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# Estimating internal variability under changing external forcing

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A robust estimate of internal variability is crucial for a wide range of climate-study applications, be it model evaluation, predictions, projections, or attribution studies. While internal variability can readily be estimated from standard pre-industrial control simulations, under changing forcing ensemble simulations are required to estimate internal variability. However, such estimate is only possible for those models that provide several ensemble simulations. To overcome this limitation, we here show how internal variability for a changing forcing can be estimated for all models from their pre-industrial control simulation provided that at least some models of the ensemble provide several simulations. To obtain the total internal variability of forced simulations largely independent of the ensemble size of individual models, we correct for the small ensemble sizes the models provide. This allows us to show that across the CMIP5 model ensemble, the time-period-averaged internal variability of global-mean surface temperature remains unchanged for historical and future simulations even for large $CO_2$ forcing, while the time-period-averaged internal variability of most sea-ice-related variables decreases proportionally to their mean state. This emergent constraint for sea ice allows one to roughly estimate the internal variability simply based on the mean state and illuminates how the changing external forcing alters the system's internal variability. Our findings show that the internal variability estimate from each pre-industrial control simulation can be used for the present and translated to the future and thus limits the need of large ensembles for internal variability studies. Applying our approach to model evaluation of sea-ice simulations, we confirm that the plausibility of simulations differs widely and that internal variability can explain most of the model's deviation from the observed trend, but often not the model's deviation from the mean state. The results thus allow for a distinction between model deviations that might be plausible due to internal variability and reference data uncertainty and those that cannot be explained by these sources of uncertainty pointing to shortcomings of model formulation and parameterisation.