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Partitioning uncertainty components of an incomplete ensemble of climate projections using data augmentation

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The quantification of internal variability and model uncertainty sources in Multi-scenario Multi-model Ensembles of climate experiments (MMEs) is a key issue. It is expected to both help decision makers to identify robust adaptation measures and scientists to identify where their efforts are needed to narrow uncertainty. The setup of available MMEs makes however uncertainty analyses difficult. In the popular single-time ANOVA approach for instance, a precise estimate of internal variability requires multiple members for each simulation chain (e.g. each emission scenario/climate model combination) but multiple members are typically available for a few chains only (Hingray et al. 2019). In almost all ensembles also, the matrix of available scenario/models combinations is incomplete making a precise estimate of the main effects of each model difficult (e.g. projections are typically missing for some GCM/RCM combinations) (Evin et al. 2019).

We present QUALYPSO, a Bayesian approach developed to assess the different sources of uncertainty in incomplete MMEs (Evin et al. submitted). It is based on the quasi-ergodic assumption for transient climate projections and uses data augmentation (Hingray and Said, 2014). The climate response of each available simulation chain is first estimated with a trend model fitted to raw climate projections. Residuals from the climate change response are used to estimate the internal variability of the chain. Scenario uncertainty and the different components of model uncertainty (e.g. GCM uncertainty, RCM uncertainty) are then estimated with a Bayesian ANOVA model applied to the climate change responses of all available chains. The different parameters of the ANOVA model and the missing quantities associated to the missing chains (e.g. missing scenario/GCM/RCM combinations) are jointly estimated using data augmentation techniques.

QUALYPSO presents many advantages over classical estimation approaches. It first exploits all available experiments, avoiding a dramatic loss of information (the classical case when standard approaches are applied; where the typical solution is to select a complete subset of climate experiments). Along with the estimation of missing data, it also provides an assessment of the estimation uncertainty and adequately propagates the uncertainty due to missing chains. With the

explicit treatment of missing experiments, it is then expected to produce unbiased estimates of all parameters, in contrast to direct empirical estimates.

QUALYPSO can be applied to any kind of climate variable and any kind of MMEs. We present examples of application for different hydroclimatic variables from different ensembles of projections including EUROCORDEX and CORDEX-Africa.

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