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Exploring coupled 4D-Var data assimilation using an idealised atmosphere-ocean model

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The successful application of data assimilation techniques to operational numerical weather prediction and ocean forecasting systems has led to an increased interest in their use for the initialisation of coupled atmosphere-ocean models in prediction on seasonal to decadal timescales. Coupled data assimilation presents a significant challenge but offers a long list of potential benefits including improved use of near-surface observations, reduction of initialisation shocks in coupled forecasts, and generation of a consistent system state for the initialisation of coupled forecasts across all timescales.

In this work we explore some of the fundamental questions in the design of coupled data assimilation systems within the context of an idealised one-dimensional coupled atmosphere-ocean model. The system is based on the European Centre for Medium-Range Weather Forecasts (ECMWF) Integrated Forecast System (IFS) atmosphere model and a K-Profile Parameterisation (KKP) mixed layer ocean model developed by the National Centre for Atmospheric Science (NCAS) climate group at the University of Reading. It employs a strong constraint incremental 4D-Var scheme and is designed to enable the effective exploration of various approaches to performing coupled model data assimilation whilst avoiding many of the issues associated with more complex models. Working with this simple framework enables a greater range and quantity of experiments to be performed.

Here, we will describe the development of our simplified single-column coupled atmosphere-ocean 4D-Var assimilation system and present preliminary results from a series of identical twin experiments devised to investigate and compare the behaviour and sensitivities of different coupled data assimilation methodologies. This includes comparing fully and weakly coupled assimilations with uncoupled assimilation, investigating whether coupled assimilation can eliminate or lessen initialisation shock in coupled model forecasts, and exploring the effect of the assimilation window length in coupled assimilations. These experiments will facilitate a greater theoretical understanding of the coupled atmosphere-ocean data assimilation problem and thus help guide the design and implementation of different coupling strategies within operational systems.

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