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A Scaling Model for the Anthropocene Climate Variability with Projections to 2100

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The determination of the climate sensitivity to radiative forcing is a fundamental climate science problem with important policy implications. We use a scaling model, with a limited set of parameters, which can directly calculate the forced globally-average surface air temperature response to anthropogenic and natural forcings. At timescales larger than an inner scale τ, which we determine as the ocean-atmosphere coupling scale at around 2 years, the global system responds, approximately, linearly, so that the variability may be decomposed into additive forced and internal components. The Ruelle response theory extends the classical linear response theory for small perturbations to systems far from equilibrium. Our model thus relates radiative forcings to a forced temperature response by convolution with a suitable Green's function, or climate response function. Motivated by scaling symmetries which allow for long range dependence, we assume a general scaling form, a scaling climate response function (SCRF) which is able to produce a wide range of responses: a power-law truncated at τ. This allows us to analytically calculate the climate sensitivity at different time scales, yielding a one-to-one relation from the transient climate response to the equilibrium climate sensitivity which are estimated, respectively, as $1.6^{+0.3}_{-0.2}K$ and $2.4^{+1.3}_{-0.6}K$ at the 90 % confidence level. The model parameters are estimated within a Bayesian framework, with a fractional Gaussian noise error model as the internal variability, from forcing series, instrumental surface temperature datasets and CMIP5 GCMs Representative Concentration Pathways (RCP) scenario runs. This observation based model is robust and projections for the coming century are made following the RCP scenario 2.6, 4.5 and 8.5, yielding in the year 2100, respectively : $1.5^{+0.3)_{-0.2}K}$, $2.3 \pm 0.4K$ and $4.0 \pm 0.6K$ at the 90 % confidence level. For comparison, the associated projections from a CMIP5 multi-model ensemble(MME) (32 models) are: $1.7 \pm 0.8K$, $2.6 \pm 0.8K$ and $4.8 \pm 1.3K$. Therefore, our projection uncertainty is less than half the structural uncertainty of this CMIP5 MME.