Southern Ocean variability over the last centuries in coupled data assimilation experiments with particle filtering

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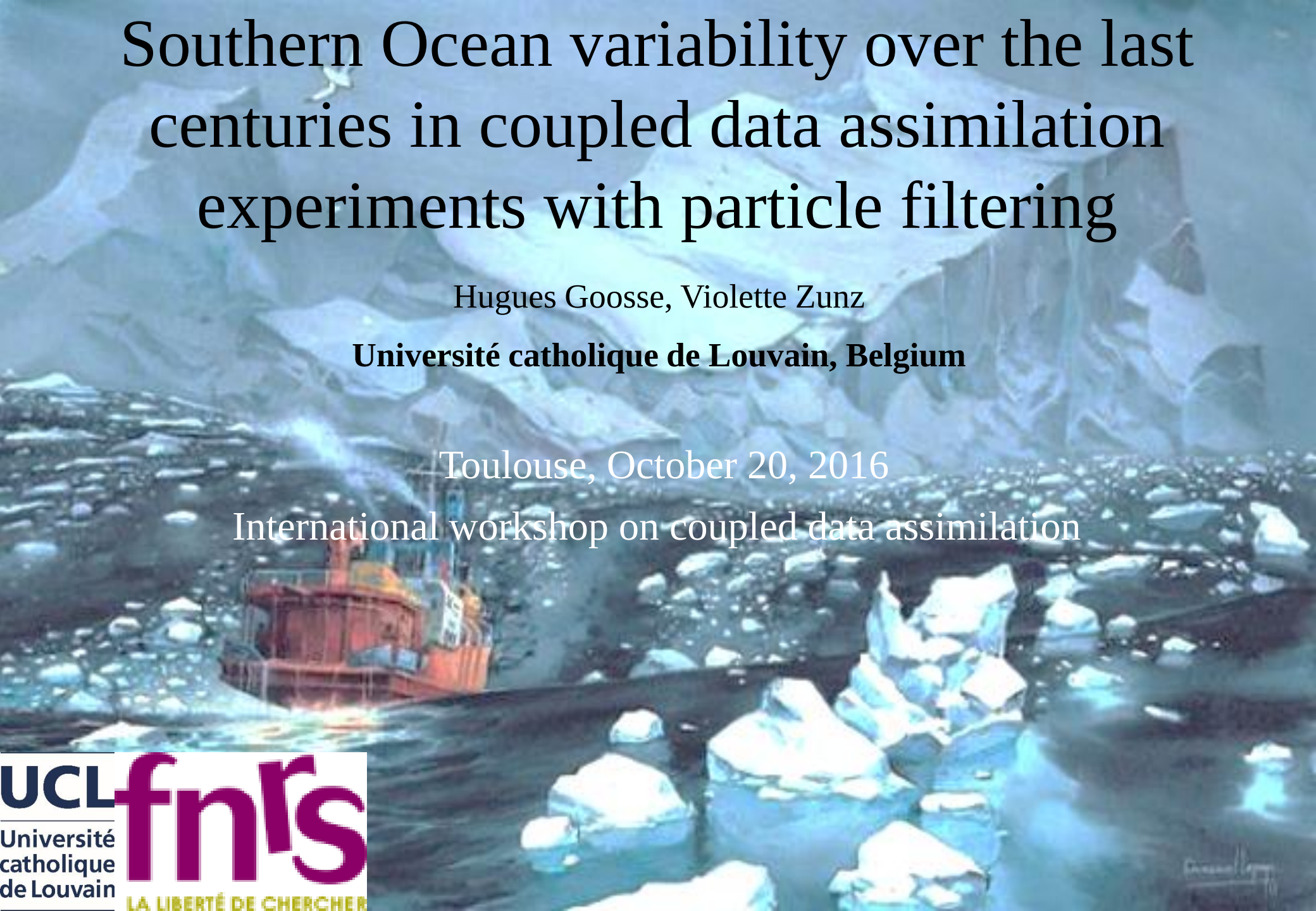
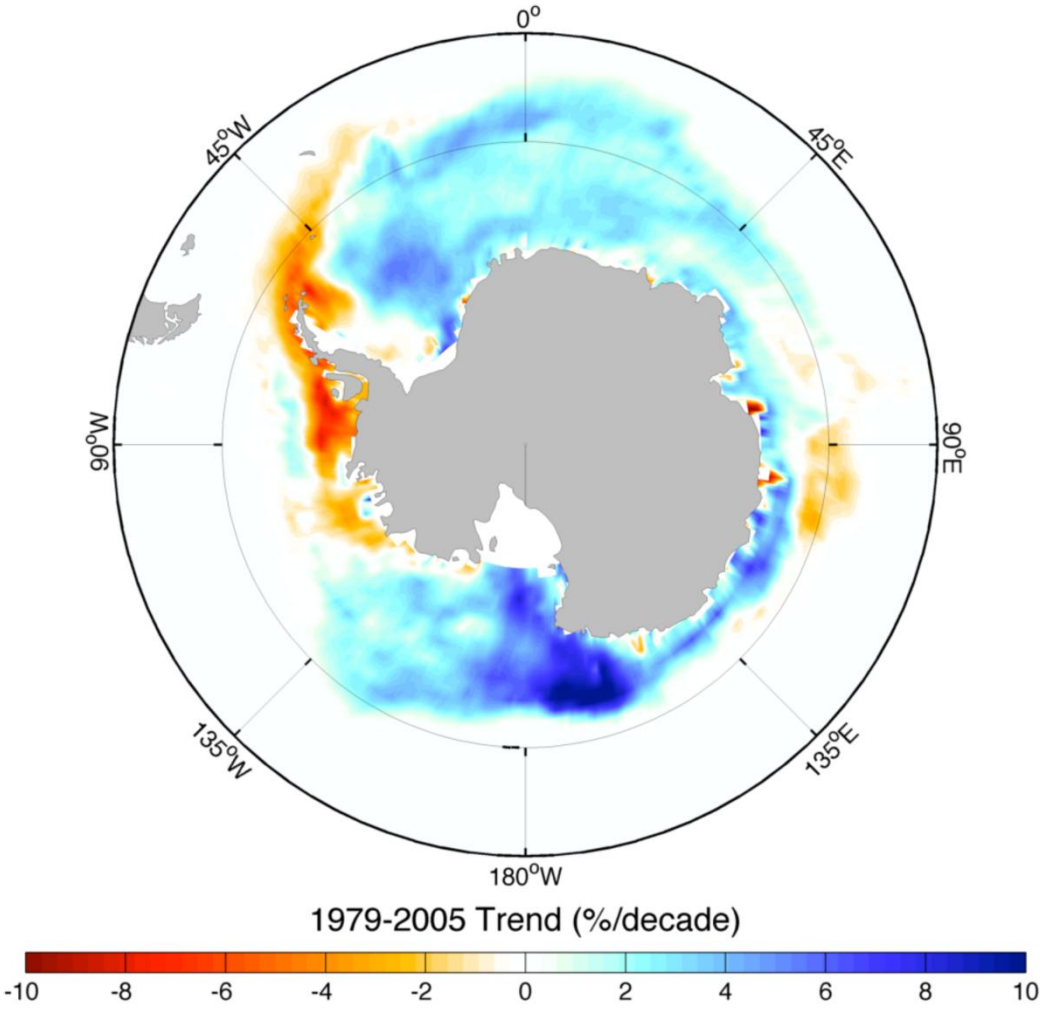
International workshop on coupled data assimilation



Sea ice changes over the last decades

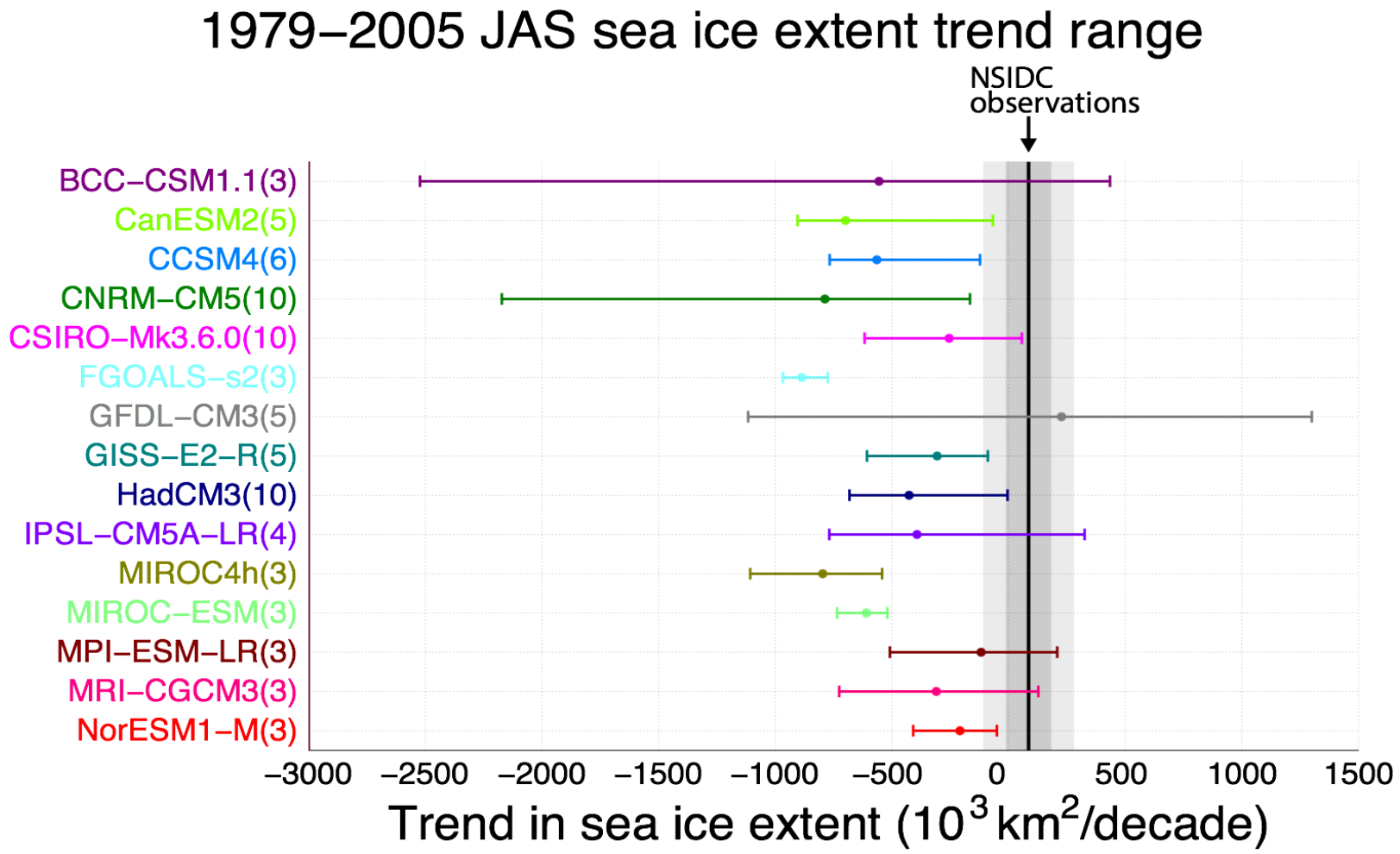
Observed trend in sea ice concentration over the period 1978-2010 (data from NSIDC)



Satellite observations indicate a **significant positive sea ice extent trend** of 1.7 10^5 ± 2 10^4 km^2 per decade in the Southern Ocean for the period November 1978–December 2010, (Cavalieri and Parkinson, 2012).

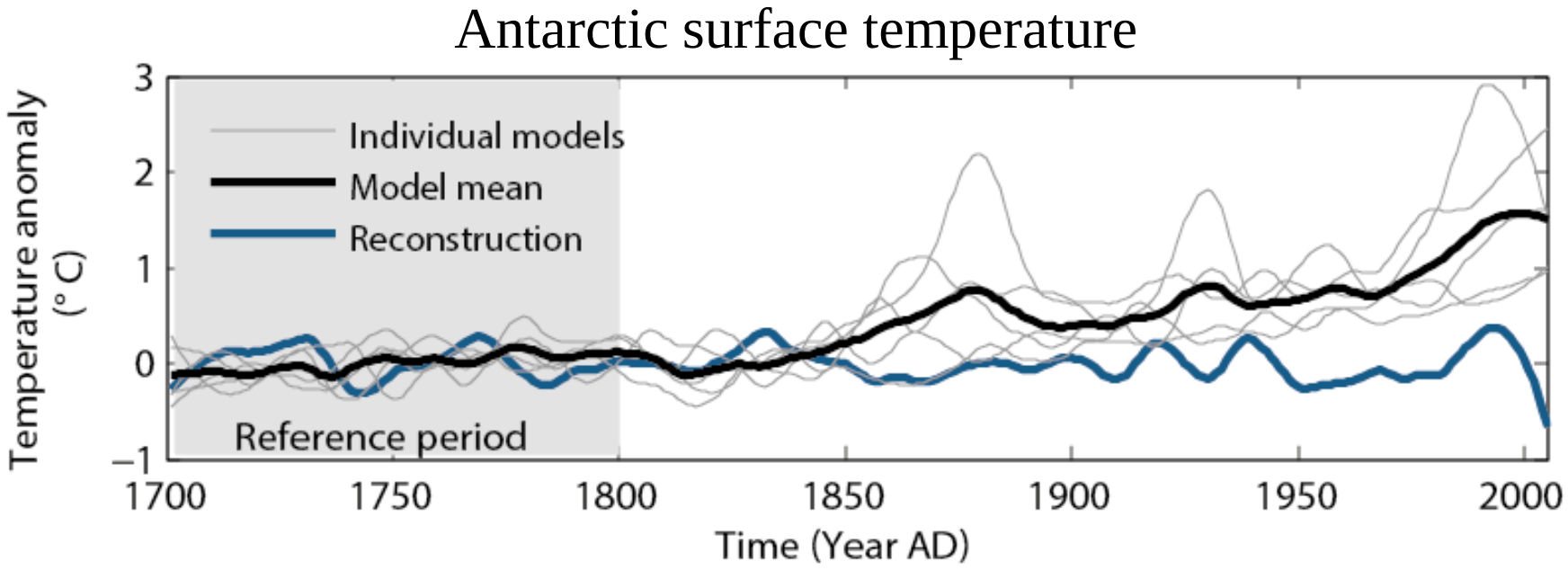
Simulated trends over the last decades

Among the members of the CMIP5 ensemble, only a few display a positive trend in sea ice extent.



Temperature changes over the last centuries

Models suggest a large temperature increase in Antarctica over the 20th century while the warming is much weaker in reconstructions

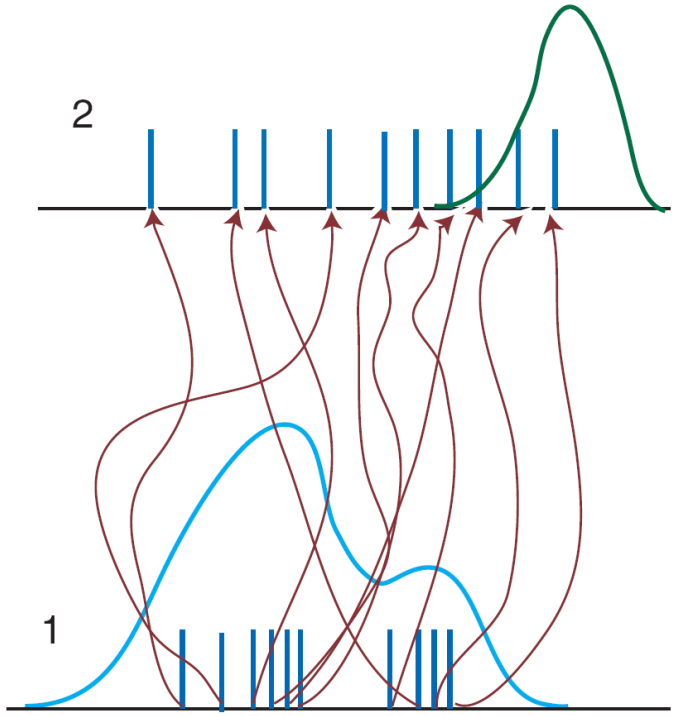


Annual mean surface temperature averaged over Antarctica simulated by five climate models following the PMIP3-CMIP5 protocol over the past 300 years and PAGES2k reconstruction for the same period (PAGES2k-PMIP3 working group, 2015).

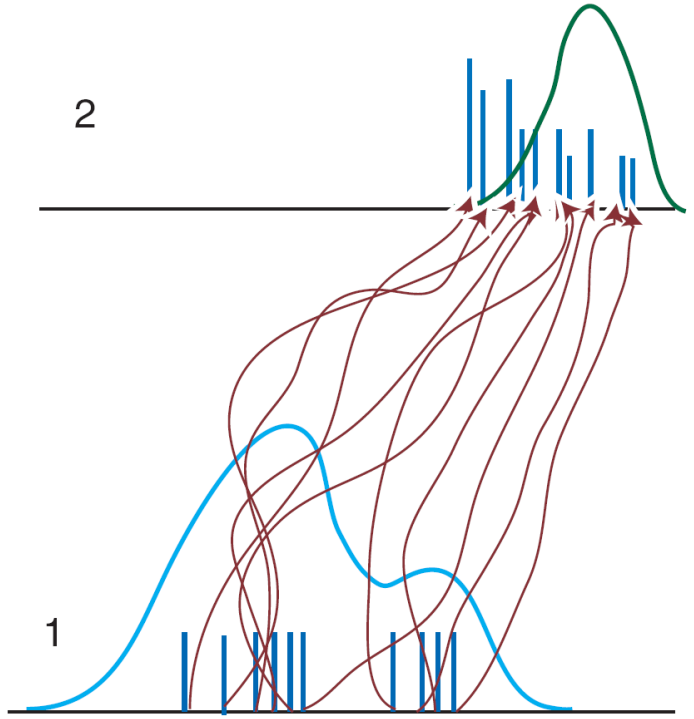
Insights gained through data assimilation

Methods

Particle filter with sequential importance resampling (SIR)

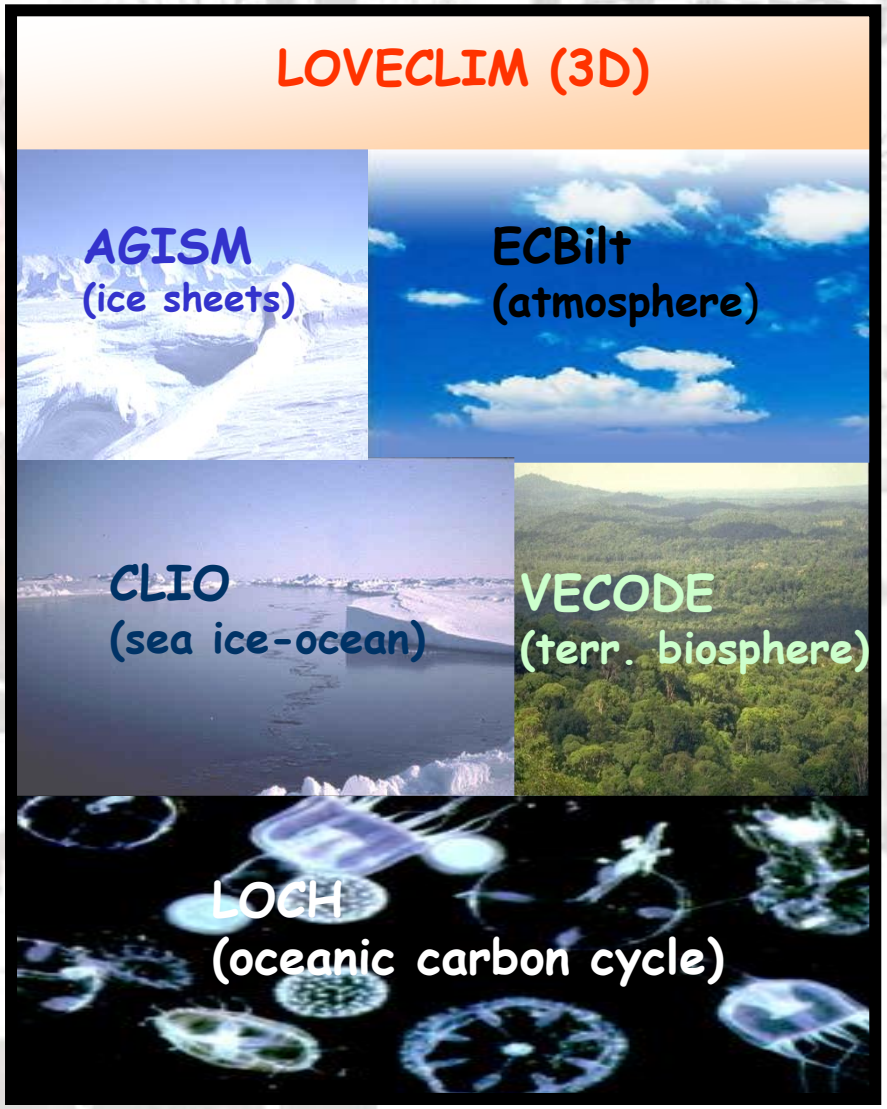


Nudging proposal particle filter (NPPF)



From P.J. van Leeuwen 2010

Description of LOVECLIM



ECBilt (Opsteegh et al., 1998)
Quasi-geostrophic atmospheric model (prescribed cloudiness; T21, L3).

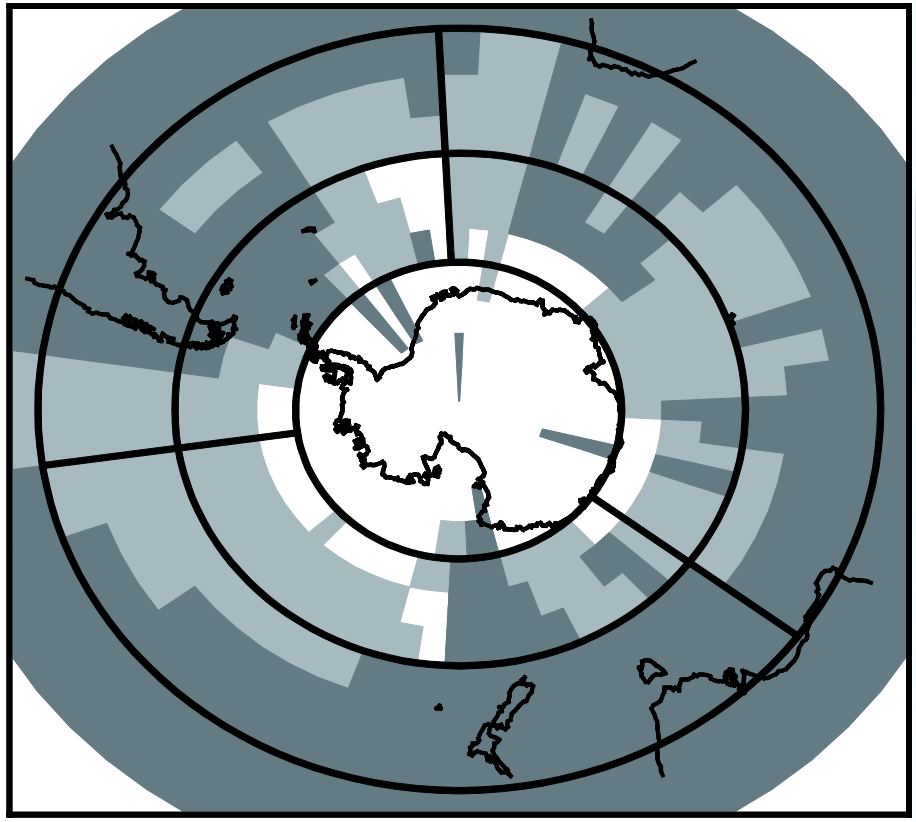
CLIO (Goosse and Fichefet, 1999)
Ocean general circulation model coupled to a thermodynamic-dynamic sea ice model (3 x 3, L20).

VECODE (Brovkin et al., 2002)
Reduced-form model of the vegetation dynamics and of the terrestrial carbon cycle (same resolution as ECBilt).

200 years of simulation on a single core in one day

Simulation over the last 150 years constrained by HadCRUT3 dataset

Data constrain: surface temperature (HadCRUT3)
Assimilation step: 3 months (Time averaged observations)
Method : nudging Particle Filter (96 simulations)



Data coverage:

- The dark grey area represents the model grid boxes for which observations are available since 1960
- The light grey area represents the model grid boxes for which observations are available since 1980.
- No data is available in the white grid boxes.

Zunz and Goosse, 2015

Simulation over the last 150 years constrained by HadCRUT3 dataset

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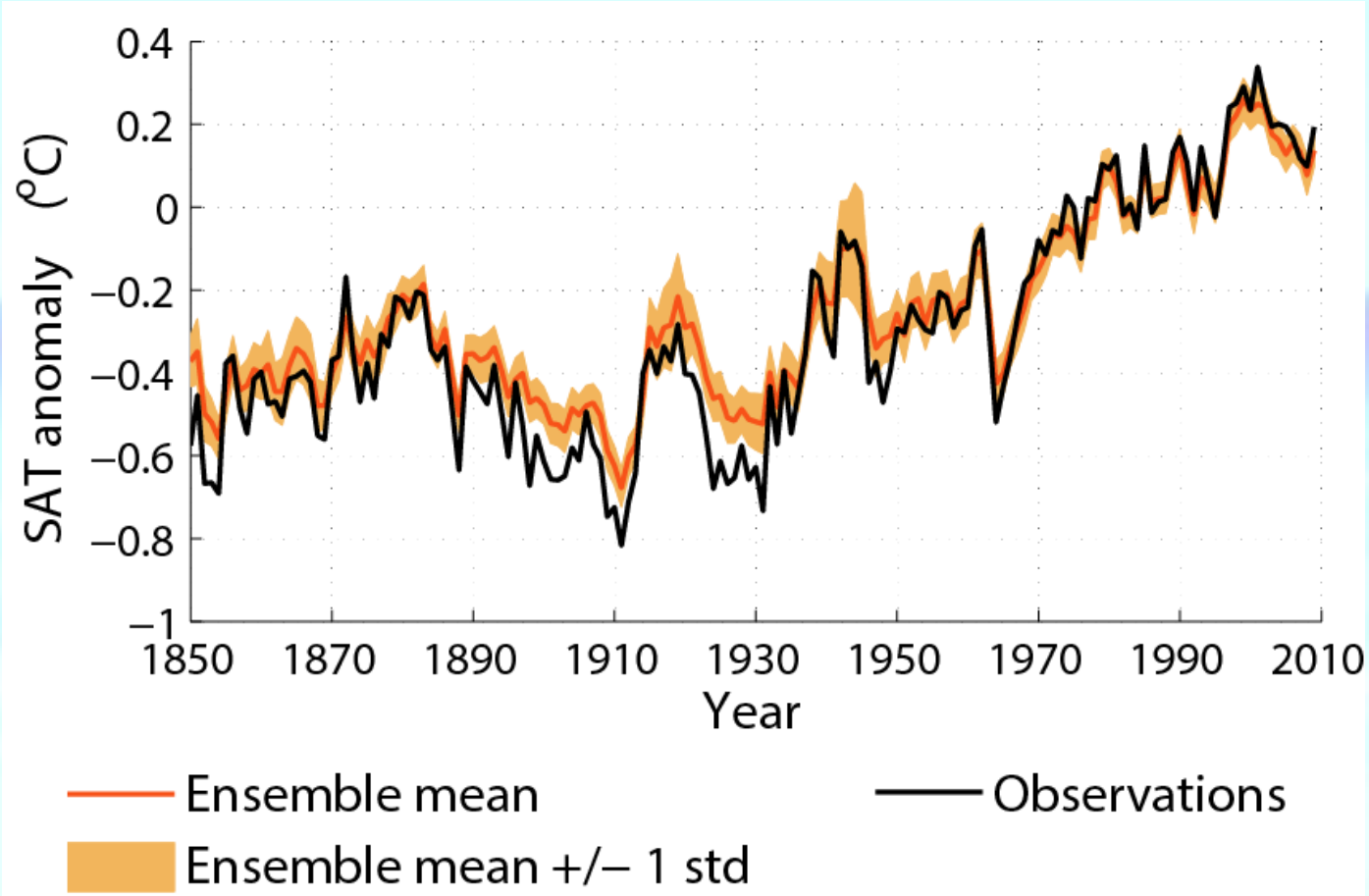
Yearly mean surface air temperature anomalies with regard to 1961–1990, averaged over the area south of 30°S.



Zunz and Goosse, 2015

Simulation over the last 150 years constrained by HadCRUT3 dataset

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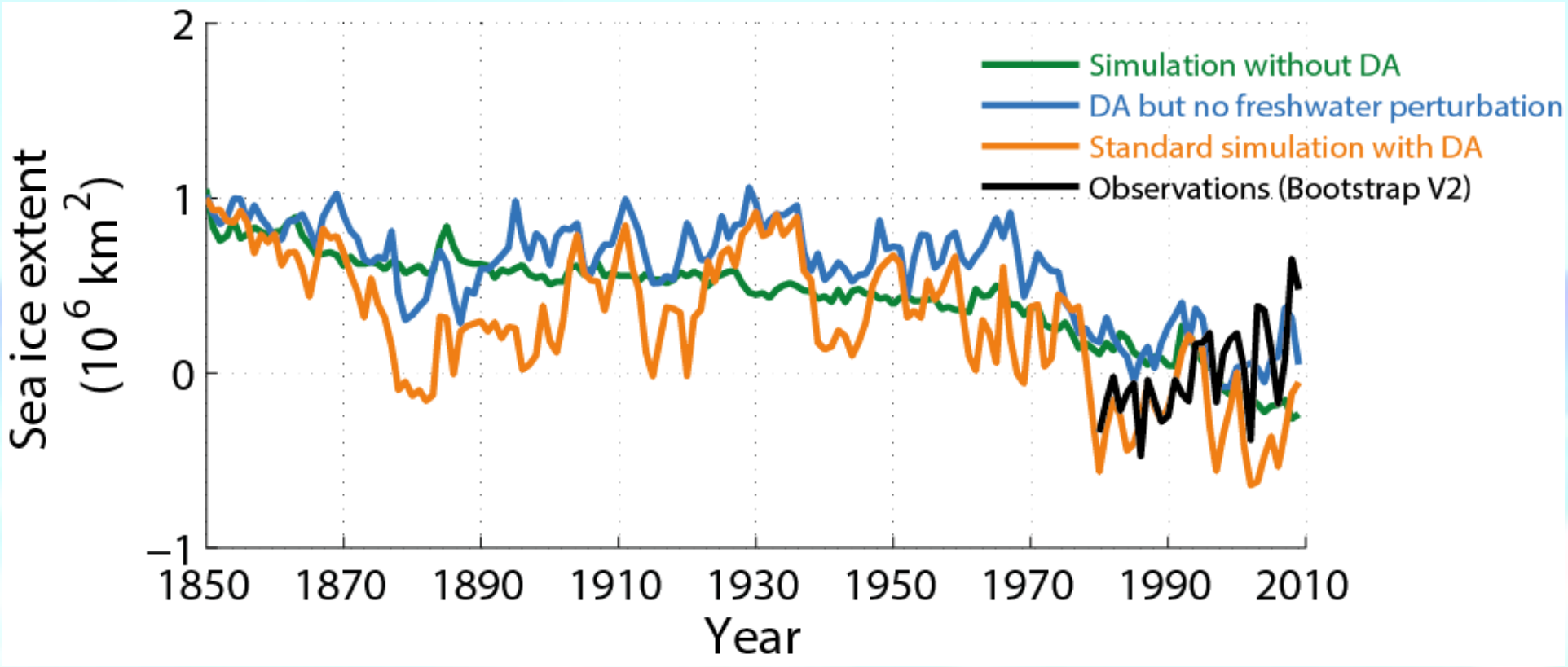
Ensemble mean of yearly mean sea ice extent anomalies with regard to 1980–2009 (10^6 km^2) in the Southern Ocean



In response to the forcing, the decreasing trend is relatively constant.
The simulation with data assimilation shows a large shift between the 1960's and the 1980's.

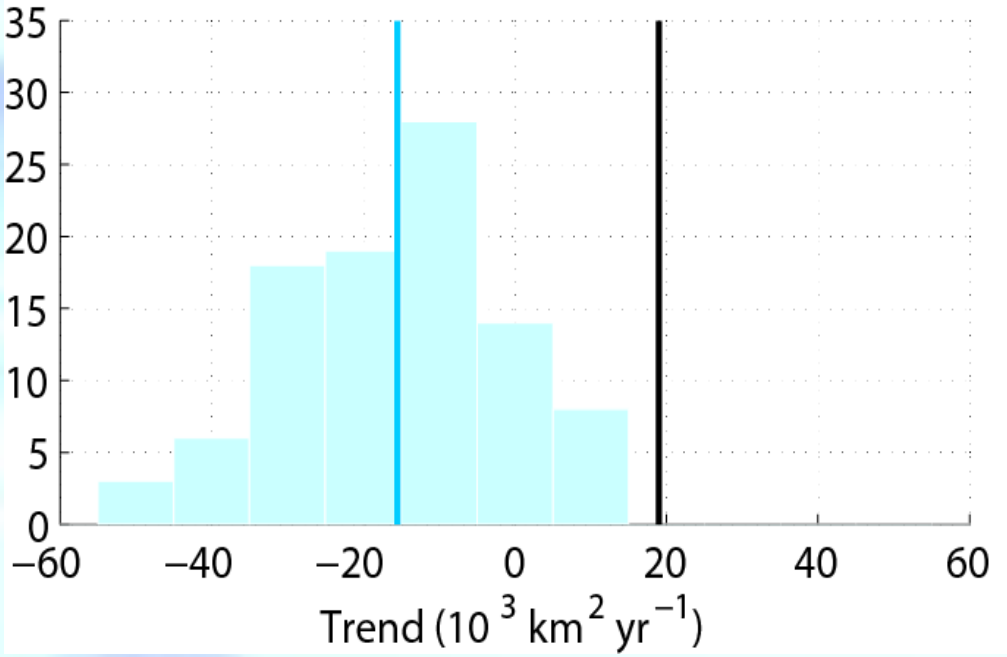
“Predicting” trends over the last 30 years

Simulations initialized in 1980 from an ensemble of 96 simulations with the EMIC LOVECLIM using a nudging Particle Filter

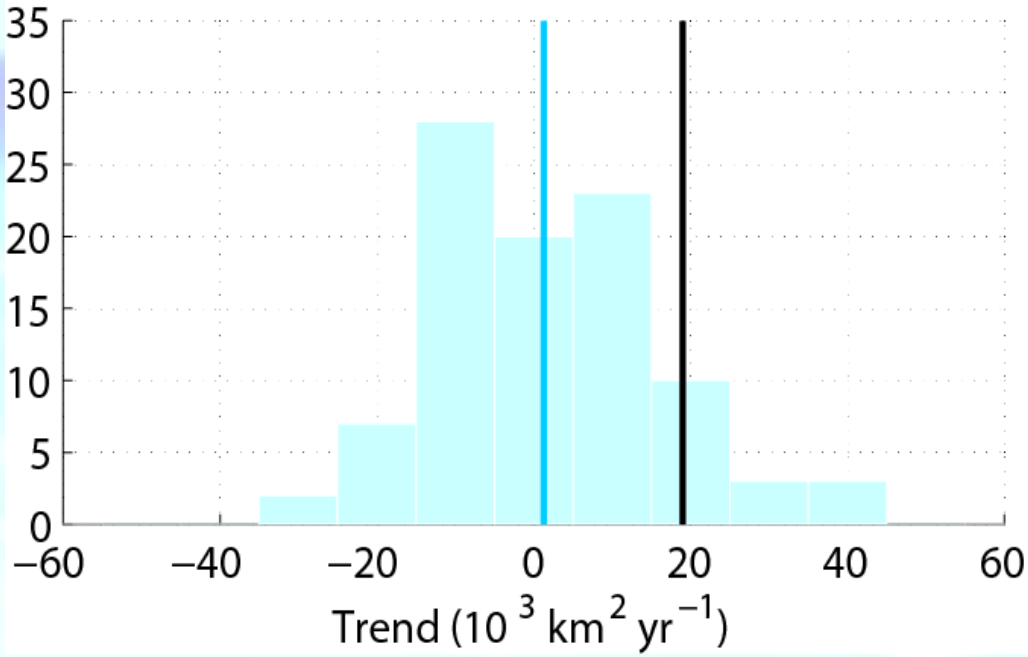
No data constraint is applied after 1979.

1980–2009 trend in annual mean sea ice extent

Non-initialized hindcast



Initialized hindcast (STD)

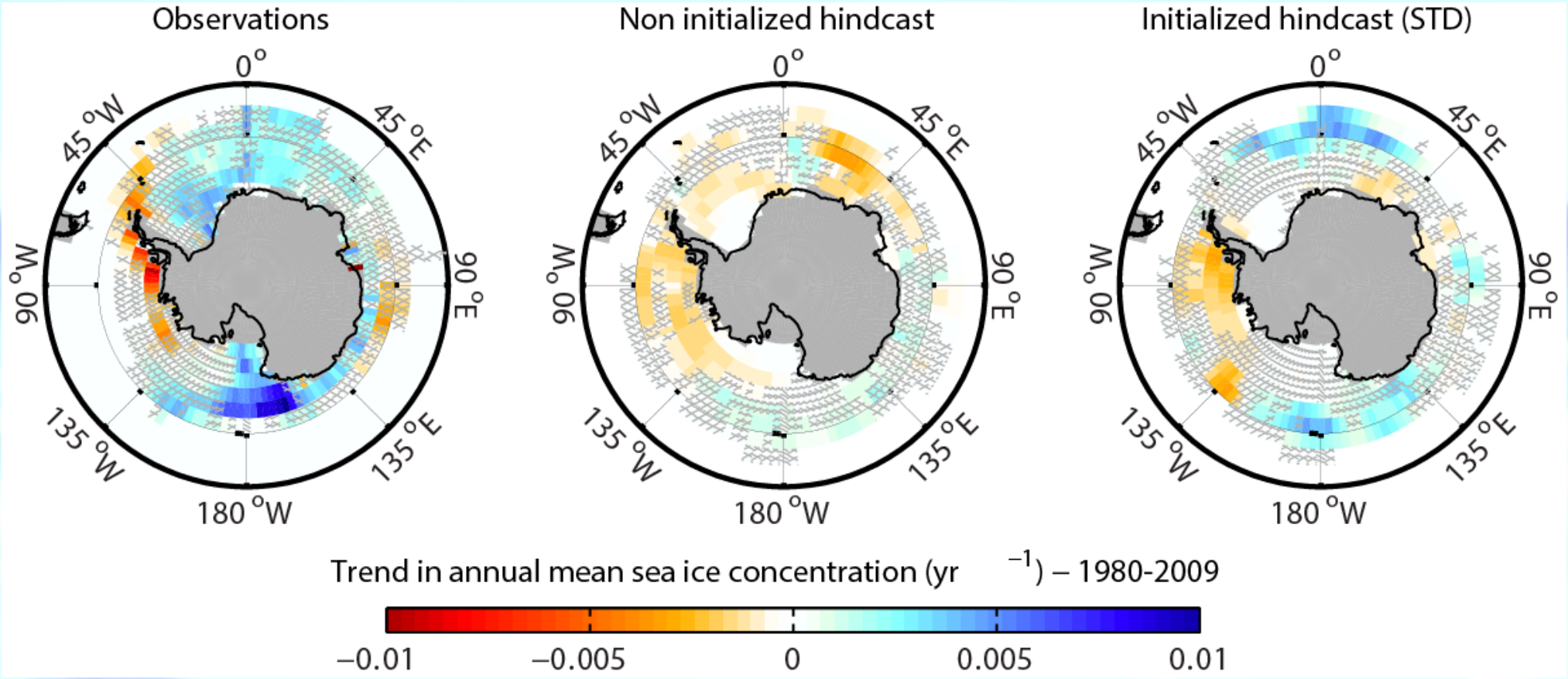


Zunz and Goosse 2015

‘Predicting’ trends over the last 30 years

Simulations initialized from an ensemble of 96 simulations with the EMIC LOVECLIM using a nudging Particle Filter

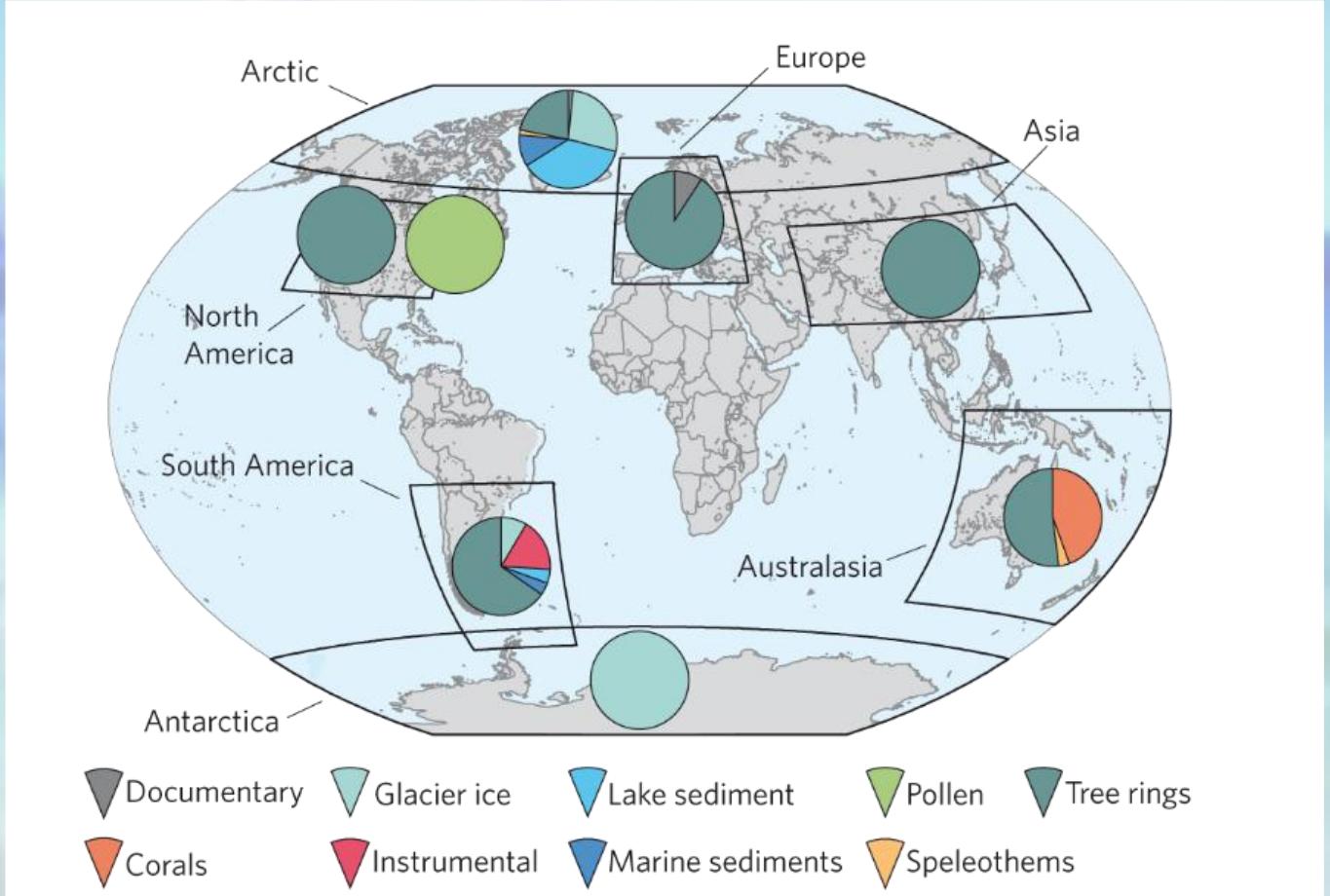
Trend in annual mean sea ice concentration 1980-2009



Zunz and Goosse 2015

Simulations over the last centuries constrained by PAGES2k continental-scale reconstructions

Data constrain: surface temperature in 7 continental regions
Assimilation step: 1 year
Method : Particle Filter Importance Resampling (96 simulations)

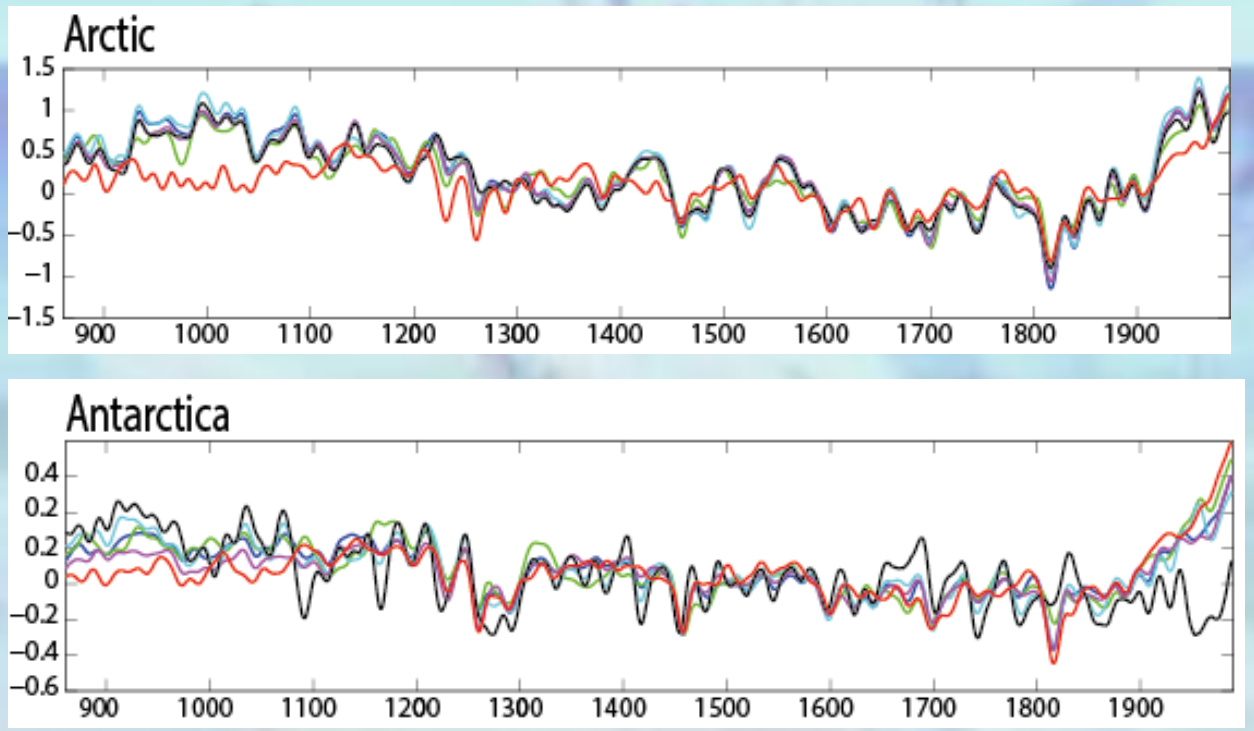


PAGES2k 2013

Simulations over the last centuries constrained by PAGES2k continental-scale reconstructions

Simulations initialized from an ensemble of 96 simulations with the EMIC LOVECLIM using a Particle Filter

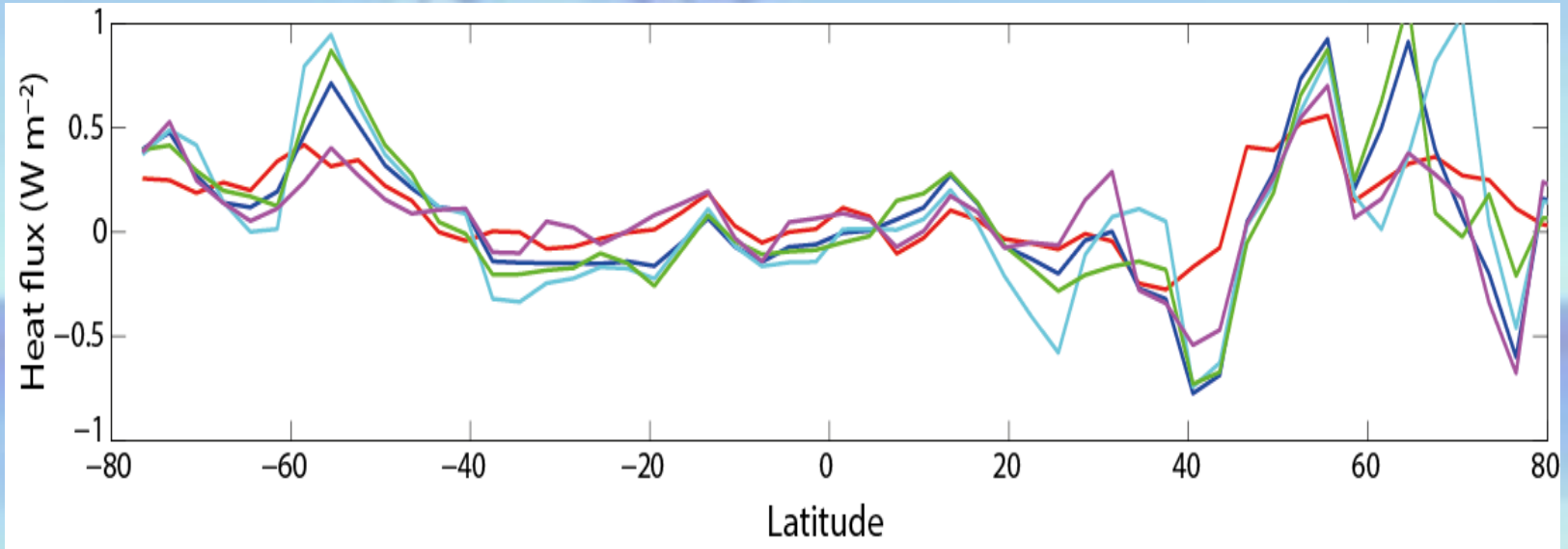
Smoothed time series of simulated temperatures and Pages2k reconstructions for two continent-scale regions



Goosse 2016

Influence of ocean dynamics

Atmosphere-ocean heat flux anomaly (in W m^{-2}) averaged over the period 850-1050



Simulations without data assimilation (ensemble mean)

Simulations with data assimilation

Conclusions

- Particle filtering is an interesting tool for coupled data assimilation on long time scales.

- The ocean has potentially played a large role in the increase in sea ice extent over the last decades.

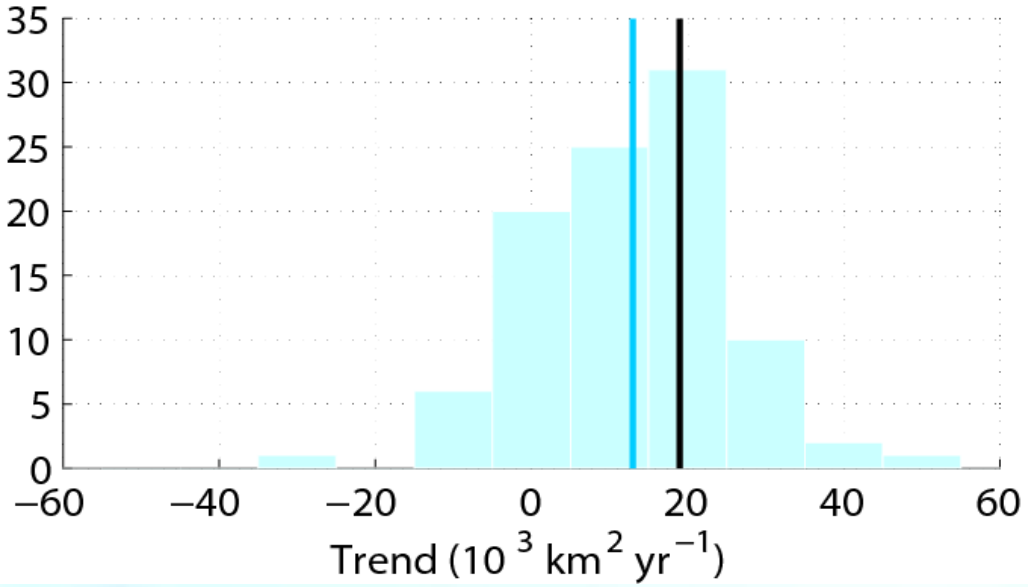
- A strong incompatibility exists between simulated warming in Antarctica over the 20th century and reconstructions.

‘Predicting’ trends over the last 30 years

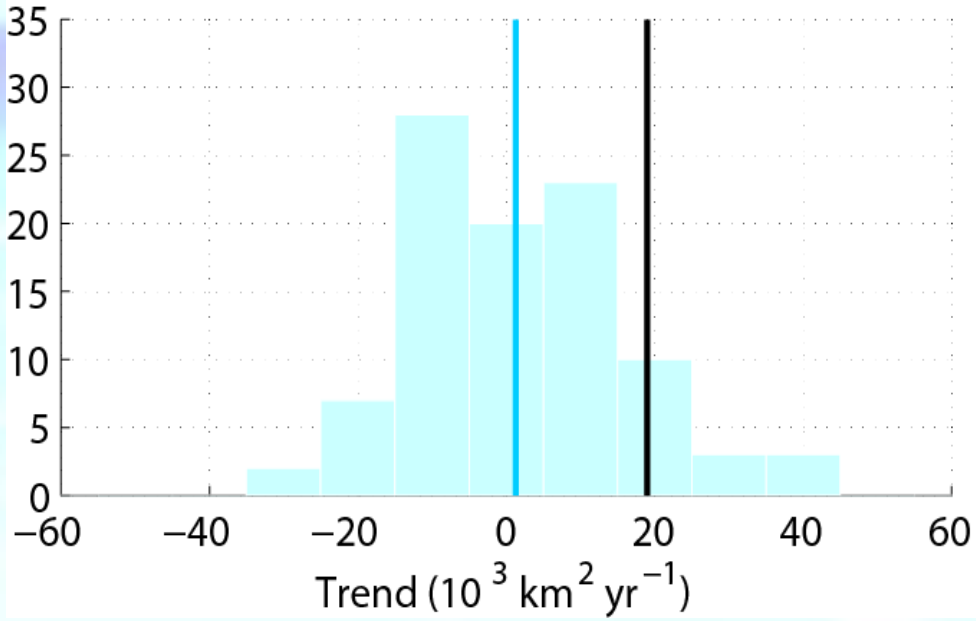
Simulations initialized from an ensemble of 96 simulations with the EMIC LOVECLIM using a nudging Particle Filter

1980–2009 trend in annual mean sea ice extent

with additional freshwater flux during the hindcast



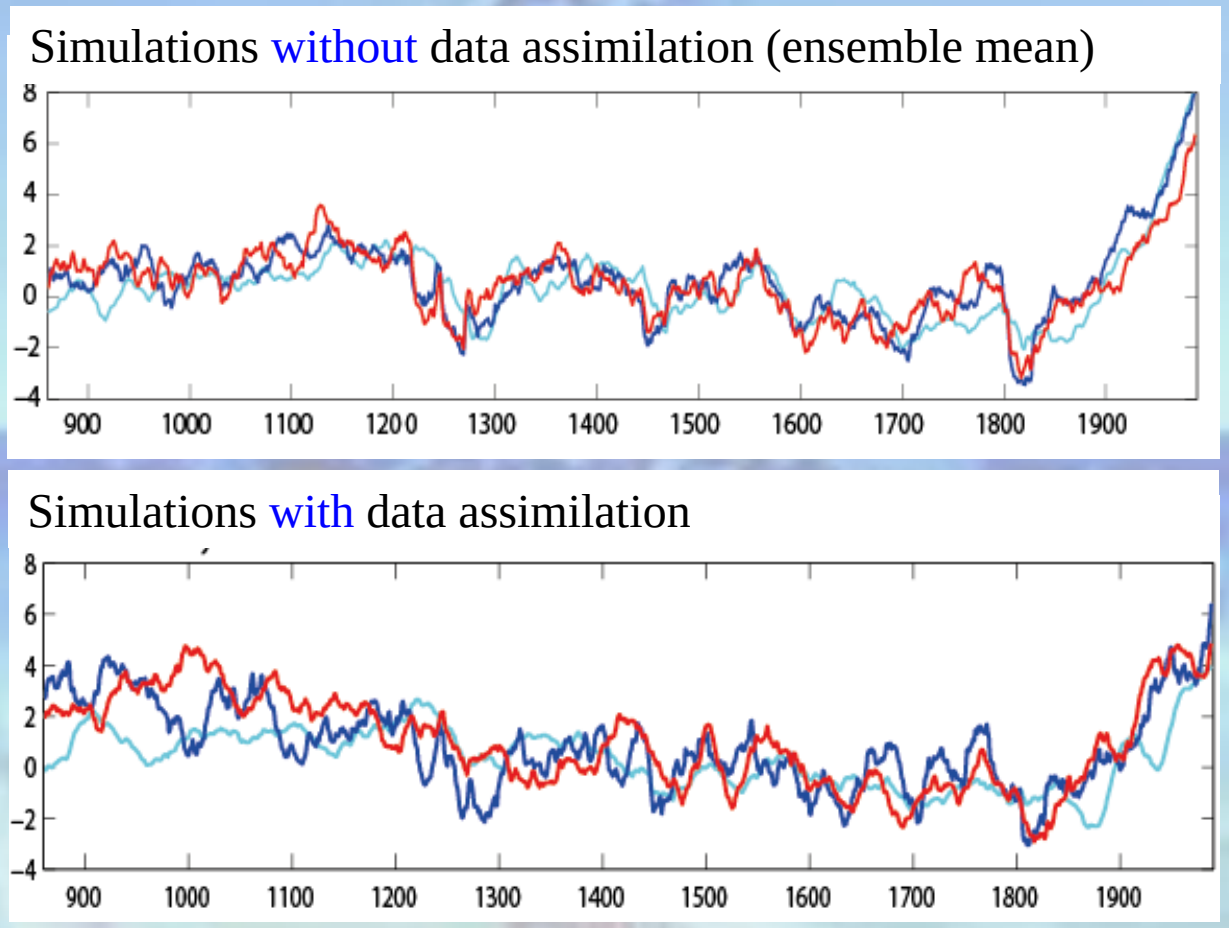
without additional freshwater flux during the hindcast (STD)



Zunz and Goosse 2015

Link between regions

Comparison of temperature changes in various latitude bands



Annual mean sea ice concentration

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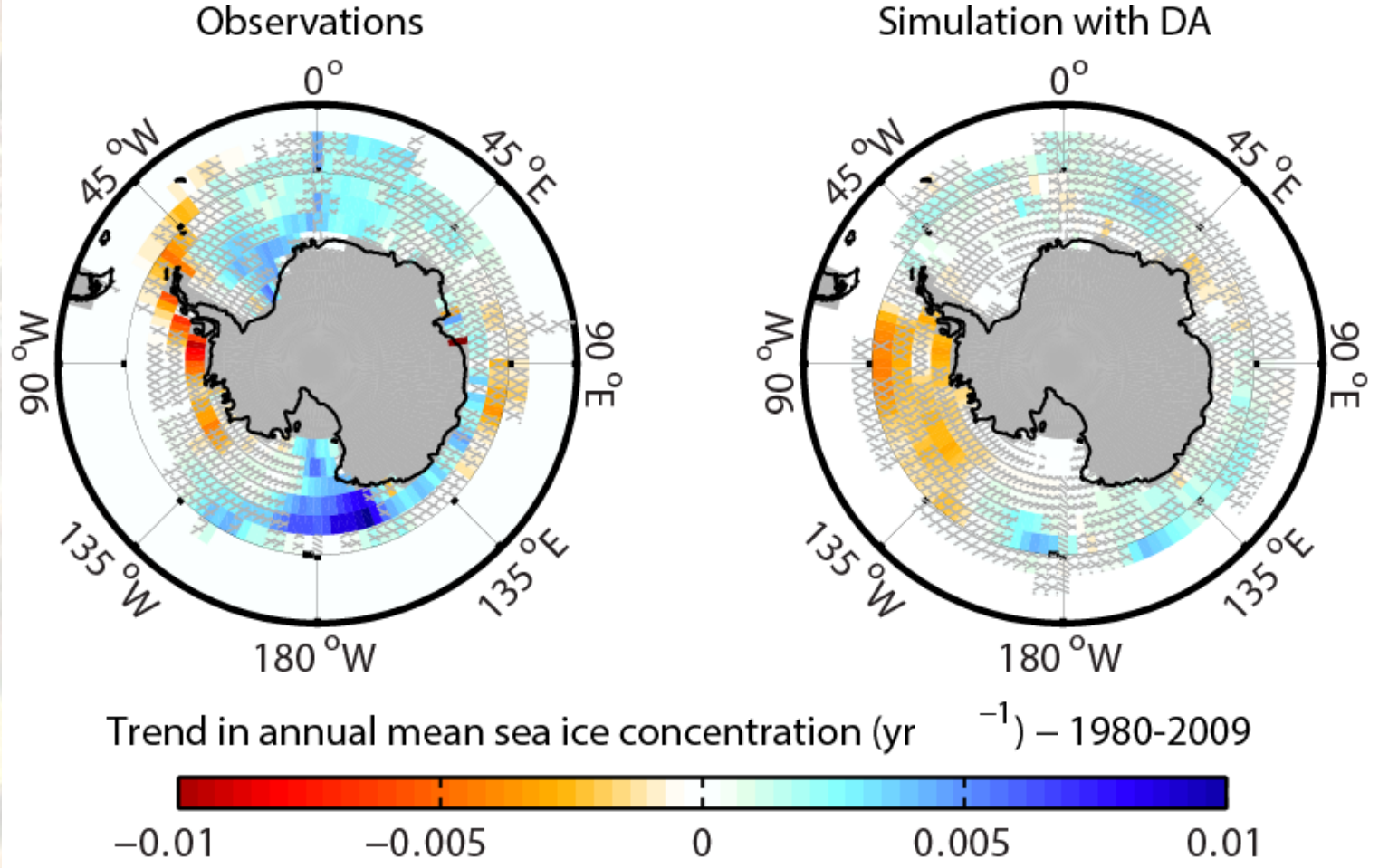
Trends of sea ice concentration over the period 1979-2009

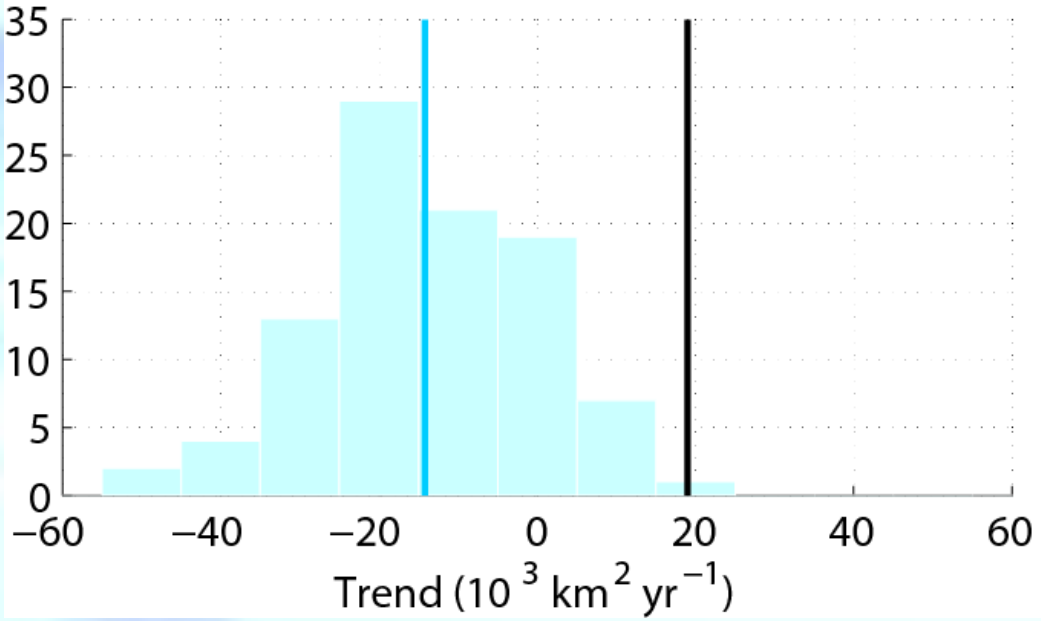


Predicting trends over the last 30 years

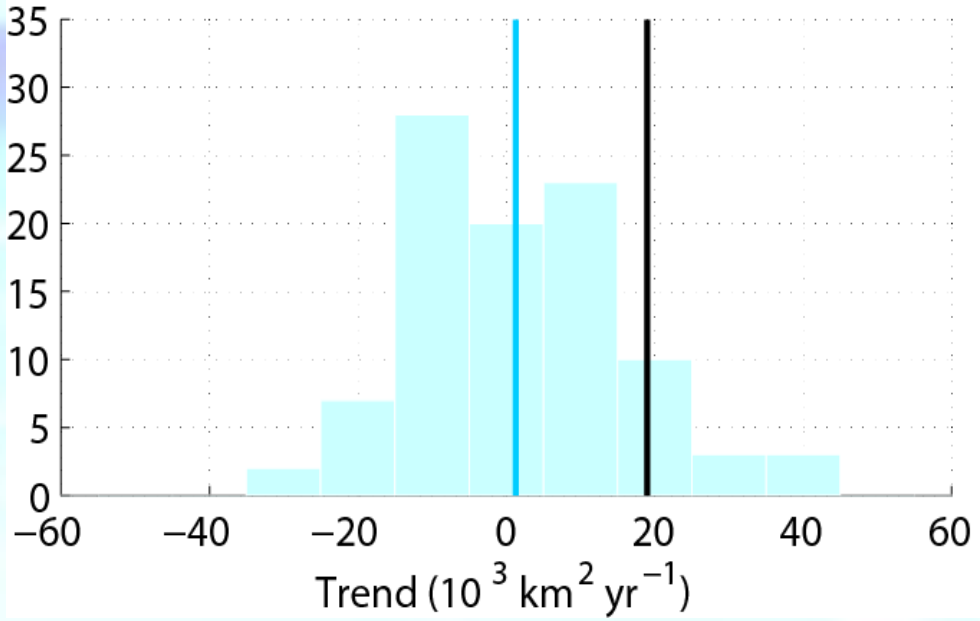
Simulations initialized from an ensemble of 96 simulations with LOVECLIM using a nudging Particle Filter

1980–2009 trend in annual mean sea ice extent in hindcasts initialized from a simulation with data assimilation

without perturbation of the freshwater flux before 1980



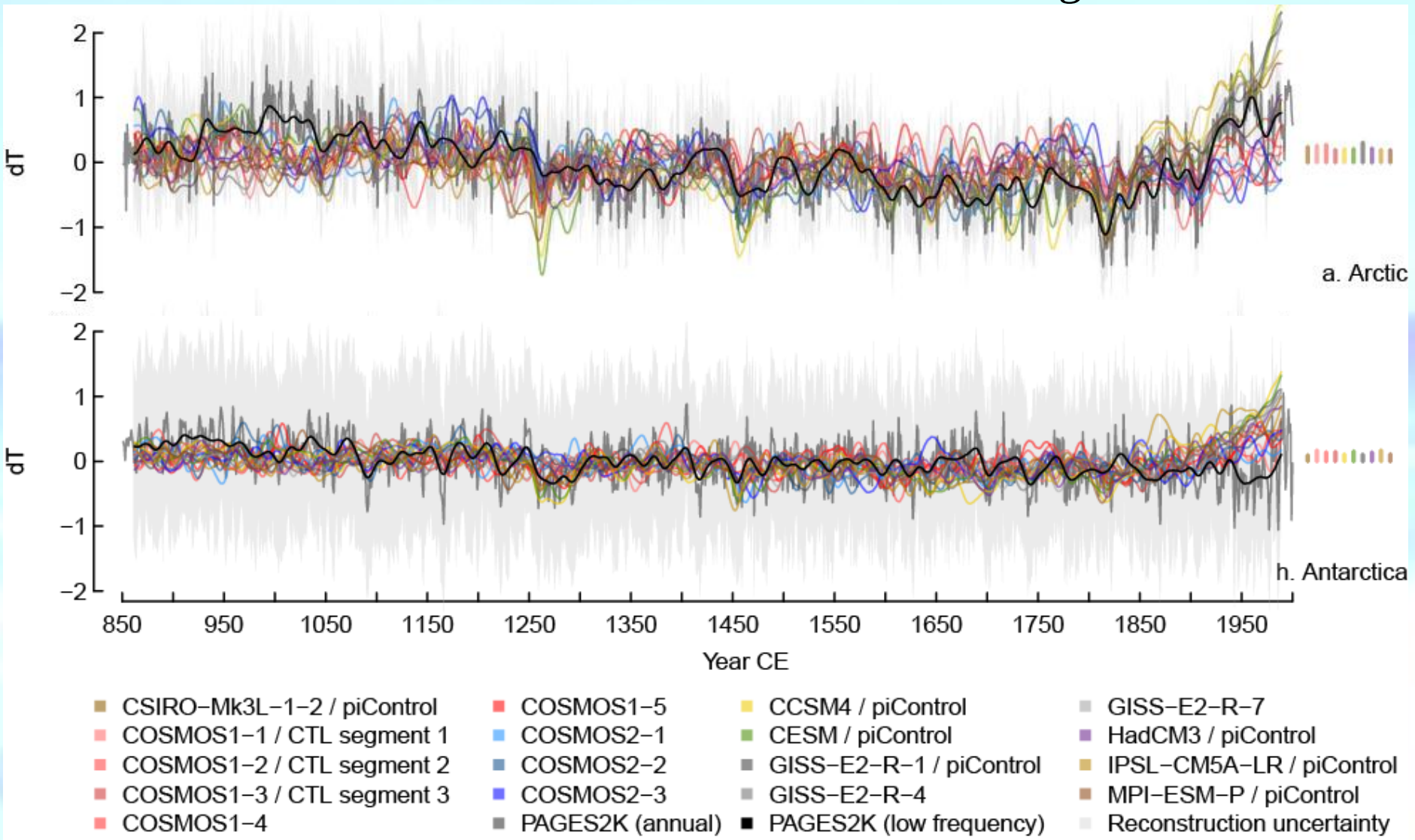
with a perturbation of the freshwater flux before 1980 (STD)



Zunz and Goosse 2015

Model-data comparison at the regional scale

Smoothed time series of simulated temperatures and Pages2k reconstructions for two continent-scale regions



Role of atmospheric dynamics

Spatial distribution of the geopotential height anomaly at 800 hPa (in m^2s^{-2}) in a simulation with data assimilation