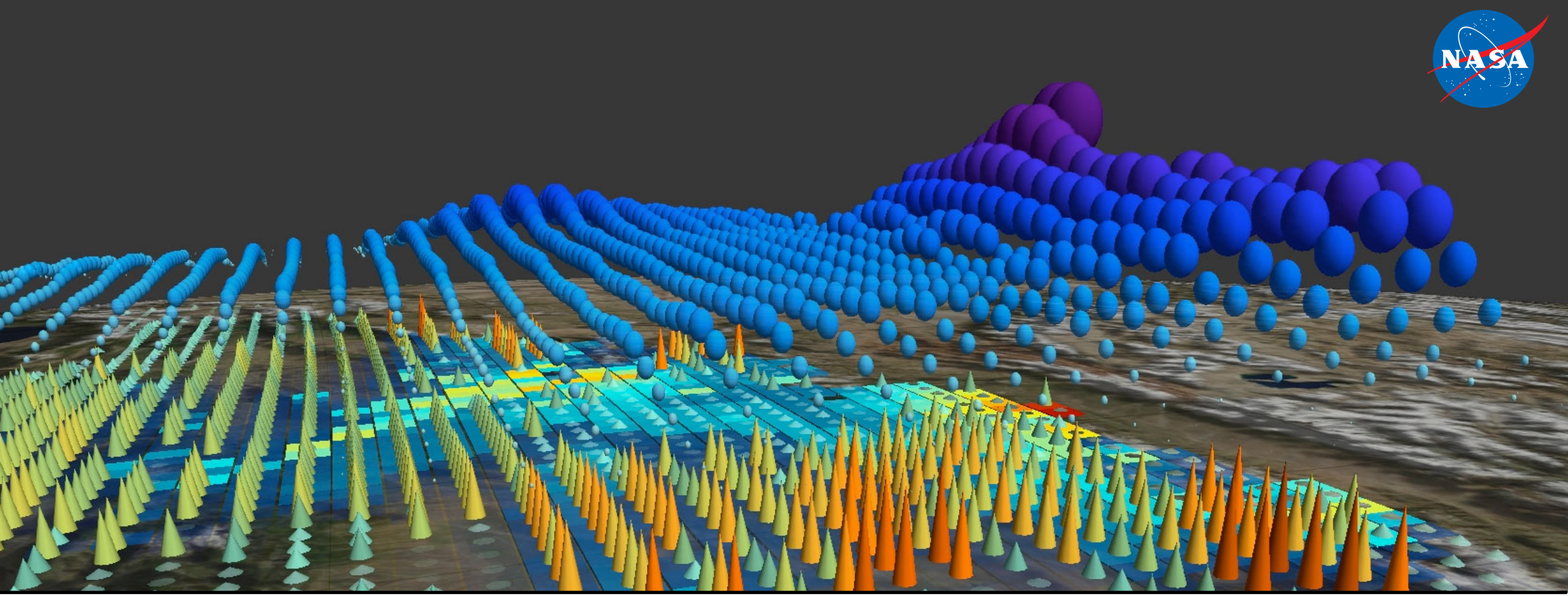


Introduction to Using the VIC Model with NASA Earth Observations

Amita Mehta & Kel Markert (SERVIR Global)

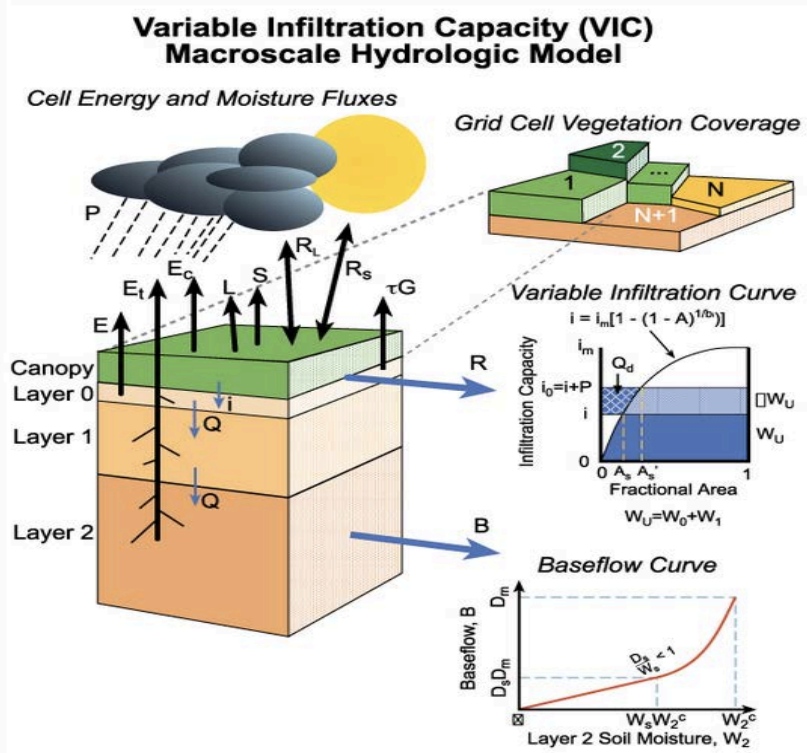
February 15, 22, and March 1, 2018

Image Credit: AralDIF, University of Washington

Training Outline

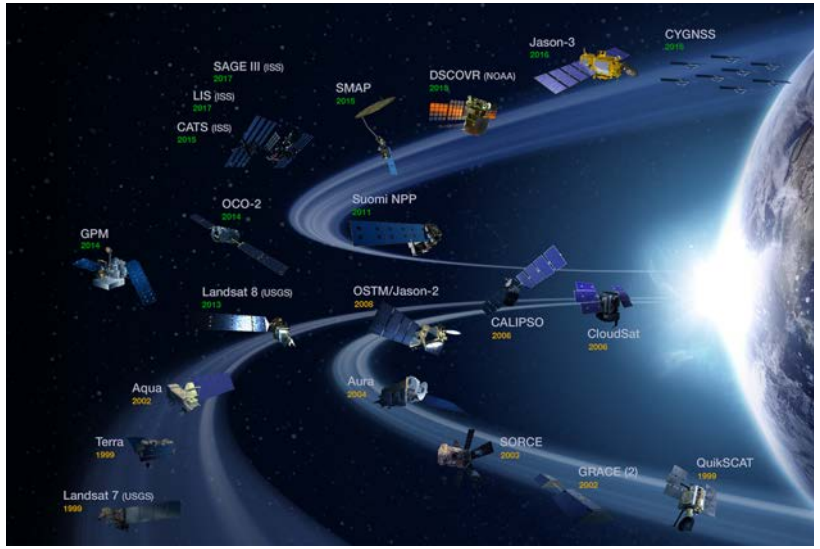
Three Sessions, 09:00-10:00 or 18:00-19:00 EST (UTC-5)

Session 1: Feb 15, 2018



Introduction to the VIC Hydrological Model

Session 2: Feb 22, 2018



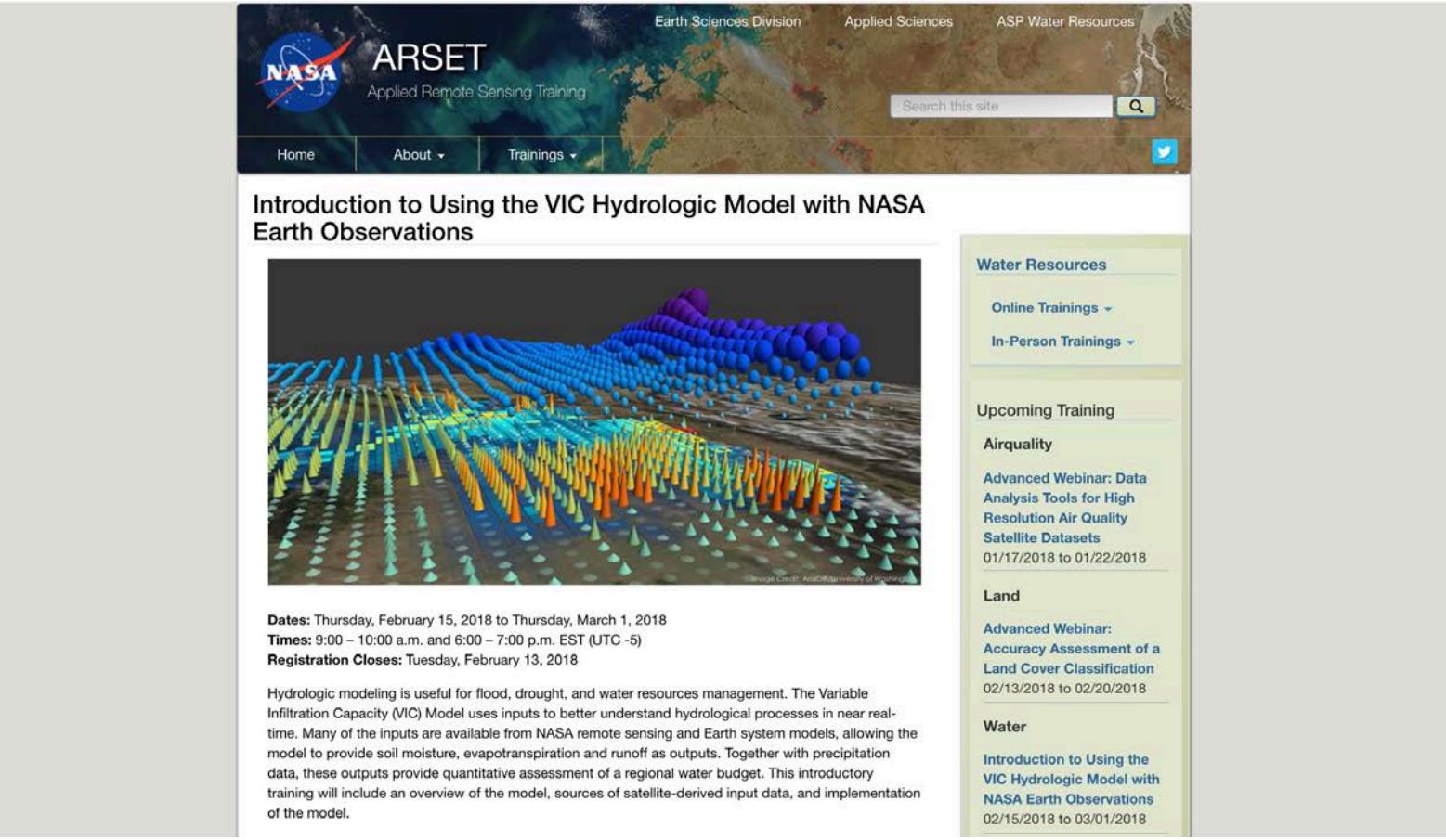
Overview of Remote Sensing-Based Input Data for VIC

Session 3: Mar 1, 2018

Overview of VIC Implementation for a River Basin

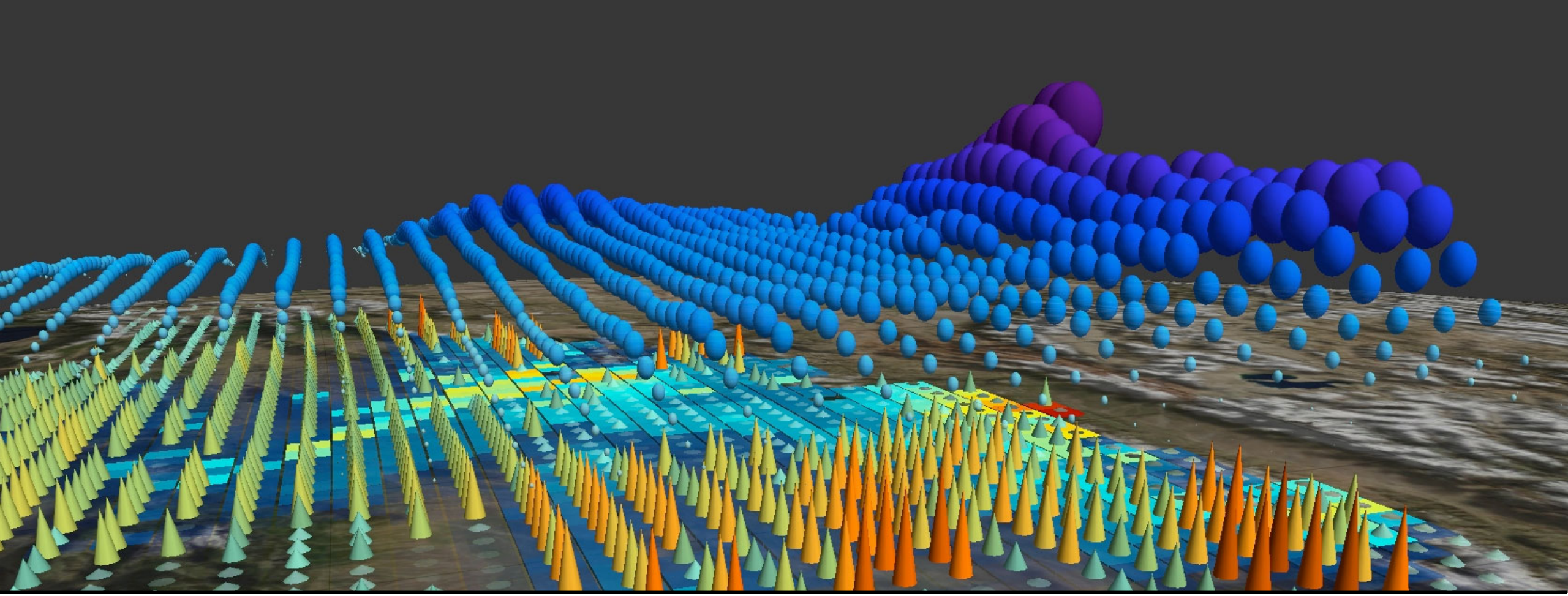
Course Material

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

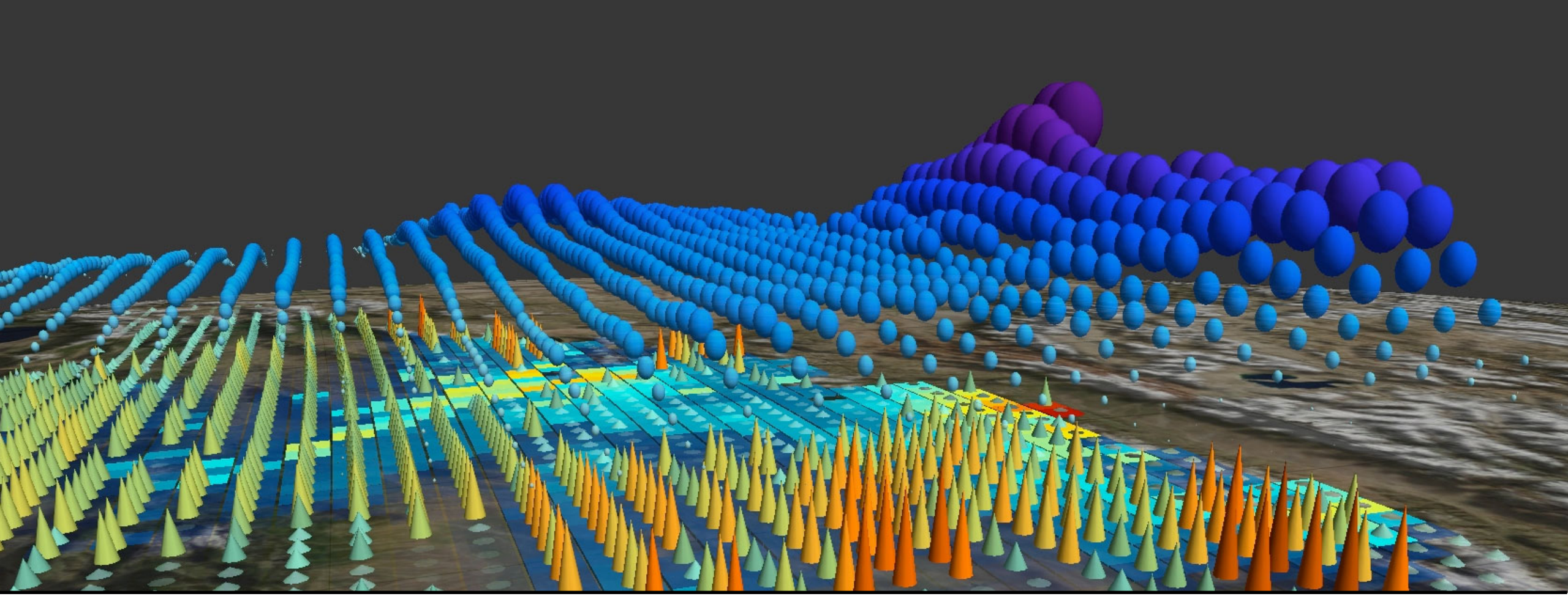


Overview of VIC Implementation for a River Basin
Example: The Mekong River Basin

Image Credit: AralDIF, University of Washington

Session 3 Outline

- VIC Input Data Formatting
- VIC Simulation and Output Analysis
- Examples of VIC Applications
- Summary



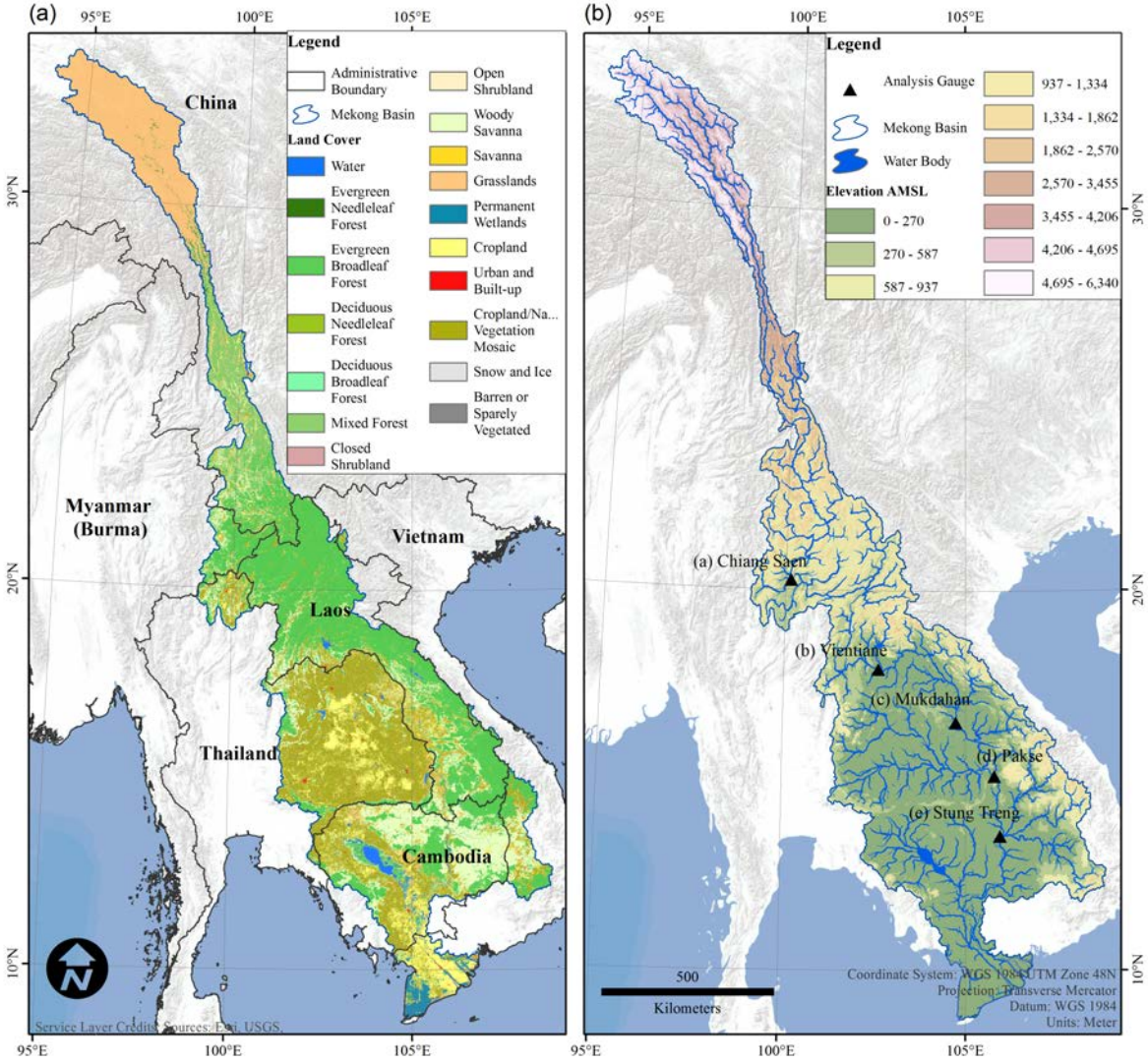
VIC Input Data Formatting

Image Credit: AralDIF, University of Washington

VIC Mekong Application

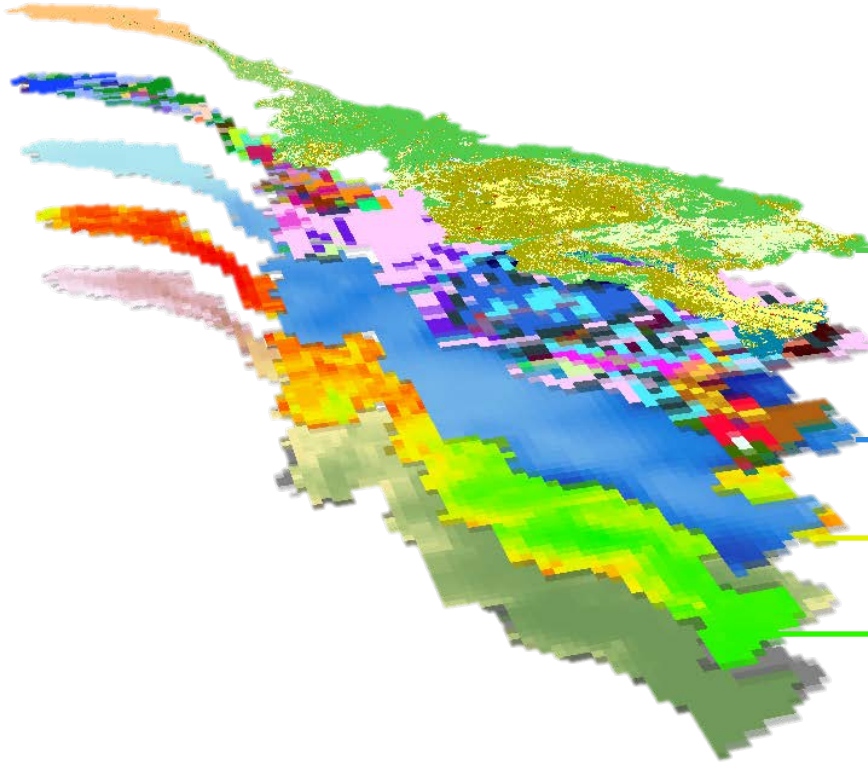
- Set the VIC model up for Mekong basin
- 0.1° resolution - 16 land cover classes – 100m elevation bands
- IMERG precipitation and MERRA2 reanalysis metrological forcings

- Example applications:
  - Flooding/streamflow monitoring
  - Drought monitoring
  - Basin management



VIC Mekong Data preparation

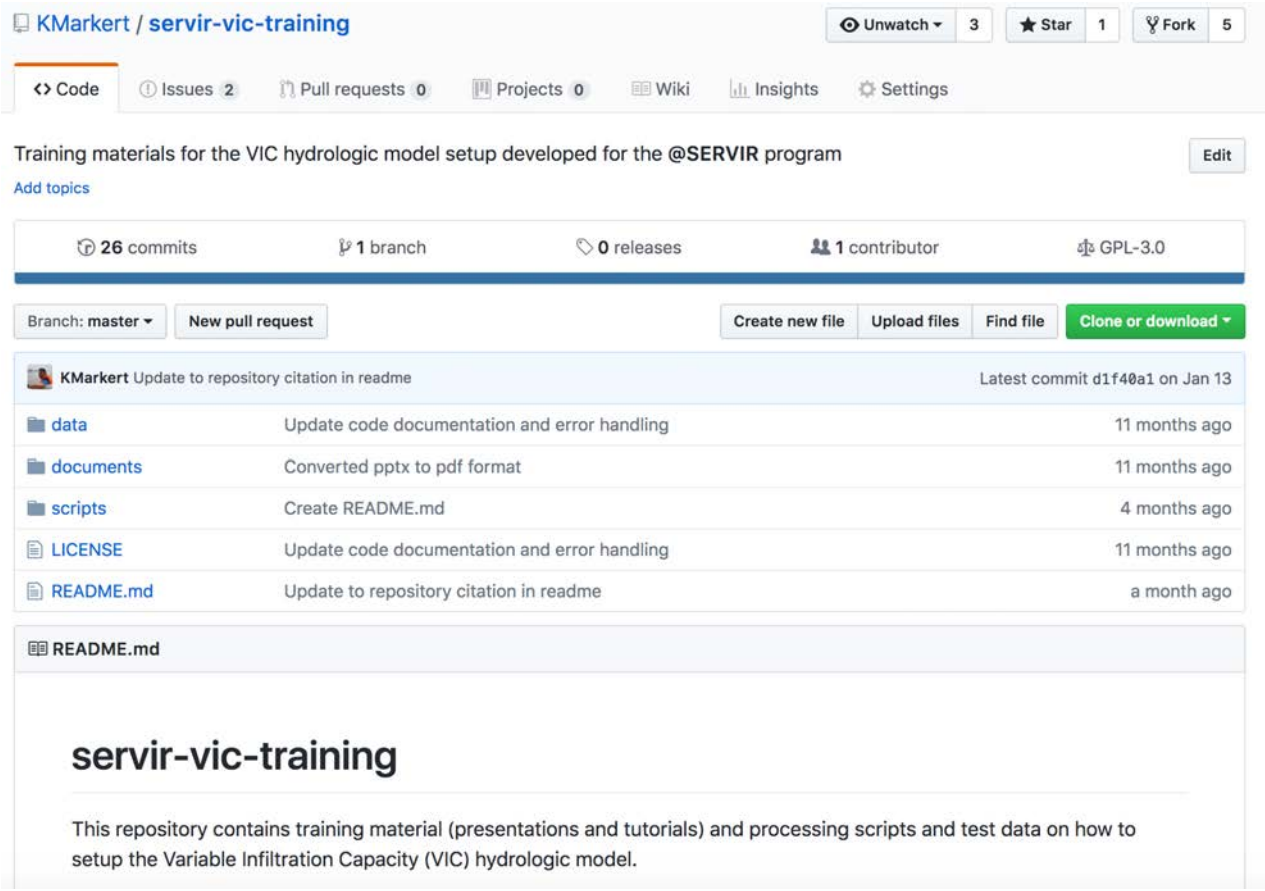
- Data was preprocessed to
  - only cover the Mekong Basin (clipped)
  - have all of the pixels align spatially
- Additional data was derived
  - slope
  - average annual precipitation



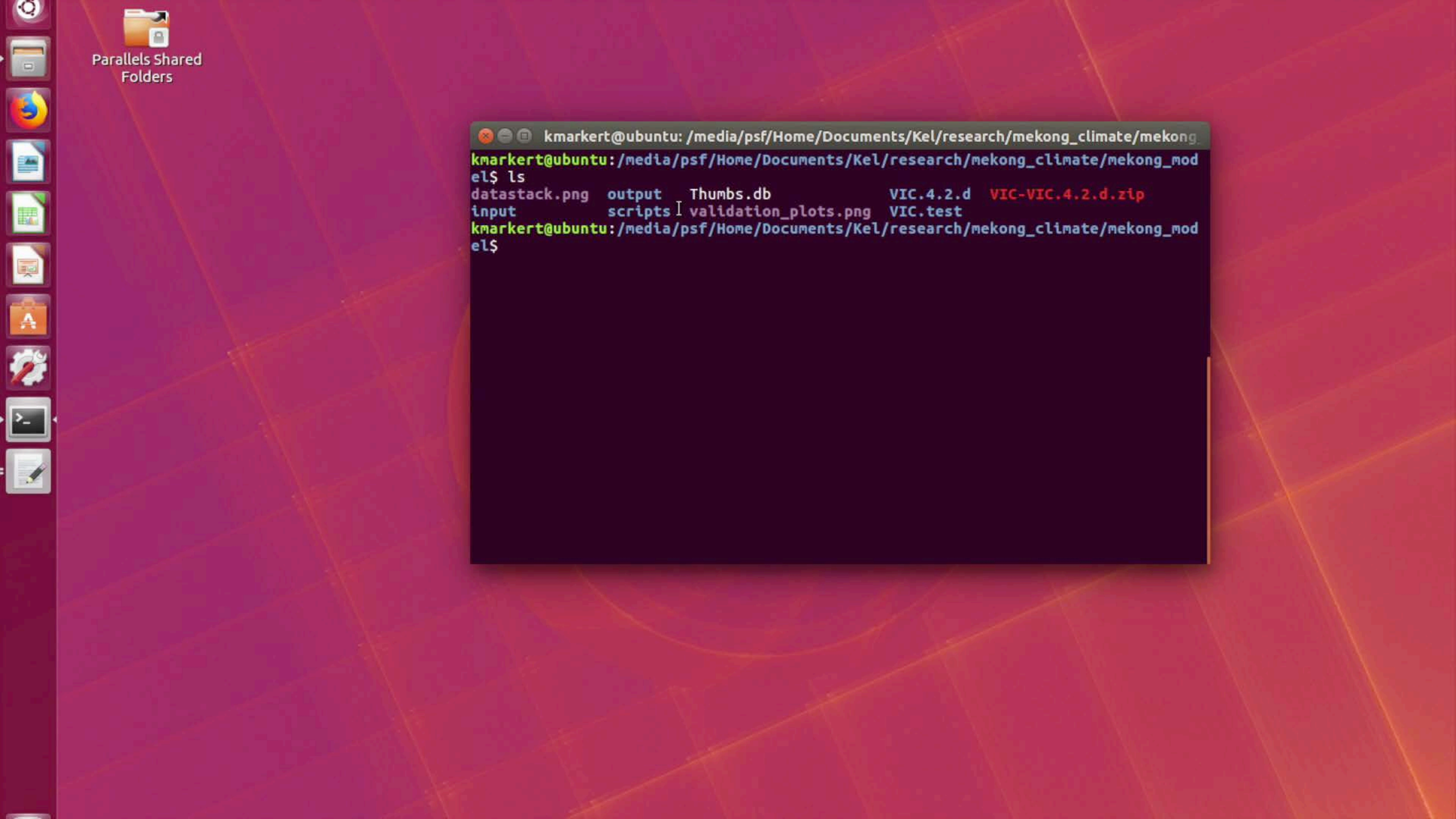
- Land cover
- HWSD soil classes
- Annual precipitation
- Slope
- Elevation

VIC Mekong Model Setup

- Will demonstrate the VIC model setup using processing scripts and framework from Markert, et al. [2018]
- Data and processing scripts are available online at https://github.com/kmarkert/servir-vic-training

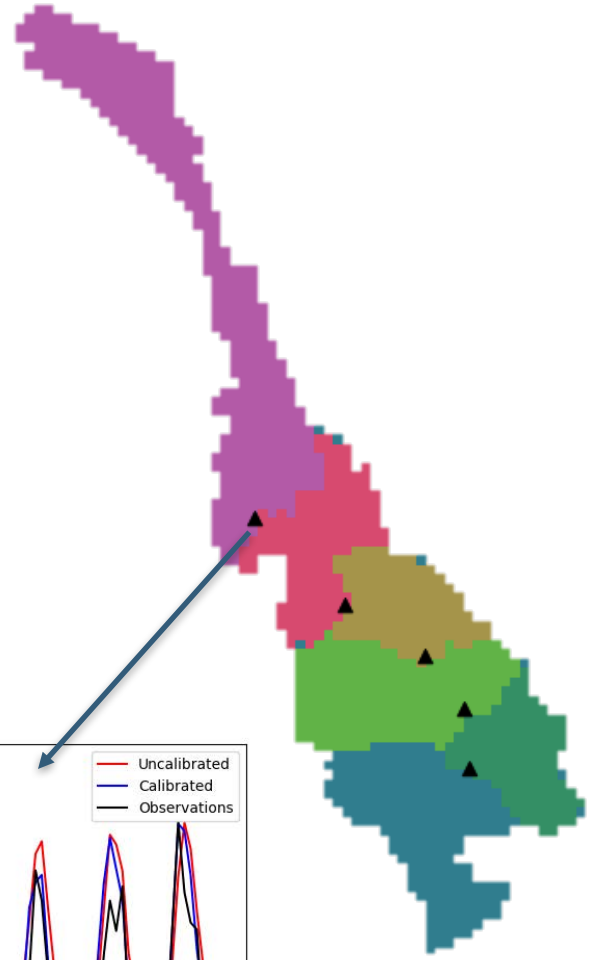


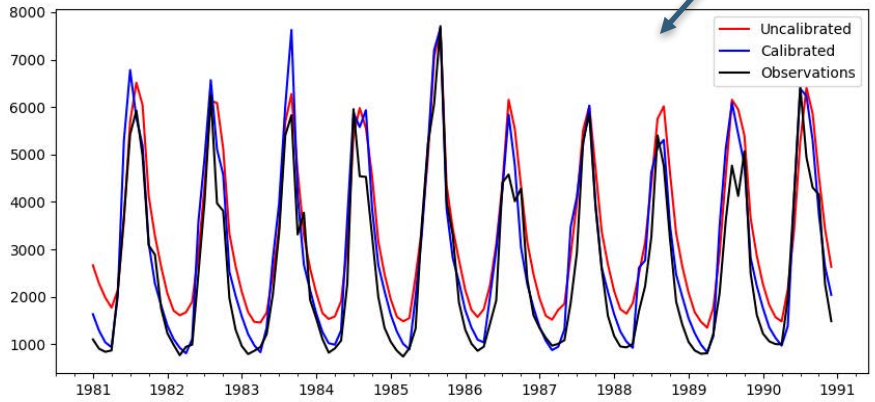
Markert, K.N., Griffin, R.E., Anderson, E.R. (2018), An open source software suite for building capacity in using the VIC hydrology model, *Open Water Journal, Accepted*


Parallels Shared Folders
kmarkert@ubuntu: /media/psf/Home/Documents/Kel/research/mekong_climate/mekong
kmarkert@ubuntu:/media/psf/Home/Documents/Kel/research/mekong_climate/mekong_mod
el$ ls
datastack.png output Thumbs.db VIC.4.2.d VIC-VIC.4.2.d.zip
input scripts validation_plots.png VIC.test
kmarkert@ubuntu:/media/psf/Home/Documents/Kel/research/mekong_climate/mekong_mod
el$

VIC Calibration Process

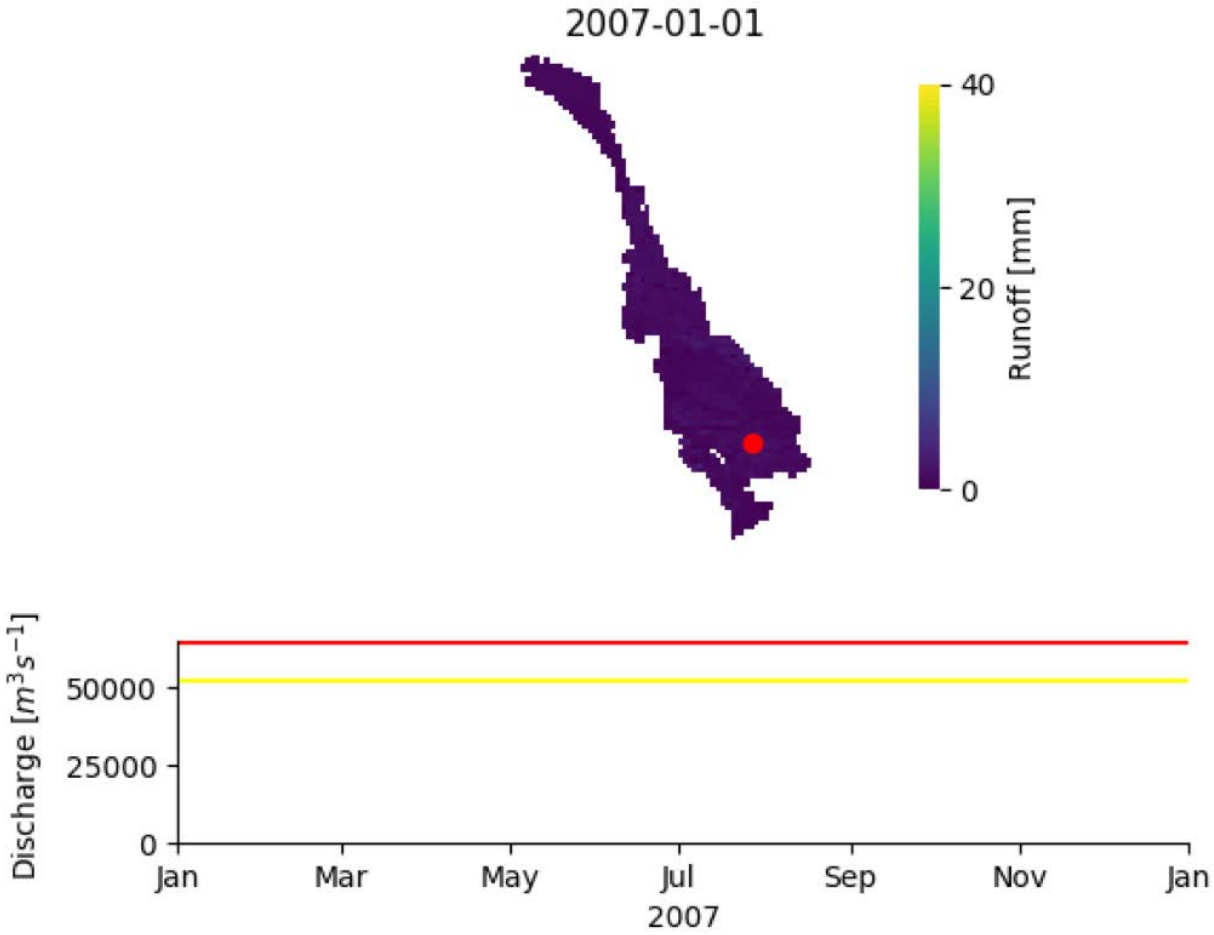
- Programmatically setup and iterate the model using different parameterizations to best fit observations
- Apply optimization algorithm until best parameters are found
- Necessary to have an **independent record for calibration and validation** (or evaluation) of the hydrologic simulation
  - Typically save approximately half of observed time series for validation
- Calibrate by sub-basin and combine for entire region





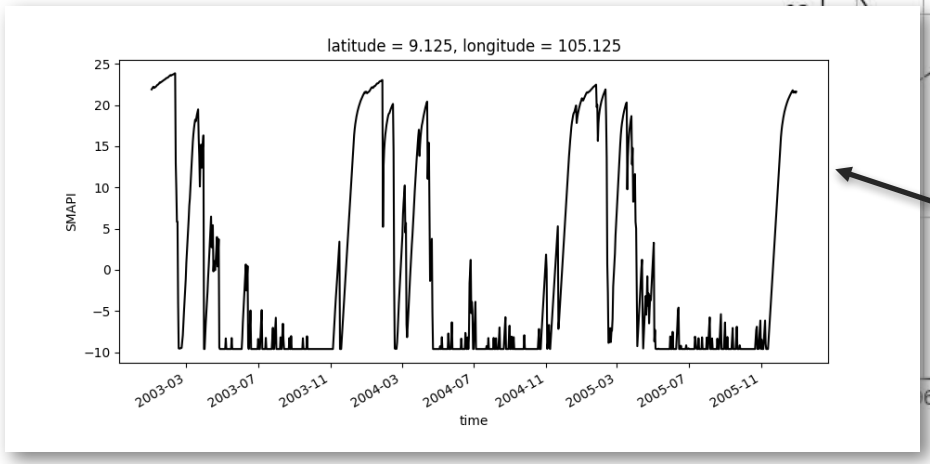
VIC Output and Applications: Streamflow/Flood Monitoring

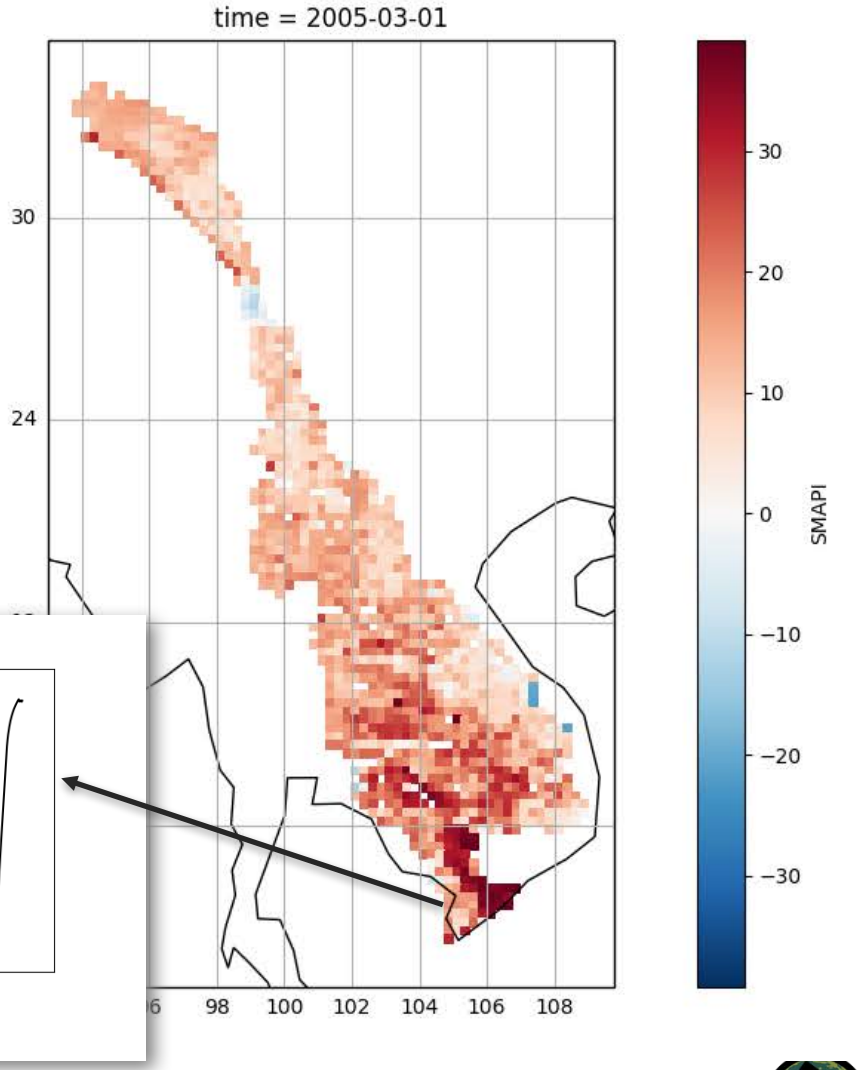
- Routed VIC outputs are often used to simulate river discharge data
  - Either for flooding forecasting or monitoring cases
- This case highlights a flooding event in the Mekong basin for 2007
  - Heavy rainfall in early Aug. produced flood level discharge at an upstream gauge



VIC Output and Application: Drought Monitoring

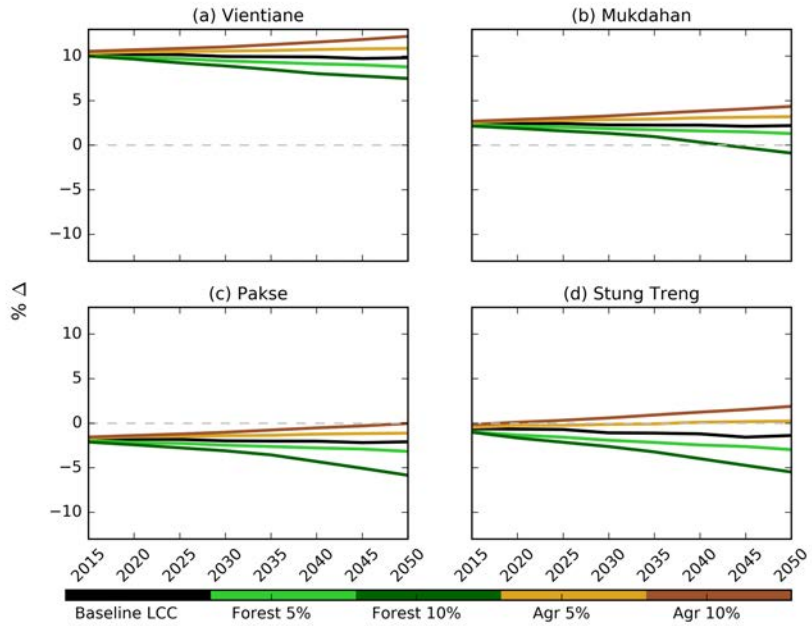
- VIC outputs can be used for monitoring drought conditions
  - The flexible outputs of VIC allow for a wide array of drought indices to be computed
- Here we see moderate to severe drought across most of the Mekong Basin during the dry season due to El Niño events
  - Used Soil Moisture Anomaly Percentage Index (SMAPI) to quantify drought



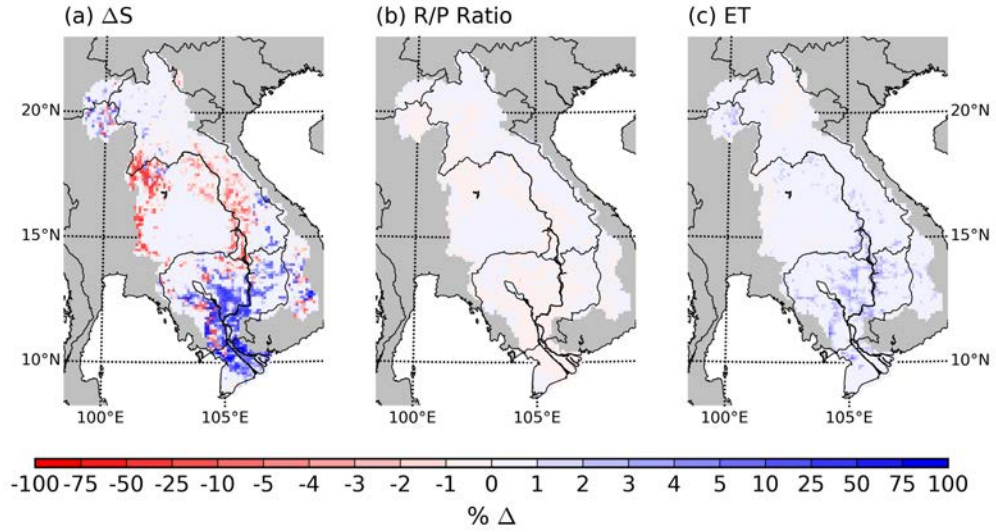


VIC Application: Basin Management

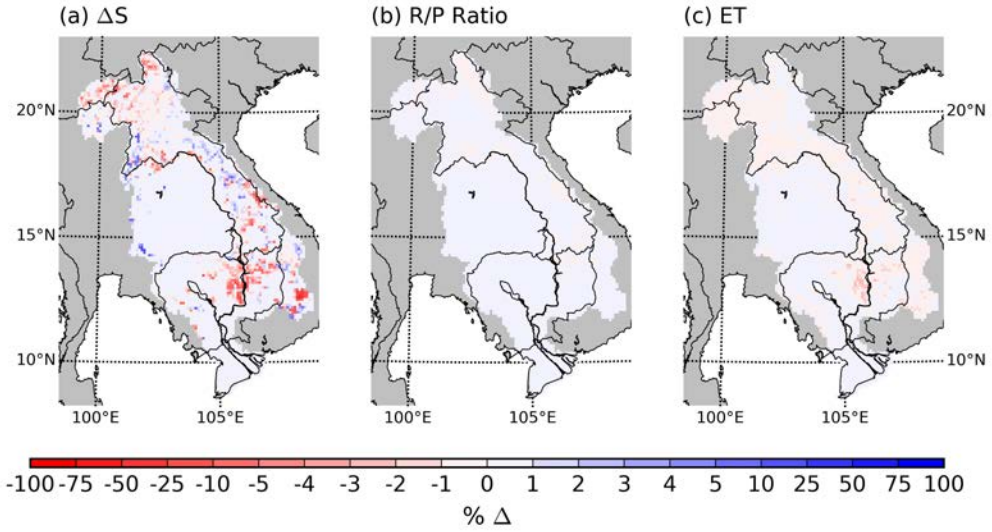
- Basin management scenarios can be used as inputs into VIC
- Specific case to assess effects of land cover change on the hydrologic system in the Lower Mekong Basin



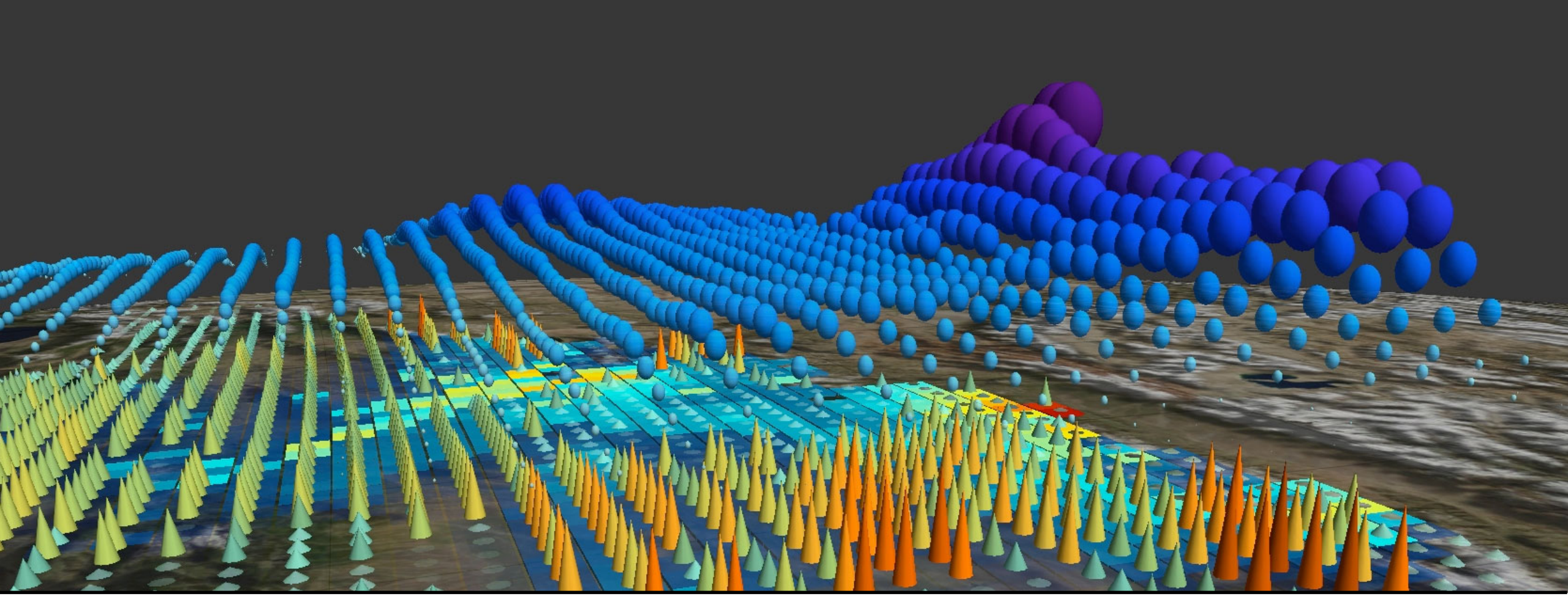
Increase in forest area



Increase in agriculture area



Figures taken from: Markert, K.N., et al. (2018). Spatial Modeling of Land Cover/Land Use Change and Its Effects on Hydrology Within the Lower Mekong Basin. In Vadrevu, K.P., Ohara, T., and Justice, C. (Eds). Land Atmospheric Research Applications in Asia. Springer Verlag. (ISBN: 978-3-319-67473-5). Pp.667-698.



Examples of VIC Applications

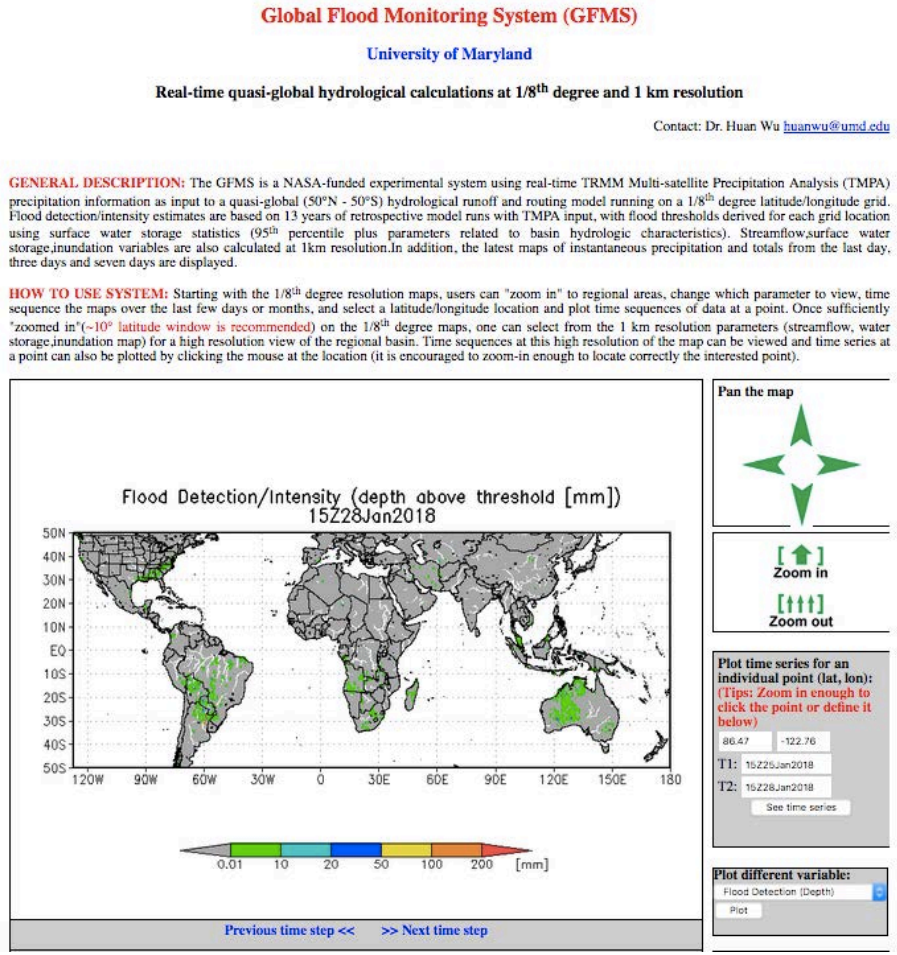
Image Credit: AralDIF, University of Washington

Global VIC Application: Streamflow and Flood Monitoring

Global Flood Monitoring System (GFMS): http://flood.umd.edu/

VIC simulations are conducted every 3 hours by using:

- Near real-time TRMM Multi-satellite Precipitation Analysis (TMPA) data
- Other meteorological forcing from MERRA analysis
- University of Maryland Dominant River Tracing Routing (DRTR) model



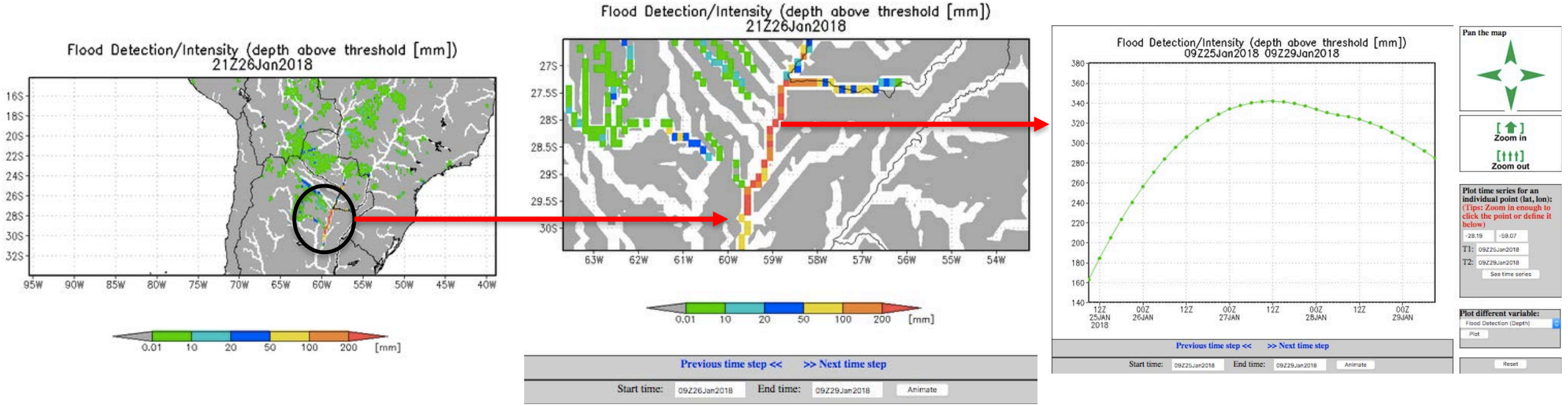
Wu, H., R. F. Adler, Y. Tian, G. J. Huffman, H. Li, and J. Wang (2014), Real-time global flood estimation using satellite-based precipitation and a coupled land surface and routing model, Water Resour. Res., 50, 2693.2717, doi:10.1002/2013WR014710.

Wu H., R. F. Adler, Y. Hong, Y. Tian, and F. Policelli (2012), Evaluation of Global Flood Detection Using Satellite-Based Rainfall and a Hydrologic Model. J. Hydrometeor, 13, 1268.1284.

Global VIC Application: Recent Flood Monitoring in Paraguay

Global Flood Monitoring System (GFMS): http://flood.umd.edu/

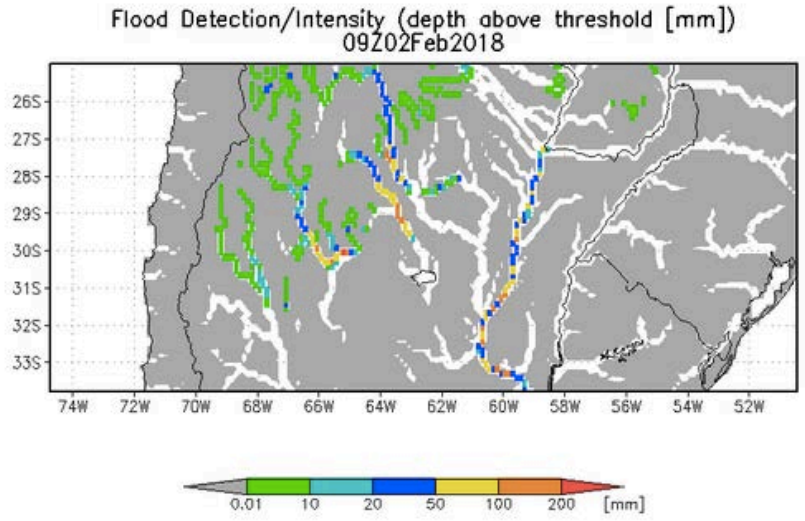
Paraguay River Floods 25-26 January 2018

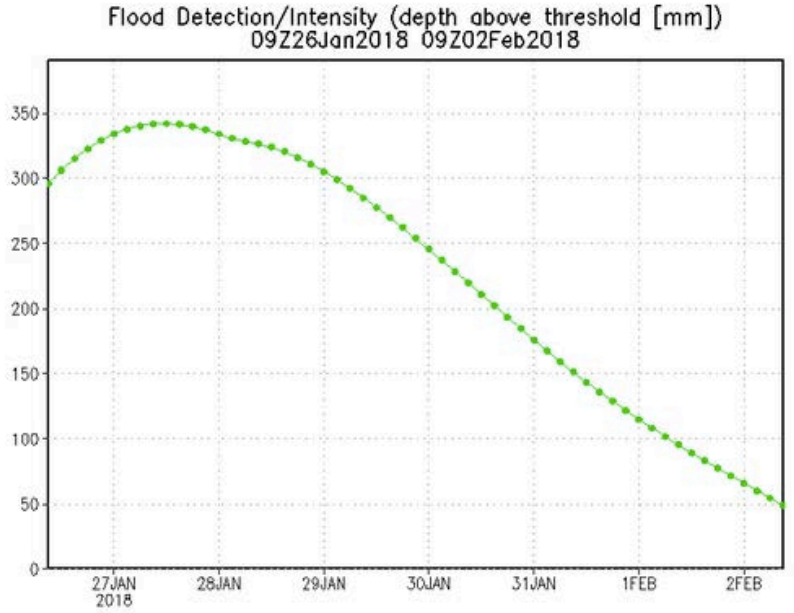


Global VIC Application: 4-5 Day Flood Forecasting

Global Flood Monitoring System (GFMS): http://flood.umd.edu/

VIC coupled with UMD River Routing and meteorological forcing from Goddard Earth Observing System (GEOS) model forecast





Paraguay River Flood Forecast for
9:00 a.m. UTC, 2 February 2018

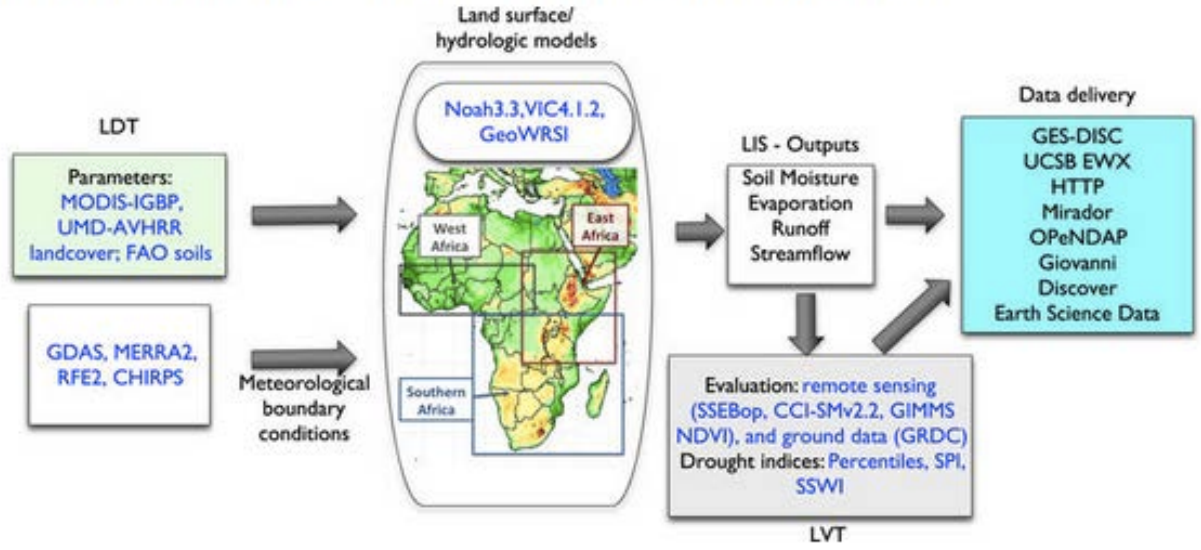
Continental VIC Application: Water Resources Management

Land Data Assimilation System (LDAS): http://ldas.gsfc.nasa.gov/index.php/

- VIC is used in Global, North American, and FEWS NET* Land Data Assimilation (GLDAS, NLDAS, FLDAS) models in which satellite and ground-based data are ingested
- Based on surface water and energy balance, water resources components [precipitation, evapotranspiration, runoff, soil moisture] are available for the LDAS systems

*Famine Early Warning System Network

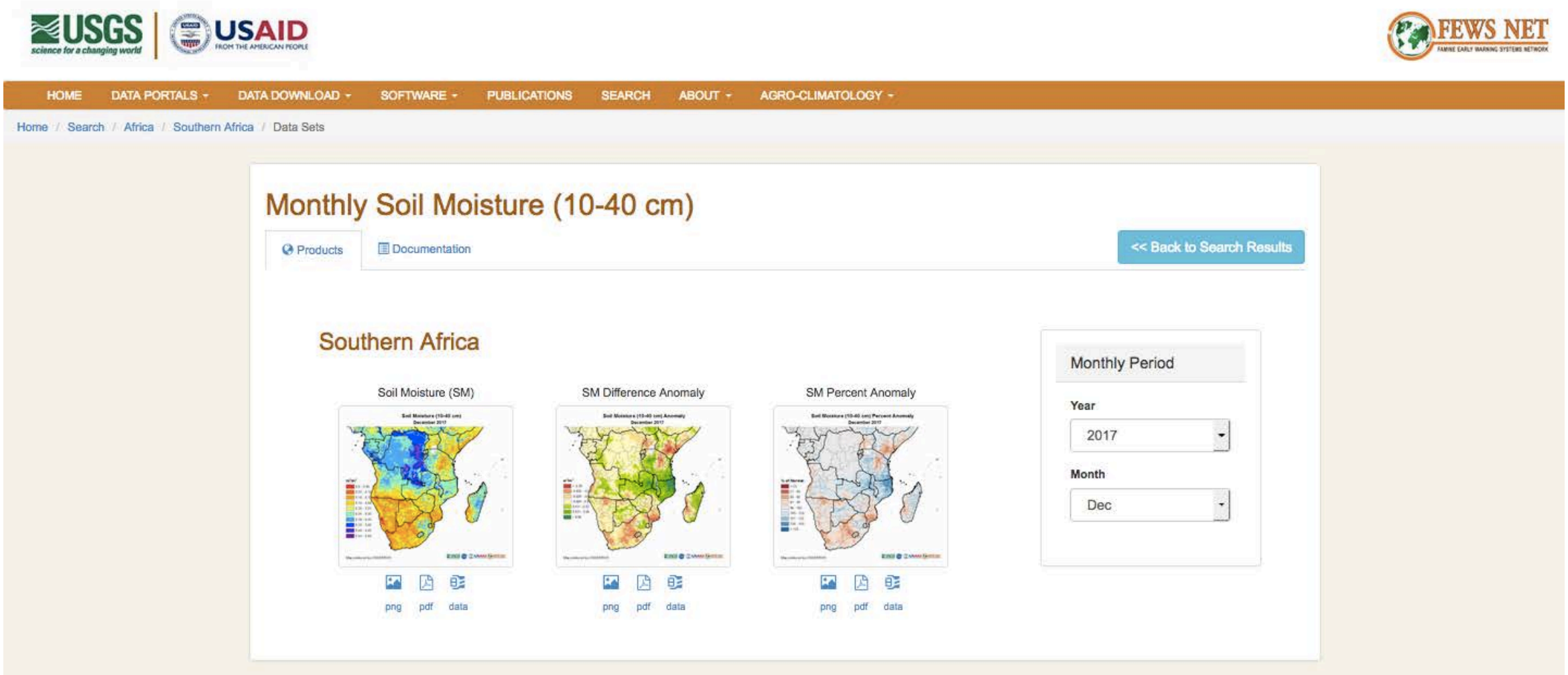
Figure 1: Schematic of the Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System (FLDAS).



McNally et al., 2017: A land data assimilation system for sub-Saharan Africa food and water security applications, *Scientific Data* **volume 4**, Article number: 170012 (2017) doi:10.1038/ https://www.nature.com/articles/sdata201712

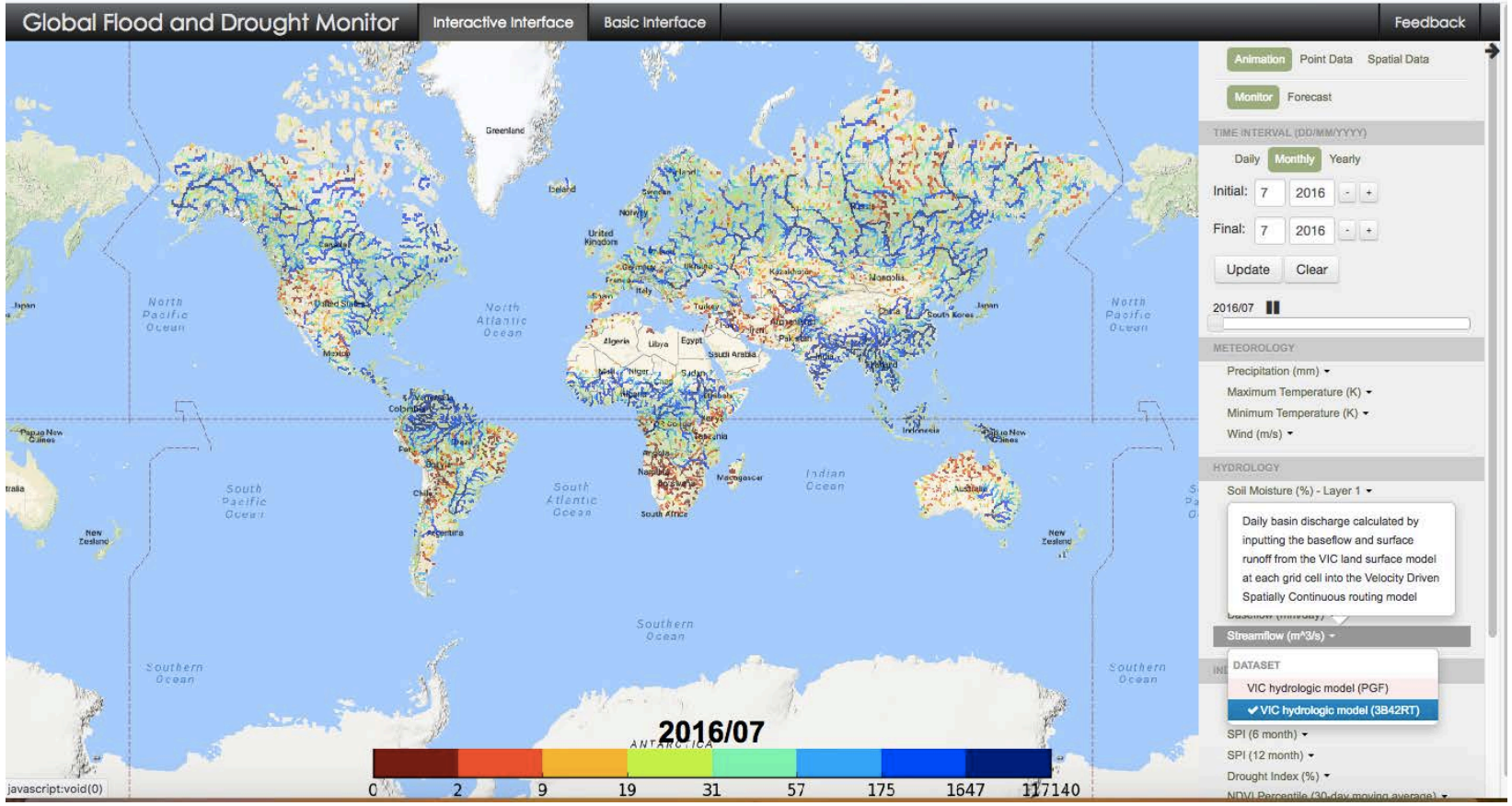
FLDAS for Water Resources Monitoring and Management in Africa

https://earlywarning.usgs.gov/fews/product/313



Princeton Global Flood and Drought Monitor

http://stream.princeton.edu/GFDM/WEBPAGE/interface.php?locale=en



VIC-derived streamflow (m^3/s) based on TRMM and Multi-satellite Precipitation Analysis (TMPA) for July 2016

VIC Application: Water Resources Management

https://www.usbr.gov/lc/region/programs/crbstudy/Report1/TechRptB.pdf

VIC has been used by the US Bureau of Reclamation for Colorado river water supply studies

VIC Validation Summary for Colorado River at Lees Ferry, Arizona

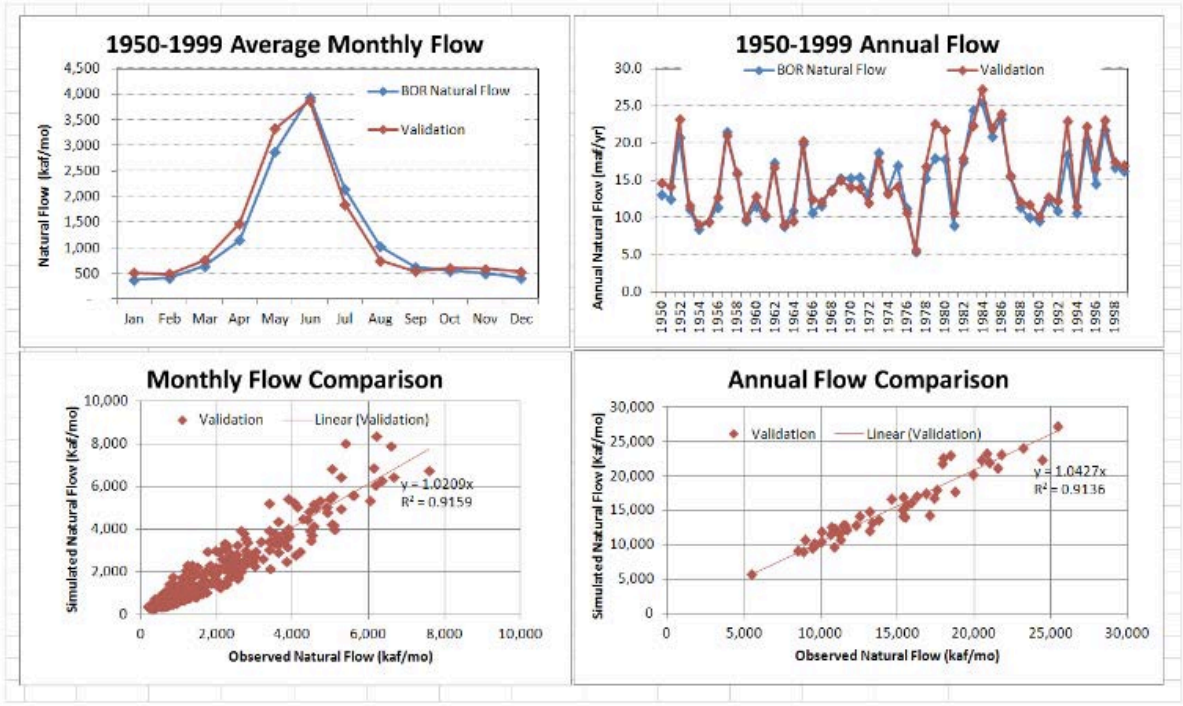
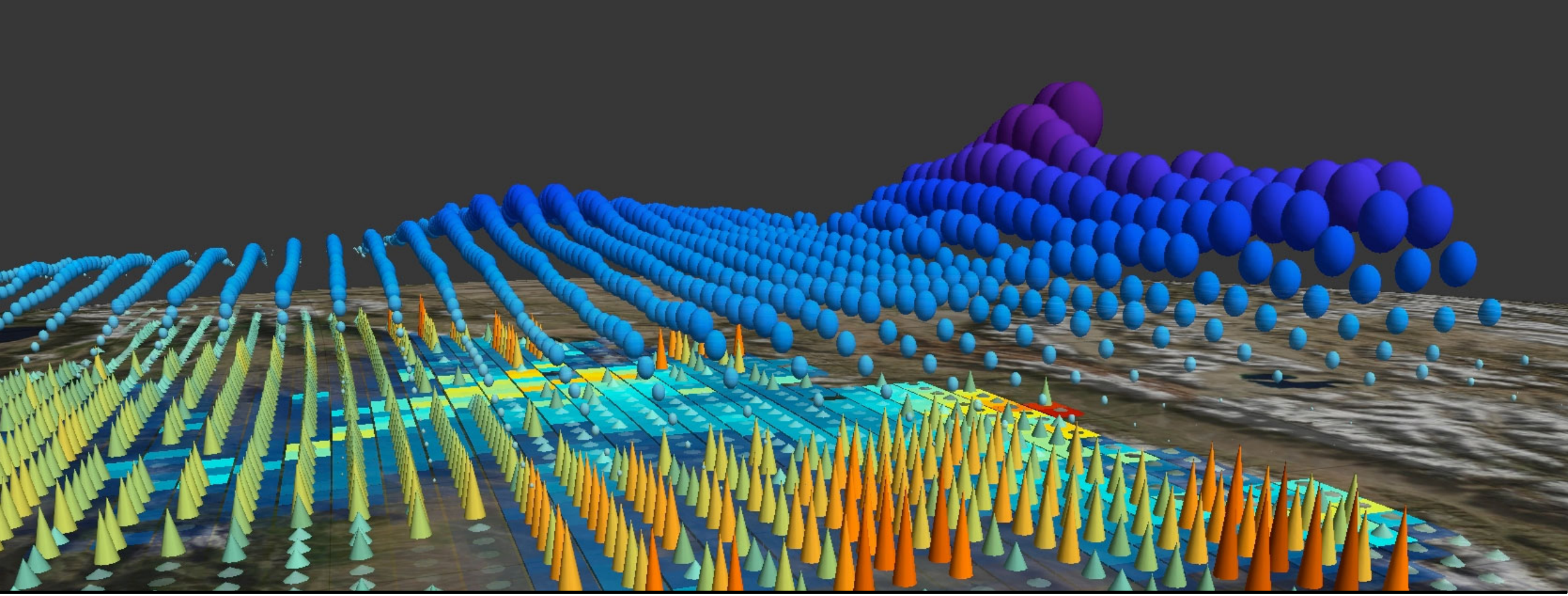


Image Credit: Colorado River Basin Water Supply and Demand Study; Technical Report B – Water Supply Assessment. (2011, June). https://www.usbr.gov/lc/region/programs/crbstudy/Report1/TechRptB.pdf. Appendix B4: Variable Infiltration Capacity (VIC) Hydrologic Modeling Methods and Simulations



Summary

Image Credit: AralDIF, University of Washington

VIC Summary

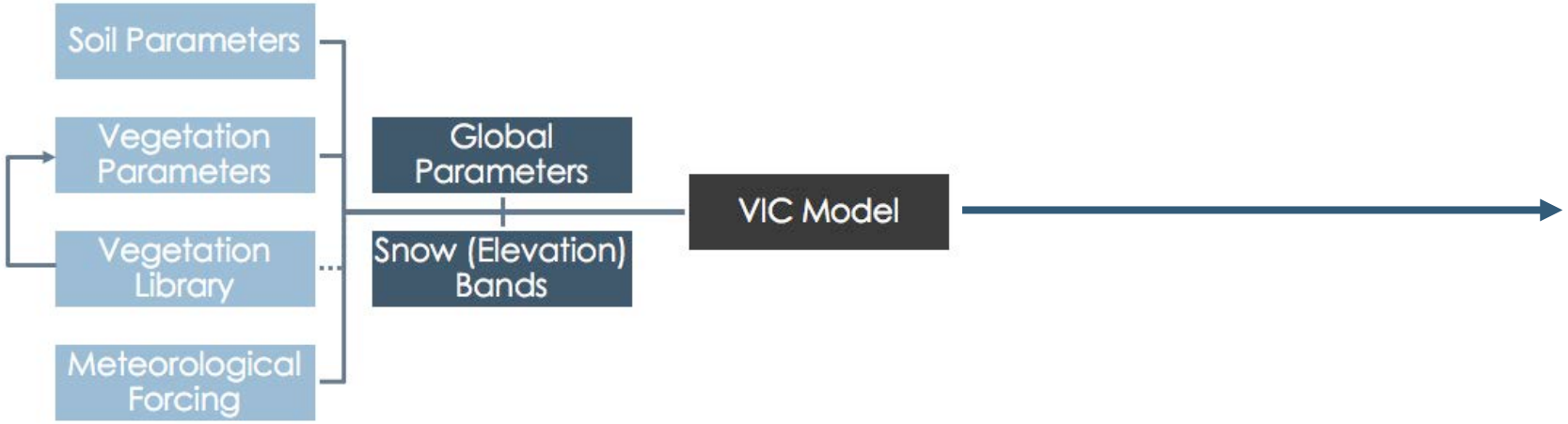
- VIC is an open source, grid-based hydrological model
  - https://github.com/UW-Hydro/VIC/tree/master/vic/drivers/classic/src
- VIC code is written in C language and tested on computers with Unix/Linux operating system
- VIC can be set up to run at grid resolutions from >3 km to 2 degree
- VIC requires daily input data for water balance mode while sub-daily data are required for energy balance mode
- A routing scheme is required in conjunction with VIC to simulate streamflow
- VIC requires regional calibration

VIC Summary: Inputs and Outputs

VIC requires input data at each grid point, including:

- precipitation
- surface air temperature (daily minimum and maximum)
- surface wind speed
- vegetation cover, leaf area index
- surface albedo
- initial soil moisture conditions
- soil characteristics data
- elevation

Requires pre-processing of input data in a specific format – a time consuming process



VIC outputs

- soil moisture
- evapotranspiration
- runoff and streamflow
- snow water equivalence

VIC Summary: 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** https://disc.sci.gsfc.nasa.gov/
	Land Cover, **LAI** and Albedo	**Terra** and **Aqua MODIS** https://search.earthdata.nasa.gov/
	Soil properties	Harmonized World Soil Database http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/HWSD_Data.html?sb=4
	Elevation	Shuttle Radar Topography Mission (**SRTM**) http://csi.cgiar.org/WhtisCGIAR_CSI.asp

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

VIC Summary: Applications

- Facilitate planning and decision support by monitoring and prediction of:
  - water resources
  - flood and drought conditions

Thank you!

Homework due on March 15, 2018