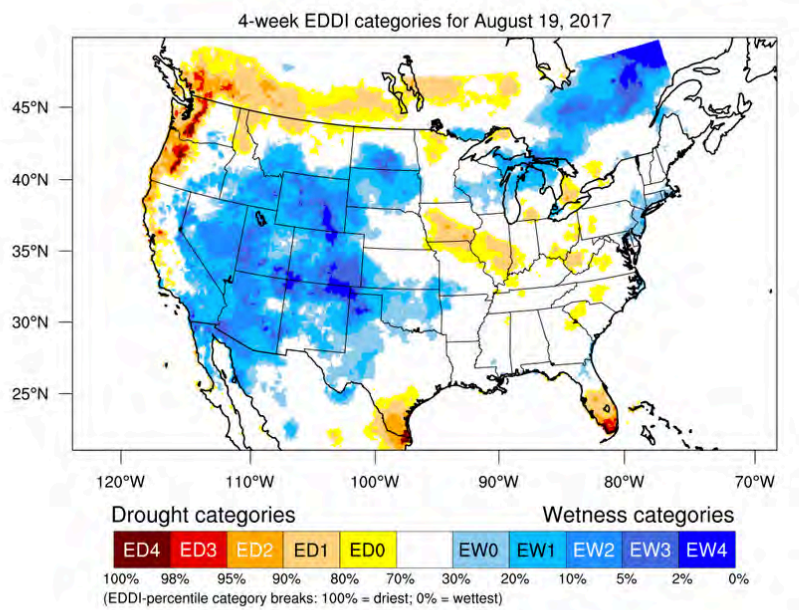
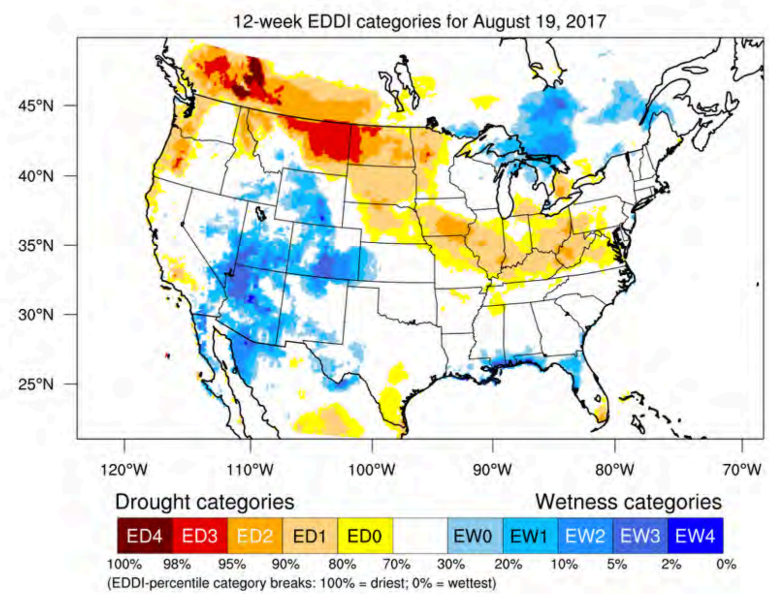
EDDI Evaporative Demand Drought Index





The EDDI User Guide

v1.0 – September 2017

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

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM NIDIS Drought.gov U.S. Drought Portal
NOAA
DRI Desert Research Institute
Western Regional Climate Center
WESTERN WATER ASSESSMENT A NOAA RISA TEAM
NORTH CENTRAL CLIMATE SCIENCE CENTER UNIVERSITY CONSORTIUM

Contents - *Use Bookmarks in PDF to navigate*

This User Guide is intended for:

- ***Managers:*** Those who monitor drought conditions in order to manage resources and make decisions; e.g., ag producers, and water, fire, forests, range, and wildlife managers

- ***Translators:*** Those who work closely with the above groups in an advisory or outreach role and/or disseminate drought information; e.g., NWS forecasters, State climatologists, drought coordinators

- ***Researchers:*** Those who study the drought phenomenon to better understand its causes, manifestations, and impacts

- *The level of information in the Guide is most suited for the first two groups.* But researchers may find the overview useful before delving more into the technical background on EDDI.

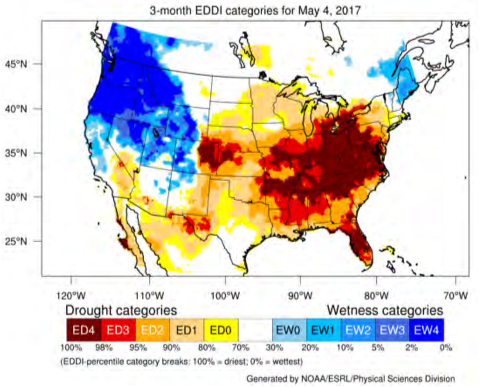
What this User Guide provides

Clear and concise explanations of:

- Evaporative Demand (E_0) and why it is important to drought
- How EDDI is calculated and how it depicts Evaporative Demand
- How EDDI relates to other drought indicators
- How to interpret EDDI maps over different time windows

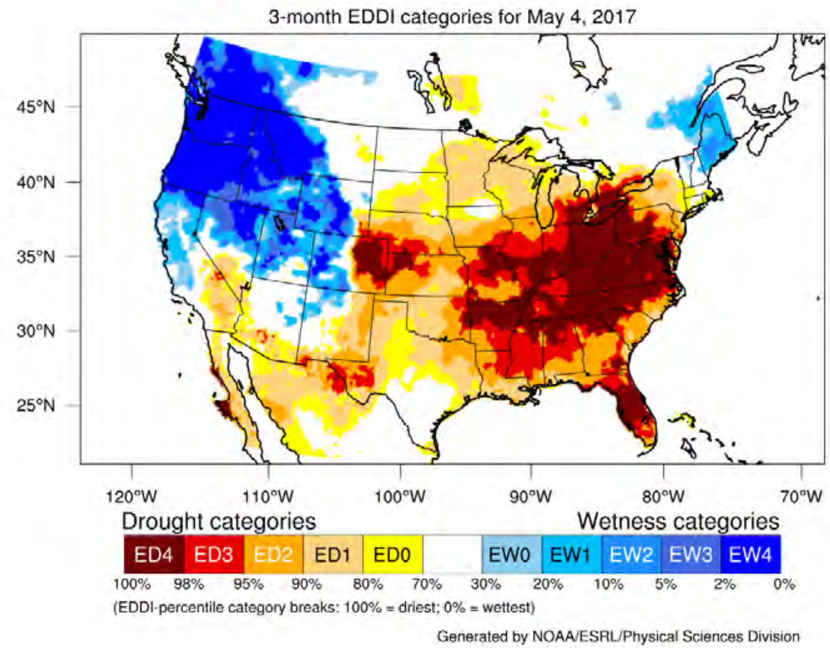
This User Guide will be updated based on user feedback. Please let us know if it was helpful, and how it might be improved.

Send feedback to Jeff Lukas, lukas@colorado.edu



EDDI in a nutshell

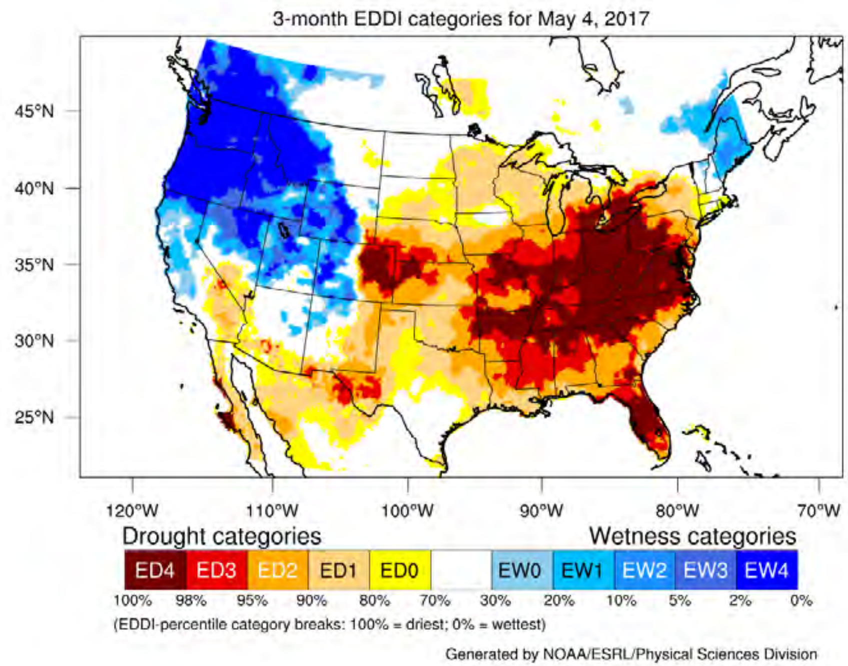
- EDDI is a drought index based on the "thirst" of the atmosphere—which leads to the drying of soils and vegetation, and also reflects that drying
- More technically: EDDI shows the anomaly* in daily **evaporative demand** aggregated over a specified time window, at a given location
- EDDI is calculated from observations of the atmosphere near the land surface: temperature, humidity, windspeed, and solar radiation
- EDDI can provide added value to other drought indicators, especially for early warning and flash drought detection



*i.e., the unusualness of the current conditions as compared to the range of historical conditions

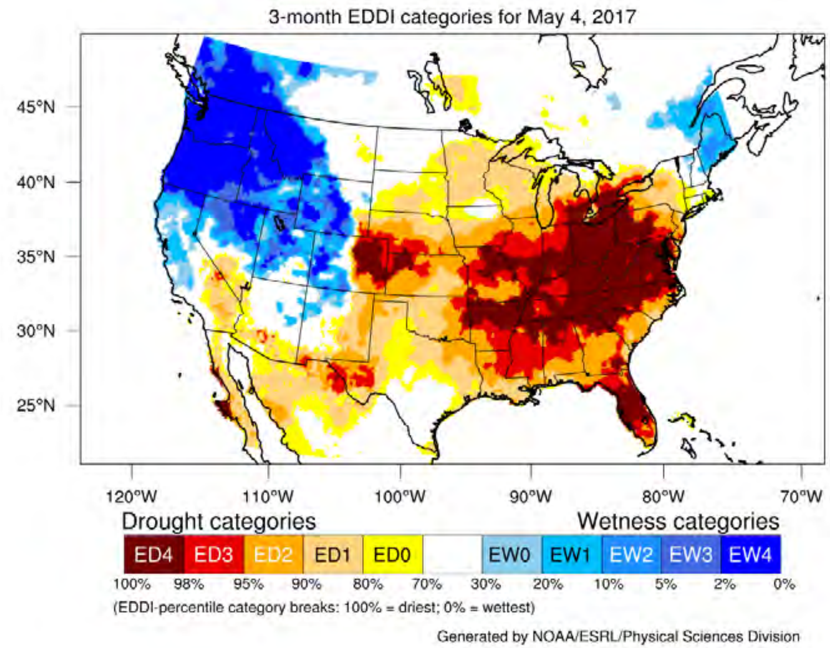
Key features of EDDI

- EDDI maps are produced in near-real-time, with a ~5-day lag
- EDDI is calculated over multiple time windows (like the Standardized Precipitation Index; SPI), to suit different applications
- EDDI maps have a spatial resolution of 1/8-degree (~12 km or ~7 miles)
- EDDI uses a classification scheme that is equivalent to the US Drought Monitor categories (D0, D1, D2, etc.)
- EDDI is not sensitive to the land-cover type, so it is appropriate for use in all regions



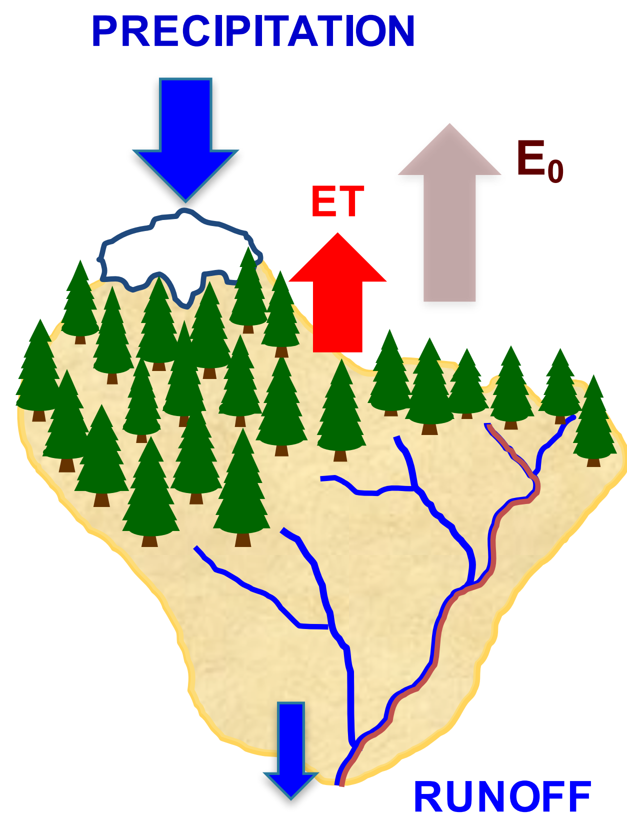
What EDDI is not

- EDDI doesn't directly measure on-the-ground conditions—though EDDI values are *strongly influenced* by surface moisture conditions
- EDDI is not a drought *prediction*, but at short timescales, it indicates the *potential* for drought emergence
- EDDI is not a measure of actual evapotranspiration (i.e., ET)



Drought results from moisture imbalance at the land surface

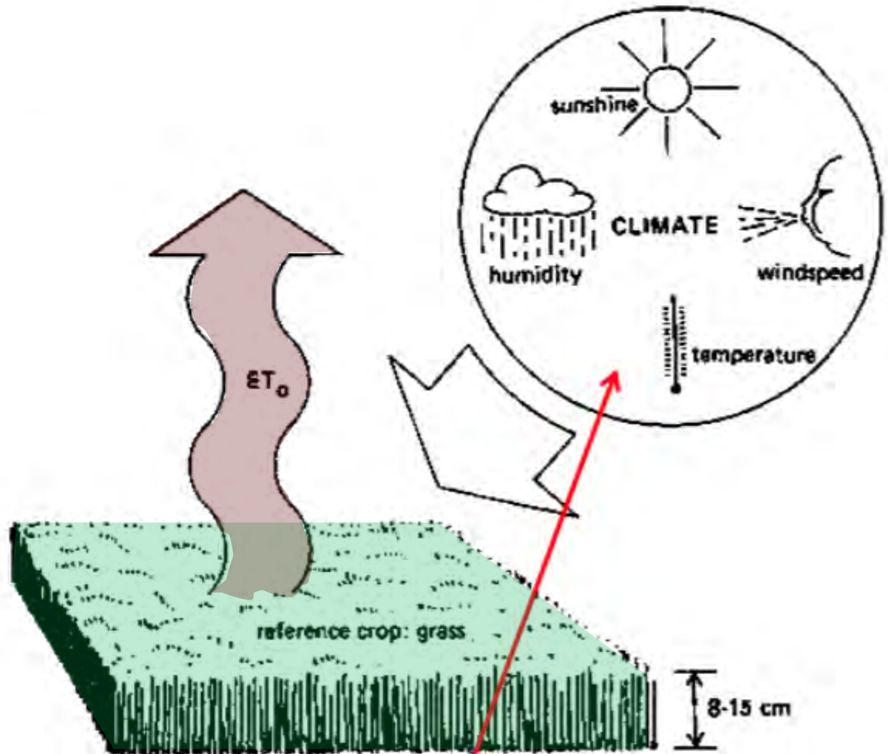
- The moisture status at the land surface reflects the balance of gains from **precipitation** and losses from **evapotranspiration** (ET)
- Drought (inadequate surface moisture) is typically initiated by below-normal precipitation (reduced gains), and *worsened* by above-normal evaporative demand (increased losses)
- ET is the rate of actual moisture loss to the atmosphere, usually expressed as in./day or mm/day, from soils, open water, and/or vegetation at one location
- ET is coupled to **evaporative demand (E_0)** but unlike **E_0**, ET is constrained by the surface moisture supply
- ET can never exceed **E_0**, and is often less



Evaporative demand (E_0) is the "thirst of the atmosphere"

- E_0 is the ET that would occur given an unlimited surface moisture supply
- E_0 is easier to quantify than ET
- E_0 can estimated by one of several methods:
  - **Reference *ET*** *(ET_0)*
  - Potential *ET (PET)*
  - Pan evaporation
- Accurate estimates of **Reference ET,** such as used in EDDI, require these variables:
  - Temperature
  - Humidity
  - Wind speed
  - Solar radiation

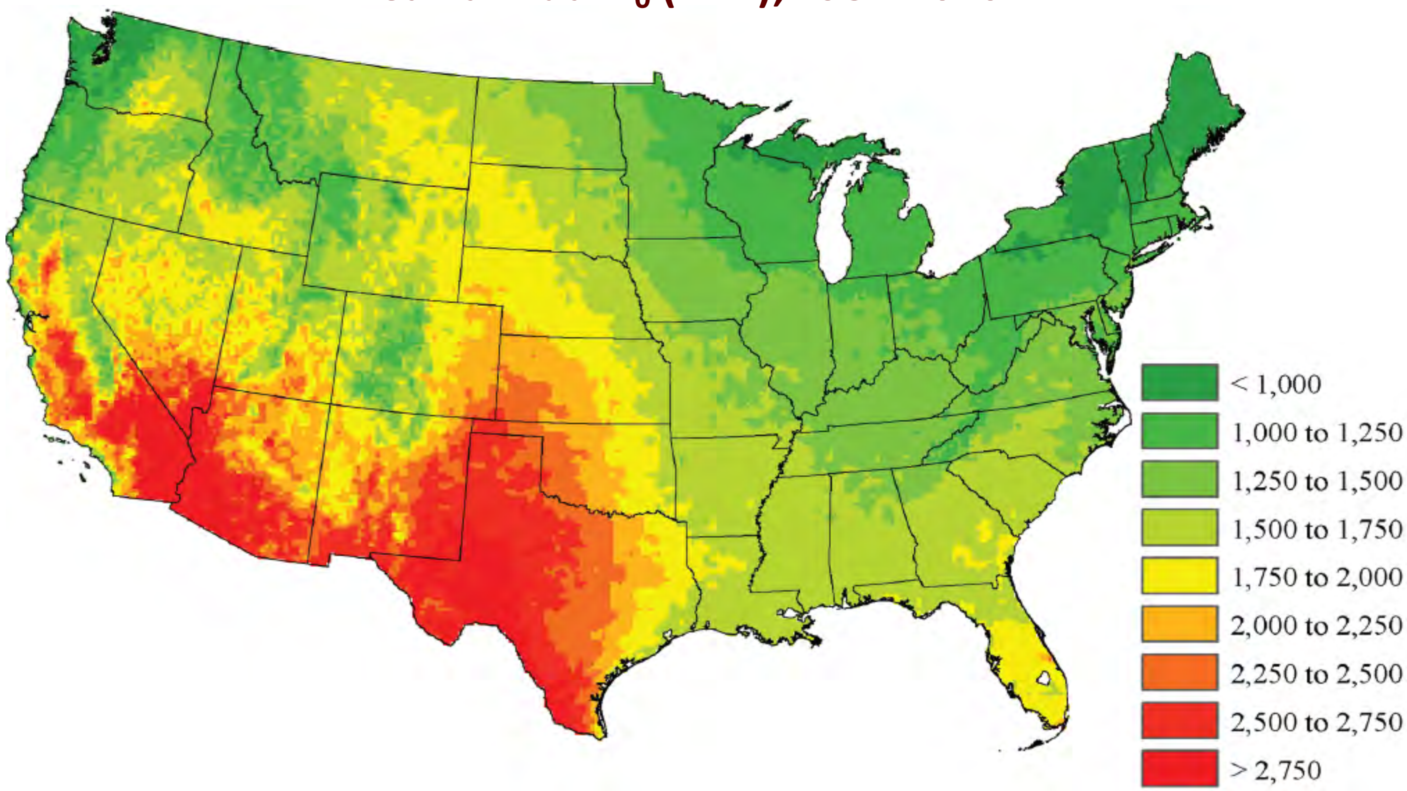
also known as a "fully physical" estimate



fao.org

The "normal" E_0 varies widely from place to place, with higher E_0 in dry and hot places like west Texas, and lower E_0 in cool and wet places like Maine

Mean annual E_0 (mm), 1981-2010



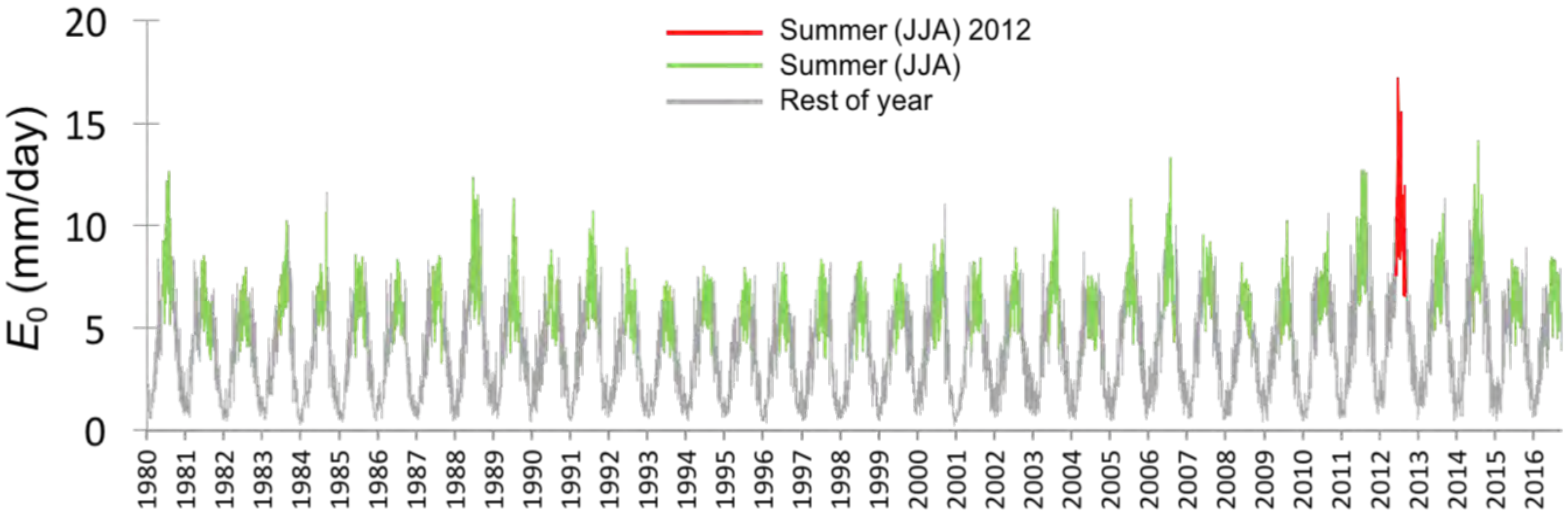
The mean annual E_0 varies by a factor of ~3 between the dry-hot Southwest and the cool-wet Northeast

Figure: Mike Hobbins, adapted from Hobbins (2016), Trans. ABABE

E_0 has a large seasonal cycle, peaking in the summer

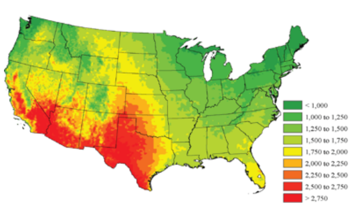
- When E_0 in the summer is even higher than usual (as in 2012, below) it often reflects the onset or rapid intensification of drought conditions

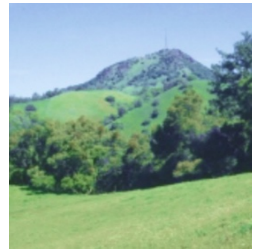
Daily $\mathbf{E_0}$ for the Midwest US (1980-2016), with summer values highlighted

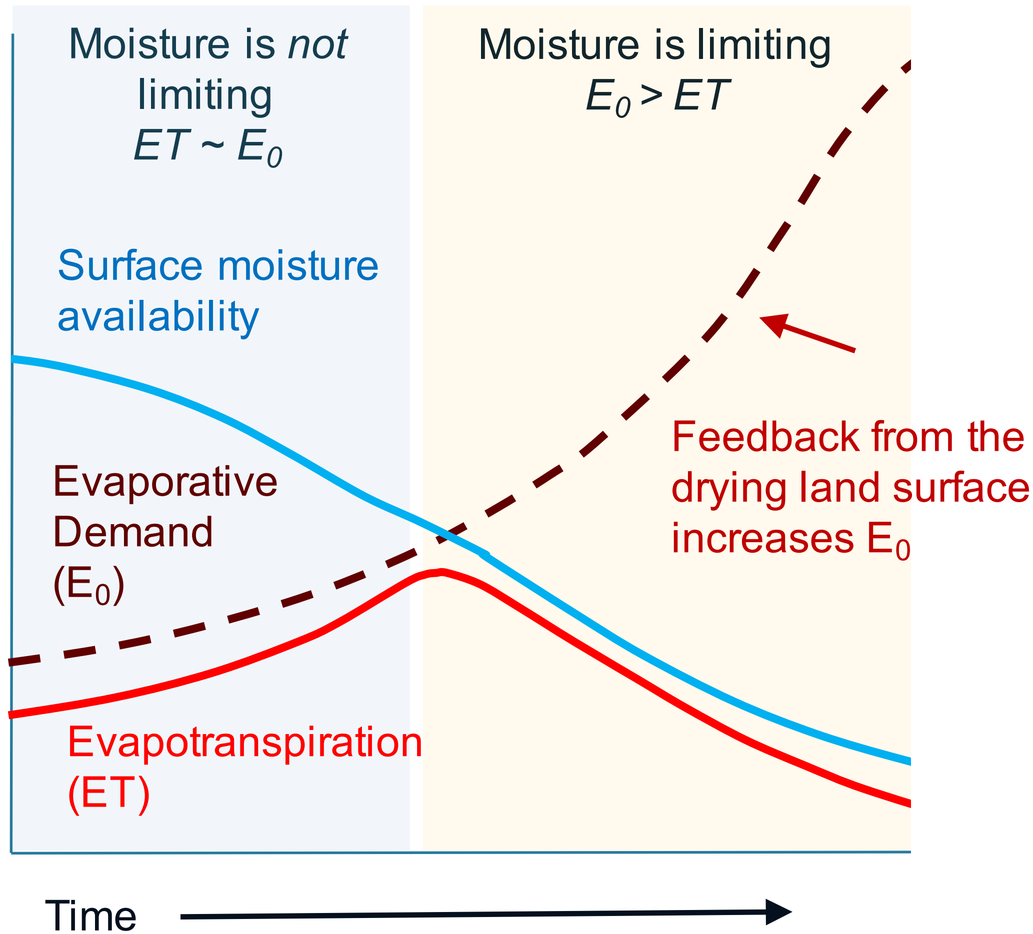


The relationship between E_0 and *ET* changes as the land surface dries out

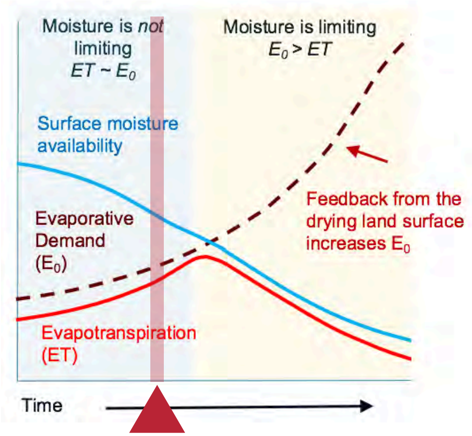
- When sufficient surface moisture is available, rising E_0 leads to rising *ET*
- When moisture is limited, *ET* declines, while E_0 rises even more steeply
- Regions with a more arid climate (yellow and red below) are often in the *moisture-limited* state under 'normal' conditions

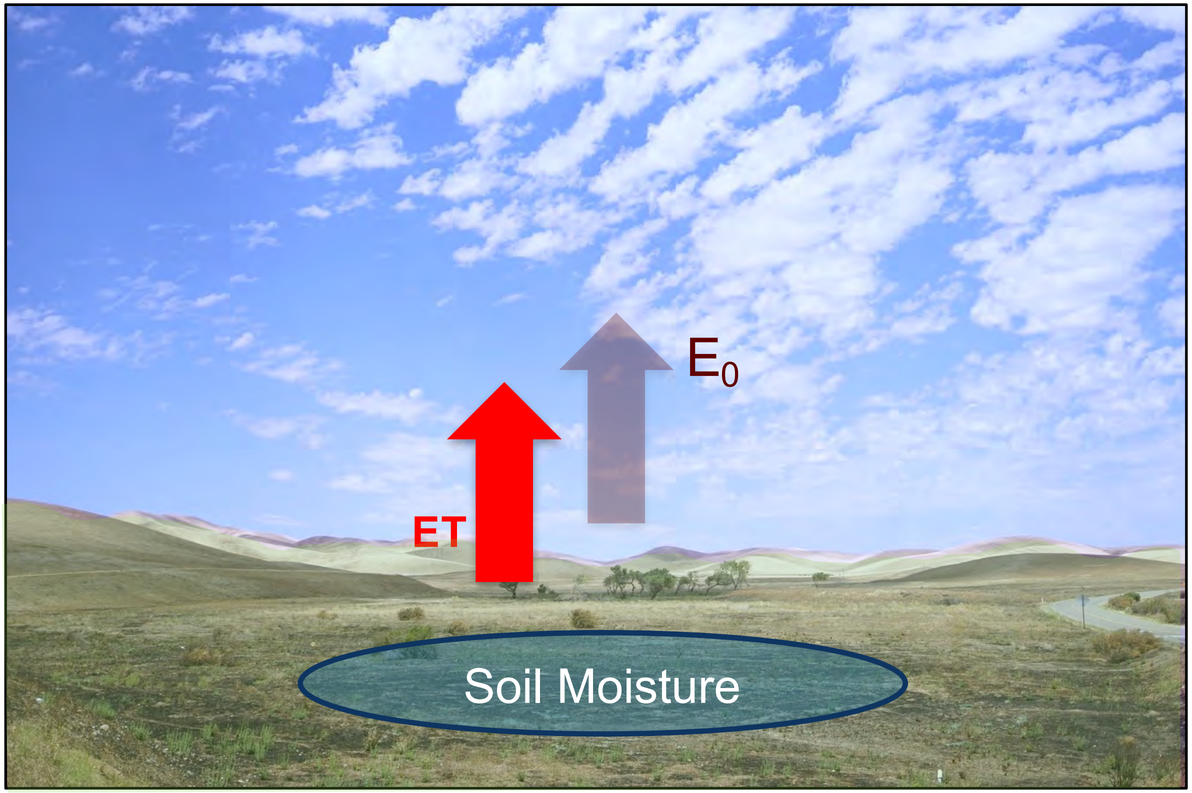




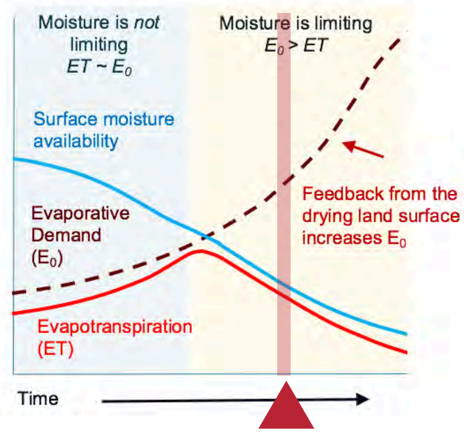


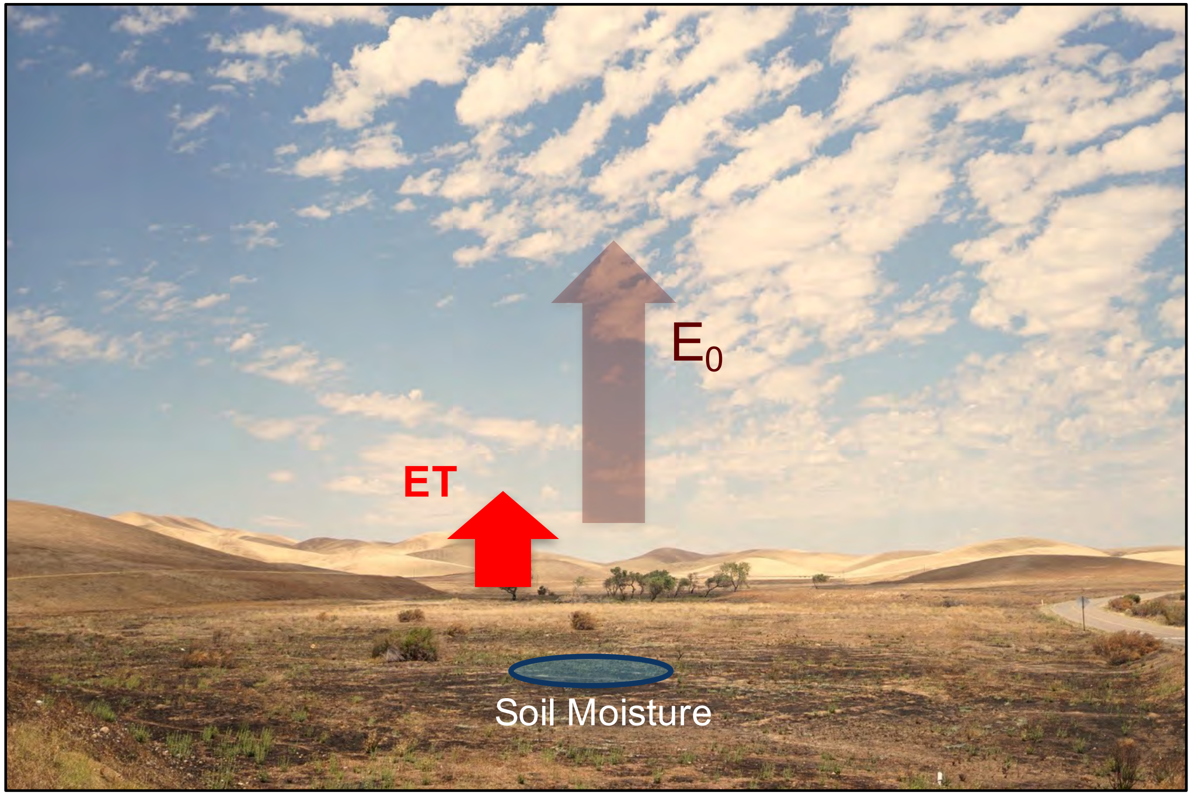
In other words: Unusually high evaporative demand (***E*$_0$**) can lead to *moisture stress* on the land surface, and ultimately to *drought*—even when precipitation has been near-normal



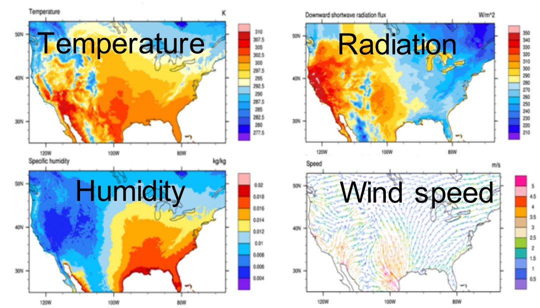


Once drought has developed, the now-dry land surface makes the air above the surface warmer and drier—which further increases **evaporative demand**





How EDDI is calculated



Start with meteorological inputs for each gridcell (temperature, humidity, wind speed, solar radiation)
from NLDAS-2, 1/8-degree gridded met data

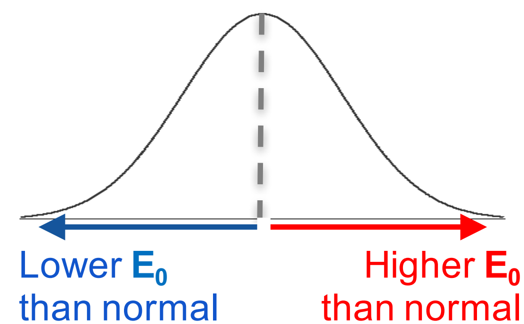
Calculate daily *Reference ET* (ET_0; estimate of $\mathbf{E_0}$) and aggregate it over the selected time window
using the ASCE variant of the Penman-Monteith equation*

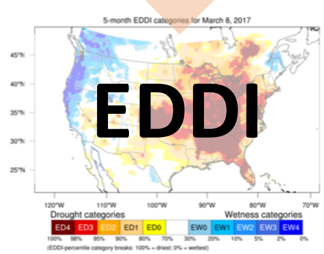
Radiation Temperature Humidity

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

Wind speed

Determine where that aggregated $\mathbf{E_0}$ value slots into the climatology (1980-present) for each gridcell
using rank-based non-parametric probabilities

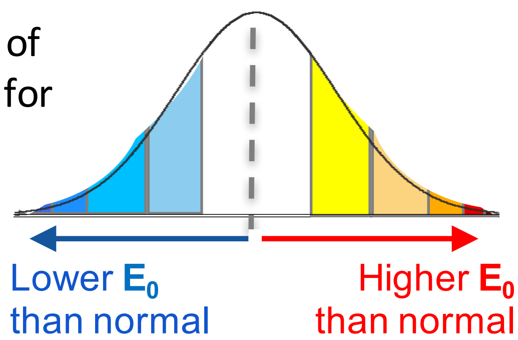


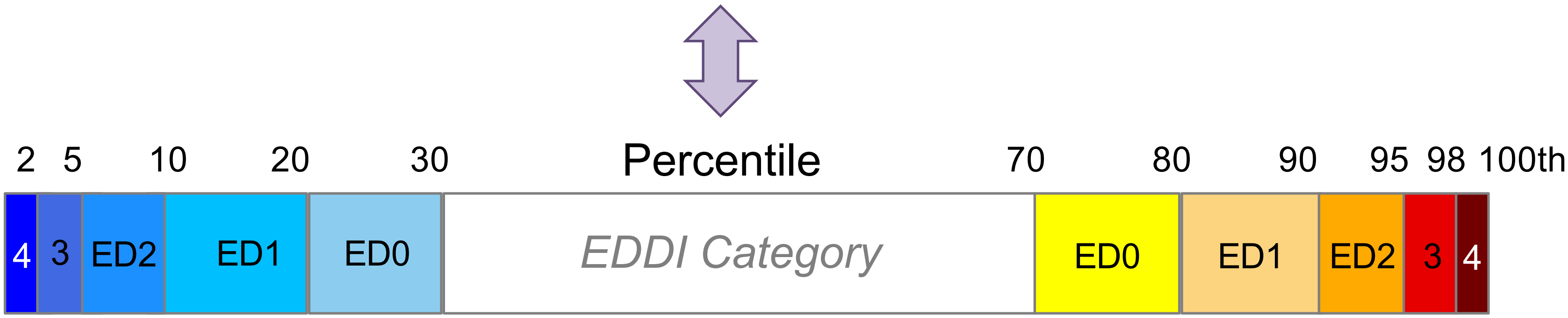


*identical to the FA0 56 variant of the Penman-Monteith at daily timescales

EDDI categories are derived from the distribution of aggregated E_0 values; selected percentiles used as thresholds for the categories

Observed distribution of E_0 from 1980-present for the given location and time window



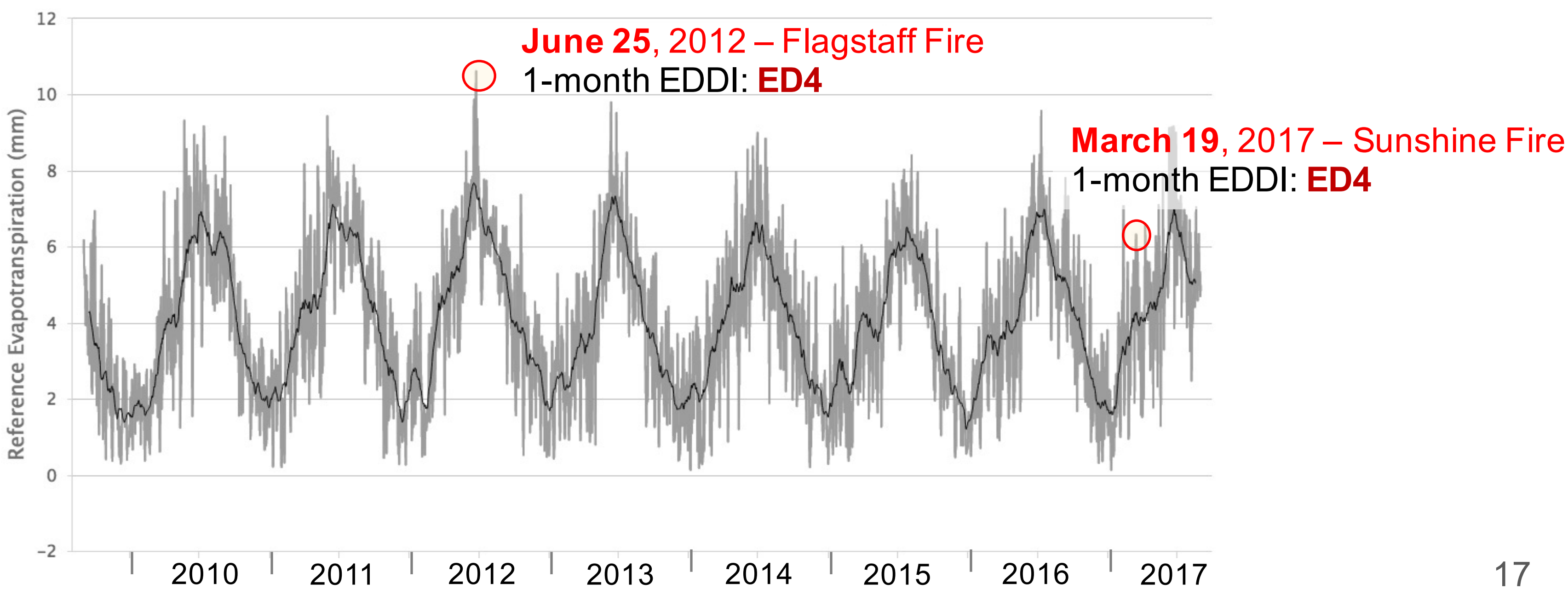


On the dry end, EDDI uses the same percentile breaks as in the US Drought Monitor

In the summer, any given EDDI category will reflect a much larger aggregated E_0 value than in other seasons

- So when EDDI is in a drought category during the summer, the drought impacts are generally greater than during the cooler seasons
- That said, emergence of ED3 or ED4 in other seasons can still indicate high risk of significant impacts, such as wildfires (below, Sunshine Fire)

Daily $\mathbf{E_0}$ for Boulder, CO, with 30-day running mean (2009-2017)

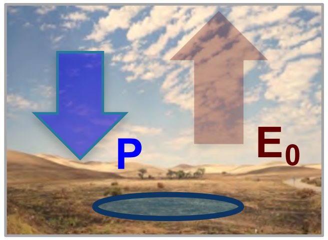


How the physical basis of EDDI compares with other drought indicators - part I

EDDI
Anomaly in estimated Evaporative Demand (E_0) over a user-selected time window, where E_0 is estimated from observed Temperature, Humidity, Wind speed, and solar Radiation

SPI (Standardized Precipitation Index)
Anomaly in observed Precipitation (P) over a user-selected time window of interest

SPEI (Standardized Precipitation-Evapotranspiration Index)
Anomaly in the difference between observed Precipitation (P) and estimated Potential Evapotranspiration (PET; equivalent to E_0*) over a user-selected time window



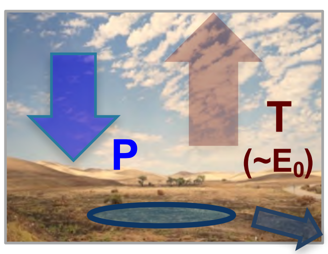
PDSI (Palmer Drought Severity Index)
Simulated soil-moisture balance anomaly, calculated from observed Precipitation (P) and an estimate of E_0*, with an effective time window of ~6-12 months

*Some sources of SPEI and PDSI maps and data use a fully physical estimate of E_0; others use a rough estimate of E_0 from Temperature only

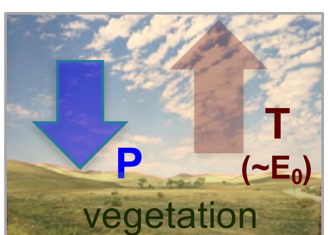
How the physical basis of EDDI compares with other drought indicators - part II

EDDI
Anomaly in estimated Evaporative Demand (E_0) over a user-selected time window, where E_0 is estimated from observed Temperature, Humidity, Wind speed, and solar Radiation

ESI (Evaporative Stress Index)
Anomaly in the ratio of ET to E_0, where ET is calculated using leaf-area index (LAI) and land-surface Temperature from satellite data, and E_0 is from a fully physical estimate, over a user-selected time window

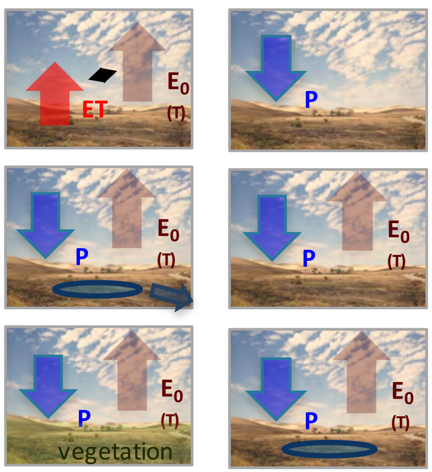


USDM (U.S. Drought Monitor)
Quasi-objective blend of multiple drought indicators: SPI, Palmer Indices, modeled soil moisture, observed streamflow, reported drought impacts, and other indicators; inherent time window varies by season/region



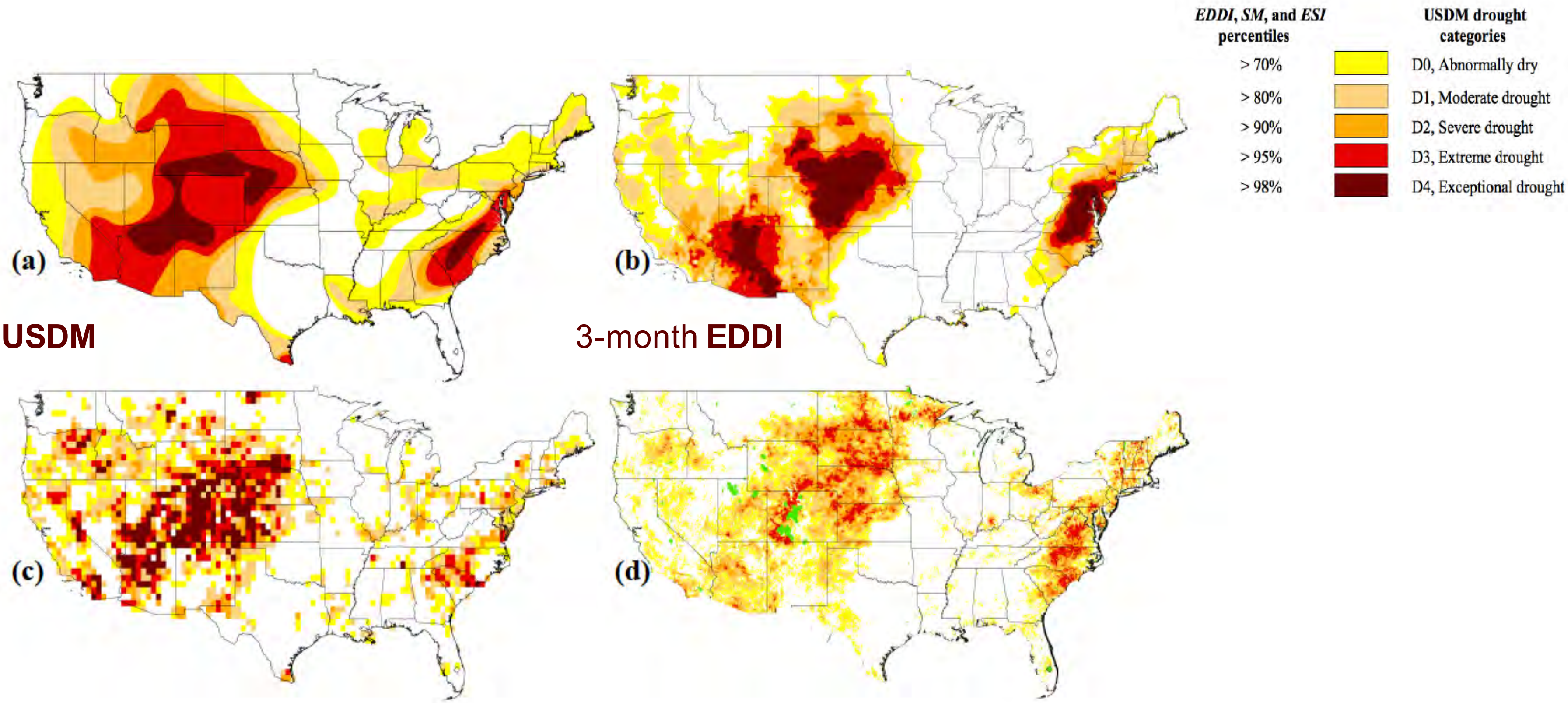
VegDRI
Blend of multiple drought indicators: 9-month SPI, Palmer Index, and satellite-sensed vegetation greenness and leaf-out anomaly; effective time window of several months

It's good practice to compare different drought indicators



- EDDI and the other indicators capture different aspects of the moisture balance at the land surface; EDDI is unique in focusing on evaporative demand
- Different indicators also have different time windows over which conditions are aggregated—whether the window is user-selected or “baked into” that index
- Thus, different indicators can speak to some drought impacts better than others
- Looking at multiple indicators provides a “convergence of evidence”, e.g., to support a drought designation
- The differences between indicators can also provide insight into how drought conditions are emerging and causing impacts

For example, the 3-month EDDI for May-July 2002 shows a drought pattern very similar to other indicators used for *agricultural* drought impacts ("convergence of evidence")



USDM

3-month **EDDI**

VIC-modeled **Soil Moisture**

3-month **Evaporative Stress Index (ESI)**

July 31, 2002

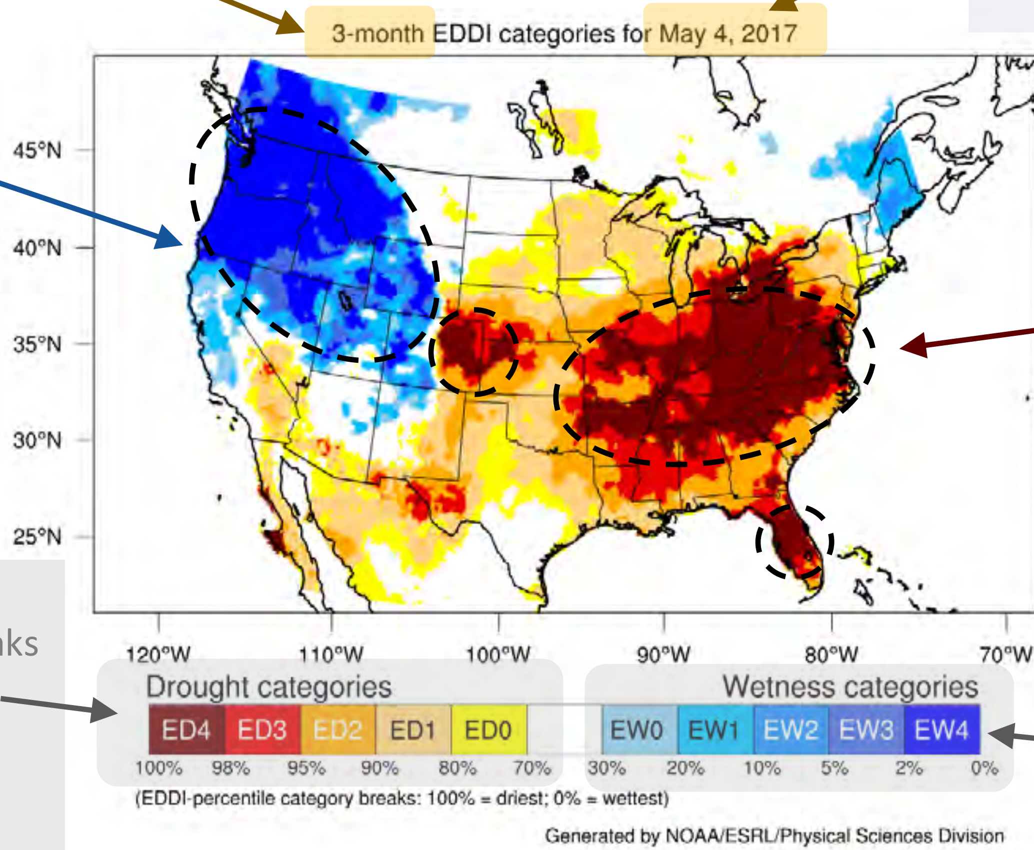
EDDI Evaporative Demand Drought Index

The basics of reading an EDDI map

An “EDDI month” is 30 days, so this 3-month map is based on evaporative demand from February 4 to May 4, 2017 (90 days).

The most recent EDDI maps lag the current date by ~5 days—so this map was released around May 9, 2017

Evaporative demand was unusually **low** for Feb 4-May 4 in the Pacific Northwest into the Rockies.



Evaporative demand was unusually **high** for Feb 4-May 4 in the Ohio Valley, Florida, and the western Great Plains. (ED4 means that conditions this dry are expected in only 2% of Feb 4-May 4 periods.)

The names, colors, and percentile breaks for the drought categories are analogous to those for the US Drought Monitor.

The Drought and Wetness categories for a given number have the same expected frequency (e.g., ED2 and EW2).

EDDI Evaporative Demand Drought Index

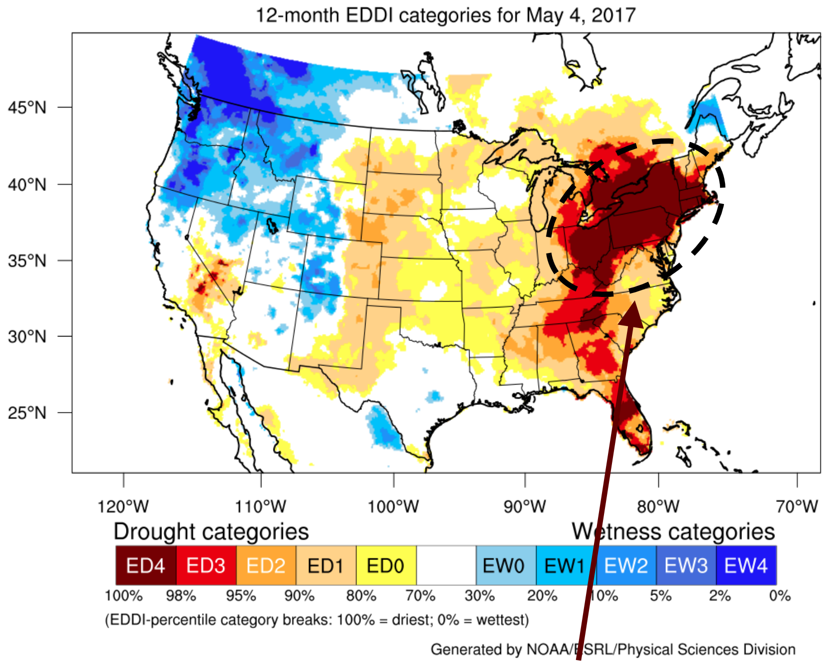
Interpreting EDDI at different time scales

The simple version:

Long-term (>3-month)= drought has emerged or is persisting

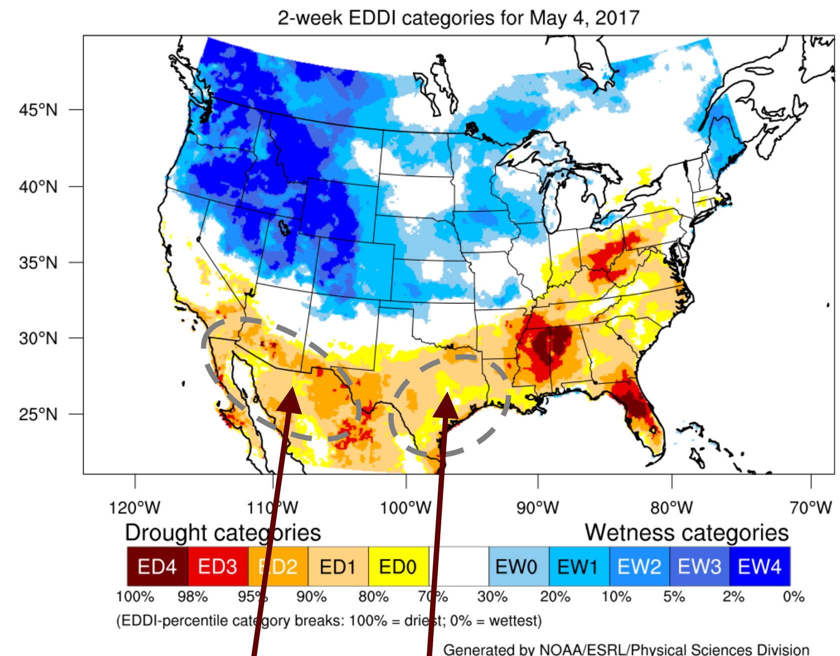
Short-term (2-week to 3-month)= *potential* for drought emergence/intensification

12-month EDDI



Unusually high evaporative demand over past 12 months in southern New England and Ohio Valley reflects persistently dry surface conditions (i.e., drought)

2-week EDDI

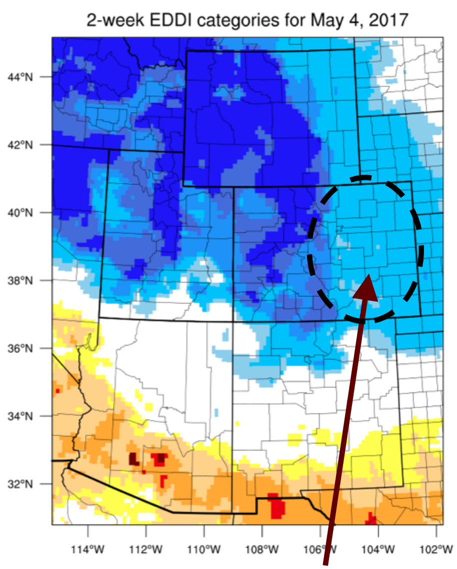


Above-normal evaporative demand over 2 weeks in Southwest and Southern Plains could signal drought emergence

Interpreting EDDI at different time scales

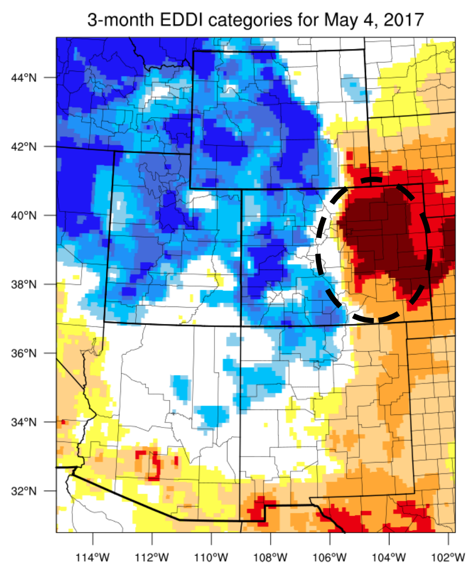
By comparing different time windows, you can infer changes and trends

2-week
(Apr 21 – May 4)



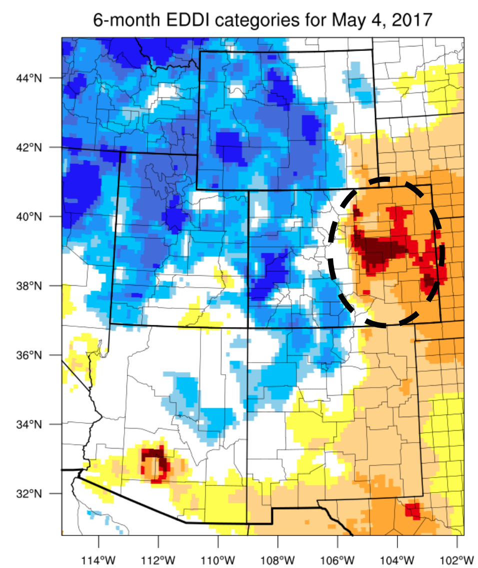
Eastern Colorado
Most recent 2 weeks have had below-normal evaporative demand (EW1), a change from prior above-normal demand

3-month
(Feb 5 – May 4)



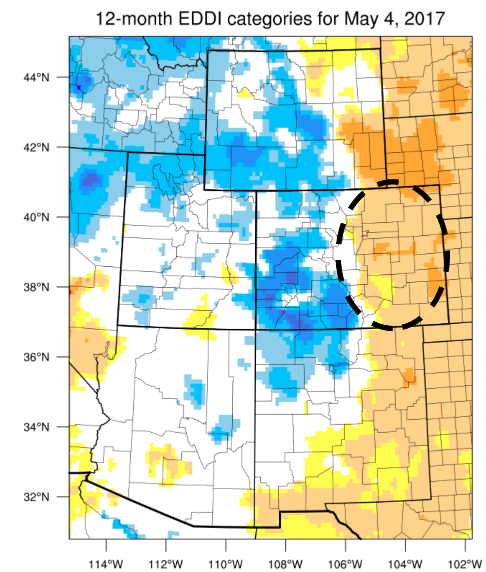
Overall, early spring had unusually high evaporative demand (ED3 and ED4), strongly indicating drought emergence

6-month
(Nov 5 – May 4)

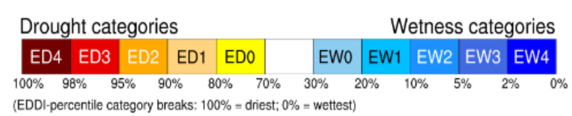


Winter and early spring had high evaporative demand overall (ED1-ED4), with higher values for early spring than for winter

12-month
(May 5 - May 4)

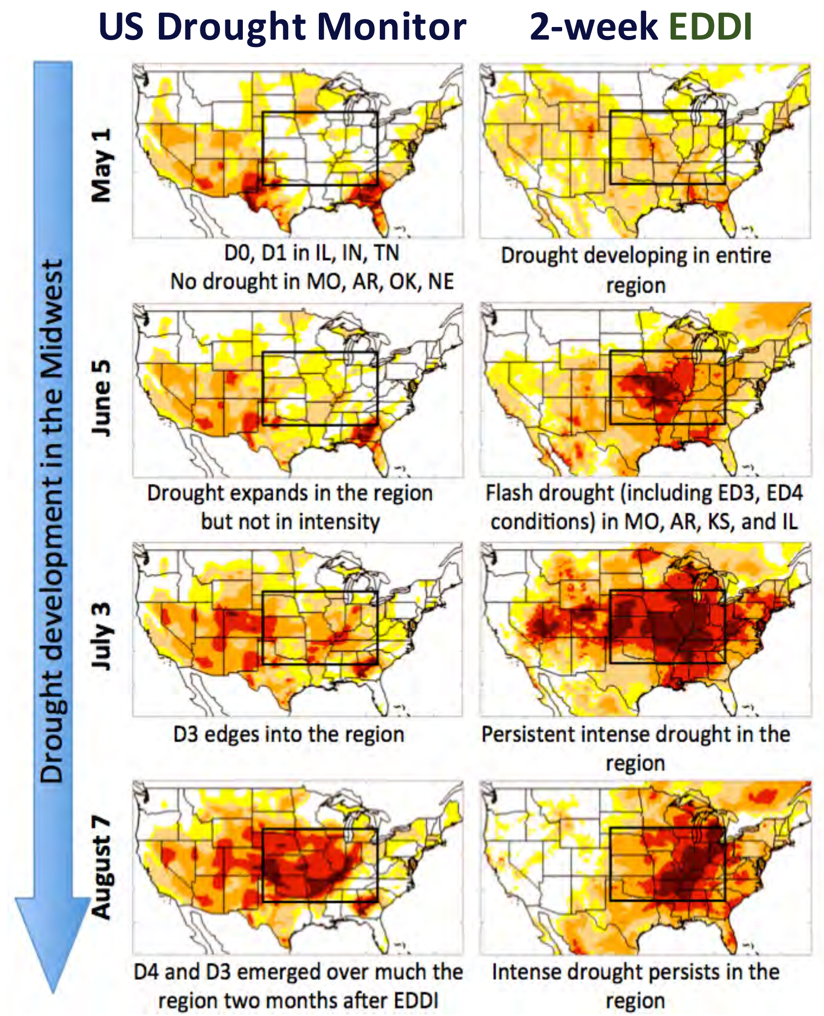


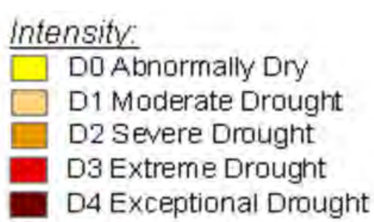
The past 12 months saw high evaporative demand overall (mainly ED1), led by the very high values in winter and early spring



EDDI can give early warning of *flash drought*—i.e., rapid-onset drought that develops in several weeks

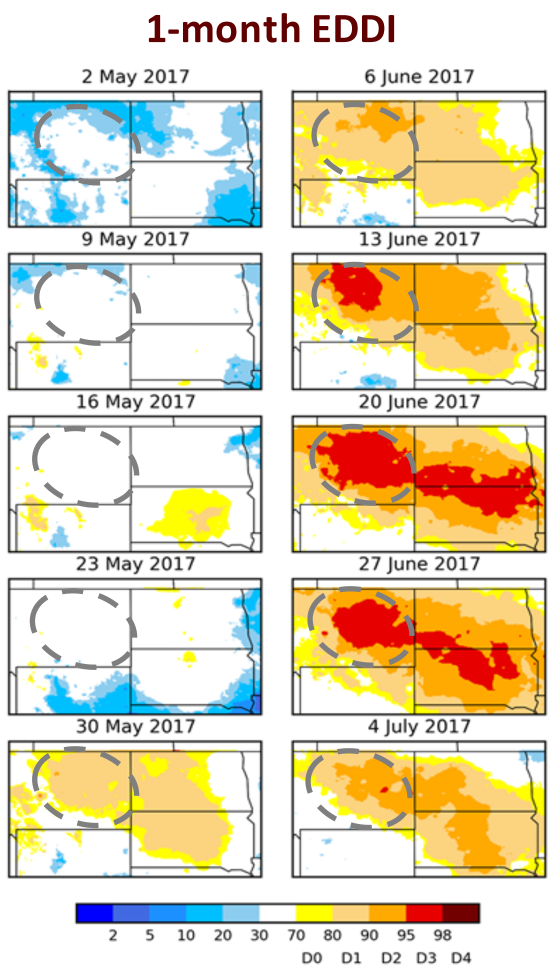
- In May-July 2012, the 2-week EDDI captured severe drought conditions in the Midwest up to ~2 months before the US Drought Monitor

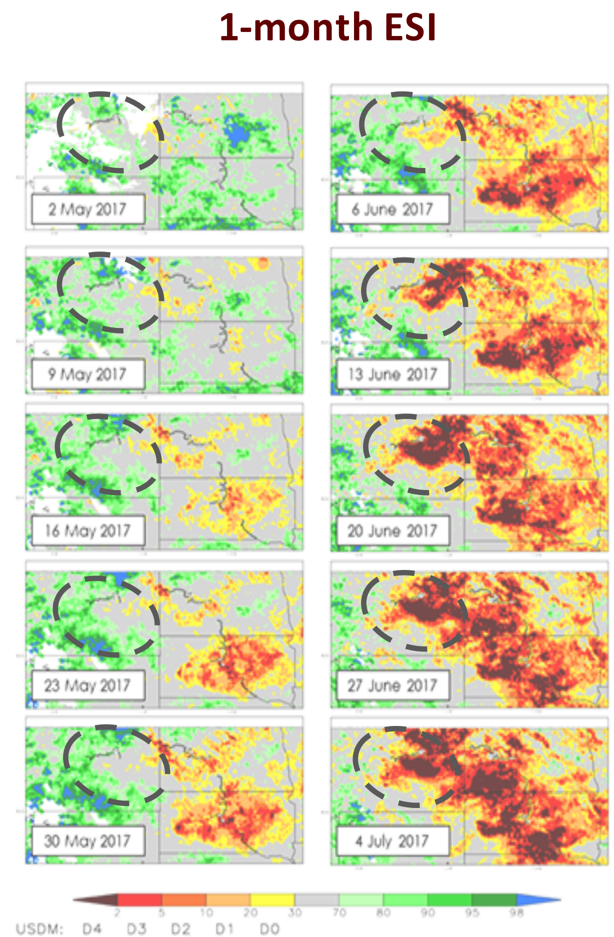




More flash-drought early warning:

In May-July 2017 in the Northern Plains, the 1-month EDDI picked up the drought signal in eastern Montana 1-4 weeks ahead of the 1-month ESI

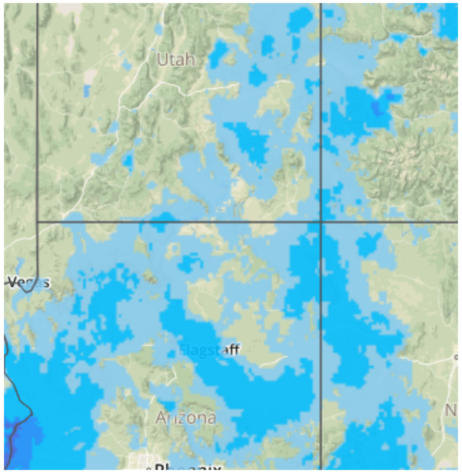




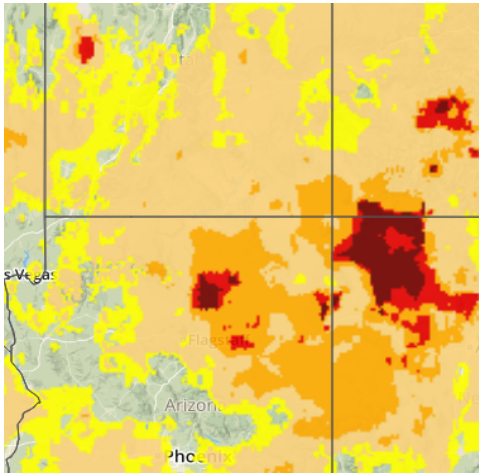
Figures: Dan McEvoy (EDDI); Chris Hain (ESI)

Keep in mind: Not all areas with new EDDI "hotspots" at short time windows (e.g., 2 weeks, 1 month) will see persistence of dry conditions and emergence of drought impacts, but many will—so they are worth keeping an eye on, especially in spring and summer

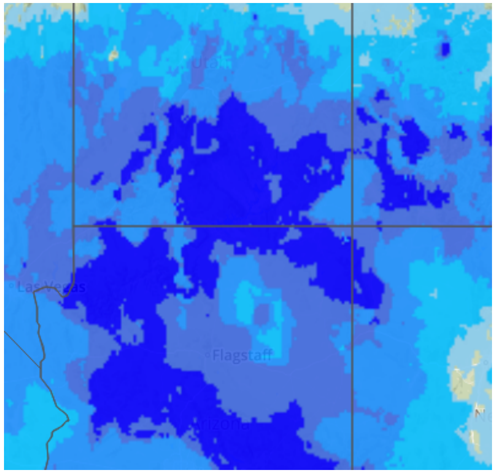
1-month EDDI in Four Corners region (UT, CO, AZ, NM)



June 4, 2017
Evaporative demand normal or low across region



July 4, 2017
Unusually high evaporative demand in June – which is typically a dry month anyways – WATCH OUT



August 4, 2017
OK - July monsoon rains came in well above normal; unusually low evaporative demand

Agricultural drought monitoring with the 2-week EDDI

Summer 2015 in the Wind River Indian Reservation, north-central Wyoming: EDDI shows anomalously high E_0 from early August; ag impacts occurred throughout September; USDM finally shows some drying in late September

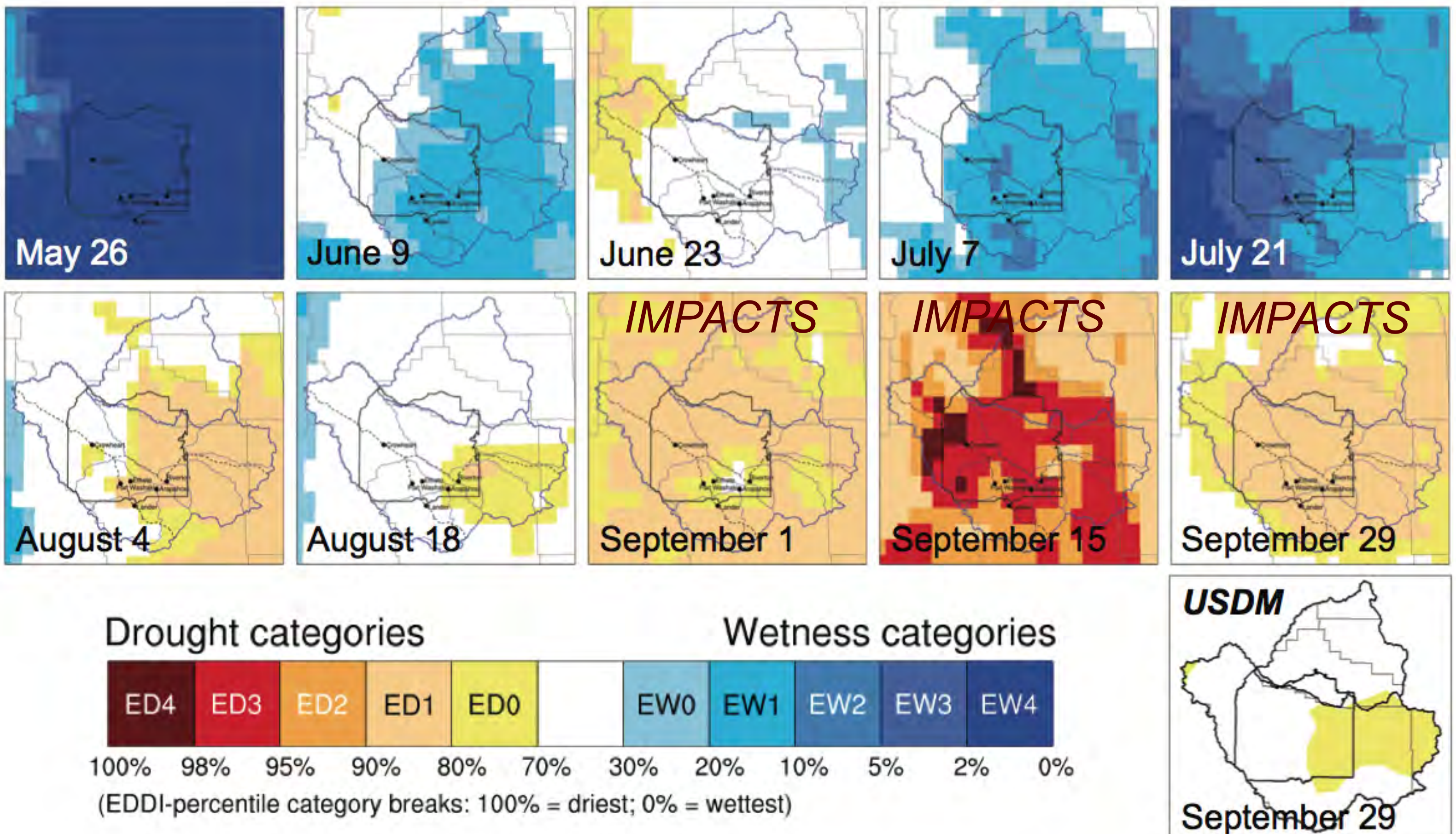


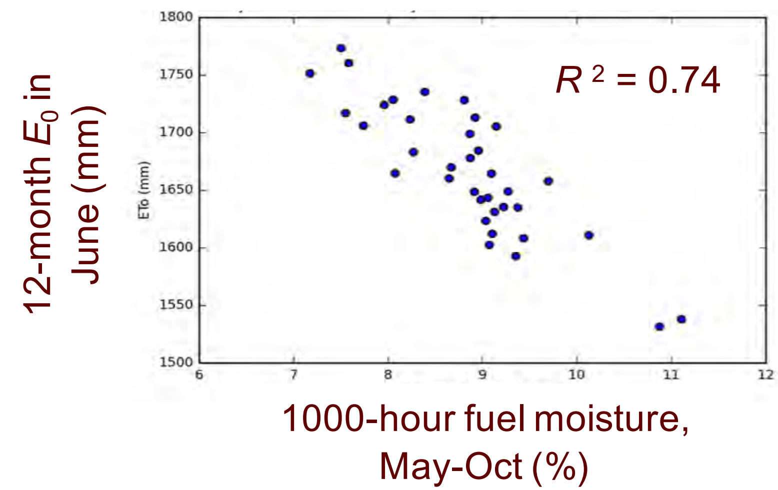
Figure: Candida Dewes, NOAA PSD

Ongoing research: Potential applications of EDDI in wildfire risk monitoring and hydrologic monitoring are being evaluated

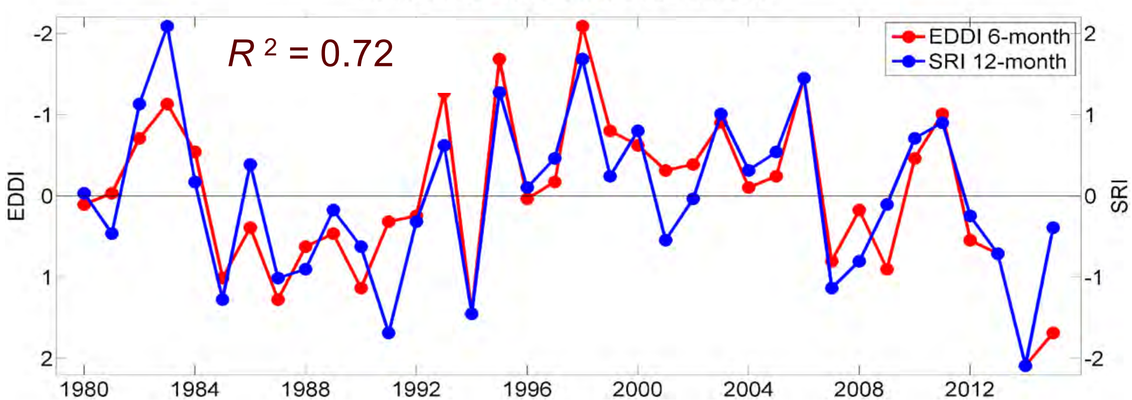
- E_0 /EDDI show strong relationships with seasonal fuel moisture (right) and seasonal runoff (below), despite not including precipitation directly

- Research is ongoing to assess the added value of EDDI relative to more traditional indicators in these fields

E_0 - fuel moisture relationship across S. California



Sacramento River Basin EDDI vs. Runoff Index (SRI)



Figures: Dan McEvoy

EDDI Evaporative Demand Drought Index

Ongoing research: Splitting evaporative demand (E_0) into its four meteorological drivers can help diagnose the causes of the demand side of drought

Example: Drought intensification (increasing E_0) was caused by:

- First, below-normal *Humidity*
- Then, increasing *Temperature* and, to a lesser degree, *Radiation*
- *Wind speed* played little role

Sacramento River basin, CA – February - July 2014

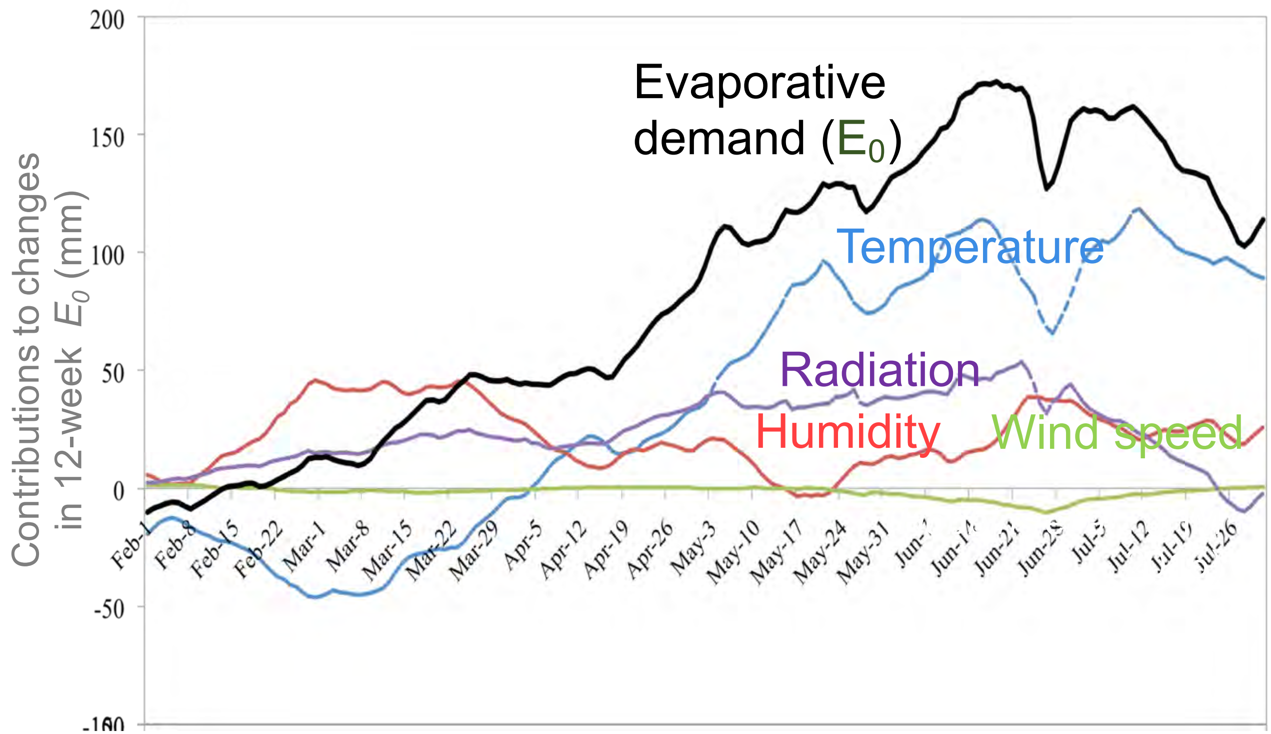
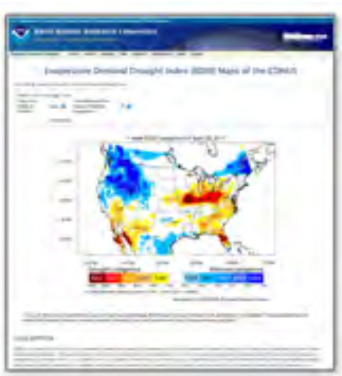


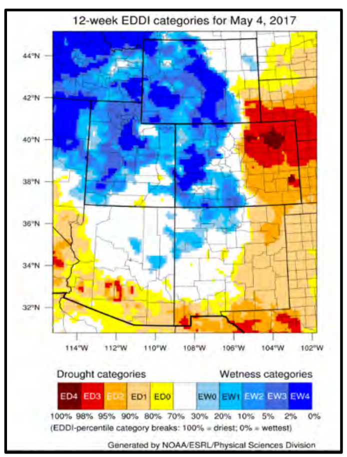
Figure: Mike Hobbins

Where to get current EDDI maps



US maps, all time windows from 1 week to 12 months:

EDDI homepage
https://www.esrl.noaa.gov/psd/eddi/
and click the "Current Conditions" tab
Or Google: EDDI drought

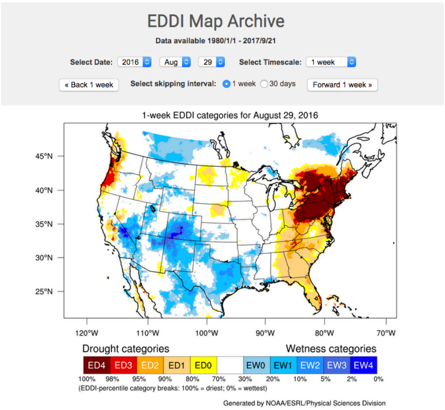


Regional maps in western US, selected time windows:

CCC-NIDIS Intermountain West Drought Briefing
http://climate.colostate.edu/~drought/

WWA Climate Dashboards
http://wwa.colorado.edu/climate/dashboard.html
http://wwa.colorado.edu/climate/dashboard2.html

Where to get past EDDI maps



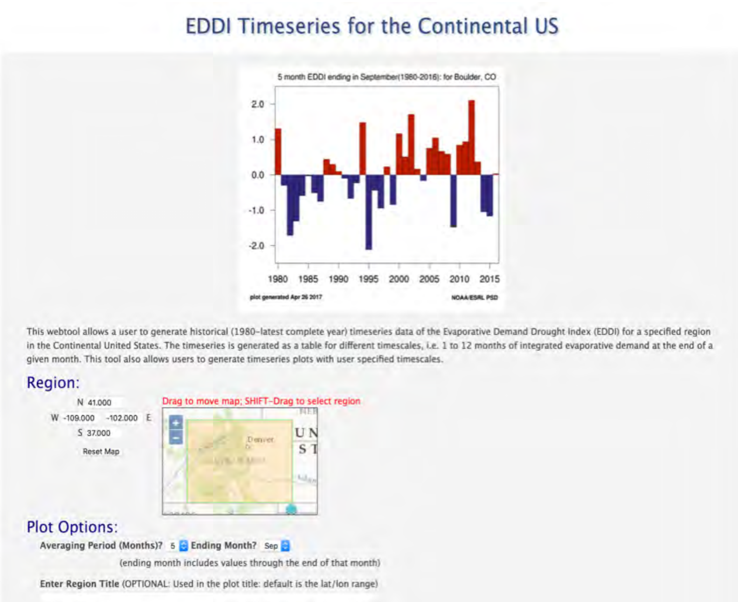
US maps, all time windows from 1 week to 12 months, from 1980 to present.

EDDI homepage – EDDI Map Archive

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

and click the "EDDI Map Archive" tab

Where to get historical time-series of EDDI



EDDI homepage
https://www.esrl.noaa.gov/psd/eddi/
and click the "Time Series" tab
Or Google: EDDI drought

Other EDDI data needs?
Contact mike.hobbins@noaa.gov or daniel.mcevoy@dri.edu

For further technical background on EDDI, see this pair of peer-reviewed papers

- M. Hobbins, A. Wood, D. McEvoy, J. Huntington, C. Morton, M. Anderson, and C. Hain (June 2016): **The Evaporative Demand Drought index: Part I –Linking Drought Evolution to Variations in Evaporative Demand.** *Journal of Hydrometeorology*, **17**(6),1745-1761, doi:10.1175/JHM-D-15-0121.1

- D. McEvoy, J. Huntington, M. Hobbins, 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.** *Journal of Hydrometeorology*, **17**(6), 1763-1779, doi:10.1175/JHM-D-15-0122.1

If you can't access these papers via the above links, or need other technical information about EDDI, contact contact mike.hobbins@noaa.gov or daniel.mcevoy@dri.edu

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  - [3]Western Water Assessment, CIRES, University of Colorado
  - [4]DOI North Central Climate Science Center