Assessing the Evolution of Soil Moisture and Vegetation Conditions During the 2012 United States Flash Drought

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Dataset Descriptions

- Evaporative Stress Index (ESI) – Depicts standardized anomalies in evapotranspiration (ET) using satellite thermal infrared imagery

- VegDRI – Empirical method that combines satellite observations with climate data to identify drought-stressed vegetation

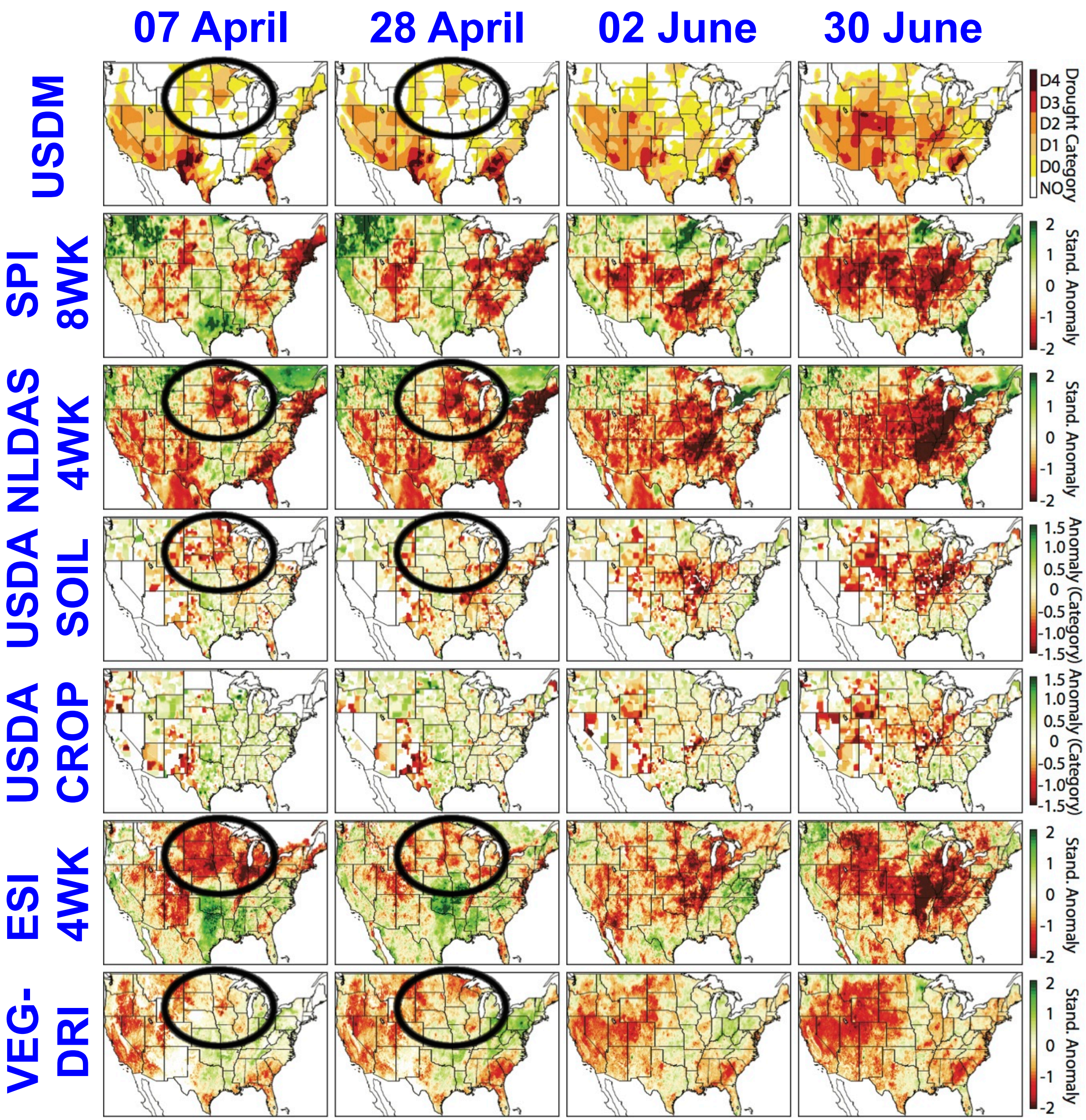
- Standardized Precipitation Index (SPI) – Precipitation anomalies

- NLDAS – Topsoil (0-10 cm) and total column soil moisture (0-2 m) anomalies from the Noah, Mosaic, and VIC models

- U.S. Drought Monitor – Widely used drought analysis

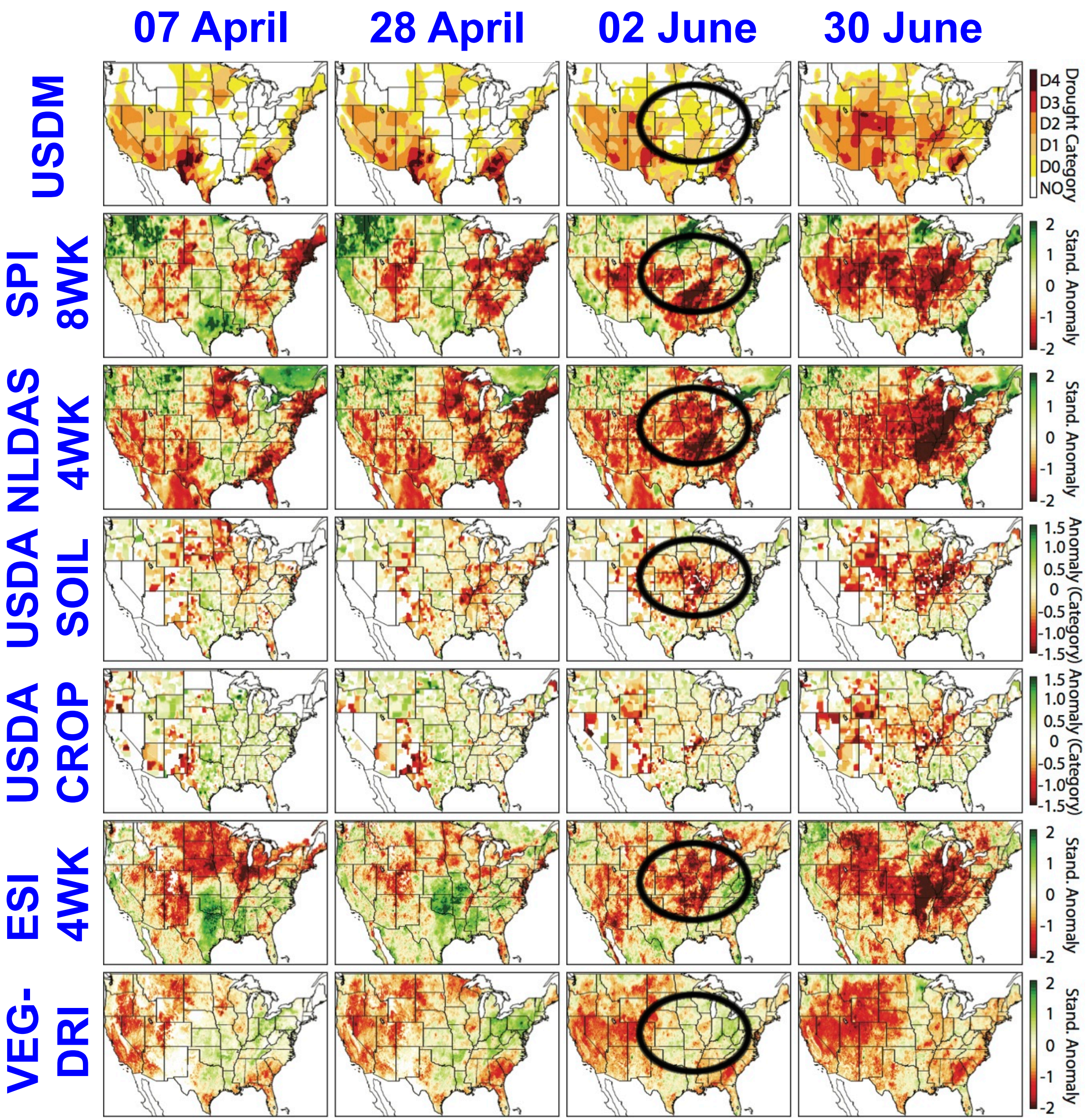
- USDA Soil Moisture and Crop Conditions – Provides county level estimates of top soil and subsoil moisture conditions as well as the conditions of major agricultural crops (e.g. corn, soybeans, winter wheat, and spring wheat)

2012 Flash Drought Evolution



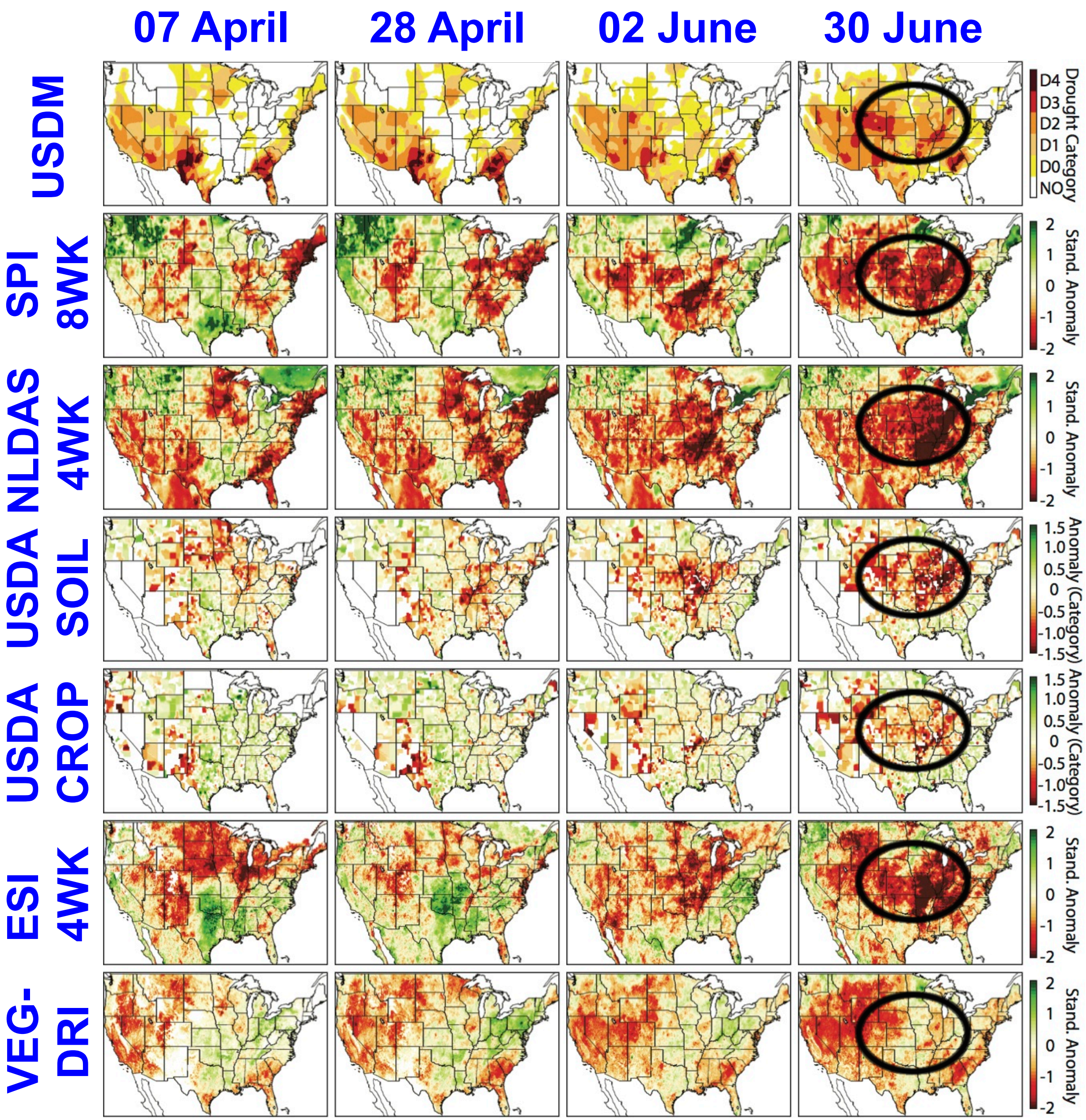
- In April, drought was present across the SW, NC, and eastern U.S.
- Well captured by the NLDAS and ESI
- Large negative ESI anomalies across the north-central U.S.
- Indicate short-term moisture stress in new vegetation consistent with USDA anomalies
- Drought continued to slowly expand during April according to most of the datasets

2012 Flash Drought Evolution



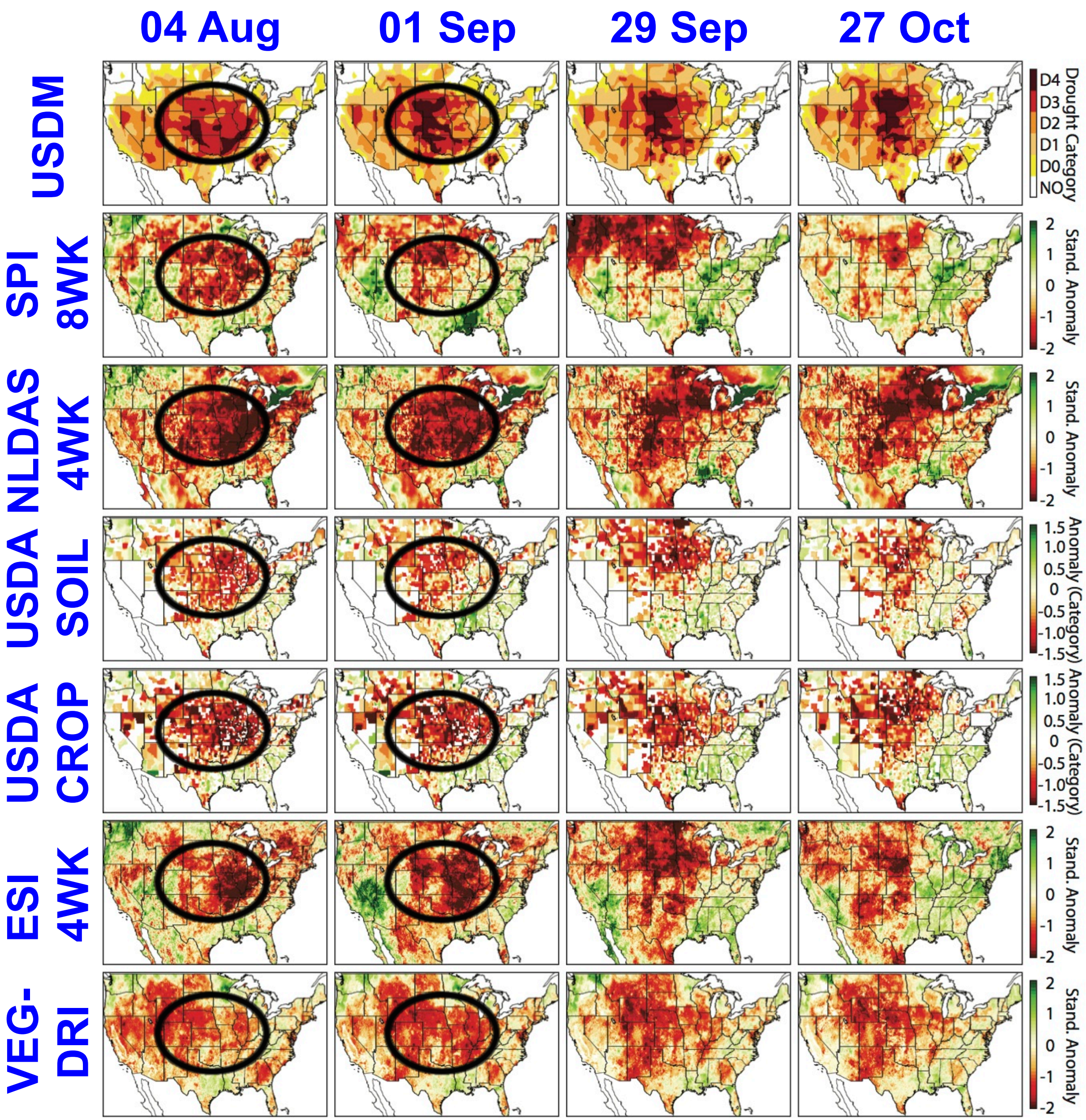
- By beginning of June, large negative SPI values had developed across the SC U.S.
- Rapid transition also evident in the ESI and NLDAS datasets
- Consistent with the negative anomalies in the USDA topsoil moisture dataset
- VegDRI response to rapidly changing conditions was slower because of reliance on long-term climate data

2012 Flash Drought Evolution



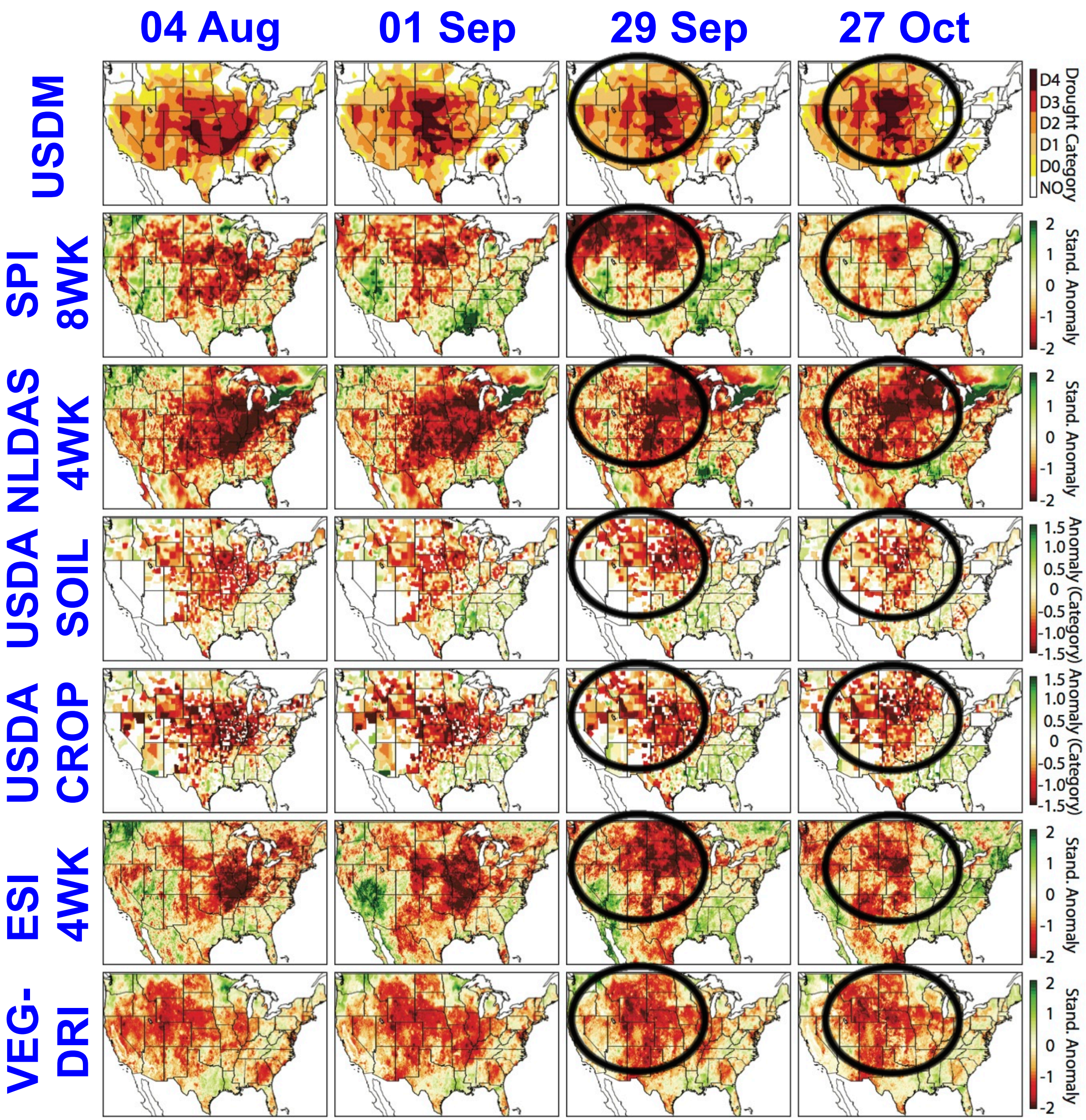
- Conditions continued to rapidly deteriorate during June due to onset of very hot and dry weather
- Large negative topsoil anomalies in NLDAS and USDA datasets
- Crop conditions were beginning to rapidly deteriorate
- ESI and NLDAS datasets accurately represent spatial extent, but are more severe than the USDM

2012 Flash Drought Evolution



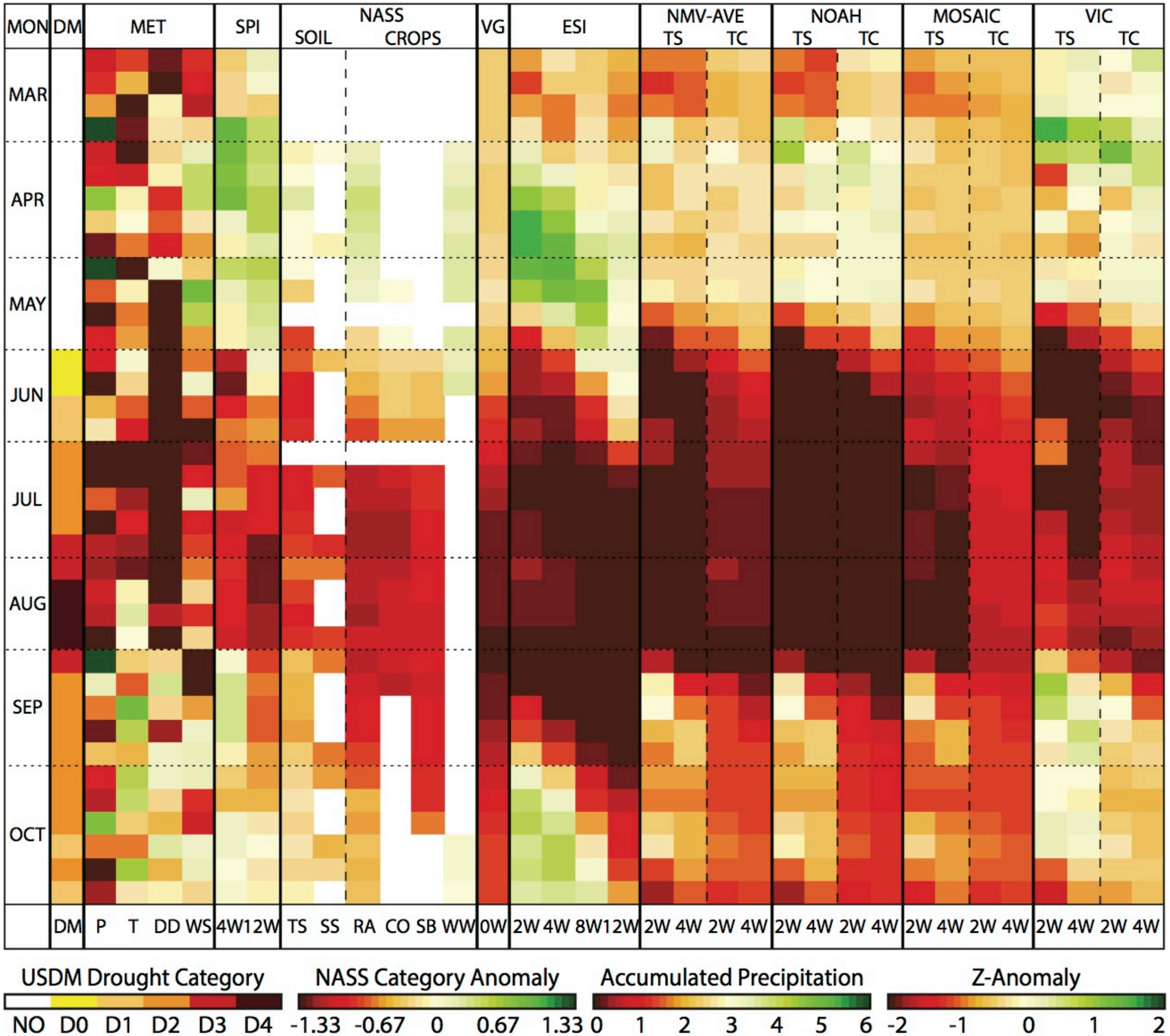
- Many locations had experienced flash drought during the previous two months
- Very large ESI and NLDAS anomalies co-located with negative SPI anomalies
- Improvements along eastern edge of core drought region
- Crop conditions did not improve much
- VegDRI accurately captures the spatial extent of the drought

2012 Flash Drought Evolution



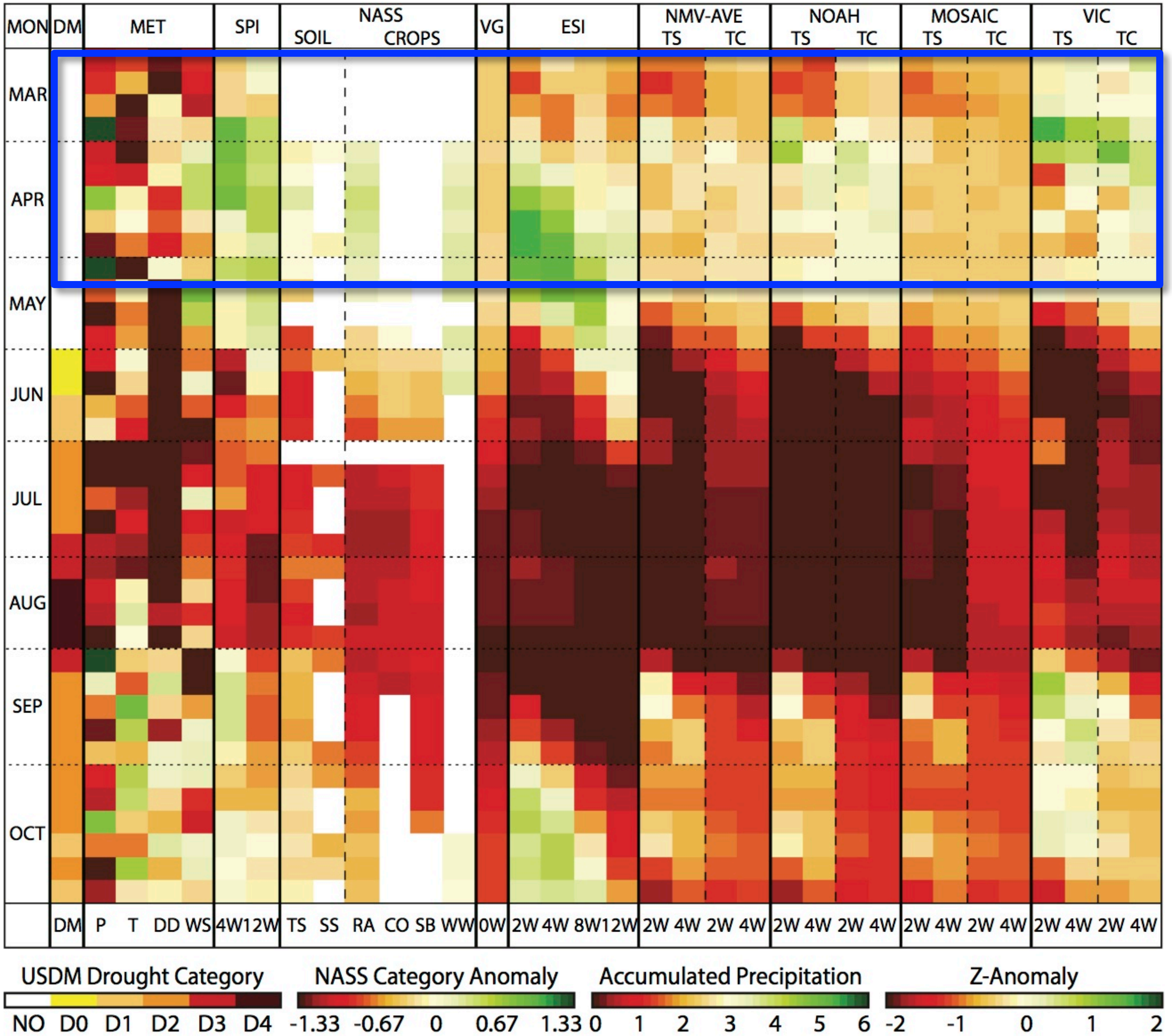
- Warm, dry weather led to northwestward expansion of drought
- Large negative ESI, NLDAS, and VegDRI anomalies across the central U.S.
- USDA crop condition and topsoil moisture anomalies have also become larger
- Wet weather to the east improved crop conditions and soil moisture status along Mississippi River

West-Central Missouri Drought Evolution



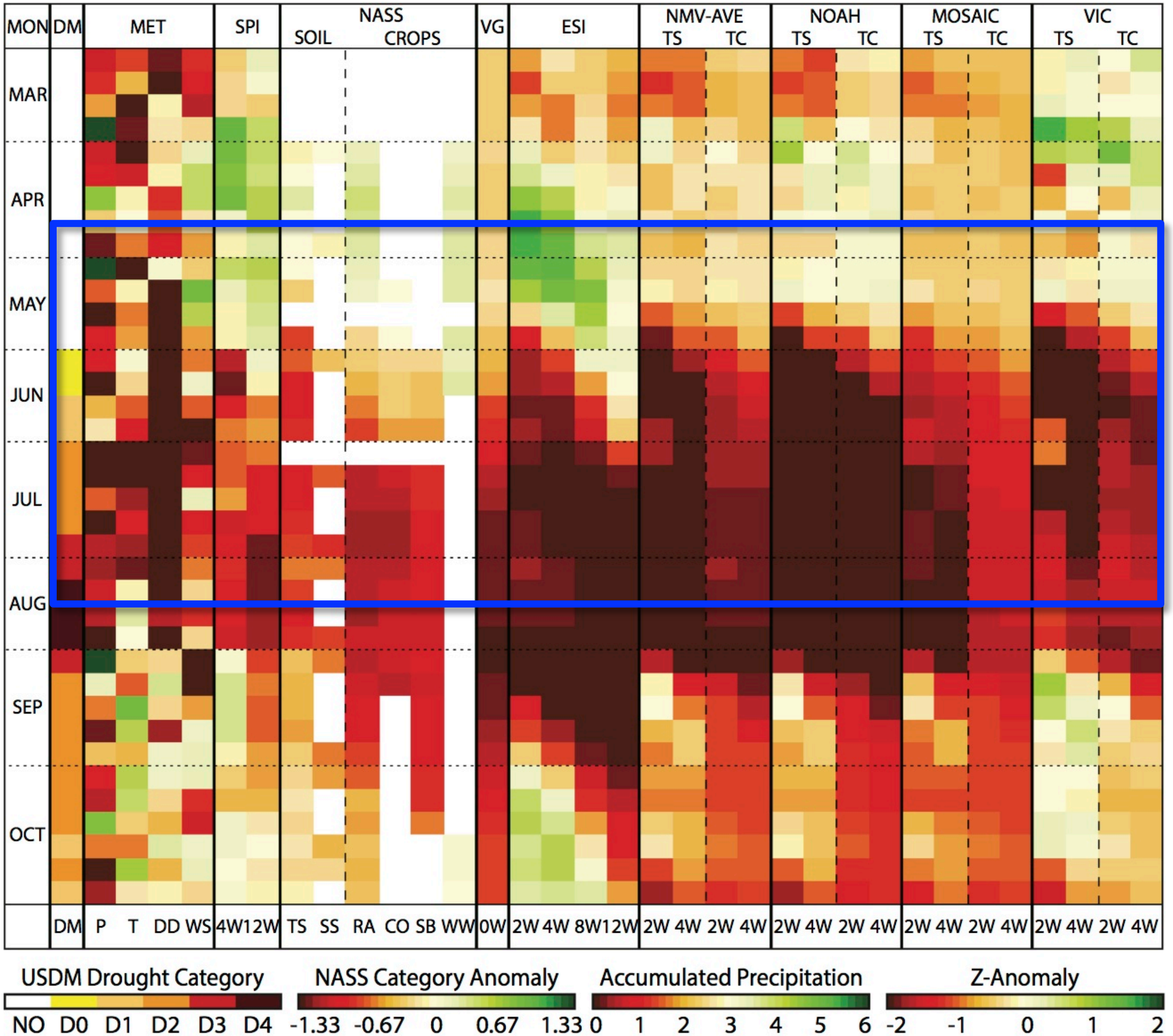
- **Column 1** –USDM
- **Cols 2-5** – Surface weather anomalies
- **Cols 6-7** – 4 and 12-week SPI
- **Cols 8-13** – USDA NASS soil and crop condition anomalies
- **Col 14** – VegDRI anomalies
- **Col 15-19** – 2, 4, 8, and 12 week ESI anomalies
- **Columns 20-35** – NLDAS topsoil and total column soil moisture anomalies

West-Central Missouri Drought Evolution



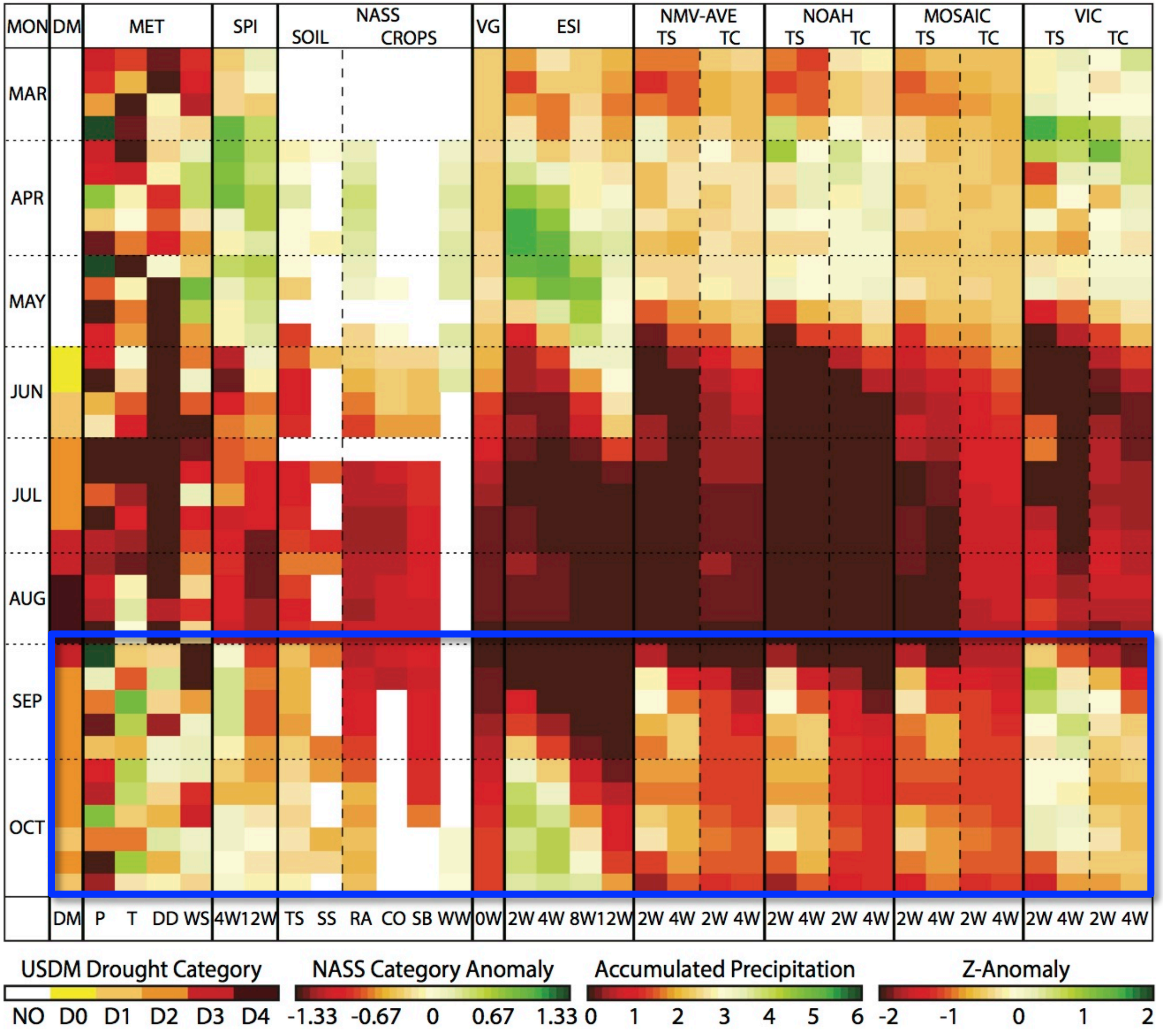
- Abnormally dry conditions during March alleviated by heavy rainfall in April and May
- Positive ESI anomalies indicate that the vegetation responded well to the heavy rainfall
- Consistent with improved USDA range and winter wheat conditions
- Improvements also noted in the VegDRI and NLDAS datasets

West-Central Missouri Drought Evolution



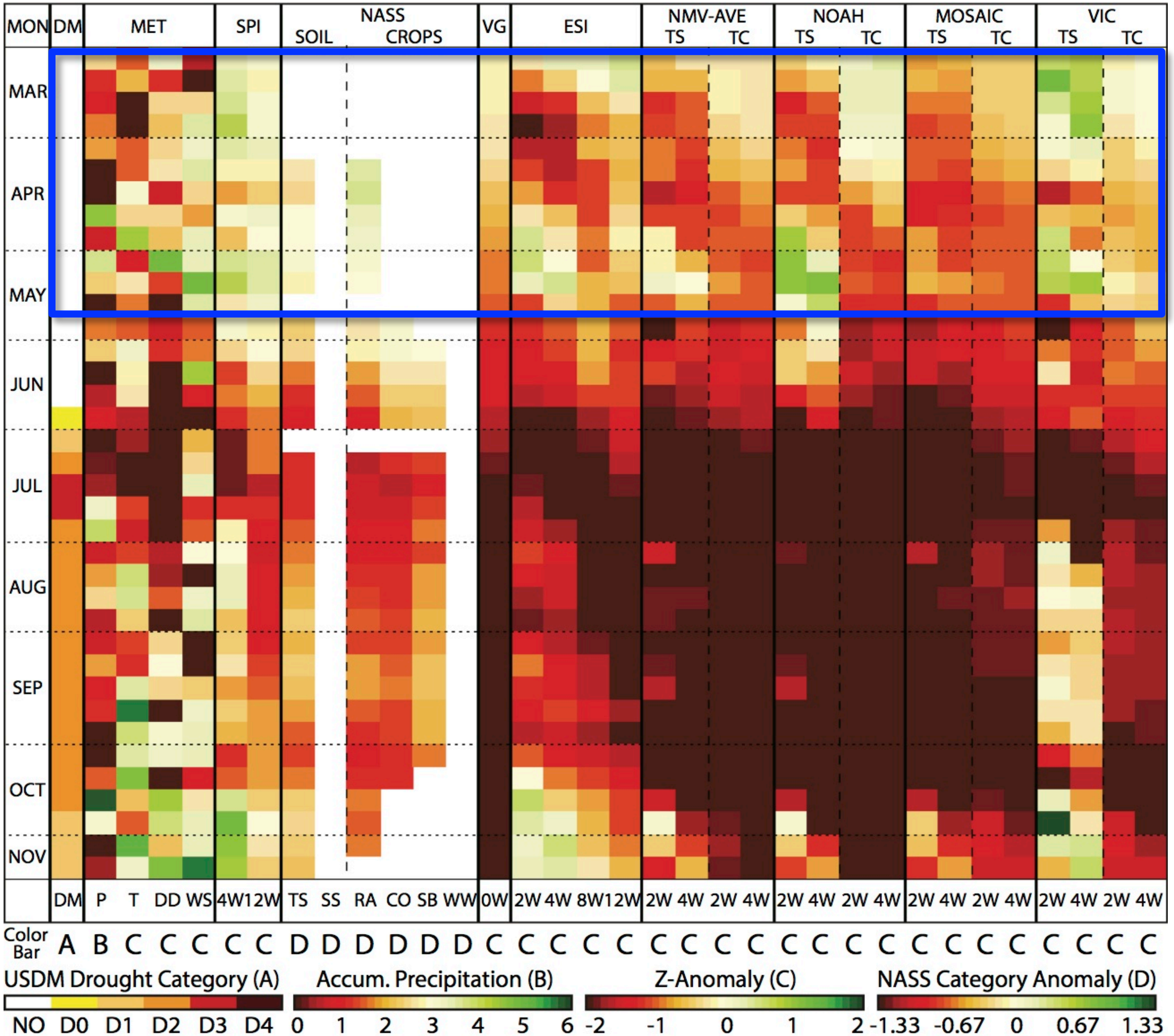
- Crop and soil moisture status deteriorated in May and June
- Short-range ESI anomalies rapidly decreased during drought onset
- NLDAS models also show rapid decreases
- Changes first appeared in the topsoil moisture
- VIC model more sensitive to small rainfall events

West-Central Missouri Drought Evolution



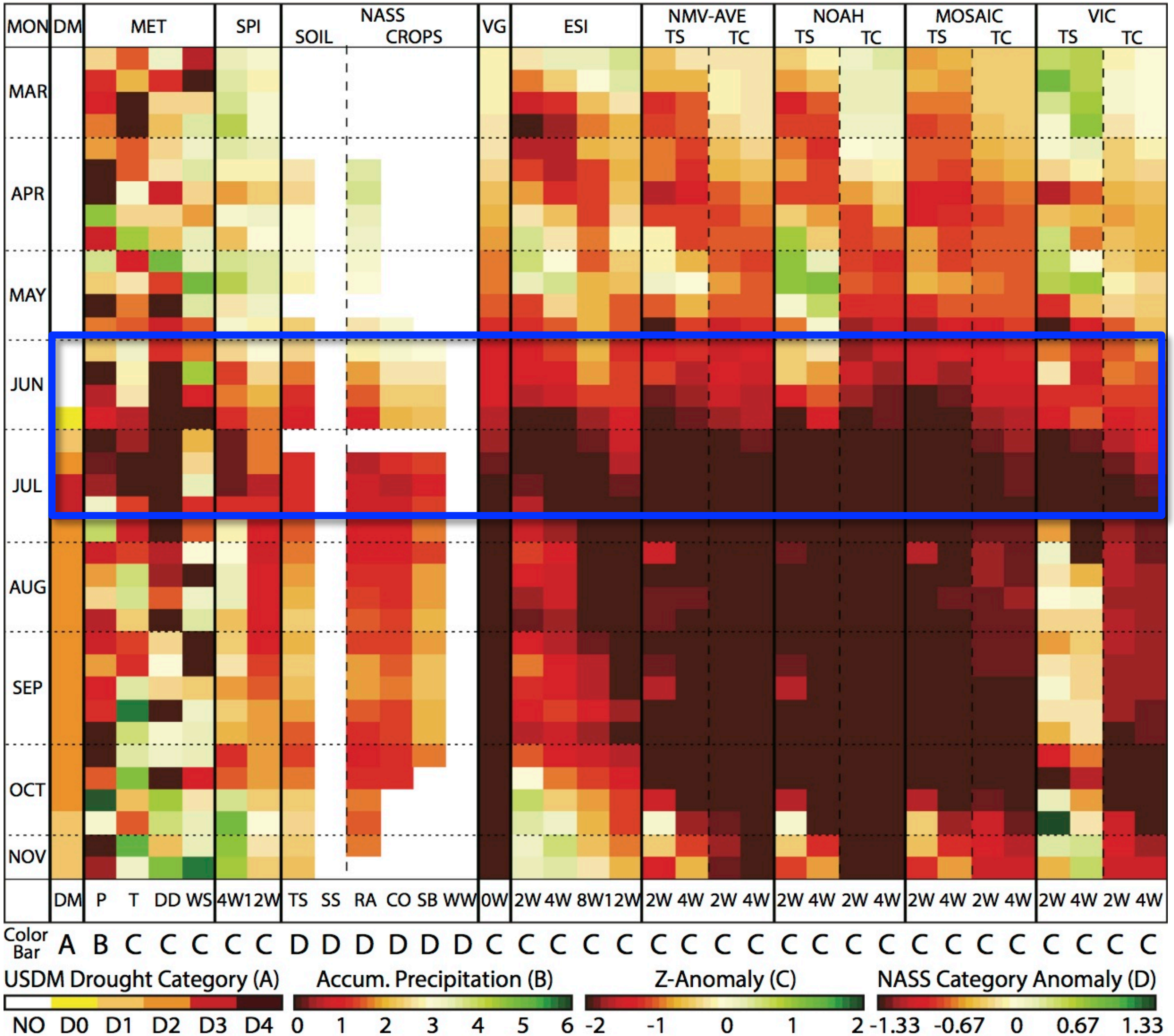
- Heavy rainfall in September led to large improvement in NLDAS models
- ESI did not recover as quickly because the vegetation was so badly damaged
- Initial lack of improvement in the ESI anomalies is consistent with USDA crop health
- Improvement in USDM due to the rainfall rather than vegetation health

South-Central Wisconsin Drought Evolution



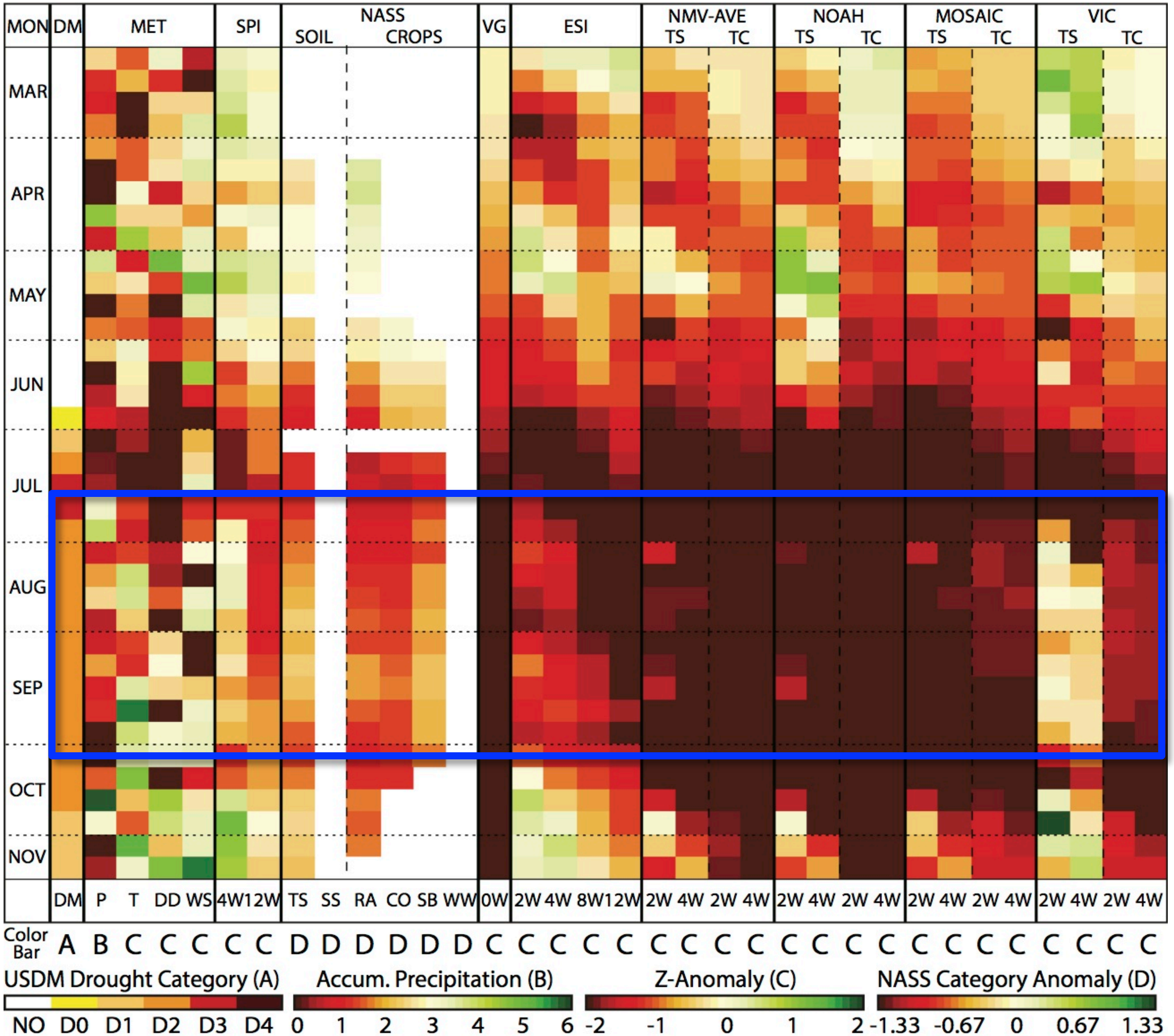
- Record warm temperatures in March led to neg. anomalies in most datasets
- Exception was VIC model, which had positive TS anomalies
- Rainfall in April led to positive TS anomalies in Noah and VIC, but not Mosaic
- Correspondence between NLDAS TS anomalies and short-range ESI

South-Central Wisconsin Drought Evolution



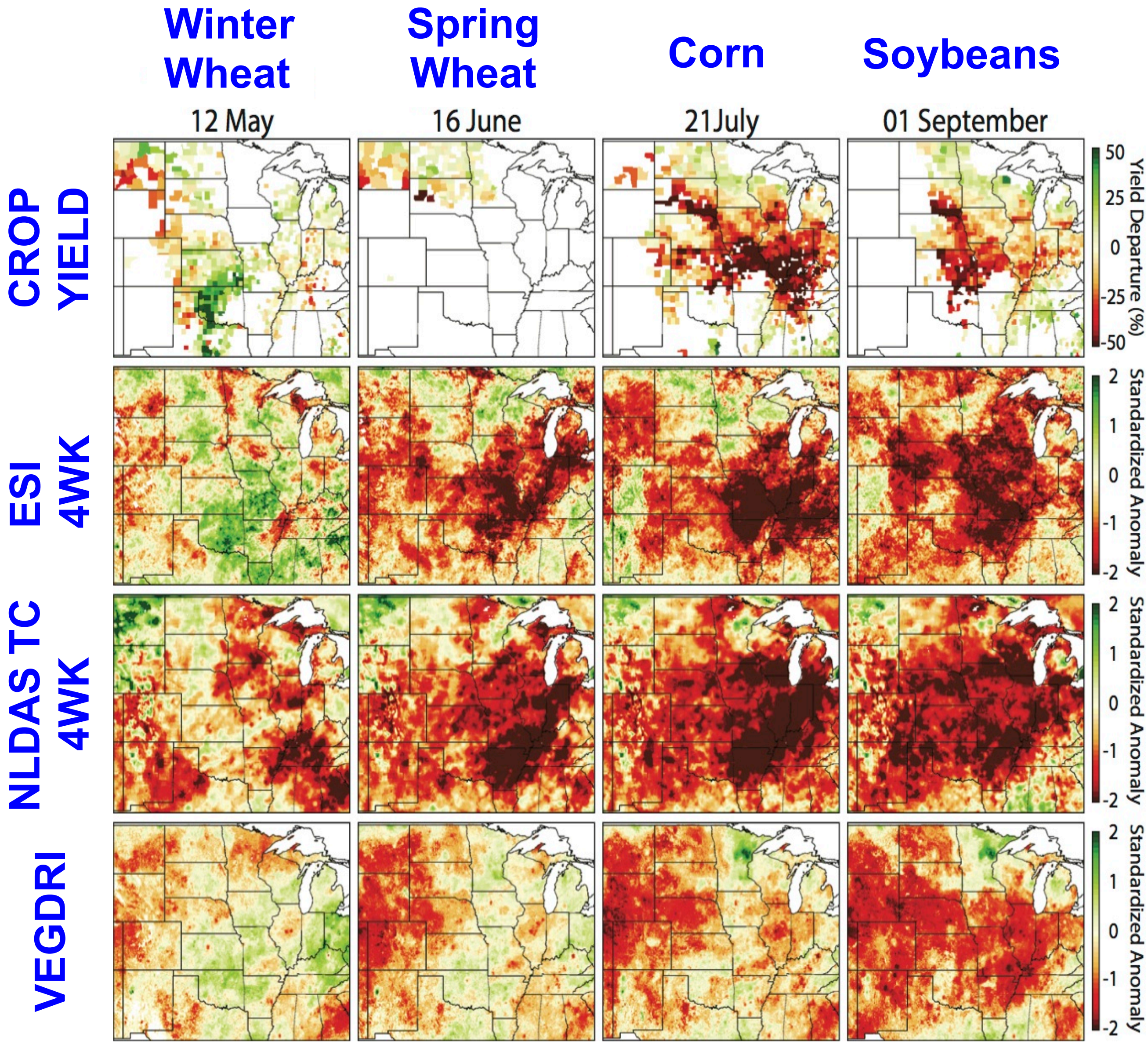
- Extreme weather anomalies in June and July
- ESI and NASS datasets rapidly deteriorated
- All of the NLDAS models were very negative for both TS and TC
- USDM depicted a 4-cat increase in drought severity over 4 weeks
- **Very rapid flash drought development**

South-Central Wisconsin Drought Evolution



- Heavy rainfall in late July allowed for some minor improvement in the ESI
- Only the VIC model had similar improvements in the topsoil moist.
- Based on NASS and ESI datasets, VIC is likely too wet, but Noah and Mosaic are too dry
- **Again shows the wide range of responses to the same input**

Crop Yield Impact Analysis



- Examine drought conditions during critical crop stages
- Strong relationship between wheat yield and the ESI and VegDRI during critical crop stages
- NLDAS has strong (weak) relationship to corn/soybeans (wheat) yield
- ESI had strongest correlation to the wheat, corn, and soybean yield departures

References

Otkin, J. A., and CoAuthors, 2016: Assessing the evolution of soil moisture and vegetation conditions during the 2012 United States flash drought. *Agr. Forest Meteorol.*, **218–219**, 230–242.

Otkin, J. A., M. Shafer, M. Svoboda, B. Wardlow, M. C. Anderson, C. Hain, and J. Basara, 2015: Facilitating the use of drought early warning information through interactions with stakeholders. *Bull. Am. Meteorol. Soc.*, **96**, 1073-1078.

Otkin, J. A., M. C. Anderson, C. Hain, and M. Svoboda, 2015: Using temporal changes in drought indices to generate probabilistic drought intensification forecasts. *J. Hydrometeor*, **16**, 88-105.

Otkin, J. A., M. C. Anderson, C. Hain, and M. Svoboda, 2014: Examining the relationship between drought development and rapid changes in the Evaporative Stress Index. *J. Hydrometeor.*, **15**, 938-956.

Otkin, J. A., M. C. Anderson, C. Hain, I. Mladenova, J. Basara, and M. Svoboda, 2013: Examining flash drought development using the thermal infrared based Evaporative Stress Index. *J. Hydrometeor.,* **14***,* 1057-1074.

Anderson, M. C., C. Hain, J. A. Otkin, X. Zhan, K. Mo, M. Svoboda, W. Dulaney, and A. Pimstein, 2013: An intercomparison of drought indicators based on thermal remote sensing and NLDAS-2 simulations with U.S. Drought Monitor classifications. *J. Hydrometeor.,* **14***,* 1035-1056.