Evapotranspiration (ET) Index Revision

July 14, 2022

Water Resources Commission Meeting

Executive Office of Energy and Environmental Affairs

dcr Massachusetts

DMP Indices

- Precipitation
- ET

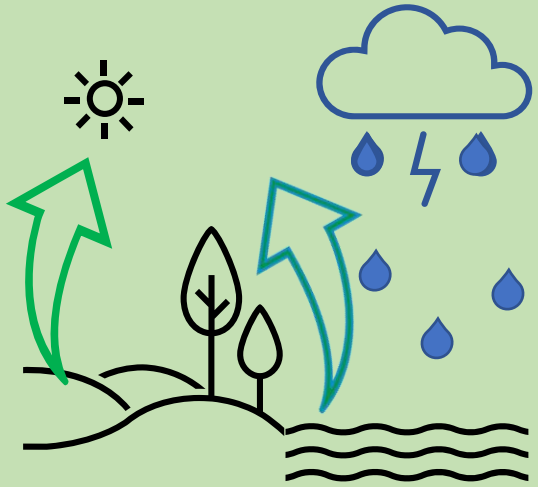
Causes → *One or both Index Severity Levels elevate first*

- Streamflow
- Groundwater
- Lakes & impoundments
- Fire – soil moisture in top 8”

Impacts → *Index Severity Levels elevate after Precipitation &/or ET*

Goals for Revision

- **Timely identification of drought onset/intensification**
  - Currently, no signal from Crop Moisture Index (CMI) - can cause delays in drought onset/intensification identification



- Show the **effect of temperature/ET on "available" precipitation**
  - Help identify "flash droughts" by knowing when impacts will occur more quickly than when just low precip
  - With climate change, importance of identifying **heat/ET in addition to precip-induced dryness**

Process

- Analyses conducted by Cornell University

- Evaluation of results by technical group similar to 2019 DMP revision
  - State and federal staff comprised of USGS, NOAA NWS, NOAA NERFC, MassDEP, DFG, DCR, EEA
  - Reviewed analyses and made recommendation
- Presented to and approved by the DMTF on June 15, 2022
- Draft redline of the Drought Management Plan to be shared with the DMTF and public for comment
- Draft Final DMP to WRC for review and approval

Options Evaluated

- **Gravity Recovery and Climate Experiment (GRACE), National Water Model (NWM), Climate Prediction Center Soil Moisture (CPCSM)** – Soil moisture → net effect of precip, ET and infiltration

- **Evaporative Stress Index** (ESI)– ET as calculated by energy balance using remotely sensed temperature

- **Standardized Precipitation and Evapotranspiration Index (SPEI)** – Precip minus theoretical maximum ET

- **Evaporative Demand Drought Index (EDDI)** – Theoretical maximum ET (based on temperature, radiation, wind, etc.), aka ‘thirst of the atmosphere’

Evaluation Criteria

Logistics

- Spatial resolution - unique value per drought region
- Historical availability of data for evaluating against past droughts
- Long reference period/period of record for calculating percentiles
- Appropriate look-back periods or depths for drought monitoring
- Update frequency (at least 1/week)
- Timely availability

Performance

- Timely drought onset/intensification identification, especially when precipitation amounts are still near normal
- Effect of temperature/ET on drought – amount of precipitation expected to remain available

How to Evaluate Performance

- Frequency – Matching the Index Severity Level percentiles specified in the DMP

- Timing – Earlier elevated signal relative to other indices and historical droughts when there are high temperatures
  - Early similar to precipitation index so it signals onset and/or intensification

Index Severity Level	Percentile Range
0	>30%
1	>20 and ≤30%
2	>10 and ≤20%
3	>2 and ≤10%
4	≤2%

Matching Index Severity Level Percentiles

Index Severity Level	**0**	**1**	**2**	**3**	**4**
DMP Percent of Months	**70**	**10**	**10**	**8**	**2**
+/-10%	**63-77**	**9-11**	**9-11**	**7.2-8.8**	**1.8-2.2**
CMI	96	3	1	0	0
ESI-04wk	71	11	7	6.1	4.8
GRACE-rtzsm-100cm	67	11	12	10.3	0.4
NWM-SM-40cm	74	13	8	5.5	0
SPEI-02mn	73	10	8	7.9	1.5
EDDI-02mn	67	11	12	7.2	3.2

Most indices perform well:

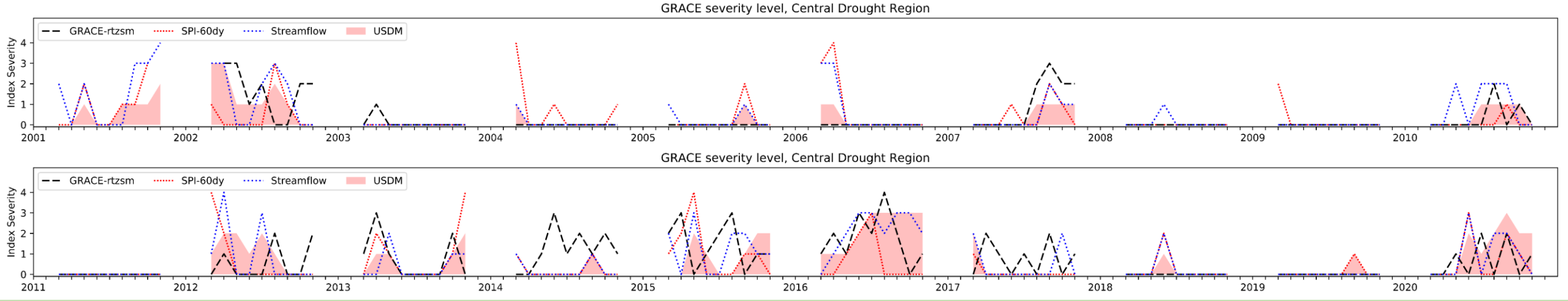
- relative to CMI
- for Level 0 and Level 1 droughts (i.e., onset)

Crop Moisture Index (CMI), Central Region

- Rarely provides a signal
- Can delay drought calls
  - 1 of 3 onset signals like precipitation & streamflow
- More important with newer, faster developing flash droughts
- Why doesn't it work? Developed and calibrated for central US; not as appropriate for the NE US

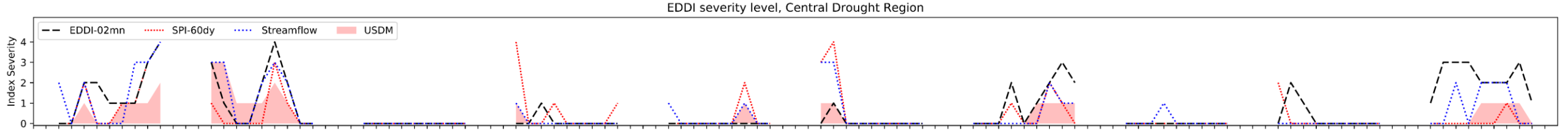
Used USDM drought levels in analyses because more consistent methods across time than MA DMP but the 5 USDM drought levels were converted to the corresponding 4 MA drought levels

GRACE


GRACE severity level, Central Drought Region
GRACE-rtzsm
SPI-60dy
Streamflow
USDM
Index Severity
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010

GRACE severity level, Central Drought Region
GRACE-rtzsm
SPI-60dy
Streamflow
USDM
Index Severity
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

EDDI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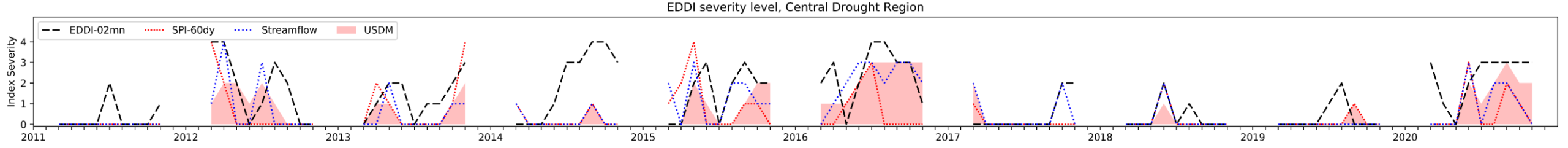
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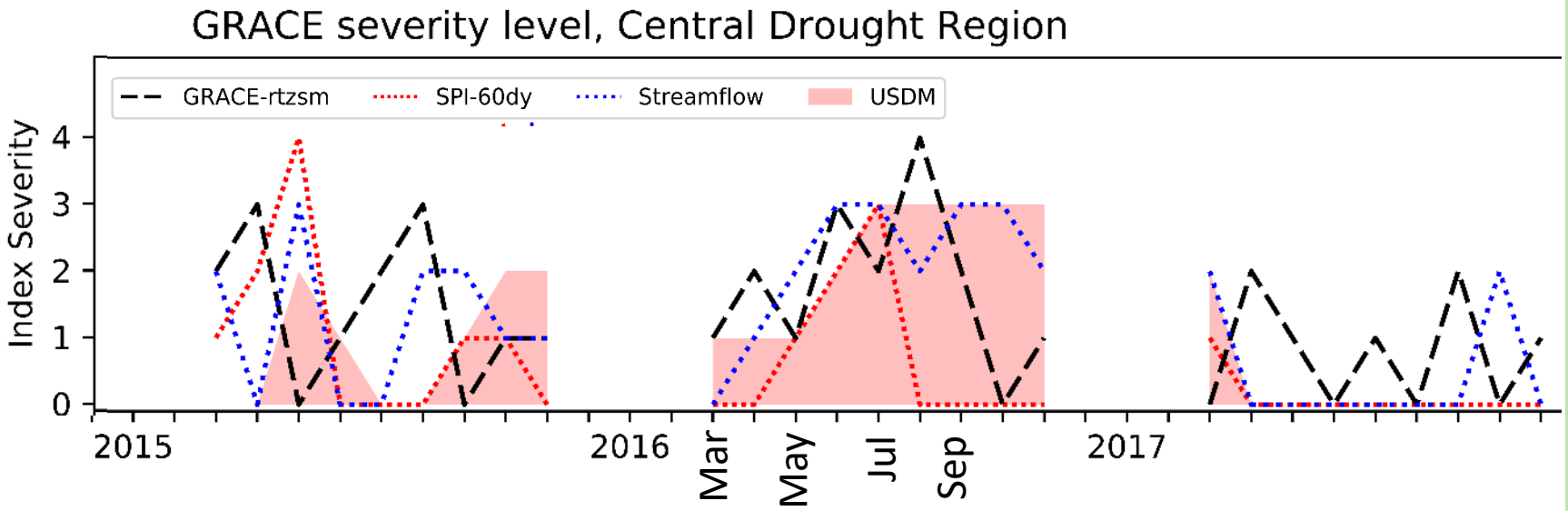
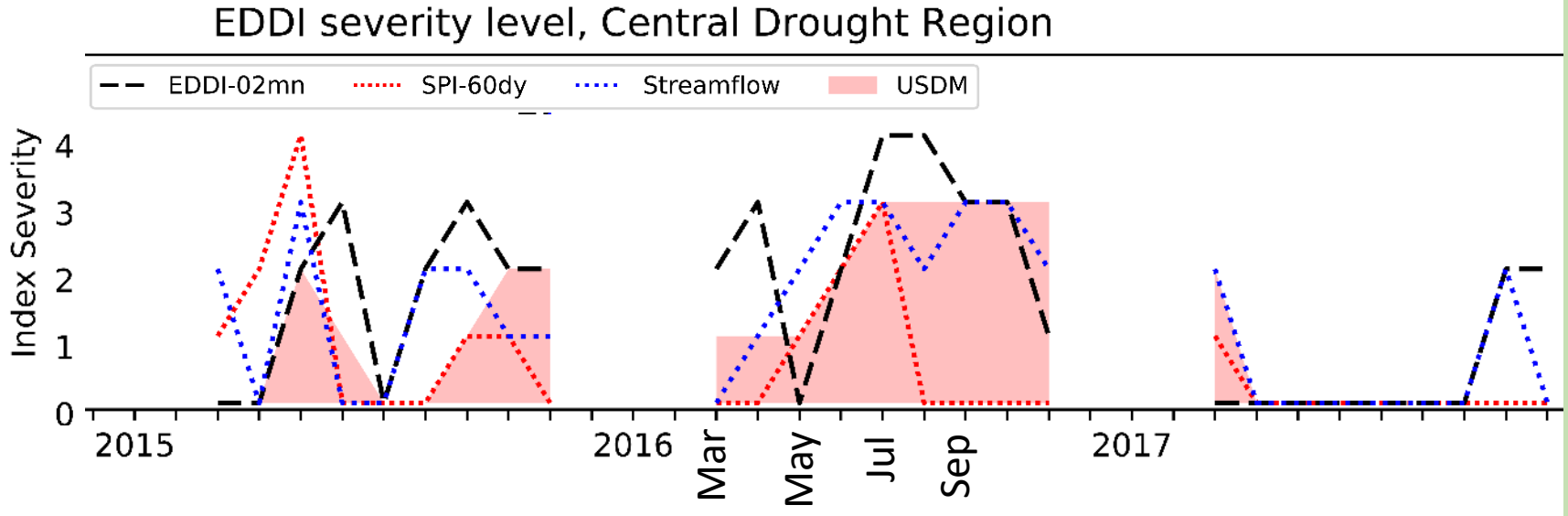
Product Comparison - 2016 Drought





GRACE root zone – soil moisture at 40 in

- Satellite product
- Ref period: 1948-2014

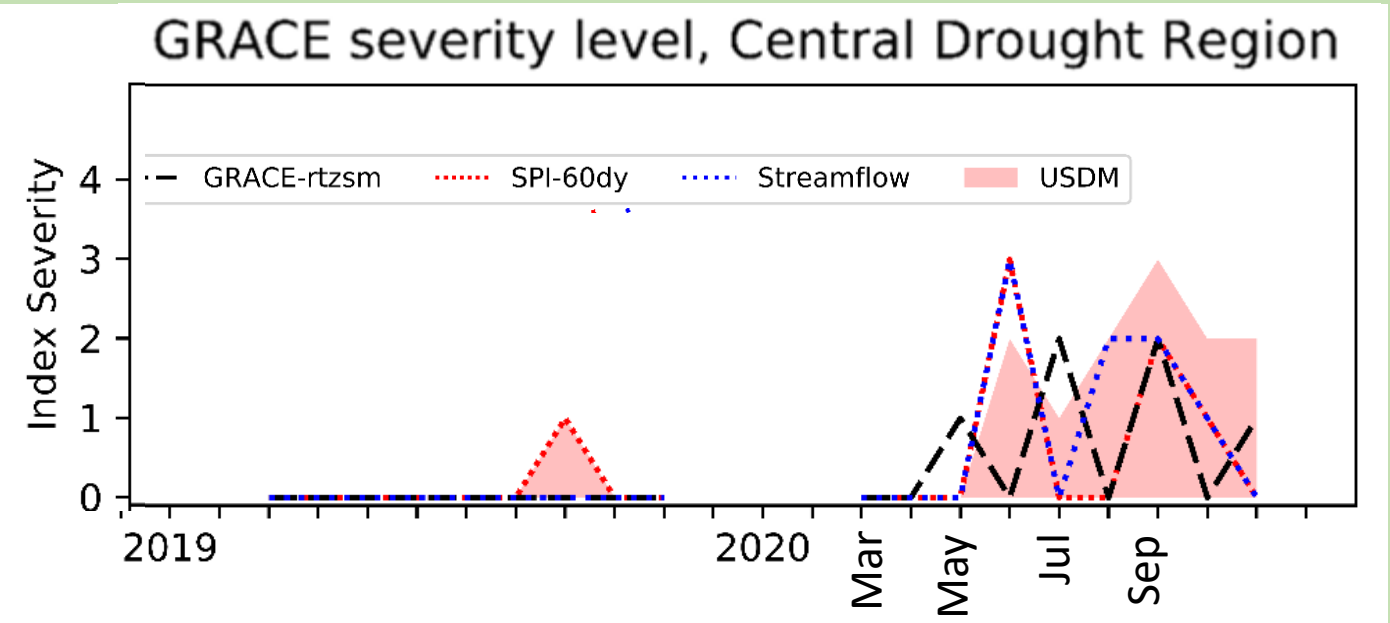
EDDI – max evapotranspiration demand/PET

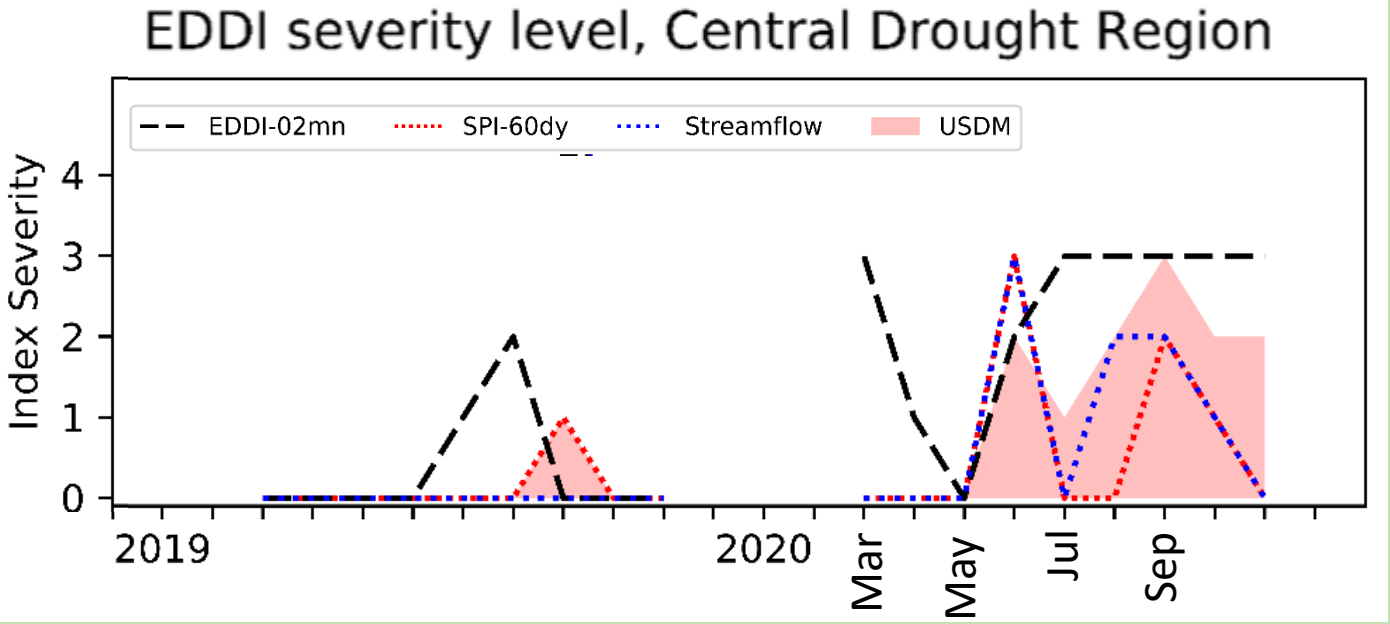
- Penman-Monteith, uses reference crop of well watered 0.5m alfalfa
- Ref period 1979-2015

2016 Average Temperature	
Month	**Percentile over POR**
Mar	**11th**
Apr	67th
May	51th
Jun	47th
Jul	**23th**
Aug	**7th**
Sep	**15th**
Oct	47th
Nov	**23th**
Annual	***12th***

Percentiles are for the 129 years between 1892 and 2021. Lower percentiles=warmer months/year

Product Comparison - 2020 Drought





2020 Average Temperature	
Month	**Percentile over POR**
Mar	**12th**
Apr	85th
May	63th
Jun	**15th**
Jul	**2th**
Aug	**7th**
Sep	**28th**
Oct	43th
Nov	**2th**
Annual	***4th***

record high summer

Percentiles are for the 129 years between 1892 and 2021. Lower percentiles=warmer months/year

<u>GRACE</u>

-generally running low despite **record** heat months

- may be due to moderation by precip rewetting soil moisture as seen by relatively low index levels

Recommendation: 2-month EDDI

- EDDI is better than CMI and other options at signaling the role of temperature and ET in drought
- Helps identify drought onset/intensification in a timelier manner especially when it is ET rather than precipitation-induced
- Provides additional information to complement the other indices