Prospects for better seasonal Arctic sea ice predictions from multivariate initialization

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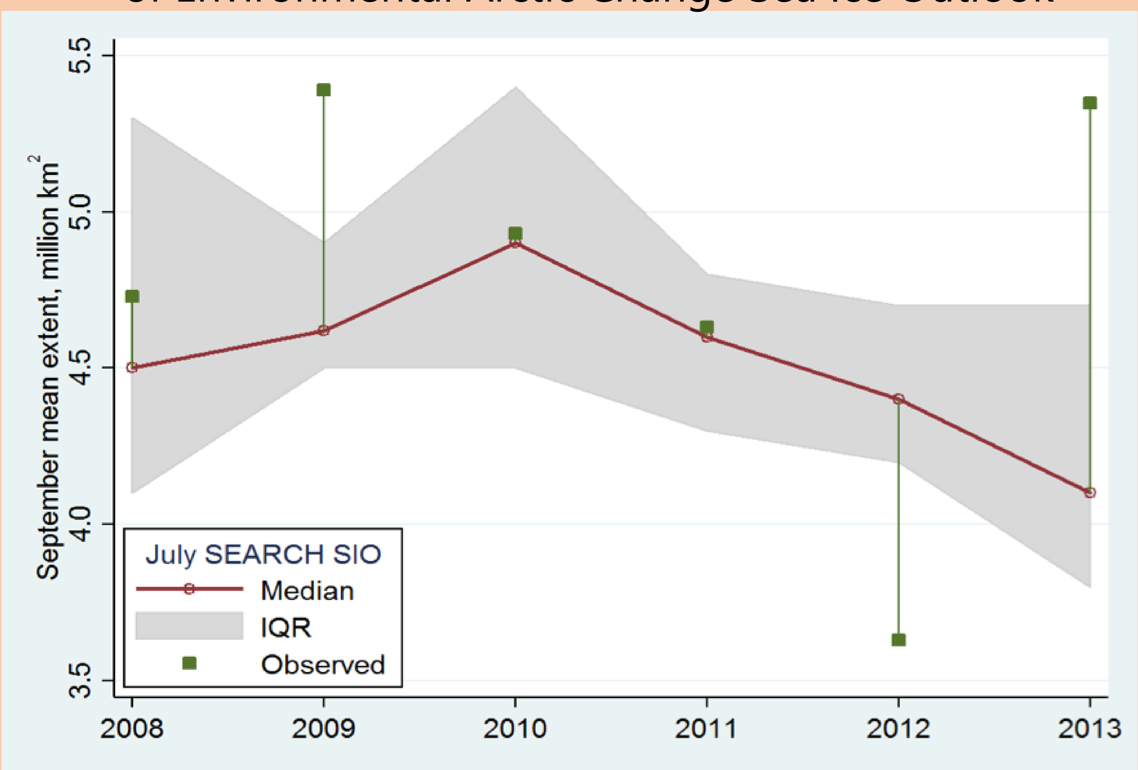
Predicting sea ice concentration or extent at seasonal scales is challenging

Predictions of September sea ice extent from the Study of Environmental Arctic Change Sea Ice Outlook



[Stroeve et al., 2014]

Several methods are currently used to predict the state of Arctic sea ice in summer (heuristic, statistical, models).

Prediction skill is low and forecasts over-confident for anomalous years.

A part of the skill in seasonal sea ice prediction resides in the knowledge of initial conditions.

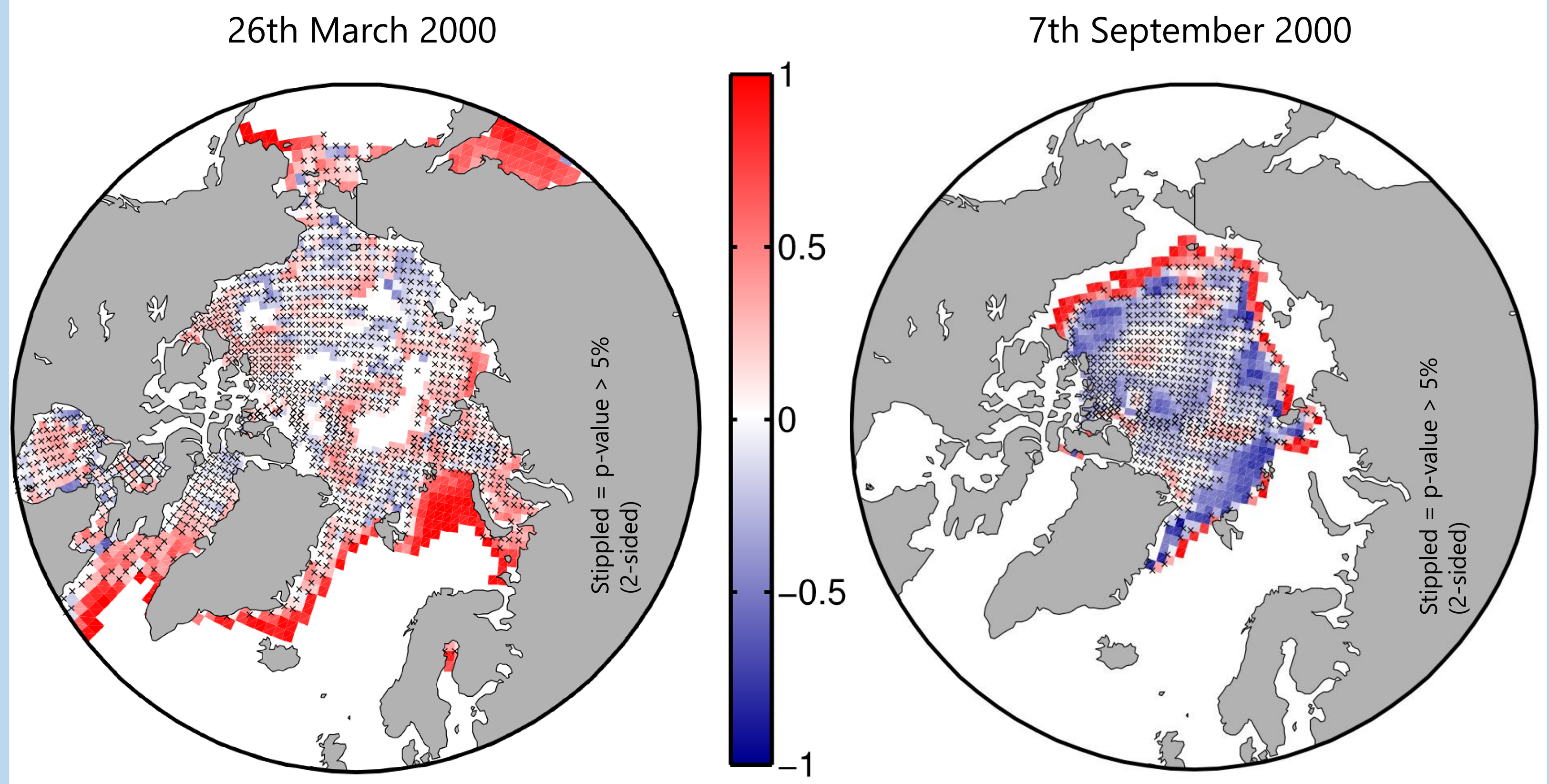
Therefore we propose to improve the Arctic sea ice initial conditions with the help of data assimilation

The ensemble Kalman filter updates the whole model state given observations

1. An ensemble of forecasts is propagated in time. This sample is used to estimate the model error covariance, i.e. the relationship between model variables.

Example: *Ocean-sea ice model NEMO-LIM3 at ORCA2 resolution. 25 simulations are run in parallel for 5 days, with different atmospheric forcings in order to ensure sufficient spread in the ensemble*

Correlation between ice concentration and thickness, in an ensemble of 25 members

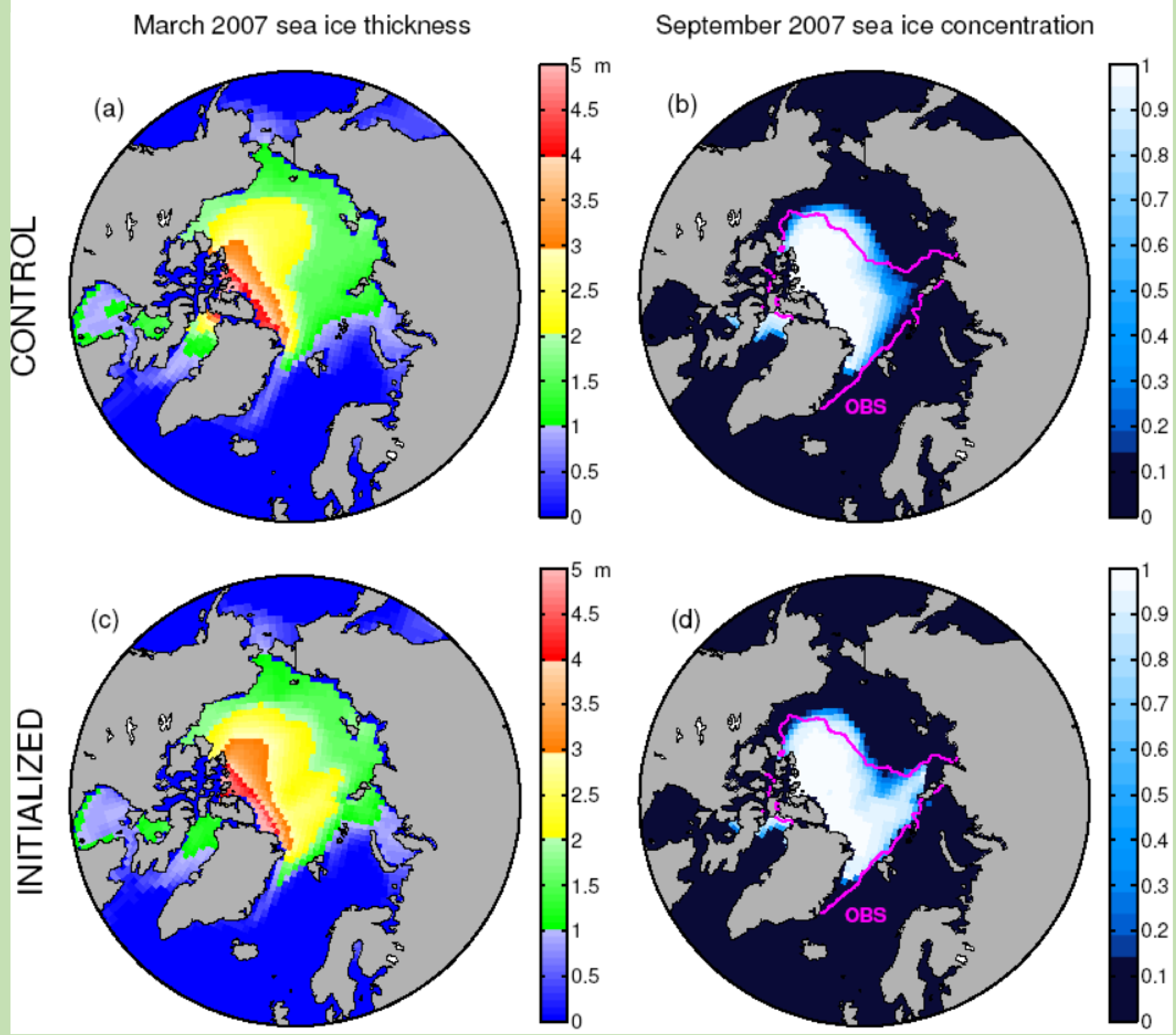


The relationships between model variables are time- and space-dependent!

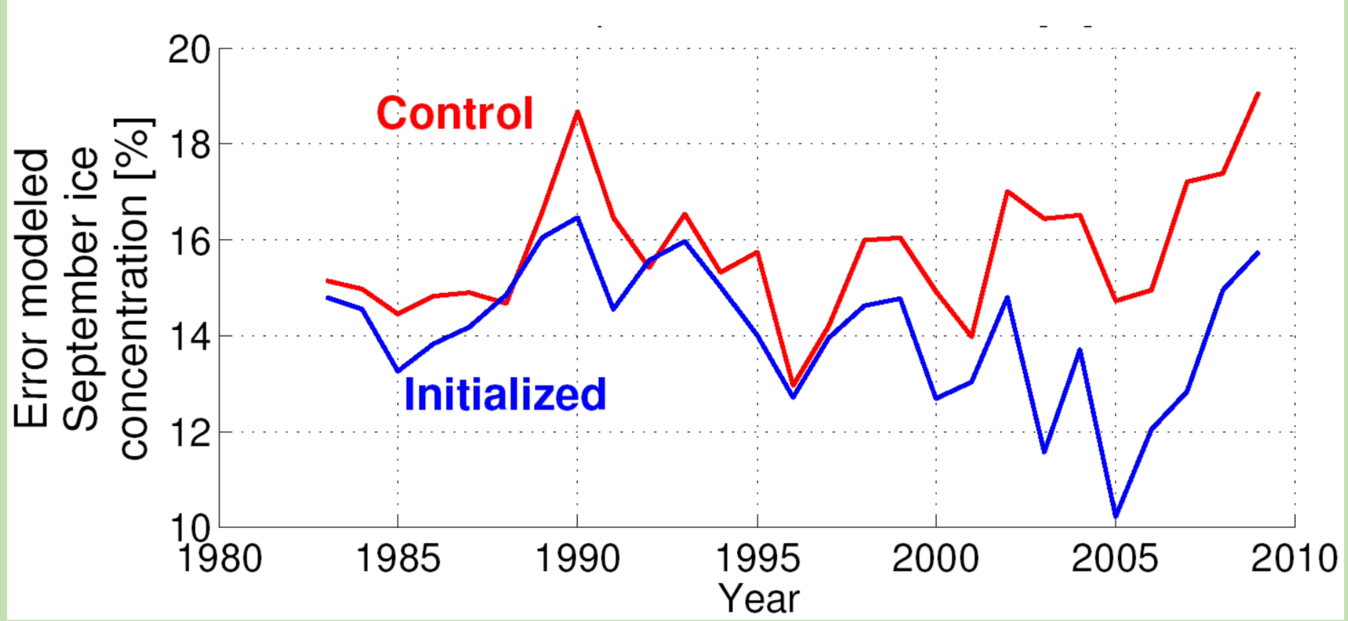
2. Given observations, the whole model state is updated. Even the non-observed variables are updated, and their updates are realized according to how they covary with the observed variable. The figure above shows that these covariances are not necessarily straightforward.

Indirect initialization of sea ice thickness with multivariate assimilation of ice concentration

Initial sea ice thickness for the 2007 prediction (left) and prediction outcome (right). The top row corresponds to the control, uninitialized run. The bottom row corresponds to the initialized run.



Root Mean Square Error of forecasted September sea ice concentration as compared to Eastwood et al., 2011 (satellite concentration data)



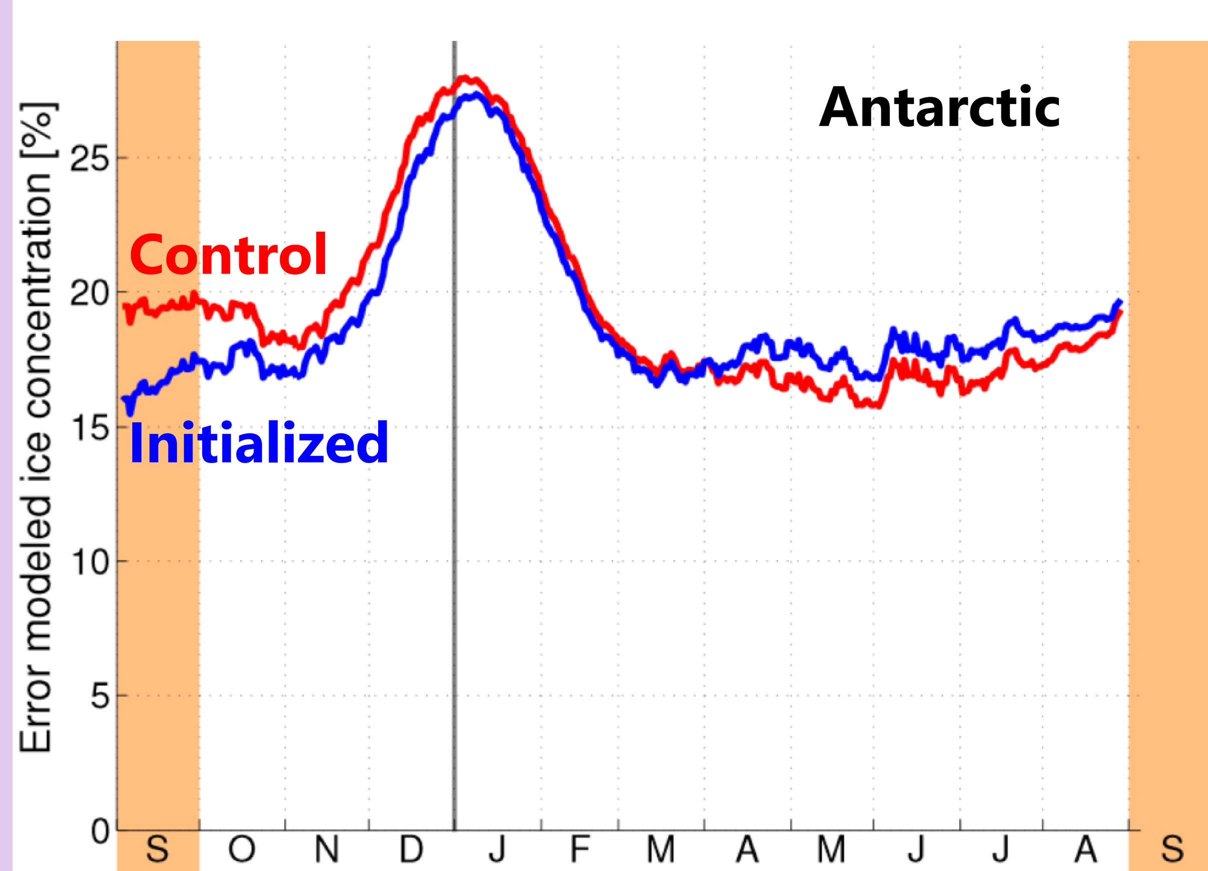
Methods: - The ocean-sea ice model NEMO-LIM3 (Madec, 2008; Vancoppenolle et al., 2009) driven by the NCEP/NCAR atmospheric forcing and various climatologies (see Vancoppenolle et al., 2009 for details), as well as the sea ice concentration data of Eastwood et al. (2011) are used to reanalyze the whole sea ice state since 1979 up to 2009.
- Every 5 days and if observational data of sea ice concentration is available, the whole sea ice state is updated using the deterministic ensemble Kalman filter of Sakov and Oke (2008).
- The « initialized » run consists of 6-months hindcasts (atmosphere-forced) started in March from the sea ice reanalysis; the « control » hindcasts are also atmosphere-forced, started in March but from a state that has not been subject to data assimilation.

Conclusions

- Winter Arctic sea ice conditions, and in particular thickness, determine in part late summer conditions.
- Initializing sea ice thickness directly is possible, but depends on the availability in space and time of observational data.
- Multivariate data assimilation is a convenient work-around, provided that the relationships between observed (concentration) and non-observed (thickness) variables in the model are correct.

In our setup, no prediction skill for Antarctic sea ice concentration

Average (1980-2008) Root Mean Square Error of Antarctic ice concentration in the 12 months after initialization in September, as compared to Eastwood et al., 2011 (satellite concentration data)



Additional information

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