Near-term and Large-scale Coupled Climate System Responses to Arctic Sea-ice Loss

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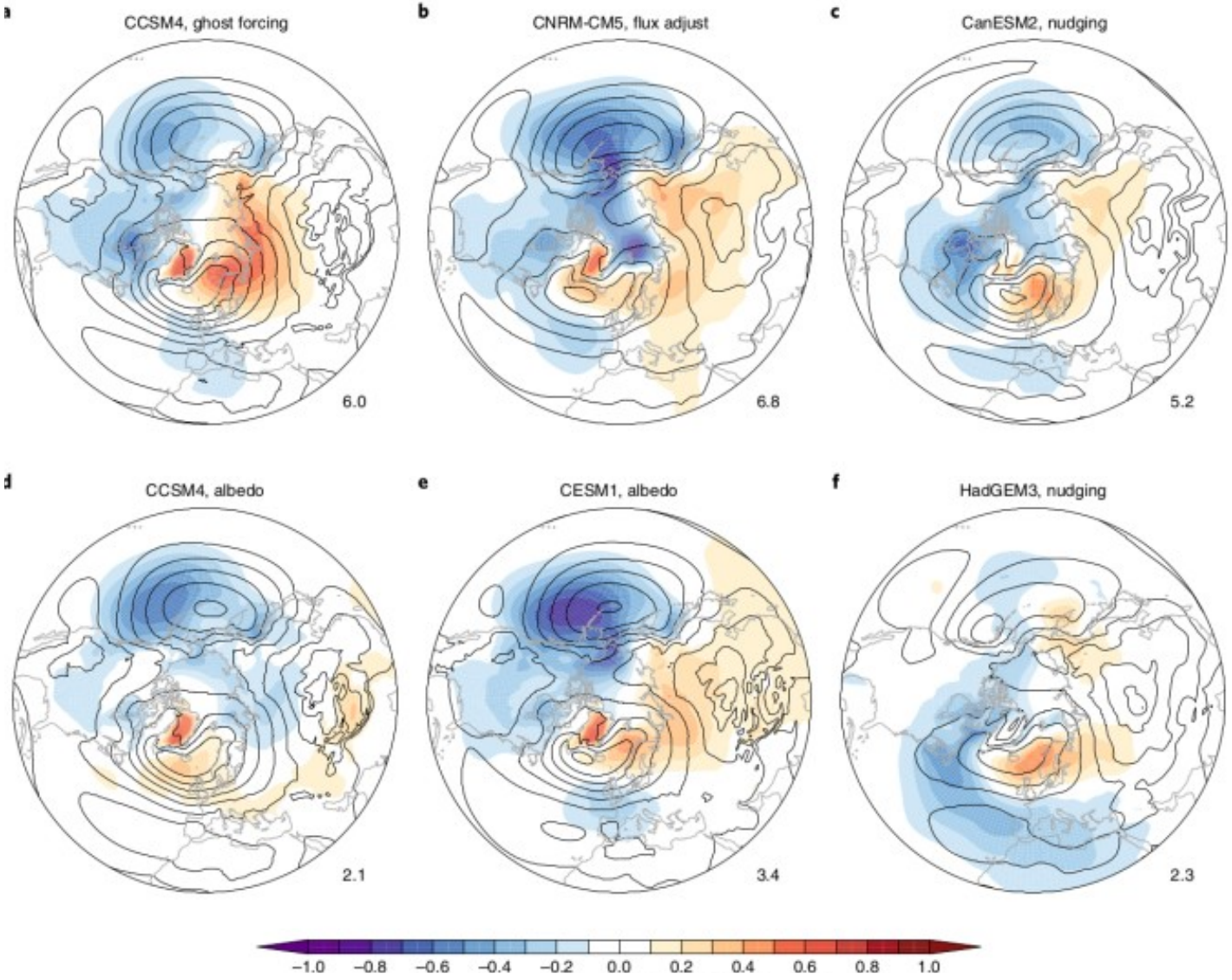
Potential impacts due to Arctic sea-ice melting on …

North Atlantic Oscillation

Observation (NAO-):
King et al., 2015
Garcia-Serrano et al., 2015
Simon et al., 2020

Atmosphere model (NAO-/NAO+/no NAO):
Magnusdottir et al. 2004,
Screen et al. 2014,
Seierstad et al. 2009

Coupled model (NAO-):
Deser et al., 2015
Blackport & Kushner, 2016 & 2017
Smith et al., 2017
Oudar et al., 2017
McCusker et al., 2017



SLP responses in boreal winter (hPa per 10^6 km^2 ice loss)

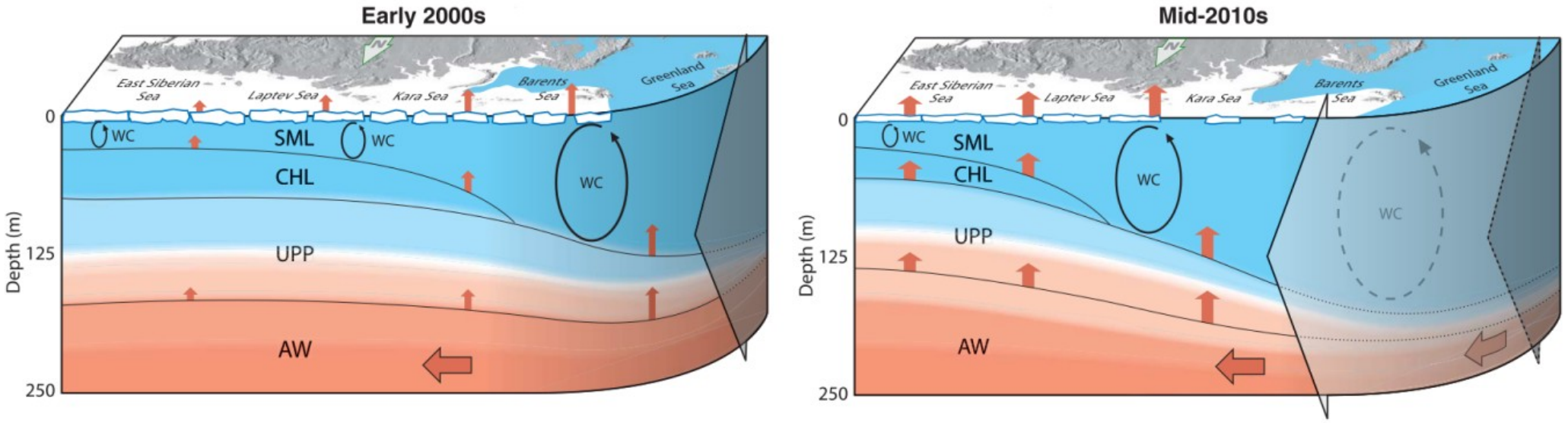
Screen et al., 2018

Potential impacts due to Arctic sea-ice melting on …

North Atlantic Oscillation

Atlantification

Arthun et al., 2012
Polyakov et al. 2017
Lind et al., 2018



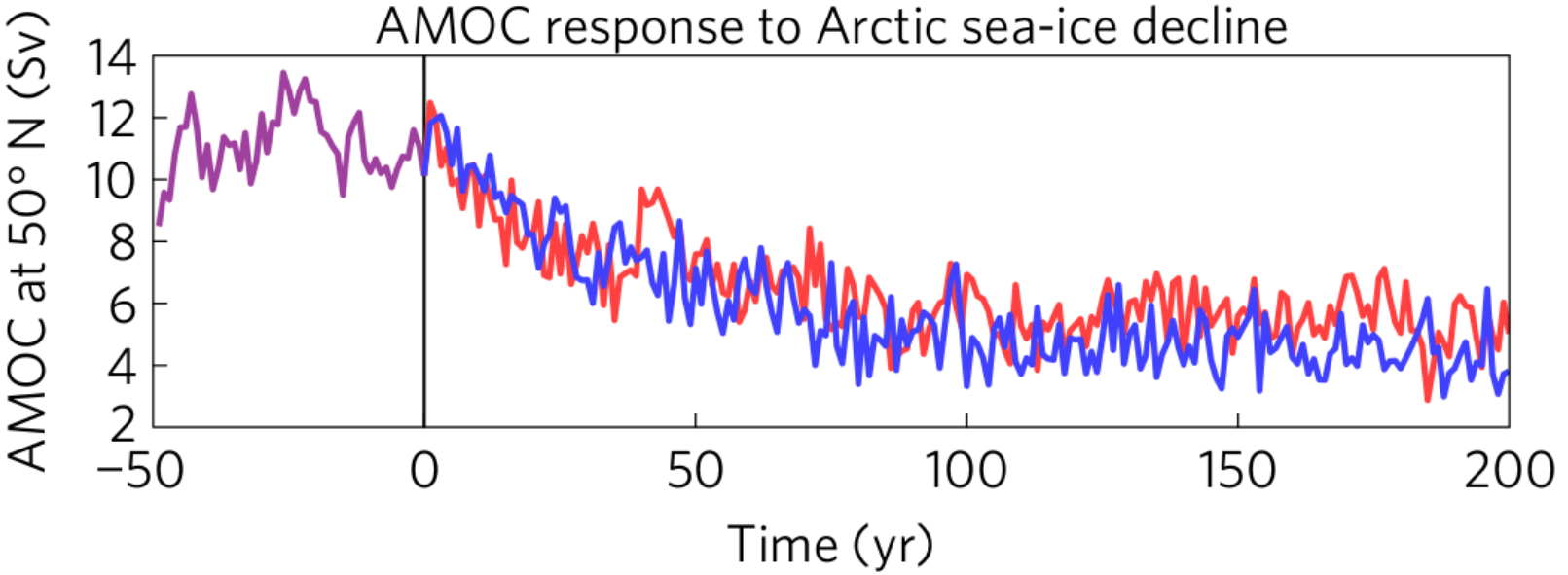
Polyakov et al., 2017

Potential impacts due to Arctic sea-ice melting on …

North Atlantic Oscillation

Atlantification

AMOC



Sévellec et al., 2017,
Suo et al., 2017
Liu and Fedorov, 2019
And many others

Sévellec et al, 2017

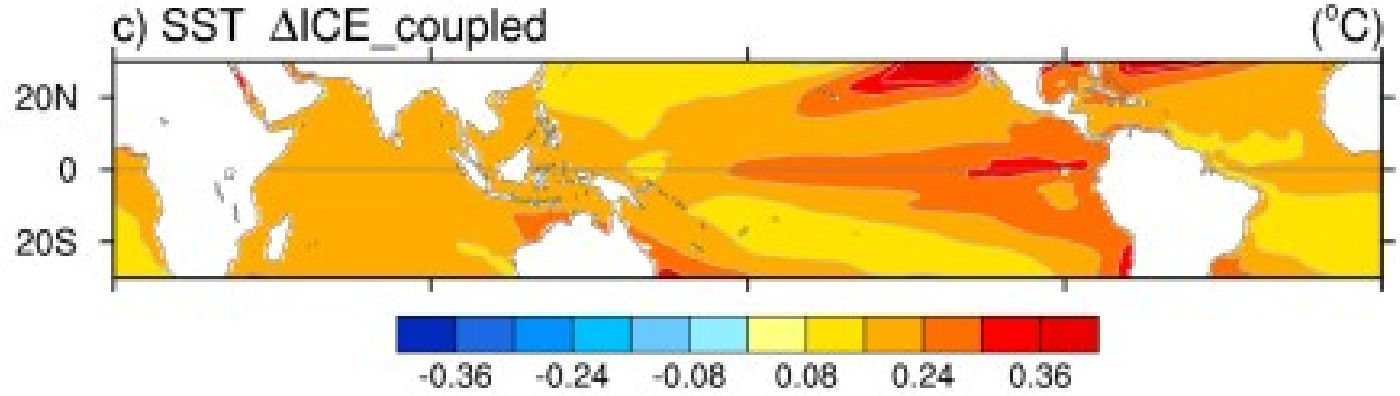
Potential impacts due to Arctic sea-ice melting on …

North Atlantic Oscillation

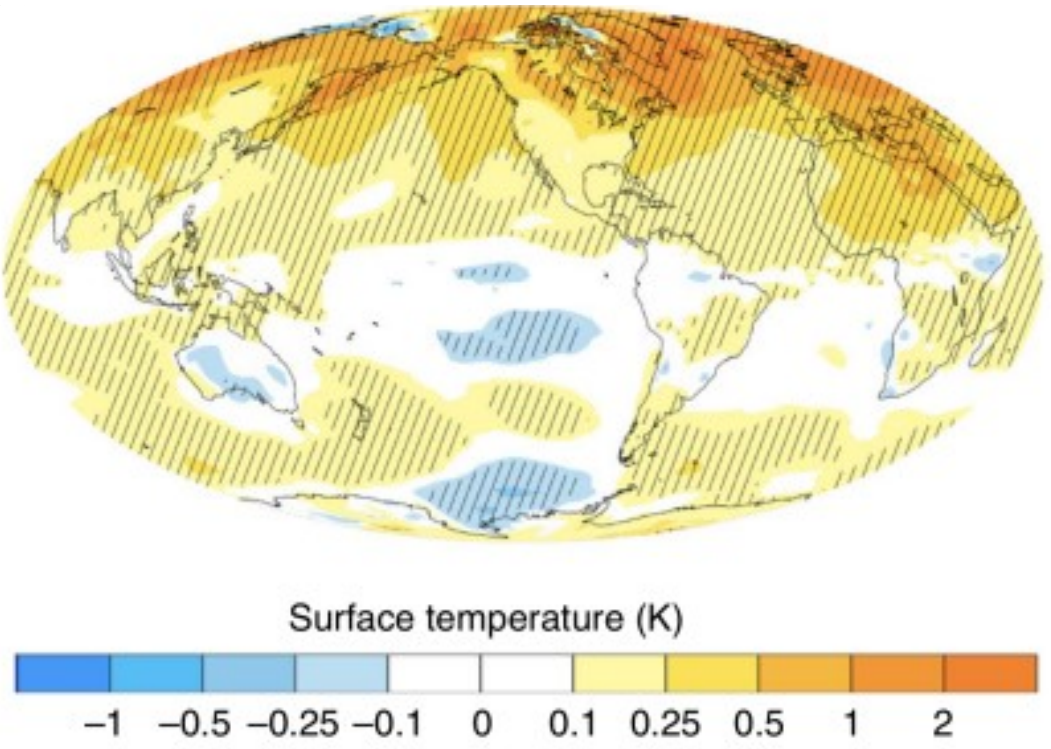
Atlantification

AMOC

Tropical Pacific



Deser et al, 2015



Cvijanovic et al. 2017

Objectives

Most previous coupled model studies

Large & Abrupt Arctic sea-ice loss

impact on equilibrium climate

using one method

In this study (IPSL-CM5 coupled model)

Small & gradual Arctic sea-ice loss

impact on transient climate

using two methods

Objectives

Most previous coupled model studies	**In this study (IPSL-CM5 coupled model)**
Large & Abrupt Arctic sea-ice loss	Small & gradual Arctic sea-ice loss
impact on equilibrium climate	impact on transient climate
using one method	using two methods

Does the methodology used to force the sea-ice matter ?

What are the local & remote transient climate responses to near-term Arctic sea-ice ?

Methodology

CTRL
(external forcing of year 2000)

RCP8.5
(average of 2035-2055 period
=+2°C warming / CTRL)

ALB
(Arctic sea-ice albedo reduction)

THCD
(Arctic sea-ice
thermal conductivity reduction)

30-years ensemble of 10 members

Methodology

Same external forcing
Same initial conditions

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(external forcing of year 2000)

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Same Arctic sea-ice area

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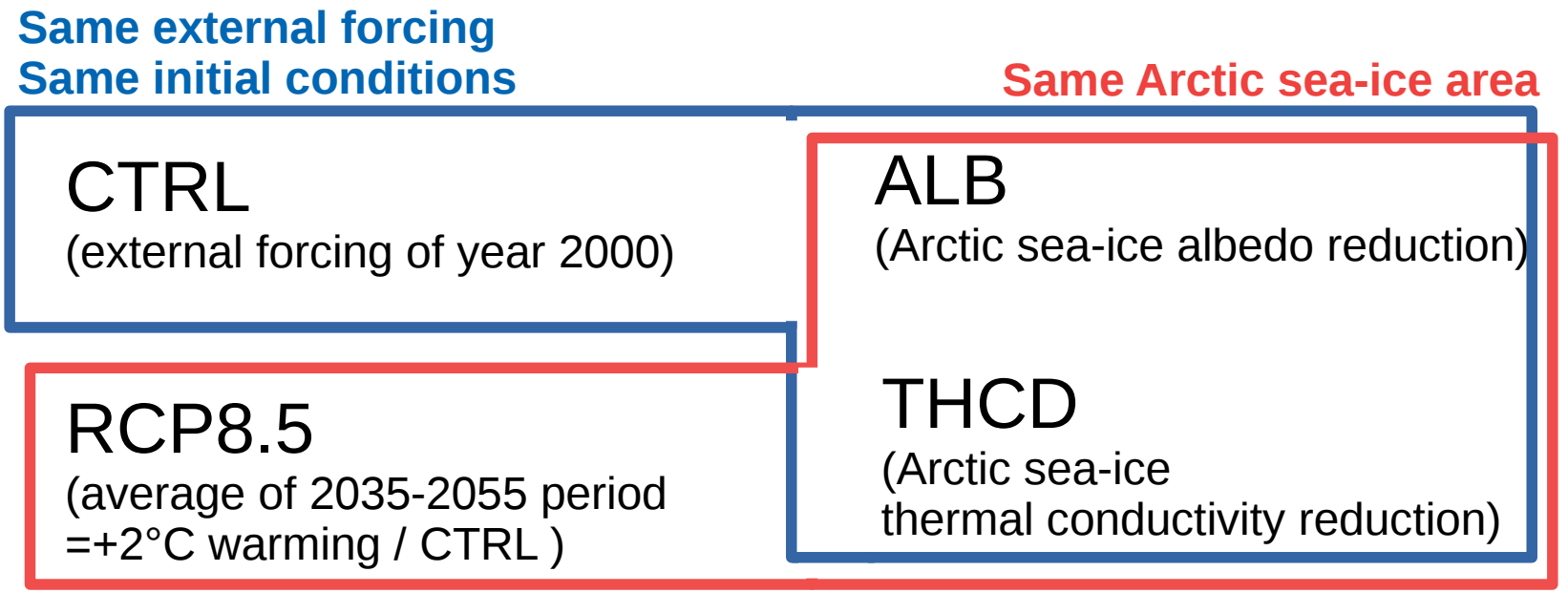

30-years ensemble of 10 members

Impact of near-term (period 2035-2055) Arctic sea-ice = **ALB (or THCD) – CTRL**

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Same Arctic sea-ice area

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(external forcing of year 2000)

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(Arctic sea-ice albedo reduction)

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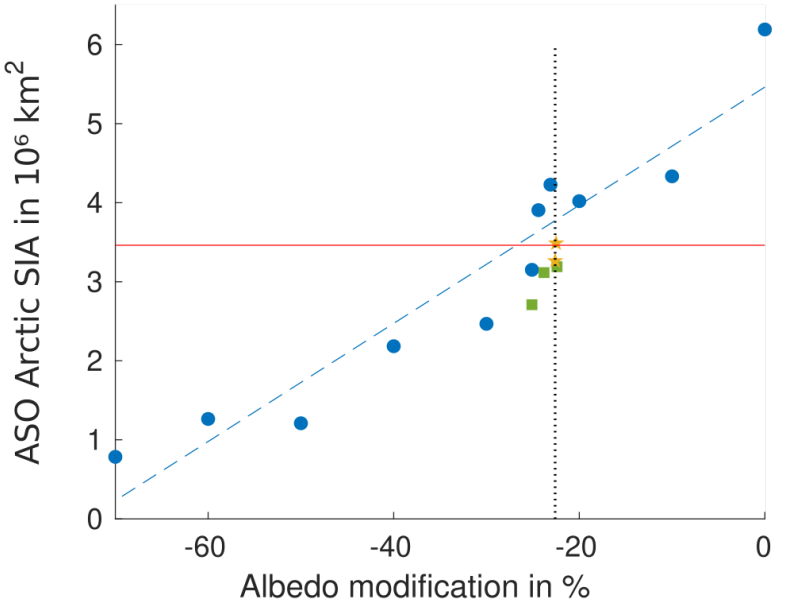
30-years ensemble of 10 members

Impact of near-term (period 2035-2055) Arctic sea-ice = **ALB (or THCD) – CTRL**

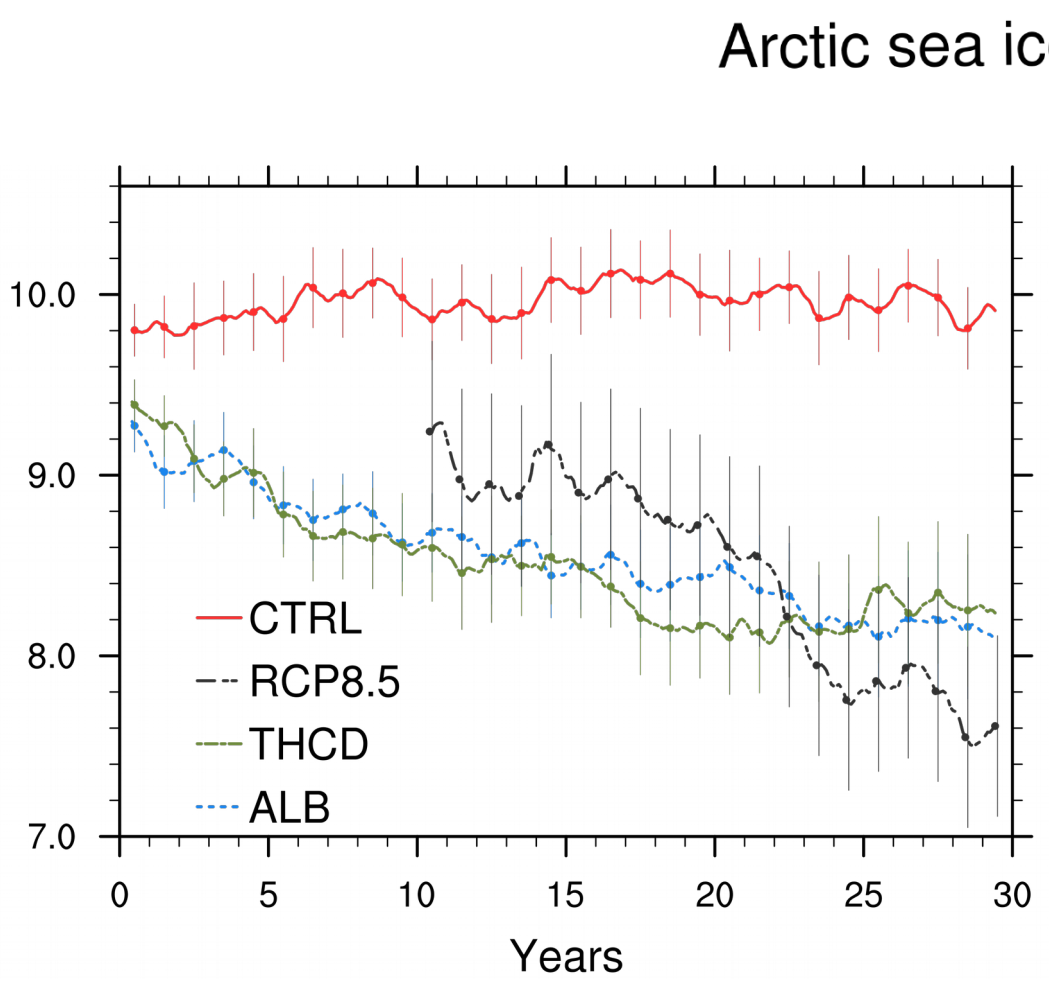
Which albedo (thermal conductivity) to obtain the 2035-2055 Arctic sea-ice (without changing GHG) ?

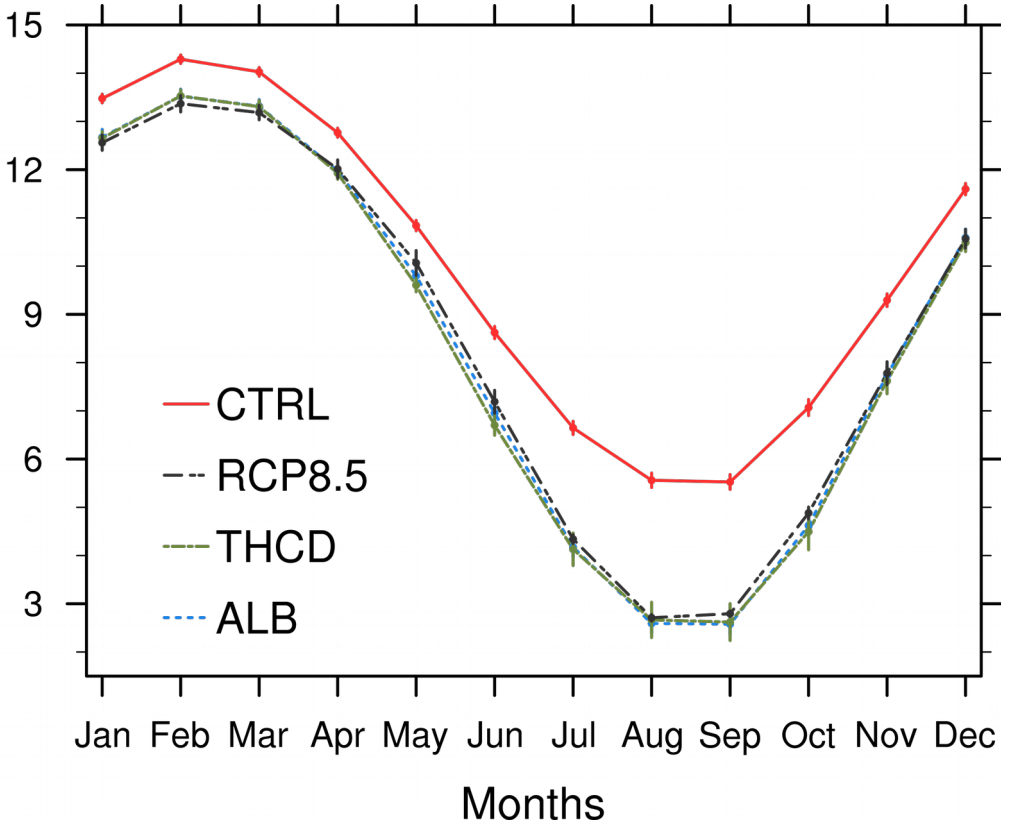
ALB = - 22.6% of sea-ice albedo / CTRL

THCD = -33 % of sea-ice thermal conductivity / CTRL

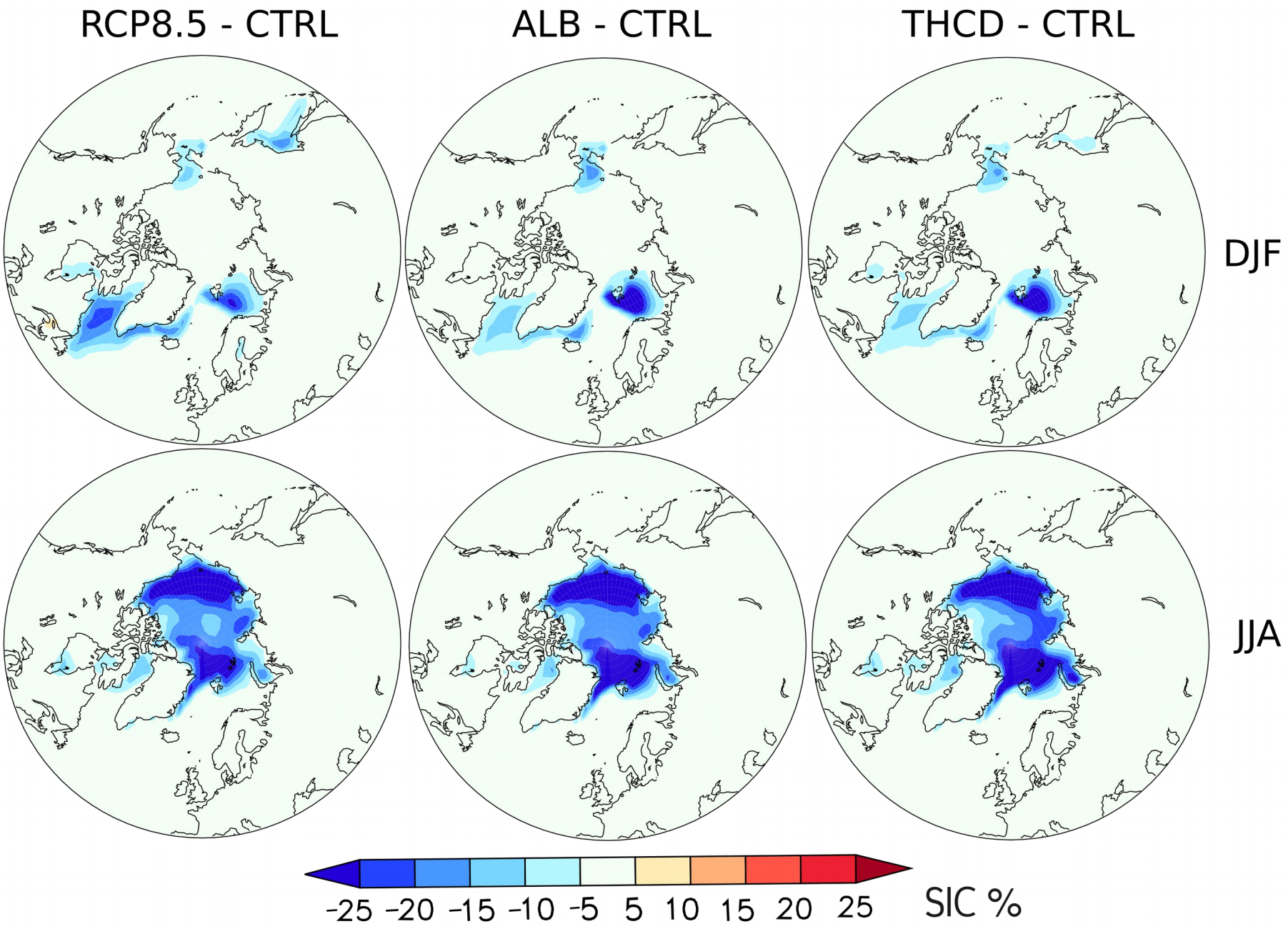


Similitude for RCP8.5, ALB, THCD



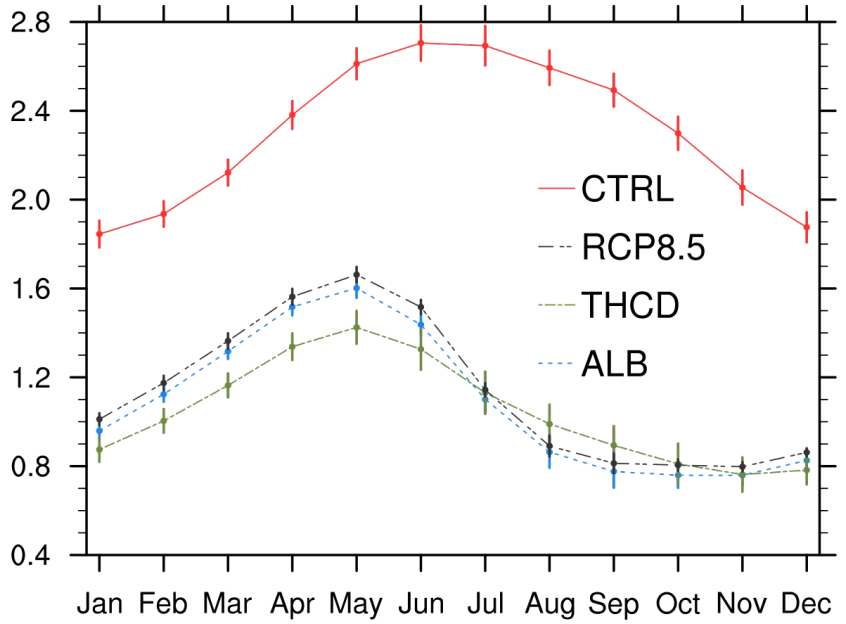


Similitude for RCP8.5, ALB, THCD

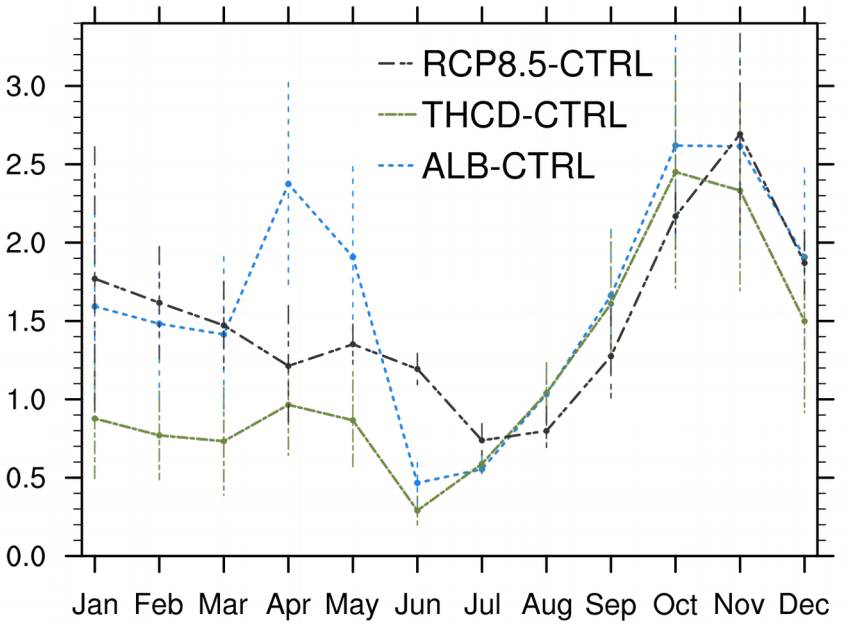


Differences for RCP8.5, ALB, THCD

Arctic sea-ice thickness [m]

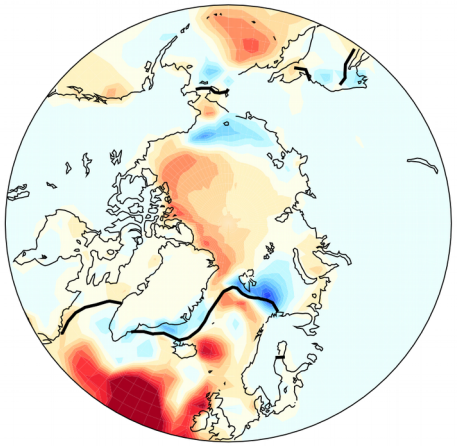


Air temperature at 2m (K) above 70°N

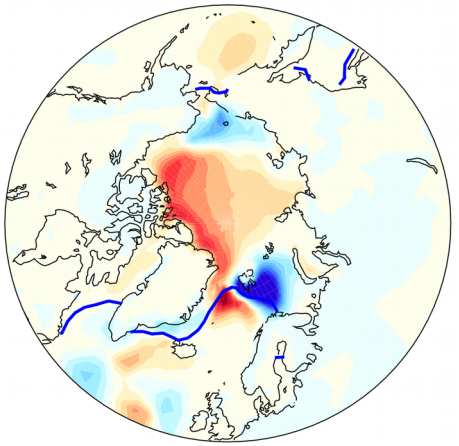


90 % confidence interval

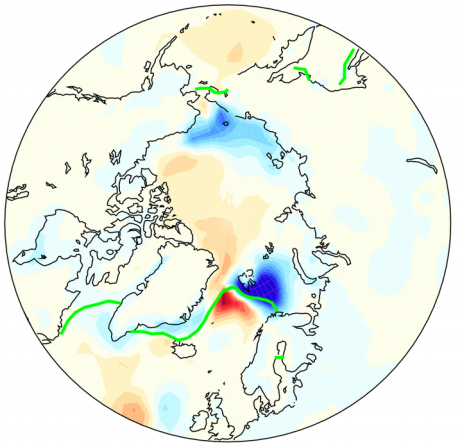
RCP8.5 - CTRL

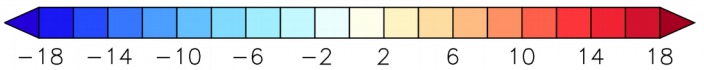


ALB - CTRL



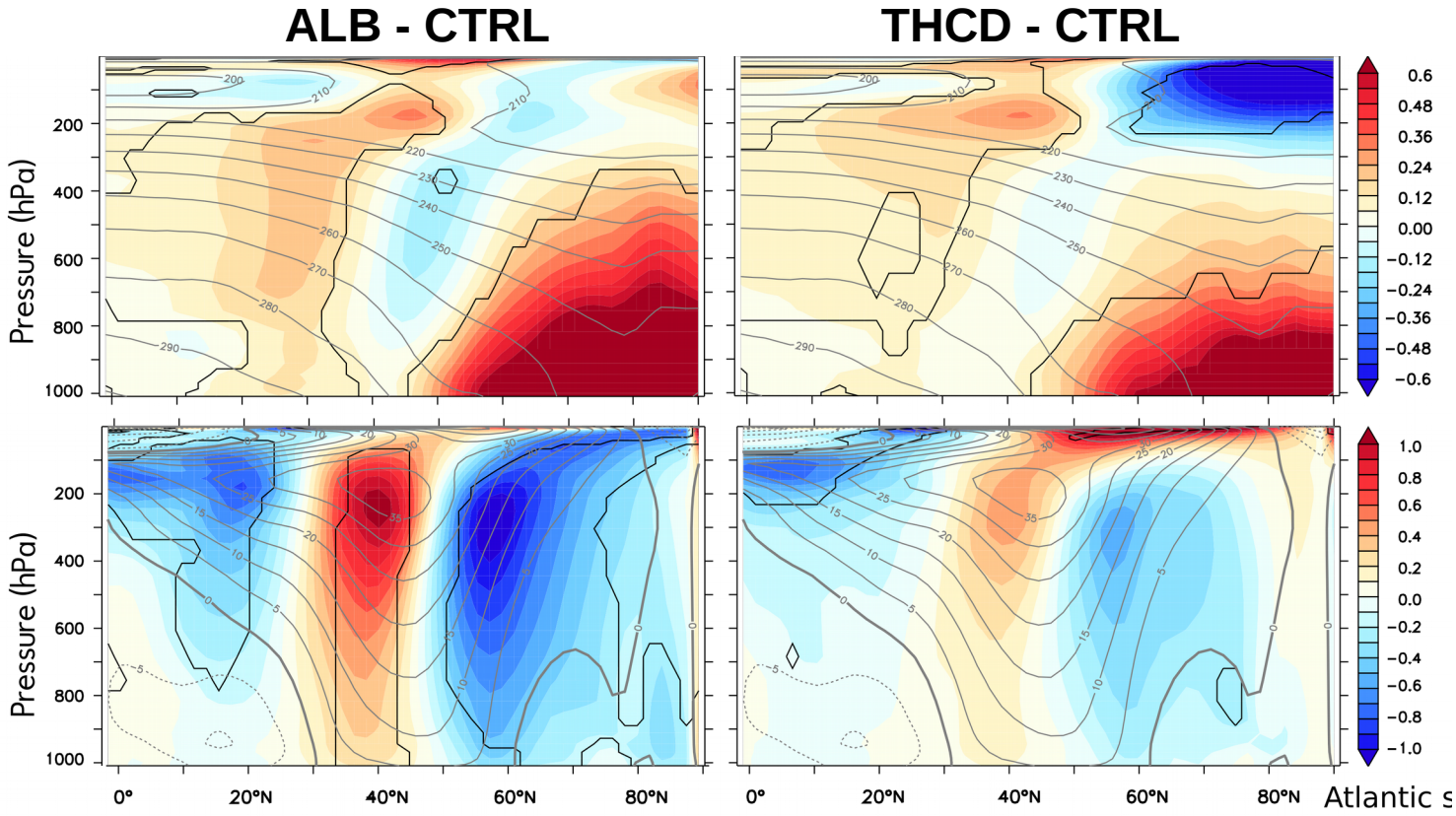
THCD - CTRL





Annual heat flux (W/m²)

Arctic and North Atlantic responses : atmosphere circulation

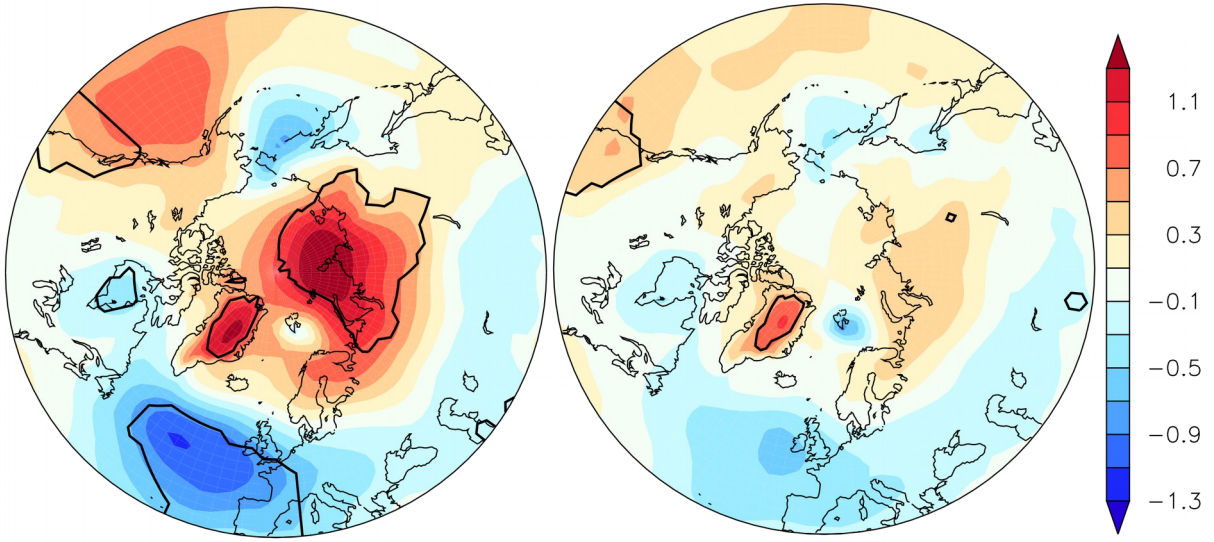


Atlantic zonal air Temperature response in DJF (°C)

Atlantic zonal winds response in DJF (m/s)

90 % confidence level (black line)

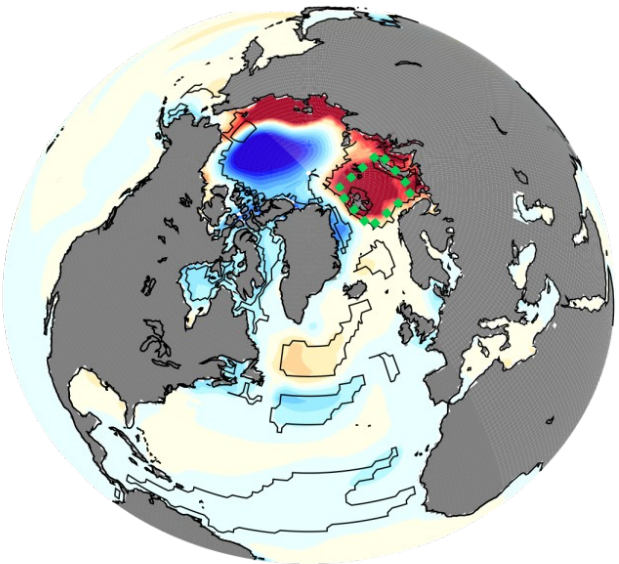
Climatology (grey line)



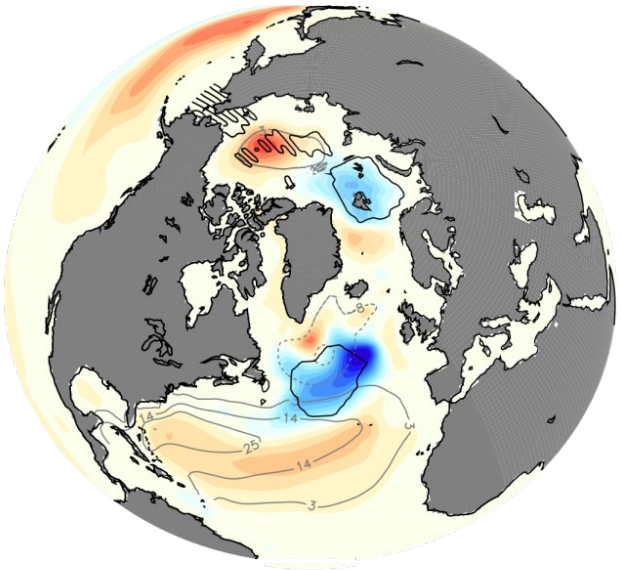
Sea-level pressure anomaly in DJF (hPa)

Arctic and North Atlantic responses : oceanic circulation

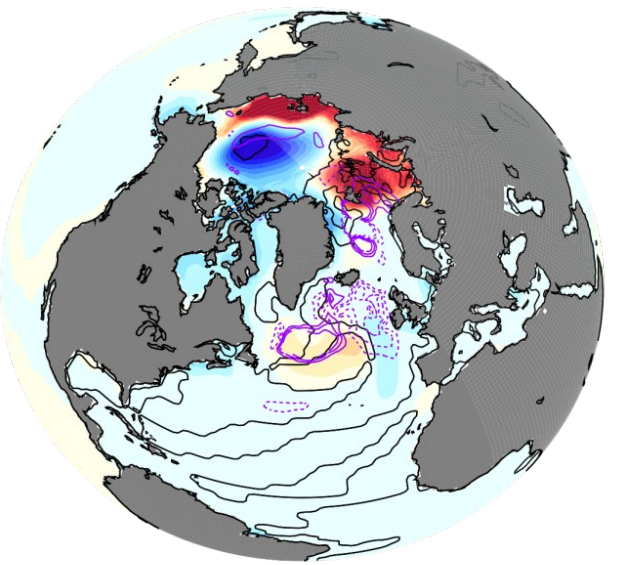
ALB - CTRL



0-300 m salinity (psu)



barotropic stream function (Sv)

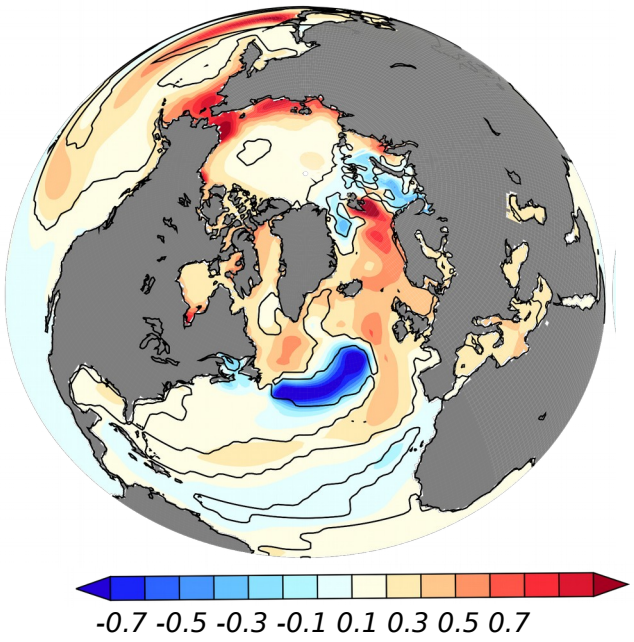


0-300 m density (kg/m^3)

90 % confidence level (black line)

Climatology (grey line)

MLD (purple line)



0-300m temperature (K)

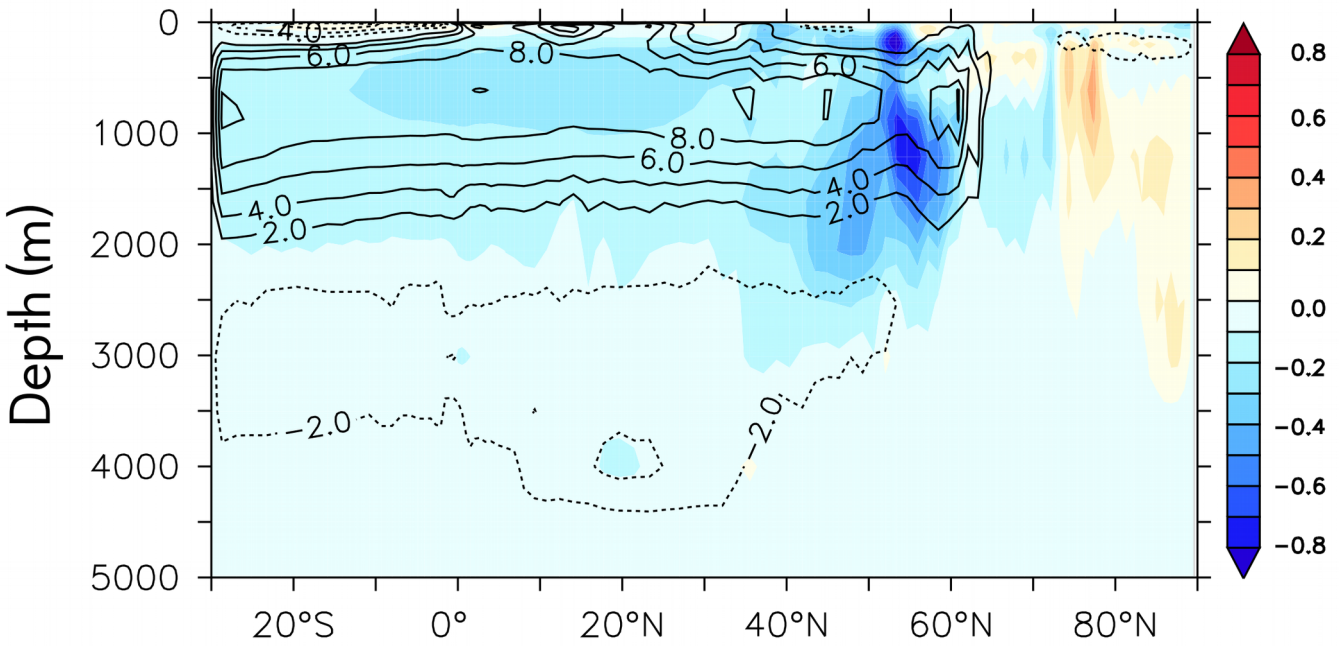
Intensification of Beaufort gyre
(less sea-ice export so freshens, Zhang et al.,2016)

Atlantification-like in Eastern Arctic and Barents :
Expansion of North Atlantic inflow
Weaker stratification

Fresh and cold anomaly in North Atlantic (50 °N):
(i) Atmospheric turbulent energy
associated with NAO-like
(ii) Subtropical Gyre shift south
& intensification of the Subpolar Gyre

Large-scale responses

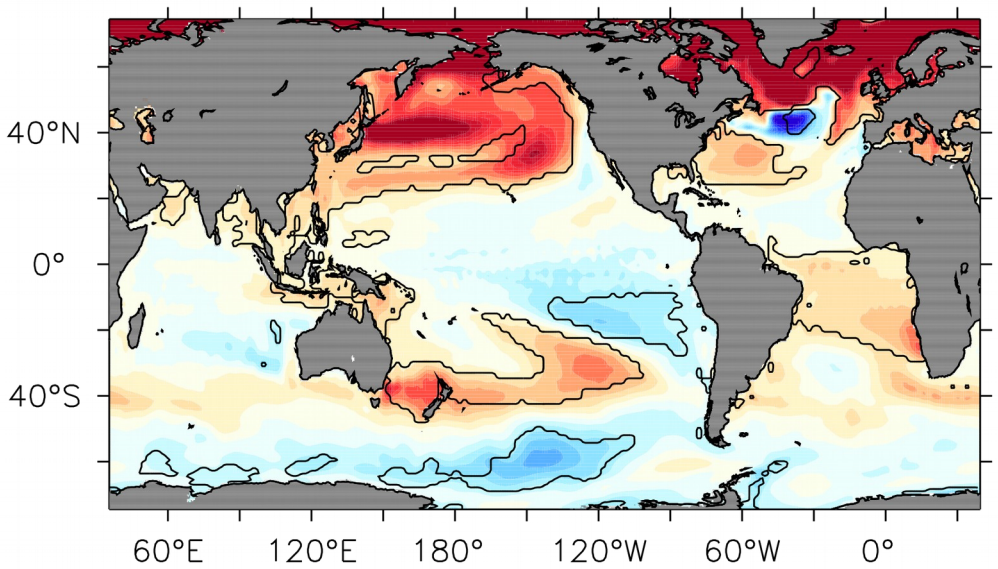
ALB - CTRL



Atlantic meridional Stream Function (shading) and its climatology (contour) in Sv

90 % confidence level (black contour)

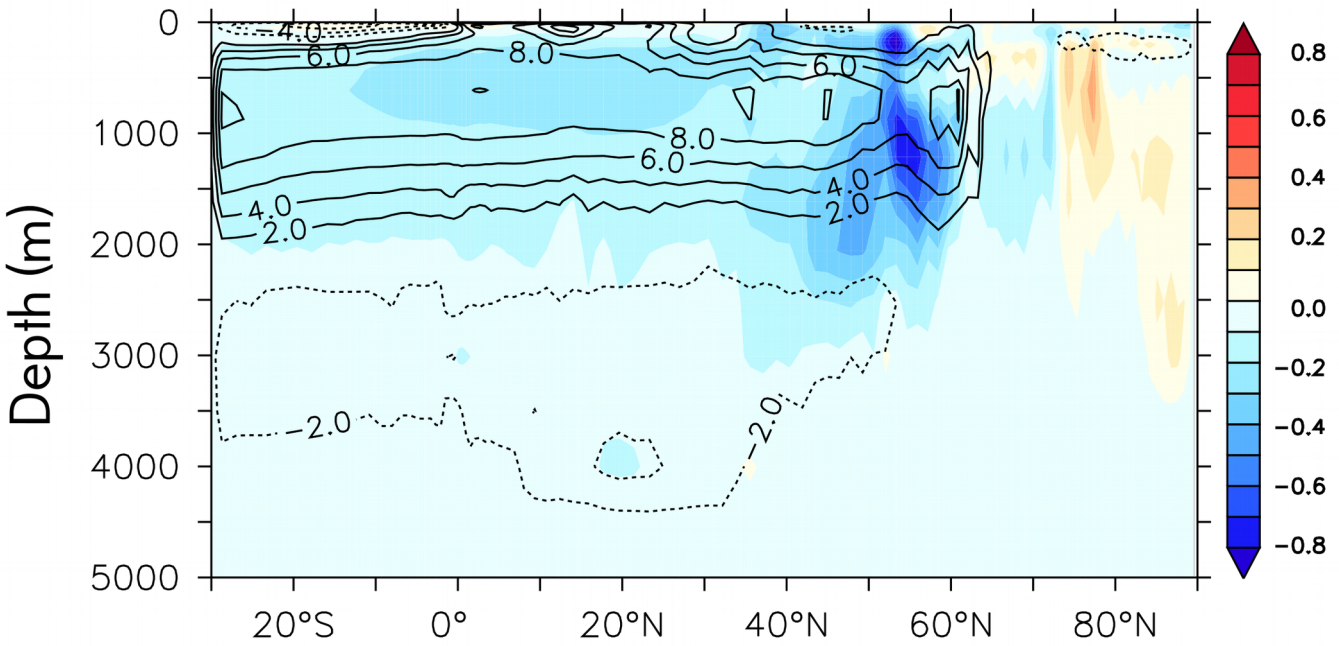
ALB - CTRL



Sea surface temperature anomaly (°C)

Large-scale responses

ALB - CTRL



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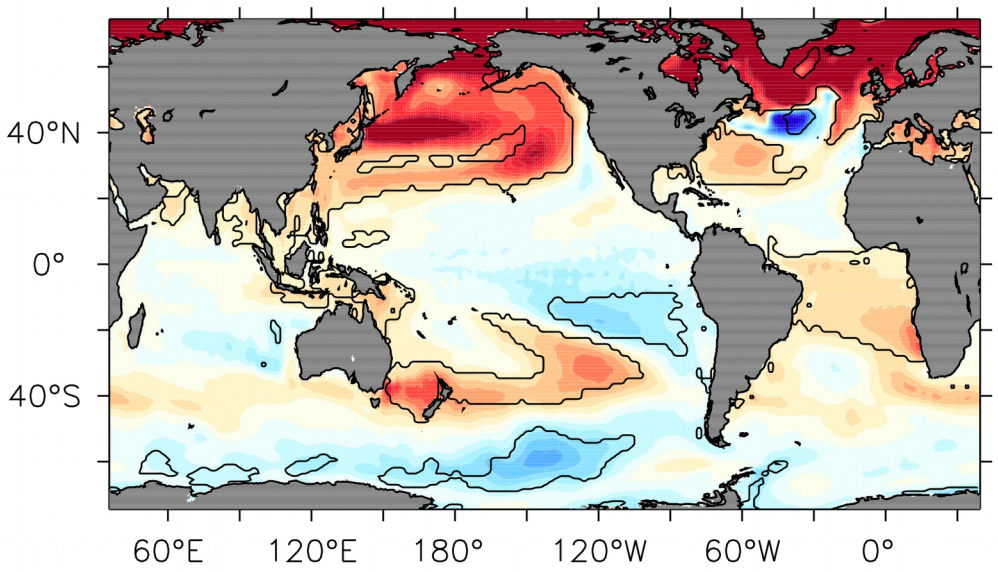

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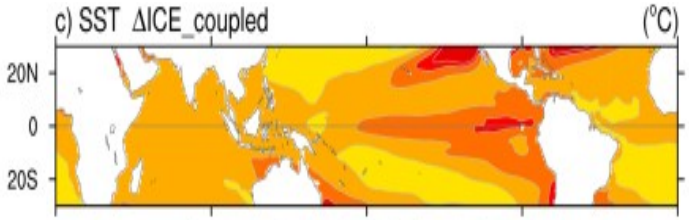
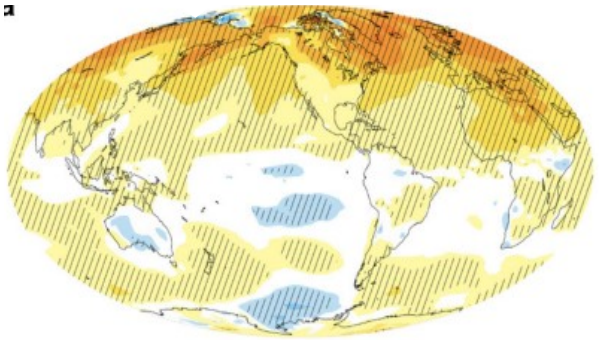


Deser et al, 2015



Cvijanovic et al. 2017

Large-scale responses

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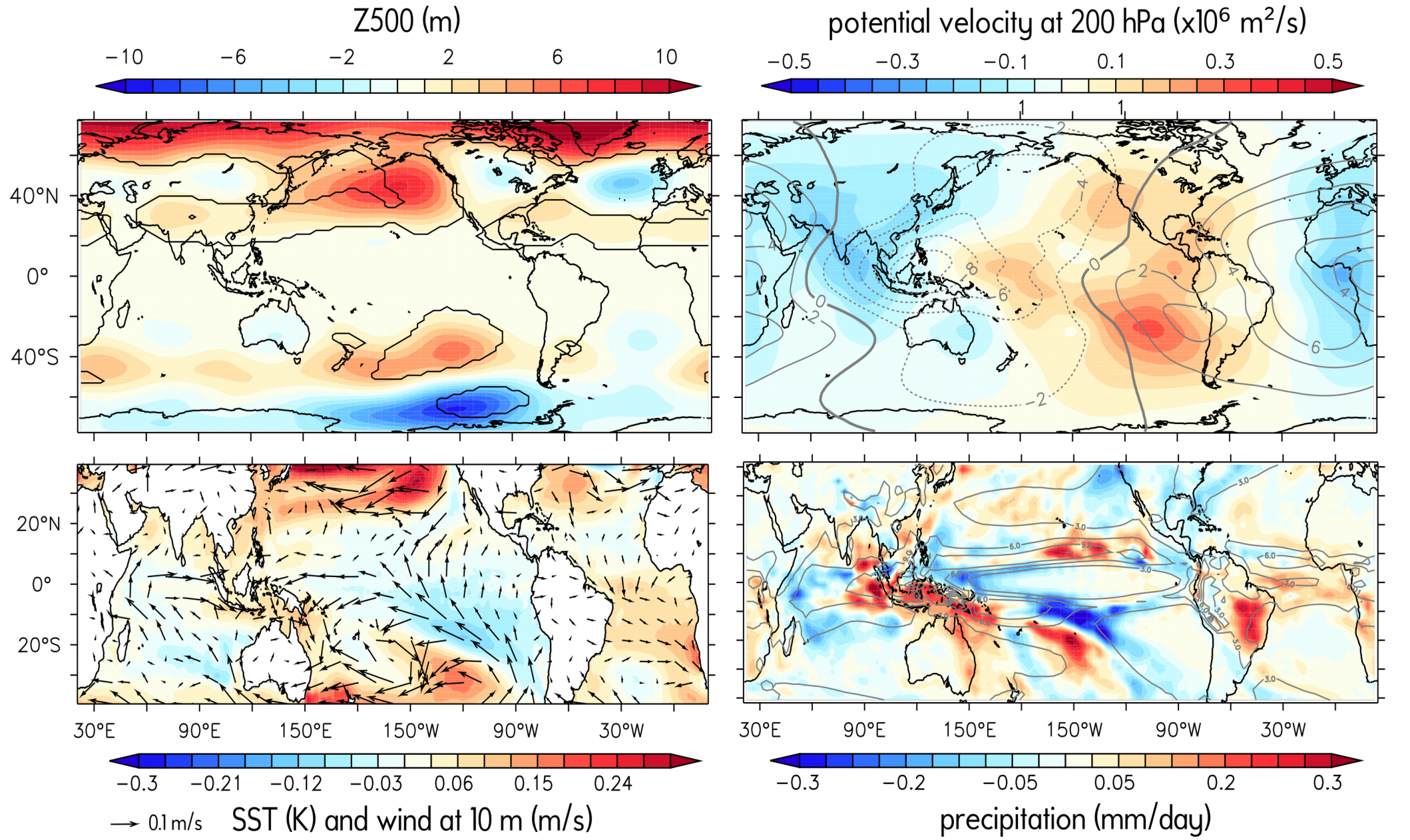


Conclusions

Does the methodology used to force the sea-ice matter ?

- Albedo method induces a larger Arctic warming, especially in spring.
- Thermal conductivity method leads to thinner sea-ice in winter/spring.
- Similar climate responses but with different magnitude, for a same Arctic sea-ice loss

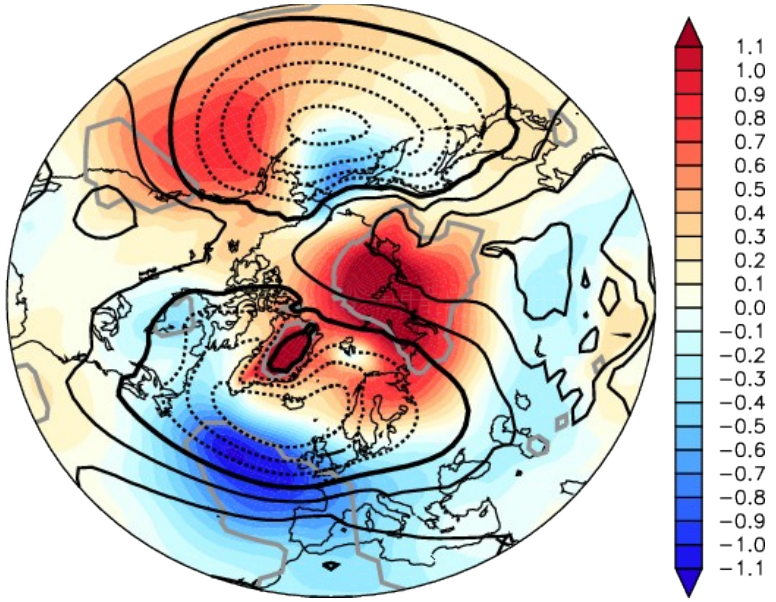
What is the local & remote transient climate responses to near-term and gradual Arctic sea-ice loss ?

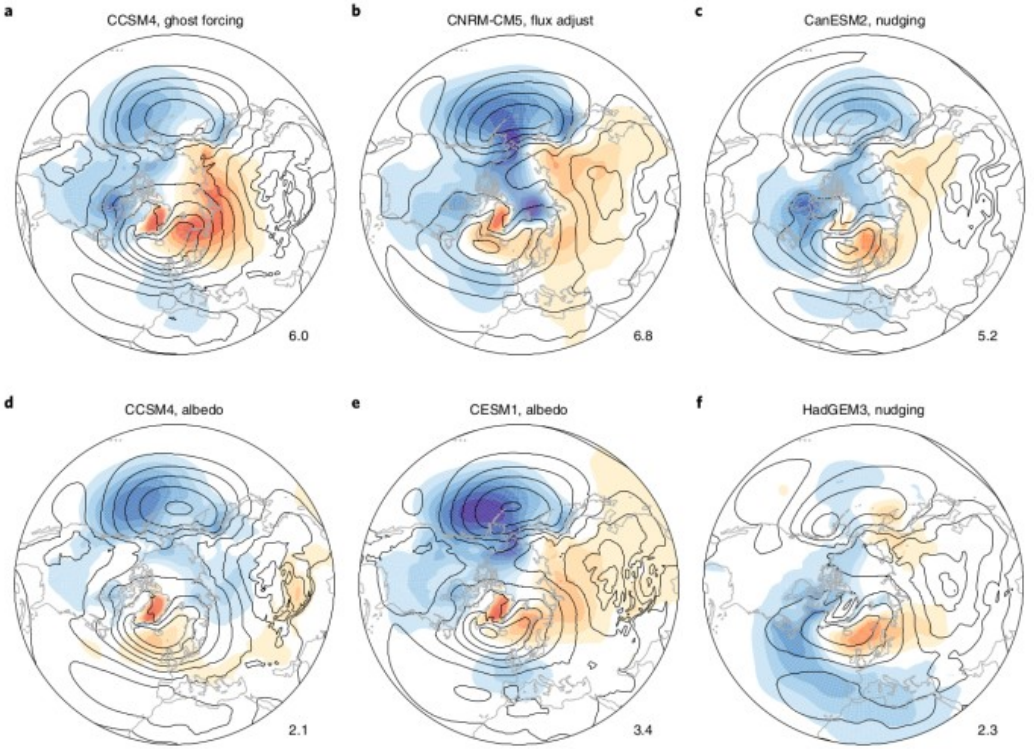
Arctic and North Atlantic : - negative NAO associated with a shift south of westerlies
- water mass properties changes: ”Atlantification” with larger North Atlantic inflow and weaker stratification
- AMOC decrease

Large-scale:
- South tropical Atlantic warming (Atlantic ITCZ shift south)
- Subtropical Pacific cooling (anticyclones North & South Pacific, Pacific ITCZ shift north)
- Shift west of Westerlies (rain in Brazil and dry NW America)

Discussions

Coupled responses to Arctic sea-ice melting show some robust aspects (AMOC weakening, negative NAO-(like)) but link with Pacific is not.





→ need to assess those links in coordinated framework

To be submitted soon : Simon et al., “Transient climate response to near-term Arctic sea-ice loss”

Thank you for your attention

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