

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

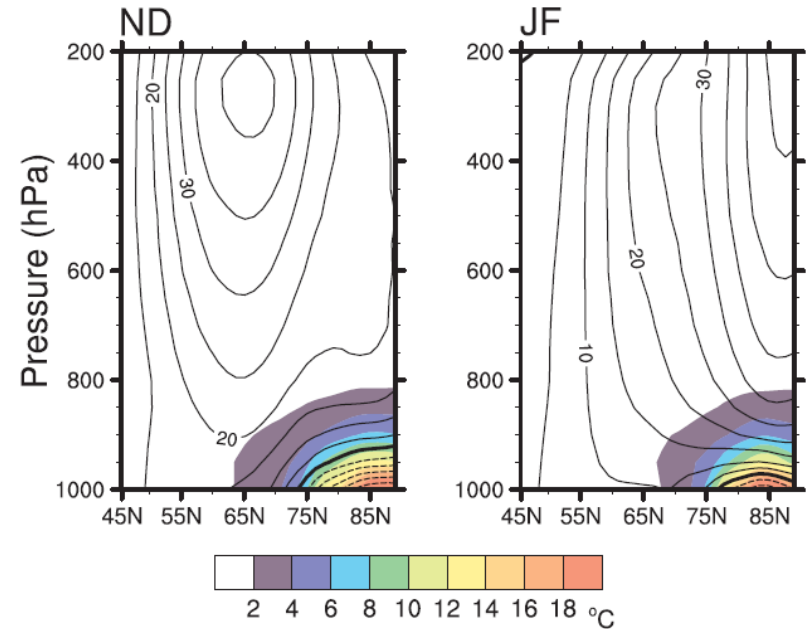
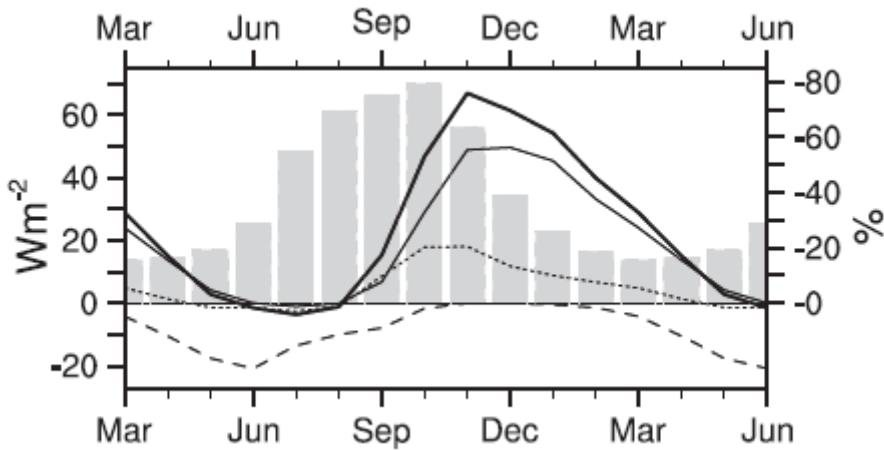
Russell Blackport and Paul Kushner
University of Toronto

PCWG meeting, February 10th 2016



Background

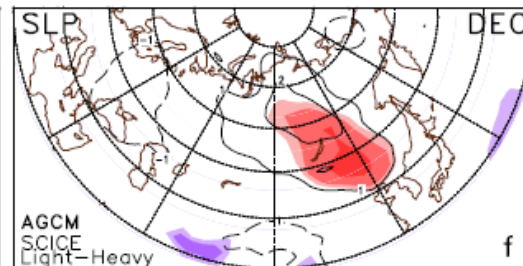
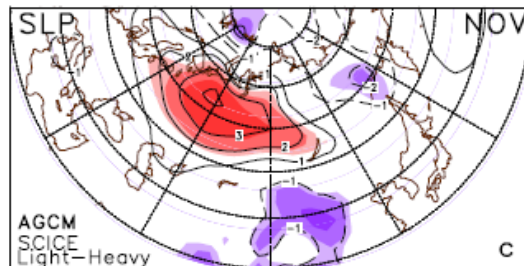
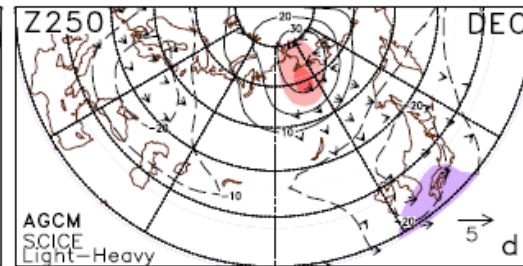
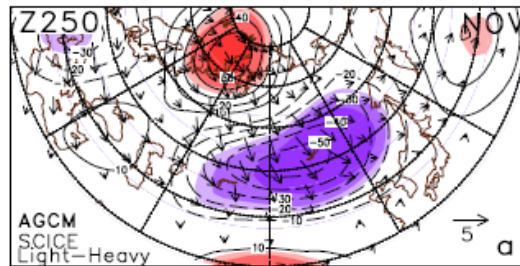
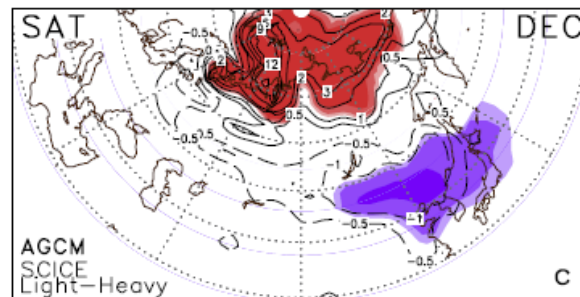
- Sea ice loss directly impacts the atmosphere through increased heatfluxes from the ocean into the atmosphere



Deser et al. 2010

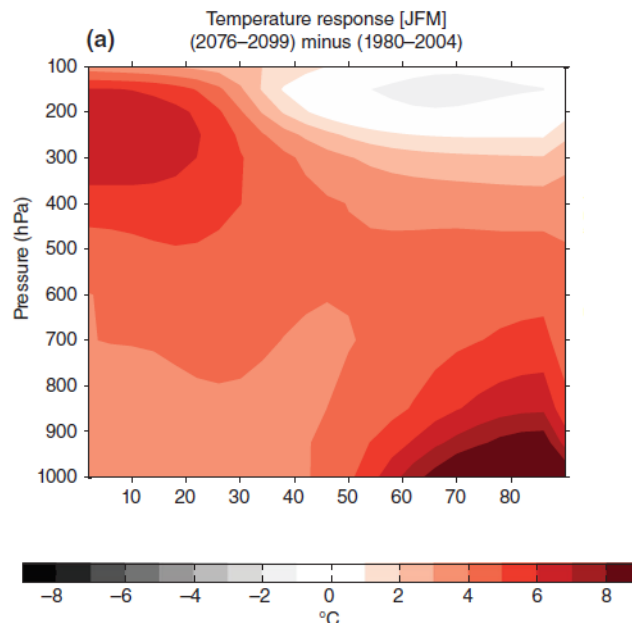
Background

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



Background

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



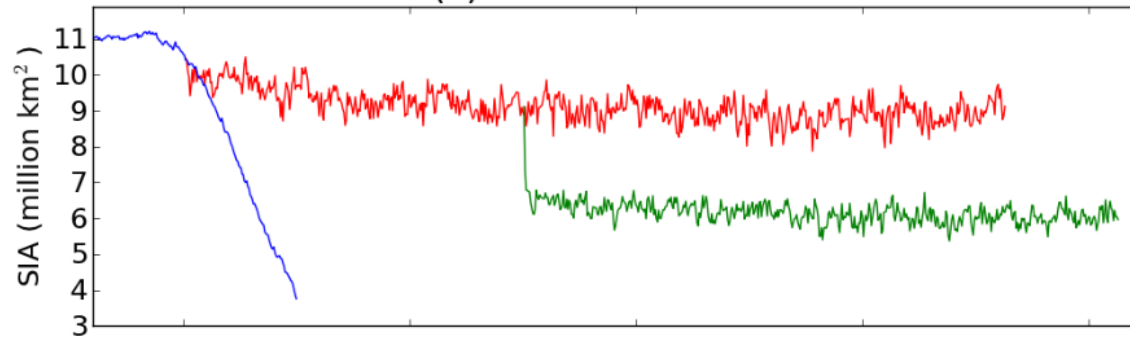
Barnes and Screen, 2015

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

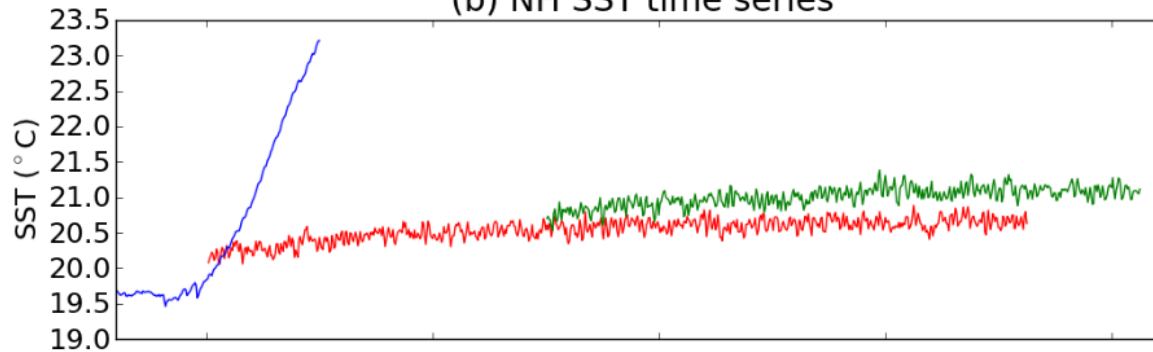
Experiments

- 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

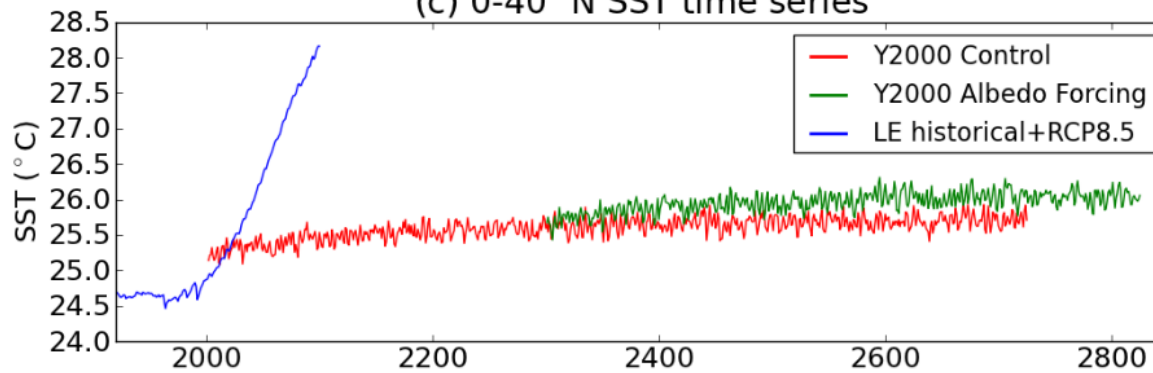
(a) NH SIA time series



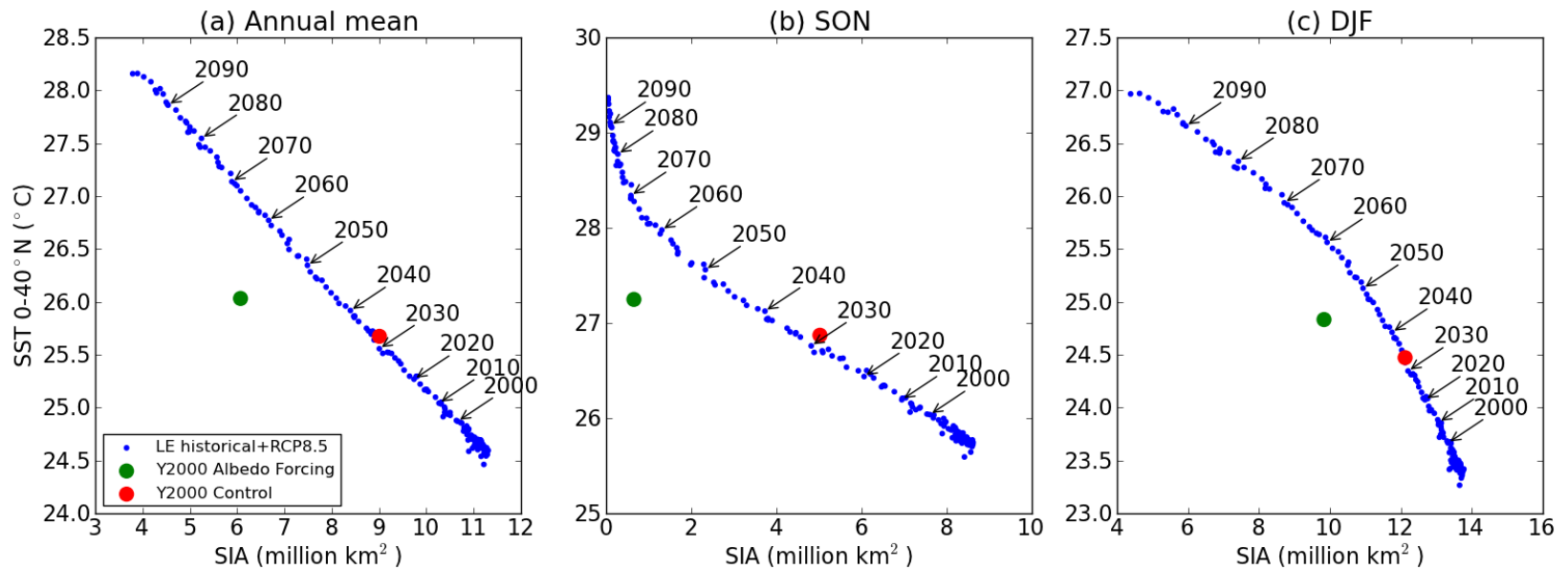
(b) NH SST time series



(c) 0-40° N SST time series



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) :

$$Z500 = Z500(I, T)$$

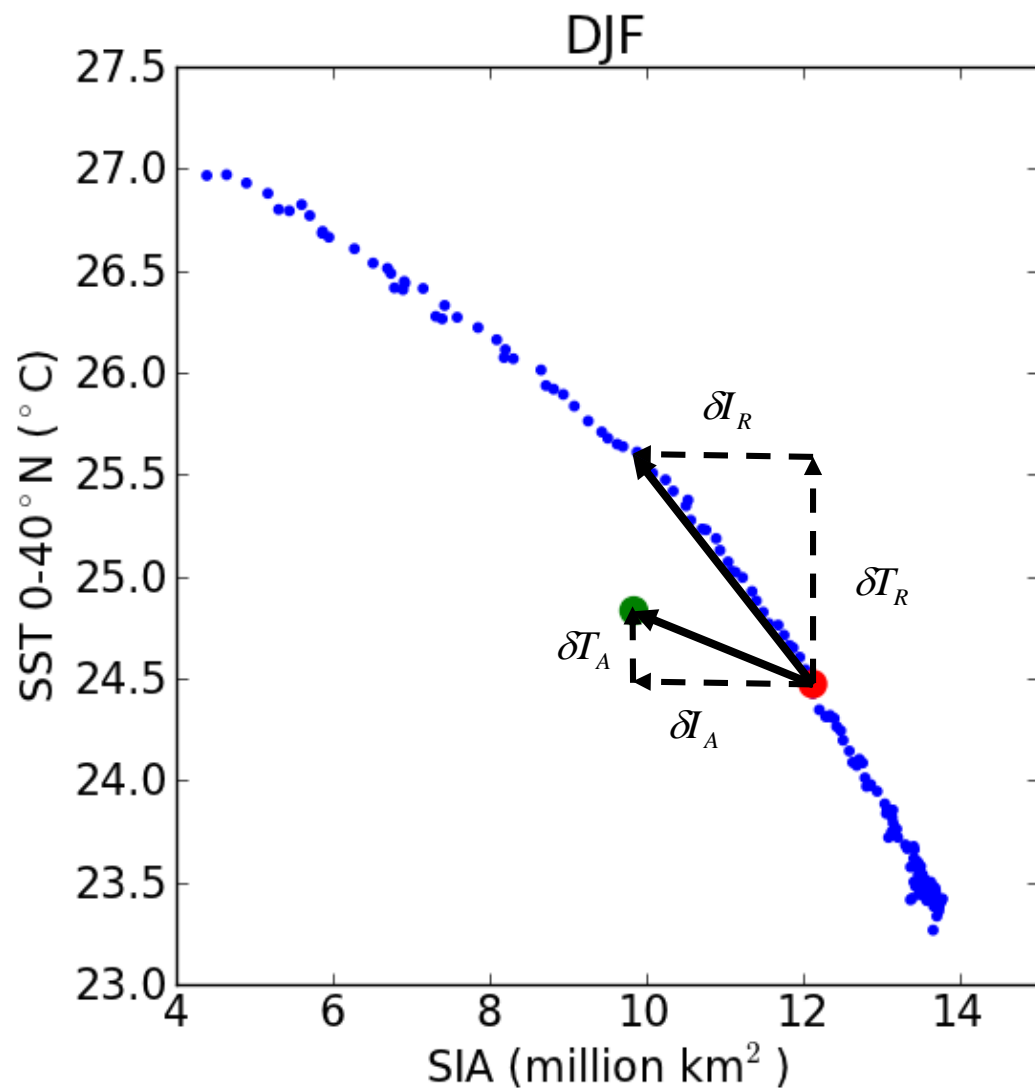
- We can decompose a change in Z500 into a part that scales with sea ice and a part that scales with lower latitude temperature for both the albedo forcing experiment (A subscript) and RCP8.5 experiment (R subscript):

$$\delta Z500_A = \left. \frac{\partial Z500}{\partial I} \right|_T \delta I_A + \left. \frac{\partial Z500}{\partial T} \right|_I \delta T_A$$

$$\delta Z500_R = \left. \frac{\partial Z500}{\partial I} \right|_T \delta I_R + \left. \frac{\partial Z500}{\partial T} \right|_I \delta T_R$$

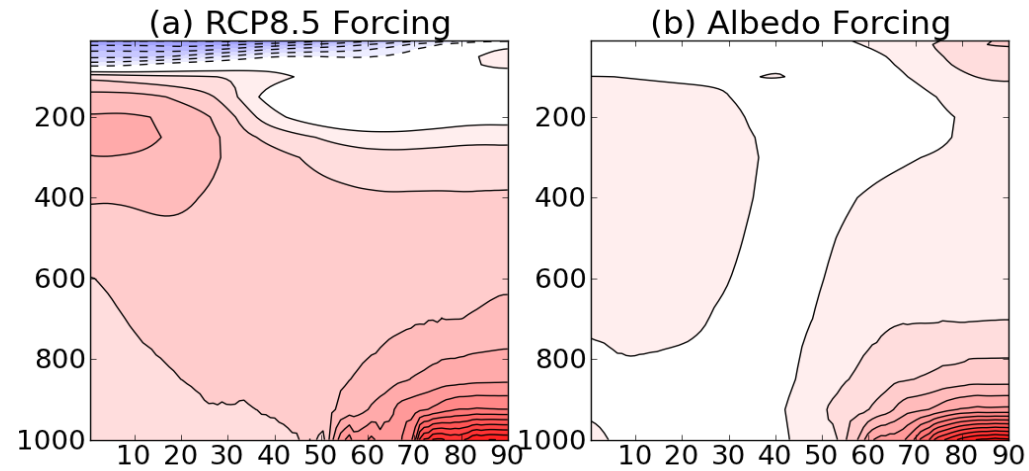
- Solve for $\left. \frac{\partial Z500}{\partial I} \right|_T$ and $\left. \frac{\partial Z500}{\partial T} \right|_I$:

$$\begin{pmatrix} \left. \frac{\partial Z500}{\partial I} \right|_T \\ \left. \frac{\partial Z500}{\partial T} \right|_I \end{pmatrix} = \frac{1}{\delta I_A \delta T_R - \delta I_R \delta T_A} \begin{pmatrix} \delta T_R & -\delta T_A \\ -\delta I_R & \delta I_A \end{pmatrix} \begin{pmatrix} \delta Z500_A \\ \delta Z500_R \end{pmatrix}$$



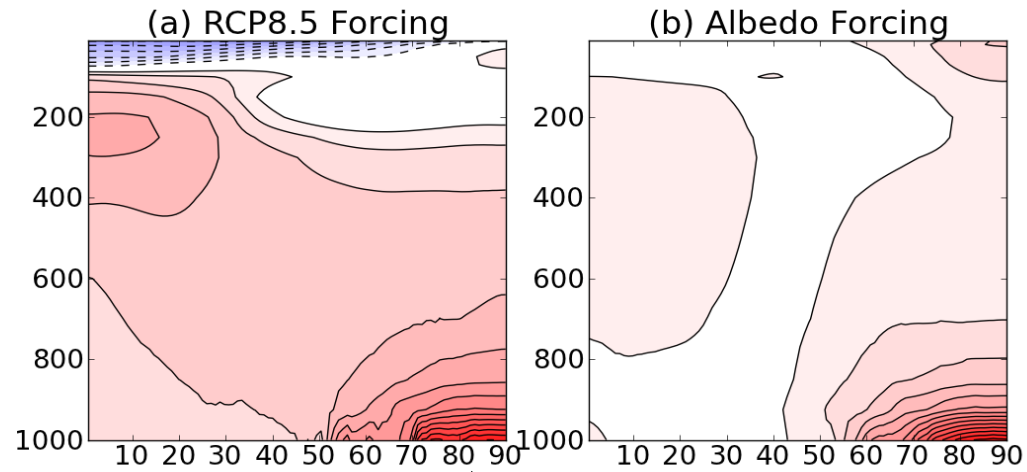
Zonal mean T

Coupled model
experiments

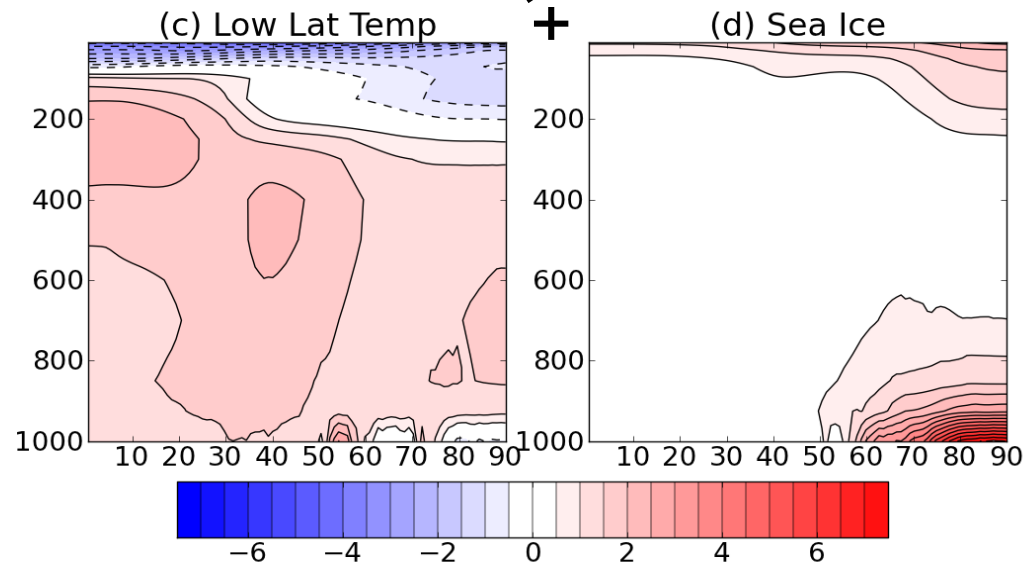


Zonal mean T

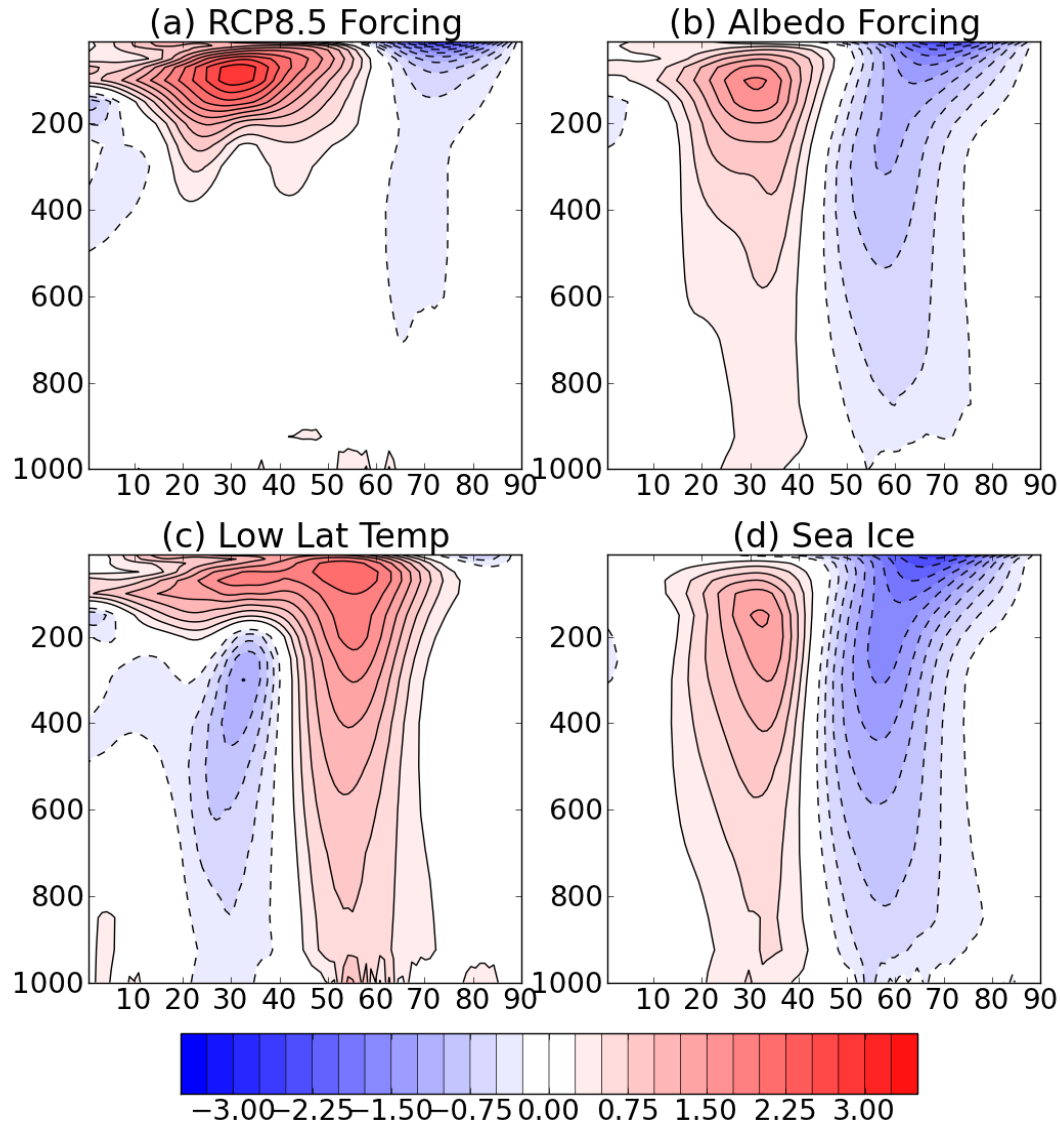
Coupled model experiments



Calculated decomposition

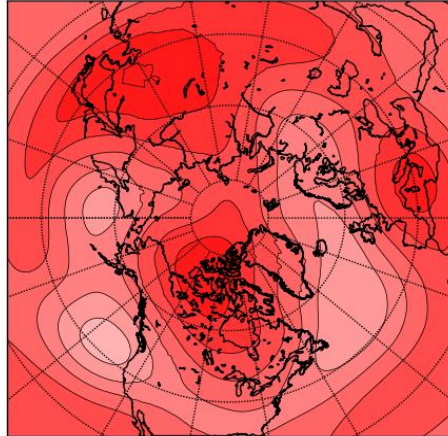


Zonal mean U

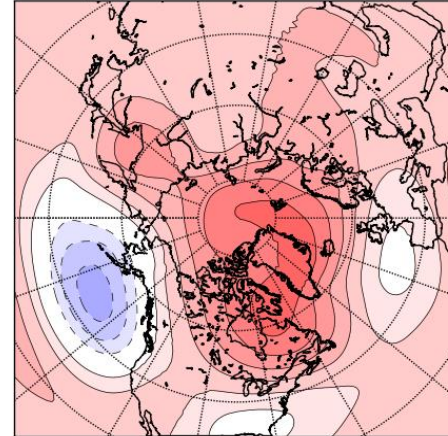


Z500

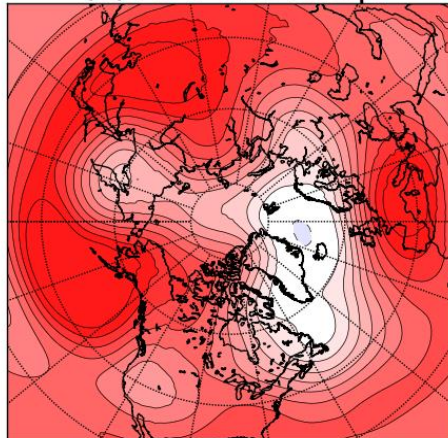
(a) RCP8.5 Forcing



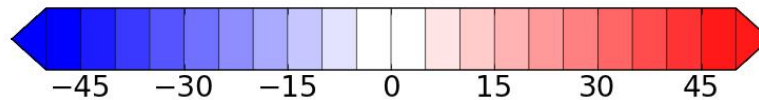
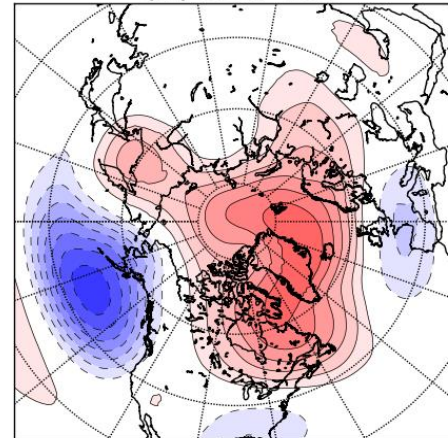
(b) Albedo Forcing



(c) Low Lat Temp

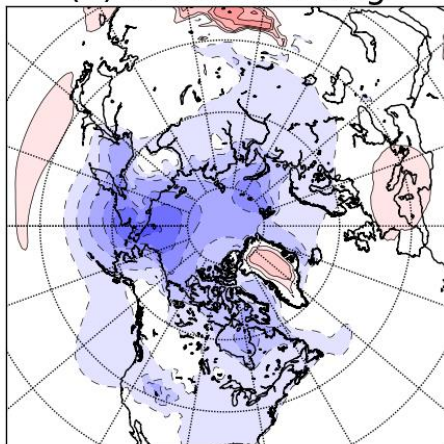


(d) Sea Ice

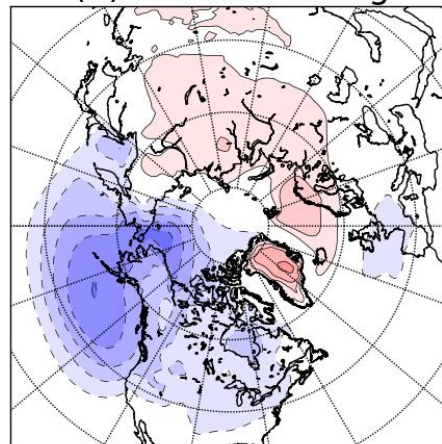


SLP

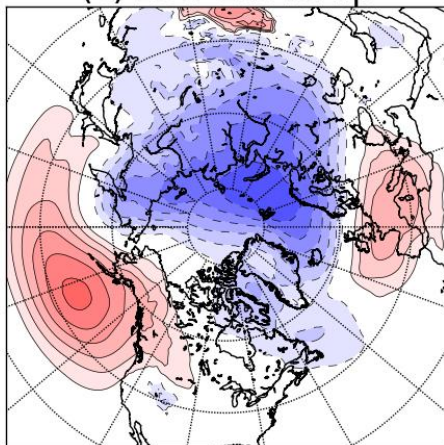
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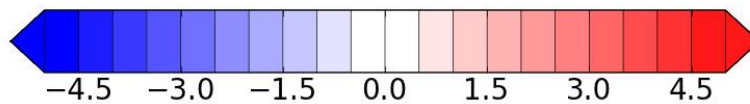
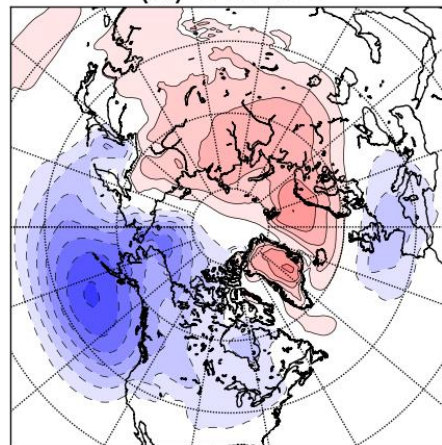
(b) Albedo Forcing



(c) Low Lat Temp

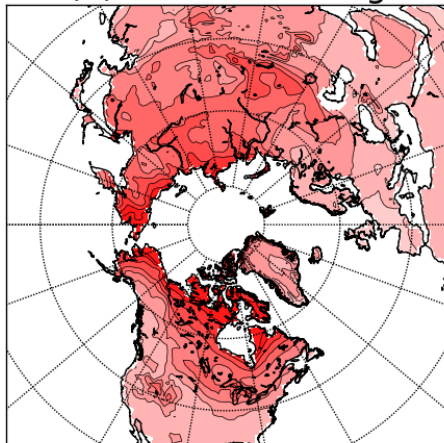


(d) Sea Ice

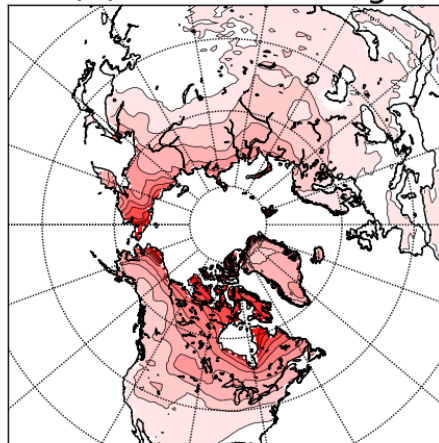


2m Land T

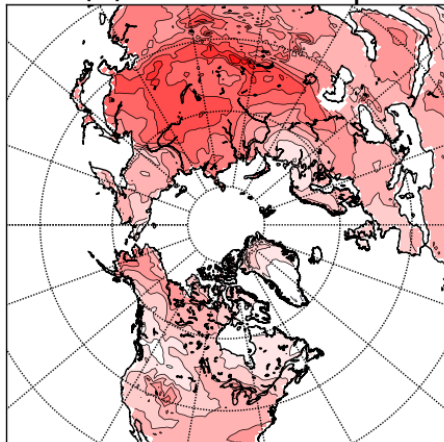
(a) RCP8.5 Forcing



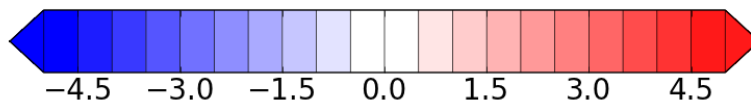
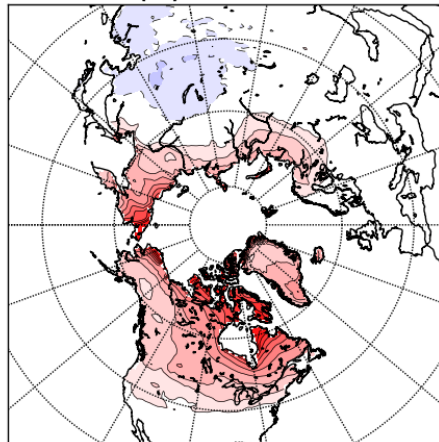
(b) Albedo Forcing



(c) Low Lat Temp

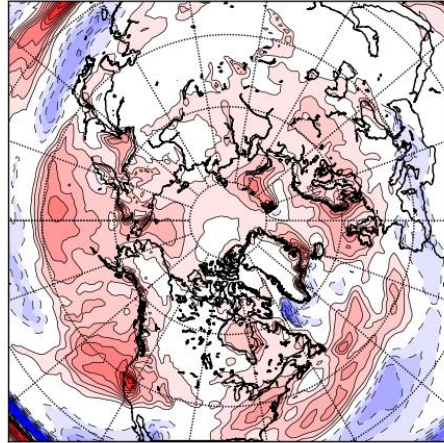


(d) Sea Ice

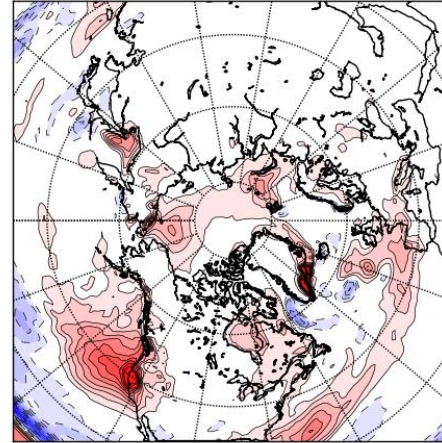


Precipitation

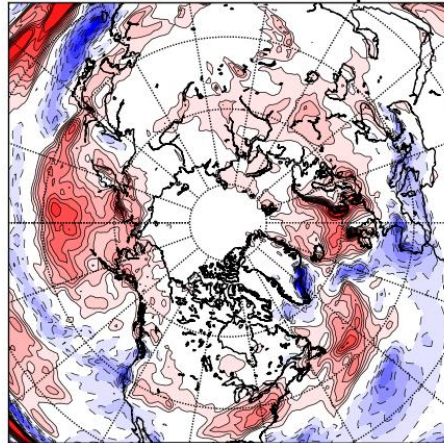
(a) RCP8.5 Forcing



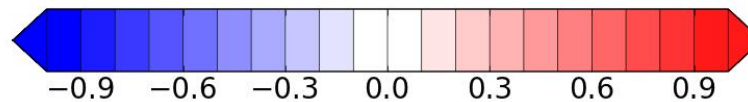
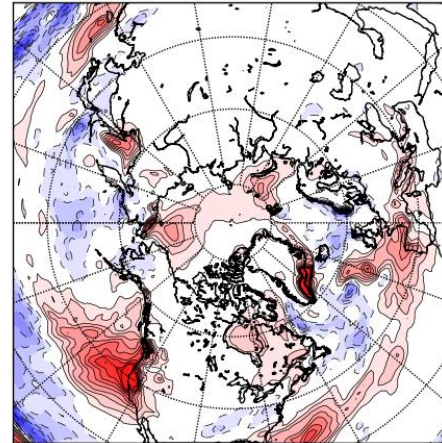
(b) Albedo Forcing



(c) Low Lat Temp

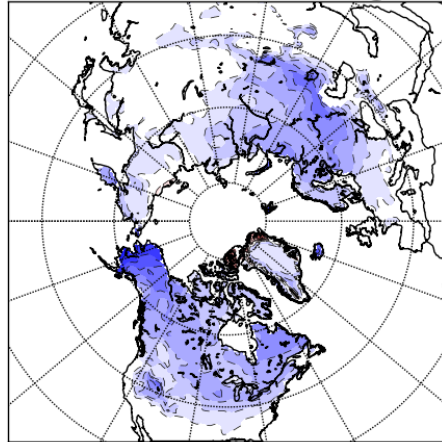


(d) Sea Ice

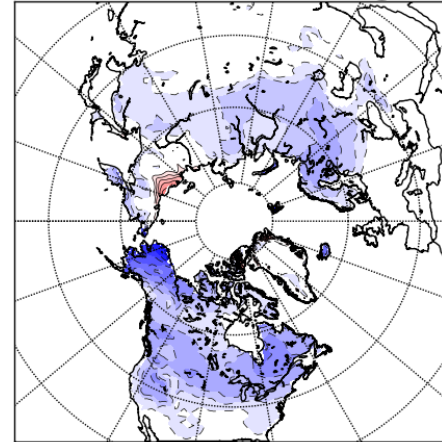


Subseasonal 2m land T variability

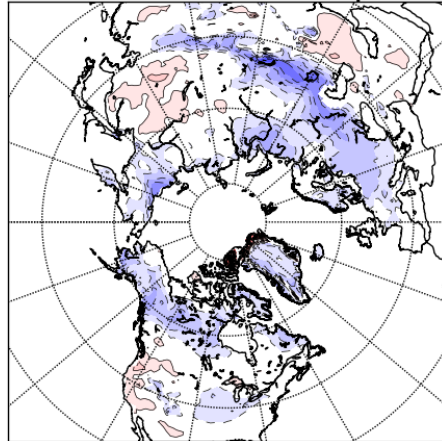
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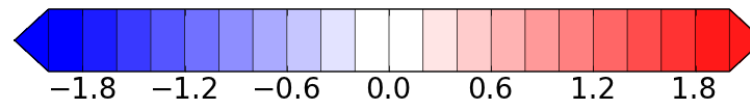
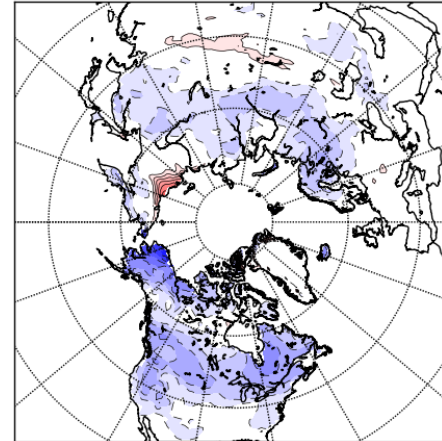
(b) Albedo Forcing



(c) Low Lat Temp



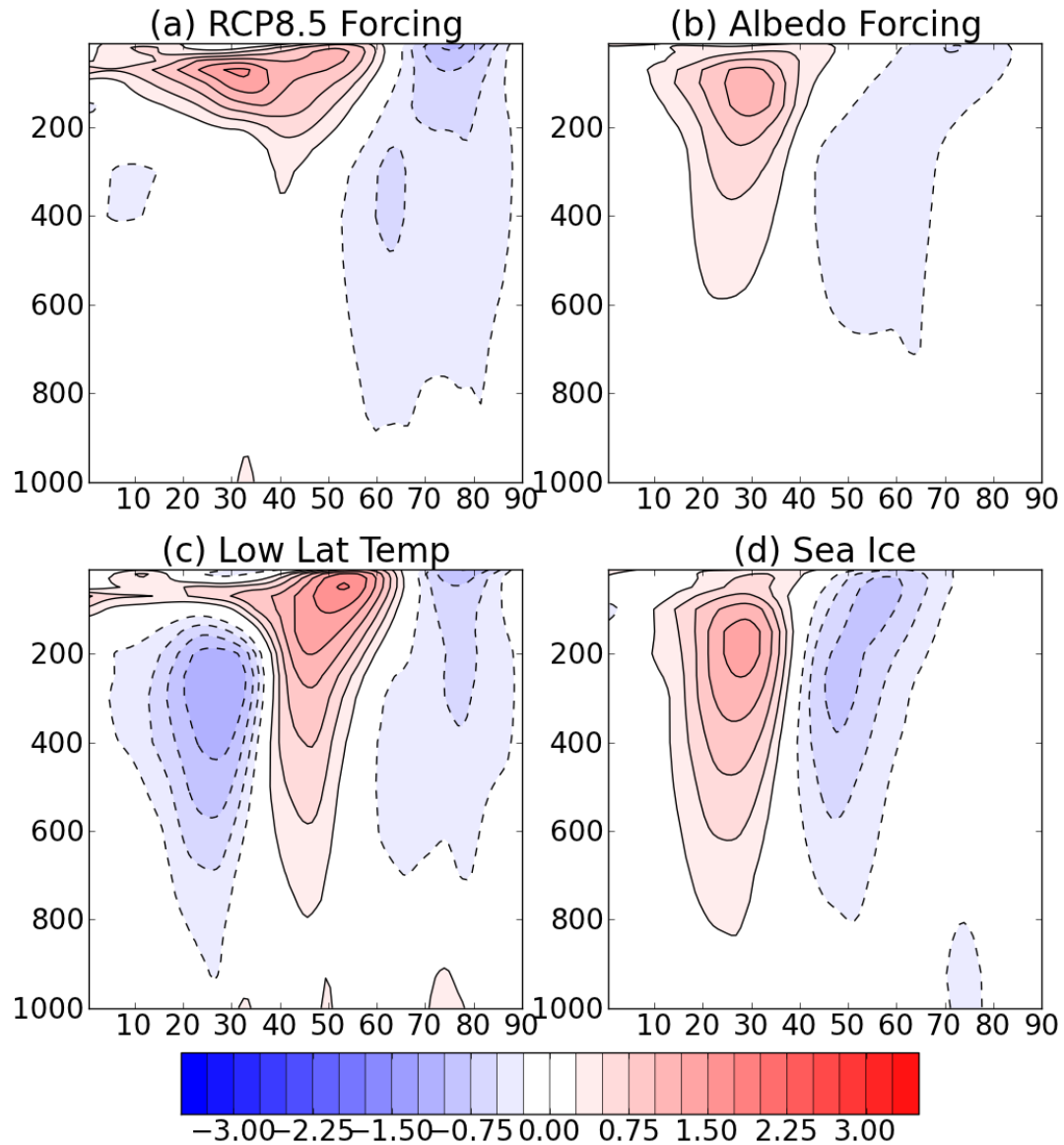
(d) Sea Ice



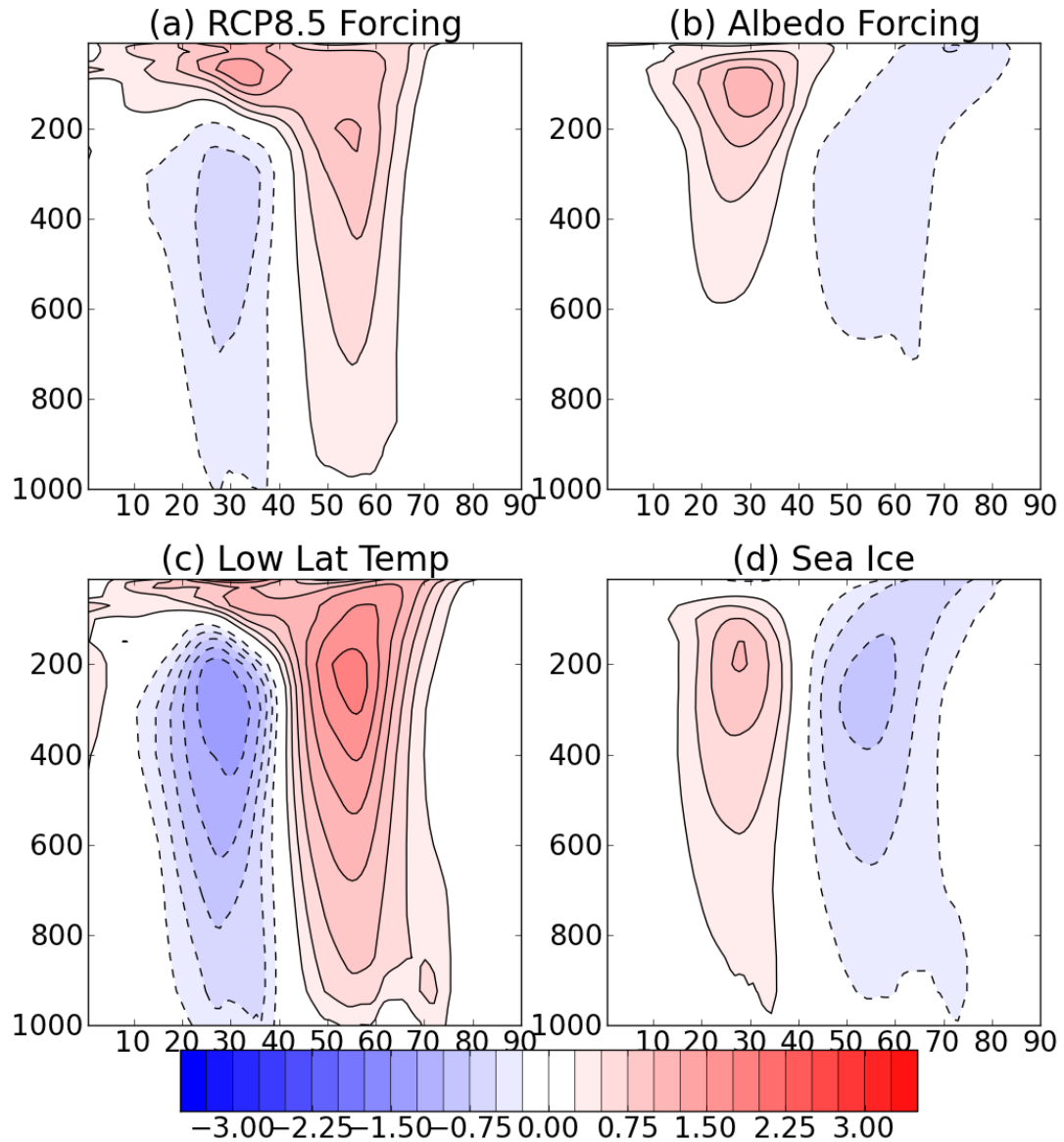
Summary

- 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 seen in RCP8.5 experiment

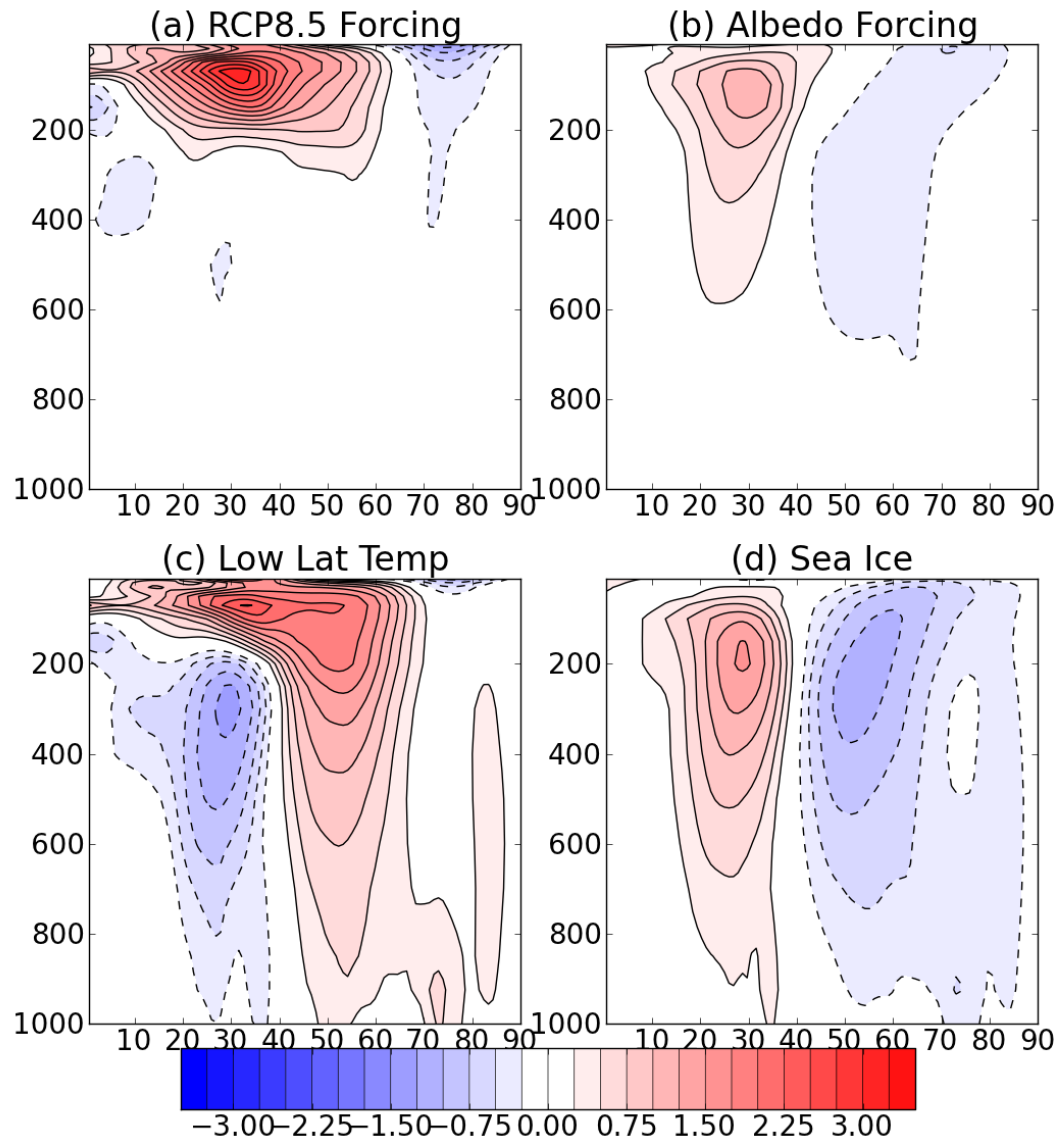
CCSM4 U 2052:2071-2032:2051



CCSM4 U 2042:2061-2022:2041

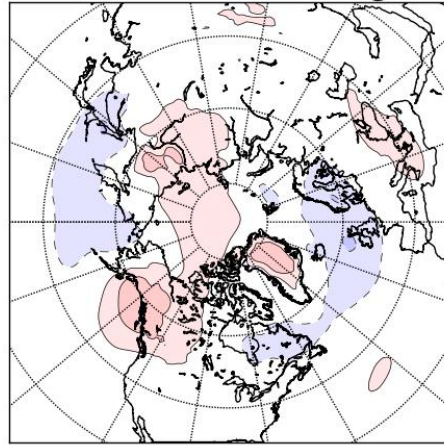


CCSM4 U 2045:2074-2005:2034

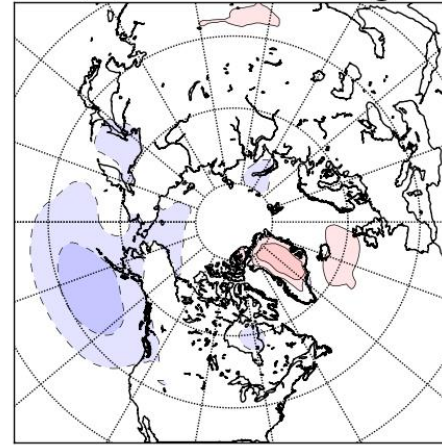


CCSM4 SLP 2052:2071-2032:2051

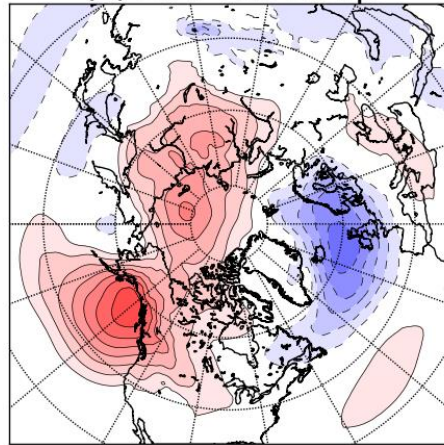
(a) RCP8.5 Forcing



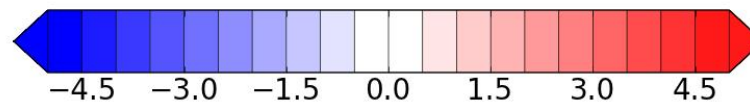
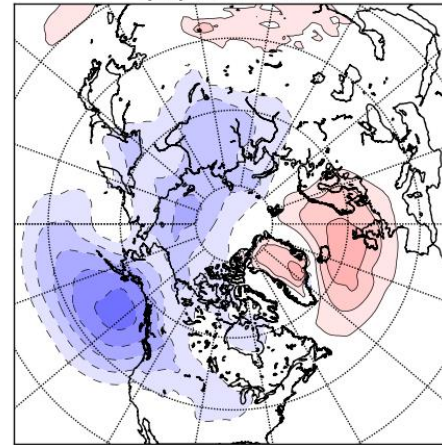
(b) Albedo Forcing



(c) Low Lat Temp

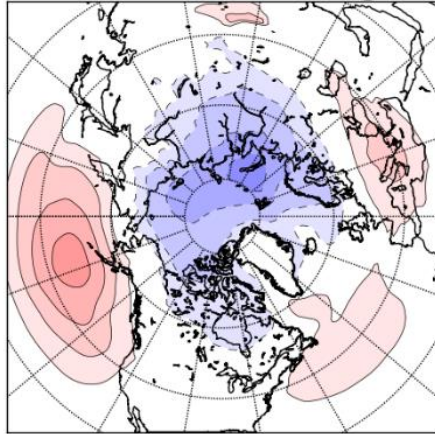


(d) Sea Ice

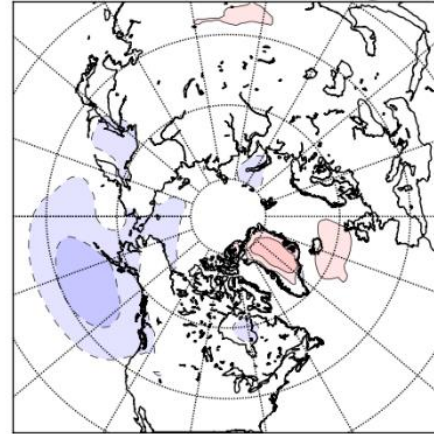


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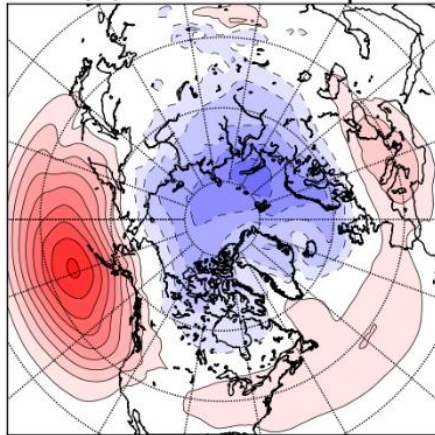
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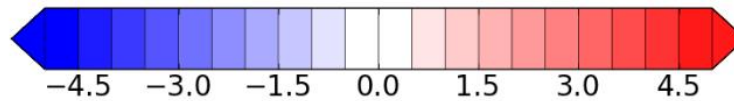
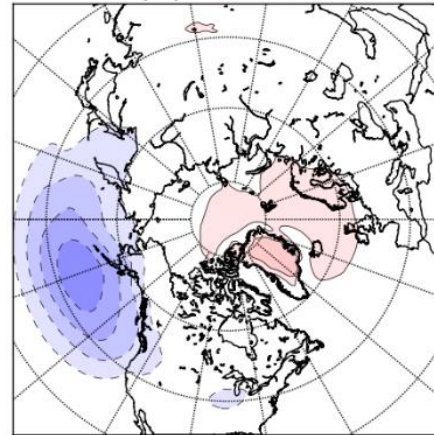
(b) Albedo Forcing



(c) Low Lat Temp

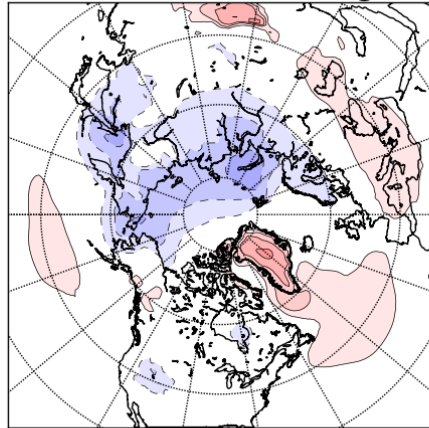


(d) Sea Ice

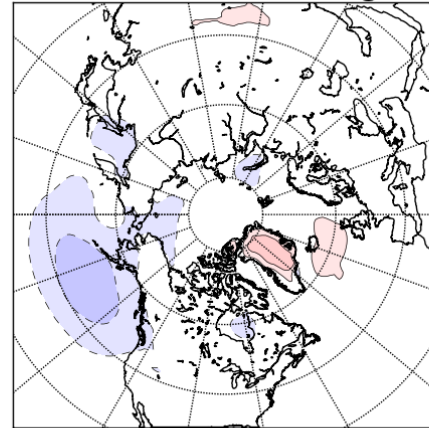


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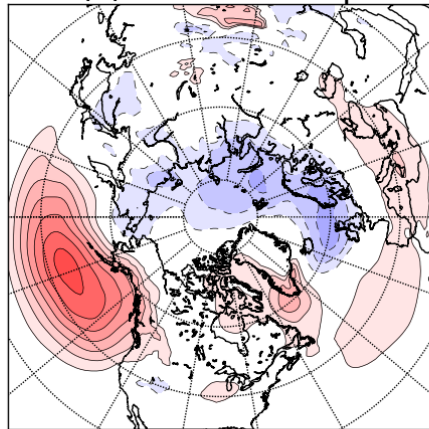
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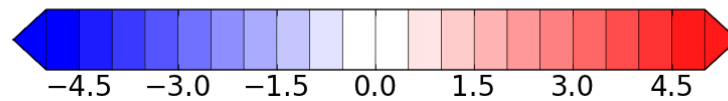
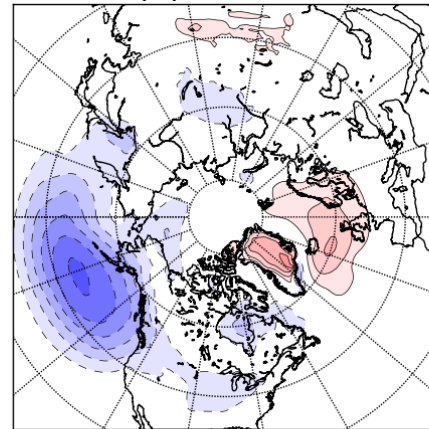
(b) Albedo Forcing



(c) Low Lat Temp

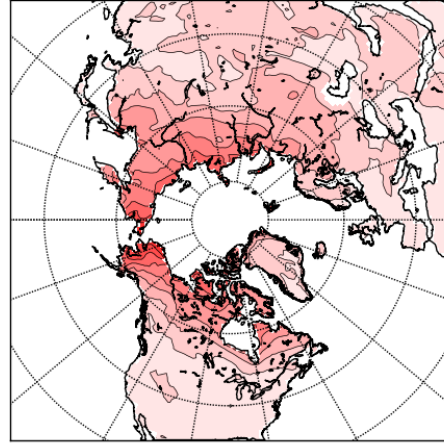


(d) Sea Ice

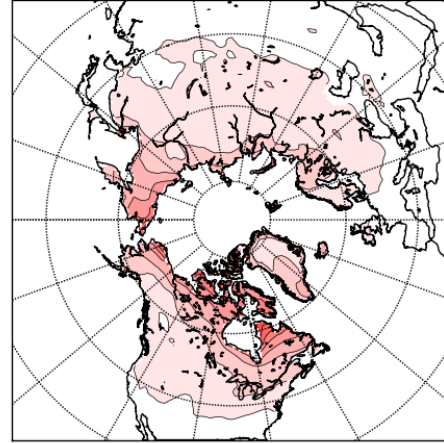


CCSM4 2m T 2052:2071-2032:2051

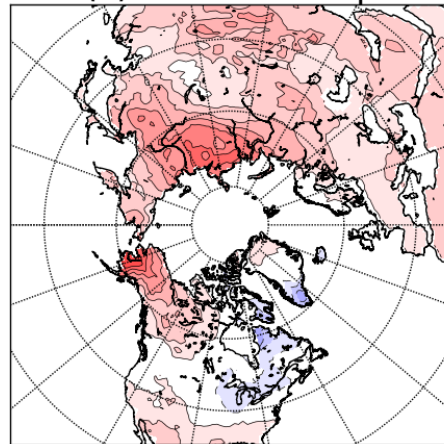
(a) RCP8.5 Forcing



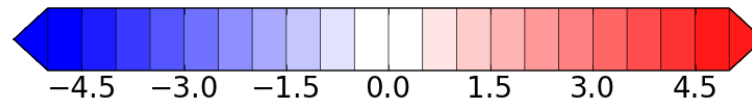
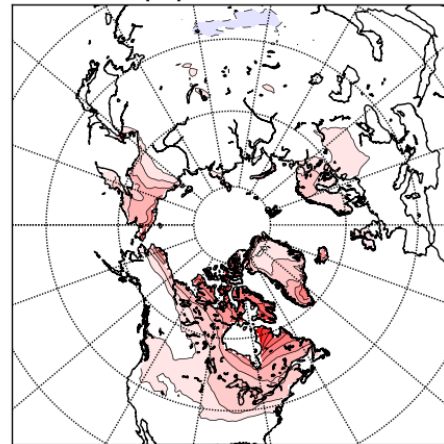
(b) Albedo Forcing



(c) Low Lat Temp

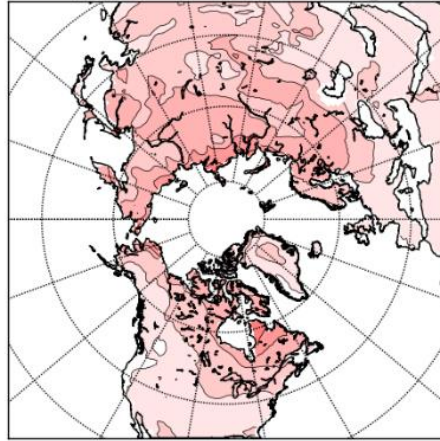


(d) Sea Ice

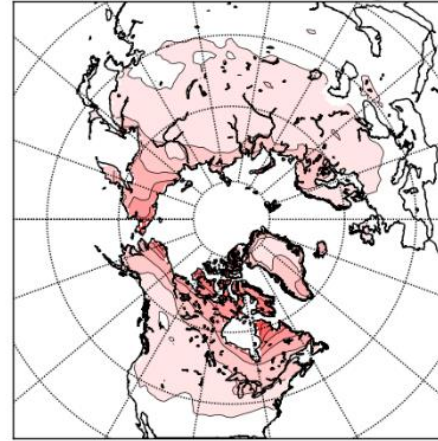


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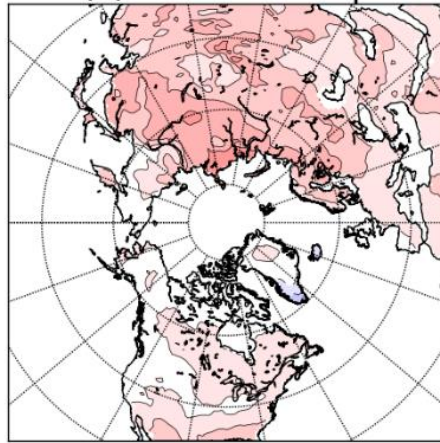
(a) RCP8.5 Forcing



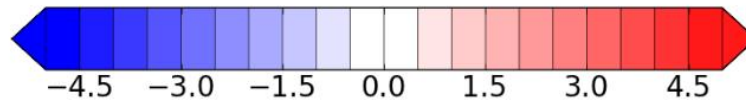
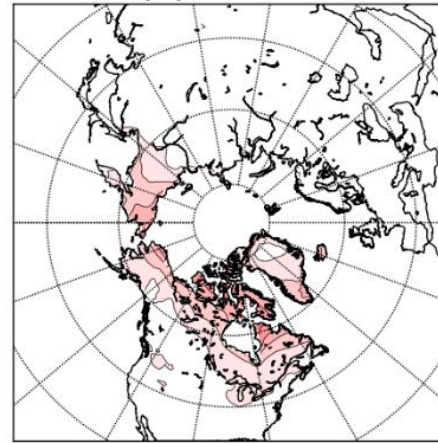
(b) Albedo Forcing



(c) Low Lat Temp

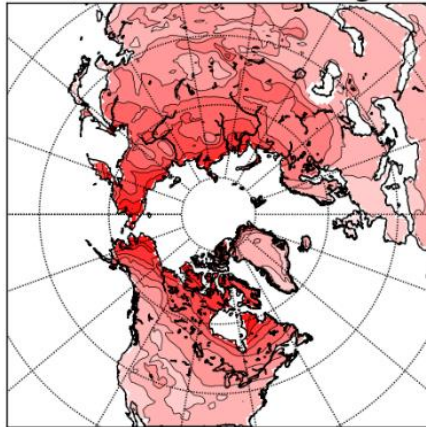


(d) Sea Ice

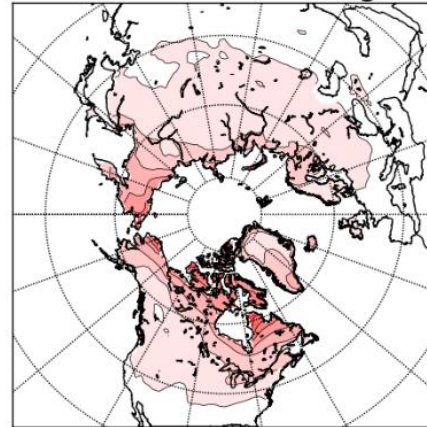


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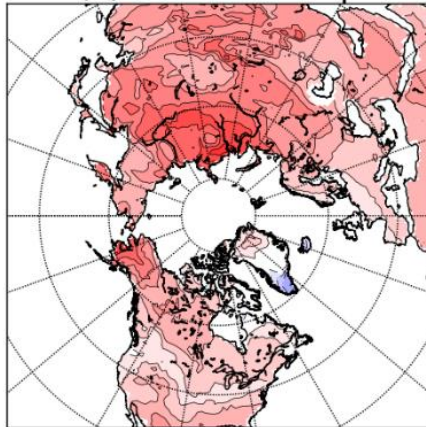
(a) RCP8.5 Forcing



(b) Albedo Forcing



(c) Low Lat Temp



(d) Sea Ice

