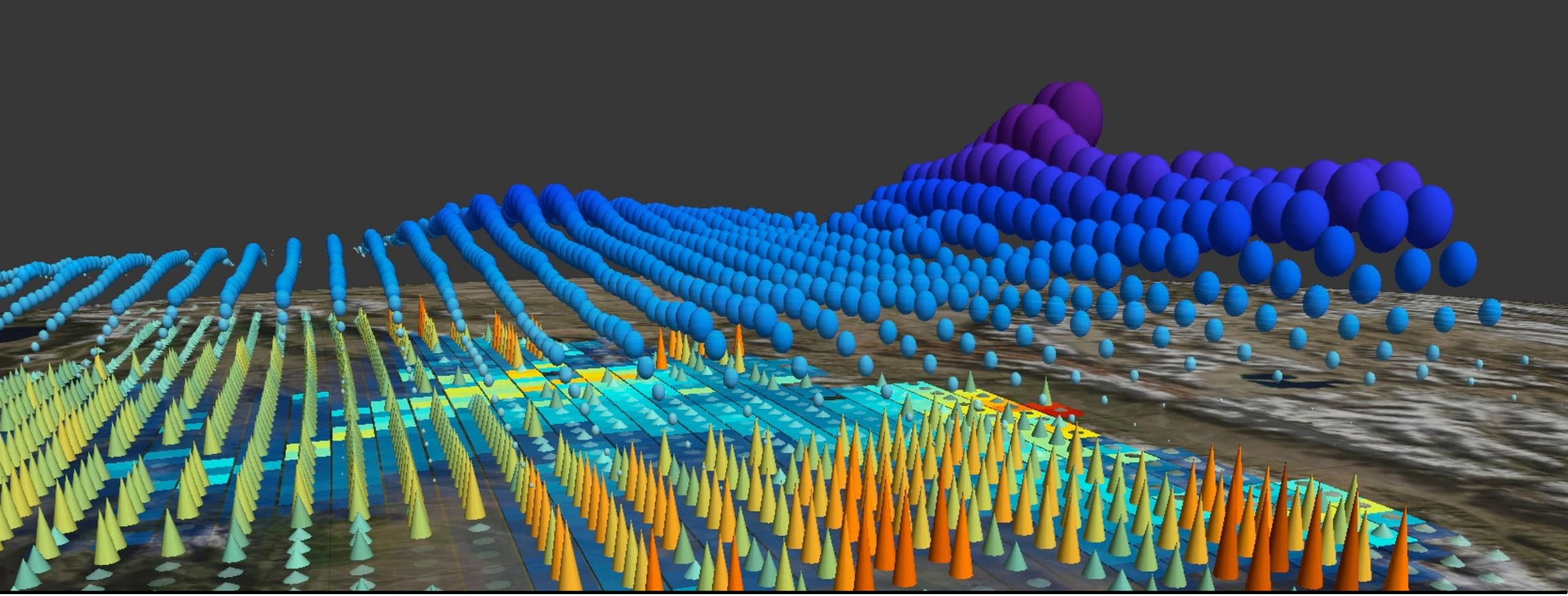


Overview of Remote Sensing-Based Input Data for VIC

Image Credit: AralDIF, University of Washington

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

Image Credit: AralDIF, University of Washington

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/

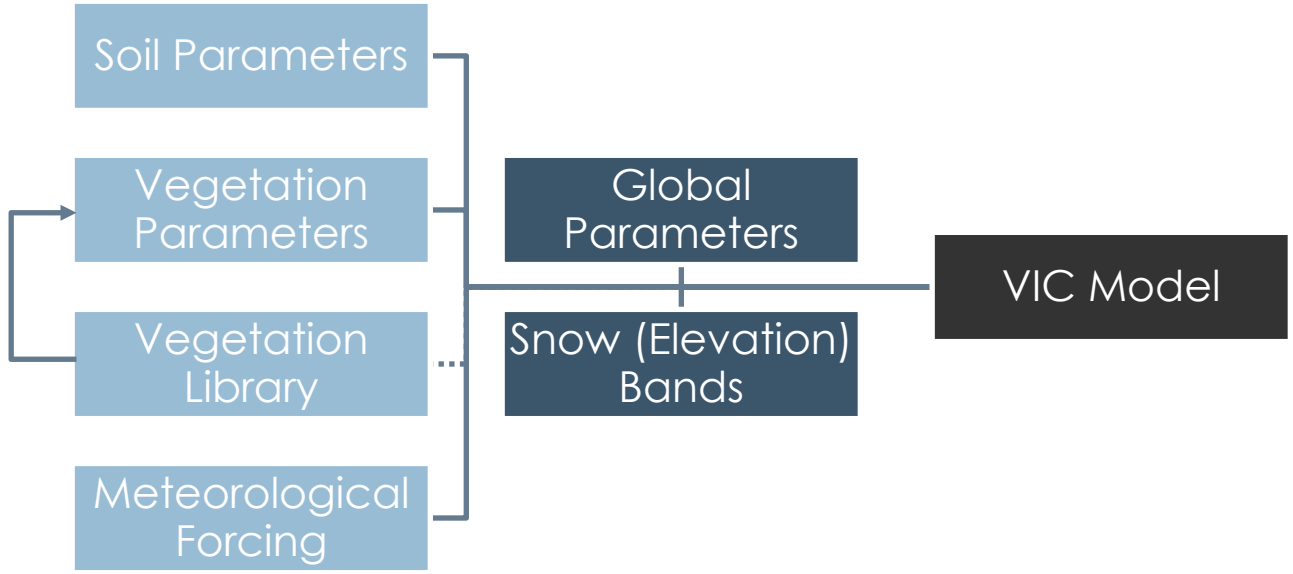
- VIC model source code modules are available at:
  - https://github.com/UW-Hydro/VIC/tree/master/vic/drivers/classic/src

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
STARTHOUR   00  # hour model simulation starts
ENDYEAR     2000    # year model simulation ends
ENDMONTH    12  # month 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 shoula
# 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	infilt	N/A	1	Variable infiltration curve parameter (binfilt)
6	Ds	fraction	1	Fraction of Dsmax where non-linear baseflow begins
7	Dsmax	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 : (Nlayer+9)	expt	N/A	Nlayer	Exponent n (`=3+2/lambda`) in Campbell's eqn for hydraulic conductivity, HBH 5.6 (where lambda = soil pore size distribution parameter). Values should be `> 3.0.`
(Nlayer+10): (2*Nlayer+9)	Ksat	mm/day	Nlayer	Saturated hydrologic conductivity
(2*Nlayer+10): (3*Nlayer+9)	phi_s	mm/mm	Nlayer	Soil moisture diffusion parameter
(3*Nlayer+10): (4*Nlayer+9)	init_moist	mm	Nlayer	Initial layer moisture content
(4*Nlayer+10)	elev	m	1	Average elevation of grid cell
(4*Nlayer+11): (5*Nlayer+10)	depth	m	Nlayer	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/

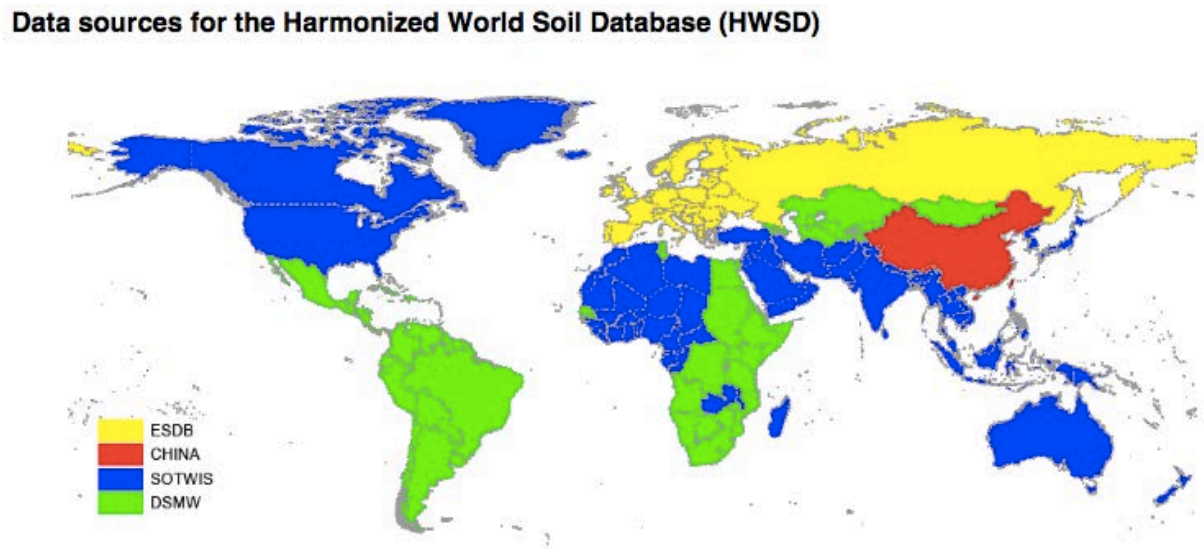
- Available from Harmonized World Soil Database (HWSD)
- Worldwide characterization of soil parameters
  - organic Carbon, pH, water storage capacity, soil depth, cation exchange capacity of the soil and the clay fraction, total exchangeable nutrients, lime and gypsum contents, sodium exchange percentage, 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

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



- 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
veg_class	N/A	Vegetation class identification number (reference index to vegetation library) *NOTE 1*: 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. *NOTE 2*: 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/

Suppliments 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

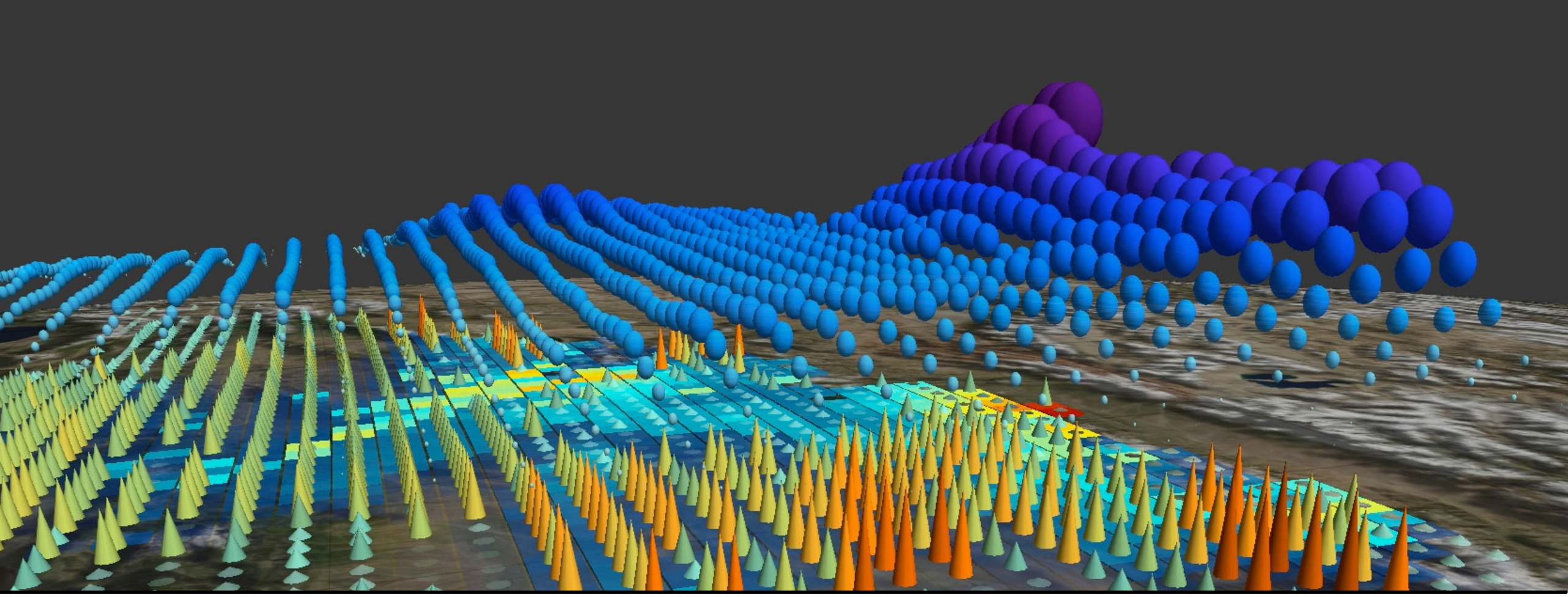
Elevation Data

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

Image Credit: AralDIF, University of Washington

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

Input Data and Sources

	Data Parameter	Source
Meteorological Forcing	Minimum & Maximum Temperatures Surface Winds	**MERRA-2** Model With Assimilated Satellite Observations
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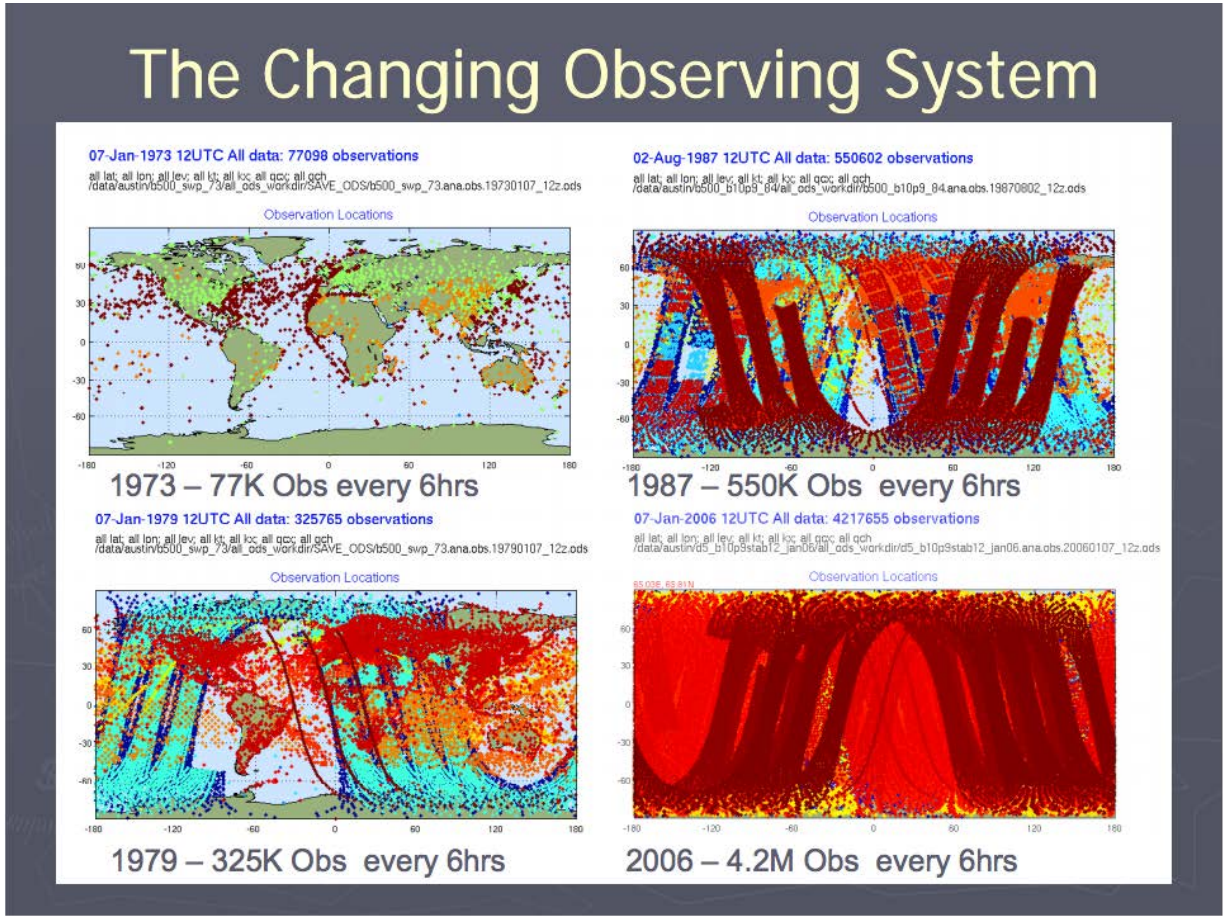
About MERRA-2

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



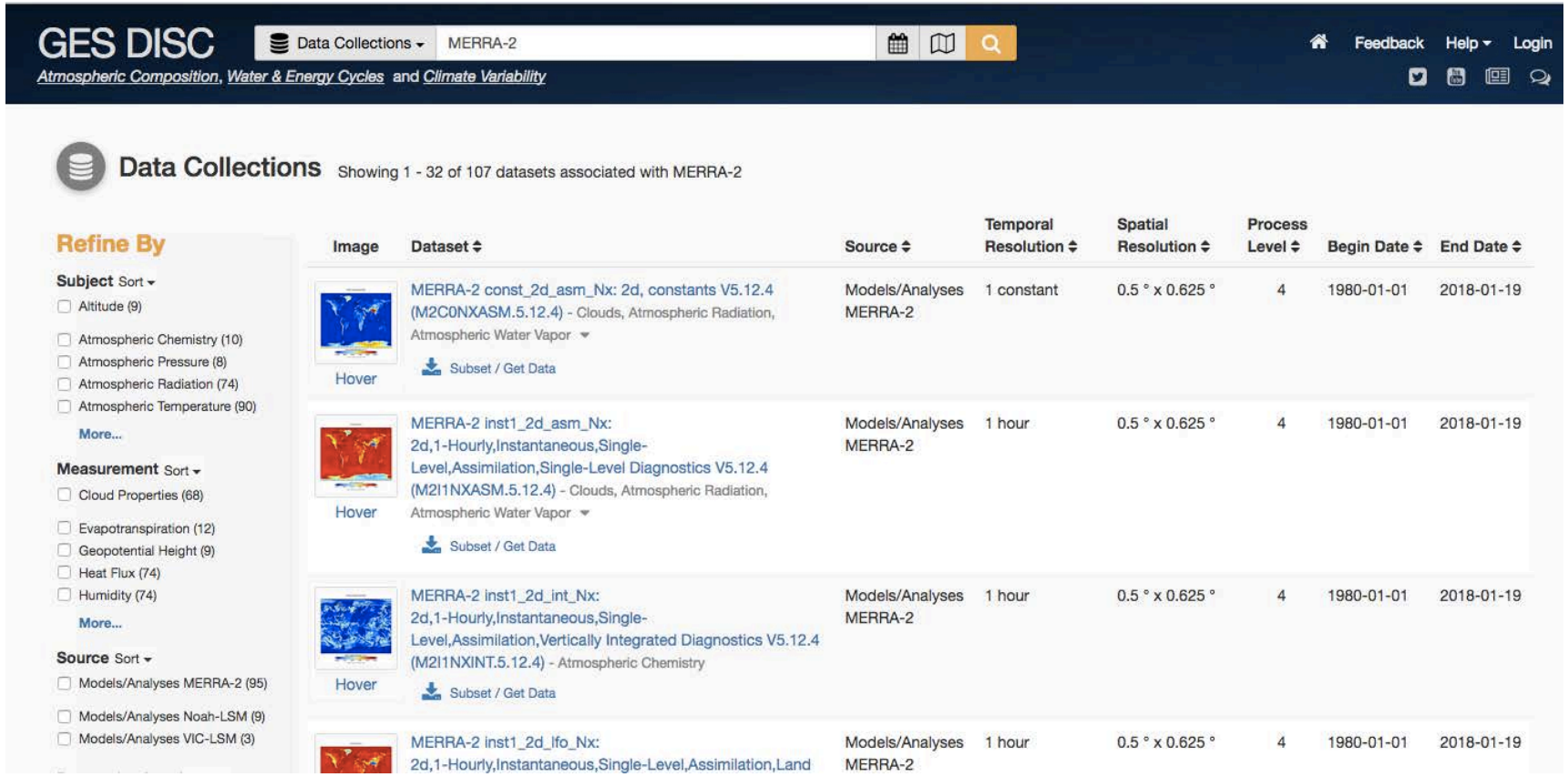
Coverage of satellite data assimilated in MERRA

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



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 5/8x1/2 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

For ; +2-meter Winds, *2-meter Min/Max Temperatures

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**
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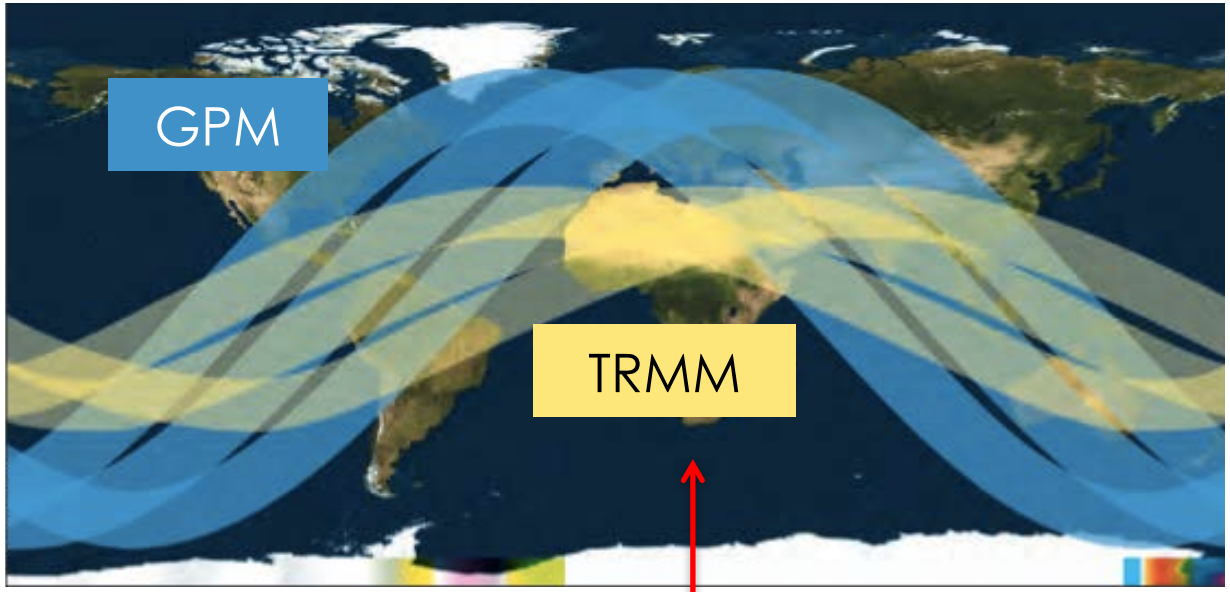
See *Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management* for more information

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

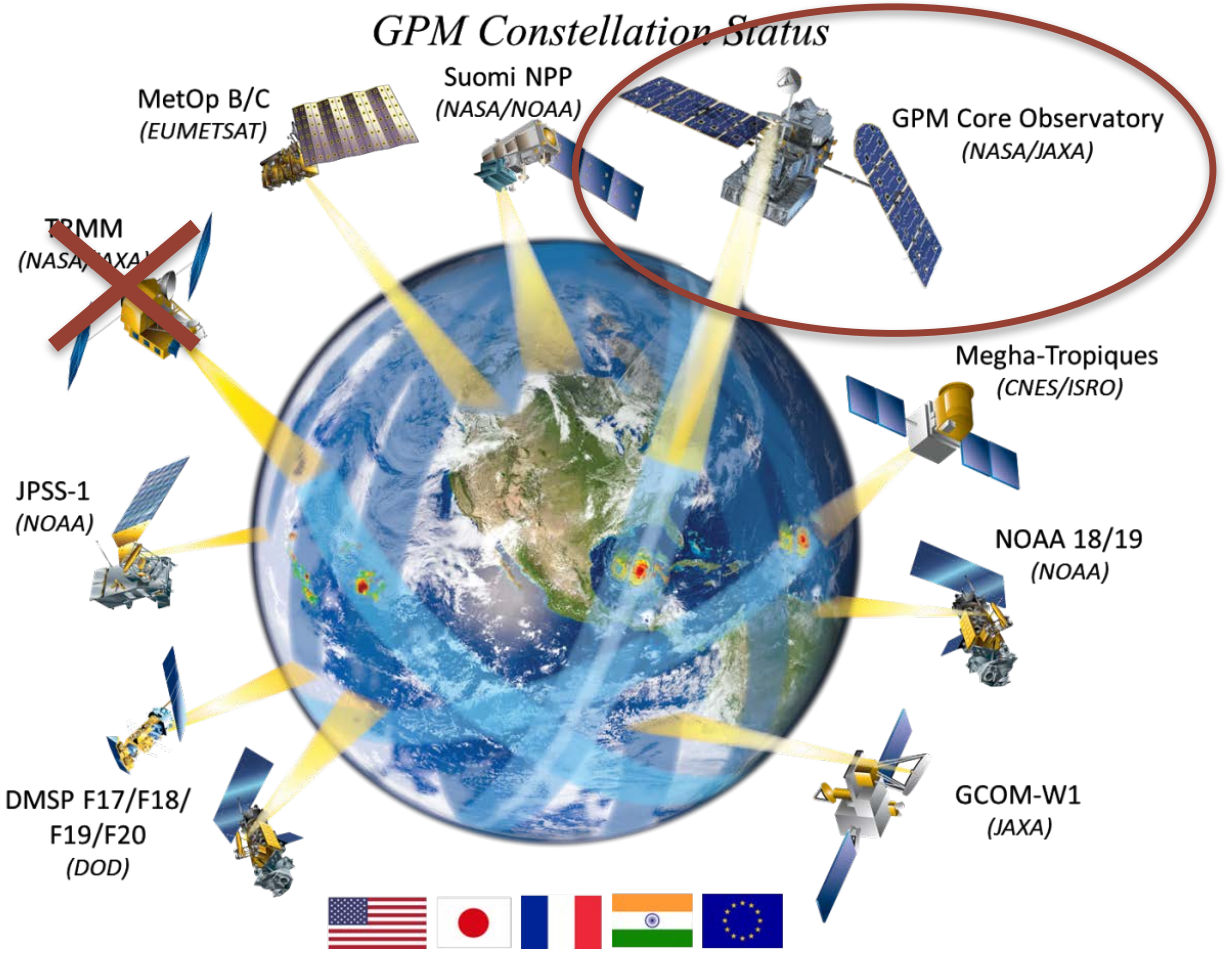


Tropical Rainfall Measurement Mission

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



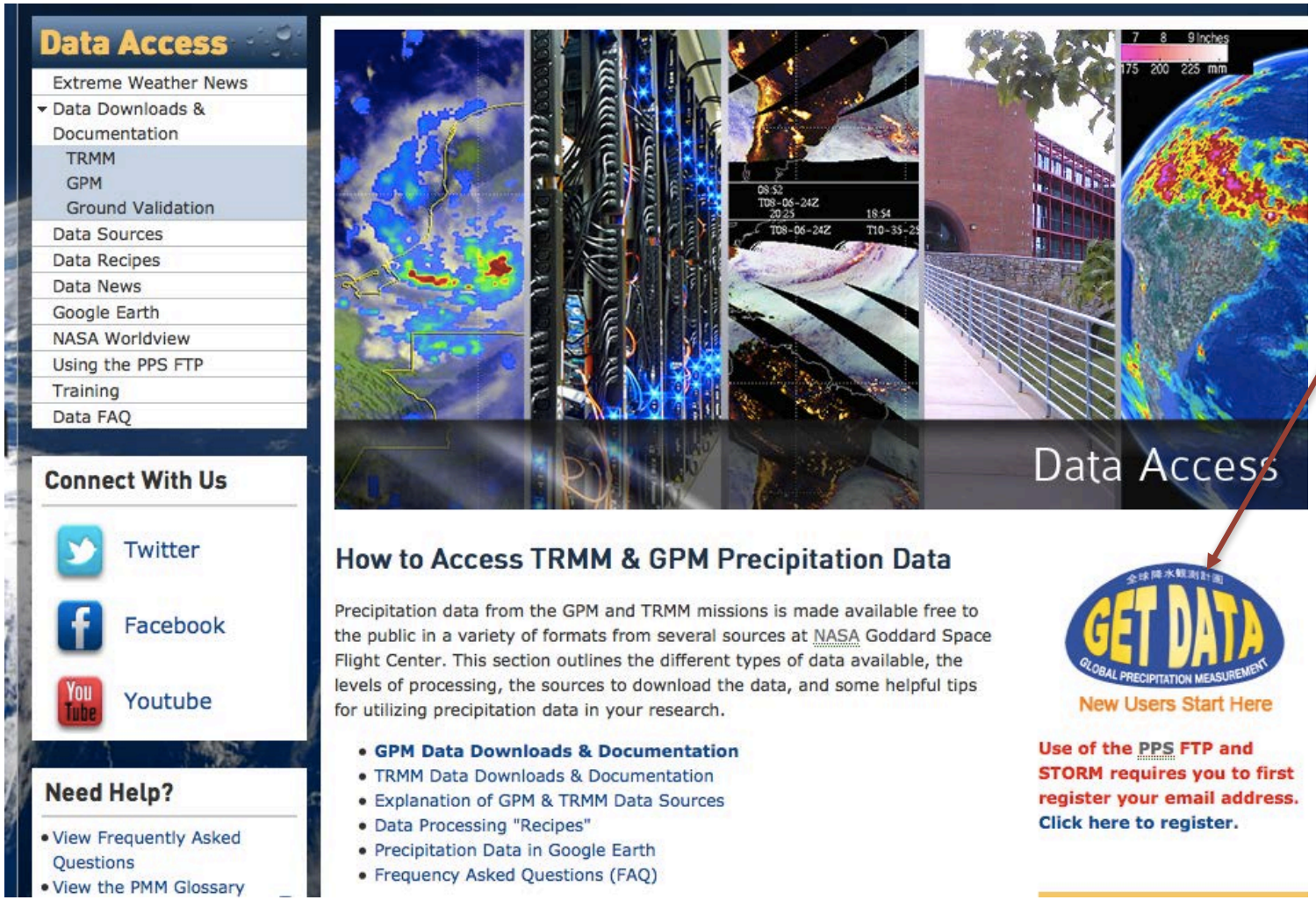
Integrated Multi-satellitE Retrievals for GPM (IMERG)

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

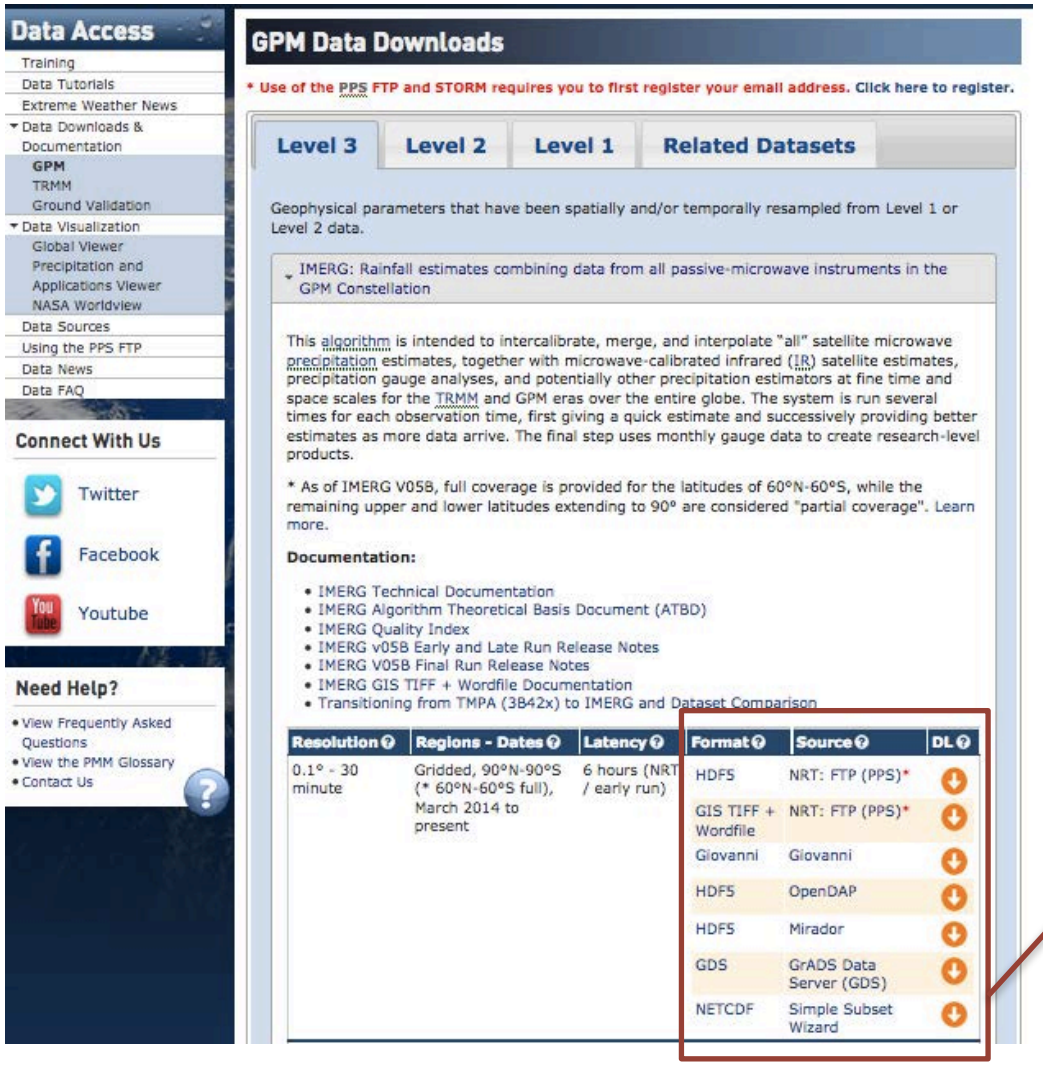
https://pmm.nasa.gov/data-access

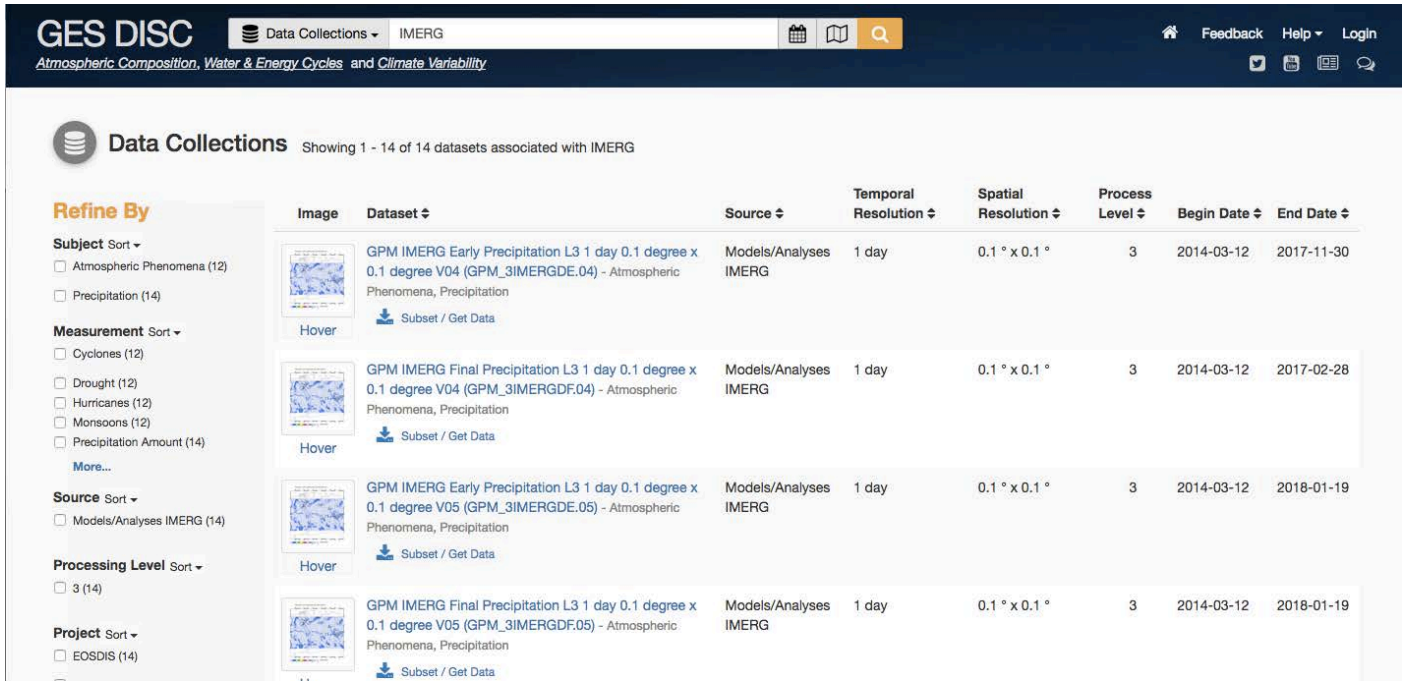


- All about GPM data
  - Including updates, news, and FAQ
- Quick data access links and user registration
- For more information about GPM and about data access visit: https://pmm.nasa.gov/training

IMERG Data Access

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

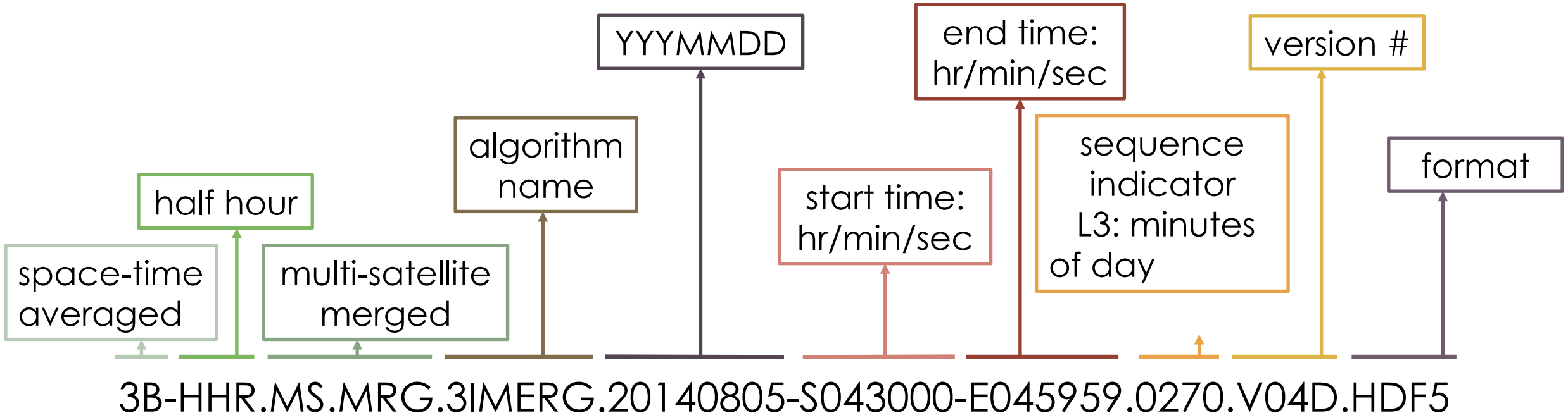




https://disc.sci.gsfc.nasa.gov/datasets?page=1&keywords=IMERG

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**
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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

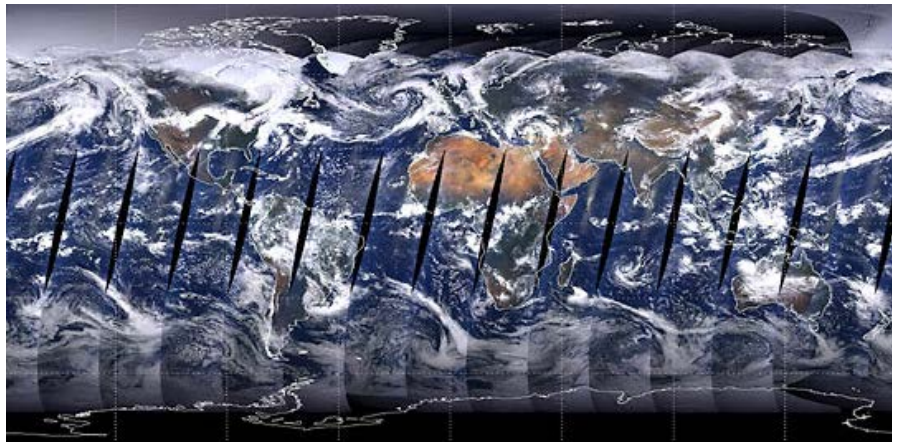
http://aqua.nasa.gov/

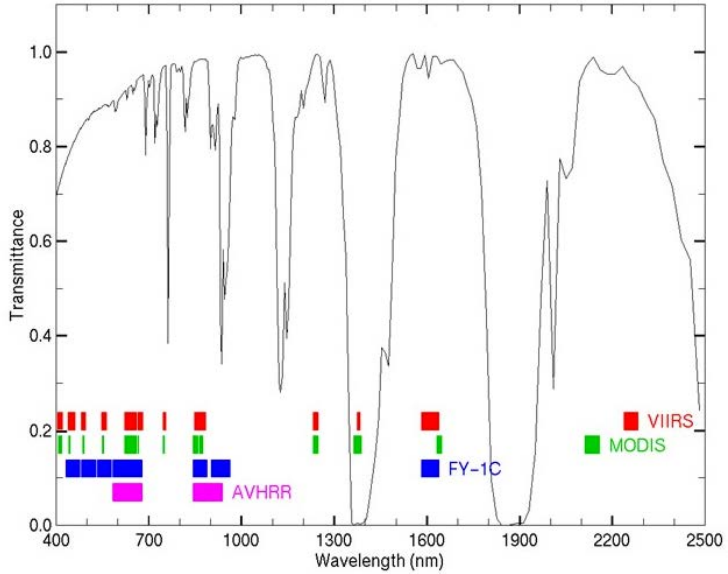
- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day

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
  - Hierarchal 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	MCD12QI	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

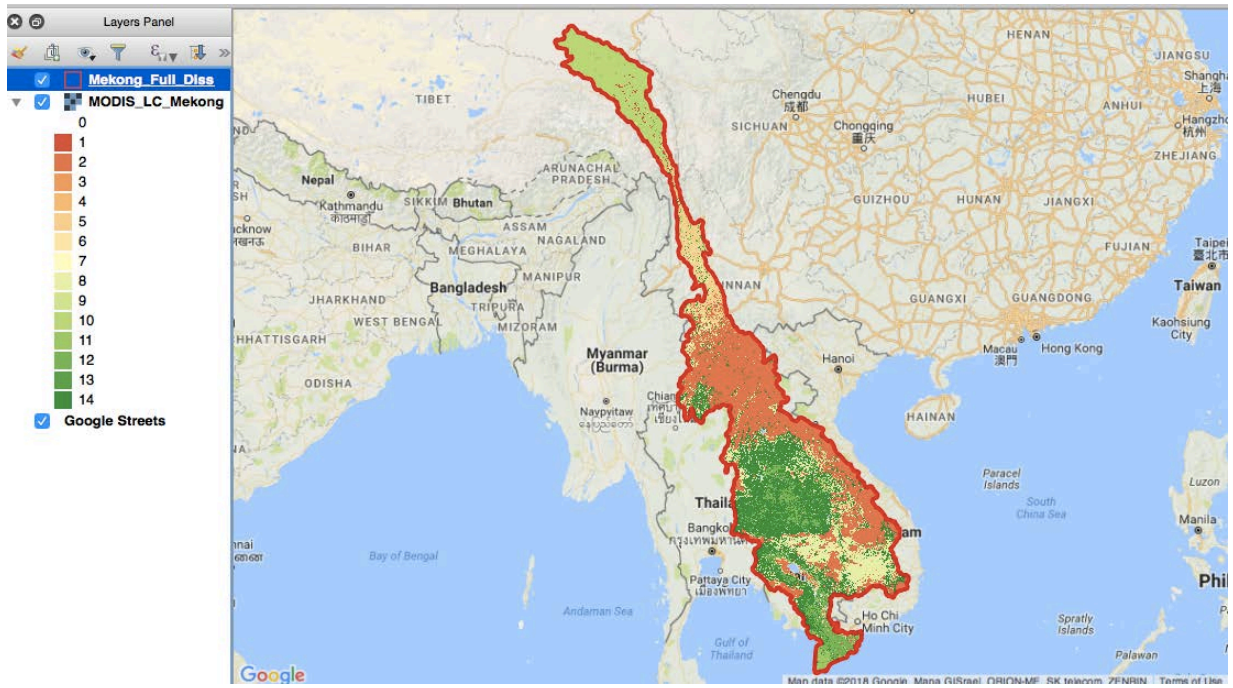
https://modis.gsfc.nasa.gov/data/dataprod/mod12.php

MODIS IGBP Land Cover Classes

Class	IGBP (Type 1)
0	Water
1	Evergreen Needleleaf forest
2	Evergreen Broadleaf forest
3	Deciduous Needleleaf forest
4	Deciduous Broadleaf forest
5	Mixed forest
6	Closed shrublands
7	Open shrublands

Class	IGBP (Type 1)
8	Woody savannas
9	Savannas
10	Grasslands
11	Permanent wetlands
12	Croplands
13	Urban and built-up
14	Cropland/Natural vegetation mosaic
15	Snow and ice
16	Barren or sparsely vegetated

MODIS IGBP Land Cover in the Mekong Basin

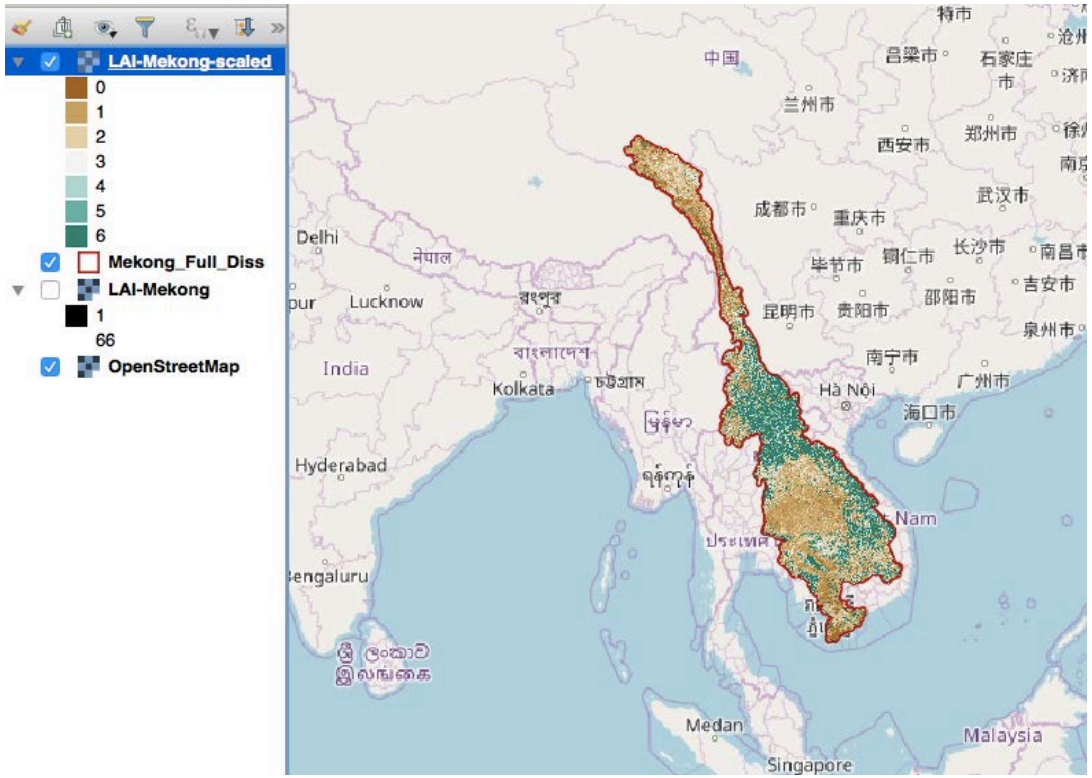


MODIS LAI

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: * 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

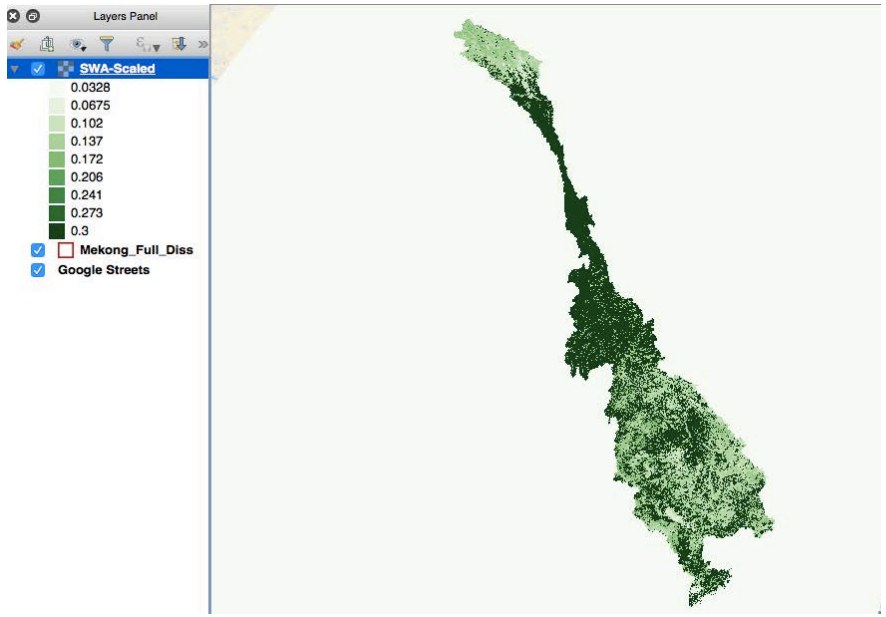
Also available from https://earthengine.google.com/

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

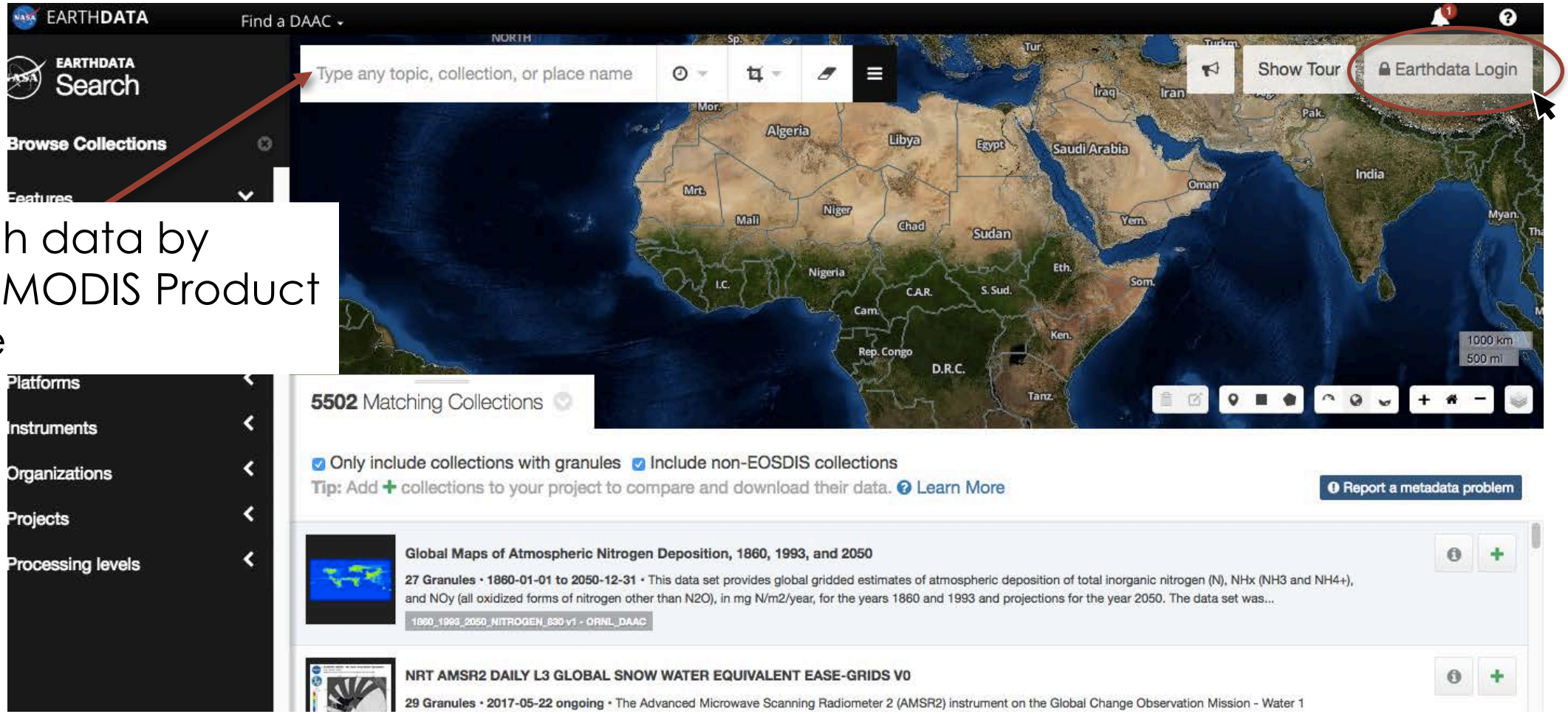


MODIS Shortwave Albedo
July 18, 2016

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

MODIS Data Access Using NASA Earthdata

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

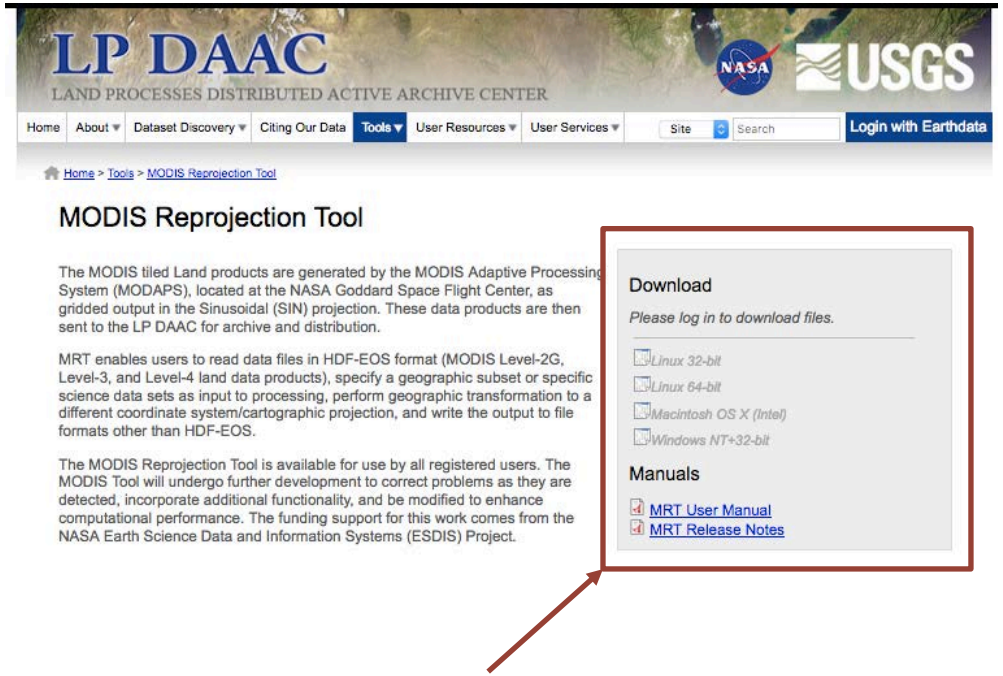


Search data by using MODIS Product name

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



Download and Installation Required

Input Data and Sources

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**)

Meteorological Forcing

MERRA: Modern-Era Retrospective analysis for Research and Application
IMERG: Integrated Multi-satellitE Retrievals for GPM
MODIS: MOderate Resolution Imaging Specroradiometer

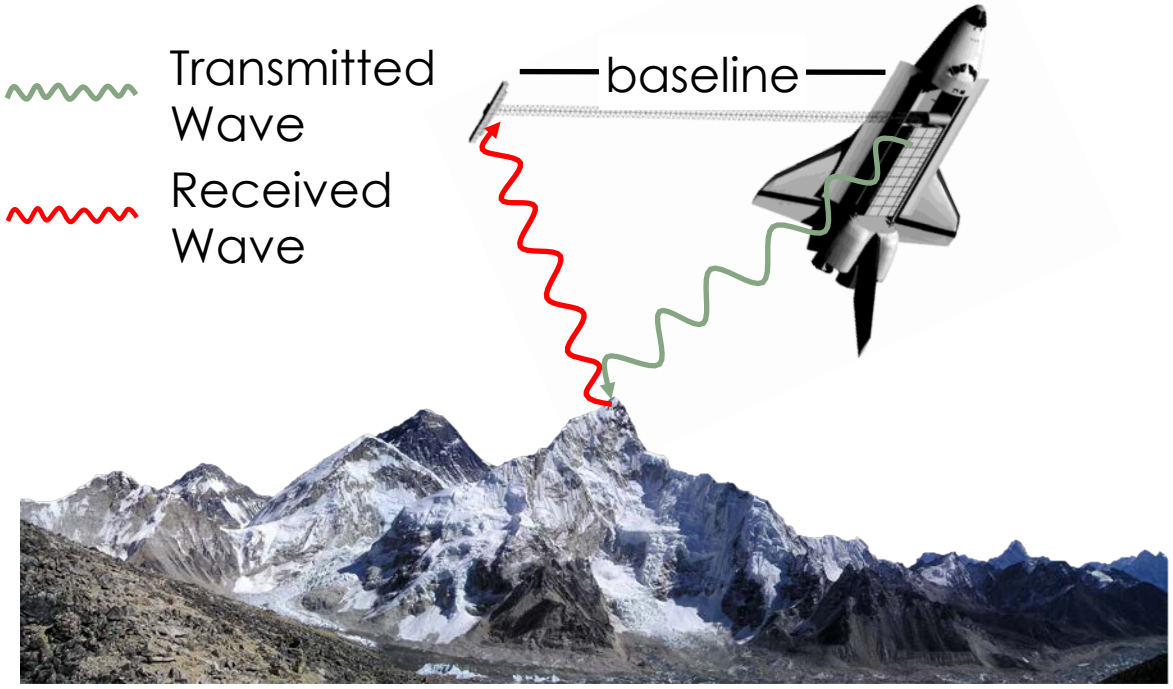
See *Session 2B: Satellites, Sensors, and Earth Systems Models for Water Resources Management* for more information

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

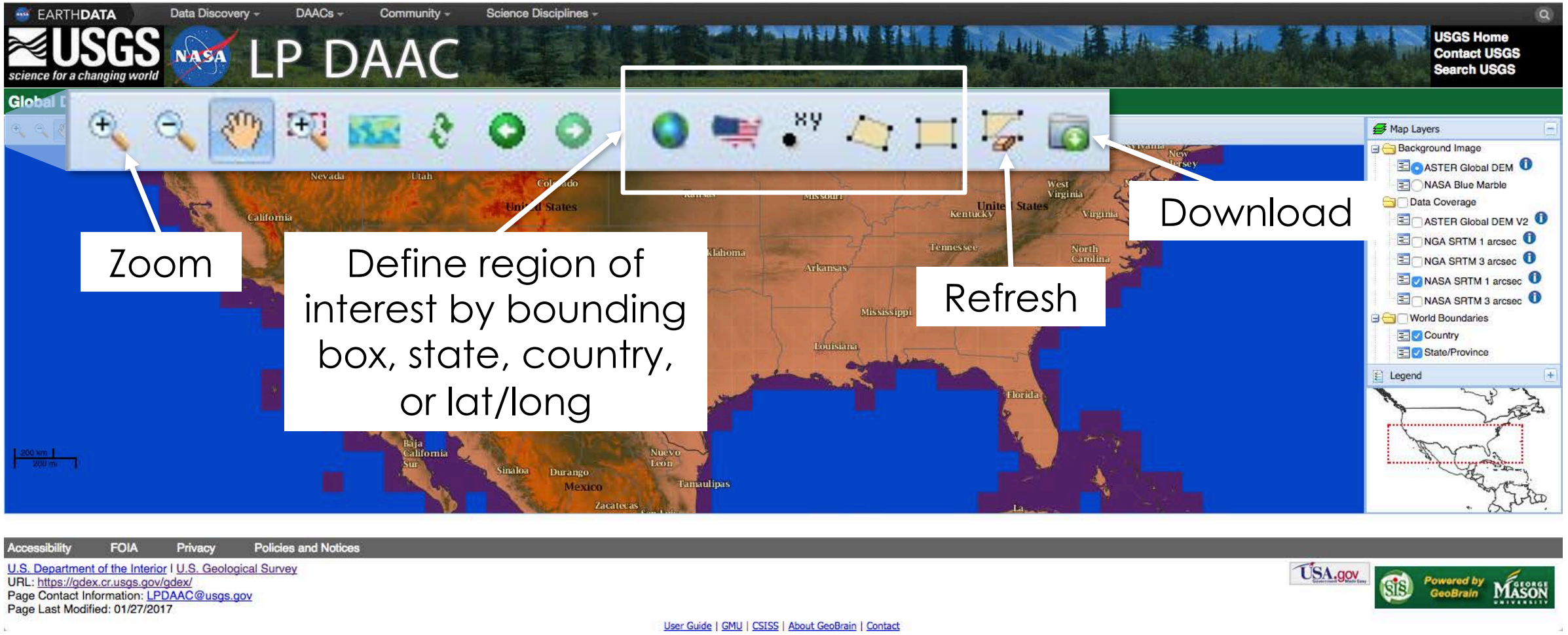
Radar signals being transmitted and received on the SRTM mission (not to scale)



Spatial Resolution: 30 m

SRTM Elevation Data Access From Global Data Explorer (GDEx)

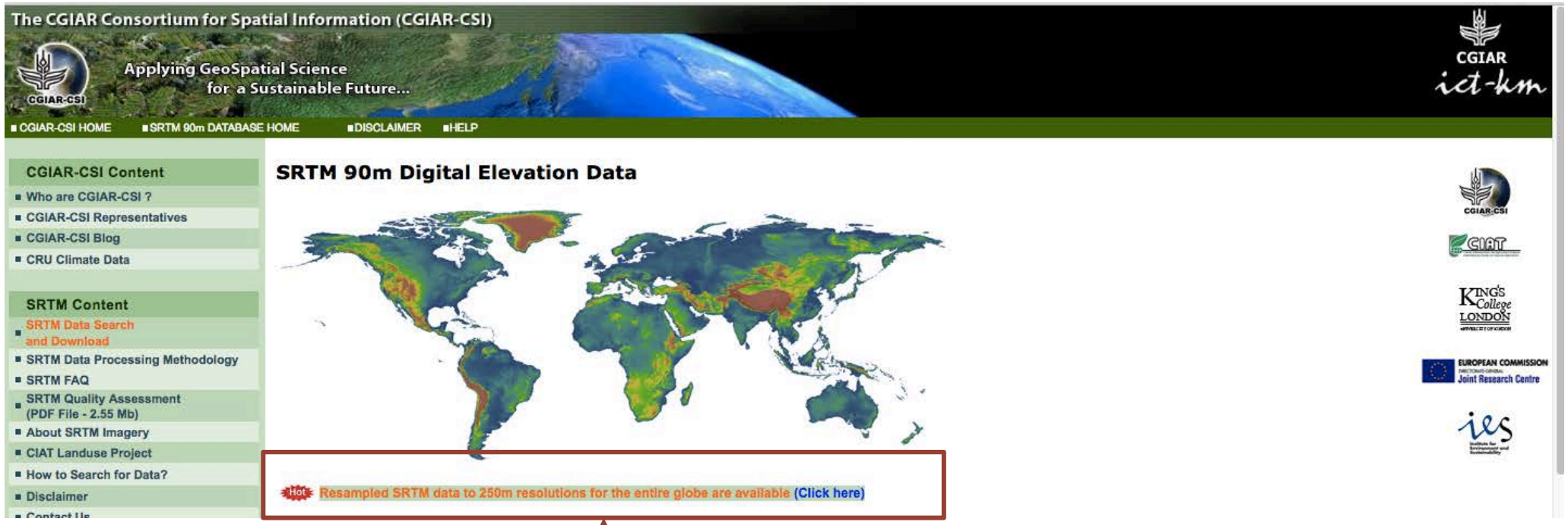
http://gdex.cr.usgs.gov/



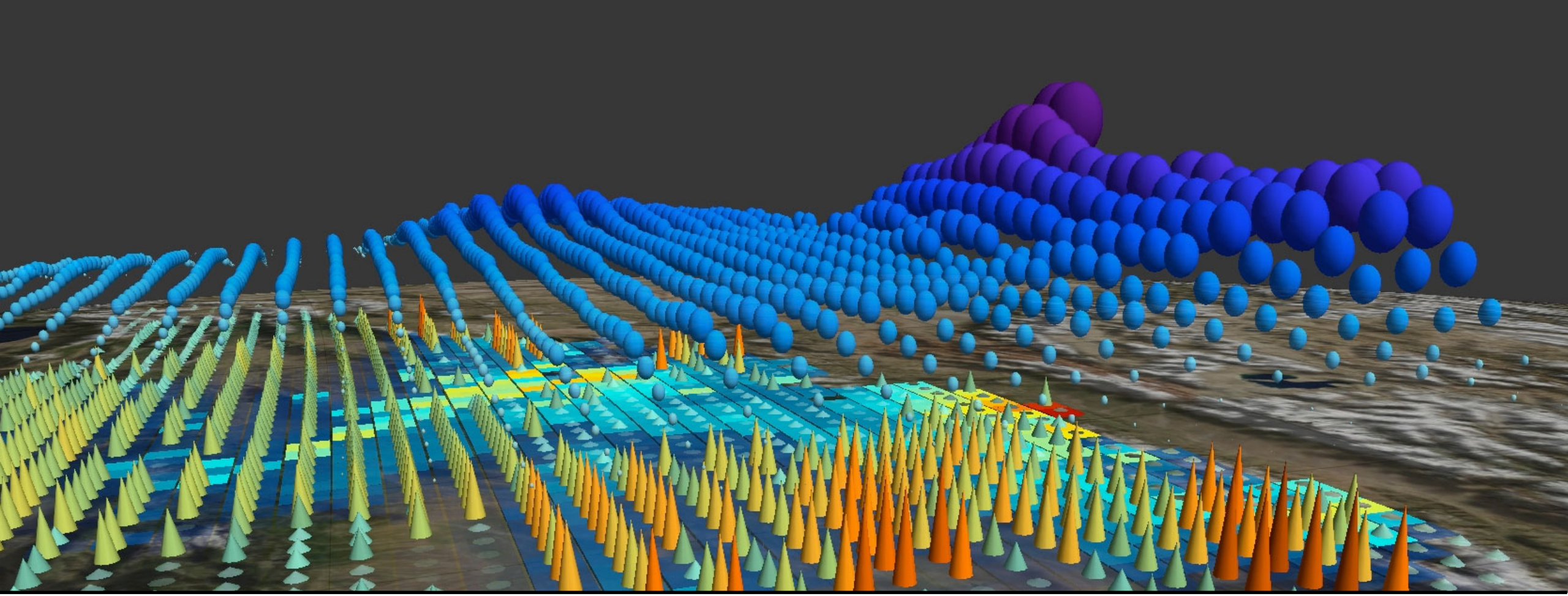
SRTM Elevation Data from CGIAR-CSI

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

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



A new 250 m composite elevation data from SRTM



Demonstration of Data Access for VIC Simulation for the Mekong Basin

Image Credit: AralDIF, University of Washington

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]