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**Figure 2: Winter Eurasian surface air temperature (SAT) anomalies.** Histograms and associated probability distributions of winter Eurasian SAT anomalies (2002-12 minus 1979-89) sampled from the CGCM ensemble (gray) and anomalies sampled from the AGCM timeslice ensemble (blue). The red vertical line shows the observed anomaly computed from the GIStemp 1200km smoothed dataset. Gray circles indicate the Eurasian SAT anomalies in the 5 simulations whose Arctic sea ice concentration is used as boundary conditions to the AGCM ensemble. The inset is as the main panel but shows the probability distribution mean (line), 5-95% confidence range on the mean (shading), and 5-95% range of the probability distribution (box).

In order to strengthen the statistics of the results, we add the NAT LE to the ALL LE by first removing its mean, and then adding the ALL mean. We are justified in doing so because the variability in the two ensembles is not statistically significantly different from one another. Likewise, we combine the Average SIC forcing and Individual SIC forcing ensembles for the same reasons.

Eurasian SAT exhibits a forced warming in CGCM, with a large spread due to internal variability, with just @@% showing a Eurasian cooling.

The response of Eurasian SAT to sea-ice loss in isolation has a mean value of approximately 0oC (@@), and again a large spread due to internal variability. There is no evidence of a systematic cooling of Eurasia due to total Arctic sea ice loss.

@@ Even when the boundary conditions are unchanged for 600 years of simulation, Eurasian SAT anomalies show no prevalence toward cool or warm anomalies (Supplementary Figure xx).

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**Figure 3: Winter Barents/Kara 500 hPa geopotential height (Z500) anomalies versus winter Eurasian SAT anomalies.** Ellipses depict the 5-95% confidence range of the relationship between anomalies in Barents/Kara Z500 (m) and associated anomalies in Eurasian SAT (oC) in the CGCM ensemble (dashed) and the AGCM ensemble (solid). Regression lines are shown for the CGCM (dashed) and AGCM (solid) ensembles. Plus markers show the value composited on the 10 smallest sea ice loss anomalies (red) and 10 largest sea ice loss anomalies (blue) in each ensemble. For both CGCM and AGCM, Barents/Kara Z500 composite anomalies are statistically different at the 95% level (@@), but Eurasian SAT composite anomalies are not. The red circle indicates the observed value from ERA-Interim and GIStemp for Z500 and SAT, respectively.

Figure 2 shows that decadal Eurasian SAT can cool or warm in simulations with isolated sea-ice loss, even when boundary conditions are held constant, suggesting that Eurasian SAT anomalies are at the whim of internal variability and not forced by sea ice loss. Indeed, we find a strong relationship between the change in Eurasian SAT and the change in geopotential height at 500 hPa (Z500), which we use as a proxy for circulation, averaged over the Barents/Kara Seas region of the Arctic (Figure 3). High BKS Z500 height anomalies are associated with cold Eurasian SAT anomalies and vice versa. This relationship is consistent with the notion that high geopotential height (or sea level pressure) over areas of sea ice loss in the Barents/Kara Seas is associated with colder Eurasian winters (cite@@). The slopes of the regression lines in CGCM and AGCM are nearly identical, suggesting that the relationship is not a feature of sea ice loss alone. While the relationship is highly significant in both ensembles (p<0.001 @@), the variance explained by the regression is greater in AGCM (r2=0.65 compared with r2=0.17 for CGCM), most likely due to the number of additional forcings at play in CGCM (changes in greenhouse gases, tropospheric aerosols, as well as occasional volcanic eruptions, for example). [@@check relationship in PI.]

The change in Eurasian SAT composited on the bottom 10 BKS sea ice anomalies (“low” relative sea ice concentration) is not significantly different from the change in Eurasian SAT composited on the top 10 BKS sea ice anomalies (“high” relative sea ice concentration) in CGCM (p=@@), providing further support for the lack of influence of BKS SIC on Eurasian SAT. Because AGCM has just 5 different sea ice boundary conditions total, the composite is made up of ten 11-year anomaly periods subsampled from the simulation with the greatest amount of sea ice (“high”) and subsampled from the simulation with the smallest amount of sea ice (“low”). The result is the same as for CGCM; the changes in Eurasian SAT composited on “high” and “low” BKS SIC are not significantly different from one another (p=@@), although “low” BKS SIC does show a colder Eurasian SAT.

Thus, if we think of the relationship between BKS sea ice and Eurasian SAT as a 3 link chain of events starting from a BKS SIC decrease, leading to an increase in BKS Z500, and finally a decrease in Eurasian SAT, we can begin to parse@@

We find a robust relationship between Eurasian SAT and <internally generated fluctuations in> the circulation over the Barents/Kara Seas region of the Arctic in both the CGCM and AGCM (r2=@@, … p=@@ and @@ for CGCM and AGCM regression slopes; Figure 3). High Z500 height anomalies are associated with cold Eurasian SAT anomalies and vice versa. However, while a composite of the top 10 BKS sea ice anomalies (“high” relative sea ice concentration; red plus symbol) versus the bottom 10 BKS sea ice anomalies (“low” relative sea ice concentration; blue plus symbol) does not show a distinct Eurasian SAT change related to the change in Barents/Kara sea ice concentration (p=@@ and p=@@ for the CGCM and AGCM ensembles, respectively), there is a weak relationship with geopotential height overhead. Barents/Kara Z500 anomalies associated with “low” sea ice concentrations are higher than those associated with “high” sea ice concentrations (p=@@ and @@ for the CGCM and AGCM ensembles, respectively). Although the CGCM relationship merely indicates an association of variables with no possibility of separating cause and effect, the interpretation is more straightforward for AGCM because sea ice is prescribed. Here we find that a larger amount of sea ice loss can cause a slight increase in the Z500 anomaly overhead, but this difference is/is not@@ significant.

The observed value of Eurasian SAT, as seen already in Figure 2, is just outside the range of anomalies in the CGCM, which displays a warm bias when compared to other model responses to historical forcing (@@).

The relationship between BKS Z500 and Eurasian SAT has comparable slopes in both of the ensembles presented in Figure 3, indicating it is not a distinct feature of either sea-ice loss or human@@



**Figure 4: Winter composites on Eurasian surface air temperature (Eur SAT), Barents/Kara sea ice concentration (BKS SIC), and Barents/Kara geopotential height at 500 hPa (BKS Z500):** Spatial patterns of change in surface air temperature (shading) and Z500 (contours) in CGCM associated with the a) “low-high” (cold-warm) composite of Eur SAT, b) “low-high” composite of BKS SIC, and c) “high-low” composite of BKS Z500. Z500 contour interval @@@. d-f) show regional average anomalies, indicated on the y-axis, associated with the 3 composites shown in a-c. d) The change in SAT (oC) averaged over Eurasia (35oN – 60oN, 40oE – 120oE) associated with the “low-high” composite of BKS SIC (left column; map shown in a.), and associated with the “high-low” composite of BKS Z500 (right column; map shown in c.) for each of the ensembles (CGCM, Preindustrial, AGCM). e) and f) are as d) but showing the change in SIC in the Barents/Kara Seas (%) and change in Z500 (m) averaged over the Barents/Kara seas, respectively, and only show anomalies for composites on fields other than itself.

We have seen that circulation in the Barents/Kara Seas region is robustly correlated with Eurasian SAT, and that anomalies in Barents/Kara Seas SIC are correlated with the circulation anomalies overhead, with AGCM evidence supporting a causal link from SIC to Z500 (and not the other way round)@@@. Yet, the full chain from Barents/Kara SIC to Eurasian SAT is not supported in these results. To understand the breakdown in this chain of linkages further, we examine the spatial patterns in CGCM of SAT and Z500 associated with composites on the three links in the chain: i. Eurasian SAT, ii. Barents/Kara SIC (BKS SIC), and iii. BKS Z500 (Figure 4a-c). Figure 4a shows the “low” (cold) Eurasian SAT composite minus the “high” (warm) Eurasian SAT composite@@@@

Thus, BKS sea ice loss is correlated with a high height anomaly overhead, consistent with previous work (cite@@), however notably, there is no change in SAT over Eurasia associated with the sea ice loss. Compositing on Eurasian SAT instead (Figure 4b) shows that the circulation associated with a cold Eurasia does include high height anomalies over the Barents/Kara Seas, however the structure is distinct from that of Figure 4a, particularly across the GIN Seas and Greenland. Furthermore, the gradient of geopotential height anomalies associated with a cold Eurasia is much stronger and better oriented to induce advection of cold polar air south and west across the continent. This pattern is also found in the AGCM and Preindustrial ensembles (Supplementary Figure xx), suggesting that it is not a feature of anthropogenic forcing.

In CGCM, the BKS sea ice anomaly associated with the cold Eurasian SAT composite in Figure 4b is in fact positive (Figure 4d, middle column), which suggests that cold Eurasian temperatures occur during more widespread cool events that also produce an increase in sea ice area. Similarly, neither Preindustrial nor AGCM ensembles have a statistically significant decrease in BKS SIC associated with cold Eurasian SAT.

% These patterns are similar to those computed from AGCM and Preindustrial composites (Supplementary Figure xx). Figure 4a shows the “low” BKS SIC composite minus the “high” BKS SIC composite (see plus symbols in Figure 3). Associated with sea ice loss in the Barents/Kara are increased SATs in the region, extending west to Greenland, and a local increase in geopotential height aloft, although it is not significant (@@: Supplementary Figure xx).