The Evaporative Demand Drought Index (EDDI):

an emerging drought-monitoring & early warning tool

Mike Hobbins, for the EDDI team

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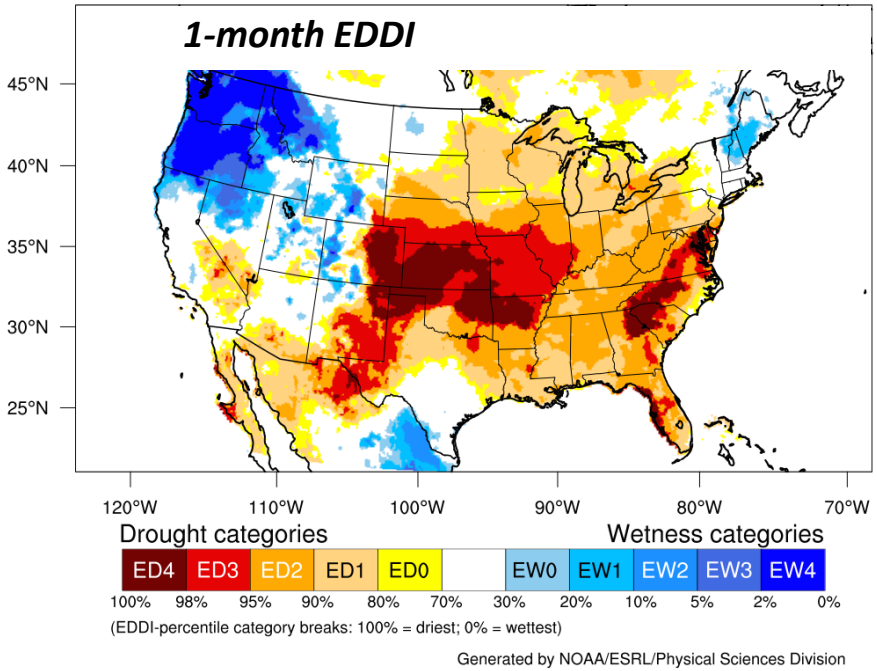
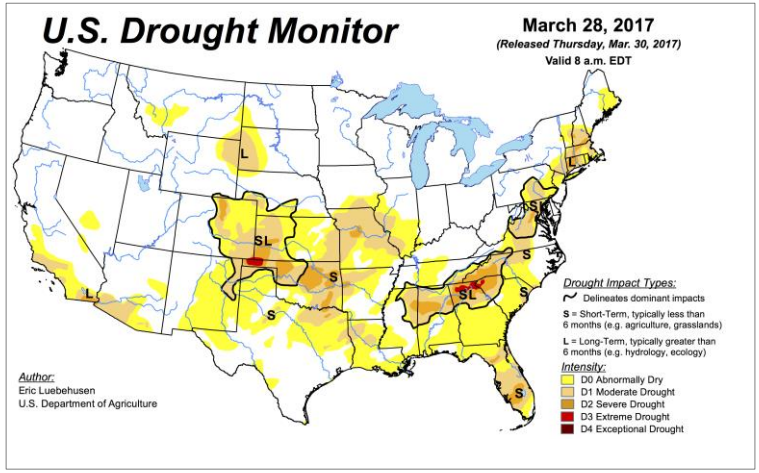
NOAA/ESRL/Physical Sciences Division &
University of Colorado/Cooperative Institute for Research in the Environmental Sciences

United States Drought Monitor Forum, April 3-5, 2017

Current conditions

March 28, 2017





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 ~ $f(Prcp, ET)$

$ET \sim f(\theta, E_0)$

Traditionally:

Drought ~ $f(Prcp, T)$

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

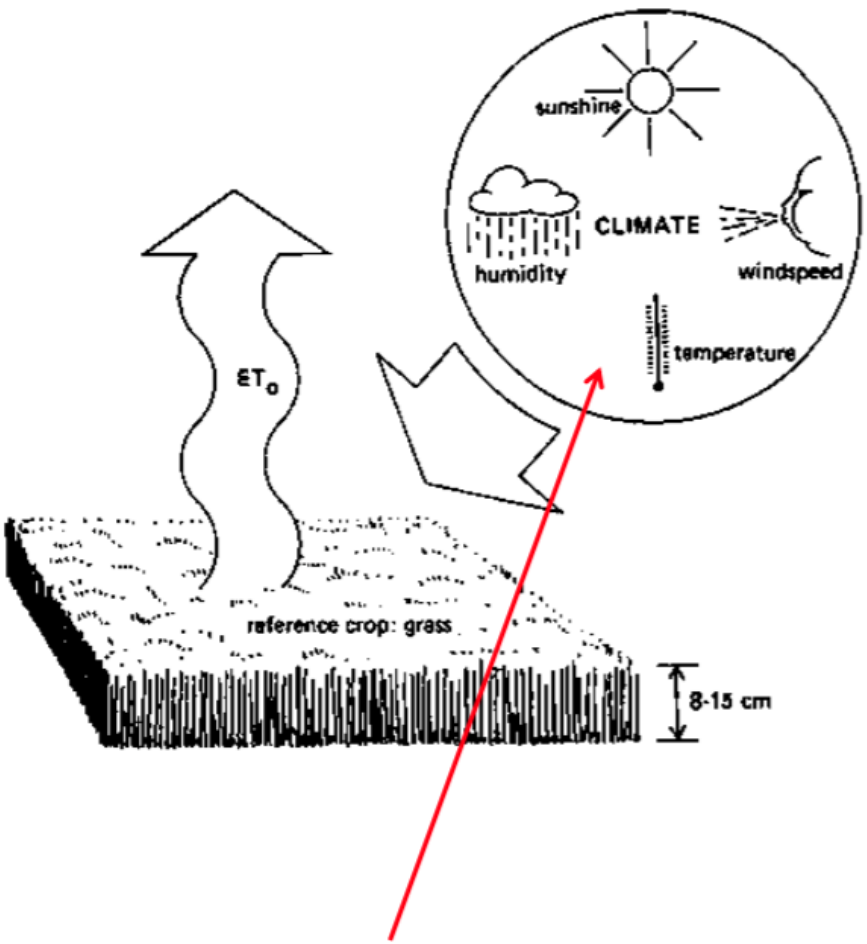
But more physical E_0 formulations are available.

$E_0 \sim f(T, q, R_d, U_2)$ - 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

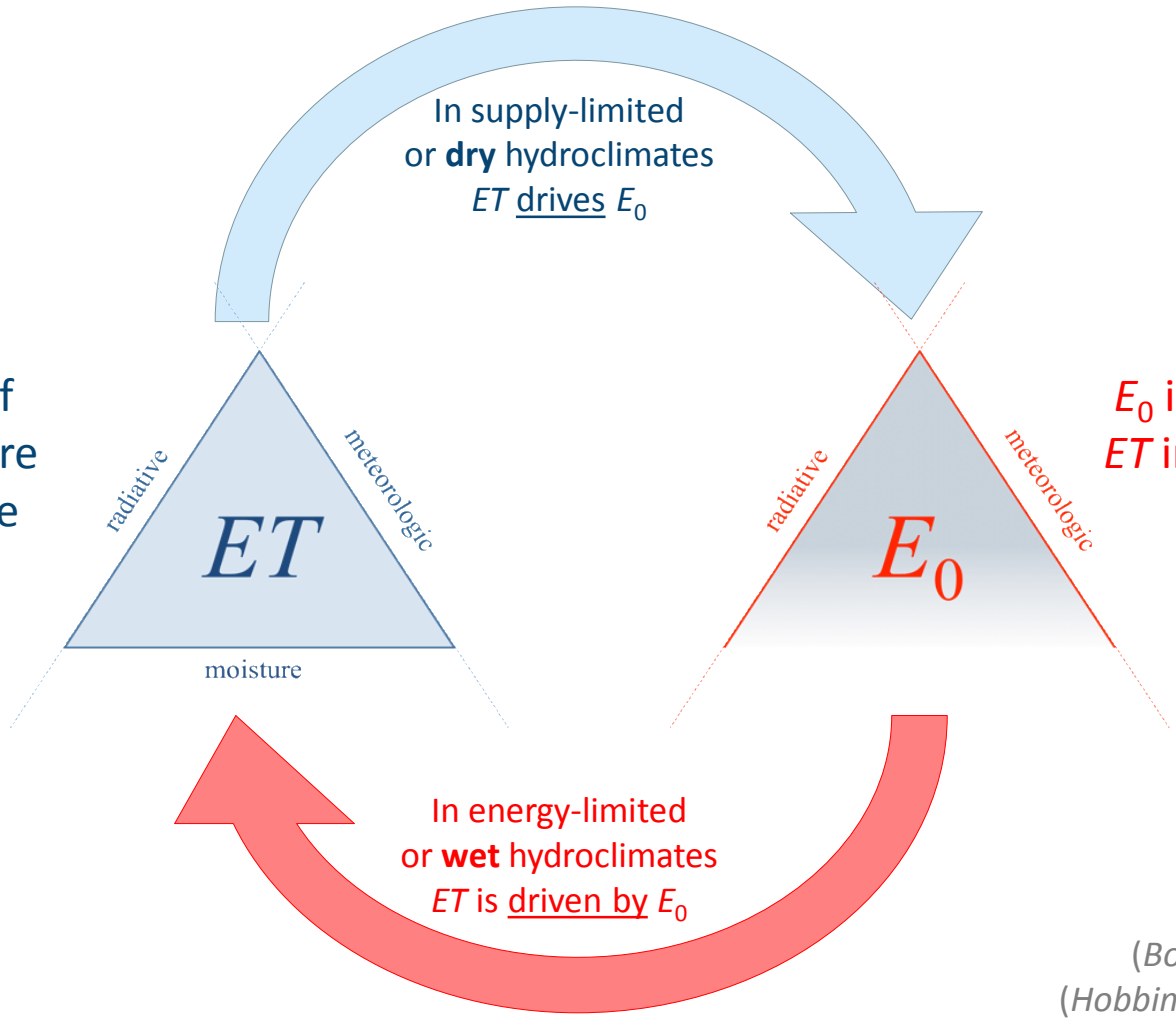


Physically-based ET_o contains valuable information related to drought dynamics

Why Evaporative Demand?

ET = actual evapotranspiration
E_0 = evaporative demand

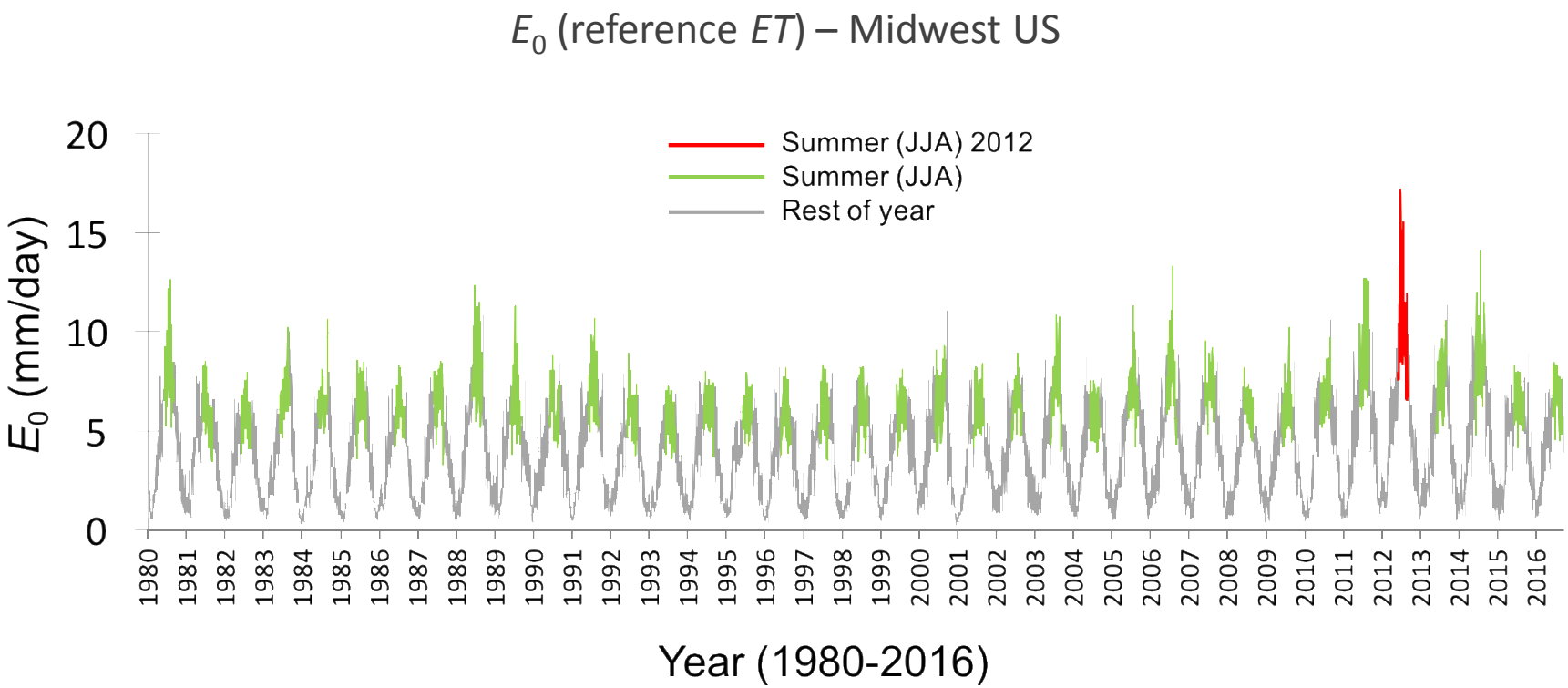
ET is supply of surface moisture to atmosphere



E_0 is demand for *ET* in atmosphere

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

How do we calculate EDDI?



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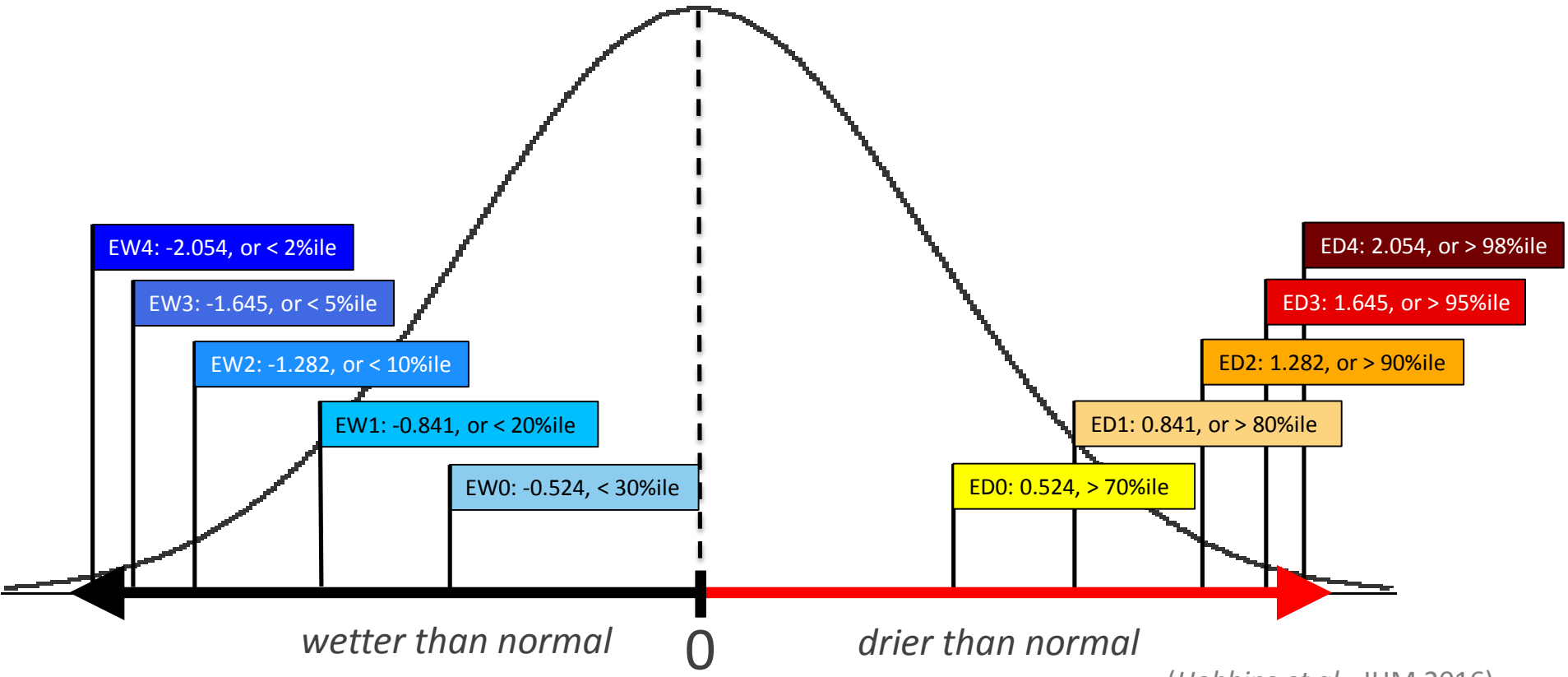
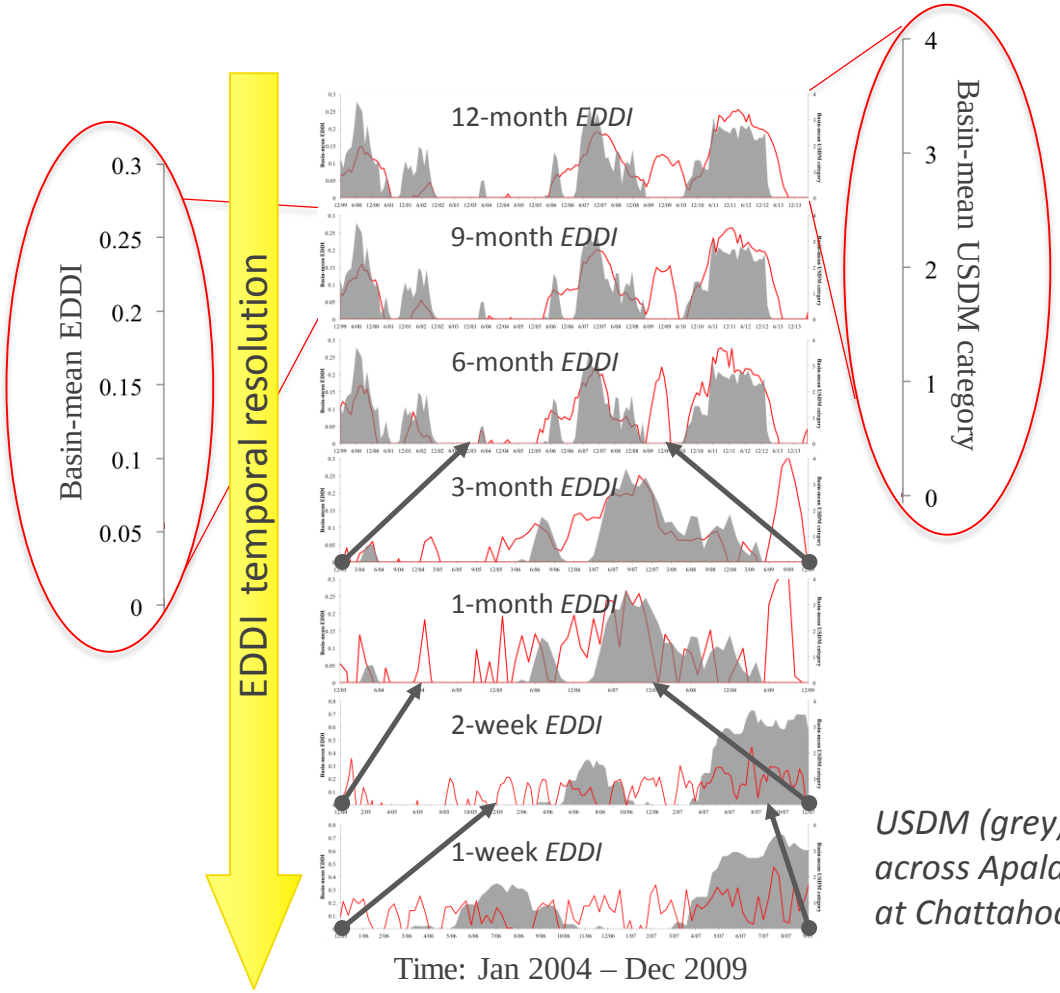


(*Hobbins et al.*, JHM 2016)
(*McEvoy et al.*, JHM 2016)

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

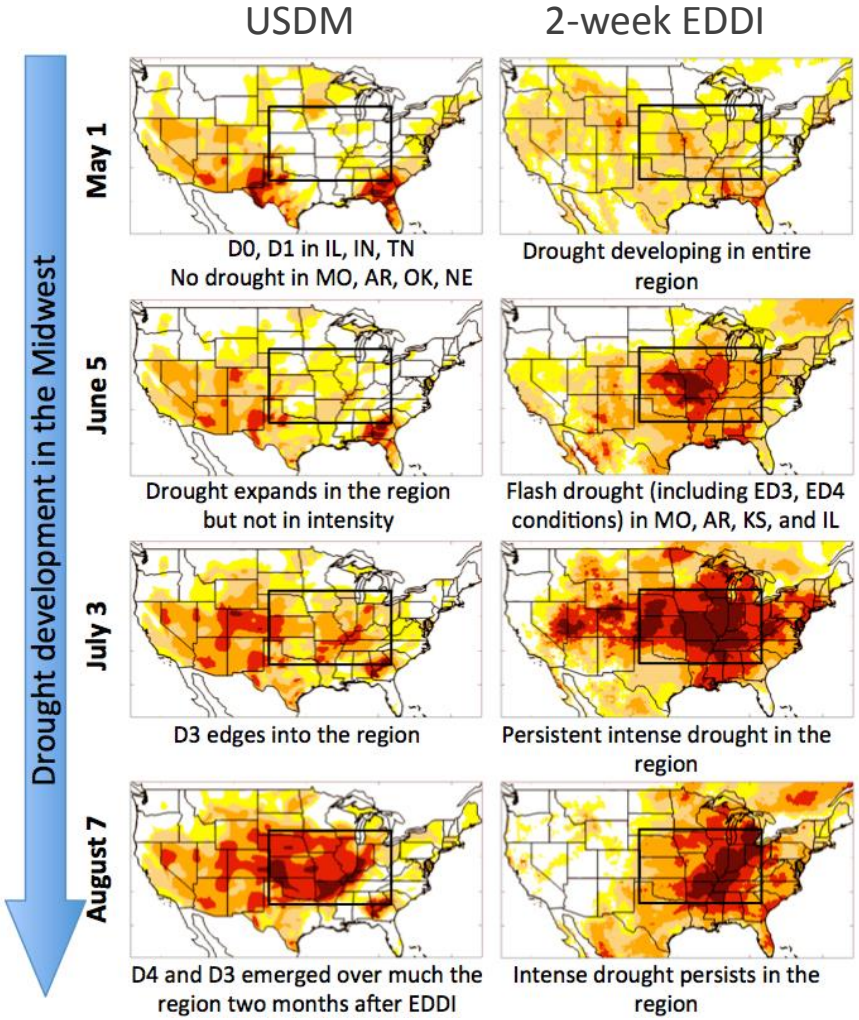
USDM (grey) and EDDI (red) across Apalachicola River basin at Chattahoochee, FL.

2012 Midwest Flash Drought

Leading indication of drought

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

"Flash drought" in the US Midwest, 2012

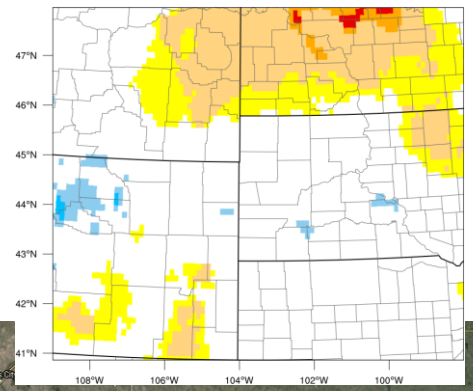


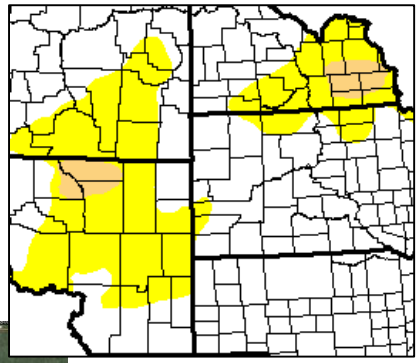
2016 Black Hills drought

End-Dec, 2015

1-mon EDDI

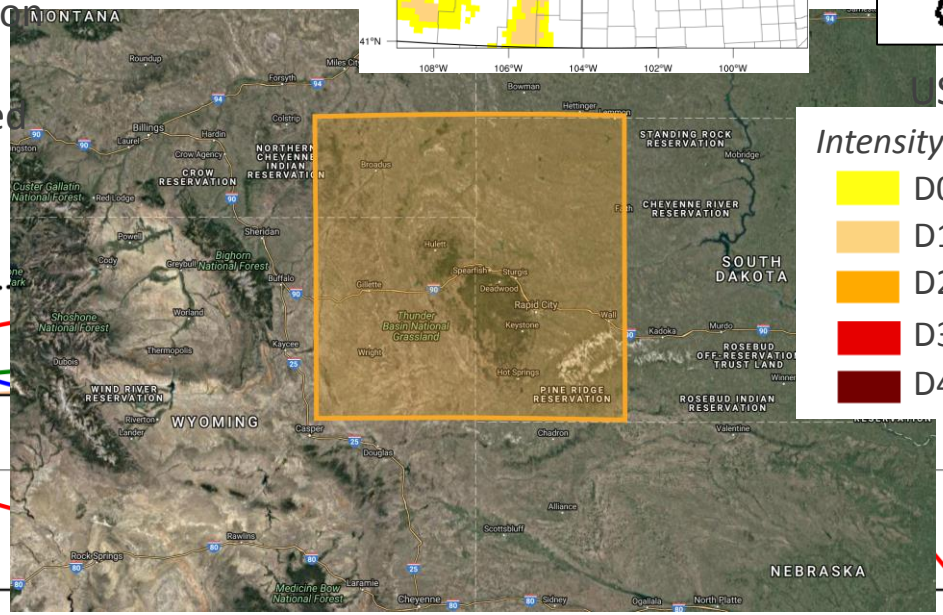
USDM





Attribution: How much E_0 changes due to:

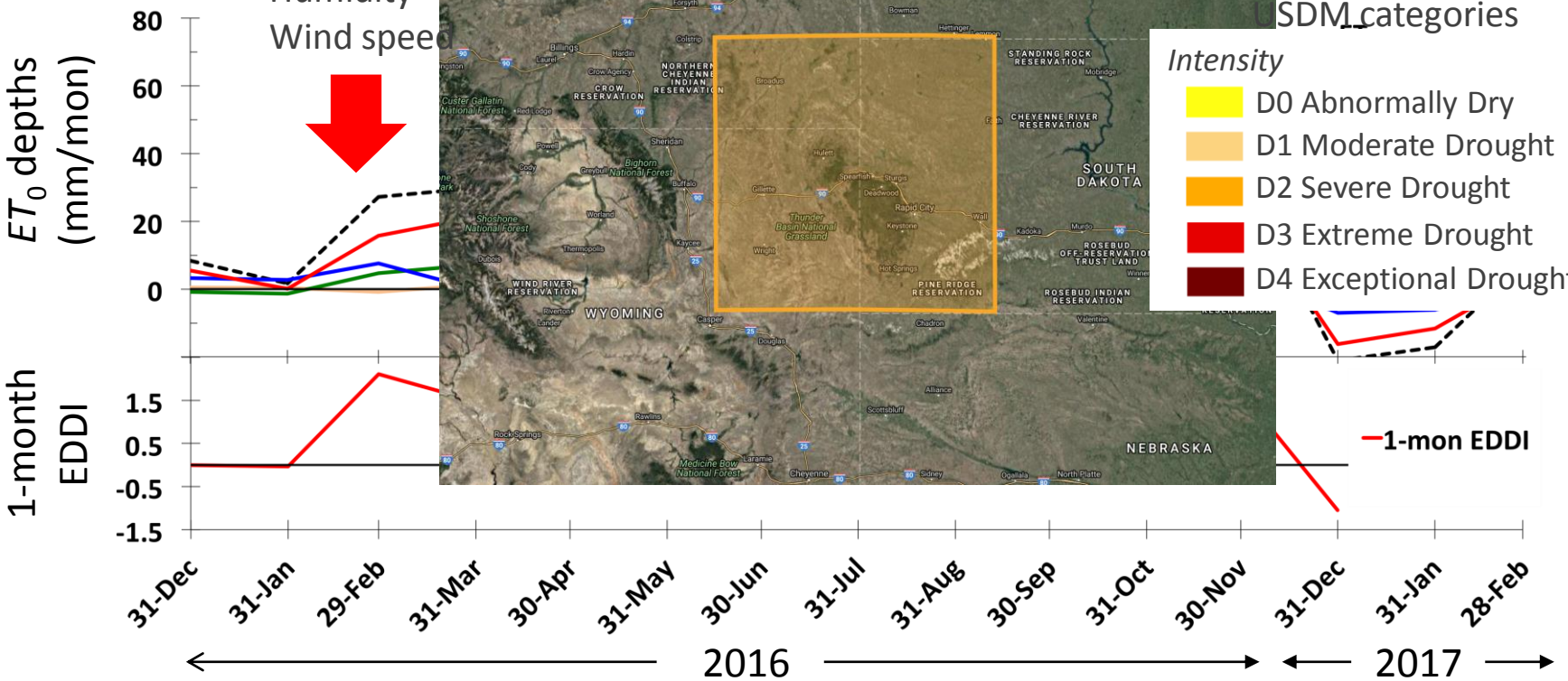
- Temperature
- SW radiation
- Humidity
- Wind speed



USDM categories

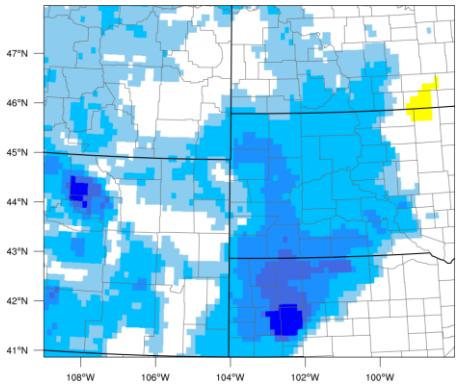
Intensity

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



2016 Black Hills drought

1-mon EDDI



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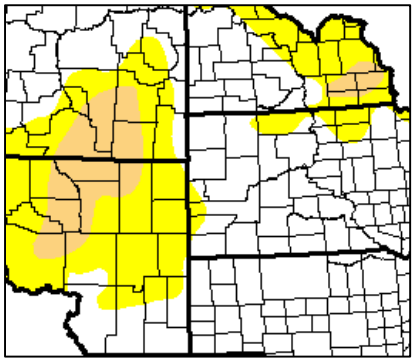

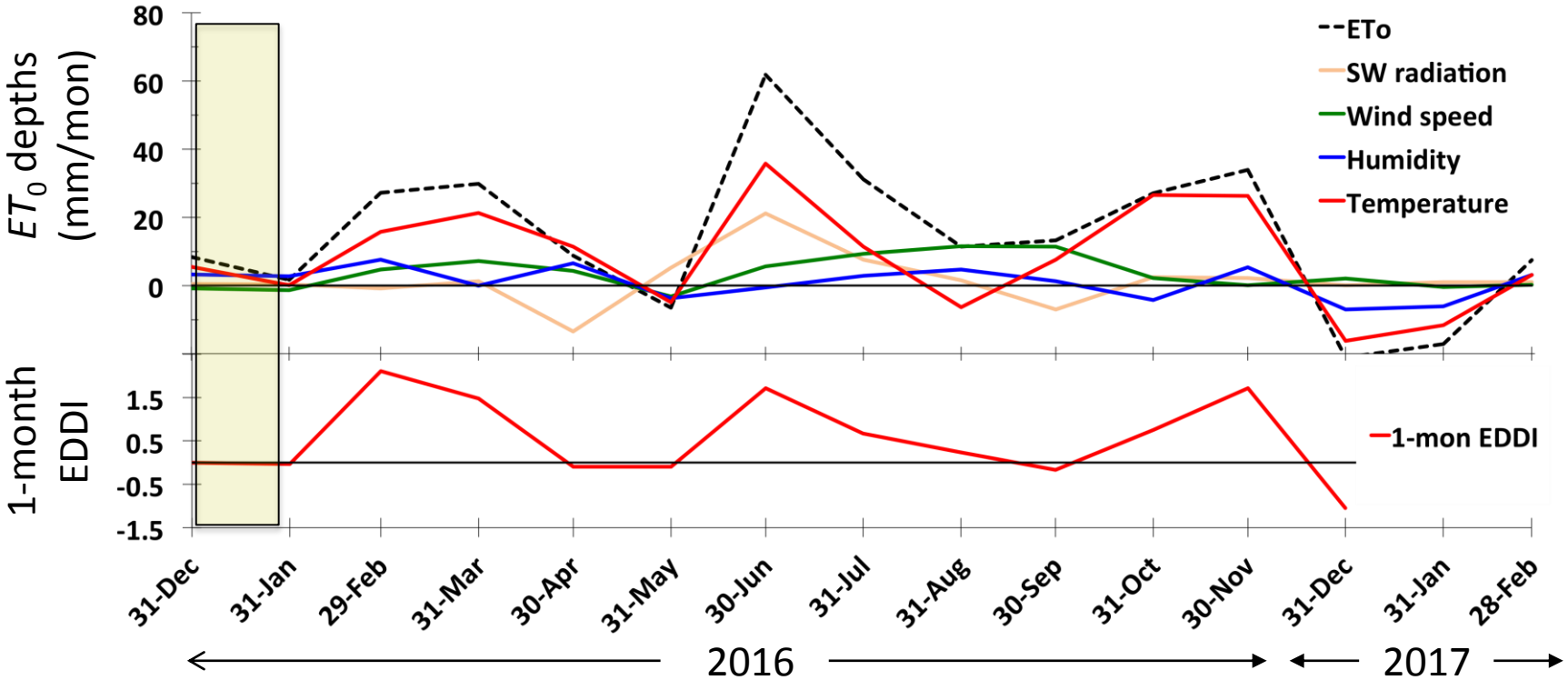

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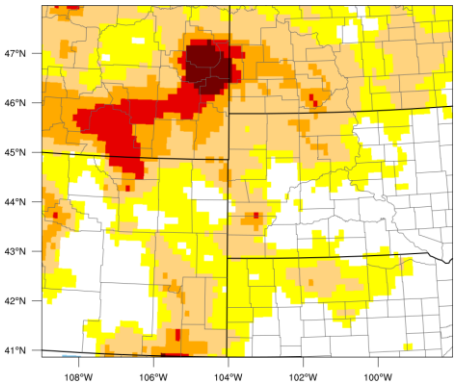

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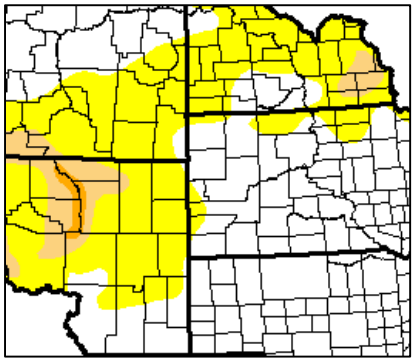

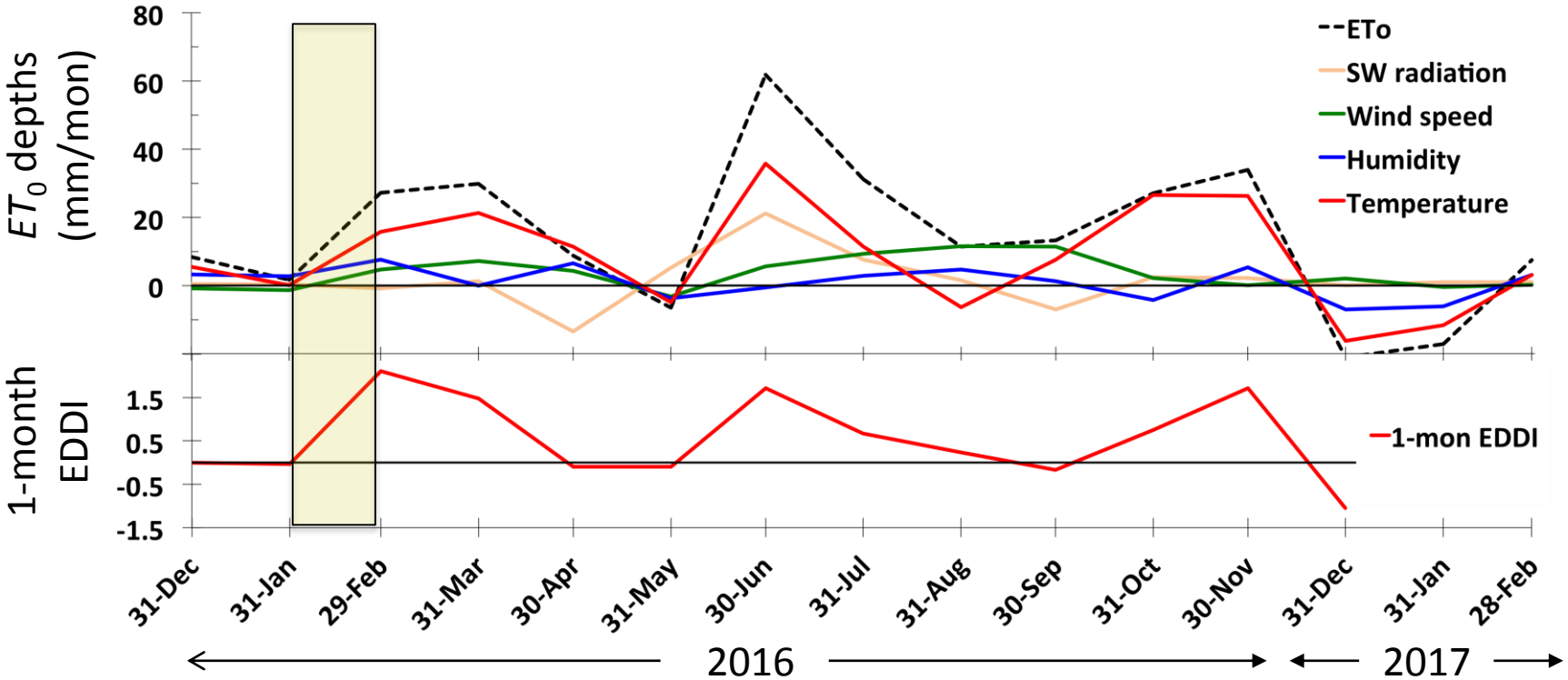

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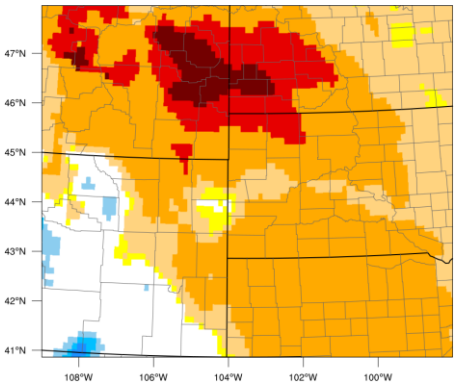

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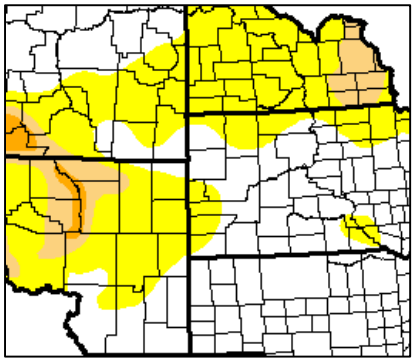

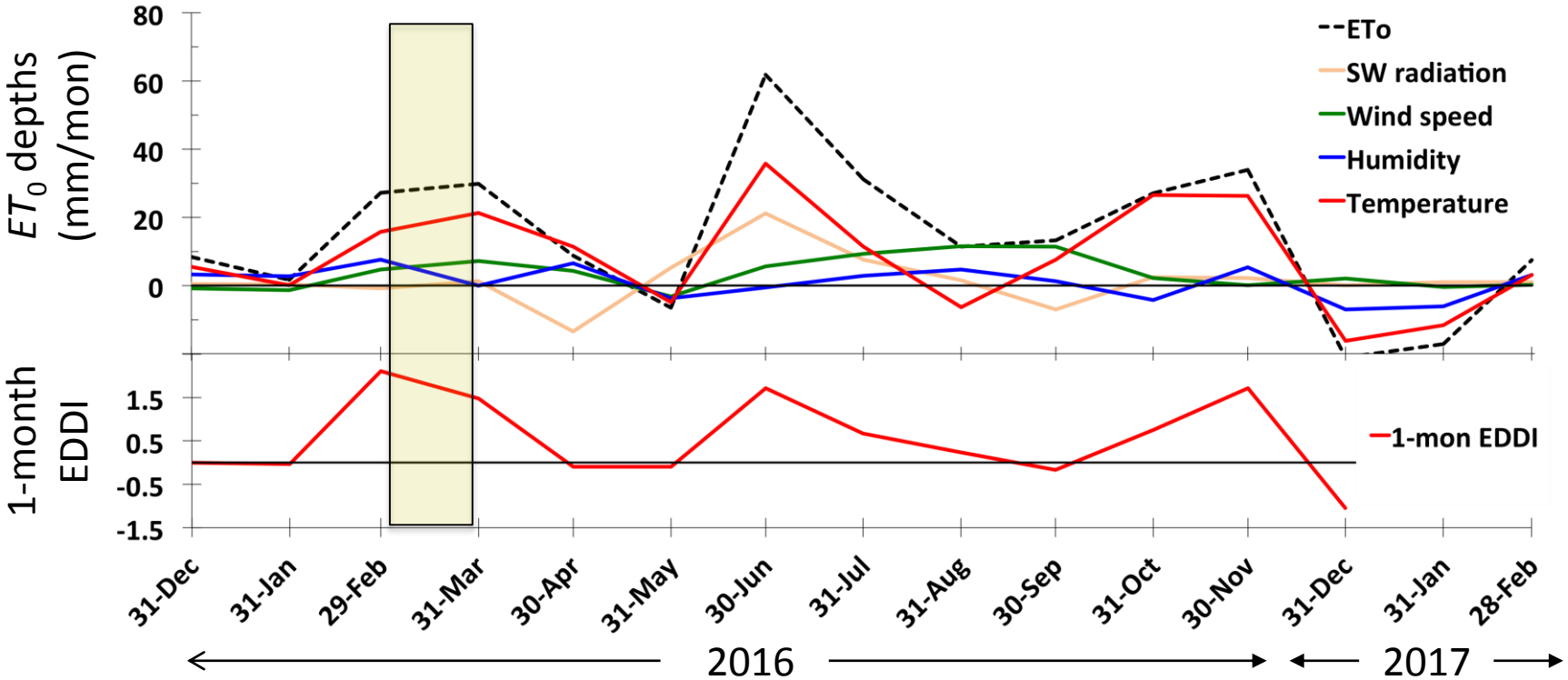

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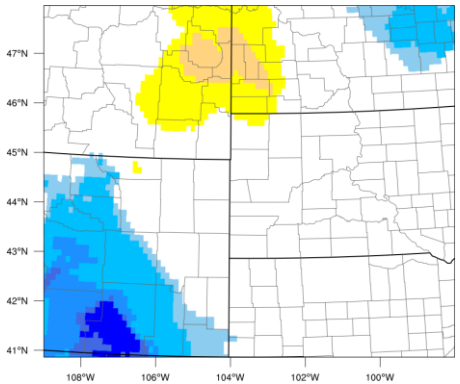

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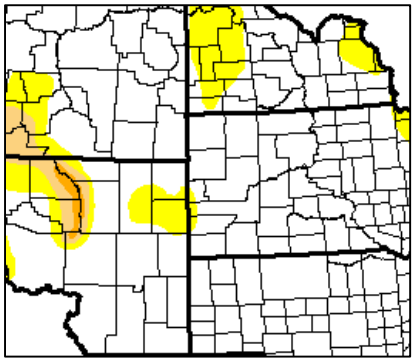

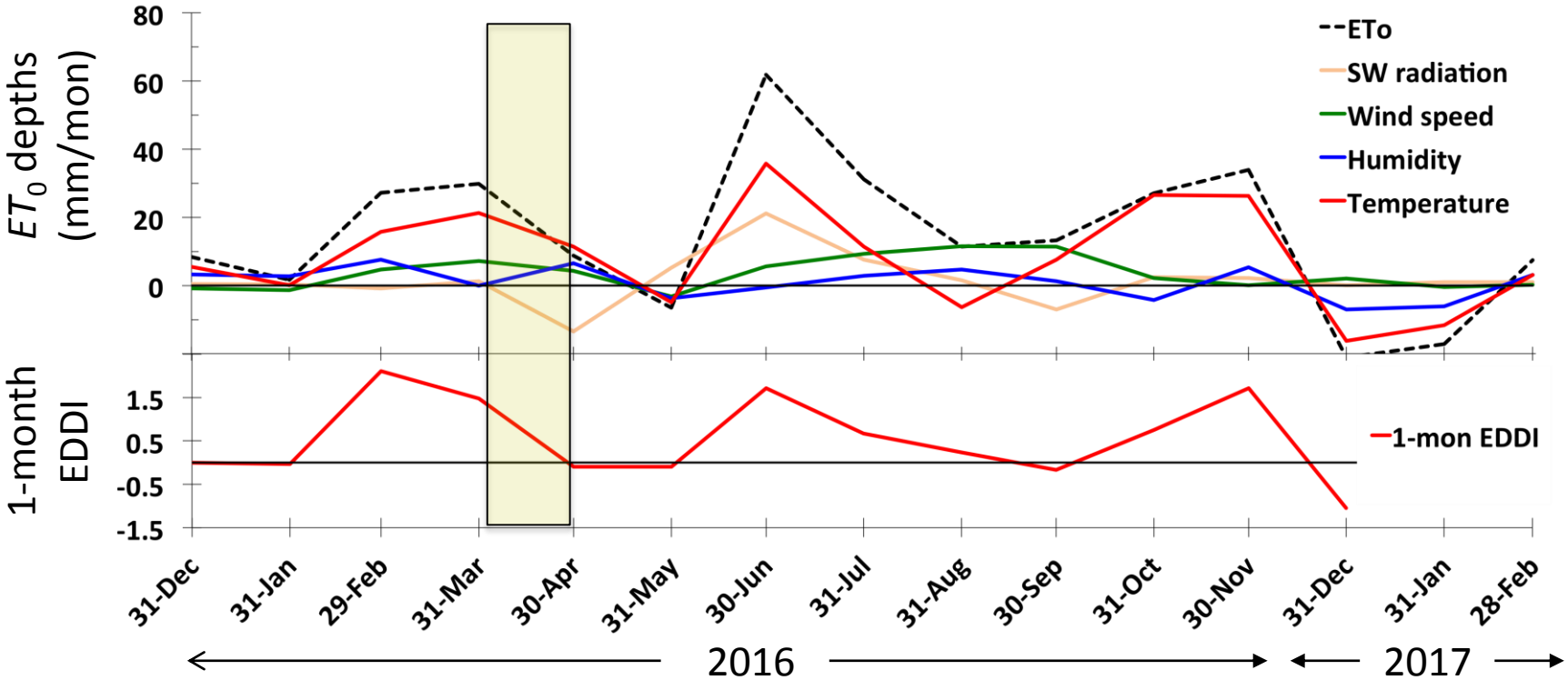

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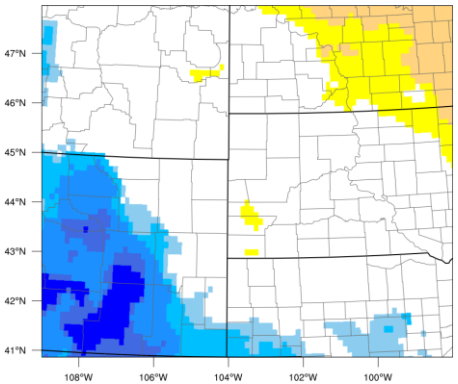

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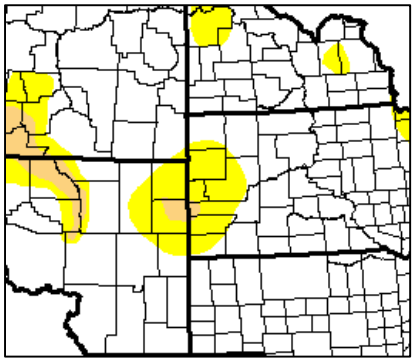

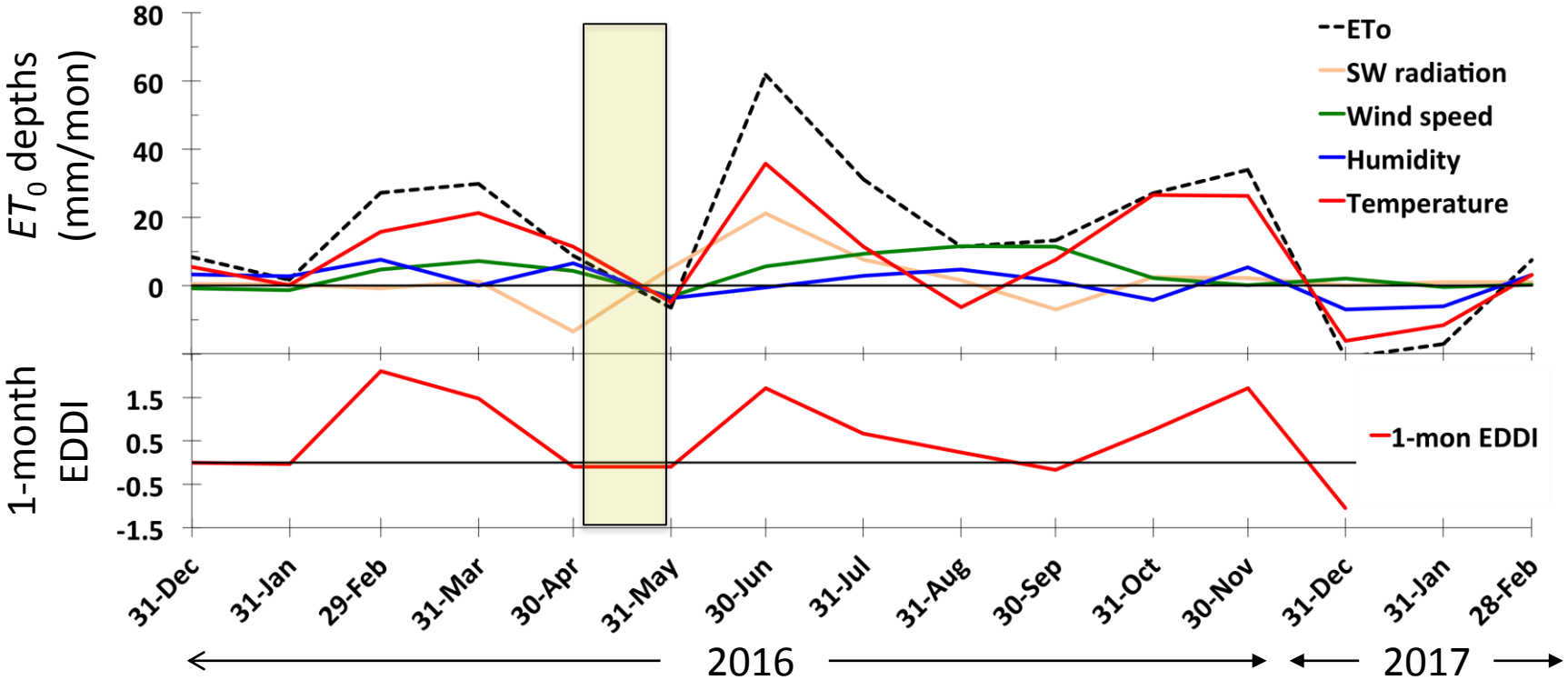

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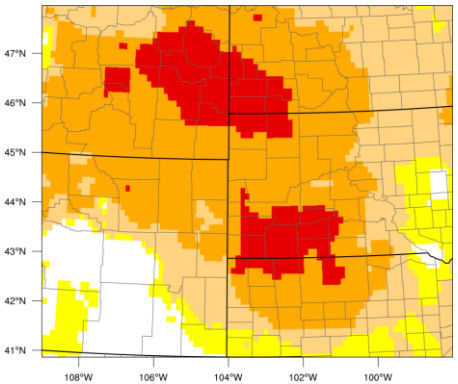

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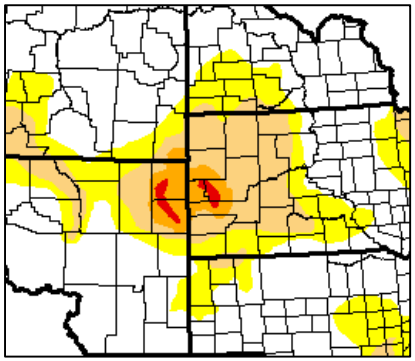

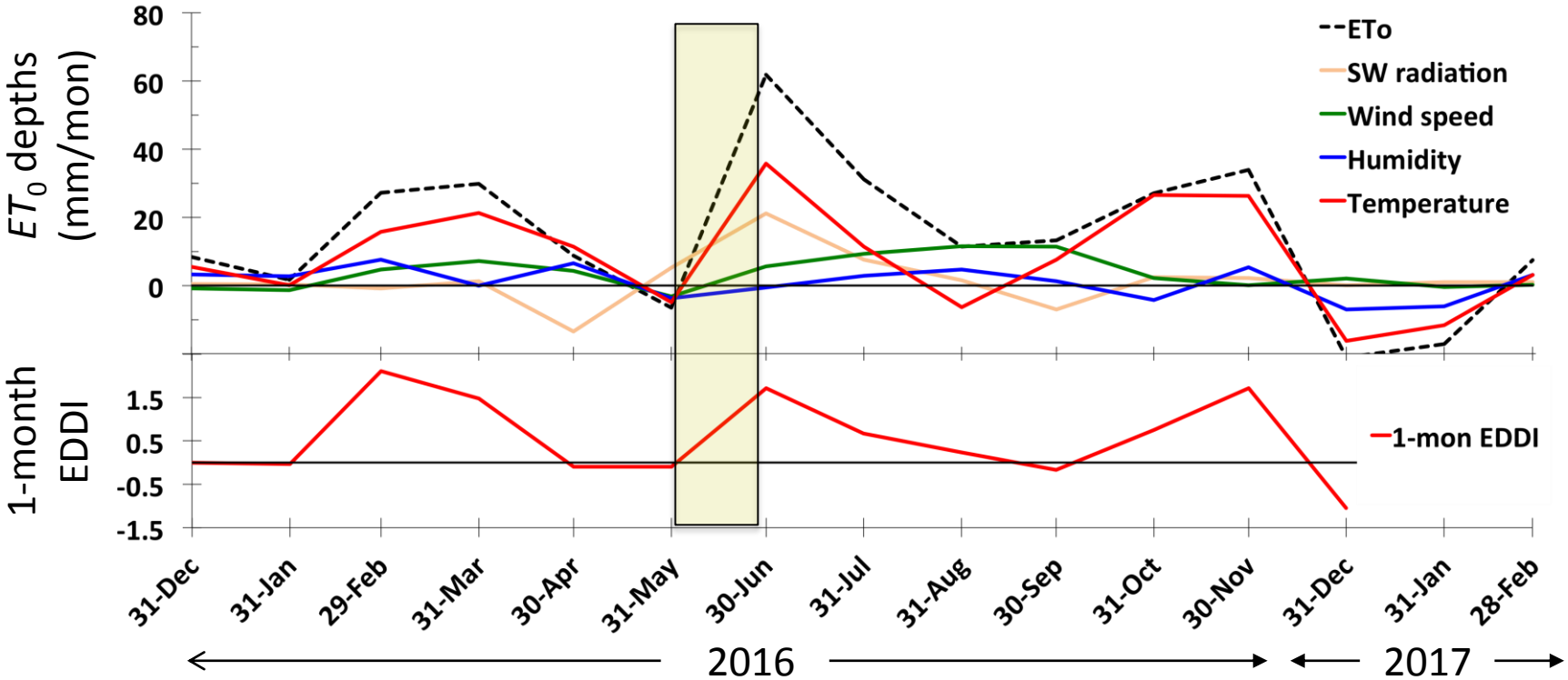

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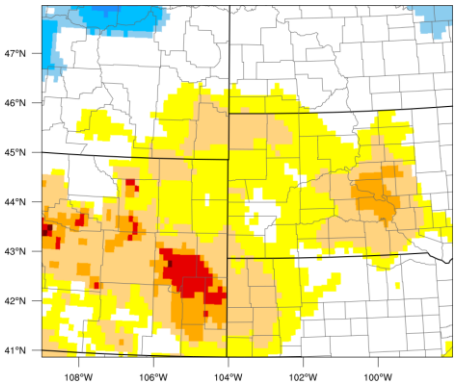

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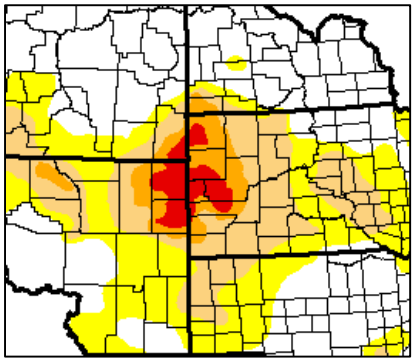

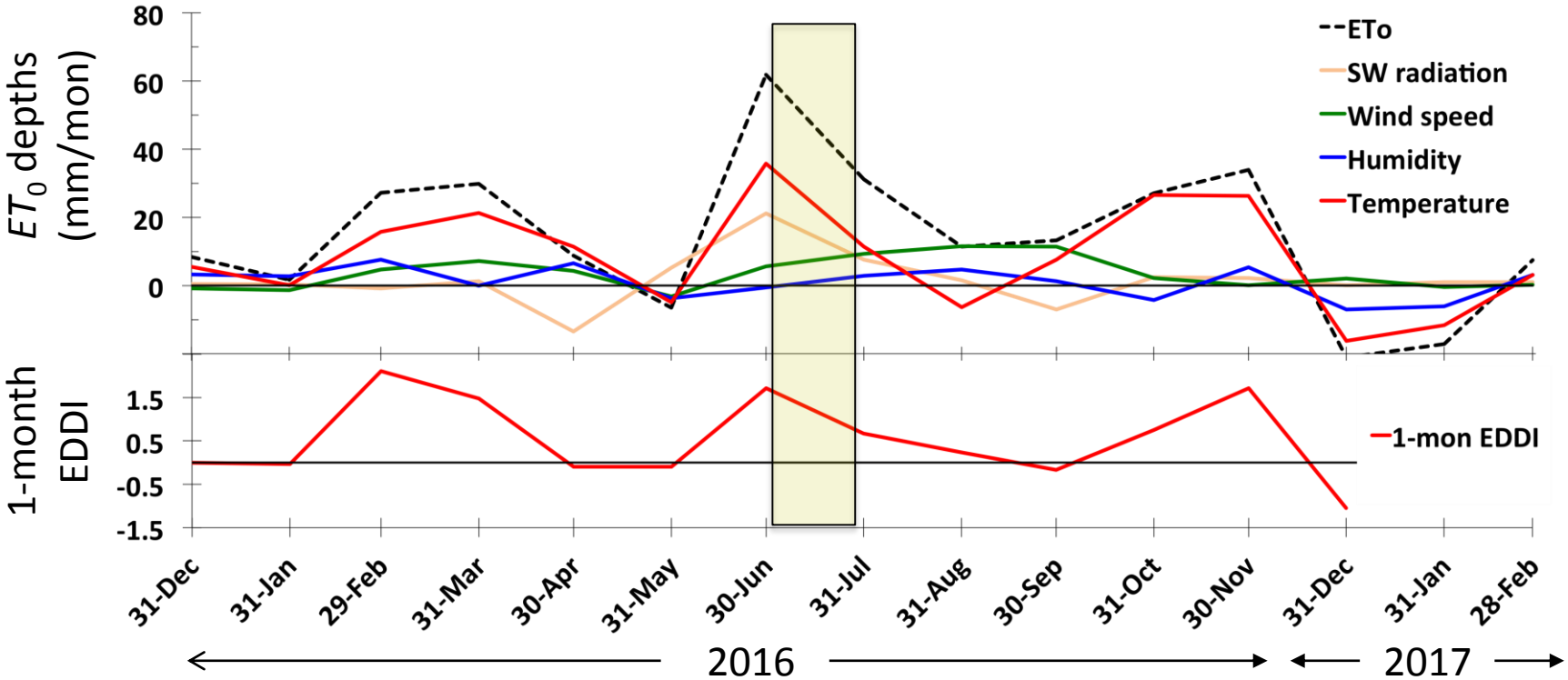

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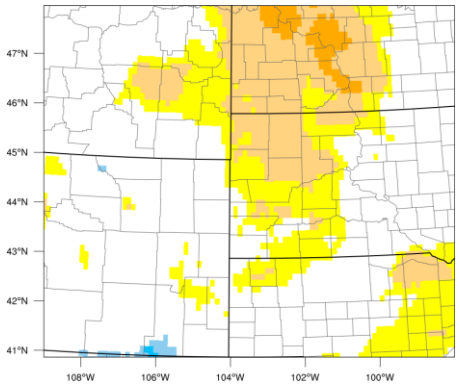

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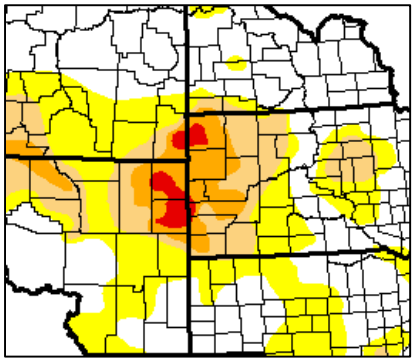

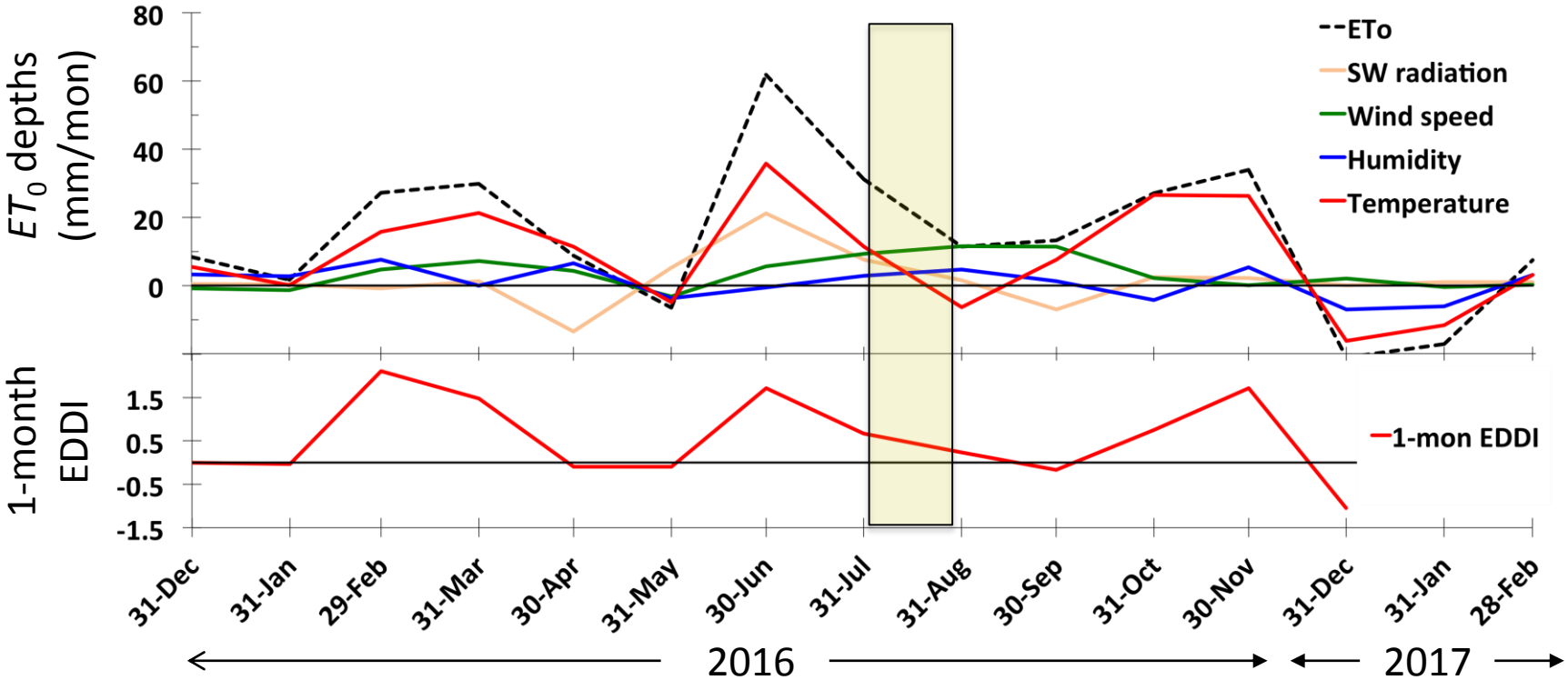

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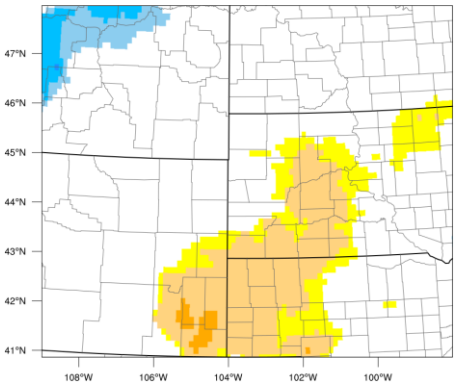

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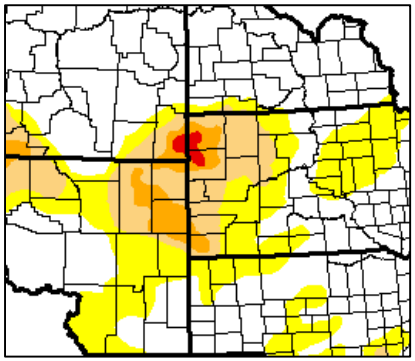

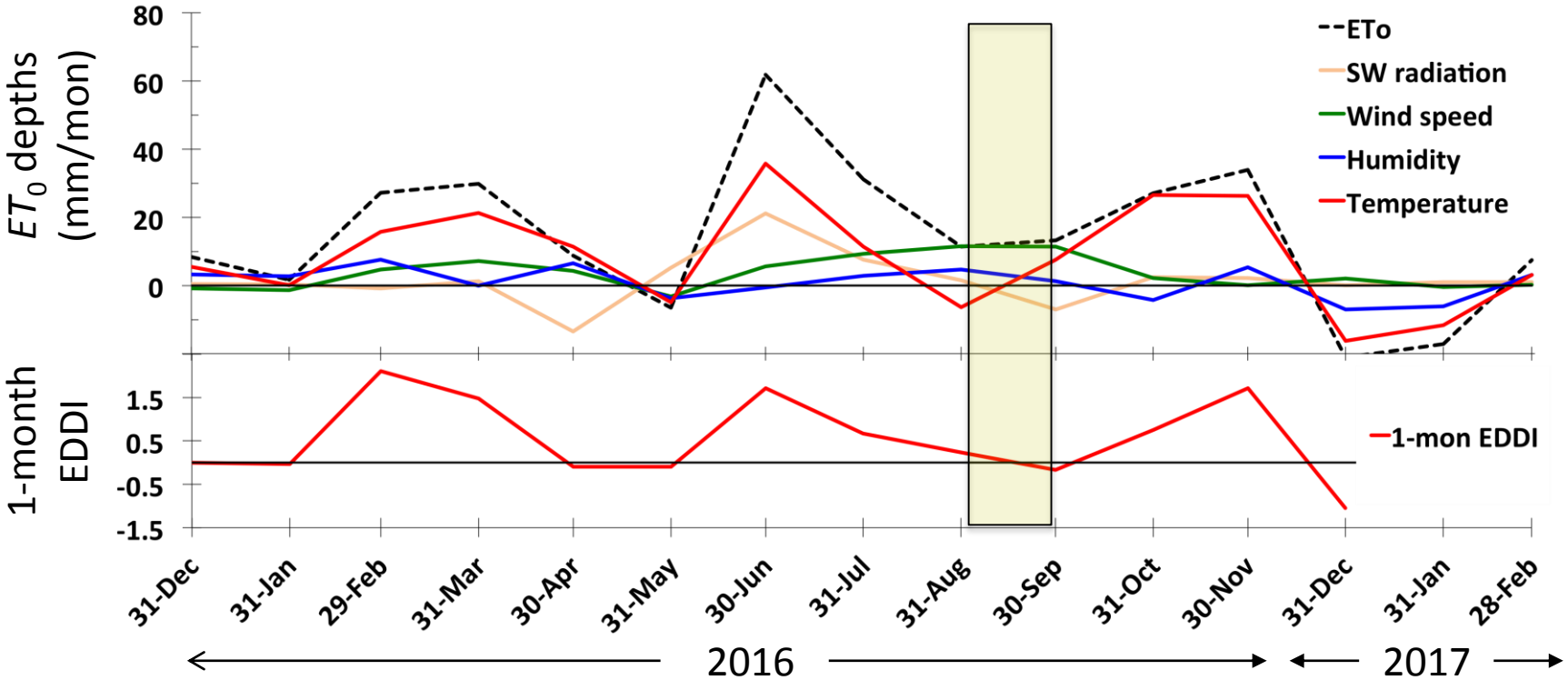

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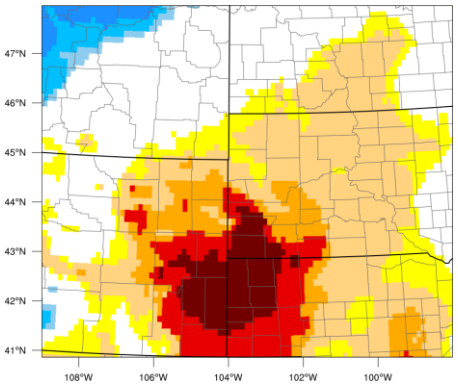

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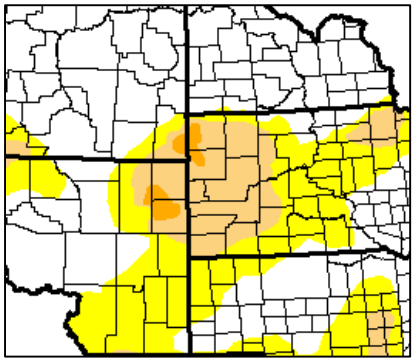

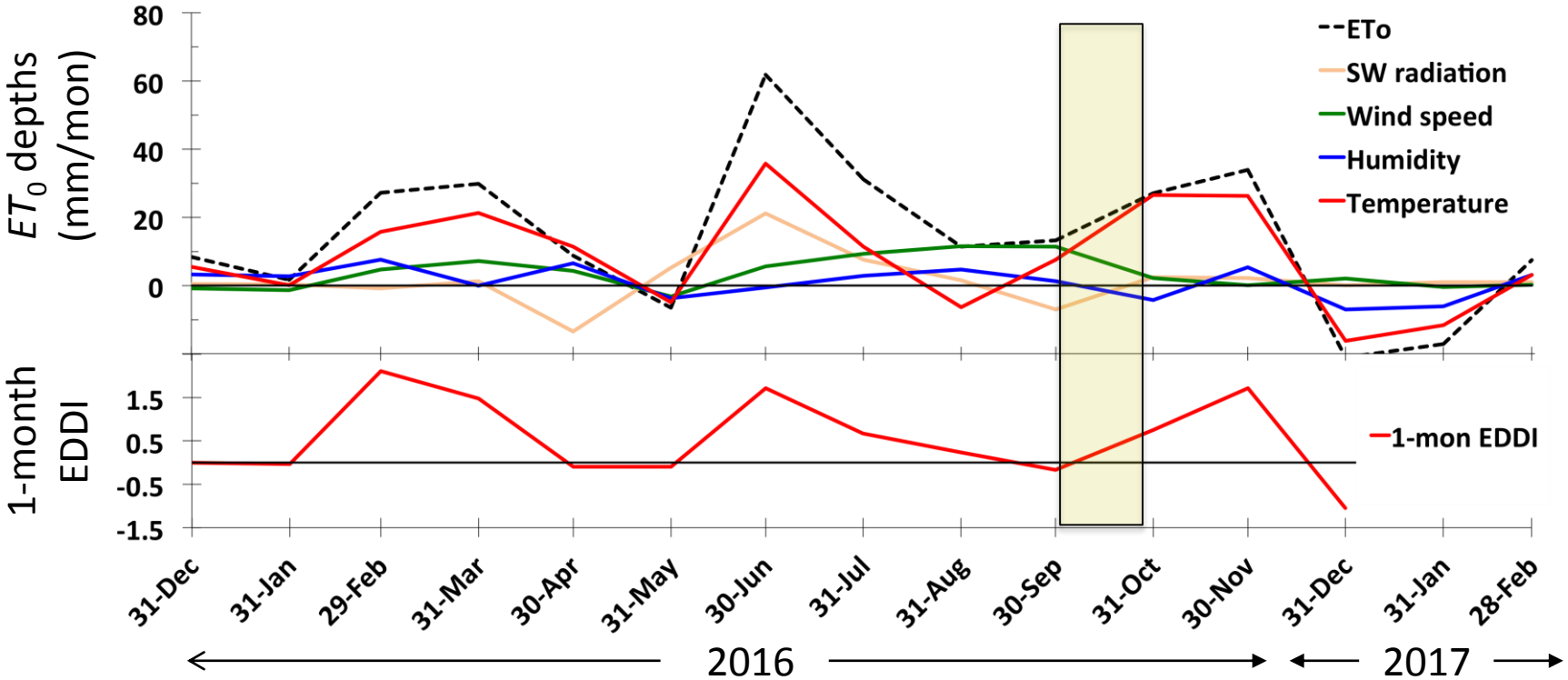

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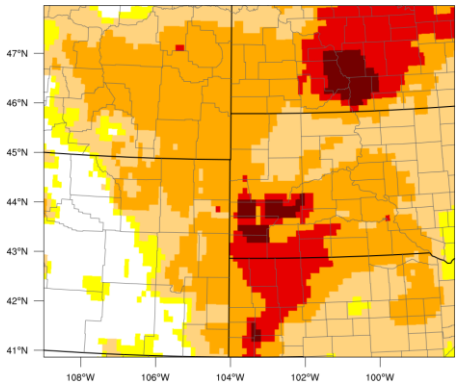

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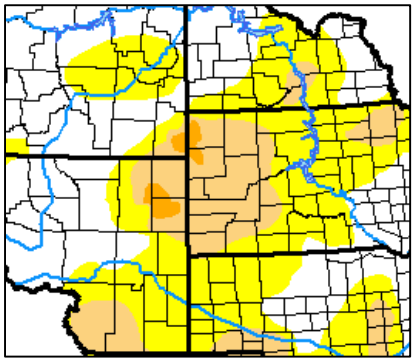

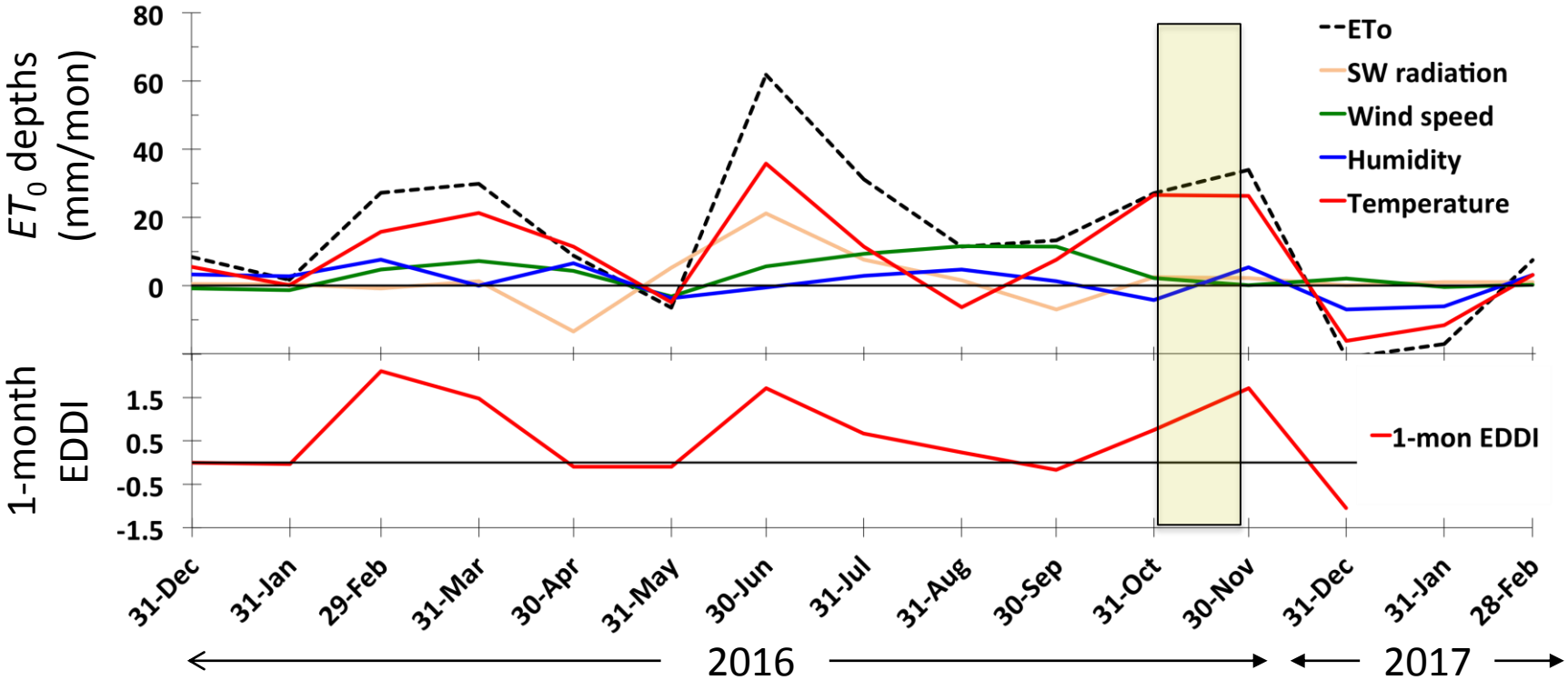

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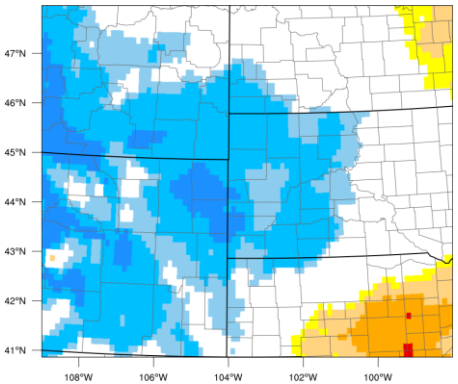

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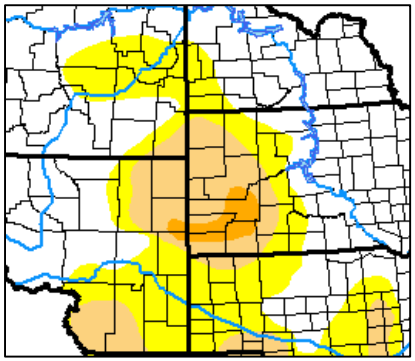

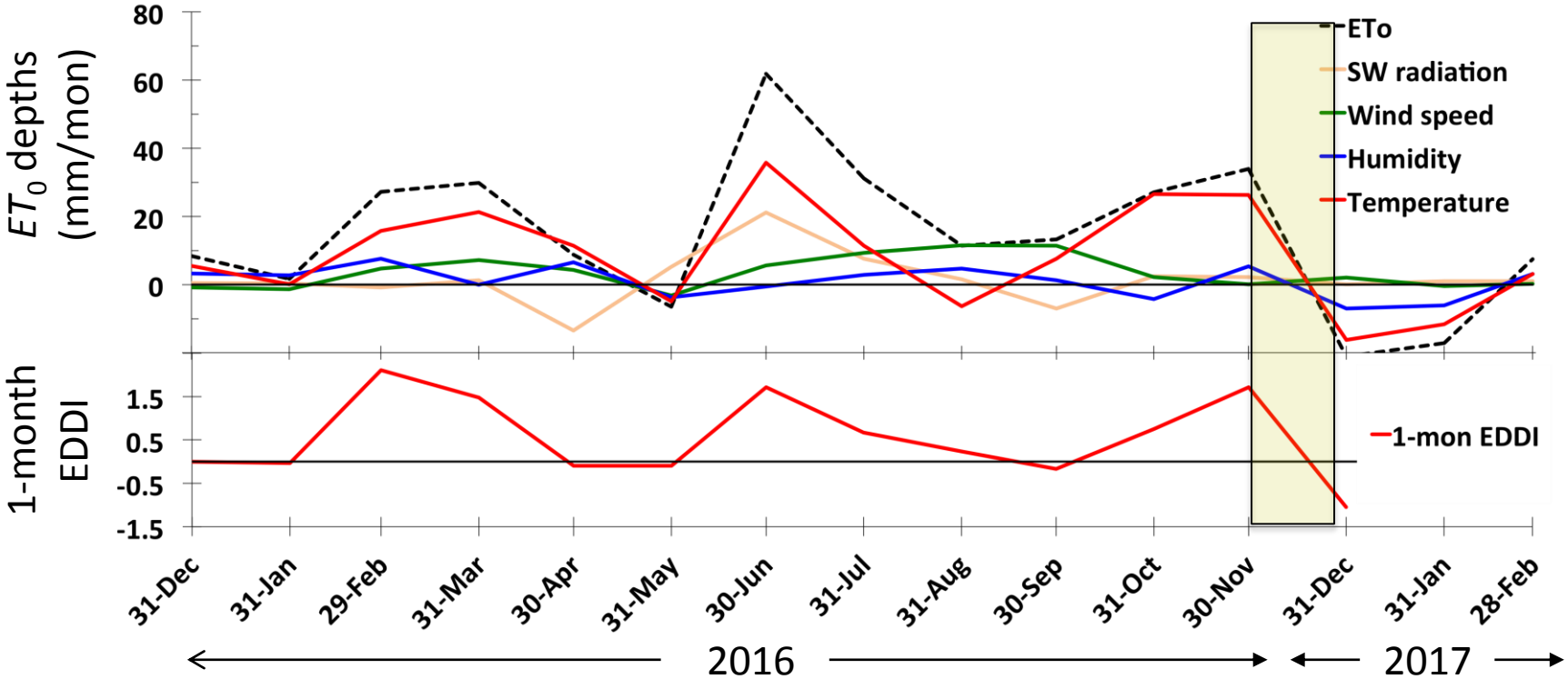

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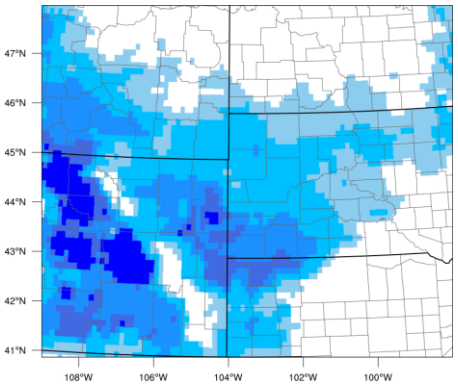

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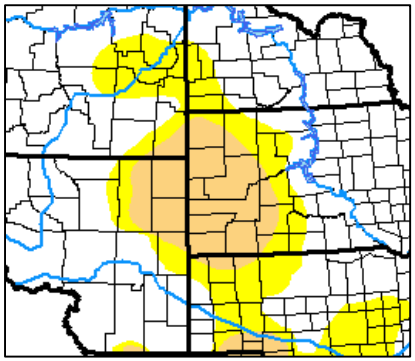

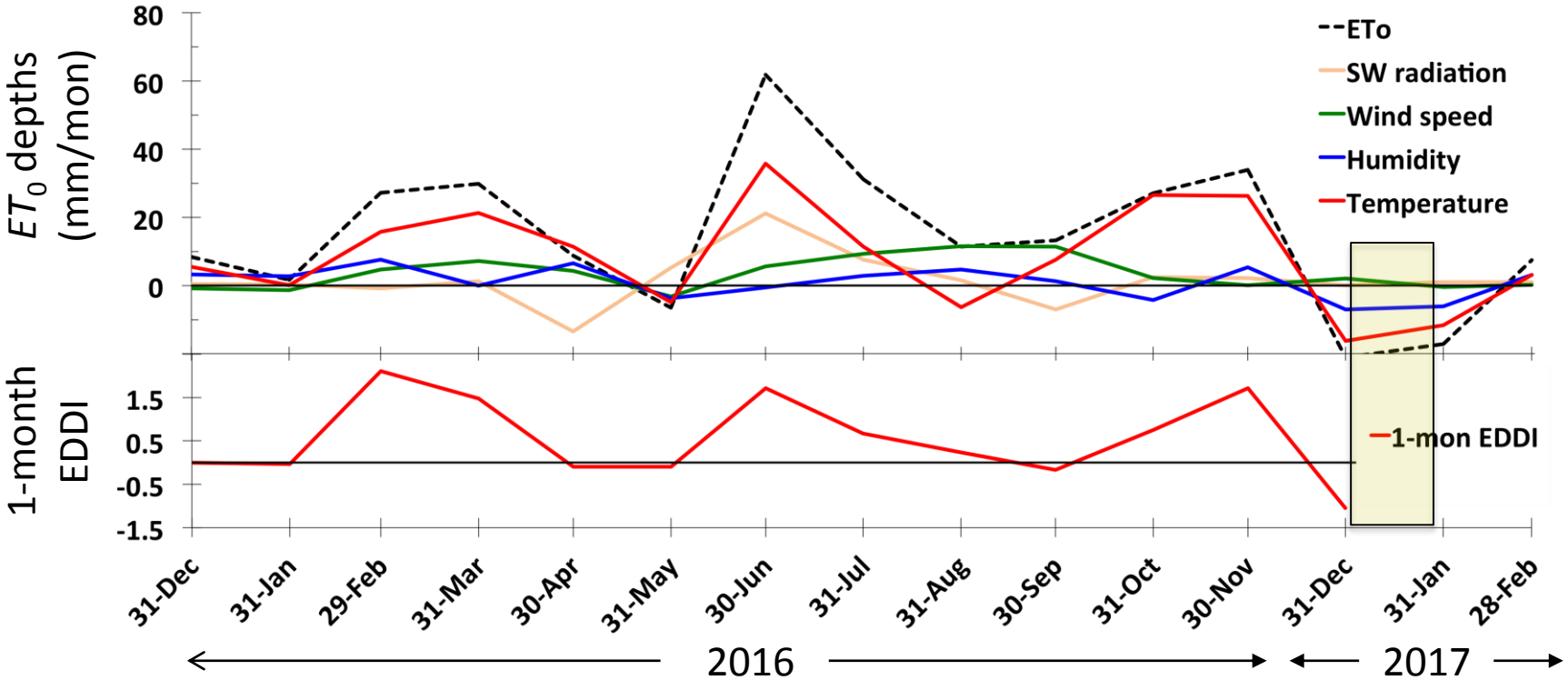

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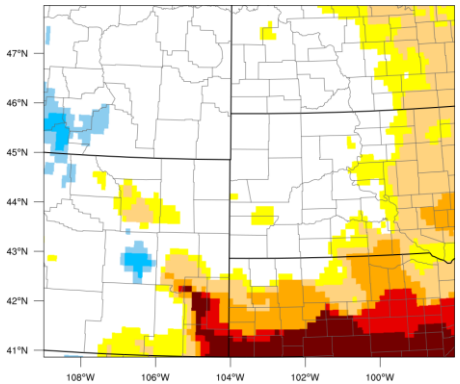

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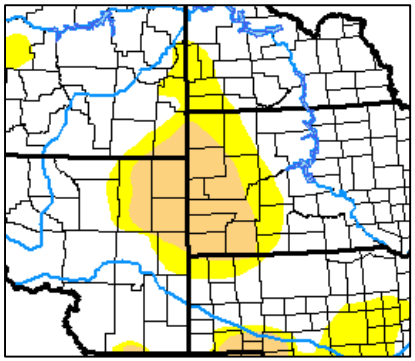

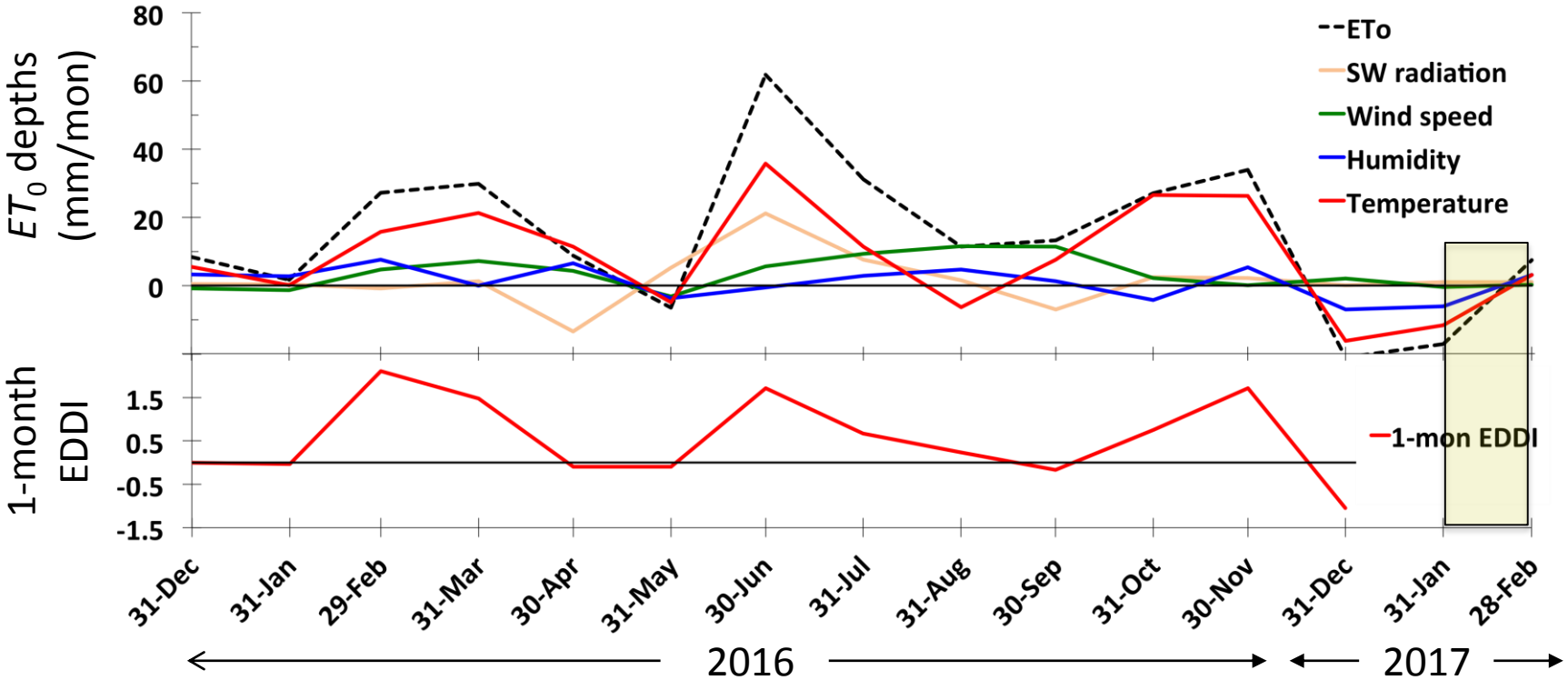

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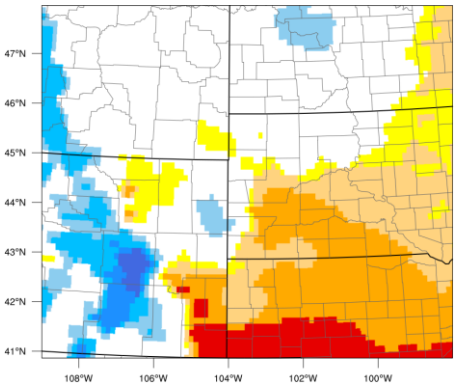
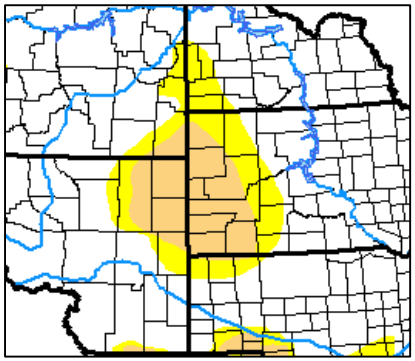
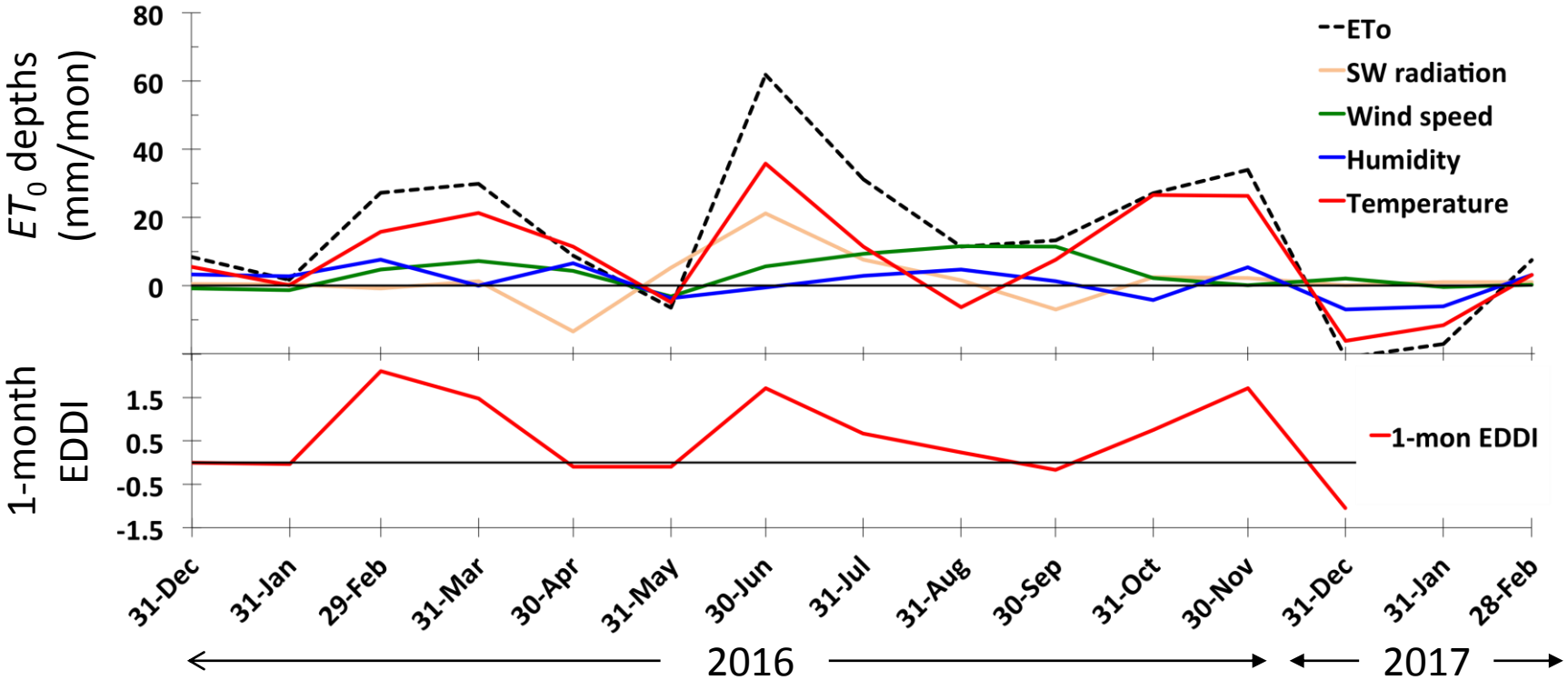


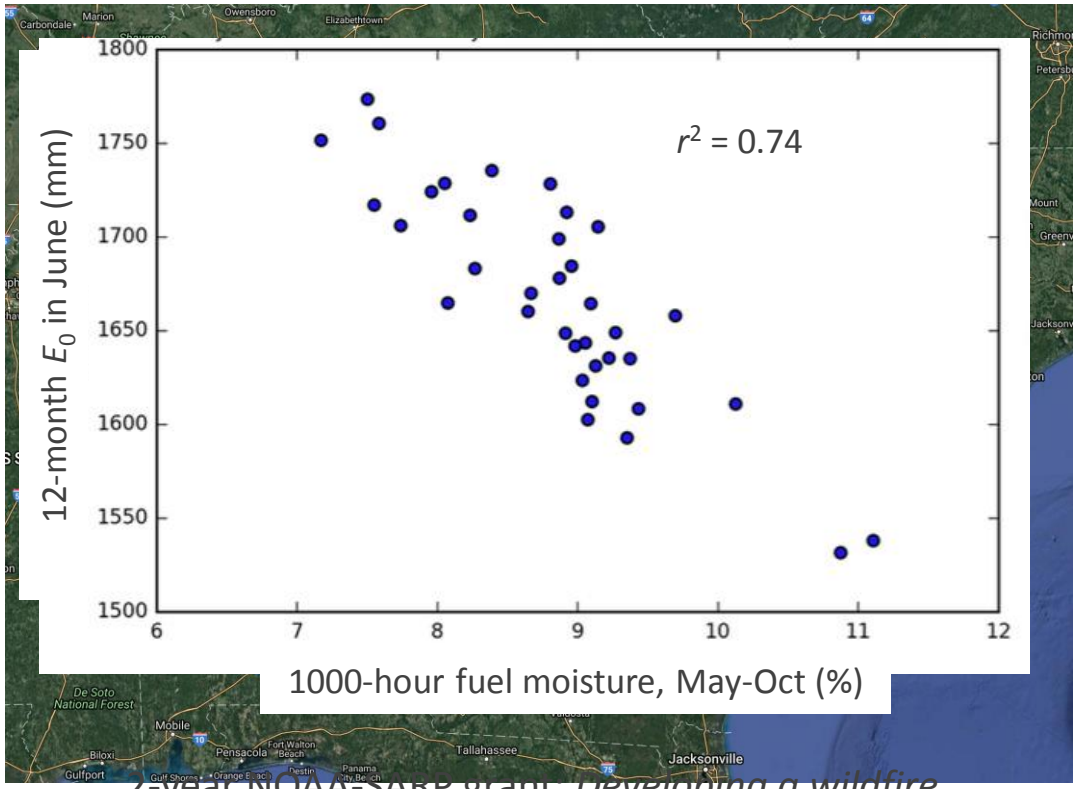
USDM





2016 Southeast drought / fires

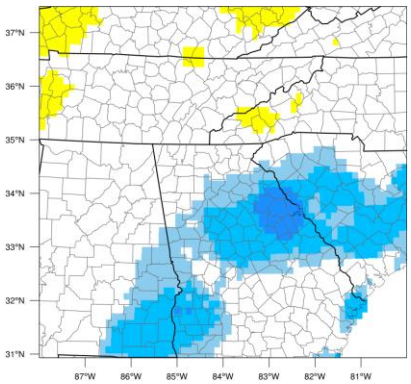
E_0-fuel load relationship across S. California GACC



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

2016 Southeast drought / fires

1-mon EDDI



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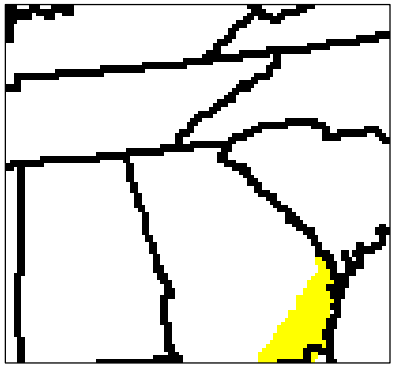
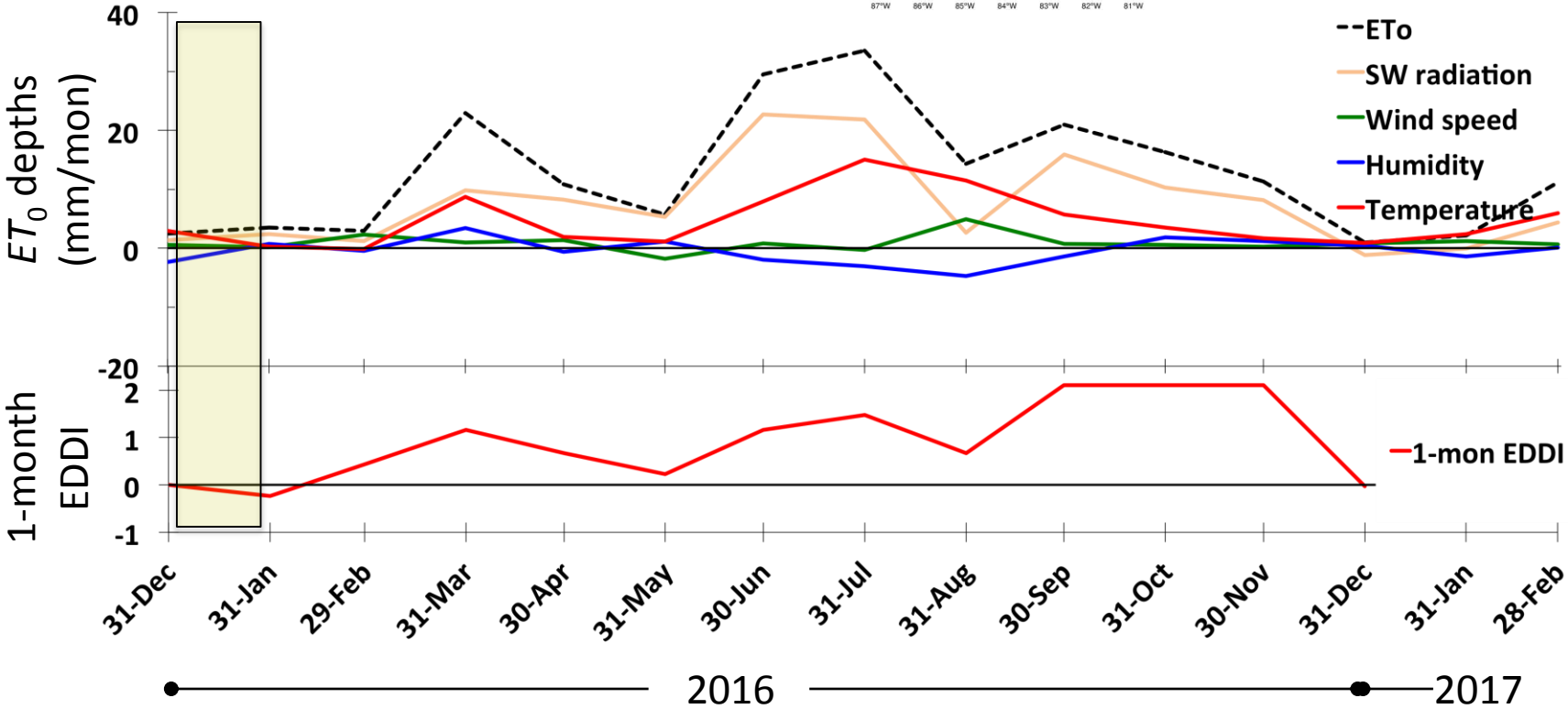
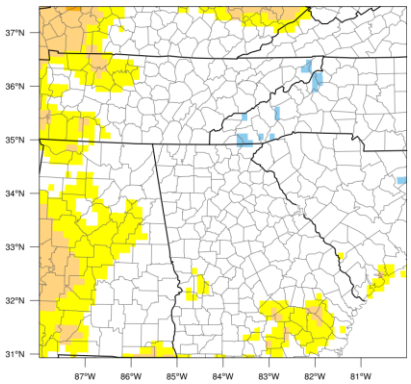




2016 Southeast drought / fires

1-mon EDDI



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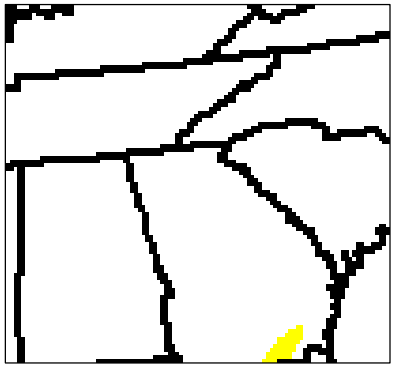
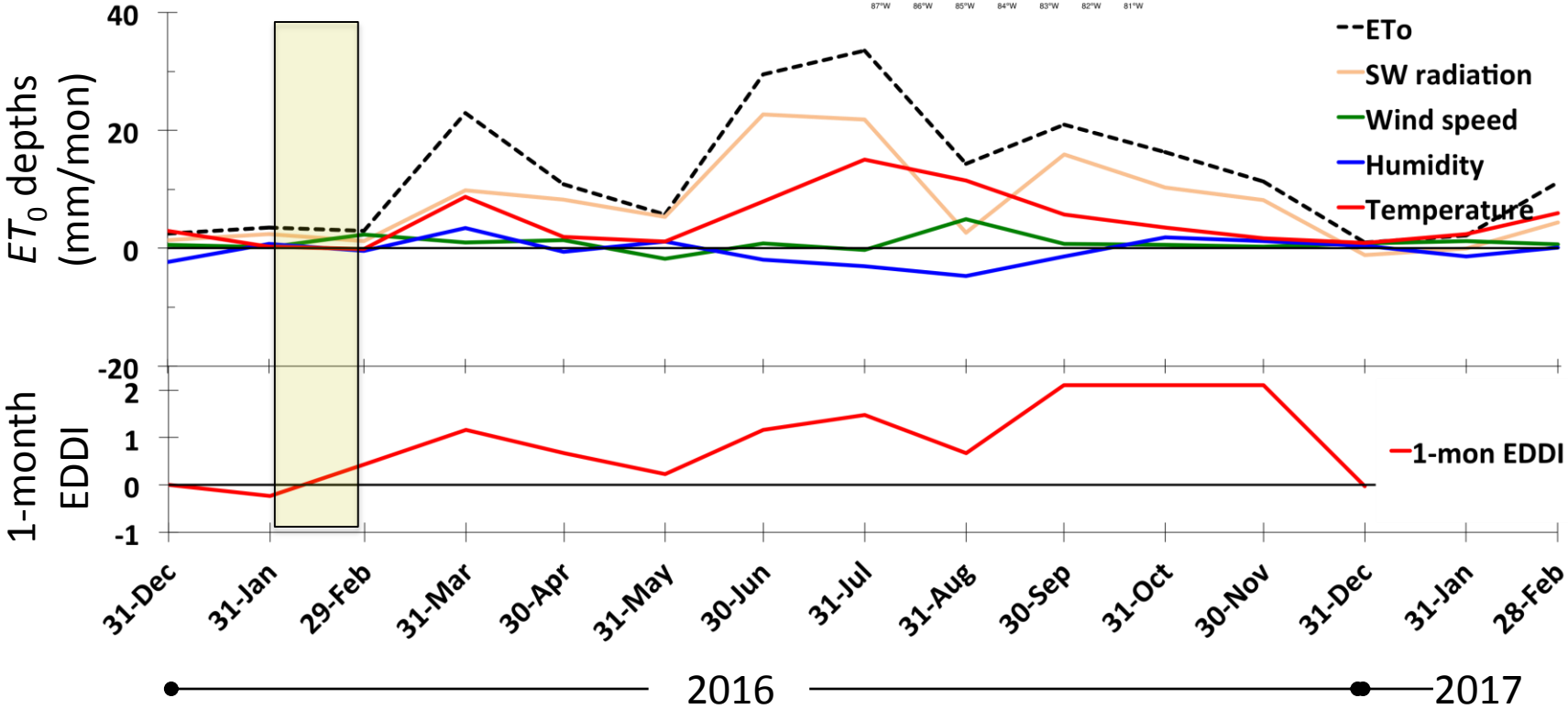
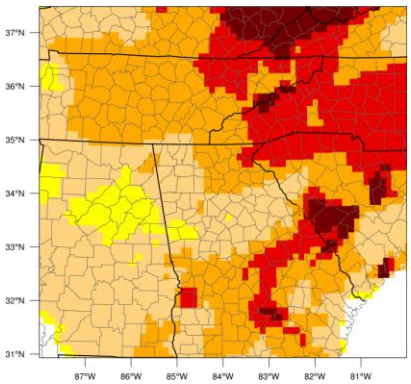




2016 Southeast drought / fires

1-mon EDDI



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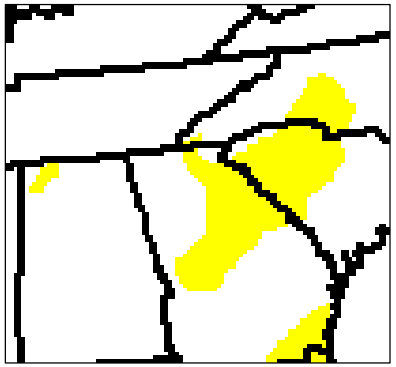
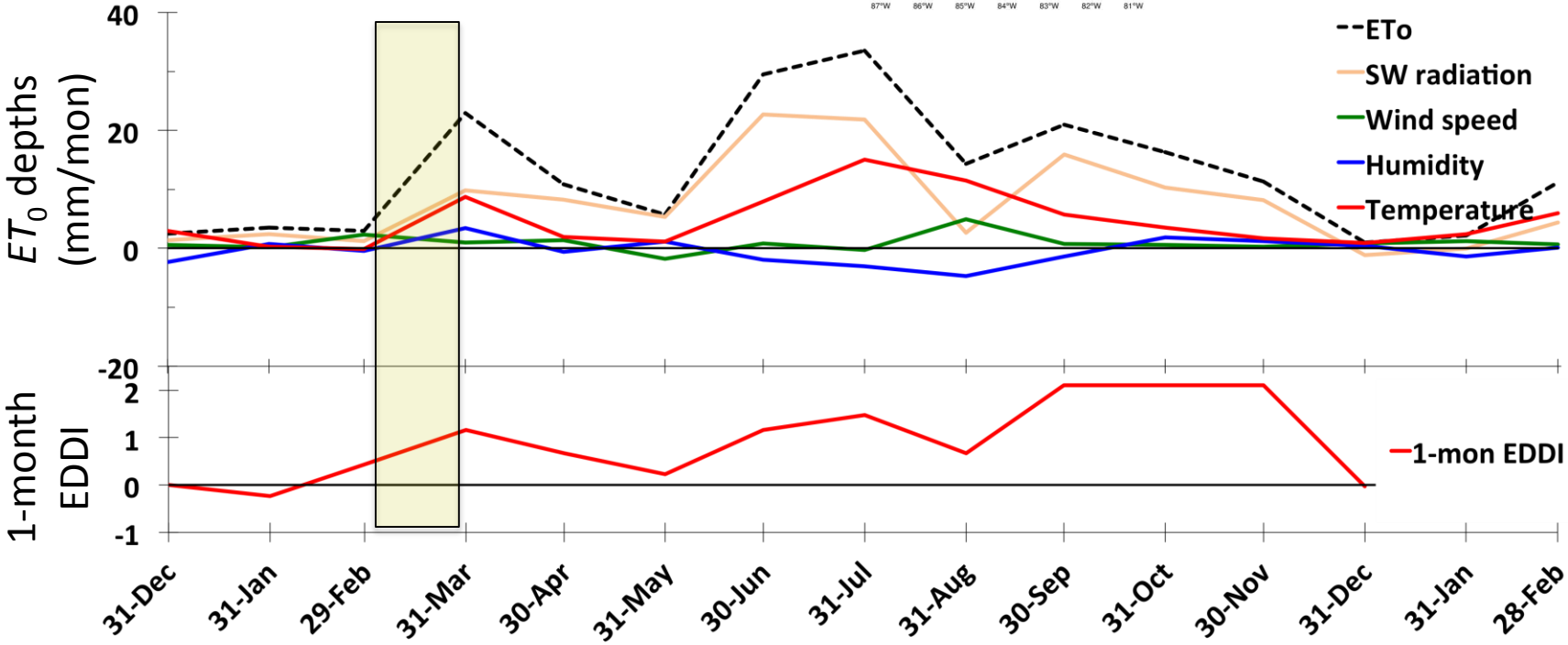
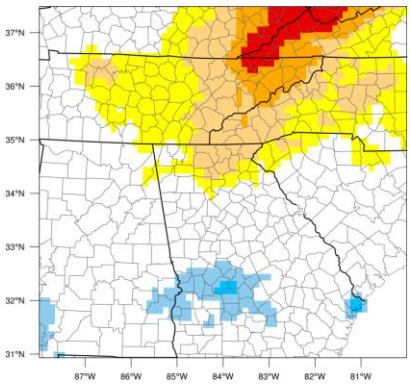




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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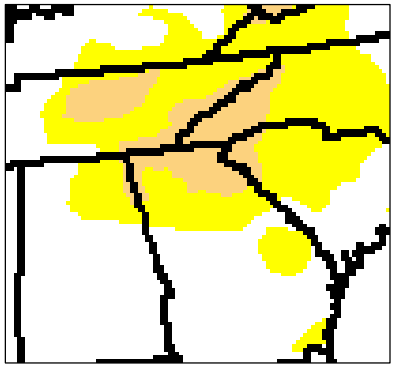
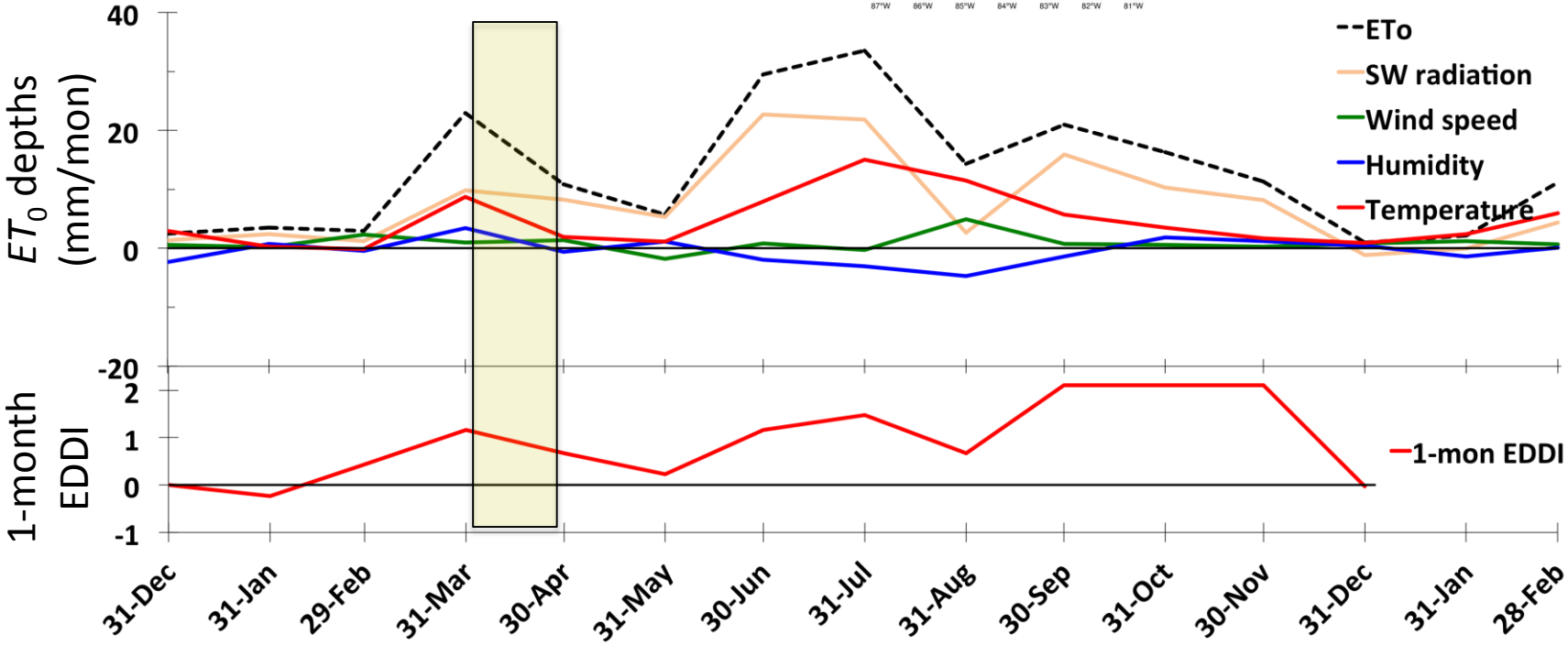
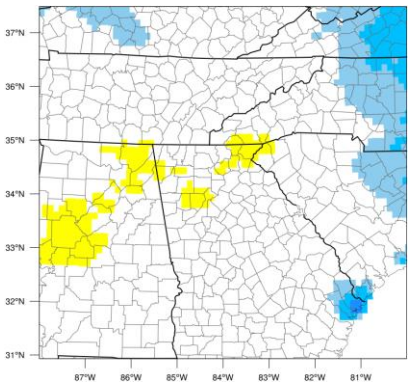




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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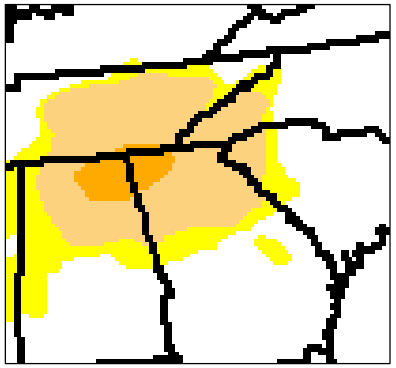
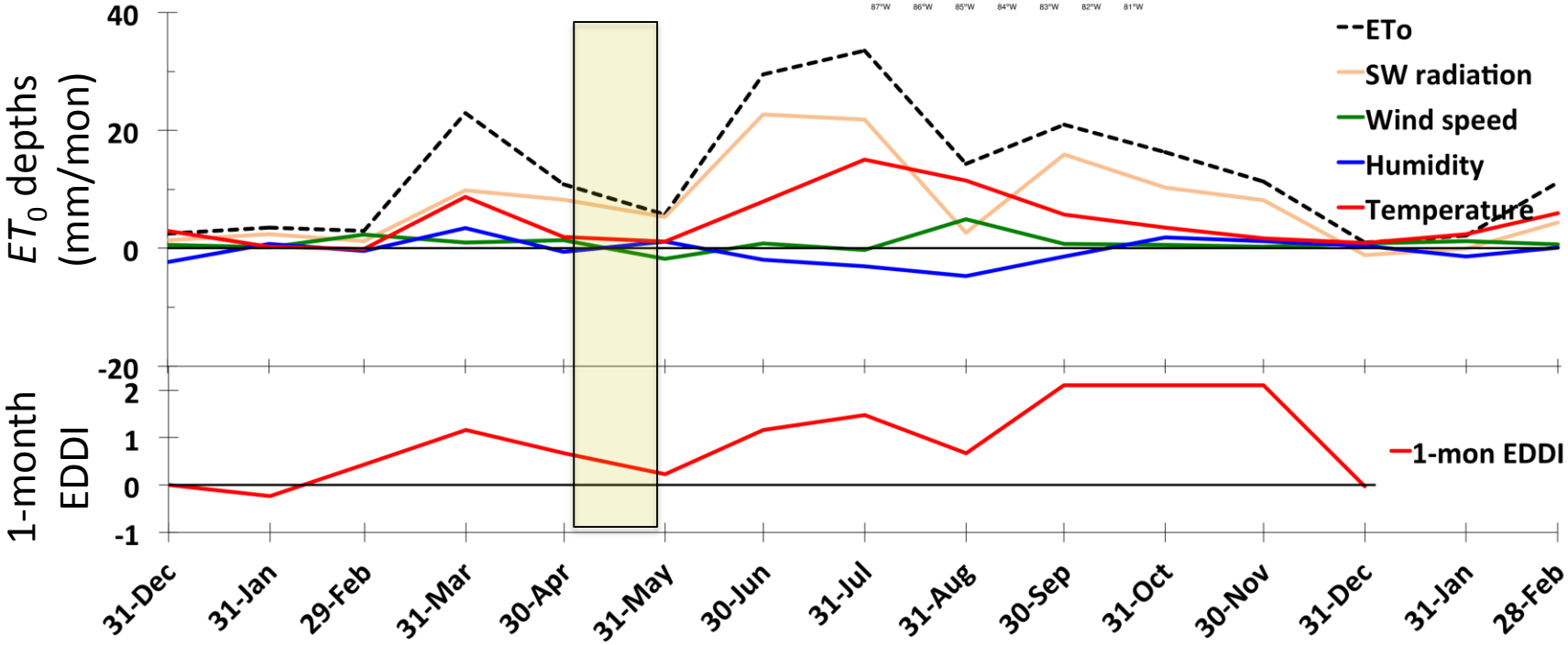
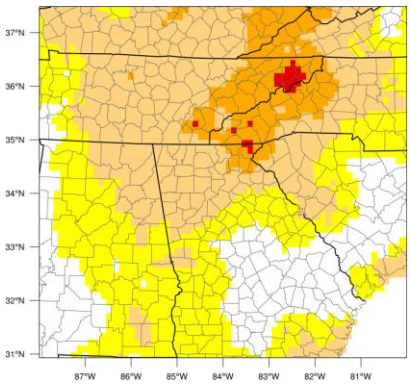




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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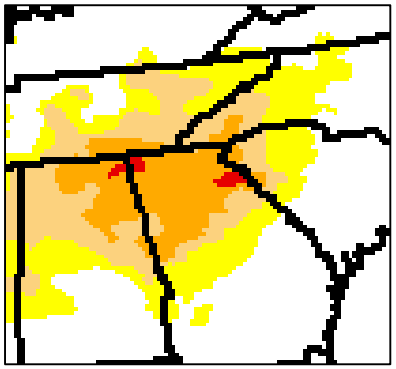
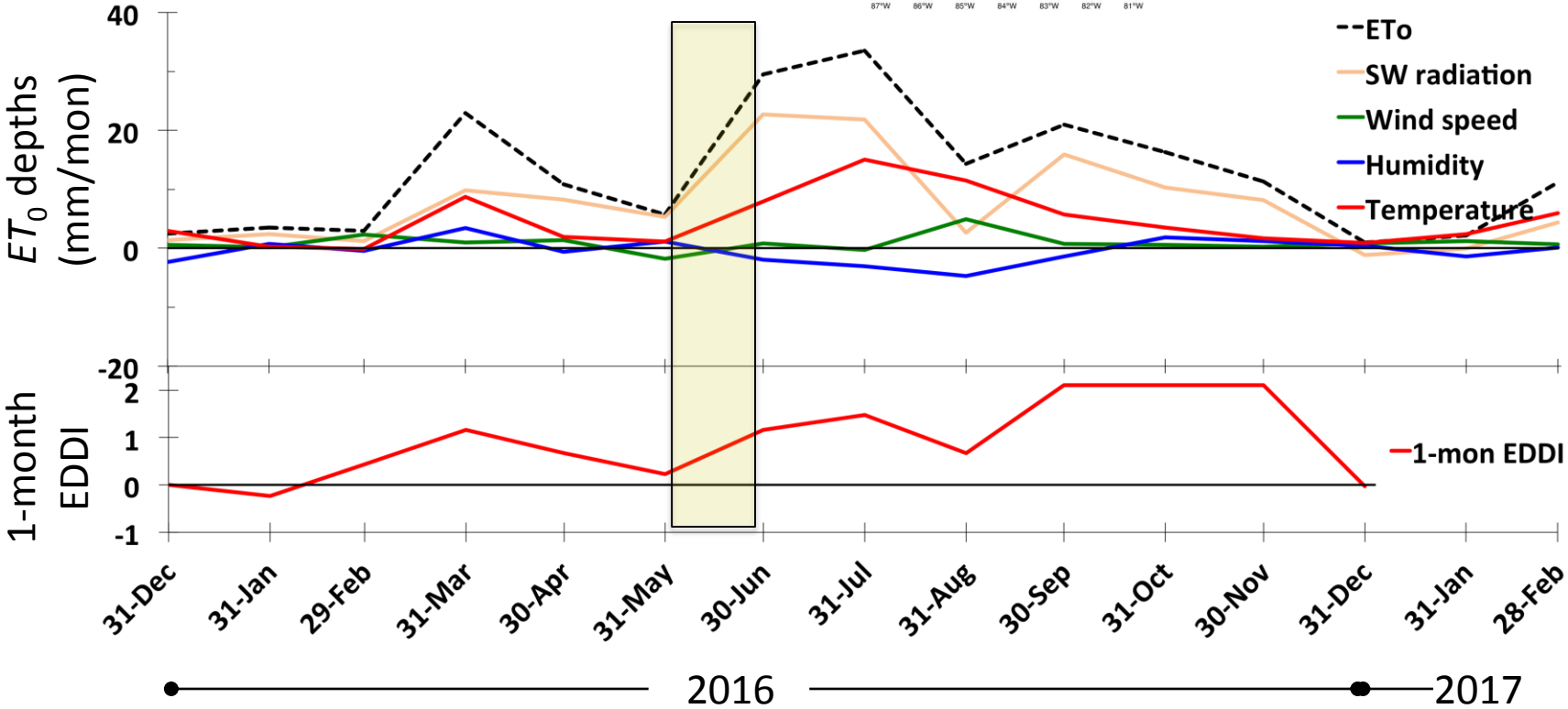
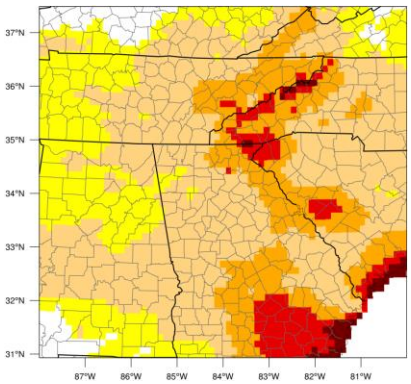




2016 Southeast drought / fires

1-mon EDDI



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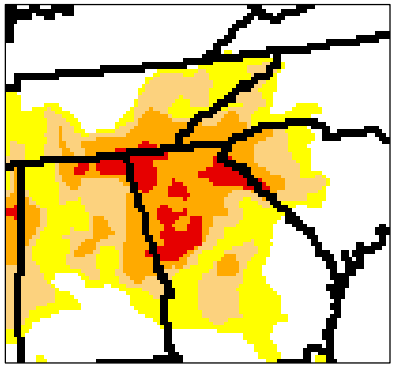
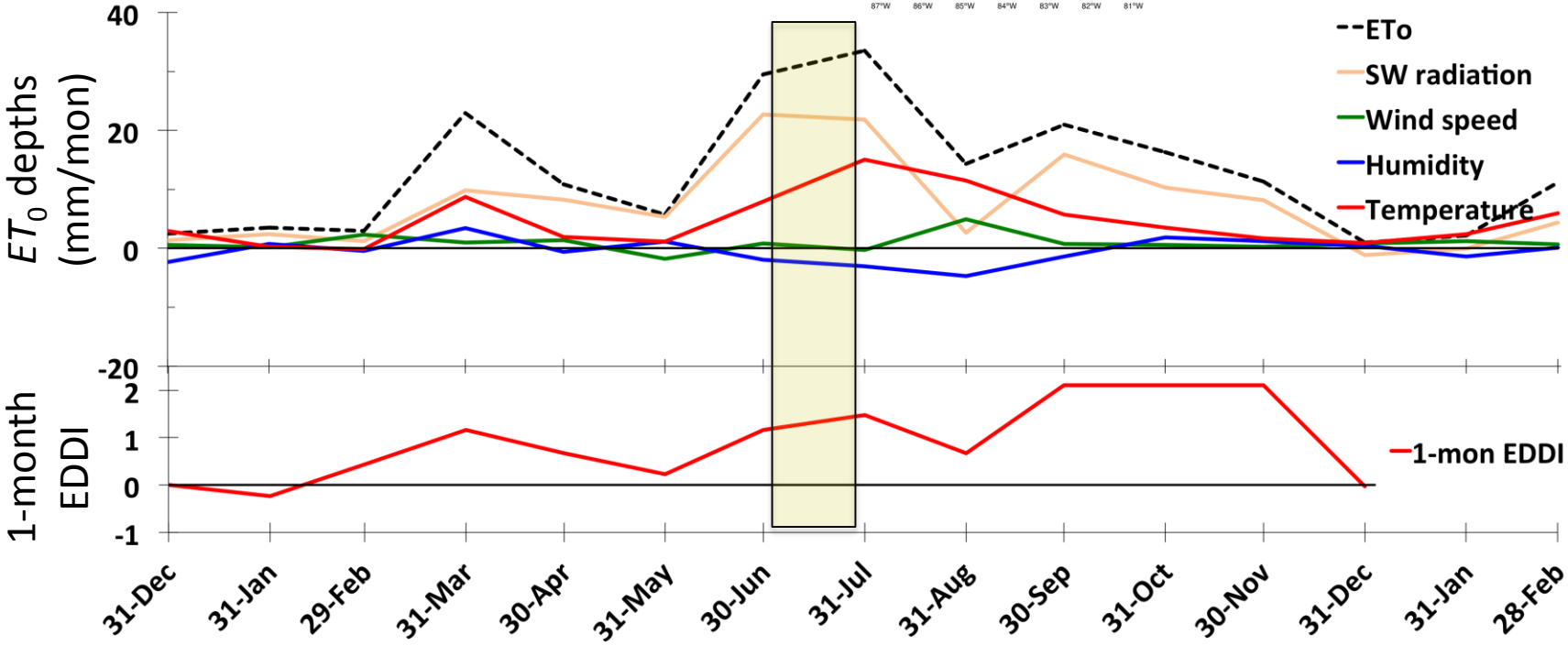
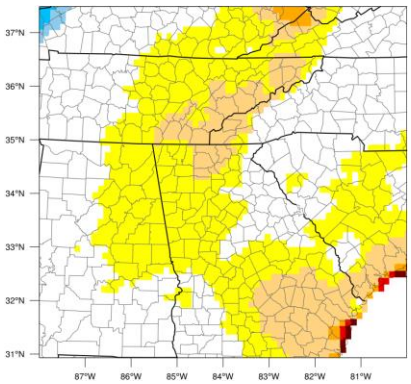




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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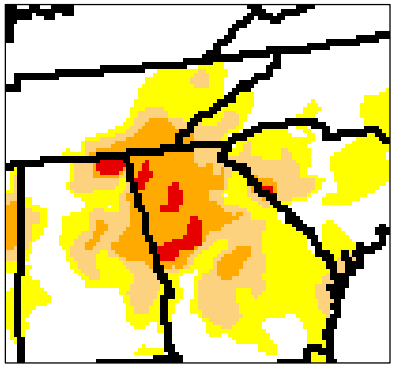
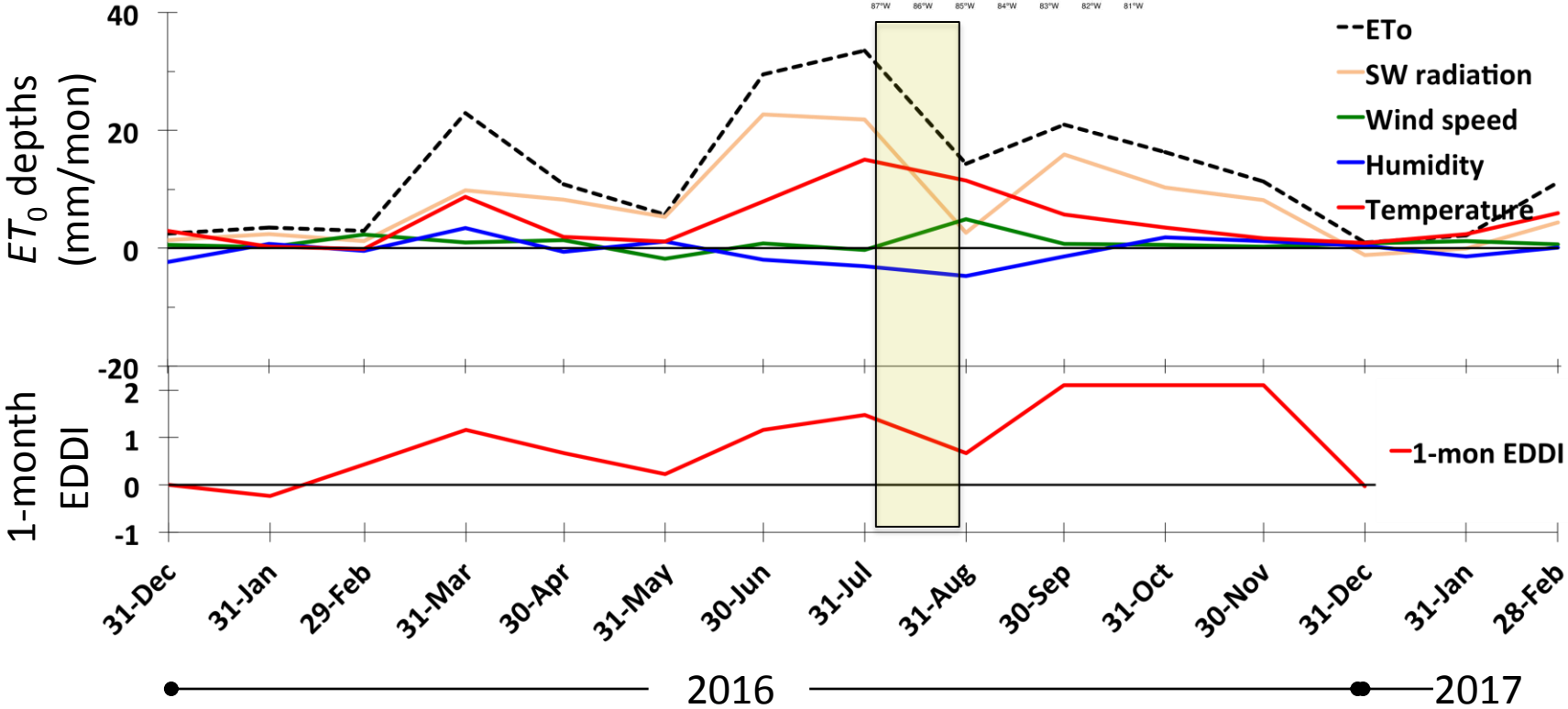
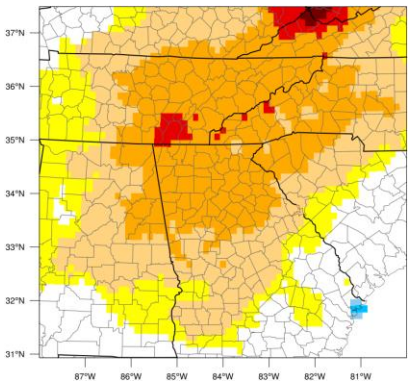




2016 Southeast drought / fires

1-mon EDDI



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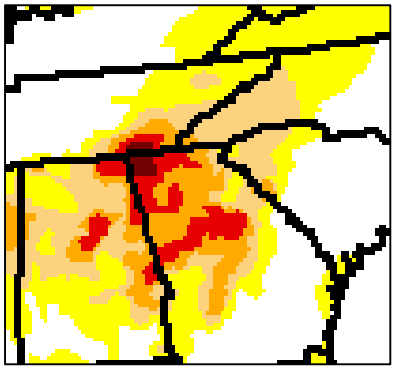
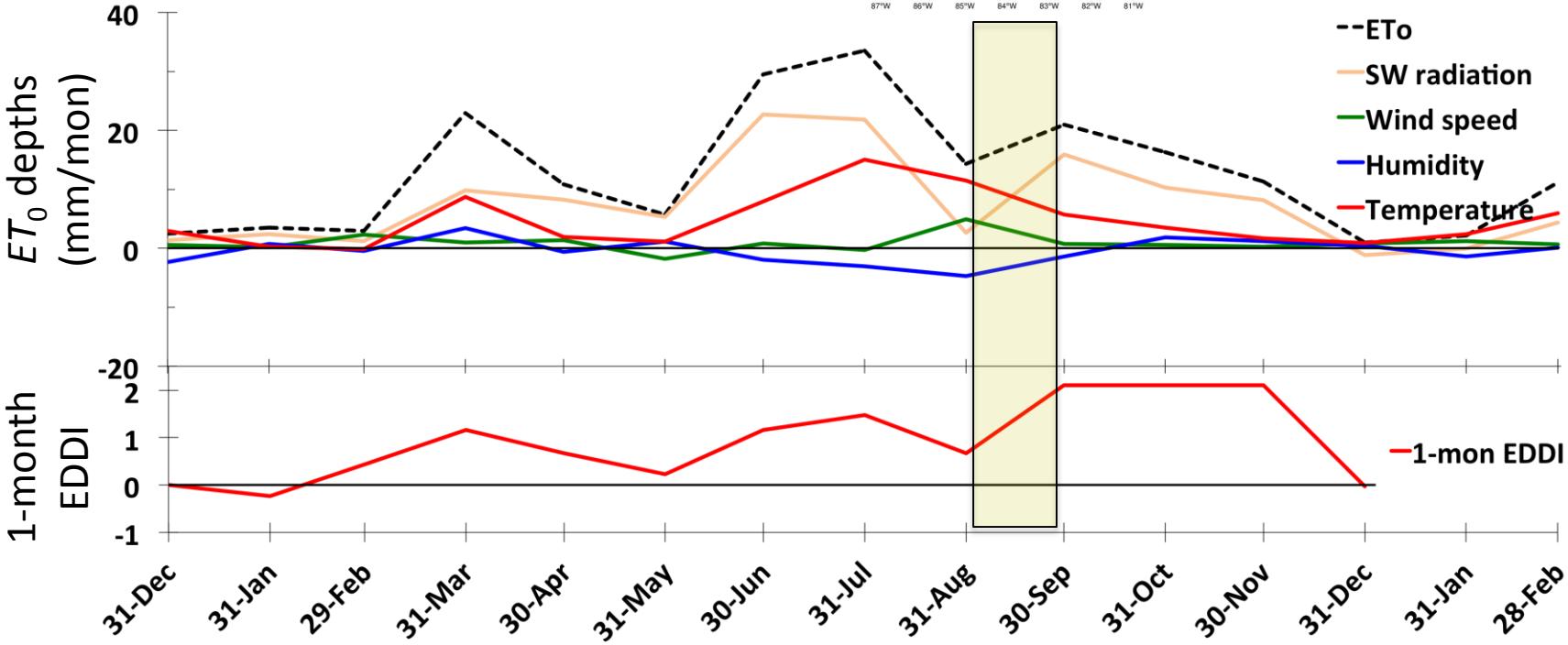
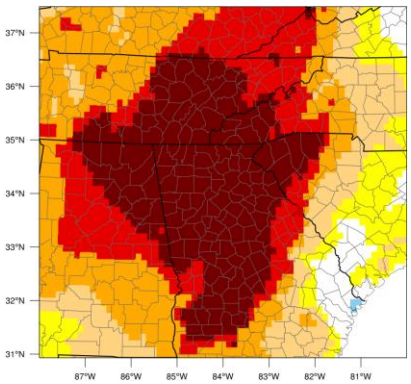




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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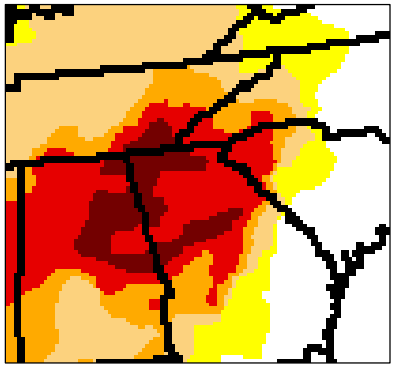
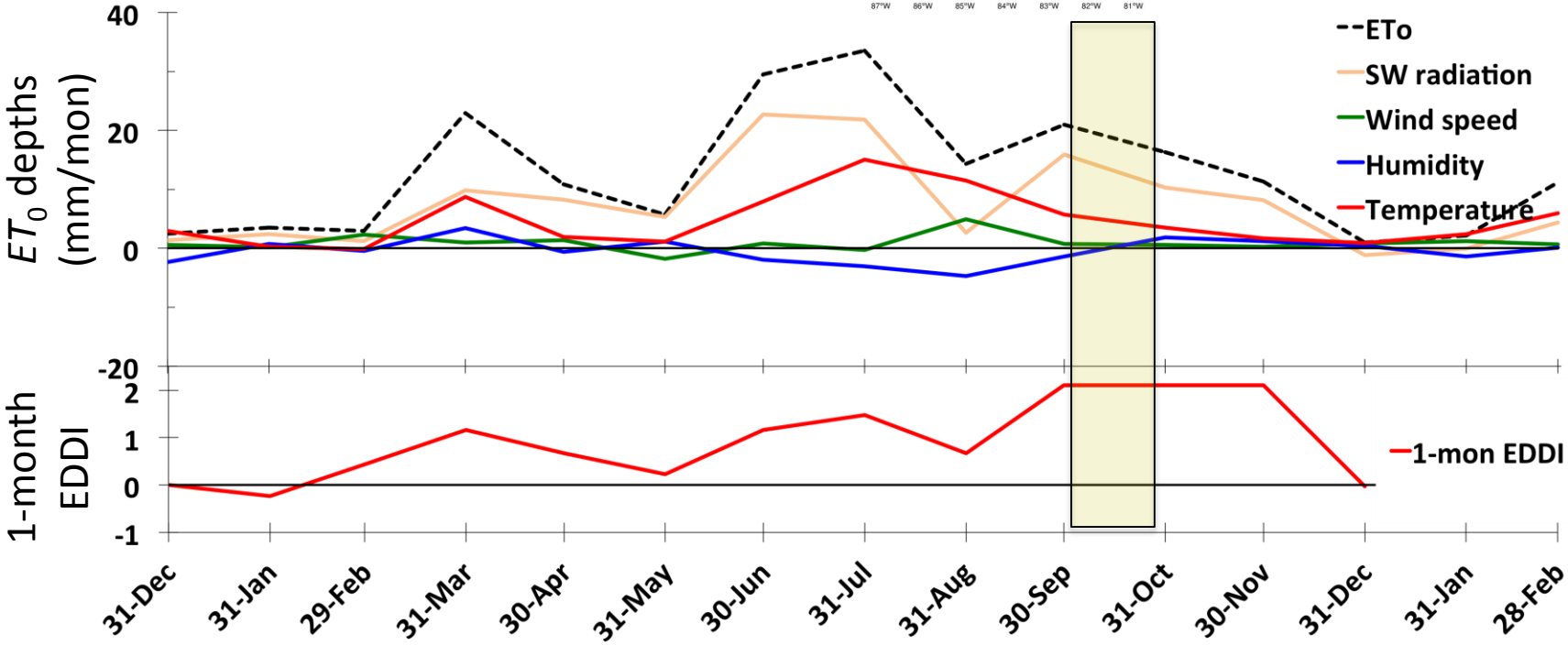
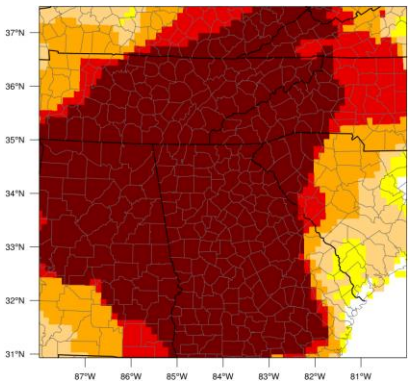




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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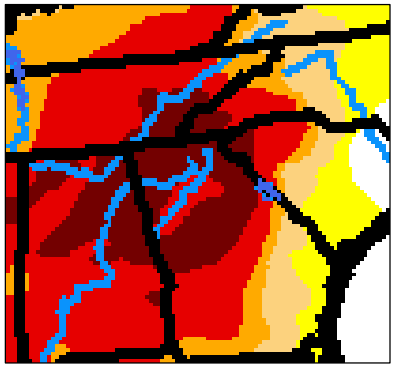
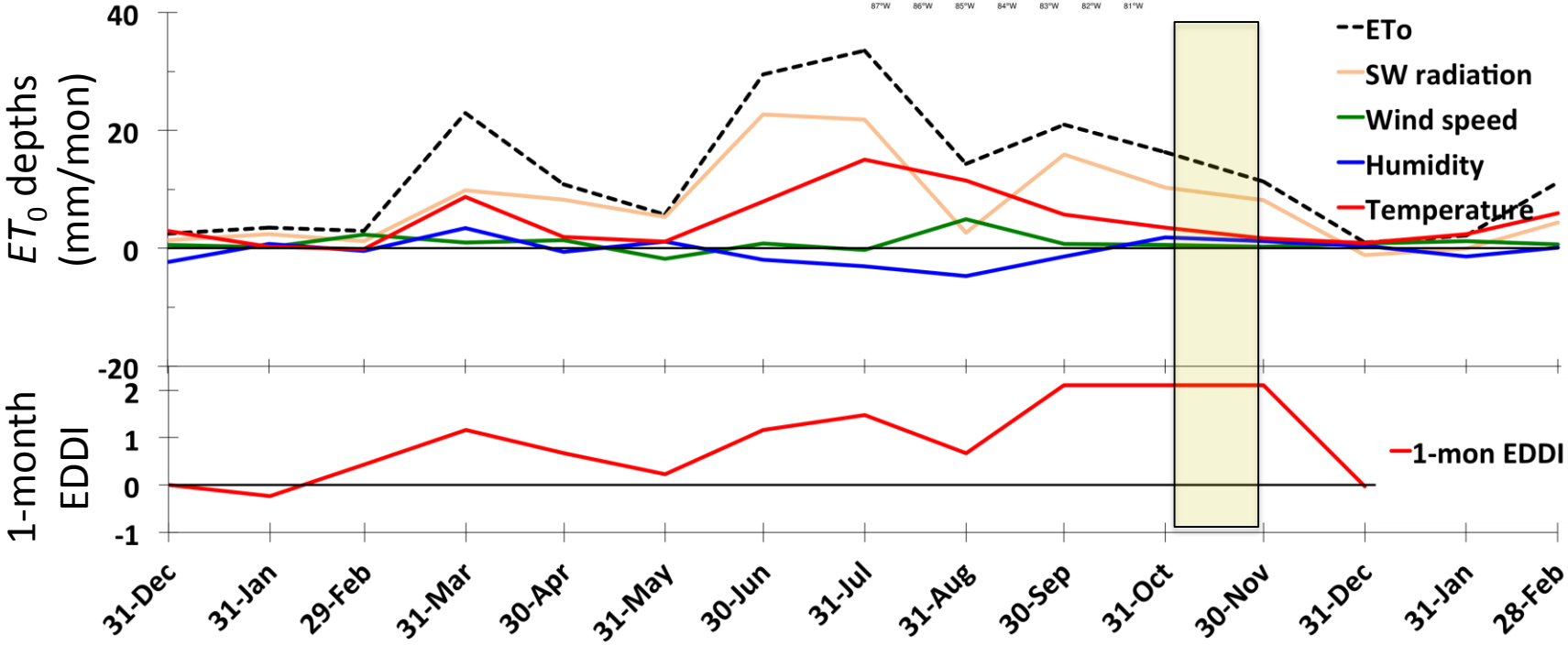
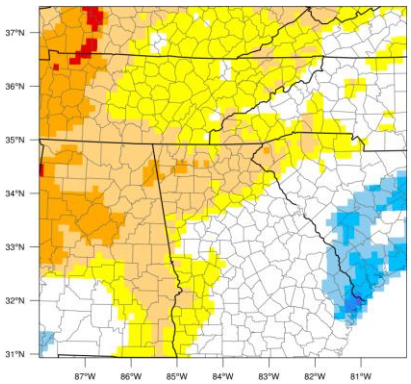




2016 — 2017

2016 Southeast drought / fires

1-mon EDDI



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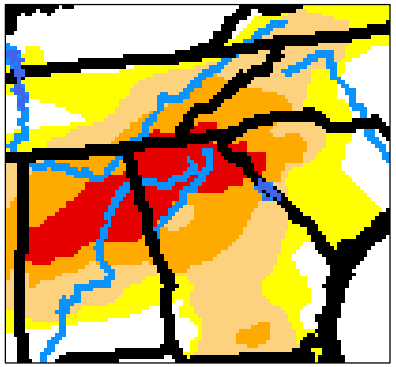
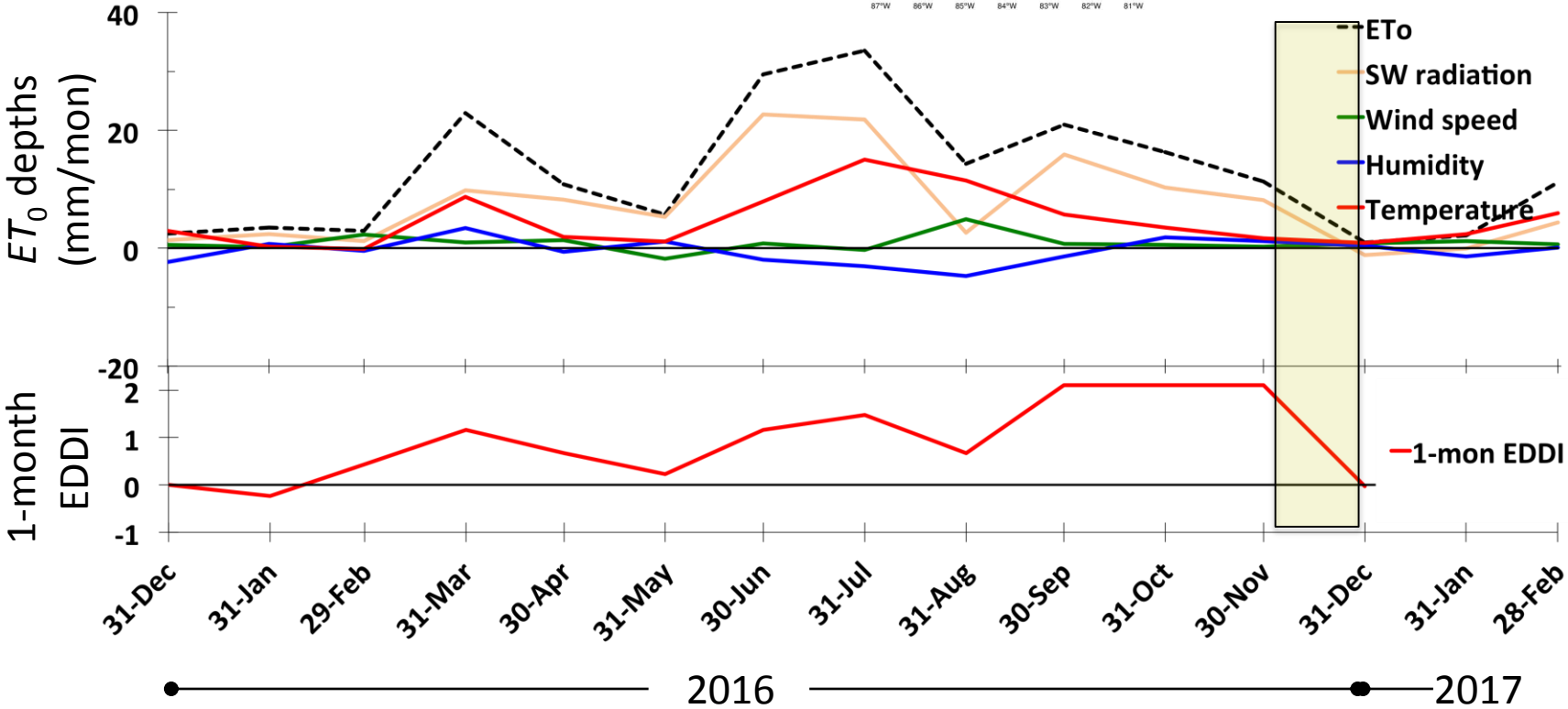




Summary

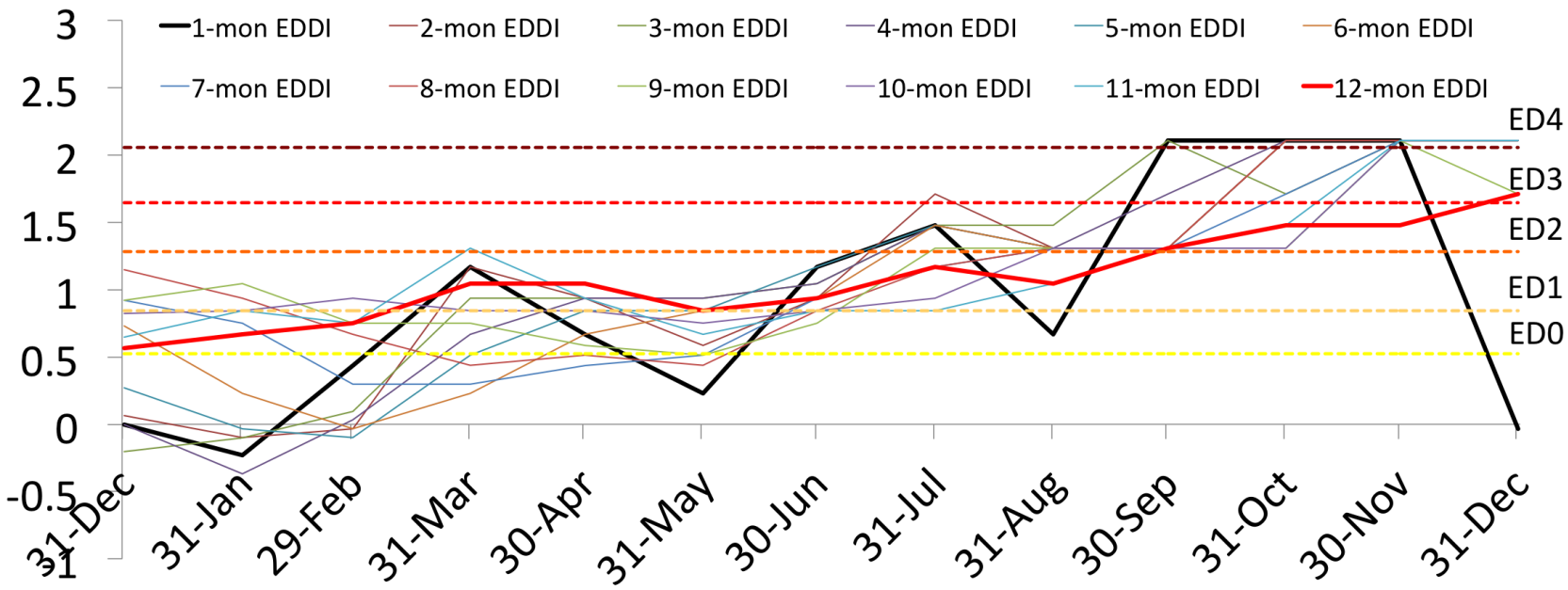
mike.hobbins@noaa.gov 303-497-3092

E_0 and drought:

- Physically related to drought
- Leads effects on *ET* in humid areas; reflects them in arid areas
- Decomposition of drought's demand side

Back-up slides

EDDI information at various timescales



Different drying dynamics occur at different timescales

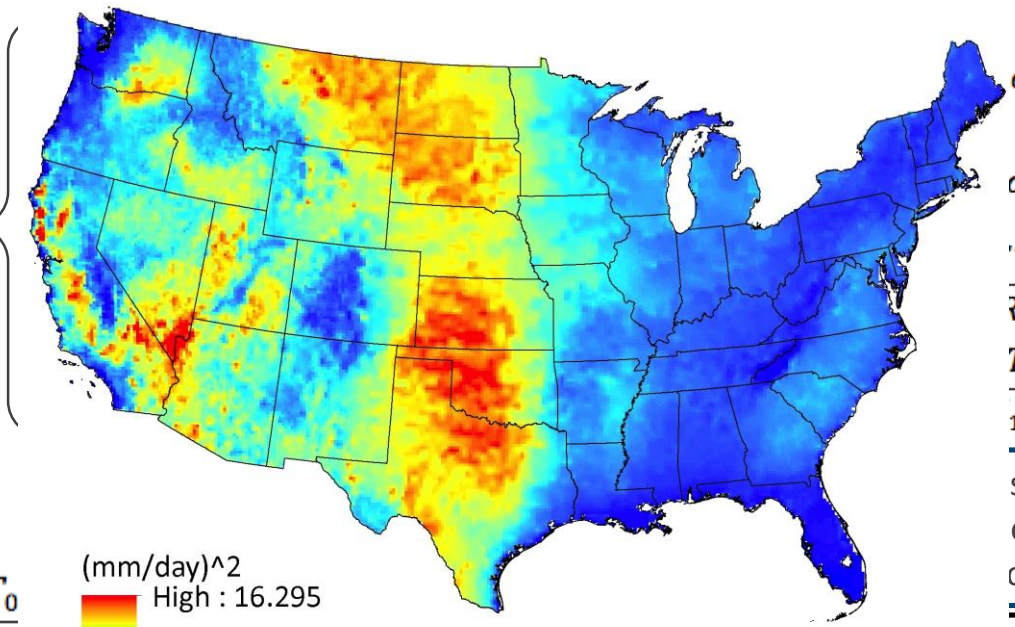
Optimal timescale(s) will be sector-, region-, and season-specific.

Decomposition and attribution

$$ET_0 = \frac{0.408\Delta}{\Delta + g(1 + C_d U_2)}(R_n - G)\frac{86400}{10^6} + \frac{g\frac{C_n}{T}}{\Delta + g(1 + C_d U_2)} U_2 \frac{(e_{sat} - e_a)}{10^3} = \boxed{g(T, q, U_{10}, R_d)}$$

(1) Variability analysis

$$\sigma^2_{ET_0} = F_T + F_q + F_{U_{10}} + F_{R_d} = \left\{ \sigma_{T,R_d} \quad \sigma_{q,R_d} \quad \frac{T_0}{R_d}\sigma_{U_{10},R_d} \quad \frac{T_0}{10}\sigma_{R_d,U_{10}} \right\}$$



s in (1) and
ons in (2)
om dataset

(2) Change attribution

$$\Delta ET_0 = \frac{\partial ET_0}{\partial T}\Delta T + \frac{\partial ET_0}{\partial q}$$

nd (2) derived
analytically from model formulation
[*Hobbins et al., Trans. ASABE 2016*]

Decomposition and attribution

Explicit sensitivity equations

$$\frac{\partial \mathrm{ET}_r}{\partial T} = \frac{\left\{ 0.408\overline{\Delta}\left[\overline{R}_n \frac{4169.871 - 2\overline{T}}{\left(\overline{T} - 35.85\right)^2} - 4\sigma f_{cd}\left(0.34 - 0.14\sqrt{\overline{e}_a}\right)\overline{T}^3 \right] + \gamma C_n \frac{\overline{U}}{\overline{T}}\left[\overline{e}_{sat} \frac{4098.171}{\left(\overline{T} - 35.85\right)^2} - \frac{1}{\overline{T}}\left(\overline{e}_{sat} - \overline{e}_a\right) \right] \right\}}{\overline{\Delta} + \gamma\left(1 + C_d\overline{U}\right)} + \frac{\frac{4169.871 - 2\overline{T}}{\left(\overline{T} - 35.85\right)^2}\overline{\Delta}\left[0.408\overline{\Delta}\,\overline{R}_n + \gamma \frac{C_n}{\overline{T}}\overline{U}\left(\overline{e}_{sat} - \overline{e}_a\right) \right]}{\left[\overline{\Delta} + \gamma\left(1 + C_d\overline{U}\right)\right]^2}$$

$$\frac{\partial \mathrm{ET}_r}{\partial q} = 0.622 P_a \frac{0.02856\overline{\Delta}\sigma f_{cd}\overline{T}^4 \frac{1}{\sqrt{\overline{e}_a}} - \gamma \frac{C_n}{\overline{T}}\overline{U}}{\left[\overline{\Delta} + \gamma\left(1 + C_d\overline{U}\right)\right]\left(0.622 + 0.378\overline{q}\right)^2}$$

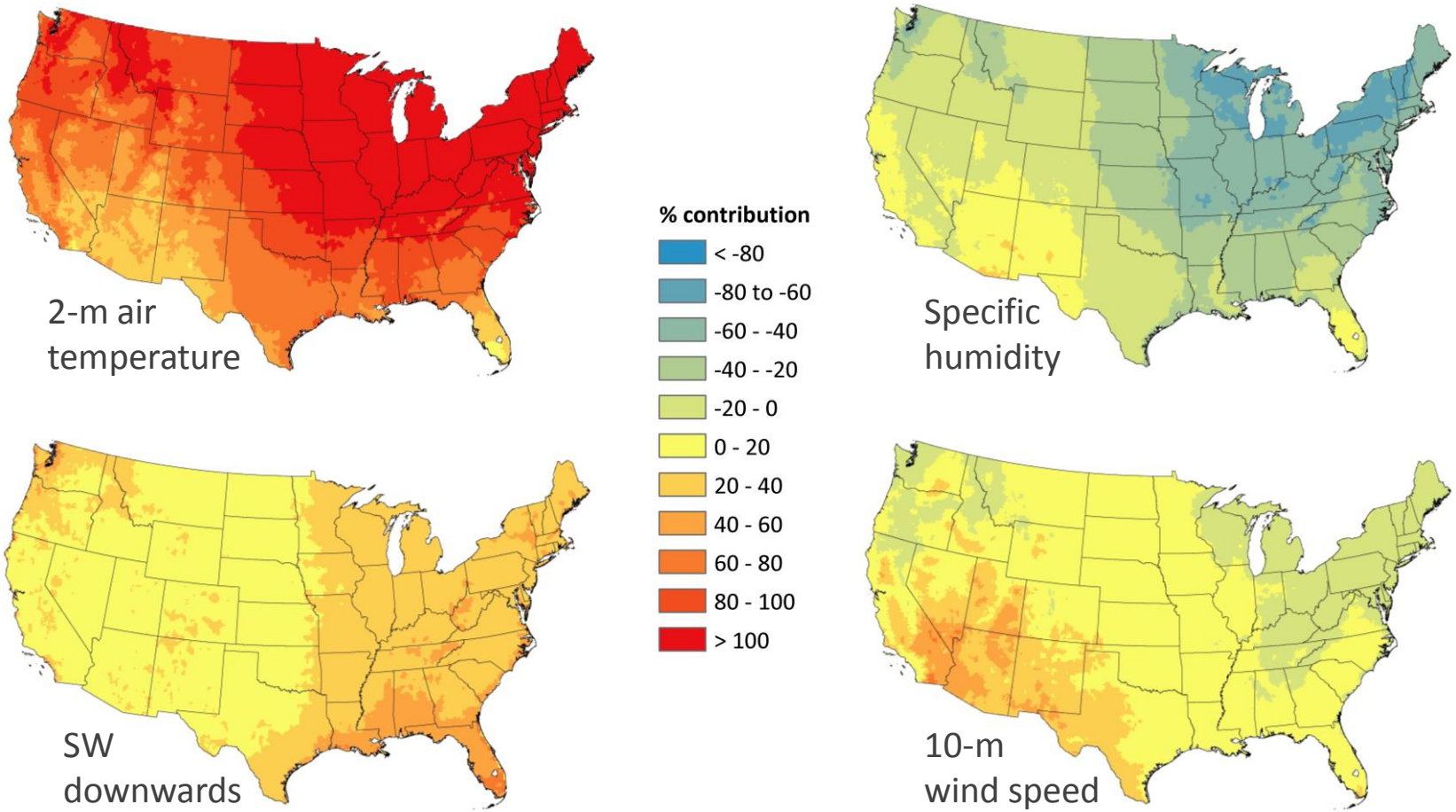
$$\frac{\partial \mathrm{ET}_r}{\partial R_d} = 0.408\overline{\Delta}\frac{1 - \alpha - \sigma \frac{1.35}{R_{so}}\left(0.34 - 0.14\sqrt{\overline{e}_a}\right)\overline{T}^4}{\overline{\Delta} + \gamma\left(1 + C_d\overline{U}\right)}$$

$$\frac{\partial \mathrm{ET}_r}{\partial U} = \gamma \frac{\left[\overline{\Delta} + \gamma\left(1 + C_d\overline{U}\right)\right]\frac{C_n}{\overline{T}}\left(\overline{e}_{sat} - \overline{e}_a\right) - C_d\left[0.408\overline{\Delta}\,\overline{R}_n + \gamma \frac{C_n}{\overline{T}}\overline{U}\left(\overline{e}_{sat} - \overline{e}_a\right) \right]}{\left[\overline{\Delta} + \gamma\left(1 + C_d\overline{U}\right)\right]^2}$$

[*Hobbins et al., Trans. ASABE 2016*]

Decomposition and attribution

MJJASO variability contributions, daily ET_0, by driver

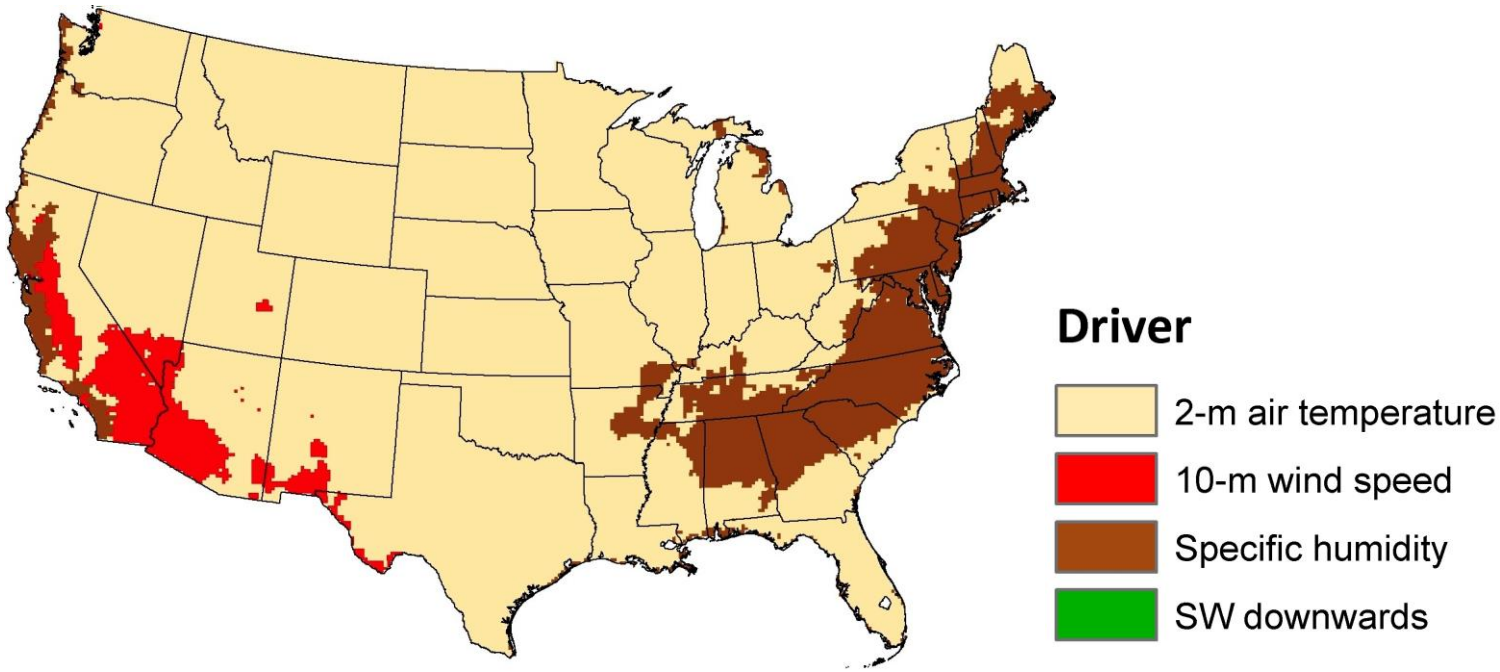


[*Hobbins et al., Trans. ASABE 2016*]

Decomposition and attribution

Top driver of daily variability, by month

December



[*Hobbins et al., Trans. ASABE 2016*]