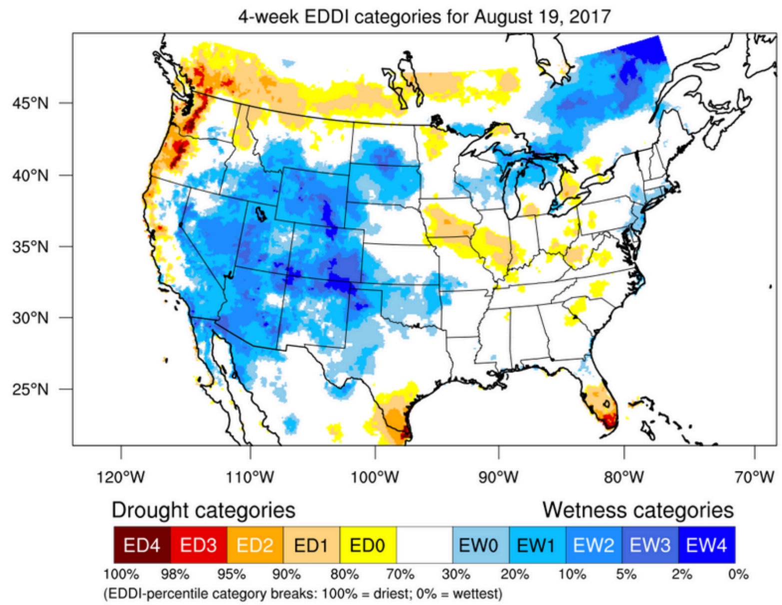
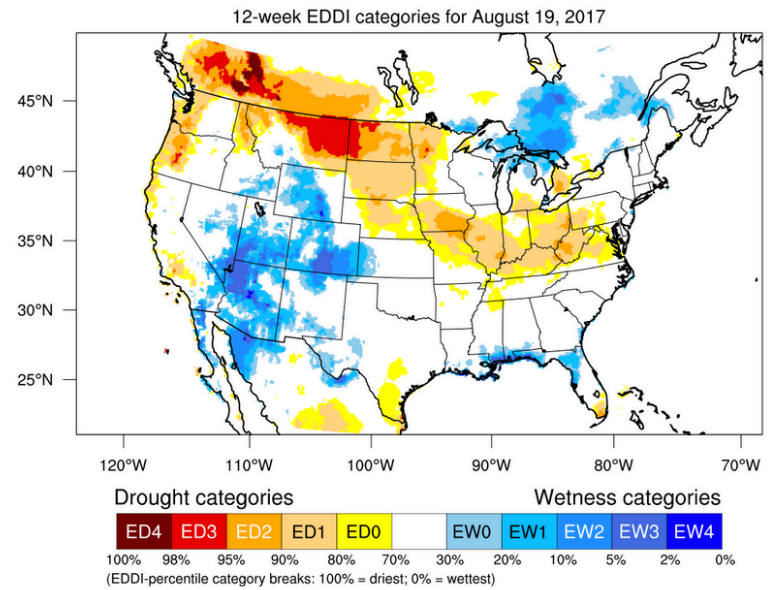
EDDI Evaporative Demand Drought Index





The EDDI User Guide

DRAFT 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 WATER ASSESSMENT A NOAA RISA TEAM

NORTH CENTRAL CLIMATE SCIENCE CENTER UNIVERSITY CONSORTIUM

Contents

Who is this User Guide 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 or conduct broader dissemination of 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 [link to slide 3x].

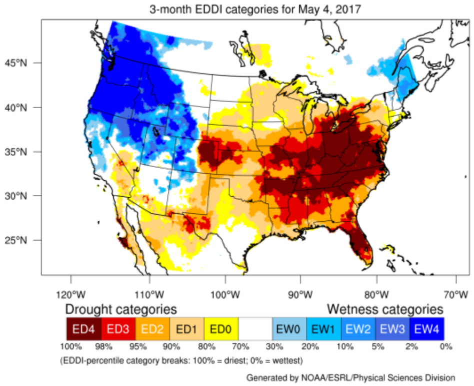
What is this User Guide intended to provide?

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 timescales

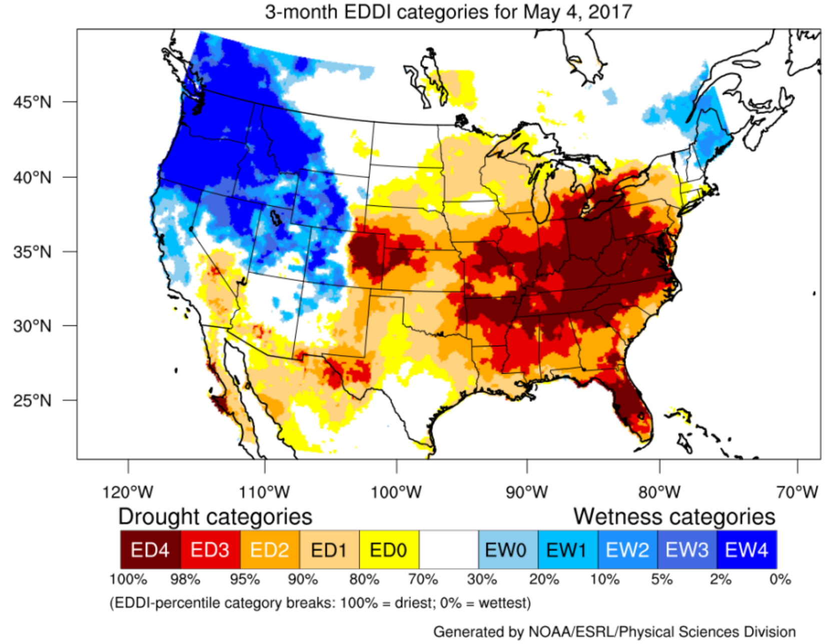
This User Guide will be updated based on user feedback. Please let us know if it was helpful, and how it might be improved.

Contact Jeff Lukas, lukas@colorado.edu.



What is EDDI?

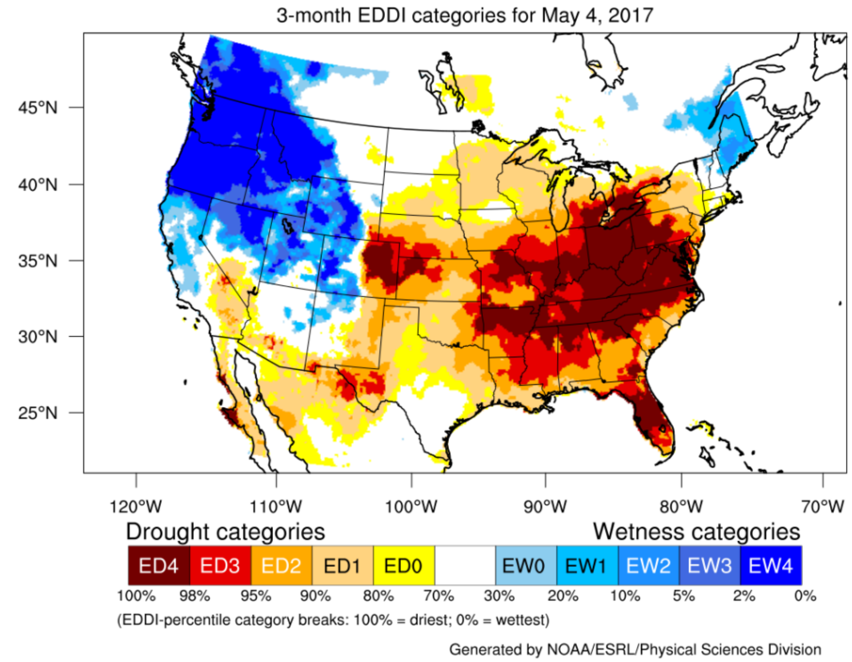
- EDDI is a drought index that depicts the “thirst” of the atmosphere—which leads to the drying of soils and vegetation, and also reflects that drying
- More technically: EDDI shows the anomaly* in daily **evaporative demand** aggregated over a specified time window, at a given location
- EDDI is calculated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



*i.e., the difference between current conditions and the long-term average

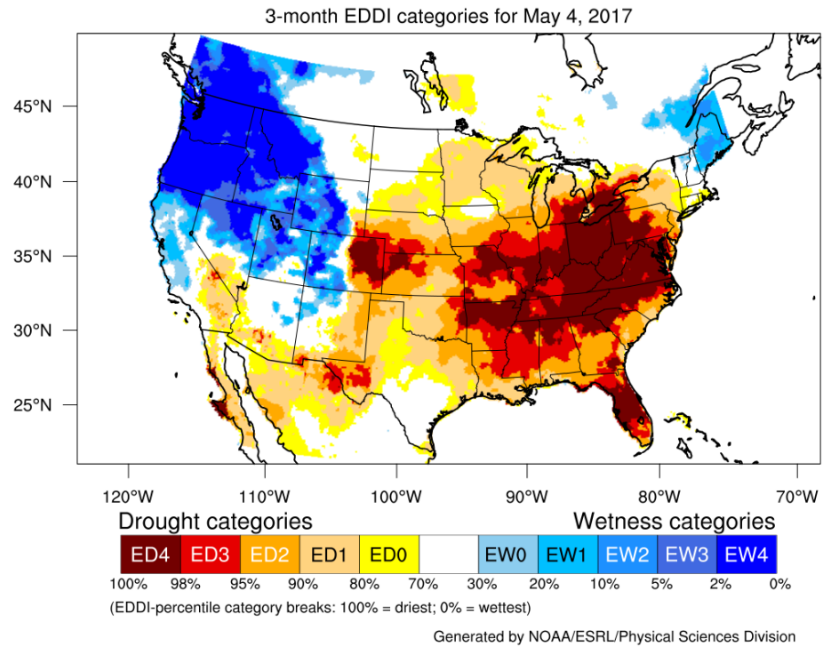
Key features of EDDI

- 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 12 km (~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's appropriate for use in all regions



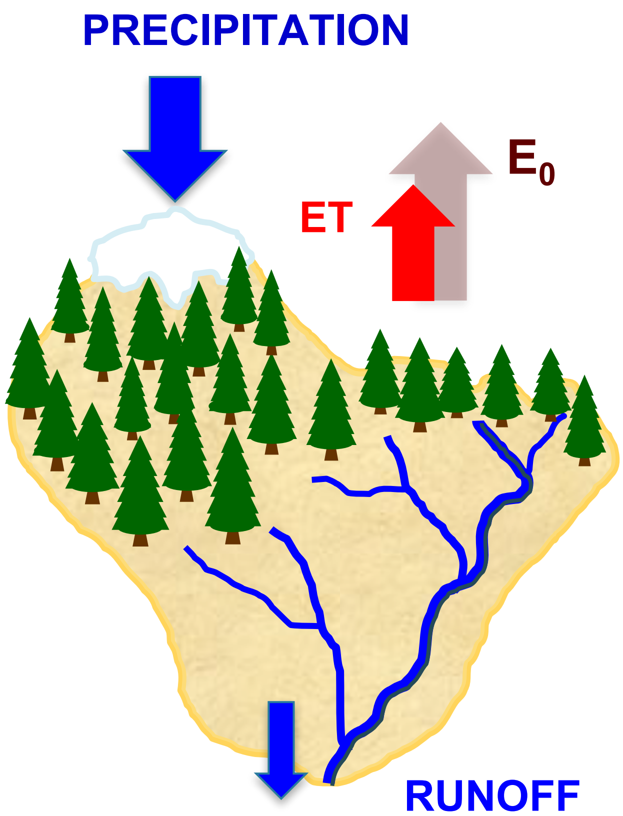
What EDDI is not

- 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



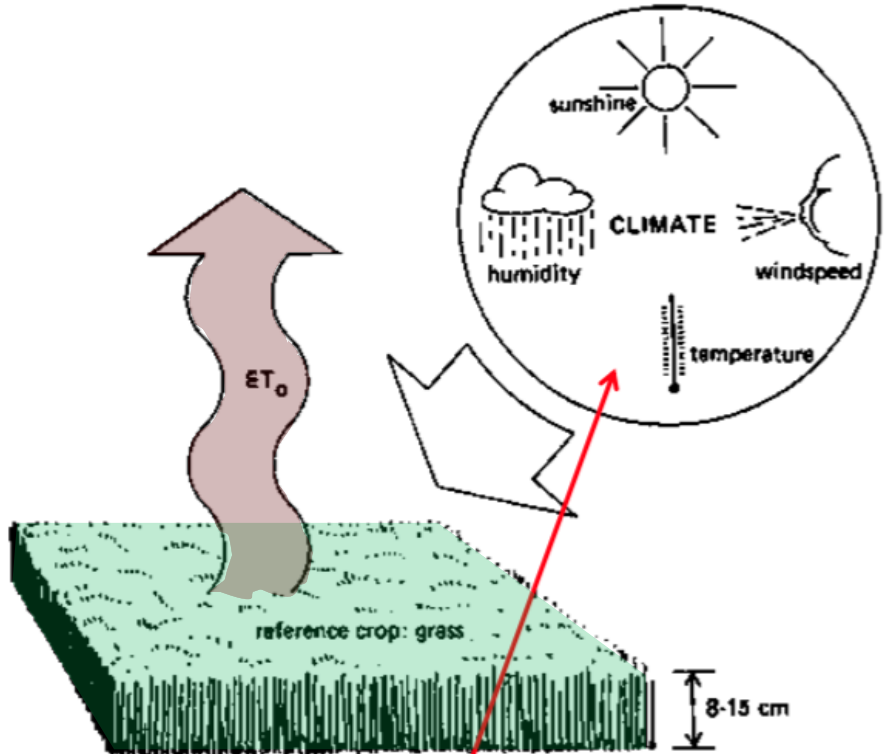
Drought is a problem of moisture imbalance at the land surface

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



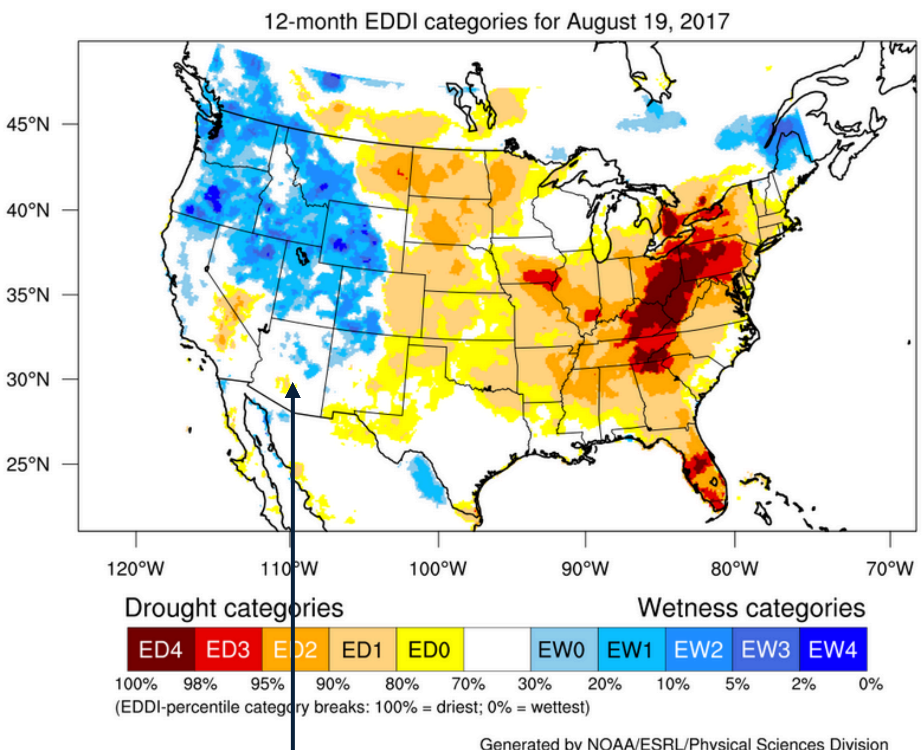
Evaporative demand (E_0) is the "thirst of the atmosphere"

- 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 in EDDI, require these variables:
  - Temperature
  - Humidity
  - Wind speed
  - Net radiation

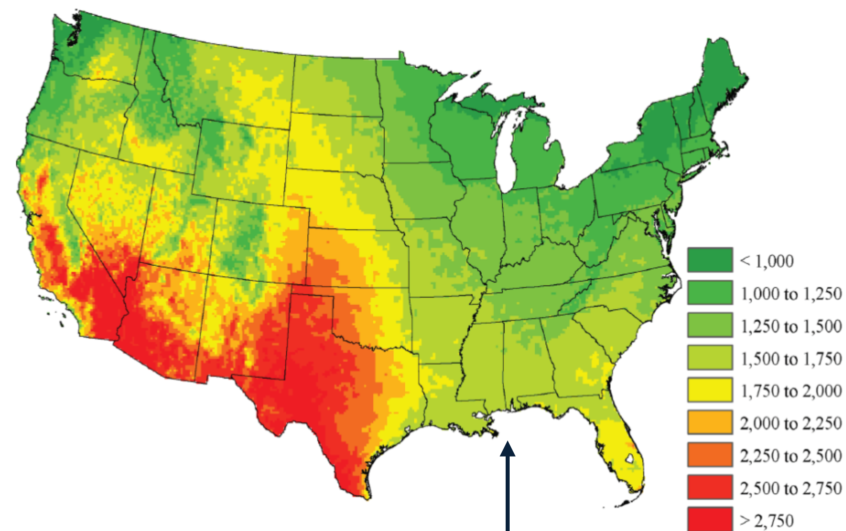


fao.org

The “normal” evaporative demand (E_0) varies substantially from place to place, so EDDI shows the *anomaly* in E_0 relative to the *local (*and *seasonal)* climatology—similar to what the SPI does with precipitation



Mean annual (12-month) $\mathbf{E_0}$ (mm), 1981-2010

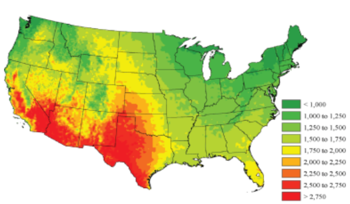


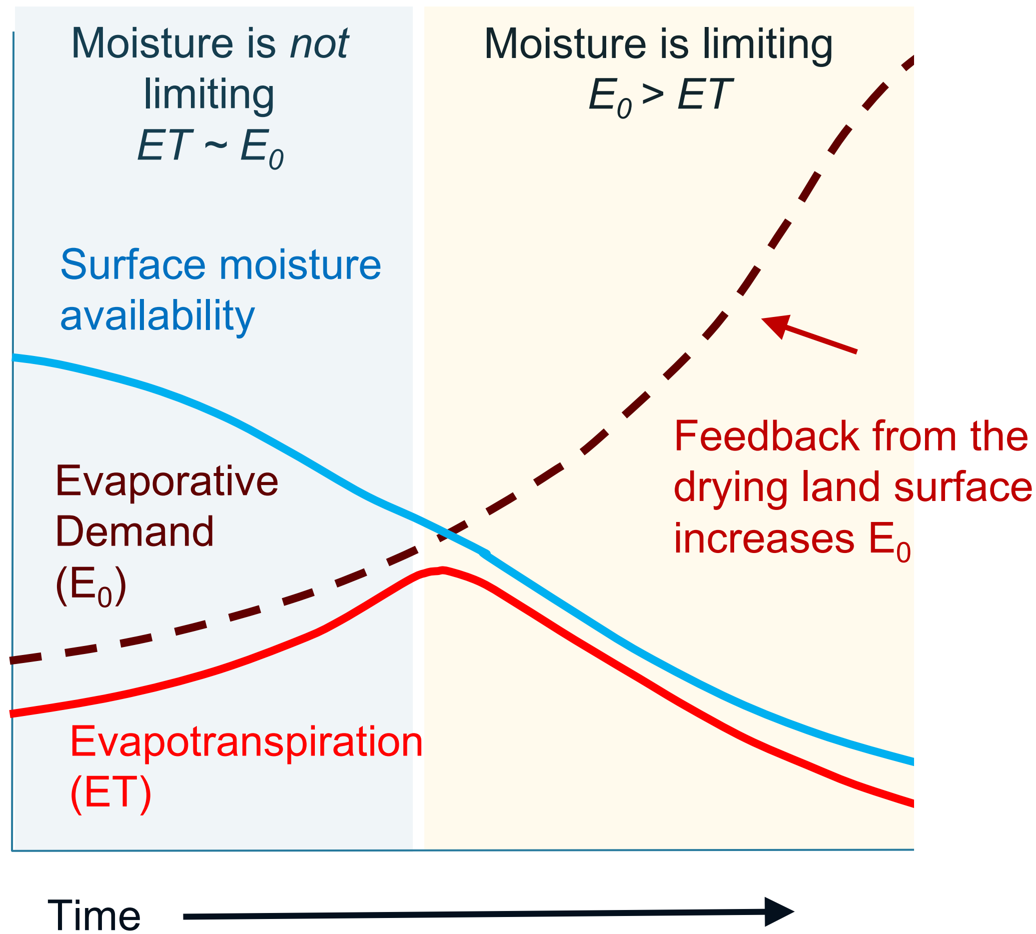
12-month EDDI categories for each gridbox are calculated relative to the **12-month climatology of** $\mathbf{E_0}$

EDDI Evaporative Demand Drought Index

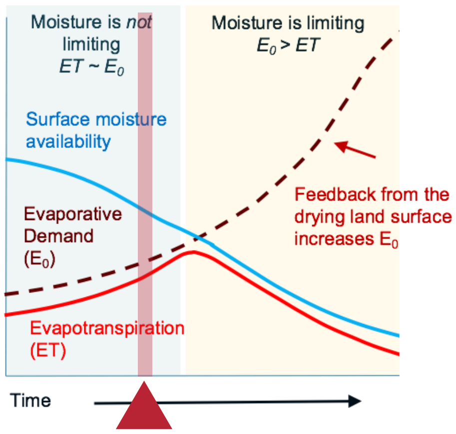
The relationship between E_0 and *ET* changes as the land surface dries out

- 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) will usually be in a *moisture-limited* state to begin with





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



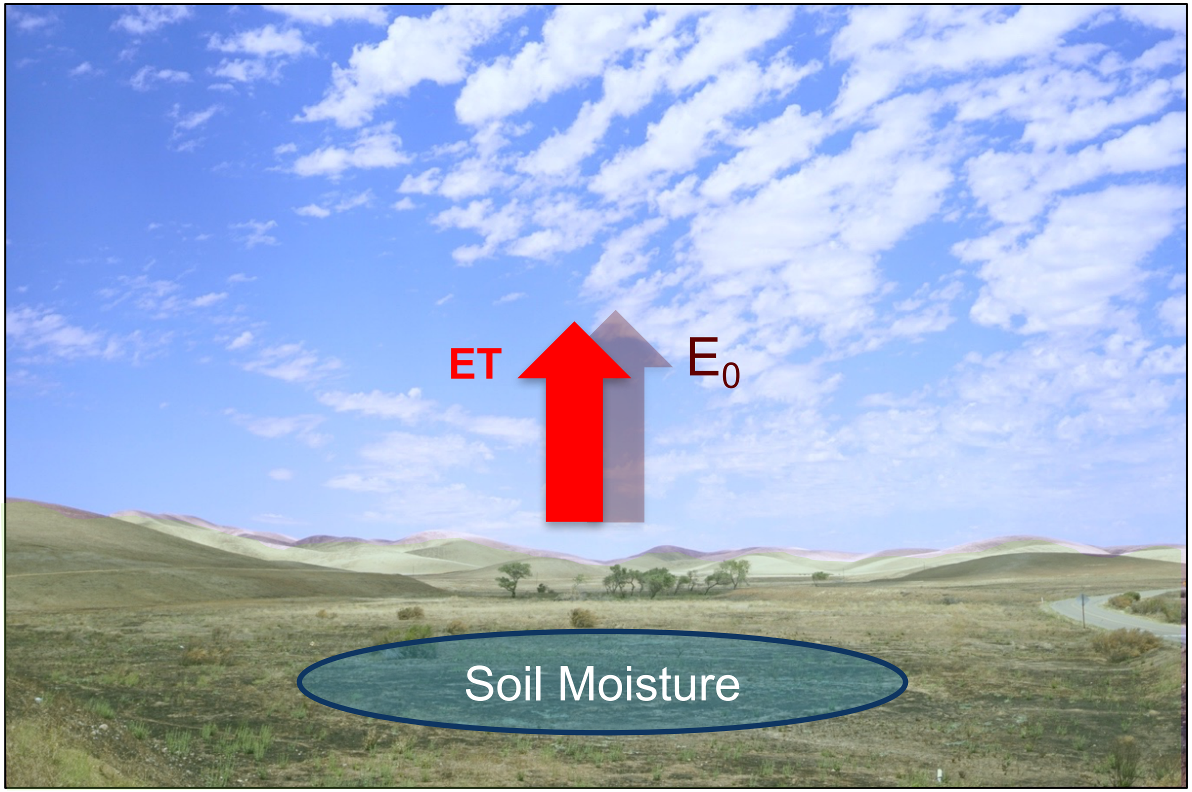
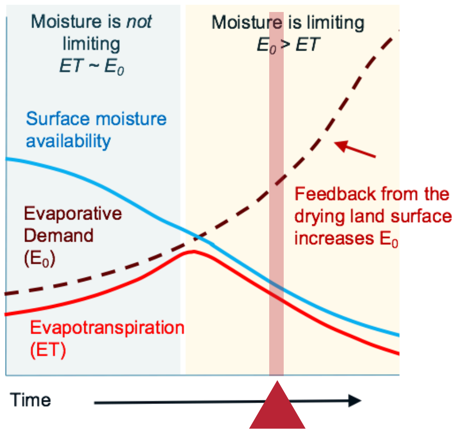


Image: pixabay.com

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



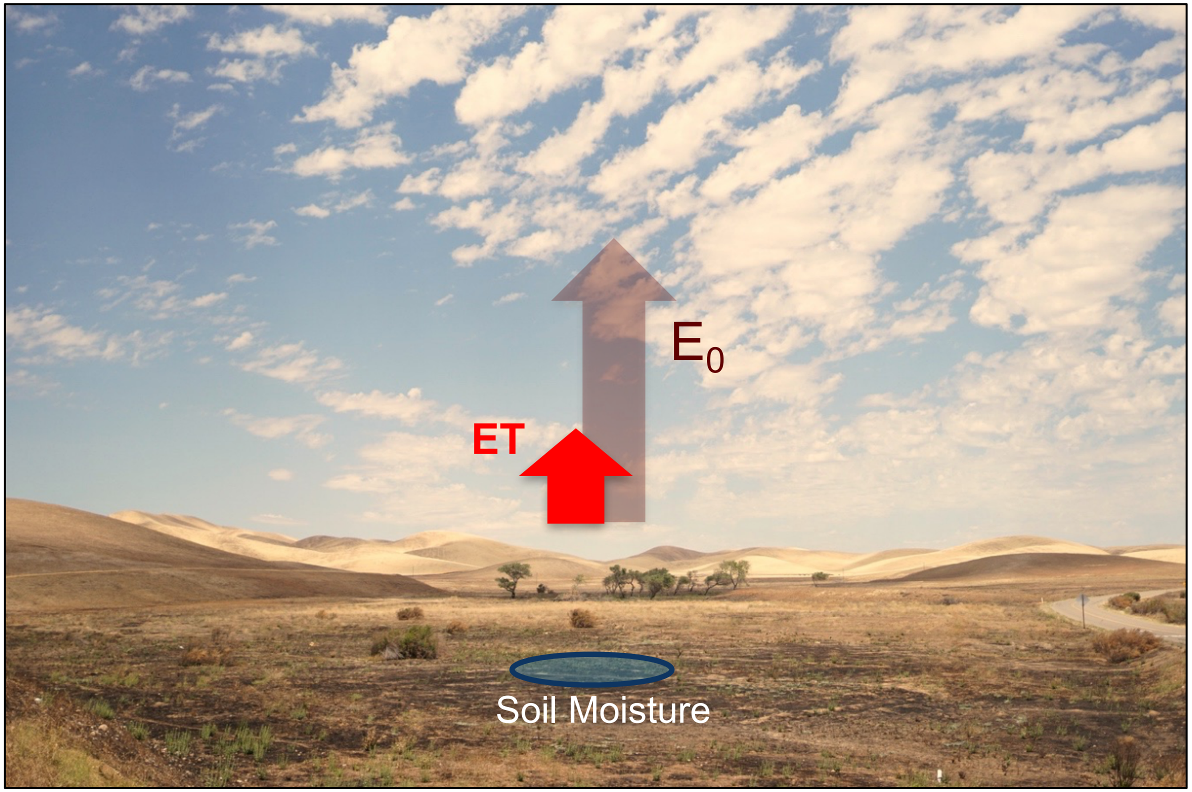
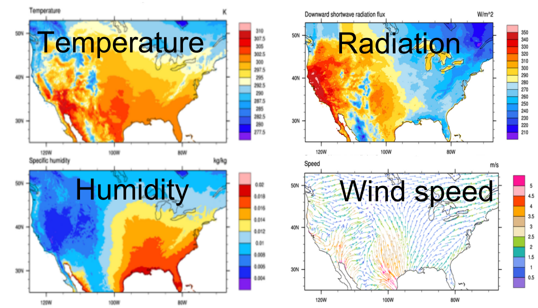


Image: pixabay.com

How EDDI is calculated

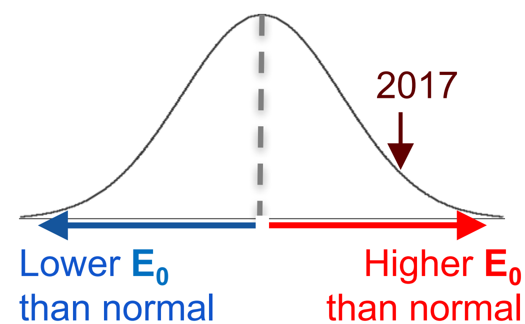
Start with meteorological inputs for each gridcell (temperature, humidity, wind speed, net radiation)
from NLDAS-2, 12km gridded met data



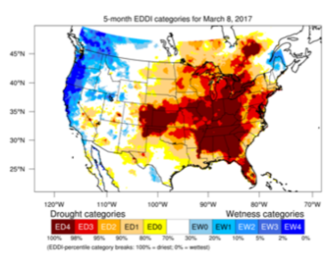
Calculate daily *Reference ET* (ET_0; same as $\mathbf{E_0}$) and aggregate over the time window of interest
using the Penman-Monteith FAO56 equation

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

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

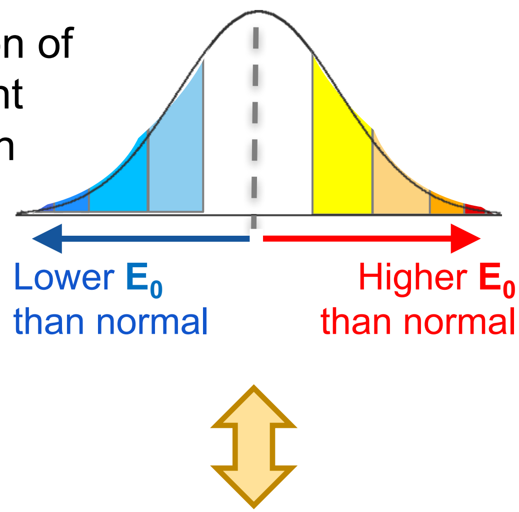


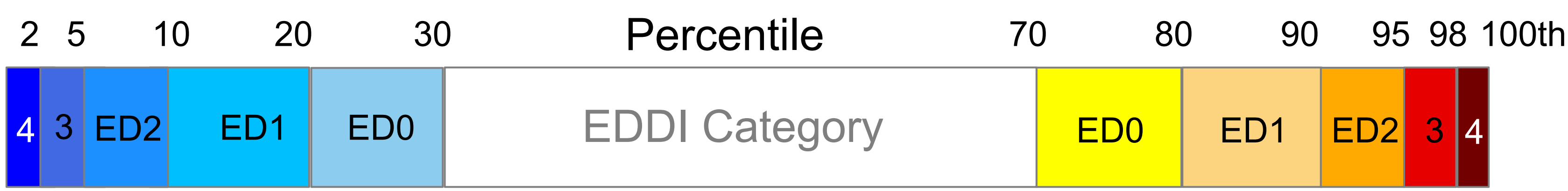
EDDI



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



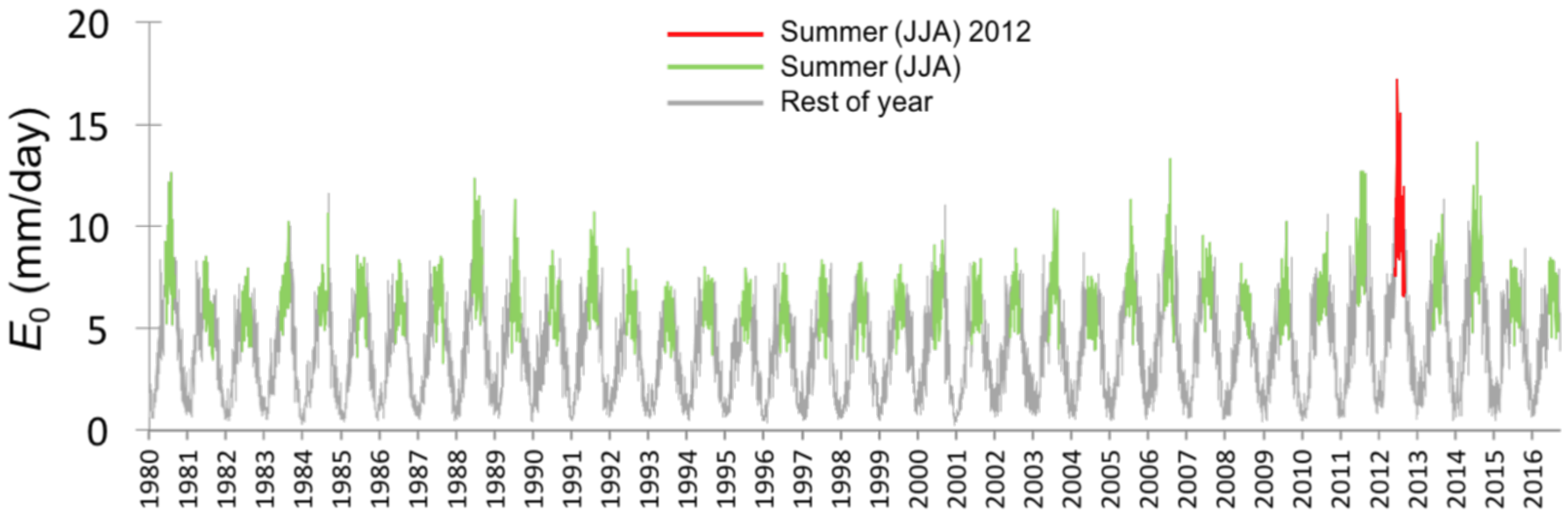


On the dry end, EDDI used the same percentile breaks as in the US Drought Monitor

Daily evaporative demand (E_0) has a large seasonal cycle

- In the warm season, a given EDDI category reflects a much larger aggregated E_0 value than in the cool season
- So when EDDI shows drought during the warm season, the land-surface impacts are generally greater than during the cool season
- That said, emergence of ED3 or ED4 in the cool season can still lead to significant impacts, like wildfires

Seasonal cycle of $\mathbf{E_0}$ for the Midwest region, 1980-2016, with summer values highlighted

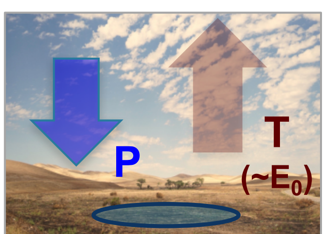


How the physical basis of EDDI compares with other drought indicators - part I

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

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

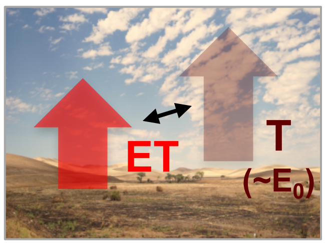
SPEI (Standardized Precipitation-Evapotranspiration Index)
Anomaly in the difference between observed Precipitation (P) and estimated Potential Evapotranspiration (PET; equivalent to E_0) over a user-selected time-window, where PET is a fully-physical calculation



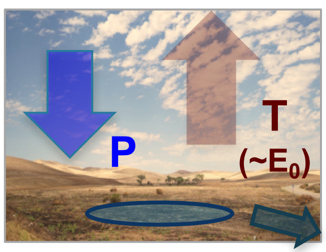
PDSI (Palmer Drought Severity Index)
Simulated soil-moisture balance anomaly, calculated from observed Precipitation (P) and Temperature (as a rough proxy for E_0), with an effective time-window of ~6-12 months

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

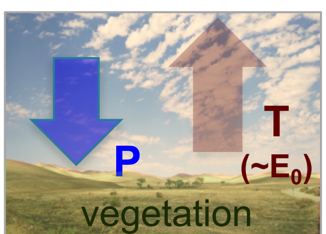
EDDI
Anomaly in estimated Evaporative Demand (E_0) over a user-selected time-window, where E_0 is calculated from observed Temperature (T), Humidity (H), Wind speed (W), and net Radiation (R)



ESI (Evaporative Stress Index)
Anomaly in the ratio of ET to E_0, calculated by an energy-balance model using satellite-sensed leaf-area index (LAI) and land-surface Temperature (proxy for E_0), over a user-selected time window

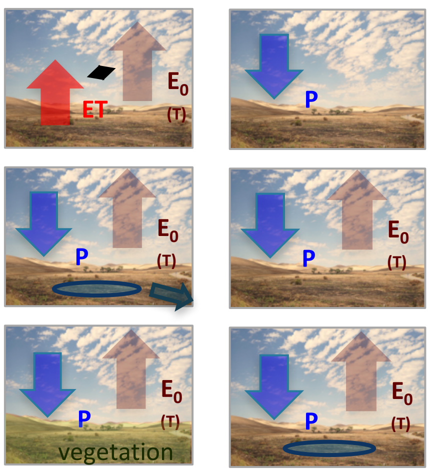


USDM (U.S. Drought Monitor)
Quasi-objective blend of multiple drought indicators: SPI (P), Palmer Index (P + T), modeled soil moisture (P + T), observed streamflow, and other indicators; inherent time-window varies by season/region



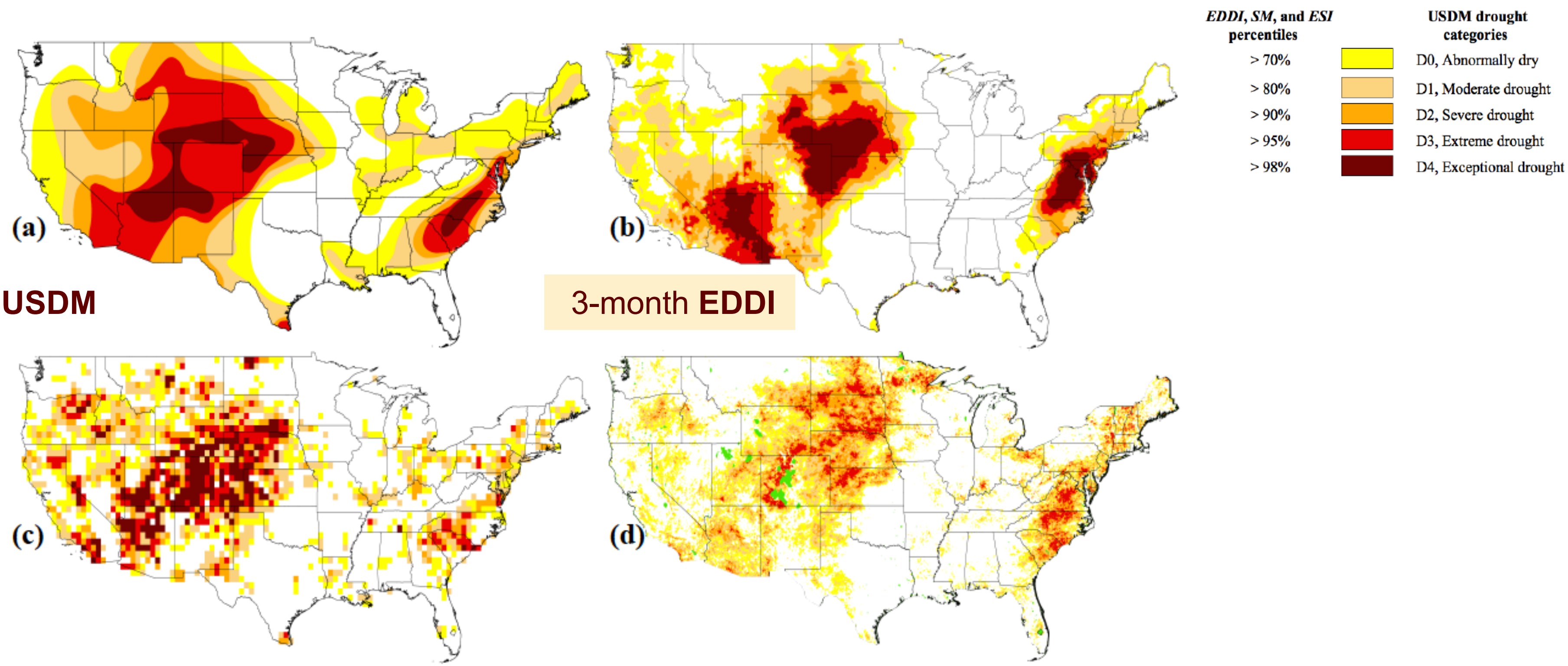
VegDRI
Blend of multiple drought indicators: 9-month SPI (P), Palmer Index (P + T), and satellite-sensed vegetation greenness and leaf-out anomaly; effective time-window of 6-9 months [???]

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-scales over which conditions are aggregated (whether it’s user-selected or inherent to 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 causing impacts

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")



VIC-modeled **Soil Moisture**

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

July 31, 2002

(*Hobbins et al.*, JHM 2016)

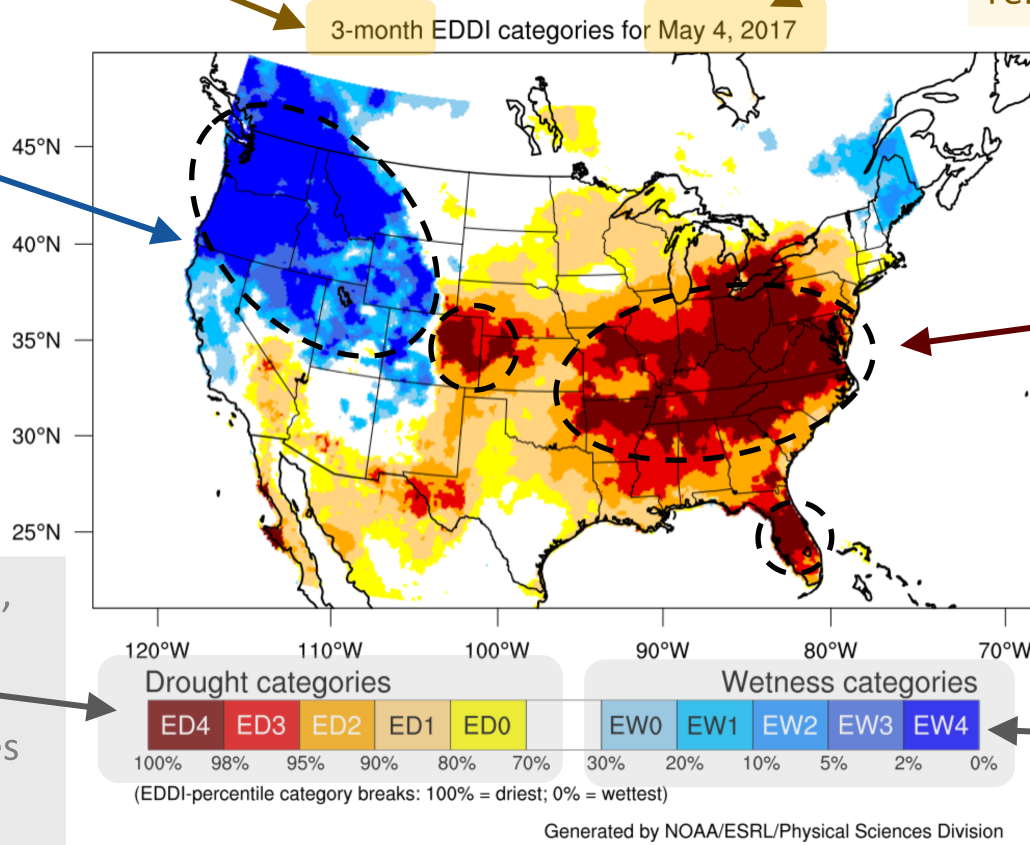
EDDI Evaporative Demand Drought Index

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).

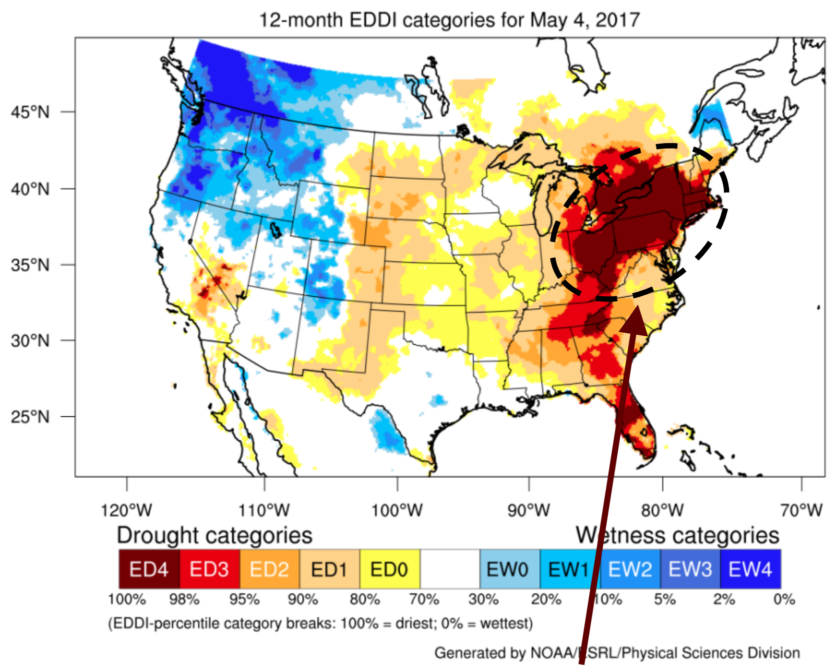
Interpreting EDDI at different time scales

The simple version:

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

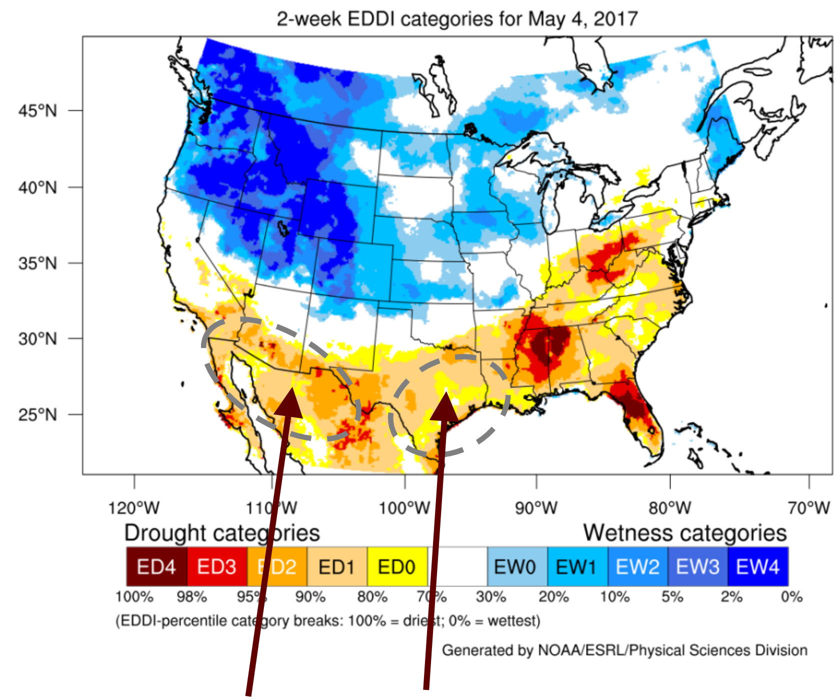
Short-term (2-week to 1-month)= *potential* for drought emergence/intensification

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



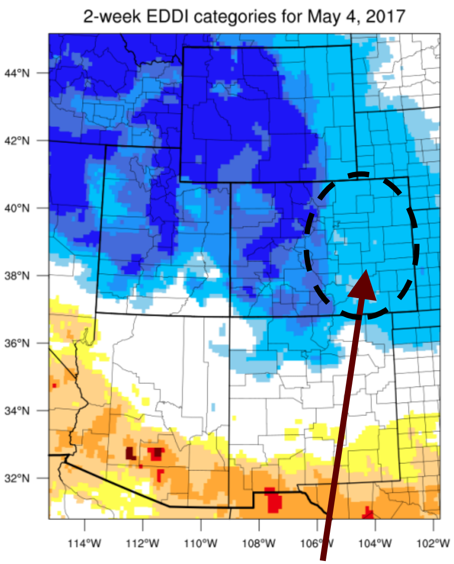
Above-normal evaporative demand over 2 weeks in Southwest and Southern Plains could signal drought emergence

EDDI Evaporative Demand Drought Index

Interpreting EDDI at different time scales

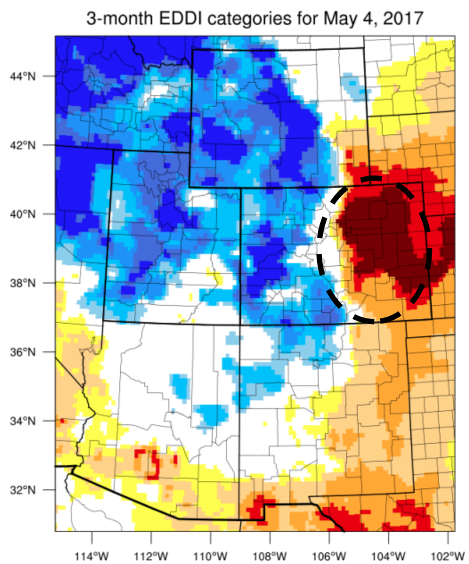
By comparing different time windows, you can infer changes and trends

2-week
(Apr 21 – May 4)



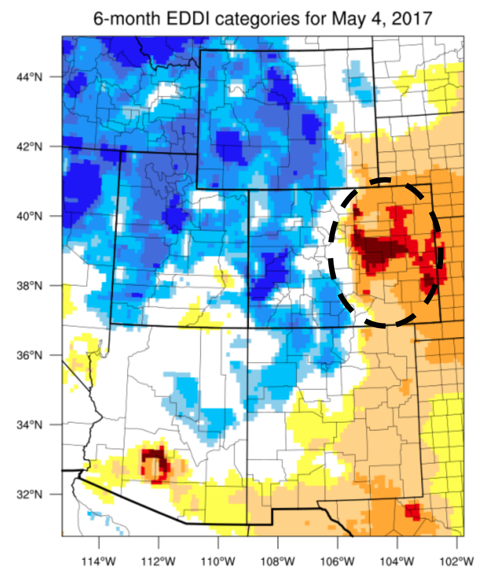
Eastern Colorado
Most recent 2 weeks have had below-normal evaporative demand (EW1), a change from prior above-normal demand

3-month
(Feb 5 – May 4)



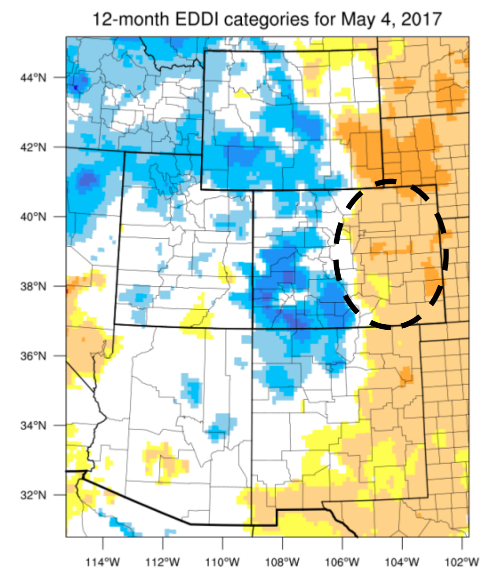
Overall, early spring had unusually high evaporative demand (ED3 and ED4), strongly indicating drought emergence

6-month
(Nov 5 – May 4)

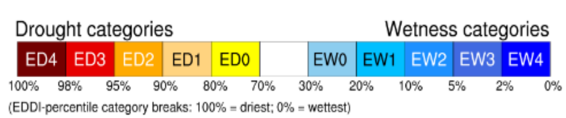


Winter and early spring had high evaporative demand overall (ED1-ED4), with higher values for early spring than for winter

12-month
(May 5 - May 4)

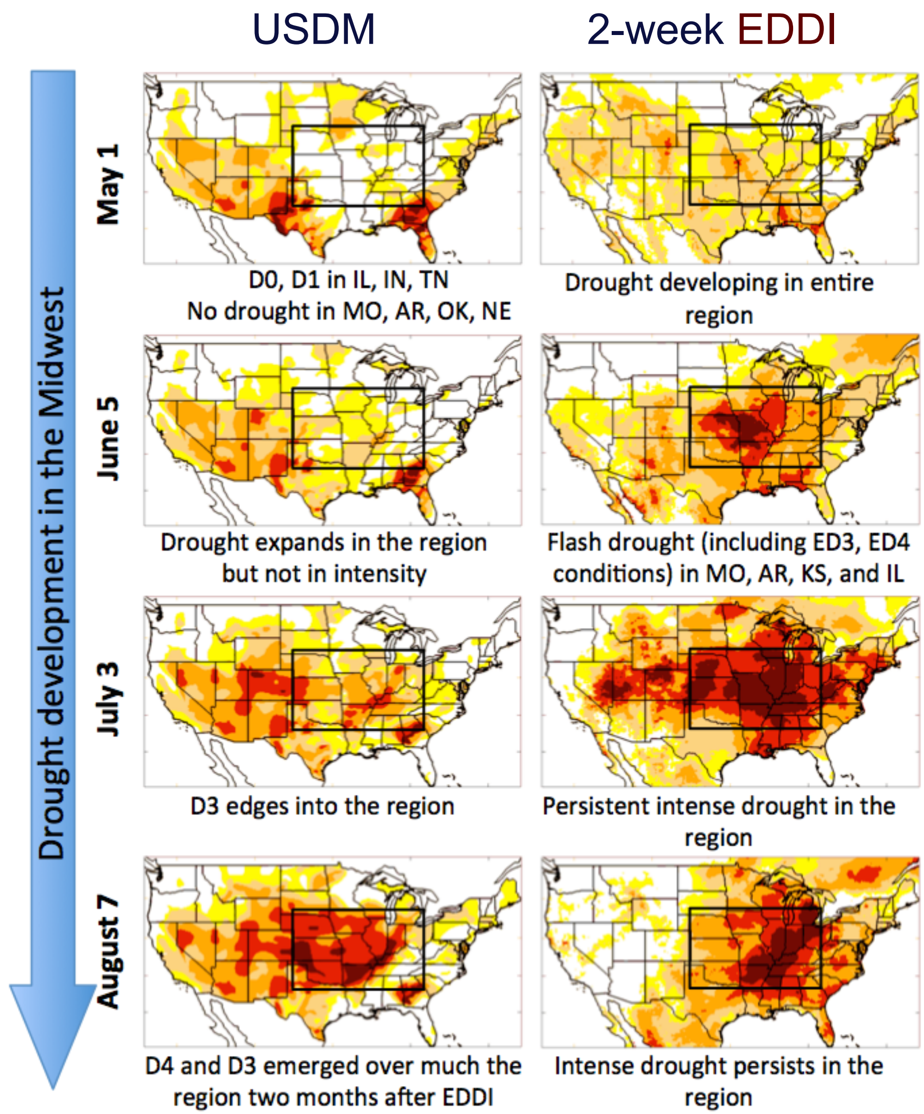


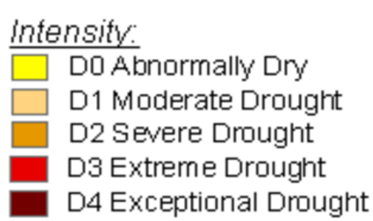
The past 12 months saw high evaporative demand overall (mainly ED1), led by the very high values in winter and early spring



EDDI can give early warning of flash drought

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

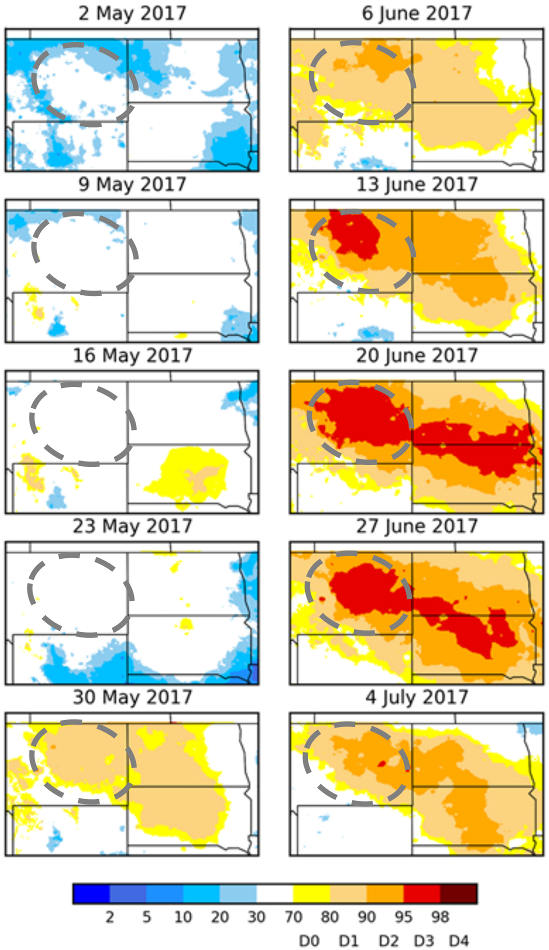




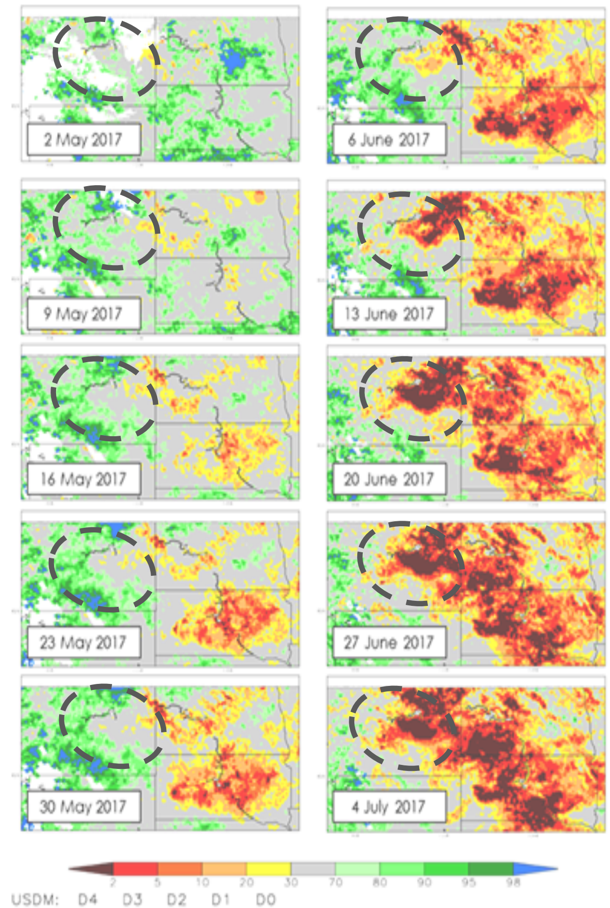
More flash-drought early warning:

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

1-month EDDI



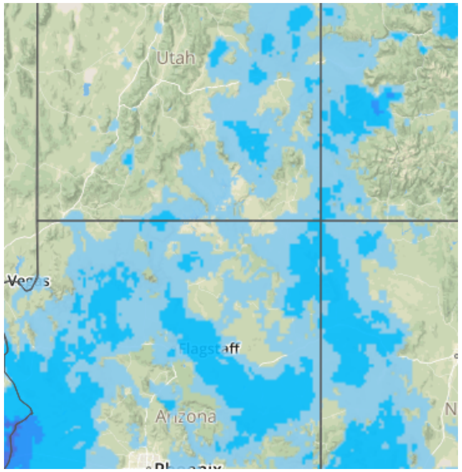
1-month ESI



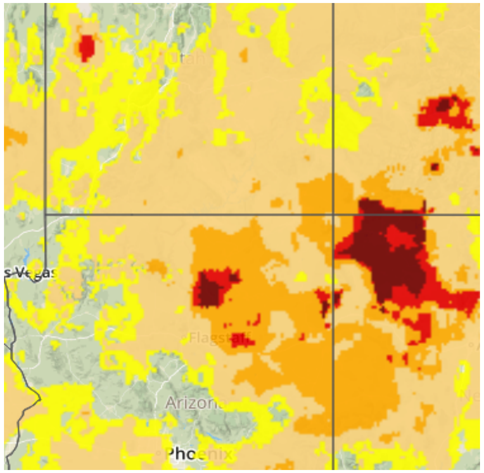
Images: Dan McEvoy, DRI

Keep in mind: Not all areas with new EDDI "hotspots" at short time-scales (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

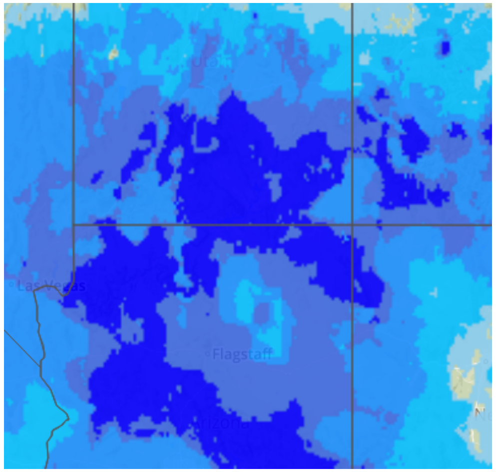
1-month EDDI in Four Corners region (UT, CO, AZ, NM)



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

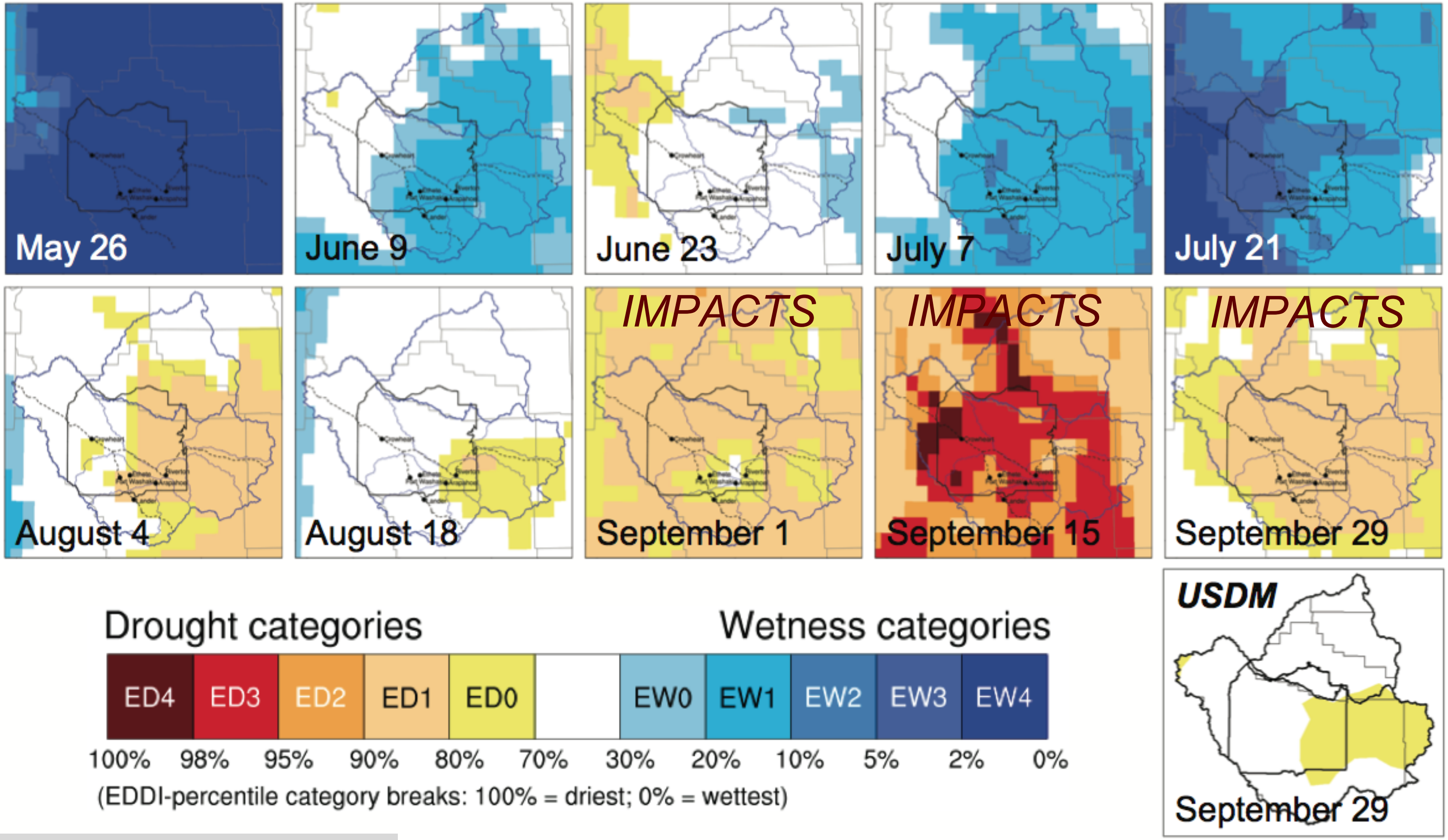
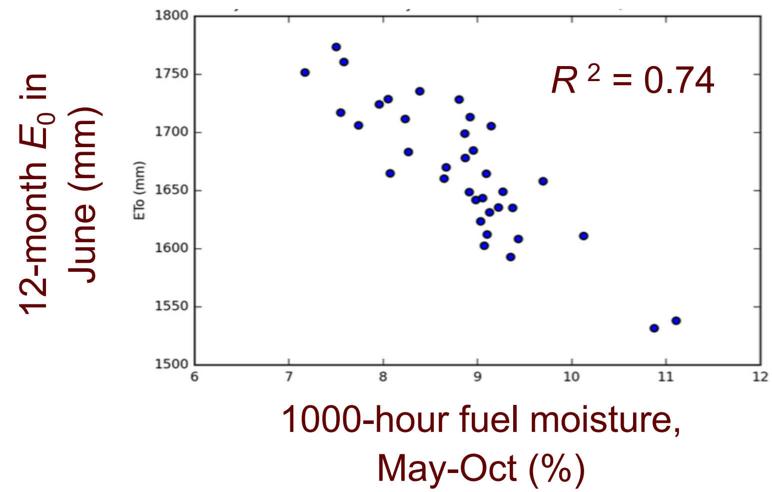


Figure: Candida Dewes, NOAA PSD

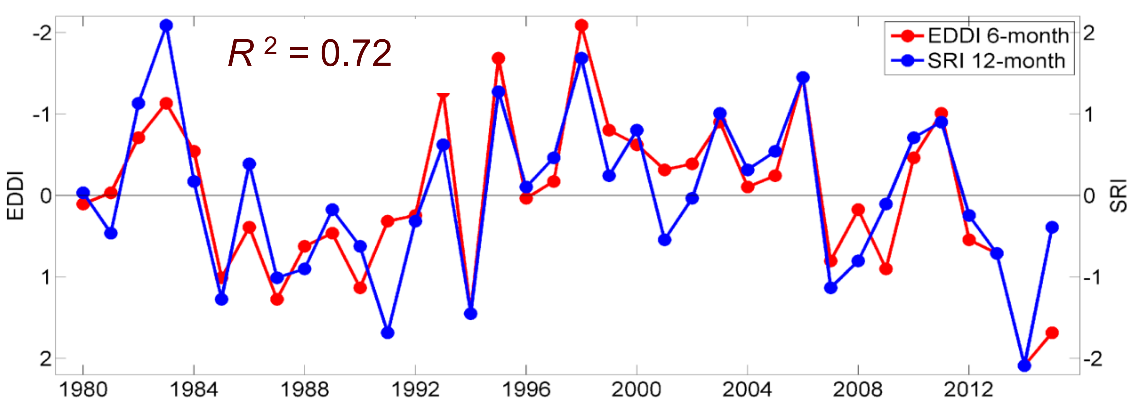
The potential applications of EDDI in wildfire risk monitoring and hydrologic monitoring are being evaluated

- 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)



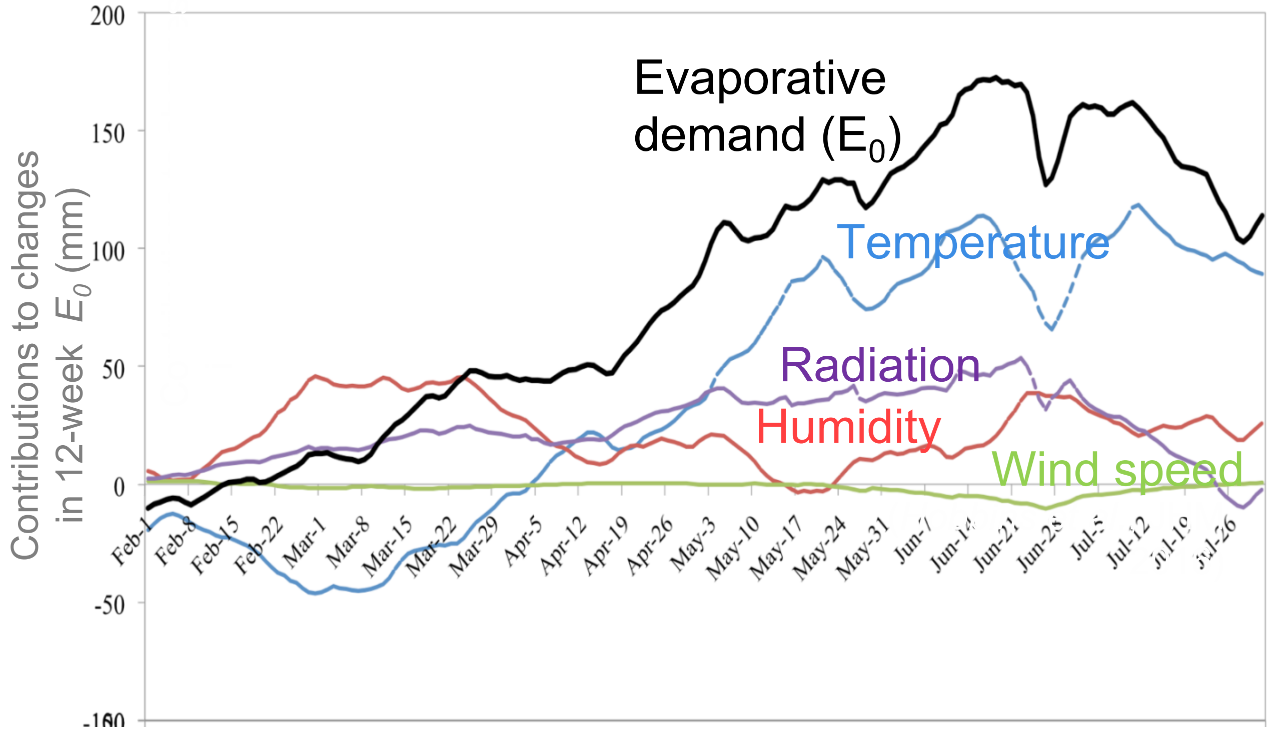
Figures: Dan McEvoy, DRI

Evaporative demand (E_0), as estimated for EDDI, can be decomposed into its four drivers to diagnose the causes of the demand side of drought

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

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

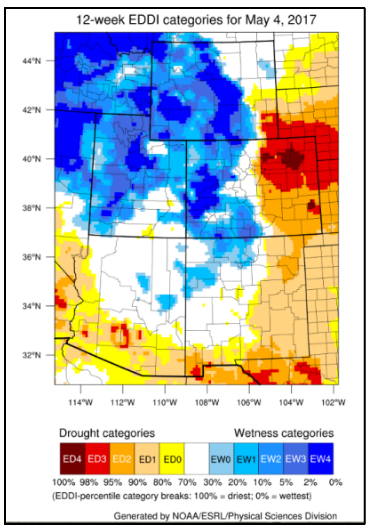
Sacramento River basin, CA



Where to get current EDDI maps

US maps, all timescales:

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

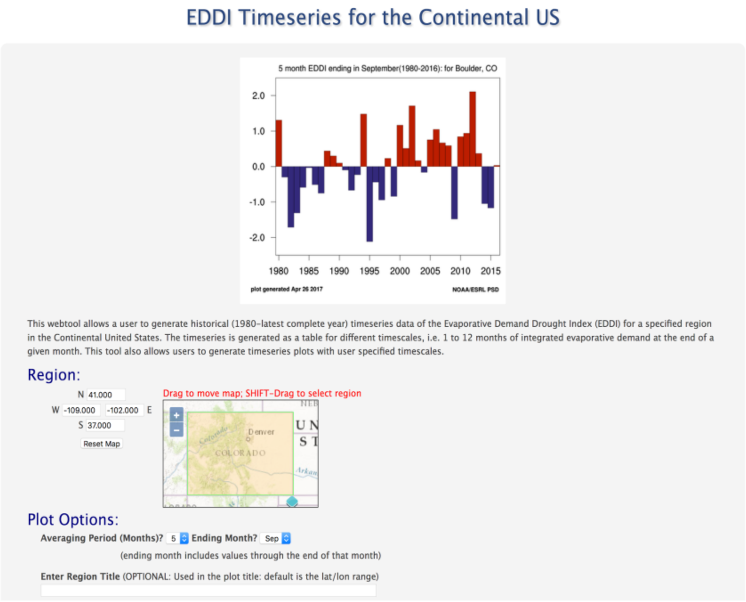


Regional maps in western US, selected timescales:

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 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

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

- Michael Hobbins, Andrew Wood, Daniel McEvoy, Justin Huntington, Charles Morton, Martha Anderson, and Christopher 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

- Daniel J. McEvoy, Justin L. Huntington, Michael T. Hobbins, Andrew Wood, Charles Morton, Martha Anderson, and Christopher 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 mike.hobbins@noaa.gov

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