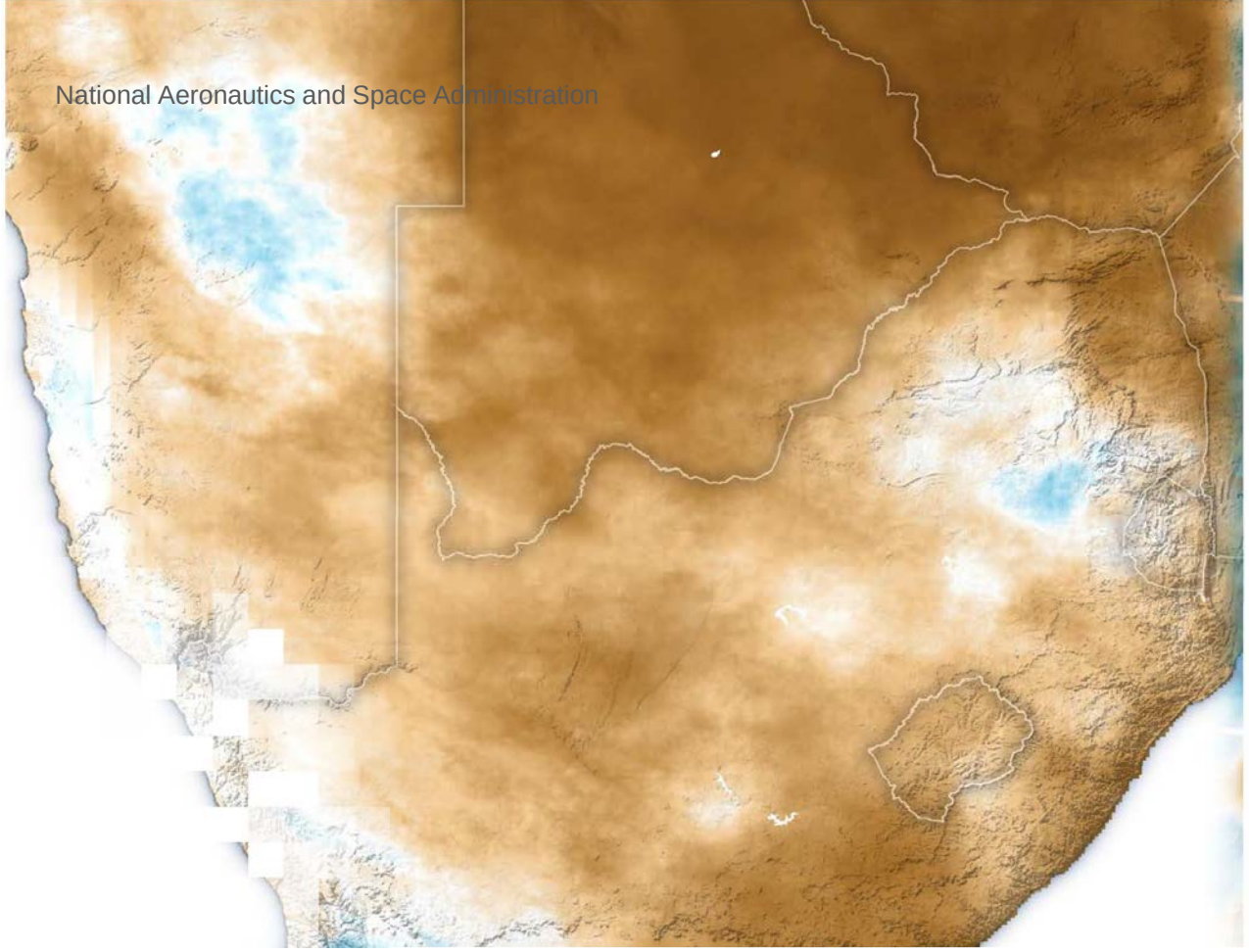
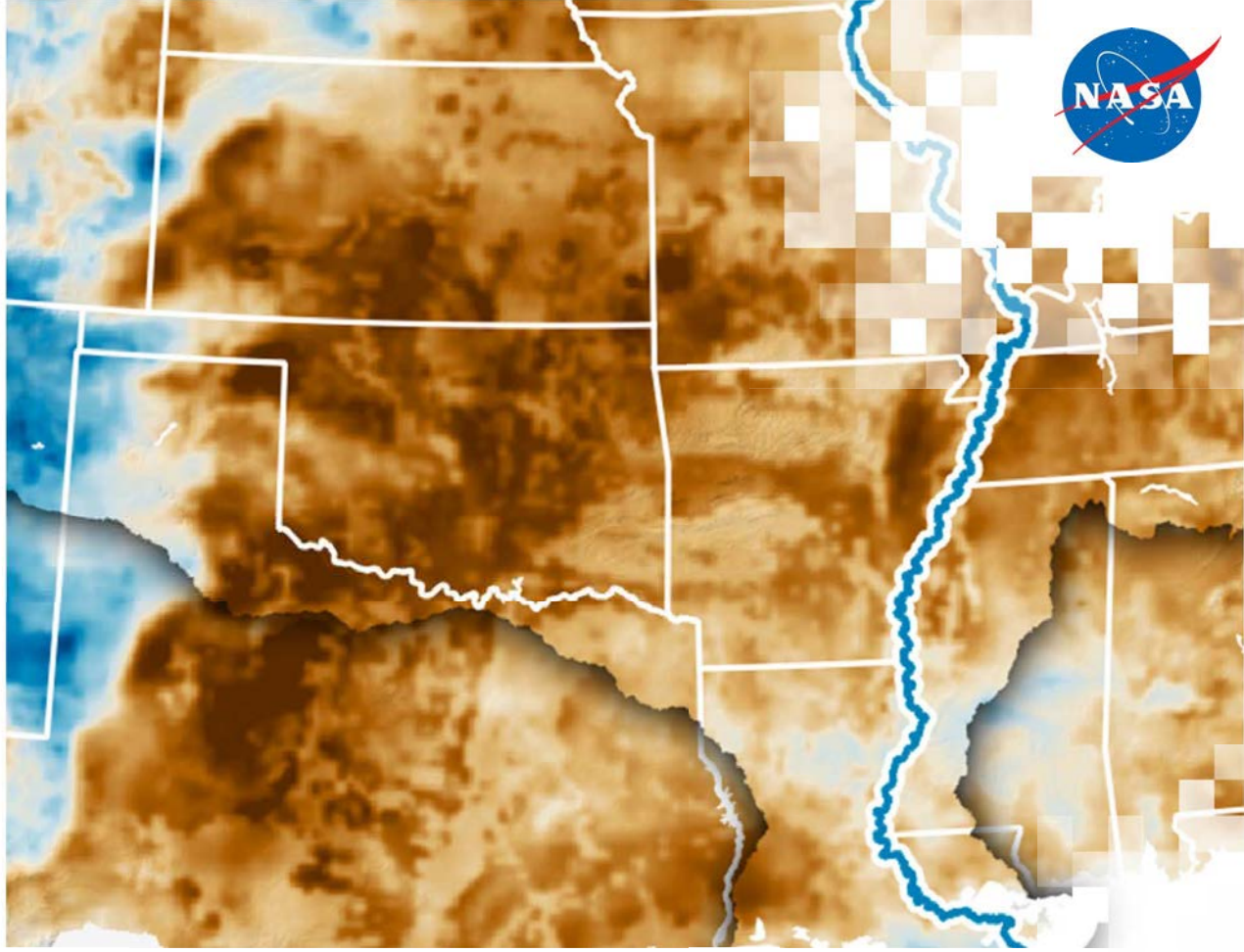




Drought Monitoring, Prediction, and Projection using NASA Earth System Data

Part 4: Regional Drought Monitoring Tools

ARSET Host: Amita Mehta (NASA GSFC) **ARSET Instructor**: Erika Podest (NASA JPL)
Guest Speakers: Amber Jean McCullum (NASA AMES); Reetam Majumder (NCSU)

1 August 2024

Training Outline

Part 1
Overview of Drought Monitoring Data and Tools using Earth Observations

July 23, 2024

Part 2
Drought Prediction using NASA Sub-seasonal to Seasonal (S2S) Predictions

July 25, 2024

Part 3
Climate Change Projections and Droughts

July 30, 2024

Part 4
Demonstration of Regional Drought Monitoring Tools

August 1, 2024

Homework

Opens August 1 – Due August 15 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Part 4 Objectives

- Identify regional drought projects with NASA's Western Water Applications Office.
- Explore how the WWAO-developed Navajo Nation Drought Severity Evaluation Tool (DSET) is used to calculate drought metrics and vegetation health anomalies.
- Explore Sustainable Forest Management and Information System (SFMIS) using Jupyter Notebook to assess impact of drought on forest cover change.

How to Ask Questions

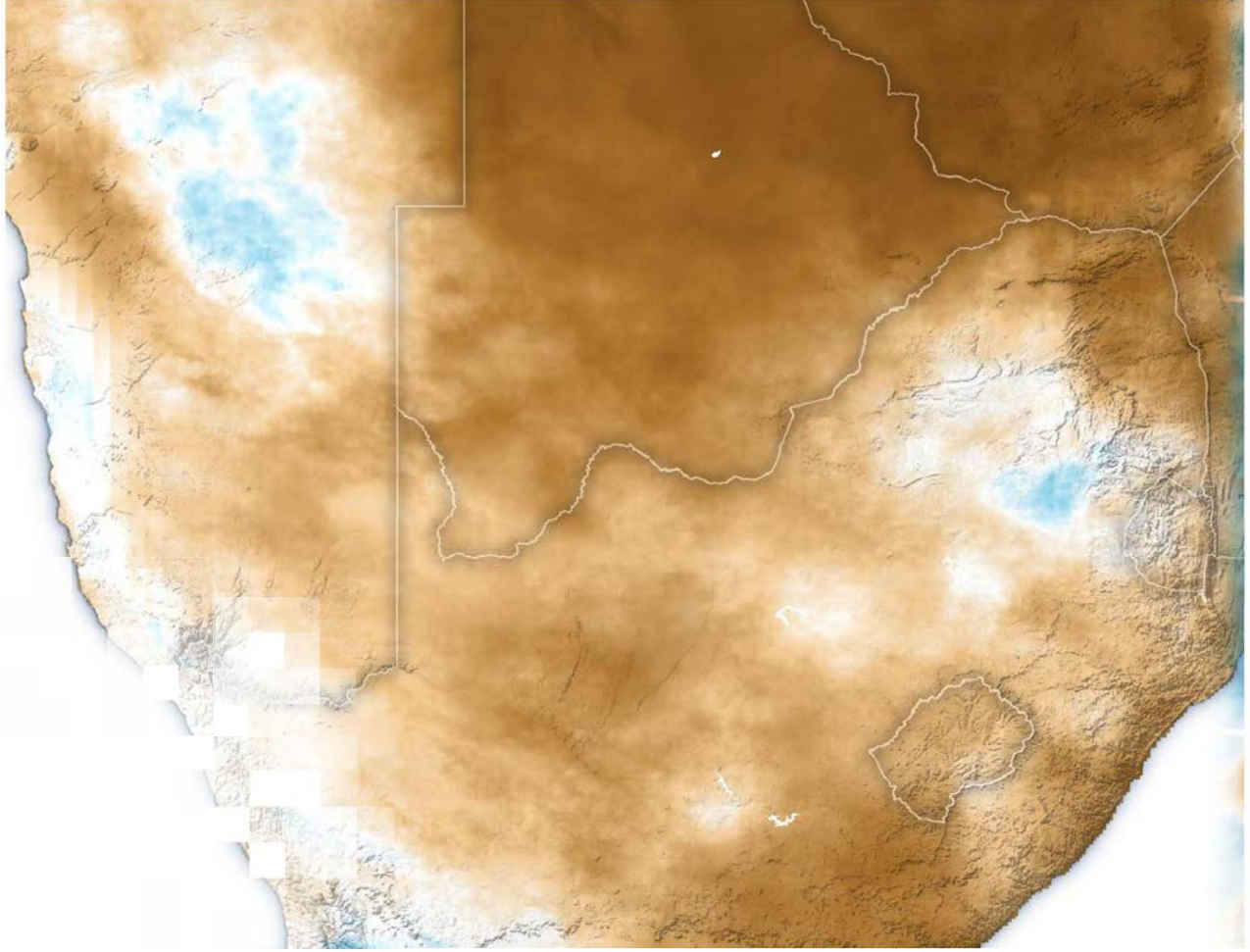
- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

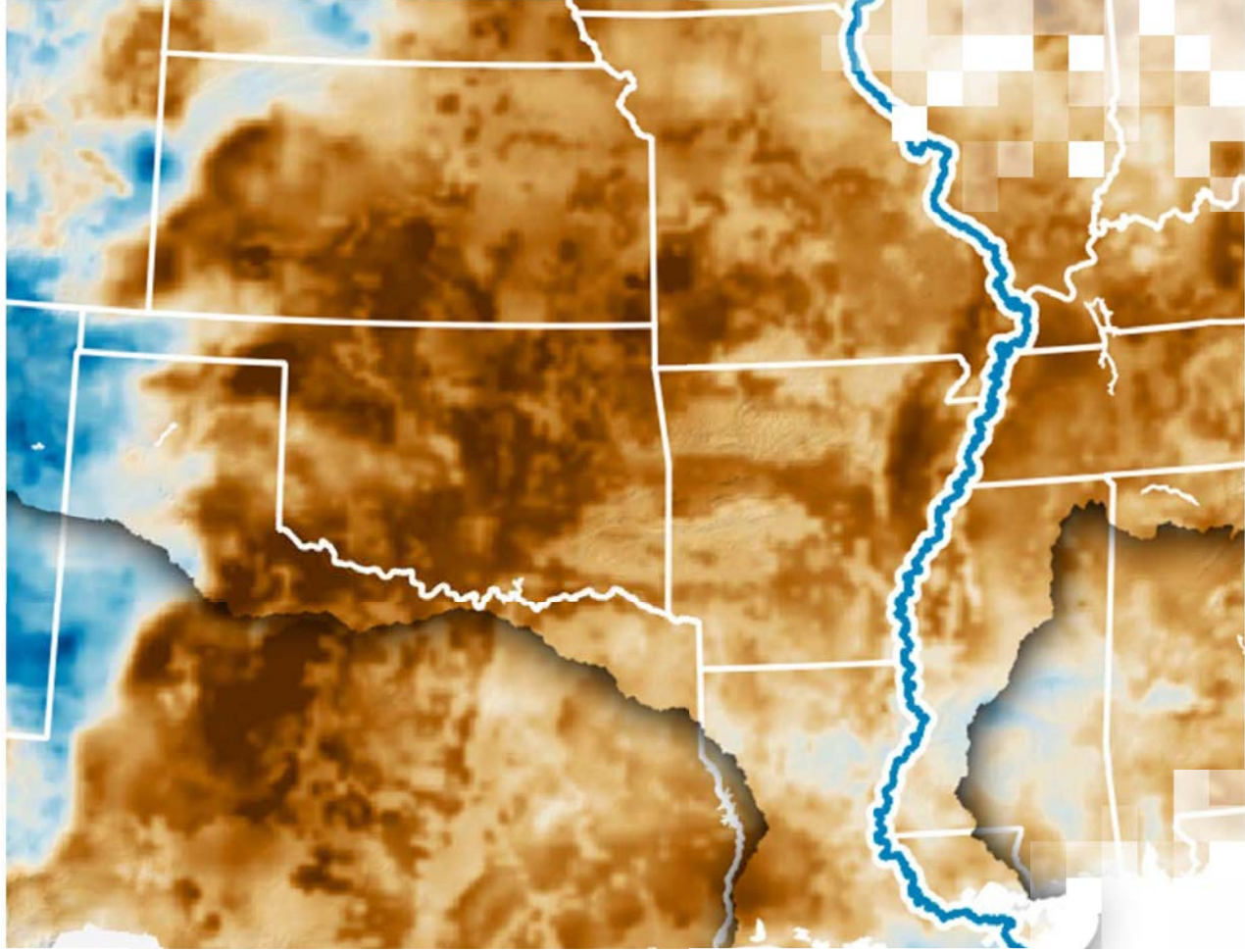
Part 4 Instructors

Amber McCullum
Guest Instructor
NASA AMES

Erika Podest
ARSET Instructor
NASA JPL & Cal Tech

Reetam Majumder
Guest Instructor
NCSU





NASA's Western Water Applications Office (WWAO)

Drought Project Highlights and Applications

Amber McCullum (amberjean.mccullum@nasa.gov)

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

NASA's Water Resources Program Area

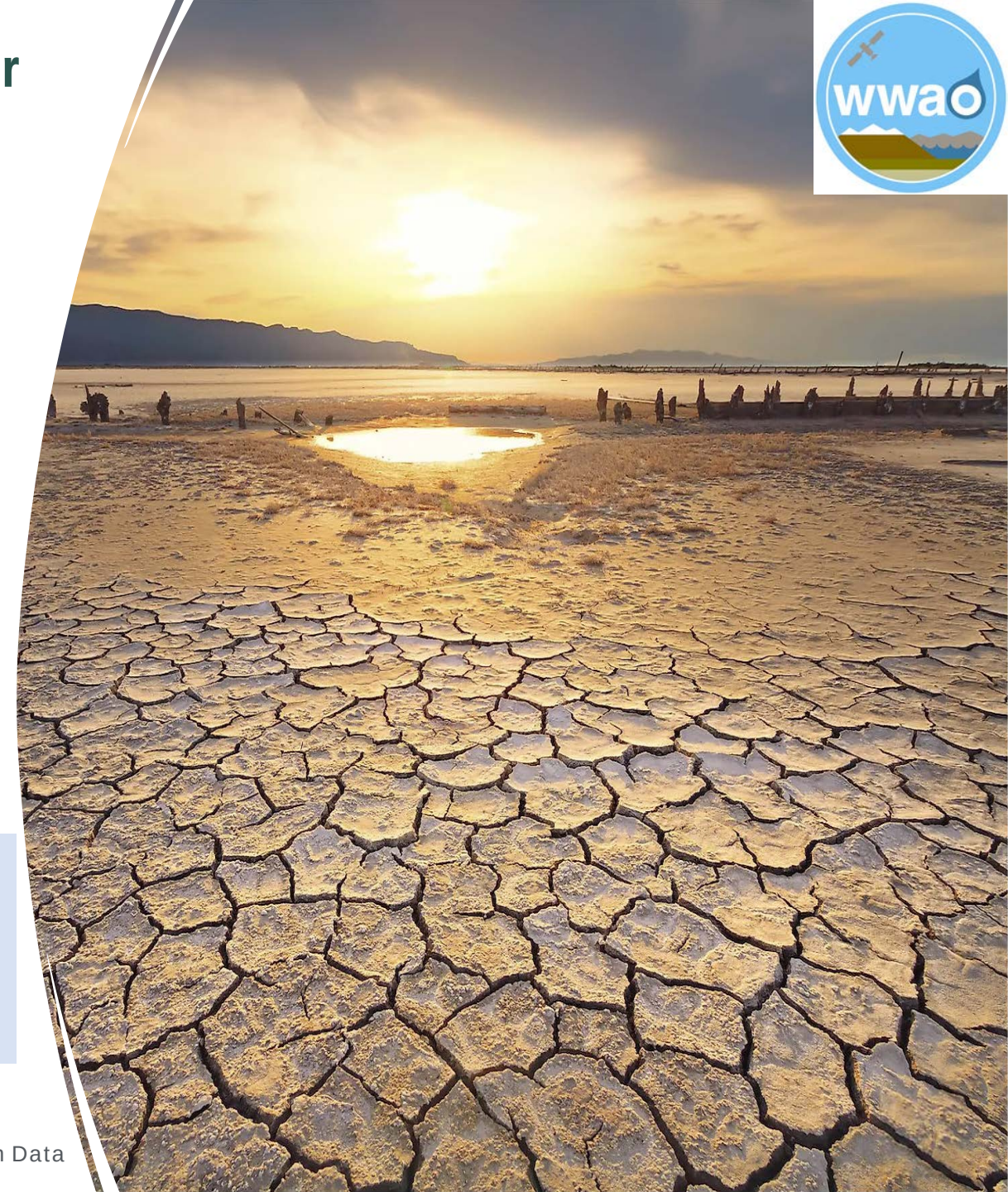
- Supports the use of Earth observations in water management related to water demand, supply, and quality
- Develops innovative solutions to water resources issues in partnership with stakeholders
- Long history of partner relationships working on projects such as:
  - Snowpack measurements for water availability
  - Evapotranspiration and soil moisture for agriculture
  - Land subsidence due to groundwater withdrawals
- NASA's Western Water Applications Office (WWAO) was established in 2016 by the NASA Applied Sciences Program to build on these successes in the Western U.S.

Source: NASA Earth Action Water Resources

The Western U. S. Faces Major Fresh Water Challenges

- Diminishing snowpack
- Timing and amount of runoff
- Increasingly frequent and intense of droughts and floods
- Falling groundwater levels
- Greater uncertainty about future water supplies

Demand is growing for decision support tools using satellite Earth Observations (EO) to provide managers with vital information needed to meet these challenges.



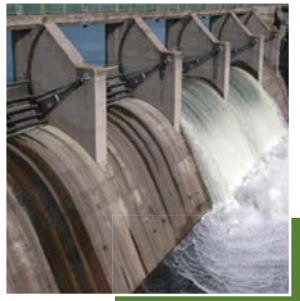
The NASA WWAO Mission

WWAO's mission is to directly benefit water management in the western US by getting NASA data, technology, and tools into the hands of decision makers.

- Harnesses NASA's unique ability to convene regional water management communities to collectively identify gaps and needs
- Increases access and use of NASA Earth Observations (data) for decision-making by connecting NASA's Earth science capabilities with water management gaps
- Transitions mature projects to operational use for sustained use and impact

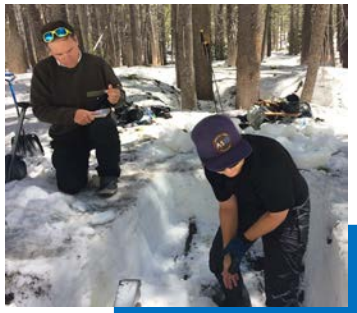
User-centric ***Rooted in science*** ***Towards sustainability and scalability*** ***Impact-focused***

WWAO Program Process



Identify

- Build strategic relationships with key water managers and stakeholders **Conduct needs assessments**
- Develop catalog of water needs



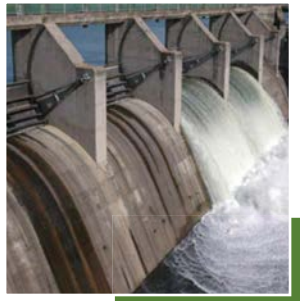
Connect

- Develop catalog of NASA applications
- Match needs to capabilities
- Build projects that are **needs-driven** and/or have strong stakeholder buy-in

Transition

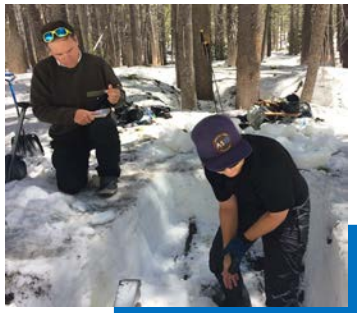
- Develop business cases and transition plans for promising applications
- Establish a **research to operations community** in water management

WWAO Program Success



Identify

- 4 needs assessments completed
- 7 western basins / watersheds studied
- 60+ use cases documented
- 150+ participants in workshops / surveys



Connect

- 5 award rounds
- 15 completed projects
- ~40 project partners
- 20+ papers/articles on project results
- Multiple private sector partnerships

Transition

- 6 capabilities transitioned
- 1 new company formed
- 1 Research to Operations workshop
- 2 interagency Research to Operations publications
- 3 impact assessments

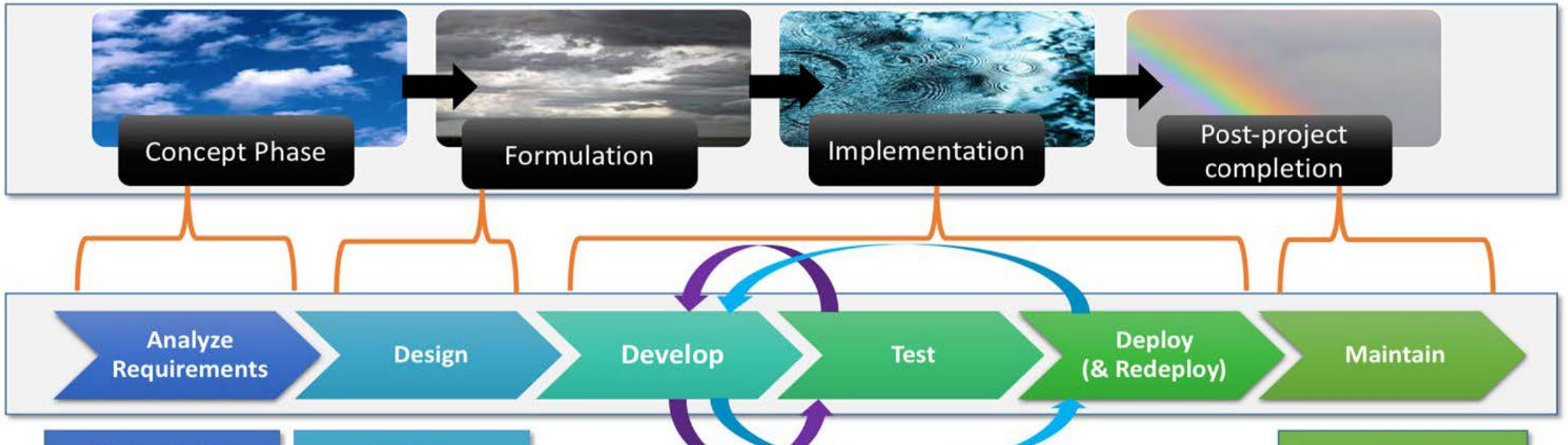
River Basin Needs Assessments

- Multi-part process to identify and understand water resources gaps (needs) in the Western U.S.

Basin Management Survey	Conduct Needs Assessment	Complete Needs Assessment	Develop Projects
Identify Water Management Challenges	Refine Gaps	Iterate with Water Partners to Complete	Inform Request for Information
Preliminary Gaps Identified	Initial Needs Identified	Needs Assessment Completed	Projects (co)-led with Partners Underway

Identify → Connect

Application Transition Lifecycle



Understand project partner's decision context to determine whether NASA capabilities can have a high potential to transition.

Create application design then estimate the resources needed for transition & include this in the budget.

Implement design of application. Release draft of software to project partner for feedback.

Verify application outputs meet project partner requirements (data accuracy, latency, resolution, etc.)

Transfer application to project partner. This includes technical trainings and other capacity building efforts.

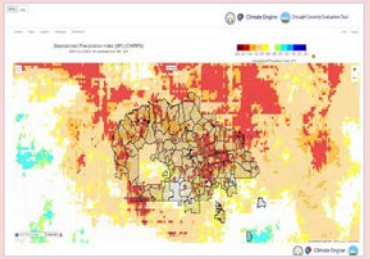
Partner operates the application (i.e. uses in decision making) and maintains it (i.e. replaces outdated data streams, fixes bugs, etc.).

WWAO Water Solutions

Snow

- Airborne Snow Observatory (ASO)
- Snow Today data system (NSIDC)
- Satellite-based snow sensing for monitoring and forecasting (NRCS)
- Near-real-time snowpack estimation from satellite data (CA DWR)

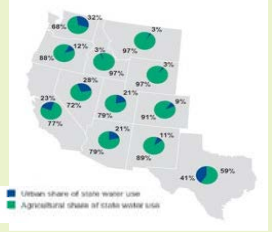
Drought

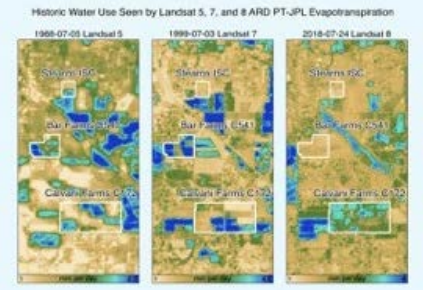


- High-resolution drought indicators via the Drought Severity Evaluation Tool (DSET) and the Western Land Data Assimilation System (WLDAS)
- Identification of drought-related groundwater changes in California with VIRGO

Evapotranspiration and Agricultural Water

- **Operational Evapotranspiration Visualizer** for the New Mexico State Engineer's Office
- WWAO's **Intercomparison Study of Satellite ET Models** with the U.S. Bureau of Reclamation
- **OpenET**, an effort supported by NASA and philanthropic foundations to make satellite ET data available online
- Columbia River Basin Evapotranspiration Mapping Tool
- WWAO's **Crop-CASMA Soil Moisture App** delivers field-scale soil wetness to the USDA
- NASA satellite data have been incorporated into the **CropManage** tool to improve irrigation management





Connect to WWAO

- Visit our website and water information portal:
  - wwao.jpl.nasa.gov/
  - wwao.jpl.nasa.gov/portal/

- Reach out to WWAO's Program Manager, Stephanie Granger: stephanie.l.granger@jpl.nasa.gov

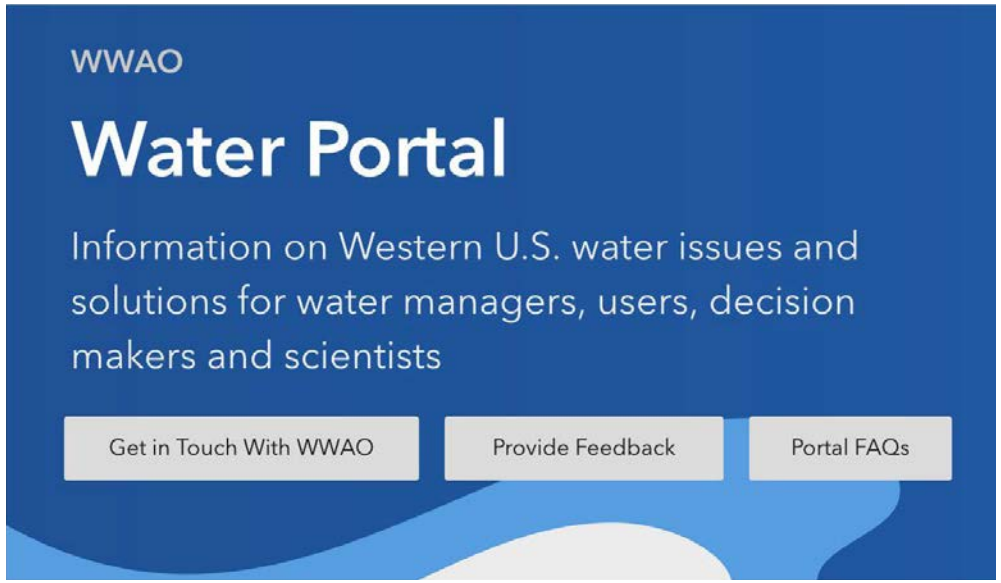
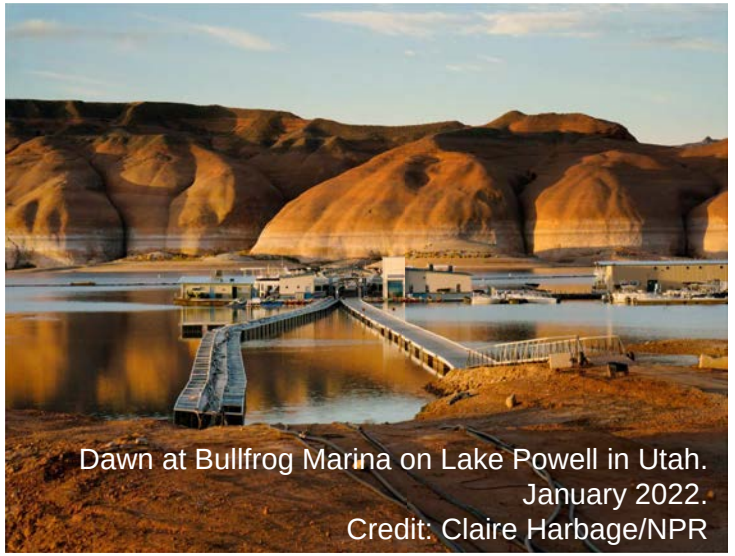
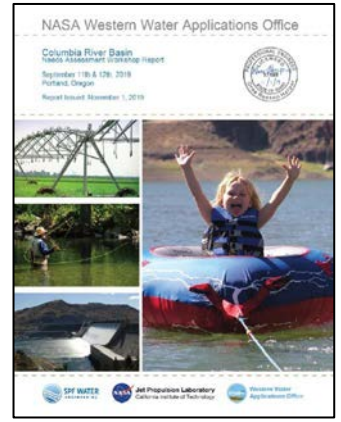
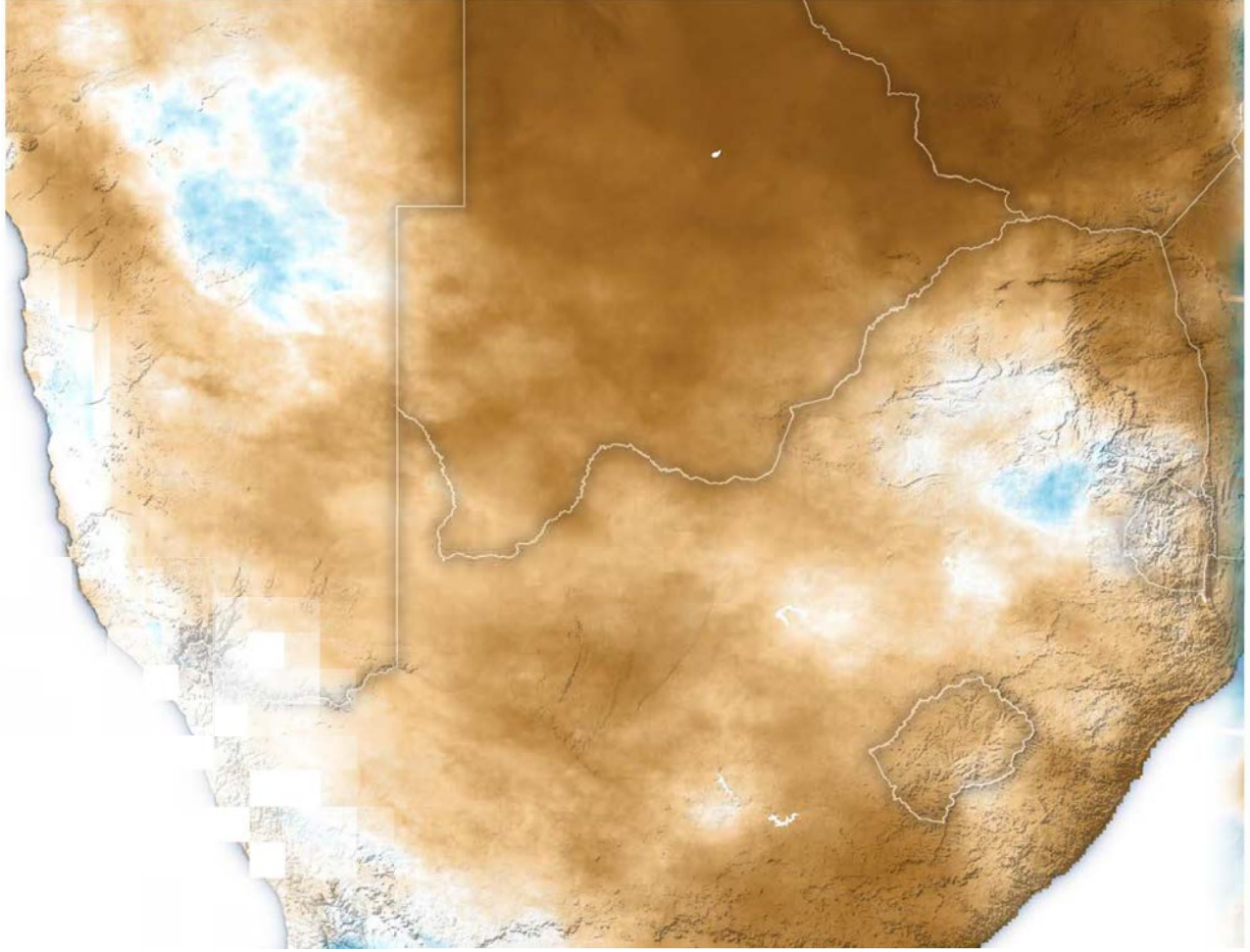
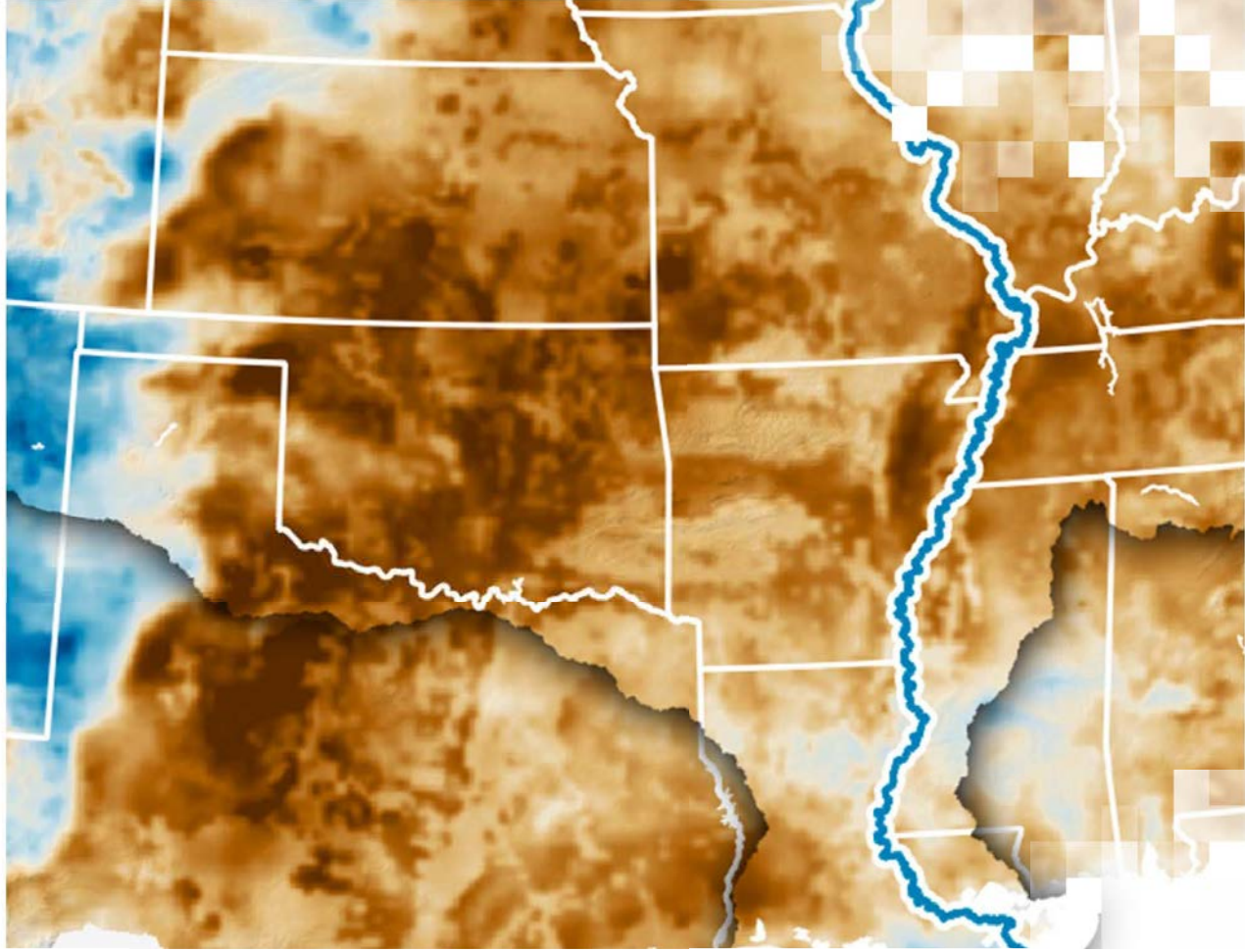



Image Credit: UCRC Resolution


Dawn at Bullfrog Marina on Lake Powell in Utah. January 2022. Credit: Claire Harbage/NPR







WWAO Drought Project Examples

The Western Land Data Assimilation System (LDAS) and Drought Monitoring in Colorado

Jessica Erlingis (UMD/GSFC)

Matt Rodell (GSFC)

Sujay Kumar (GSFC)

Bailing Li (UMD/GSFC)

Scott Rheingrover (SAIC)

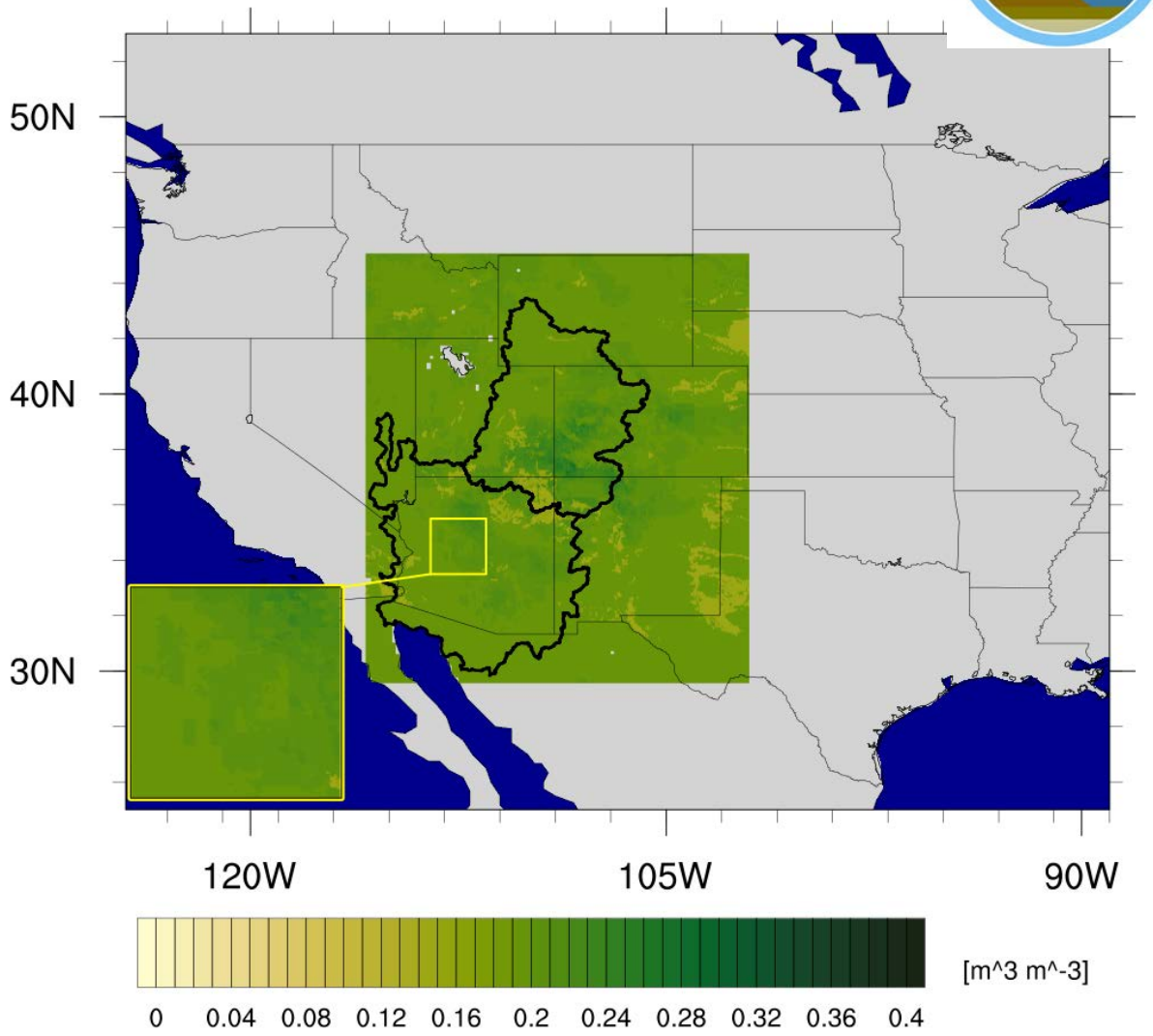
Project Partners: Russ Schumacher and Peter
Bennett Goble (CCC)

The Western LDAS: Motivation

Goal: Support decision makers with data on water availability

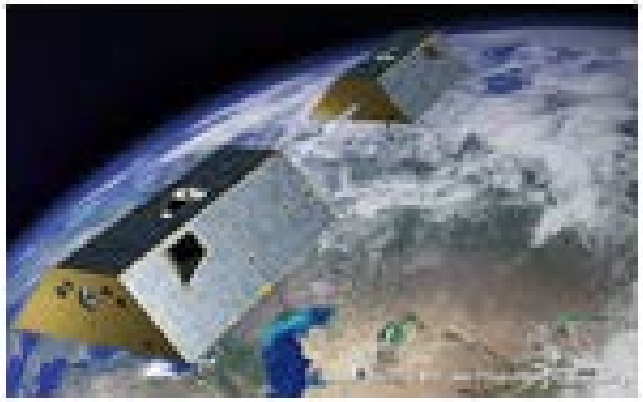
- Partner with the Colorado Climate Center and other state and local agencies to assist with drought assessment, groundwater and agricultural management needs

Approach: Use NASA's Land Information System (LIS) software to integrate data from multiple sources (GRACE, MODIS, NLDAS-2, PRISM, STATSGO, FAO, SRTM) in a configuration optimized for the Western U.S.



Drought Monitoring, Prediction, and Projection Using NASA Earth System Data

GRACE/GRACE FO twin satellites



Inter-satellite ranging data → Gravity fields

Temporal variability of gravity → Terrestrial water storage (TWS)

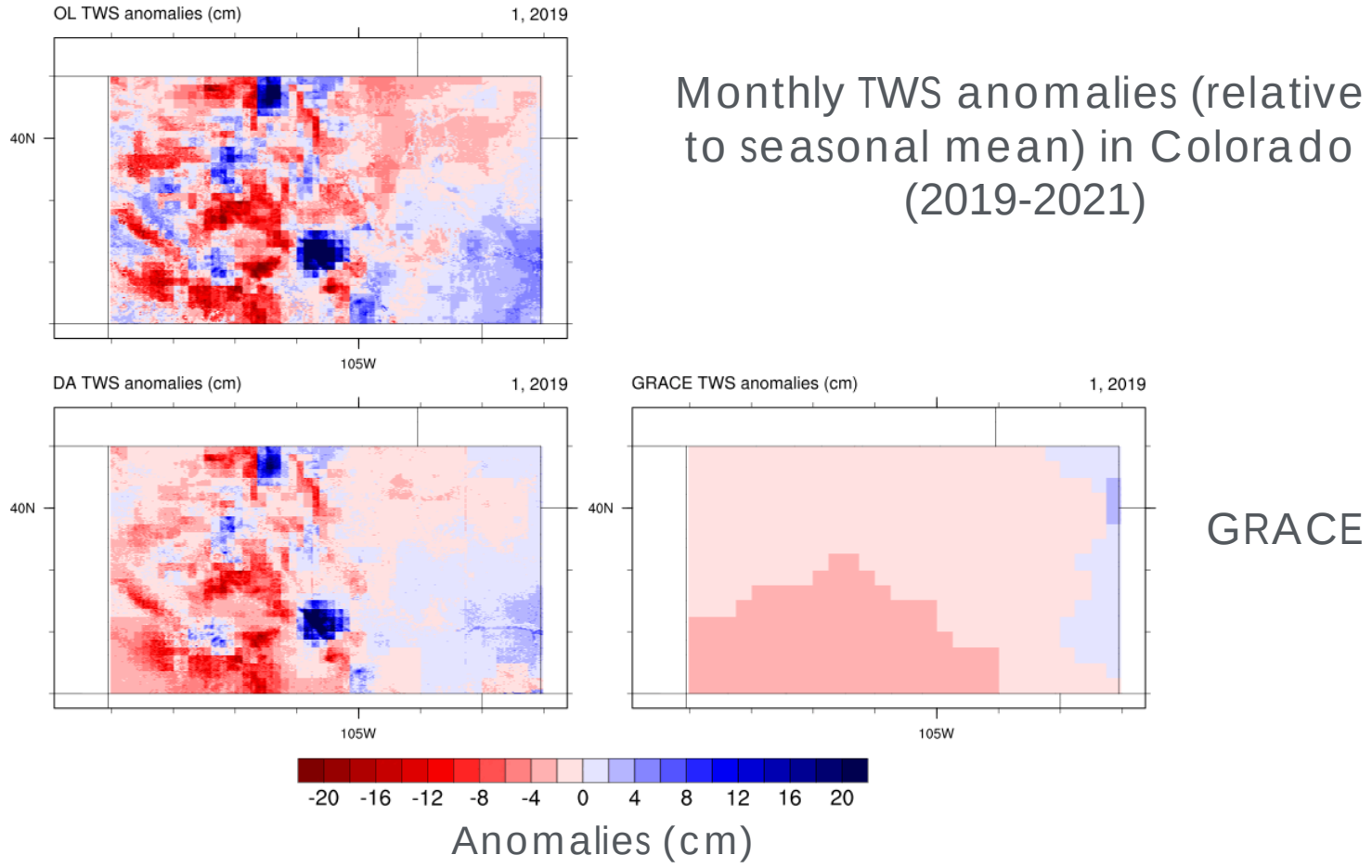
TWS is the sum of soil moisture, groundwater, snow and surface water

GRACE-based Drought Indicators for Colorado

Spatial Downscaling Effects of GRACE Data Assimilation

Open loop (1 km)

Downscaled GRACE (1 km)



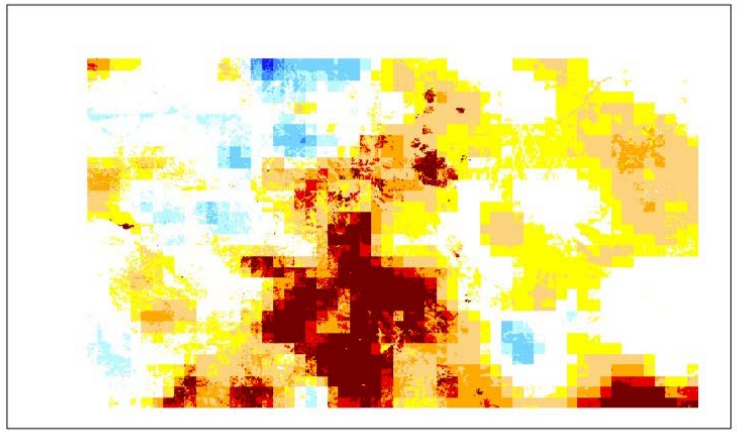
Monthly TWS anomalies (relative to seasonal mean) in Colorado (2019-2021)

GRACE

GRACE-based Drought Percentile Maps for September 21, 2021

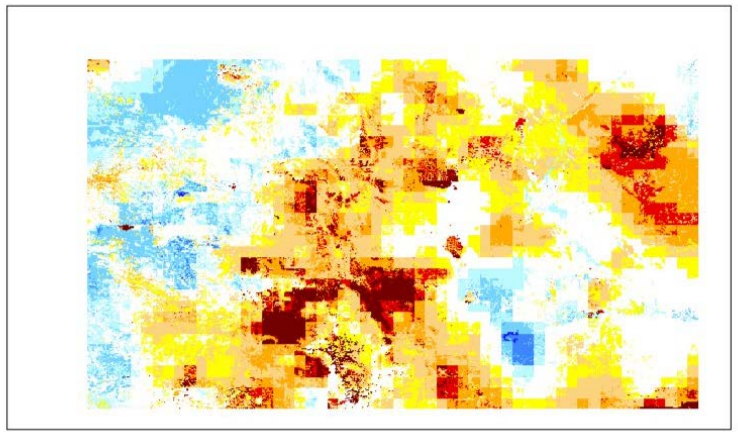
Surface soil moisture

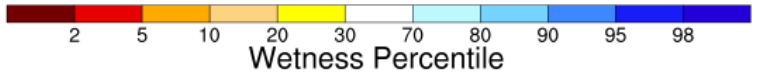
20210921



Root zone soil moisture

20210921





Groundwater storage

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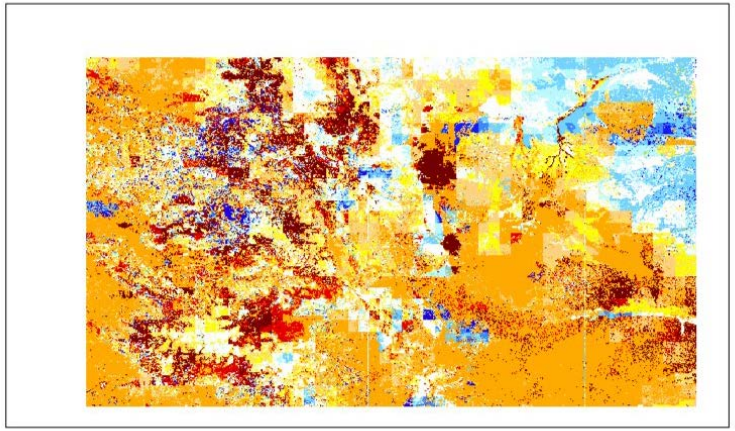
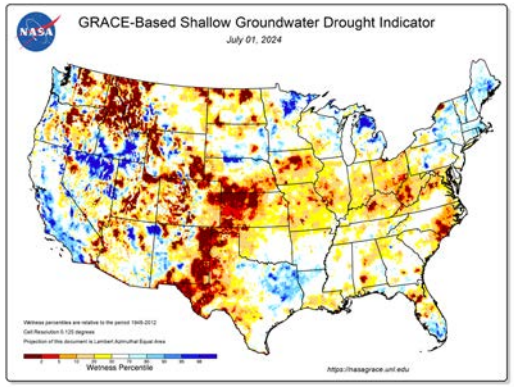
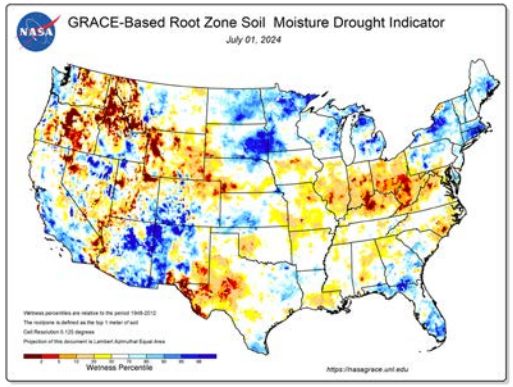
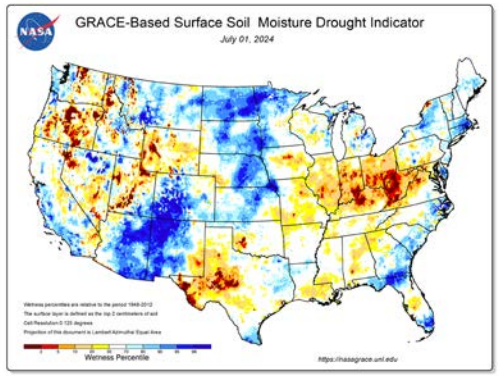
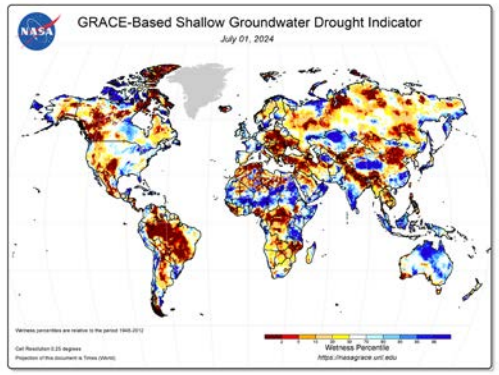


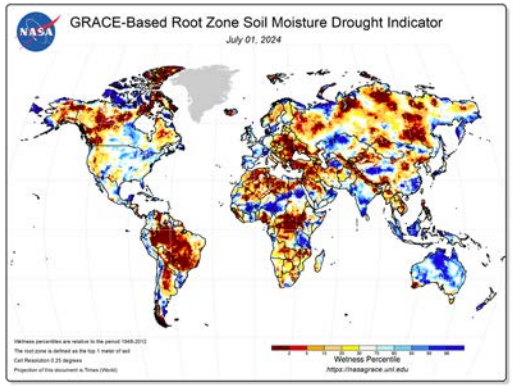
GRACE-based Drought Indicators for Continental U.S. and the Globe

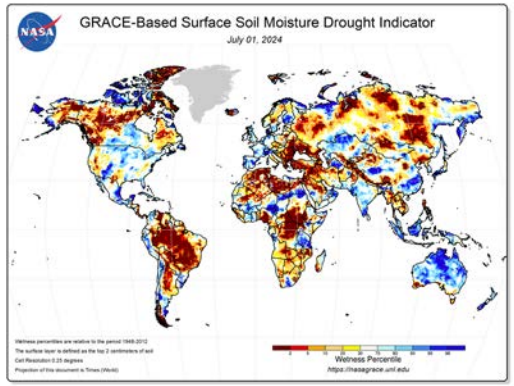






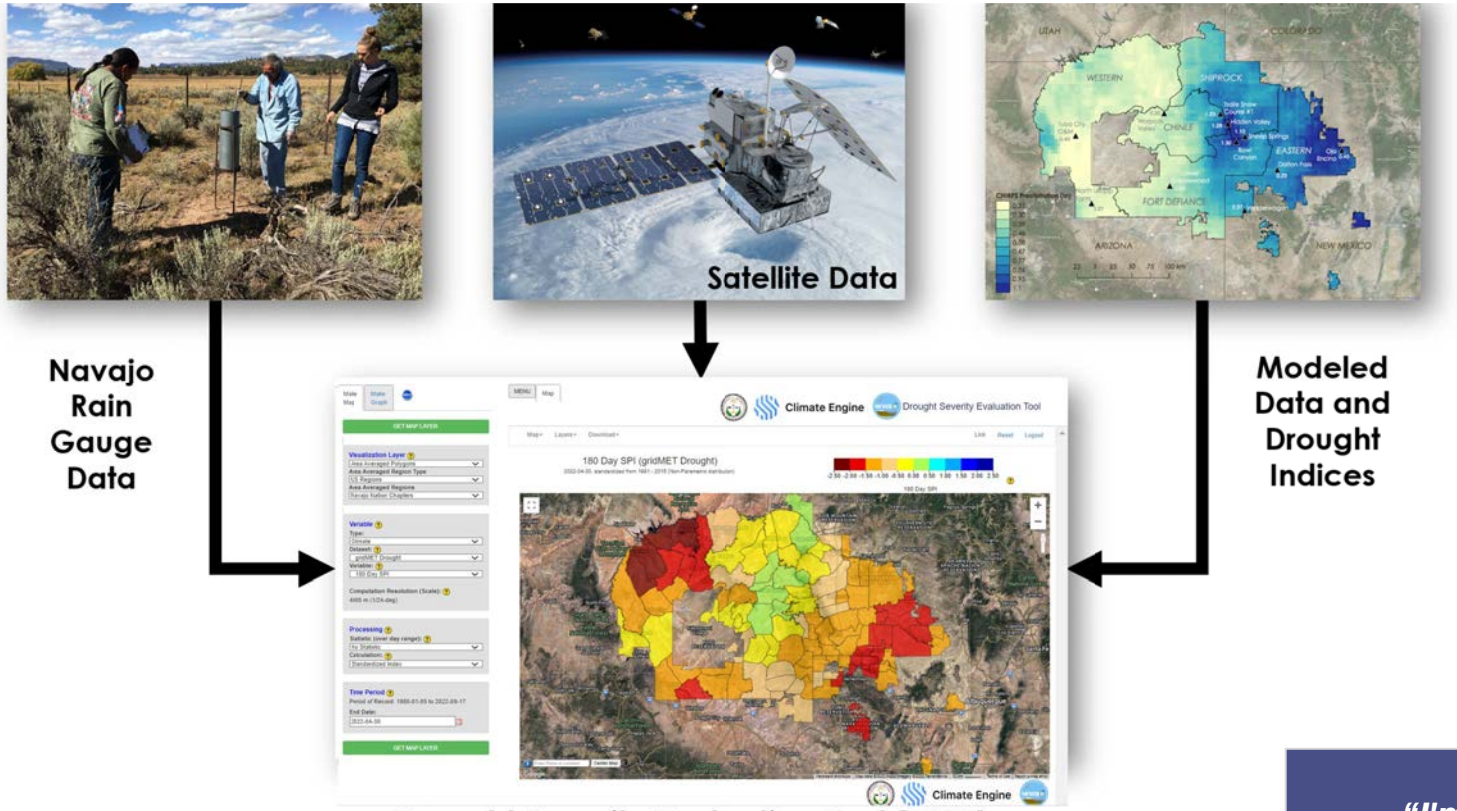






https://nasagrace.unl.edu/

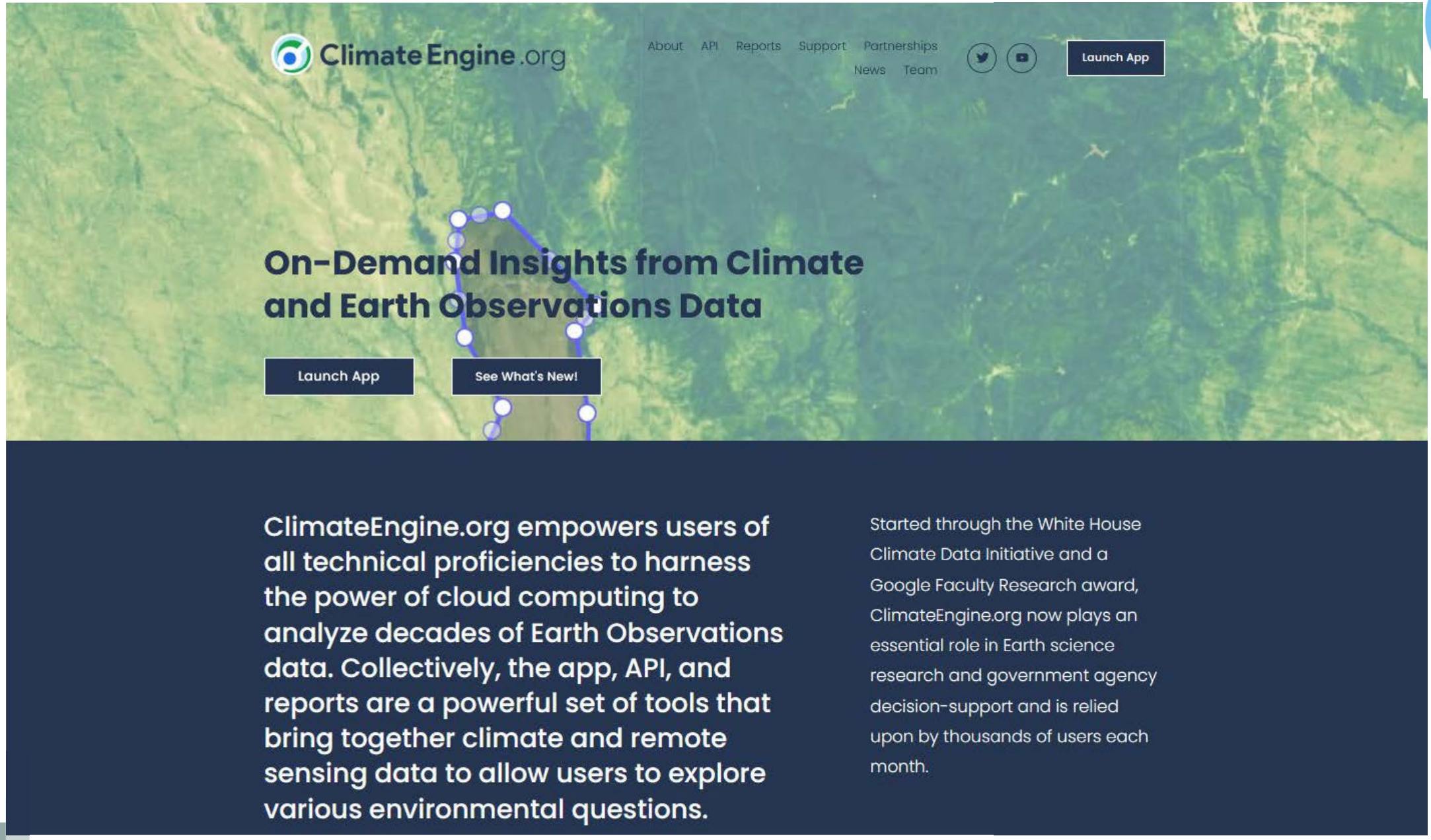
Navajo Nation Drought Severity Evaluation Tool (DSET)



- Goal to improve upon drought reporting for the Navajo Nation Department of Water Resources
- Partner-driven tool where co-development and sustained relationships were key
- Acknowledgment of preexisting Indigenous knowledge systems and capacity building efforts ensured continued use of the tool
- User guide link

"I'm...Navajo – I grew up on the Navajo Reservation. It is monumental to have an organization like NASA work with us to diversify and augment the water tools we have at our disposal."

Carlee McClellan, Navajo Nation Department of Water Resources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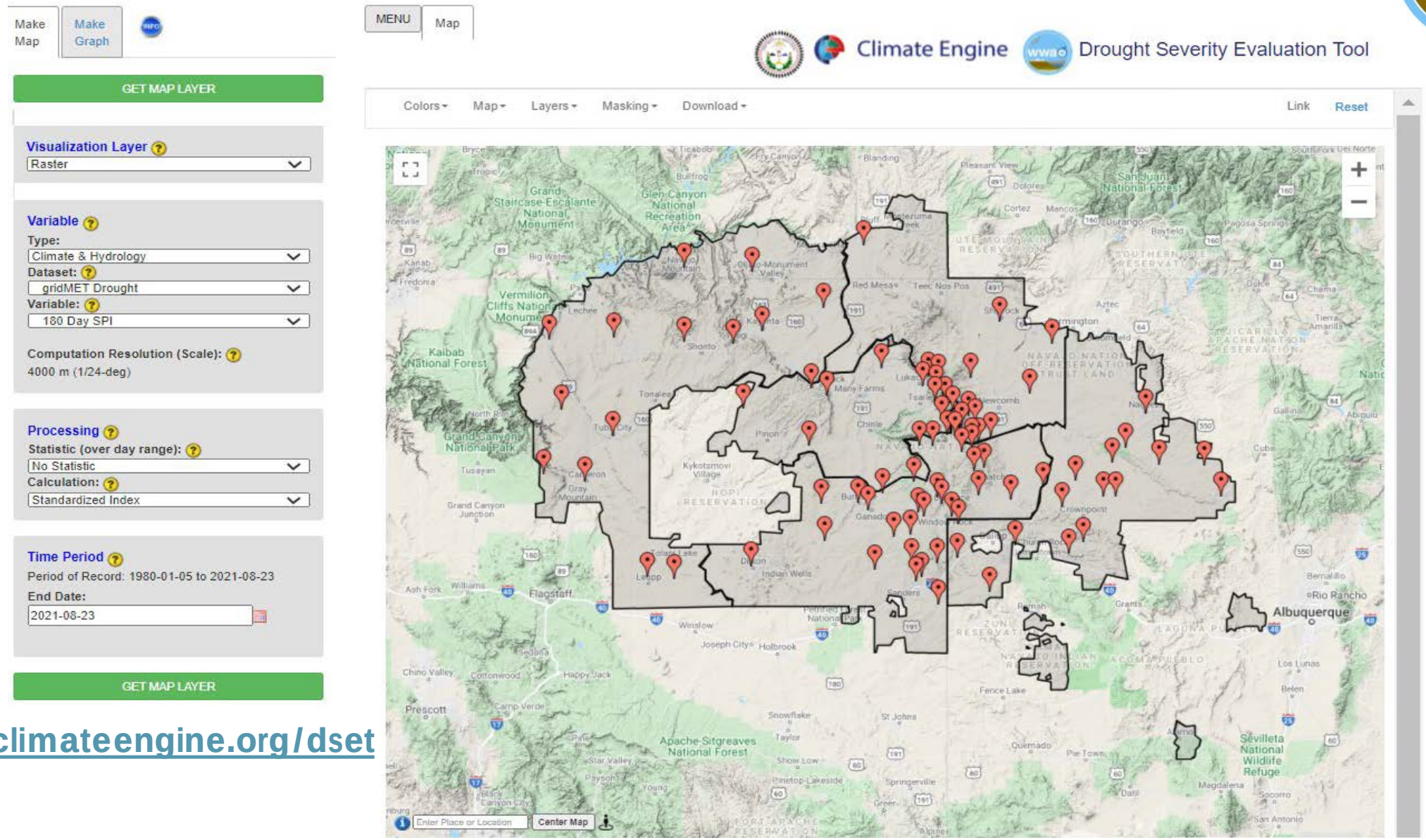
On-Demand Insights from Climate and Earth Observations Data
Launch App
See What's New!
ClimateEngine.org empowers users of all technical proficiencies to harness the power of cloud computing to analyze decades of Earth Observations data. Collectively, the app, API, and reports are a powerful set of tools that bring together climate and remote sensing data to allow users to explore various environmental questions.
Started through the White House Climate Data Initiative and a Google Faculty Research award, ClimateEngine.org now plays an essential role in Earth science research and government agency decision-support and is relied upon by thousands of users each month.

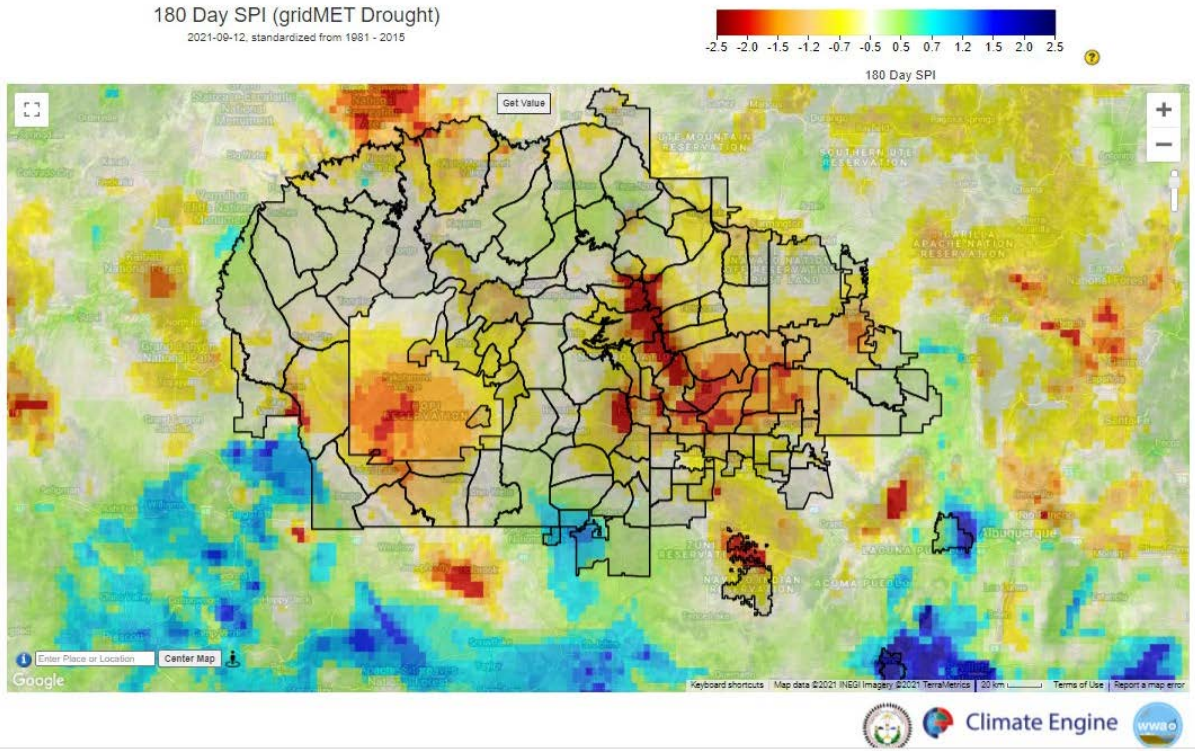
DSET Overview: Navajo Nation Data



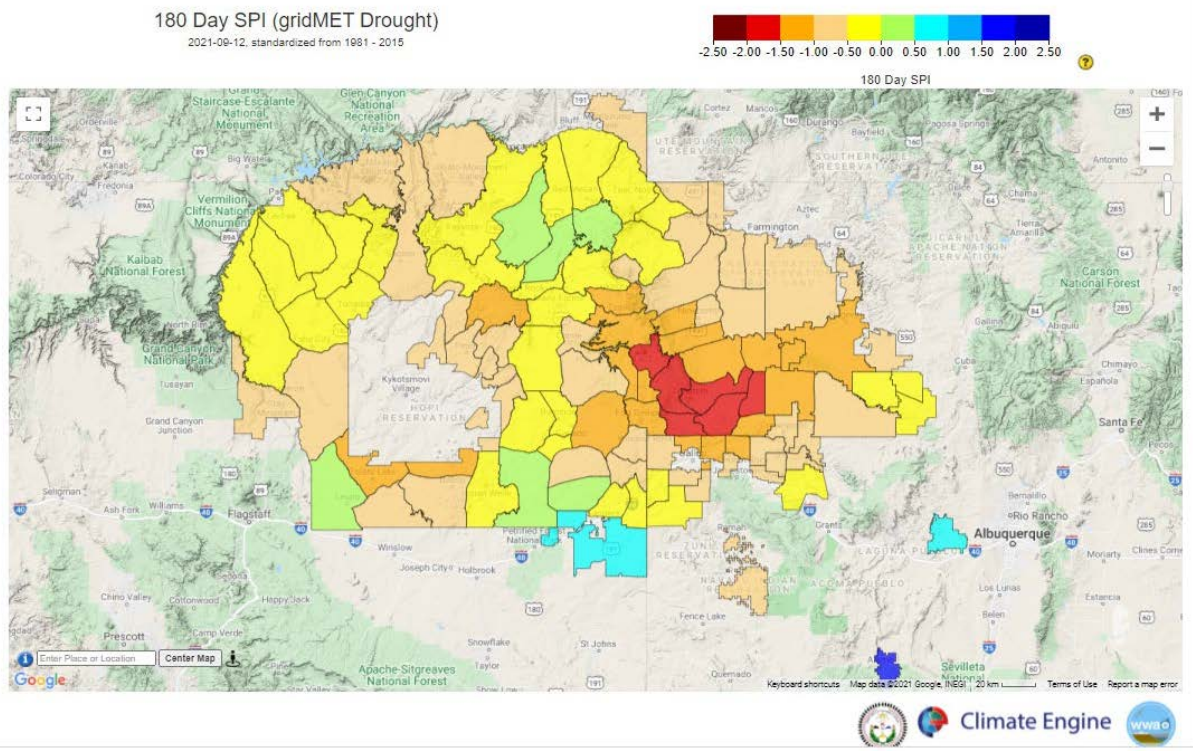
https://app.climateengine.org/dset

DSET Overview: Maps

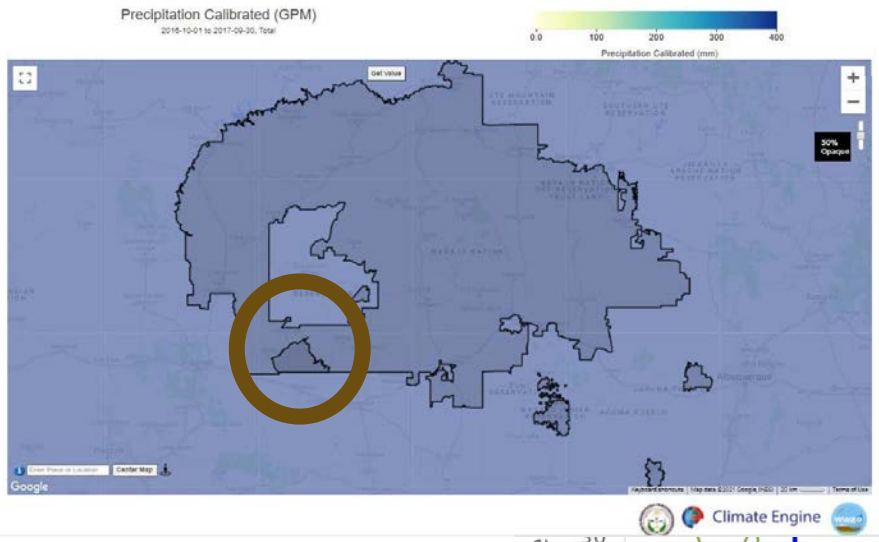
Gridded

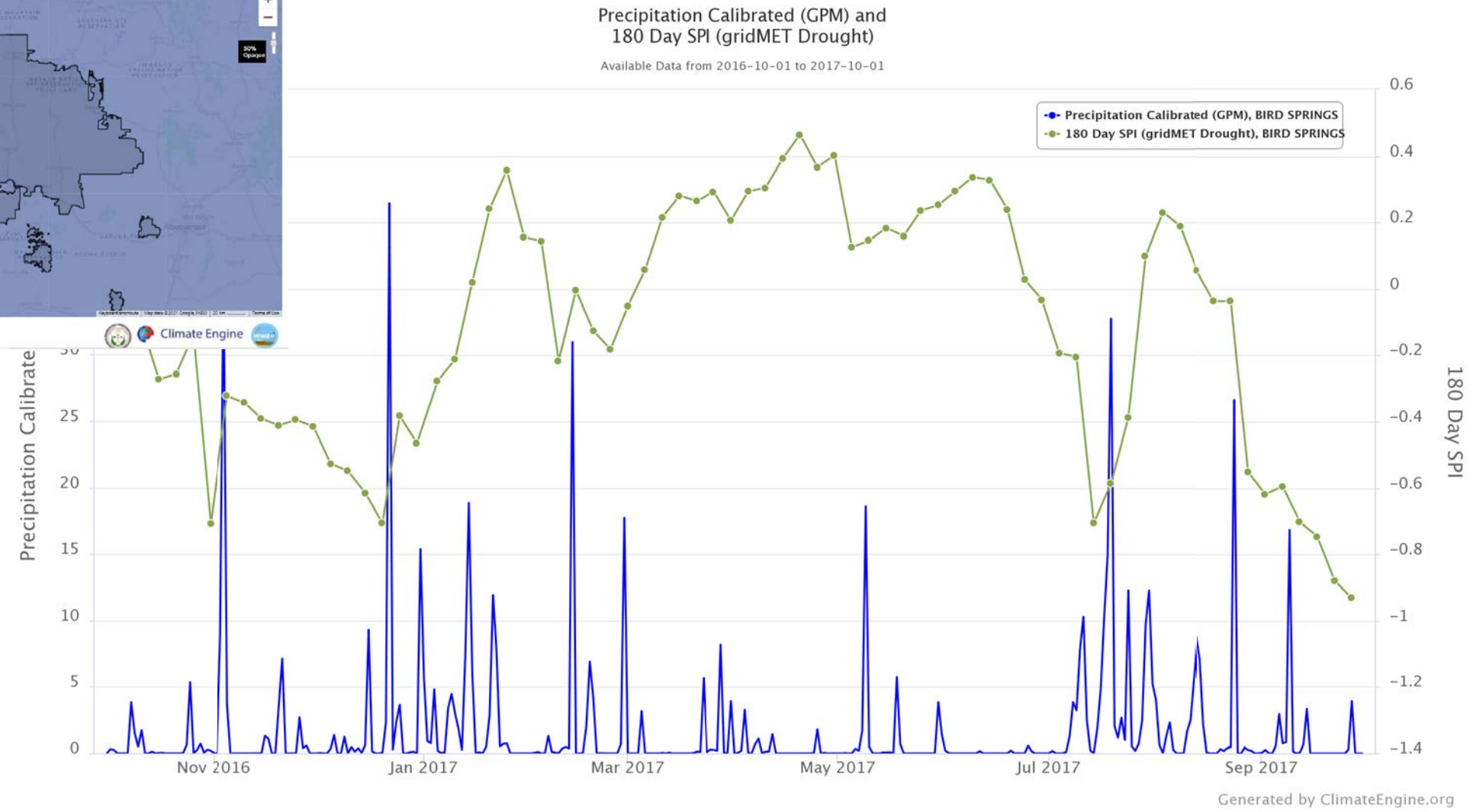


Area-Averaged Polygons

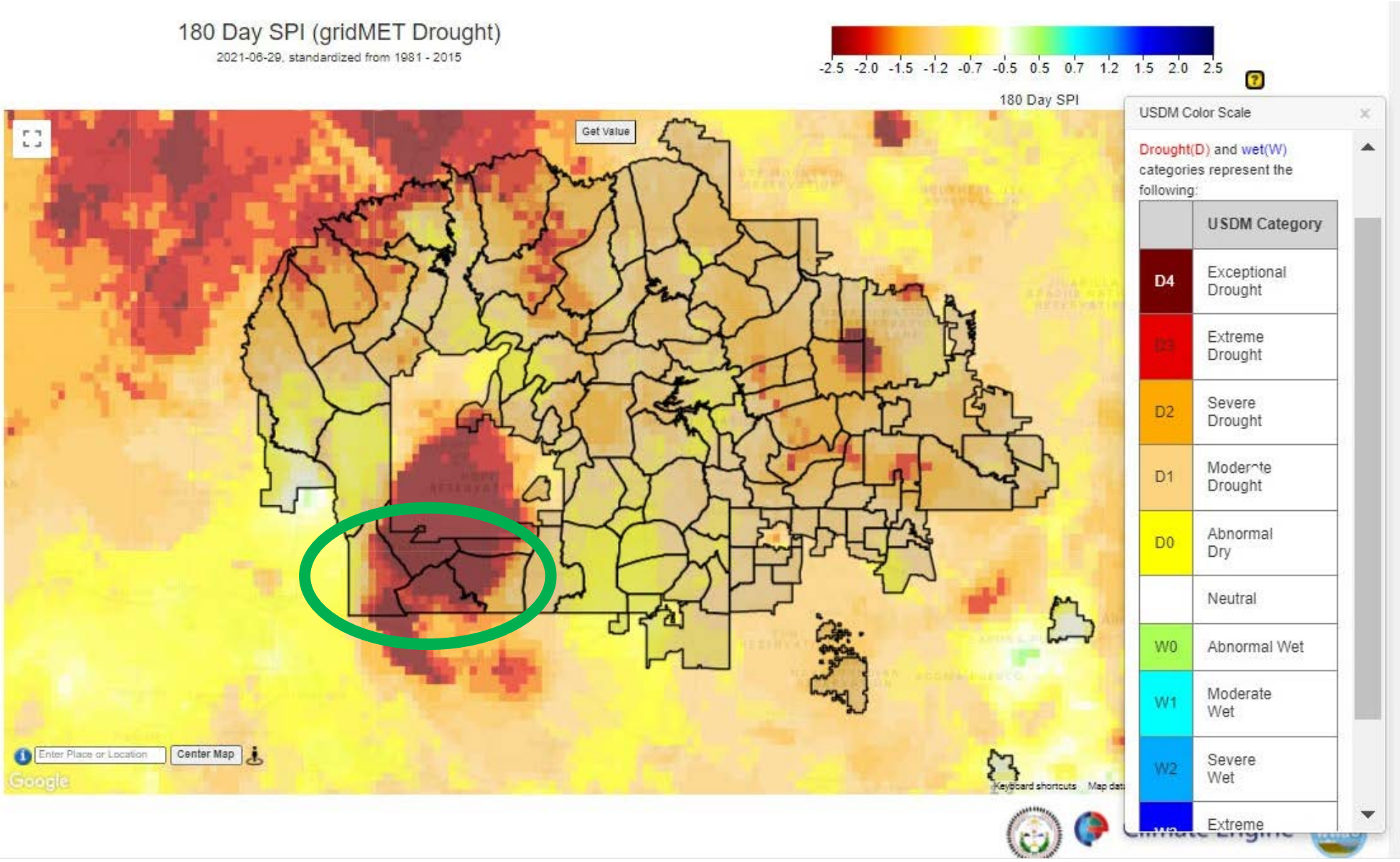


DSET Overview: Time Series



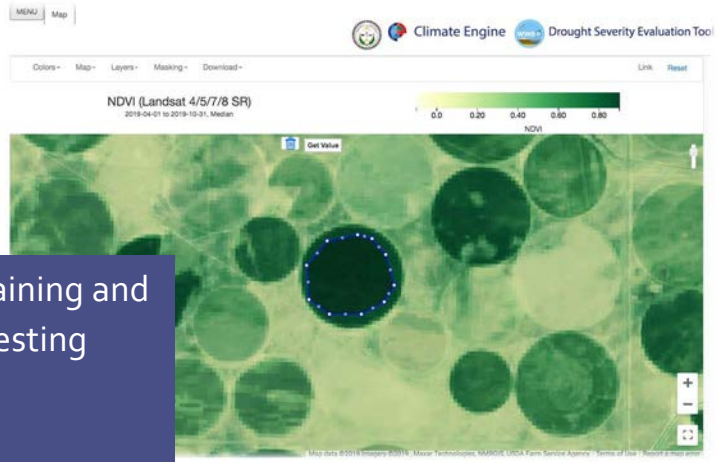


DSET Overview: Information for Drought Declarations



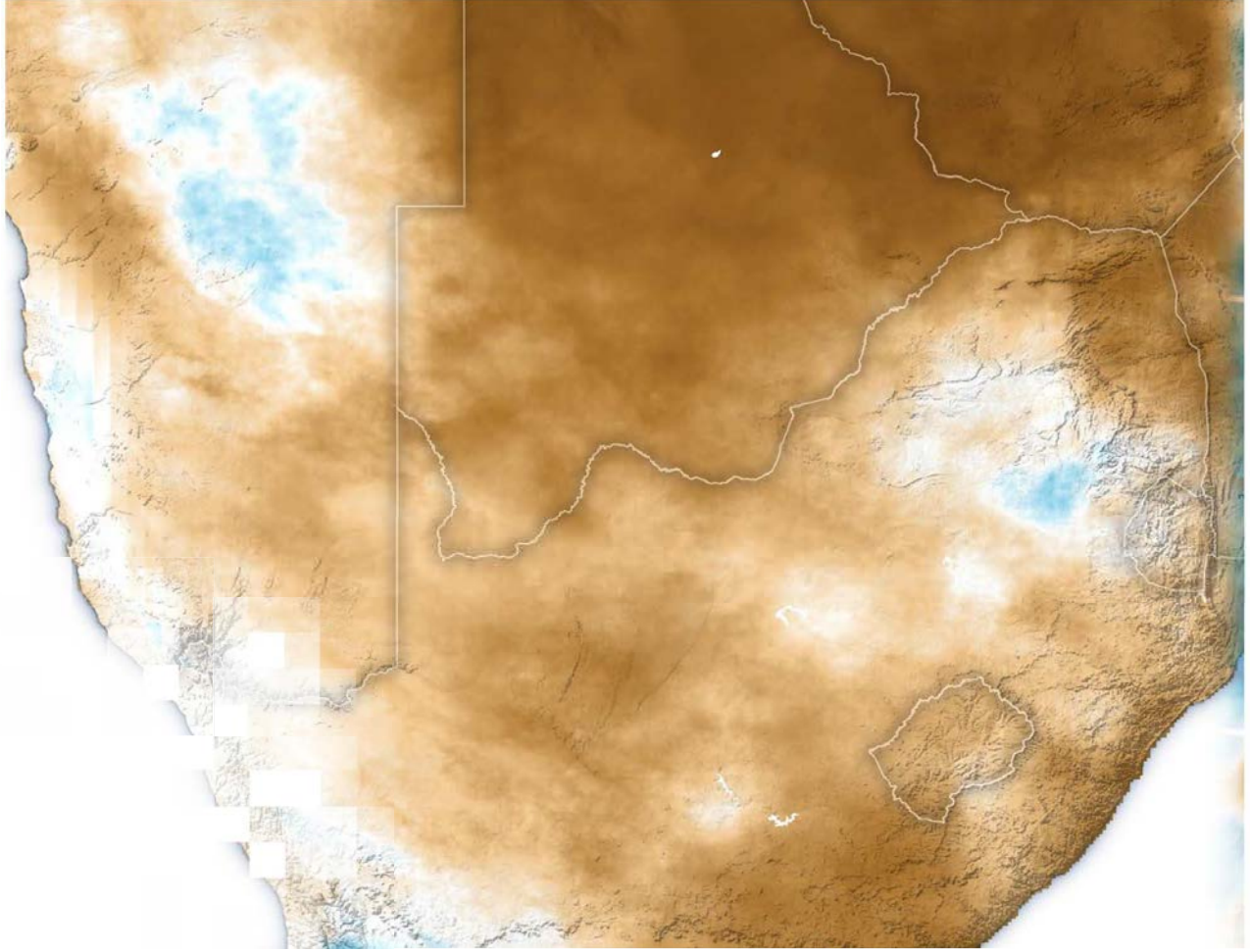
Partner-driven Tools Start with Relationships

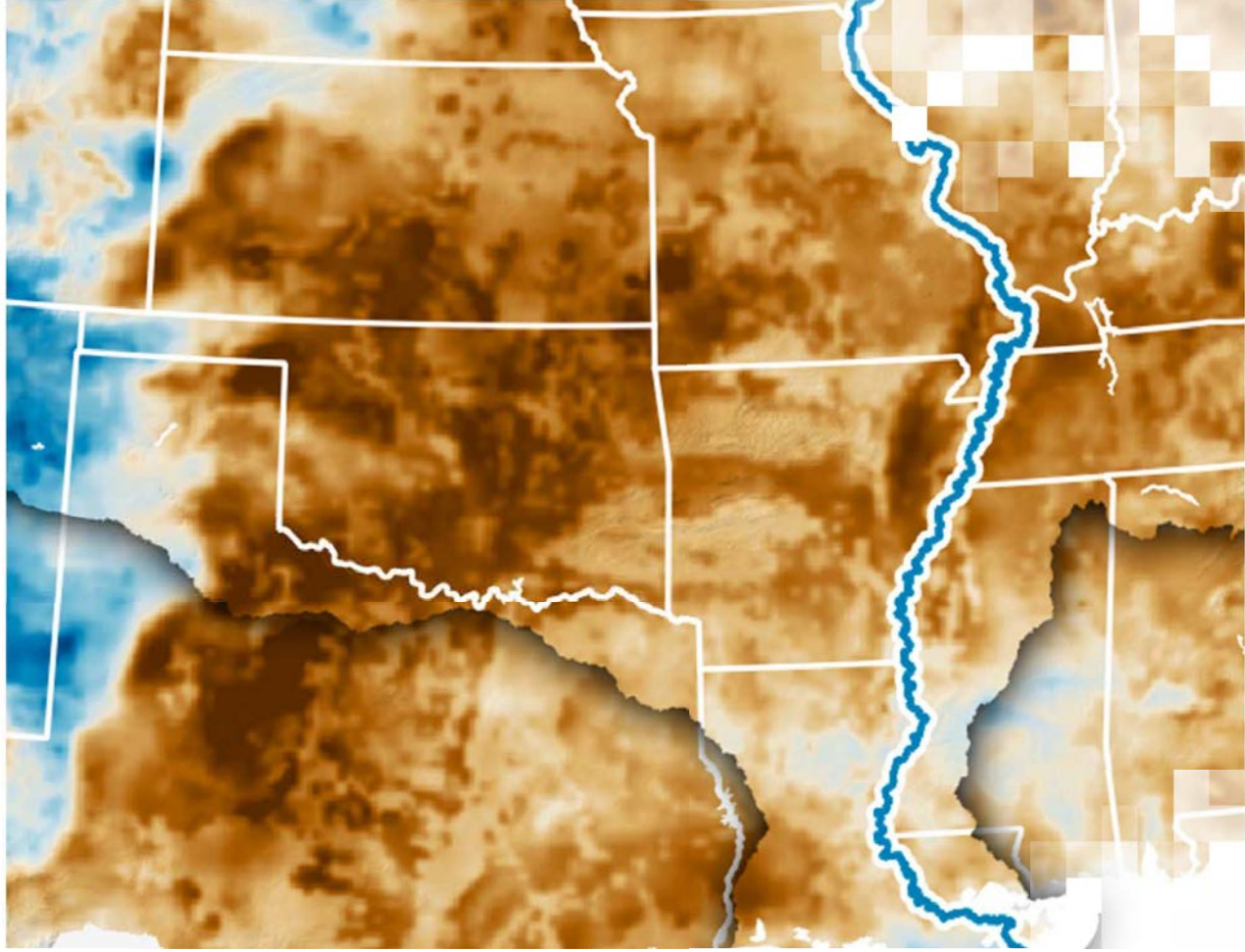
Partner training and beta testing



- Online interactive User guide

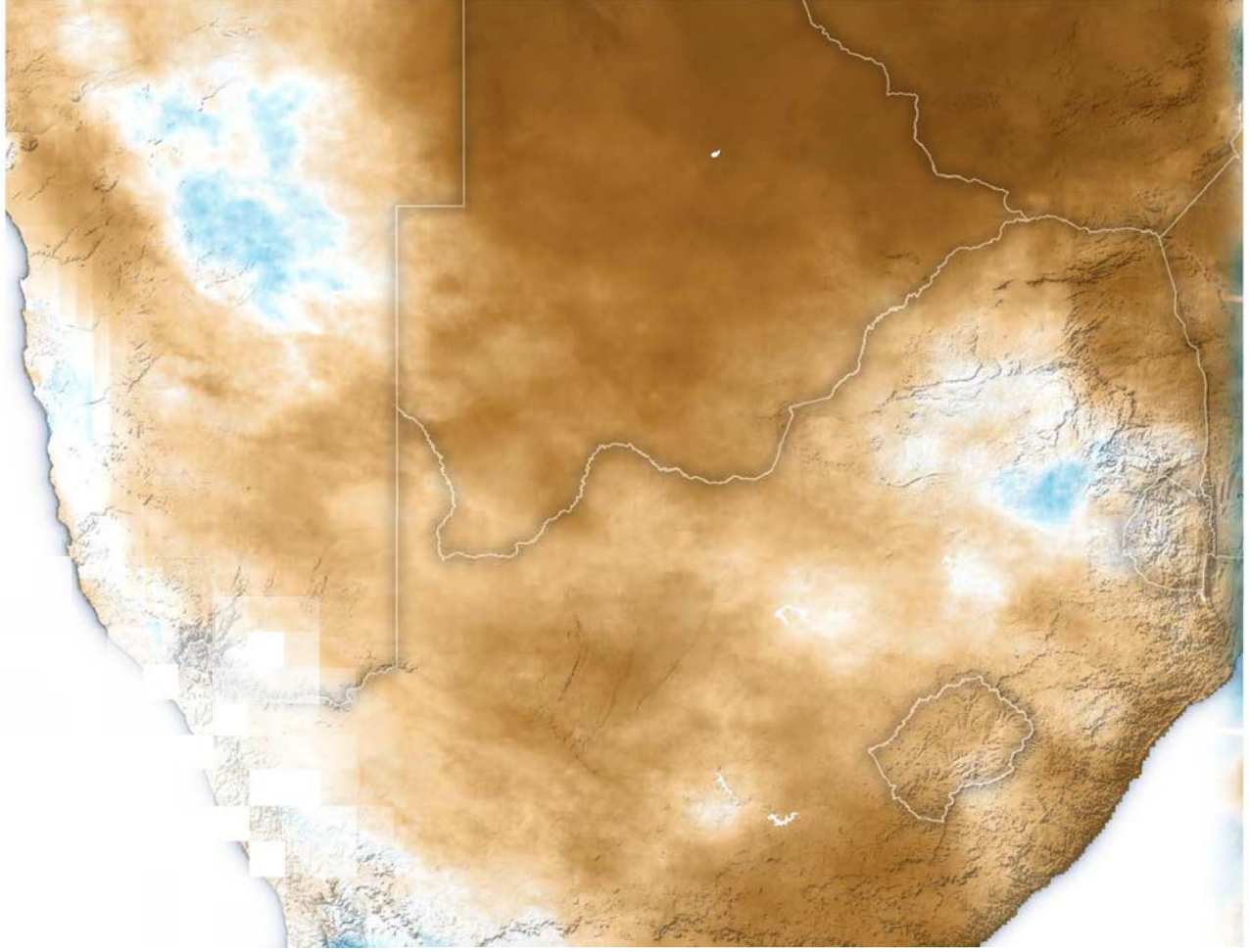
- April 2019: 2-Day hands-on training in Flagstaff, AZ
- Dec 2019: 1-Day hands-on training in Window Rock, AZ

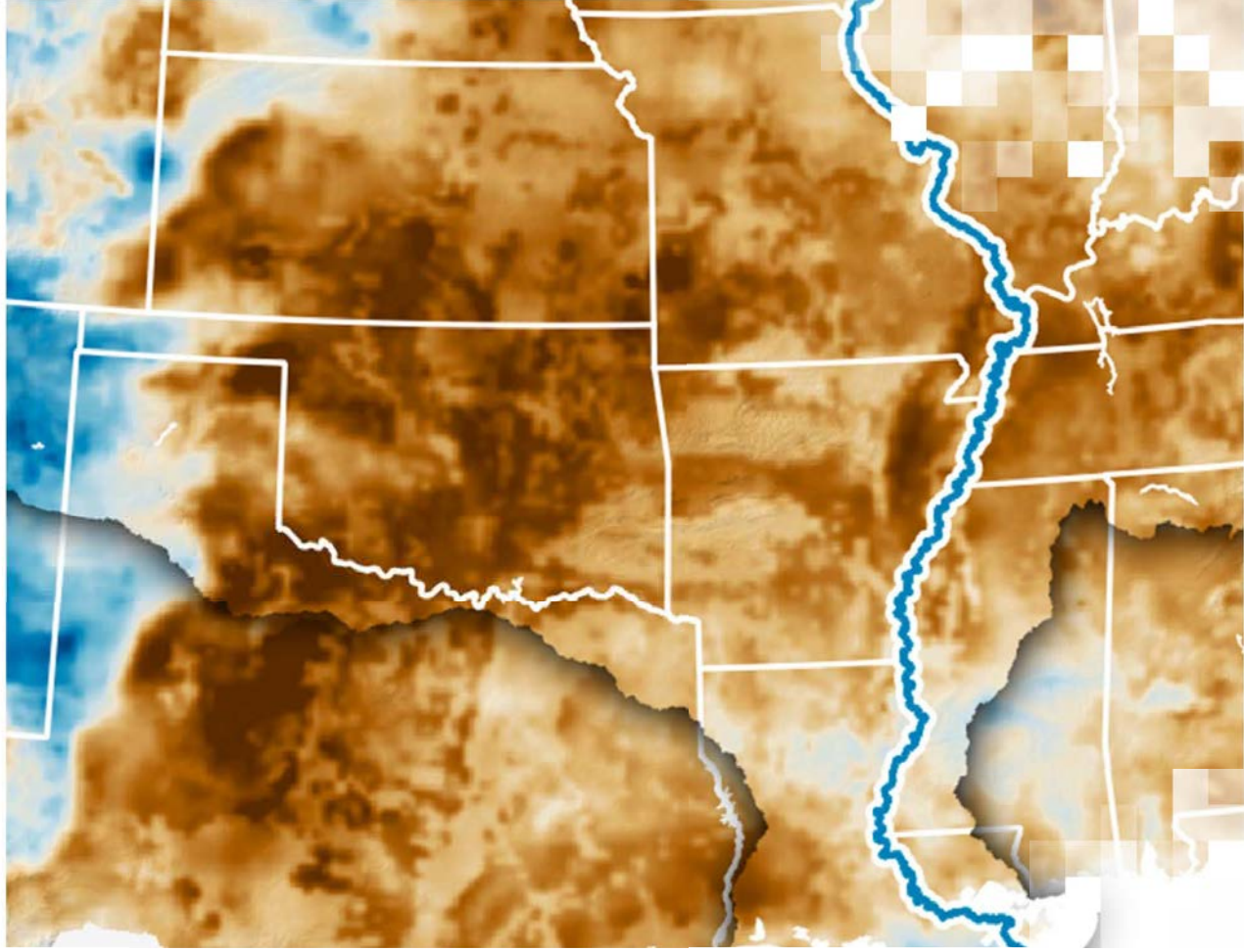




DSET Demo

https://app.climateengine.org/dset



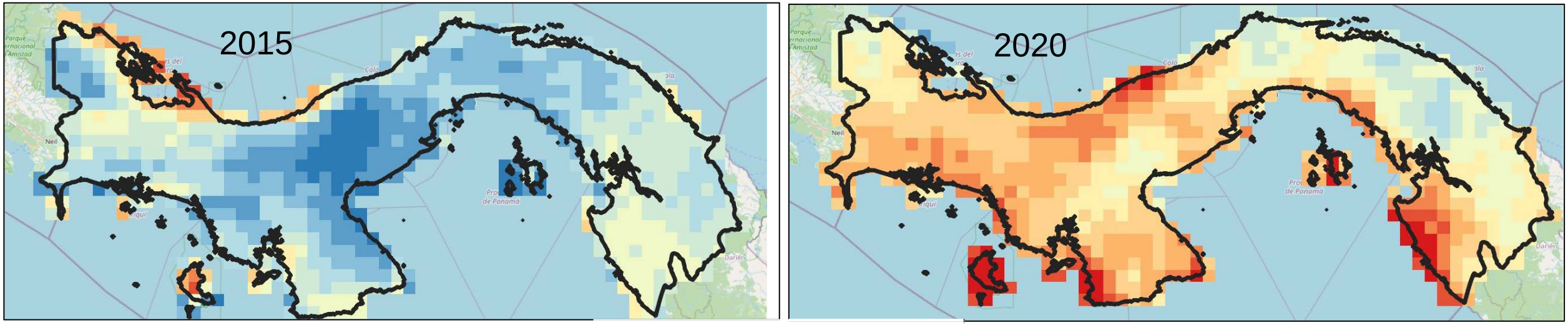


Sustainable Forest Management Information System (SFMIS) Tool Demo Overview

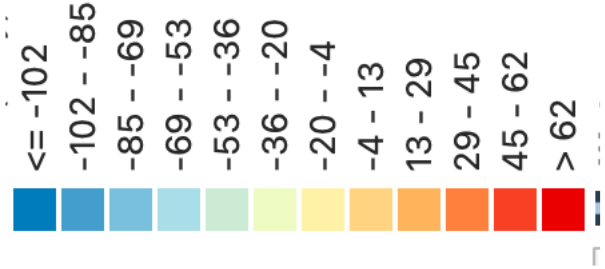
Demonstration Overview

- This demonstration will show how to run the SFMIS tool to assess vegetation cover change due to a drought.
- The example is focused in an area in Panama for 2015 (drought) and 2020 (non-drought).

Precipitation Anomaly: Wet Season (May – Early Dec.)



Source: GPM IMERG Precipitation



The SFMIS Tool

- **Platform**: SFMIS is a Jupyter Notebook based tool.
- **Satellite data**: Can be modified to run with a combination of different satellite data (optical and radar). In this example we will use optical data from Landsat-8.
- **Ancillary data**: Digital elevation model (DEM)
- **Classification algorithm**: Random Forest
- **Training**: A landcover reference map generated by the Panamanian Ministry of the Environment (MiAmbiente)

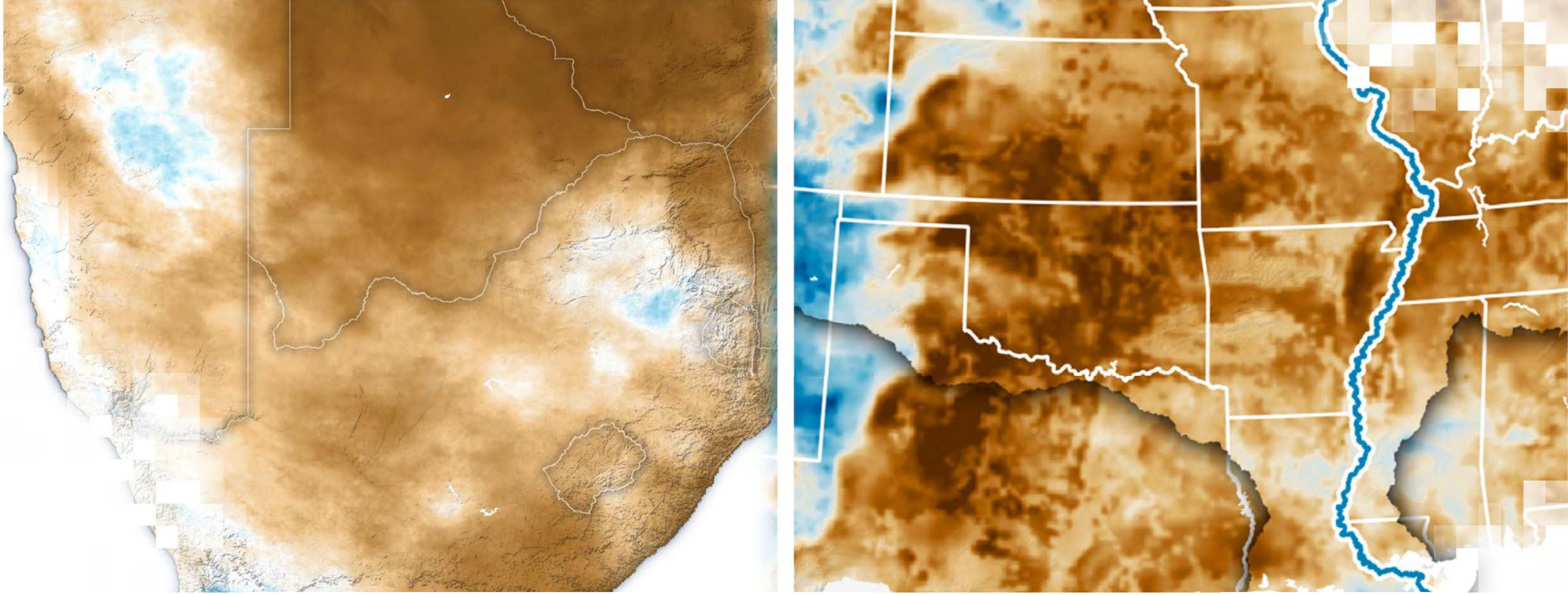
Classification Approaches:

Single Sensor:

- **Classification Approach 1**: Classify the Landsat-8 median composite for the wet season (May – early Dec.)
- **Classification Approach 2**: Classify each image in the Landsat-8 collection for the wet season and then assign the class that each pixel was most voted.

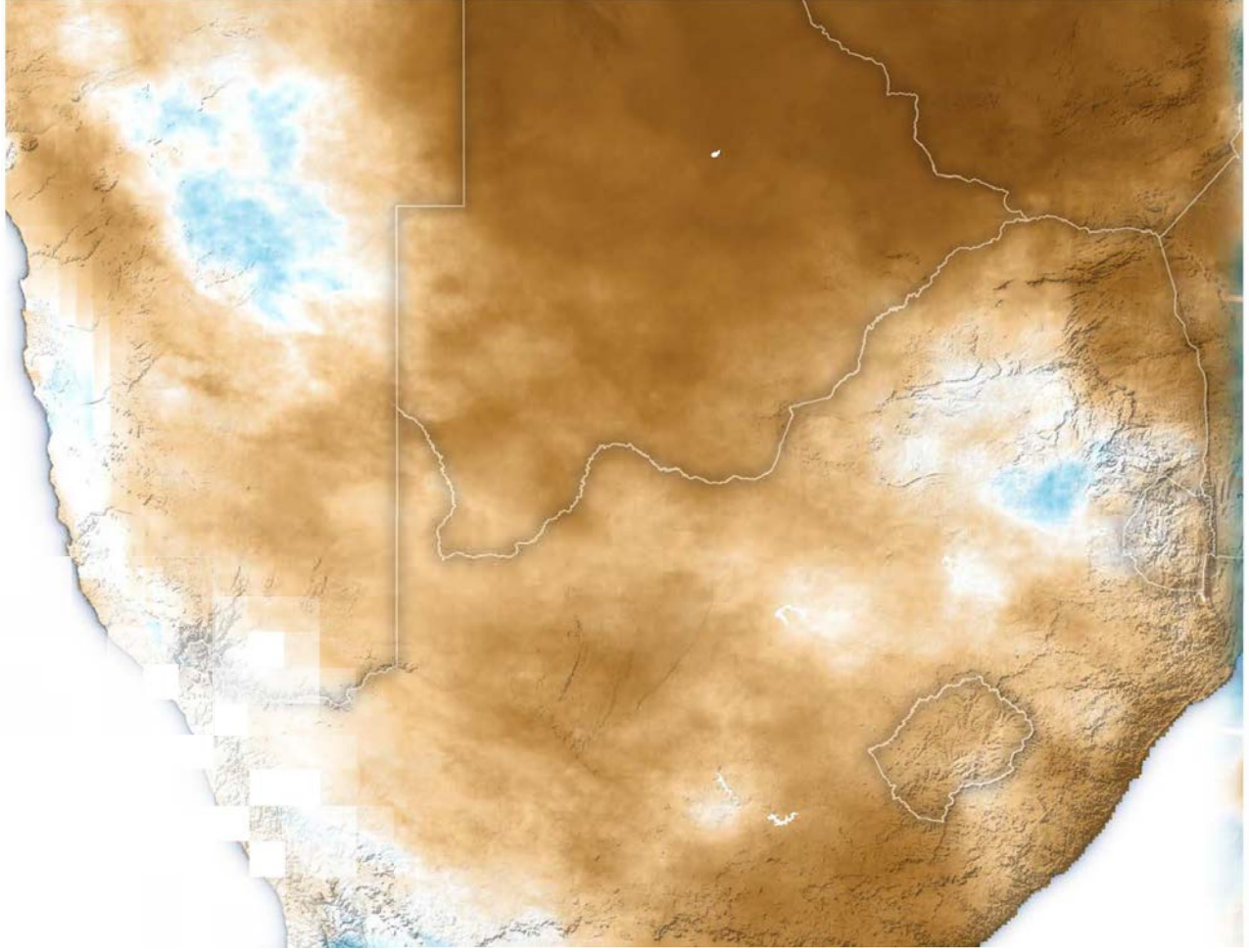
Multiple Sensors:

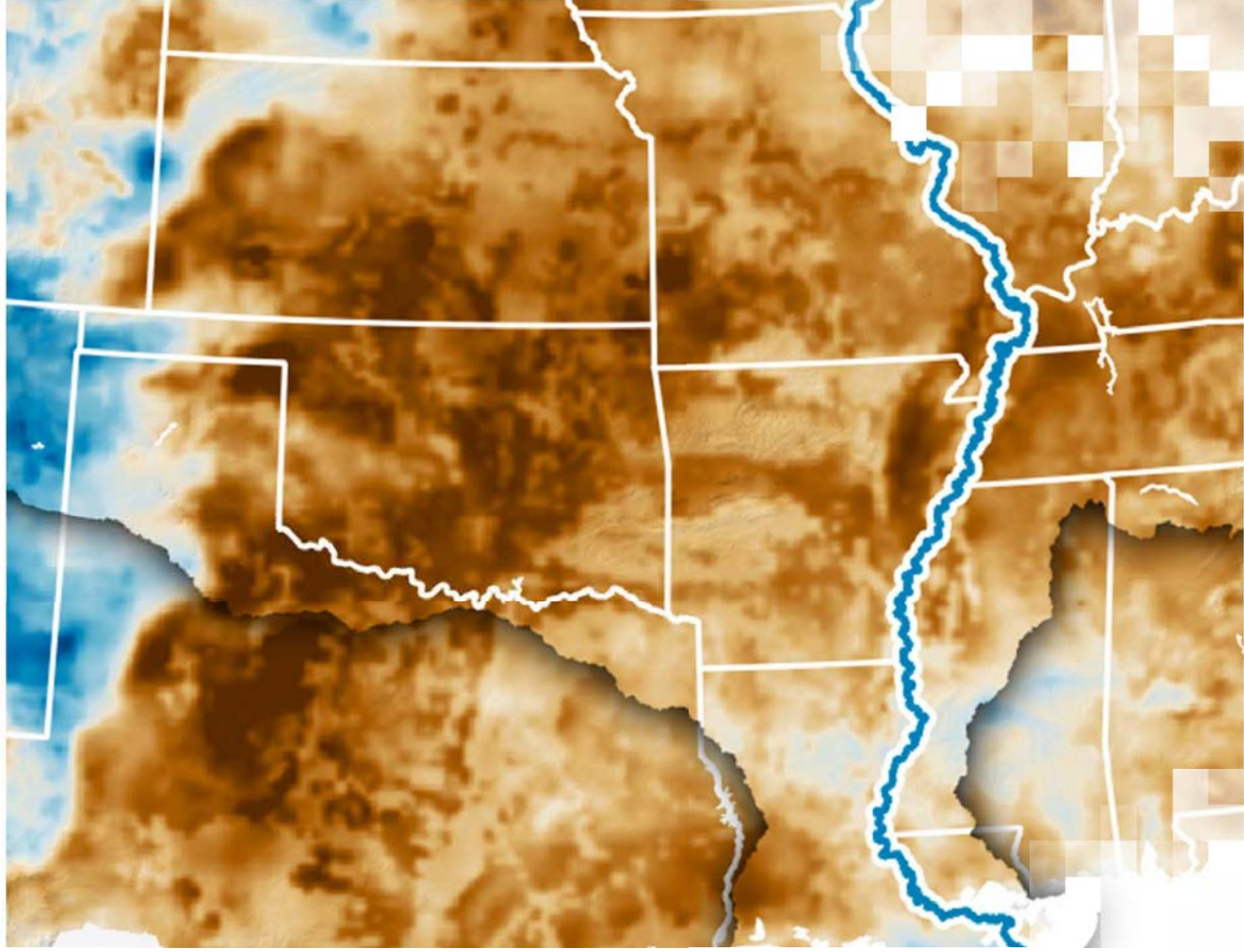
- **Classification Approach 3**: Classify image collections (e.g. Sentinel-2 and Landsat-8) separately and combine their information.



Sustainable Forest Management Information System (SFMIS) Tool Demo

https://github.com/NASAARSET





Drought Monitoring, Prediction, and Projection using NASA Earth System Data

Summary

Summary of Training: Overview

This four-part training focused on drought monitoring, prediction, and projection based on Earth system observations and models.

- **Time scales** of droughts: weekly to multi-year range
- **Drought classifications**:
  - **Meteorological** (precipitation deficit)
  - **Agricultural** (soil moisture deficit, low vegetation/crop yield)
  - **Hydrological** (low streamflow, reduced groundwater)

- NASA Earth observations provide **near-real time to 10+ years of data** for drought monitoring, including precipitation, surface temperatures, vegetation cover, soil moisture, and groundwater.

- **NASA sub-seasonal to seasonal (S2S) prediction system** provides ensemble of forecasts of temperature, precipitation, and soil moisture on monthly to seasonal time scales, useful for water resources and drought management.

- NASA Earth Exchange Global Daily Downscaled Projections for Coupled Model Intercomparison Project Phase 6 (**NEX-GDDP-CMIP6**) climate projections for the 21st century are available from multiple global climate models, downscaled at daily, 0.25x0.25 degree resolutions.

Summary: Indicators, Satellites and Sensors

Earth observations for drought monitoring:
precipitation, soil moisture, vegetation index, temperature, ground water

Type of Drought	Parameter Indicators (Satellites & Sensors)
Meteorological Drought	Precipitation (GPM IMERG) Temperature (Terra & Aqua MODIS, SNPP& JPSS VIIRS, Landsat TIRS,)
Agricultural Drought	Normalized Difference Vegetation Index (NDVI), Evapotranspiration (Terra & Aqua MODIS, SNPP& JPSS VIIRS, Landsat OLI)
Hydrological Drought	Soil Moisture (SMAP), Ground Water (GRACE-FO)

GPM: Global Precipitation Measurements
SNPP: Suomi National Polar Partnership (NSPP
IMERG: Integrated Multi-satellitE Retrievals for GPM
JPSS: Joint Polar Satellite System
MODIS: MODerate-resolution Imaging Spectroradiometer

VIIRS: Visible Infrared Imaging Radiometer Suite
SMAP: Soil Moisture Active Passive
GRACE: Gravity Recovery and Climate Experiment Follow On (FO)
TIRS: Thermal Infrared Sensor
OLI: Operational Land Imager

Summary: Projects and Tools

Drought Indices: Standardized Precipitation Index (SPI), Palmer Drought Severity Index (PDSI), Normalized Difference Vegetation Index (NDVI), and Vegetation Condition Index (VCI)

- NDVI and Solar Induced Fluorescence (SIF) applications for agricultural drought monitoring
- NASA Global Modeling and Assimilation Office (GMAO) **S2S Prediction System**
- **NEX-GDDP-CMIP6** Climate Projections
- NASA Western Waters Association Office (WWAO) Drought Projects:
  - Western Land Data Assimilation System (**LDAS**)
  - **GRACE**-based drought indicators
- Navajo Nation Drought Severity Evaluation Tool (**DSET**)
- Sustainable Forest Management Information System (**SFMIS**) Tool

Review of Demonstrations

- **Drought Monitoring and Evaluation tools**:
  - drought.gov
  - U.S. Drought Monitor
  - Navajo Nation Drought Severity Evaluation Tool (DSET)

- **Drought Impact Tool:**
  - Sustainable Forest Management Information System (SFMIS) Tool

- **Calculations and Analysis for Drought Assessment:**
  - SPI and VCI using Google Earth Engine (GEE)
  - S2S predictions of temperature and precipitation anomalies using QGIS
  - Climate Change Projections of temperature and precipitation till 2100 from NEX-GDDP using GEE

Homework and Certificates

- **Homework:**
  - One homework assignments
  - Opens **8/1/2024**
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 08/15/2024**

- **Certificate of Completion:**
  - Attend all four live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

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APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!