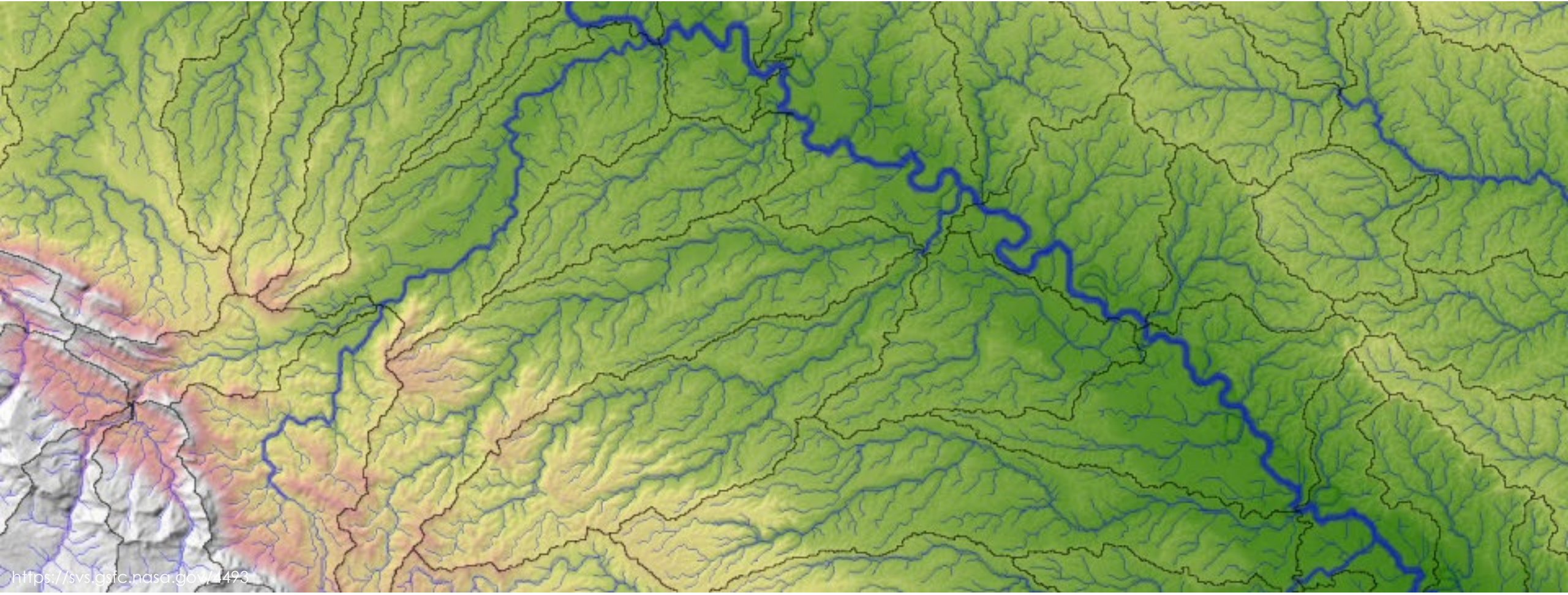


River Basin Delineation Based on NASA Digital Elevation Data

Sean McCartney and Amita Mehta

26 November 2019

Training Objectives

Become familiar with:

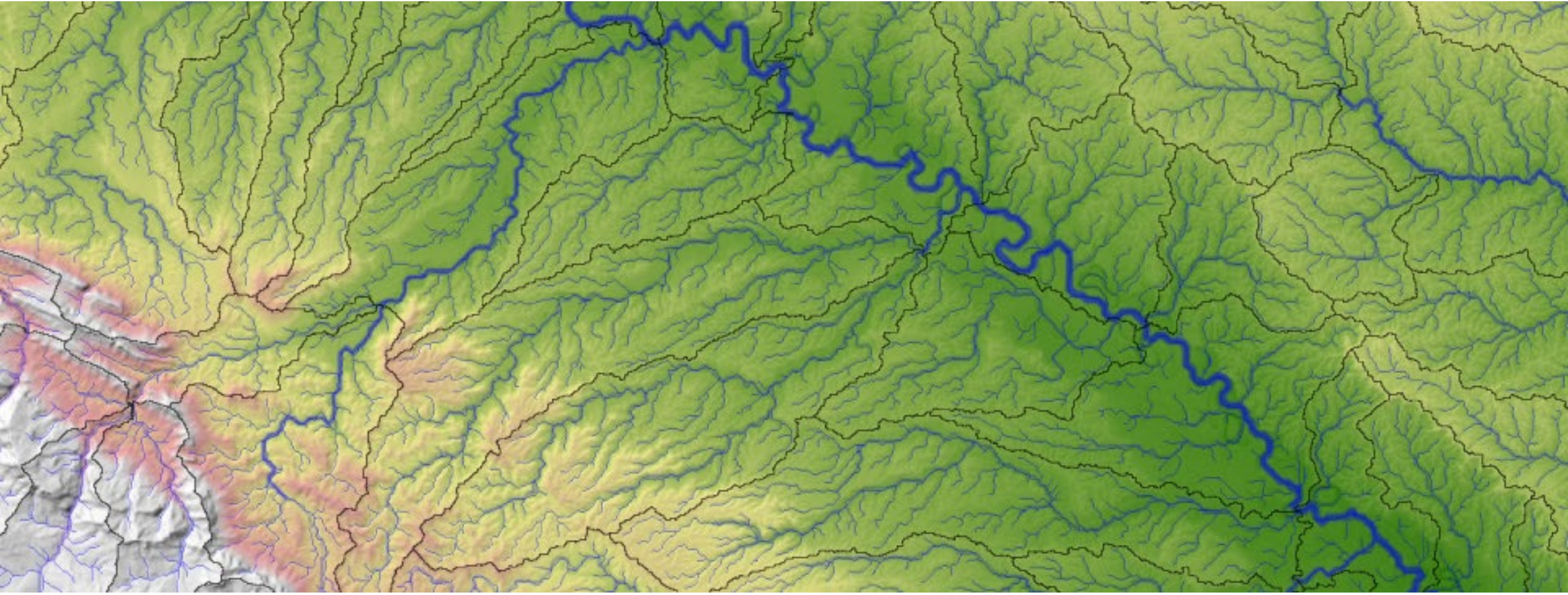
- HydroSHEDS (**Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple **S**cales) https://www.hydrosheds.org/

Learn to:

- Delineate a river basin and sub-basins based on a geographic location
- Determine drainage direction in a river basin and sub-basins

Outline

- About ARSET
- Importance of river basin delineation
- Overview of NASA digital elevation data
- Overview of HydroSHEDS
- Demonstration of HydroSHEDS for river basin delineation and drainage direction



About ARSET

NASA's Applied Remote Sensing Training Program (ARSET)

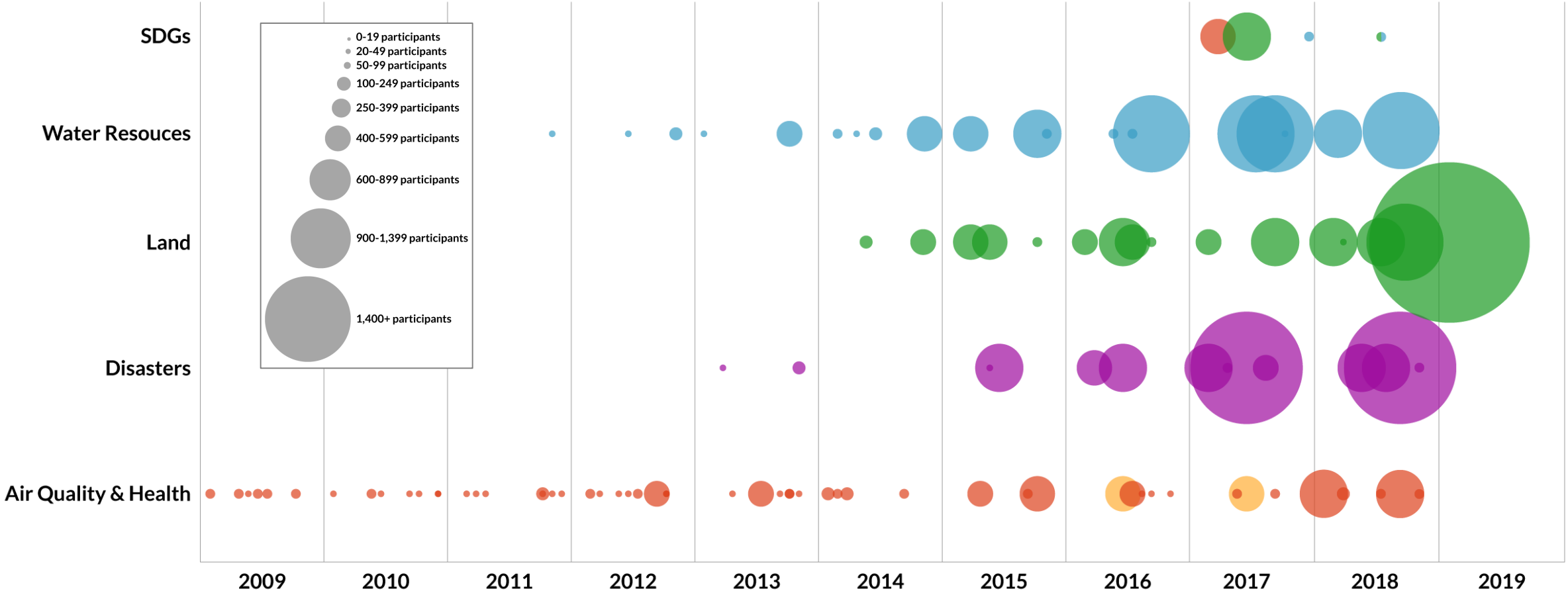
http://arset.gsfc.nasa.gov/

- Part of NASA's Applied Sciences Capacity Building Program
- Empowering the global community through remote sensing training
- Goal to increase the use of Earth science in decision-making through training for:
  - policy makers
  - environmental managers
  - other professionals in the public and private sector

Topics for trainings include:

Capacitaciones ARSET

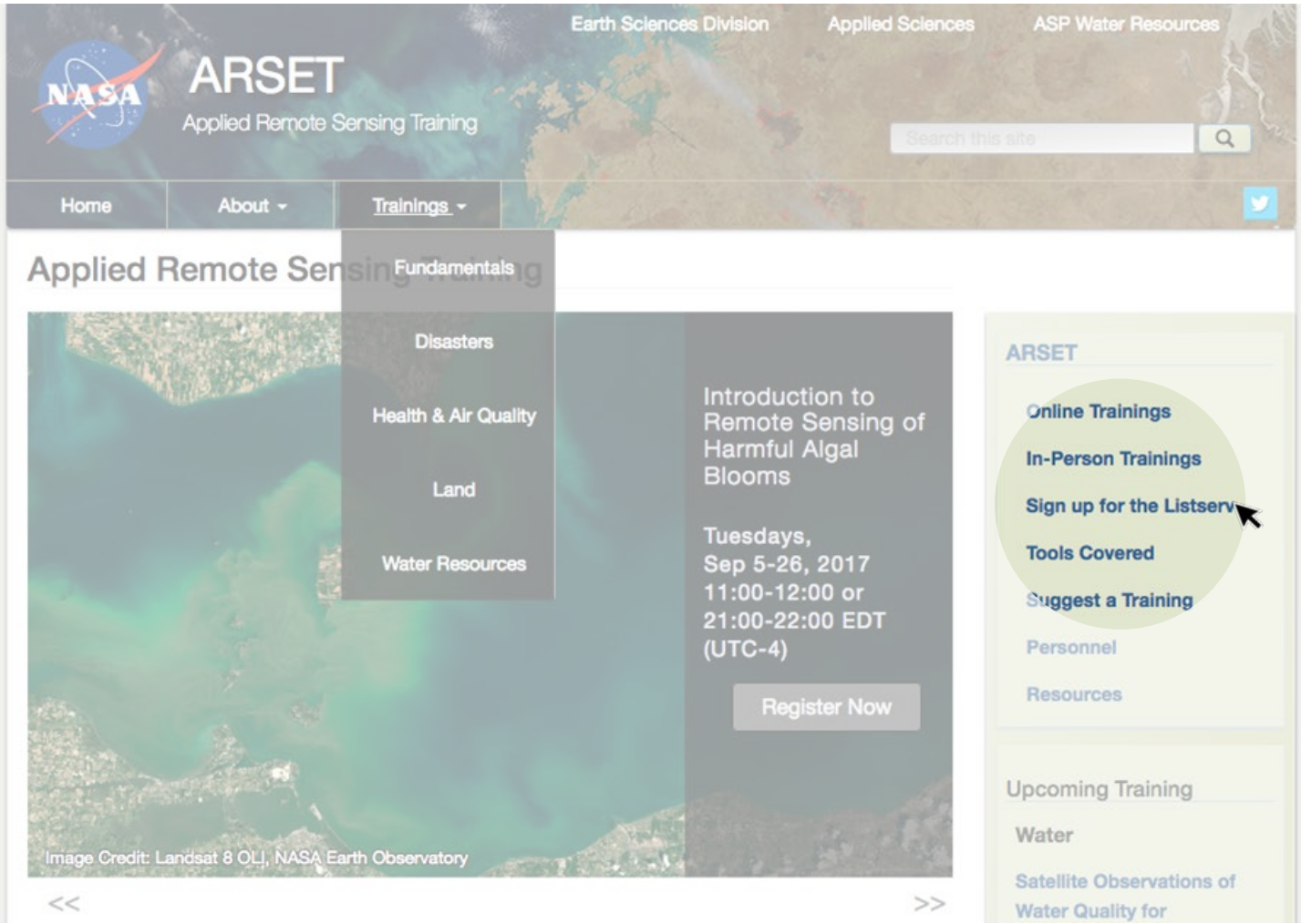
110+ trainings 19,400+ participants 160+ countries 5,000+ organizations

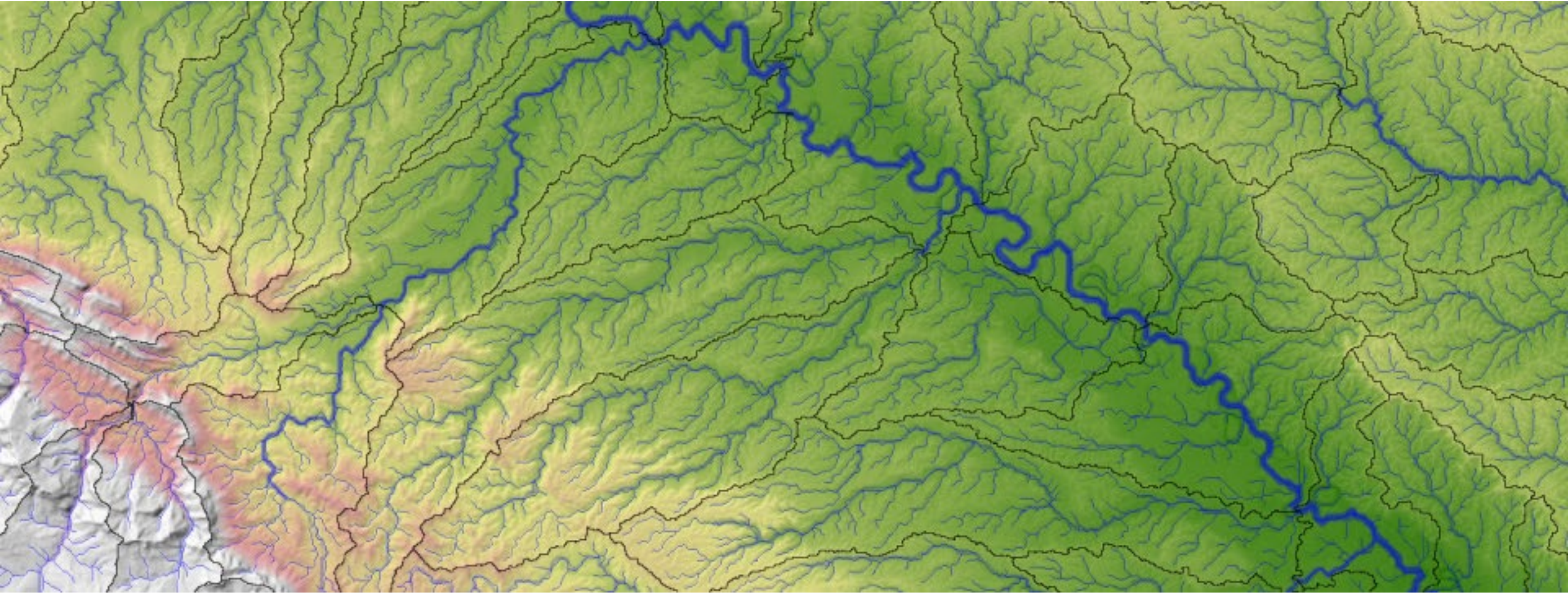


* Size of bubble corresponds to number of attendees

Learn More About ARSET

http://arset.gsfc.nasa.gov/





Importance of River Basin Delineation

What is a River Basin?

- An area of land that drains water into a river and its tributaries
- A river basin usually has multiple drainage catchments or watersheds separated by ridges and hills called the drainage divide
- Each watershed in a river basin collects rain and/or snow water and drains to a common outlet such as a stream, tributary, lake, or wetland – eventually contributing water to the river
- A river basin consists of surface water and also underlying groundwater

Indus River Basin

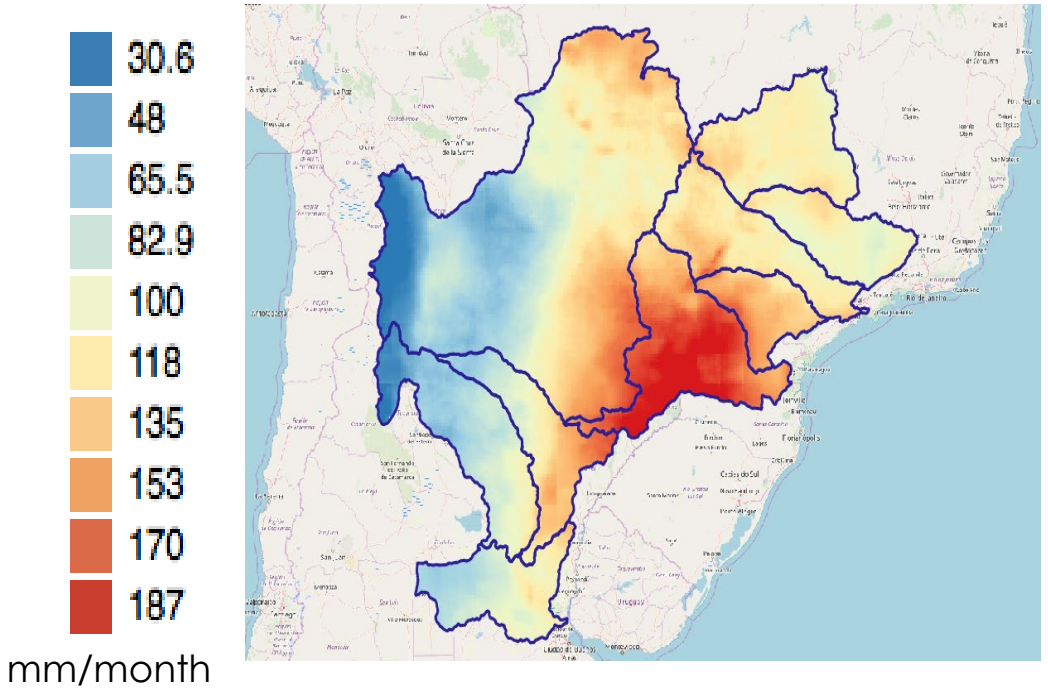
Source: Keenan Pepper, https://commons.wikimedia.org/wiki/File:Indus_River_basin_map.svg

- https://water.usgs.gov/edu/watershed.html

Why Delineation of River Basin?

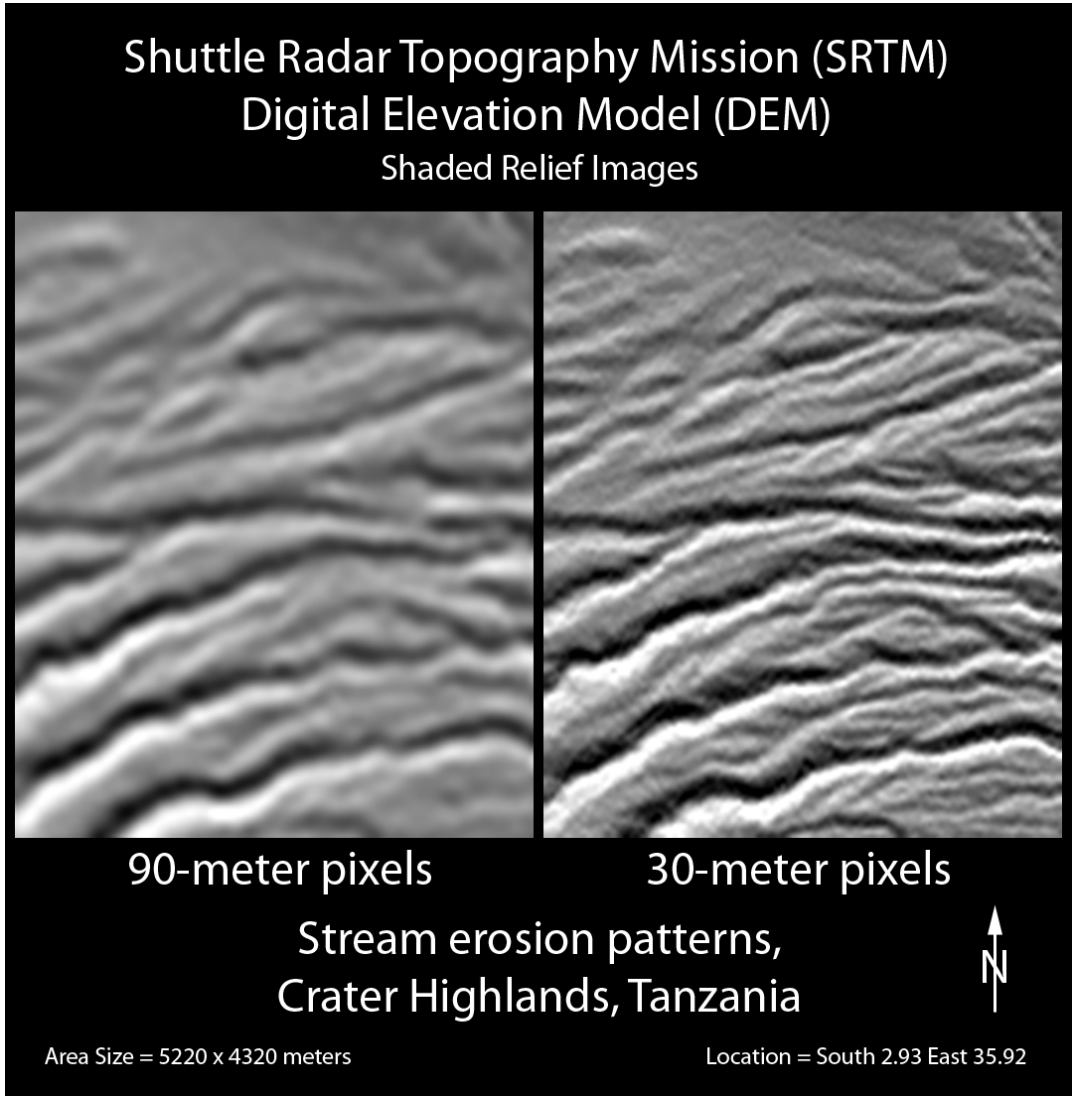
- Land surface processes, precipitation, storm water, and wastewater runoff within a river basin have substantial impact on quantity and quality of the water draining in the river
- Delineation of the basin is crucial for planning for water resources and flood management
- Delineation of watersheds within the basin is also crucial as it allows monitoring amount of water drained by each watershed to the river channel

Mean precipitation (April 2014 – June 2018) over the Parana River Basin from IMERG – Integrated Multi-satellitE Retrievals for Global Precipitation Measurement (GPM)

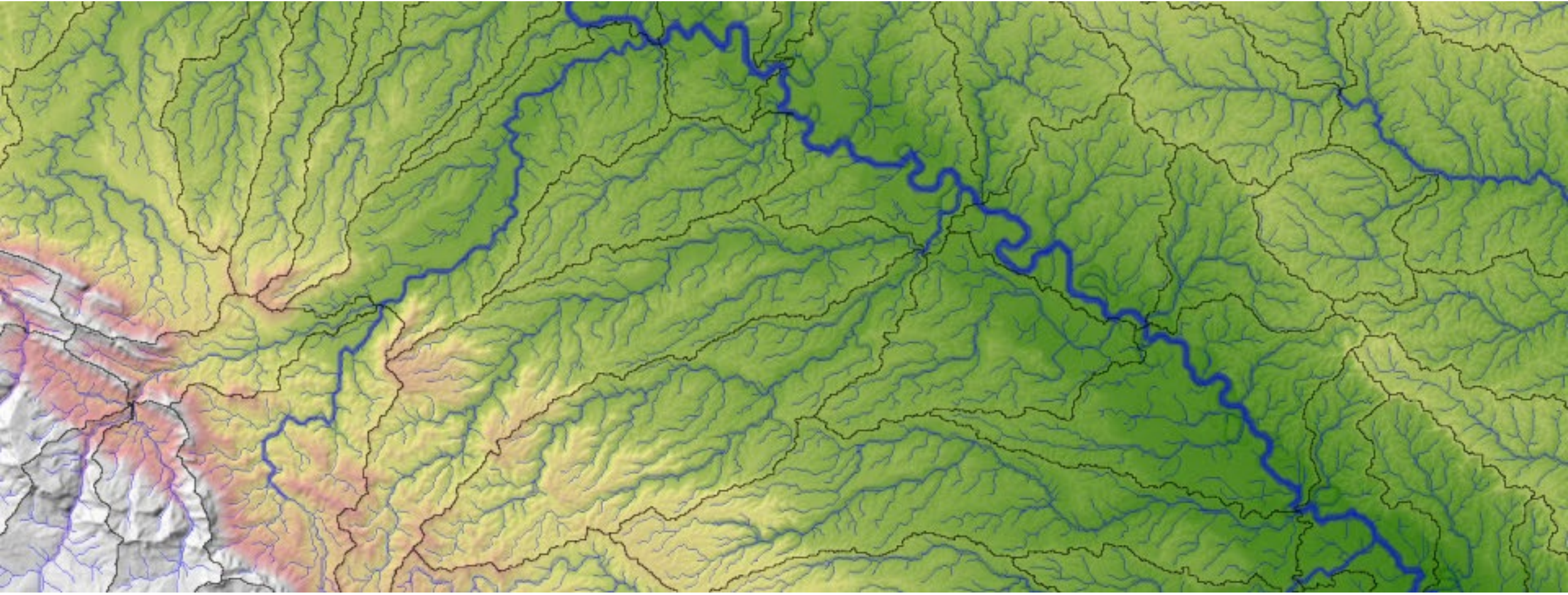


River Basin Delineation

- Surface topography and elevation generally determine boundaries or drainage divides of a river basin and between sub-basins
- NASA digital elevation data from the Shuttle Radar Topography Mission (SRTM) has been widely used for determining boundaries of river basins



Source: NASA/JPL-Caltech/National Geospatial Intelligence Agency



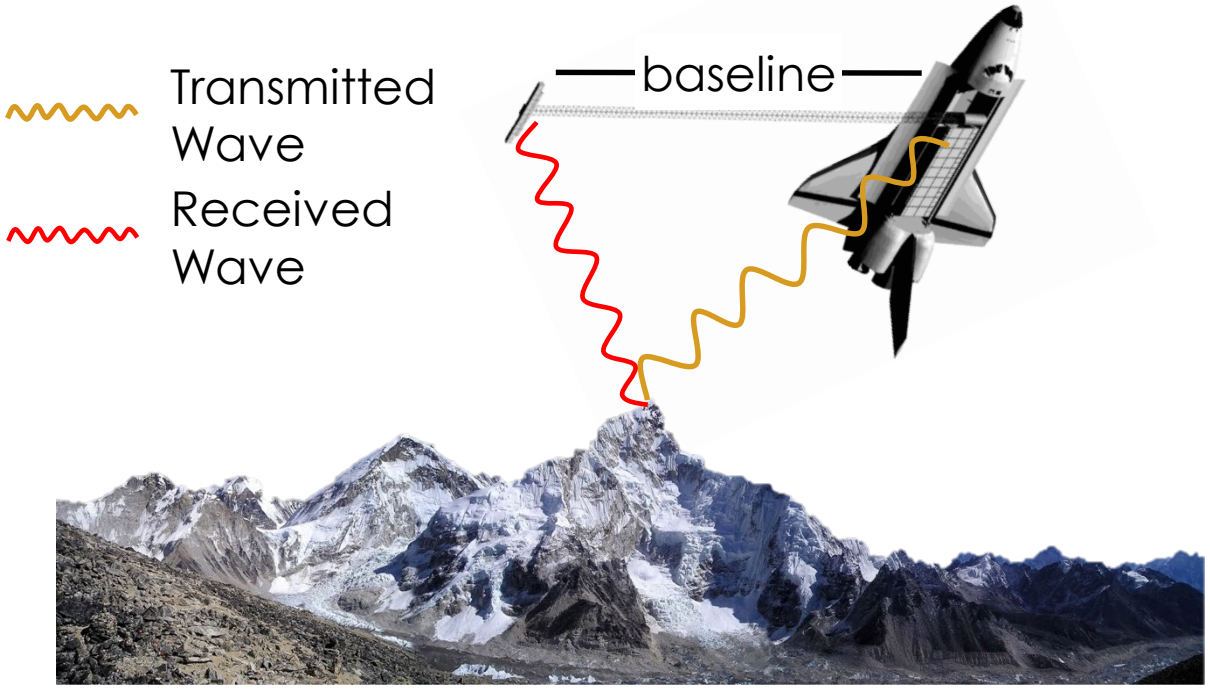
Overview of NASA Digital Elevation Data and HydroSHEDS

Terrain Data from Shuttle Radar Topography Mission (SRTM)

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

- C-band (5.6 cm) SAR mission
- NASA Space Shuttle Endeavour
- Completed in February 2000
- 176 orbits around Earth in 11 days
- Generated digital elevation maps of all land between 60°N-56°S latitude
- ~80% of Earth's total land mass
- SRTM used interferometry to generate topographic (elevation) maps
- For detailed information see the Appendix

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

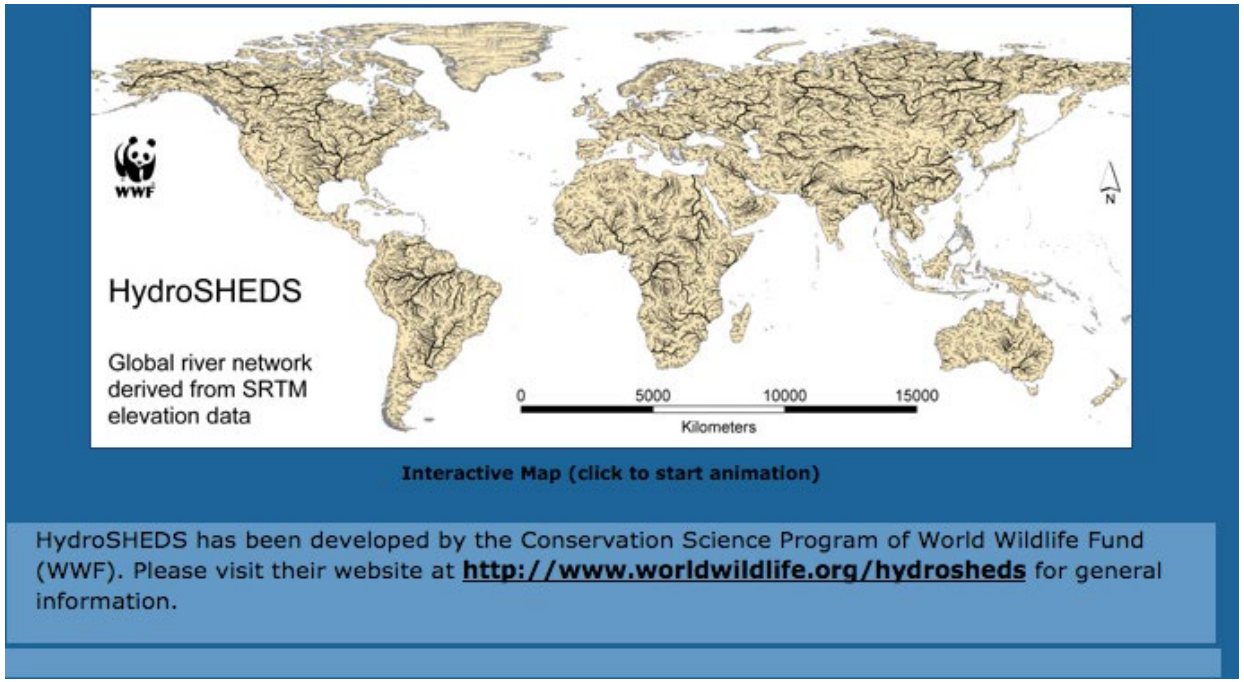


Spatial resolution: 30 m

HydroSHEDS: River Basin Network Based on SRTM

https://www.hydrosheds.org/ https://hydrosheds.cr.usgs.gov

- **Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple **S**cales **(HydroSHEDS)** provides data sets of stream networks, river basin boundaries, drainage directions, flow accumulations, distances, and river topology information
- HydroSHEDS uses digital elevation data derived from SRTM



HydroSHEDS: River Basin Network Based on SRTM

https://hydrosheds.cr.usgs.gov/datasets.php

- Data void filling
- Stream identification and hydrologic conditions derived using GIS
- Removing spurious features
- Coastal zone "weeding" to reduce the impact of mangroves and vegetation on digital elevation data
- Stream "burning" to enforce known river courses onto an elevation surface
- Modeling valley courses to improve river delineation in low lying areas
- Quality checking – more uncertainty in flat and vegetated areas

River Basin Data Availability from HydroSHEDS

https://hydrosheds.cr.usgs.gov/dataavail.php

- Data are available for download with the following filename convention: **Extent_DataType_Resolution**

Extent

Identifier	Continent
Af	Africa
As	Asia
Au	Australasia
Eu	Europe
Na	North America
Sa	South America

Data Type

Identifier	Type of data
DEM	Digital elevation model (void-filled)
CON	Hydrologically conditioned elevation
DIR	Drainage directions
ACC	Flow accumulation (number of cells)
RIV	River network (stream lines)
BAS	Drainage basins (watershed boundaries)

Resolution

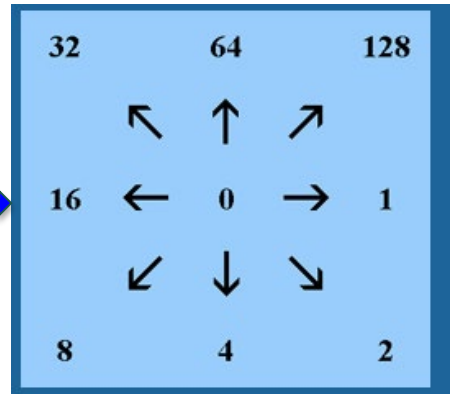
Identifier	in sec/min	in degree	in meters/km
3s	3 arc-second	0.0008333333333333	approx. 90 m at the equator
15s	15 arc-second	0.0041666666666667	approx. 500 m at the equator
30s	30 arc-second	0.0083333333333333	approx. 1 km at the equator
5m	5 minute	0.0833333333333333	approx. 10 km at the equator

River Basin Data Layers and Format from HydroSHEDS

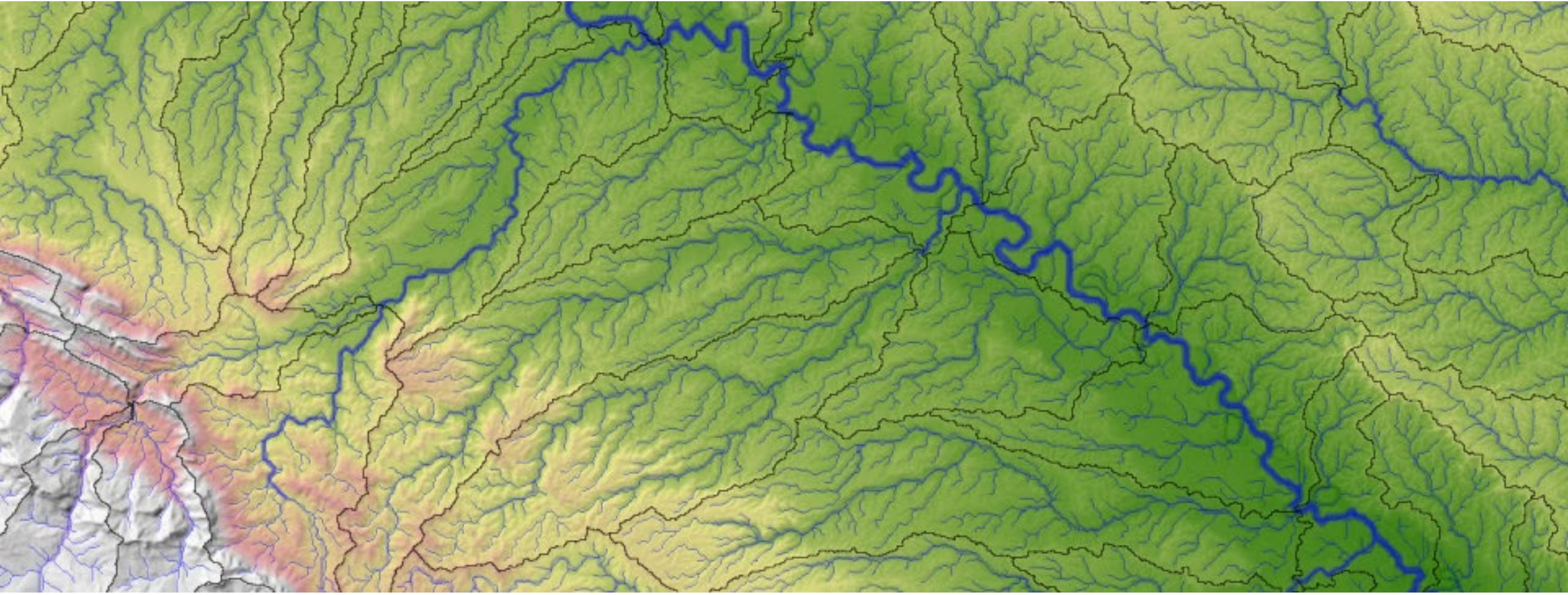
https://hydrosheds.cr.usgs.gov/data.php

- Data are available in ESRI vector and raster* format in WGS84

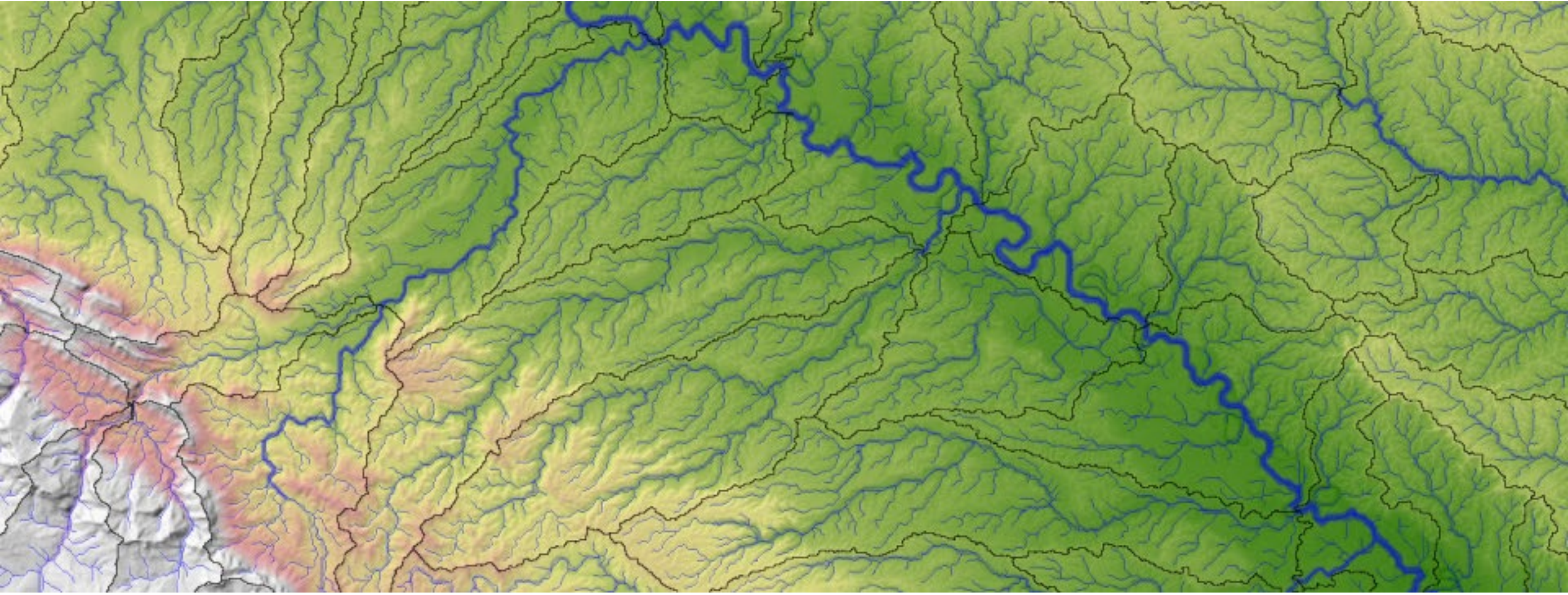
Layer Name	Format	Data	Resolution
DEM Void-filled Digital Elevation Model	Raster	Elevation in meters	3 arc-sec 15 arc-sec
CON Hydrologically Conditioned Elevation	Raster	Elevation in meters	3 arc-sec
DIR Drainage Direction	Raster	ESRI flow direction numbers	3 arc-sec 15 arc-sec
ACC Flow Accumulation	Raster	Number of upstream cells draining into each cell	15 arc-sec
RIV River Network	Vector	Unique identifier and maximum flow accumulation number of cells	15 arc-sec
BAS Drainage Basin	Vector	Unique identifier and surface area in km^2	15 arc-sec



*Raster data are also available in binary images in Band Interleaved by Line (BIL) format

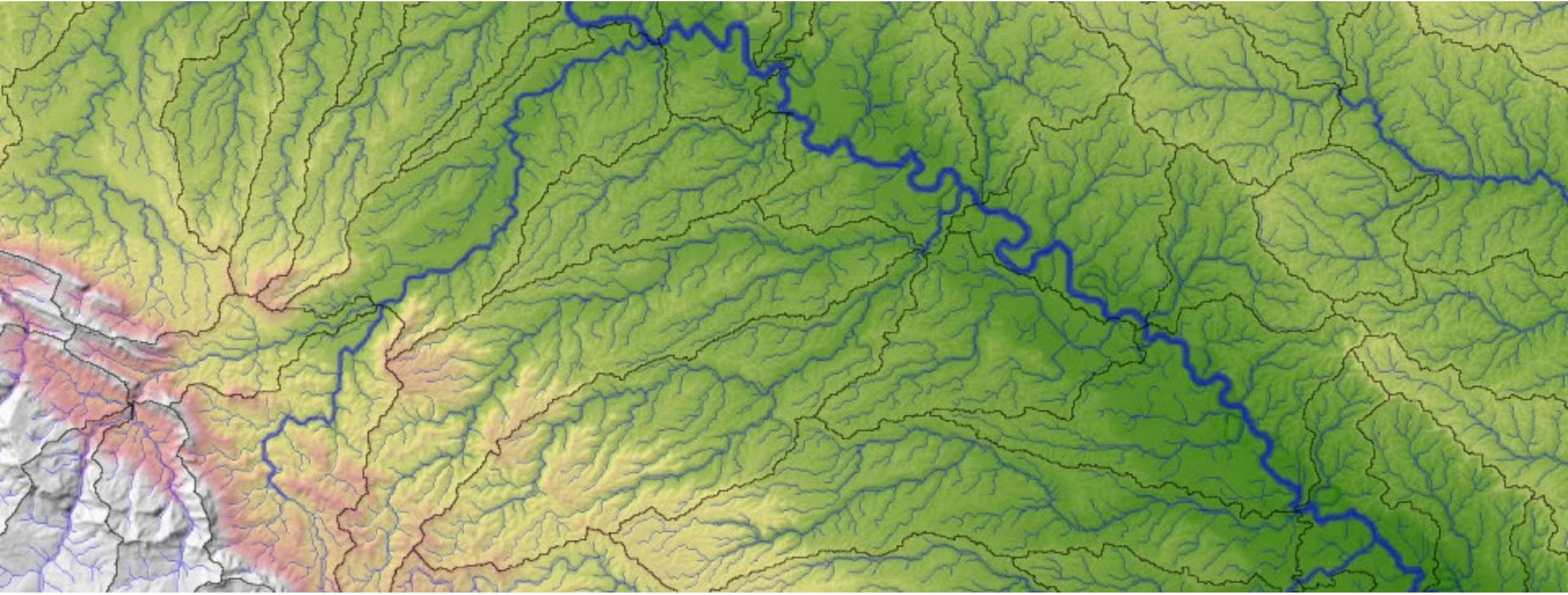


Demonstration of HydroSHEDS for River Basin Delineation and Determining Drainage Direction



Upcoming ARSET trainings:

Advanced Webinar: SAR for Disasters and Hydrological Applications
December 3-5, 2019
https://arset.gsfc.nasa.gov/webinars



Appendix: SRTM and ASTER DEM

Outline

- SRTM and ASTER DEM Data
- SRTM and ASTER DEM Data Access
  - Application for Extracting and Exploring Analysis Ready Samples (AppEEARS) https://lpdaac.usgs.gov/tools/appeears/

What is 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

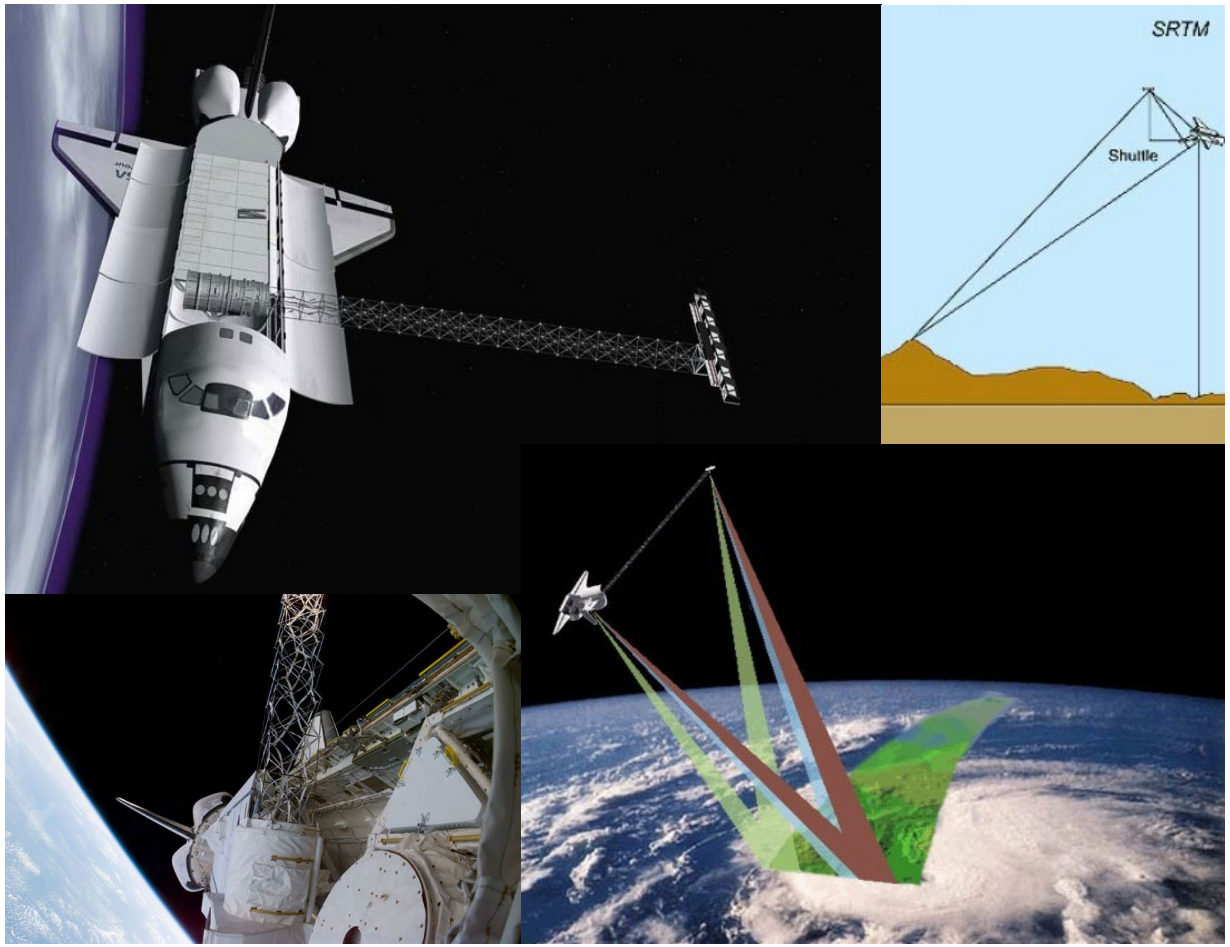


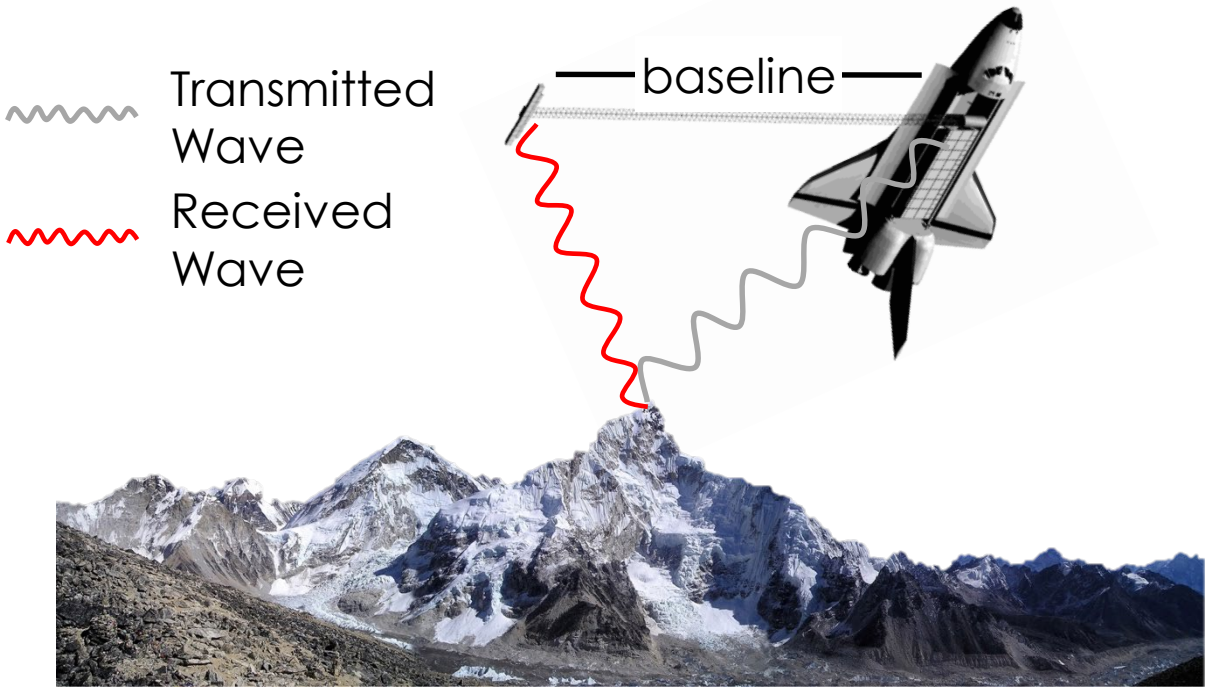
Image Credit (Top Right): DLR

SRTM Digital Terrain Data

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

- SRTM used interferometry to gather topographic (elevation) data
- Interferometry:
  - two radar images of the same area are taken from different views
  - the difference in the two images determines the height of the surface in the digital elevation model (DEM)

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



Based on a JPL graphic: http://www2.jpl.nasa.gov/srtm/instrumentinterferometry.html

NASA SRTM Version 3.0 (SRTM Plus)

- As of 2015, terrain data are available at 1 arc second or 30 m spatial resolution
- Eliminated voids in SRTM data by filling it with:
  - ASTER GDEM2
  - USGS GMTED2010
  - USGS National Elevation Dataset (NED)

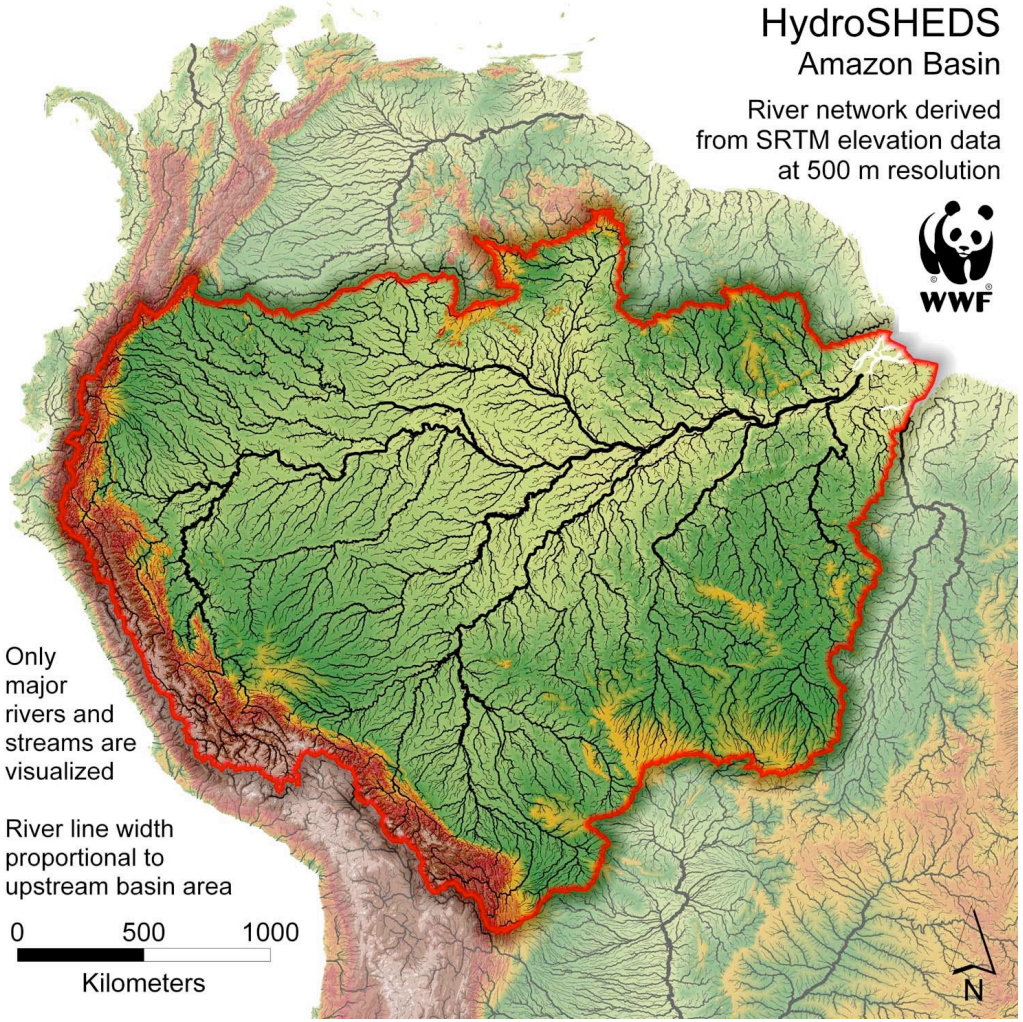
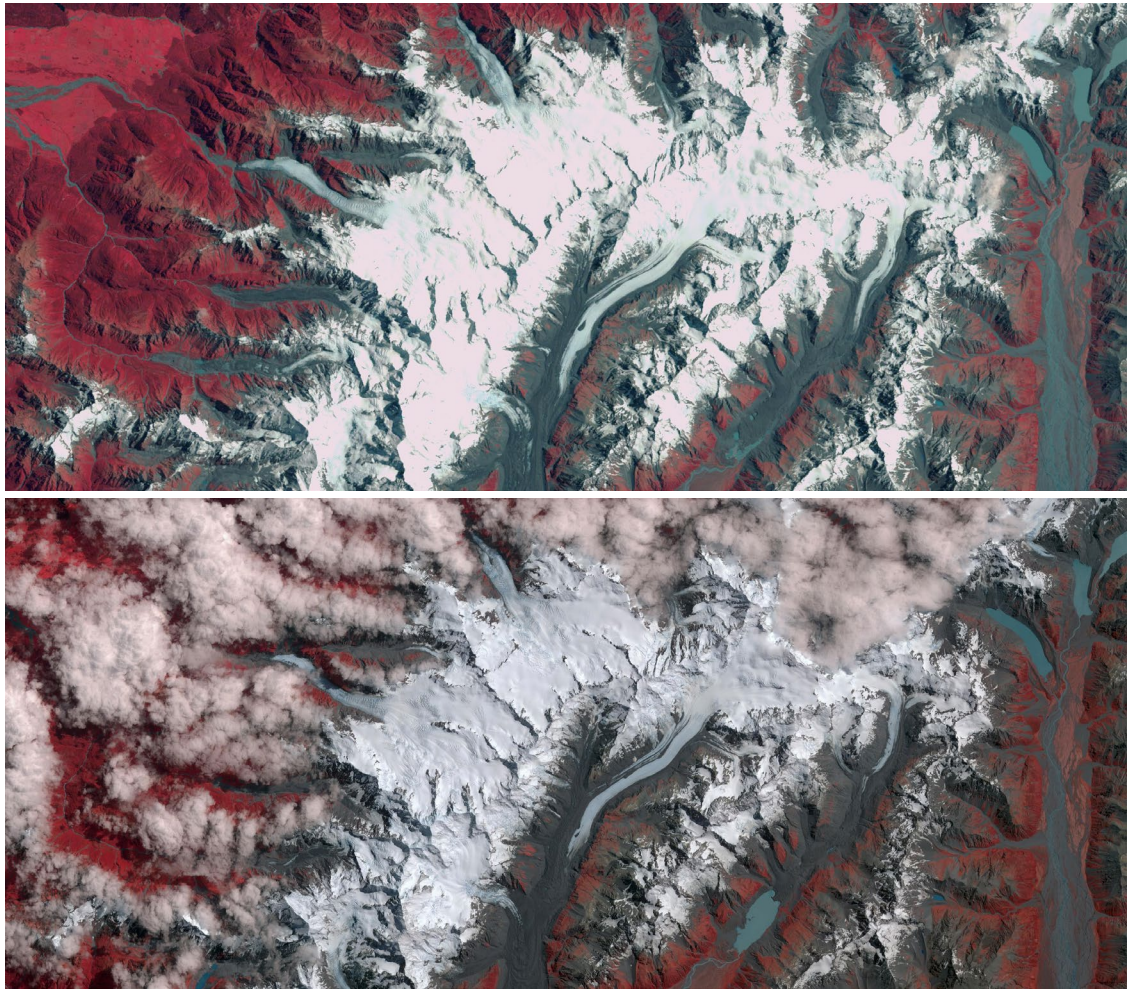


Image Credit: WWF, Text Reference: https://earthdata.nasa.gov/community/community-data-system-programs/measures-projects/nasadem

Advanced Spaceborne Thermal and Reflection Radiometer (ASTER)

http://asterweb.jpl.nasa.gov/

- Onboard Terra
  - Polar orbiting satellite launched Dec 1999
- Spatial Coverage and Resolution
  - Global
  - Swath Width: 60 km
  - Spatial Resolution Varies:
    - 15 m
    - 30 m
    - 90 m



Images of New Zealand glaciers in 1990 (Top: Landsat; Bottom: ASTER)

Advanced Spaceborne Thermal and Reflection Radiometer (ASTER)

http://asterweb.jpl.nasa.gov/

- Spectral Bands
  - **14 bands** (visible to thermal IR bands)
    - Bands 1-3: 15 m (VNIR)
    - Bands 4-9: 30 m (SWIR)
    - Bands 10-14: 90 m (TIR)
- Status alert: ASTER SWIR data acquired since Apr 2008 not usable

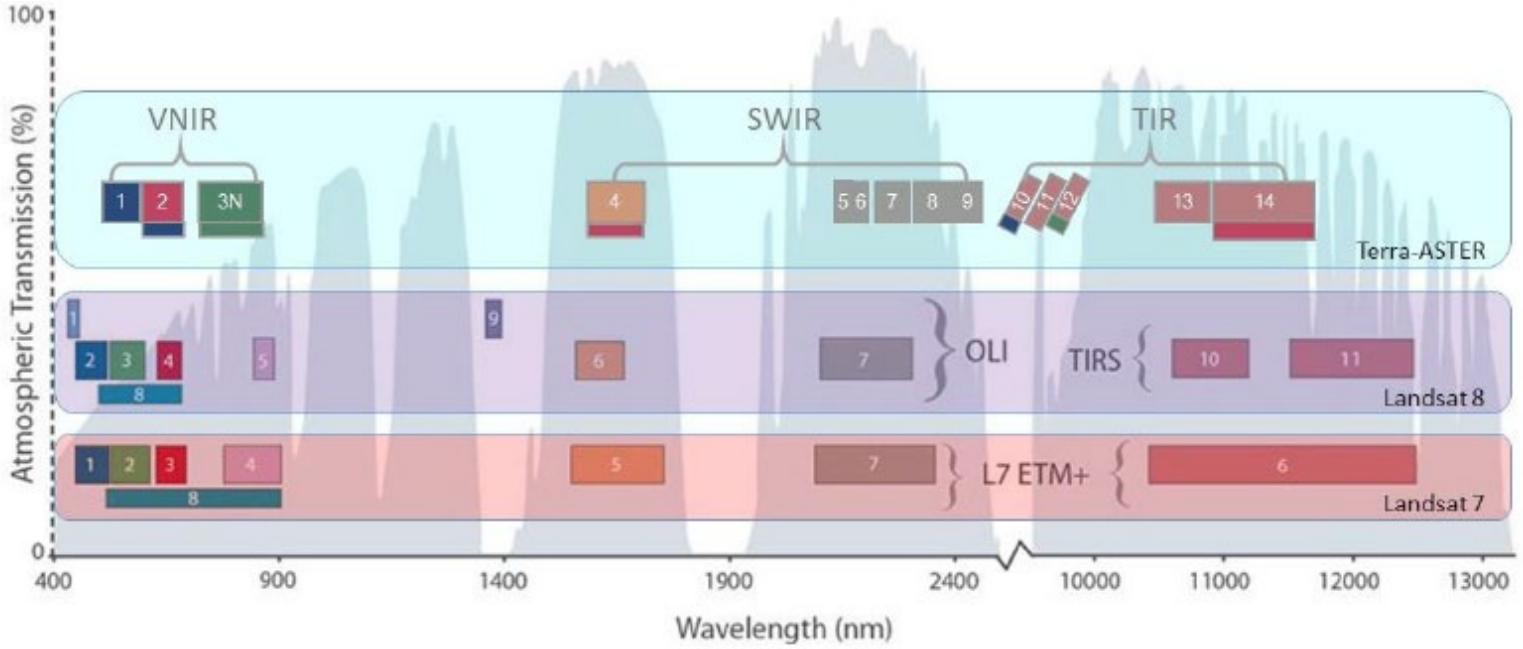
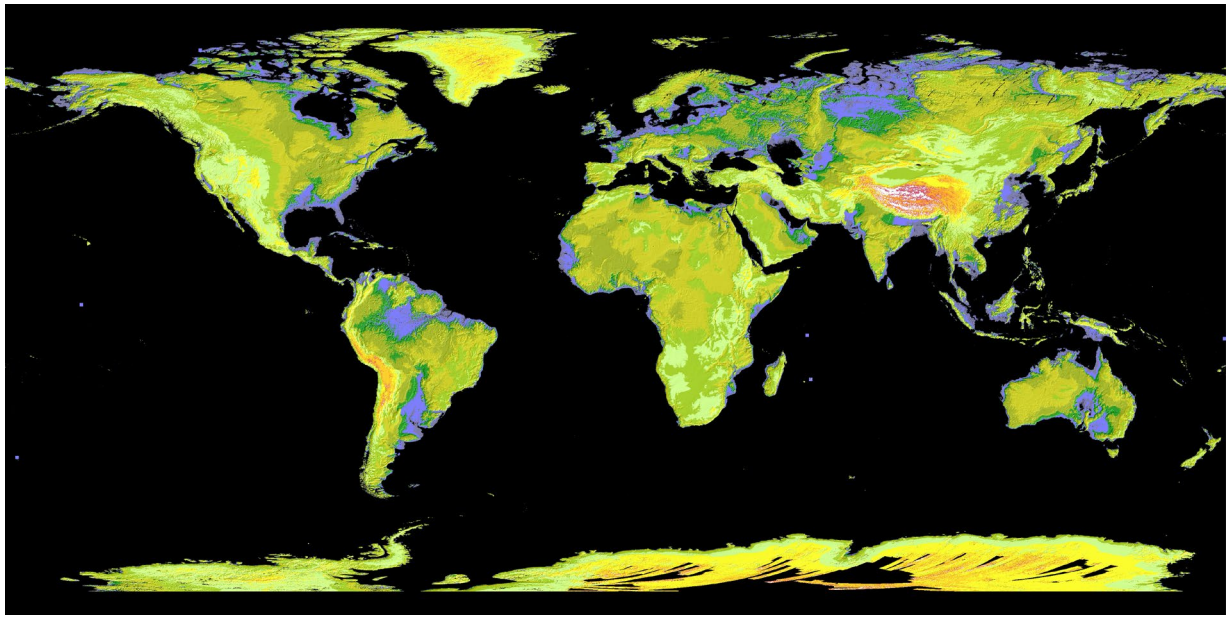


Image Credit: Vincheh, Z.H. and Arfania, R. (2017) Lithological Mapping from OLI and ASTER Multispectral Data Using Matched Filtering and Spectral Analogues Techniques in the Pasab-e-Bala Area, Central Iran. Open Journal of Geology, 7, 1494-1508.

ASTER Global Digital Elevation Model (GDEM V2)

https://asterweb.jpl.nasa.gov/gdem.asp

- A joint product developed by NASA and the Ministry of Economy, Trade, and Industry (METI) of Japan
- Uses ASTER VNIR stereo pair images to derive DEM
- GDEM version 2 is available since 2011, based on all available ASTER stereo images
- Covers land surfaces between 83°N – 83°S and is composed of 22,600 1° by 1° tiles of 30 m resolution



SRTM and GDEM2 Accuracy

Results from the CONUS Absolute Vertical Accuracy Assessment (in meters)

DEM	Minimum	Maximum	Mean	Standard Deviation	RMSE	LE95
GDEM2	-137.37	64.80	-0.20	8.68	**8.68**	**17.01**
NED	-46.21	16.42	-0.33	1.81	1.84	3.61
SRTM	-28.67	28.58	0.73	3.95	**4.01**	**7.86**
GDEM1	-127.74	105.41	-3.69	8.58	9.34	18.31

- Based on comparison with 18,000 geodetic points over the U.S.
- "…the GDEM validation team recommends the release of the GDEM2 to the public, acknowledging that, while vastly improved, some artifacts still exist which could affect its utility in certain application" - ASTER GDEM team [https://pubs.er.usgs.gov/publication/70005960]

RMSE: Root Mean square Error; LE95: Linear error at 95% Confidence Level

SRTM and GDEM2 Accuracy

DEM data accuracy depends on location and land cover categories

Land Cover	SRTM (rmse m)	GDEM2 (rmse m)
Grass & Shrub	12.36	16.6
Deciduous	25.49	20.79
Evergreen	24.76	22.23
Mixed	18.81	10.03

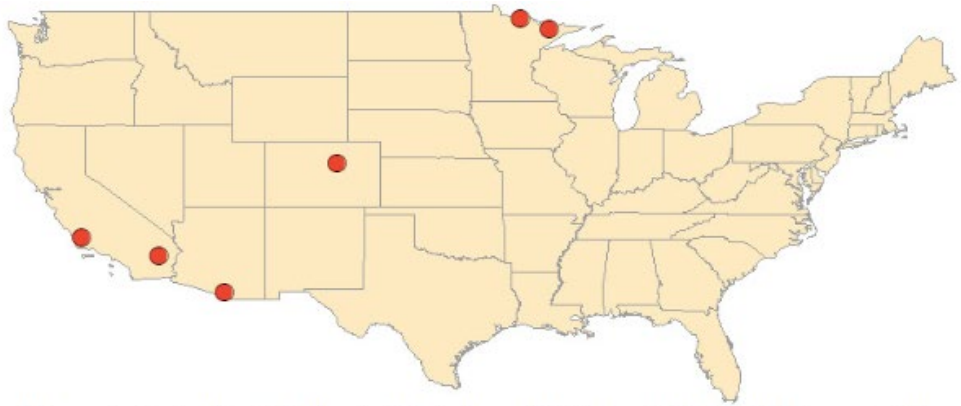


Figure 1. Study sites (California [2], Arizona [1], Colorado [1], and Minnesota [2]).

- Tighe, M. L., & Chamberlain, D. (2009). Accuracy Comparison of the SRTM, ASTER, NED, NEXTMAP USA Digital Terrain Model Over Several USA Study Sites. In *ASPRS/MAPPS 2009 Conference Proceedings*. San Antonio, TX. Retrieved from http://www.asprs.org/a/publications/proceedings/sanantonio09/Tighe_2.pdf

DEM Applications

- Useful for mapping hazardous terrain
- Calculate:
  - slope and aspect
  - catchment area
  - forest canopy height
- Models:
  - runoff
  - stream networks
  - landslides

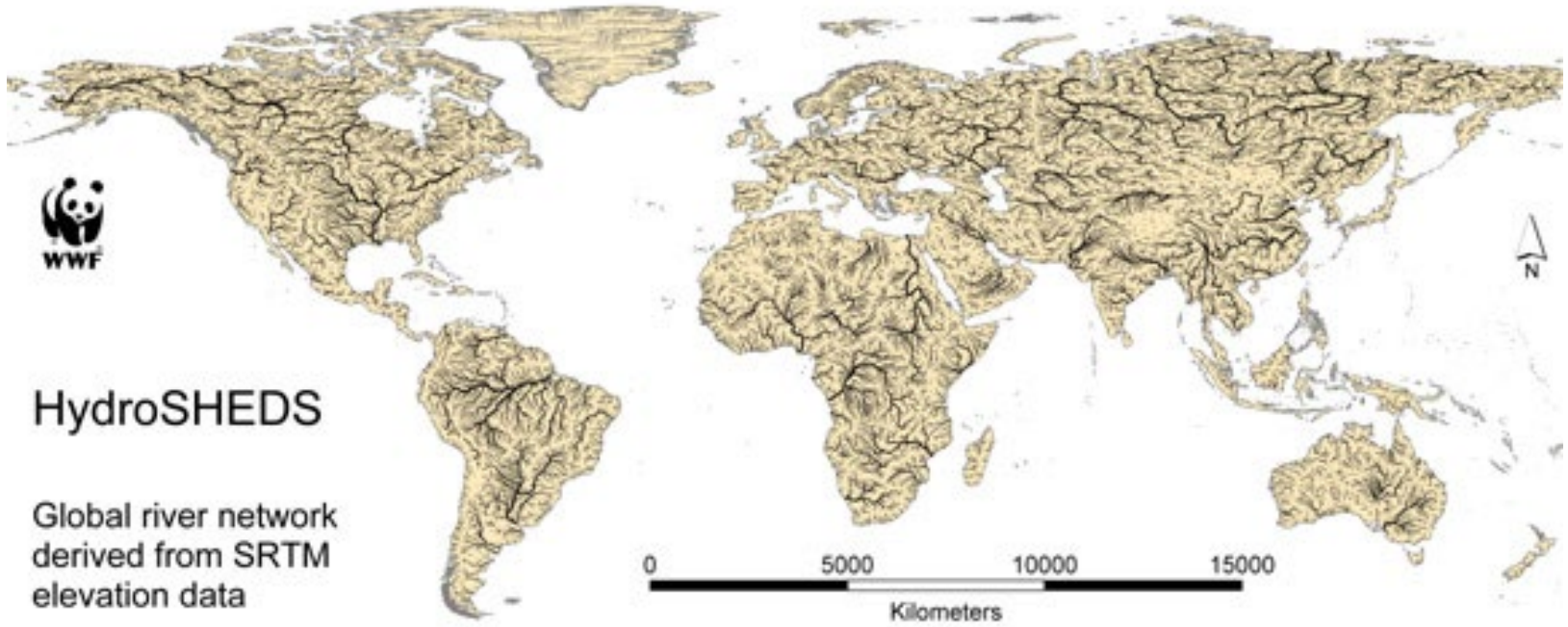
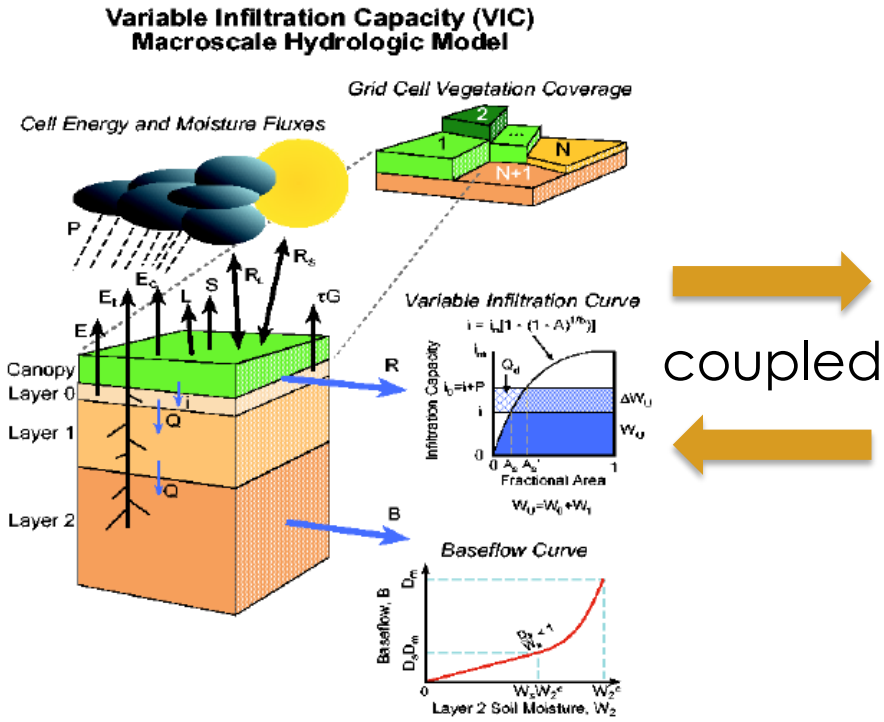


Image Credit: USGS HydroSHEDS/WWF

SRTM DEM Application in Flood Modeling

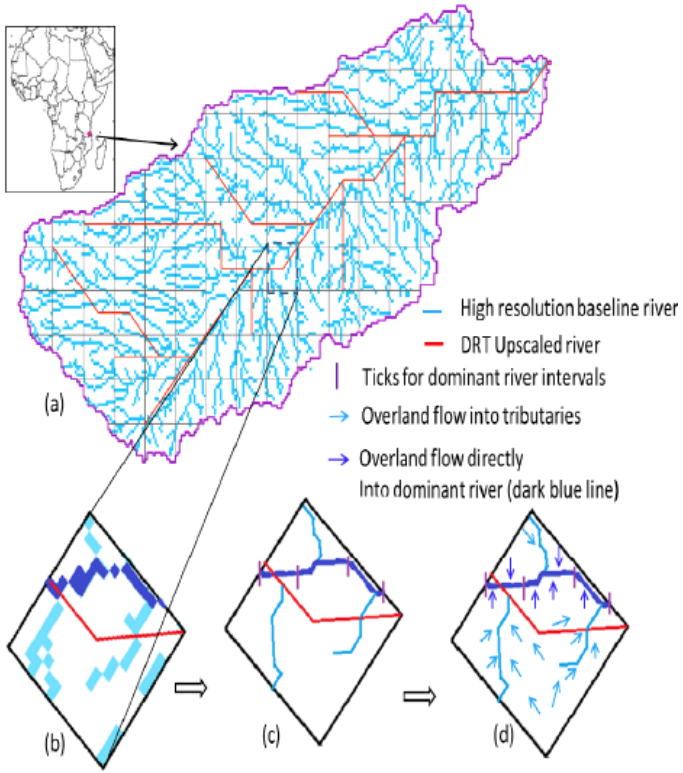
VIC



University of Washington

coupled

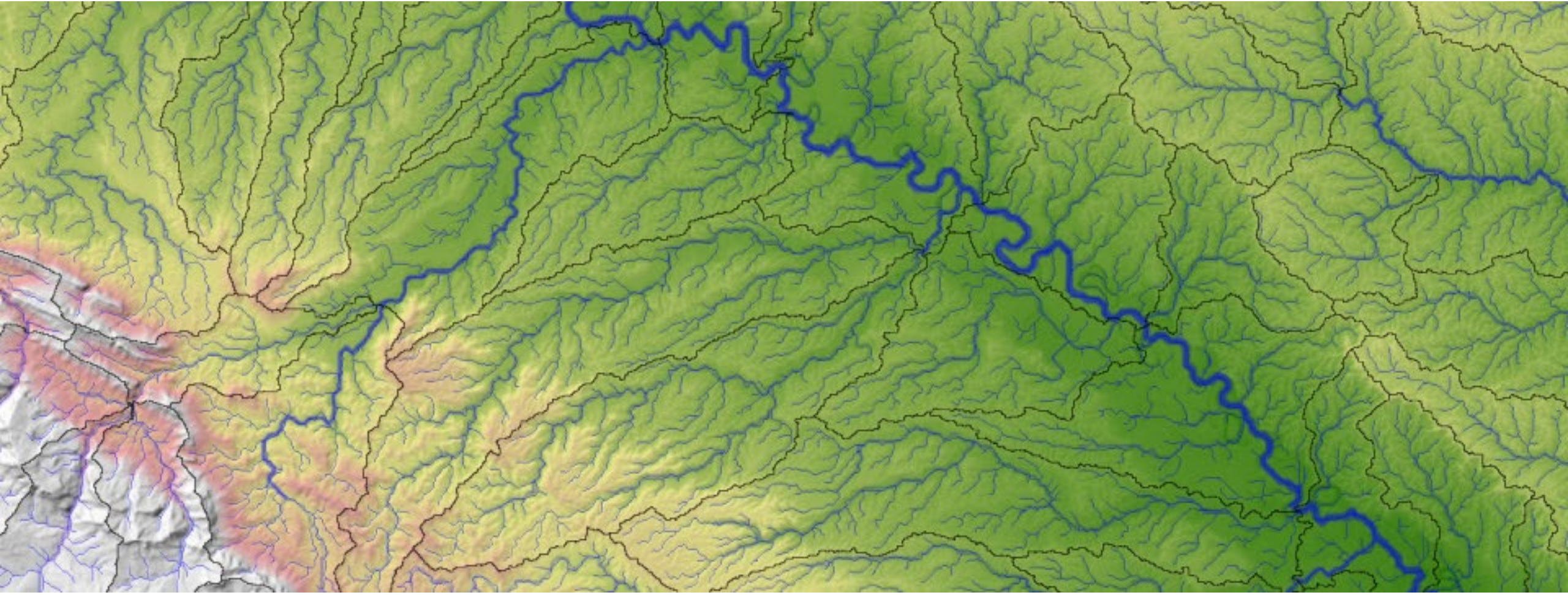
DRTR – Dominant River Tracing Based Routing



University of Maryland

- The Global Flood Monitoring System (GFMS) uses HydroSHEDS derived from SRTM DEM for identifying river networks for routing models
- http://hydrosheds.org/

Wu et al., *Real-time Global Flood Monitoring and Forecasting using an Enhanced Land Surface Model with Satellite and NWP model based Precipitation*. GFMS. http://flood.umd.edu/GFMS_conference.pdf

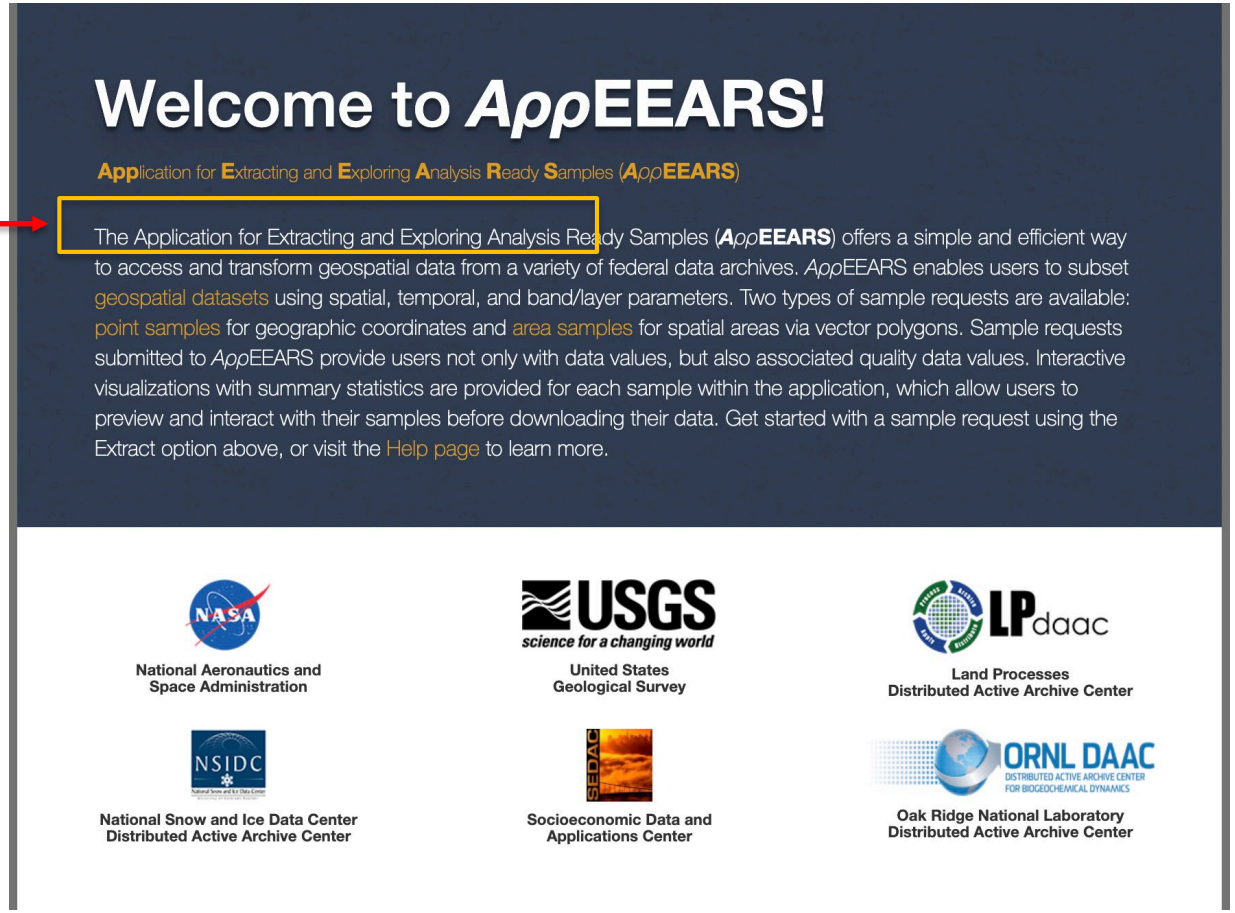


SRTM and ASTER DEM Data Access

Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)

https://lpdaac.usgs.gov/appeears/

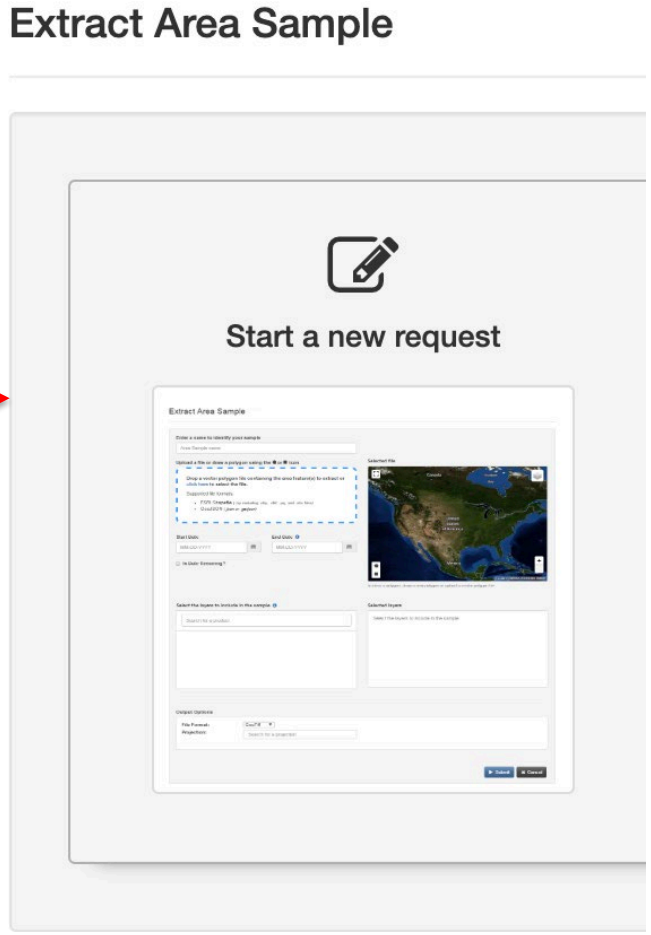
- Seamless data viewer that provides access to SRTM and ASTER DEM
- Users can subset and download data by area of interest in multiple formats (GeoToff and NetCDF) and projections
- Requires user registration via http://urs.earthdata.nasa.gov
- Data requests are submitted via an email to LP-DAAC



AppEEARS: Data Search and Access Request

https://lpdaac.usgs.gov/appeears/

Allows for search and request a data product via a GUI



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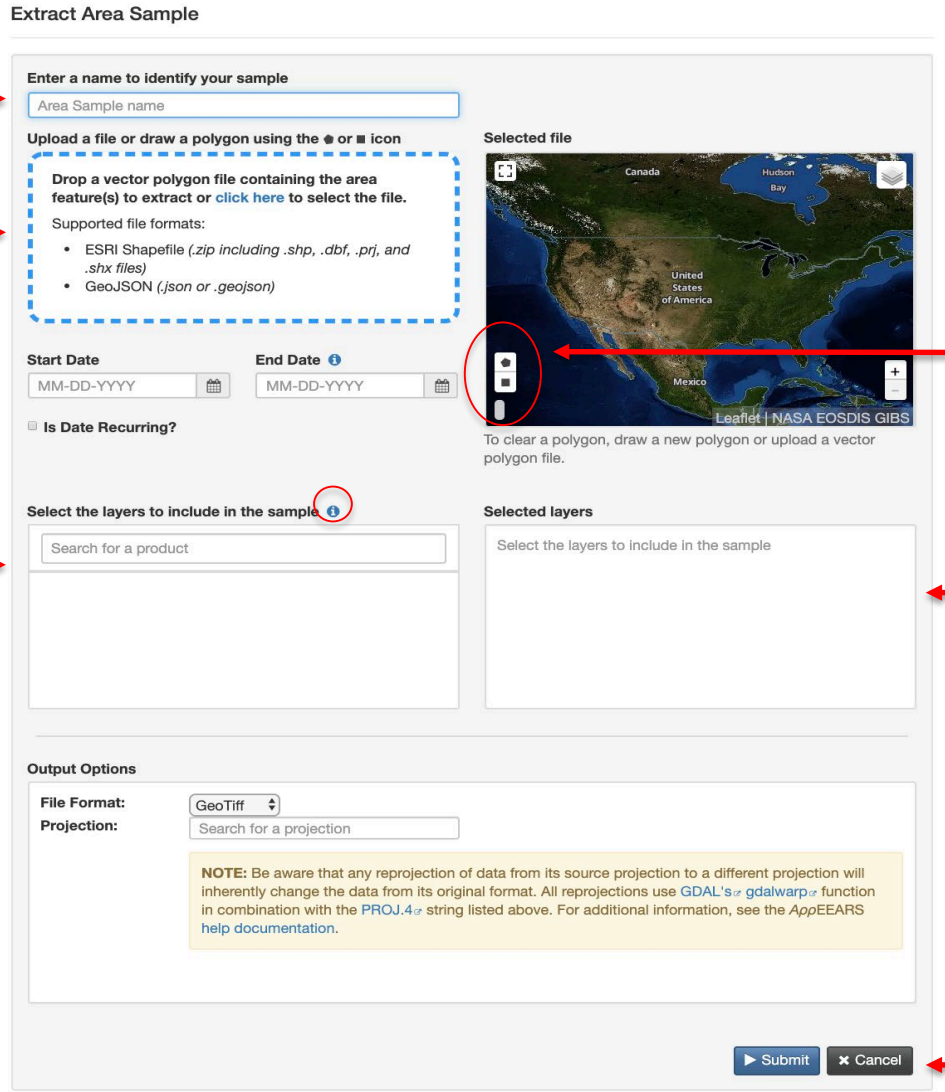

User-defined Data Request Title

Spatial Sub-setting by a Shapefile

Temporal Selection

Data Product List

Data Product Search by Name

Data Format Options

Spatial Sub-setting by a Polygon or Rectangle Area

Data Layer Selection

Submit Data Request

AppEEARS: SRTM Data Search and Access Request

https://lpdaac.usgs.gov/appeears/

User-defined Data Request Title

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Data Product Search by Name

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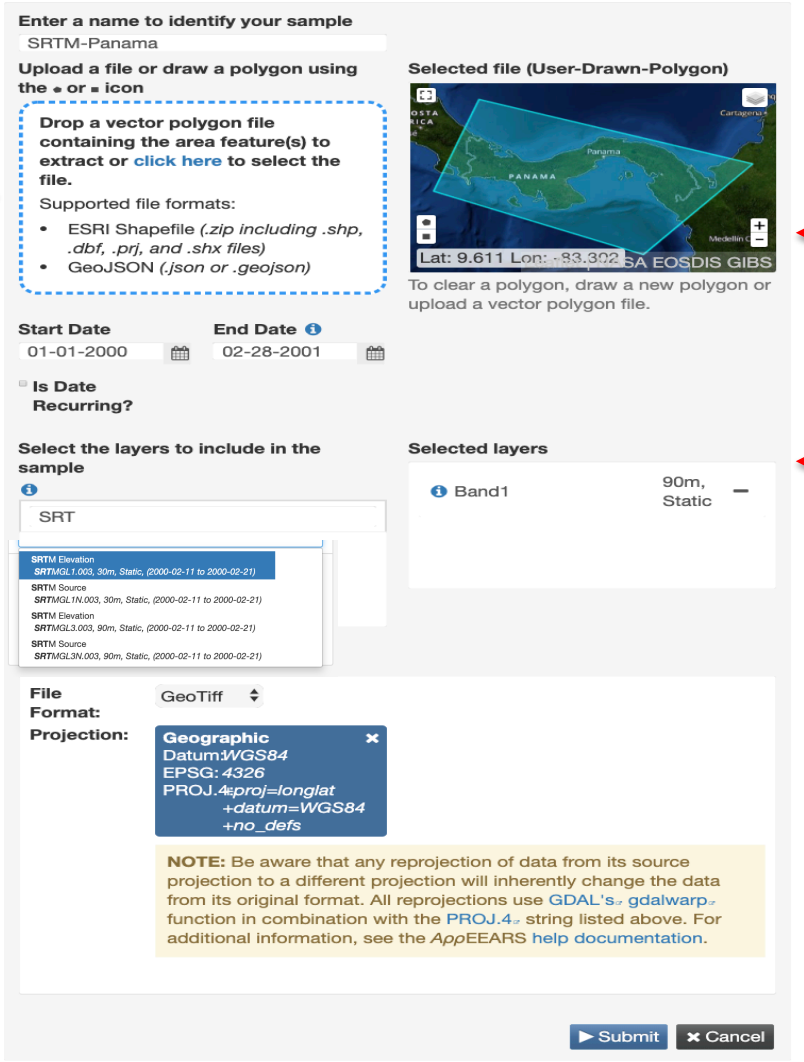

Spatial Sub-setting by a Polygon

Data Layer Selection

Submit Data Request

Data link is sent by an email for data download