

## Granger Causality

- References:

- Salvucci, G. D., J. A. Saleem, and R. Kaufmann, 2002: Investigating soil moisture feedbacks on precipitation with tests of Granger causality. *Adv. Water Resour.*, **25**, 1305-1312, doi: [10.1016/S0309-1708\(02\)00057-X](https://doi.org/10.1016/S0309-1708(02)00057-X).
- Granger, C. W. J., 1969: Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, **37**(3), 424, doi: [10.2307/1912791](https://doi.org/10.2307/1912791).

- Principle:

- This is a general statistical principal not specific to land-atmosphere coupling. It comes from the field of econometrics –models are formed with and without an input  $S$  (e.g., soil moisture) and a significant difference in response indicates the causality of  $S$ .
- For the potential dependence of precipitation  $P$  on soil moisture  $S$ , the conditional distributions tested are:

$$F(P_t | W_{t-Dt}) \neq F(P_t | W_{t-Dt} - S_{t-Dt})$$

within some range of confidence, where  $W_{t-Dt}$  is all knowledge available up to time  $t - Dt$  (which includes previous precipitation, soil moisture and potentially other variables as well) and  $W_{t-Dt} - S_{t-Dt}$  means all knowledge except that of soil moisture.

- $W_{t-Dt}$  must not contain any future information from  $t$  or later,
- $W_{t-Dt}$  must not contain redundant information (e.g., multiple functionally-related variables)

- Data needs:

- Observational or model data can be used – multiple linear regression or other models are common. The method is non-restrictive, however, as long as two conditional distributions can be constructed and statistically tested.

- Observational data sources:

- Observed soil moisture and precipitation (or any data pertinent to the causality test).

- Caveats:

- Care must be taken to avoid detection of false causal relationships (e.g., effect-effect relationships or apparent causation due to persistence).