Learning to Represent the Physics of Climate Transitions as an Inverse Problem

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Abstract

Beyond the rise of global mean surface temperature, there is growing evidence that anthropogenic climate change may trigger rapid climate transitions if certain environmental thresholds, known as tipping points, are surpassed. Formulating effective policies to prevent and mitigate the effect of these transitions requires Earth System Models (ESMs) that can simulate them accurately across a range of possible socioeconomic pathways. Advances in computational power now enable simulating some of these transitions regionally at an unprecedented resolution and scale, providing valuable information about their underlying mechanisms. Physical parameterizations within ESMs can be trained to represent such transitions, by minimizing the mismatch between the ESM statistics and those of the resolved regional simulations for a wide range of conditions across the tipping point of interest. This training task can be formulated as an inverse problem and solved using ensemble Kalman methods. The methodology is gradient-free, non-intrusive, and provides means to quantify the parametric uncertainty of the trained model. We demonstrate this approach by training a turbulence and convection model to represent the stratocumulus to cumulus transition in the eastern Pacific Ocean.