



The Evaporative Demand Drought Index (EDDI): early warning and monitoring of drought from the demand side

Mike Hobbins^{1,2}, Joe Barsugli^{1,2}, Candida Dewes^{1,2}, Justin Huntington³,
Jeff Lukas^{2,4}, Daniel McEvoy³, Charles Morton³, Imtiaz Rangwala^{1,2},
Andrea Ray¹, Cathy Smith^{1,2}, Andy Wood⁵, & Heather Yocum^{1,2,4}

1. NOAA/ESRL Physical Sciences Division
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 (JTII)
- 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).

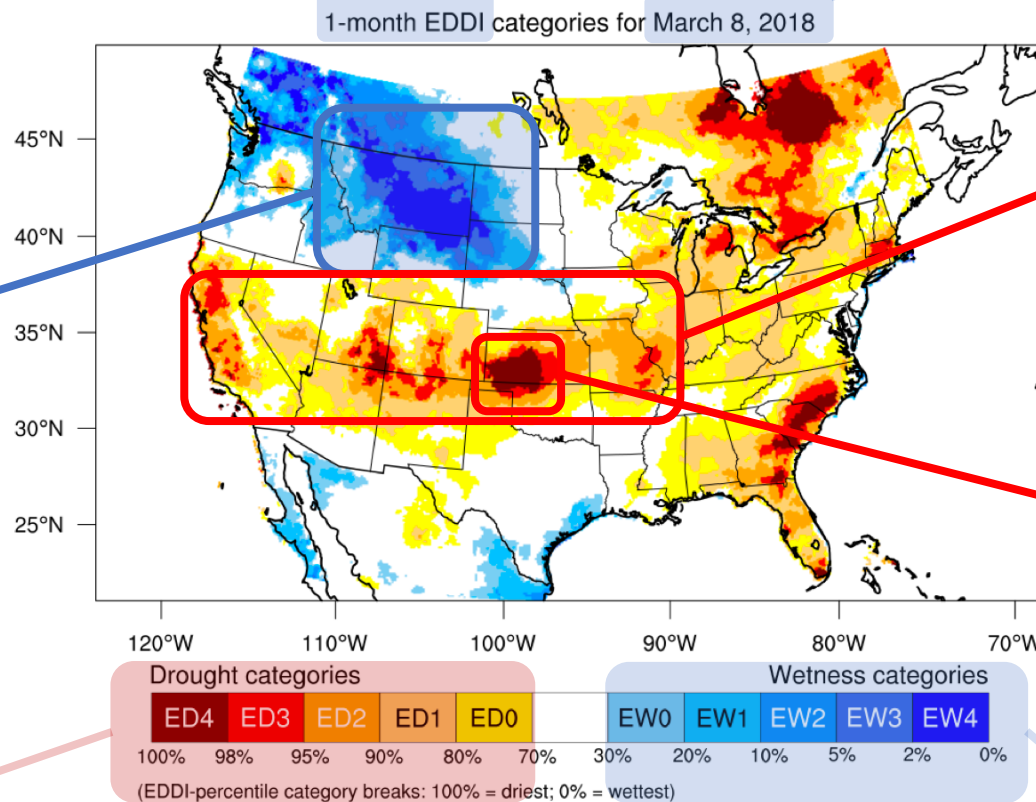
There are 24 time scales: 1-12 weeks, 1-12 months.

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.

Generated by NOAA/ESRL/Physical Sciences Division

Background: Relevance of E_0 to drought

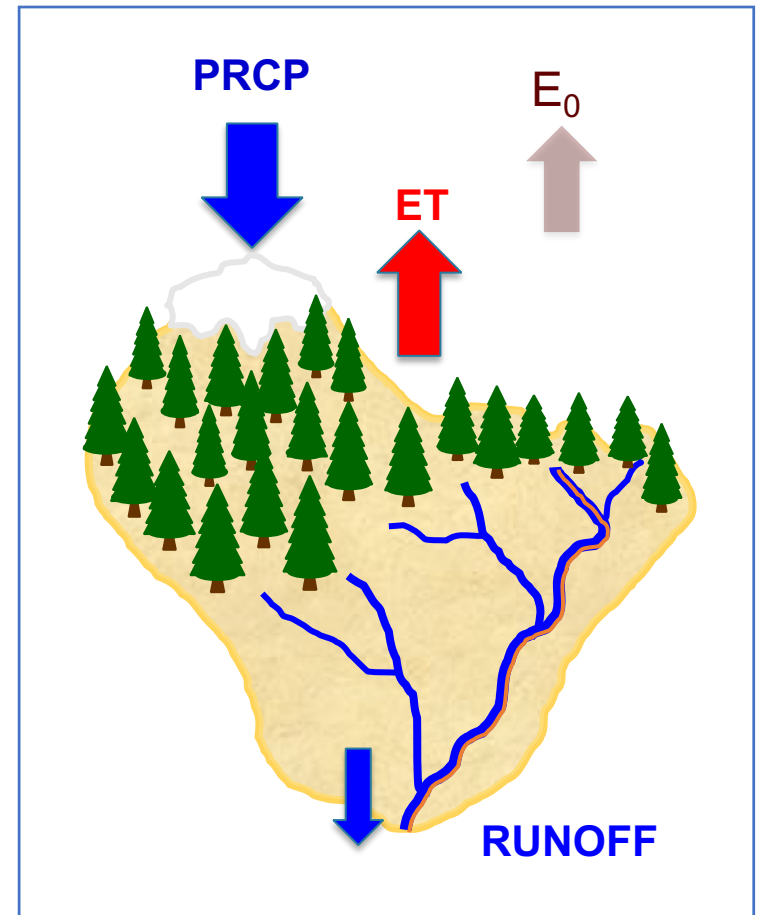
Water balance on a land surface:

$$\sim f(\text{Prctp}, \text{ET})$$

where ET is driven by:

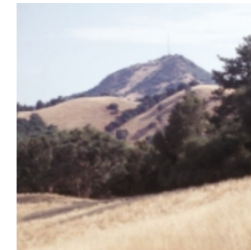
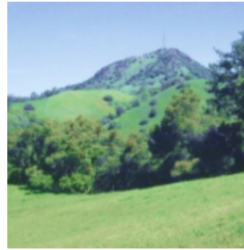
- evaporative demand (E_0),
- surface moisture status.

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



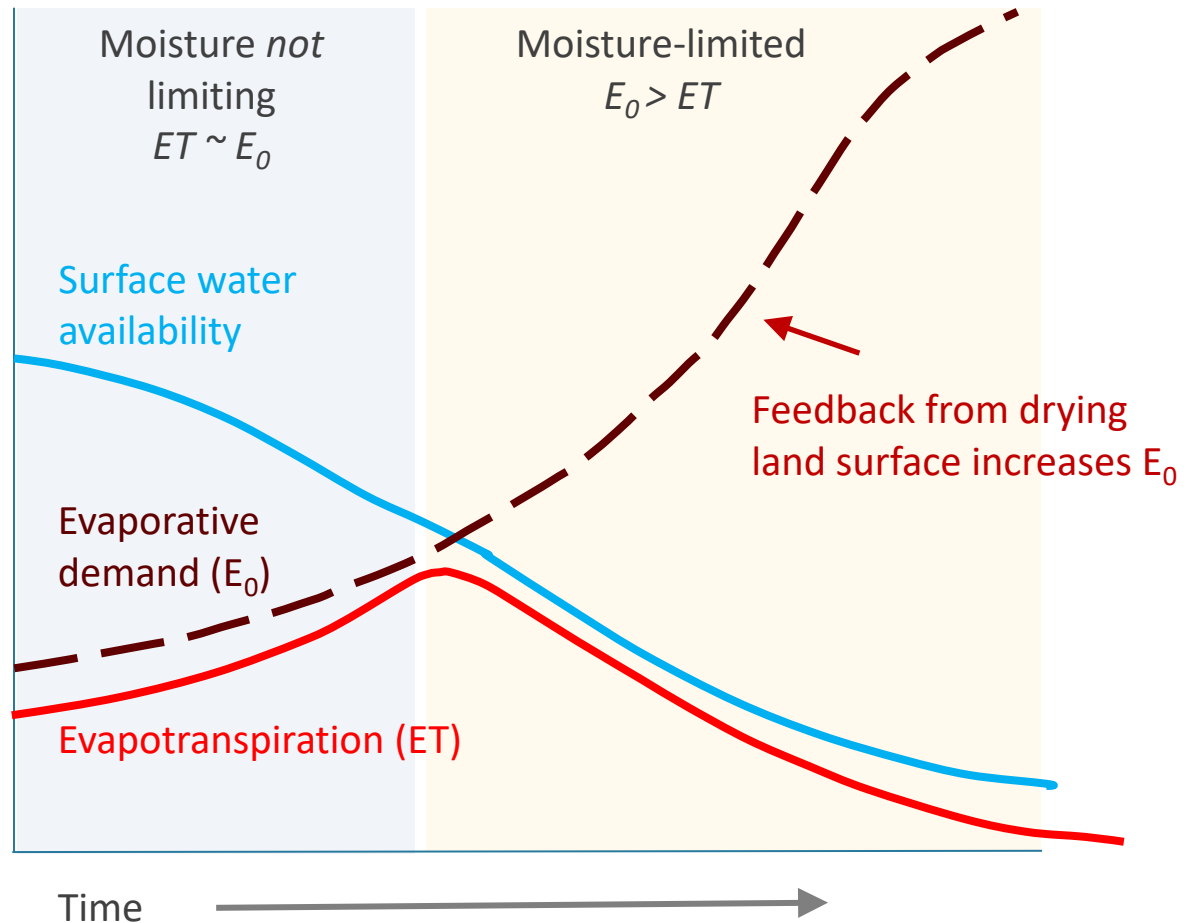
Background: Relevance of E_0 to drought

Relationship between E_0 and ET changes as land surface dries out



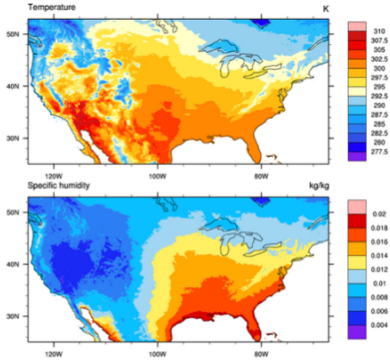
- When surface moisture is sufficient, rising E_0 leads to rising ET
- When moisture is limited, ET declines, while E_0 rises even more steeply

Evaporative demand rises in all forms of drought.



Background: How is EDDI calculated?

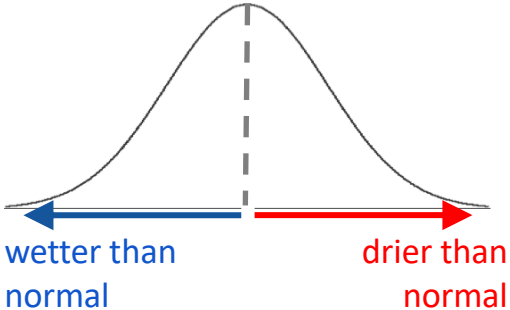
Meteorological Inputs
temperature, humidity, wind speed, solar radiation
NLDAS-2, 12-km gridded, daily



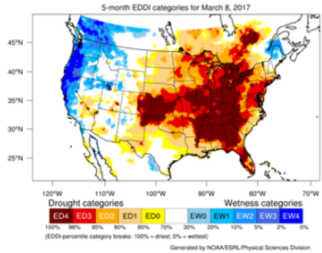
Reference Evapotranspiration calculation
Penman-Monteith FAO56

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

Rank-based non-parametric standardization
based on historic climatology of ET_0

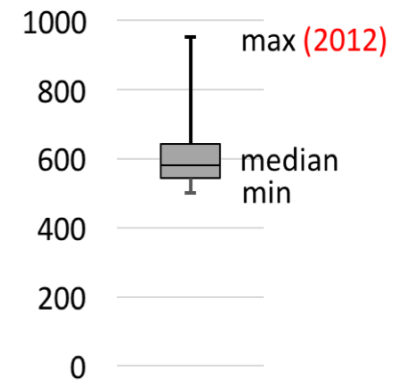
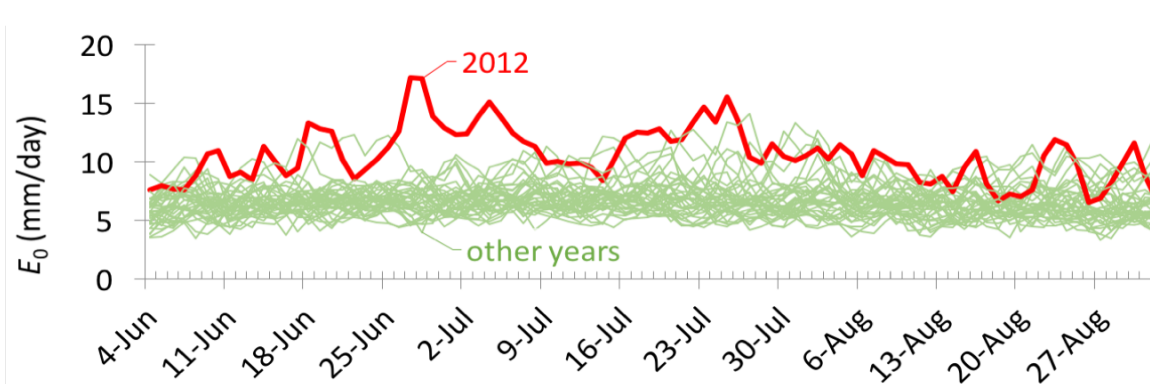
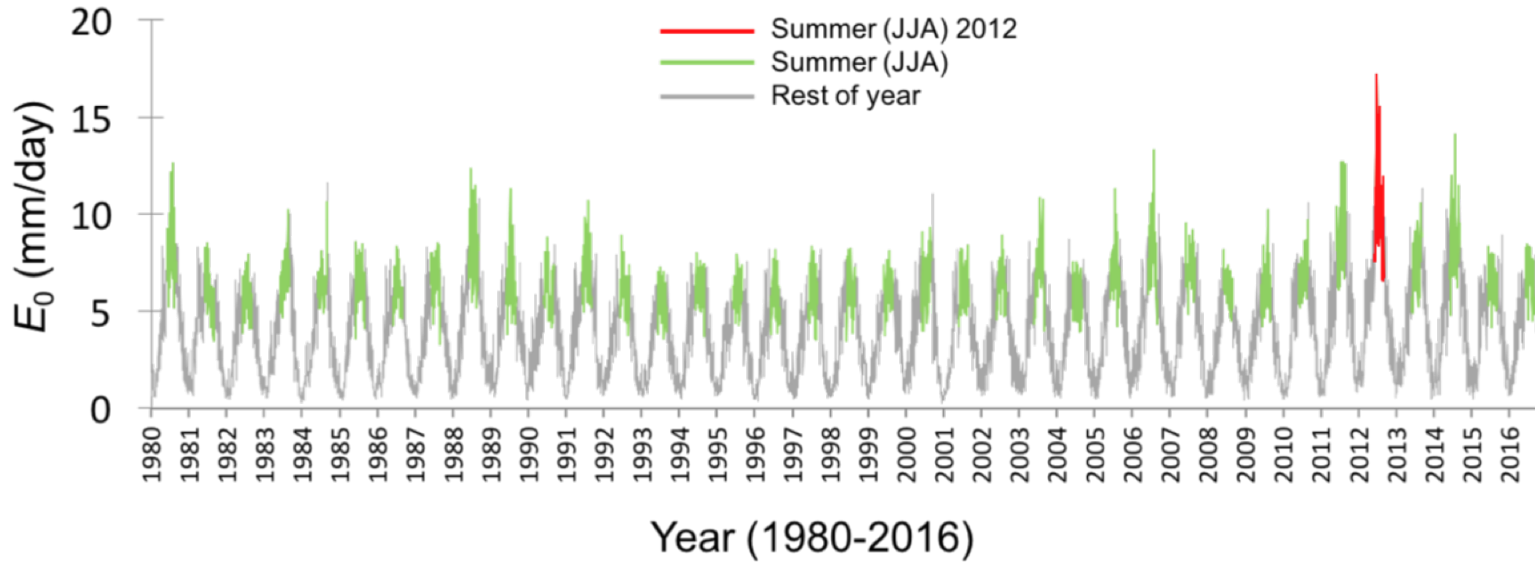


EDDI



Background: Calculating EDDI

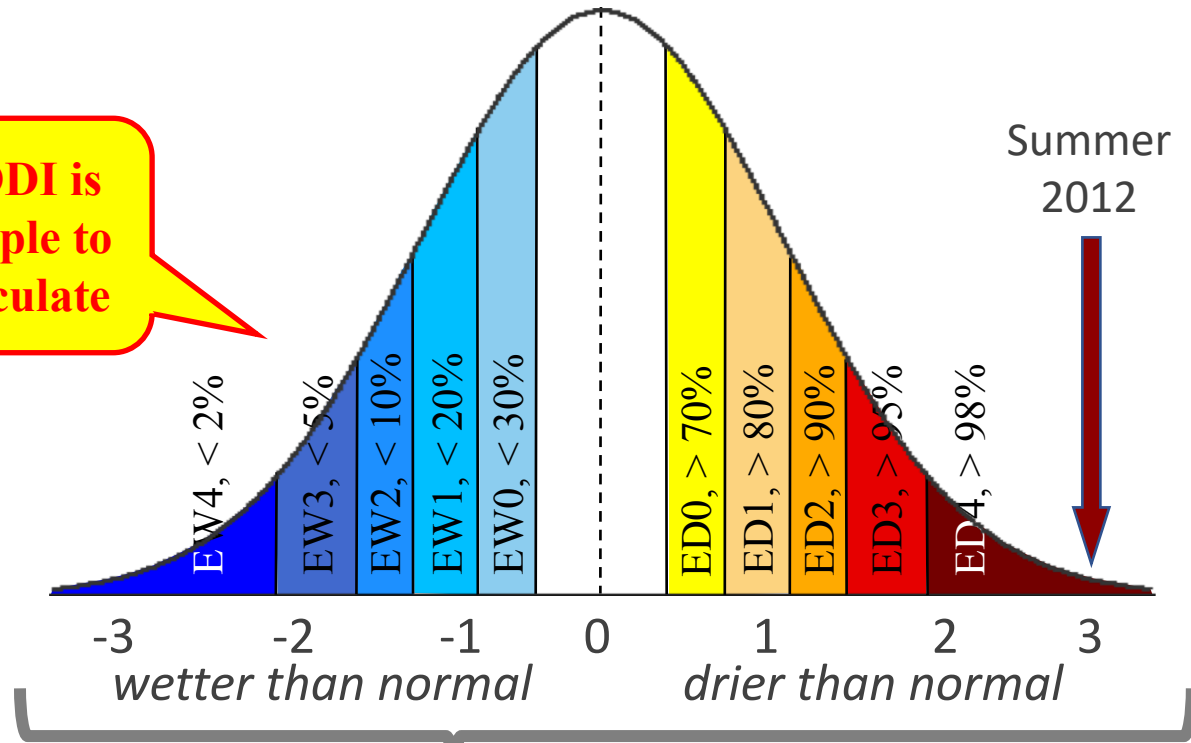
E.g., deriving 3-month EDDI on August 31, 2012, Midwest



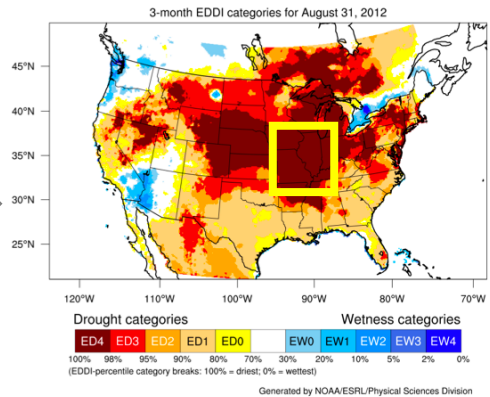
Background: Calculating EDDI

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

EDDI is simple to calculate



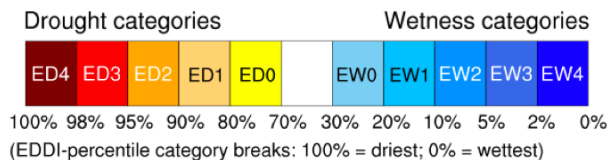
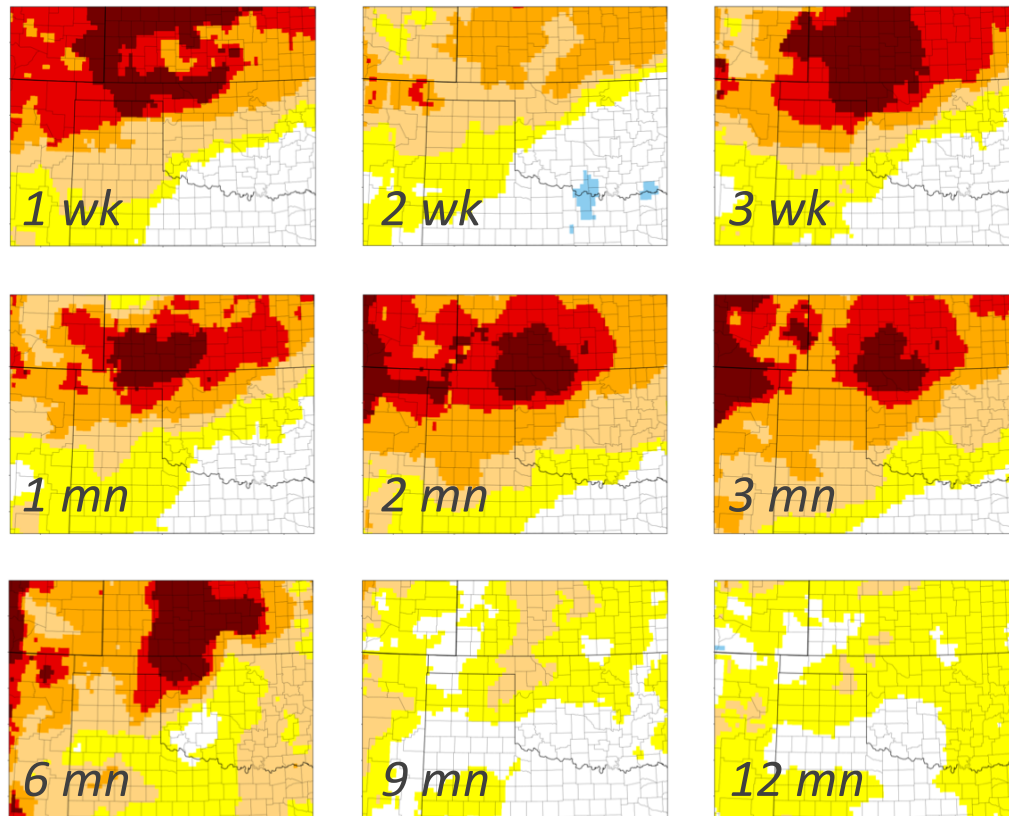
mapping



Background: Multi-scalar drought monitor

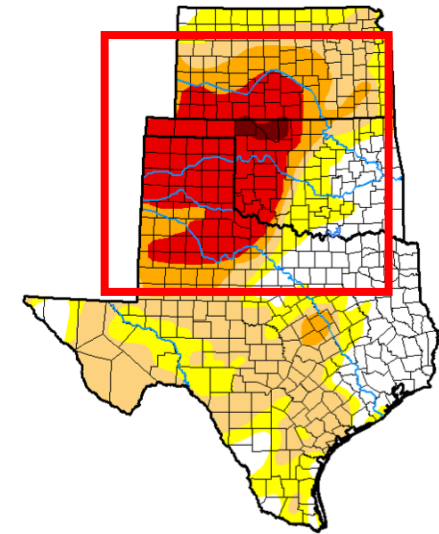
March 6, 2018

EDDI



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US Drought Monitor



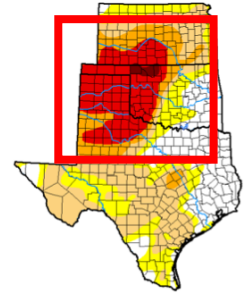
**EDDI is available
at 24 timescales:**

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

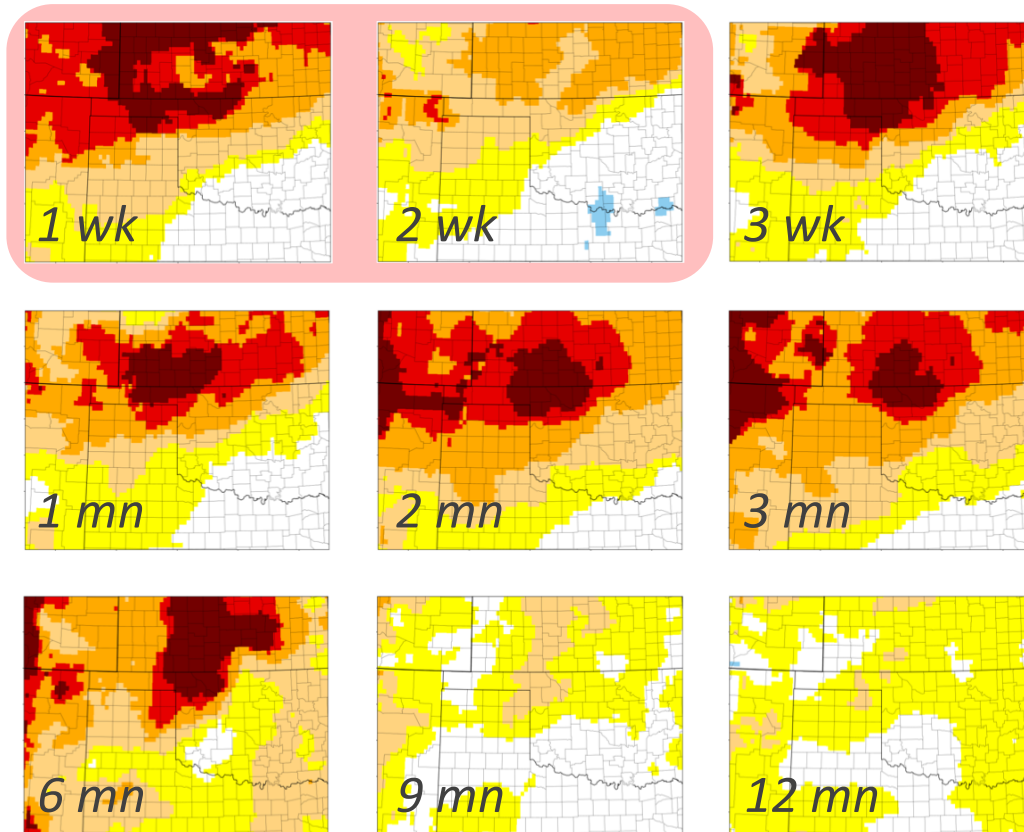
Background: Multi-scalar drought monitor

March 6, 2018

EDDI

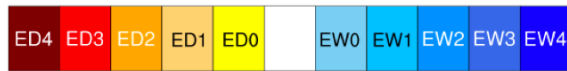


Flash drought potential (1- to 3-week EDDI)



Drought categories

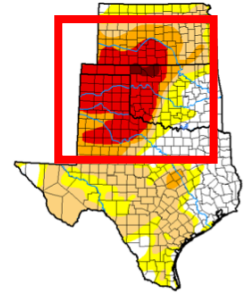
Wetness categories



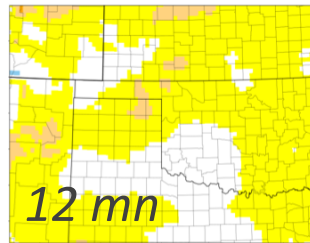
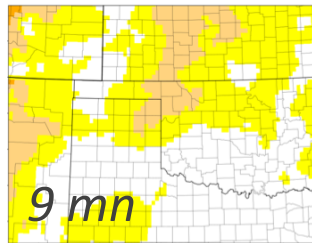
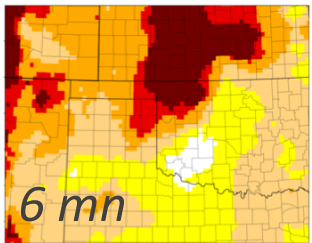
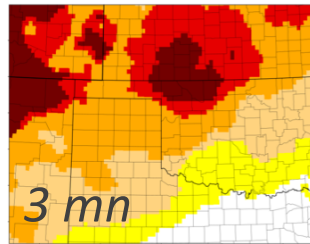
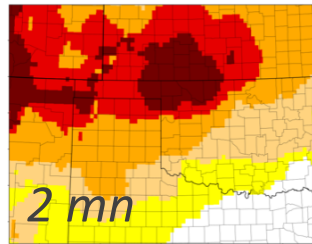
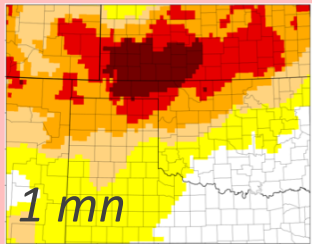
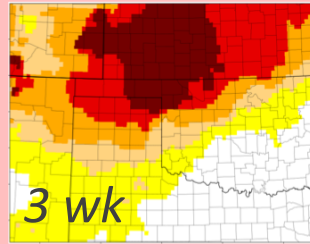
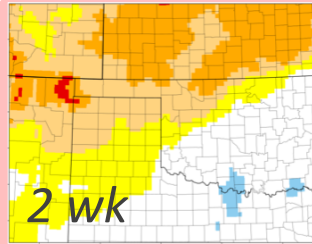
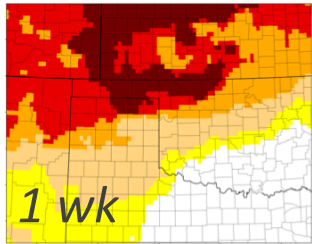
100% 98% 95% 90% 80% 70% 30% 20% 10% 5% 2% 0%
(EDDI-percentile category breaks: 100% = driest; 0% = wettest)

Background: Multi-scalar drought monitor

March 6, 2018



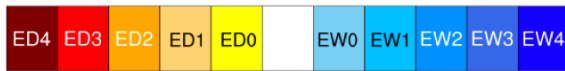
EDDI



Emerging conditions
(that *could* lead to drought)
(2-week to 1-month EDDI)

Drought categories

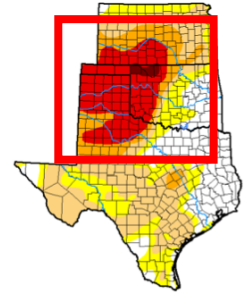
Wetness categories



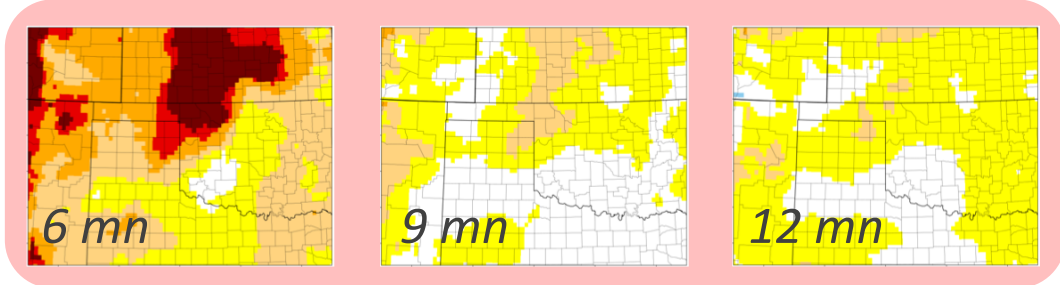
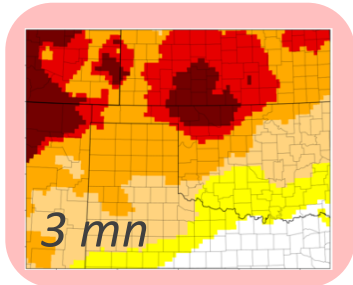
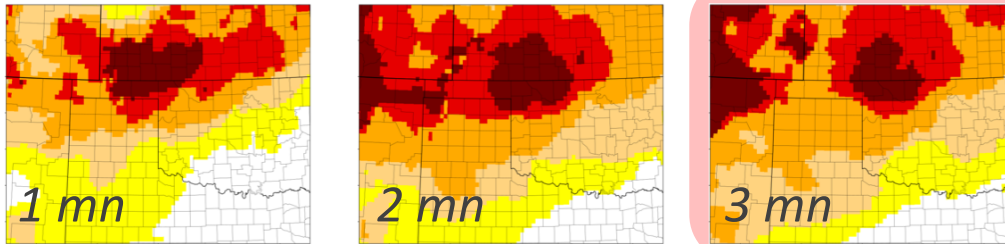
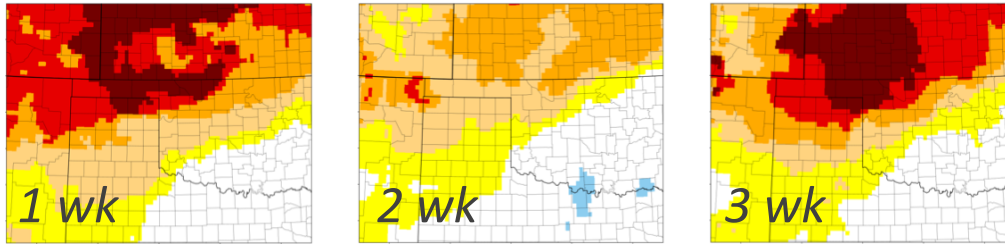
100% 98% 95% 90% 80% 70% 30% 20% 10% 5% 2% 0%
(EDDI-percentile category breaks: 100% = driest; 0% = wettest)

Background: Multi-scalar drought monitor

March 6, 2018



EDDI



Persistent drought conditions
(> 3-month EDDI)



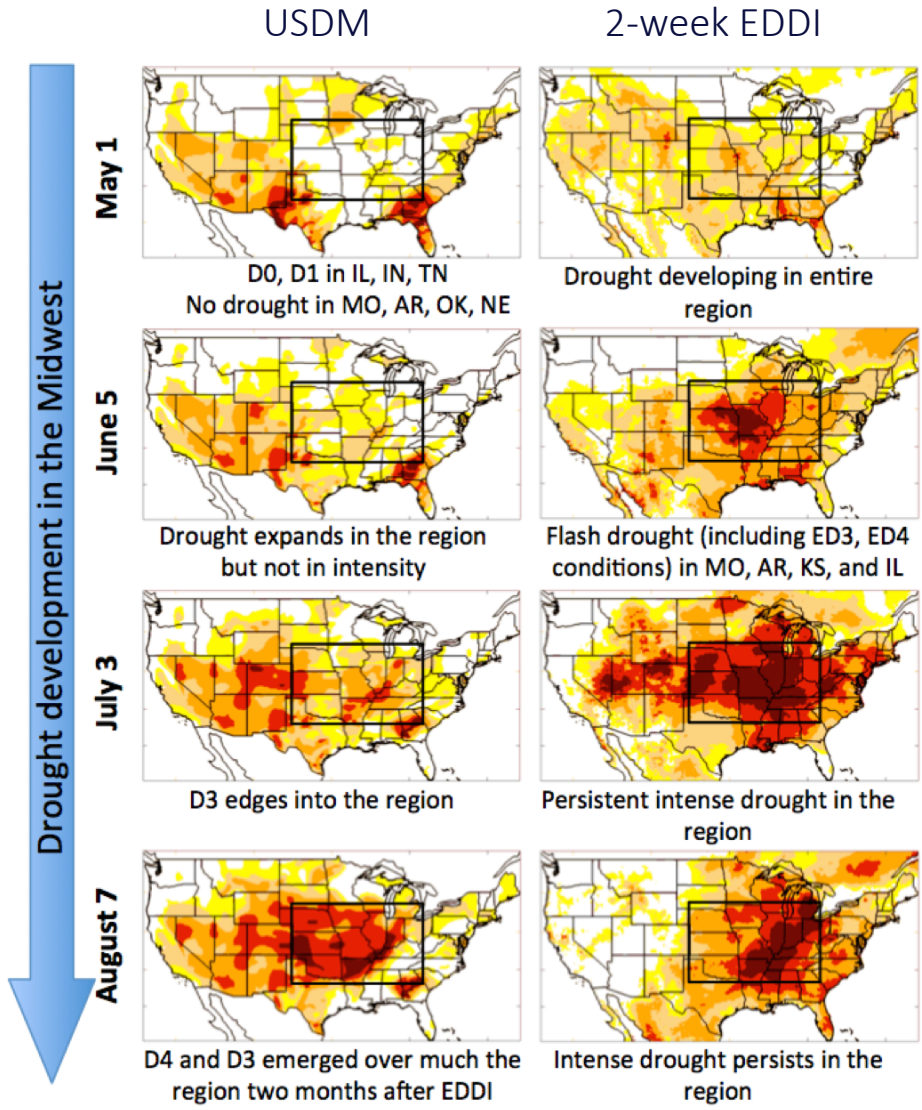
Application: EDDI as early warning of flash drought

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

- Intensity:
- D0 Abnormally Dry
 - D1 Moderate Drought
 - D2 Severe Drought
 - D3 Extreme Drought
 - D4 Exceptional Drought



Application: EDDI in sector-specific monitoring



AGRICULTURAL
DROUGHT

- soil moisture
- grazing health
- ET

HYDROLOGIC
DROUGHT

- streamflow
- snowfall



FIRE-RISK
MONITORING

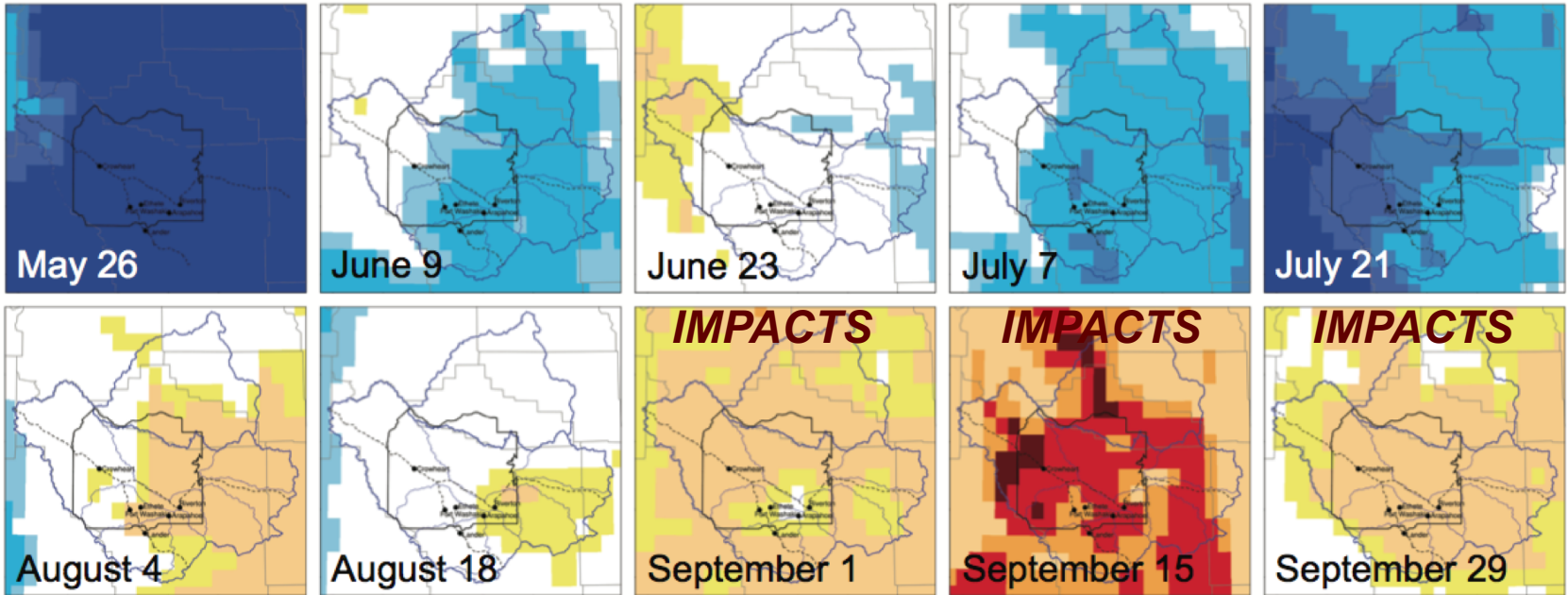
- weather
- fuel loads



ECOLOGICAL
DROUGHT

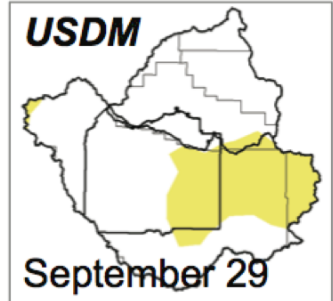
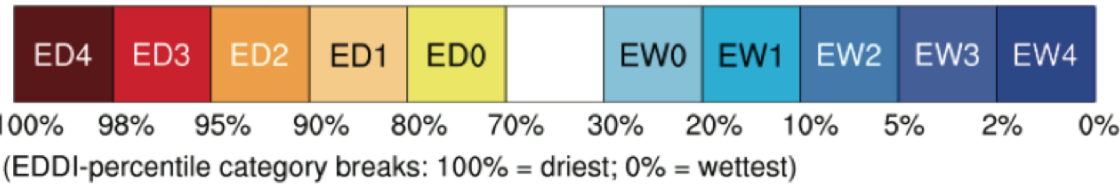
Application: Agricultural drought monitoring

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



Drought categories

Wetness categories

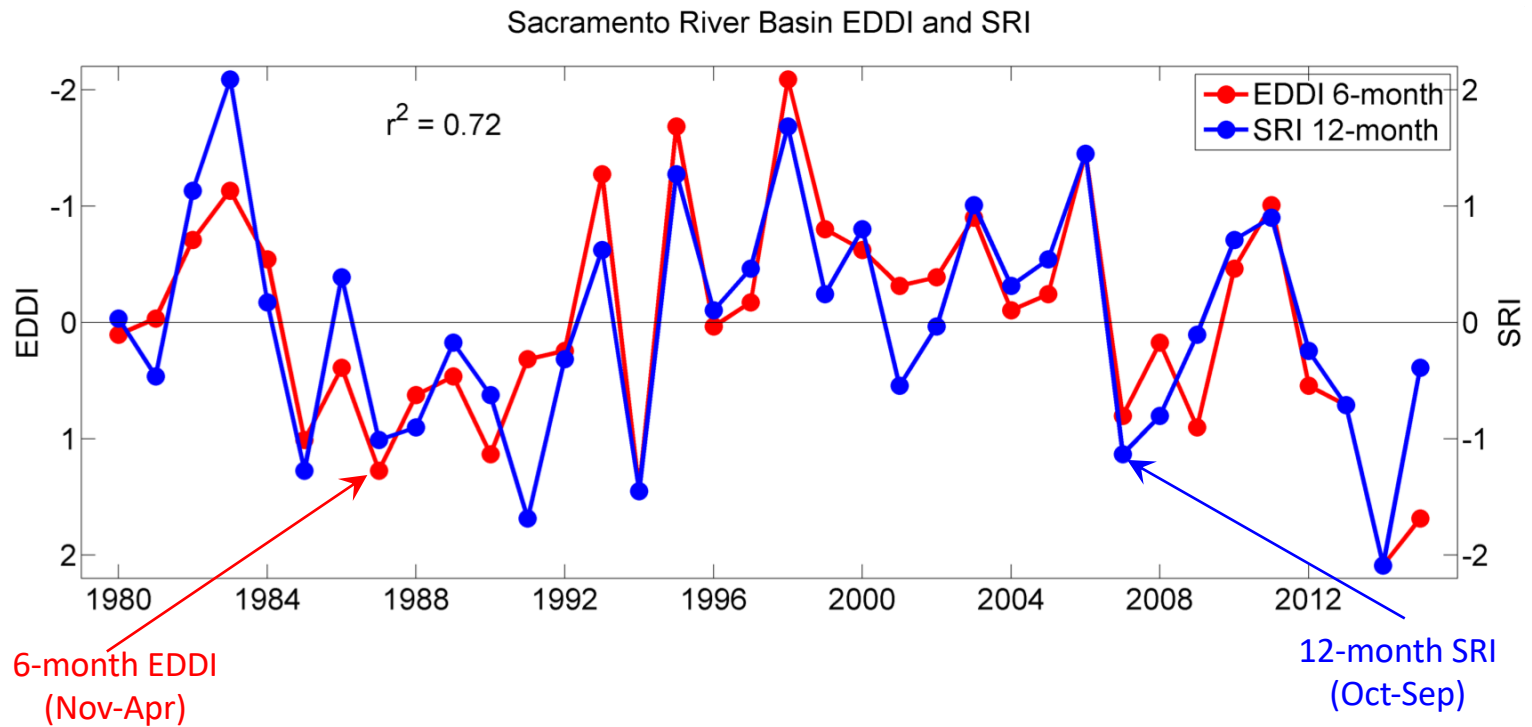


Application: Hydrological drought prediction

6-month EDDI in Sacramento River Basin, CA



- Potential to improve late summer low flow streamflow predictions



**EDDI contains no
Prcp information!**

SRI = Standardized Runoff Index

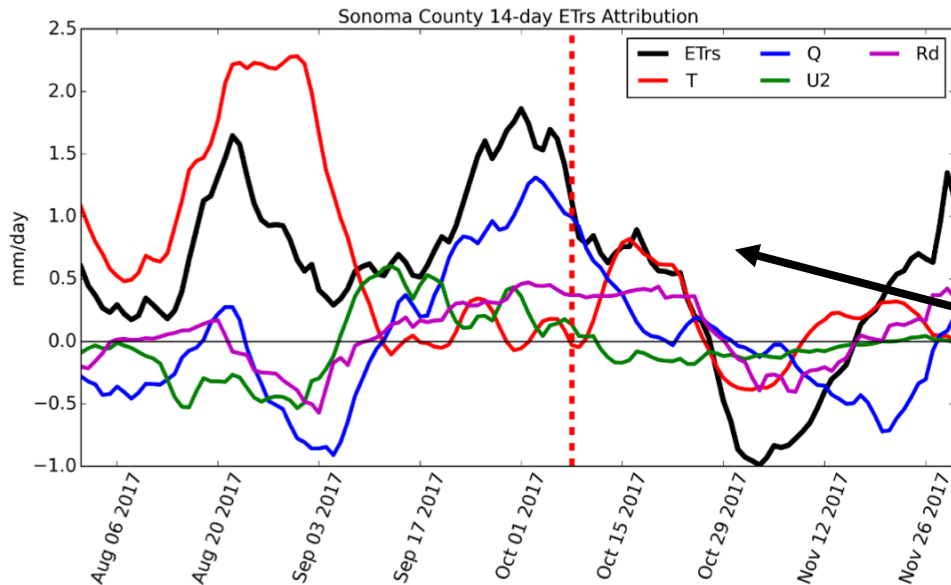
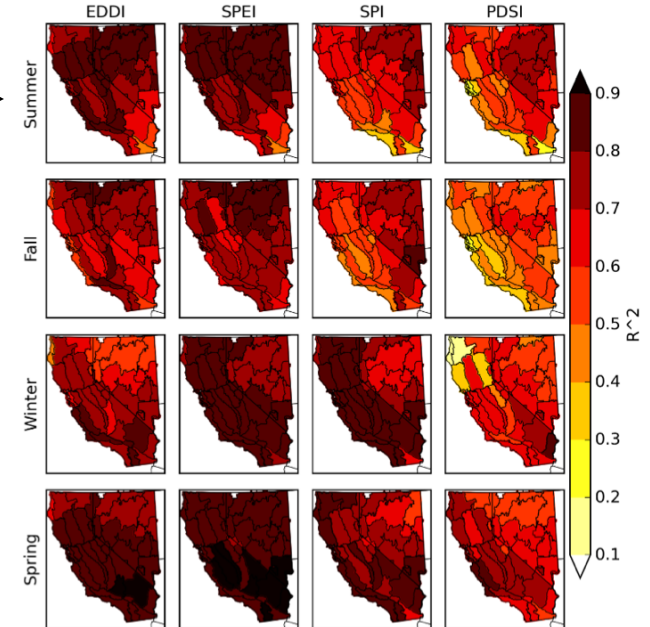
Application: Wildfire risk management

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

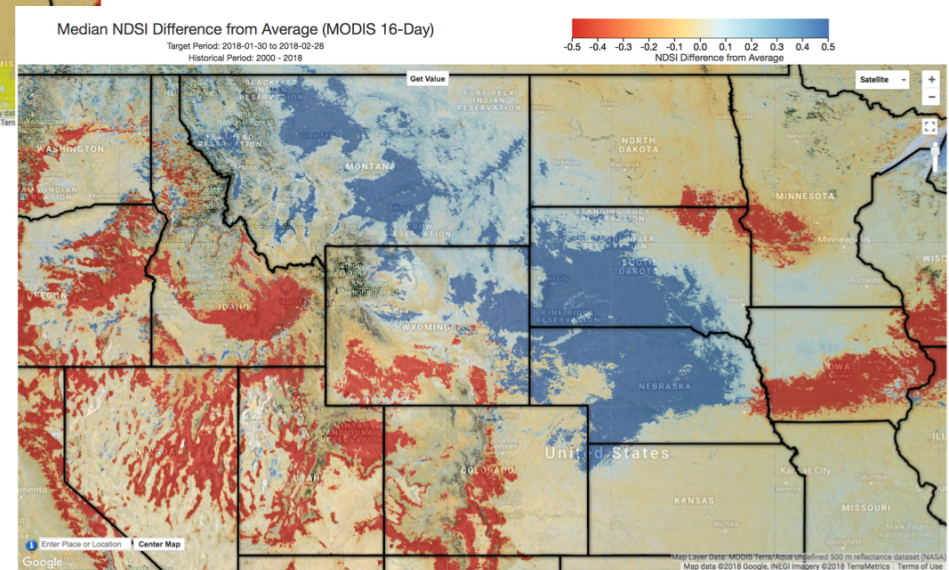
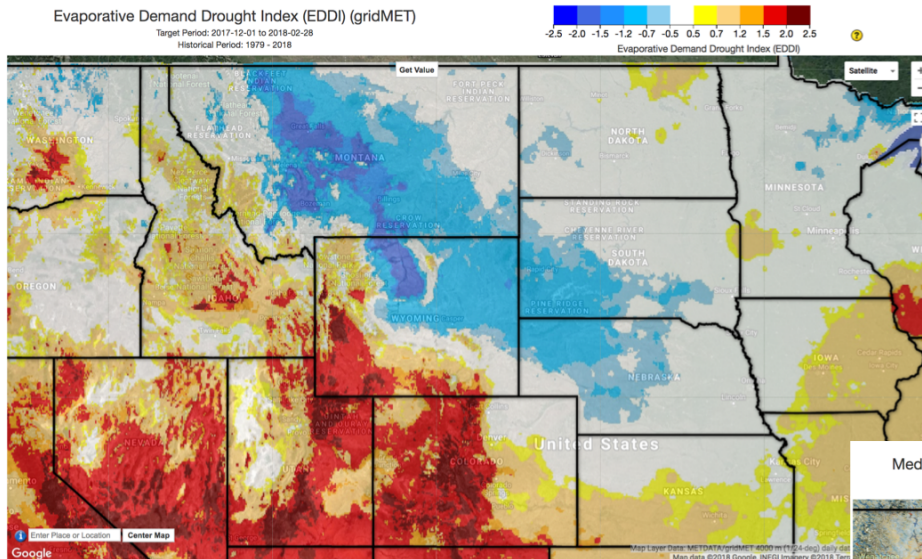


- Tubbs Fire, October, 2017
- EDDI decomposition indicates shift to humidity-driven E_0 spike

Application: Snow and snow drought

December – February, 2018

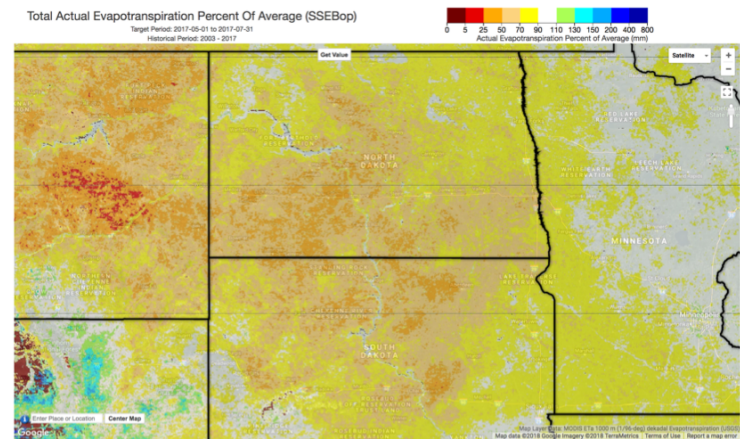
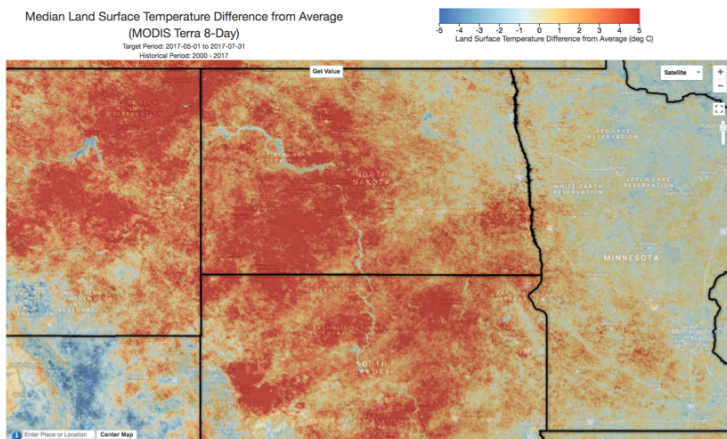
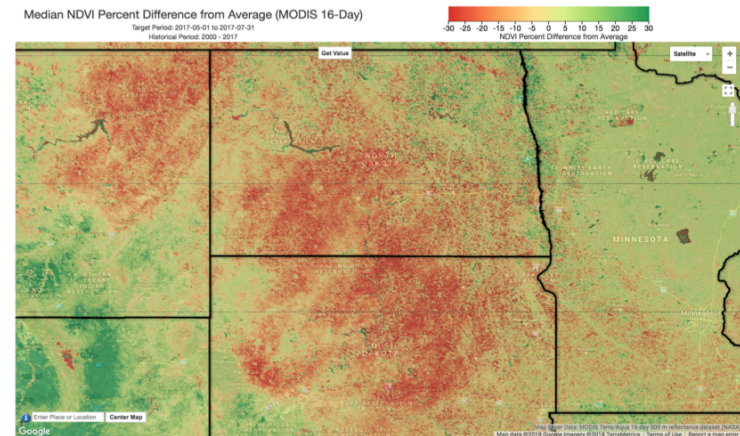
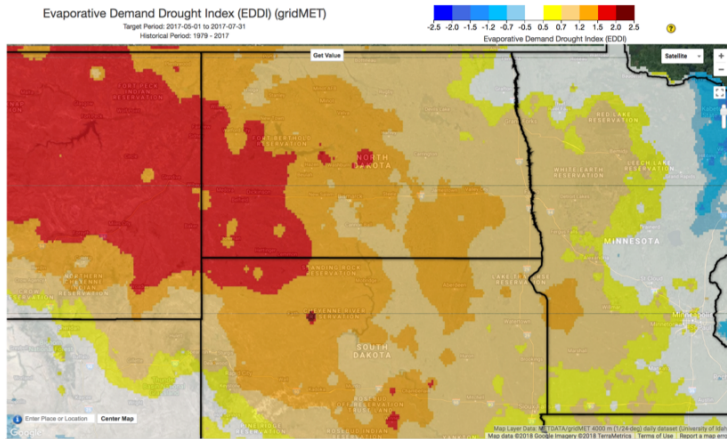
- EDDI is useful for evaluating snow and snow drought
- Snow drought can occur due to low *Prcp*, or average *Prcp* but rain vs. snow



Application: Complementing remote sensing

May – July, 2017

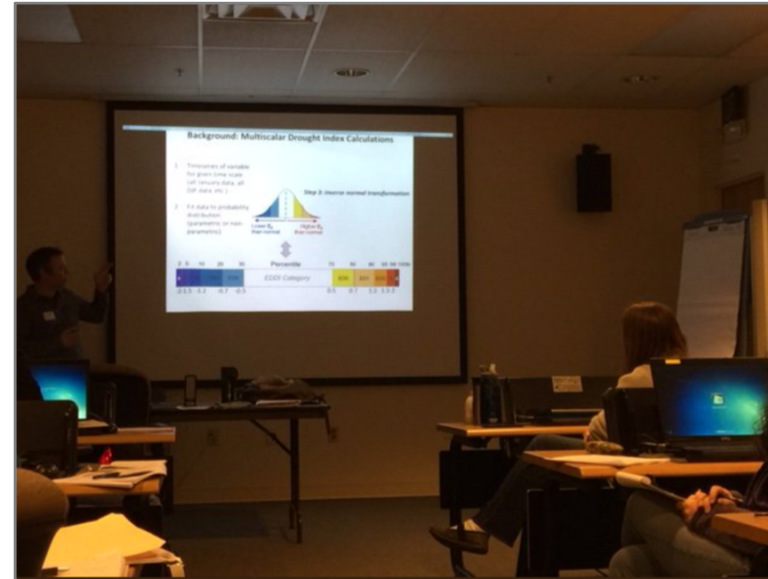
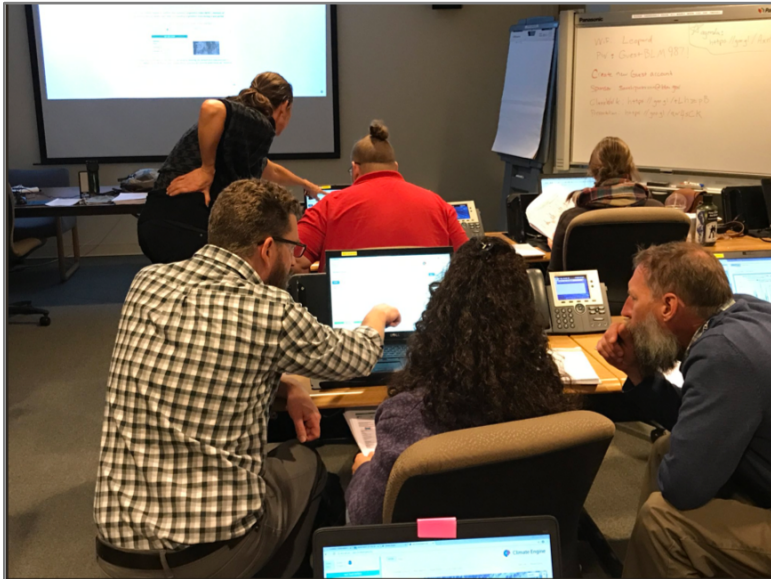
- EDDI is useful for understanding remote sensing anomalies of land surface temperature, vegetation, and actual ET



EDDI outreach: Hands-on training

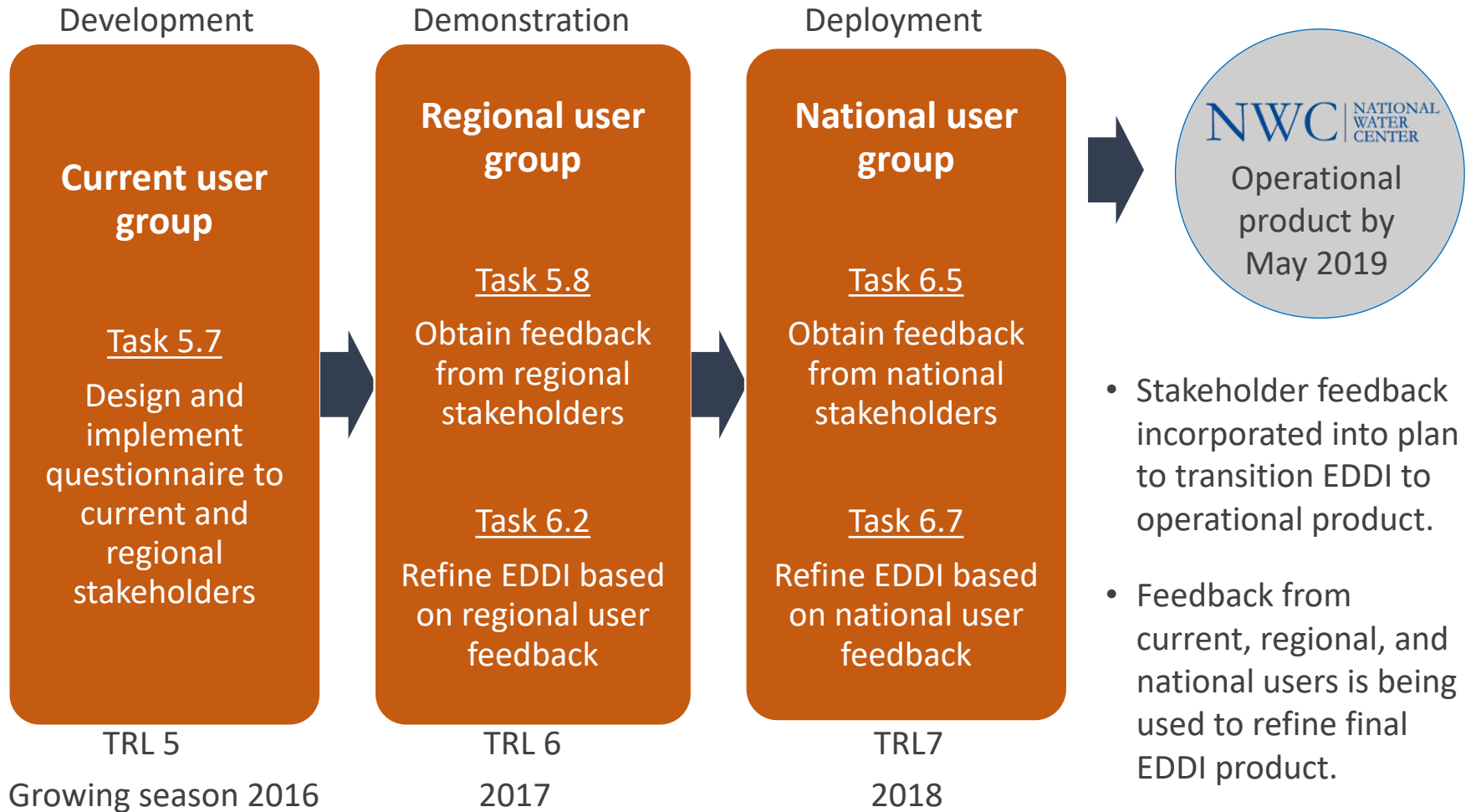


- DRI partners conducting extensive EDDI hands-on training with state and federal agency scientists and managers in the western US



Nevada BLM State Office – March 8, 2018

Stakeholder engagement: Co-development of EDDI



New developments: EDDI website

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About

What is EDDI?

The **Evaporative Demand Drought Index (EDDI)** is an experimental drought monitoring and early warning guidance tool. It examines how anomalous the atmospheric evaporative demand (E_0 ; also known as 'the thirst of the atmosphere') is for a given location and across a time period of interest. EDDI is multi-scalar, meaning that this period—or 'timescale'—can vary to capture drying dynamics that themselves operate at different timescales; we generate EDDI at 1-week through 12-month timescales.

This webpage offers a frequently updated assessment of **current conditions** across CONUS, southern parts of Canada, and northern parts of Mexico; it also to generate historical **time series** of EDDI for a user-selected region; introductions to the **EDDI team**; and a list of **resources** for users to explore EDDI and its applications further.

Why use EDDI?

EDDI can offer early warning of agricultural drought, hydrologic drought, and fire-weather risk by providing near-real-time information on the emergence or persistence of anomalous evaporative demand in a region. A particular strength of EDDI is in capturing the precursor signals of water stress at weekly to monthly timescales, which makes EDDI a strong tool for preparedness for both flash droughts and ongoing droughts.

How often is EDDI updated?

Currently, EDDI is generated daily—though with a 5-day lag-time—by analyzing a near-real-time atmospheric dataset. This lag-time results from the procedures to quality control the meteorological data used to estimate evaporative demand. There is also an ongoing effort to forecast EDDI based on seasonal climate-forecast information.

Acknowledgements

This work is supported in part by grants from (i) NOAA's Joint Technology Transfer Initiative (JTTI) for the project titled 'Operationalizing an Evaporative Demand Drought Index (EDDI) service for drought monitoring and early warning'; (ii) NOAA's Sectoral Applications Research Program (SARP): Coping with Drought in Support of the National Integrated Drought Information System (NIDIS) program for the project titled 'Developing a wildfire component for the NIDIS California Drought Early Warning System'; (iii) DOI's North Central Climate Science Center for the project (Grant #G16AP00152) titled 'Ecological Drought, Climate Extremes and the Water Cycle across Timescales'; and (iv) Western Water Assessment, an NOAA RISB program, for the project titled 'Enhancing the usability of EDDI with funding originating from NIDIS.

Any issues with accessing the plots and other information on this page are welcome and should be sent to esri.psd.data@noaa.gov.

Logos for NIDIS, NOAA, Western Water Assessment, CIRCES, CU, DRI, and North Central Climate Science Center.

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<http://www.esrl.noaa.gov/psd/eddi/>

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Plot EDDI Maps of the Continental U.S.

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Resources

Primary Background Material

- EDDI User Guide
- How to Use EDDI

Related Links

- EDDI: A New Drought Index Provides Early Warnings of Flash Droughts
- A New NOAA tool is helping to predict U.S. droughts, wildfire severity
- New NOAA tool is helping to predict U.S. droughts, wildfire severity
- EDDI: A powerful tool for early drought warning
- NOAA's Experimental Demand Drought Index
- EDDI: A new tool for early drought warning
- NOAA's new tool identifies both natural and human-induced drought
- NOAA's new tool identifies both natural and human-induced drought
- Time series of monthly U.S. climate indices: EDDI and other variables

References

8000 Developments

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- McHadden, A. J., Huntington, M. J., Morison, M., Anderson, and C. (June 2016). The Evaporative Demand Drought Index: Part 2 - CNRM-Weather Assessment Against Common Drought Indicators. *J. Hydrometeorology*, 17(6): 1762-1774. doi:10.1175/JHM6-D-15-0122.1

8000 Related

- Deems, C. F., Bergman, J., Barstow, W. T., Hobbie, and R. Kumar (March 2017). Drought risk assessment under climate change is sensitive to model choice: An evaluation of evaporative demand. *PLoS ONE*, 12(3): e0171444. doi:10.1371/journal.pone.0171444
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- Hobbie, R. J., L. Deems, and A. D. Apple (January 2015). Phenological characterization of reported severe drought through drought stress species. *Hydrological Earth System Science*, 19(1): 1-11. doi:10.5194/hess-19-1-1-2014
- Stiles, T. A., Deems, C. F., Hobbie, and C. L. Anderson (2015). Managing Climate Risk on the South and Central United States Drought. *Climate Risk*. doi:10.1016/j.cris.2015.01.002

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Earth System Research Laboratory | Physical Sciences Division
<http://www.esrl.noaa.gov/psd/eddi/>

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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:

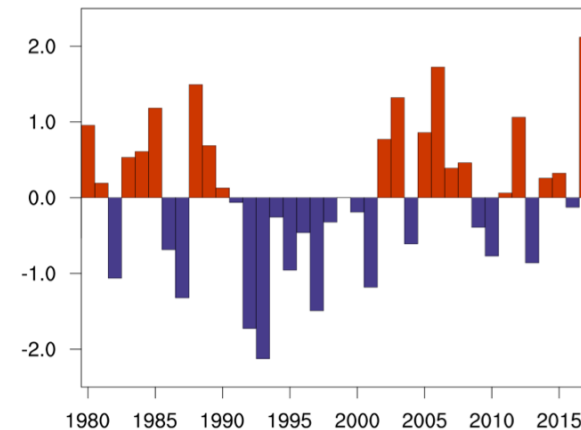
- user guide
- papers
- related links

New developments: Historical EDDI time series

The screenshot shows the NOAA Earth System Research Laboratory website. The main heading is "EDDI Evaporative Demand Drought Index". Below it, there is a navigation menu with "Time Series" highlighted. The main content area is titled "Plot EDDI Time Series of the Continental U.S." and features a bar chart showing "5 month EDDI ending in September(1980-2016) for Boulder, CO". The chart shows values ranging from -2.0 to 2.0 over the period 1980-2015. Below the chart, there is a form for generating time series data, including a map of the United States and options for region, averaging period, and ending month.

- 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

1 month EDDI ending in July(1980-2017): for NE Montana (46.5-49N, 104-108.5W)



plot generated Mar 6 2018

NOAA/ESRL PSD

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

New developments: Resources and EDDI User Guide

U.S. Department of Commerce | National Oceanic & Atmospheric Administration | NOAA Research
Earth System Research Laboratory
Physical Sciences Division

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EDDI Evaporative Demand Drought Index

About | Current Conditions | EDDI Map Archive | Time Series | Team | Resources

Resources

Primary Background Material

- EDDI User Guide
- How to read an EDDI map

Related Links

- EDDI: A New Drought Index Provides Early Warning of Flash Droughts
- A new NOAA tool is helping to predict US droughts, global famine
- New NOAA tool is helping to predict U.S. droughts, global famine
- EDDI: A powerful tool for early drought warning
- WVA: Intermountain West Climate Dashboard
- PSD News: New tool effectively identifies both rapid-onset and sustained droughts
- CONUS maps of monthly US climate division PSDI
- Time series of monthly US climate division PSDI and other variables

References

EDDI Development

- M. Hobbs, A. Wood, D. McEvoy, J. Huntington, J. Baranowski, J. Anderson, and C. Hain (June 2016). The Evaporative Demand Drought Index: Part I – Linking Drought Evolution to Variations in Evaporative Demand. *J. Hydrometeorol.*, doi:10.1175/JHM-D-15-0121.1
- D. J. McEvoy, J. L. Huntington, M. T. Hobbs, A. Wood, C. Morton, M. Anderson, and C. Hain (June 2016). The Evaporative Demand Drought Index: Part II – CONUS-wide Assessment Against Common Drought Indicators. *J. Hydrometeorol.*, 17(6), 1763-1779, doi:10.1175/JHM-D-15-0122.1

EDDI-Related

- Dewes, C. F., Rangwala, I., J. Barsugli, M. T. Hobbs, and S. Kumar (March 2017). Drought risk assessment under climate change is sensitive to methodological choices for the estimation of evaporative demand. *PLoS ONE*, 12(3), e0174045, doi:10.1371/journal.pone.0174045
- McNeeley, S. M., C. F. Dewes, C. J. Stiles, J. Huntington, I. Rangwala, M. T. Hobbs, and C. L. Knutson CL (2017). Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation. *Clim. Risk Mgt.*, doi:10.1016/j.crm.2017.09.004
- Rondeau, R. J., K. L. Decker, and G. A. Doyle (January 2018). Potential consequences of repeated severe drought for shortgrass steppe species. *Rangeland Ecol. Mgt.*, 71(1), 91–97, doi:10.1016/j.rama.2017.07.009
- Shrum, T., W. Travis, T. Williams, and E. Lih (Online February 2018). Managing Climate Risk on the Ranch with Limited Drought Information. *Clim. Risk Mgt.*, doi:10.1016/j.crm.2018.01.002

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http://www.esrl.noaa.gov/psd/

EDDI Evaporative Demand Drought Index

8-week EDDI categories for August 10, 2017

12-week EDDI categories for August 10, 2017

The EDDI User Guide

v1.0 – September 2017

Jeff Lukas, Mike Hobbs, Imtiaz Rangwala
and the EDDI team

NOAA Drought.gov | NWS | DRI | WESTERN WATER ASSESSMENT

(Lukas et al., WWA 2017)

EDDI

A Powerful Tool for Early Drought Warning

What is EDDI? EDDI is an Evaporative Demand Drought Index that is a drought index that provides an early warning of drought conditions. It is based on the physical basis for drought, which is the lack of water available to plants. EDDI is a powerful tool for early drought warning. It is based on the physical basis for drought, which is the lack of water available to plants. EDDI is a powerful tool for early drought warning. It is based on the physical basis for drought, which is the lack of water available to plants.

What is the physical basis for EDDI? EDDI is based on the physical basis for drought, which is the lack of water available to plants. EDDI is a powerful tool for early drought warning. It is based on the physical basis for drought, which is the lack of water available to plants.

Imtiaz Rangwala and the EDDI team

(Rangwala et al., NOAA 2015)

The Evaporative Demand Drought Index. Part I: Linking Drought Evolution to Variations in Evaporative Demand

MICHAEL T. HOBBS,^{a,b} ANDREW WOOD,^c DANIEL J. MCEVOY,^d JUSTIN L. HUNTINGTON,^d CHARLES MORTON,^d MARTHA ANDERSON,^e AND CHRISTOPHER HAIN^f

The Evaporative Demand Drought Index. Part II: CONUS-Wide Assessment against Common Drought Indicators

DANIEL J. MCEVOY,^a JUSTIN L. HUNTINGTON,^a MICHAEL T. HOBBS,^{b,c} ANDREW WOOD,^d CHARLES MORTON,^a MARTHA ANDERSON,^e AND CHRISTOPHER HAIN^f

RESEARCH ARTICLE

Drought risk assessment under climate change is sensitive to methodological choices for the estimation of evaporative demand

Candida F. Dewes^{1,2,3,*}, Imtiaz Rangwala^{1,2,3*}, Joseph J. Barsugli^{1,2,3†}, Michael T. Hobbs^{1,2†}, Sanjiv Kumar^{2†}

Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation

Shannon M. McNeeley^{a,b}, Candida F. Dewes^{a,b,c}, Crystal J. Stiles^d, Tyler A. Beeton^a, Imtiaz Rangwala^{a,b,c}, Michael T. Hobbs^{b,c}, Cody L. Knutson^c

Original Research

Potential Consequences of Repeated Severe Drought for Shortgrass Steppe Species

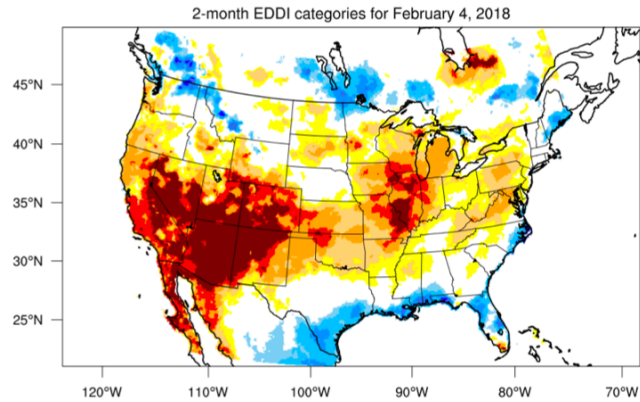
Renee J. Rondeau^{a,*}, Karin L. Decker^b, Georgia A. Doyle^b

Managing climate risks on the ranch with limited drought information

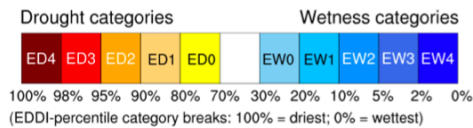
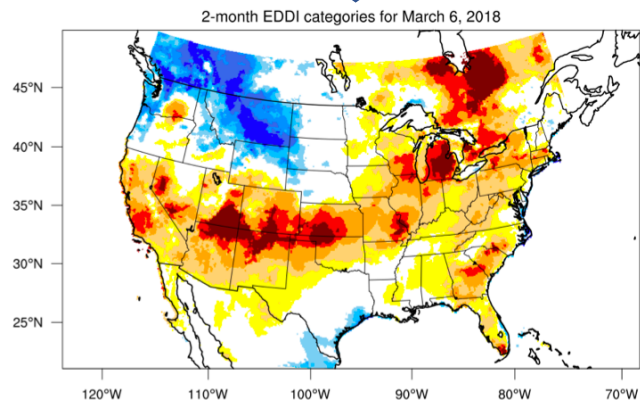
Erisha R. Shrum^{a,b,c}, William R. Travis^{a,b,c}, Travis M. Williams^{a,c}, Evan Lih^a

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

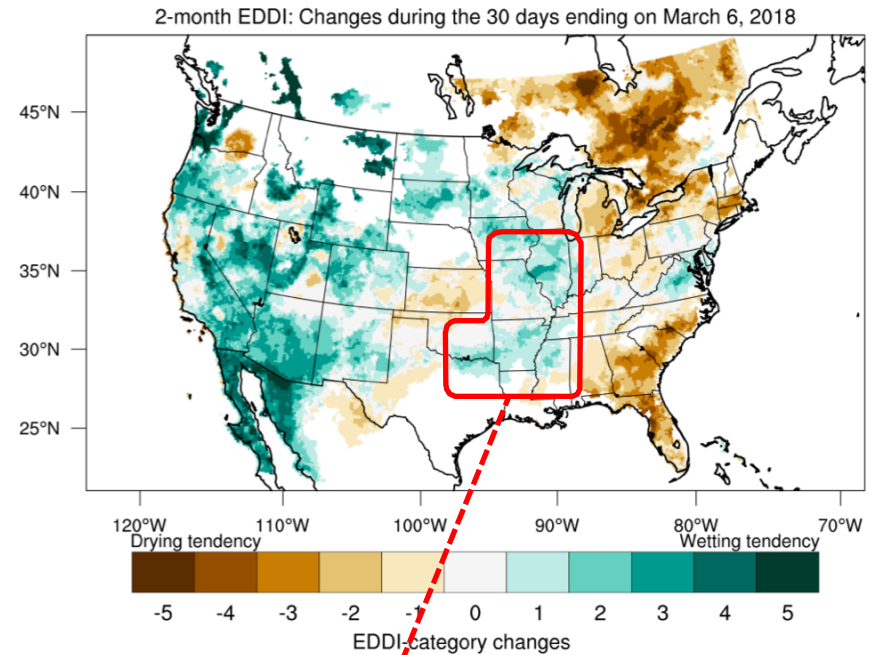
New developments: EDDI change maps



30 days



Generated by NOAA/ESRL/Physical Sciences Division

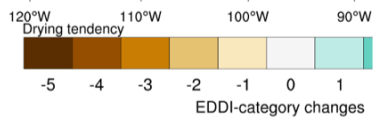
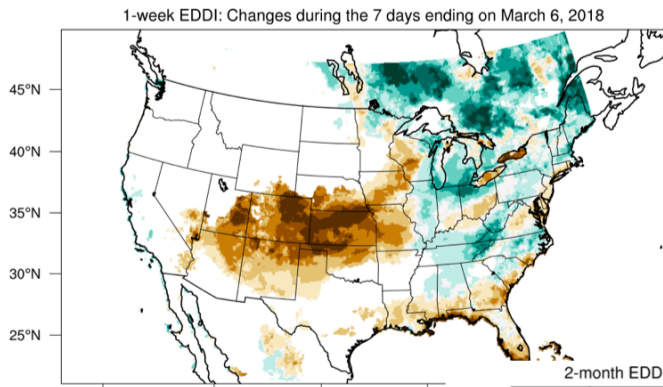


Only regions that start or end at above the 70th percentile (i.e., ED0) are shown.

Generated by NOAA/ESRL/Physical Sciences Division

Wetting in response to heavy Prcp

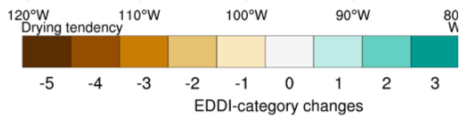
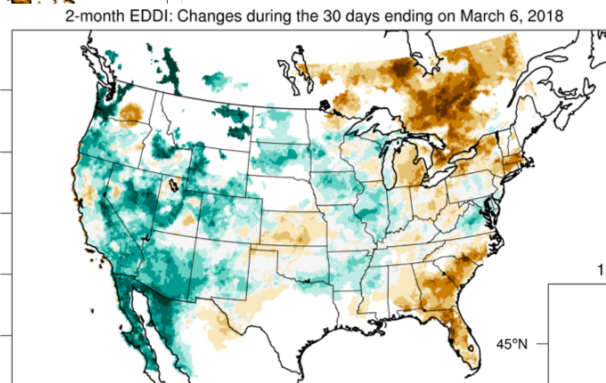
New developments: EDDI change maps



Only regions that start or end at above the 70th percentile

Generated by NOAA/ESF

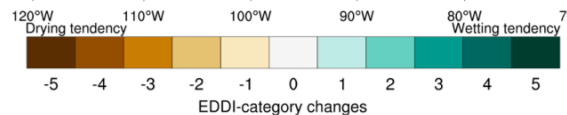
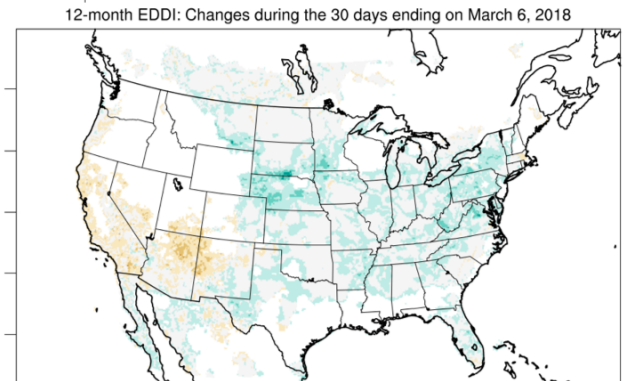
Very dynamic:
timescale = change interval



Only regions that start or end at above the 70th percentile (i.e., ED0) are shown.

Generated by NOAA/ESRL/Physical Sc

Long memory:
timescale = 12 x change interval



Only regions that start or end at above the 70th percentile (i.e., ED0) are shown.

Generated by NOAA/ESRL/Physical Sciences Division

New developments: Attribution of drivers of drought

Diagnosing drought's demand side

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

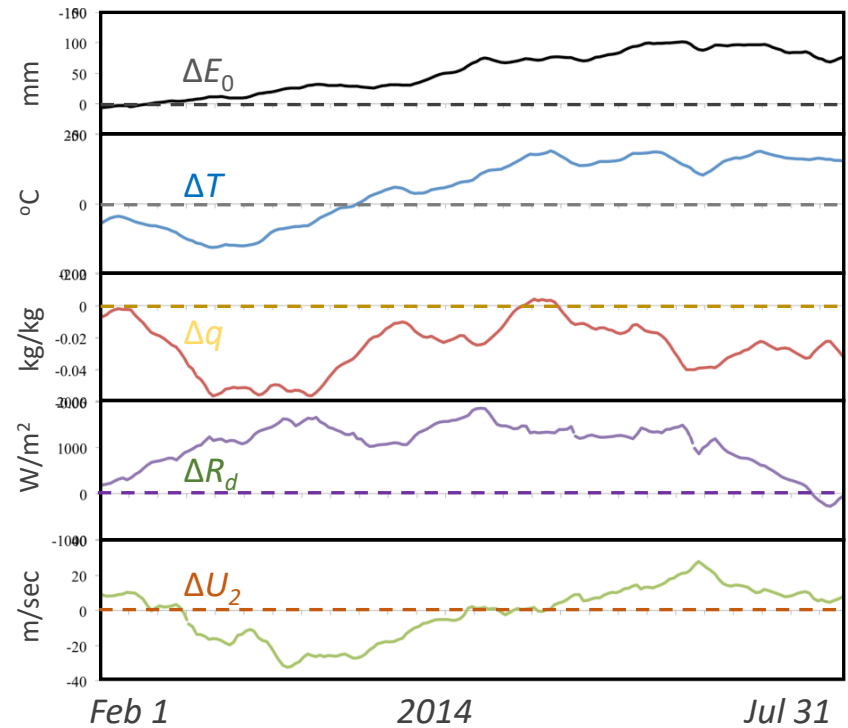
$$\Delta E_0 = \frac{\partial E_0}{\partial T} \Delta T + \frac{\partial E_0}{\partial R_d} \Delta R_d + \frac{\partial E_0}{\partial q} \Delta q + \frac{\partial E_0}{\partial U_2} \Delta U_2$$

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

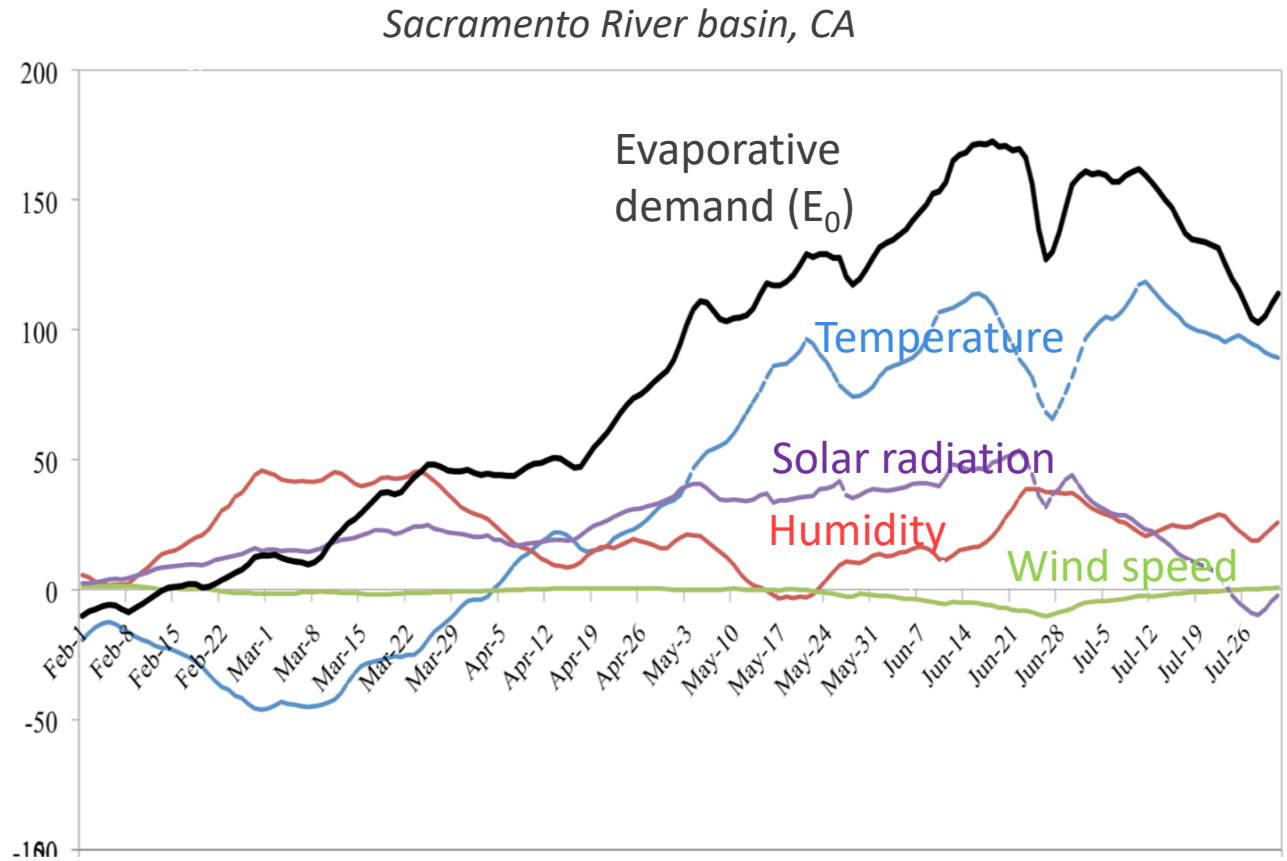


New developments: Attribution of drivers of drought

Diagnosing drought's demand side

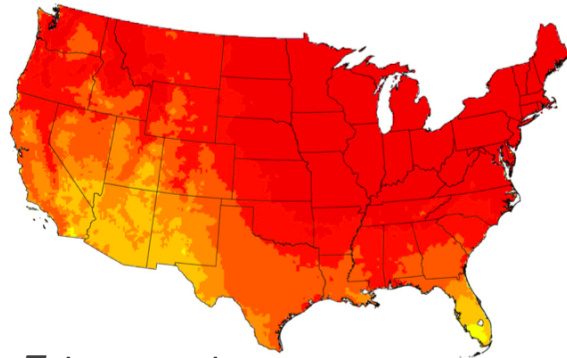
E.g., drought intensification (rising E_0) forced by:

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

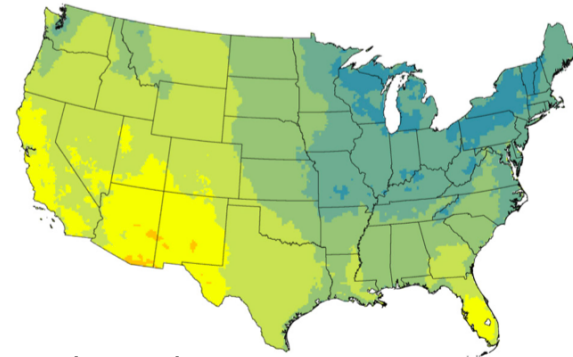


Under development: Attribution maps

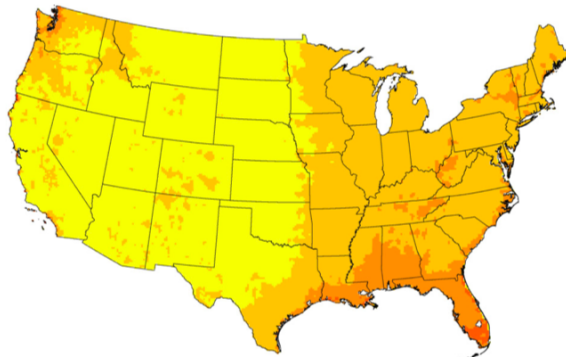
$$\Delta E_0 = \frac{\partial E_0}{\partial T} \Delta T + \frac{\partial E_0}{\partial R_d} \Delta R_d + \frac{\partial E_0}{\partial q} \Delta q + \frac{\partial E_0}{\partial U_2} \Delta U_2$$



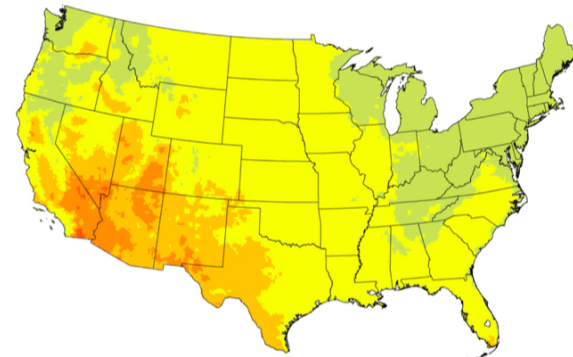
T temperature



q humidity

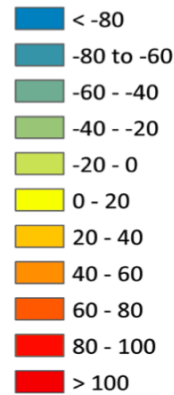


R_d solar radiation



U_2 wind speed

% contribution



(conceptual maps only)

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/>

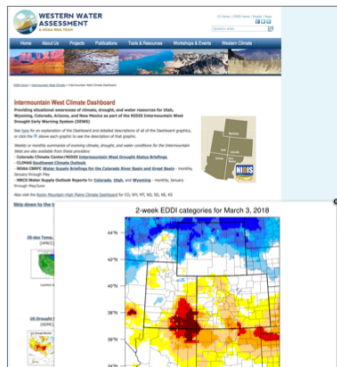
Entire EDDI history (1980-present) – CONUS-wide data and maps

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

Regional climate dashboards:

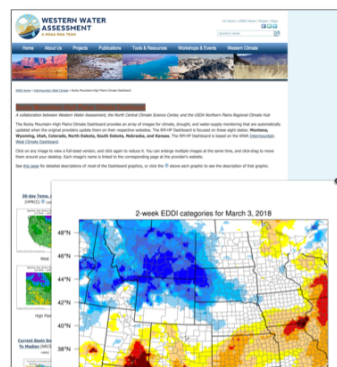
e.g., Western Water Assessment

Rocky Mountains-High Plains Climate Dashboard



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

Intermountain West Climate Dashboard



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

Coming soon: US Drought Portal

<https://www.drought.gov/drought/>

EDDI take-home messages

Mike Hobbins

303-497-3092

mike.hobbins@noaa.gov

<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**

