

# Introduction to Using the VIC Model with NASA Earth Observations

Amita Mehta & Kel Markert (SERVIR Global)

February 15, 22, and March 1, 2018



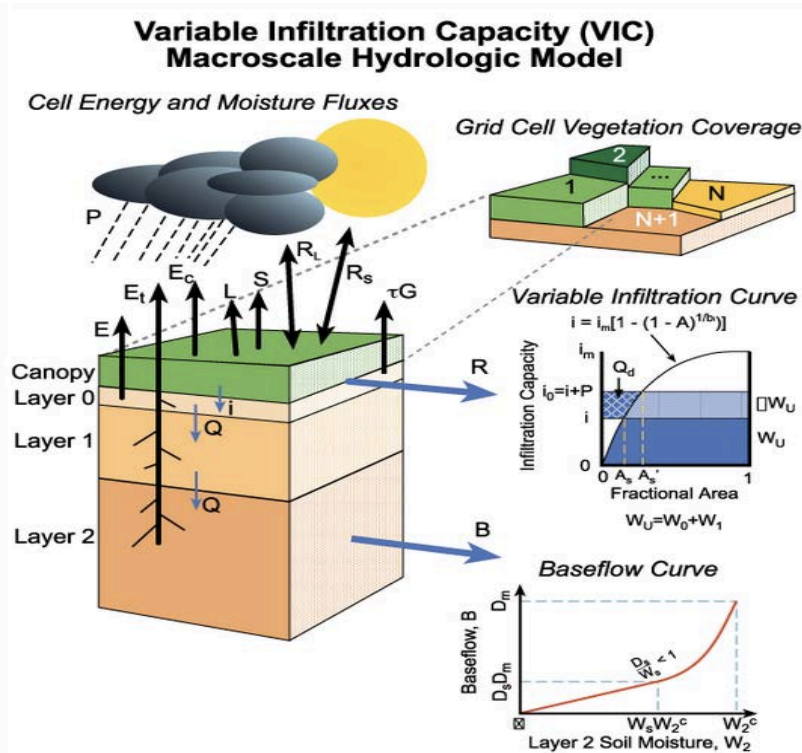
# Training Outline

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

Session 1: Feb 15, 2018

Session 2: Feb 22, 2018

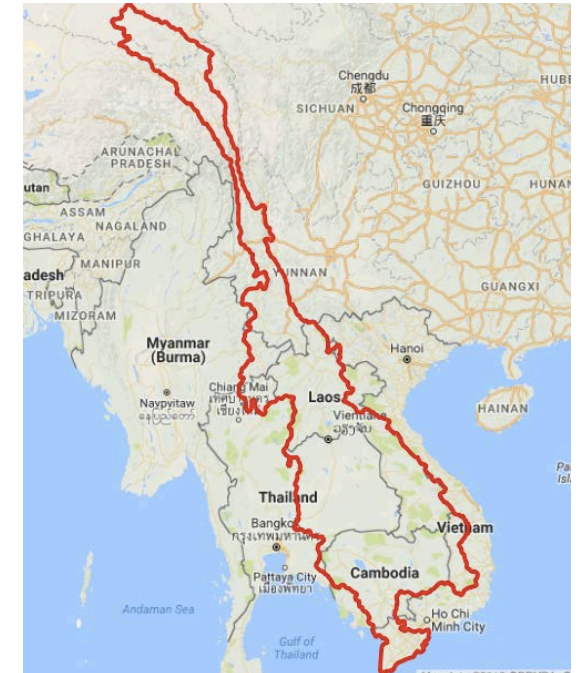
Session 3: Mar 1, 2018



Introduction to the VIC Hydrological Model



Overview of Remote Sensing-Based Input Data for VIC



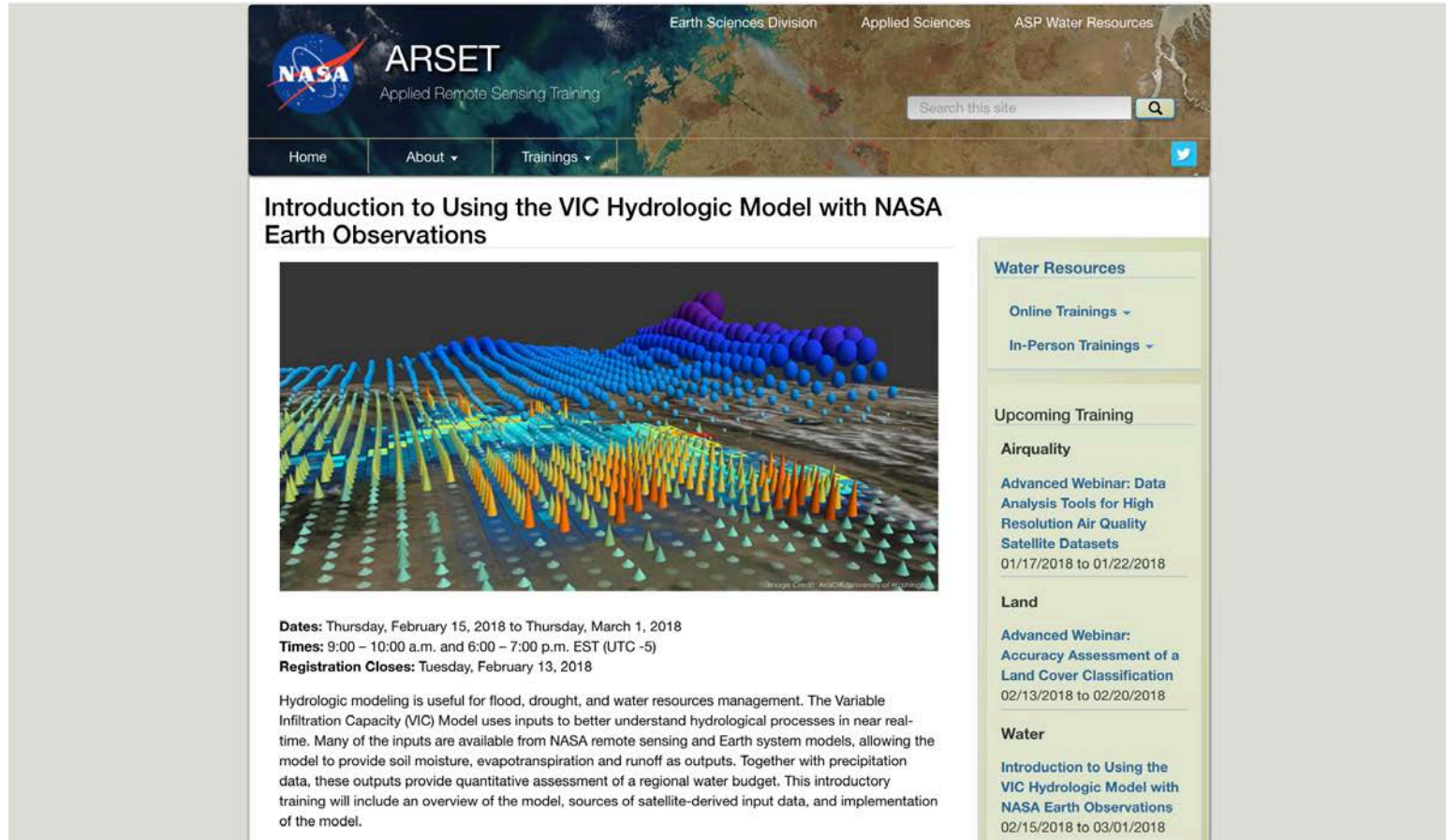
Overview of VIC Implementation for a River Basin





# 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 are 'Thursday, February 15, 2018 to Thursday, March 1, 2018', the times are '9:00 – 10:00 a.m. and 6:00 – 7:00 p.m. EST (UTC -5)', and the registration closes on 'Tuesday, February 13, 2018'. A paragraph of text describes the model's use for flood, drought, and water resources management. On the right side, there is a sidebar with sections for 'Water Resources', 'Online Trainings', 'In-Person Trainings', 'Upcoming Training', 'Airquality', 'Land', and 'Water'. The 'Water' section lists the current webinar with its dates: '02/15/2018 to 03/01/2018'.

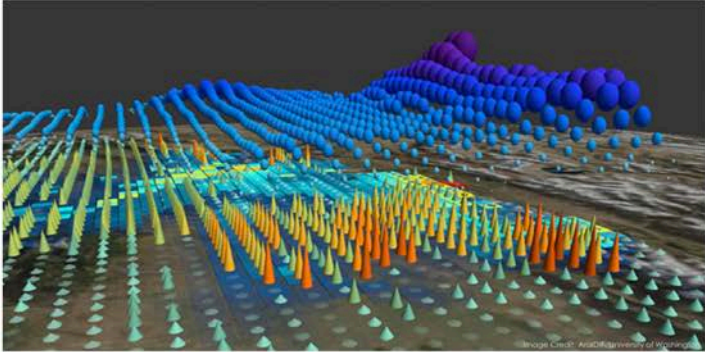
**ARSET**  
Applied Remote Sensing Training

Earth Sciences Division Applied Sciences ASP Water Resources

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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**

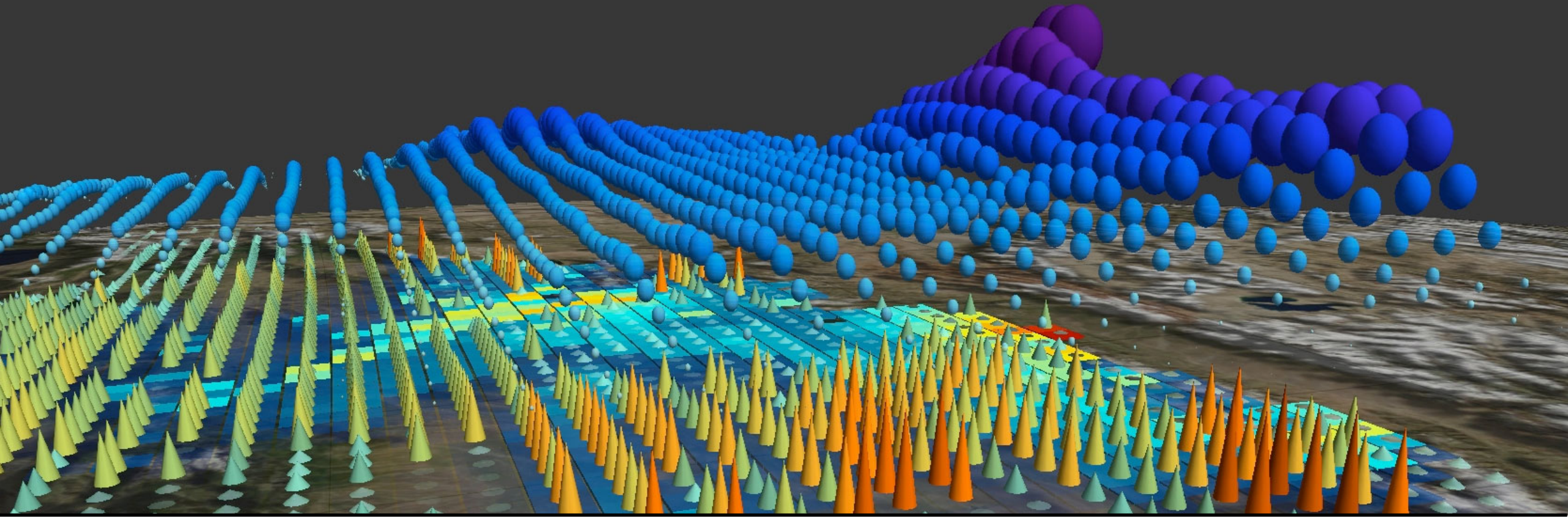
Introduction to Using the VIC Hydrologic Model with NASA Earth Observations  
02/15/2018 to 03/01/2018



# 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](mailto:marines.martins@ssaihq.com)



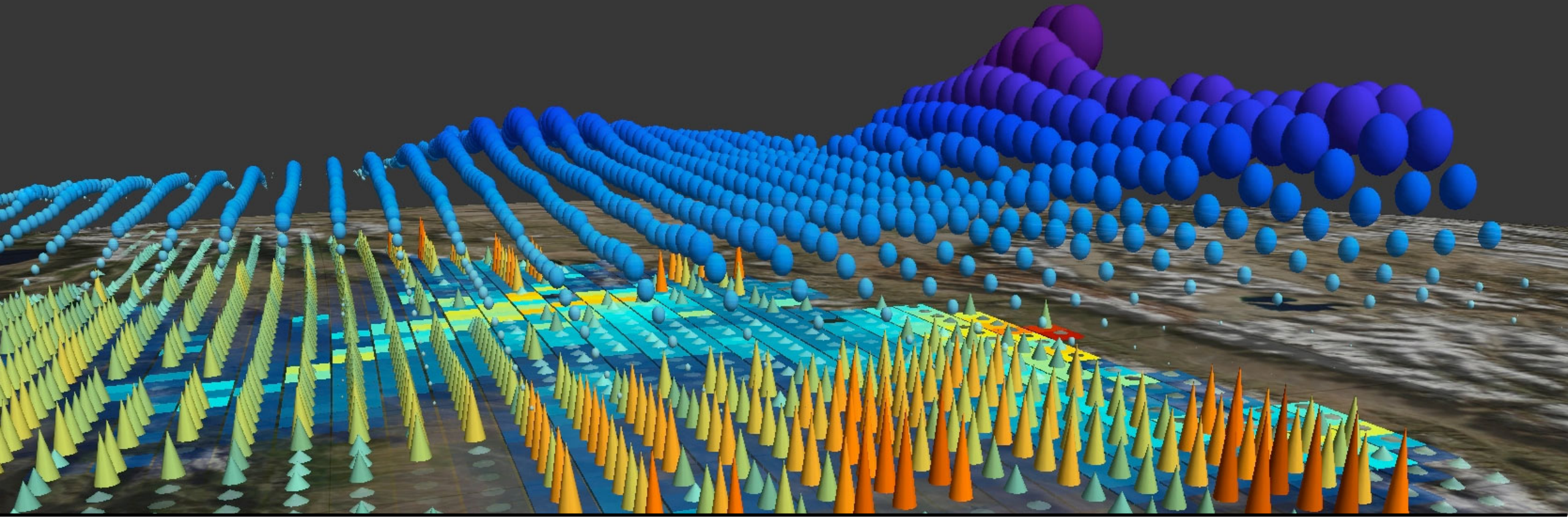


# Overview of VIC Implementation for a River Basin Example: The Mekong River Basin

# Session 3 Outline

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

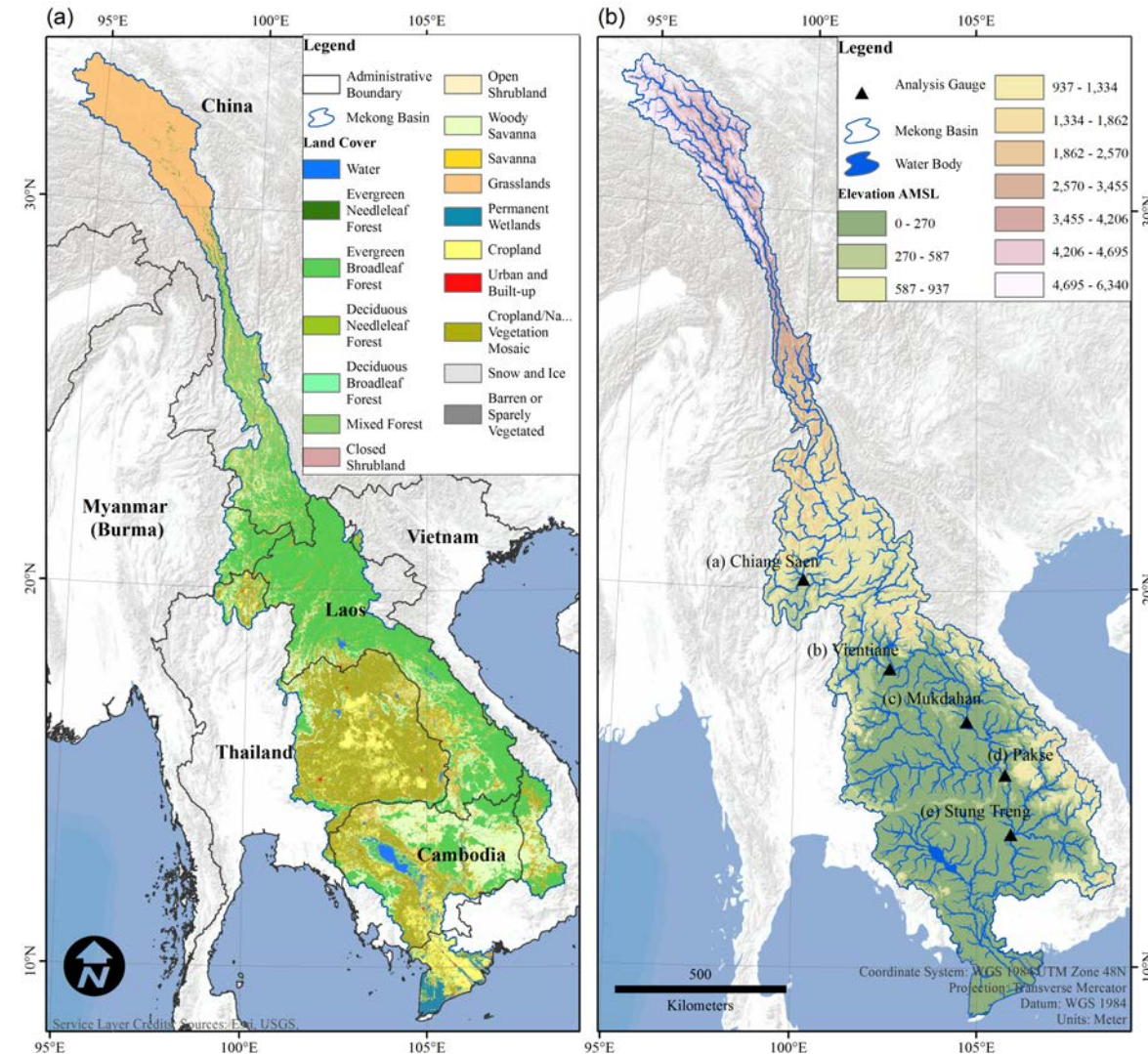




# VIC Input Data Formatting

# VIC Mekong Application

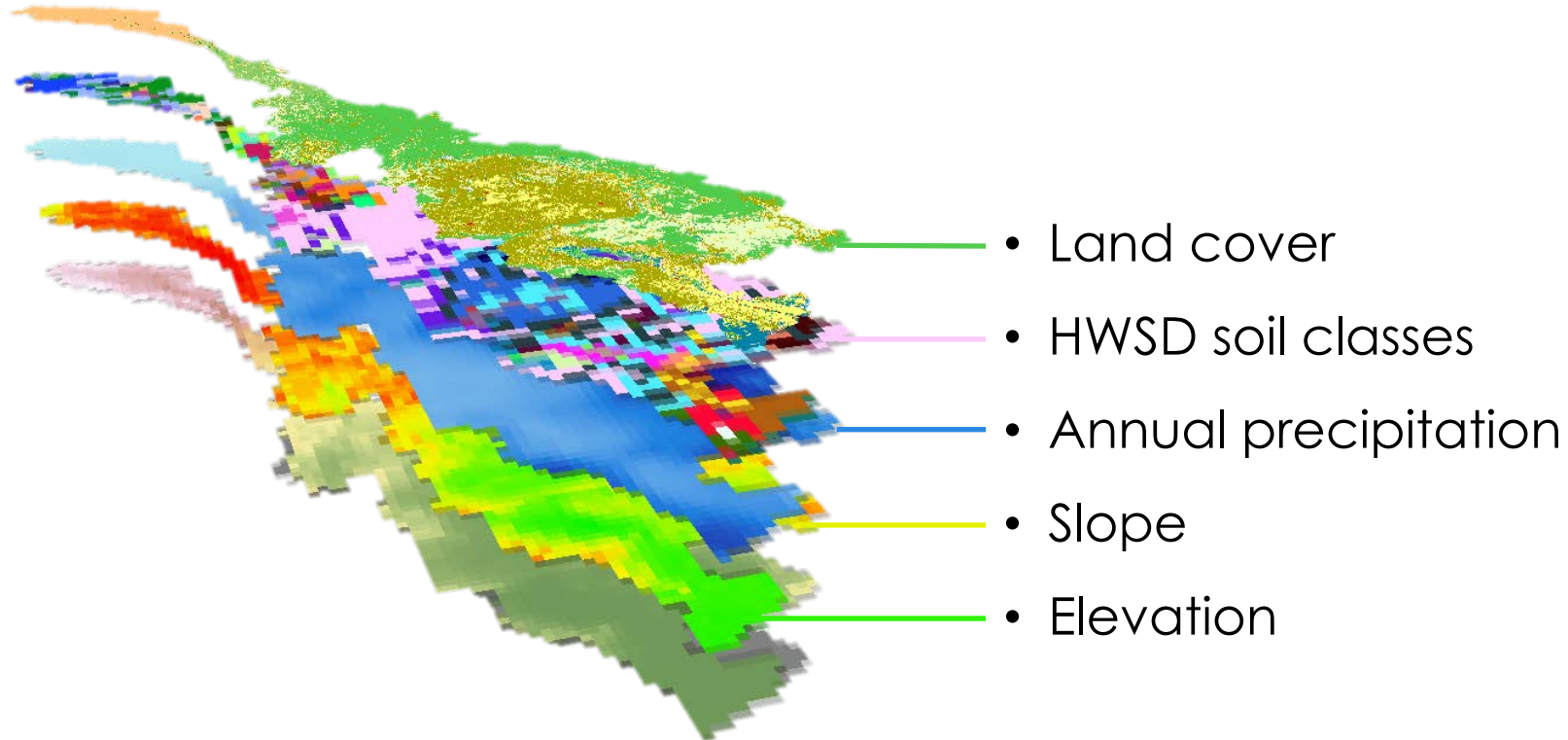
- Set the VIC model up for Mekong basin
- 0.1° resolution - 16 land cover classes – 100m elevation bands
- IMERG precipitation and MERRA2 reanalysis meteorological forcings
  
- Example applications:
  - Flooding/streamflow monitoring
  - Drought monitoring
  - Basin management





# 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



# 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>

KMarkert / **servir-vic-training** Unwatch 3 Star 1 Fork 5

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Training materials for the VIC hydrologic model setup developed for the @SERVIR program Edit

Add topics

26 commits 1 branch 0 releases 1 contributor GPL-3.0

Branch: master New pull request Create new file Upload files Find file Clone or download

Commit	Description	Time
KMarkert	Update to repository citation in readme	Latest commit d1f40a1 on Jan 13
	data	Update code documentation and error handling 11 months ago
	documents	Converted pptx to pdf format 11 months ago
	scripts	Create README.md 4 months ago
	LICENSE	Update code documentation and error handling 11 months ago
	README.md	Update to repository citation in readme a month ago

README.md

## servir-vic-training

This repository contains training material (presentations and tutorials) and processing scripts and test data on how to setup the Variable Infiltration Capacity (VIC) hydrologic model.

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



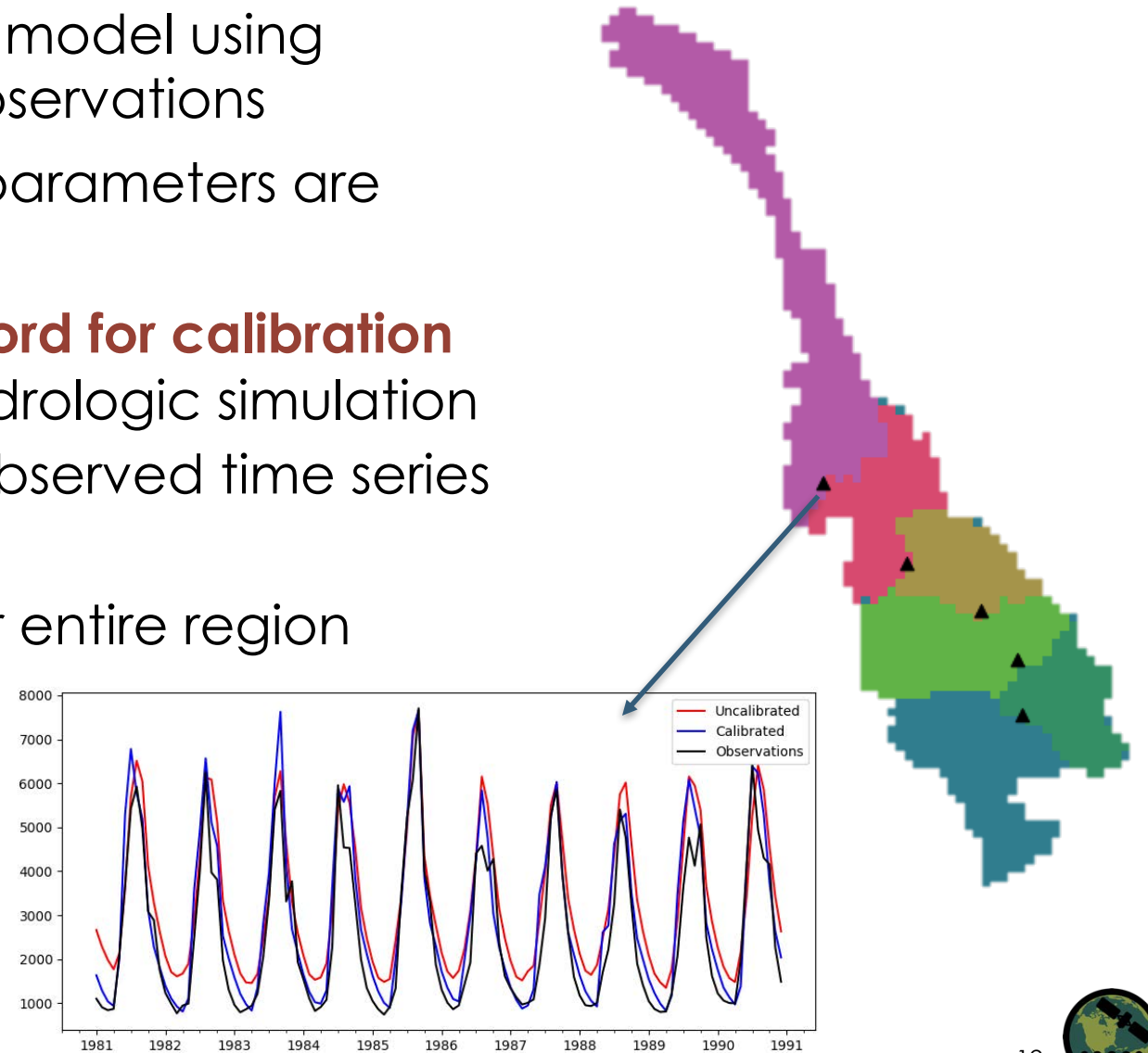


Parallels Shared  
Folders

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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

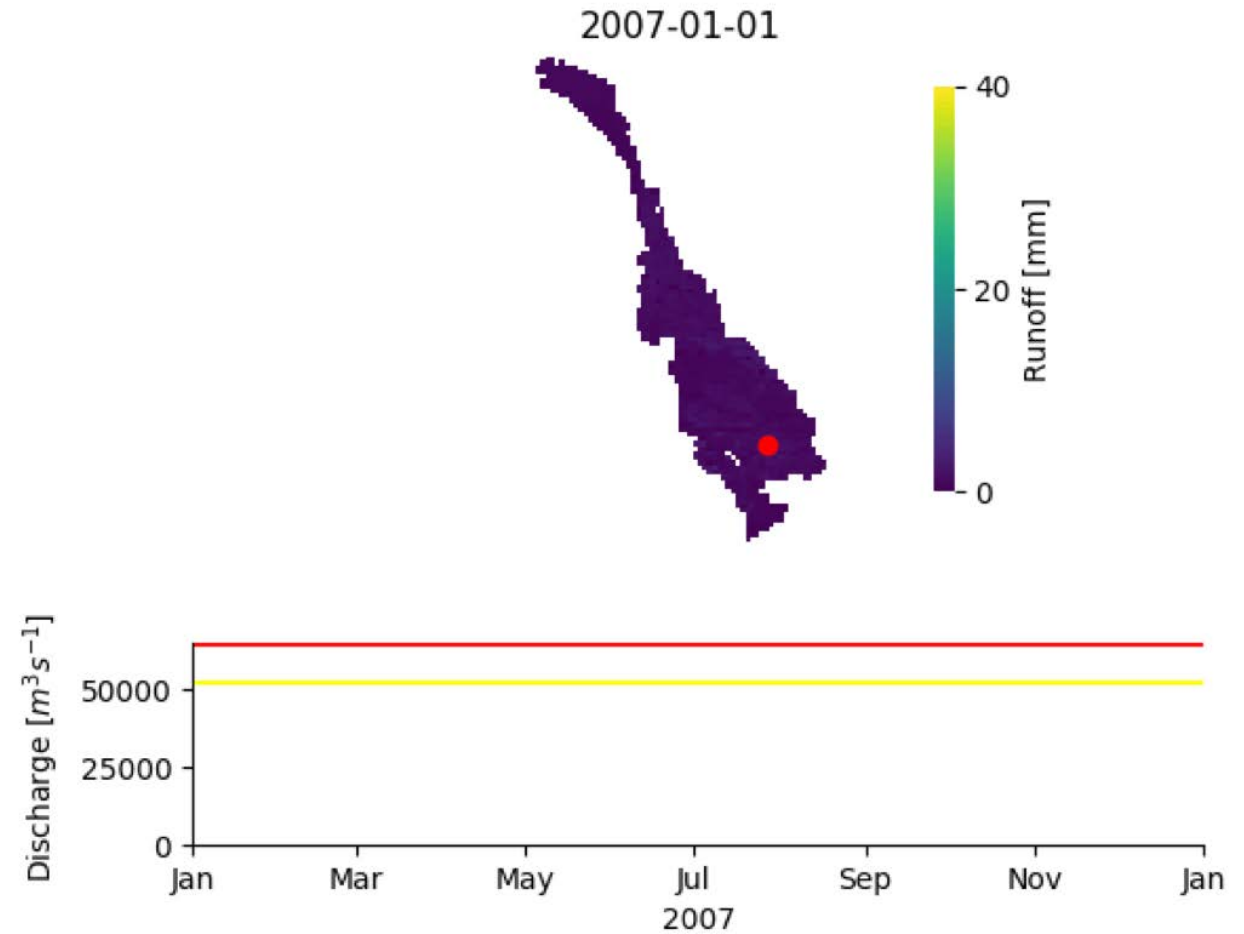
- Programmatically setup and iterate the model using different parameterizations to best fit observations
- Apply optimization algorithm until best parameters are found
- Necessary to have an **independent record for calibration and validation** (or evaluation) of the hydrologic simulation
  - Typically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





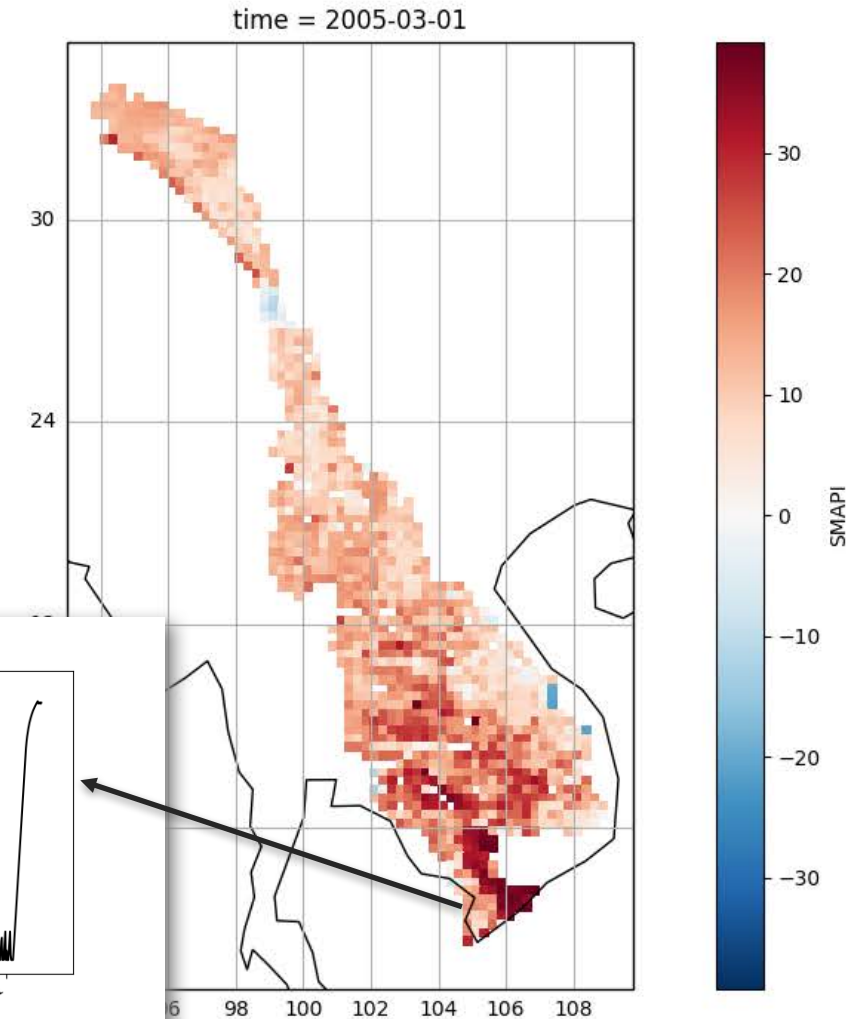
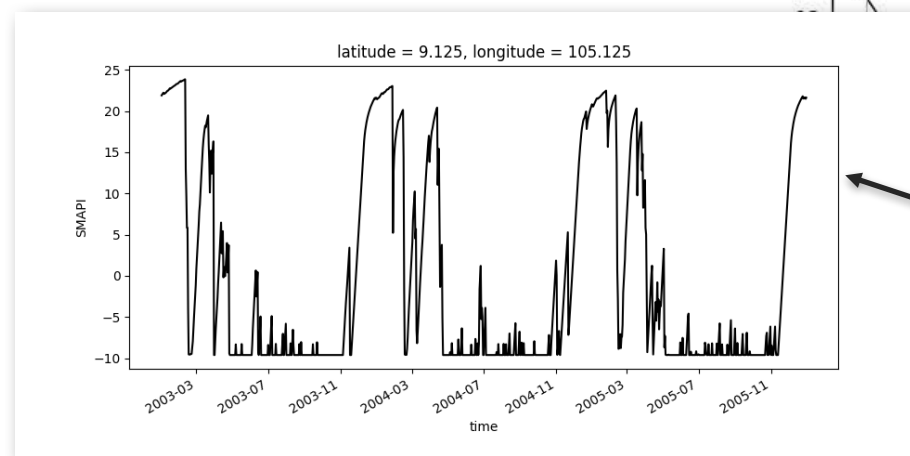
# VIC Output and Applications: Streamflow/Flood Monitoring

- 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

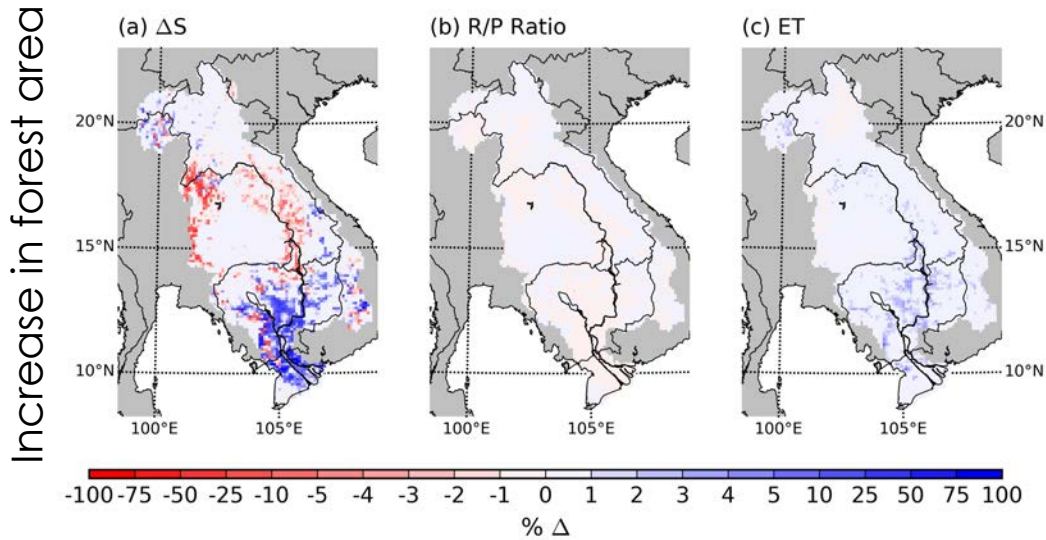
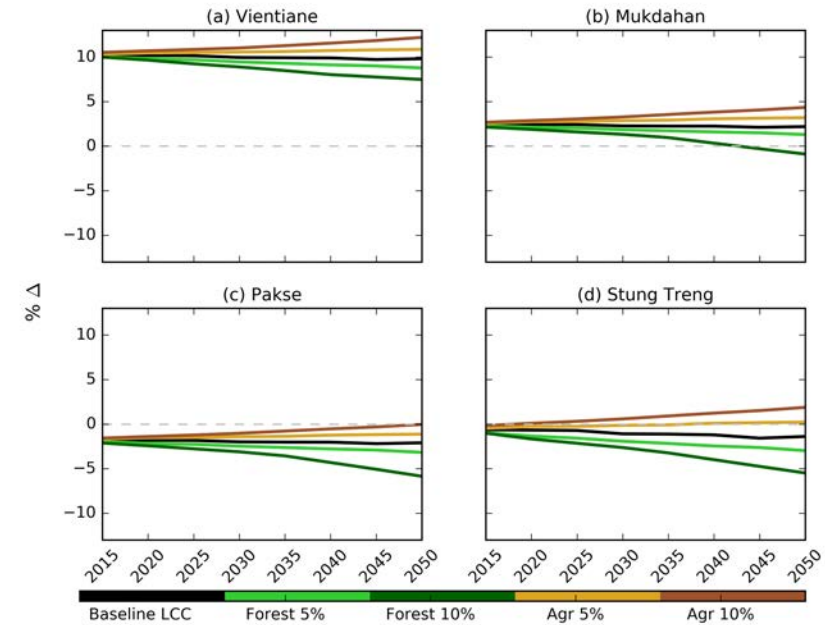
- VIC outputs can be used for monitoring drought conditions
  - The flexible outputs of VIC allow for a wide array of drought indices to be computed
- Here we see moderate to severe drought across most of the Mekong Basin during the dry season due to El Niño events
  - Used Soil Moisture Anomaly Percentage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



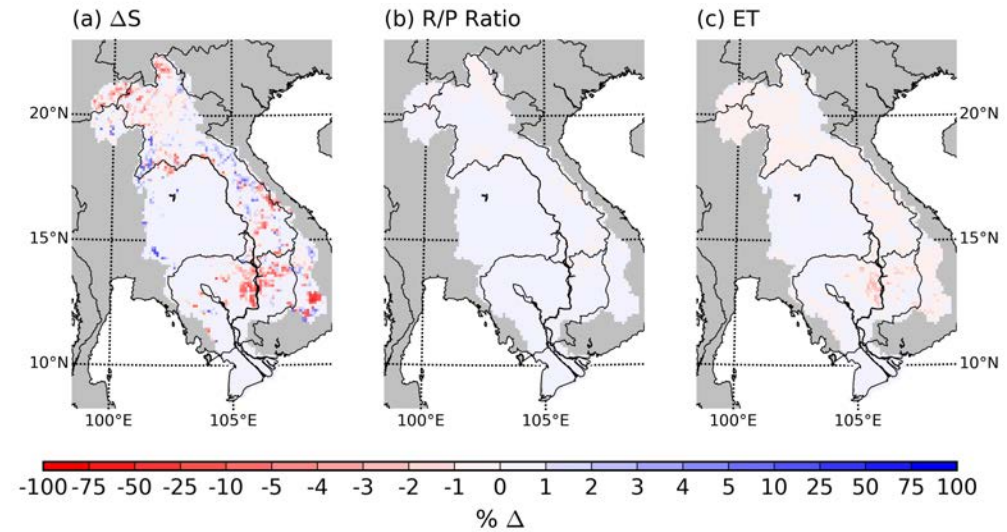


# VIC Application: Basin Management

- 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

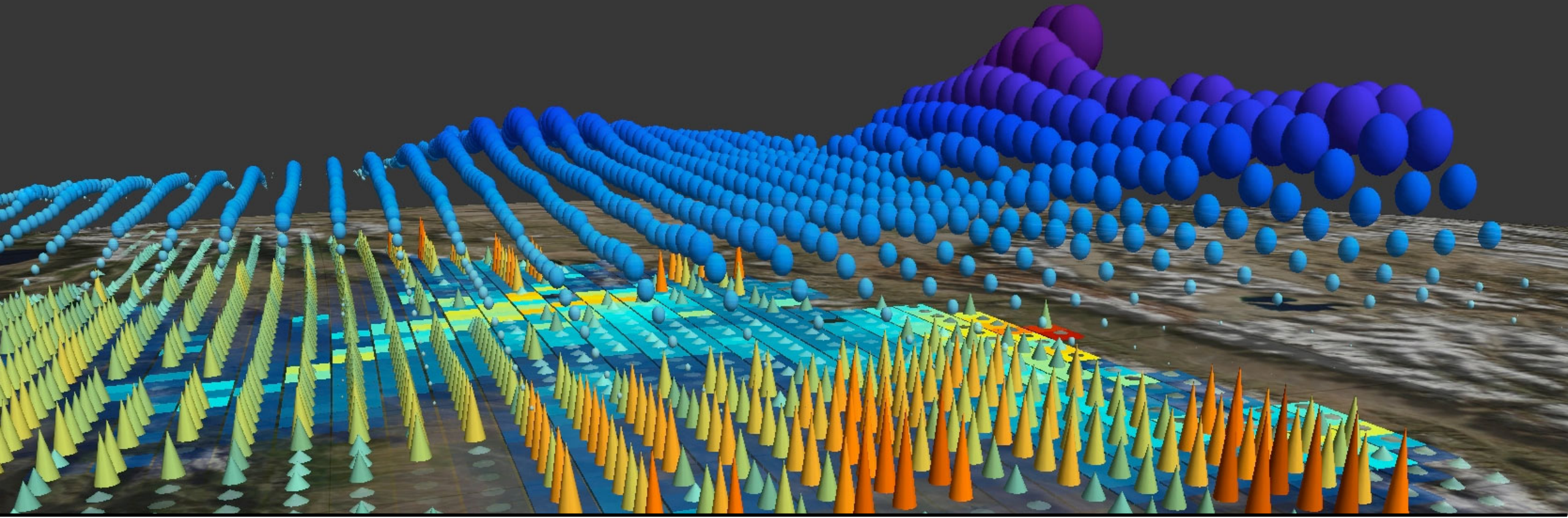


Increase in agriculture area



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



# Global VIC Application: Streamflow and Flood Monitoring

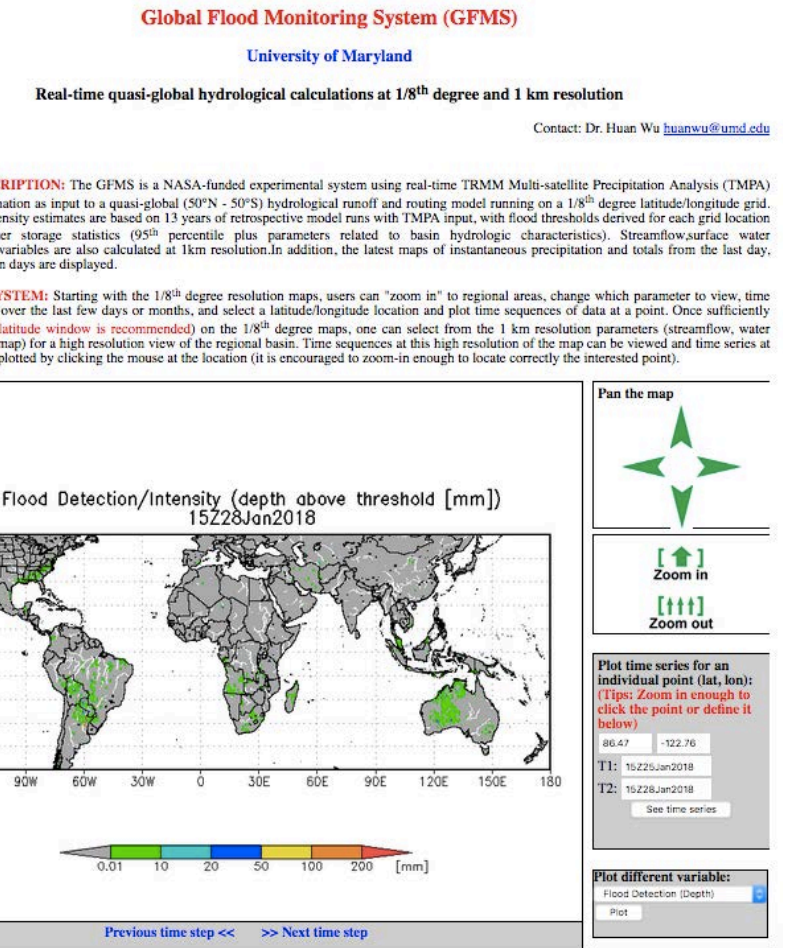
Global Flood Monitoring System (GFMS): <http://flood.umd.edu/>

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.

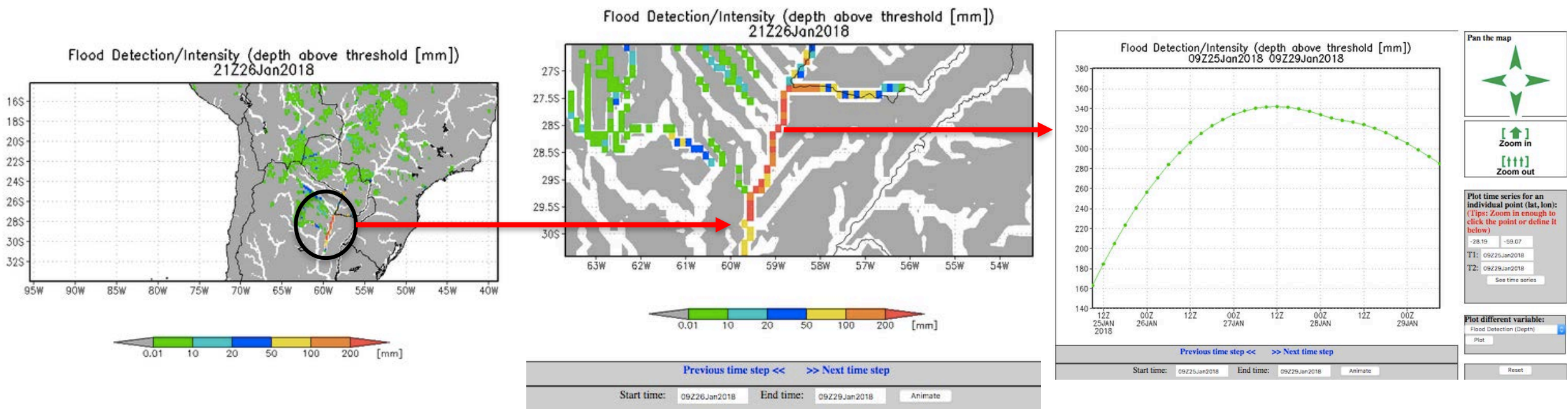




# Global VIC Application: Recent Flood Monitoring in Paraguay

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

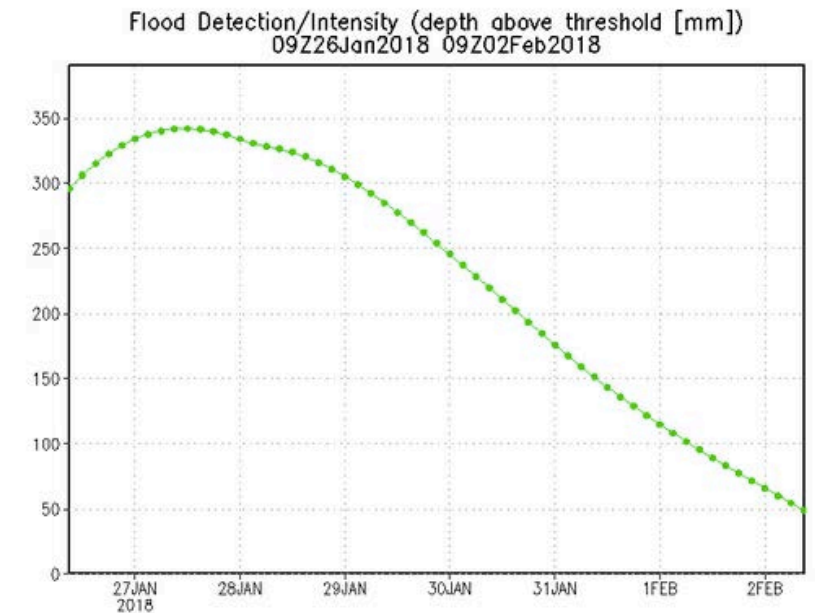
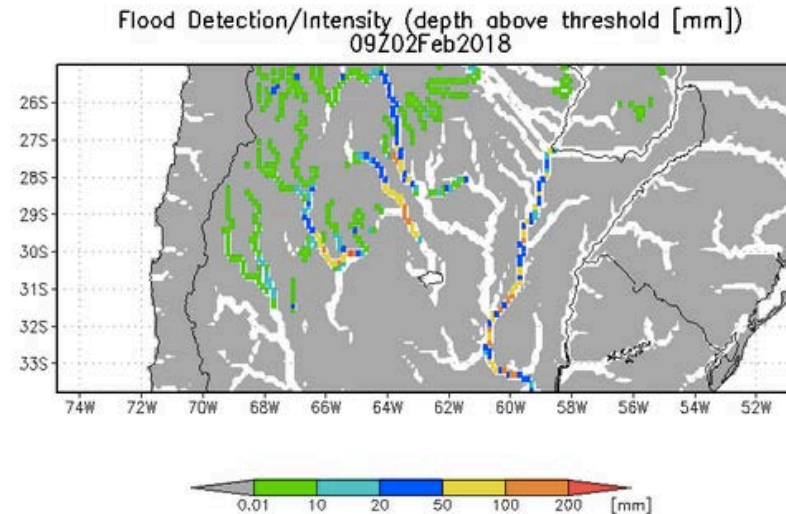
Paraguay River Floods 25-26 January 2018



# 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



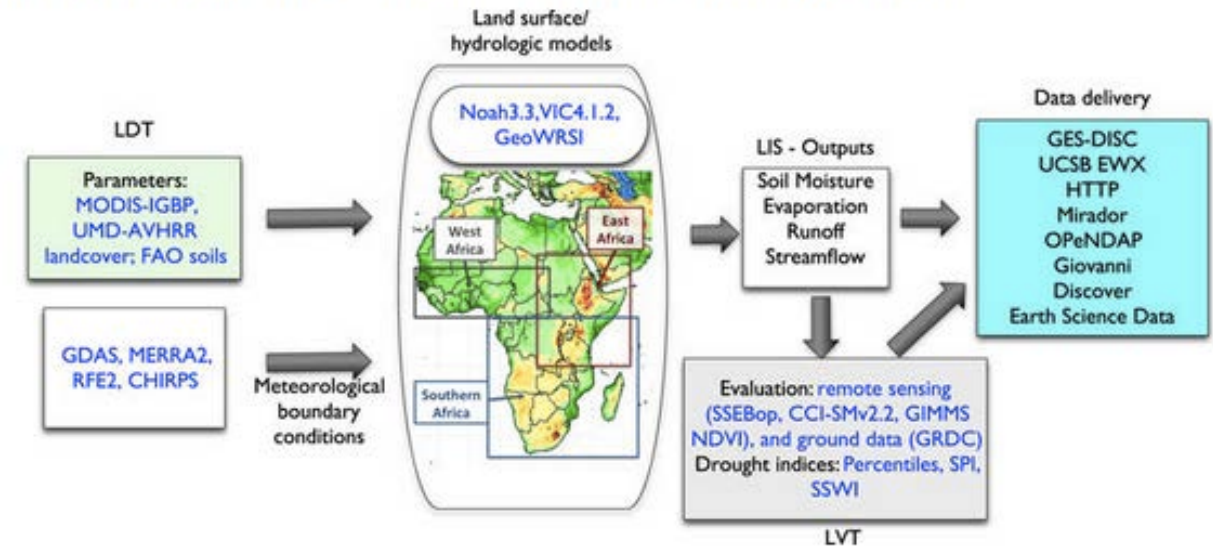
# Continental VIC Application: Water Resources Management

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>



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## Monthly Soil Moisture (10-40 cm)

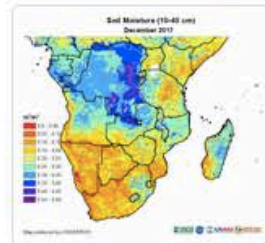
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Documentation

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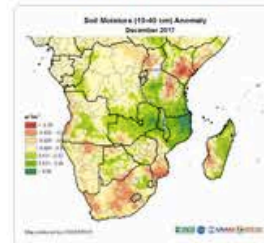
### Southern Africa

Soil Moisture (SM)



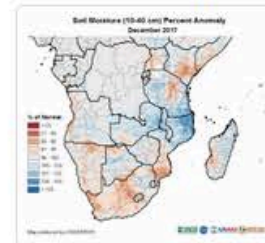
png pdf data

SM Difference Anomaly



png pdf data

SM Percent Anomaly



png pdf data

Monthly Period

Year

2017

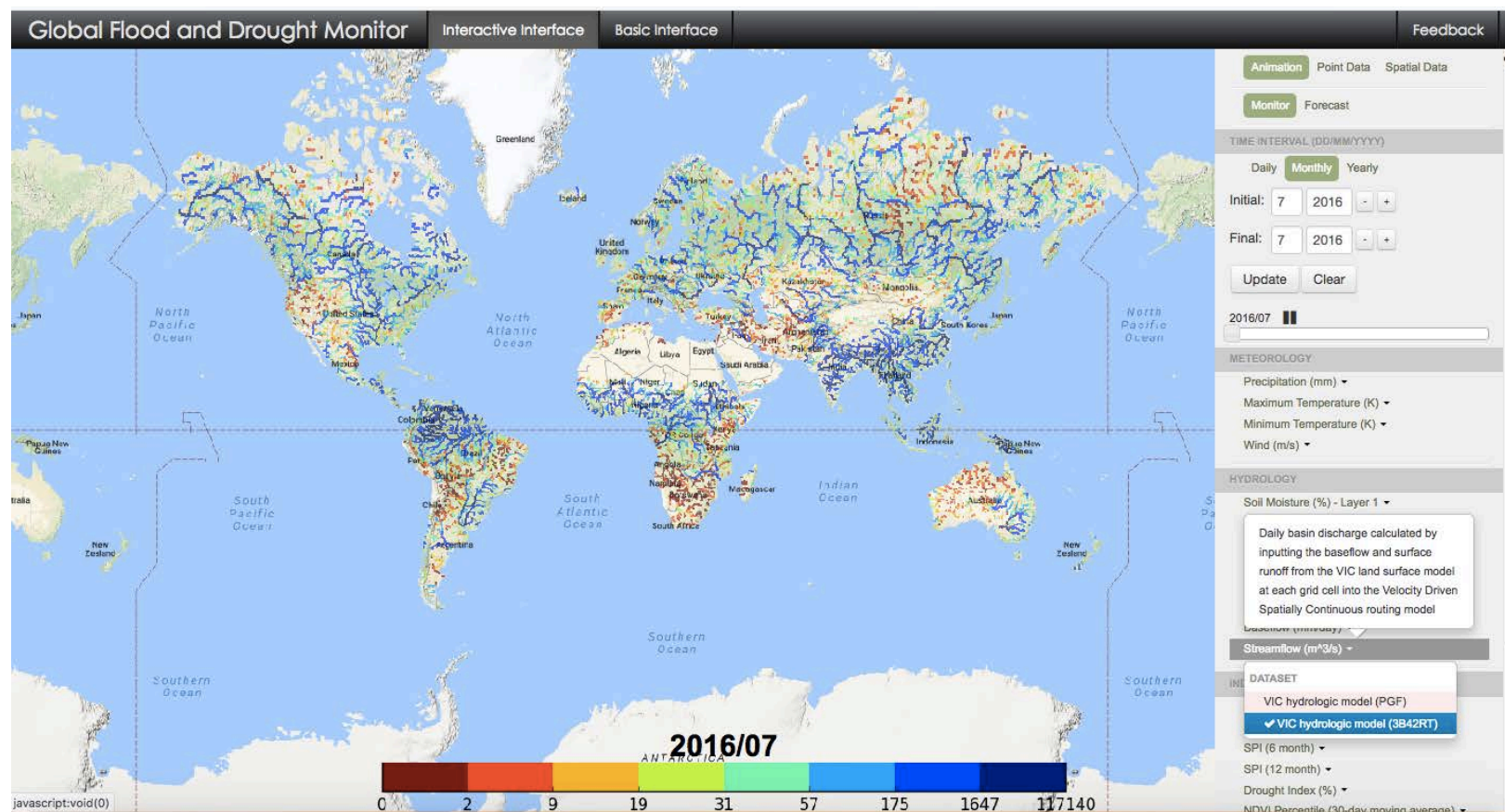
Month

Dec



# Princeton Global Flood and Drought Monitor

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



VIC-derived streamflow ( $\text{m}^3/\text{s}$ ) 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

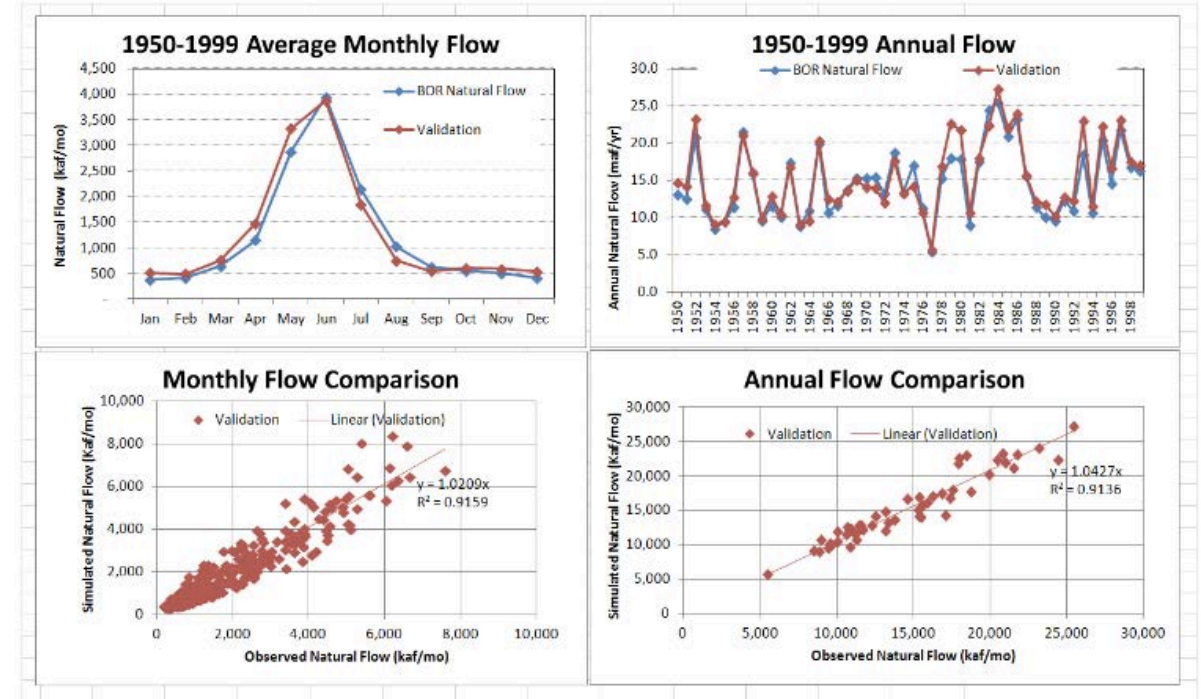
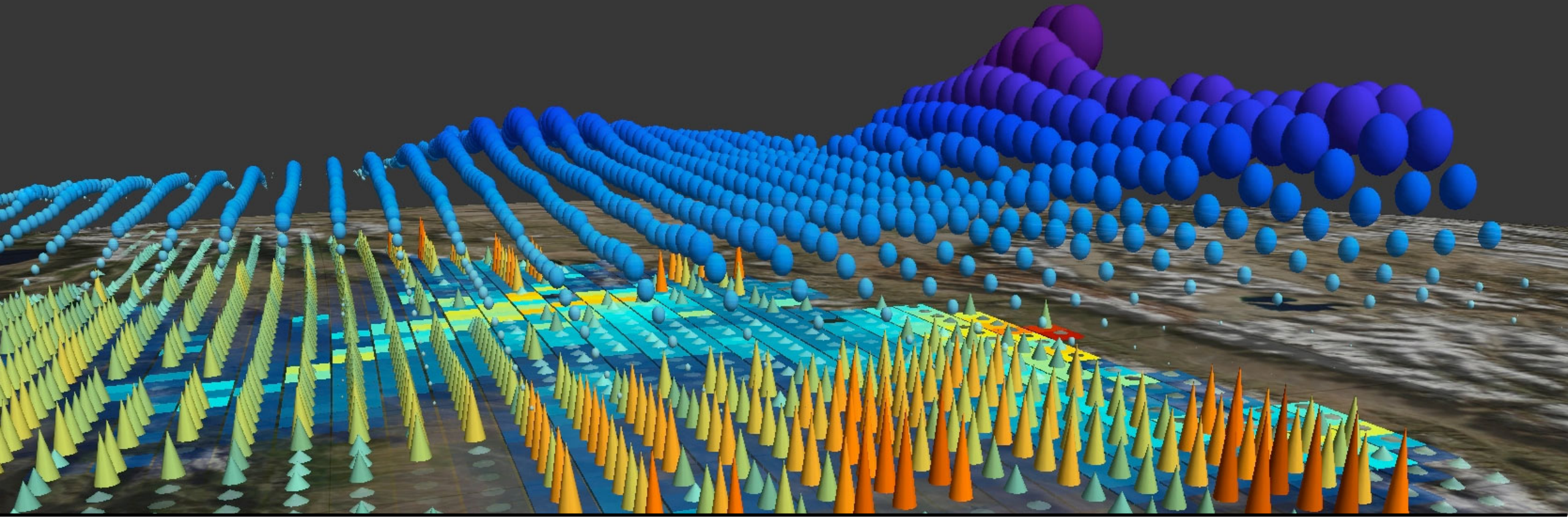


Image Credit: Colorado River Basin Water Supply and Demand Study; Technical Report B – Water Supply Assessment. (2011, June).

<https://www.usbr.gov/lc/region/programs/crbstudy/Report1/TechRptB.pdf>. Appendix B4: Variable Infiltration Capacity (VIC) Hydrologic Modeling Methods and Simulations







# Summary

# 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

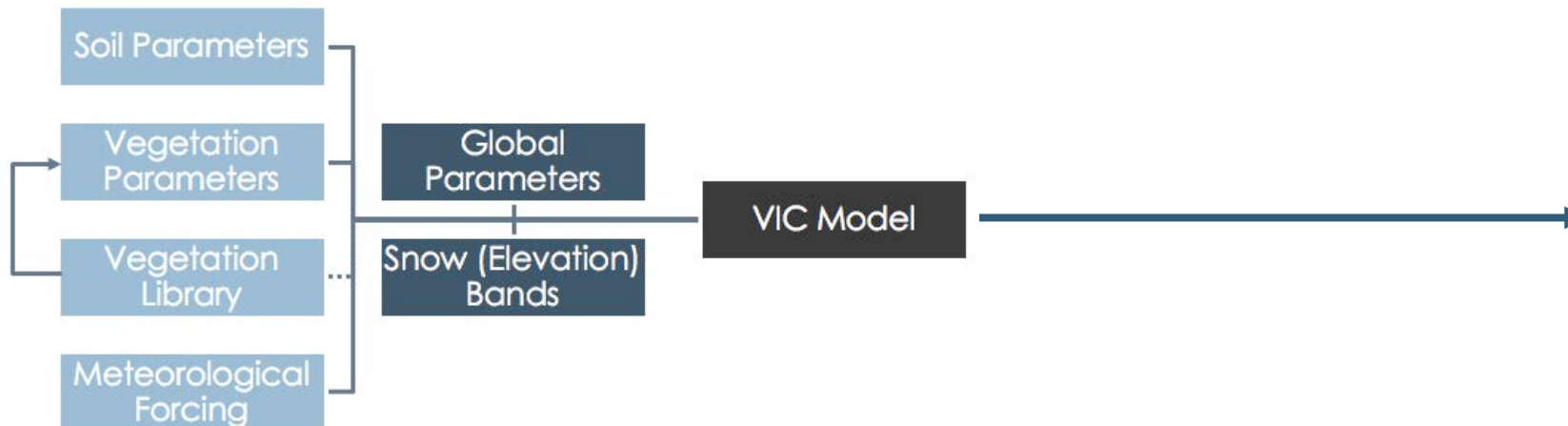


# VIC Summary: Inputs and Outputs

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

Meteorological Forcing

Data Parameter	Source
Minimum & Maximum Temperatures Surface Winds	<b>MERRA-2</b> Model With Assimilated Satellite Observations
Precipitation	Global Precipitation Measurement ( <b>GPM</b> ) Mission - <b>IMERG</b> <a href="https://disc.sci.gsfc.nasa.gov/">https://disc.sci.gsfc.nasa.gov/</a>
Land Cover, <b>LAI</b> and Albedo	<b>Terra and Aqua MODIS</b> <a href="https://search.earthdata.nasa.gov/">https://search.earthdata.nasa.gov/</a>
Soil properties	Harmonized World Soil Database <a href="http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/HWSD_Data.html?sb=4">http://webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database/HTML/HWSD_Data.html?sb=4</a>
Elevation	Shuttle Radar Topography Mission ( <b>SRTM</b> ) <a href="http://csi.cgiar.org/WhtisCGIAR_CSI.asp">http://csi.cgiar.org/WhtisCGIAR_CSI.asp</a>

**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