The Evaporative Demand Drought Index (EDDI):

an emerging drought-monitoring & early warning tool

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New approach to drought

Treatment of demand side

Prcp = precipitation
ET = evapotranspiration
Θ = moisture availability proxy
T = air temperature
q = specific humidity
R_d = downwelling SW
U_2 = 2-m wind speed

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

Water-balance:

Drought ~ $f(Prcp, ET)$

$ET = f(\theta, E_0)$

Traditionally:

Drought ~ $f(Prcp, T)$

$E_0 = f(T)$ - e.g., Thornthwaite, Hamon, Hargreaves, PDSI

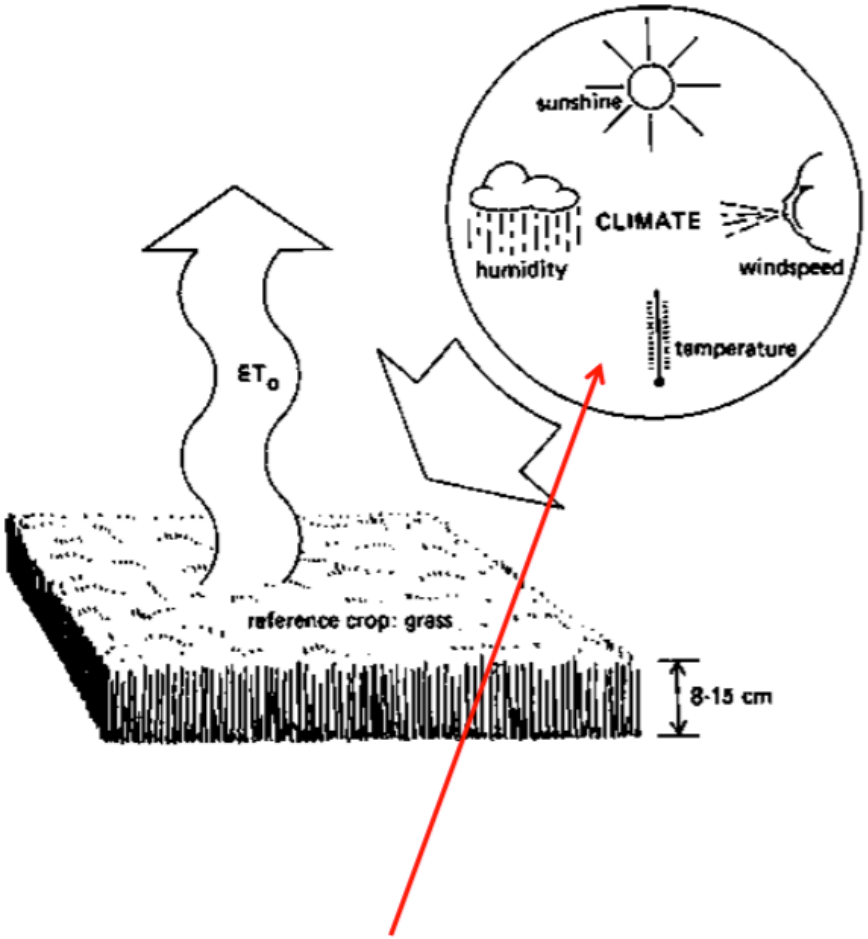
But more physical E_0 formulations are available.

$E_0 = f(T, q, R_d, U_2)$ - e.g., Penman-Monteith

What is Evaporative Demand?

ET = actual evapotranspiration
E_0 = evaporative demand

- "Thirst of the atmosphere"
- *ET* occurring given an unlimited moisture supply
  - **Reference *ET***
  - Potential *ET ("PET")*
  - Pan evaporation
- There are good estimates and bad estimates:
  - **physically based**
  - temperature-based



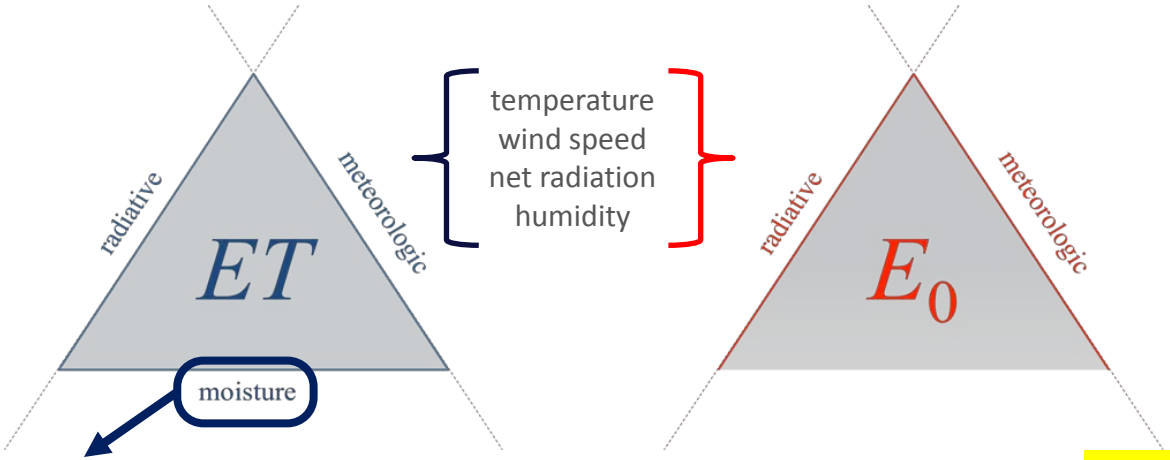
Physically-based ET_o contains valuable information related to drought dynamics

Why Evaporative Demand?

ET = actual evapotranspiration
E_0 = evaporative demand

ET is <u>supply</u> of surface moisture to atmosphere

E_0 is atmospheric <u>demand</u> for *ET*



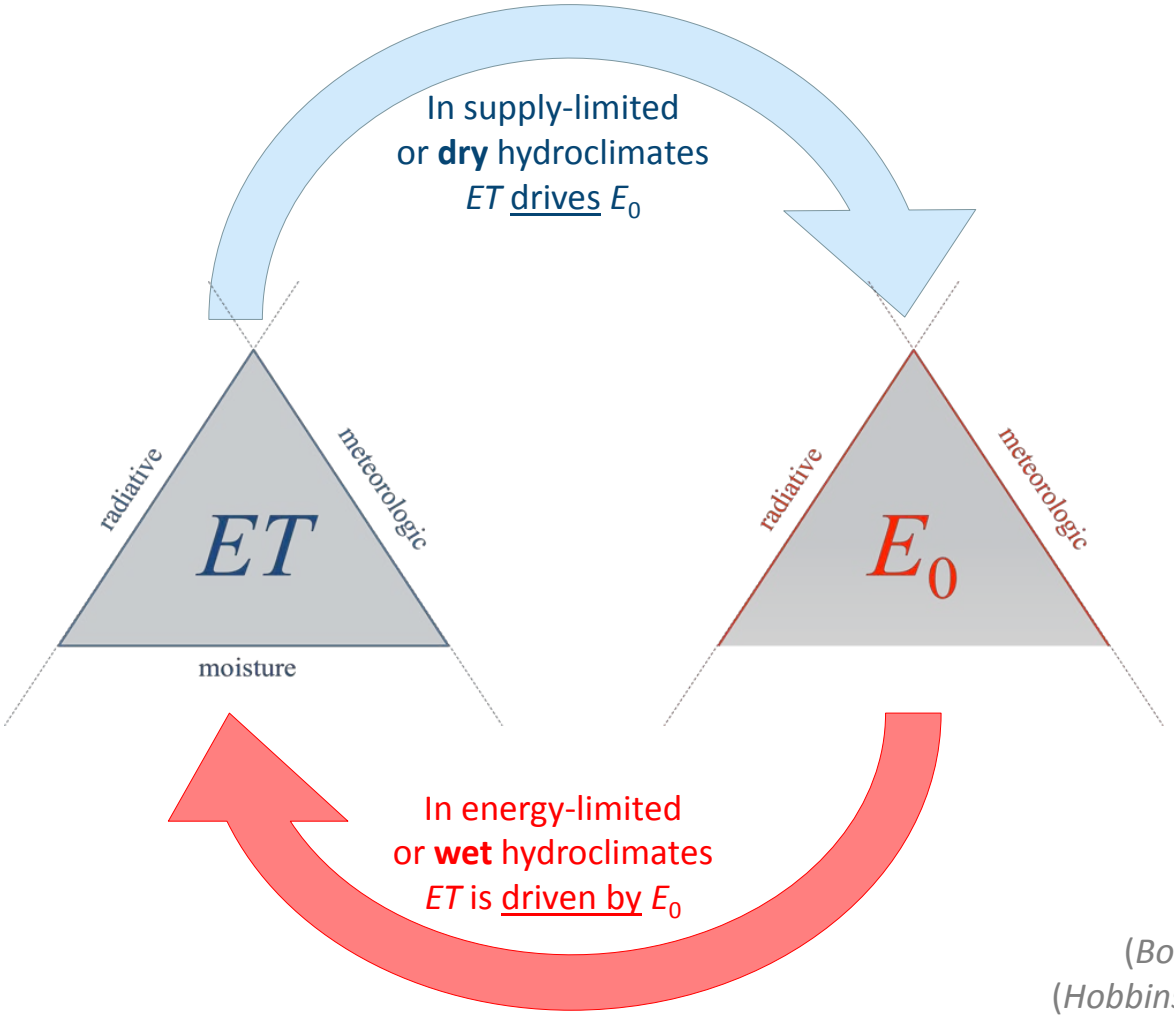
unknown on useful space/time scales

E_0 much easier to estimate than *ET*

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

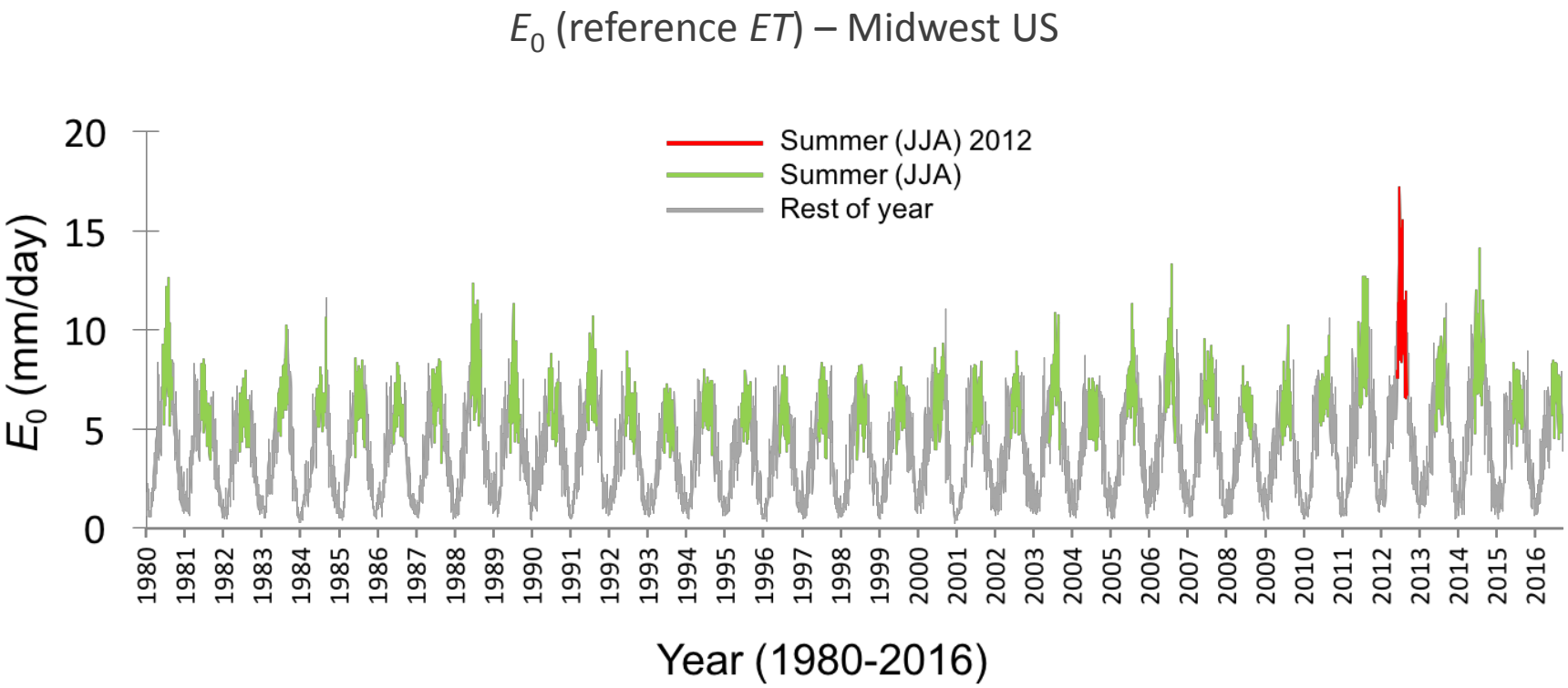
Why Evaporative Demand?

ET = actual evapotranspiration
E_0 = evaporative demand



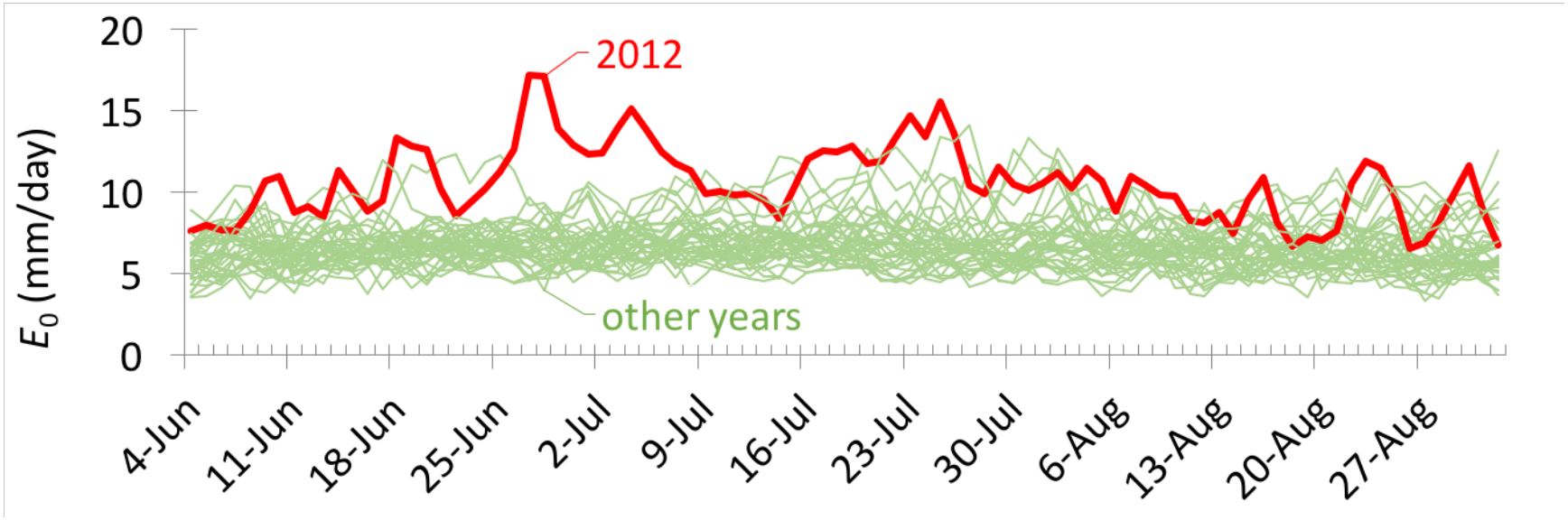
(*Bouchet*, IAHS 1963)
(*Hobbins et al.*, GRL 2004)

How do we calculate EDDI?

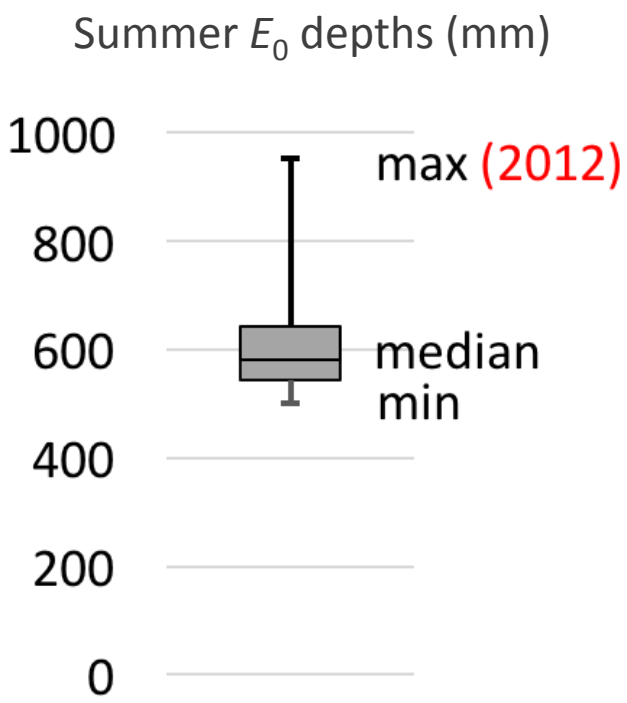


How do we calculate EDDI?

37 years of summer E_0 – Midwest US



How do we calculate EDDI?



*2012 has **rank of 1** in 37-year E_0 climatology*

How do we calculate EDDI?

rank in climo

CDF matching

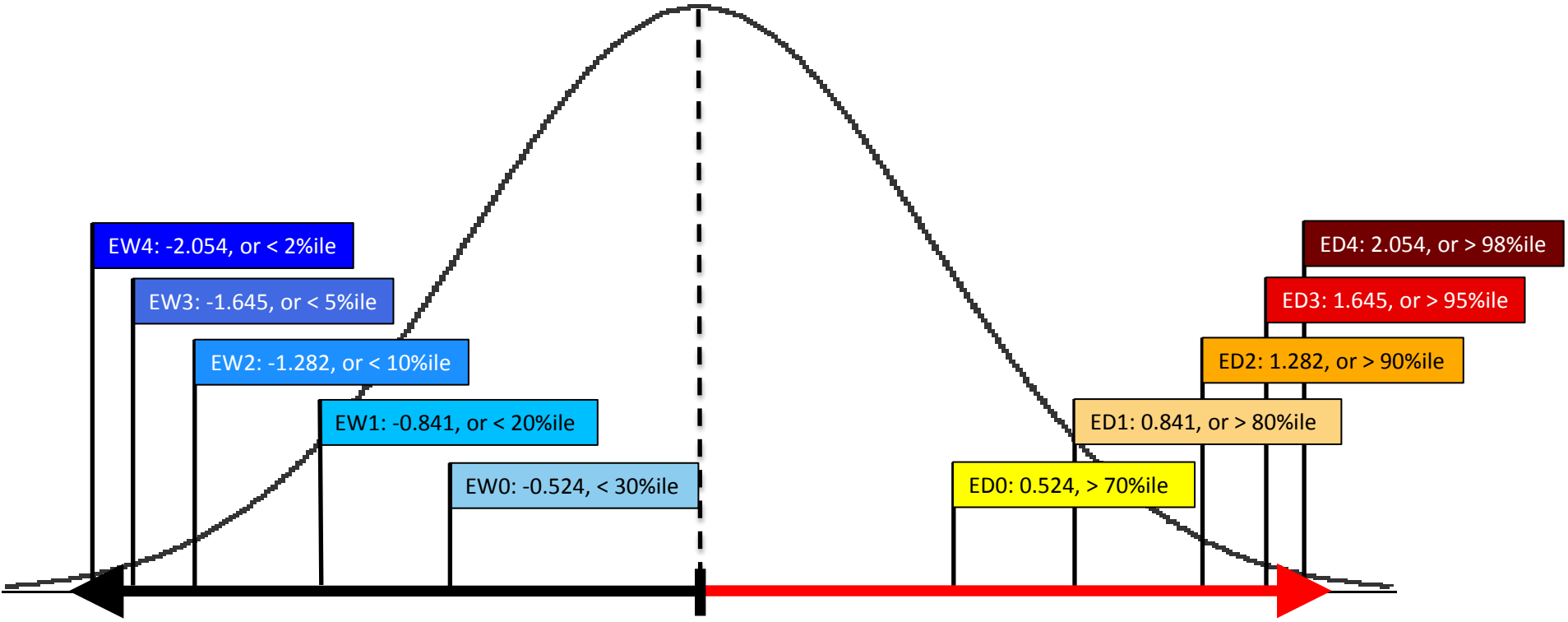
$$P(E_{0_t}) = \frac{i_t(E_{0_t}) - 0.33}{n + 0.33} \sim N(0,1)$$

years in climo (37: 1980-2016)

- Tukey plotting position – non-parameteric
- Recommended for comparing drought indices (*Hao and AghaKouchak*, 2014)
- *t* is period during which E_0 is observed.
  - e.g., *t* for 3-month EDDI on September 1, 2012 starts June 4, 2012.

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

How do we calculate EDDI?

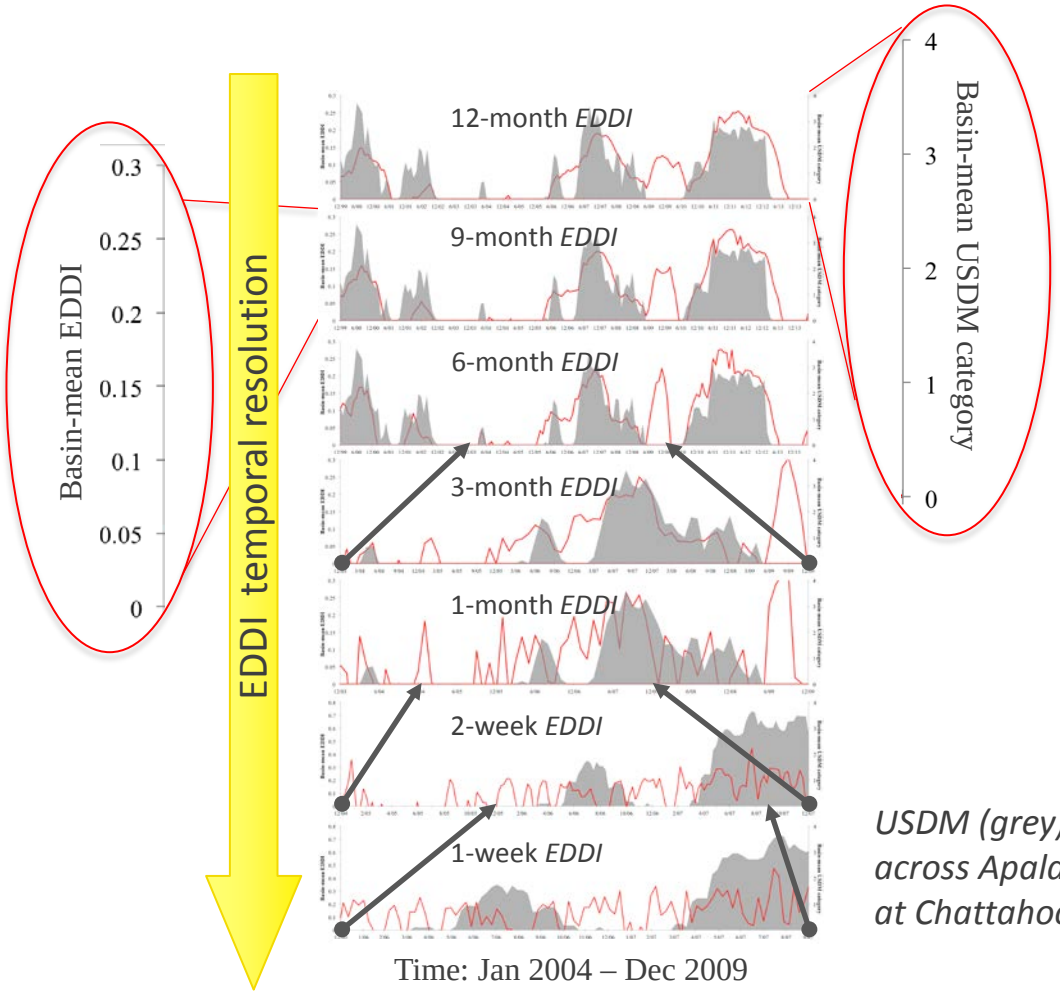


(*Hobbins et al.*, JHM 2016)
(*McEvoy et al.*, JHM 2016)

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

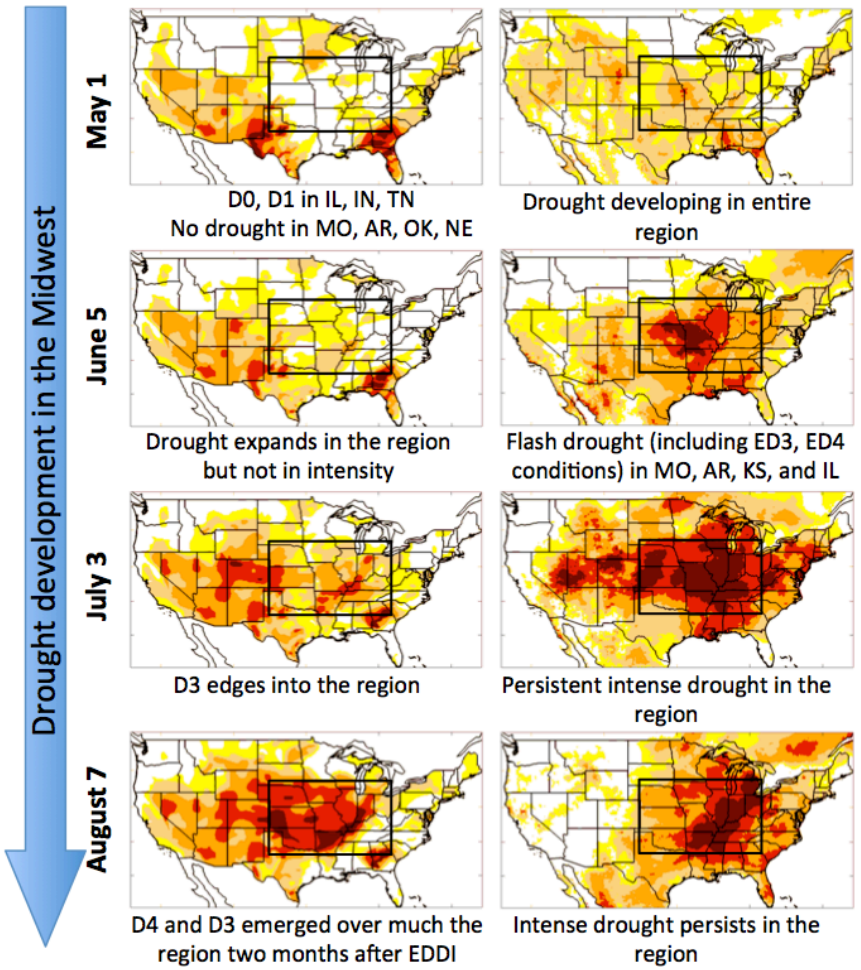
USDM (grey) and EDDI (red) across Apalachicola River basin at Chattahoochee, FL.

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

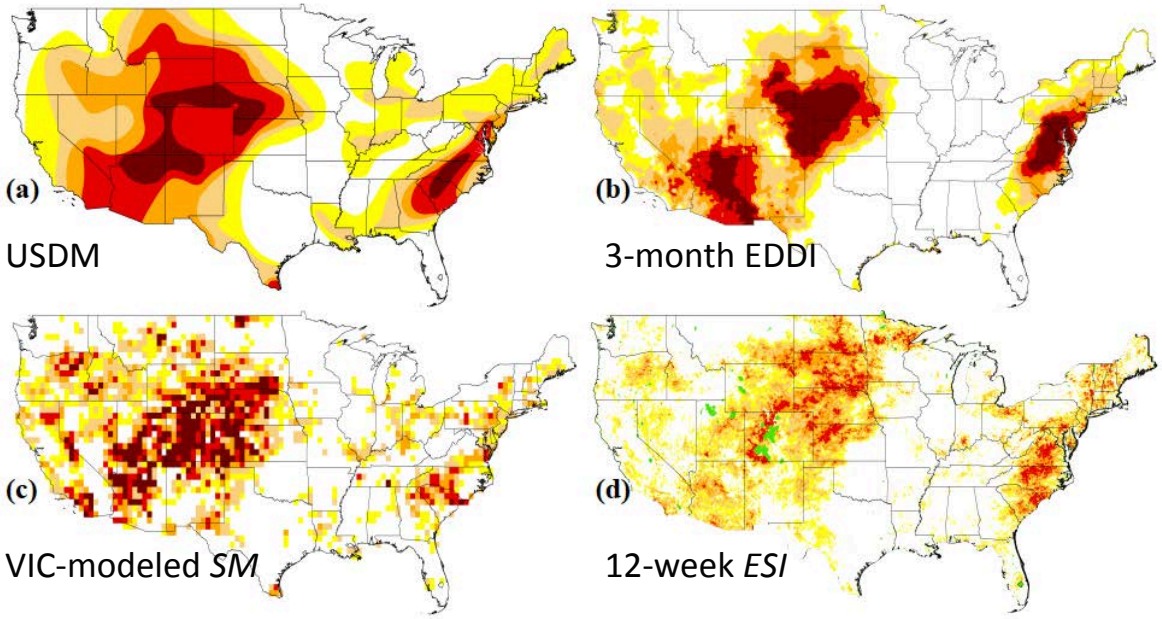
HYDROLOGIC DROUGHT
- streamflow
- snowfall

FIRE-RISK MONITORING
- weather
- fuel loads

What does EDDI offer?

Agricultural drought monitoring

VIC = Variable Infiltration Capacity model
ESI = Evaporative Stress Index



EDDI, *SM*, and *ESI* percentiles	USDM drought categories
> 70%	D0, Abnormally dry
> 80%	D1, Moderate drought
> 90%	D2, Severe drought
> 95%	D3, Extreme drought
> 98%	D4, Exceptional drought

Agricultural drought across CONUS, July 31, 2002

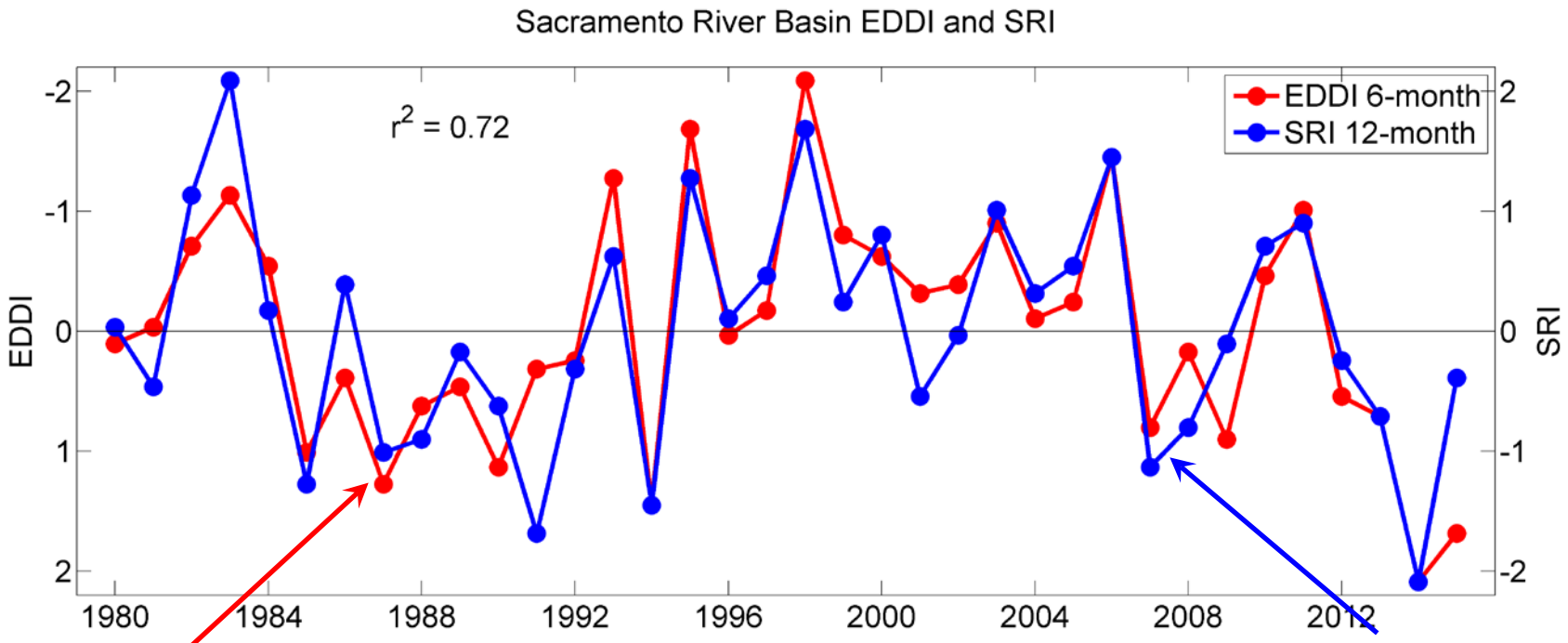
(*Hobbins et al.*, JHM 2016)

What does EDDI offer?

Hydrological drought prediction

SRI = Standardized Runoff Index

Can EDDI help predict late-summer (low-flow) streamflow?



6-month EDDI (Nov-Apr)

EDDI contains no *Prcp* information!

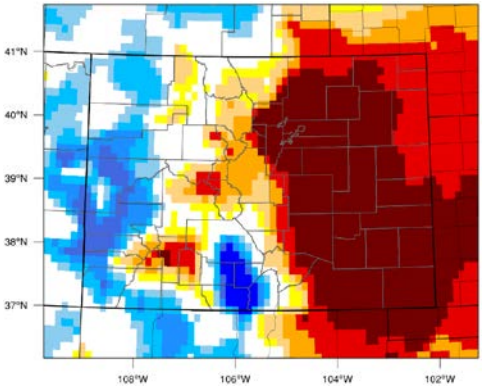
12-month SRI (Oct-Sep)

(EDDI - *McEvoy et al.,* JHM 2016)
(SRI - *Shukla and Wood,* GRL 2008)

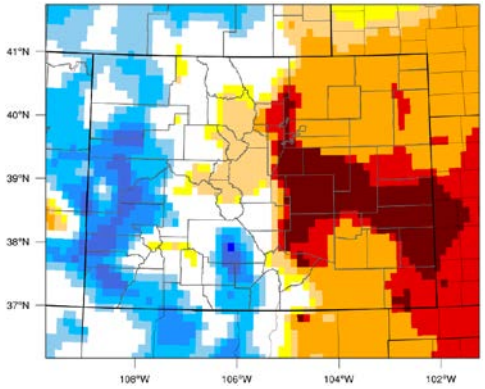
What does EDDI offer?

EDDI current conditions (March 15):

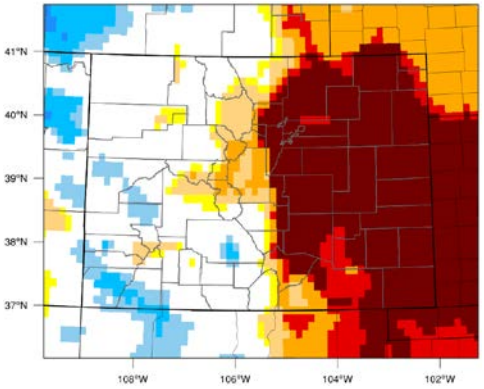
2-week



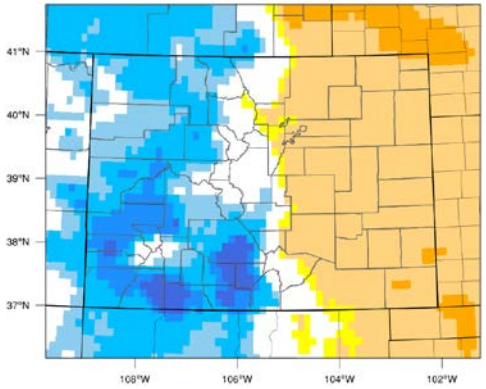
3-month



6-month

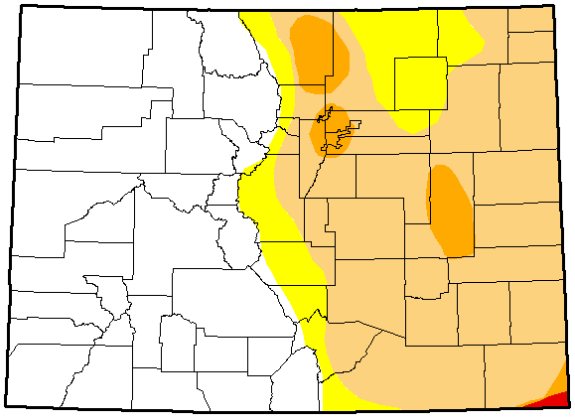


12-month



Live EDDI maps for CO available:
ftp.cdc.noaa.gov/Public/mhobbins/EDDI/CO/ [go]

US Drought Monitor: (March 14)

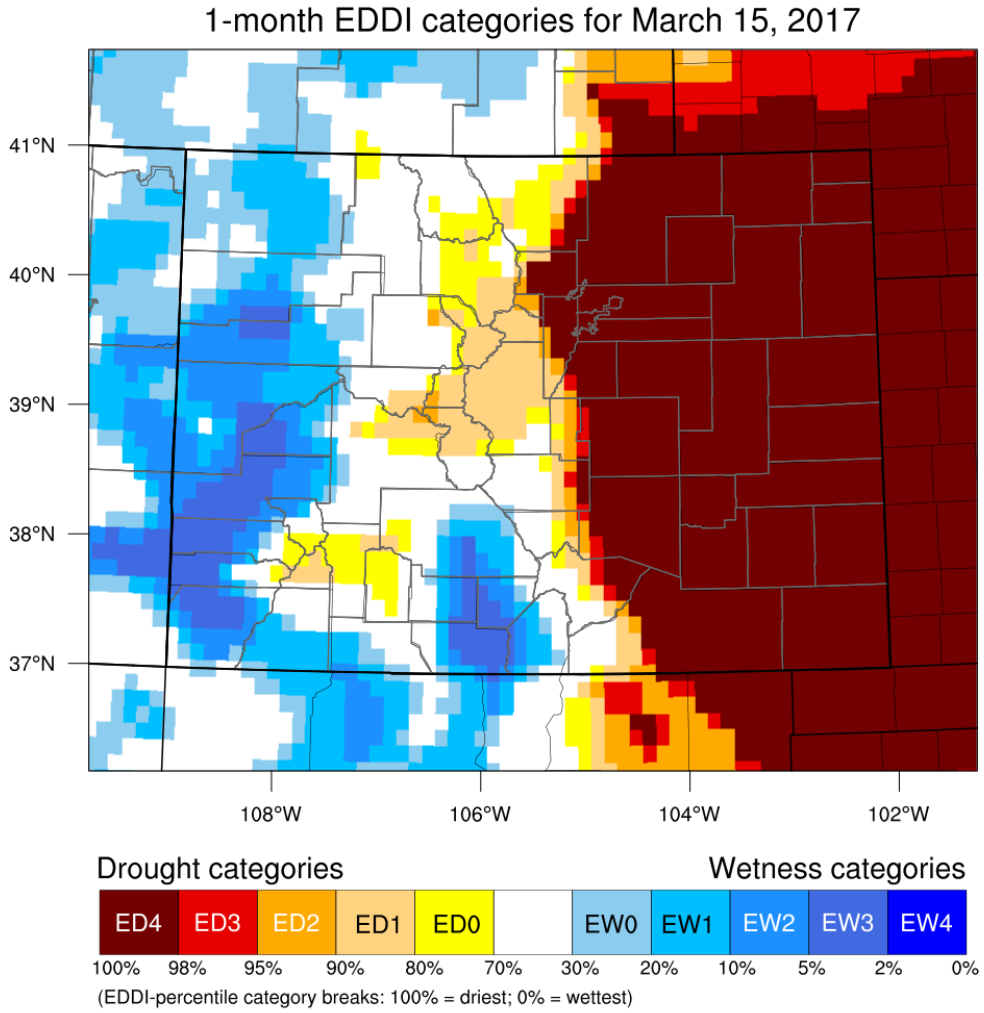


Intensity:

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

What does EDDI offer?

1-month EDDI development, 2-week intervals, from start of WY 2017



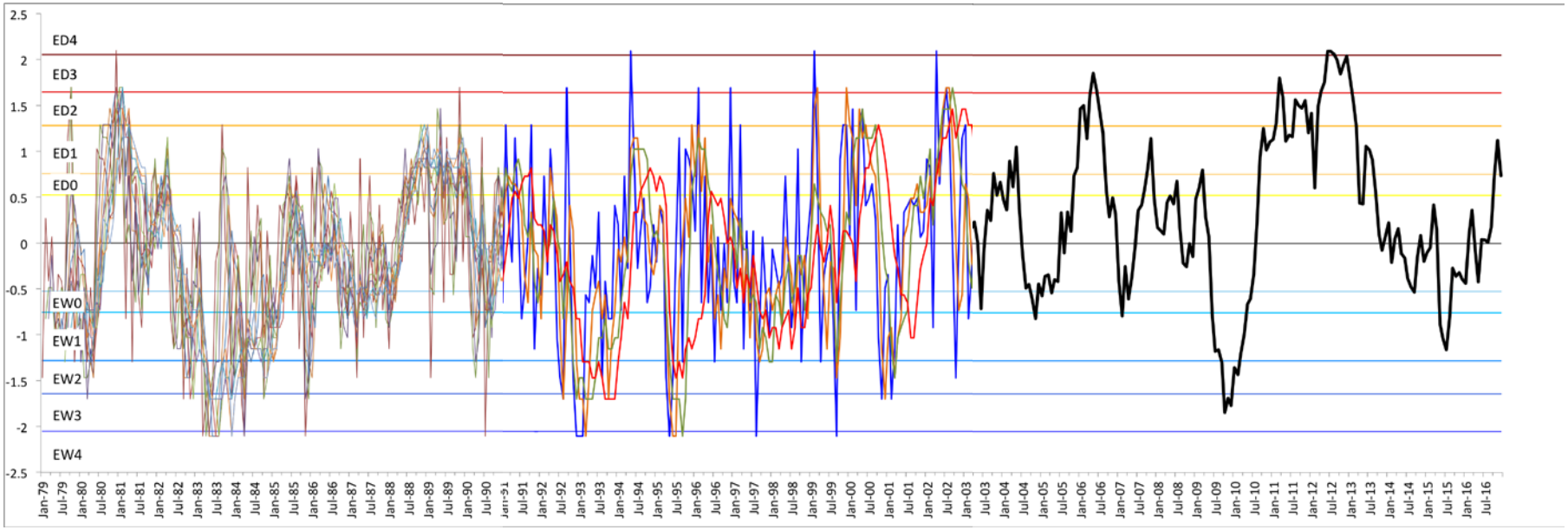
EDDI slider: http://eddi-dri.appspot.com/ [go]

FTP delivery: ftp.cdc.noaa.gov/Public/mhobbins/EDDI/CO/ [go]

What does EDDI offer?

Multi-scalar drought history for Morgan County, CO, 1979-present. Multiple EDDI timescales.

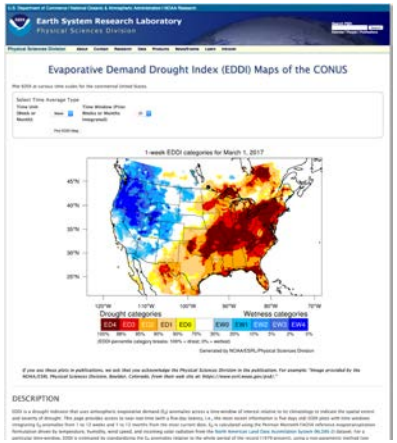
1- to 12-month EDDI Selected EDDI timescales Weighted-average EDDI



Ongoing work

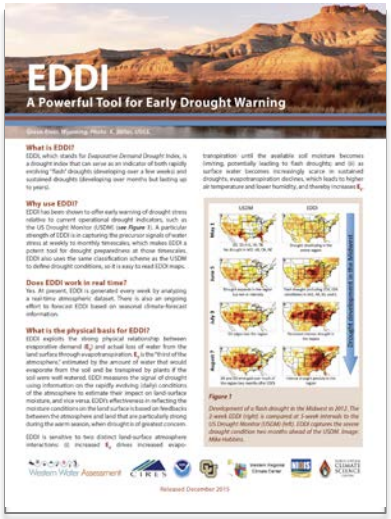
User outreach, operationalizing, research

EDDI on the web:



https://www.esrl.noaa.gov/psd/eddi/realtime_maps/ [go]

Two-pager:



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

Next steps:

- Operationalizing EDDI at NOAA National Water Center
- Enlarge and engage user-base
- EDDI User's Manual
- Continued research and development collaboration with research partners (DRI):
  - attribution component
  - forecast component
  - wildfire prediction
- EDDI on the web

NATIONAL INTEGRATED DROUGHT INFORMATION SYSTEM
NIDIS
Drought.gov
U.S. Drought Portal

Drivers of drought

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

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

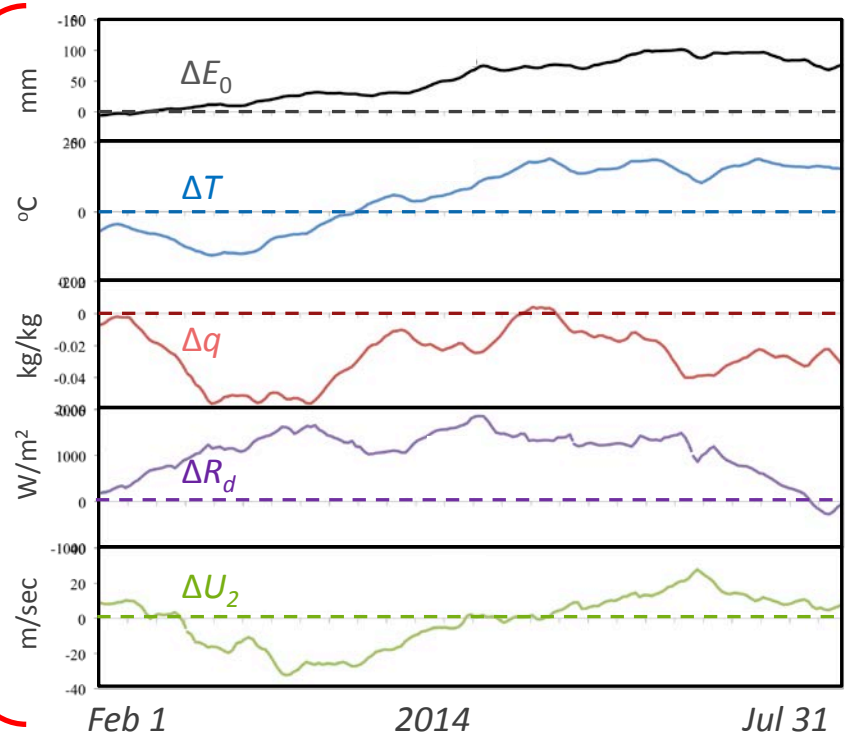
anomalies observed in reanalyses

derived analytically (*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)

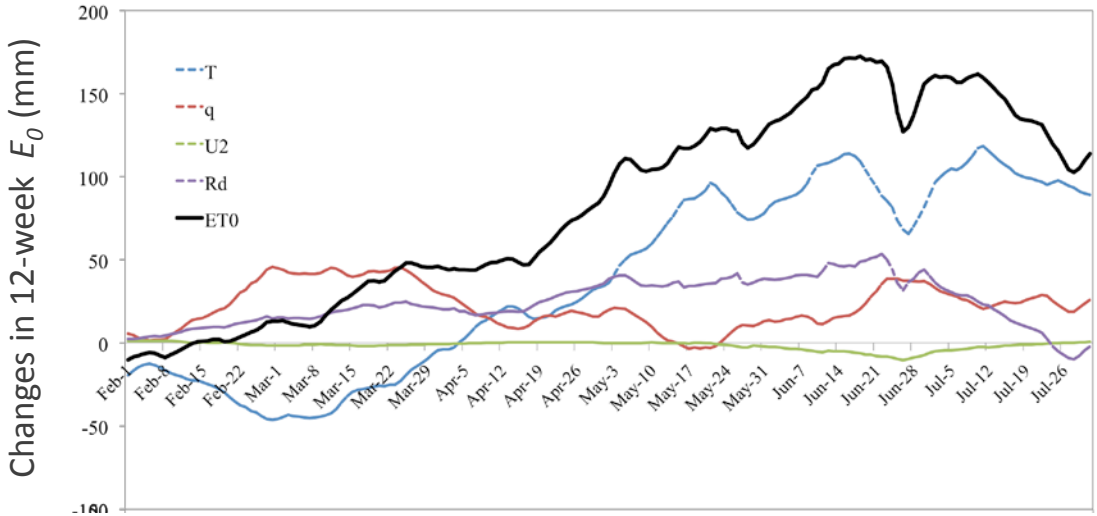
Drivers of drought

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_2 plays little role

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

Sacramento River basin, CA



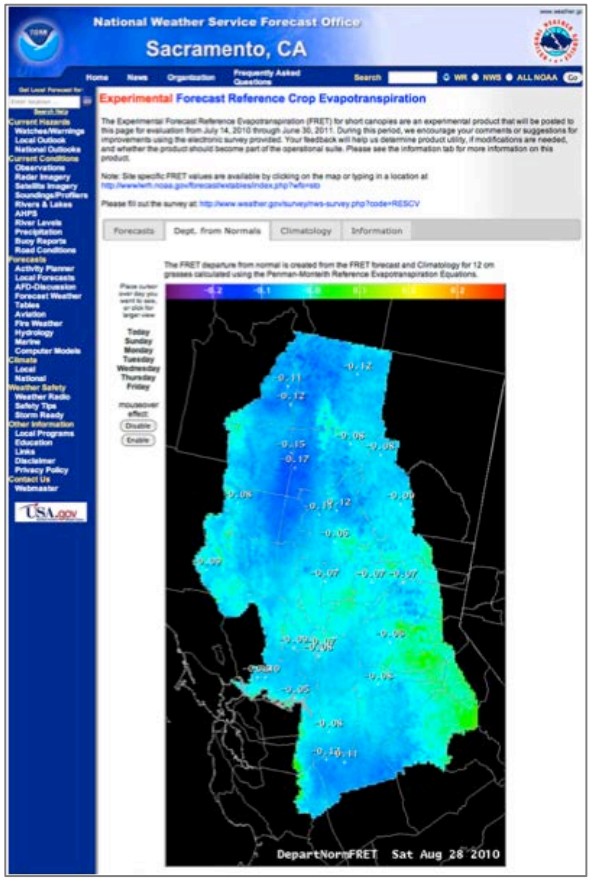
(*Hobbins et al.*, JHM 2016)

OPERATIONAL ATTRIBUTION COMING FOR 2017!

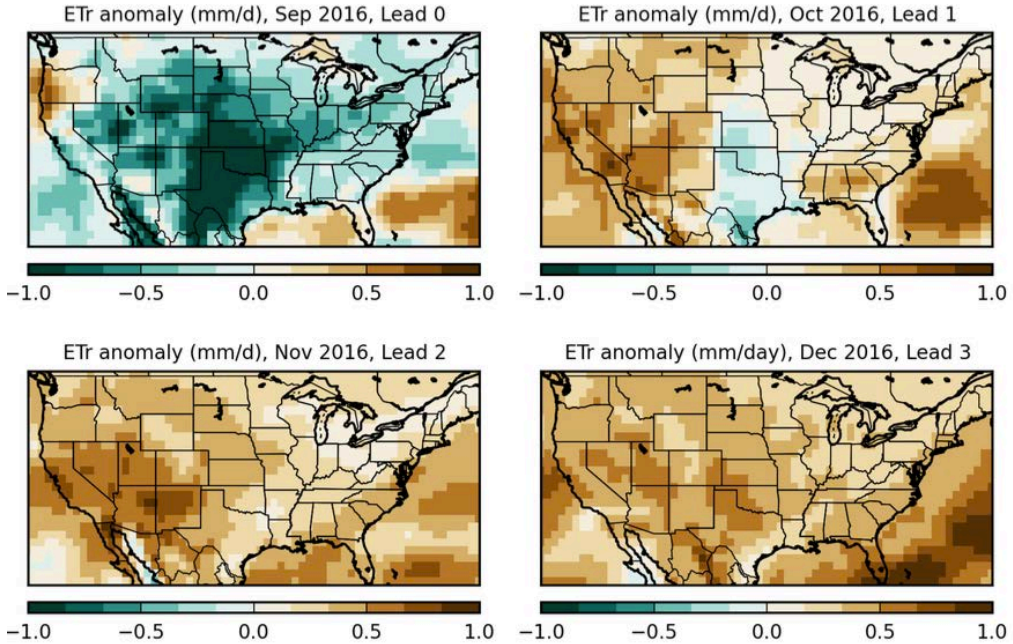
Forecasting of E_0 (and drought)

FRET = Forecast Reference Evapotranspiration
Prcp = precipitation

Daily, weekly - FRET



Seasonally (with greater skill than *Prcp*)



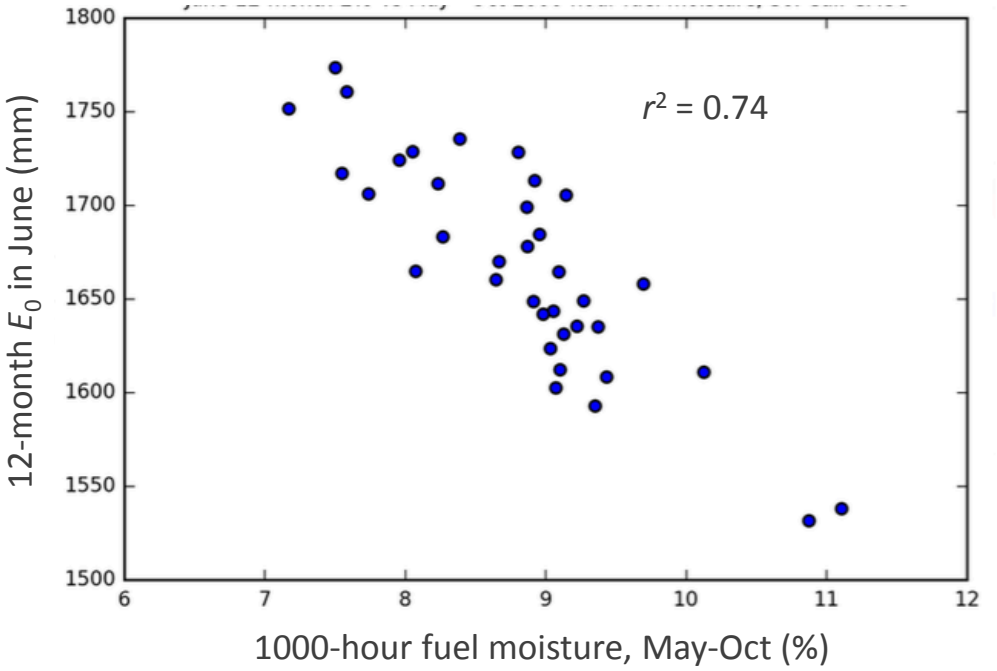
CFSv2 4-member ensemble mean initialized Sept 8 (00Z, 06Z, 12Z, and 18Z) – Dan McEvoy, DRI

SEASONAL FORECASTING COMING SOON!

Predicting wildfire risk

COMING SOON!

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
- More readily available than *ET* (than *Prcp*, often)
  - latency is ~ 5 days
- Permits decomposition of evaporative drought drivers
- E_0 is forecastable (*McEvoy et al.*, GRL 2016)