Evaporative demand and drought @ PSD: opportunities in early warning, and monitoring.

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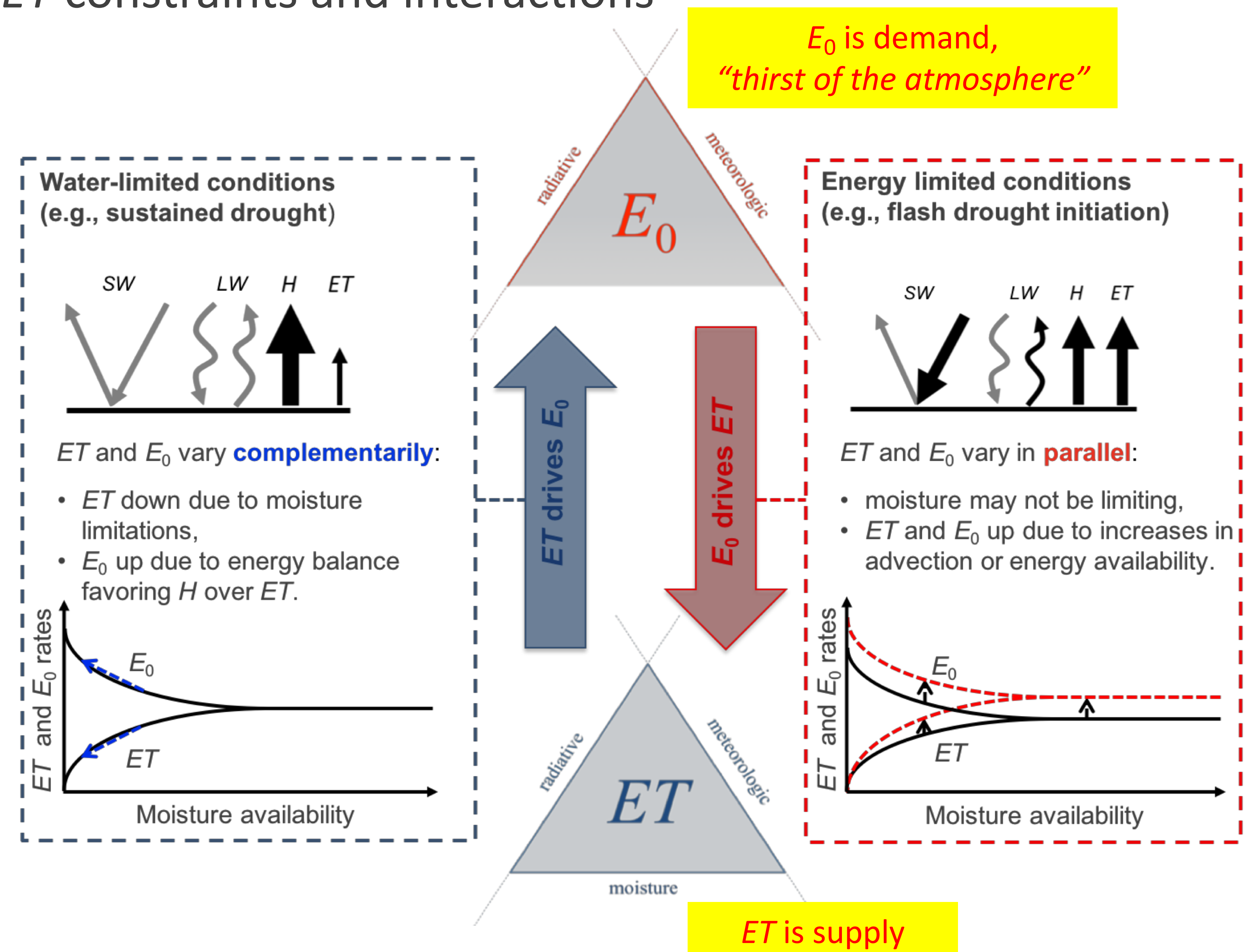
E_0 / ET constraints and interactions



E_0
- much easier to estimate than *ET*
- increases in all drought types.

A demand-side treatment of drought

T = air temperature
q = specific humidity
U_2 = wind speed
R_d = solar radiation

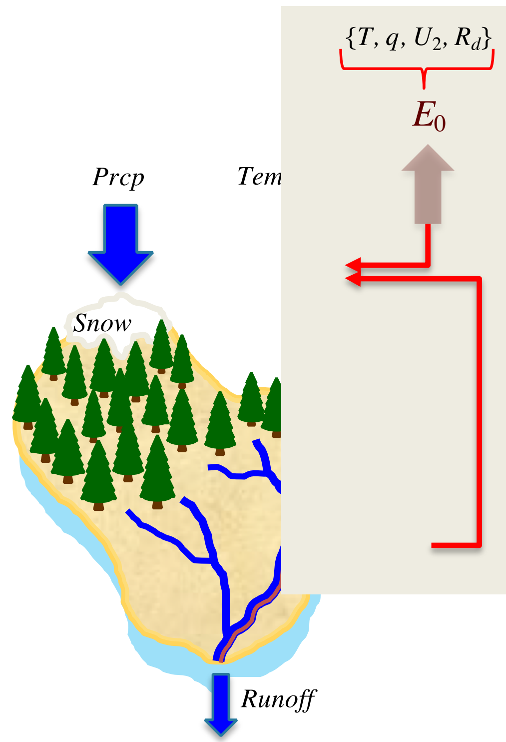
Drought = imbalance of <u>supply</u> to, and <u>demand</u> for, surface moisture

Water balance at land surface:

~ *f*(*Prcp*, *ET*)

where *ET* is more physically driven by:

- surface moisture status,
- evaporative demand (E_0),
    - e.g., Penman-Monteith.



Estimating E_0 from reference *ET*

Reference *ET* from FAO-56 (Penman-Monteith):

$$ET_0 = \underbrace{\frac{0.408\Delta}{\Delta+\gamma(1+C_dU_2)}(R_n - G)\frac{86400}{10^6}}_{\substack{\text{Radiative forcing} \\ \text{(sunshine, } T\text{)}}} + \underbrace{\frac{\gamma \frac{C_n}{T}}{\Delta+\gamma(1+C_dU_2)}U_2\frac{(e_{sat}-e_a)}{10^3}}_{\substack{\text{Advective forcing} \\ \text{(wind, humidity, } T\text{)}}}$$

Reference crop specified:

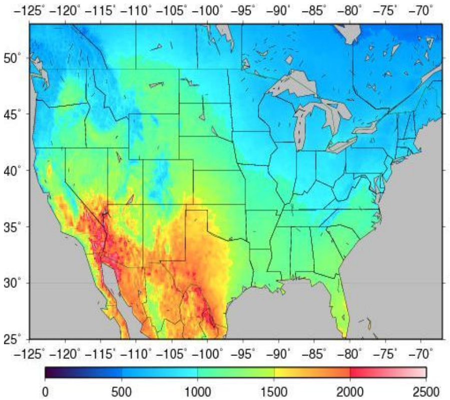
- 0.12-m grass or 0.50-m alfalfa
- well-watered , actively growing,
- completely shading the ground,
- albedo of 0.23.

Drivers:

- *T*, temperature at 2 m
- *q*, specific humidity at surface
- R_d, downward SW at surface
- U_2, wind speed at 2 m

Two reference *ET* reanalyses

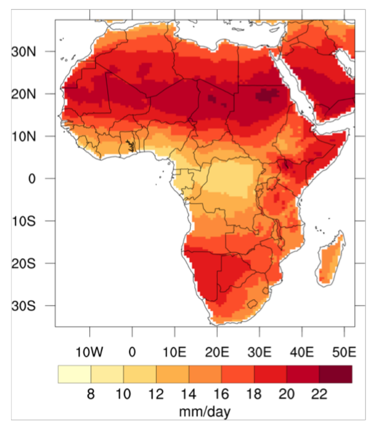
CONUS



Drivers from **NLDAS-2**:

- daily, Jan 1, 1979 – present
- latency ~ 5 days
- **0.125° lat x lon,**
- **CONUS+ (25°N to 53°N)**

GLOBAL



Drivers from **MERRA2**:

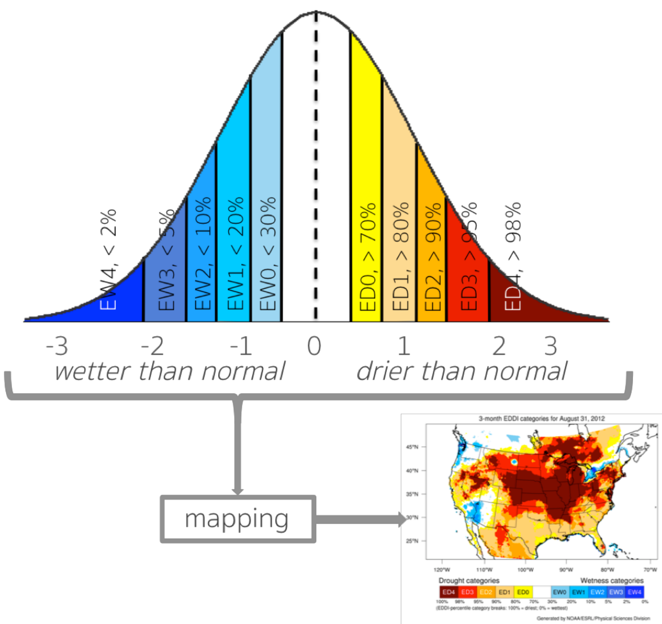
- daily, Jan 1, 1980 – present
- latency ~ 10 days
- **0.5° lat x 0.625° lon**
- **global**

Mean daily E_0 (mm), 1981-2010

Evaporative Demand Drought Index (EDDI)

Hobbins et al., *JHM*, 2016

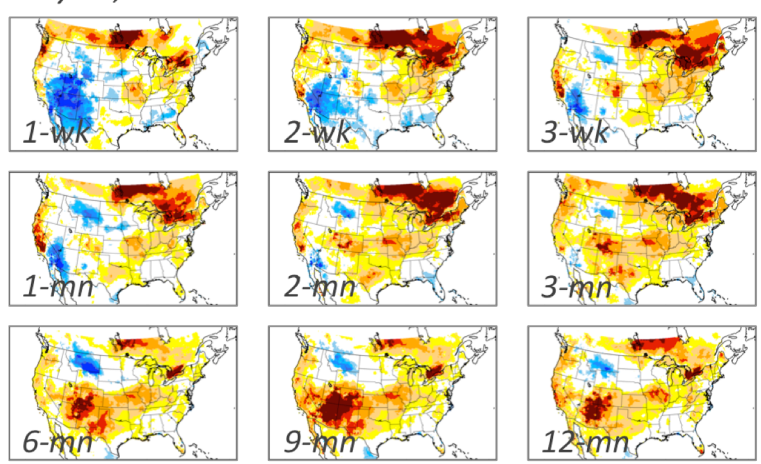
McEvoy et al., *JHM*, 2016



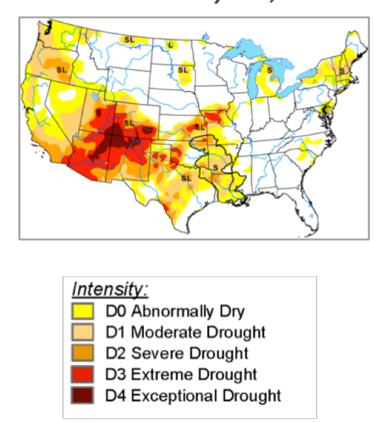
https://www.esrl.noaa.gov/psd/eddi/

or search for "EDDI NOAA"

EDDI,
July 17, 2018



US Drought Monitor,
July 17, 2018



EDDI is multi-scalar:
optimal timescale(s) specific to
region, season, and sector.

EDDI – cross-sectoral monitoring

AGRICULTURAL DROUGHT
- soil moisture
- grazing health
- ET

HYDROLOGIC DROUGHT
- streamflow
- snowfall

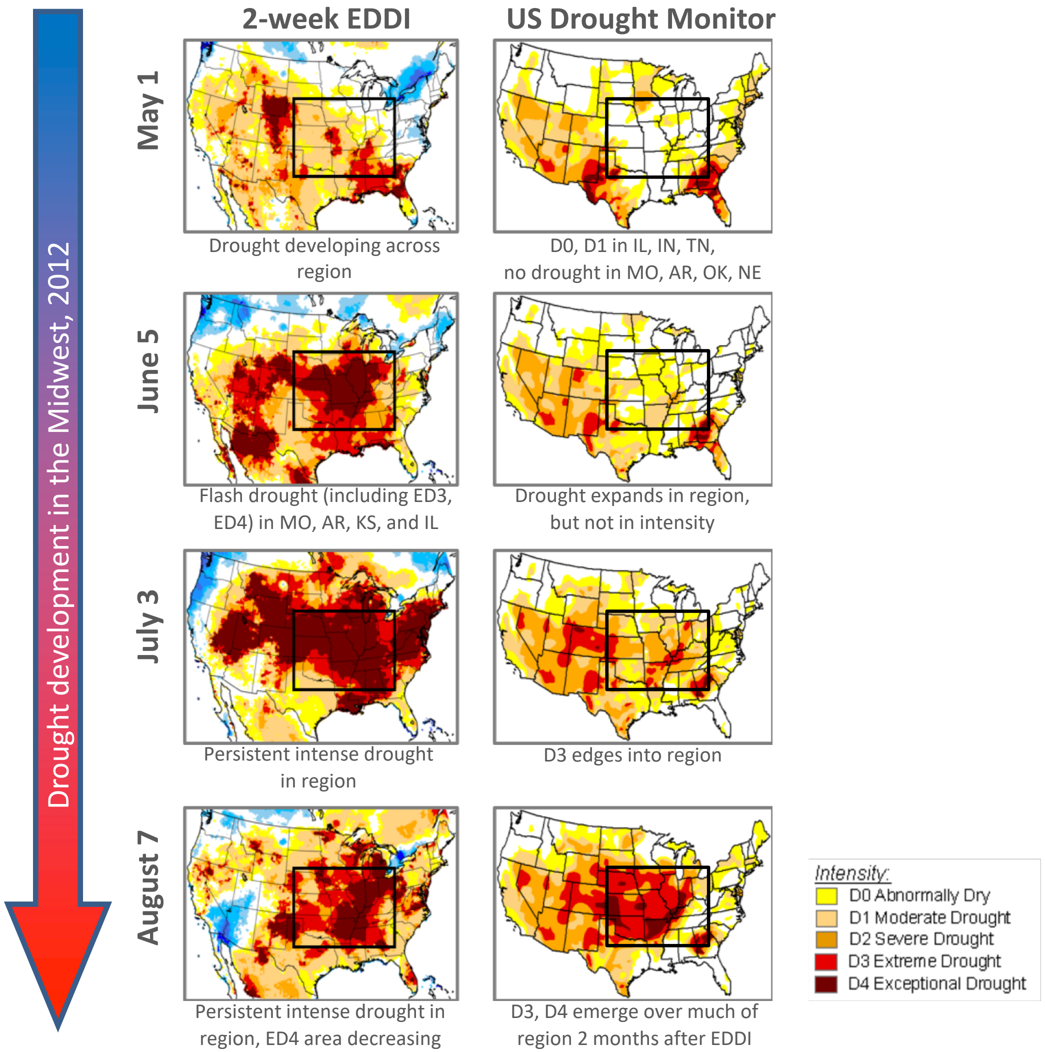
FIRE-RISK MONITORING
- weather
- fuel loads

ECOLOGICAL DROUGHT

EDDI – flash drought / early warning

Midwest US: 2012

EDDI captured severe drought conditions ~2 months before the US Drought Monitor

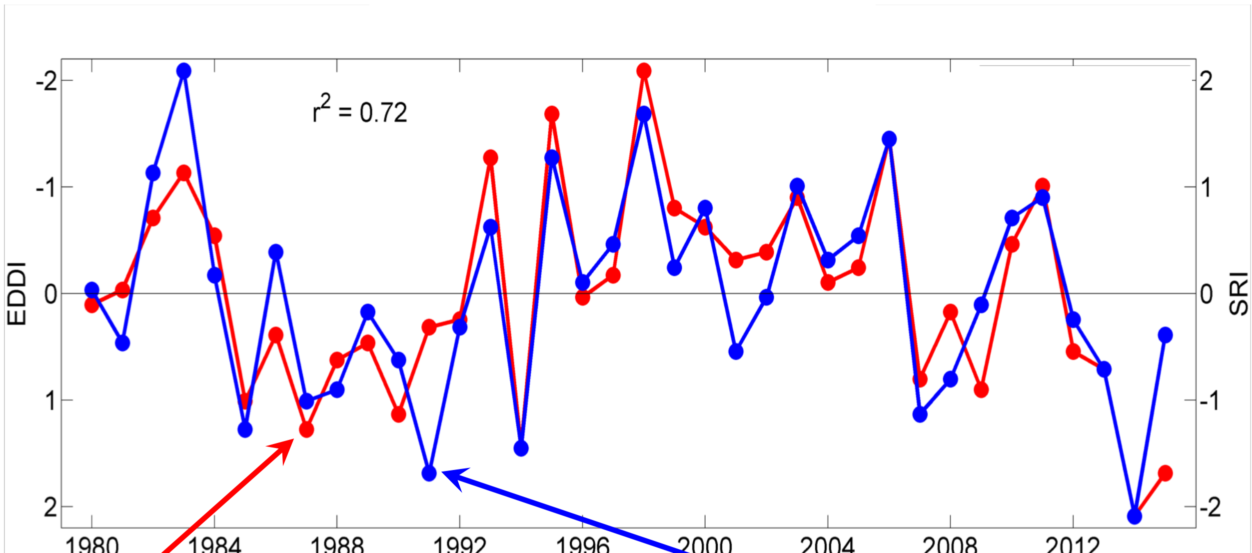


Hobbins et al., *CRC Press*, 2017

EDDI – early warning of hydrological drought

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

Sacramento River Basin, CA



6-month EDDI (Nov-Apr)

12-month SRI (Oct-Sep)

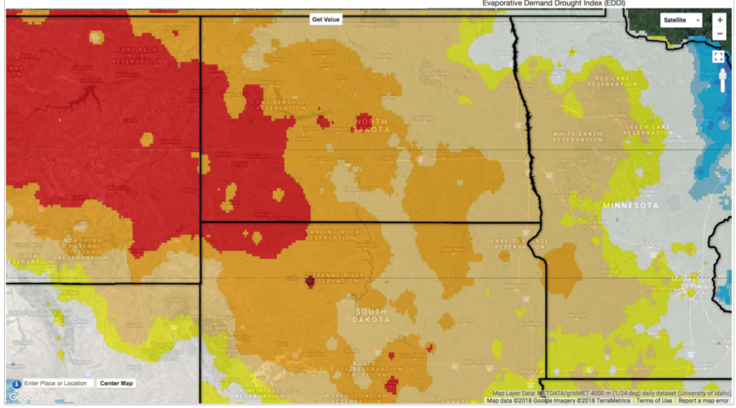
SRI = Standardized Runoff Index

EDDI – complementing remote sensing

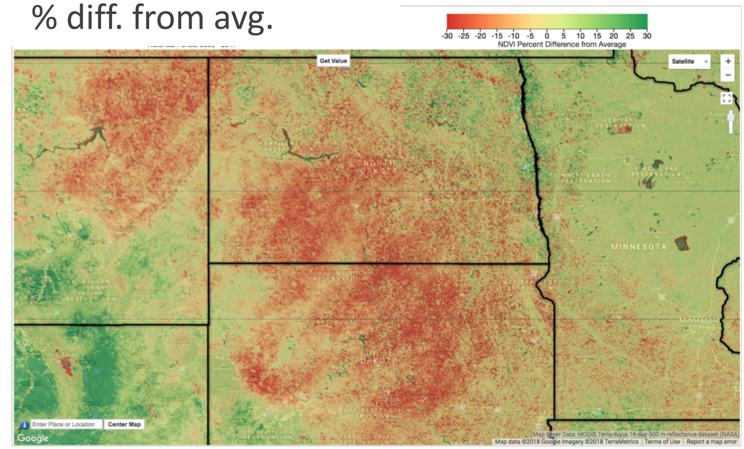
Understanding remote sensing anomalies of land surface temperature, vegetation, and ET

Northern Great Plains: May – July, 2017

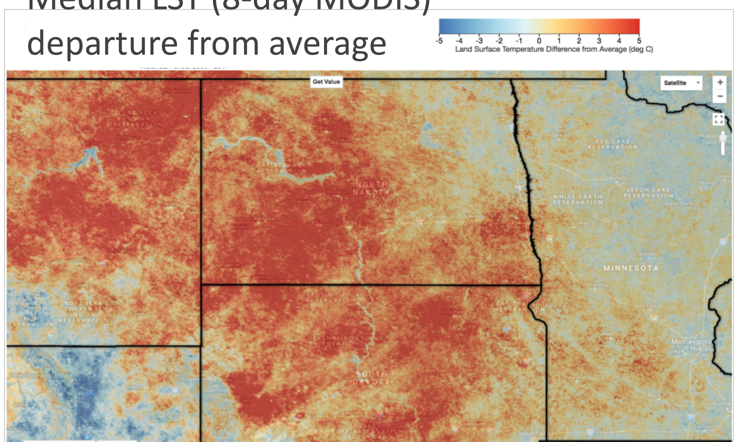
3-month EDDI (gridMet)



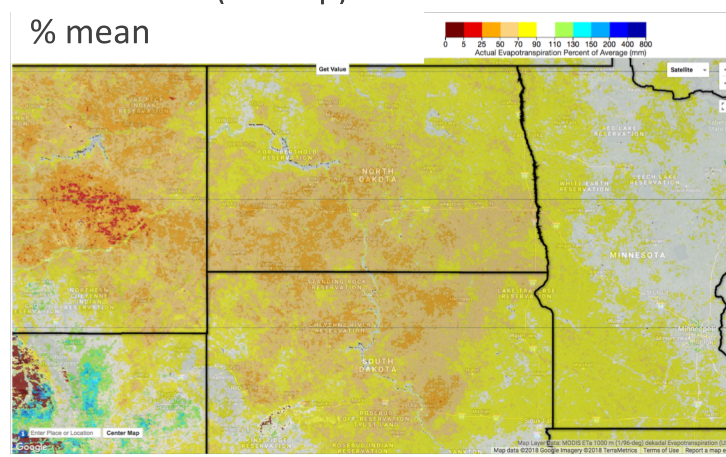
Median NDVI (16-day MODIS)
% diff. from avg.



Median LST (8-day MODIS)
departure from average



3-month *ET* (SSEBop)
% mean



Attribution – diagnosing drought's demand side

Northern Great Plains: 2017

How much are changes in E_0 due to each driver's changes?

Decomposition of 6-month E_0 anomaly, as of July 25, 2017

$E_0 = f(T, R_d, q, U_2)$, so

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

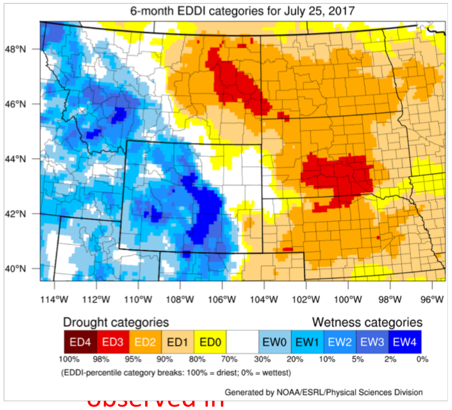
$$\Delta E_0 = \frac{\partial E_0}{\partial T}\Delta T + \frac{\partial E_0}{\partial R_d}\Delta R_d + \frac{\partial E_0}{\partial q}\Delta q + \frac{\partial E_0}{\partial U_2}\Delta U_2$$

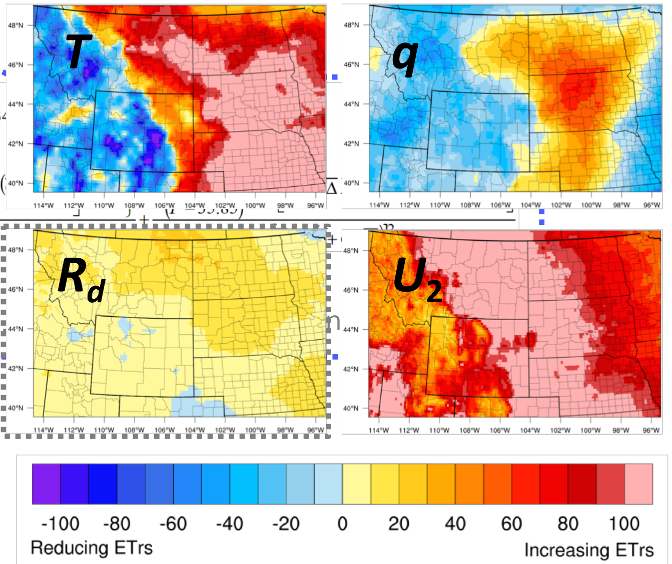
derived analytically

observed in reanalyses

$$\frac{\partial \mathrm{ET}_r}{\partial T} = \frac{\left\{ 0.408\overline{\Delta}\left[\overline{R}_n \frac{4169.871 - 2\overline{T}}{(\overline{T} - 35.85)^2} - 4\sigma f_{cd}(0.34 \ldots \right] + \gamma C_n \frac{\overline{U}}{\overline{T}}\left[\overline{e}_{sat}\frac{4098.171}{(\overline{T}-35.85)^2} - \frac{1}{\overline{T}}(\ldots \right] \right.}{\overline{\Delta} + \gamma(1 + C_d\overline{U})}$$

EDDI across 6-month period of drought



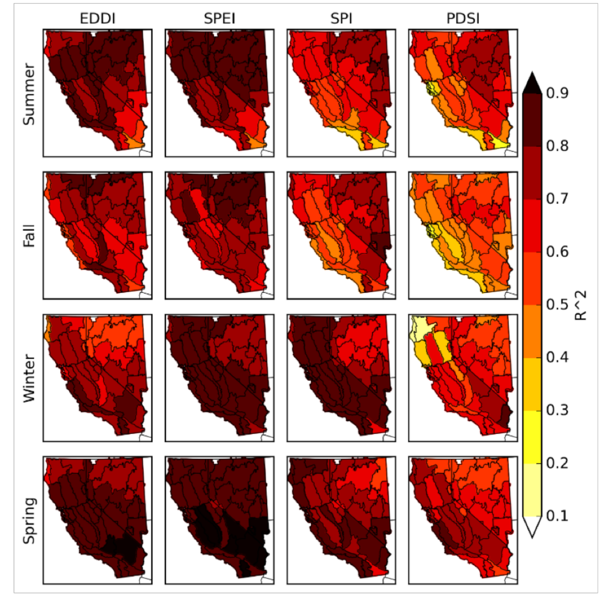


Contributions to 6-month E_0 anomaly (mm)

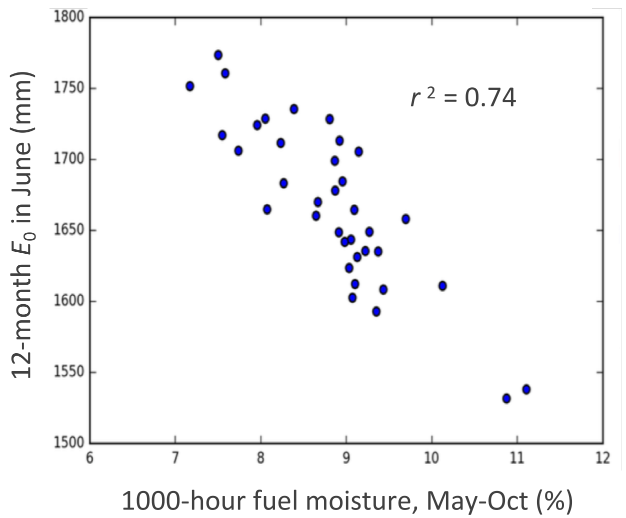
EDDI – wildfire risk monitoring

California and Nevada

Correlations to 1000-hour fuel moisture

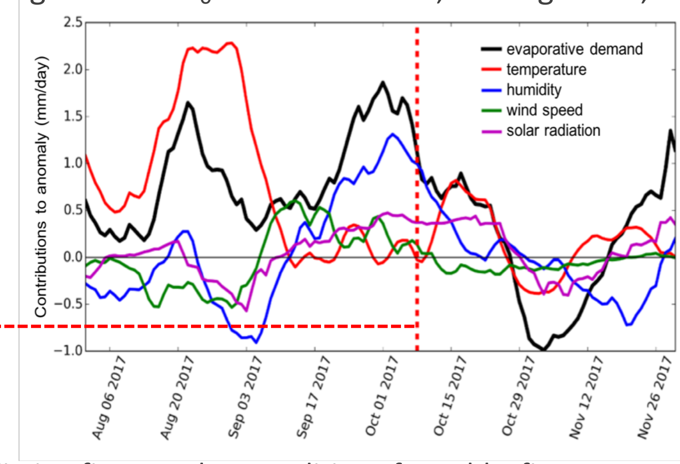


E_0 - fuel moisture relationship across S. California GACC



Can EDDI provide early warning of wildfire risk?

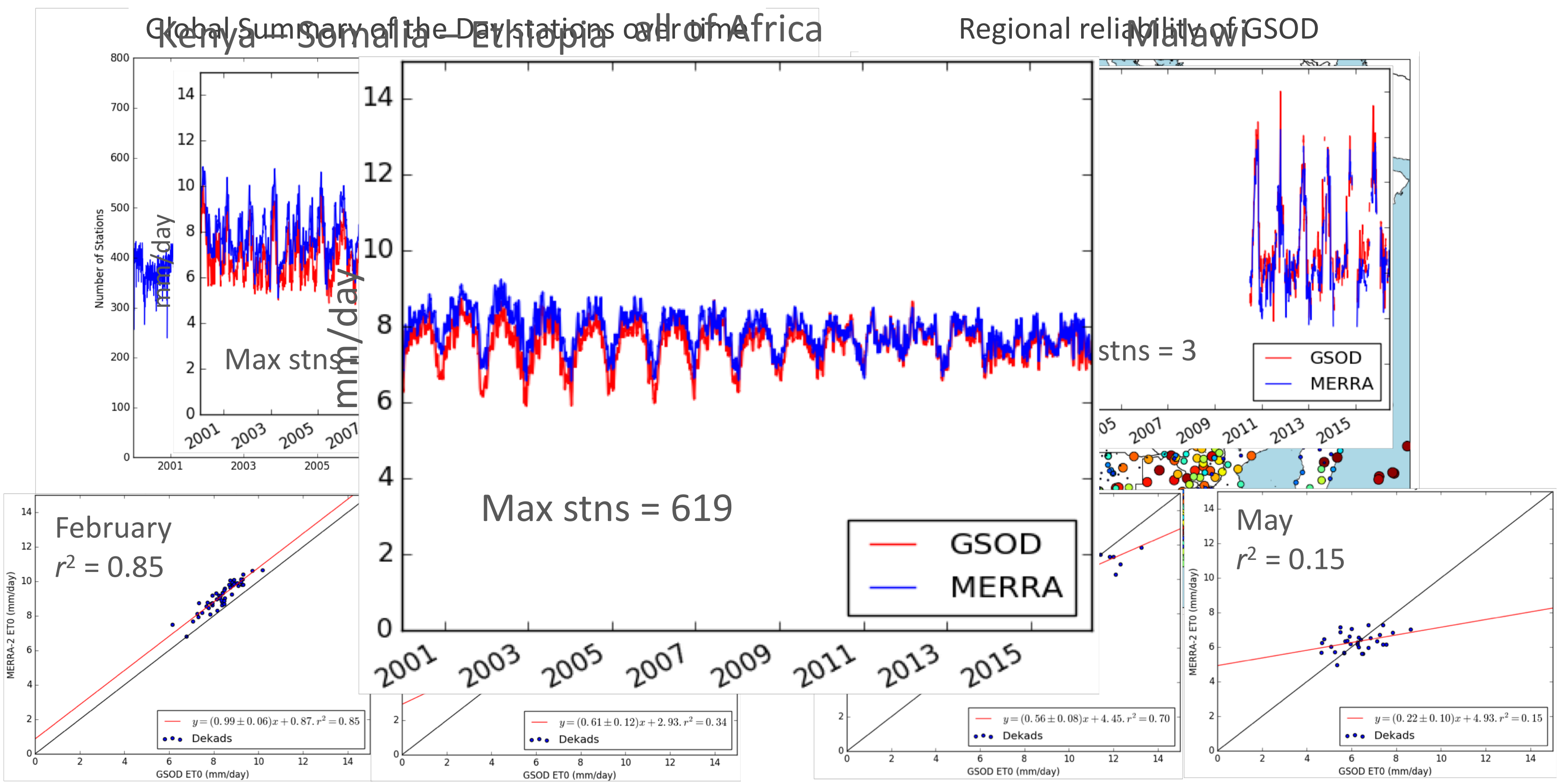
Diagnosis of ΔE_0 for Sonoma Co., CA Aug – Nov, 2017



Predicting fire-weather conditions for Tubbs fire:

- Decomposing EDDI into its drivers indicates a shift to a humidity-driven spike in E_0 about 4 weeks before the fire.

Verification of E_0 across Africa

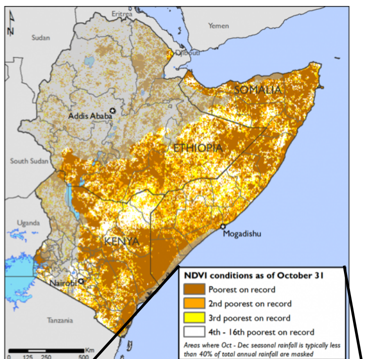


GSOD = Global Summary of the Day

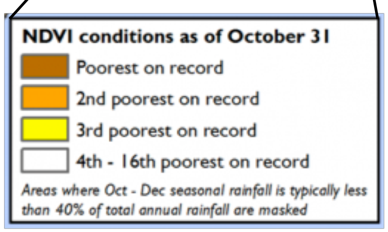
Attribution of demand side of drought

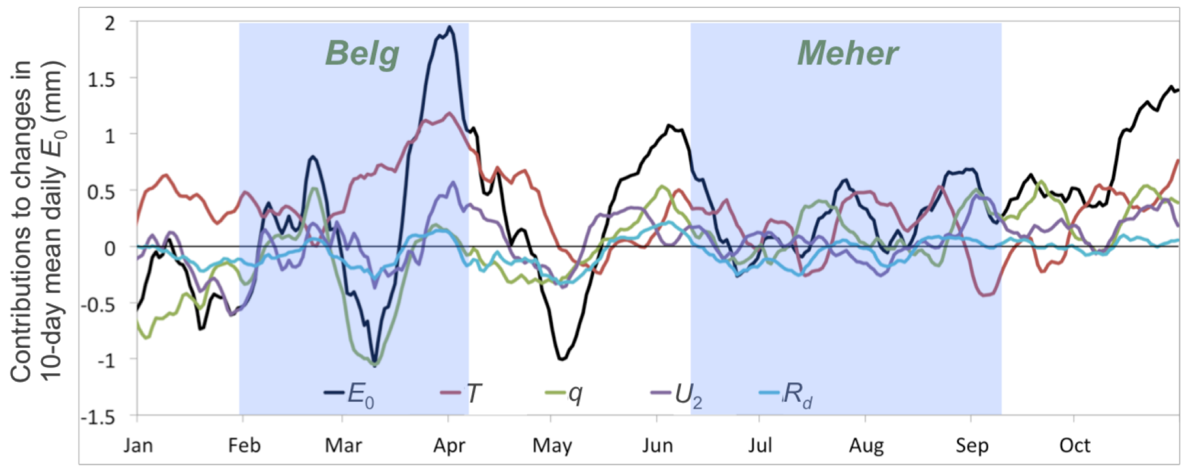
T = air temperature
q = specific humidity
U_2 = wind speed
R_d = solar radiation

Horn of Africa, 2016 drought



Source: FEWSNET

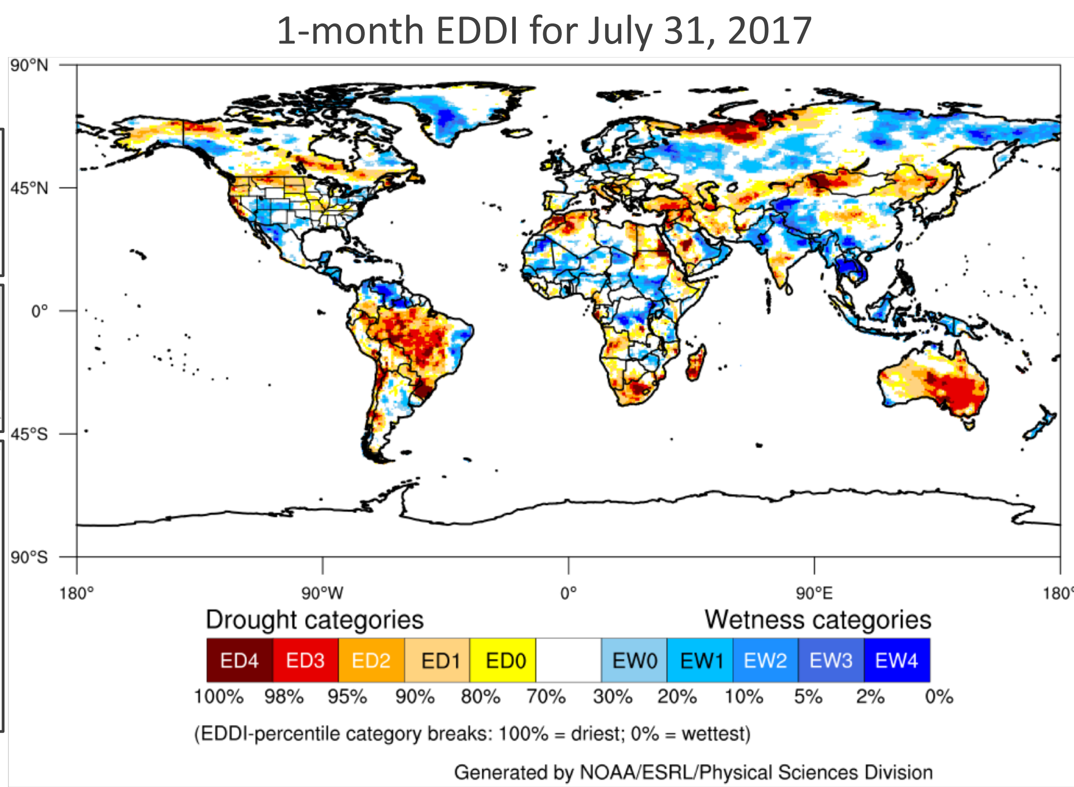


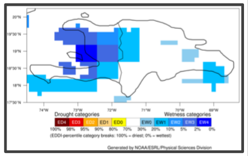


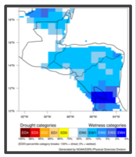
Changing E_0 dynamically forced by:

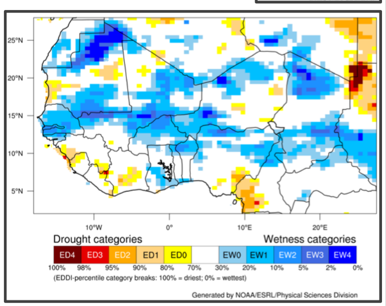
- elevated T,
- Peaks coincide with elevated U_2 and/or q minima, troughs with q maxima.
- R_d plays little role

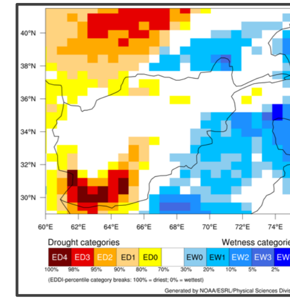
Global EDDI for famine early warning

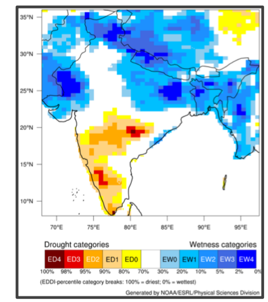


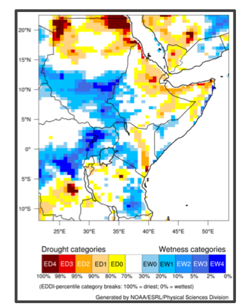


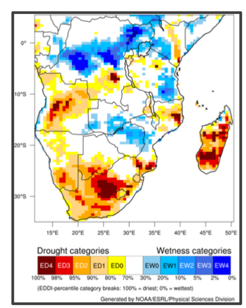












Opportunities for collaboration

CONUS product:

- transition to National Water Model-forcing of EDDI (1 km, daily)
- examining drought linkages between NWM-derived soil moisture, evaporative demand, EDDI, and *ET*

Global product:

- data assimilation of reference *ET* observations
- improved downscaling of reference *ET* to 0.125°
- verification of EDDI in agricultural / hydrologic drought and early warning against independent R/S-based drought metrics (e.g., NDVI)