Identifying stochastic model parameter non-stationarity over multi-centennial timescales

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Abstract: Drought risk estimates - which inform the design of water supply infrastructure and management plans - are traditionally inferred using statistical timeseries models (i.e., stochastic models) and assume model parameters are constant in time (i.e., the stationarity assumption). However, validating the stationarity assumption is difficult because the instrumental measurements used to calibrate stochastic models are short and serially dependent. This leads to significant parameter uncertainty. This uncertainty makes it hard to identify whether stochastic model parameters derived from different time periods are different (i.e., non-stationary). Palaeoclimate proxy records derived from climate-sensitive geological/biological layers can be used to assess stochastic model parameter stationarity. This is because they are sufficiently long (i.e., hundreds/thousands of years) to reduce parameter uncertainty. In this study, we used the Law Dome summer sea salt record – a ~2000-year ice core record with links to east Australian rainfall – to examine stochastic model parameter stationarity. Two stochastic models capable of reproducing low-frequency – the ARMA(1,1) and ARFIMA(0,D,0) models – were used. These models were calibrated to different centennial/millennium-length time periods of the proxy record using Bayesian methods, which resulted in estimates of parameter uncertainty (i.e., parameter posteriors). Parameter posteriors derived from the different time periods were then compared, with significantly different posteriors being indicative of parameter non-stationarity. We found that at multi-centennial and millennial timescales (a) mean and standard deviation parameters are non-stationary and (b) persistence parameters are stationary. These findings highlight that stochastic models calibrated to short (e.g. less than ~100 years) instrumental records are poorly suited for estimating long-term historic climate risk. These findings also demonstrate that, irrespective of anthropogenic climate change, historic climate risk inferred from stochastic models calibrated to the instrumental record is not necessarily representative of long-term future risk.

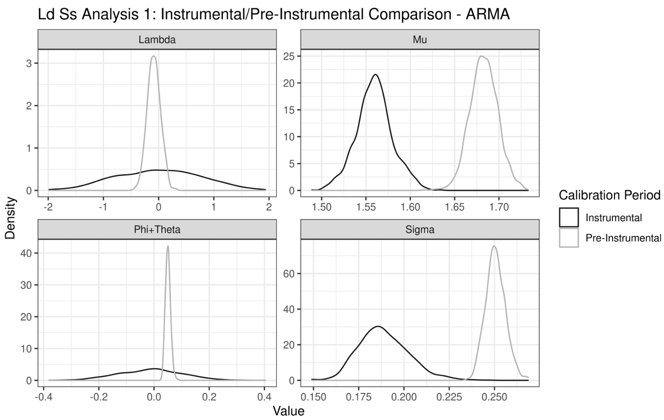

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Figure 1. ARMA(1,1) model posteriors derived from paleoclimate proxy instrumental and pre-instrumental periods. 'Lambda' refers to the Box-Cox transformation parameter, 'Mu' refers to the mean, 'Sigma' refers to the standard deviation, and 'Phi+Theta' refers to the sum of ARMA(1,1) persistence parameters.

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