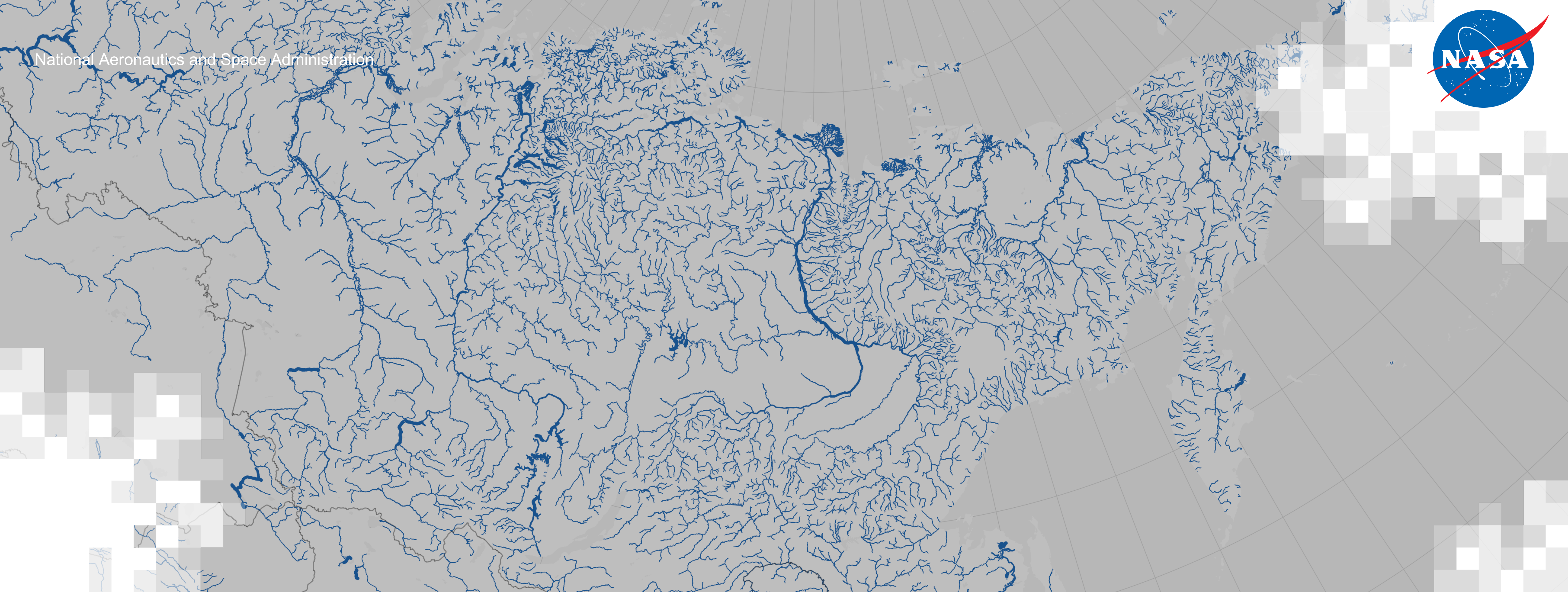
National Aeronautics and Space Administration



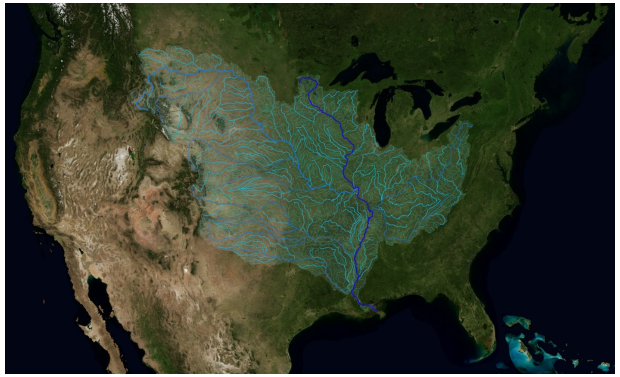
Using Earth Observations to Monitor Water Budgets for River Basin Management II

Amita Mehta and Sean McCartney

August 4, 2020

Training Outline

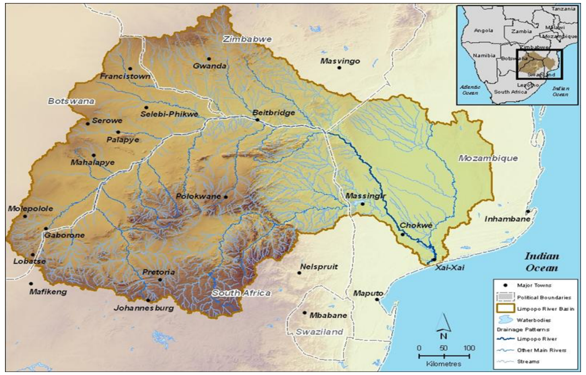
21 July 2020



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

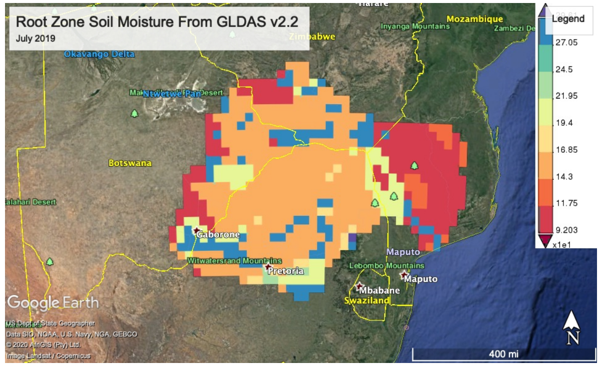
Review and Access of Earth Observations and Earth System-Modeled Data for River Basin Monitoring and Management

28 July 2020



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

4 August 2020



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Water Budget Estimation using Global Land Data Assimilation Model

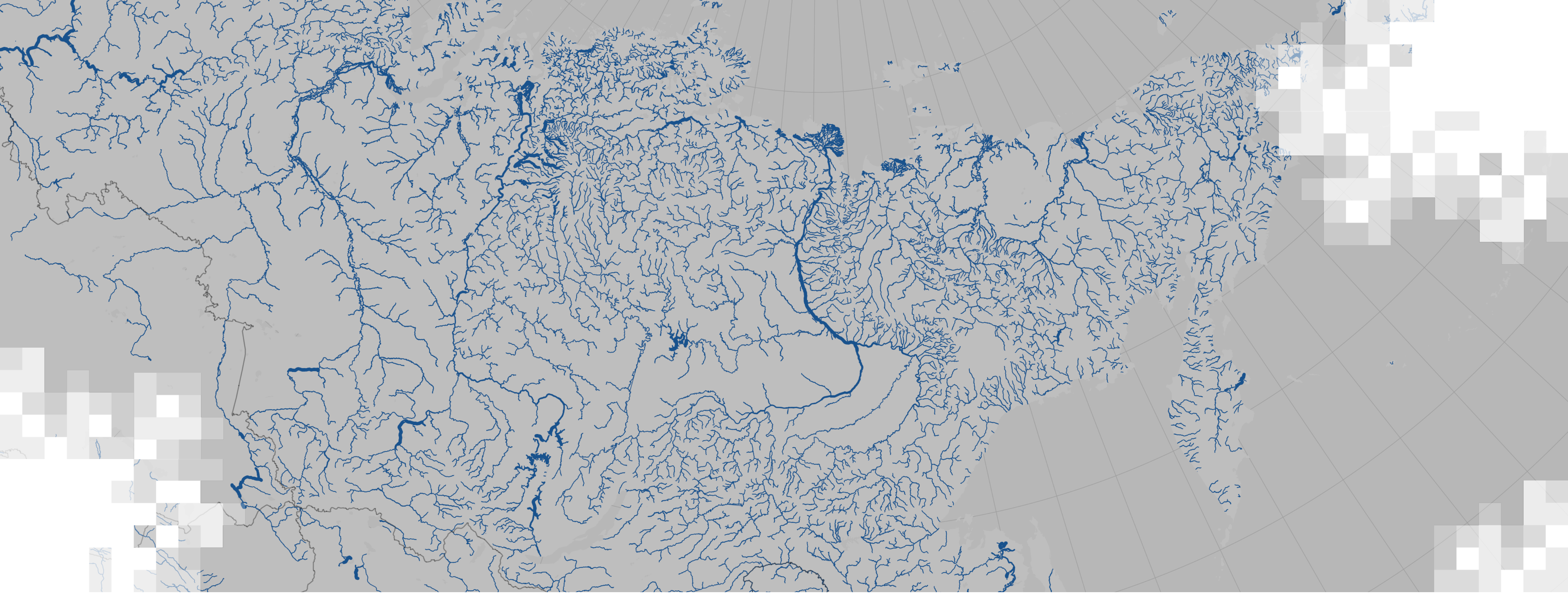
Water Budget Estimation using Remote Sensing Observations

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

Session 3 Outline

- Review of GLDAS Data for Water Budget Estimation
- Demonstration: Estimate water budget components for the Limpopo river basin from GLDAS 2.1 and 2.2 for 2015-16 wet and dry seasons
- Summary:
  - Sources of uncertainties in water budget estimates from remote sensing observations (Session 2) and from GLDAS
- Lab-time for Exercise 3: Replicate steps to estimate water budget components for the Limpopo river basin from GLDAS 2.1 for 2018-19 wet and dry seasons
- Question and Answer Session



Review of GLDAS Data for Water Budget Estimation

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

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

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 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.

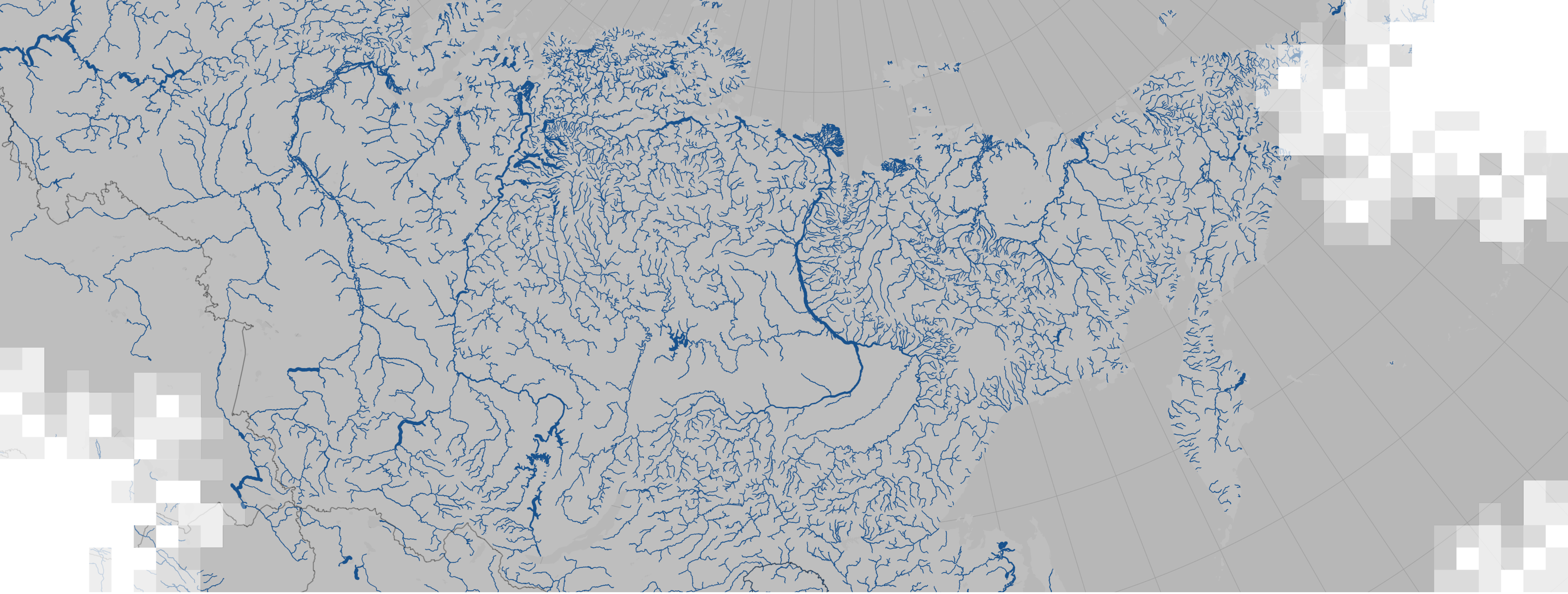
GLDAS Inputs

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-CLSM Outputs

Model	Parameters	Spatial and Temporal Resolutions
GLDAS 2.1	Precipitation Evapotranspiration Surface/Sub-Surface Runoff Terrestrial Water Storage Snow Water Equivalent	1.0° x 1.0° 3-Hourly, Monthly
GLDAS 2.2	Evapotranspiration Surface/Sub-Surface Runoff Terrestrial Water Storage Snow Water Equivalent	0.25° x 0.25° Daily



Demonstration: Estimate water budget components for the Limpopo River Basin from GLDAS 2.1 and 2.2 for 2015-16 wet and dry seasons

Summary

- This 3-session webinar is primarily focused on demonstration and hands-on exercises to learn GIS-based analysis of key water budget components over a river basin from i) remote sensing observations and ii) GLDAS model outputs.
- Using an example from the Limpopo River Basin (415,000 km^2), amounts of precipitation, evapotranspiration, and change in terrestrial storage in the basin for dry and wet seasons were calculated from:
  - i) GPM IMERG, MODIS, and GRACE/GRACE-FO observations
  - ii) GLDAS-CLSM
- For the year considered in the demonstration (2016), annual precipitation, evapotranspiration, and the water storage change obtained from remote sensing observations and GLDAS-2.1/2.2 have differences ranging approximately 13% for precipitation,16% for ET, 21% for water storage change, and 8% for Runoff (GLDAS 2.1 and 2.2) in the Limpopo Basin.
- More accurate, quantitative estimation of water budget continues to be a challenge for a variety of reasons. The spread of estimates can be used for assessing the uncertainty.

Sources of Uncertainties in Water Budget Estimation

- There are barriers in estimating total water budget using remote sensing and GLDAS data due to limitations in observing/modeling all the water components and anthropogenic effects (e.g. streamflow, irrigation, ground water pumping, and diversion).
- Terrestrial water storage anomalies from GRACE & GRACE-FO have resolutions of ~3 x 3 degrees and can not provide accurate information for watersheds smaller than ~150,000 km^2. Uncertainty becomes larger for smaller area of study and depends on the shape and latitude of the area.
- MOD16 Evapotranspiration may have significant uncertainties depending on watershed characteristics (e.g. Dzikiti et al., 2019, Souza et al., 2019, Du and Song, 2018, Khan et al., 2018).

Sources of Uncertainties in Water Budget Estimation

- The GLDAS model has several versions with various Land Surface Model parameterizations (e.g. CLSM, Noah, VIC) with their strengths and limitations, and varying spatial resolutions. These models do not include streamflow routing or representation of surface water (lakes and reservoirs).
  - GLDAS2 simulations have included the HyMAP2 routing scheme that we are planning to release after concluding the analyses. The routing outputs include rivers and floodplains.
- The LDAS models and retrievals of remote sensing-based water components are continually evolving and improving – regional validation of these data with in situ measurements are required to assess bias and uncertainties.

Recommendations

- Use of improved, more accurate products:
  - Remote sensing-based evapotranspiration data are being produced and will be available in 2021 from https://etdata.org/.
  - More accurate GRACE & GRACE-FO data can be calculated by using a combination of products from JPL, GeoforschungsZentrum Potsdam (GFZ), and Center for Space Research (CSR) at University of Texas, Austin.

  (See https://arset.gsfc.nasa.gov/water/webinars/GRACE for more information.)
  - A newer version of GRACE Mascon data can be used (https://podaac-tools.jpl.nasa.gov/drive/files/allData/tellus/L3/mascon/RL06/JPL/v02/CRI/netcdf).

- A customized, ensemble modeling approach (e.g. Land Information System – https://lis.gsfc.nasa.gov/ using in situ and remote sensing data), with appropriate streamflow routing model would yield better water component estimates.

Concluding Remarks

- Despite the uncertainties, remote sensing and GLDAS data can be used to assess seasonal and inter-annual variations in individual water components and to get indications of increase/decrease in water availability for relatively large river basins.
- The remote sensing and GLDAS data should be validated with in situ measurements, including precipitation, streamflow, soil moisture, and vegetation in the area of your interest.
- Evaluation of empirical methodology or local knowledge in your watershed with the remote sensing and GLDAS data may help in assessing the usefulness of the data.
- Feedback about usefulness and limitations of using these data in your own watershed are welcome.

Acknowledgments

We extend our gratitude to the following GLDAS, hydrology, and GRACE data experts for their guidance with this webinar:

Dr. Hiroko Beaudoing (hirioko.kato-1@nasa.gov)

Dr. Augusto Getirana (augusto.getirana@nasa.gov)

Dr. Benjamin Zaitchik (zaitchik@jhu.edu)

Dr. Felix Lenderer (felix.w.landerer@jpl.nasa.gov)

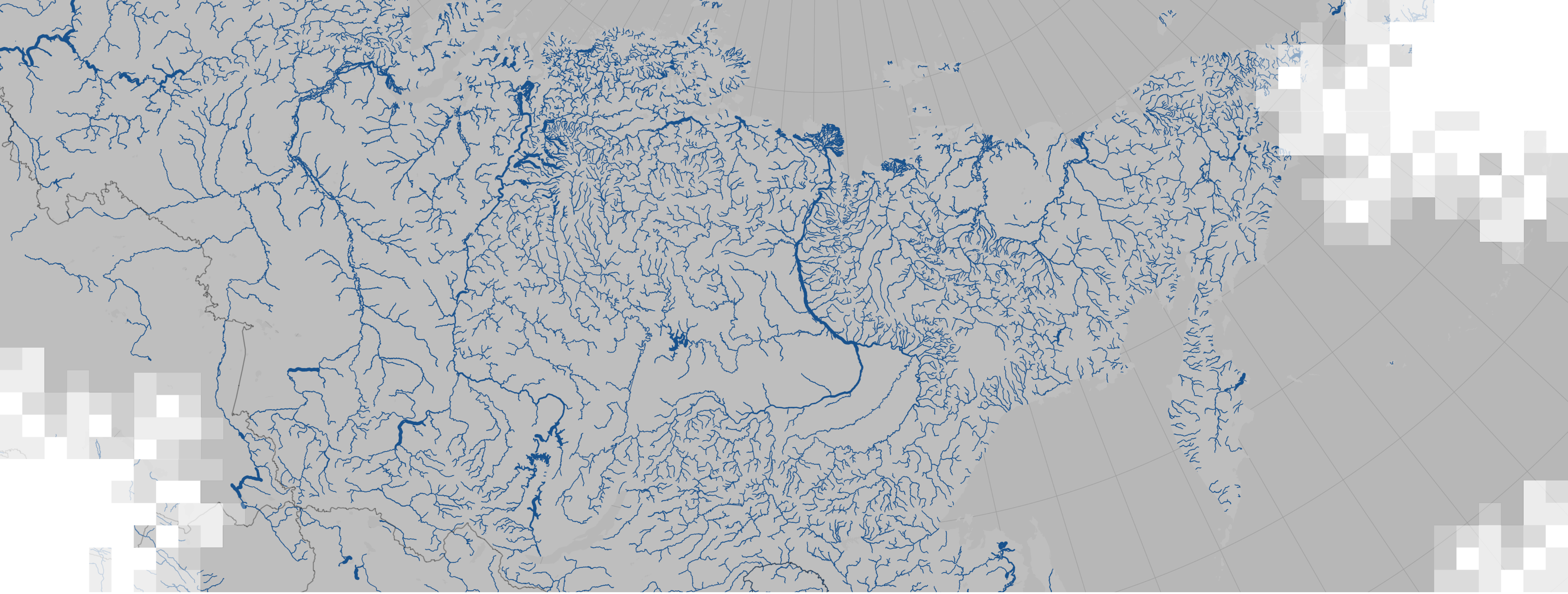
References

Du and Song, 2018: Validation of Global Evapotranspiration Product (MOD16) Using Flux Tower Data from Panjin Coastal Wetland, Northeast China, CHINESE GEOGRAPHICAL SCIENCE, 28, 420-429, DOI: 10.1007/s11769-018-0960

Dzikiti et al., 2019: Comparison of two remote sensing models for estimating evapotranspiration: algorithm evaluation and application in seasonally arid ecosystems in South Africa2019: Comparison, Journal of Arid Land, 11, 495-512. DOI:10.1007/s40333-019-0098-2

Khan et al., 2018: Stand-alone uncertainty characterization of GLEAM, GLDAS and MOD16 evapotranspiration products using an extended triple collocation approach, Agricultural and forest meteorology, 252, 256-268, DOI: 10.1016/j.agrformet.2018.01.022.

Souza et al., 2019: Evaluation of MOD16 Algorithm over Irrigated Rice Paddy Using Flux Tower Measurements in Southern Brazil, Water (Basel), 11, DOI:10.3390/w11091911



Lab Time: Estimate water budget components for the Limpopo River Basin from GLDAS 2.1 for 2018-19 wet and dry seasons

Lab time

- Please enter your questions in the Q&A box.
- We will address your questions as we receive them and post answers to the training website:

  https://arset.gsfc.nasa.gov/water/webinars/water-budgets-river-basin

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