Using AIRS Products to Monitor Drought for the USDM

Best practices for USDM authors in the use of drought products from the Atmospheric Infrared Sounder

AIRS Project Drought Team
NASA Jet Propulsion Laboratory

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Please Note: This training session will be recorded.

AIRS Drought Team

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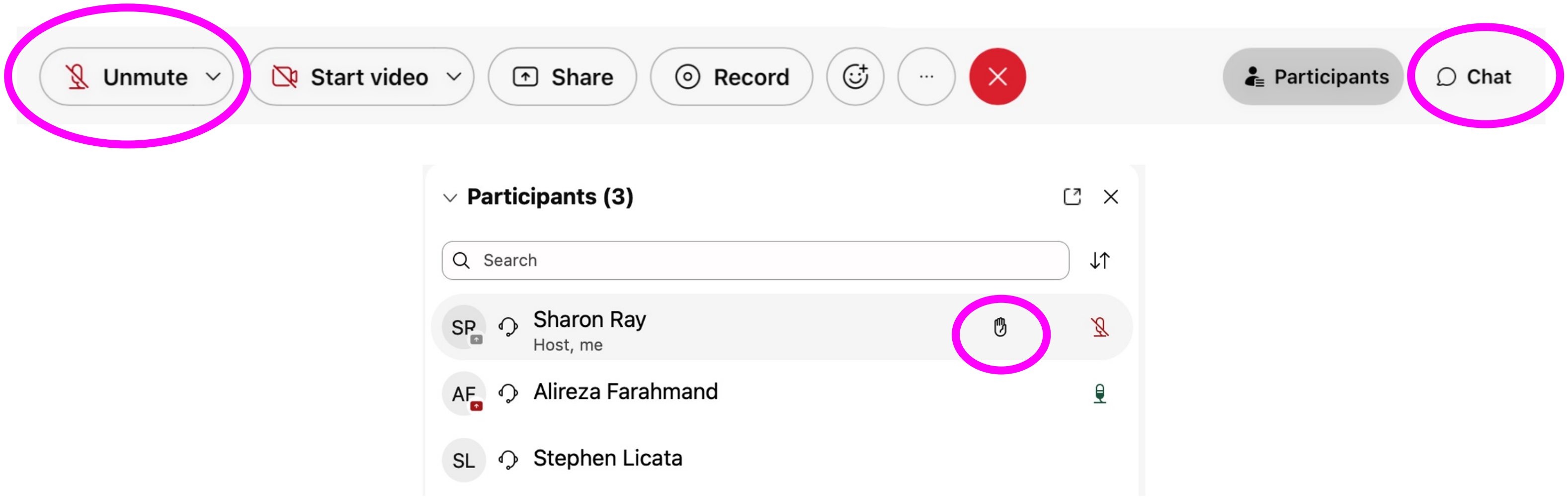
Using WebEx

- Please make sure you are muted except when asking a question.
- If you have a question or comment, please enter it in the WebEx chat.
- There will be a Q&A period when you can raise your hand & unmute.
- If you need technical assistance during the training, please use the chat or email sharon.ray@jpl.nasa.gov.



Agenda

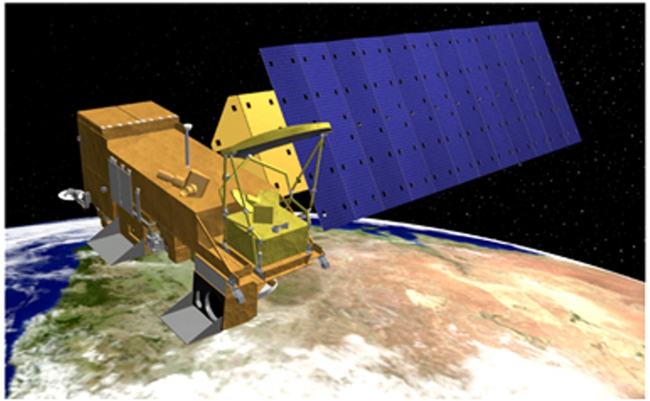
AGENDA - AIRS Products for USDM *(please note all times in PDT)*		
12:00	*10*	**Introductions & Webex Overview**
12:10	*10*	**Context** 1. Using satellite data to help detect drought 2. About AIRS 3. AIRS and the U.S. Drought Monitor 4. AIRS drought products for USDM development
12:20	*20*	**Best Practices for Interpreting the Imagery** 1. Color in the imagery 2. Methodology 3. Use Case 1: 2012 Midwest Flash Drought 4. Use Case 2: 2019 Southeast Flash Drought 5. Use Case 3: 2020-2022 Western US Drought
12:40	*15*	**Going Forward** 1. Data continuity 2. Validation 3. AIRS Version 7 data 4. Resources
12:55	*5*	*Break*
1:00	*10*	**Q & A**
1:10	*20*	**Short Survey**
Following the survey there will be additional Q&A time as needed until 2PM.		

Using satellite data to help detect drought

- **Ground-based observations** provide valuable climate information for drought monitoring such as precipitation, **but they have limitations:**

1) Uneven distribution
2) Temporal and spatial inconsistencies
3) Lack of observations in remote regions

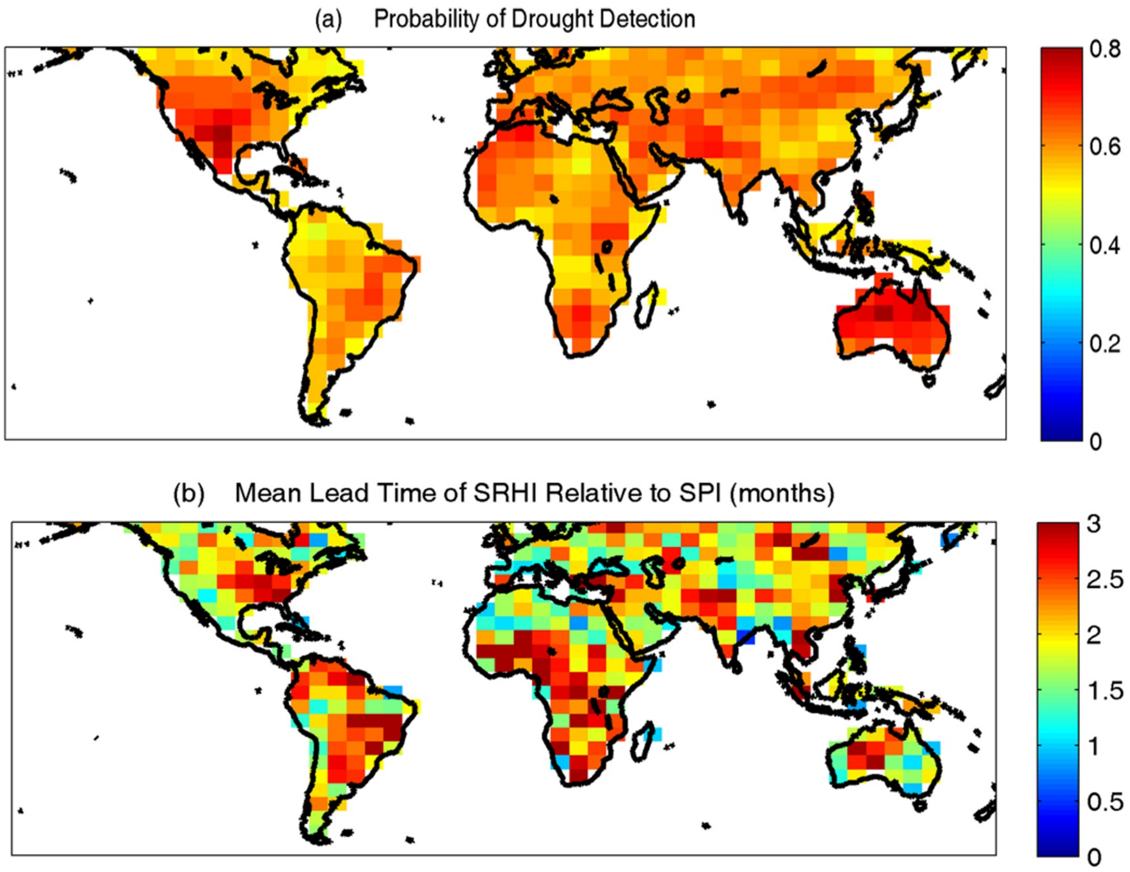
Satellite-based products



Artist rendering of the Aqua satellite. Credit: NASA

Drought Monitoring

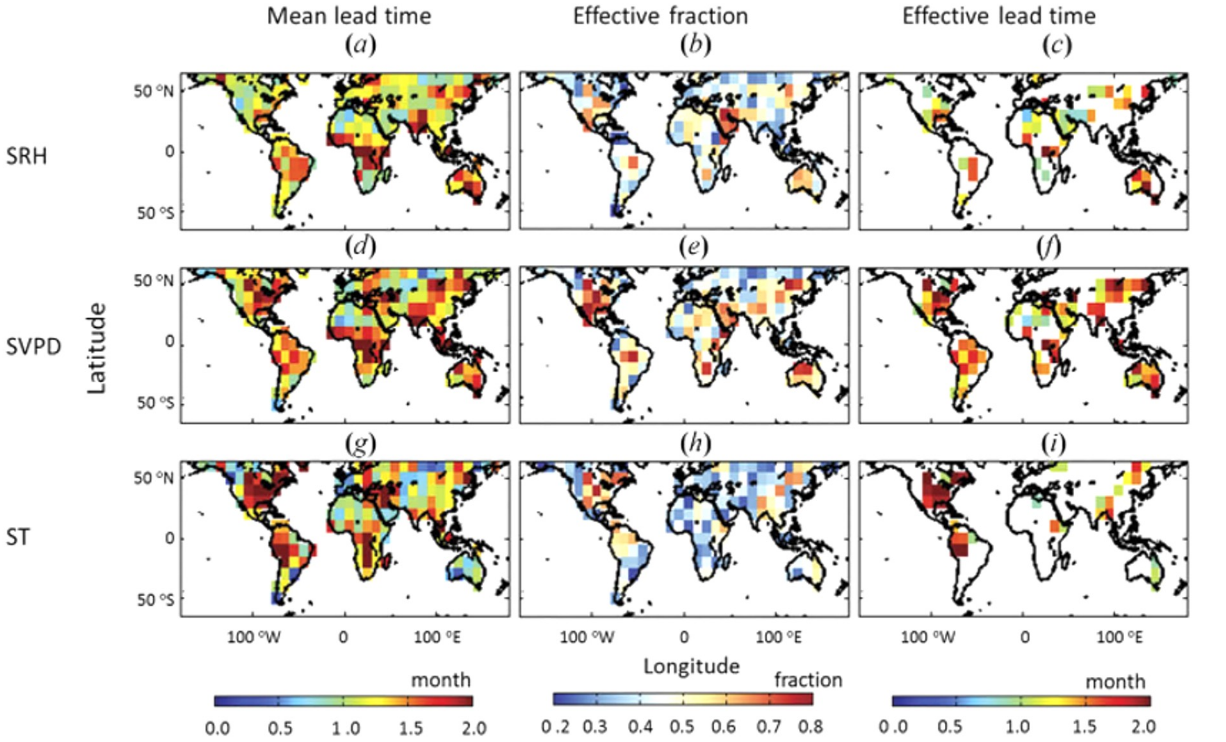
- Early drought detection is important in several sectors including water and agriculture:
    - Water managers – for water resource planning
    - Farmers – purchase less fertilizers and increase insurance coverage before growing season
- Standardized Precipitation Index (SPI) is the most commonly used index for drought onset detection.
- Research shows near-surface air relative humidity, temperature, and Vapor Pressure Deficit (VPD) have the potential to detect drought earlier than SPI



Mean Probability of Relative Humidity Early Detection compared to Precipitation:
0.6

Mean Lead Time:
2 months

Paper – Farahmand, A., AghaKouchak, A., & Teixeira, J. (2015). A vantage from space can detect earlier drought onset: An approach using relative humidity. *Scientific reports*, *5*(1), 1-6.



Vapor Pressure Deficit (VPD) and Air Temperature also show great potential for drought onset detection

VPD is the difference between the amount of moisture in the air and how much moisture the air can hold when it is saturated

VPD incorporates both elements of temperature and humidity

Paper – Behrangi, A., Fetzer, E. J., & Granger, S. L. (2016). Early detection of drought onset using near surface temperature and humidity observed from space. *International Journal of Remote Sensing*, *37*(16), 3911-3923.

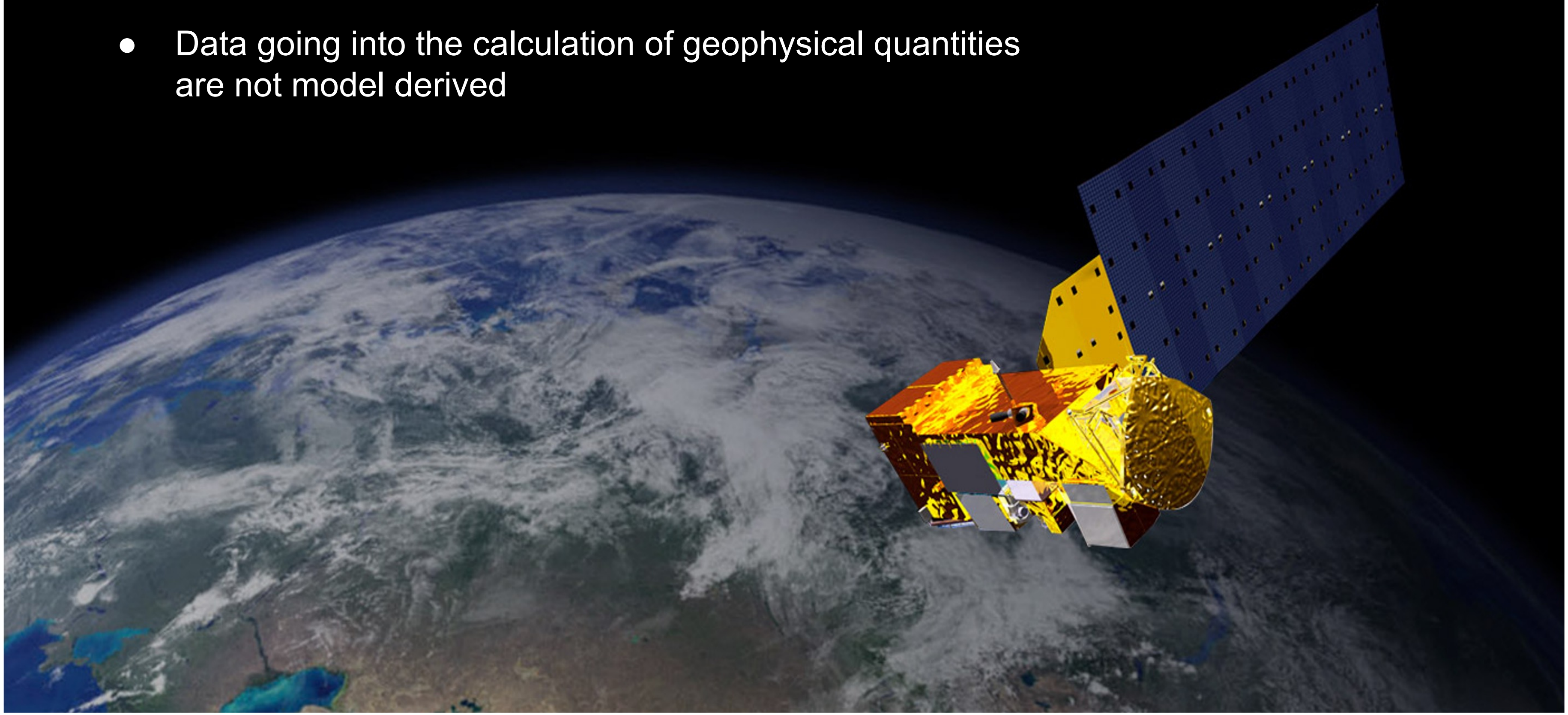
AIRS, the Atmospheric Infrared Sounder on NASA's Aqua satellite

- **Goal: Support climate research and improve weather forecasting**
  - Launched in 2002
  - End of mission nominally expected 2025
- **Hyperspectral IR**
  - Measures infrared radiances (brightness temperatures) emitted from Earth
  - ~2400 detectors create profiles of temperature & water vapor
  - Polar orbit: minimum of 2 overpasses/day (more at poles)
  - Global coverage: 16 day repeat cycle (same lat/lon & nadir lighting conditions)
  - Level 2 data: 45 km resolution

AIRS soundings are equivalent to launching more than 300,000 radiosondes on a 45 km grid over the globe each day

AIRS data are *direct observations*

- Data going into the calculation of geophysical quantities are not model derived



AIRS and the U.S. Drought Monitor

- **2016**
  - Stephanie Granger (JPL), Ali Behrangi (JPL*) visit NDMC
  - Showcase AIRS VPD, RH, and T drought products
- **Agreement secured**
  - NDMC evaluates AIRS VPD, RH, and T drought products

From left: Mark Svoboda (NDMC), Ali Behrangi (formerly JPL, now Univ. of Arizona), Stephanie Granger (JPL), Tsegaye Tadesse (NDMC), Brian Fuchs (NDMC)
Photo credit: Stephanie Granger

*Now at University of Arizona

AIRS products for the USDM

- **Anomalies of Near Surface quantities provided as percentiles**:
  - **Air Temperature**
  - **Relative Humidity**
  - **Vapor Pressure Deficit**
- Binned into 7-day, 14-day, 28-day, 56-day averages
- Geotiffs delivered weekly (currently on Monday) to FTP server
- Data source
  - AIRS Level 2 standard and near real-time swath data
  - Data used to make a custom ½-degree gridded product
  - Only use science data tagged with quality flags of 0 (best) or 1 (good).
  - No data used with a QC value of 2 (suspect).
- Coverage: CONUS

About the climatology

- Monthly mean generated weekly
- Climatology updated weekly

AIRS 7-day products available since April 2017

AIRS 14-day products available since August 2018

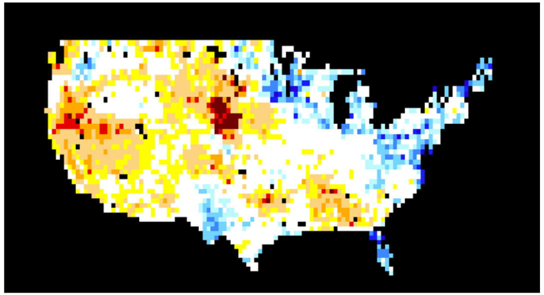
AIRS 28 & 56-day products available since August 2017

Example of AIRS Drought Products

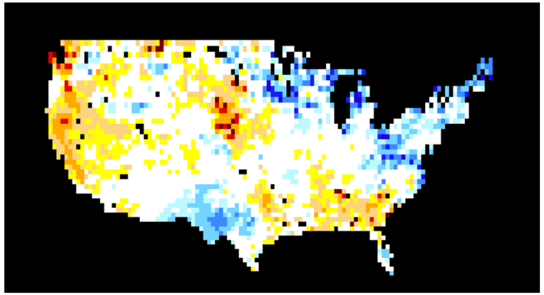
We deliver 12 maps every week

- 7, 14,28, 56-day average RH
- 7, 14,28, 56-day average T
- 7, 14,28, 56-day average VPD

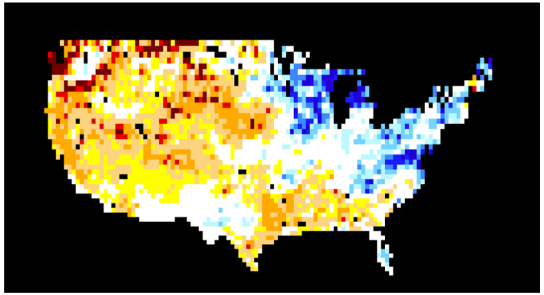
Example showing AIRS VPD products from 1/31/22 in all 4 bin sizes



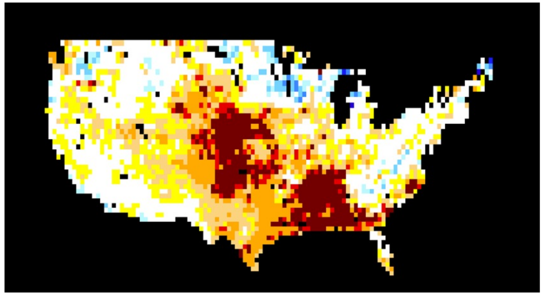
7-day avg



14-day avg



28-day avg

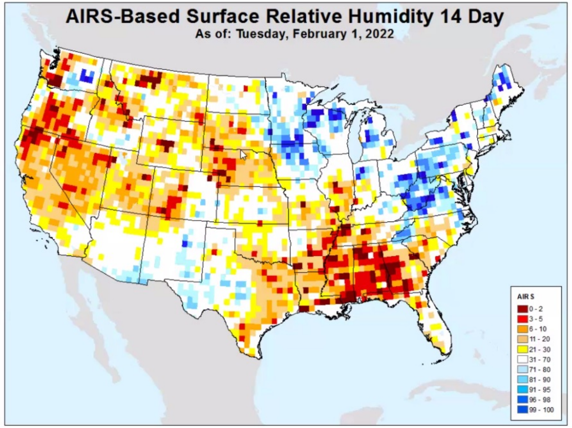


56-day avg

Color in the AIRS drought product imagery

- USDM uses a standard color bar that assigns colors based on a parameter’s percentile ranking. The AIRS drought imagery follows this color scheme.

- For regions that are red (D3-Extreme Drought) to brown (D4-Exceptional Drought)
    - These regions are hotter, drier or have a higher evaporative factor than 95-99 percent of all weekly averages collected since Sept 1, 2002.



Example AIRS image that will be seen by USDM authors

Important note regarding black or white pixels in the AIRS imagery:

- Black: indicates missing or bad data
- Blue: indicates cooler, wetter, or lower evaporative index
- White: indicates near-normal conditions
    - Please note: In USDM maps, the AIRS white & blue pixels have been incorporated into the white pixel category, which in the USDM context means missing, near-normal, or non-drought data.

Interpreting the imagery: The Methodology

1. Data source: AIRS V6 Daily Daytime L2 IR-Only Standard (RetStd), which provides
   - Surface Air Temperature (T)
   - Surface Relative Humidity (RH)

Note: The first 7-days of T and RH data come from the Near Real Time (NRT) Standard product. All subsequent daily datasets come from the final archived Standard product.

2. We calculate dew point temperature (Td) from T and RH:

$$\mathrm{Td} = \frac{b \ \times \propto (\mathrm{T}, \mathrm{RH})}{a - \propto (\mathrm{T}, \mathrm{RH})}$$

$$\propto (\mathrm{T}, \mathrm{RH}) = \ln\left(\frac{\mathrm{RH}}{100}\right) + \frac{(a \ \times \mathrm{T})}{(b + \mathrm{T})}$$

T: Air Surface Temperature °c
RH: Relative Humidity (%)
Td: Dew Point Temperature °c

$a = 17.625 \qquad b = 243.04$

3. VPD is then calculated as:

$$VPD = c1 \times \exp\left(\frac{c2 \times \mathrm{T}}{c3 + \mathrm{T}}\right) - c1 \times \exp\left(\frac{c2 \times \mathrm{Td}}{c3 + \mathrm{Td}}\right)$$

$c1$ =0.611 kPa , $c2$=17.5, $c3$= 240.978 °c

4. Files are gridded in 0.5 degree daily datasets

5. We calculate a ranking from the following table for the climatology of RH, T, and VPD:

Climatology for a **7-day VPD** drought product of **June 23-29 2021** period is built as follows:

19*8=152 points

2021	**Jun 23-29**	Jun 22-28	Jun 21-27	Jun 20-26	Jun 19-25	Jun 18-24	Jun 17-23	Jun 16-22
…								
2003	Jun 23-29	Jun 22-28	Jun 21-27	Jun 20-26	Jun 19-25	Jun 18-24	Jun 17-23	Jun 16-22

Since the AIRS data record is relatively short, we include these additional points from each yearly data set to generate a progressively robust climatology. This methodology is commonly used in the literature*

*Behrangi, A., Nguyen, H., & Granger, S. (2015). Probabilistic seasonal prediction of meteorological drought using the bootstrap and multivariate information. *Journal of Applied Meteorology and Climatology*, *54*(7), 1510-1522.

6. We need to compare current data against the climatology to obtain the drought status

- To that end, we calculate the empirical Gringorten probability percentiles (0 to 100) for RH, T, and VPD:

$$p(x_i) = \frac{i - 0.44}{n + 12}$$

i Rank of non zero data from the smallest RH and largest VPD and T

n Sample size

x Data vector

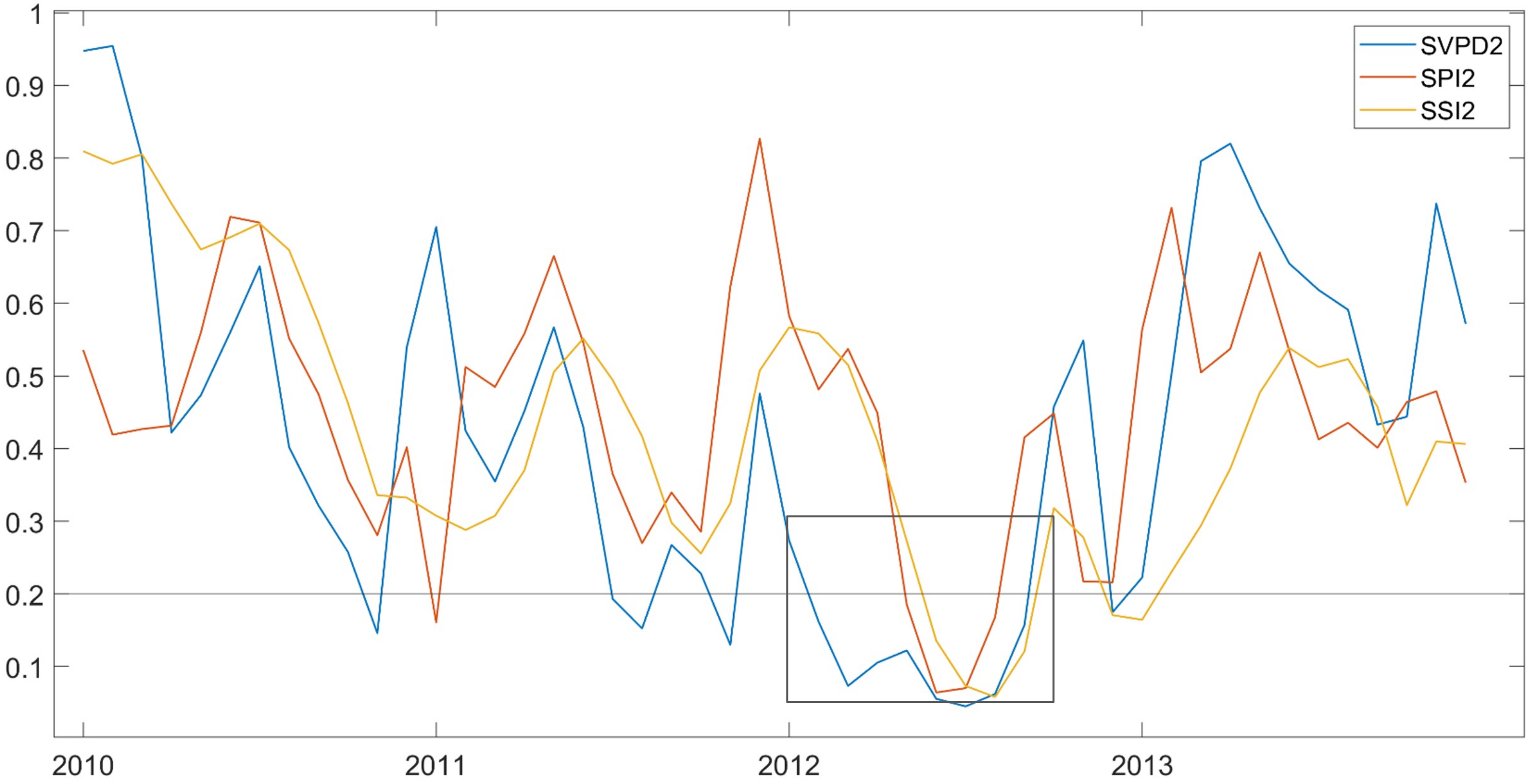
Case studies

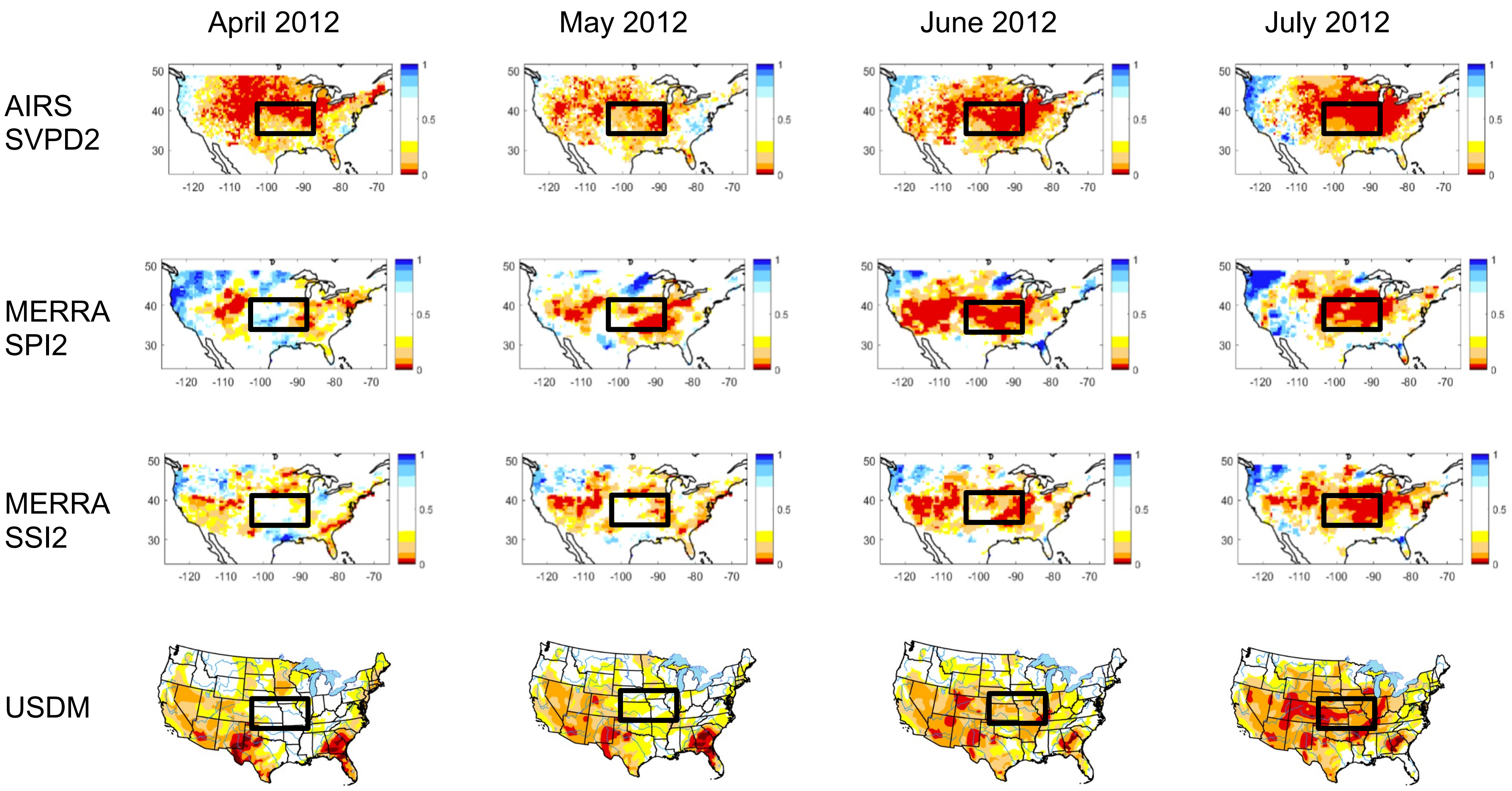
1. 2012 Midwest Flash Drought
2. 2019 Southeast Flash Drought
3. 2020-2022 Western US Drought

Please note:

- We compare the AIRS drought indicators to re-analysis based MERRA SPI (Standardized Precipitation Index) and SSI (Standardized Soil Moisture Index)
- We use the Moderate drought threshold of 20 Percentile
- For simplicity:
    - We only showcase AIRS VPD drought indicator (SVPD) results
    - We use the typical climatology calculation method of using same block of time averaged over each year of the mission.

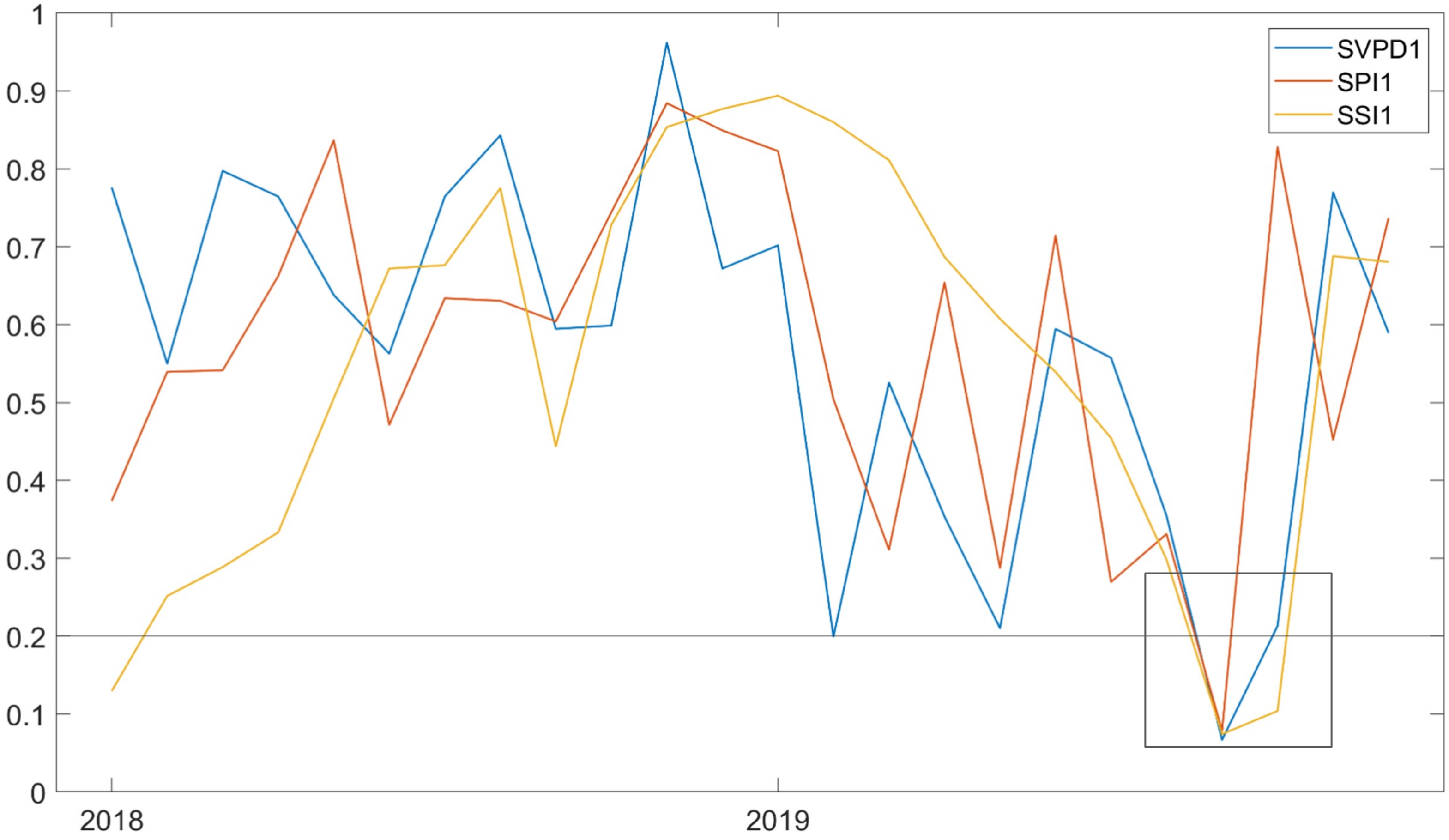
Use Case 1 - 2012 Midwest Flash Drought

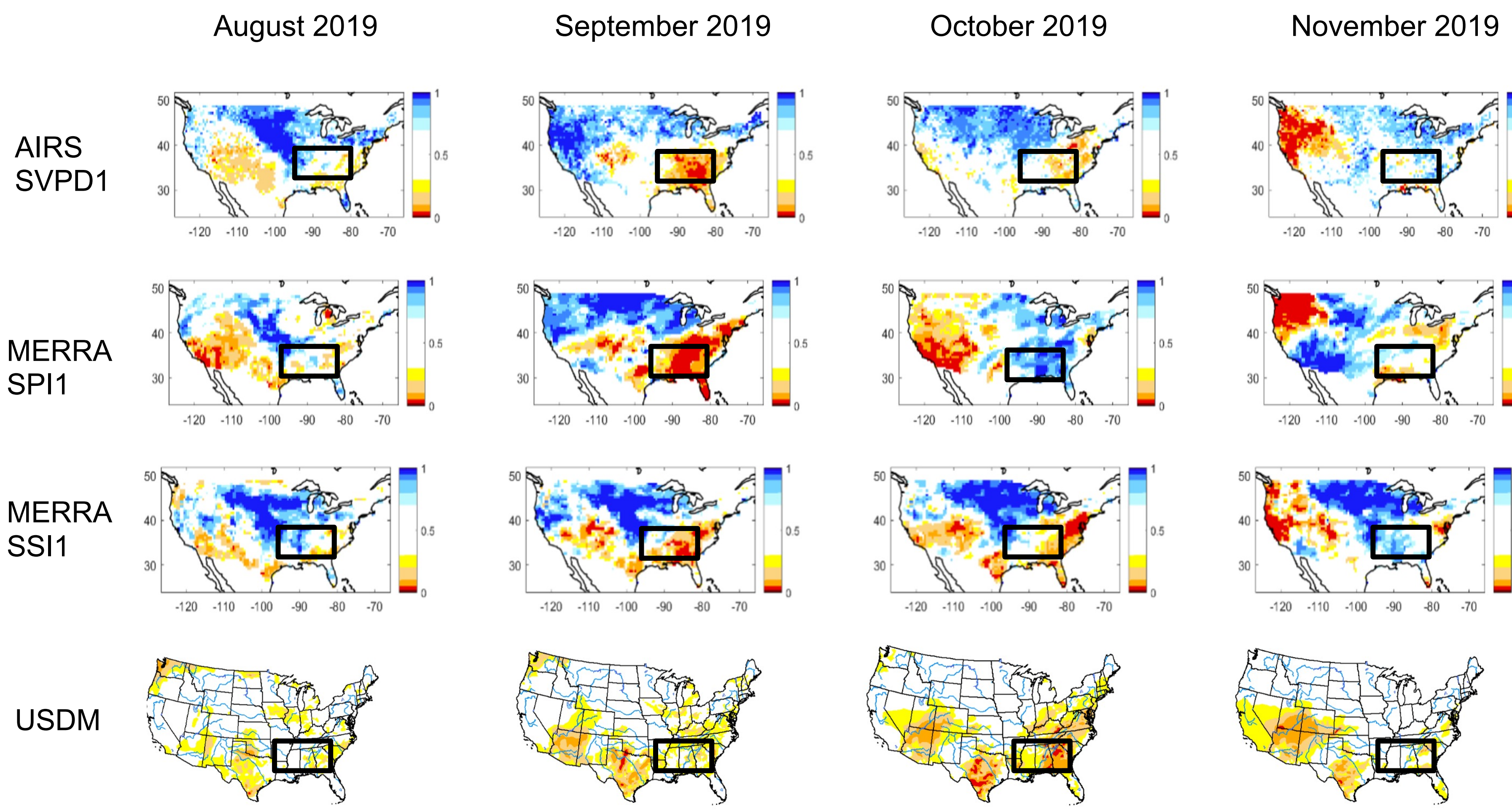




April 2012
May 2012
June 2012
July 2012
AIRS SVPD2
MERRA SPI2
MERRA SSI2
USDM

Use Case 2 - 2019 Southeast Flash Drought





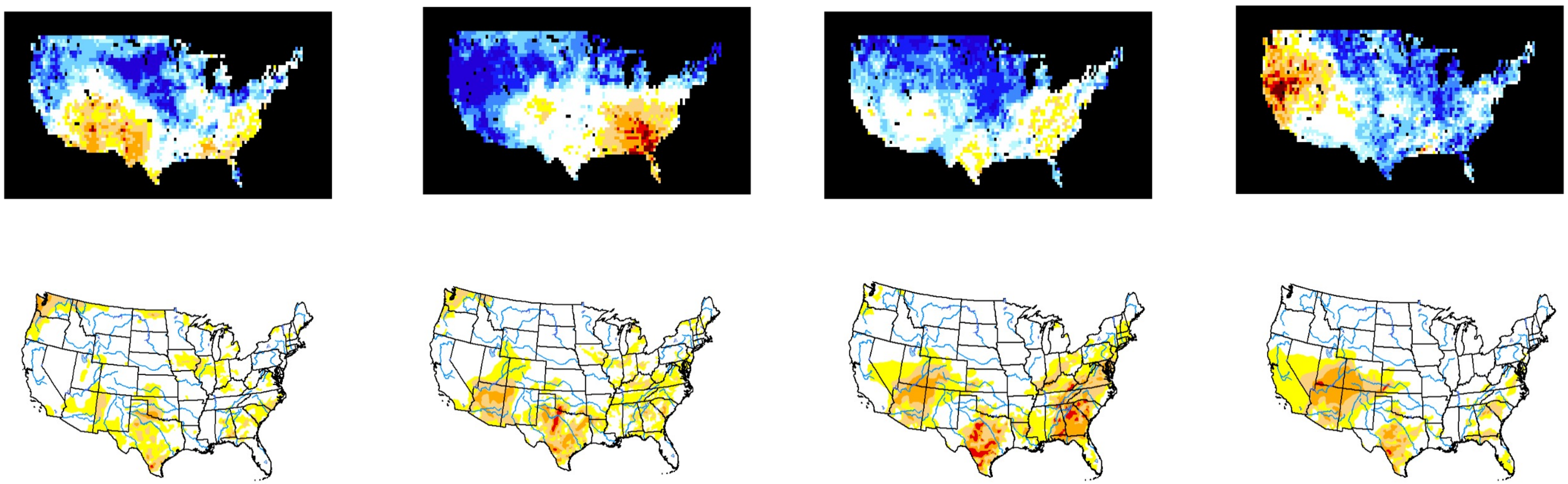
August 2019
September 2019
October 2019
November 2019
AIRS
SVPD1
MERRA
SPI1
MERRA
SSI1
USDM
50
40
30
-120
-110
-100
-90
-80
-70
1
0.5
0

Actual AIRS VPD drought images in 2019 Drought 28-day product

August 2019 | September 2019 | October 2019 | November 2019

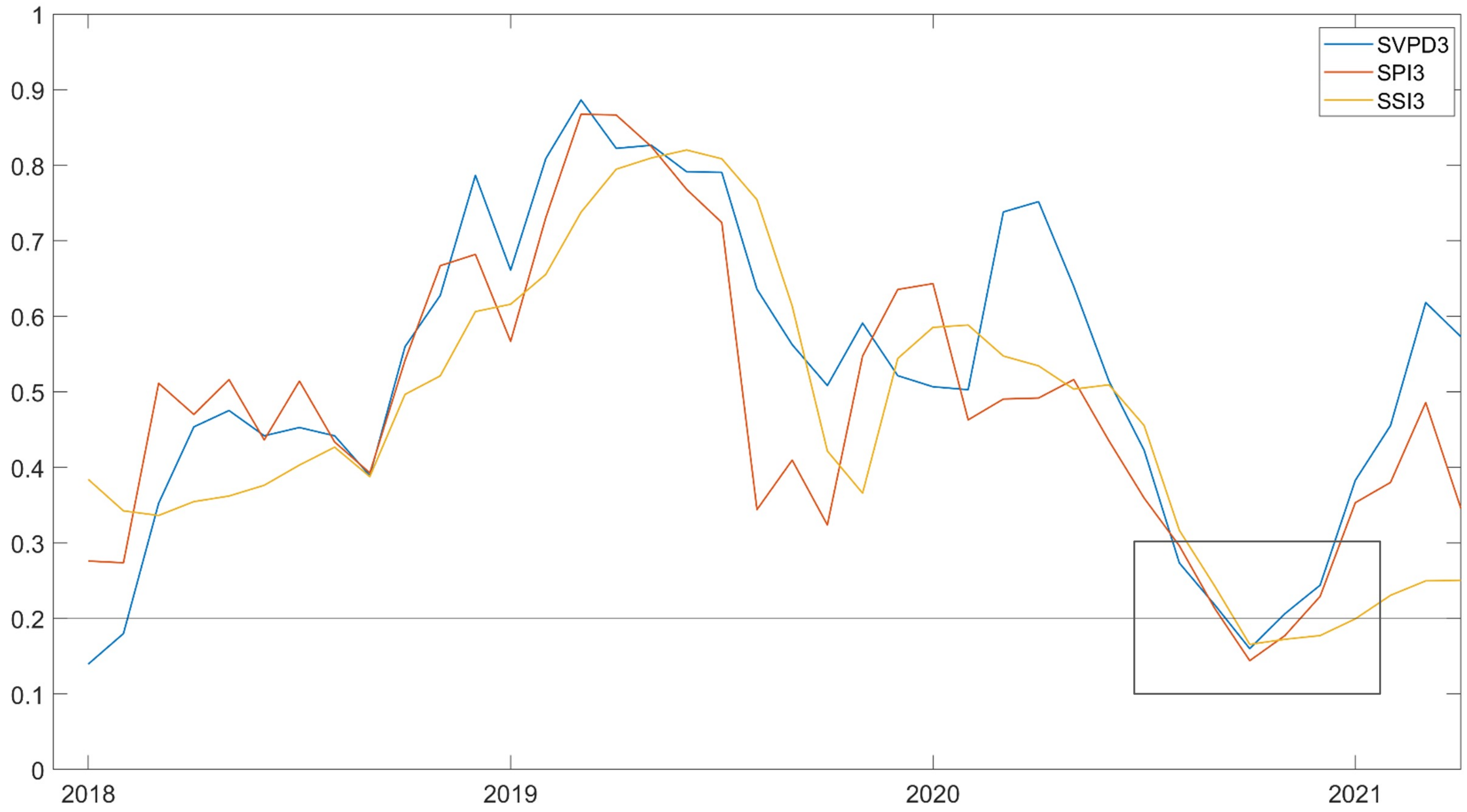
AIRS*

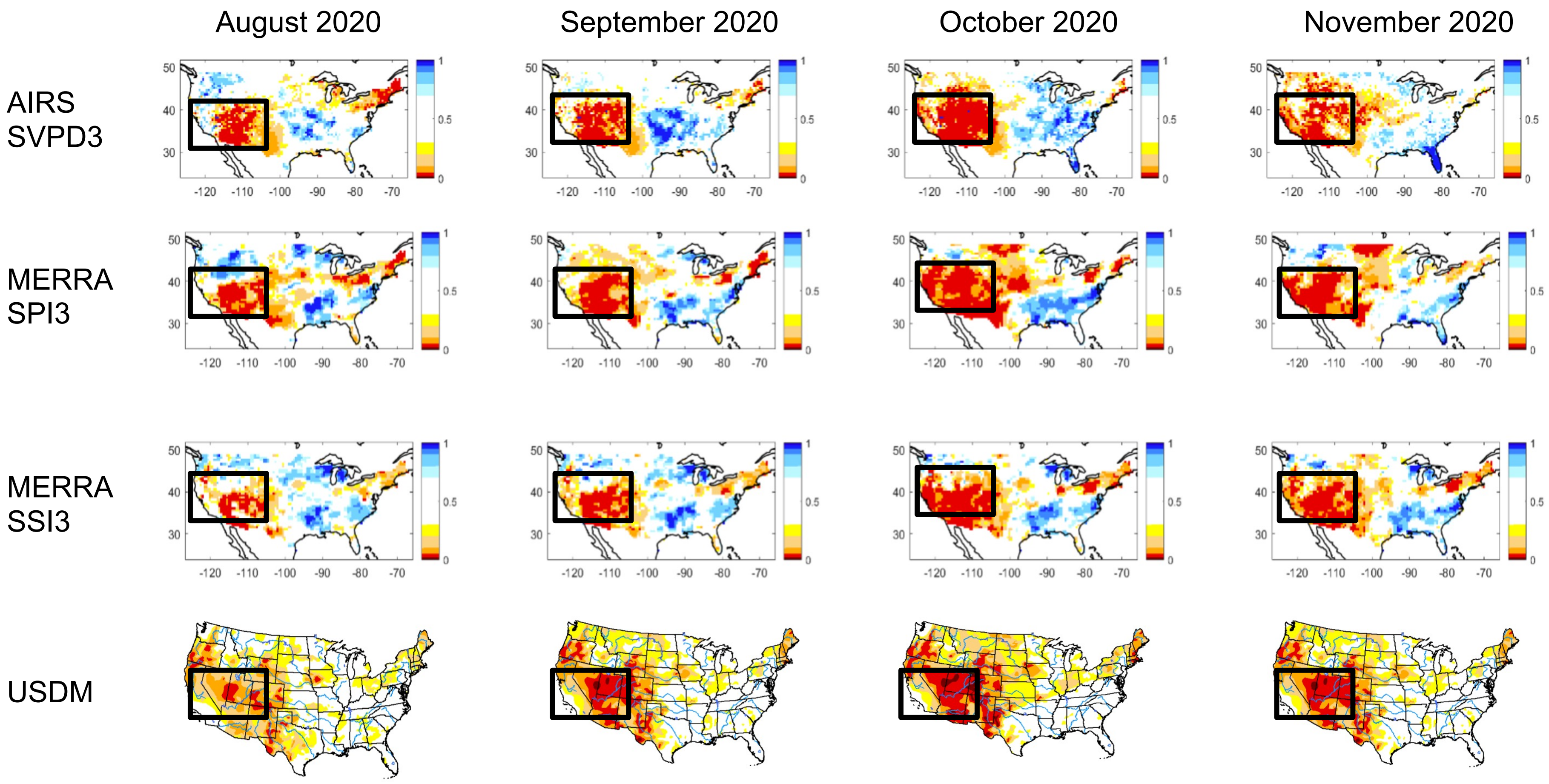
USDM



*USDM authors receive geotiffs of AIRS percentile data that have been reprojected. The AIRS images shown here are a visual representation of the geotiffs using the USDM colors.

Use Case 3 - 2020-2022 Western US Drought




August 2020
September 2020
October 2020
November 2020
AIRS SVPD3
MERRA SPI3
MERRA SSI3
USDM
50
40
30
-120 -110 -100 -90 -80 -70
1
0.5
0

Continuity

- **AIRS instrument to nominally cease operation ~2025, but sounder data to continue**
- **CrIS-ATMS will continue delivering similar capability**
    - Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) instruments onboard of Joint Polar Satellite System (JPSS) construct global atmospheric temperature, pressure and moisture profiles from space since 2011.
    - It’s likely the drought products will continue using data from the CrIS instrument. Plans are being considered at this time but are not in place.

Validation of products used in the generation of AIRS drought products

- Processing timeline – AIRS processing software is updated every three to five years and the entire mission data set is reprocessed using the new version
- All key variables are validated and compared with independent datasets such as from ground-based stations, other satellites and reanalysis datasets
- Results published in validation and testing reports
- AIRS Level 2 near-surface air temperature and relative humidity data used to produce the AIRS drought products released to the USDM are validated as part of this process
- Latest test report includes analysis of VPD, RH, and T
    - Based on the two latest versions of AIRS data
    - Focusing on the case of the 2011 major drought in Texas.
    - Both Version 6 and 7 are found to capture anomaly locations and time series in the 2011 Texas drought.

VPD in AIRS Version 7 Data Set

- Latest version of AIRS data available to the public is **Version 7**
  - Includes a global, daily VPD product
- Level 2 product:
  - Data organized according to satellite swath path at ~ 45 km resolution
  - Not gridded
- Same equations are used to calculate VPD as are used in AIRS products for USDM
- Comparison to long term data record is not included (data are not reported as percentiles)
  - But all the data needed to create a long term record for temperature, humidity and VPD are available from 2002-present
- Quality indicators are included for each data point

Resources

- **Website**
  - airs.jpl.nasa.gov/applications/drought
  - Training materials can be found on this page

- **Papers**

  - Farahmand, A., AghaKouchak, A., & Teixeira, J. (2015). A vantage from space can detect earlier drought onset: An approach using relative humidity. *Scientific reports*, *5*(1), 1-6.
  - Behrangi, A., Fetzer, E. J., & Granger, S. L. (2016). Early detection of drought onset using near surface temperature and humidity observed from space. *International Journal of Remote Sensing*, *37*(16), 3911-3923.
  - Behrangi, A., Nguyen, H., & Granger, S. (2015). Probabilistic seasonal prediction of meteorological drought using the bootstrap and multivariate information. *Journal of Applied Meteorology and Climatology*, *54*(7), 1510-1522.

- **AIRS data and user guides**
  - Data
    - Get AIRS data on NASA's Earthdata gateway
  - User Guides
    - About the AIRS data - entry point on the AIRS website for detailed information about the AIRS data
    - AIRS User Guide Suite archived at the GES DISC

Surveys

- **Brief survey immediately after today's training**
  - A short survey will immediately follow our training today
  - Help gauge the effectiveness of the training
  - Determine how much time is needed before a longer follow up survey is distributed
- **Longer survey after a TBD period of time**
  - After a period of time has passed where authors have had the opportunity to use the AIRS data products, you will be contacted to participate in an online survey
  - Determine if the training was helpful
  - Determine if there are ways we can improve the drought products from AIRS or other drought related products from NASA

5 minute break - *regroup at* ***1:00PM PT***

Q&A

1. We will first cover any questions from the chat.
2. If you have additional questions or comments, please raise your hand. If we run out of time to answer your question, please add it in the chat so we can answer it via email.

Thank you for your time!

And thank you to Brian Fuchs for his help in support of this training.

If you have further questions about the AIRS drought products, please contact:

Alireza Farahmand at alireza.farahmand@jpl.nasa.gov
or Sharon Vasquez-Ray at sharon.ray@jpl.nasa.gov

Today's materials can be found on the AIRS website at:
airs.jpl.nasa.gov/drought

End recording. Next up - survey