Ensemble Kalman filter in sea ice modeling

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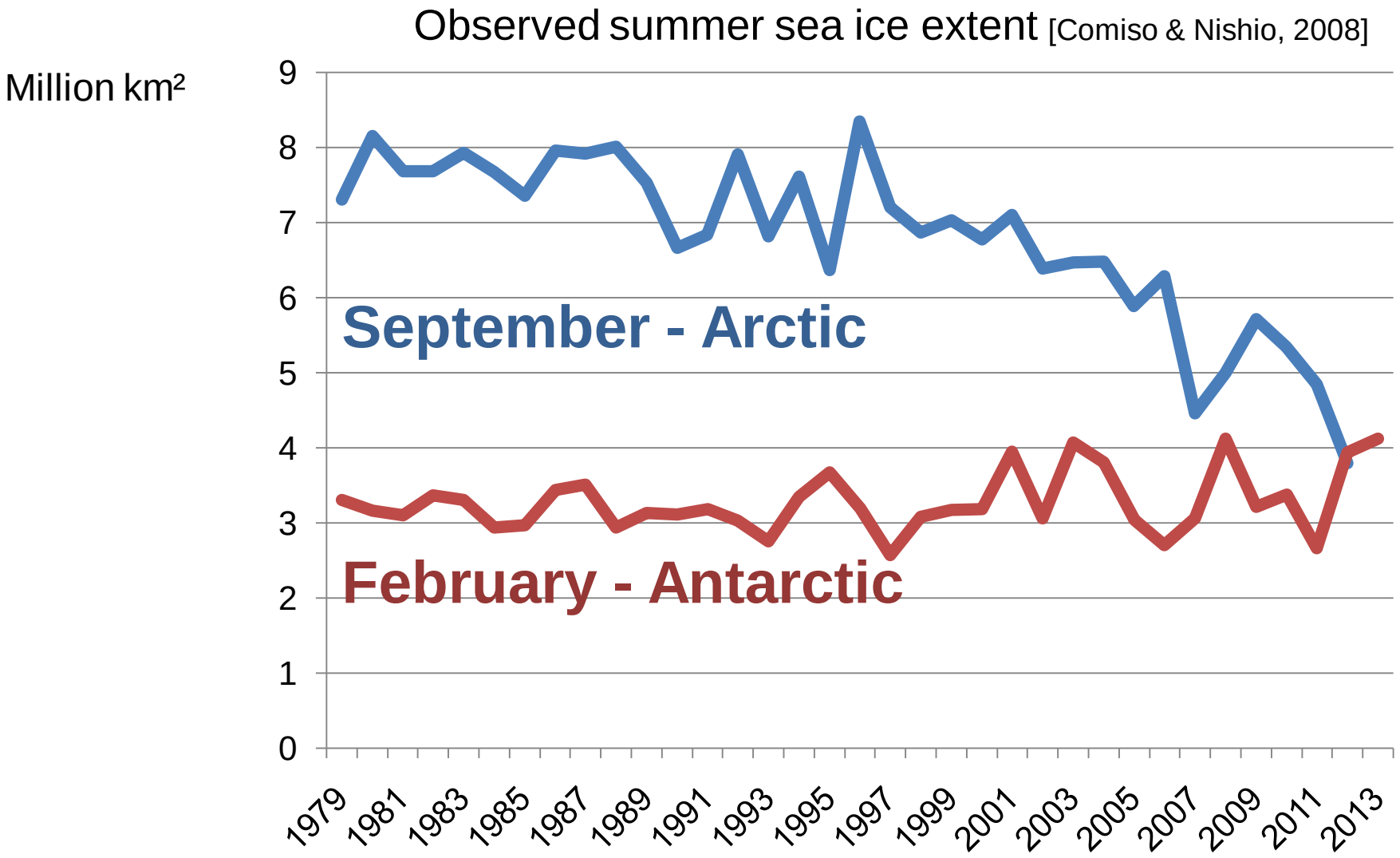
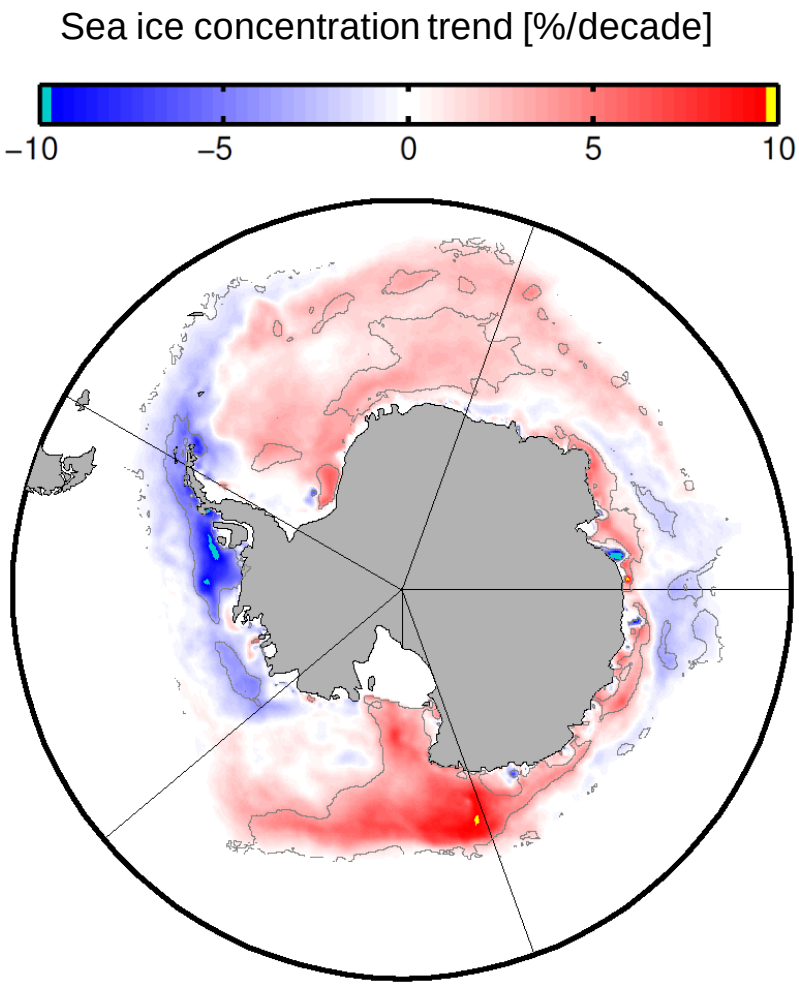
The 2012 sea ice kiss: two pending challenges



Challenge 1
Expanding Antarctic sea ice



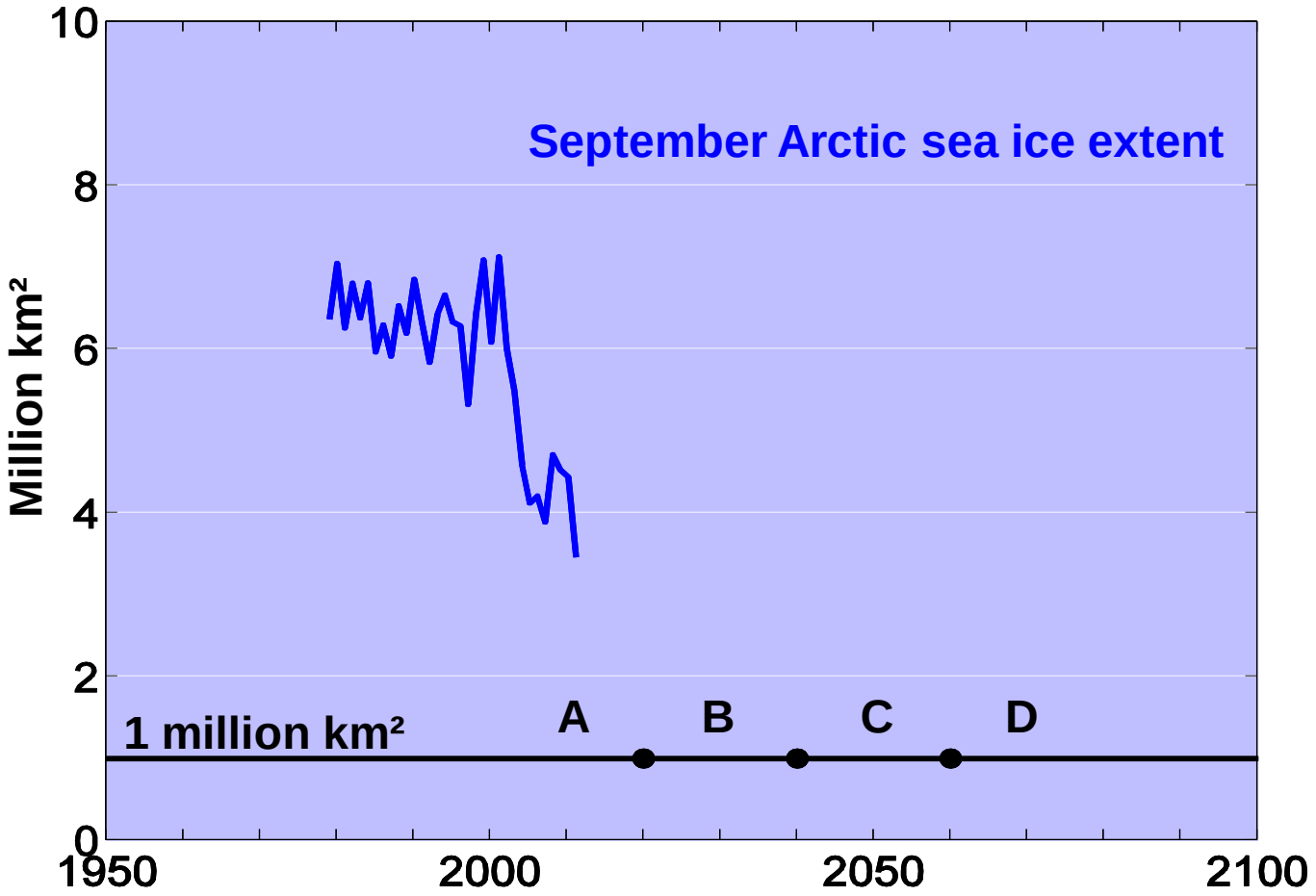
[data: Comiso and Nishio, 2008]

- Mostly **areal** observations

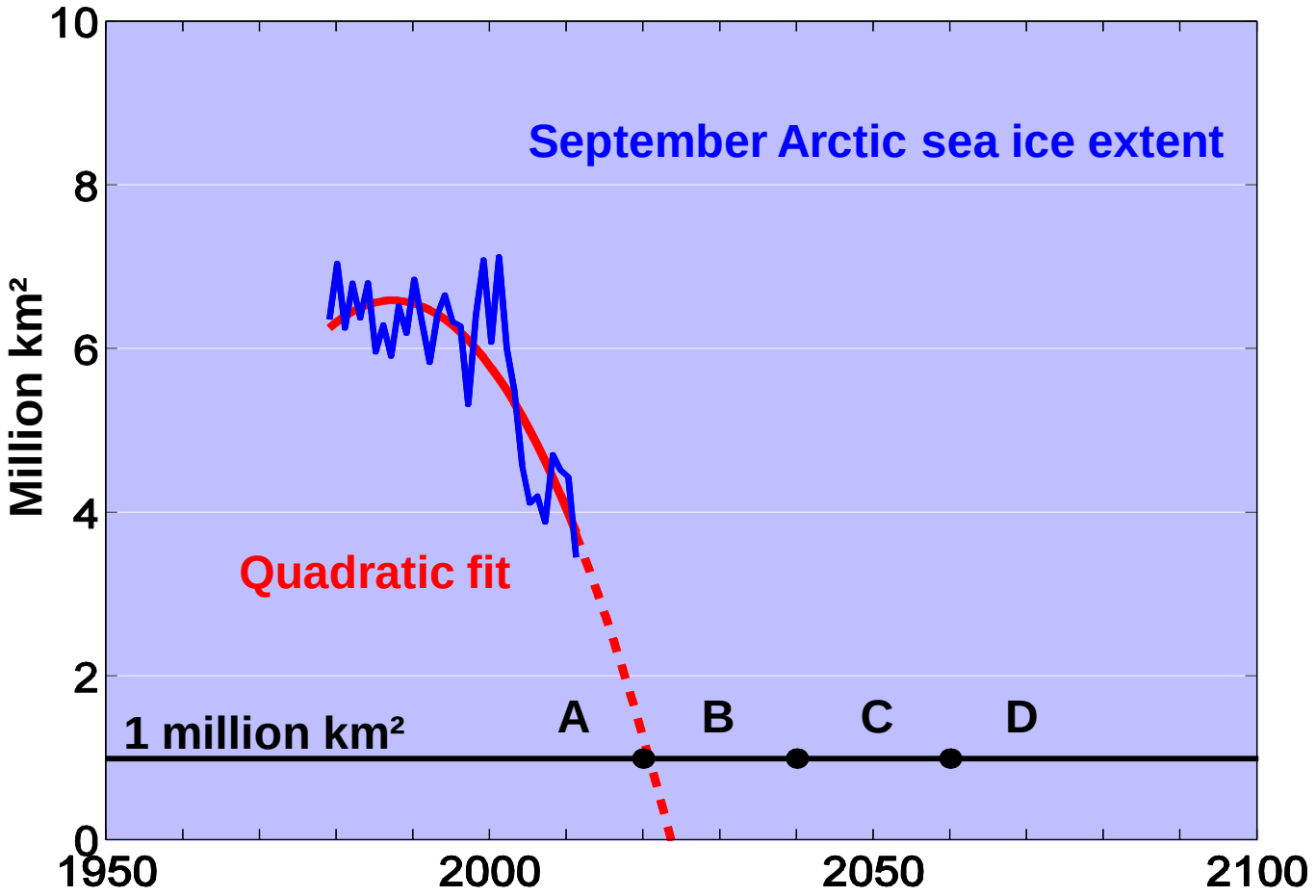
- **GCMs are of limited utility** because of biased mean state and variability [Zunz et al., 2013]

- **Several interpretations proposed**
  - Changes in winds [Holland and Kwok, 2012]
  - Changes in hydrological cycle [Zhang, 2007; Bintanja et al., 2013]
  - Unforced variability [Polvani & Smith, in rev.]
  - …

Challenge 2
Summer Arctic sea ice predictability

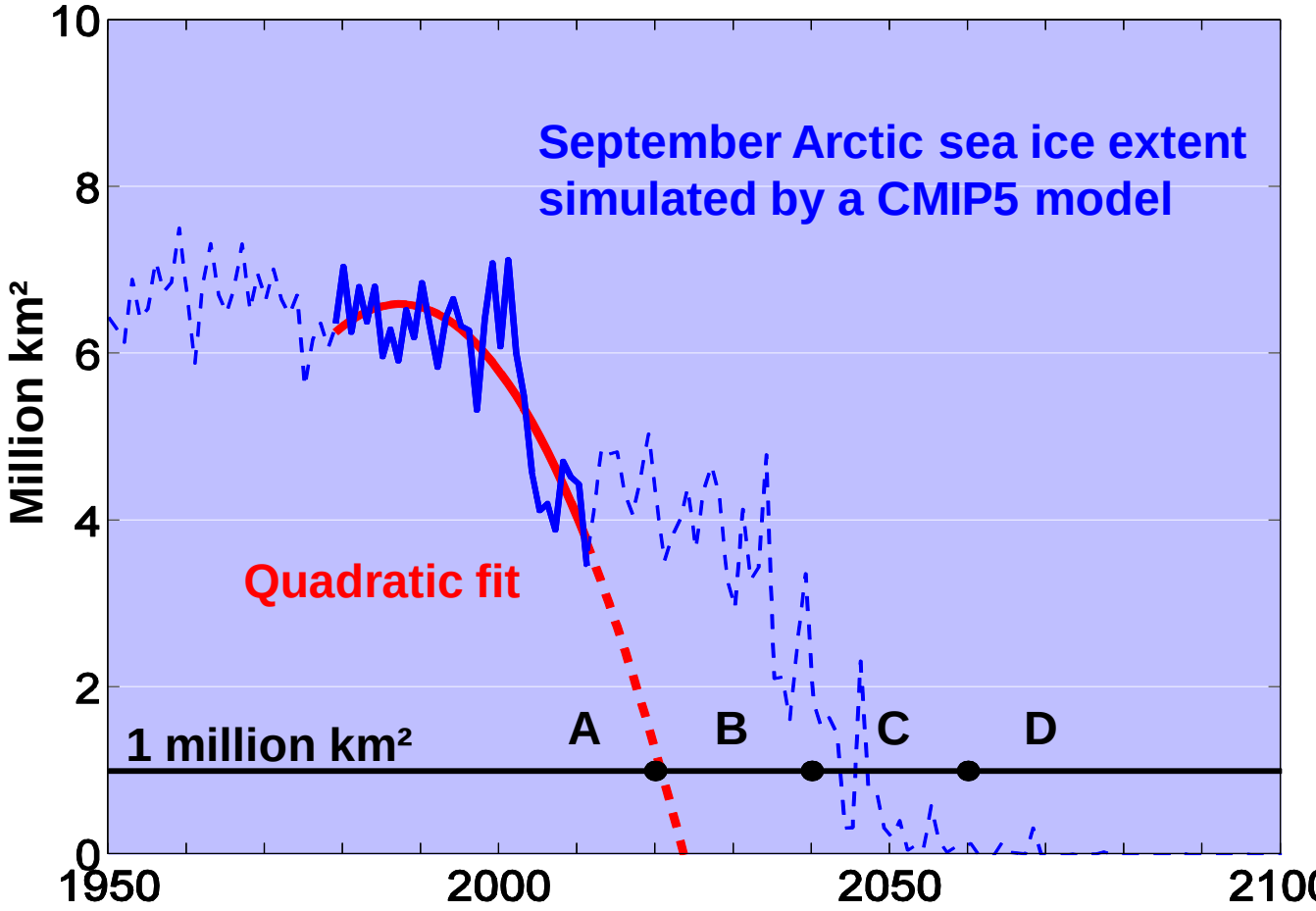


Challenge 2
Summer Arctic sea ice predictability



Challenge 2
Summer Arctic sea ice predictability

Never rely on your first
intuition for complex systems!



Data assimilation and ensemble Kalman filter

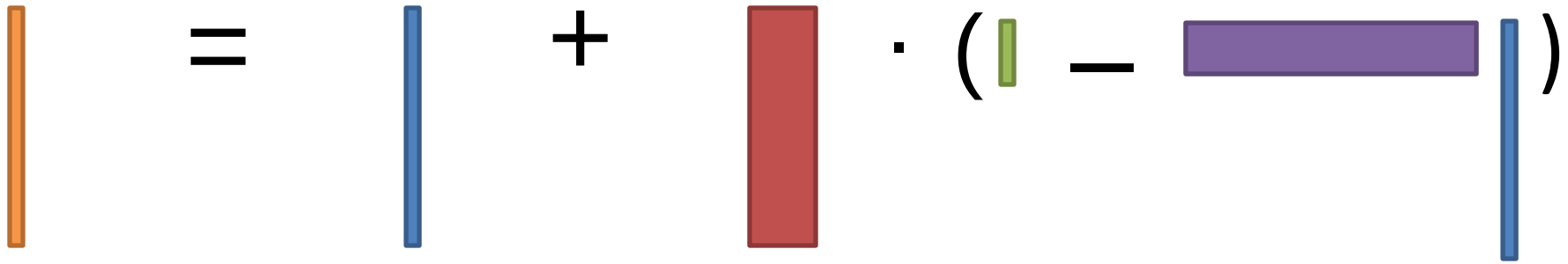
Reconstructing Antarctic sea ice changes

Is there an added value from sea ice initialization?

The ensemble Kalman filter is a multivariate data assimilation method

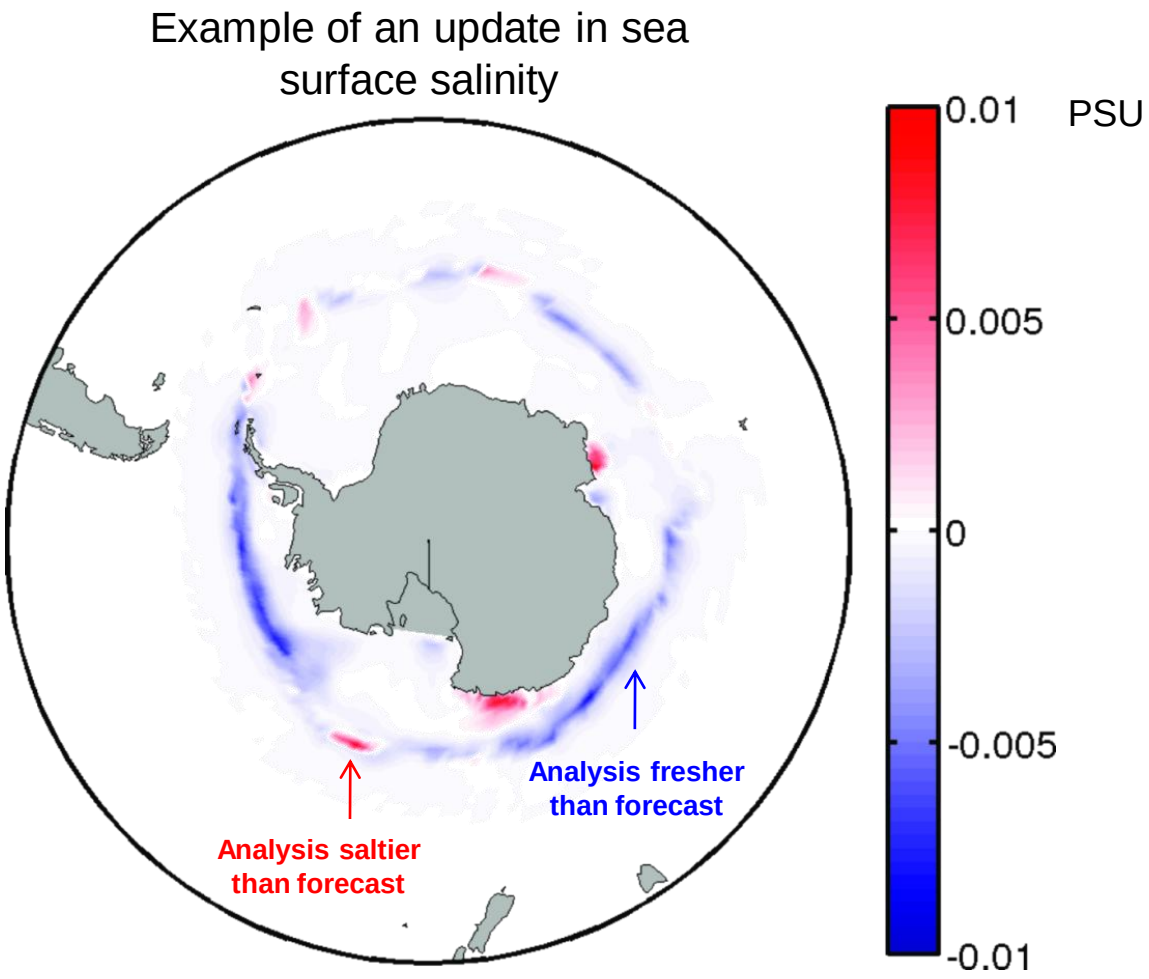
Analysis **Forecast** (NEMO-LIM) **Kalman gain** **Observations** Global, daily sea-ice **concentrations** **[OSISAF – met.no]**

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



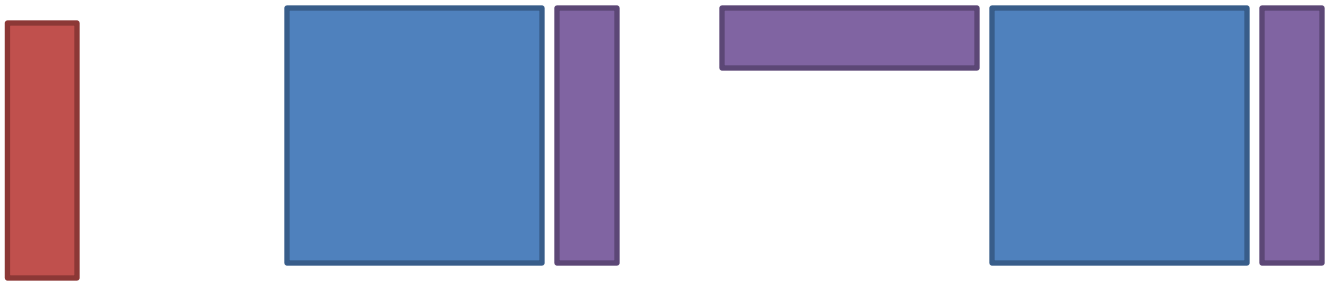
[Evensen, 2003]

The ensemble Kalman filter is a multivariate data assimilation method



The ensemble Kalman filter relies on ensemble simulations

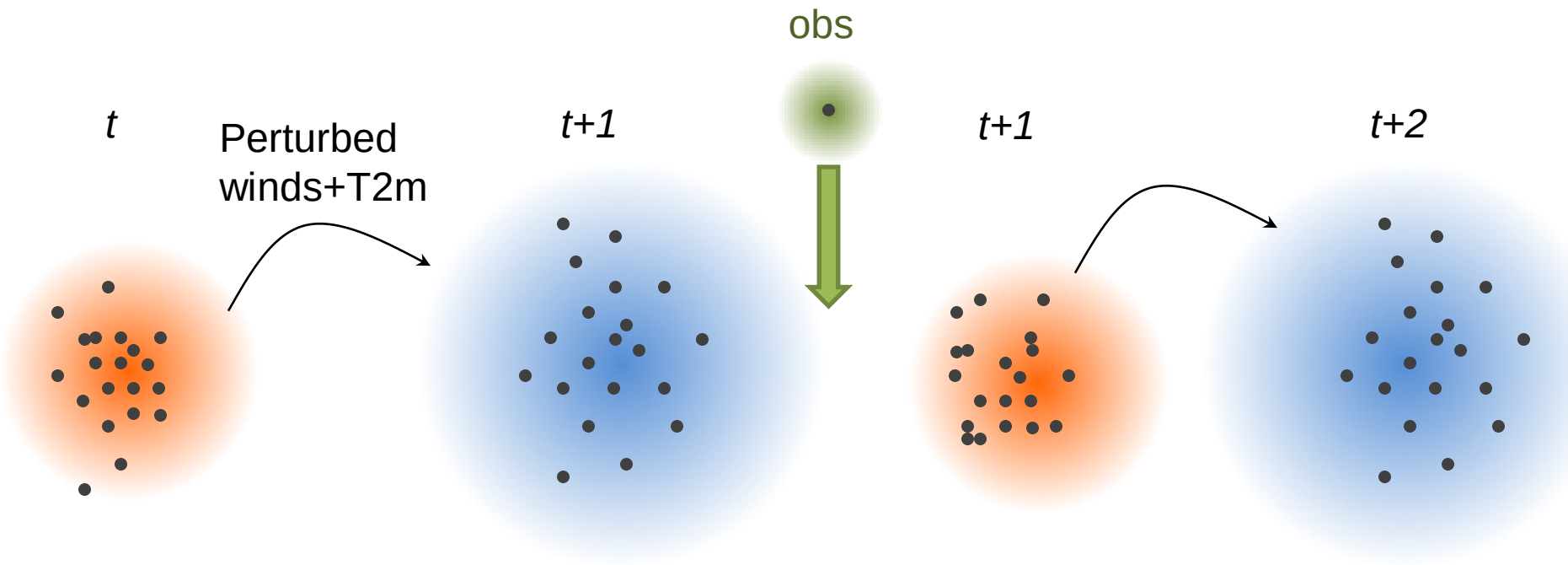
$$K = P H^T (H P H^T + R)^{-1}$$



Model error covariance matrix (from 25 members)

Obs. error covariance matrix (diagonal for now)

The ensemble Kalman filter is a forecast-analysis method



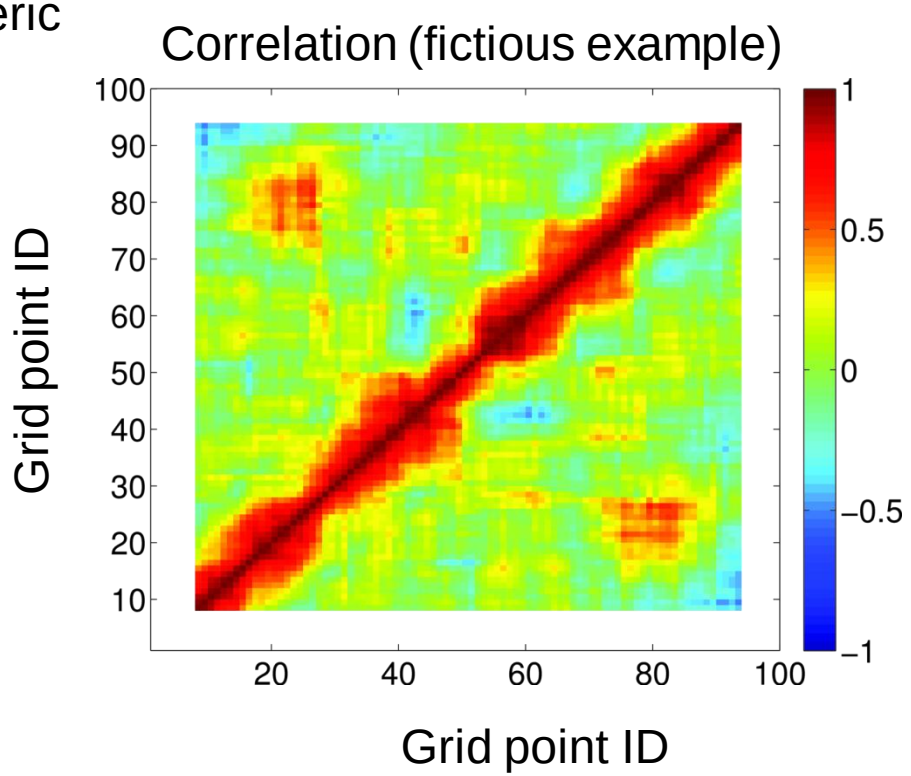
Ensemble spread, restartability and limitations

The distribution of ensemble members should reflect the full model uncertainty

* 25 members with perturbed atmospheric forcing (winds/2m-air temperature)

* Localization [Sakov and Bertino, 2010]

* Use of perturbed observations [Burgers et al., 1998]



Ensemble spread, restartability and limitations

A « sanity check » for the model is necessary because gaussianity assumption is rarely fulfilled

> Reset negative ice concentrations/thickness to zero

> Bound total ice concentration by 1

> Ice thickness stays within category bounds

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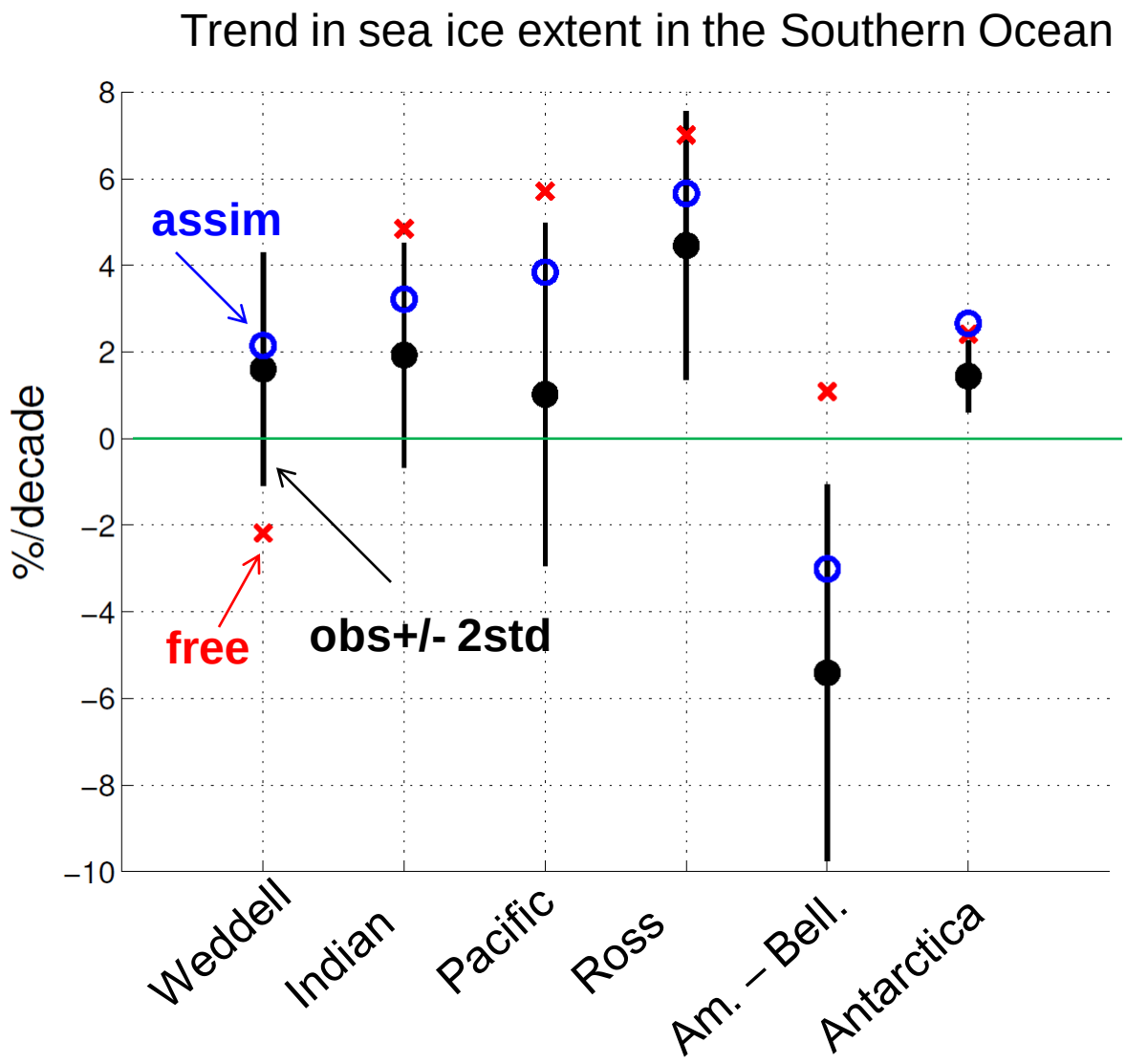
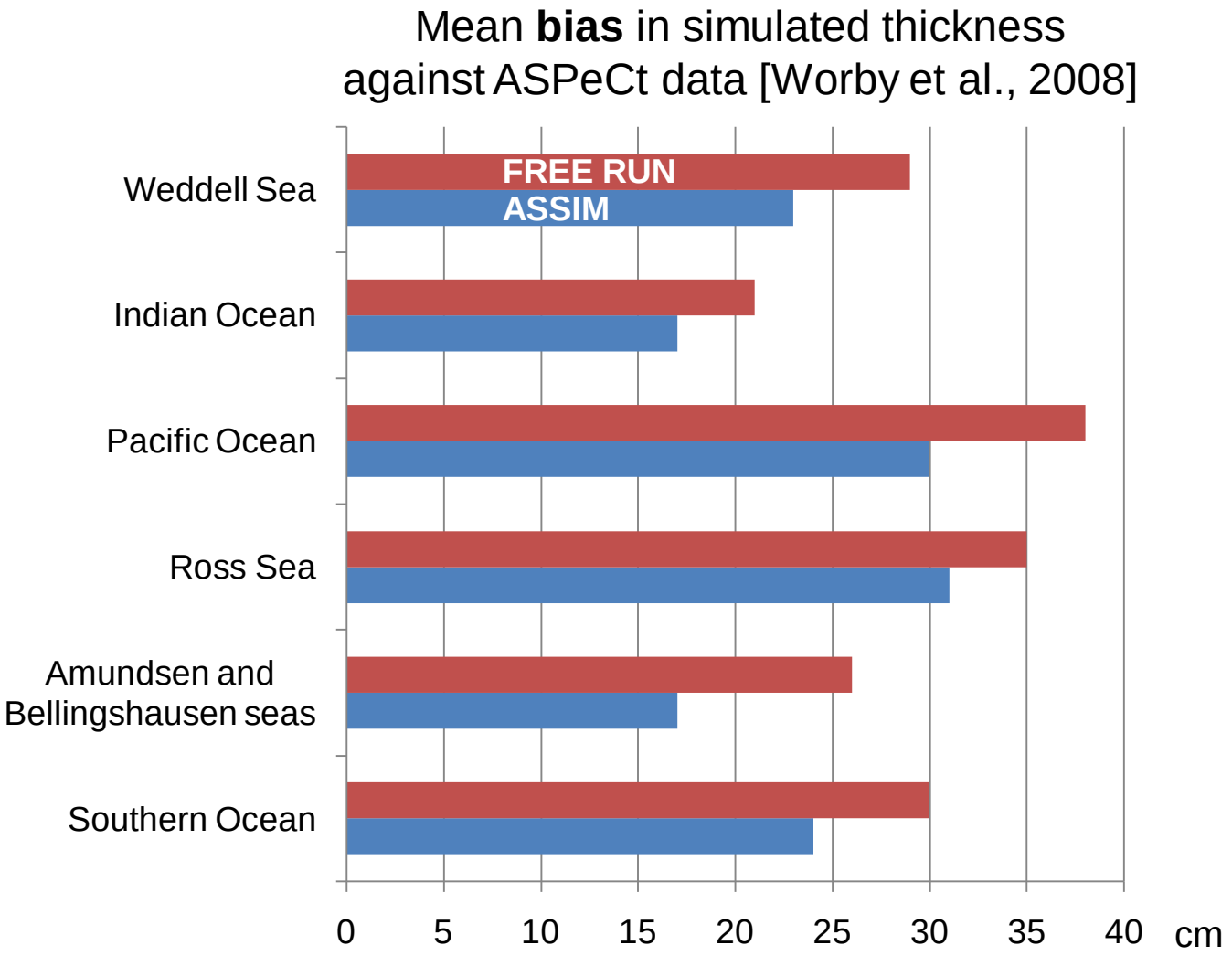
Is there an added value from sea ice initialization?

Improved sea ice extent variability

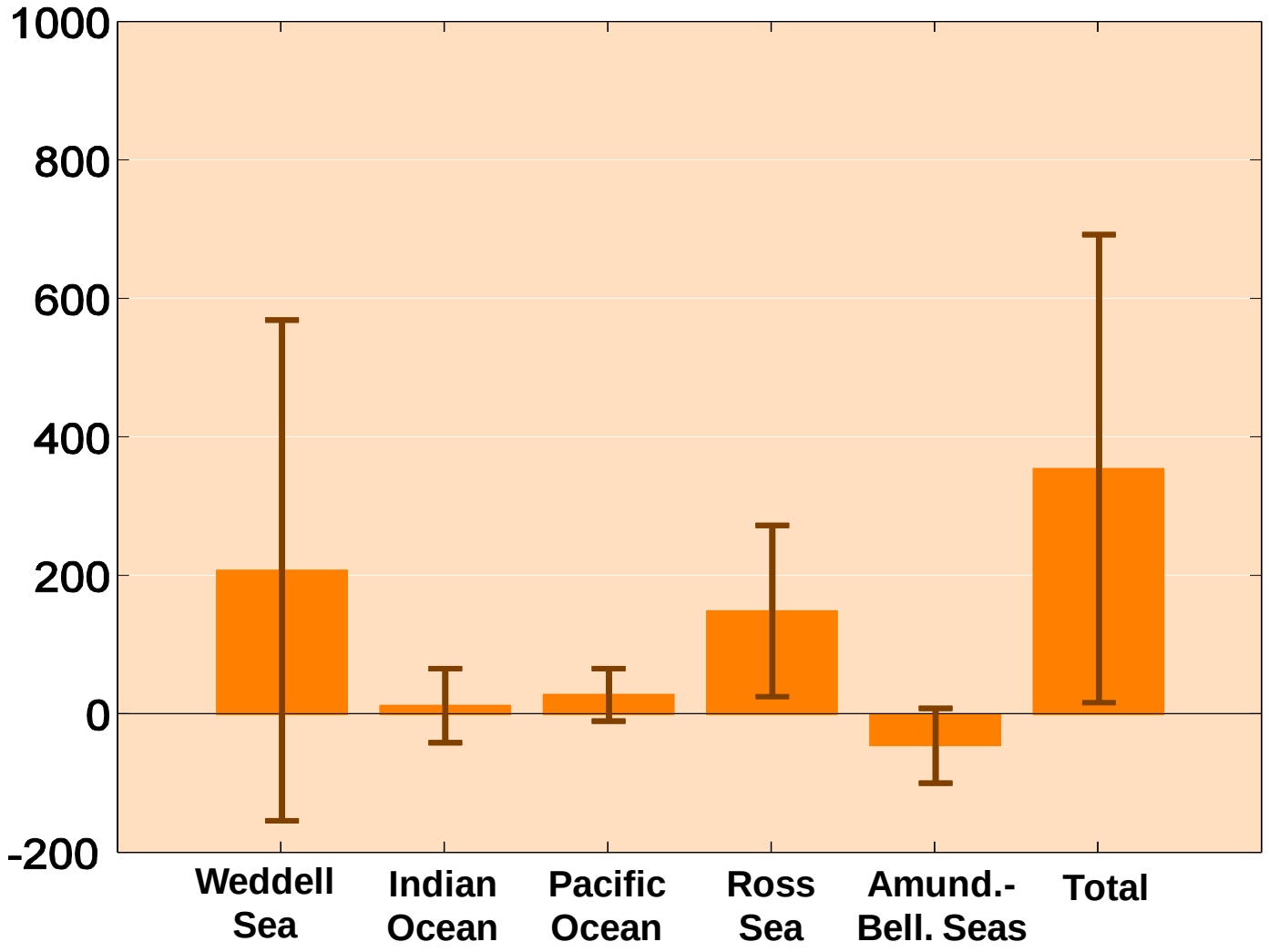


Improved simulated sea ice thickness

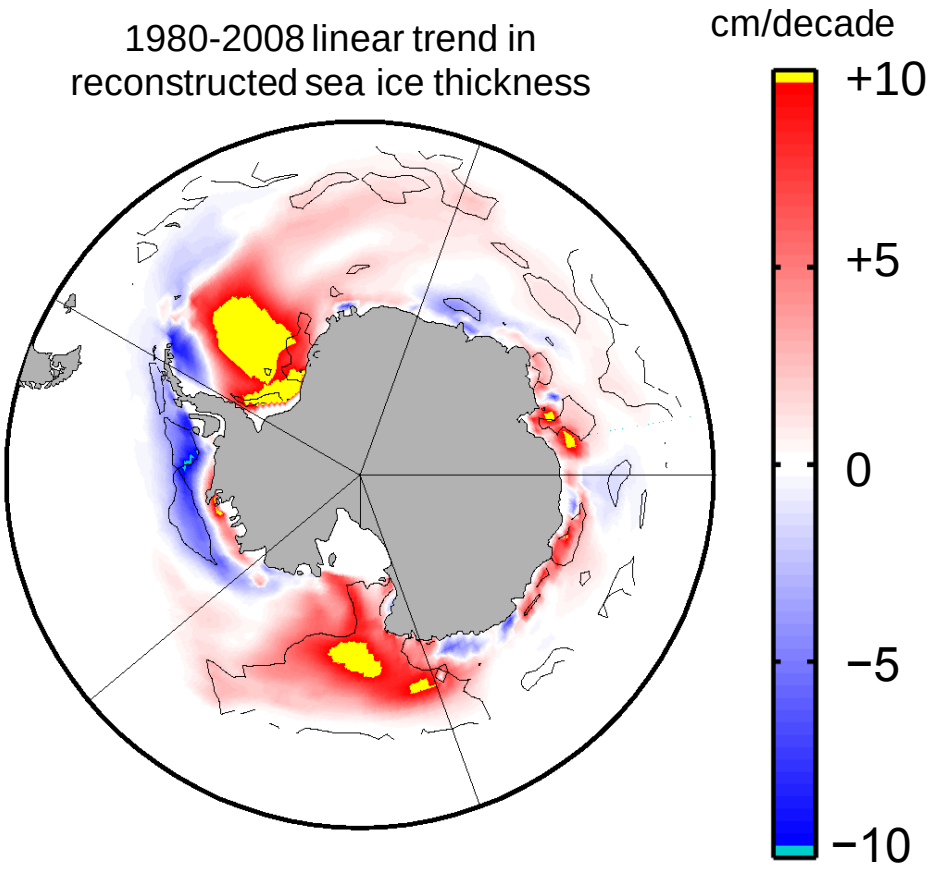


Weak, regionalized and noisy increase in Antarctic sea ice volume

1980-2008 trend in sea ice volume [km³/decade]



Mechanisms for Southern Ocean sea ice variability



The global increase in volume
should be analyzed
at the regional scale first

Regional signed responses
are a result of regional dynamical
and thermodynamical processes

- Changes in winds [Holland and Kwok, 2012]
- Changes in hydrological cycle [Zhang, 2007; Bintanja et al., 2013]
- Unforced variability [Polvani & Smith, in rev.]
- …

Data assimilation and Ensemble Kalman filter

Reconstructing Antarctic sea ice changes

Is there an added value from sea ice initialization?

The predictive skill from a model may depend on

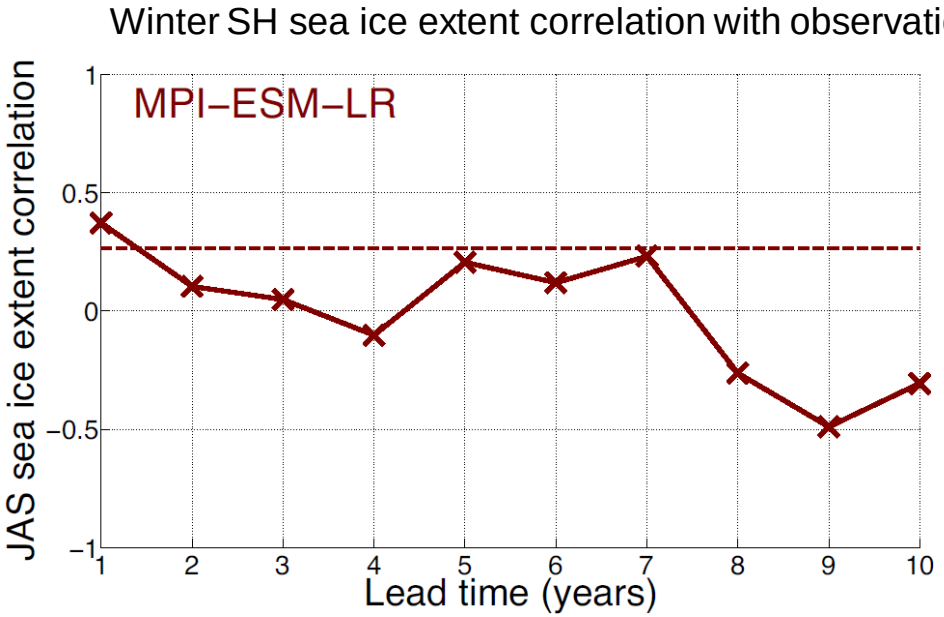
> The metrics used to measure it

> The model used

> The data assimilation method used

Antarctic ocean/sea ice initialization efforts

Initialization of 3-D ocean does not significantly improve sea ice predictability

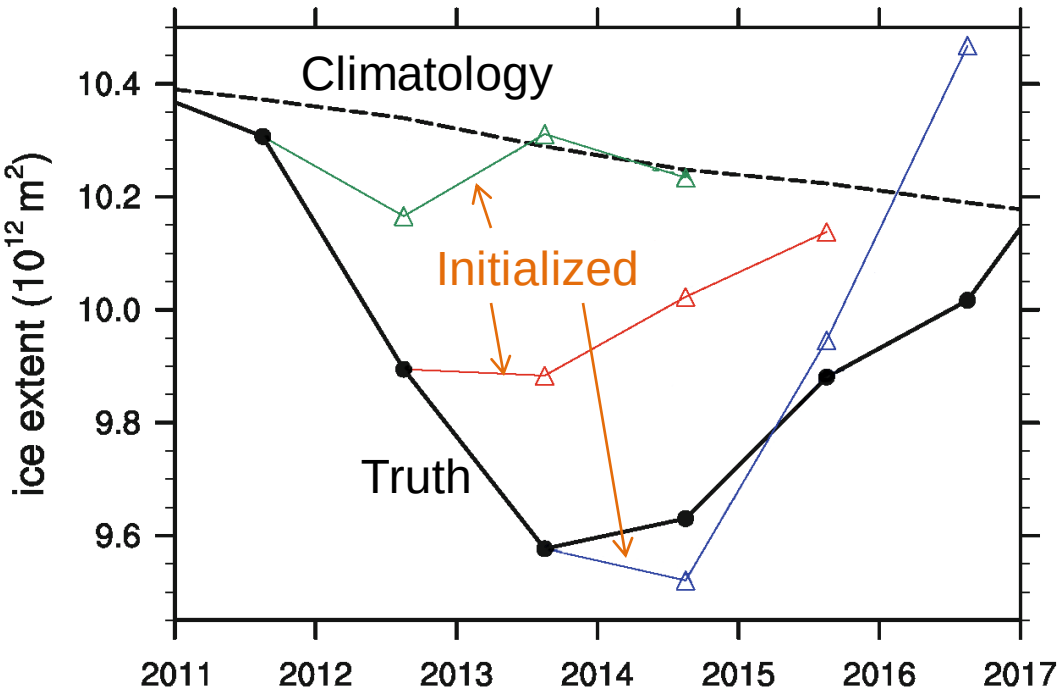


[Zunz et al., 2013]

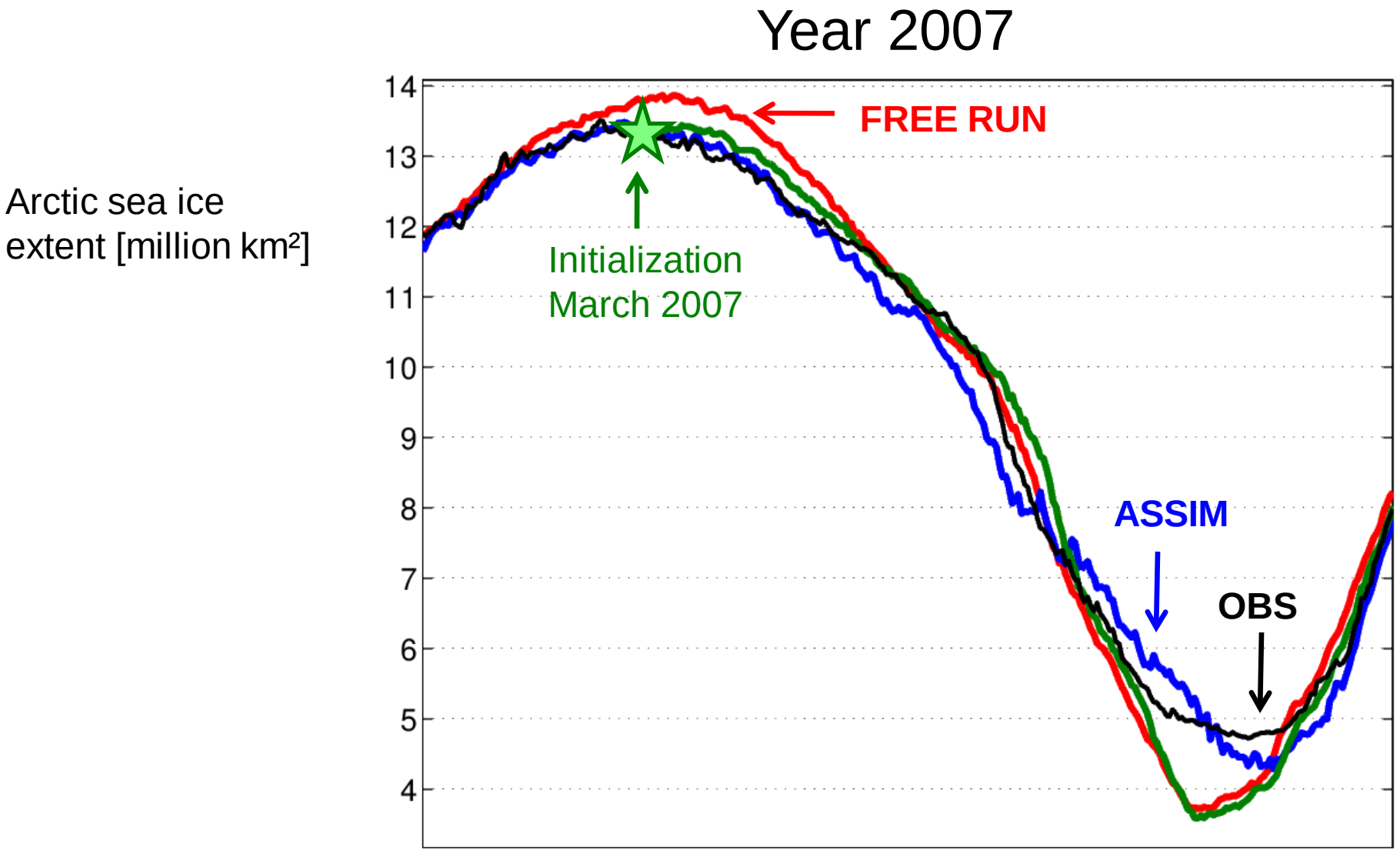
Arctic sea ice initialization efforts

The onset, timing and amplitude of large sea ice anomalies are hardly predictable

[adapted from Tietsche et al., 2013]



Arctic sea ice initialization efforts



Conclusions

Arctic & Antarctic sea ice data assimilation

Useful for sea ice state reconstruction

Marginal improvements for sea ice predictability

Prospects for joint state/parameter estimation

Thank you

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