North Atlantic and large-scale response to a warming Arctic with a coupled model

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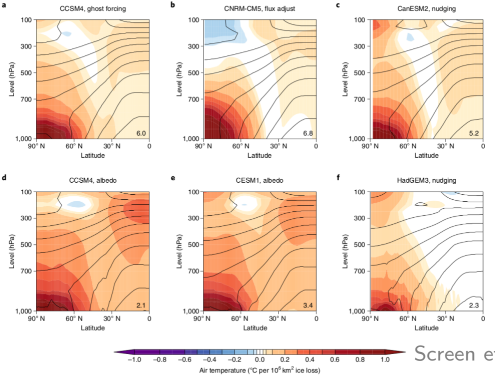
EGU General Assembly
April 8, 2019

Context

- Arctic is a region of pronounced climate change with impacts for the Northern Hemisphere (NH)

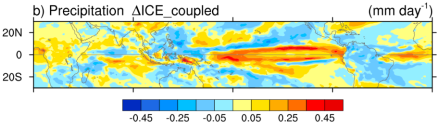
- No consensus on numerical methodology to recover the Arctic warming (AW) (nudging[1,2], flux adjustement[3,4], ghost forcing[5,6,7], sea ice properties (albedo[8,9,10,11], emissivity[10]) or snow on ice properties[12])

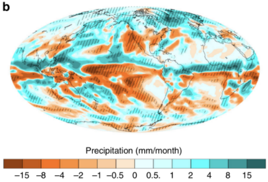


Screen et al.(2018), NG

- No consensus on AW teleconnections within coupled model studies

Deser et al.(2017), JCLI





Cvijanovic et al.(2017), NC

[1] Smith et al. (2017), J Clim; [2] Suo et al.(2017), ERL [3] Oudar et al. (2017), Clim Dyn; [4] Monerie et al. (2018), Clim Dyn [5] Deser et al. (2015) J.Clim; [6] Deser et al., (2016) GRL; [7] Tomas et al., (2016) J Clim [8] Blackport et al. (2016), J Clim [9] Blackport et al. (2017), J Clim [10] Sévellec et al. (2017), NCC; [11] Liu et al. (2019), GRL; [12] Cvijanovic et al.(2017), NC

How do we investigate Arctic Warming teleconnections ?

- Change Arctic sea ice (and snow above it) properties in Northern Hemisphere (NH)
  → Ensure water and energy conservation

- Which properties ? albedo and thermal conductivity

- Fully coupled model IPSLCM5 (CMIP5 version)

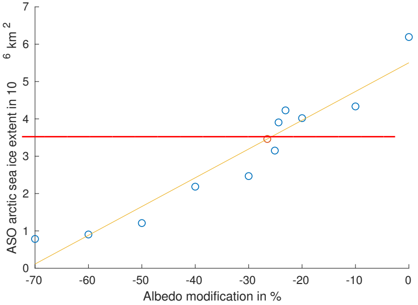
- Three ensembles (10 members) of 30 years (averaged last 20 years) with same GHG but two different Arctic SIE climatology :

- One ensemble (SIE_{pdctrl}) - Present day control (**pdctrl**)

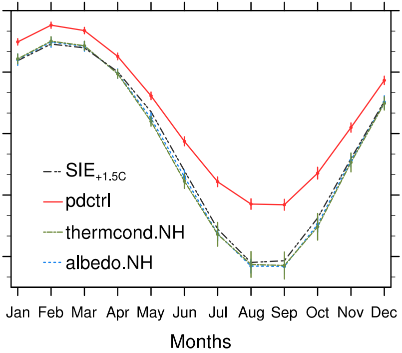
- Two reduced-sea ice ensembles ($SIE_{+1.5C}$) obtained with two methods (**albedo.NH**, **thercond.NH**)

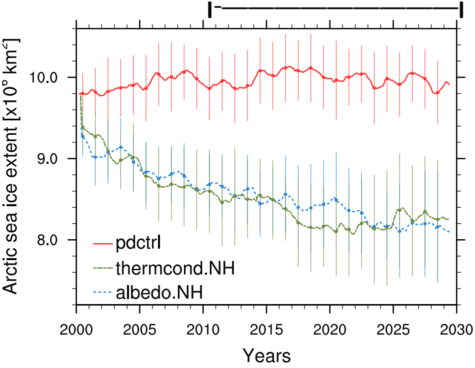
$SIE_{+1.5C}$ is the SIE of 1.5°C warming RCP8.5 scenario (period 2035-2055)

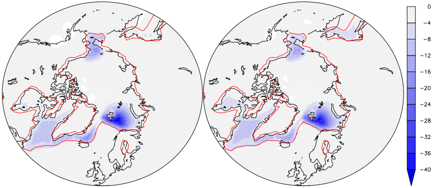
- How to get the optimal value (albedo and thermal conductivity) ?
  Iterative linear regression



Similitudes for reduced-ice ensembles

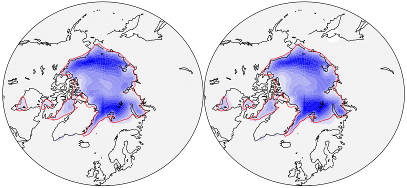






winter sea ice concentration (SIC) anomaly

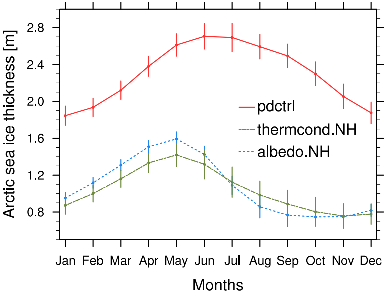
albedo.NH **thercond.NH**

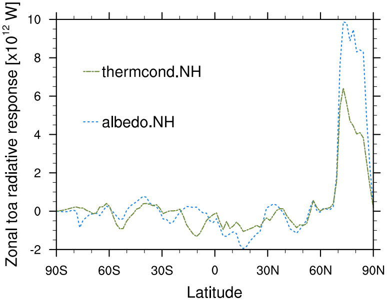


Summer SIC anomaly

albedo.NH **thercond.NH**

Differences in Arctic within reduced-ice ensembles

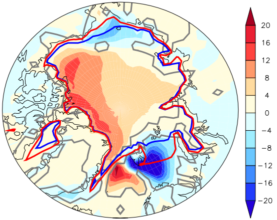




albedo.NH

+2.9 K

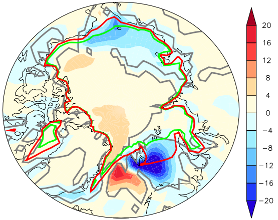
surface temperature in the Arctic



Total surface heat flux anomaly [W/m2]

thercond.NH

+1.7 K



Contour of 50 % annuel SIC for pdctrl, albedo.NH, thercond.NH

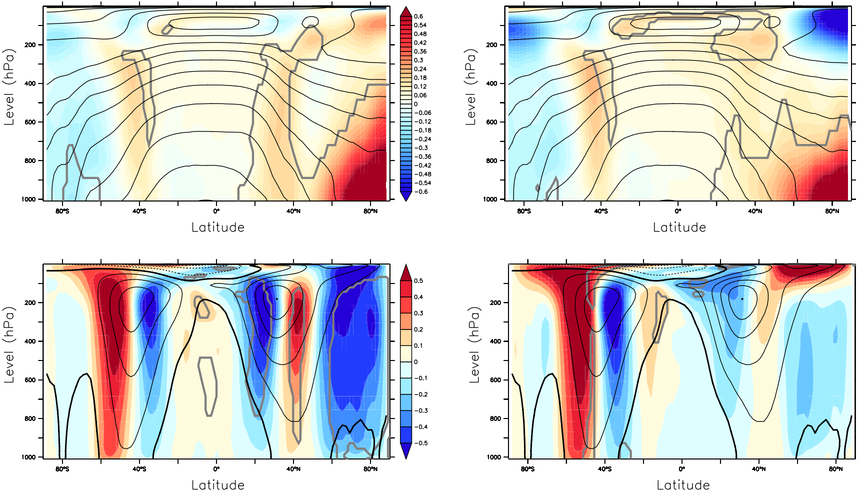
Contour of 95 % significant levels

Global response (DJF)

albedo.NH | **thercond.NH**

Zonal air temp. [°C]

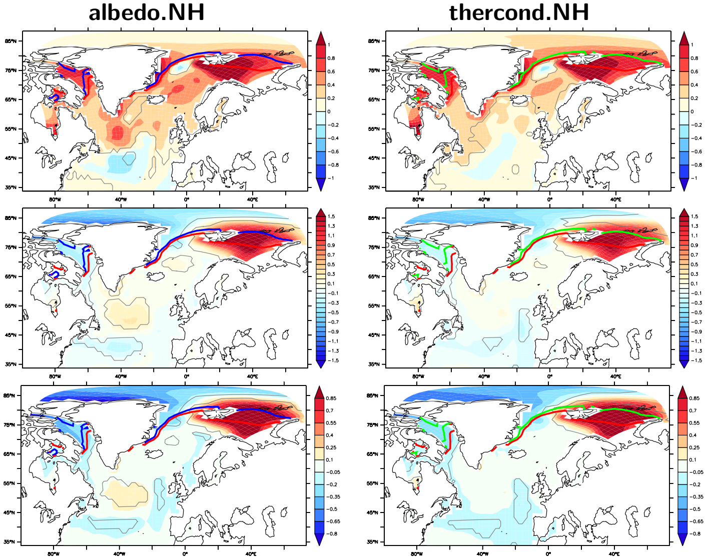
Zonal winds [m/s]



Contour of **present day climatology**

Contour of 95 % statistical significant

North Atlantic Basin (annual mean)



Sea surface temperature (SST) response [°C]

Sea surface salinity (SSS) response [10^{-3}]

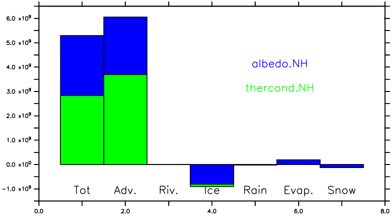
Density response [kg/m^3]

→ SSS drives the density (in anomaly).

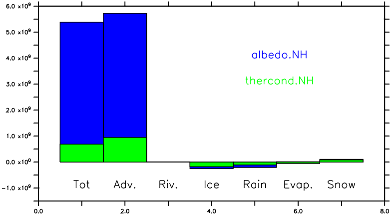
North Atlantic basin (annual mean)

Salt flux $[10^{-3} kg/s]$

Barents sea

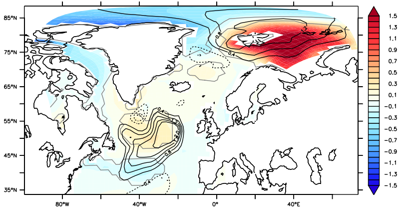


Northwest Atlantic

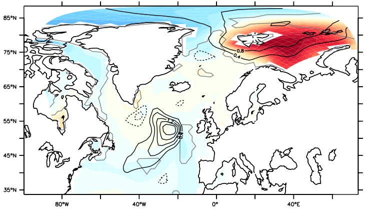


SSS (shading) $[10^{-}3]$ *barotropic stream function (contour) responses [Sv]*

albedo.NH



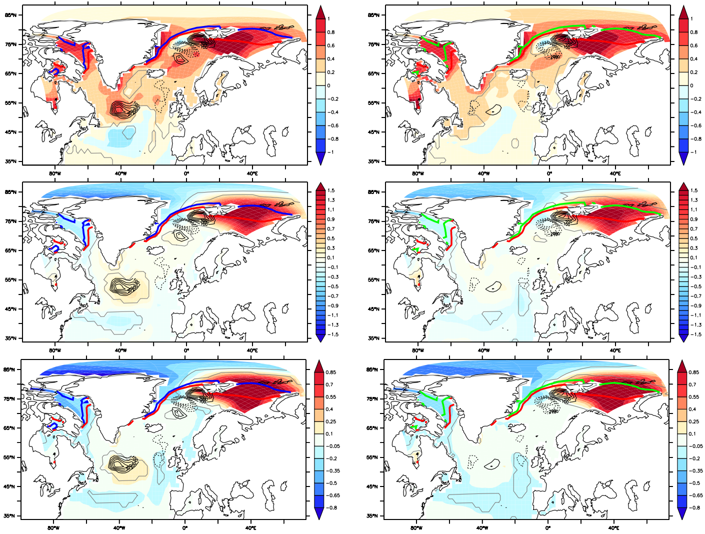
thercond.NH



→ SSS anomaly come from the advection. The sub-polar gyre and the North Atlantic current are expanded and brings hot and salty water in the Barents and in the Northwest Atlantic.

North Atlantic Basin (annual mean)

albedo.NH **thercond.NH**



Sea surface temperature (SST) response [°C]

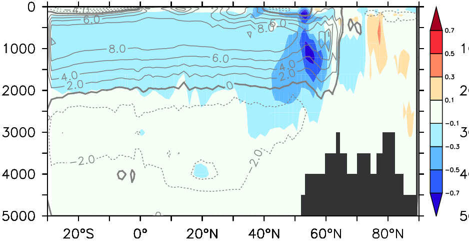
Mix layer depth response (FMA) [m] (contour)

Sea surface salinity (SSS) response [10^{-3}]

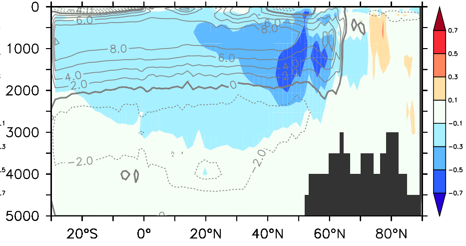
Density response [kg/m^3]

→ Deep convection site is shallower

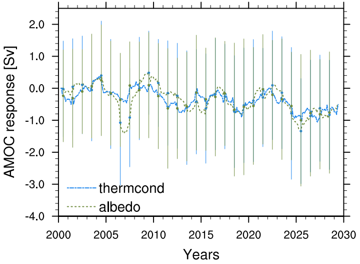
Atlantic meriodional overturning circulation (AMOC)



albedo.NH



thercond.NH



Contour of present day climatology
AMOC at 55°N

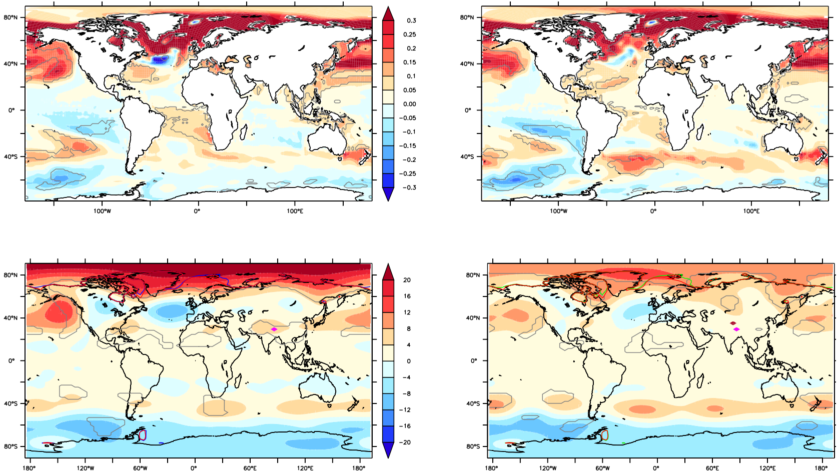
Slow decline of AMOC at 55 N for both method (0.7 Sv out of 8 Sv)

Large-scale response

albedo.NH **thercond.NH**

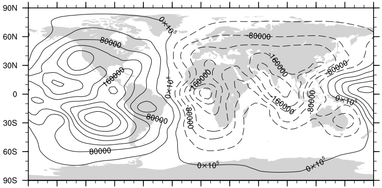
Annual SST response [°C]

DJF Z500 response [m]

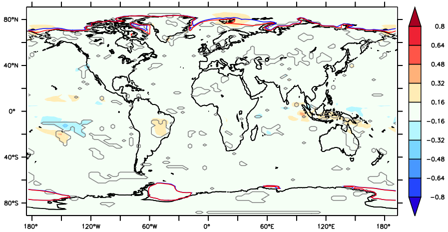


Large-scale response (albedo.NH)

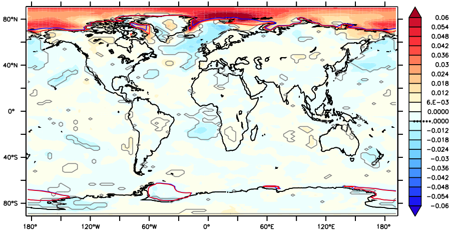
Potential velocity at 200 hPa response



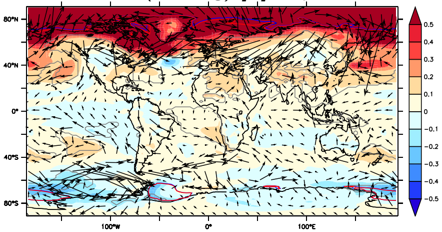
Precipitation response [$10^5 kg/m^2 s$]



Low clouds response [-]



Wind stress [Pa] (vectors) and T2M (shading) [C] response



Conclusion & Discussion

- **Arctic Warming** (AW) teleconnections are investigated with **fully coupled model IPSLCM5**.

- **Two ensembles** with the **same SIE** but different **SIT** and **energy input** leads to different **AW**.

- Changes of the **water mass properties** in the North Atlantic and Nordic seas (Atlantification Arthùn et al.(2012), JCLI) associated with **shallower mixed layer** at the main convection site, **AMOC decreases** (Sévellec et al. (2017), NCC; Suo et al.(2017), ERL)

- **Atlantic tropical warming** might be due to both **atmospheric and oceanic contributions**. **Tropical Pacific cooling** appears as a results to sea-ice reduction, in contradiction with other results (Kang et al. (2011), Clim Dyn; Screen et al.(2018), NG)

- Arctic warming = SIE ? (method matters ?) (coordinated experiments PAMIP, Blue Action)

- AW ?→? Tropical Atlantic Warming ?→? Tropical Pacific cooling (Timmermann et al., (2007), J Cli; Cattiaux and Cassou (2013), J Cli; Martin-Rey et al. (2018), J Cli)

- 10 - 30 years. Different results for shorter or longer period ? (Liu et al. (2019), GRL)

This research was supported by the Blue-Action project (European Union's Horizon 2020 research and innovation programme, grant number: 727852)