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A unified nonlinear stochastic time series analysis for climate science

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Earth's orbit and axial tilt imprint a strong seasonal cycle on climatological data. Climate variability is typically viewed in terms of fluctuations in the seasonal cycle induced by higher frequency processes. We can interpret this as a competition between the orbitally enforced monthly stability and the fluctuations/noise induced by weather. Here we introduce a new time-series method that determines these contributions from monthly-averaged data. We find that the spatio-temporal distribution of the monthly stability and the magnitude of the noise reveal key fingerprints of several important climate phenomena, including the evolution of the Arctic sea ice cover, the El Niño Southern Oscillation (ENSO), the Atlantic Niño and the Indian Dipole Mode. In analogy with the classical destabilising influence of the ice-albedo feedback on summertime sea ice, we find that during some period of the season a destabilising process operates in all of these climate phenomena. The interaction between the destabilisation and the accumulation of noise, which we term the *memory effect*, underlies phase locking to the seasonal cycle and the statistical nature of seasonal predictability.