"A data assimilation approach for reconstructing sea ice volume in the Southern Hemisphere"

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A data assimilation approach for reconstructing sea ice volume in the Southern Hemisphere

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1. Puzzling Antarctic sea ice

Arctic sea ice...
- extent is rapidly shrinking
- concentration trends distribution is relatively homogeneous (see below).
- is thinning almost everywhere
- simulated by models follows the same negative trends
- changes are significant

Antarctic sea ice...
- extent is slightly expanding
- concentration trends distribution is heterogeneous (see below).
- is not sufficiently sampled to derive robust trends of sea ice thickness
- simulated by coupled climate models shows contradictory trends
- changes are not systematically significant

Observe trends of Arctic (left) and Antarctic (right) sea ice concentration, 1983-2007. See ice concentration data: OSISAF, 2010.

2. EnKF data assimilation

The Ensemble Kalman Filter (Evensen, 2003)

\[ x^a = x^f + K (d - H x^f) \]

Analysis (daily, LIME (Fichefet and Morison Maqueda, 1997), ORCA2)
Kalman gain
Includes obs. error and model forecast error covariance matrices
Observations Global, daily sea ice concentrations 1979-2005 (OSISAF, 2010)
Projection Interpolation model-observation grids

\[ \rightarrow \text{EnKF is statistically consistent} \]
\[ \rightarrow \text{Multivariate data assimilation} \]

Note that...
- ice concentration only is assimilated
- no correction (yet) on the freshwater budget after assimilation time step

Objective

Attempt to reconstruct the recent decadal variability of the Antarctic sea ice volume by statistical-based combinations of observations and model hindcasts, emphasizing the regional contributions of the different sectors in the Southern Ocean.

3. Collateral benefits

By the nature of the EnKF, the assimilation of a variable \( i \) has an impact on any other variable \( j \) as long as \( i \) and \( j \) are correlated.

Mean absolute difference of sea ice thickness with respect to the ASPeCT data set (Worby et al., 2008), in different ocean sectors of Antarctica. « FREE RUN », resp. « ASSIM RUN » denotes the run without and with assimilation of sea ice concentration.

|                | \( \text{mean} \) | \( \text{\( |\Delta h| \) (m)} \) |
|----------------|-----------------|-----------------|
| FREE RUN       |                 |                 |
| Weddell        | 0.29            | 0.22            |
| Ind. Ocean     | 0.21            | 0.17            |
| West Pacific   | 0.38            | 0.30            |
| Ross           | 0.35            | 0.32            |
| Amund. –Bel.   | 0.26            | 0.18            |
| Whole Antarctica| 0.30            | 0.23            |

4. SH volume changes

Regional variability of the 1983-2007 SH ice volume as reconstructed by the NEMO-UM2 ocean-sea ice model constrained by the EnKF. Black lines: 1-yr running mean of sea ice volume monthly anomalies; Red lines: linear fit of the anomalies with the ±2σ envelope of the fit.

Conclusions

- Unlike its Arctic counterpart, Antarctic sea ice variability cannot be analyzed as a whole but rather as a sum of contributing sectors.
- Antarctic sea ice thickness/volume trends patterns resemble those of sea ice concentration/extent.
- This is a first attempt. Only the ice concentration is assimilated, and the freshwater budget is not corrected after assimilation.

References