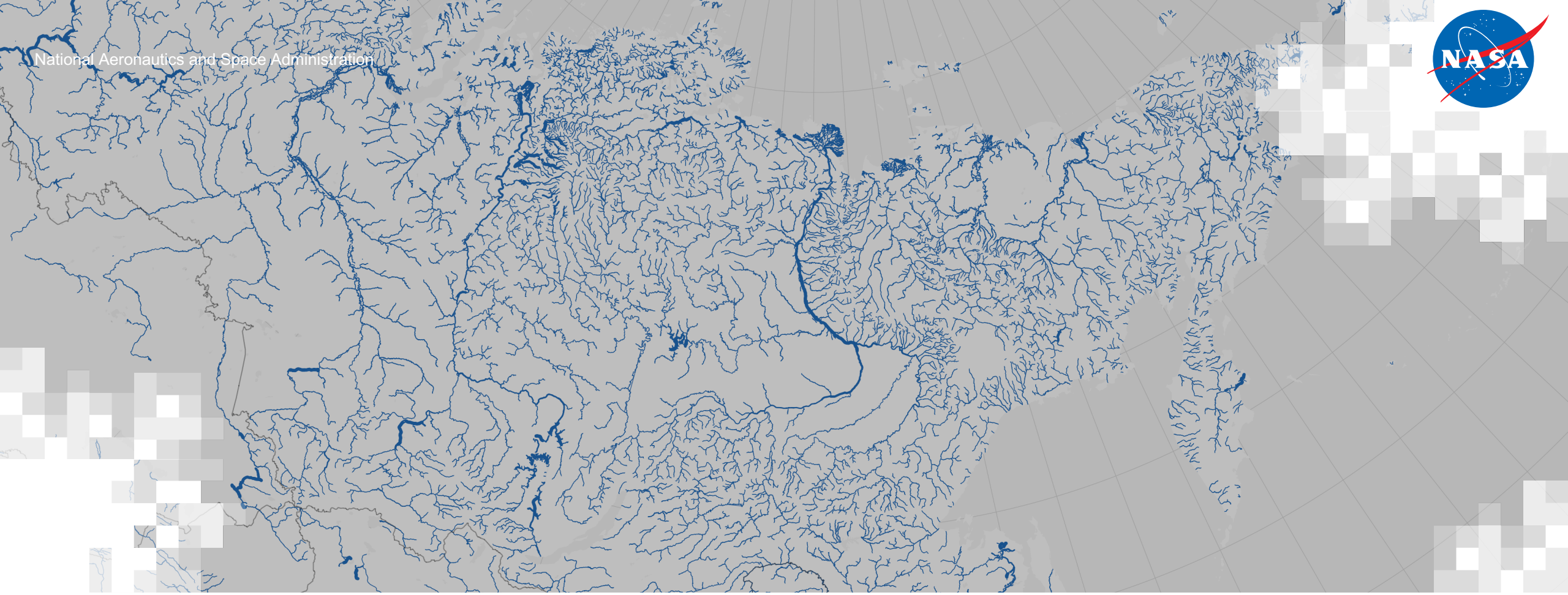


Using Earth Observations to Monitor Water Budgets for River Basin Management II

Amita Mehta and Sean McCartney

July 21, 2020

Objectives

- Identify and access remote sensing and Earth system-modeled data for estimating water budgets in a river basin
- Replicate the steps for estimating water budgets for a river basin and sub-watersheds using remote sensing products and GIS
- Understand the source of uncertainties involved in estimating water budgets for river basins

Training Outline

21 July 2020

https://svs.gsfc.nasa.gov/4493

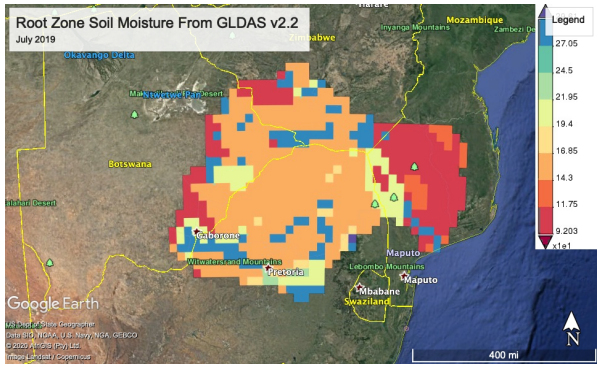
Review and Access of Earth Observations and Earth System-Modeled Data for River Basin Monitoring and Management

28 July 2020

http://www.limpopo.riverawarenesskit.org/

Water Budget Estimation using Remote Sensing Observations

4 August 2020



https://giovanni.gsfc.nasa.gov/

Water Budget Estimation using Global Land Data Assimilation Model

Training Format and Certificate

- Three 2-hour sessions, each with:
  - Part 1: Presentations and demonstrations of data access, calculations, and analysis
  - Part 2: Lab time with hands-on, computer-based exercises
- Homework Assignments will be available after all three sessions from: https://arset.gsfc.nasa.gov/water/webinars/water-budgets-river-basin
  - Answers must be submitted via Google Form
  - Due Dates: 11, 18, and 25 August 2020
- A Certificate of Completion will be awarded to those who:
  - Attend all webinars
  - Complete all homework assignments
- You will receive a certificate approximately two months after the completion of the course from: marines.martins@ssaihq.com

Prerequisites

Attendees that do not complete the prerequisites will not be adequately prepared for the pace of the training.

- Fundamentals of Remote Sensing
- Introductory Webinar: Using Earth Observations to Monitor Water Budgets for River Basin Management
- Introductory Webinar: Groundwater Monitoring using Observations from NASA's Gravity Recovery and Climate Experiment (GRACE) Missions

Register on NASA Earthdata

- https://earthdata.nasa.gov/

Install QGIS Version 3.x

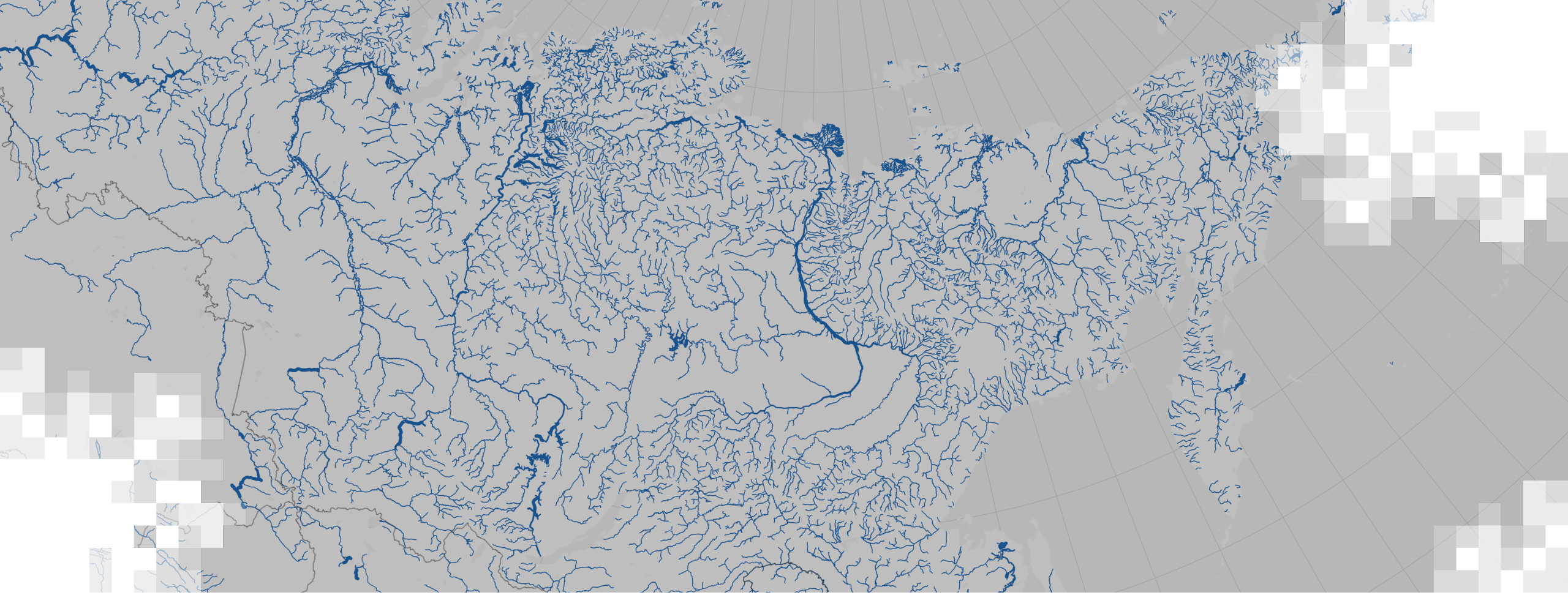
- https://qgis.org/en/site

Additional Relevant ARSET Webinars

- Introductory Webinar: River Basin Delineation Based on NASA Digital Elevation Data
- Advanced Webinar: Applications of GPM IMERG Reanalysis for Assessing Extreme Dry and Wet Periods

Session-1 Outline

- About ARSET
- Review of water budget in a river basin
- Review of data for water budget estimation from
  - Remote sensing observations
  - Global Land Data Assimilation System (GLDAS)
- Demonstration: Remote sensing and GLDAS data download
  - Case study: Limpopo River Basin

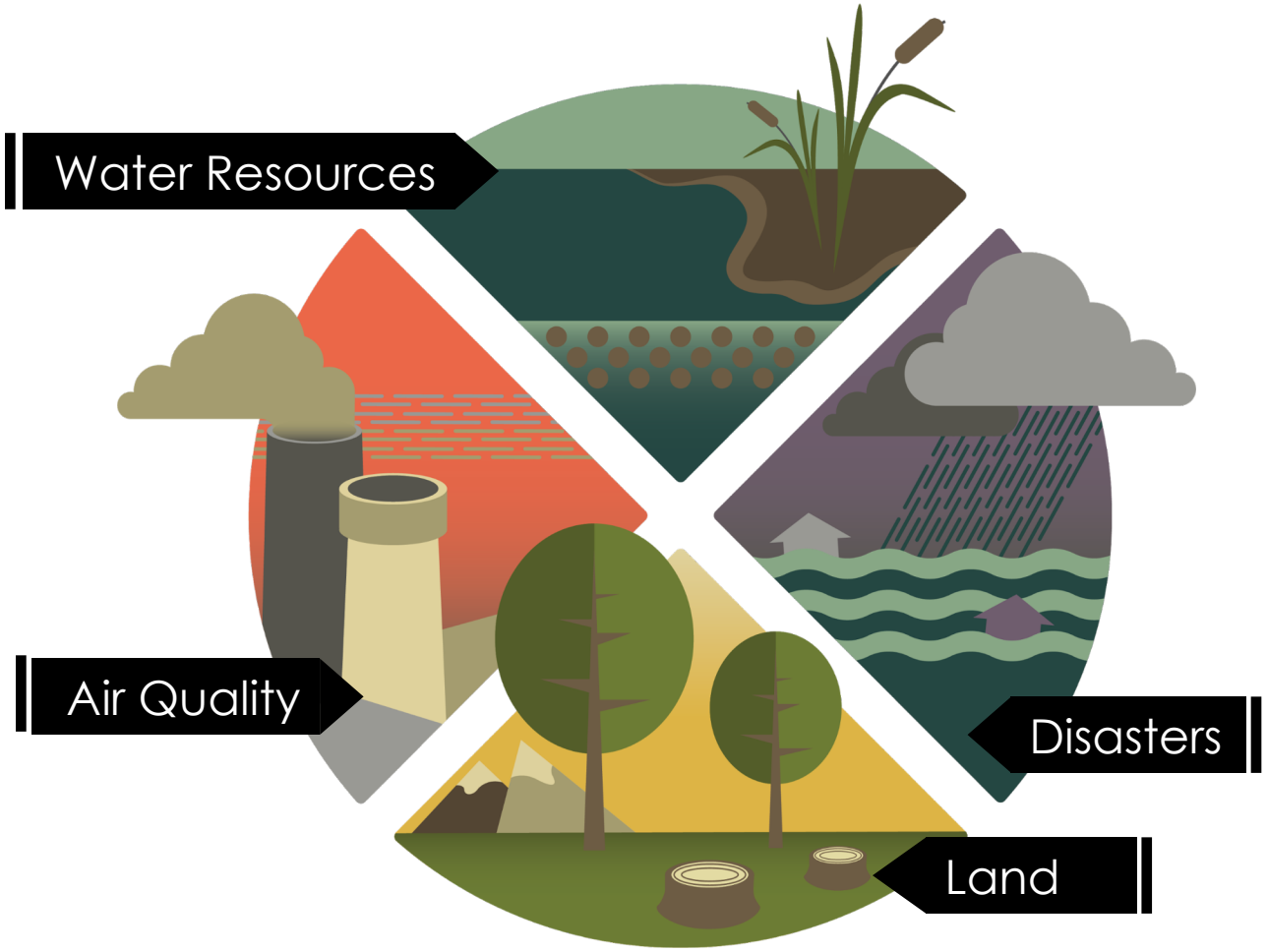


About ARSET

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 online and in-person remote sensing training
- Topics for trainings include:
  - Air Quality
  - Disasters
  - Land
  - Water Resources

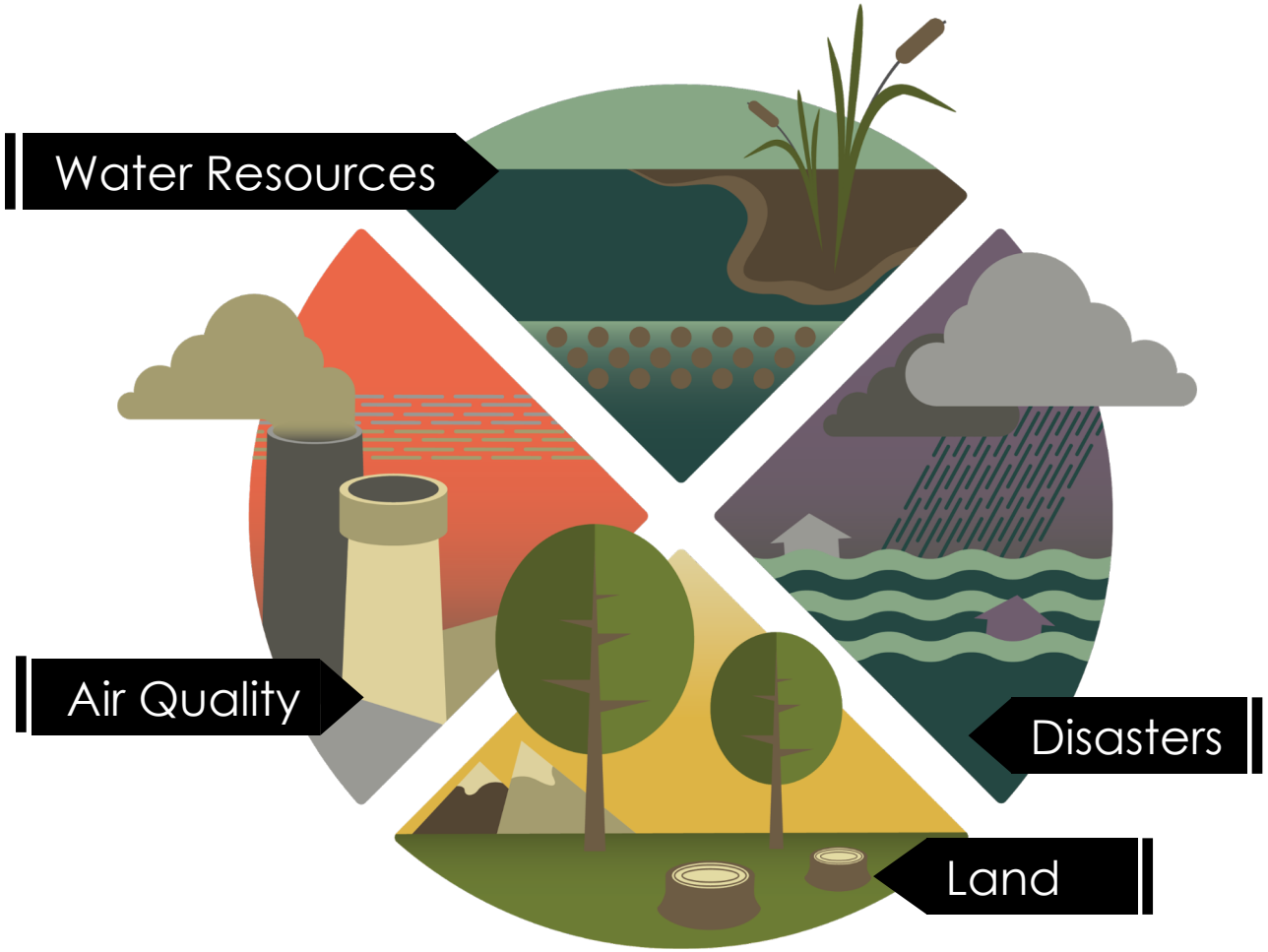


NASA's Applied Remote Sensing Training Program (ARSET)

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

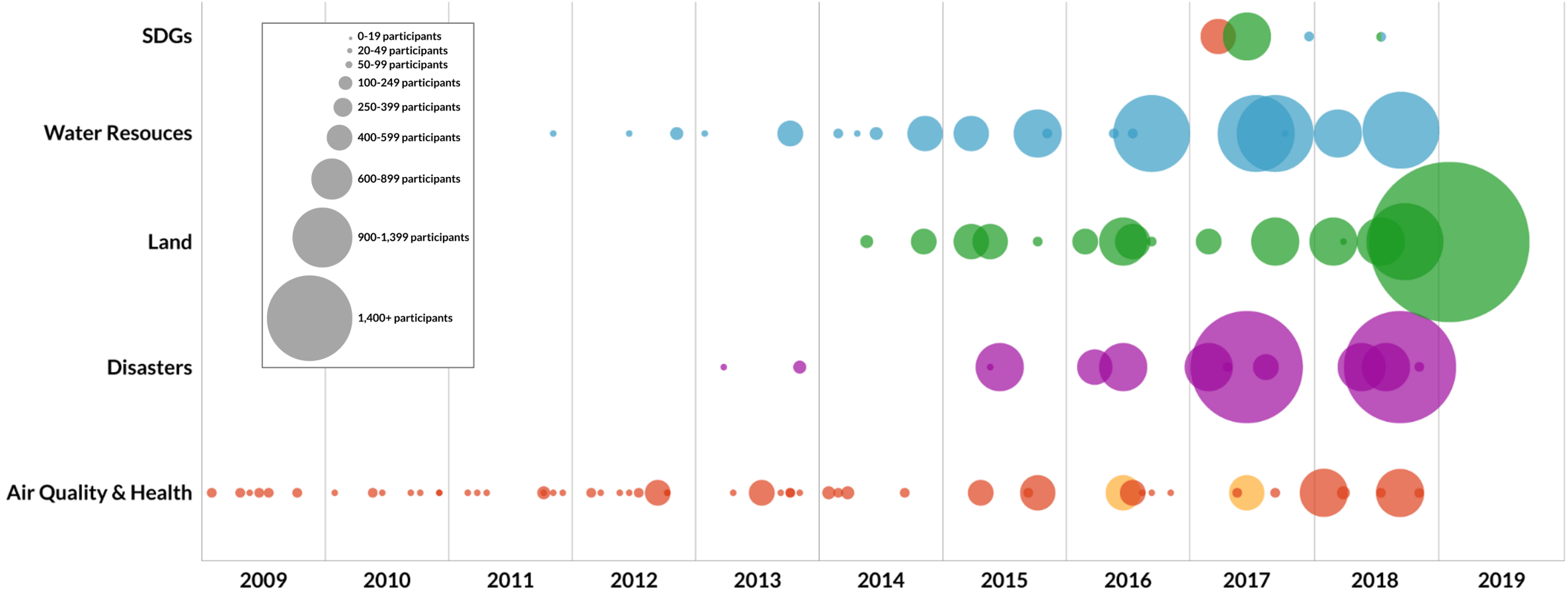
- ARSET's goal is to increase the use of Earth science in decision-making through training for:
  - Policy makers
  - Environmental managers
  - Other professionals in the public and private sector

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.



ARSET Trainings

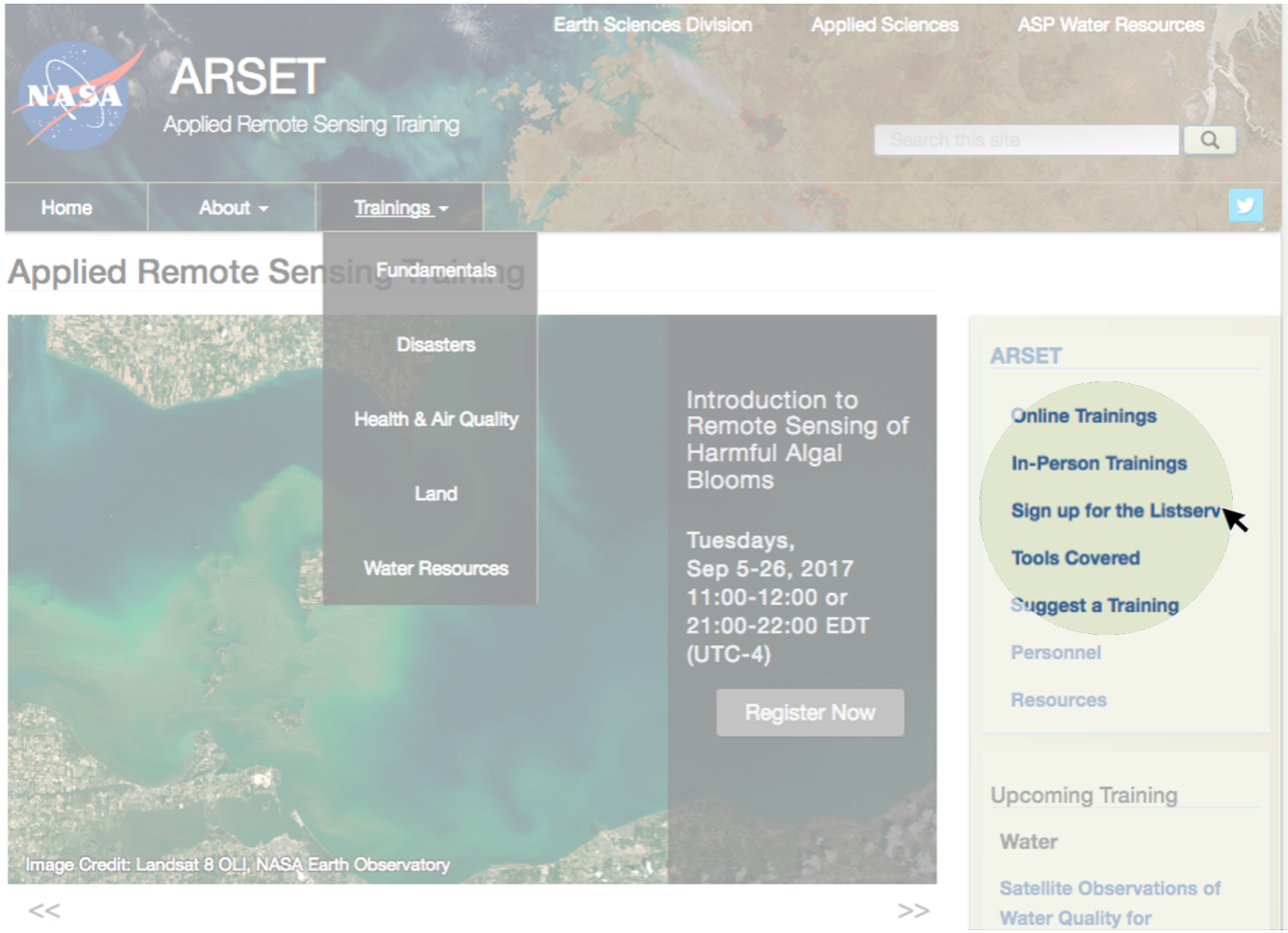
150+ trainings 40,000+ participants 170 countries 7,500+ organizations

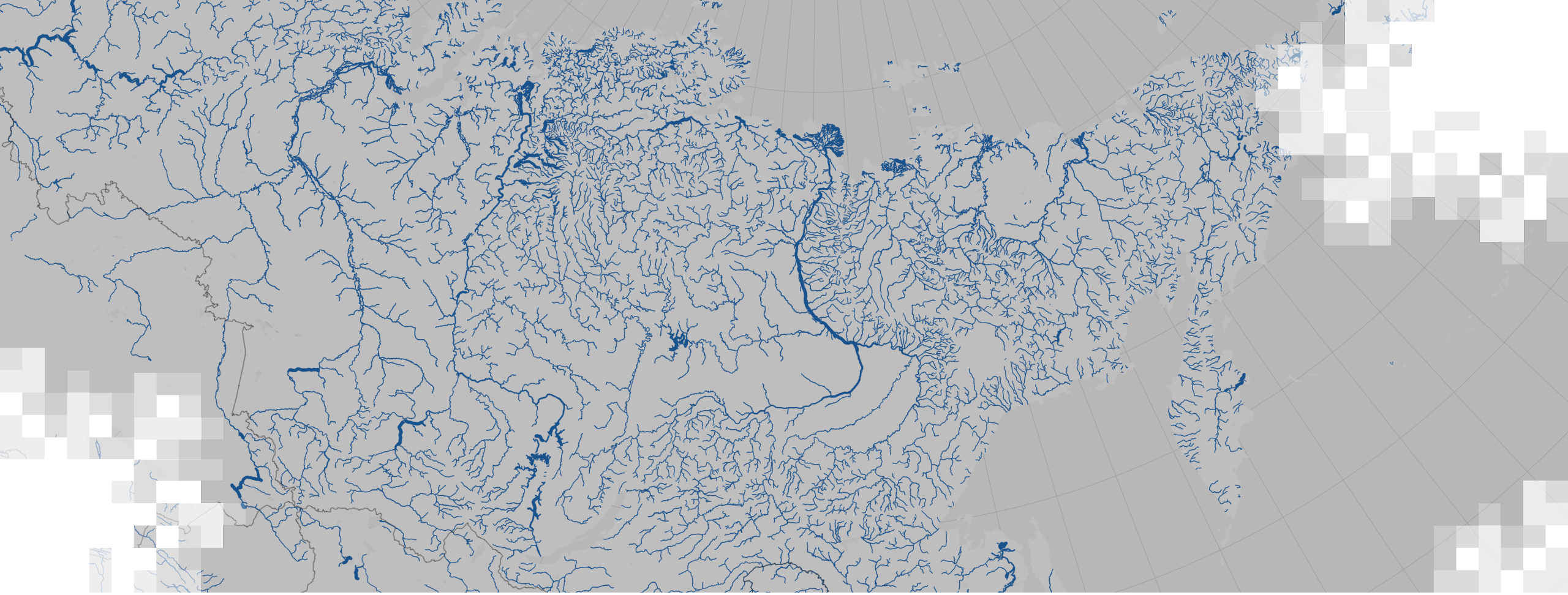


* Bubble size corresponds to number of attendees

Learn More About ARSET

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





Review of Water Budget in a River Basin

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 underlying groundwater.

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

Mississippi River Basin

https://svs.gsfc.nasa.gov/20055

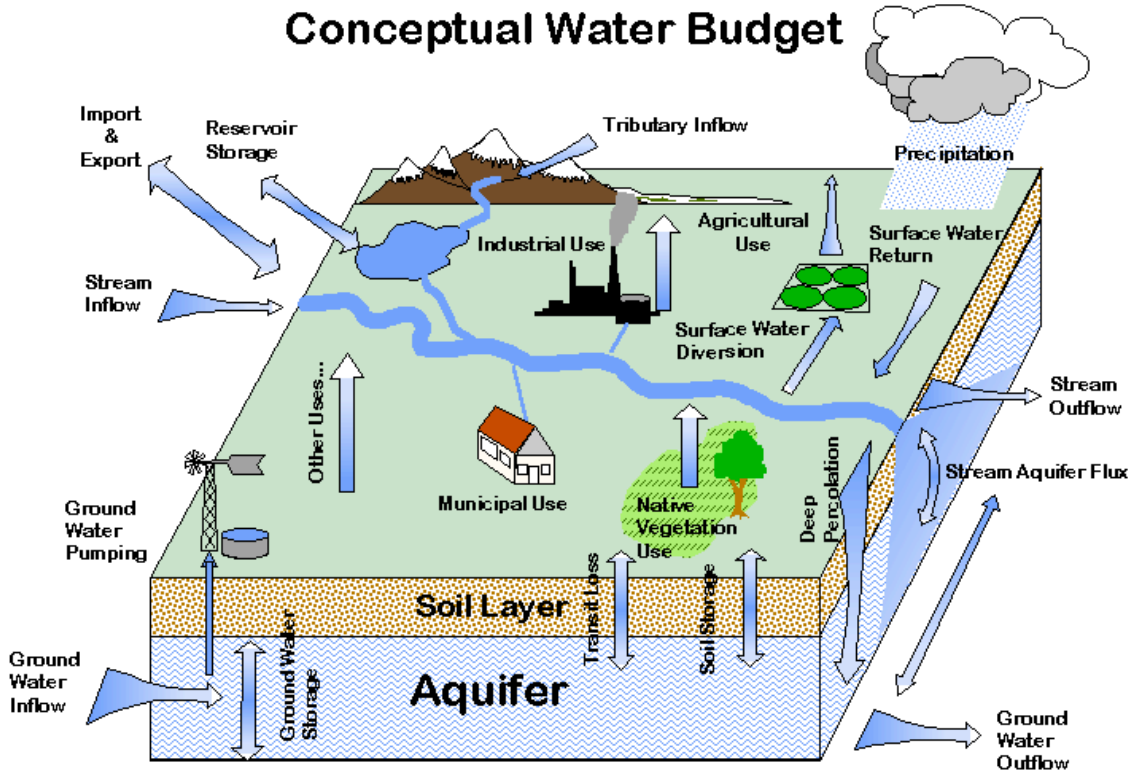
Importance of River Basin Management

http://www.unwater.org/water-facts/transboundary-waters/

- For water allocation, distribution, and sharing among states/regions within a country or among various countries in the same river basin, river basin management is crucial.
- There are 263 transboundary river basins covering roughly half the Earth's surface.
- 145 states have territory within transboundary lake or river basins, and 30 countries lie entirely within them.
- Since 1948, 37 incidents of acute conflict over water have occurred, and approximately 295 international water agreements have been negotiated and signed.

River Basin Management

- River Basin Management primarily requires monitoring water availability and demand in the basin.
- Water availability depends on basin hydrology and ecology and is influenced significantly by weather and climate.
- Monitoring water availability within a river basin is crucial for efficient and effective basin management*.



* Water quality monitoring also is an important part of river basin management. This webinar focuses on data relevant for monitoring water quantity.

River Basin Management

Also requires:

- Accurate identification and delineation of watersheds and stream channels within a basin based on terrain and slope
- Characteristics of the basin – soil and vegetation, lakes and reservoirs, aquifer/groundwater storage
- Information about water demand – residential, agricultural, and industrial – in the basin

This webinar will focus on the application of remote sensing-based data for monitoring water budget components in river basins.

Monitoring Water Availability in River Basins

- Water flow in streams within the basin requires information/observations/modeling of water budget components in the basin.
- Water flow in a stream/river depends on the following components in the watershed contributing to the flow:
  - Precipitation
  - Evaporation and Transpiration
  - Infiltration
  - Surface Water and Groundwater Storage
  - Runoff

Monitoring Water Availability in River Basins

- Water flow in a stream/river depends on the following components in the watershed contributing to the flow:

  - Precipitation
  - Surface Water: Soil moisture and reservoirs
  - Groundwater
  - Evaporation and Transpiration
  - Infiltration: Soil characteristics, soil moisture, terrain, and slope
  - Runoff

Can be obtained from surface-based and remote sensing observations
Can be calculated based on other observable geophysical parameters
Can be calculated based on a water balance equation

Estimating River Basin Water Budget

https://water.usgs.gov/watercensus/AdHocComm/Background/WaterBudgets-FoundationsforEffectiveWater-ResourcesandEnvironmentalManagement.pdf

The water-budget equation for a watershed can be expressed as:

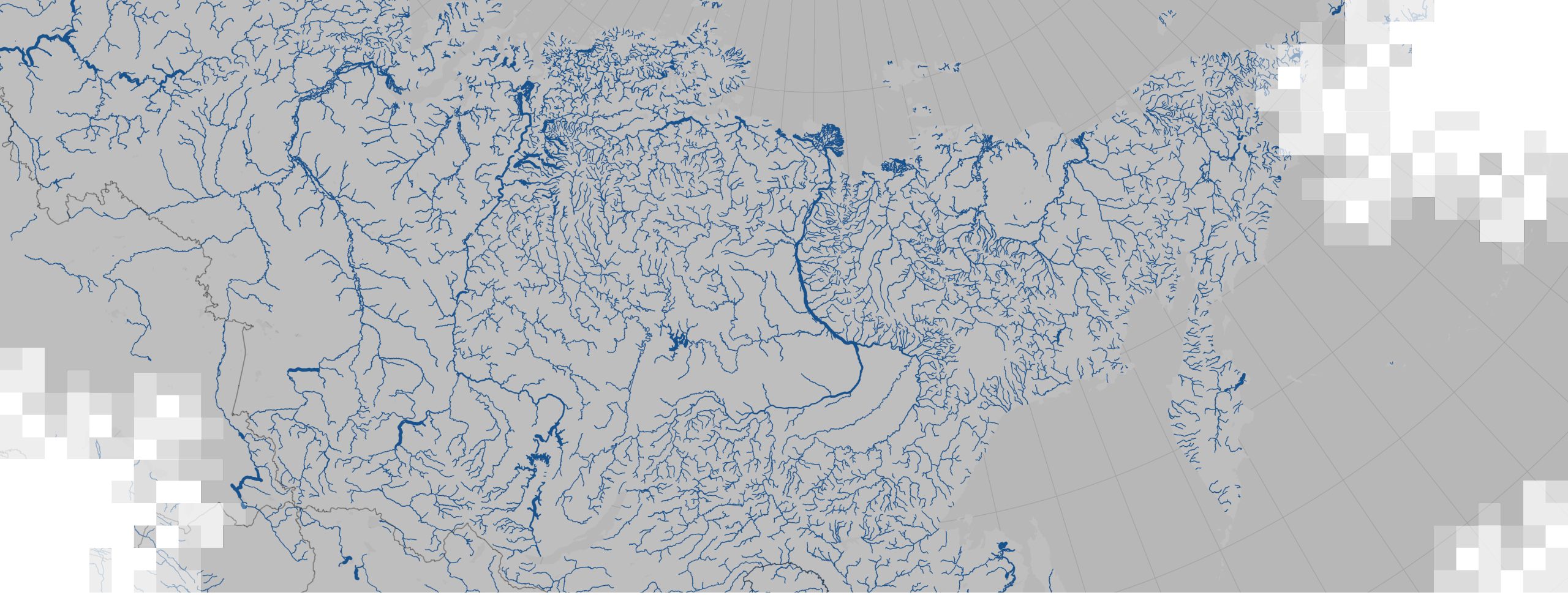
Pr = ET + DS + Discharge

Discharge or Runoff = Pr - ET - DS

Where…

- Pr = Precipitation
- ET = Evapotranspiration
- DS = Change in water storage in the watershed can include surface (snow, soil moisture), and sub-surface (root zone moisture, groundwater component)

These components are available from remote sensing observations and Global Land Data Assimilation System (GLDAS) model based on remote sensing observations.



Review of Remote Sensing and GLDAS Data for Water Budget Estimation

Water Budget Components from Remote Sensing

Water Budget Component	Satellite	Temporal Coverage
Precipitation	Combined TRMM & GPM	06/2000 – Present
Snow Cover, Evapotranspiration	Terra Aqua	12/1999 – Present 05/2002 - Present
Evapotranspiration	Landsat 7 Landsat 8	04/1999 – Present 02/2013 - Present
Soil Moisture	SMAP	01/2015 - Present
Terrestrial Water Storage Change	GRACE GRACE-FO	03/2002 - 10/2017 05/2018 - Present
Reservoir Height	Jason 2 Jason 3	06/2008 – Present 01/2016 - Present

Note:
Each data product has different spatial and temporal resolutions.

TRMM: Tropical Rainfall Measurement Mission
GPM: Global Precipitation Measurements
SMAP: Soil Moisture Active Passive

GRACE: Gravity Recovery and Climate Experiment
GRACE-FO : GRACE Follow-On

For details, see **Session 2B** on https://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing

Satellites and Sensors for Monitoring Water Budget

Satellites	Sensors	Spectral Measurements
TRMM GPM	Microwave Radiometer and RADAR TMI, PR GMI, DPR	TMI: 10-85 GHz GMI: 10-183 GHz PR (Ku) and DPR (Ku and Ka)
Terra & Aqua	MODIS	Visible, Near IR, Middle IR
Landsat 7, 8	ETM+, OLI	Visible, Near IR, Middle IR, Thermal IR
SMAP	Microwave Radiometer	L-Band
GRACE & GRACE-FO	Microwave Radar	K-Band
Jason 2, 3	Altimeter	C-Band and Ku-Band

TMI : TRMM Microwave Imager
PR: Precipitation Radar
GMI: GPM Microwave Imager
DPR: Dual-frequency Precipitation Radar

MODIS: MODerate resolution Imaging Spectroradiometer
TM: Thematic Mapper
ETM+: Enhanced Thematic Mapper Plus
OLI: Operational Land Imager

For details see **Session 2B** on https://arset.gsfc.nasa.gov/webinars/fundamentals-remote-sensing

Satellite Data Products used for Estimation of Water Budget

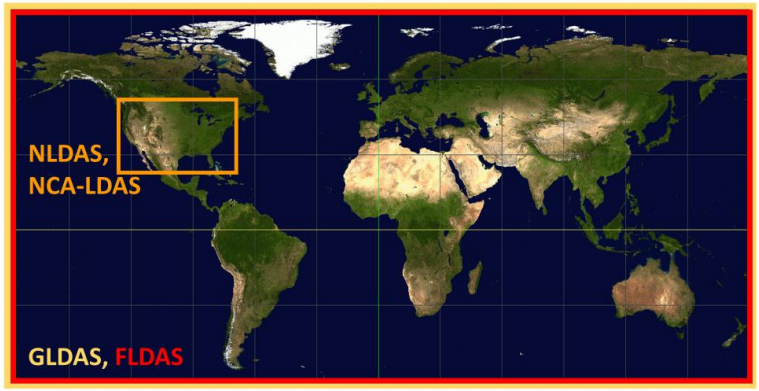
Satellites	Product	Spatial and Temporal Resolutions
Combined TRMM and GPM Precipitation	Integrated Multi-satellitE Retrievals for GPM (IMERG)	0.1° x 0.1° 30-minute, Daily, Monthly
Terra and Aqua MODIS ET	MOD16A2 & MYD16A2	500 m 8-Daily, Annual
Terrestrial Water Storage Change	JPL Tellus GRACE Level-3 Land Water-equivalent Thickness Anomalies	1.0° x 1.0° Monthly

LDAS for Monitoring Water Budget

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

- LDAS integrates surface-based and remote sensing observations in land surface models to solve for the interaction of energy, momentum, and mass between the surface and the atmosphere.
- Provides uniformly gridded, frequent information of water and energy components.
- LDAS provides quantities that are not directly observed by satellites (e.g. runoff, evapotranspiration, snow water equivalence).

Global and Regional LDAS



GLDAS: Global Land Data Assimilation System

NLDAS: North American Land Data Assimilation System

FLDAS: Famine Early Warning Systems Network (FEWS NET) Land Data Assimilation System

NCA-LDAS: The National Climate Assessment - Land Data Assimilation System

GLDAS Versions 2.1 and 2.2

https://daac.gsfc.nasa.gov/datasets/GLDAS_CLSM10_M_2.1/summary?keywords=GLDAS_CLSM10_M_2.1
https://disc.gsfc.nasa.gov/datacollection/GLDAS_CLSM025_DA1_D_2.2.html

- There are two versions: GLDAS 2.1and GLDAS 2.2.
- Both the models use a Vegetation mask, Land/Water mask, and Leaf Area Index (LAI) from MODIS.
- Both use forcing – precipitation, meteorological data, surface radiation – from different sources.
- GLDAS 2.2 assimilates GRACE terrestrial water storage anomaly data in Catchment-F2.5 Land Surface Model (CLSM) for simulation of land surface fields while GLDAS 2.1 does not.
- GLDAS 2.1 data are available from January 2000 to present.
- GLDAS 2.2 data are available from January 2003 to present.

GLDAS Inputs

Inputs	GLDAS 2.1	GLDAS 2.2
Precipitation	Global Precipitation Climatology Project (GPCP) based on multi-satellite and gauge data	*European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecasting System
Meteorological Data	National Center for Environmental Prediction Global Data Assimilation System	
Surface Radiation	Air Force Weather Agency	

* ECMWF data used for forcing fields are not open source

GLDAS Outputs

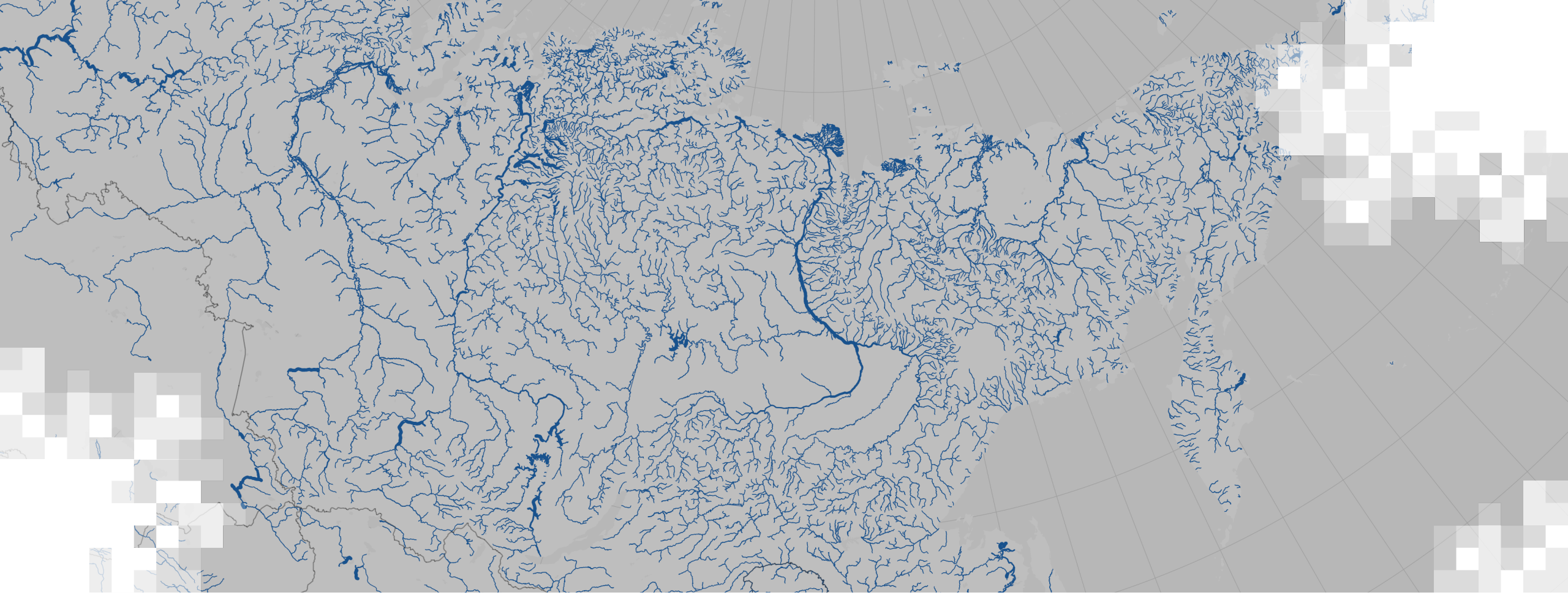
Integrated outputs from GLDAS 2.1 & 2.2 include:

- Soil Moisture
- Evapotranspiration
- Surface/Sub-Surface Runoff
- Snow Water Equivalent

- Since the GPCP and GRACE data have a 2-6-month latency, GLDAS 2.1 & 2.2 outputs are first created without these data and are designated as the Early Product (EP).
- Once the GPCP and GRACE data become available, the model outputs are updated.

GLDAS Data Products used for Estimation of Water Budget

Model	Parameters	Spatial Temporal resolutions
GLDAS 2.1	Precipitation Evapotranspiration Surface/Sub-Surface Runoff Terrestrial Water Storage	1.0° x 1.0° 3-hourly, Monthly
GLDAS 2.2	Evapotranspiration Surface/Sub-Surface Runoff Terrestrial Water Storage	0.25° x 0.25° Daily



Demonstration -
Remote Sensing and GLDAS Data Download
Case Study: Limpopo River Basin

Case Study: Limpopo River Basin

http://www.limpopo.riverawarenesskit.org/

- Located in Southern Africa
- Drainage Area = 408,250 km²
- Number of Major Sub-Basins = 27
- The sub-basins cover portions of:

  Botswana, Mozambique, South Africa, and Zimbabwe

Area and percentage of the river basin for the four riparian states.

Country	Area in each country (km²)	Percentage of the Basin
Botswana	81 400	20 %
Mozambique	79 800	20 %
South Africa	184 150	45 %
Zimbabwe	62 900	15 %
Total	**408 250**	

Source: LBPTC 2010

Limpopo river sub-basins delineated using **Hydro**logical data and maps based on **SH**uttle **E**levation **D**erivatives at multiple **S**cales (HydroSHDES) https://hydrosheds.org/

Introductory Webinar: River Basin Delineation Based on NASA Digital Elevation Data

Demonstration

- Download Data for Water Budget Components

Data	Website
IMERG Precipitation	Giovanni https://giovanni.gsfc.nasa.gov/giovanni/
MODIS ET	**App**lication for **E**xtracting and **E**xploring **A**nalysis **R**eady **S**amples (***App*EEARS**) https://lpdaacsvc.cr.usgs.gov/appeears/
GRACE & GRACE-FO	JPL GRACE Tellus https://grace.jpl.nasa.gov/
GLDAS 2.1& 2.2 Water Budget Components	GES DISC https://daac.gsfc.nasa.gov/

Requires: NASA Earthdata Account
Register using https://urs.earthdata.nasa.gov/home

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