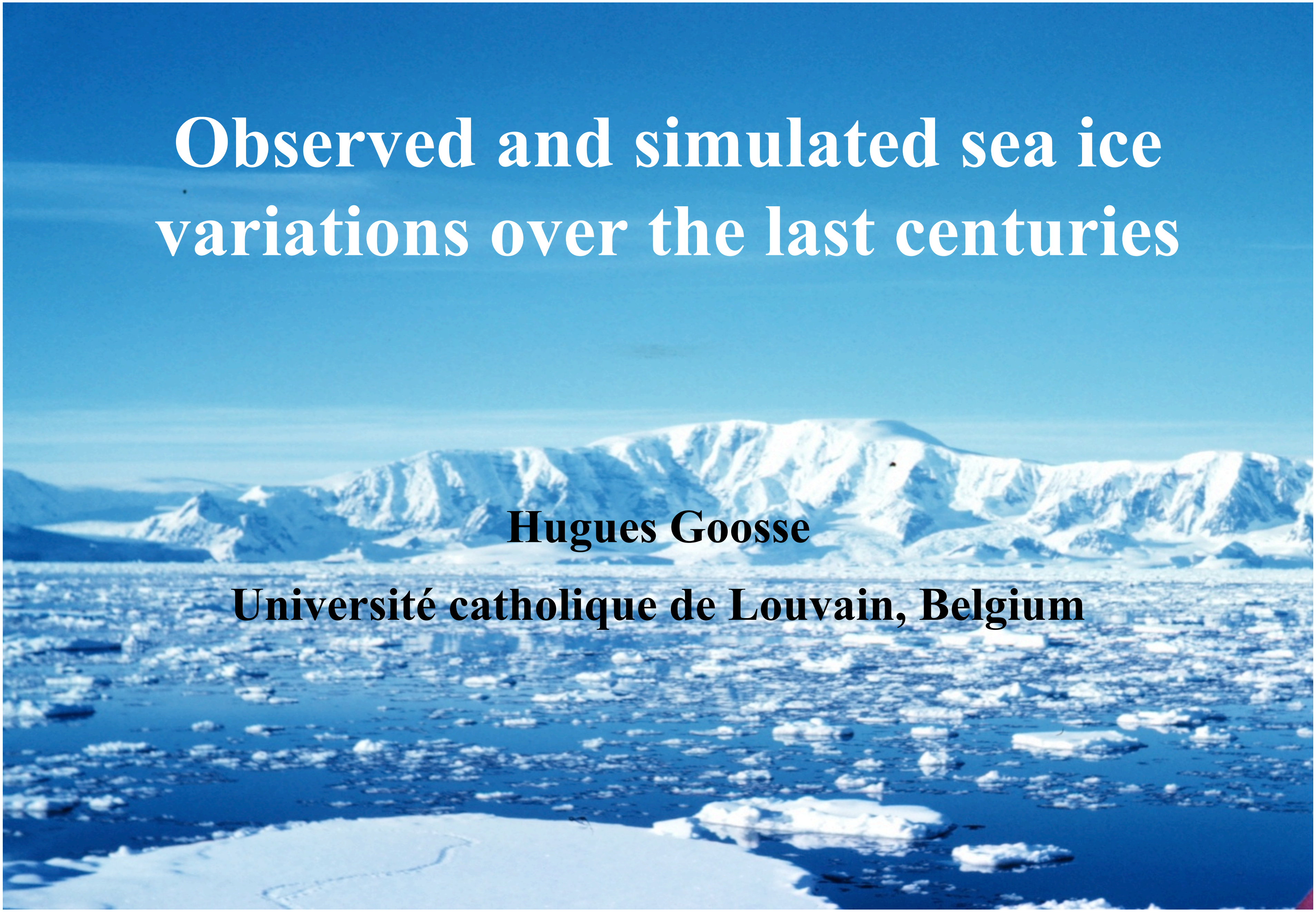

Observed and simulated sea ice variations over the last centuries

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Putting the recent changes in a longer term perspective

Goal: long term series are required to estimate precisely the patterns of (multi-)decadal variability and to improve our knowledge of the mechanisms responsible for this variability.

Data sources:

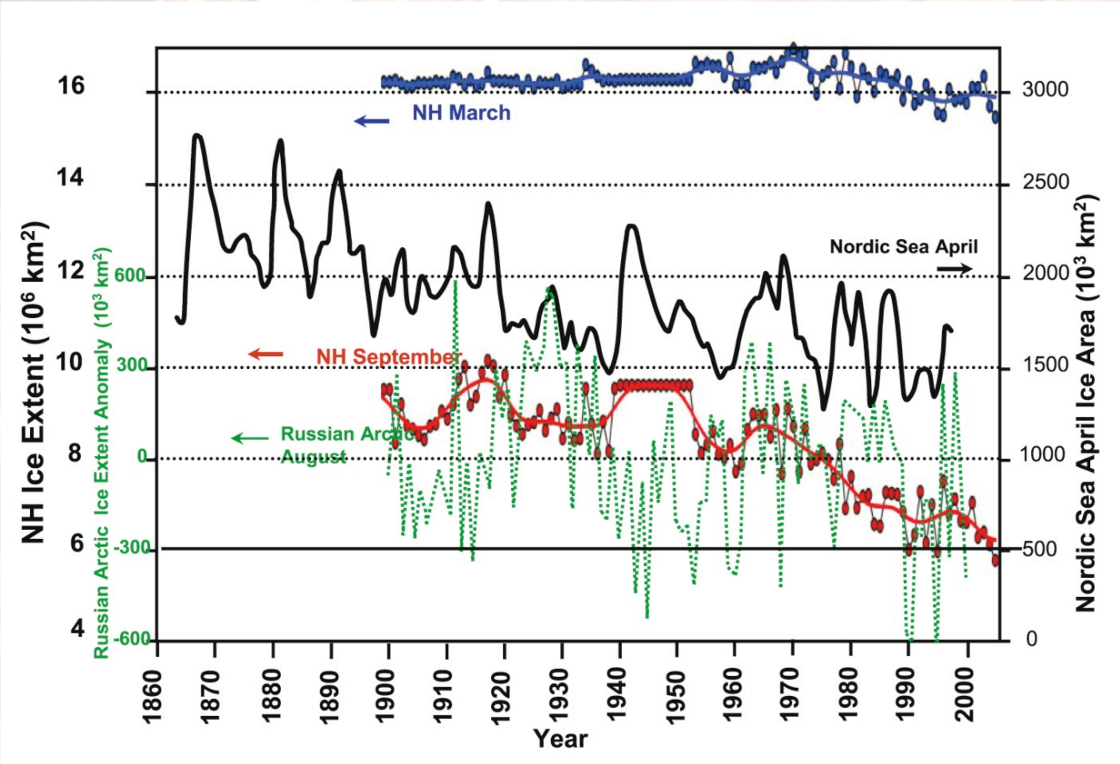
•Satellite records: since the 1970’s

•Historical records (ice charts, ship logs, historical sources): a few decades to a several centuries

•Proxies (marine sediment records, coastal records, driftwood, ice cores, ...): all time scales with different precision and time resolution

Historcial reconstructiuons in the Arctic

Time series of NH sea ice extent for March and September

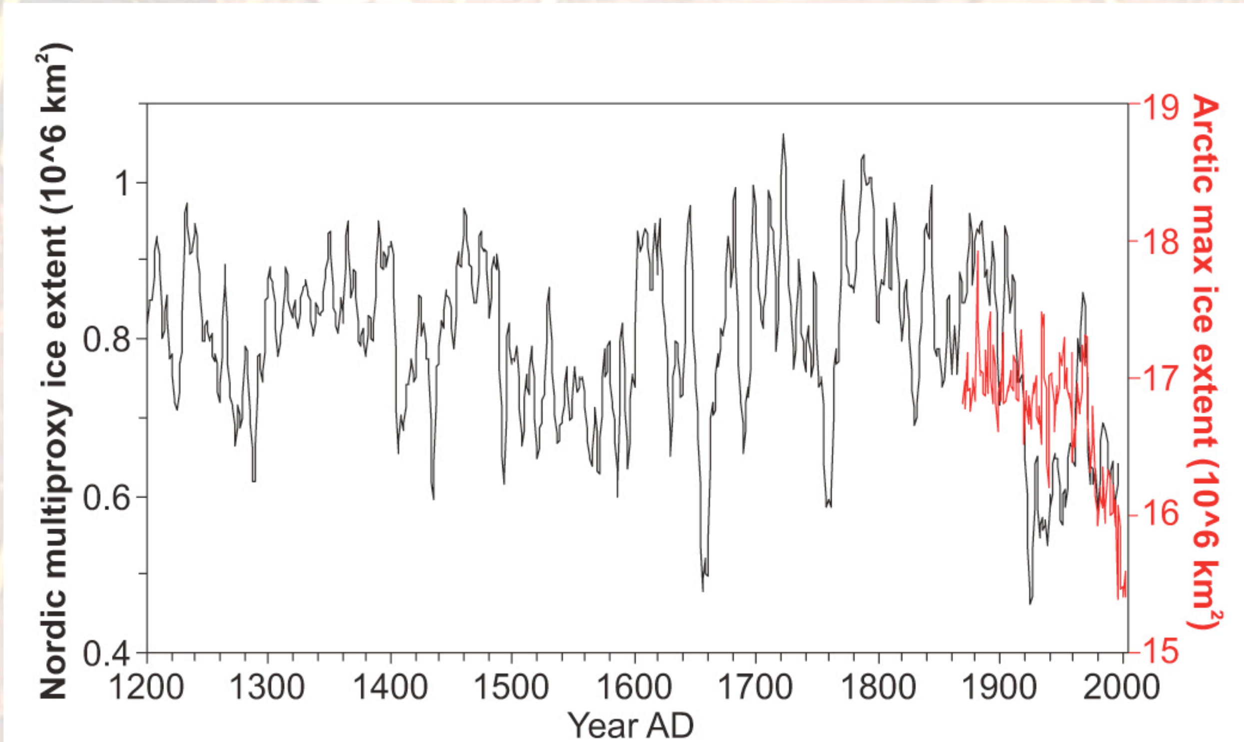


Data sources: the Hadley Centre Sea Ice and Sea Surface Temperature (HadISST) data set (the blue and red curves, updated from Rayner et al., 2003), the April Nordic Sea ice extent (the black curve, redrafted from Vinje, 2001) and the August ice extent anomaly in the Russian Arctic seas – Kara, Laptev, East Siberian and Chukchi (dotted green curve, redrafted from Polyakov et al., 2003). For the NH time series, the symbols indicate yearly values while thecurves show the decadal variation.

Lemke et al. 2007

Proxy records in the Arctic

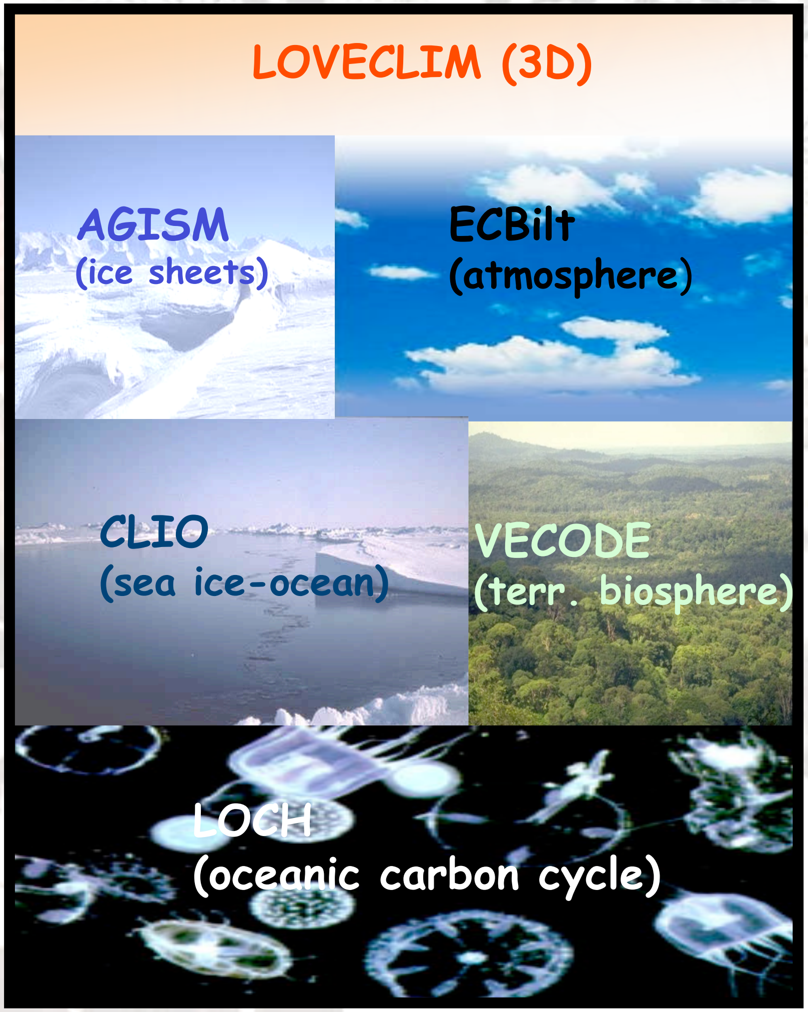
Reconstruction of the maximum sea-ice in the Nordic Seas



Comparison of a multi-proxy reconstruction of maximum sea-ice extent in the Nordic Seas during1200–1997 AD (black curve; Macias-Fauria et al.,2010) and maximum Arctic-wide ice extent during1870–2003 (red curve; Kinnard et al.,2008).

Polyak et al. 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).

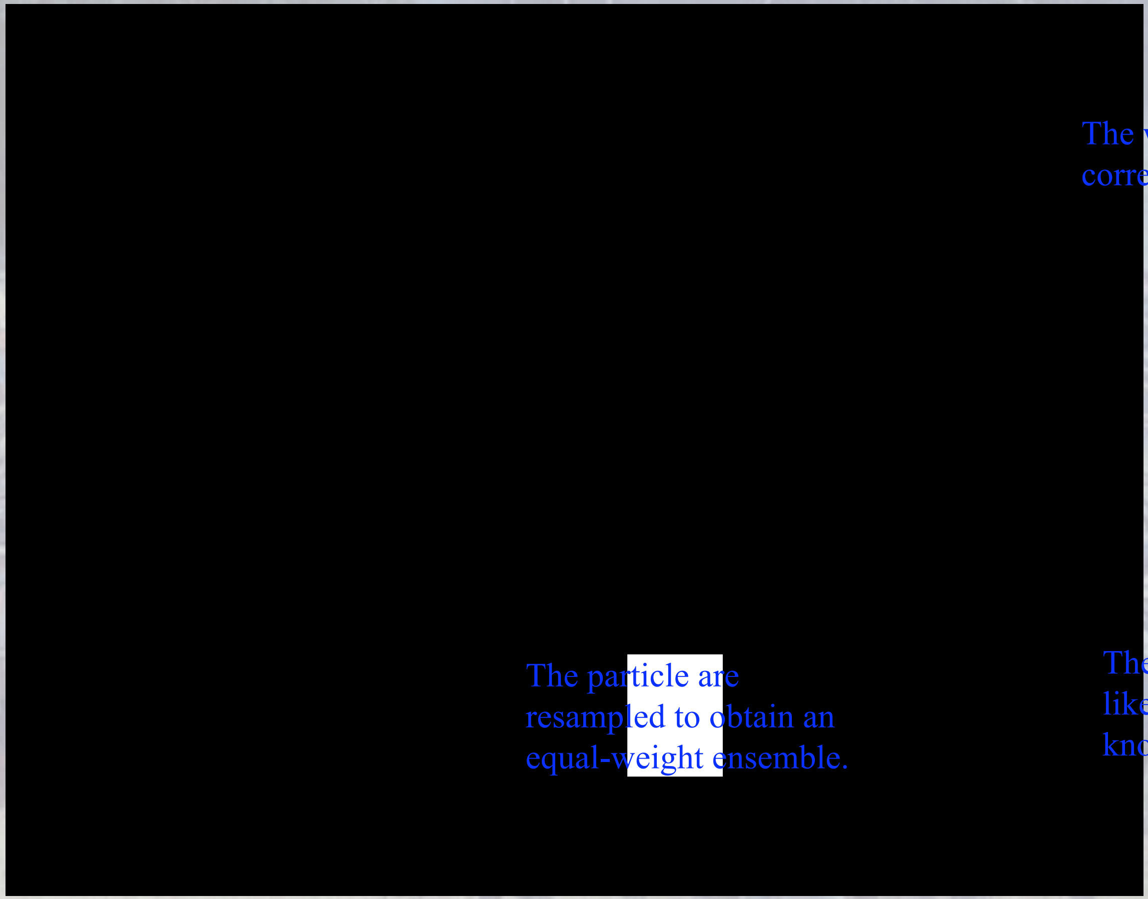
VECODE (Brovkin et al., 2002)
Reduced-form model of the vegetation dynamics and of the terrestrial carbon cycle (same resolution as ECBilt).

LOCH (Mouchet and François, 1996)
Comprehensive oceanic carbon cycle model (same resolution as CLIO).

AGISM (Huybrechts, 2002)
Thermomechanical model of the ice sheet flow + visco-elastic bedrock model + model of the mass balance at the ice-atmosphere and ice-ocean interfaces (10 km x 10 km, L31).

Particle filter with resampling

Model states



The weight of each particle corresponds to the size of the bullets.

The weight is proportional to the likelihood of the model state, knowing the observations.

Time

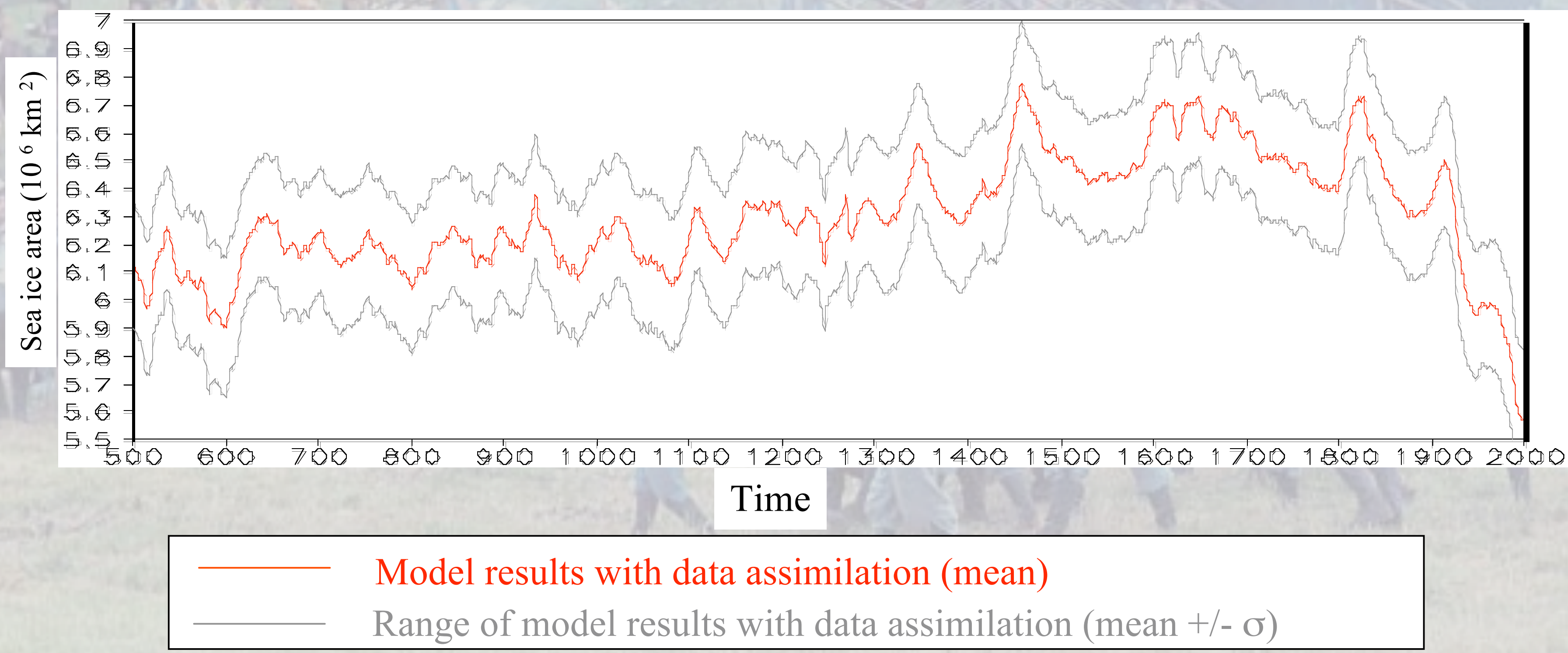
The observations are available at a time interval of 10 time units.

Adapted from van Leeuwen 2010

Simulation over the last 1500 years

The simulation is constrained by proxy records of past temperature changes

Sea ice area in summer

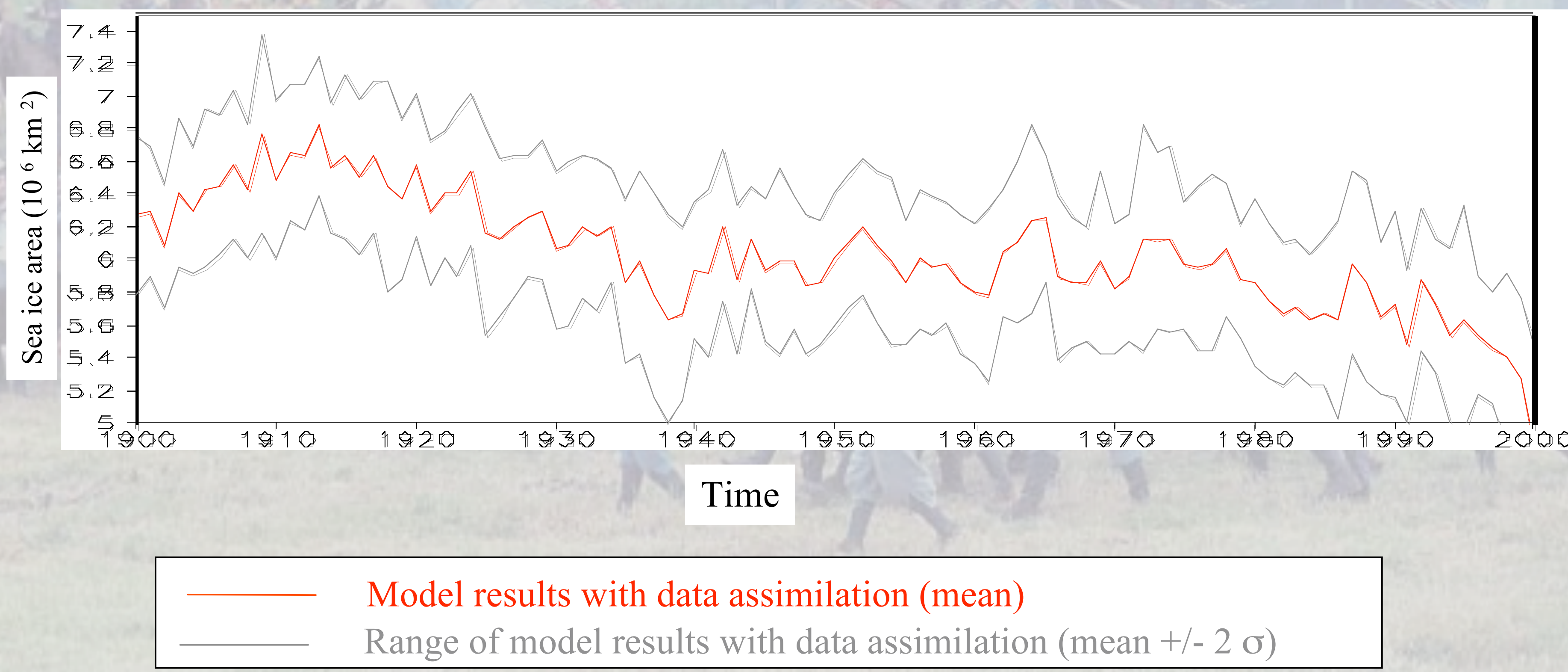


Time series are smoothed with a 21 yr running mean

Simulation over the last 1500 years

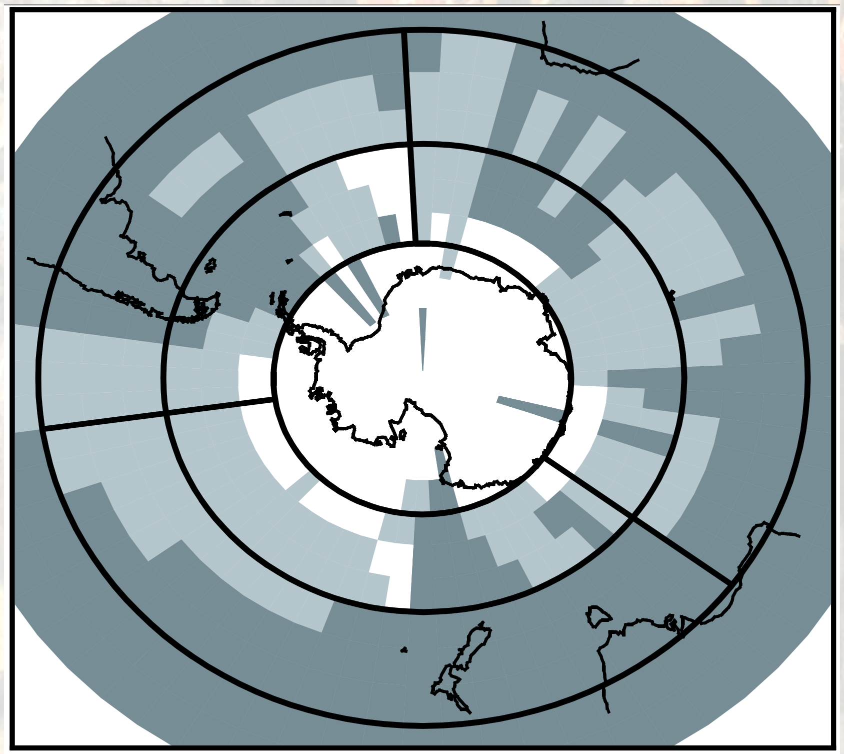
The simulation is constrained by proxy records of past temperature changes

Sea ice area in summer



Simulation over the last 150 years constrained by HadCRUT3 dataset

The region southward of 30°S has been divided in 7 boxes. 96 simulations are performed in the ensemble

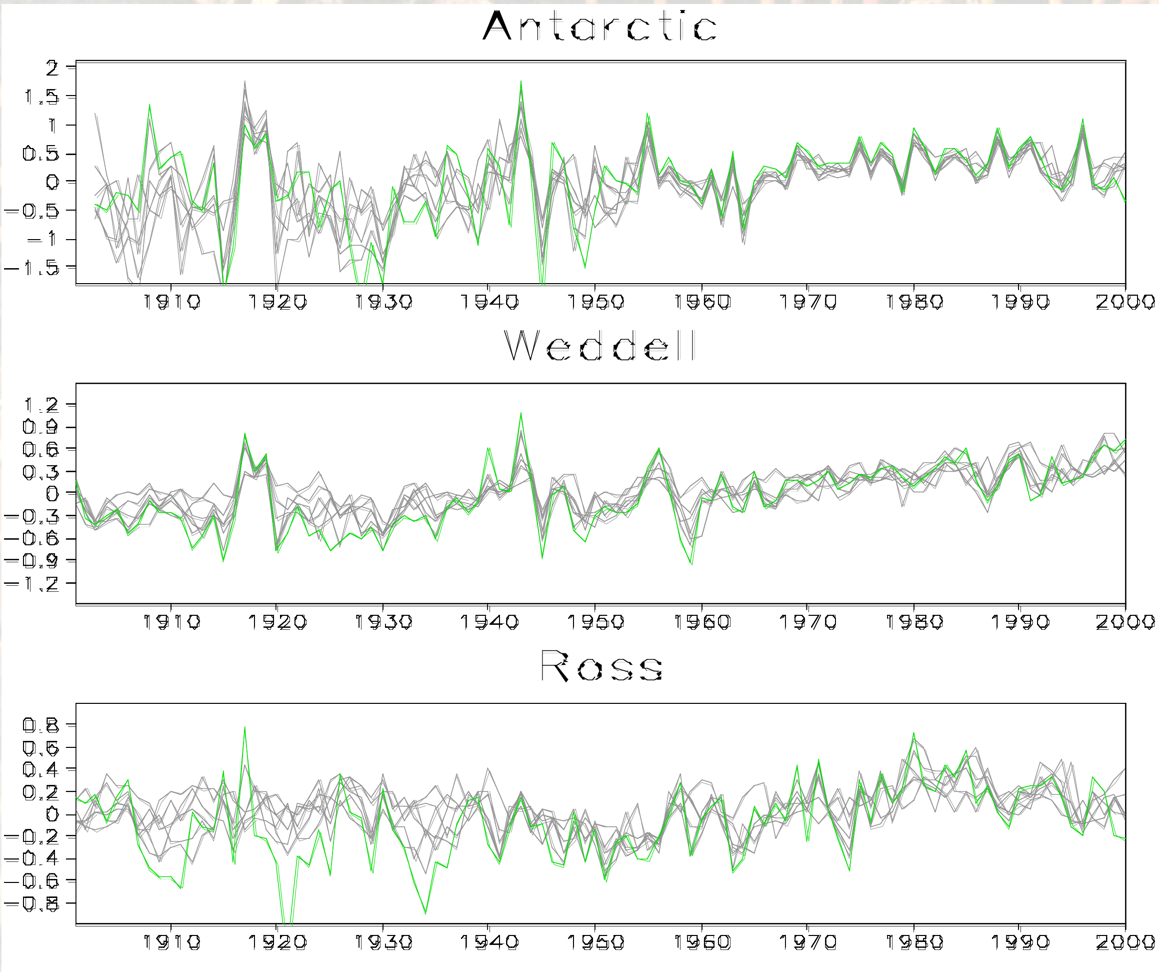


The boundaries of the seven boxes used to compute the cost function CF. The dark grey area represents the model grid boxes for which observations are available since 1960 while the light grey area represents the model grid boxes for which observations are available since 1980. No data is available in the white grid boxes.

Goosse et al., 2009

Anomaly of near surface temperature

Surface temperature in 3 boxes at high latitude



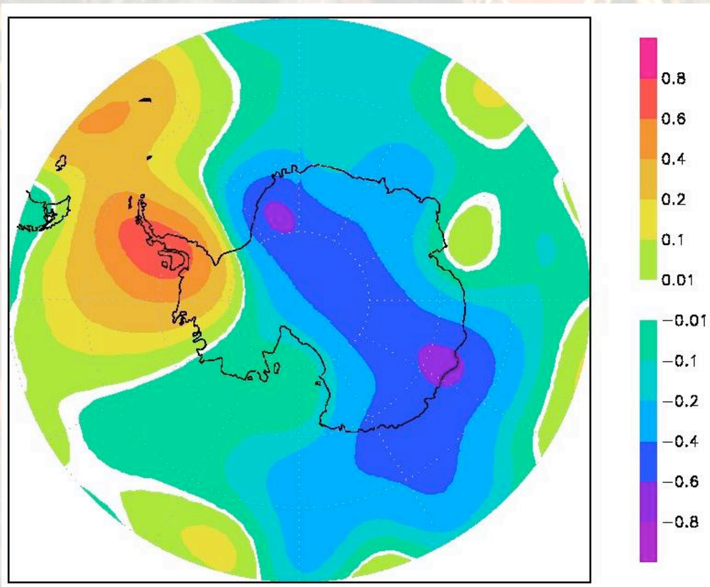
The green line is the HADCRUT3 dataset (Brohan et al., 2006) and the grey lines are the results of the 6 model simulations. The "Antarctic" box corresponds to an average over all the longitudes southward of 67°S. For the three other boxes, the average has been performed over the latitude 50-67°S and longitudes 135°E-85°W ("Ross") and 85°W-0°E ("Weddell")

Goosse et al., 2009

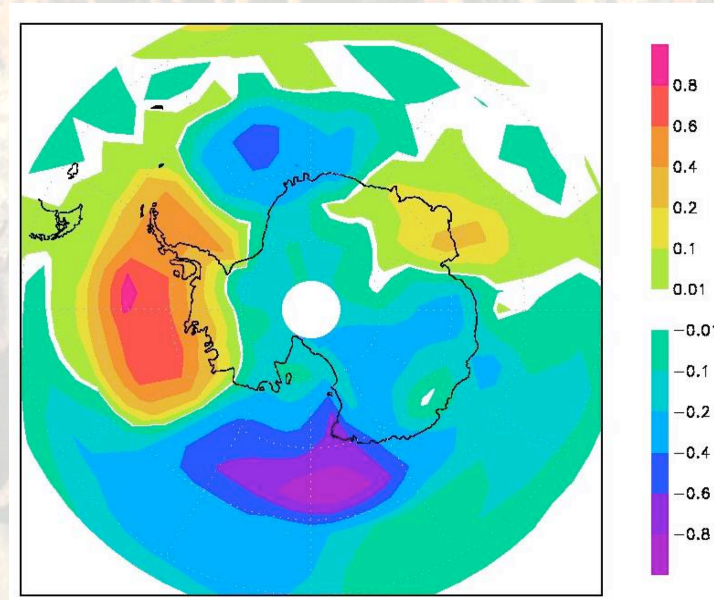
Anomaly of near surface temperature

The trend of annual mean near surface temperature over the period 1980-2000.

Observations



Model

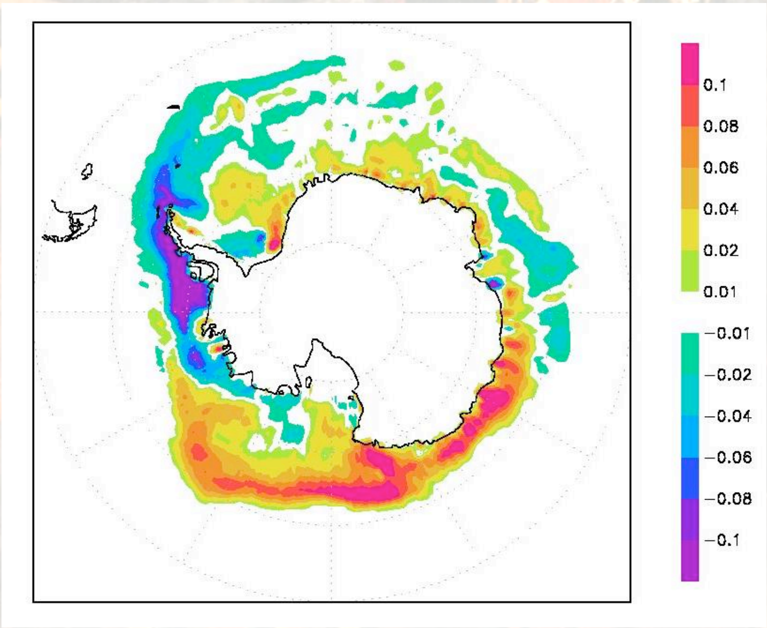


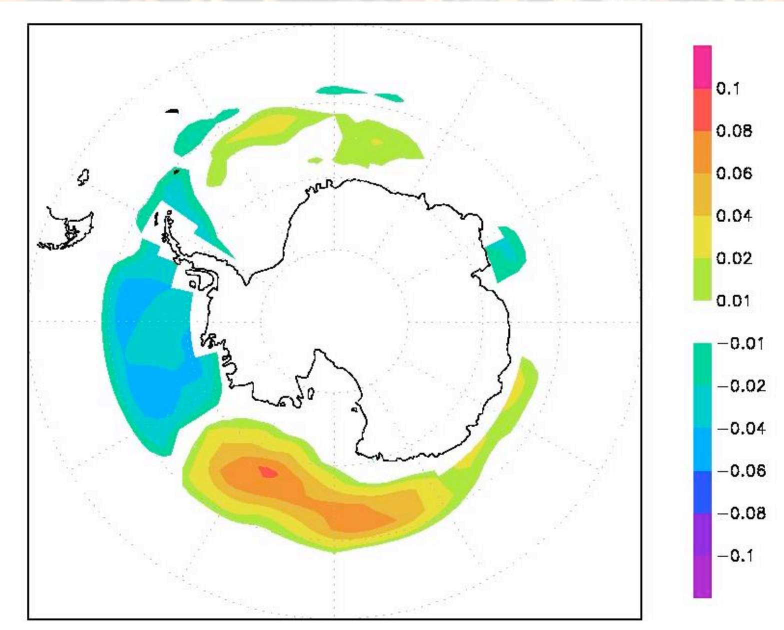
The trend of annual mean near surface temperature over the period 1980-2000 for the observation (Chapman and Walsh, 2007) and for the model results averaged over the 6 simulations with data assimilation (units are K per decade).

Goosse et al., 2009

Annual mean sea ice concentration

The trend of annual mean near sea ice concentration over the period 1980-2000.



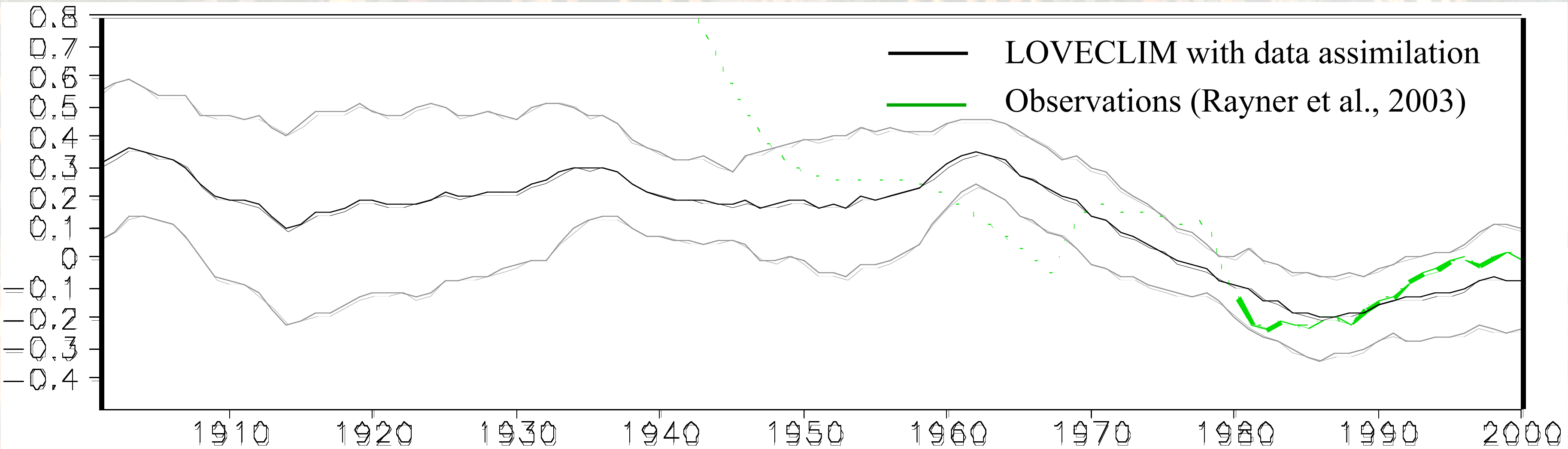


The trend of annual mean sea-ice concentration over the period 1980-2000 for the observation (Rayner et al. 2003) and for the model results averaged over the 6 simulations with data assimilation (units are per decade).

Goosse et al., 2009

Annual mean sea ice area

Anomaly of annual mean sea-ice area (in 10^6 km^2) in the Southern Ocean

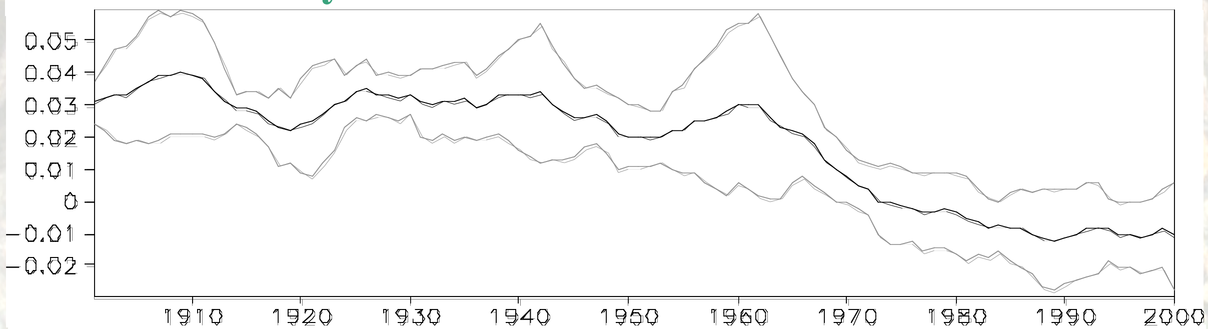


The green curve is the estimate based on the HADISST data set (Rayner et al. 2003). The black line is the averaged over the 6 model simulations while the grey lines are the mean plus and minus one standard deviation of the ensemble. A 11-year running mean has been applied to the time series. The reference period is 1960-2000.

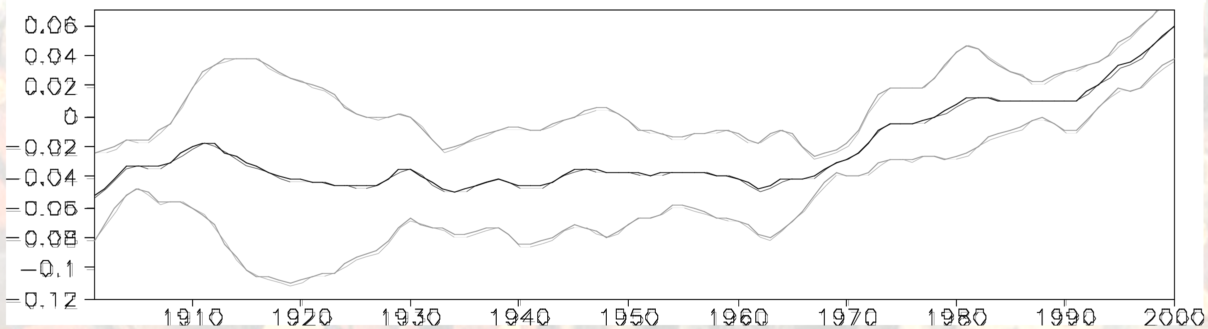
Goosse et al., 2009

Salinity and temperature in the Ross Sea

Surface salinity on the continental shelf



Surface temperature at 300 m out of the shelf

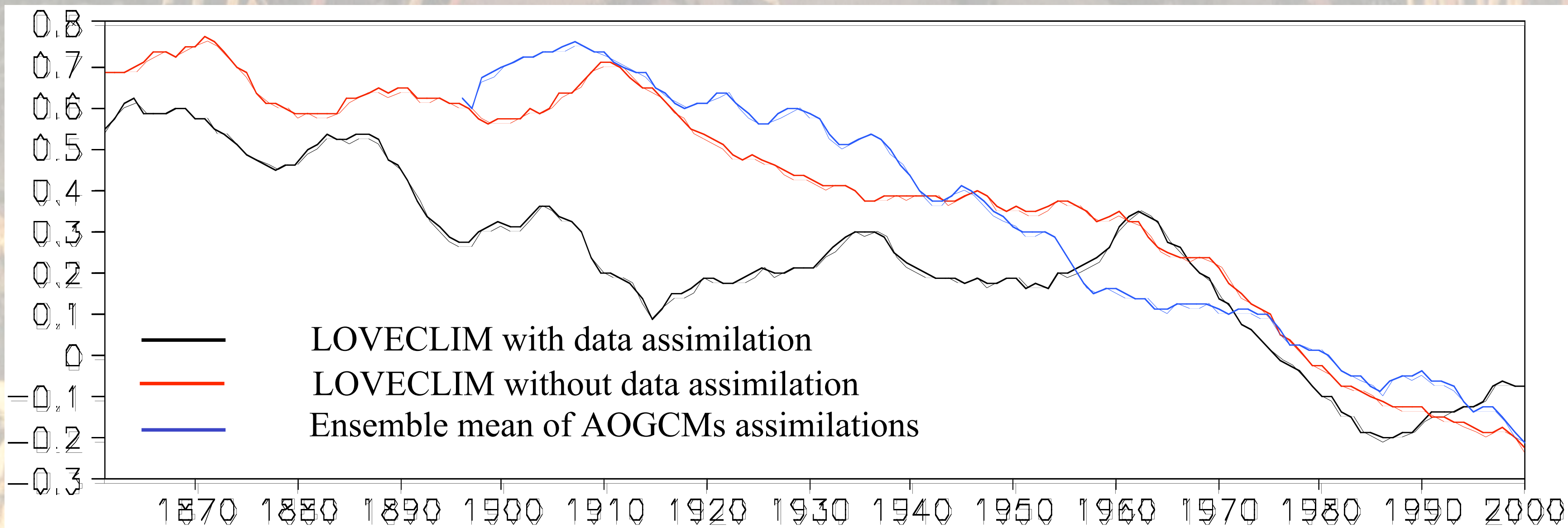


Surface salinity anomaly in psu averaged over the continental shelf of the Ross Sea (170-200°E, 73.5-79.5°S) and (b) Ocean temperature anomaly in °C at a depth of 300m averaged over the region north of the continental shelf of the Ross Sea (170-200°E, 67.5-73.5 S). The black line is the averaged over the 6 model simulations while the grey lines are the mean plus and minus one standard deviation of the ensemble. A 11-year running mean has been applied to the time series. The reference period is 1960-2000.

Goosse et al., 2009

Annual mean sea ice area

Anomaly of annual mean sea-ice area (in 10^6 km^2) in the Southern Ocean

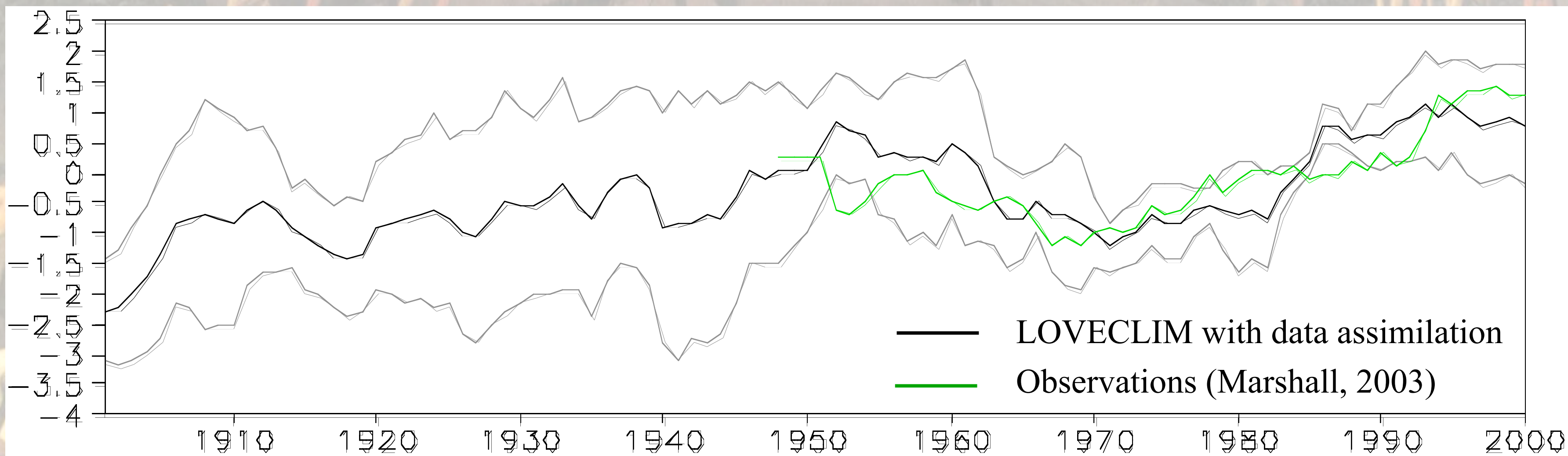


The black line is the averaged over the 6 model simulations. The red line is the mean of an ensemble of 20 simulations made with LOVECLIM but without data assimilation. The blue line is the mean over 16 model simulations included in the 4th IPCC report.

Goosse et al., 2009

Annual SAM index

Annual mean Southern Annular mode index over the 20th century.



The green curve is the estimate of Marshall (2003), based on station data. The black line is the averaged over the 6 model simulations while the grey lines are the mean plus and minus one standard deviation of the ensemble. A 11-year running mean has been applied to the time series. Because of the different definition of the SAM index, the model results have been scaled to have the same mean and variance as the observed index over the period 1960-2000.

Goosse et al., 2009

Conclusions

♦ The sea ice in both hemispheres displayed **large decadal to multi-decadal variability** in the pre-satellite era. The **last 30 years** are not necessarily **a representative sample** of the variability of the system.

♦ **Describing and understanding those changes** is essential for improving our ability to perform decadal forecasts and to test their skill.

♦This will likely require **adequate techniques** in order to **combine** the information from **models and observations** on all timescales. This is also important for obtaining **initial states** for predictions

♦Use **key past periods** as **benchmarks** for our ability to perform good predictions ?