# Climate influence of sea-ice and its link with the Pacific and Atlantic Ocean

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*Ongoing work*

# Climate impacts of sea ice variability

- Sea ice variability over the Barents and Kara (BK) Seas in fall has a negative NAO-like signature in winter (King et al. 2015; Garcia-Serrano et al. 2015, and *many others*),
  - -> through tropospheric pathway
  - -> through stratospheric pathway

- Snow cover variability in fall is tightly linked to BK sea ice, with snow cover having the dominant effect on the atmosphere (Gastineau et al. 2017).

## Outline

1. Observational analysis of the sea ice influence
2. Sea-ice influence in atmosphere-only experiments
3. Climate response to sea ice melting, through ocean-atmosphere feedbacks.

# Observational analysis

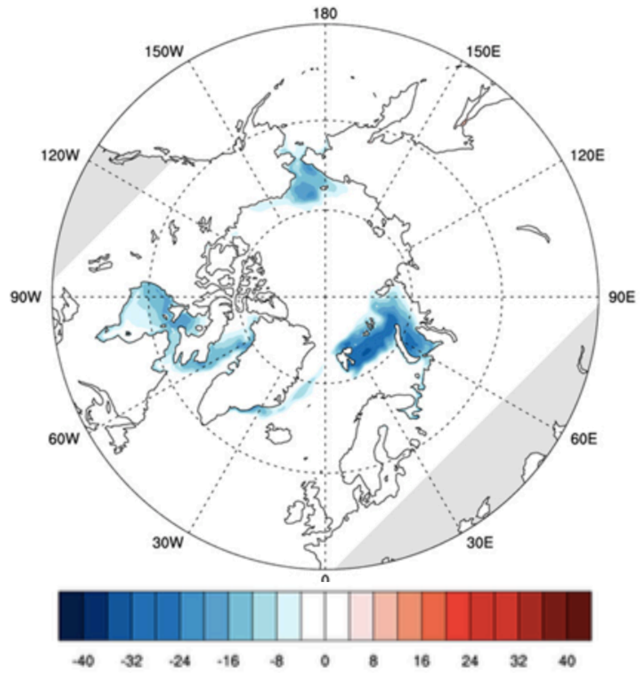
<u>Datasets</u>:

- Observation 1979-2017 from : (1) ERA-Interim
  (2) NOAA/NSIDC passive microwave sea ice concentration
  (3) NOAA/NCDC snow cover (Comiso, 2012)

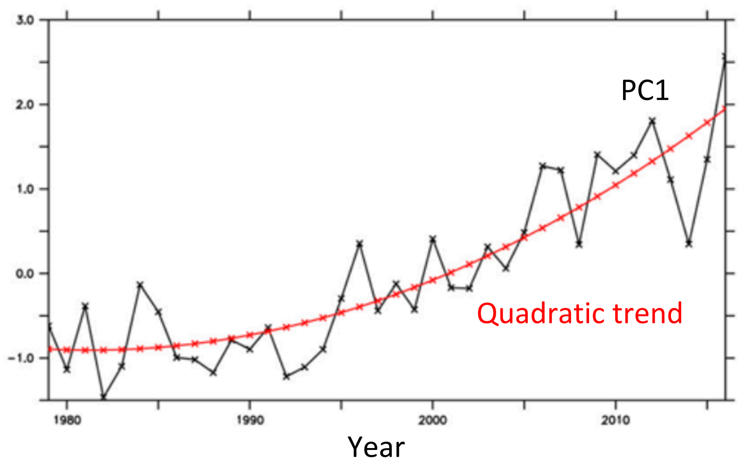
<u>Methods</u> :

- EOF of SIC data,
- Detrended PC1, called dPC1,
- Linear regressions,
- Statistical significance established using t-test, and field significance using false discovery rate (Wilks, 2016).

EOF1
SIC (%)
November

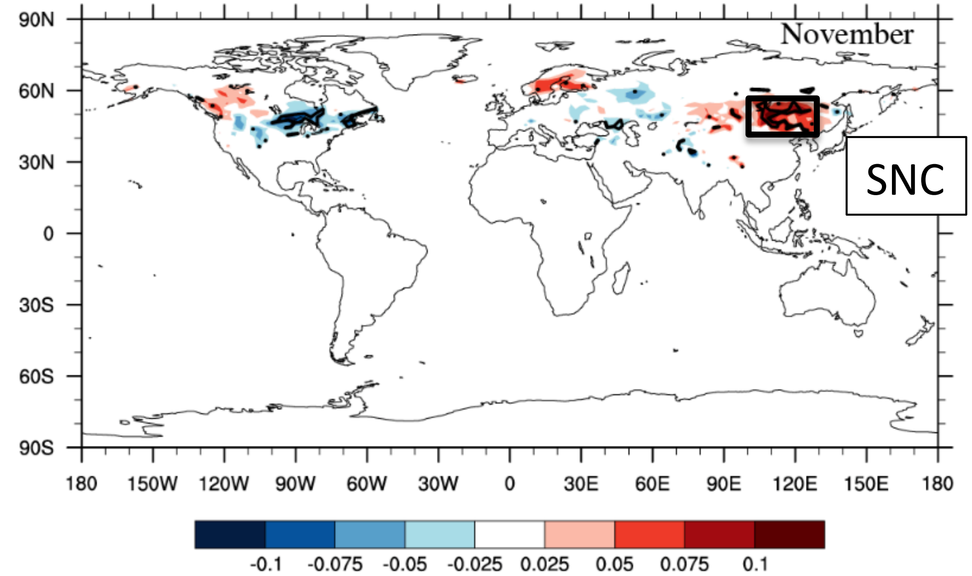



dPC1 = PC1 – Quadratic trend



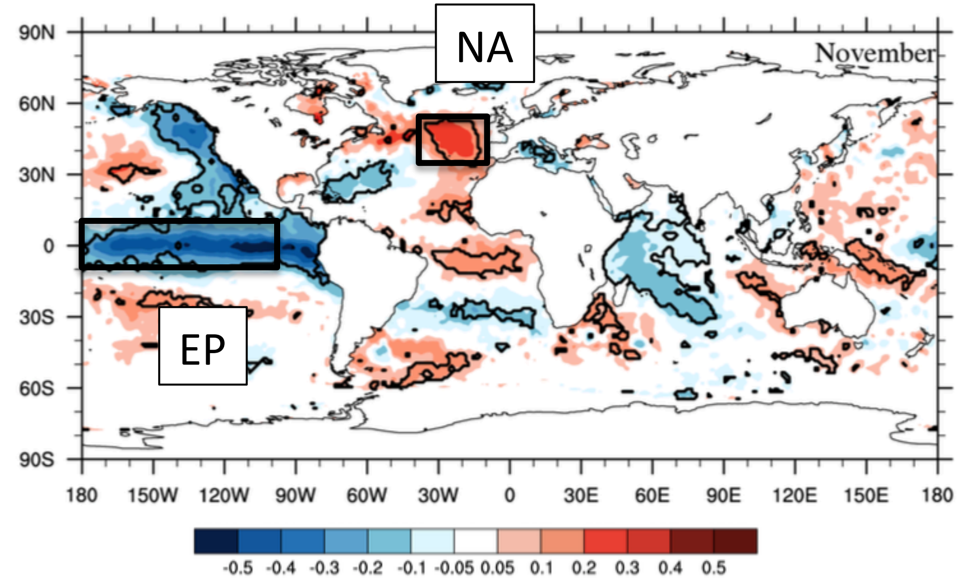
# Simultaneous forcing

Snow cover (in %)




- Positive snow cover anomalies over eastern Eurasia
- Negative snow cover anomalies over NE North America.

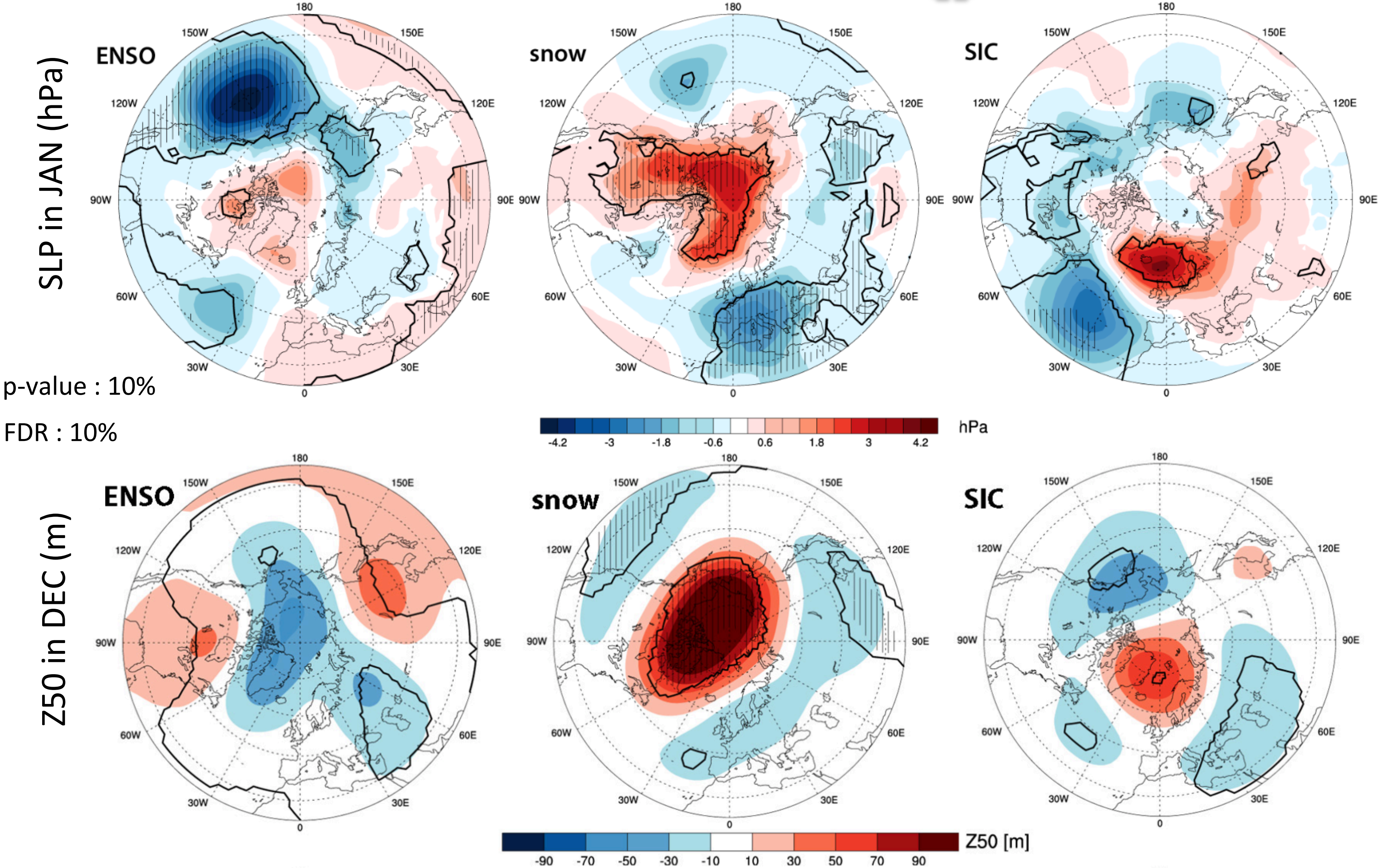
SST (in K)




- Negative SSTA in Eastern Pacific (La Niña-like)
- Positive SSTA in NE Atlantic

# Multiple regression of SLP and Z50

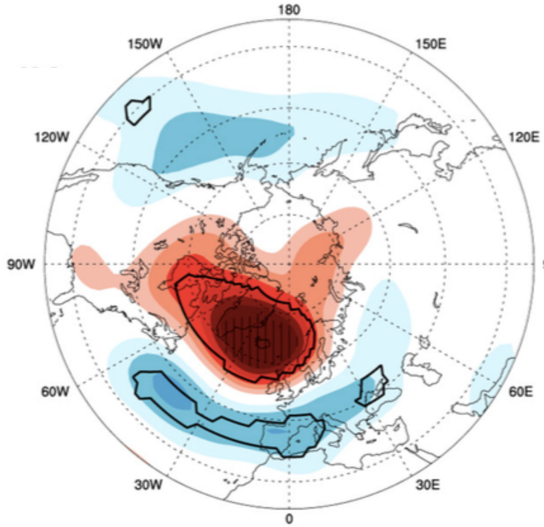
$$SLP(t) = a + b\,EP(t) + c\,SNC(t) + d\,NA(t) + e\,dPC1_{NOV}(t)$$



# Late Winter sea ice influence

Multiple regression $dPC1_{DEC}$

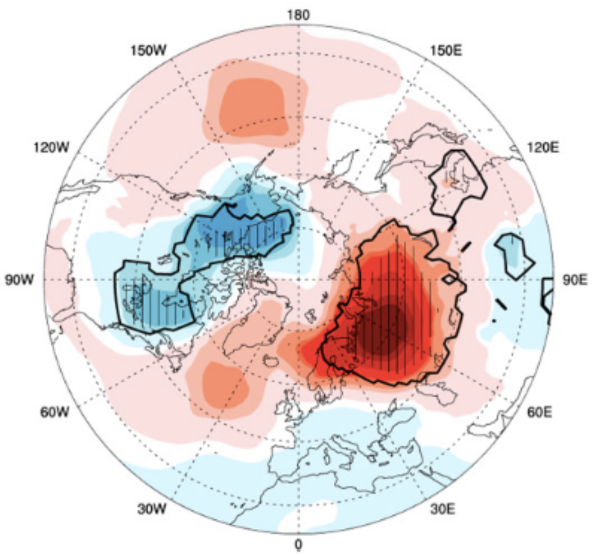
SLP in JAN (hPa)



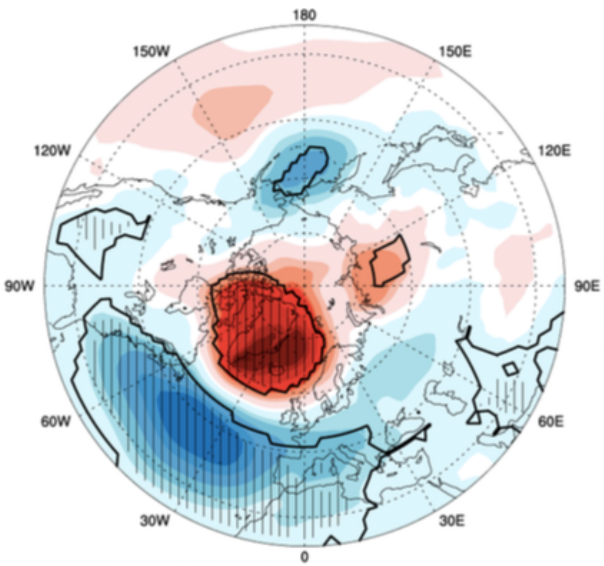

- Influence of winter sea ice more significant when using multiple regression (typically 2 or 3hPa),
- No stratospheric anomalies found (not shown).

Multiple regression $dPC1_{JAN}$

SLP in FEB (hPa)




SLP in MAR (hPa)




# Blue-Action Experiments

### Experimental Protocol

Atmosphere-only simulations :

- CMIP6 external forcing,
- Daily varying SST and SIC (from HadISST2.0.0) from 1979 to 2014,
- Nine different AGCM (from 10 to 30 members).

Four different experiments following:

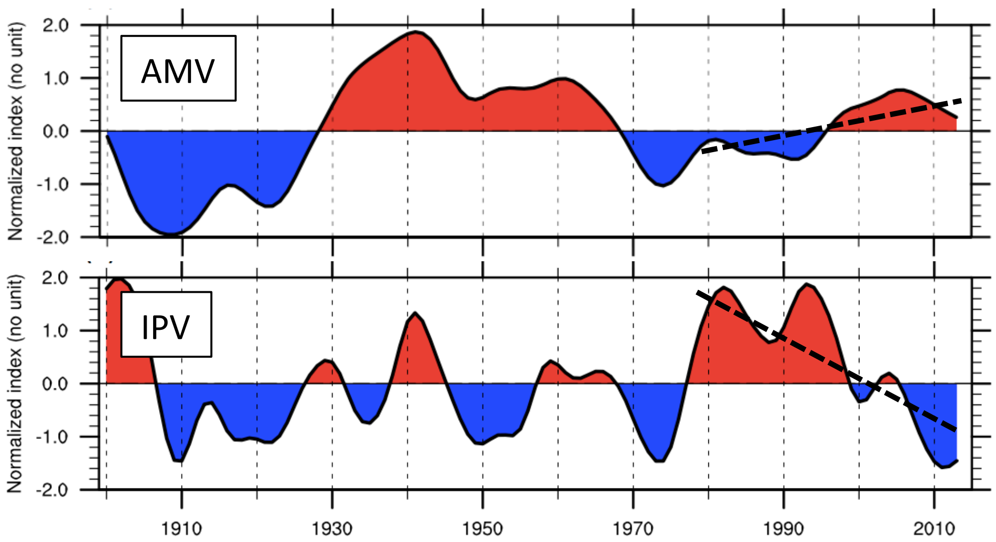
- **ALL** : SST and SIC vary (AMIP-like).
- **NoSIC** : SST varies, but SIC fixed to a climatology,
- **NoIPV** : SST and SIC vary, but IPV (*Interdecadal Pacific Variability*) removed,
- **NoAMV** : SST and SIC vary, but AMV (*Atlantic Multidecadal Variability*) removed.

### AMV and IPV estimation from DCPP-C

1. Estimation of the forced signal by signal-to-noise maximizing EOF (Ting et al. 2009)

2. From the residual SST :

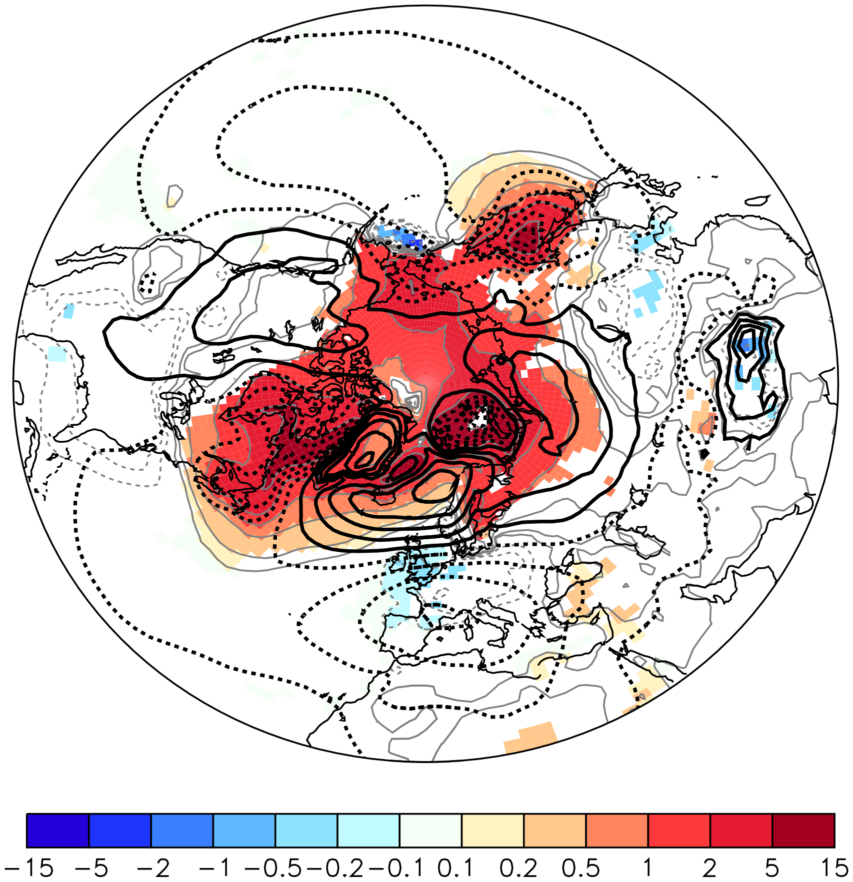
- AMV : Atlantic SST 0°N-60°N, low pass 10-yr,
- IPV : PC1 of yearly Pacific SST (40°S-60°N), low pass 13-yr.




From Boer et al. 2016

# Influence of sea-ice on 1979-2014 DJF trend

**ALL** minus **NoSIC**
T2m (in K dec$^{-1}$, color) and SLP (CI 0.4 hPa dec$^{-1}$, contours)




Mean of 5 models:

- CAM5 (NorESM) low-top
- CAM5 (WACCM) high-top
- LMDZOR (IPSL)
- CAM5 (CMCC)
- IFS (EC-Earth)

*… 4 other models to be included…*

Pattern somehow in agreement with observation:
-> SLP dipole over North-Atlantic (negative NAO-like)
-> Ural blocking, negative NPO, and negative SLP over sea-ice retreat.

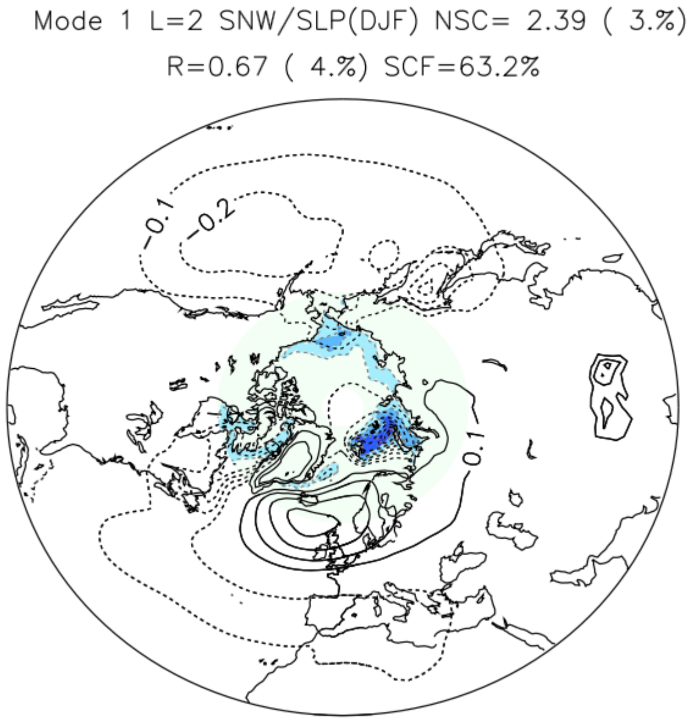
Similarity and differences with Ogawa et al. (2018).

# Interannual Variability

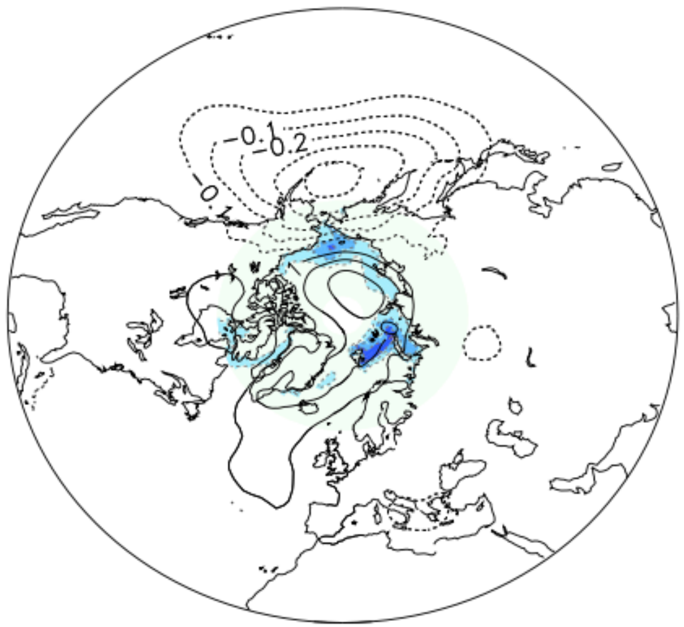
Atmospheric anomalies decomposition:

$$X(m,e,t) = \boxed{X_{MM}(t)} + \boxed{X_{EM}(m,t)} + X_{res}(m,e,t)$$

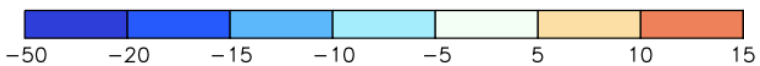
MCA between DJF $SLP_{MM}$ (in hPa) of ALL minus NoSIC and OND SIC (in %)




Same, but for $SLP_{EM}$
Mode 1 (SCF=32%)



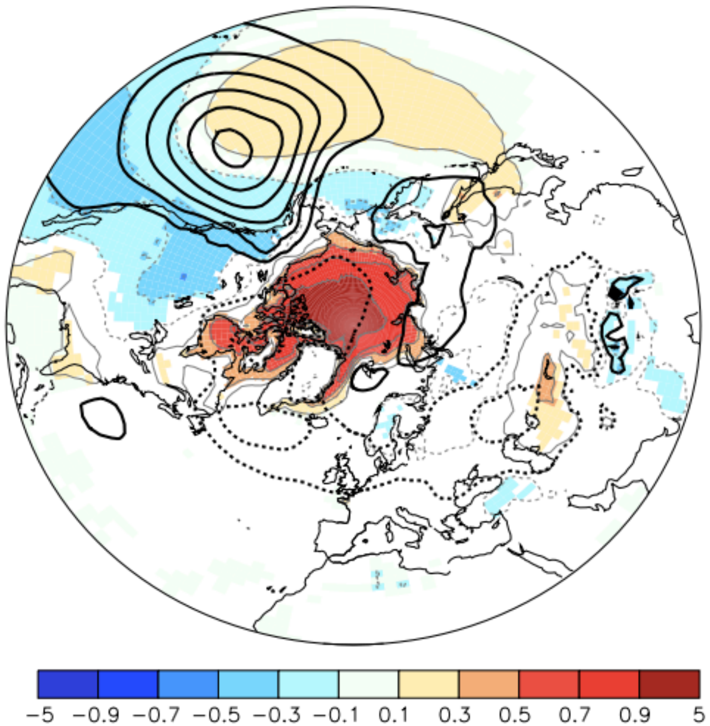

=> About 0.5 hPa



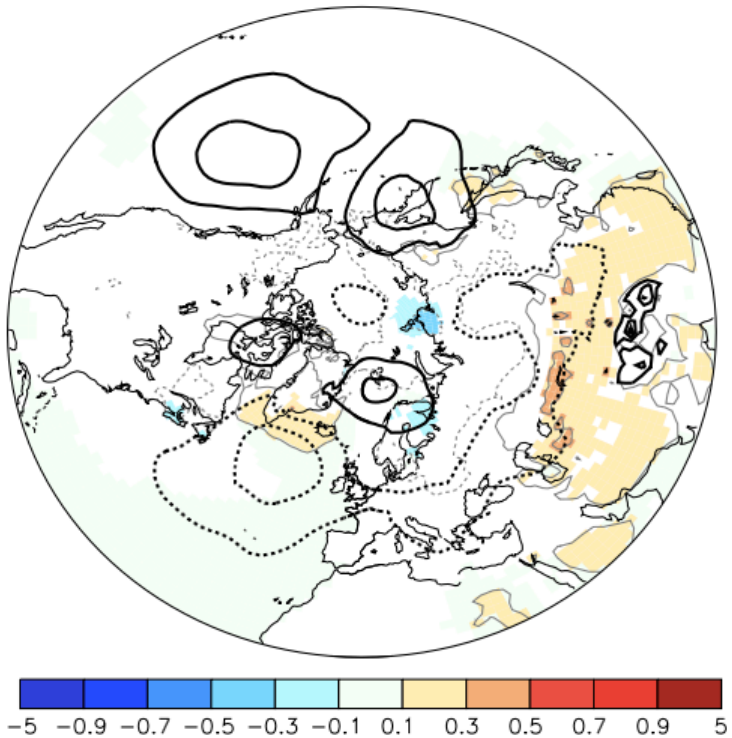
# Role of decadal SST variability

T2m (in K/dec, color) and SLP (CI: 0.1 hPa/dec, contours), LMDZORv6-only

**ALL - NoIPV**




**ALL - NoAMV**




- Polar amplification strongly modulated by IPV (and AMV in some models)
  *-> How robust is this signal among models?*

# Coupled model response

**Method:**

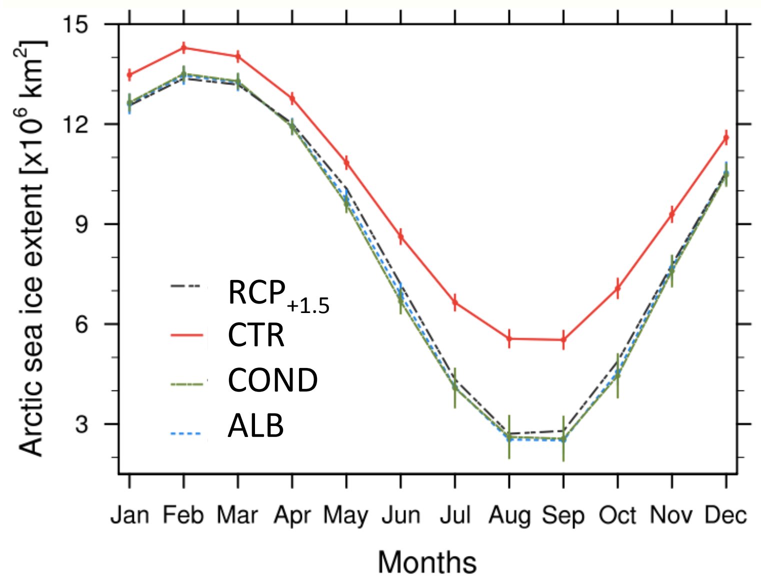
Model: IPSLCM5A2 (3.7°x2.5°L39)

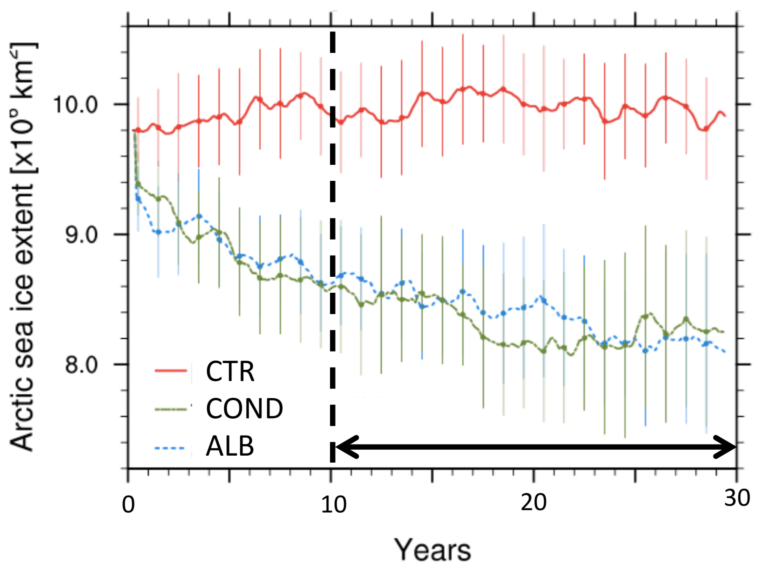
30-yr experiments (10 members):

- **CTR**: present-day control
- **ALB**: reduction (-22.6%) of SI albedo
- **COND**: reduction (-33%) of SI thermal conductivity

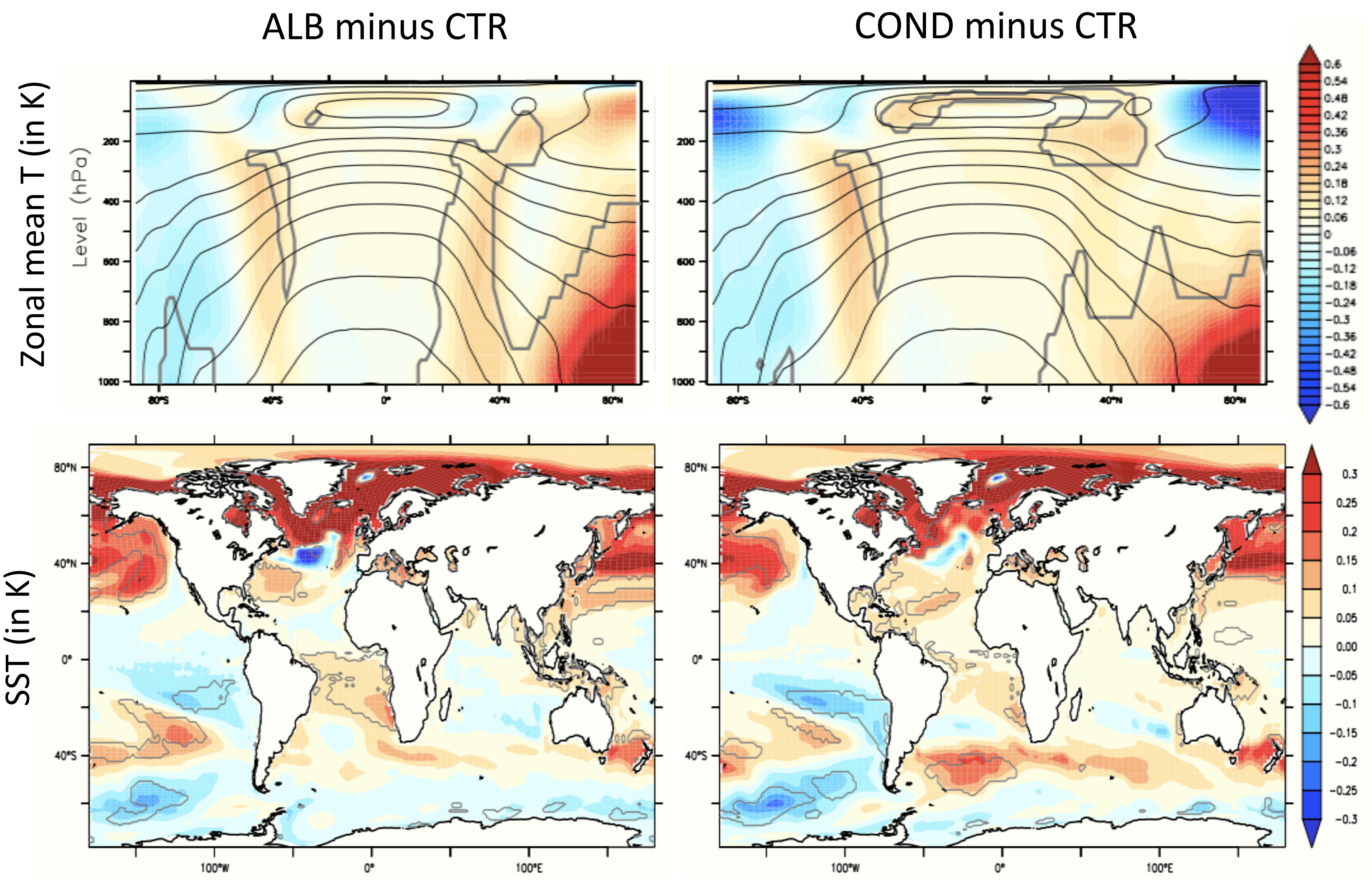
-> Values adjusted to reproduce RCP4.5 +1.5°C warming

We only focus on the years from 10 to 30 (after adjustment).

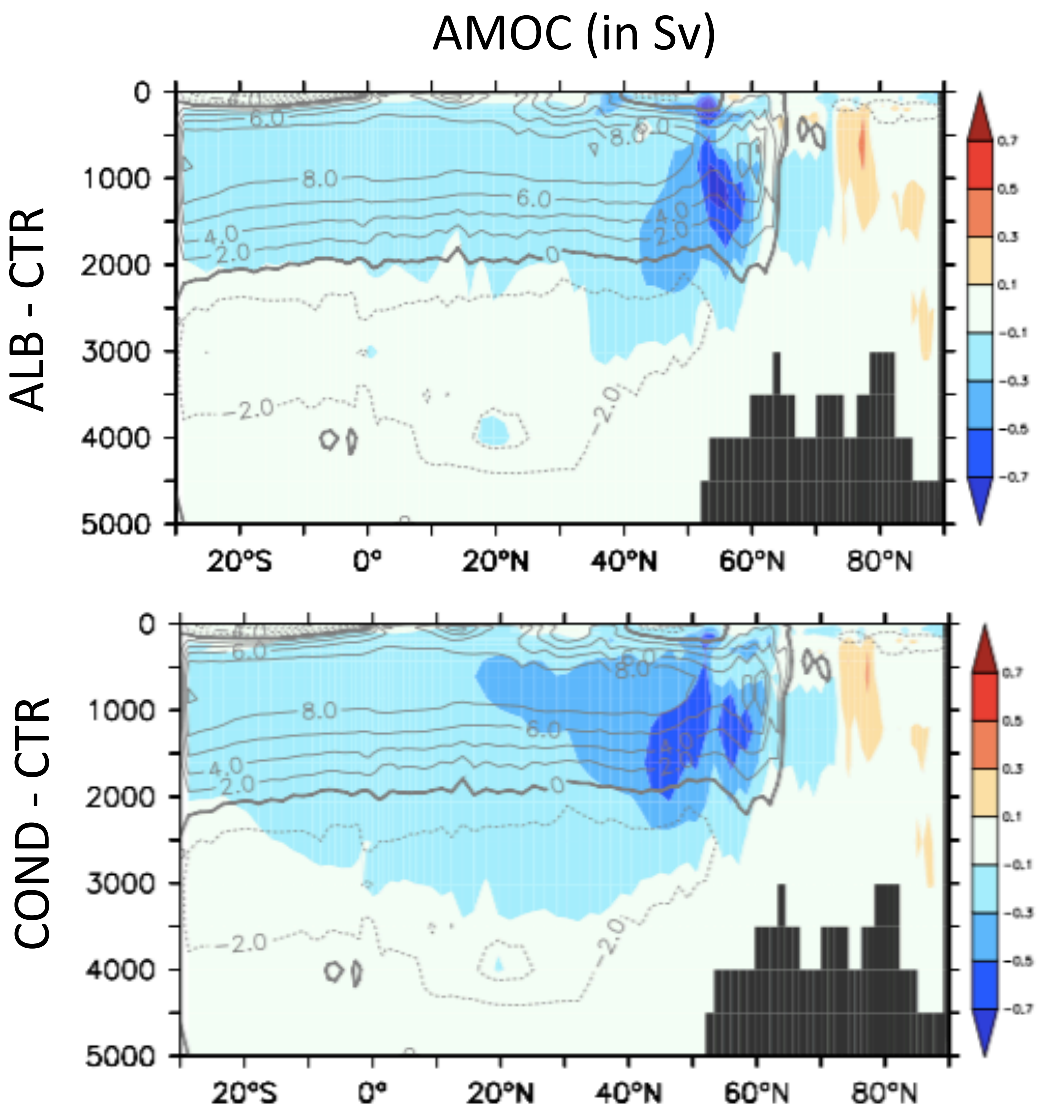


# Ocean-atmosphere response



# Coupled response to sea ice melting




Mechanism:

- Sea ice melting changes water mass properties and atmospheric circulation changes

⇩

- AMOC decrease,

⇩

- South Atlantic cooling

⇩

- Walker circulation change, causing a cooling in the SE tropical Pacific.

# Conclusions

- Observations show that years with low Arctic sea ice extension have SLP dipolar anomalies in later winter (Jan, Feb and Mar) with a negative NAO-like pattern, with no clear anomalies in the stratosphere.

- AMIP simulations from models can reproduce some aspect of the NAO-like response.

- PAMIP simulations and AMIP-like with observed SST and SIC show contrasted results.
  - -> non linear response to sea-ice conditions?
  - -> time scale of the response?

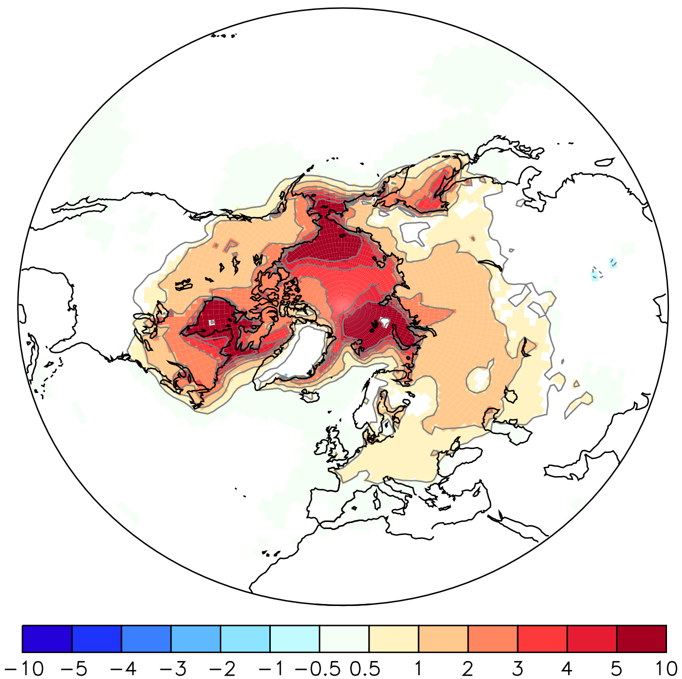
- Coupled response to sea-ice melting show some robust aspects (AMOC decreases) but link with tropical Pacific are not.
  - -> need to assess those link in coordinated framework.

*Thank you for your attention*

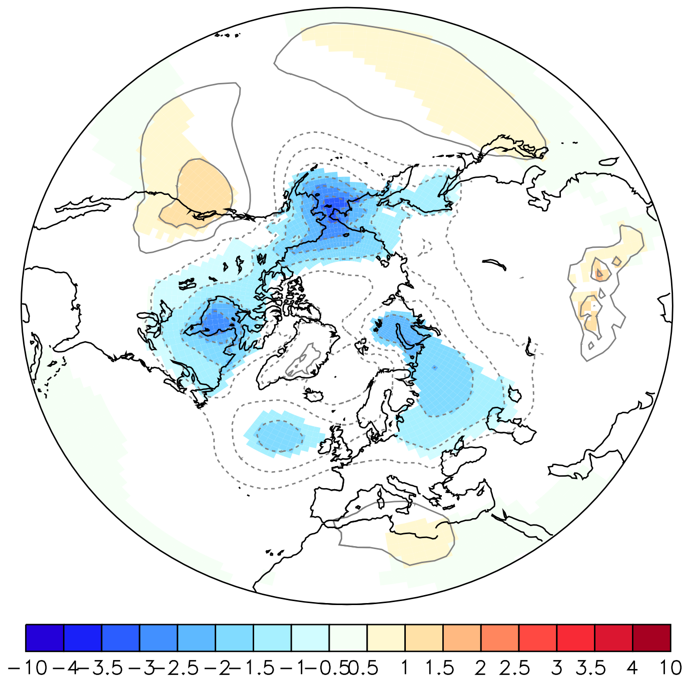
# PAMIP experiments

- Model: LMDZOR (IPSLCM6)
- Northward expansion of tropics.
- Negative SLP anomalies over the region with sea-ice retreat.

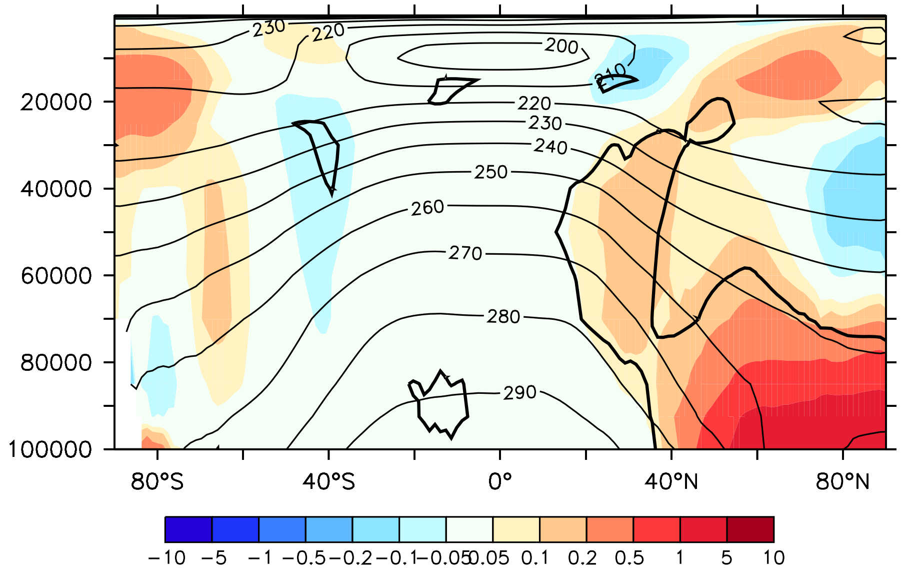
**pdSST-futArcSIC** minus **pdSST-pdSIC**
DJF T2m (K)




Same, for DJF SLP (hPa)




Same, for zonal mean DJF T (K)



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