

The background of the slide is a dark blue network map with numerous nodes and connecting lines. A semi-transparent globe is centered behind the text.

IIT Bombay Winter School
Geospatial Models
Session 1



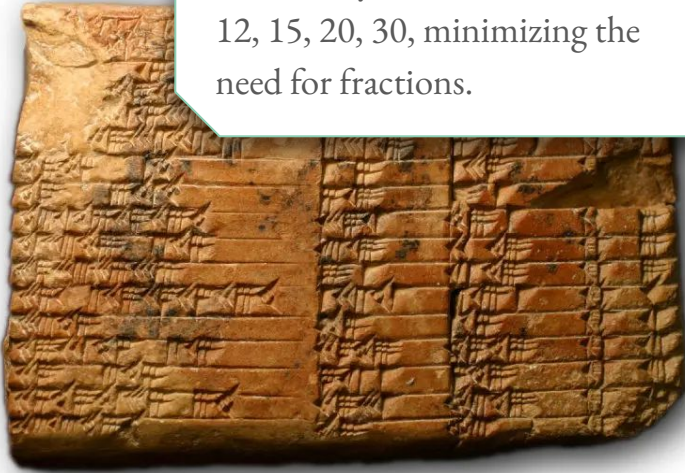
GIS Concepts and USGS Hydrology Model

By: Paul Churchyard, Chief Geospatial Engineer @HSR.health

Time	Session	Speakers
0930-1000	Recap	Sumit Sen
1000-1100	U.S. Geological Survey Data Model and GIS Background	Paul Churchyard, Ajay Gupta
1100-1145	Activity 1: Explore data available through the USGS	Paul Churchyard, Ajay Gupta
1145-1200	Tea	
1200-1300	First Discussion Session	Paul Churchyard, Ajay Gupta, Sumit Sen
1300-1400	Lunch	
1400-1500	Intro into specialized Earth Observation Data Models	Paul Churchyard, Ajay Gupta
1500-1545	Activity 2: Create a Flood Shelter Suitability Data Model	Paul Churchyard, Ajay Gupta
1545-1600	Tea	
1600-1700	Second Disucssion Session	Paul Churchyard, Ajay Gupta, Sumit Sen

What is an arc?

In base 60, each number cycle is divisible by 1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, minimizing the need for fractions.



PLIMPTON 322
Christine Proust and Columbia University

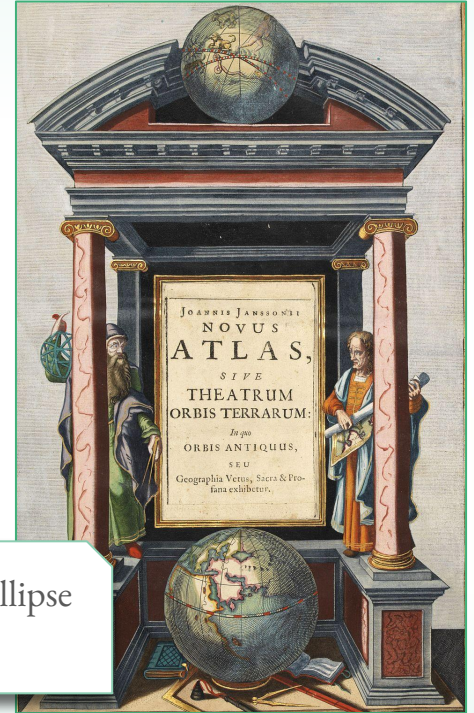
02:43:15

Two hours, forty-three minutes, and fifteen seconds

2° 43' 15"

Two degrees, forty-three arcminutes, and fifteen arcseconds

An arc-degree represents $\frac{1}{360}$ th of an ellipse
An arcsecond is $\frac{1}{360}$ th of a degree



JANSSONIUS, J., Amsterdam, 1650

Marinus of Tyre and and Claudius Ptolemaeus as depicted on later translations of "Geographia"

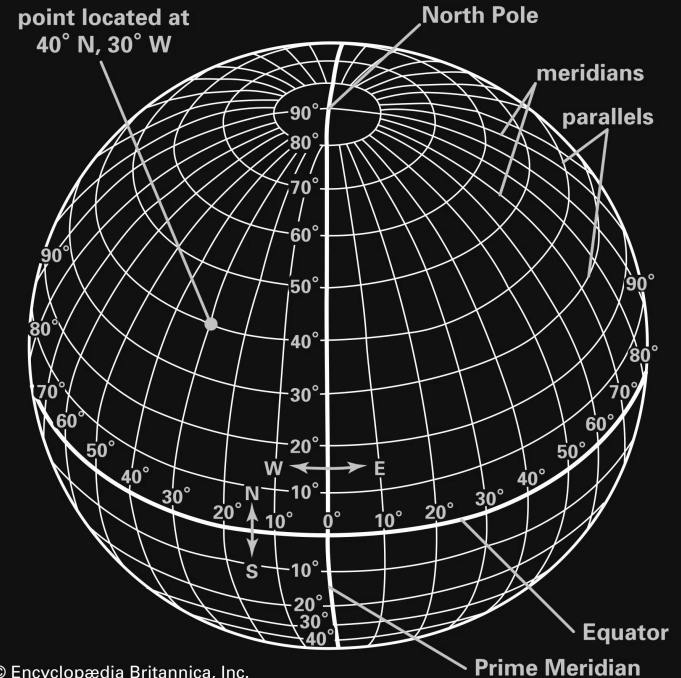
Parallels and Meridians

- Latitude: 0° (equator) to 90° (north pole) and -90° (south pole)
- Longitude: 0° (prime meridian) to 180° (east) and 180° (west)
- $0^\circ, 0^\circ$: Gulf of Guinea, off the coast of Ghana
- $0^\circ, 180^\circ$: Pacific Ocean , surrounded by atoll islands



Soul Buoy
AKA "Null Island"

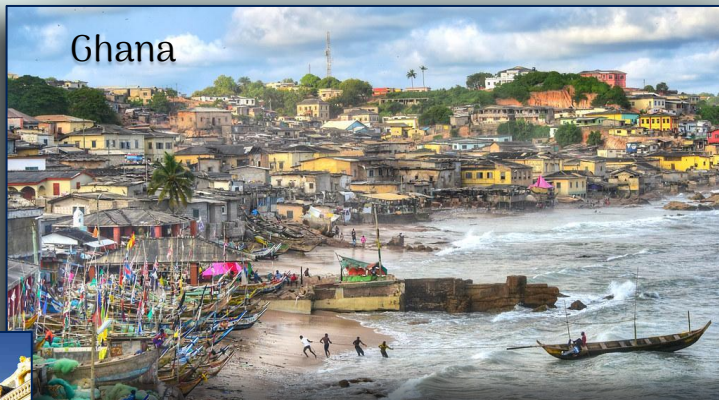
PARALLELS OF LATITUDE AND MERIDIANS OF LONGITUDE



Algeria



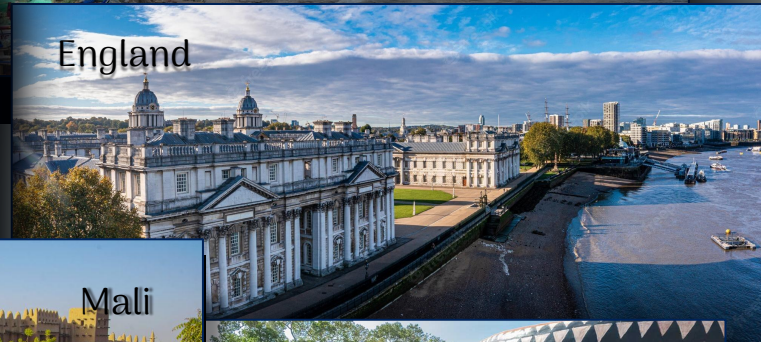
Ghana



France



England



Spain



Mali



Togo



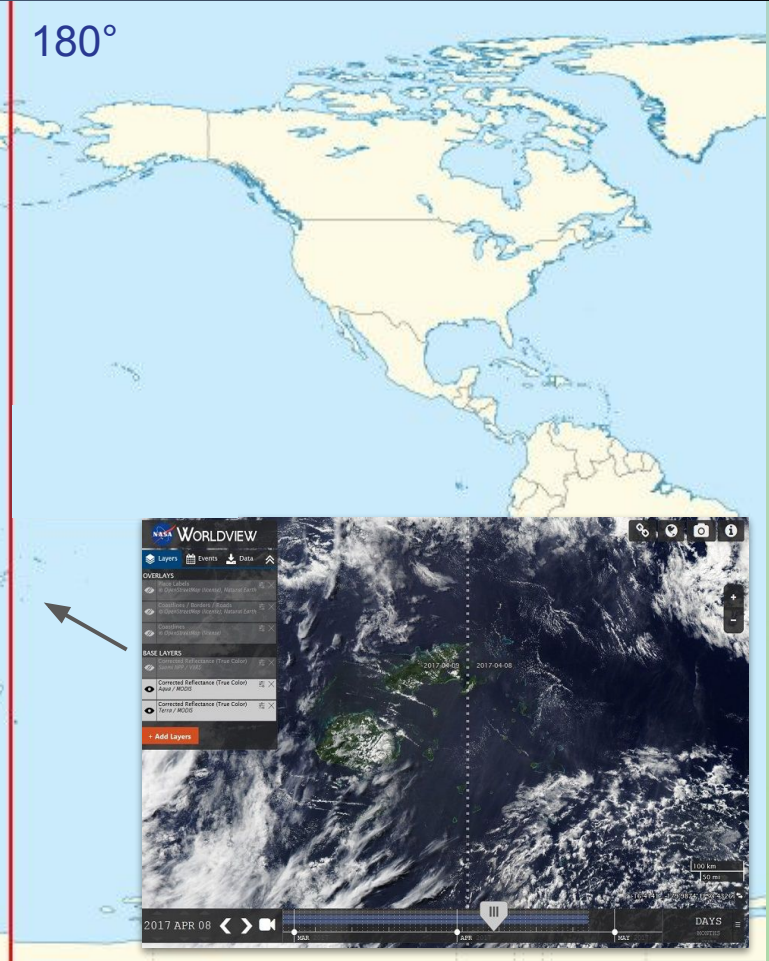
Burkina Faso





180°

Antimeridian



Reference Datums

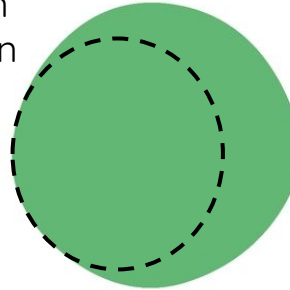
Local datum

- Arc best fit for a specified region
- USGS systems use the North American Datum of 1983

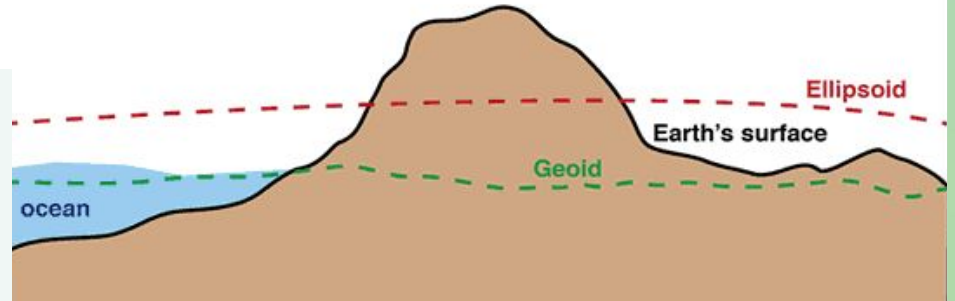
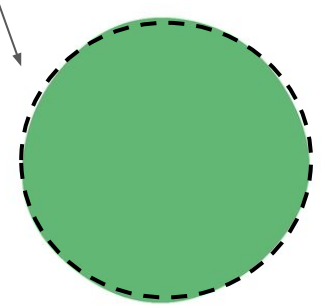
Global datum

- Elliptical approximation global average sea level
- Global standard established in 1984 World Geodetic System (WGS)
- Commercial and recreational GPS use WGS 1984 as default

Fits well in one region



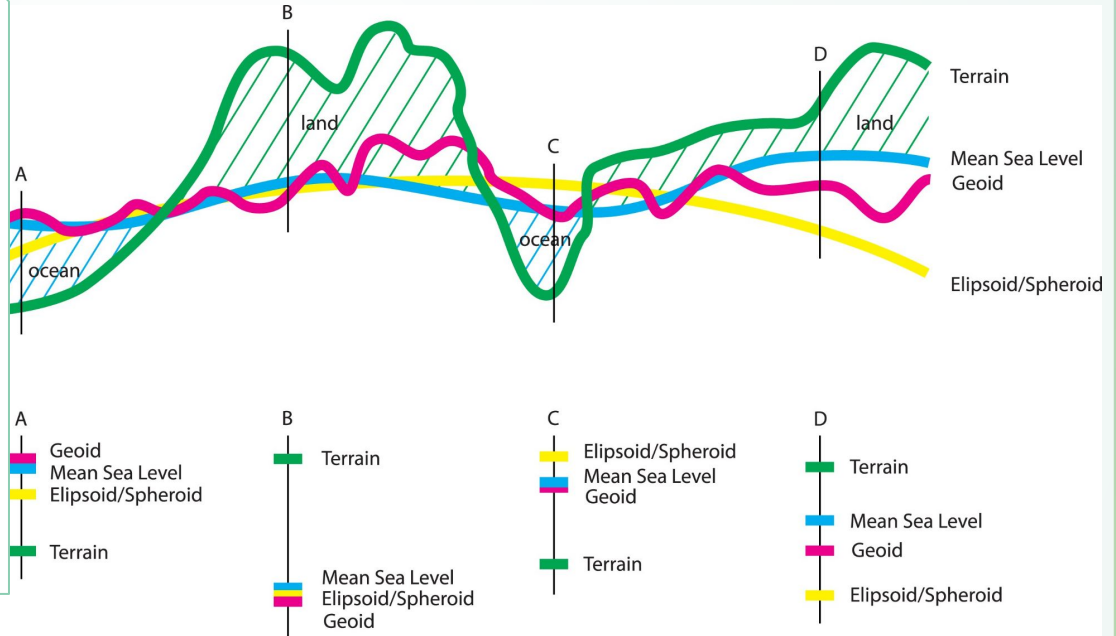
Fits approximately planet wide



Geoid










Geoid

- *“The equipotential surface of the Earth's gravity field which best fits, in the least squares sense, (global) mean sea level.” - NOAA*
- Theoretical calculation of average sea level based on gravity field
- Does not follow topography and is usually underneath land





LEGEND

-  Triangulation
-  U.S. Coast & Geodetic Survey
-  U.S. Survey of the 40th Parallel [King]
-  U.S. Geological Survey of the Territories [Hayden]
-  U.S. Geological & Geographical Survey of Rocky Mtn. Region [Powell]
-  U.S. Geographical Surveys West of the 100th Meridian [Wheeler]
-  U.S. Geological Survey
-  New Hampshire Geological Survey
-  New Jersey Geological Survey

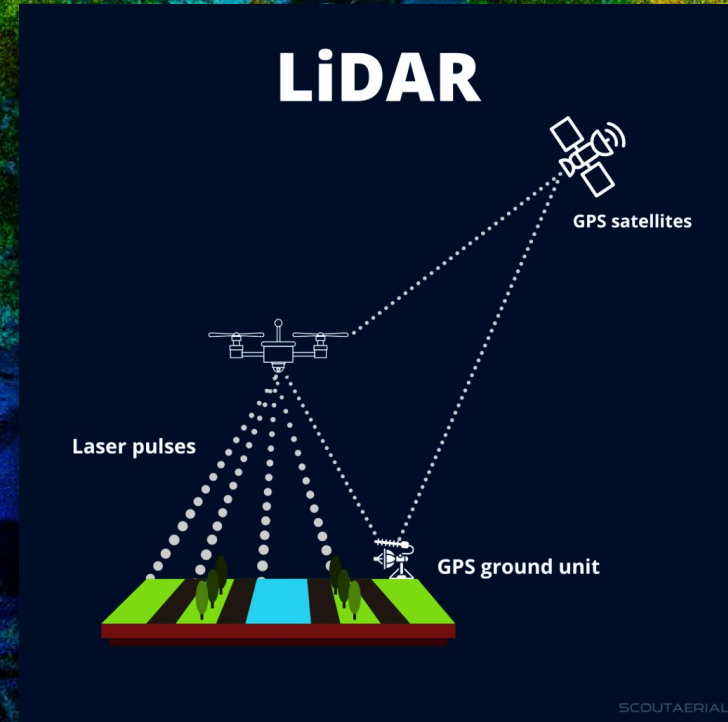
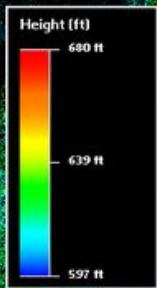
M A P
OF THE
UNITED STATES

SHOWING AREAS SURVEYED ON A SCALE
SUITABLE FOR THE PURPOSES OF THE
U.S. GEOLOGICAL SURVEY
1883.

M A P
OF THE
UNITED STATES
SHOWING AREAS SURVEYED ON A SCALE
SUITABLE FOR THE PURPOSES OF THE
U.S. GEOLOGICAL SURVEY
1883.

What is LiDAR?

LiDAR is a laser that measures the distance of a point using the time it takes for the pulse to be reflected back to the sensor



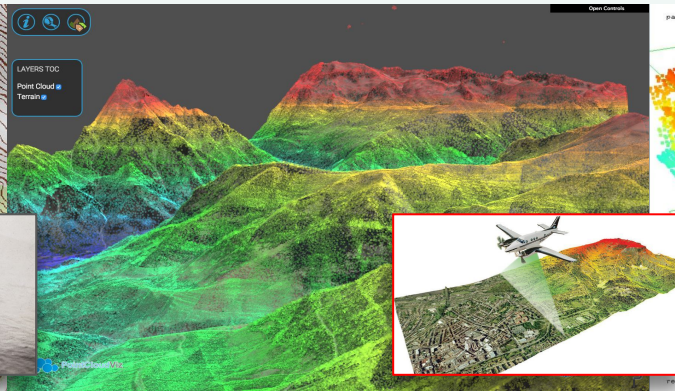
Data Visualization

- Traditional topography: Contour lines representation a set change in elevation between lines
- LiDAR point cloud: raw matrix of points collected from laser imaging
- Voxel model: (x, y, z) points displayed as cubes

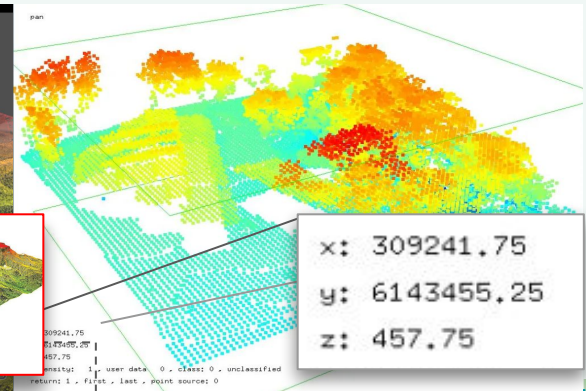
Traditional



LiDAR Point Cloud



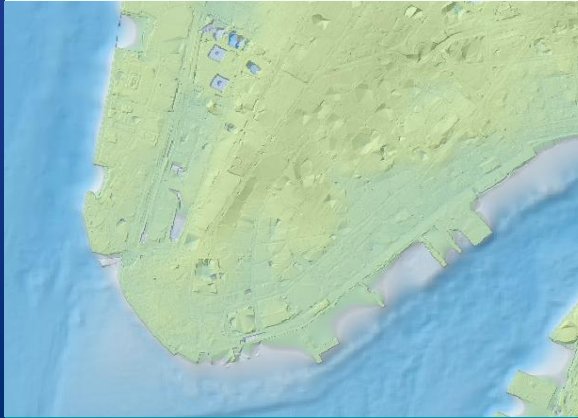
Voxel



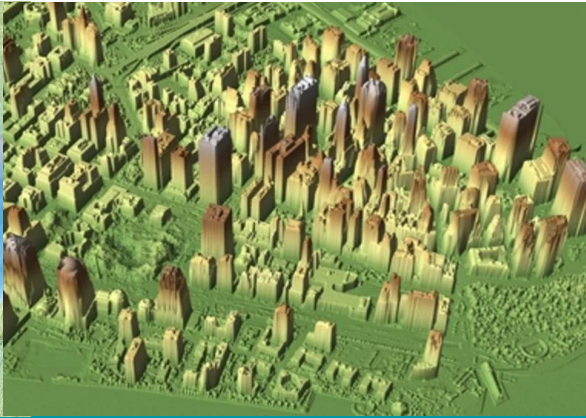
Digital Elevation Models

- LiDAR performs extremely well in urban environments
- DEM attempts to flatten surfaces that have been altered by human construction, creating faint outlines of bridges, roads, foundations, and piers

DEM



LiDAR in 2001

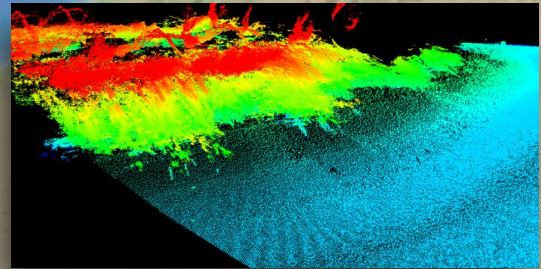


LiDAR in 2018





Irregular, low density data may not be informative as a LiDAR cloud. DEMs are ideal for terrain with large changes in elevation, like mountains.



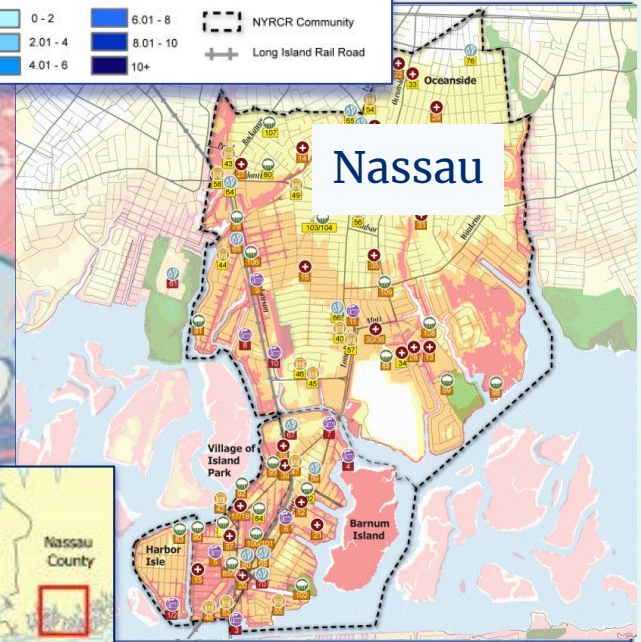
Before LiDAR



Lower
Manhattan

Percent of flood
area predicted:

- Queens: 54%
- Nassau: 89%

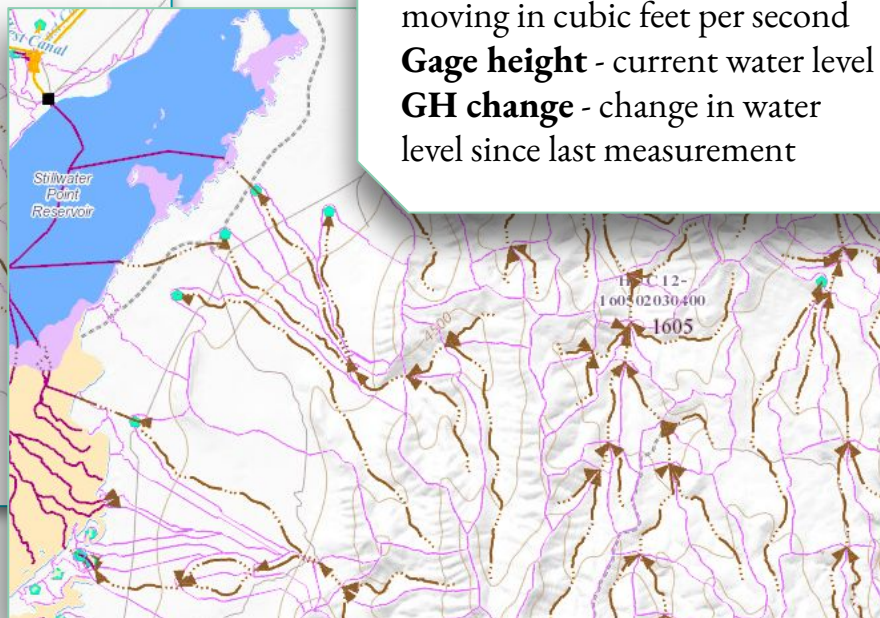
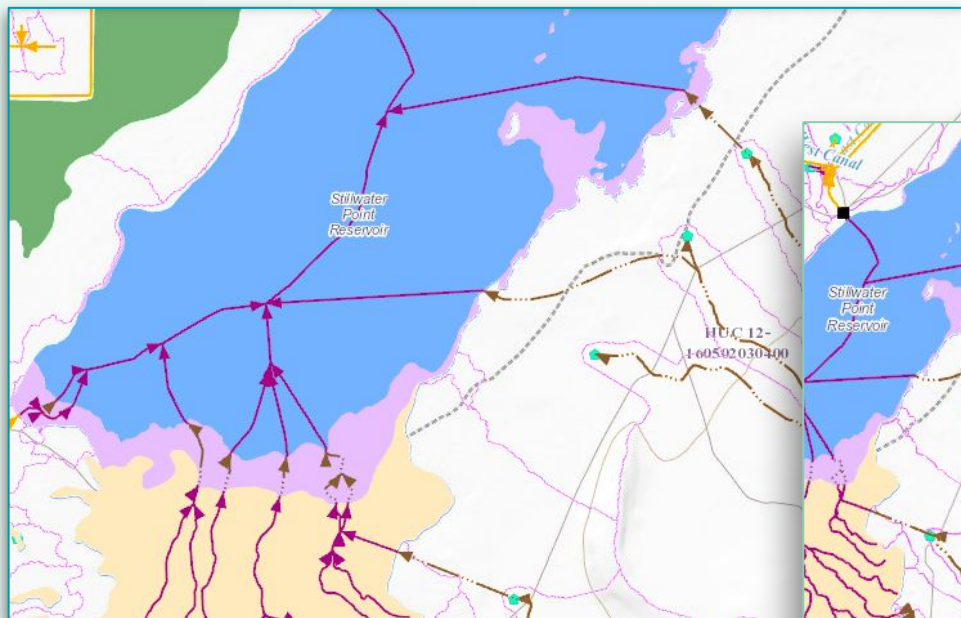
Storm surge inundation extent (feet)



 Sandy Flood Area
 Existing Flood Hazard Zones

NYS Department of State
NYC Open Data

Challenges of Hydrology



Flow rate: how fast the water is moving in cubic feet per second
Gage height - current water level
GH change - change in water level since last measurement

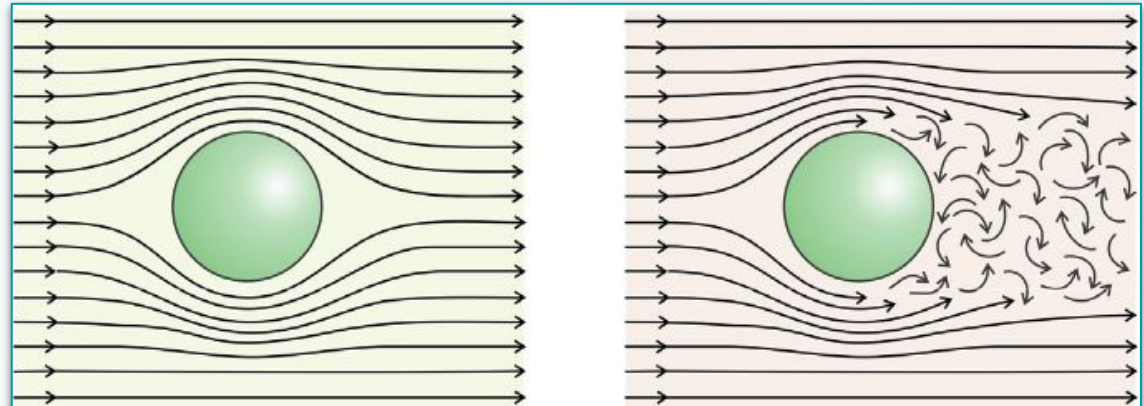
Flow Principles

Laminar

- Smooth with a regular path

Turbulent

- Mixing, with chaotic changes in pressure and velocity



Laminar

$$\mathcal{R} < 1$$

Turbulent

$$\mathcal{R} > 1000$$

Lamina: latin for 'thin layer'

Turbulentus: latin for 'restless' or 'stormy'

Particle Simulation

This level of complexity is often impractical and reserved for smaller points of interest



Fluid Particles

Blender is a open source 3D graphics software that is free to download

Data Layering

Feature layer numerically representing water flow, area, and volume.

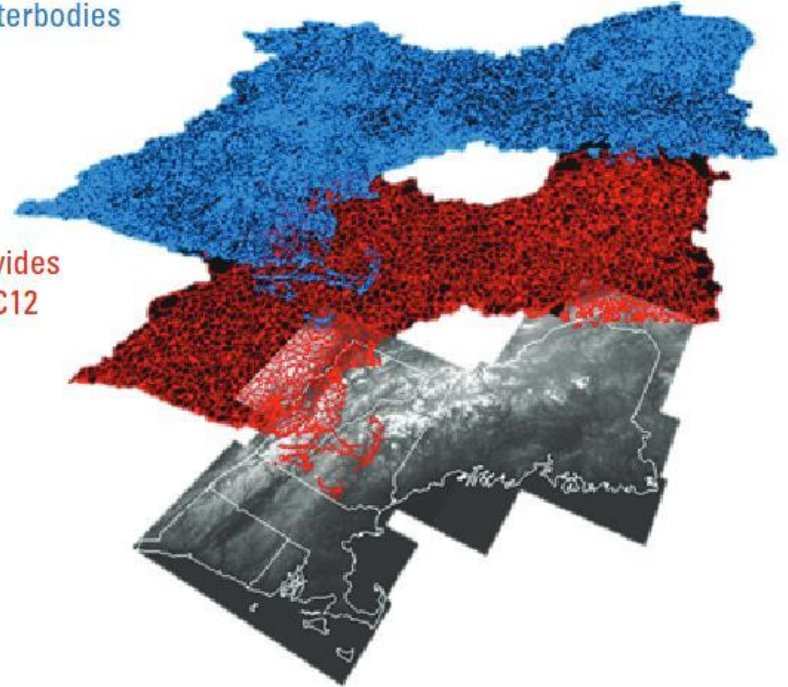
Partition layer that divides and organizes data in hierarchical structure

DEM to anchor other layers to x and y coordinates

Stream and waterbodies
(from NHD)

Topographic divides
(from WBD HUC12
boundaries)

Elevation Data
(from 3DEP)



National Watershed Boundaries

6 Federal Standards and Procedures for the National Watershed Boundary Dataset

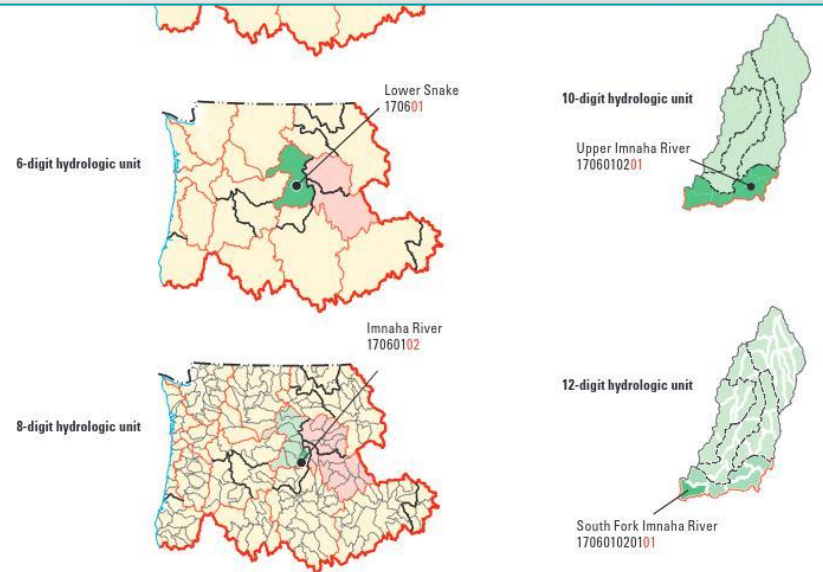
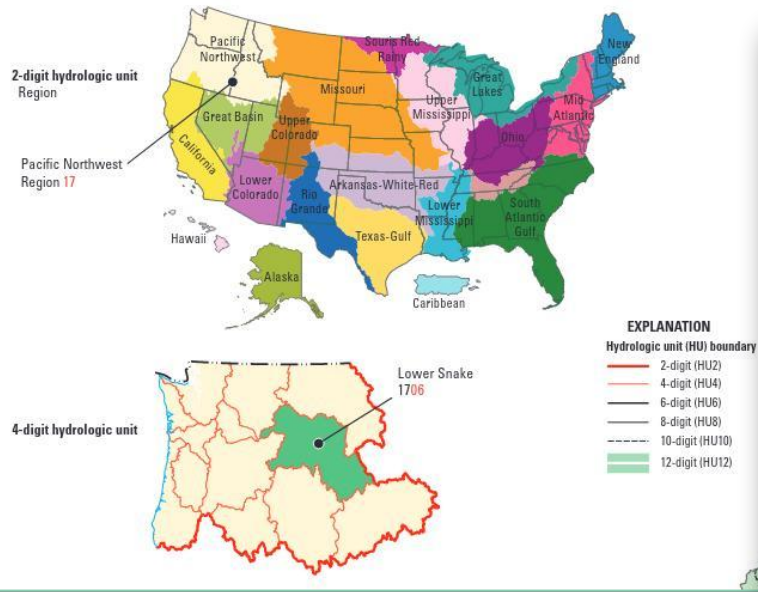


Figure 2. Hierarchy for 2- through 12-digit hydrologic units: the numbering scheme of the hydrologic unit codes increases by two digits as the hydrologic units are successively subdivided. Optional 14- and 16-digit delineations are not

Watershed Background

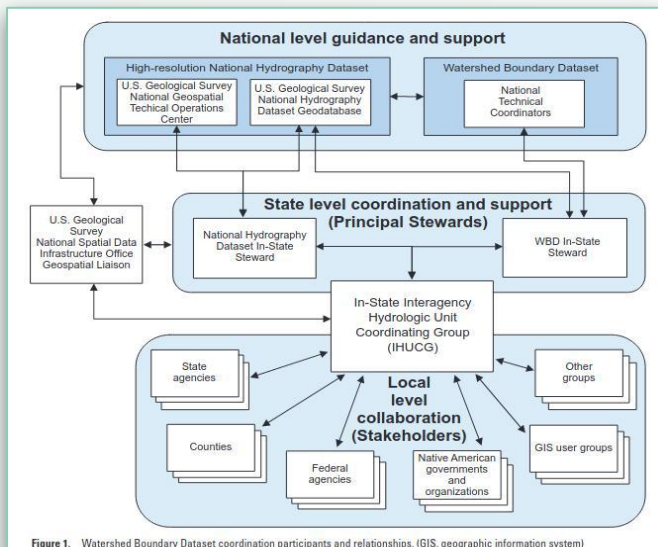
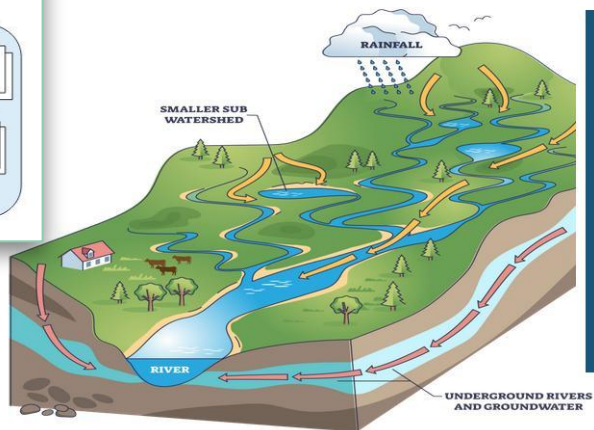


Figure 1. Watershed Boundary Dataset coordination participants and relationships. (GIS, geographic information system)



HOW WATERSHEDS WORK

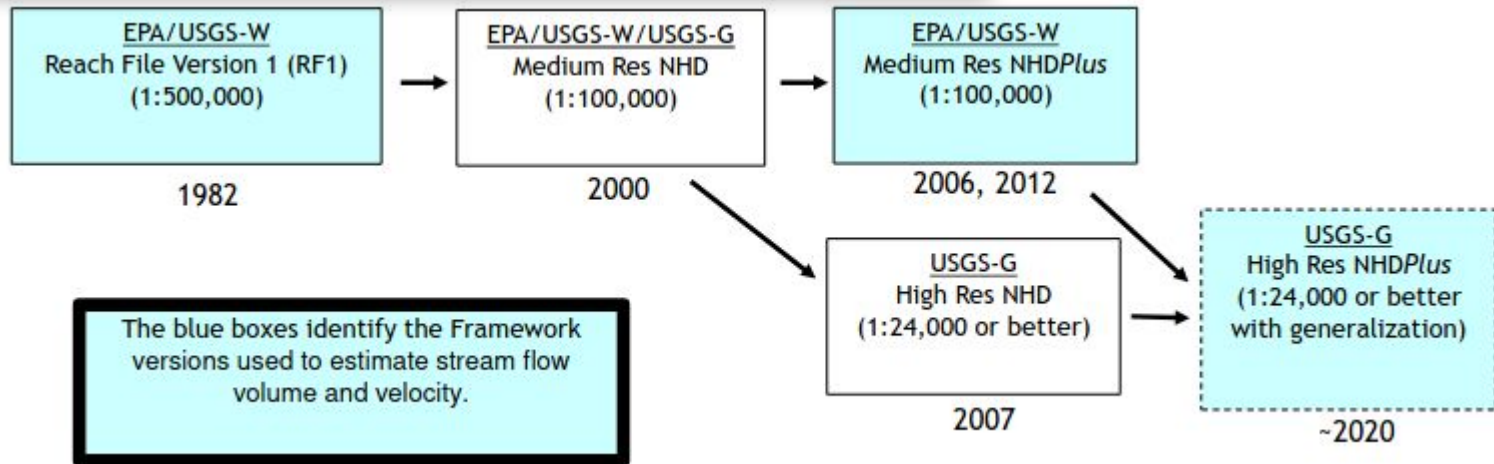
Inside Look at Watersheds

Rain and snow fall into watersheds that are ecosystems themselves. A healthy watershed naturally filters and stores water, prevents flooding and impedes wildfires, and conserves habitat.

US Department of Agriculture

NHDPlus Evolution

Older models created directly from hand drawn topography collected over several decades had significant variation in recording standards, time of year, and changing physical properties of the land over time.



NHDPlus Applications

- NHDPlus: combined data from hydrology, DEM, and watershed datasets
- GIS is the most effective method of contaminant tracking
- Large nonprofit and government organizations are investing in GIS solutions to improve the health of their community

EPA Takes Aim at PFAS

PFAS, or poly- and perfluoroalkyl substances, have become notorious as drinking water contaminants. They are used in a wide range of products and our exposure comes from multiple sources and routes. The two most common forms of PFAS are perfluorooctanoic acid (PFOA) and perfluorooctanesulfonic acid (PFOS). DEQ will work with our water systems once the EPA action plan is finalized to determine if there are PFAS levels of concern that are affecting drinking water sources in the Utah.



On February 14, 2019, EPA established health advisories for PFOA and PFOS based on the agency's assessment of the latest peer-reviewed science. EPA is committed to supporting states and public water systems as they determine the appropriate steps to reduce exposure to PFOA and PFOS in drinking water. As science on health effects of these chemicals evolves, EPA will continue to evaluate new evidence.

4 years

It can take up to **4 YEARS** for the level of PFAS in the body to go down by half.

6 million

SIX MILLION U.S. residents live with drinking water above PFAS safety levels.

4,000

PFAS is a group of more than **4,000** very stable synthetic chemicals.

70 ppt

EPA's drinking water health advisory level is **70 PARTS PER TRILLION** for PFAS.



Health Effects

Exposure to these compounds has been linked to a number of health concerns including cancer, hormone disruption, liver and kidney toxicity, harm to immune system, and reproductive and development toxicity.



Sources of Contamination

Many products are made with these compounds, including: food packaging; chemicals used for stain-resistant carpets, rugs, and furniture; non-stick cookware; outdoor gear with a "durable water repellent" coating; aerospace, medical, and automotive applications; and many specialty items such as firefighting foams, ski wax, and industrial applications.



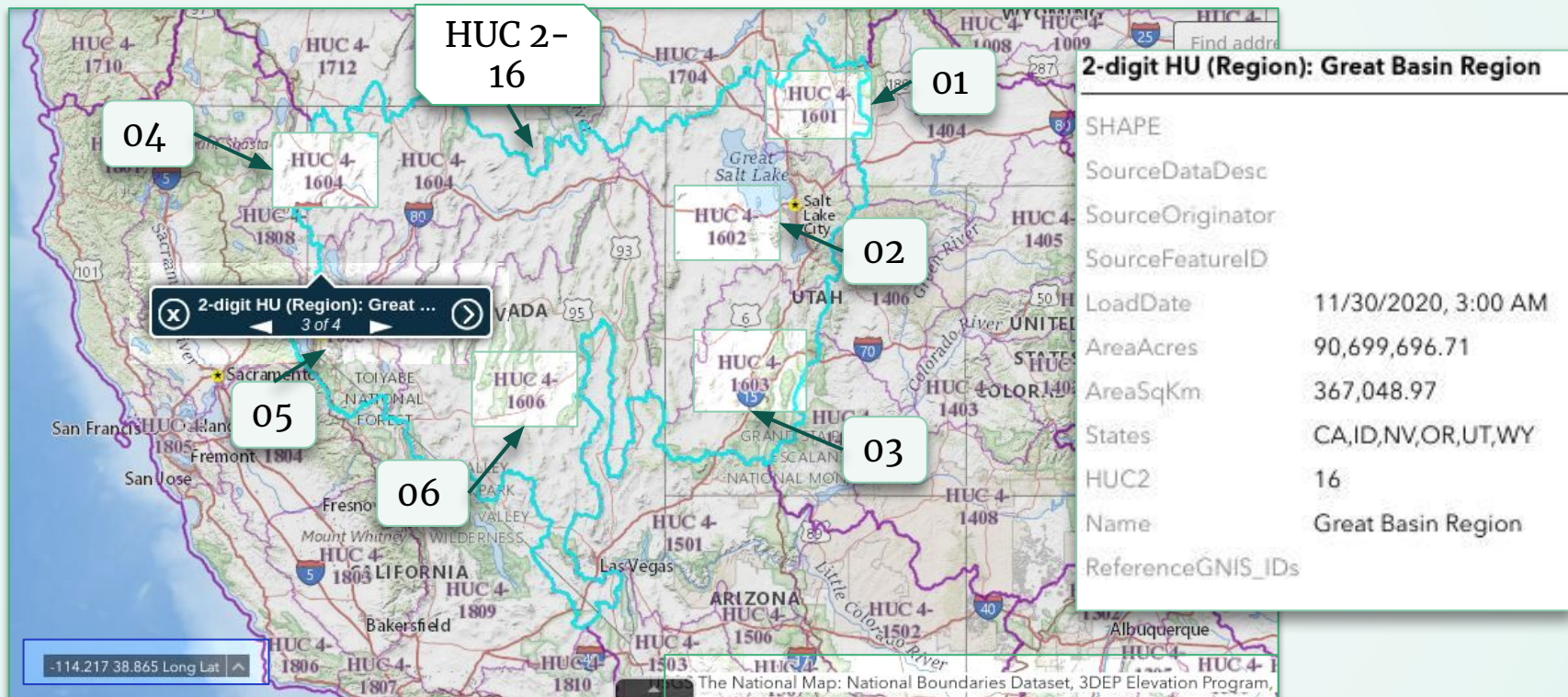
Drinking Water

Initial testing of some water systems in 2013-2015 revealed an estimated six million U.S. residents with drinking water supplies contaminated with PFAS. To provide Americans with a margin of protection from a lifetime of exposure to PFAS from drinking water, EPA has established the health advisory levels at 70 parts per trillion.

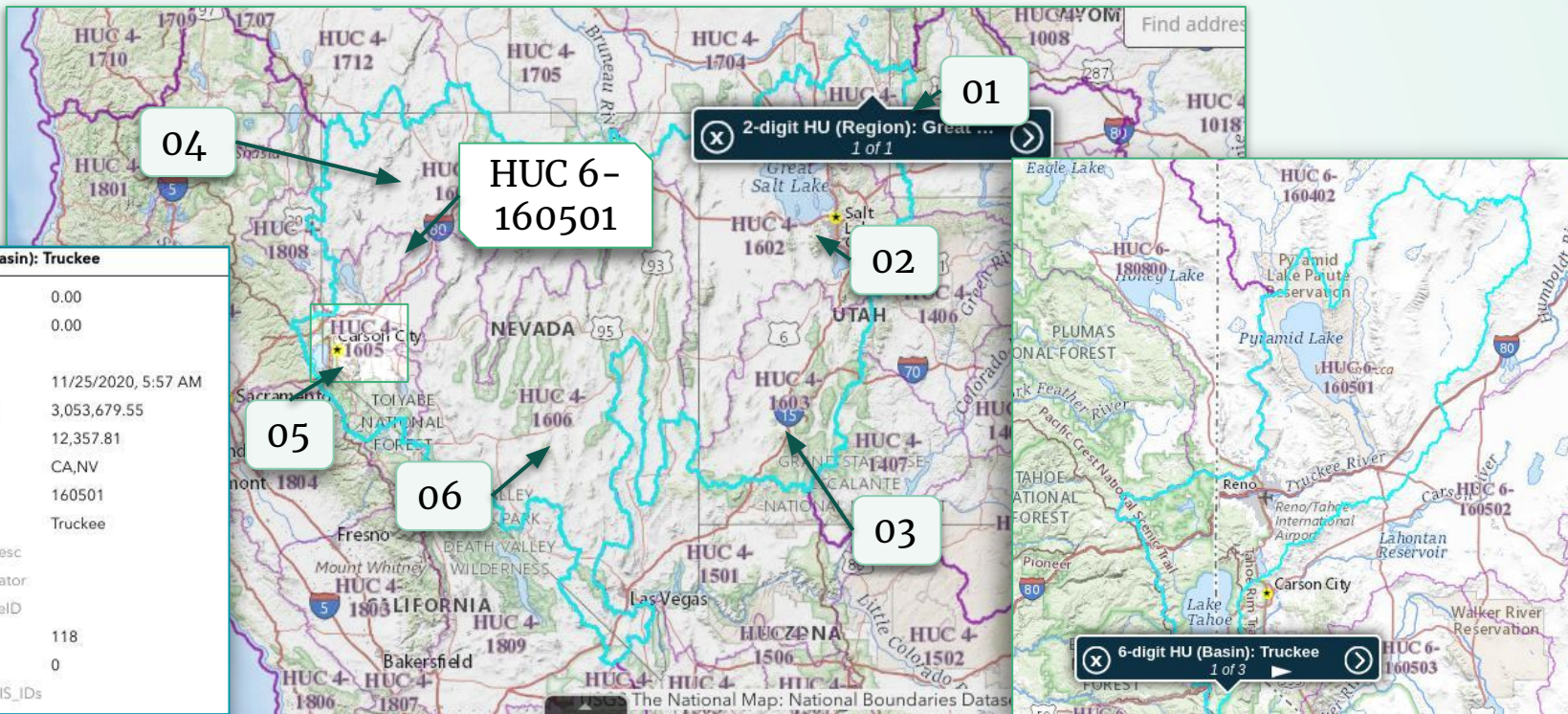


UTAH DEPARTMENT OF ENVIRONMENTAL QUALITY

Data Viewing



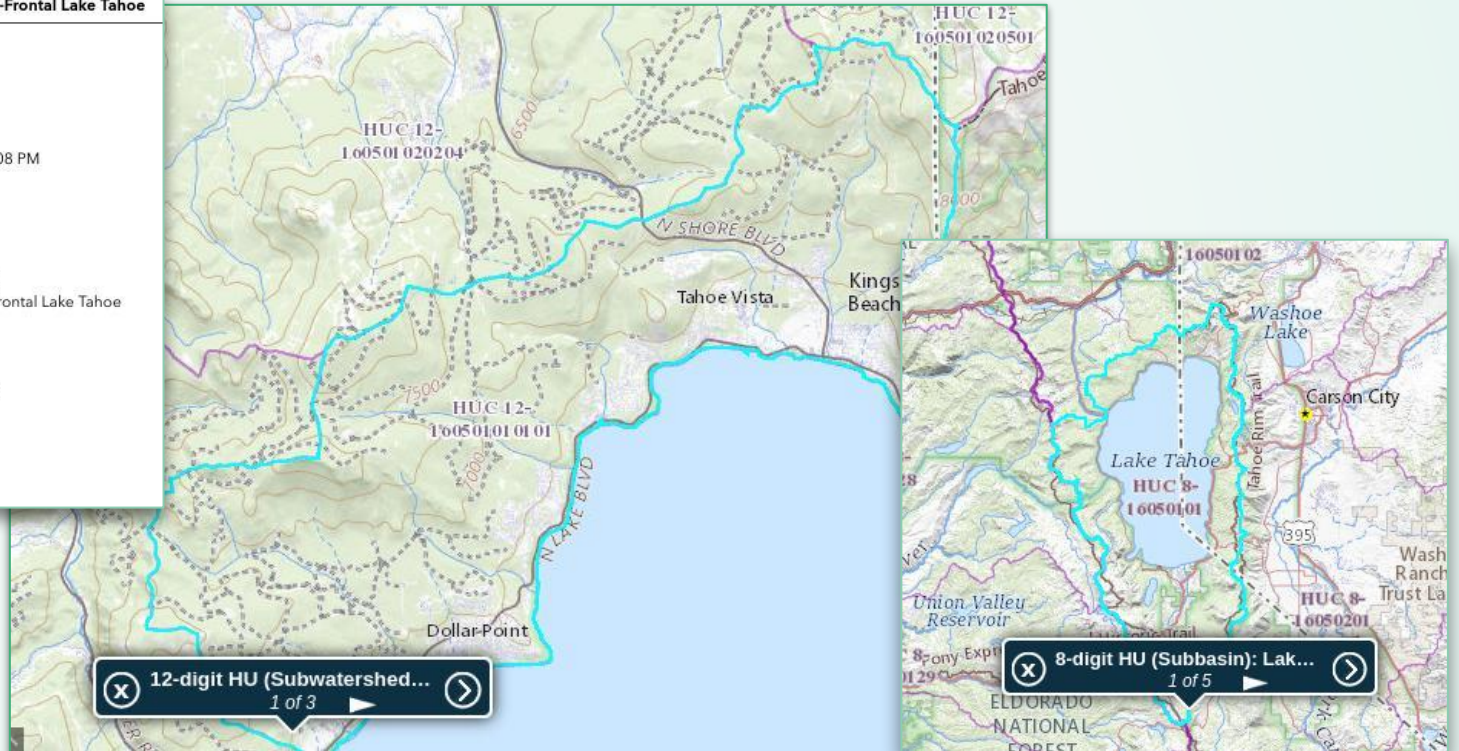
Basins



Drainage Types

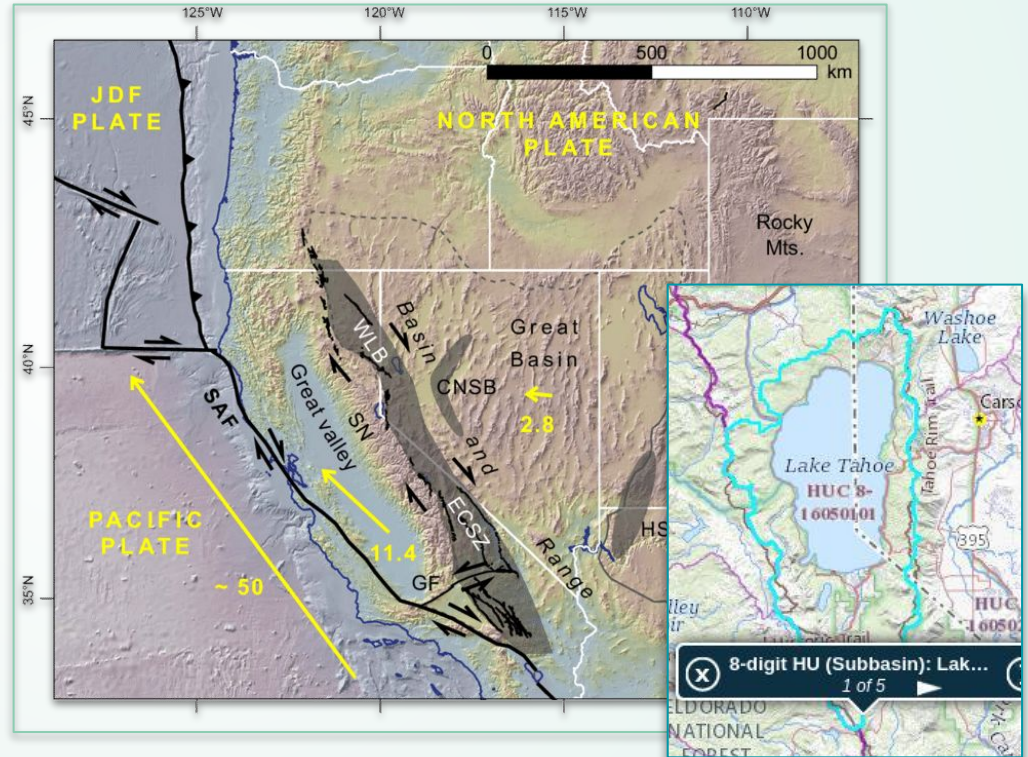
12-digit HU (Subwatershed): Burton Creek-Frontal Lake Tahoe

SHAPE	
SourceDataDesc	
SourceOriginator	
SourceFeatureID	
LoadDate	1/17/2013, 11:08 PM
AreaAcres	20,509.25
AreaSqKm	83.00
States	CA,NV
HUC12	160501010101
Name	Burton Creek-Frontal Lake Tahoe
HUType	Frontal
HUMod	NM
ToHUC	160501010500
NonContributingAreaAcres	0.00
NonContributingAreaSqKm	0.00
ReferenceGNIS_IDs	



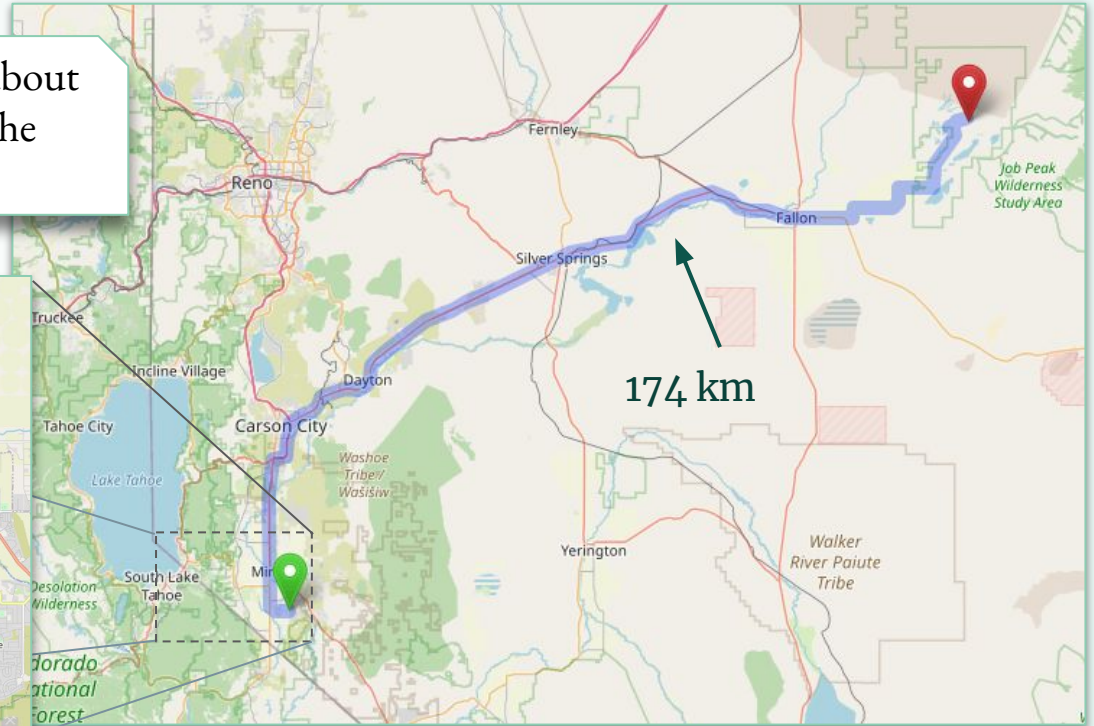
Tahoe

Lake Tahoe is surrounded by a massive ridge that acts like a bowl, collecting water until it is high enough to reach the basin's outlet at Truckee River.

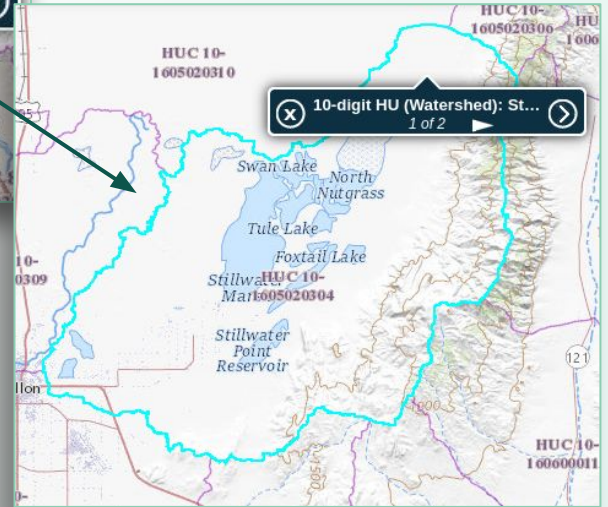
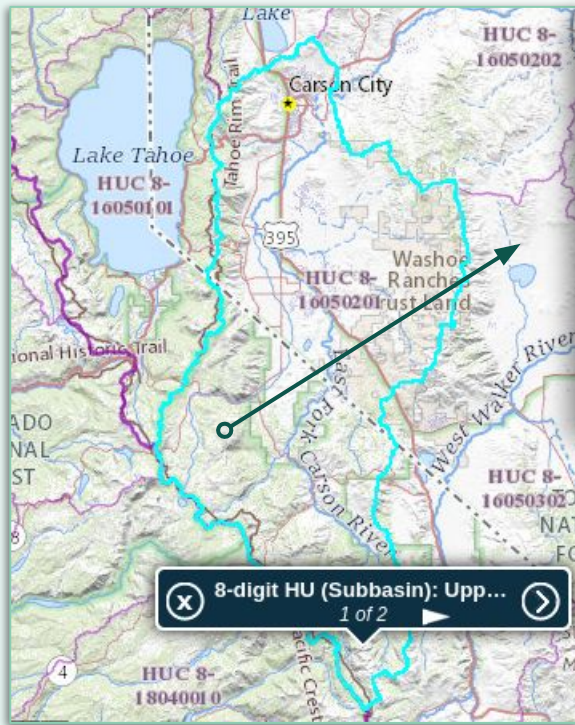


Distance and Elevation

In a straight line, Gardnerville is about 20 km from Lake Tahoe, but on the *opposite* side of the ridge.



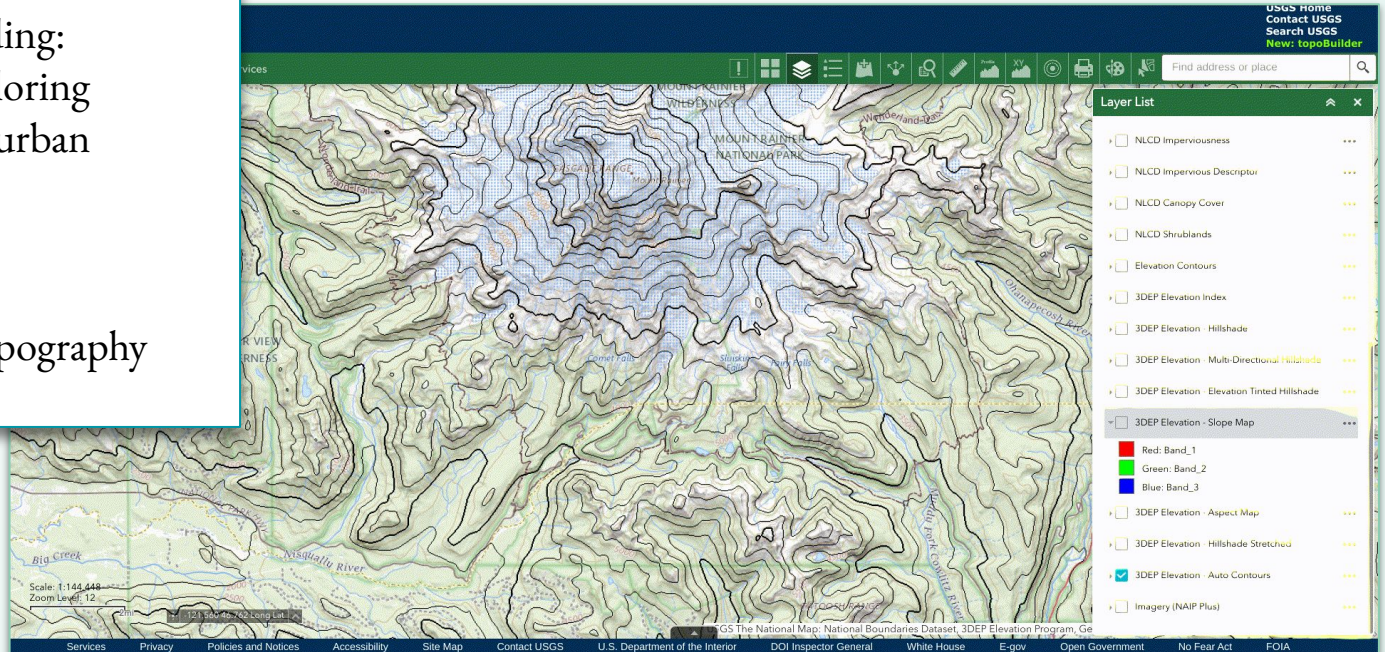
Carson



Other DEM layers

The national map has several other layers including:

- elevation coloring
- impervious urban surfaces
- terrain type
- tree canopy
- historical topography



Activity: Explore the Data

1. Choose a location in the US
2. Choose a pollutant or naturally occurring hazardous material
3. Identify that location's watershed boundaries on <https://apps.nationalmap.gov/viewer/>
4. Find how far a hazard incident in that location would spread
5. What other factors might you need to consider for an accurate prediction?
6. What other resources could you use to make your prediction more accurate?
7. What sort of environment does your location drain to?
8. What are the possible ecological consequences?
9. How might this information be useful to an employer or public official?
10. How might you use this kind of data system in your own profession?

USGS Web Tools

National Map

- Access DEM, hydrology, vegetation cover, and other integrated layers
- <https://apps.nationalmap.gov/viewer/>

Water Watch

- Real time water monitoring of over 400 locations
- <https://waterwatch.usgs.gov/wqwatch/>

National Climate Change Viewer

- Change in temperature, precipitation, runoff, soil storage, and more
- Can open with government or watershed boundaries
- <https://www.usgs.gov/tools/national-climate-change-viewer-nccv>

Topo Viewer

- Historic maps allow viewing topographic changes back to the late 1800's
- <https://ngmdb.usgs.gov/topoview/viewer/>

The background of the slide is a dark blue network map with numerous nodes and connecting lines. A semi-transparent globe is centered behind the text.

IIT Bombay Winter School
Geospatial Models
Session 2



Building Models with Satellite Data

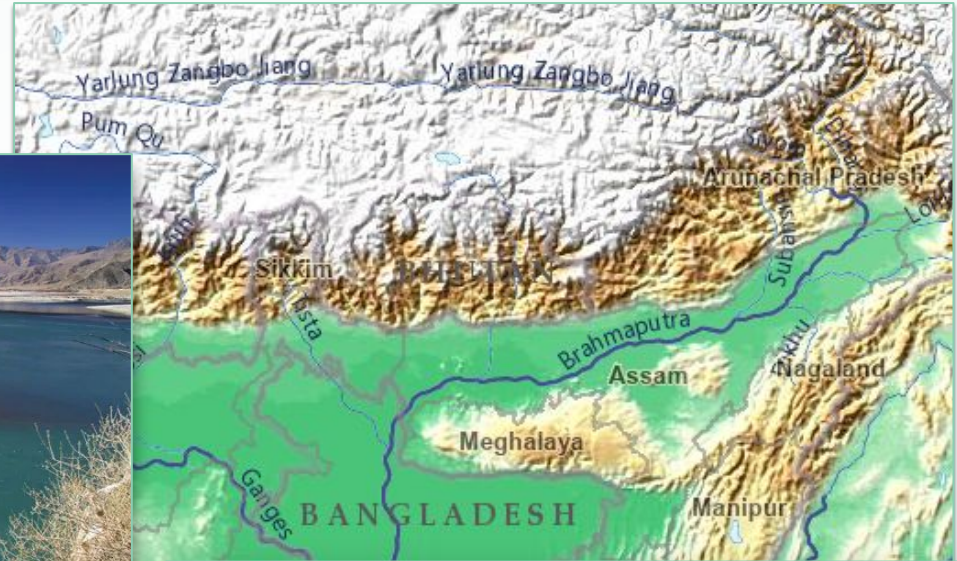
By: Paul Churchyard, Chief Geospatial Engineer @HSR.health

A black satellite with a large parabolic dish antenna is shown in orbit, positioned above the 'A' in the NISAR logo. A blue arc is also visible above the 'A' and 'R'.

NISAR

The Brahmaputra

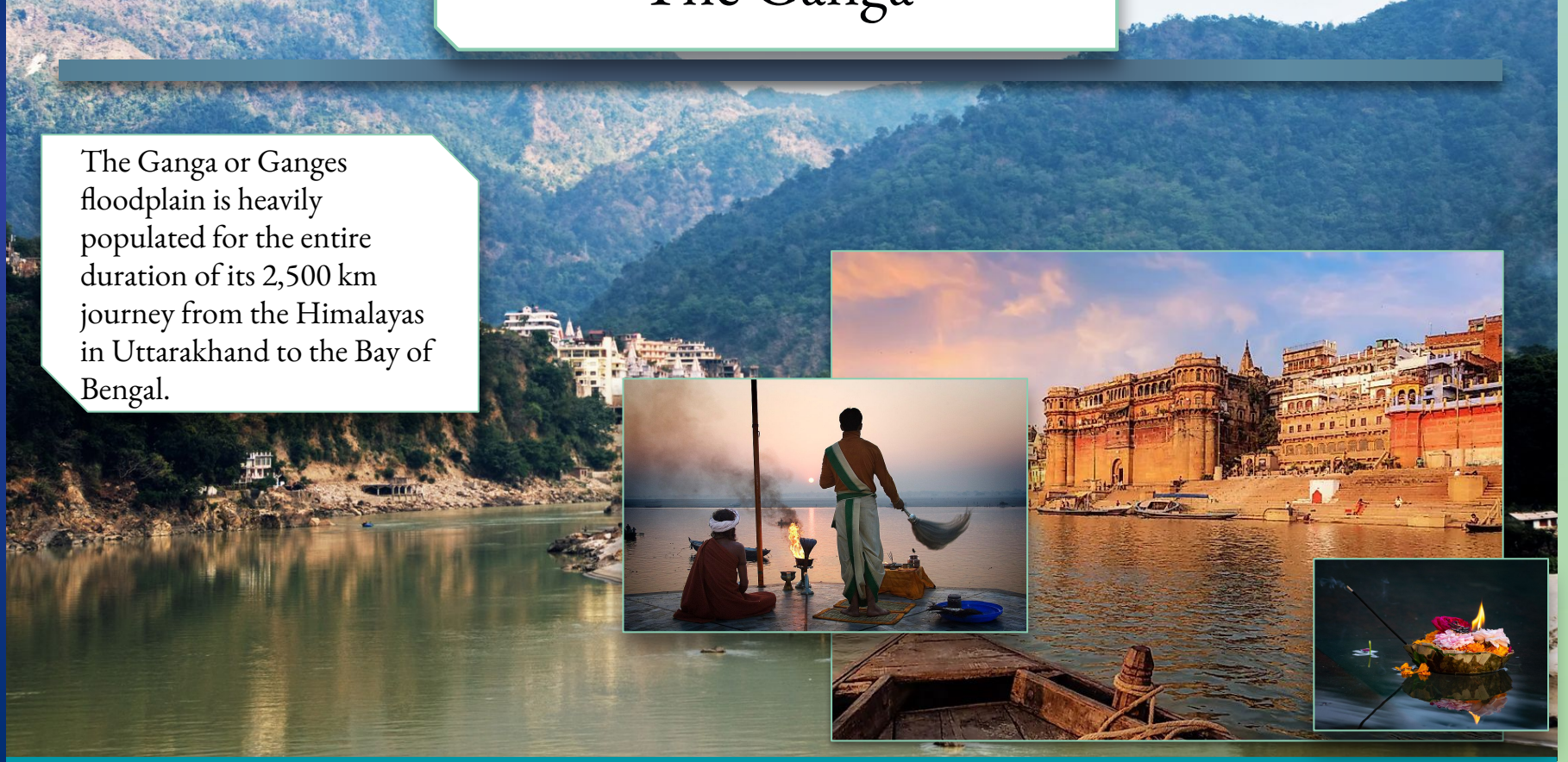
Snowmelt in the Himalayas creates several massive rivers, including the Brahmaputra.



The Brahmaputra has many names, including Yarlung Tsangpo in Tibet, Siang in Arunachal Pradesh, Luit in Assam, and Jamuna in Bangladesh.

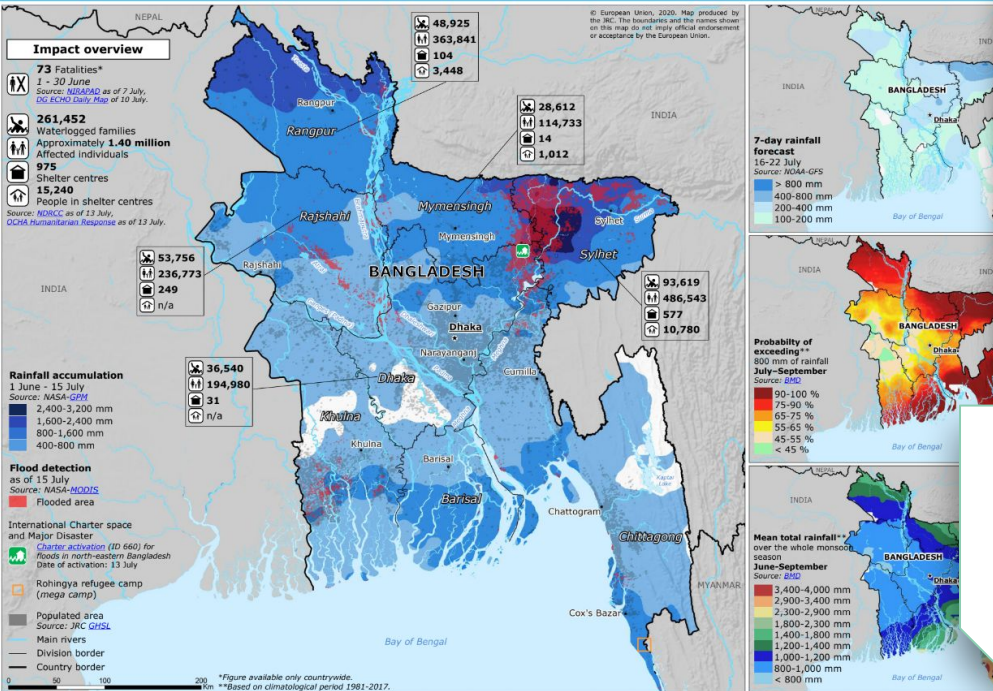
The Ganga

The Ganga or Ganges floodplain is heavily populated for the entire duration of its 2,500 km journey from the Himalayas in Uttarakhand to the Bay of Bengal.



Emergency Shelters

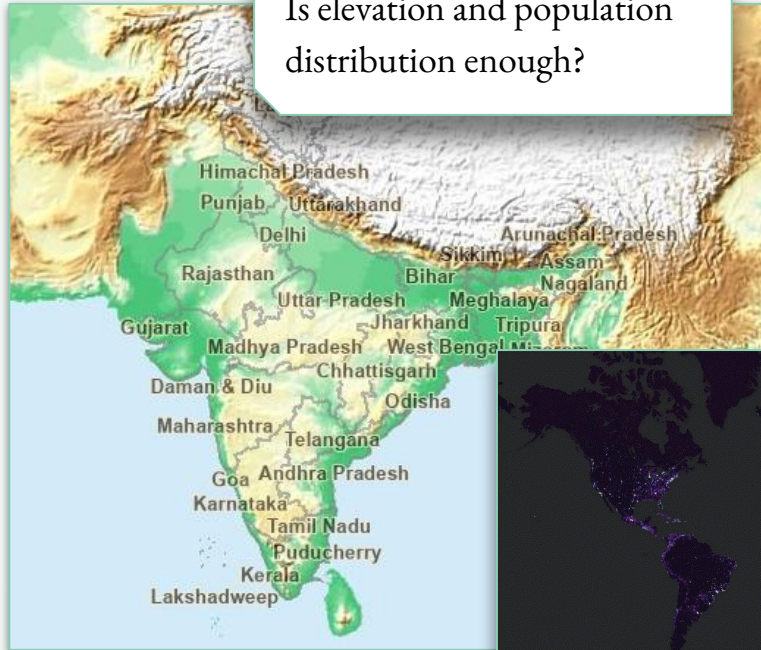
Emergency Response Coordination Centre (ERCC) | DG ECHO Daily Map 16/07/2020
Bangladesh | Monsoon Rains



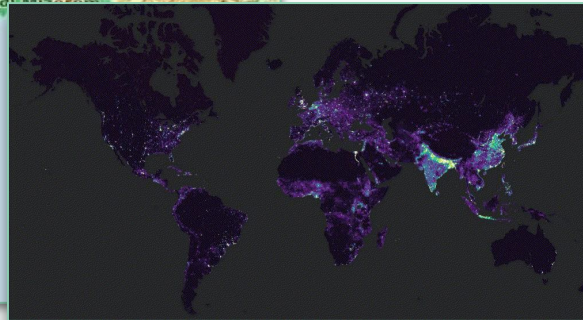
80% of Bangladesh is nearly at sea level and prone to flooding. Cyclone shelters are primarily located near the coast, far from the increasing river floods in the north

Factors to Map

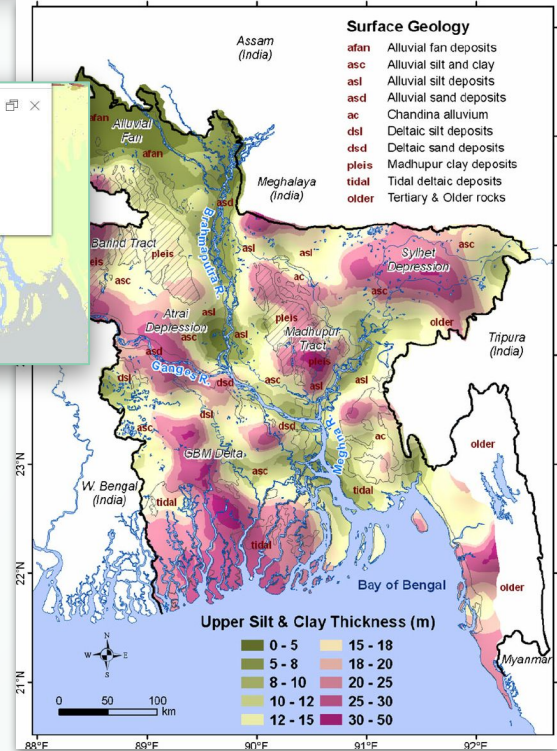
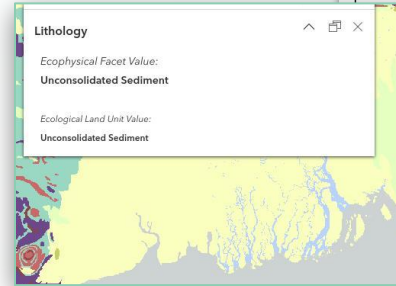
Is elevation and population distribution enough?



Elevation colored

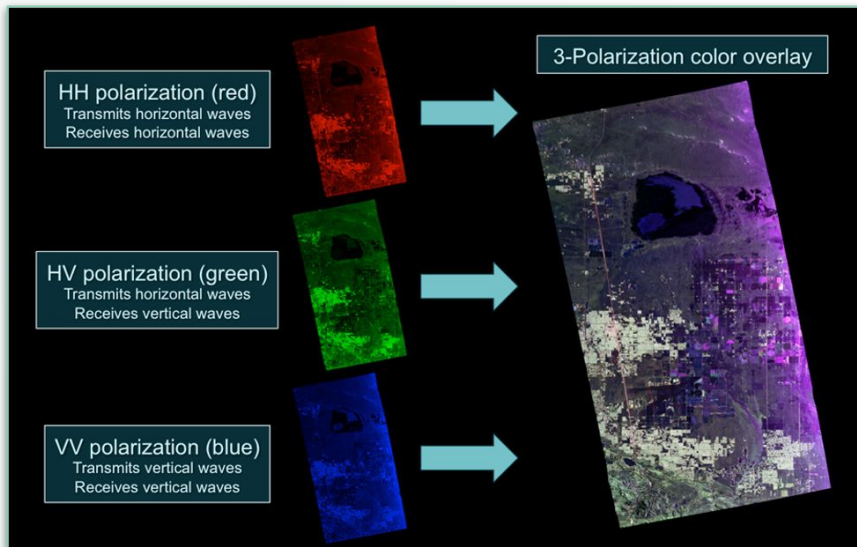


Global population density

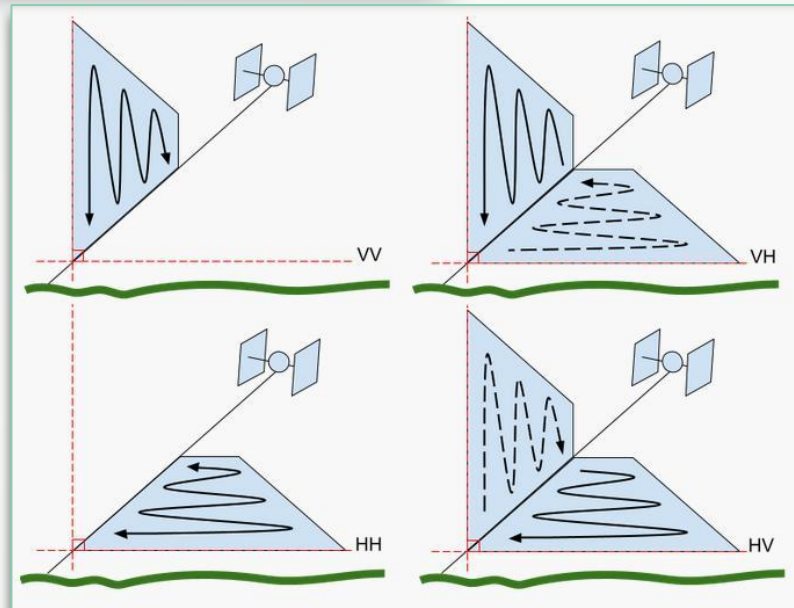


Synthetic Aperture Radar (SAR)

SAR signals are transmitted and received either vertically (V) or horizontally (H)



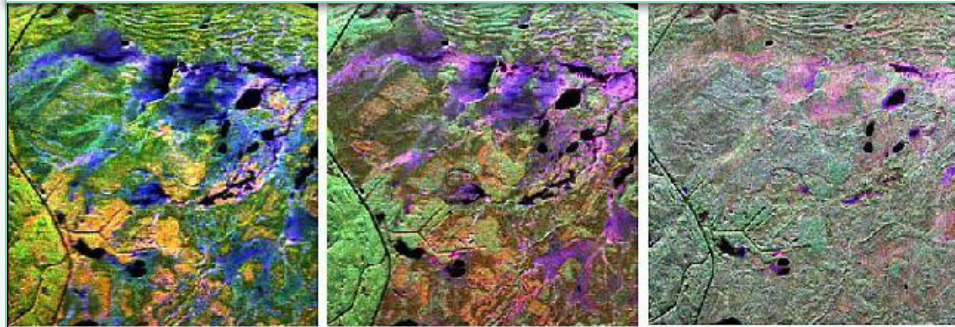
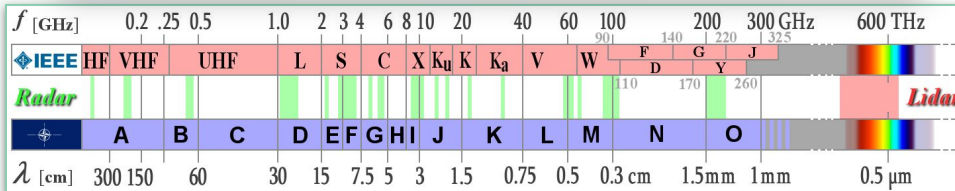
NASA-ISRO SAR Mission



Alaska Satellite Facility
(transmit listed first, receive second)

SAR Bands

Multispectral wavelengths allows collection and combination of different bands to accurately depict surface elevation, texture, and density.

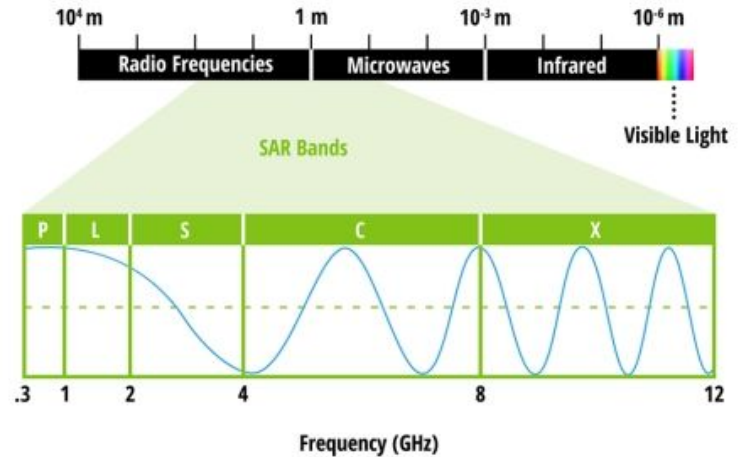


P-Band (HH, HV, VV)

L-Band (HH, HV, VV)

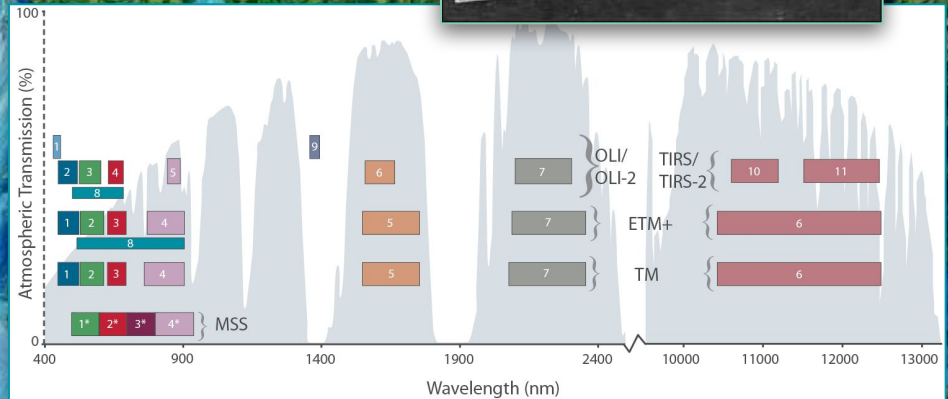
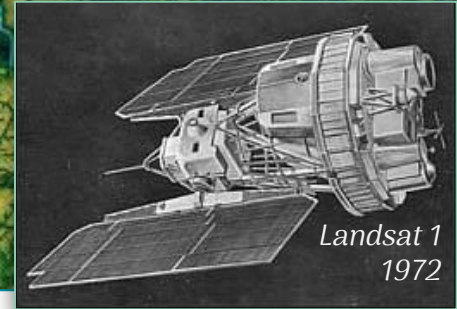
C-Band (HH, HV, VV)

P	L	S	C	X
0.3–1 GHz	1–2 GHz	2–4 GHz	4–8 GHz	8–12 GHz
100–30 cm	30–15 cm	15–7.5 cm	7.5–3.8 cm	3.8–2.4 cm



Landsat

Landsat 8 & 9 share an orbit to capture all land on earth at least once every 8 days.



Open Data

The screenshot displays the Copernicus Open Access Hub interface. At the top, the logos for the European Commission, ESA, and Copernicus are visible. The main header reads "Copernicus Open Access Hub". Below this, there are several panels: "Footprint" showing a map of a region, "Quicklook" showing a satellite image, and "Inspector" showing a detailed view of the satellite image. On the left, there are search filters for "Satellite Platform" (S1A_*), "Polarisation" (VV+VH), "Relative Orbit Number (from 1 to 175)", "Product Type" (GRD), and "Sensor Mode" (SM). The "Mission: Sentinel-2" checkbox is checked. On the right, a map shows a region with several green rectangular overlays indicating search areas. The map includes labels for various cities and regions such as Shigatse, Lhasa, Nyingchi, Kathmandu, and Guwahat.

Satellite Platform
S1A_*

Polarisation
VV+VH

Relative Orbit Number (from 1 to 175)

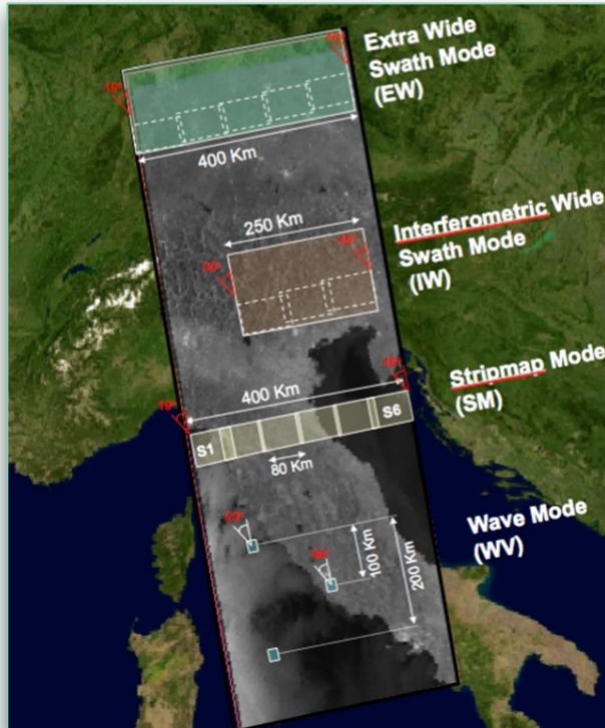
Mission: Sentinel-2

Product Type
GRD

Sensor Mode
SM

- *Single Look Complex (SLC)* - contains both the intensity and phase information
- *Ground Range Detected (GRD)* - has already been despeckled (noise reduction) and had the phase information removed

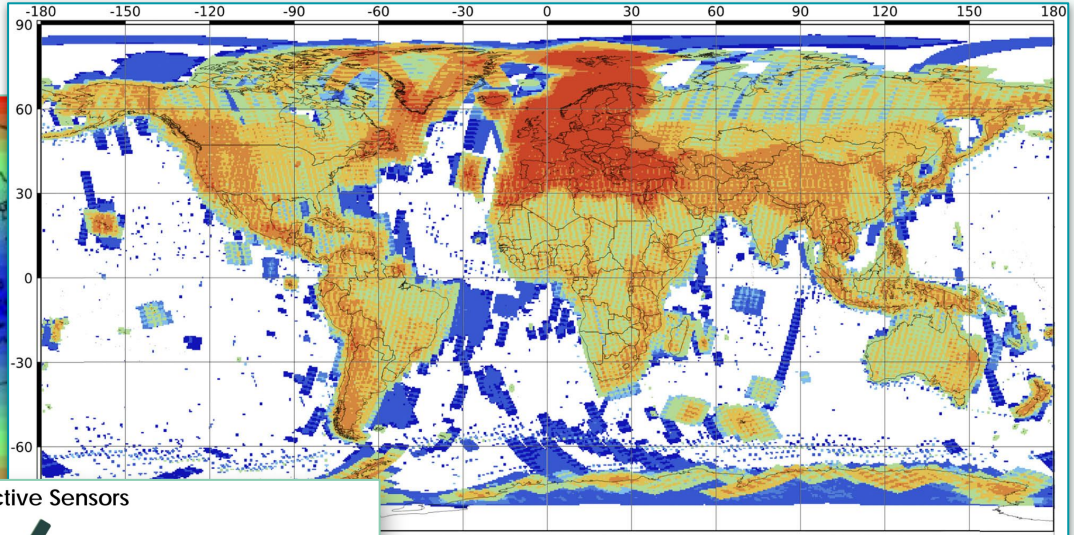
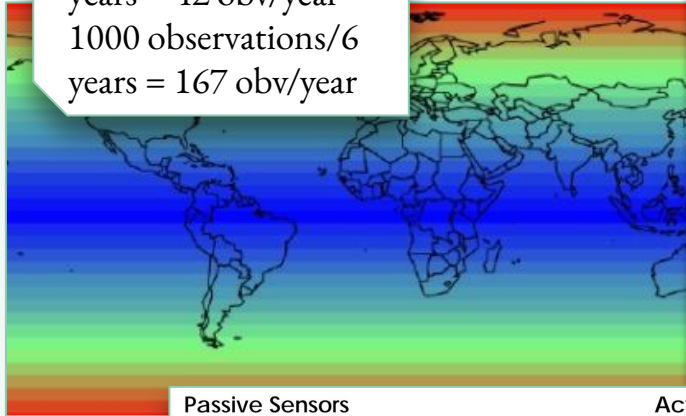
Swath and Orbit



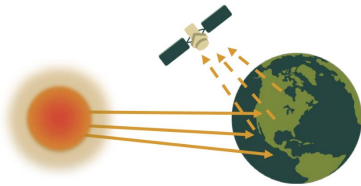
Changing the scan angle focuses rays to capture a wider or more narrow area.

Observation Frequency

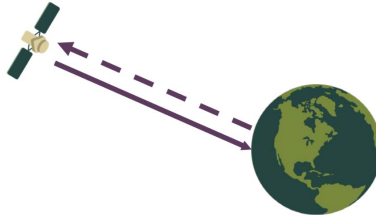
250 observations/6
years = 42 obv/year
1000 observations/6
years = 167 obv/year



Passive Sensors

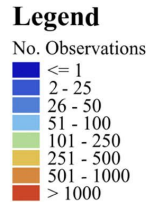


Active Sensors



Coverage Copernicus Sentinel-1A and Sentinel-1B data,
2014-2020
Current: 31 May 2020

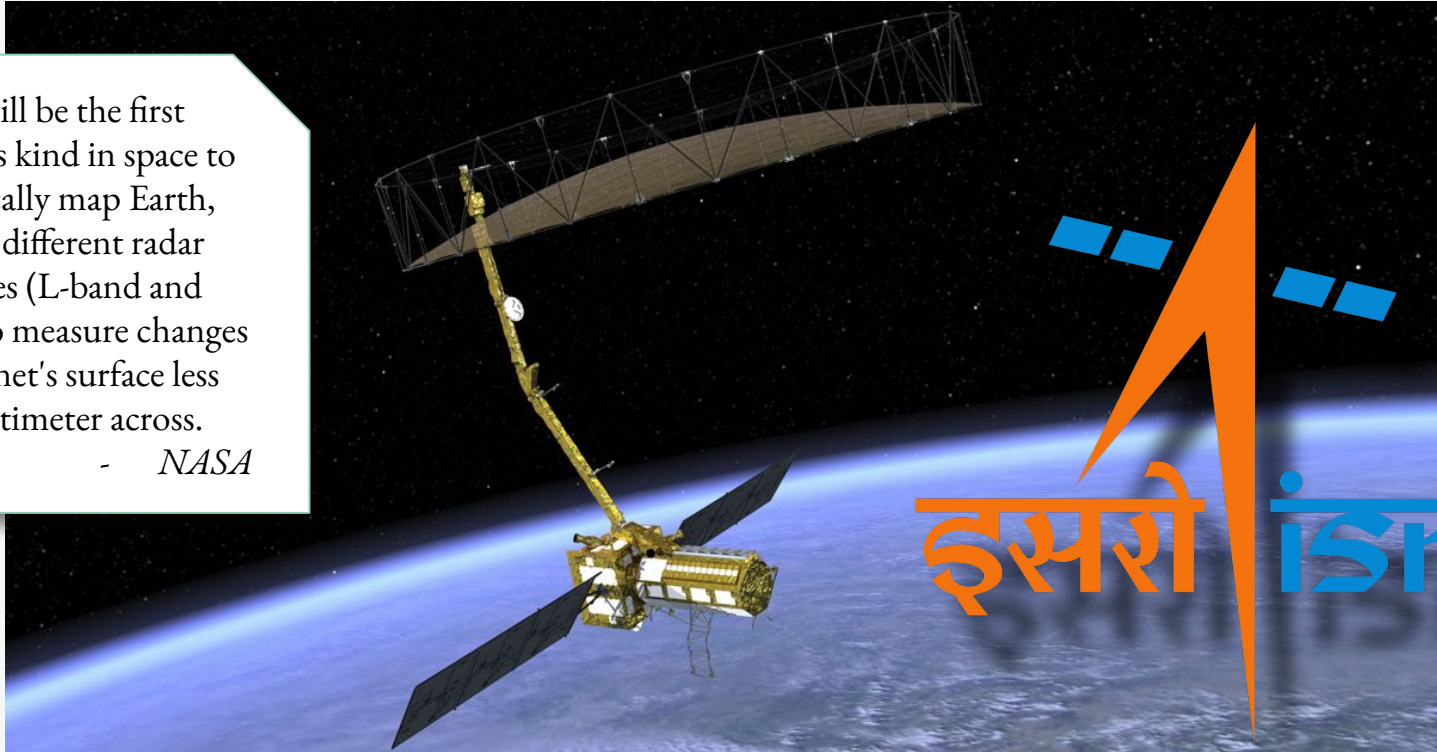
Map shows the total of Sentinel-1 SLC product
global coverage.
Sentinel-1 data are open access and can be
downloaded using the ASF Data Search portal
[<https://search.asf.alaska.edu>]



NISAR

NISAR will be the first radar of its kind in space to systematically map Earth, using two different radar frequencies (L-band and S-band) to measure changes in our planet's surface less than a centimeter across.

- *NASA*



Other Challenges

Warning systems have often failed to give adequate lead time to citizens to evacuate. Communication delays are exacerbated by blackouts, some caused by the storm and some not.



From Data to Solutions

Investigation: Flood Shelter Suitability Analysis

1. What data layers would you need as an input? Is this data available?
2. What data do you wish you had that you weren't able to find?
3. What area do you intend to focus on?
4. What statistical analyses would you want to run?
5. What type of radar would you use (ideally)?

Key Workflow Concepts:

- Source
 - What are the relevant factors and data sources?
 - Where is the data coming from?
- Transformation:
 - How can the data inputs be combined to generate the proper output
- Output
 - What does the output mean?
 - Who and how could use the output?
 - What is the best way to display the output?

Time to complete: 1 hour
1 hour discussion afterwards

Implementation Considerations:

1. Would you develop a structural mitigation strategy or a communication strategy? How would you attempt to put the output of your analysis into action?
2. How much do you think your strategy would cost?
3. What tools (other than GIS) do you think would be helpful?
4. What system would you use to implement your strategy? (ex: host infrastructure for a software tool, disseminating a communication plan through district governments, hiring a contractor for shelter improvements.)

From Data to Solutions

Investigation: Flood Shelter Suitability Analysis

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Additional Considerations

- Assam lies in a very steep part of the basin. There is less distance between most of the population and higher ground, but the fast-moving water down the mountains increases potential for flash floods.
- Uttar Pradesh, Bihar, West Bengal, and Bangladesh have very large populations that would need to travel a great distance to leave the floodplain.
- Uttar Pradesh and Assam have some of the lowest electricity access in India.
- Don't dismiss low-tech and no-tech ideas! Sometimes technical data can guide us to non-technical solutions.
- Some of your peers may have first hand experience. Experience is just as valuable as data.

**Time to complete: 1 hour
1 hour discussion afterwards**

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