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Fusing model ensembles and observations together with Bayesian neural networks

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To fuse together output from ensembles of climate models with observations, we have developed a custom Bayesian neural network that produces more accurate and uncertainty aware projections.

Ensembles of physical models are typically used to increase the accuracy of projections and quantify projective uncertainties. However, few methods for combining ensemble output consider differing model performance or similarity between models. Current weighting strategies that do, typically assume model weights are invariant in time and space though this is rarely the case in models.

Our Bayesian neural network infers spatiotemporally varying model weights, bias and uncertainty to capture that some regions or seasons are better simulated in certain models. The Bayesian neural network learns how to optimally combine multiple models in order to replicate observations and can also be used to infill gaps in historic observations. In regions of sparse observations, it infers from both the surrounding data and similar physical conditions. Although we are using a typically black box technique, the attribution of model weights and bias maintains interpretability.

We demonstrate the utility of the Bayesian neural network by using it to combine multiple chemistry climate models to produce continuous historic predictions of the total ozone column (1980-2010) and projections of total ozone column for the 21st century, both with principled uncertainty estimates. Rigorous validation shows that our Bayesian neural network predictions outperform standard methods of assimilating models.