Supplementary file for "Projected increase of Arctic coastal erosion and its sensitivity to climate warming in the 21st Century"

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Content

q	Historical m/year	SSP2-4.5 m/year (% increase)	SSP5-8.5 m/year (% increase)
0.1	0.86±0.42	1.64±0.50 (91±58)	2.11±0.61 (145±71)
0.5	0.89±0.45	1.99±0.66 (124±74)	2.62±0.84 (193±94)
0.9	0.93±0.48	2.36±0.79 (154±86)	3.12±1.03 (236±111)

Table S1: Arctic-mean erosion rate projections in the historical period (1850-1950) and by the end of the 21st Century (2081-2100) in three scenarios of proportionality factors between $\overline{H}$ and $\overline{T}$ to compose $\overline{E}$ for the observational period. A factor of $q = 0.1$ represents a 10% contribution from $\overline{H}$ and a 90% contribution from $\overline{T}$, for example. Values are ensemble mean ± two standard deviations from the distribution of uncertainties, obtained with a bootstrap method for the estimation of the coastal erosion temporal component coefficients, plus the ensemble spread.

	Sediment (x10^2 Tg/year)			Organic Carbon (Tg/year)		
	Historical	SSP2-4.5	SSP5-8.5	Historical	SSP2-4.5	SSP5-8. 5
Pan-Arctic	2.78±1.38	6.69±1.85	9.43±2.32	6.89±2.70	13.05±3.33	17.19±4.09
Laptev	0.99±0.67	2.60±0.86	3.80±1.06	3.50±1.45	5.94±1.72	7.66±2.08
East Siberian	0.54±0.28	1.38±0.35	1.93±0.44	1.84±0.71	3.65±0.81	4.78±0.99
Beaufort	0.25±0.09	0.62±0.13	0.88±0.17	0.70±0.25	1.62±0.34	2.26±0.44
Chukchi	0.31±0.10	0.53±0.12	0.66±0.14	0.39±0.12	0.73±0.16	0.95±0.20
Kara	0.38±0.15	0.99±0.26	1.40±0.35	0.26±0.11	0.75±0.21	1.08±0.28
Barents	0.31±0.10	0.58±0.14	0.75±0.17	0.19±0.06	0.36±0.08	0.47±0.10

Table S2: Annual sediment and organic carbon fluxes from Arctic coastal erosion. Uncertainties represent one standard deviation from the distribution of erosion model coefficients and ensemble spread.

Step No.	Variables
0	θ
1	OWS
2	T_{day}
3	T
4	H_{day}
5	H
6	θ + OWS
7	$\theta + T_{day}$
8	$\theta + T$
9	$\theta + H_{day}$
10	$\theta + H$
11	OWS + T_{day}
12	OWS + T
13	OWS + H_{day}
14	OWS + H
15	$T_{day} + H_{day}$
16	$T_{day} + H$
17	$T + H_{day}$
18	$T + H$
19	θ + OWS + T_{day}
20	θ + OWS + T
21	θ + OWS + H_{day}
22	θ + OWS + H
23	$\theta + T_{day} + H_{day}$
24	$\theta + T_{day} + H$
25	$\theta + T + H_{day}$
26	$\theta + T + H$
27	OWS + $T_{day} + H_{day}$
28	OWS + $T_{day} + H$
29	OWS + $T + H_{day}$
30	OWS + $T + H$
31	θ + OWS + $T_{day} + H_{day}$
32	θ + OWS + $T_{day} + H$
33	θ + OWS + $T + H_{day}$
34	θ + OWS + $T + H$

Table S3: Combinations of explanatory variables tested in multiple linear regression models to explain the observed spatial variability of erosion. Performance metrics are displayed in Fig. S2. A list of symbols is presented in Table S4.

Symbol	Description	Unit
E	Erosion rate	m year^{-1}
H	Yearly-accumulated daily significant wave heights	m day year^{-1}
T	Yearly-accumulated daily positive degrees	^{o}C day year^{-1}
H_{day}	H divided by the number of open-water days per year	m year^{-1}
T_{day}	T divided by the number of positive-degree days per year	^{o}C year^{-1}
OWS	Open-water season duration	day
SIC	Sea-ice concentration	% area
θ	Ground-ice content	% volume
a_{TA}	Empirical temporal coefficient for Arctic-mean thermo-abrasion	m m^{-1} day^{-1}
a_{TD}	Empirical temporal coefficient for Arctic-mean thermo-denudation	^{o}C m^{-1} day^{-1}
b_θ	Spatial regression coefficient for ground ice (non-extreme segments)	m % year^{-1}
b'_θ	Spatial regression coefficient for ground ice (extreme segments)	m % year^{-1}
b_T	Spatial regression coefficient for T_{day}	m ^{o}C^{-1}
b_H	Spatial regression coefficient for H_{day}	m m^{-1}
C_{conc}	Soil organic-carbon concentration	% weight
C_{flux}	Soil organic-carbon flux	Tg year^{-1}
ρ	Soil bulk density	kg m^{-3}
L	Coastal segment length	m
h	Coastal segment mean height	m
$\overline{(\ )}$	Spatial Arctic mean, weighted by coastal segment length	
$\Delta(\ )$	Spatial anomalies with respect to Arctic mean	
x	Spatial dimension	ACD coastal segment
t	Temporal dimension	year

Table S4: List of symbols.

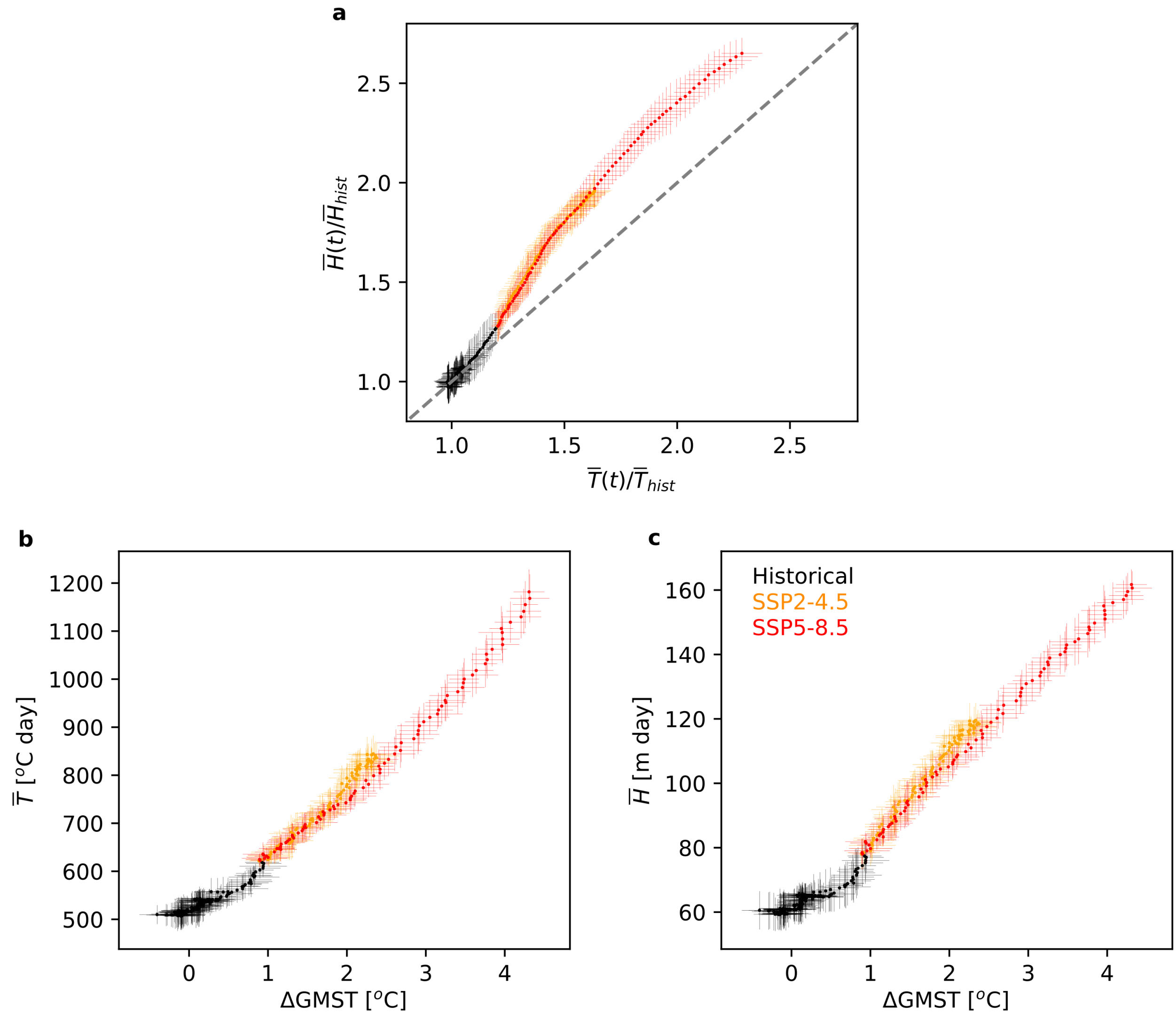

Figure S1: **a)** Arctic-mean mechanical driver of erosion $\overline{H}$ [m day year^{-1}] normalized by its historical value (1850-1950), as a function of the Arctic-mean thermal driver of erosion $\overline{T}$ [^{o}C day year^{-1}] also normalized by its historical value. $\overline{H}$ increases proportionally more than $\overline{T}$. The mechanical driver increases more than the thermal driver in the 21$^{\text{st}}$ century with respect to historical values. By 2100, $\overline{H}$ and $\overline{T}$ increases 2.65 and 2.29 (1.63 and 1.96) times their respective historical values in the SSP5.8-5 (SSP2.4-5) scenario. By 2100, the mechanical and thermal drivers increase 2.65 and 2.29 (1.63 and 1.96) times their respective historical values in the SSP5.8-5 (SSP2.4-5) scenario. The erosion drivers $\overline{T}$ in **b**, and $\overline{H}$ in **c**, as a function of global mean surface temperature changes ΔGMST. Dots are the ensmble mean and lines depict 2 standard deviations of the ensemble spread. The erosion drivers, especially $\overline{H}$, increase sharply in the transition between the historical and future scenarios, at ΔGMST$\simeq$ 1, as a consequence of the apparent hiatus in global warming.

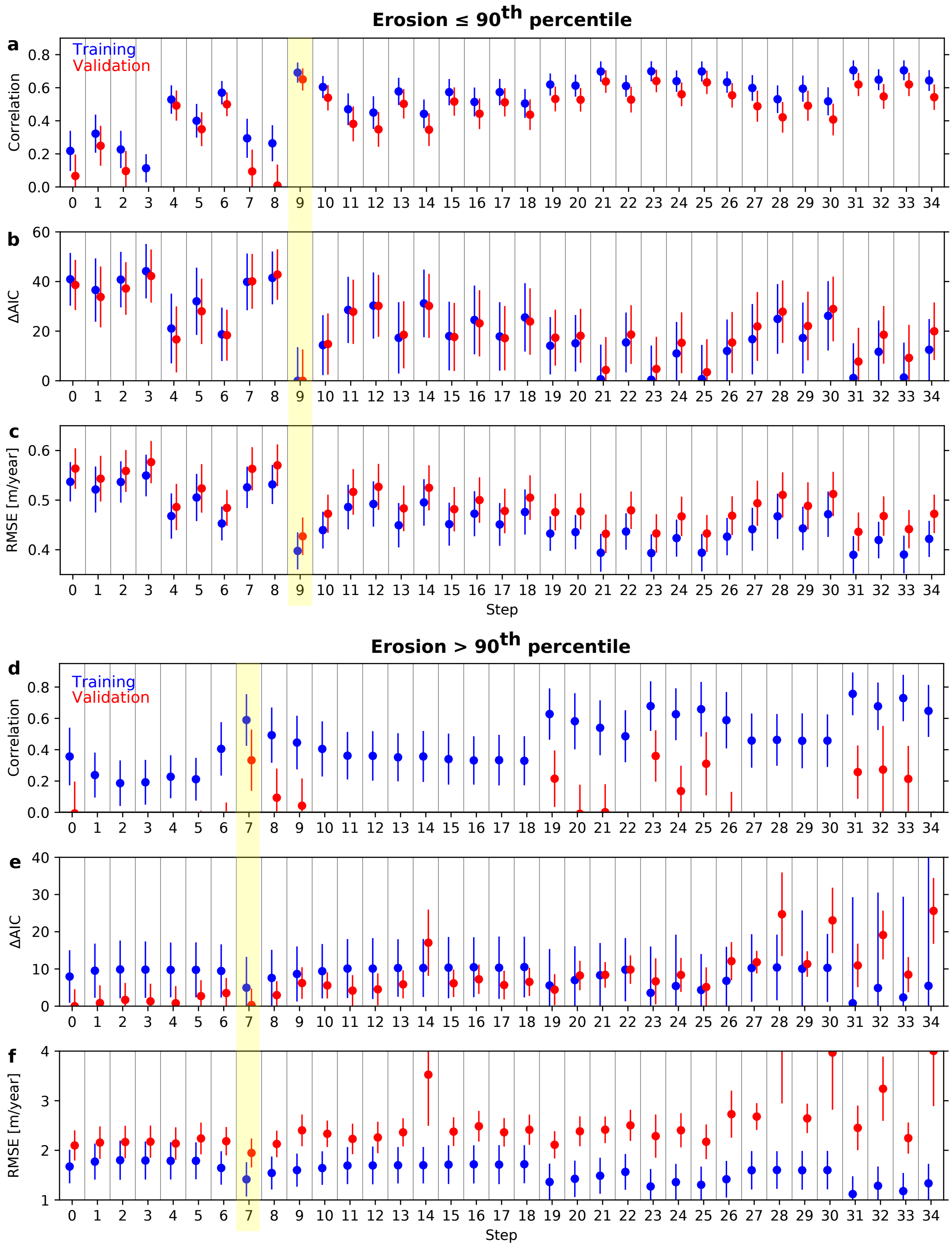

Figure S2: Goodness-of-fit metrics for each variable combination (step) tested in multiple linear regression models to explain the spatial variability of observed erosion rates. Shown are the correlation coefficients (a, c), Akaike's Information Criterion differences (ΔAIC) (b, e) and root mean square errors (RMSE) (c, f) for the non-extreme (top) and extreme (bottom) erosion segments. Blue and red markers represent training and leave-one-out cross validation results. Vertical bars represent two standard deviations of distributions calculated with a Bootstrapping method. The best performing steps, highlighted in yellow, are selected with trade-off between high correlation and low ΔAIC and RMSE. The steps are described in Table S3.

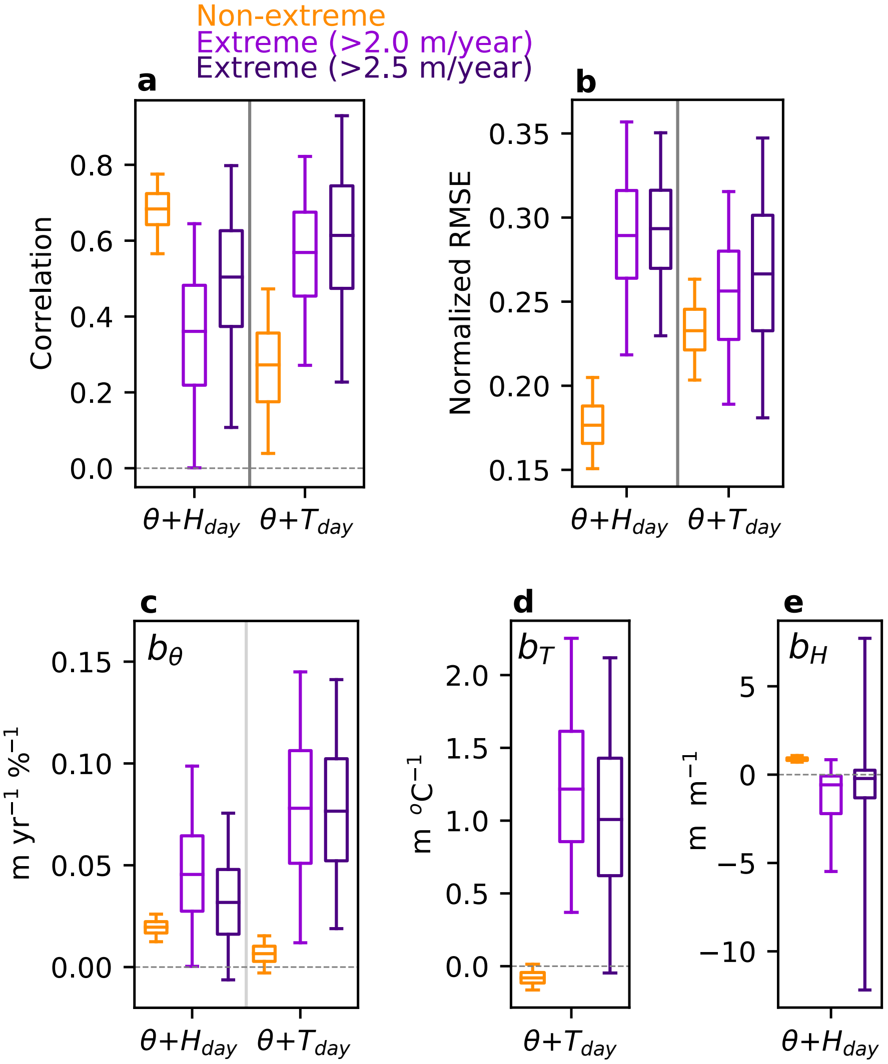

Figure S3: Spatial erosion model component parameters for the non-extreme erosion group and for two different extreme-erosion groups, differing on the threshold. Correlation **a** and normalized root-mean squared error (RMSE) **b** between modelled and observed erosion rates. Multiple linear regression coefficients for combinations $\theta+H_{day}$ and $\theta+T_{day}$, for the extreme and non-extreme coastal segments. Regression coefficients for **c**: ground-ice content θ, **d**: daily mean positive-degree sum T_{day}, and **e** daily mean wave heights H_{day}. Horizontal lines represent the median, bnxes represent the 25-75% percentile range, and whiskers the 9-95% percentile range. All parameter distributions are obtained with a 10-thousand sampling Bootstrap method.