Alleviation of an Arctic Sea Ice Bias in a Coupled Model through Modifications in the Subgrid-scale Orographic Parameterization

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Introduction

- The representation of subgrid-Scale Orography (SSO) in global climate models is a major challenge. In models two main effects are parametrized:

    - SSO blocking => opposite to local flow
    - SSO lift => normal to the local flow

- Previous studies suggested that many biases of the CMIP5 models (regarding blocking characteristics or mid-latitude climate variability) could be alleviated by increasing the SSO blocking (Pithan et al., 2016).

- Here, we assess the influence of SSO modification over the Arctic, where most models have a warm bias at surface (Graham et al., 2019).

Methods

- Sensitivity experiments with a low resolution GCM (2.5°x1.25°-L79 atmosphere) :
  -> LMDZOR-6A :land-atmosphere model used in IPSL-CM6A, with climatological SST from AMIP 1979-2010 (Hourdin et al., 2020).
  -> IPSL-CM6A ocean-atmosphere model (Boucher et al., 2020, *submitted*).

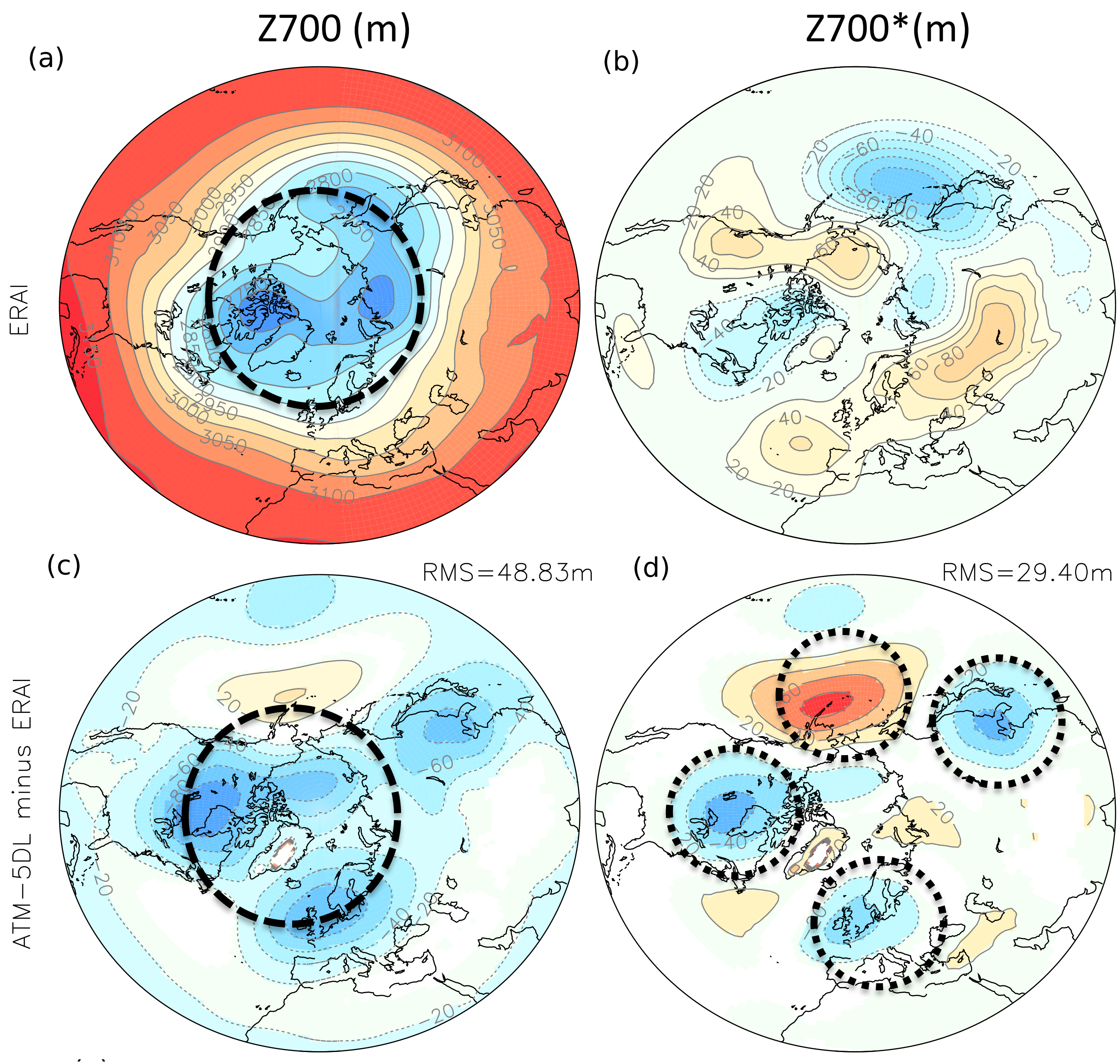
- The sensitivity to SSO is studied with variation of the unitless scaling parameter used in the blocking (C_d) and lift (C_l) schemes.
  -> **5DL** uses the C_d and C_l from the CMIP5 version
  -> **6A** uses the standard C_d and C_l from the CMIP6 version

Name	Model	Length (in yr)	Parameters	
			C_d	C_l
Atm-6A	LMDZOR-6A	30	0.6	0.1
Atm-5DL	LMDZOR-6A	30	0.2	0.25
Atm-6A-Drg+	LMDZOR-6A	30	1.2	0.1
Atm-6A-Drg-	LMDZOR-6A	30	0.2	0.1
Atm-6A-Lft-	LMDZOR-6A	30	0.6	0.0
Atm-6A-Lft+	LMDZOR-6A	30	0.6	1.0
AO-6A	IPSL-CM6A-LR	200	0.6	0.1
AO-5DL	IPSL-CM6A-LR	5 x 80	0.2	0.25

Part I.

Influence of the subgrid scale orography onto the Arctic bias in the atmosphere-only model

Atmospheric circulation at 700-hPa



Z700 = 700-hPa geopotential

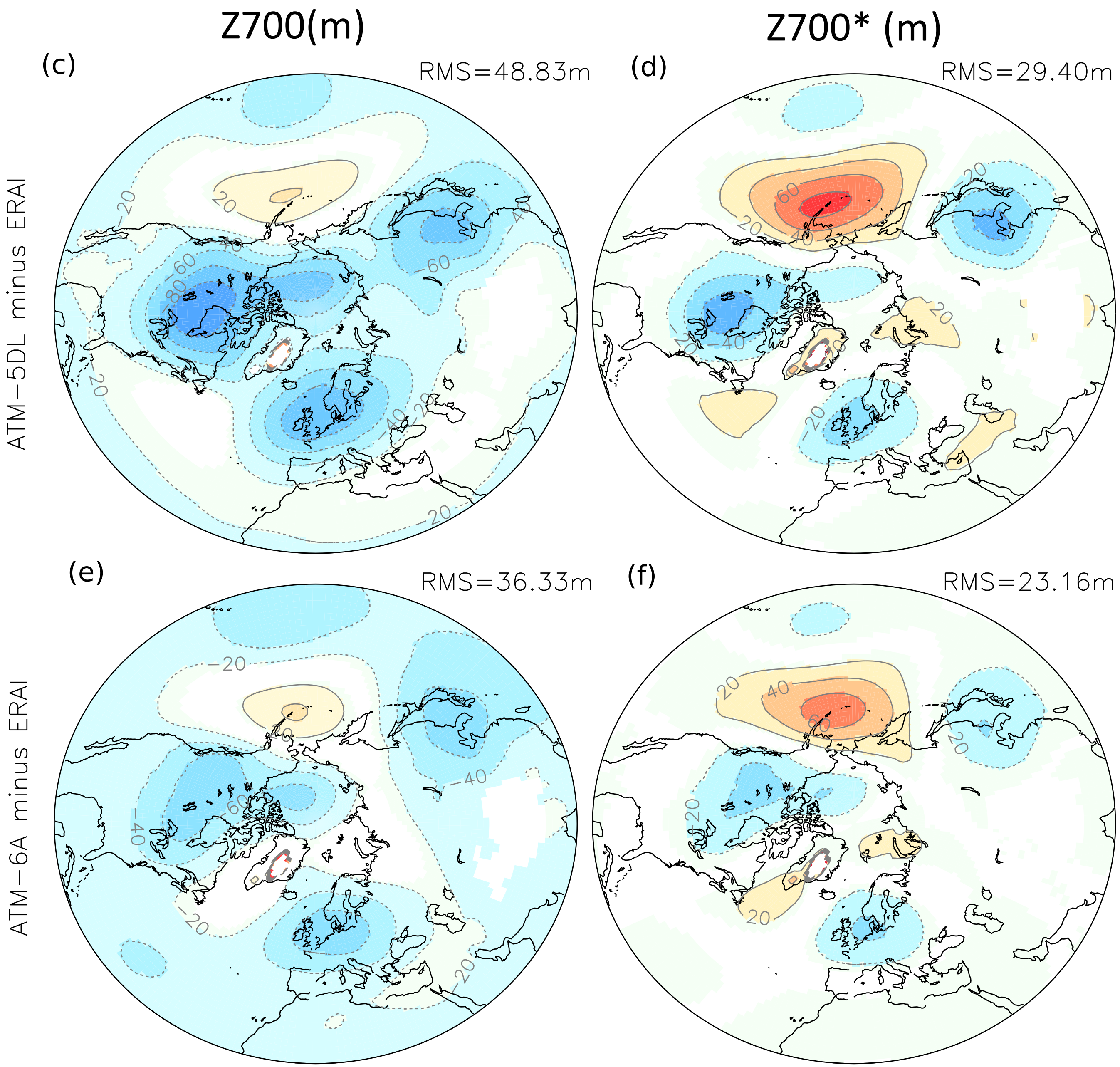
Z700* = zonally asymetric component of Z700

In **Atm-5DL**:

- polar depression is too deep,
- 3 anomalous throughs over North America/Europe/East Asia

=> Typical biases that could be alleviated using increasing SSO blocking and decreasing lift

Atmospheric circulation at 700-hPa



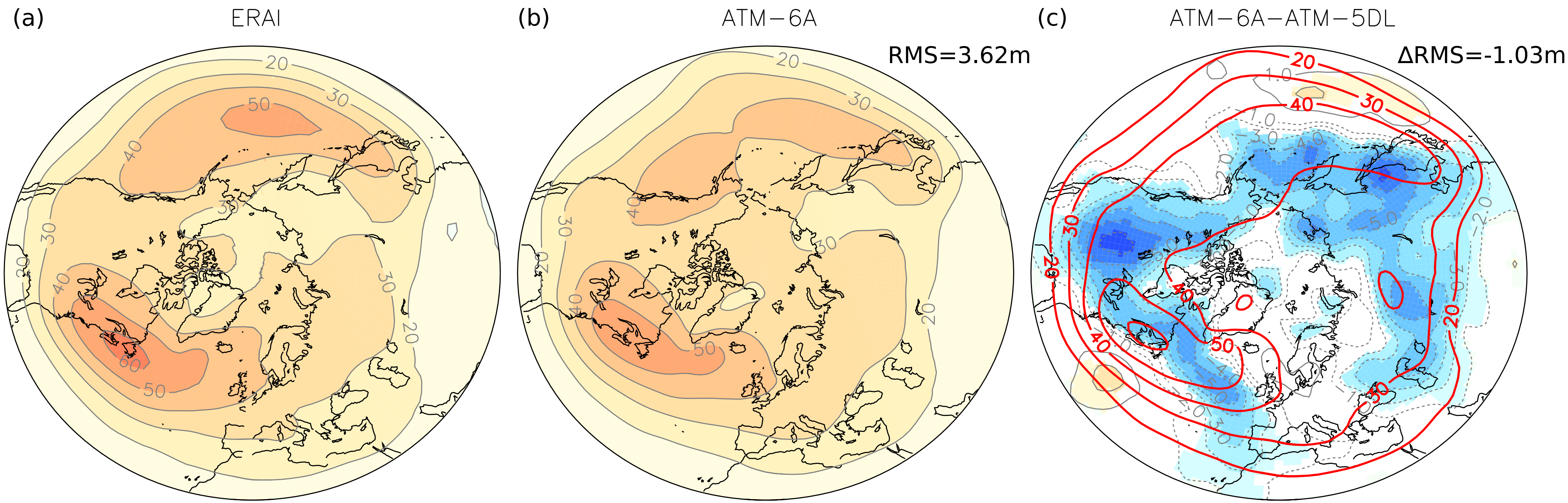
In **Atm-6A**:

- Large reduction of the bias of the polar depression,

- Better simulation of the stationary planetary wave (RMS error reduced).

Atmospheric high frequency variability

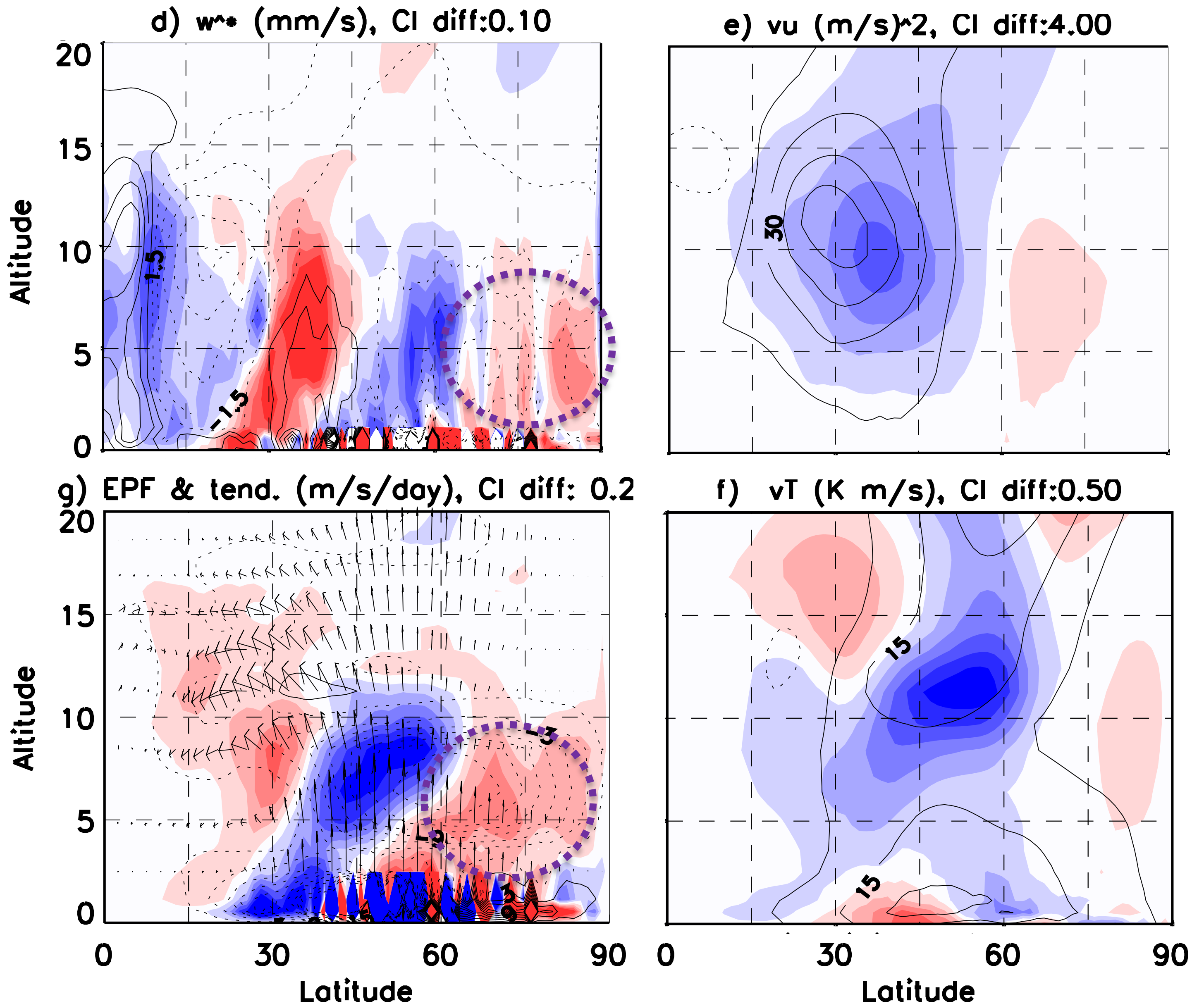
Standard deviation (in m) of daily 2.5-6 day band-pass filtered 500-hPa geopotential height (Blackmon, 1976)



- The Standard deviation is too small in the model over the stormtracks, and too large over land
- A general decreases of the variance is simulated over land in 6A

Transformed Eulerian Mean

Contour : **Atm-6A** / Color : **Atm-6A** minus **Atm-5DL**

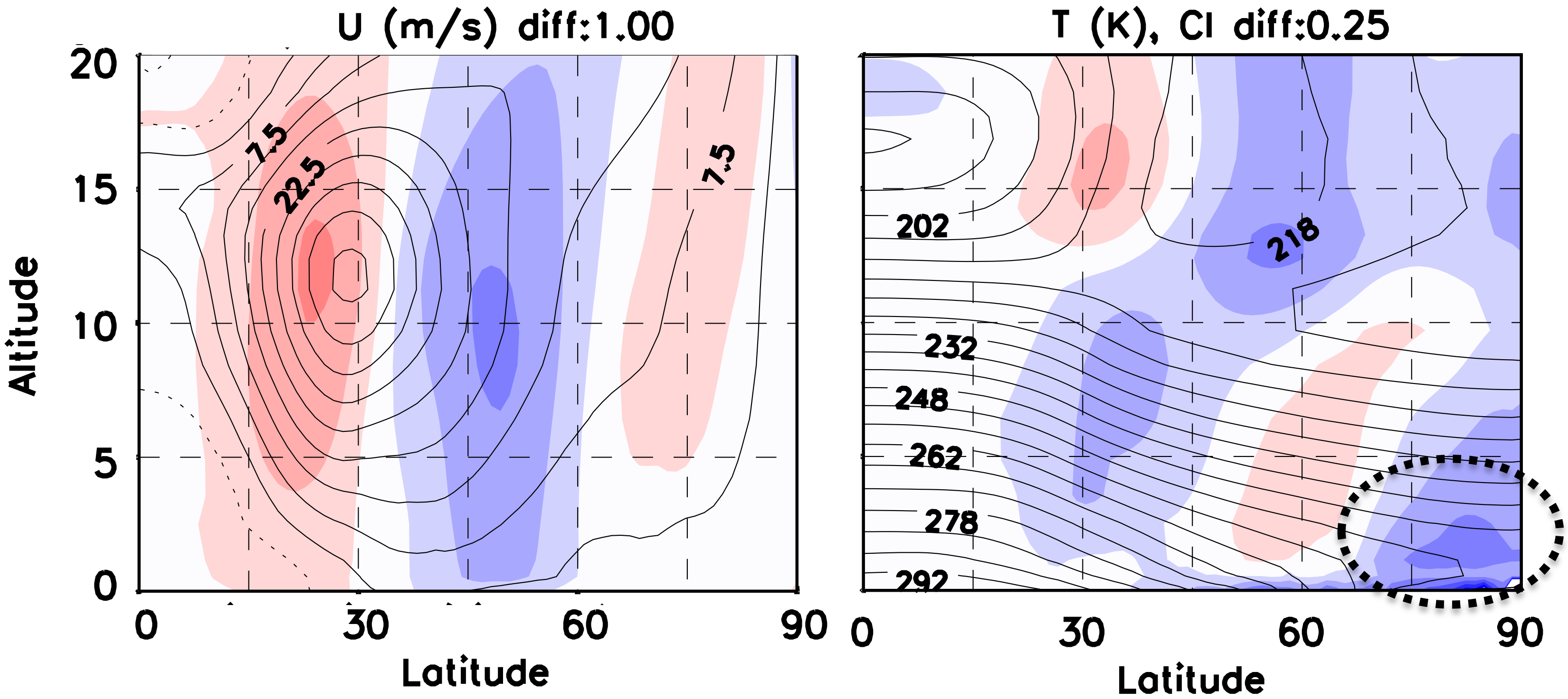


- Weakening of the eddy momentum and temperature transport (v'u') and (v'T'),
- Weakening of the Eliassen-Palm flux convergence over 70°N.
- Ascending residual vertical velocity (w*) north of 70°N.

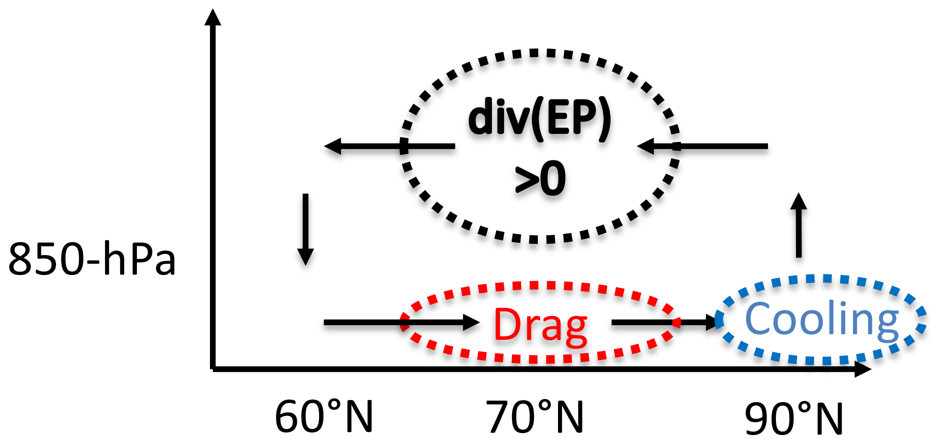
=> Consistent with a downward control mechanism.

Zonal mean circulation

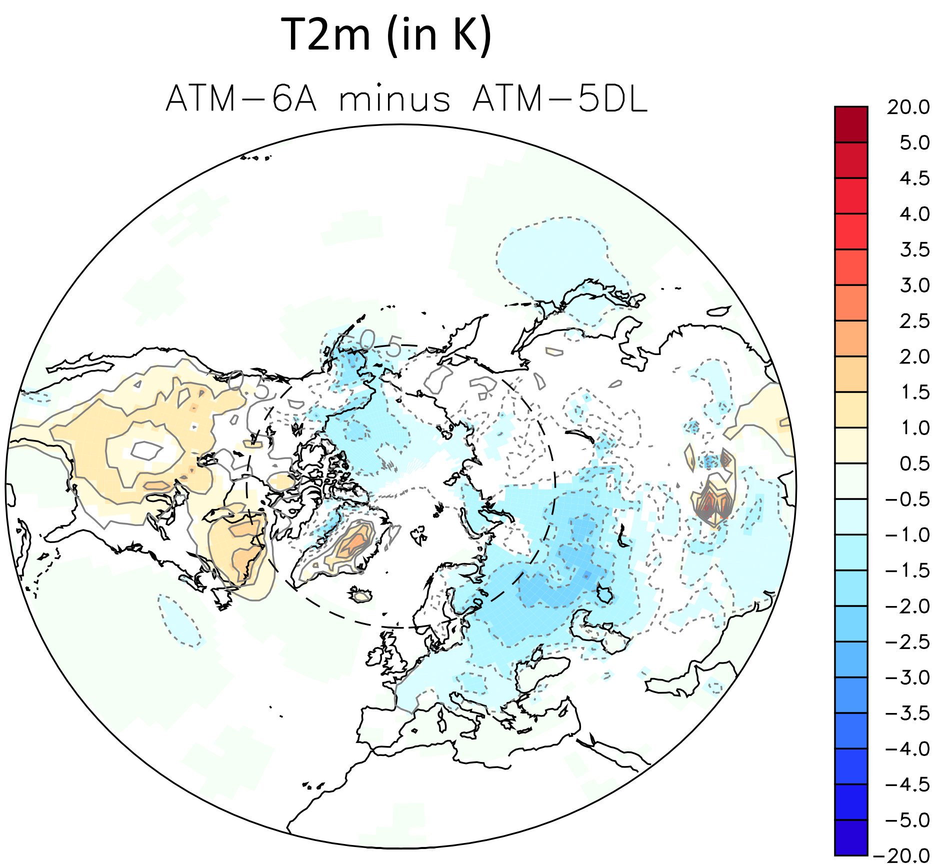
Contour : **Atm-6A** / Color : **Atm-6A** minus **Atm-5DL**

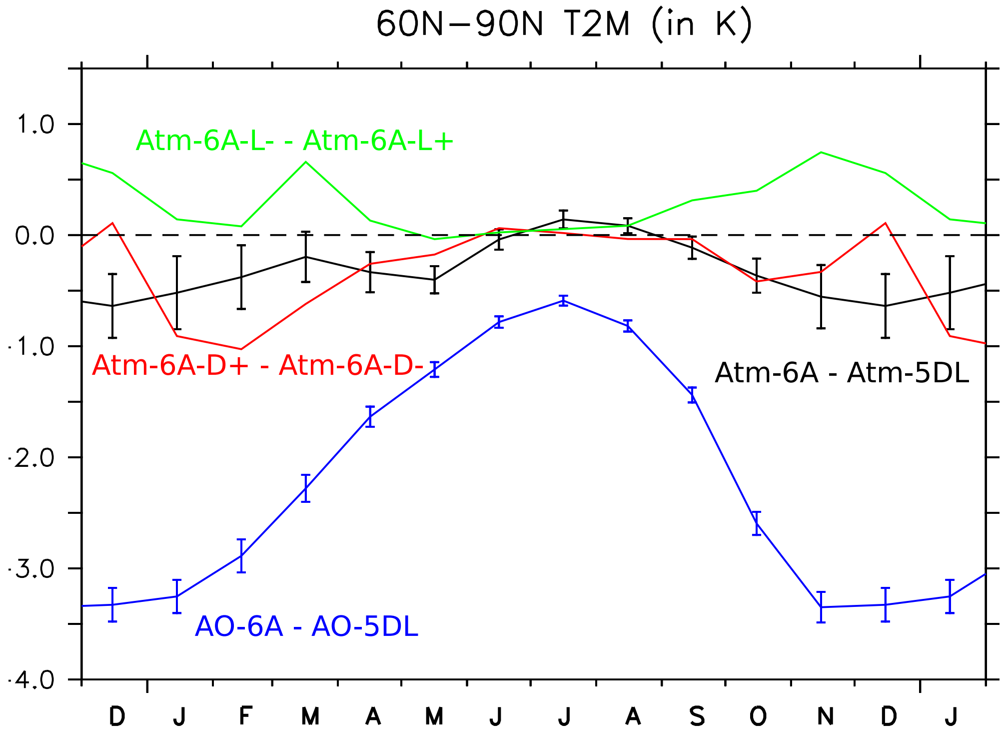


- Equatorward shift of the westerly jet
- Large lower-tropospheric cooling North of 70°N



Near surface temperature



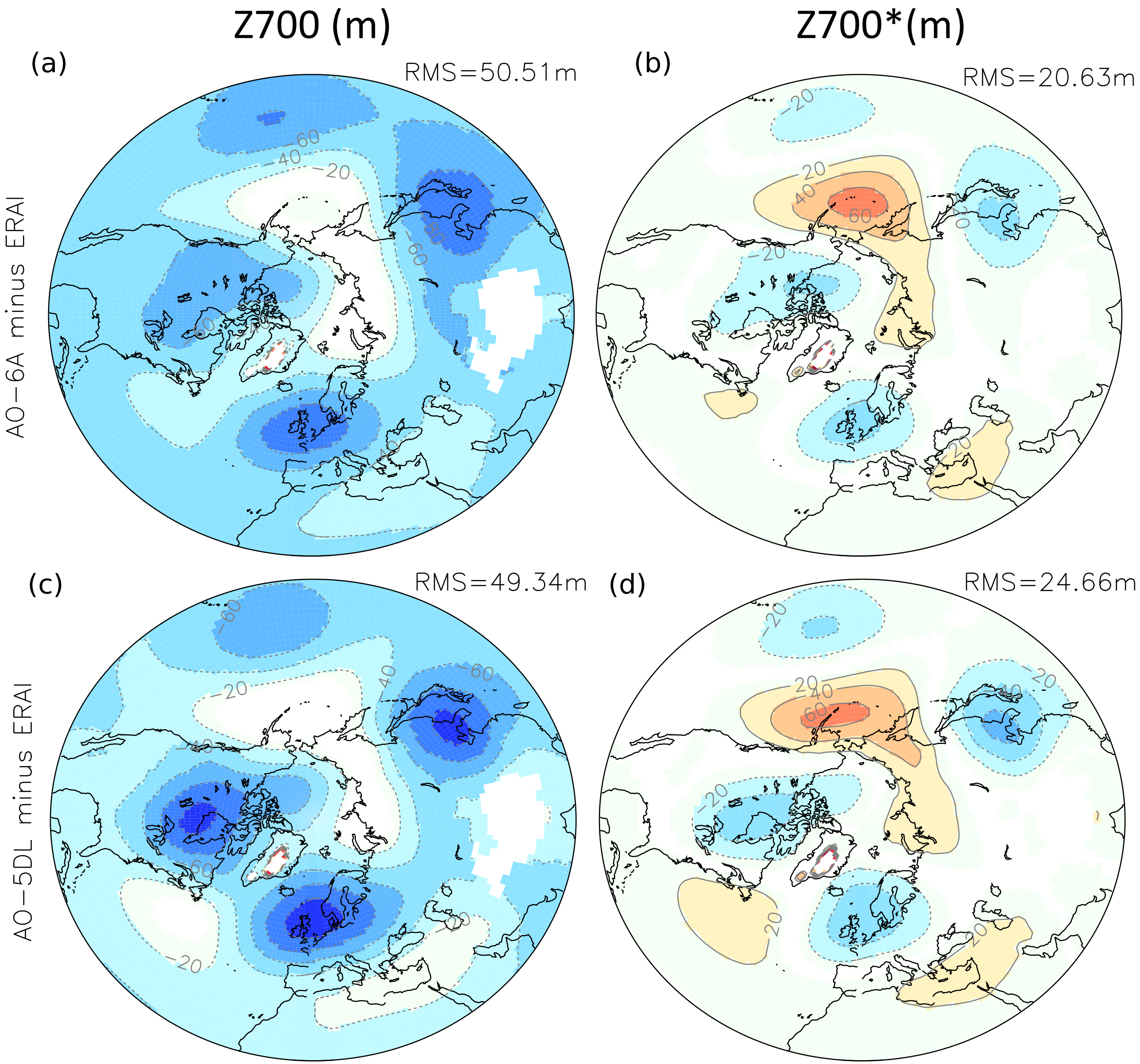


- Polar cooling amplified in winter where the stationnay planetary wave is most affected.

Part II.

Alleviation of the Arctic bias in the Ocean-atmosphere model

Atmospheric circulation at 700-hPa



Z700 = 700-hPa geopotential

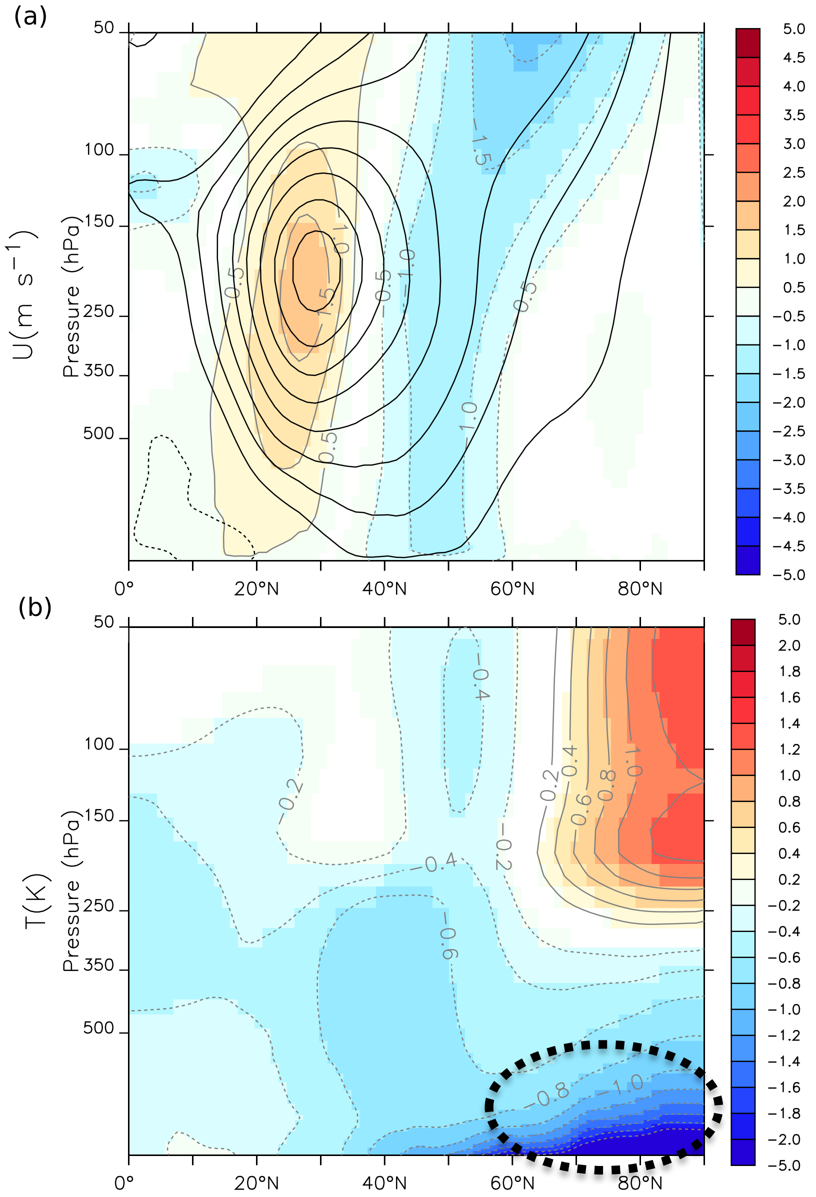
Z700* = zonally asymetric component of Z700

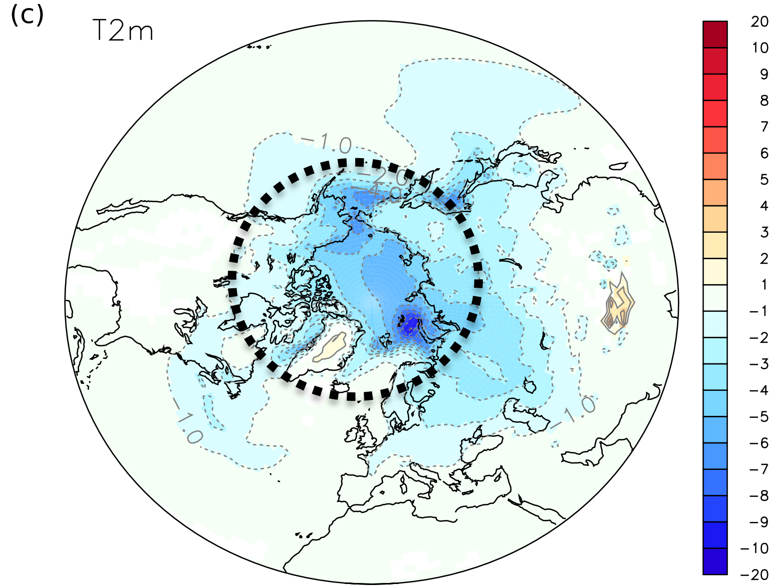
In **AO-6A**:

- Reduction of the polar depression less clear.
- Smaller reduction of 3 anomalous throughs over North America/Europe/East Asia (when compared to atm-only experiments) .

Amplification of surface cooling

AO-6A minus **AO-5DL**



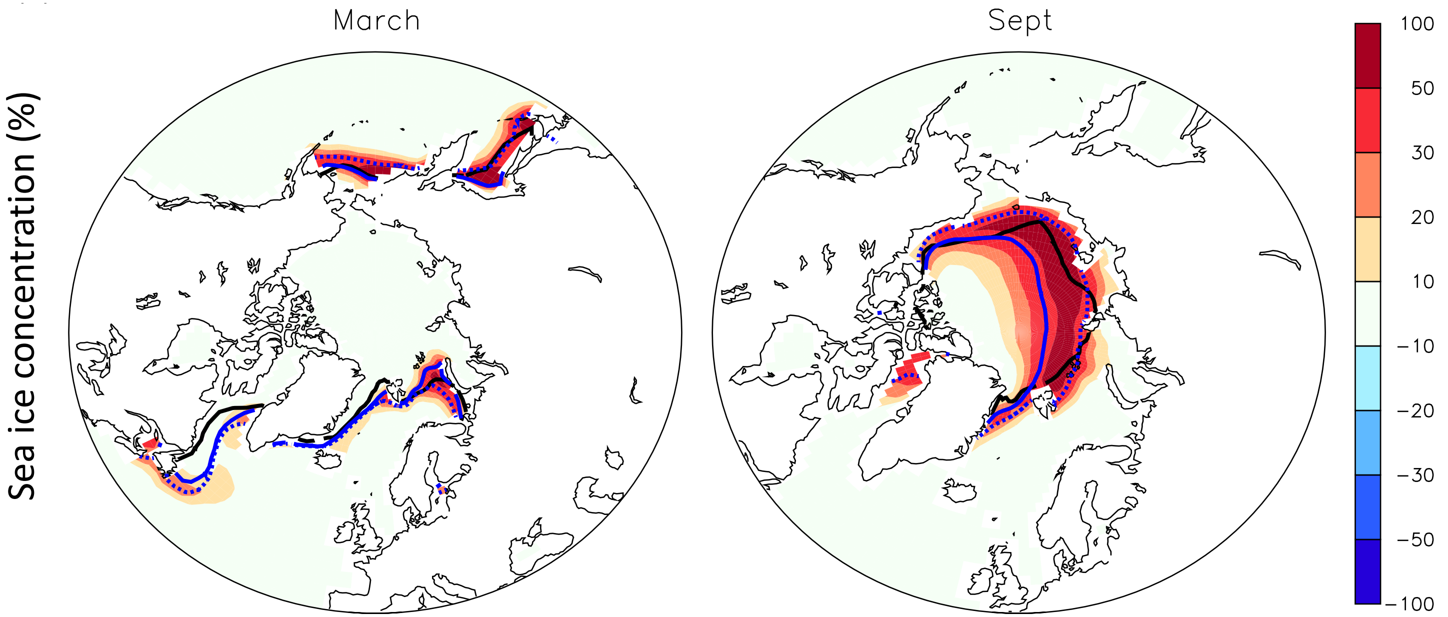


when compared to atmosphere-only simulations :

- Similar equatorward shift of the westerly jet
- Amplification of the lower-tropospheric cooling North of 70°N.

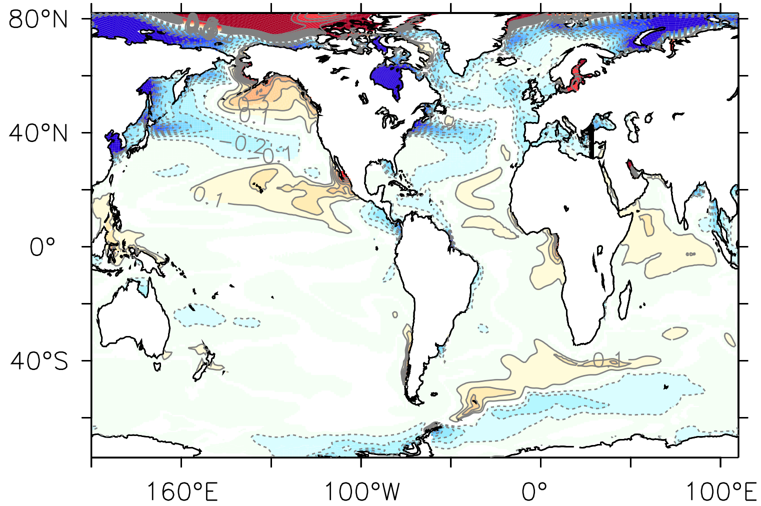
Sea-ice and oceanic changes

AO-6A minus **AO-5DL**

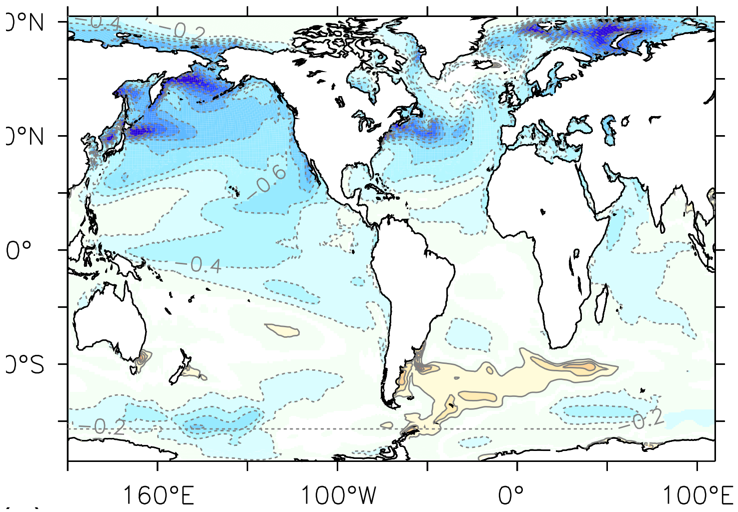


- Large sea ice decrease -> positive feedback for the lower tropospheric cooling.

Sea surface salinity (psu)



Sea surface temperature (K)



- Weakening of the eddy-driven jet shift southward the western boudary current

-> major impacts on oceanic circulation

Conclusion

- The planetary standing wave pattern was adjusted in the atmosphere-only and ocean-atmosphere IPSL-CM6-LR model,
- Increasing the low-level drag lead to an anomalous residual overturning circulation consistent with a downward control mechanism,
- Increase low-level subgrid scale orographic blocking can alleviate the warm winter sea ice biases present in ocean-atmosphere models,
- The sub-grid scale orography also have impact on the oceanic circulation, as the salinity transport toward North Atlantic decreases, the Atlantic overturning circulation also slows down.