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Assessment of representations of model uncertainty in monthly and seasonal forecast ensembles

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A goal for the development of a forecasting system, of weather or climate, is the provision of reliable predictions. This necessarily implies that predictions must take explicit account of inherent uncertainties in the prediction process, and therefore be probabilistic in nature. The inevitable approximations needed to solve the equations of weather and climate are a major source of forecast error and uncertainty on all timescales, from hours to centuries and longer. Over recent years, the multi-model ensemble has emerged in weather and climate prediction, as a pragmatic tool for representing the effects of model uncertainty. However, such ensembles are limited by the number of models available, and moreover there is no prior guarantee that the available models span the actual model uncertainty. The first of these problems is mostly solved in the alternative approach of perturbing free sub-grid scale parameters within a single model framework. However, the second problem, that of ensuring true model uncertainty is properly represented, is even more acute in the perturbed parameter framework, since uncertainty in the structural form of the parameterisations is not addressed. A third approach to representing model uncertainty has emerged in recent years and relies on the idea of stochastic parameterisation. In this approach the underlying deterministic bulk-formulae are replaced by an inherently stochastic formulation, recognising that the problem of representing sub-grid tendencies as a function of the resolved variables may not be consistent with the underlying dynamical equations or with observations of the real atmosphere. In this paper we assess the skill of the different representations of model uncertainty (multi-model ensemble, perturbed parameter ensemble, stochastic physics ensemble) using IPCC-class global coupled ocean atmosphere models, in seasonal forecast mode. We focus on the analysis of probabilistic predictions of precipitation and near-surface temperature over land areas on time scales of one month to one season, and on seasonal forecasts of SST in the tropical equatorial Pacific. On the monthly timescale, the ensemble forecast system with stochastic parameterisation provides overall the most skilful probabilistic forecasts. On the seasonal timescale the results depend on variable under study: for temperature the multi-model ensemble is most skilful overall, for precipitation it is the ensemble with stochastic parameterisation. The representation of model uncertainty in climate change projections is particularly problematic as there is as yet little verification data to assess potential representations. As a result, the concept of seamless prediction has arisen, that climate models can and should be tested in weather and seasonal prediction mode. Our results indicate that moves should begin in earnest to develop stochastic parameterisations for multi-decadal climate predictions using earth-system models.