The Evaporative Demand Drought Index (EDDI):
an emerging drought-monitoring & early warning tool

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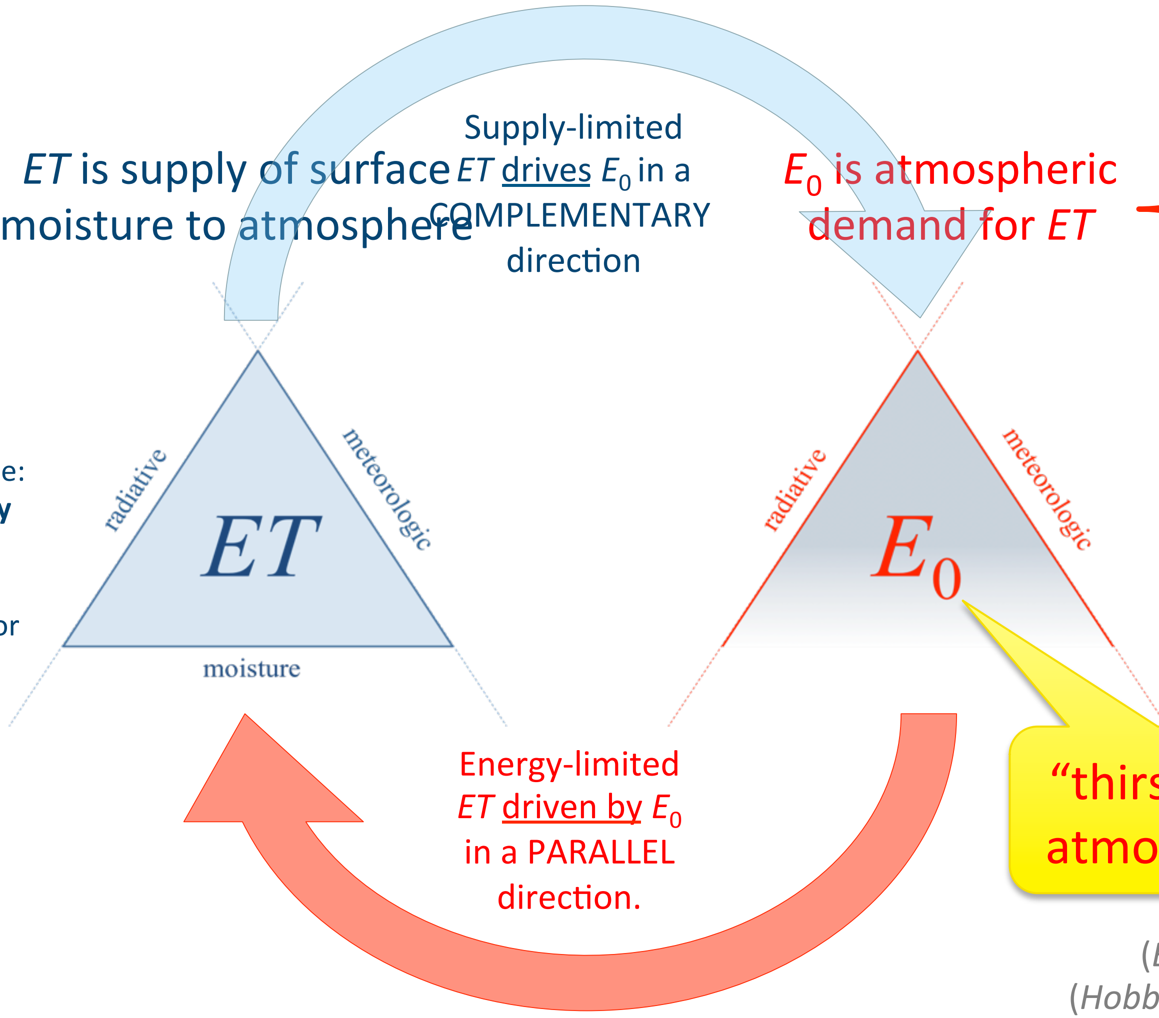
Why Evaporative Demand?

ET = actual evapotranspiration
E_0 = evaporative demand

Temperature
Wind speed
Net radiation
Humidity
Moisture availability

ET not easy to estimate:
- **Moisture availability unknown on useful scales.**
- Generally modeled or remotely sensed



Temperature
Wind speed
Net radiation
Humidity

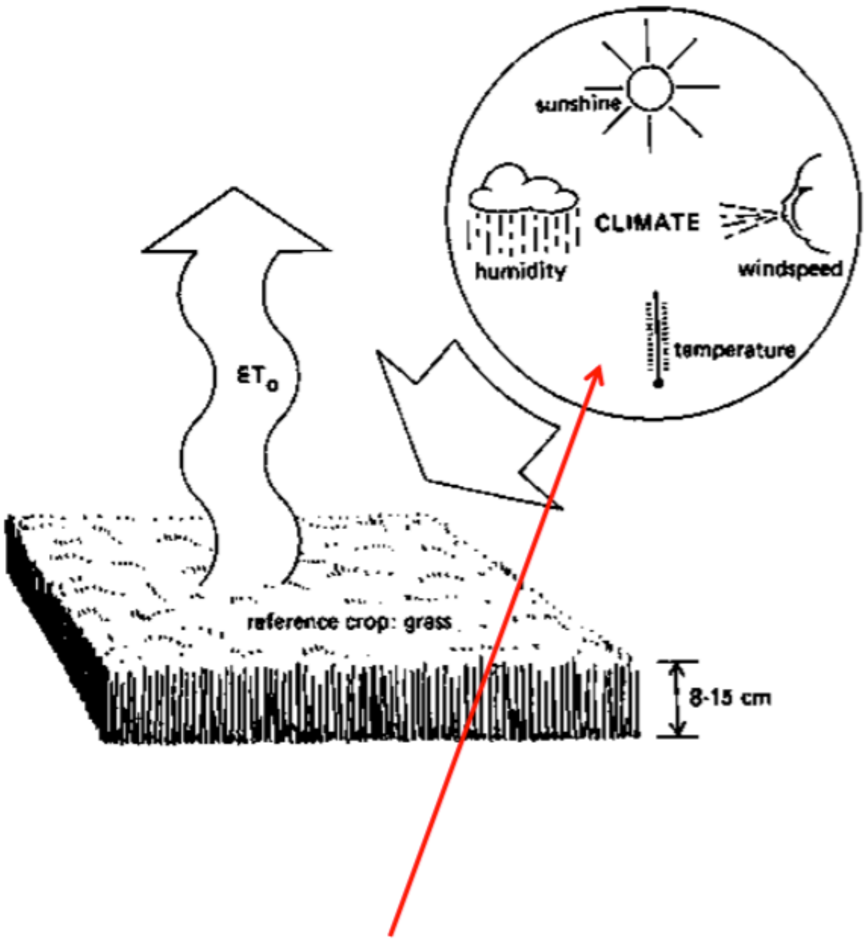
E_0 easy to estimate:
- **Reference *ET***
- Potential *ET*
- Pan evaporation

"thirst of the atmosphere"

(*Bouchet*, IAHS 1963)
(*Hobbins et al.*, GRL 2004)

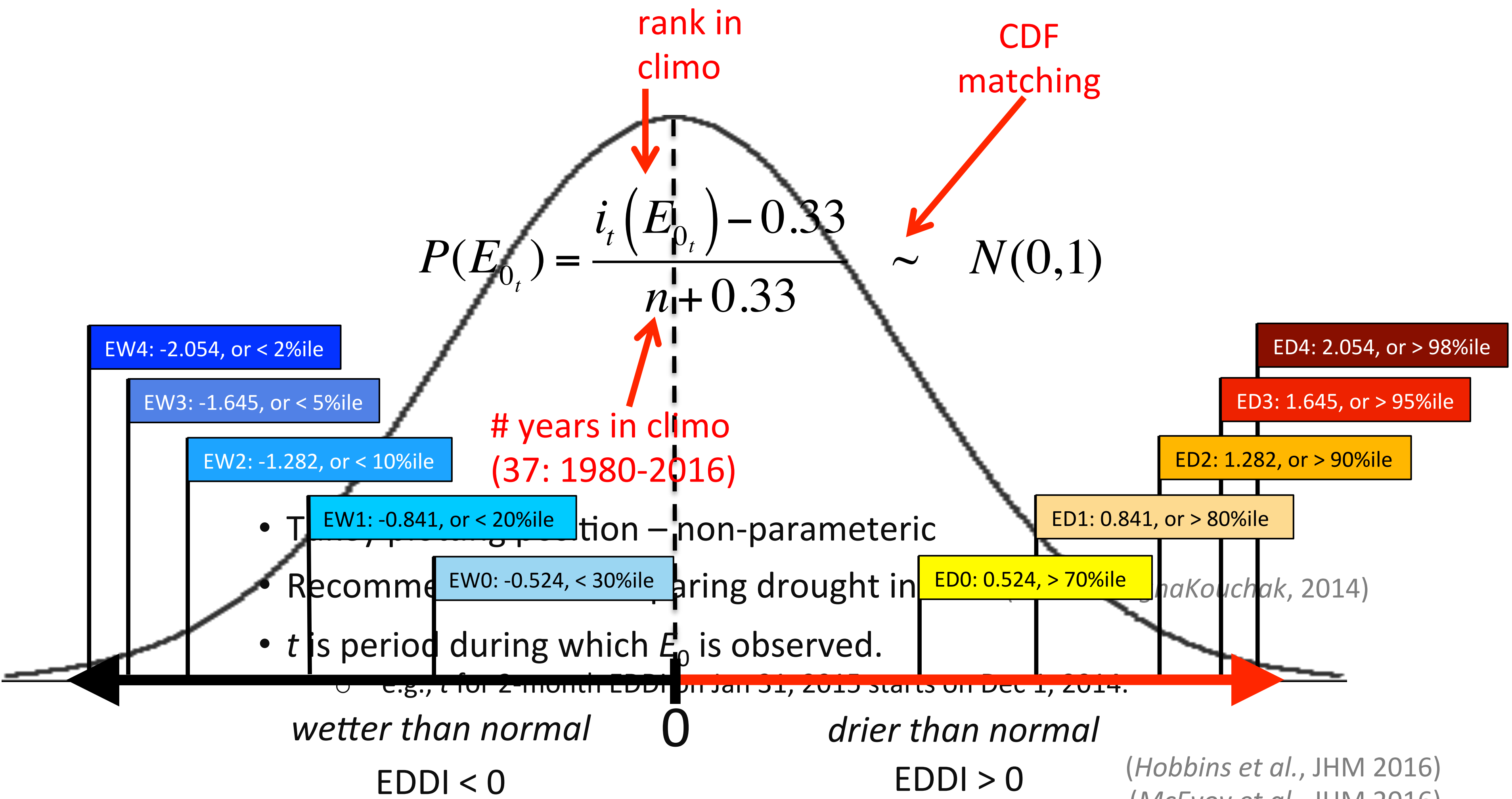
What is Evaporative Demand?

- Evapotranspiration rate that could occur given an unlimited water supply
- Potential evapotranspiration
- Atmospheric demand
- **Reference evapotranspiration**
- Often estimated using temperature alone, but a physically based model should be used



Physically-based ET_o **contains valuable information related to drought dynamics**

How do we calculate EDDI?



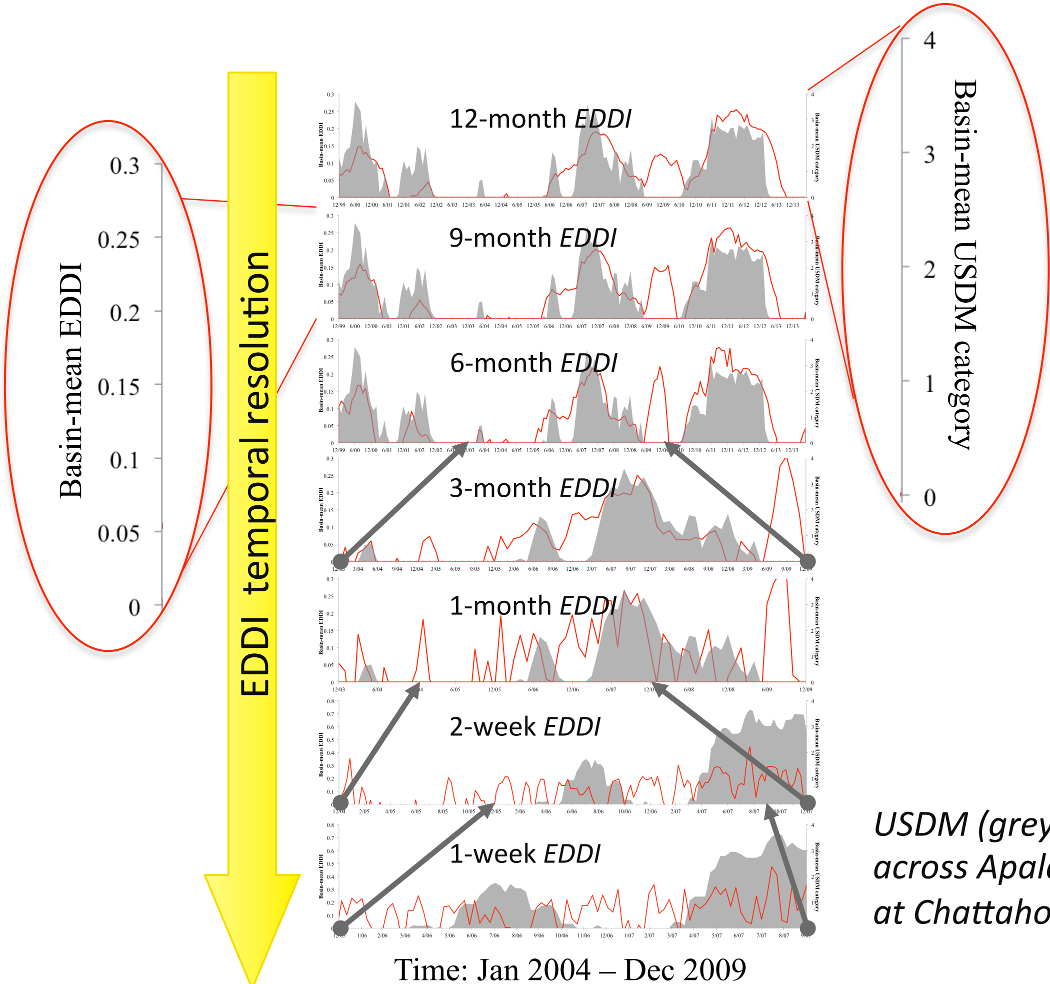
$$P(E_{0_t}) = \frac{i_t\left(E_{0_t}\right) - 0.33}{n + 0.33} \sim N(0,1)$$

- T... ...tion – non-parameteric
- Recomme... ...aring drought in ... ...naKouchak, 2014)
- t is period during which E_0 is observed.
  - e.g., t for 2-month EDDI on Jan 31, 2015 starts on Dec 1, 2014.

(*Hobbins et al.*, JHM 2016)
(*McEvoy et al.*, JHM 2016)

What does EDDI offer?
A multi-scalar drought estimator

USDM = United States Drought Monitor



Signals of different drying dynamics are evident at different time-scales

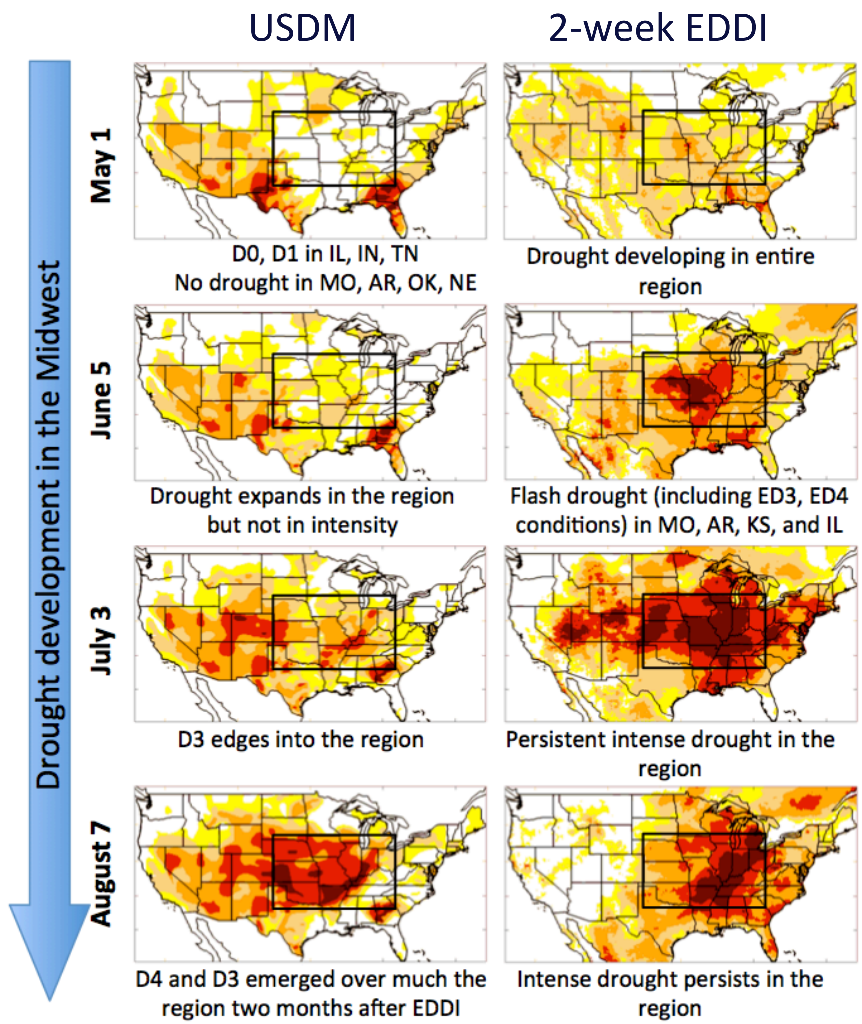
USDM (grey) and EDDI (red) across Apalachicola River basin at Chattahoochee, FL.

What does EDDI offer?

Leading indication of drought

2-week EDDI captures severe drought conditions ~2 months before USDM

"Flash drought" in the US Midwest, 2012



What does EDDI offer?
Monitoring across sectors

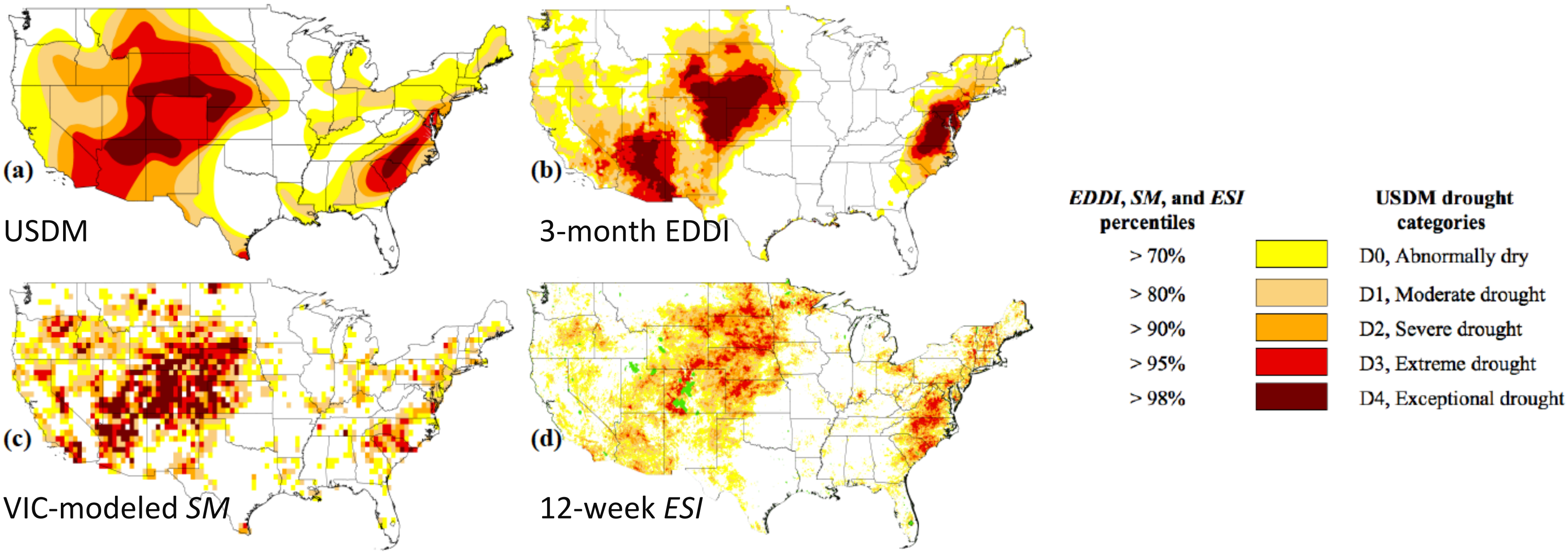
AGRICULTURAL DROUGHT
- soil moisture
- grazing health
- ET

HYDROLOGIC DROUGHT
- streamflow
- snowfall

FIRE-RISK MONITORING
- weather
- fuel loads

What does EDDI offer?
Agricultural drought monitoring

VIC = Variable Infiltration Capacity model
ESI = Evaporative Stress Index



Agricultural drought across CONUS, July 31, 2002

(*Hobbins et al.*, JHM 2016)

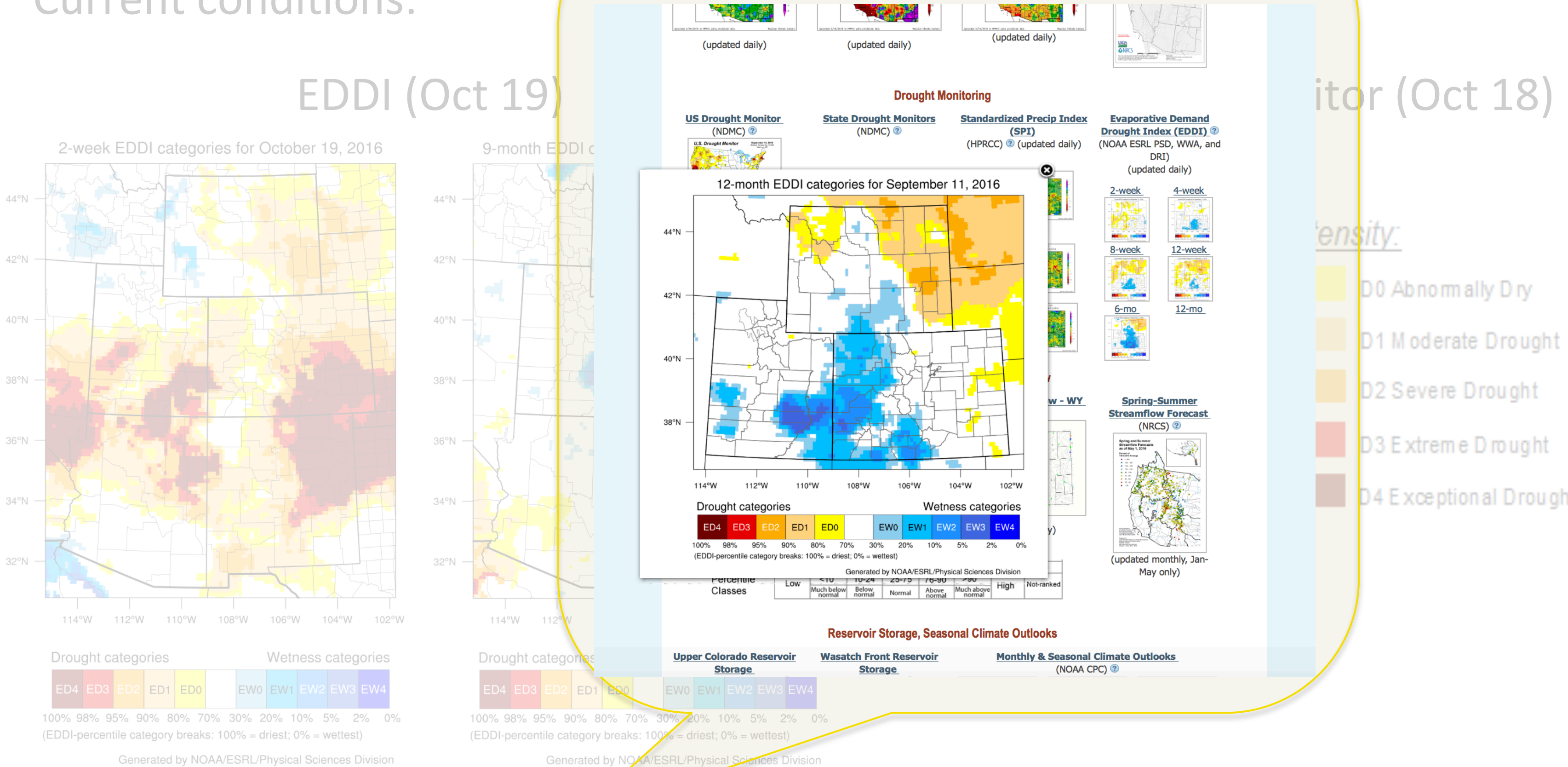
What does EDDI offer?

Current conditions:

EDDI (Oct 19)

...itor (Oct 18)

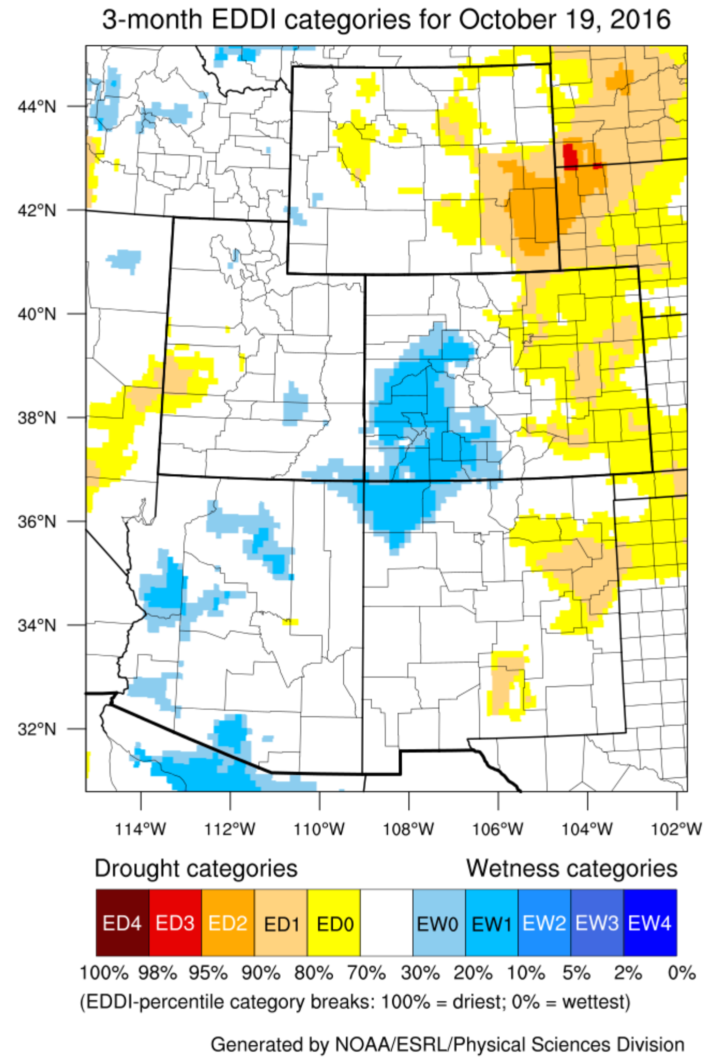
Western Water Assessment's
Intermountain West Climate Dashboard



Live EDDI maps available:
ftp://ftp.cdc.noaa.gov/Public/mhobbins/EDDI/IMW_DEWS/

What does EDDI offer?

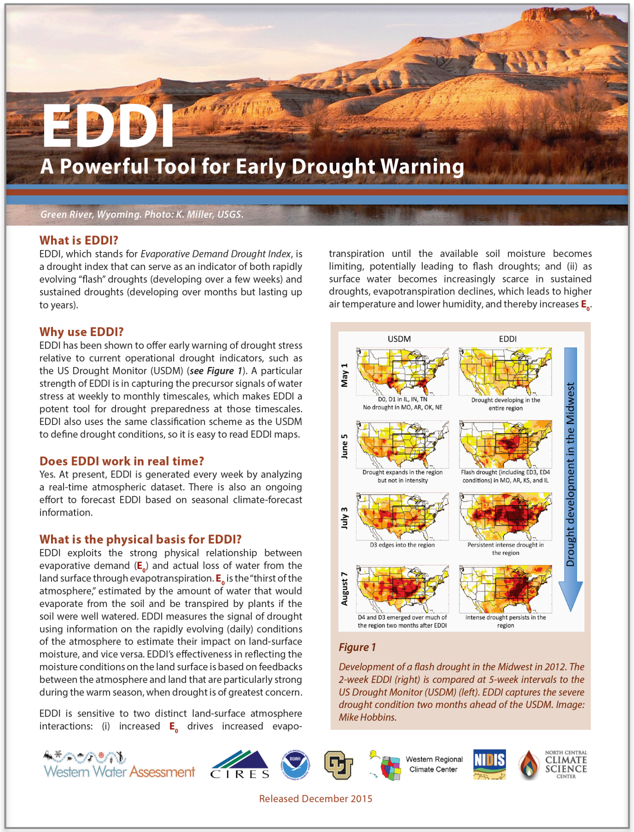
3-month EDDI development, WY 2016



What's next for EDDI?

User outreach and operationalizing

Two-pager:



EDDI

A Powerful Tool for Early Drought Warning

Green River, Wyoming. Photo: K. Miller, USGS.

What is EDDI?

EDDI, which stands for *Evaporative Demand Drought Index*, is a drought index that can serve as an indicator of both rapidly evolving "flash" droughts (developing over a few weeks) and sustained droughts (developing over months but lasting up to years).

Why use EDDI?

EDDI has been shown to offer early warning of drought stress relative to current operational drought indicators, such as the US Drought Monitor (USDM) (***see Figure 1***). A particular strength of EDDI is in capturing the precursor signals of water stress at weekly to monthly timescales, which makes EDDI a potent tool for drought preparedness at those timescales. EDDI also uses the same classification scheme as the USDM to define drought conditions, so it is easy to read EDDI maps.

Does EDDI work in real time?

Yes. At present, EDDI is generated every week by analyzing a real-time atmospheric dataset. There is also an ongoing effort to forecast EDDI based on seasonal climate-forecast information.

What is the physical basis for EDDI?

EDDI exploits the strong physical relationship between evaporative demand (E_0) and actual loss of water from the land surface through evapotranspiration. E_0 is the "thirst of the atmosphere," estimated by the amount of water that would evaporate from the soil and be transpired by plants if the soil were well watered. EDDI measures the signal of drought using information on the rapidly evolving (daily) conditions of the atmosphere to estimate their impact on land-surface moisture, and vice versa. EDDI's effectiveness in reflecting the moisture conditions on the land surface is based on feedbacks between the atmosphere and land that are particularly strong during the warm season, when drought is of greatest concern.

EDDI is sensitive to two distinct land-surface atmosphere interactions: (i) increased E_0 drives increased evapotranspiration until the available soil moisture becomes limiting, potentially leading to flash droughts; and (ii) as surface water becomes increasingly scarce in sustained droughts, evapotranspiration declines, which leads to higher air temperature and lower humidity, and thereby increases E_0.

Figure 1

Development of a flash drought in the Midwest in 2012. The 2-week EDDI (right) is compared at 5-week intervals to the US Drought Monitor (USDM) (left). EDDI captures the severe drought condition two months ahead of the USDM. Image: Mike Hobbins.

Western Water Assessment · CIRES · Western Regional Climate Center · NIDIS · North Central Climate Science Center

Released December 2015

Next steps:

- 3-year NOAA-RTAP grant to operationalize EDDI at NOAA National Water Center
- Enlarge and engage user-base
- 2-year NOAA-SARP grant for wildfire prediction
- Continued collaboration with DRI
  - research & development
  - add forecast component
- EDDI User's Manual

(2-pager: *Rangwala et al.,* NOAA 2015)

What's next for EDDI?
Development plans for EDDI

Coming developments:

- Operational attribution of drought dynamics
- GIFs showing development in time
- EDDI at distinct spatial aggregations (including historical)

Research plans:

- Increase spatial resolution – to 4 km
- Forecasting – short-term and seasonal
- EDDI as a predictor of fire risk

Attribution of drought dynamics

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

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

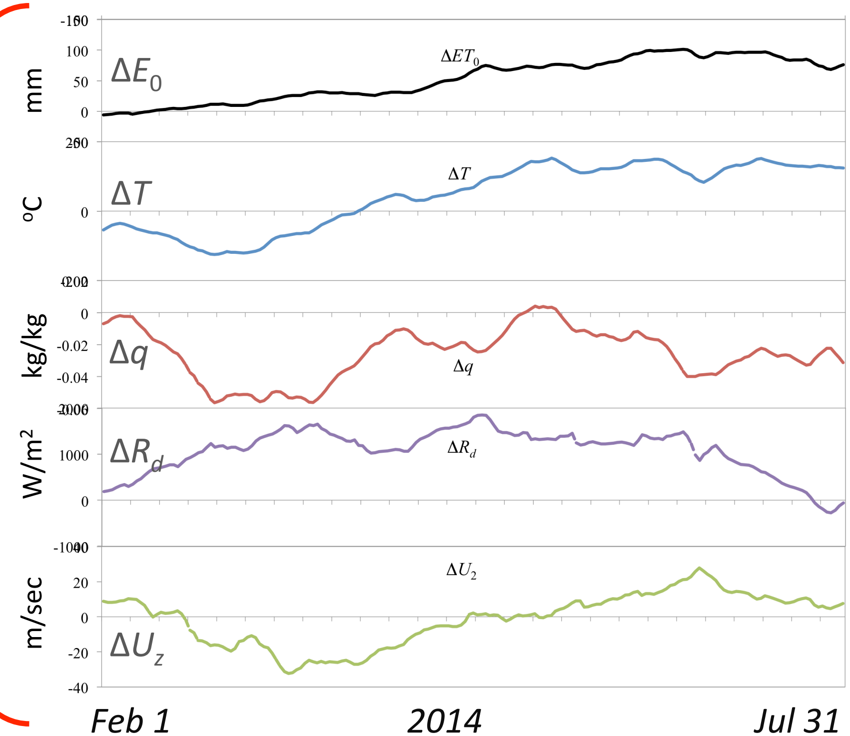
anomalies observed in reanalyses

derived analytically (*Hobbins*, 2016)

E_0 changes due to changes in:

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

Sacramento River basin, CA



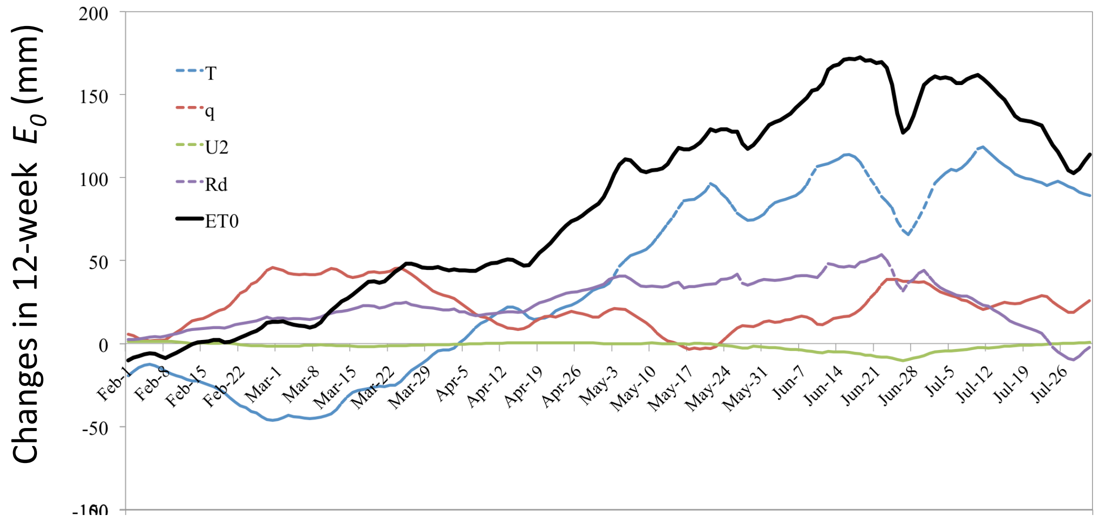
(*Hobbins et al.*, JHM 2016)

Attribution of drought dynamics

Drought intensification (increasing E_0) forced by

- first, below-normal q (while T falling)
- then, increasing T and, to a lesser degree, R_d
- U_z plays little role

Sacramento River basin, CA



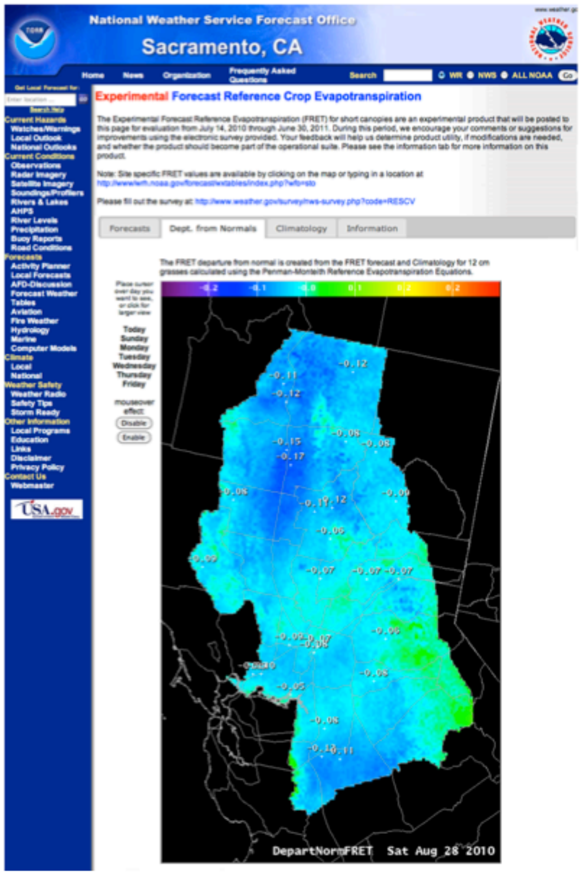
T = air temperature
R_d = downwelling SW
q = specific humidity
U_2 = wind speed

(*Hobbins et al.*, JHM 2016)

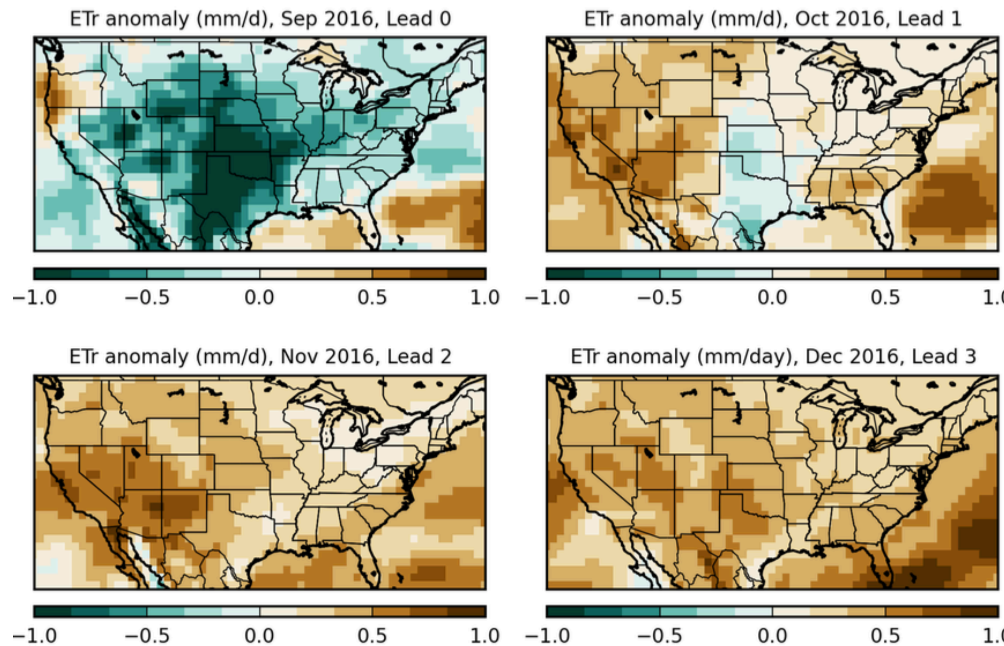
Forecasting of E_0 (and drought)

FRET = Forecast Reference Evapotranspiration
Prcp = precipitation

Daily, weekly - FRET



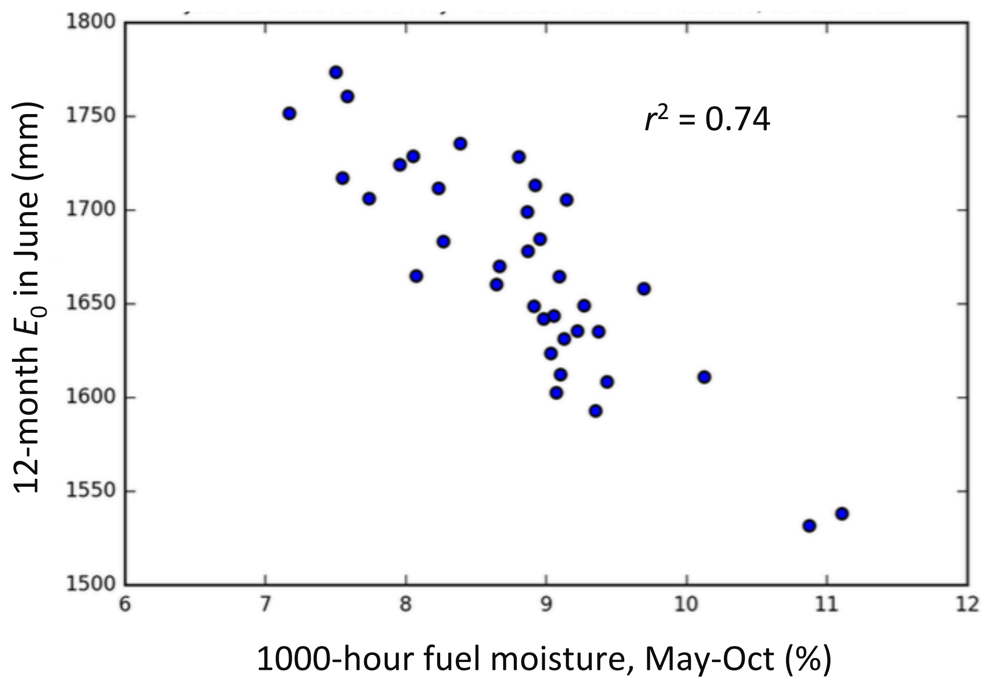
Seasonally (with greater skill than *Prcp*)



CFSv2 4-member ensemble mean initialized Sept 8 (00Z, 06Z, 12Z, and 18Z) – Dan McEvoy, DRI

Predicting wildfire risk

E_0-fuel load relationship across S. California GACC



2-year NOAA-SARP grant: *Developing a wildfire component for the NIDIS CA DEWS* – DRI

Summary

E_0 and drought:

Physically rational relationship to drought, responding…

- rapidly to drying and wetting
- to both sustained and flash droughts

More readily available than *ET* (than *Prcp*, often)

- latency can be significant

Permits decomposition of evaporative drought drivers

E_0 is forecastable (*McEvoy et al.*, GRL 2016)

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