Local land-atmosphere Coupling (LoCo): Forecast precipitation skill for different land-atmosphere coupling regimes in the Southeast United States

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C31-138A

1. Motivation

Extreme hydrologic events in the form of droughts are a significant source of social and economic damage in the Southeast United States. Having sufficient warning of these extreme events allows managers to prepare for and reduce the severity of their impacts. A seasonal hydrologic forecast system can be used to provide early warning; however, the skill of the forecasts greatly depends on the skill of the precipitation forecast. During the convective season the land-atmosphere interaction (coupling) impacts the diurnal precipitation cycle through the surface heat and moisture fluxes. This leads to the questions, **what is the role of coupling over the Southeast United States and how does it affect drought and the skill of precipitation forecasts from seasonal forecast models?**

2. Methods

The approach follows that of (Findell and Eltahir 2003) which was applied globally by (Ferguson and Wood 2011) with reanalysis and remote sensing data to analyze land atmosphere coupling through Convective Triggering Potential (CTP) and the low level humidity index (HI). We use the Modern Era Retrospective-analysis for Research and Applications (MERRA) reanalysis and Earth Observing System (EOS) remote sensing data products, including Atmospheric Infrared Sounder (AIRS) to calculate CTP and HI. The CTP-HI space is then divided into equally spaced bins which are then classified into a coupling regime based on the distributions of soil moisture of convective precipitation days, non-convective days and the seasonal climatology (See Figure 1). The soil moisture is from the Variable Infiltration Capacity model (VIC) and from Advanced Microwave Scanning Radiometer (AMSR-E). Convective and non-convective days are defined by afternoon precipitation from NLDAS2 using a 1mm threshold. The MERRA and VIC data is from 1981-2010, while the remote sensing data spans 2003-2009.

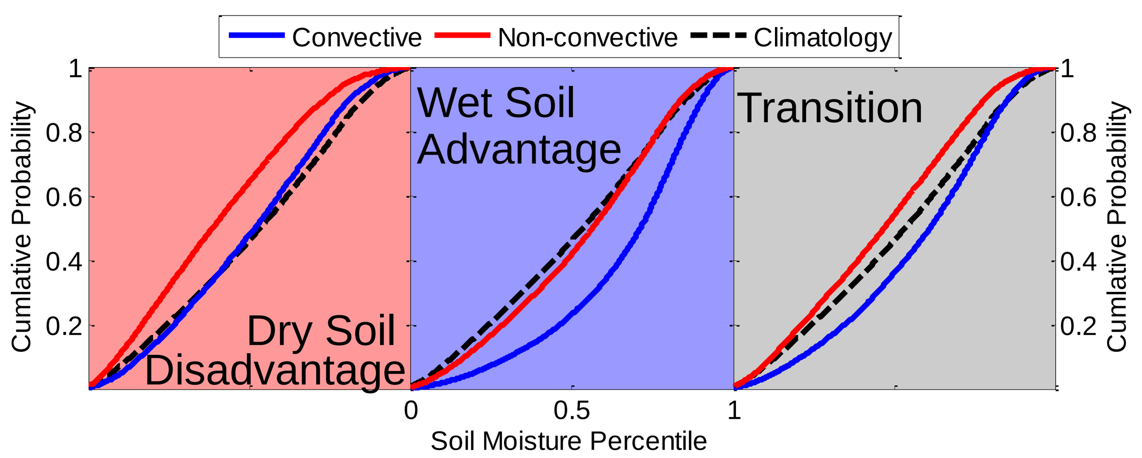

Figure 1 – Examples of classifying the CTP-HI space based on soil moisture distributions for each CTP-HI bin.

3. Coupling Classification

The coupling classification shows a variety of regime frequency across data combinations (See Figure 2), but generally shows similar structure in the CTP-HI space starting with wet soil advantage and transitioning into dry soil disadvantage. The MERRA-AMSR-E combination showed no wet soil advantage. This is most likely due to the heavy vegetation cover in the Southeast which limits the ability of the remote sensing to capture the variability of soil moisture. The differences in the MERRA-AIRS data can be attributed to the timing of the CTP-HI measurements, as the AIRS data is later in the day and influenced by the coupling. The MERRA-VIC data has the advantage of a greater temporal resolution and is used for the rest of the analysis.

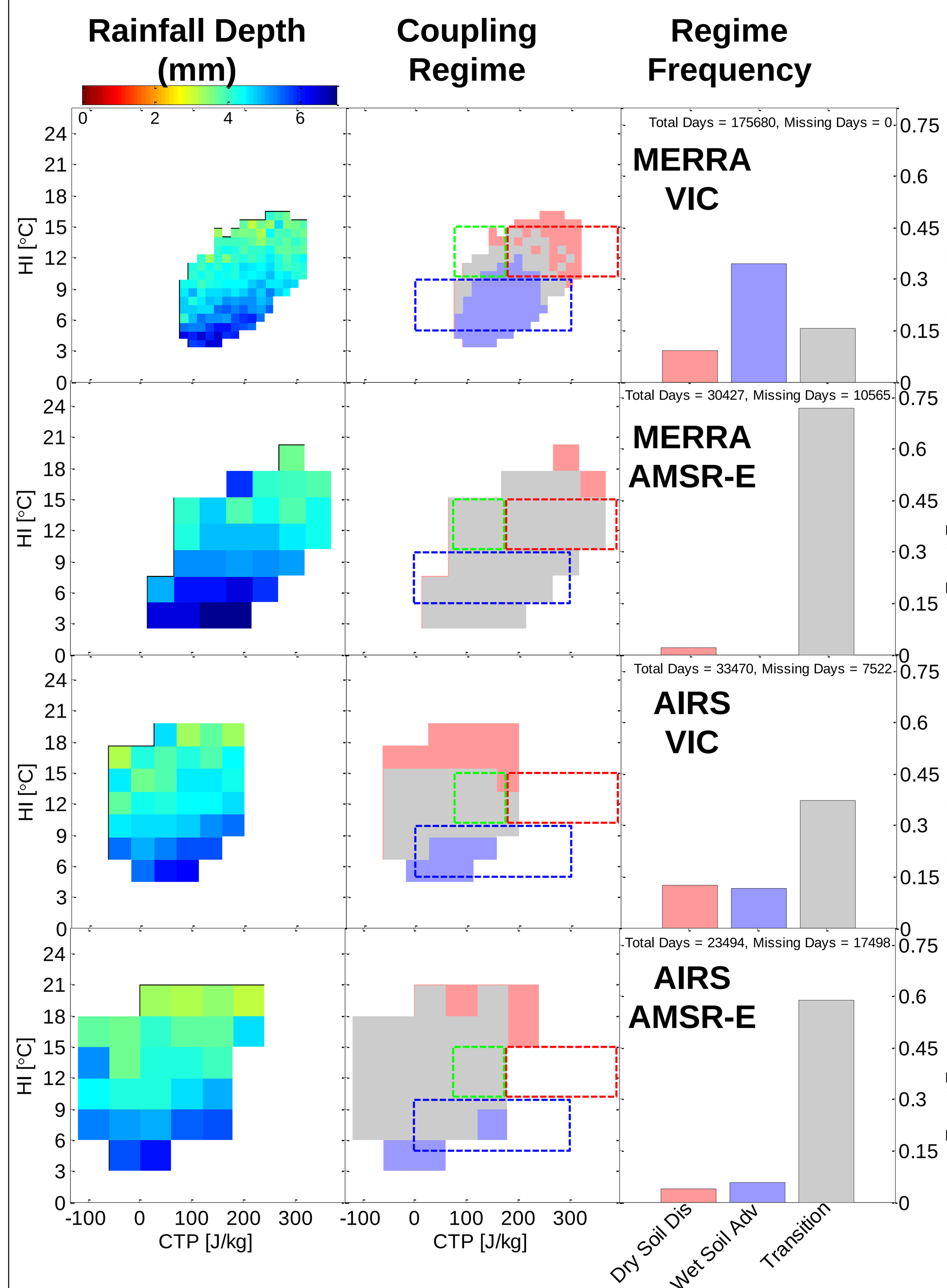

Figure 2 – (Column one) Average event rainfall depth, (Column two) coupling regimes overlaid by regimes defined by Findell and Eltahir 2003 (Blue–Wet Soil Advantage) (Red-Dry Soil Advantage)(Green-Transition) and (Column three) frequency of coupling regimes. Rows are different dataset combinations.

4. Coupling and Drought

The top panel of Figure 3 shows the cumulative frequency of dry soil disadvantage and wet soil advantage events normalized by the annual average for two different drought years (2002 & 2007). The difference in the cumulative frequency of these two coupling regimes is defined as the drought intensification factor. The second panel shows this drought intensification factor and the percent area of drought from the US drought monitor. The two years have similar percentage of drought at the beginning of the convective season; however, the 2002 drought diminished and showed weak coupling intensification during the convective season. In contrast 2007 showed high coupling intensification and the drought intensified.

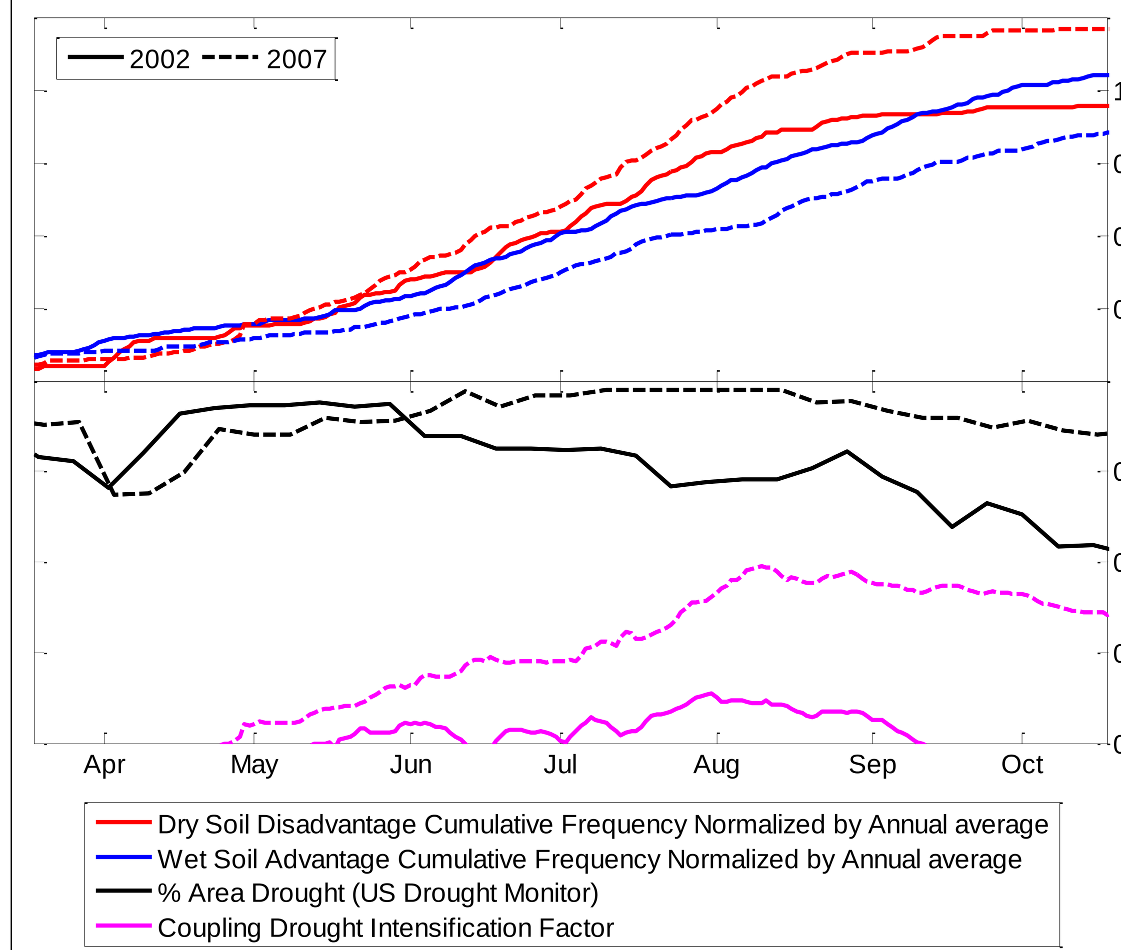

Figure 3 – (Top panel) Cumulative frequency of dry and wet coupling regimes and (Bottom panel) the percent drought area and the coupling drought intensification factor for two drought years 2002 and 2007.

5. Coupling and Forecasts

Figure 4 shows the relationship of the monthly frequency of different coupling regimes with the monthly mean bias at a four month lead time from NCEP's Climate Forecast System (CFS), which was recently updated to version two. The top panel of Figure 4 is for the dry soil disadvantage events and shows linear relationship with a positive slope. The x intercept is the coupling frequency where the model shows the most skill. Left of this indicates less dry coupling, which results in a negative bias, meaning the model underestimates the precipitation. The converse is true to the right of the x-intercept, which is consistent with the dry coupling regime. Panel two and three show the wet soil advantage and transition regimes which are consistent with their respective coupling. The graph to the right of each panel shows the frequency at the minimum bias with lead time of the forecast, which is nearly constant after month one.

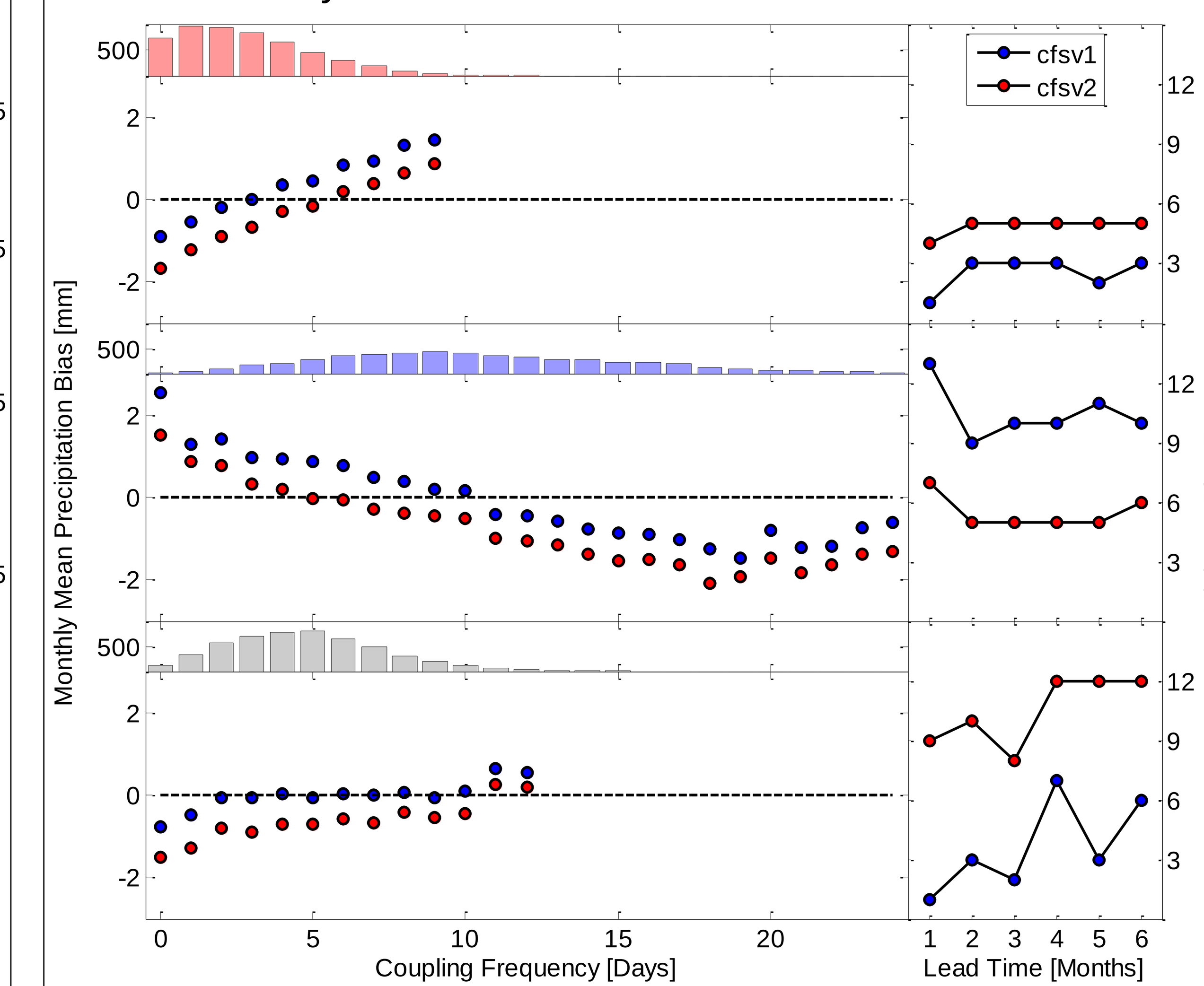

Figure 4 – (Column one) Frequency of coupling regimes versus average precipitation bias from forecast models and (Column two) minimum bias frequency with lead time.

6. Conclusions

- **The AMSR-E data is limited by the vegetation cover in the Southeast, but over a less vegetated area could give different results.**
- **The 2007 drought showed intensification due to land atmosphere coupling that was not seen in the 2002 drought.**
- **The average precipitation bias of seasonal forecast models shows a linear relationship consistent with the different coupling regimes. The new version of CFS shows different coupling from the original, which could be useful in constructing a multi-model forecast.**

References
Ferguson, C. R. and E. F. Wood (2011). "Observed land-atmosphere coupling from satellite remote sensing and re-analysis." Journal of Hydrometeorology.
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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