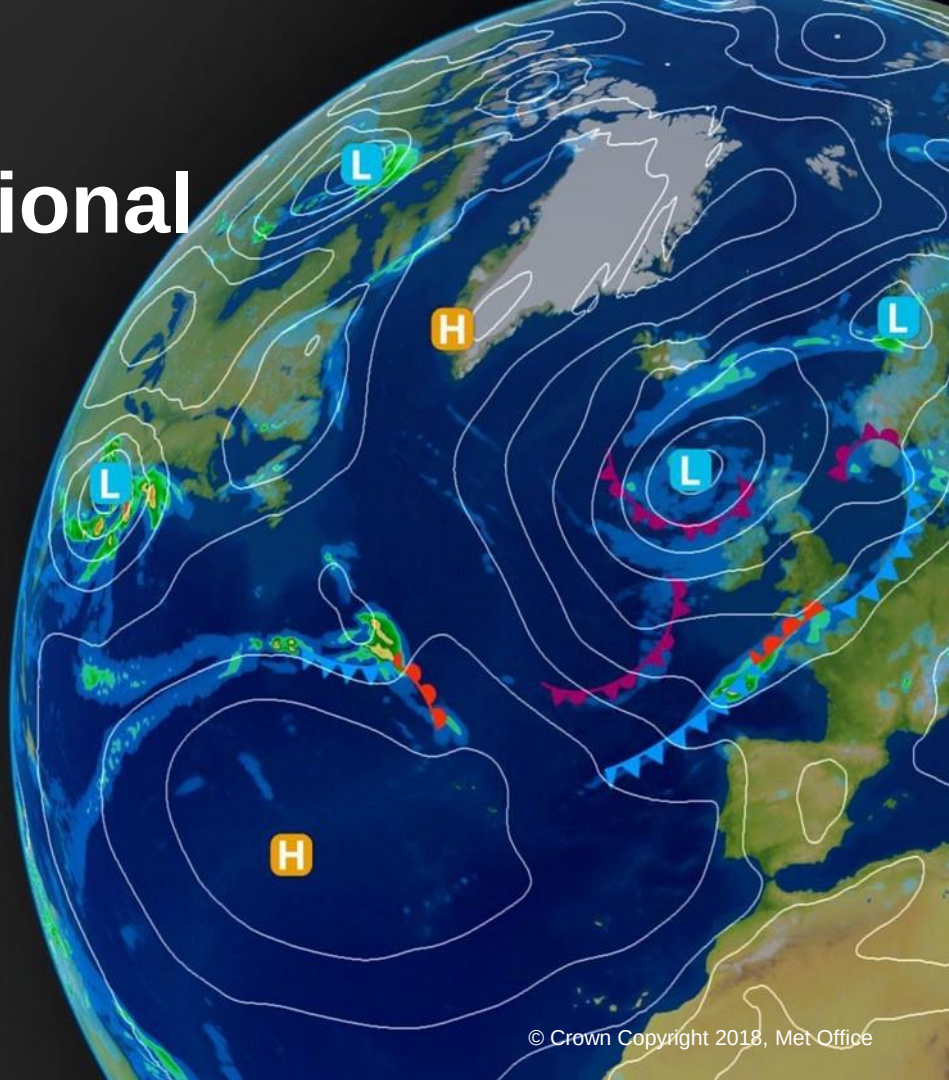
Met Office
Hadley Centre

Global response to regional winter sea ice loss

Rosie Eade, Doug Smith, Leon Hermanson, Nick Dunstone (Met Office, Exeter).

PAMIP Meeting, June 2019, Devon.



CMIP6-PAMIP

Set of large ensemble experiments, **AMIP** and Coupled
14 months (from 1st April 2000), 150 members, Met Office model **HadGEM3 N216**

Different combinations of **prescribed global SIC and SST fields**
pdSST_pdSIC present day (P.I. +0.57°C GMT)
pdSST_fuArcSIC future sea-ice in Arctic, rcp8.5 (P.I. +2°C GMT)
fuBKSeasSIC, **fuOkhotskSIC, fuAntSIC**
pdSST_piArcSIC pre-industrial (P.I.) **, piAntSIC**

Differences of experiments with same SST but different SIC → estimate contribution of SIC reduction to polar amplification

- Arctic SIC reduction in different regions may have different impacts
- Projections of SIC show different rates of loss in different regions → impacts may vary over time

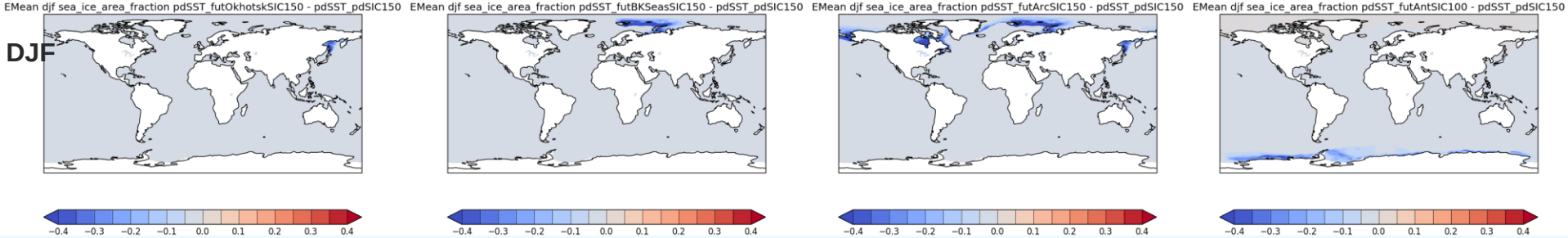
Smith et al, 2018, Geosci. Model Dev. Discuss., The Polar Amplification Model Intercomparison Project (PAMIP) contribution to CMIP6: investigating the causes and consequences of polar amplification

MO Model Response to reduced sea ice – sub regions

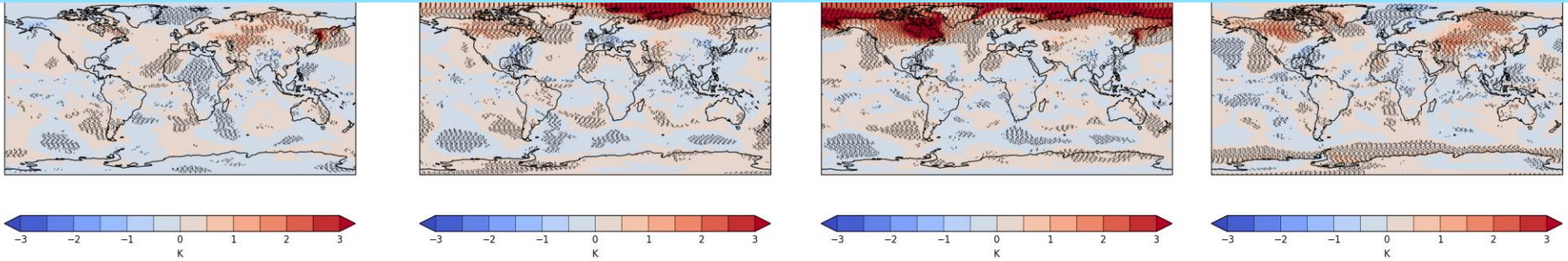
Sea Ice Concentration: Future - Present Day

Sea of Okhotsk | Barents/Kara Seas | Arctic | Antarctic

DJF



Temperature: Future - Present Day



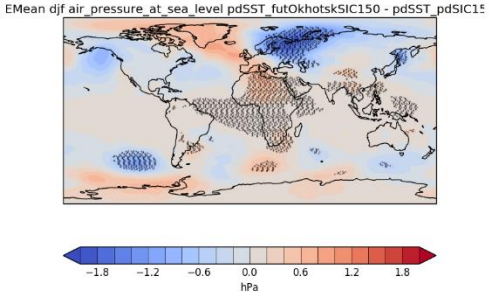
Local surface warming in DJF

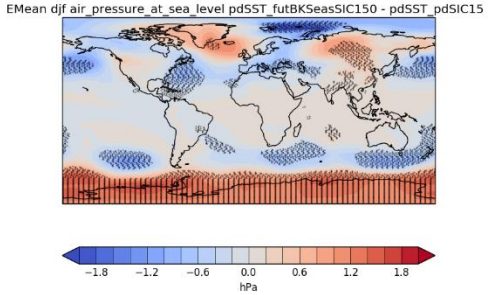
MO Model Response to reduced sea ice – sub regions

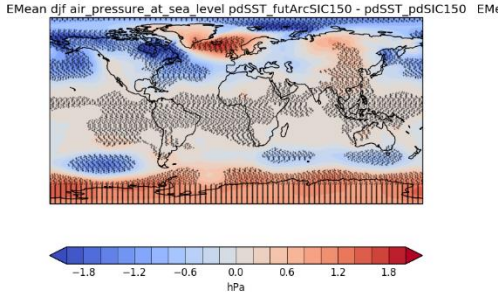
Mean Sea Level Pressure: Future - Present Day

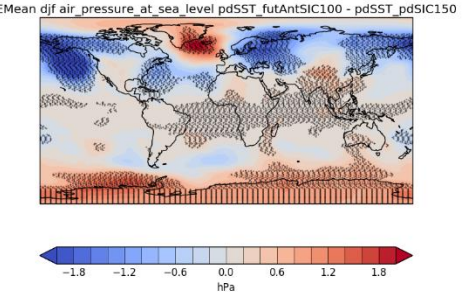
Sea of Okhotsk | Barents/Kara Seas | Arctic | Antarctic

DJF









Increase over Iceland in DJF → possible negative NAO response

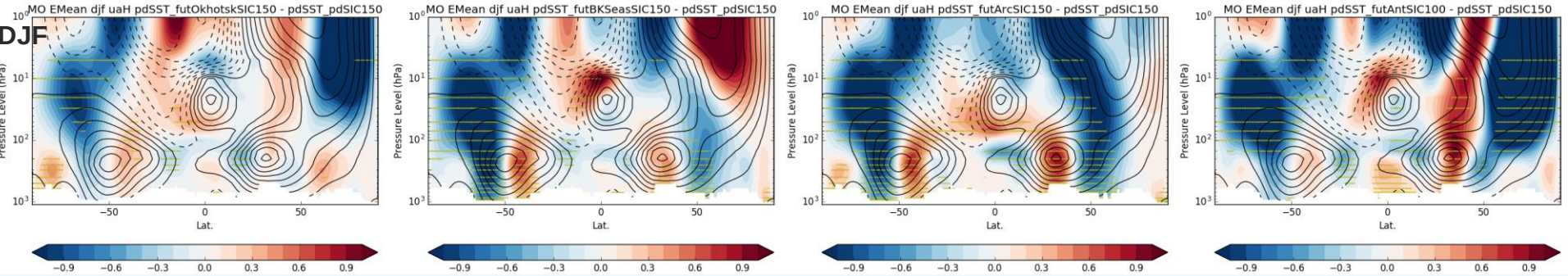
- Similar response seen from Antarctic sea ice loss
- Also increase over Antarctic
- Sea of Okhotsk weaker response (smaller region sic change)

MO Model Response to reduced sea ice – sub regions

Zonal mean u-wind: Future - Present Day

Sea of Okhotsk | Barents/Kara Seas | Arctic | Antarctic

DJF



Troposphere: strengthen jet equatorward side (equatorward shift)

- Symmetric response in both hemispheres
- Similar response in ALL experiments
- Also similar response seen from Antarctic sea ice loss

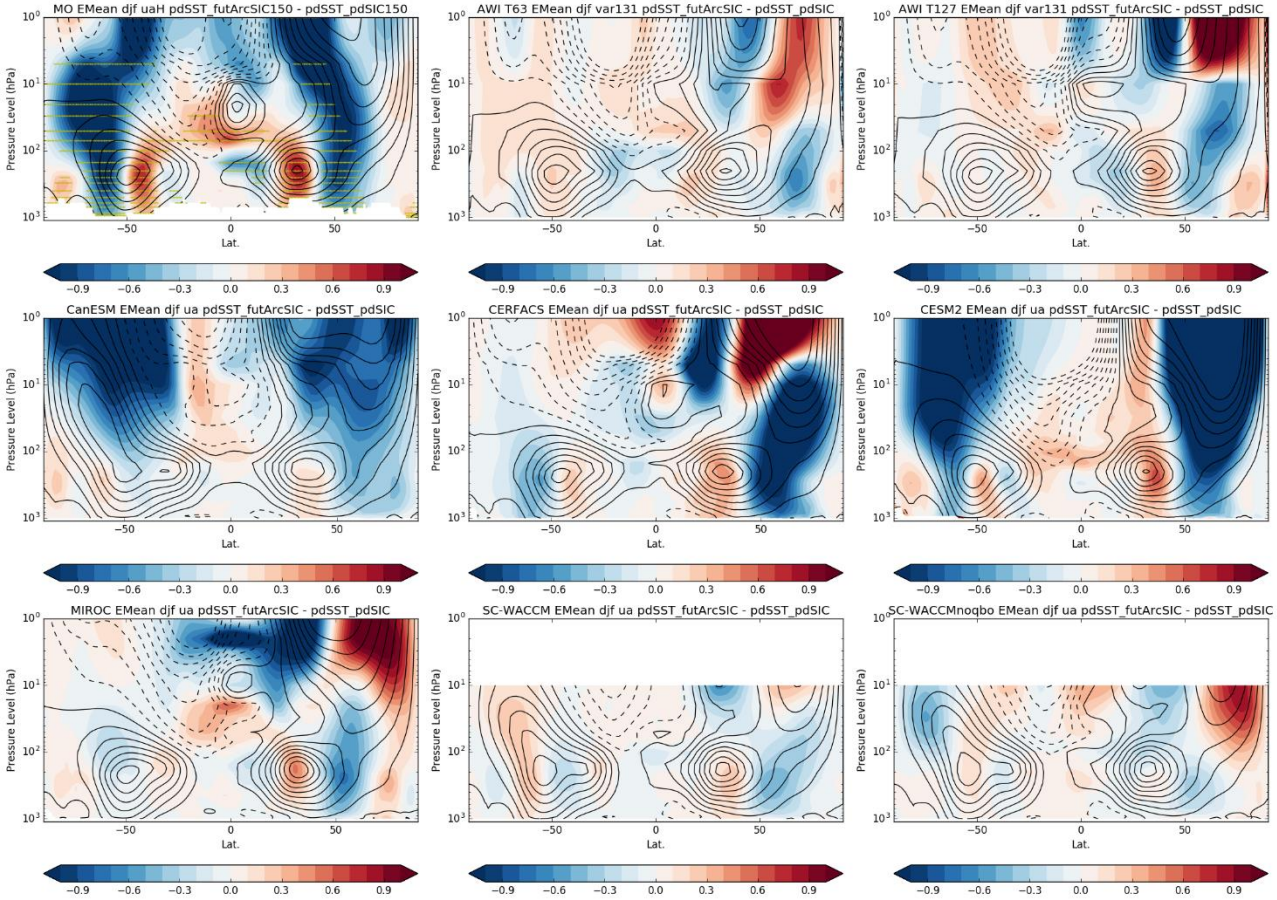
Stratosphere: Arctic sea ice loss → weaker N hemi polar jet equatorward (poleward shift)

- Antarctic sea ice loss → stronger N hemi polar jet equatorward (equatorward shift)
- ALL experiments → weaker S hemi winds

MO Model Response to reduced sea ice – sub regions

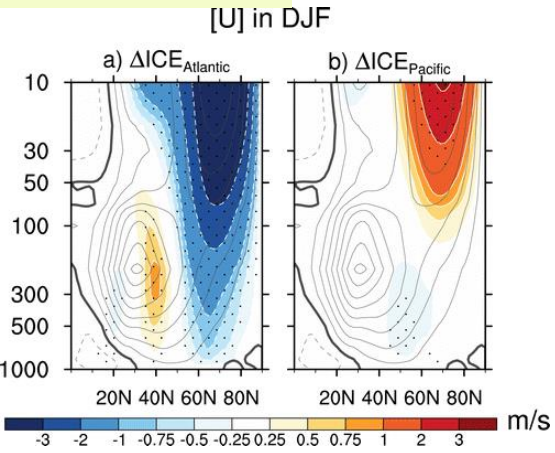
Zonal mean u-wind: Future - Present Day Multi Model

Dual hemisphere responses seen across multi-model PAMIP experiments, with varying strengths

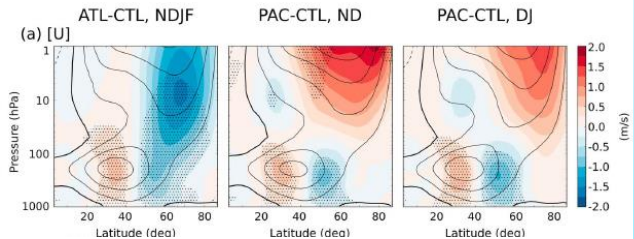


Background: Response to reduced winter Arctic sea ice – sub regions

Sun et al, 2015

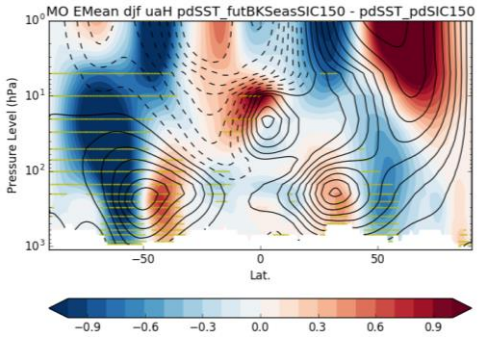


McKenna et al, 2015

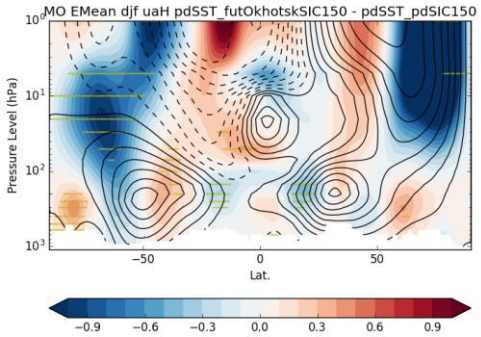


Zonal mean u-wind: Future - Present Day

Barents/Kara Seas



Sea of Okhotsk



Dynamic response sensitive to location/extent of sea ice loss

- Lit: Atlantic vs Pacific SIC loss → opposite stratosphere response
- MO model also shows opposite response, but other way round to Lit. and not significant.

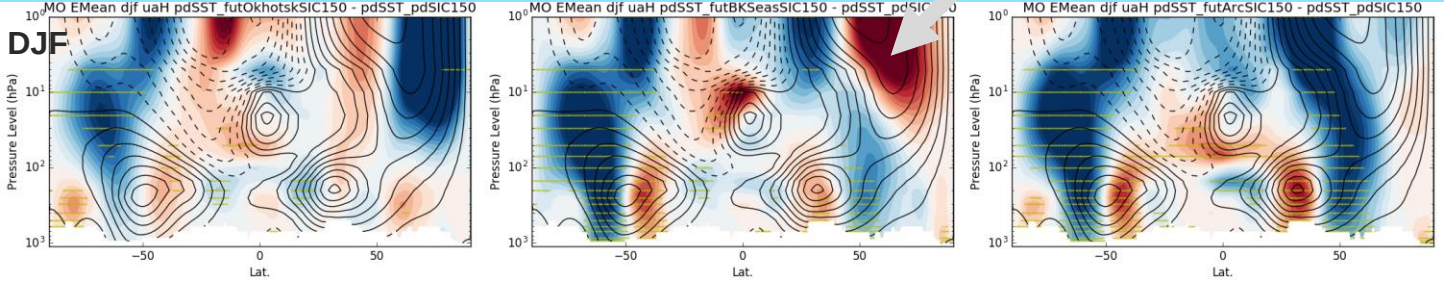
Importance of Large Ensembles especially in stratosphere

Zonal mean u-wind: Future - Present Day

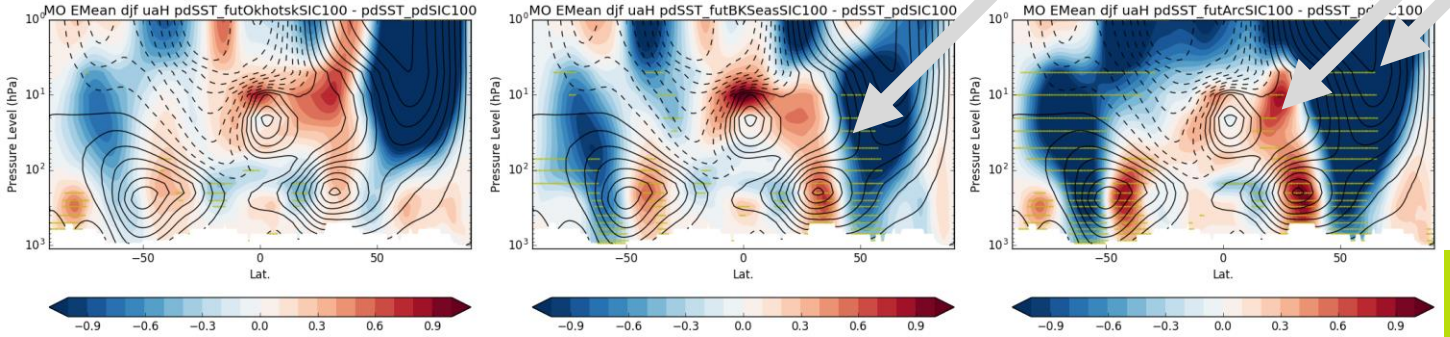
Sea of Okhotsk | Barents/Kara Seas | Arctic

150 Members

DJF



100 Members

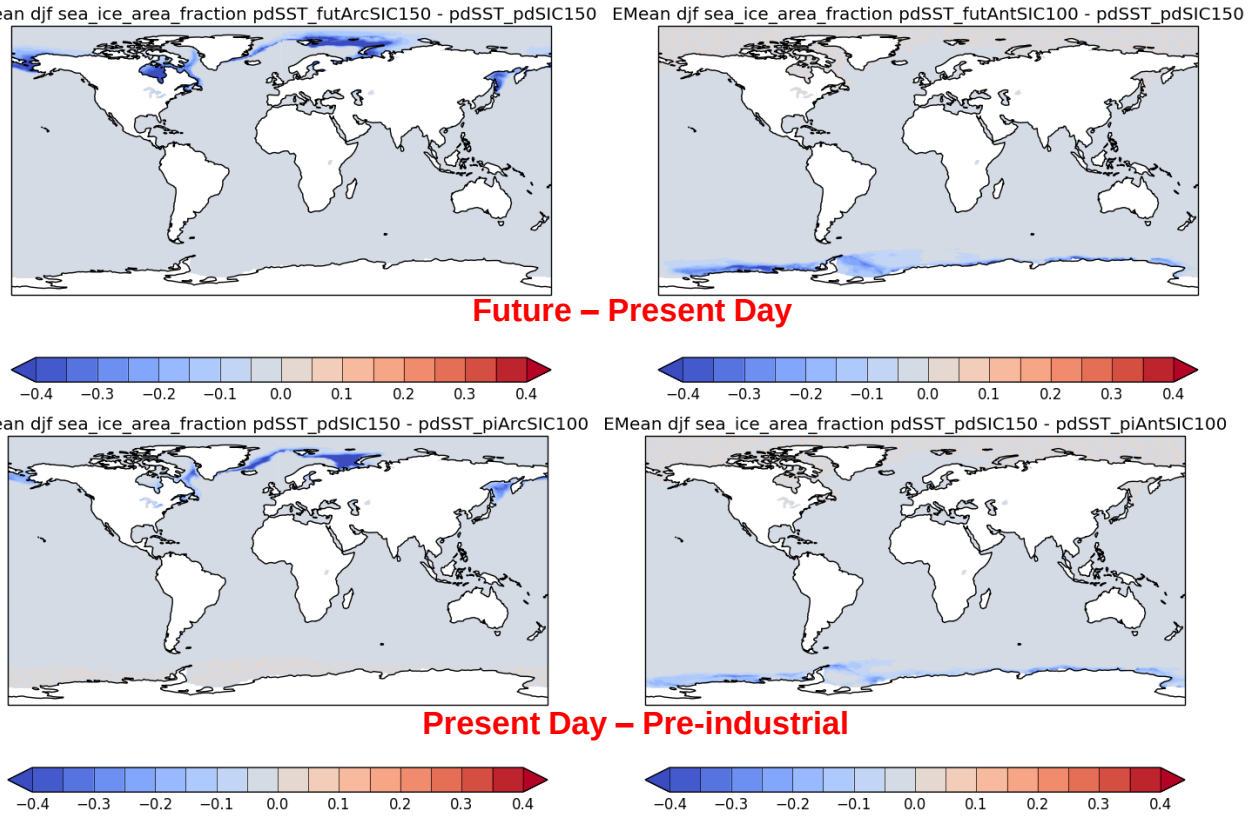


Need *large ensemble* to bring out robust response

MO Model Response to reduced DJF sea ice

Sea Ice Concentration:

	Arctic	Antarctic
Future – Present Day	EMean djf sea_ice_area_fraction pdSST_futArcSIC150 - pdSST_pdSIC150	EMean djf sea_ice_area_fraction pdSST_futAntSIC100 - pdSST_pdSIC150
Present Day – Pre-industrial	EMean djf sea_ice_area_fraction pdSST_pdSIC150 - pdSST_piArcSIC100	EMean djf sea_ice_area_fraction pdSST_pdSIC150 - pdSST_piAntSIC100



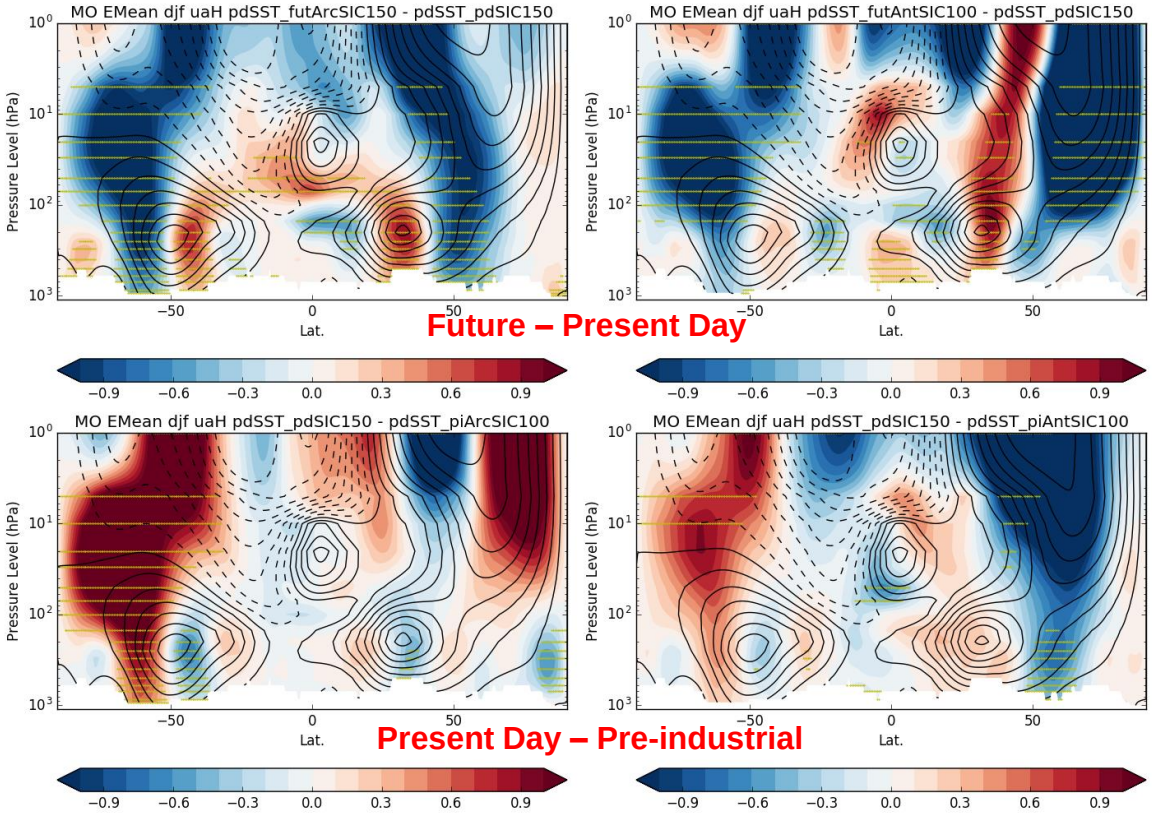
MO Model Response to reduced DJF sea ice

Zonal mean u-wind :

- Some opposing results for present day – pre-industrial

Arctic

Antarctic



Global response to regional winter sea ice loss

Summary

Future – Present Day

- MSLP increase over Iceland in DJF in ALL experiments → possible negative NAO response
  - Also seen for reduced Antarctic sea ice
- Tropospheric jet shifts equatorward in ALL experiments
  - Symmetric response in both hemispheres
  - Similar response from Antarctic sea ice loss
- Stratospheric polar jet: Arctic sea ice loss → shifts poleward
  - BKSeas vs SeaOkhotsk show opposite polar jet responses (not sig)
  - But signal is reversed compared to Mckenna et al, 2015 and Sun et al, 2015.
  - Note the need for *large ensemble* to bring out robust response
  - Antarctic sea ice loss → polar jet shifts equatorward
  - ALL experiments → sig weaker S hemi stratospheric winds

Present day – Pre-industrial

- Some opposing results compared to Future – PD
  - NB different size of sea ice change e.g. non linearity of response proposed by Mckenna et al, 2015

Next Steps

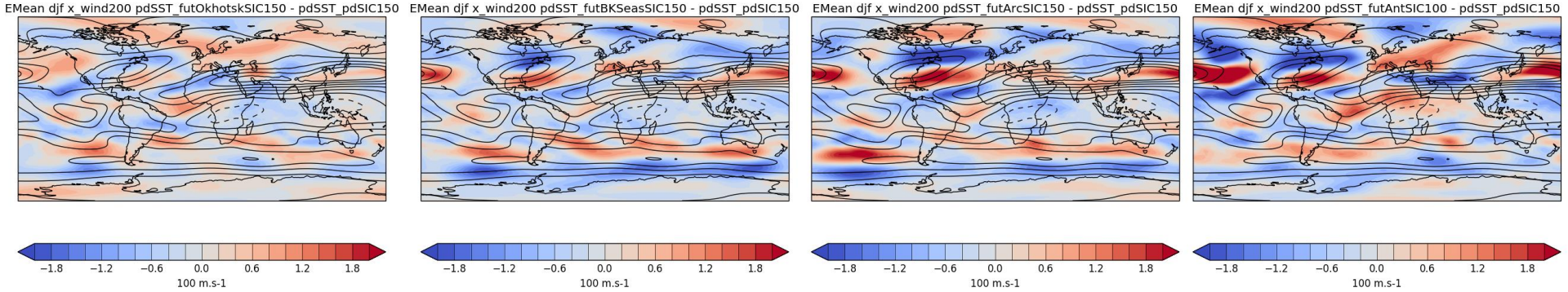
- Investigate robustness of results across models and determine mechanisms

MO Model Response to reduced sea ice – sub regions

U-wind 200hPa : Future - Present Day

Sea of Okhotsk | Barents/Kara Seas | Arctic | Antarctic

DJF



Troposphere DJF: symmetric response, strengthen jet equatorward side (shift)

JJA S-hemi equatorward shift, N-hemi poleward shift from Antarctic sea ice loss

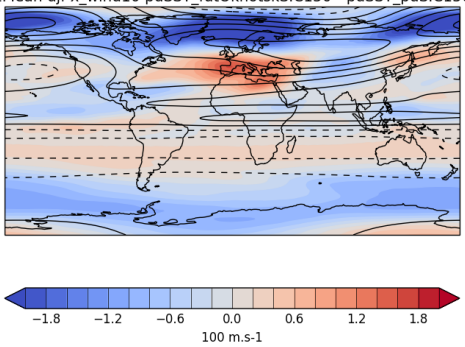
MO Model Response to reduced sea ice – sub regions

U-wind 10hPa : Future - Present Day

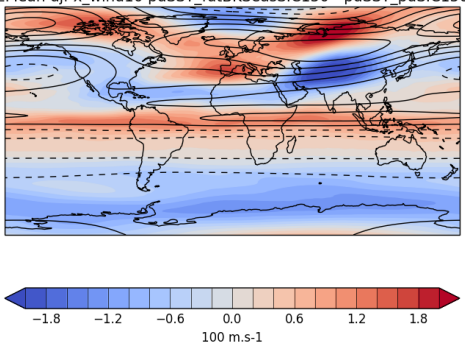
Sea of Okhotsk | Barents/Kara Seas | Arctic | Antarctic

DJF

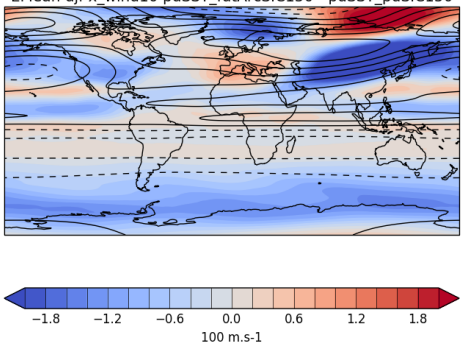
EMean djf x_wind10 pdSST_futOkhotskSIC150 - pdSST_pdSIC150



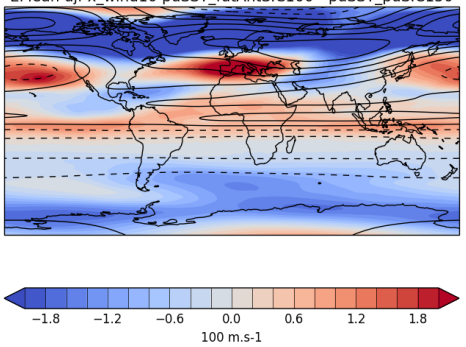
EMean djf x_wind10 pdSST_futBKSeasSIC150 - pdSST_pdSIC150



EMean djf x_wind10 pdSST_futArcSIC150 - pdSST_pdSIC150



EMean djf x_wind10 pdSST_futAntSIC100 - pdSST_pdSIC150



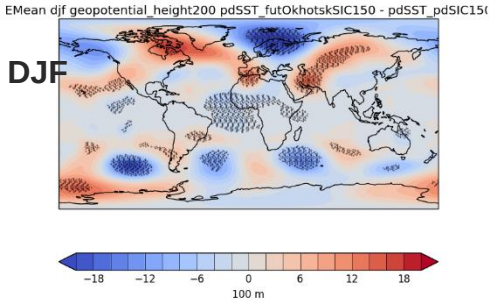
Stratosphere DJF: fuArc → weaker N hemi jet equatorward; Sub-reg → opposite sign in N hemi but not significant; all → weaker S hemi winds

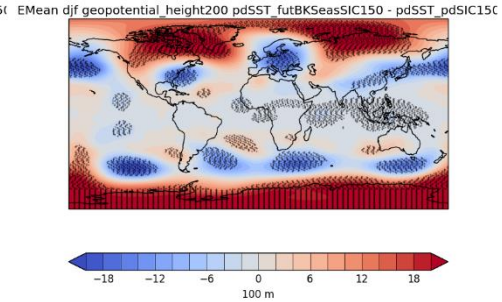
fuAnt → DJF stronger N hemi jet equatorward; JJA stronger S hemi jet equatorward

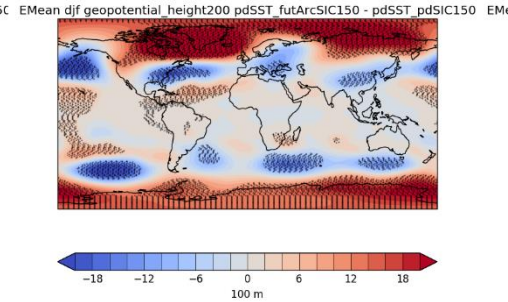
MO Model Response to reduced sea ice – sub regions

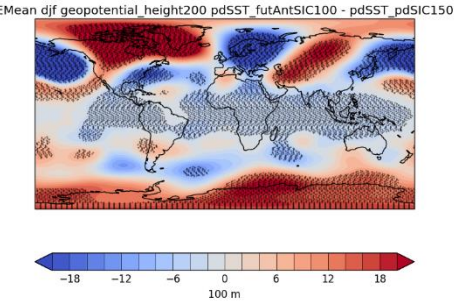
GPH 200hPa: Future - Present Day

Sea of Okhotsk	Barents/Kara Seas	Arctic	Antarctic
DJF			









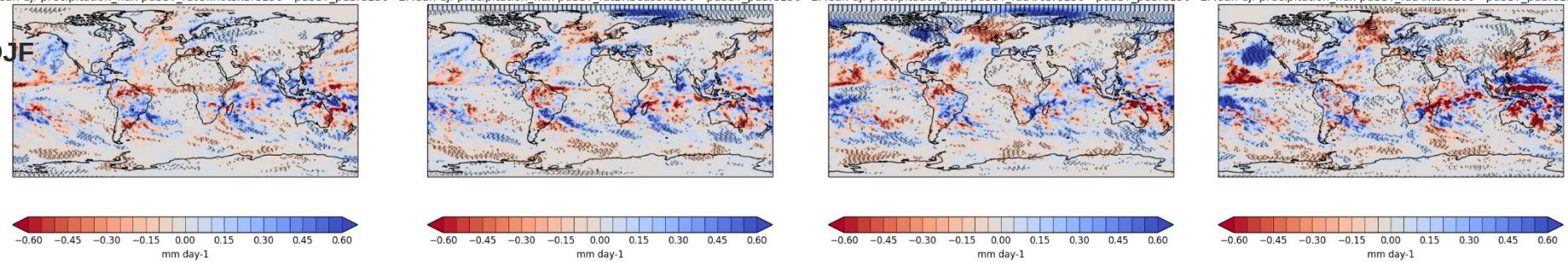
…

MO Model Response to reduced sea ice – sub regions

Precipitation: Future - Present Day

Sea of Okhotsk	Barents/Kara Seas	Arctic	Antarctic
EMean djf precipitation_flux pdSST_futOkhotskSIC150 - pdSST_pdSIC150	EMean djf precipitation_flux pdSST_futBKSeasSIC150 - pdSST_pdSIC150	EMean djf precipitation_flux pdSST_futArcSIC150 - pdSST_pdSIC150	EMean djf precipitation_flux pdSST_futAntSIC100 - pdSST_pdSIC150

DJF



...

Importance of Large Ensembles especially in stratosphere

u-wind 10 hPa: Future - Present Day

Sea of Okhotsk Barents/Kara Seas Arctic

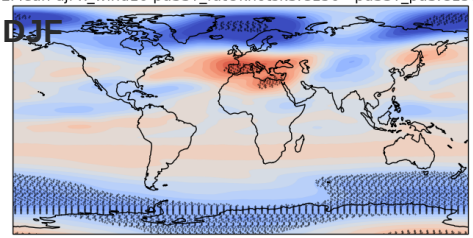
150 Members

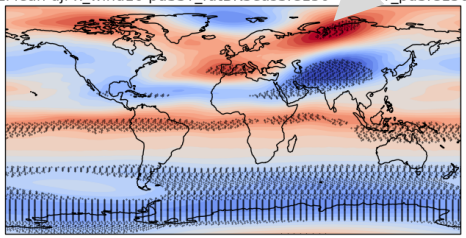
EMean djf x_wind10 pdSST_futOkhotskSIC150 - pdSST_pdSIC150

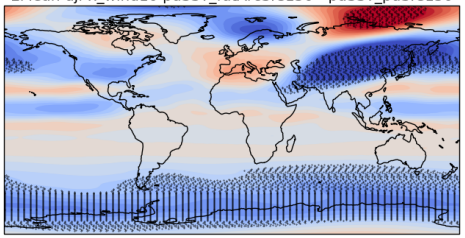
EMean djf x_wind10 pdSST_futBKSeasSIC150 - pdSST_pdSIC150

EMean djf x_wind10 pdSST_futArcSIC150 - pdSST_pdSIC150

DJF





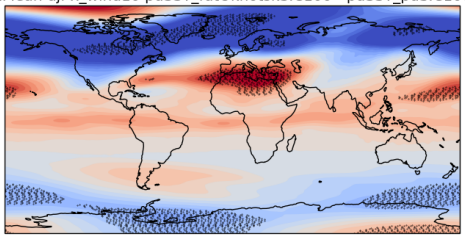


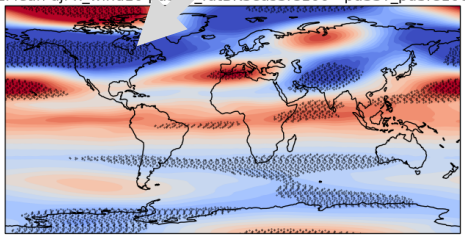
100 Members

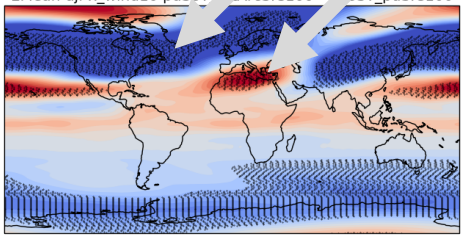
EMean djf x_wind10 pdSST_futOkhotskSIC100 - pdSST_pdSIC100

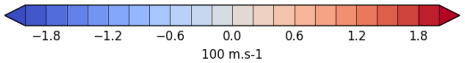
EMean djf x_wind10 pdSST_futBKSeasSIC100 - pdSST_pdSIC100

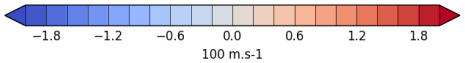
EMean djf x_wind10 pdSST_futArcSIC100 - pdSST_pdSIC100

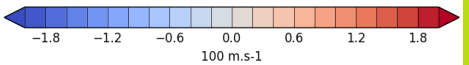












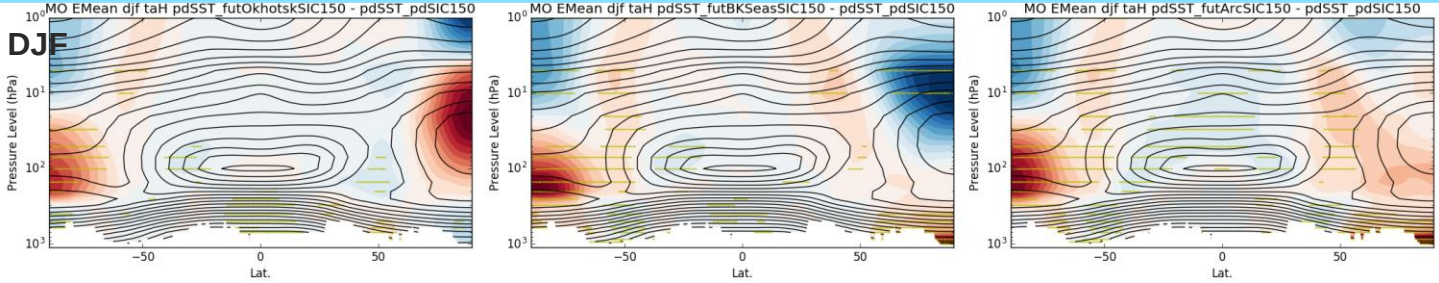
Importance of Large Ensembles especially in stratosphere

Zonal mean temperature: Future - Present Day

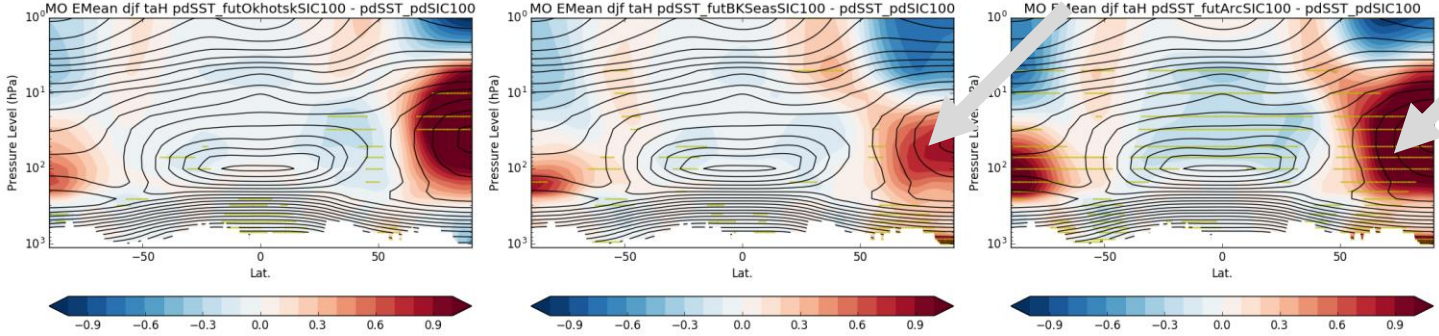
Sea of Okhotsk Barents/Kara Seas Arctic

150 Members

DJF

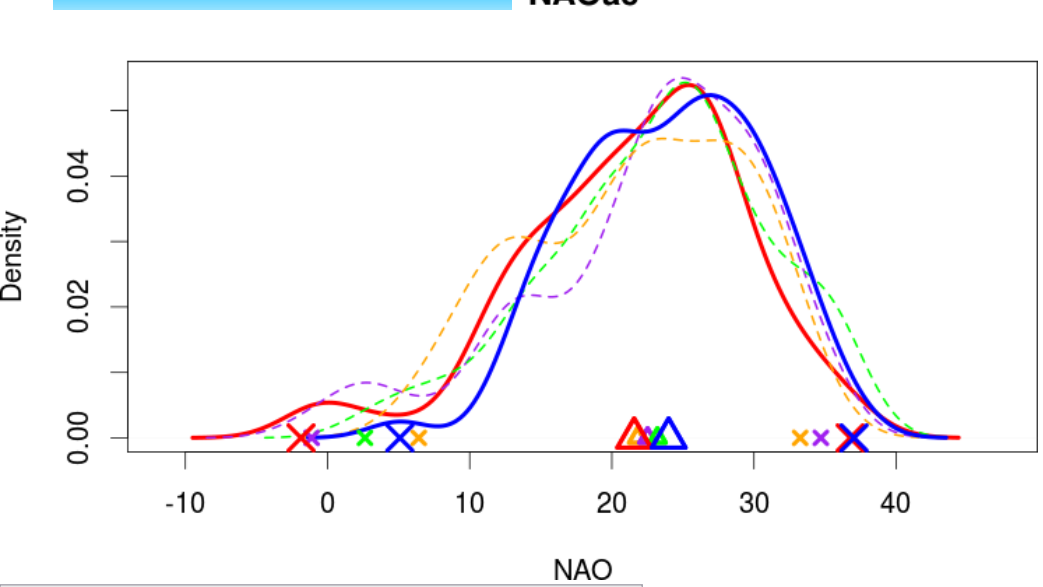


100 Members



MO Model Response to reduced winter Arctic sea ice – sub regions

MSLP NAO index



Present Day = blue, *s.d. 6.5*

Future Arctic = red *s.d. 7.8*

Future BKSeas = purple *s.d. 8.3*

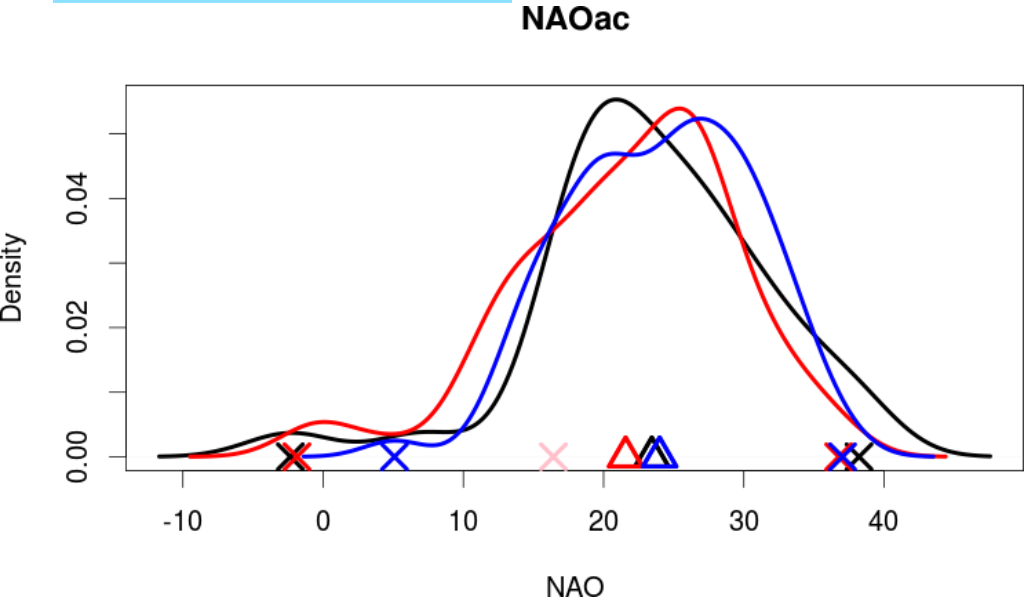
Fut Okhotsk = green *s.d. 7.8*

Future Antarctic = orange *s.d. 7.4*

- No Mean NAO response
  - fairly close for all experiments (also max NAO)
  - fuArc only slight mean shift from Present-Day (-2.4 hPa)
- fuArc & fuBKSeas → more extreme negative NAO events
  - ~ 7hPa difference ~ 1s.d.
  - Future s.d. larger than Present-Day

Reduced Arctic Sea Ice

MSLP NAO index



Compare to original historical run? How much is the NAO constrained by the initial conditions?

- Mean NAO: PAMIP Exps centred around historical,
  - not constrained by I.C.s to be near 2001 NAO value
- Min NAO for historical closer to fuArc than pd

Historical 1980-2014= black (pink = 2001)

Future Arctic = red

Present Day = blue

Background: Response to reduced winter Arctic sea ice

Screen et al, 2018 *(90N-0)*

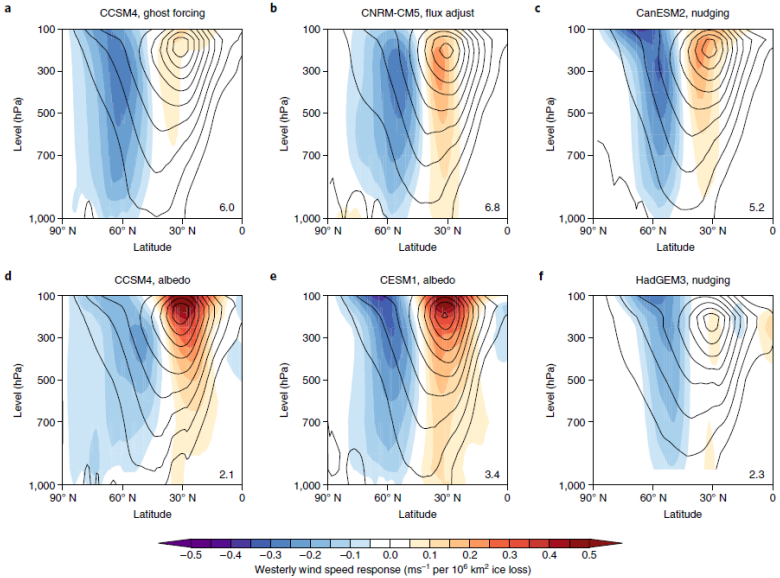


Fig. 3 | Effects of Arctic sea-ice loss on winter atmospheric circulation. Boreal winter zonal-mean westerly wind response (coloured shading) to Arctic sea-ice loss in six unique sets of coupled ocean–atmosphere model simulations. The responses have been scaled by the reduction in sea-ice extent in each case (provided in the lower-right corner of each panel in million square kilometres; see Methods). The black contours indicate the baseline climatology (contour interval of 5 m s⁻¹). The simulations presented in **a**–**f** are described in refs [15,23,24,25,26] and [16], respectively. The panel titles provide the model and

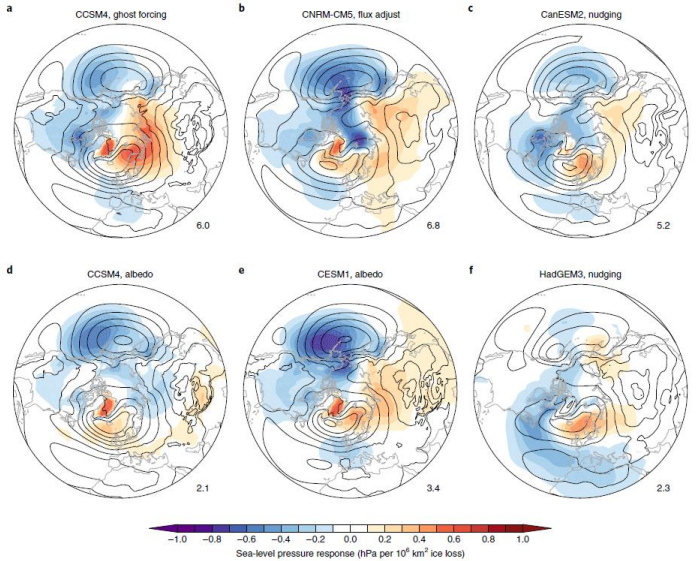


Fig. 2 | Effects of Arctic sea ice loss on winter sea-level pressure. Boreal winter mean sea-level pressure response (coloured shading) to Arctic sea-ice loss in six unique sets of coupled ocean–atmosphere model simulations. The responses have been scaled by the reduction in sea-ice extent in each case (provided in the lower-right corner of each panel in million square kilometres; see Methods). The black contours indicate the baseline climatology (contour interval of 5 hPa). The simulations presented in **a**–**f** are described in refs [15,23,24,25,26] and [16], respectively. The panel titles provide the model and protocol (refer to Box 1 for more details) used. Continental outlines are shown in grey.

Thermodynamic response is robust across models (local warming)

Dynamic response varies across models, e.g.

- Tropospheric jet shifts equatorward; Negative NAO