[Coupling metrics to diagnose land-atmosphere interactions]

Critical Soil Moisture (CSM)

- Reference:
  - Denissen, J. M. C., Teuling, A. J., Reichstein, M., & Orth, R. (2020). Critical soil moisture derived from satellite observations over Europe. J. Geophys. Res., **125**, e2019JD031672. Doi: 10.1029/2019JD031672.

- Principle:
  - Vegetation variables are correlated more strongly with water variables where water is limited, and with energy variables where energy is limited. The crossover point, where the correlations are equal, defines a critical value – when the water variable is soil moisture, a critical soil moisture (CSM) can be found.
  - Taking evapotranspiration ET as the vegetation variable, surface soil moisture W as the water variable, and skin temperature T as the energy variable, CSM is defined as W at which $\Delta r = r(T, ET) - r(W, ET) = 0$.
  - Δr is itself an aridity index: positive where water limited, negative where energy limited.

- Data needs:
  - Denissen et al. (2020) use bi-monthly anomalies in satellite skin temperature, soil moisture (from the ESA-CCI blended satellite product) and ET from FLUXCOM.
  - Any co-located data from satellite, *in situ* measurements or models can be used.
  - Appropriate for data at timescales ranging from daily to monthly.

- Observational data sources:
  - Any co-located data from satellite, and/or *in situ* measurements (e.g., flux towers).
  - Radiometer data could be substituted for temperature as the energy variable. For the vegetation variable, LAI or SIF data could be appropriate at longer time intervals (bimonthly to monthly).

- Caveats:
  - Denissen et al. (2020) use Kendall's rank correlations to assuage nonlinear impacts.
  - As different vegetation exerts different controls on ET (e.g., by different stomatal conductance response functions), CSM can be a function of vegetation type. Likewise, different soil types may also cause differences.
  - This is similar in concept to Benson & Dirmeyer (2020) but requires data from 3 time series to compute, rather than just 2.

Supported by NASA/MAP Grant: NNX13AQ21G