National Aeronautics and Space Administration

# SMAP L4 Assessment of the US Northern Plains 2017 Flash Drought

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# Study Scope

**Motivation**:

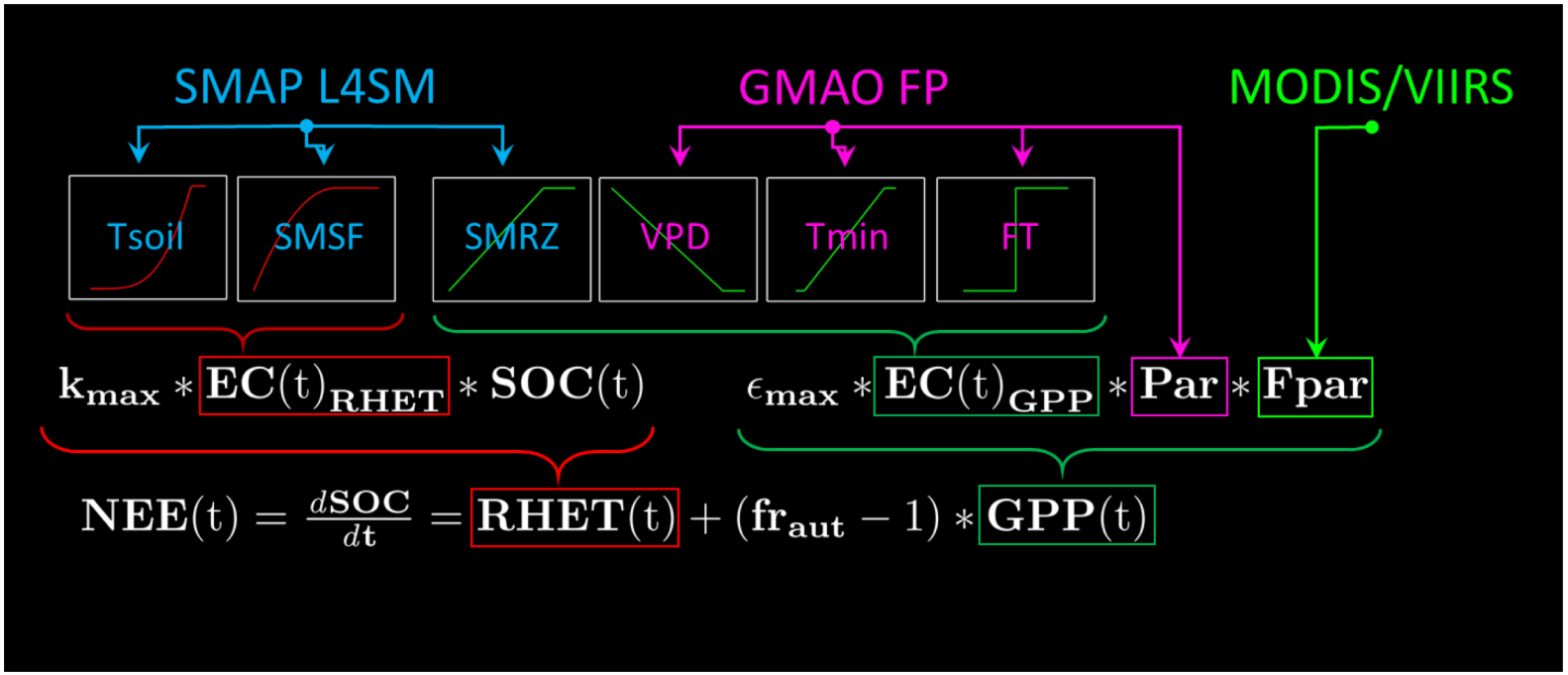
- Drought frequency & severity expected to increase with climate warming, potentially degrading ecosystem productivity & services.
- Rapidly developing "flash drought" impacted the US Northern Plains (NP) in 2017, spurred by anomalous warm/dry conditions causing severe regional productivity decline and $2.6B in agricultural losses[1].
- SMAP mission spans >4-yr operational record (Apr-2015 to present)
  - SMAP L4C product provides global record of daily gross primary production (GPP) that includes both atmosphere & soil moisture constraints on vegetation growth.
  - Favorable L4C global accuracy & performance for distinguishing GPP variability[2].

**Objective**:

- Clarify seasonal behavior & regional impact of the NP drought on regional productivity using the SMAP L4C record.

[1]Jencso et al., 2019. NOAA NIDIS drought report.
[2]Jones et al., 2017. *IEEE TGRS* 55, 11.

# SMAP L4C Algorithm Summary




- [1]Satellite data-driven C-flux model, incl. net ecosystem CO2 exchange (NEE), GPP, respiration (RHET) and surface soil organic carbon (SOC) estimates.
- **GPP** derived using LUE model driven by SMAP L4SM (0-1m), MODIS (FPAR) and GMAO (GEOS-5) daily meteorology (VPD, Tmin, PAR) inputs.
- Model calibrated using global tower CO2 flux records (FLUXNET).
- Links estimated C-fluxes with underlying environmental controls, including atmosphere (VPD, T) and soil moisture constraints to productivity.

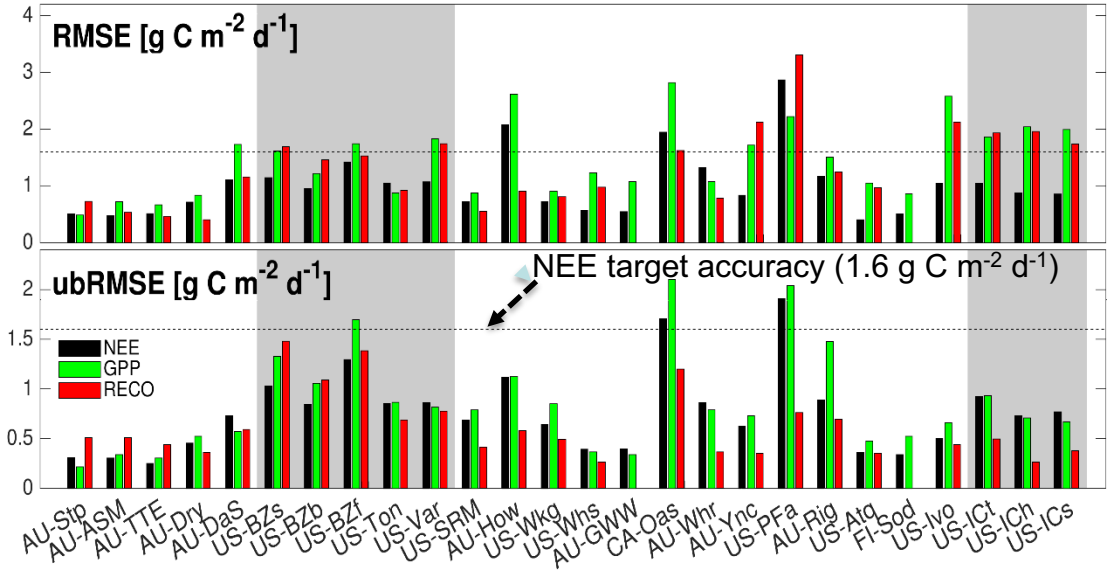
[1]Jones, Kimball, Reichle, et al. 2017. *IEEE TGARS,* 55, 11

# SMAP L4C Product Performance

[1]L4C performance vs CVS site observations (26 global tower sites)

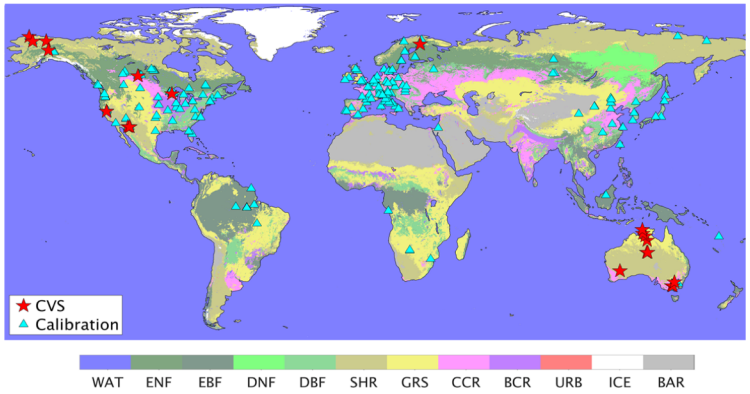
| NEE [g C m-2 d-1] | | | GPP [g C m-2 d-1] | | | RECO [g C m-2 d-1] | | |
|---|---|---|---|---|---|---|---|---|
| R | RMSE | ubRMSE | R | RMSE | ubRMSE | R | RMSE | ubRMSE |
| 0.54 | 1.02 | 0.76 | 0.70 | 1.47 | 0.86 | 0.64 | 1.32 | 0.62 |

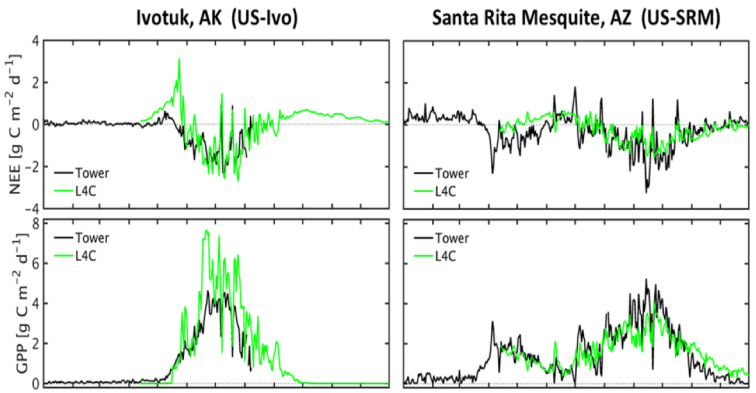
[1]Jones et al., 2017. *IEEE TGRS* 55, 11.

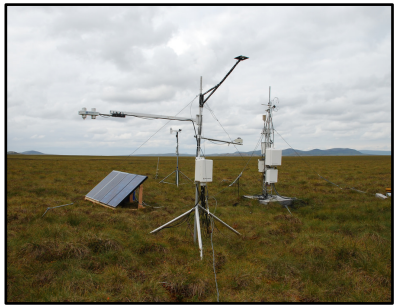



[**]Grey shades denote towers sharing the same SMAP footprint

Tower Cal/Val Sites

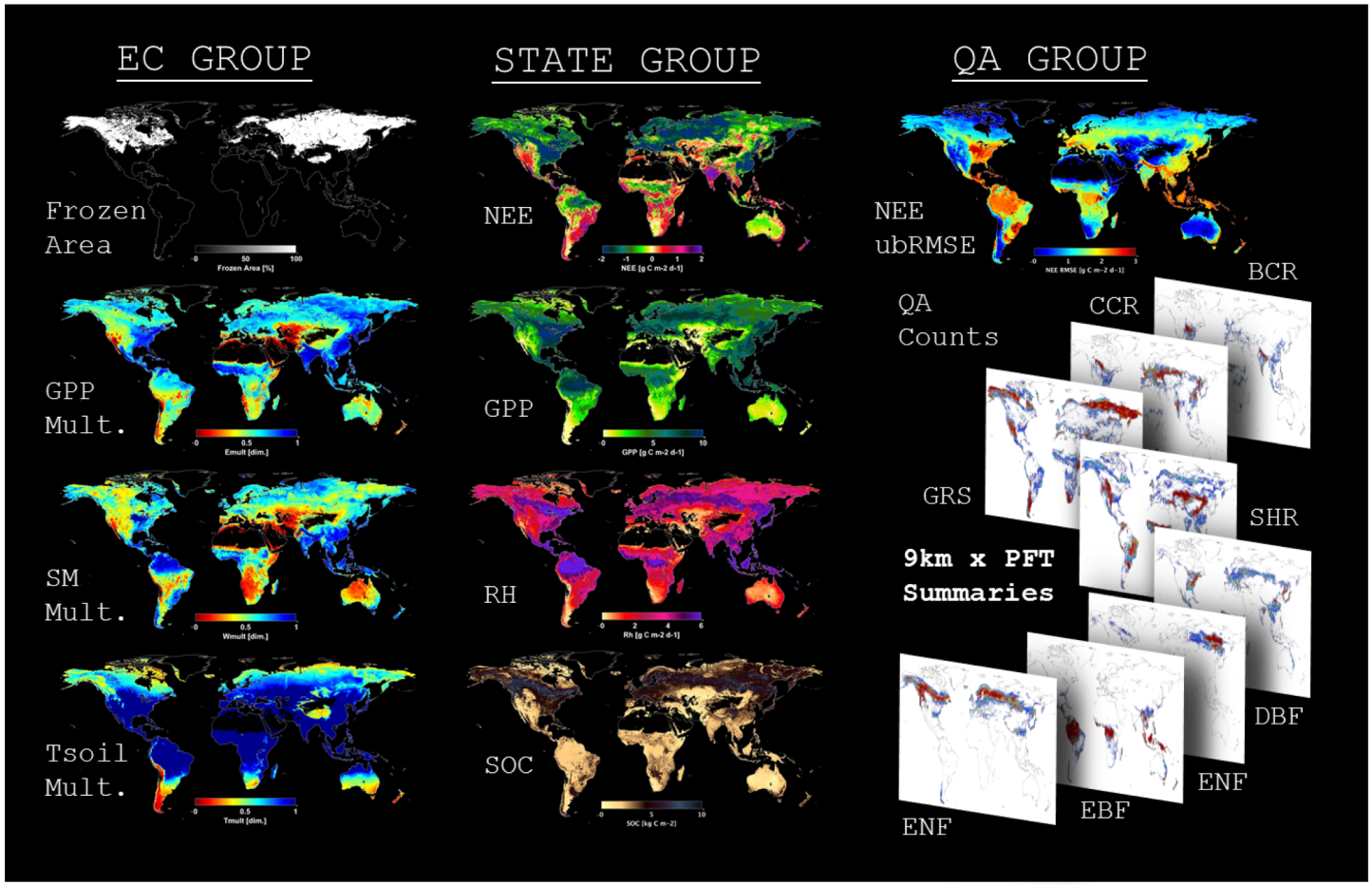


# SMAP L4C Daily Product Set

- Includes Carbon state, environmental control (EC) and quality (QA) variables
- Internally consistent C-budget & favorable performance (mean NEE RMSE <1.6 g C $m^{-2}$ $d^{-1}$)
- Global daily 1-km processing posted to 9-km grid while preserving sub-grid PFT means

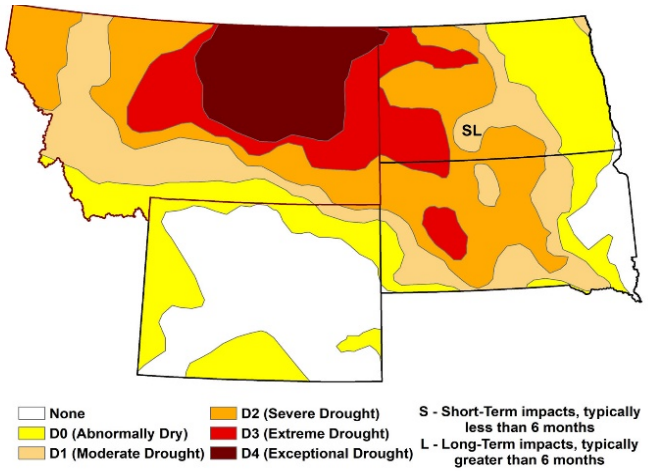


# 2017 Northern Plains (NP) Flash Drought

- Drought epicenter located over extensive rain-fed agriculture in Northcentral MT
- Anomalous warm, dry spring & summer conditions

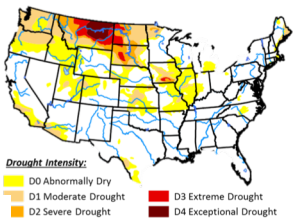
NP region


US Drought Monitor (Sep 5th, 2017)

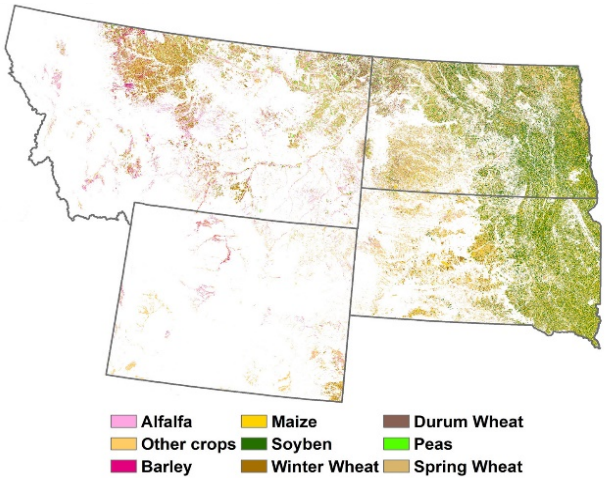



**Relative area affected:**

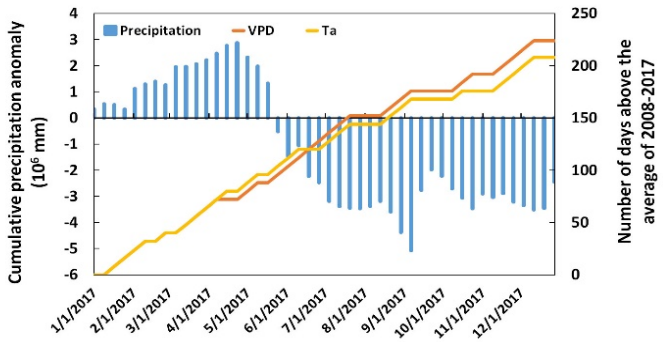
**D0: 83%,**
**D3: 23%**
**D4: 11%**




Major NP croplands (NASS CDL)



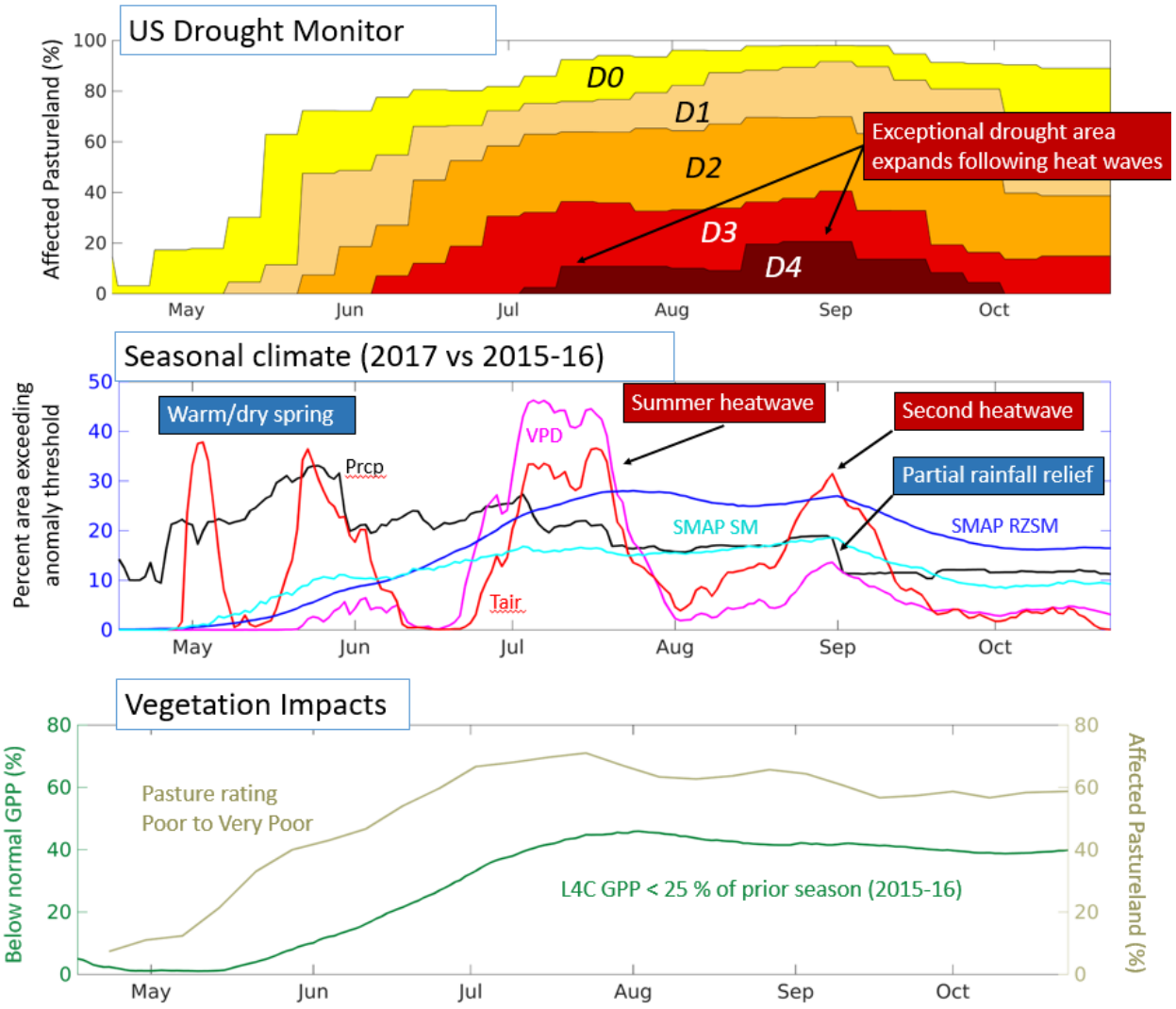

NP seasonal climate anomalies in 2017




He et al., 2019. *ERL*

# Northern Plains Drought Cycle in 2017

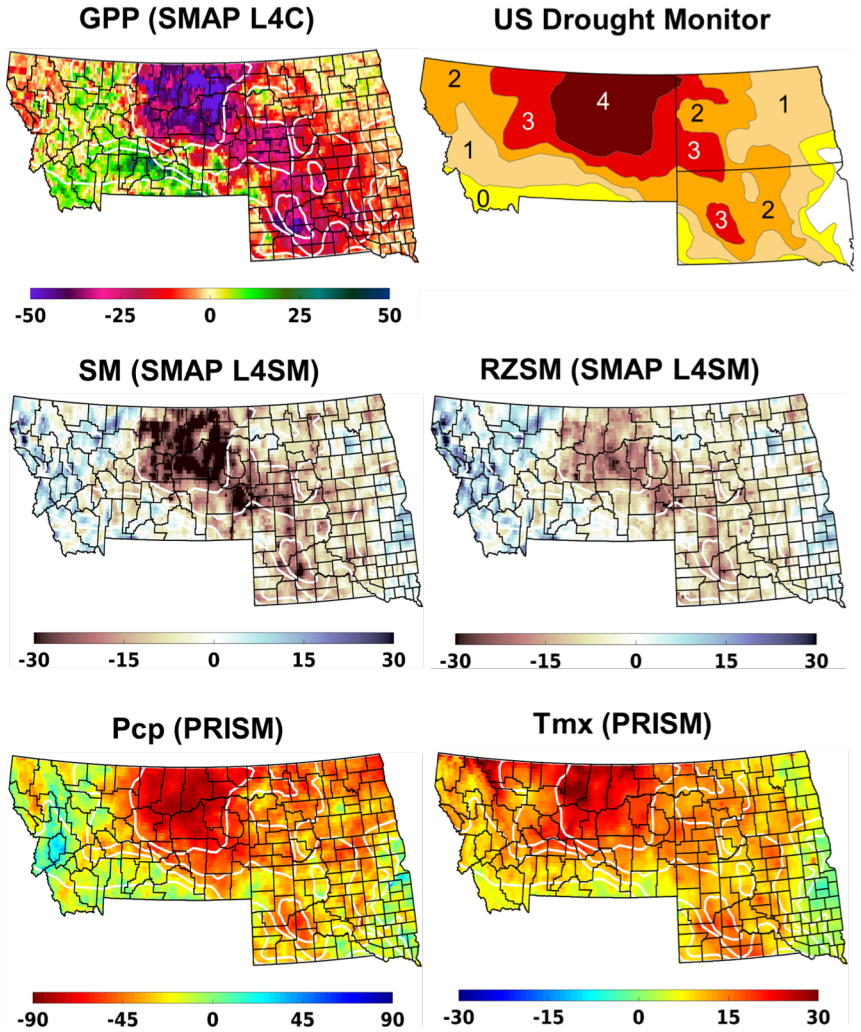
- Rapid soil drying (SMAP) from warm spring intensified subsequent summer drought severity.
- Summer heatwave preceded exceptional (D4) drought intensification by ~2wks.
- Drought onset coincided with widespread productivity decline, incl. pasture quality (NASS CDL) & GPP (L4C)



# 2017 NP Summer Drought Pattern

- L4C GPP reductions coincide with USDM drought zones.
- GPP reductions larger in more severe drought areas (D2-D4).
- GPP reductions also coincide with dry soil moisture anomalies (SMAP L4SM).
- SMAP GPP and SM reductions also consistent with warm/dry conditions from independent climate data (PRISM).

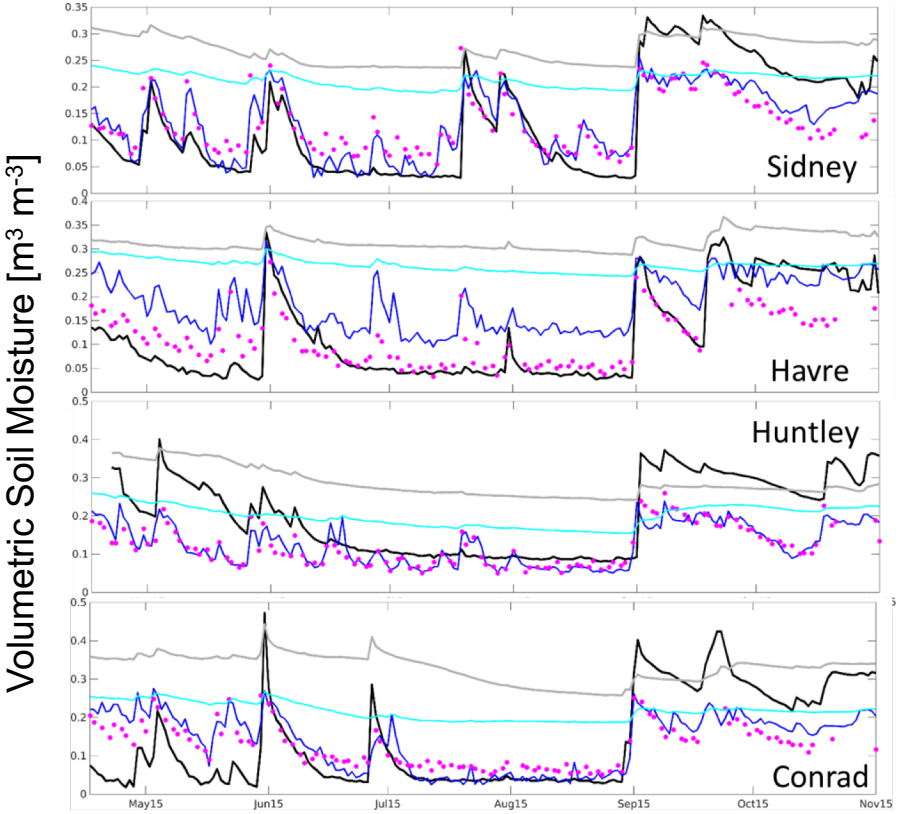
Cumulative anomalies (%) on Sept. 12, 2017 relative to 2015-2016 record & USDM



# SMAP vs in situ Soil Moisture Observations

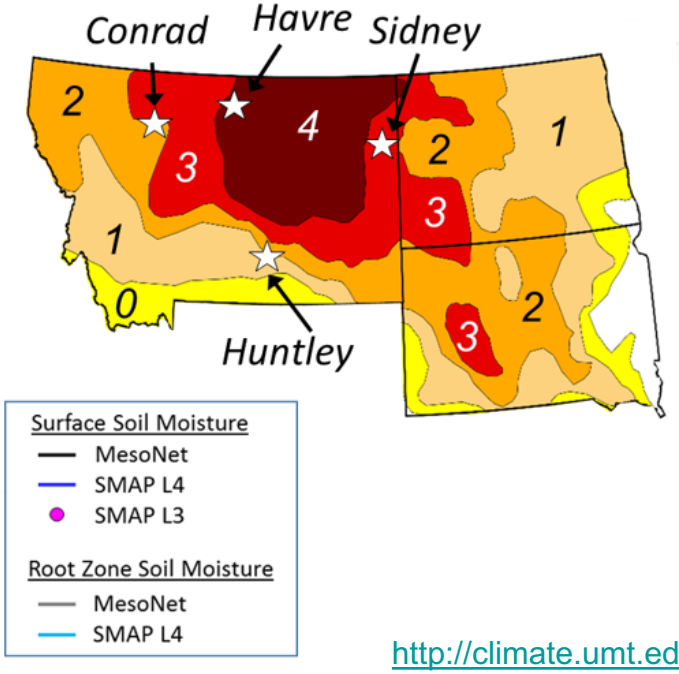
- SMAP L4 Root Zone Soil Moisture (RZSM) is a key L4C input for estimating GPP.
- Favorable SM accuracy despite coarse (9-km) L4 gridding

SM validation over 2017 Drought Period





Montana MesoNet sites

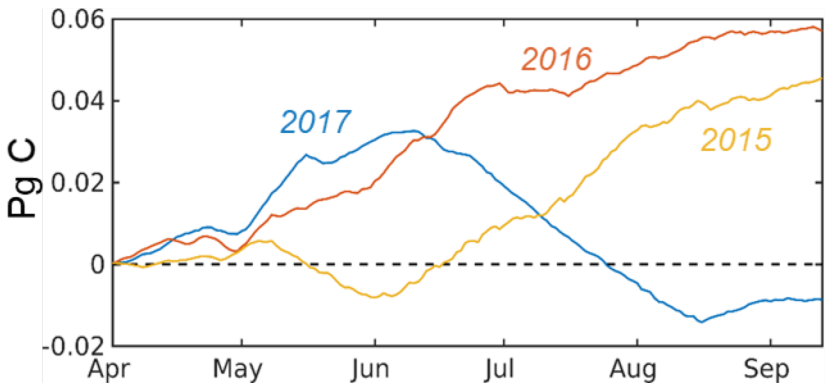



http://climate.umt.edu/mesonet/

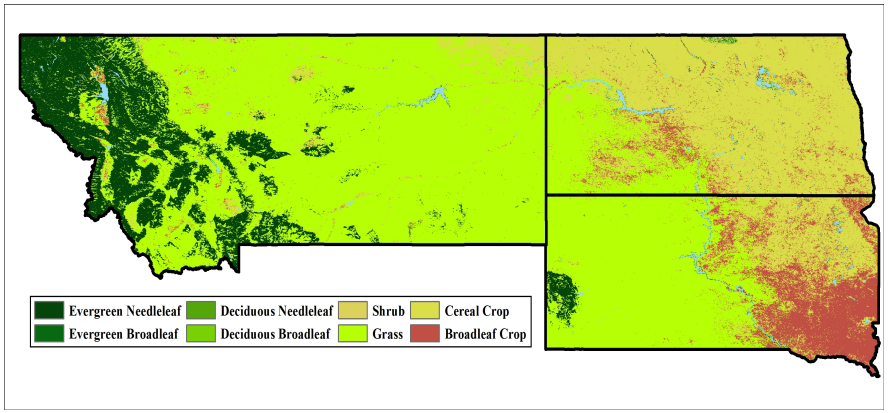
# NP Monthly GPP Anomalies by Year and PFT Class

- Early spring GPP onset followed by drought-induced summer productivity collapse in 2017.
- Larger GPP reductions in productive croplands relative to other vegetation classes.

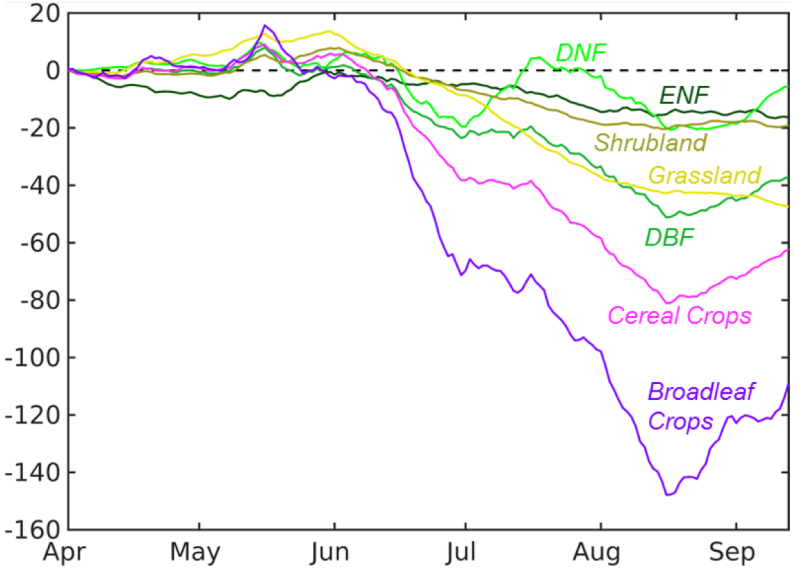
Cumulative GPP (SMAP L4C)




MODIS Vegetation (PFT) Classes

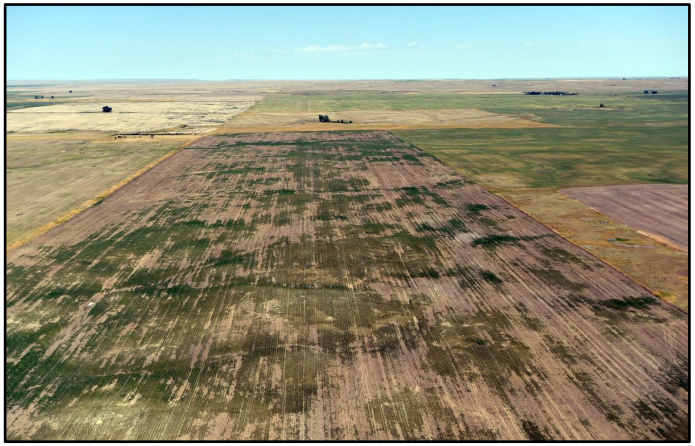



NP Cumulative GPP Difference by PFT Class
(2017 – 2016, g C $m^{-2}$)



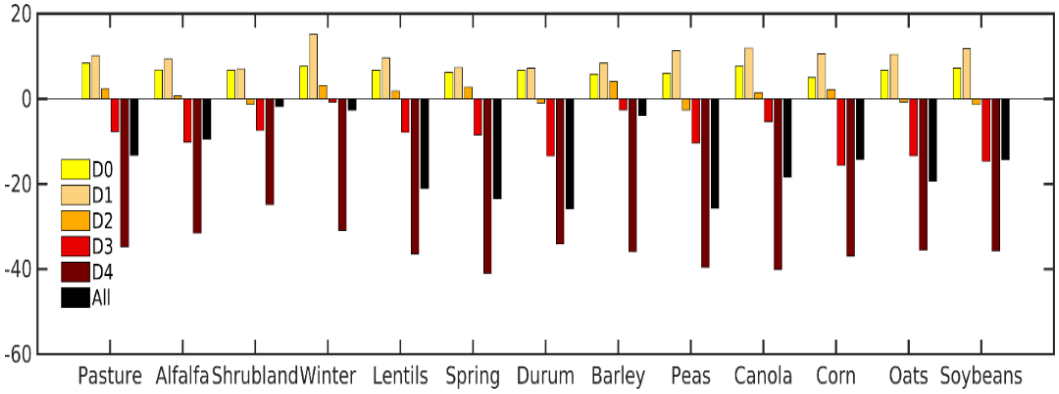
# 2017 Drought Impact on Montana Agriculture

- Productivity (%) decline greater in more severe (D3, D4) drought zones
- Similar L4C and NASS reported production losses in 2017
- Larger productivity losses in croplands than pasture and rangeland

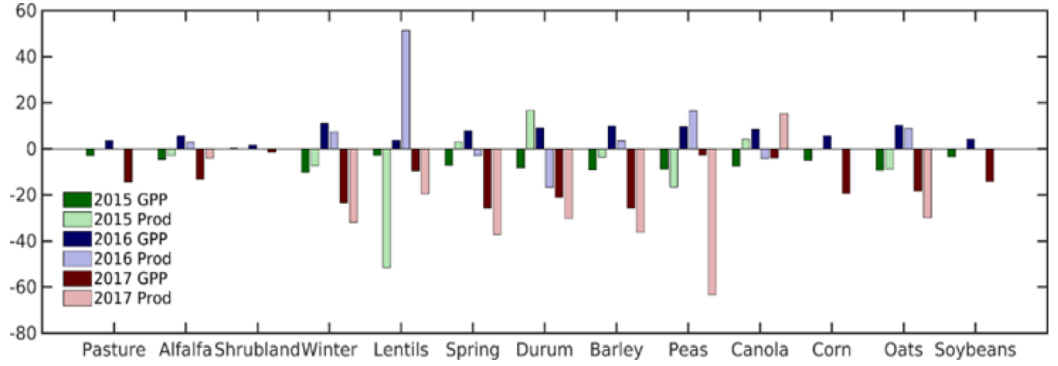


Central MT (Aug 19, 2017)

L4C GPP crop anomalies by USDM drought zones



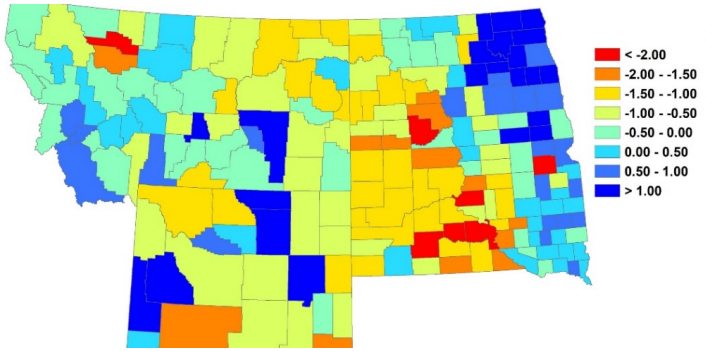

L4C GPP vs NASS crop, pasture & range production (2015-2017)



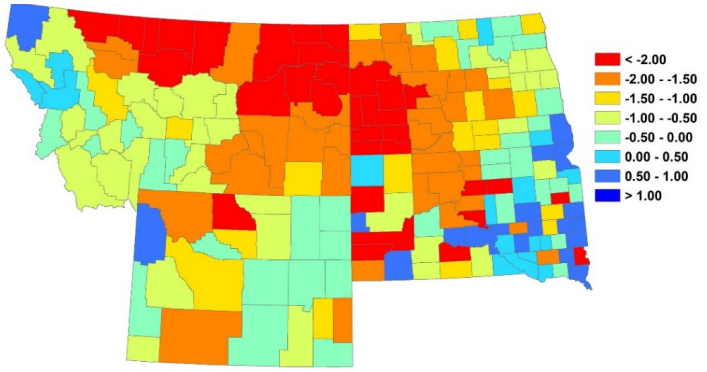
# Corroborating SMAP NP Drought Assessment

- Other satellite productivity (SIF) and ET data show similar NP 2017 drought impact as SMAP.
- ~25% annual drop in cropland ET; 6% drop in county crop production (NASS); 11% productivity (SIF) loss
- Larger ET (~80%) and SIF (~70%) declines in exceptional drought (D4) areas with extensive agriculture.

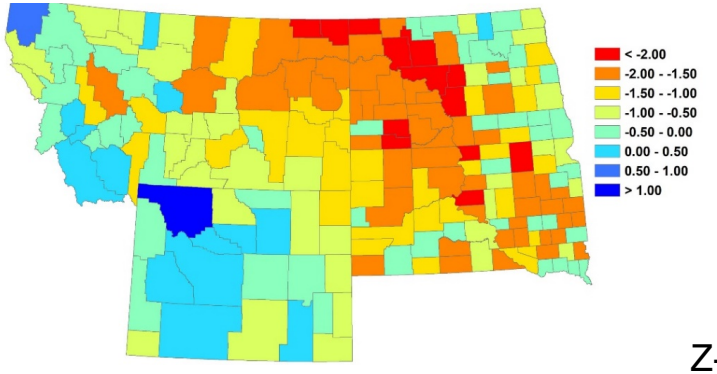
Annual crop production (NASS)



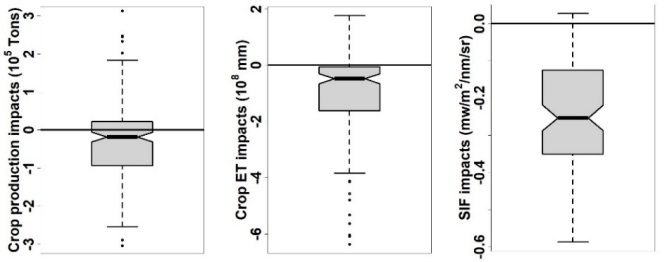

Cropland ET (MOD16)




Ecosystem productivity (GOME-2 SIF)




Annual drought Impacts

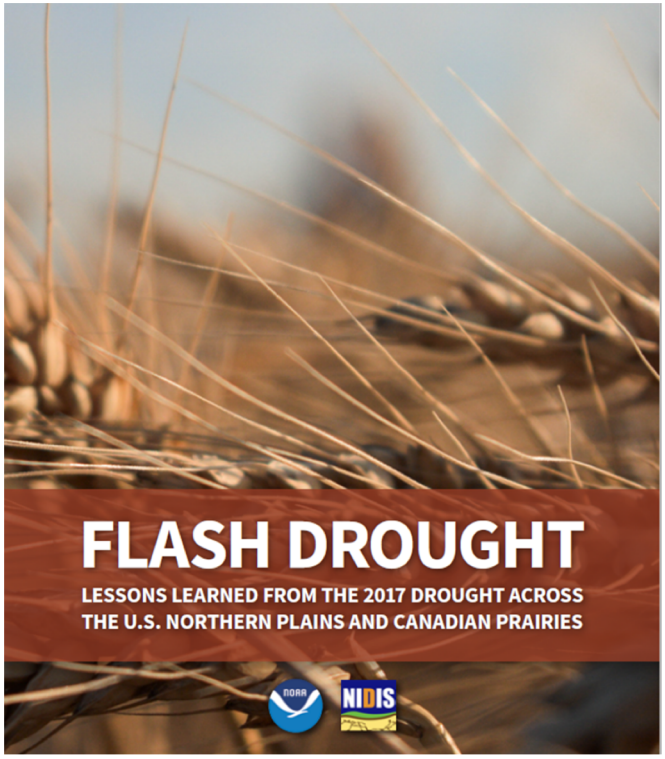



Z-score anomalies from 2008-2017 record

Source: He et al., 2019. *ERL*

# Summary and Conclusions

- SMAP L4 offers new insight into the 2017 NP flash drought that align with other independent assessments from management agencies, regional weather stations, and complimentary satellite records (SIF, ET).
- Early spring onset and warm/dry atmosphere facilitated rapid soil drying, exacerbating subsequent summer drought severity triggered by a mid-July heatwave
- Enhanced spring productivity preceded widespread summer GPP collapse, with greater productivity losses in croplands and severe drought (USDM D3-D4) zones
- SMAP L4C operational record provides consistent global daily observations, favorable accuracy, and ~10-day latency suitable for drought monitoring.




**Jencso et al., 2019. NOAA NIDIS drought report:

https://www.drought.gov/drought/documents/flash-drought-lessons-learned-2017-drought-across-us-northern-plains-and-canadian-0

# THANK YOU!

**SMAP L4C v4 operational record available at NSIDC:**

**http://nsidc.org/data/SPL4CMDL**

**L4C browse images on NASA Worldview :**

**https://worldview.earthdata.nasa.gov**

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