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Decadal predictions of Southern Ocean sea ice: testing different initialization methods with an Earth-system Model of Intermediate Complexity

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The sea ice extent in the Southern Ocean has increased since 1979 but the causes of this expansion have not been firmly identified. In particular, the contribution of internal variability and external forcing to this positive trend has not been fully established. In this region, the lack of observations and the overestimation of internal variability of the sea ice by current General Circulation Models (GCMs) make it difficult to understand the behaviour of the sea ice. Nevertheless, if its evolution is governed by the internal variability of the system and if this internal variability is predictable, a suitable initialization method should lead to simulations results that better fit the reality. Current GCMs decadal predictions are generally initialized through a nudging towards observations. This relatively simple method does not seem to be appropriated to the initialization of sea ice in the Southern Ocean. The present study aims at identifying an initialization method that could improve the quality of decadal predictions of Southern Ocean sea ice. We use LOVECLIM, an Earth-system Model of Intermediate Complexity that allows us to perform, within a reasonable computational time, the large amount of simulations required to test systematically different initialization procedures. These involve three data assimilation methods: a nudging, a particle filter and an efficient particle filter. In a first step, simulations are performed in an idealized framework, i.e. data from a reference simulation of LOVECLIM are used instead of observations, herein after called pseudo-observations. In this configuration, the internal variability of the model obviously agrees with the one of the pseudo-observations. This allows us to get rid of the issues related to the overestimation of the internal variability by models compared to the observed one. This way, we can work out a suitable methodology to assess the efficiency of the initialization procedures tested. It also allows us to determine the upper limit of improvement that can be expected if more sophisticated initialization methods are used in decadal prediction simulations and if models have an internal variability agreeing with the observed one. Furthermore, since pseudo-observations are available everywhere at any time step, we also analyse the differences between simulations initialized with a complete dataset of pseudo-observations and the ones for which pseudo-observations data are not assimilated everywhere. In a second step, simulations are realized in a realistic framework, i.e. through the use of actual available observations. The same data assimilation methods are tested in order to check if more sophisticated methods can improve the reliability and the accuracy of decadal prediction simulations, even if they are performed with models that overestimate the internal variability of the sea ice extent in the Southern Ocean.