

Reconstruction of sea ice volume changes in the Southern Ocean, 1980-2008

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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.

Conclusions

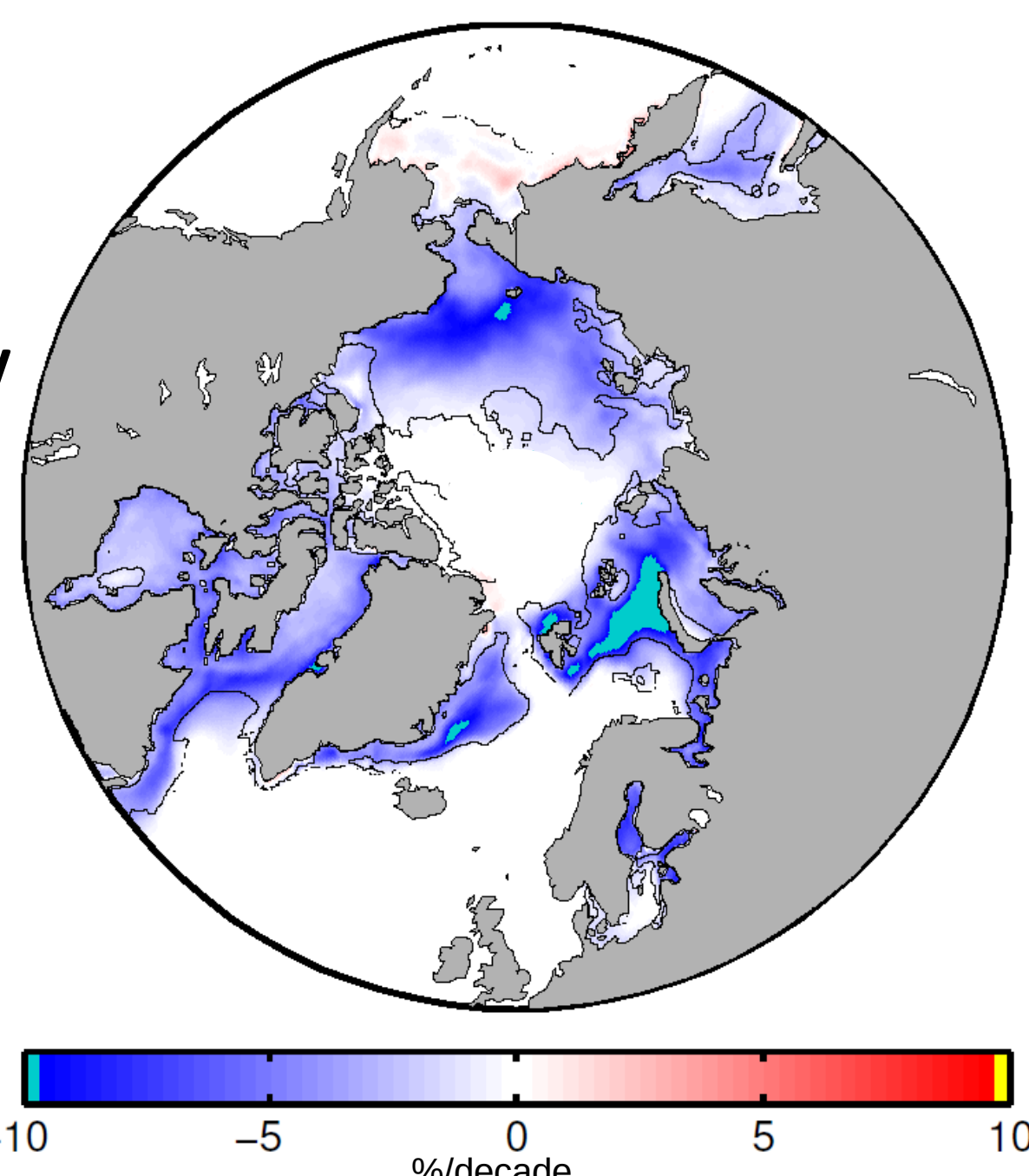
- Significant increase in Antarctic sea ice volume over 1980-2008...
- ...resulting from positive and negative contributions in the Southern Ocean...
- ... according to a global ocean/sea ice model reconstruction with assimilation of sea ice concentration (ensemble Kalman filter, multivariate)
- Antarctic sea ice volume trends patterns resemble those of sea ice extent
- This is a **first attempt**. Only the ice concentration is assimilated, and the freshwater budget is not corrected after assimilation

1. Puzzling Antarctic sea ice

In a global warming context,

Arctic sea ice...

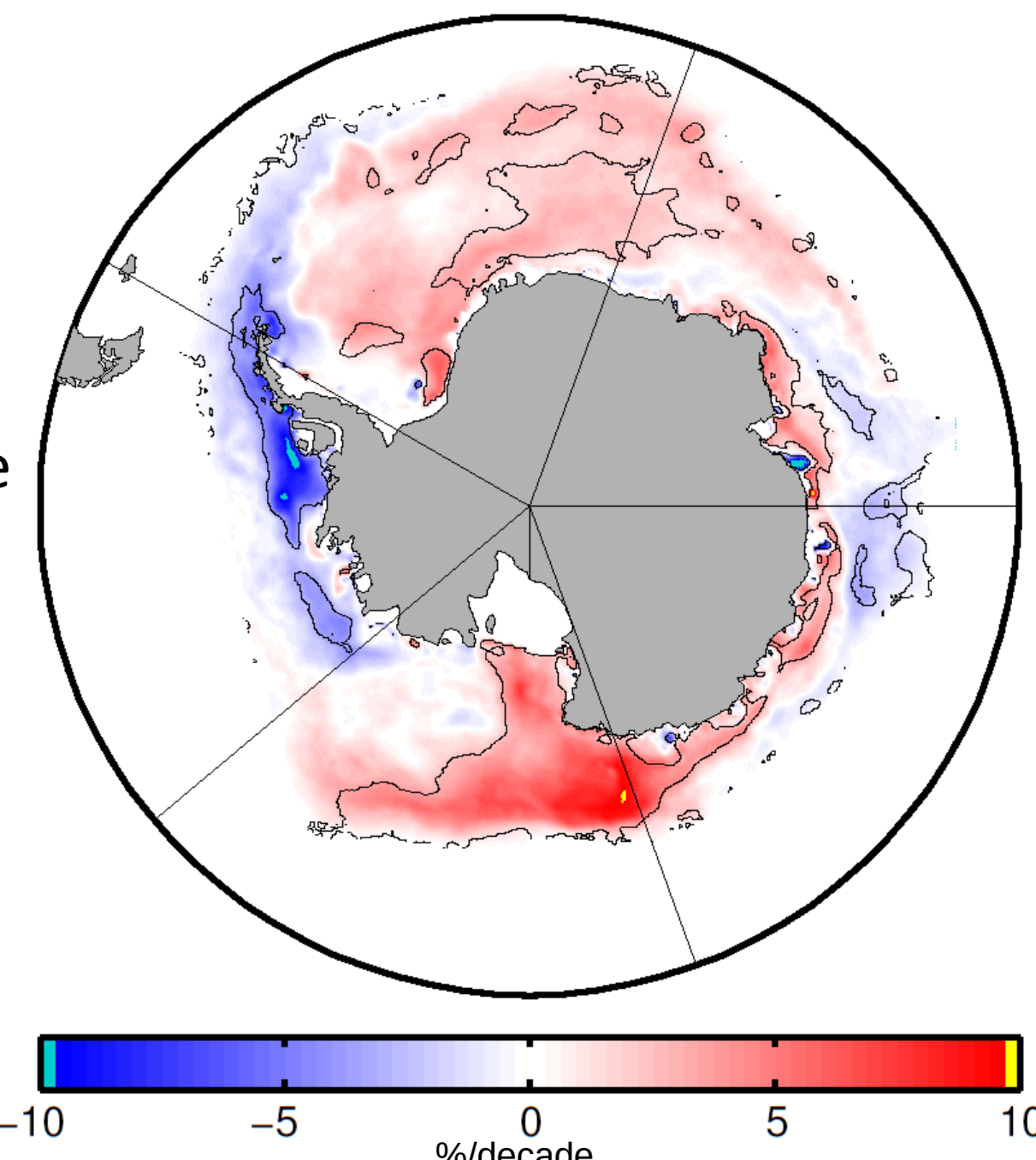
- extent is rapidly **shrinking**,
- concentration trends distribution is **relatively homogeneous**,
- is **thinning** almost everywhere,
- simulated by models follows the same negative trends,
- changes are **significant**.



Observed trends of Arctic (left) and Antarctic (right) sea ice concentration, 1980-2008. Contours indicate 95% significance levels of the trends Sea ice concentration data: Comiso, 2008

Antarctic sea ice...

- extent is slightly **expanding**,
- concentration trends distribution is **heterogeneous**,
- 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**.



2. EnKF data assimilation

The **Ensemble Kalman Filter** (Evensen, 2003)

$$\mathbf{x}^a = \mathbf{x}^f + \mathbf{K} (\mathbf{d} - \mathbf{H} \mathbf{x}^f)$$

Analysis

Forecast
(daily, LIM2
(Fichefet and
Morales
Maqueda, 1997),
ORCA2)

Kalman gain
Includes obs. error
and model forecast
error covariance
matrices

Observations
Global, daily sea-ice
concentrations
1980-2008 (OSISAF,
2011)

Projection
Interpolation model-
observation grids

- EnKF is statistically consistent
- Multivariate data assimilation

Possibility for cross-variable improvements (e.g. sea ice thickness through concentration)

Note that...

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

3. Collateral benefits

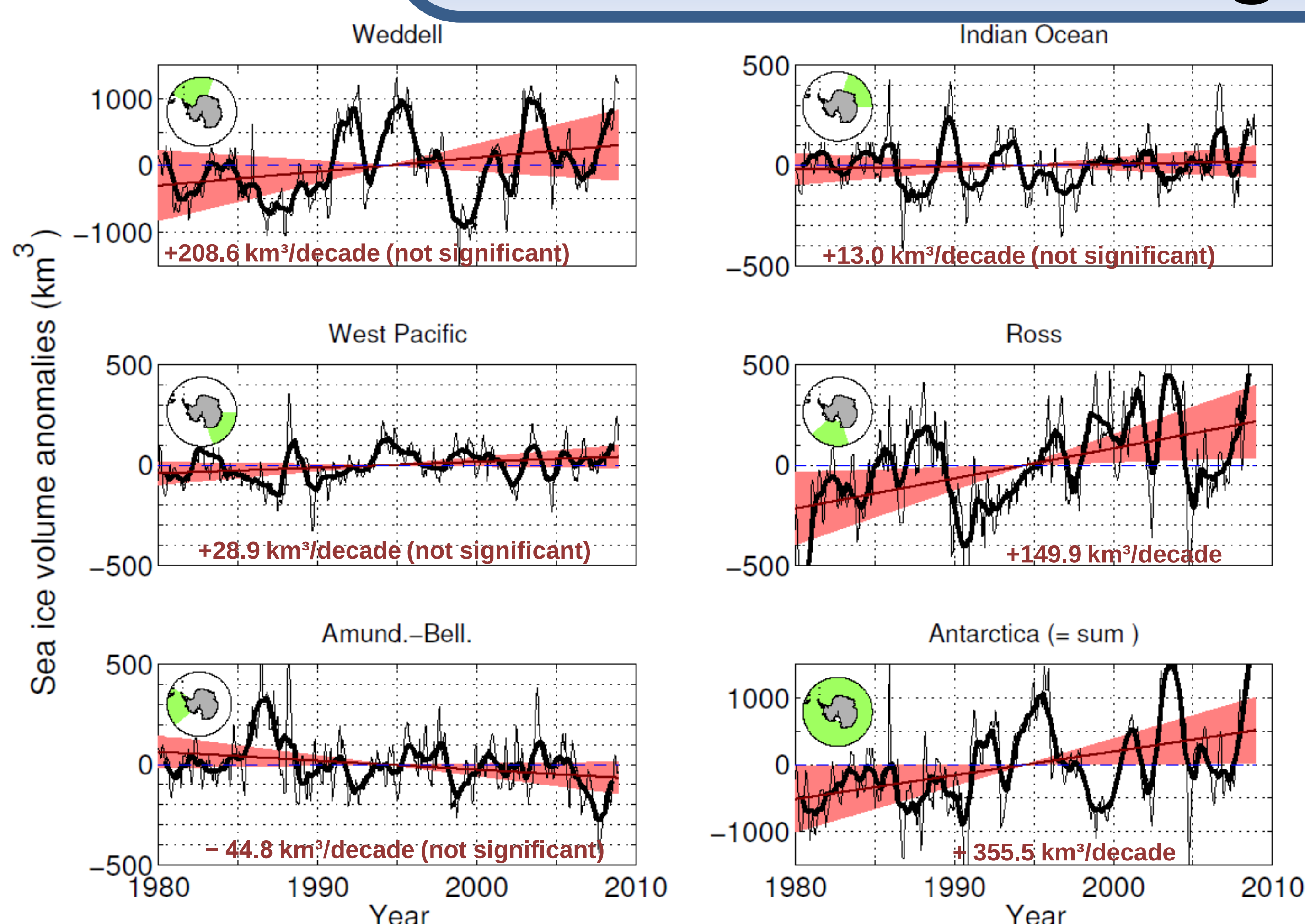
By the nature of the EnKF, the assimilation of a variable i has an impact on any other variable j as long as i and j are correlated.



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**.

	mean $ \Delta h $ (m)	
	FREE RUN	ASSIM RUN
Weddell	0.29	0.23
Ind. Ocean	0.21	0.17
West Pacific	0.38	0.30
Ross	0.35	0.31
Amund. -Bell.	0.26	0.17
Whole Antarctica	0.30	0.24

4. SH volume changes



Regional variability of the 1980-2008 SH sea ice volume as reconstructed by the NEMO-LIM2 ocean-sea ice model constrained by the EnKF. Thin black lines: 1-yr running mean of sea ice volume monthly anomalies; **Thick black lines**: 5-yr running mean. **Red lines**: linear fit of the anomalies with the $\pm 2\sigma$ envelope of the fit.

References

- OSISAF : <http://osisaf.met.no>, 2011
- Comiso, J. and Nishio, F. doi:10.1029/2007JC004257, 2008
- Evensen, G. Doi:10.1007/s10236-003-0036-9, 2003
- Fichefet, T. and Morales Maqueda, M. A. : JGR, 102, 12 609-12 646, 1997
- Worby, A. P., et al. doi:10.1029/2007JC004254, 2008