Supplementary Information

Effective Sample Size for Statistical Significance

This method is an implementation of the method outlined in Guemas et al. (2014). An existing formula for effective sample size $N*$ is taken:

$$N* = \frac{N}{1 + 2\sum_{\tau=1}^{N-1} \frac{N-\tau}{N} \hat{\rho}(\tau)}, \tag{1}$$

where N is the actual sample size, τ lag time and $\hat{\rho}(\tau)$ the sample estimate of the autocorrelation $\rho(\tau)$ at lag τ. Sample autocorrelations for large lags have high uncertainty in short timeseries. Non-zero autocorrelation is assumed to be as a result of an 1st order autogressive (AR(1)) system, written as:

$$x(t) = \alpha x(t-1) + \epsilon(t) \tag{2}$$

where $\epsilon(t)$ is white noise with zero mean and variance $\mathrm{Var}(x) - \alpha^2$. This leads to the following equation for effective sample size:

$$N* = \frac{N}{1 + 2\sum_{\tau=1}^{N-1} \frac{N-\tau}{N} \alpha^{\tau}}. \tag{3}$$

A value of α is computed which minimizes the following function:

$$f(\alpha) = \sum_{\tau=1}^{N-1} \left(\frac{\hat{\rho}(\tau) - \alpha^{\tau}}{\tau} \right)^2, \tag{4}$$

i.e. the mean square difference of autocorrelations estimated through the available timeseries and autocorrelations estimated by the AR(1) process, with the differences inversely weighted by the lag τ to account for increasing uncertainty with increased lag. To minimise the function, values of α between 0 and 0.99 with intervals of 0.01 are considered, with the value with the lowest $f(\alpha)$ chosen.

Where this method has been used, the calculation has been applied to the observational reference for years where it overlaps with the hindcast, on a grid point-by-grid point basis.