WWA/NIDIS Webinar:
Evaporative Demand Drought Index (EDDI):
Tracking the “atmospheric demand” side of drought for monitoring and early warning

Thursday, May 11, 2017 – 11am-12pm

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for the EDDI team
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The **Intermountain West DEWS**
(Regional Drought Early Warning System)

- *Formerly the Upper Colorado River Basin DEWS*
- Provides regular drought & climate updates and outlooks
- Engages the drought preparedness community
- **Presents webinars and workshops to build capacity**
- Identifies information needs, coordinates information providers
- **NIDIS Partners: Federal, state, local, tribal, university**
You may have seen **EDDI** maps in these IMW DEWS resources...

**CCC/NIDIS Intermountain West Drought Status Briefings**

**WWA Intermountain West Climate Dashboard**
What is EDDI?

• The anomaly in **evaporative demand** over a specified timescale, at a given location

• Provides added value as a drought indicator, especially for early warning and flash drought detection
Key features of EDDI

- Near-real-time (~5-day lag)
- Moderately high resolution (12 km)
- Can be calculated over multiple timescales (like SPI) to suit different applications
- Uses similar classification scheme as US Drought Monitor (D0, D1, D2, etc.)
- Not sensitive to land-surface type, so valid for use in all regions
- Available now through several web resources
Relevance of evaporative demand to drought

Anomally high evaporative demand can lead to *moisture stress* on the land surface, even when precipitation is near-normal.
Drought = imbalance of supply to, and demand for, moisture at land surface

Water balance on a land surface:
\[ \sim Function \ (Precip, \ ET) \]

Where \( ET \) is driven by
- evaporative demand (\( E_0 \))
- surface moisture status
Relationship between $E_0$ and \( ET \) changes as land surface dries out

- When surface moisture is sufficient, rising $E_0$ leads to rising ET
- When moisture is limited, ET declines, while $E_0$ rises even more steeply
Evaporative Demand \((E_0)\) – “thirst of the atmosphere”

- \(ET\) that would occur given an unlimited moisture supply; estimated from:
  - Reference \(ET\) \((ET_0)\)
  - Potential \(ET\) \((PET)\)
  - Pan evaporation
- \(E_0\) easier to quantify than \(ET\)
- Often estimated using temperature only
- But fully **physically based** method is much better, e.g., *Penman-Monteith*

Physically-based \(ET_0\) contains valuable information related to drought dynamics
Observed vs. physically estimated evaporative demand

**Observed** mean Pan Evaporation, May-September, 1979-2005 (mm)

**Estimated** mean $ET_0$ from Penman-Monteith (FAO56; 12km NLDAS) May-September, 1979-2005 (mm)

Source: Candida Dewes
How is EDDI calculated?

Meteorological Inputs
temperature, humidity, wind speed, solar radiation
NLDAS-2, 12km gridded met data

Reference Evapotranspiration (ET₀) calculation
Penman-Monteith FAO56

Rank-based non-parametric standardization based on historic climatology of ET₀

EDDI
Reading an EDDI Map

3-month EDDI categories for May 4, 2017

Drought categories

ED4 | ED3 | ED2 | ED1 | ED0
--- | --- | --- | --- | ---
100% | 98% | 95% | 90% | 80%

Wetness categories

EW0 | EW1 | EW2 | EW3 | EW4
--- | --- | --- | --- | ---
10% | 5% | 2% | 0% | 0%

(EDDI-percentile category breaks: 100% = driest; 0% = wettest)

Generated by NOAA/ESRL/Physical Sciences Division
EDDI at multiple timescales

2-week EDDI

Emerging conditions (that could lead to drought)
(2-weeks to 1-month EDDI)

12-month EDDI

Persistent drought conditions
(> 3-month EDDI)

Source:
http://wwa.colorado.edu

http://www.esrl.noaa.gov/psd/eddi/realtime_maps/
Interpretation of current EDDI conditions in IMW DEWS

as of May 4, 2017
Interpretation of current EDDI conditions in IMW DEWS

3-month EDDI
3-month EDDI categories for May 4, 2017

3-month SPI
(Standardized Precipitation Index)
Decomposing $E_0$ to diagnose the drivers of the demand side of drought

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

- First, below-normal Humidity
- Then, increasing Temperature and, to a lesser degree, Radiation
- Winds played little role
Application: EDDI in sector-specific monitoring

**Agricultural Drought**
- soil moisture
- grazing health
- ET

**Hydrologic Drought**
- streamflow
- snowfall

**Fire-risk Monitoring**
- weather
- fuel loads
**Application: EDDI as 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.

- **May 1:** No drought in MO, AR, OK, NE. Drought developing in entire region.
- **June 5:** Drought expands in the region but not in intensity. Flash drought (including ED3, ED4 conditions) in MO, AR, KS, and IL.
- **July 3:** D3 edges into the region. Persistent intense drought in the region.
- **August 7:** D4 and D3 emerged over much the region two months after EDDI. Intense drought persists in the region.

**Intensity:**
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought
Ag drought monitoring – 3-month EDDI

EDDI shows similar spatial patterns to USDM & other ag-related monitors

(a) USDM
(b) 3-month EDDI
(c) VIC-modeled Soil Moisture
(d) 12-week Evaporative Stress Index (ESI)

Agricultural drought, July 31, 2002

(Hobbins et al., JHM 2016)
Ag drought monitoring – 2-week EDDI
2015 Growing Season in Wind River Indian Reservation, WY

Source: Candida Dewes
Wildfire-risk monitoring - 12-month EDDI - California

$E_0$ - fuel moisture relationship across S. California GACC

2-year NOAA-SARP grant: Developing a wildfire component for the NIDIS CA DEWS – DRI
Can EDDI help predict late-summer (low-flow) streamflow?

**6-month EDDI (Nov-Apr)**

**12-month SRI (Oct-Sep)**

EDDI contains no precipitation information!

(EDDI - McEvoy et al., JHM 2016)
(SRI - Shukla and Wood, GRL 2008)
Where to get current EDDI maps

**US maps, all timescales:**

**EDDI homepage**
https://www.esrl.noaa.gov/psd/eddi/realtime_maps/
Or Google: EDDI drought

**Regional maps, 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
EDDI historical time-series tool

http://esrl.noaa.gov/psd/eddi/timeseries/

EDDI Timeseries for the Continental US

This webtool allows a user to generate historical (1980–latest complete year) timeseries data of the Evaporative Demand Drought Index (EDDI) for a specified region in the Continental United States. The timeseries is generated as a table for different timescales, i.e. 1 to 12 months of integrated evaporative demand at the end of a given month. This tool also allows users to generate timeseries plots with user specified timescales.

Region:

Plot Options:

Other EDDI data needs? Contact mike.hobbins@noaa.gov
Application: EDDI Historical Time-series Data

❖ Time Period: 1980-present
❖ Research into understanding past impacts
❖ Helpful for exploring relevant EDDI timescales for user-relevant impacts
Next steps with EDDI

- Writing an EDDI User Manual (EDDI homepage)
- Enlarge and engage user base
  - contact Heather Yocum (heather.yocum@noaa.gov)
- Continued research and development collaboration with research partners (DRI)
  - attribution component
  - forecast component
  - wildfire prediction
- Transition to NOAA operational product by 2019
EDDI Resources

• EDDI 2-page handout
  http://wwa.colorado.edu/publications/reports/EDDI_2-pager.pdf

• EDDI Homepage (US Maps, technical references)
  https://www.esrl.noaa.gov/psd/eddi/realtime_maps/

• EDDI Historical Time-series Tool
  https://www.esrl.noaa.gov/psd/eddi/timeseries/

• Evaporative demand methodological issues – Dewes et al., 2017
  https://doi.org/10.1371/journal.pone.0174045
Additional Slides
How is EDDI calculated? (Example: 3-month EDDI)

37 years of summer $E_0$ – Midwest US

$E_0$ (mm/day)

Year (1980-2016)

$E_0$ (mm/day)

max (2012)

median

min

How is EDDI calculated?

- Tukey plotting position – non-parametric
- Recommended for comparing drought indices (Hao and AghaKouchak, 2014)
- $t$ is period during which $E_0$ is observed

EDDI < 0  
vetter than normal

EDDI > 0  
Drier than normal

EW0: -0.524, < 30%ile
EW1: -0.841, < 20%ile
EW2: -1.282, < 10%ile
EW3: -1.645, < 5%ile
EW4: -2.054, < 2%ile

ED0: 0.524, > 70%ile
ED1: 0.841, > 80%ile
ED2: 1.282, > 90%ile
ED3: 1.645, > 95%ile
ED4: 2.054, > 98%ile

Summer 2012

(Hobbins et al., JHM 2016)
(McEvoy et al., JHM 2016)
Why Evaporative Demand?

$E_0 / ET$ constraints and interactions

(Bouchet, IAHS 1963)

(Hobbins et al., GRL 2004)
Estimating $E_0$ from reference ET

Penman-Monteith Reference ET (FAO-56):

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

- Radiative forcing (sunshine, $T$)
- Advective forcing (wind, humidity, $T$)

“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 from NLDAS-2:
- temperature at 2 m
- specific humidity at surface
- downward SW at surface
- wind speed at 10 m
- daily, Jan 1, 1979 – present
- ~12-km, CONUS-wide

Mean annual $E_0$ (mm), 1981-2010
Why Evaporative Demand?

$E_0 / ET$ constraints and interactions

$ET = \text{actual evapotranspiration}$

$E_0 = \text{evaporative demand}$

- **In supply-limited or dry hydroclimates**, $E_0$ drives $ET$, **complementary**.
- **In energy-limited or wet hydroclimates**, $ET$ is driven by $E_0$, **parallel**.

$E_0$ is demand for $ET$ in atmosphere.

$ET$ is supply of surface moisture to atmosphere.

$E_0$ much easier to estimate than $ET$.

(Bouchet, IAHS 1963)
(Hobbins et al., GRL 2004)
Features of EDDI
Attribution of demand side of drought

How much does $E_0$ change due to:
- $T$, temperature,
- $q$, humidity,
- $R_d$, solar radiation,
- $U_2$, wind speed?

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

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

anomalies observed in reanalyses

derived analytically (Hobbins, 2016)

Sacramento River basin, CA

(Hobbins et al., JHM 2016)