
U. Toronto Campus, 3/2018

Simulated Arctic Atmospheric Response to Climate Change

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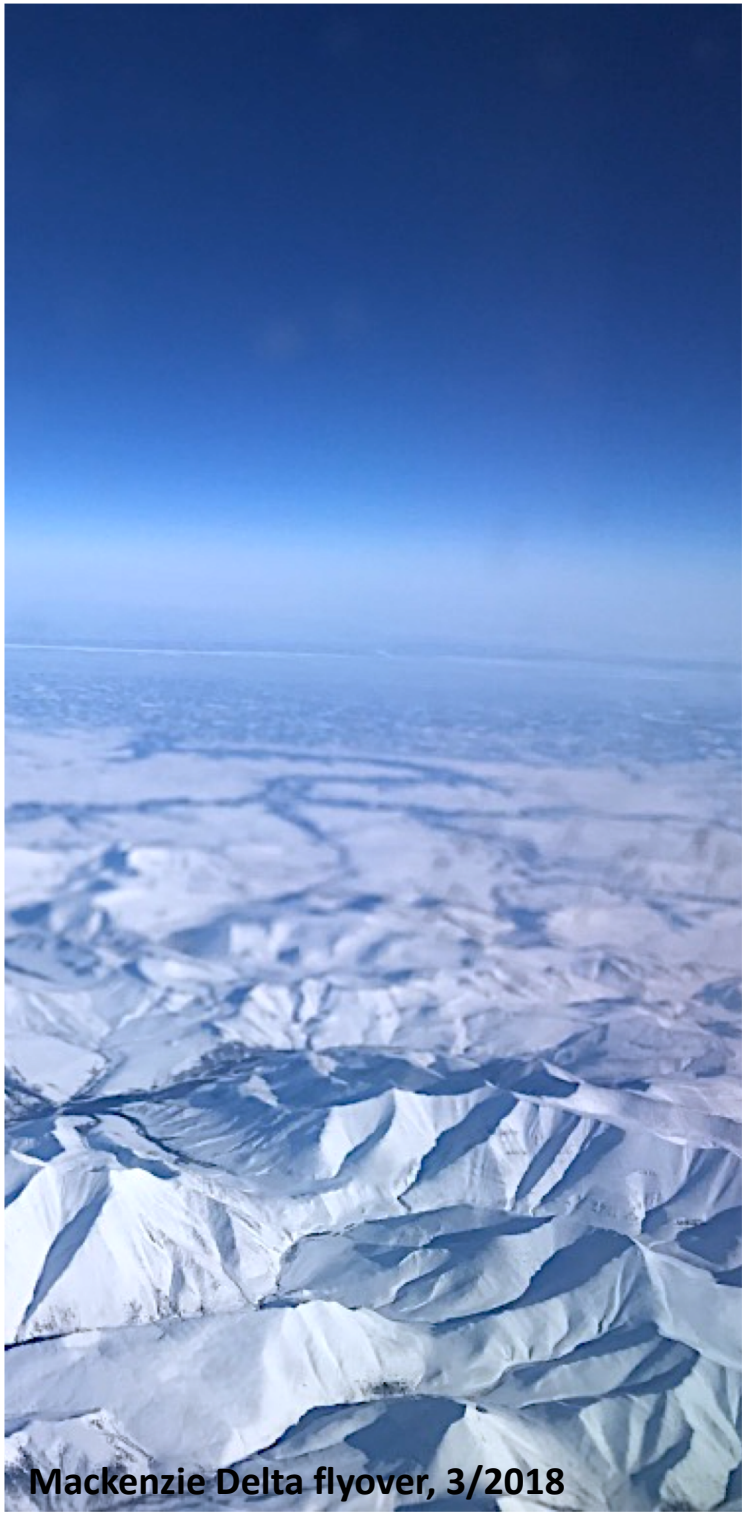
Thanks to:

- Russell Blackport & James Screen (Exeter)
- Stephanie Hay & Thomas Oudar (Toronto)
- Kelly McCusker (Rhodium Group)
- Clara Deser (NCAR)

Arctic System Change Workshop, April 2018

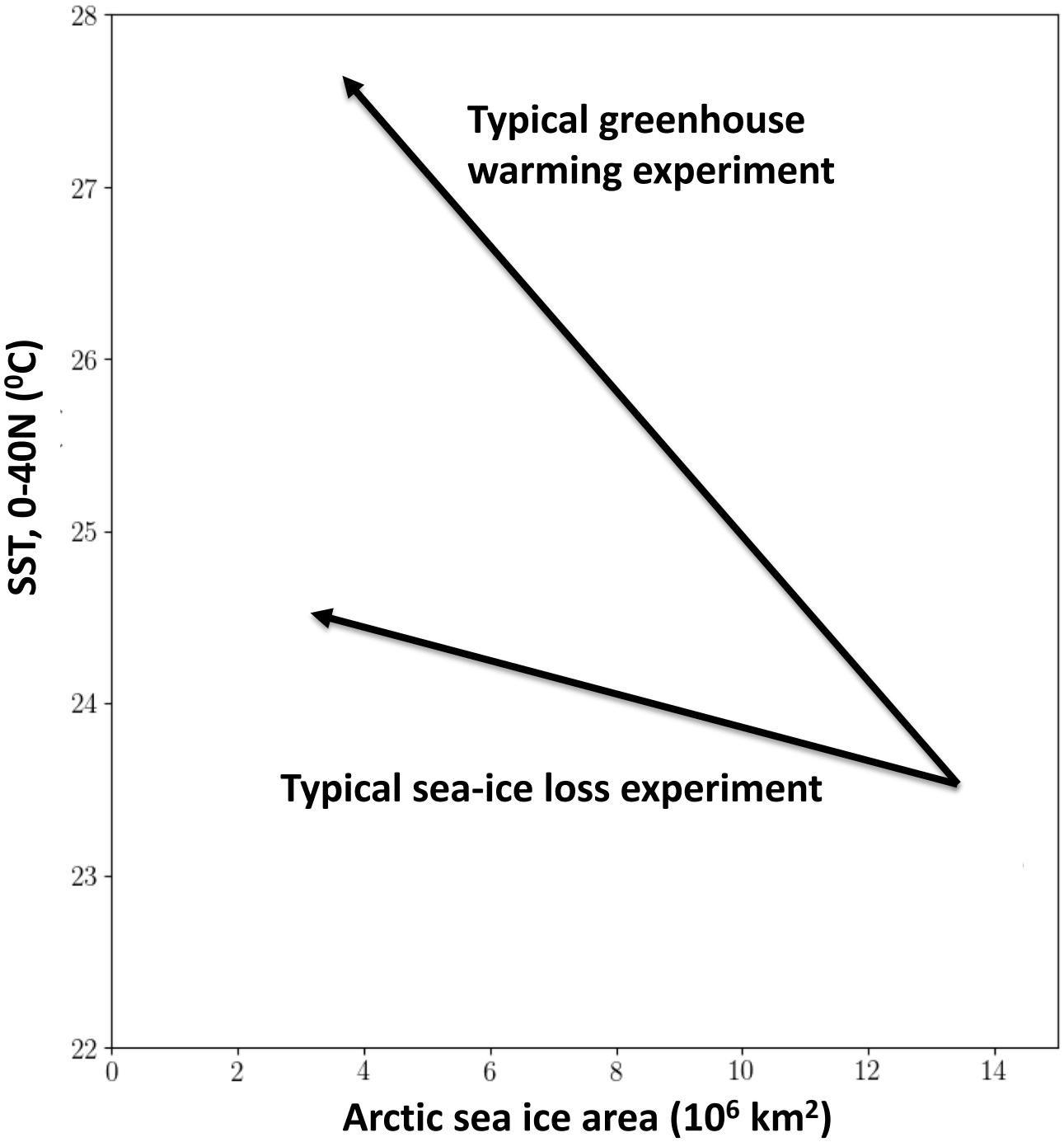
CANSISE
Canadian Sea Ice and Snow Evolution Network


Mackenzie Delta flyover, 3/2018

How Do ESMs Simulate Arctic Atmospheric Change?

- We can separate a robust response to sea ice loss from "the remainder" of global warming.
- The impact of this "remainder" seems less robust.
- There are overlapping mechanisms of Arctic tropospheric change.

Arctic and Tropical Change Are Entangled



In well-sampled coupled ocean-atmosphere models:

- Global warming drives sea-ice loss.
- Induced sea-ice loss drives 'mini' global warming (Deser et al. 2015).

How can we disentangle these effects?

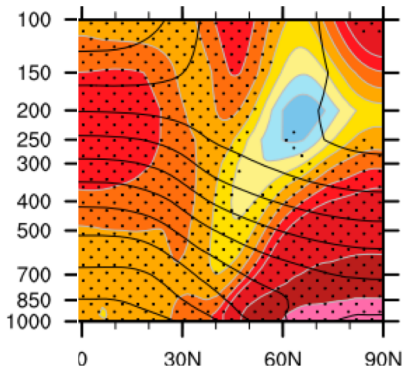
Zonal-Mean Temperature Response

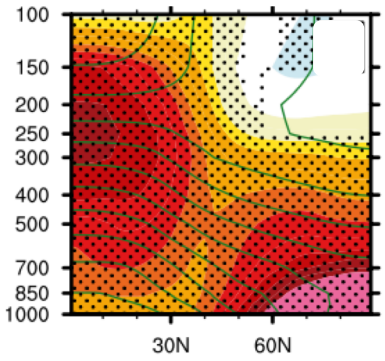
- Annual mean
- CCSM4
- Deser et al. 2015

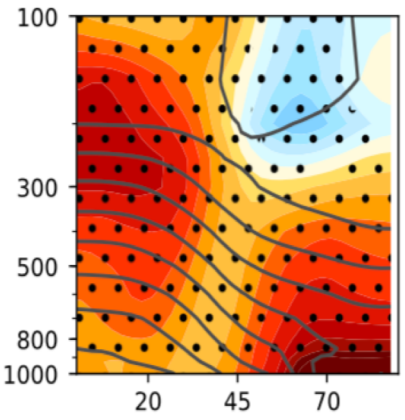
- DJF mean
- CNRM-GAME
- Oudar et al. 2017

- DJF mean
- CanESM2
- McCusker et al. 2017

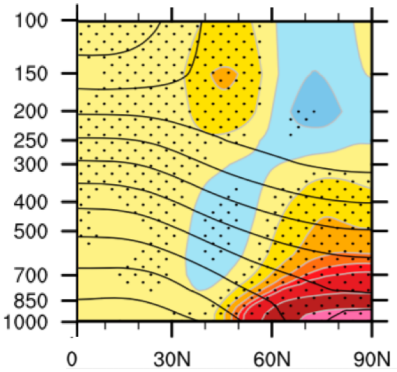
GHG Forcing

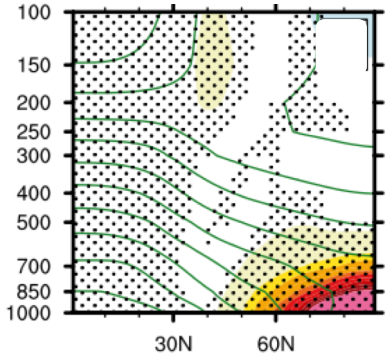


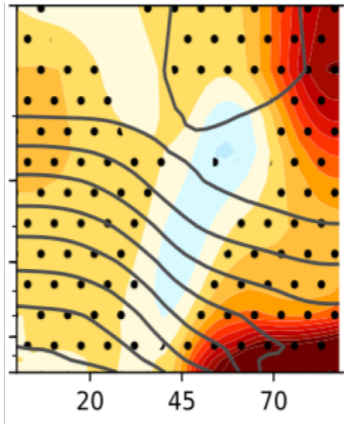




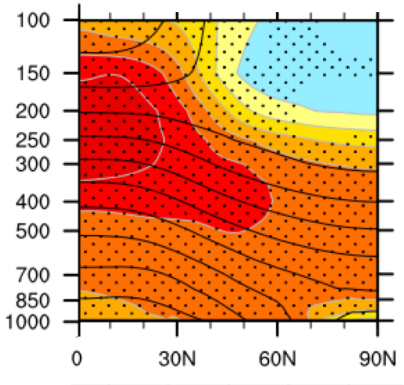
Ice Loss

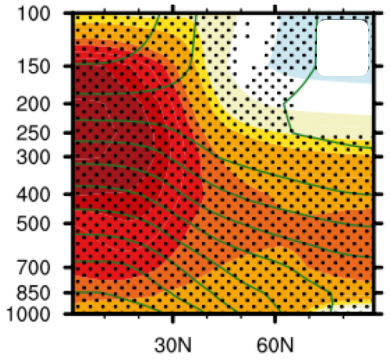


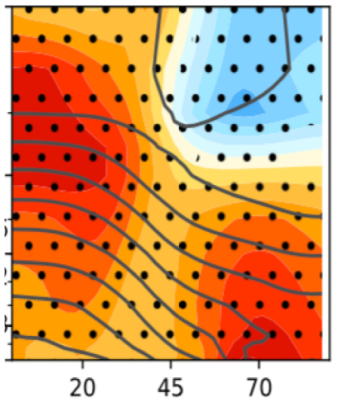




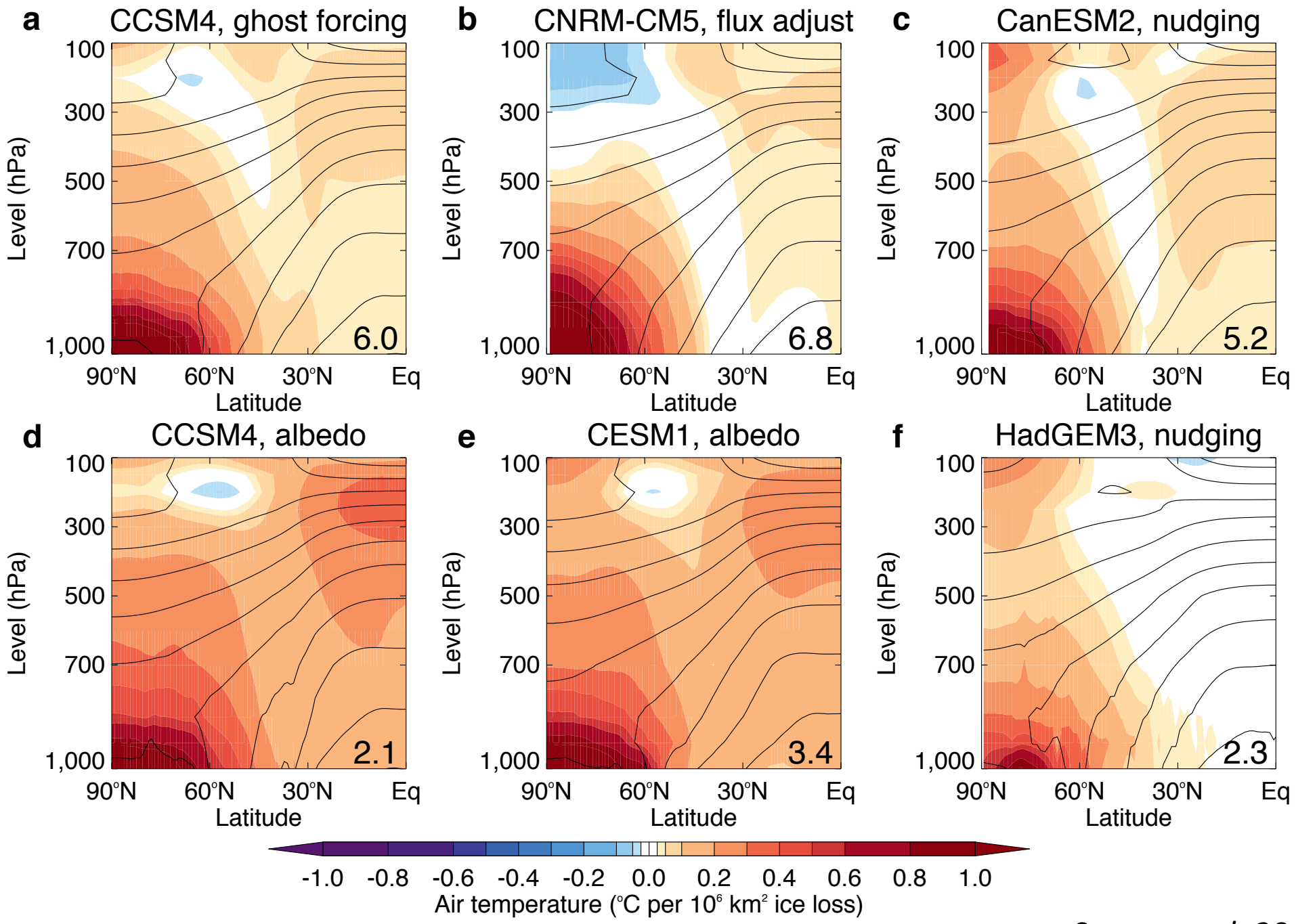
GHG Forcing without Ice Loss







“Consistency & Discrepancy”: Temperature Response to Sea Ice Loss

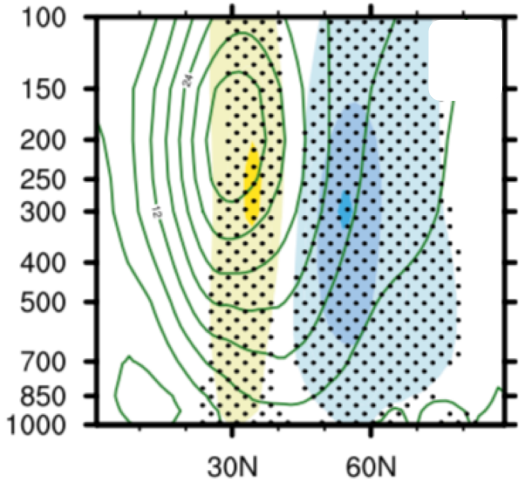


Screen et al. 2018

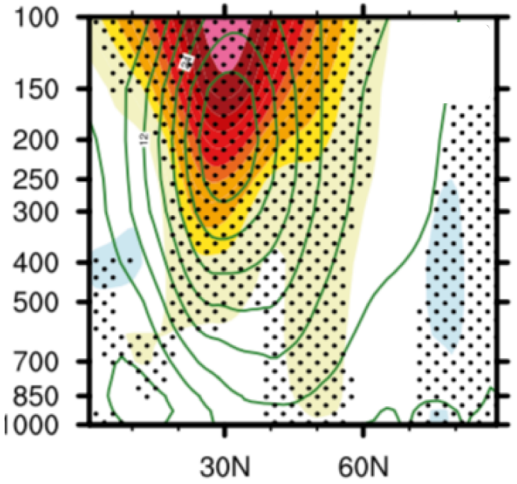
DJF Zonal Mean U Response

- CNRM-GAME
- Oudar et al. 2017

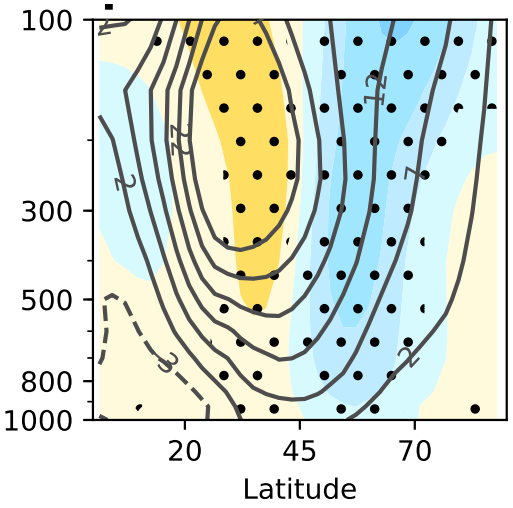
Ice Loss

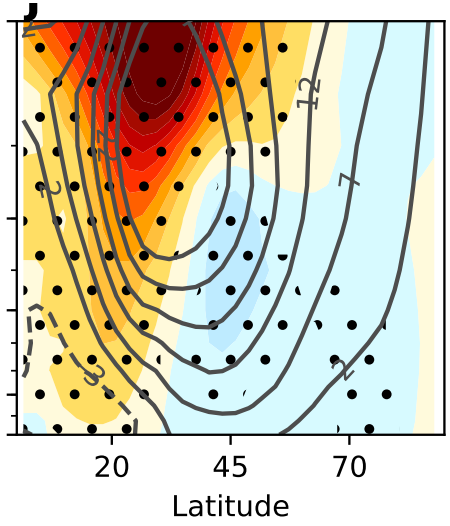


GHG Forcing without Ice Loss



- CanESM2
- McCusker et al. 2017

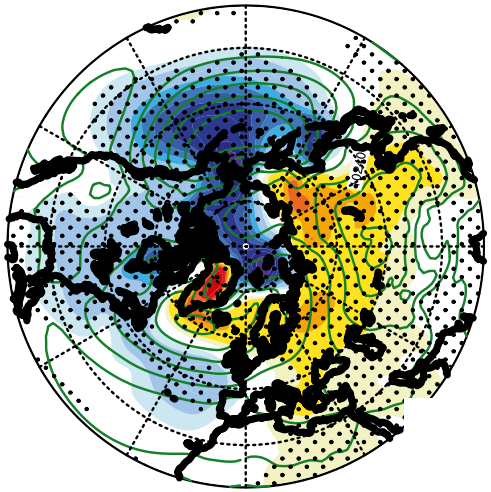




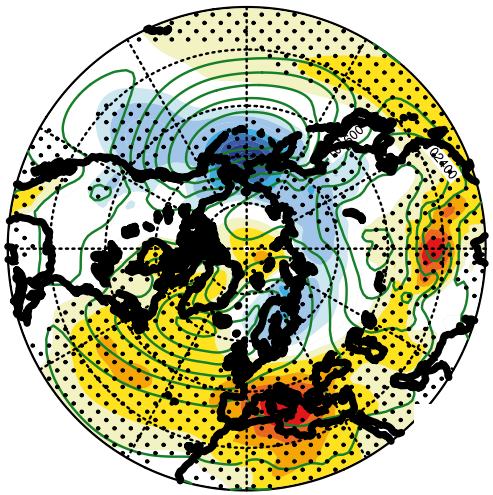
DJF SLP Response

- CNRM-GAME
- Oudar et al. 2017

Ice Loss



GHG Forcing without Ice Loss



- CanESM2
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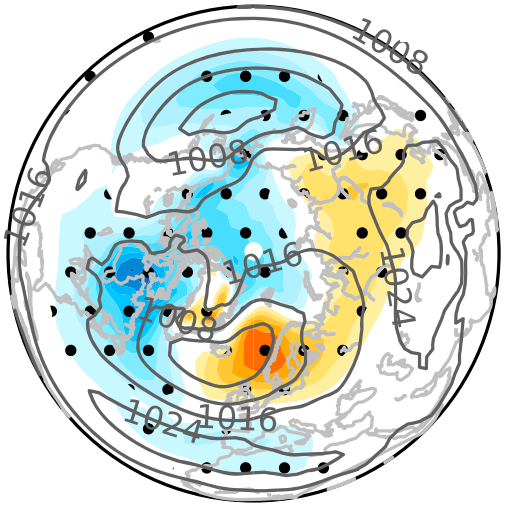
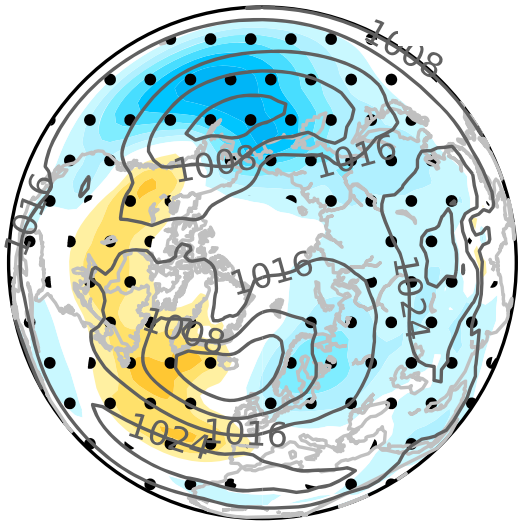
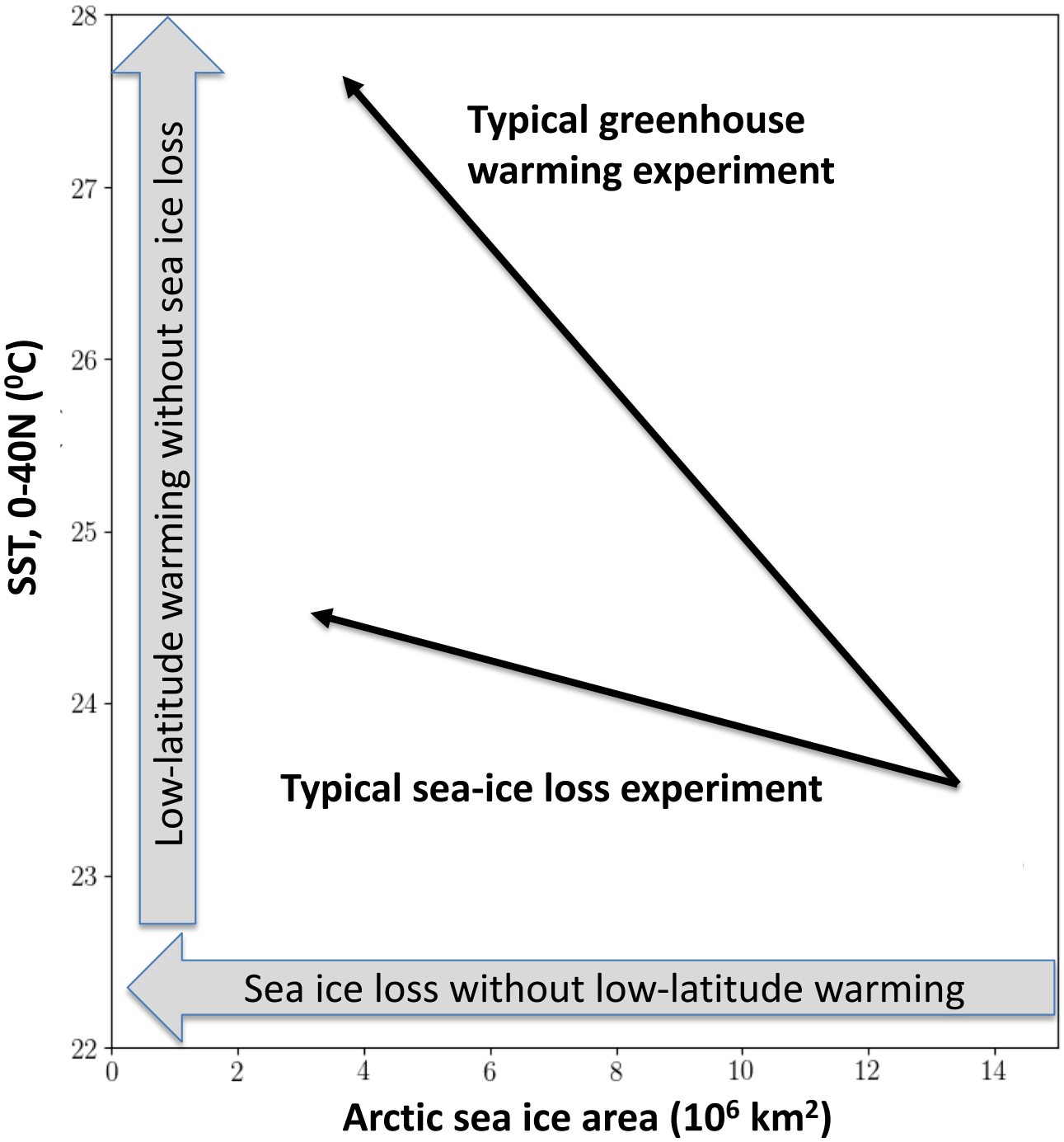




(See Screen et al. 2018 for more ice loss figures)

Arctic and Tropical Change Are Entangled



How can we disentangle them?

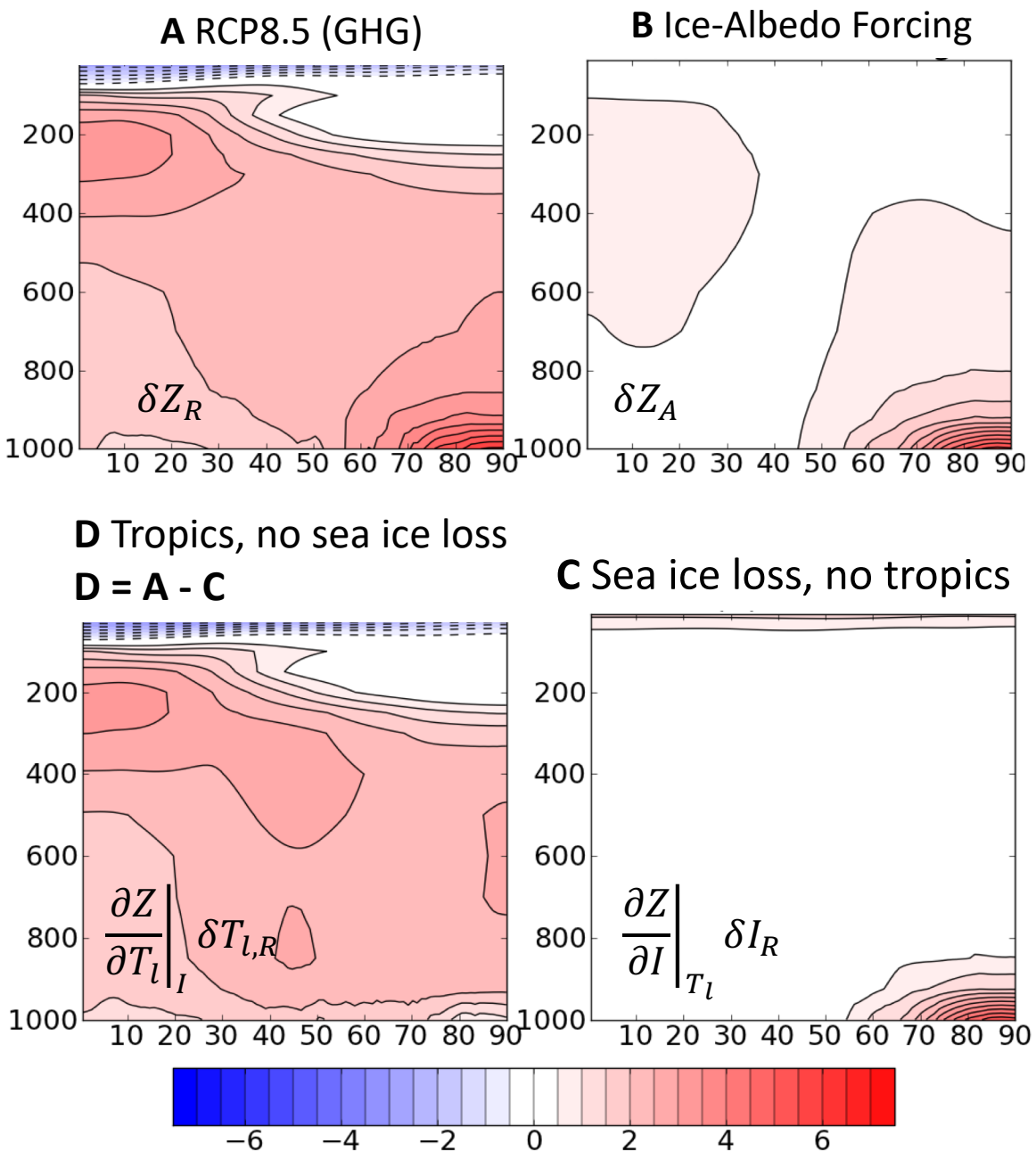
- "Two-parameter pattern scaling" (Blackport and Kushner 2017; Hay et al. submitted and in prep,)

Pattern Scaling for Annual T Response

RHS: from coupled model simulations.

$$\begin{pmatrix} \left.\frac{\partial Z}{\partial T_l}\right|_I \\ \left.\frac{\partial Z}{\partial I}\right|_{T_l} \end{pmatrix} = \begin{pmatrix} \delta T_{l,R} & \delta I_R \\ \delta T_{l.A} & \delta I_A \end{pmatrix}^{-1} \begin{pmatrix} \delta Z_R \\ \delta Z_A \end{pmatrix}$$

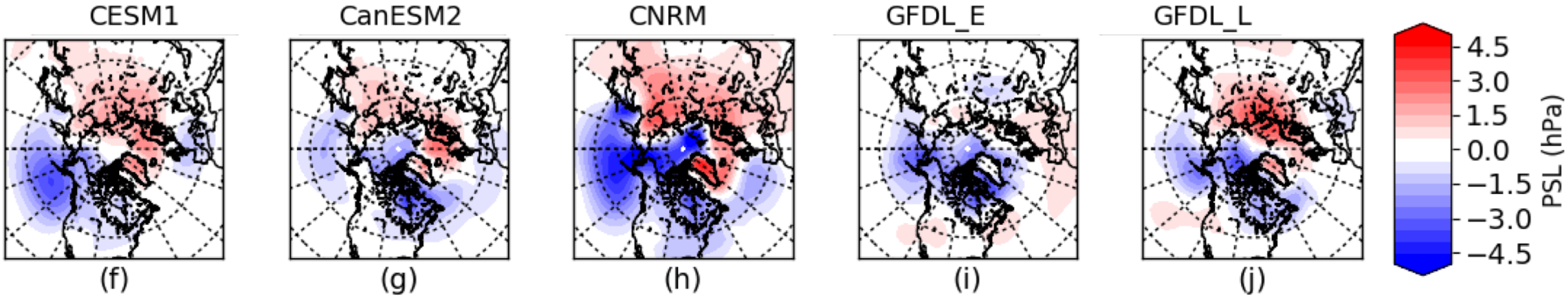
LHS: Diagnosed sensitivity to ice loss or low latitude warming in isolation.



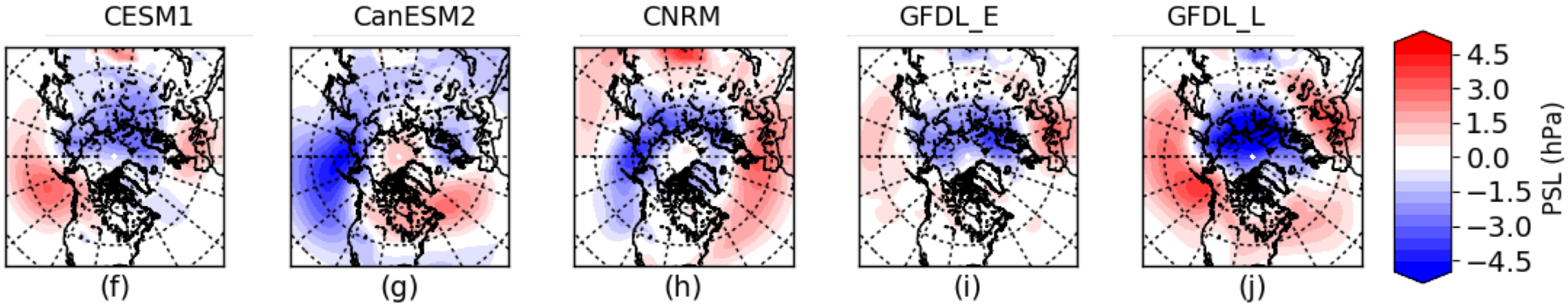
Blackport and Kushner 2017, using CESM1

Pattern Scaling across many Models

Diagnostic: Sea-ice Loss, No Tropics, DJF SLP



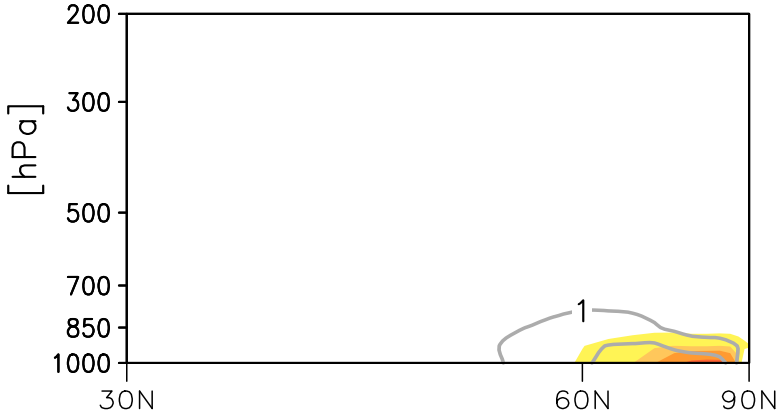
Diagnostic: Tropics, No Sea-Ice Loss, DJF SLP



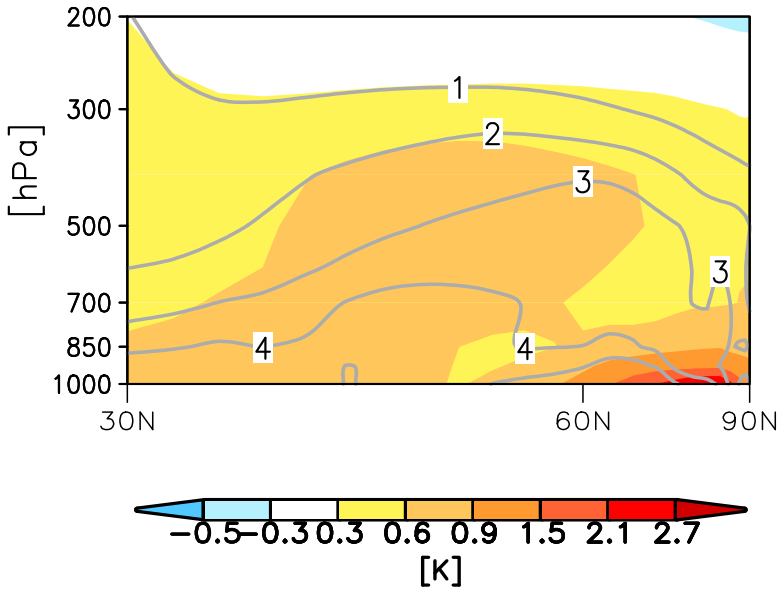
Screen et al. 2018, Hay et al., in review and in prep.

Why Does the Arctic Troposphere Warm?

- Response to Observed Sea Ice Loss, October-December
- AGCM CAM4



- Adding the impact of SST change (warming)

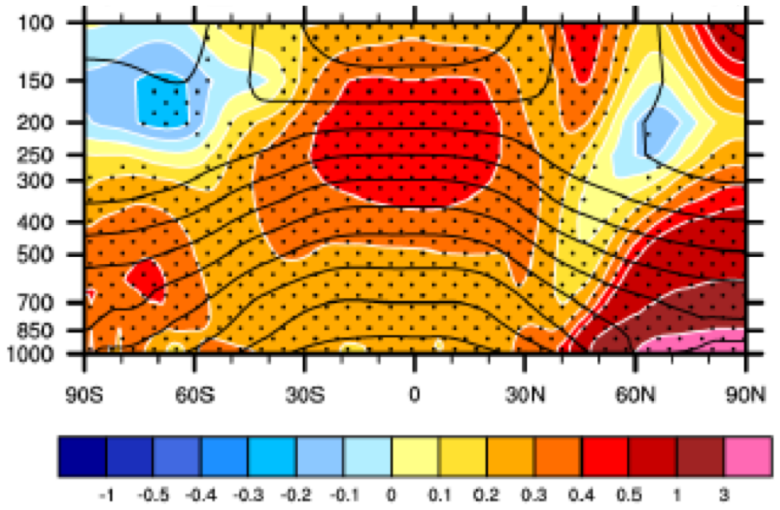


Perlwitz et al. 2015 (also Screen et al. 2012. Deser et al. 2015)

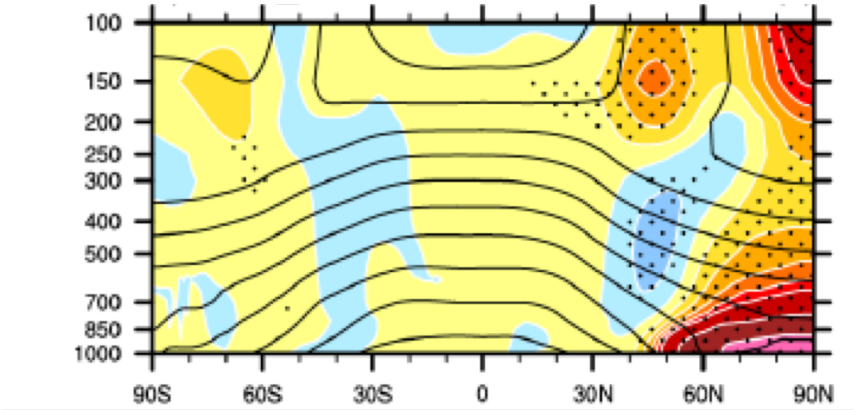
Why do remote SSTs warm the Arctic troposphere?

Why Does the Arctic Troposphere Warm?

- Response to Induced Sea Ice Loss, DJF T
- Coupled CCSM4



- Response to Imposed Sea Ice Loss from the above sea ice.
- AGCM CAM4



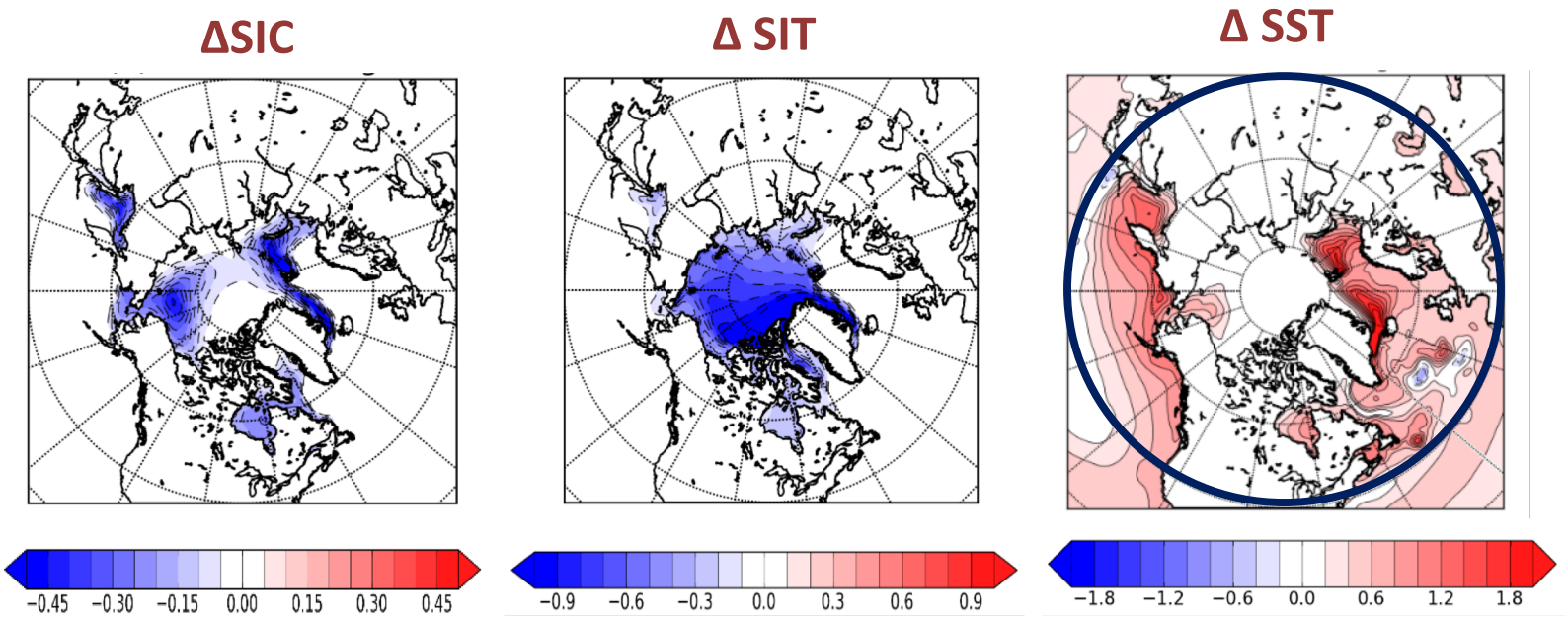
Deser et al. 2015

Why does coupling warm the Arctic troposphere?

Why Does the Arctic Troposphere Warm? Is It ….

- Tropically forced atmospheric responses (e.g. Ding et al. 2014)?
- Tropically forced coupled ocean-atmosphere dynamics (e.g. Tomas et al. 2016)?
- Radiative impacts of poleward advected moisture (e.g. Lee et al. 2017, Caballero et al. 2016)?
- Latent heat release through poleward (and upward) moisture transport (e.g. Skific et al. 2013, Laliberte and Kushner 2013, Caballero et al. 2016, Merlis and Henry in review, Armour et al. in review)?

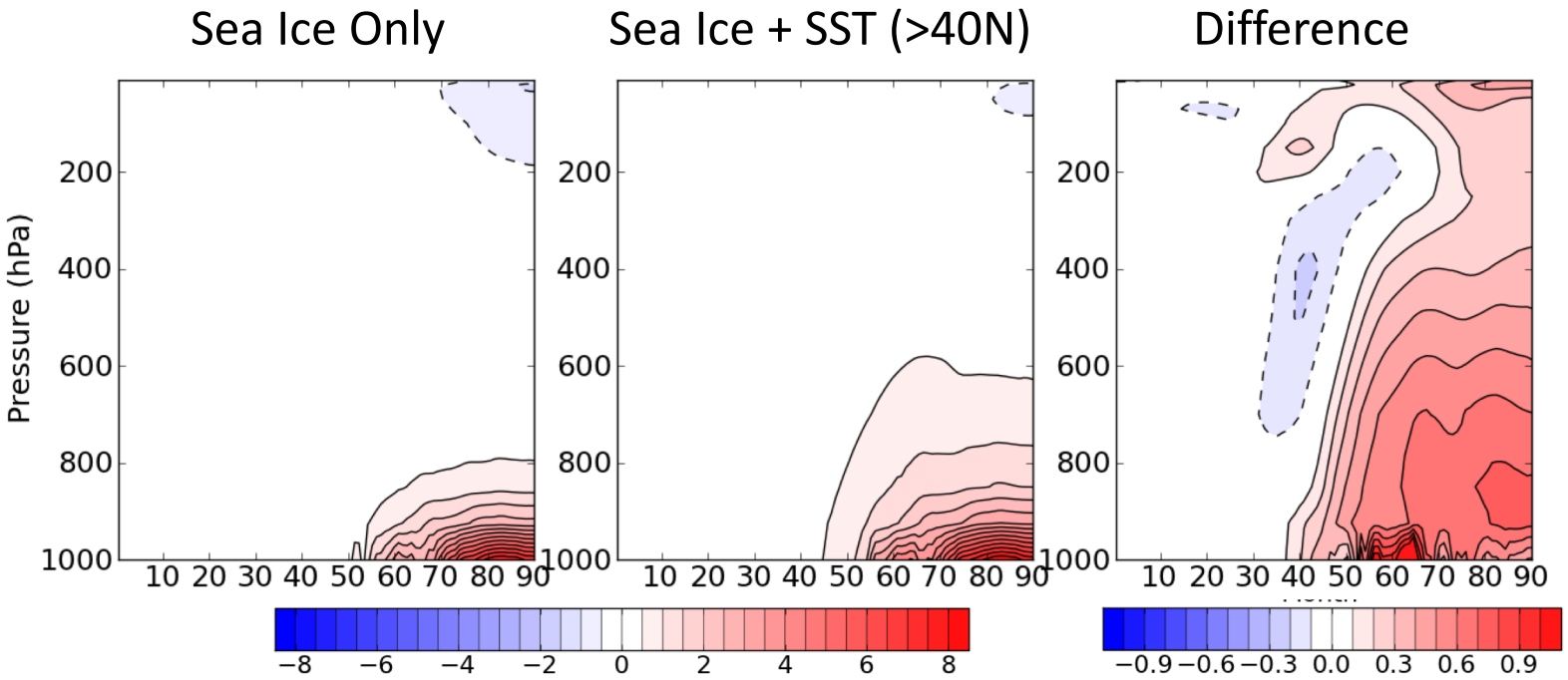
Why Does the Arctic Troposphere Warm? Is it a back effect of sea ice loss?



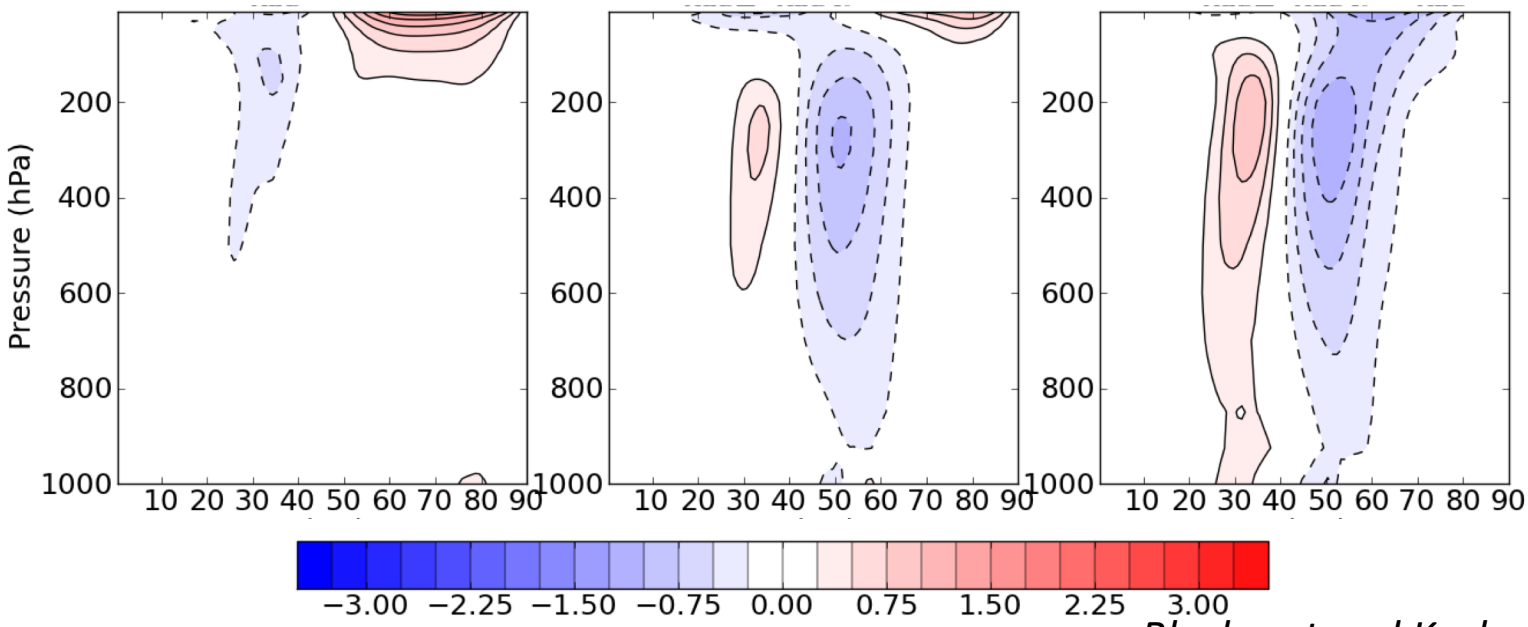
- These are the ice-loss and SST warming patterns from Russell Blackport's sea ice loss simulations.
- What is the impact of the SST warming on the Arctic troposphere?
- Test using AGCM CAM5.

Blackport and Kushner submitted

DJF T Response



DJF U Response



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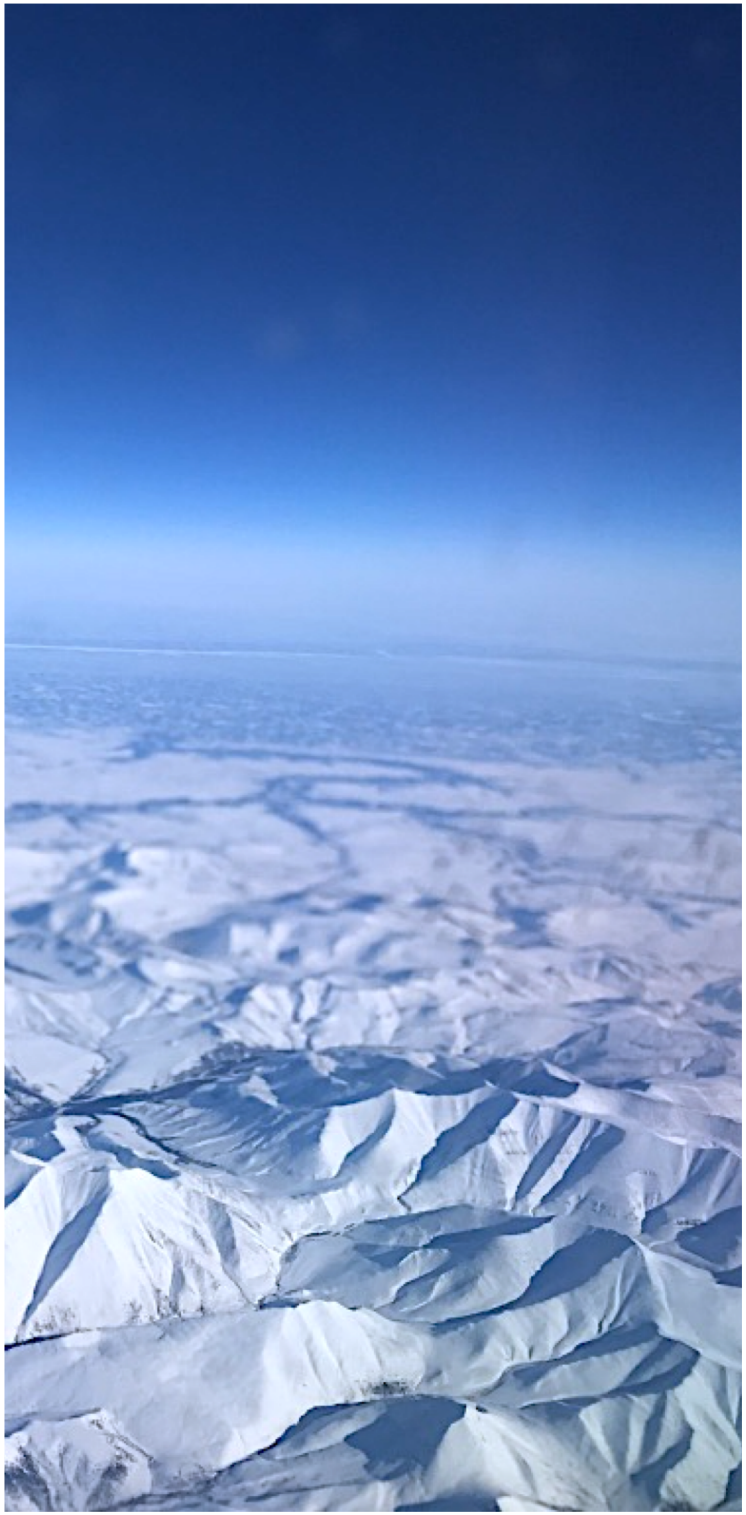

How Do ESMs Simulate Arctic Atmospheric Change?

- We should learn why the response to sea ice loss is more robust than the remainder of the response. In particular, how do coupling and remote SSTs warm the Arctic troposphere?
  - Tropical driving and midlatitude SSTs could play a role.
  - Watch for impact on Arctic lapse rate and on surface warming.
- “This is all models – is this stuff relevant or observable?”
  - Sea ice loss frequently counteracts the circulation response to GHGs (negative feedback, ‘tug of war’).
  - Hard to separate from internal variability.

The Bagel House, Toronto, 4/2018