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Sea-ice freeboard or thickness? Design choices in the context of data assimilation in the coupled numerical prediction system EC-Earth3 for seasonal Arctic sea ice prediction

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It is well established that winter and spring Arctic sea-ice thickness anomalies are a key source of predictability for late summer sea-ice concentration. While numerical general circulation models (GCMs) are increasingly used to perform seasonal predictions, they are not systematically taking advantage of the wealth of polar observations available. Data assimilation, the study of how to constrain GCMs to produce a physically consistent state given observations and their uncertainties, remains, therefore, an active area of research in the field of seasonal prediction. With the recent advent of satellite laser and radar altimetry, large-scale estimates of sea-ice thickness have become available for data assimilation in GCMs. However, the sea-ice thickness is never directly observed by altimeters, but rather deduced from the measured sea-ice freeboard (the height of the emerged part of the sea ice floe) based on several assumptions like the depth of snow on sea ice and its density, which are both often poorly estimated. Thus, observed sea-ice thickness estimates are potentially less reliable than sea-ice freeboard estimates. Here, using the EC-Earth3 coupled forecasting system and an ensemble Kalman filter, we perform a set of sensitivity tests to answer the following questions: (1) Does the assimilation of late spring observed sea-ice freeboard or thickness information yield more skilful predictions than no assimilation at all? (2) Should the sea-ice freeboard assimilation be preferred over sea-ice thickness assimilation? (3) Does the assimilation of observed sea-ice concentration provide further constraints on the prediction? We address these questions in the context of a realistic test case, the prediction of 2012 summer conditions, which led to the all-time record low in Arctic sea-ice extent. We finally formulate a set of recommendations for practitioners and future users of sea ice observations in the context of seasonal prediction.