

# Overcoming the Creeping Nature of Drought by Tracking Invisible Energy Fluxes

Daeha Kim  
Climate Analytics Department  
APEC Climate Center

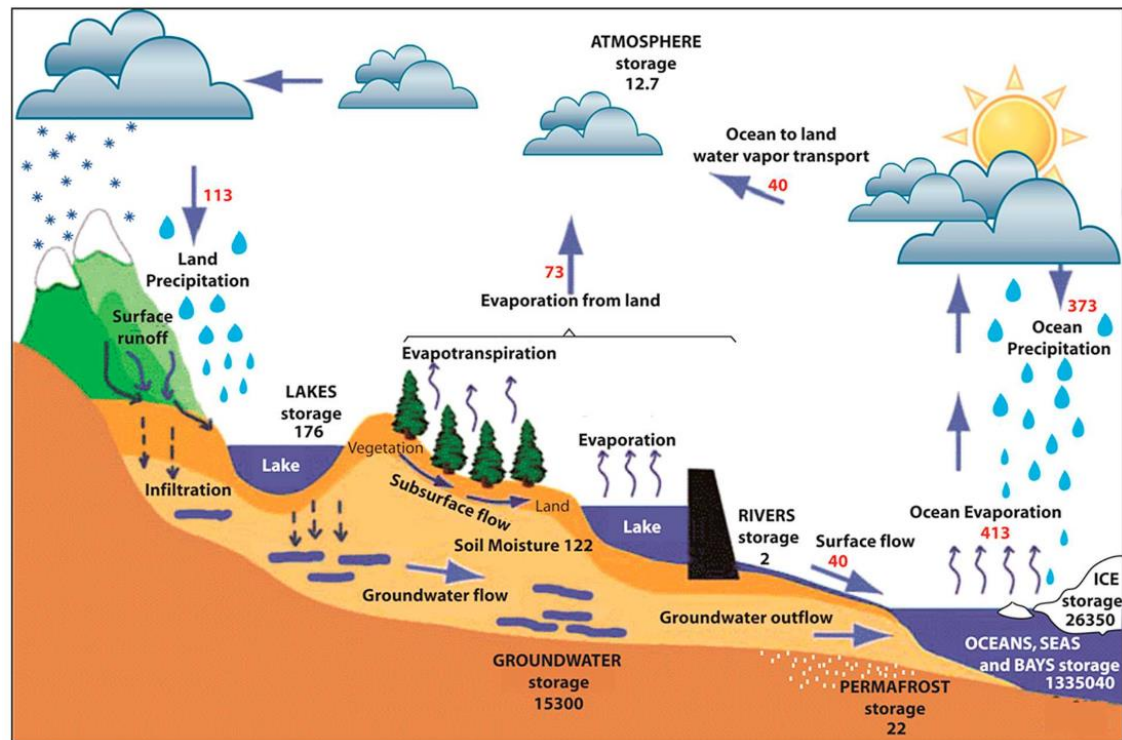


# 1 Background

# ABOUT THE DEFINITION OF DROUGHT

A typical drought definition is “precipitation deficiency”

*It is reasonable because it drives water shortages in general...*

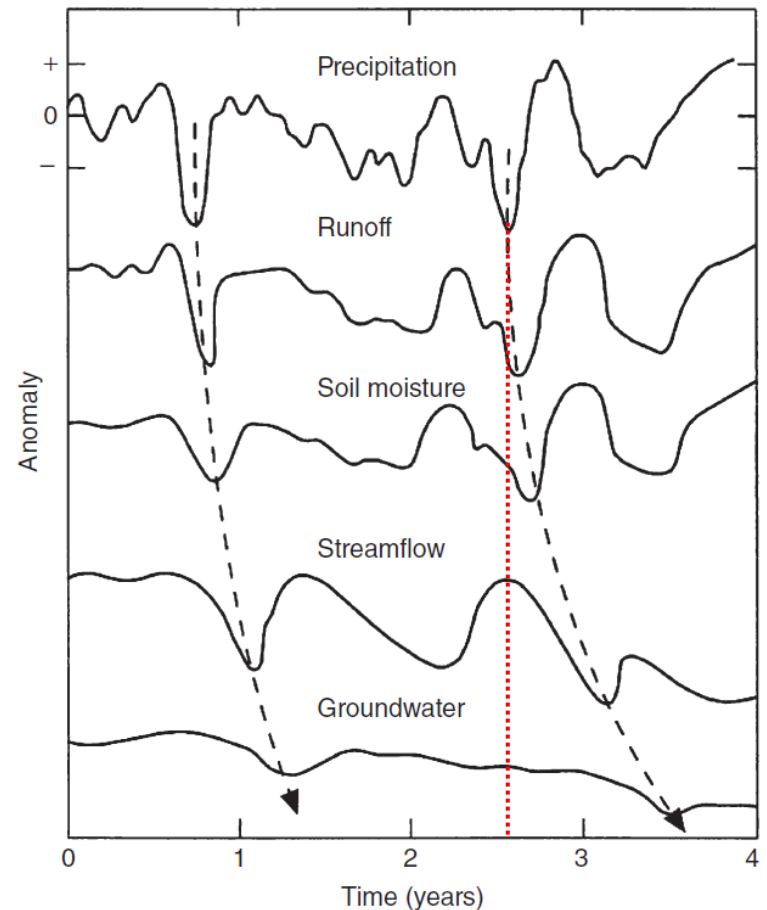


*Gimeno et al. (2012)*

# ABOUT THE DEFINITION OF DROUGHT

Water deficits could differ from rainfall anomalies:

- ✓ *Effects of prcp deficit could be delayed by land-surface processes*
- ✓ *Tracking-prcp-only strategy seems insufficient and impractical*



< Propagation of rainfall deficit (van Loon, 2015) >

# ABOUT THE DEFINITION OF DROUGHT

For practical consideration, a drought definition should be:

1. *process-specific*
2. *Indicating where & when*
3. *predicated upon climatology*

*A question is*

*"Is the conventional drought definition good for early warning?"*

Theor Appl Climatol (2014) 117:607–611  
DOI 10.1007/s00704-013-1025-7

ORIGINAL PAPER

## The impracticality of a universal drought definition

Benjamin Lloyd-Hughes

Received: 21 March 2013 / Accepted: 30 September 2013 / Published online: 19 October 2013  
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**Abstract** This paper demonstrates the impracticality of a comprehensive mathematical definition of the term 'drought' which formalises the general qualitative definition that drought is 'a deficit of water relative to normal conditions'. Starting from the local water balance, it is shown that a universal description of drought requires reference to

The Oxford English Dictionary (2011) defines drought as follows:

1. The condition or quality of being dry; dryness, aridity, lack of moisture.
2. Dryness of the weather or climate; lack of rain.

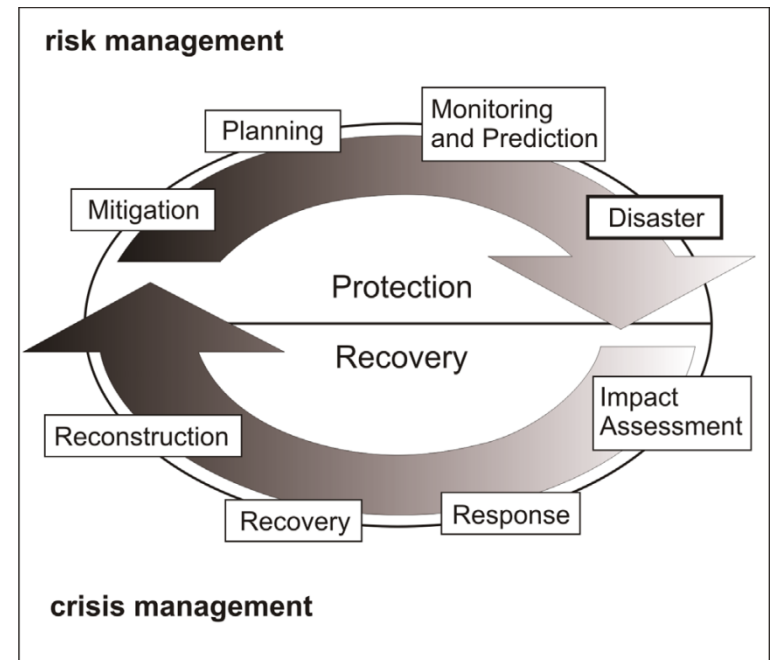
Lloyd-Hughes (2014)

# WHY DO WE NEED EARLY WARNING?

Simply because we may have no solutions at a perception of drought:

- ✓ *The perception implies no resource for resources managers...*

→ *"Proactive" risk management is essential!*

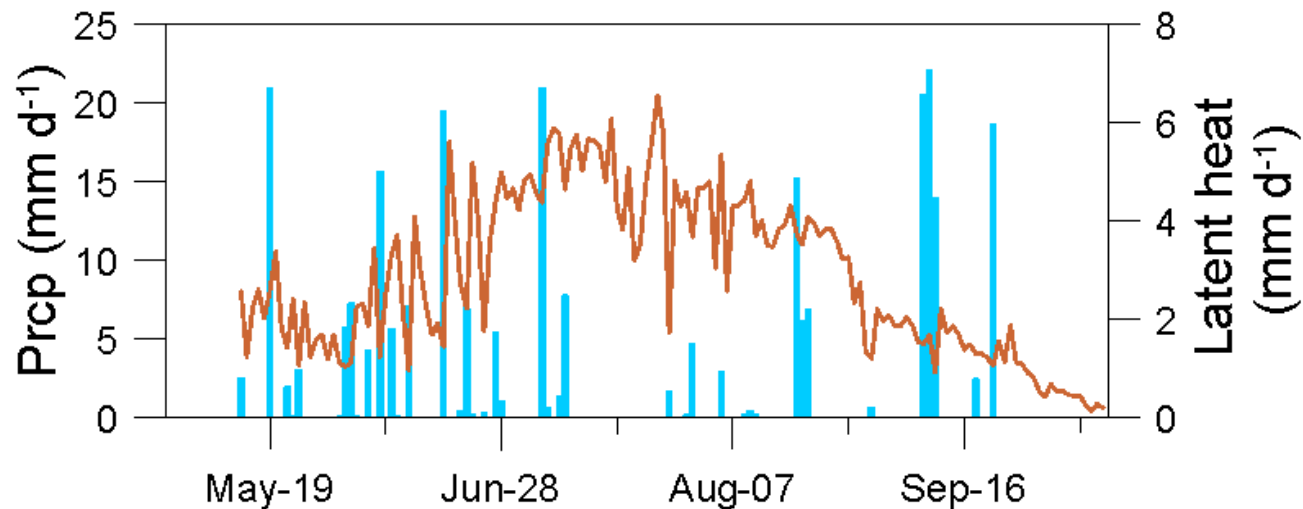


< Drought preparedness plans by National Drought Mitigation Center >

# DEMERITS OF TRACKING PRECIPITATION

Early warning of precipitation deficits could be difficult, because of

1. High intermittency  
(difficulty in identifying climatological means)
2. High uncertainty and low predictability



# 2 ET & Drought

# WHY ET FOR TRACKING DROUGHT?

It supplements demerits of precipitation

- ✓ *ET is a continuous process (less uncertain)*
- ✓ *ET is more "process-specific" for identifying vegetation and soil moisture status*
- ✓ *ET anomalies could be drought onsets (early warning)*

# EVAPOTRANSPIRATION AS A DROUGHT INDEX

ET has already been a drought indicator!

- ✓ *Evapotranspiration Stress Index*  
(Anderson et al., 2010)
- ✓ *Standardized ET Deficit Index*  
(Kim & Rhee, 2016; Vicente-Serrano et al., 2018)
- ✓ *Evaporative Demand Drought index*  
(Hobbins et al., 2016; McEvoy et al., 2016)



Potential ET  
(demand)

vs.

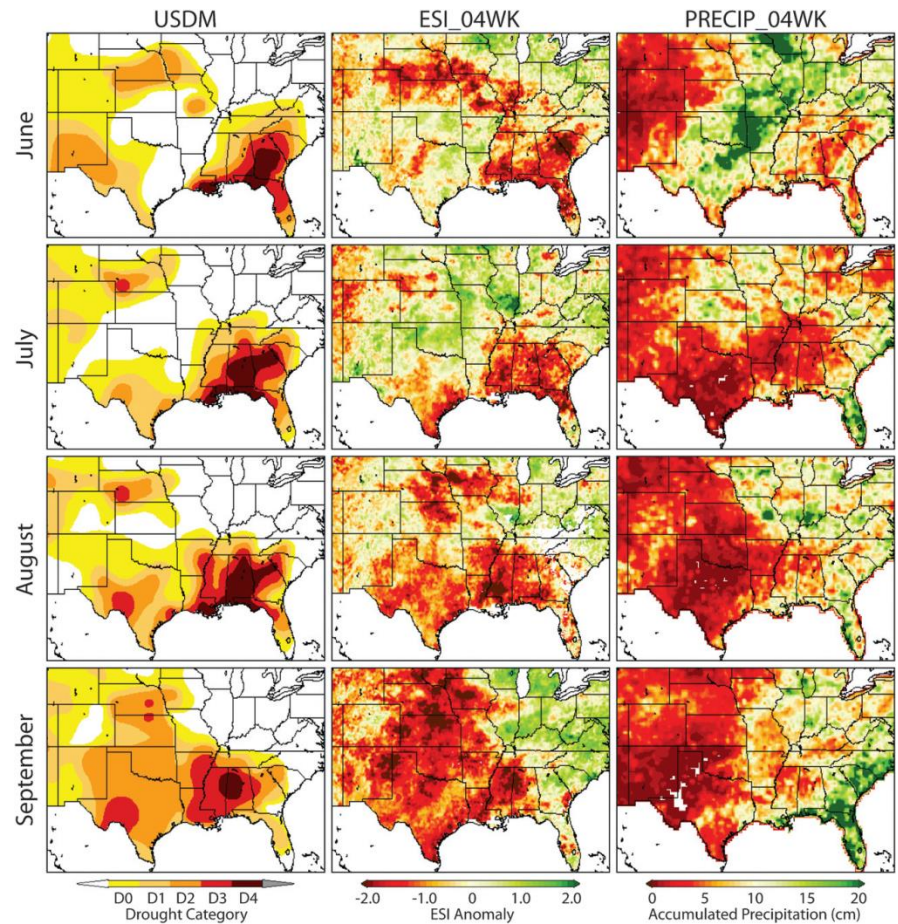


Actual ET  
(consumption)

# A REMOTE-SENSING-BASED INDEX

## Evaporative Stress Index (Anderson et al., 2011):

- ✓ *tracks AET/PET*
- ✓ *indicates vegetation status*
- ✓ *captures rapid onset drought development*

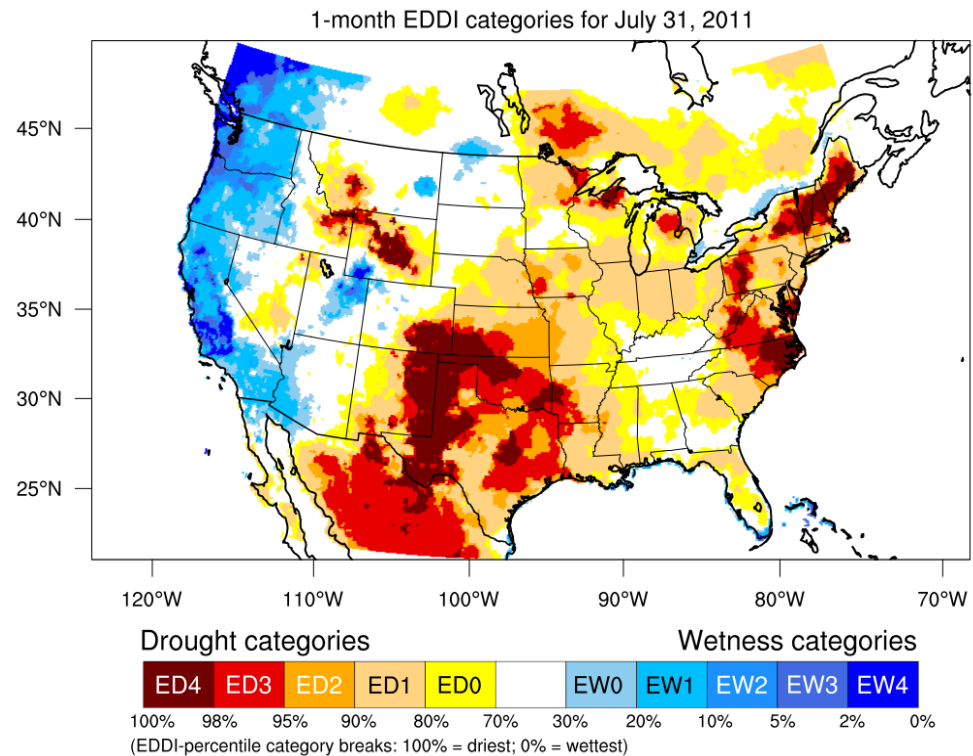


< Otkin et al., 2013 >

# METEOROLOGICAL-DATA-BASED INDICES

## Evaporative Demand Drought Index (Hobbins et al., 2016):

- ✓ *tracks PET*
- ✓ *indicates surface dryness*
- ✓ *can capture onset of flash droughts*

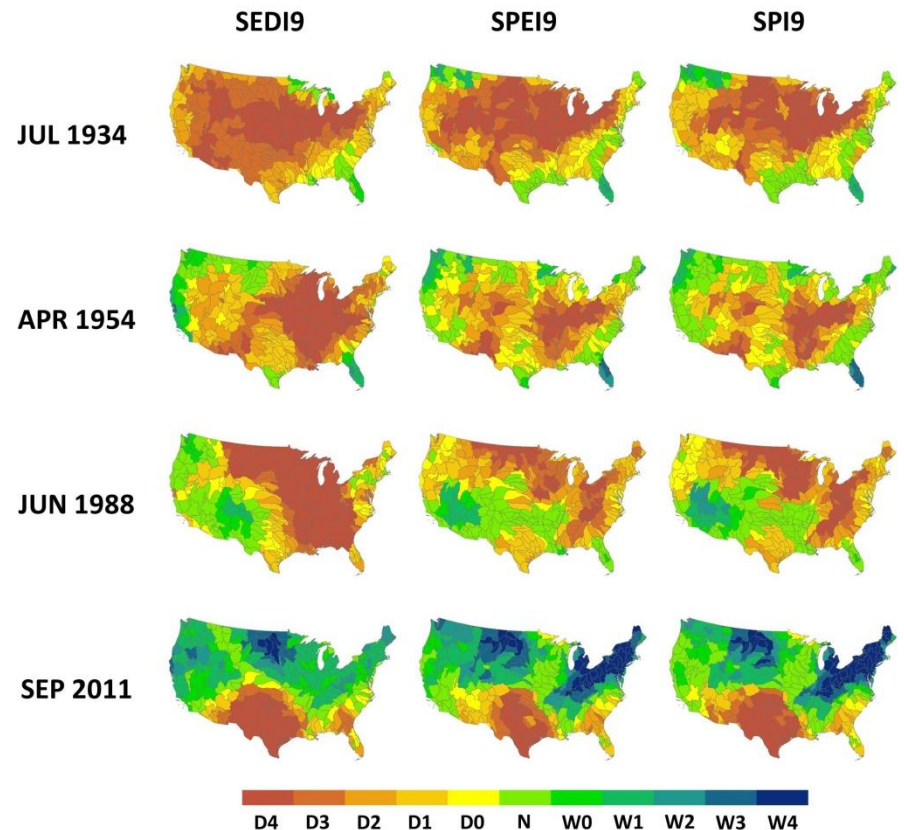


<https://www.esrl.noaa.gov/psd/eddi>

# METEOROLOGICAL-DATA-BASED INDICES

## Standardized ET Deficit Index (Kim and Rhee, 2016):

- ✓ *tracks AET – PET*
- ✓ *Indicates water deficit & vegetation status*
- ✓ *captures heat-wave-driven droughts*

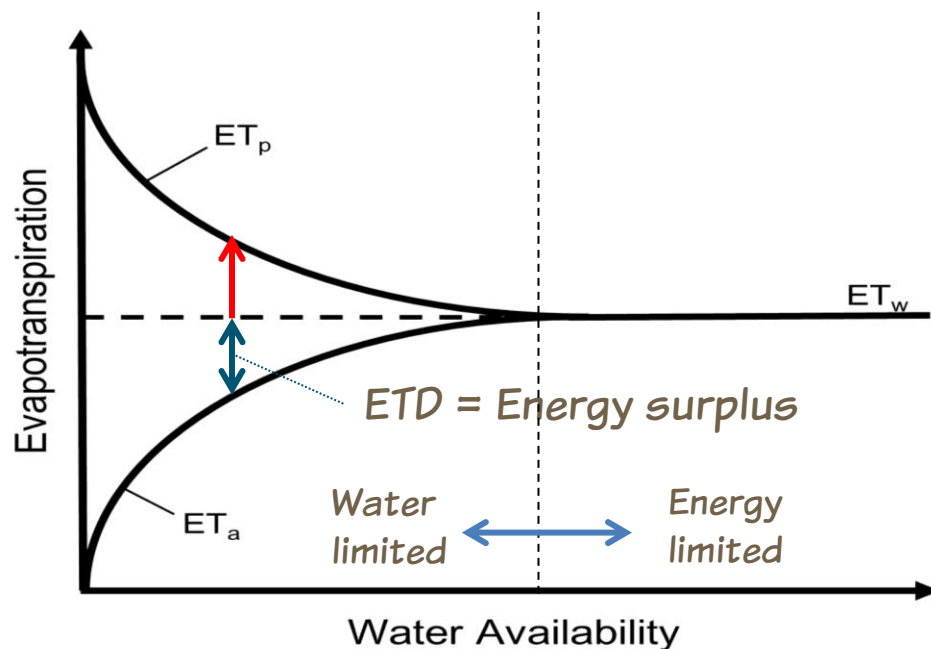


< Kim et al., 2019 >

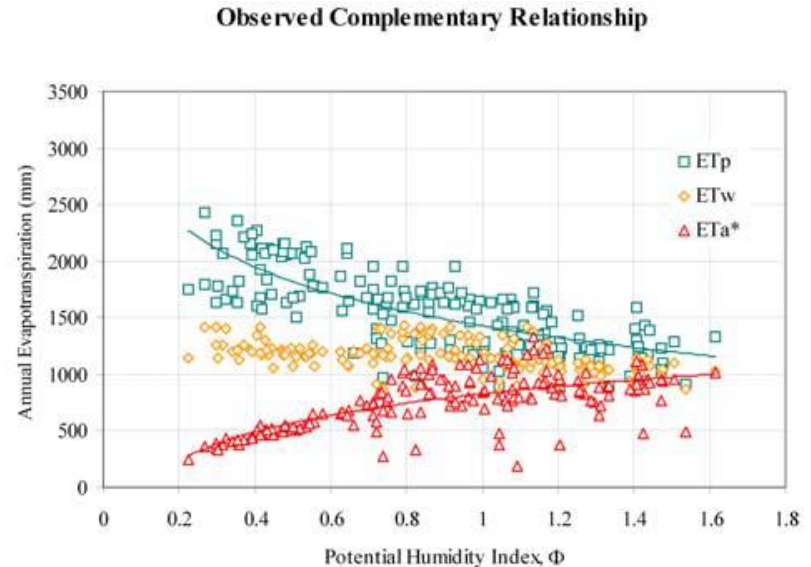
# COMPLEMENTARITY btw. PET & AET

Both could be tracked with meteorological observations:

- ✓ *Dryness of a land surface could raise the evaporative demand of the lower atmosphere!*
- ✓ *Raised PET could be a predictor of AET!*



< Surface moisture – ET relation >

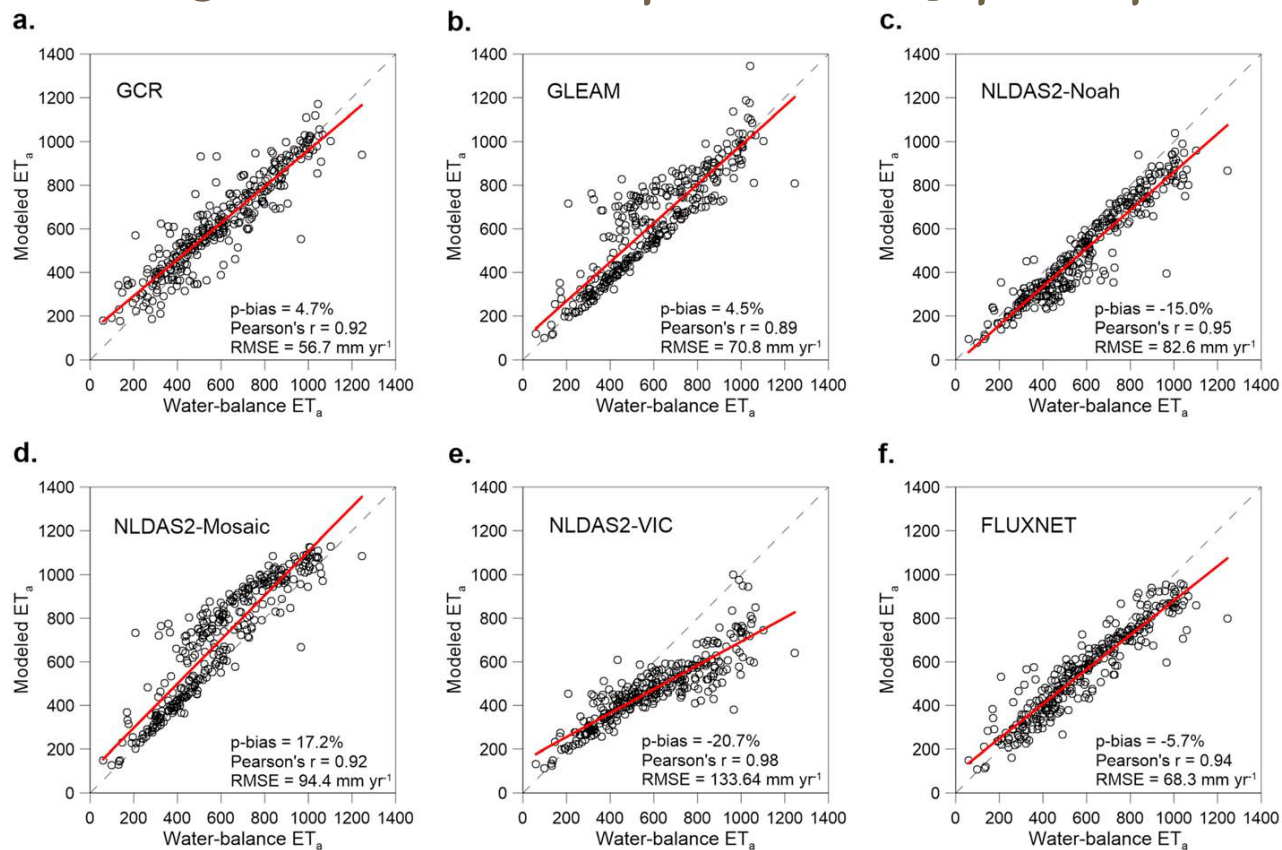


< Ramirez et al., 2005 >

# COMPLEMENTARITY btw. PET & AET

AET could be better quantified than LSMs and RS models!

✓ With the generalized complementary principle

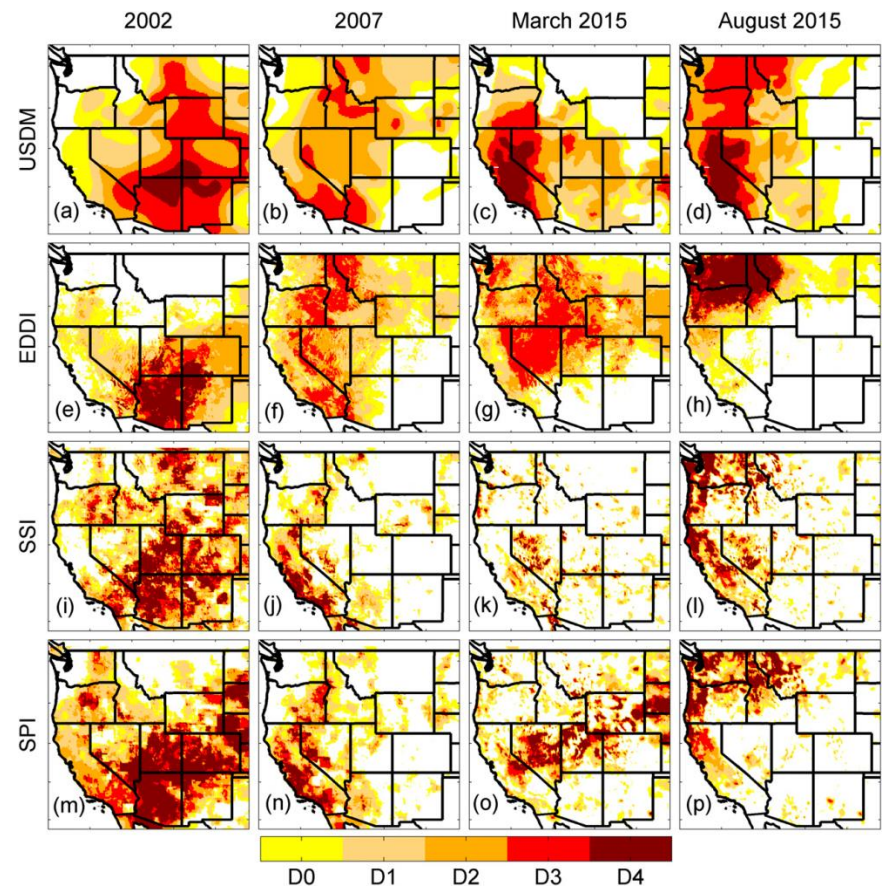


< Performance of GCR; Kim et al., 2019 >

# COMPLEMENTARITY btw. PET & AET

Drought could be tracked with PET only!

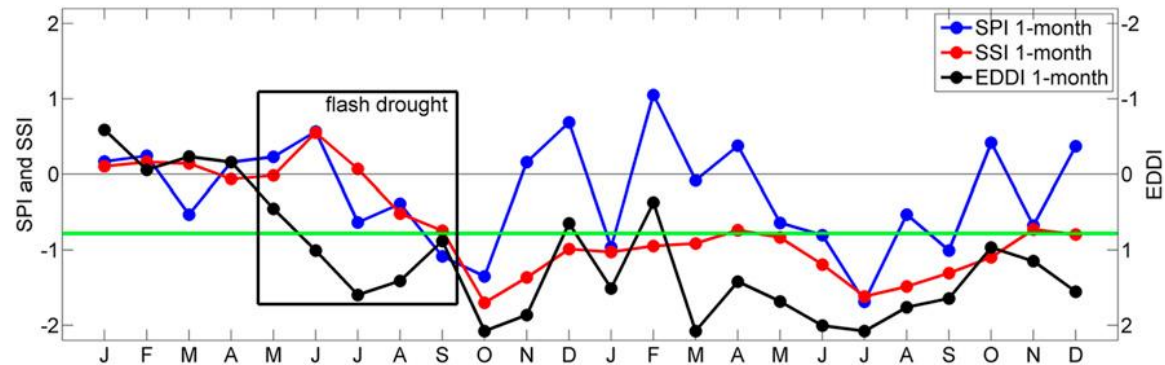
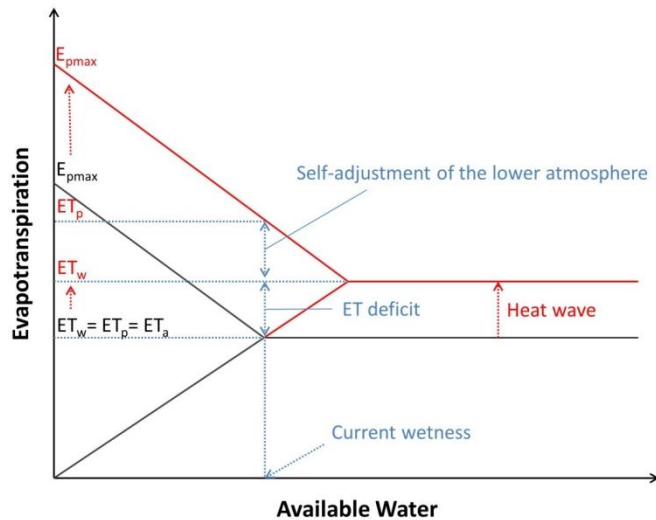
- ✓ *PET could indicate surface dryness with no AET estimates*
- ✓ *It could supplement tracking precipitation!*



# COMPLEMENTARITY btw. PET & AET

Flash Drought could be captured by ET-based indicators!

- ✓ Heat-wave-driven droughts could be onsets of lasting water-deficit-driven droughts

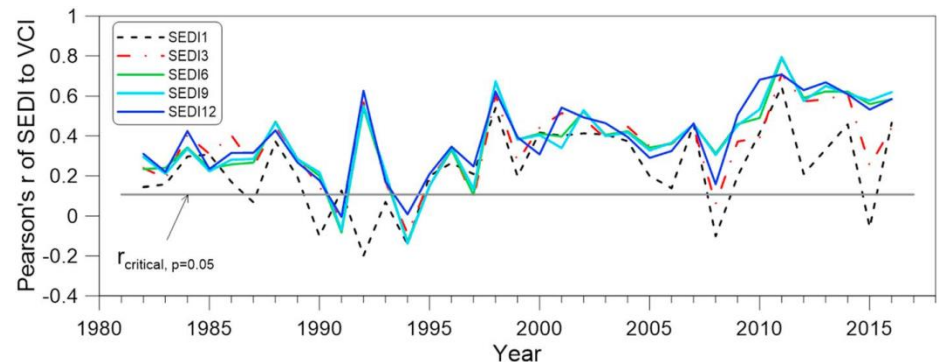
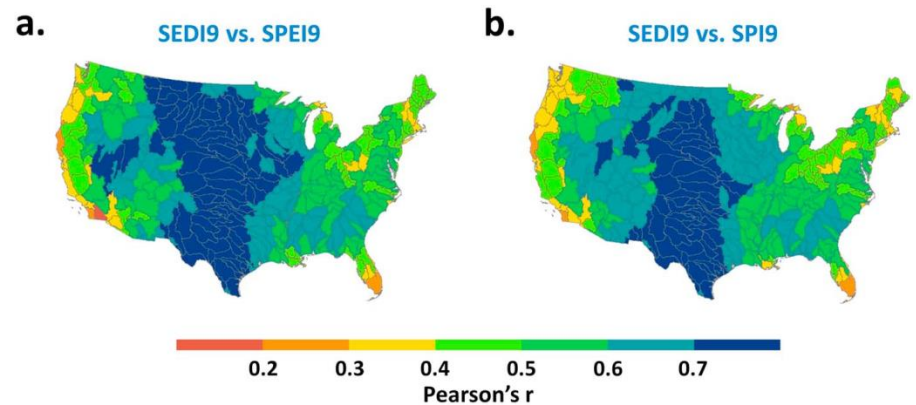


< McEvoy et al., 2016 >

# COMPLEMENTARITY btw. PET & AET

How about precipitation deficiency and vegetation?

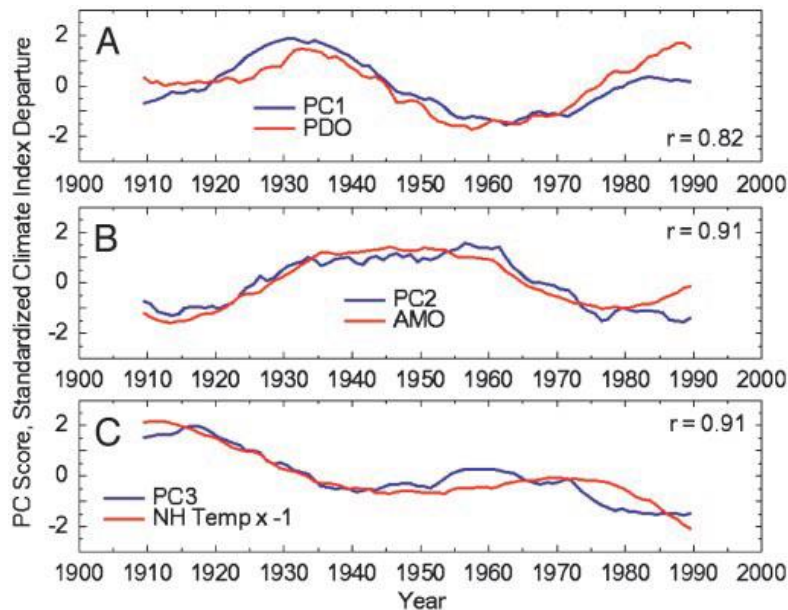
- ✓ *ET can reappear as precipitation!*
- ✓ *ET deficits captures vegetation status*



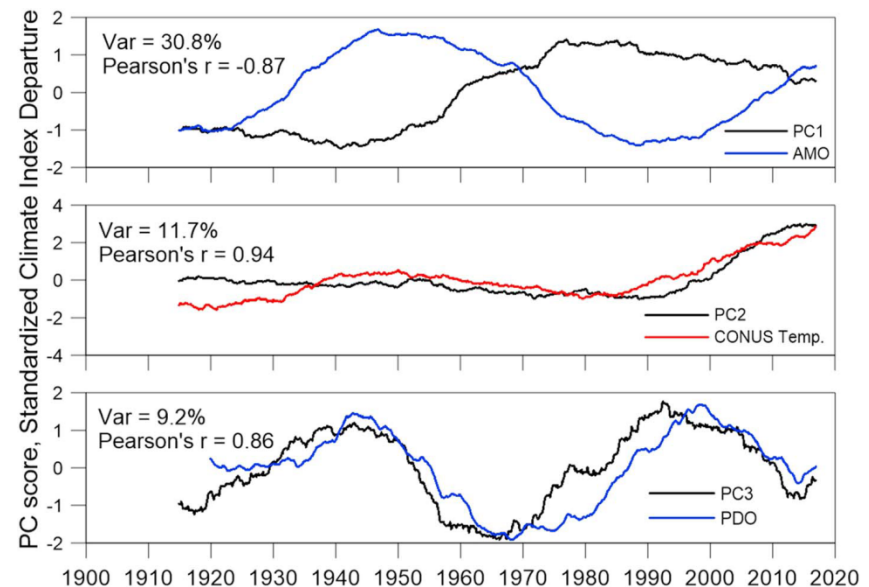
# COMPLEMENTARITY btw. PET & AET

Remote modulators of prcp and ET deficits are similar!

- ✓ AMO, PDO, and Mean temp. are major controls of ET and prcp. deficits over CONUS



< McCabe et al., 2004 >



< Kim et al., 2019 >

# 3 OPERATIONAL USES

# MERITS OF ET-BASED DROUGHT MONITORING

ET-based drought identification only requires:

- ✓ *"Solar rad.", "Mean Temp.", "Humidity", and "wind speed"*

Benefits are:

- ✓ *to identify surface dryness*
- ✓ *to detect heat-wave-driven drought onsets*
- ✓ *to find vegetation stress*
- ✓ *to link to teleconnected modulators*

**However, they are often unemployed in operational systems...**

# LIMITED OPERATIONAL USE!

## US Drought Monitor includes:



### Current Conditions

Conditions & Outlooks > Current Conditions

Vegetation (RS)

PDSI

SPI

Streamflow

Soil moisture

VHI

Select products to display:

- Experimental Objective Blends of Drought Indicators
- Vegetation Drought Response Index (VegDRI)
- National Weather Service's Precipitation Analysis
- U.S. Drought Impact Reporter
- Weekly Weather and Crop Bulletin
- Palmer Drought Severity Index
- Crop Moisture Index
- Standardized Precipitation Index
- Percent of Normal Rainfall
- Current Streamflow
- Mountain Snowpack
- Soil Moisture
- U.S. and Global Soil Moisture Monitoring
- STAR - Global Vegetation Health Products
- Fire Danger maps
- Other Current Conditions Information

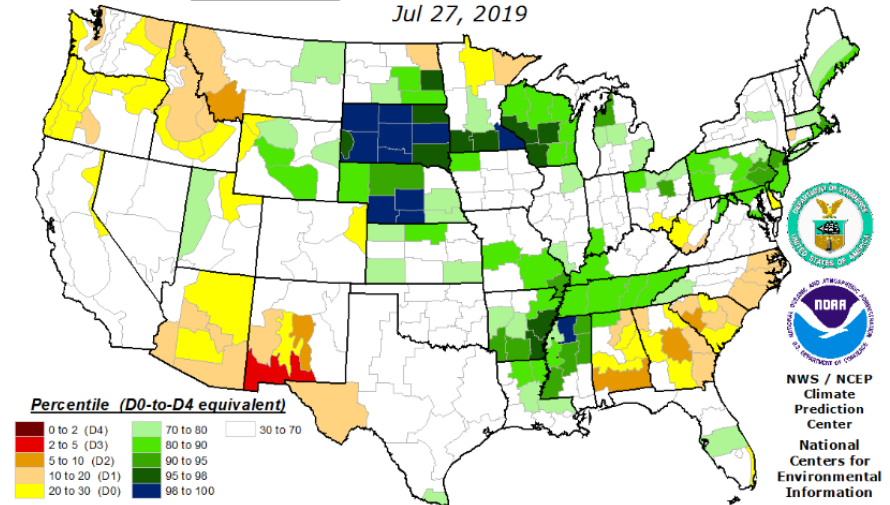
### Experimental Objective Blends of Drought Indicators

#### Short-Term Percentiles

The Objective Short-Term Drought Indicator Blend Percentiles map approximates drought-related impacts that respond to precipitation (and secondarily other factors) on time scales ranging from a few days to a few months, such as wildfire danger, non-irrigated agriculture, topsoil moisture, range and pasture conditions, and unregulated streamflows.

#### Objective Short-Term Drought Indicator Blend Percentiles

Jul 27, 2019



< <https://droughtmonitor.unl.edu>; accessed on Aug-12/2019 >

# LIMITED OPERATIONAL USE!

## European Drought Observatory:

EDO - European Drought Observatory

Emergency Management Service

EC > Copernicus > Emergencies > Droughts > EDO > Mapping Drought > Interactive Mapviewer

EDO HOME | CURRENT DROUGHTS | MAPPING DROUGHT | DROUGHT EVOLUTION | REFERENCE DATA

WARNING ! From the 11th of March 2019, soil moisture and low-flow index data have been upgraded to a new version with a larger spatial extent, based on the latest LISFLOOD model. Please note that these new data are still under evaluation and are not fully validated.

Monitoring | Forecast | Timeseries

European Drought Products

Combined Drought Indicator

- Watch: rainfall deficit
- Warning: soil moisture deficit
- Alert: vegetation stress following rainfall / soil moisture deficit
- Partial recovery of vegetation
- Full recovery of vegetation to normal conditions

Precipitation

Low Flow

Temperature

Soil Moisture

Vegetation Response

Disaster Monitoring

Regional, National, Local Products

Base Layers

Geographic Background

Tip: right click or double click on layer name to access layer menu

Map

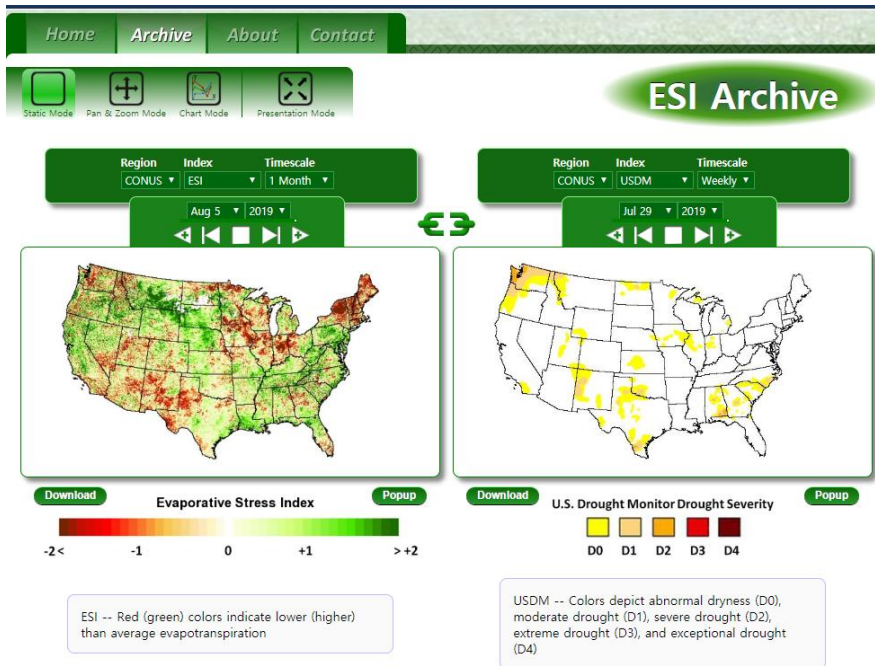
France, Spain, Italy, Germany, Poland, Czech R., Austria, Hungary, Romania, Bulgaria, Turkey, Ukraine, Denmark, Sweden, Finland, Estonia, Latvia, Lithuania, Belgium, Netherlands, Ireland, Iceland, Russia

< <https://edo.jrc.ec.europa.eu>; accessed on Aug-12/2019 >

# SOME EXAMPLES

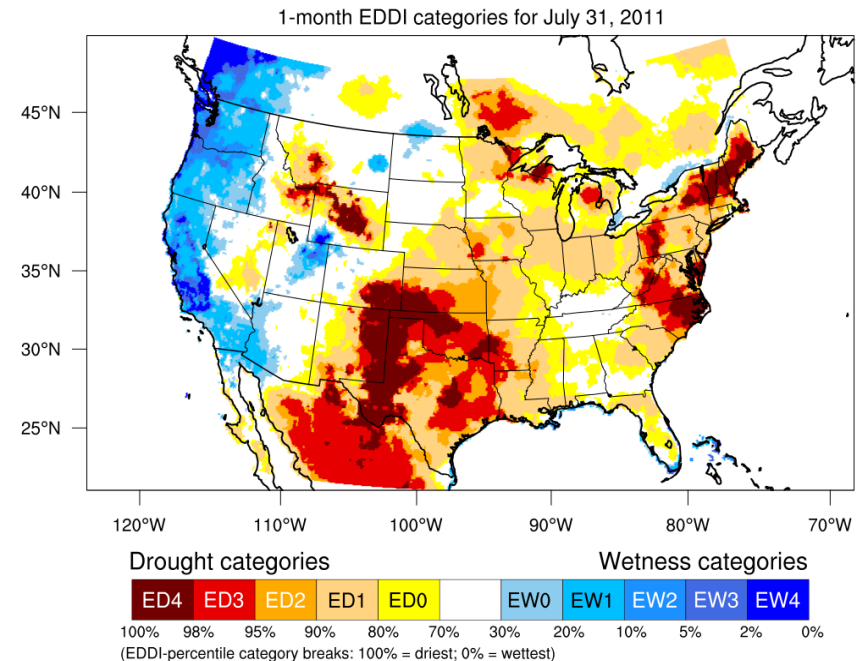
ET-based indices are separated from major drought monitoring systems!

## USDA ESI ARCHIVE



< <https://hrsl.ba.ars.suda.gov> >

## NOAA EDDI ARCHIVE



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

# 4 SUGGESTIONS FOR FUTURE

# CAN THE GENERAL DEFINITION BE PRACTICAL?

Seems negative, because

- (a) precipitation deficits become divergent*
- (b) precipitation deficits could be remote from "specific" processes*
- (c) precipitation deficits may not indicate exact "locations" and "timing" of water deficits*

*→ Nevertheless, operational drought monitoring over-relies on precipitation anomalies*

# LESSONS FROM CLIMATE CHANGE STUDIES

Climate change risks are scientifically estimated, but with

(a) HIGH UNCERTAINTY  
& AMBIGUITY

(b) UNCLEAR LOCATIONS  
& TIMING

**Policymakers are of  
"Risk-averse" behaviors!**

**→ LIMITED ACTIONS  
FOR MITIGATION &  
ADAPTATION**



Ambiguity: A new way of thinking about responses to climate change



Fleming A.<sup>a,b,\*</sup>, Howden S.M.<sup>c</sup>

<sup>a</sup> Land and Water, CSIRO, Battery Point, Hobart, Tasmania, Australia, 7000

<sup>b</sup> Centre for Marine Socio-ecology, Battery Point, Tasmania, Australia, 7000

<sup>c</sup> ANU Climate Change Institute, Canberra, Australia, 2601

## HIGHLIGHTS

- Embracing ambiguity offers rich potential for interdisciplinary science.
- Interdisciplinary sciences should focus on developing ambiguity methods.
- Ambiguity can help climate adaptation researchers and practitioners by promoting interdisciplinary responses.
- Further research is needed to understand how to operationalise ambiguity.

## ARTICLE INFO

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## ABSTRACT

Diversity, interdisciplinarity and transdisciplinarity are now recognized as vital to tackling wicked problems such as those presented by a changing climate (Nature editorial 2015, Ledford 2015; Dick et al., 2016). Including diverse disciplines in science projects enables a range of different views which often facilitate the creation of innovative solutions. Supporting multiple views and options requires a different way of working beyond traditional reductionist approaches to science, communication and decision-making. To embrace diversity in scientific project teams in order to tackle complex, integrated and urgent issues but to expect singular and linear pathways forward is paradoxical. Much has been written about the need for the scientific community to embrace uncer-

# WHAT IF THE GENERAL DEFINITION REMAINS?

Precipitation-deficits-only indications,

*(a) cloud the concept of water deficits*

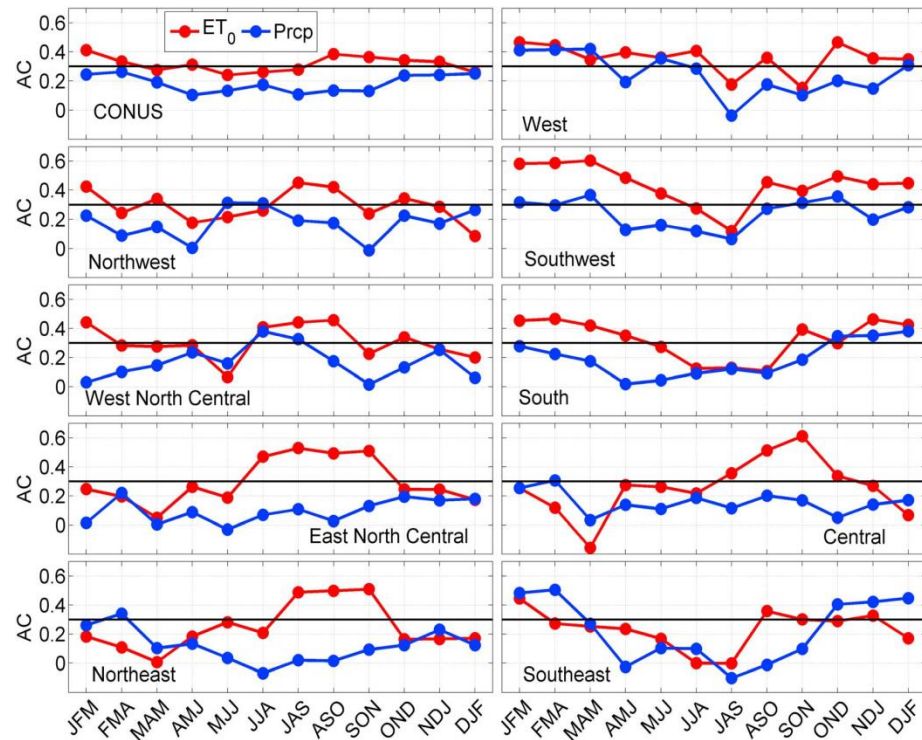
*(b) cause unclear identification of location and timing of water deficits*

*→ Isn't it likely to cause no actions for drought risks?  
Why not use estimates of specific processes for drought identification?*

# PREDICTABILITY OF ET MAY BE HIGHER

For better monitoring and predictability, ET is necessary...

- ✓ Rainfall generation requires
  - a. cooling of air
  - b. condensation on nuclei
  - c. growth of droplets
  - d. importation of water vapor
- ✓ ET occurs continuously on land surfaces



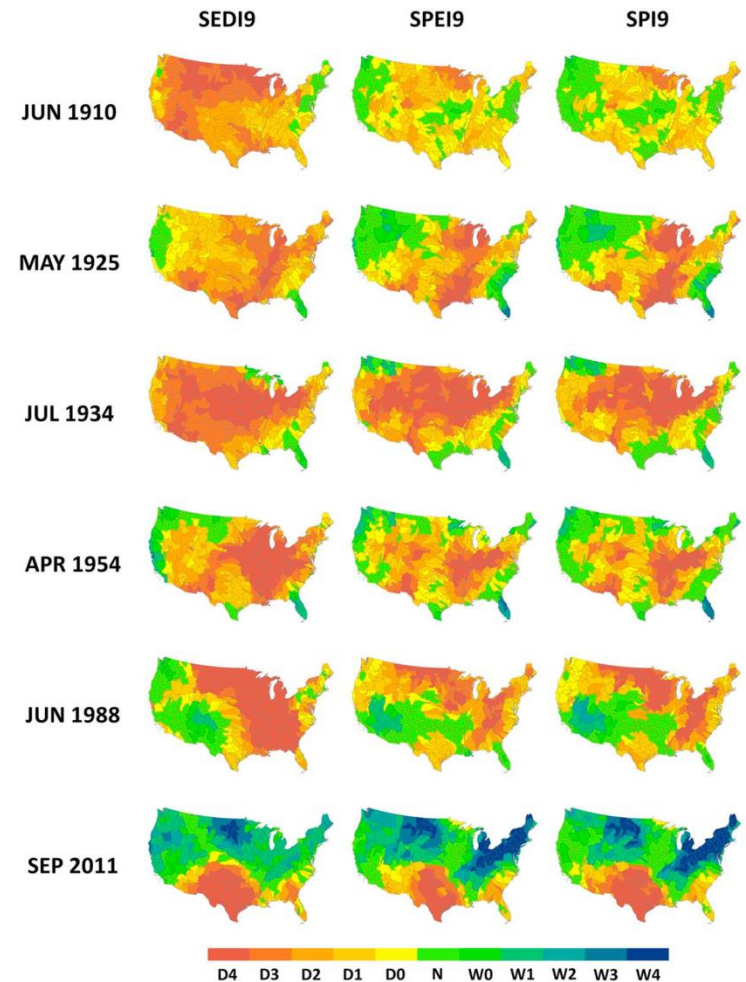
< Predictive skills of ET<sub>0</sub> and prcp (CFSv2); McEvoy et al., 2016 >

# FOR PROACTIVE DROUGHT RISK MANAGEMENT

ET is an invisible energy flux, but  
(a) more process-specific  
(b) less uncertain  
(c) more predictable

Drought communities emphasize  
proactive management...

Then, why not incorporating ET  
into operational systems?



< Kim et al., 2019 >

