Decadal Drought Risk Assessment and Scenario Development for Food and Bio-fuels Agriculture in Four Sub-basins in the Missouri River Basin

Acknowledgements

Projects supported by NOAA-CPO-Sectoral Applications Research Program 2015-2018

and

USDA-National Institute for Food and Agriculture 2011-2017

The Project People

Vikram Mehta and Katherin Mendoza

The Center for Research on the Changing Earth System, Catonsville, Maryland

Cody Knutson, Nicole Wall, and Tonya Bernadt

National Drought Mitigation Center, Univ. of Nebraska – Lincoln, Nebraska

Project Objectives

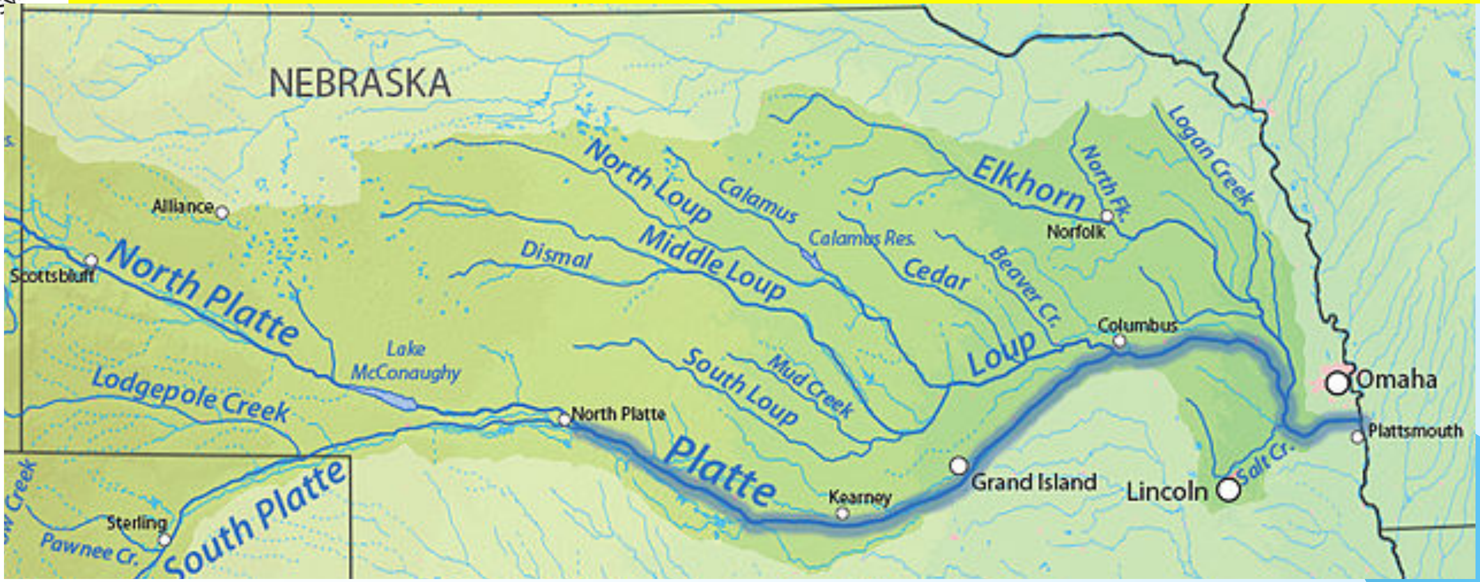
- To define decadal drought information needs of agricultural stakeholders in four selected sub-basins of the Missouri River Basin.

- To conduct a scenario-planning exercise for coping with multiyear to decadal droughts in these sub-basins.

Round 1

31 March 2017

Development of Climate-Adaptive Water and Agriculture Management System in the Central Platte Sub-basin



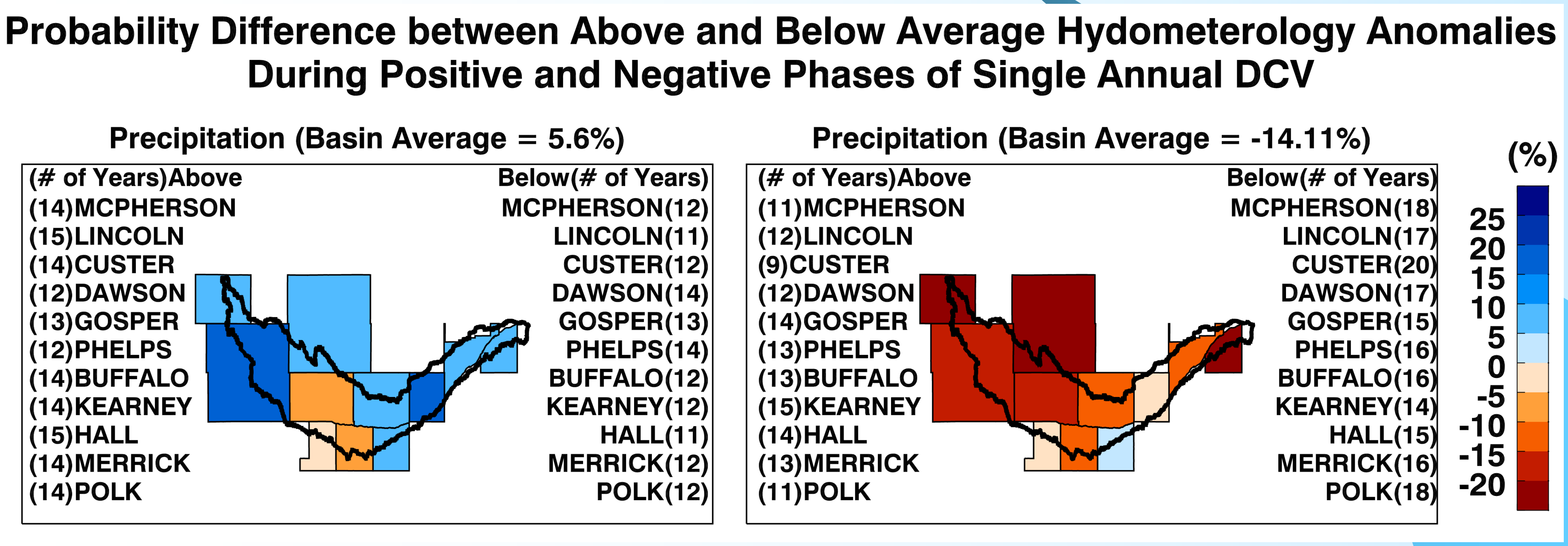
Why the Central Platte?

- One of the most endangered waterways in the country.
- Substantial and identifiable DCV signals in precipitation, temperature, crops, and stream flow.
- Important agricultural region with mostly irrigated crops (corn, soybeans, alfalfa).
- Recreation and wildlife/conservation sectors also important.
- Management of Platte River during drought to benefit ag. producers and urban areas, and during floods to prevent property damage.

The PDO and Differences in Probabilities of Above/Below Average Precipitation: 1961-2015

PDO Warm

PDO Cold

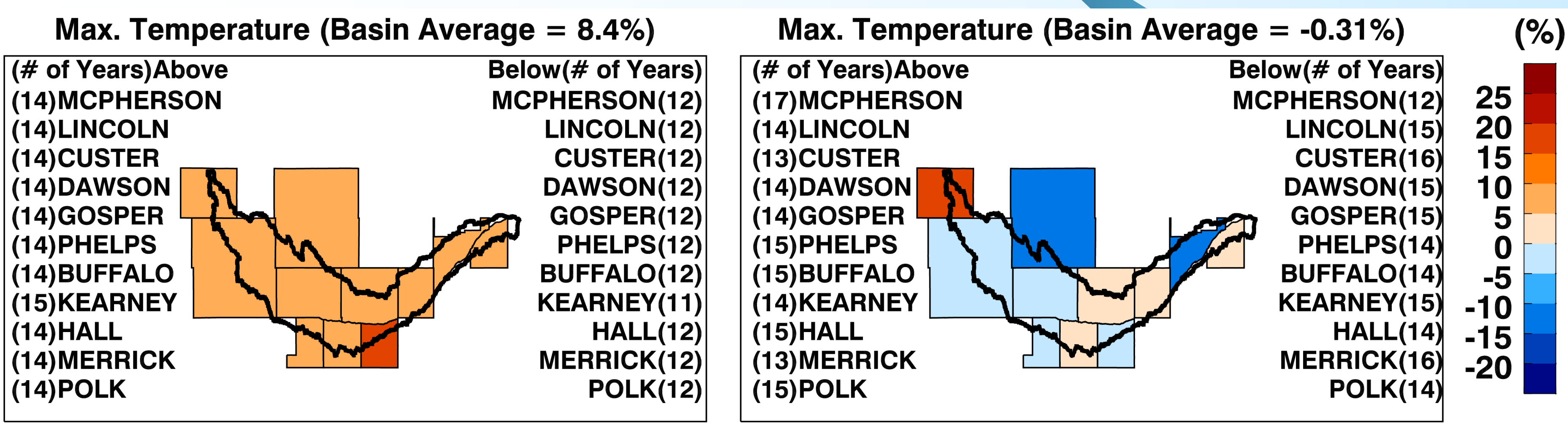


PDO Warm – Wet; PDO Cold - Dry

The PDO and Differences in Probabilities of Above/Below Average Daily Max. Temperature: 1961-2015

PDO Warm

PDO Cold



PDO Warm – Warm; PDO Cold - Cool

PDO Warm – Wet and Warm; PDO Cold – Dry and Cool

The PDO and Differences in Probabilities of Above/Below Average Streamflow, Precipitation, and Daily Max. Temperature: 1961-2015

Location (County)	PDO State	Probability Difference of Above/Below Average Streamflow (%)	Probability Difference of Above/Below Average Precipitation (%)	Probability Difference of Above/Below Average Daily Max. Temperature (%)
Platte River near Grand Island, NE (Hall)	Warm/Cold	-15/-45	15/-3	8/3
South Loup River near St. Michael, NE (Buffalo)	Warm/Cold	-8/-59	8/-10	8/3
Platte River near Overton, NE (Dawson)	Warm/Cold	-8/-59	-8/-17	8/-3
Platte River near Duncan, NE (Platte)	Warm/Cold	-23/3	8/-24	8/3

Probabilities of streamflow changes are in physical agreement with probabilities of precipitation and daily max. temperature changes where we have USGS streamflow data.

The PDO and Crop Yields in the Central Platte Sub-basin

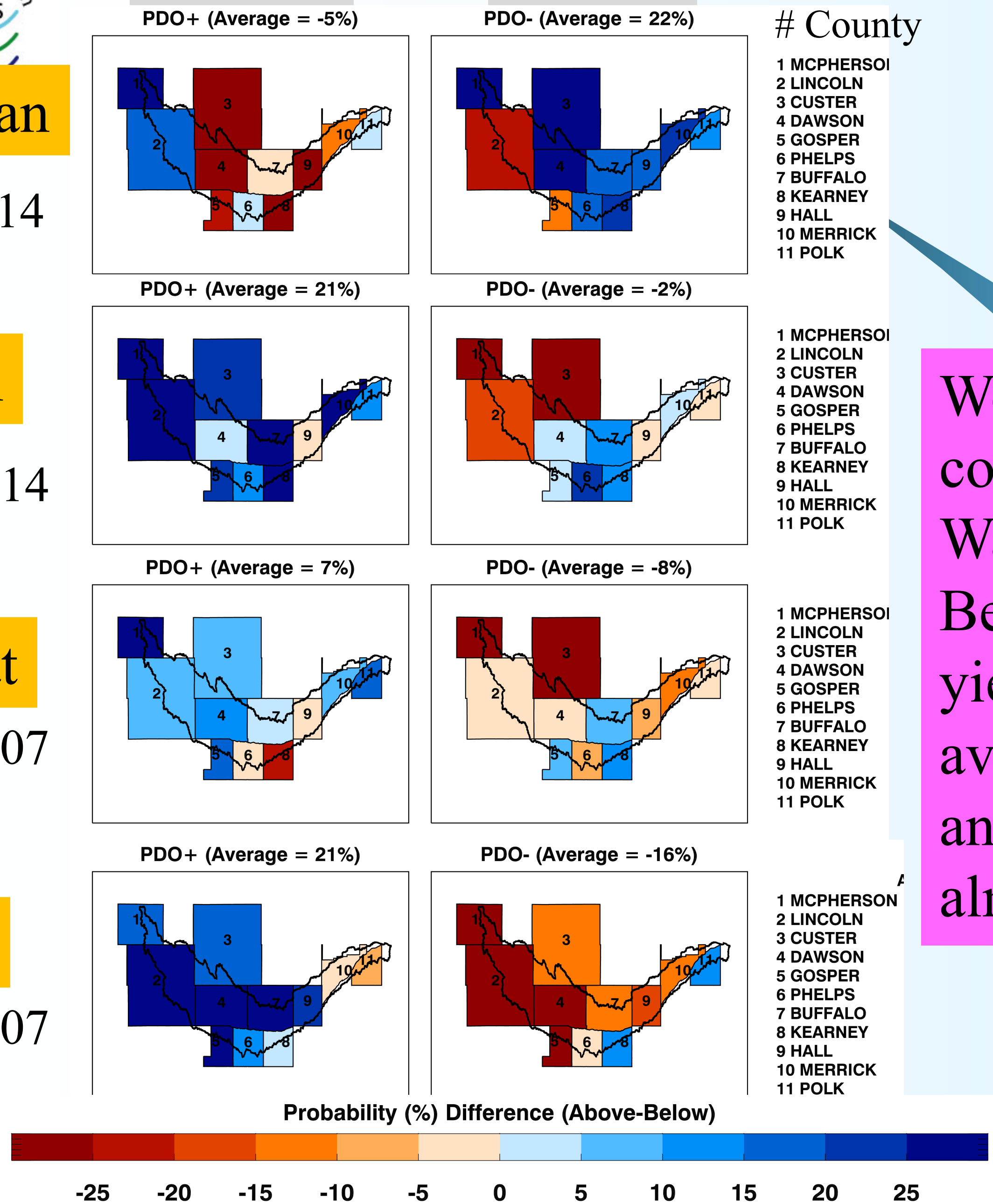
PDO Warm | PDO Cold

Soybean
1961-2014

Corn
1961-2014

Wheat
1961-2007

Hay
1961-2007



USDA-NASS data from 1961 to 2014

Wetter and warmer conditions in PDO Warm phase:
Below average soybean yields; and above average wheat, corn, and hay yields in almost all counties

Roles of the Project and Stakeholder Advisory Teams

Project Team

☞ Introduced natural decadal climate variability (DCV) phenomena or cycles.

☞ Showed associations between these climate cycles, and dry/wet cycles, crop yields and productions in the Central Platte sub-basin (JSB).

Stakeholder Advisory Team

☞ Provided detailed and quantitative information about agriculture and water resources in CP; and about present and future use of corn and other crops to produce bio-fuels.

☞ Described perceptions of these dry/wet cycles and impacts on water and crops.

☞ Discussed how they might have used this information if provided as forecasts.

Your Responses

Agriculture and Water Resources

☞ Surface and ground water used for irrigation.

☞ 75% of irrigated land in the MRB in CP; a large increase in irrigated land in last 30 years.

☞ Land irrigated by surface water first to suffer from drought.

☞ Most farms change from surface to ground water during lower precipitation, so a substantial change in crops due to drought not seen.

☞ Irrigation highest priority, then hydro-electricity; low flow conditions, hydro-electricity plants shut down.

☞ No irrigated wheat, only dryland wheat.

☞ Corn/soybean rotation 65:35, with 2 years of corn and 1 of soybean.

Your Responses

Perceptions of Dry and Wet Cycles

☞ CP can withstand 3-5 years of drought.

Potential usefulness of predictions

☞ To decide between soybean and sorghum in dryland planting.

☞ Forecast in autumn would help in planting decisions (what and how much to plant) following spring.

☞ Forecast of PDO impacts on Rocky Mountain snow pack.

☞ Forecast during various times in the crop cycle – Autumn, winter, early spring.

☞ Forecast in four categories – Very Dry, Dry, Wet, Very Wet.

Bio-fuels production

☞ 40-45% corn grown in Nebraska used for ethanol; not much soybean for bio-diesel.

Round 2
Today

To conduct a scenario-planning exercise for coping with multiyear to decadal droughts.

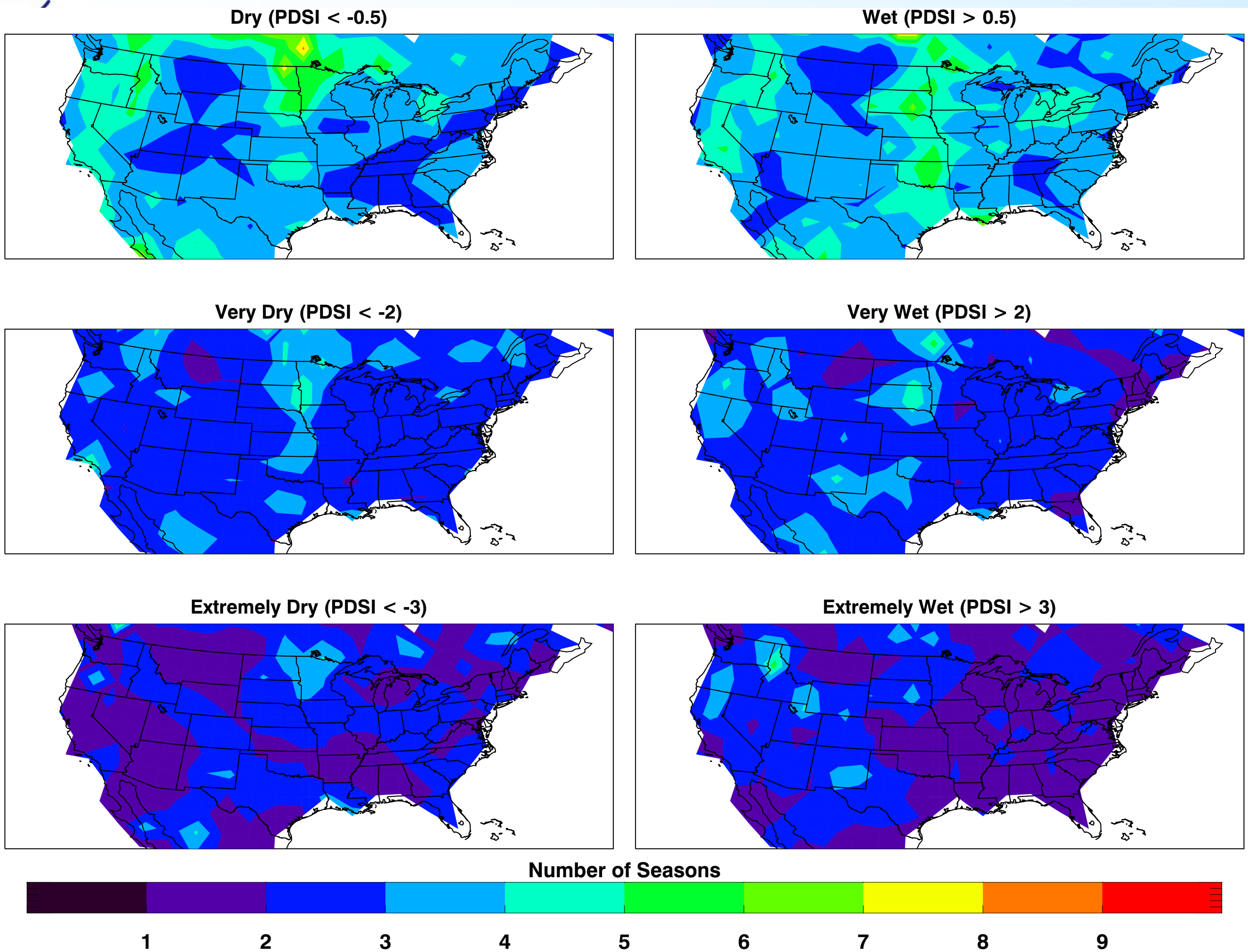
Two types of scenarios

1. **Based on observed data in the last 10 years**
2. **Based on a hydrology-land use-crop model the Soil and Water Assessment Tool (SWAT)**
   - **Average climatic conditions**
   - **Extreme climatic conditions**

Average persistence of dryness/wetness: 1915 - 2014

DRYNESS

WETNESS



1.5 yrs.

1.5 yrs.

1 yr.

1 yr.

.5-1 yrs.

< 1 yr.

Maximum persistence of dryness/wetness: 1915 - 2014

The Center for Research on the Changing Earth System

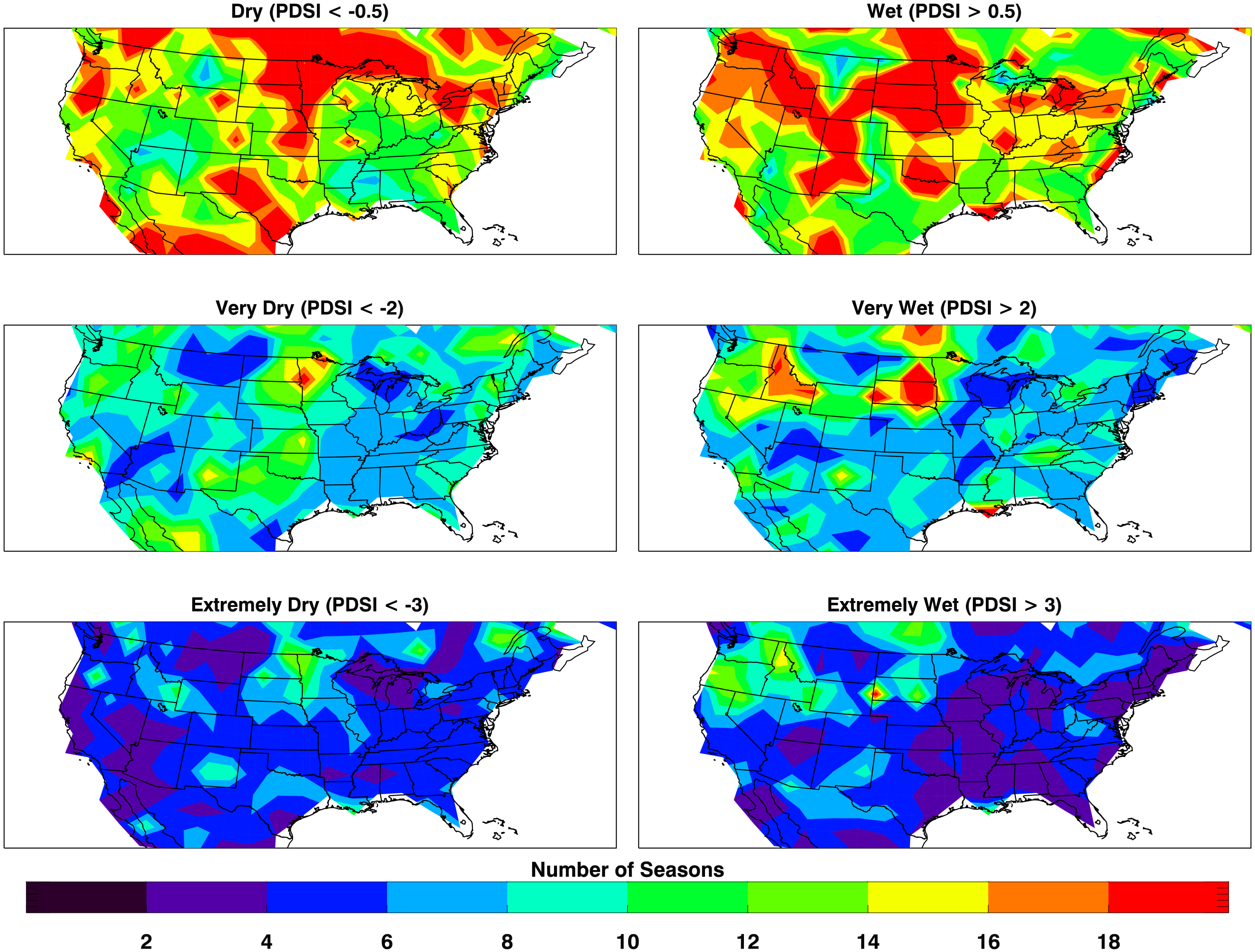
CRCES

DRYNESS | WETNESS

4 yrs. and longer | 4 yrs. and longer

2-3 yrs. | 3-4 yrs.

1-2 yrs. | 1-2 yrs.



Frequencies of dry and wet epochs 1915 - 2014

DRYNESS

Severity	4 to 7 seasons	8 to 11 seasons	12+ seasons
Low	7	6	2
Medium	7	1	0
High	4	0	0

WETNESS

Severity	4 to 7 seasons	8 to 11 seasons	12+ seasons
Low	12	3	3
Medium	4	1	2
High	3	0	0

Potential predictability of dryness/wetness using SON PDO and TAG indices as predictors: 1915 - 2014

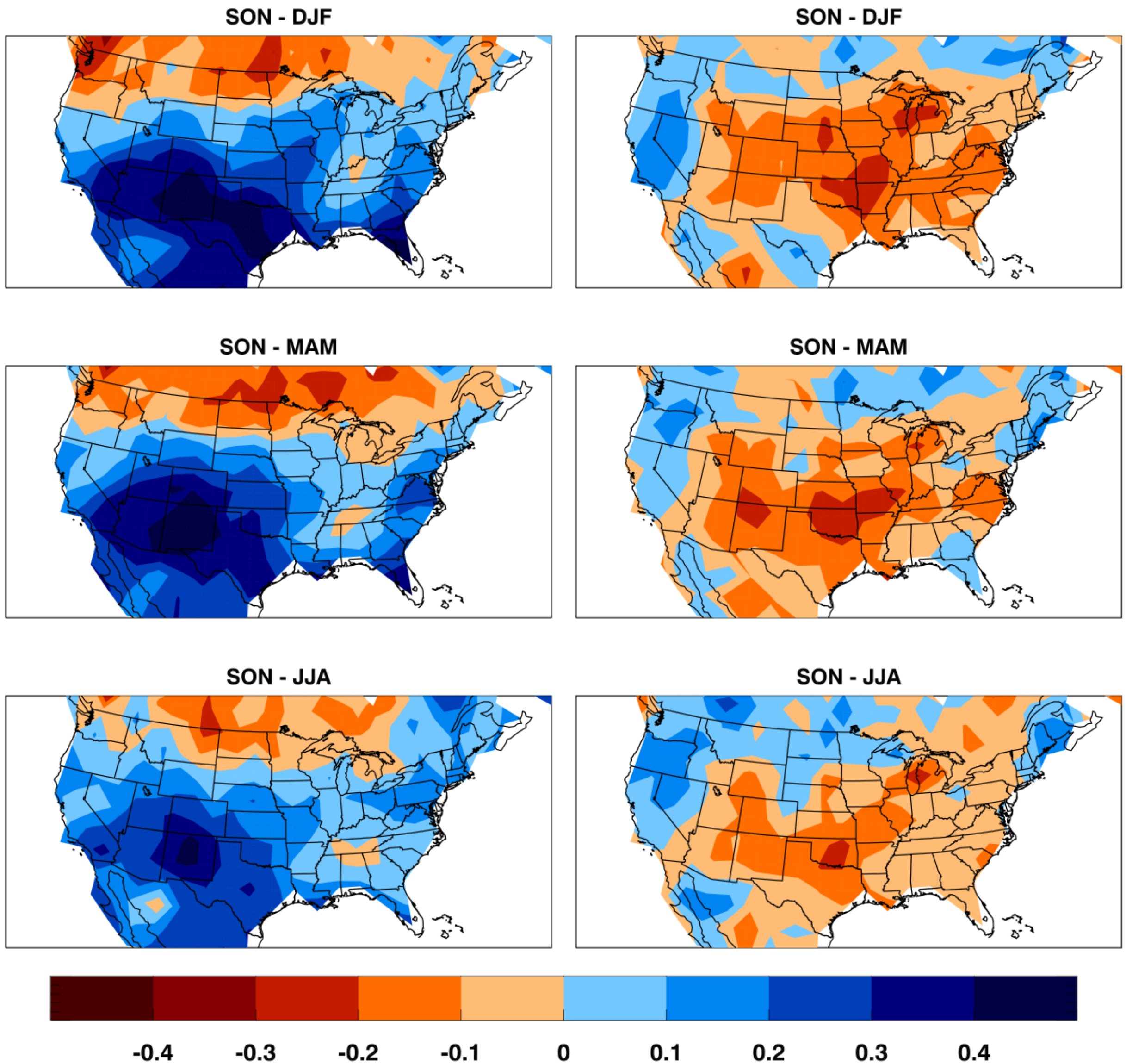
PDO

TAG

DJF pred. Blue-wet, Red-dry if SON PDO positive

MAM pred. Blue-wet, Red-dry if SON PDO positive

JJA pred. Blue-wet, Red-dry if SON PDO positive



DJF pred. Blue-wet, Red-dry if SON TAG positive

MAM pred. Blue-wet, Red-dry if SON TAG positive

JJA pred. Blue-wet, Red-dry if SON TAG positive

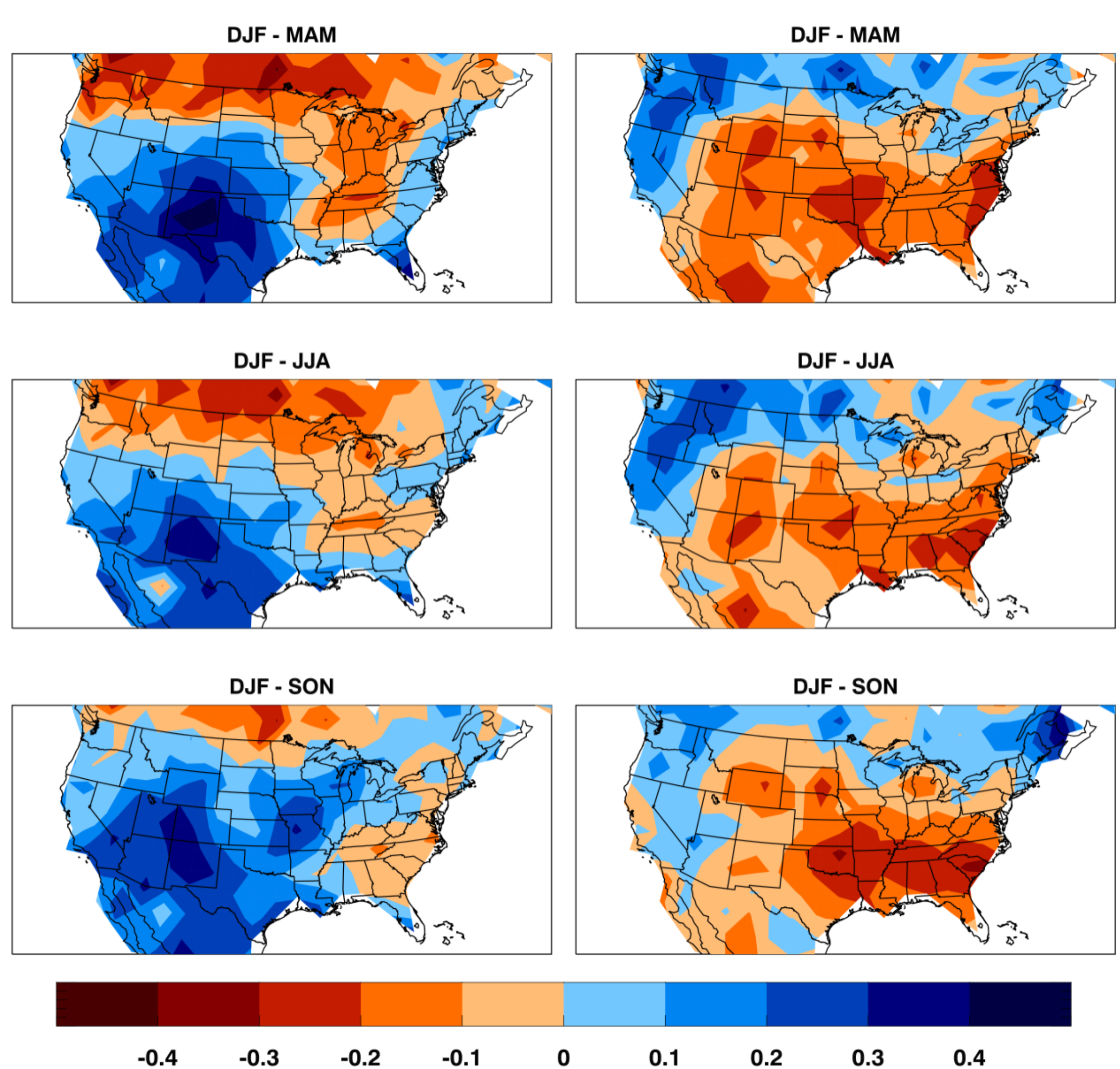
Potential predictability of dryness/wetness using DJF PDO and TAG indices as predictors: 1915 - 2014

PDO | TAG

MAM pred. Blue-wet, Red-dry if DJF PDO positive

JJA pred. Blue-wet, Red-dry if DJF PDO positive

SON pred. Blue-wet, Red-dry if DJF PDO positive

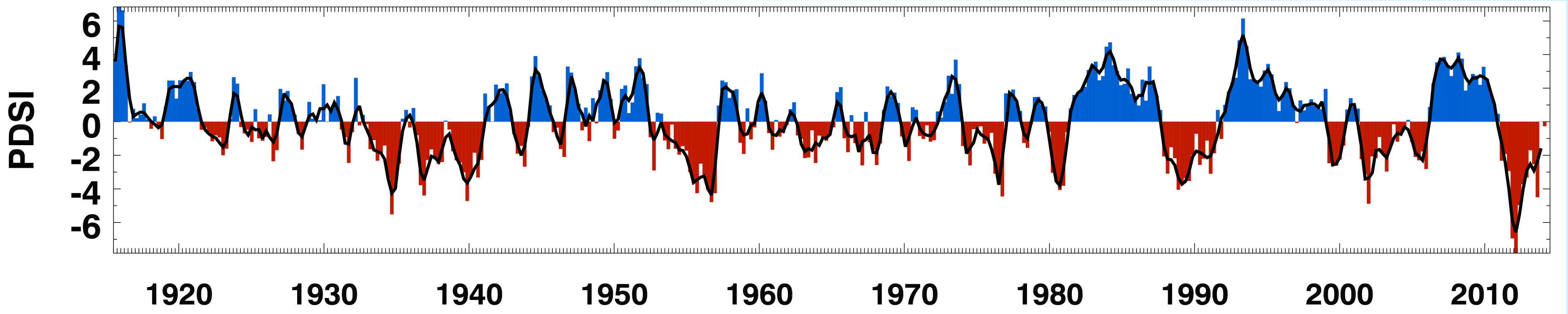


MAM pred. Blue-wet, Red-dry if DJF TAG positive

JJA pred. Blue-wet, Red-dry if DJF TAG positive

SON pred. Blue-wet, Red-dry if DJF TAG positive

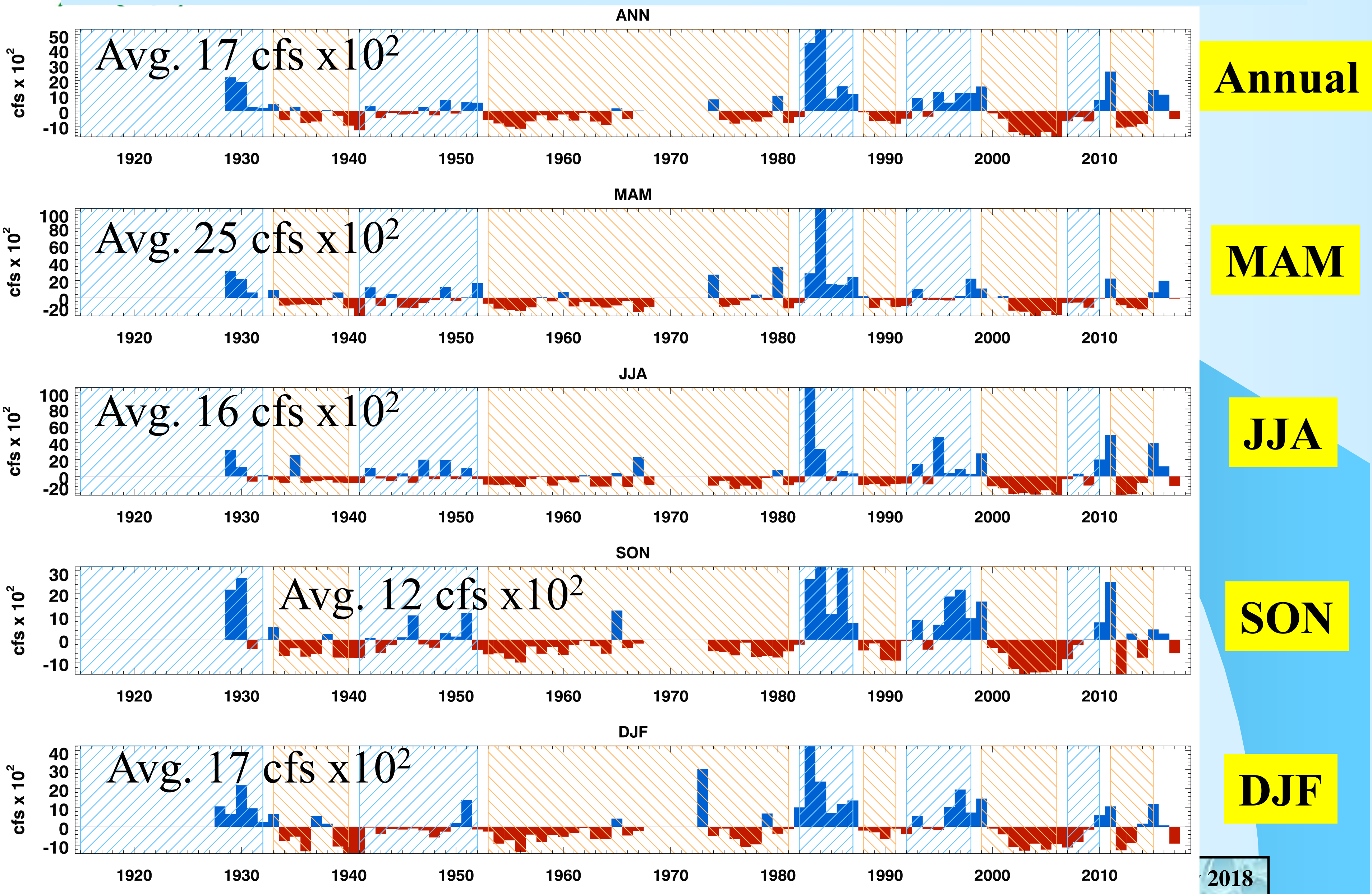
Dry-wet cycles in Central Platte
Palmer Drought Severity Index (PDSI) 1915 to 2014



- Red – negative PDSI – dry
- Blue – positive PDSI – wet
- Pronounced dry-wet cycles for at least last 100 years
- Very dry epoch from early 1950s to early 1980s
- Very wet to very dry and back to very wet … in a decade in the last 35 years

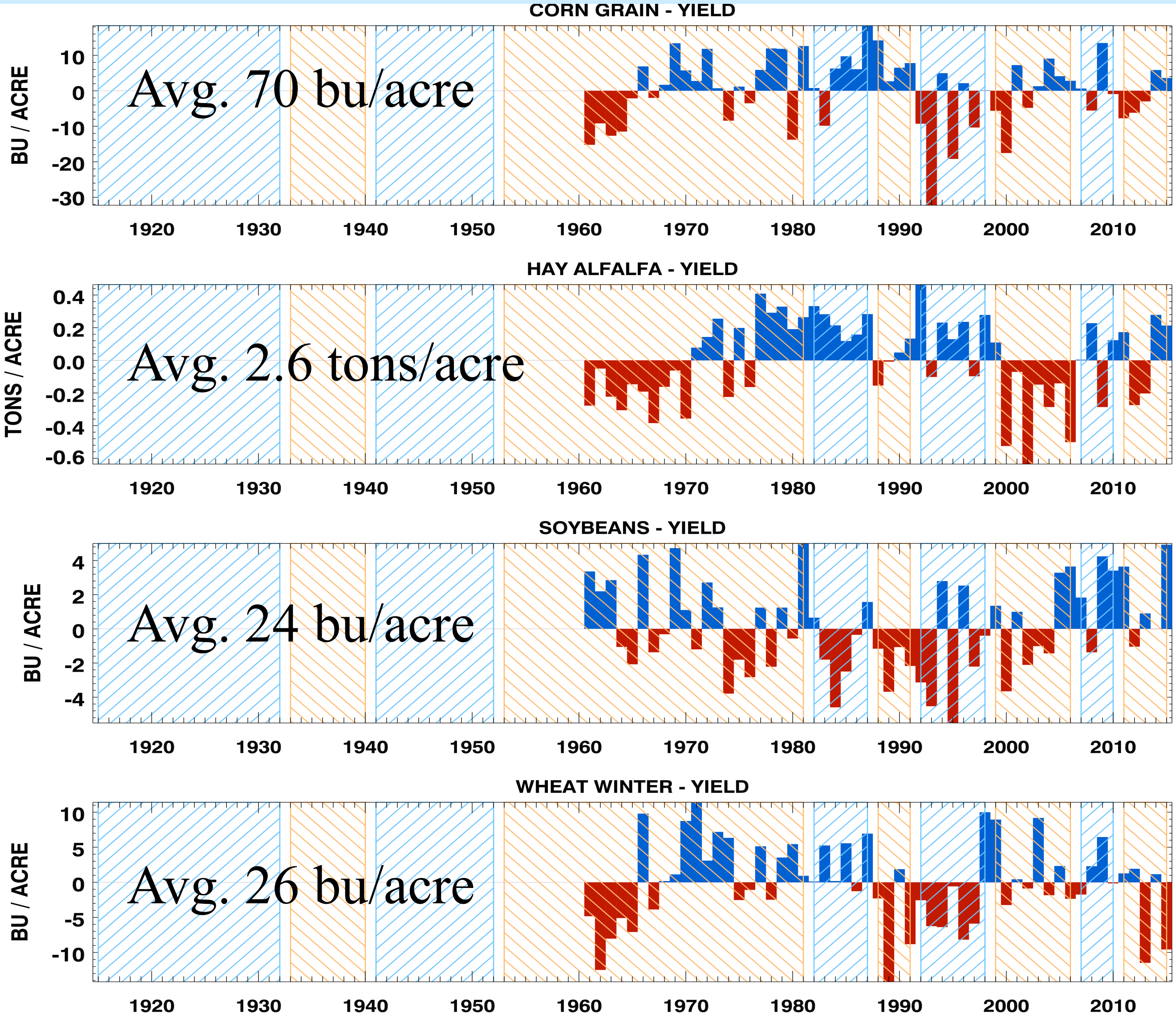
Stream flow anomalies in Central Platte 1930s to 2017

Physical agreement with dry and wet hydro-met. epochs



Detrended Crop Yields in Central Platte 1961 to 2015

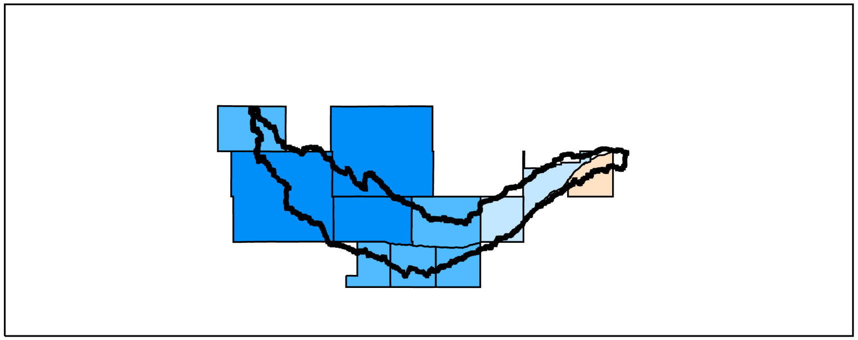
Some agreement with dry and wet hydro-met. epochs



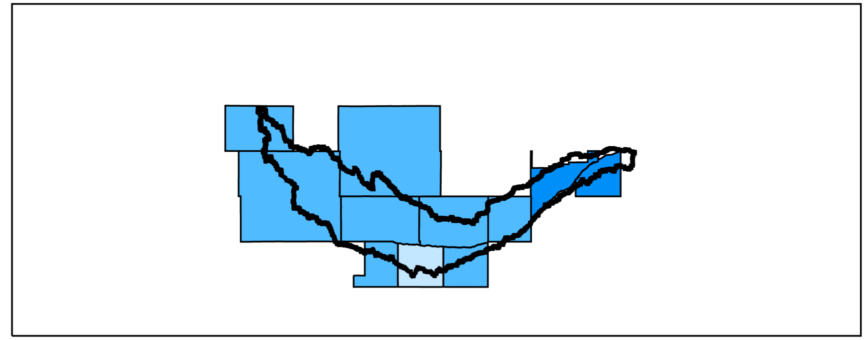
Wet and Cool Epoch: 2007-2010

March-April-May **Precipitation** June-July-August

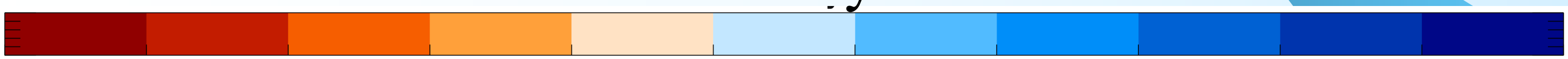
2007-2010 (Basin Ave = 0.56 mm/day)



2007-2010 (Basin Ave = 0.60 mm/day)

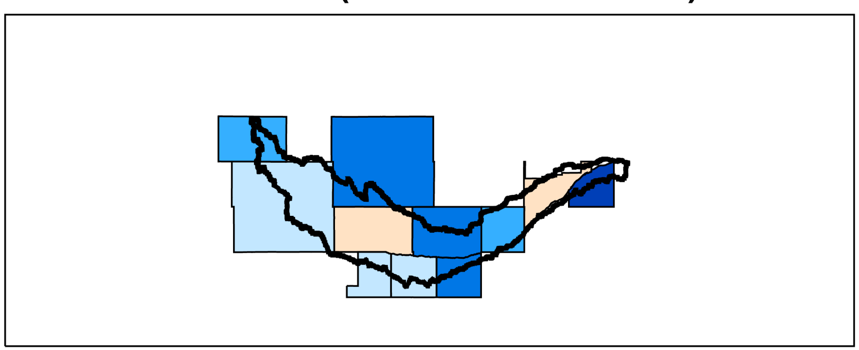


mm/day

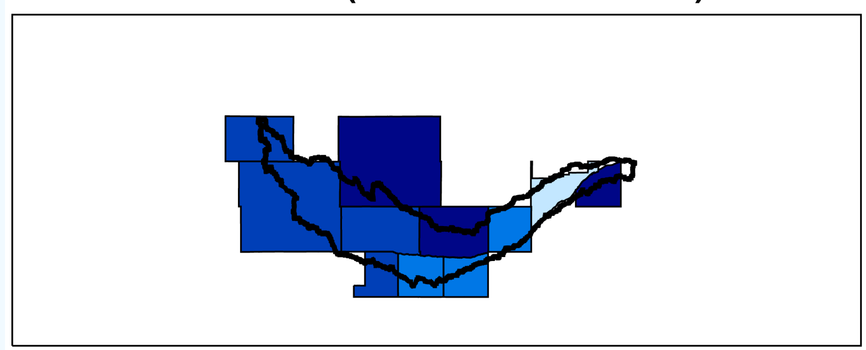


Max. temp.

2007-2010 (Basin Ave = -0.26 °C)



2007-2010 (Basin Ave = -0.64 °C)



°C

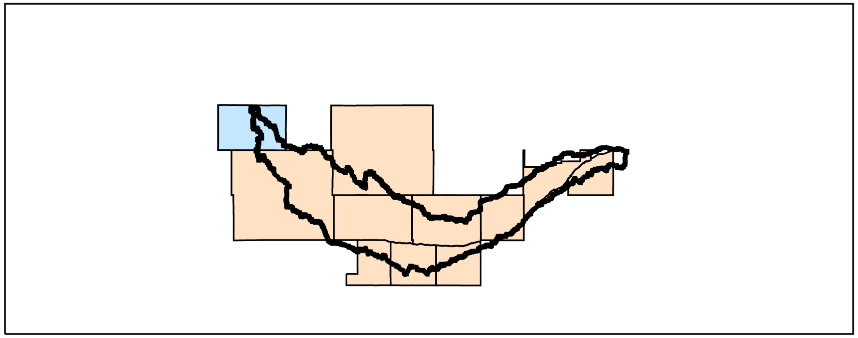
Dry and Warm Epoch: 2011-2015

March-April-May

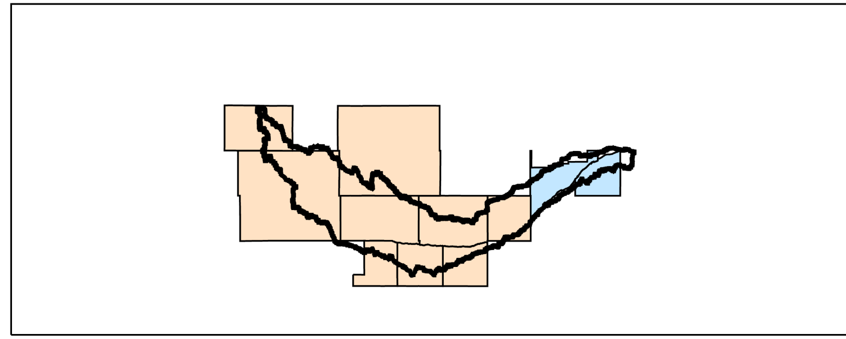
Precipitation

June-July-August

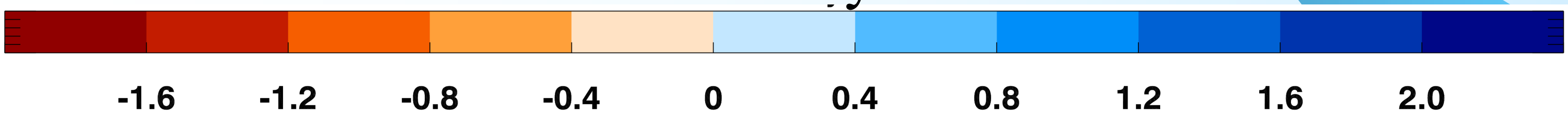
2011-2015 (Basin Ave = -0.13 mm/day)



2011-2015 (Basin Ave = -0.09 mm/day)

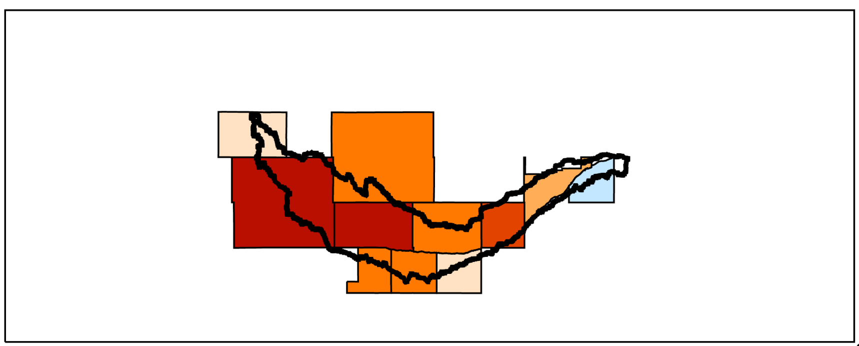


mm/day

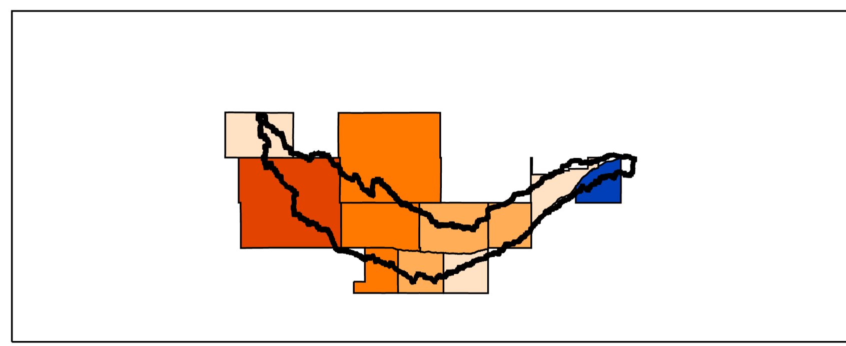


Max. temp.

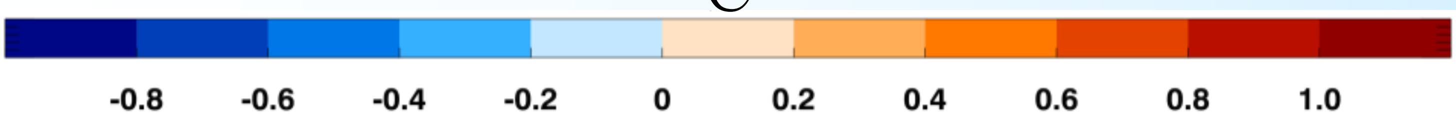
2011-2015 (Basin Ave = 0.45 °C)



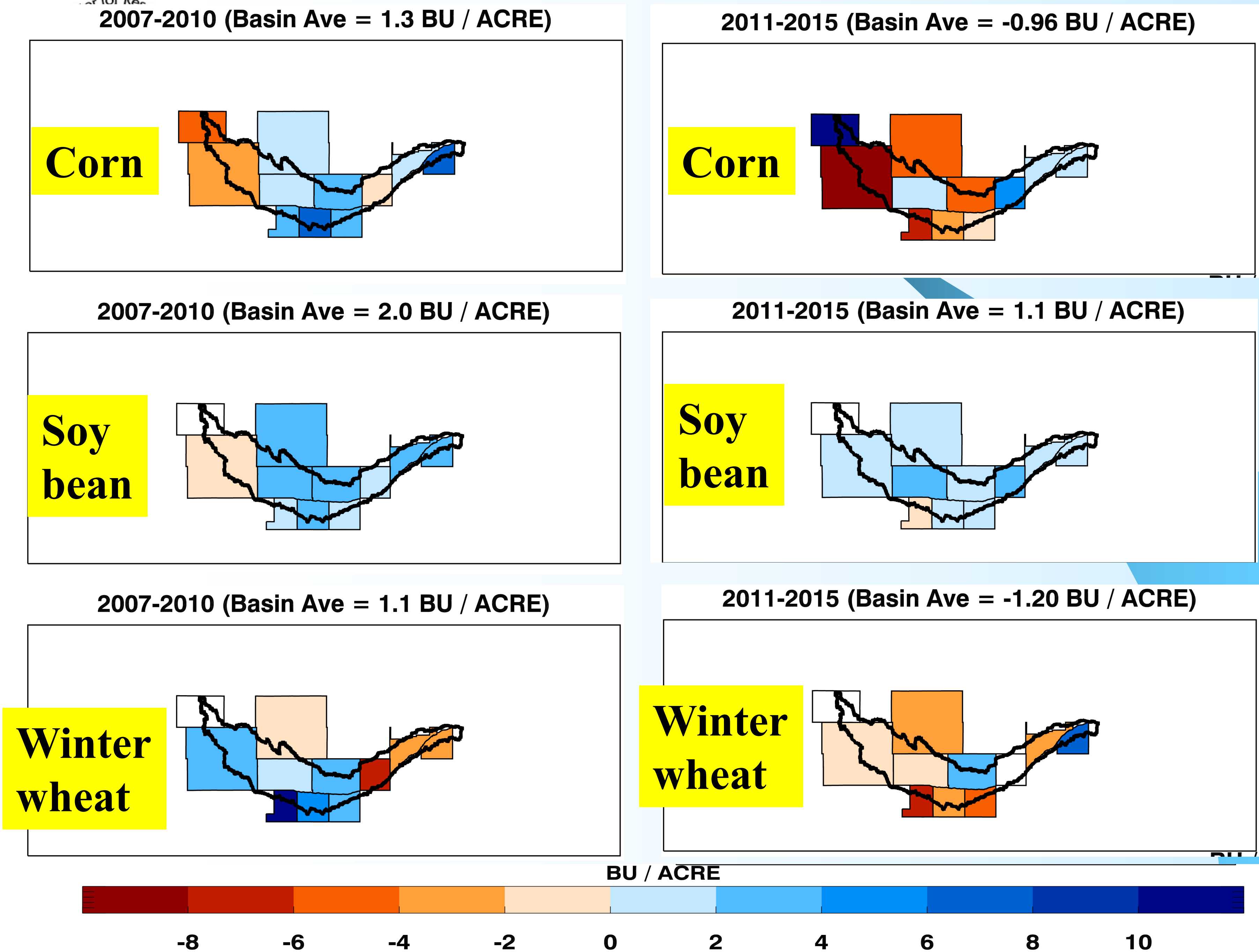
2011-2015 (Basin Ave = 0.26 °C)



°C



Wet-Cool Epoch: 2007-2010 Dry-Warm Epoch: 2011-2015



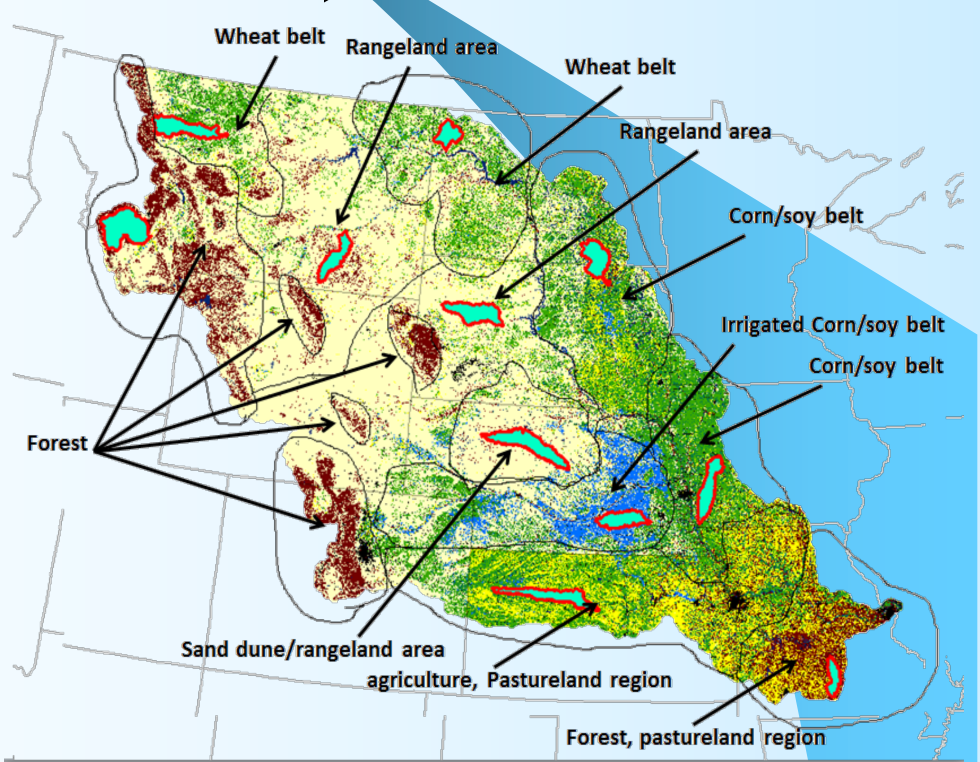
Let's Discuss

- ☞ Do you remember these wet (2007-10) and dry (2011-15) epochs?
- ☞ Specifically, what do you remember about these two epochs?
- ☞ What did you and others do to cope with these wet and dry epochs?
- ☞ Was the precipitation anomaly more important or the temperature anomaly?

SWAT Setup and Calibration - Validation

- Characterization of ~ 14,000 watersheds
- Sub-watersheds and streams
- Land use – land cover at 30 m resolution, crop rotation and irrigation
- Irrigated land and soil data
- Precipitation, temperature, winds, solar radiation data at 12 km x 12 km
- Crop yield calibration; Winter and spring wheat, corn (dryland and irrigated), soybean (dryland and irrigated)
- Water yield (total surface and base flow) calibration
- Water abstractions and other man-made changes not captured

Calibration and validation in each of these 11 land use classes



Types of SWAT Experiments

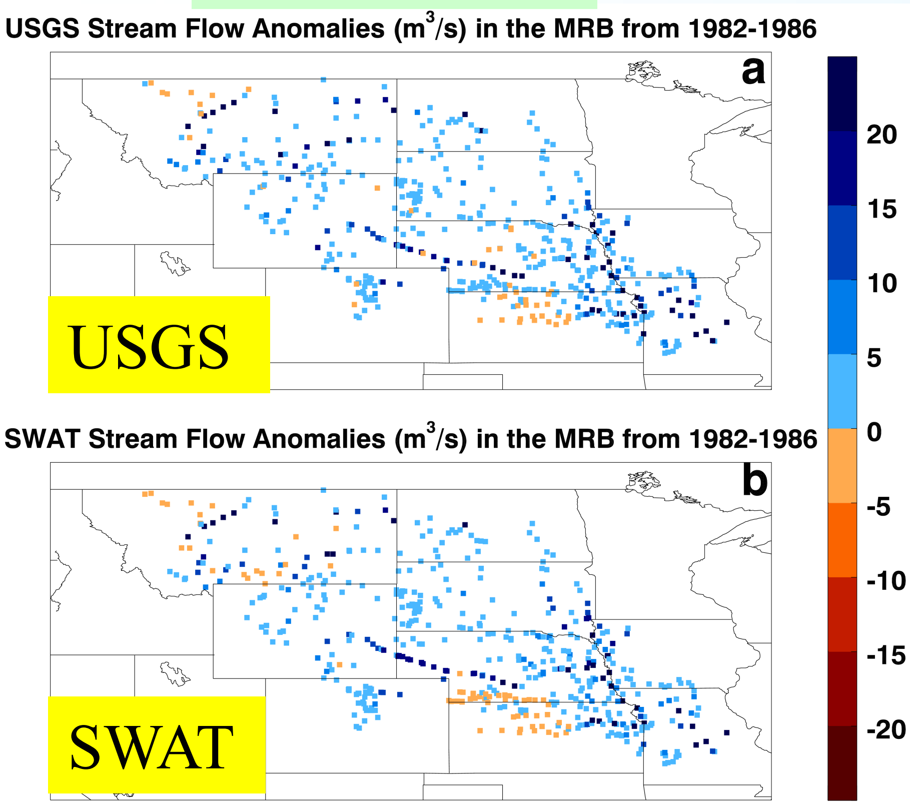
Observed Hydro-meteorological data; 1961 - 2010 → SWAT → Water yield, stream flow, crop yields → Comparison with observed data; 1961 - 2010

Idealized Hydro-meteorological data from DCV scenarios → SWAT → Water yield, stream flow, crop yields → Inter-comparison of impacts of scenarios

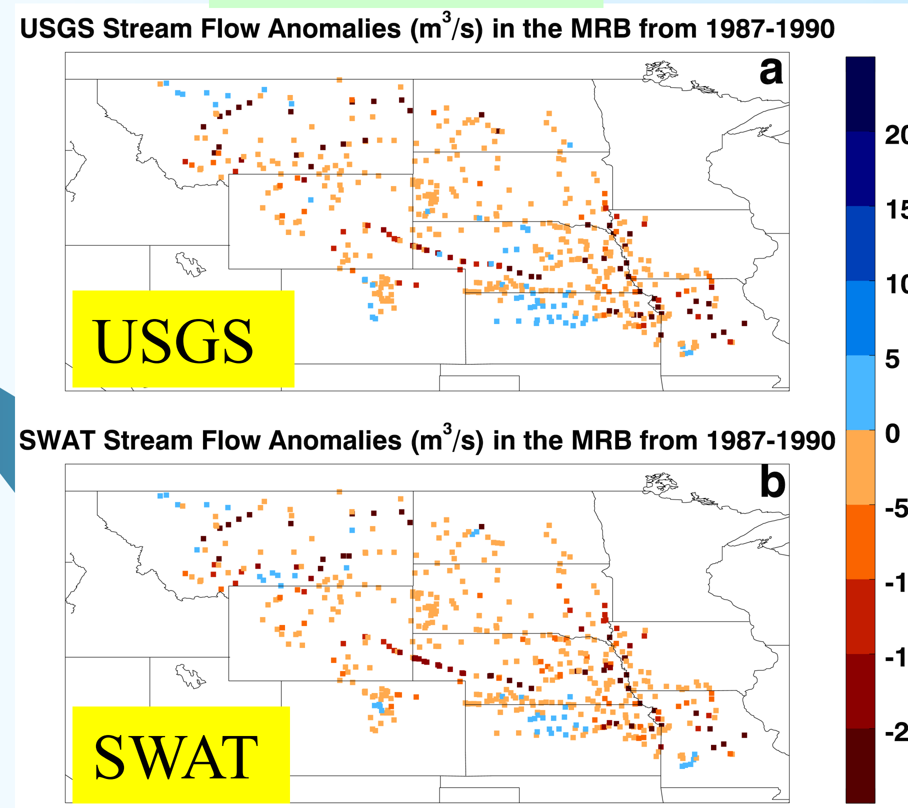
Hindcast Hydro-meteorological data; 1961 - 2010 → SWAT → Water yield, stream flow, crop yields → Comparison with observed data; 1961 - 2010

Observed and SWAT-simulated streamflow anomalies (cu. m/s) in wet (1982-86) and dry (1987-90) Epochs

Wet: 1982 - 86



Dry: 1987 - 90

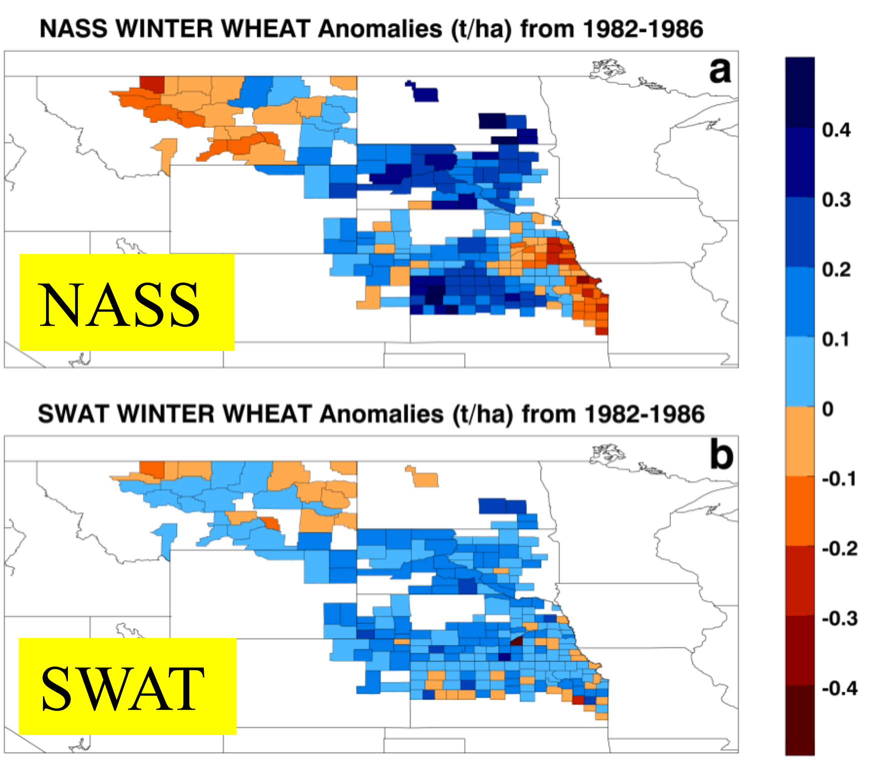


Decreased flows in western Montana and northern Kansas, and increased flows elsewhere

Increased flows in western Montana and northern Kansas, and decreased flows elsewhere

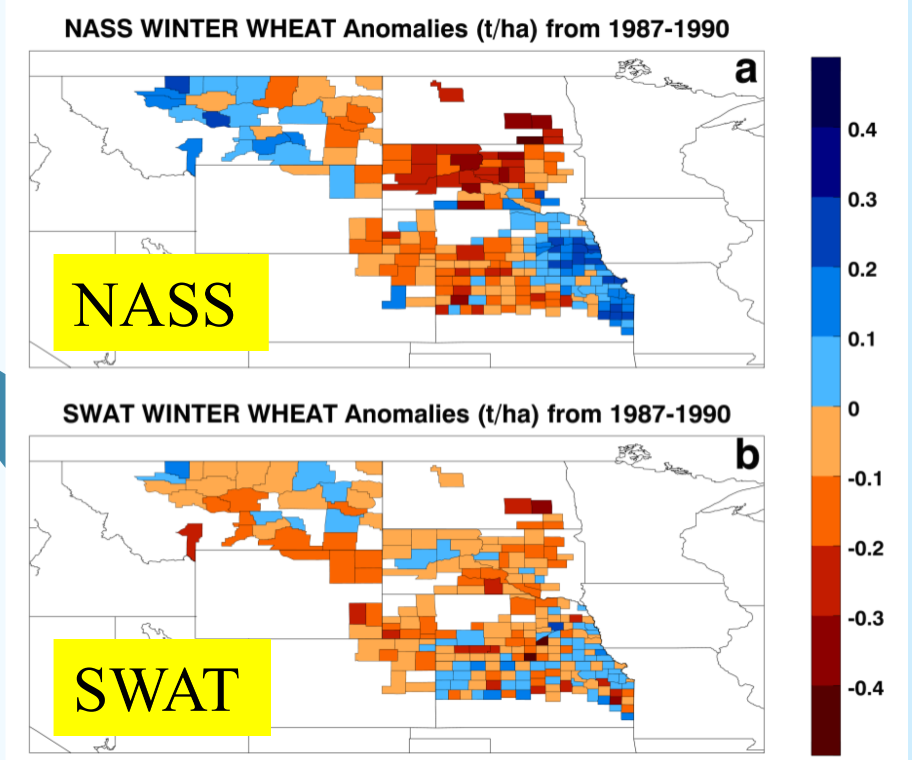
Observed and SWAT-simulated winter wheat yield anomalies (t/ha) in wet (1982-86) and dry (1987-90) Epochs

Wet: 1982 - 86



Decreased yields in western Montana and southeast MRB, and increased yields elsewhere

Dry: 1987 - 90



Increased yields in western Montana and southeast MRB, and decreased yields elsewhere

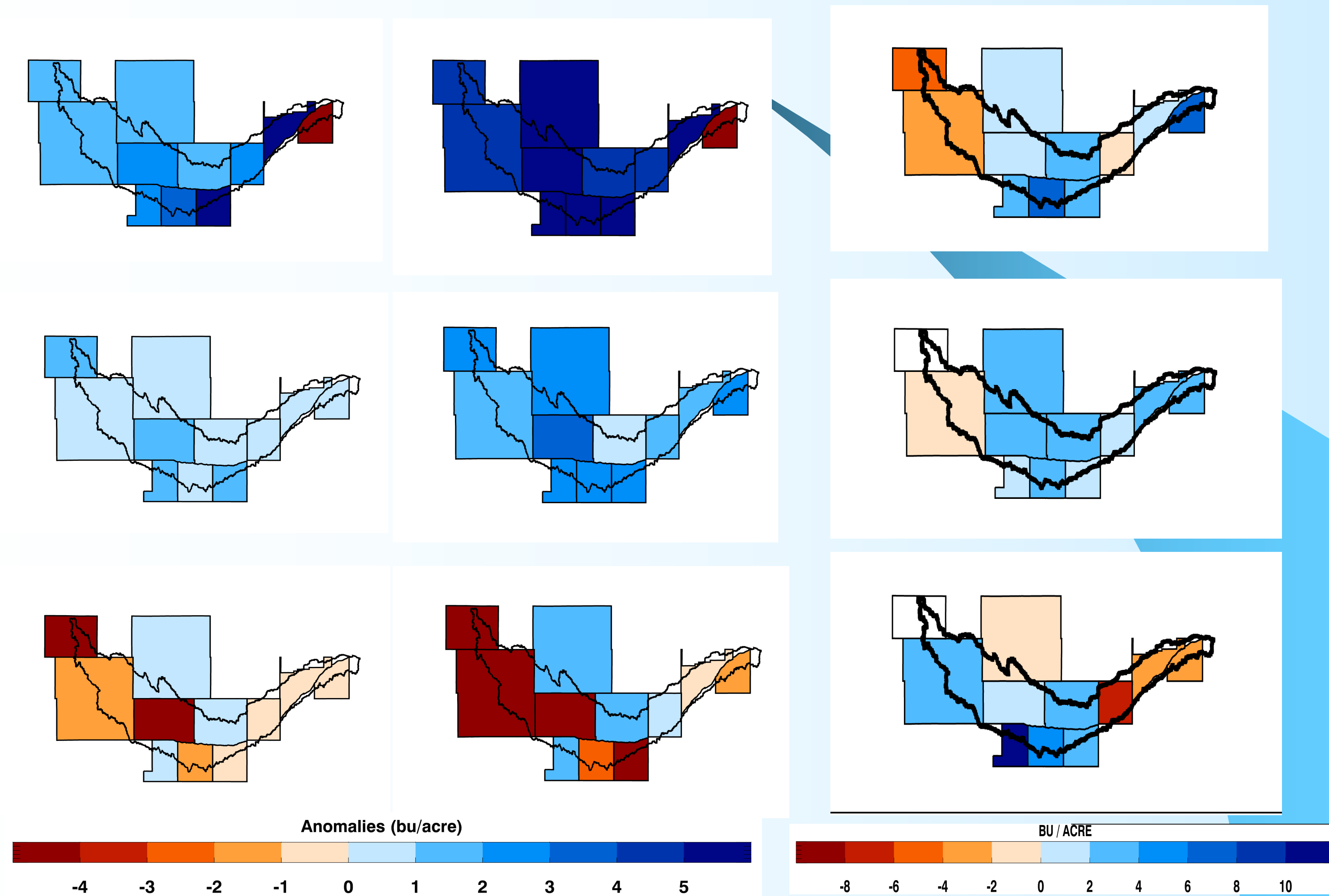
SWAT-simulated crop yield anomalies, Wet Epoch 2007-10
PDO negative, TAG negative, WPWP positive

Average indices | **Extreme indices** | **NASS observed**

Corn

Soybean

Winter wheat



SWAT-simulated crop yield anomalies, Dry Epoch 2011-15

PDO negative, TAG positive, WPWP positive

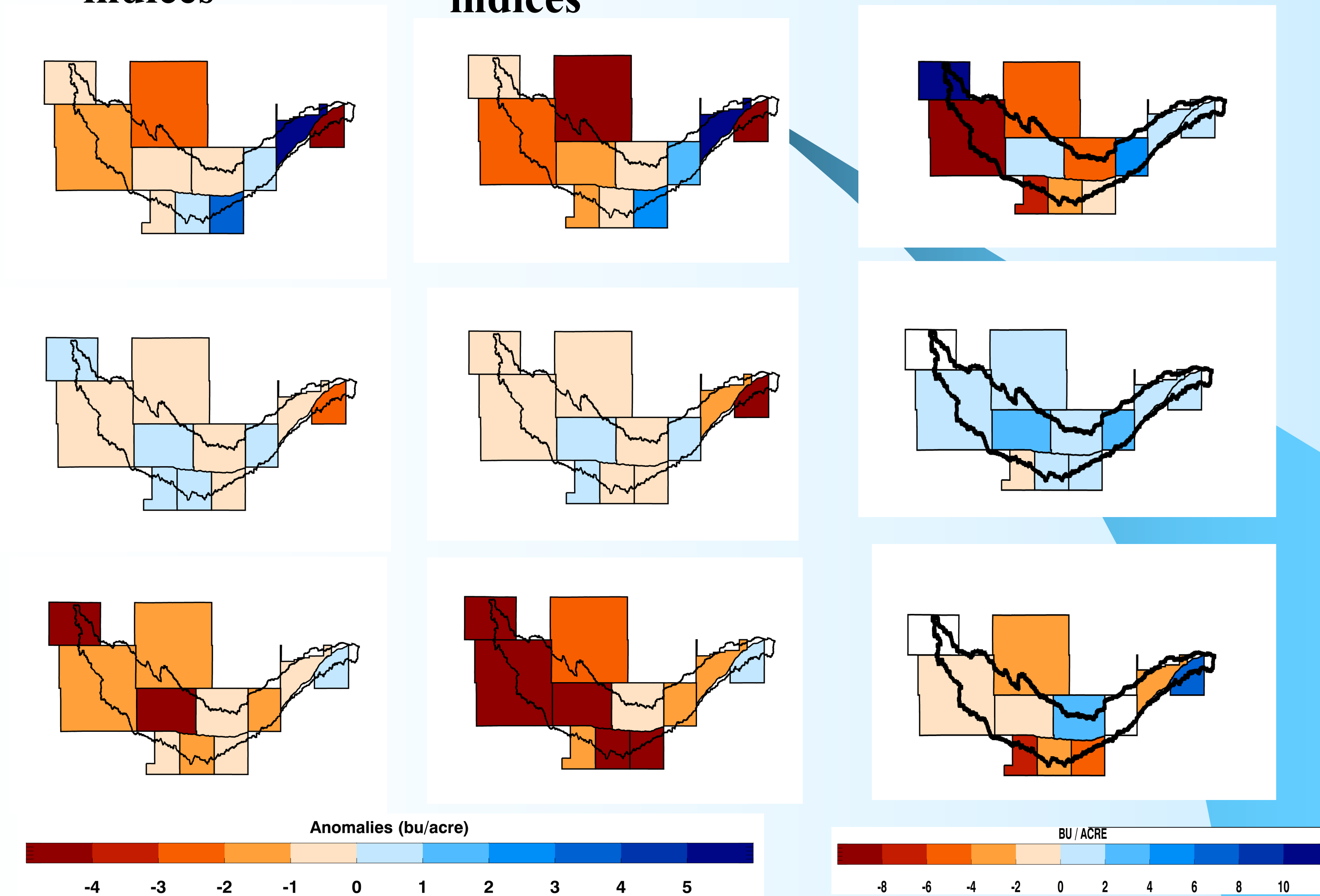
The Center for Research on the Changing Earth System
CRCES

Average indices | **Extreme indices** | **NASS observed**

Corn

Soybean

Winter wheat



Let's Discuss

- ☞ If these scenarios were provided to you before/while transitioning from wet to dry or dry to wet, how would you use this information to make decisions if you were a farmer, rancher, water manager, local-county-state official, extension service provider?
- ☞ Would there be any difference(s) in coping with dry and wet epochs?
- ☞ Would the precipitation anomaly be more important or the temperature anomaly?
- ☞ What would you like in the predicted outlook of these epochs to take action and when?

Thank you!!