Ensemble sea ice data assimilation with NEMO-LIM3

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Arctic /Antarctic sea ice • Ensemble Kalman filter • Comprehensive sea ice modelling • Assimilation of sea ice concentration

For the first time, observed sea ice concentrations are succesfully assimilated with a multivariate scheme into a comprehensive ocean-sea ice model with explicit sea ice thickness distribution and halo-thermodynamics.

Two hemispheres, one question

1. Because of increased variability under warming conditions[1,2], seasonal-to-decadal predictions of the **Arctic** sea ice evolution will become more challenging than ever.

2. State-of-the-art climate models still struggle to simulate the mean state and interannual variability of the **Antarctic** sea ice[3], so that confidence in their near-term projections remains low.

A knowledge of the full ocean-sea ice state constrained by available observations is probably a first step towards improved predictions.
How can we handle a clean model initialization in practice?

One true state, two interpretations

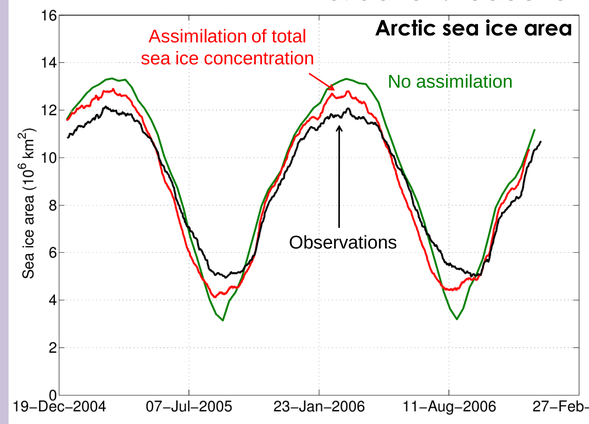
Due to technical constraints, the knowledge of the full actual ocean-sea ice state is inaccessible to us. However,

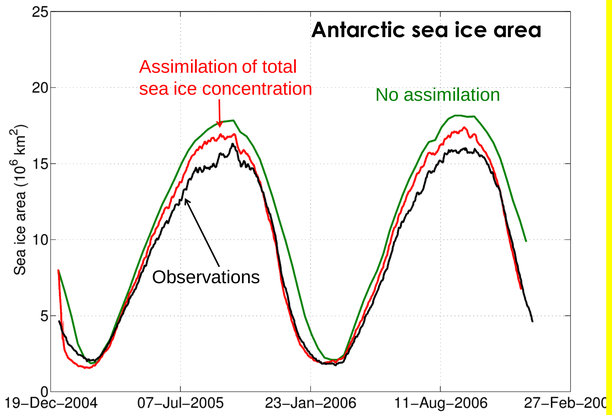
1. The sea ice surface is continuously monitored by **satellites.** These provide daily estimates of sea ice concentration with their uncertainties[4].

2. Comprehensive ocean-sea ice **models**[5,6] simulate the full 3-D evolution of ocean and sea ice fields

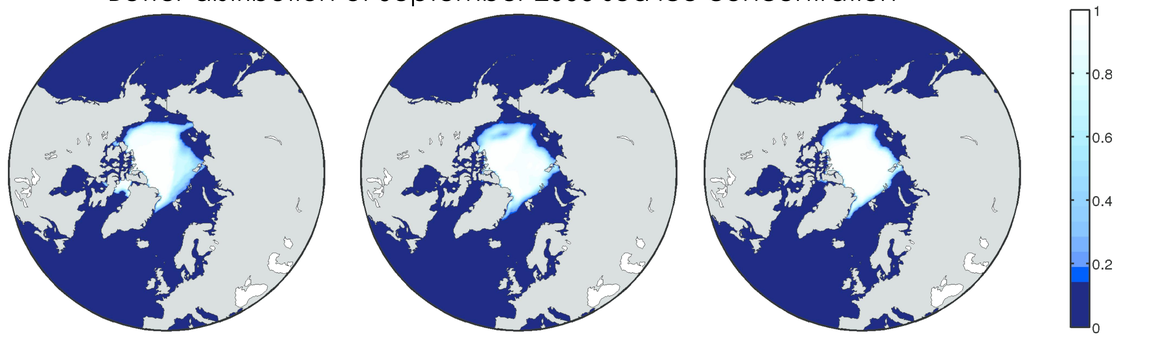
The Ensemble Kalman filter[7] (EnKF) theory provides a consistent solution to the state estimation problem.

Validation: reduction of sea ice area biases

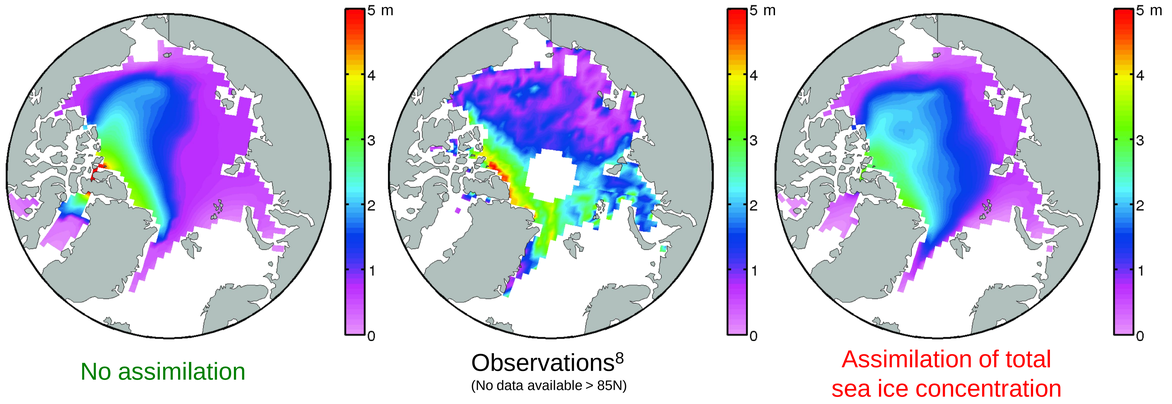




Better distribution of September 2006 sea ice concentration



Correction of ice thickness (Nov 2006) by multivariate mechanism



Key points

- The ocean-sea ice NEMO-LIM3 is **succesfully integrated** for two years (2005-2006) with data assimilation of daily sea ice concentration
- Assimilation **improves the ice edge location**
- After one year of integration, **corrections in ice thickness** fields are present within the ice pack.
- The filter has some difficulties for correcting biases in sea ice concentration **within the sea ice pack**, particularly in the Southern Ocean (not shown here).

Setup

1) 25 members are propagated for one day with NEMO-LIM3 (~2° resolution), each with a perturbed[9] wind and temperature forcing[10]
2) Real observations of sea ice concentration[4] are assimilated daily with the EnKF. Update of non-assimilated fields such as sea ice thickness, ocean temperature and salinity, is handled by the EnKF.
3) A « sanity check » is applied to each corrected member, in order to ensure e.g. positive sea ice concentration and thickness everywhere
4) The ocean-sea ice model is restarted with the assimilated ocean-sea ice state for each of the 25 members; back to 1).

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[2] Holland et al., 2010. doi: 10.1007/s00382-010-0792-4
[3] Zunz et al., 2013. doi:10.5194/tc-7-451-2013
[4] Eastwood et al., 2011. http://osisaf.met.no/
[5] Vancoppenolle et al., 2009. doi:10.1016/j.ocemod.2008.10.005
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[7] Evensen, 2003. doi:10.1007/s10236-003-0036-9
[8] Kwok and Cunningham, 2008. doi:10.1029/2008JC004753
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