

Projected future sea ice retreat and its impacts

Tom Bracegirdle



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Antarctic Survey

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Outline

- Sea ice projections of future change from climate models
- Proximal impacts of ice retreat
- Larger-scale impacts on lower-latitudes
- Sea ice and Antarctic and Southern ocean climate projections

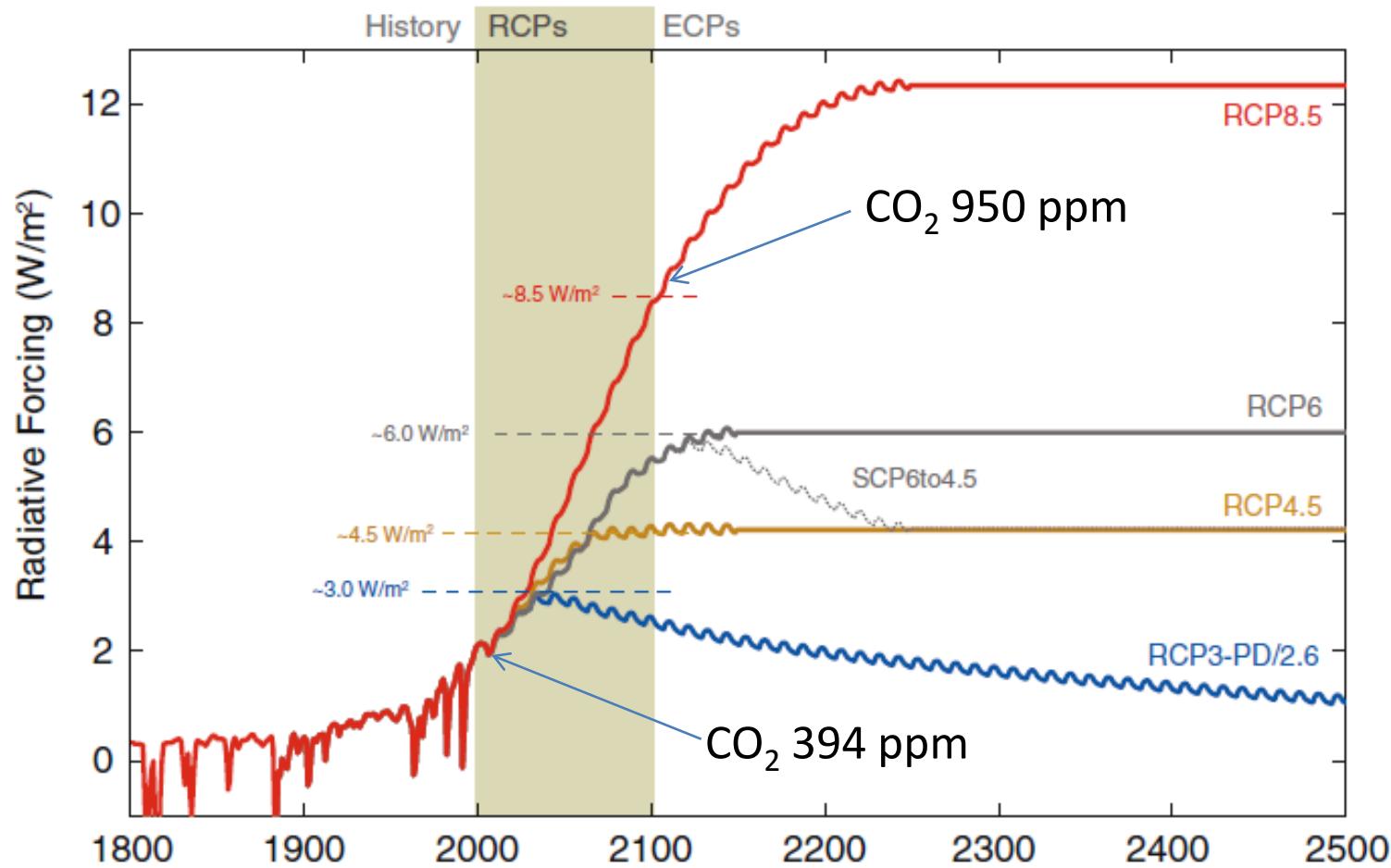


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Scenarios for climate projections



Meinshausen et al. (2011)

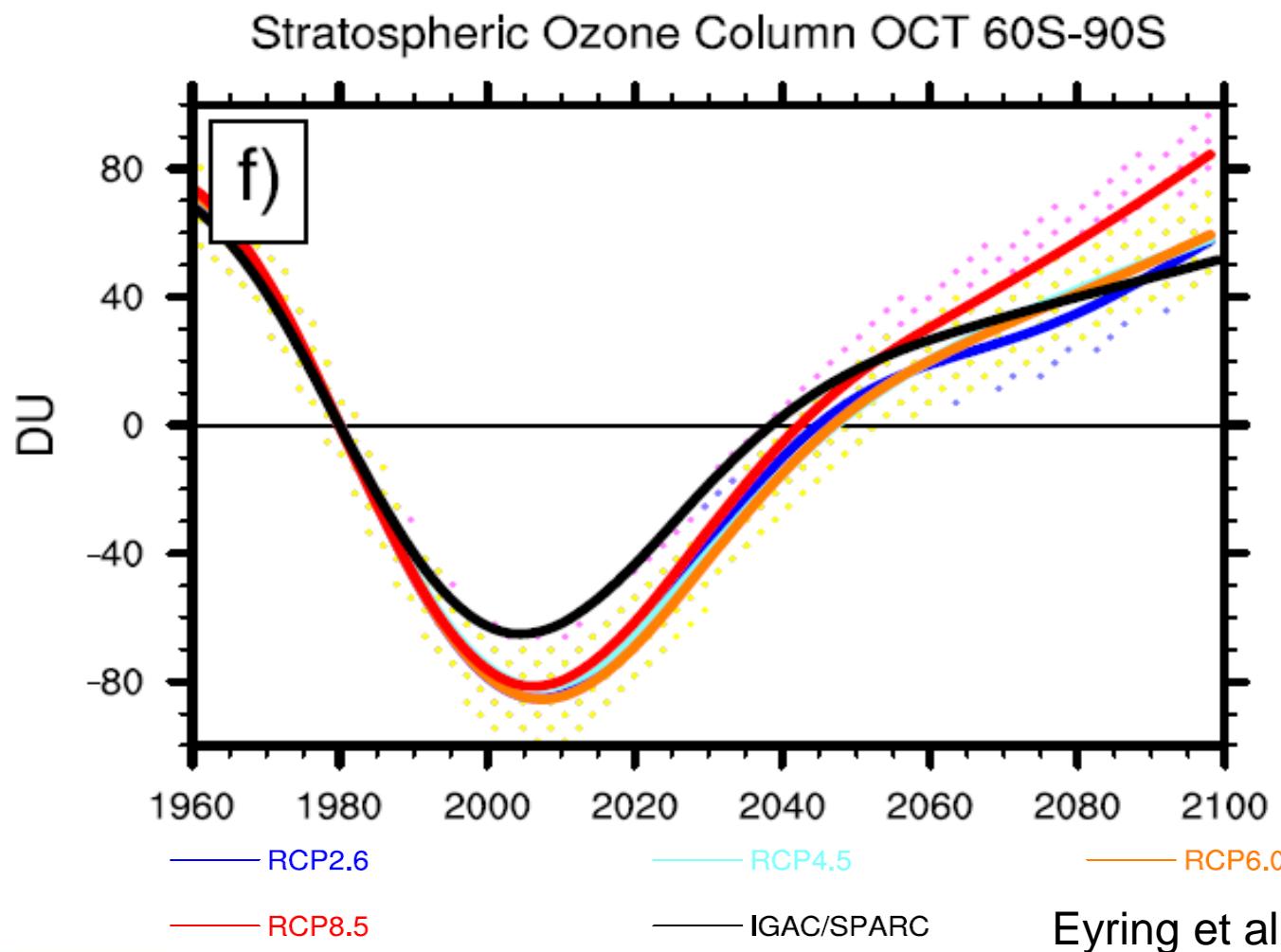


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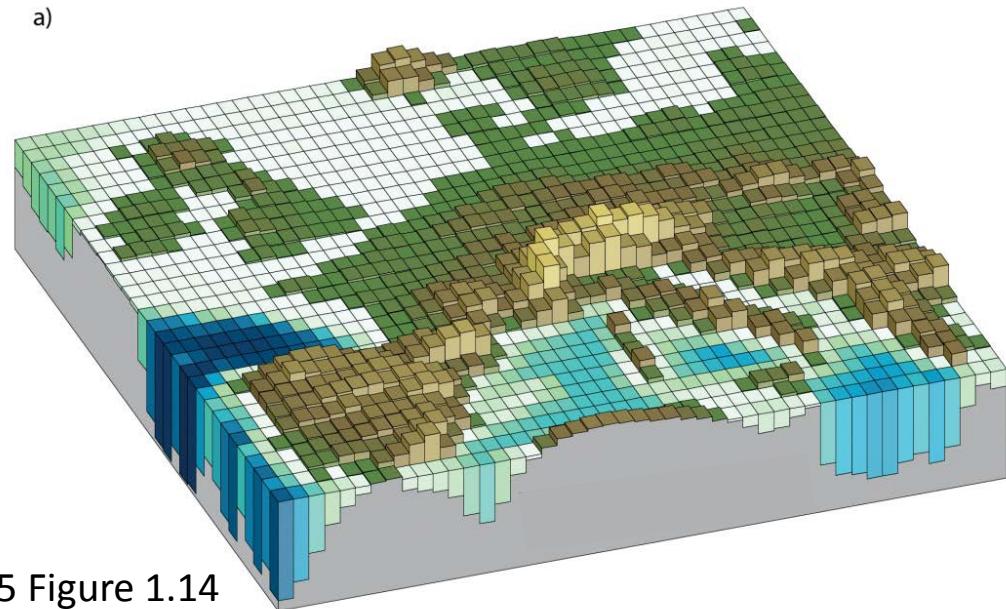
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Stratospheric ozone



Global climate models

- The most comprehensive dataset from the latest generation of global climate models is the CMIP5 dataset
- This was used in the IPCC AR5 and is a valuable resource, but there is a wide spread across projections of polar climate change from different models
- Approximations to reality with grid boxes of typically 200 km across in the horizontal



Source: IPCC AR5 Figure 1.14



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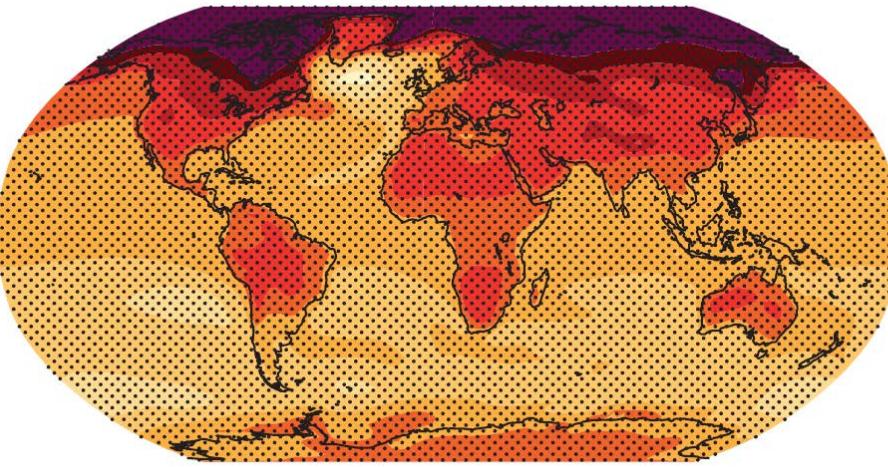
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Future projections

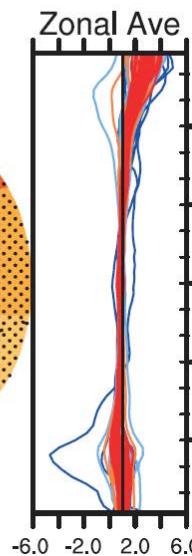
- A robust feature that emerges from the IPCC climate models is that the high latitudes are projected to become warmer and ‘wetter’ under future scenarios
- The “ozone hole” is expected to fill

Temperature scaled by global T ($^{\circ}\text{C}$ per $^{\circ}\text{C}$)

2081-2100

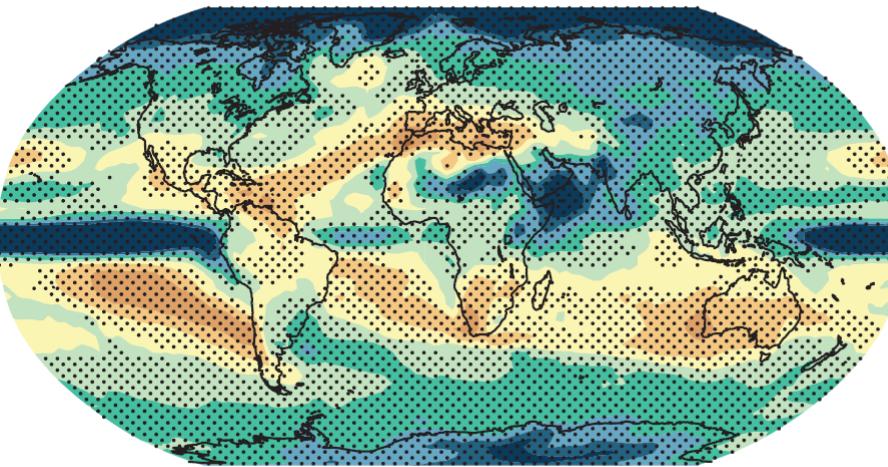


Zonal Ave

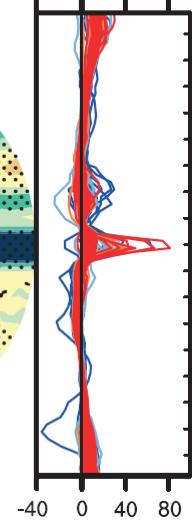


Precipitation scaled by global T ($\%$ per $^{\circ}\text{C}$)

2081-2100



Zonal Ave



Source: IPCC AR5 Figure 12.10 (p1061)



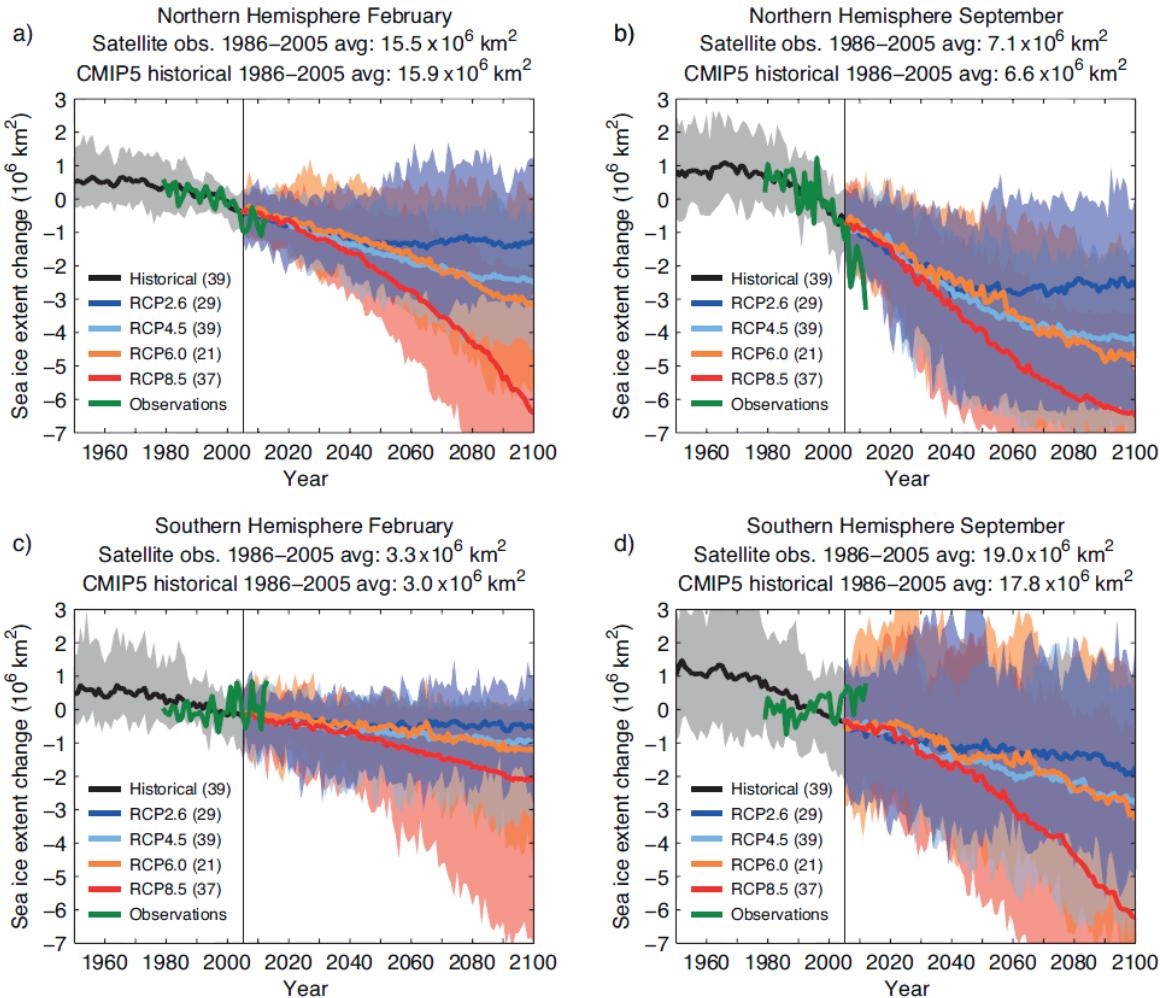
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CMIP5 sea ice extent projections

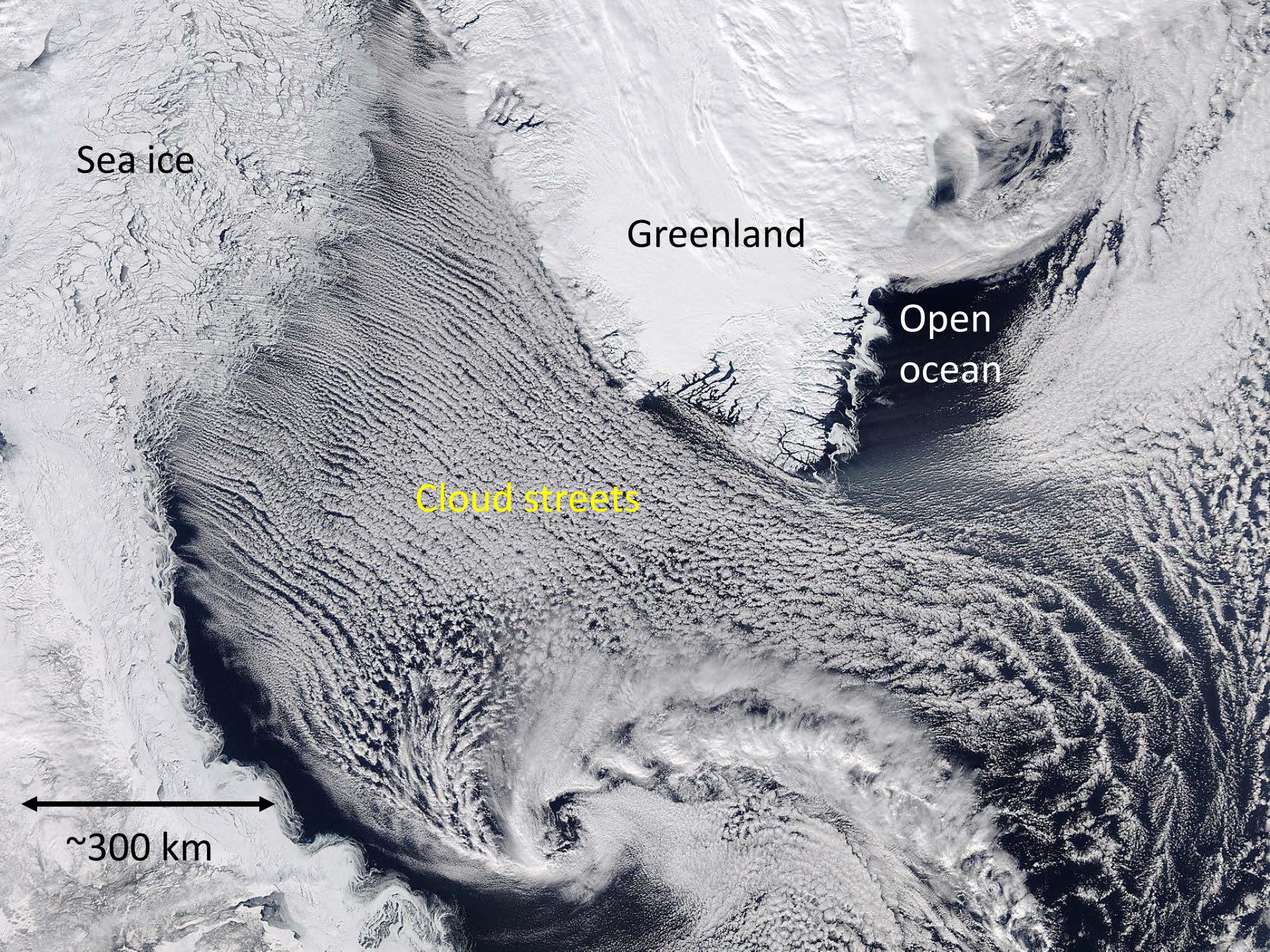
Source: IPCC AR5 Figure 12.28



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Sea ice

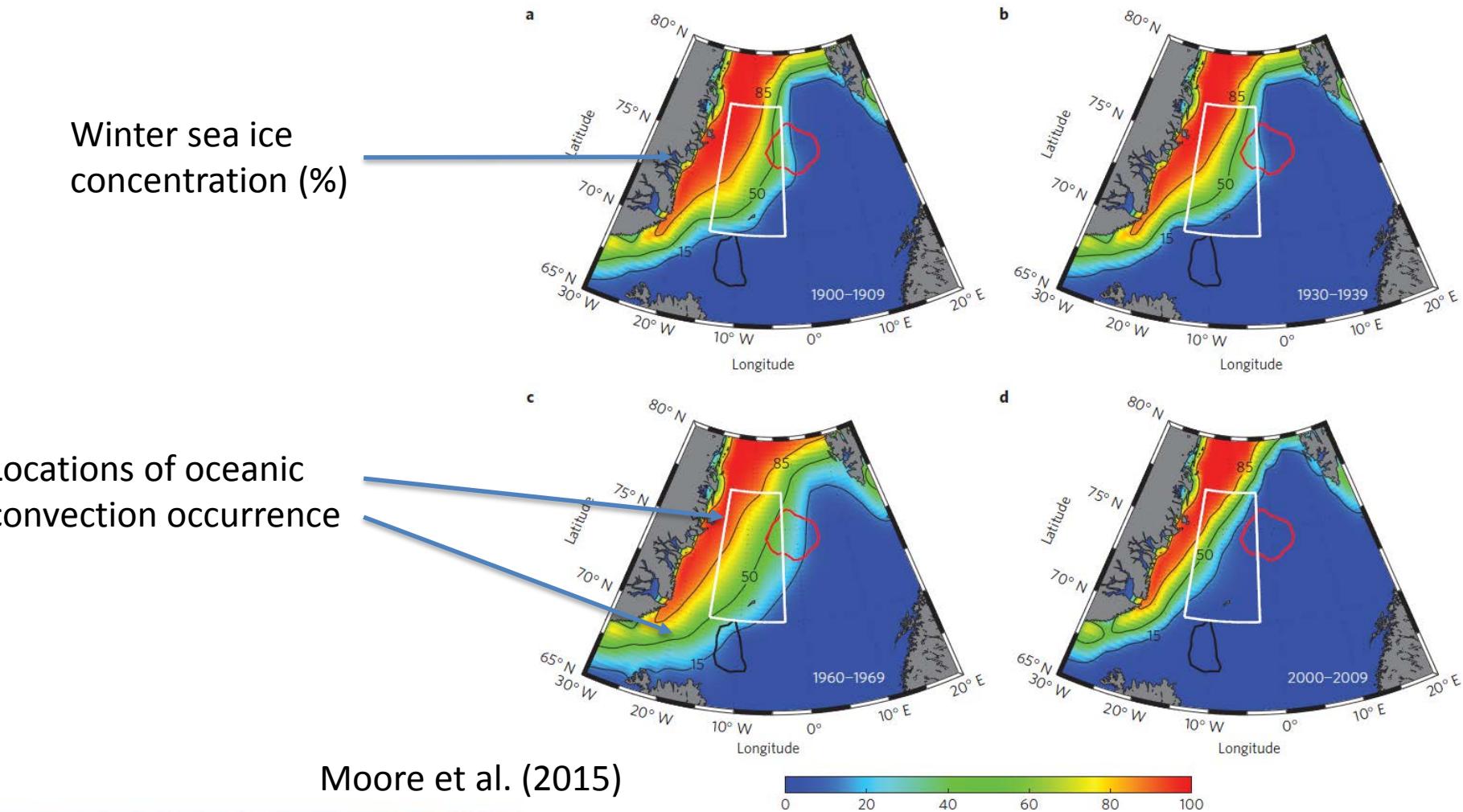
Greenland

Open
ocean

Cloud streets

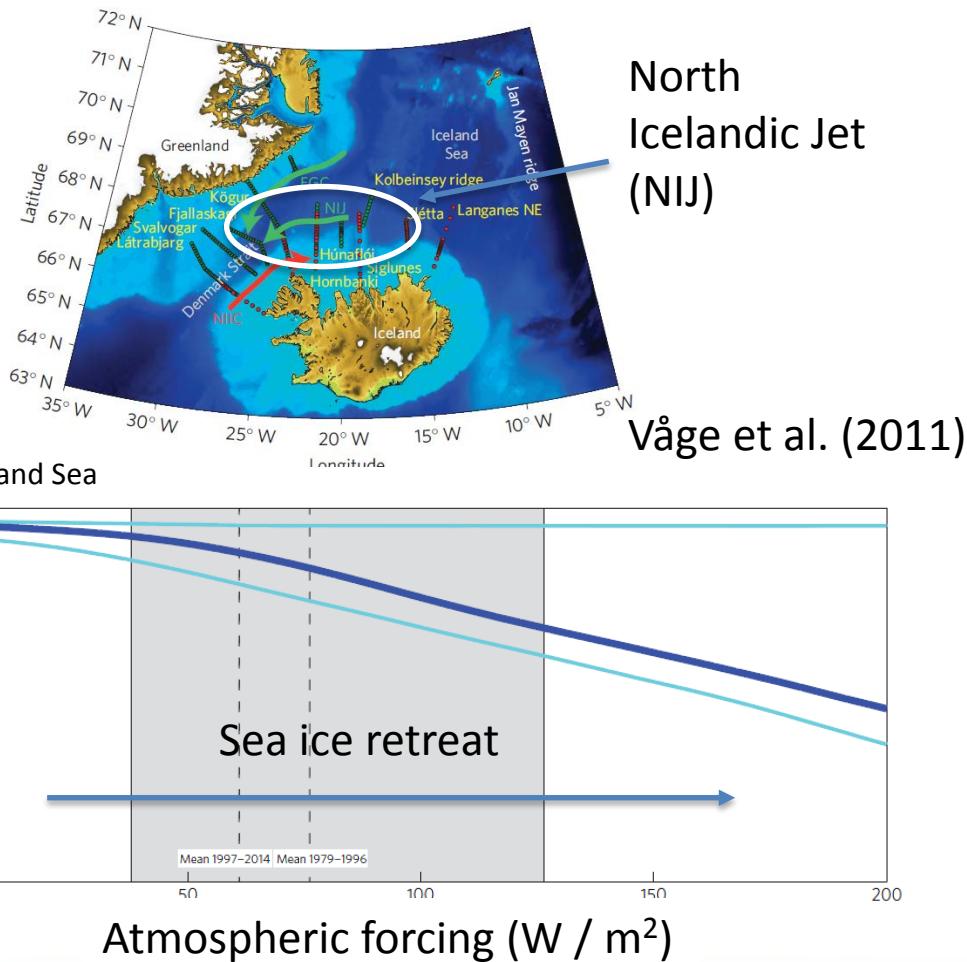
~300 km

Impacts on ocean convection in the Iceland-Greenland seas



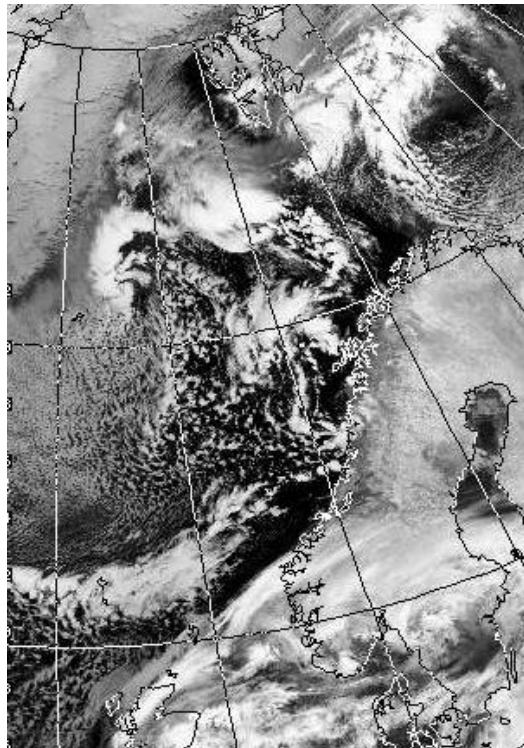
Impacts on ocean convection in the Iceland-Greenland seas

- It appears that:
 - sea-ice retreat leads to stronger atmospheric forcing and a deeper mixed layer.
- Such changes could affect the recently-discovered North Icelandic Jet, but this connection is not well understood.
- BAS is making a significant contribution to the recently-funded Iceland-Greenland Seas project (NERC, NSF and others), aims to address this question.

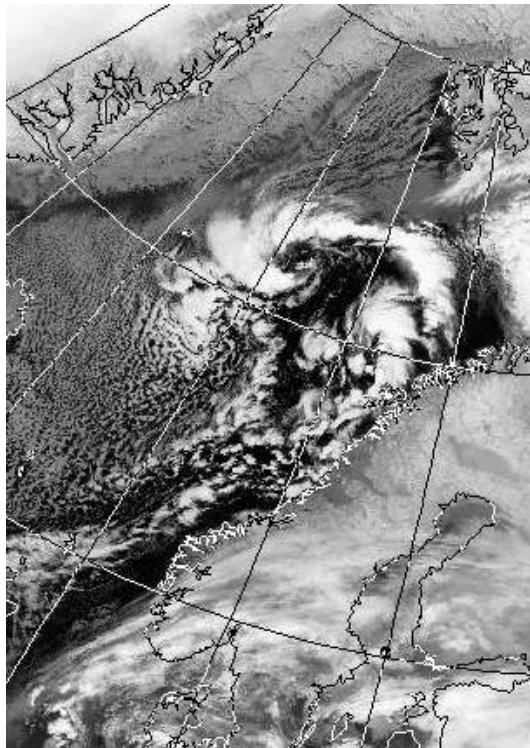


Cold air outbreaks over the ocean and associated severe weather

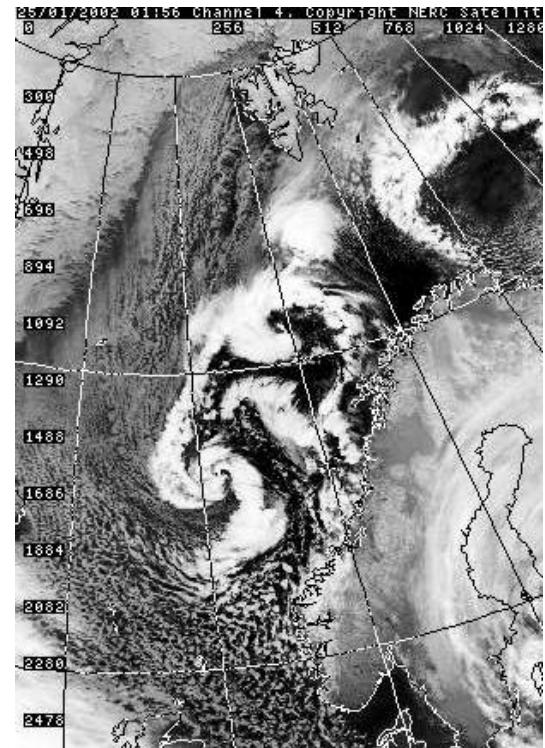
(a)



(b)



(c)



NOAA IR imagery for (a) 0207UTC 24/1/2002, (b) 1202UTC 24/1/2002 and (c) 0156UTC 25/1/2002. Courtesy of the NERC Dundee Satellite Receiving Station.

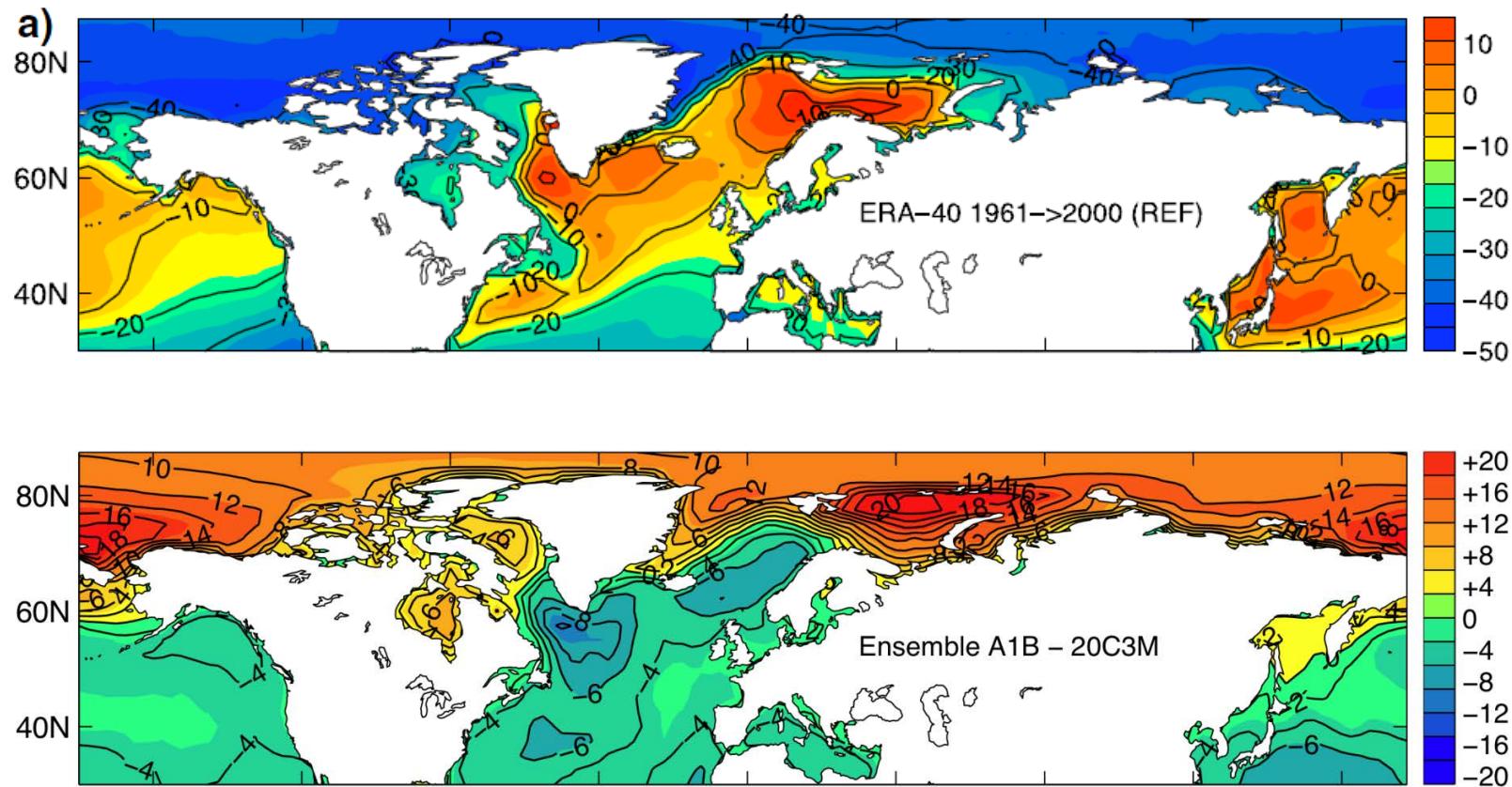


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Current regions of strong marine cold air outbreaks and projections of future change



Kolstad and Bracegirdle (2008)

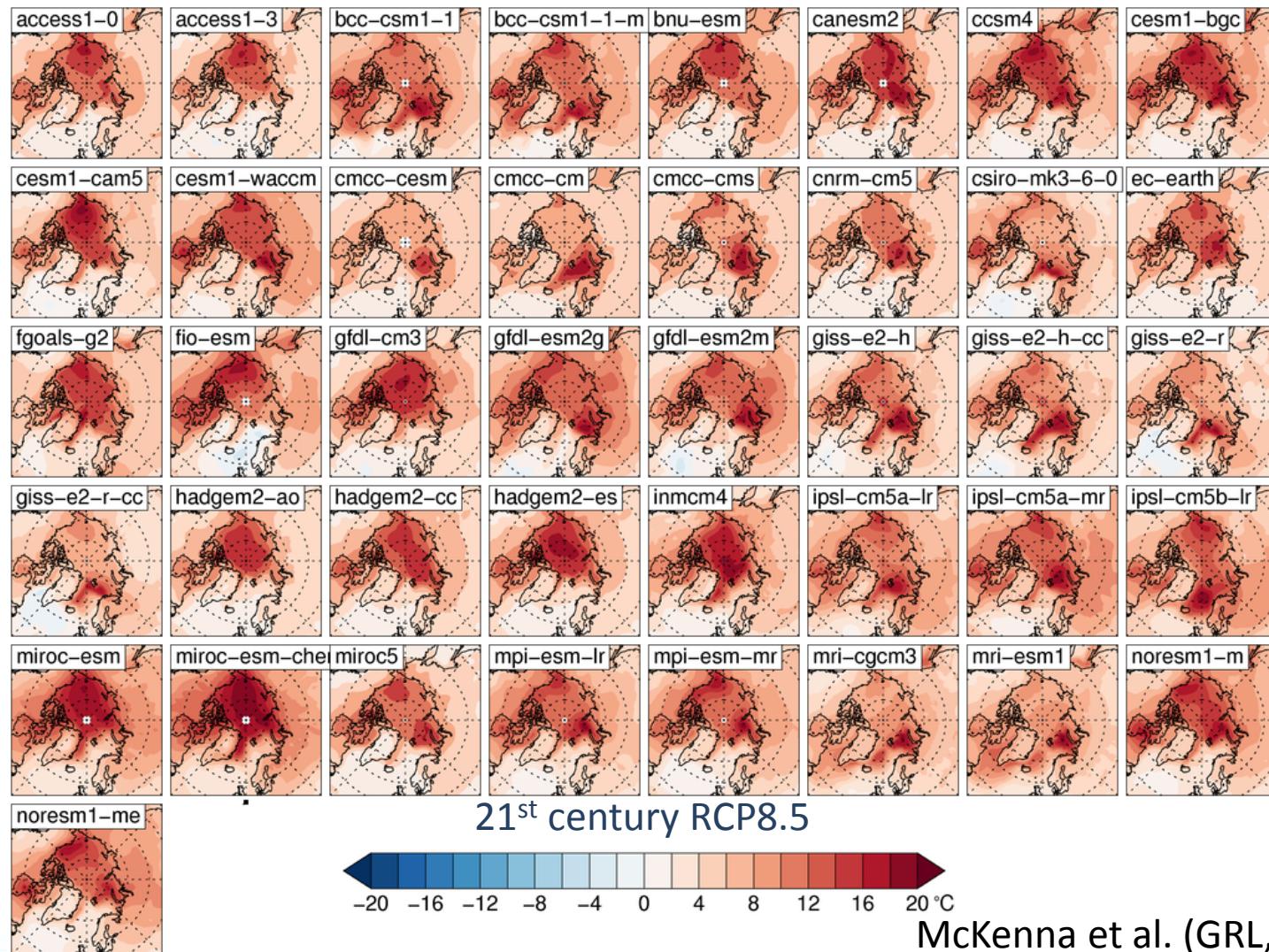


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- **Larger-scale impacts on lower-latitudes**
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CMIP5 model diversity in Arctic sea ice retreat influence surface warming projections



McKenna et al. (GRL, in review)



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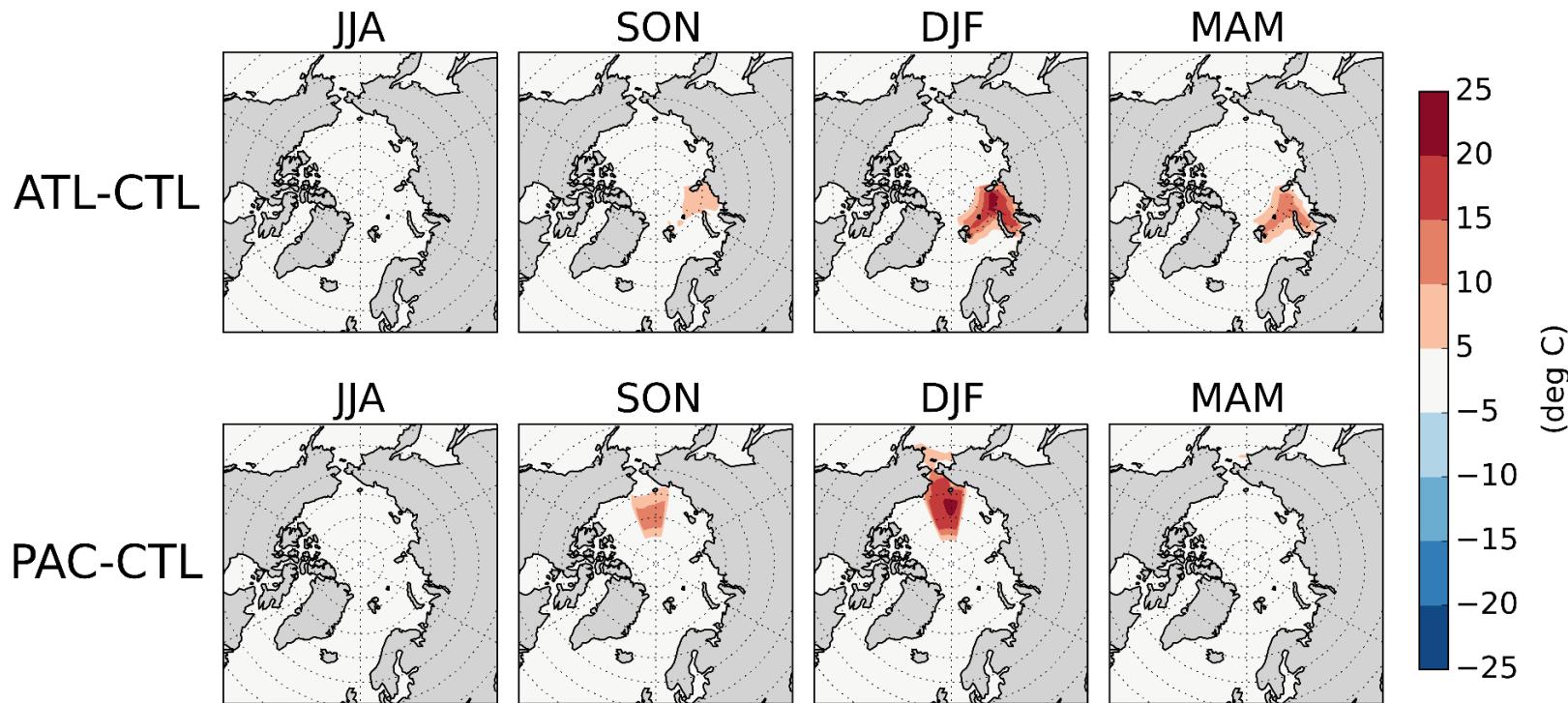
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Exploring impacts of different patterns of warming

- Atmospheric model with prescribed surface warming in two regions
(McKenna et al., GRL, in review)

Sea surface temperature



McKenna et al. (GRL, in review)

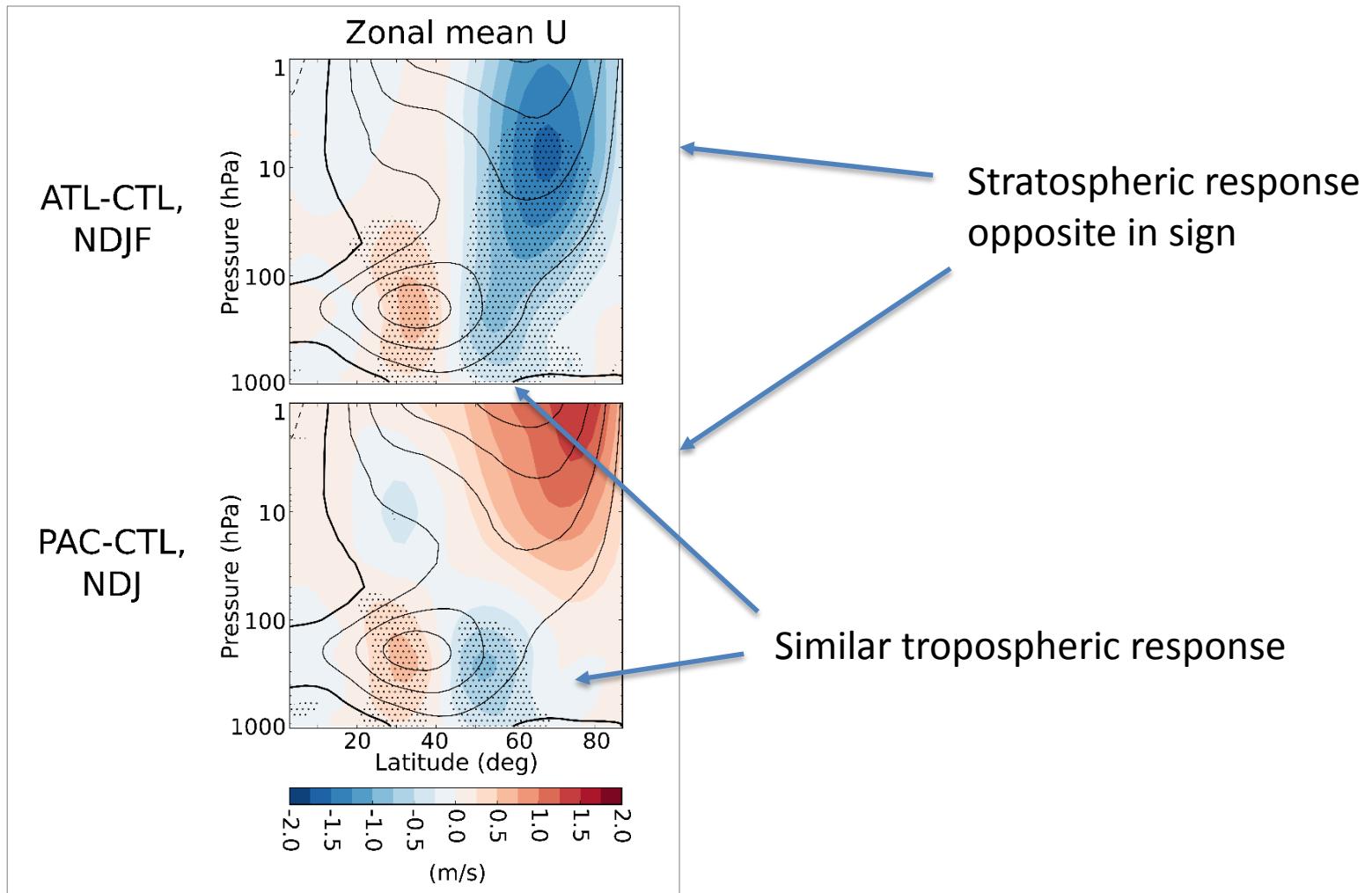


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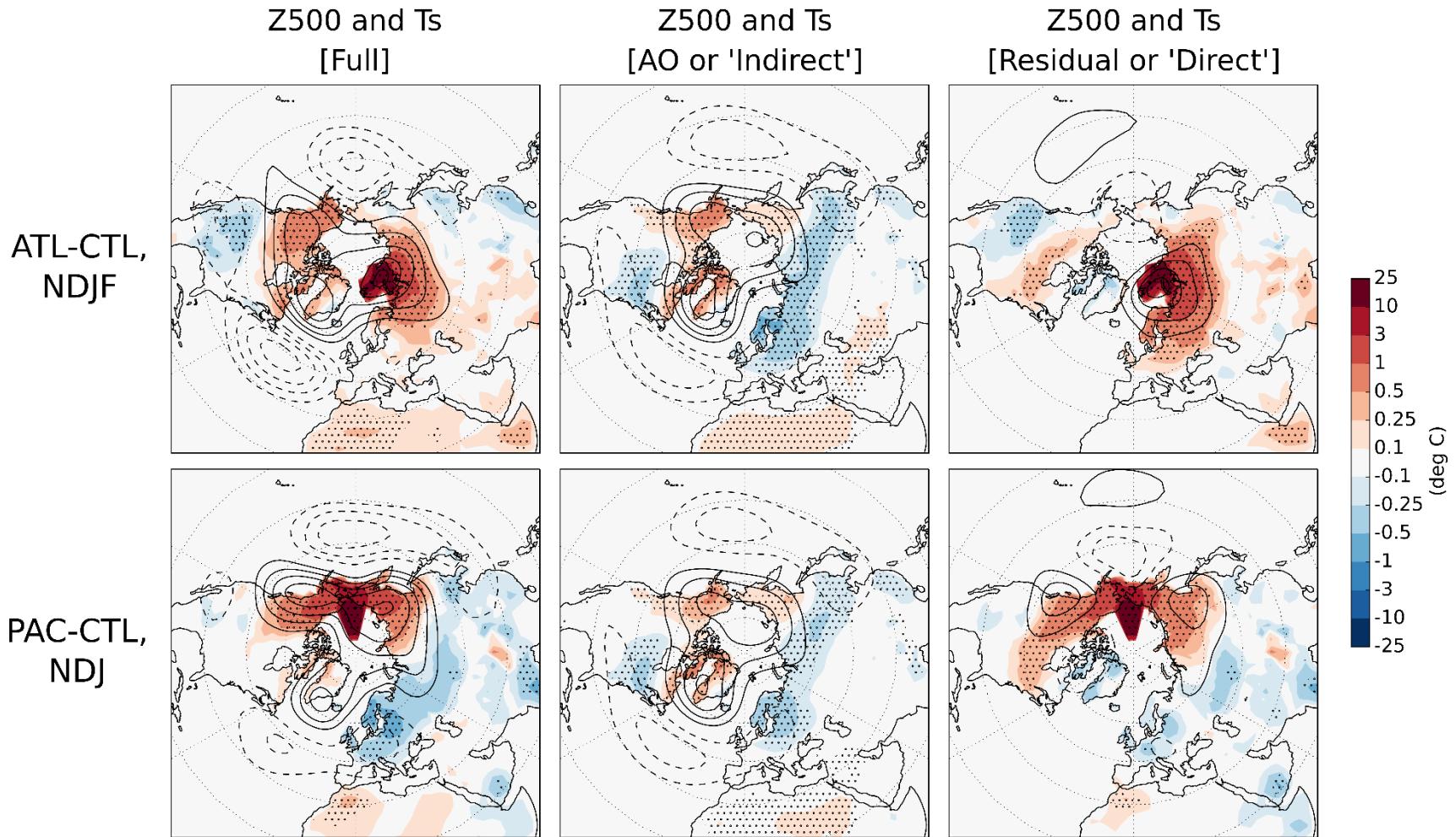
UEA
University of East Anglia

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Zonal mean westerly wind response



Surface temperature response

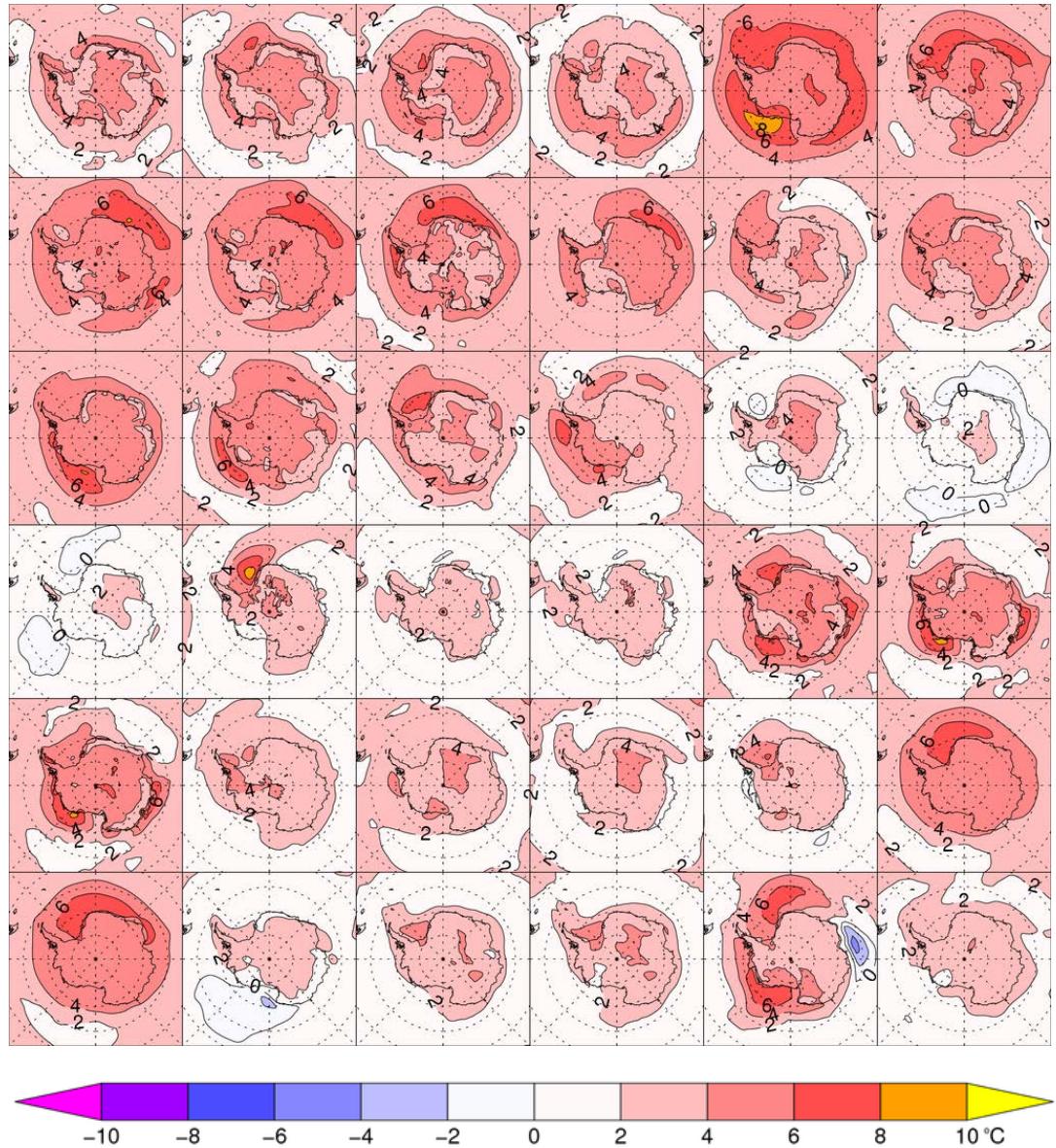


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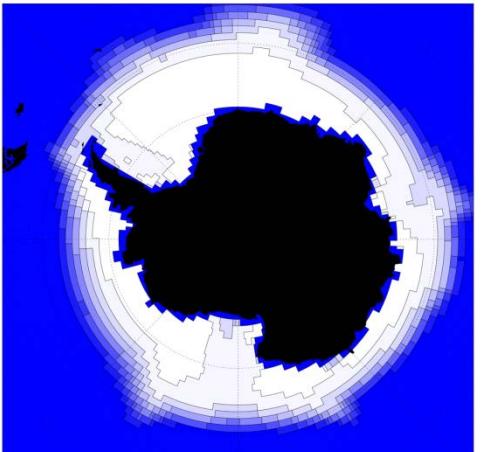


- There are also large inter-model differences in the regional detail over Antarctica
- This can be seen in projections of 21st century Antarctic temperature change from different climate models following the same (RCP8.5) emissions scenario

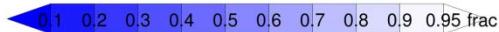
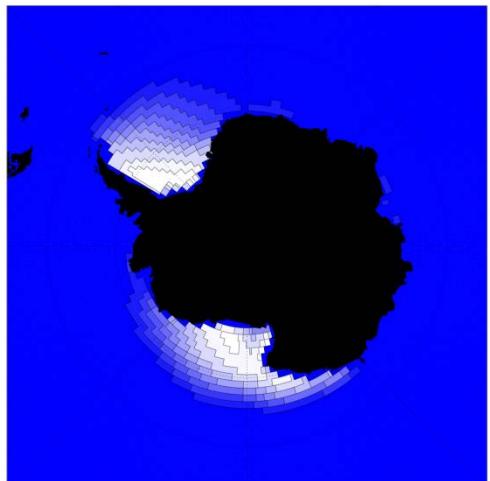
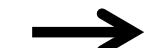


Simulated sea ice concentration
climatology (1970-1999)

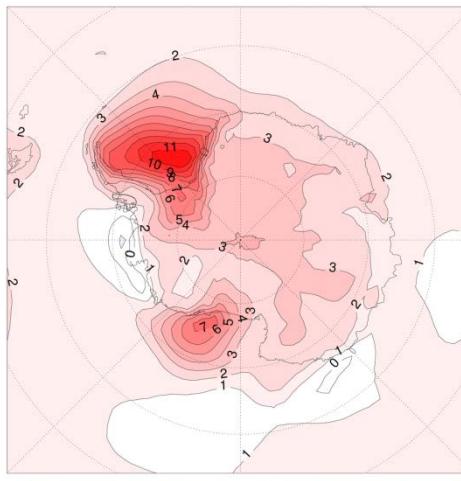
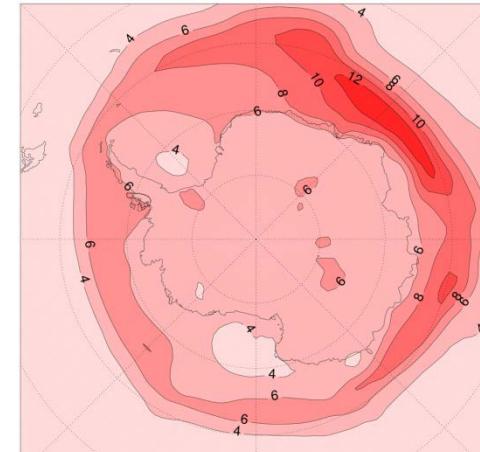
Model with
excessive sea ice
in winter (ccsm4)



Model with
too little sea ice
in winter (ipsl-cm5b-lr)



Projected temperature change
(2070-2099 minus 1970-1999)



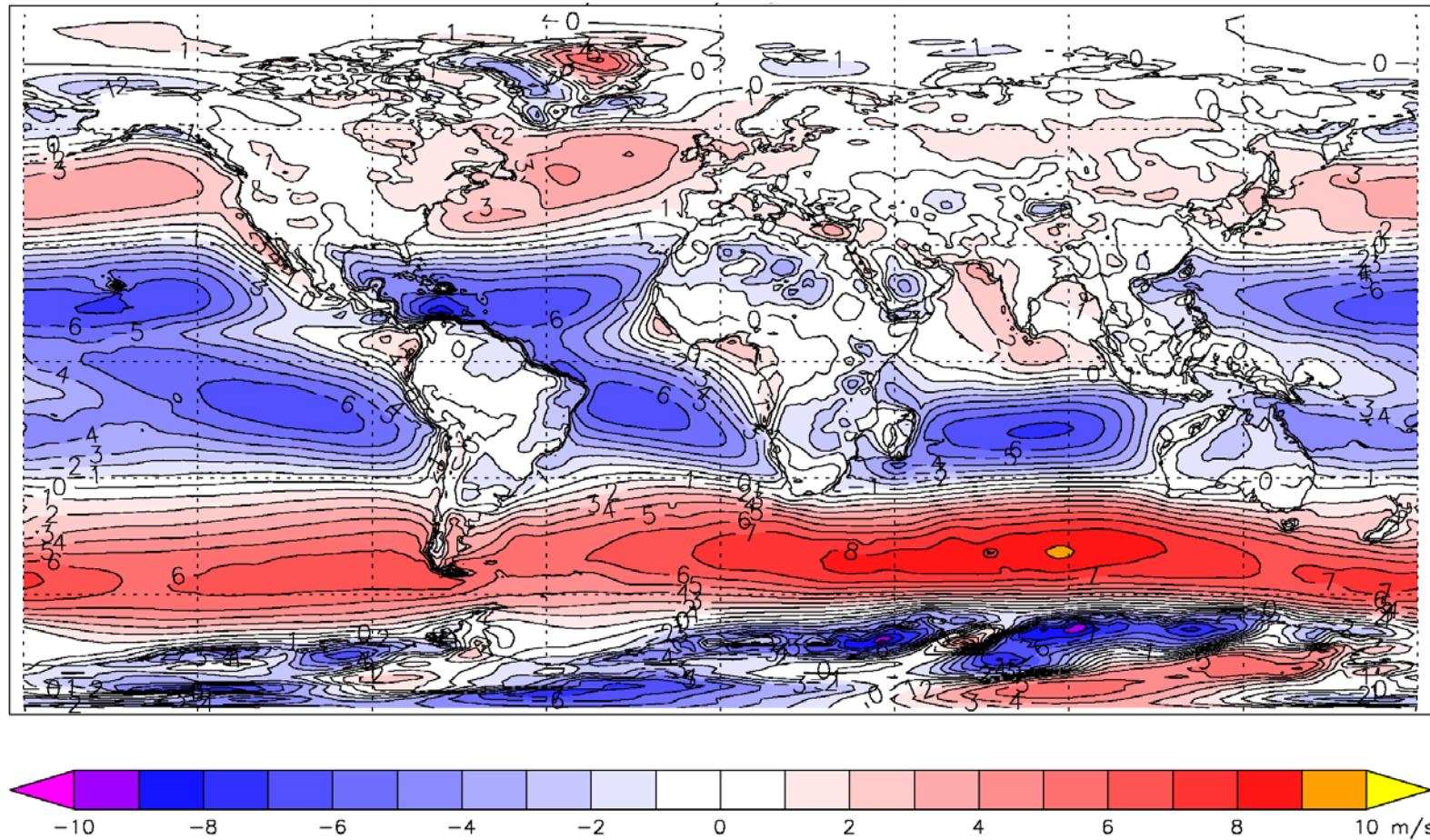
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Circumpolar westerlies

Annual mean 10 m westerly wind (1979-2002) (ERA-40)



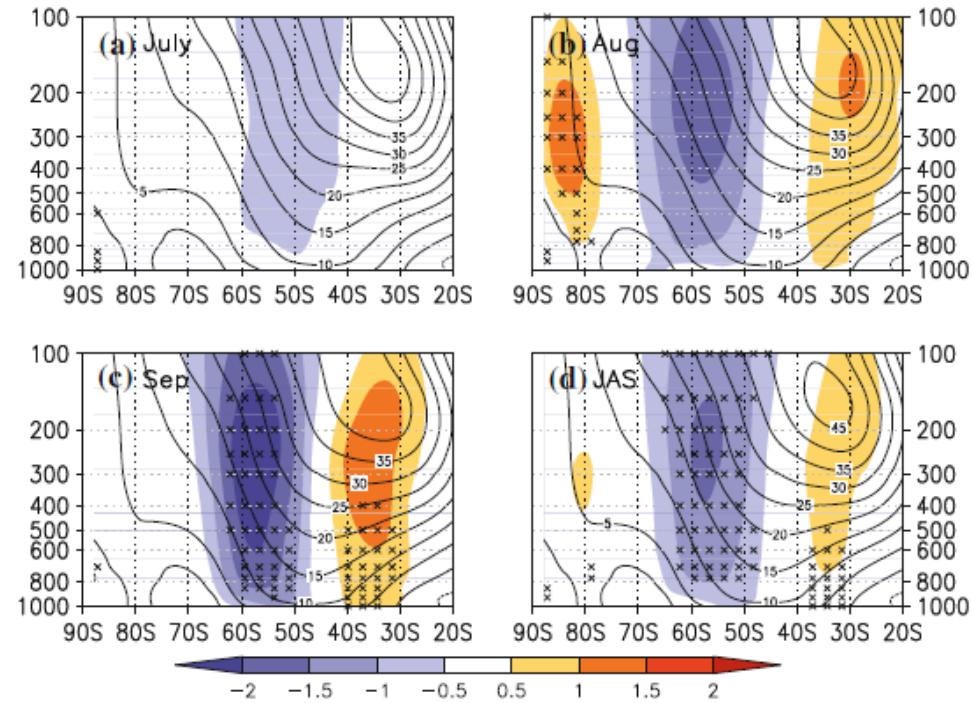
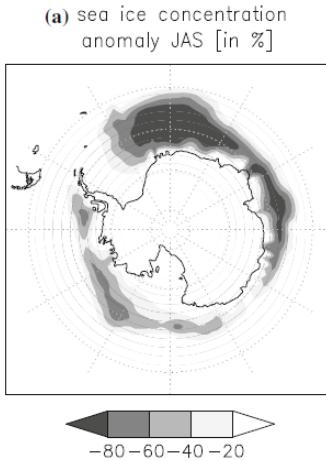
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Impact of sea ice on the SH mid latitude jet

- Sea ice retreat causes equatorward shift in some models (Bader et al., 2013) but little effect in others (Kidston et al., 2011).
- Suggested explanations are (i) differences in background atmospheric wave propagation properties (Smith et al., 2017) and (ii) relative ice-edge / jet latitudes.
- Model diversity in sea ice projections and the impacts thereof is potentially a key contributor to uncertainty in projections of the SH jet.



Bader et al. (2013)



Summary

- Getting sea ice right in climate models really matters!
 - This of course requires accurate representation of the ocean and atmosphere!
- Examples of impacts of sea ice retreat are:
 - Changes in the distribution of high-impact weather events
 - Impacts on atmosphere-ocean interactions which are important for ocean circulation
 - Non-local impacts on mid-latitude westerly winds and regional climate (e.g. European temperatures, Antarctic Peninsula climate).



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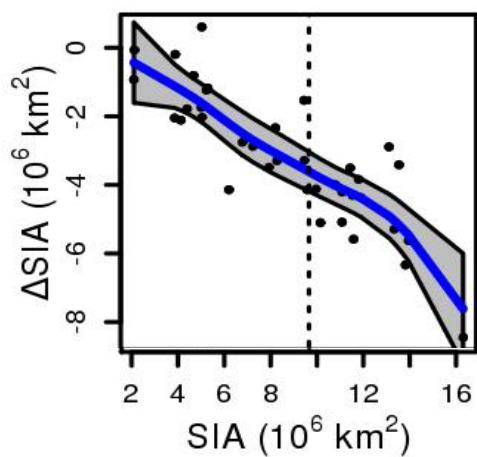
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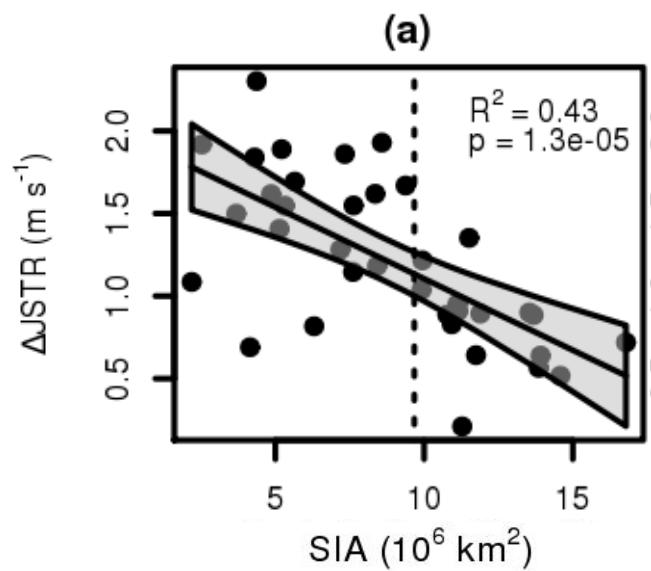
Additional slides for Q&A

CMIP5 sea ice and westerly jet projections

Sea ice area (SIA) highly correlated with Δ SIA (and Antarctic amplification).



RCP8.5 21C
jet strength
response
(ANN)



Bracegirdle et al., (in review) J. Clim.

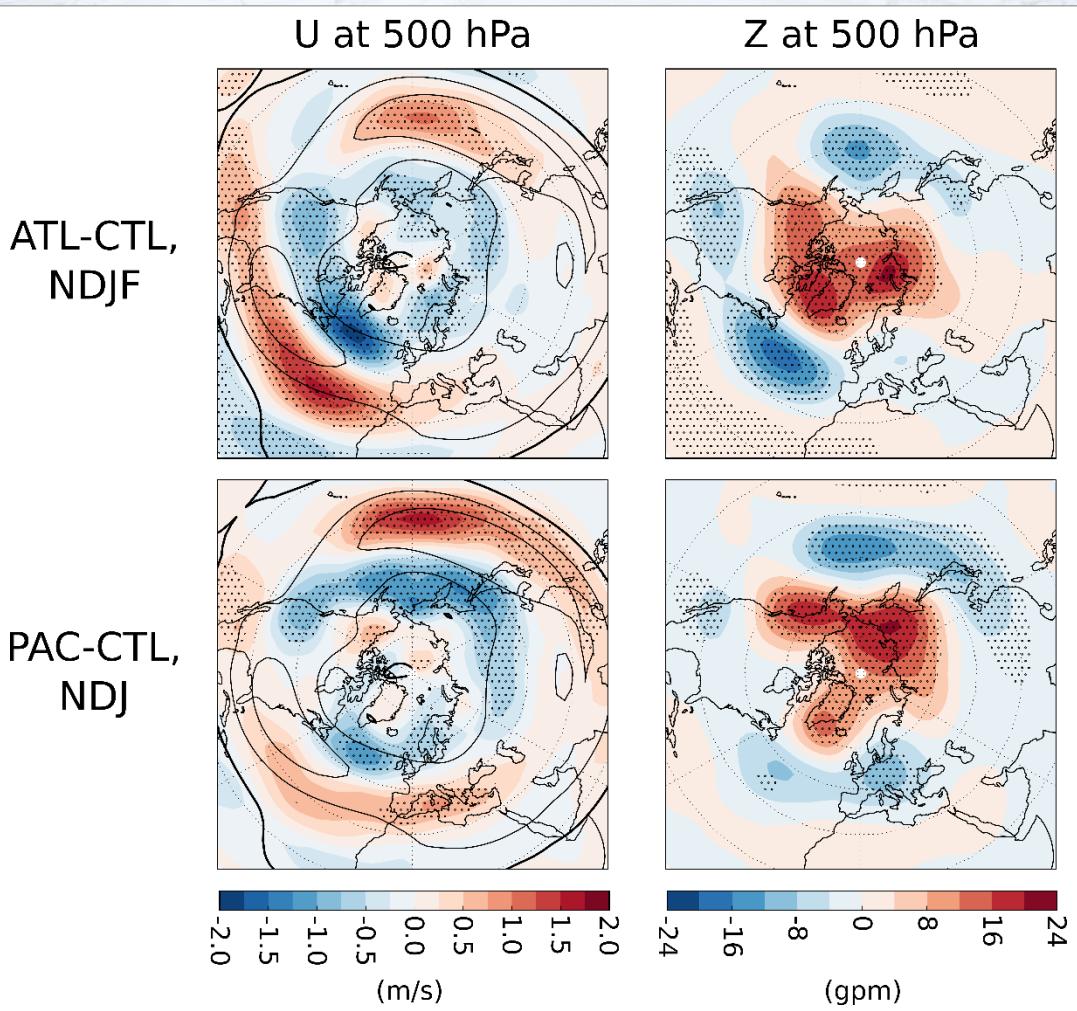


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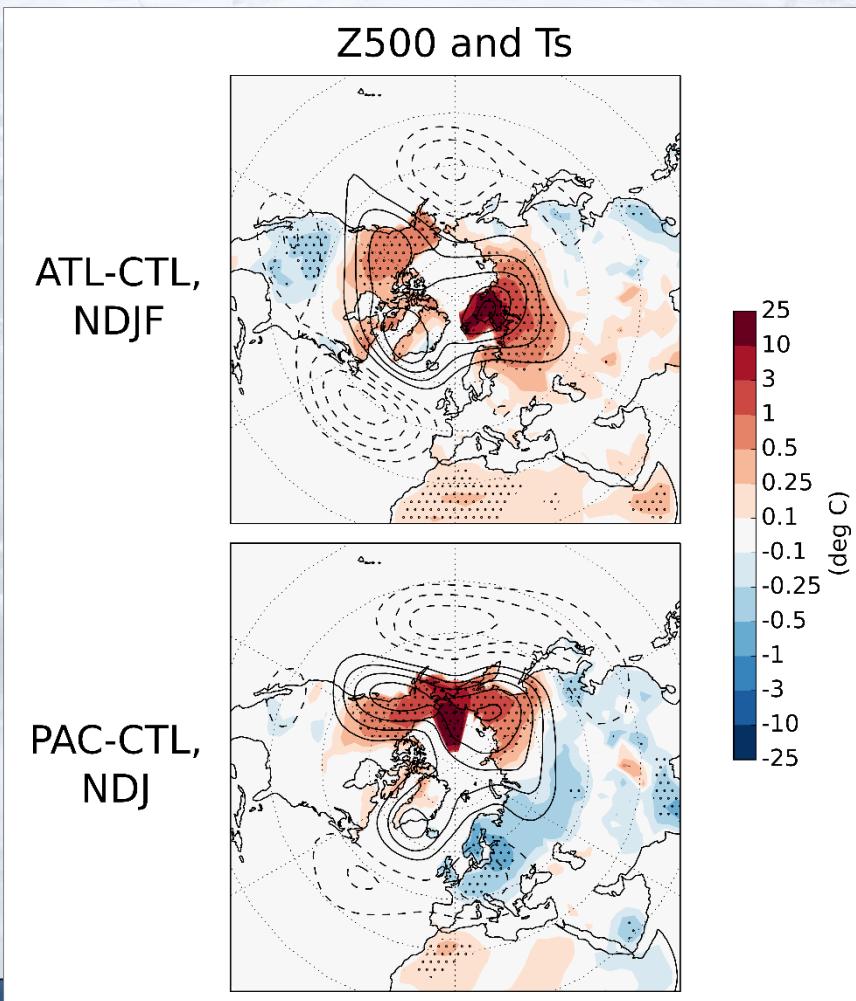
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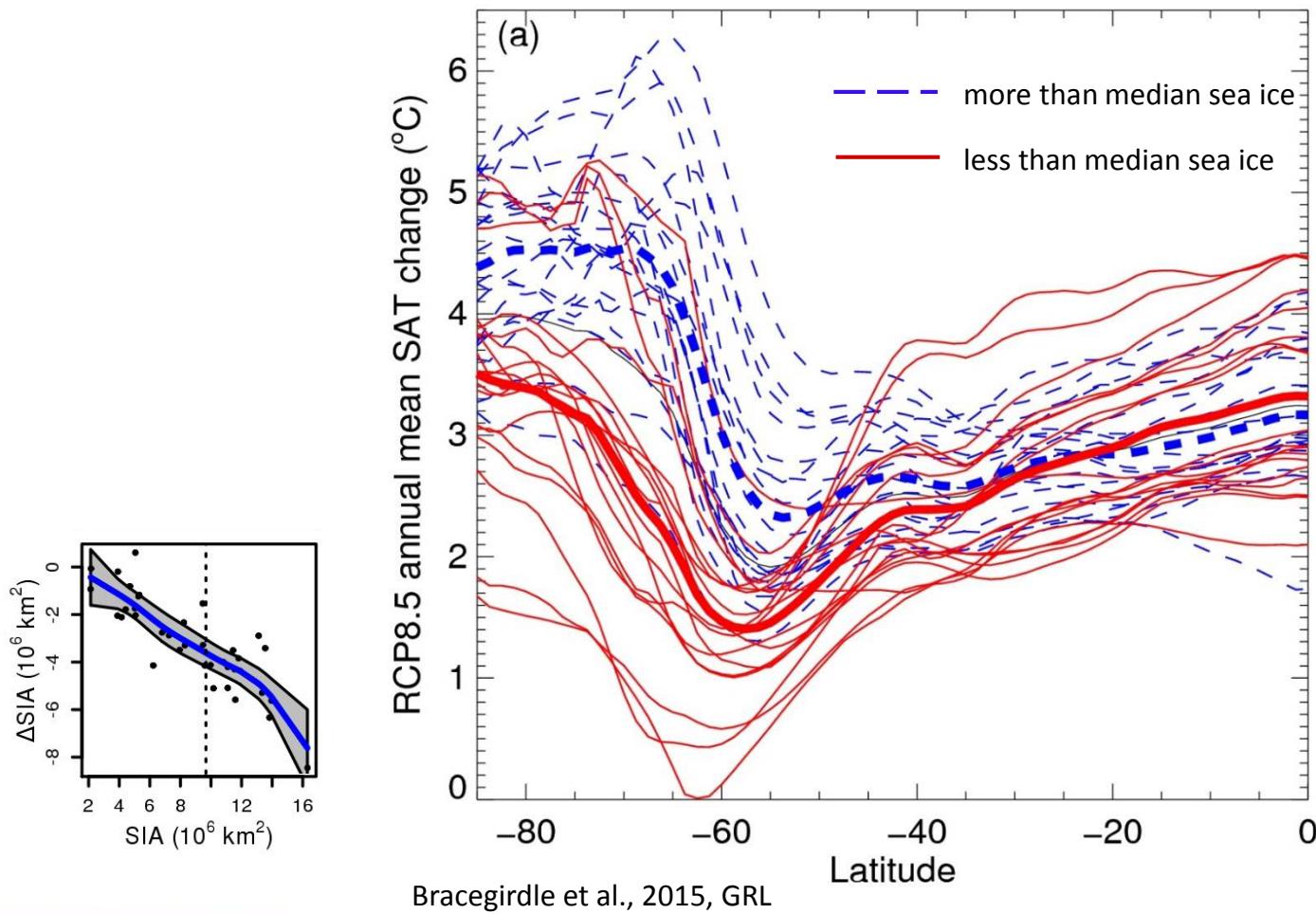
Results: (Q2) tropospheric response



Results: (Q3) surface temperature response



CMIP5 SH sea ice and surface temperature projections



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