

## Multivariate Mutual Information

- References:

- Roundy, J. K., C. R. Ferguson, and E. F. Wood, 2013a: Temporal variability of land–atmosphere coupling and its implications for drought over the Southeast United States. *J. Hydrometeor.*, **14**, 622–635, doi: [10.1175/JHM-D-12-090.1](https://doi.org/10.1175/JHM-D-12-090.1).
- Roundy, J. K., C. R. Ferguson, and E. Wood, 2013b: Impact of land-atmospheric coupling in CFSv2 on drought prediction. *Clim. Dyn.*, **43**, 421–434, doi: [10.1007/s00382-013-1982-7](https://doi.org/10.1007/s00382-013-1982-7).

- Principle:

- CTP and  $HI_{Low}$  indices and categories from Findell and Eltahir (2003) are paired with soil moisture estimates to provide an additional dimensionality, and to account for evaporation effects.
  - A 3-D CDF is compiled for a region based on historical data.
  - In the 2-D CTP and  $HI_{Low}$  space a marginal distribution of soil moisture is considered for each bin (representing a specific range of CTP and  $HI_{Low}$ ). A Kolmogorov-Smirnov test between the marginal and total soil moisture distributions is applied and a “regime” is assigned.
    - Dry coupling if  $\{SM_{Bin}\} \square \{SM_{All}\}$  where brackets indicate the distribution and double sign indicates significance
    - Wet coupling if  $\{SM_{Bin}\} \square \{SM_{All}\}$
    - Transitional if  $\{SM_{Bin}\} \gg \{SM_{All}\}$
    - Atmospherically controlled where cases are few
  - The process is repeated for different bin counts and significance levels of the K-S test to establish uncertainties, and smoothing is applied to create a final distribution of regimes in CTP -  $HI_{Low}$  space.
  - Time series of regimes at a point are then constructed.
  - Coupling drought index for a period of  $N$  days:  $CDI = \frac{N_d - N_w}{N}$  where  $N_d$  and  $N_w$  are the number of days in dry coupling and wet coupling respectively.
    - Negative values near -1 indicate consistent wet coupling or drought recovery
    - Positive values near +1 indicate dry coupling or drought intensification and persistence.

- Data needs:

- Temperature and humidity profiles through the lowest 300hPa (approximately 3 km) of the atmosphere during early morning, soil moisture estimates (daily mean).

- Observational data sources:

- Well suited for application to radiosonde profiles, namely where early morning soundings are available, but need co-located soil moisture measurements.
- Roundy and Santanello (2017) extends to AIRS satellite profiles.

- Caveats:

- Calibrated to the area and time period over which the CDF is compiled – makes this a *relative* rather than *absolute* metric, which may be either advantageous or disadvantageous depending on the application.