ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Climate response functions of the joint freshwater budget of the Arctic and North Atlantic oceans to changes in external wind forcing in an otherwise fully coupled earth system model

Tamas Kovacs, Rüdiger Gerdes

HELMHOLTZ ASSOCIATION

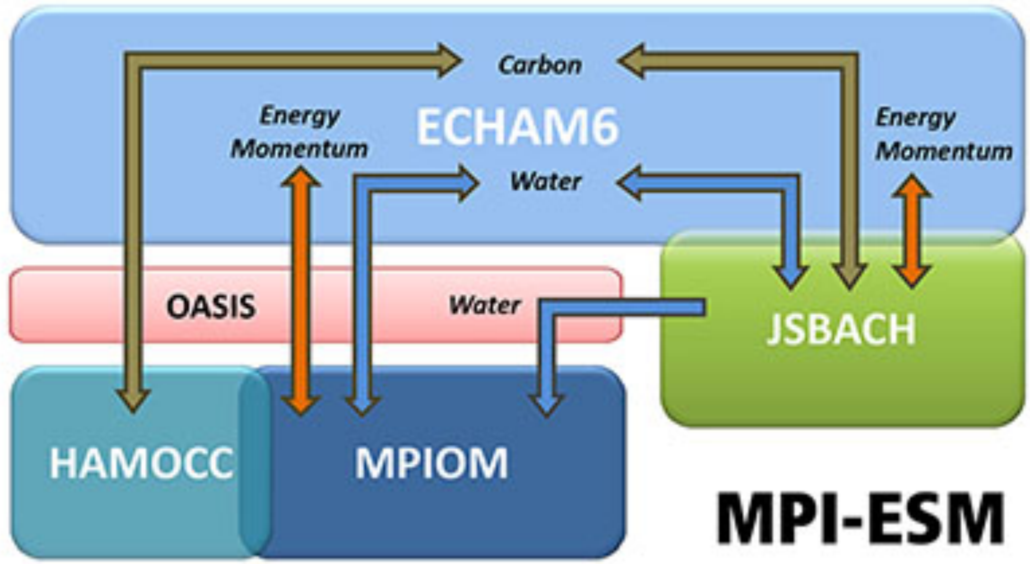
6th FAMOS meeting | 24-27 October 2017

Outline

- Methods - A fully coupled Earth System Model
  - with a partial coupling technique
- Model run setup - CRF experiments with wind forcing anomalies
- Model results - sea ice
  freshwater content

Methods – MPI-ESM

- Max Planck Institute Earth System Model



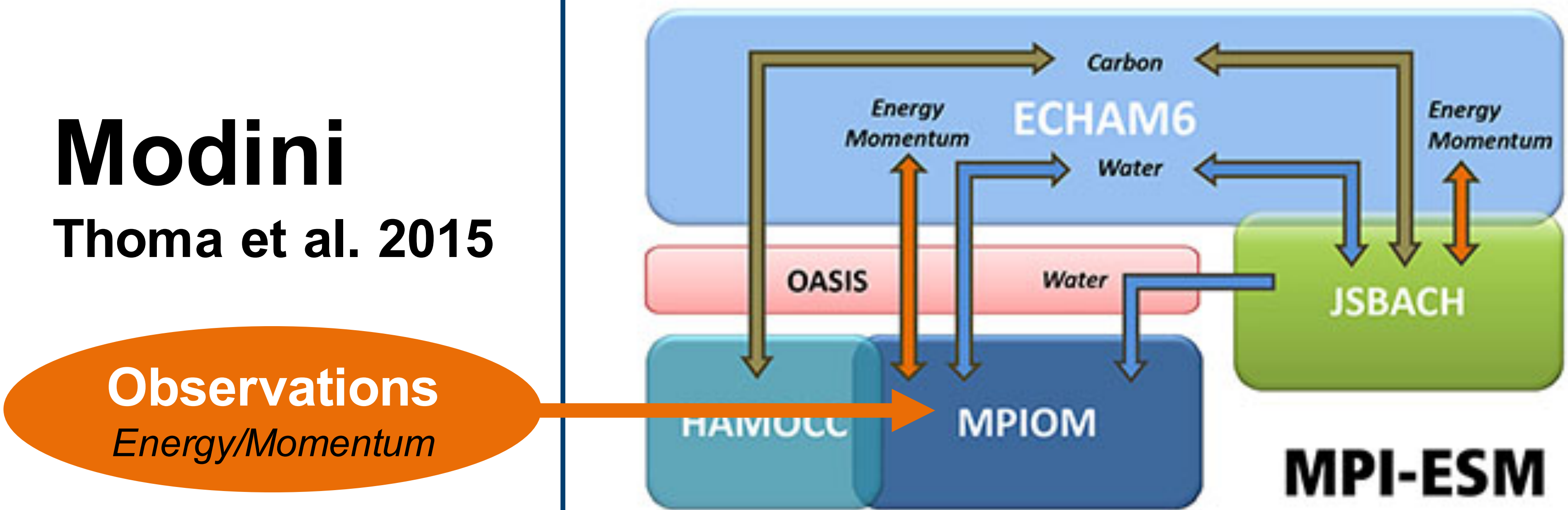
MPI-ESM structure of model components (*Giorgetta et al., 2013*)

- Fully coupled
- Low resolution version – MPIOM ocean component:
  - 1.5° horizontal resolution (15 - 185 km)
  - poles over Antarctica and Greenland
  - non eddy-resolving (*Jungclaus et al. 2013*)

Methods – Modini

Modini

Thoma et al. 2015



MPI-ESM structure of model components (*Giorgetta et al., 2013*)

- Partial coupling technique (*Thoma et al. 2015*)
- MPIOM driven by prescribed wind stress anomalies
- Wind stress forcing from NCEPcfsr (*Saha et al. 2010*)

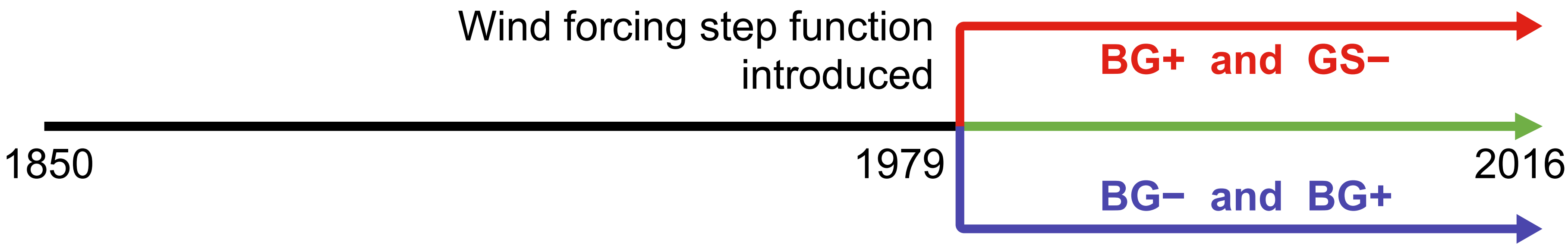
Methods – Experiment setup

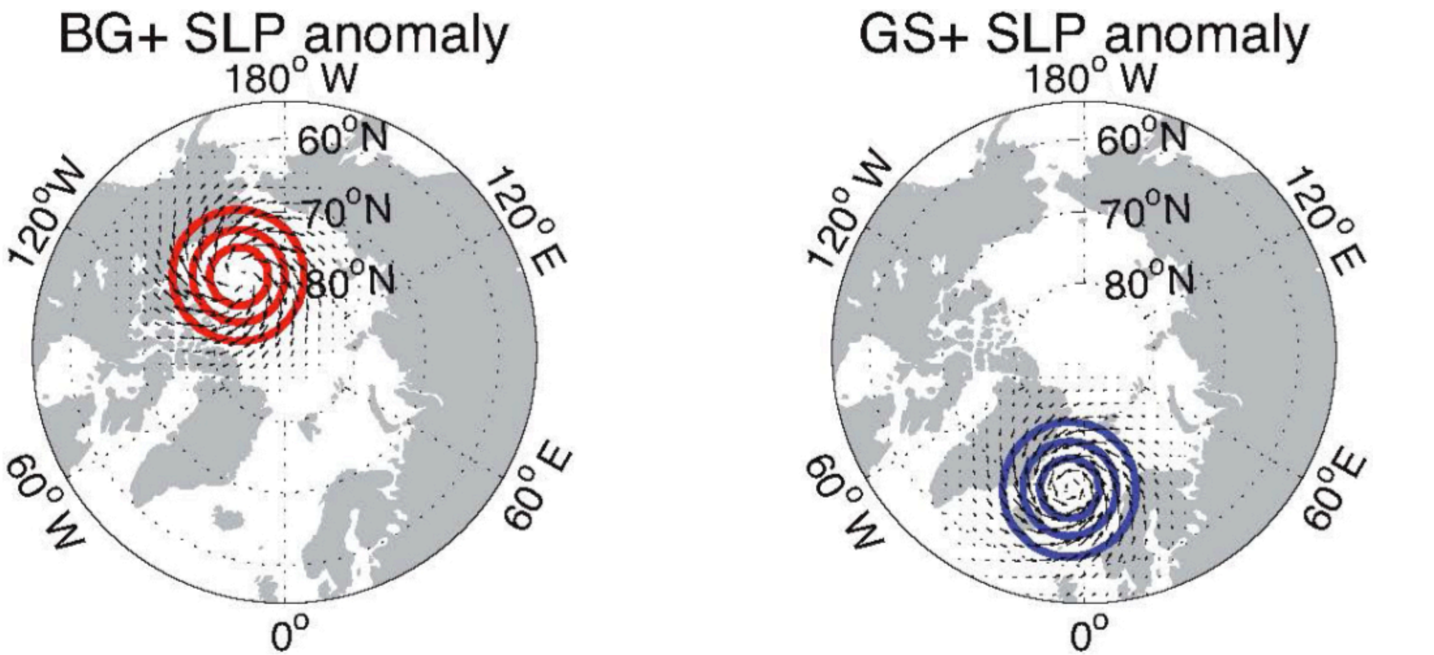
Fully coupled run with wind speed from coupling, then with NCEPcfsr wind anomaly

(with historical CMIP5 scenario) (+ RCP4.5 from 2006)

1850 1979 2016

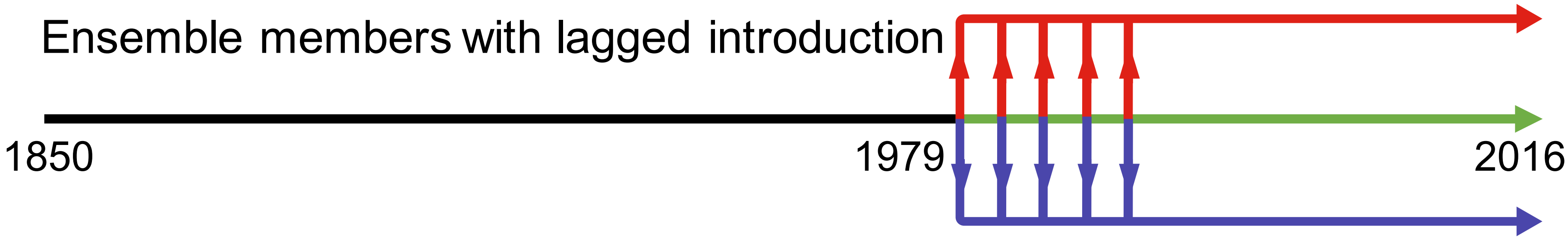
Methods – Experiment setup

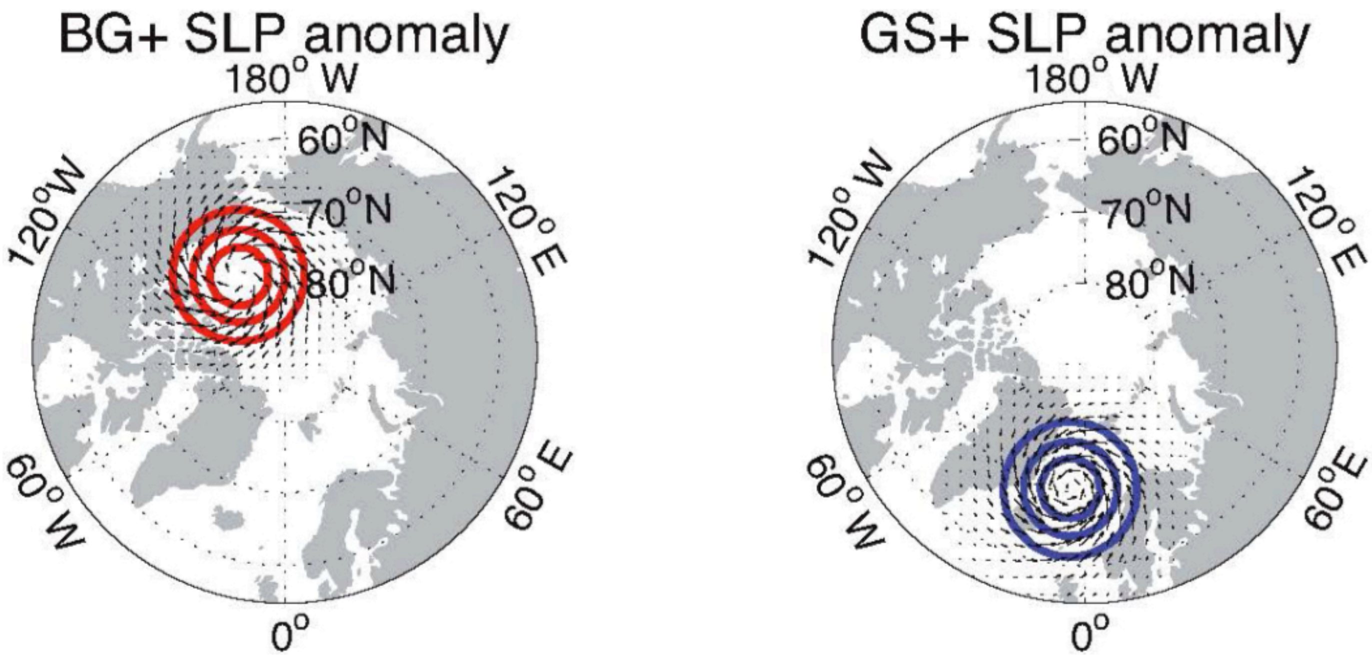




Sea level pressure anomalies and associated wind fields (*Marshall et al. 2017*)

Methods – Experiment setup

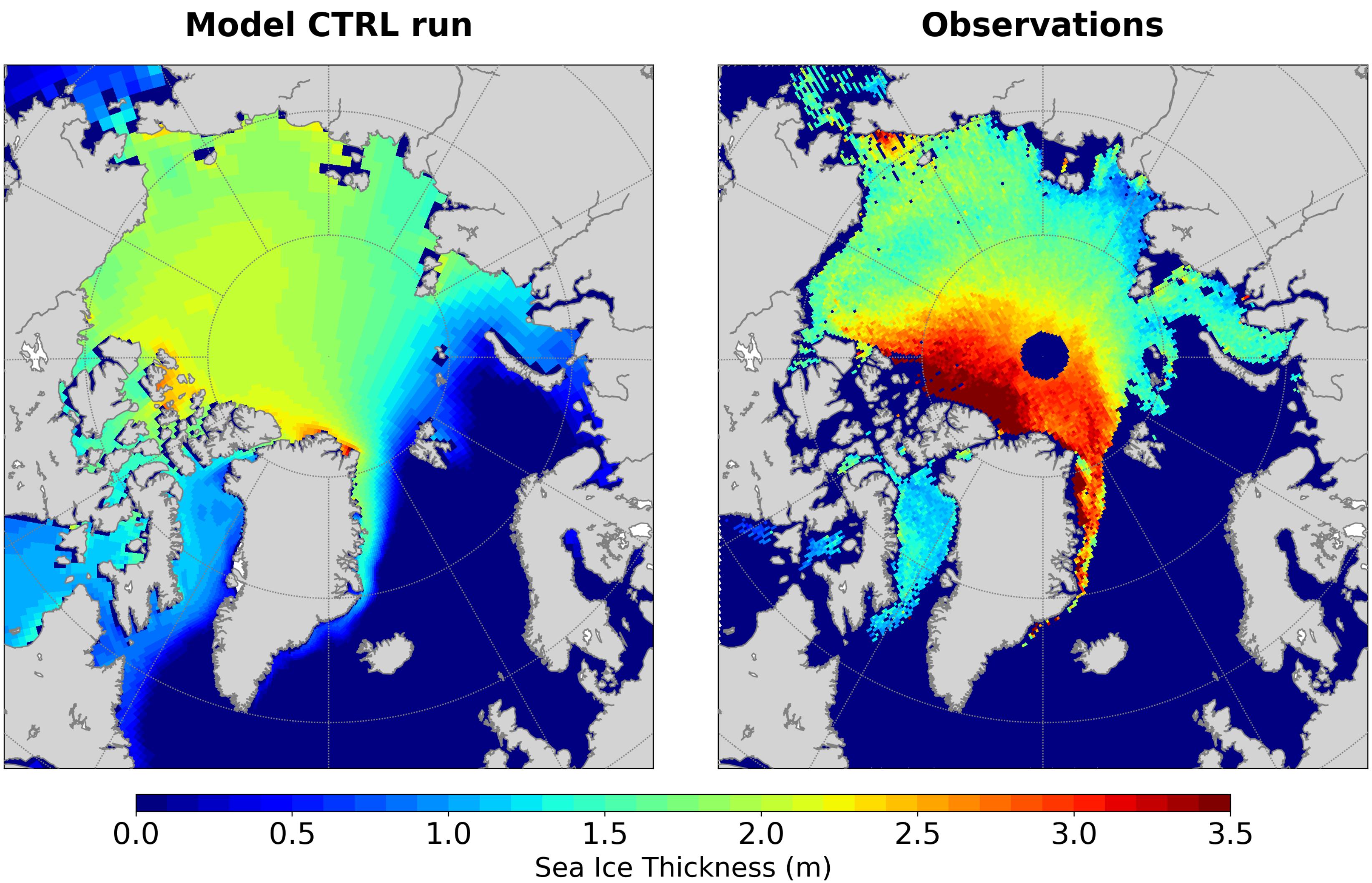




Sea level pressure anomalies and associated wind fields (*Marshall et al. 2017*)

Results – Arctic Sea Ice

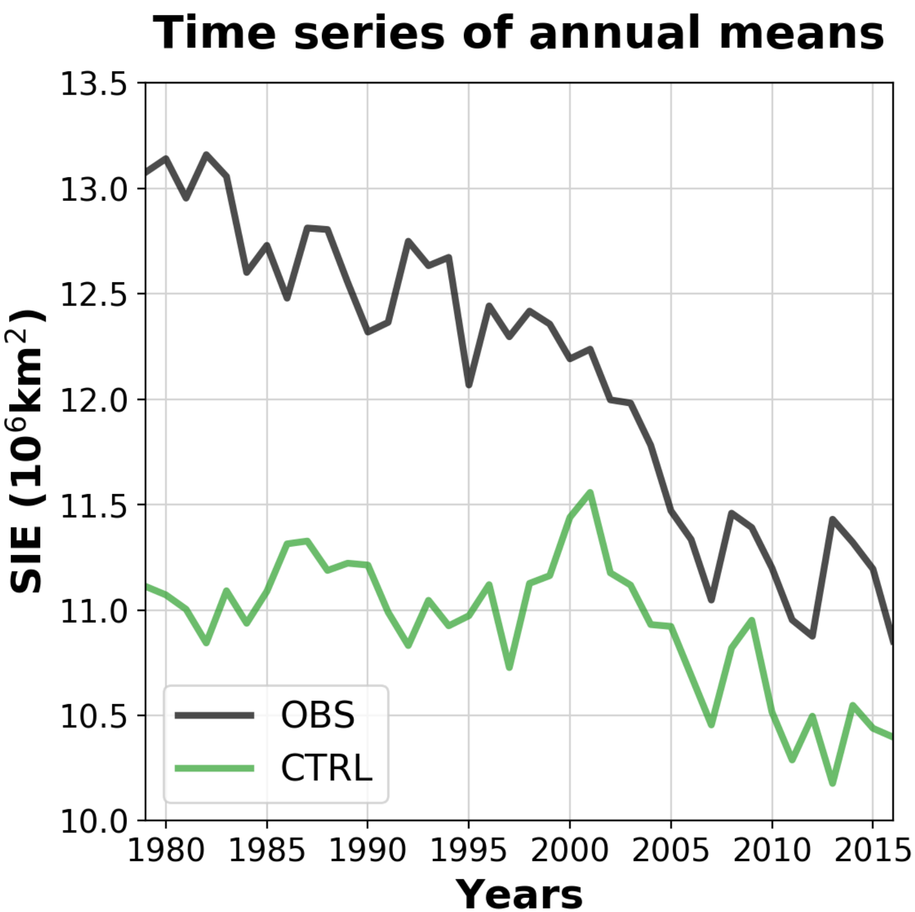
Sea Ice Thickness Climatology - March 2011-2016

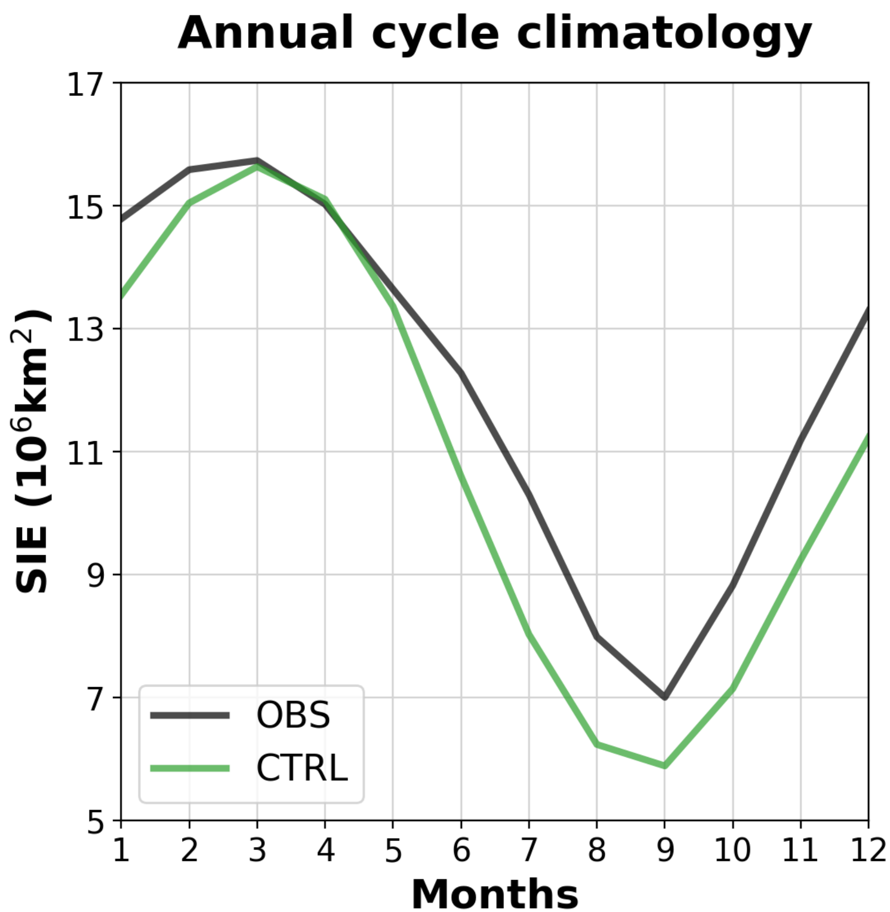


Observational data from CryoSat-2 (*Ricker et al. 2014*), downloaded from www.meereisportal.de

Results – Arctic Sea Ice

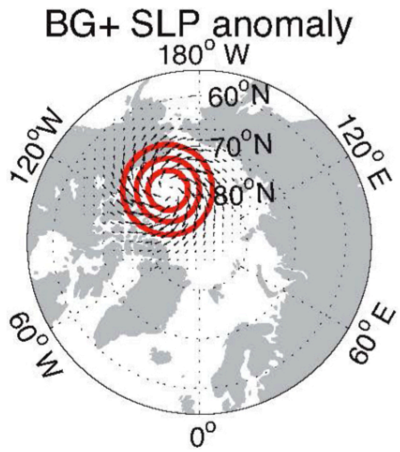
Arctic Sea Ice Extent

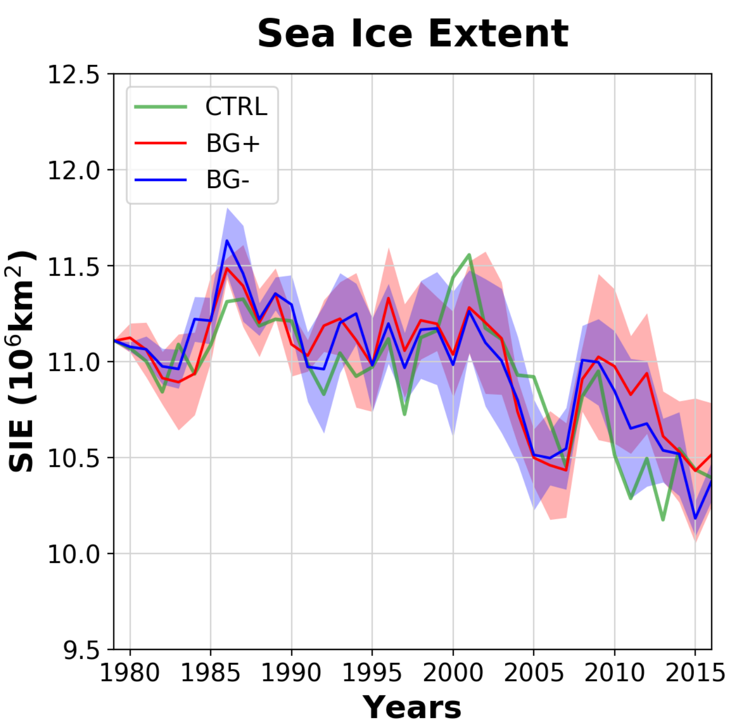




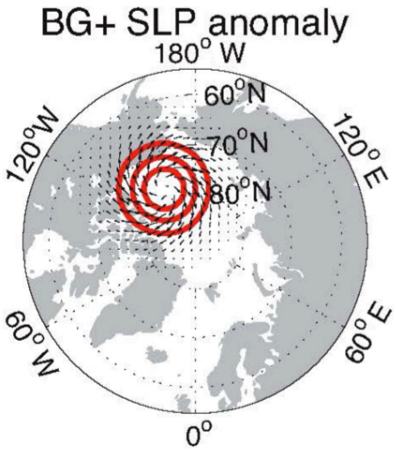
Observational data: OSISAF (*Andersen et al. 2012*)

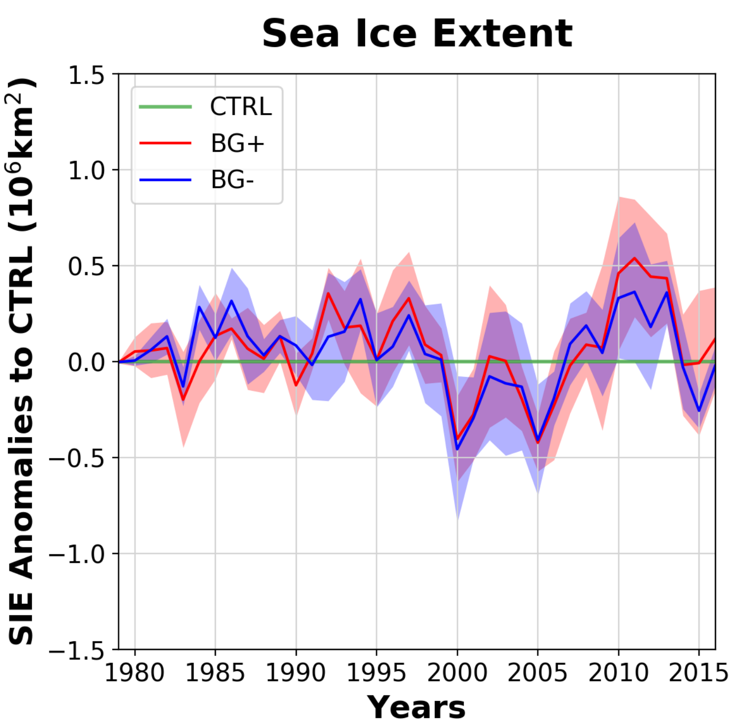
Results – Arctic Sea Ice



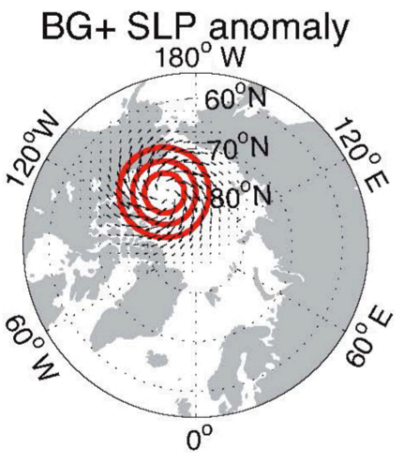


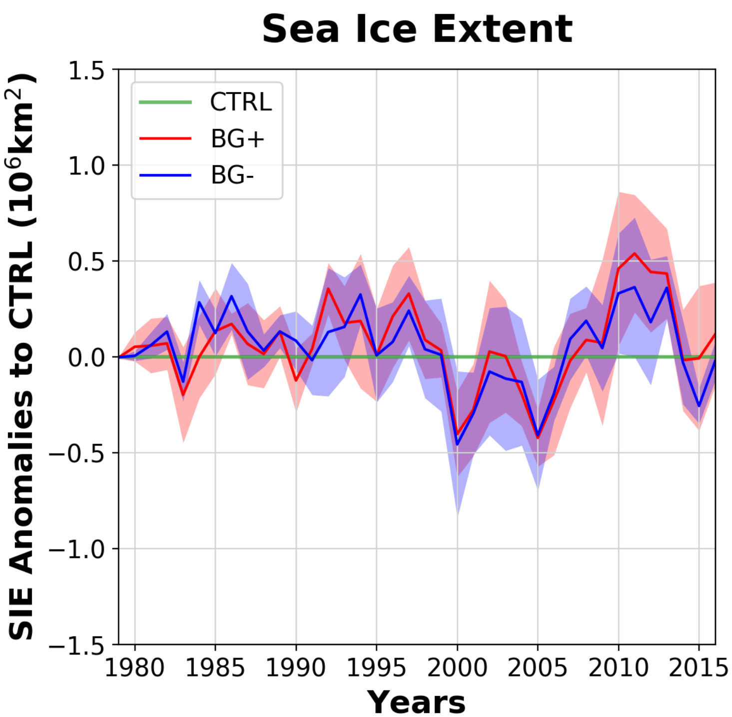
Results – Arctic Sea Ice

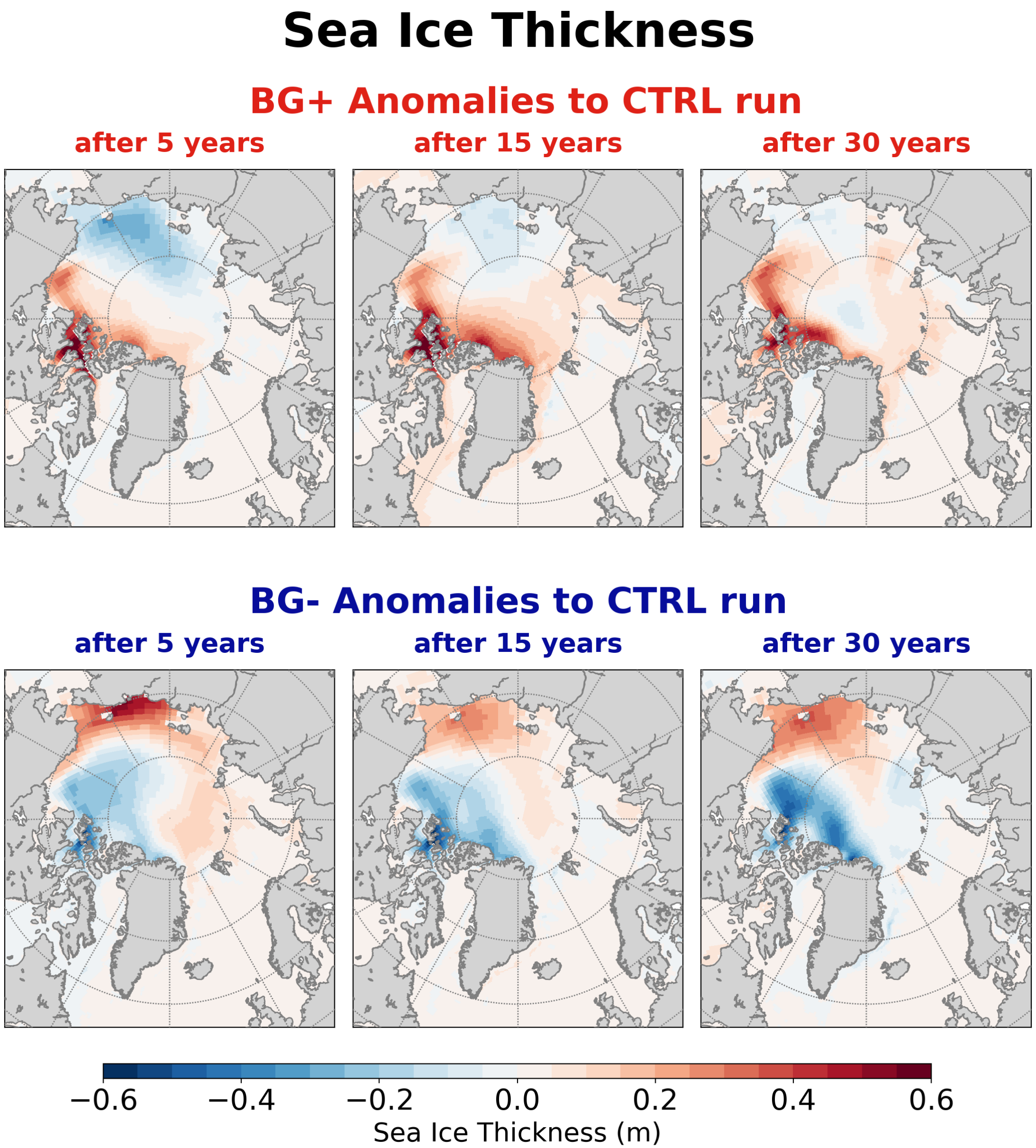




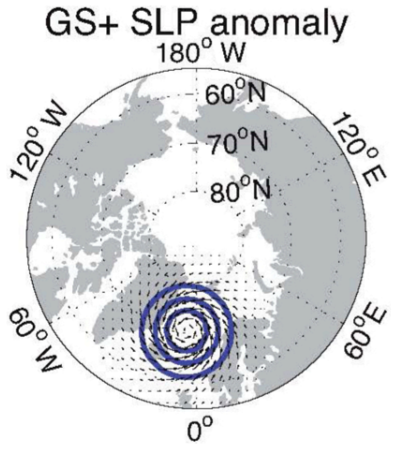
Results – Arctic Sea Ice

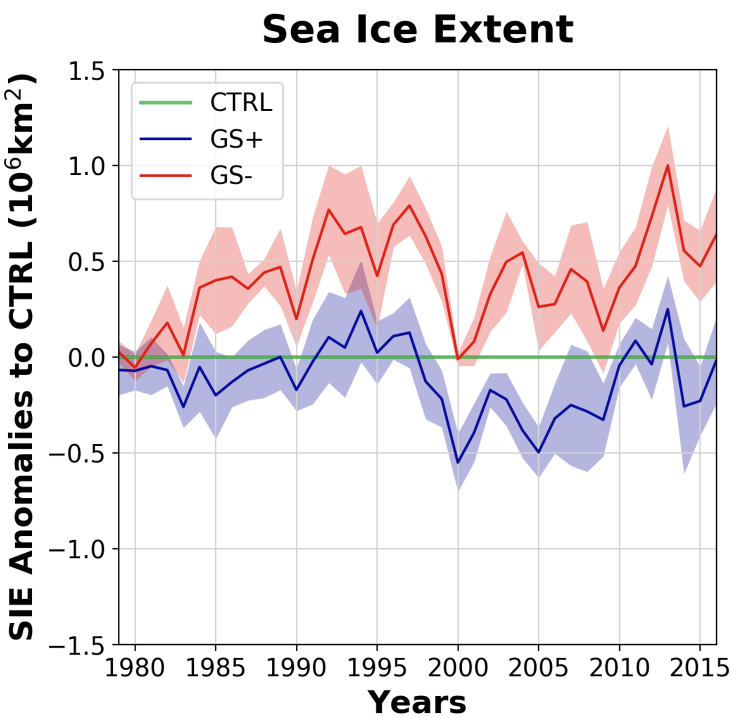




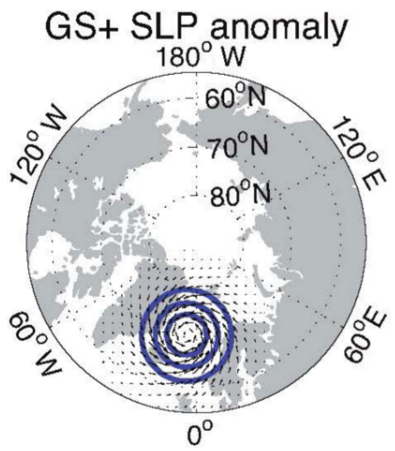


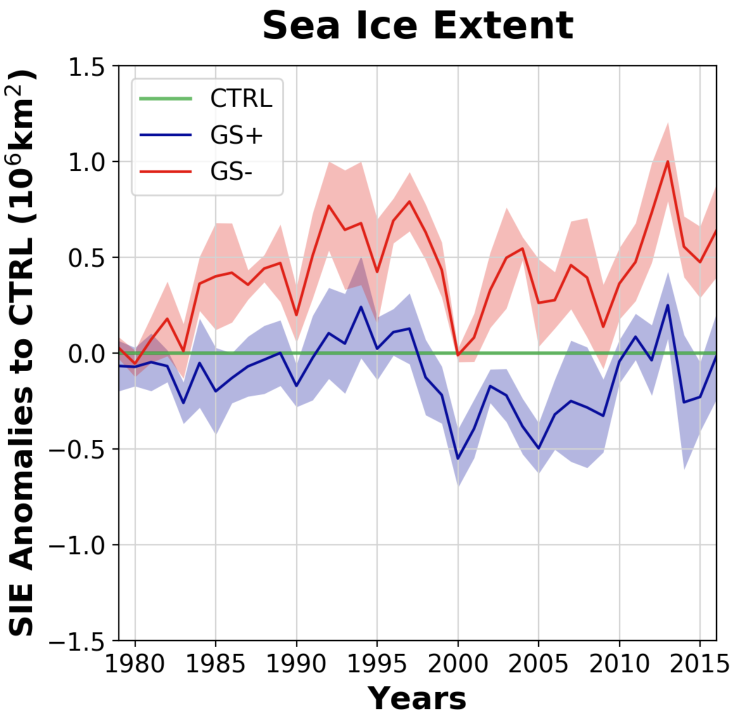
Results – Arctic Sea Ice

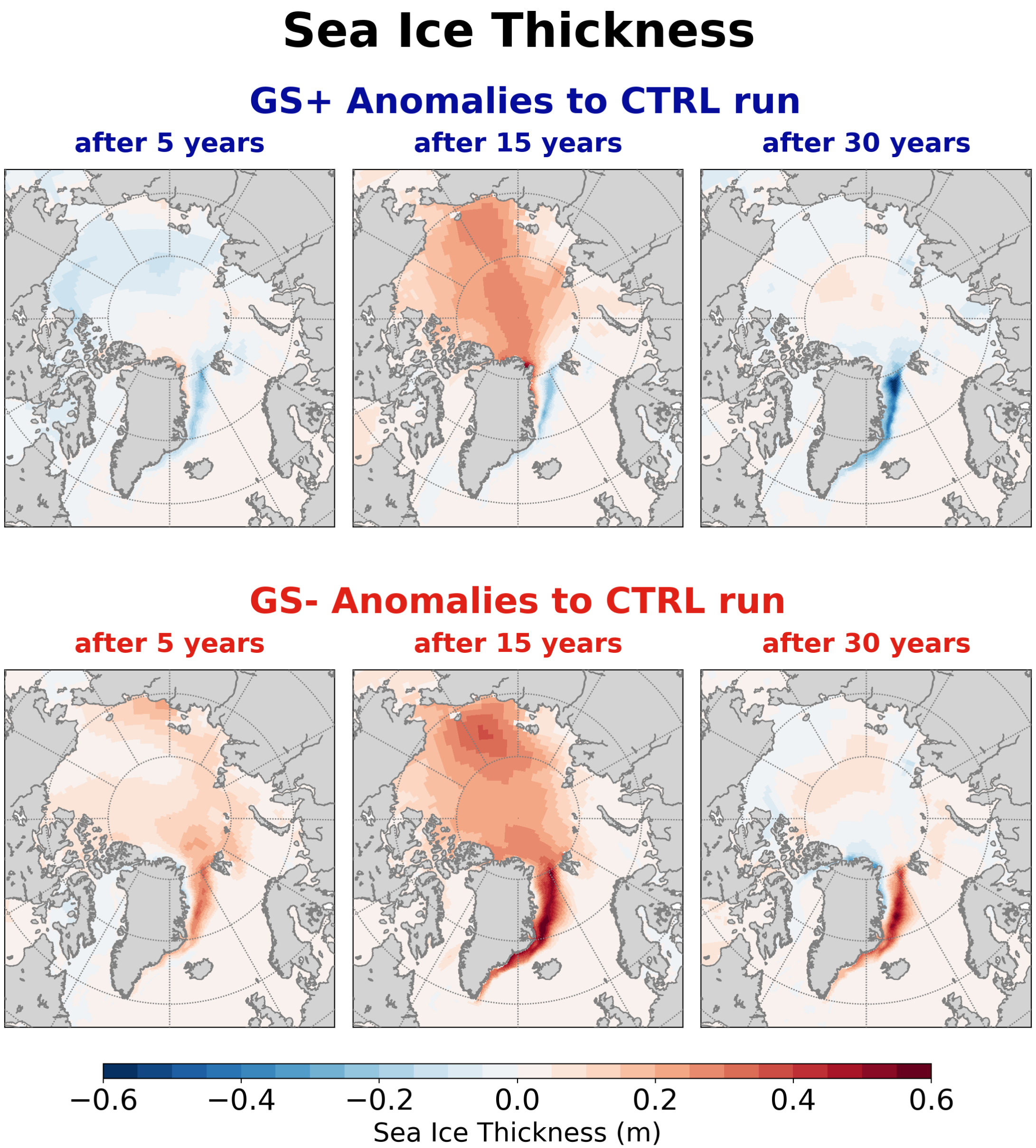




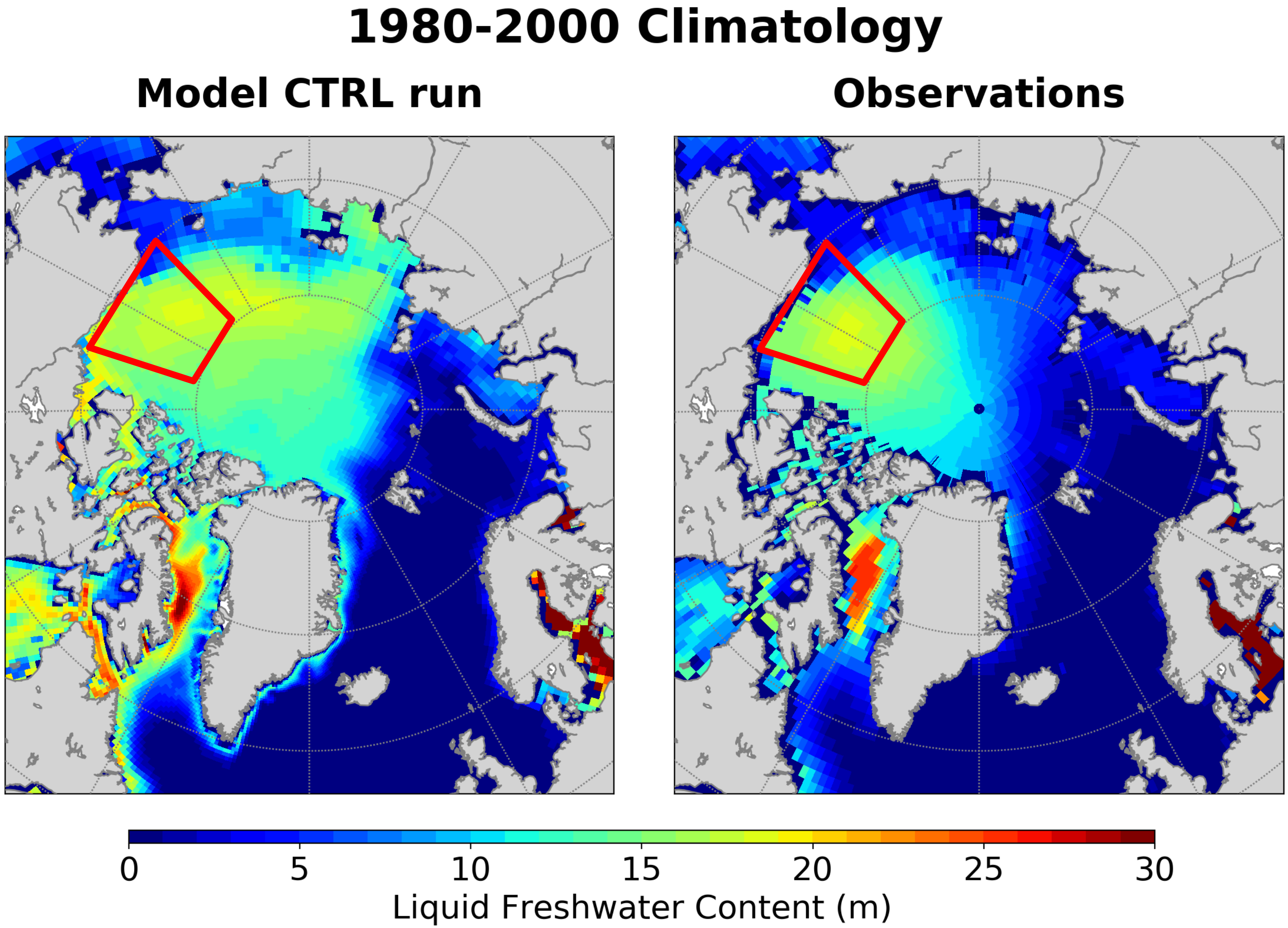
Results – Arctic Sea Ice







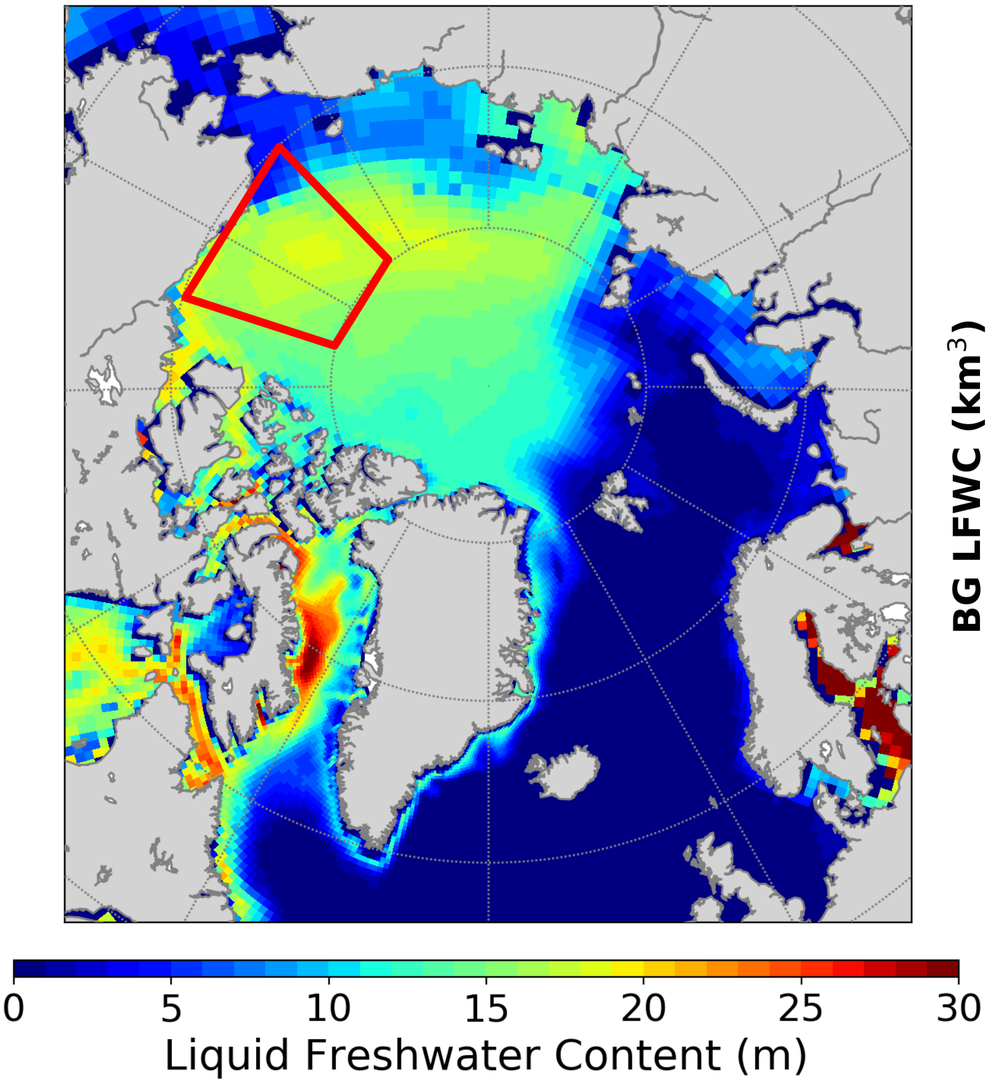
Results – Freshwater Content

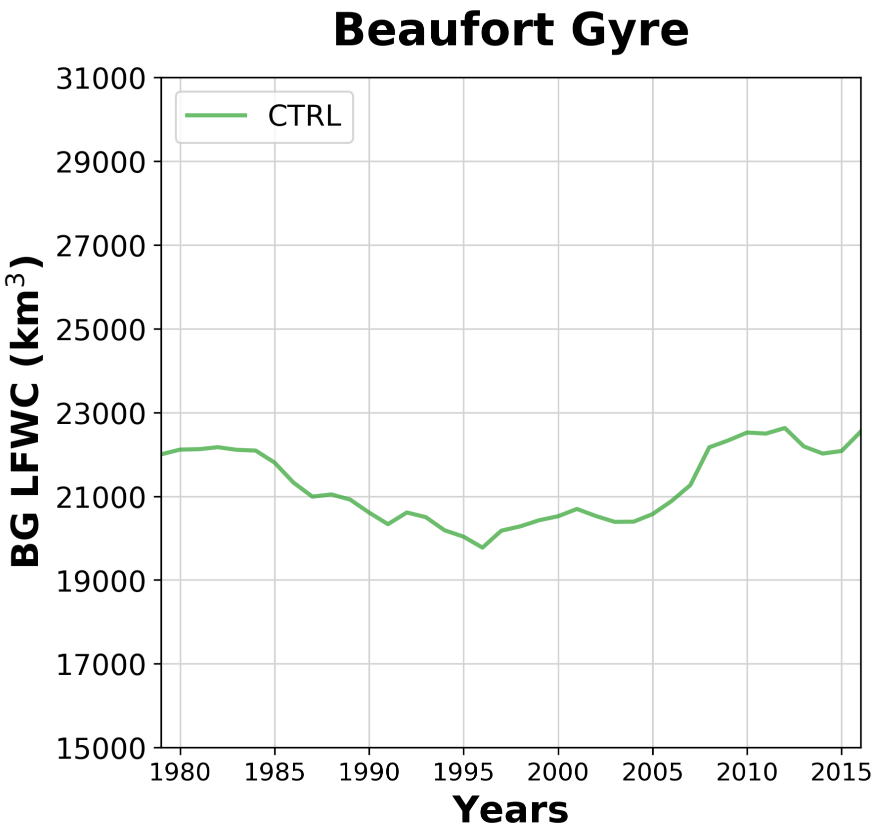


Observational data: from PHC3.0 (*Steele et al. 2001*)

Results – Freshwater Content

1980-2000 CTRL clim





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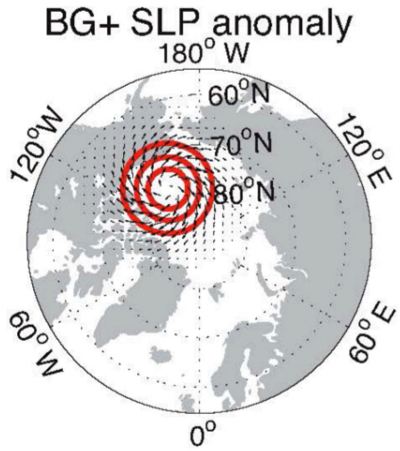
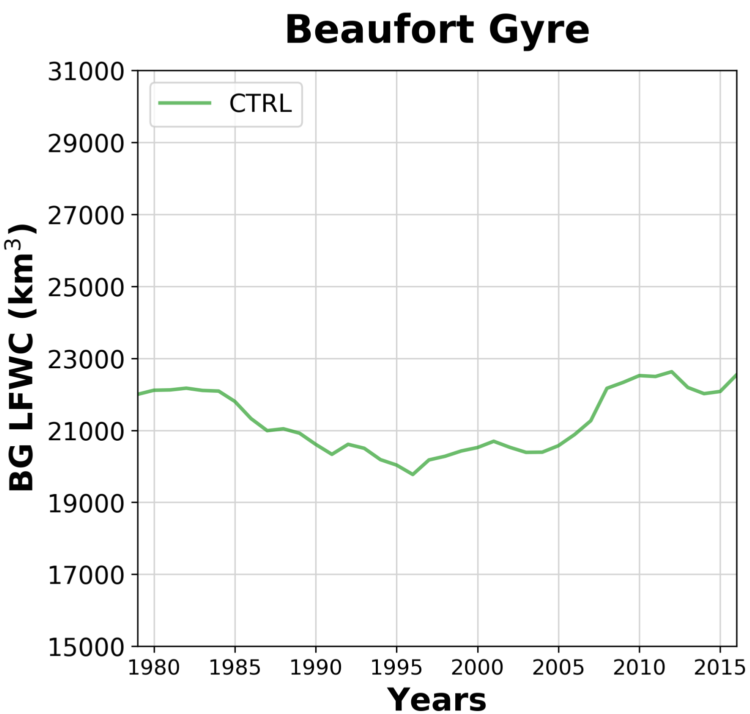
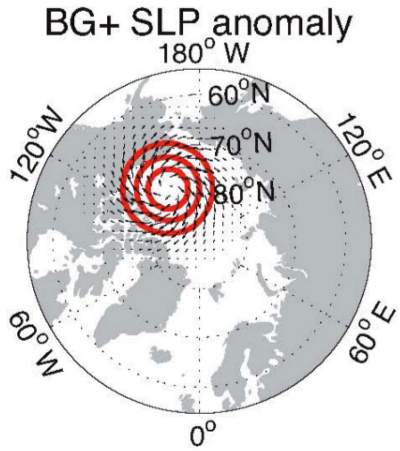
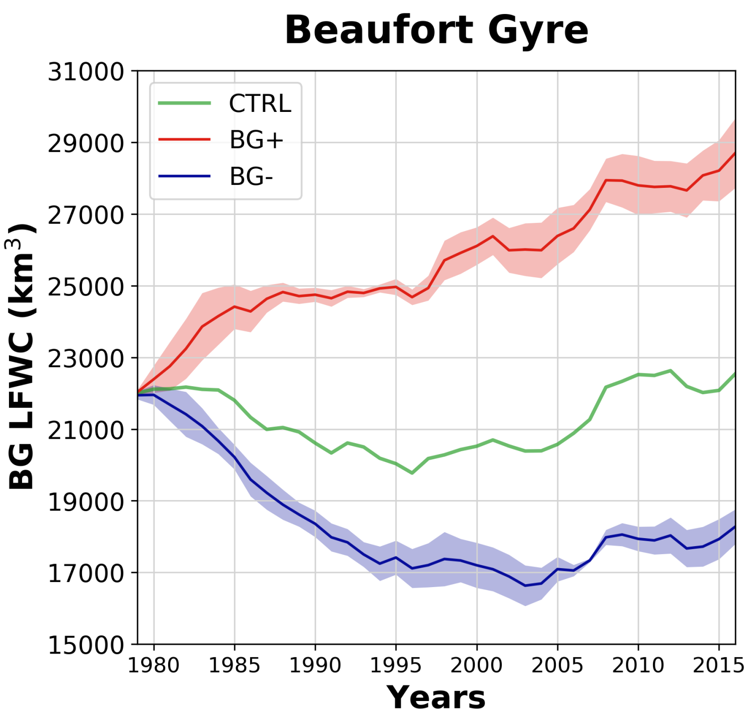
Results – Freshwater Content





Results – Freshwater Content





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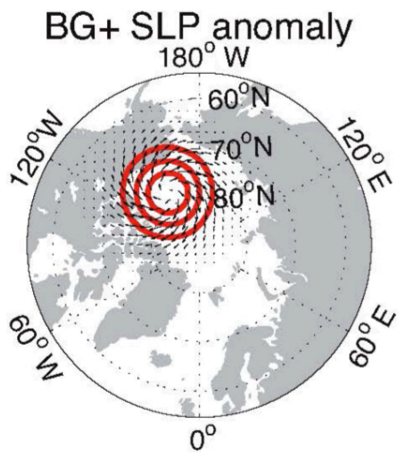
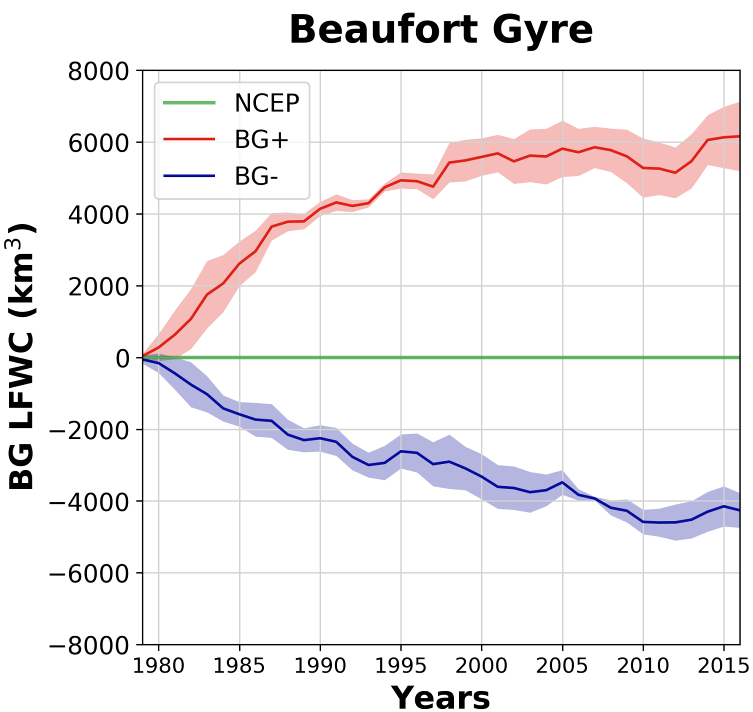
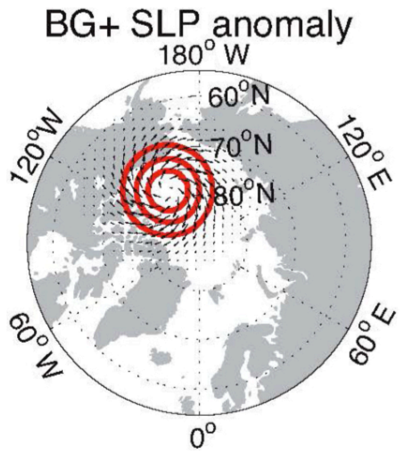
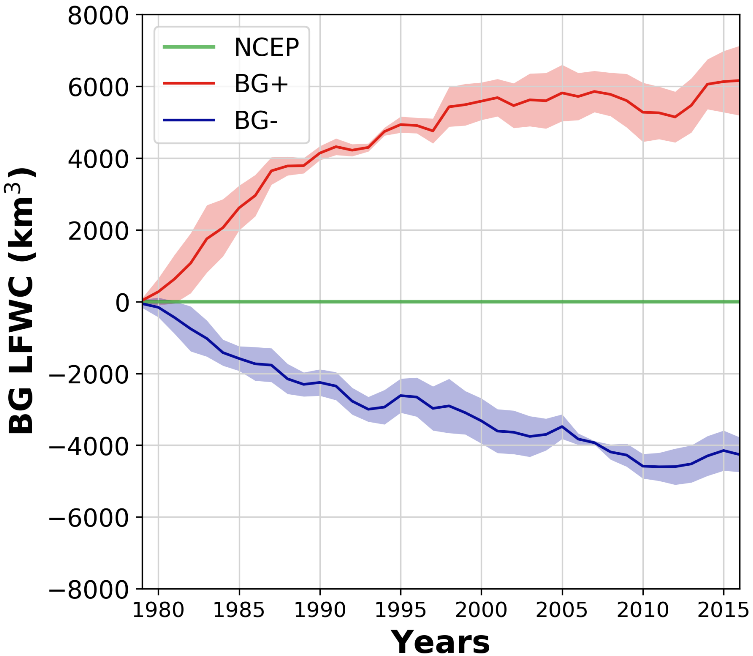




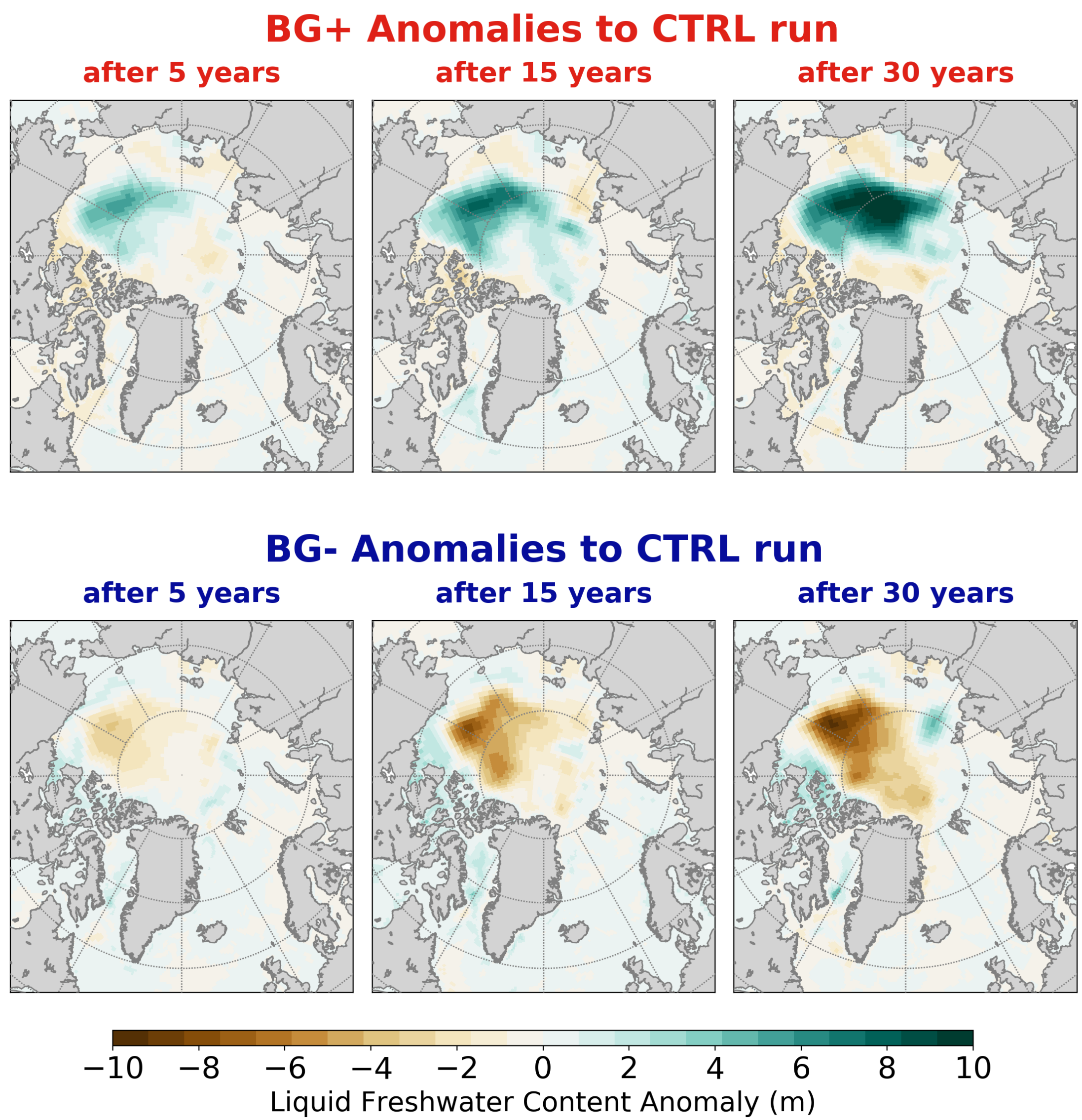
Results – Freshwater Content



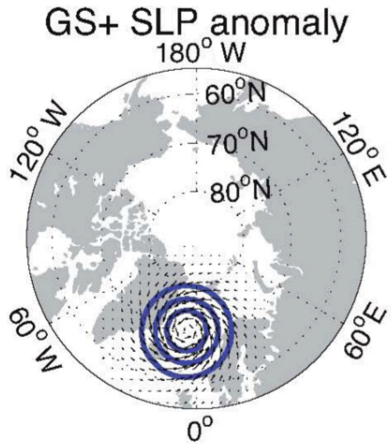
Beaufort Gyre

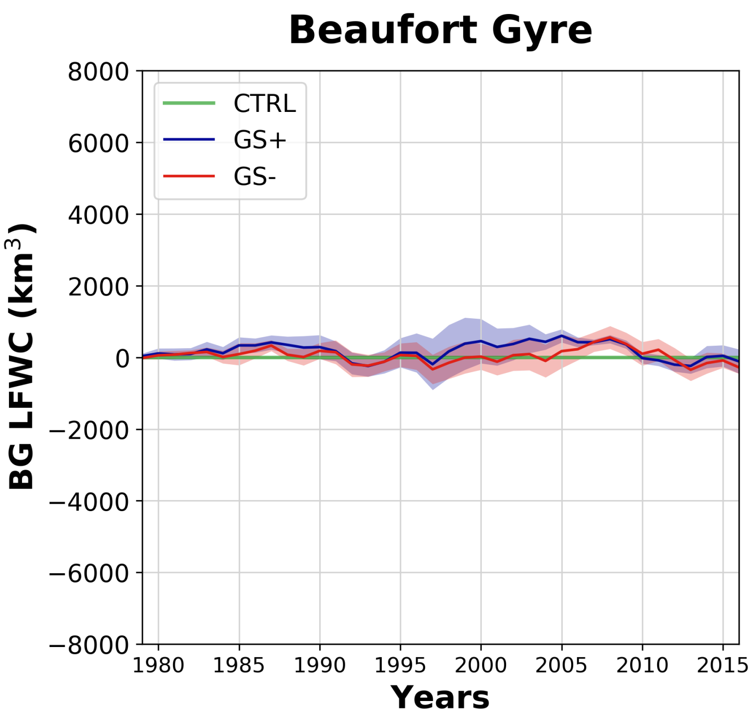


Freshwater Content Anomalies



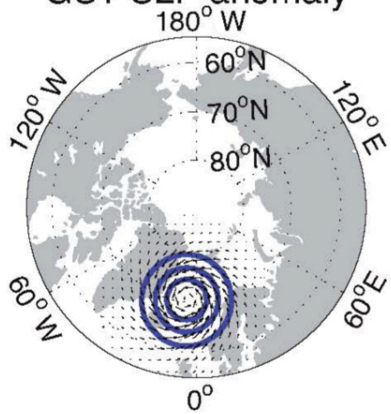
Results – Freshwater Content



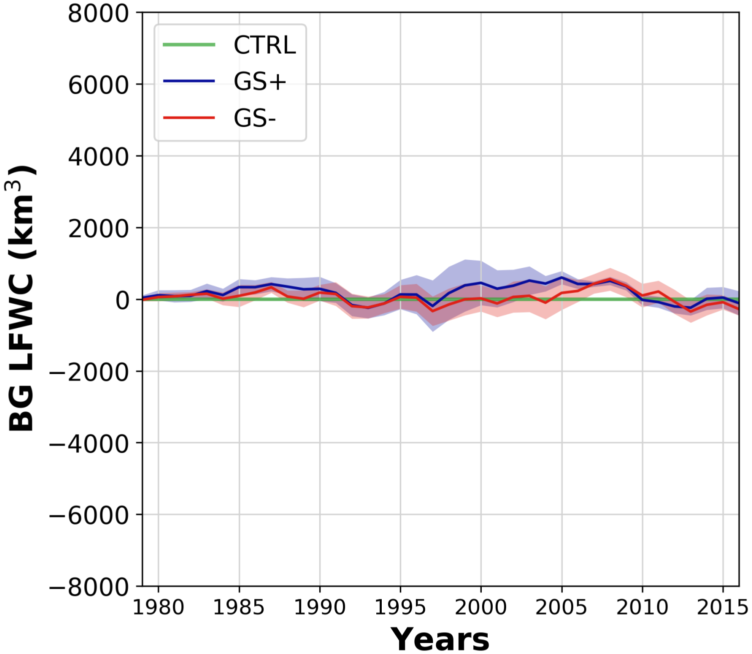


Results – Freshwater Content

GS+ SLP anomaly



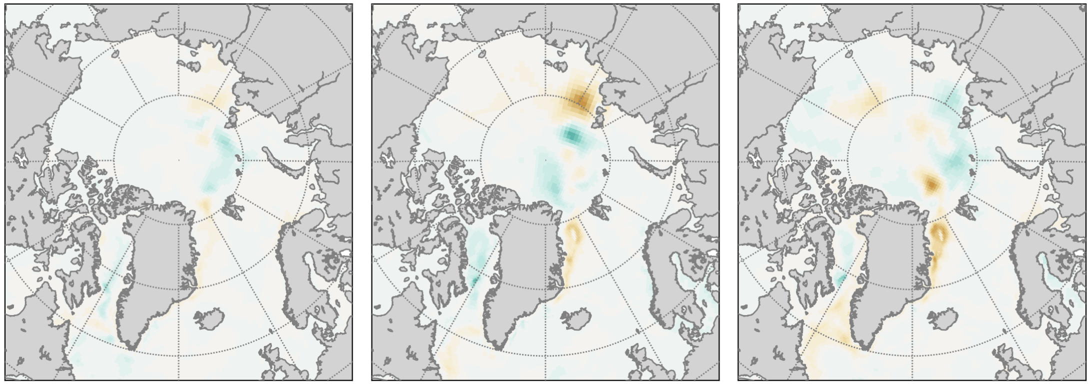
Beaufort Gyre



Freshwater Content Anomalies

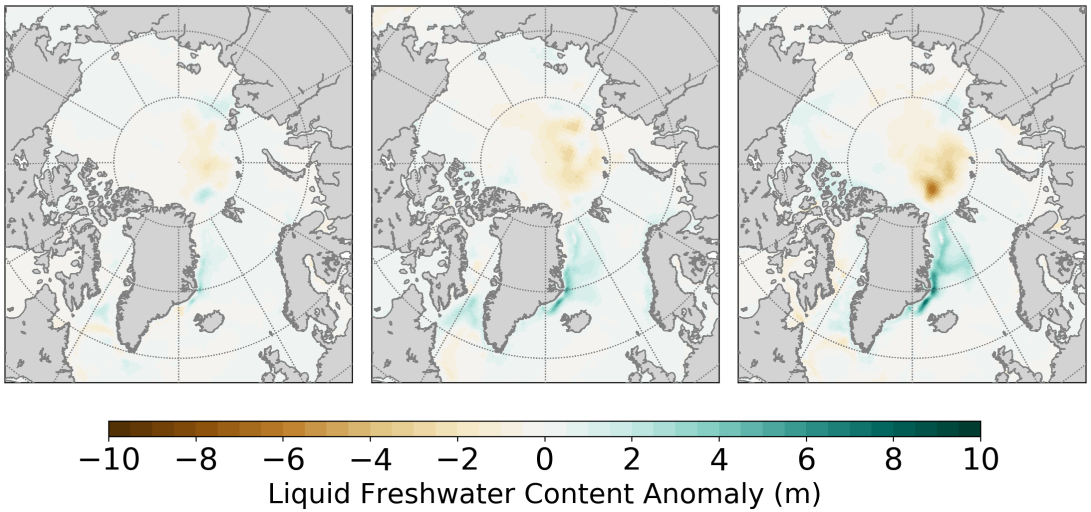
GS+ Anomalies to CTRL run

after 5 years | **after 15 years** | **after 30 years**



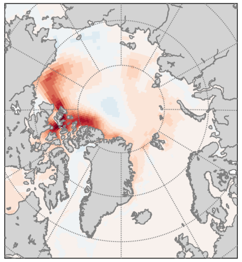
GS- Anomalies to CTRL run

after 5 years | **after 15 years** | **after 30 years**

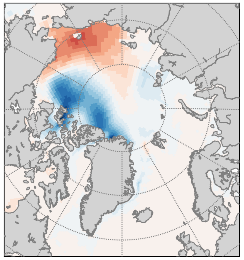


Summary

BG+

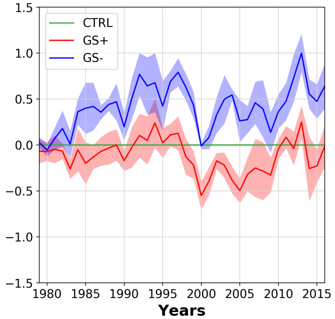


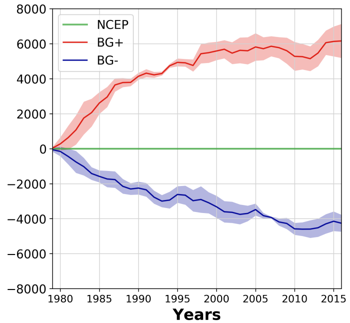
BG-



Sea Ice

- BG anomalies do not affect the total Arctic SIE, but ice thickness shows a distinct spatial pattern.
- GS anomalies influence total Arctic SIE, and the thickness east of Greenland. There is no clear response of ice thickness in higher latitudes.

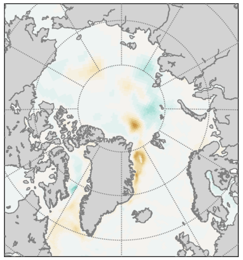




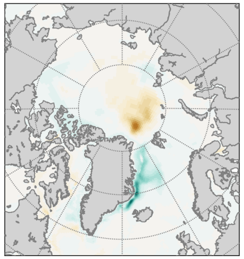
Freshwater content

- BG anomalies result in significant quasi-symmetric changes in the Beaufort Gyre and beyond. There is a much weaker response of opposite sign in the rest of the Arctic.
- GS anomalies do not influence the FWC of the Beaufort Gyre, but have an effect on the FWC of the East Greenland Current

GS+



GS-



References

- **MPI-ESM structure**: Giorgetta, M. A., J. Jungclaus, C. H. Reick, S. Legutke et al. 2013: Climate and carbon cycle changes from 1850 to 2100 in MPI- ESM simulations for the Coupled Model Intercomparison Project phase 5, *J Adv Model Earth Sy*, **5** (3), 572-597.
- **MPIOM**: Jungclaus, J. H., N. Fischer, H. Haak, K. Lohmann, J. Marotzke, D. Matei, U. Mikolajewicz, D. Notz, and J. S. von Storch, 2013: Characteristics of the ocean simulations in the Max Planck Institute Ocean Model (MPIOM) the ocean component of the MPI-Earth system model, *J Adv Model Earth Sy*, **5** (2), 422-446.
- **Modini**: Thoma, M., R. Gerdes, R. J. Greatbatch, and H. Ding, 2015a: Partially coupled spin-up of the MPI-ESM: implementation and first results, *Geosci Model Dev*, **8** (1), 51-68.
- **NCEPcfsr**: Saha, S., S. Moorthi, H. L. Pan, X. R. Wu, J. D. Wang, S. Nadiga et al., 2010: The Ncep Climate Forecast System Reanalysis, *B Am Meteorol Soc*, **91** (8), 1015-1057.
- **CRF background**: Marshall, J., J. Scott, and A. Proshutinsky, 2017: "Climate response functions" for the Arctic Ocean: a proposed coordinated modelling experiment, *Geosci Model Dev*, **10** (7), 2833-2848.
- **CryoSat-2**: Ricker, R.; Hendricks, S.; Helm, V.; Skourup, H. and Davidson, M. (2014), Sensitivity of CryoSat-2 Arctic sea-ice freeboard and thickness on radar-waveform interpretation, The Cryosphere, 8 (4), 1607-1622
- **OSISAF**: Andersen, S., Breivik, L.-A., Eastwood, S., Øystein Godøy, Lavergne, T., Lind, M., Porcires, M., Schyberg, H., and Tonboe, R.: Ocean & Sea Ice SAF Sea Ice Product Manual, version 3.8, 2012.
- **PHC**: Steele, M., Morley, R., Ermold, W., 2001. A global ocean hydrography with a high quality Arctic Ocean. J. Clim. 14, 2079–2087.

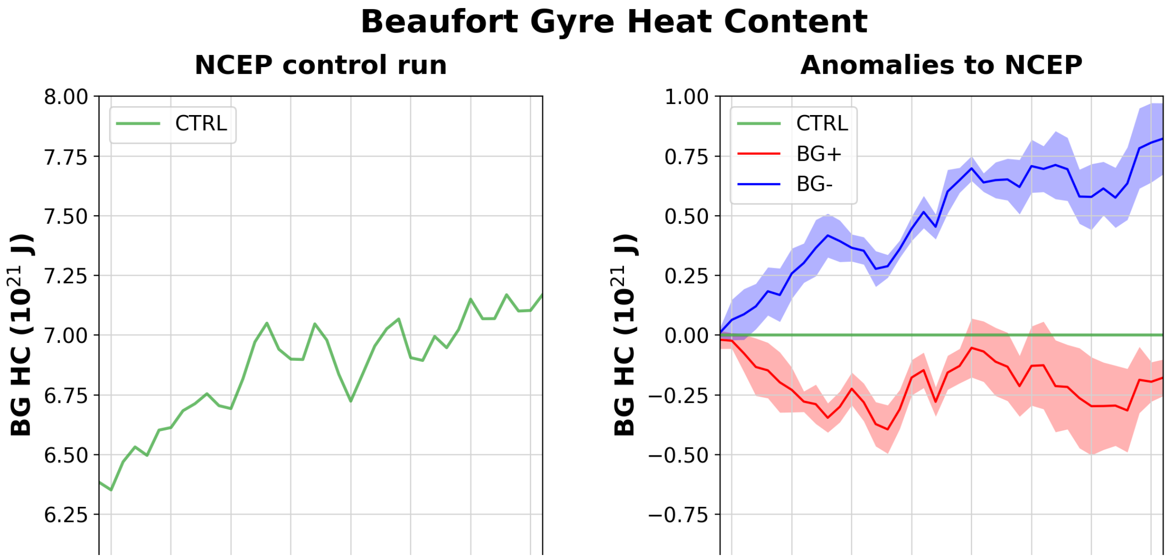
Liquid Freshwater Content

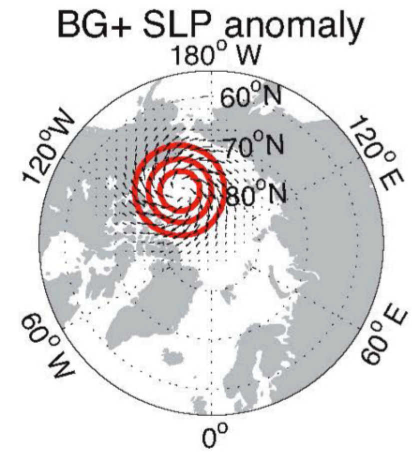
$$LFWC = \oint \int_{z=0m}^{h} \frac{S_{ref} - S}{S_{ref}} dz \; dA$$

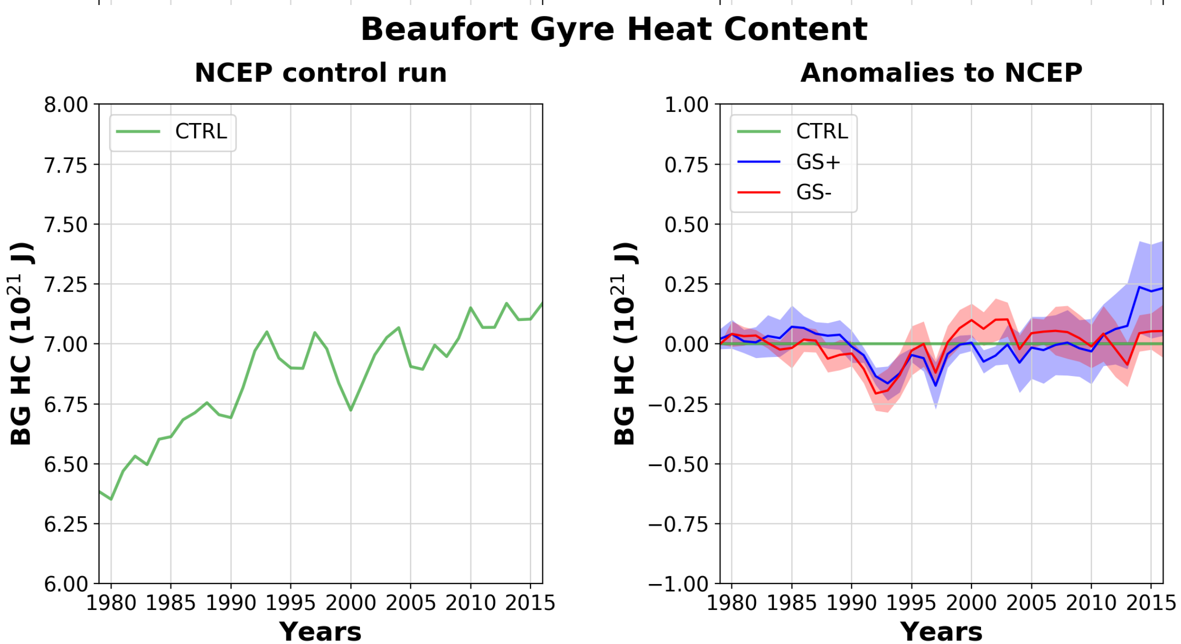
$$S_{ref} = 34.8$$

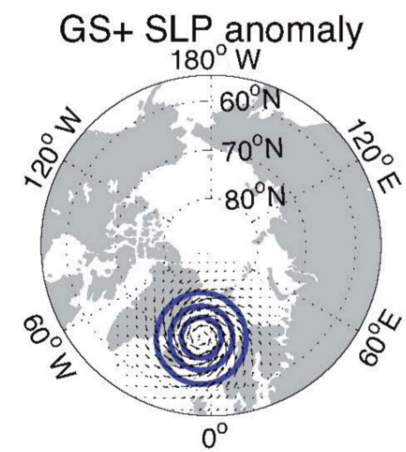
$$\text{h} = \text{depth of 34.8 isohaline}$$

Results









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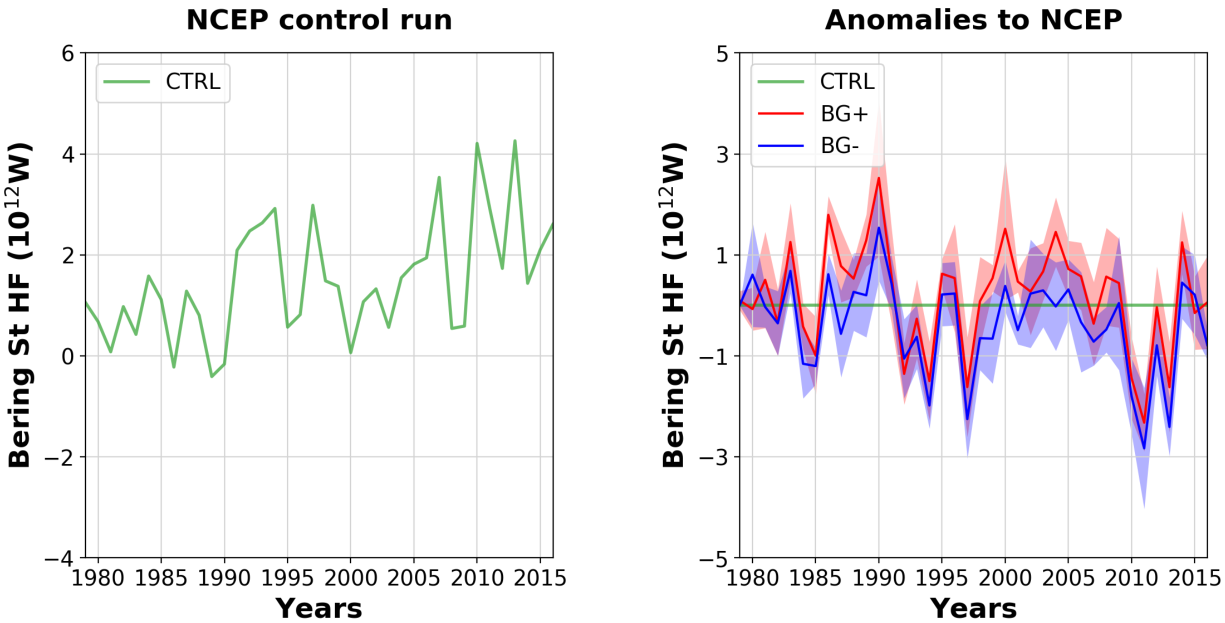
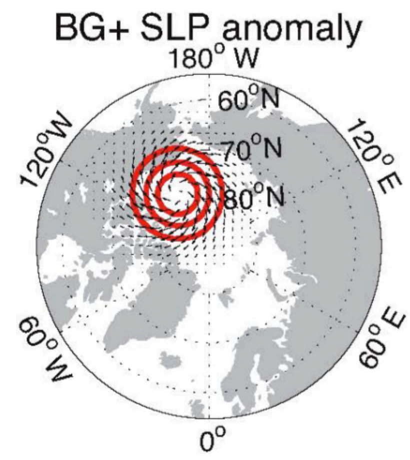
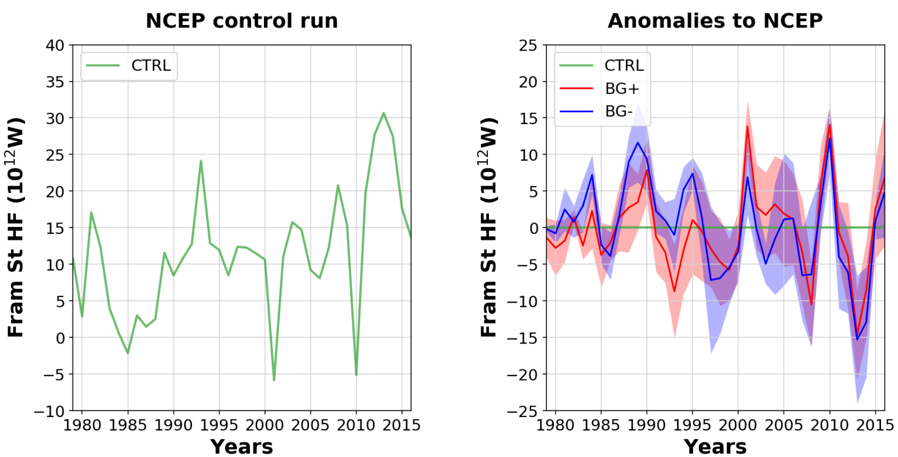
Results

Bering Strait Heat Flux

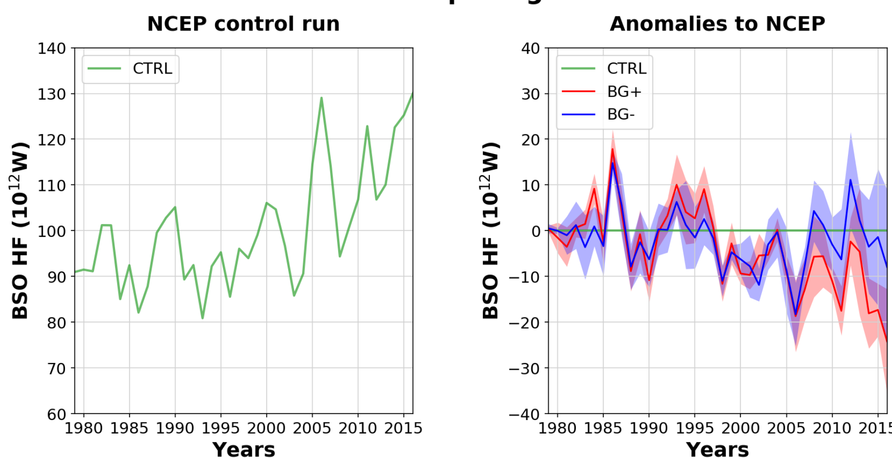




Fram Strait Heat Flux

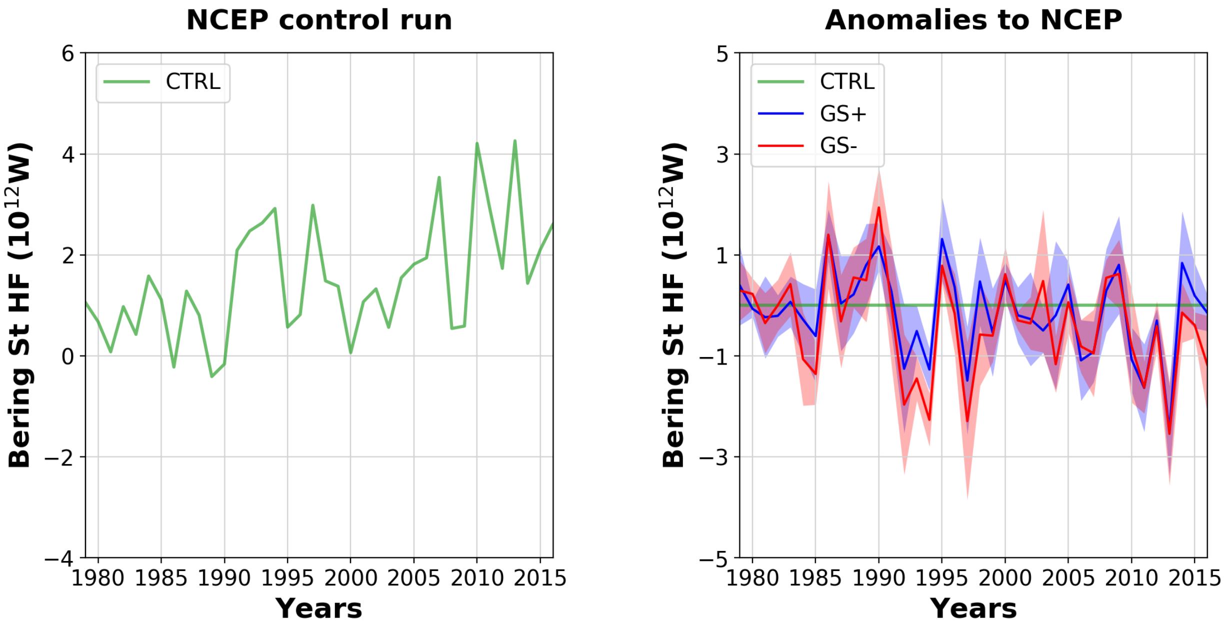


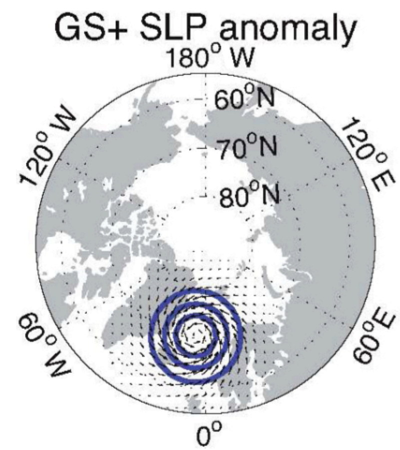
Barents Sea Opening Heat Flux



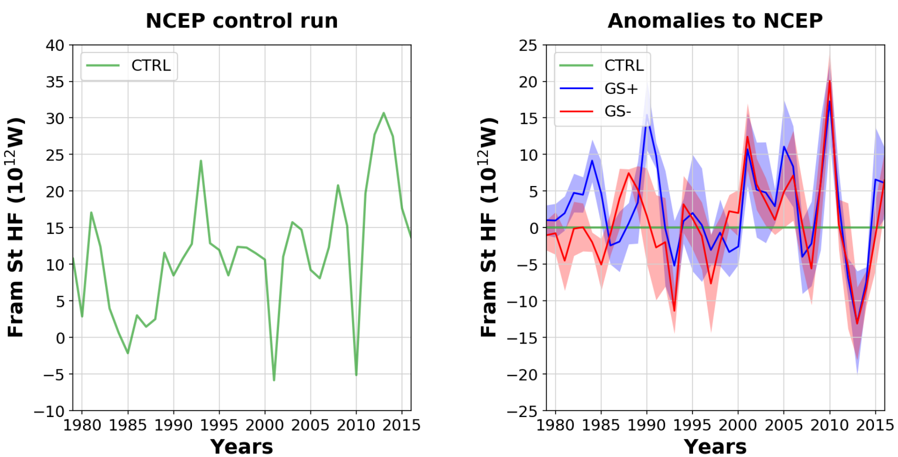
Results

Bering Strait Heat Flux

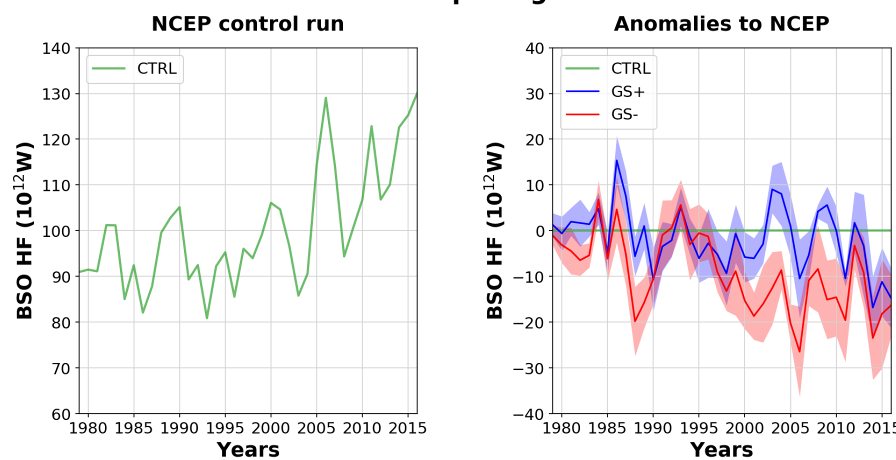




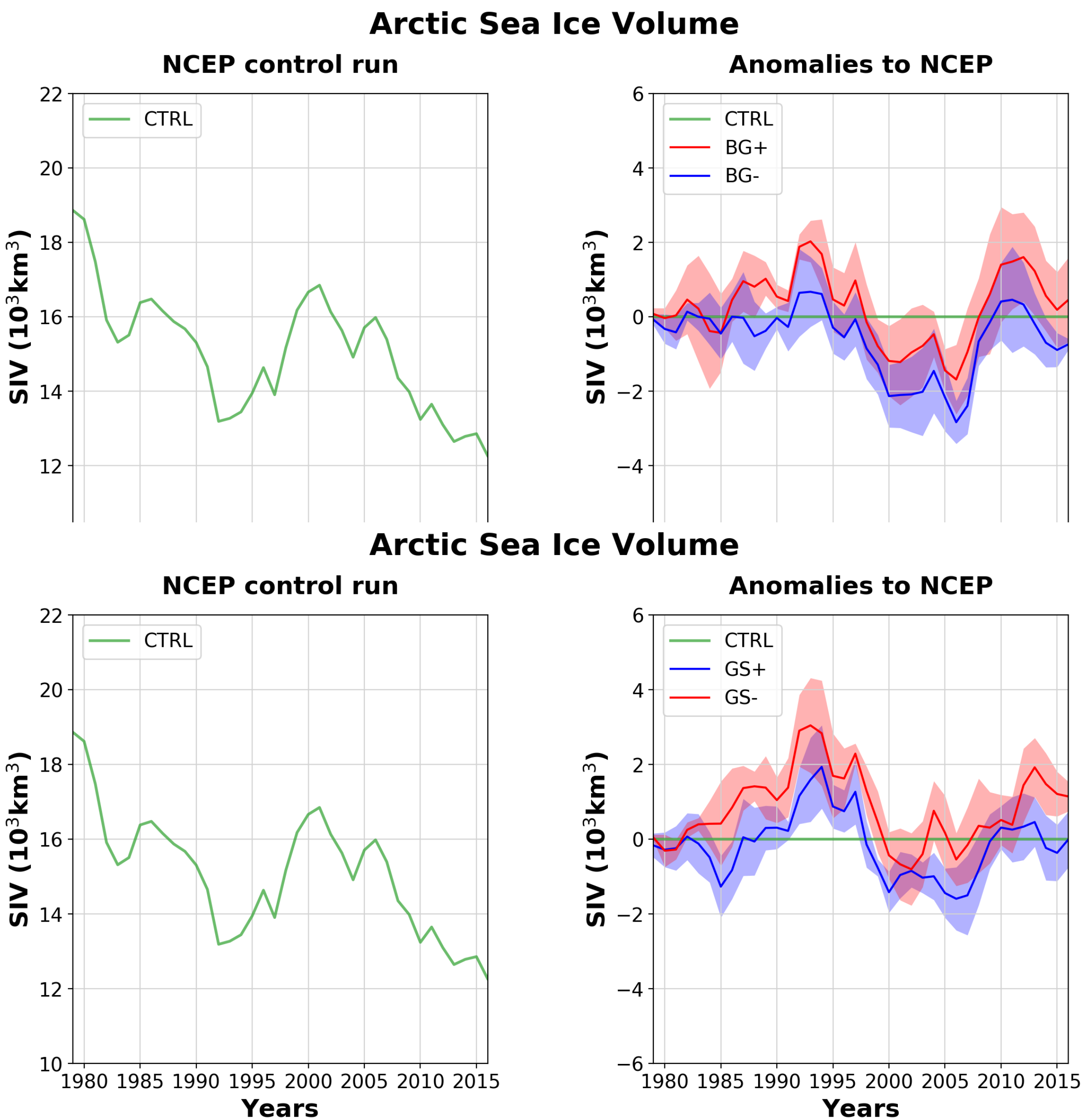
Fram Strait Heat Flux

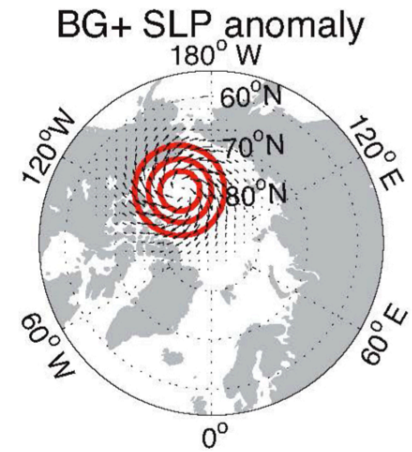


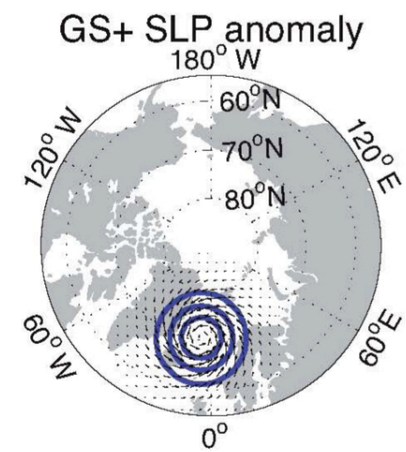
Barents Sea Opening Heat Flux



Results







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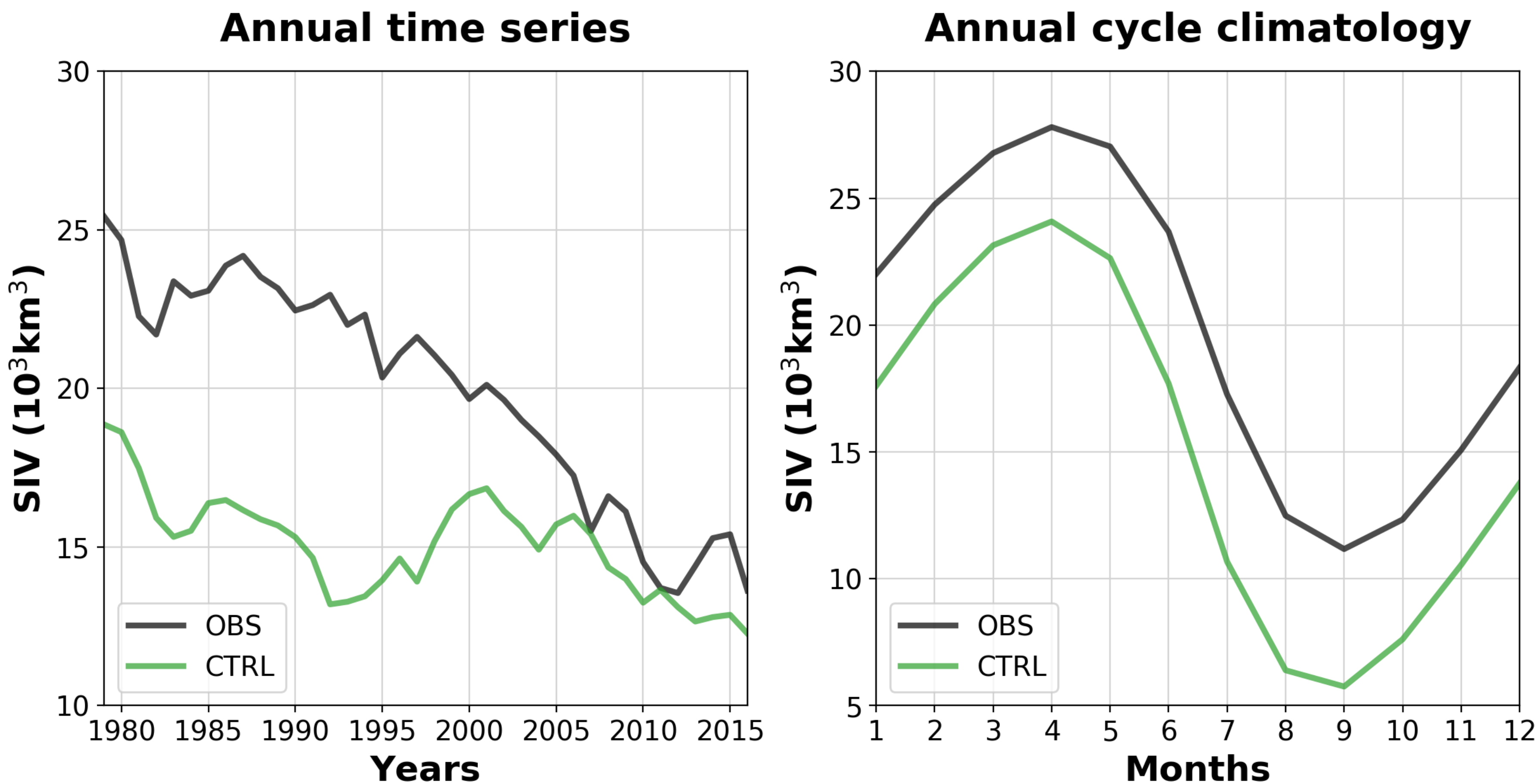
Results

Arctic Sea Ice Volume



Observational data: PIOMAS (Zhang and Rothrock, 2003)