The Evaporative Demand Drought Index (EDDI):

early warning and monitoring of drought from the demand side

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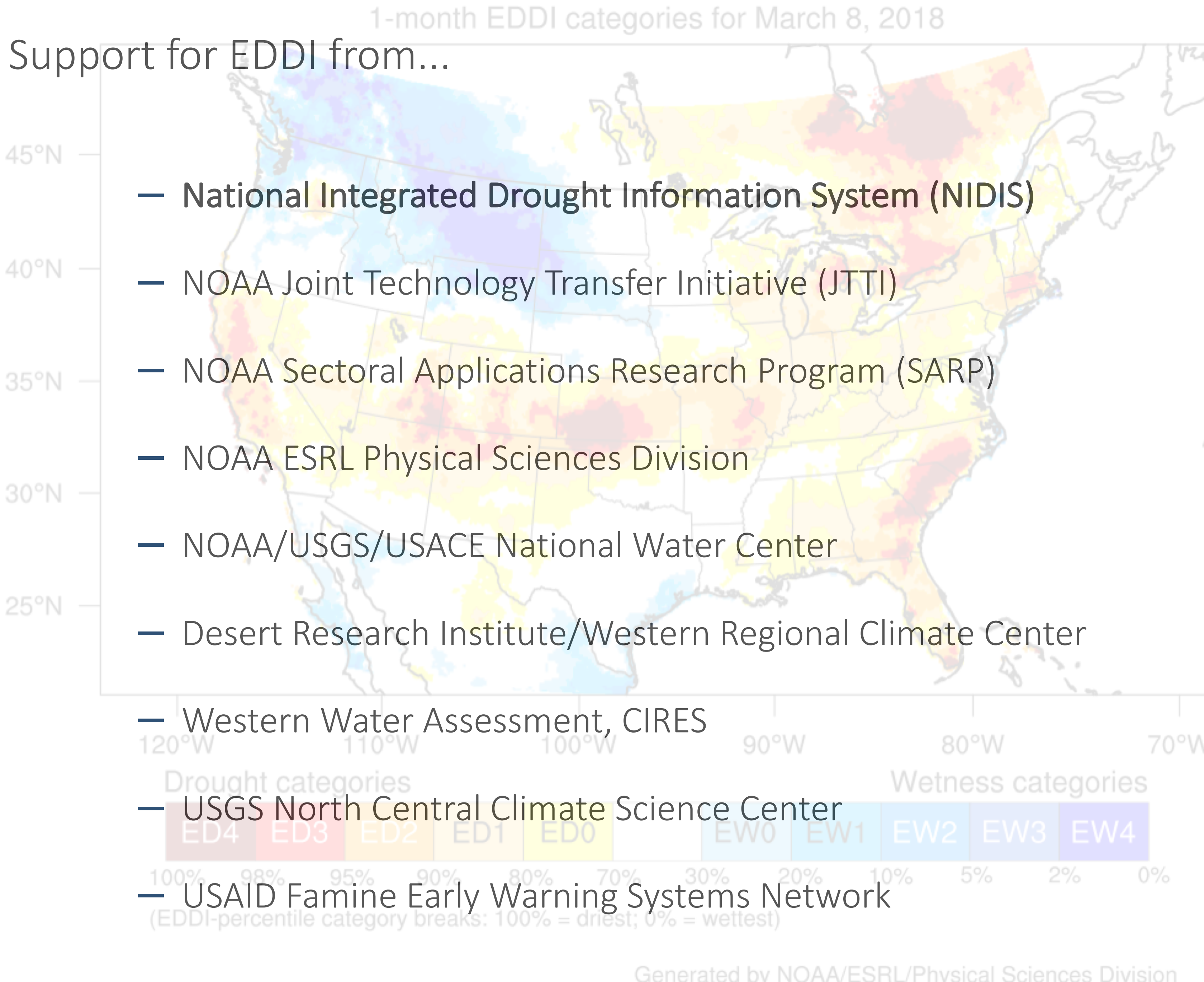
2. University of Colorado/Cooperative Institute for Research in Environmental Sciences
3. Desert Research Institute
4. Western Water Assessment
5. University Corporation for Atmospheric Research

Wednesday, March 14, 2018

Support for EDDI from...

- National Integrated Drought Information System (NIDIS)
- NOAA Joint Technology Transfer Initiative (JTTI)
- NOAA Sectoral Applications Research Program (SARP)
- NOAA ESRL Physical Sciences Division
- NOAA/USGS/USACE National Water Center
- Desert Research Institute/Western Regional Climate Center
- Western Water Assessment, CIRES
- USGS North Central Climate Science Center
- USAID Famine Early Warning Systems Network



Outline

Purpose:

- *introduce potential users to EDDI*
- *familiarize existing EDDI users with ancillary products*
- *update all users on new developments*
- *generate feedback from users on experience, formats, by-products, etc.*

What does an EDDI map tell you?

Background:

- relevance of evaporative demand to drought
- developing EDDI from evaporative demand

Applications:

- early warning
- agricultural drought
- hydrologic drought
- wildfire risk

New developments

EDDI access and availability

Take-home messages

Questions?

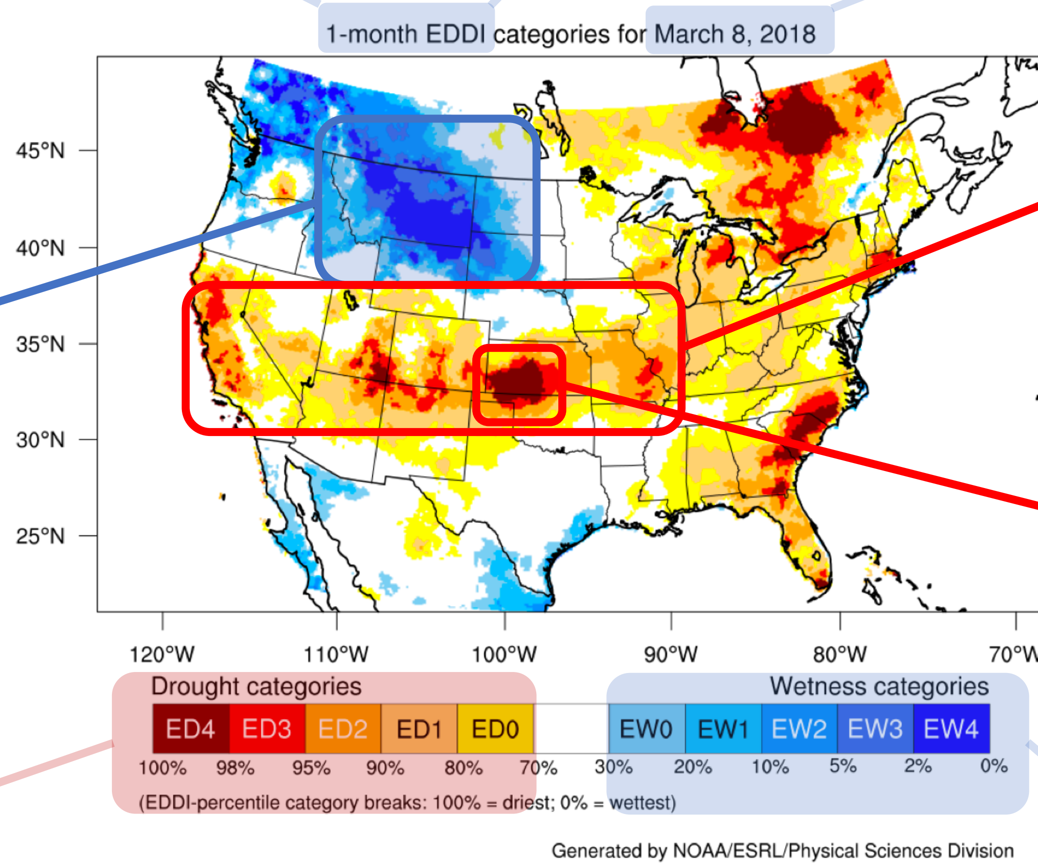
What is the Evaporative Demand Drought Index (EDDI)?

An EDDI month is 30 days, so this 1-month EDDI map is based on E_0 from Feb 7 - Mar 8 (30 days).

There are 24 time scales: 1-12 weeks, 1-12 months.

Lag of ~ 5 days, so this map was released on March 13

E_0 is unusually low in the Northern Great Plains and Rockies, indicating wetter-than-normal surface conditions and atmosphere.



E_0 is unusually high across the Southwest in the Southern Great Plains, indicating drier-than-normal surface conditions and atmosphere.

ED4 in OK/KS means that such dry conditions are expected only 2% of Feb 2 – Mar 3 periods. EDDI picked up this dryness one month (Feb 8) before USDM (Mar 6)

Names, colors, and %ile breaks for EDDI drought categories reflect those of the US Drought Monitor.

Wetness and dryness categories mirror each other, so ED2 and EW2 have identical expected frequency.

The anomaly in **evaporative demand** at a specified timescale, for a given location, expressed as a percentile.

Background: Relevance of E_0 to drought

Water balance on a land surface:

~ f(*Prcp*, *ET*)

where *ET* is driven by:

- evaporative demand (E_0),
- surface moisture status.

Drought = imbalance of supply to, and demand for, surface moisture

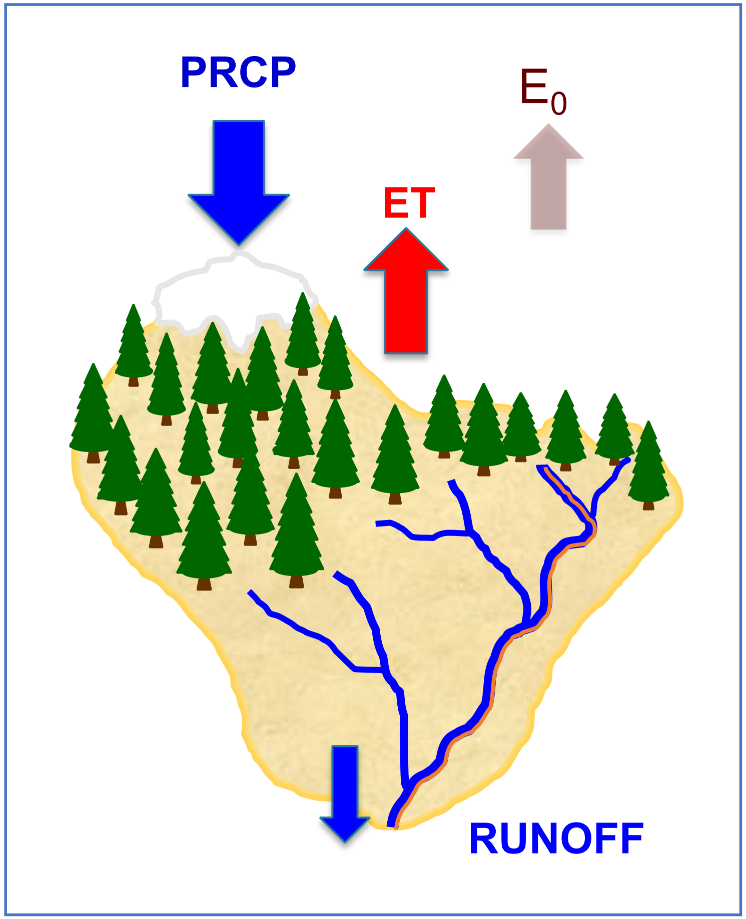
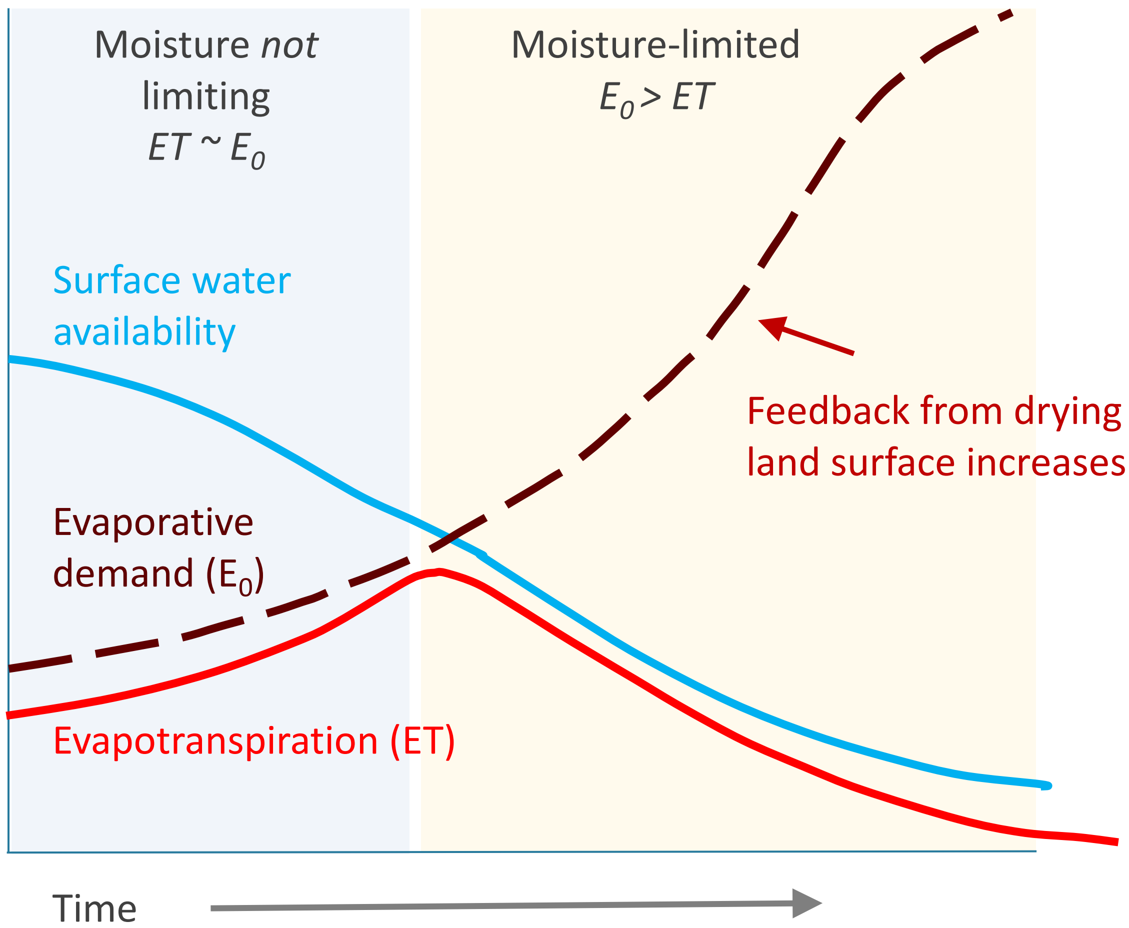


Image: pixabay.com

Background: Relevance of E_0 to drought

Relationship between E_0 and *ET* changes as land surface dries out



- When surface moisture is sufficient, rising E_0 leads to rising ET
- When moisture is limited, ET declines, while E_0 rises even more steeply

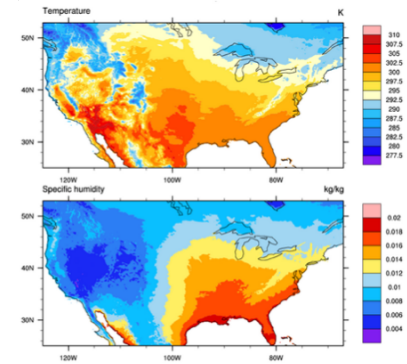
Evaporative demand rises in all forms of drought.

Background: How is EDDI calculated?

Meteorological Inputs

temperature, humidity, wind speed, solar radiation

NLDAS-2, 12-km gridded, daily



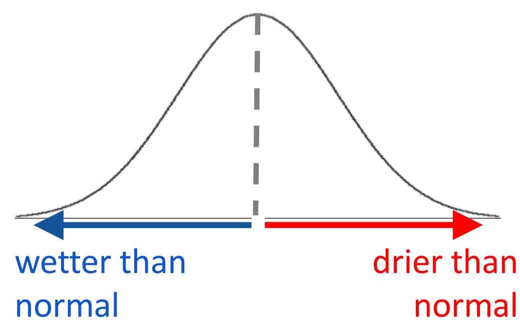
Reference Evapotranspiration calculation

Penman-Monteith FAO56

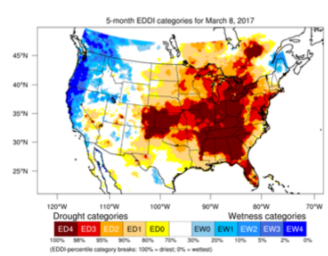
$$E_0 \approx ET_0 = \underbrace{\frac{0.408\Delta}{\Delta+\gamma(1+C_d U_2)}(R_n - G)\frac{86400}{10^6}}_{\text{Radiative forcing (sunshine, } T\text{)}} + \underbrace{\frac{\gamma \frac{C_n}{T}}{\Delta+\gamma(1+C_d U_2)} U_2 \frac{(e_{sat}-e_a)}{10^3}}_{\text{Advective forcing (wind, humidity, } T\text{)}}$$

Rank-based non-parametric standardization

based on historic climatology of ET_0



EDDI



Background: Estimating E_0 from reference *ET*

Penman-Monteith Reference *ET* (FAO-56):

$$E_0 \approx ET_0 = \frac{0.408\Delta}{\Delta+\gamma\left(1+C_dU_2\right)}\left(R_n - G\right)\frac{86400}{10^6} + \frac{\gamma\frac{C_n}{T}}{\Delta+\gamma\left(1+C_dU_2\right)}U_2\frac{\left(e_{sat}-e_a\right)}{10^3}$$

Radiative forcing (sunshine, *T*)

Advective forcing (wind, humidity, *T*)

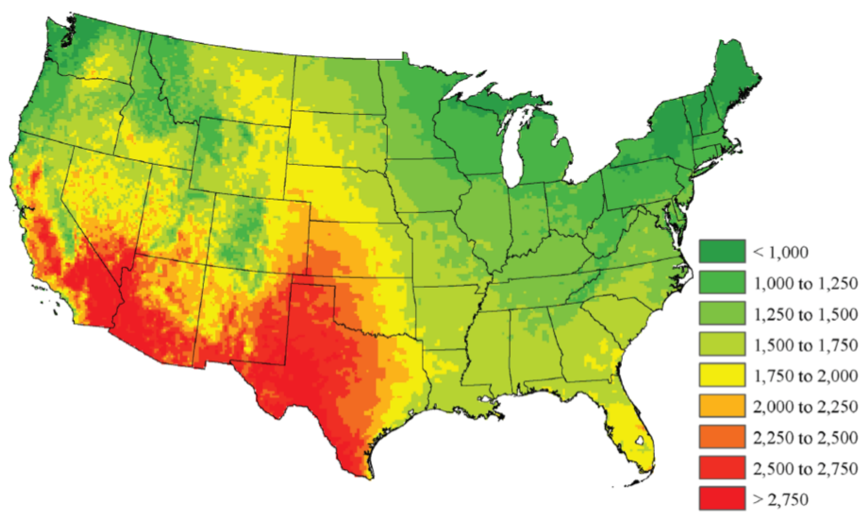
"Reference" crop specified:

- 0.12-m grass or 0.50-m alfalfa
- well-watered , actively growing,
- completely shading the ground,
- albedo of 0.23.

Drivers from NLDAS-2:

- temperature at 2 m
- specific humidity at surface
- downward SW at surface
- wind speed at 10 m

- daily, Jan 1, 1979 – present
- ~12-km, CONUS-wide

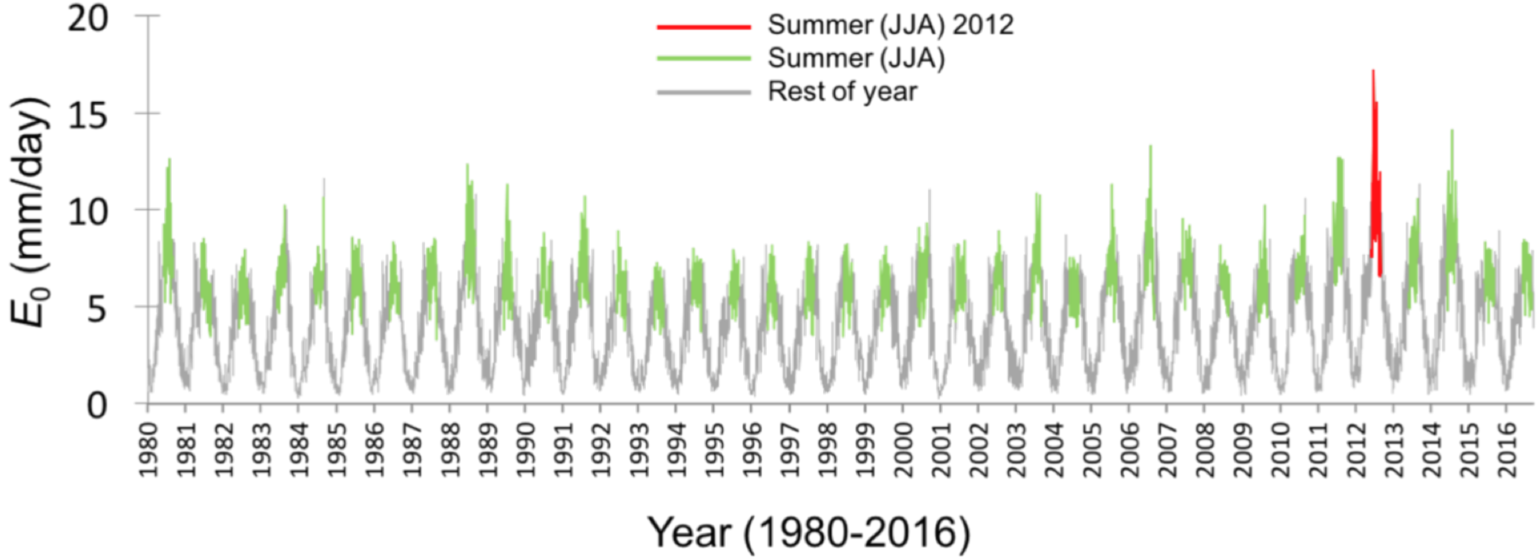


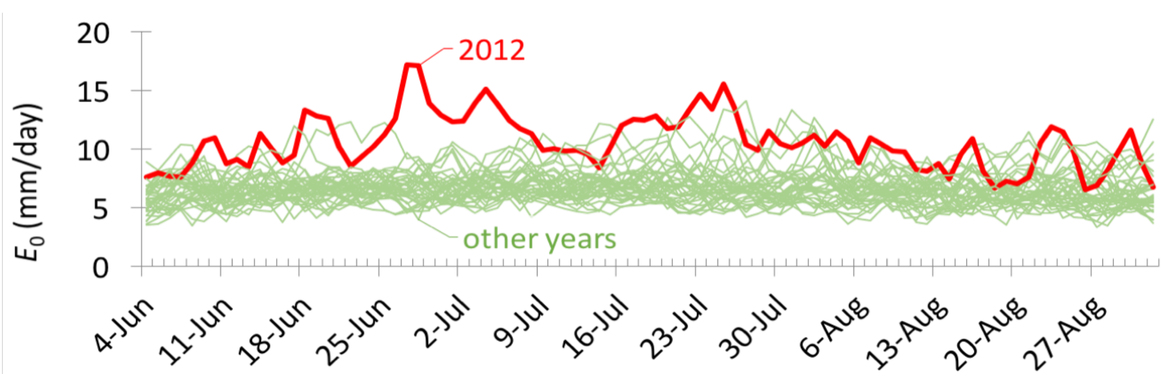
Mean annual E_0 (mm), 1981-2010

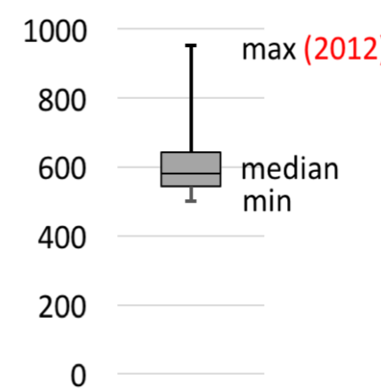
λ = latent heat of vaporization
R_n = net radiation (SW + LW) at crop surface
G = ground heat flux
U_2 = 2-m wind speed
e_{sat} / e_a = saturated / actual vapor pressure
$\Delta = de_{sat}/dT$ at air temperature T
γ = psychrometric constant
C_n, C_d = constants for crop type and time-step

Background: Calculating EDDI

E.g., deriving 3-month EDDI on August 31, 2012, Midwest

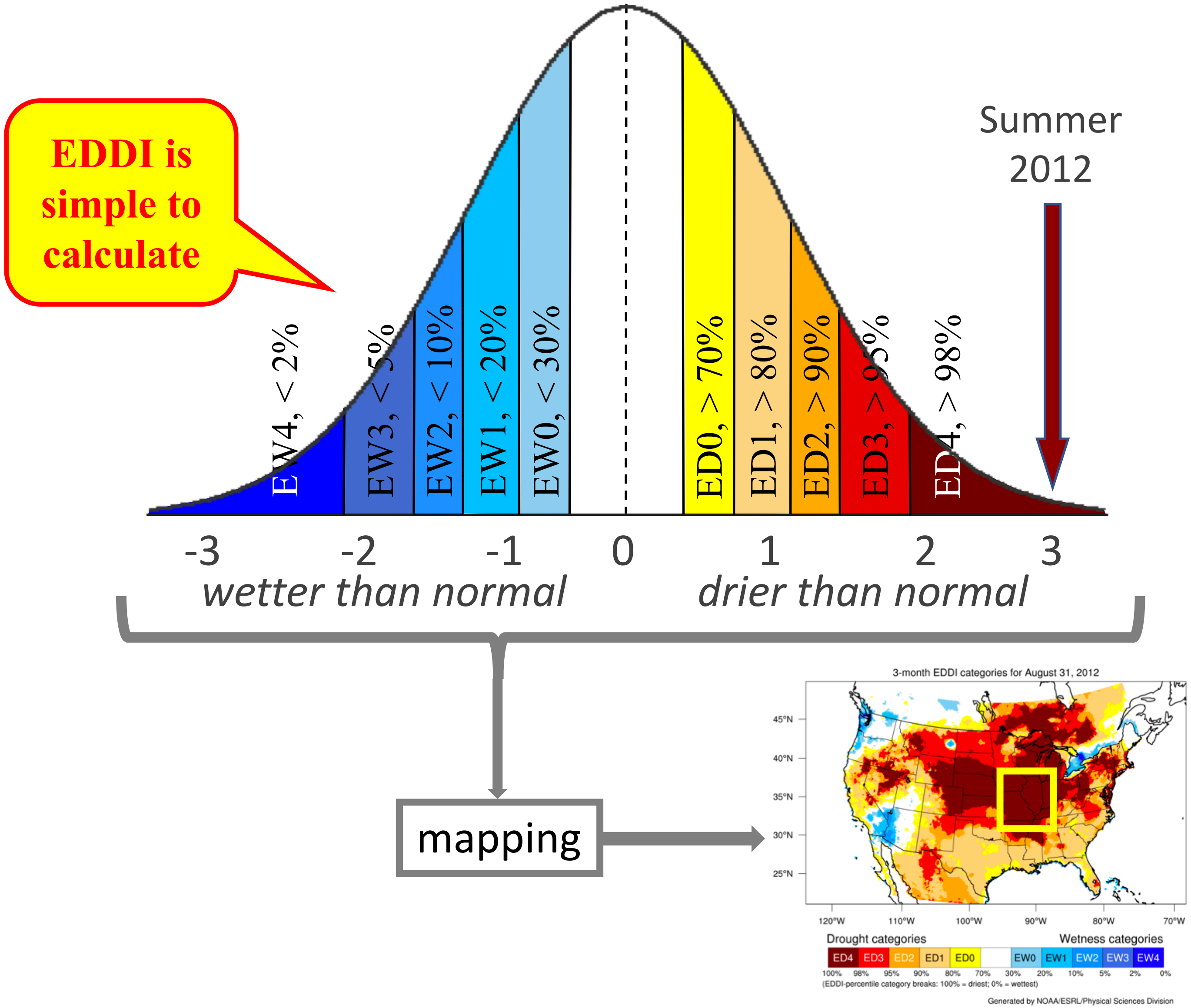






Background: Calculating EDDI

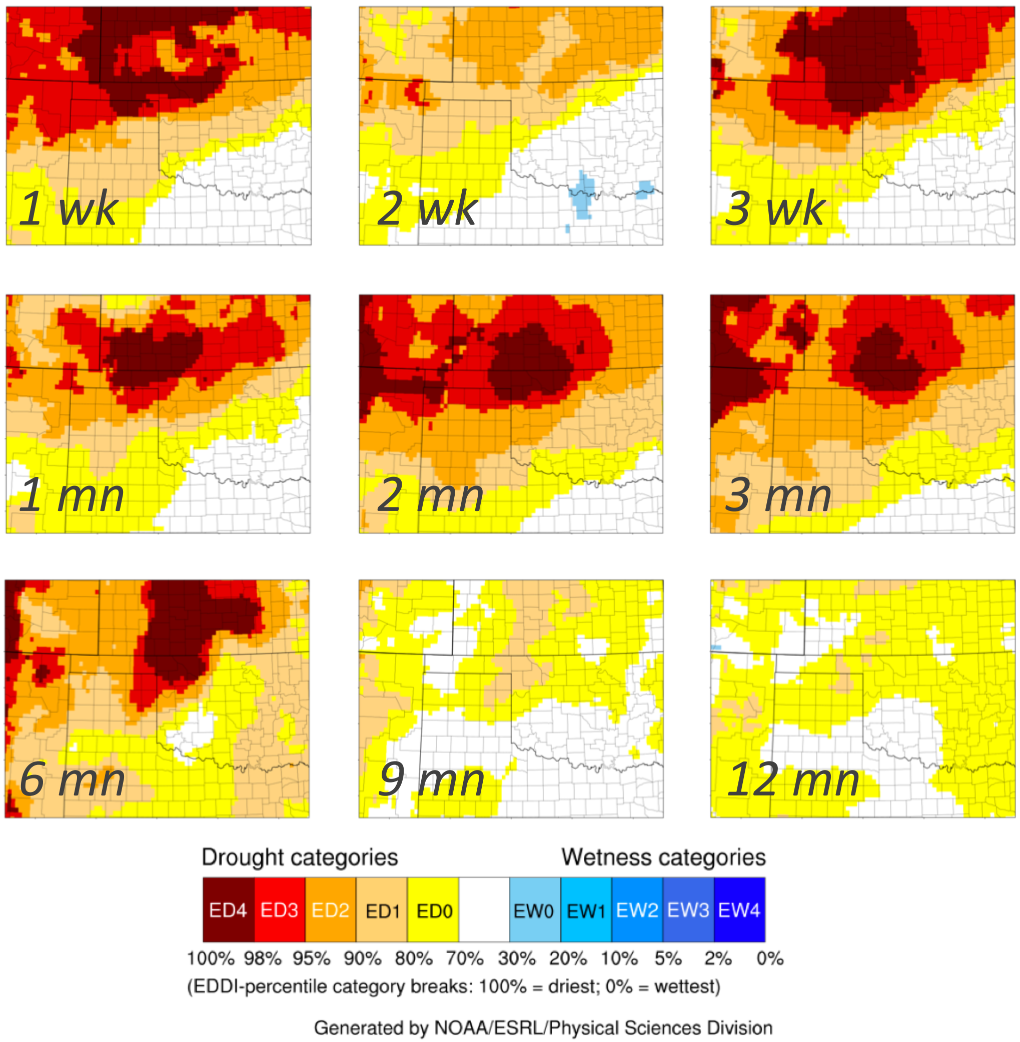
E.g., deriving 3-month EDDI on August 31, 2012, Midwest



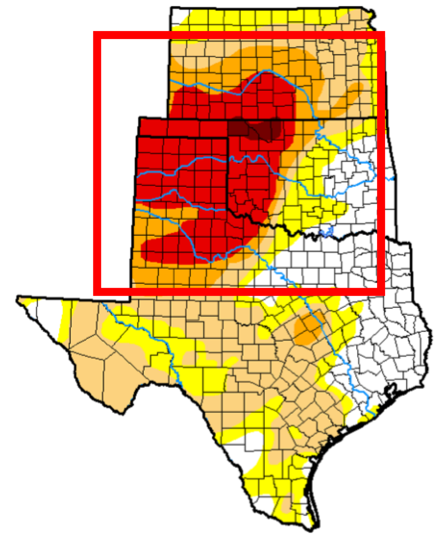
Background: Multi-scalar drought monitor

March 6, 2018

EDDI



US Drought Monitor



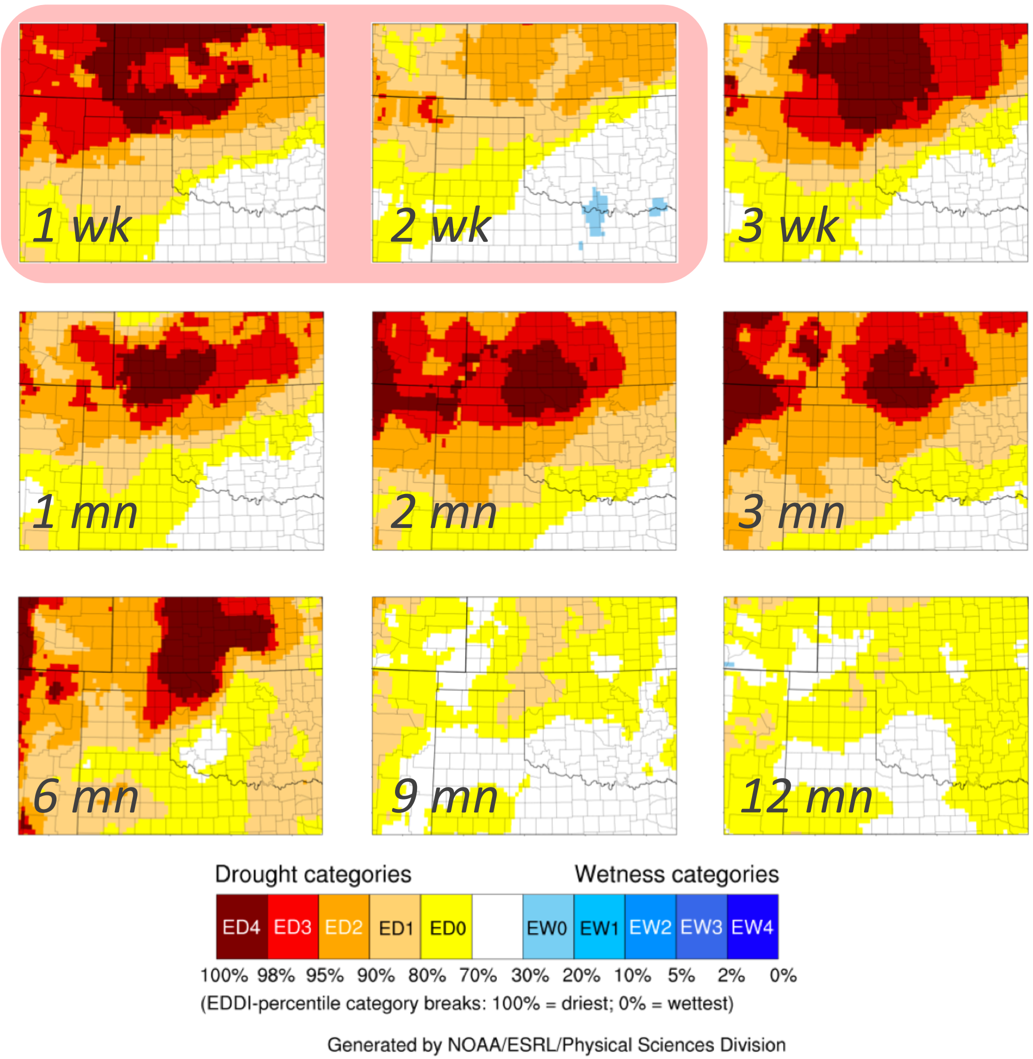
EDDI is available at 24 timescales:

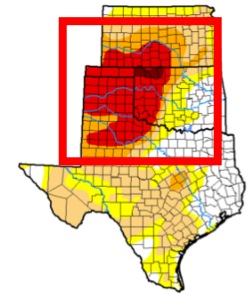
- **1 ... 12 weeks**
- **1 ... 12 months**

Background: Multi-scalar drought monitor

March 6, 2018

EDDI





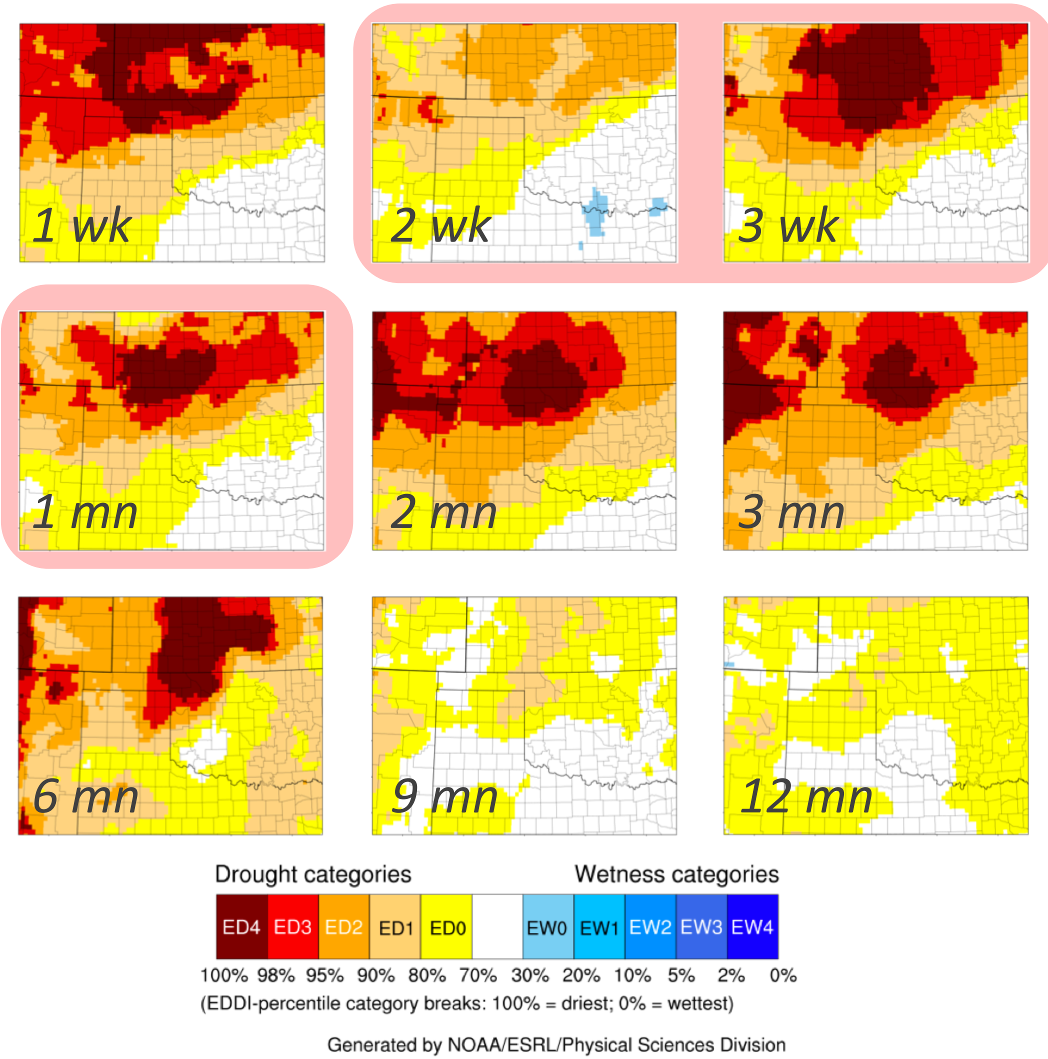
Flash drought potential

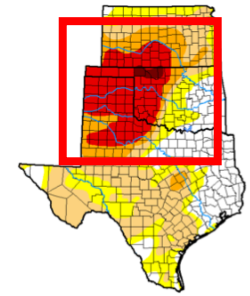
(1- to 3-week EDDI)

Background: Multi-scalar drought monitor

March 6, 2018

EDDI





Emerging conditions

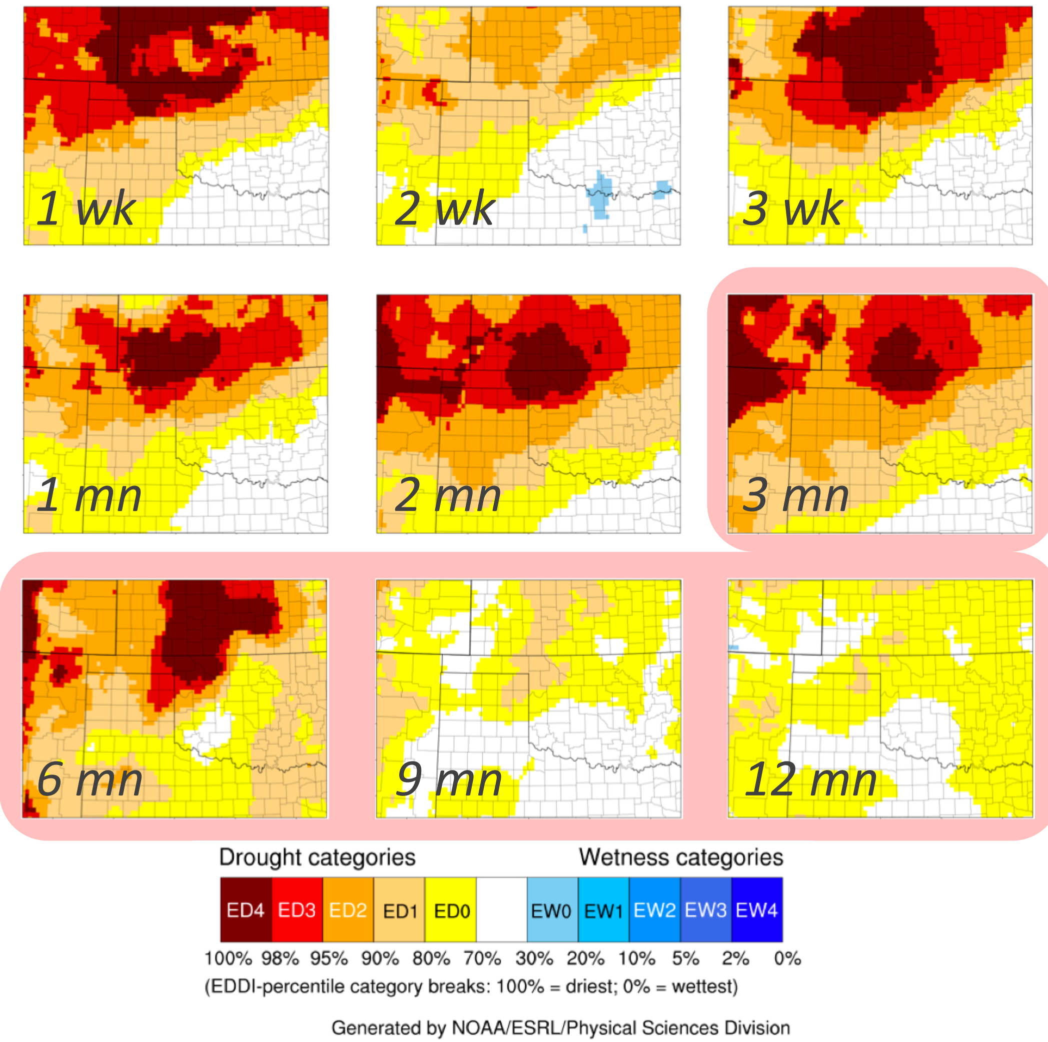
(that *could* lead to drought)

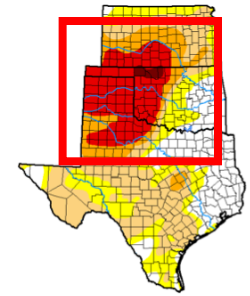
(2-week to 1-month EDDI)

Background: Multi-scalar drought monitor

March 6, 2018

EDDI





Persistent drought conditions

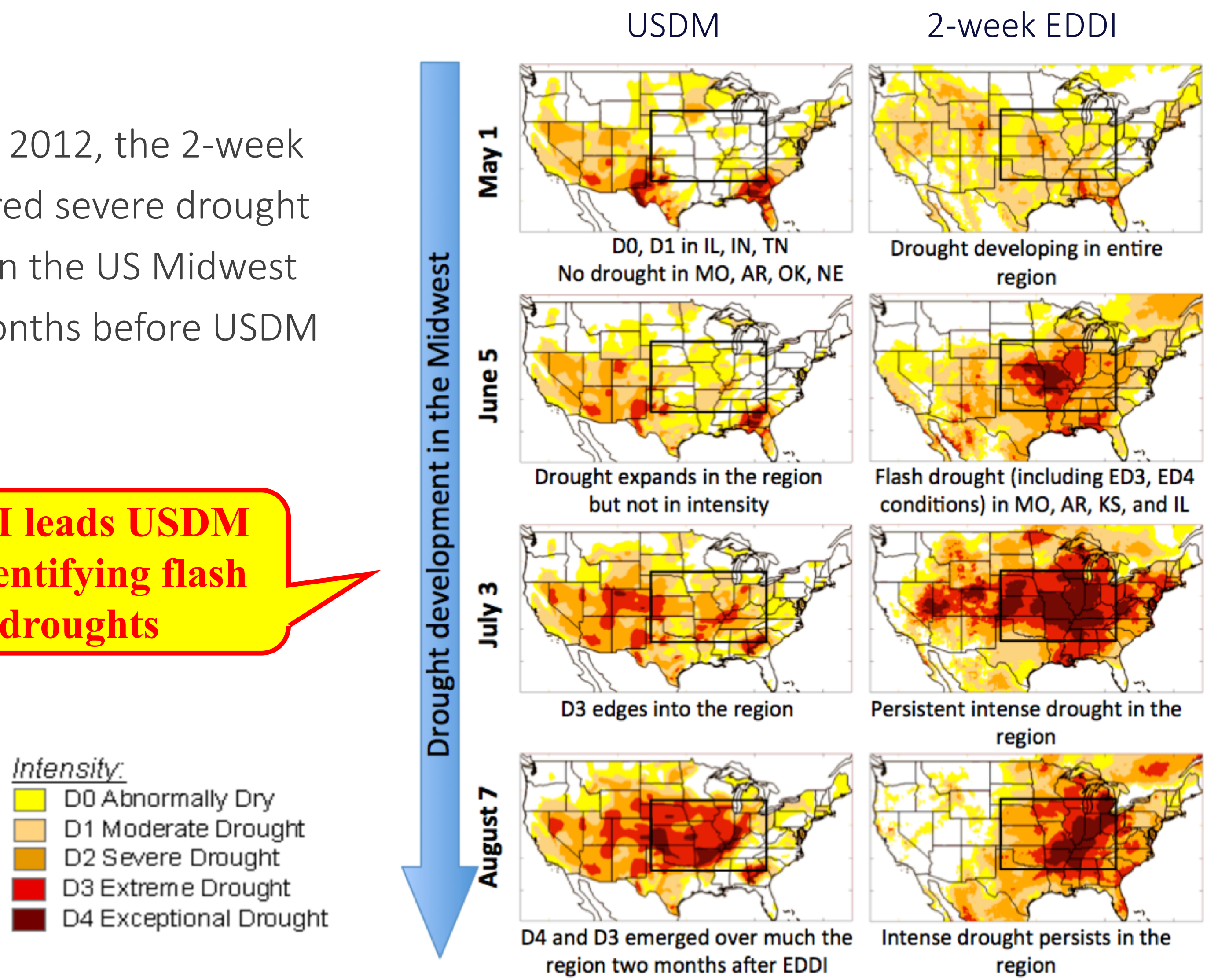
(> 3-month EDDI)

Application: EDDI as early warning of flash drought

2-week EDDI in the Midwest

In May-July, 2012, the 2-week EDDI captured severe drought conditions in the US Midwest up to ~2 months before USDM

EDDI leads USDM in identifying flash droughts



Application: EDDI in sector-specific monitoring

AGRICULTURAL DROUGHT
- soil moisture
- grazing health
- ET

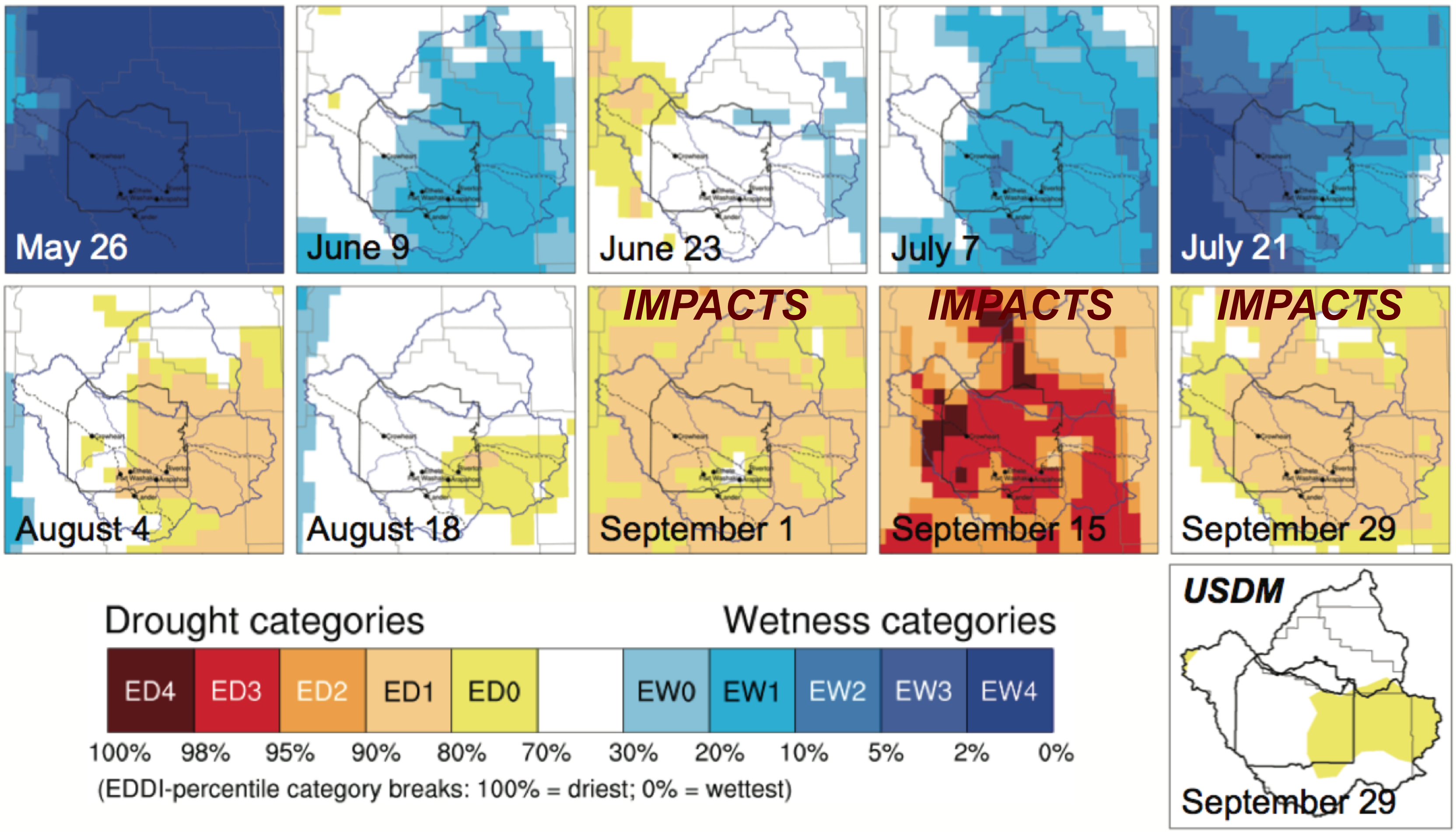
HYDROLOGIC DROUGHT
- streamflow
- snowfall

FIRE-RISK MONITORING
- weather
- fuel loads

ECOLOGICAL DROUGHT

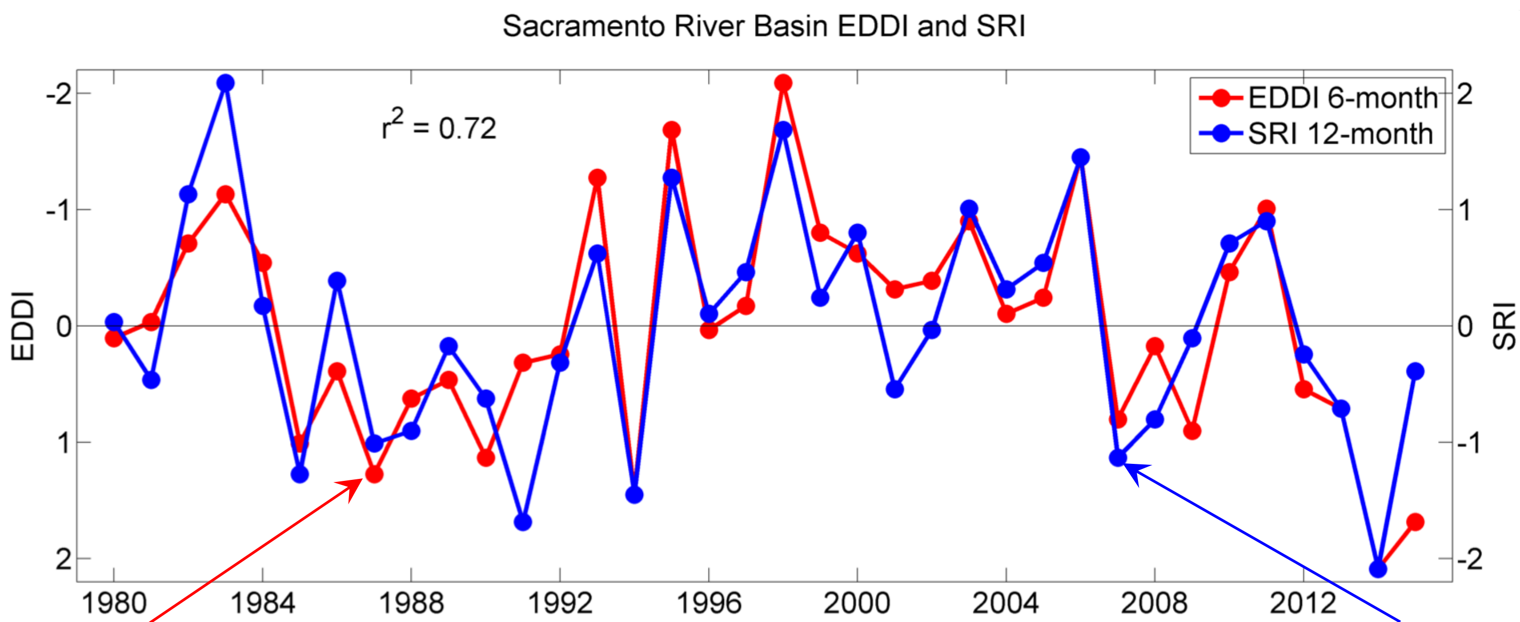
Application: Agricultural drought monitoring

2-week EDDI, 2015 growing season in Wind River IR, WY



Application: Hydrological drought prediction
6-month EDDI in Sacramento River Basin, CA

- Potential to improve late summer low flow streamflow predictions



6-month EDDI
(Nov-Apr)

12-month SRI
(Oct-Sep)

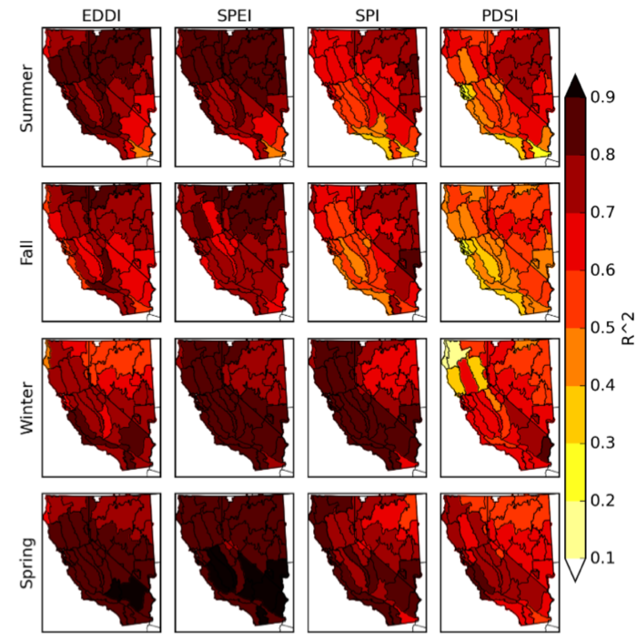
EDDI contains no *Prcp* information!

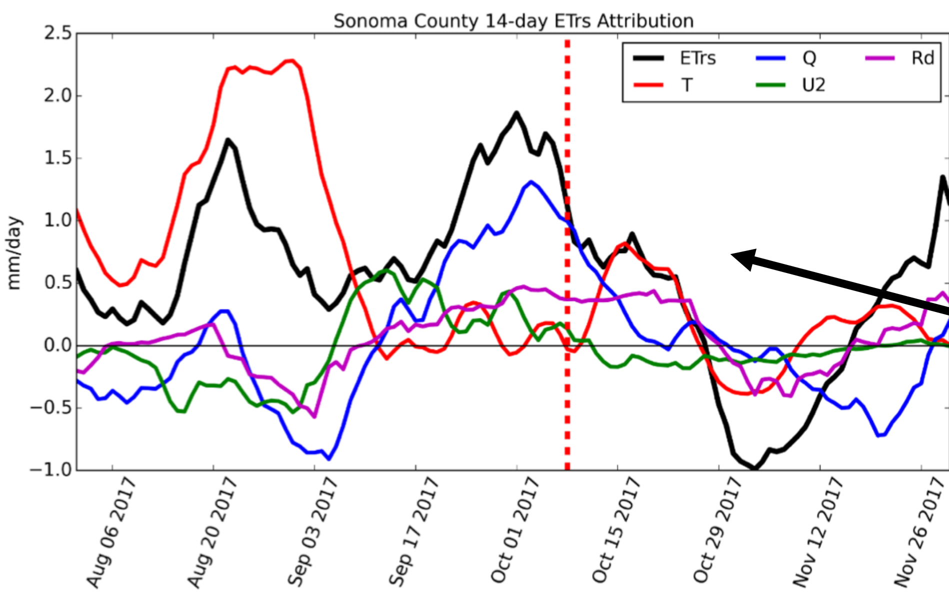
SRI = Standardized Runoff Index

Application: Wildfire risk management
12-month EDDI in Southern California

- NOAA Sectoral Applications Research Program (SARP) grant, 2016-2018
- How do drought indices relate to fire danger indices (different measures of fuel moisture)?
- Can EDDI provide early warning of wildfire risk?

Correlations to 1000-hour fuel moisture

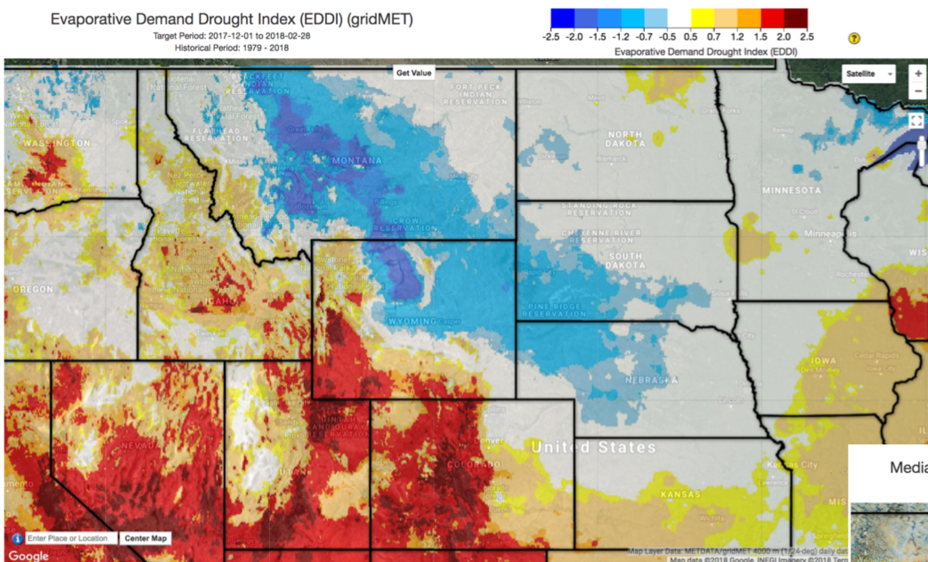


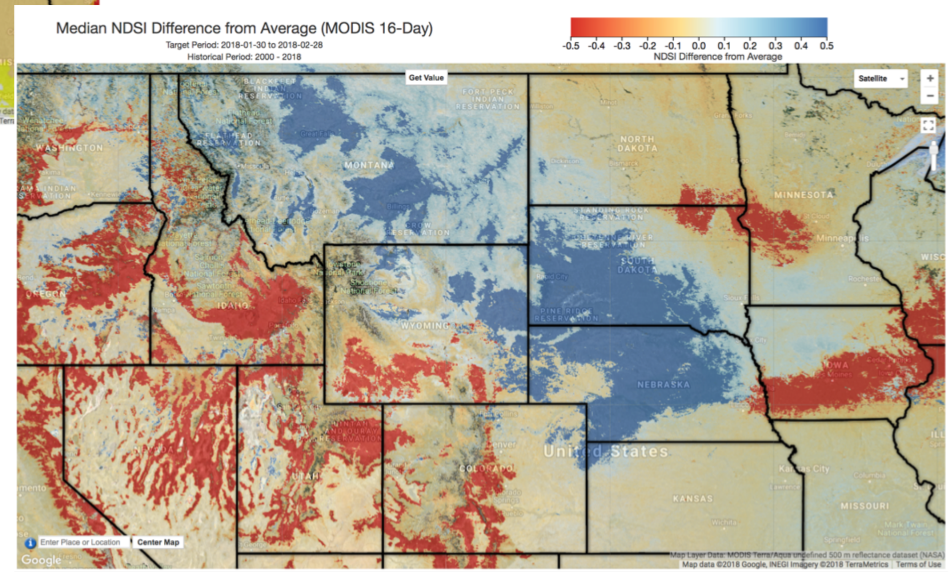


- Tubbs Fire, October, 2017
- EDDI decomposition indicates shift to humidity-driven E_0 spike

Application: Snow and snow drought
December – February, 2018

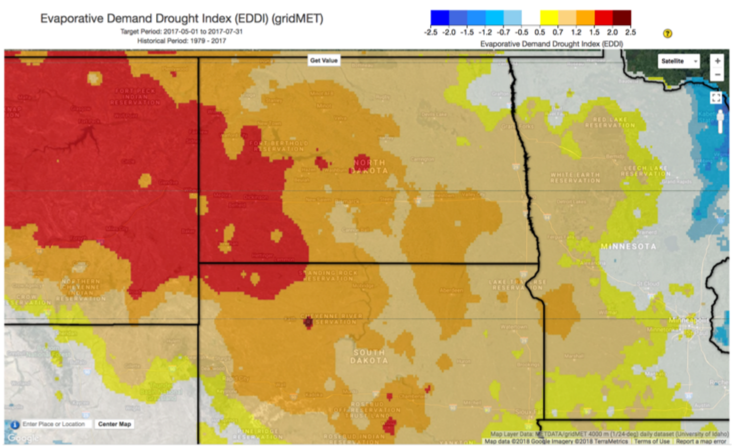
- EDDI is useful for evaluating snow and snow drought
- Snow drought can occur due to low *Prcp*, or average *Prcp* but rain vs. snow

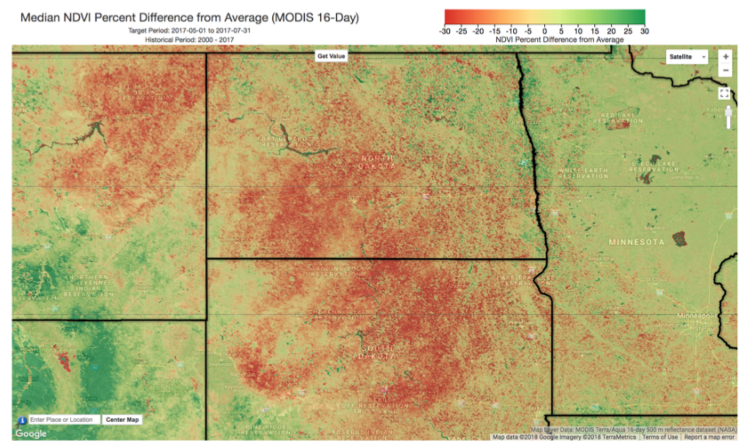


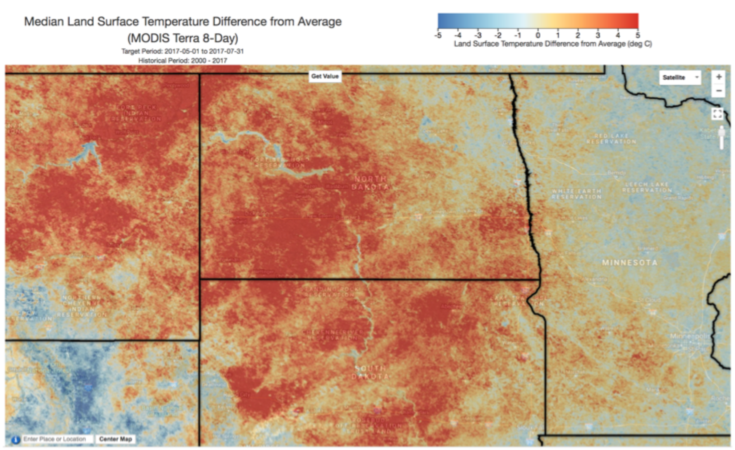


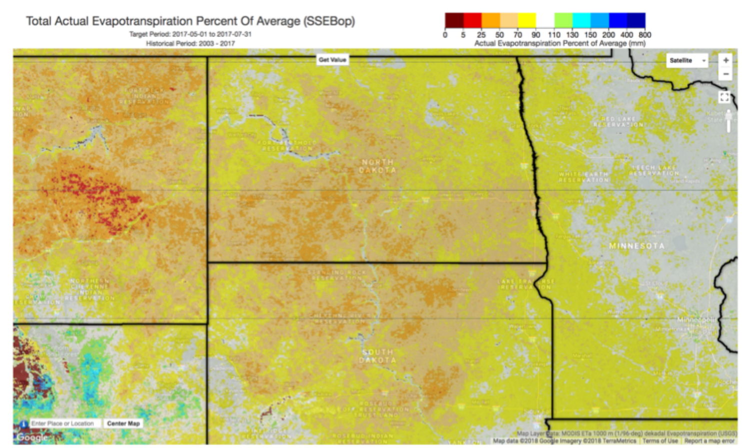
Application: Complementing remote sensing
May – July, 2017

- EDDI is useful for understanding remote sensing anomalies of land surface temperature, vegetation, and actual ET



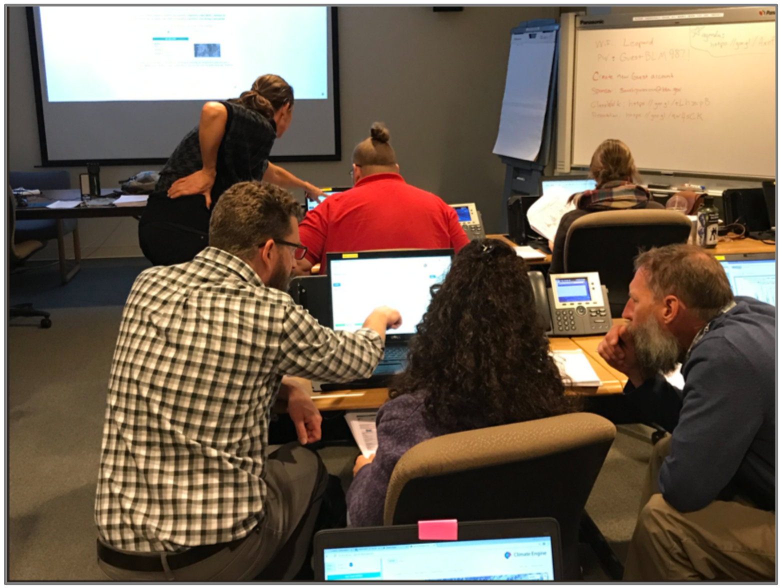


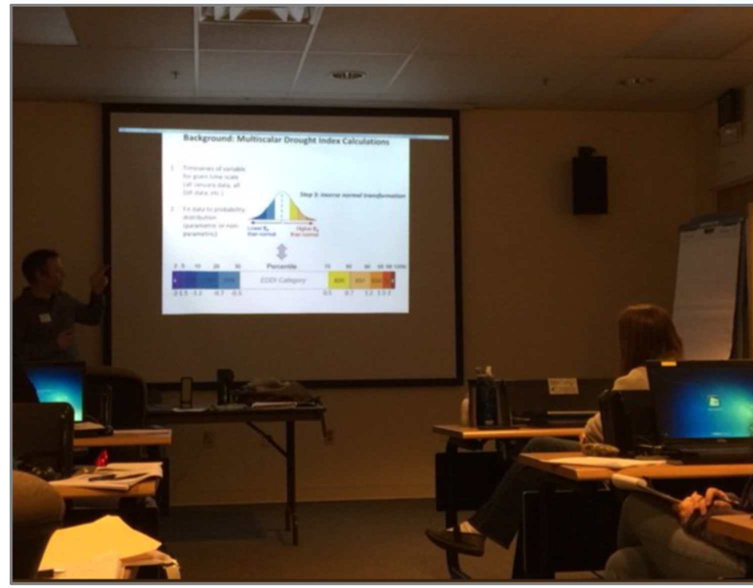




EDDI outreach: Hands-on training

- DRI partners conducting extensive EDDI hands-on training with state and federal agency scientists and managers in the western US





Nevada BLM State Office – March 8, 2018

Stakeholder engagement: Co-development of EDDI

Development

Current user group

Task 5.7

Design and implement questionnaire to current and regional stakeholders

TRL 5

Growing season 2016

Demonstration

Regional user group

Task 5.8

Obtain feedback from regional stakeholders

Task 6.2

Refine EDDI based on regional user feedback

TRL 6

2017

Deployment

National user group

Task 6.5

Obtain feedback from national stakeholders

Task 6.7

Refine EDDI based on national user feedback

TRL7

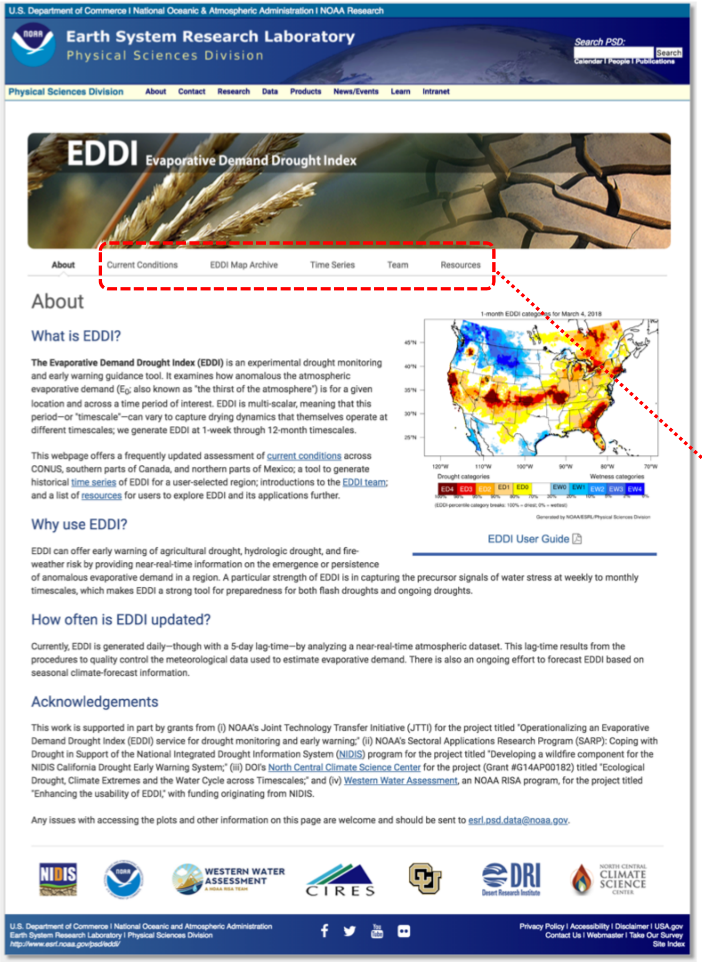
2018

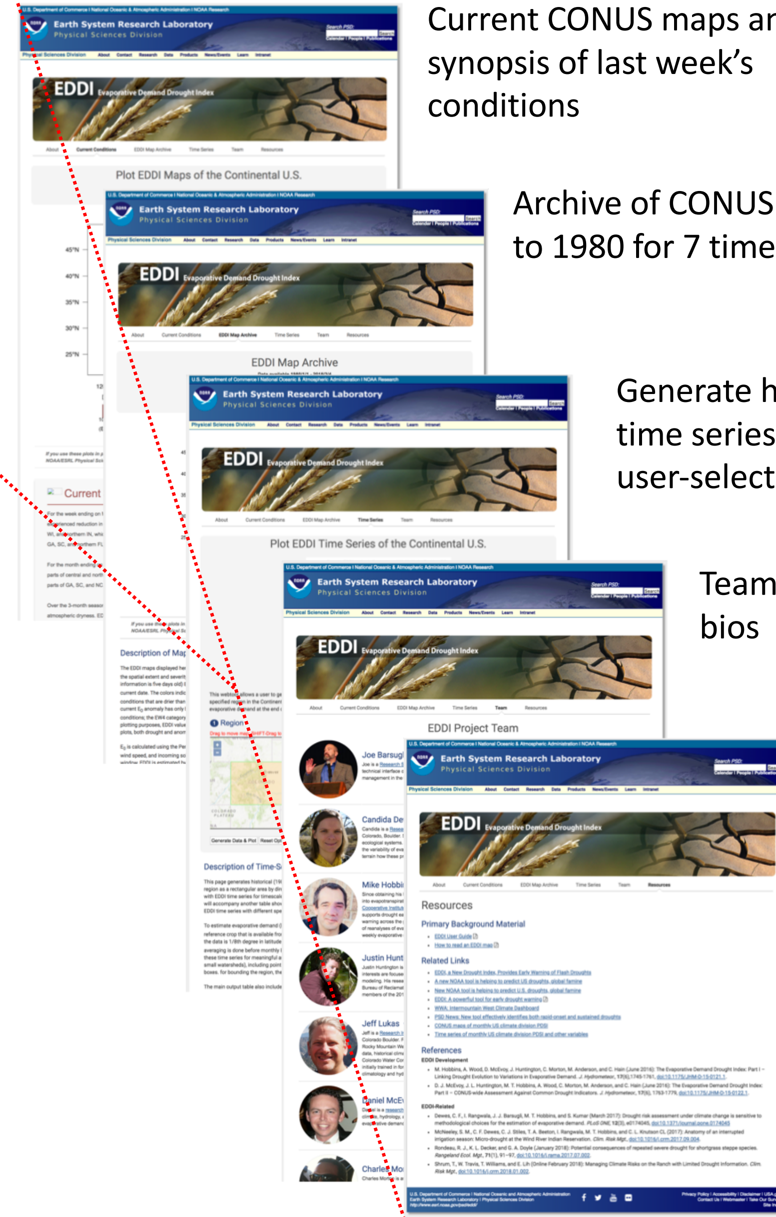
NWC NATIONAL WATER CENTER

Operational product by May 2019

- Stakeholder feedback incorporated into plan to transition EDDI to operational product.
- Feedback from current, regional, and national users is being used to refine final EDDI product.

New developments: EDDI website





Current CONUS maps and synopsis of last week's conditions

Archive of CONUS maps back to 1980 for 7 time scales

Generate historical (> 38-year) time series of EDDI values for user-selected rectangle

Team bios

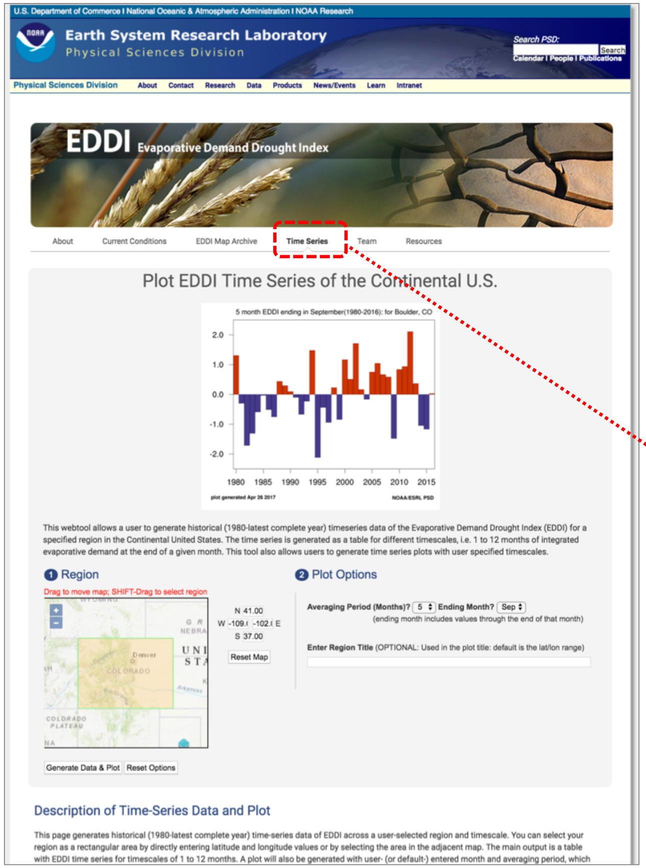
Resources:

- user guide
- papers
- related links

https://www.esrl.noaa.gov/psd/eddi/

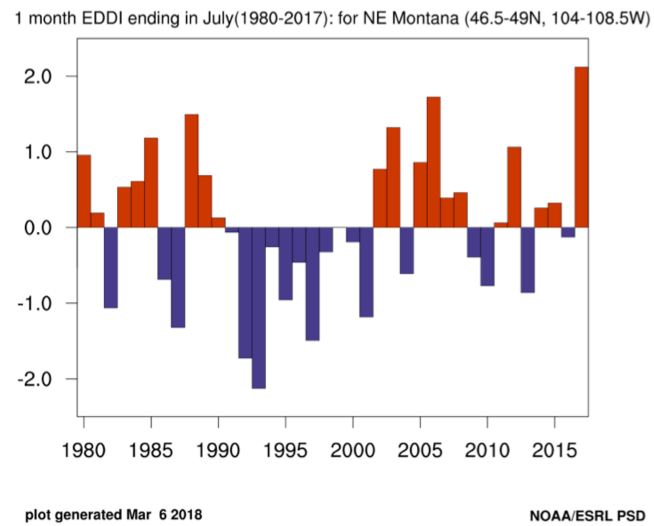
Search for "EDDI NOAA"

New developments: Historical EDDI time series

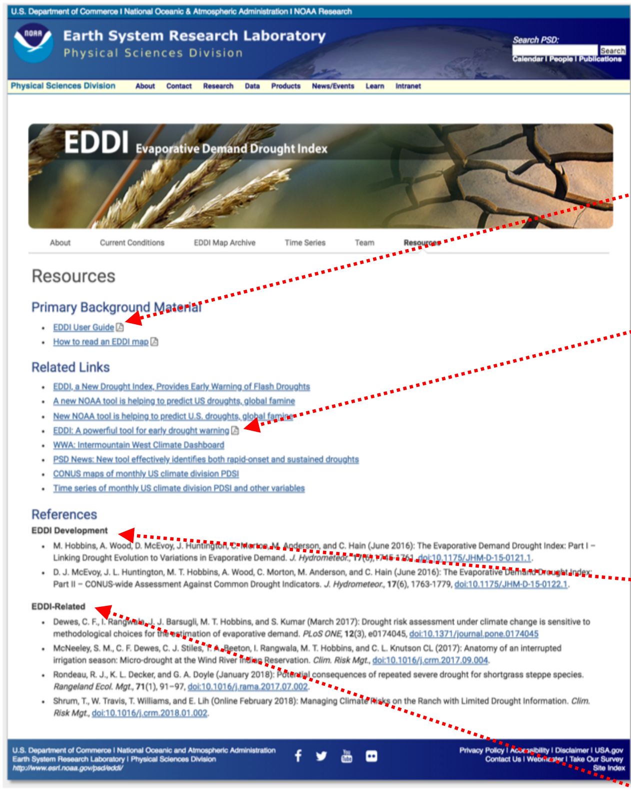


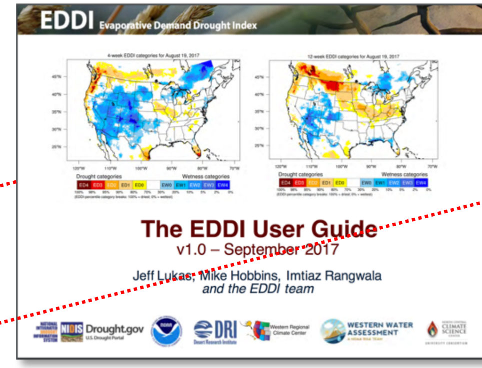
https://www.esrl.noaa.gov/psd/eddi/#timeseries

- Tool generates and plots historical EDDI time series for user-selected rectangle at 1- to 12-monthly time scales
- Time period: 1980-present
- Research into understanding past impacts
- Helpful for exploring relevant EDDI timescales for user-relevant impacts



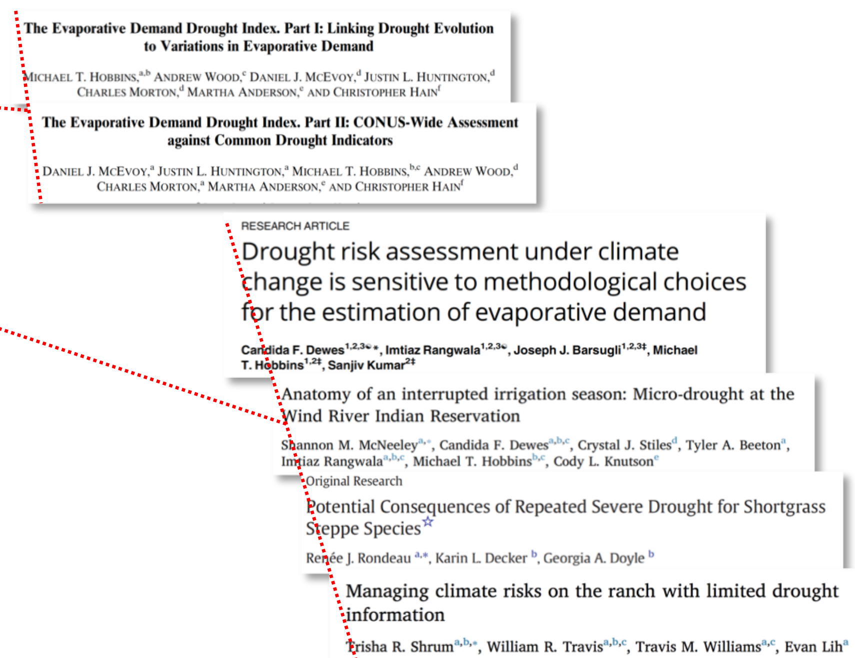
New developments: Resources and EDDI User Guide





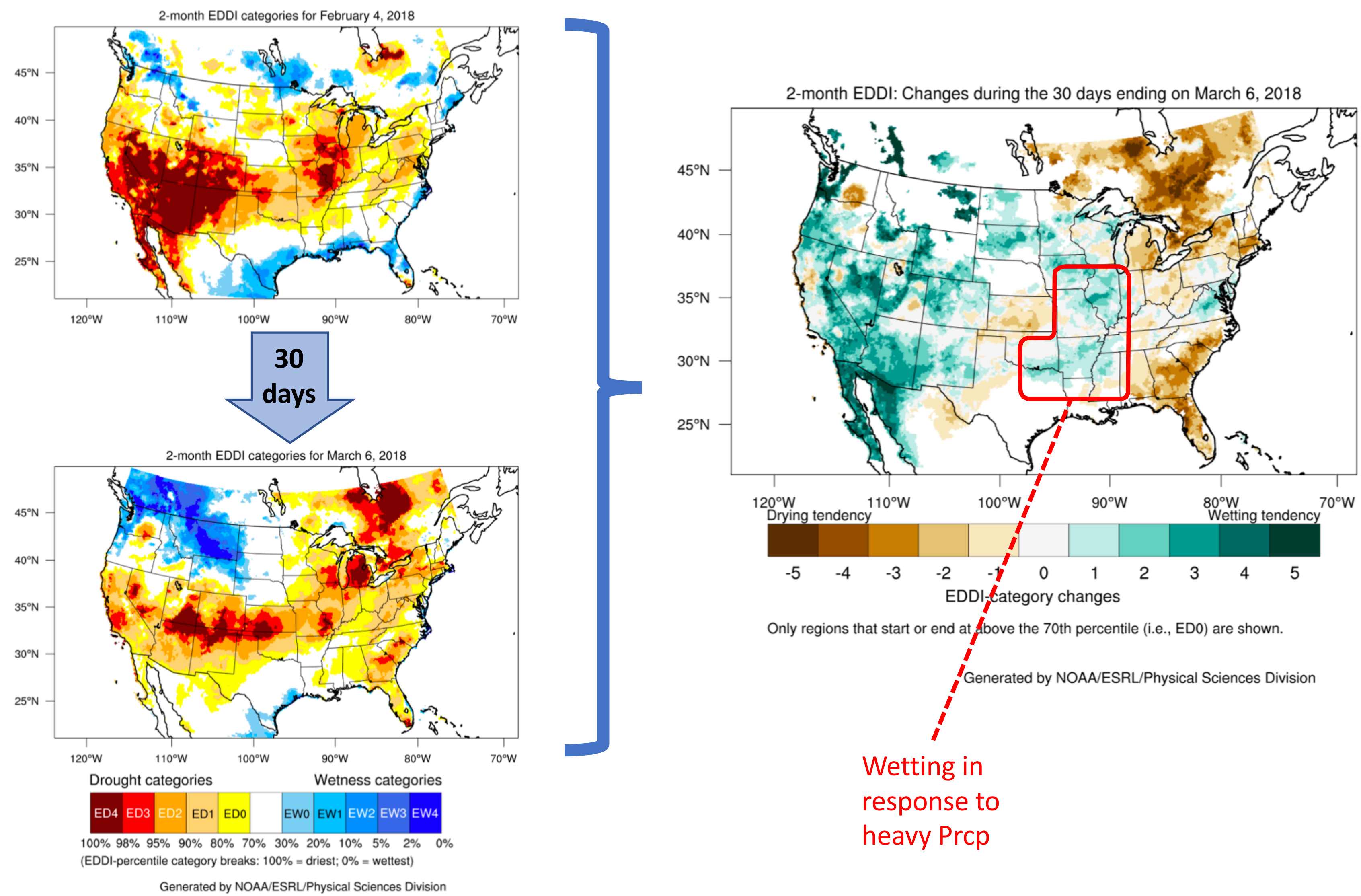
(*Lukas et al.*, WWA 2017)

(*Rangwala et al.*, NOAA 2015)

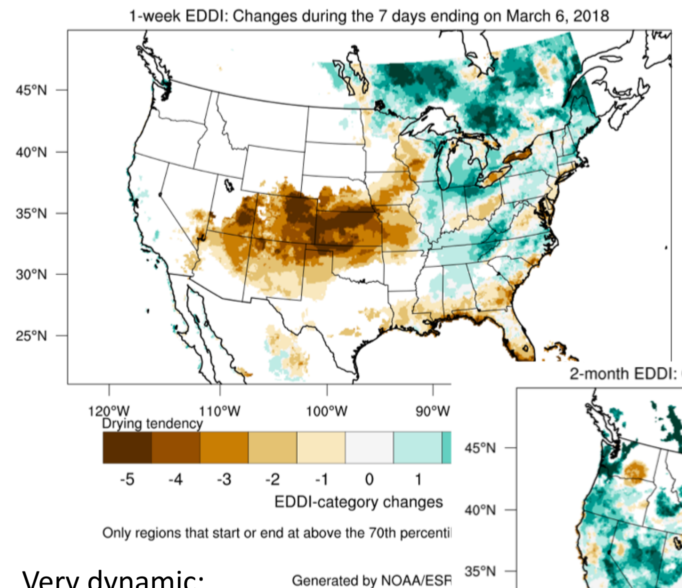


https://www.esrl.noaa.gov/psd/eddi/#resources

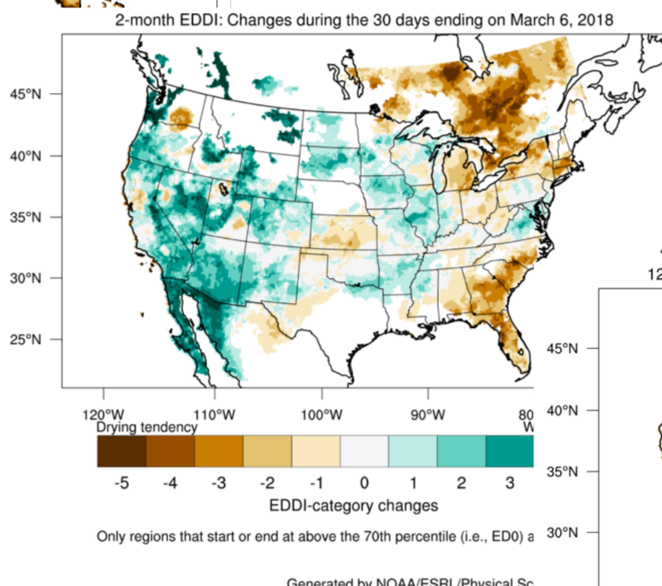
New developments: EDDI change maps



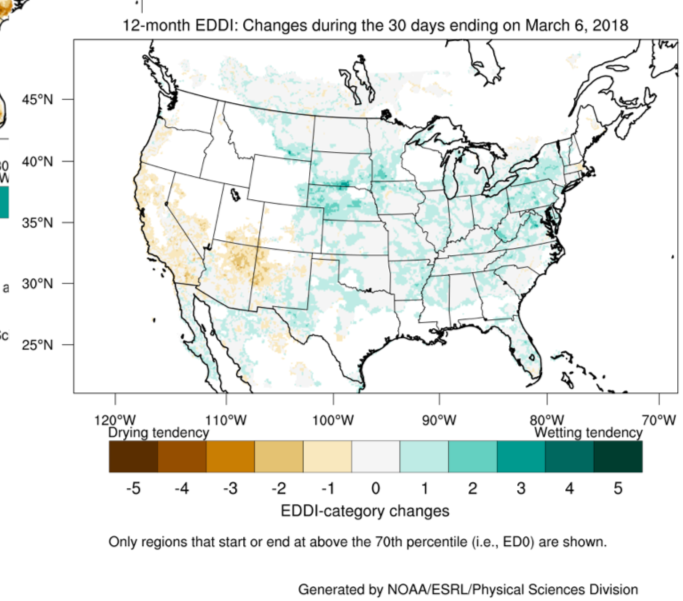
New developments: EDDI change maps



Very dynamic:
timescale = change interval



Long memory:
timescale = 12 x change interval



New developments: Attribution of drivers of drought

Diagnosing drought's demand side

$$E_0 = f\left(T, R_d, q, U_2\right), \text{ so}$$

$$\Delta E_0 = \frac{\partial E_0}{\partial T}\Delta T + \frac{\partial E_0}{\partial R_d}\Delta R_d + \frac{\partial E_0}{\partial q}\Delta q + \frac{\partial E_0}{\partial U_2}\Delta U_2$$

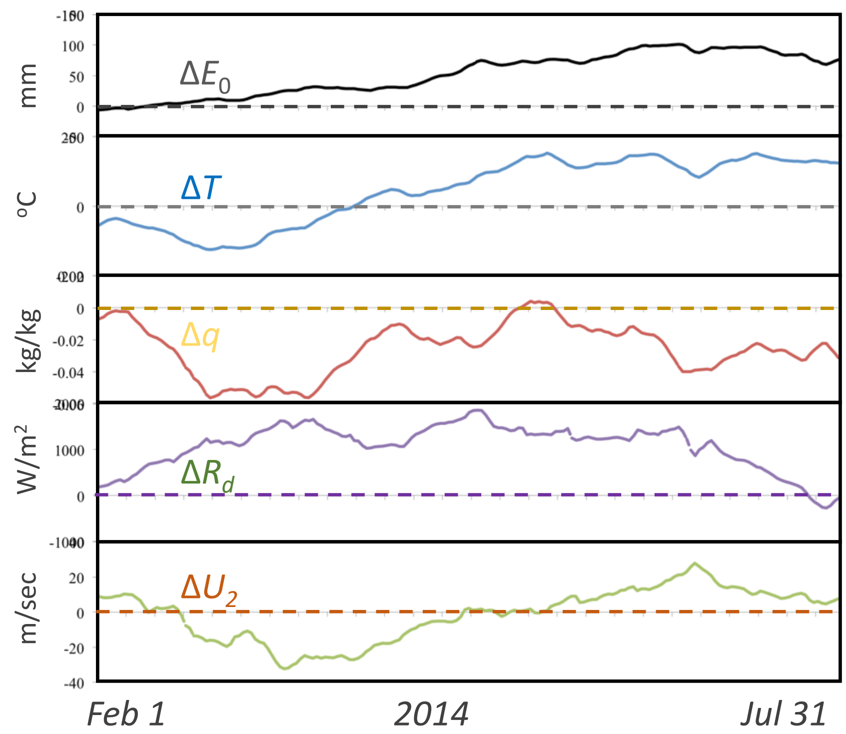
anomalies observed in reanalyses

derived analytically

E_0 changes due to changes in:

- T temperature
- R_d solar radiation
- q humidity
- U_2 wind speed

Sacramento River basin, CA, 2014



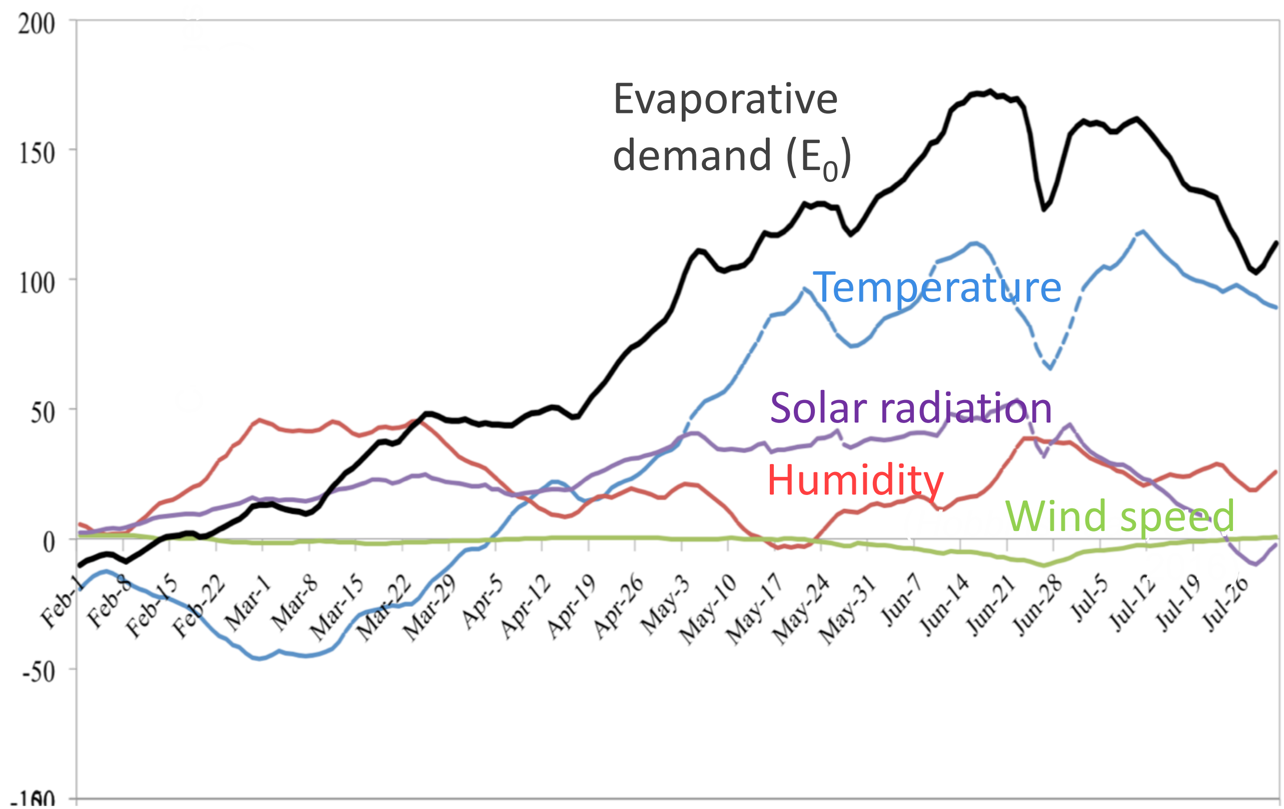
New developments: Attribution of drivers of drought

Diagnosing drought's demand side

E.g., drought intensification (rising E_0) forced by:

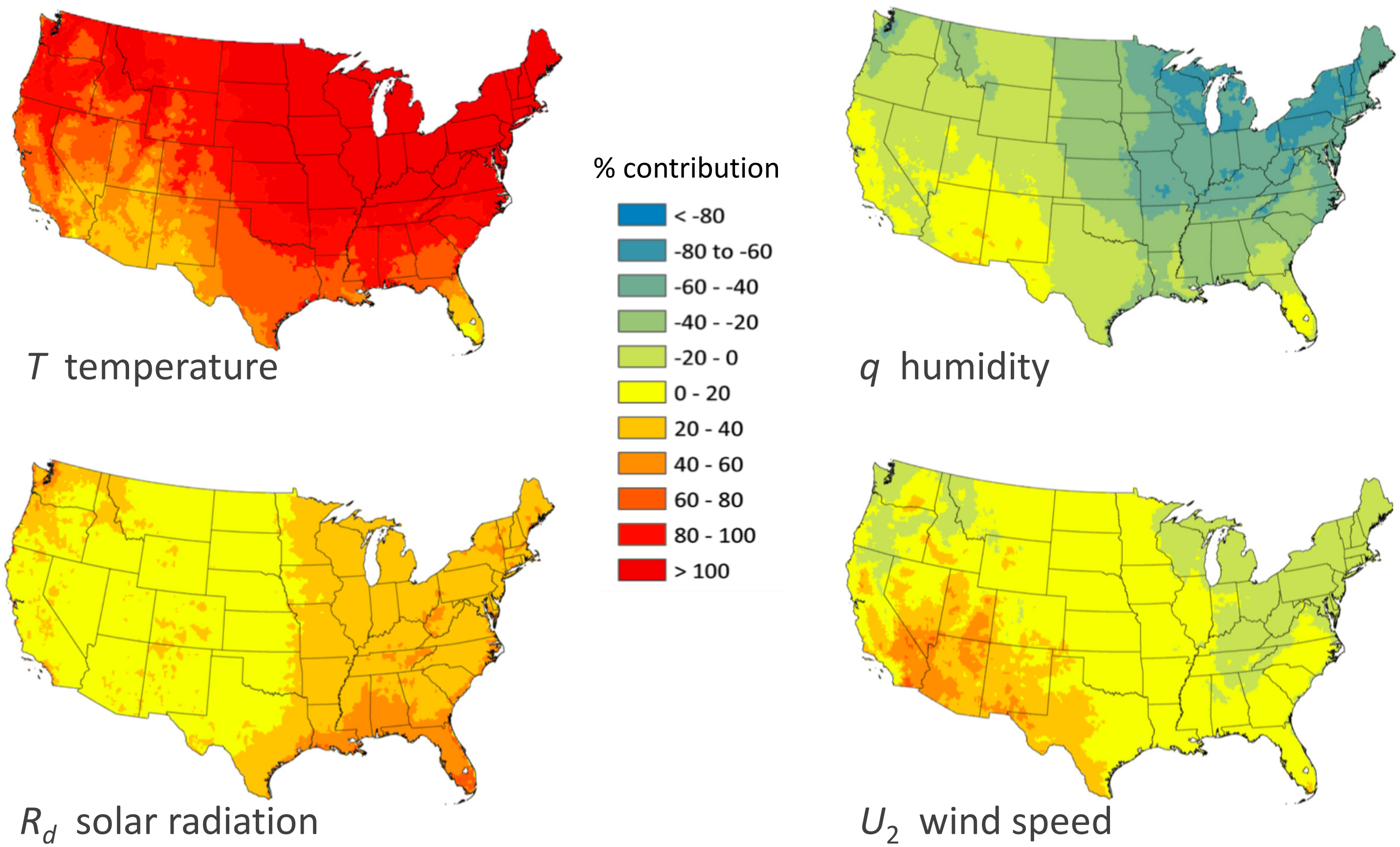
- First, below-normal *humidity*
- Then, increasing *temperature* and, to a lesser degree, *solar radiation*
- Little role played by *wind speed*

Sacramento River basin, CA



Under development: Attribution maps

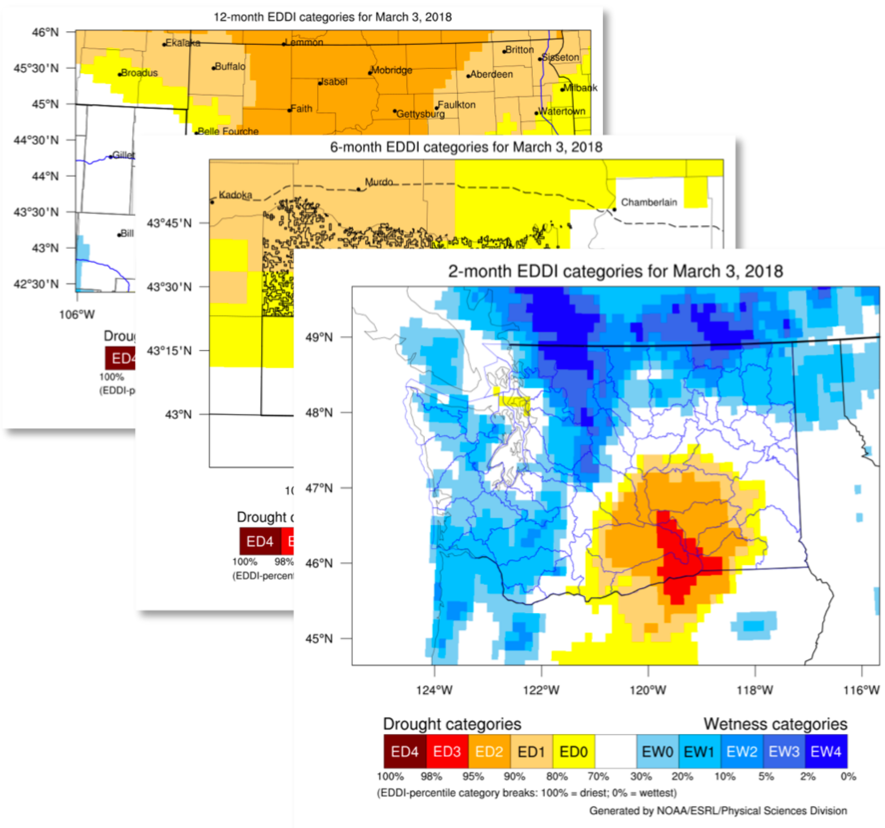
$$\Delta E_0 = \frac{\partial E_0}{\partial T}\Delta T + \frac{\partial E_0}{\partial R_d}\Delta R_d + \frac{\partial E_0}{\partial q}\Delta q + \frac{\partial E_0}{\partial U_2}\Delta U_2$$



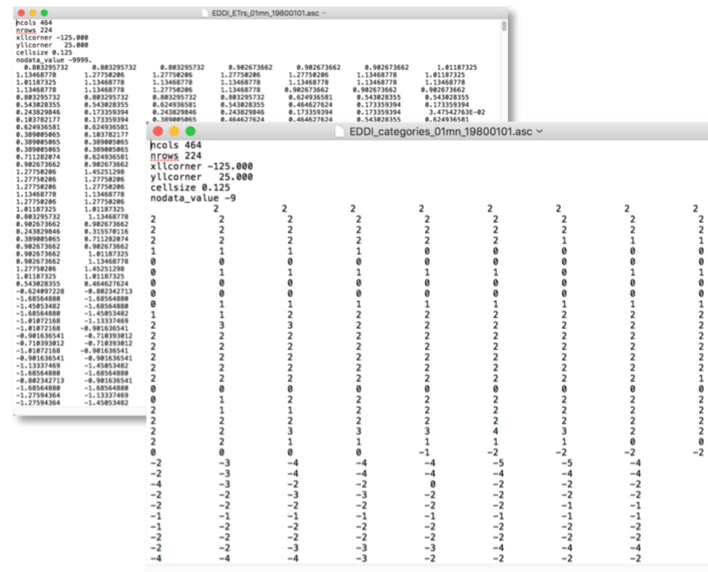
(conceptual maps only)

EDDI availability: Variety of customized formats

EDDI maps with user-provided context:
e.g., highways, towns, reservations, watersheds, rivers



Flat ascii grids of EDDI data:
e.g., raw EDDI values, EDDI drought / wetness categories



Call me, maybe: set-up only takes a few minutes.

EDDI availability: Variety of locations

Public ftp access from NOAA:

Daily updated EDDI data and/or maps, customized to users' regions and context

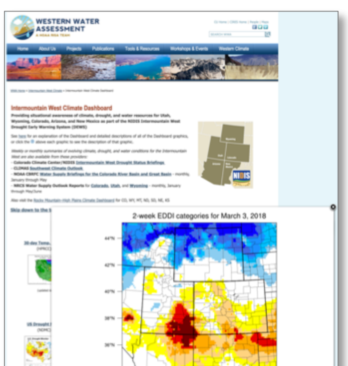
ftp://ftp.cdc.noaa.gov/Public/mhobbins/EDDI/

Entire EDDI history (1980-present) – CONUS-wide data and maps

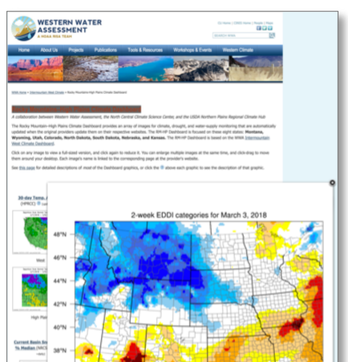
ftp://ftp.cdc.noaa.gov/Projects/EDDI/CONUS_archive/

Regional climate dashboards:
e.g., Western Water Assessment

Rocky Mountains-High Plains Climate Dashboard



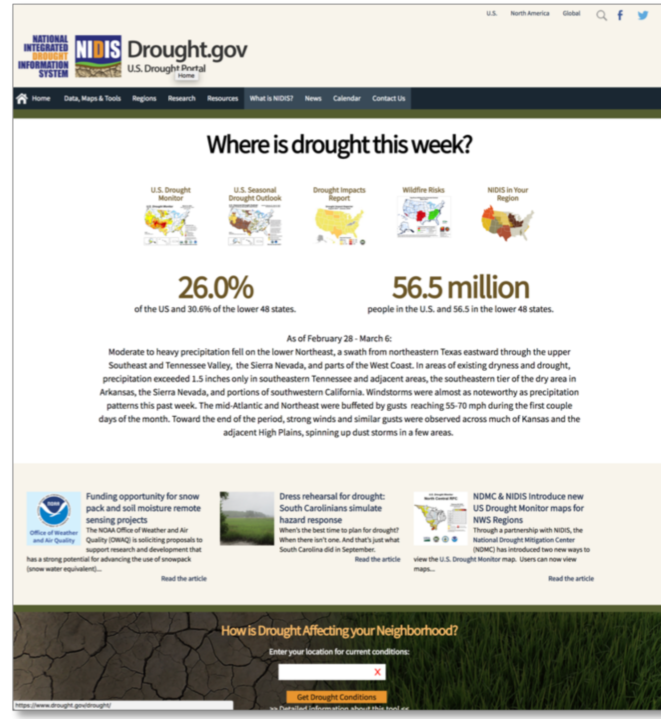
Intermountain West Climate Dashboard



http://wwa.colorado.edu/climate/dashboard2.html

http://wwa.colorado.edu/climate/dashboard.html

Coming soon: *US Drought Portal*



https://www.drought.gov/drought/

EDDI take-home messages

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https://www.esrl.noaa.gov/psd/eddi/
(or search “NOAA EDDI”)

- Works solely with evaporative demand
- Standardized index
- Near real-time: 5-day lag
- Medium-to-high resolution
- Works across different time and space scales
- Timescale may be optimized for:
  - early warning relative to other monitors
  - demands specific to hydroclimates and sectors
- Effective for early warning and real-time monitoring:
  - agricultural drought, hydrologic drought, wildfire risk
- Drought can be attributed to meteorological drivers
- Complete (> 38 years) history available via ftp and website
- EDDI maps/data delivery can be customized
- **Fully operational at National Water Center by May 2019**