EARTH SCIENCE
APPLIED SCIENCES

ENHANCING WATER MANAGEMENT

EARTH SCIENCE APPLICATIONS WEEK 2021

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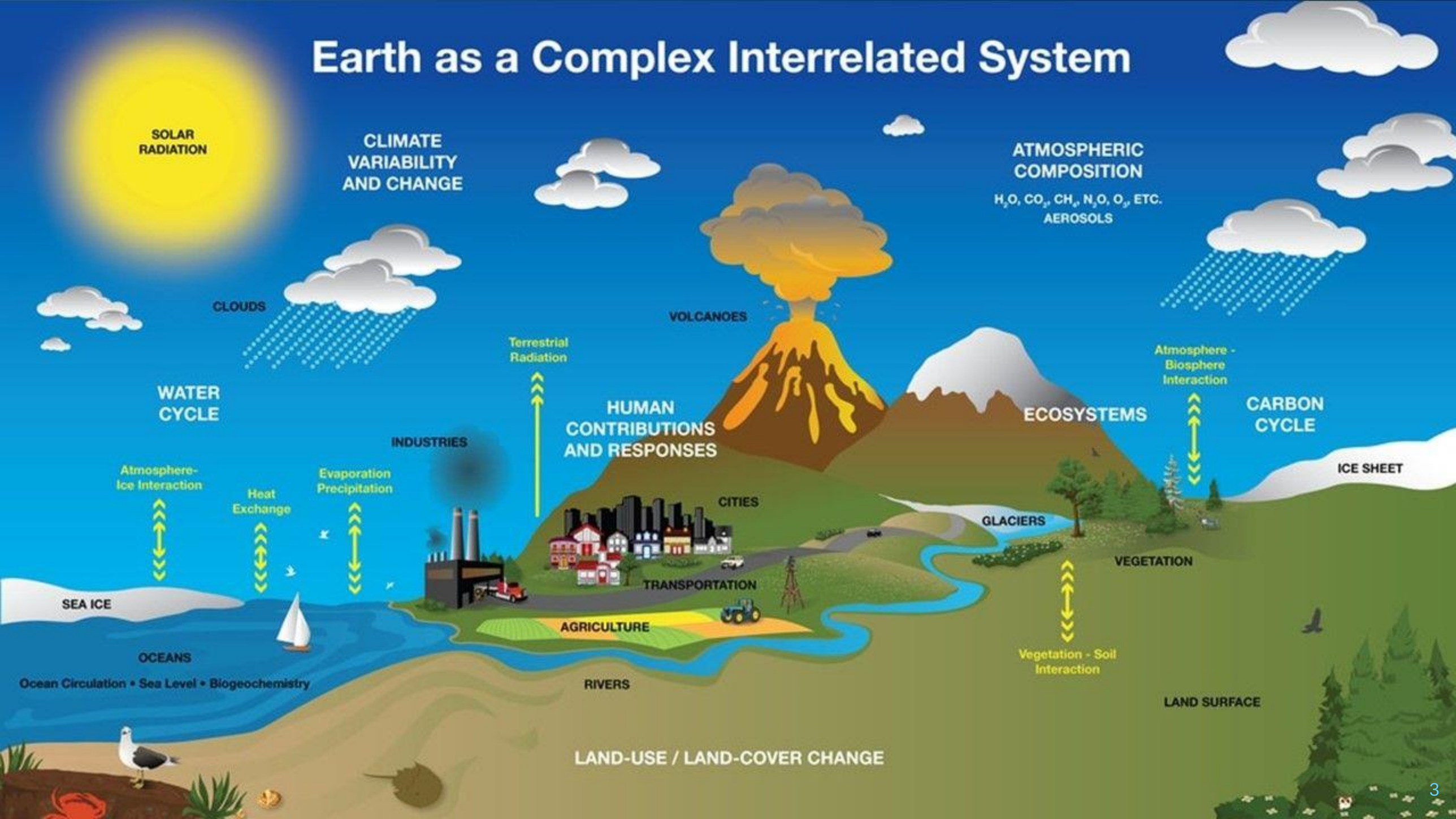
Leveraging Data & Tools to Develop New Capabilities

Dr. John D. Bolten

EARTH SCIENCE APPLICATIONS WEEK 2021


Earth as a Complex Interrelated System
SOLAR RADIATION
CLIMATE VARIABILITY AND CHANGE
ATMOSPHERIC COMPOSITION
H_2O, CO_2, CH_4, N_2O, O_3, ETC.
AEROSOLS
CLOUDS
VOLCANOES
Terrestrial Radiation
WATER CYCLE
HUMAN CONTRIBUTIONS AND RESPONSES
ECOSYSTEMS
Atmosphere - Biosphere Interaction
CARBON CYCLE
INDUSTRIES
Atmosphere-Ice Interaction
Heat Exchange
Evaporation Precipitation
CITIES
ICE SHEET
GLACIERS
VEGETATION
TRANSPORTATION
SEA ICE
AGRICULTURE
Vegetation - Soil Interaction
OCEANS
Ocean Circulation • Sea Level • Biogeochemistry
RIVERS
LAND SURFACE
LAND-USE / LAND-COVER CHANGE

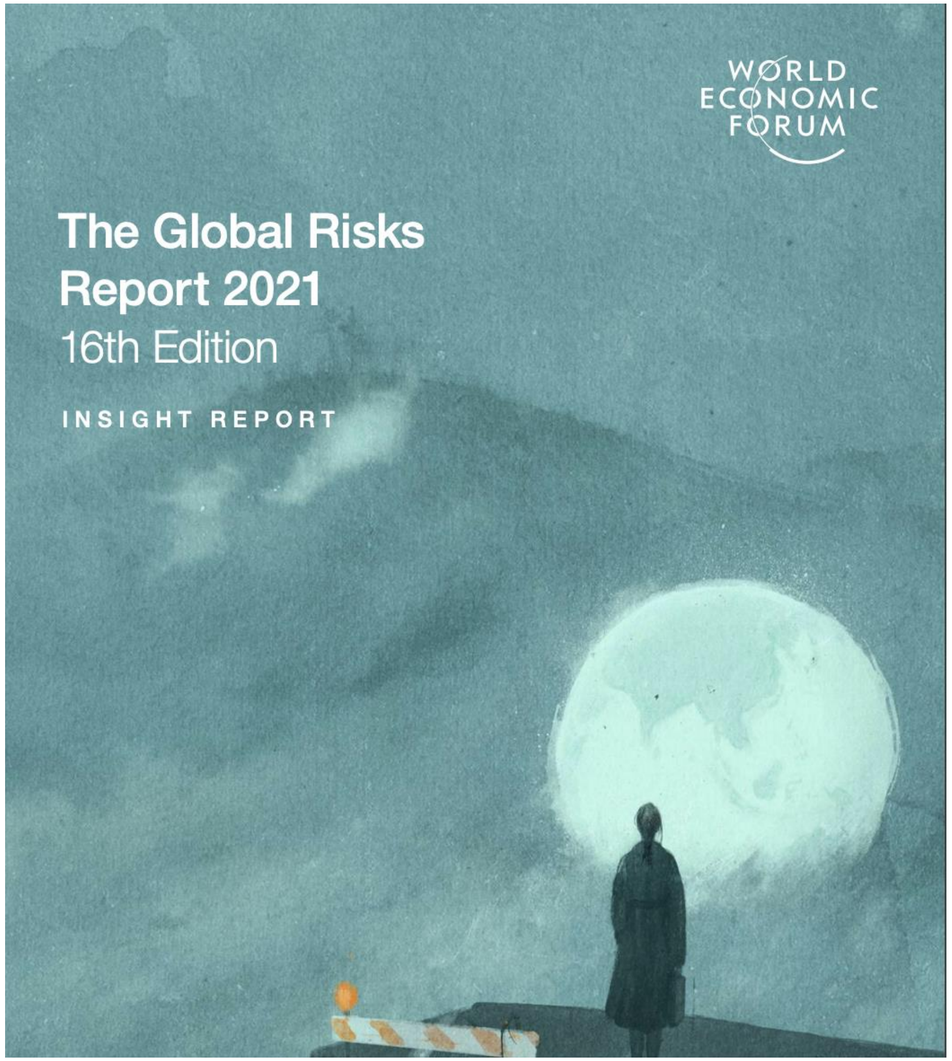
Earth Science Division | Applied Sciences Program

Water-Related Capacity Building Program Activities

Passing the Baton *From Concepts to Capabilities*

- Ideas
- Research
- Mentorship
- Applications
- Capabilities

Why Hurry?



- "….Pivotal point in our humanity…"
- "….need to translate data to actionable information..." -Dr. Karen St. M. Germain

- *Risk of Climate Action Failure*

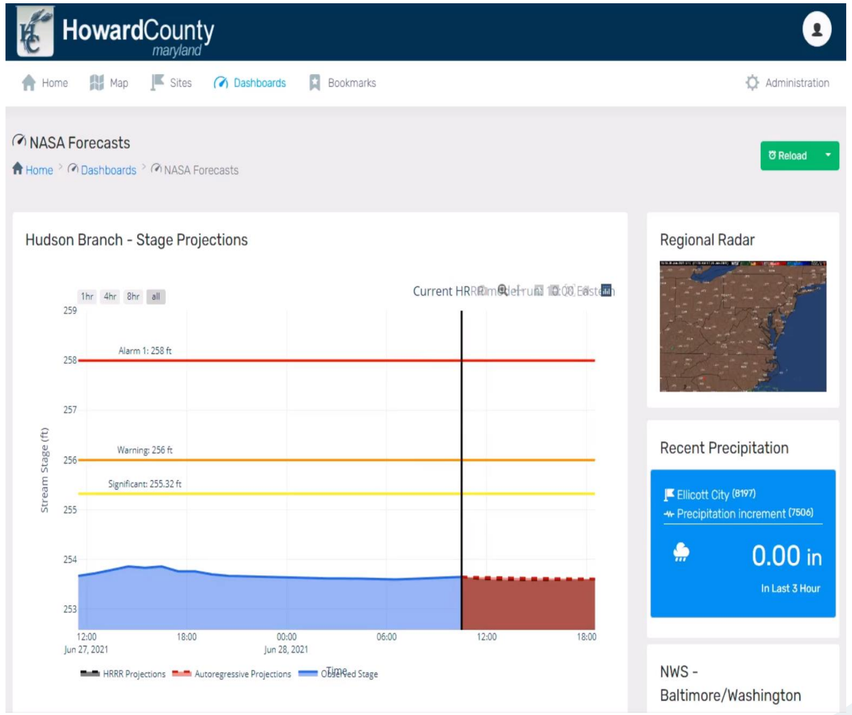
- *Urgent need for water security and food system resilience*

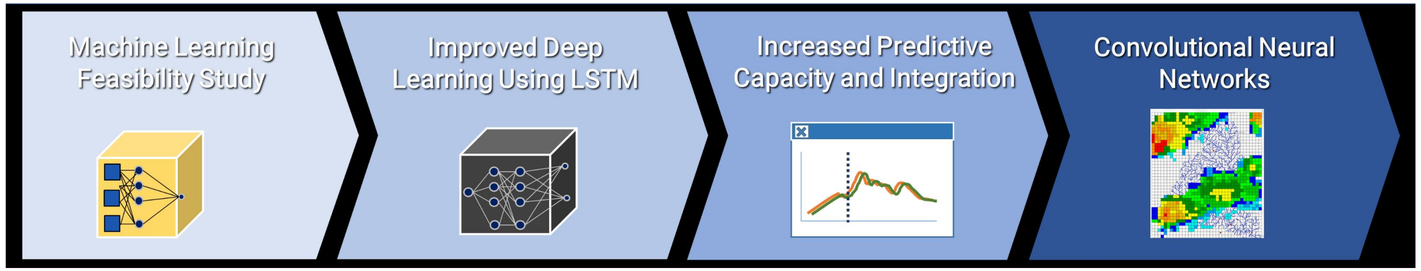
Teamwork! New Capabilities

- We are cultivating a reinvigoration of data and tools through *innovation*, *testbeds*, and *teamwork*

Setting Race Goals… Innovate to Dominate

- Howard County Office of Emergency Management
- DEVELOP
- SSAI
- National Weather Service

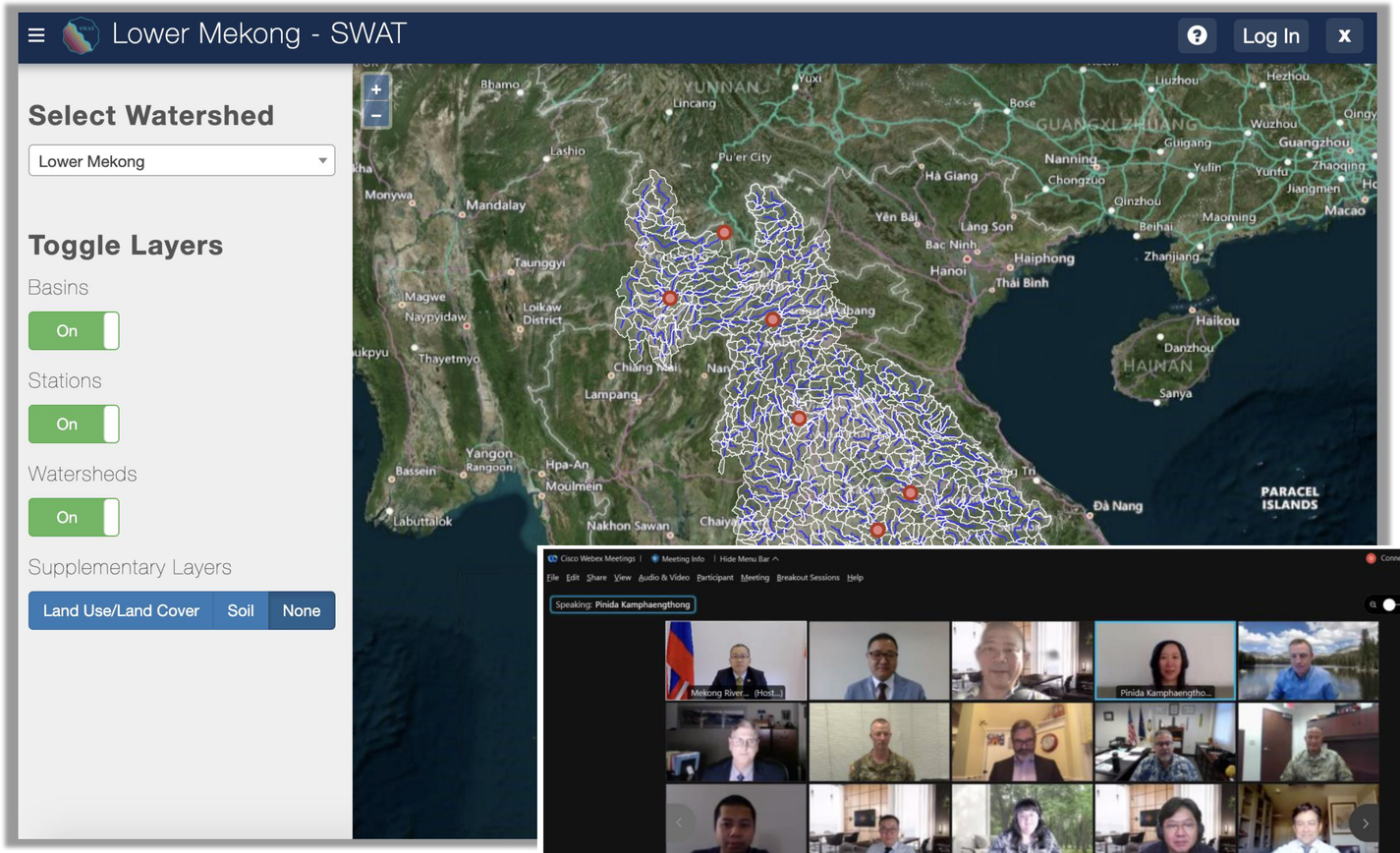




Teamwork! New Teams

- *Innovation from a cross pollination of ideas and capabilities between scientists, partnerships, and NASA programs*

Don’t Stop! Keep Moving!



Department of State Interagency Water Working Group Science and Applications Team (ISAT) recently initiated the Strategic Hydrologic and Agricultural Remote-sensing of Environments (**SHARE**) program.

- DEVELOP
- Disasters
- SERVIR
- Ecological Forecasting
- Water Resources
- Mekong River Commission
- DoS ISAT

https://tethys.servirglobal.net/apps/swat2/

Science Has Momentum! Keep Running!

August 5th Cover of Nature features previous DEVELOPer Colin Doyle's work.

Article

Satellite imaging reveals increased proportion of population exposed to floods

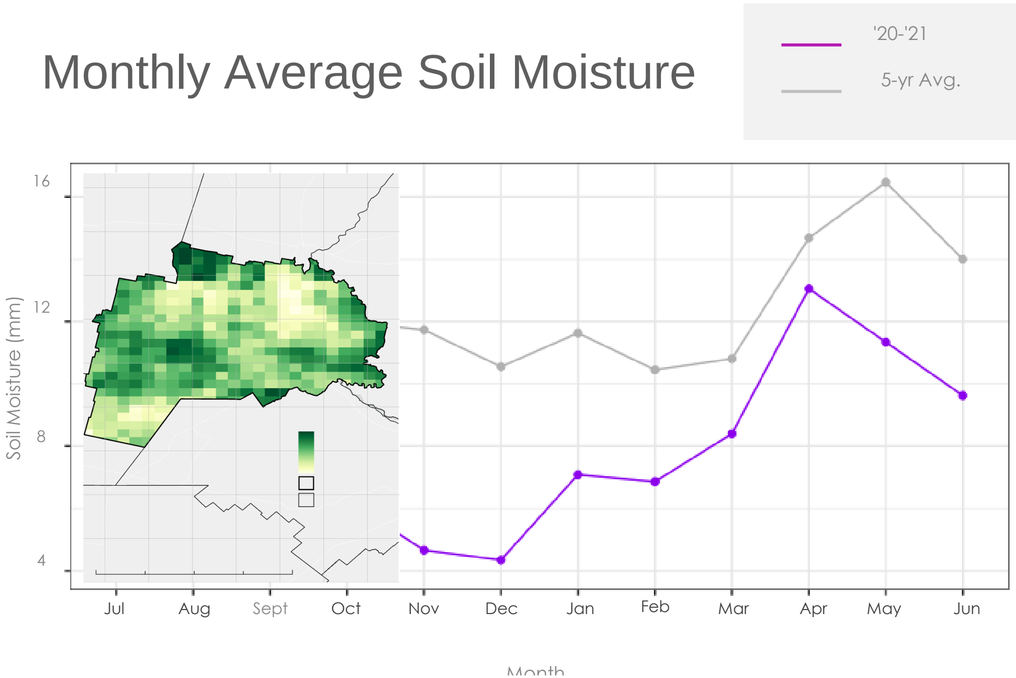
B. Tellman[1,2,3,10], J. A. Sullivan[2,3,4,10], C. Kuhn[5], A. J. Kettner[6], C. S. Doyle[2,7], G. R. Brakenridge[6], T. A. Erickson[8] & D. A. Slayback[9]

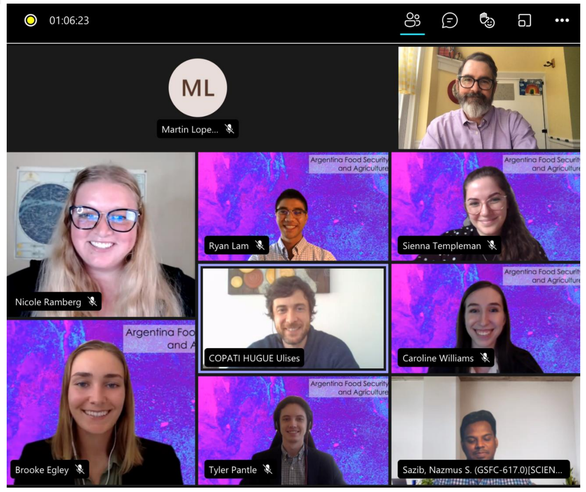
https://doi.org/10.1038/s41586-021-03695-w
Received: 25 August 2020
Accepted: 3 June 2021
Published online: 4 August 2021
Check for updates

Flooding affects more people than any other environmental hazard and hinders sustainable development[1,2]. Investing in flood adaptation strategies may reduce the loss of life and livelihood caused by floods[3]. Where and how floods occur and who is exposed are changing as a result of rapid urbanization[4], flood mitigation infrastructure[5] and increasing settlements in floodplains[6]. Previous estimates of the global flood-exposed population have been limited by a lack of observational data, relying instead on models, which have high uncertainty[3,7–11]. Here we use daily satellite

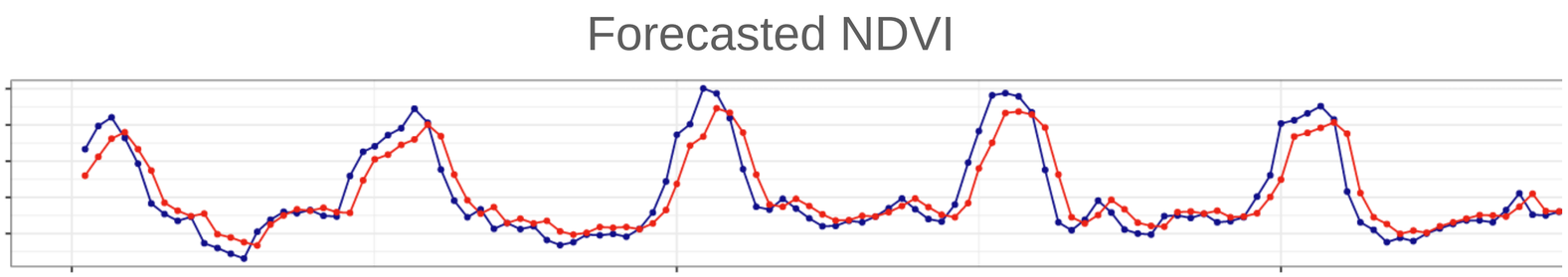
Passing the Baton… to Argentina

"…To come up with a tool like this for us, is incredible!" Esteban Capoti, Buenos Aires Grain Exchange, 08/10/21





- **Water Resources Program**
- **USDA**
- **NASA Harvest**
- **Terrestrial Hydrology Program**
- **DEVELOP**
- **Buenos Aires Grain Exchange**



In the End, We All Win

Thank you!

John D. Bolten

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Earth Science Missions for Water Resources

Dr. Christine M. Lee

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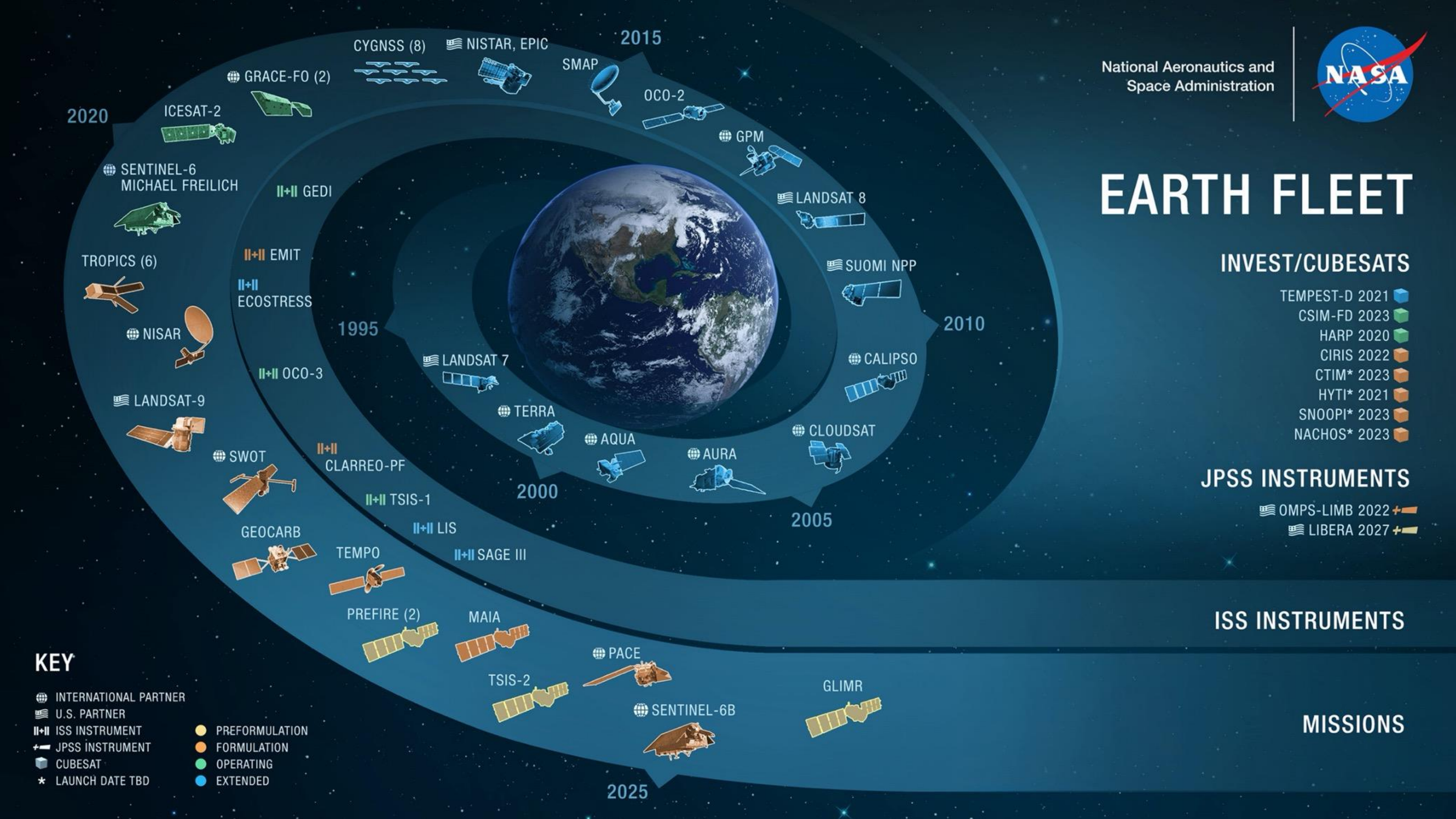
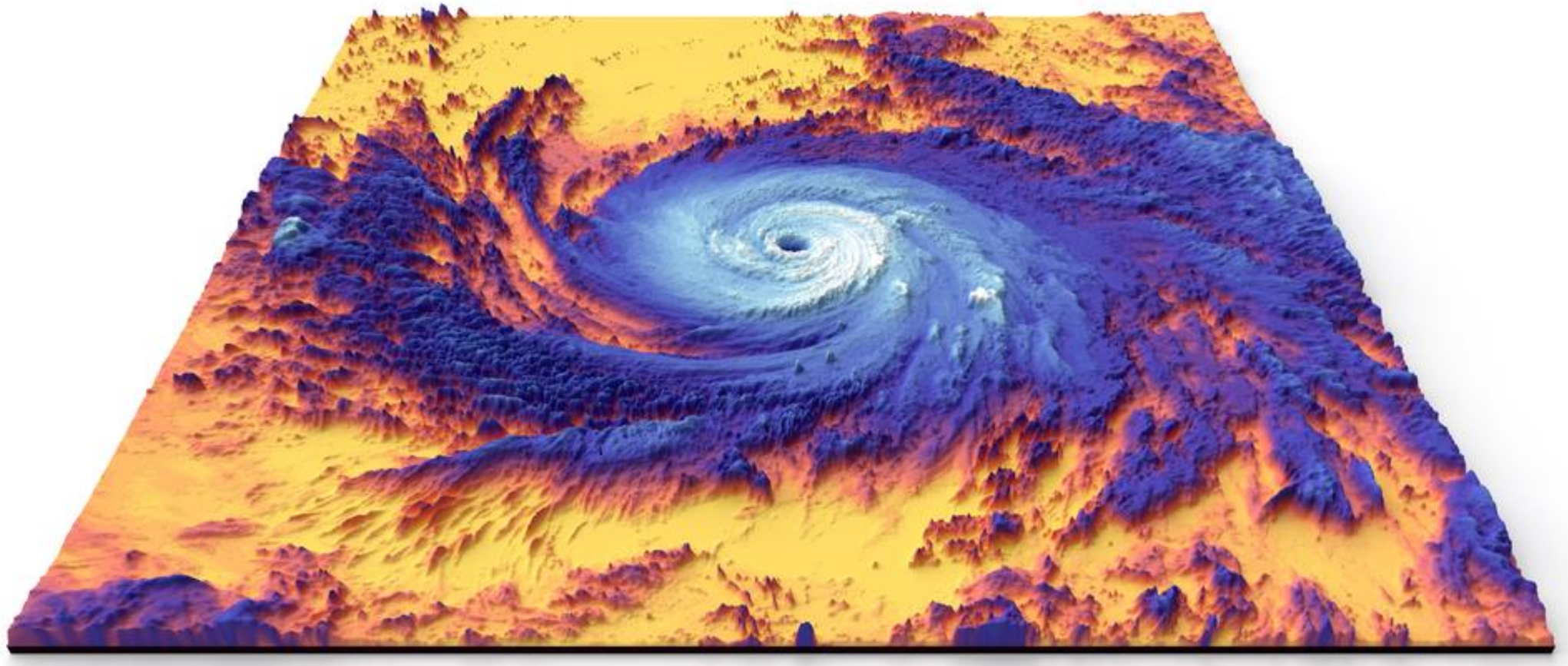

National Aeronautics and Space Administration
NASA
EARTH FLEET
INVEST/CUBESATS
TEMPEST-D 2021
CSIM-FD 2023
HARP 2020
CIRIS 2022
CTIM* 2023
HYTI* 2021
SNOOPI* 2023
NACHOS* 2023
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
ISS INSTRUMENTS
MISSIONS
2015
2020
1995
2010
2000
2005
2025
CYGNSS (8)
NISTAR, EPIC
SMAP
OCO-2
GPM
LANDSAT 8
SUOMI NPP
CALIPSO
CLOUDSAT
AURA
AQUA
TERRA
LANDSAT 7
GRACE-FO (2)
ICESAT-2
SENTINEL-6 MICHAEL FREILICH
GEDI
EMIT
ECOSTRESS
TROPICS (6)
NISAR
OCO-3
LANDSAT-9
SWOT
CLARREO-PF
TSIS-1
LIS
SAGE III
GEOCARB
TEMPO
PREFIRE (2)
MAIA
PACE
TSIS-2
SENTINEL-6B
GLIMR
KEY
INTERNATIONAL PARTNER
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
PREFORMULATION
FORMULATION
OPERATING
EXTENDED

May 24, 2021

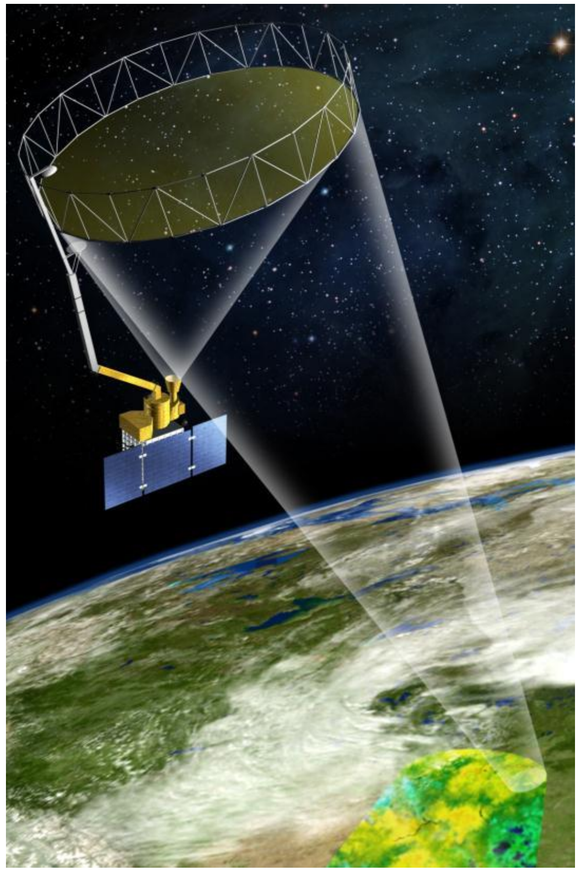
RELEASE 21-070

New NASA Earth System Observatory to Help Address, Mitigate Climate Change



Soil Moisture Active Passive (SMAP)

Launched – June 2015



J. Bolten
(GSFC)

SMAP at a glance

- Global mission to map soil moisture and determine freeze or thaw states using radar
- Launched in 2015, 2-3 day revisit, 9km resolution

Common Applications of SMAP

- Improving weather forecasts and streamflow/hydrologic models Informing agriculture monitoring and forecasting irrigation scheduling
- Improving flood and drought forecasting
- Assessing fire risk
- Landslides
- Human health and vectorborne disease

Surface Water Ocean Topography (SWOT)

SWOT at a glance

- Global mission to better understand world's oceans and its terrestrial surface waters
- Launching in 2022, 21 day revisit, 1km spatial resolution

Common Applications of SWOT

Hydrology Applications

Floods | Drought | Reservoirs | River Commerce | Insurance | Transboundary Rivers

Ocean Applications

Marine Operations | Coastal Zone Mgmt | Climate | Fisheries

M. Srinivasan
(JPL)

MASS CHANGE (MC)

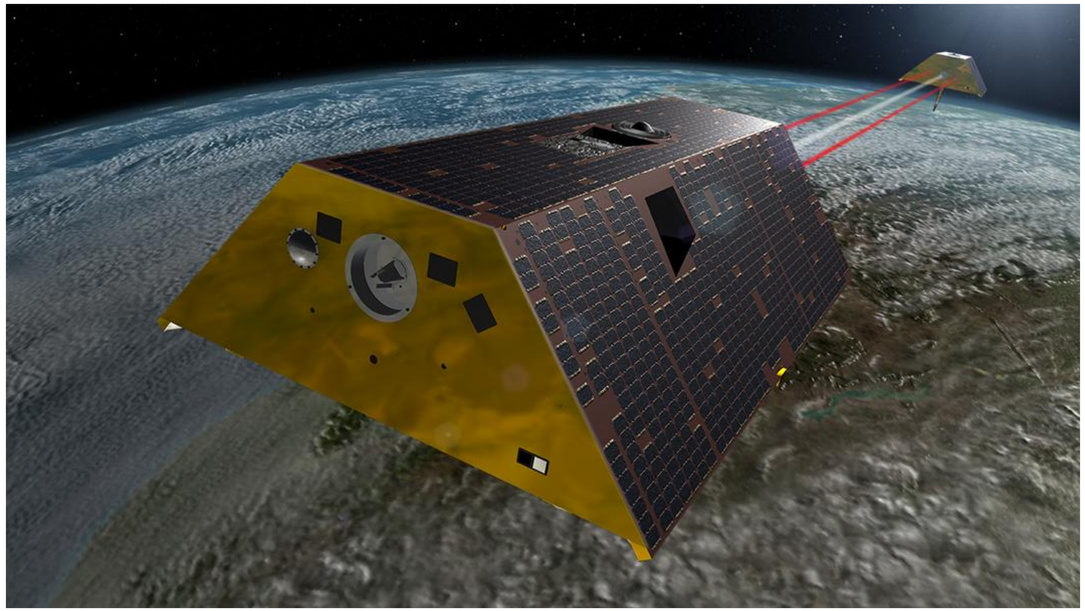
Mass Change at a glance

- Global mission to continue GRACE and GRACE-FO mass change observations and assess terrestrial water storage anomalies
- Launch date 5+ years

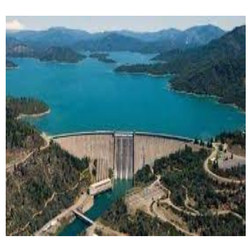
Mass Change Applications

- Water Resources and Drought (improve understanding of water supply/quantity/use)
- Assessing flood vulnerability
- Agriculture
- Sea Level Rise
- Natural Hazards (ie, earthquake hazard assessments)

GRACE-FO



GRACE-FO consists of two nearly identical satellites. One follows the other along the same orbit as both continually measure the distance between them by means of microwave ranging instruments



M. Srinivasan
(JPL)

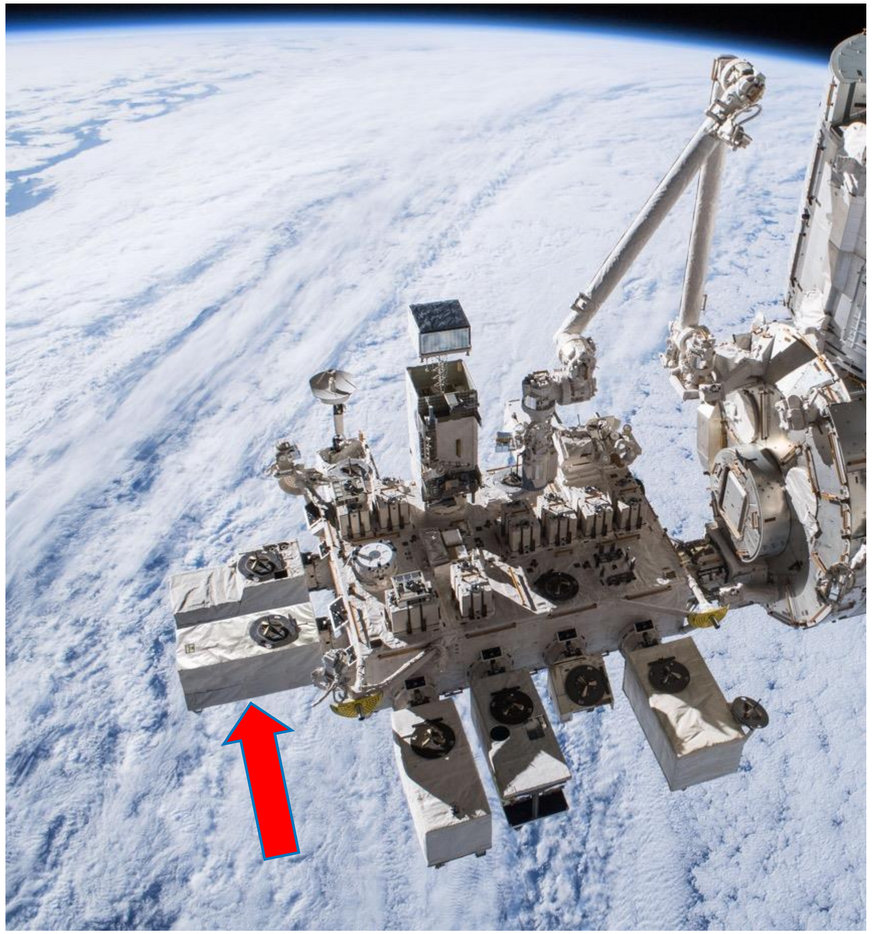
ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

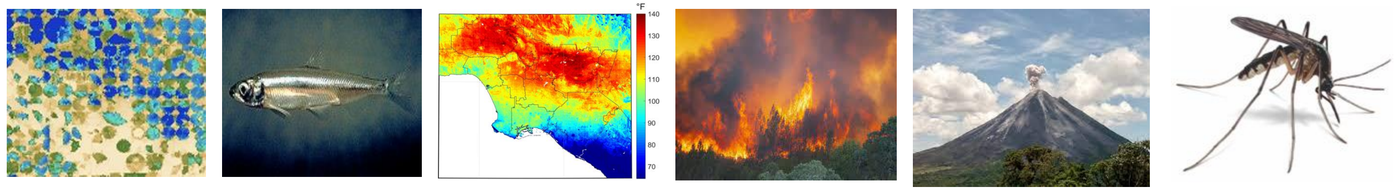
ECOSTRESS at a glance

- ISS instrument mapping temperature and evapotranspiration in plants around the world
- Launched in 2018, 1-5 day revisit at different times of day, 70-m spatial resolution

ECOSTRESS Applications

- Water resources, agriculture, drought, vegetation stress
- Public Health – urban heat and vectorborne illness
- Aquatic habitat and coastal ecosystems
- Wildfires (Pre/Active/Post)
- Geologic (Volcanoes) and geothermal applications





Surface Biology and Geology Earth (SBG) Observing System

SBG at a glance

- Global mission to study the Earth's active terrestrial, aquatic, and geologic surfaces
- Launch 5+ years out
- Thermal: 60m resolution, 1-3 day revisit
- VSWIR: 30m resolution, 8-16 day revisit

SBG Applications

- Water Resources, Agriculture, Drought, Cryosphere
- Biodiversity and Conservation
- Water Quality, Marine and Inland Aquatic Ecosystems
- Wildfires
- Natural Hazards
- Geology and Mineral Applications

Thank you

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Fostering Partnerships through Needs Assessments

Stephanie Granger

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TOWARD MUTUAL UNDERSTANDING

"Partnerships take time to establish and nurture…and should begin with the belief that an important need can best be fulfilled through partnership."

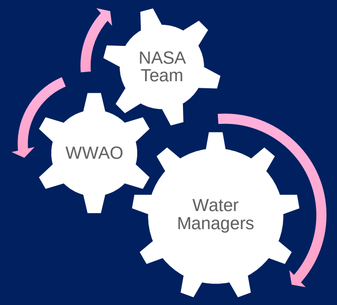
- Brian O'Neill, Superintendent of Golden Gate National Parks

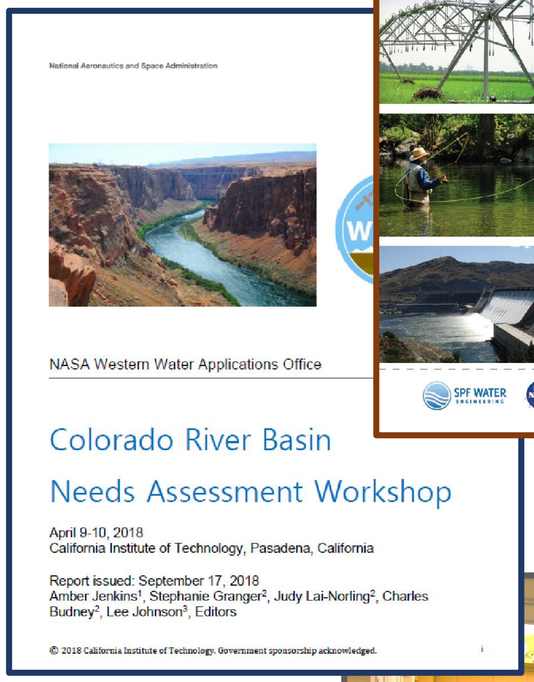
WWAO conducts Management Studies and Needs Assessments of major western U. S. river basins to:

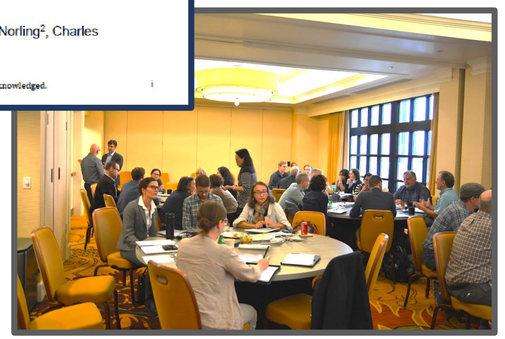
- **Identify** NASA data, research, and technology that adds value to water management;
- **Develop projects** that address critical needs;
- **Develop, curate, and grow** a Needs Catalog and make it widely available to the applied science community

WWAO Project Development Process

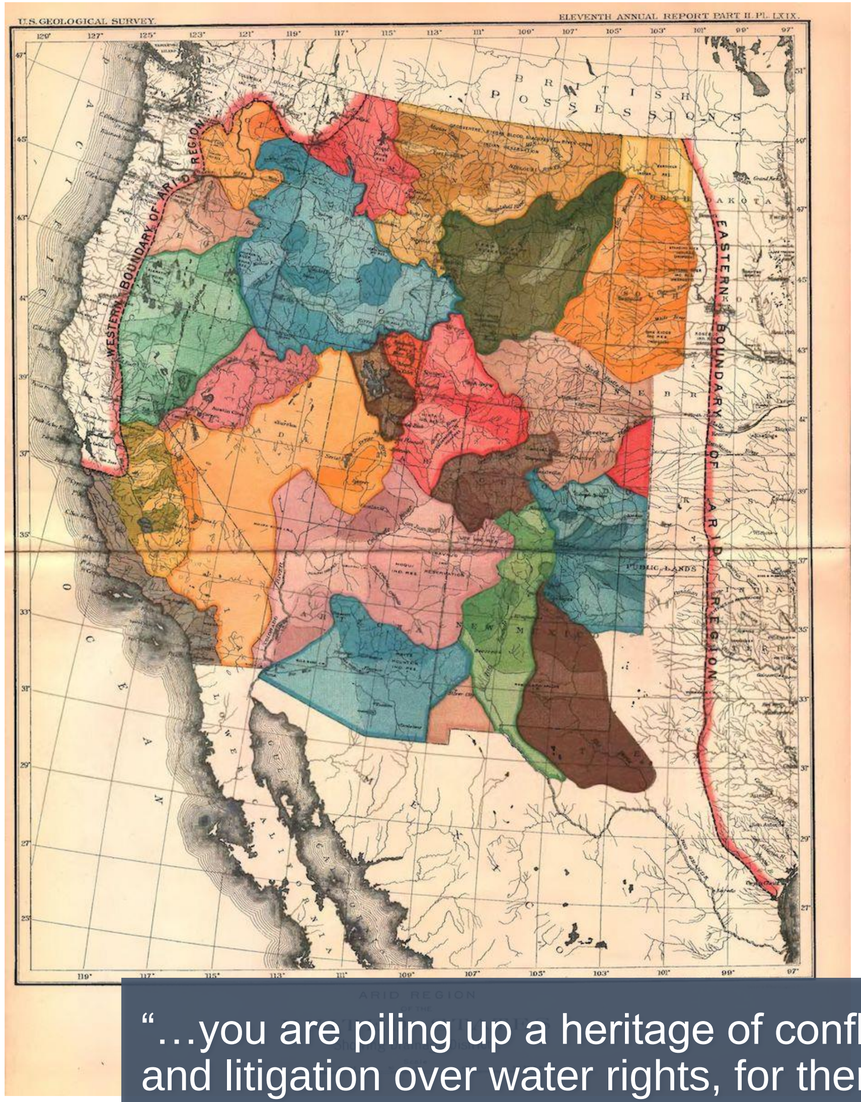
Collaborative, Interactive, Iterative







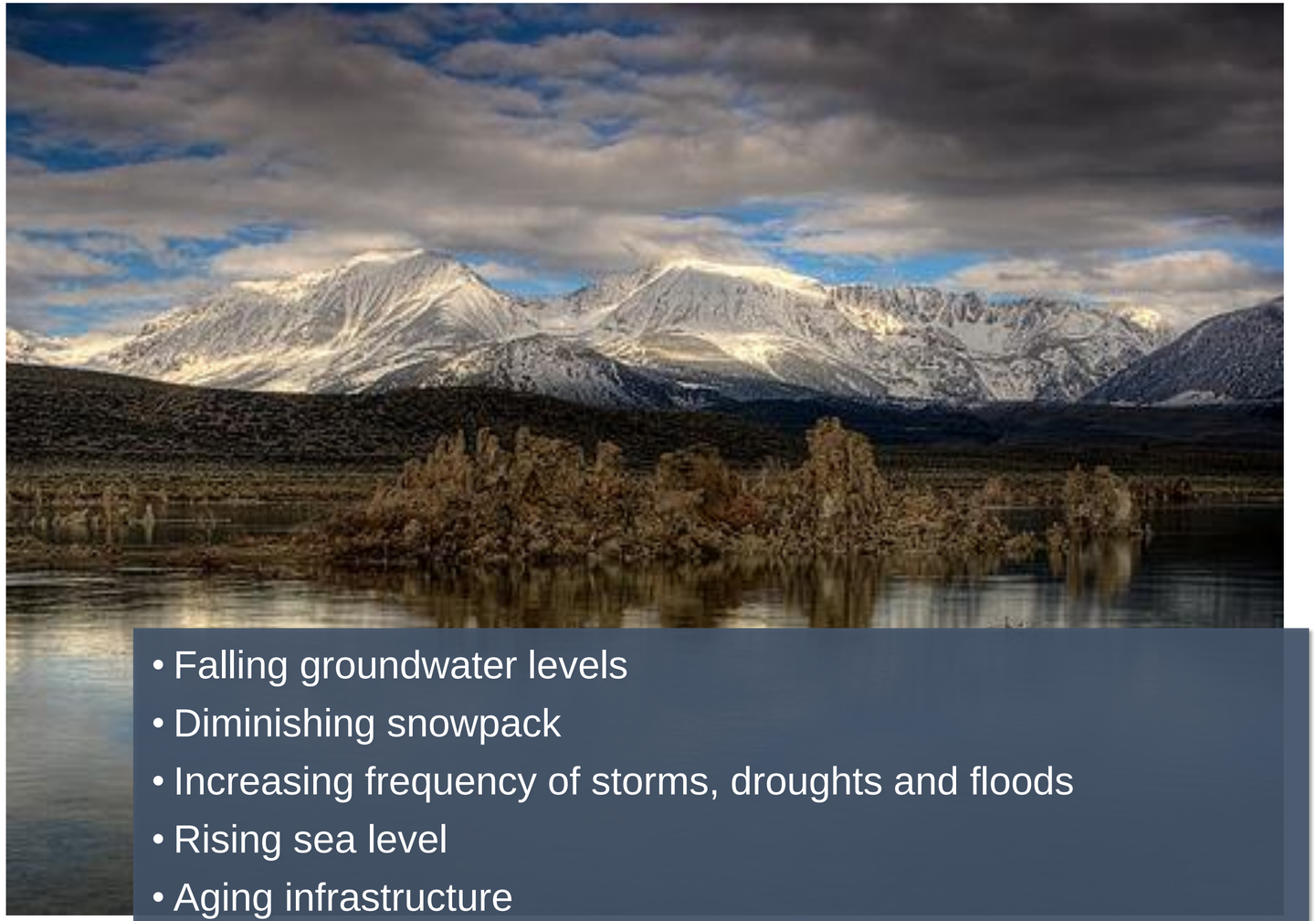
HISTORICAL COMPLEXITY



"…you are piling up a heritage of conflict and litigation over water rights, for there is not sufficient water to supply the land."

-John Wesley Powell 1883

MODERN CHALLENGES



- Falling groundwater levels
- Diminishing snowpack
- Increasing frequency of storms, droughts and floods
- Rising sea level
- Aging infrastructure
- Increased uncertainty about future water supplies
- Increasing population
- Higher air/water temperatures impacting ecosystem health

UPPER AND LOWER COLORADO RIVER BASIN

Survey and Needs Assessment represented a diverse, yet focused group of water managers keenly interested in working with NASA

- All Colorado River basin states represented.
- Broad array of needs/gaps identified for water supply, consumptive use, and drought monitoring.

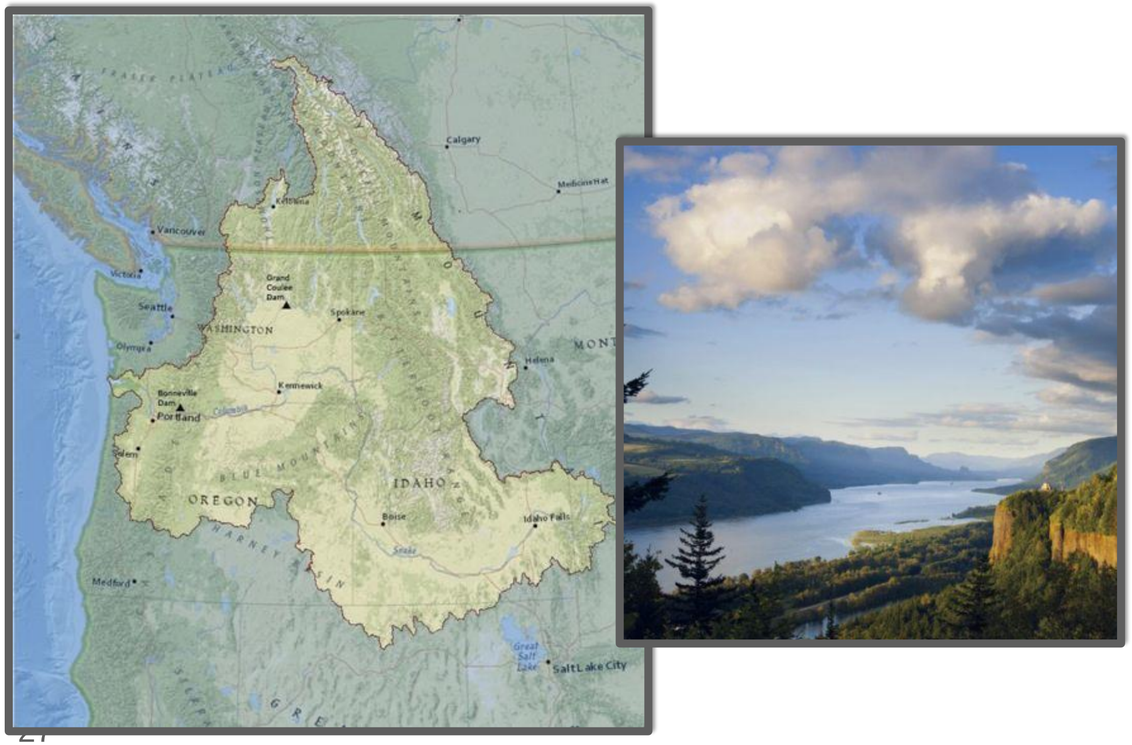
Notable Partnership Established

- Two project partner organizations engaged.
- WWAO invited to participate in the **Colorado River Hydrology Working Group (CRHWG)**
  - Cooperative organization made up of state, municipal, academic, and federal agencies representing all states in the basin.
  - Focus on mutually beneficial model improvement, new observations, science- and data-driven decisions.

COLUMBIA RIVER BASIN

Twenty-seven water managers and practitioners representing state, municipal, agricultural and federal organizations who manage water in the Columbia River Basin.

- Gaps and needs identified for water supply, watershed health, water quality, and agriculture.



Partnerships Established

- Collaboration with USDA-NRCS to evaluate the use of NASA EO in new forecast models and for quality control.
- Projects in development with state and federal agencies, NGOs including the Columbia River Inter-tribal Fish Commission (CRITFC), and academia.

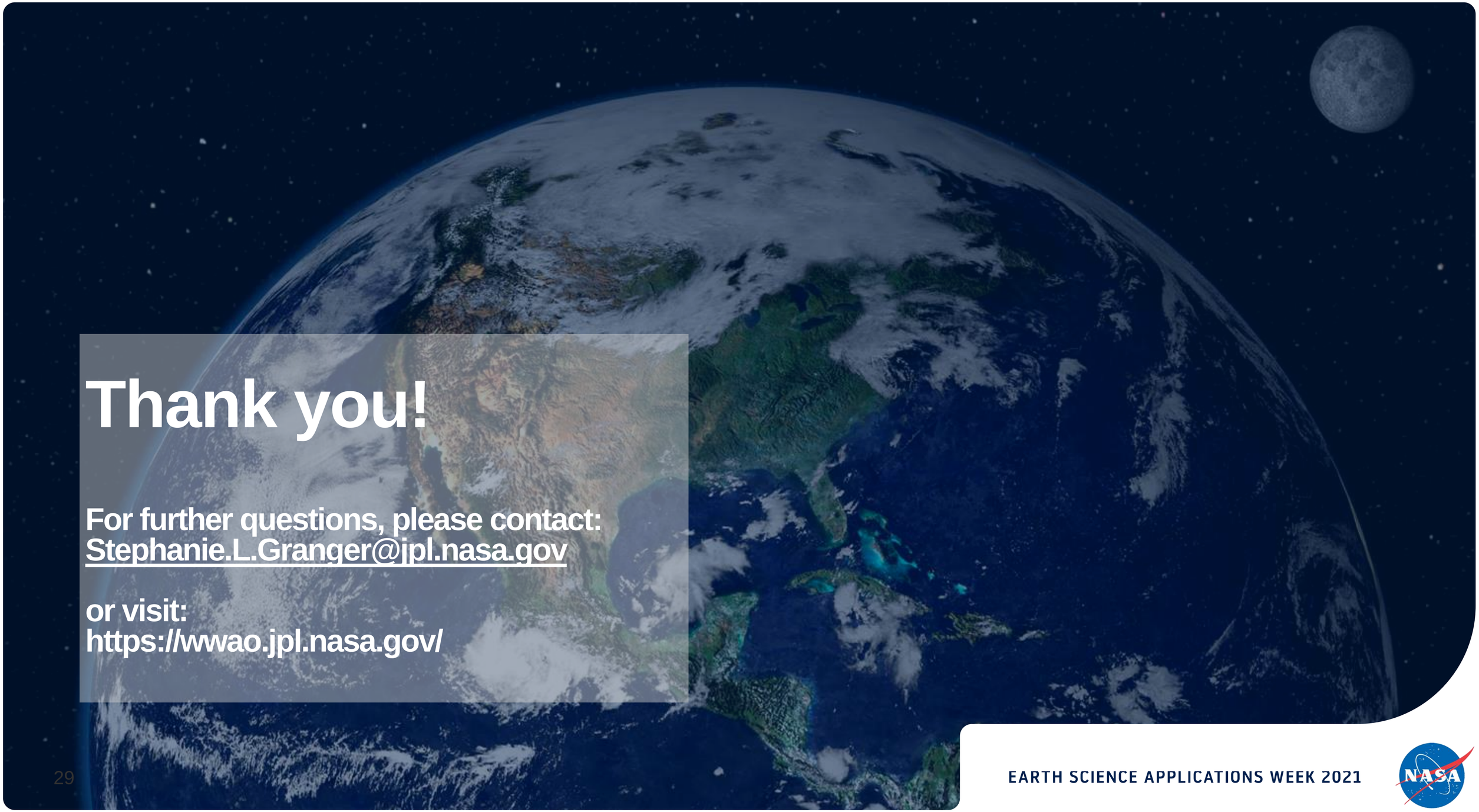
Notable Outcome

- New connections between water practitioners with common interests were made at the in-person Needs Assessment meeting.

TRUST IS KEY

"…the most important keys to success have proven to be **strong relationships, well understood mutual goals, and deep trust** between NASA and the water management community. WWAO has sought to promote these principles in all the work it does.",

- *Indrani Graczyk, WWAO Manager*



Thank you!

For further questions, please contact:
Stephanie.L.Granger@jpl.nasa.gov

or visit:
https://wwao.jpl.nasa.gov/

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Use of Modeling and Remote Sensing to Study the Water Cycle

Venkataraman Lakshmi
Prakrut Kansara
University of Virginia

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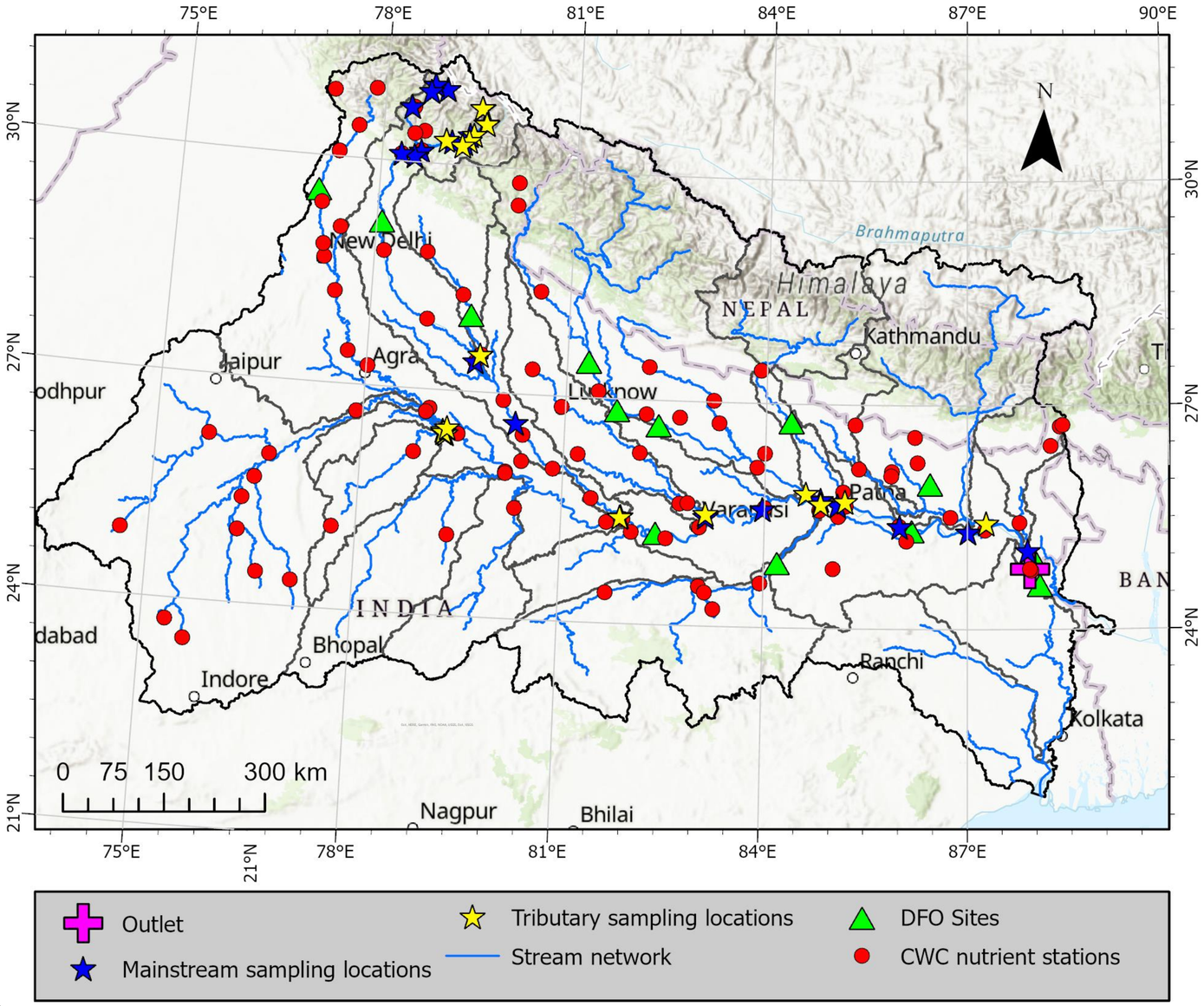
Statement of the Problem

In most developing countries of the world, the lack of observations of streamflow and precipitation necessitates use of satellite data. In-situ data may not be collected/publicly-available and/or of poor-quality

- Impact of land use and land cover change on streamflow and nutrients
- Use of hydrological modeling for determining impact of climate change
- Changes in water quality of lakes and rivers that impact drinking water and aquatic life
- Tradeoff between use of water for agriculture and hydropower

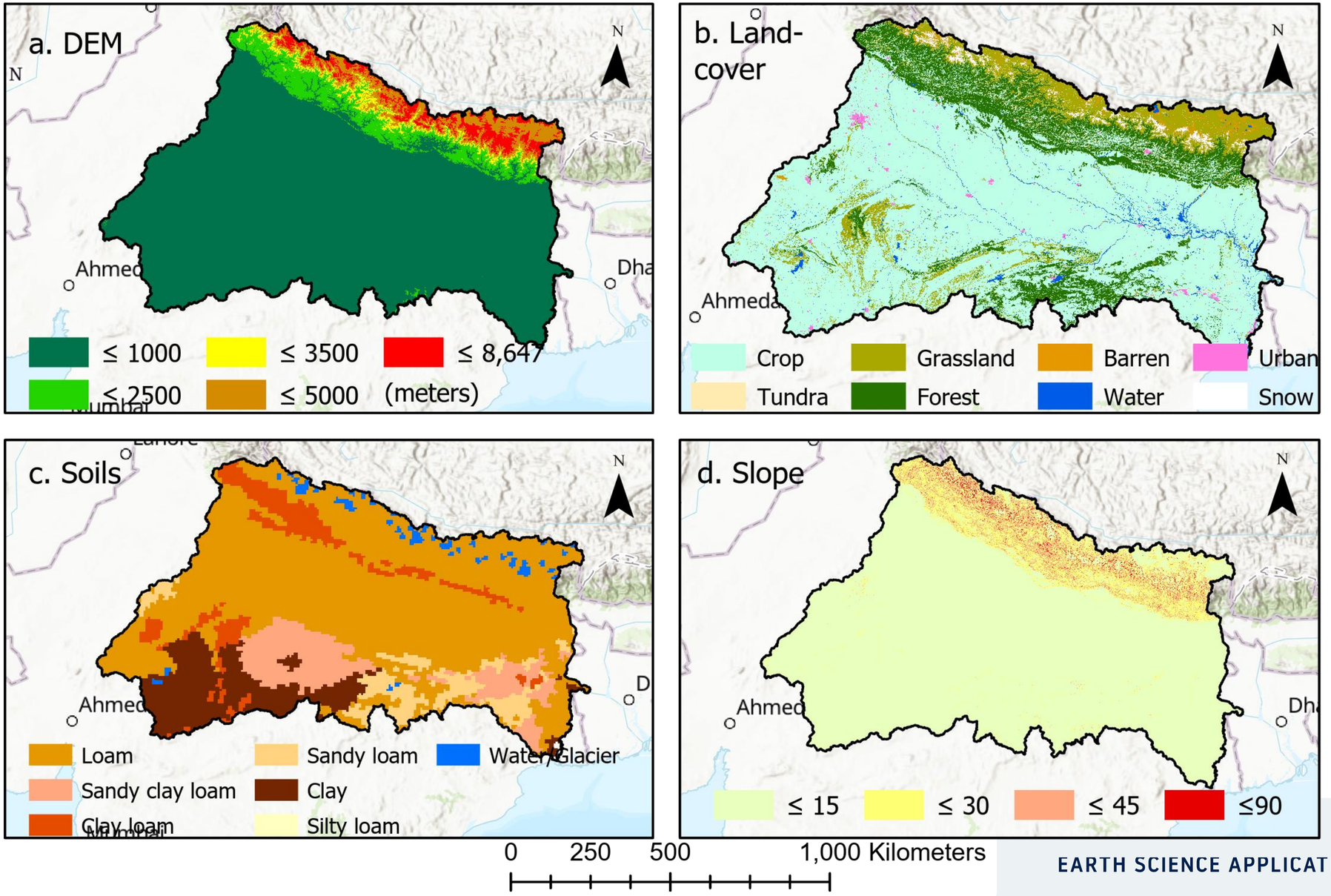
Streamflow and nutrients in the Ganga River Basin

Ganga River Basin

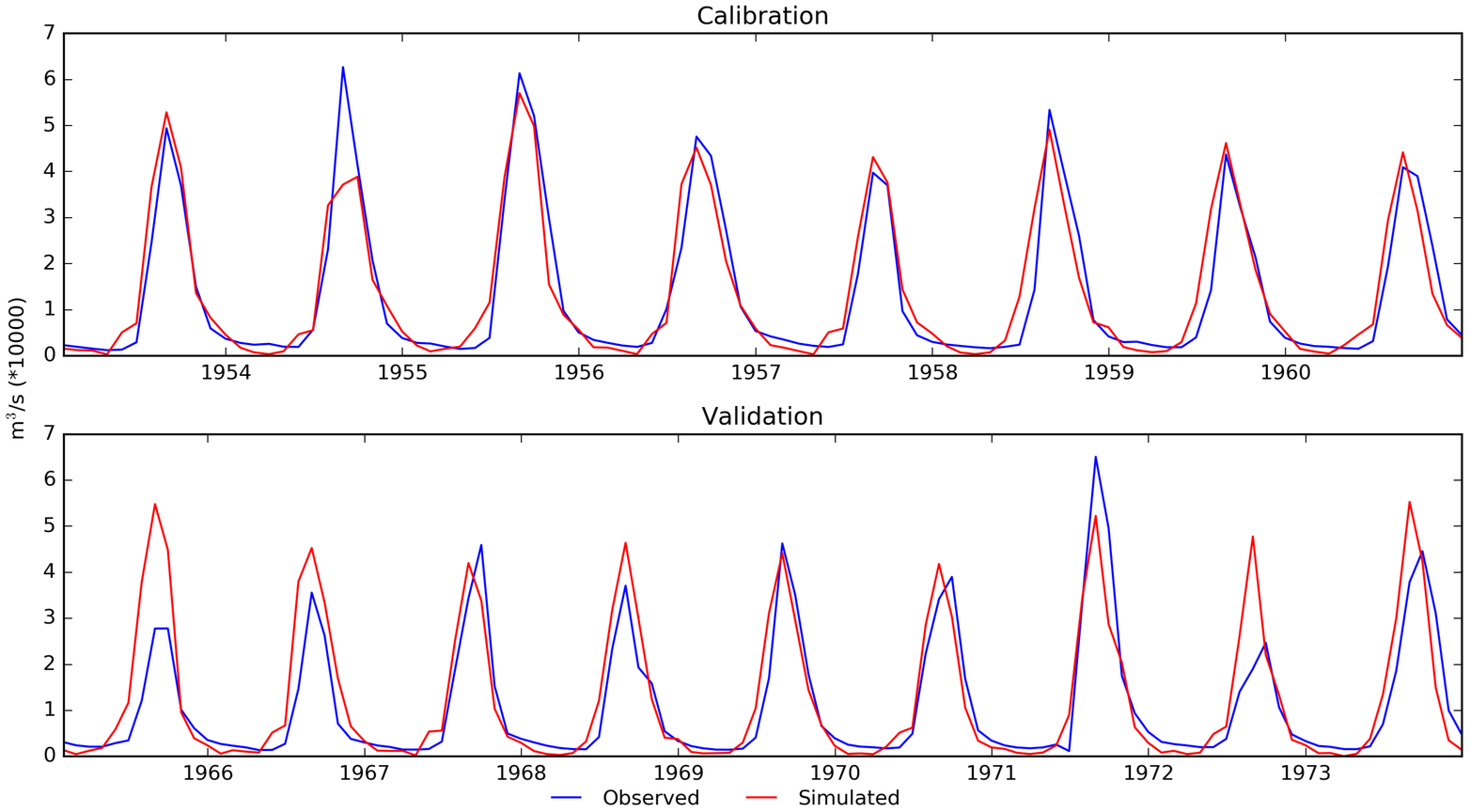


- 2,525 km long perennial river
- 1.08 million km^2
- Lifeline for one-third of the Indian population
- 100 gauging stations (Central Water Commission – CWC, India)
- 38 nutrient sampling locations
- 13 Dartmouth Flood Observatory (DFO) discharge sites

Watershed Characteristics



Streamflow Calibration and Validation - Farakka



The Soil Water Assessment Tool (SWAT) model for Ganga River Basin was calibrated and validated for streamflow using observed data from Central Water Commission (CWC) of India at Farakka, West Bengal (Lon: 88.027; Lat: 24.964).

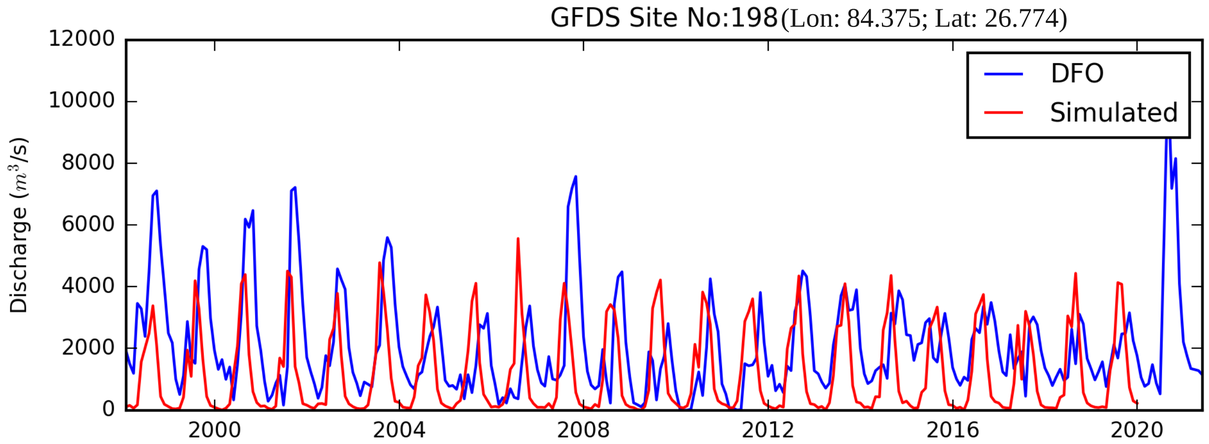
Calibration:

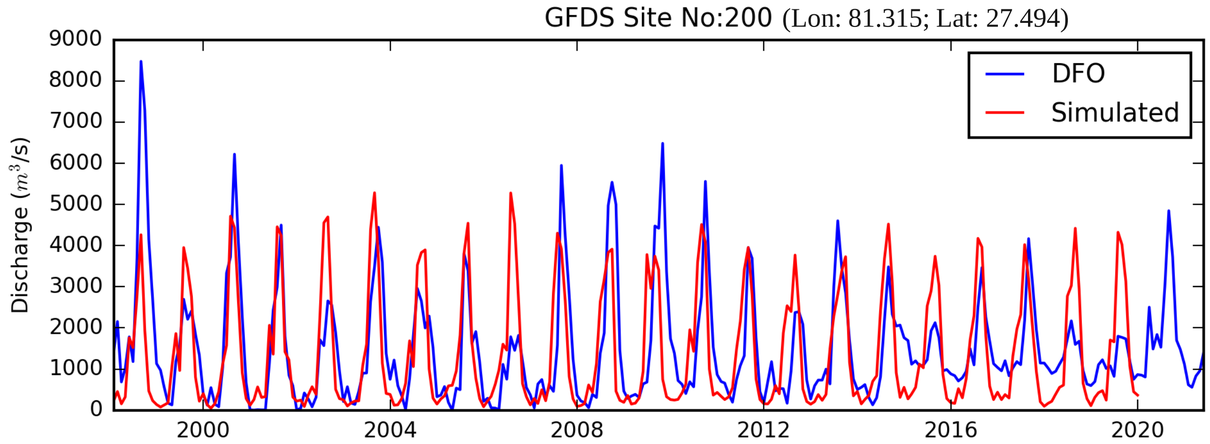
R^2 = 0.88, NSE = 0.88

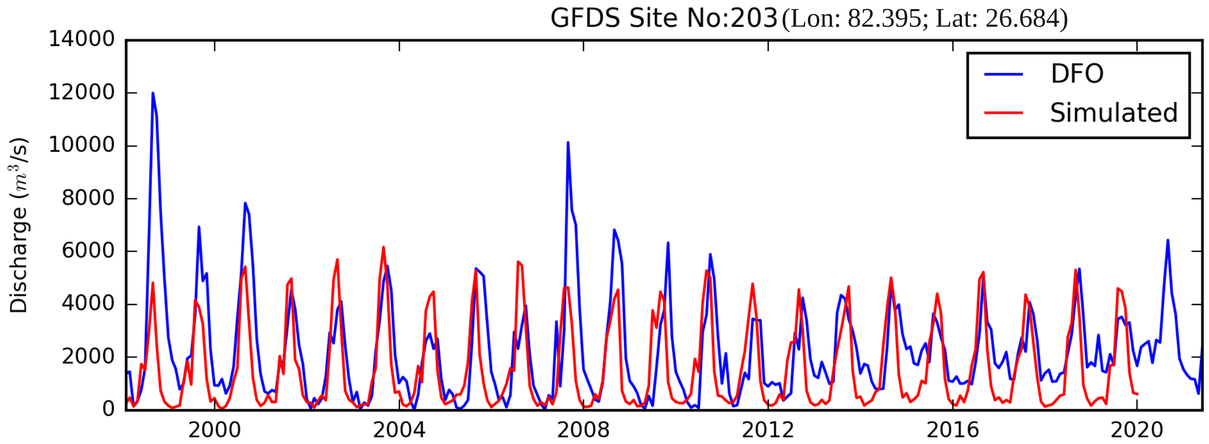
Validation:

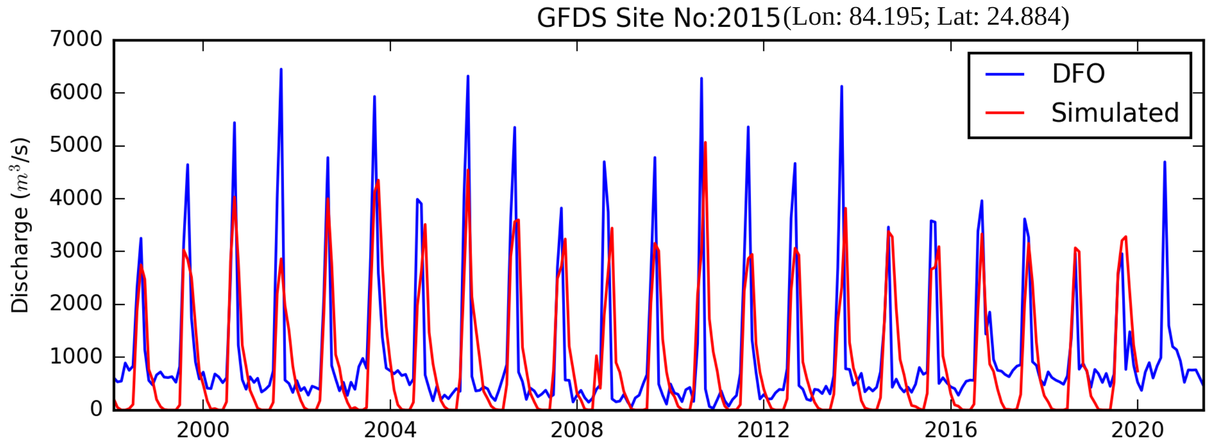
R^2 = 0.77, NSE = 0.68

Verification with Dartmouth Flood Observatory Data



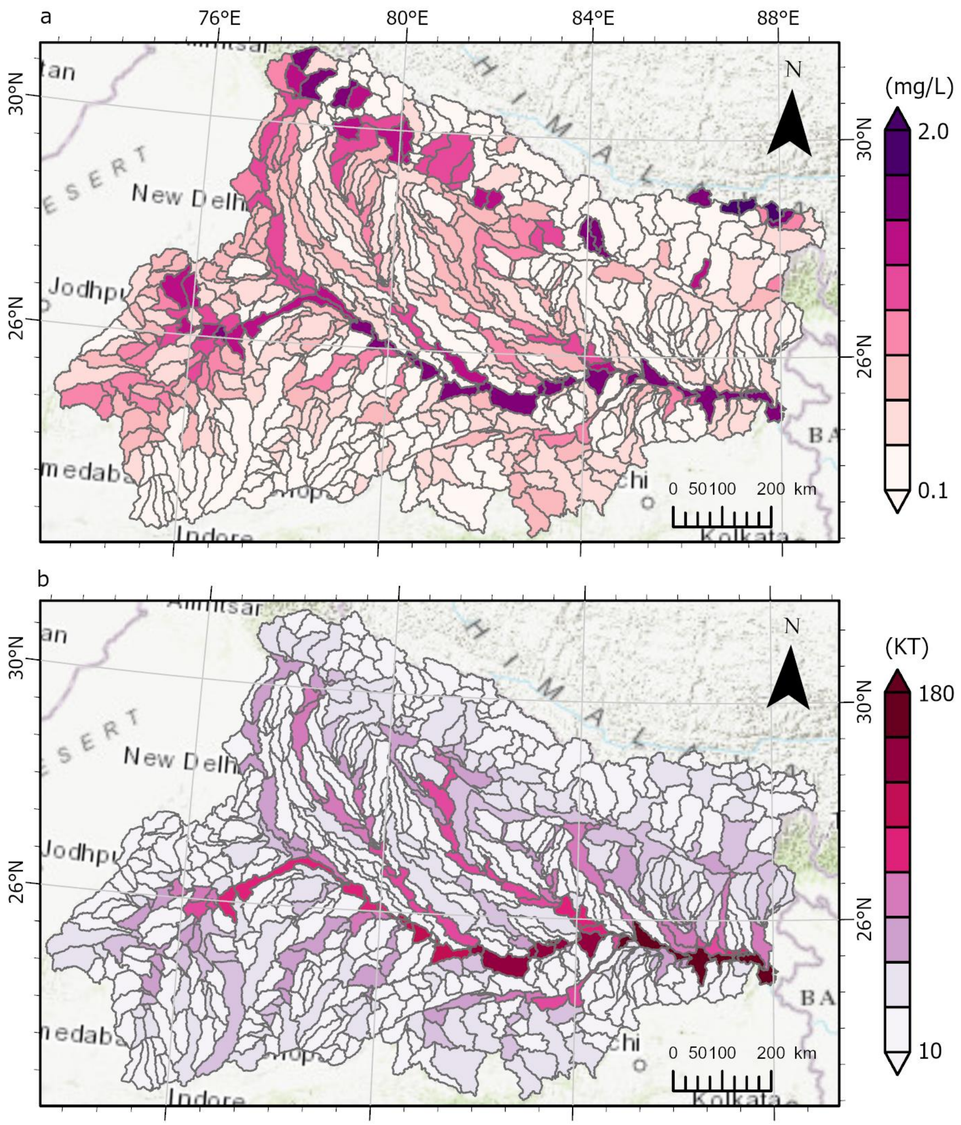


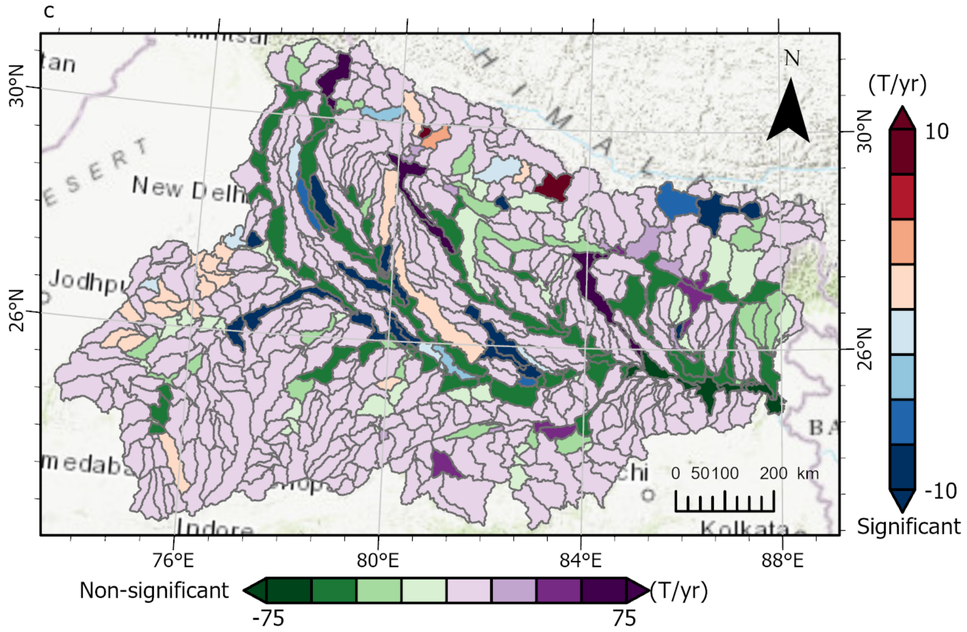




Simulated streamflow was compared to the Dartmouth Flood Observatory(DFO) data: https://floodobservatory.colorado.edu/.
The discharge data was downloaded from the Global Flood Detection System (GFDS) on the DFO website.

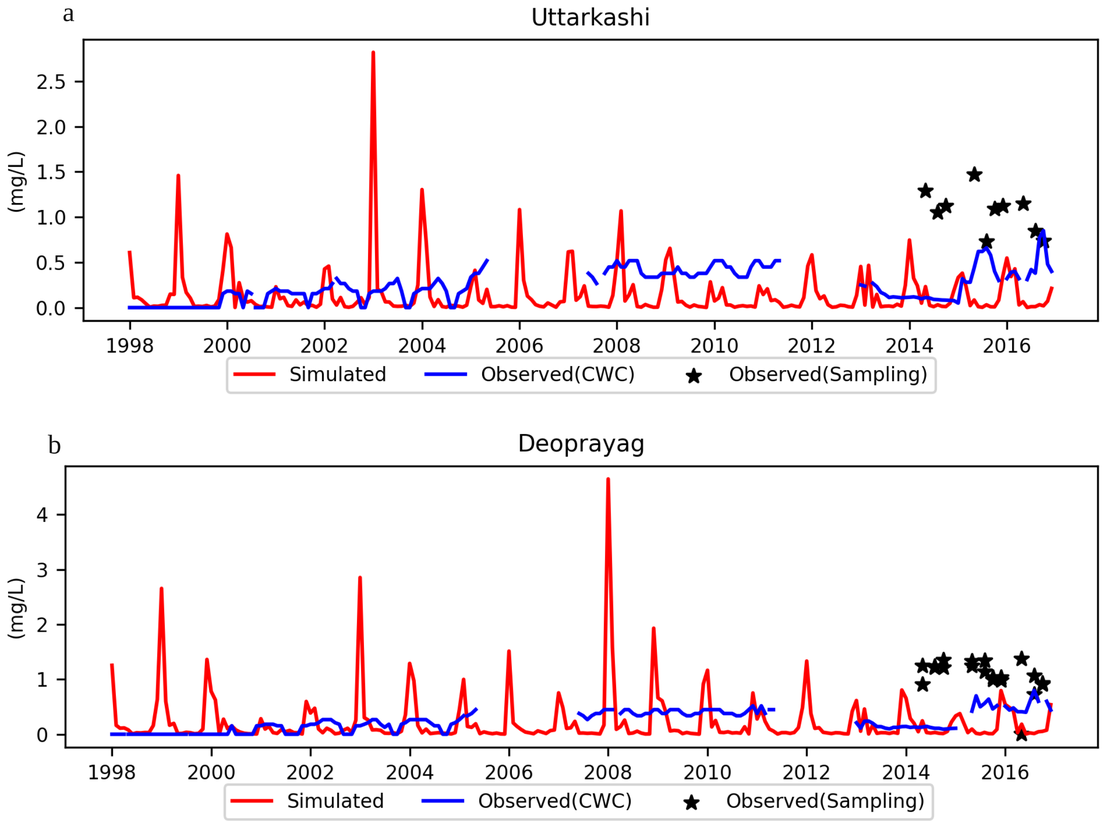
Monsoonal Spatial Variation – (Nitrite and Nitrate)

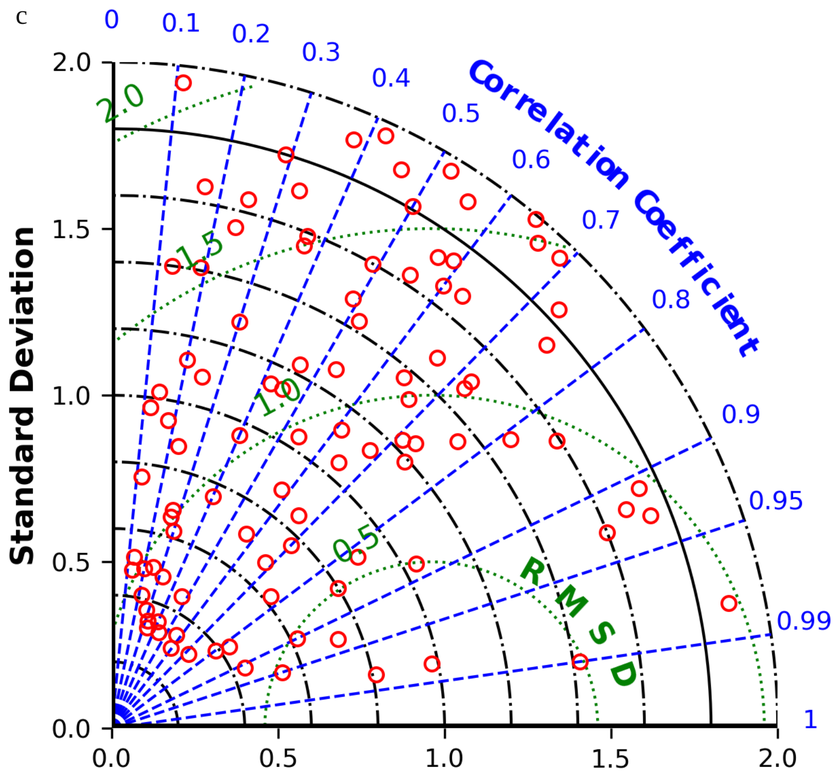




'a' shows the average monsoonal (Nitrite and Nitrate) concentration from 1998-2016. 'b' shows the average monsoonal (Nitrite and Nitrate) flux from 1998-2016. 'c' shows the Sen's slope obtained from Seasonal Mann-Kendall trend test for (Nitrite and Nitrate) from 1998-2016.

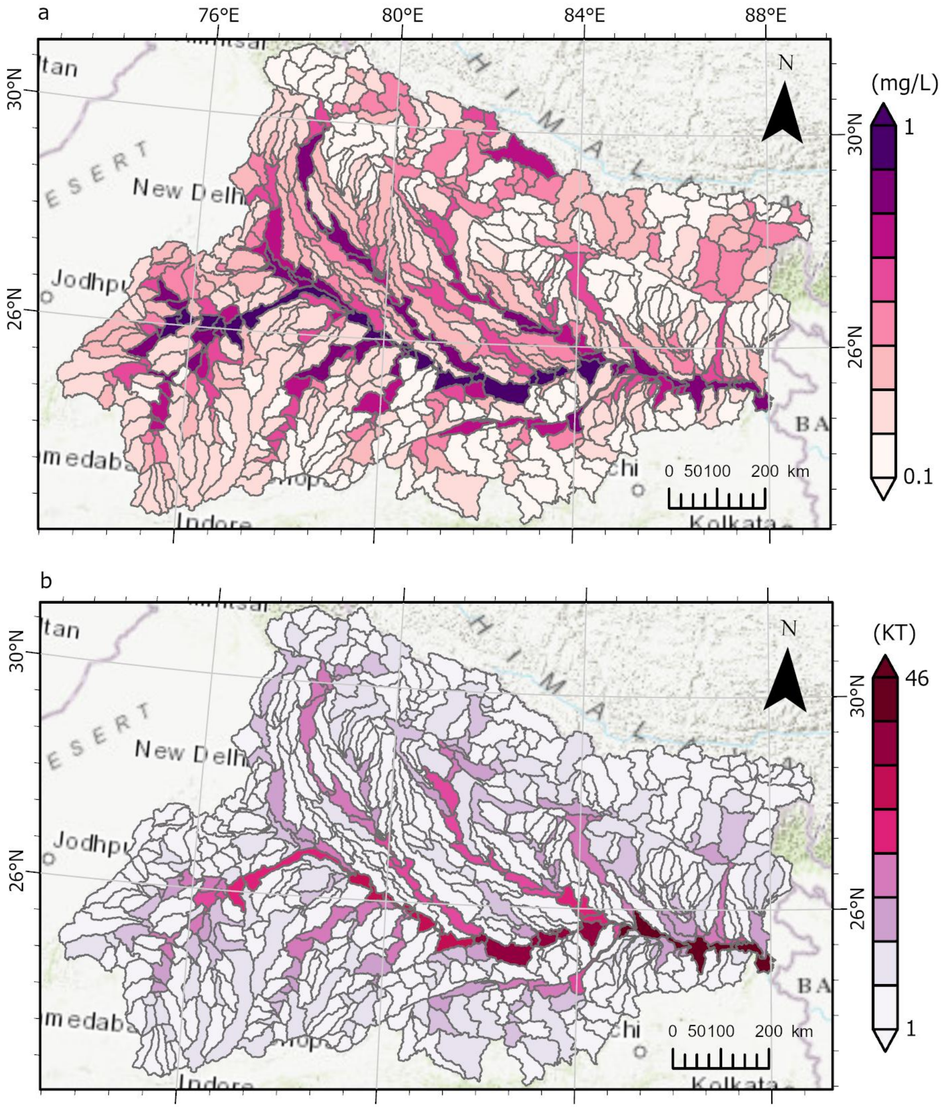
Temporal Variation – (Nitrite and Nitrate)

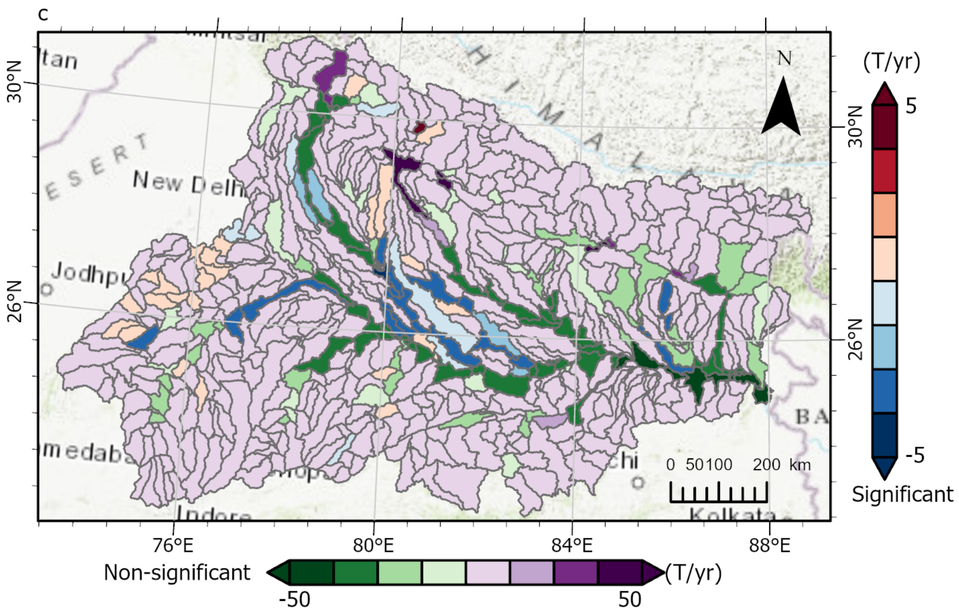




'a' and 'b' show the time series plots for (Nitrite and Nitrate) concentration from 1998-2016. Simulated output from SWAT model was compared with observed nutrient data from CWC as well as from the sampling conducted during this study. 'c' shows the Taylor diagram for 100 CWC nutrient gauge stations.

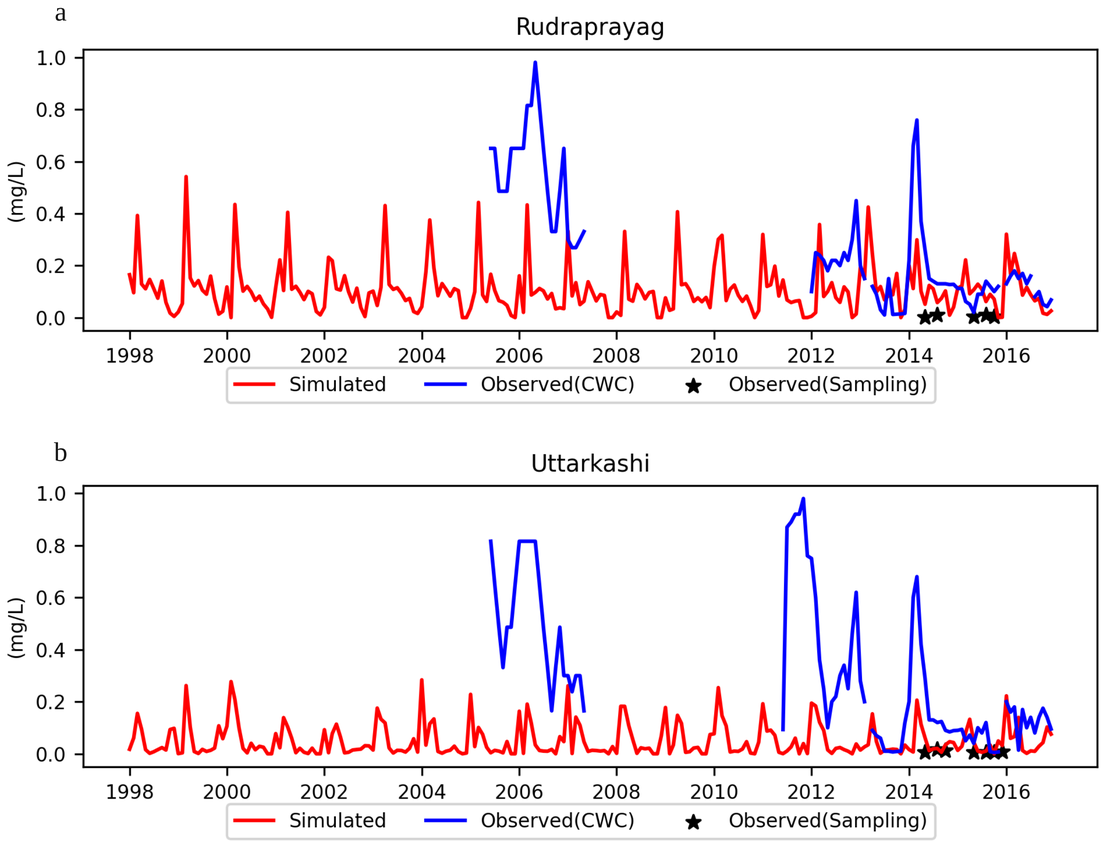
Monsoonal Spatial Variation – (Phosphate)

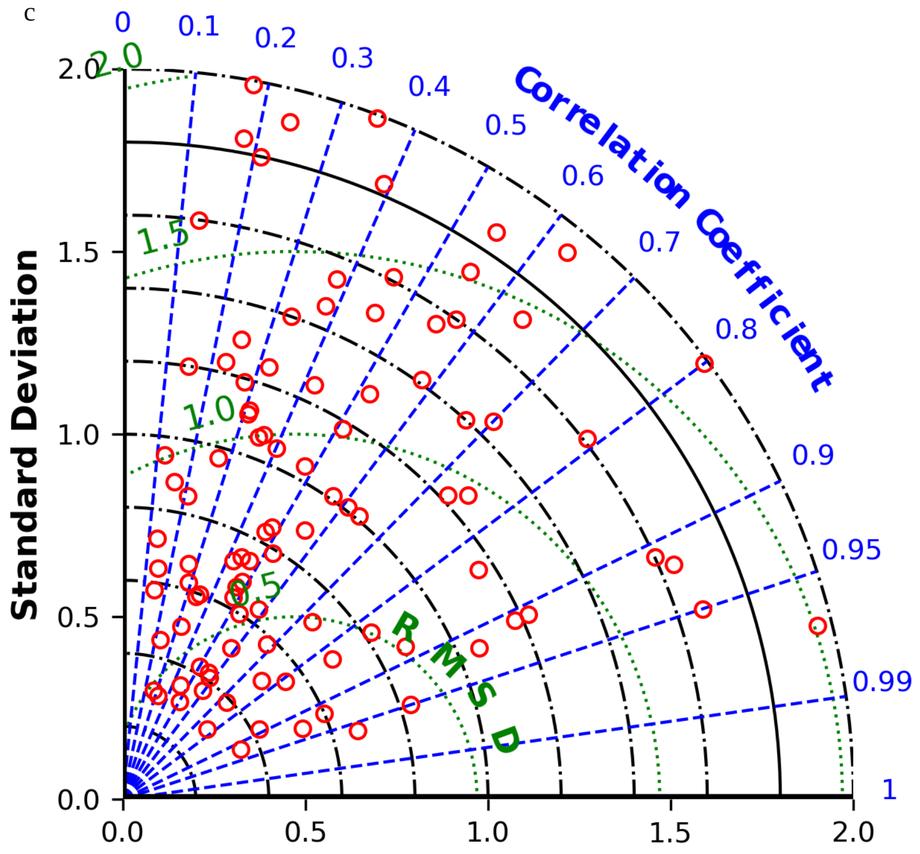




'a' shows the average monsoonal phosphate concentration from 1998-2016. 'b' shows the average monsoonal phosphate flux from 1998-2016. 'c' shows the Sen's slope obtained from Seasonal Mann-Kendall trend test for Phosphate from 1998-2016.

Temporal Variation – (Phosphate)





‘a’ and ‘b’ show the time series plots for phosphate concentration from 1998-2016. Simulated output from SWAT model was compared with observed nutrient data from CWC as well as from the sampling conducted during this study. ‘c’ shows the Taylor diagram for 100 CWC nutrient gauge stations.

Conclusions

- The combination of satellite data for precipitation and land use along with a hydrological model is able to simulate flow and nutrient transport in data sparse regions
- The same setup can be used to examine land use and/or climate change
- This can be used by managers to set policy for irrigation, application of nutrients and other water use, specifically in periods of low flows
- Policies can be set for use of water in different sectors, viz., agriculture, industrial, hydropower and domestic usage

Funding for this study was provided by NASA Applied Sciences, Water Resources: Program Manager Brad Doorn, Associate Program Manager – John Bolten

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Co-Production of Water Management Tools in Navajoland

Dr. Amber McCullum

EARTH SCIENCE APPLICATIONS WEEK 2021

Connecting space to water, land, and culture

- Partner-driven tools start with relationships
- Co-development is key
  - Cultural context of relationship to land
  - Preexisting knowledge systems
- Continued use through capacity building

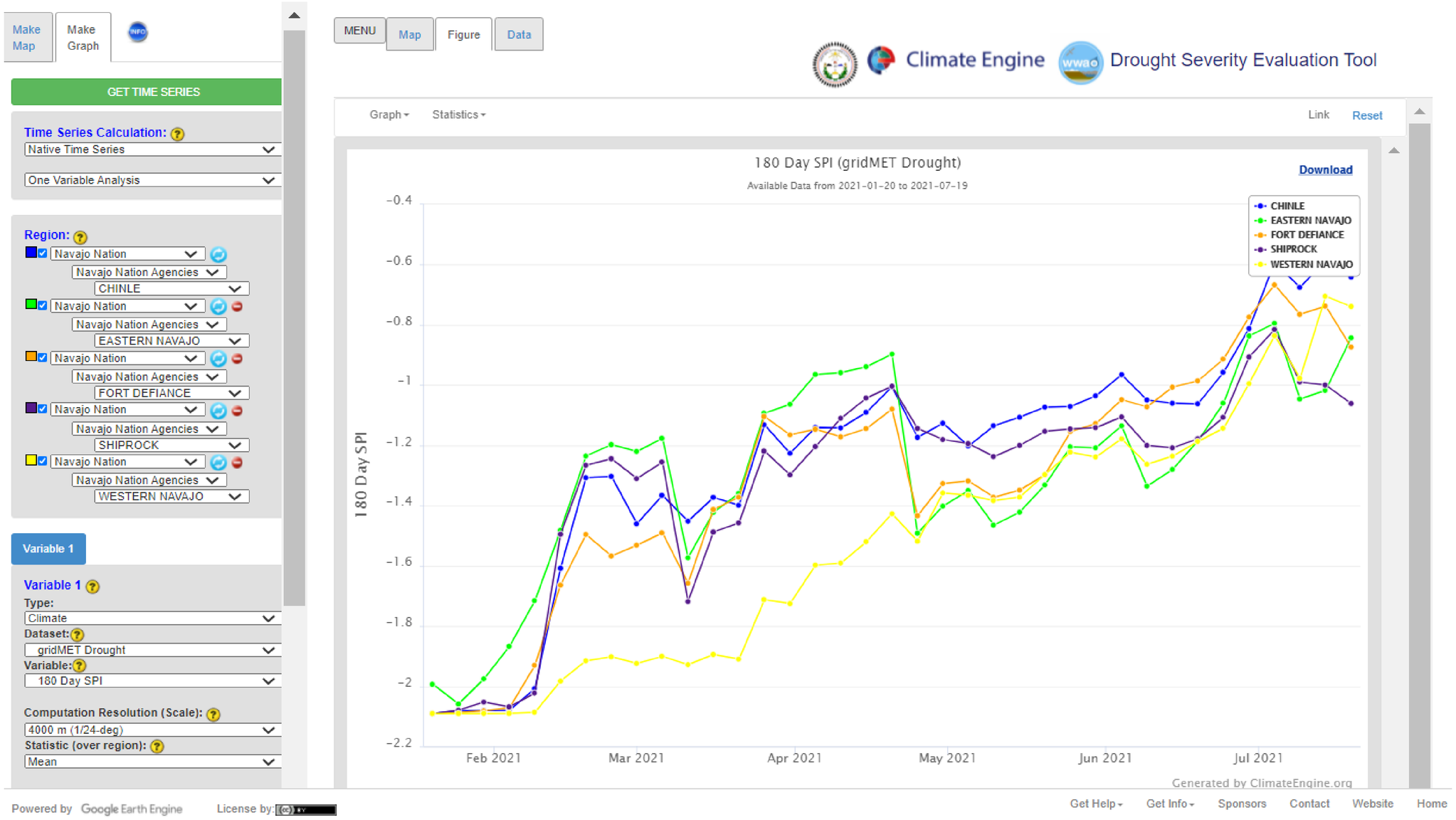
Drought Severity Evaluation Tool

Project Team:
Amber McCullum (BAERI/NASA Ames Research Center)
Carlee McClellan (NN DWR)
Justin Huntington (DRI)
Britta Daudert (DRI)
Nikki Tulley (University of Arizona/BAERI)
Krystal Sanchez-Castaneda (San Jose State University/BAERI)

A collaboration of Sovereignty and Science for the Navajo Nation

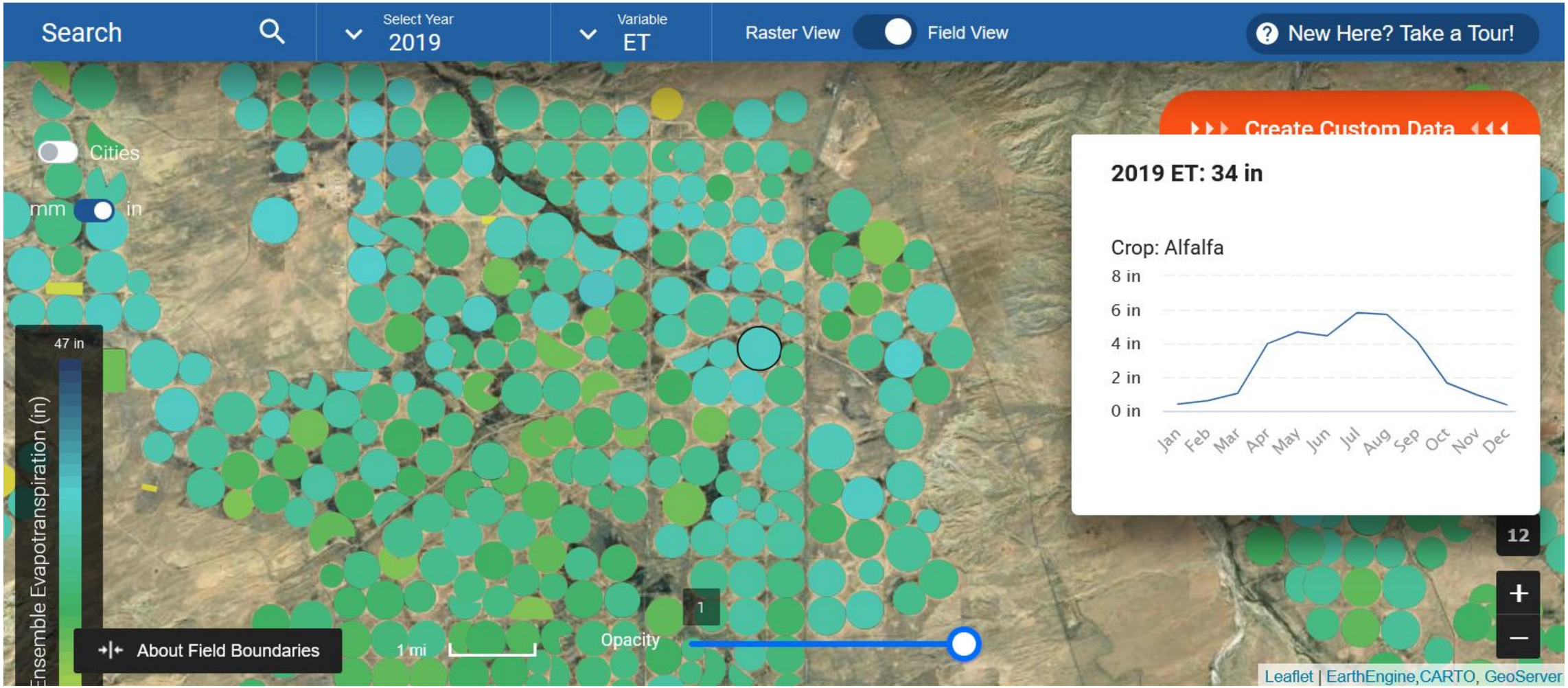
DSET Overview

- Free Web Application
- User Friendly
- Time & Storage Saver
- Analyzing & Visualizing Data made easier



DSET: https://app.climateengine.org/dset

OPENET



OpenET: openetdata.org

Thank you

Amber McCullum
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PANEL DISCUSSION

Moderator

Dr. John Bolten

NASA Goddard

Panelist

Stephanie Granger

WWAO / Jet Propulsion Laboratory

Panelist

Dr. Venkat Lakshmi

University of Virginia

Panelist

Dr. Amber McCullum

WWAO / ARSET

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Jobos Bay Water Resources

Using Earth Observations to Analyze Shoreline Changes and Understand the Effects of Sea Level Rise in Southern Puerto Rico

Ethan McGhee*, Milton Muñoz-Hincapié (Jobos Bay National Estuarine Research Reserve)*, Olivia Spencer, Liliana Hernandez Gonzalez, Taylor Conklin, & Andrew Altizer

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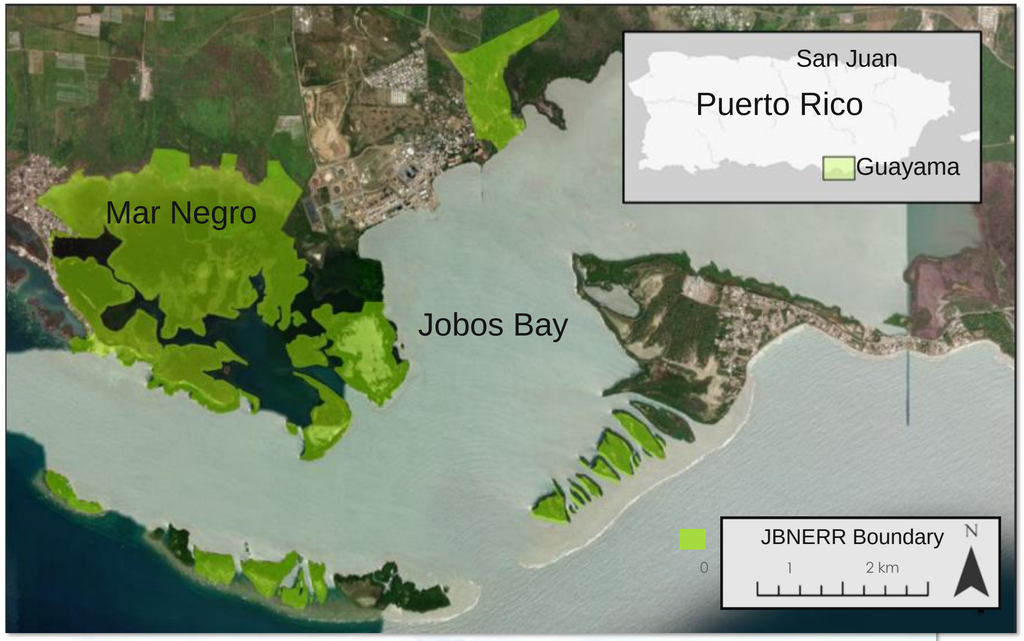
What Is The Issue?



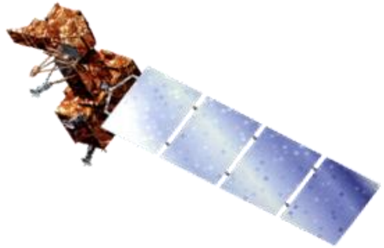
- Puerto Rico is exposed to an **active hurricane season**, threatening **natural resources**
- **Anthropogenic growth** near the Jobos Bay watershed impacts **water quality** in the estuary
- **Cutting of mangrove forests** increases risk of **erosion** during storm events
- **Drinking water** could potentially be **contaminated by salt-water intrusion as sea level rises**

Jobos Bay National Estuarine Research Reserve (JBNERR)

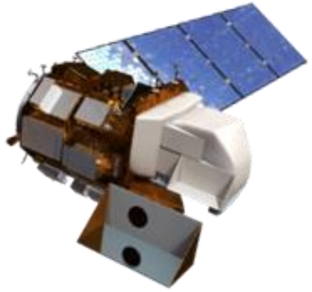
Image Credit: JBNERR

Methods

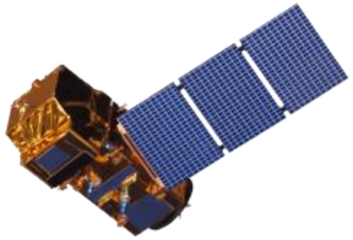
Landsat 5 Thematic Mapper (TM)



Landsat 7 Enhanced Thematic Mapper (ETM+)



Landsat 8 Operational Land Imager (OLI)



Sentinel-2 Multispectral Instrument (MSI)

Project Objectives

Observe **coastal change** over time

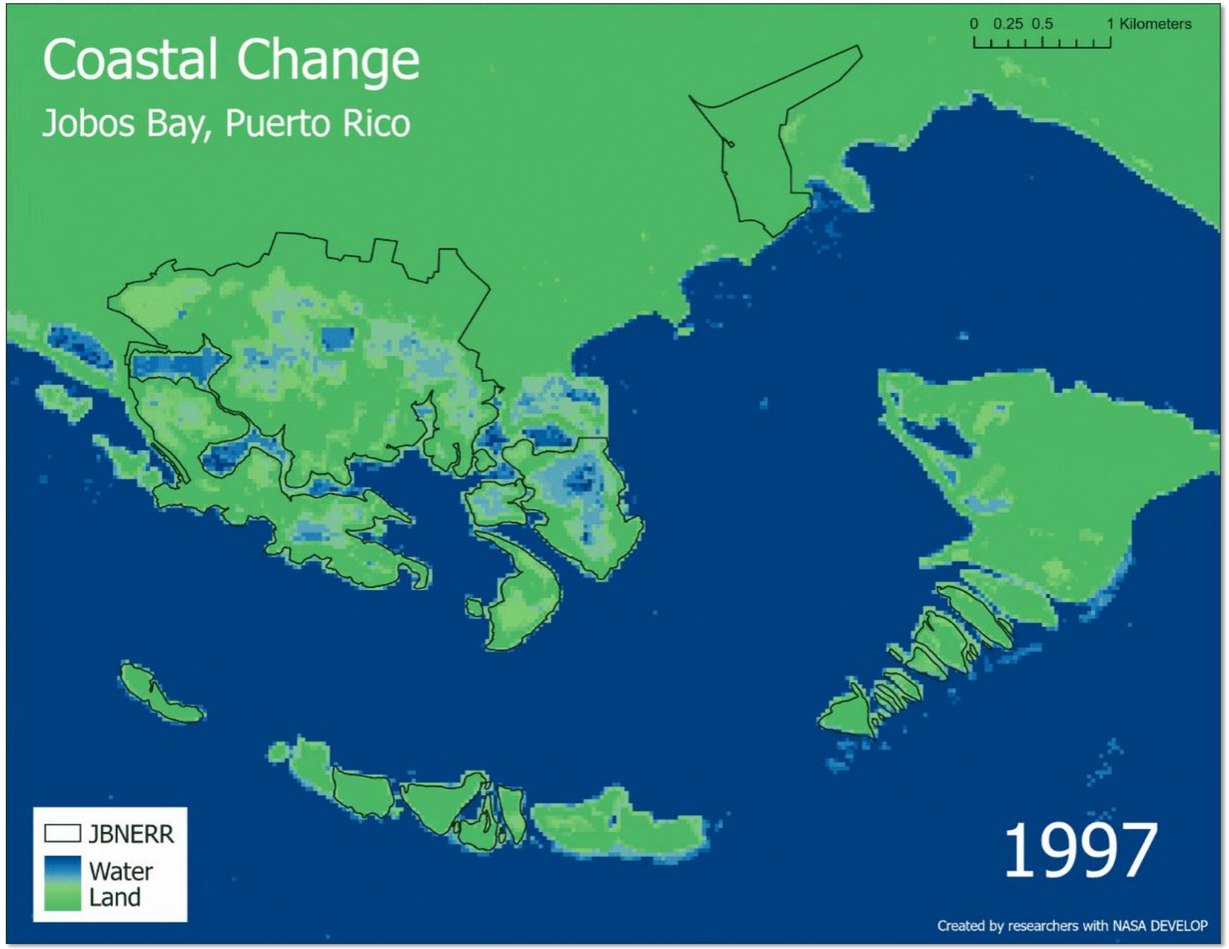
Create high-res **LULC analysis**

Image Credit: JBNERR

Evaluate **water quality parameters**

Highlight **mangrove forest extent** over time

Results

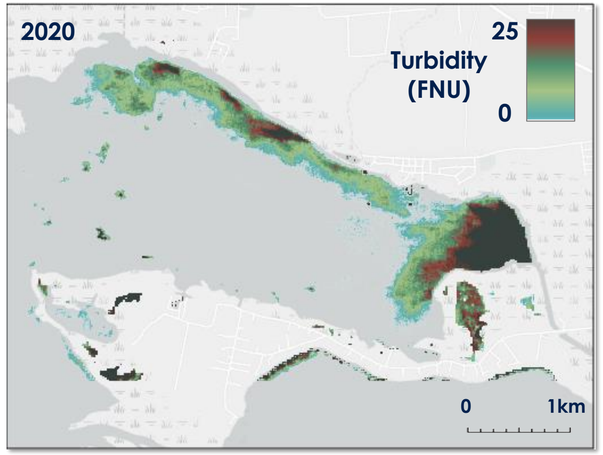


1. 17% of the reserve experienced a major shift towards **water**

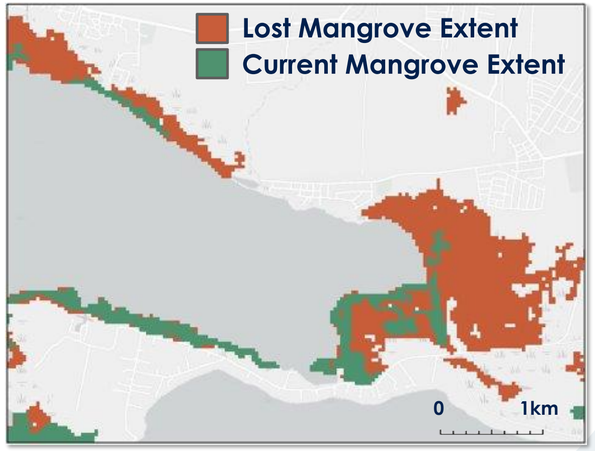
2. Shifts in turbidity and CDOM water parameters, particularly in NE inlet

3. 55% **loss** in mangrove extent from 2010 to 2020 (retaining only 4 km^2)

Turbidity

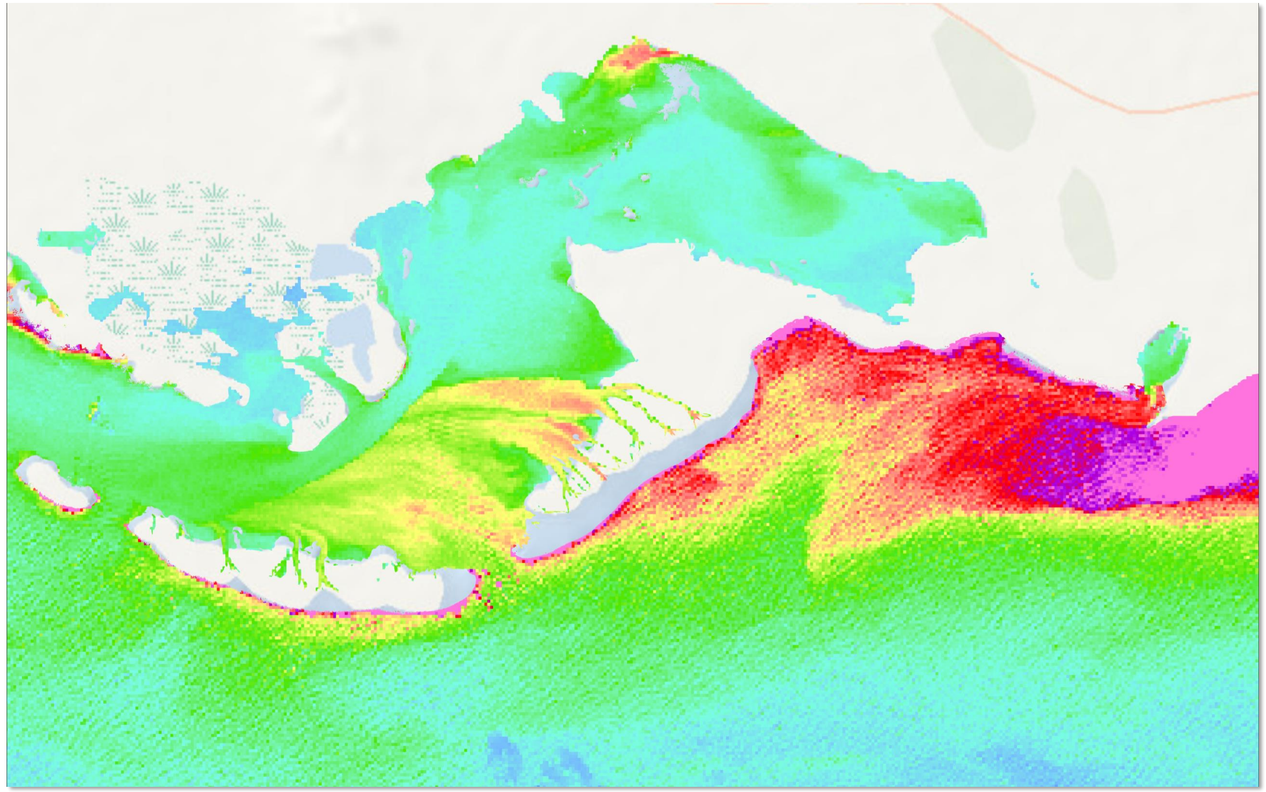


Mangrove Extent



Project Impact

Turbidity Visualization: 2017 Wet Season (Apr-Oct) Median



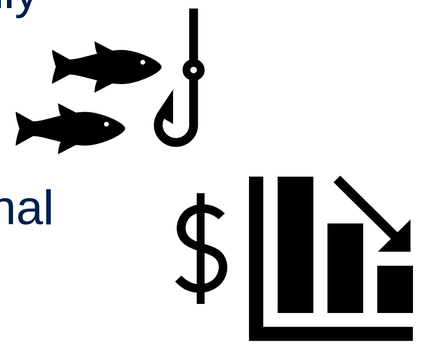
Major Event: Hurricane Maria (Sep 2017)

Ecological Significance

- 2,883 acres of protected area
- Home to endangered species

Economic Significance

- Jobos Bay is commercially important for:
  - Marine recreation
  - Commercial/recreational fishing
  - Ecotourism



Moving Forward

- Partners can use DEVELOP end products to inform their community

Acknowledgments

Team Members:

- Olivia Spencer (Team Lead)
- Dr. Lilana Hernandez Gonzalez
- Andrew Altizer
- Taylor Conklin
- Ethan McGhee

Partners at JBNERR

- Aitza E. Pabón Valentín (Director)
- Angel Dieppa (Research and Monitoring Coordinator)
- Milton Muñoz Hincapié (Stewardship Coordinator)

Science Advisors:

- Dr. Kenton Ross (DEVELOP Lead Science Advisor)
- Dr. Juan Torres-Perez (NASA Ames Research Center)
- Adriana Le Compte (LaRC Fellow)
- Lauren Childs-Gleason (DEVELOP Science Manager)

Additional thanks to Hayley Pippin (DEVELOP Senior Fellow) and Egla Ochoa-Madrid (LaRC Assistant Fellow).

Image Credit: JBNERR

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THANK YOU!

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