National Aeronautics and Space Administration

Monitoring and Modeling Floods using Earth Observations

Amita Mehta & Sean McCartney
Guest Speaker: Caroline Williams, NASA DEVELOP

September 14, 2022

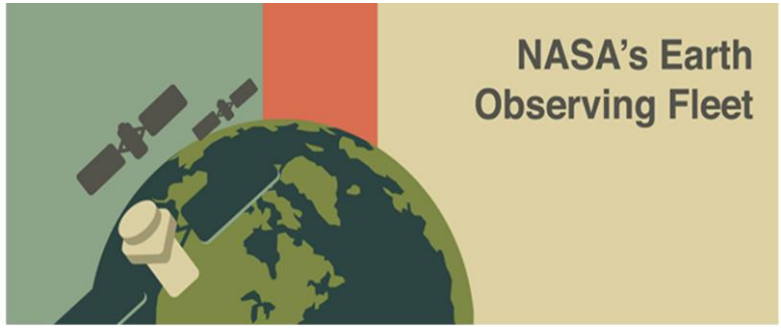
Training Objectives

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

- Identify observation-based flood monitoring and mapping tools
- Identify selected open-source flood models
- Understand and plan for using hydrologic and flood routing modeling techniques

Prerequisites

- Fundamentals of Remote Sensing, Sessions 1, 1A and 2B:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-fundamentals-remote-sensing



Prerequisites

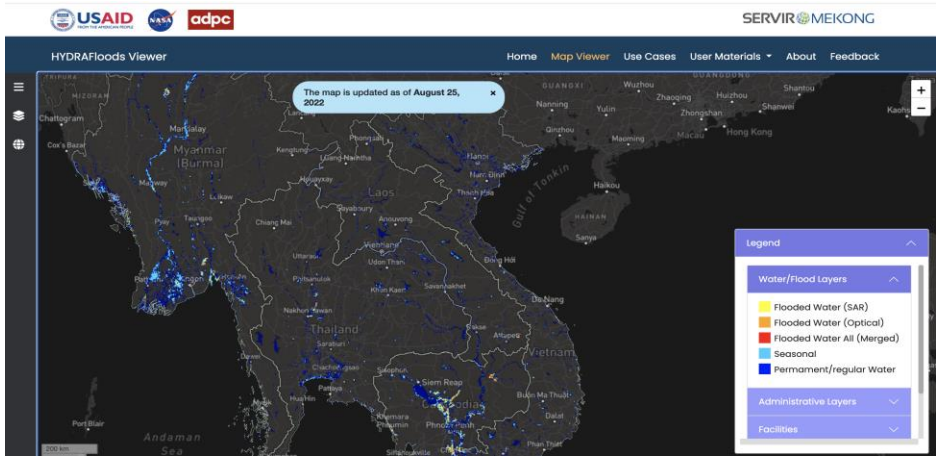
- The following ARSET flood training provides details of observational-based flood monitoring techniques and tools:
  - https://appliedsciences.nasa.gov/join-mission/training/satellite-remote-sensing-flood-monitoring-and-management

Training Outline

Two 2-hour sessions offered in English with materials available in Spanish

Part 1: September 14, 2022

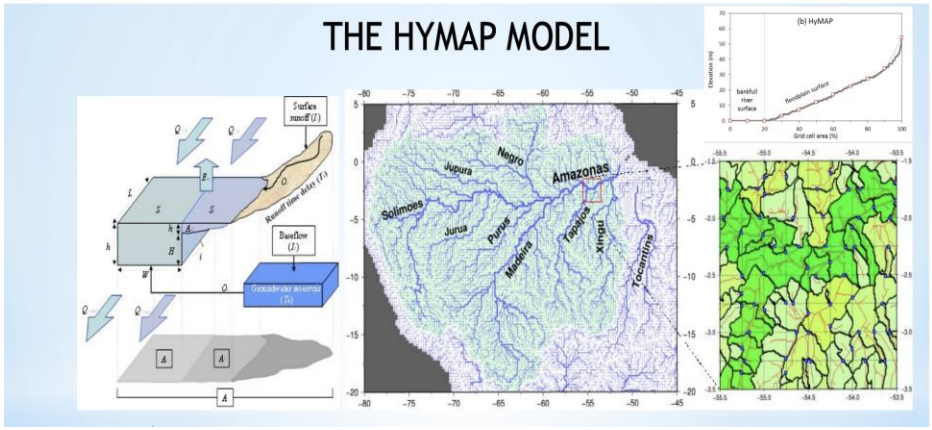
Overview: Flood Monitoring and Modeling



https://hydrafloods-servir.adpc.net/map/

Part 2: September 21, 2022

Introduction: The Hydrological Modeling and Analysis Platform (HyMAP)



https://ldas.gsfc.nasa.gov/sites/default/files/ldas/nldas/presentations/Getirana_NLDAS_HyMAP_10Nov2016.pdf

Outline for Part 1

- About ARSET
- Flood Monitoring Tools Based on Remote Sensing
- Overview of Selected Flood Models
- Demonstrations of Flood Tools
- Introduction and Demonstration: The HYDrologic Remote Sensing Analysis for Floods (HYDRAFloods)

Homework and Certificate

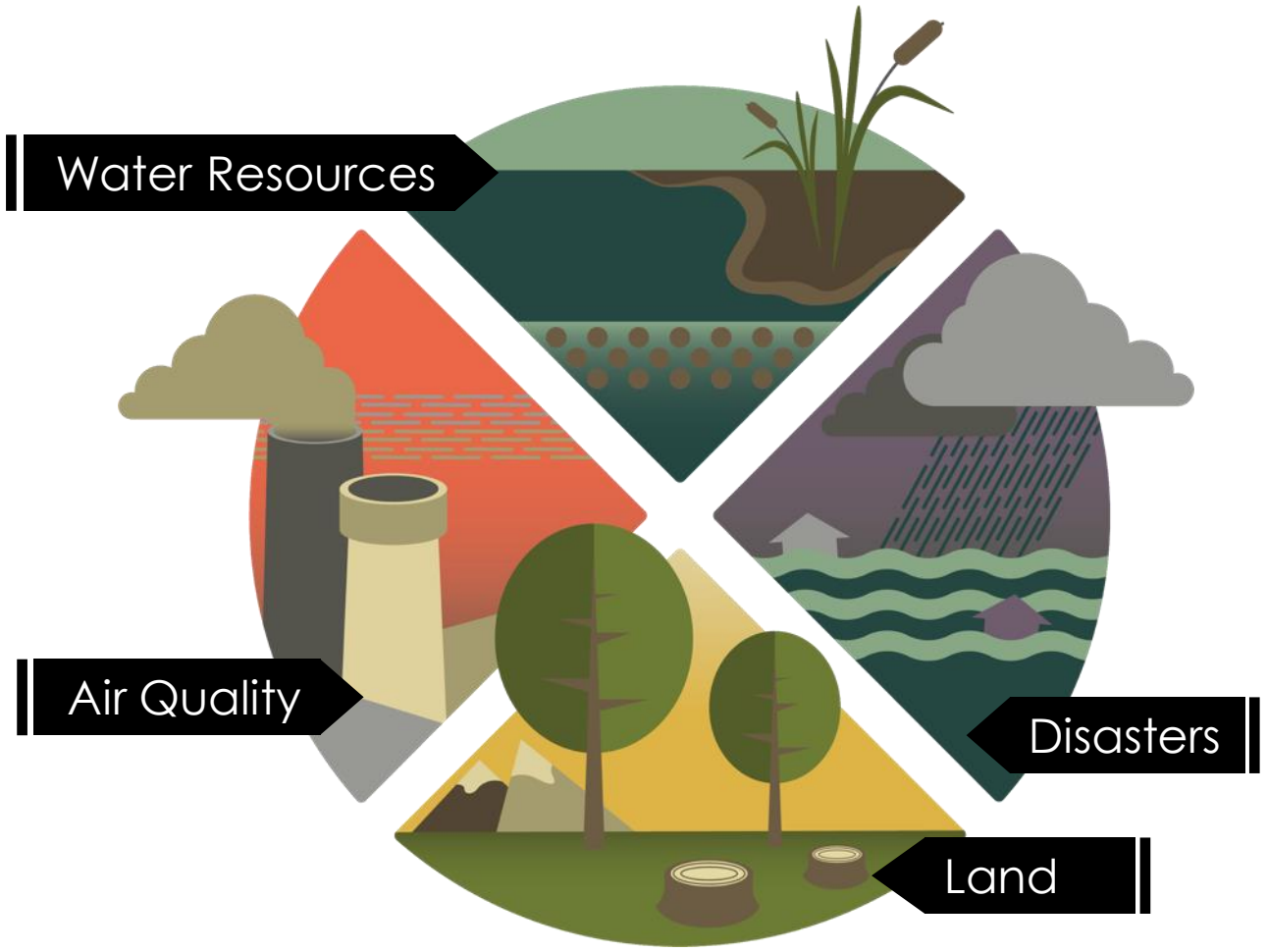
- One homework assignment:
  - Answers must be submitted via Google Form accessed from the ARSET website
  - Homework will be made available on September 21, 2022.
  - Due date for homework: **October 7, 2022**.
- A certificate of completion will be awarded to those who:
  - Attend all live webinars
  - Complete the homework assignment by the deadline
  - You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

About ARSET

NASA's Applied Remote Sensing Training Program (ARSET)

https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

- Part of NASA's Applied Sciences Capacity Building Program
- Empowering the global community through online and in-person remote sensing training
- Topics for trainings include:
  - Water Resources
  - Air Quality
  - Disasters
  - Land
  - Climate (recently added)



NASA's Applied Remote Sensing Training Program (ARSET)

https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

- ARSET's goal is to increase the use of Earth science remote sensing and model data in decision-making through training for:
  - Professionals in the public and private sector
  - Environmental managers
  - Policy makers

All ARSET materials are freely available to use and adapt for your curriculum. If you use the methods and data presented in ARSET trainings, please acknowledge the NASA Applied Remote Sensing Training (ARSET) program.

Flood Monitoring Tools Based on Remote Sensing

About Floods

https://www.ready.gov/floods

- Flooding is a temporary overflow of water onto land that is normally dry.
  - The most common disaster affecting human lives
  - Can cause infrastructure damage & power outages
  - Disrupts transportation
  - Creates landslides
  - About six inches (15 cm) of moving water can knock a person down, and one foot (30 cm) of moving water can sweep a vehicle away!

Globally in 2021, a total of 432 catastrophic events were recorded, which is considerably higher than the average of 357 annual catastrophic events for 2000 – 2020. **Floods dominated these events,** with 223 occurrences, up from an average of 163 annual flood occurrences recorded across the 2001–2020 period.
- Reliefweb

Flood Monitoring and Management

- Require geophysical and socioeconomic data:
  - Floodplain Map: Terrain, Digital Elevation Model, Low-Lying Areas
  - Precipitation Intensity, Frequency
  - River Stage, Streamflow, Inundation
  - Coastal Surges and Inundation
  - Land Use Change: Exposed Soil versus Built-Up Areas, Soil Moisture
  - Population, Infrastructure, Drainage, and Storm Water System Capacity (Urban Floods)
  - Flood Return Period
  - Hydrology and Routing Model

https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-urban-floods-using-remote-sensing

Remote Sensing-Based Flood Detection

There are several approaches to using remote sensing observations for flood monitoring:

- Detecting flood water on previously dry land surfaces using satellite-derived land cover observations
- Hydrology models that derive streamflow and runoff using precipitation and weather data from satellites and models
- Inferring flooding conditions using satellite-derived precipitation rate and amount and soil moisture conditions using statistical methodology

Note: Each flooding approach also uses model and/or surface-based data in addition to satellite data.

Flood Monitoring Tools

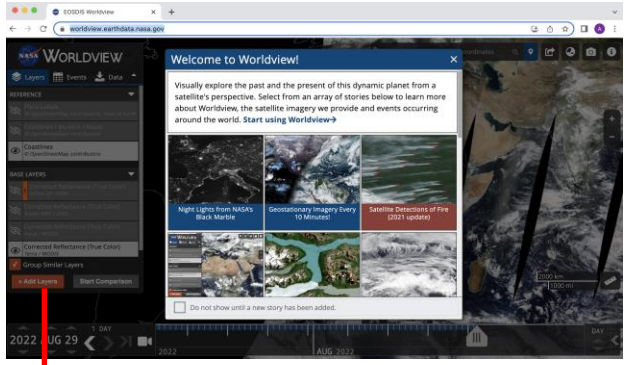
- [1]MODIS-Based Flood Mapping (NASA Worldview)
- [1]Dartmouth Flood Observatory River Watch (DFO River Watch)
- [2]Global Disaster Alert and Coordination System (GDACS)
- Advanced Rapid Imaging and Analysis (ARIA)
- **The HYDrologic Remote sensing Analysis for Floods (HYDRAFloods)**

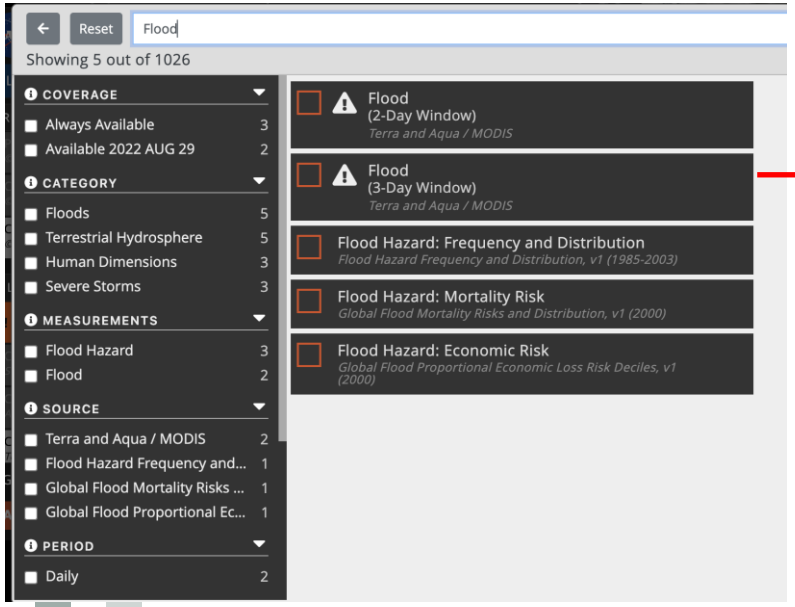
[1]https://appliedsciences.nasa.gov/join-mission/training/satellite-remote-sensing-flood-monitoring-and-management

[2]https://appliedsciences.nasa.gov/join-mission/training/english/arset-overview-global-disaster-alert-and-coordination-system-gdacs

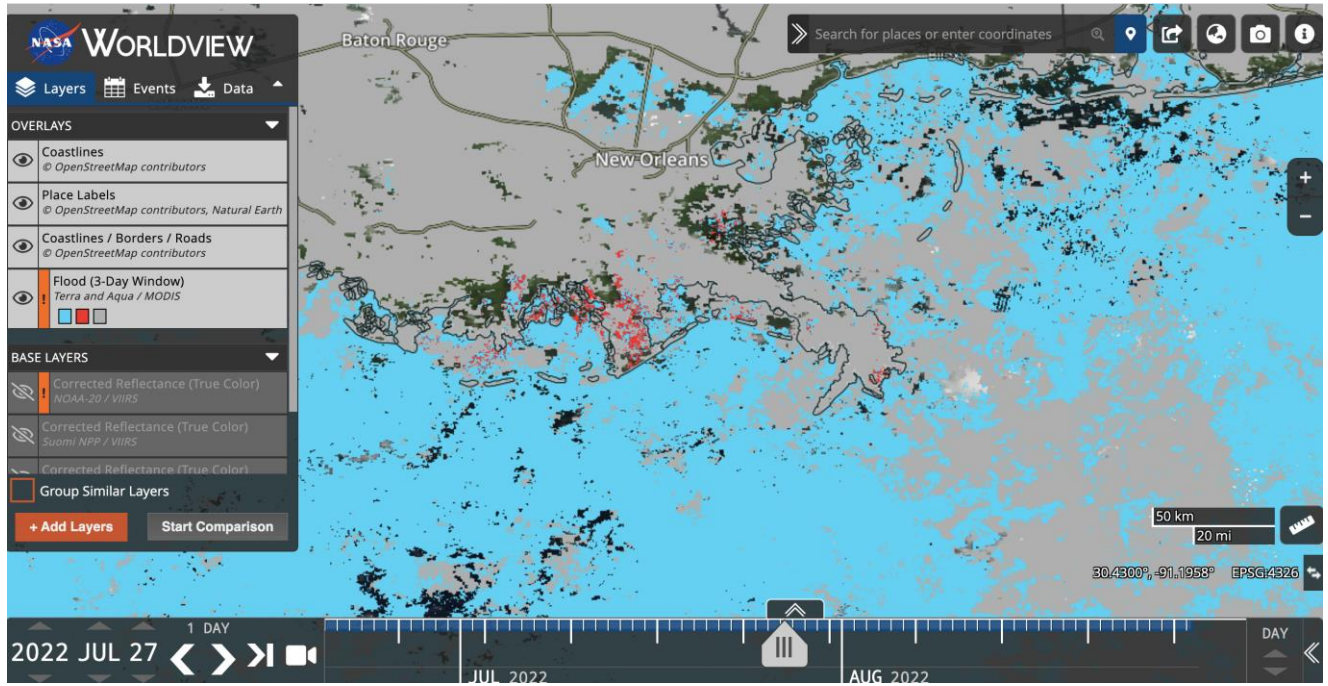
NASA Worldview

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





3-Day Composite Flooding from MODIS

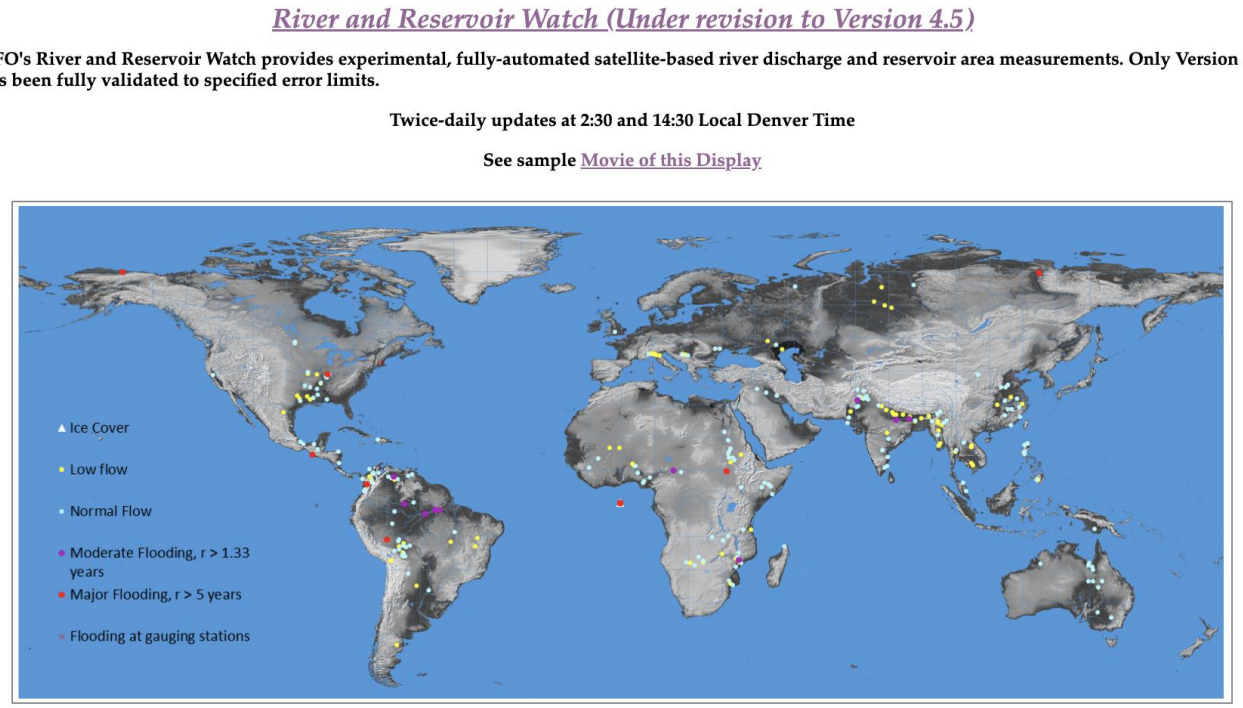


Replacing the MODIS NRT Flood Map Portal
https://floodmap.modaps.eosdis.nasa.gov/

Dartmouth Flood Observatory (DFO River Watch)

http://floodobservatory.colorado.edu/

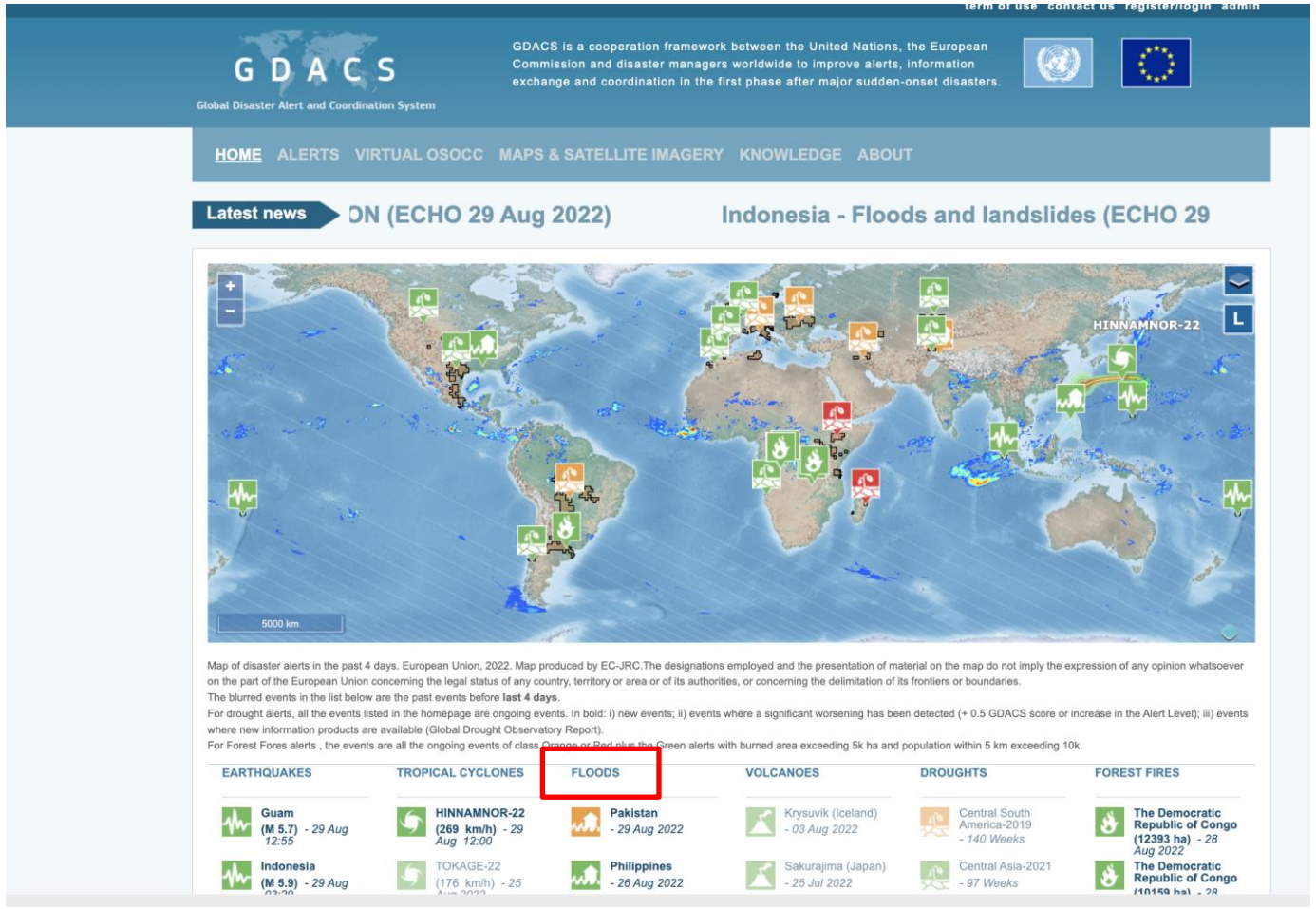
- Based on passive microwave observations and river gauge measurements.
- Currently, a new version and validation of river discharge methodology is underway.

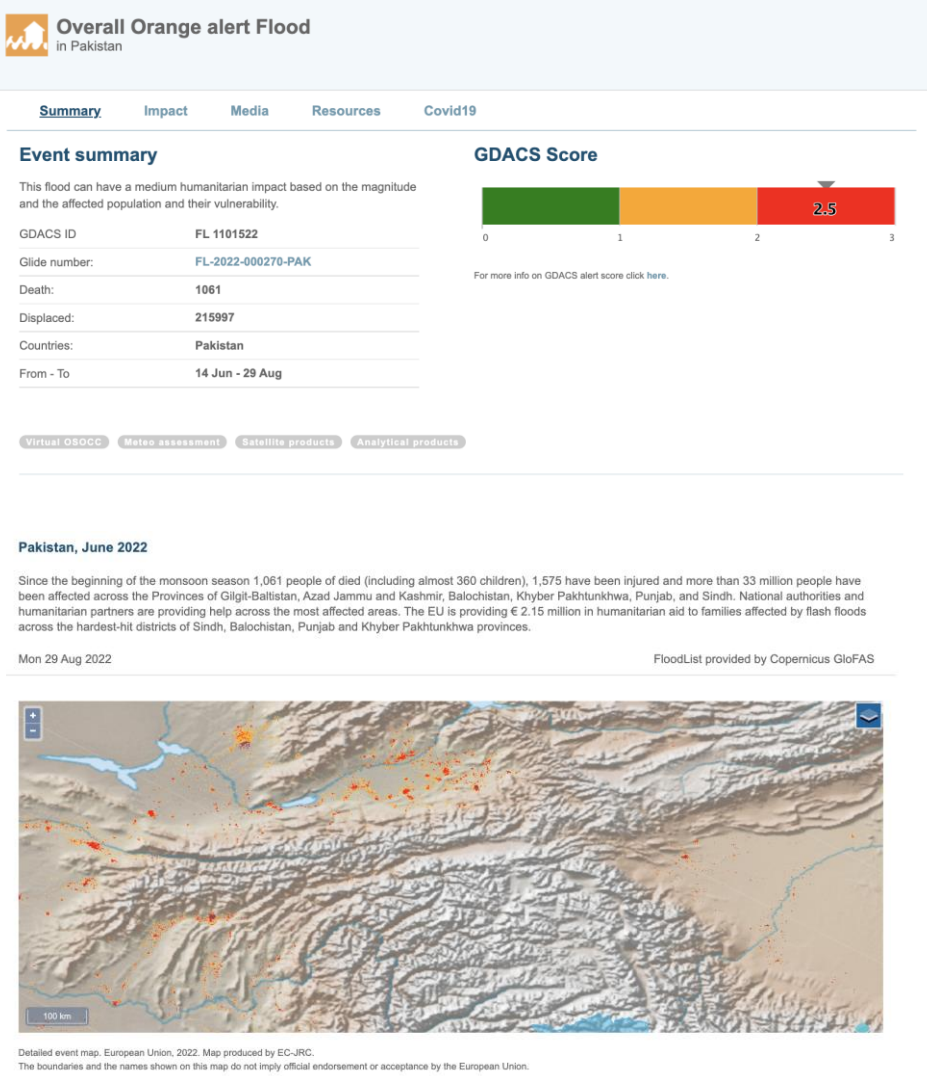


https://floodobservatory.colorado.edu/DischargeAccess.html

Global Disaster Alert and coordination System (GDACS)

https://gdacs.org/

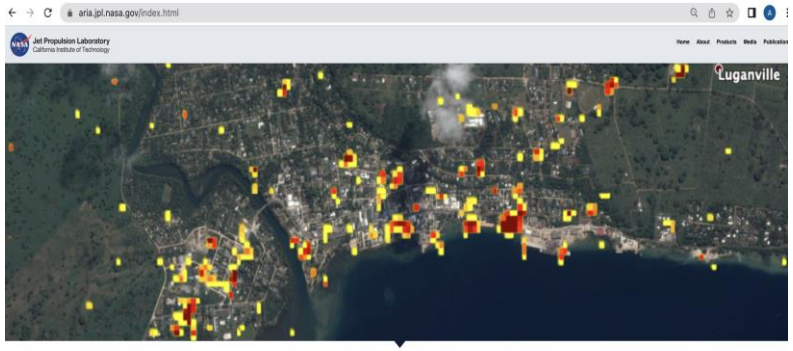




Advanced Rapid Imaging and Analysis (ARIA)

https://aria.jpl.nasa.gov/index.html

- A collaboration between JPL and Caltech to exploit radar and optical remote sensing, GPS, and seismic observations for hazard science and response.
- ARIA investigates the processes and impacts of multiple natural hazards.
- Primarily focused on ground deformation change measurements, also includes flood damage proxy maps.



Products

Overview

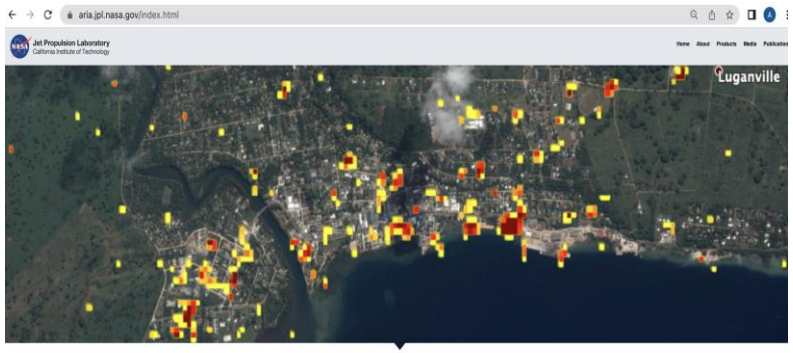
Below is a schematic showing what Level 2 (L2) and Level 3 (L3) data sets are available. Available products are in blue, and clicking on them will take you to additional information about the product specfications and background.

	Science Products		Urgent Response Products
Product	InSAR	GPS	SAR
Level 2	Standard Displacement Products	PS Time-Series	
Level 3	Time Series		Damage Proxy Maps (DPM)
	Coseismic	GPS Coseismic Offsets	Flood Proxy Maps (FPM)

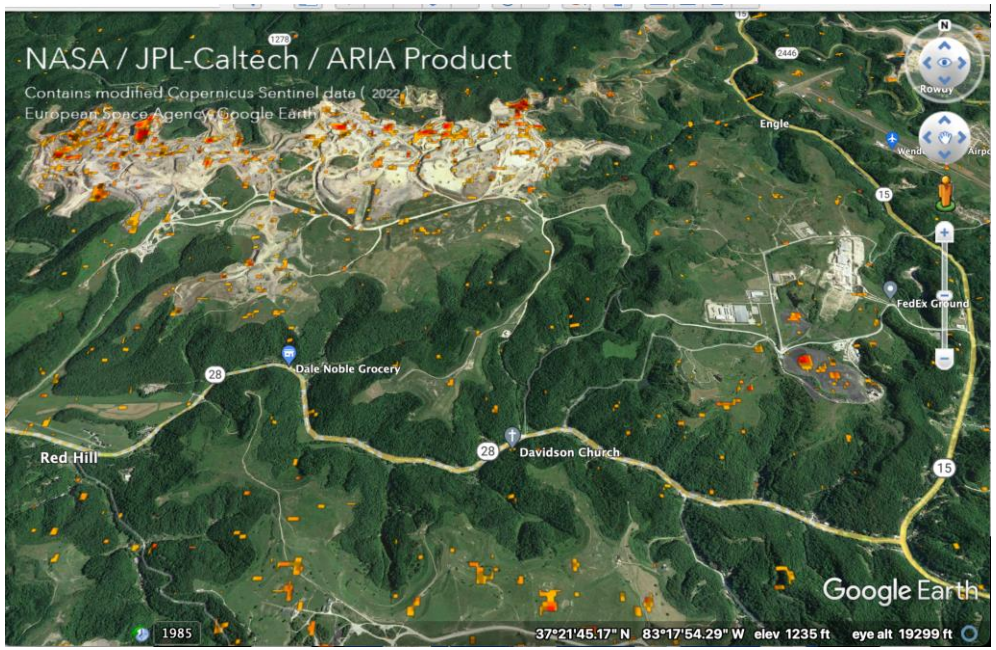
Advanced Rapid Imaging and Analysis (ARIA)

https://aria.jpl.nasa.gov/index.html

- A collaboration between JPL and Caltech to exploit radar and optical remote sensing, GPS, and seismic observations for hazard science and response.
- ARIA investigates the processes and impacts of multiple natural hazards.
- Primarily focused on ground deformation change measurements; also includes flood damage proxy maps.



Kentucky Floods (July 2022)



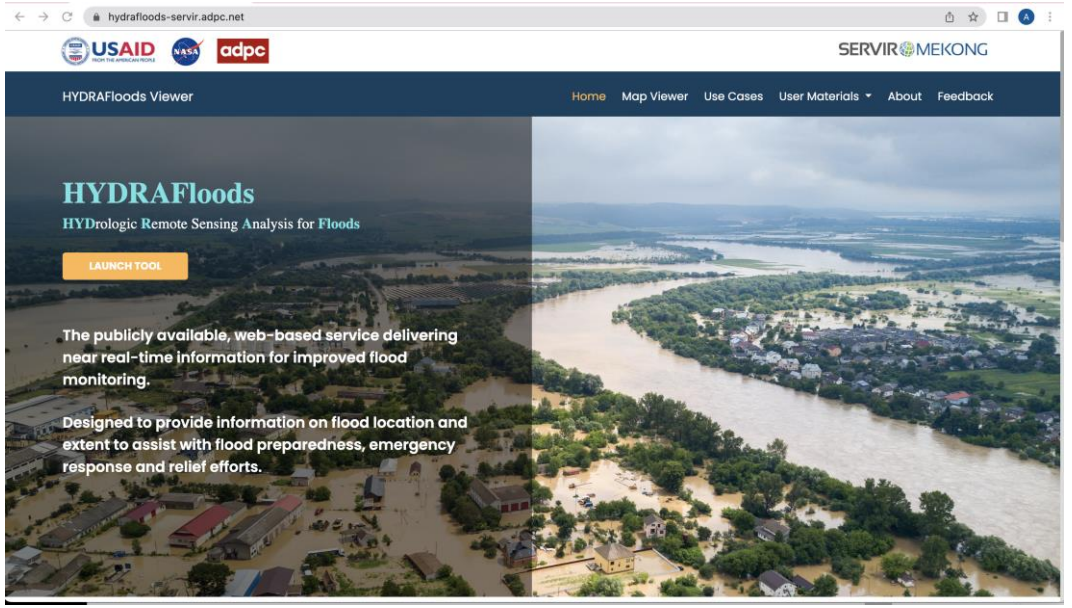
ARSET Webinar: https://appliedsciences.nasa.gov/join-mission/training/english/arset-radar-remote-sensing-land-water-disaster-applications

The HYDrologic Remote Sensing Analysis for Floods (HYDRAFloods)

HYDrologic Remote Sensing Analysis for Floods (HYDRAFloods)

https://hydrafloods-servir.adpc.net/

- A publicly available, web-based, near real-time flood monitoring tool to help emergency response and relief sectors by providing flood extent information.
- This flood monitoring system uses open-source satellite remote sensing data from optical and Synthetic Aperture Radar (SAR) sensors.
- Developed using Google Earth Engine and Google Cloud Platform with Python API.



Currently available for the Mekong River Basin, from NASA – US Agency for International Development (USAID) – SERVIR – Asian Disaster Preparedness Center (ADPC) Initiative

HYDrologic Remote Sensing Analysis for Floods (HYDRAFloods)

https://servir-mekong.github.io/hydra-floods/algorithms/

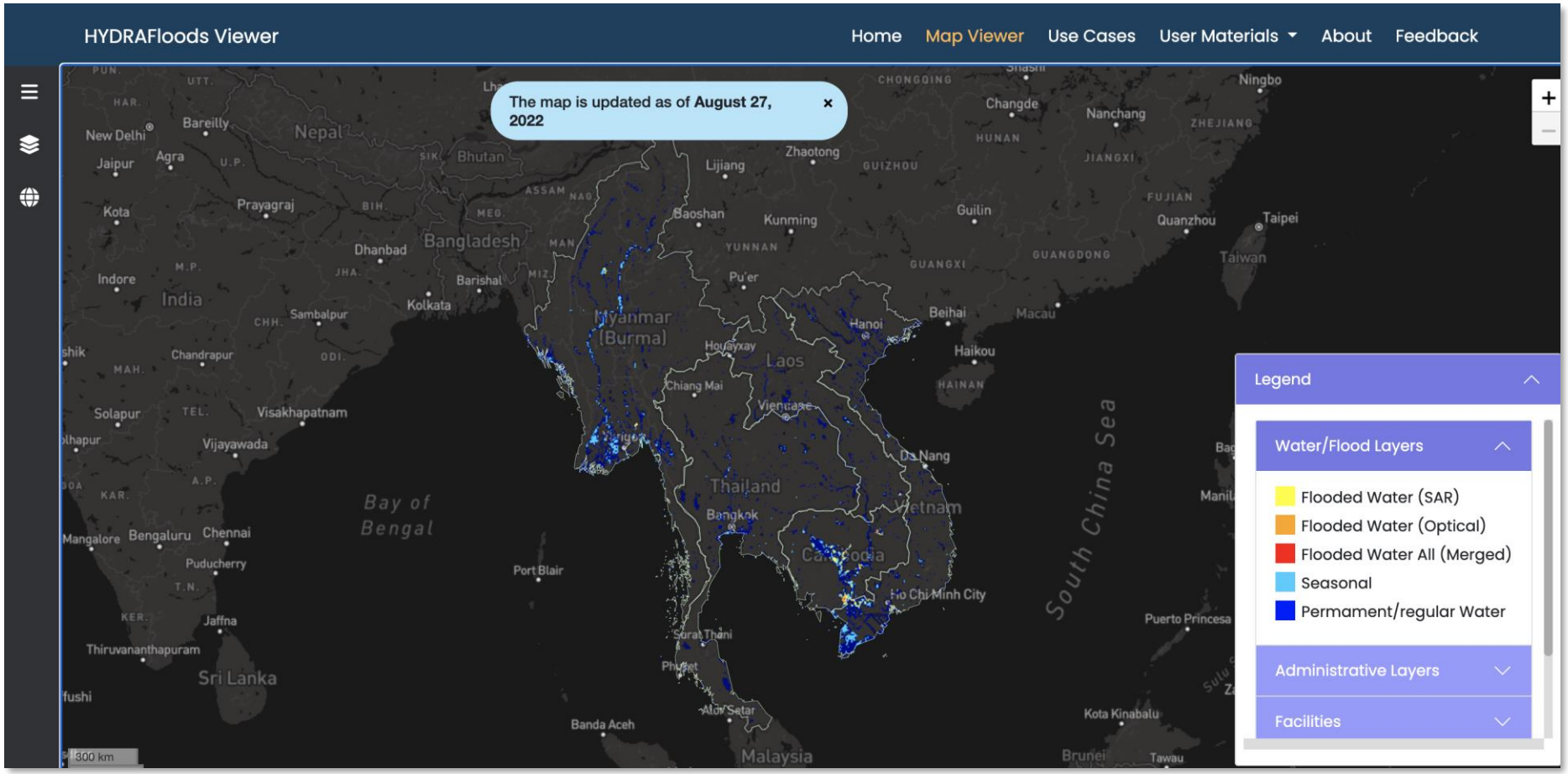
- HYDRAFloods uses the following remote sensing inputs:
  - Sentinel-1 C-band SAR data
  - Sentinel-2 optical data
  - Landsat 7 & 8 optical data
  - VIIRS and MODIS optical data

- HYDRAFloods allows access to high-quality, cloud-based surface water mapping algorithms:
  - SAR Speckle Filtering Algorithms
  - Correction Algorithms
  - Applying Illumination Correction on Optical Imagery
  - Applying Slope Correction on SAR Imagery
  - Generic Water Mapping Algorithms

HYDrologic Remote Sensing Analysis for Floods (HYDRAFloods)

https://hydrafloods-servir.adpc.net/map/

- Map Viewer allows visualization of permanent and seasonal surface water



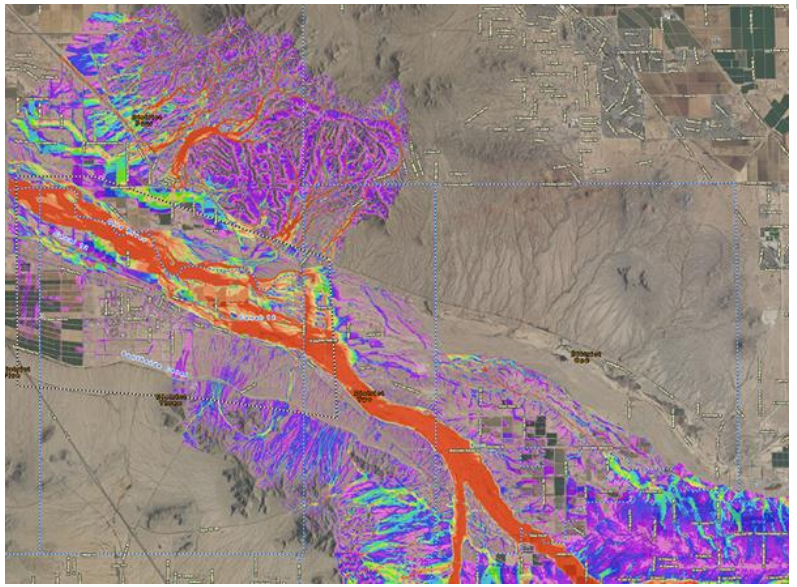
Overview of Selected Flood Models

Flood Modeling Techniques

Two broad groups of flood modeling approaches:

- Empirical and statistical models based on observations, including remote sensing.
- Hydrodynamic models with 1-, 2-, or 3-dimensional representation of water flow in an open or closed channel.
  - Hydrologic and Hydraulic models

Tenh et al., 2017: https://doi.org/10.1016/j.envsoft.2017.01.006

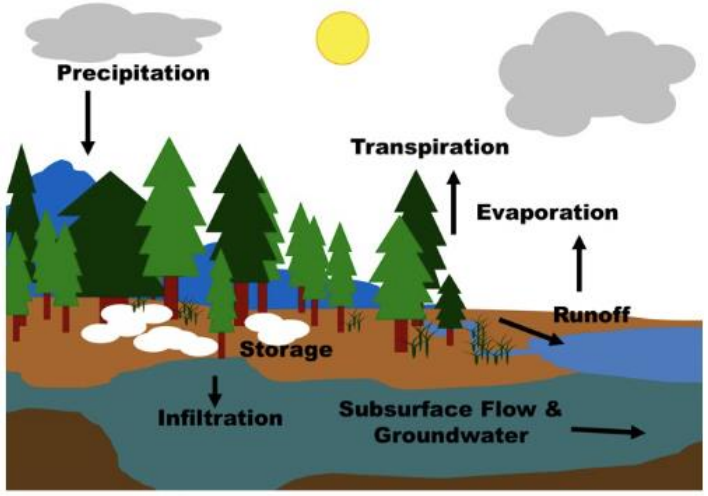


Flood modeling and management use hydrologic, hydraulic, and sediment transport modeling and analyses.

http://www.helm.world/hydrology-hydraulics.html

Hydrologic and Hydraulic Flood Modeling

- **Hydrologic Models**: Circulation of water through the hydrologic cycle and quantification of runoff flow produced by precipitation. It deals with precipitation, evaporation, infiltration, groundwater flow, surface runoff, and streamflow.



https://ncar.github.io/hydrology/projects/hydrologic_modeling

- **Hydraulics Models**: The mechanical behavior of water in open or closed channels. It provides water flow and depth as water moves from one point to the next in a channel.

boise river 2d modelling software

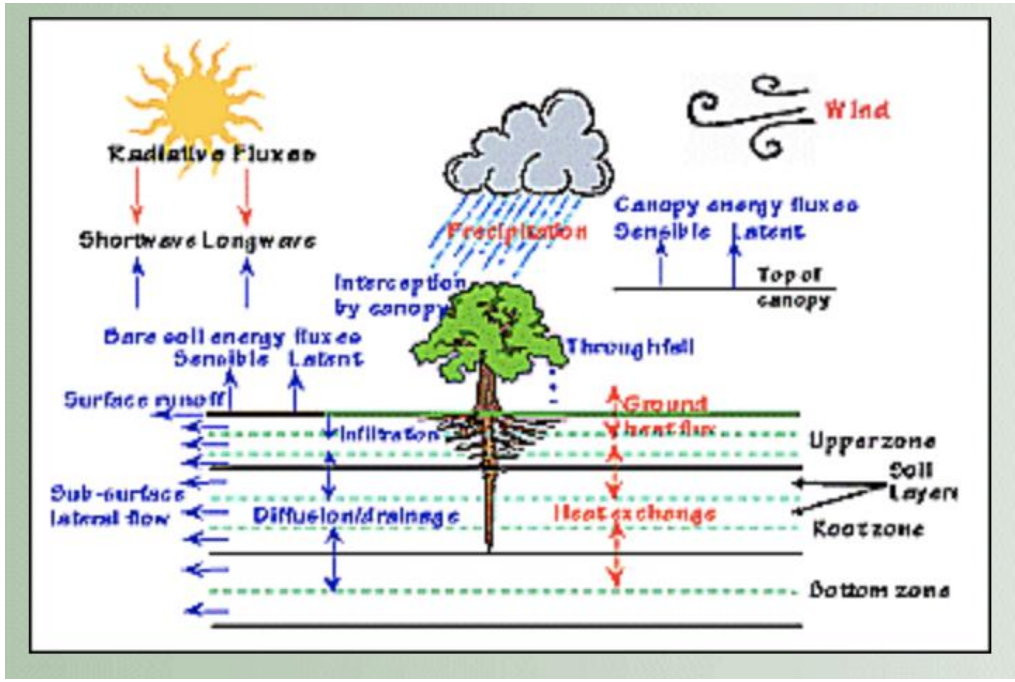
https://dudek.com/do-you-know-the-difference-between-hydrology-and-hydraulics/

https://www.nww.usace.army.mil/Media/Images/igphoto/2002565818/

Hydrologic Flood Modeling

USGS National Hydrologic Model Infrastructure

- Used for understanding water movement processes in a watershed land-atmosphere system.
- Provides an estimate of runoff in response to rainfall.
  - All of it may not end up in streams or river channels.
- Hydrologic models can be based on 1) water balance in a watershed or 2) rainfall-runoff relationship.
- Hydrologic model inputs include:
  - Rainfall and other weather parameters
  - Watershed delineation and terrain elevation
  - Landcover, vegetation types/canopy information
  - Soil characteristics

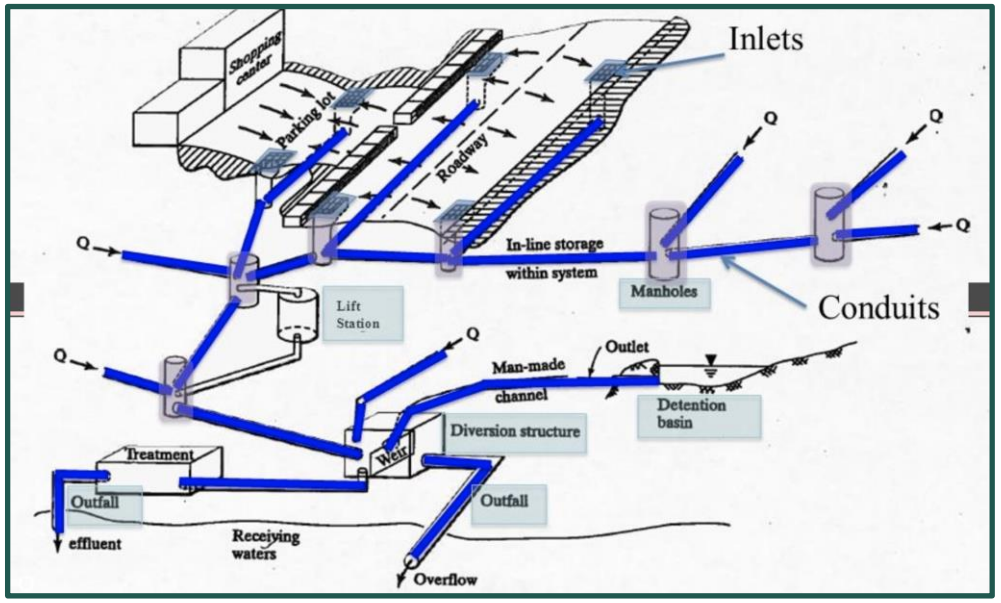


https://weather.msfc.nasa.gov/surface_hydrology/hydrologic_modeling.html

Hydraulic Flood Modeling

FEMA Guidance for Flood Risk Analysis and Mapping

- Used for getting water flow velocity and depth in streams, channels, and other surfaces for mapping flood extent and for mapping flood risk and analysis.
- For simple 1-D, steady state flow* models, the following inputs are necessary:
  - Cross-section geometry and hydraulic structures
  - Energy loss coefficients (frictional loss due to channel roughness)
  - Water-surface elevation at the most downstream cross section (details about the channel cross section and elevation are important)
  - Peak flow discharge



https://hydrologicmodels.tamu.edu/hydraulic-models/

*For unsteady flow models or 2-D models, more input information and boundary conditions are required.

Flood Modeling

- Both hydrologic and hydraulic modeling are required for flood mapping and flood risk mapping at watershed level.
- Remote sensing observations are routinely used for inputs:
  - Weather and precipitation data
  - Digital elevation
  - Land cover
- Calibration of flood model parameters is necessary and is performed using historic floods on stream reaches where discharge, flood flow, and elevation data are available.

- NASA Earth observations used for flood monitoring, mapping, and modeling from:
  - MODIS
  - Landsat
  - GPM
  - SRTM
  - SMAP
  - Sentinel-1and -2 (ESA)

Munawar et al. 2022: Remote Sensing Methods for Flood Prediction: A Review, Sensors (Basel). 2022 Jan 26;22(3):960. doi: 10.3390/s22030960. PMID: 35161706; PMCID: PMC8838435.

Examples of Open-Source Flood Models

The following models are widely used for flood inundation mapping at the watershed/river basin scale:

- U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS)

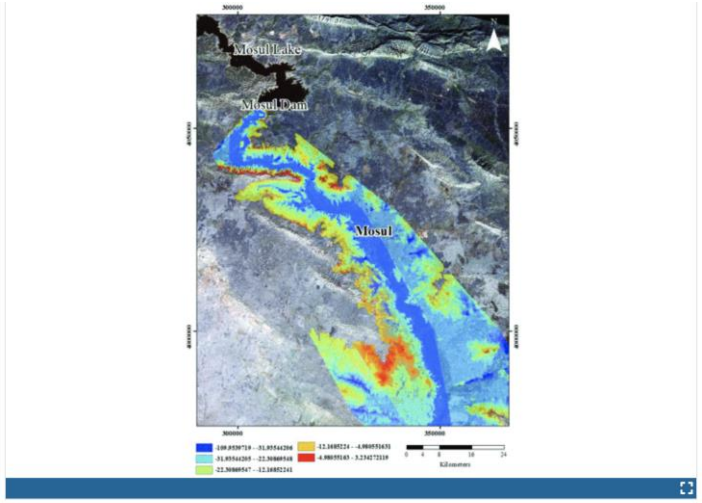


Fig. 3.
Flood map of hypothetical failure scenario for Mosul-Dam.

https://ieeexplore.ieee.org/document/8900379

- The Soil & Water Assessment Tool (SWAT)

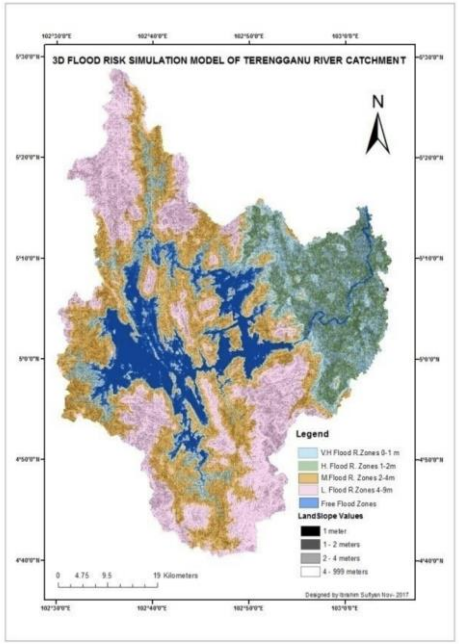


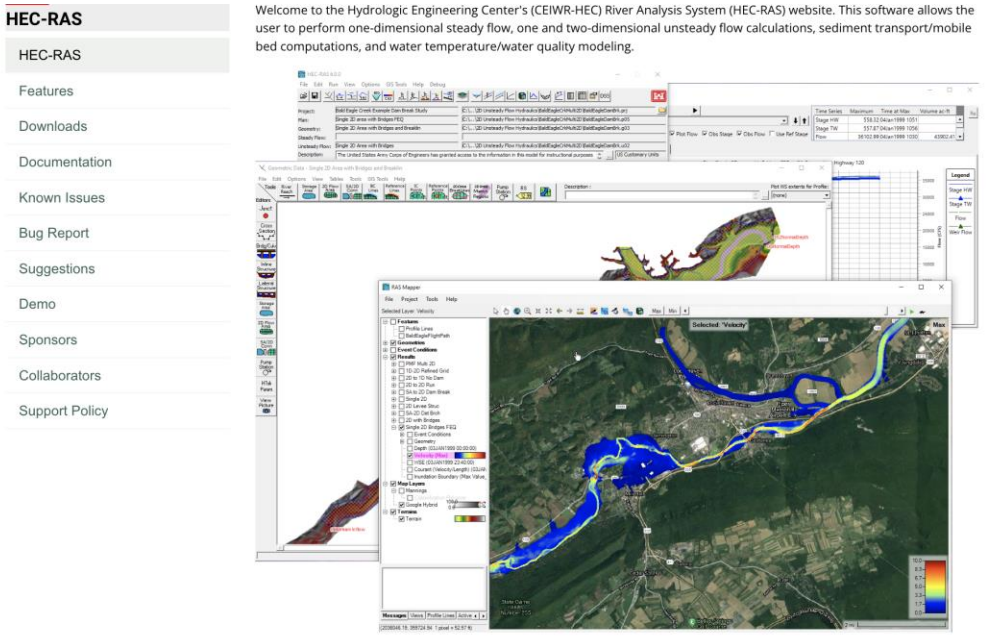
Figure 10: Flood Simulation Model of the Terengganu River Catchment

DOI : http://doi.org/10.26480/jcleanwas.02.2018.19.24

About HEC-RAS

https://www.hec.usace.army.mil/software/hec-ras/

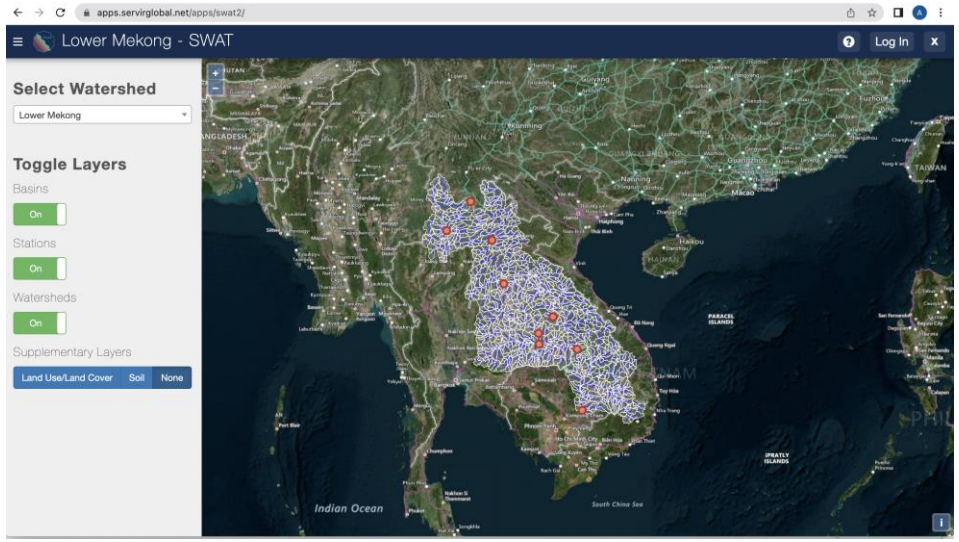
- Contains the following river analysis components using the same geometry and hydraulic structure:
  - One- and two-dimensional steady and unsteady flow simulations of water surface profile computations
  - Movable boundary sediment transport computations
  - One-dimensional water quality analysis
- An extensive spatial data integration and mapping system (HEC-RAS Mapper)



About SWAT

https://swat.tamu.edu/

- SWAT is a watershed to river basin-scale model:
  - Simulates quality and quantity of surface and groundwater
  - Predicts environmental impact of land use- and management practices
  - Predicts impact of climate change
- Used for assessing soil erosion prevention control
- Used for non-point source pollution control
- One- and two-dimensional steady and unsteady flow simulations of surface water

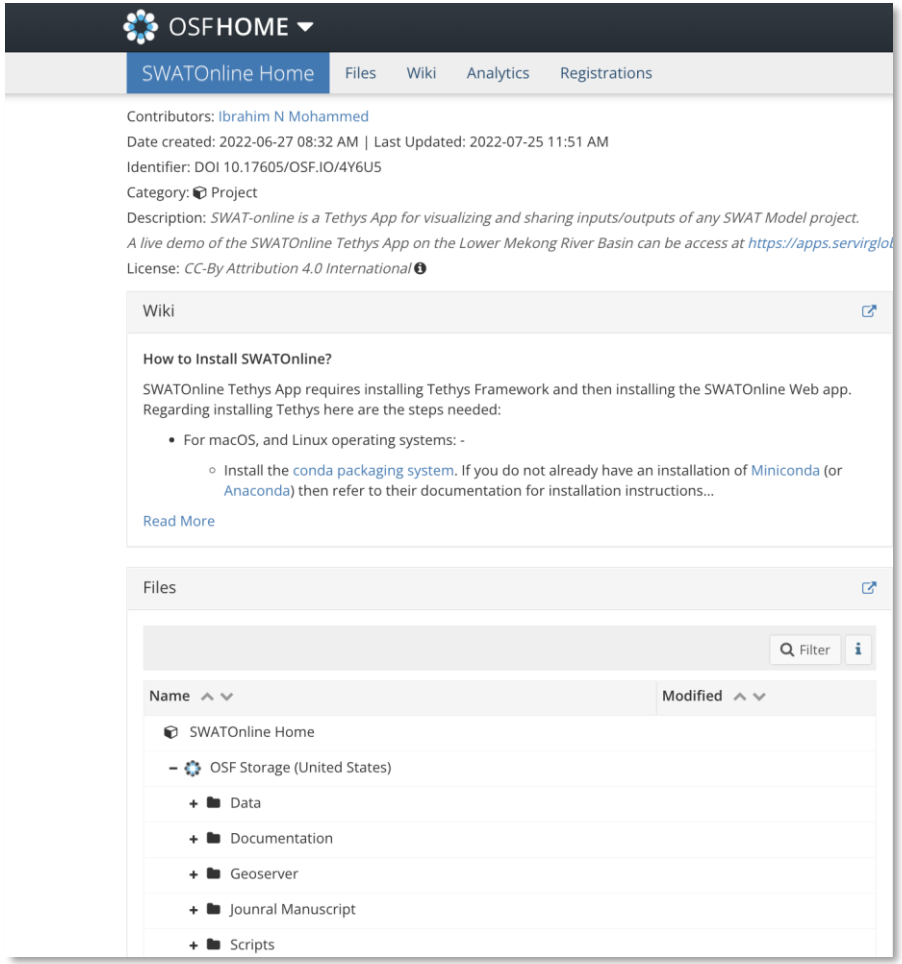


https://apps.servirglobal.net/apps/swat2/

SWAT Online

https://doi.org/10.17605/OSF.IO/4Y6U5

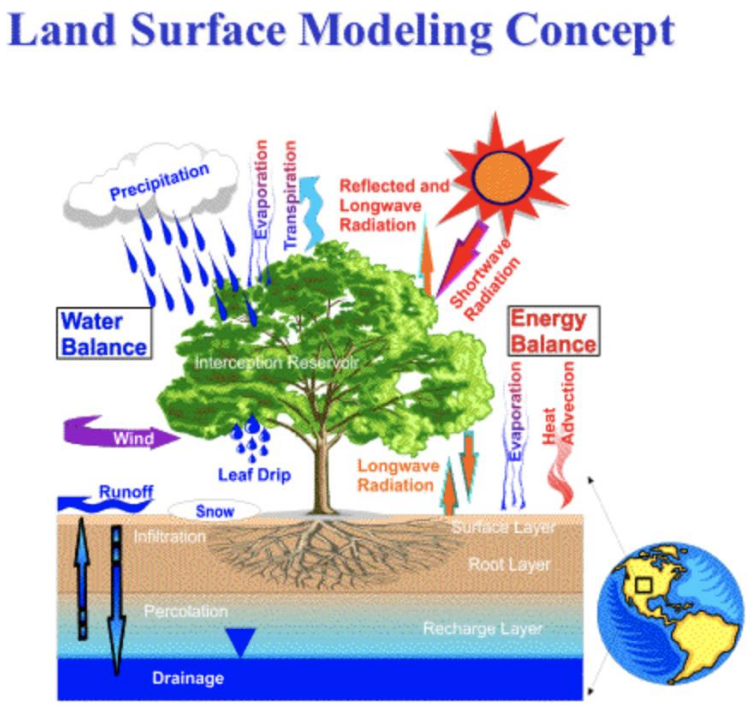
- SWAT Online was developed for customization, execution, and visualization of SWAT input/output data.
- A web application development tool for climate data retrieval – accesses, fetches, extracts, and reformats NASA climate data for SWAT (description).
- An example for the lower Mekong River Basin is available.
  - Contributors: Ibrahim N Mohammed, Identifier: DOI 10.17605/OSF.IO/4Y6U5



Global Land Surface & Hydrology Models

https://ldas.gsfc.nasa.gov/

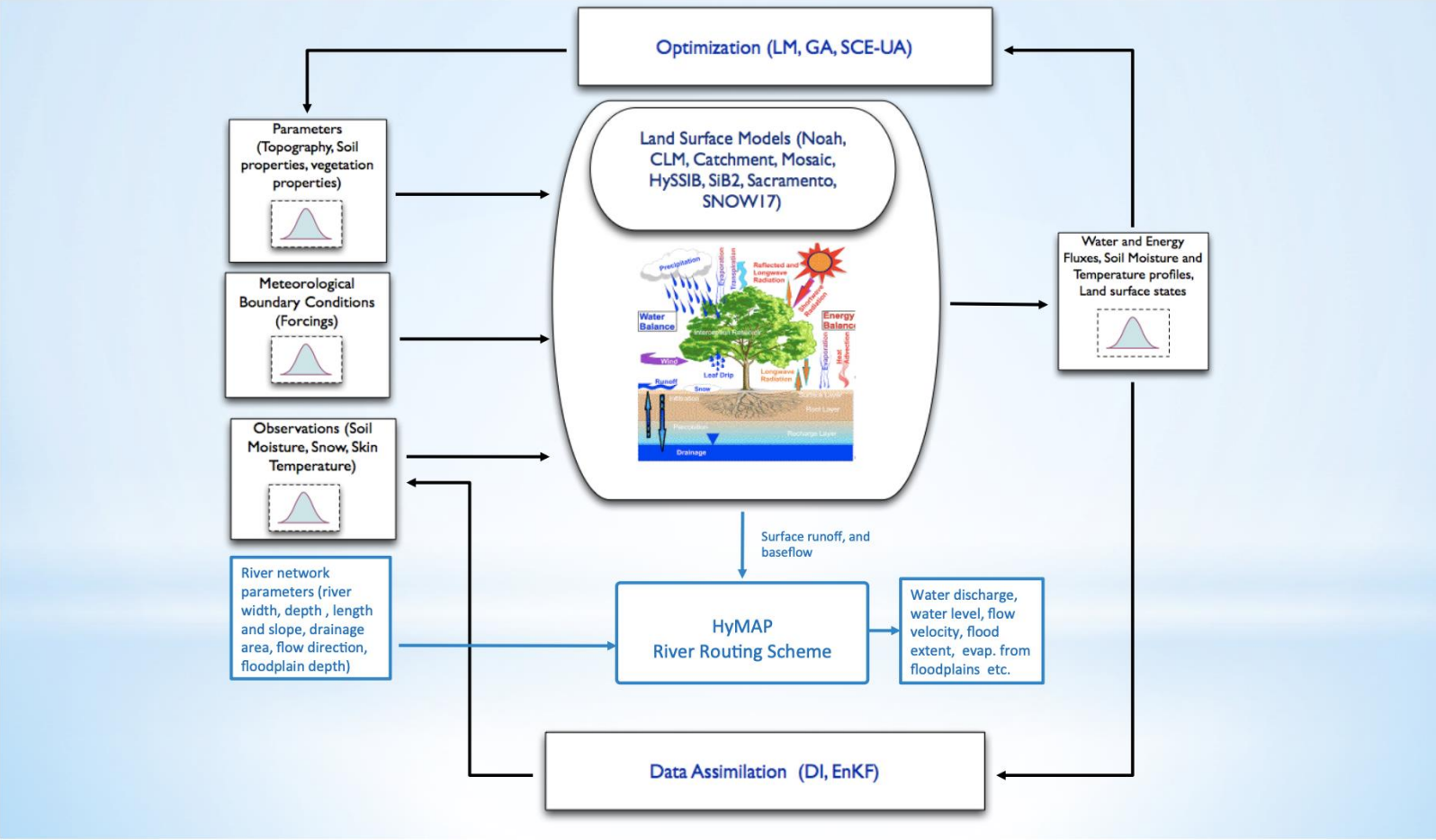
- A class of global or regional (much larger than watershed-level) models are available based on land surface processes and water balance approach.
- These models utilize weather information for forcing and calculate runoff at model grid points.
- The runoff can then be used with a routing model to diagnose stream flow in river channels.



https://lis.gsfc.nasa.gov/software/lis

Part 2: NASA Land Information System and HyMAP Routing Model

https://lis.gsfc.nasa.gov/software/lis

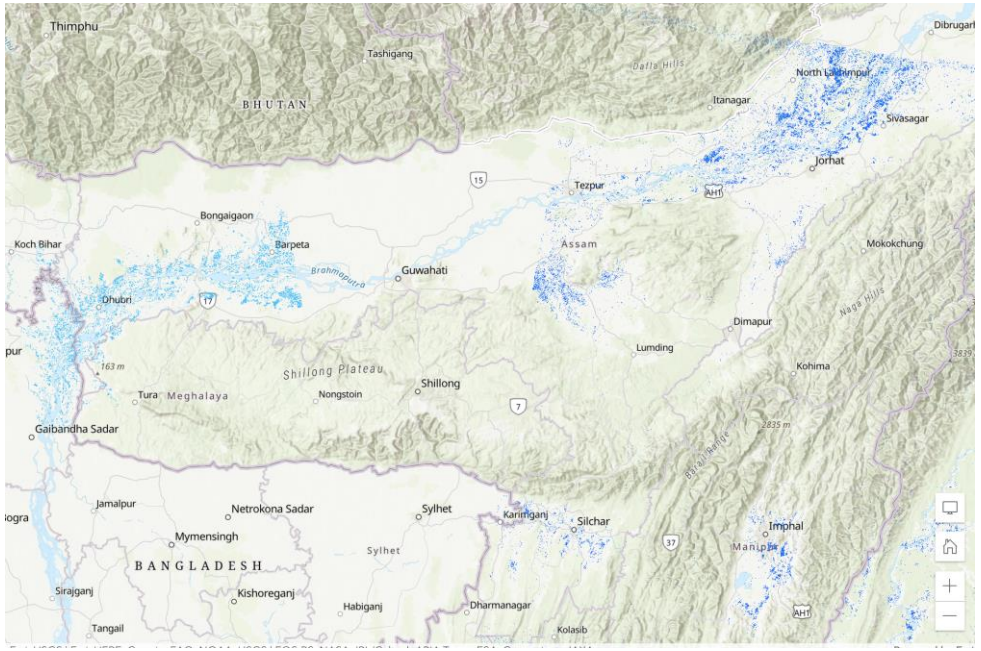


https://ldas.gsfc.nasa.gov/sites/default/files/ldas/nldas/presentations/Getirana_NLDAS_HyMAP_10Nov2016.pdf

Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.

Bangladesh Floods – June 2022



https://maps.disasters.nasa.gov/arcgis/home/item.html?id=9e49f039612741878e7f560a67f2d4e5

Contacts

- Trainers:
  - Amita Mehta: amita.v.mehta@nasa.gov
  - Caroline Williams: caroline.williams@ssaihq.com
  - Sean McCartney: sean.mccartney@nasa.gov
- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-monitoring-and-modeling-floods-using-earth-observations
- ARSET Website:
  - https://appliedsciences.nasa.gov/arset
- Twitter: @NASAARSET

Check out our sister programs:


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!