# Isolating the atmospheric response to Arctic sea ice loss in the coupled climate system

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### Background

• Sea ice loss directly impacts the atmosphere through increased heatfluxes from the ocean into the atmosphere



### Background

• Sea ice loss may lead to a response outside the Arctic through teleconnections



Honda et al. 2009

### Background

Arctic sea ice loss and its associated warming are not occurring in isolation



• Can we determine what the role of sea ice melt is compared to other factors like warming at lower latitudes?

### Experiments

- CESM Large Ensemble (LE)
  - 30 member initial condition ensemble
  - 1920-2100 (historical + RCP8.5 emissions scenario)
- CESM sea ice albedo forcing simulation
  - Year 2000 control simulation (700+ years)
  - Albedo forcing simulation to melt sea ice (500+ years)
- CCSM4 sea ice albedo and RCP8.5 forced experiments



### Sea ice vs low latitude SST scatter plots



 There are different amounts low latitude SST warming relative to the amount of sea ice loss

## Decomposing the response

• We can define any field (e.g. Z500) to be a function of the amount sea ice (*I*) and the lower latitude temperature (*T*) :

Z500 = Z500(I,T)

• We can decompose a change in Z500 into a part that scales with sea ice and a part that scales with lower latitude temperature for both the albedo forcing experiment (A subscript) and RCP8.5 experiment (R subscript):

$$\delta Z 500_{A} = \frac{\partial Z 500}{\partial I} \Big|_{T} \delta I_{A} + \frac{\partial Z 500}{\partial T} \Big|_{I} \delta T_{A}$$
$$\delta Z 500_{R} = \frac{\partial Z 500}{\partial I} \Big|_{T} \delta I_{R} + \frac{\partial Z 500}{\partial T} \Big|_{I} \delta T_{R}$$

• Solve for  $\frac{\partial Z500}{\partial I}\Big|_{T}$  and  $\frac{\partial Z500}{\partial T}\Big|_{I}$ :

$$\left( \frac{\partial Z500}{\partial I} \right|_{T} \\
\frac{\partial Z500}{\partial T} \right|_{I} = \frac{1}{\delta I_{A} \delta T_{R} - \delta I_{R} \delta T_{A}} \begin{pmatrix} \delta T_{R} & -\delta T_{A} \\ -\delta I_{R} & \delta I_{A} \end{pmatrix} \begin{pmatrix} \delta Z500_{A} \\ \delta Z500_{R} \end{pmatrix}$$



# Zonal mean T



Coupled model experiments

# Zonal mean T



### Zonal mean U











## Precipitation









# Subseasonal 2m land T variability





# Summary

- We have hypothesised a method to separately estimate the atmospheric response that scales with sea ice loss and lower latitude SSTs using RCP8.5 and sea ice albedo forced experiments
- The warming in the Arctic lower troposphere can be attributed to sea ice loss
- The wintertime circulation responses that occur due to sea ice loss are not seen in RCP8.5 experiment due to cancellation with the response due to lower latitude temperature increases
- Sea ice loss contributes significantly to the decrease in wintertime temperature variability see in in RCP8.5 experiment

#### CCSM4 U 2052:2071-2032:2051



#### CCSM4 U 2042:2061-2022:2041



#### CCSM4 U 2045:2074-2005:2034



### CCSM4 SLP 2052:2071-2032:2051



#### CCSM4 SLP 2042:2061-2022:2041



#### CCSM4 SLP 2045:2074-2005:2034





#### CCSM4 2m T 2042:2061-2022:2041



#### CCSM4 2m T 2045:2074-2005:2034

