The Impact of Land-Atmosphere Coupling on the development of Flash Droughts

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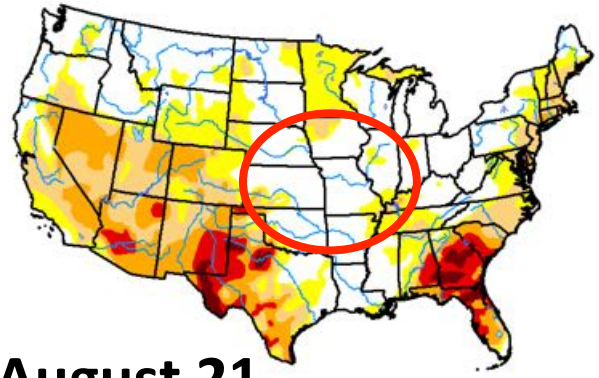
Wednesday May 9, 2018, 15:00 - 15:15
Droughts in Present and Future Climate
GEWEX Meeting 8th , Canmore, Alberta, Canada

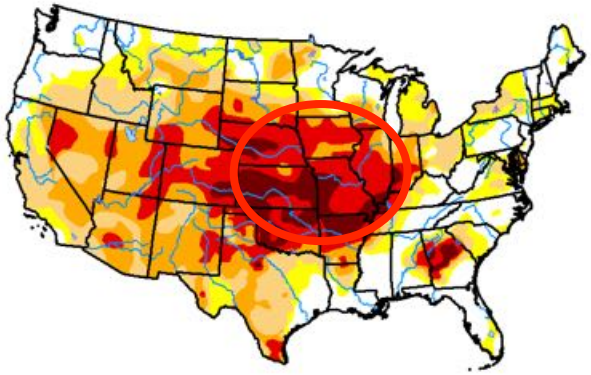
Rapid development of drought between May and August in 2012 and 2017

2012

May 8

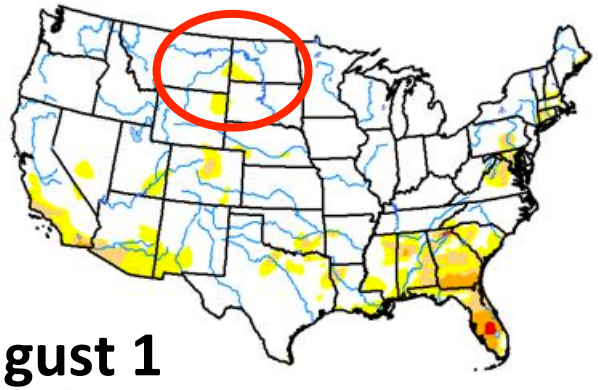


August 21

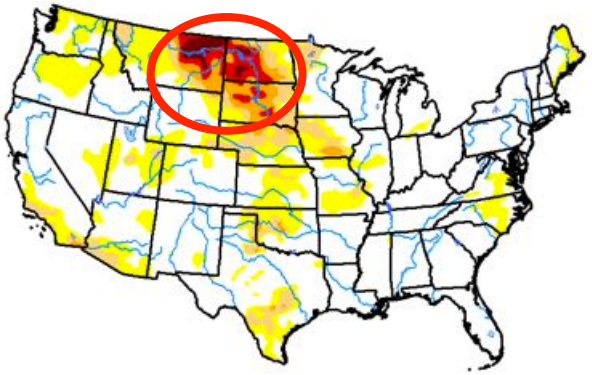


2017

May 2



August 1



Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

Deborah Bathke
National Drought Mitigation Center

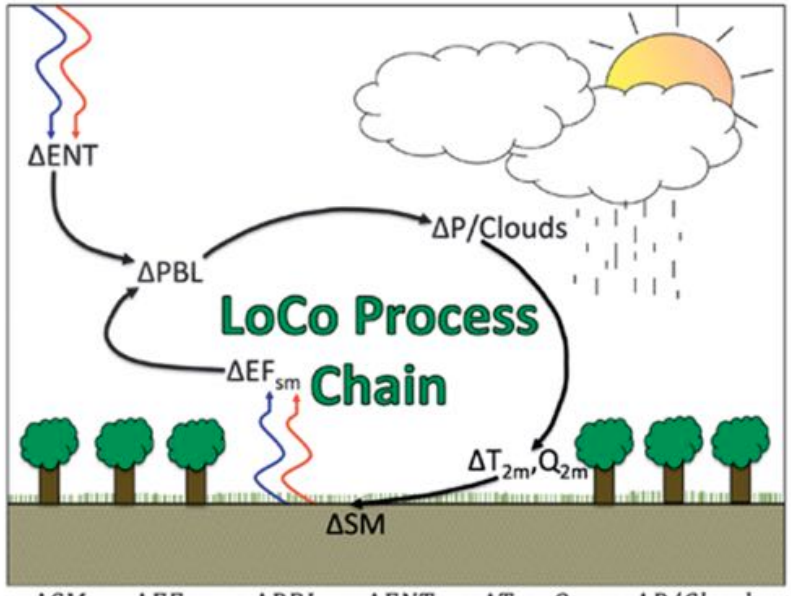
http://droughtmonitor.unl.edu/

What impact did Land-Atmosphere interactions play in the rapid development of drought?

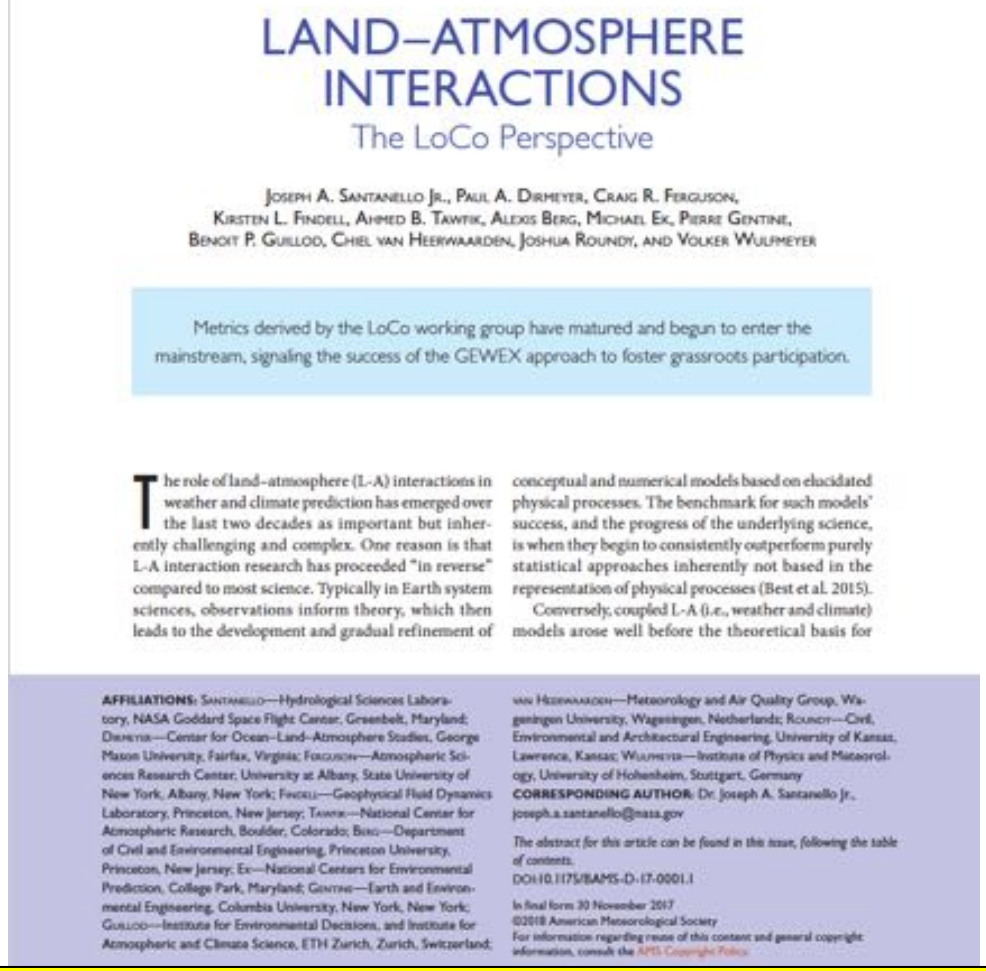
The LoCo process chain

•The complexity of land-atmosphere (L-A) interactions can be synthesized into simple processes chain of **Local L-A Coupling ('LoCo')**:

$$\underset{\text{(a)}}{\Delta SM} \rightarrow \underset{\text{(b)}}{\Delta EF} \rightarrow \underset{\text{(c)}}{\Delta PBL} \rightarrow \underset{\text{(d)}}{\Delta ENT} \rightarrow \Delta T_{2m}, Q_{2m} \blacktriangleright \Delta P/Clouds$$



$$\underset{\text{(a)}}{\Delta SM} \rightarrow \underset{\text{(b)}}{\Delta EF_{sm}} \rightarrow \underset{\text{(c)}}{\Delta PBL} \rightarrow \underset{\text{(d)}}{\Delta ENT} \rightarrow \Delta T_{2m}, Q_{2m} \triangleright \Delta P/Clouds$$



LAND–ATMOSPHERE INTERACTIONS

The LoCo Perspective

Joseph A. Santanello Jr., Paul A. Dirmeyer, Craig R. Ferguson, Kirsten L. Findell, Ahmed B. Tawfik, Alexis Berg, Michael Ek, Pierre Gentine, Benoit P. Guillod, Chiel van Heerwaarden, Joshua Roundy, and Volker Wulfmeyer

Metrics derived by the LoCo working group have matured and begun to enter the mainstream, signaling the success of the GEWEX approach to foster grassroots participation.

The role of land–atmosphere (L-A) interactions in weather and climate prediction has emerged over the last two decades as important but inherently challenging and complex. One reason is that L-A interaction research has proceeded "in reverse" compared to most science. Typically in Earth system sciences, observations inform theory, which then leads to the development and gradual refinement of conceptual and numerical models based on elucidated physical processes. The benchmark for such models' success, and the progress of the underlying science, is when they begin to consistently outperform purely statistical approaches inherently not based in the representation of physical processes (Best et al. 2015).

Conversely, coupled L-A (i.e., weather and climate) models arose well before the theoretical basis for

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The abstract for this article can be found in this issue, following the table of contents.
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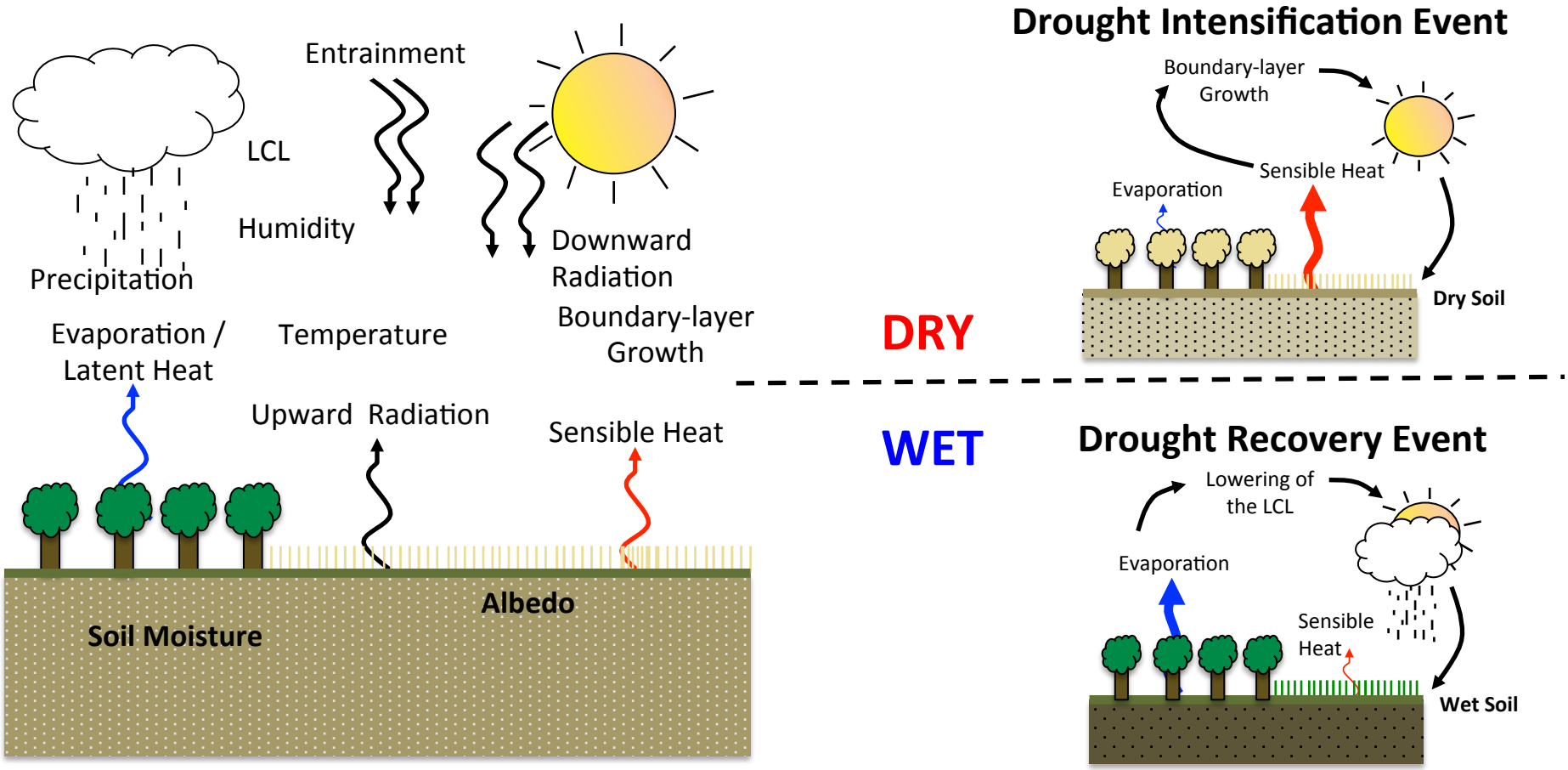
In final form 30 November 2017

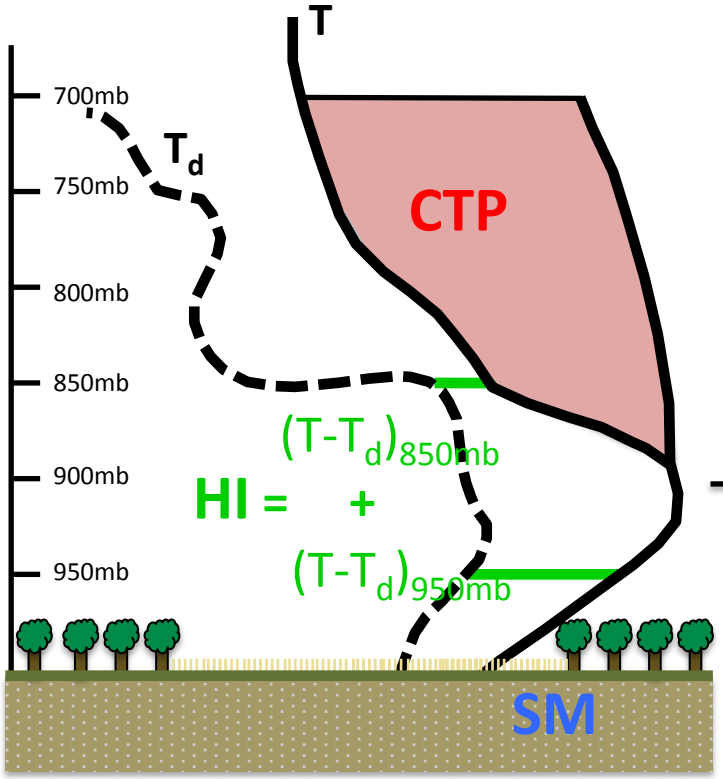
Santanello, J. A., et al. (2018): **Land-Atmosphere Interactions: The LoCo Perspective**.
Bulletin of the American Meteorological Society, June 2018 (in press).

Development of extreme events are impacted by Land-Atmosphere Coupling



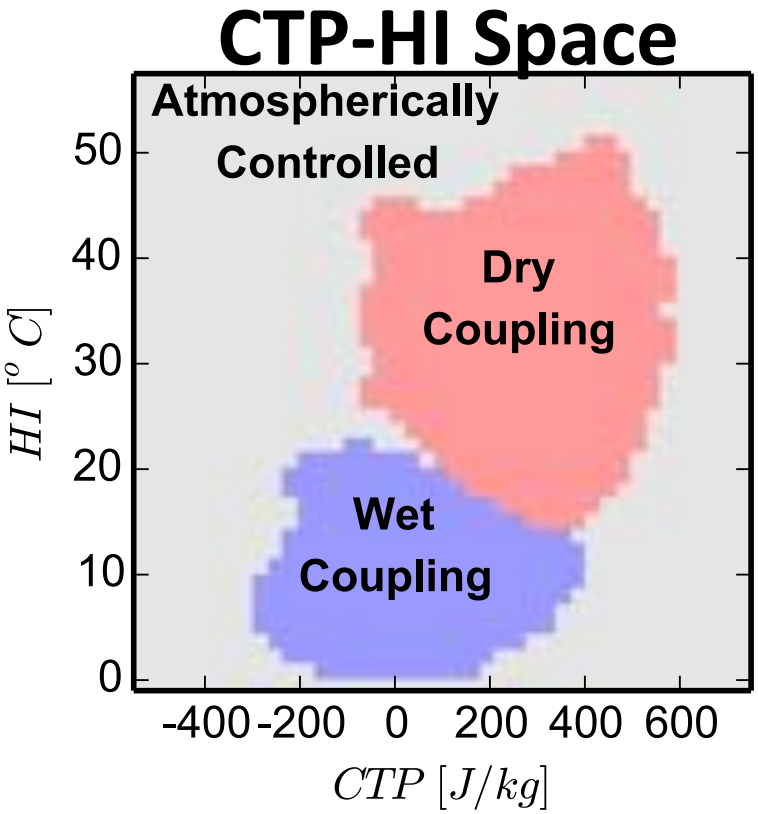
While land-atmosphere coupling plays a role in these events, consistent large scale forcing is also necessary

The CTP-HI and SM are used to classify these coupling regimes



Based on the work of Findell and Eltahir (JHM, 2003).

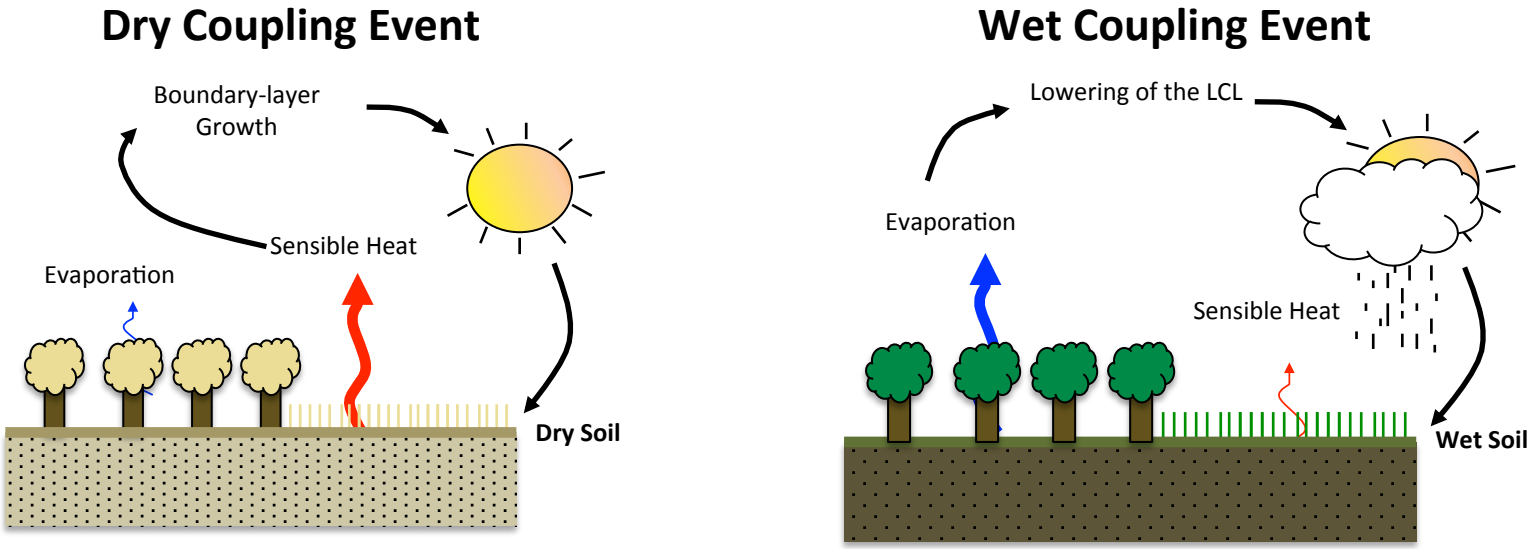
Historic Sample



Roundy et al. (JHM, 2013)

Once the CTP-HI space is classified, only CTP-HI is needed for daily classification

The strength of the coupling events are quantified by the CDI



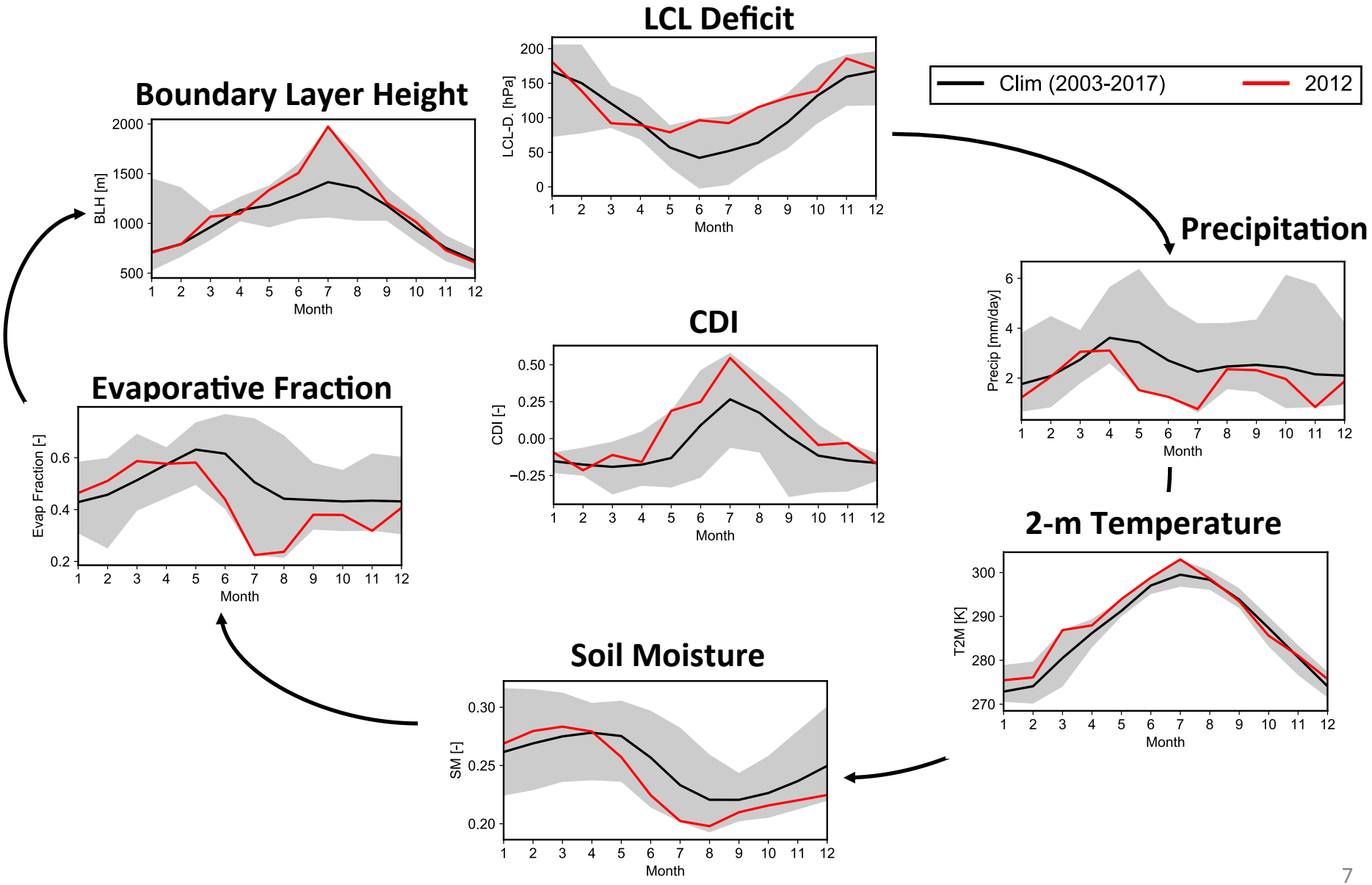
$$\textit{Coupling Drought Index (CDI)} = \frac{Dry_{Coupling} - Wet_{Coupling}}{Total_{Days}}$$

Roundy et al. (JHM, 2013)

Using reanalysis data we can look at the LoCo coupling chain and the CDI for the 2012 and 2017 droughts.

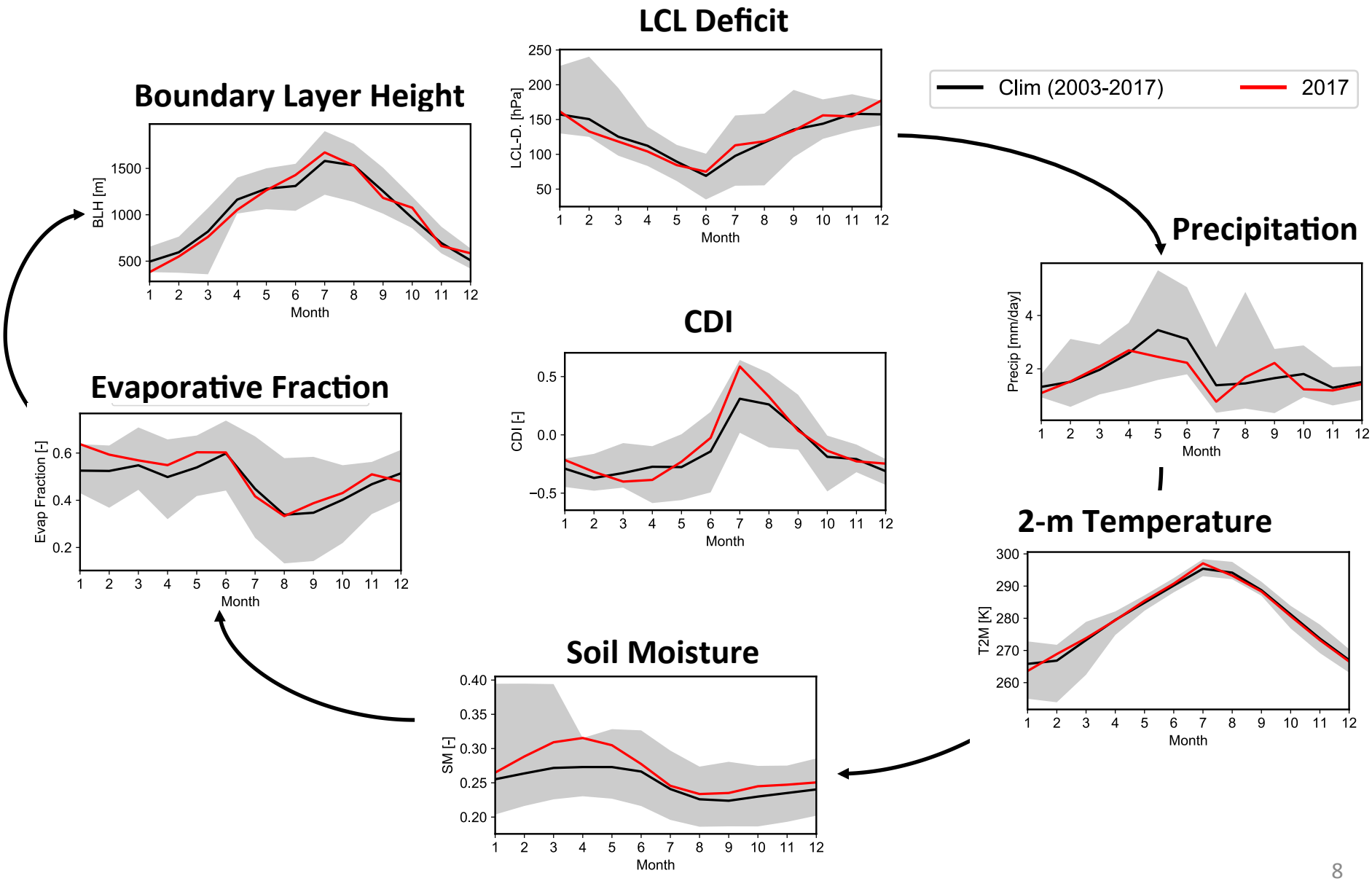
Coupling Process Chain for 2012 CFSR

2012 – Low Plains (Illinois, Missouri, Iowa, Nebraska, Kansas, Oklahoma, Arkansas)



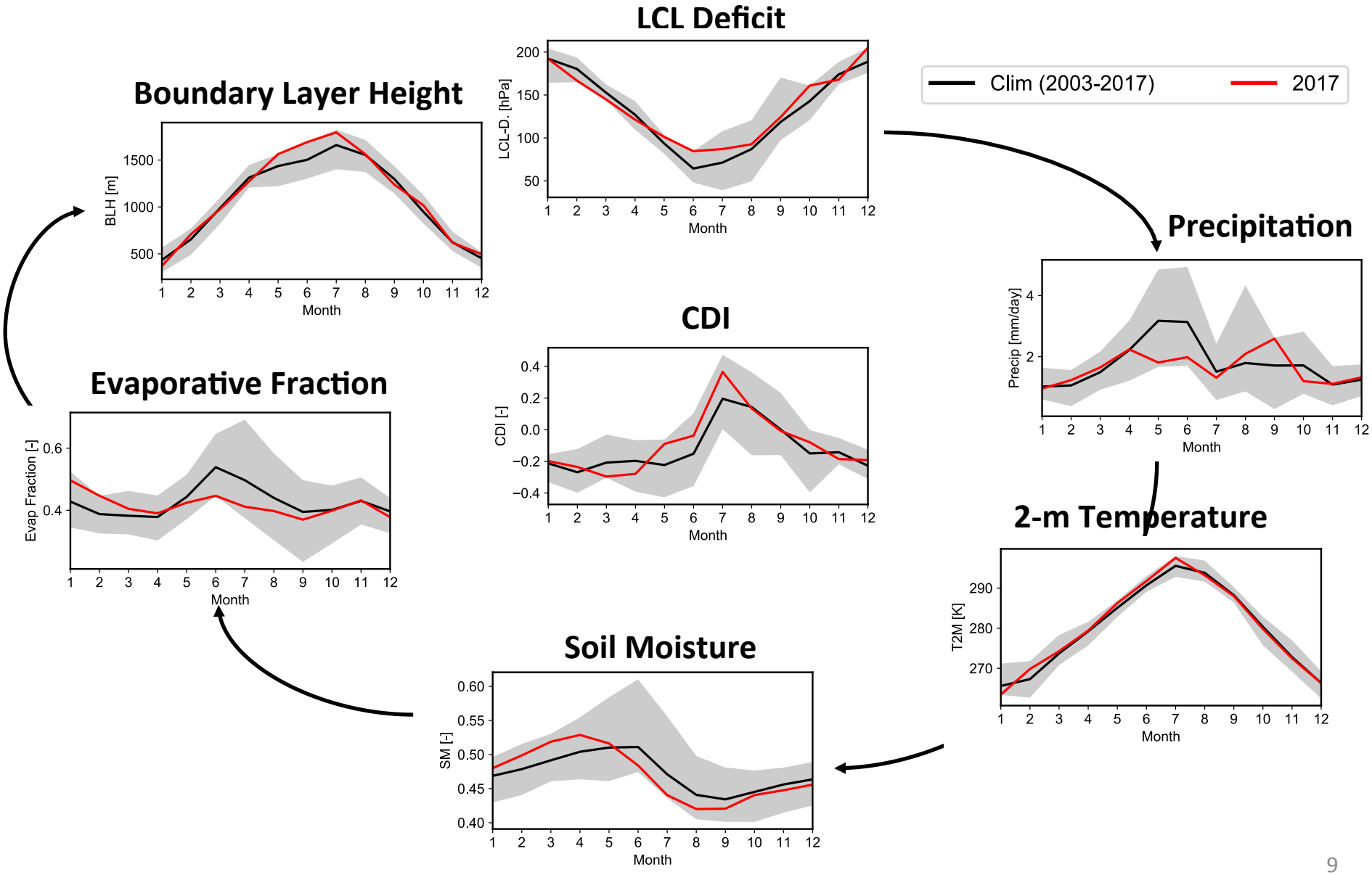
Coupling Process Chain for 2017 CFSR

2017 – High Plains (South Dakota, North Dakota, Montana)



Coupling Process Chain for 2017 MERRA2

2017 – High Plains (South Dakota, North Dakota, Montana)



Satellite CDI provides a needed observation of land-atmosphere coupling

NASA EOS AQUA Satellite

Atmospheric Infrared Sounder (AIRS) V6 -L3

Atmospheric T, Q (12 levels), 2003 - Present

CTP - Convective Triggering Potential (Atmospheric Stability)

HI – Humidity Index (Atmospheric Moisture)

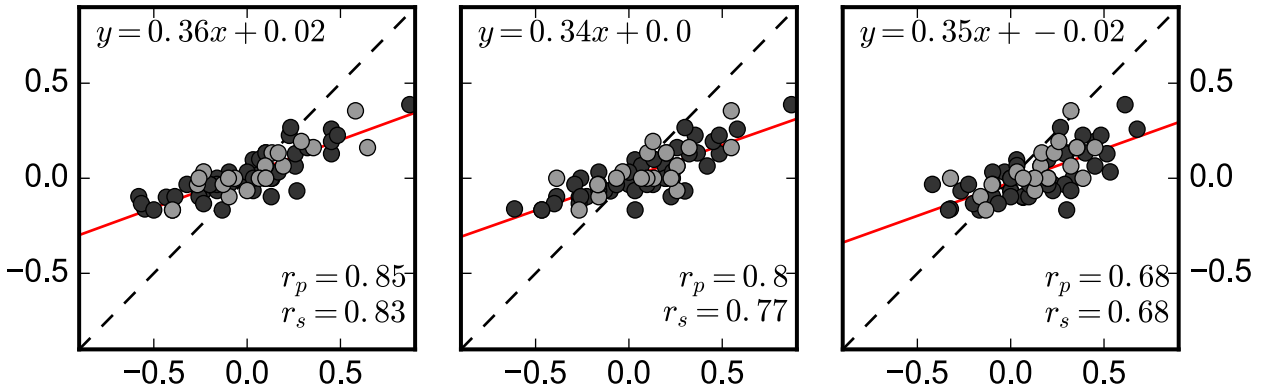
Advanced Microwave Scanning Radiometer-Earth (AMSR-E), 2003-2011

SM - Soil Moisture

Monthly CDI 2003-2015 (May – Sep Only)

SGP ARM

In-situ

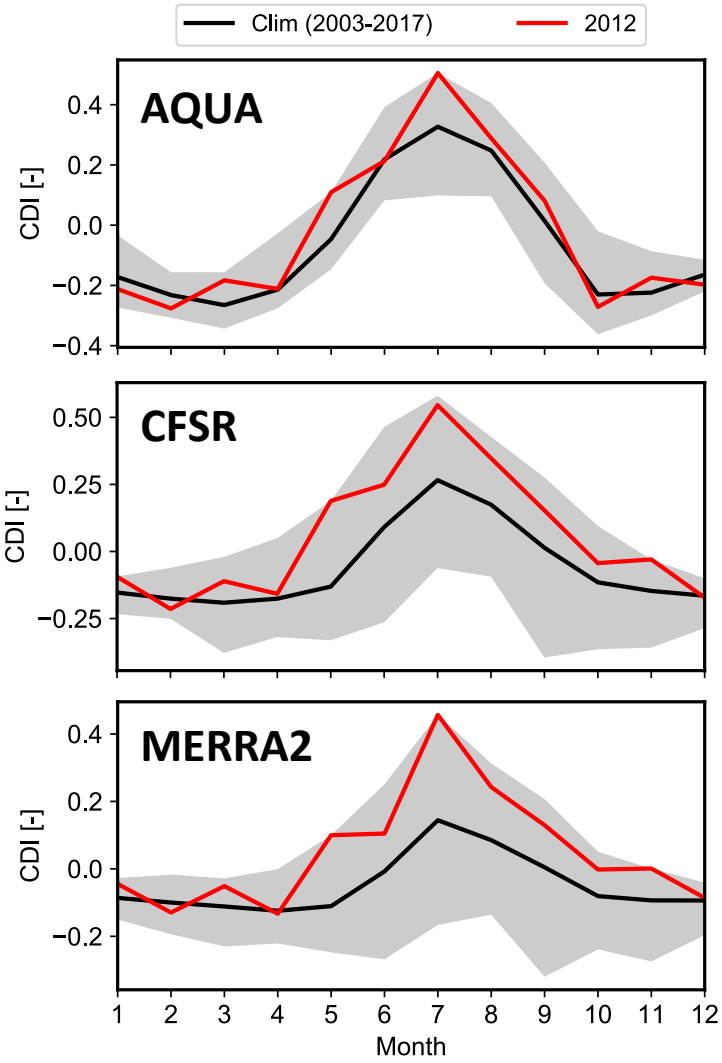


MERRA **CFSR** **AQUA**

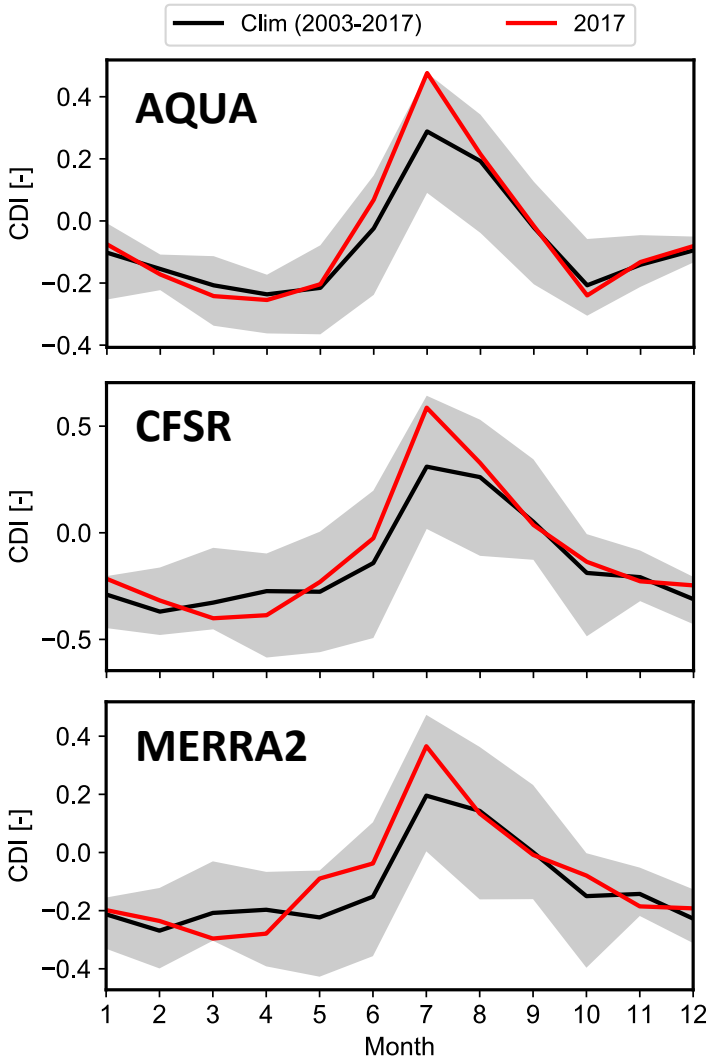
Roundy and Santanello (JHM, 2017)

The CDI for the 2012 and 2017 droughts

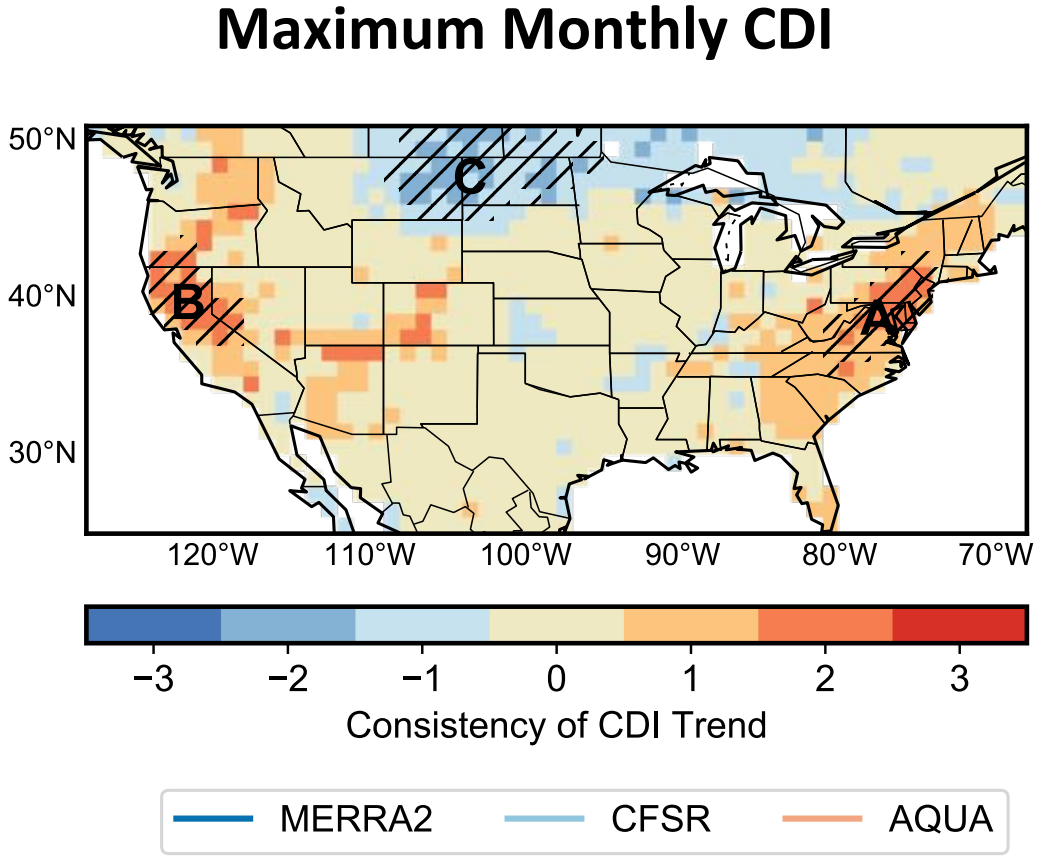
2012 – Low Plains (Illinois, Missouri, Iowa, Nebraska, Kansas, Oklahoma, Arkansas)

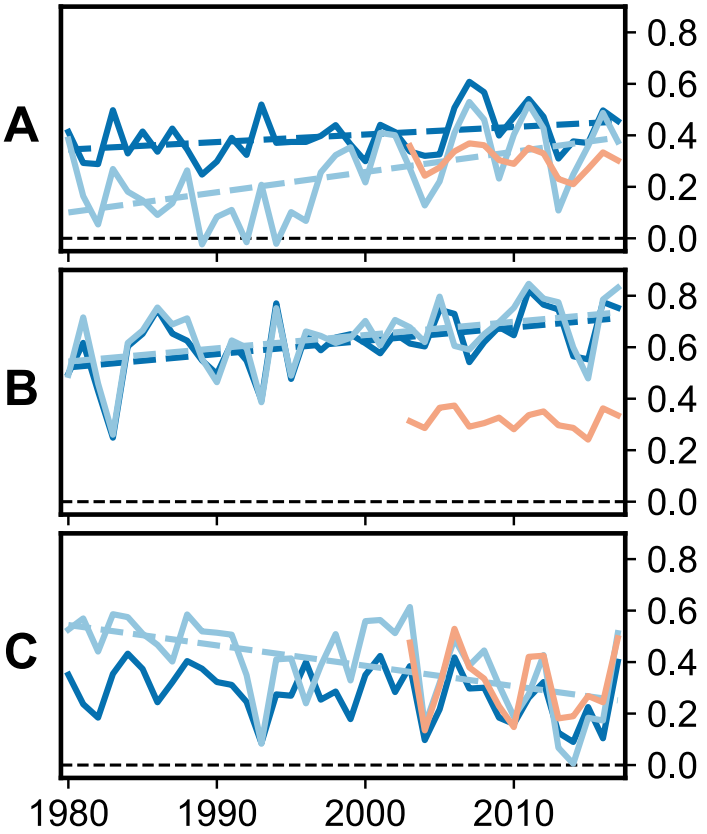


2017 – High Plains (South Dakota, North Dakota, Montana)

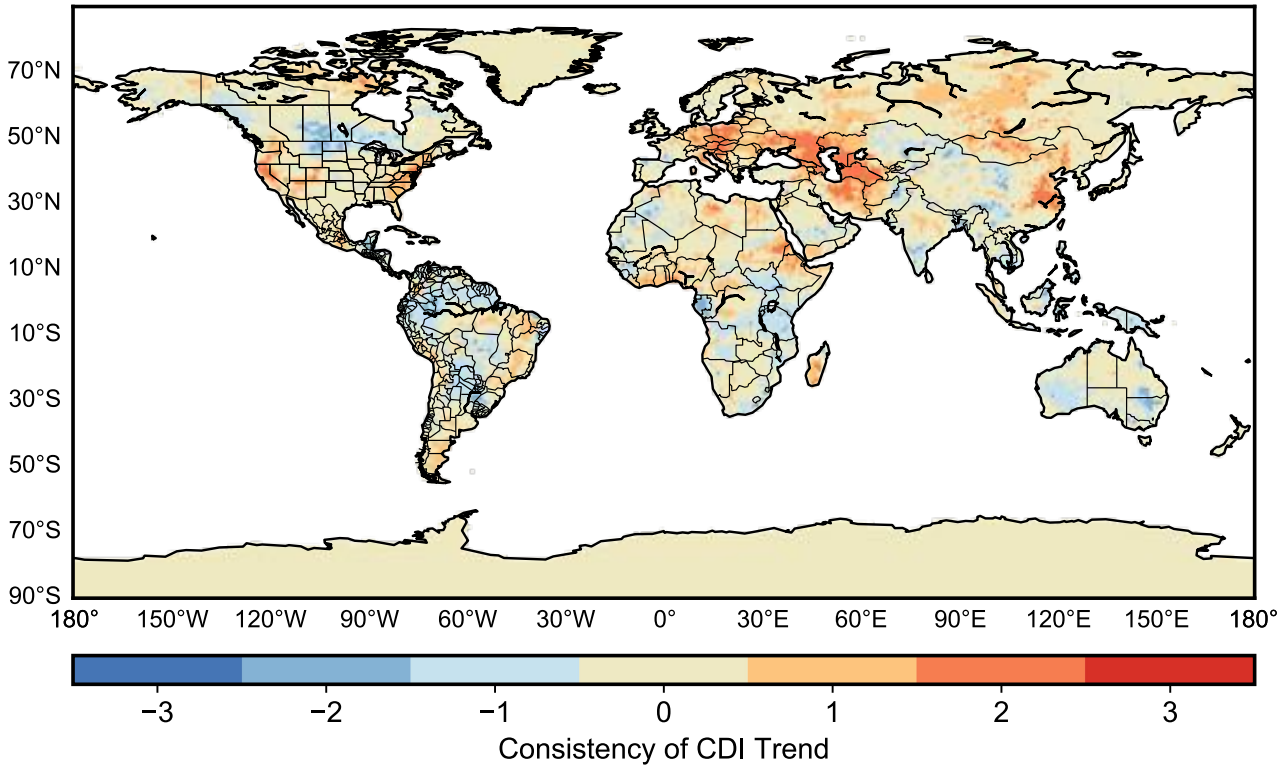


How has the coupling changed (1980-2017)?





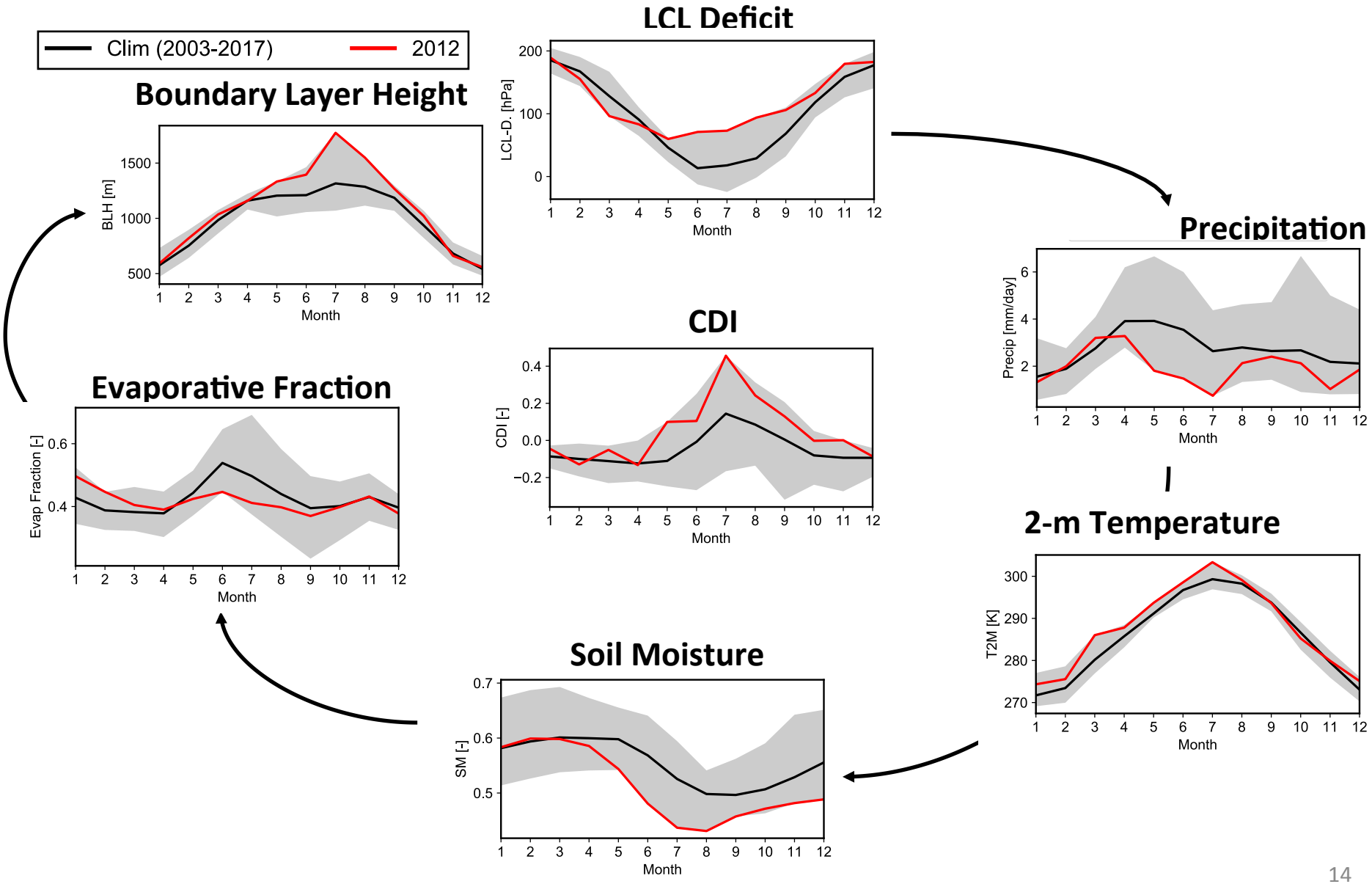
Summary and Conclusions:



- **The 2017 and 2012 Droughts show different L-A Feedbacks from reanalysis data that is captured by the CDI.**
- **The dry down in the reanalysis plays an important role in the L-A feedbacks during a flash drought.**
- **More work needs to be done to understand the differences in coupling between reanalysis and satellite**

Coupling Process Chain for 2012 MERRA2

2012 – Low Plains (Illinois, Missouri, Iowa, Nebraska, Kansas, Oklahoma, Arkansas)



How has the coupling changed (1980-2017)?