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# Investigating Granger causality with state-space representation of time series: a case study of the total water storage anomaly over Australia

**Karim Douch**, Peyman Saemian, and Nico Sneeuw
GIS, Stuttgart university, Germany

Originating from econometrics, the concept of Granger causality (GC) has been widely used in a variety of fields, including climate sciences, to infer directional dependencies between stochastic variables. Going one step further than the simple detection of lag-correlations, GC evaluates the directed interaction of a variable Y on a variable X by quantifying the improvement of prediction of future values of X when past values of Y are considered or omitted. Although not prescribed initially as such, GC is routinely computed from an estimated vector autoregressive model of the data of interest X, with and without the exogenous variable Y. However, such a modelling is somewhat restrictive and not suitable for filtered, sampled and noisy time series which may contain a moving-average component, impairing at the same time the quality of the GC estimator. Conversely, state-space representation offers a much more general framework for linear time series modelling.

In this study, we use Granger causality in the framework of a state-space modelling of time series to infer the presence of causal influences of the sea surface temperature (SST) and the 500hPa geopotential height on the Terrestrial Water Storage Anomaly (TWSA) over Australia[PS1] . A first and critical step is to reduce the high-dimension of the spatio-temporal data to a size compatible with classical state-space modelling algorithms. To do that we extract a limited number of leading modes of variability from the geophysical fields. Next, the state-space models of the extracted modes are identified using subspace-based methods. Then, the Granger causality of every mode of SST (resp. 500hPa geopotential height) on TWSA is estimated. Finally, we discuss the capability of the presented method to detect real directional dependencies in the light of current knowledge on Australia's rainfall climatology and compare it to the results obtained with the classical vector autoregressive models.