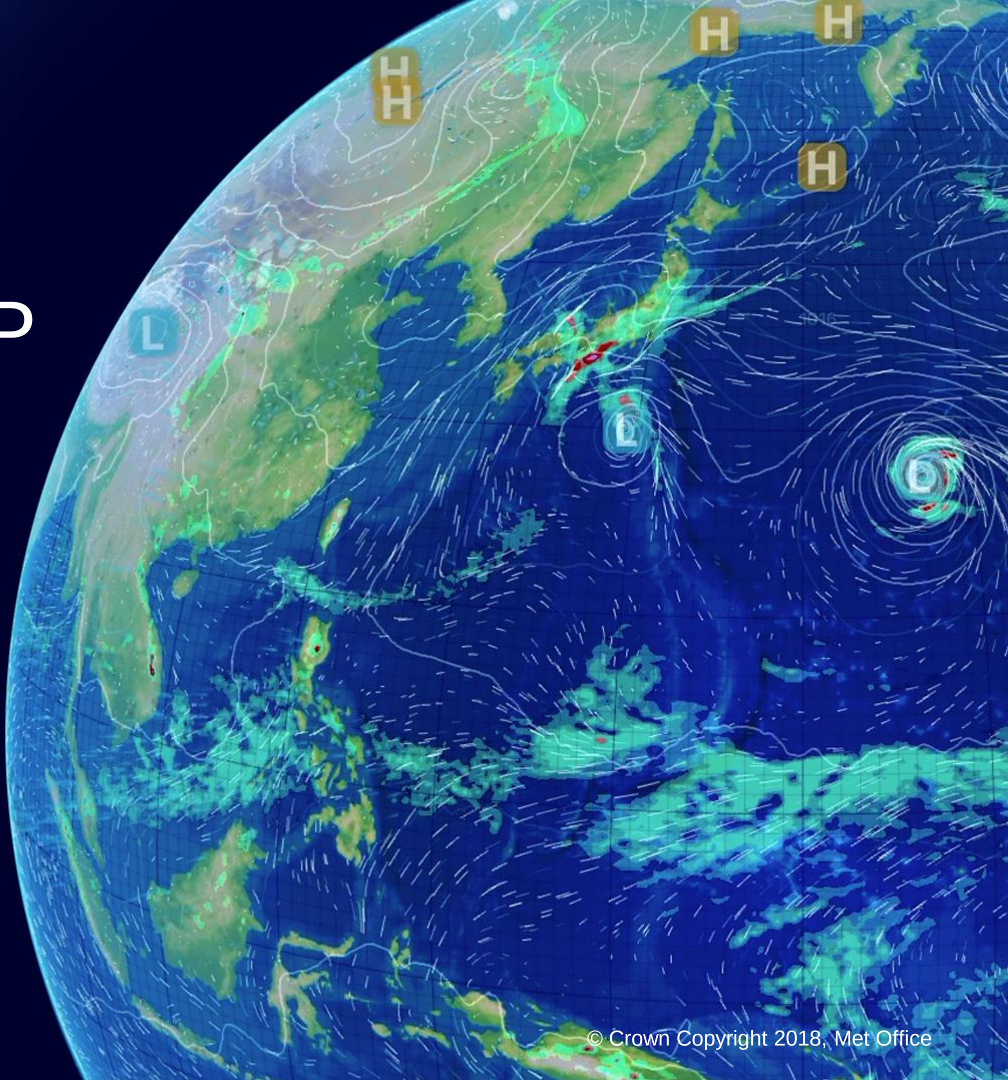
Initial results from the Polar Amplification MIP

APPLICATE 29th Jan 2019, Reading.

Rosie Eade & Doug Smith



APPLICATE WP3 – Aims

Atmospheric & Oceanic Linkages

Determine the influence of Arctic climate change on N. Hemisphere mid-latitudes e.g. via retreating sea ice, warming seas and atmosphere.
Explore sensitivity to background flow and regional patterns of ice anomalies.

Key Questions

What is the impact of Arctic climate change on mid latitudes?
What are the mechanisms of these mid-latitude responses to the Arctic?

CMIP6-PAMIP ← → APPLICATE

Set of large ensemble experiments, **AMIP** and Coupled
14 months (from 1st April 2000), 100 members, Met Office model **HadGEM3 N216**

Different combinations of **prescribed global SIC and SST fields**
pdSST_piArcSIC (pre-industrial sea-ice in Arctic <= hist)
pdSST_pdSIC (present day)
pdSST_fuArcSIC (future sea-ice in Arctic, rcp8.5), **fuBKSeasSIC**, **fuOkhotskSIC**

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

CMIP6-PAMIP Sea Ice Loss

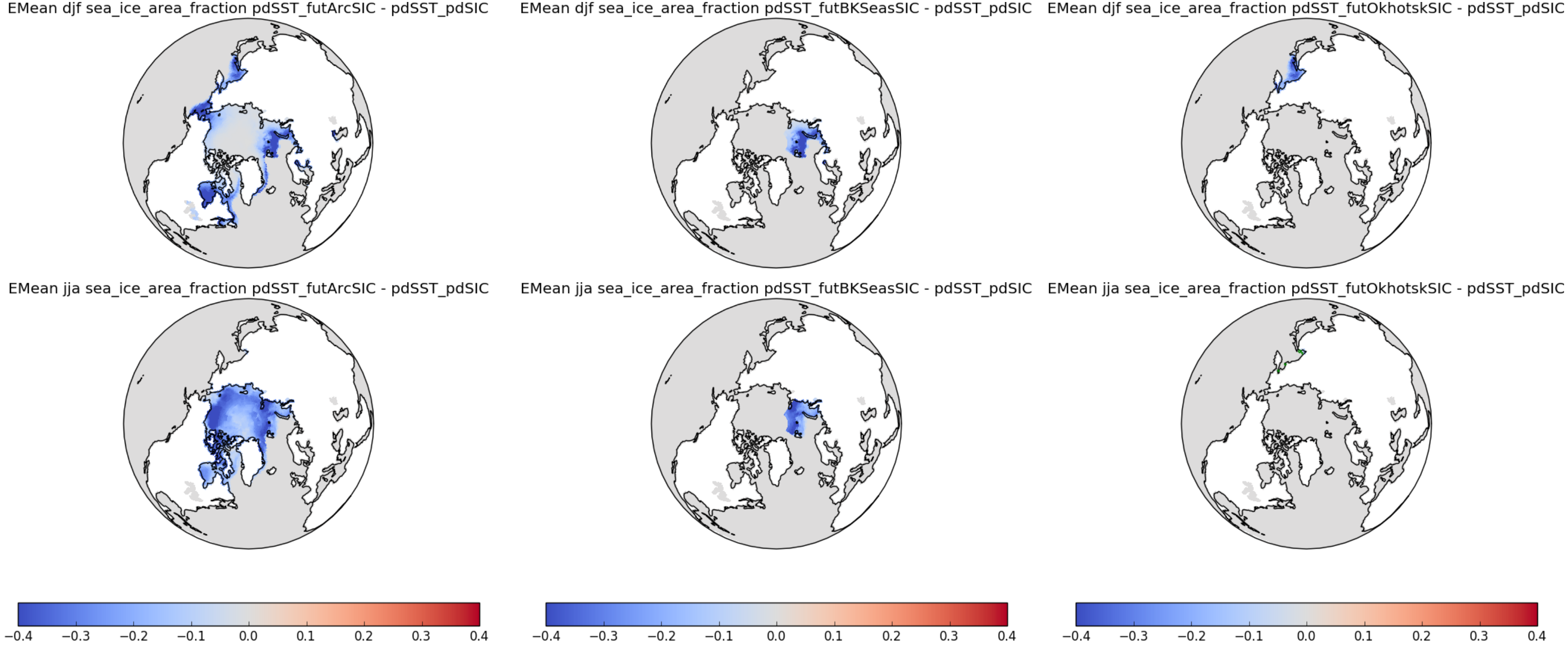
SIC

pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC	fuBKSeasSIC	fuOkhotskSIC

DJF

JJA



Reduced SIC around edge in winter; across most of Arctic in summer.

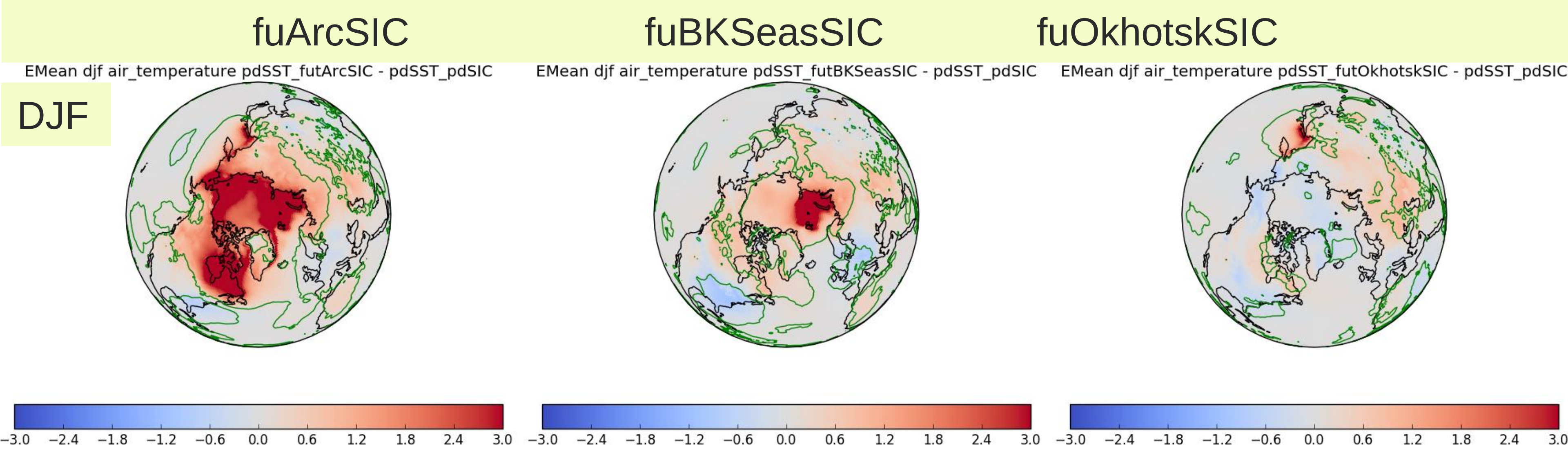
Preliminary Results

Winter response to reduced Arctic sea ice (DJF)

pdSST_fuArcSIC – pdSST_pdSIC

PAMIP Responses

pdSST_fu*SIC – pdSST_pdSIC



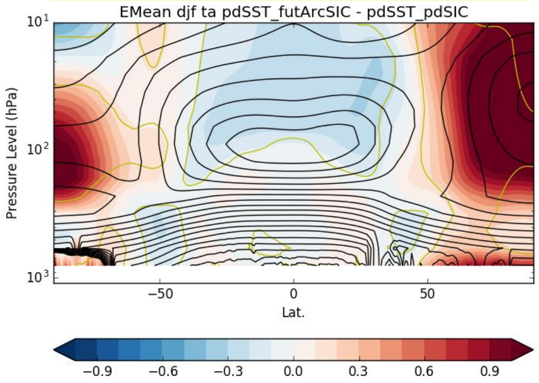
Local response - significant warming (as seen in other studies)

PAMIP Responses - Arctic

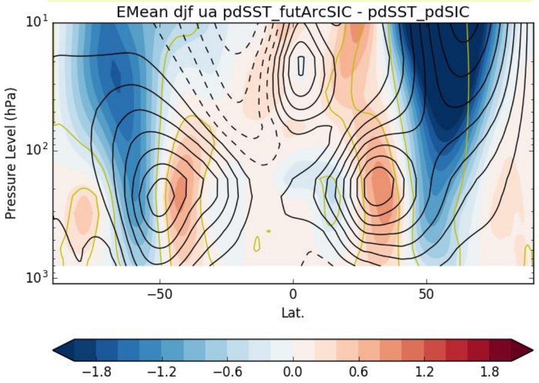
TA,UA

DJF

TEMPERATURE



U-WIND



Met Office

fuArcSIC – pdSIC Met Office Model

Local warming, equator-ward shift of jet.

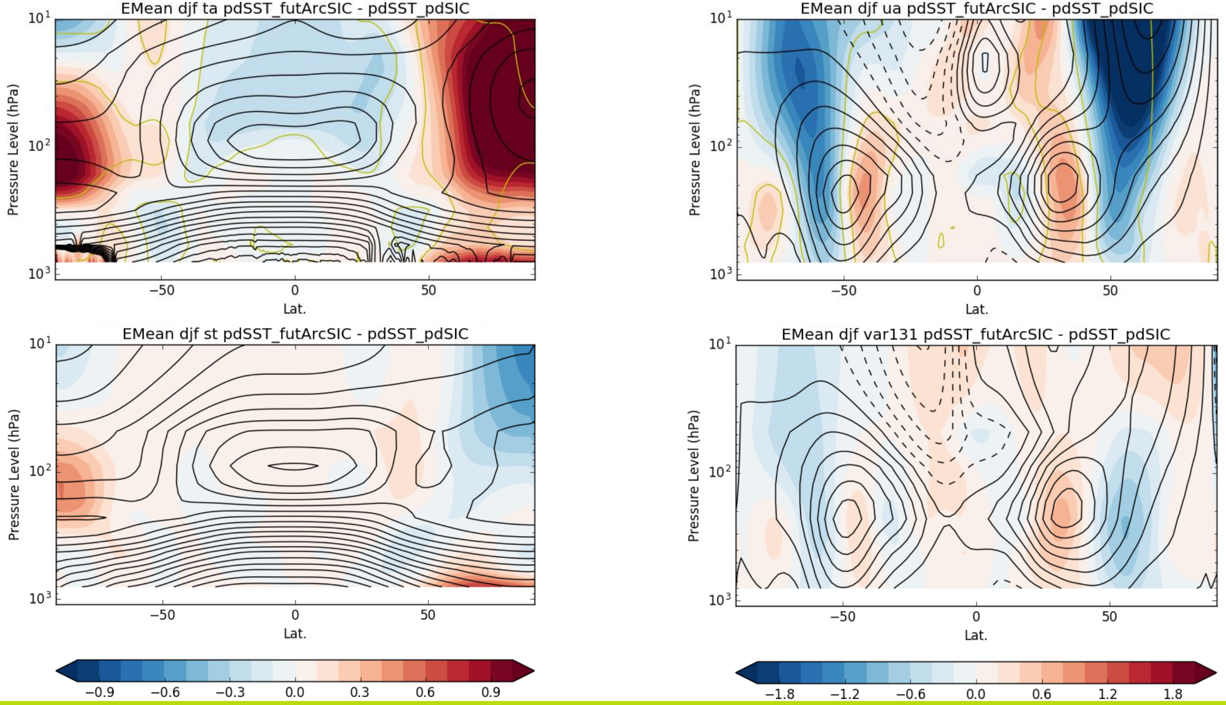
PAMIP Responses - Arctic

TA,UA

DJF

TEMPERATURE

U-WIND



Met Office

AWI

fuArcSIC – pdSIC Model Comparison

MO stronger response to AWI, & different sign in stratosphere.

Met Office Hadley Centre

APPLICATE.eu Advanced prediction in polar regions and beyond

PAMIP Responses - Arctic

UA

DJF

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

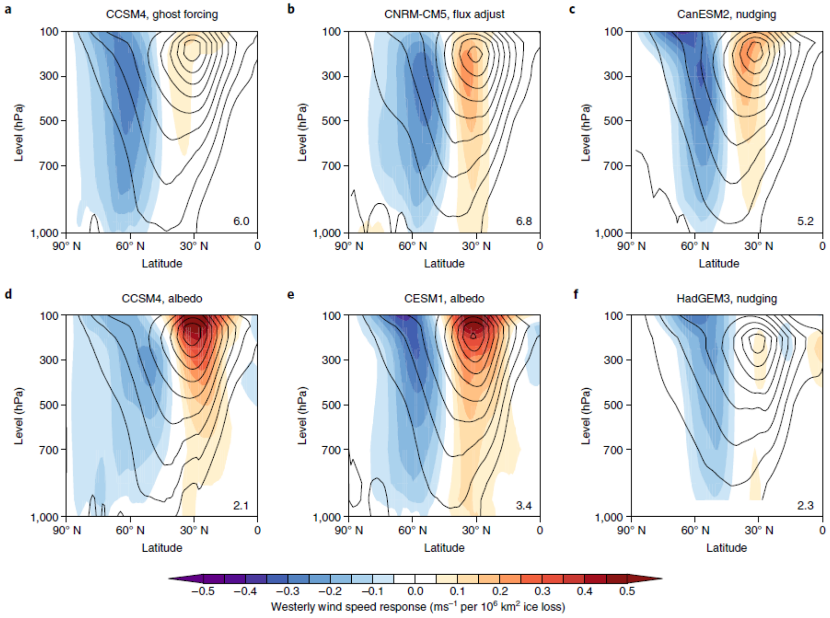
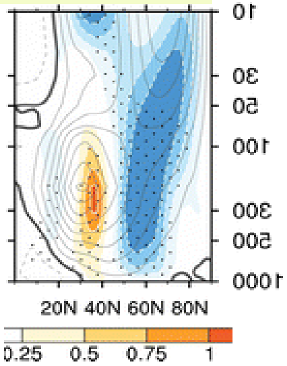


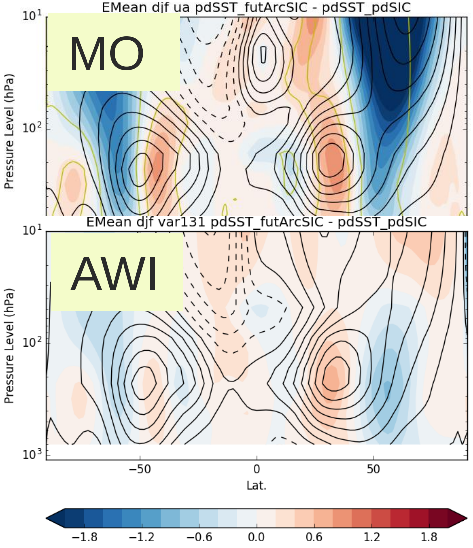
Fig. 3 | Effects of Arctic sea-ice loss on winter atmospheric circulation. Boreal winter zonal-mean westerly wind response (coloured shading) to Arctic sea-ice loss in six unique sets of coupled ocean-atmosphere model simulations. The responses have been scaled by the reduction in sea-ice extent in each 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 protocol (refer to Box 1 for more details) used.

Sun et al, 2015



MO

AWI



fuArcSIC – pdSIC:
Why do results vary across models?

PAMIP Responses - Arctic

MSLP

DJ

DJF

Screen et al, 2018

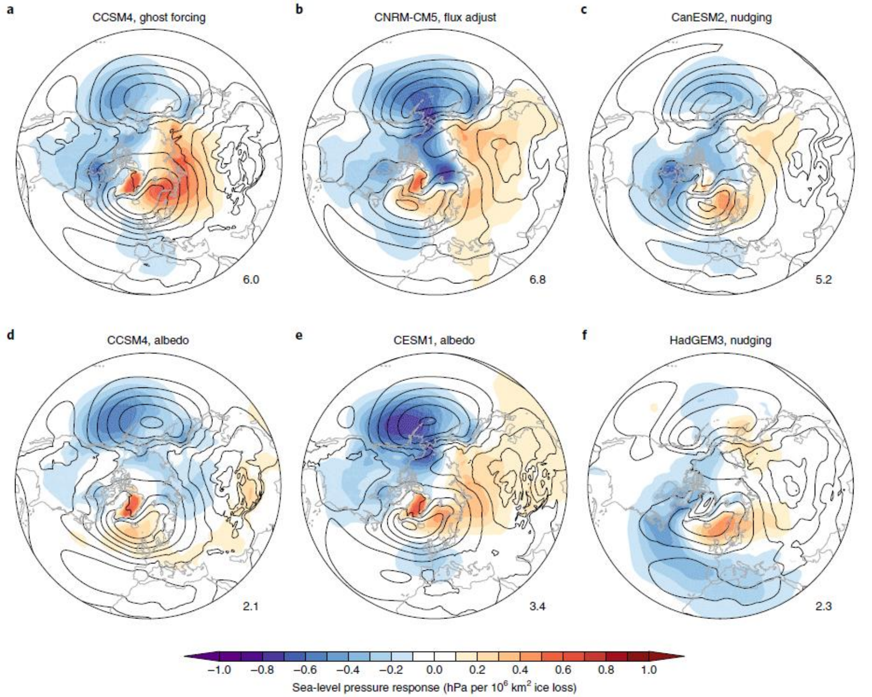
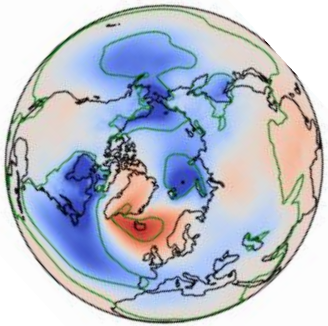


Fig. 2 | Effects of Arctic sea ice loss on winter sea-level pressure. Boreal winter mean sea-level pressure response (coloured shading) to Arctic sea-ice loss in six unique sets of coupled ocean-atmosphere model simulations. The responses have been scaled by the reduction in sea-ice extent in each case (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.

Met Office



fuArcSIC – pdSIC: -ve NAO like response

Why do results vary across models?

PAMIP Responses - Arctic

DJF

Smith et al, 2017

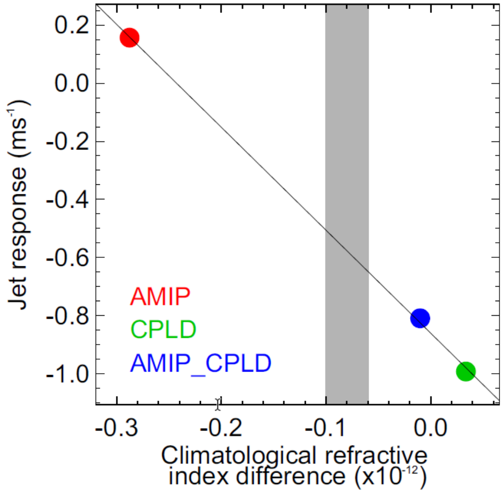
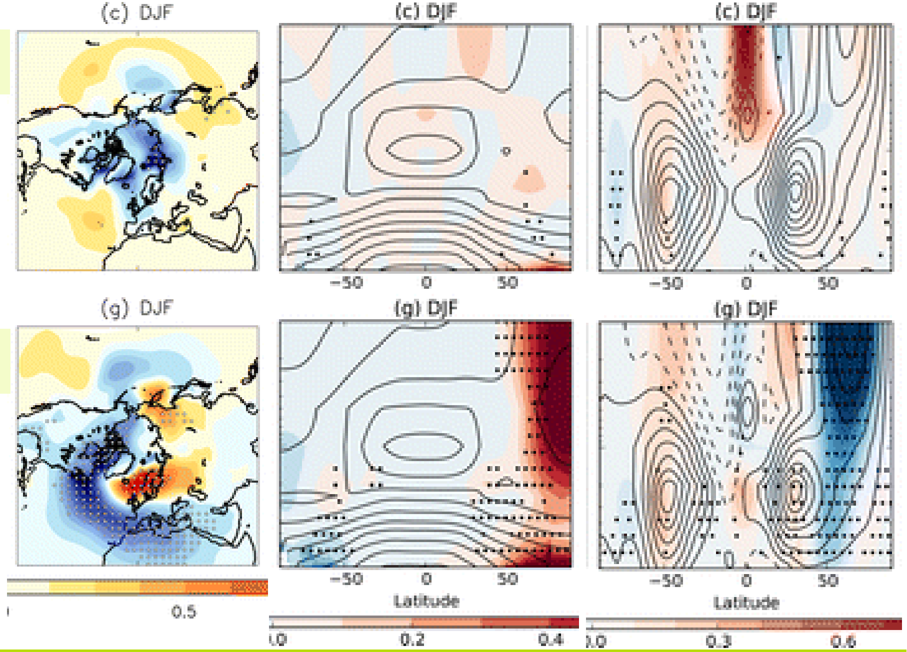


FIG. 14. Dependence of Atlantic jet response on the background climatological refractive index difference between middle (25°–35°N) and high (60°–80°N) latitudes at 200 hPa. Gray shading shows the observed range from ERA-Interim and NCEP II.

MSLP | TEMP | U-WIND

AMIP

Coupled



Model response may depend on background state

- RIGHT comparison of AMIP vs CPLD experiments
- LEFT comparison of jet response vs model refractive index (emergent constraints)

Preliminary Results

Winter response to reduced SUB-REGIONS of Arctic sea ice (DJF)

pdSST_fuArcSIC – pdSST_pdSIC

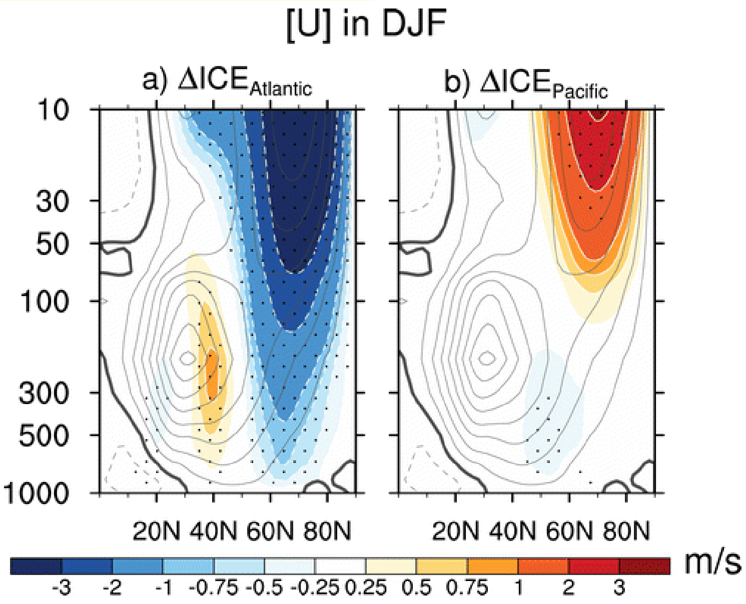
pdSST_fuBKSeasSIC – pdSST_pdSIC (Atlantic)

pdSST_fuOkhotskSIC – pdSST_pdSIC (Pacific)

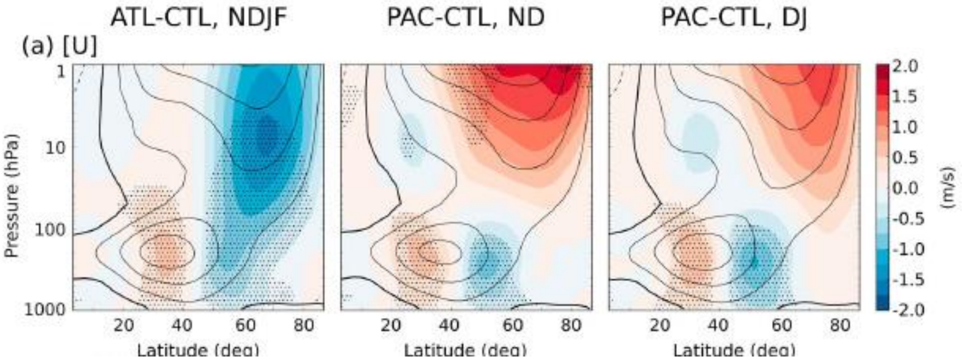
UA

PAMIP Responses – Sub Regions

Sun et al, 2015



McKenna et al, 2015



Other studies find opposite U-Wind responses for **Atlantic** vs **Pacific** SIC loss (Atlantic similar to total Arctic)

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Advanced prediction in polar regions and beyond

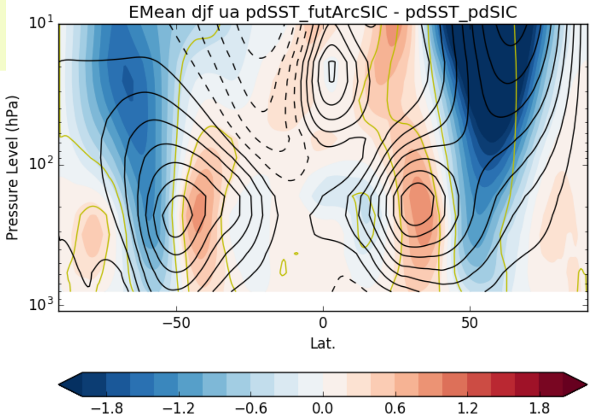
UA

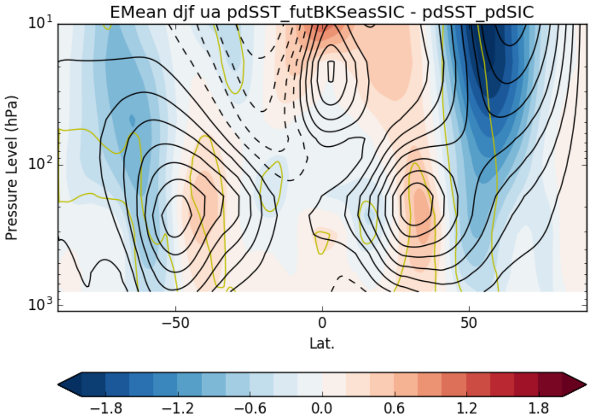
PAMIP Responses – Sub Regions

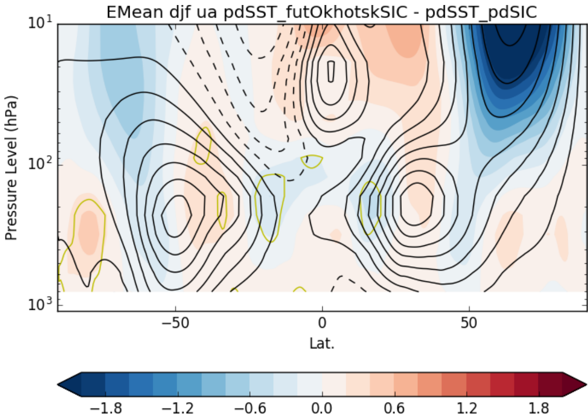
pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC | fuBKSeasSIC | fuOkhotskSIC

DJF







Shading = difference, Black contours = pdSST_pdSIC, Green contours = 95% significance (2-tailed t-test)

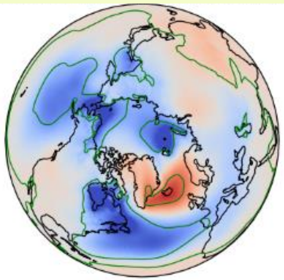
Equator-ward shift of band of max westerly winds for all

- Okhotsk (Pacific) experiment has **same** response, but weaker

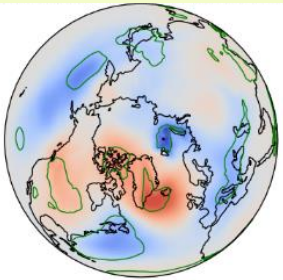
PAMIP Responses – Sub Regions

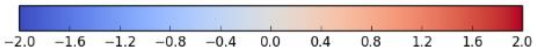
pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC

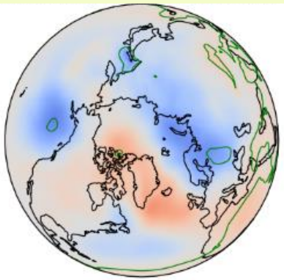


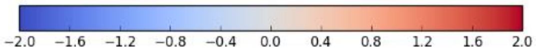
fuBKSeasSIC





fuOkhotskSIC





DJF

MSLP Consistent pattern for all: N Atlantic has -ve NAO like response

- Weaker response from Okhotsk

Summary – Future Work

- Models get some similar responses
  - Local surface warming
  - Equator-ward shift of tropospheric zonal mean winds
- Improve understanding of why models respond differently
  - Upper atmosphere responses
  - Sensitivity to sub-region SIC loss
  - Strength of response
- Emerging constraints to compare models, e.g. wind vs refractive index (Smith et al, 2017)
- Additional Experiments to come
  - Coupled
  - Background State

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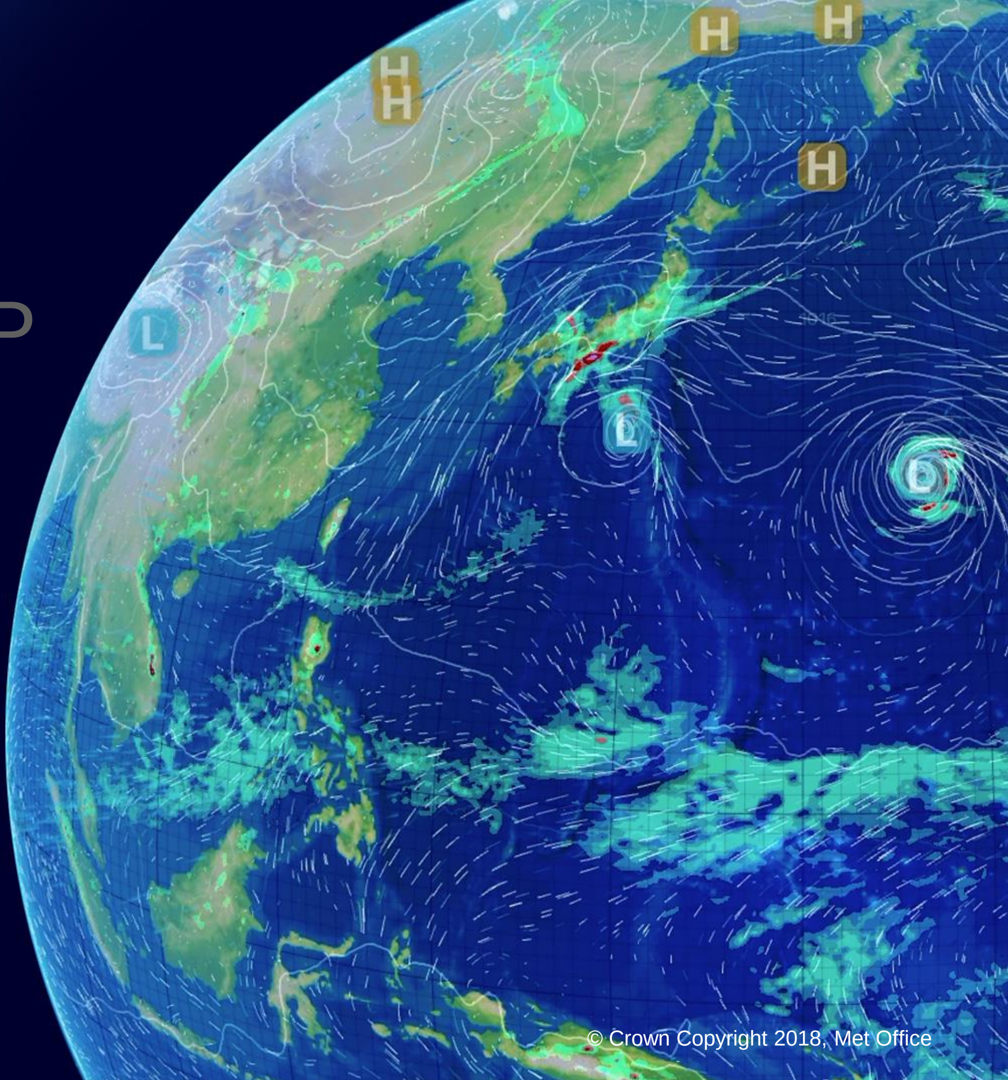


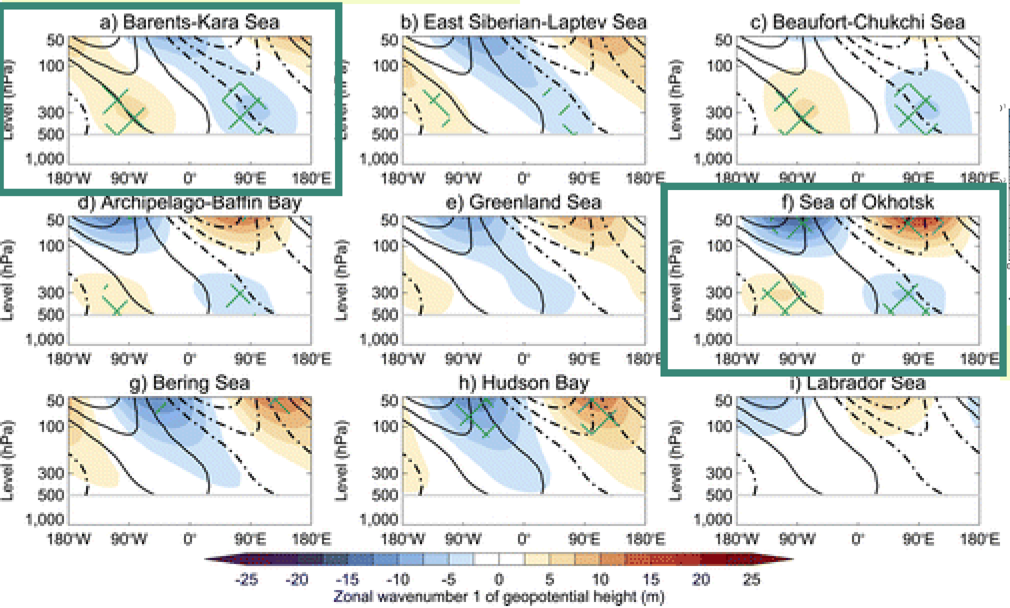
Thanks for listening.

Any questions/comments?

PAMIP Responses – Sub Regions

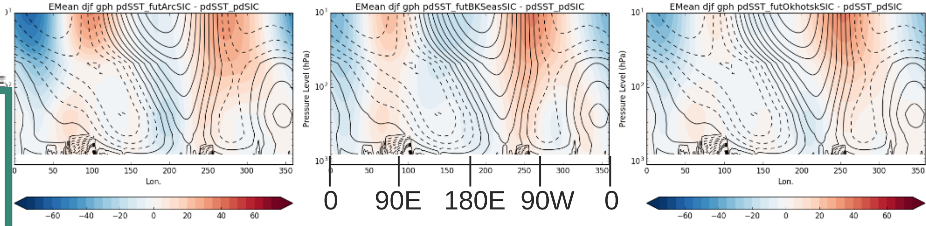
pdSST_fu*SIC – pdSST_pdSIC

JF, Screen, 2017



DJF

fuArcSIC fuBKSeasSIC fuOkhotskSIC



Shading = difference, Black contours = pdSST_pdSIC (- zonal mean)

Left: BKSeas has some constructive interference; Okhotsk destructive as almost opposite phase

Right: No such striking differences?

EP Flux

PAMIP Responses – Sub Regions

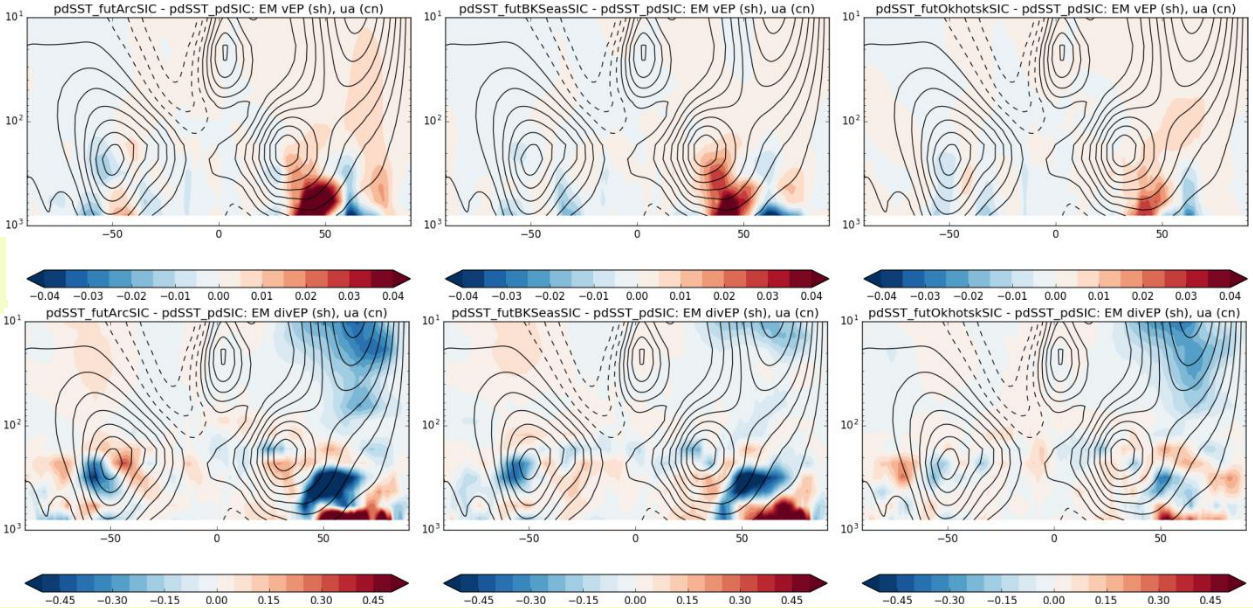
pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC | fuBKSeasSIC | fuOkhotskSIC

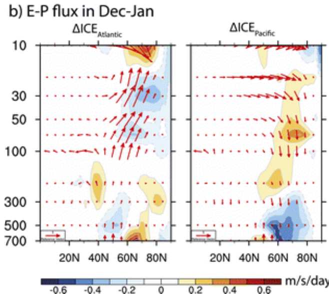
Vert EP Flux

DJF

EP Flux Div



DJ, EPdiv, Sun et al, 2015



Shading = difference, Black contours = pdSST_pdSIC U-Wind

..

DJF

Smith et al, 2017

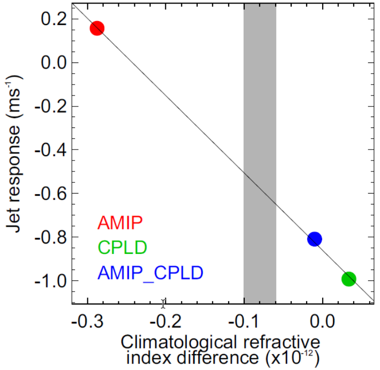
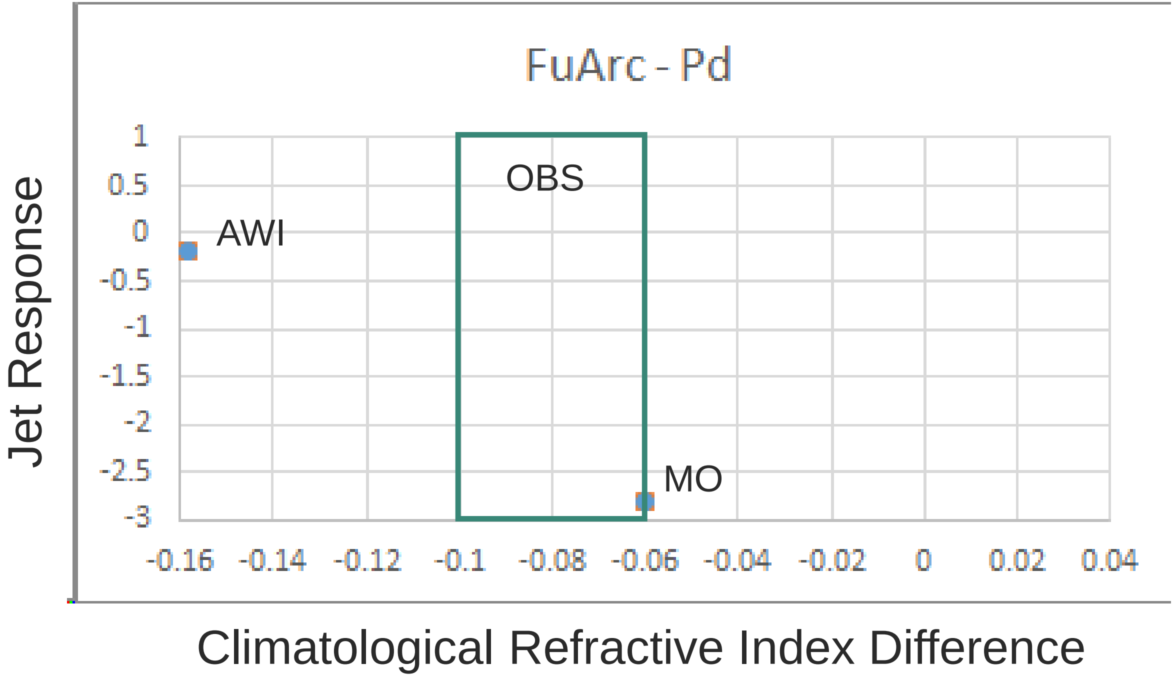


FIG. 14. Dependence of Atlantic jet response on the background climatological refractive index difference between middle (25°–35°N) and high (60°–80°N) latitudes at 200 hPa. Gray shading shows the observed range from ERA-Interim and NCEP II.



Jet Response = mean U200 (50-60N, 60-0W)

Refractive Index Diff = mean (25-35N) – mean (60-80N)

Obs box copied from Smith et al, 2017

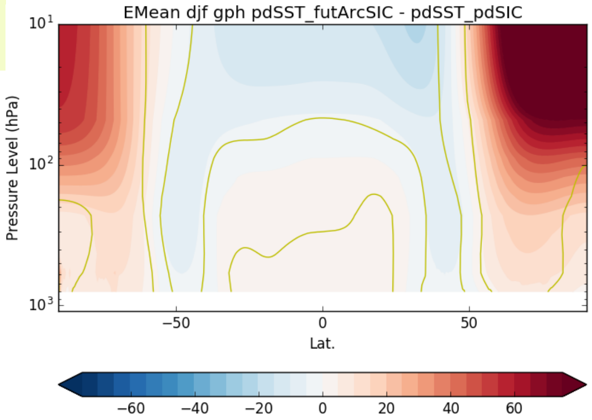
PAMIP Responses – Sub Regions

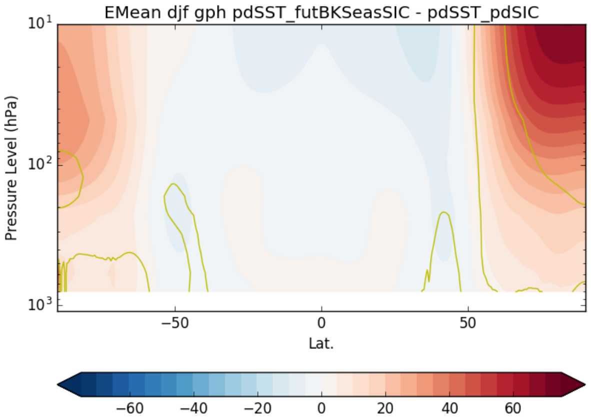
GPH

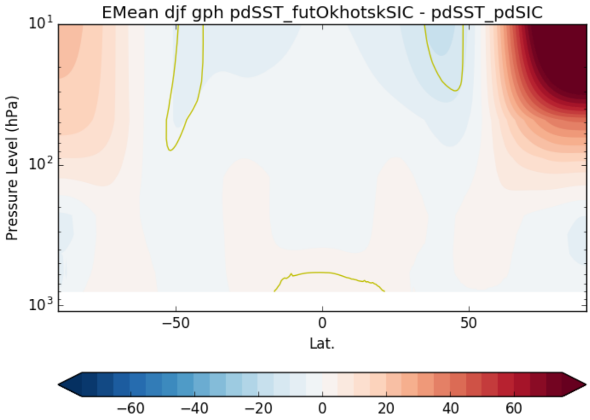
pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC | fuBKSeasSIC | fuOkhotskSIC

DJF







Shading = difference, Black contours = pdSST_pdSIC, Green contours = 95% significance (2-tailed t-test)

Strong local increase, especially at high altitude

- also sig decrease at mid lat surface extending across tropics at high altitude
- weaker response from Okhotsk

PAMIP Responses – Sub Regions

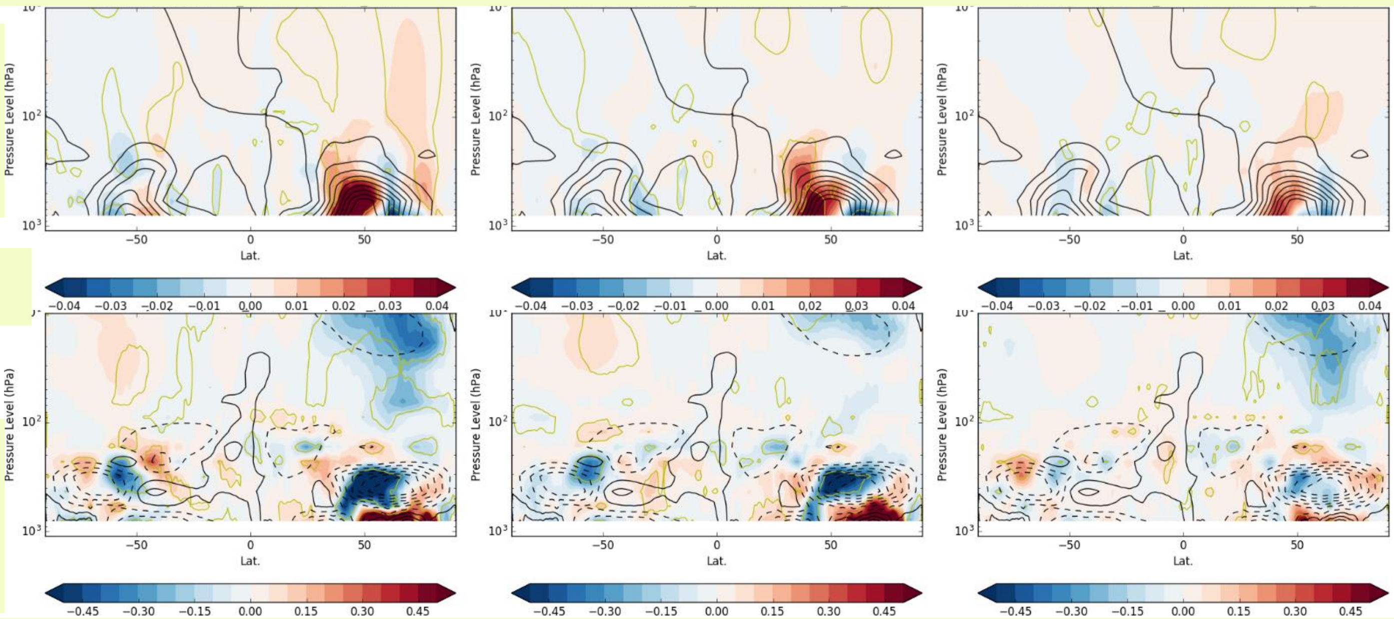
pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC | fuBKSeasSIC | fuOkhotskSIC

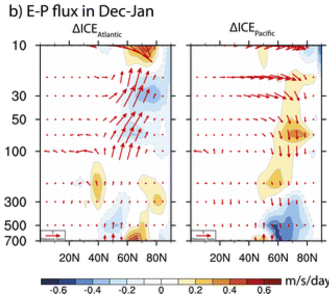
Vert EP Flux

DJF

EP Flux Div



DJ, EPdiv, Sun et al, 2015



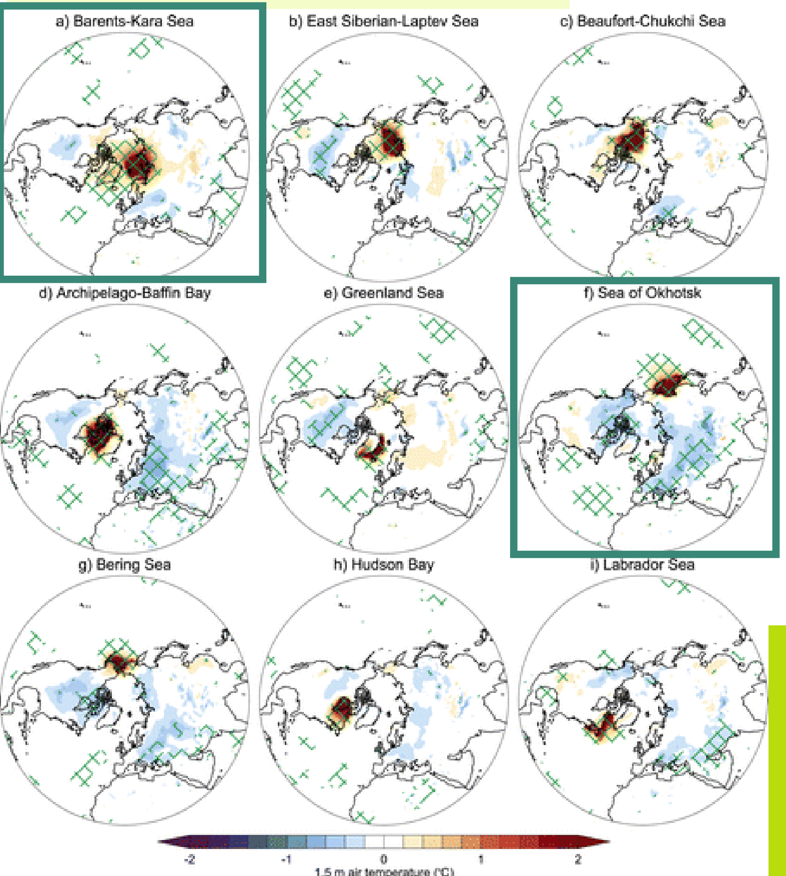
Shading = difference, Black contours = pdSST_pdSIC, Green contours = 95% significance (2-tailed t-test)

…

SAT

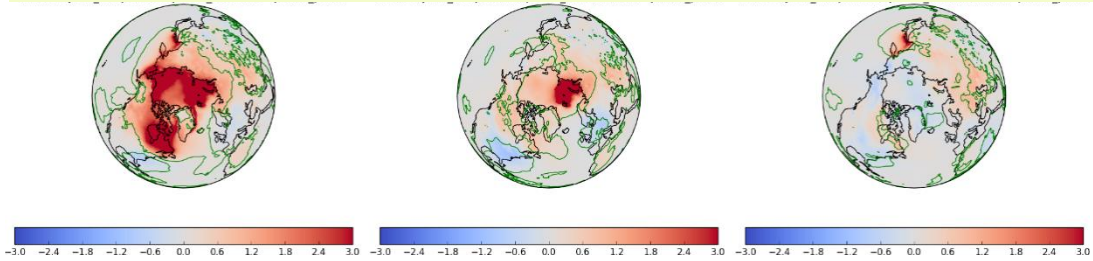
PAMIP Responses – Sub Regions

ONDJFM Screen, 2017



DJF HadGEM3

fuArcSIC fuBKSeasSIC fuOkhotskSIC



Local response significant warming
Similar results for other models and regions

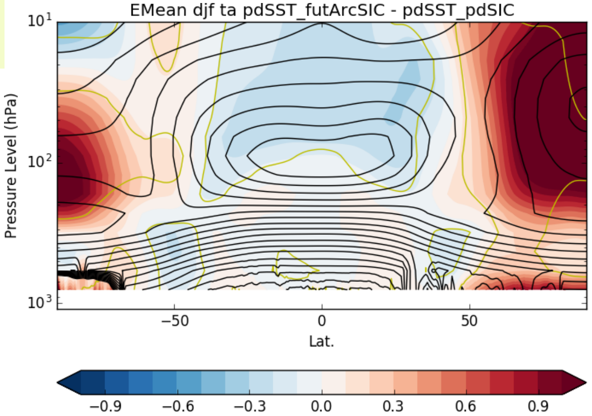
PAMIP Responses – Sub Regions

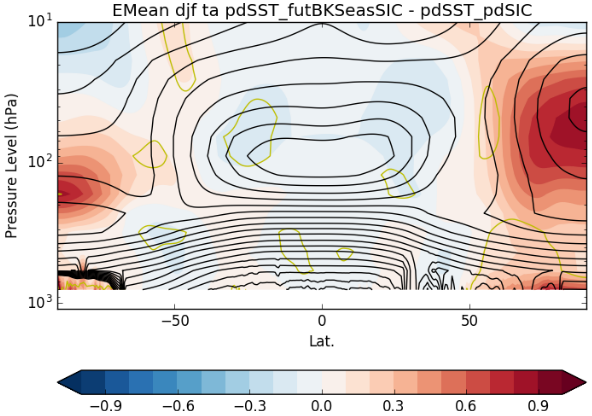
TA

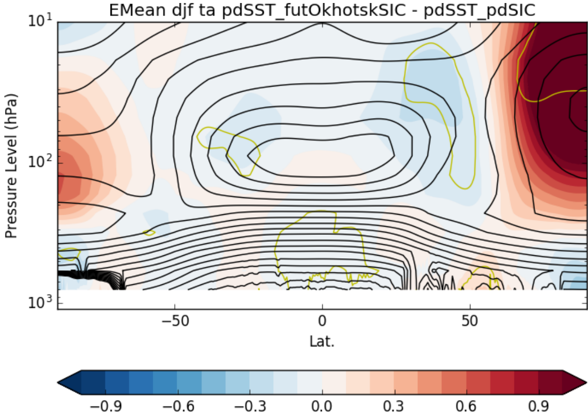
pdSST_fu*SIC – pdSST_pdSIC

fuArcSIC	fuBKSeasSIC	fuOkhotskSIC

DJF







Shading = difference, Black contours = pdSST_pdSIC, Green contours = 95% significance (2-tailed t-test)

Local warming at pole at surface and high altitudes

- Surface warming very localised for fuOkhotsk as only small regions of sic change ~50N.

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PAMIP Responses

TA

DJF

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

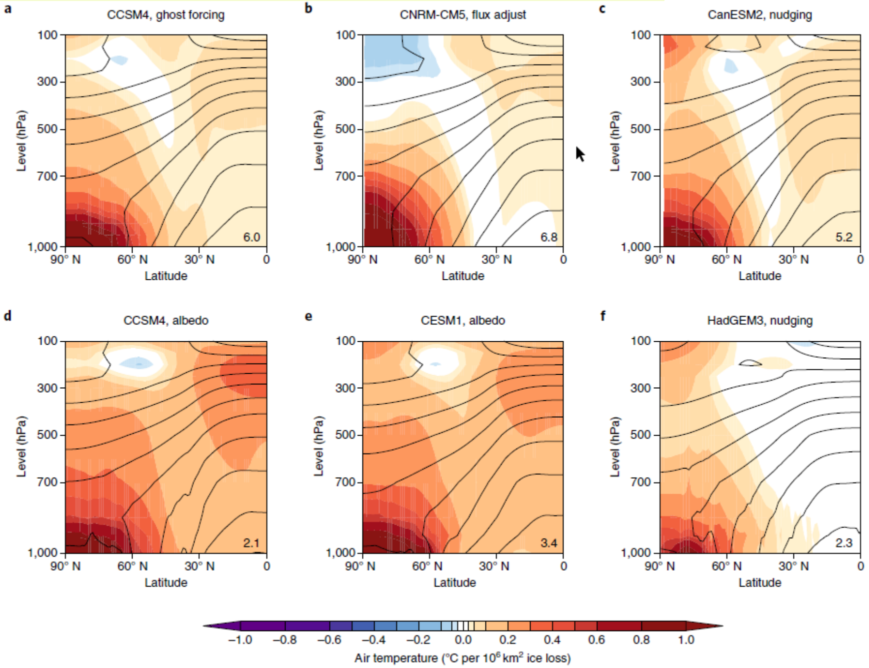
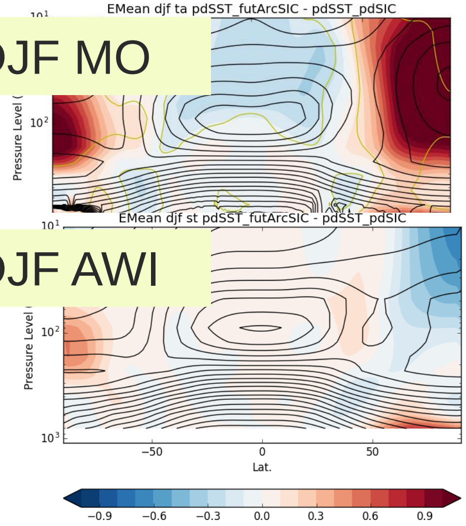


Fig. 1 | Effects of Arctic sea-ice loss on winter air temperature. Boreal winter (December–January–February) zonal-mean air temperature response (coloured shading; note the non-linear colour scale) to Arctic sea-ice loss in six unique sets of coupled ocean-atmosphere model simulations. The responses 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 10 °C). 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.



DJF MO

DJF AWI

fuArcSIC – pdSIC:

Why do results vary across models?