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Efficient Bayesian inference for natural time series using ARFIMA processes

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Many geophysical quantities, such as atmospheric temperature, water levels in rivers, and wind speeds, have shown evidence of long memory (LM). LM implies that these quantities experience non-trivial temporal memory, which potentially not only enhances their predictability, but also hampers the detection of externally forced trends. Thus, it is important to reliably identify whether or not a system exhibits LM. We present a modern and systematic approach to the inference of LM. We use the flexible autoregressive fractional integrated moving average (ARFIMA) model, which is widely used in time series analysis, and of increasing interest in climate science. Unlike most previous work on the inference of LM, which is frequentist in nature, we provide a systematic treatment of Bayesian inference. In particular, we provide a new approximate likelihood for efficient parameter inference, and show how nuisance parameters (e.g., short-memory effects) can be integrated over in order to focus on long-memory parameters and hypothesis testing more directly. We illustrate our new methodology on the Nile water level data and the central England temperature (CET) time series, with favorable comparison to the standard estimators [1]. In addition we show how the method can be used to perform joint inference of the stability exponent and the memory parameter when ARFIMA is extended to allow for alpha-stable innovations. Such models can be used to study systems where heavy tails and long range memory coexist.

[1] Graves et al, Nonlin. Processes Geophys., 22, 679–700, 2015; doi:10.5194/npg-22-679-2015.