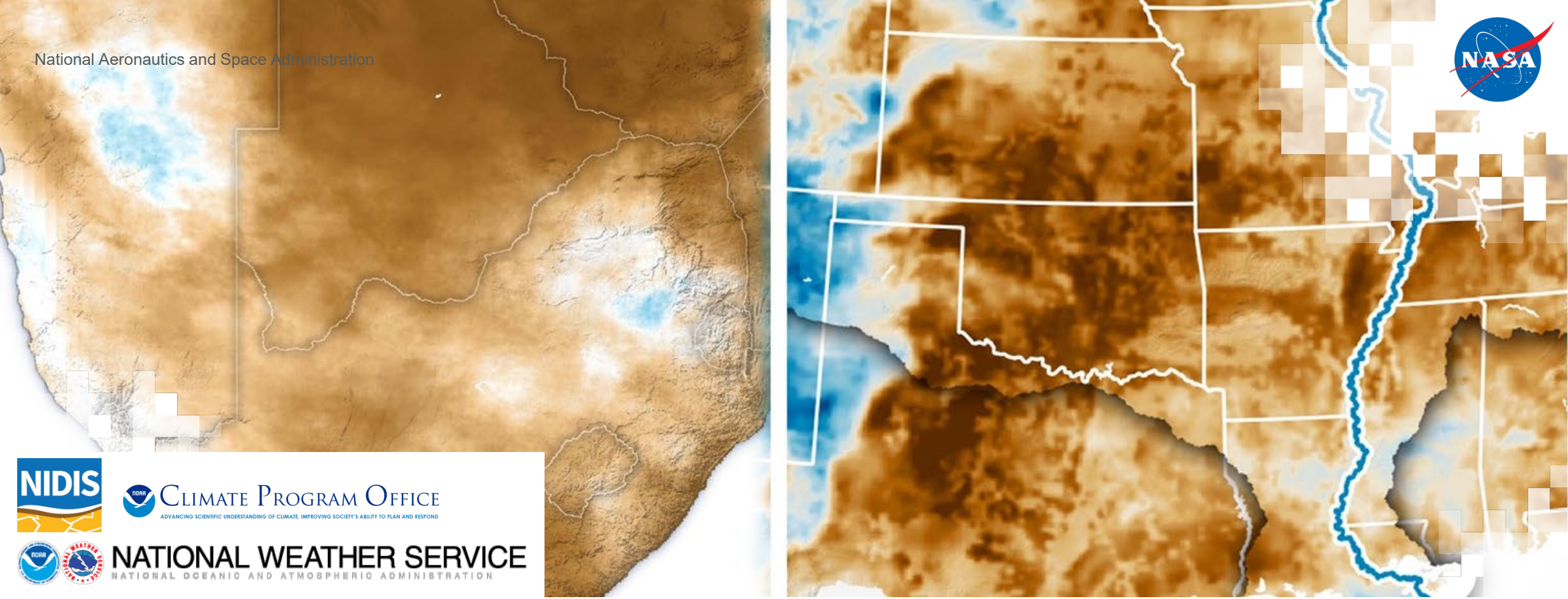
National Aeronautics and Space Administration



NIDIS

CLIMATE PROGRAM OFFICE
ADVANCING SCIENTIFIC UNDERSTANDING OF CLIMATE, IMPROVING SOCIETY'S ABILITY TO PLAN AND RESPOND

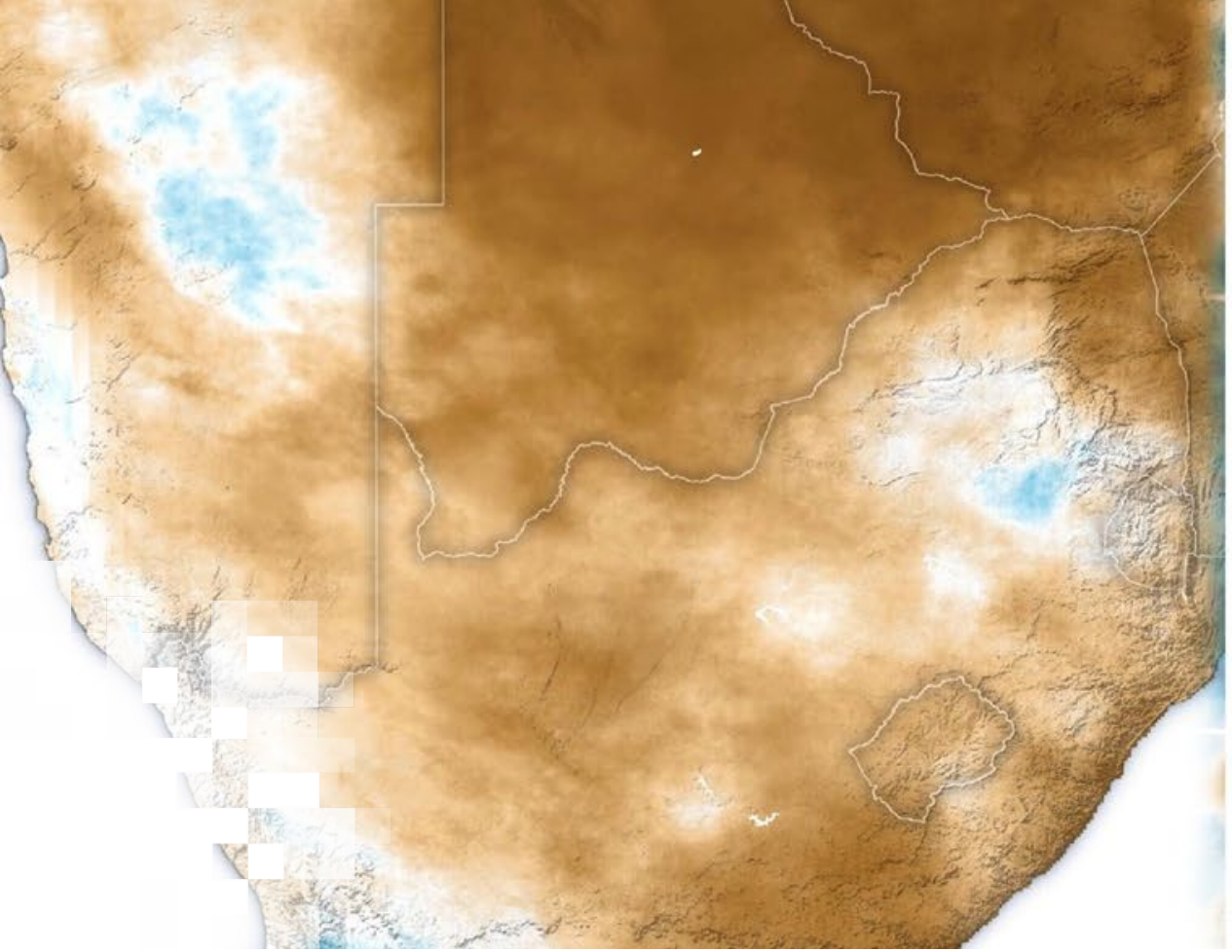
NATIONAL WEATHER SERVICE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

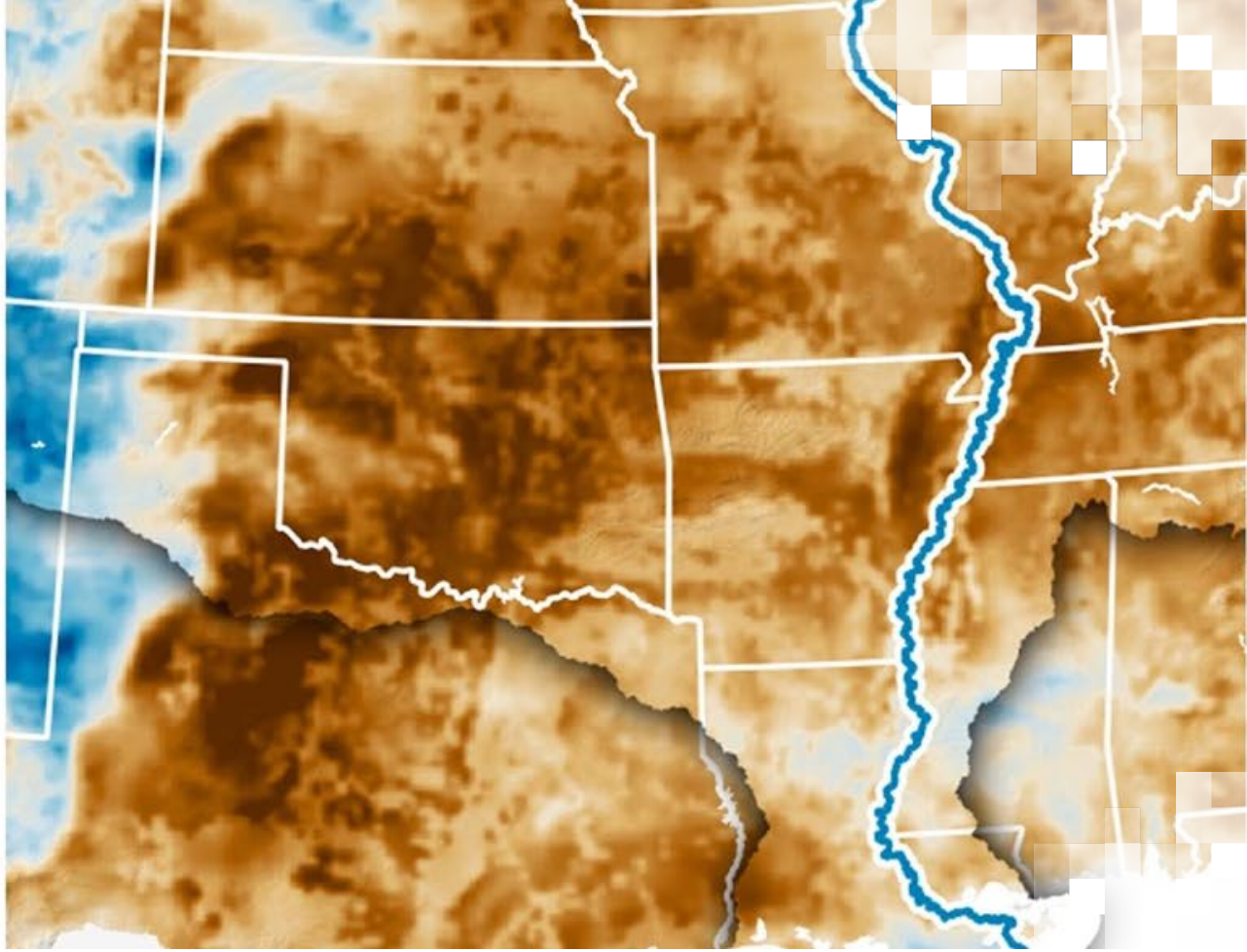
Drought Monitoring, Prediction, and Projection using NASA Earth System Data

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

ARSET Hosts: Amita Mehta, Sean McCartney **Guest Speakers:** Kelsey Satalino (CIRES/NOAA/NIDIS), Brad Pugh (NOAA-NWS), Steve Ansari, (NOAA), Compton Tucker (GSFC) **Coordinator:** Margaret Hurwitz (NOAA)

23 July 2024





About ARSET

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.

AGRICULTURE

CLIMATE & RESILIENCE

DISASTERS

ECOLOGICAL CONSERVATION

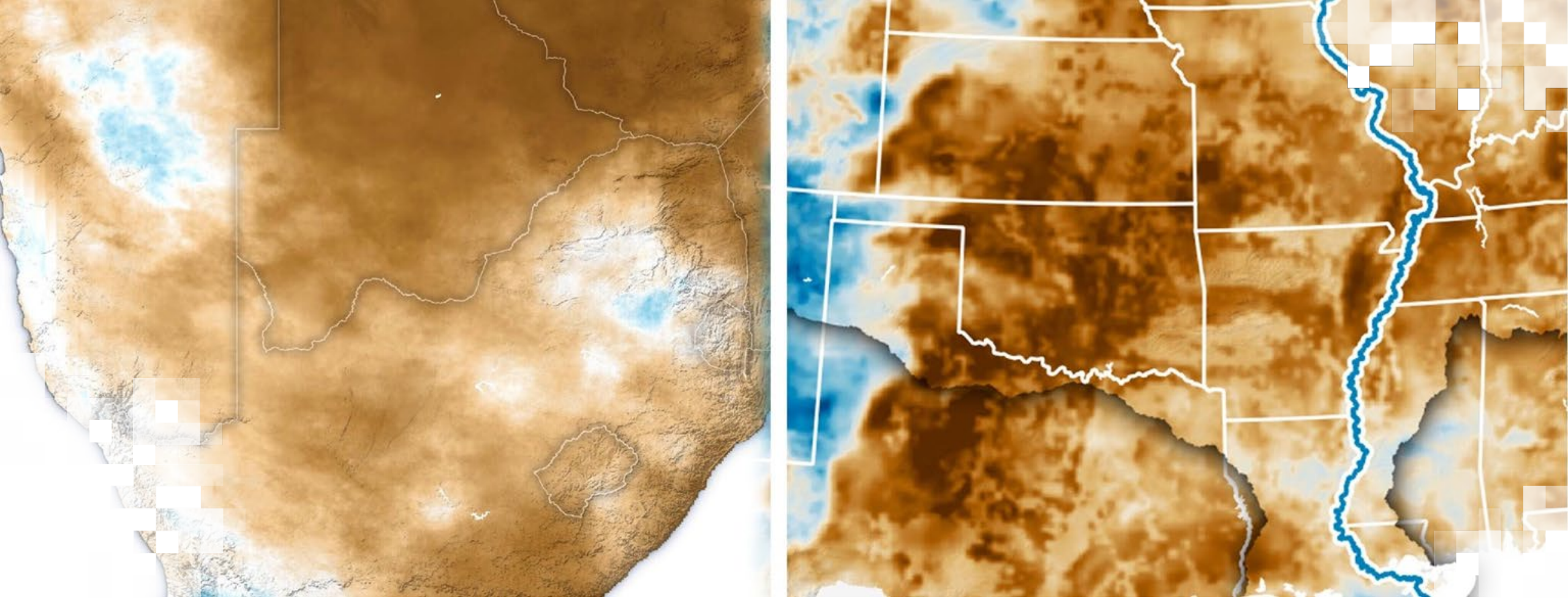
HEALTH & AIR QUALITY

WATER RESOURCES

About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Only use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.

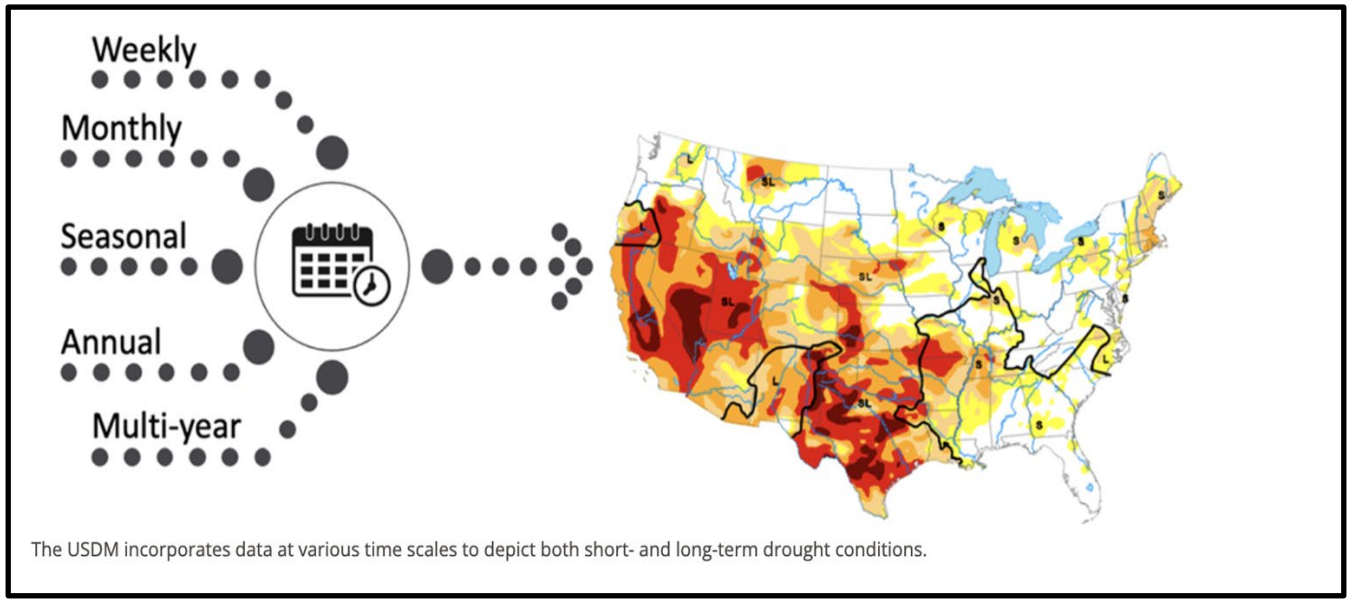


Drought Monitoring, Prediction, and Projection using NASA Earth System Data

Training Overview

Drought – A Period of Water Shortages

- Drought frequency and duration have increased globally since 2000.
- Drought killed 650,000 people between 1970 and 2019.
- Approximately 2.3 billion people around the world are currently facing water stress.
- By 2050, drought could affect more than 75% of the world's population.



University of Nebraska-Lincoln - Many Time Scales of Droughts

- **Droughts affect drinking water availability, crop production, and ecosystems.**
- **For better water, agricultural, and socioeconomical management and planning it is crucial to monitor and forecast drought conditions.**

Reference: UN NEWS: World 'at a crossroads' as droughts increase nearly a third in a generation

Training Learning Objectives

By the end of this training, participants will be able to:

- Identify important Earth observations and tools for assessing short term (week to month) to long-term (seasonal to multi-decadal) drought conditions.
- Identify drought portals and relevant geophysical parameters for monitoring droughts globally and regionally.
- Access and analyze sub-seasonal to seasonal forecasts of temperature and precipitation for evolving drought conditions for a region of interest.
- Access and analyze climate change projection data to assess impacts on long term drought conditions for a region of interest.
- Explore selected regional drought monitoring tools that can be customized for a user's region of interest.

Prerequisites

- Fundamentals of Remote Sensing
- Remote Sensing of Drought

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

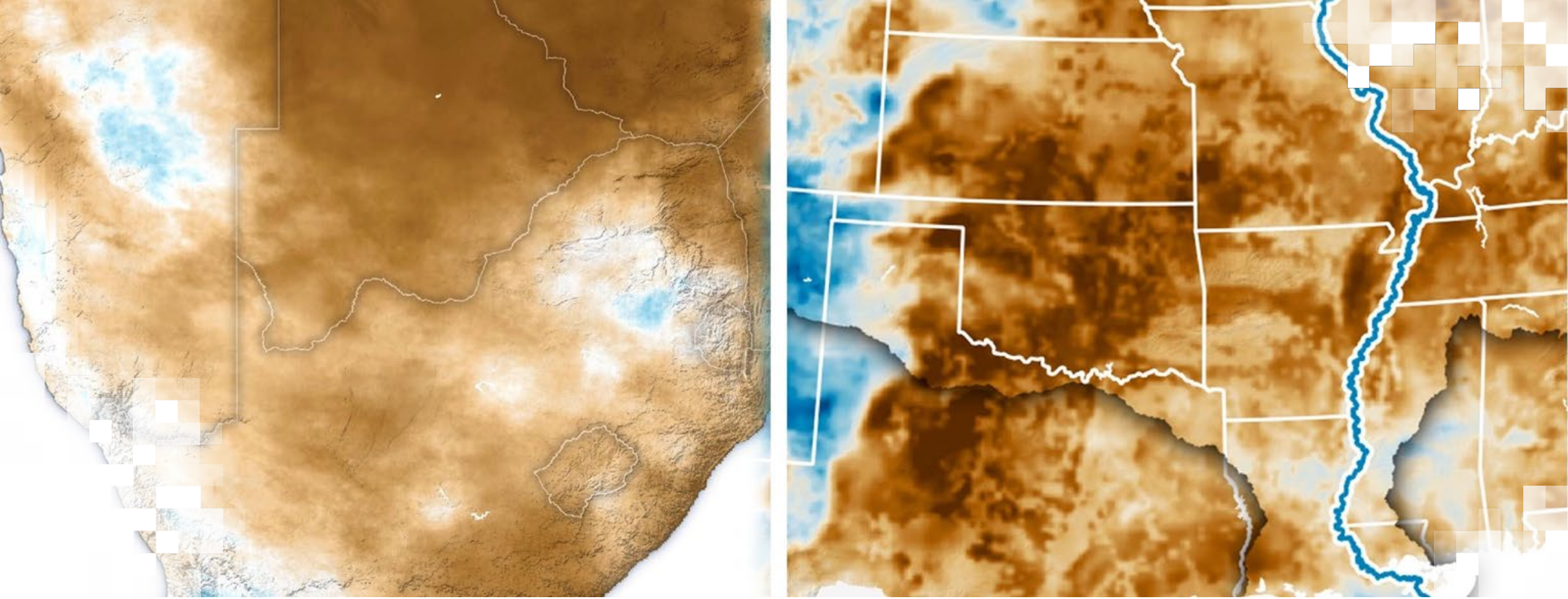
Part 4
Demonstration of Regional Drought Monitoring Tools

August 1, 2024

Homework-1

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.



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

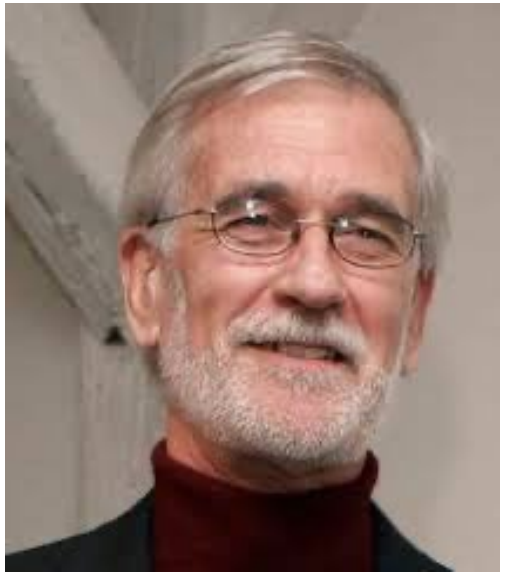
Part 1: Overview of Drought Monitoring Data and Tools using Earth Observations

Part 1 Trainers

Amita Mehta
ARSET Instructor
NASA GSFC, UMBC-GESTAR II

Sean McCartney
ARSET Instructor
NASA GSFC, SSAI

Compton Tucker
Senior Scientist
NASA GSFC



Part 1 Trainers

Kelsey Satalino

Guest Instructor

National Integrated Drought Information System (NIDIS)

Steve Ansari

Guest Instructor

National Centers for Environmental Information (NCEI)

Brad Pugh

Guest Instructor

National Weather Service

Margaret Hurwitz

Part-1 NOAA Coordinator

National Weather Service

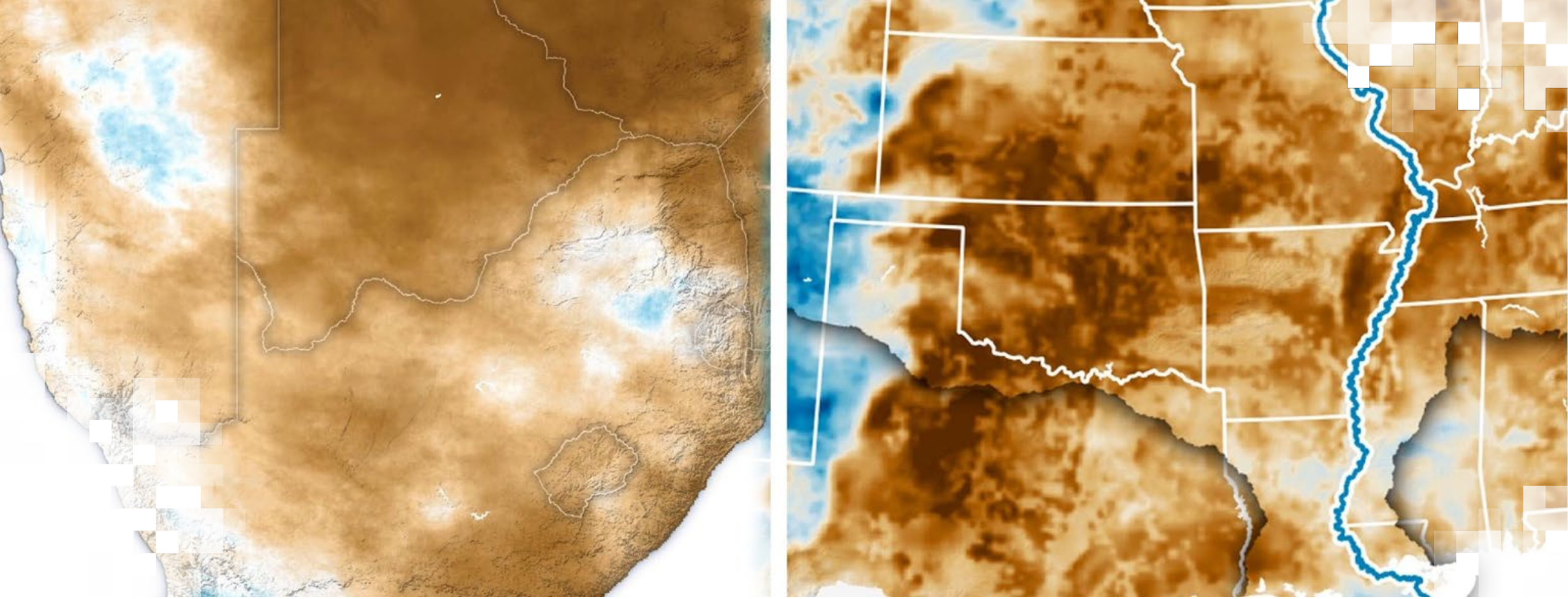
Part 1 Objectives

By the end of Part 1, participants will be able to:

- Identify Earth observation data sets and tools for both global and regional drought monitoring.
- Explore regional drought monitoring tools for analyzing drought conditions in the US.
- An overview of drought mapping for food security using Global Inventory Modeling and Mapping Studies (GIMMS) Global Agricultural Monitoring (GLAM).
- Calculate drought indices for a selected time and region of interest using Google Earth Engine (GEE).

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.



Earth Observations and Tools for Monitoring Drought Conditions

Types of Droughts

- Meteorological
  - Indicator: Precipitation
- Agricultural
  - Indicator: NDVI (Normalized Difference Vegetation Index)
- Hydrological
  - Indicator: Soil Moisture, Ground Water

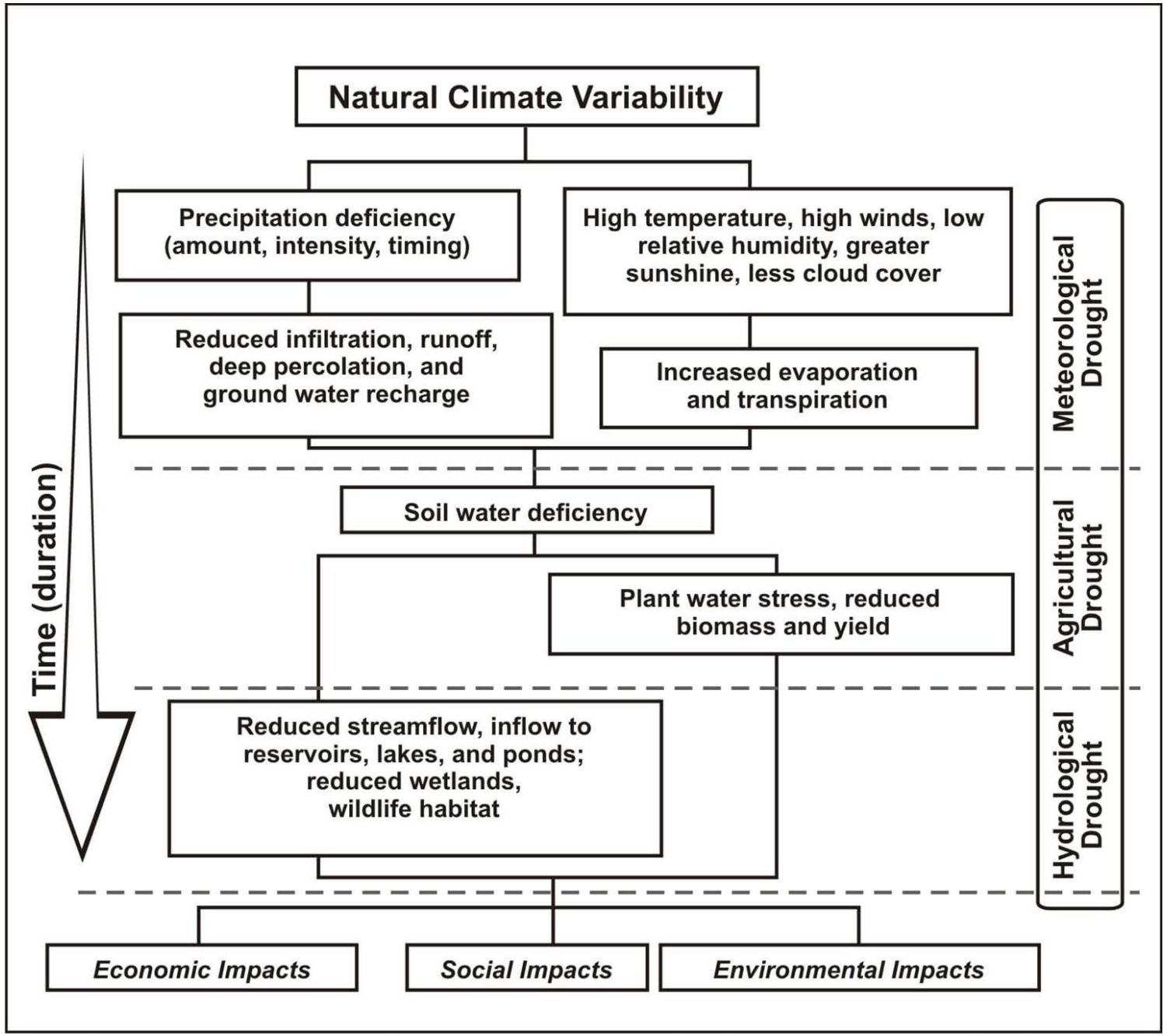


Image Credit:
National Drought Mitigation Center

Satellites and Sensors for Drought Monitoring

Parameter	Satellite	Sensors	Spatial/Temporal Resolutions and Coverage
Precipitation	Combined TRMM & GPM With Multiple Satellite Constellation **IMERG**	Microwave Radiometer (TMI, GMI) and RADAR (PR, DPR) Microwave Imagers and Sounders Calibrated with GPM Sensor Data	0.1° x 0.1° 30-Minute, Daily, Monthly 06/2000 to Present
Soil Moisture	SMAP	L Band Microwave Radiometer	9 km x 9 km & 36 km x 36 km 2–3 Day 3/2015 to Present
Ground Water	GRACE GRACE-FO	K Band Microwave Radar Altimeters	March 2002 – October 2017 May 2018 – Present

TRMM: Tropical Rainfall Measurement Mission
GPM: Global Precipitation Measurements
SMAP: Soil Moisture Active Passive
GRACE: Gravity Recovery and Climate Experiment & GRACE-Follow On (FO)

Satellites and Sensors for Drought Monitoring

Parameter	Satellite	Sensors	Spatial/Temporal Resolutions and Coverage
	*Landsat 4 Landsat 5 Landsat 7 Landsat 8 Landsat 9	Thematic Mapper (TM) Enhanced Thematic Mapper (ETM+) Operational Land Imager (OLI & OLI2) Thermal Infrared Sensor (TIRS & TIRS2)	30 m, 185 km Swath 16-Day 7/1982 – 12/1993 3/1984 – 01/2013 4/1999 – Present 02/2013 – Present 09/2021 – Present
land Surface Temperature NDVI Evapotranspiration	Terra Aqua	MODerate-resolution Imaging Spectroradiometer (MODIS)	250m – 1 km, 2350 km Swath 12/1999 – Present Daily, 8-days, Monthly 04/2002 – Present
	Suomi National Polar Partnership (SNPP) Joint Polar Satellite System (JPSS)	Visible Infrared Imaging Radiometer Suite (VIIRS)	375 m and 750 m 3000 km Swath Daily, 10/2011 – Present 11/2018 – Present

*Landsat 1, 2, and 3 had Multi Spectral Scanner and did not have thermal IR bands

Drought Indices

- Drought indices are mathematical representation of water deficit (and excess) compared to historical data.
- Help decide when to start implementing water conservation or drought response measures.
- Can be used to analyze drought frequency, severity, and duration for a given location and period.

Commonly used operational drought indices are:

- **Standardized Precipitation Index (SPI)**
- **Palmer Drought Severity Index (PDSI)**
- **Normalized Difference Vegetation Index (NDVI) anomalies**

Review: Remote Sensing of Drought

Source: National Drought Mitigation Center

Standardized Precipitation Index (SPI)

About SPI

- Primarily defined to characterize meteorological drought.
- Mathematically, historical rainfall data at any location fitted with gamma distribution represent cumulative probability function.
- If a rainfall event is a low probability on the cumulative probability function, it is indicative of a drought event.
- The SPI values can be interpreted as the number of standard deviations by which the observed rainfall anomaly deviates from the long-term mean.
- SPI averaged over different time periods (3, 6, 9, 12 months) indicate severity and duration of drought.

Reference: Guttman, N. B., 1999: Accepting the Standardized Precipitation Index: A calculation algorithm. J. Amer. Water Resour. Assoc.., 35(2), 311-322.

Palmer Drought Severity Index (PDSI)

About PDSI

- An index for evaluating the severity and frequency of prolonged periods of abnormally dry or wet conditions
- Uses **temperature** and **precipitation** data and a physical water balance model to estimate relative dryness
- A standardized index that goes from -10 (dry) to +10 (wet)

PDSI(m)=PDSI{m-1+[Z(m)/3-0.103 PDSI(m-1)}

- m = month index
- Z(m) = moisture anomaly index (based on a water balance model)

References:

Palmer, W. C., 1965: Meteorological drought. Research Paper 45, U.S. Dept. of Commerce, 58 pp.

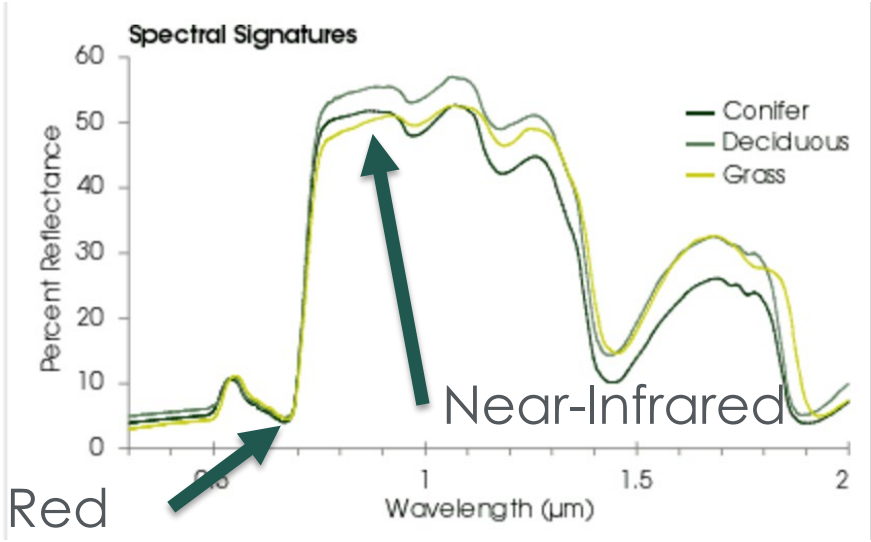
Dai, A., K. E. Trenberth, and T. Qian, 2004: A global data set of Palmer Drought Severity Index for 1870-2002: Relationship with soil moisture and effects of surface warming. J. Hydrometeorology, 5, 1117-1130.

Normalized Difference Vegetation Index (NDVI)

Measuring Vegetation From Space

- Normalized Difference Vegetation Index
  - Based on the relationship between red and near-infrared wavelengths
  - Chlorophyll strongly absorbs visible (red)
  - Plant structure strongly reflects near-infrared
- Values range from -1.0 to 1.0.
- Values close to 1 indicate the highest possible density of green leaves.
  - Negative values to 0 mean no green leaves.
- NDVI anomalies (departure from long-term mean) can be used to monitor drought conditions.

$$NDVI = \frac{\text{Near Infrared - Red}}{\text{Near Infrared + Red}}$$



Drought Monitoring and Early Warning Tools

EOTEC DEVNET Drought Data and Tool Matrix

Global and Regional Drought Monitoring Tools

MODIS Terra Vegetation Indices	GlobalDrought Information System	Global and regional (Europe, Central and South America, **Africa**) Drought Observatory	Mekong Drought and Crop Watch	UN-SPIDER Recommended Practice: Drought monitoring using the Vegetation Condition Index (VCI)
NASA Drought GIS Web App	ClimateSERV	East Africa Drought Watch - ICPAC	Risk and Resilience Portal (Asia Pacific	UN-SPIDER Recommended Practice: Drought monitoring using the Standard Vegetation Index (SVI)
North American Drought Monitor	Drought Central	African Flood and Drought Monitor	South Asia Drought Monitoring System (SADMS)	Drought Toolbox by UNCCD International Drought Resilience Alliance
National Integrated Drought Information System	Drought Monitoring System	Africa Drought Advisory	Regional Drought Monitoring and Outlook System (RDMOS)	
North America Drought Indices and Indicators Assessment		Africa Flood and Drought Monitor (WASA Secure Africa Initiatives)	City Drought Risk Management Toolkit	

Drought Monitoring and Early Warning Tools

EOTEC DEVNET Drought Data and Tool Matrix

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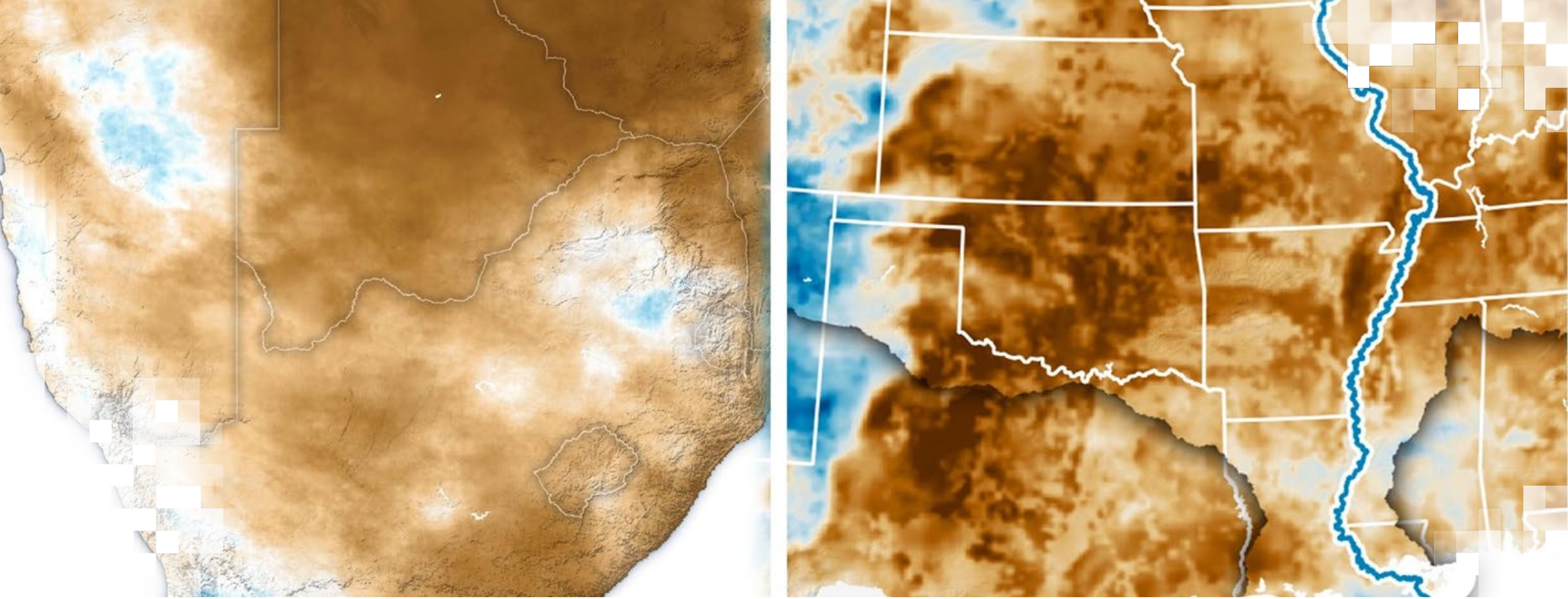
North America Drought Indices and Indicators Assessment		Africa Flood and Drought Monitor (WASA Secure Africa Initiatives)	City Drought Risk Management Toolkit	**Global Agricultural Monitoring**

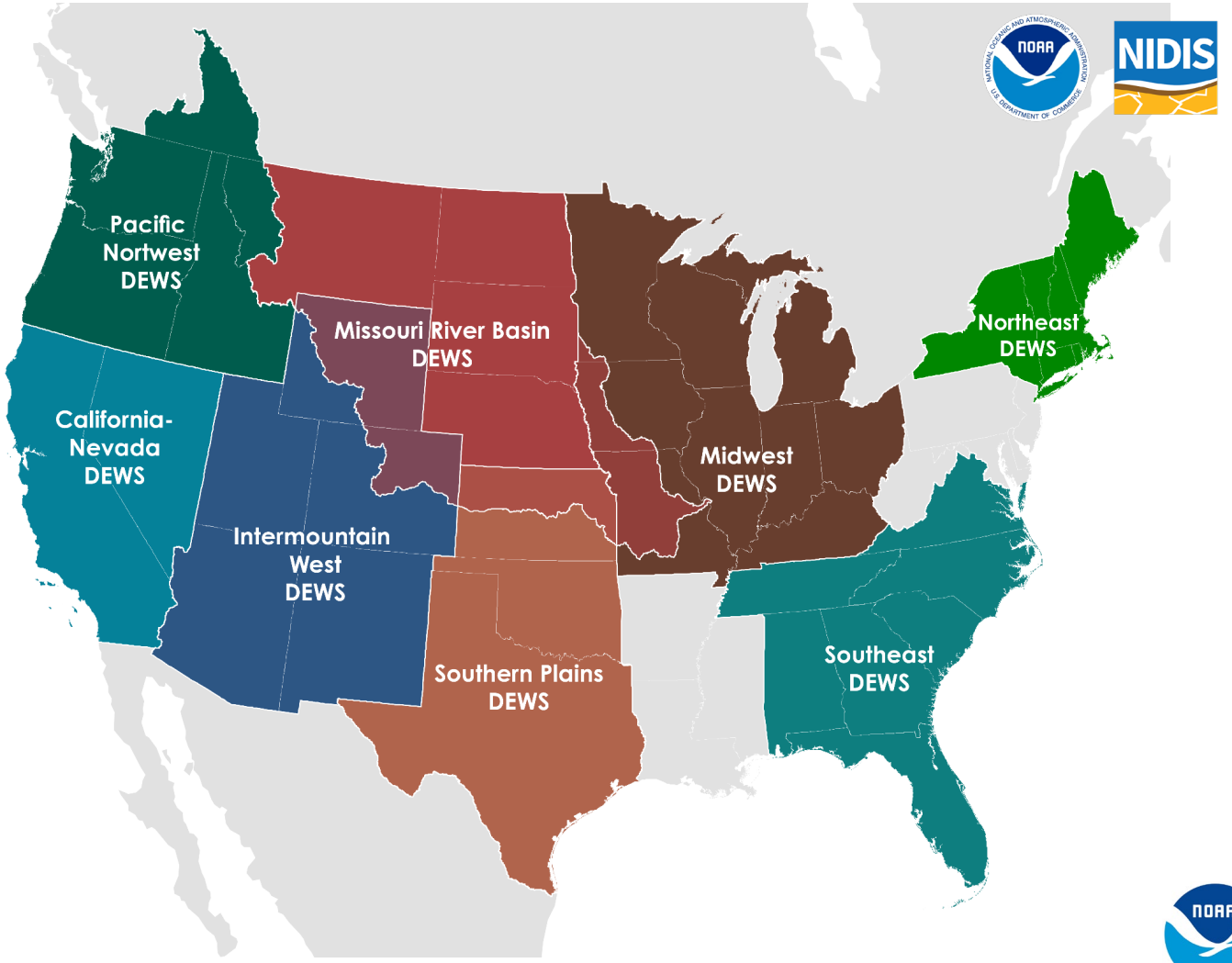


Drought.gov Resources for Monitoring Drought

Kelsey Satalino (Cooperative Institute for Research in Environmental Sciences (CIRES), NOAA's National Integrated Drought Information System (NIDIS); Steve Ansari, NOAA's National Centers for Environmental Information (NCEI)

NOAA's National Integrated Drought Information System (NIDIS)

- NIDIS is a multi-agency U.S. government program with a mandate to develop and provide a **national drought early warning system.** NIDIS is advancing this goal through its 8 regional drought early warning systems (DEWS).
- NIDIS coordinates drought monitoring, forecasting, planning, and information at federal, tribal, state, and local levels across the country.
- Mission: Enable the Nation to move **from a reactive to a more proactive** approach to managing drought risks and impacts.

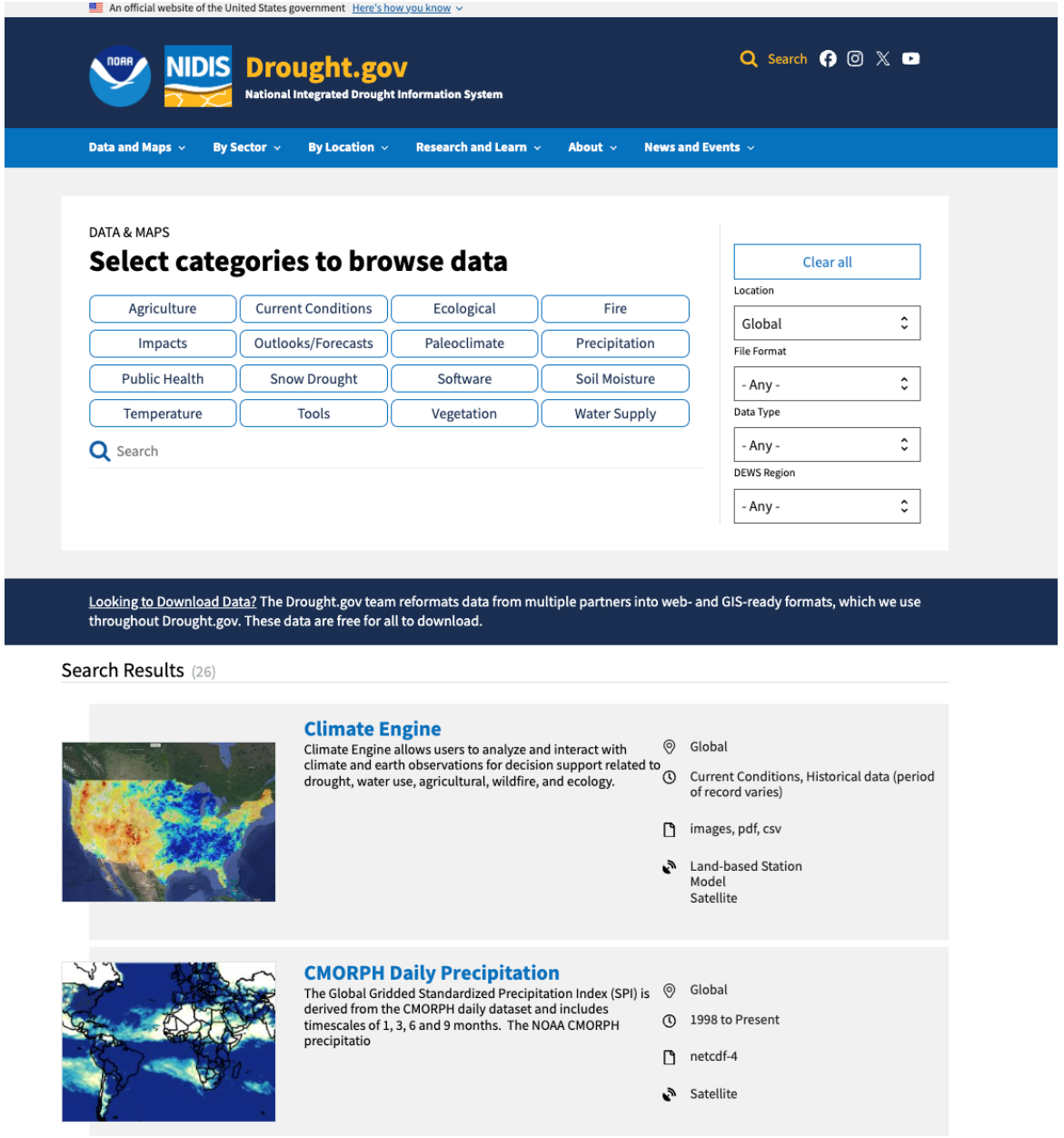


U.S. Drought Portal: A One-Stop Shop for Trusted Drought Information

- NIDIS established the U.S. Drought Portal (www.drought.gov) in 2008.
- **The Portal is the U.S. government's authoritative, interagency drought information website**, integrating data, maps, tools, and decision-support resources from across government and other agencies.
- It is managed by a development team at NOAA's National Centers for Environmental Information (NCEI), led by the U.S. Drought Portal Manager, Steve Ansari.

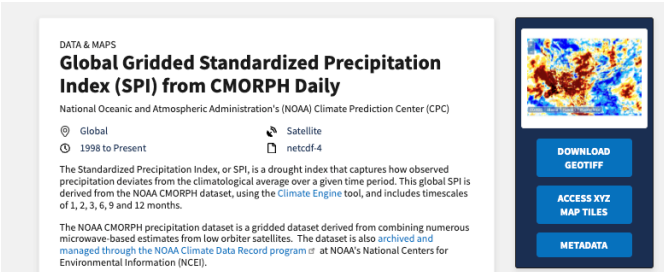
About Drought.gov

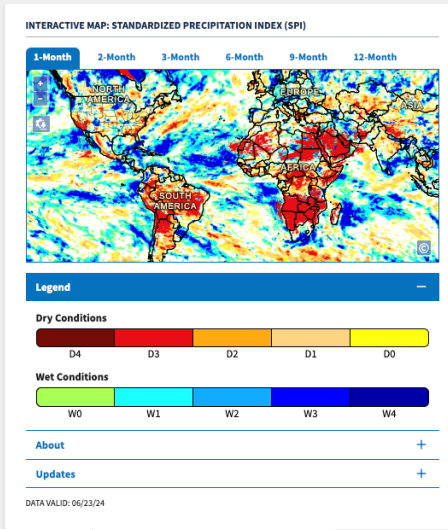
- Focuses primarily on **U.S. data**, but includes **global data** and resources as well
- **Interactive and customizable maps & tools** allow users to visualize data in new ways and to download data files & high-quality, customized images
- Explore drought data by **location**, **topic**, or economic **sector**
- **Data catalog** features background information, documentation, links, and data downloads for national and global drought & climate datasets

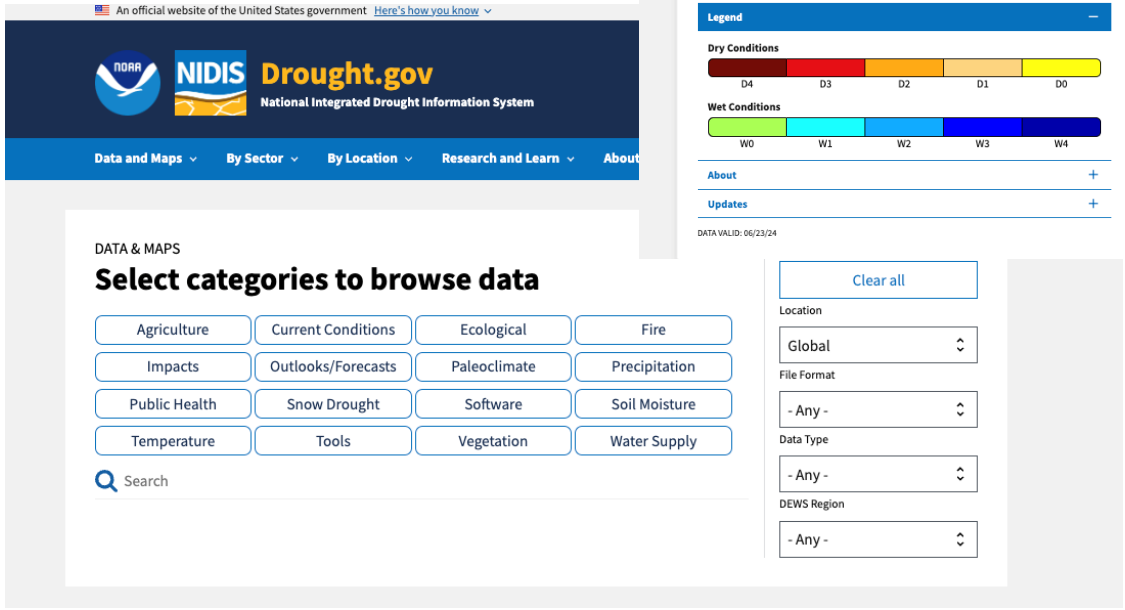


Data Catalog: Explore Drought & Climate Tools

- Curated collection of drought datasets, maps, and tools
- Search for a specific tool in the search bar
- Or, filter by **data category**, **geographic coverage**, **file format**, or **data type** (e.g., in situ, remote sensing)
- Each data catalog page includes an **overview** of the dataset or tool, **documentation**, **links** to the original source, and (where available) **data downloads.**







Customize & Download Every Map on the Website

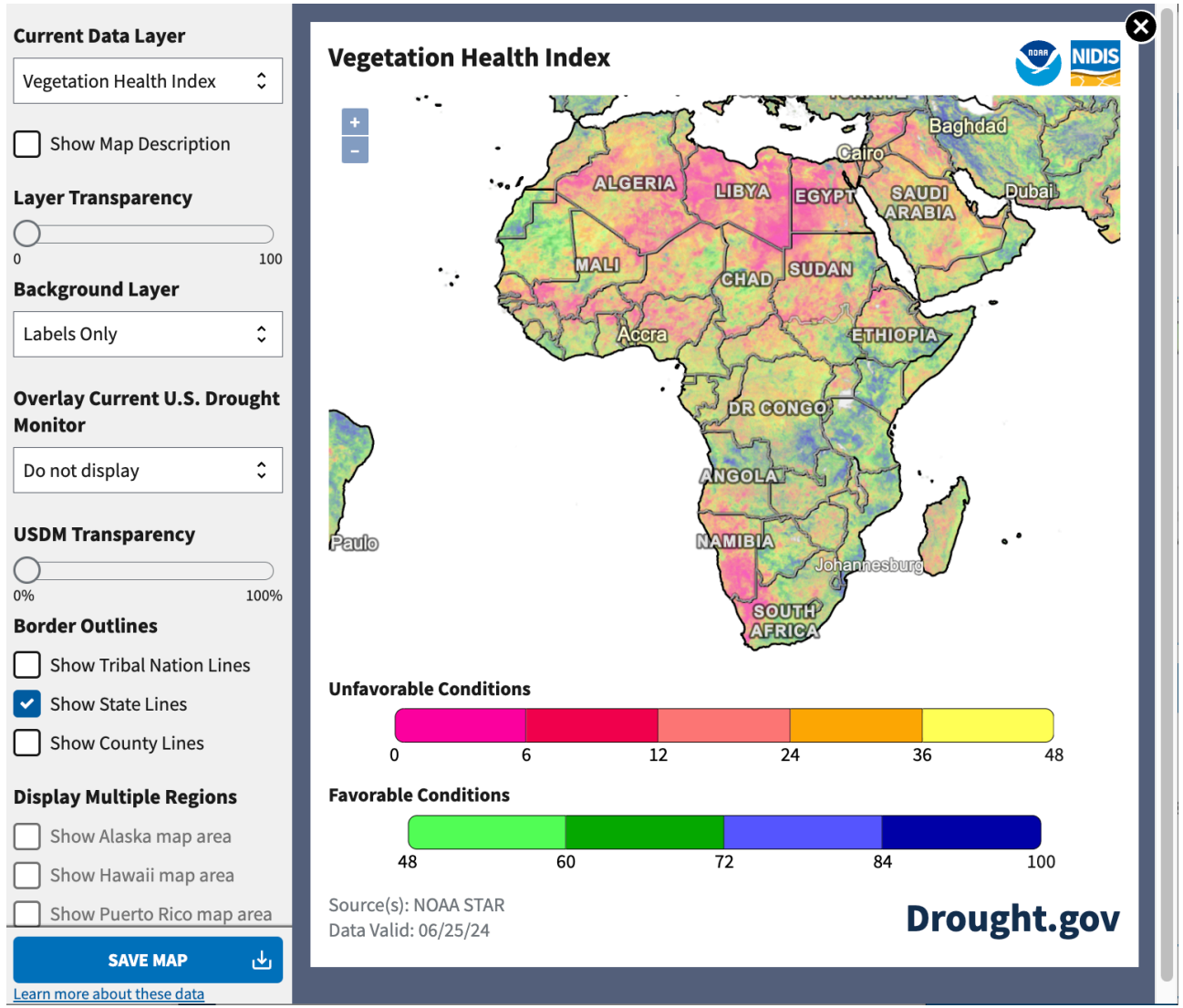
Choose data layer: toggle between maps while maintaining zoom extent

Adjust layer transparency & change the basemap

Overlay the latest U.S. Drought Monitor

U.S. datasets: Overlay geographic boundary lines for states, counties, & tribal land areas

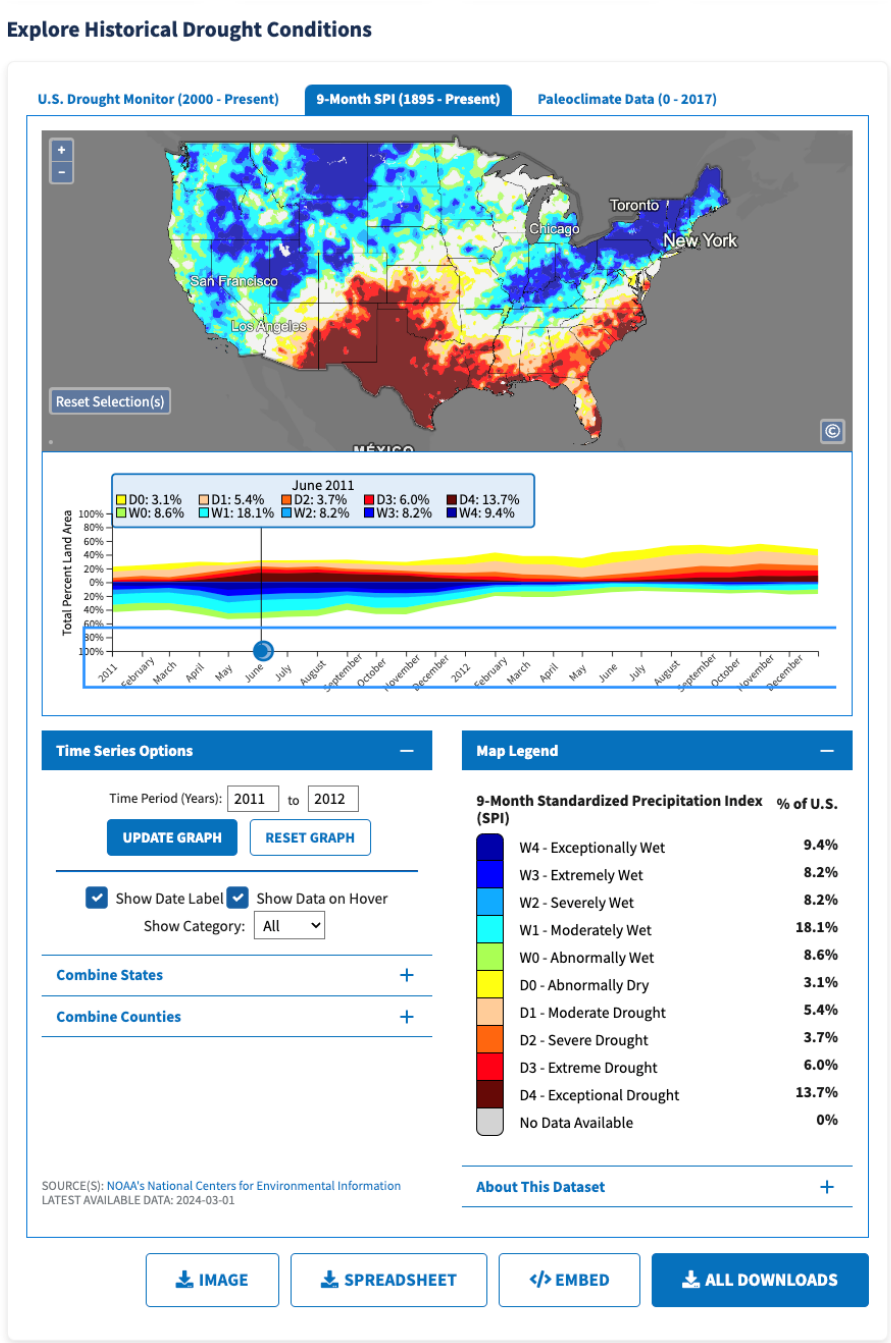
Download a high-quality PNG image



Explore Historical Conditions

Interactive time series graph & map allow you to view – and download – 3 historical drought datasets side by side:

- **U.S. Drought Monitor**
  - Issued weekly, 2000–present
- 9-Month **Standardized Precipitation Index (SPI)**
  - Issued monthly, 1985–present
- Estimated **Palmer Modified Drought Index (PMDI)**, based on paleoclimate data (tree-ring reconstructions) + instrumental data
  - Annual June–August PMDI estimate, 0–2017



Historical Conditions Tool

Choose data layer: Select a tab to view 3 historical drought datasets

Click on a state or county to load state historical data. Shift+click to select multiple states/counties.

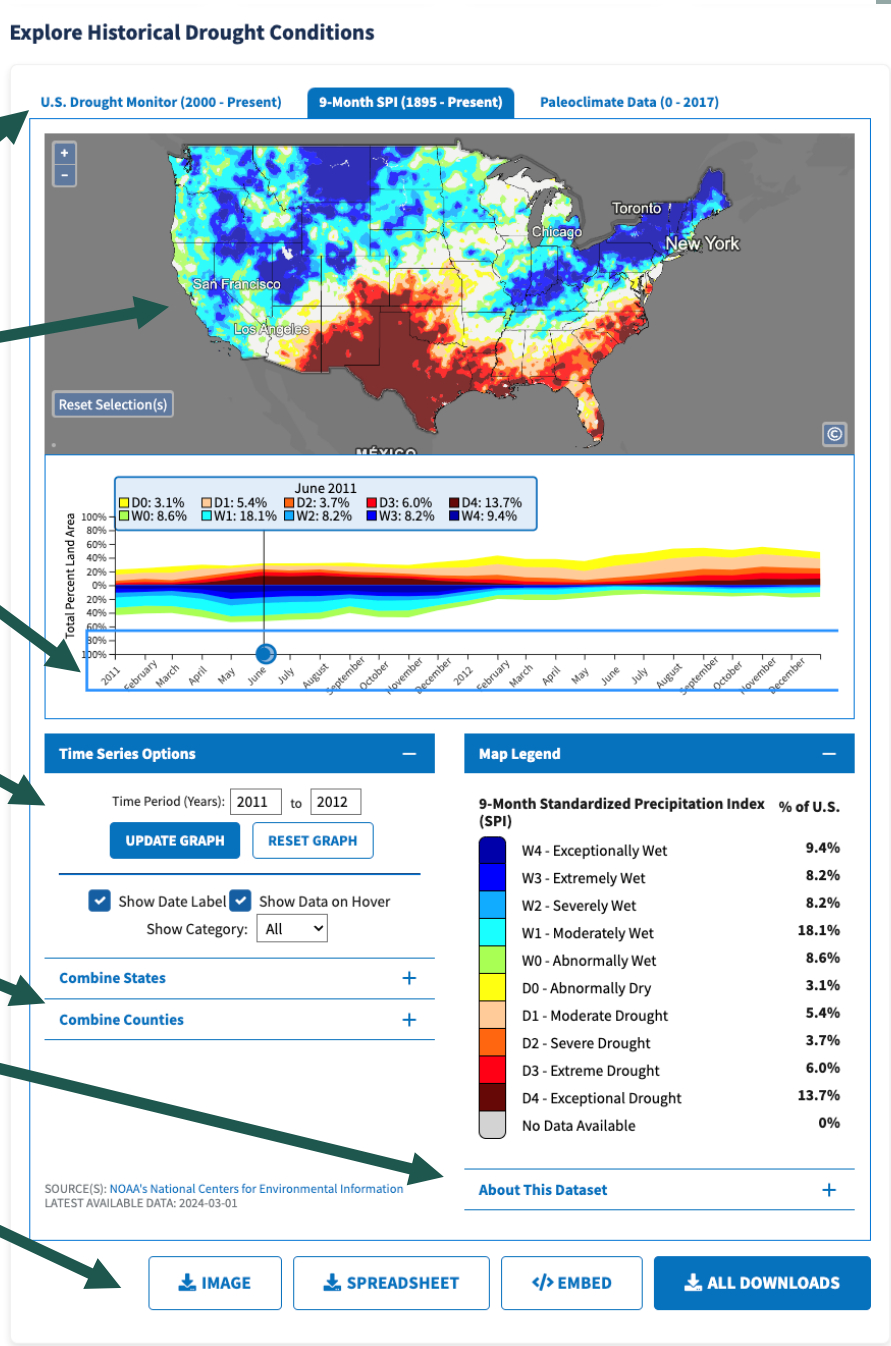
Click a point on the time series to update the map and statistics. Or, hover over the time series to view quick statistics as you scan.

Use the "**Time Series Options**" to zoom in on a time period, show or hide the date label and hoverable statistics, or isolate a specific drought category on the time series.

Use the "**Combine States**" and "**Combine Counties**" sections to select multiple regions for a custom map/time series.

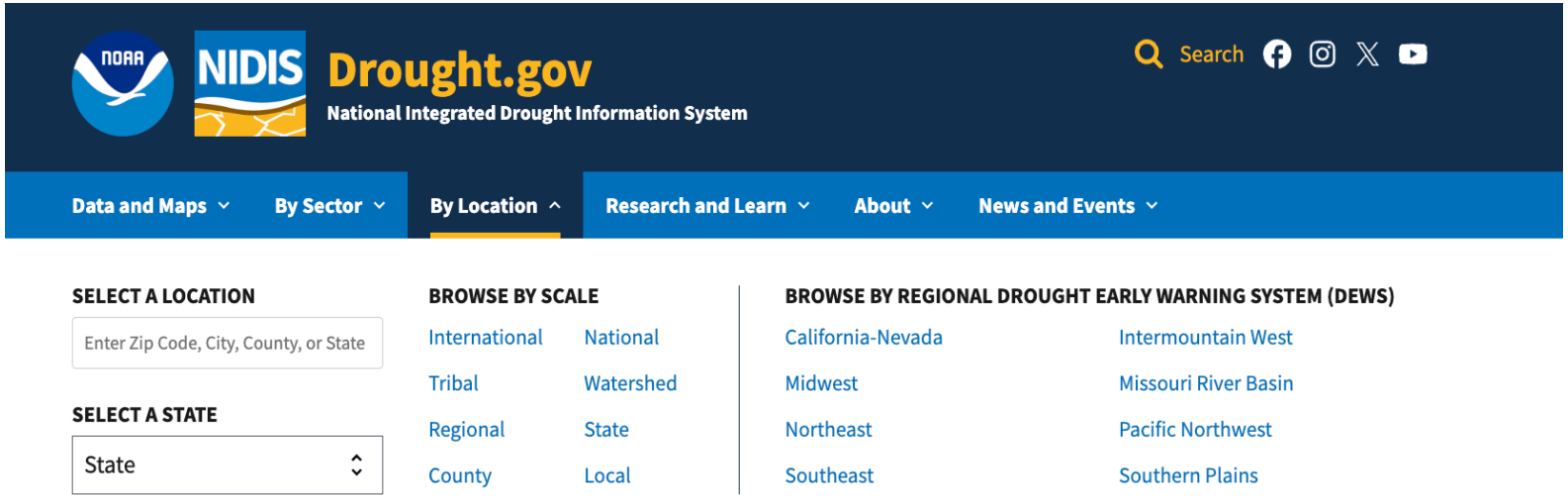
Hover over the legend and select "**About This Dataset**" to view more info on the data.

Download an image or a CSV, XML, or JSON file. Or, embed the tool in your own website.



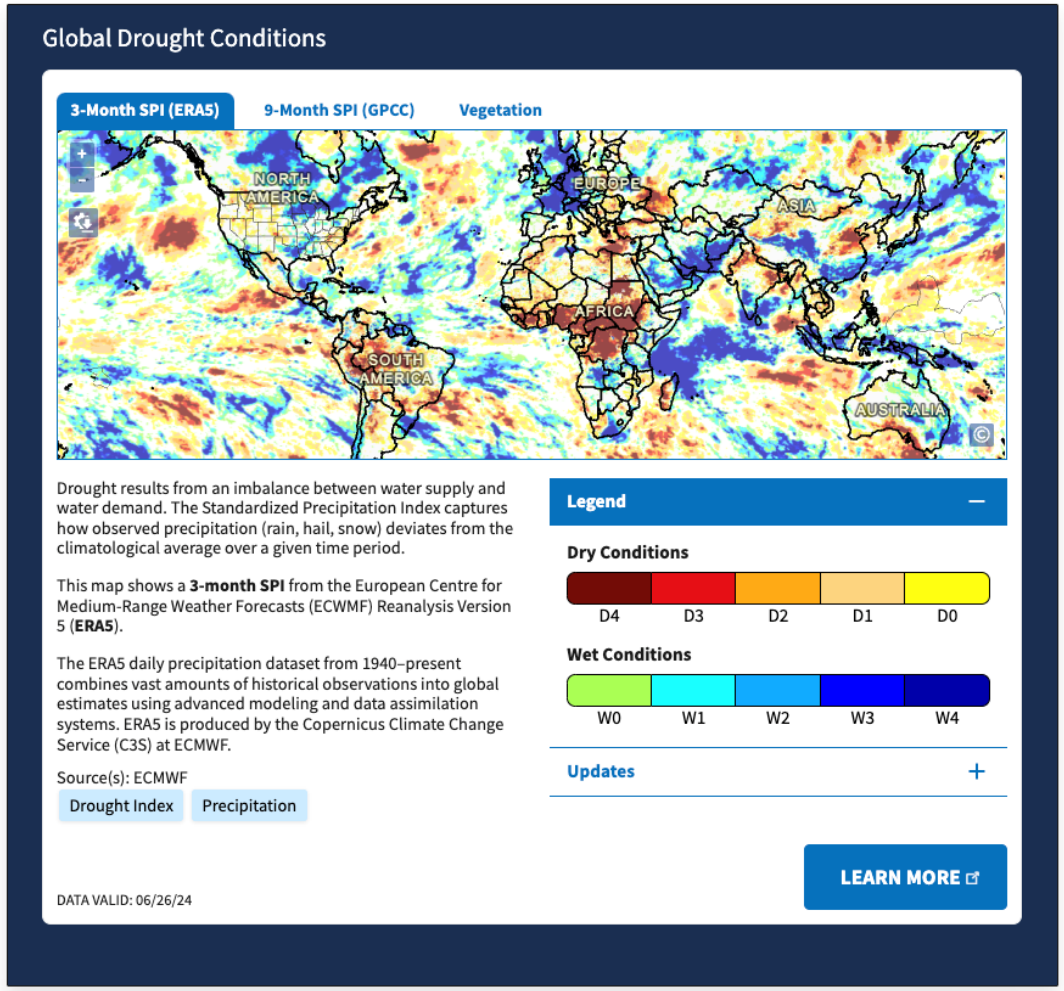
Drought Data By Location: From City/County to Global Scale

- Find drought and climate maps, statistics, and resources personalized for your location:
  - City/Zip Code
  - County
  - State or Territory
  - HUC2 Watershed
  - Tribal Nations
  - United States (National)
  - International

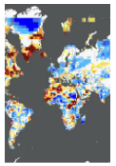


- You can also view information on NIDIS's eight regional **Drought Early Warning Systems** (DEWS) throughout the U.S.

Drought Data By Location: International Resources



Featured International Drought Maps



GLOBAL DROUGHT MONITOR

Source: NOAA's National Centers for Environmental Information

The Global Drought Information System (GDIS) is an international effort to pull together the best non-prescriptive drought information from local providers and provide an "apples to apples" comparison of drought conditions around the world. The Global Drought Monitor depicts current drought conditions across the globe using a "bottom-up" approach. This means that the drought conditions on each continent are assessed by the Nations of that continent.

VISIT WEBSITE

NORTH AMERICAN DROUGHT MONITOR

Source: USA, Canada, Mexico

The North American Drought Monitor (NADM) is a cooperative effort between drought experts in Canada, Mexico, and the United States to monitor drought across the continent on an ongoing basis. The program was initiated at a three-day workshop in late April 2002 and is part of a larger effort to improve the monitoring of climate extremes on the continent. The NADM is updated monthly and is based on the U.S. Drought Monitor.

VISIT WEBSITE ABOUT NADM

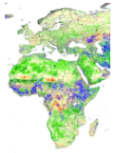
Tools to Visualize and Analyze Drought Worldwide

CLIMATE ENGINE

Source: Desert Research Institute, Western Regional Climate Center, University of California, Merced

Climate Engine uses Google's Earth Engine to process satellite and climate data on demand to visualize value and anomaly mapping, as well as time series and statistical summaries of datasets. This allows users to analyze and interact with climate and earth observations for decision support related to drought, water use, agriculture, wildfire, and ecology.

VISIT WEBSITE



GLOBAL INFORMATION AND EARLY WARNING SYSTEM ON FOOD AND AGRICULTURE

Source: Food and Agriculture Organization of the United Nations

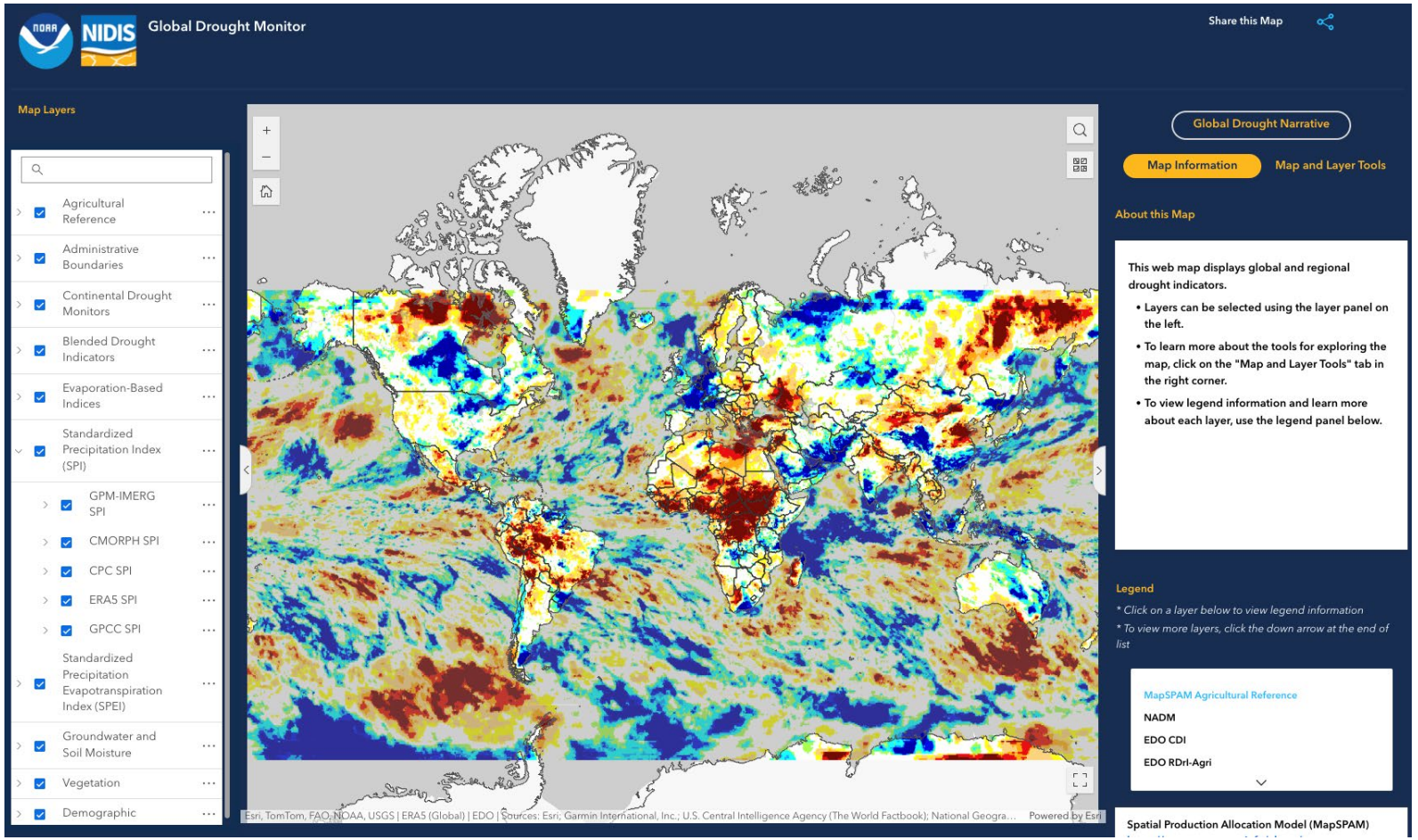
The Global Information and Early Warning System on Food and Agriculture (GIEWS) seeks to strengthen agricultural drought monitoring and early warning globally. GIEWS uses remote sensing to estimate precipitation and to monitor the following, both globally and for individual countries: Agricultural Stress Index; drought intensity; Normalized Difference Vegetation Index (NDVI) anomalies; Vegetation Condition Index; and Vegetation Health Index. A country-level Agricultural Stress Index System (ASIS) tool has been incorporated into GIEWS to support country-level monitoring and management of agricultural drought, providing more precise information on drought stress to crops. The tool will be expanded to more countries in the future.

VISIT WEBSITE

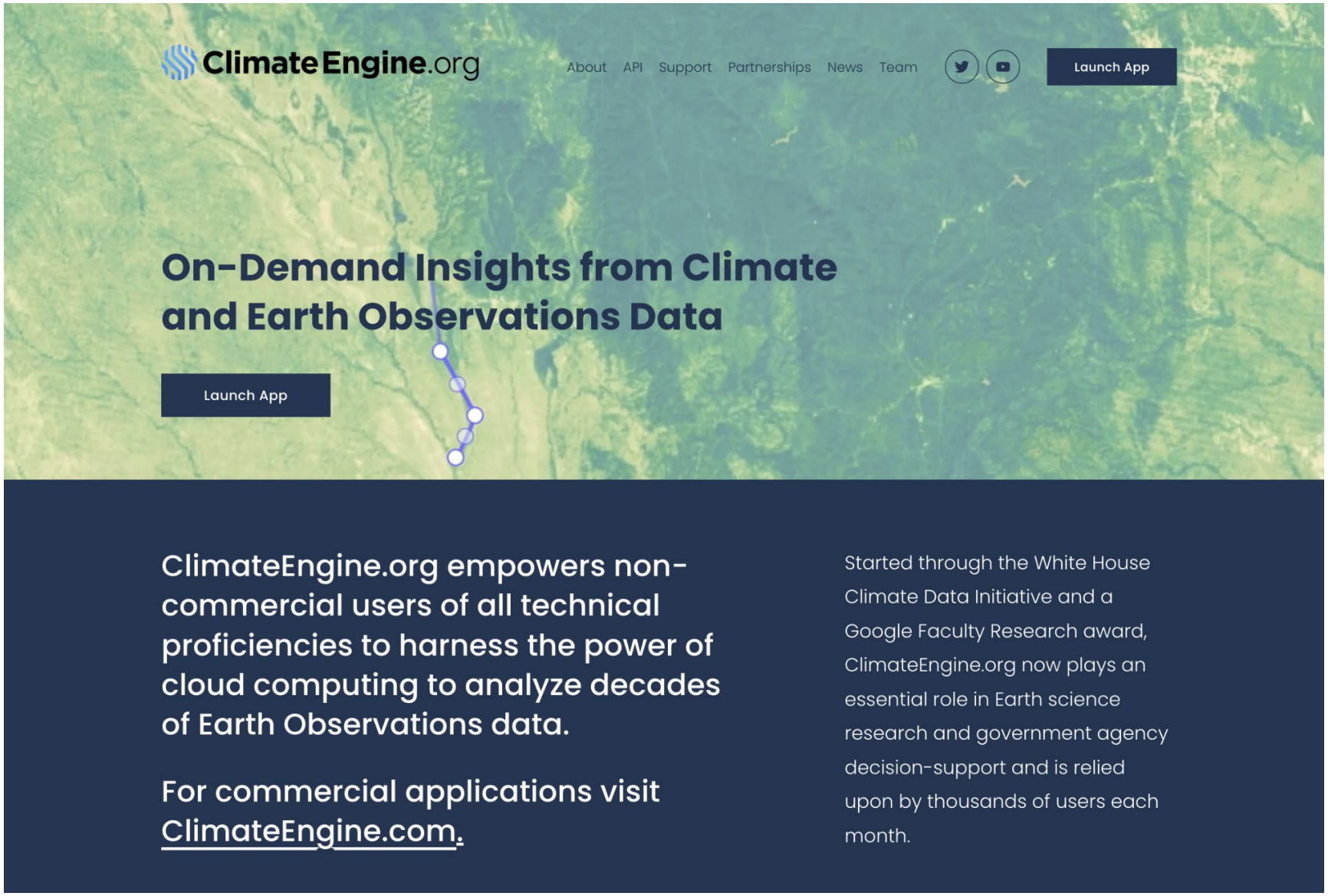
International Resources: Global Drought Information System

[Global Drought Information System (GDIS):]

An International effort to pull together the best non-prescriptive drought information from local to national providers and provide an "apples to apples" comparison of drought conditions and resources from around the world.



International Resources: Climate Engine



International Resources: Climate Engine

- Drought.gov leverages Climate Engine to process large high-resolution gridded datasets with substantially lower costs and effort, including precipitation, temperature, sub-monthly PDSI, and drought indicator blends.
- Developed by the Western Regional Climate Center (WRCC) / Desert Research Institute
- Launched for researchers in **2014**, with a commercial launch in **2020**
- Climate Engine provides an **App/User Interface** and **an API** for accessing common climate and Earth observation products quickly, such as:
  - Precipitation stats (totals, averages, min/max, diff from normal, percentiles)
  - Temperature stats (averages, min/max, diff from normal, percentiles)
  - Drought Indices (SPI, SPEI, EDDI)

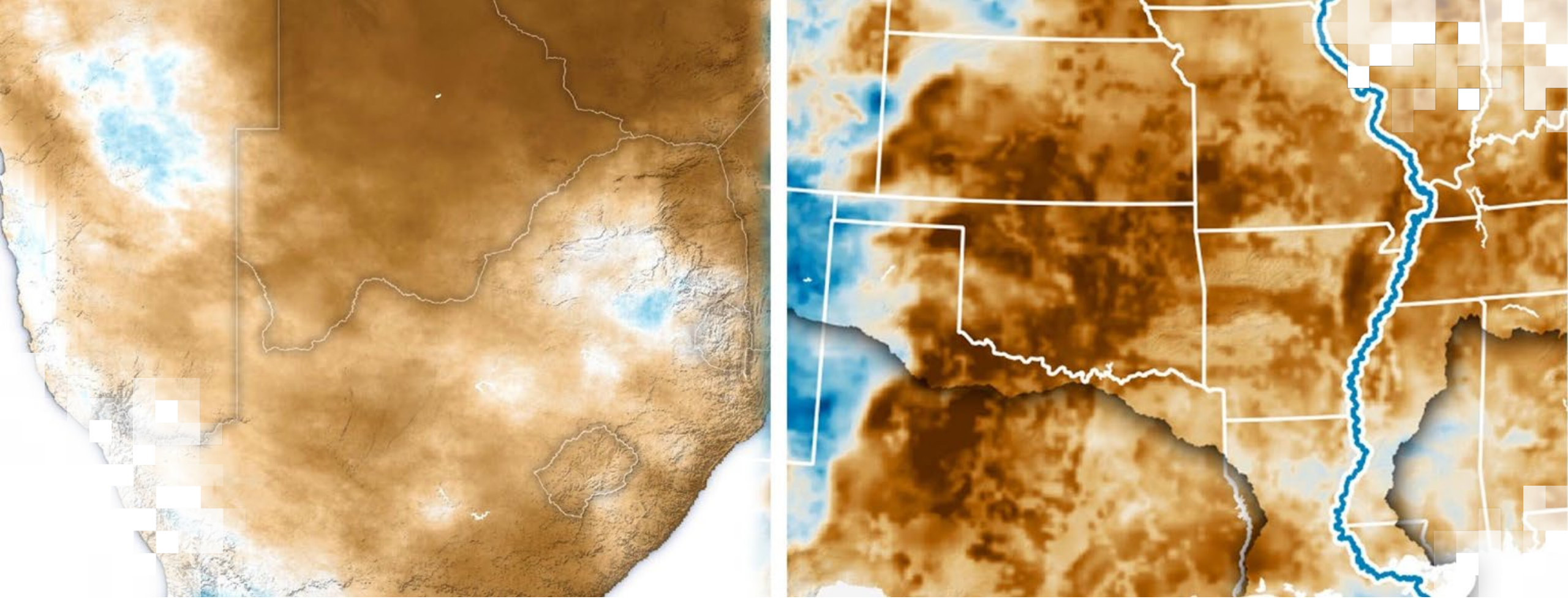
ClimateEngine.org

Summary

- NIDIS is a multi-agency U.S. government program whose mission is to enable the U.S. to move **from a reactive to a more proactive** approach to managing drought risks and impacts.
- The U.S. Drought Portal (www.drought.gov) **is U.S. government's authoritative, interagency drought information website.**
- Drought.gov features timely, high-resolution drought monitoring maps & resources:
  - **Data catalog of maps, data, and tools** that you can filter by geographic coverage, period of record, file type, and more
  - **Interactive maps of key drought indicators and indices**, by topic, economic sector, and geographic scale
  - **Historical conditions tool**, including data downloads
  - International page featuring **global drought maps & resources**, such as:
    - Climate Engine
    - Global Drought Information System (GDIS)
- Questions? Contact us at drought.portal@noaa.gov

Resources

- **U.S. Drought Portal (Drought.gov):**
  - Historical Conditions Tool
  - International Drought Resources
  - U.S. Drought Resources by Watershed, State, County, and City
  - Data Catalog
  - Data Downloads
  - Drought Assessment in a Changing Climate
- **Global Drought Information System (GDIS)**
- **Climate Engine**
- **NOAA's National Integrated Drought Information System (NIDIS):**
  - About NIDIS
  - Sign Up for NIDIS Emails
  - Follow us on Facebook, Twitter/X, and Instagram at @NOAADrought



U.S. Drought Monitor

Brad Pugh, Climate Prediction Center/NCEP/NWS/NOAA

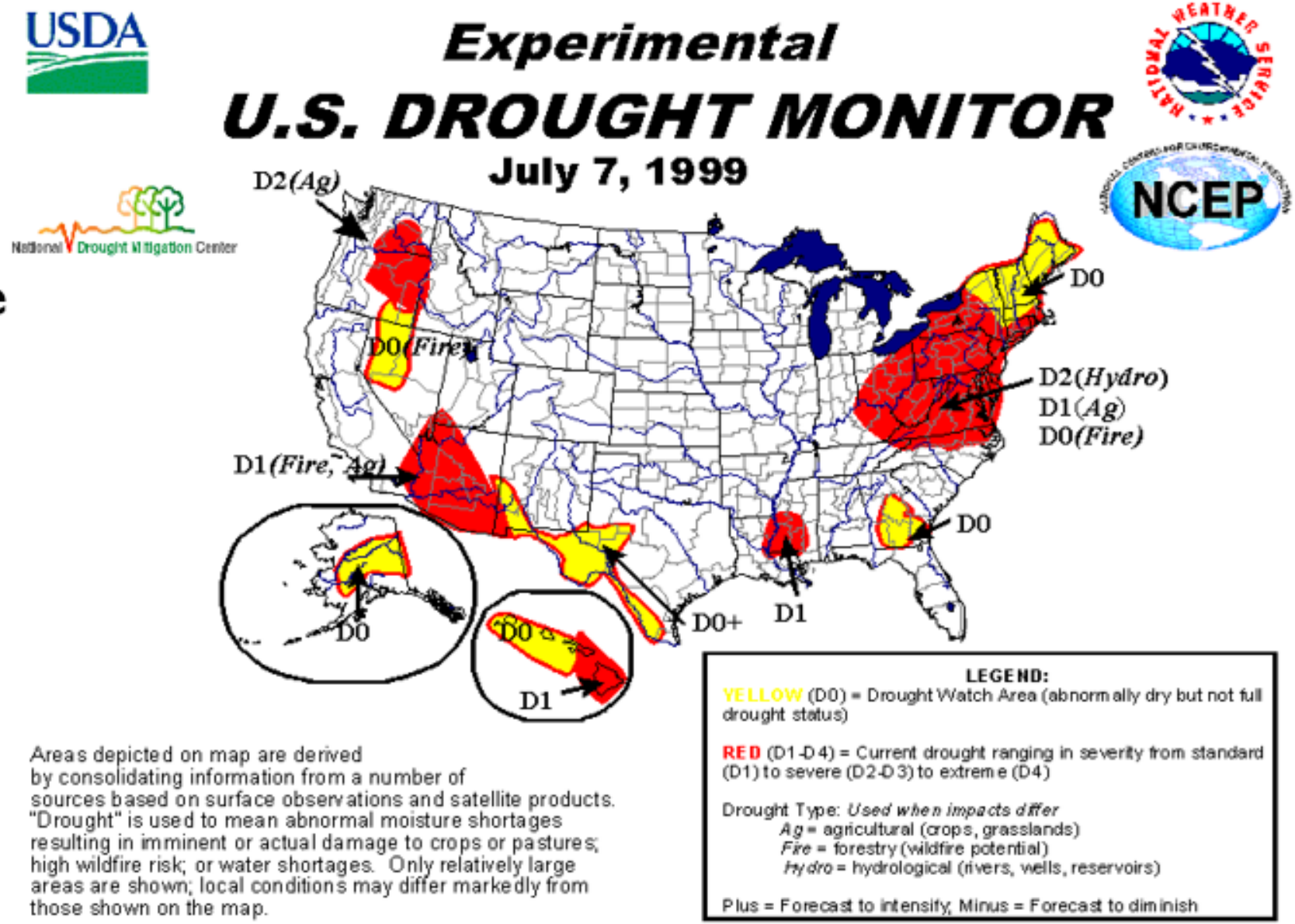
Thanks to Brian Fuchs and Mark Svoboda at the Nat'l Drought Mitigation Center

Outline

- History of the U.S. Drought Monitor
- Indicators and Methodology
- Real-time Authoring Example
- Historical Time Series

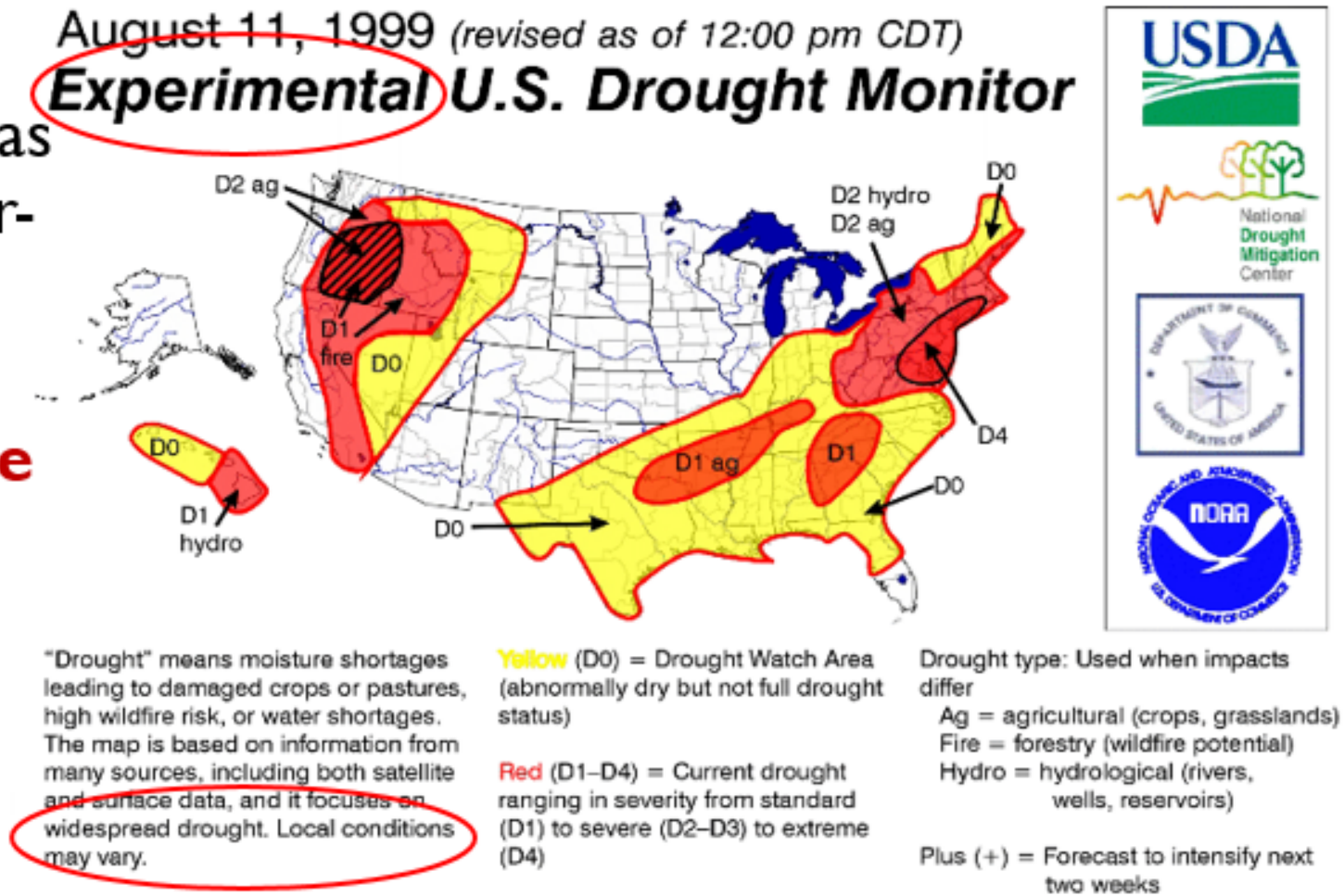
Summer 1999

- **Authors refined the map areas and tweaked the colors**



August 11 1999

- The revised map was presented to senior-level government officials at a
- **Secretarial White House Briefing.**
- They liked it so much…



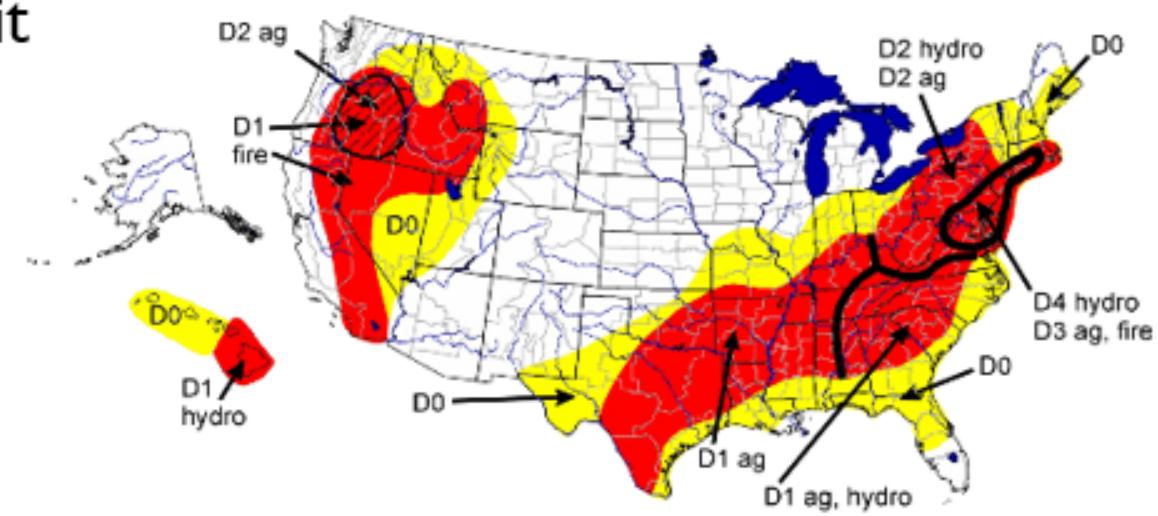
NATIONAL DROUGHT MITIGATION CENTER NDMC UNIVERSITY OF NEBRASKA

August 18 1999

- …the following week, it went operational, making this **the first "official" U.S. Drought Monitor!**
- This might have been the ***fastest Experimental to Operational*** product in government history!
- ***~24 experts made up the initial DROUGHT listserver***

August 18, 1999 (scheduled release time Thursday a.m.)

U.S. Drought Monitor



"Drought" means moisture shortages leading to damaged crops or pastures, high wildfire risk, or water shortages. The map is based on information from many sources, including both satellite and surface data, and it focuses on widespread drought. Local conditions may vary.

Yellow (D0) = Drought Watch Area (abnormally dry but not full drought status)

Red (D1–D4) = Current drought ranging in severity from standard (D1) to severe (D2–D3) to extreme (D4)

Crosshatching () = Overlapping drought type areas

Drought type: Used when impacts differ
- Ag = agricultural (crops, grasslands)
- Fire = forestry (wildfire potential)
- Hydro = hydrological (rivers, wells, reservoirs)

Plus (+) = Forecast to intensify next two weeks

Minus (-) = Forecast to diminish next two weeks

USDA

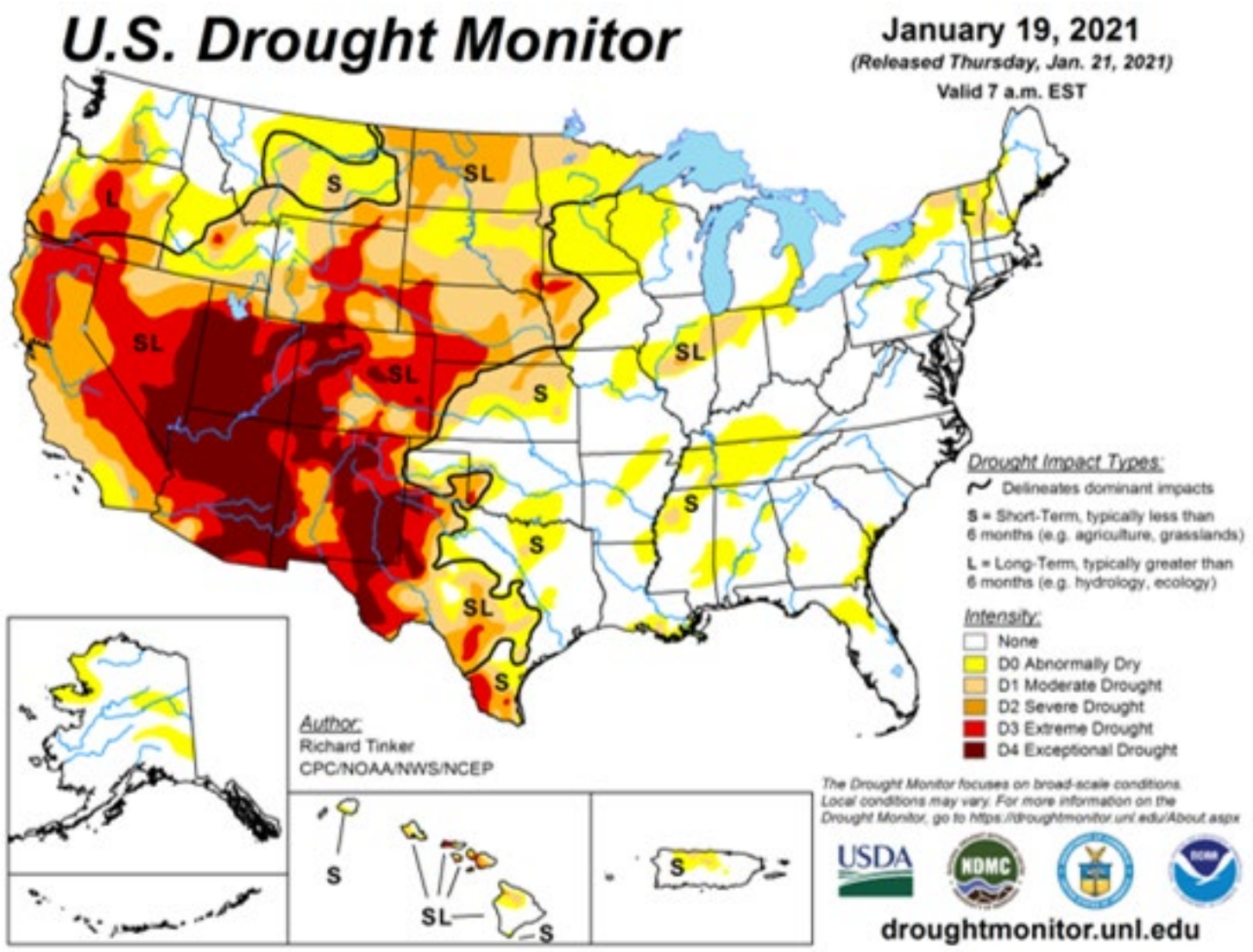
National Drought Mitigation Center

NOAA

US Drought Monitor (USDM) Hybrid Approach

Replace use of single indicator/index with both:

- **Objective** Physical indicators and indices
- **Subjective** local expertise and impacts



Percentiles and the US Drought Monitor

- How many occurrences are expected in a given period of time.
- Every input can be put into percentiles to compare current data with historical records.
- Period of record is important.

Advantages

- Can be applied to any parameter used in drought analysis
- Can be applied to all indicators and indices regardless of length of data record
- Puts the drought in historical perspective

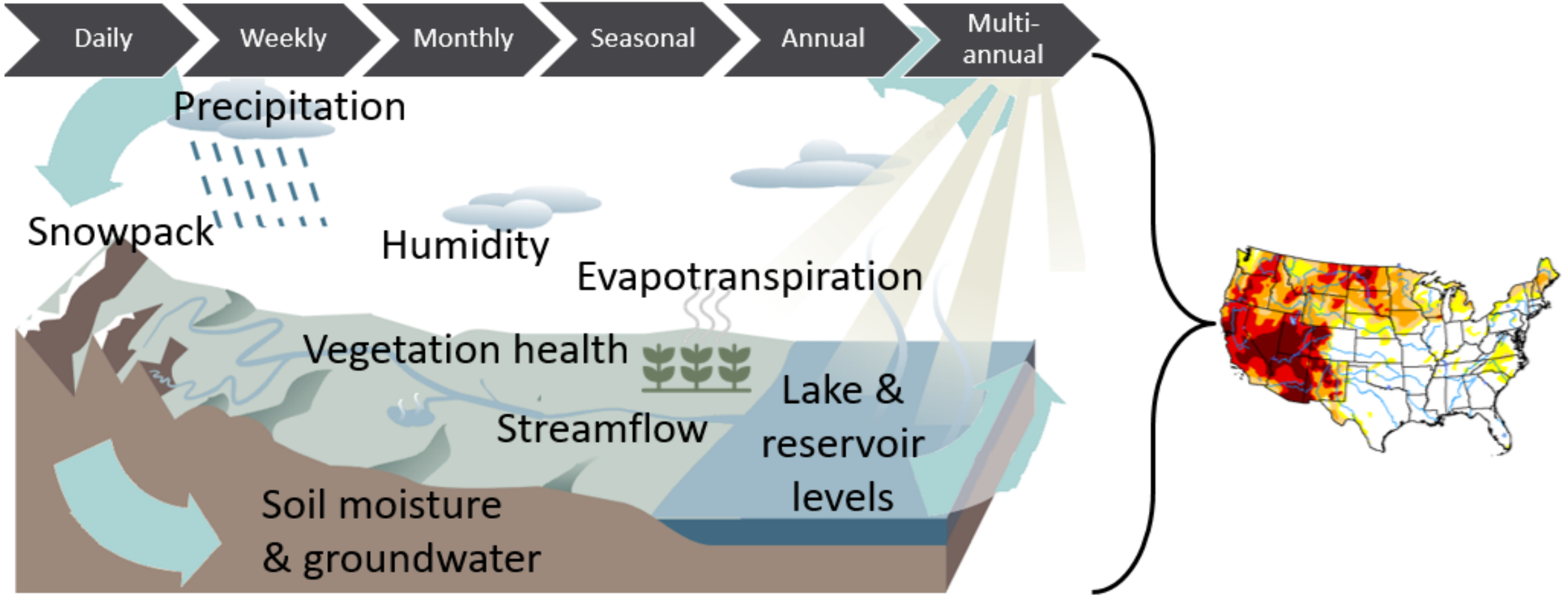
Drought Levels

- D4: Exceptional (1st-2nd percentile)
- D3: Extreme (3rd-5th percentile)
- D2: Severe (6th-10th percentile)
- D1: Moderate (11th-20th percentile)
- D0: Abnormally Dry (21st-30th percentile)

The USDM Map is…

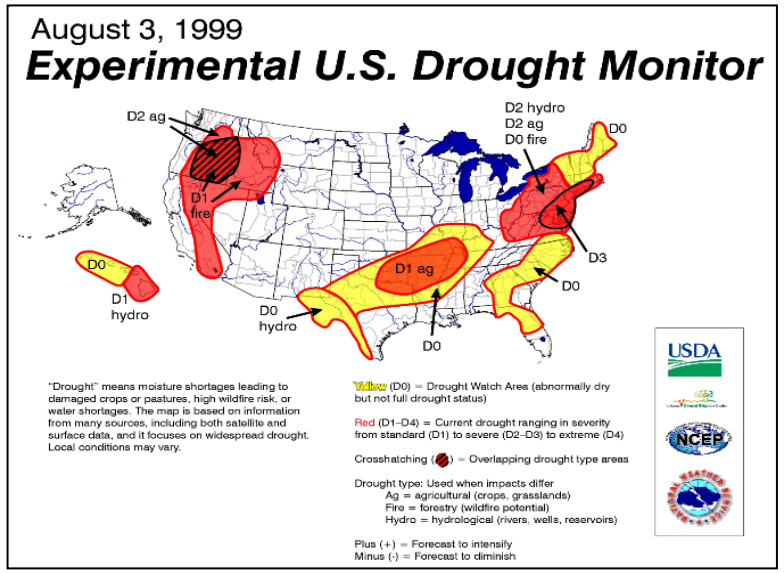
An attempt to represent **all** of the different types of drought on one map

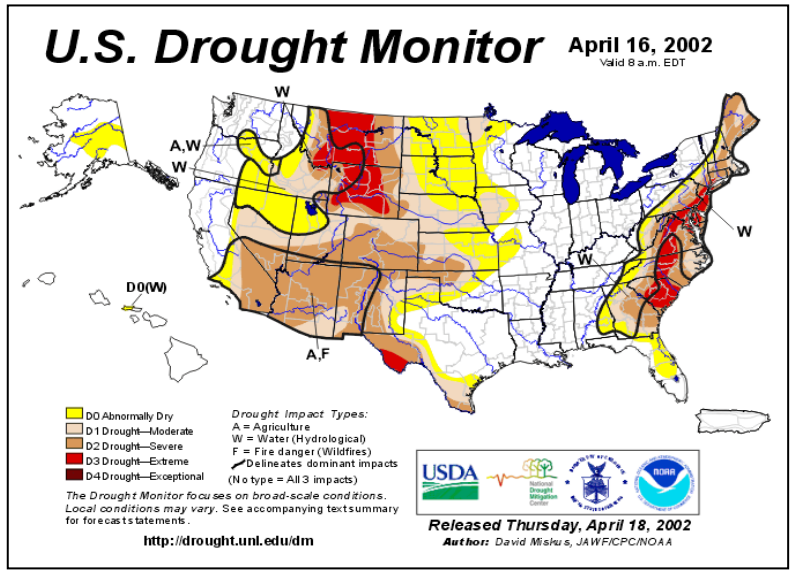
Map Incorporates Multiple Types of Data and Timescales

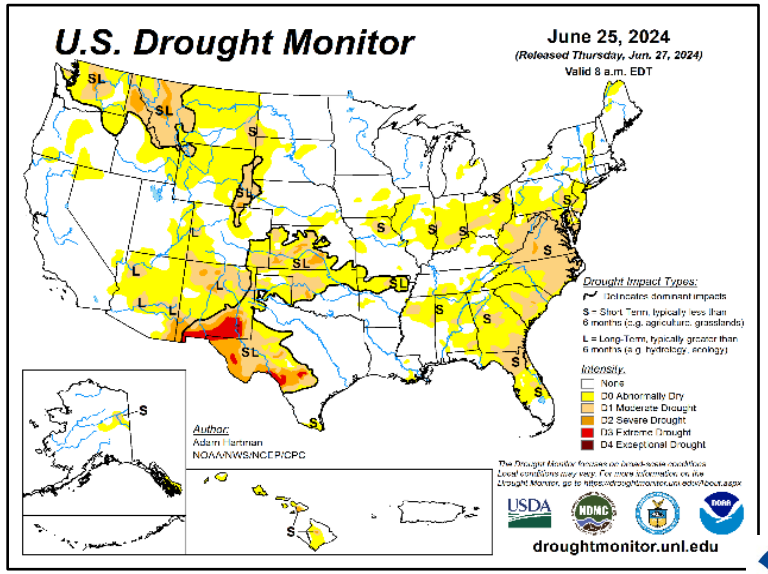


USDM Background

- Since 1999, 10 to 12 authors between NOAA (CPC & NCEI), NDMC, USDA, & RCC's (WRCC) have produced a **weekly** composite drought map with input from numerous federal & non-federal partners (~450 experts).
  - Released Thursday 8:30 am ET for the period 8am ET last Tuesday to 8 am ET this Tuesday;
  - 5 Drought Categories (D0=Abnormal dryness; D1=Moderate; D2=Severe; D3=Extreme; D4=Exceptional)







USDM Background

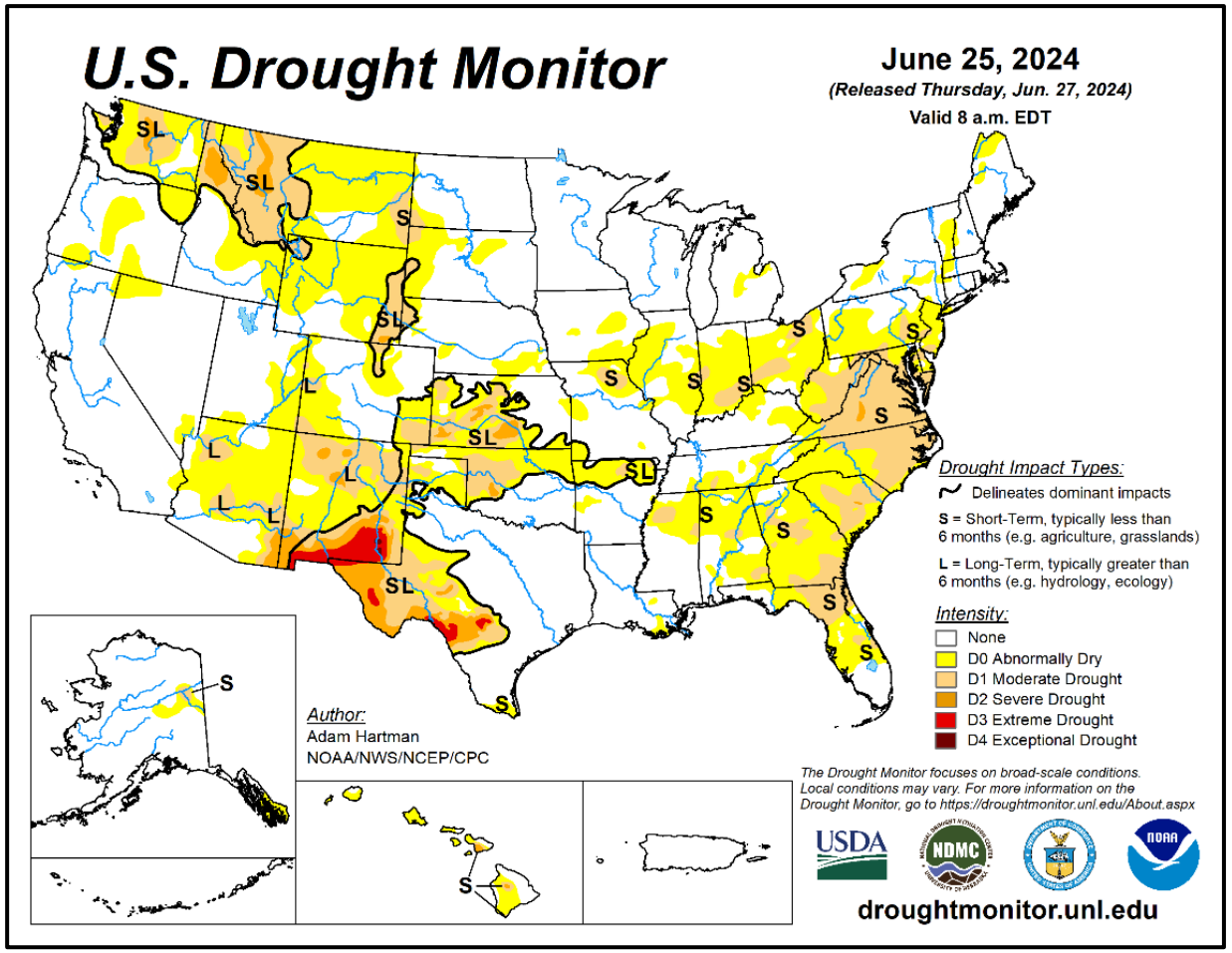
- UDSM is a **consolidation** of current conditions and current impacts into one comprehensive national drought map.
- The DM…
  - Is NOT a model (manually made weekly based off previous map);
  - Is NOT just interpreting precipitation;
  - Is NOT a forecast (see Drought Outlook) or drought declaration;
  - Incorporates local expert input (by email, impact reports, & tweets);
  - Identifies impacts (“S” <6-months; “L” >6-months; “SL” both).

  Be as **objective** as possible (using percentiles methodology). The physical data & indicators must support the map depiction. The impact data validates physical data.

USDM Background

- USDM uses a **"Convergence of Evidence"** approach.
  - Many types of drought "information" can be collectively analyzed.
    - Determine if majority of information is "converging" (telling the same story) about the accuracy, or inaccuracy, of the drought as depicted by the DM.
  - Authors need to look at 100% of the data, but don't believe in any one piece of data input 100% when making a decision.
  - Multiple indicators & many types of info are part of the analysis.
    - These data will identify different climatic & hydrologic parameters which are needed to understand the complete picture of a drought indicator's performance and how they interact.
  - Impacts are the "ground truth," yet aren't monitored to the extent which other data are… you can't measure what you don't monitor!

USDM Interpretation



Drought Intensity Categories – by Percentiles

- D0 **Abnormally Dry (30%tile)** (once every 3-5 years)
- D1 Drought – **Moderate (20%tile)** (once every 5-10 years)
- D2 Drought – **Severe (10%tile)** (once every 10-20 years)
- D3 Drought – **Extreme (5%tile)** (once every 20-50 years)
- D4 Drought – **Exceptional (2%tile)** (once every 50+ years)

Impacts ("S" <6-months; "L" >6-months; "SL" both);

Drought Categories and Indicators

Drought Severity Classification			Ranges				
Category	Description	Possible Impacts	Palmer Drought Severity Index (PDSI)	CPC Soil Moisture Model (Percentiles)	USGS Weekly Streamflow (Percentiles)	Standardized Precipitation Index (SPI)	Objective Drought Indicator Blends (Percentiles)
D0	Abnormally Dry	Going into drought: ▪ short-term dryness slowing planting, growth of crops or pastures Coming out of drought: ▪ some lingering water deficits ▪ pastures or crops not fully recovered	-1.0 to -1.9	21 to 30	21 to 30	-0.5 to -0.7	21 to 30
D1	Moderate Drought	▪ Some damage to crops, pastures ▪ Streams, reservoirs, or wells low, some water shortages developing or imminent ▪ Voluntary water-use restrictions requested	-2.0 to -2.9	11 to 20	11 to 20	-0.8 to -1.2	11 to 20
D2	Severe Drought	▪ Crop or pasture losses likely ▪ Water shortages common ▪ Water restrictions imposed	-3.0 to -3.9	6 to 10	6 to 10	-1.3 to -1.5	6 to 10
D3	Extreme Drought	▪ Major crop/pasture losses ▪ Widespread water shortages or restrictions	-4.0 to -4.9	3 to 5	3 to 5	-1.6 to -1.9	3 to 5
D4	Exceptional Drought	▪ Exceptional and widespread crop/pasture losses ▪ Shortages of water in reservoirs, streams, and wells creating water emergencies	-5.0 or less	0 to 2	0 to 2	-2.0 or less	0 to 2

Short-term drought measures focus on precipitation on the scale of 1-3 months. Long-term blends, in contrast, focus on 6-60 months Additional indices used, mainly during the growing season, include the USDA/NASS Topsoil Moisture, Crop Moisture Index (CMI), and Keetch Byram Drought Index (KBDI). Indices used primarily during the snow season and in the West include the River Basin Snow Water Content, River Basin Average Precipitation, and the Surface Water Supply Index (SWSI). Other indicators include groundwater levels, reservoir storage, and pasture/range conditions.

USDM Monitoring Tools

USDM Monitoring Tools

Integrates Key Drought Indicators:

- Palmer Drought Index
- SPI
- SPEI
- KBDI
- Modeled Soil Moisture
  - NLDAS
- 7-14 Day Avg. Streamflow
- Precipitation Anomalies
- AHPS Precipitation
- Other data which are available

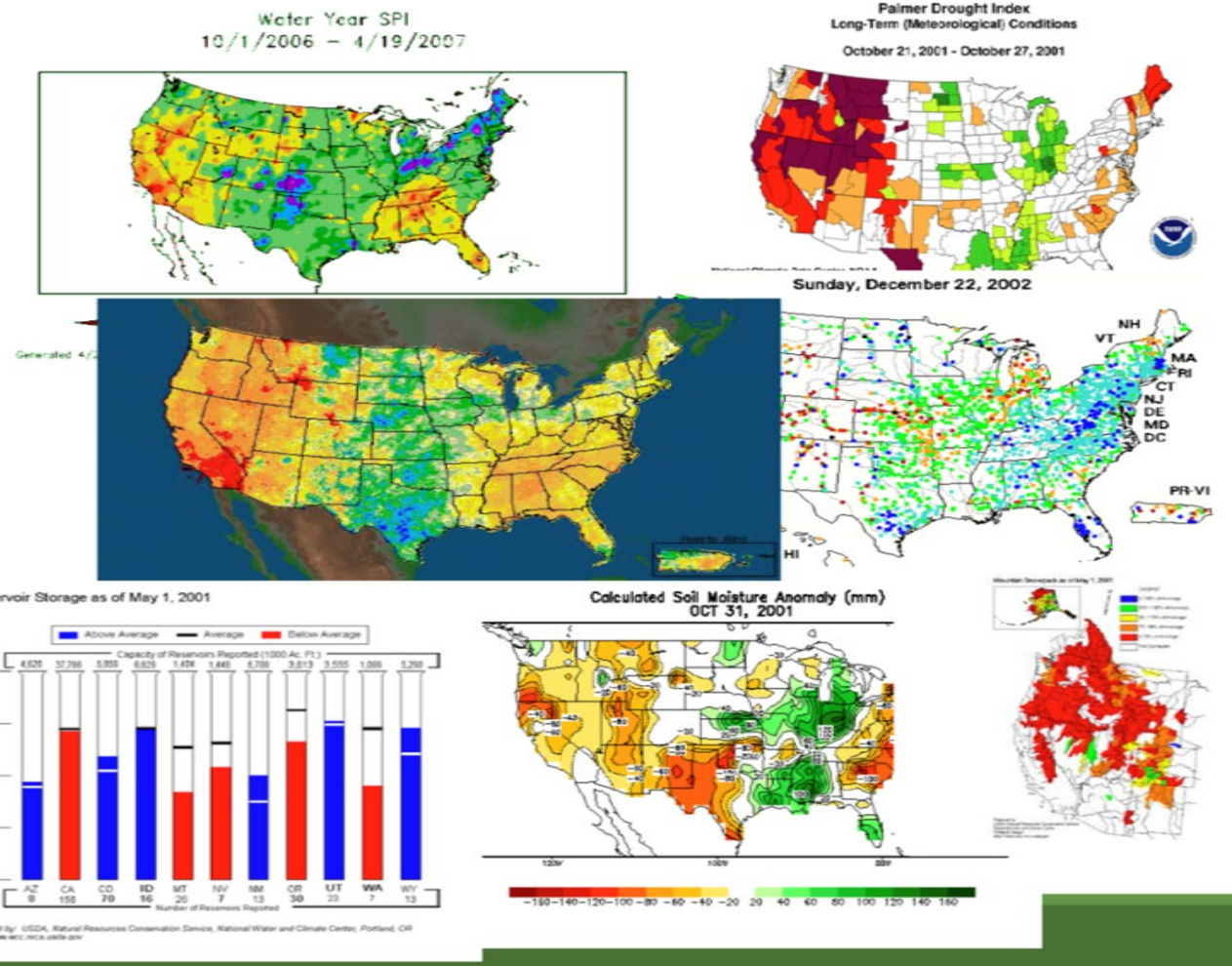
Growing Season:

- Crop Moisture Index
- Sat. Veg. Health Index
- VegDRI/ESI/etc.
- Soil Moisture
- Mesonets
- State/Regional data

In The West:

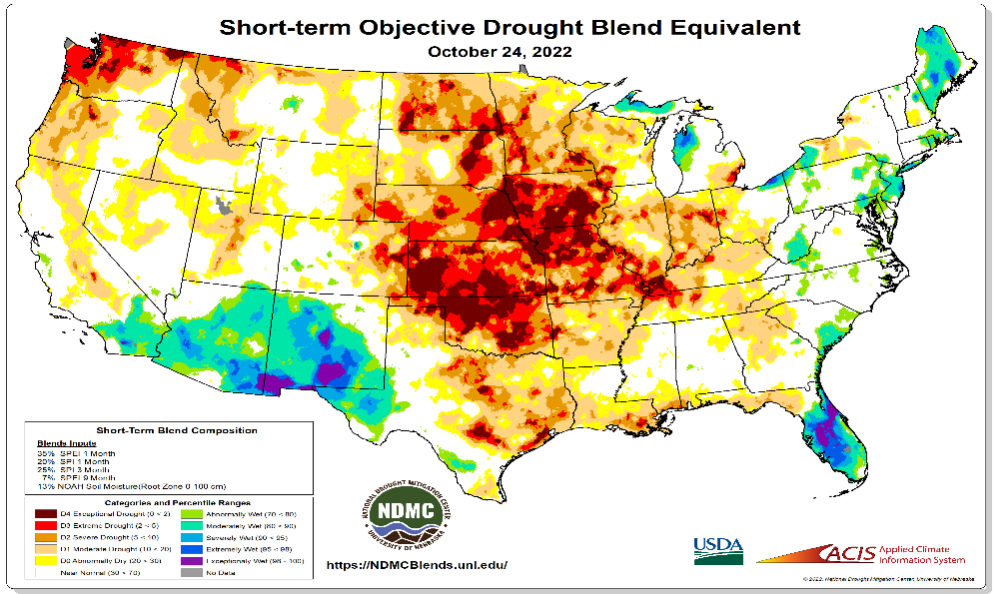
- SWSI
- Reservoir levels
- Snowpack (SNOTEL)
- SWE
- Streamflow

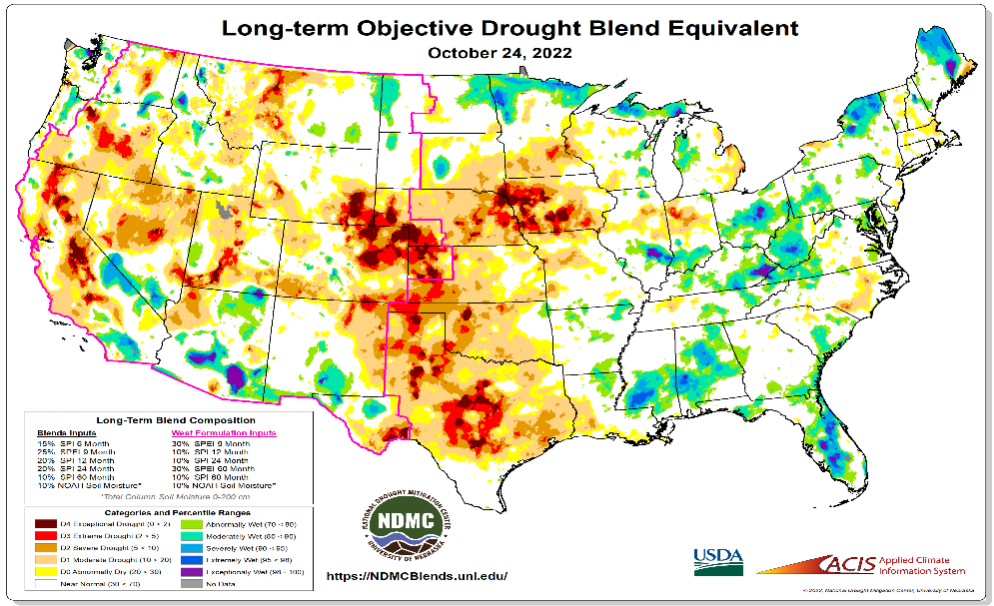
Created in ArcGIS



USDM Monitoring Tools

- Want to make USDM as objective as possible
- Several drought indices converted to percentiles, weighted, then combined to calculate Short-Term and Long-Term Objective blends
- Used to designate short and/or long-term drought

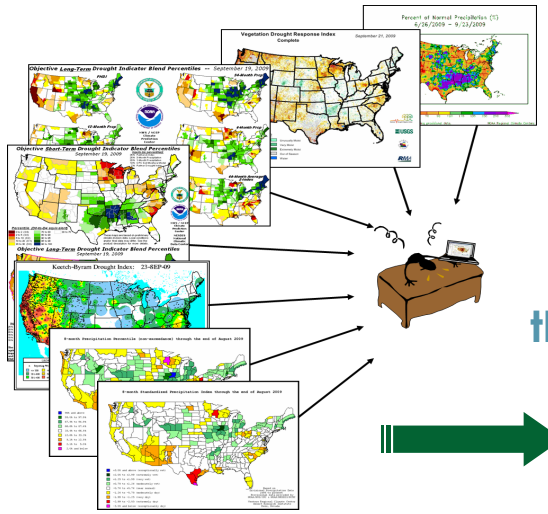




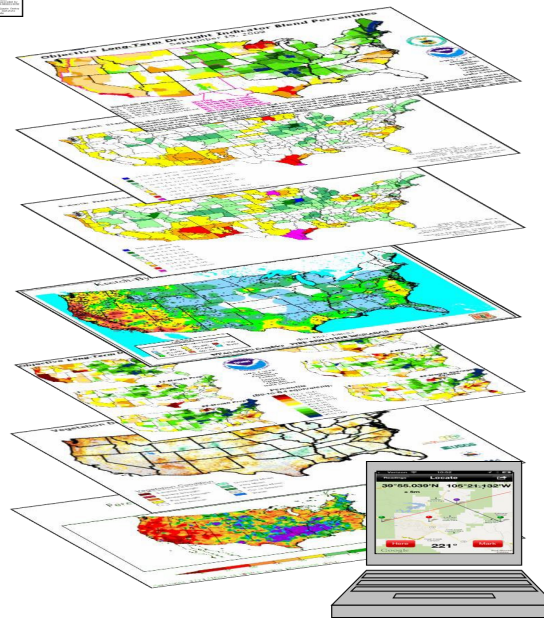
USDM Process

USDM Production *(Period starts 8 am ET last Tuesday)*

- **Monday** (5-6 Days of data available)
  - Draft map sent to local experts
- **Tuesday** (6-7 Days of data available)
  - Local expert feedback
  - Draft map(s) sent to local experts
  - Draft text sent to local experts
- **Wednesday** (7 Days available; ending 12Z yesterday)
  - Local expert feedback
  - Draft map(s) sent to local experts
  - Draft text(s) sent to local experts (Outlook)
  - Final map and text sent to secured ftp server
- **Thursday AM**
  - Final map & text released on NDMC Website

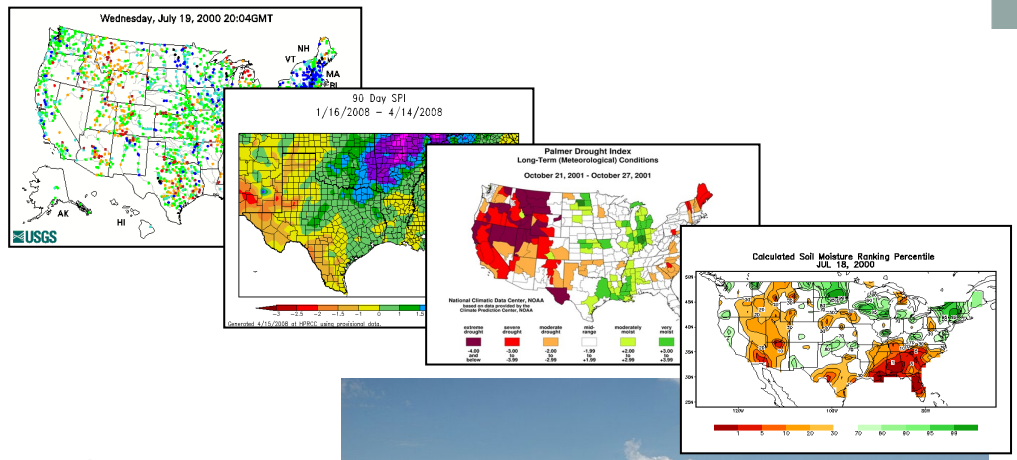


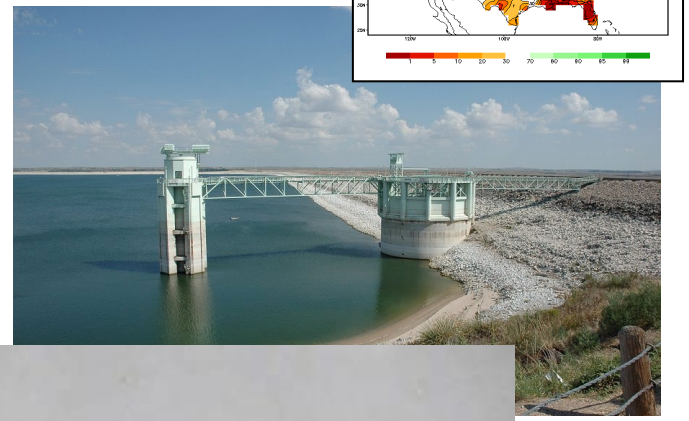
ArcGIS/ArcMap the Latest & Greatest Drought Tool



Local Experts Feedback – Reports From the Field

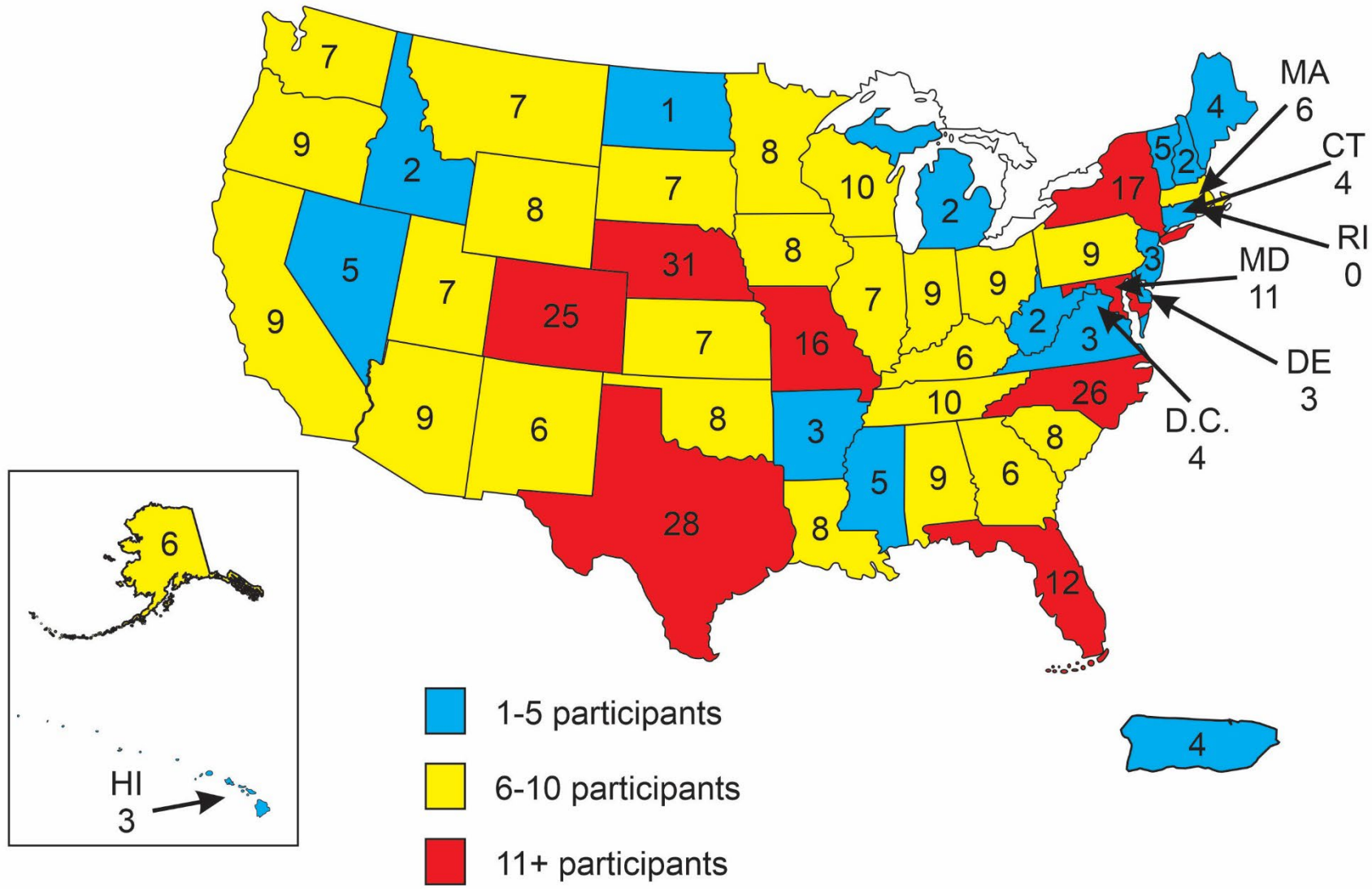
- Dozens of maps showing dozens of drought indicators.
  - But what about impacts? The rainfall may be very low, but is it affecting anybody?
- Local feedback from experts in the field provides answers.
  - Annual User Feedback Forums (USDM/NADM) since 2000
  - Various webinars/telecoms/reports/data/products
  - Regional Climate Centers & NOAA Regional Climate Service Directors & Coordinators along with Weather Forecast Offices (WFOs)
- Who are the local experts?
  - State Climatologists
  - USDA FSA/NRCS
  - Native American Tribal input
  - CoCoRaHS (impacts)
  - NIDIS DEWS basin webinars (UCRB, ACF-RB, S Plains, MORB, CA/NV, PNW, Midwest)
  - Drought Task Forces (NC, HI, OK, TX, NM, AL, FL, SD, KY, AZ, MT, CA)
  - And MANY Others





USDM Listserv Subscribers

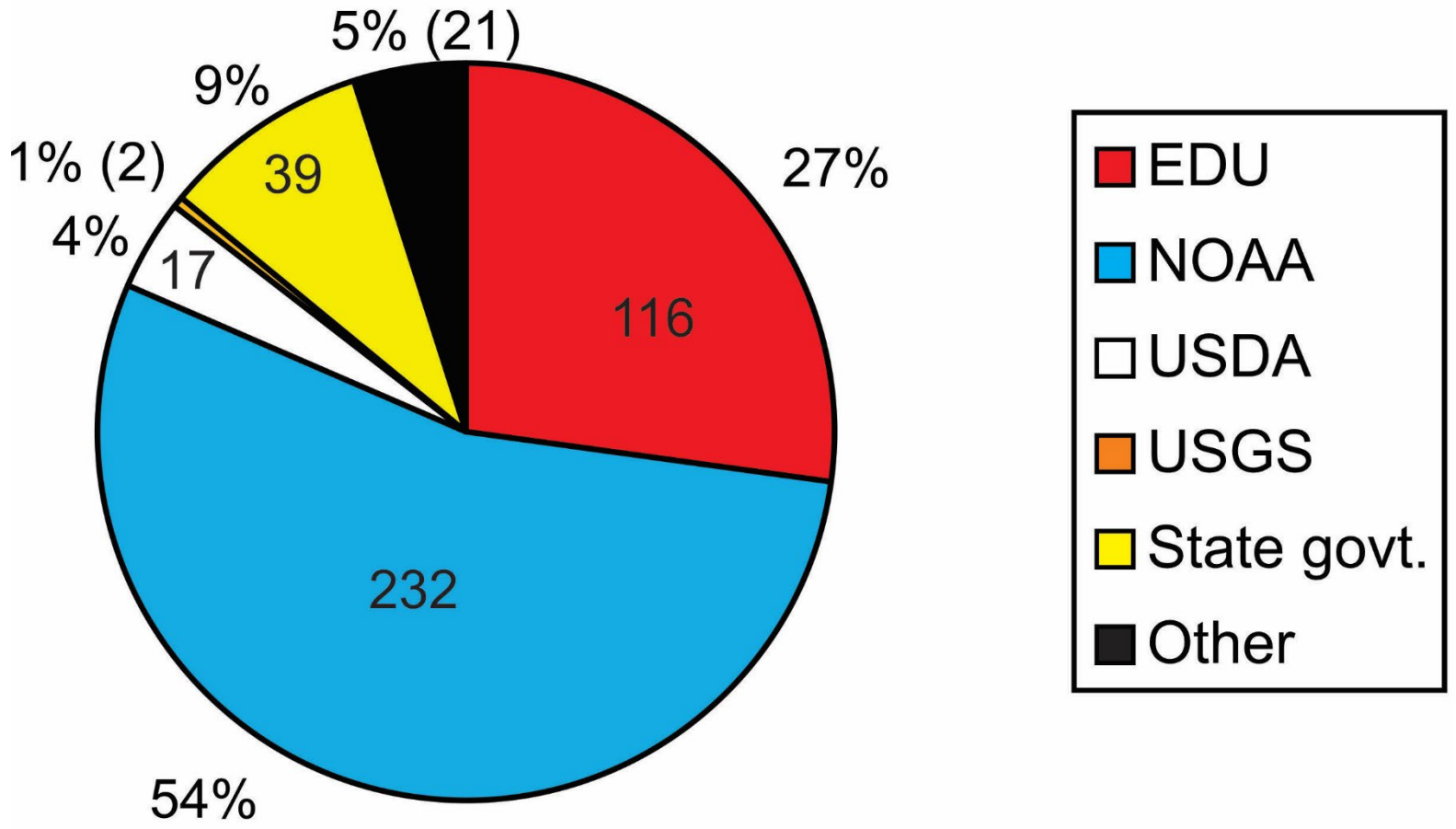
(as of April 2024)



Total: 424 (does not include 1 participant from Canada and 2 participants from Brazil)

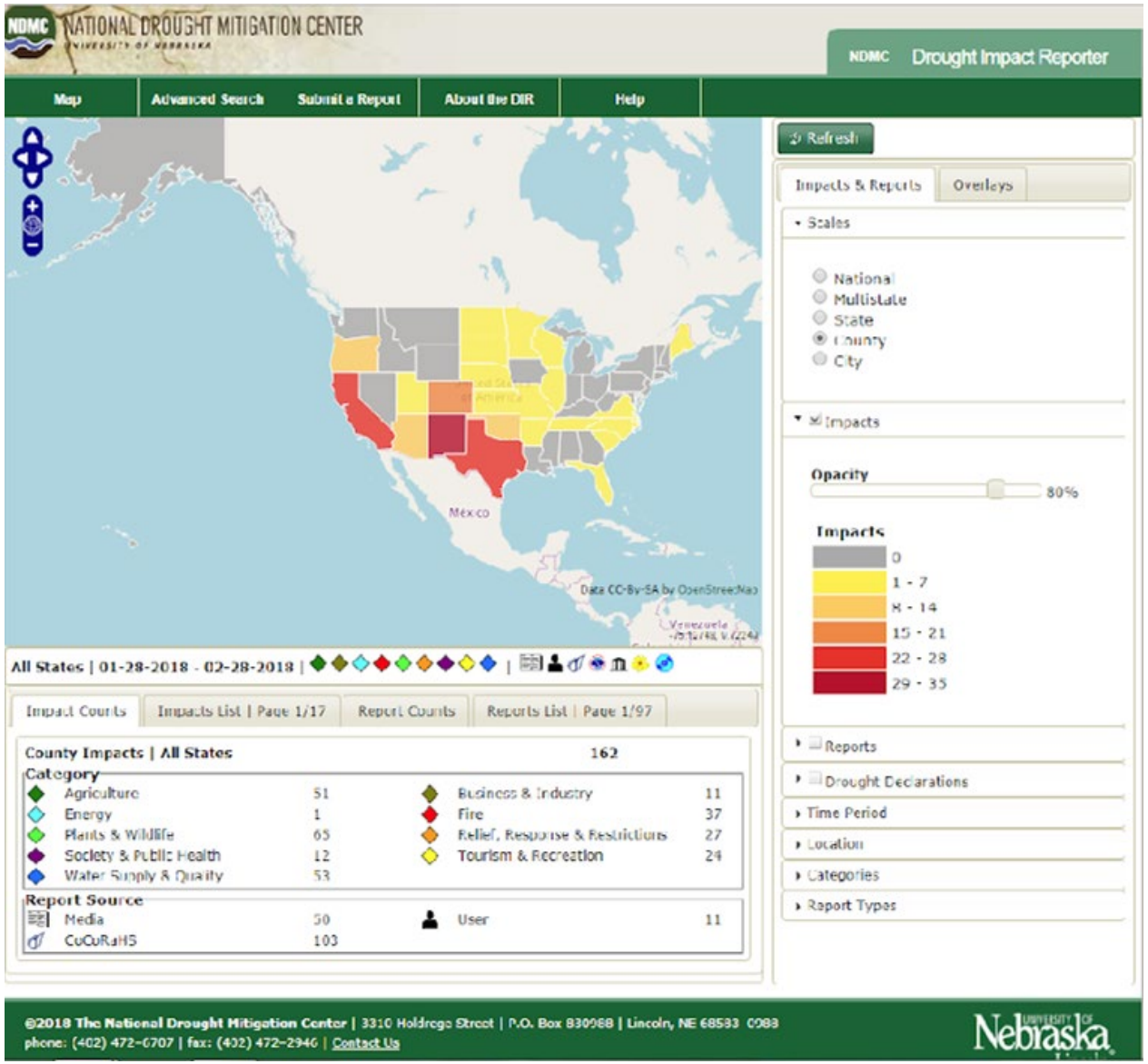
USDM Listserv Subscribers

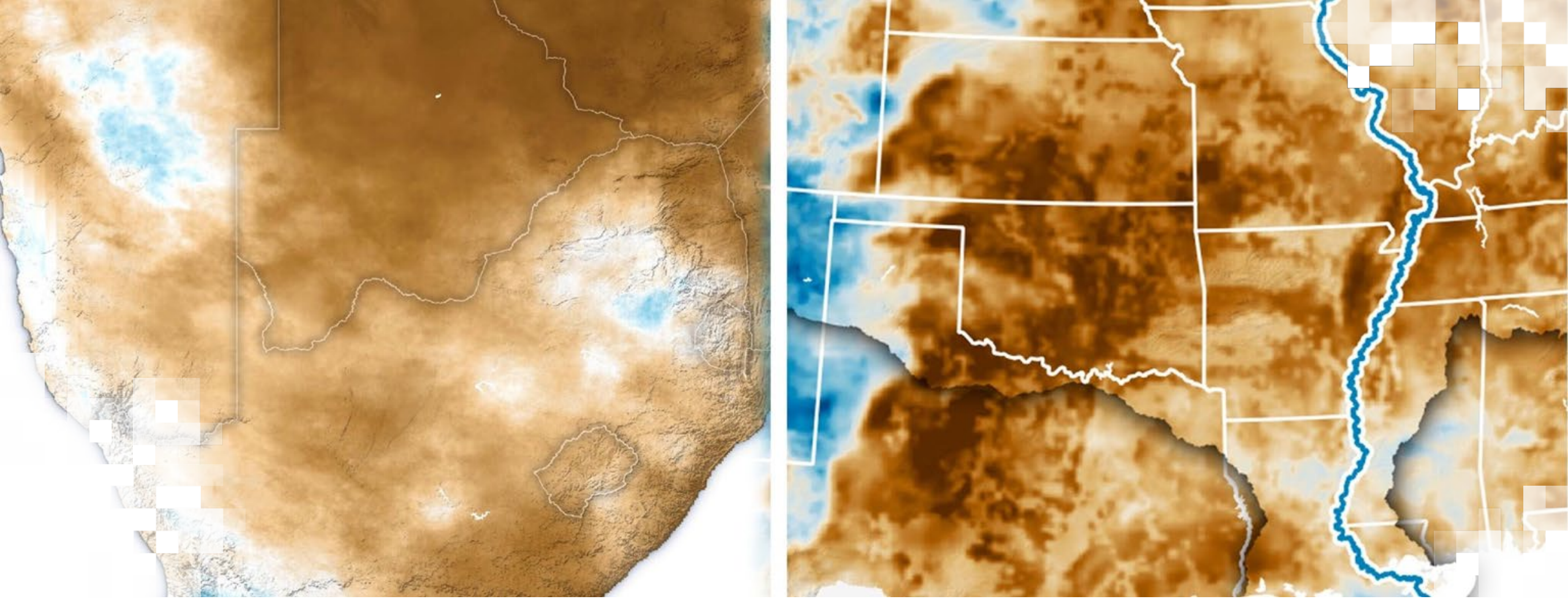
(as of April 2024)



NDMC's Drought Impact Reporter

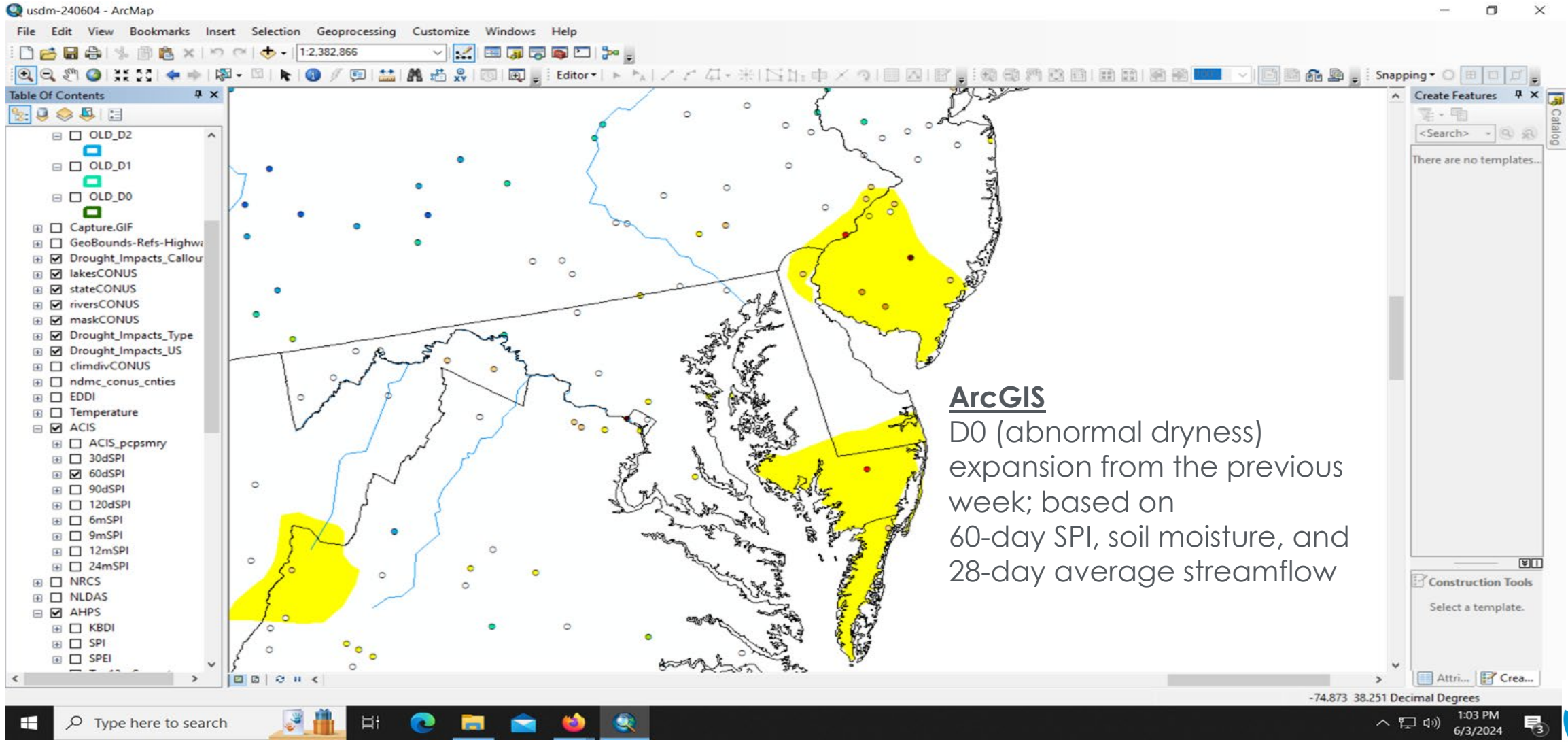
Also getting "Drought Tweets"





Real-time Authoring from the
USDM June 3rd

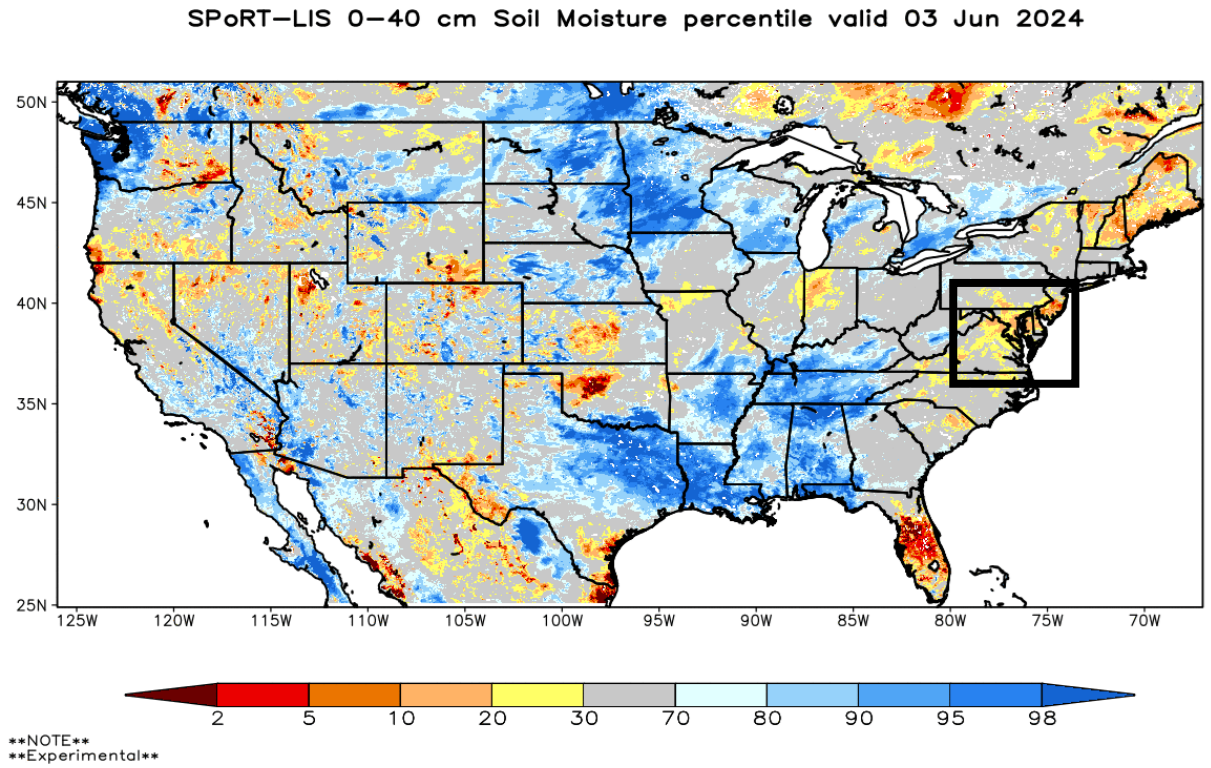
Abnormal Dryness (D0) Expansion

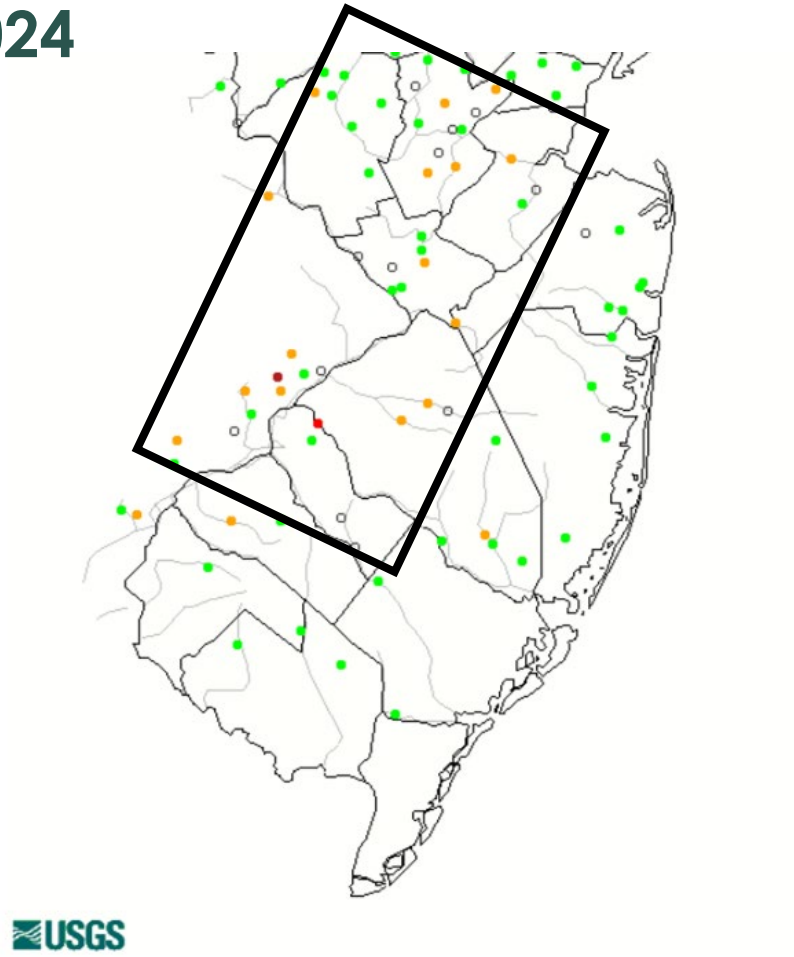


ArcGIS

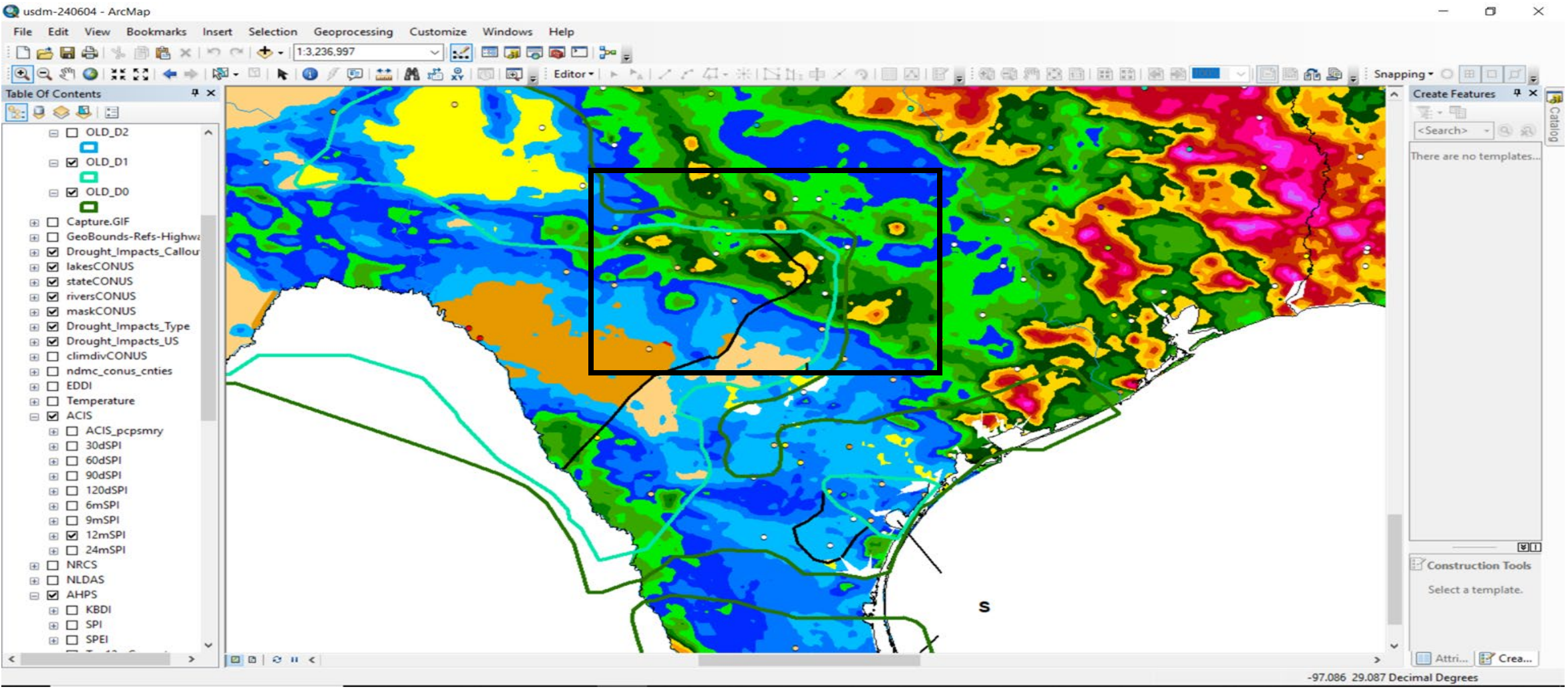
D0 (abnormal dryness) expansion from the previous week; based on 60-day SPI, soil moisture, and 28-day average streamflow

SPoRT-LIS Soil Moisture Percentile June 2024



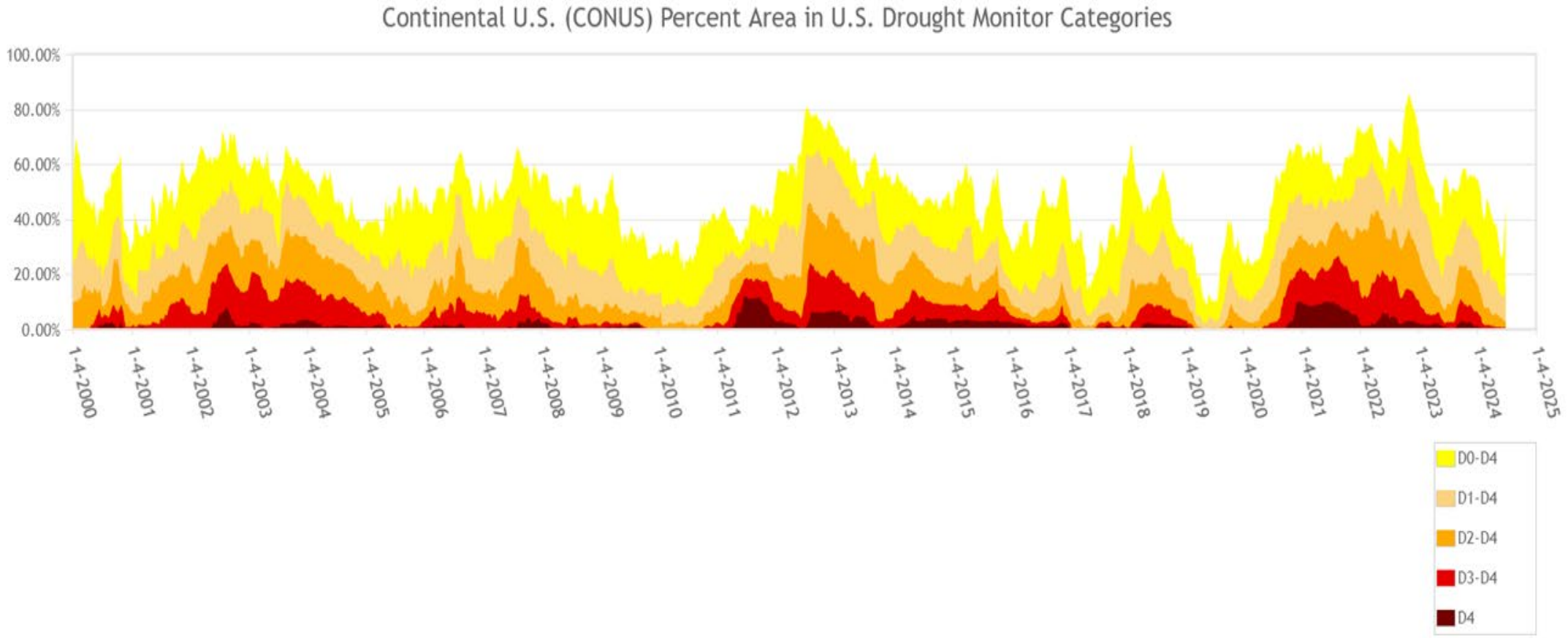


1-category improvement where more than 1.5” of rainfall in past week



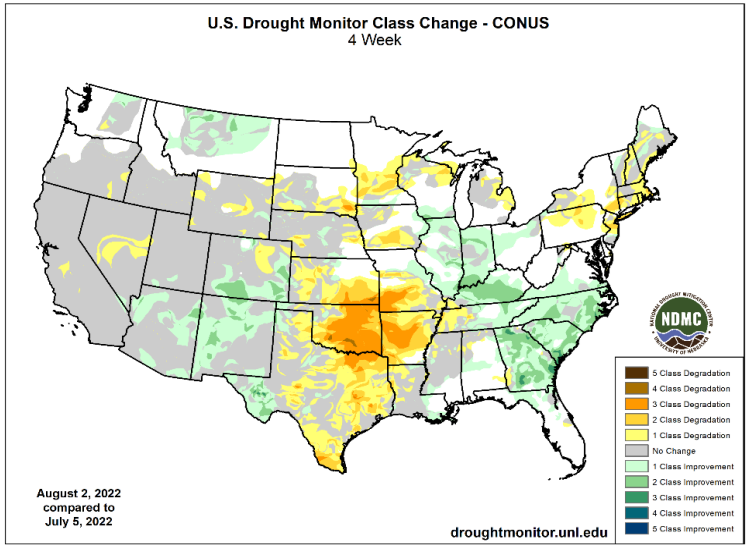
U.S. Drought Monitor

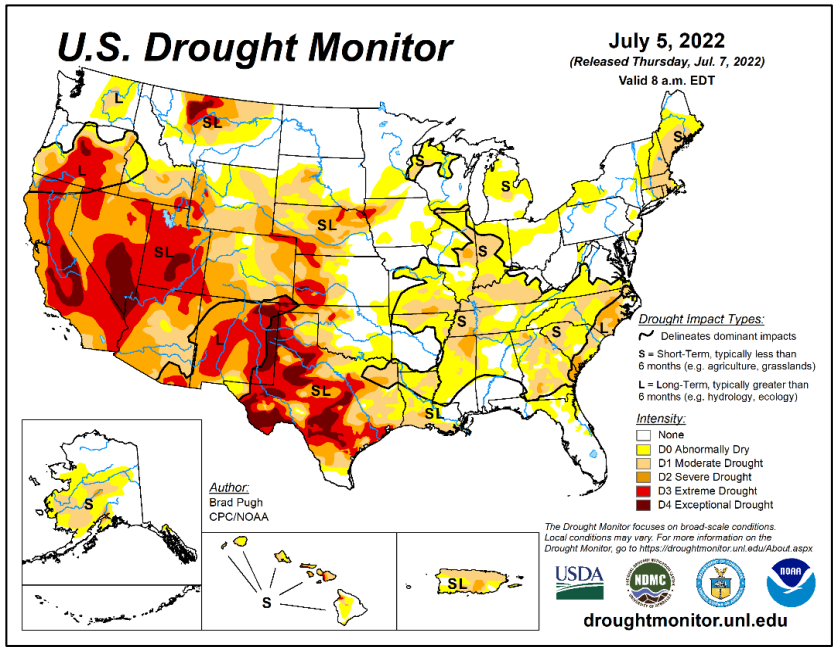
Current | Maps | Data | Summary | About | Conditions & Outlooks | Ag in Drought | En Español | NADM

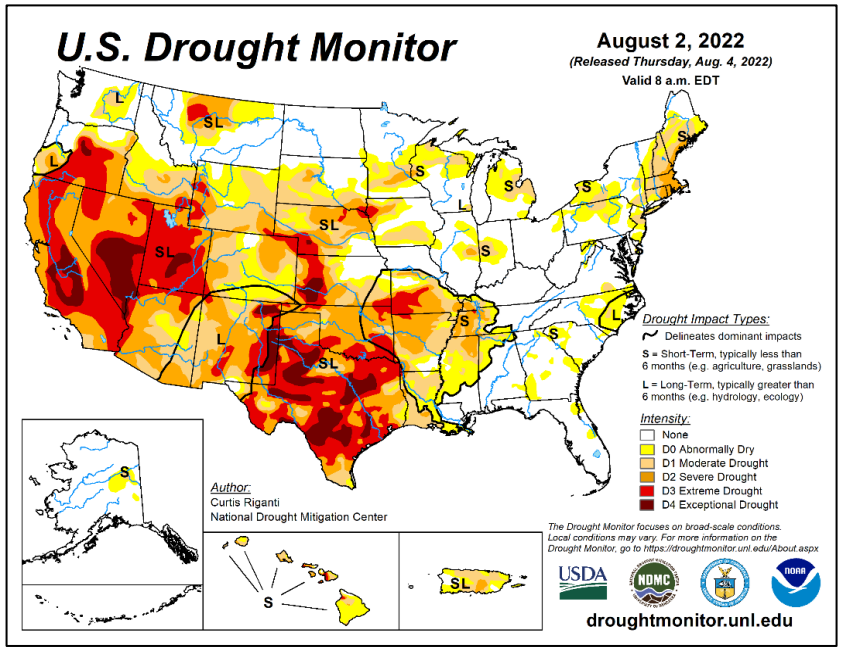


USDA | NDMC | NOAA

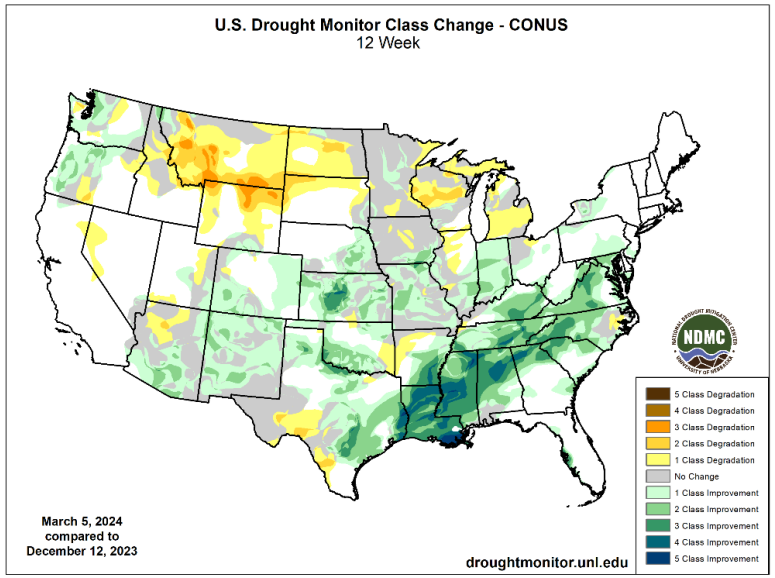
2022 Summer: Rapid Onset/Intensification Drought

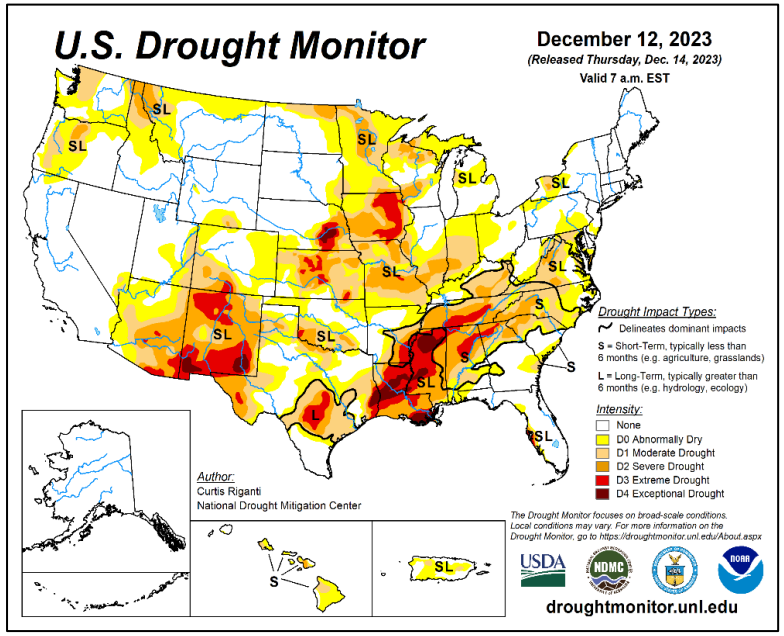


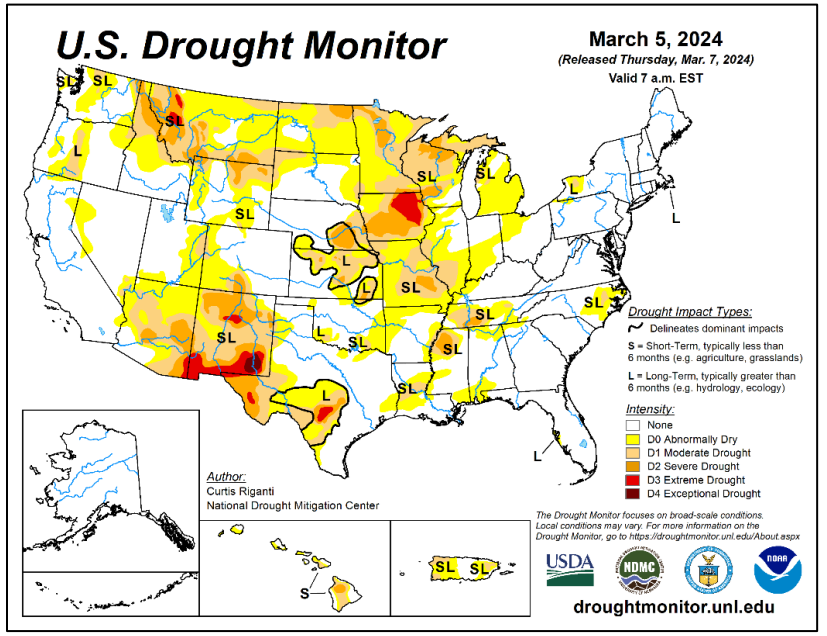




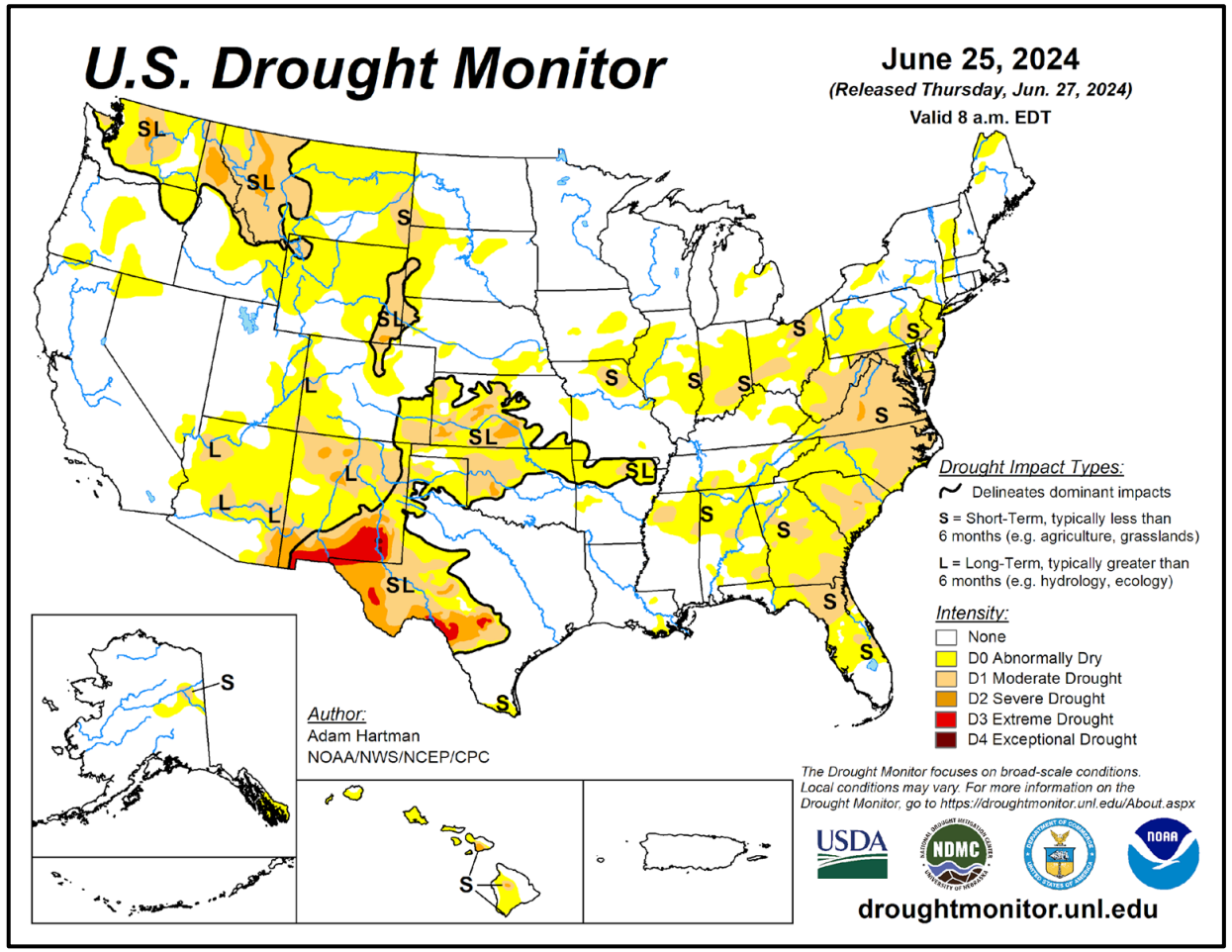
2023-2024 El Nino Winter

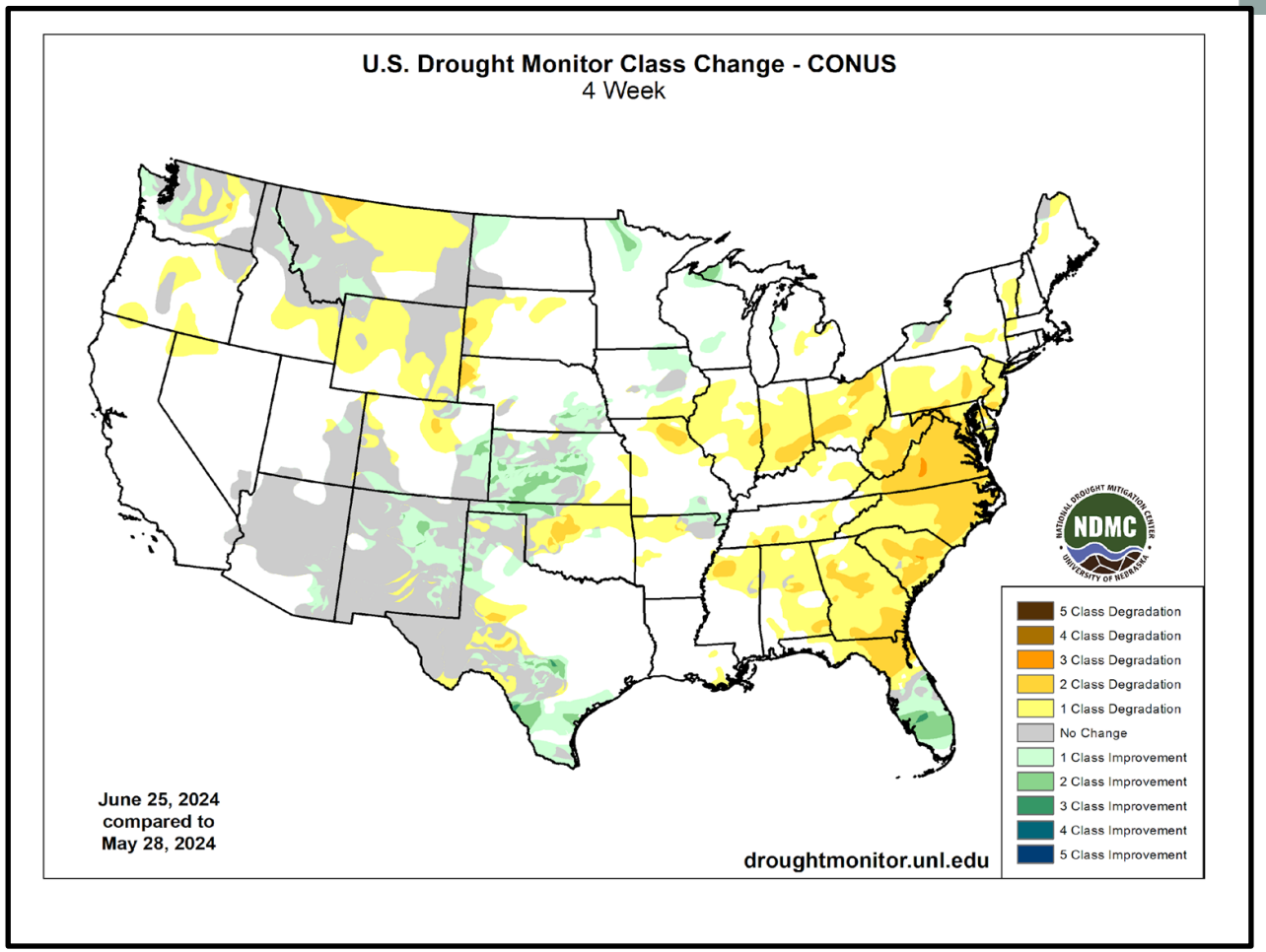






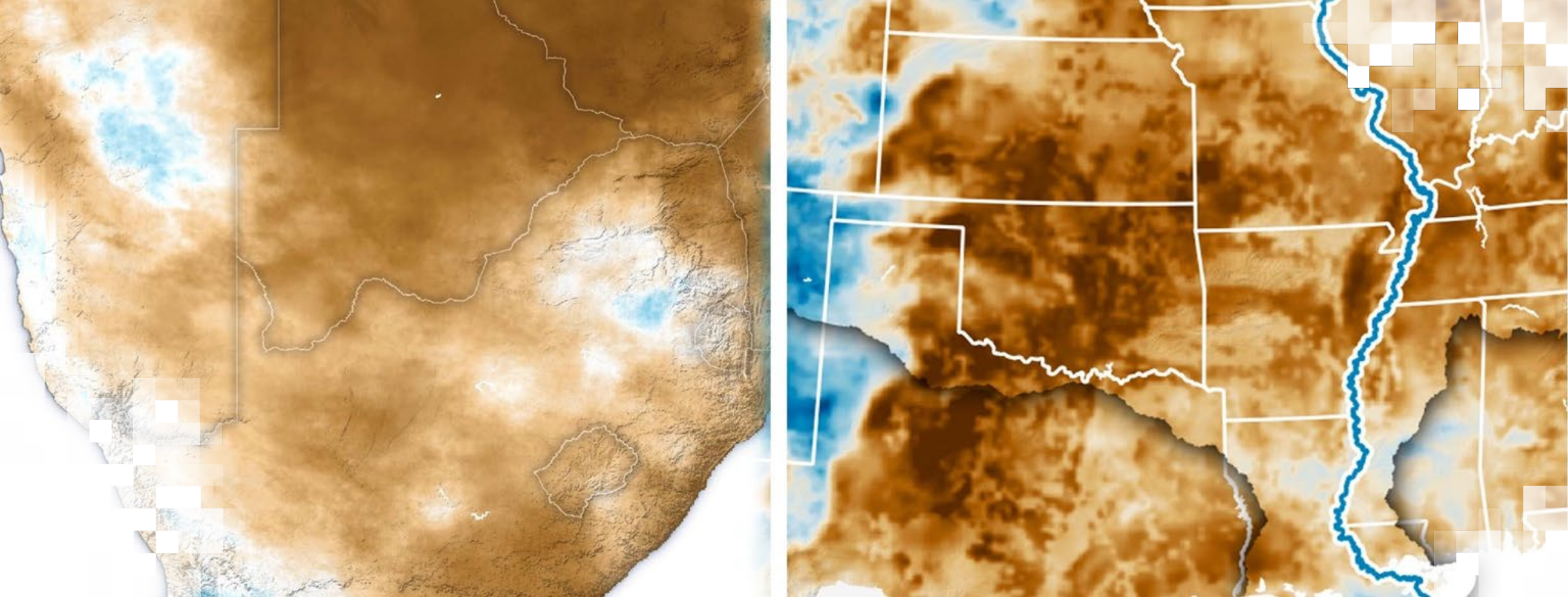
US Drought Monitor June 2024





https://www.drought.gov/

https://droughtmonitor.unl.edu/



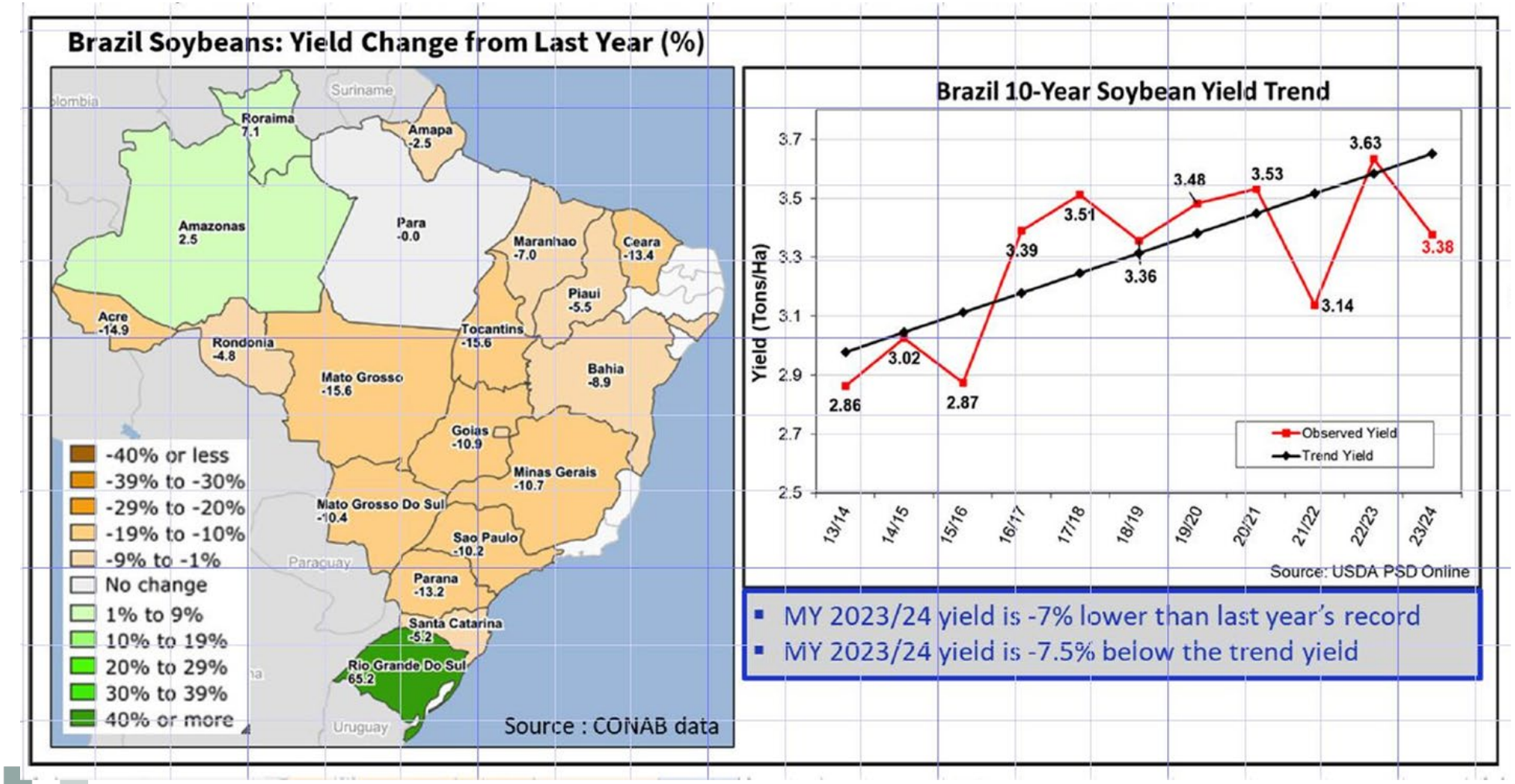
Food Security & Drought Mapping from Satellites

Compton Tucker, Goddard Space Flight Center

Variability and Trend in Brazil Soybeans Yield

World Agricultural Production

Brazil Soybeans: Production Further Reduced Based on Harvest Results

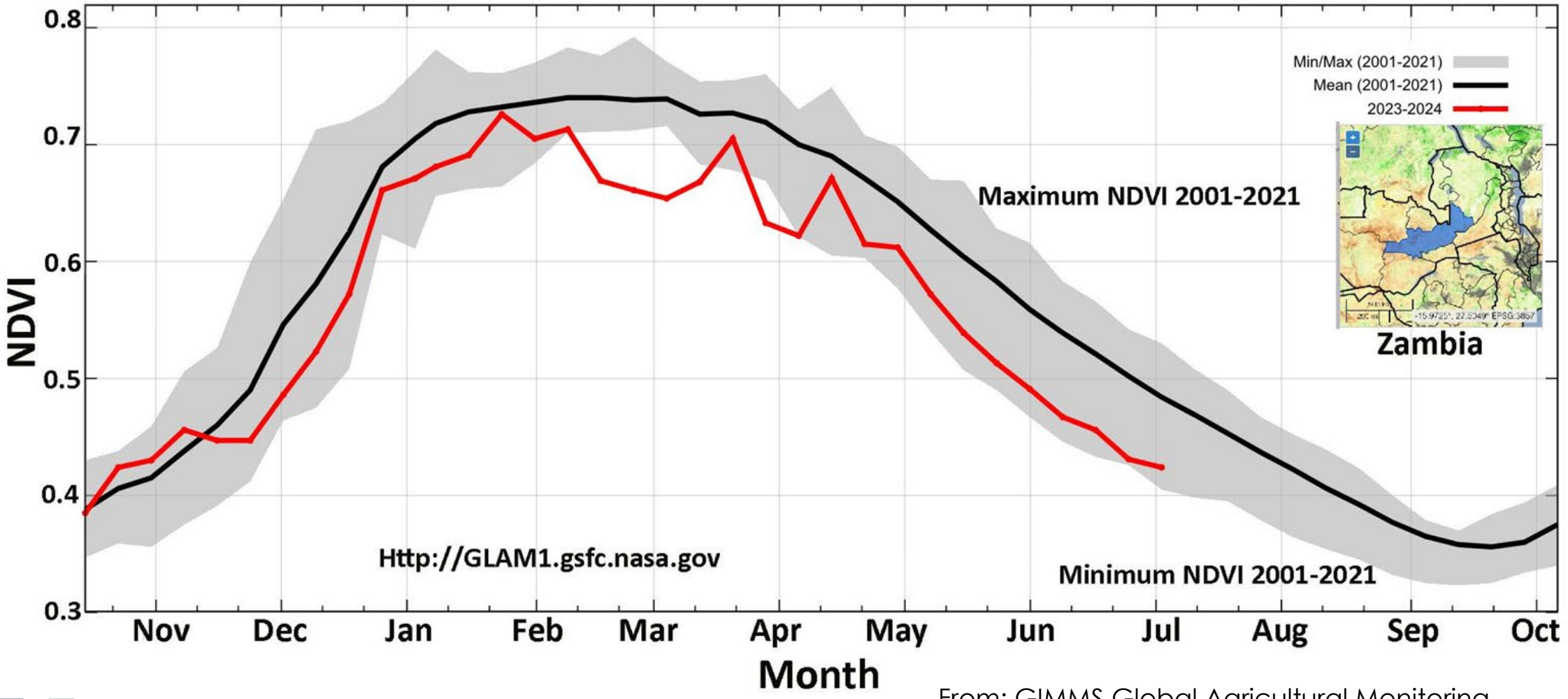


USDA Foreign Agriculture Service

Circular Series WAP 3-24 March 2024

MODIS NDVI from Aqua & Terra

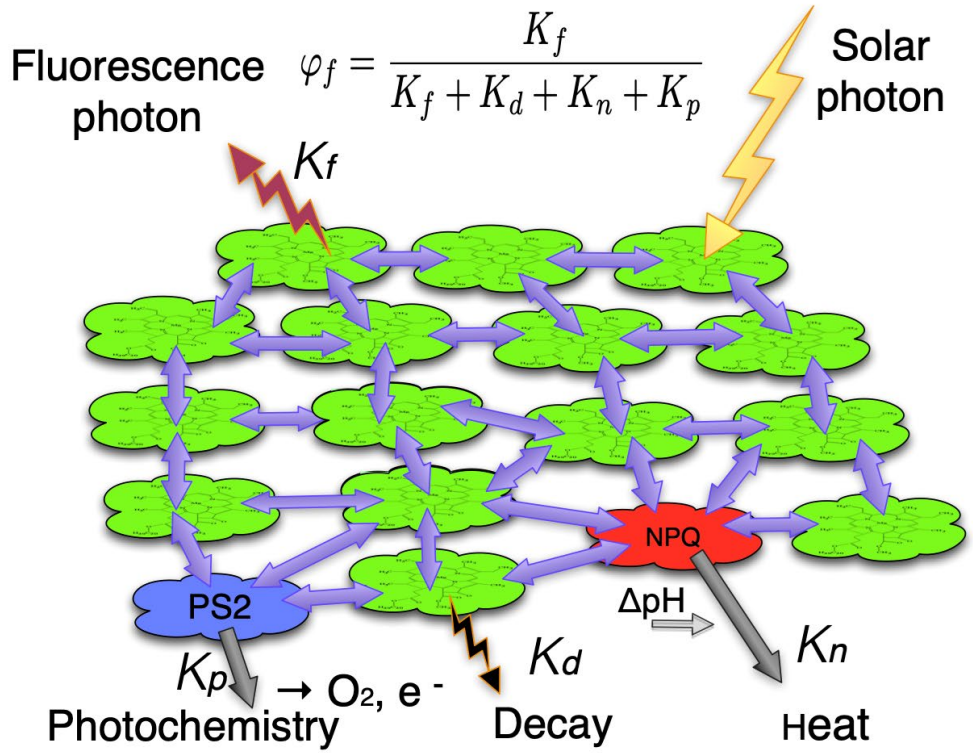
NDVI: Wonderful Photosynthetic Food Security Data



From: GIMMS Global Agricultural Monitoring

Solar Induced Fluorescence

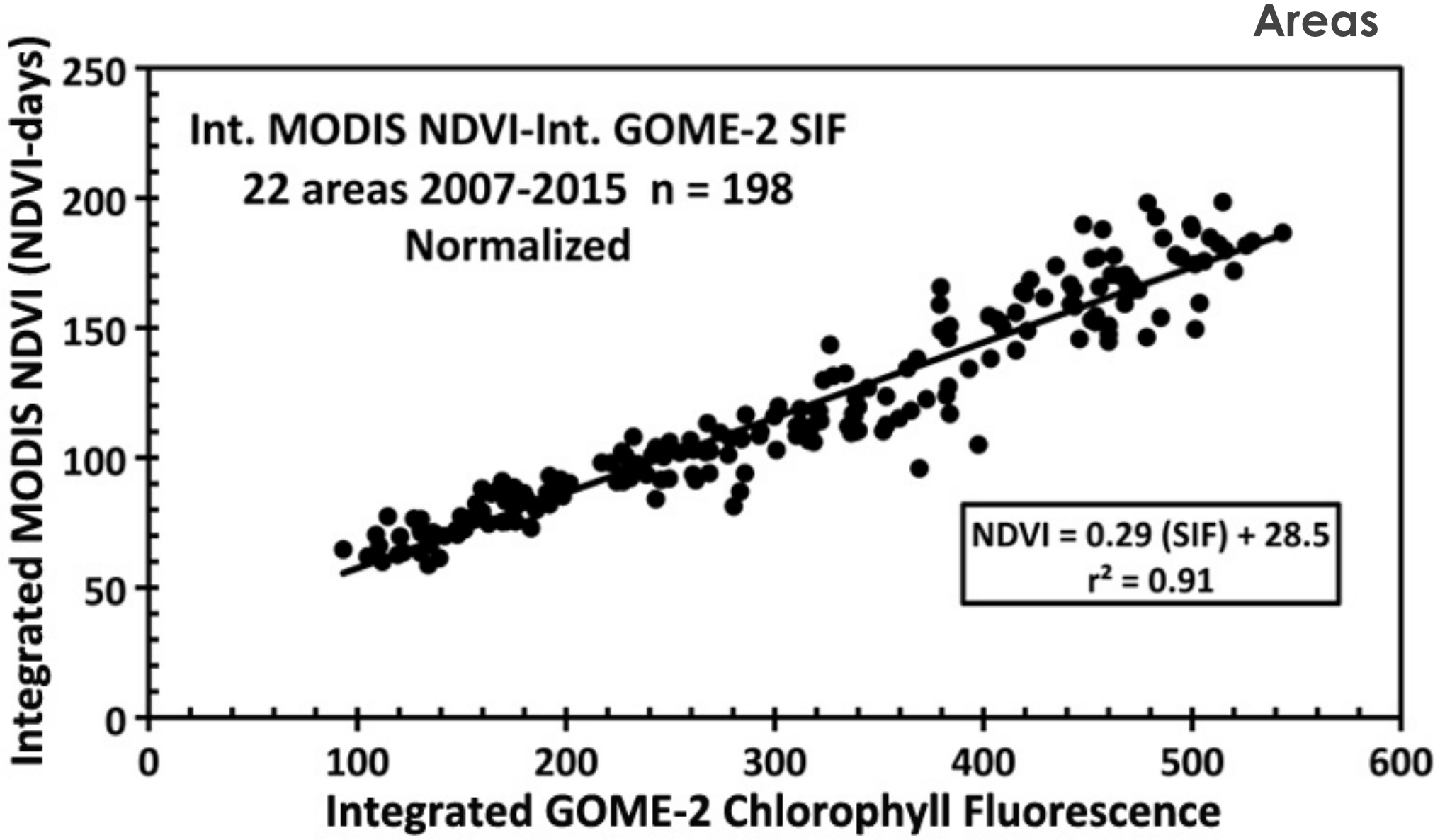
- During photosynthesis, a small fraction of energy absorbed from sunlight is emitted as light via fluorescence.
- Remote sensing instruments include measurement regions that measure this flux. However, the spatial resolution of fluorescence will never be < 300 m because fluorescence is measured within Fraunhofer lines which are a few Angstroms wide.
- Fluorescence is directly tied to photosynthetic capacity or NDVI which has a spatial resolution of 4 m from Planet Labs or 10 m from Sentinel-2. These spatial scales enable individual agricultural fields to be measured through time.
- Missions Measuring SIF: GOME-2, GOSAT, OCO-2, TROPOMI
- Missions measuring photosynthetic capacity: Planet Labs, Sentinel-2, Landsat-8 & 9, MODIS, VIIRS



from Frankenberg, Berry, Guanter, Joiner (2012)

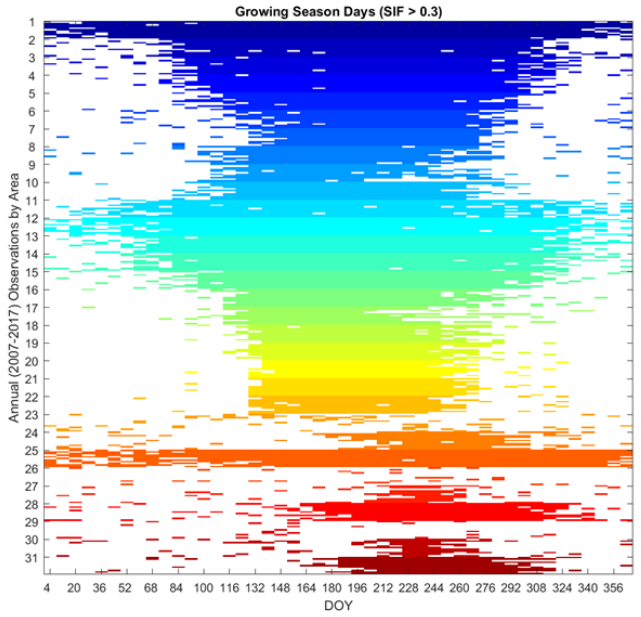
Source: Use of SIF and LIDAR to Assess Vegetation Change and Vulnerability

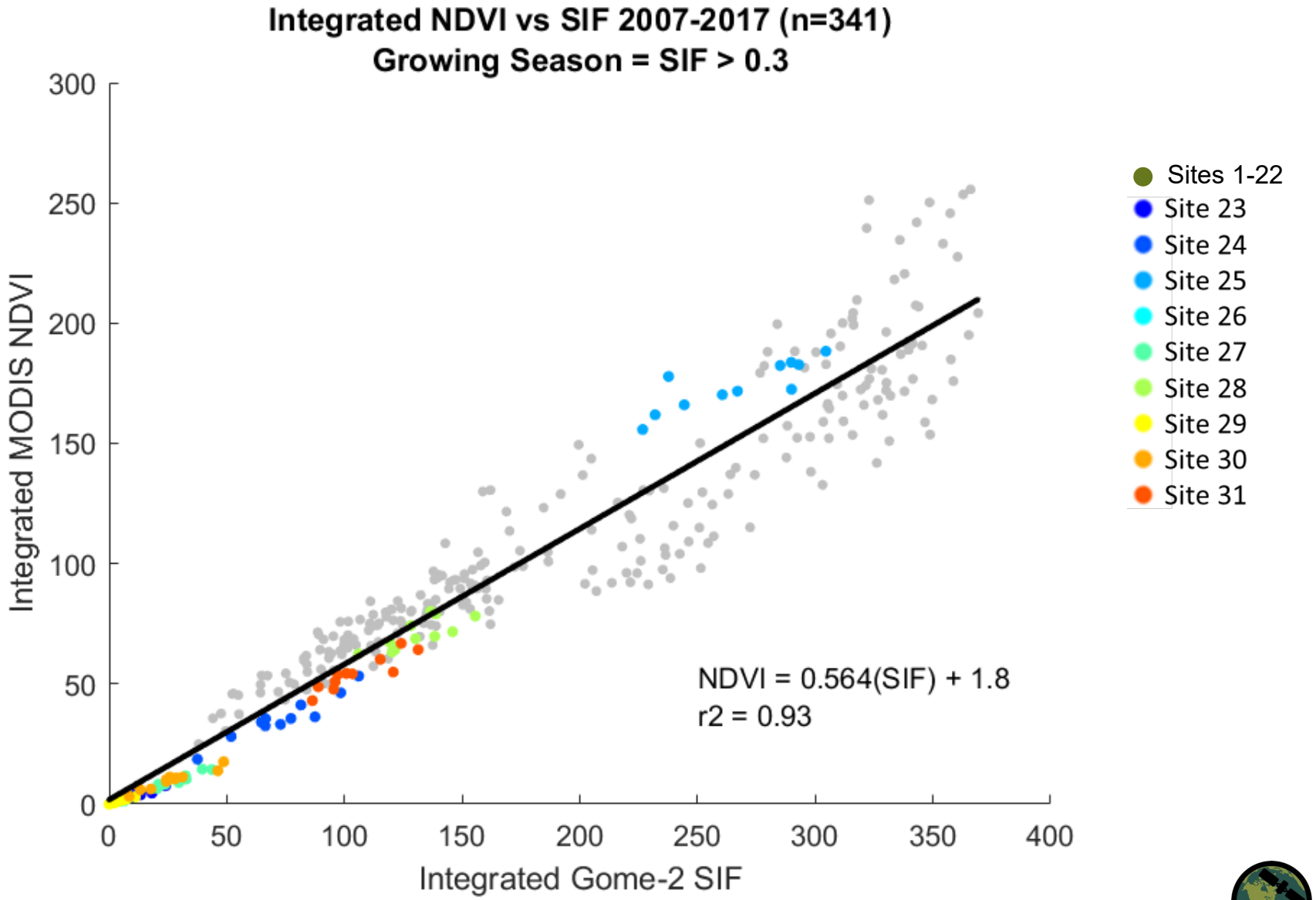
NDVI is Potential Photosynthesis & SIF is a Photosynthetic Flux



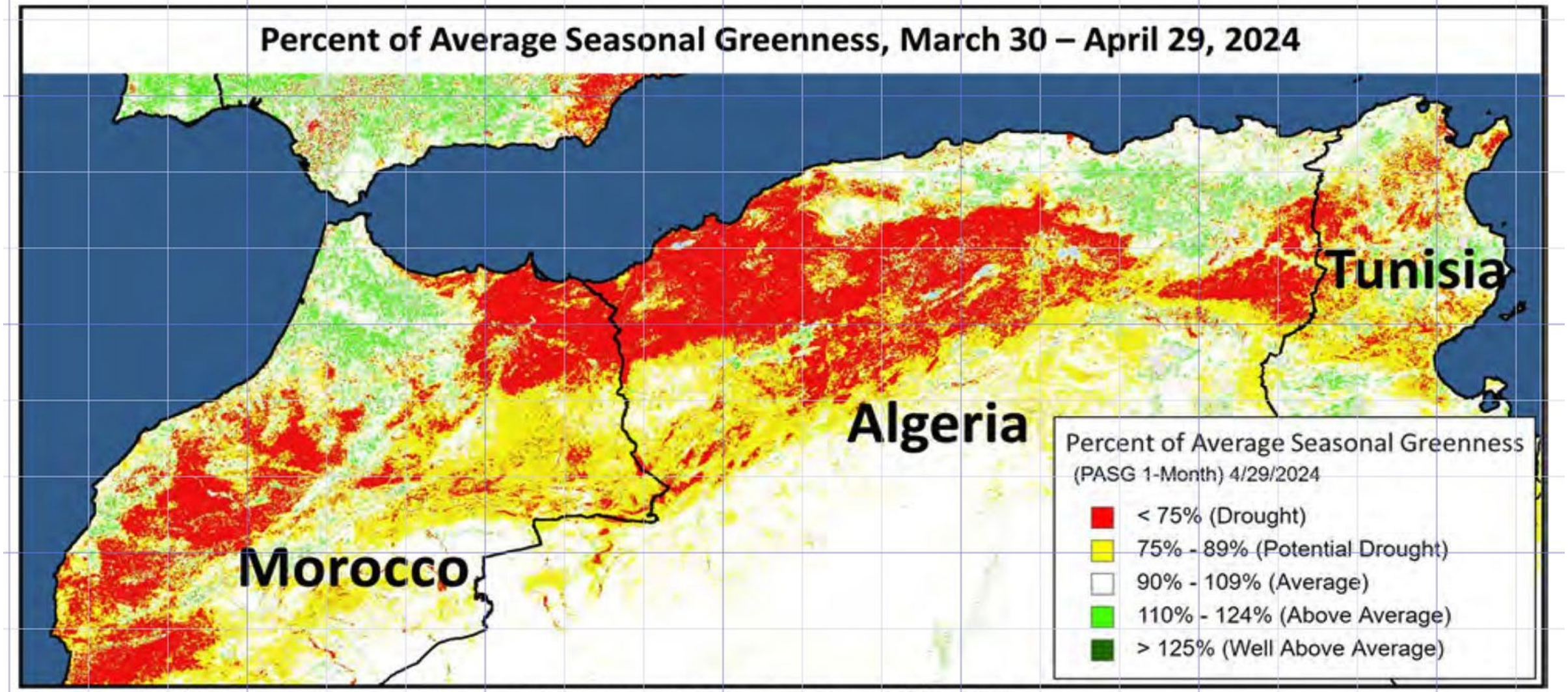
All Observations When SIF >= 0.3 are Included in Growing Season (GS)

- Number of GS days is the same between NDVI & SIF
- Constant threshold applied to all sites



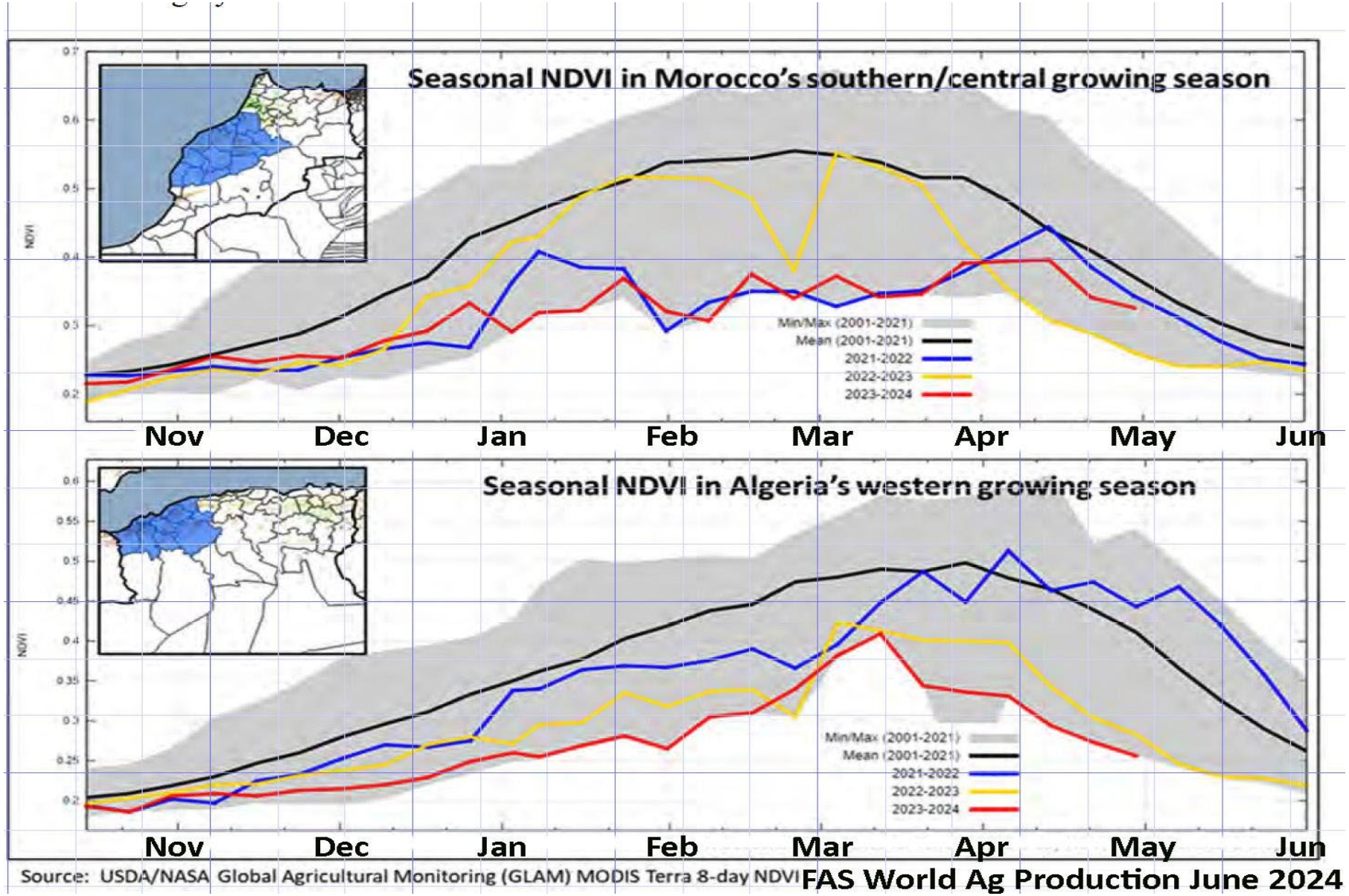


Drought has Persisted Since April 2024 in the Magreb

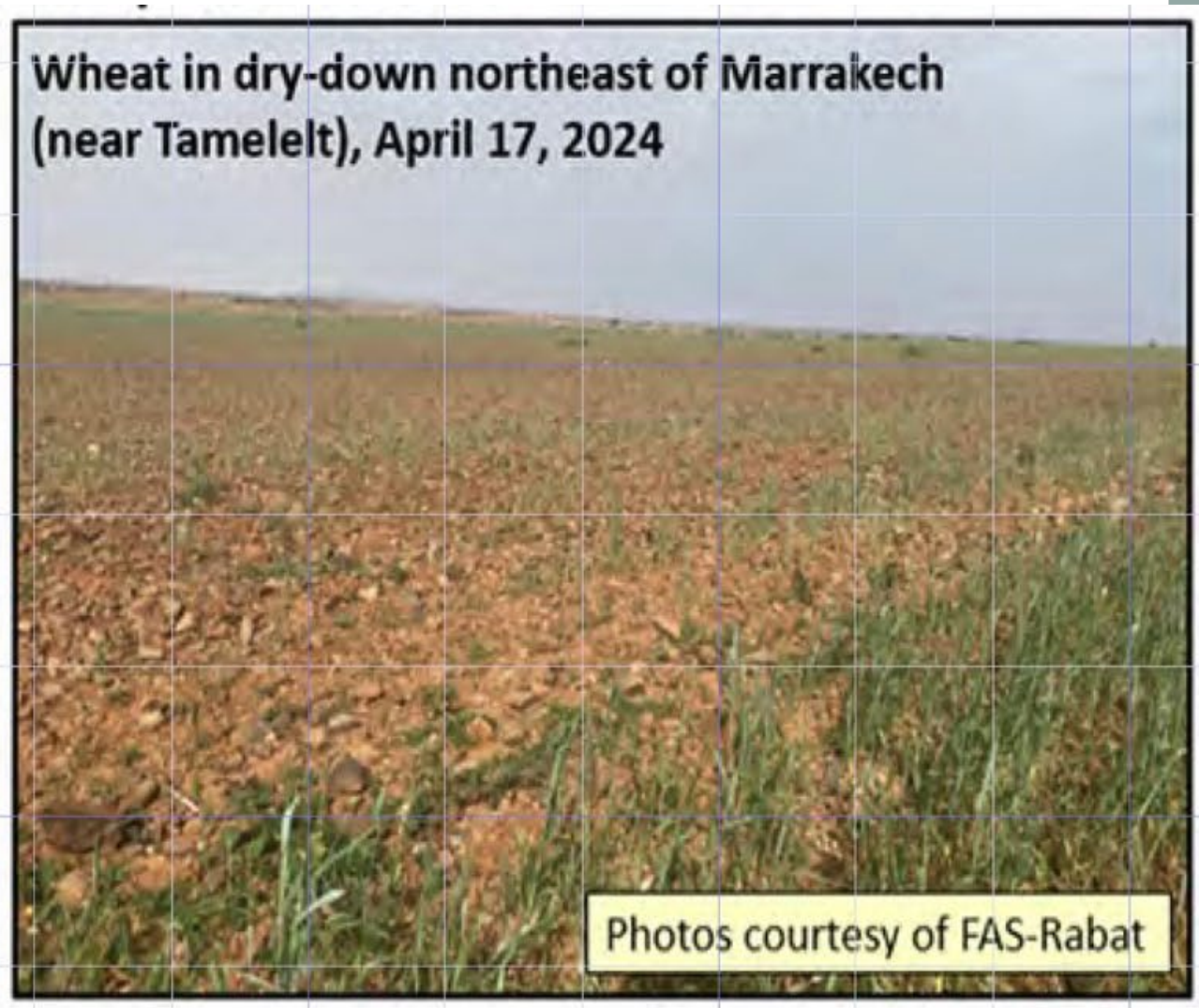


Source: USDA/NASA, Percent of Average Seasonal Greenness (PASG) derived from MODIS NDVI

GLAM MODIS Terra Seasonal NDVI

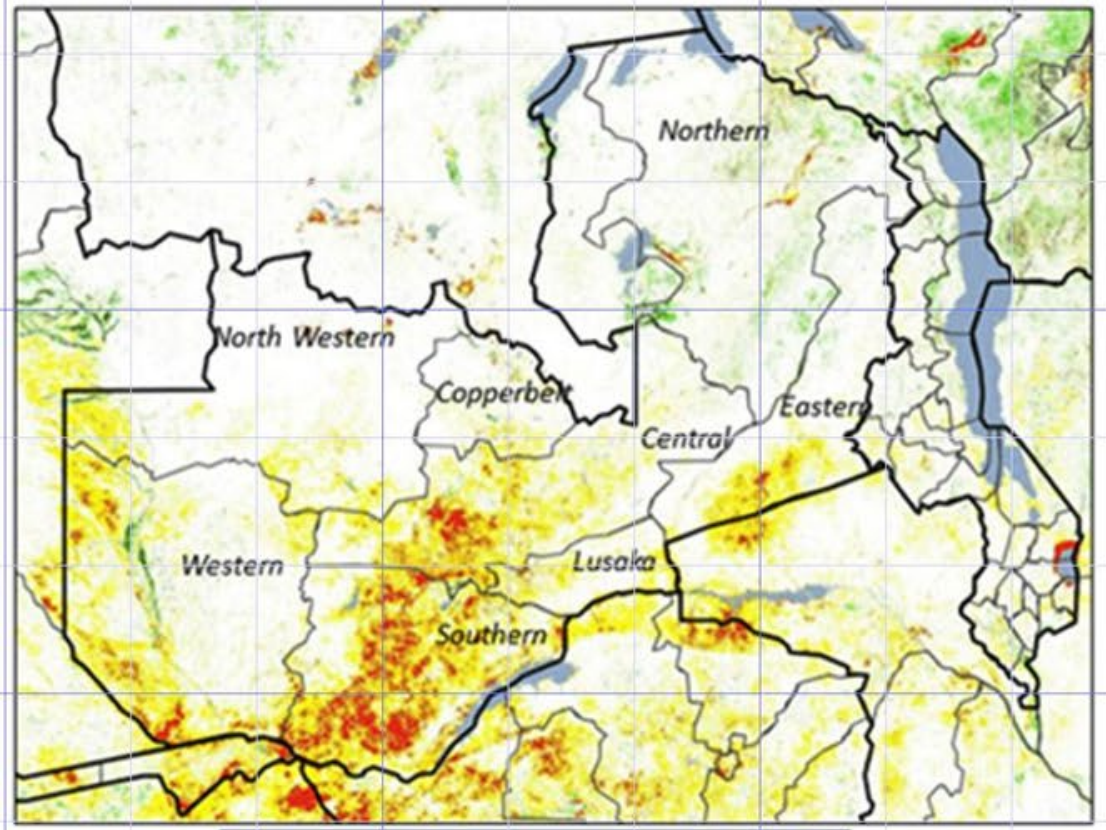


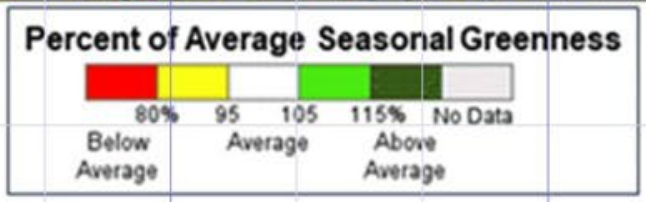
Drought has Persisted Since April 2024 in the Magreb



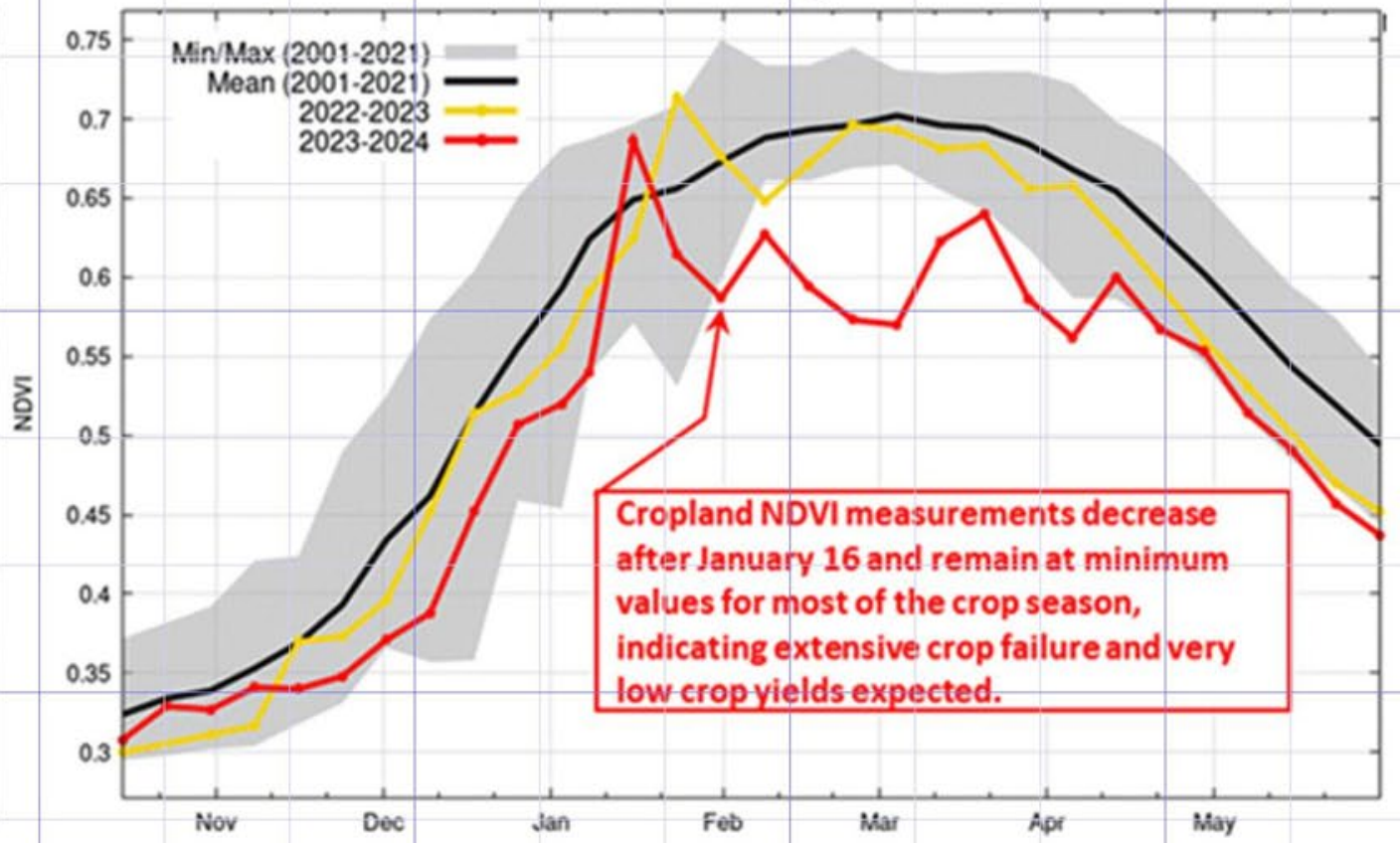
Percent of Greenness and NDVI in Zambia

Percent of Average Seasonal Greenness (PASG) from February 2 through April 29, 2024 (3-months)





Zambia Cropland NDVI-MODIS Measurements from October 2023 through June 2024

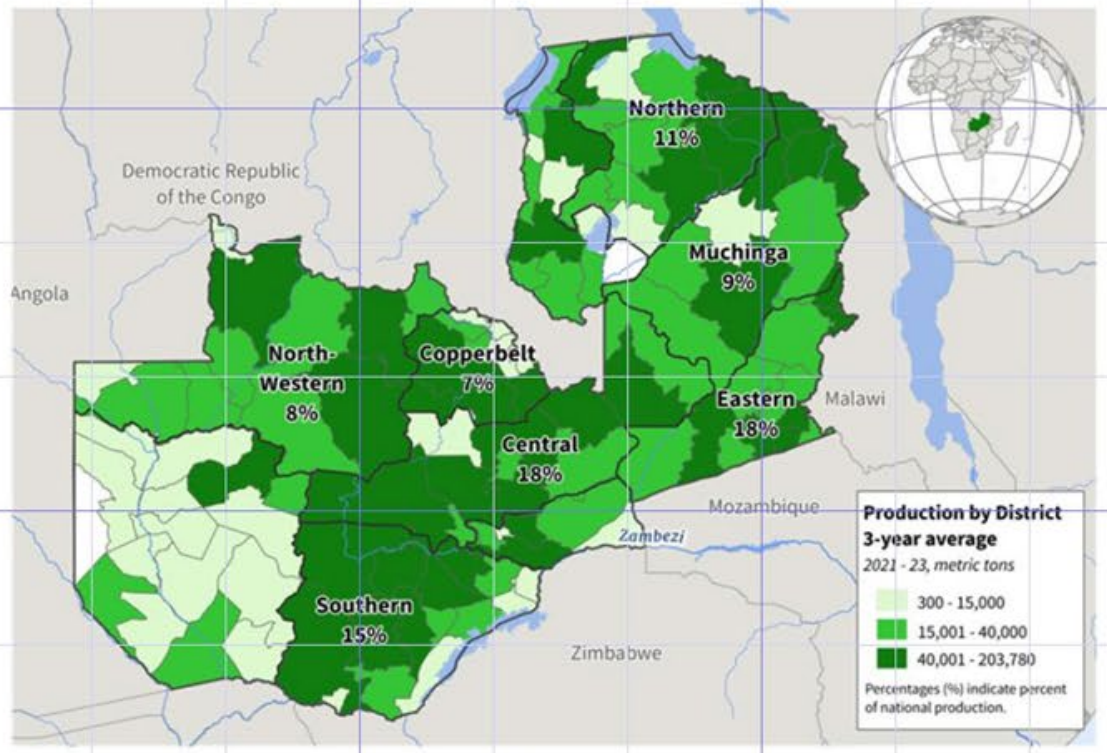


Source: USDA-NASA GLAM;
PASG-MODIS and NDVI-MODIS (250-meters) measurements from the Terra satellite.

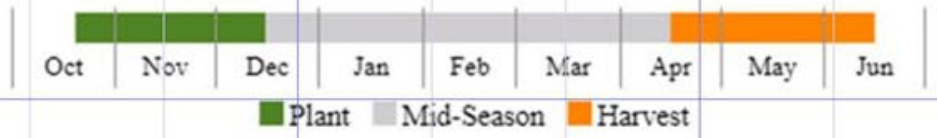
NASA-USDA Food Security: Protecting USA Farmers & Preventing Famine

Zambia Corn: El Niño Drought Reduces Production by 50 Percent from Average

Zambia Corn Production



Zambia Corn

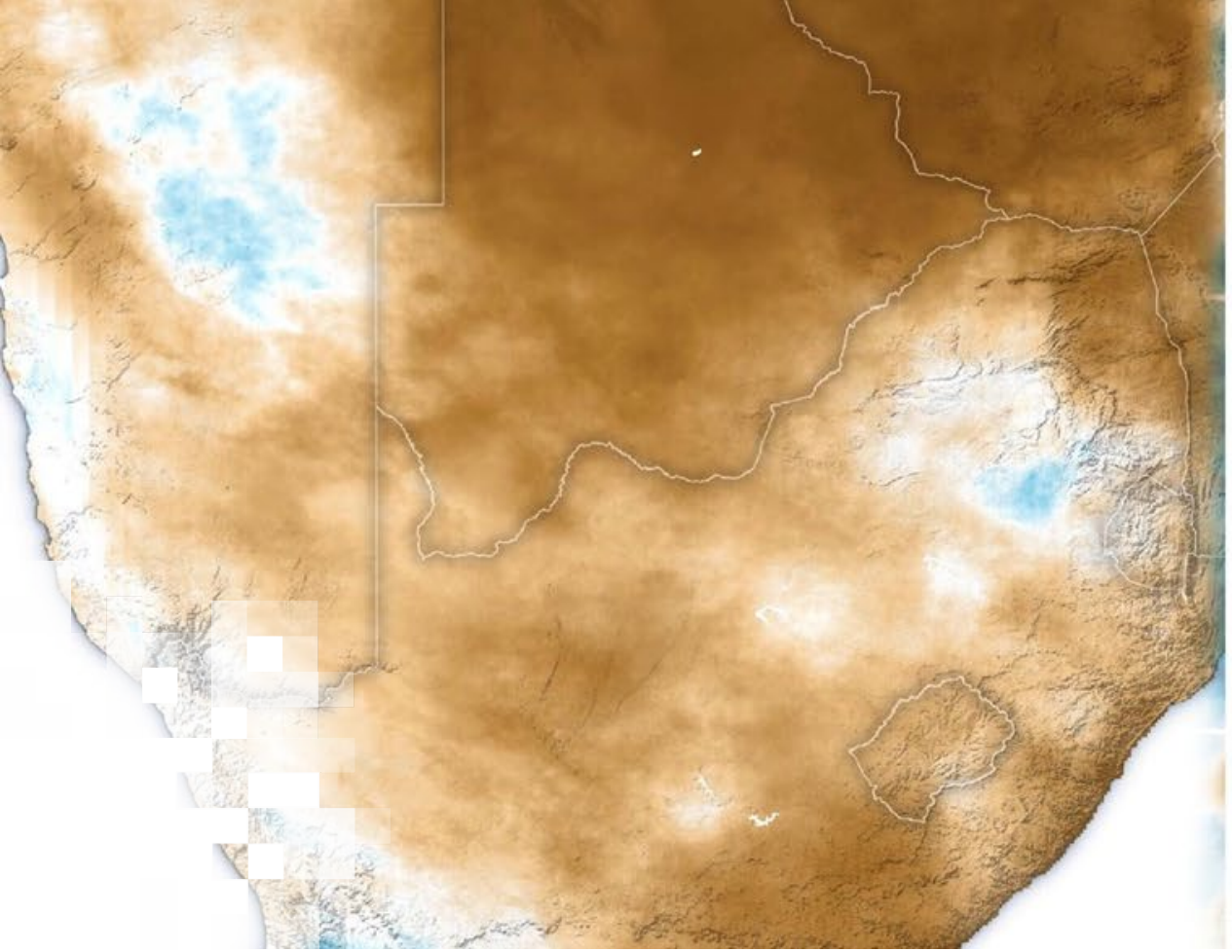


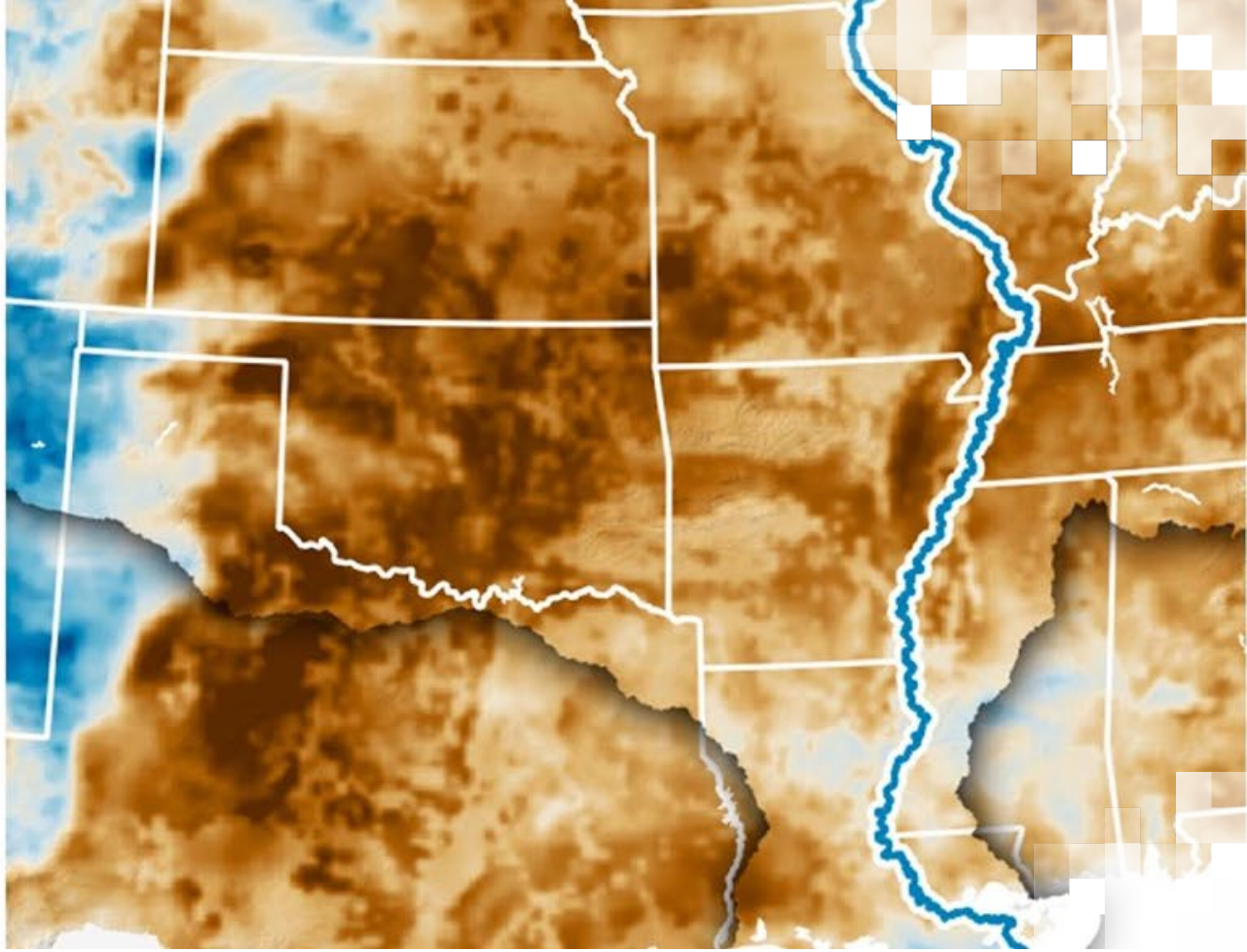
Source: Zambia Ministry of Agriculture and Livestock, and Central Statistics Office.

Zambia Corn Yield

Sources: El Niño and La Niña years defined by NOAA's Oceanic Niño Index (ONI).
Crop yields from USDA PSD Online.

June 2024 Global Ag Production





Demonstration:

Calculate SPI and VCI using GEE

https://code.earthengine.google.com/87f8fd4323288e2f722df37c71f95f5b?accept_repo=users%2Fmayanaclark%2FUHEAT

GEE Code – Instructions for using the code for your own analysis

https://code.earthengine.google.com/87f8fd4323288e2f722df37c71f95f5b?accept_repo=users%2Fmayanaclark%2FUHEAT

The following lines of code will need to be changed to run the SPI and VCI analysis for your own study area and study period.

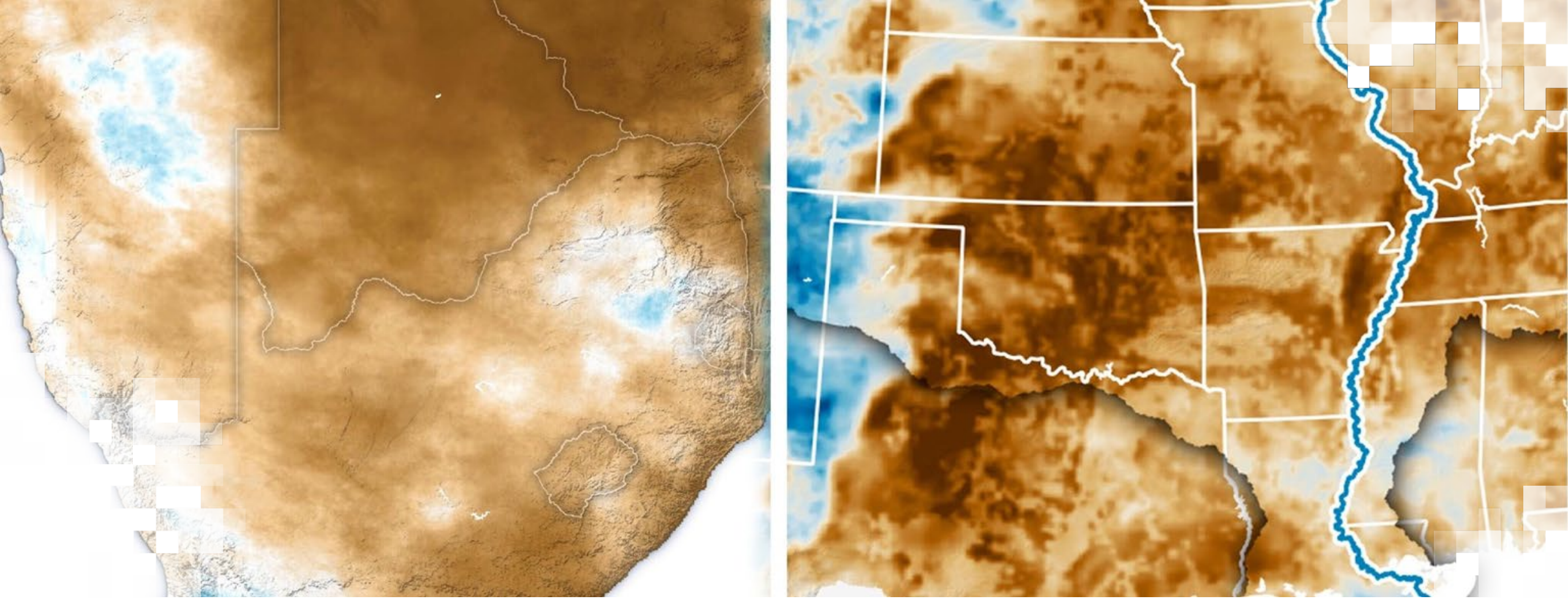
- Follow the instructions in lines 30–44 of the code for selecting your own area of interest (AOI). You will need to **delete the AOI provided in the demonstration** before creating your own AOI.
- Lines 52–53: rename the variable to the country of your choice and change the filter to select this country. Change the value in the print statement to the name of the country.
- Lines 55–56: comment these lines so they are not used when running your own script.
- Line 59: Change the variable name to the country you selected in lines 52–53.
- Line 62: Change the variable name to the country you selected in lines 52–53.
- Line 65: comment this line so it is not used when running your own script.
- Line 74: Change the date to calculate the SPI for your own study period.

GEE Code – Instructions for using the code for your own analysis

https://code.earthengine.google.com/87f8fd4323288e2f722df37c71f95f5b?accept_repo=users%2Fmayanaclark%2FUHEAT

The following lines of code will need to be changed to run the SPI and VCI analysis for your own study area and study period.

- Line 99: Change the value for calculating SPI at the time step of your choosing (see line 96).
- Line 139: Change the variable name to the country you selected in lines 52–53.
- Line 228: Change the min/max values for the results from your own SPI analysis.
- Line 337: Change the name of the map title (if applicable)
- Lines 460–468: Uncomment these lines if exporting the results to your Google Drive.
- Line 502: Change the second parameter in parentheses to the country selected in lines 52–53.
- Lines 523–524: Change the values for month and year respectively for your own calculation of VCI.
- Lines 594–595: Change min/max values for the results from your own VCI analysis.
- Lines 608–618: Uncomment these lines if exporting the results to your Google Drive.



Part 1:
Summary

Summary

- Outlined remote sensing observations and regional and global webtools for drought monitoring.
- Described indicators and methodology for determining drought categories based on percentile values of SPI, PDSI, soil moisture, and streamflow.
- Recognized the use of NDVI and SIF in drought mapping for food security.
- Reviewed features of drought.gov, global Drought Information System, and U.S. Drought Monitor portals to monitor drought conditions.
- Identified methodology to calculate SPI and VCI from remotely sensed precipitation and vegetation data in Google Earth Engine.

Looking Ahead to Part 2

- Overview of NASA Sub-seasonal to Seasonal (S2S – 45 to 90 days) forecast system.
- Access and analysis of S2S precipitation and temperature forecast data to assess drought conditions.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens August 1, 2024
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by August 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.

Contact Information

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Thank You!