

Granger Causality

- Reference:

- 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.
- Granger, C. W. J., 1969: Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, **37**(3), 424, doi: 10.2307/1912791.

- Principle:

- This is a general statistical principle 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:

$$F(P_t | \Omega_{t-\Delta t}) \neq F(P_t | \Omega_{t-\Delta t} - S_{t-\Delta t})$$

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

- $\Omega_{t-\Delta t}$ cannot contain any future information from t or later,
- $\Omega_{t-\Delta t}$ cannot 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).