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

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Coupled atmosphere-ocean data assimilation 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. Strongly-coupled data assimilation presents a significant challenge and so several operational centres are developing weakly-coupled assimilation systems as a first step. Here we use an idealised model framework to assess the expected benefits of moving towards coupled data assimilation in the context of incremental four dimensional variational assimilation (4D-Var).

An idealised 1D atmosphere-ocean model system has been built by coupling the European Centre for Medium-Range Weather Forecasts (ECMWF) single-column atmospheric model to a single-column K-Profile Parameterisation (KPP) ocean mixed layer model developed by the National Centre for Atmospheric Science (NCAS) climate group at the University of Reading. The use of these models ensures that the simplified system retains the key elements of coupling processes in a fully coupled ocean-atmosphere model system without being overly complex. The system has the capability to run both strongly- and weakly-coupled assimilations as well as uncoupled atmosphere or ocean only assimilations, thus allowing a systematic comparison of the different strategies for treating the coupled data assimilation problem. We will describe the different coupled incremental 4D-Var data assimilation methodologies and present results from a series of identical twin experiments devised to investigate the behaviour and sensitivities of each approach. Overall, our study demonstrates that significant benefits may be expected from coupled data assimilation. When compared to uncoupled initialisation, coupled assimilation is able to produce more balanced initial analysis fields, thus reducing initialisation shock and its impact on the subsequent forecast. Single observation experiments demonstrate how coupled assimilation systems are able to pass information between the atmosphere and ocean and therefore use near-surface data to greater effect. We show that much of this benefit may also be gained from a weakly-coupled assimilation system, but that this can be sensitive to the parameters used in the assimilation.

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