Building an Earth System Model emulator for local monthly temperature

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Emulators are computationally cheap statistical devices that derive simplified relationships from otherwise complex climate models. A recently developed Earth System Model (ESM) emulator, MESMER (Beusch et al. 2020), uses a combination of pattern scaling and a variability emulator to emulate ESM initial-condition ensembles. Linear scaling provides the spatially resolved yearly temperature trend projections from global mean temperature trend values. In addition, the variability emulator stochastically models spatio-temporally correlated local variability, yielding a convincing imitation of the internal climate variability displayed within a multi-model initial condition ensemble. The work presented here extends MESMER’s framework to have a monthly downscaling module, so as to provide spatially resolved monthly temperature values from spatially resolved yearly temperature values. For this purpose, a harmonic model is trained on monthly ESM output to capture monthly cycles and their evolution with changing temperature. Once the mean monthly cycle is sufficiently emulated, a process based understanding of the biases within the harmonic model is undertaken. Such entails employing a Gradient Boosting Regressor tree model (GBR) to explain the residuals from the harmonic model using biophysical climate variables such as albedo and thermal fluxes as explanatory variables. These variables can be rated according to their explanatory power when categorising residuals which furthermore elucidates the main physical processes driving biases in the harmonic model within seasons at the grid point level. Finally we add residual variability on top of the harmonic model outputs to provide convincing imitations of ESM monthly temperature realisations. The residual variability is generated using an AR(1) process coupled to a multivariate trans-gaussian process so as to maintain spatio-temporal correlations and the non-stationarity in monthly variability with increasing yearly temperatures.
