Northern Hemisphere atmospheric response to Arctic summer sea ice loss in CNRM-CM6

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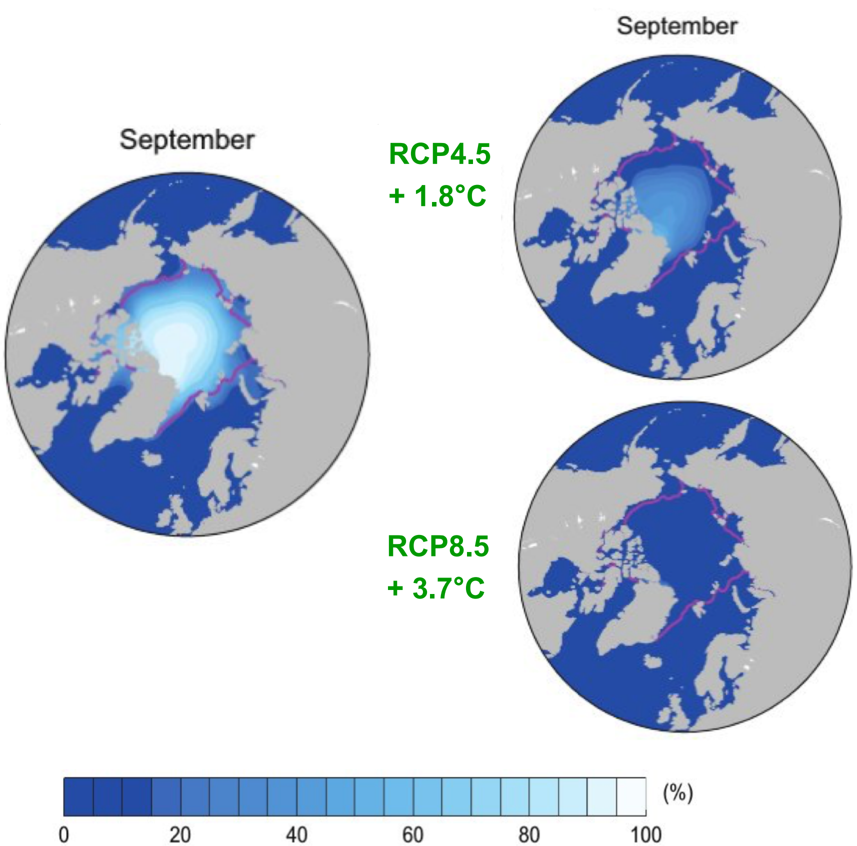
Arctic sea ice loss : does it affect the mid-latitudes?

Sea ice concentrations

1986-2005 2081-2100



(CMIP5 multi-model mean, IPCC AR5 WG1 Chap 12)

Will Arctic sea ice decrease have an effect on large-scale atmospheric circulation, independently of other external forcings? (e.g. GHGs)

Objective :
To isolate the role of Arctic sea ice loss on atmospheric circulation

PRIMAVERA WP5 albedo experiment

CNRM-CM6 (CMIP6 version)
Voldoire et al. (in prep)

Atmosphere : ARPEGE 6.27 LR, T127 (1.4°~100 km) L91
Ocean : NEMO 3.6, 1°, 75 vertical levels
Ice : GELATO 6

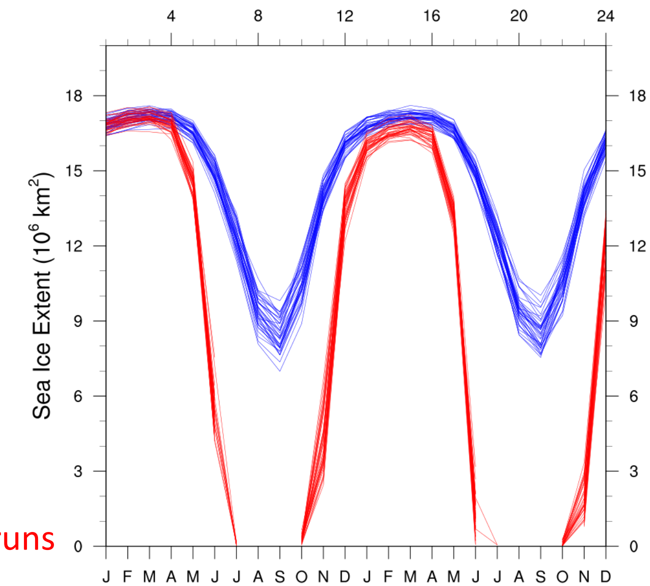
Control run : fixed GHGs 1950

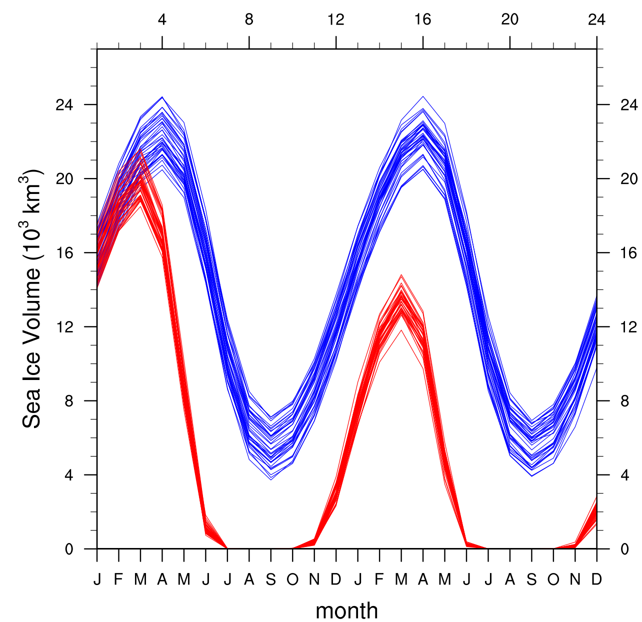
Constant perturbation : sea ice albedo reduction
→ ocean value (0.066)

Perturbed runs : 40 members
24 months (January -> December +1)

Summer (JAS) : complete sea ice loss
Winter (JFM) : SIC almost recovered but SIV loss persists

- control run
- perturbed runs





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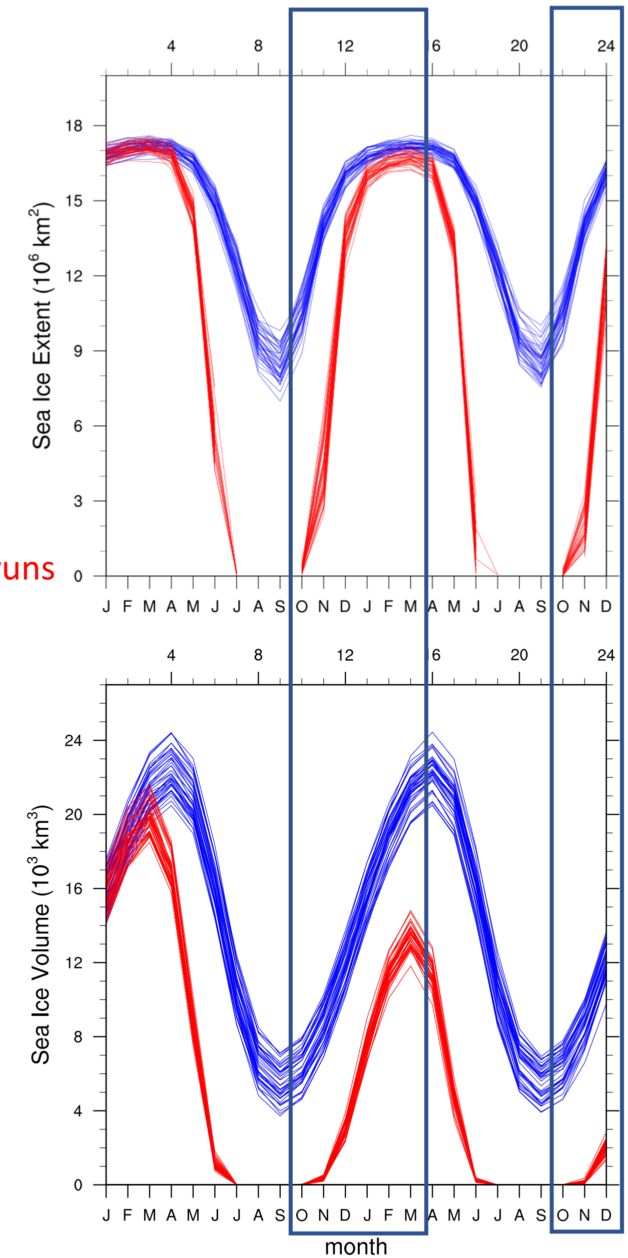
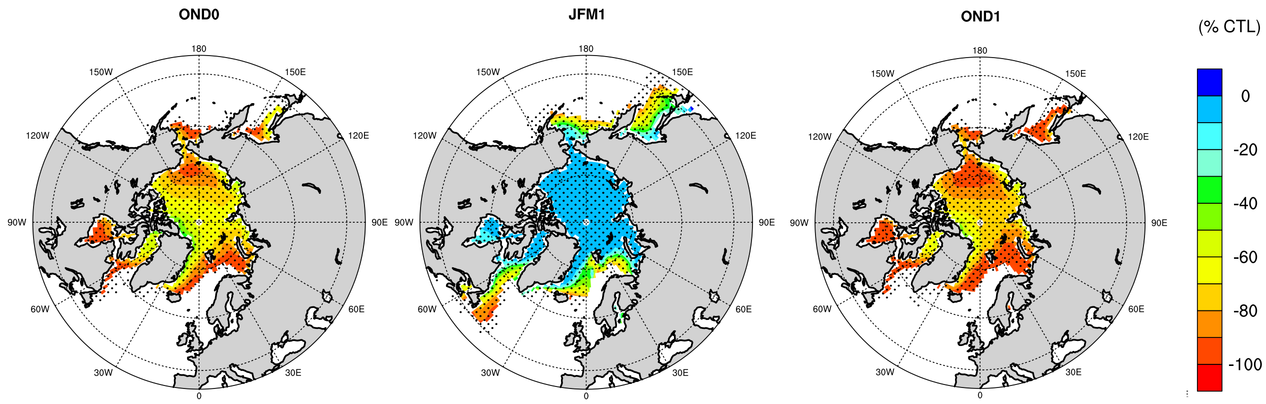


Sea ice responses

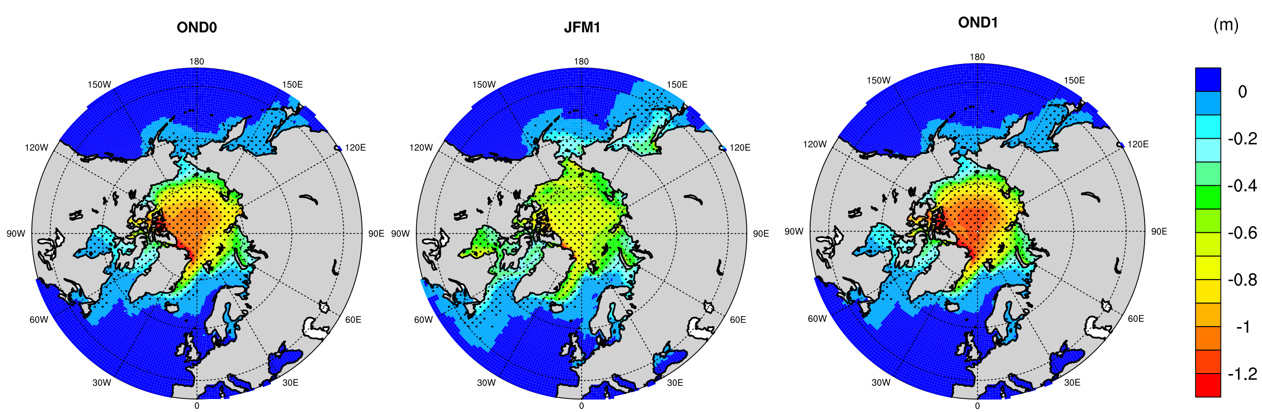
Sea ice surface concentration (SIC), PERT - CTL



sig. 90%

- Large sea ice loss in autumn
- Not completely recovered in winter (loss on the edges)
- Stronger sea ice loss the 2nd autumn

Sea ice volume (SIV) per area unit, PERT - CTL



- Largest sea ice volume loss in central Arctic

More SIC/SIV loss the 2nd autumn → stronger atmospheric response expected

Turbulent heat flux response

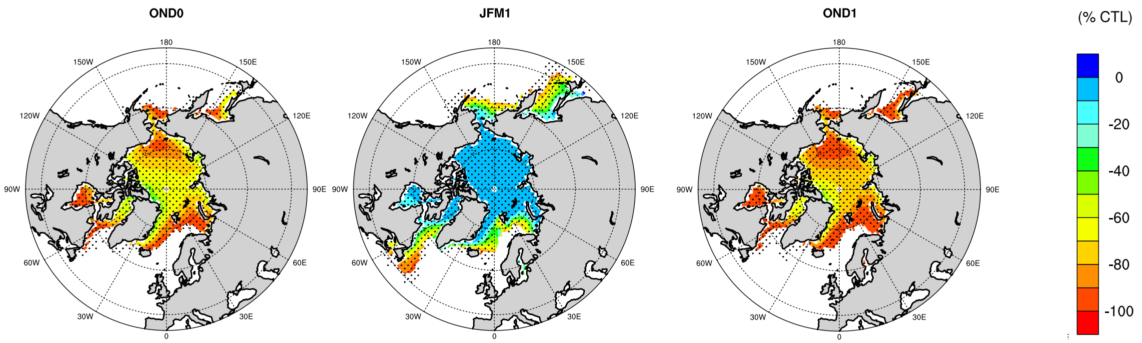
• Positive THF response where sea ice loss

• Strong response in autumn (november) and amplified the 2nd autumn (more SIC/SIV loss)

• Meridional dipole structure (Barents-Kara region)

→ southward advection of warmer air above regions with sea ice loss
(Deser et al. 2010, Screen et al. 2013)

SIC response (PERT – CTL)



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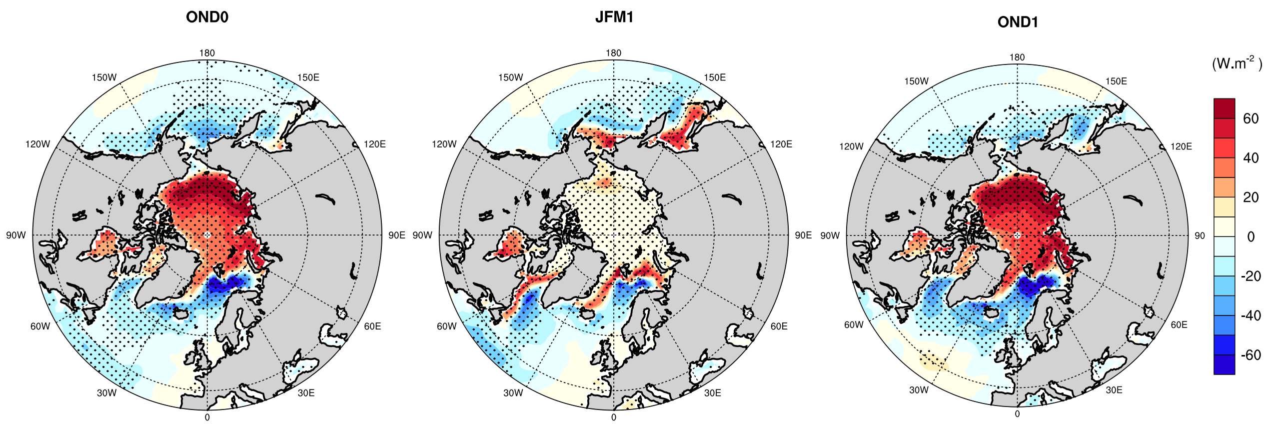
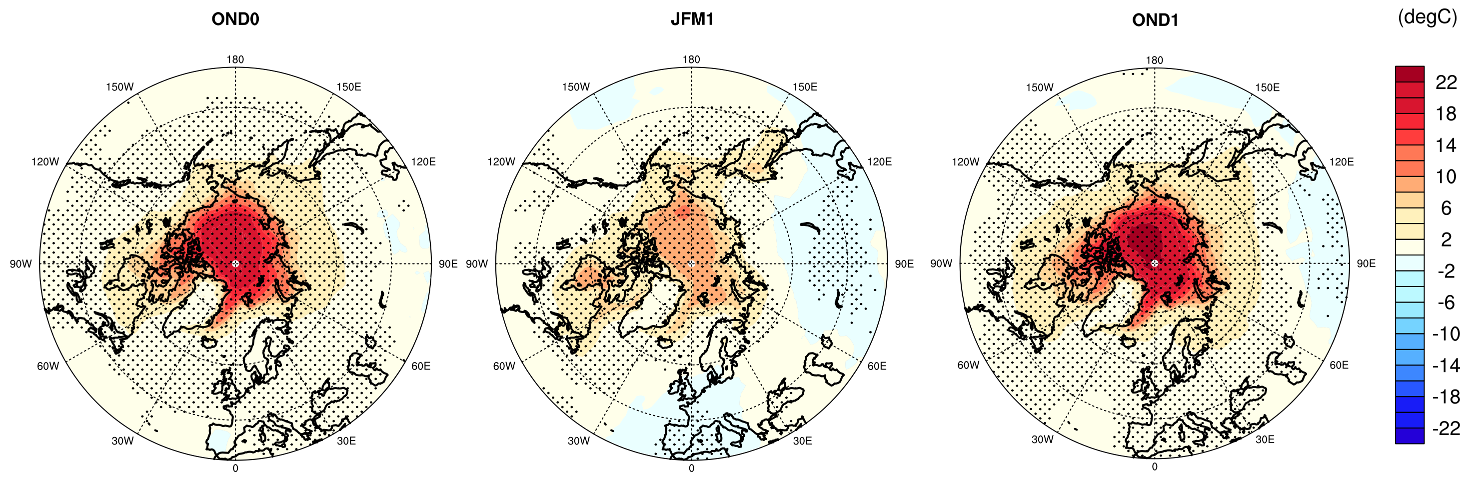


+ upward (lower atm warms)
- downward (upper ocean warms)

Surface temperature response



- Arctic amplification
- Maximum in autumn (stronger during the 2nd one)
- Significant signal over continents up to mid-latitudes : consistent with previous studies (e.g. Peings et al. 2014)

  → Warming over Siberia and North America in autumn

  → Cooling over central Asia and Western Europe in winter + over central Asia the 2nd autumn

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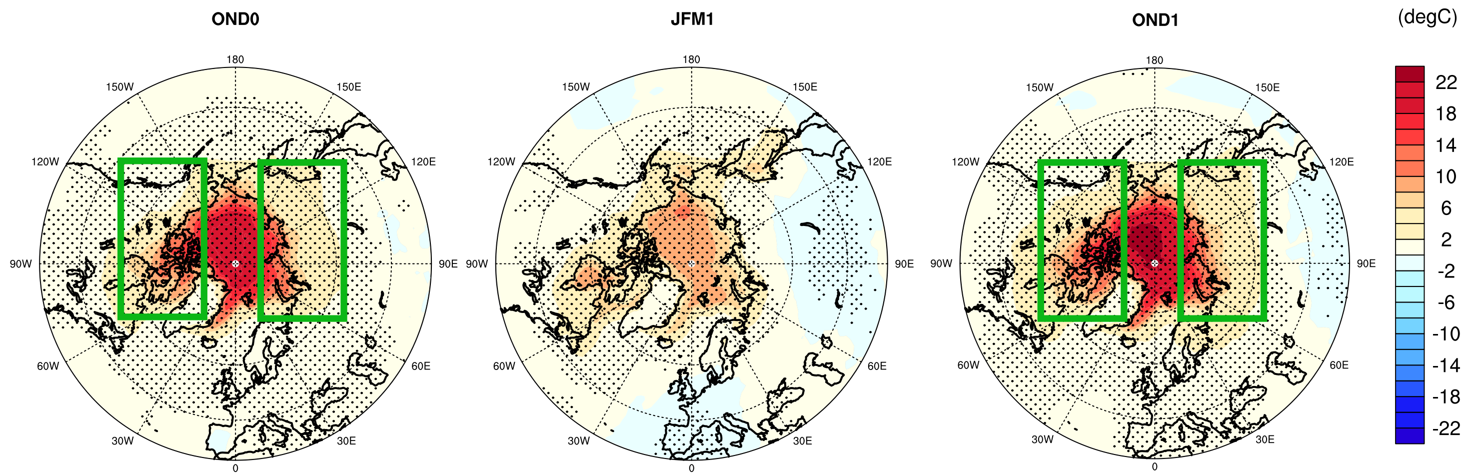

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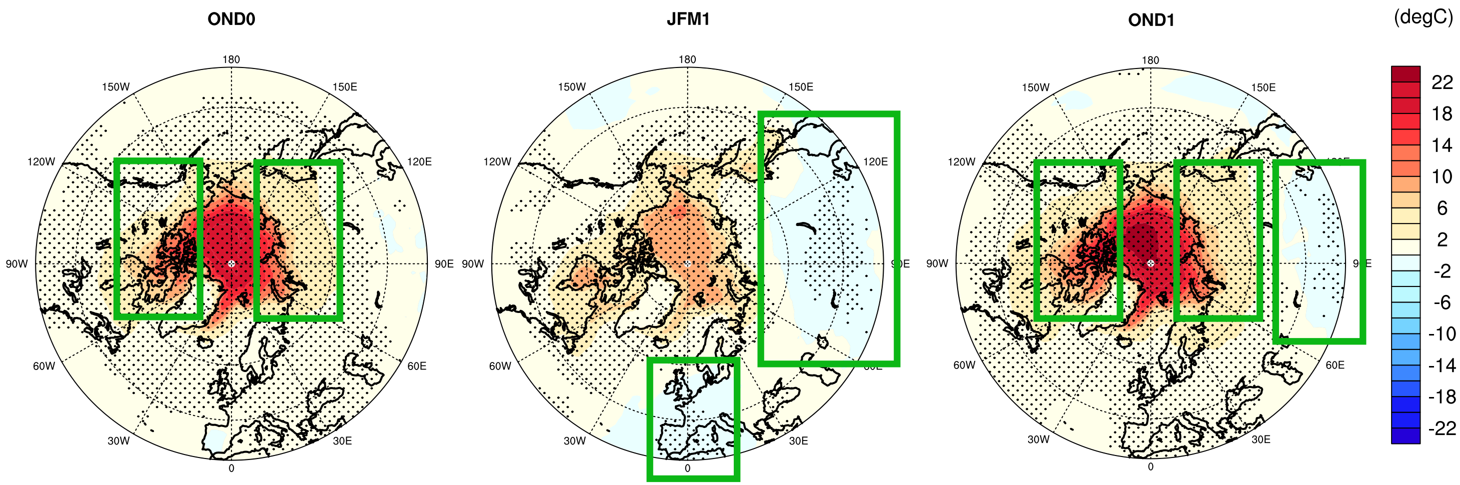

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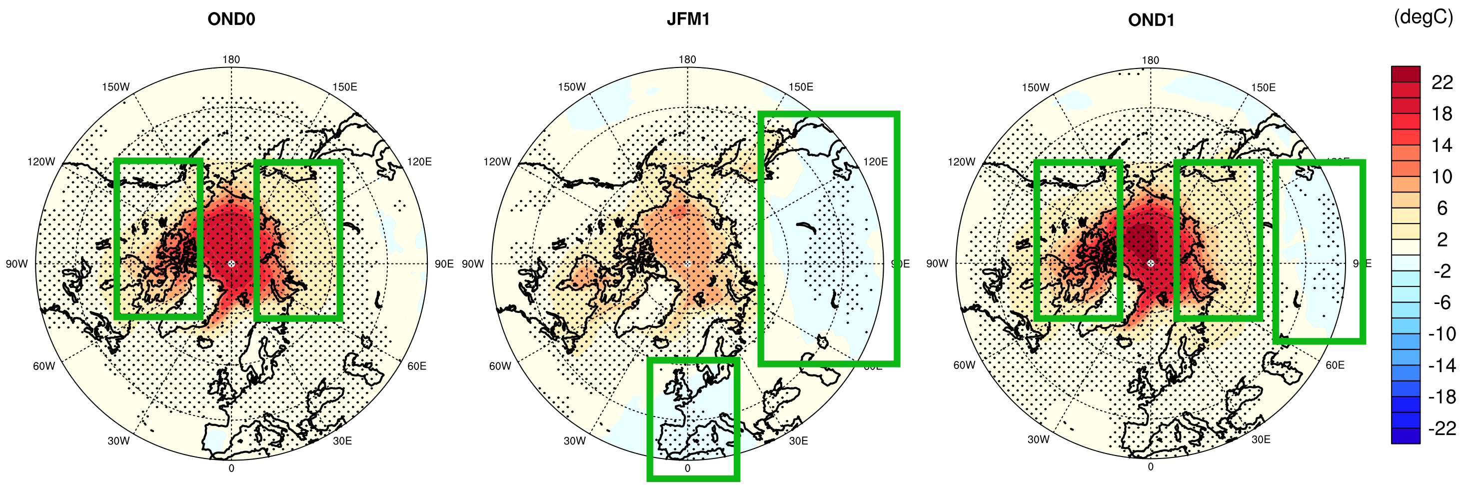

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<u>Surface temperature and turbulent heat flux responses</u> :

are they directly controlled by the sea ice forcing and/or by atmospheric variability?

Dynamical and thermodynamical TAS components

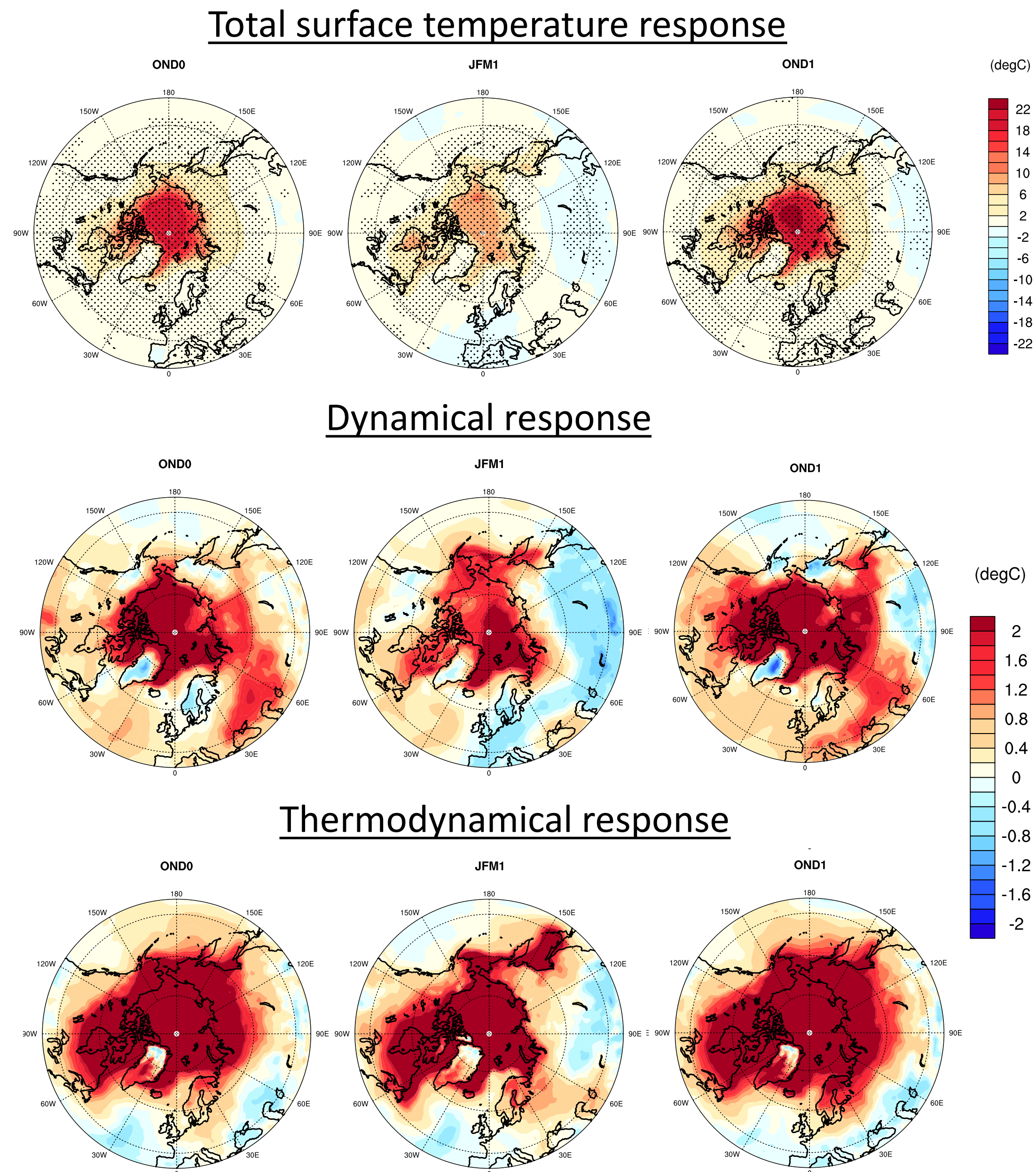
Dynamical adjustment method to isolate the contribution of atmospheric internal variability
(by Deser, Terray and Phillips 2016)

- Thermodynamical effect dominates over the Arctic

- Dynamical and thermodynamical components might cancel each other (e.g. central Europe and Greenland)
  → weak total response

- JFM : cool dynamical response in Asia (consistent with NAM-) enhanced by the thermodynamical one

  → significant cooler temperature over central Asia



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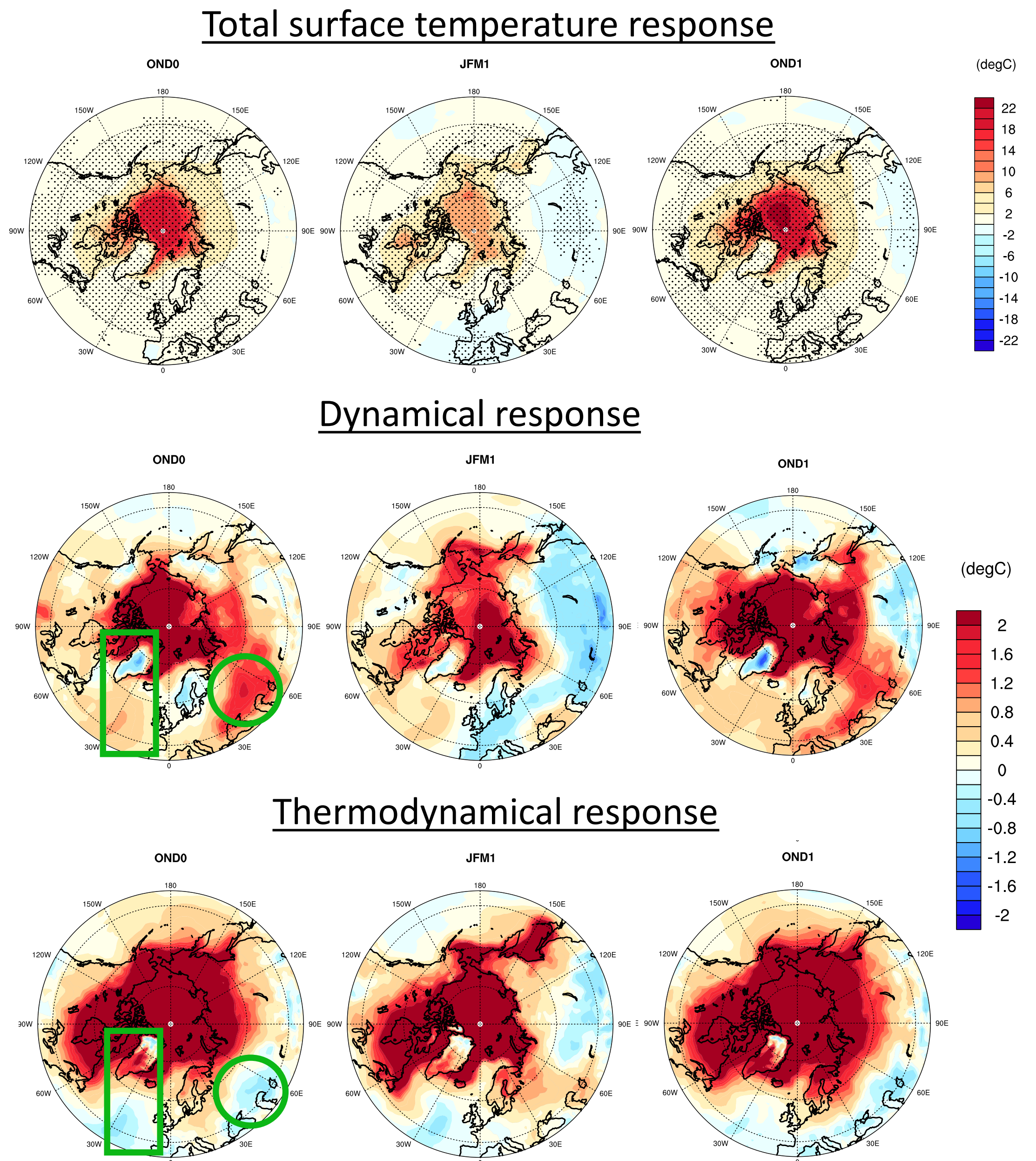

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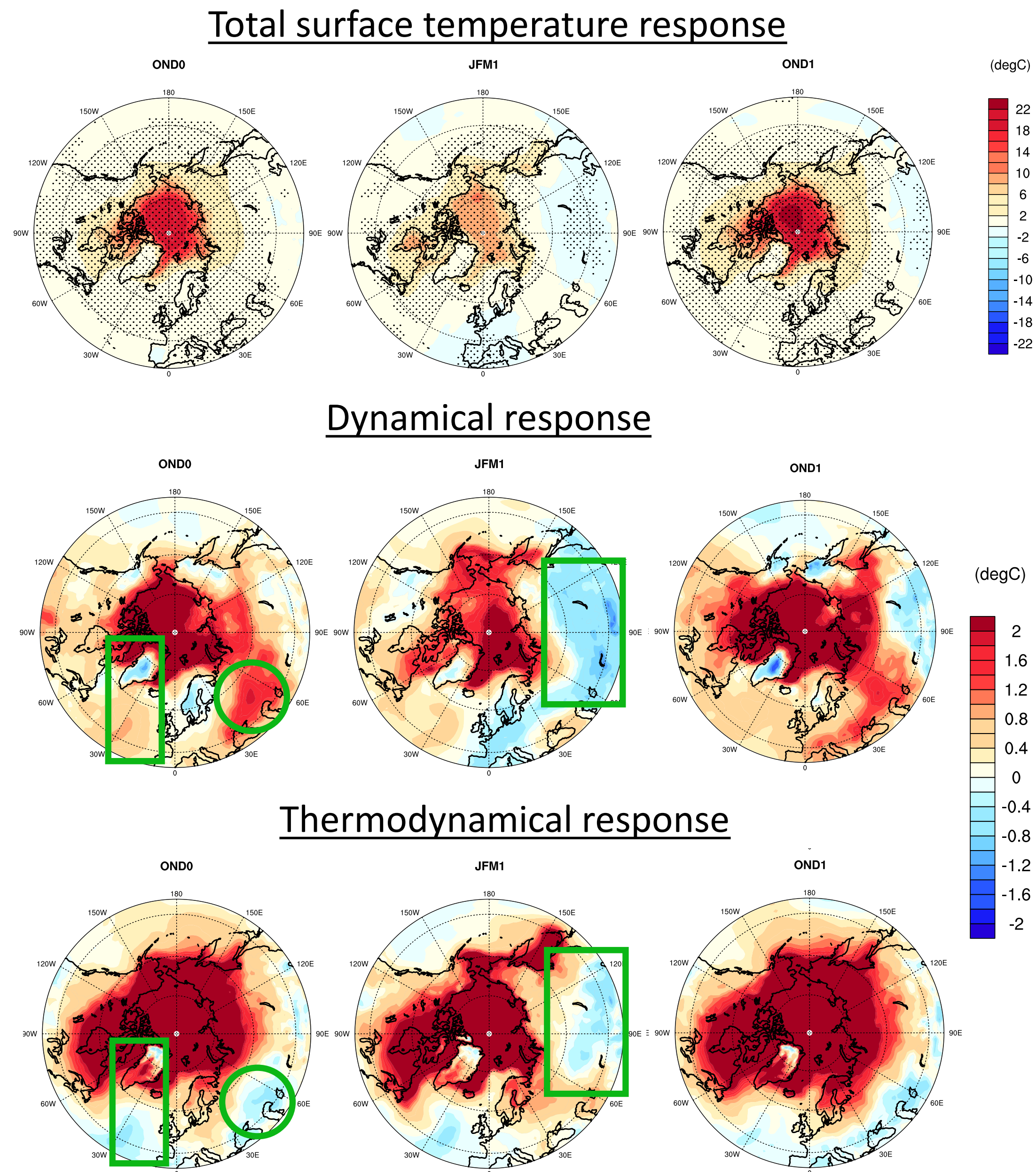

Dynamical and thermodynamical THF components

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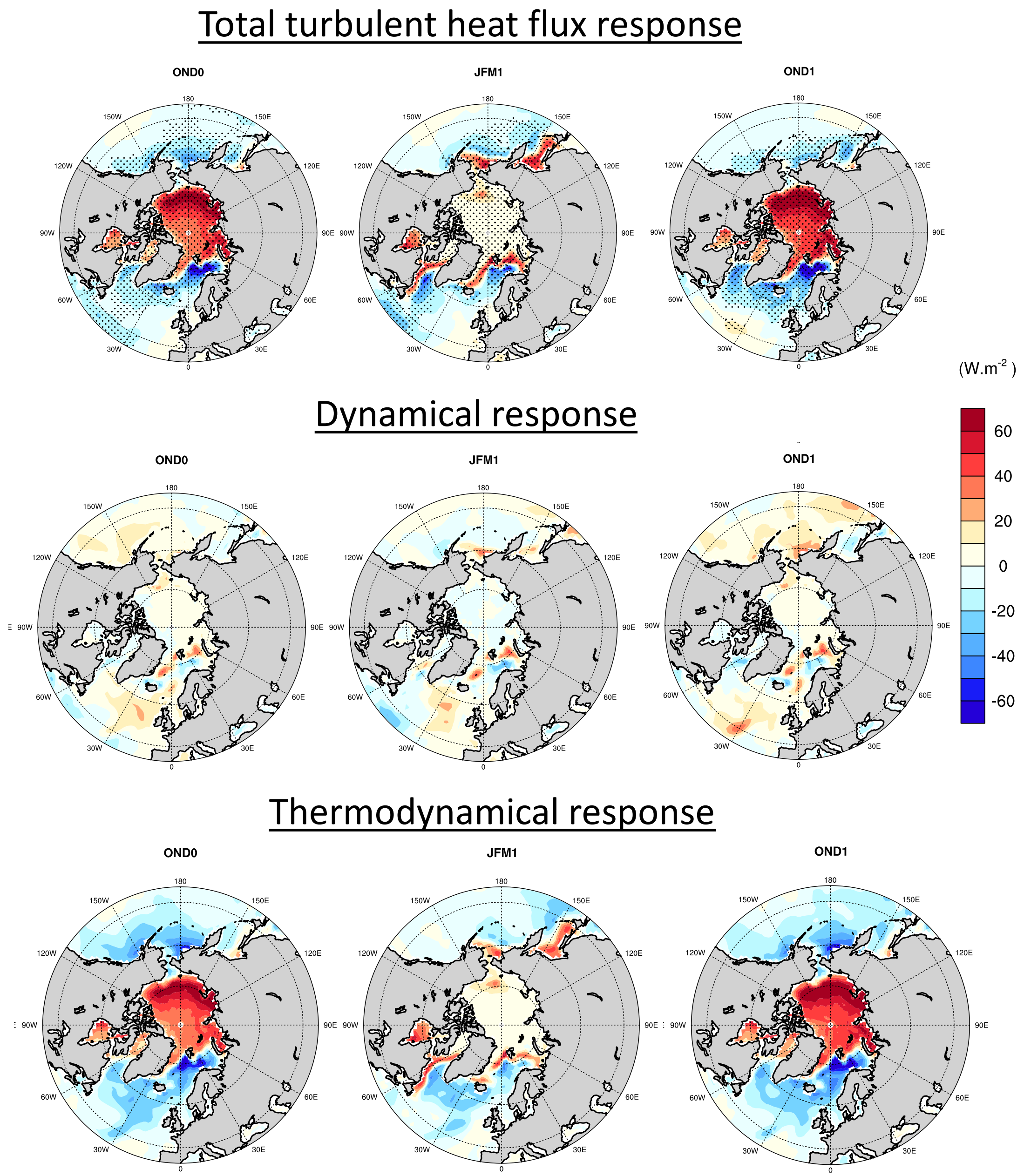
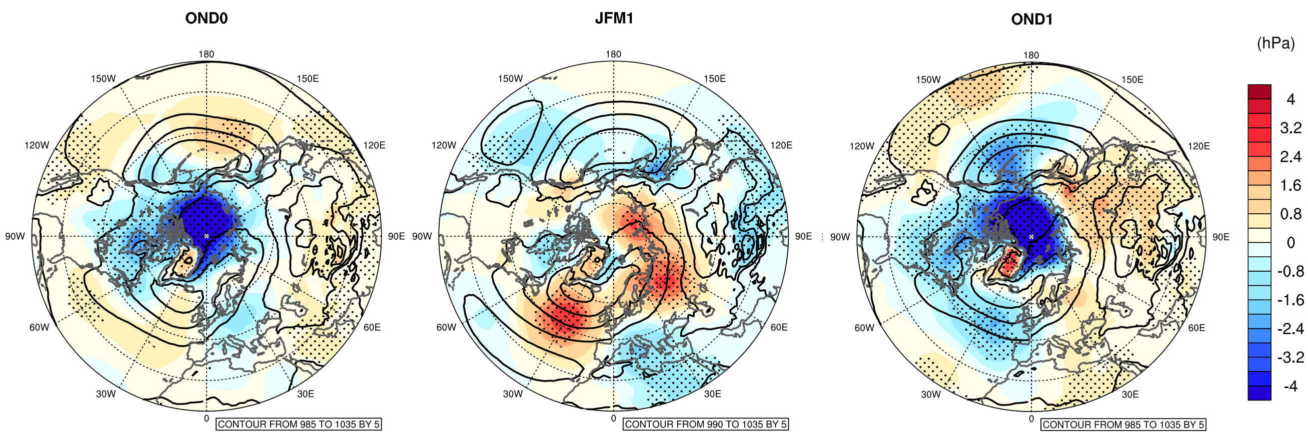


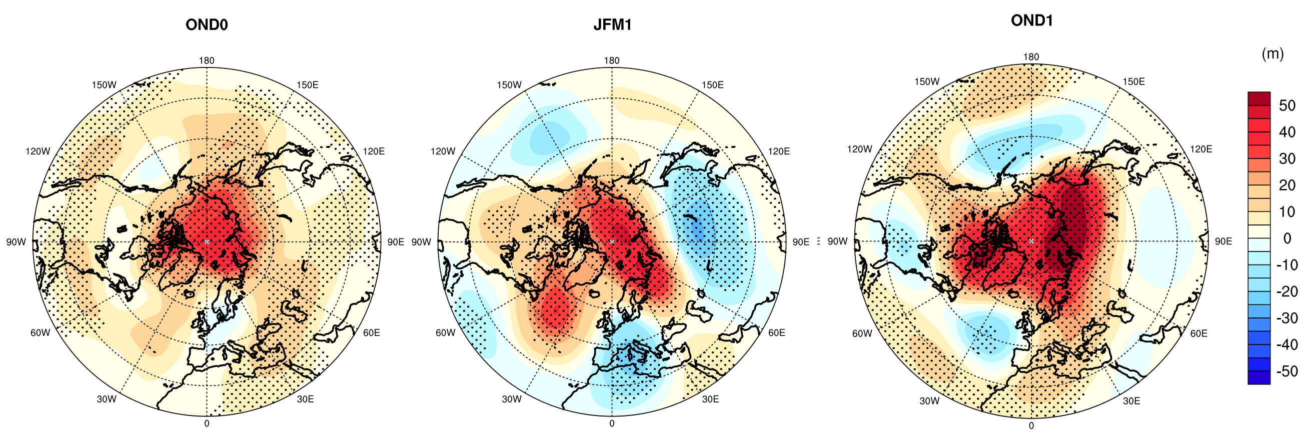
Turbulent heat flux response dominated by thermodynamical component (sea ice forcing)

Pressure response

Sea level pressure (contours : climatology)



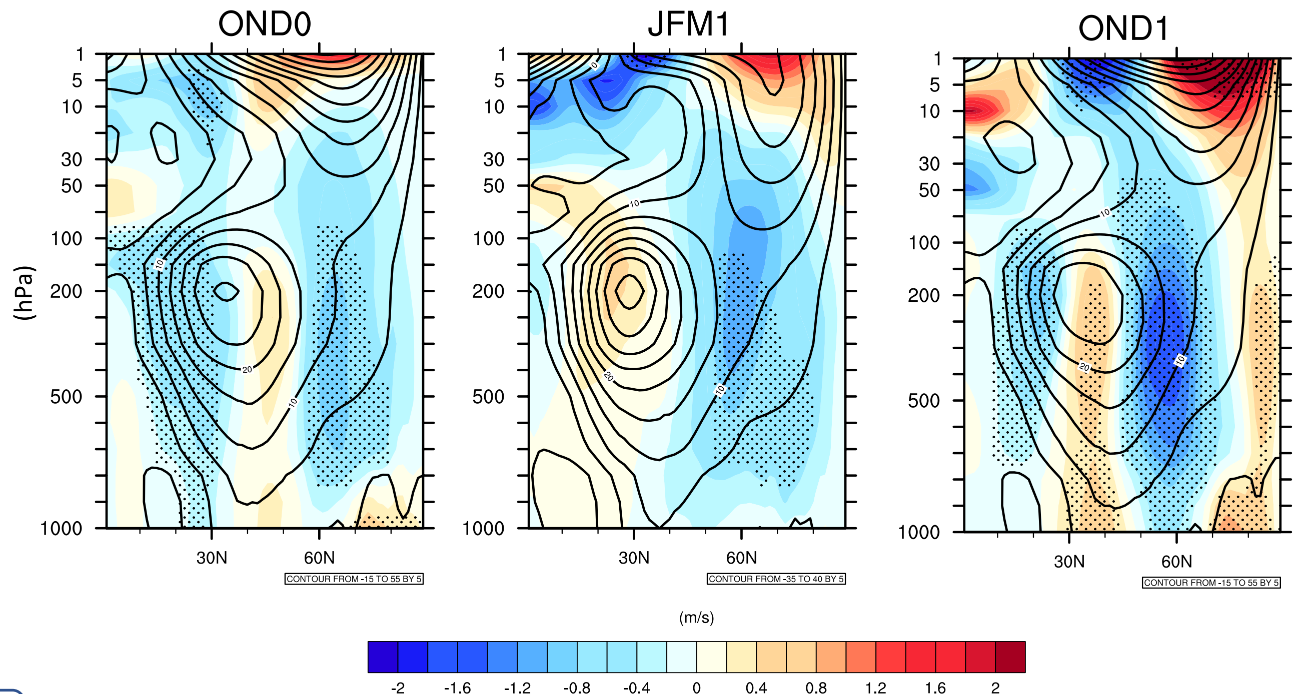
Geopotential height Z500



- Autumn : strong negative anomaly over the Arctic Ocean due to thermodynamical effect + positive Z500 anomalies
  → Baroclinic response
- Winter : 3 anticyclonic patterns over the polar cap
  → Barotropic response
- 2nd autumn : intensification of the Aleutian Low and the Siberian High (consistent with other studies using coupled models : cf. Screen et al. 2018)

Atmospheric response consistent with the NAM- in the middle troposphere the 2nd autumn

Zonal-mean zonal wind response



Troposphere

- Autumn : slight weakening of both sides of the jet stream

→ stronger the 2nd autumn with a significant narrowing of the jet stream (consistent with other studies, e.g. Sun et al. 2015)

- Winter : weakening of the poleward side of the jet stream

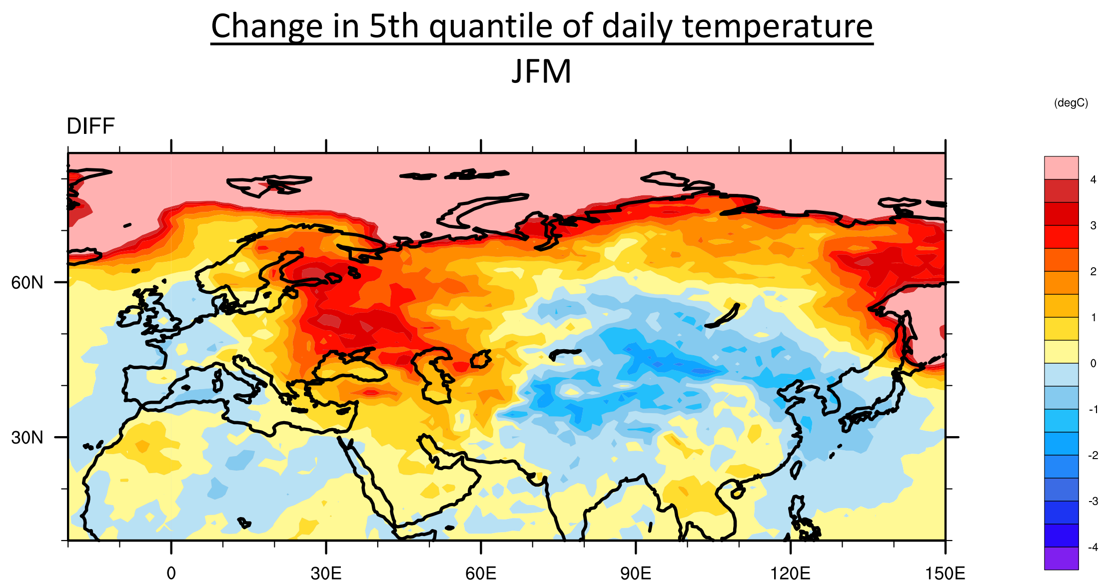
  → slight equatorward displacement

Stratosphere

- Not significant responses in OND0 and JFM1 (strong variability)
- Significant poleward displacement of the polar vortex the 2nd autumn

Modification of cold extreme temperatures in Eurasia

Winter (JFM)



Cold extremes are cooler over

central Asia (~ -1.5°C)

and warmer over Eastern Europe (~ +3°C)

(e.g. Peings et al. 2014)

Summary of autumn and winter atmospheric responses

- Stronger atmospheric response the autumn following the 2nd summer sea ice loss (more SIC/SIV loss)

  → significant narrowing of the jet stream

  → poleward displacement of the polar vortex

  → Z500 and dynamical TAS responses consistent with NAM-

- Weakly significant responses in the stratosphere (zonal-mean zonal winds) : suggesting a strong variability

→ Interaction mechanism between the troposphere and the stratosphere under investigation

- Cooler cold extremes over central Asia (~ -1.5°C) consistent with the TAS cooling response, and warmer cold extremes over Eastern Europe (~+3°C)

→ Prolongation of the simulations to study the 2nd winter response

→ Study of atmospheric response to a more realistic seasonal sea ice forcing (PAMIP experiments, WP3)