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Supplement of

Determining TTOP model parameter importance and overall performance across northern Canada

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Supplemental Data and Information

S1 Temperature Extrapolation

To support our comparison of the monitoring depth temperature directly to the TTOP model temperature at sites where the TTOP model depth does not equal the monitoring depth (159 out of 612 observations), we calculated active layer thickness (or seasonal frost depth) and extrapolated the monitoring temperature to this depth. For sites with permafrost, active layer thickness was calculated following equation S1 and Riseborough (2003) where TDD is the thawing degree days at the monitoring depth (g) and ground surface (s), D is the monitoring depth, and X is the active layer thickness.

$$\sqrt{\frac{TDD_g}{TDD_s}} = 1 - \frac{D}{X} \qquad \text{Eq S1}$$

For sites assumed to be seasonal frost (more thawing degree days than freezing degree days at the observation depth) freezing degree days (FDD) replaced TDD at the monitoring depth and ground surface. To determine temperature at the top of the frost table (or seasonal freezing depth) temperature observations were plotted against depth for each site. A logarithmic trendline was then added and the accompanying equation was used to calculate temperature at the top of the frost table (or seasonal frost depth).

When compared to the observed temperatures the extrapolated values differed by 0.2 ºC on average. The maximum discrepancy was 2.0 °C, however subsequent observations at this site yielded differences of 0.1 °C on average. It is likely then that the large difference is not representative.

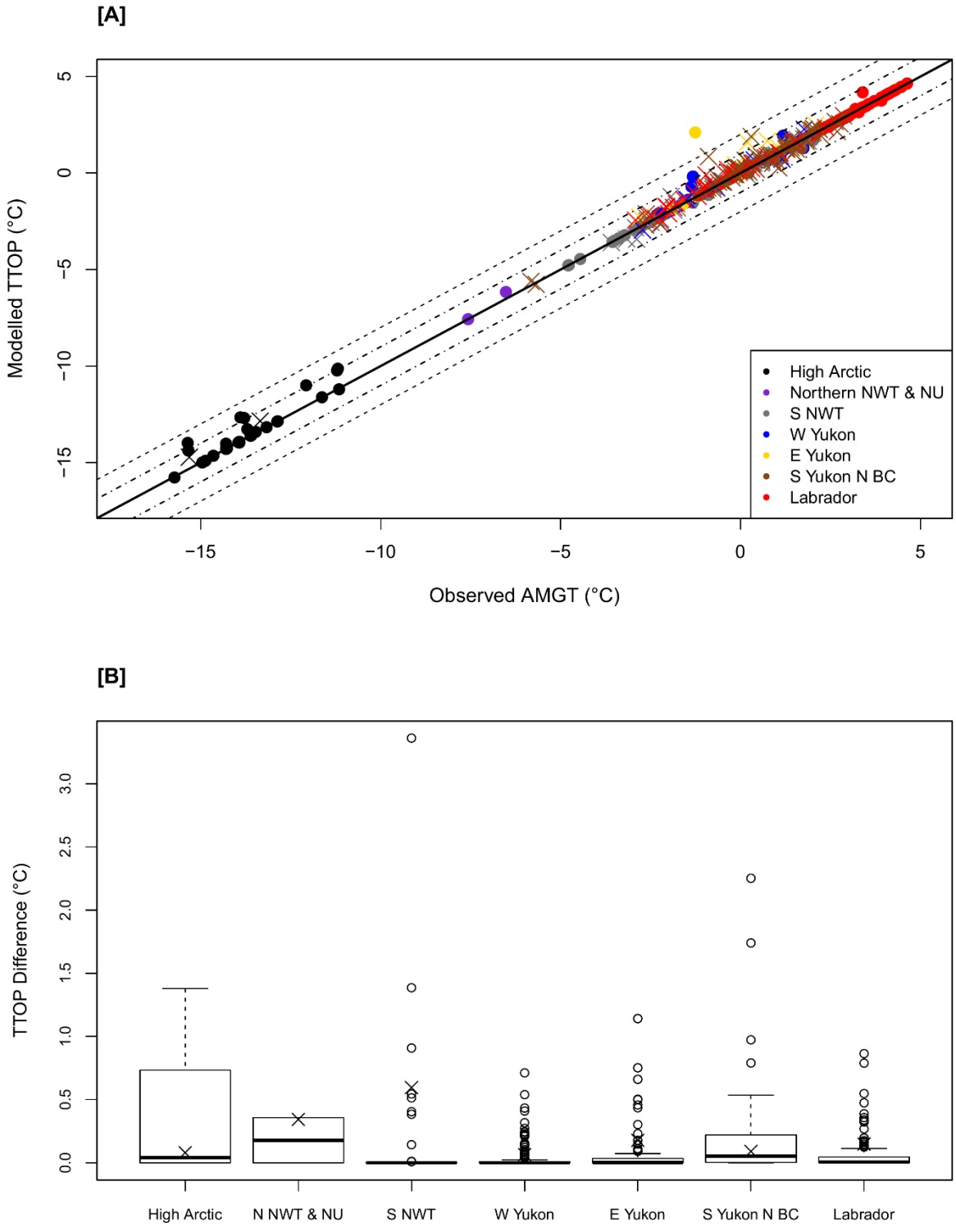

Figure S1. A) Comparison of TTOP model outputs to the measured annual mean ground temperature (AMGT) and **B)** boxplots for the absolute difference between the modelled TTOP and the measured AMGT close to the frost table across the entire study area and for individual regions. The solid line in panel A is the 1:1 relation between modelled and observed while the dashed lines indicate 1 and 2 ºC differences.

Comparing the extrapolated temperatures to TTOP model output resulted in an RMSE of 0.3 ºC compared to 0.2 ºC when comparing the observed AMGT to the TTOP model output. Figure S1 is a reproduced version of Figure 2 from the manuscript using the extrapolated temperatures instead of the observed values compared to the TTOP model output. Additionally, the number of TTOP model misclassified sites increased from 3 to 13 instances (3 in common) with one in the Western Yukon region, one in the Southern NWT, and 11 in the Southern Yukon Northern BC. Of the 13 misclassifications, 3 were false positive (TTOP model predicted permafrost when none was observed) and 10 were false negatives.

Since there was limited difference when using the observed AMGT and the extrapolated temperature. We decided to use the observed temperature directly due to the potential errors in the active layer thickness modelling and the temperature extrapolation with depth as only two temperatures (surface and ground at depth) were measured at most of the sites. Additionally, the number of sites where permafrost presence or absence was misclassified (3 or 13) was small compared to the sample size (612).

S2 Summary of input parameters

Table S1. Average value for each parameter divided by region. Values within a row followed by the same letter are not significantly different at $P \leq 0.05$.

	High Arctic	N NWT	S NWT	W Yukon	E Yukon	S Yukon N BC	Labrador
FDD_a (°C-days)	5823	4335	3210	2912	2697	2123	2316
TDD_a (°C-days)	300	1154^{a}	1911	1452^{b}	1204^{a}	1211^{a}	1516^{b}
n_f	0.83	0.36^{ac}	0.21^{b}	0.36^{ad}	0.32^{a}	0.40^{cd}	0.17^{b}
n_t	1.45	0.61^{a}	0.65^{a}	0.77^{b}	0.82^{bc}	0.91^{d}	0.88^{cd}
rk	0.81^{abc}	0.73^{bd}	0.65^{d}	0.87^{ce}	0.92^{e}	0.93^{e}	0.87^{ae}
TTOP (°C)	-12.3	-2.8	0.4^{a}	-0.2^{b}	0.12^{ab}	0.4^{a}	2.1

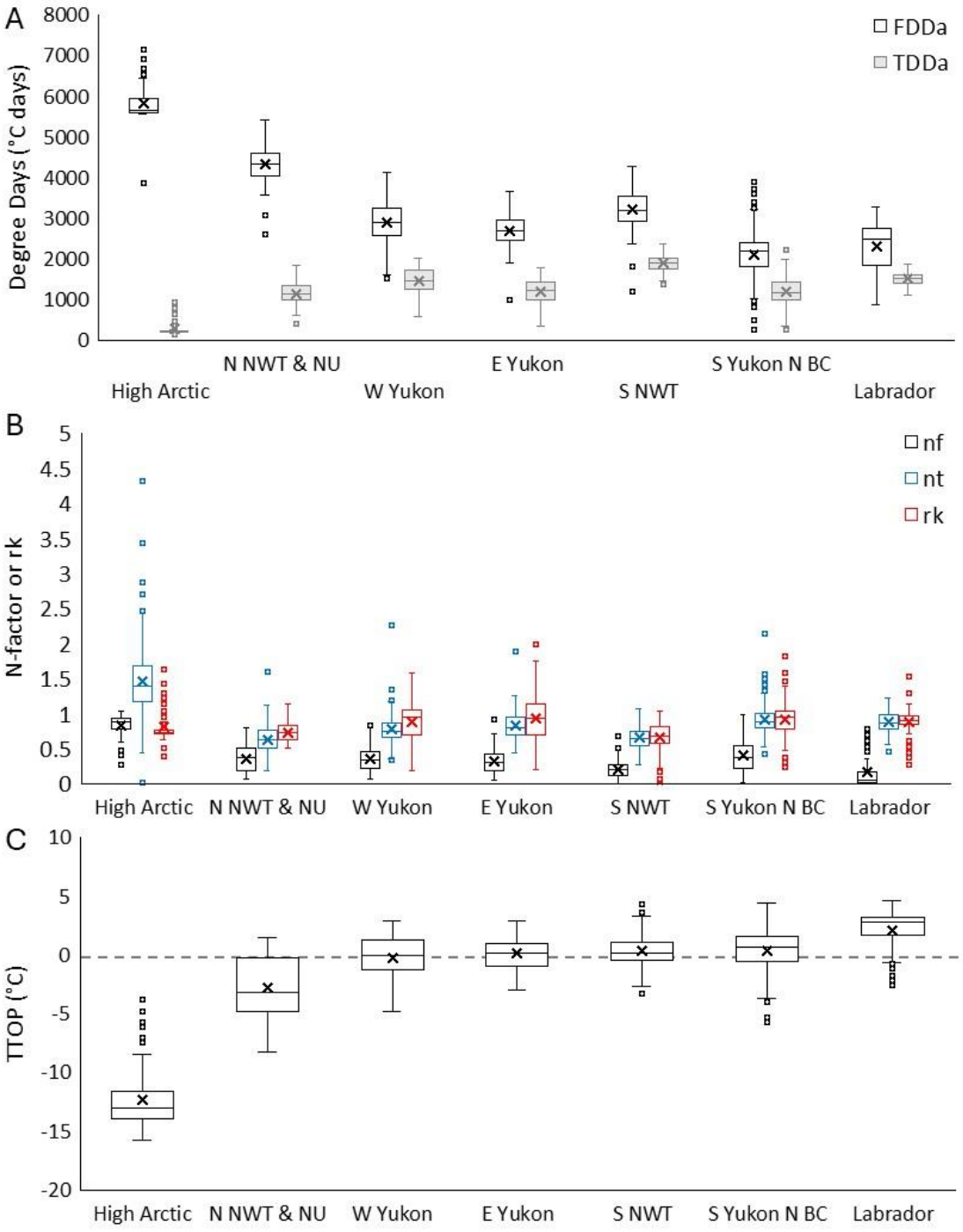

Figure S2. Boxplots for **A)** FDD_a and TDD_a, **B)** n_f, n_t, and rk and **C)** TTOP overall and for individual regions. Mean values are represented by an X. For some regions, maximum and minimum are shown by the ends of the whiskers. However, for some regions outliers are shown as circles after the whiskers and the ends of the whiskers instead show the value for one and a half times the interquartile range. The ends of the box show the first (25 percent) and third (75 percent) quartiles and the black line within the box shows the median.

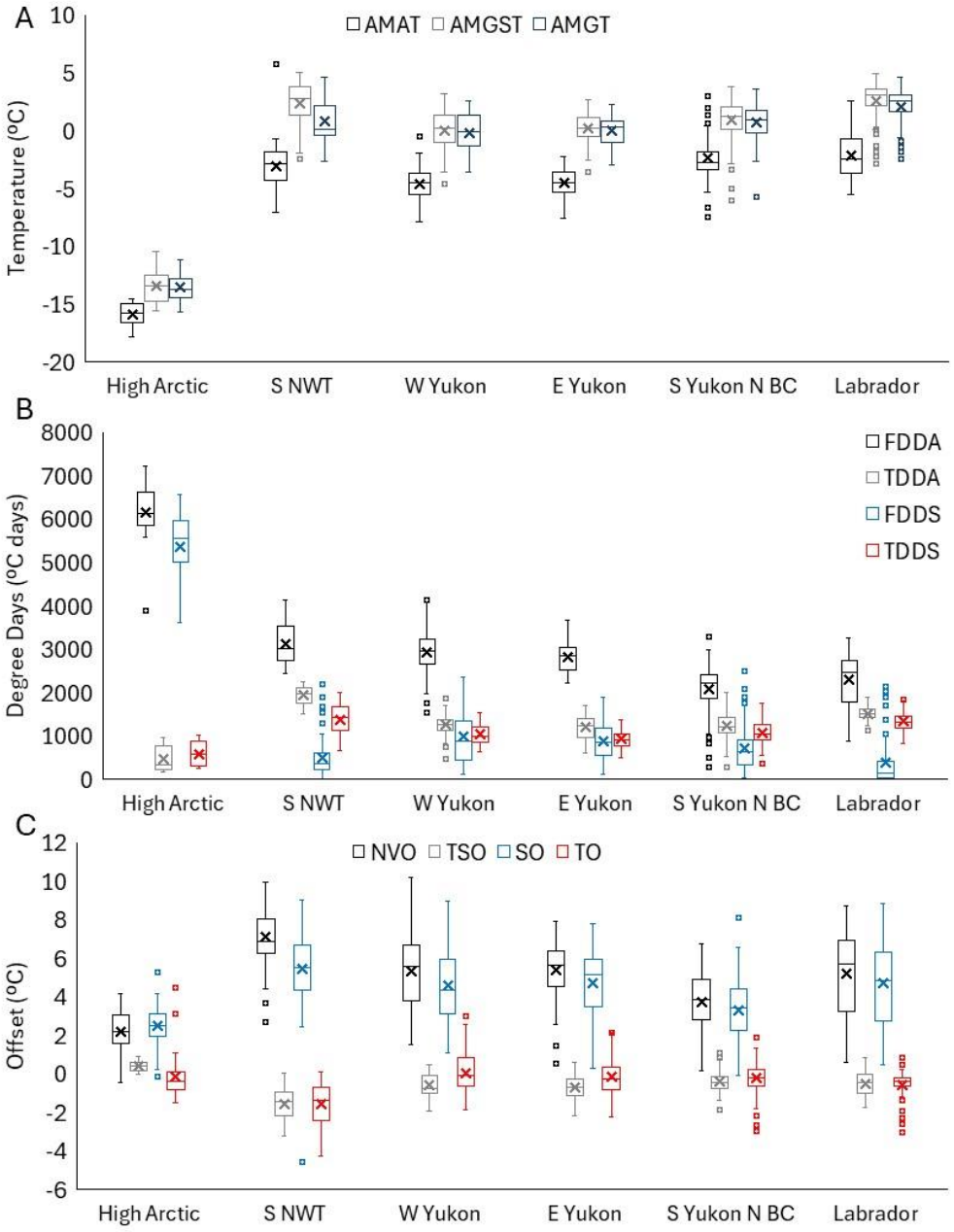

Figure S3. Boxplots for **A)** annual mean air temperature (AMAT), annual mean ground surface temperature (AMGST) and annual mean ground temperature (AMGT), **B)** freezing degree days for air (FDDa) and ground surface (FDDs) and thawing degree days for air (TDDa) and ground surface (TDDs), and **C)** Nival offset (NVO), thawing surface offset (TSO), surface offset (SO) and thermal offset (TO). Mean values are represented by an X. For some regions, maximum and minimum are shown by the ends of the whiskers. However, for some regions outliers are shown as circles after the whiskers and the ends of the whiskers instead show the value for one and a

half times the interquartile range. The ends of the box show the first (25 percent) and third (75 percent) quartiles and the black line within the box shows the median.

S3 Correlation Matrices

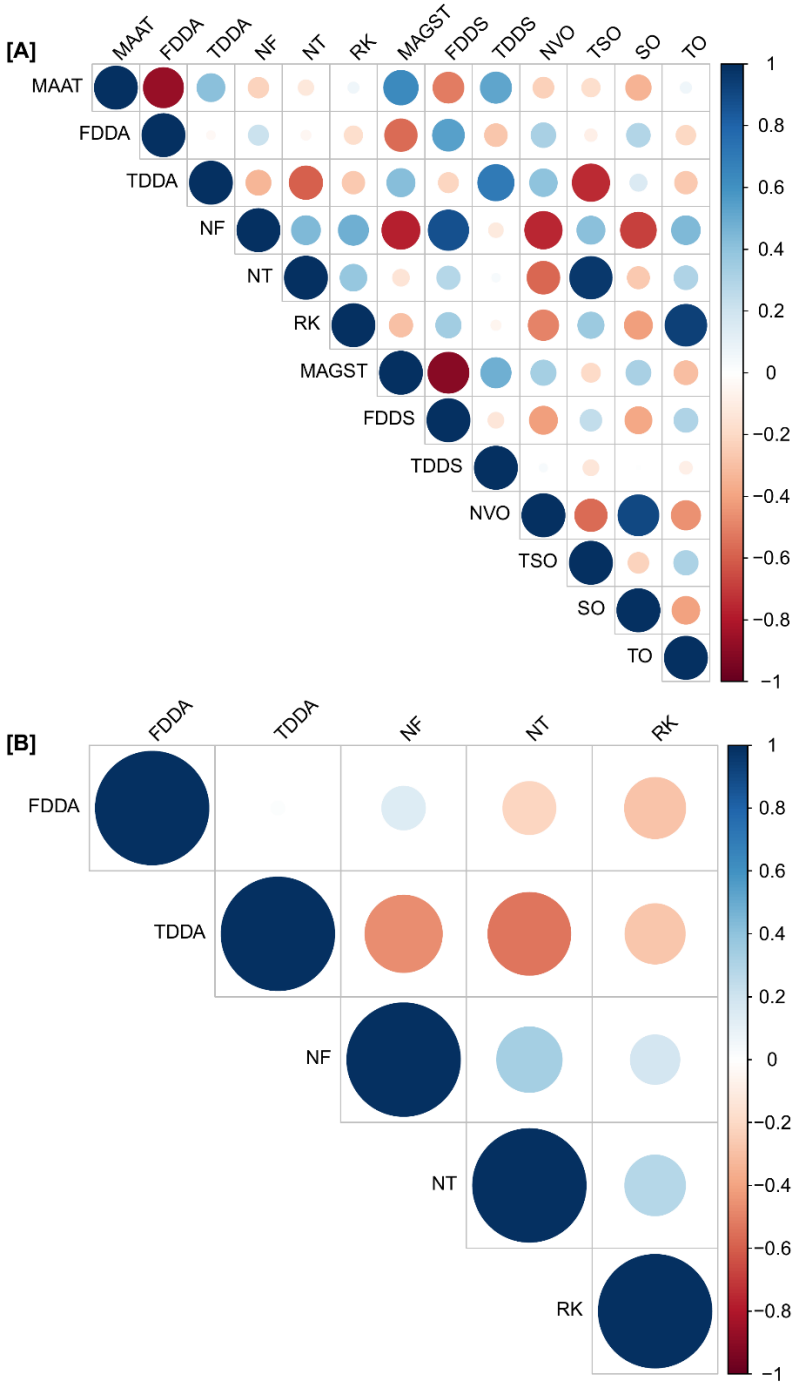

Figure S4. Spearman correlation matrices for A)All parameters and B) TTOP model parameters at all sites.

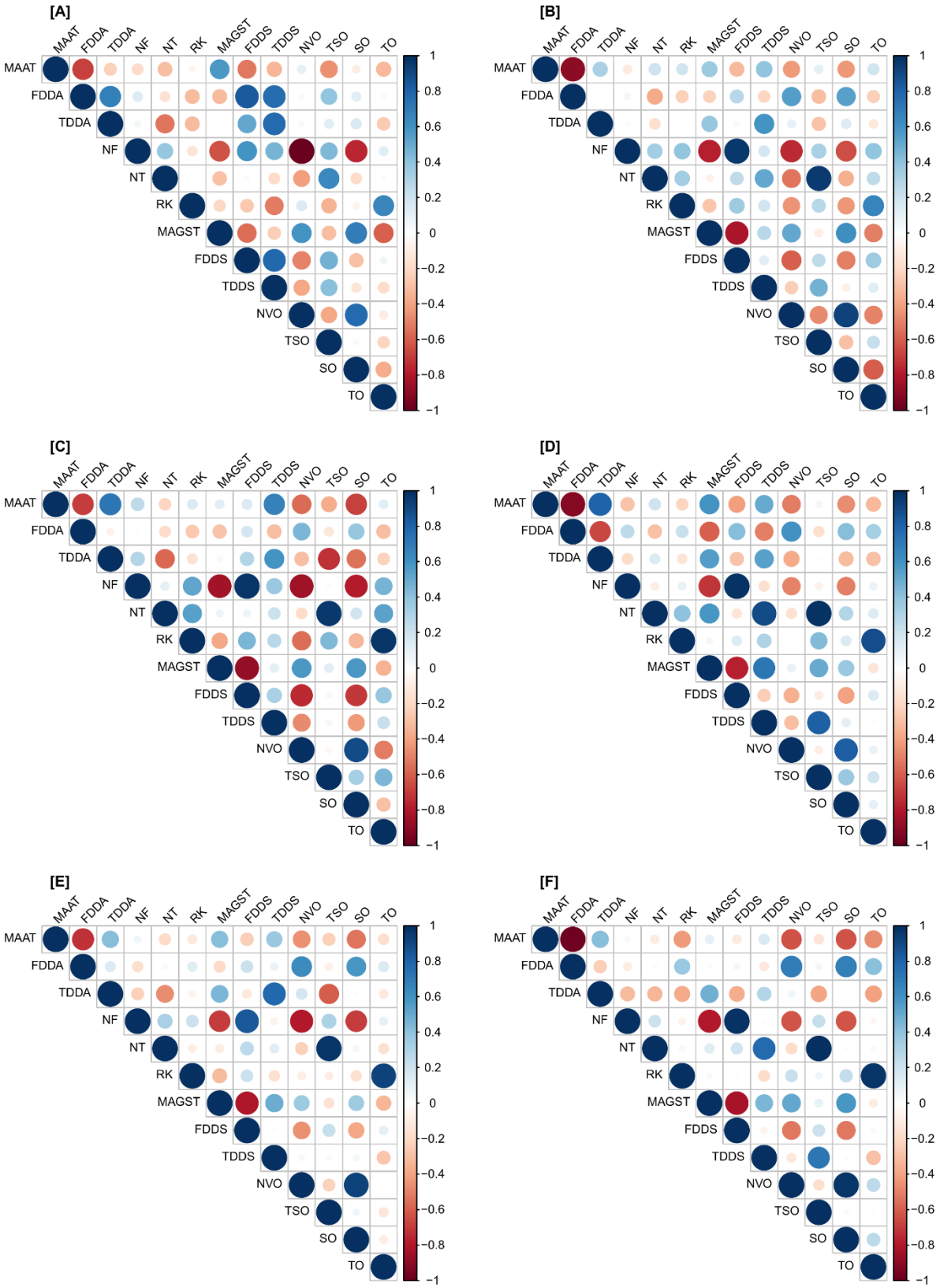

Figure S5. Spearman correlation matrices for all parameters for A) High Arctic, B) Western Yukon, C) Eastern Yukon, D) Southern NWT, E) Southern Yukon Northern BC, and F) Labrador.

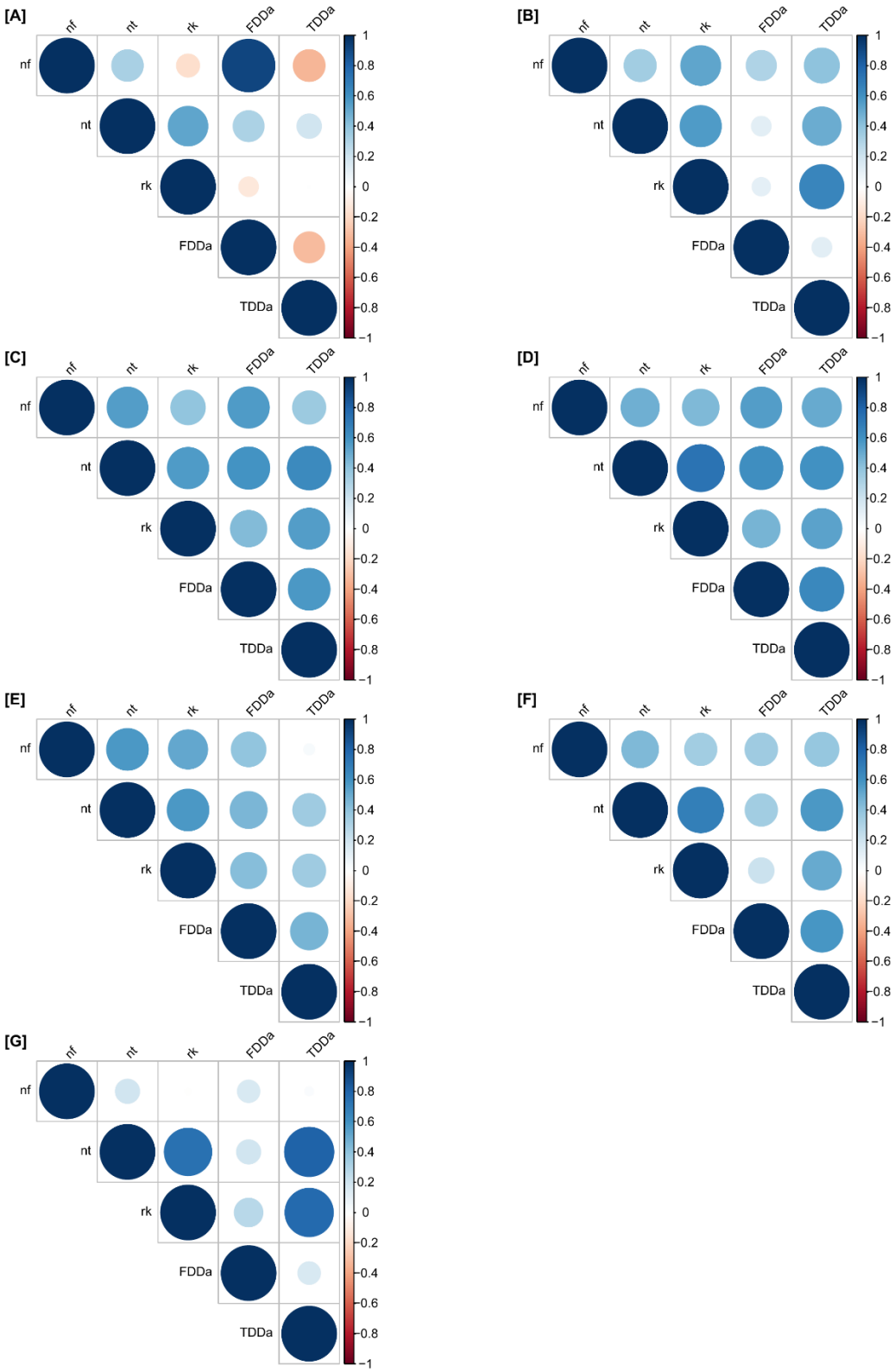

Figure S6. Spearman correlation matrices for TTOP model parameters for A) High Arctic, B) Northern NWT & NU, C) Western Yukon, D) Eastern Yukon, E) Southern NWT, F) Southern Yukon Northern BC, and G) Labrador.

S4 References

Riseborough DW (2003) Thawing and freezing indices in the ground. In: Proceedings of the 8th International Conference on Permafrost, Zurich, Switzerland. Lisse: Swets and Zeitlinger, 953–958.