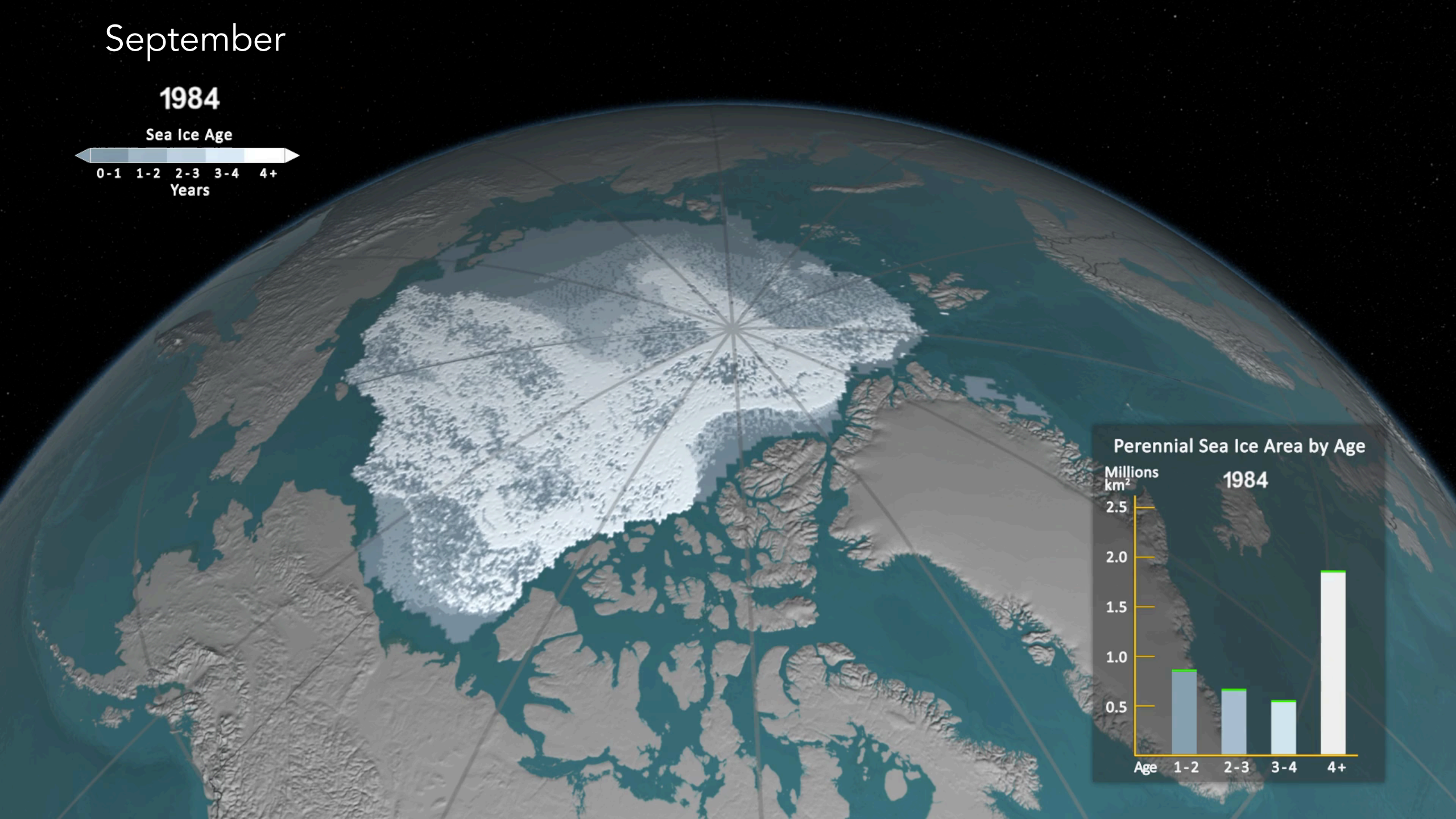
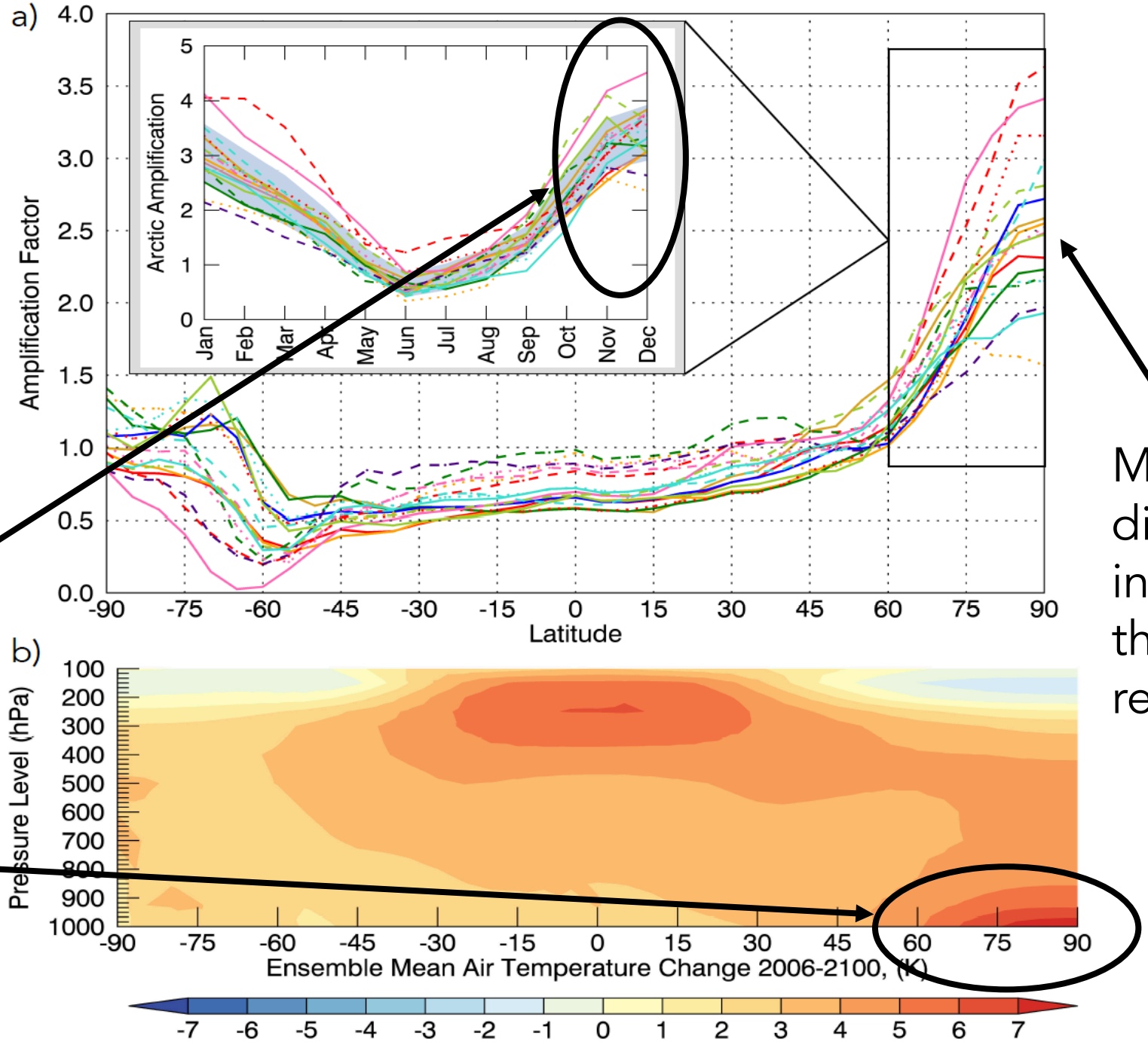
Explaining Arctic Amplification: The Critical Role of the Barents–Kara Seas

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September
1984
Sea Ice Age
0-1 1-2 2-3 3-4 4+
Years
Perennial Sea Ice Area by Age
Millions km²
1984
2.5
2.0
1.5
1.0
0.5
Age 1-2 2-3 3-4 4+

Nature of Arctic Amplification



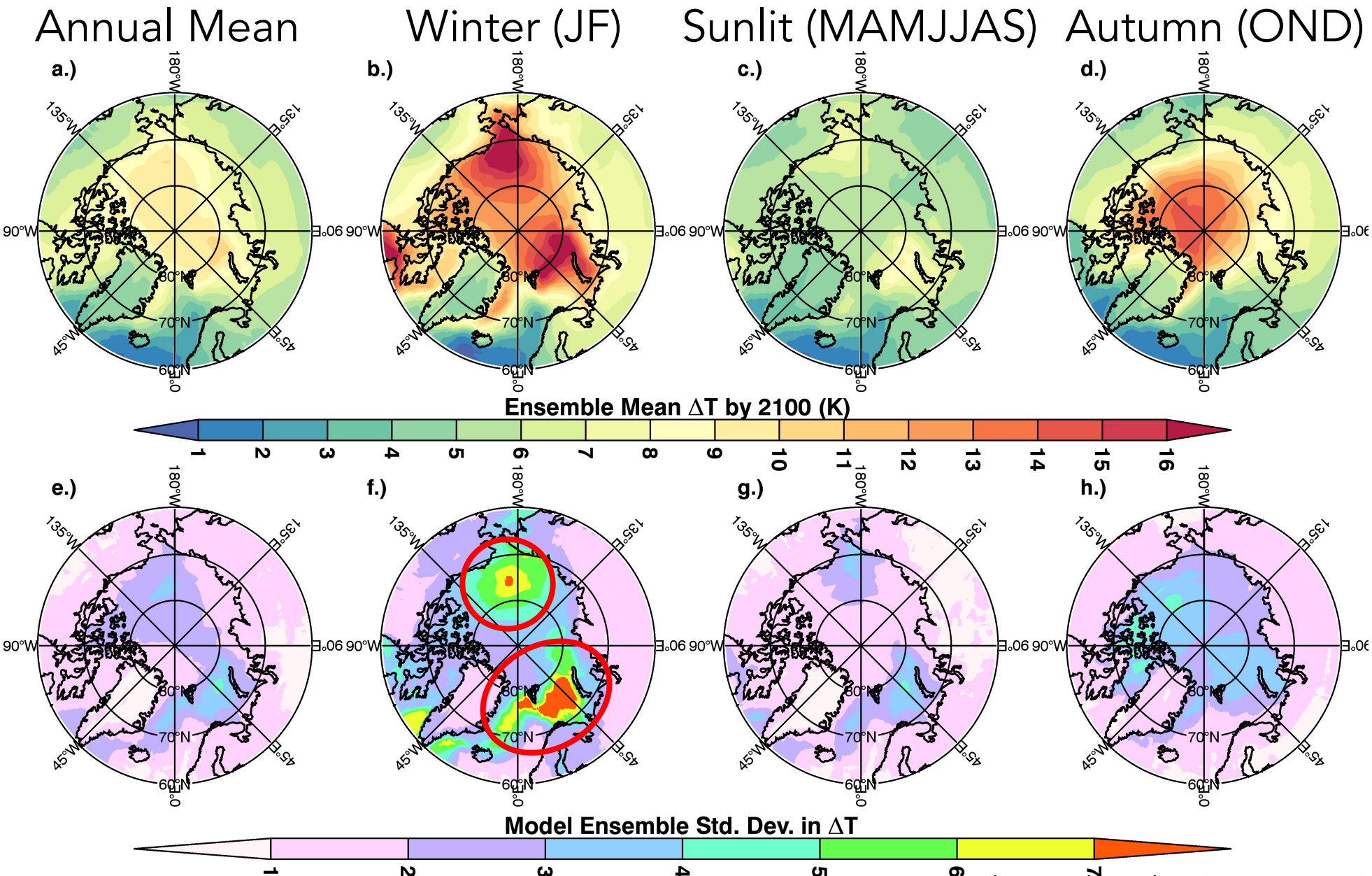
Most warming in fall/winter

Bottom heavy warming profile

More model disagreement in the Arctic than any other region

Where and when do CMIP5 model differ on Arctic warming projections?

Largest differences between CMIP5 models occur in fall and winter in the Barents-Karr Seas and the Chukchi-Beaufort Seas regions.



Boeke and Taylor (in revision)

Method: Surface energy budget decomposition Lu and Cai (2009)

Surface energy budget Eq.:

$$Q = (1-\alpha)S_{sw\ down} + F_{lw\ down} - \varepsilon\sigma T_s^4 - (S+L)$$

Rewriting using clear-sky fluxes and cloud radiative effects and solving for ΔTs

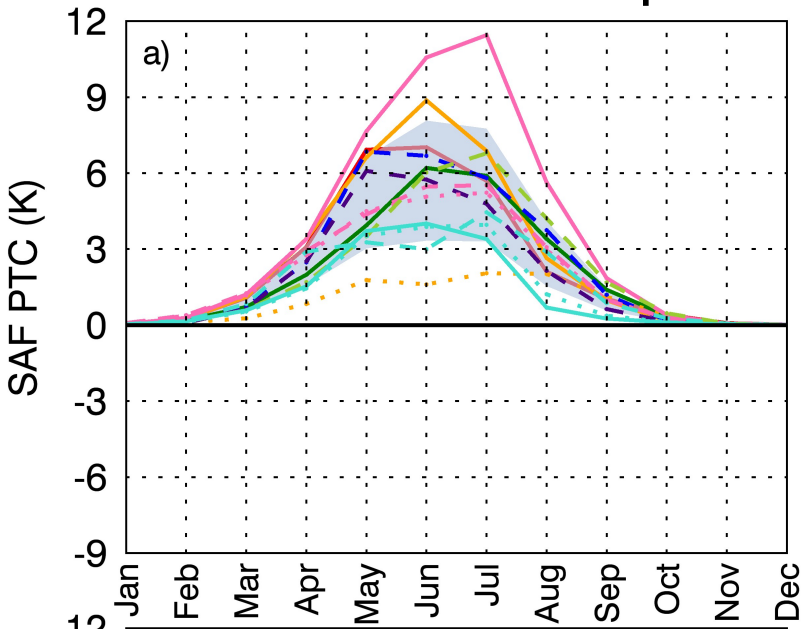
$$\Delta Ts = \text{(the sum of)}$$

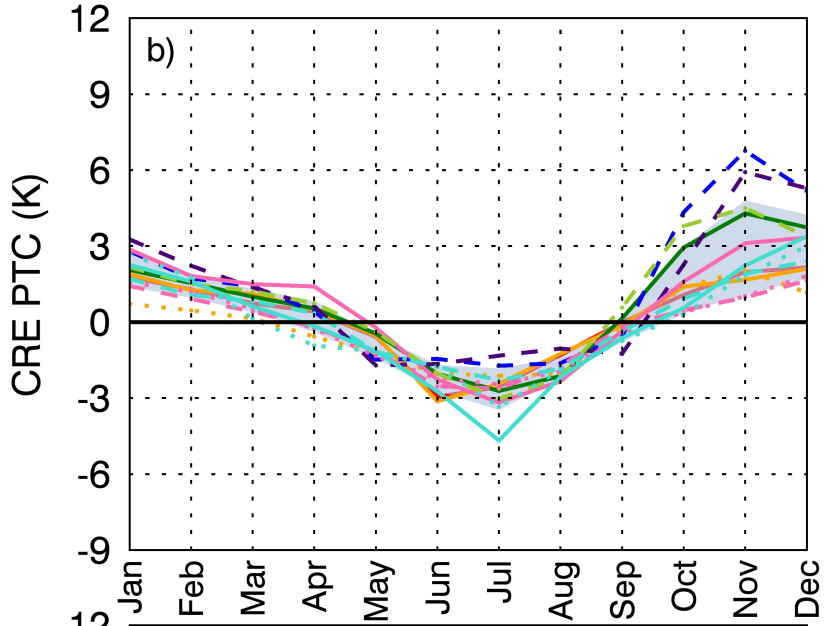
FEEDBACK	PTC	ANNUAL MEAN (K)
Surface Albedo Feedback (SAF)	$\frac{-(\Delta\alpha)(\overline{S\downarrow}+\Delta S\downarrow)}{4\sigma\overline{T_s^3}}$	1.97 ± 0.79
Cloud Forcing (CRE)	$\frac{(1-\alpha)\Delta S\downarrow_{CLD}+\Delta F\downarrow_{CLD})}{4\sigma\overline{T_s^3}}$	0.35 ± 0.78
non-SAF shortwave clear-sky feedbacks	$\frac{(1-\alpha)\Delta S\downarrow_{CLR}}{4\sigma\overline{T_s^3}}$	-0.5 ± 0.28
Longwave clear-sky feedbacks	$\frac{\Delta F\downarrow_{CLR}}{4\sigma\overline{T_s^3}}$	7.12 ± 1.2
Change in ocean heat storage (HSTOR)	$\frac{-\Delta Q}{4\sigma\overline{T_s^3}}$	0.32 ± 1.2
Change in latent and sensible heat fluxes	$\frac{-\Delta(S+L)}{4\sigma\overline{T_s^3}}$	-1.4 ± 0.71

LW clear-sky feedbacks dominate the Arctic warming signal.

Contributions to surface temperature change--Strong seasonality

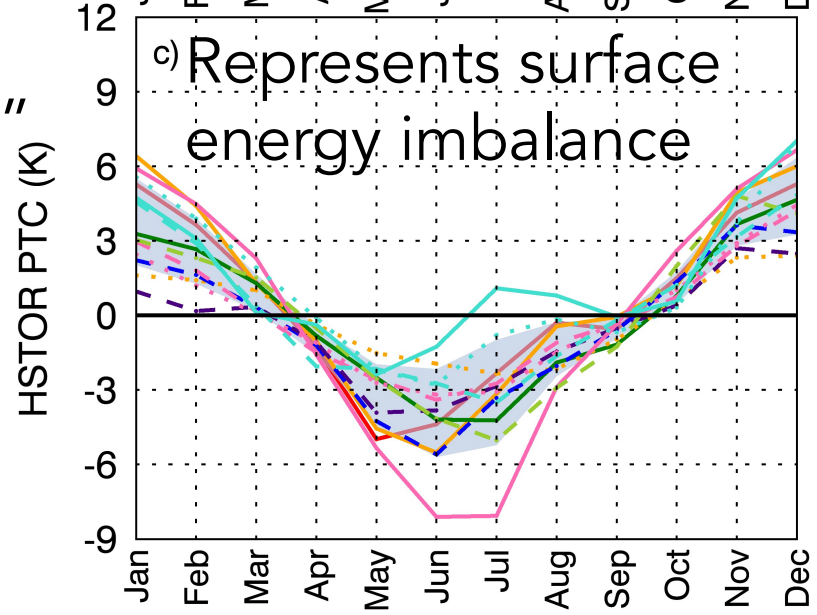
SAF strongly warms surface in summer.

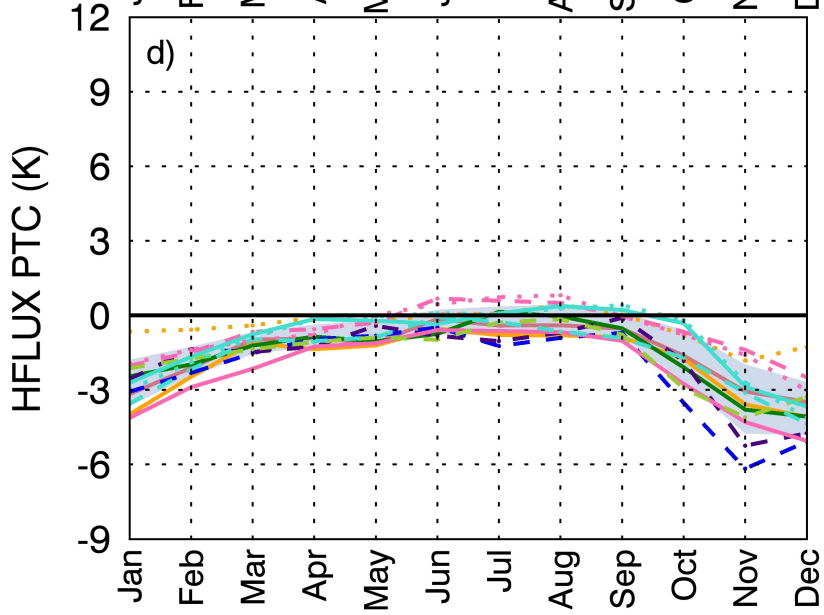




Clouds cool surface in summer and warm in fall/winter.

HSTOR "cools" surface in summer and "warms" surface in summer.



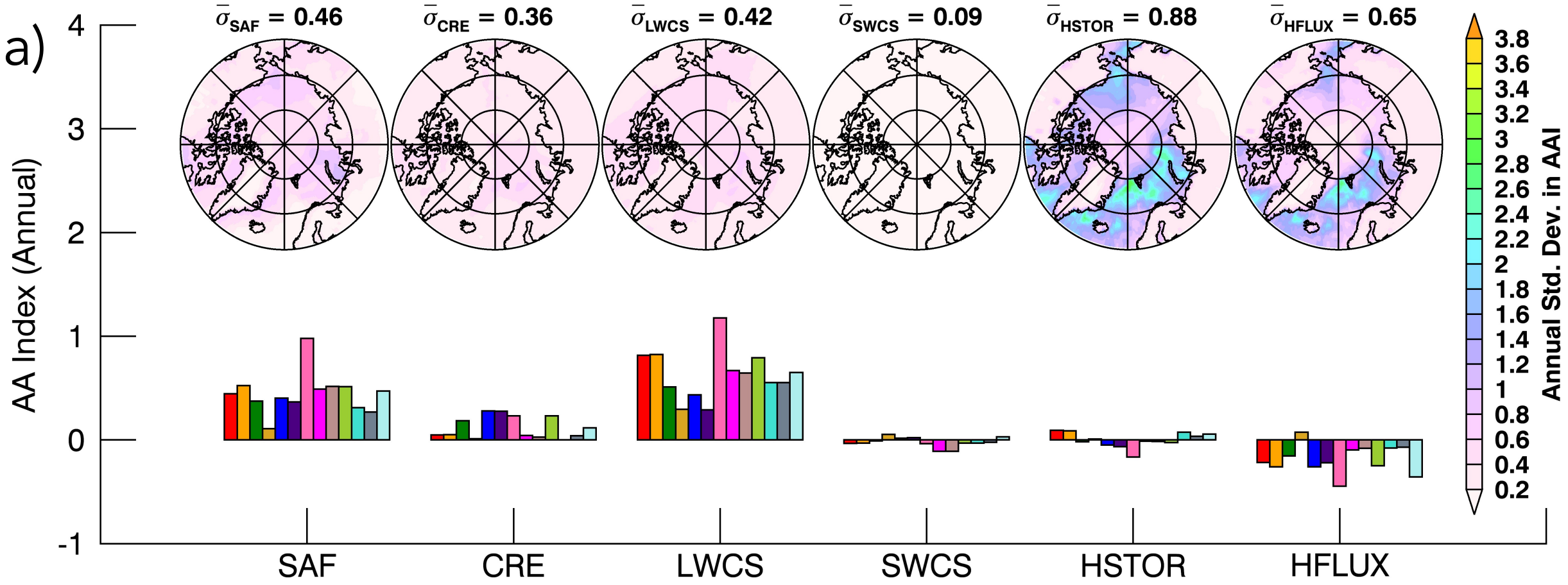


HFLUX show no change in summer and cool surface in fall/winter.

The seasonality of these contributions is amazingly consistent across models.

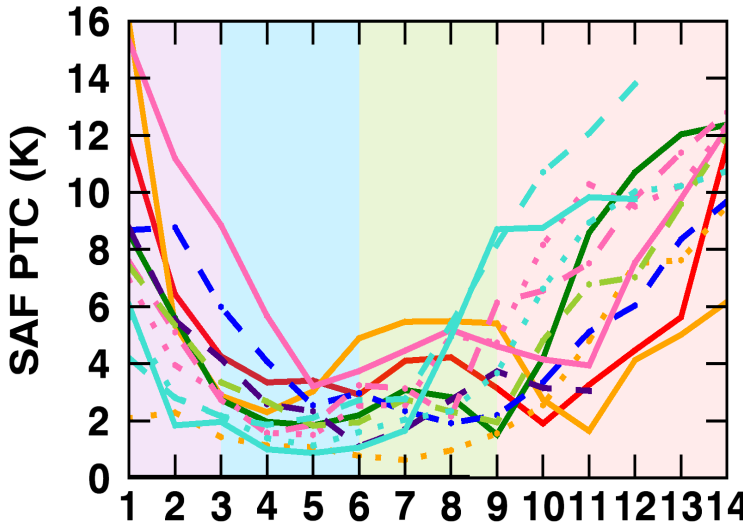
Radiative feedback spread=>spatially uniform

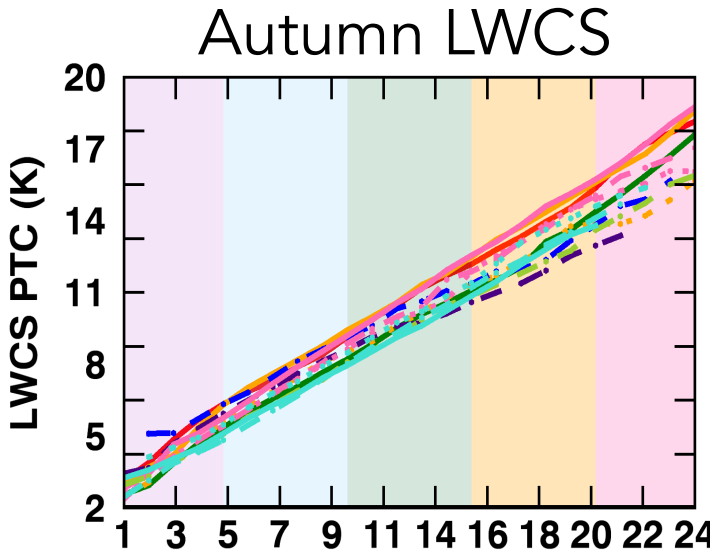
Surface non-radiative feedback spread=> regionally-focused

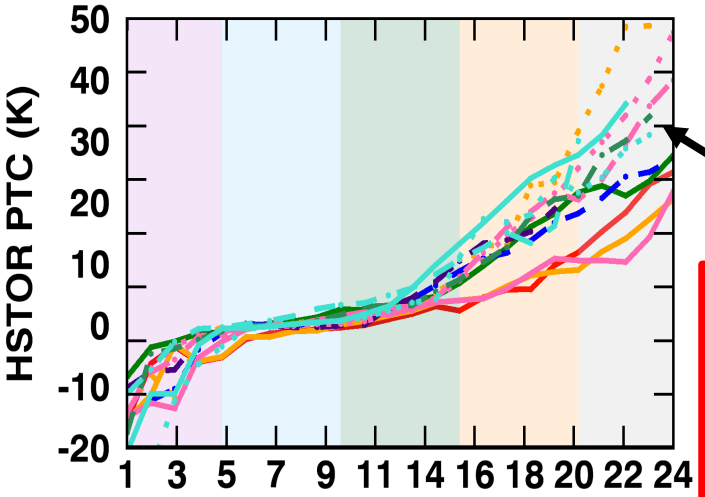


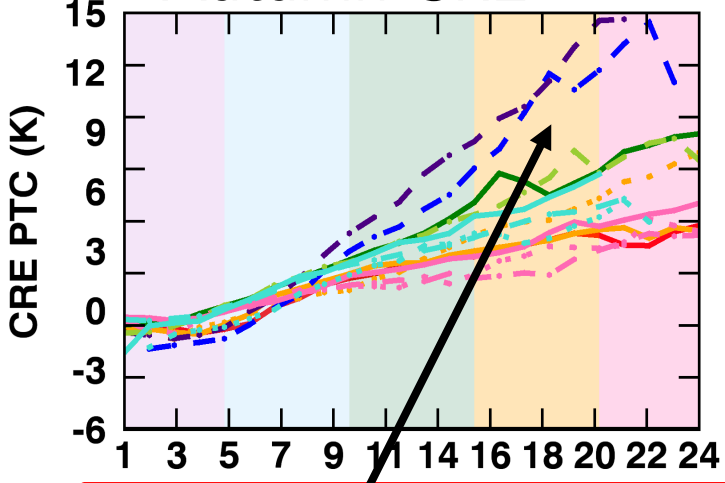
$$AAI_n = \frac{\Delta T_n^{Arctic} - \Delta T_n^{Global}}{\Delta T_{tot}^{Global}}$$

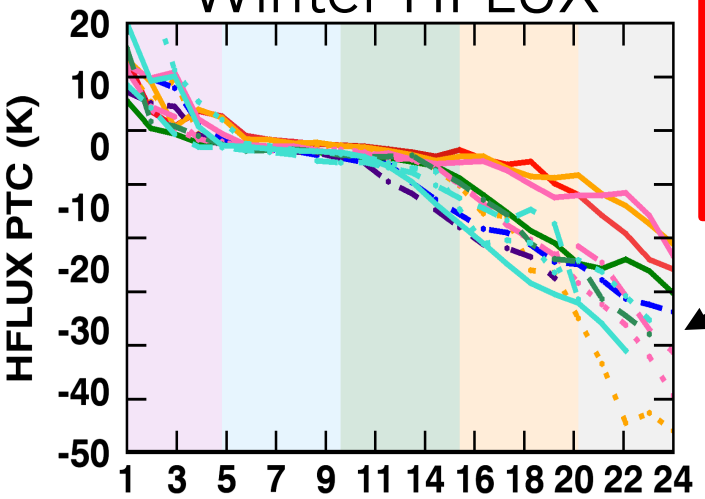
Regions that warm most have the largest feedback contributions…most of the time











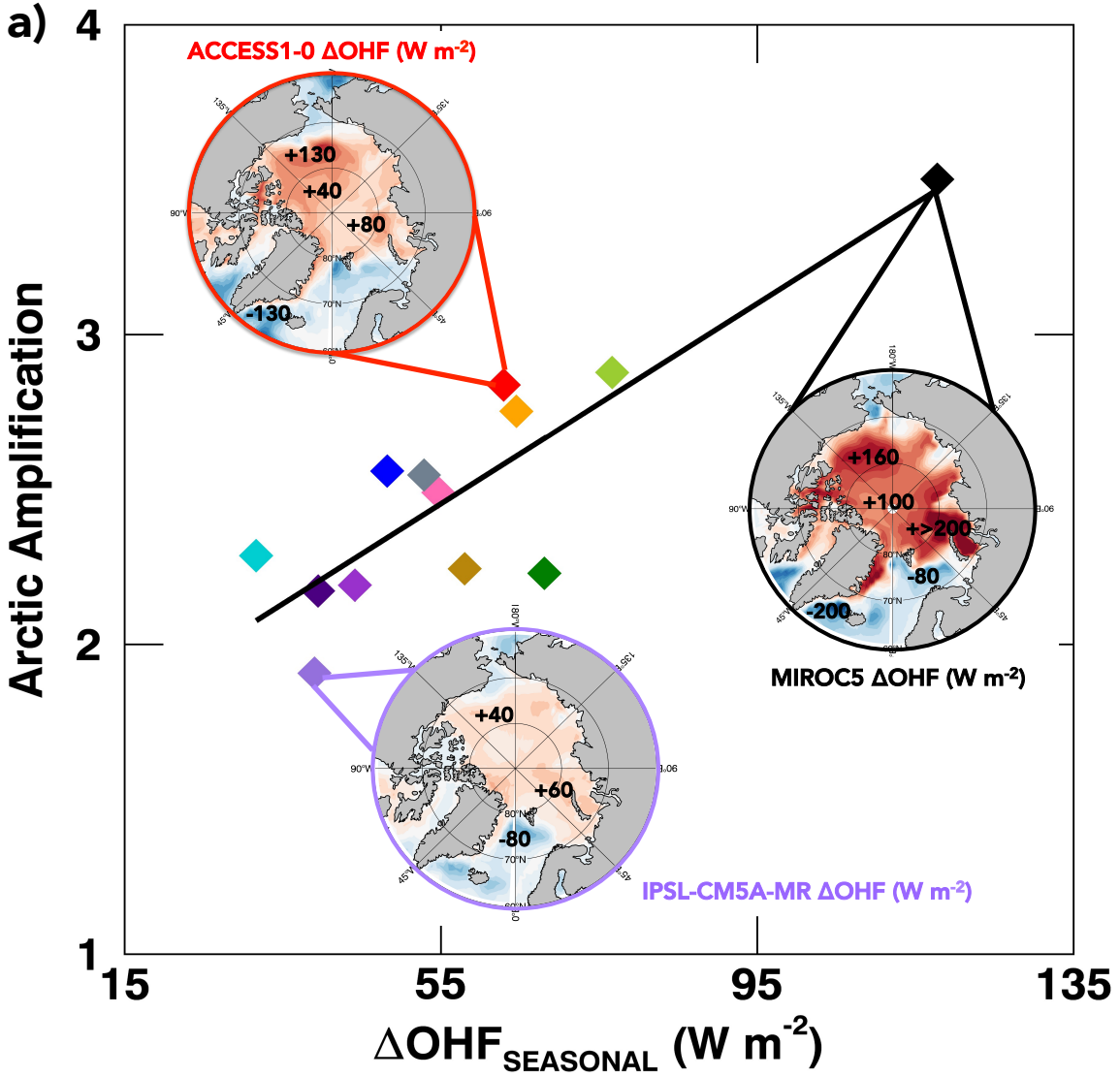
SAF exhibits a U-shape meaning that both regions of small and large warming exhibit a strong feedback.

HSTOR and HFLUX show equal and opposite values.

Two models dominate the spread in cloud feedback

Boeke and Taylor (in revision)

A larger annual cycle ocean heat storage amplitude increase=>larger projected warming



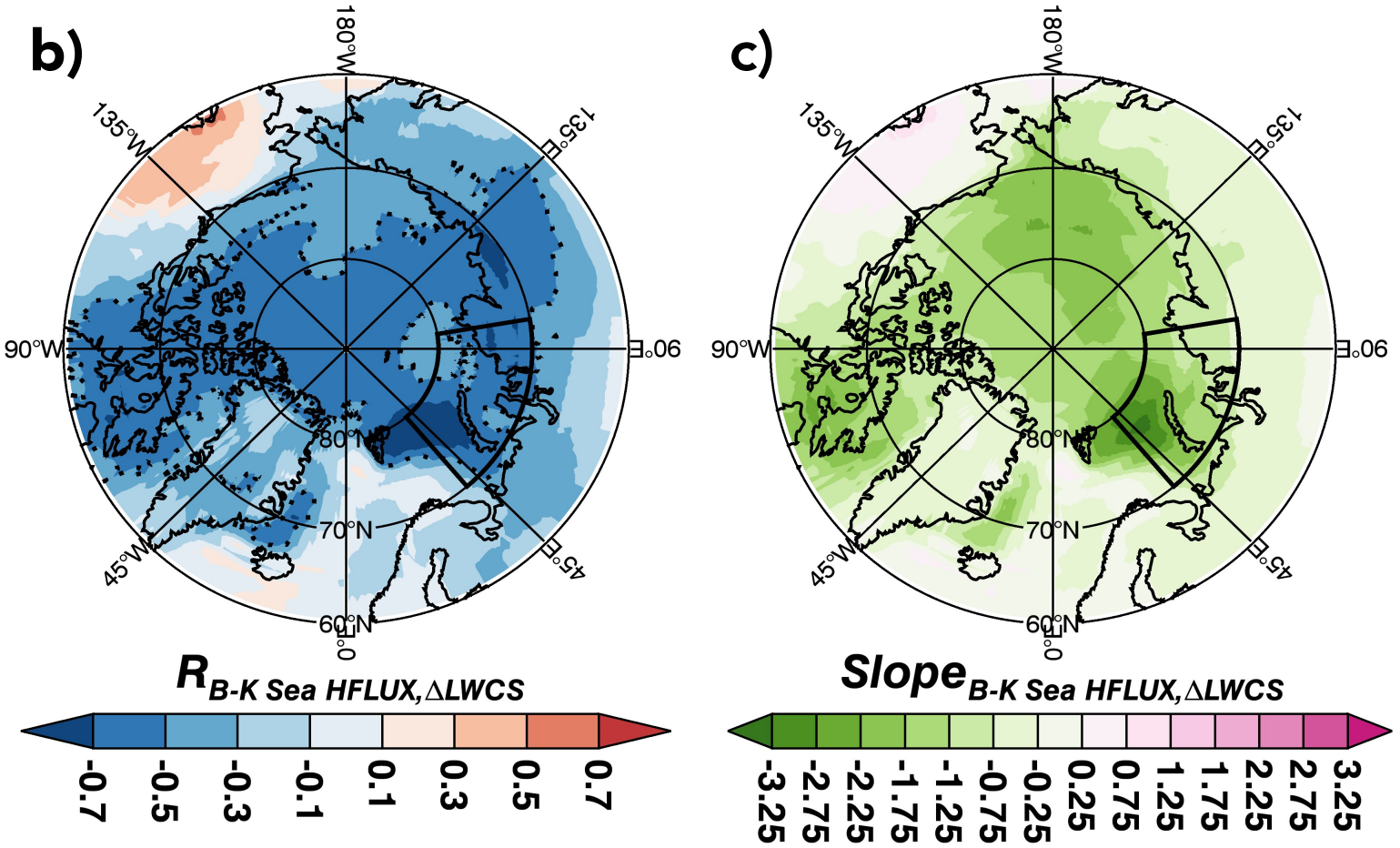
A strong positive correlation is found between the changes in the seasonal amplitude of ocean heat storage and projected Arctic Amplification.

Thus, processes controlling the seasonality of ocean heat storage (upper ocean mixing, absorbed solar radiation,) may hold the key to unraveling inter-model differences in Arctic Amplification.

Summer=>ability to store energy (mixed layer depth, ASR)
Fall/winter=>ability to release energy (surface turbulent fluxes)

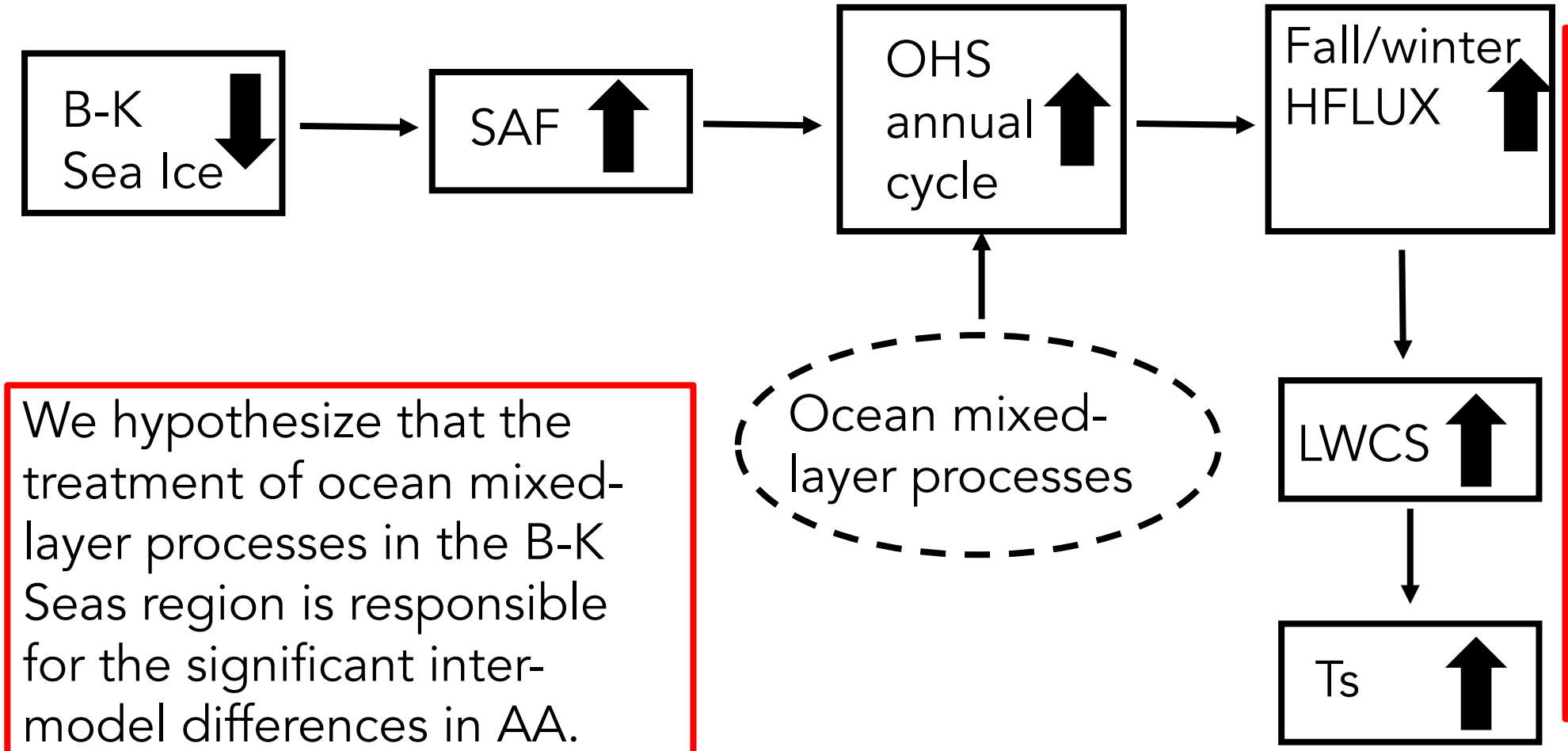
Increased B-K Sea region surface turbulent fluxes have an Arctic-wide impact

Surface turbulent flux changes in the Barents-Kara Seas region show an Arctic-wide impact on LWCS, magnitude of which is strongest locally.



A picture of AA and the inter-model spread

LWCS sets the Arctic-wide magnitude of warming, and explains way all models produce AA. Both models and spatial regions with the largest LWCS increases, warm more.



We hypothesize that the treatment of ocean mixed-layer processes in the B-K Seas region is responsible for the significant inter-model differences in AA.

We hypothesize that the connection between the B-K Seas region and the rest of the Arctic (via LWCS) is controlled by the atmospheric circulation response.

Takeaway messages:

(1) Physical process of Arctic Amplification. Barents-Kara Sea region as a pacemaker of warming.

(2) Do clouds matter to Arctic Amplification and sea ice loss? Yes. However, the most important aspect may not be the direct impact, but rather indirect impacts by modulating other responses (e.g., the circulation response)

(3) What is the way forward? System approaches and multi-disciplinary perspectives.