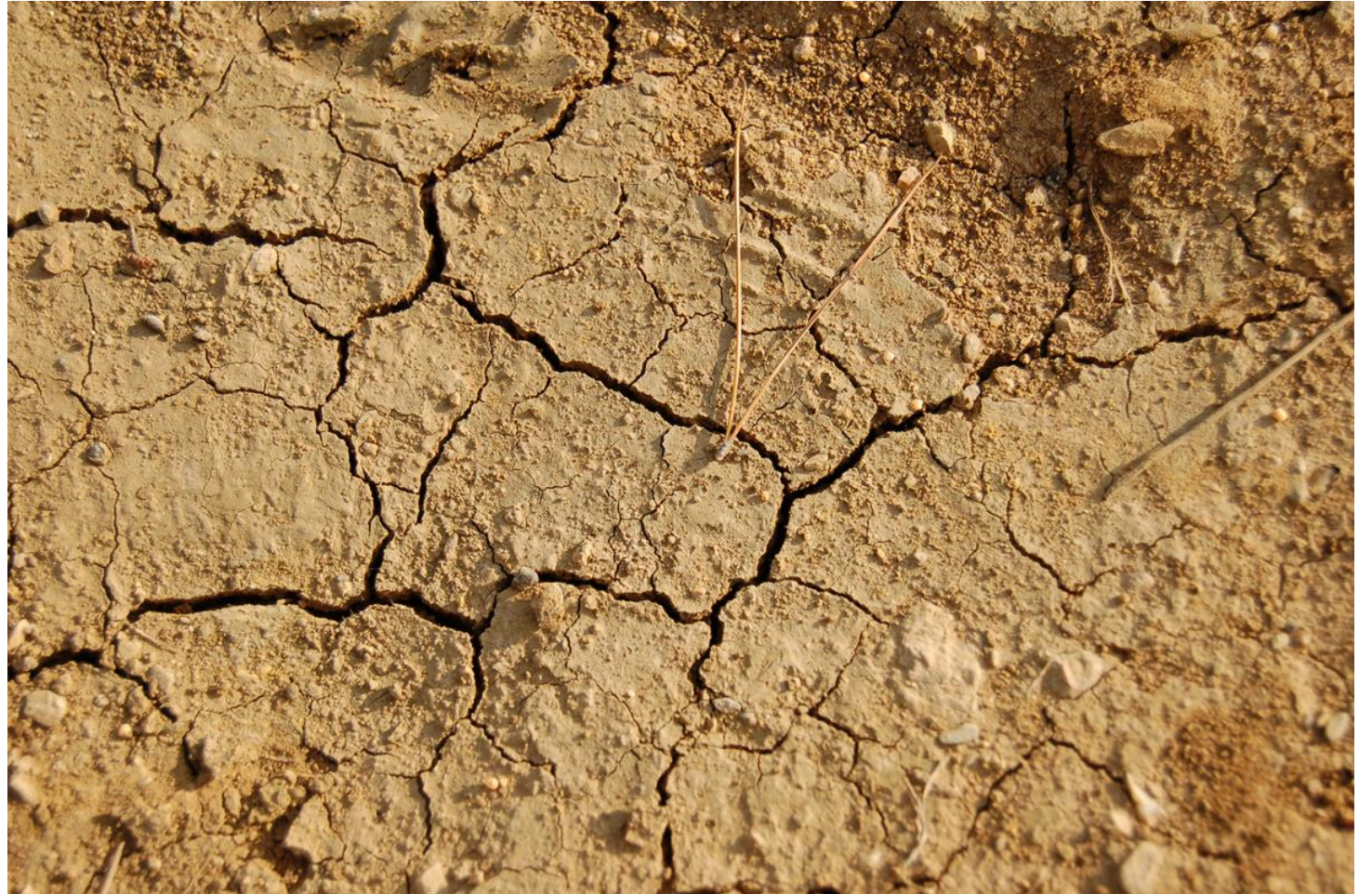


A LOOK INTO FLASH DROUGHT -- THE EVAPORATIVE DEMAND DROUGHT INDEX (EDDI)

*(Otkin et al. 2018; Hobbins et al.
2016; McEvoy et al. 2016)*

Seminar Talk:
Shuang XIA
May 6th 2019



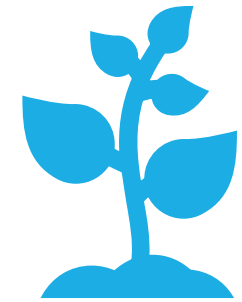
CONTENTS

- Background knowledge for drought
- Flash drought
- The Evaporative Demand Drought Index
- Assessment among other indexes

- Summary

References

1. BACKGROUND KNOWLEDGE FOR DROUGHT



DROUGHT?

Naturally occurring process:

- Depletion of water resources
- Hydrological cycle

Adverse effects:

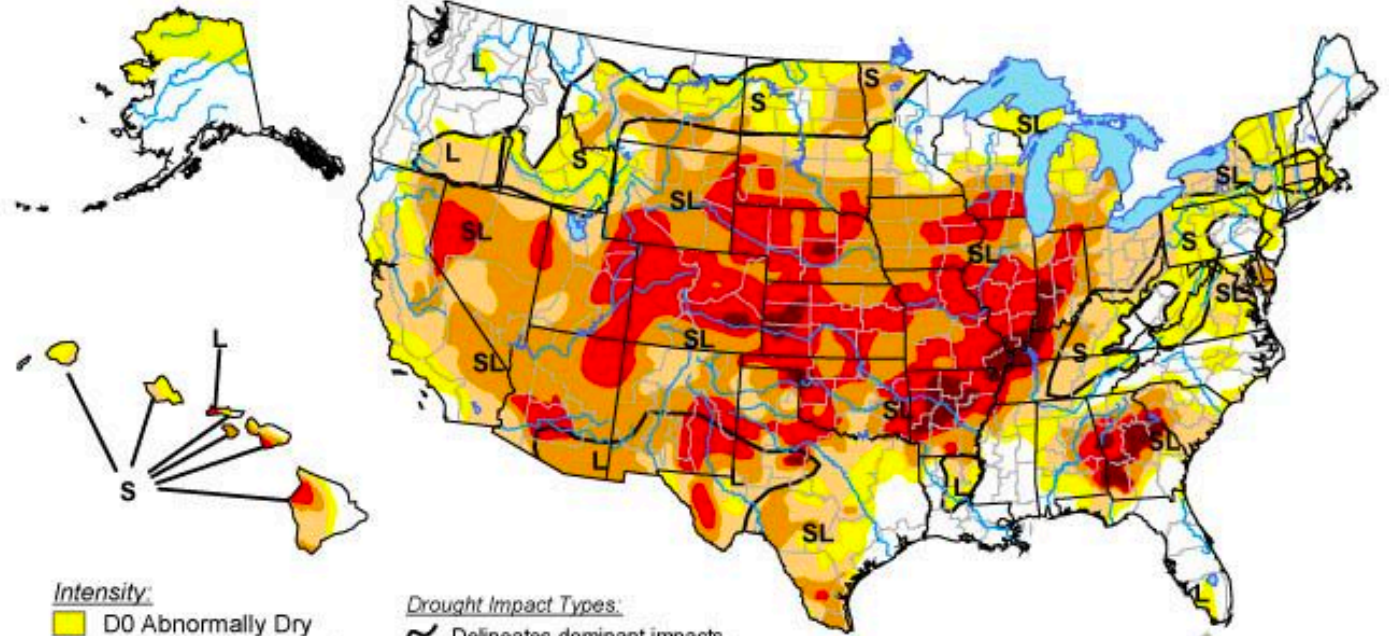
- Loss of crops
- Socioeconomic sectors
(\$35 billion Central U.S. 2012)
- Landscapes

Multiple time scales:

- Weeks to decades

U.S. Drought Monitor

July 24, 2012
Valid 7 a.m. EDT



Intensity:

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

Drought Impact Types:

- ~ Delineates dominant impacts
- S = Short-Term, typically <6 months (e.g. agriculture, grasslands)
- L = Long-Term, typically >6 months (e.g. hydrology, ecology)

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

<http://droughtmonitor.unl.edu/>



Released Thursday, July 26, 2012
Author: Richard Heim, NOAA/NESDIS/NCDC

○ Meteorological

Deficit in precipitation

○ Hydrological

Deficit becomes large

○ Agricultural

Deficit during growing season

○ Socioeconomic

Economic goods and services



TYPES OF DROUGHT

ESSENCE OF DROUGHT

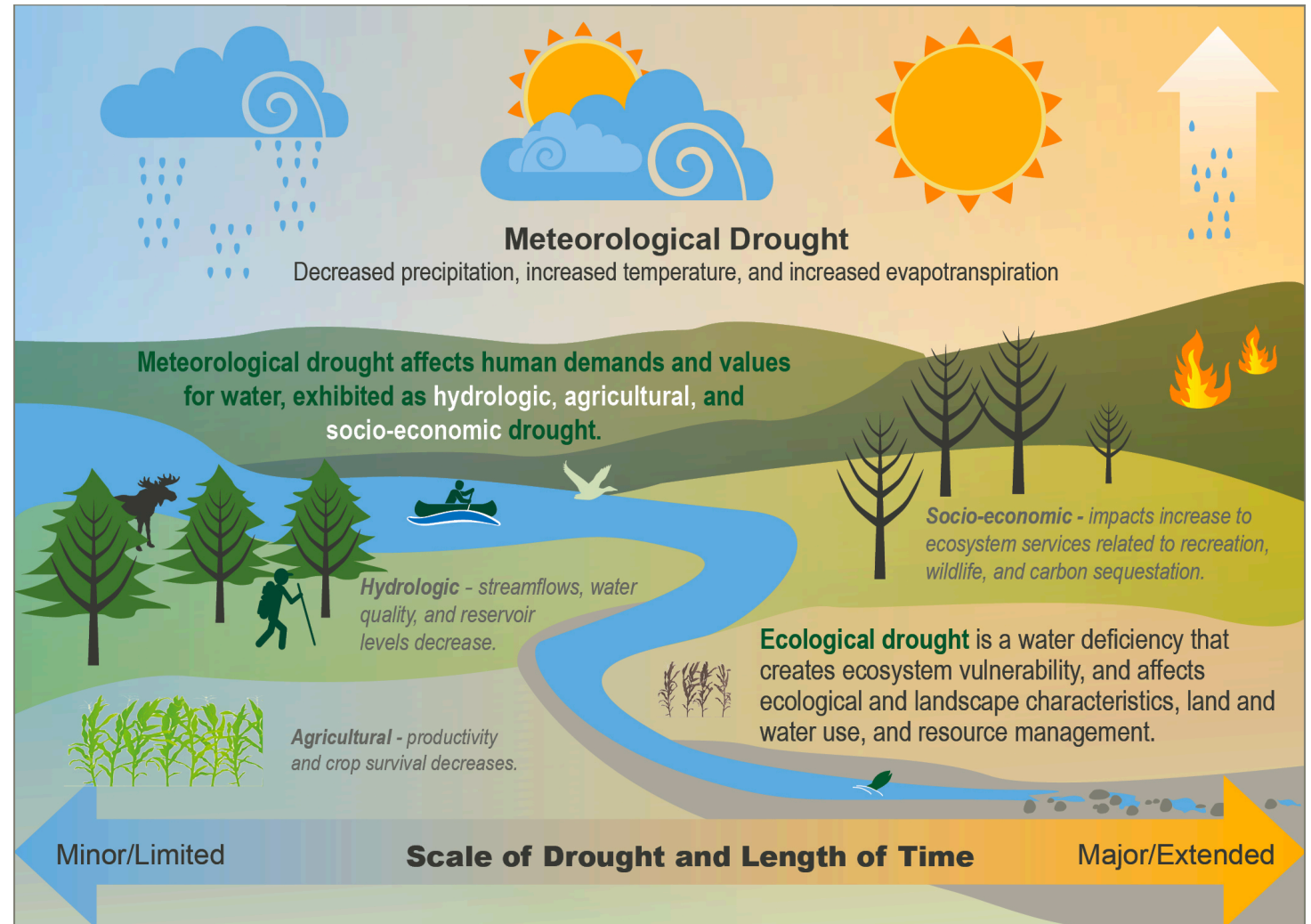
An extended imbalance between moisture **supply** and **demand**.

Supply:

- Precipitation (Prcp)
- Incoming streamflow
- Groundwater in

Demand:

- Evaporation & Transpiration (ET)
- Runoff (RO)
- Groundwater out



ABBREVIATIONS AND THEIR NATURES

ET: Evapotranspiration

‘evaporation’ and ‘transpiration’.

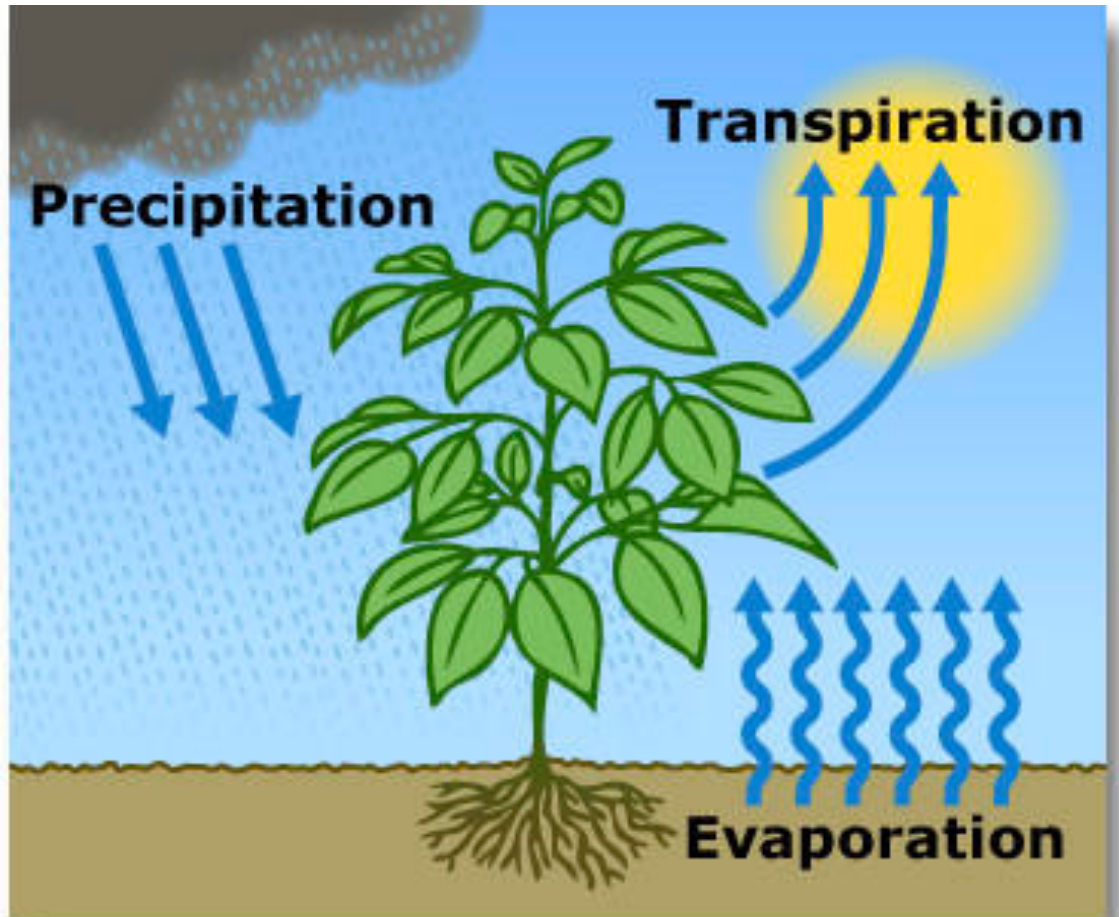
Evaporation: surface water → water vapor

Transpiration: evaporation from plant leaves. Metabolic system of plants.

A corn plant, 300kg soil water, 99% by transpiration. **What a pump!!!**

E_0 : Potential ET (evaporative demand)

The “should be” value of ET under certain surface conditions (T_{air} , q , U).



ABBREVIATIONS AND THEIR NATURES

SPI: Standardized Precipitation index

Most widely used index for precipitation.

ESI: Evaporative Stress Index

Ratio of ET over E_0 . Based on satellite data.

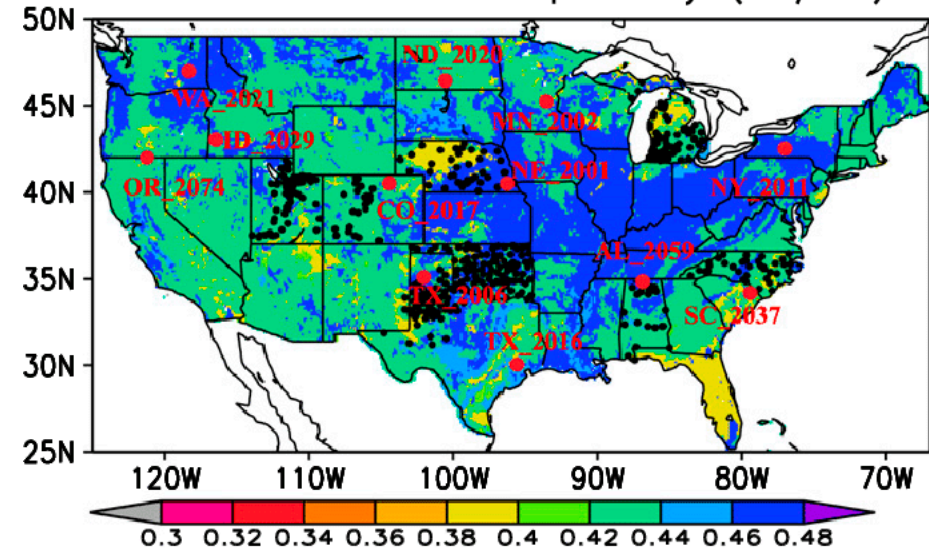
USDM: U.S. Drought Monitor

Well-known operational drought-monitoring tool

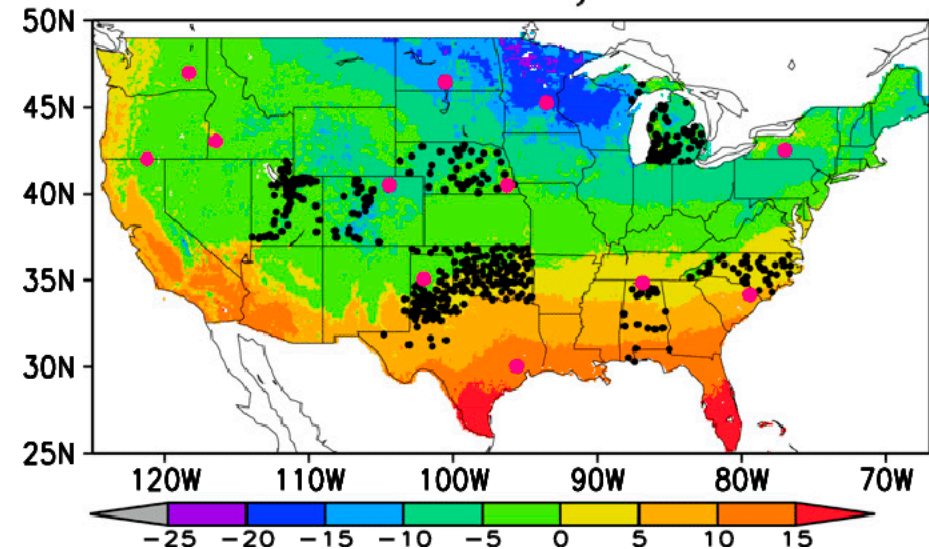
NLDAS-2: North American Land Data Assimilation System phase 2

Ground data assimilation system. Lag in only 5 days.

(a) Location of stations and NLDAS-2 Noah soil porosity (m^3/m^3)



(b) Location of stations and NLDAS-2 Noah 25 cm soil temperature ($^{\circ}\text{C}$) on 10 February 2007



2.FLASH DROUGHT



“FLASH”!!

- The speed which it develops.

Drought often takes months or years to reach its full intensity.

But recent events have shown that it can develop very rapidly if extreme weather anomalies persist.

- What condition ?

A flash flood can be caused by sudden heavy rainfall.

Suddenness of drought?

Marena, OK Phenocam - 01 July 2012



Marena, OK Phenocam - 11 August 2012



Marena, OK Phenocam - 01 July 2014



Marena, OK Phenocam - 11 August 2014



• Key features of flash drought

Intensification rather than Duration.

• Derivation of evaporative demand -- E_0

$$E_0 = \frac{0.408\Delta}{\Delta + \gamma(1 + C_d U)} (R_n + L_n - G) \frac{86400}{10^6} + \frac{\gamma \frac{C_n}{T_{air}}}{\Delta + \gamma(1 + C_d U)} U \frac{e_{sat} - e_a}{10^3}$$

Driven by:

Δ : slope of 2m saturated vapor pressure-temperature curve.

T_{air} : air temperature.

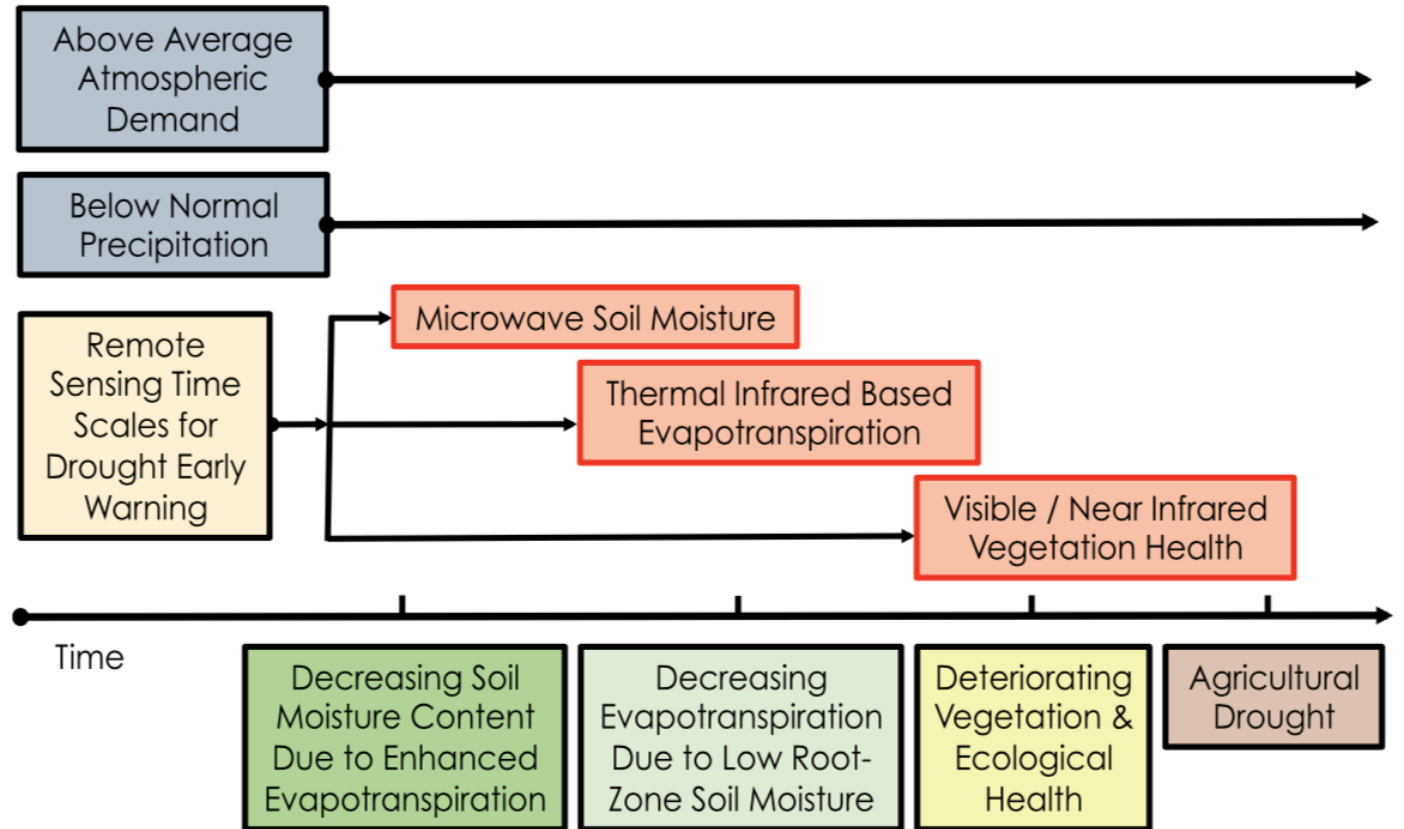
U : wind speed.

R_n & L_n : net radiation.

e_{sat} & e_a : saturated and actual vapor pressures.

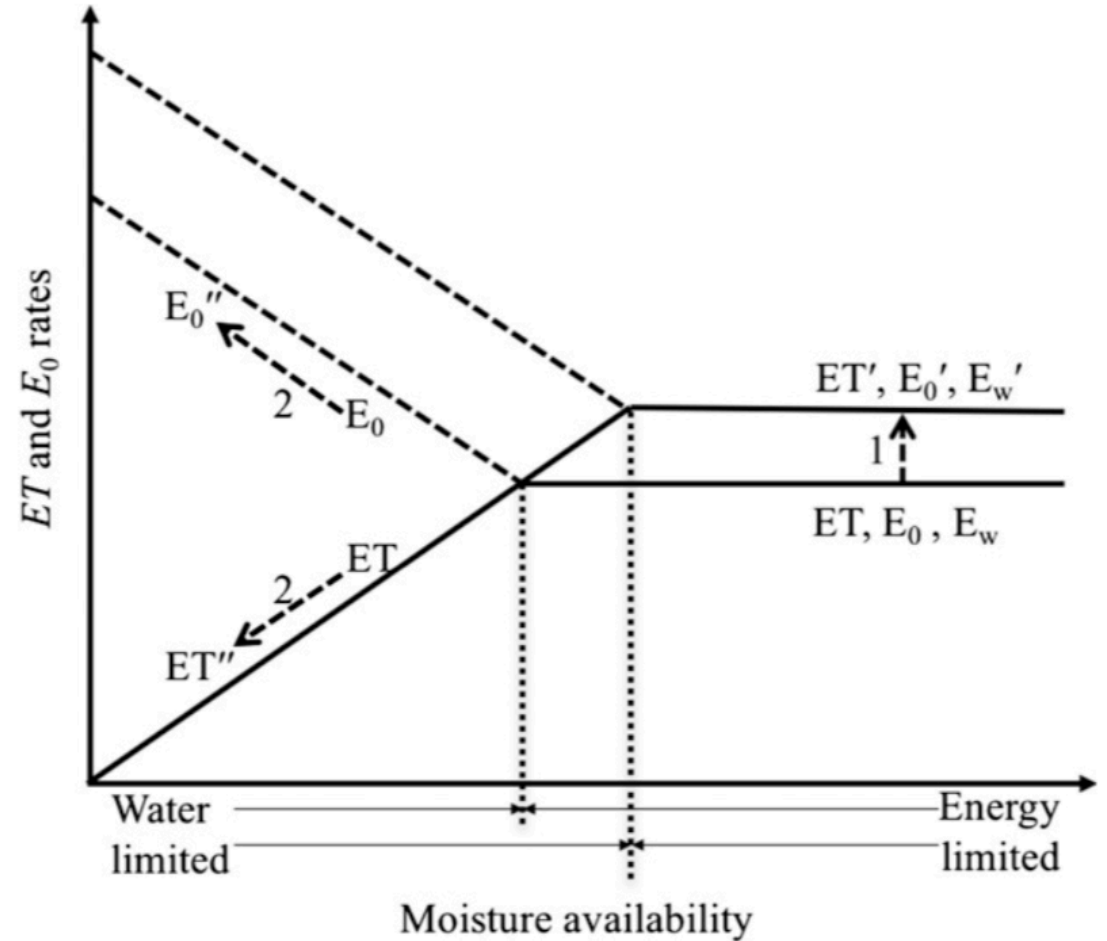
E_0 & ET

- Precipitation deficit is just one of the several factors.
- Enhanced evaporative demand.
 - High temperature
 - Low humidity
 - Strong winds
 - Sunny skies
- Most likely occur during the growing season.



ENERGY-LIMITED VS. WATER-LIMITED

- The role of E_0 :
 - Determining ET or
 - Reflective of ET
- Land-atmosphere feed backs:
ET ↓ -- sensible heat flux ↑ -- vapor pressure deficit ↑ -- E_0 ↑
- Water-limited: **sustained drought**
- Energy-limited: **flash drought (even with enough Prcp)**



3. THE EVAPORATIVE DEMAND DROUGHT INDEX (EDDI)



EDDI FORMULATION

- E_0 probabilities

$$P(E_{0i}) = \frac{i - 0.33}{n + 0.33}$$

$P(E_{0i})$: probability of E_{0i} .

i : rank of E_0 in the historical time series.

n : number of observations being ranked.

- EDDI

$$EDDI = W - \frac{C_0 + C_1W + C_2W^2}{1 + d_1W + d_2W^2 + d_3W^3}$$

For $P(E_{0i}) \leq 0.5$, $W = \sqrt{-2 \ln[P(E_{0i})]}$,

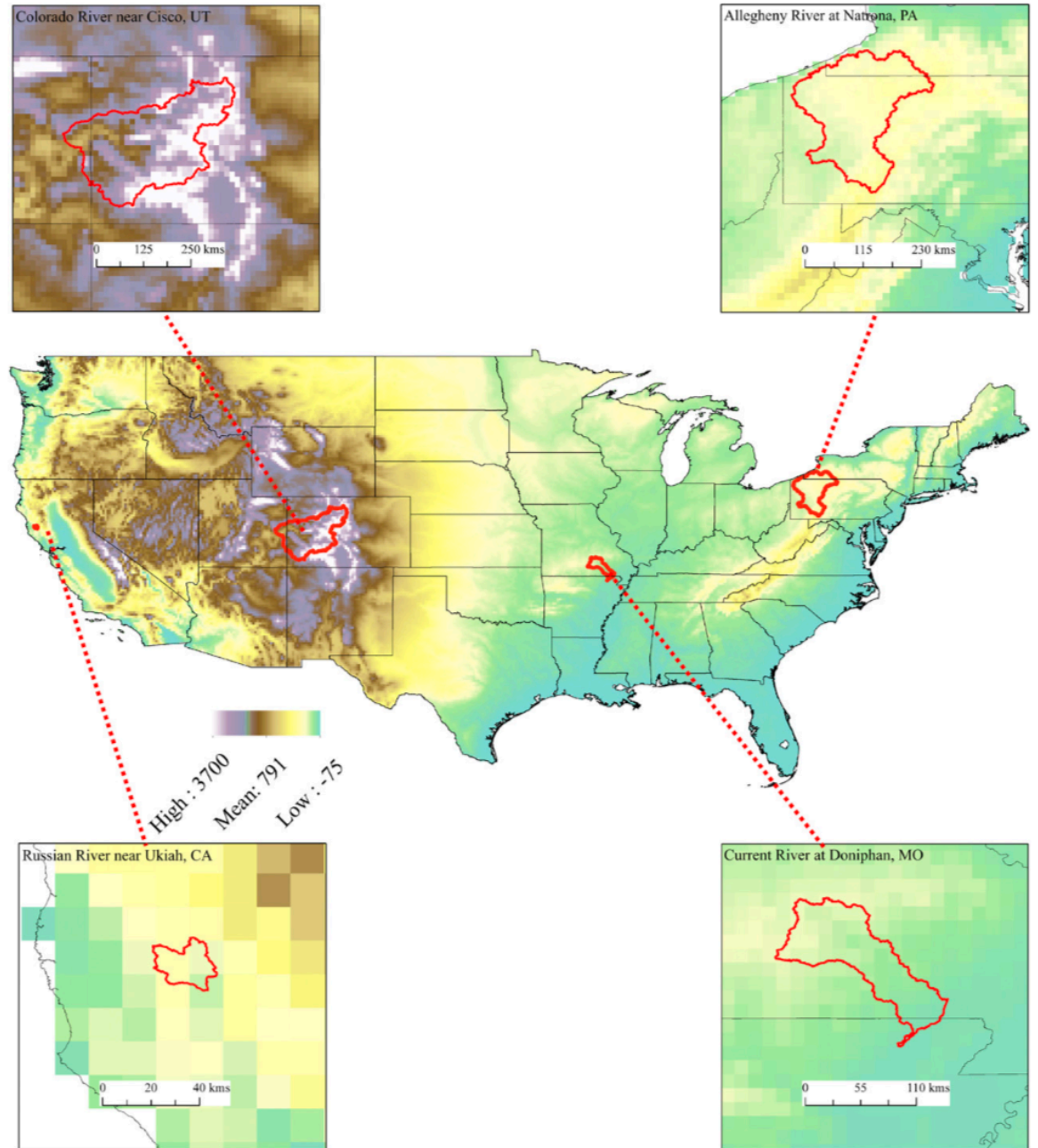
For $P(E_{0i}) \geq 0.5$, $W = \sqrt{-2 \ln[1 - P(E_{0i})]}$, reverse the sign of EDDI.

- Positive EDDI \rightarrow Drier than normal

(Wilks 2011;
Vicente-Serrano et
al. 2010)

EVALUATION APPROACH

- Four basins from across US.
- Russian River basin near Ukiah, California.
Has a wet winter and a hot dry summer climate.
- Current River basin at Doniphan, Missouri.
Forested area in the agricultural Midwest, has a rainfall-dominated climate.



EVALUATION APPROACH

- EDDI against USDM
- DATA Sources

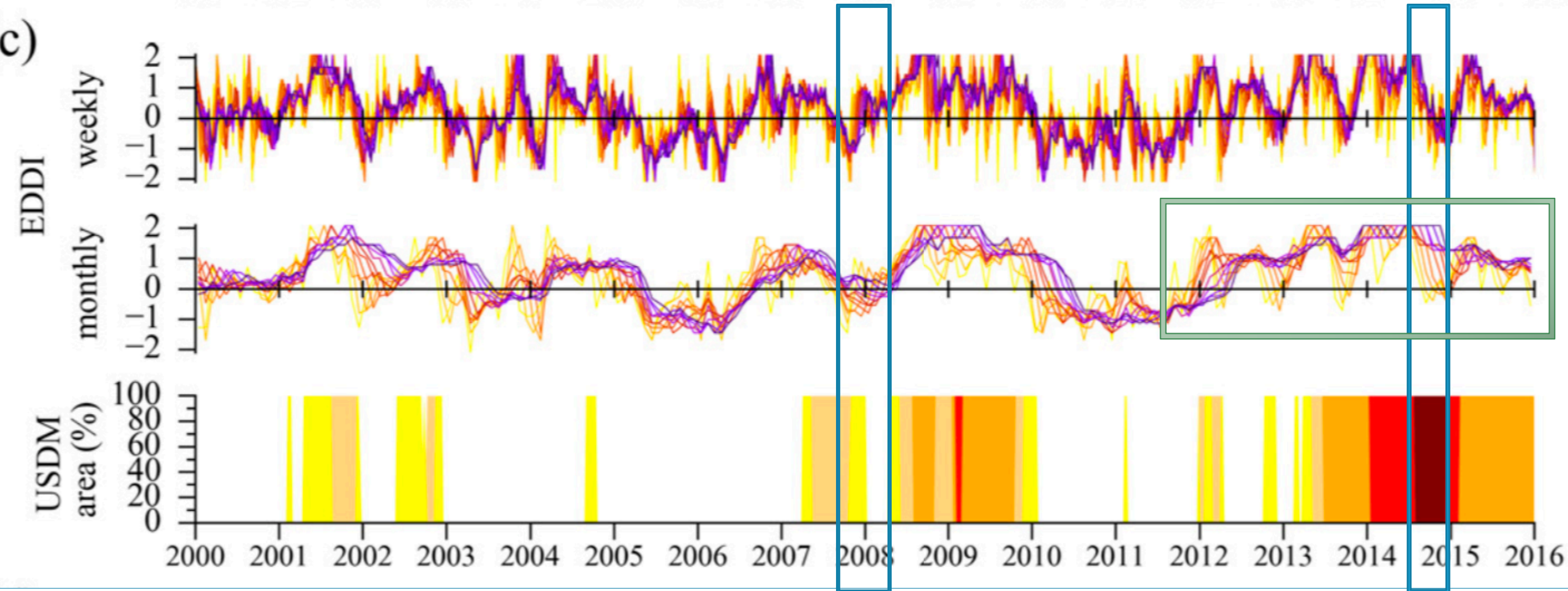
Derive EDDI: NLDAS-2

Precipitation: Parameter-Elevation Regressions on Independent Slopes Model (PRISM).

Runoff: U.S. Geological Survey (USGS).

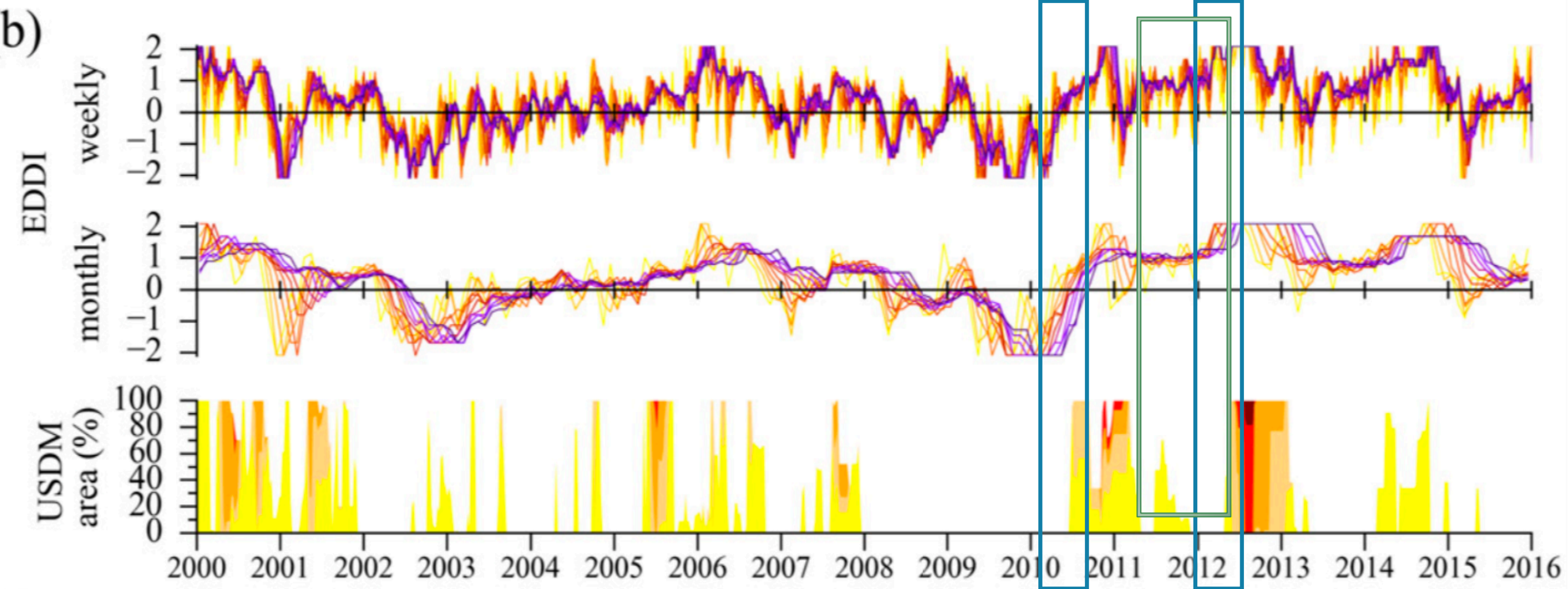
Soil Moisture: Variable Infiltration Capacity model driven by NLDAS-2 forcings

ET: Atmosphere-Land Exchange Inverse (ALEXI) surface energy balance algorithm model



WEEKLY & MONTHLY EDDI VS. WEEKLY USDm

The Russian basin



WEEKLY & MONTHLY EDDI VS. WEEKLY USDM

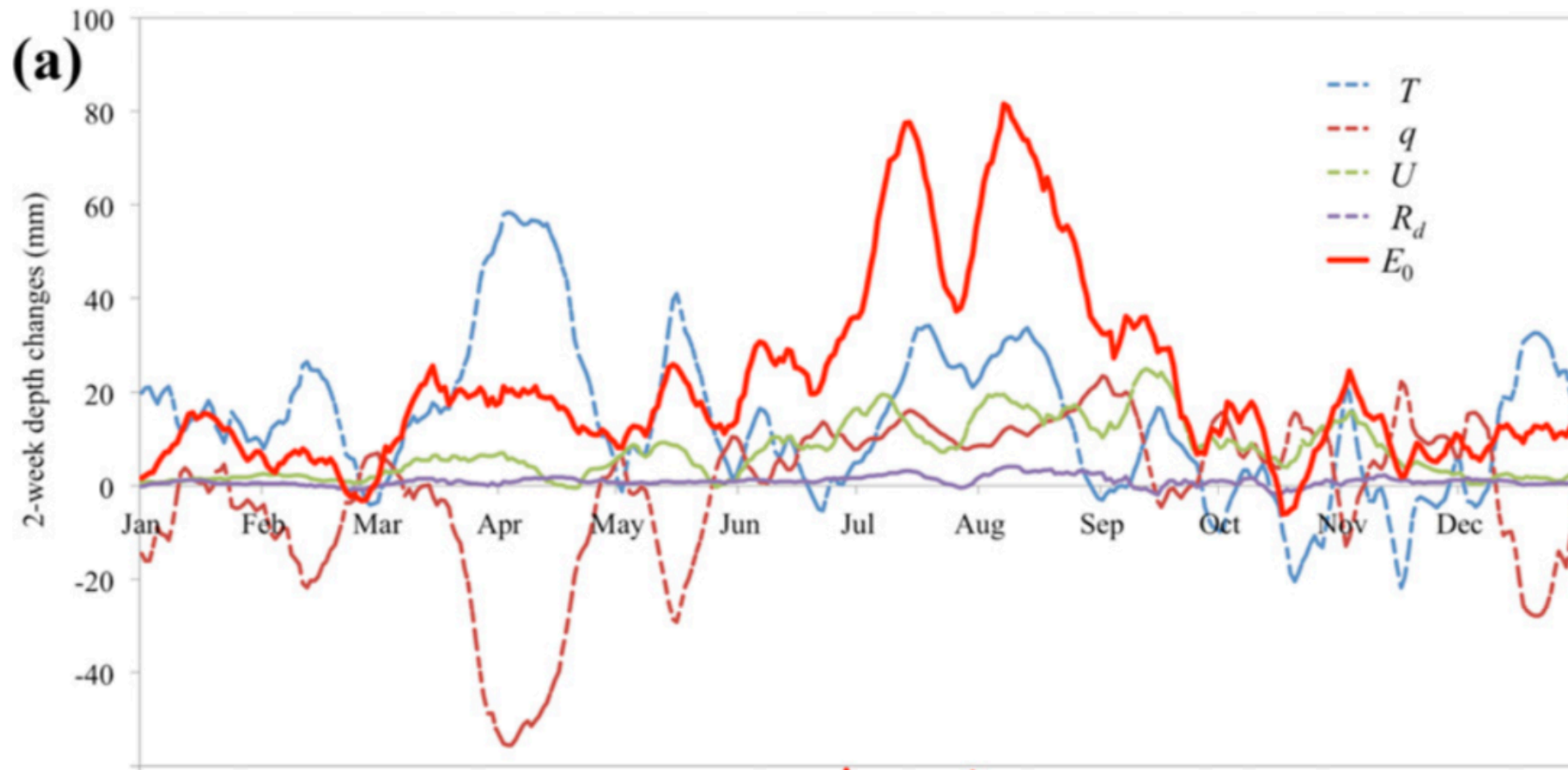
The Current basin

DECOMPOSING EVAPORATIVE DEMAND

Variation in E_0 as a function of the driving variable anomalies (the sensitivity of E_0 to them):

$$\Delta E_0 = \frac{\partial E_0}{\partial T_{air}} \Delta T_{air} + \frac{\partial E_0}{\partial q} \Delta q + \frac{\partial E_0}{\partial R_d} \Delta R_d + \frac{\partial E_0}{\partial U} \Delta U$$

RHS: contribution to E_0 by each driving variable.

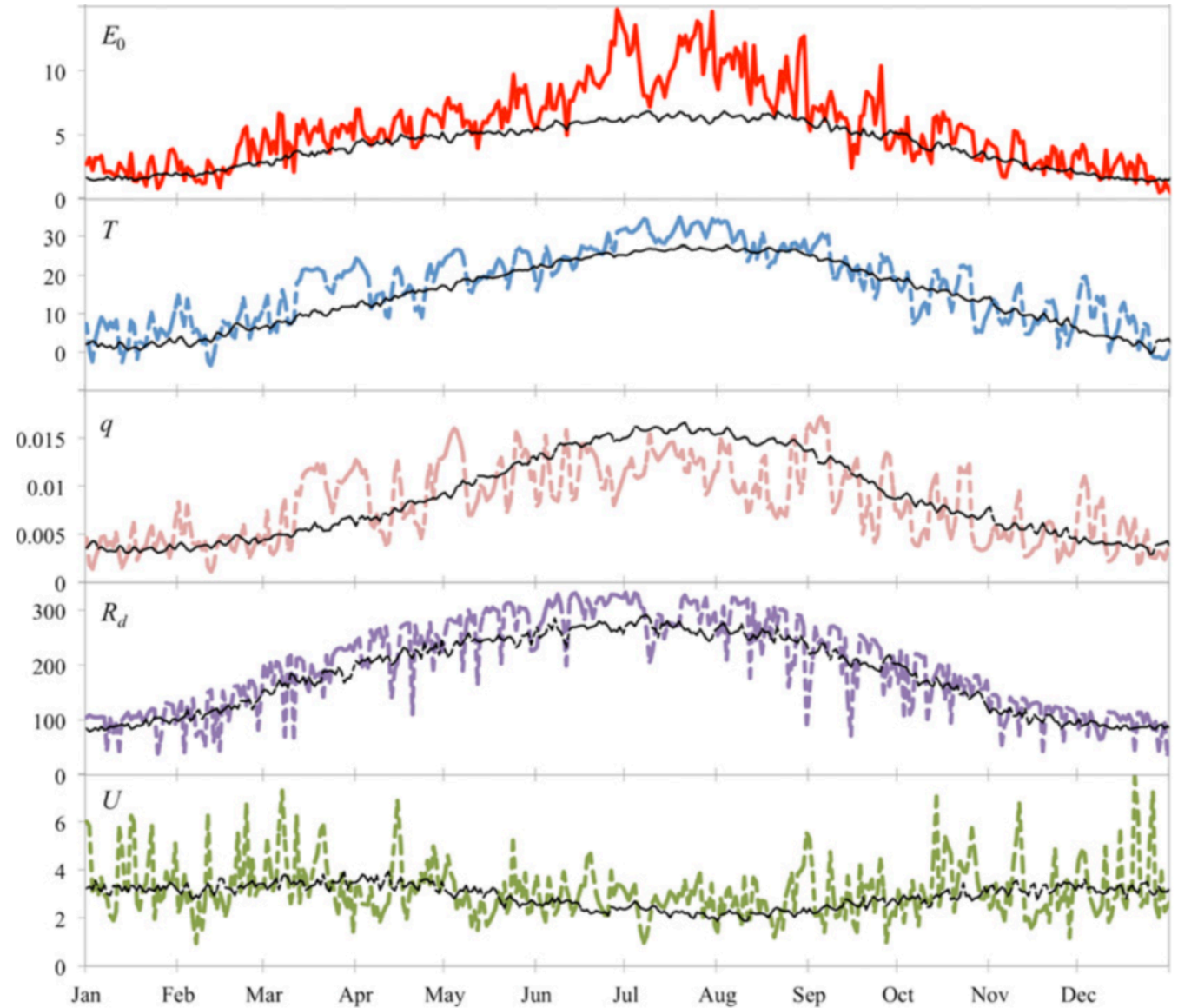


TIME SERIES OF E_0 & EACH DRIVERS' CONTRIBUTION

The Current basin 2012

DAILY TIME SERIES OF E_0 , T_{AIR} , Q , R_D , AND U

The Current basin 2012



VERIFY THE
RELATIONSHIP
BETWEEN
ET AND E_0

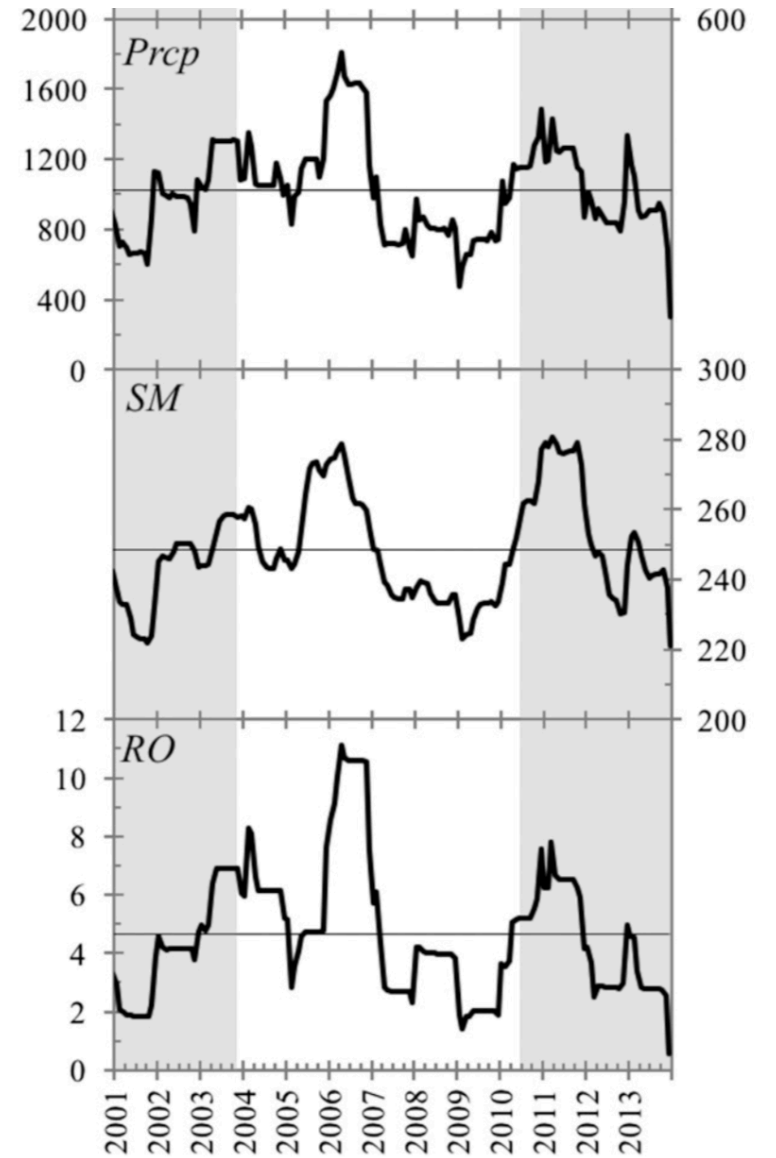
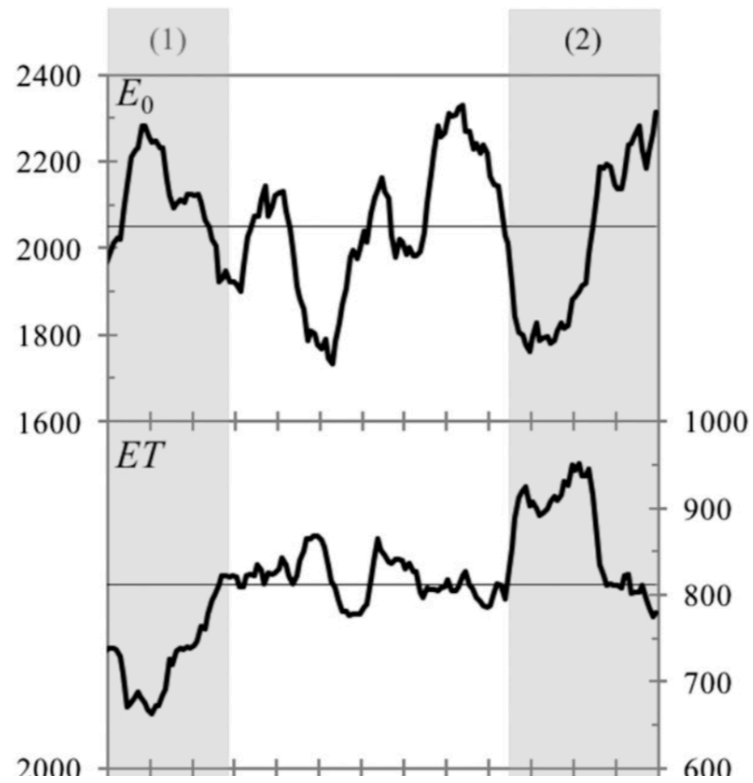
Russian basin 2010-2013

Long-term drought in California since 2011.
Suitable for investigation in linkages between water
balance components.

Water-limited: complementary ET- E_0
Energy-limited: parallel ET- E_0

WATER BALANCE COMPONENTS

The Russian basin



4. ASSESSMENT AMONG OTHER INDEXES



FULL NAMES

USDM: U.S. Drought Monitor

EDDI: Evaporative demand index

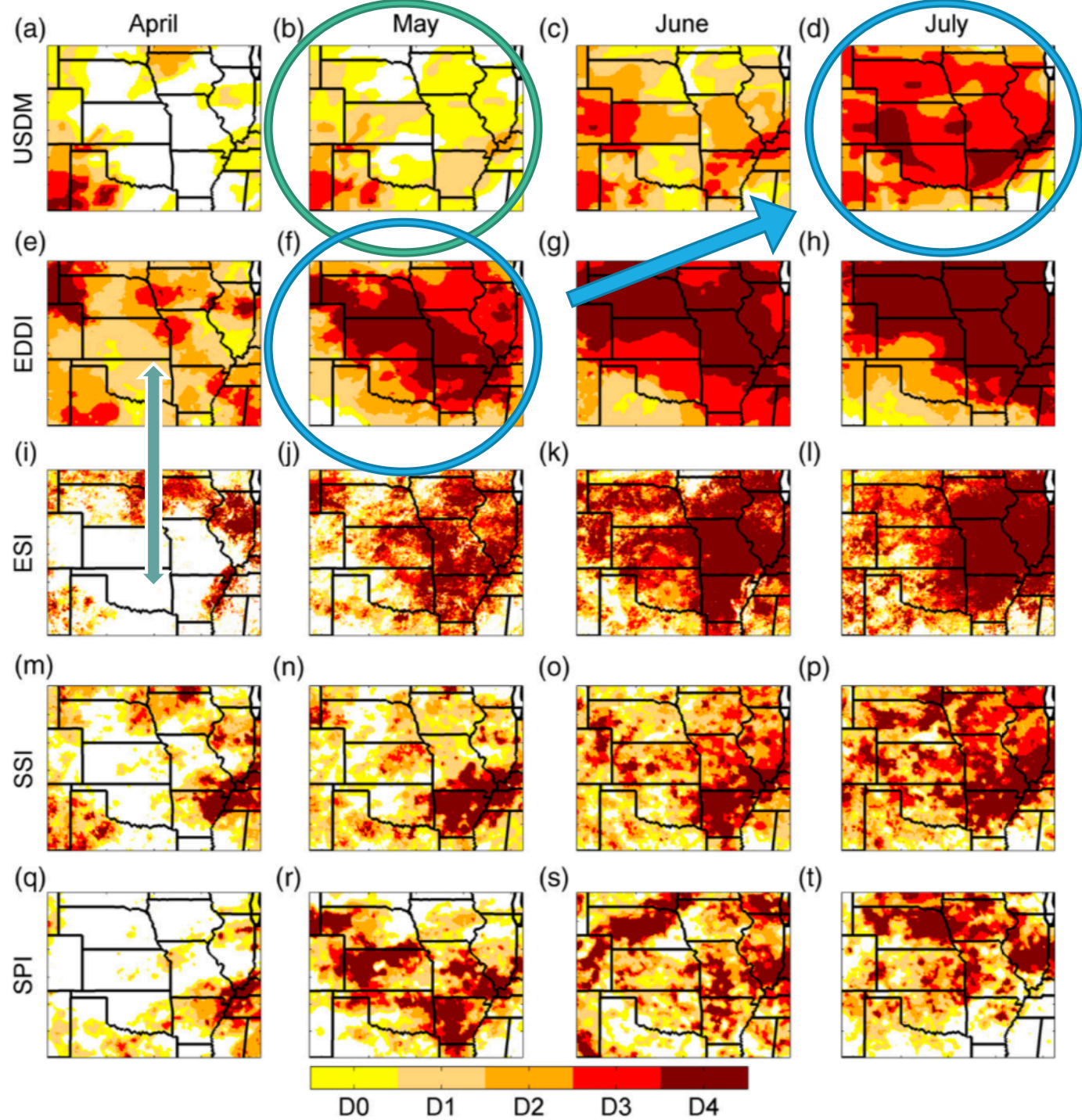
ESI: Evaporative Stress Index

SSI: Standardized Soil Moisture Index

SPI: Standardized Precipitation Index

1-MONTH SPRING TO SUMMER, 2012

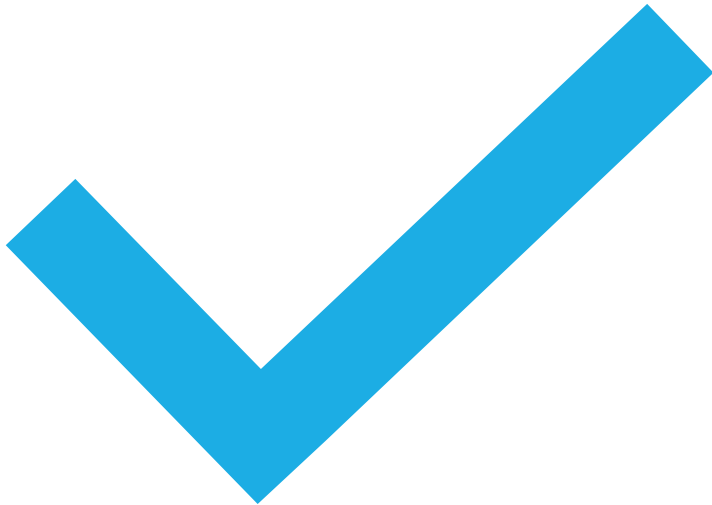
Central US



5. SUMMARY



CONCLUDING REMARKS



Flash Drought: droughts that develop much more rapidly than normal.

Impact factors:

1. Surface anomalies forcing.
2. Vulnerability of the plants.
3. Not always have to be a precipitation deficit.

EDDI: A drought index based on E_0 alone.

Key rationale:

E_0 reflects drying anomalies through feedbacks with ET.

Strengths of EDDI:

1. Early warning
2. Independent from Precp- and SM-
3. Based on reanalysis data
4. Utility in different drought dynamics

REFERENCES

- Otkin, Jason A., et al. "Flash droughts: a review and assessment of the challenges imposed by rapid-onset droughts in the United States." *Bulletin of the American Meteorological Society* 99.5 (2018): 911-919.
- Hobbins, Michael T., et al. "The evaporative demand drought index. Part I: Linking drought evolution to variations in evaporative demand." *Journal of Hydrometeorology* 17.6 (2016): 1745-1761.
- McEvoy, Daniel J., et al. "The evaporative demand drought index. Part II: CONUS-wide assessment against common drought indicators." *Journal of Hydrometeorology* 17.6 (2016): 1763-1779.
- Xia, Youlong, et al. "Automated quality control of in situ soil moisture from the North American Soil Moisture Database using NLDAS-2 products." *Journal of Applied Meteorology and Climatology* 54.6 (2015): 1267-1282.
- Wilks, D. S. "Empirical distributions and exploratory data analysis." *International Geophysics*. Vol. 100. Academic Press, 2011. 23-70.
- Vicente-Serrano, Sergio M., Santiago Beguería, and Juan I. López-Moreno. "A multiscalar drought index sensitive to global warming: the standardized precipitation evapotranspiration index." *Journal of climate* 23.7 (2010): 1696-1718.

A person is crouching in a field of young plants, possibly a farm, during the "blue hour" of twilight. The scene is dimly lit, with a dark sky and a horizon line. The person is in the lower center of the frame, looking down at the ground. The field is filled with rows of small green plants. In the background, there are rolling hills and a fence line. The overall mood is quiet and contemplative.

THANK YOU!

Questions?