The temporal variability of land-atmosphere coupling regimes in the Southeast United States

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1. Motivation

Extreme hydrologic events in the form of droughts are a significant source of social and economic damage in the Southeast United States. Understanding the development and recovery of drought could lead to better forecast, which would reduce the severity of drought. There are many classifications of drought; however, most are associated with prolonged periods of abnormally low precipitation. During the warm season, precipitation is impacted by land-atmosphere interactions (coupling) through growth and attributes of the atmospheric boundary layer from surface heat and moisture fluxes. Therefore, the temporal variability and persistence of land atmosphere interactions could play a role in the development and recovery of drought. This research addresses the questions, **what is the temporal variability of coupling over the Southeast United States and how does it play a role in drought?**

2. Coupling Classification

The approach follows that of (Findell et al. 2003) which was applied globally by (Ferguson et al. 2011) to classify land atmosphere coupling through Convective Triggering Potential (CTP) and the low level humidity index (HI) calculated from the Modern Era Retrospective-analysis for Research and Applications (MERRA) reanalysis and the remotely sensed Atmospheric Infrared Sounder (AIRS). In addition, we use soil moisture from MERRA, the Advanced Microwave Scanning Radiometer (AMSR-E) and the Variable Infiltration Capacity (VIC) model. The CTP-HI space is classified into coupling regimes based on the distribution of soil moisture as compared to a reference distribution (climatology). A timeseries of coupling is created from the classified CTP-HI space. After which the time series was gap filled and temporally filtered. The classification was applied using four combinations of datasets (CTPHI- soil moisture), all of which showed similar patterns to the regimes of (Findell et al.), however, the exact areas are different (See Figure 1).

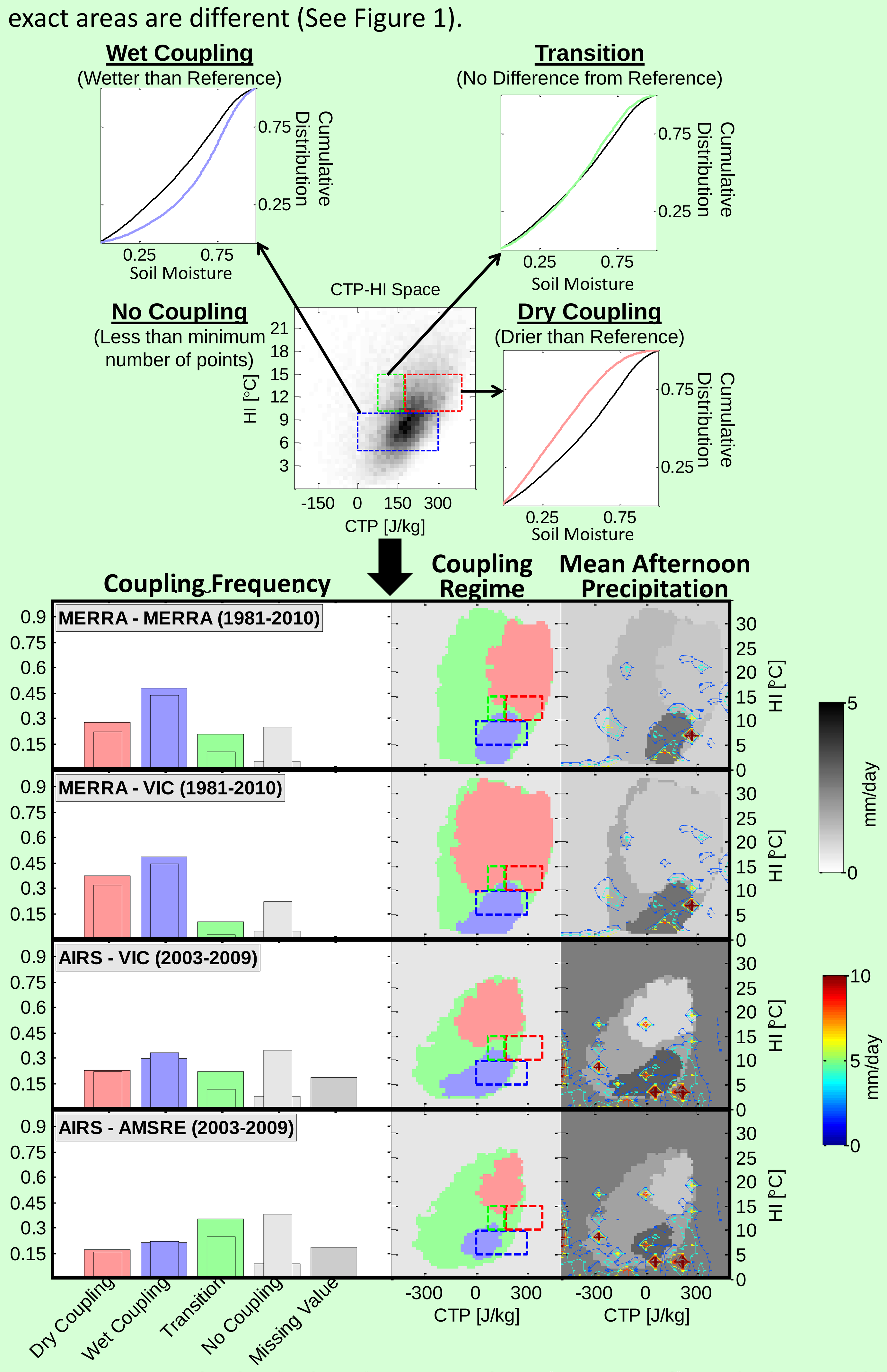

Figure 1 – Method of classifying coupling (Top panel) and the results (Bottom Panel) for different datasets (rows) over the Jun-Sep season. Column one shows the normalized frequency for the initial classification (wide bars) and after temporal filter and filling (thinner bars). Column two compares the new classification with the (Findell et al. 2003) classification and column three shows the average mean afternoon precipitation.

3. Seasonality and Persistence

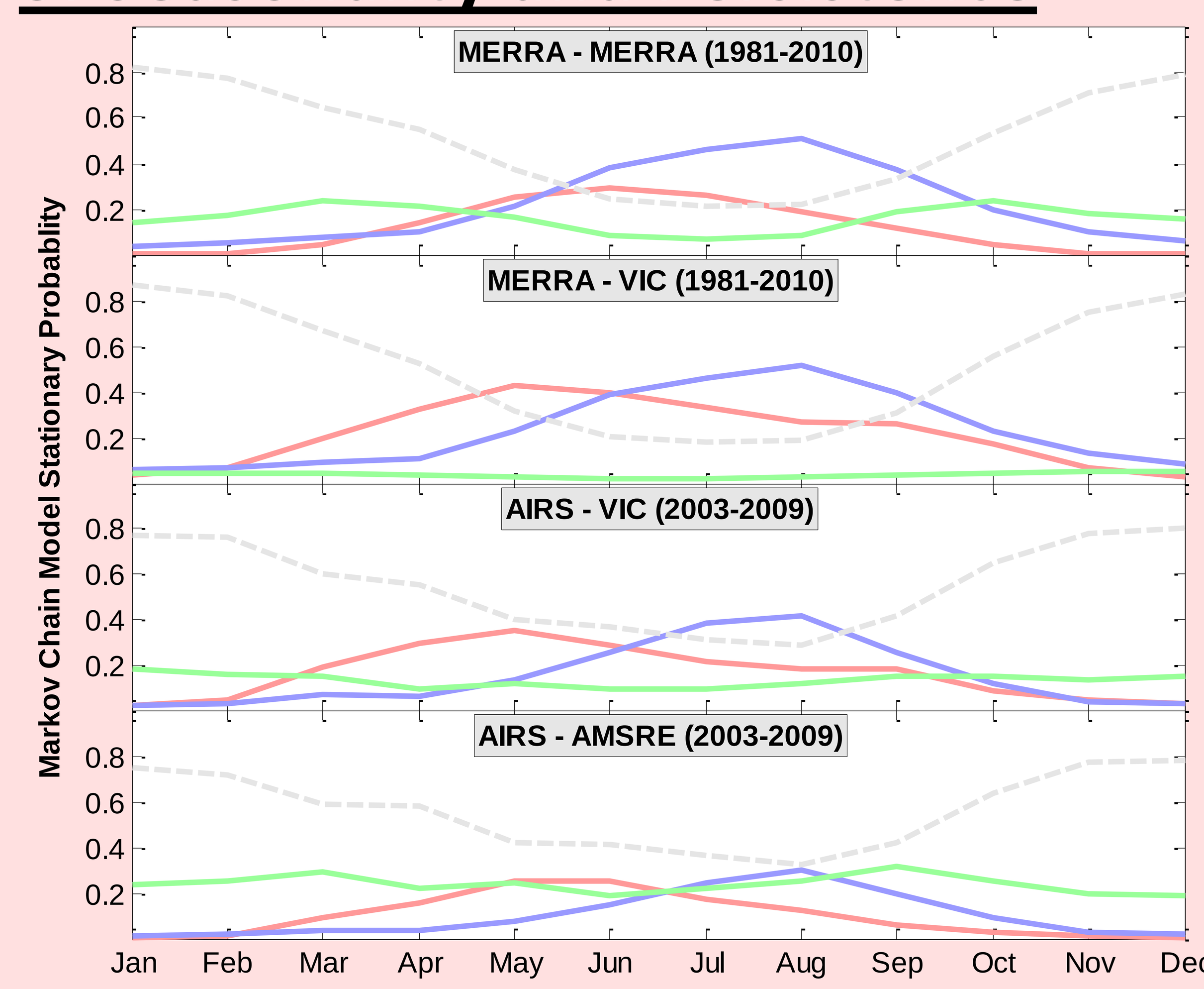

Figure 2 – The seasonal cycle of the stationary probability from a first order Markov Chain model for the coupling states for the datasets used to classify coupling.

In thinking of coupling as a first order Markov Chain process the seasonality of stationary probabilities show peaks for dry and wet coupling in May and August respectively, except the MERRA-MERRA combination which shows a peak dry coupling in June (Figure 2). All coupling states show high persistence probabilities, with wet coupling showing the most persistence (Figure 3). This is consistent for all datasets with some variation in the values (Not Shown).

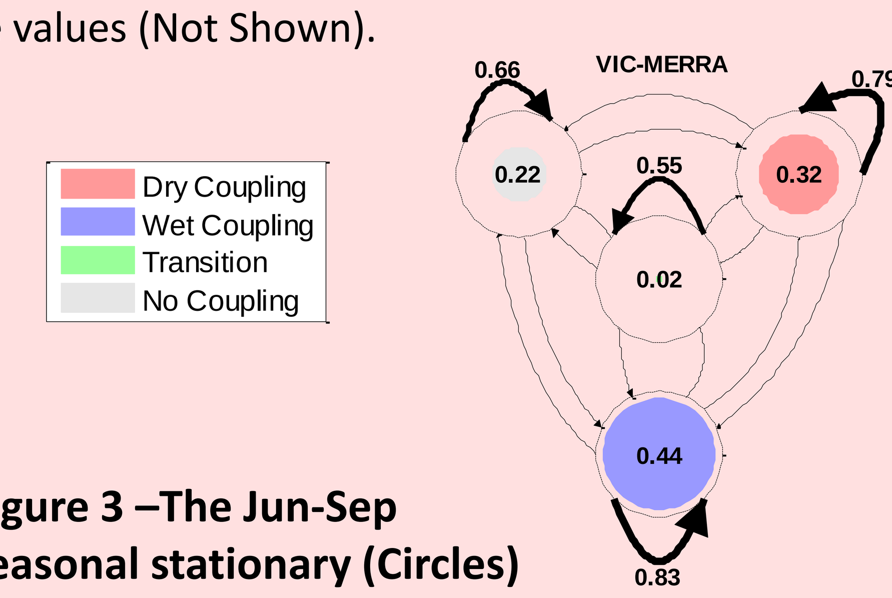

Figure 3 –The Jun-Sep seasonal stationary (Circles) and transitional (Arrows) probabilities draw proportionally with the value of the stationary and persistence probability indicated.

4. Drought and Coupling

The average response of the three soil moisture layers of VIC during a coupling event shows the top layer going to a wet or dry state, while the deepest layer shows consistent drying or wetting (Figure 4). This behavior can be associated with drought continuation and intensification (dry coupling) and recovery (wet coupling) and can be used to derive the Coupling Drought Index (CDI) (given below). Both the CDI and the average percent area in drought from the US Drought Monitor (USDM, http://droughtmonitor.unl.edu) show a consistent peak in drought during the early spring, except the MERRA-MERRA (Figure 5). The inter-annual variability of CDI for all datasets is consistent with the USDM, but the MERRA-VIC is the most consistent in terms of persistence and recovery of drought (Figure 6).

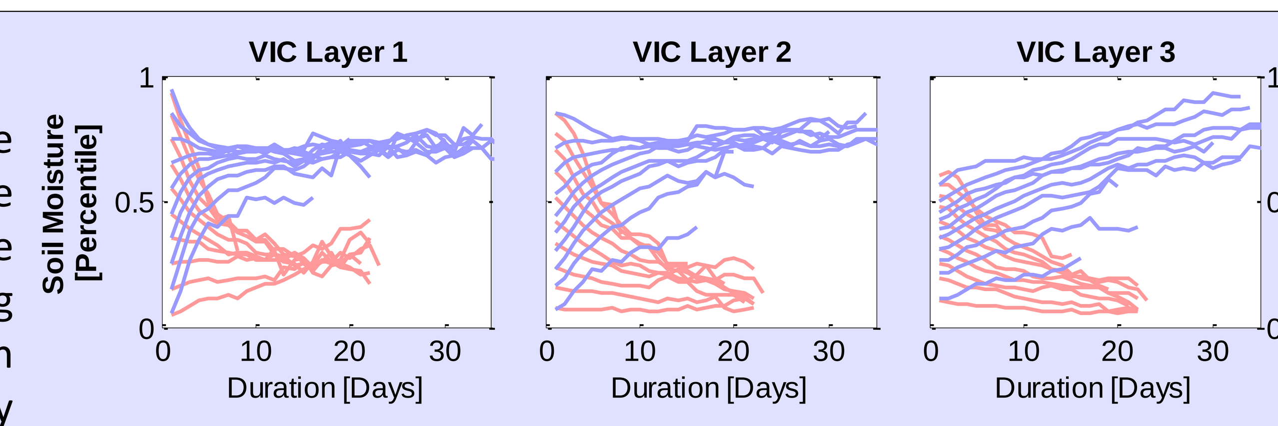

Figure 4 – Average soil moisture during coupled event for different layers of VIC model using the classification from MERRA-VIC dataset.

$$CDI = \frac{Dry\ Coupling - Wet\ Coupling}{Total\ Days}$$

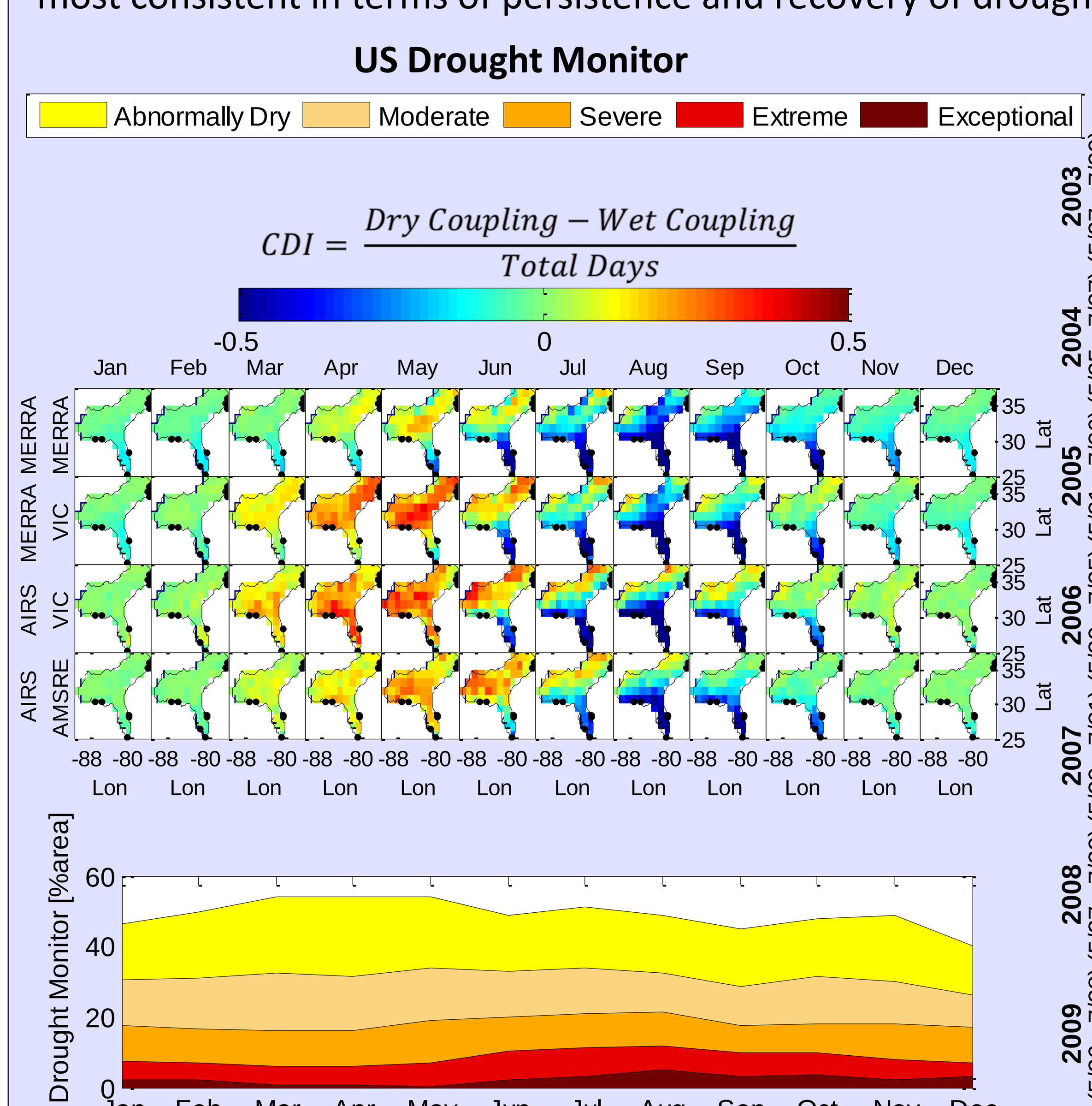

Figure 5 –Spatial and seasonal variability of the CDI (Top panel) and the seasonality of percent area drought from the USDM (Bottom panel) for the Southeast United States.

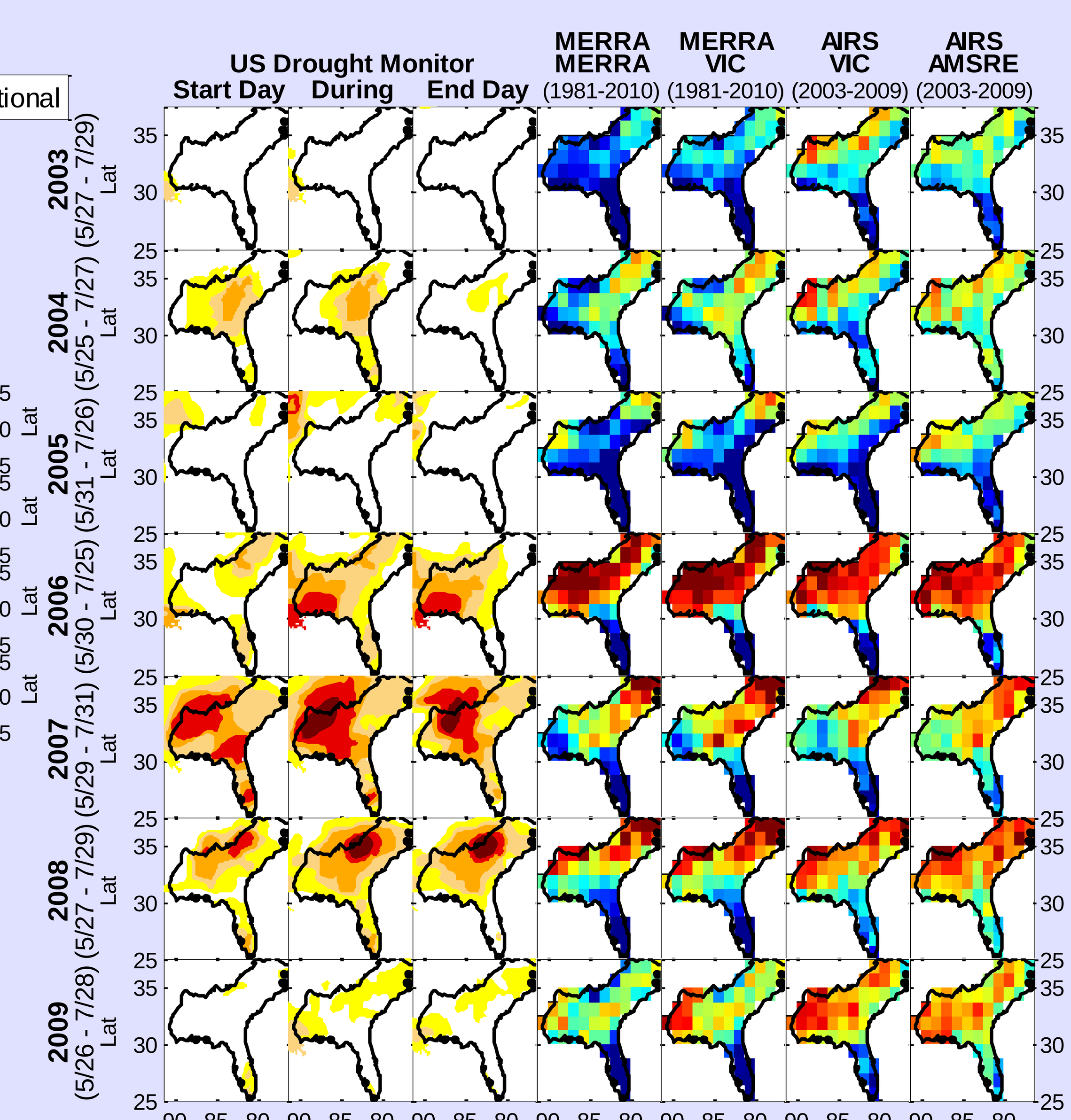

Figure 6– The Spatial variability of drought from the USDM at the start, during and end (first 3 columns) of the June-July season in comparison with the CDI for all classifications of coupling (last four columns) from 2003-2009 (row).

5. Conclusions

- Both Reanalysis and satellite data show the existence of dry and wet coupling.
- Coupling events show strong persistence and distinct seasonality, with dry coupling peaking in early spring and wet coupling peaking in late summer.
- The CDI shows consistent seasonality with US Drought monitor except for the combination of MERRA-MERRA, which shows less dry coupling in the early spring time.
- The CDI which is the difference in dry and wet coupling days is a good indicator of drought and drought recovery and is consistent with in inter-annual variability of drought.

References
Ferguson, C. R. and E. F. Wood (2011). "Observed Land-Atmosphere Coupling from Satellite Remote Sensing and Reanalysis." Journal of Hydrometeorology 12(6): 1221-1254.
Findell, K. L. and E. A. B. Eltahir (2003). "Atmospheric controls on soil moisture-boundary layer interactions. Part I: Framework development." Journal of Hydrometeorology 4(3): 552-569.

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