Harmony on Ice 2 meeting
Paris, 28-29 Nov. 2011

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

F. Massonnet, P. Mathiot, T. Fichefet, H. Goosse, C. König Beatty, M. Vancoppenolle, T. Lavergne, L. Bertino

de Laurent Bertino

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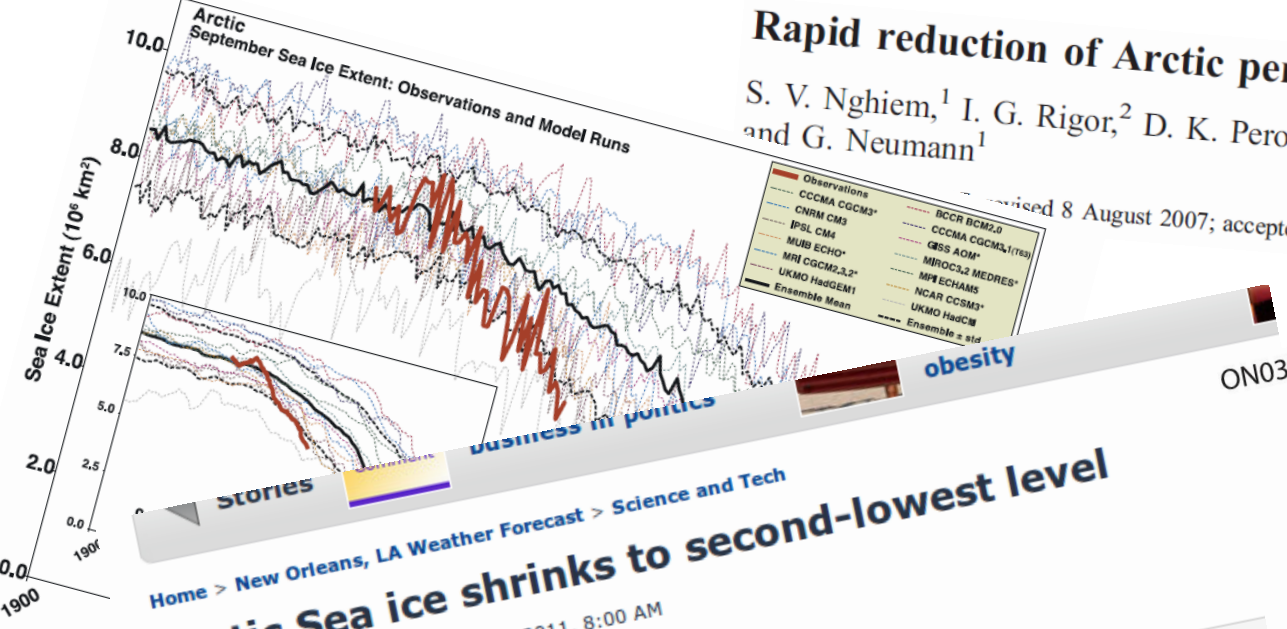
sujet **Harmony on Ice 2**

As proposed last year (attached proposal), most of the presentations should focus on the Fram Strait and issues related to the ice areal flux.
I expect the following participants:

Do you know Google Fight?

www.googlefight.com

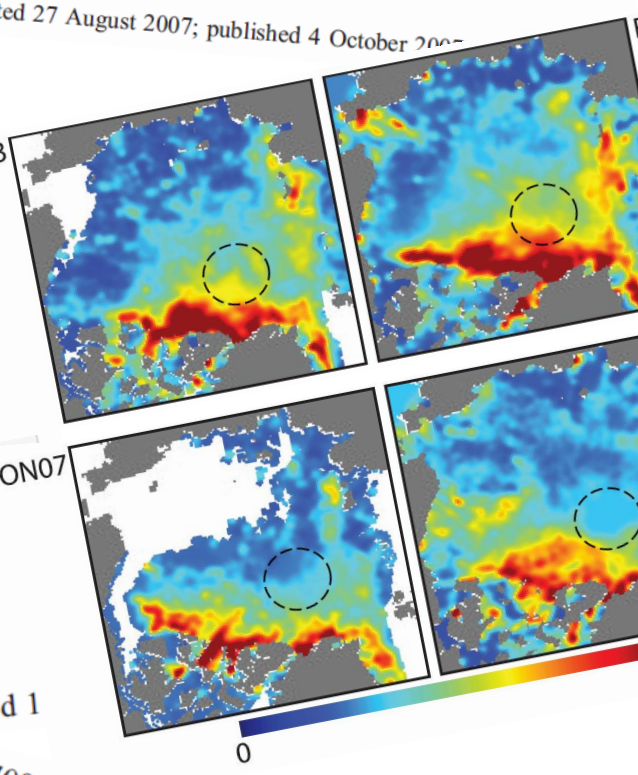

Googlefight
The classics
Funny fights
Fight of the month
Last 20 fights
Brioude Internet
raynette
ABONDANCE
Results on Google :
\"Arctic sea ice\"
161000 results
\"Antarctic sea ice\"
14500 results
"Arctic sea ice"
"Antarctic sea ice"
Make a fight



Rapid reduction of Arctic perennial sea ice

S. V. Nghiem,[1] I. G. Rigor,[2] D. K. Perovich,[3] P. Clemente-Colón,[4] J. W. Weatherly,[3] and G. Neumann[1]

...ised 8 August 2007; accepted 27 August 2007; published 4 October 200...



Stories ... obesity

Home > New Orleans, LA Weather Forecast > Science and Tech

Arctic Sea ice shrinks to second-lowest level

Saturday, September 17, 2011, 8:00 AM

...ciated Press

Click Here for Full Article

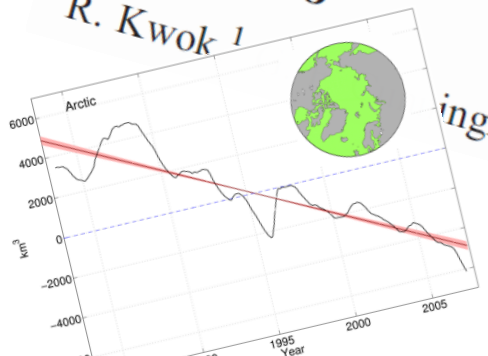
Positive trend in the mean speed of Arctic sea ice, 1979–2007

P. Rampal,[1,2] J. Weiss,[1] and D. Marsan[2]

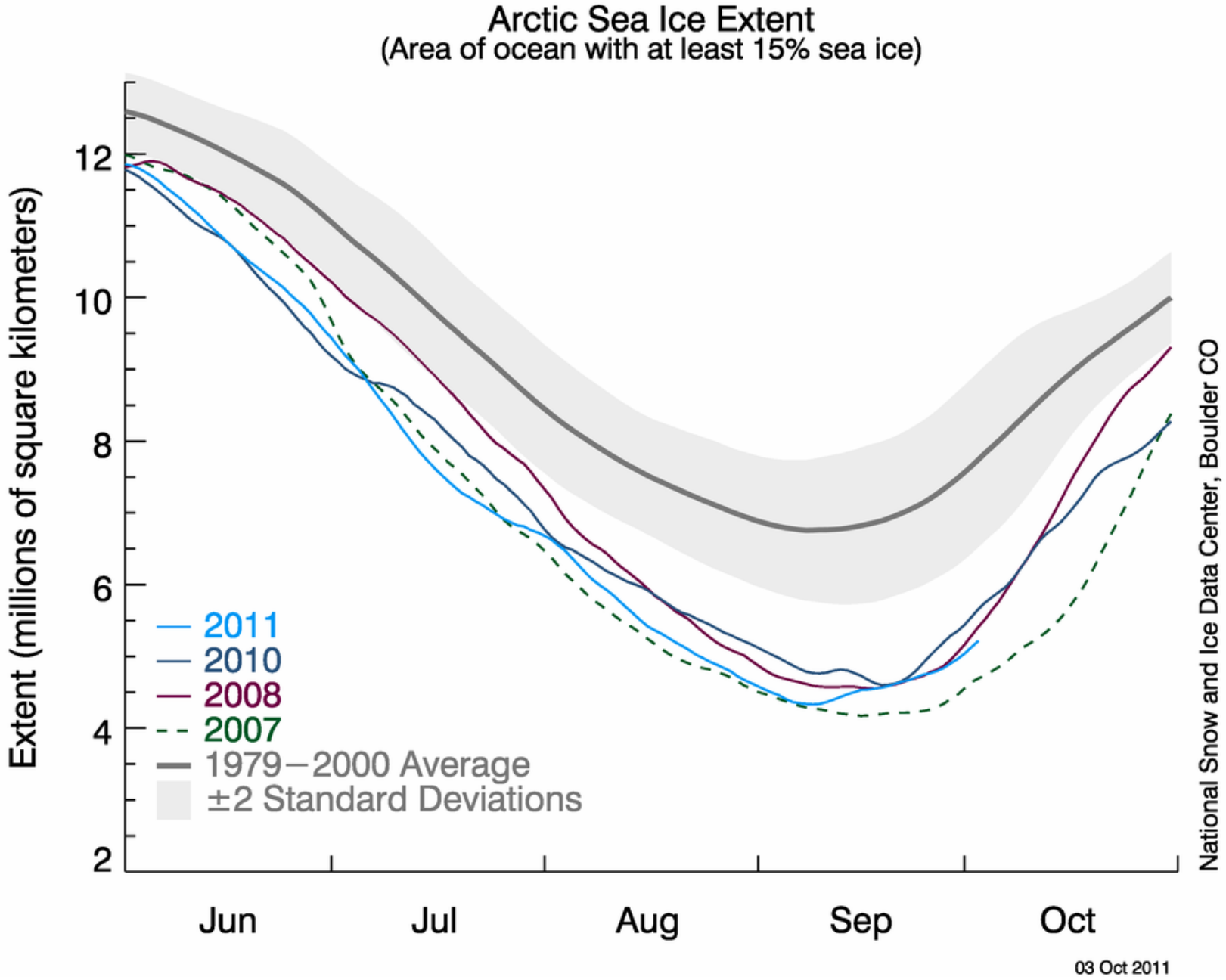
Received 1 August 2008; revised 25 February 2009; accepted 1 ... 114, C07005, ...01:10.1029/2009JC005312, 2009

Thinning and volume loss of the Arctic Ocean sea ice cover: 2003–2008

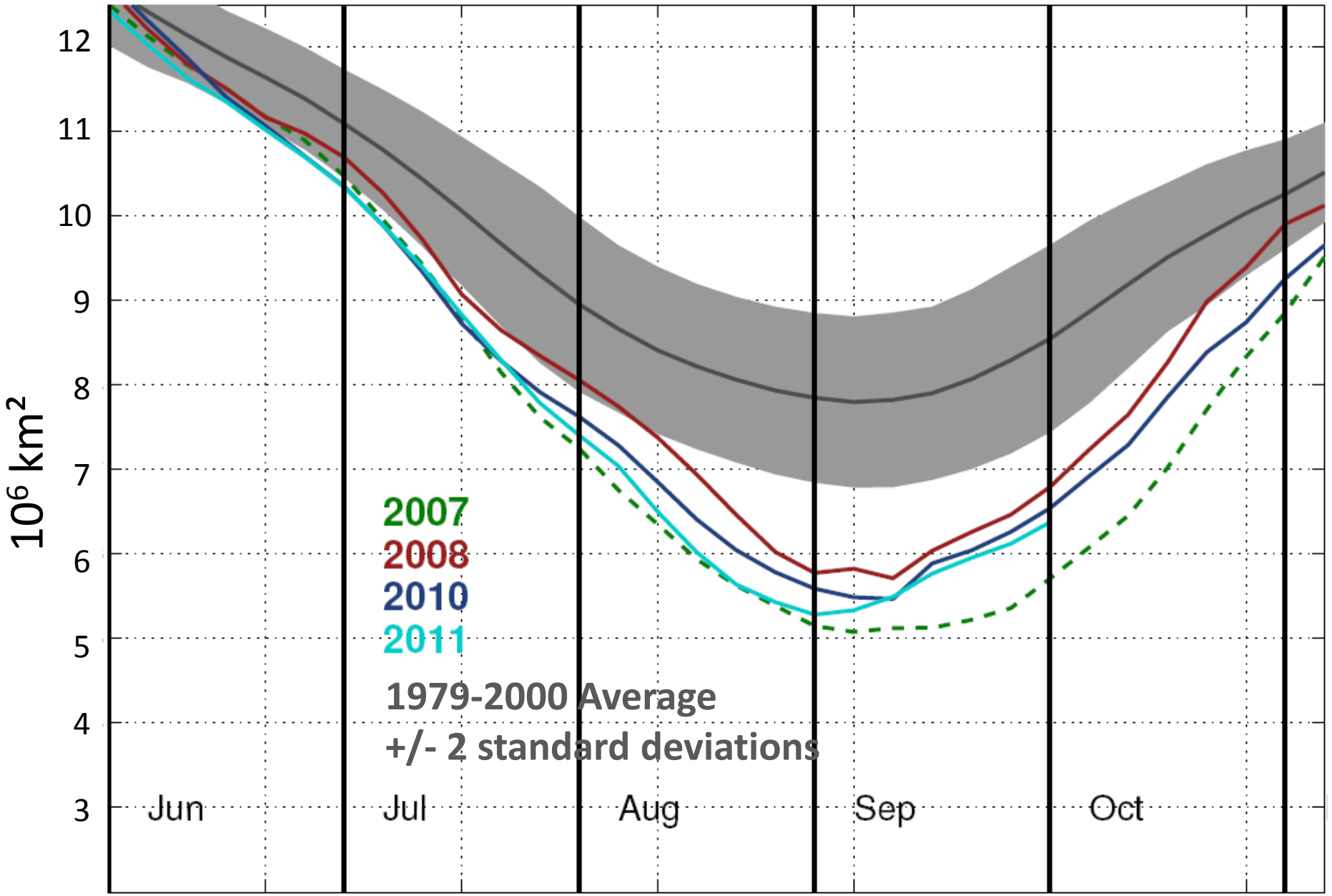
R. Kwok [1] ...ingham, [1] M. Wensnahan, [2] I. Rigor, [2] H. J. Zwally, [3] and ...



NSIDC, Oct 20th 2011

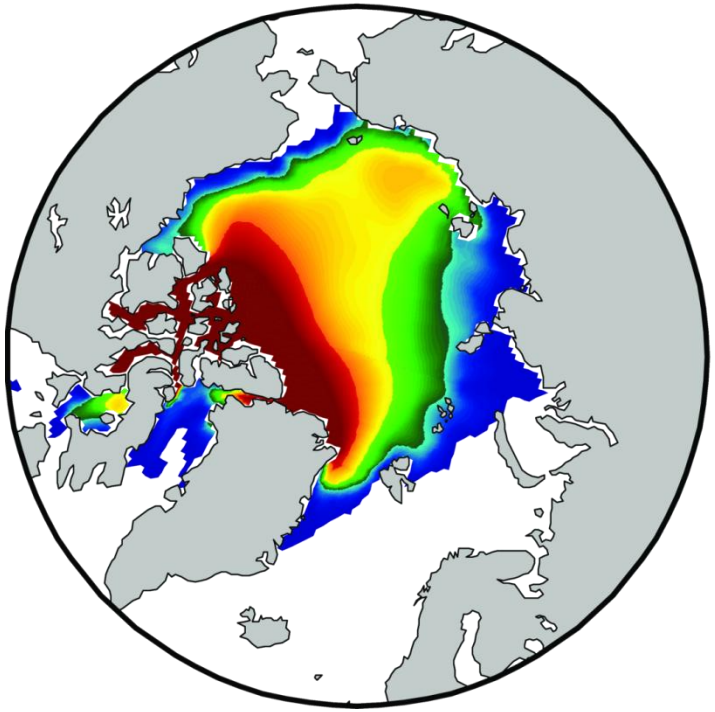


Simulated sea ice extent (NEMO-LIM + atmospheric reanalyses)



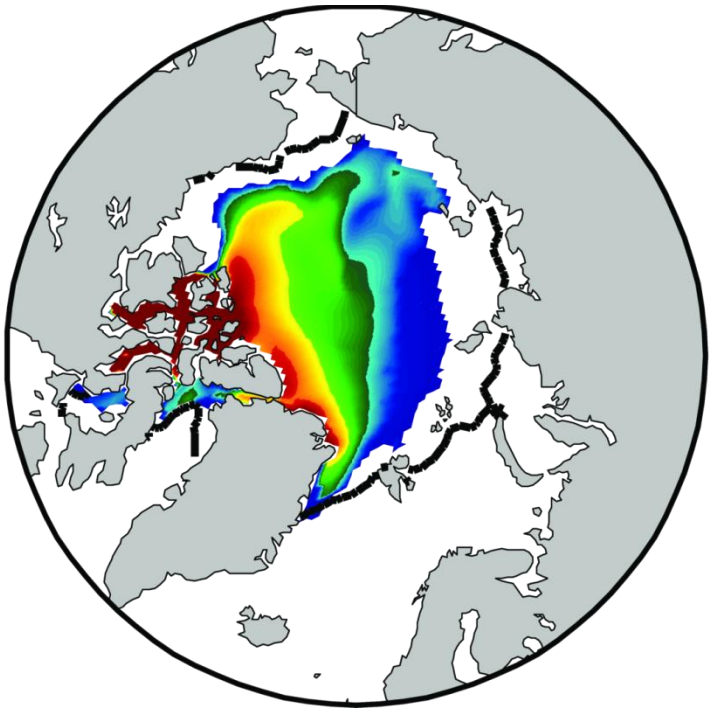
Arctic sea ice thickness (Louvain-la-Neuve sea Ice Model)

Mean September 1979-2000



Volume ≈ 26,000 km³

September 2011



Volume ≈ 10,000 km³
Lowest minimum of the model

Arctic sea ice: clear changes

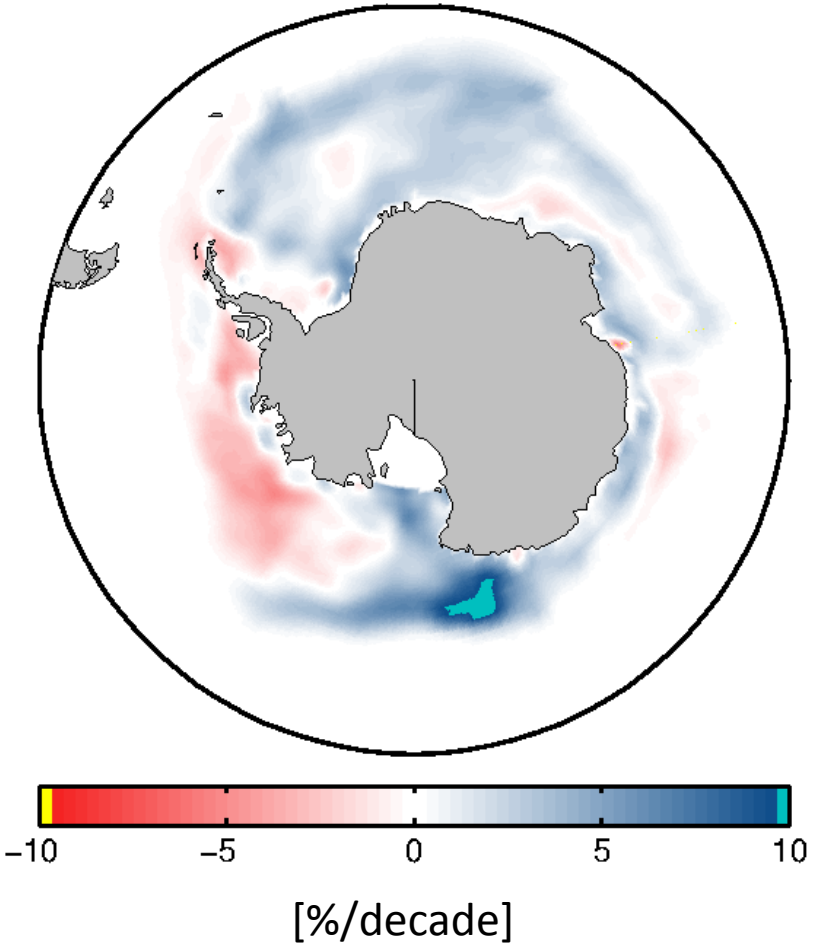
Arctic sea ice

- is **shrinking** [Comiso et al., 2008]
- is **thinning** [Kwok and Rothrock, 2009]
- is **younger** [Nghiem et al., 2007]
- has similar trends when simulated by climate models [Arzel et al., 2006]

+ these changes are **significant**

Antarctic sea ice: complicated changes

Trends of observed [OSISAF, 2010] sea ice concentrations, 1983-2007



Antarctic sea ice

- is slightly **expanding** [Turner et al., 2009]
- shows marked **regional** trends in concentration [Comiso and Nishio, 2008]
- thickness is **not sufficiently sampled** [Worby et al., 2008]
- simulated by models shows contradictory trends [Arzel et al., 2006]

+ **significance** is data set- and time period- **dependent**

« So, your claim is that Antarctic sea ice is more challenging? »

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*« Yes, that's why we'd like to reconstruct its **volume**»*

« But you just said observations of ice thickness were not well sampled »

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« Let's use a model!»

« This model has probably biases… »

« This model has probably biases… »

« It does. Let’s go for some data assimilation! »

Ensemble Kalman Filtering

[Evensen, 2003]
[Sakov and Bertino, 2011]

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

Analysis

Forecast
(daily, NEMO-LIM2, 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

- Observational errors: ➡ provided with the sea-ice concentration products
- Model forecast errors: ➡ 25 members, gaussian wind perturbations

\+ EnKF is statistically consistent
\+ Multivariate data assimilation
– No correction of freshwater budget

Multivariate DA – the quest for the Holy Grail

$$\mathbf{K} = \mathbf{P}^f \mathbf{H}^T (\mathbf{H}\, \mathbf{P}^f \mathbf{H}^T + \mathbf{R})^{-1}$$

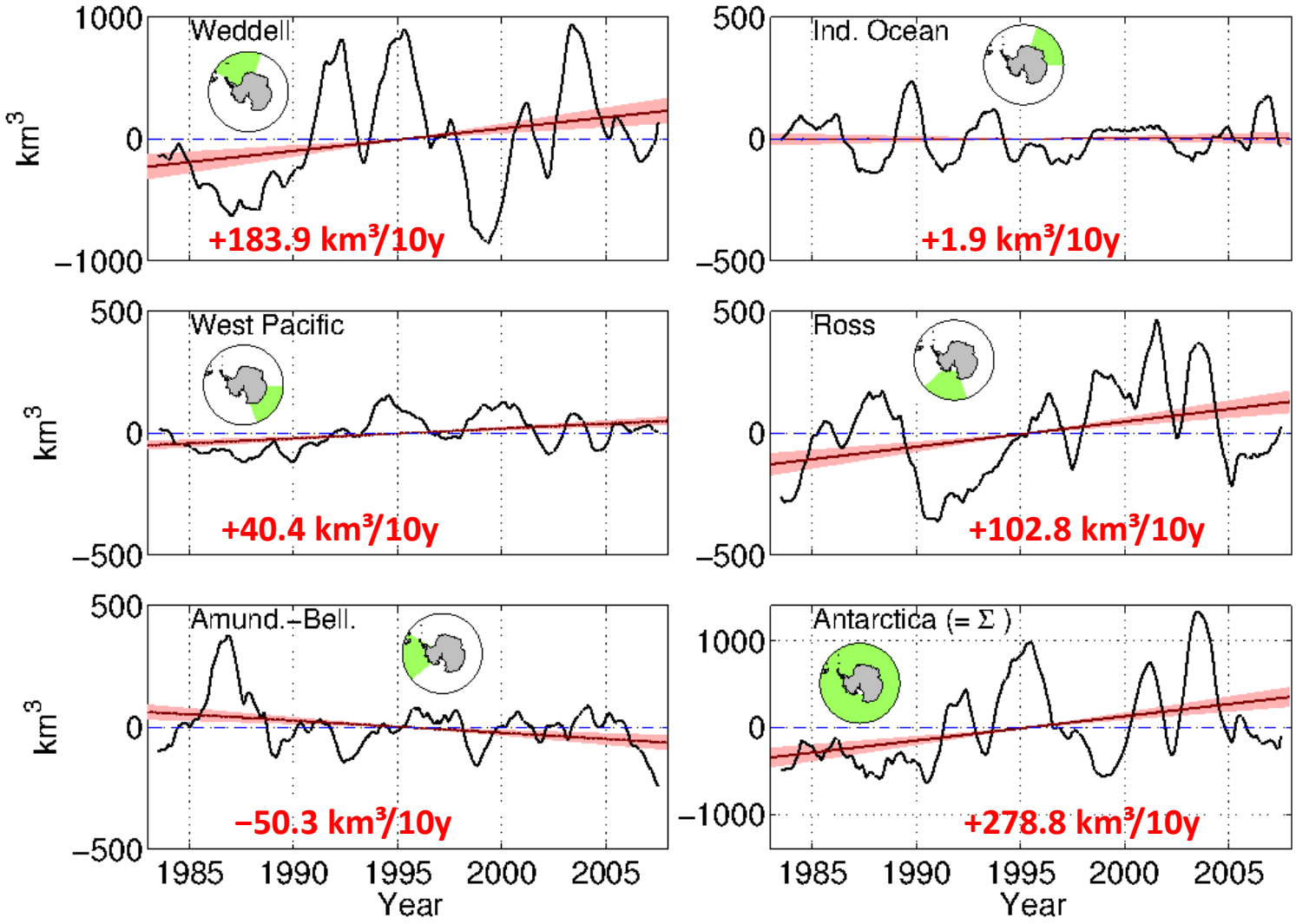
Variable *X* is impacted by assimilation of variable *Y* as long as they are correlated

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 $\lvert\Delta h\rvert$ (m)	
	FREE RUN	ASSIM 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

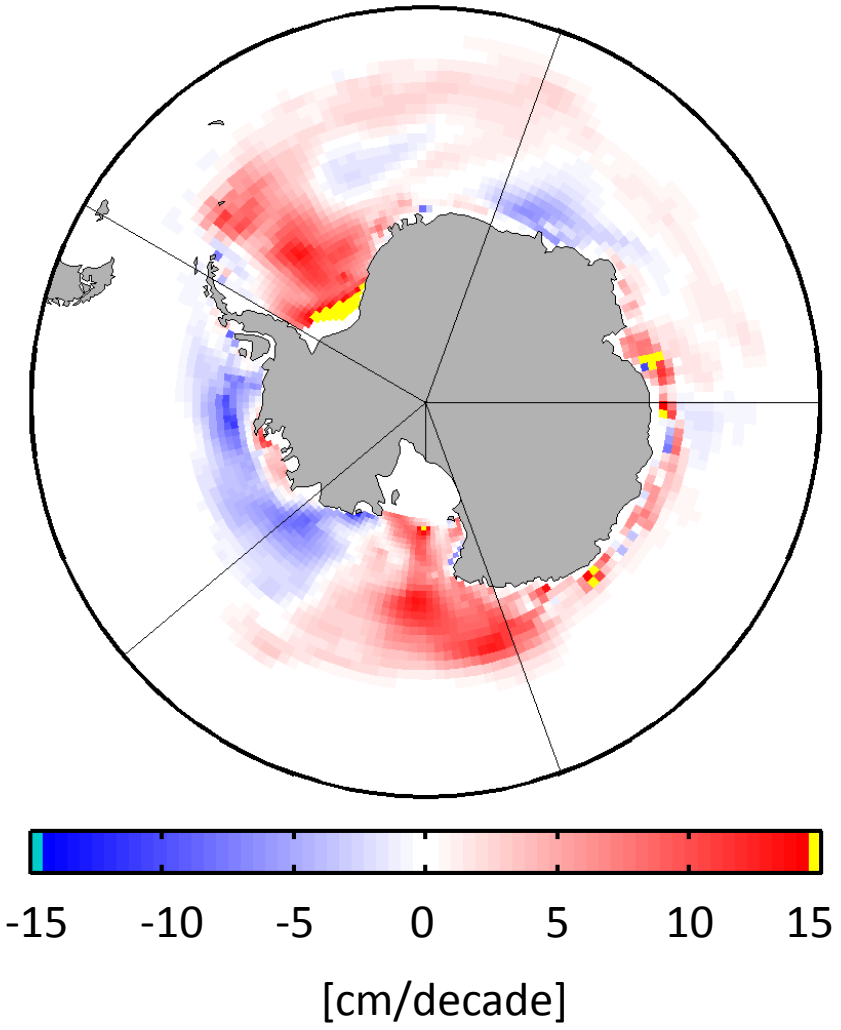
Antarctic sea ice volume changes

Anomalies of sea ice volume (NEMO-LIM2 + assim sea ice concentration) ,
linear fits +/- 2 std and their **trends**



Antarctic sea ice thickness changes

Trends of Antarctic sea ice thickness (NEMO-LIM2+assim sea ice concentration)



How to explain these changes?

On the large scale

- changes in volume follow those in extent
- increase attributed to
  - increased winds due to ozone depletion? [Turner et al., 2009]
  - enhanced ocean stratification due to warmer air temperatures? [Zhang, 2007]

On the regional scale

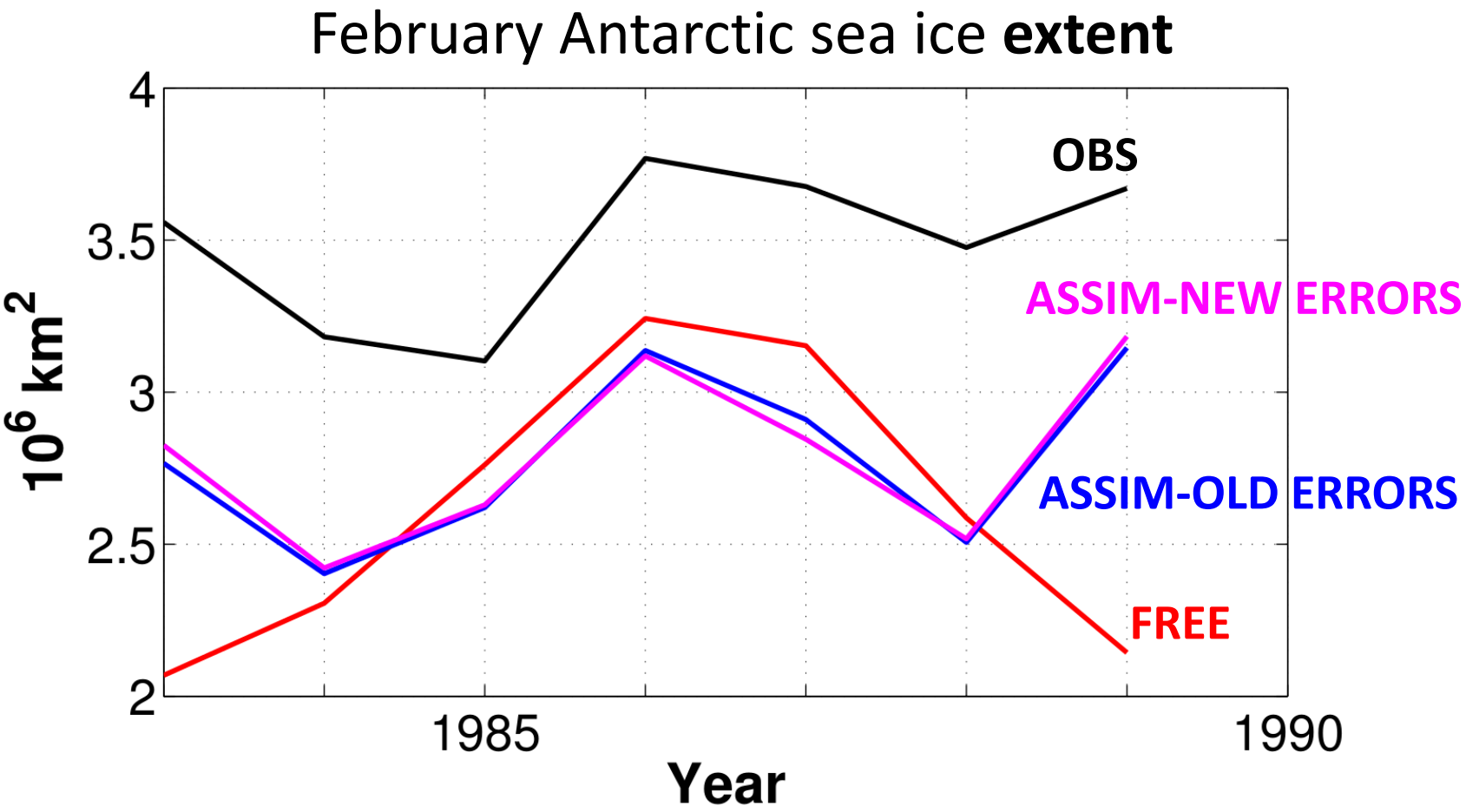
- thickness trends follow concentration
- thinning in Amundsen/Bellingshausen Sea: remote effects of Soutern Oscillation? [Kwok and Comiso, 2002]

On the importance of errors

$$\mathbf{K} = \mathbf{P}^{f}\,\mathbf{H}^{T}(\mathbf{H}\,\mathbf{P}^{f}\,\mathbf{H}^{T} + \mathbf{R})^{-1}$$

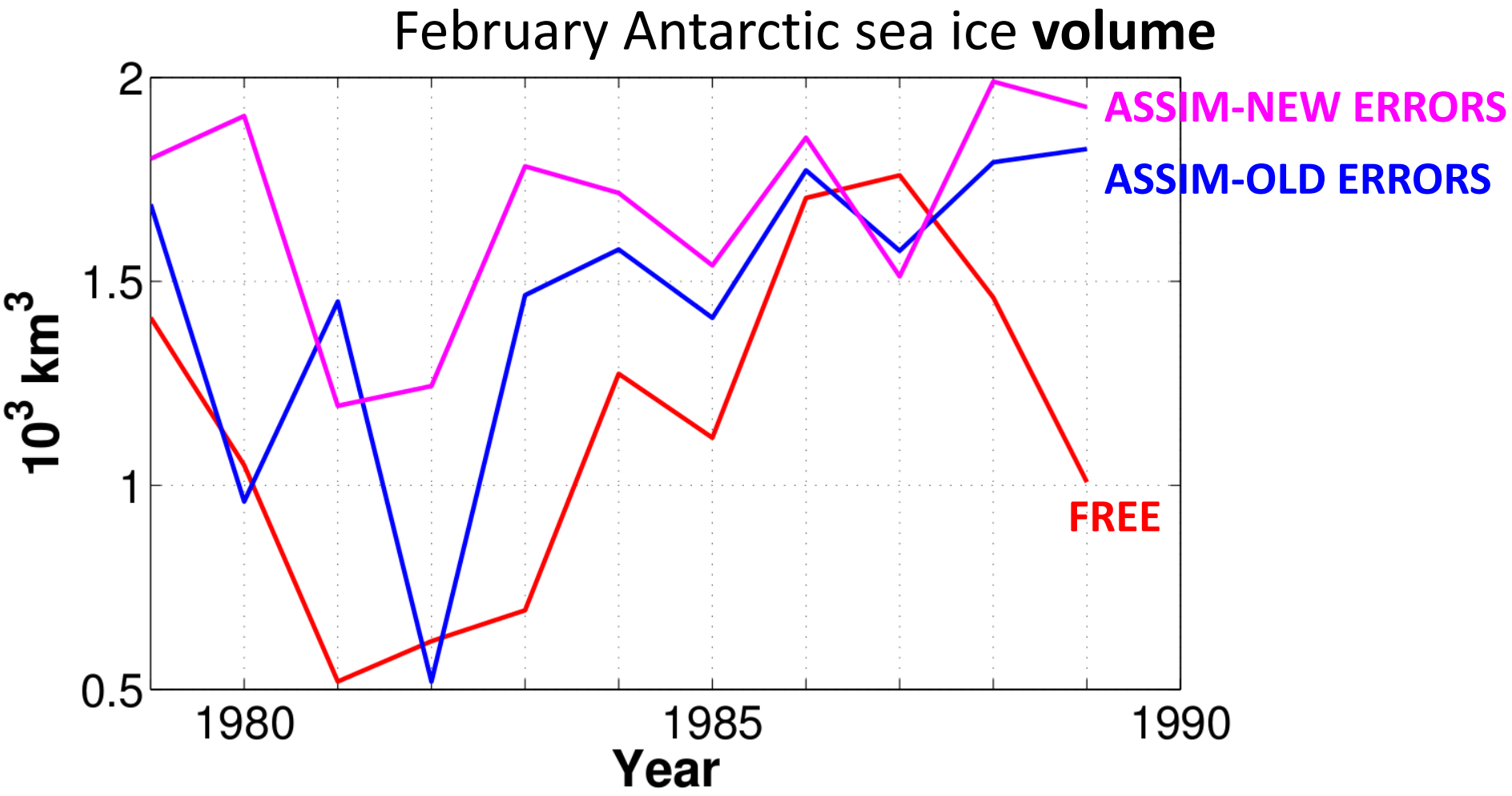
Obs. covariance error matrix

On the importance of errors (ctd)



Sea ice extent is not much sensitive to the update in observational errors

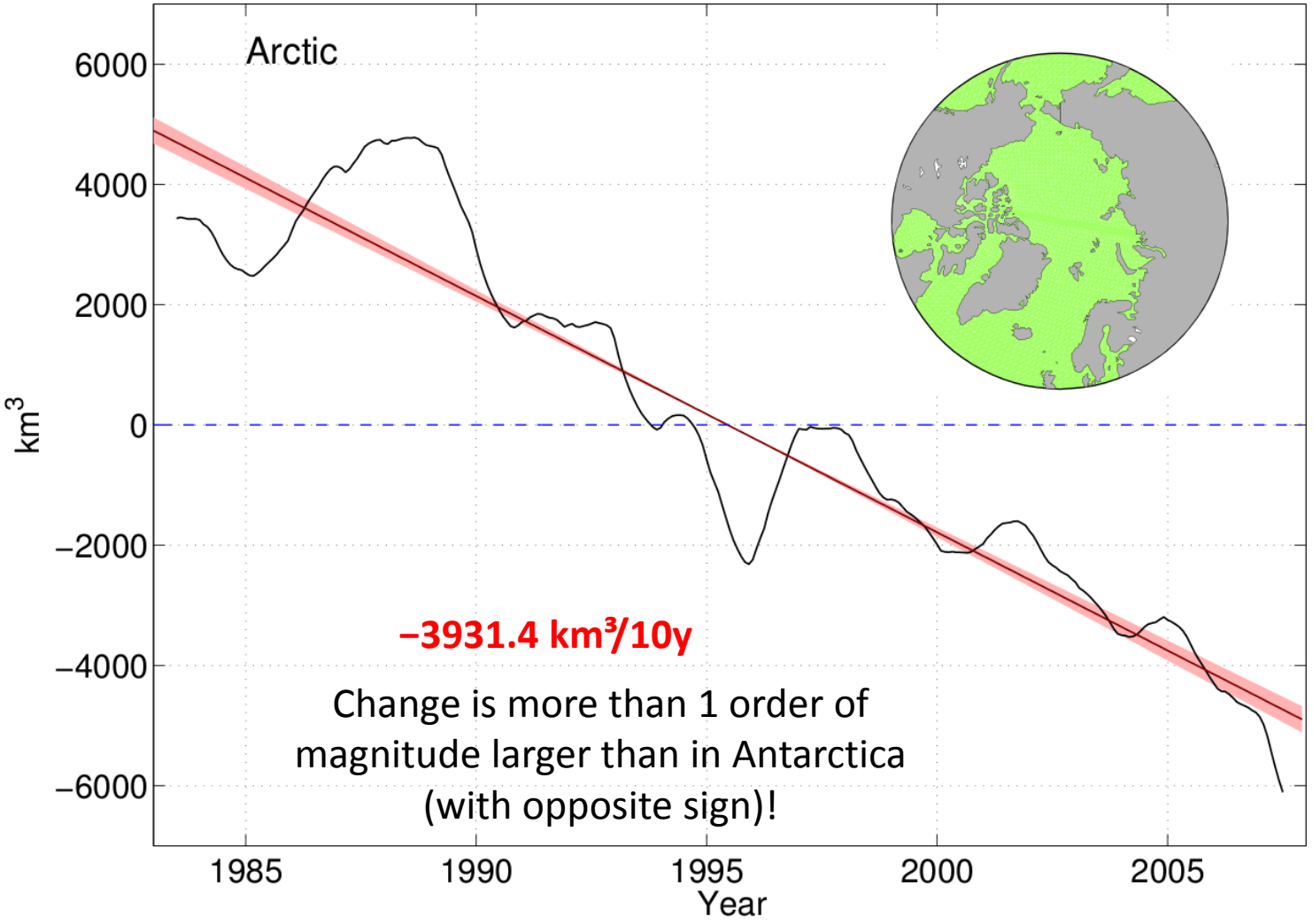
On the importance of errors (ctd)



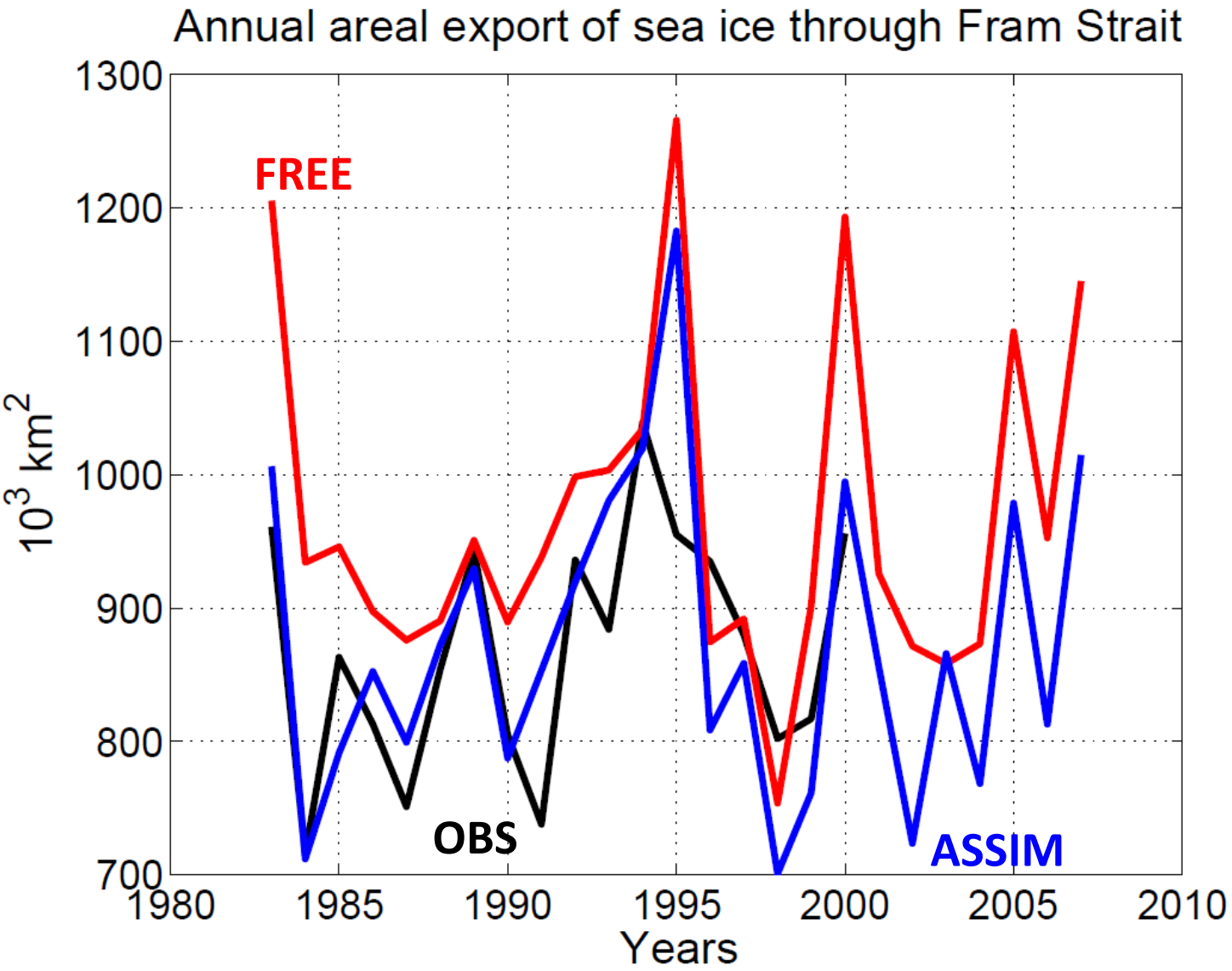
Sea ice volume is sensitive to the update in observational errors

Arctic sea ice changes

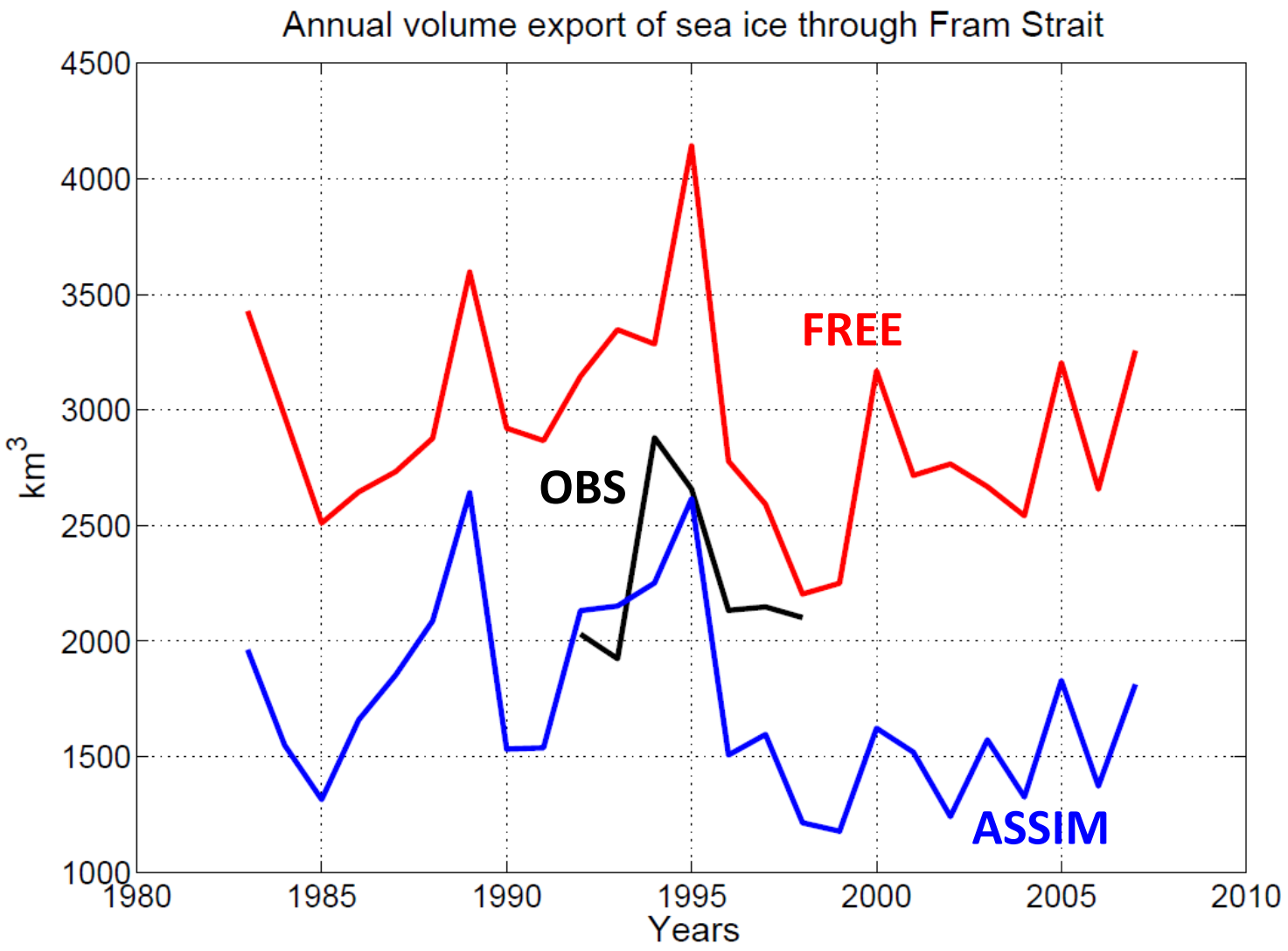
Anomalies of sea ice volume (NEMO-LIM2 + assim sea ice concentration) ,
linear fits +/- 2 std and their **trends**



Fram Strait - area



Fram Strait - volume



Recommandations

- Don’t look at Antarctic sea ice as a whole

  (« not all sea ice cells can’t talk to each other»)

- Take advantage of multivariate DA

- Never underestimate the potential of errors

- Keep in mind the limitations of the method

Thank you!

Useful links

www.climate.be/lim

This presentation is available:
www.climate.be/u/fmasson

francois.massonnet@uclouvain.be