

River Basin Delineation Based on NASA Digital Elevation Data

Sean McCartney and Amita Mehta

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Training Objectives

Become familiar with:

- HydroSHEDS (**H**ydrological data and maps based on **S**Huttle **E**levation **D**erivatives at multiple **S**cales)

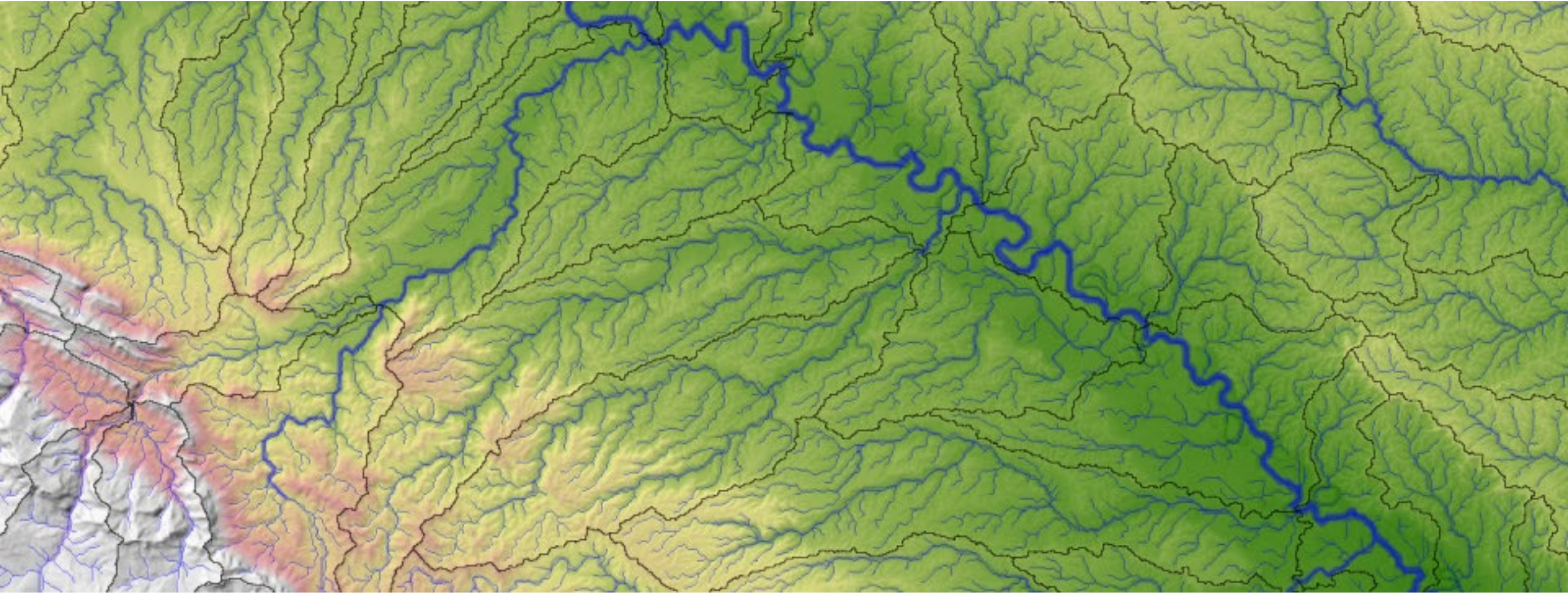
<https://www.hydrosheds.org/>

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



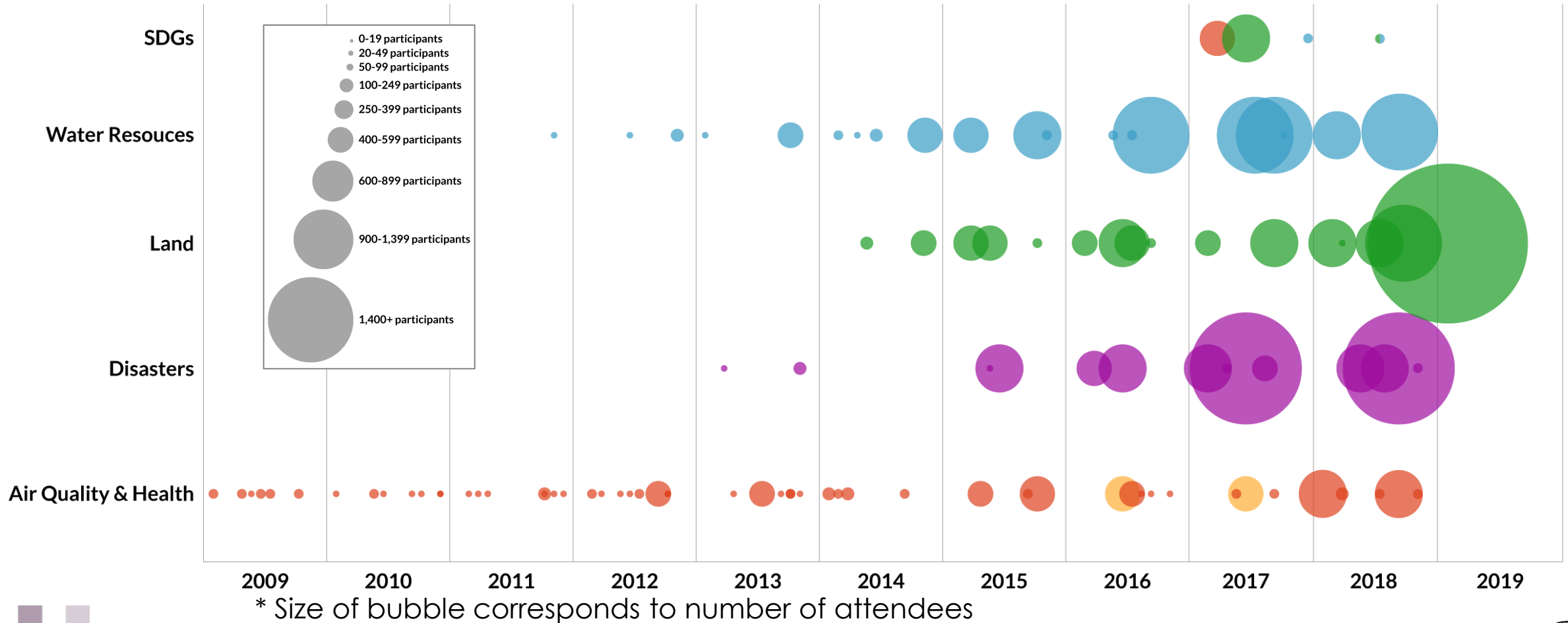
19,400+ participants



160+ countries



5,000+ organizations

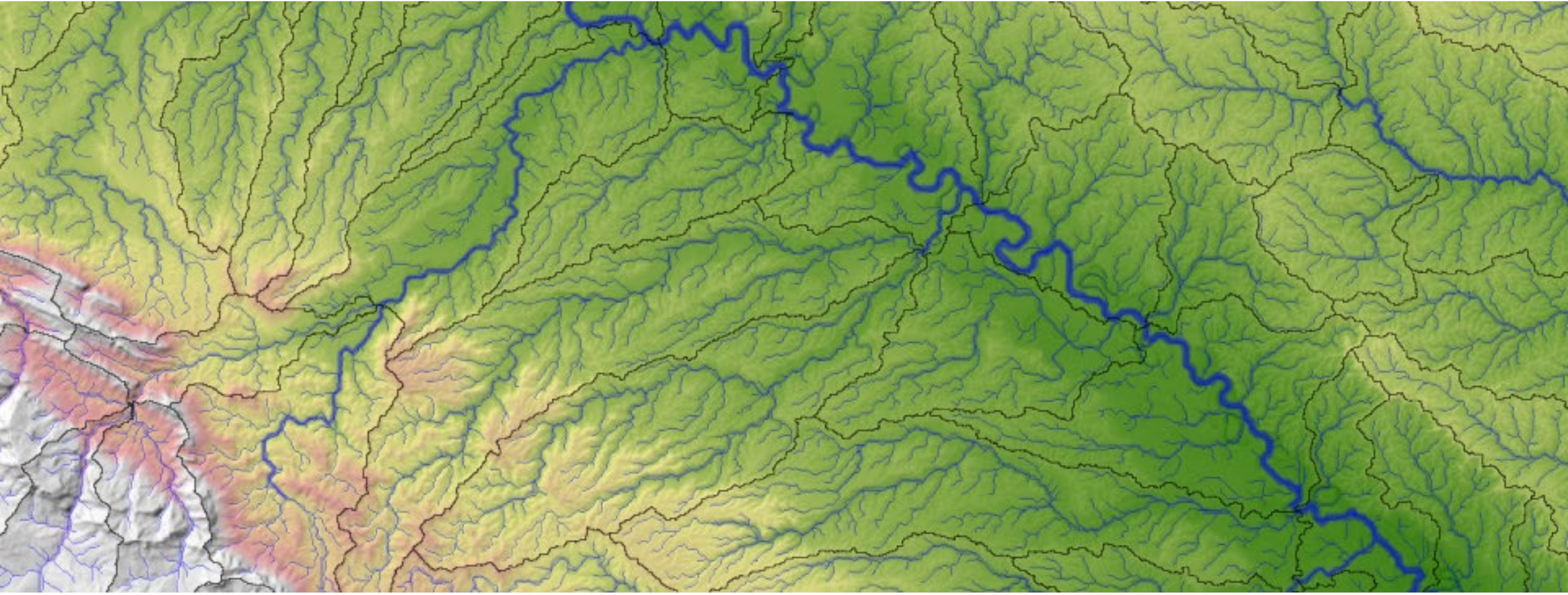


Learn More About ARSET

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

The screenshot displays the ARSET website interface. At the top, the NASA logo and 'ARSET Applied Remote Sensing Training' are visible, along with navigation links for 'Earth Sciences Division', 'Applied Sciences', and 'ASP Water Resources'. A search bar and a Twitter icon are also present. A main navigation menu includes 'Home', 'About', and 'Trainings'. The 'Trainings' menu is open, showing options for 'Fundamentals', 'Disasters', 'Health & Air Quality', 'Land', and 'Water Resources'. The 'Disasters' option is selected, leading to a featured training announcement for 'Introduction to Remote Sensing of Harmful Algal Blooms'. The announcement includes the dates 'Tuesdays, Sep 5-26, 2017' and times '11:00-12:00 or 21:00-22:00 EDT (UTC-4)', with a 'Register Now' button. A sidebar on the right contains a list of links: 'ARSET', 'Online Trainings', 'In-Person Trainings', 'Sign up for the Listserv' (highlighted with a mouse cursor), 'Tools Covered', 'Suggest a Training', 'Personnel', and 'Resources'. Below this is a section for 'Upcoming Training' with a sub-section for 'Water' and the link 'Satellite Observations of Water Quality for...'. The background of the main content area features a satellite image of a coastal area with greenish water.





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

• <https://water.usgs.gov/edu/watershed.html>

Indus River Basin

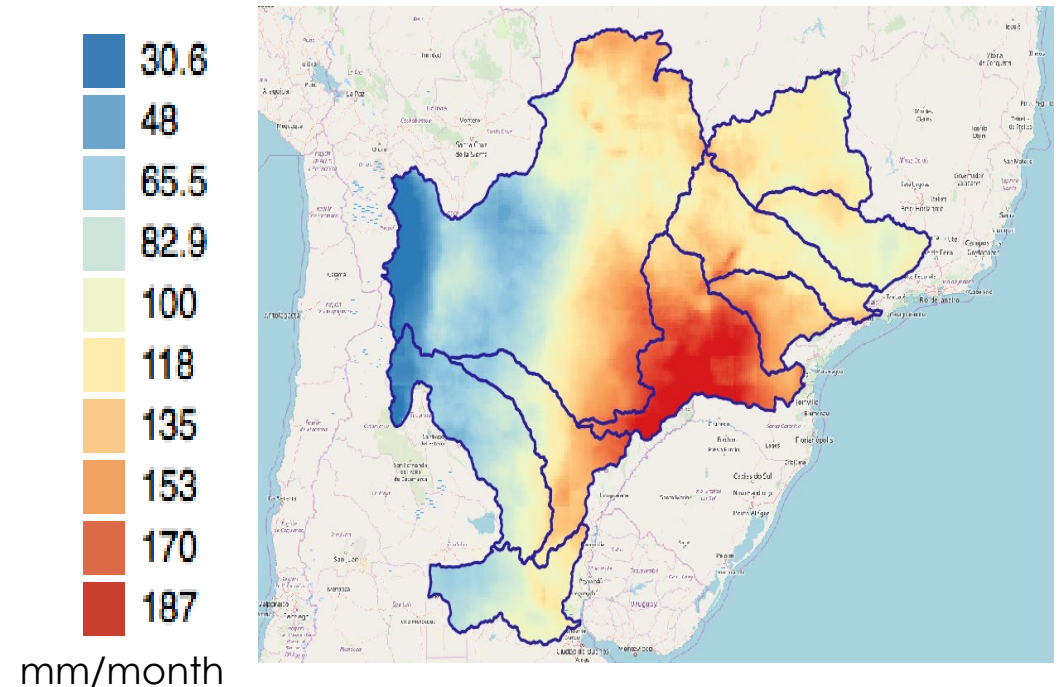


Source: Keenan Pepper,
https://commons.wikimedia.org/wiki/File:Indus_River_basin_map.svg

Why Delineation of River Basin?

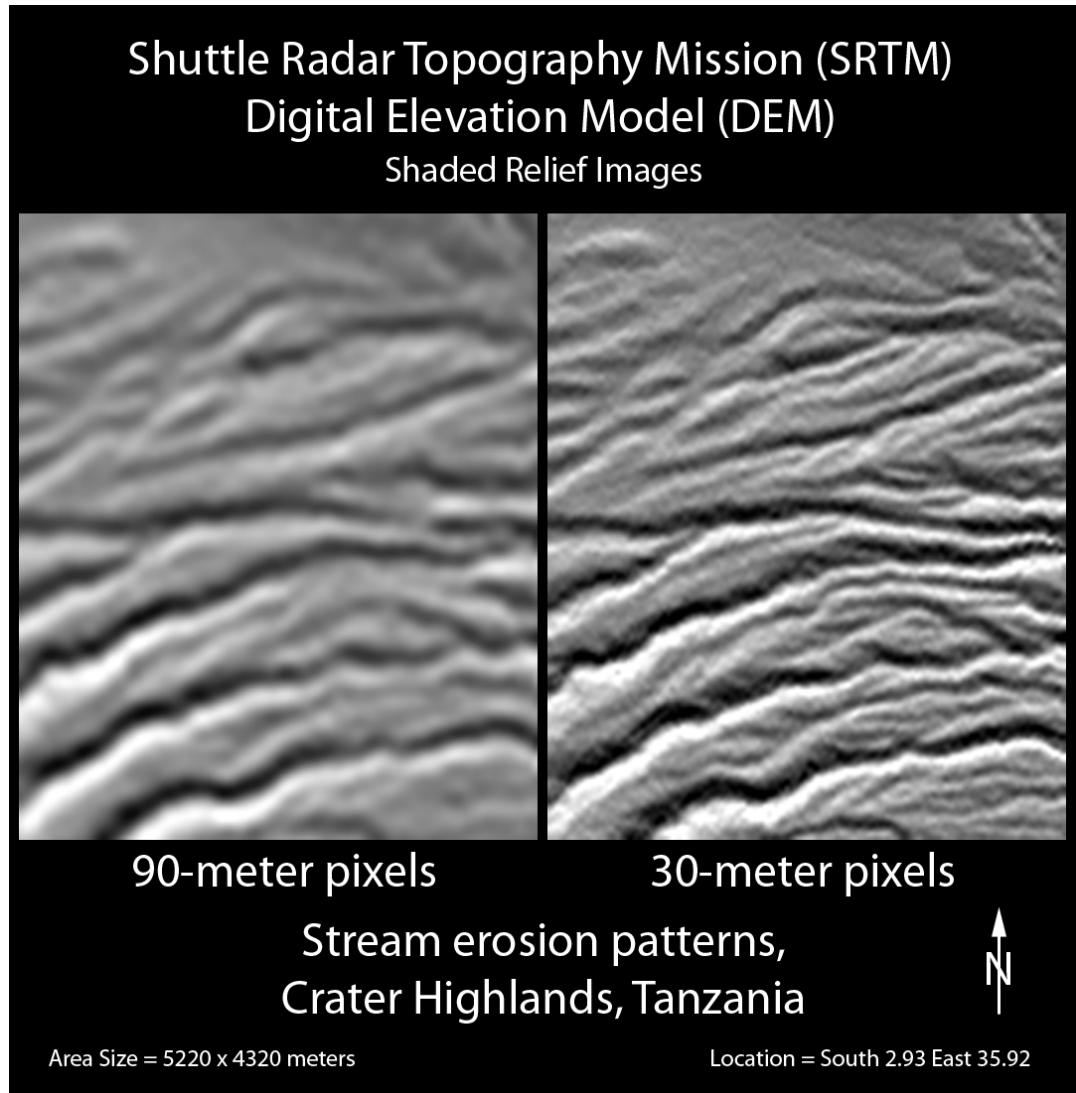
- Land surface processes, precipitation, storm water, and wastewater runoff within a river basin have substantial impact on quantity and quality of the water draining in the river
- Delineation of the basin is crucial for planning for water resources and flood management
- Delineation of watersheds within 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)

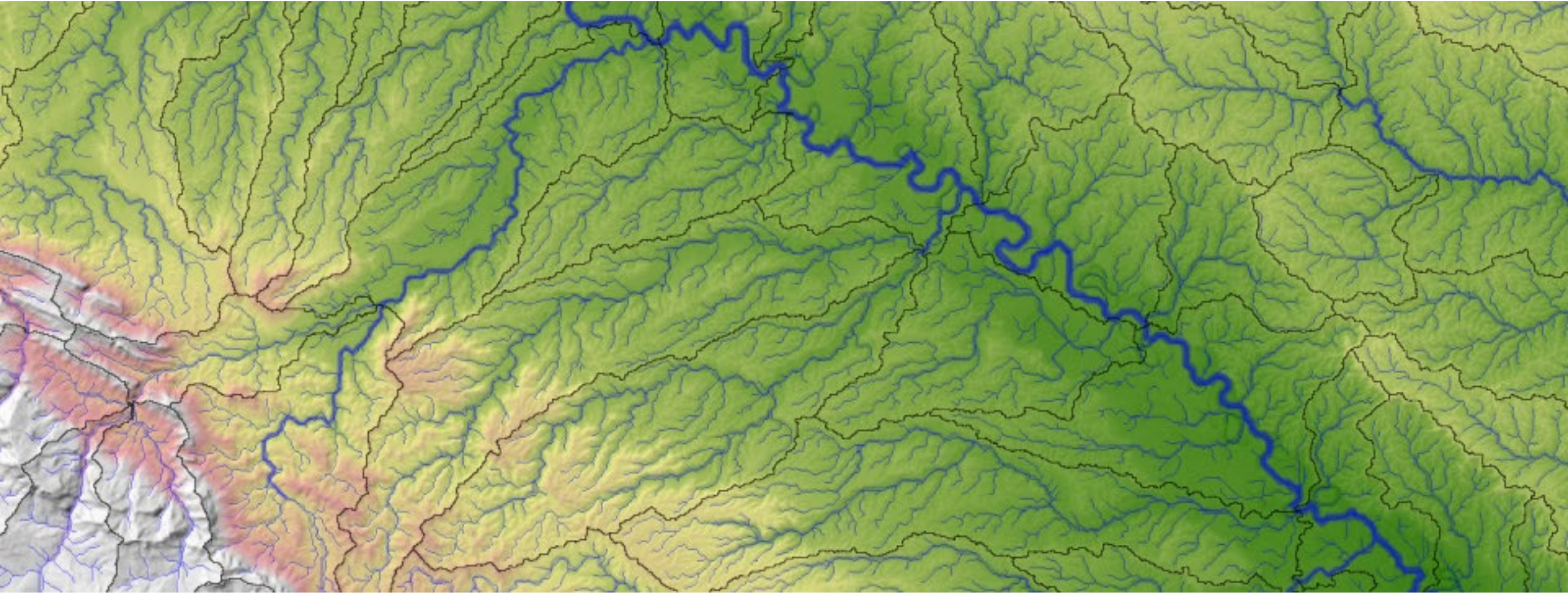


River Basin Delineation

- 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



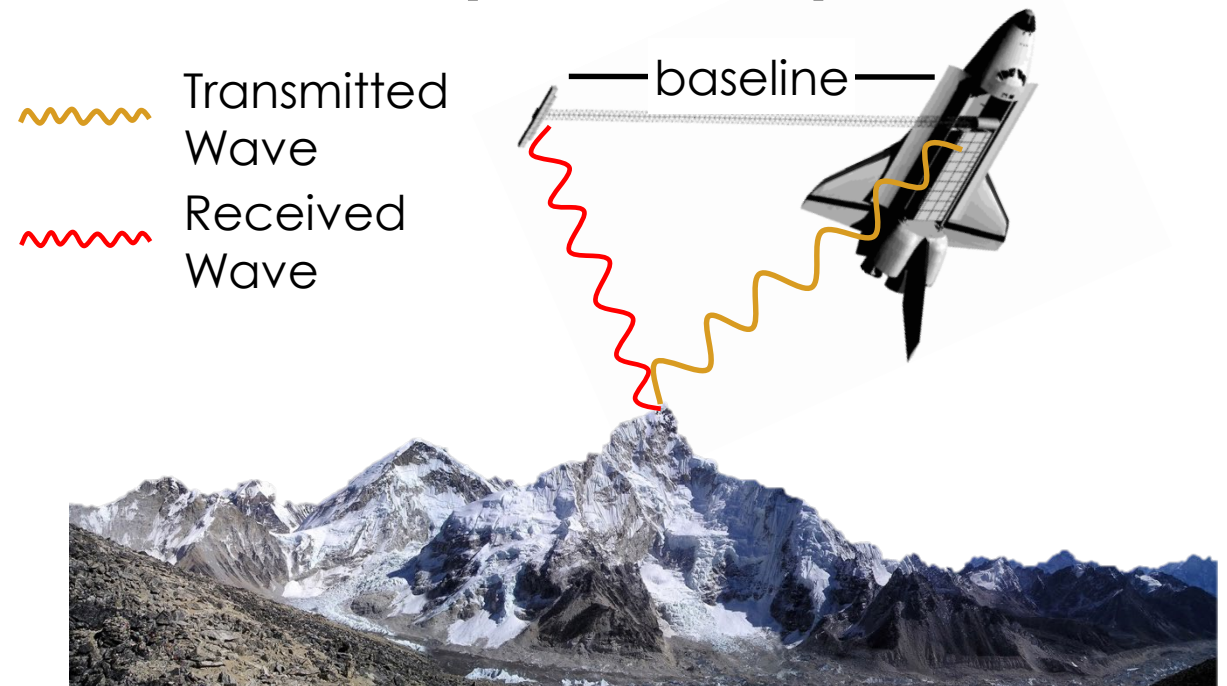
Overview of NASA Digital Elevation Data and HydroSHEDS

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)

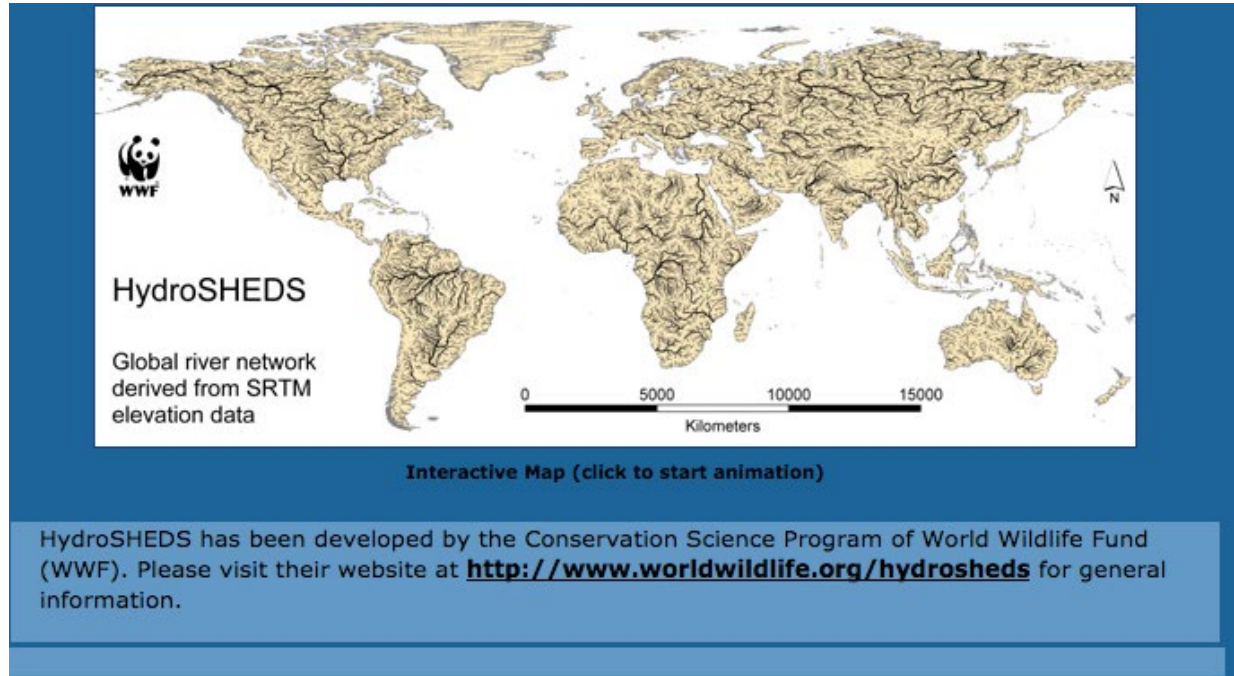


Spatial resolution: 30 m

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



The screenshot shows the HydroSHEDS website interface. At the top, there is a USGS logo with the tagline 'science for a changing world' and a WWF logo. The main heading is 'Data set development'. Below this, there is a paragraph of text explaining that users must be aware of certain characteristics of digital geospatial data sets, such as resolution, accuracy, and method of production. This is followed by a list of processing steps: 3.1 Combination of unfinished SRTM-3 and finished DTED-1 data, 3.2 Void-filling, 3.3 Sink identification, 3.4 Hydrologic conditioning, 3.5 Manual corrections, 3.6 Upscaling, and 3.7 Derived products. A sub-section titled '3.1.1 Combining SRTM-3 and DTED-1 original data' provides further details on the performance of the publicly available SRTM-3 and DTED-1 versions of SRTM at 3 arc-second resolution.

USGS
science for a changing world

HydroSHEDS

Data Produced by:

WWF

Home
Overview
Data Sources
Data Set Development
Quality Assessment
Data Availability
Data Formats
Notes for Users
References
Disclaimer

Resources:
DATA DOWNLOAD
LEAFLET
DOCUMENTATION

Acrobat® Reader is needed to view and print a PDF.

In Partnership with

Data set development

With all digital geospatial data sets, users must be aware of certain characteristics of the data, such as resolution, accuracy, method of production and any resulting artifacts, in order to better judge its suitability for a specific application. A characteristic of the data that renders it unsuitable for one application may have no relevance as a limiting factor for its use in a different application (NASA/JPL 2005).

This section provides an overview of the applied processing steps for the generation of HydroSHEDS and discusses some key technical specifications in order to allow the user to better estimate the suitability of the data set for a specific application. Additional data validation details are addressed in section 4. Please also refer to the flowchart of Appendix A in the **technical documentation**.

3.1 Combination of unfinished SRTM-3 and finished DTED-1 data
3.2 Void-filling
3.3 Sink identification
3.4 Hydrologic conditioning
3.5 Manual corrections
3.6 Upscaling
3.7 Derived products

3.1 Combination of unfinished SRTM-3 and finished DTED-1 data

3.1.1 Combining SRTM-3 and DTED-1 original data

For the generation of HydroSHEDS, the performance of the publicly available SRTM-3 and DTED-1 versions of SRTM at 3 arc-second resolution have been tested. Due to their specific characteristics, each data set showed both advantages and disadvantages for hydrological applications.

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

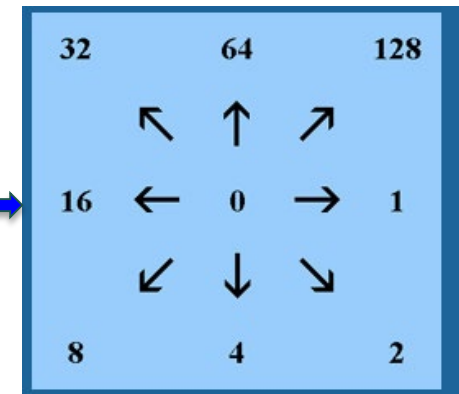
Identifier	in sec/min	in degree	in meters/km
3s	3 arc-second	0.000833333333333333	approx. 90 m at the equator
15s	15 arc-second	0.004166666666666667	approx. 500 m at the equator
30s	30 arc-second	0.008333333333333333	approx. 1 km at the equator
5m	5 minute	0.083333333333333333	approx. 10 km at the equator

River Basin Data Layers and Format from HydroSHEDS

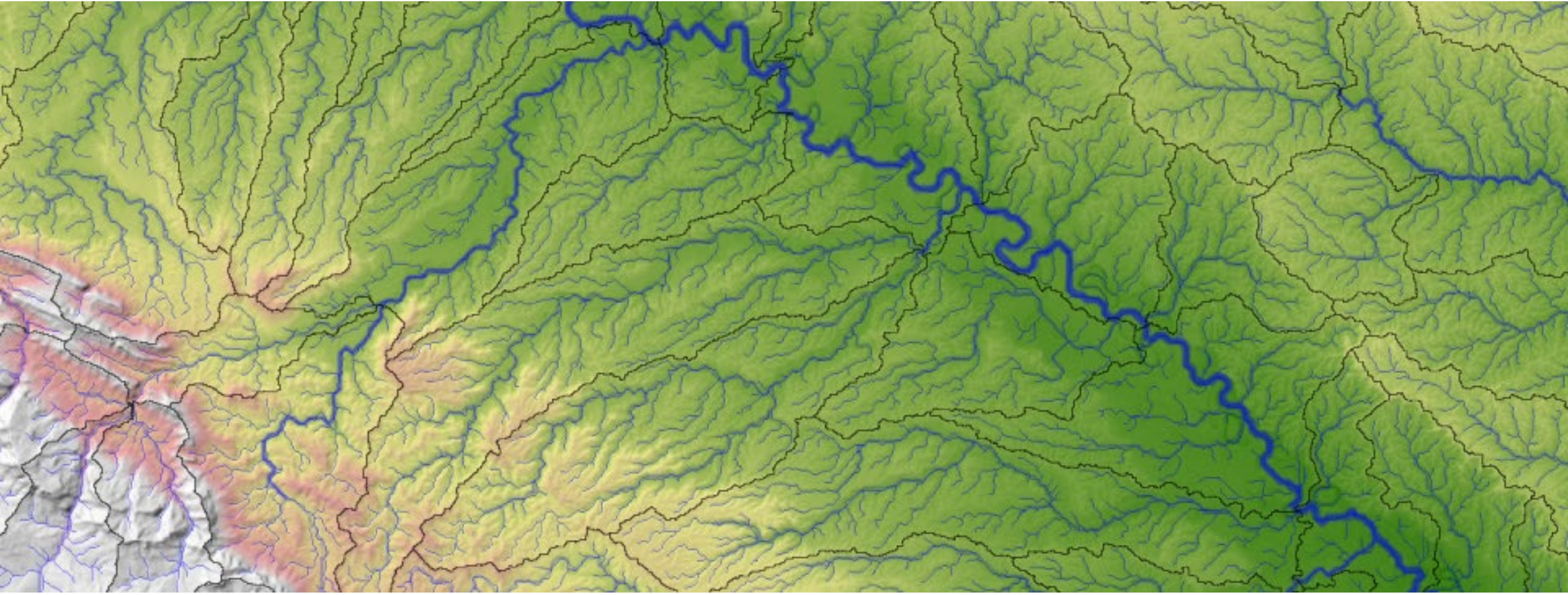
<https://hydrosheds.cr.usgs.gov/data.php>

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

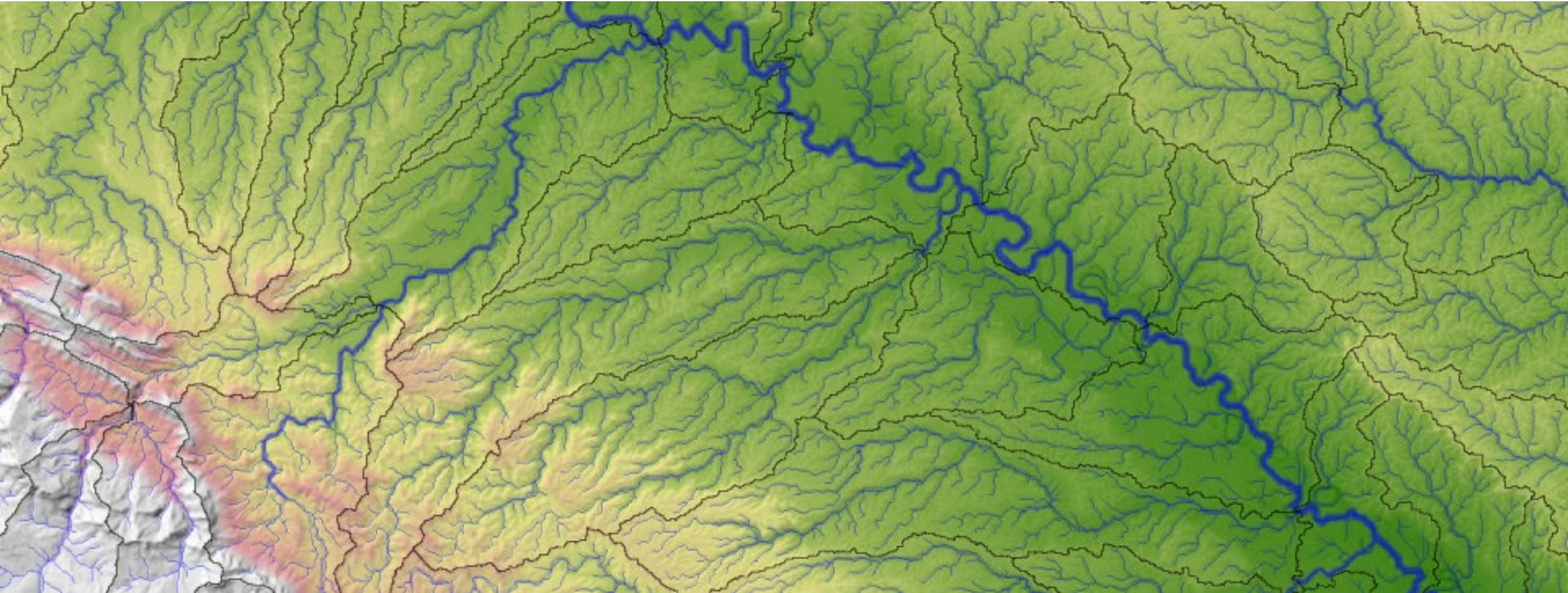
Layer Name	Format	Data	Resolution
DEM Void-filled Digital Elevation Model	Raster	Elevation in meters	3 arc-sec 15 arc-sec
CON Hydrologically Conditioned Elevation	Raster	Elevation in meters	3 arc-sec
DIR Drainage Direction	Raster	ESRI flow direction numbers	3 arc-sec 15 arc-sec
ACC Flow Accumulation	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



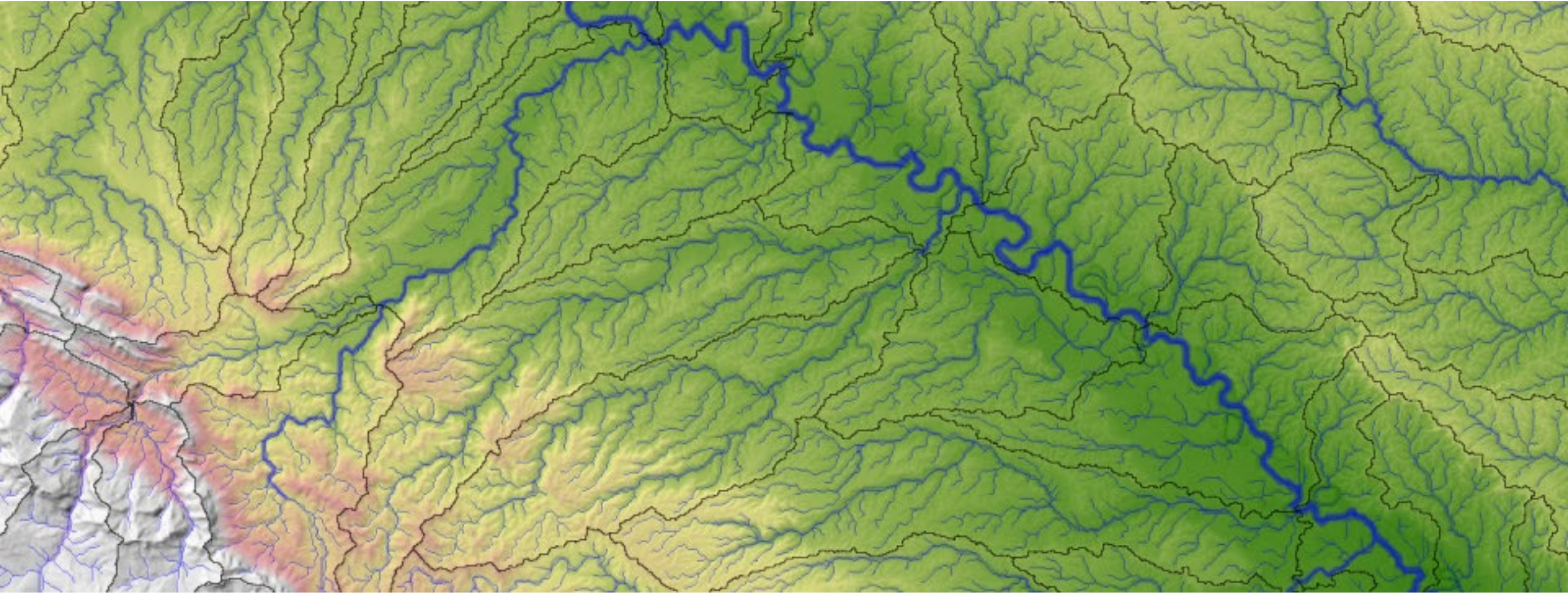
Demonstration of HydroSHEDS for River Basin
Delineation and Determining Drainage
Direction



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

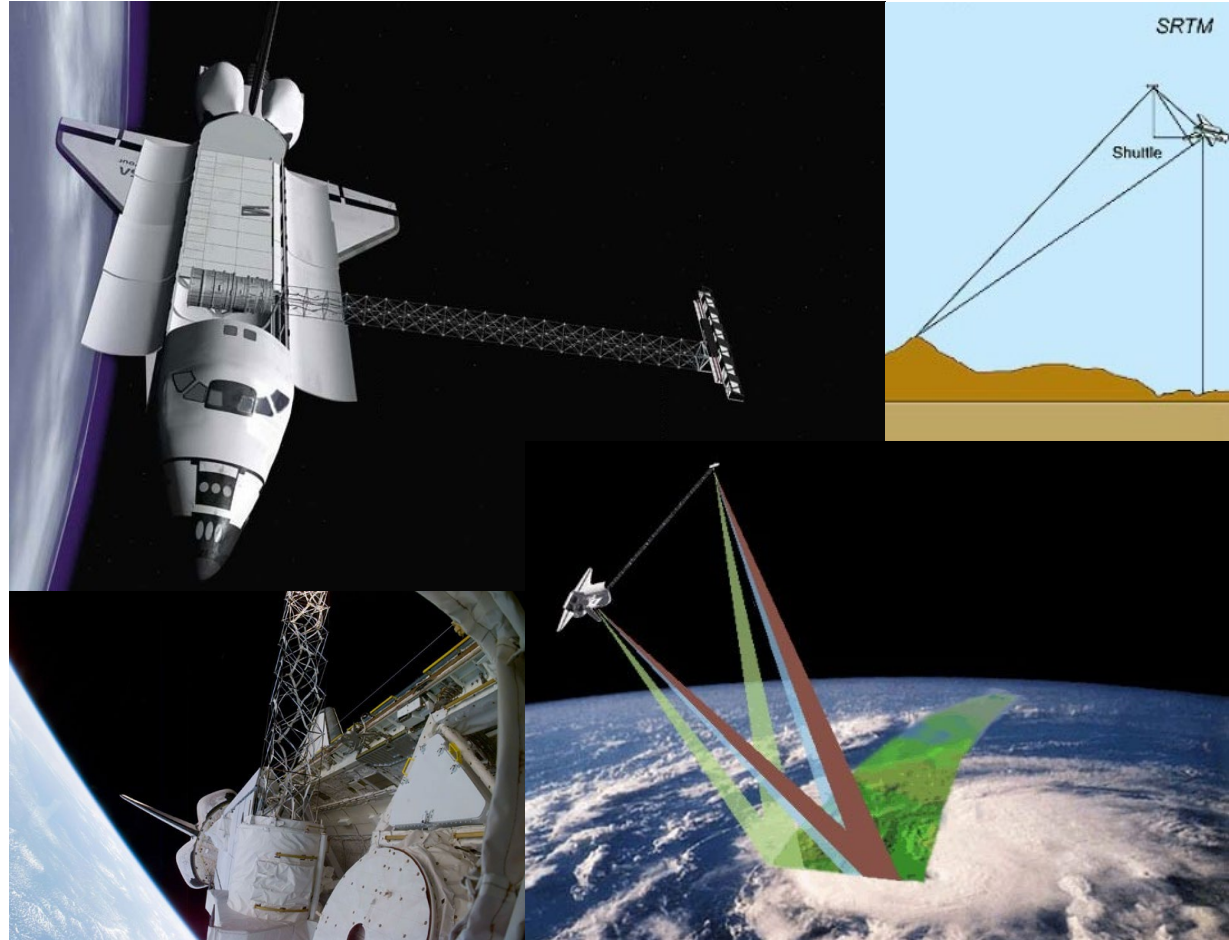


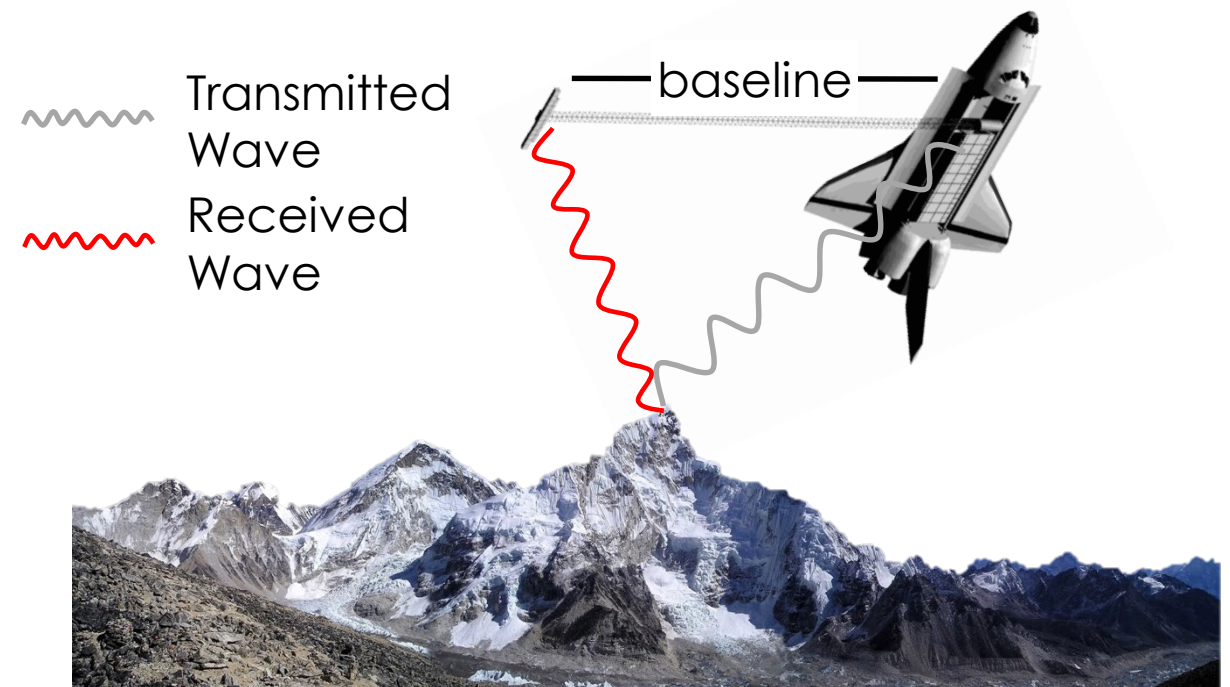
Image Credit (Top Right): DLR

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)

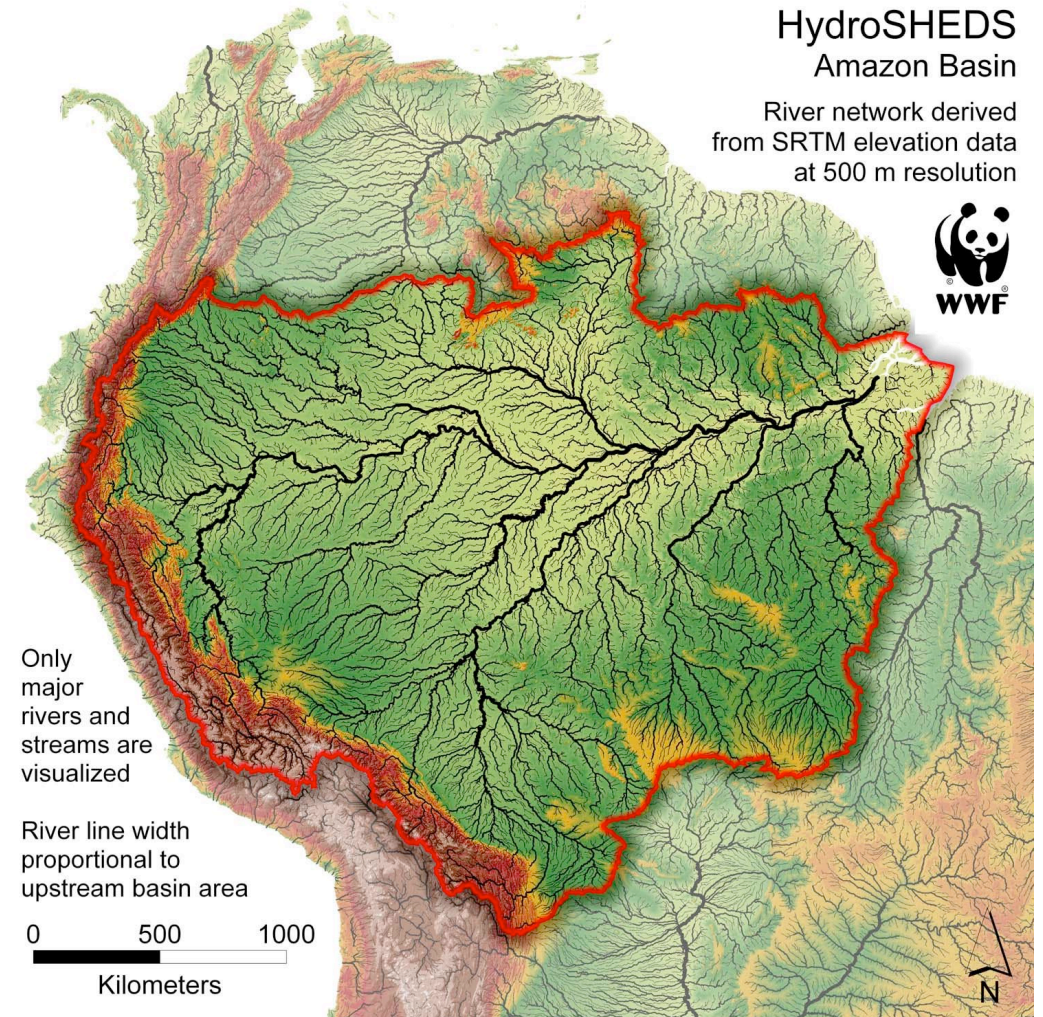
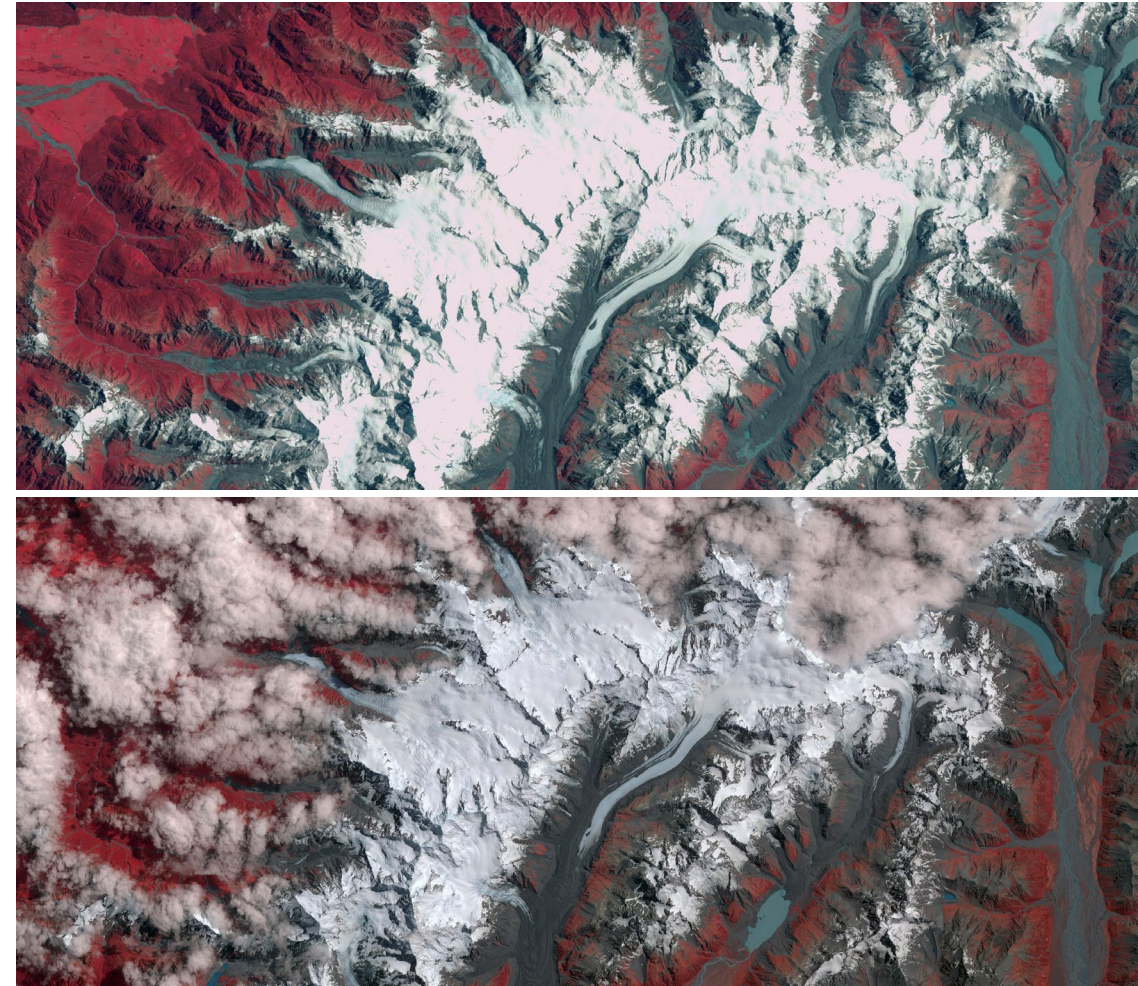


Image Credit: WWF, Text Reference: <https://earthdata.nasa.gov/community/community-data-system-programs/measures-projects/nasadem>

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

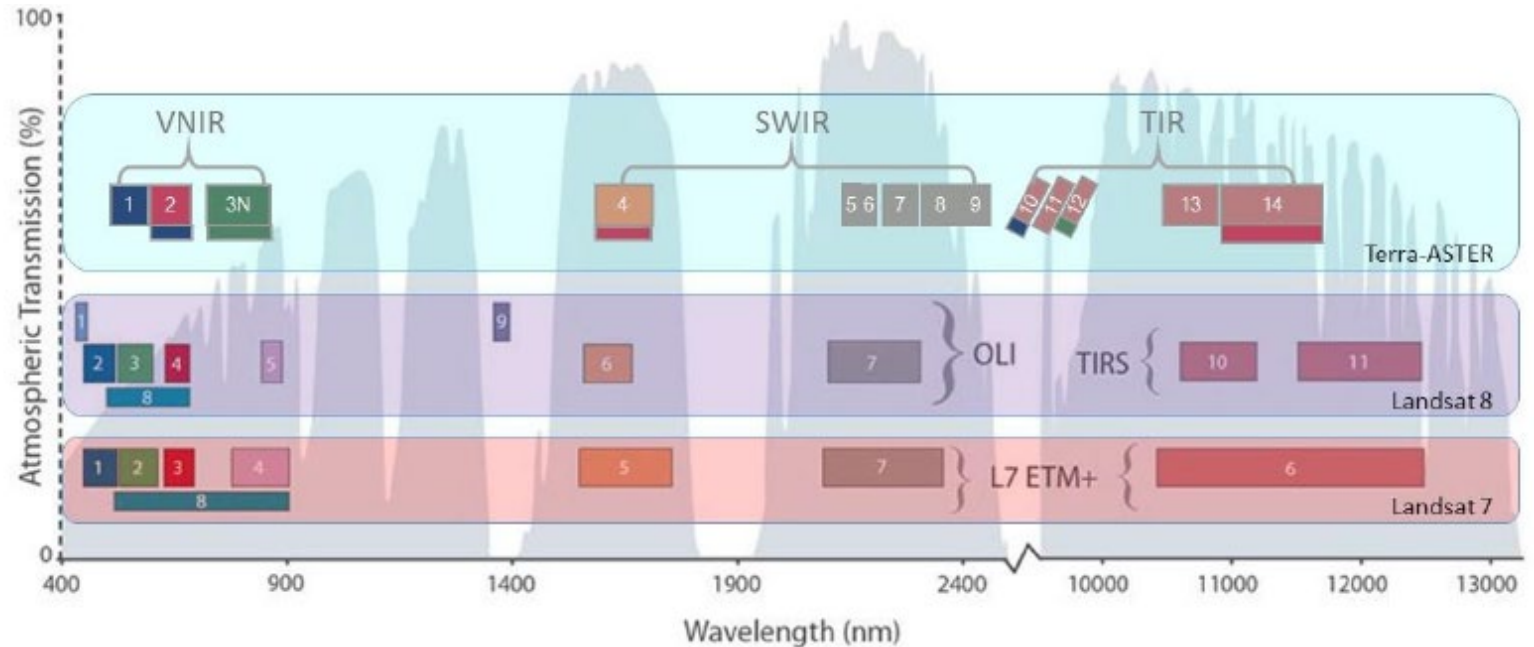
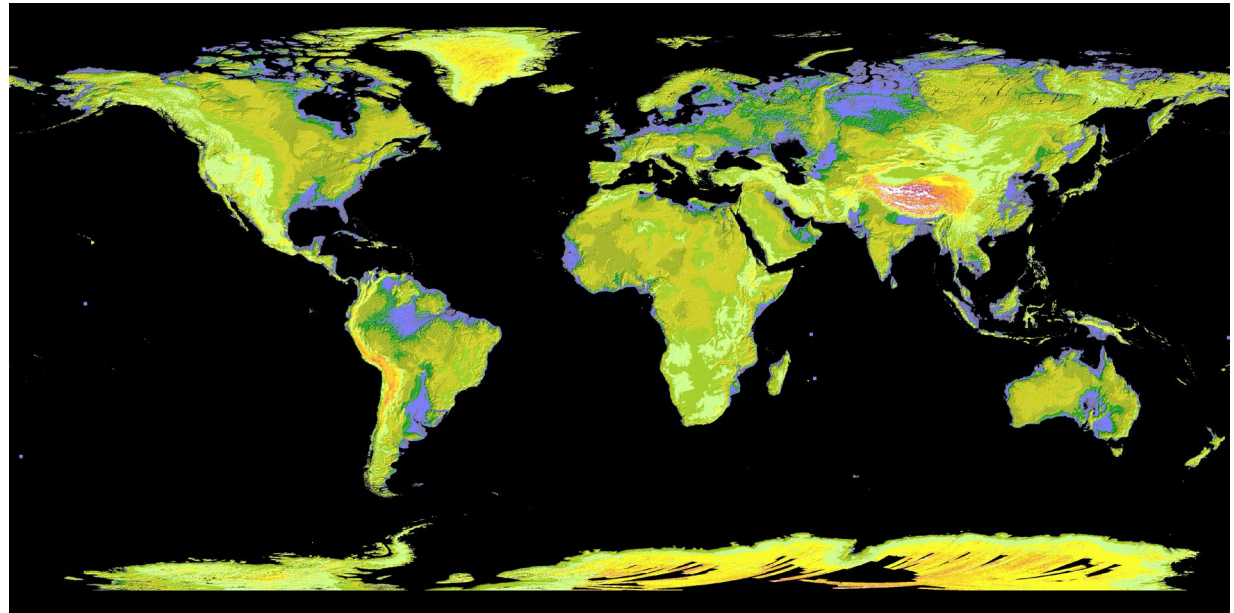


Image Credit: Vincheh, Z.H. and Arfania, R. (2017) Lithological Mapping from OLI and ASTER Multispectral Data Using Matched Filtering and Spectral Analogues Techniques in the Pasab-e-Bala Area, Central Iran. Open Journal of Geology, 7, 1494-1508.

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

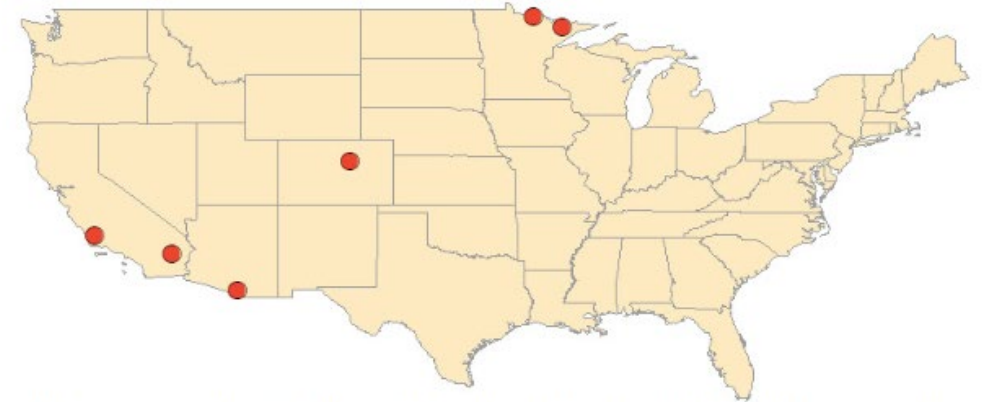


Figure 1. Study sites (California [2], Arizona [1], Colorado [1], and Minnesota [2]).

- 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

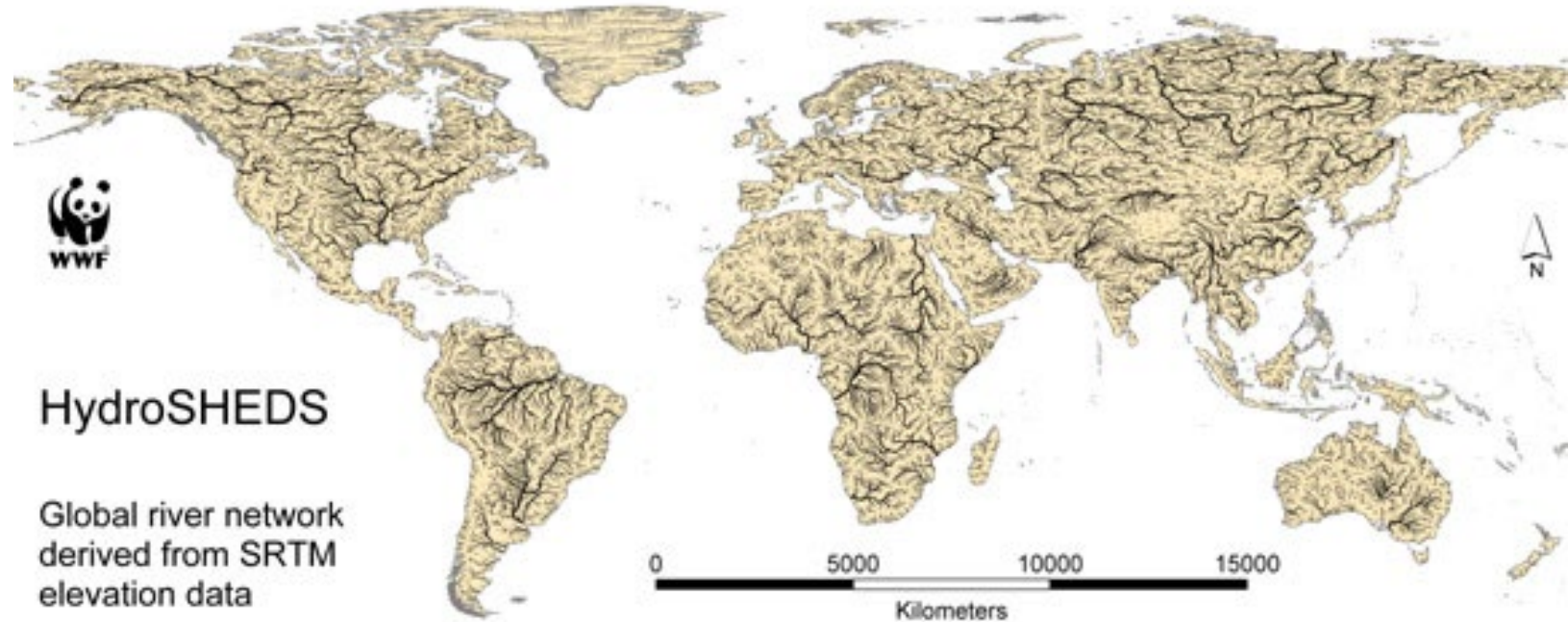
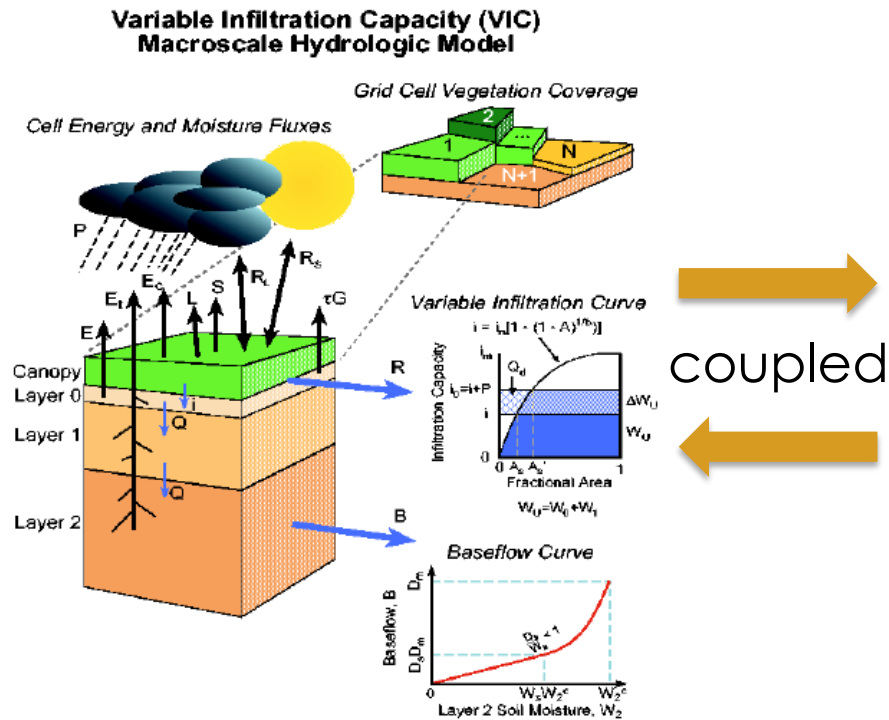


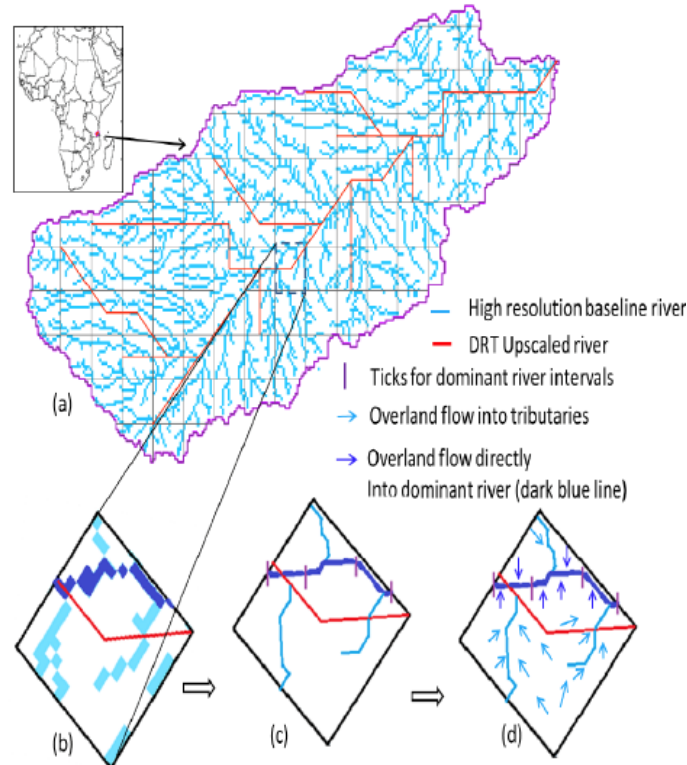
Image Credit: USGS HydroSHEDS/WWF

SRTM DEM Application in Flood Modeling

VIC



DRTR – Dominant River Tracing Based Routing



- The Global Flood Monitoring System (GFMS) uses HydroSHEDS derived from SRTM DEM for identifying river networks for routing models

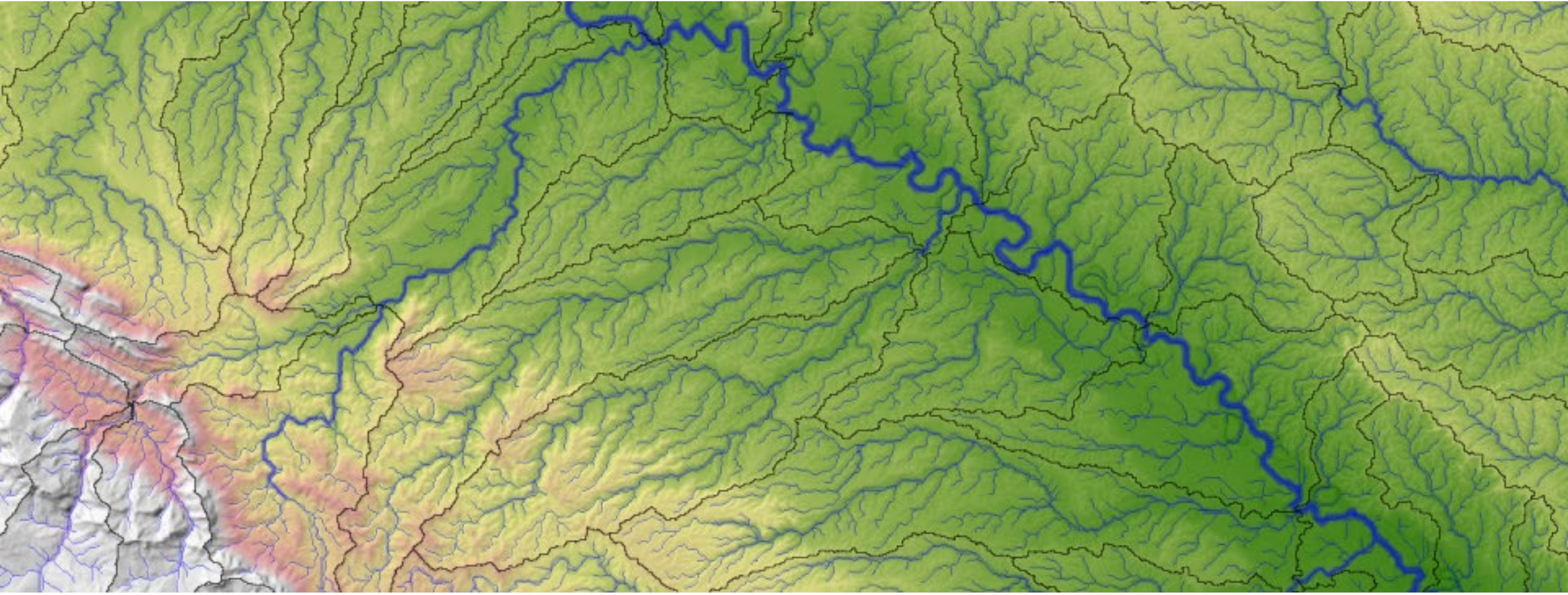
• <http://hydrosheds.org/>

University of Washington

University of Maryland

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 (GeoTiff and NetCDF) and projections
- Requires user registration via <http://urs.earthdata.nasa.gov>
- Data requests are submitted via an email to LP-DAAC

Welcome to AppEEARS!

Application for **Extracting** and **Exploring Analysis Ready Samples (AppEEARS)**

The Application for Extracting and Exploring Analysis Ready Samples (**AppEEARS**) offers a simple and efficient way to access and transform geospatial data from a variety of federal data archives. AppEEARS enables users to subset **geospatial datasets** using spatial, temporal, and band/layer parameters. Two types of sample requests are available: **point samples** for geographic coordinates and **area samples** for spatial areas via vector polygons. Sample requests submitted to AppEEARS provide users not only with data values, but also associated quality data values. Interactive visualizations with summary statistics are provided for each sample within the application, which allow users to preview and interact with their samples before downloading their data. Get started with a sample request using the Extract option above, or visit the [Help page](#) to learn more.



National Aeronautics and
Space Administration



United States
Geological Survey



Land Processes
Distributed Active Archive Center



National Snow and Ice Data Center
Distributed Active Archive Center



Socioeconomic Data and
Applications Center



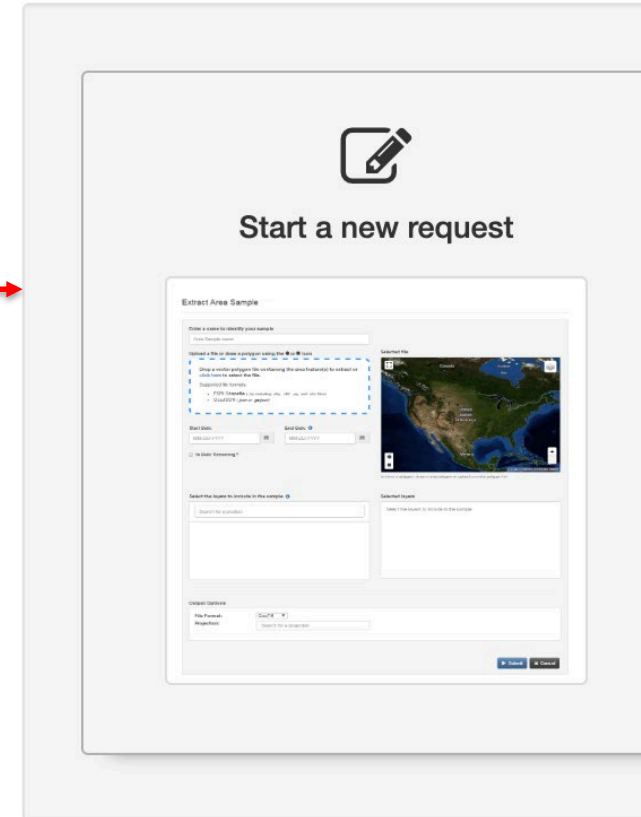
Oak Ridge National Laboratory
Distributed Active Archive Center

AppEEARS: Data Search and Access Request

<https://lpdaac.usgs.gov/appears/>

Allows for search and request a data product via a GUI

Extract Area Sample



The screenshot shows the 'Extract Area Sample' form in the AppEEARS interface. At the top, there is a pencil icon and the text 'Start a new request'. Below this, the form is titled 'Extract Area Sample'. It includes a text input field for 'Enter a name to identify your request', a 'Start date' field, an 'End date' field, a 'Select the layers to include in this sample' section with a list of layers, and an 'Output options' section with a 'File format' dropdown menu. A map of the United States is displayed on the right side of the form.

AppEEARS: Data Search and Access Request

<https://lpdaac.usgs.gov/appears/>

Extract Area Sample

User-defined Data Request Title

Spatial Sub-setting by a Shapefile

Temporal Selection

Data Product List

Data Product Search by Name

Data Format Options

Enter a name to identify your sample

Area Sample name

Upload a file or draw a polygon using the or icon

Drop a vector polygon file containing the area feature(s) to extract or [click here](#) to select the file.

Supported file formats:

- ESRI Shapefile (.zip including .shp, .dbf, .prj, and .shx files)
- GeoJSON (.json or .geojson)

Start Date: MM-DD-YYYY

End Date: MM-DD-YYYY

Is Date Recurring?

Select the layers to include in the sample

Search for a product

Selected layers

Select the layers to include in the sample

Output Options

File Format: GeoTiff

Projection: Search for a projection

NOTE: Be aware that any reprojection of data from its source projection to a different projection will inherently change the data from its original format. All reprojections use GDAL's `gdalwarp` function in combination with the PROJ.4 string listed above. For additional information, see the AppEEARS help documentation.

Submit Cancel

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/appears/>

User-defined Data Request Title

Spatial Sub-setting by a Shapefile

Temporal Selection

Data Product List

Data Product Search by Name

Data Format Options

Data link is sent by an email for data download

The screenshot shows the AppEEARS web interface with the following fields and options:

- Enter a name to identify your sample:** SRTM-Panama
- Upload a file or draw a polygon using the or icon:** A dashed box highlights the upload area. Below it, a map shows a polygon drawn over Panama. Coordinates: Lat: 9.611 Lon: -83.302 SA EOSDIS GIBS. Text below the map: "To clear a polygon, draw a new polygon or upload a vector polygon file."
- Drop a vector polygon file containing the area feature(s) to extract or click here to select the file.** Supported file formats:
 - ESRI Shapefile (.zip including .shp, .dbf, .prj, and .shx files)
 - GeoJSON (.json or .geojson)
- Start Date:** 01-01-2000 **End Date:** 02-28-2001
- Is Date Recurring?:**
- Select the layers to include in the sample:** A search box contains "SRT". A dropdown menu shows search results for SRTM Elevation and SRTM Source.
- Selected layers:** Band1, 90m, Static
- File Format:** GeoTiff
- Projection:** Geographic, Datum:WGS84, EPSG: 4326, PROJ.4=proj=longlat +datum=WGS84 +no_defs
- NOTE:** Be aware that any reprojection of data from its source projection to a different projection will inherently change the data from its original format. All reprojections use GDAL's gdalwarp function in combination with the PROJ.4 string listed above. For additional information, see the AppEEARS help documentation.
- Buttons:** Submit, Cancel

Spatial Sub-setting by a Polygon

Data Layer Selection

Submit Data Request