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.
  - 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.
- 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.

Supported by NASA/MAP Grant: NNX13AQ21G