Supplement of The Cryosphere, 20, 1771–1796, 2026
https://doi.org/10.5194/tc-20-1771-2026-supplement

The Cryosphere Open Access EGU

Supplement of

Beyond MAGT: learning more from permafrost thermal monitoring data with additional metrics

Nicholas Brown and Stephan Gruber

Correspondence to: Nicholas Brown (nick.brown@carleton.ca)

Table S1: Colourized version of Table 3 showing test statistics measuring how reliably each metric corresponds to the sensible, latent, or total ground heat content for a given averaging window and data quality. Numeric values represent the percentage of significantly positive (blue, left) or negative (orange, right) percentage relationships across all observation windows. The intensity of the colouring in each cell corresponds to its magnitude.

	Window	20 years			10 years			5 years			20 years			10 years			5 years		
	Dataset	$\mathcal{Q}_0$	$\mathcal{Q}_1$	$\mathcal{Q}_2$	$\mathcal{Q}_0$	$\mathcal{Q}_1$	$\mathcal{Q}_2$	$\mathcal{Q}_0$	$\mathcal{Q}_1$	$\mathcal{Q}_2$	$\mathcal{Q}_0$	$\mathcal{Q}_1$	$\mathcal{Q}_2$	$\mathcal{Q}_0$	$\mathcal{Q}_1$	$\mathcal{Q}_2$	$\mathcal{Q}_0$	$\mathcal{Q}_1$	$\mathcal{Q}_2$
H_l	$MAGST$	72	71	71	49	49	49	22	22	22	0	0	0	0	0	0	0	0	0
	T_{10}	93	92	90	64	62	57	28	26	18	0	0	0	0	0	0	0	0	0
	T_{15}	85	85	83	52	52	48	32	32	24	0	0	0	0	0	0	0	0	0
	T_{20}	73	75	48	47	47	23	32	32	9	0	0	22	0	0	19	1	2	8
	$\bar{\tau}^0_{10}$	88	88	88	57	57	56	27	27	27	0	0	0	0	0	0	0	0	0
	$\bar{\tau}^0_{15}$	90	90	90	57	57	57	26	26	26	0	0	0	0	0	0	0	0	0
	$\bar{\tau}^0_{20}$	90	90	90	57	57	56	26	26	25	0	0	0	0	0	0	0	0	0
	$d_{za}(warm)$	10	10	10	5	5	6	2	2	3	48	48	47	20	21	19	10	10	9
	d_{za}	44	44	44	32	32	32	14	14	14	22	22	24	9	9	10	4	4	4
	$d_{za}(cold)$	74	75	71	57	57	54	26	25	23	0	0	0	0	0	1	0	0	0
	T_{za}	59	59	55	32	34	26	14	14	11	0	0	4	1	0	2	1	1	1
	TOP	96	97	86	90	91	68	57	55	38	0	0	0	0	0	0	0	0	0
H_s	$MAGST$	75	75	75	54	54	54	22	22	22	0	0	0	0	0	0	0	0	0
	T_{10}	91	91	92	72	75	78	48	50	54	0	0	0	0	0	0	0	0	0
	T_{15}	92	93	92	64	64	67	28	27	28	0	0	0	0	0	0	0	0	0
	T_{20}	90	92	70	54	55	44	17	17	13	0	0	16	0	0	4	0	0	1
	$\bar{\tau}^0_{10}$	96	96	95	81	81	80	66	66	65	0	0	0	0	0	0	0	0	0
	$\bar{\tau}^0_{15}$	98	98	98	85	85	85	71	71	71	0	0	0	0	0	0	0	0	0
	$\bar{\tau}^0_{20}$	99	99	99	89	89	88	74	74	74	0	0	0	0	0	0	0	0	0
	$d_{za}(warm)$	2	2	2	3	3	4	2	2	2	62	62	55	25	24	19	7	7	5
	d_{za}	29	29	30	24	24	25	16	15	16	26	26	24	10	10	8	2	2	2
	$d_{za}(cold)$	48	48	48	41	41	39	26	26	25	0	0	0	0	0	0	0	0	0
	T_{za}	68	70	68	47	47	42	20	20	18	2	1	4	2	1	1	1	0	0
	TOP	78	78	64	39	38	34	18	17	16	0	0	0	0	0	0	0	0	0
H_t	$MAGST$	65	65	65	41	41	40	17	17	17	0	0	0	0	0	0	0	0	0
	T_{10}	97	98	96	86	86	86	51	51	50	0	0	0	0	0	0	0	0	0
	T_{15}	98	98	96	78	78	77	34	34	29	0	0	0	0	0	0	0	0	0
	T_{20}	93	95	71	67	68	43	27	27	11	0	0	18	0	0	16	0	0	4
	$\bar{\tau}^0_{10}$	94	94	93	69	69	68	50	50	50	0	0	0	0	0	0	0	0	0
	$\bar{\tau}^0_{15}$	97	97	97	75	75	75	55	55	55	0	0	0	0	0	0	0	0	0
	$\bar{\tau}^0_{20}$	98	98	98	79	79	78	58	58	58	0	0	0	0	0	0	0	0	0
	$d_{za}(warm)$	2	2	3	4	4	4	2	2	3	50	50	47	21	21	20	10	10	9
	d_{za}	34	34	34	29	29	29	18	18	18	20	20	21	9	9	9	4	4	3
	$d_{za}(cold)$	56	56	54	47	48	47	29	29	28	0	0	0	0	0	0	0	0	0
	T_{za}	77	77	71	51	52	45	22	22	18	0	0	3	0	0	1	0	0	1
	TOP	87	88	71	61	62	45	33	32	20	0	0	0	0	0	0	0	0	0

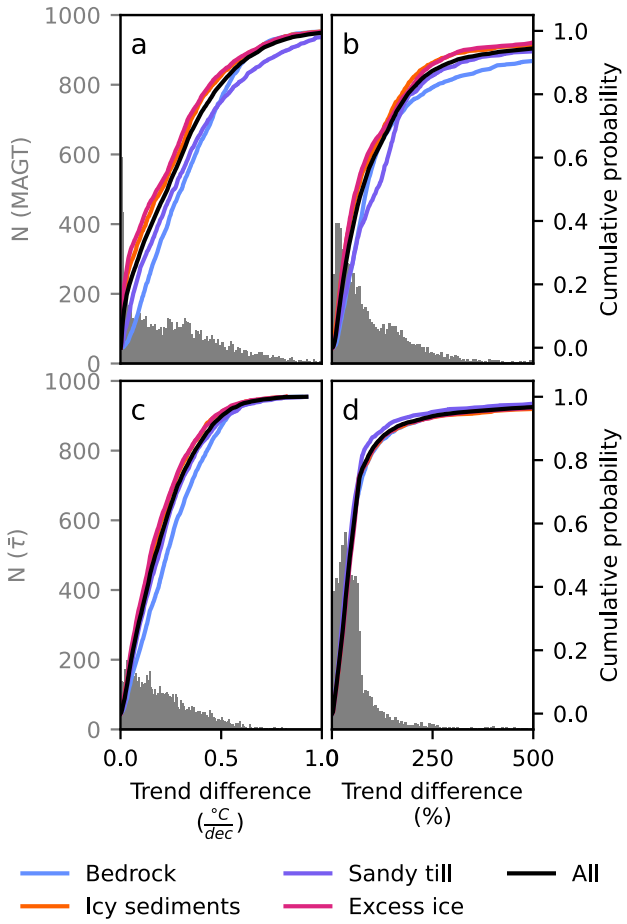

Figure S 0: Sensitivity of 10-year ground temperature trends to observation depth. The magnitude of the 10-year trend is more sensitive to measurement depth for Mean Annual Ground Temperature (MAGT; **a, b**) than it is to the total integration depth for thermal integral ($\bar{\tau}$; **c, d**). This relationship holds for both absolute (°C dec^{-1}; **a, c**) and normalized (%; **b, d**) differences. Grey histograms (left axis) show the distribution of trend differences for measurement depths between 10 m and 20 m across all terrain types. Colored lines (right axis) represent the cumulative distribution functions (CDFs) for specific materials, highlighting that bedrock (blue) consistently exhibits the highest sensitivity to depth compared to other materials.

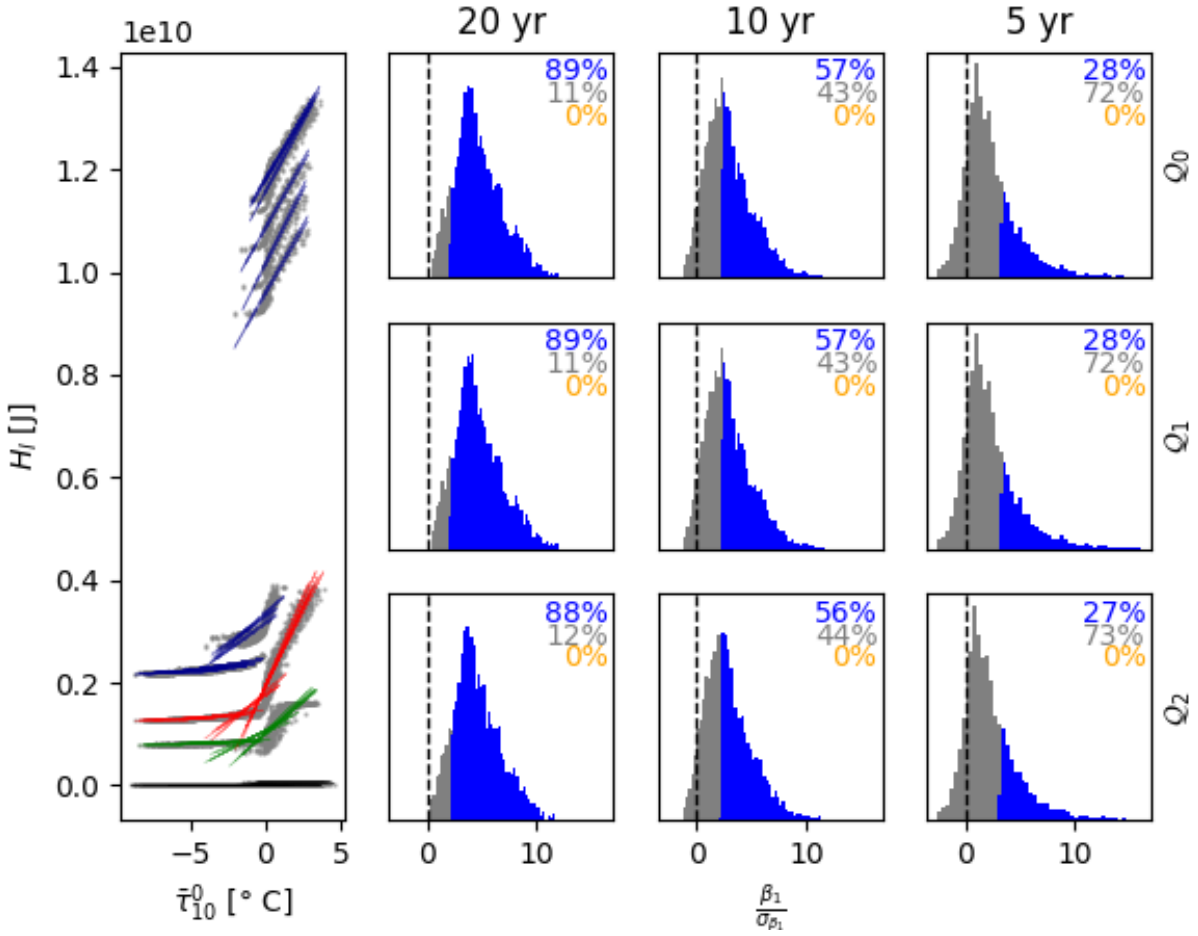

Figure S1: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{10}$) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

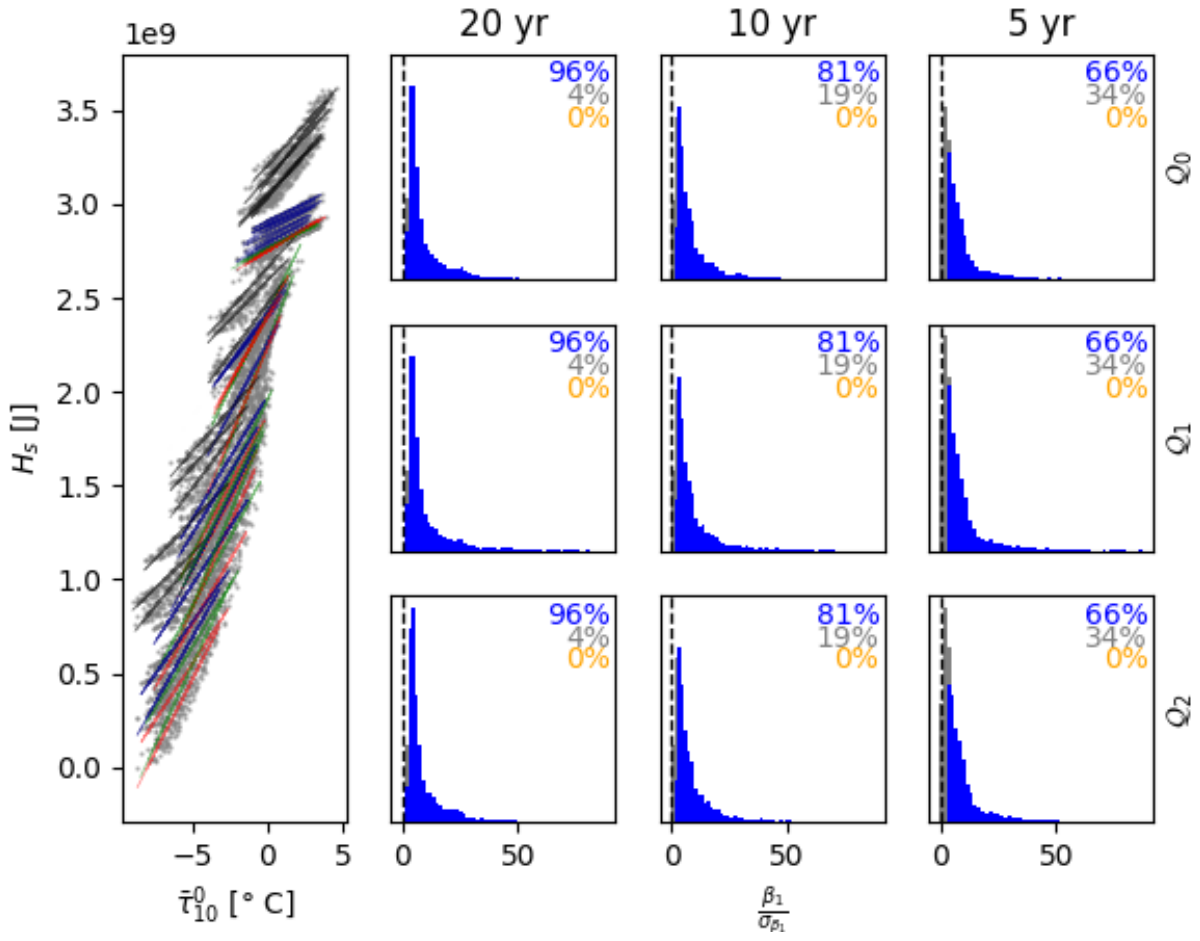

Figure S2: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{10}$) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

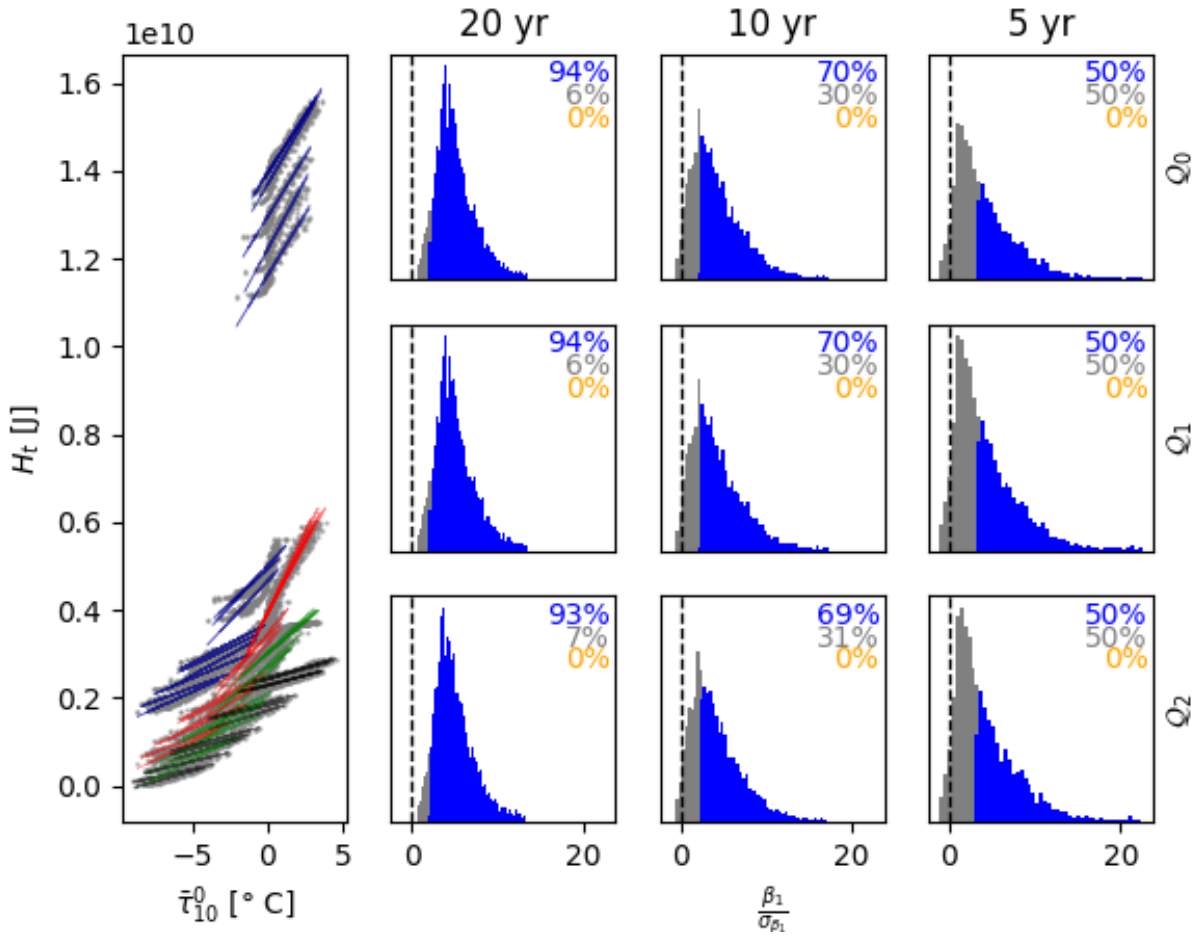

Figure S3: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{10}$) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

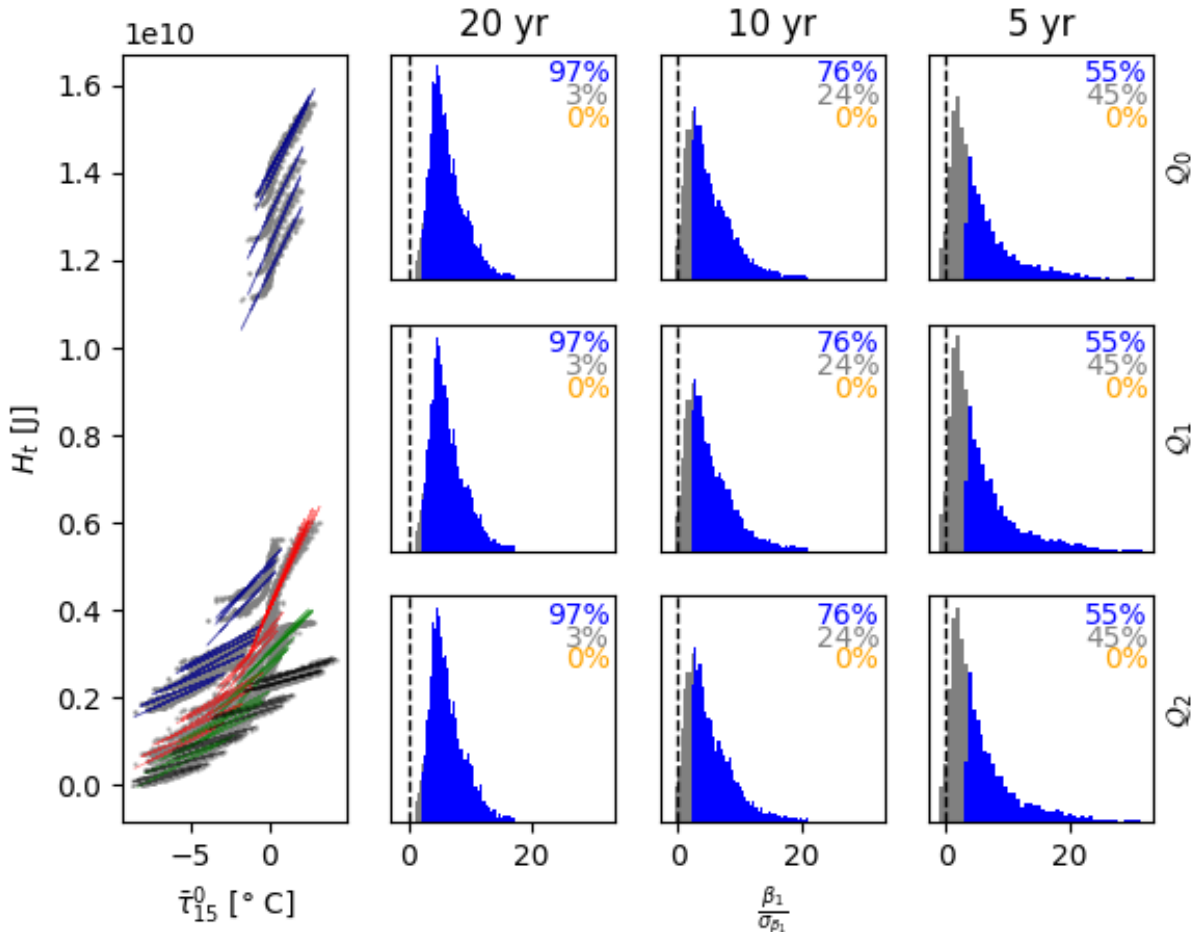

Figure S4: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{15}$) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

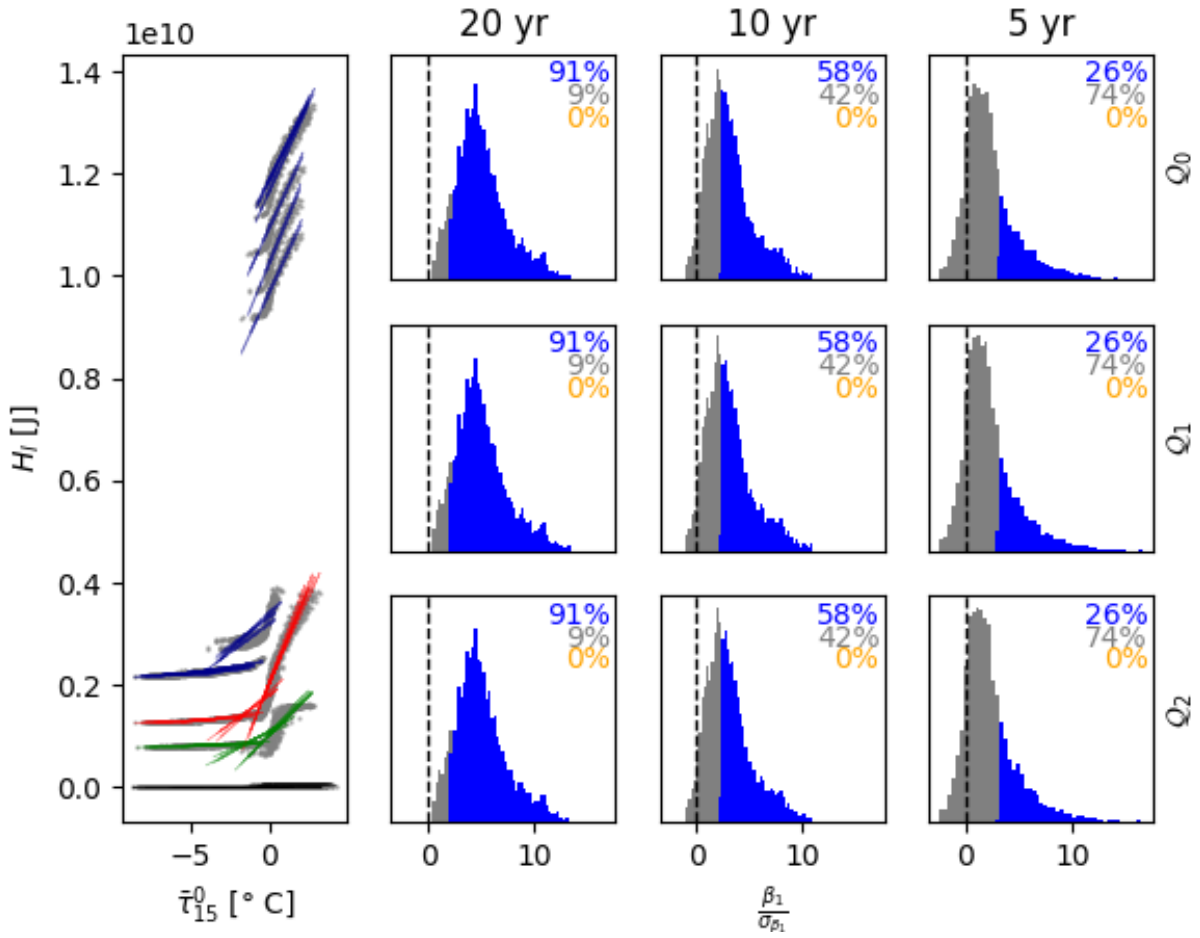

Figure S5: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{15}$) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

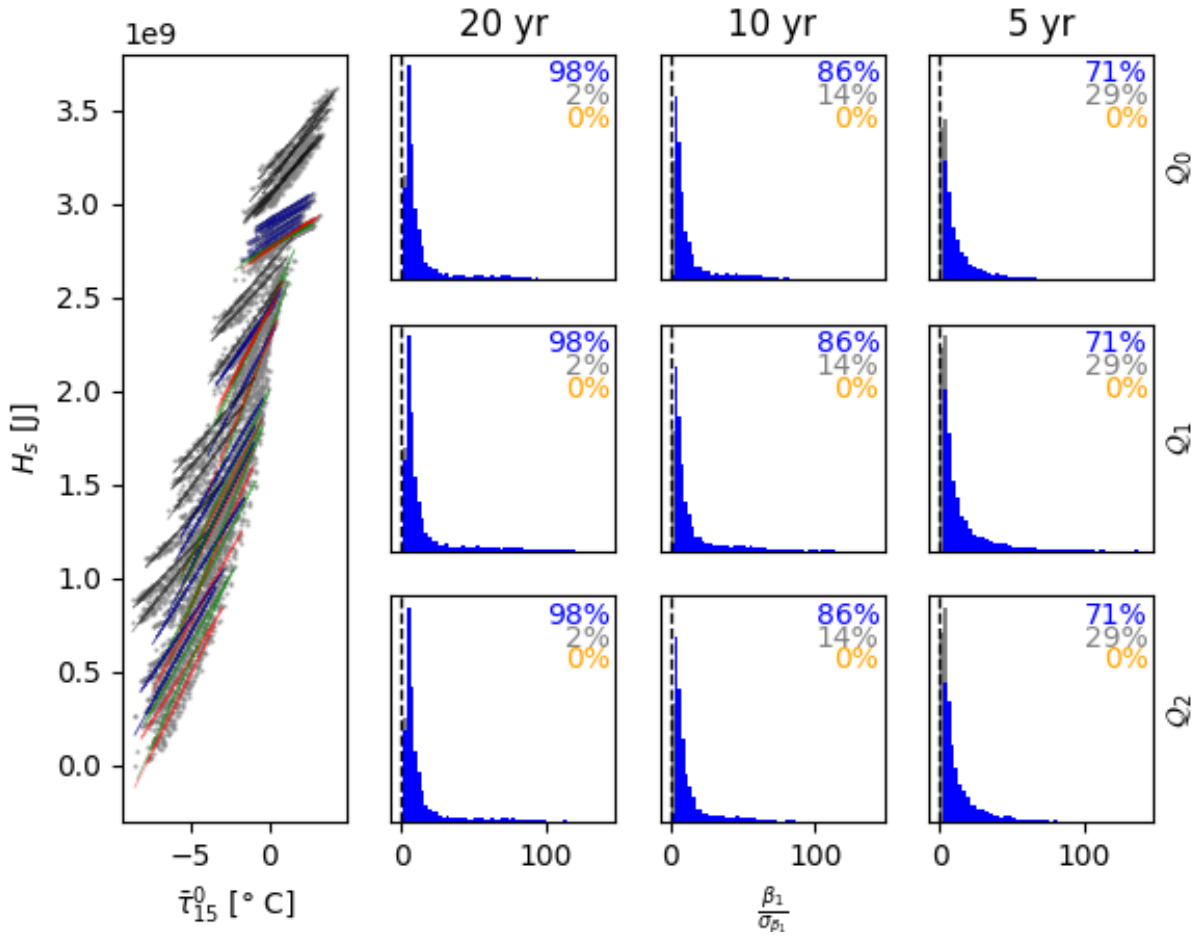

Figure S6: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{15}$) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

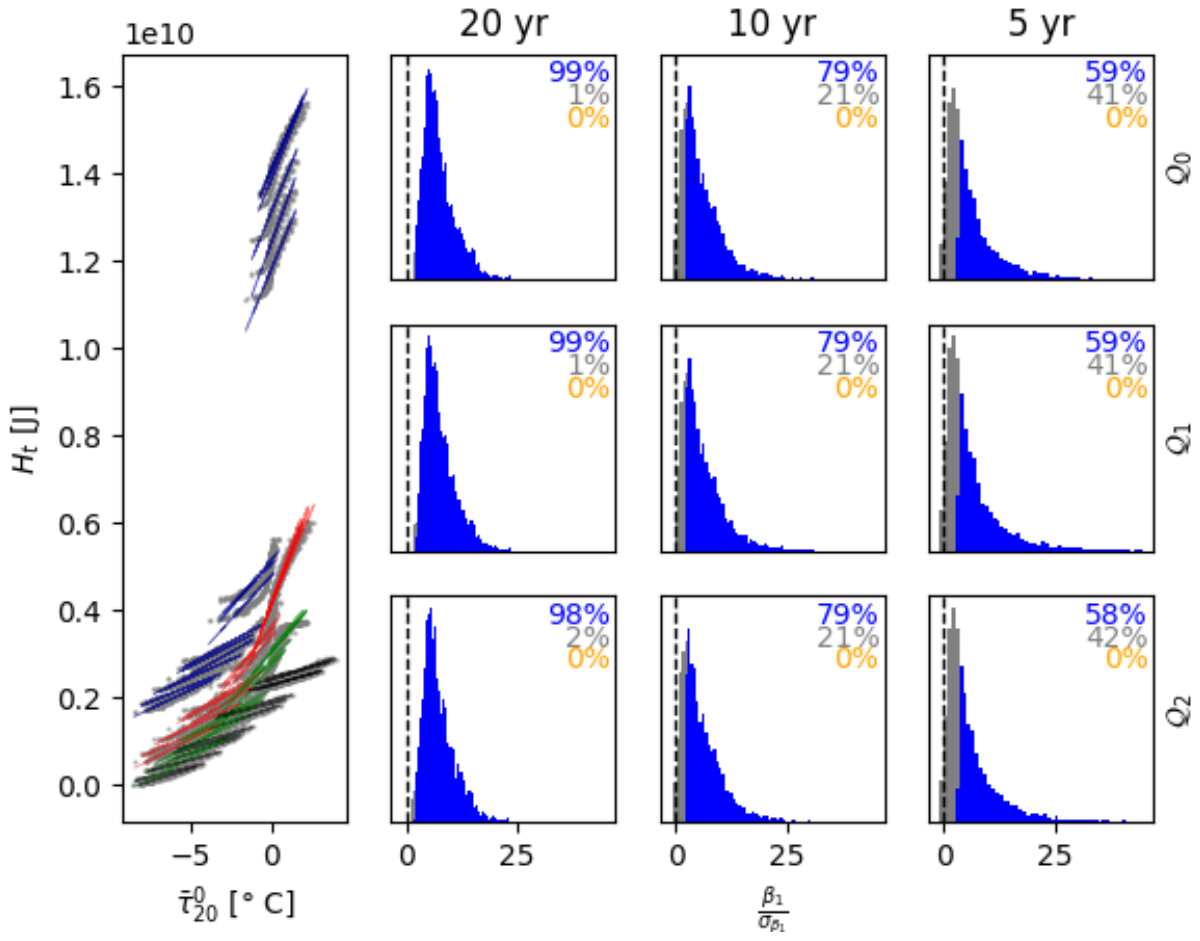

Figure S7: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{20}$) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

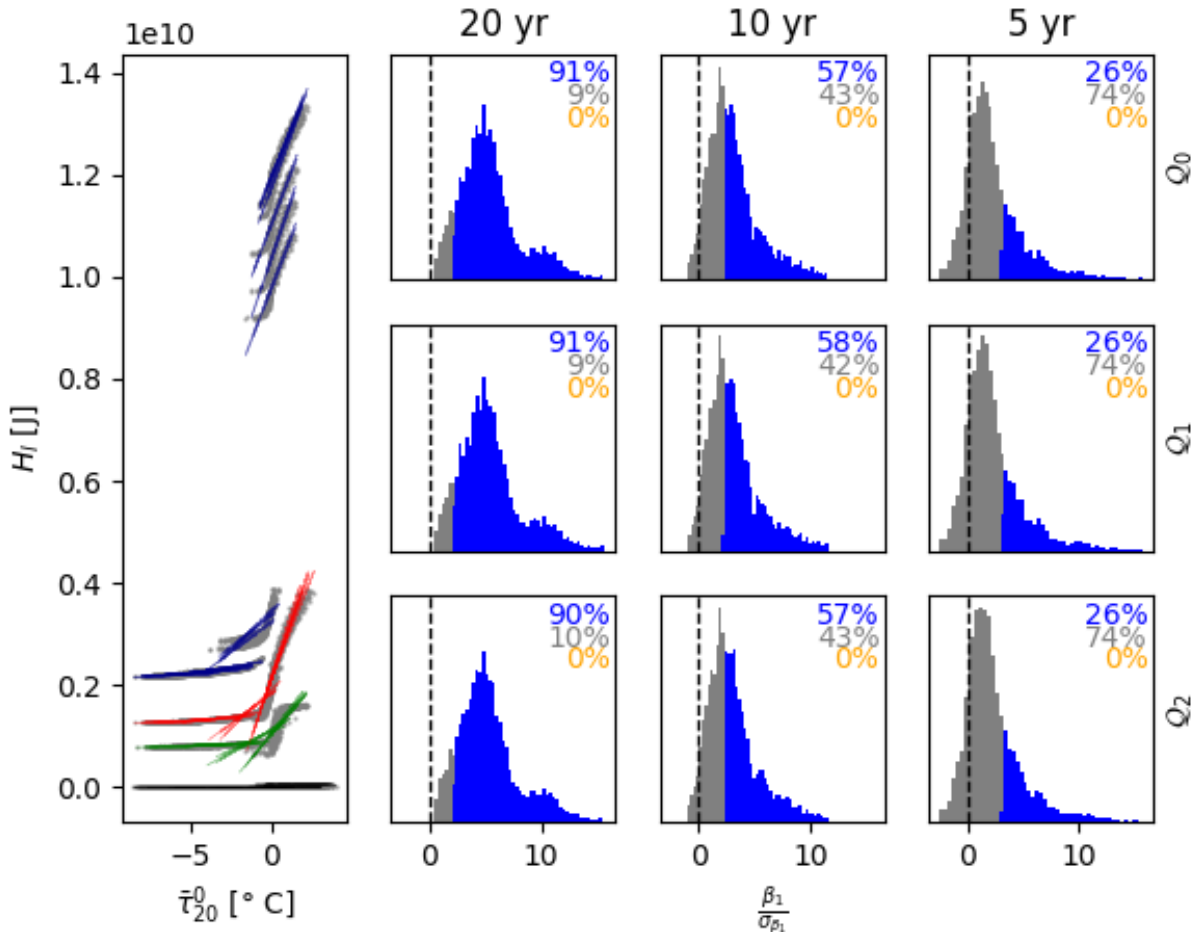

Figure S8: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{20}$) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

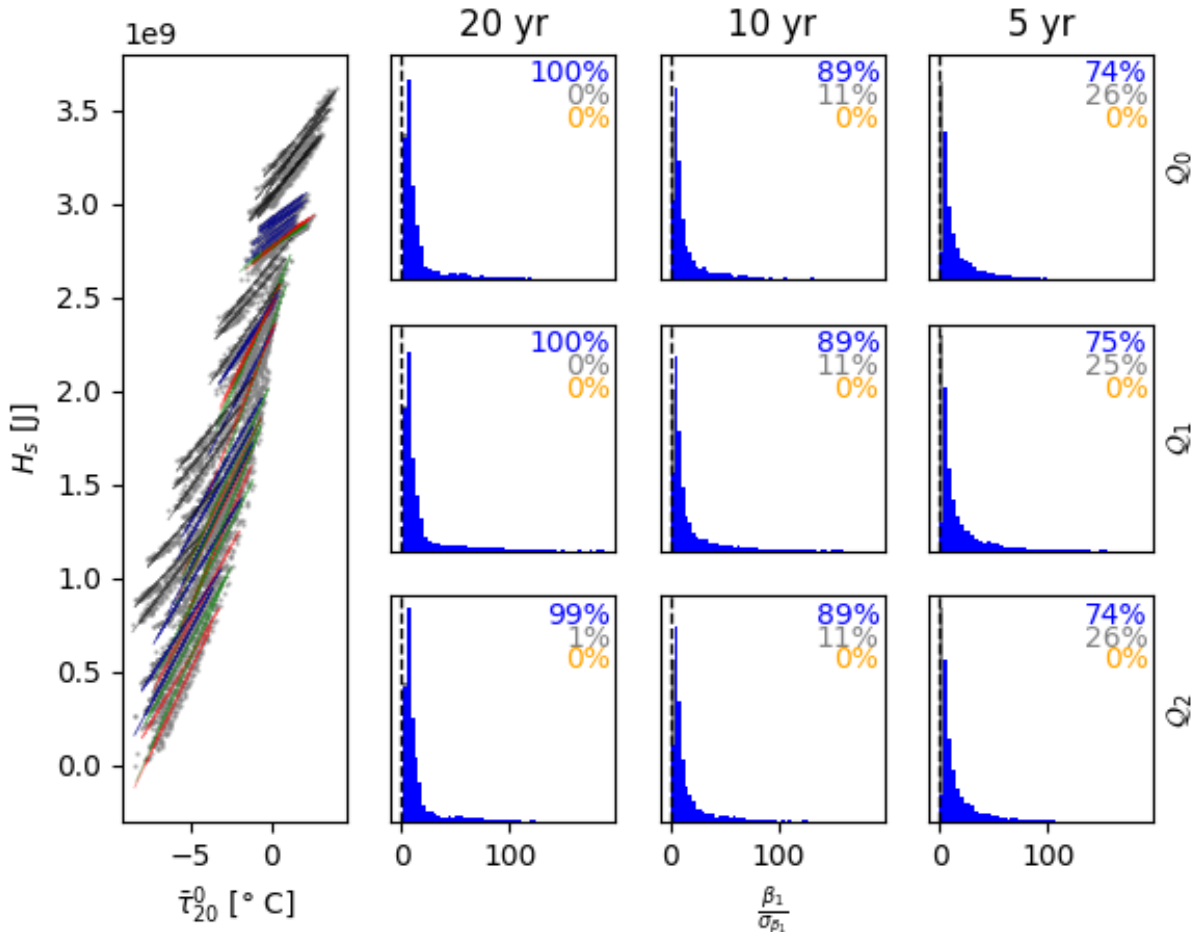

Figure S9: Effect of sensor quality and data length on the significance of metric ($\bar{\tau}^0_{20}$) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

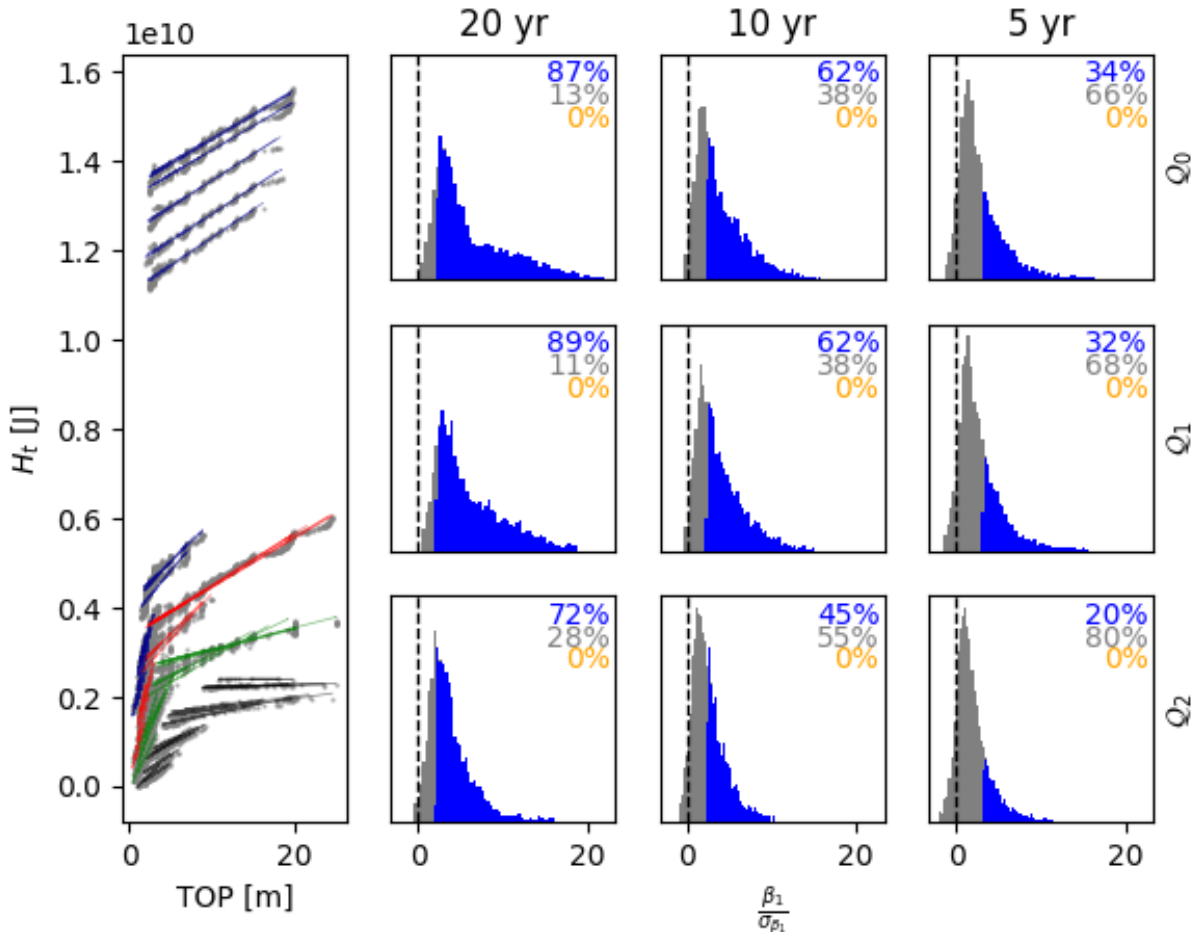

Figure S10: Effect of sensor quality and data length on the significance of metric (TOP) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

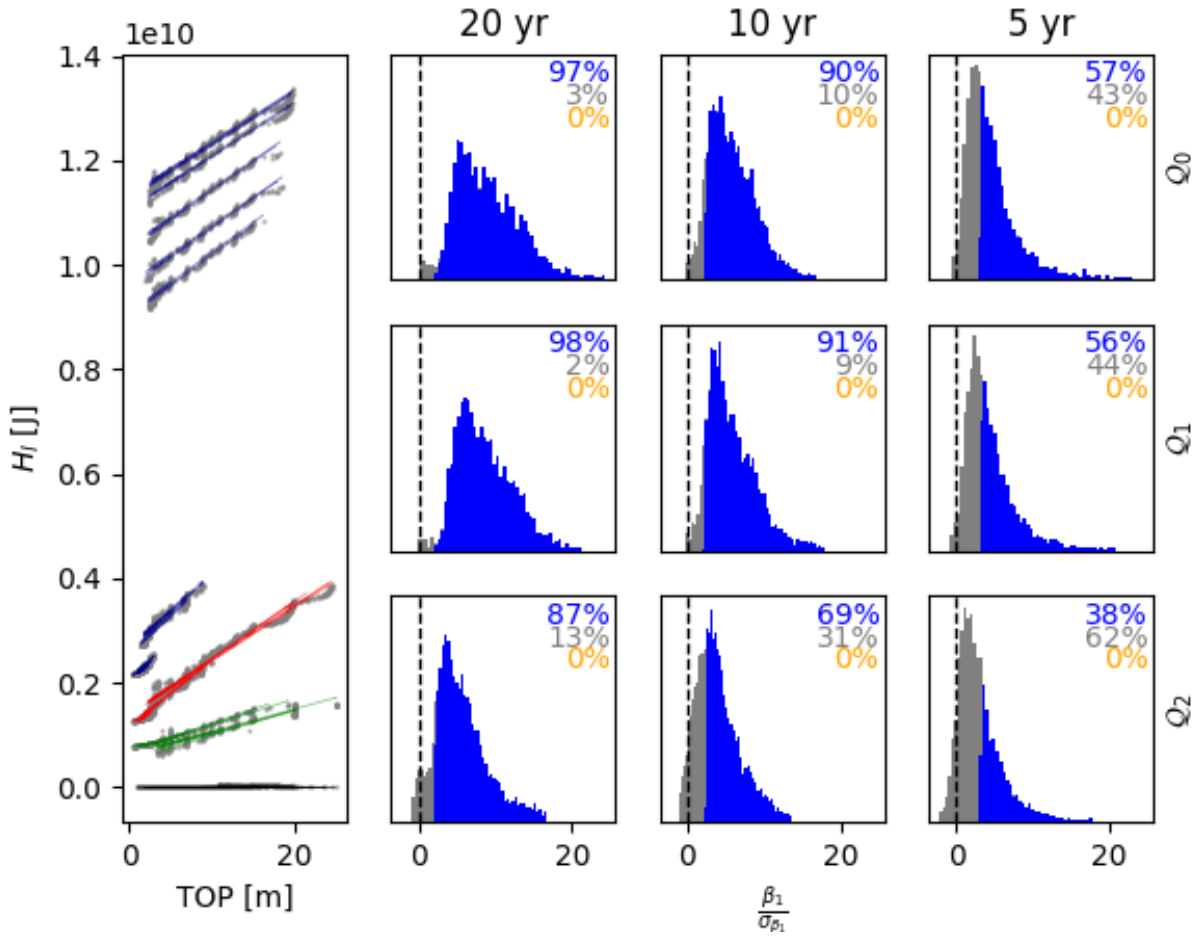

Figure S11: Effect of sensor quality and data length on the significance of metric (TOP) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

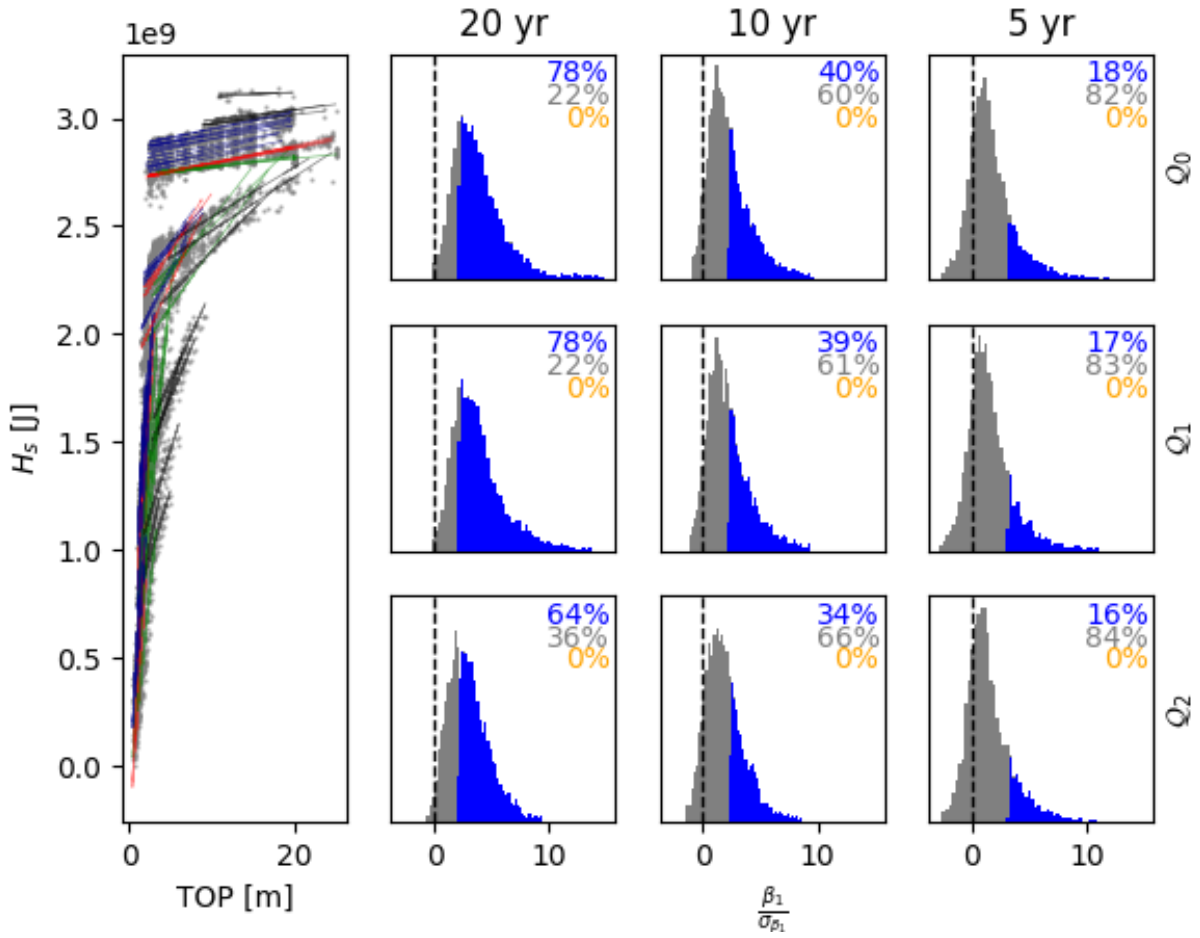

Figure S12: Effect of sensor quality and data length on the significance of metric (TOP) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

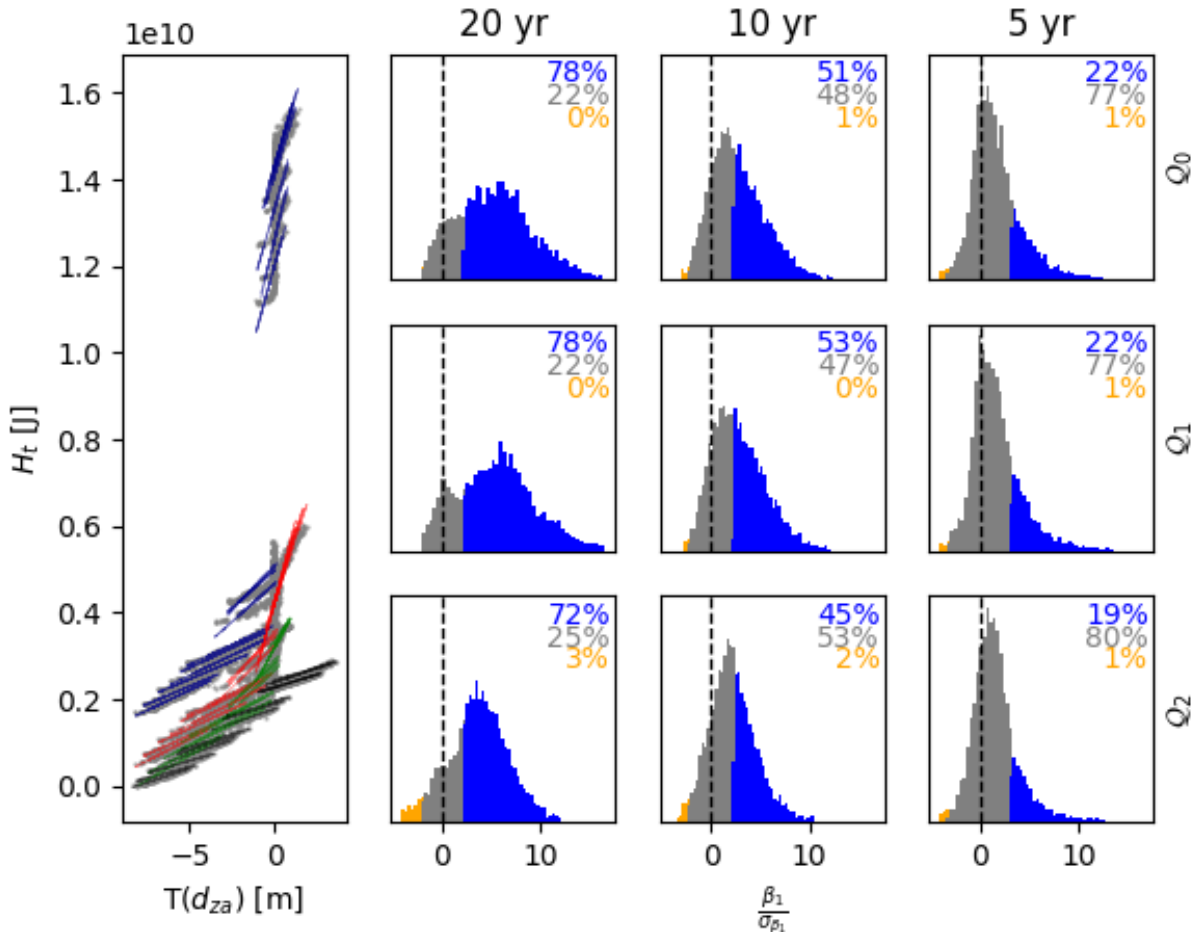

Figure S13: Effect of sensor quality and data length on the significance of metric (T_{za}) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

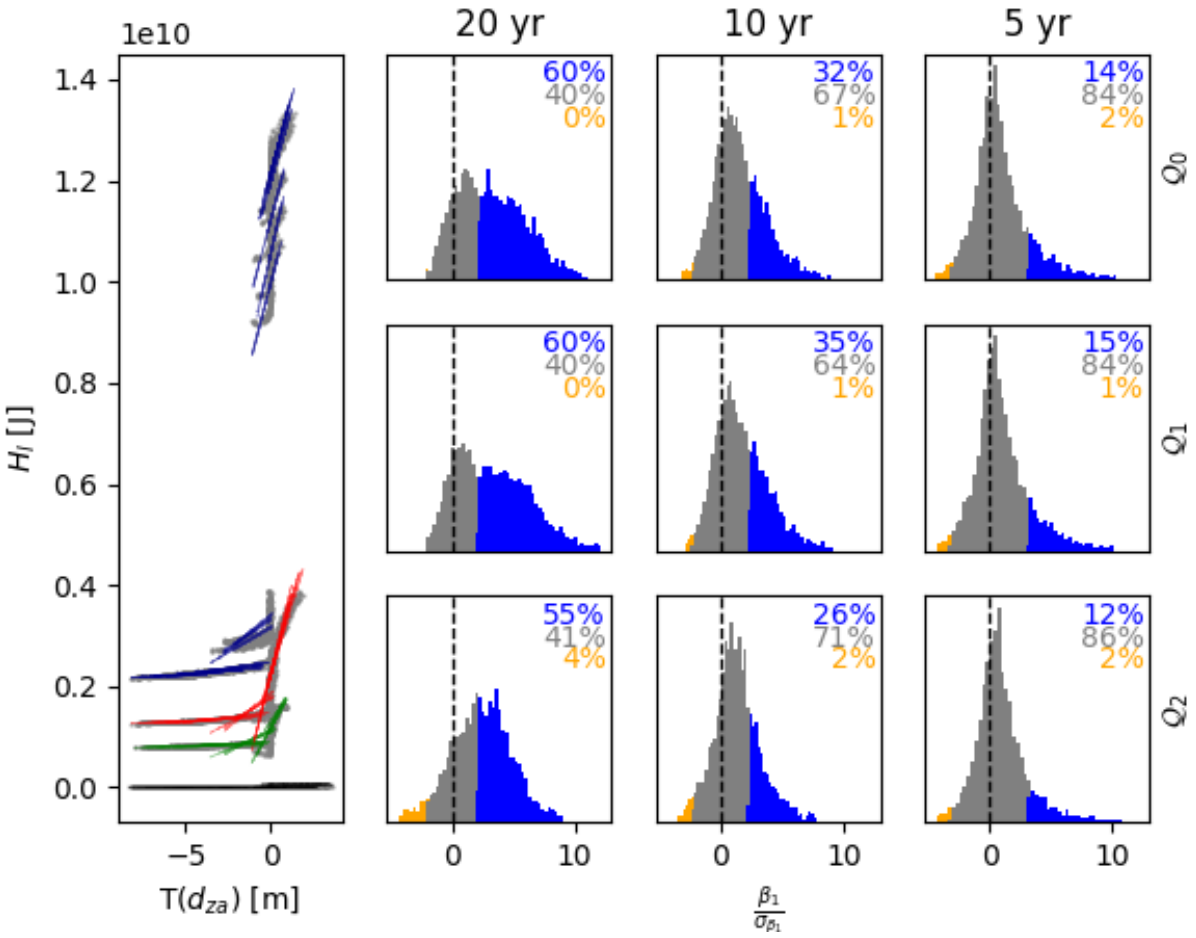

Figure S14: Effect of sensor quality and data length on the significance of metric (T_{za}) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

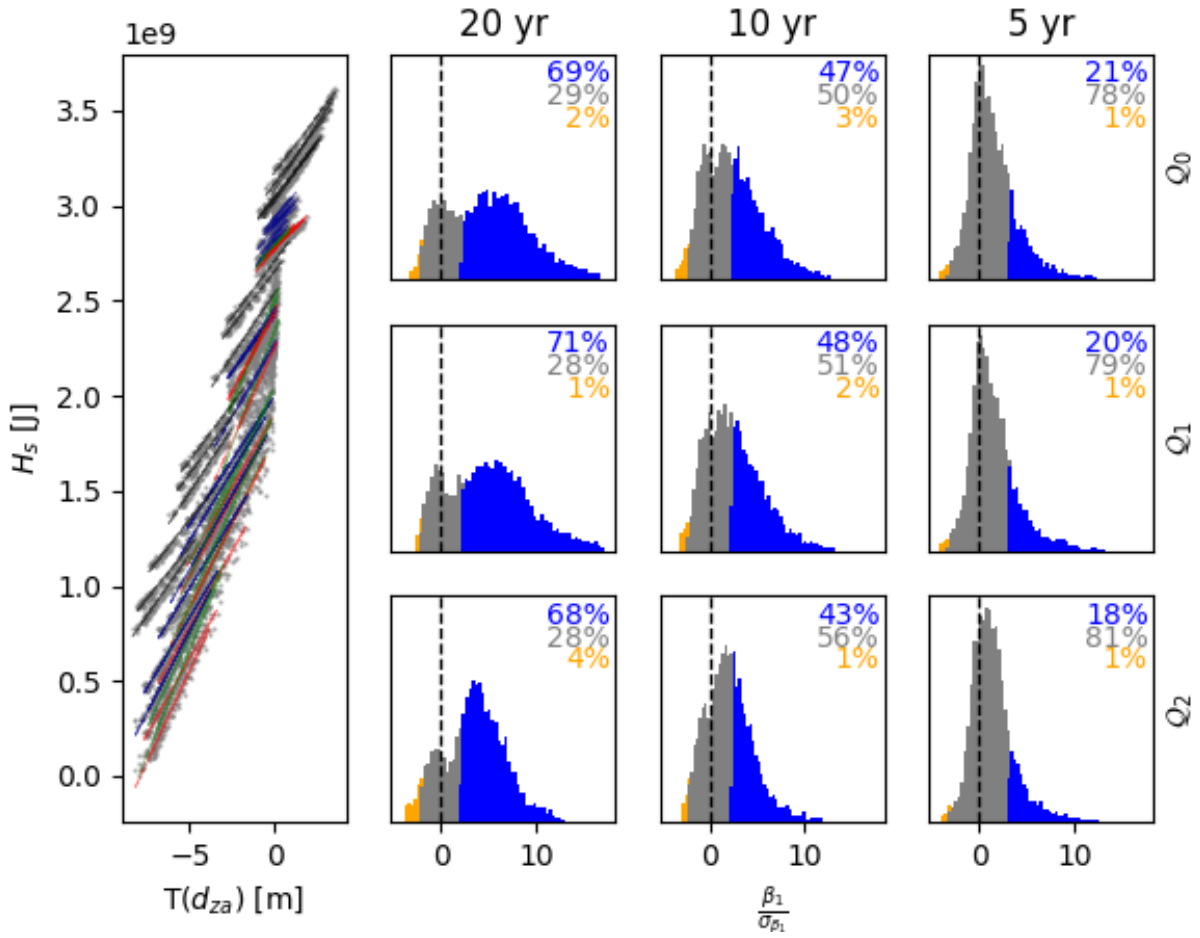

Figure S15: Effect of sensor quality and data length on the significance of metric (T_{za}) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

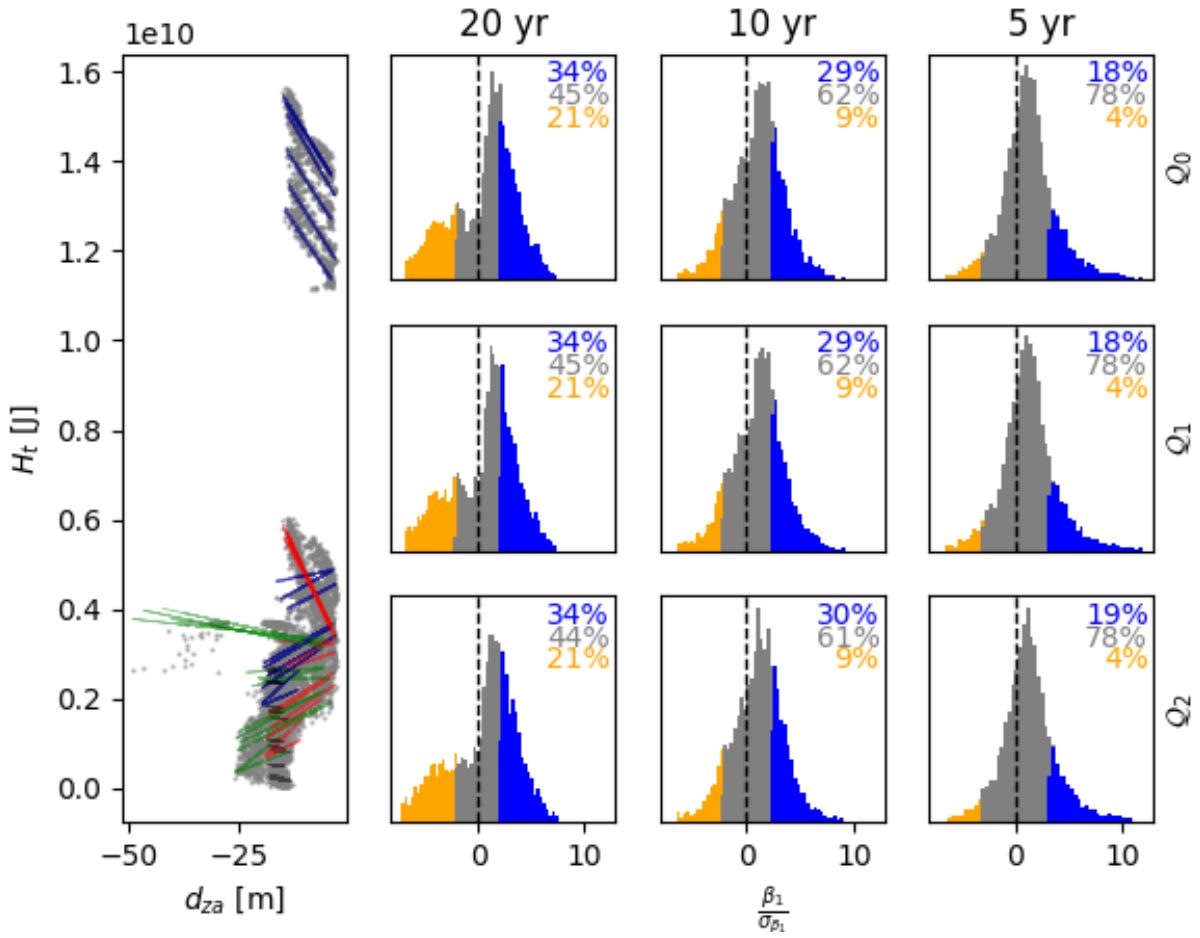

Figure S16: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

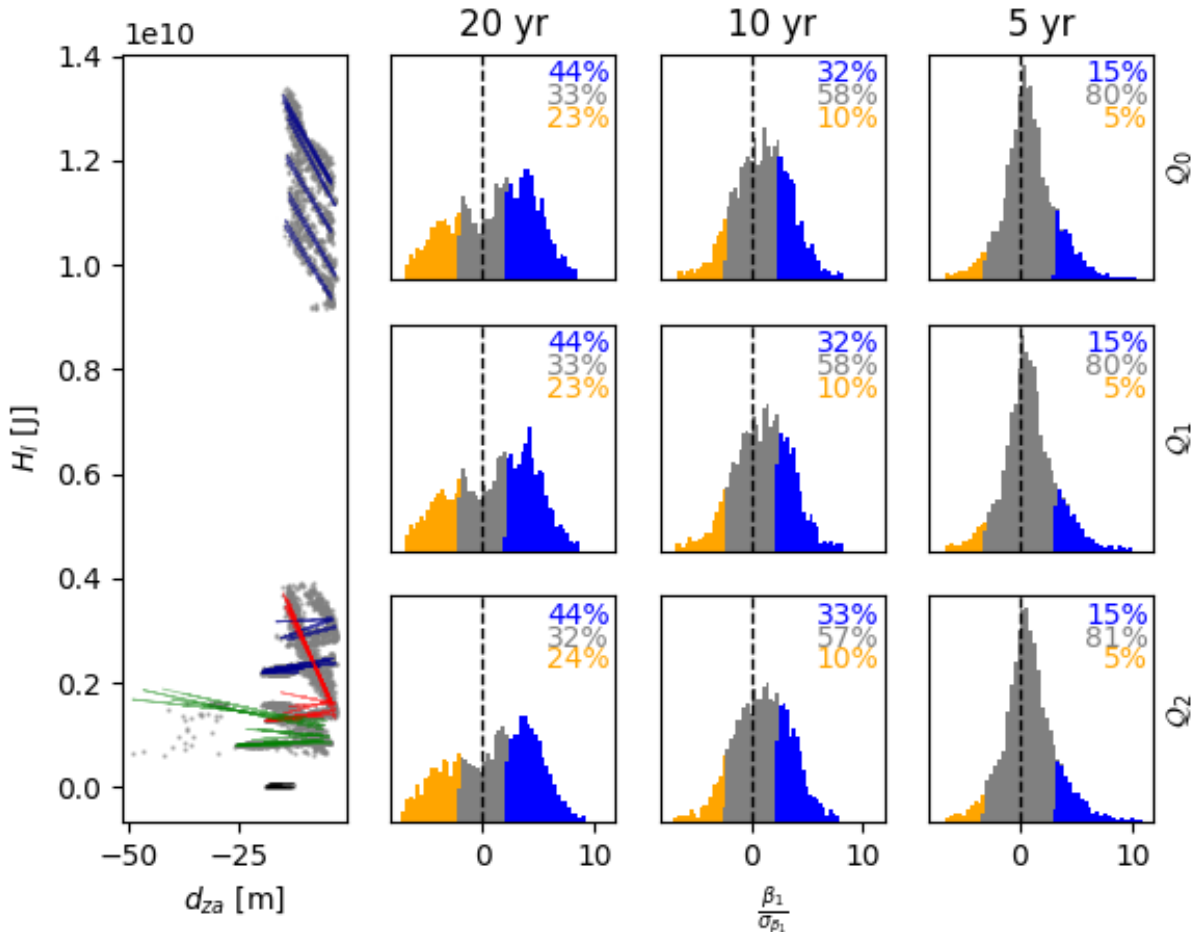

Figure S17: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

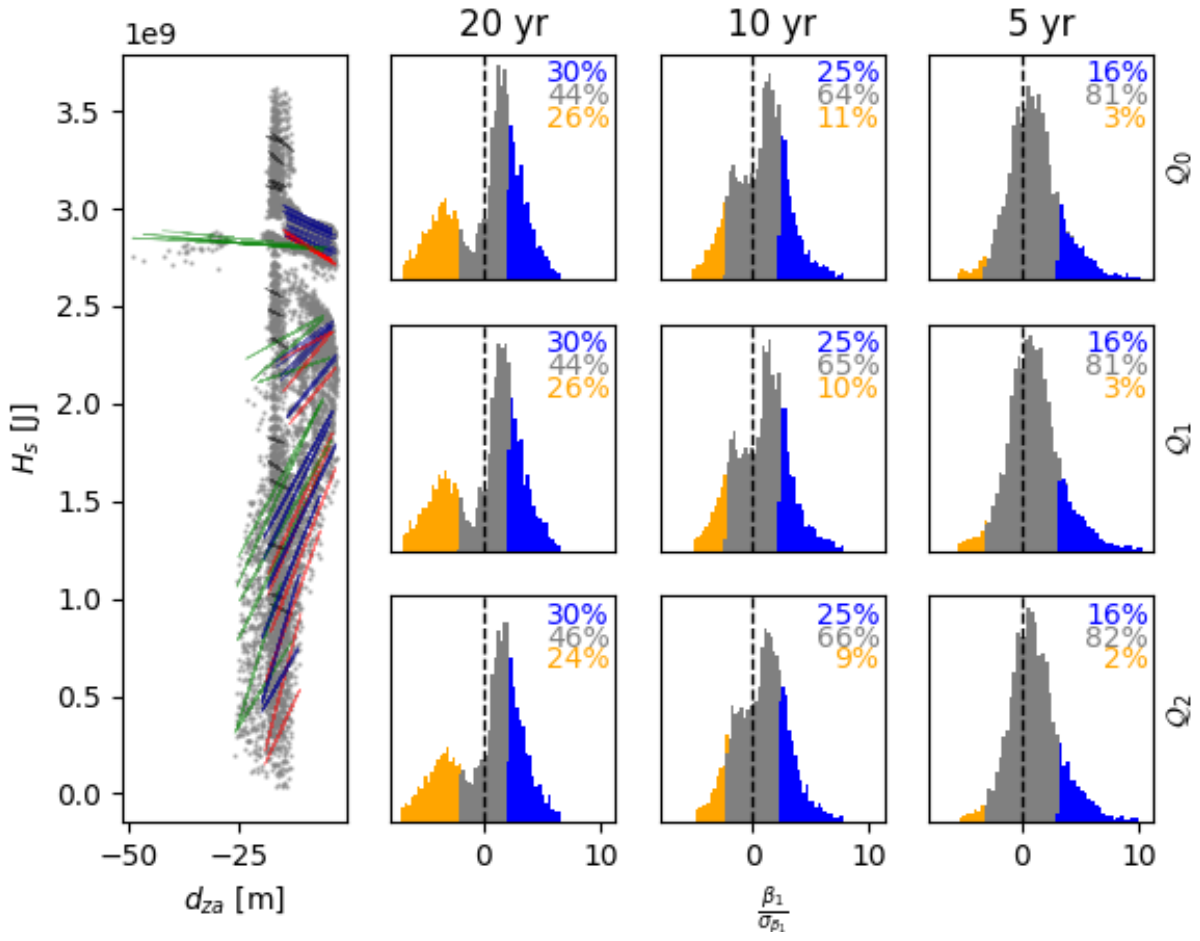

Figure S18: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

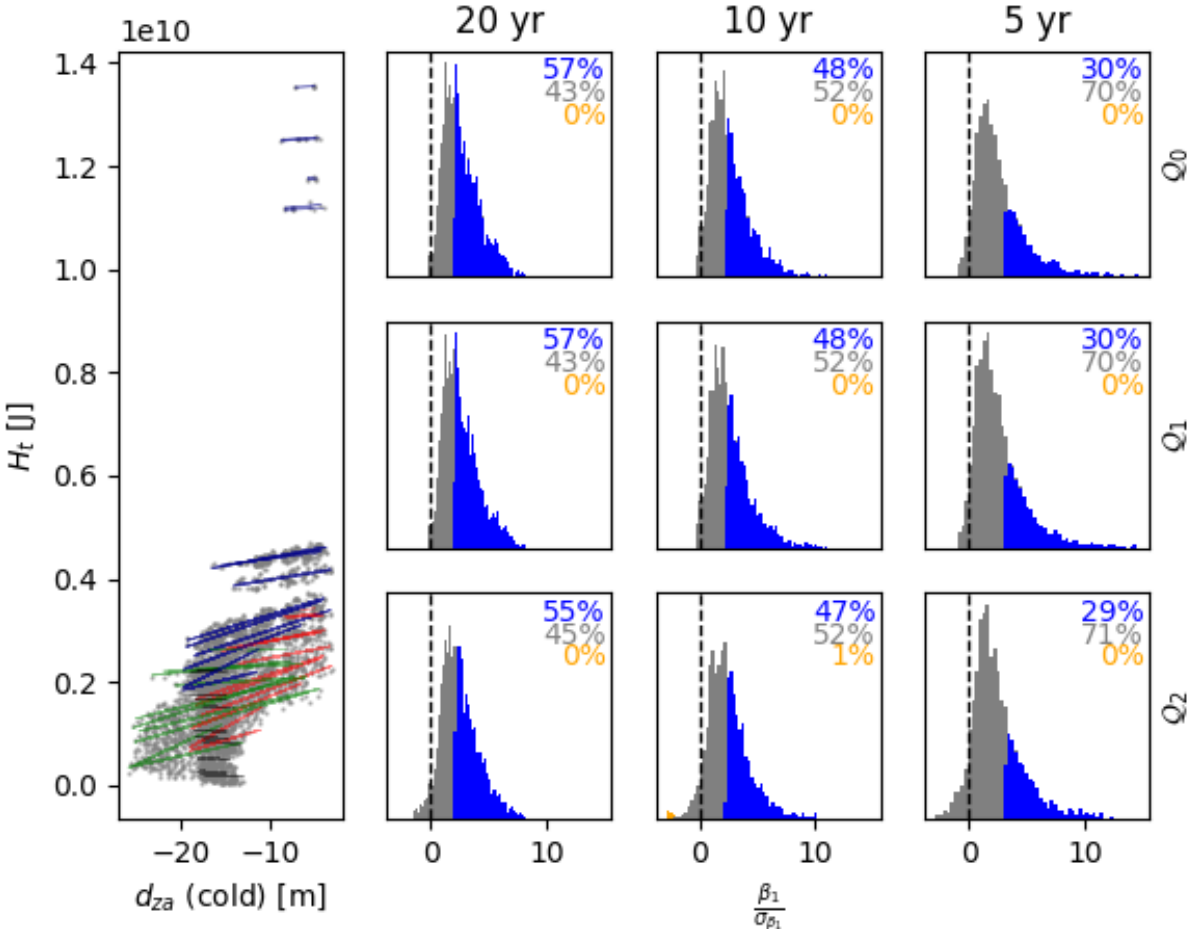

Figure S19: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_t) relationship for cold conditions. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

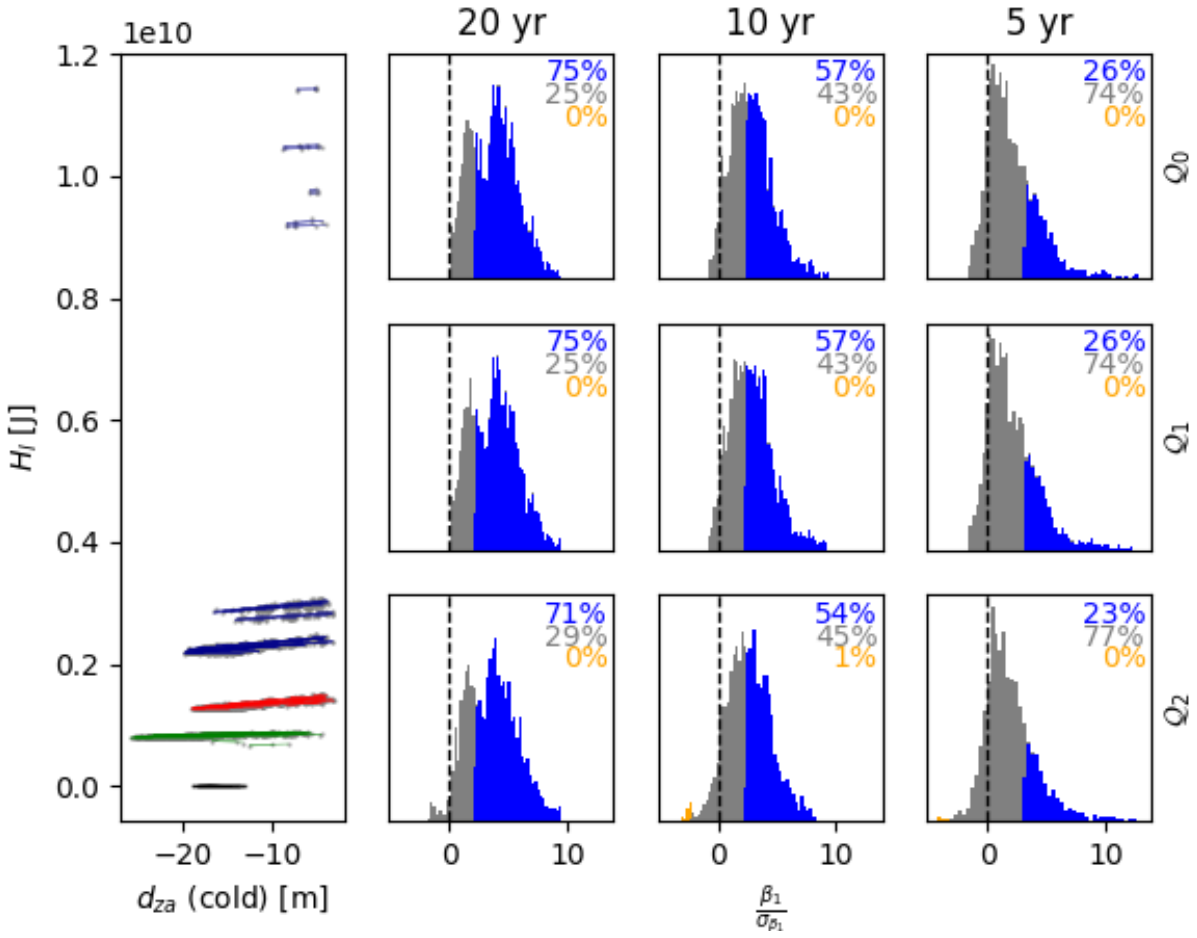

Figure S20: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_l) relationship for cold conditions. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

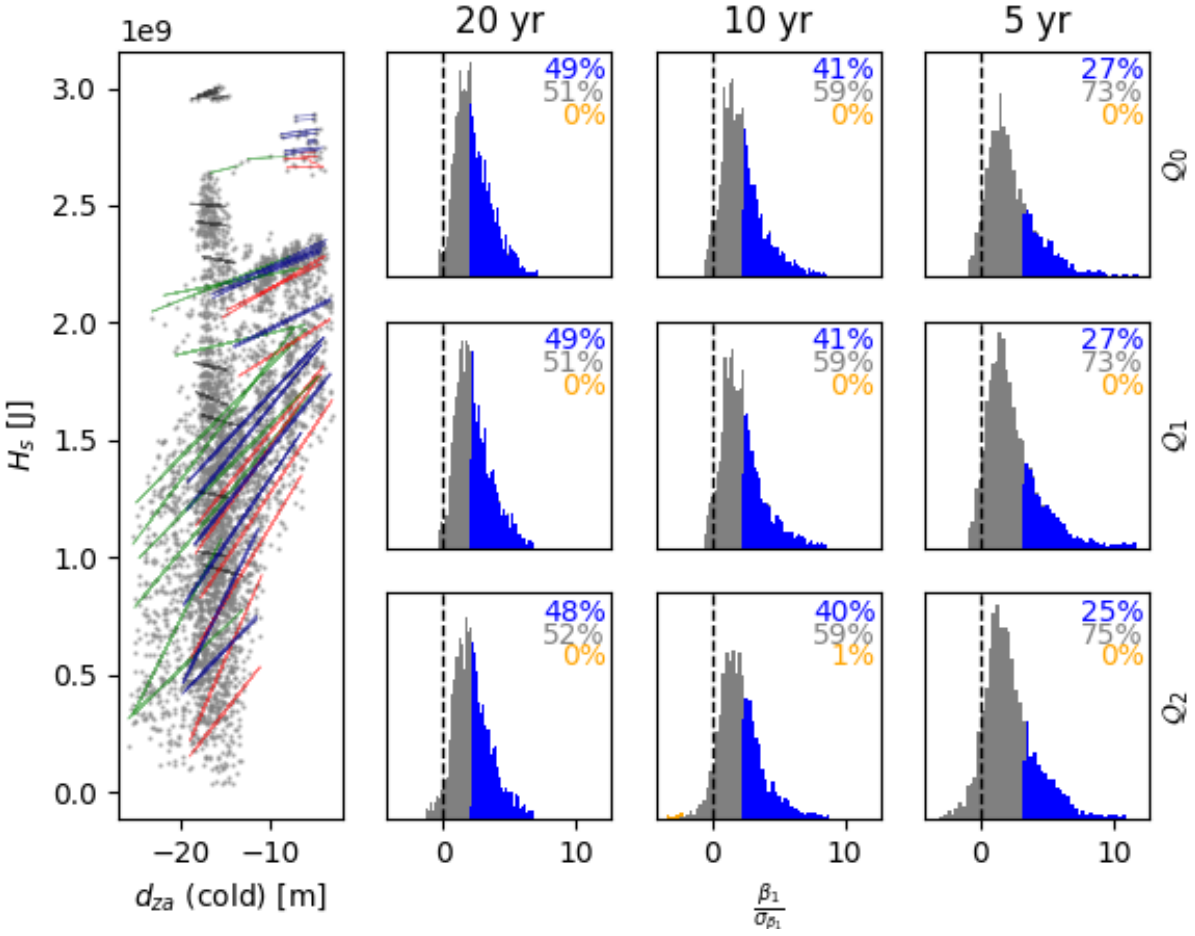

Figure S21: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_s) relationship for cold conditions. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

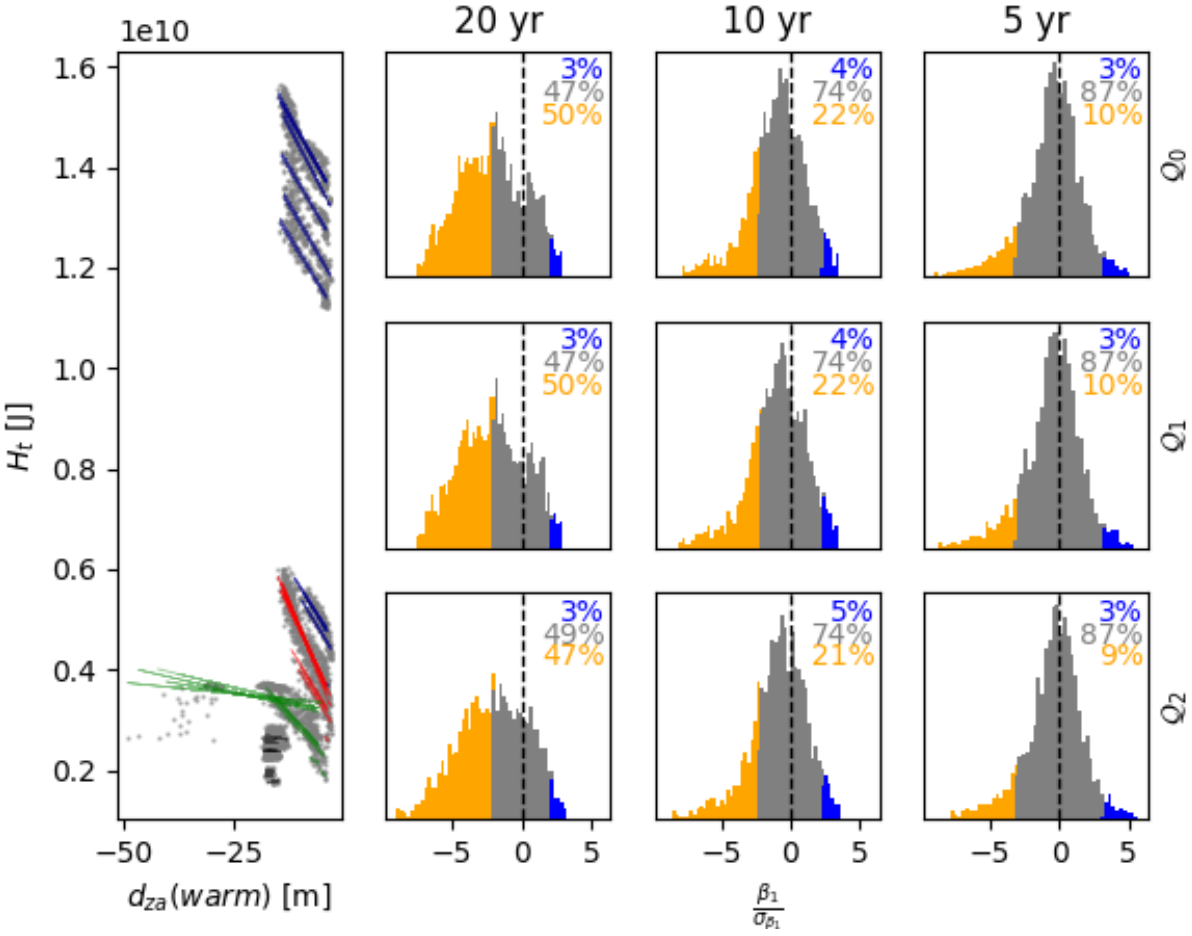

Figure S22: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_t) relationship for warm conditions. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

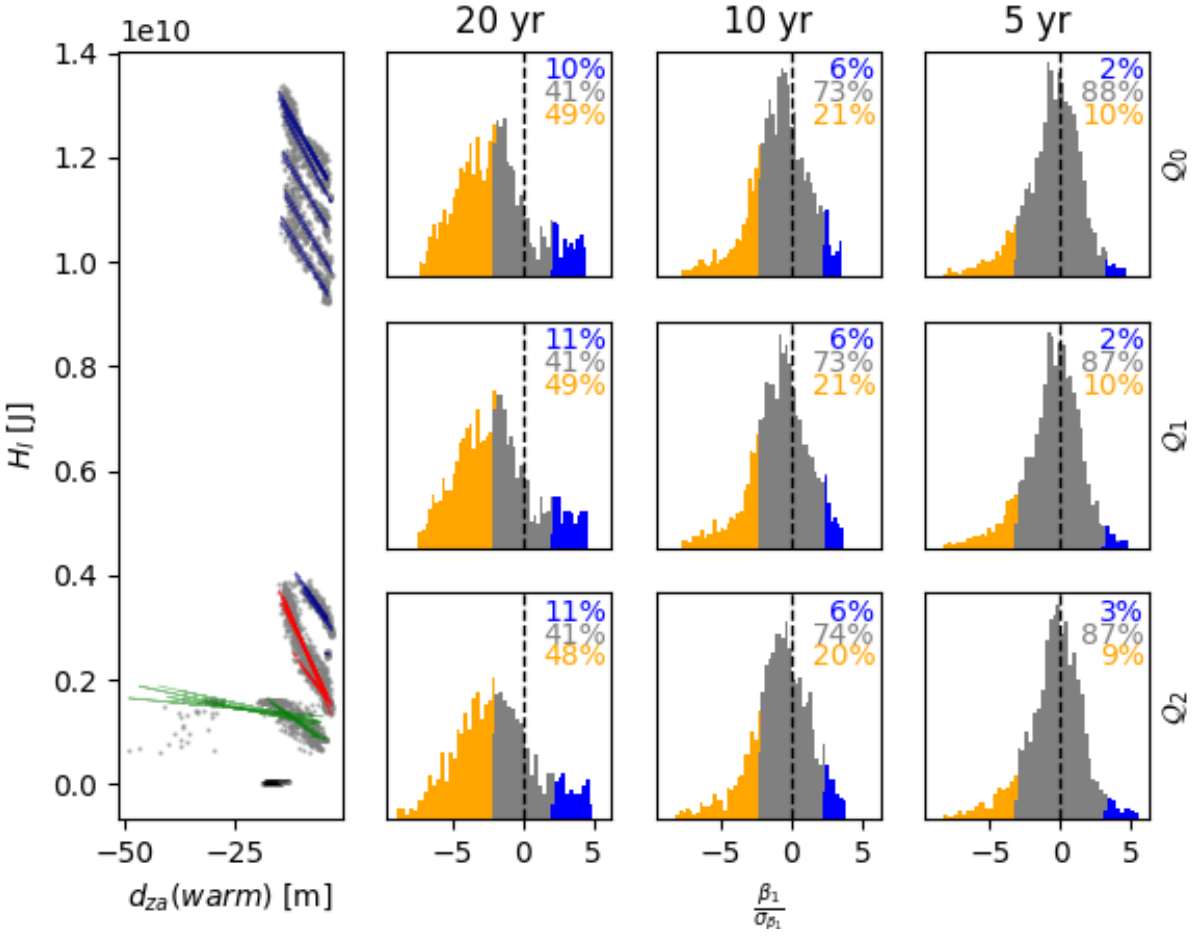

Figure S23: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_l) relationship for warm conditions. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

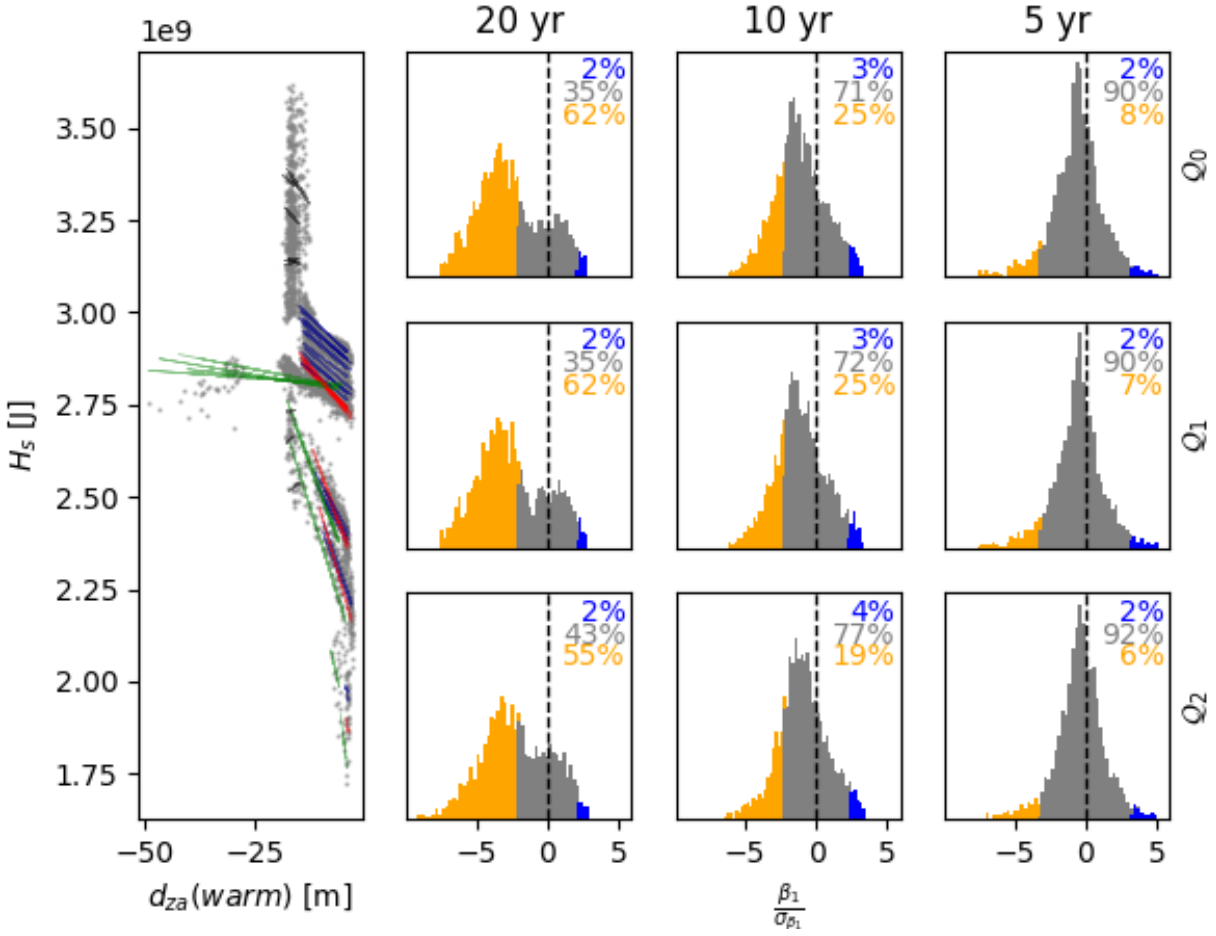

Figure S24: Effect of sensor quality and data length on the significance of metric (d_{za}) - heat (H_s) relationship for warm conditions. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

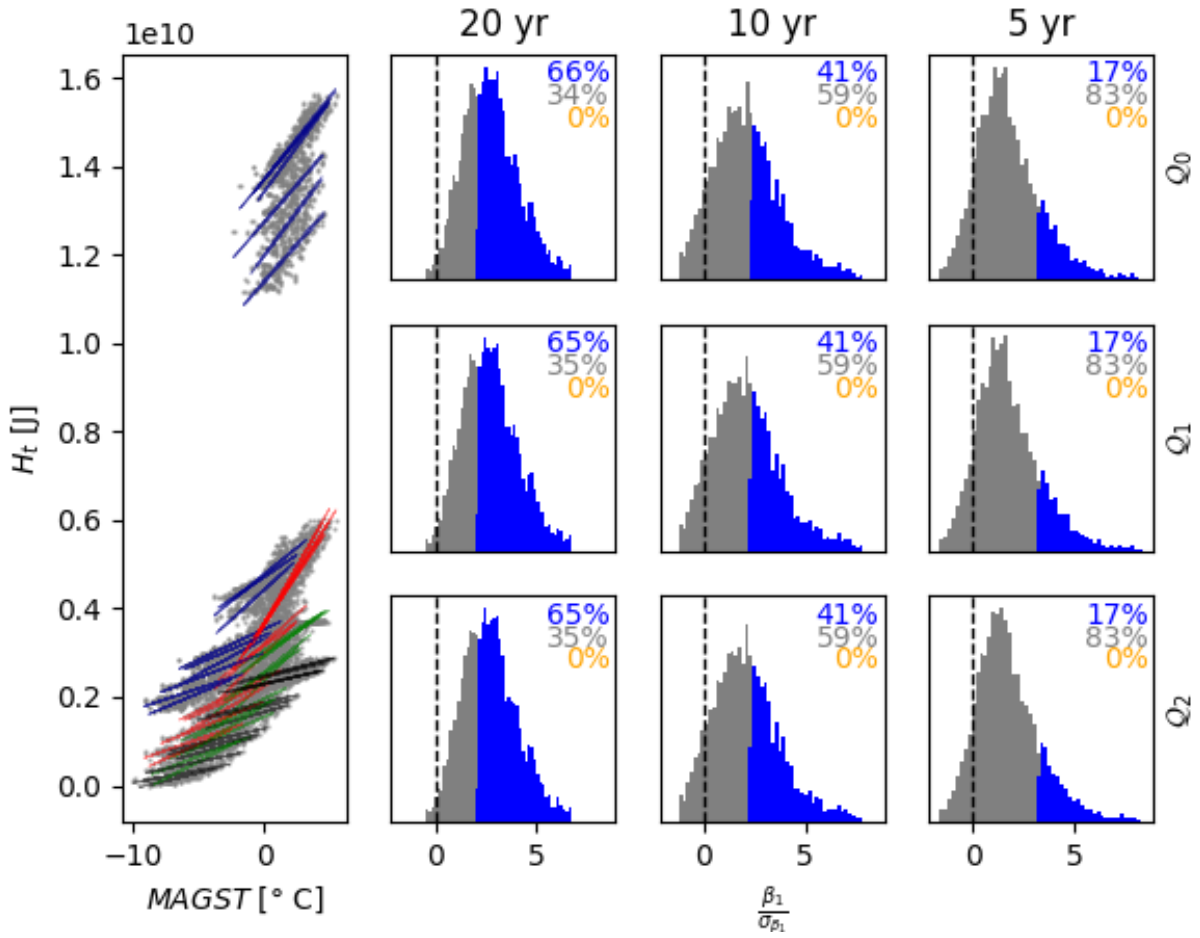

Figure S25: Effect of sensor quality and data length on the significance of metric (MAGST) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

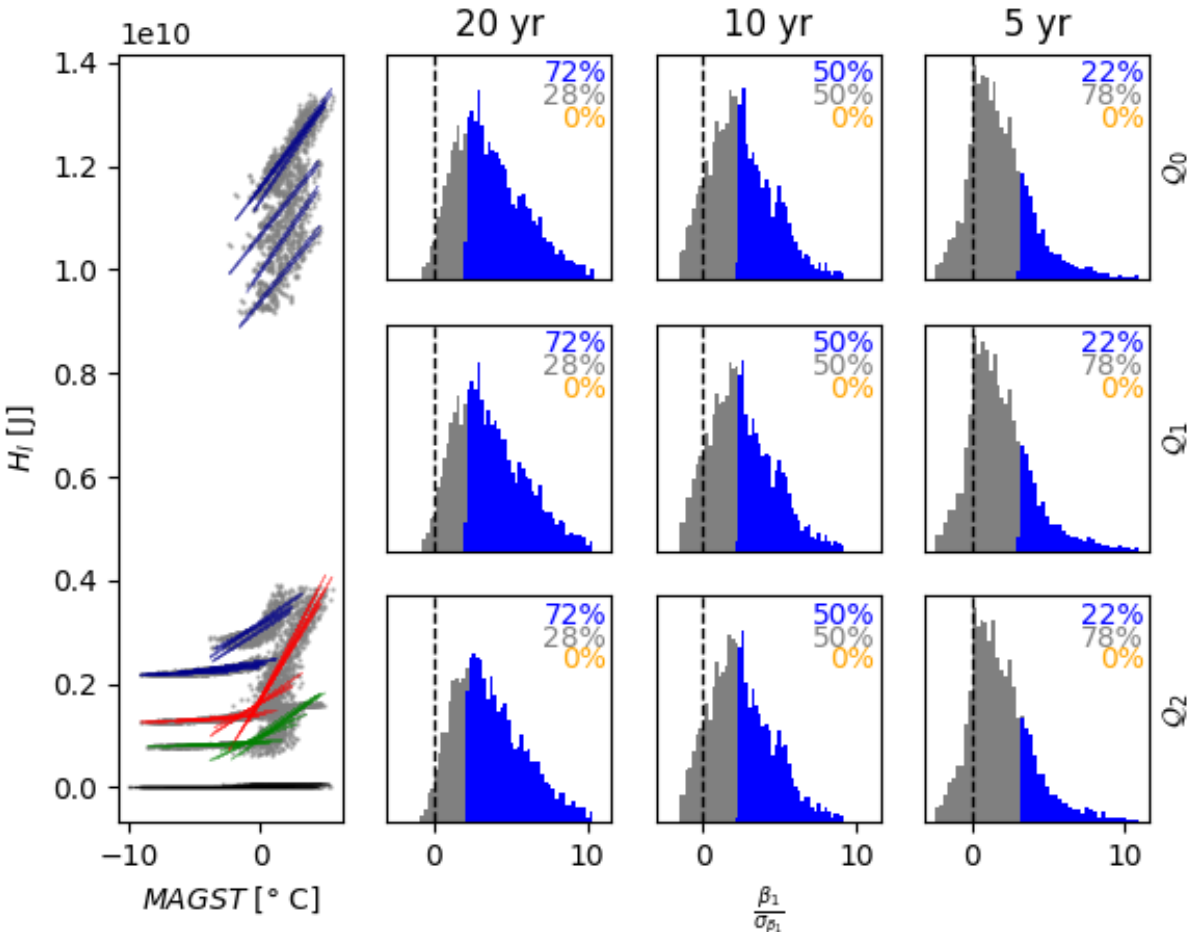

Figure S26: Effect of sensor quality and data length on the significance of metric (MAGST) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

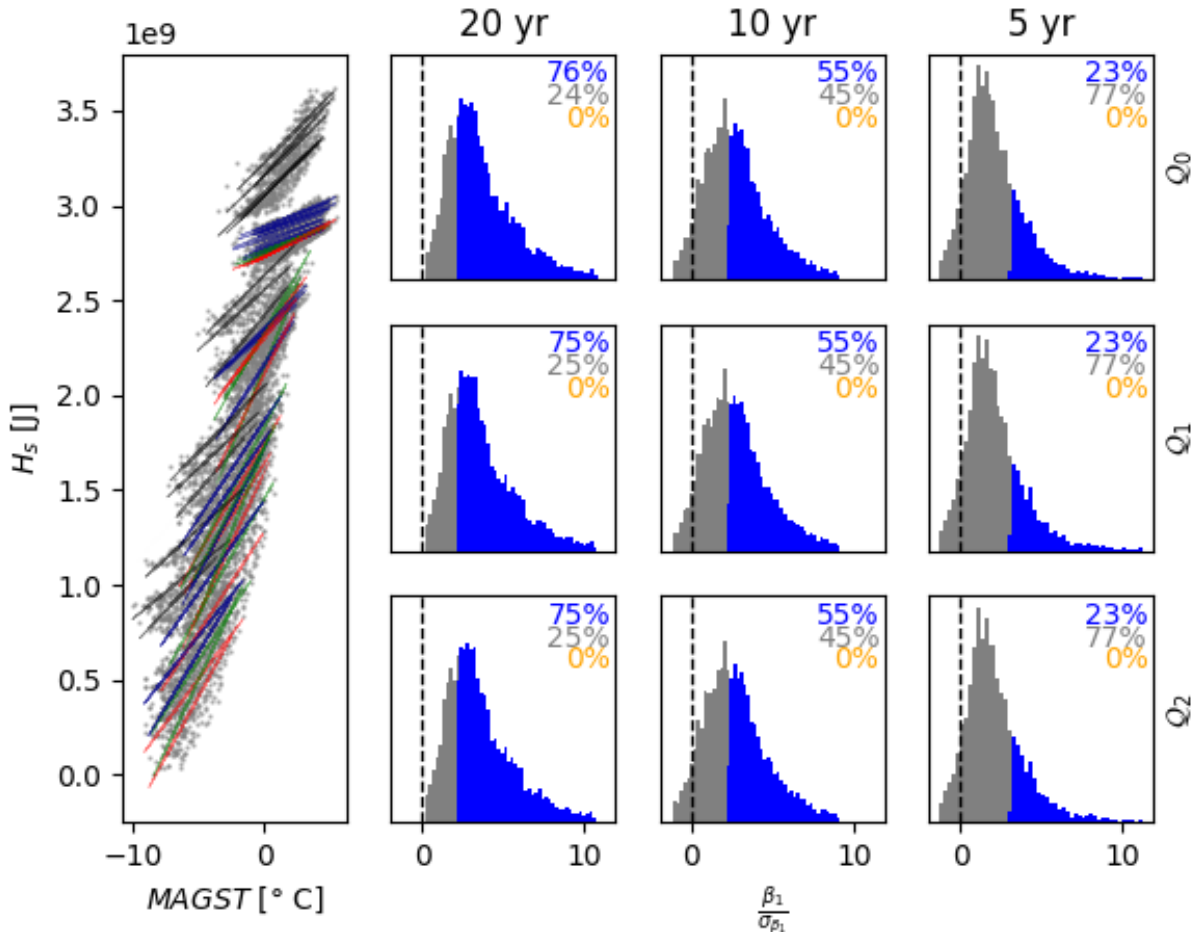

Figure S27: Effect of sensor quality and data length on the significance of metric (MAGST) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

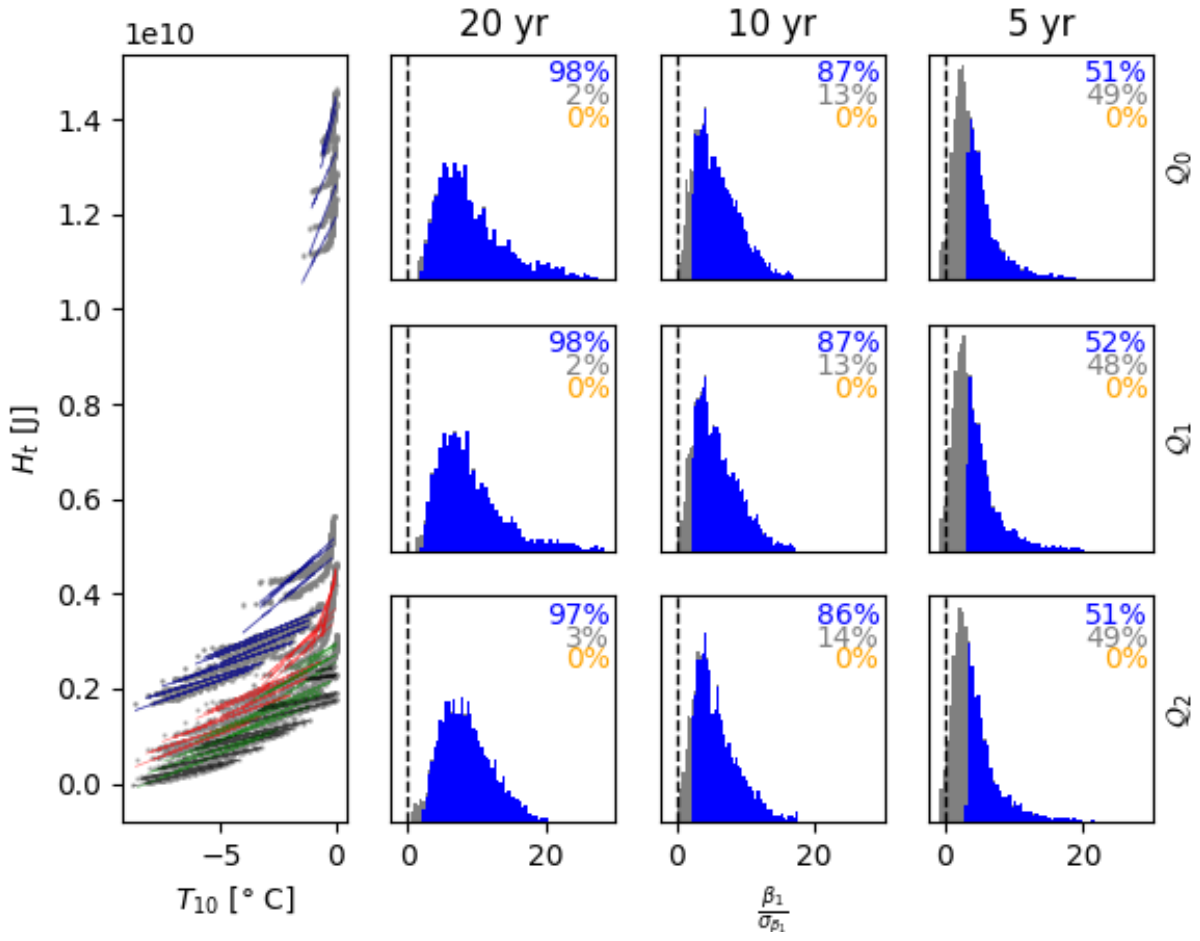

Figure S28: Effect of sensor quality and data length on the significance of metric () - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

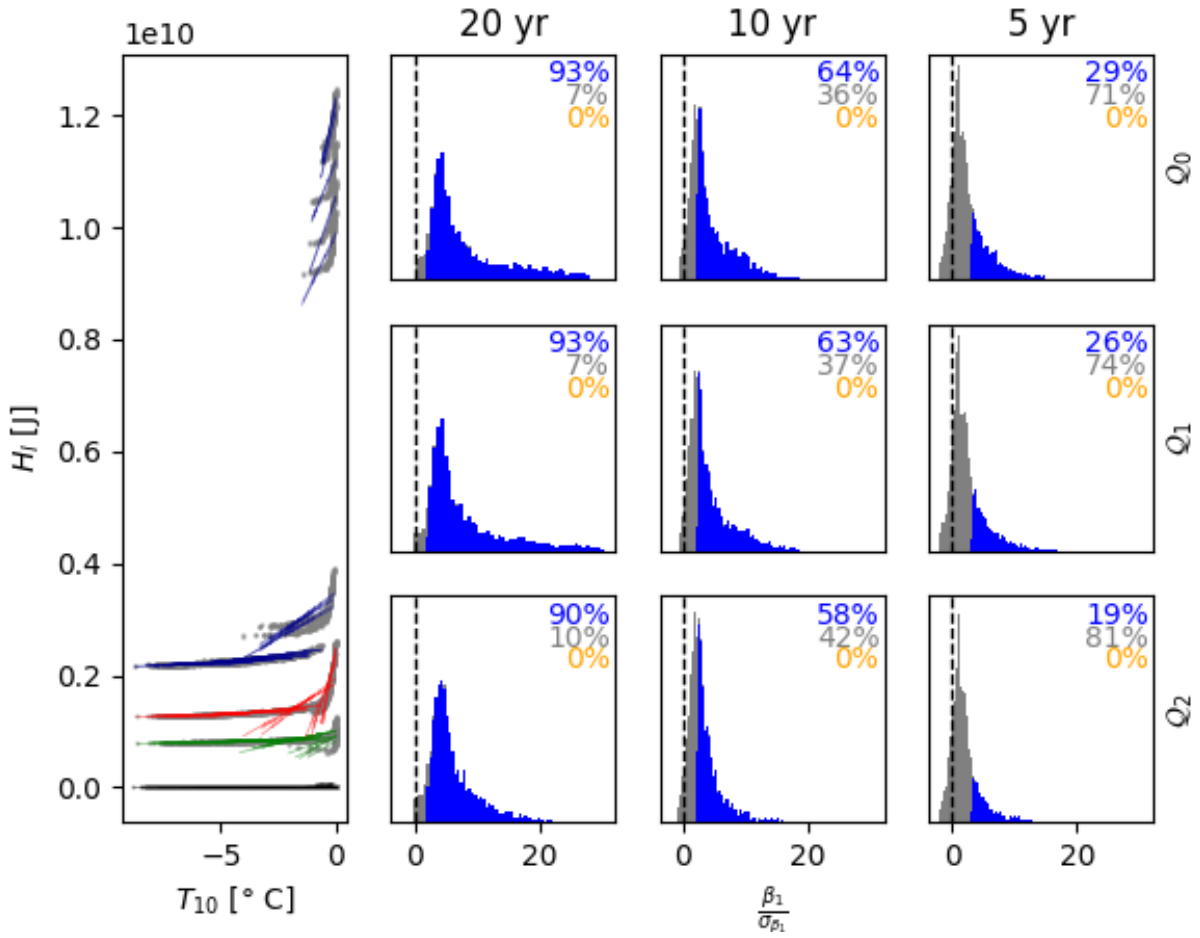

Figure S29: Effect of sensor quality and data length on the significance of metric (T_{10}) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

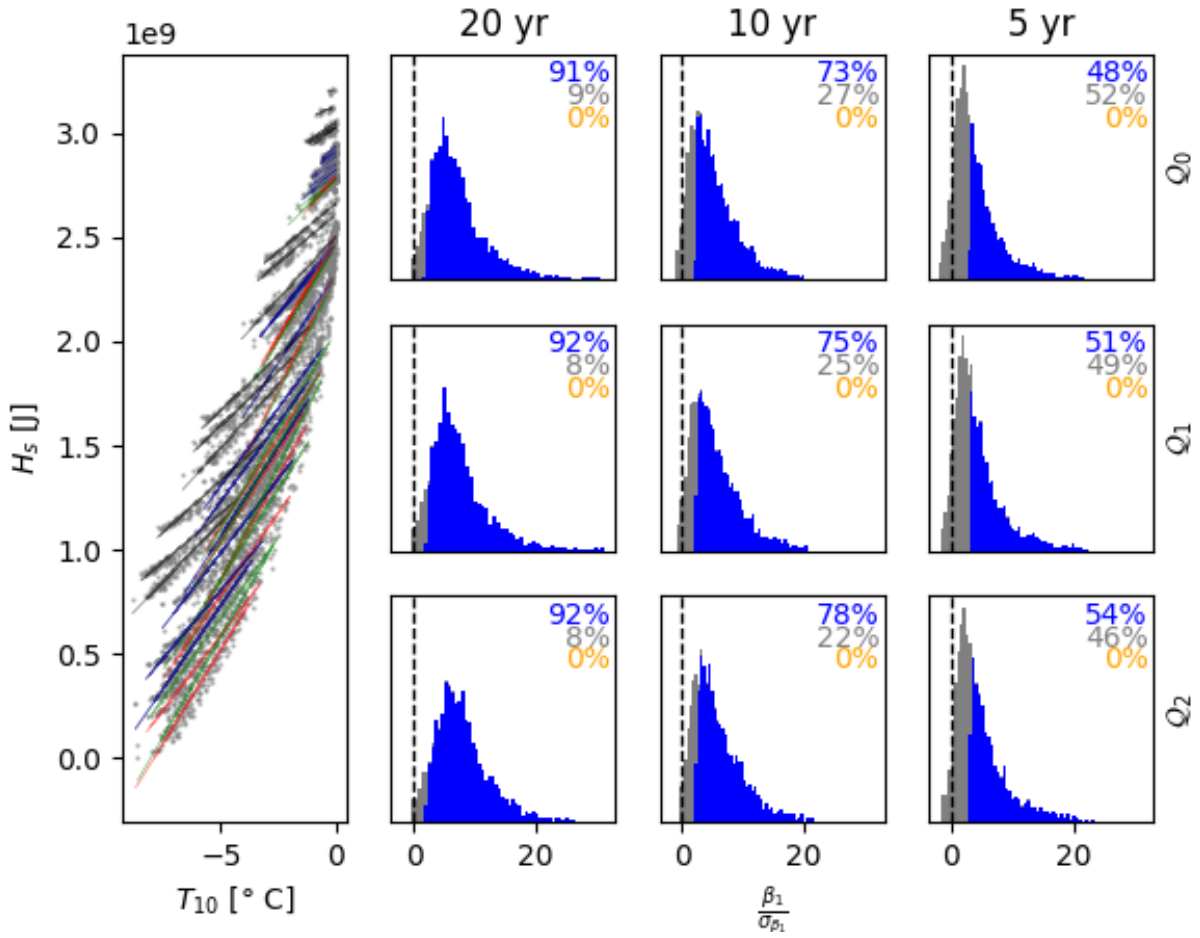

Figure S30: Effect of sensor quality and data length on the significance of metric (T_{10}) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

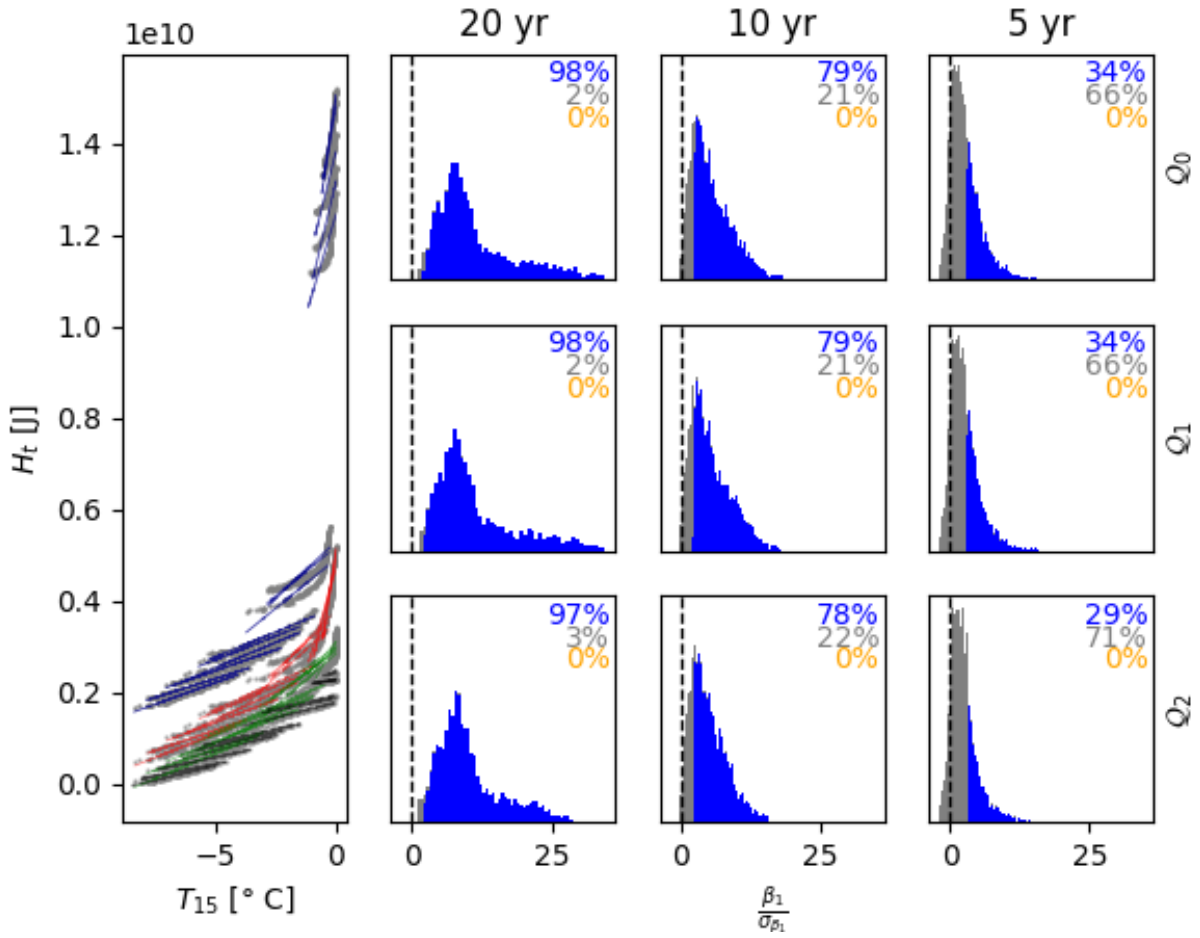

Figure S31: Effect of sensor quality and data length on the significance of metric (T_{15}) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

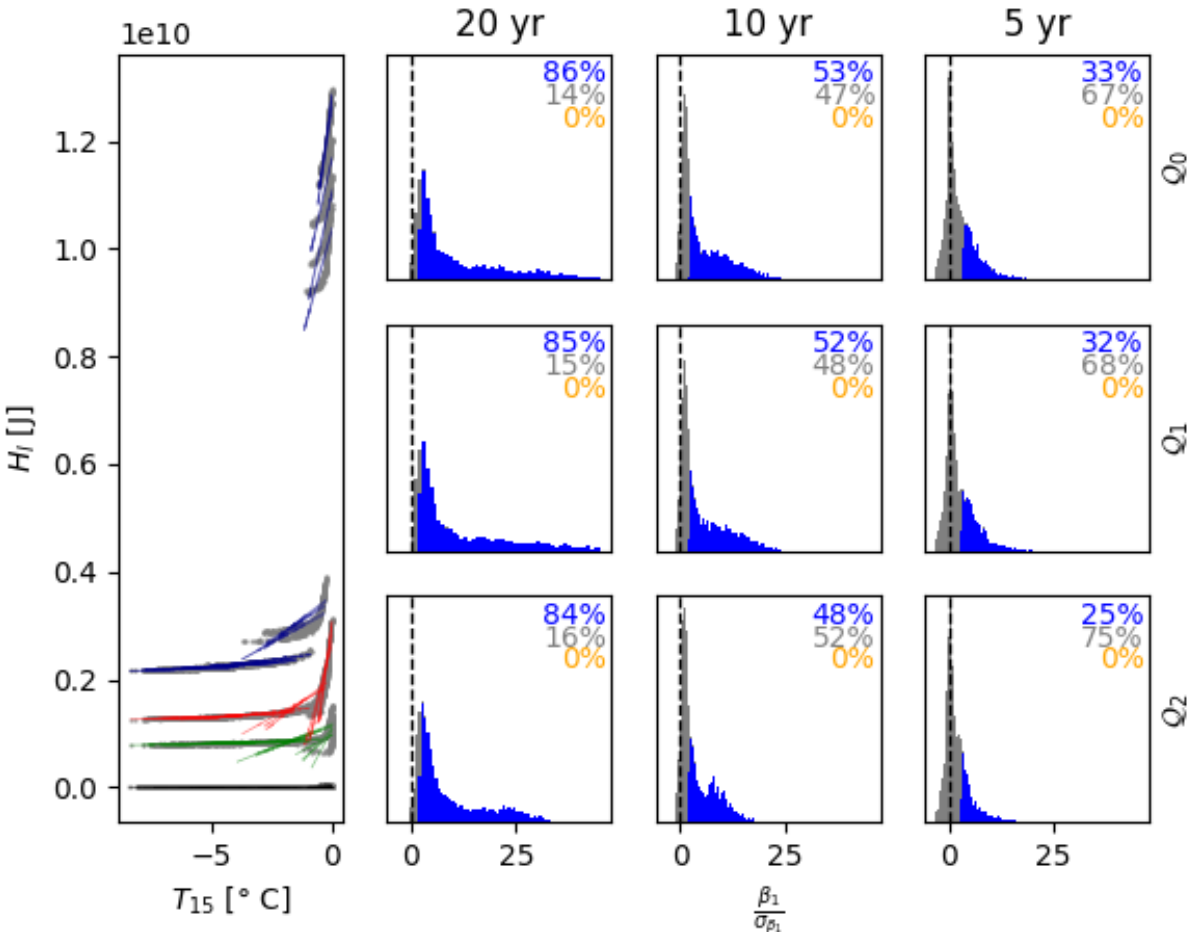

Figure S32: Effect of sensor quality and data length on the significance of metric (T_{15}) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

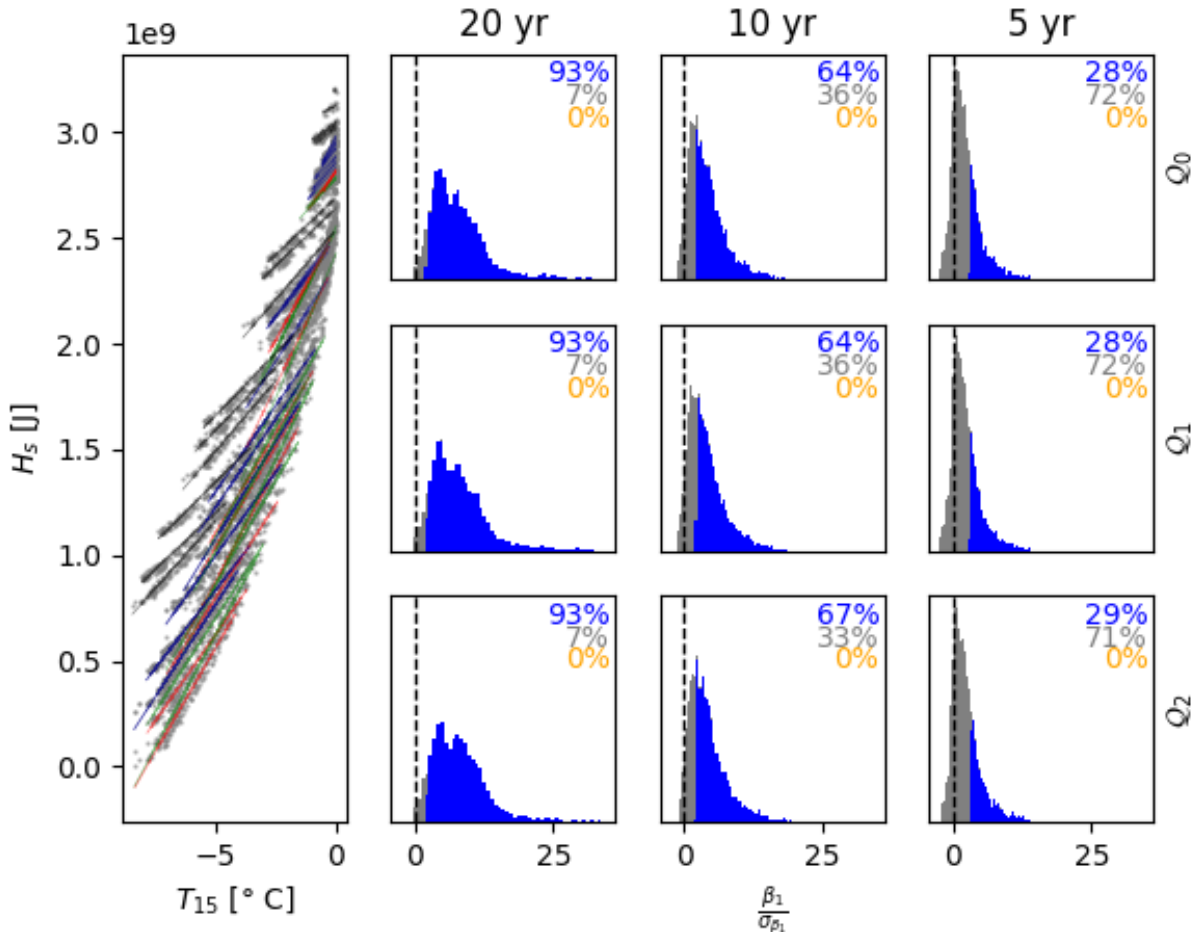

Figure S33: Effect of sensor quality and data length on the significance of metric (T_{15}) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

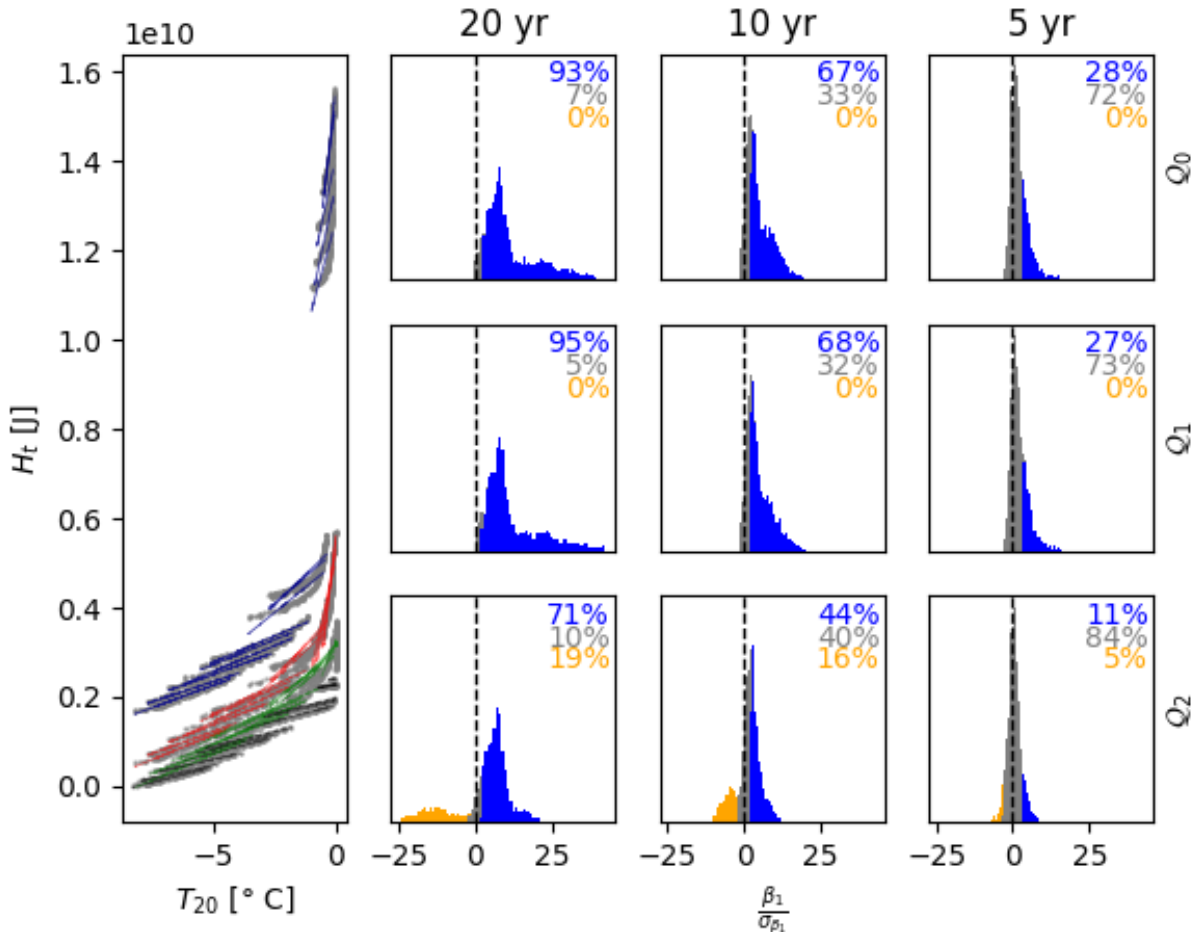

Figure S34: Effect of sensor quality and data length on the significance of metric (T_{20}) - heat (H_t) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

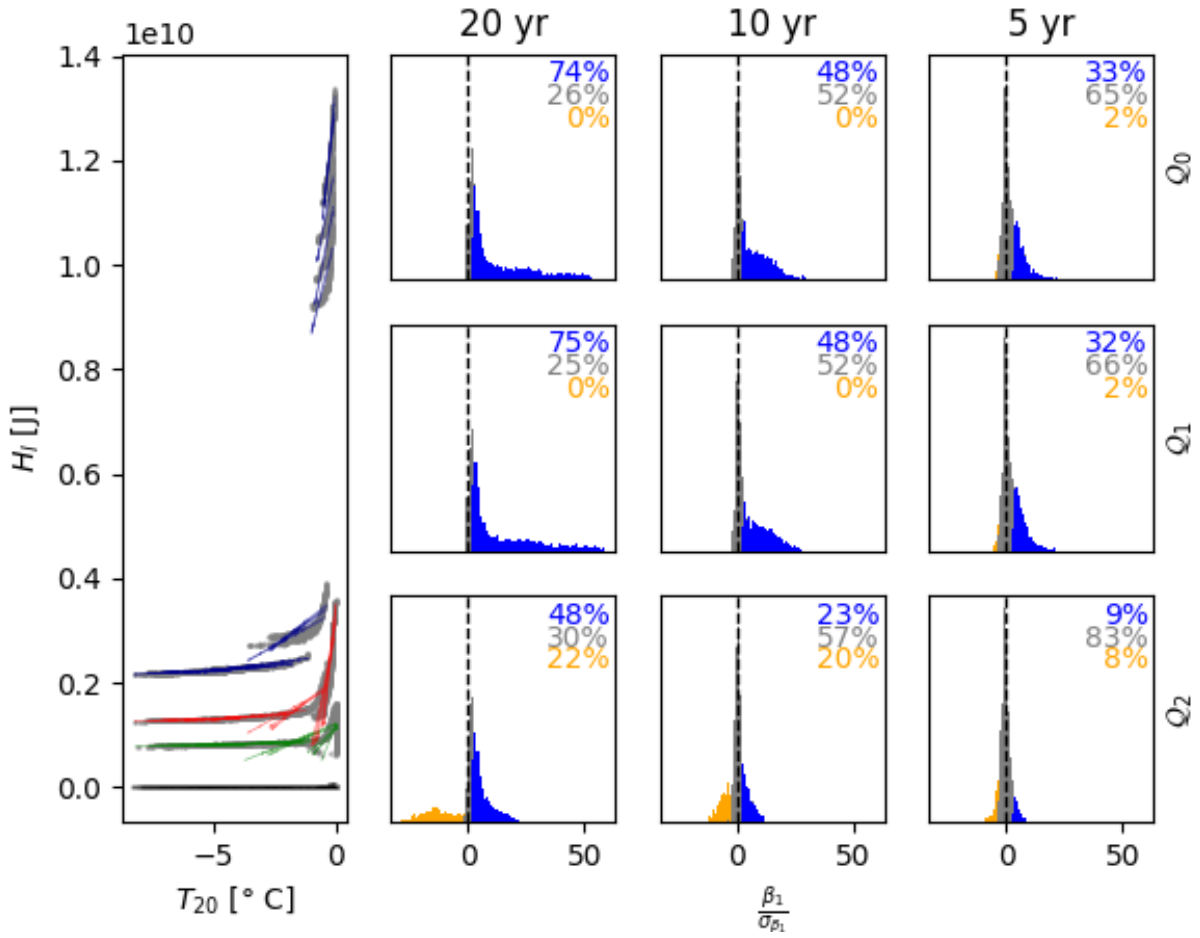

Figure S35: Effect of sensor quality and data length on the significance of metric (T_{20}) - heat (H_l) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

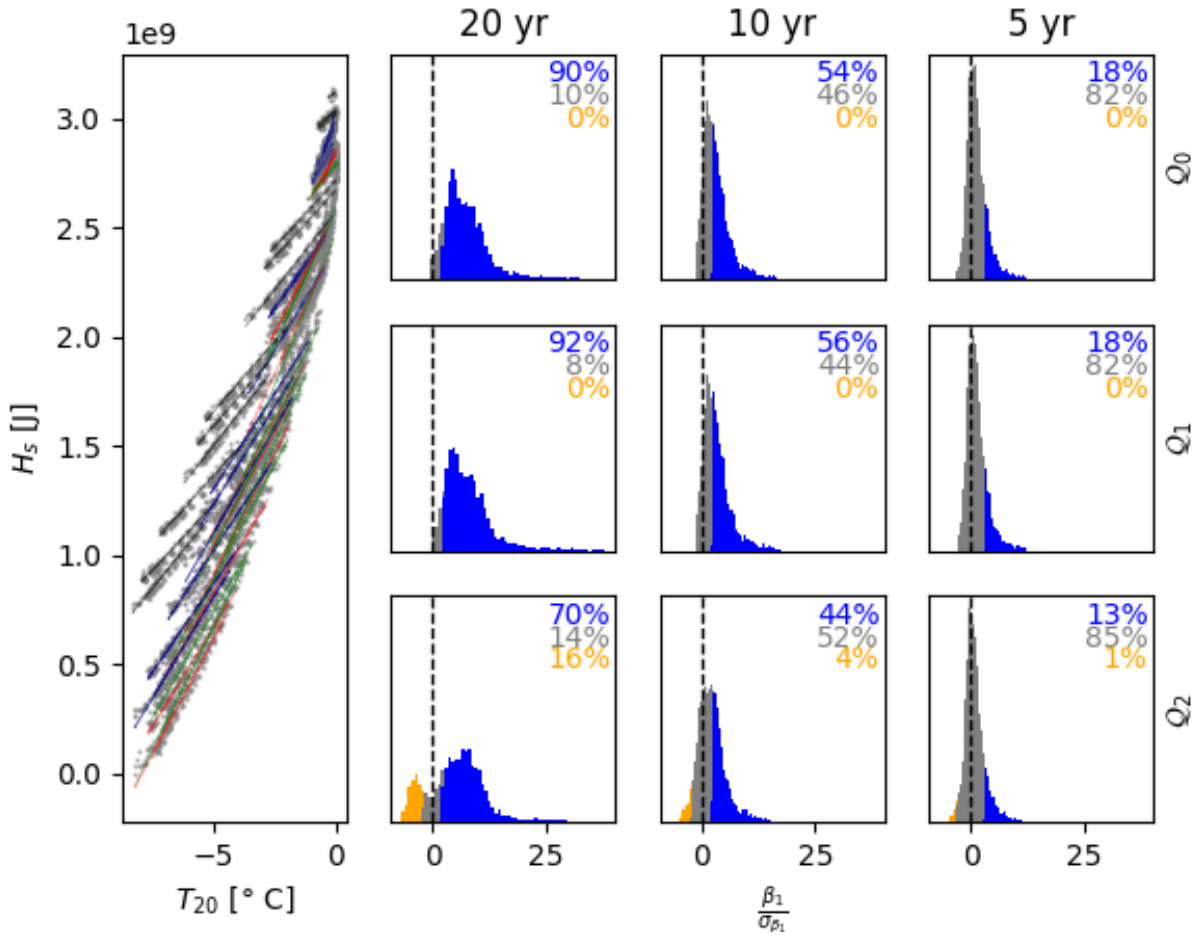

Figure S36: Effect of sensor quality and data length on the significance of metric (T_{20}) - heat (H_s) relationship. Larger t-values indicate a more reliable relationship between changes in metric and changes in heat content. More consistently positive or negative t-values demonstrate a less ambiguous interpretation from the metric.

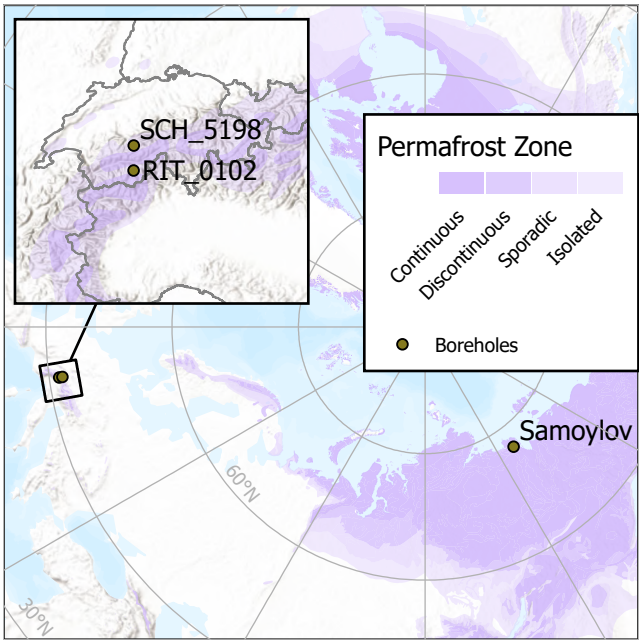

Figure S 37: Map of boreholes used in case study. Permafrost zones are shown in light purple based on data from the Circum-Arctic Map of Permafrost and Ground-Ice (Heginbottom et al., 1993).