Supplementary information

Early-twentieth-century cold bias in ocean surface temperature observations

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Supplementary Information to 'Early-twentieth-century cold bias in ocean surface temperature observations'

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43 1 Evaluation of reconstruction method

In this supplementary section, we provide a comprehensive evaluation and further discussion of 44 our reconstruction method, which was outlined in the main text. Our approach addresses the 45 measurement uncertainties and biases in historical temperature records by utilizing the uncertainty 46 and bias estimates developed for the CRUTEM5 and HadSST4 datasets (Kennedy et al. 2019; 47 Osborn et al. 2021; Morice et al. 2021). Specifically, we incorporate these models to refine our 48 regression coefficients, denoted as $\hat{\beta}^{* \text{GMST}}_{\text{Land:1895-06}}$ for coefficients that account for uncertainties (that is, 49 uncertainty estimates are added to CMIP6 model for training of the statistical model), compared to 50 $\hat{\beta}_{\text{Land},1895-06}^{\text{GMST}}$ for coefficients derived without consideration of these uncertainties and biases (that is, 51 no uncertainties added during training). The subscript indicates the source data (land or ocean) and 52 the respective time step of the mask (e.g., June 1895). The overall setup is illustrated in Extended 53 Data Fig. 1. 54

Illustrative Maps of Regression Coefficients In Extended Data Fig. 2, we show maps of regres-55 sion coefficients for an illustrative time step with sparse coverage in the early record (June 1895). 56 These maps show coefficients for the land and ocean early coverage both without considering un-57 certainties ($\hat{\beta}_{\text{Land:1895-06}}^{\text{GMST}}$, panel a; $\hat{\beta}_{\text{Ocean:1895-06}}^{\text{GMST}}$, panel c) and coefficients when uncertainty and bias 58 estimates are considered at training time ($\hat{\beta}^{* \text{ GMST}}_{\text{Land: 1895-06}}$, panel b; $\hat{\beta}^{* \text{ GMST}}_{\text{Ocean: 1895-06}}$, panel d). When training 59 is based on CMIP6 models only ($\hat{\beta}_{\text{Land:1895-06}}^{\text{GMST}}$, that is, without considering uncertainty and bias esti-60 mates), the algorithm assigns large positive weights to tropical land grid cells, particularly islands 61 and coastal stations, which thus exert a predominant influence on GMST estimates (Extended Data 62

Figure 2a). A similar behaviour is observed for coefficients over the ocean ($\hat{\beta}_{\text{Ocean:1895-06}}^{\text{GMST}}$, Extended Data Fig. 2c), where in particular coastal ocean grid cells and ocean grid cells that lie adjacent to large unobserved regions (e.g., tropical Pacific) show large positive weights. This behaviour may be understood from the fact that tropical regions are highly informative for global temperature estimates, and the pattern of regression coefficients is qualitatively consistent with other global temperature estimators, such as those similar to kriging (Cowtan et al. 2018).

However, this approach may not be ideal because observational uncertainties are not con-69 sidered, and uncertainties are not equally distributed across space. In particular tropical grid cells 70 in the early record are likely affected by large relative uncertainties and a relatively poor station 71 density. When uncertainties are incorporated at training time (see details in methods in the main 72 text), regression coefficients are distributed more evenly across the spatial domain for both land 73 and ocean (Extended Data Fig. 2b,d). This behaviour thus reflects the trade-off to make use of the 74 most informative grid cells in the reconstruction, but at the same time minimizing the effect of un-75 certainties. Overall, this methodological adjustment reduces the influence of individual, uncertain 76 grid cells. The performance of our regression method for reconstructing GMST in CMIP6 models 77 for the illustrative June 1895 ocean and land coverage is good and shown in Extended Data Fig. 3. 78

79 Systematic Evaluation of Reconstruction Error We systematically assess the error estimates across time by comparing our reconstruction method to the global temperature average estimator (Cowtan et al. 2018), a method similar to kriging. The evaluation is based on a reconstruction of CMIP6 models' GMST from a sparse coverage mask of either land or ocean. We evaluate the

reconstruction method where uncertainties are considered and not considered at training time (i.e., 83 $\hat{\beta}_{\text{Land}}^{\text{GMST}}$, $\hat{\beta}_{\text{Land}}^{* \text{ GMST}}$, pink vs. red lines in Supplementary Figure 1). Both methods are evaluated against 84 CMIP6 models not used in training, and either based on the raw output of those CMIP6 models 85 without adding uncertainty estimates (dashed lines in Supplementary Figure 1), and for a scenario 86 where uncertainty estimates are added for evaluation (solid lines in Supplementary Figure 1). The 87 benchmark GTA estimator (Cowtan et al. 2018) is adapted such that the global temperature average 88 is obtained for land and ocean separately; and in a second step we scale the obtained averages 89 in CMIP6 data to obtain a GMST estimate from land and ocean data separately. Including our 90 benchmark GTA estimator (Cowtan et al. 2018), this yields in total six scenarios. 91

The land-based reconstructions indicate a sharp reduction in annual mean squared errors for 92 all scenarios over time as coverage increases (Supplementary Figure 1a). Notably, after 1930, 93 the errors decrease strongly for the evaluation with uncertainties added, because of a large reduc-94 tion of spread in the CRUTEM5 bias ensembles (Morice et al. 2021). Before 1930, the lowest 95 mean squared errors are observed when the data is evaluated without injected uncertainty esti-96 mates, for all scenarios. However, when uncertainties are included in the evaluation, the regression 97 model trained with uncertainties $(\hat{\beta}_{\text{Land:1895-06}}^{* \text{ GMST}})$ outperforms other models and the GTA estimator 98 by approximately 15-25% before 1930 (Supplementary Figure 1c), emphasizing the importance of 99 incorporating uncertainties in both training and evaluation phases. 100

¹⁰¹ The SST-based reconstruction exhibits similar trends, although the impact of different re-¹⁰² construction techniques is less pronounced compared to land. Importantly, the model trained with ¹⁰³ uncertainties consistently achieves higher performance when evaluated against data where uncer-

tainties are considered, and it outperforms the GTA estimator as well (Supplementary Figure 1d).



Supplementary Figure 1: Evaluation of annual GMST reconstruction as a function of time and training setup a. Reconstruction MSE for land-based GMST reconstruction, and c. relative to the 'Global Temperature Average' (GTA) baseline estimator similar to kriging (Cowtan et al. 2018).
b. SST-based reconstruction MSE, and d. relative to the GTA baseline estimator (Cowtan et al. 2018).

105 2 Supplementary Reconstructions

To further evaluate our findings and reconstruction method, we provide reconstructions of different
 target metrics and methods across various source datasets:

108	Supplementary Figure 2 shows a reconstruction of GMST (similar to Figure 1 in the main
109	text), but without adding estimates of biases and uncertainties at training time. The ocean-
110	based GMST reconstruction is about 0.20°C colder than the land-based reconstruction in the
111	1900-1930 period; which is a slightly smaller discrepancy than when estimates of uncertain-
112	ties and biases are added during training time (Fig. 1 in the Main Text).
113	Supplementary Figure 3 illustrates a reconstruction of global mean sea surface temperature
114	(GMSST) from land and ocean, respectively.
115	Supplementary Figure 4 illustrates a reconstruction of global mean land surface air tem-
116	perature (GMLSAT).
117	Supplementary Figure 5 compares our GMST reconstruction estimates from land and
118	ocean to an additional SST-based reconstruction where the global mean SST has been re-
119	moved from each grid cell, similar to (Sippel et al. 2020). While the mean-removed recon-
120	struction reduces the overall trend as expected, it is nonetheless instructive to see that the
121	mean-removed SST reconstruction shows higher correlation with the land-based reconstruc-
122	tion in the early twentieth century (Supplementary Figure 5b).

Overall, the additional reconstructions shown in Supplementary Figures 2-5 all indicate a pronounced ocean cold anomaly irrespective of the target metric or the reconstruction method. Thus, all these additional reconstructions yield very similar conclusions regarding the early twentieth century to those derived in the main text.



Supplementary Figure 2: Global mean surface temperature (GMST) reconstruction from the land and ocean record, but without including biases and uncertainties in the training setup. GMST reconstructions from the SST record (HadSST4) and the land air temperature record (CRUTEM5). GMST reconstructions from HadSST4-unadj, ClassNMAT, CoastalHybridSST, BEST-Land, COBE-SST2 and ERSSTv5 are similarly derived and shown for comparison. **a.** Original GMST reconstructions, **b.** low-pass filtered reconstructions (> 20-year time scale), **c.** high-pass filtered reconstructions (< 20-year time scale), **d.** forced GMST response for each reconstruction, **e.** unforced, low-pass filtered reconstruction, **f.** unforced, high-pass filtered reconstruction. **g.** Implied global mean adjustments relative to unadjusted HadSST4 data, shown as the difference between the global reconstructions ($\hat{T}_{HadSST4}^{GMST} - \hat{T}_{HadSST4-unadj}^{GMST}$, and $\hat{T}_{CoastalHybridSST}^{GMST} - \hat{T}_{HadSST4-unadj}^{GMST}$). Shading represents the 95th percentile uncertainty ranges of the $\hat{T}_{HadSST4}^{GMST}$ and $\hat{T}_{CRUTEM5}^{GMST}$ reconstructions, obtained by propagating the HadSST4 and CRUTEM5 ensemble of uncertainty realizations; bold lines show the median across the ensemble.



Supplementary Figure 3: Global mean sea surface temperature (GMSST) reconstruction from the land and ocean record. GMSST reconstructions from the SST record (HadSST4) and the land air temperature record (CRUTEM5). GMSST reconstructions from HadSST4-unadj, ClassNMAT, CoastalHybridSST, BEST-Land, COBE-SST2 and ERSSTv5 are similarly derived and shown for comparison. **a.** Original GMSST reconstructions, **b.** low-pass filtered reconstructions (> 20-year time scale), **c.** high-pass filtered reconstructions (< 20-year time scale), **d.** forced GMSST response for each reconstruction, **e.** unforced, low-pass filtered reconstruction, **f.** unforced, high-pass filtered reconstruction. Shading represents the 95th percentile uncertainty ranges of the $\hat{T}_{HadSST4}^{GMSST}$ and $\hat{T}_{CRUTEM5}^{GMSST}$ reconstructions, obtained by propagating the HadSST4 and CRUTEM5 ensemble of uncertainty realizations; bold lines show the median across the ensemble.



Supplementary Figure 4: Global mean land surface air temperature (GMLSAT) reconstruction from the land and ocean record. GMLSAT reconstructions from the SST record (HadSST4) and the land air temperature record (CRUTEM5). GMLSAT reconstructions from HadSST4-unadj, ClassNMAT, CoastalHybridSST, BEST-Land, COBE-SST2 and ERSSTv5 are similarly derived and shown for comparison. **a.** Original GMLSAT reconstructions, **b.** low-pass filtered reconstructions (> 20-year time scale), **c.** high-pass filtered reconstructions (< 20-year time scale), **d.** forced GMLSAT response for each reconstruction, **e.** unforced, low-pass filtered reconstruction, **f.** unforced, high-pass filtered reconstruction. Shading represents the 95th percentile uncertainty ranges of the $\hat{T}_{HadSST4}^{GMLSAT}$ and $\hat{T}_{CRUTEM5}^{GMLSAT}$ reconstructions, obtained by propagating the HadSST4 and CRUTEM5 ensemble of uncertainty realizations; bold lines show the median across the ensemble.



Supplementary Figure 5: **GMST reconstruction from SSTs with global mean removed. a.** this paper's land- and ocean-based GMST reconstructions along with an experimental reconstruction where the global mean is removed from the SST pattern at each time step. This way, only relative anomalies in the pattern but not the global mean is retained in the analysis. **b** shows the Pearson correlation in 51-year windows between the land- and ocean-based reconstructions, and each reconstruction with the mean-removed SST reconstruction. The mean-removed SST reconstruction shows a higher agreement with the land reconstruction (orange line) than with the original SST reconstruction (blue line).

127 3 Analysis of individual paleoclimate proxies from terrestrial and marine sources

In addition to the analysis of the PAGES2k and Ocean2k paleoclimate reconstructions in the main text (Tierney et al. 2015; Neukom et al. 2019), we analyse individual uncalibrated paleoclimate proxy records for their multidecadal changes between 1901-20 vs. 1871-90 (similar to the main text).

We analyzed which proxies show a positive or negative anomaly from 1901-20 compared to 132 1871-90. All proxy records are uncalibrated, and are shown as standardized z-scores relative to the 133 1871-90 reference period. The analysis reveals a mixed pattern of cooling and warming between 134 the two periods for both land and ocean proxies (Extended Data Fig. 6; the darker the color, the 135 greater the cooling/warming; left panels show terrestrial proxies, right panels show marine prox-136 ies). A globally coherent cooling signal, as indicated by SST datasets does not emerge in marine or 137 terrestrial proxies. The Western Atlantic appears to be the only region where marine proxy records 138 show predominant cooling, which is consistent with our land-based reconstruction (see Main Text). 139 Overall, the additional analysis of individual paleoclimate proxy records supports the hypothesis 140 that the multi-decadal discrepancy between land and ocean temperature observations in the early 141 twentieth century may be an artefact rather than a true climatic phenomenon. 142

4 Supplementary analysis of ICOADS contributing sources

Relative offsets between data sources in ICOADS in the period 1870-1935 The International Comprehensive Ocean-Atmosphere Data Set Release 3 (ICOADS) (Freeman et al. 2017) is the largest archive of surface marine data spanning more than two centuries. It is the main marine data source used to generate many of the data products used in climate science, including global surface temperature (Gulev et al. 2021). To enable a comparison of different data sources, anomalies have been calculated from the SST reports in ICOADS relative to a climatology for the period 1991-2020 averaged to a 1° latitude/longitude grid (Embury et al. 2024).

Extended Data Fig. 8 shows boxplots of global annual mean anomalies for five ICOADS subsets, for the HSSTD subset and for reports originating from Germany, the Netherlands, the UK and Japan. The HSSTD subset is substantially colder than any other data source from the 1880s through to the 1910s and is the largest data source in the 1900s. The HSSTD subset is from the World Meteorological Organisation (WMO) Historical Sea Surface Temperature Data project (HSSTD) (WMO 1985). The contribution of each data source varies substantially over time (Extended Data Fig. 7) and regionally (not shown).

¹⁵⁸ "For more than one hundred years ships of the voluntary observing fleets and more re-¹⁵⁹ cently ocean weather ships have observed and recorded meteorological data from the ¹⁶⁰ oceans of the world. The Historical Sea Surface Temperature Data (HSSTD) Project ¹⁶¹ was setup originally to collect all available sea surface temperature records held by the 162major maritime nations for the period 1860-1960. These data were to be published in163summary form for selected representative areas complemented by summary data for164air temperature, surface wind speed and direction [...]165Sea surface temperature measurements by bucket only were selected for the summaries166[...] Although considerable effort was made to exclude non-bucket-sea surface tem-167perature measurements from the basic data it cannot be assumed that all unwanted168measurements have been eliminated." (WMO 1985)

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HSSTD reports should therefore be predominantly from buckets, as should most of the reports in this period (Kennedy et al. 2019). That the HSSTD anomalies are noticeably colder than the rest of ICOADS suggests either that there are enough unidentified reports from engine intakes in the other ICOADS data sources during this period to partly offset the expected cold bias from the bucket-derived reports (Kent and Kennedy 2021) or these data are from buckets that show a larger cold bias than other sources. After World War I the anomalies become progressively less cold.

In contrast unadjusted anomalies from German and UK data sources are warmer in each decade during the period 1800-1939. The anomalies from the different country subsets are most similar in the decade with the coldest observations, the 1910s. German, Netherlands and UK anomalies all decrease over the decades from the 1880s to the 1910s, suggesting that there are changes in bucket types or measurement protocols for each of these countries over this period (Kent et al. 2017) with observation practices for each subset becoming more similar to those from HSSTD over this period, albeit at different rates. From the 1910s to the 1930s each subset becomes warmer with each successive decade, apart from the Japanese subset which is affected by data truncation during transfer to punch cards in the period 1930 to 1953 (Chan et al. 2019). This is consistent with either improved protocols for bucket measurements leading to smaller cold biases or to an increasing contribution of measurements from engine intakes, or most likely both.

Investigation into the source of the HSSTD records in ICOADS ICOADS has been constructed 188 from a variety of different data sources using a procedure called "dupelim" (https://icoads. 189 noaa.gov/Release_1/suppK.html) to identify duplicates (different versions of the same 190 original observation) among those data sources. In earlier releases of ICOADS (prior to Re-191 lease 2.5) the discarded duplicates were excluded from the archive which means it is not pos-192 sible to compare different versions of the same record that have arrived in ICOADS through 193 different routes. The ICOADS DCK indicator gives information on the source of reports. The 194 term DCK originates from the decks of punch cards that were the sources of data used prior to 195 when ICOADS (then COADS) was assembled. Differences can arise between records from dif-196 ferent sources for a variety of reasons: conversions from local standard time to UTC may have 197 been performed differently; elements may be dropped, rounded or truncated due to restrictions 198 in the formats used; codes and derived variables may be subject to different conversions; there 199 may be systematic errors in coding or translations; or transcription problems affecting individ-200 ual reports. This means that the comparisons between sources to identify possible duplicates 201 is not an exact process and needs to employ tolerances. Whilst we have basic information on 202

the matches that were made and the characteristics of the data (for the 1800s here: https: //icoads.noaa.gov/e-doc/other/dupelim_sum_1800s and for 1900 to 1945 here: https://icoads.noaa.gov/e-doc/other/dupelim_sum_1900s) it is not possible to make more detailed comparisons using this information.

Supplementary Figure 6 shows the output of the dupelim summary for the period 1800 to 207 1899 visualised as a chord diagram for data sources identified by their "DCK" indicator (Smith 208 et al. 2022) or for the HSSTD grouping. Each chord is coloured according to the source selected 209 for each pair, the colours around the edge represent the different sources. In the 1800s most of 210 the data from HSST (red sector) get replaced with data from ICOADS DCKs 192, 193, 194 and 211 201 (data from the German, Netherlands and UK archives (see key and (Smith et al. 2022)). The 212 right hand panel shows the same information but with the log of the contributions to emphasise 213 the smaller contributions. Figure 7 presents the same information for the period 1900 to 1945, 214 with DCK contributing to fewer than 200k pairs combined as "other". For this period more of the 215 HSST data is retained. As this information on DCK matches is extracted from summaries provided 216 by ICOADS it is not possible to examine breakdowns of this information for different periods or 217 regions. 218

The characteristics of HSSTD are different from the other main sources in ICOADS. Because HSSTD were selected to be from buckets only, observations from ICOADS that were paired with HSSTD are assigned the measurement method "implied bucket". Stratifying the data for Germany, the Netherlands and the UK according to whether a match with HSSTD had been identified showed little difference between the reports for each country depending on this assignment. This suggests that the reason for the relatively cold anomalies in HSSTD is not due to unidentified engine intake observations, and that the remaining HSSTD reports in ICOADS are a distinct data source using bucket types and measurement protocols that gave a larger than typical heat loss. US observation sources are largely absent in this period, so it can be hypothesized that the HSSTD are from the missing US national archive. The observing instructions for the US published in 1906 (and also in 1910), describes a sampling protocol likely to lead to relative large cold biases in the observations:

230 "The water whose temperature is taken should be drawn from a depth of 3 feet below
231 the surface, the bucket in which it is drawn being weighted in order to sink it. The bulb
232 of the thermometer should remain immersed in the water at least three minutes before
233 reading, and the reading should be made with the bulb immersed." (Page 1906)

In 1925 the US instructions (*Instructions to Marine Meteorological Observers* 1925) remain the same, but also notes the desirability for a shorter gap of about 1 minute between sampling and measurement and recommended active stirring. A special brass sampling container is pictured but also suggests vertical stiffening for the ordinary canvas bucket. By 1929 (*Instructions to Marine Meteorological Observers* 1929) the instructions are similar but with further encouragement toward shorter measurement periods especially when the wet bulb depression is large and that measurement should be made out of both the wind and the sun.

By 1938 the US instructions provide seven steps for making accurate SST measurements 242 using buckets, emphasizing the need to make the measurement as quickly as it is safe to do (In-243 structions to Marine Meteorological Observers 1938). The benefits of stiffening of canvas buckets 244 is mentioned and the picture of the brass sampler is not included. The instructions describe the 245 engine intake method as simpler, and stresses that the method used should be chosen to be that ex-246 pected to be more accurate and that the method used should be recorded. This is again consistent 247 with a reducing cold anomaly for the HSSTD over the period 1920 onwards (Extended Data Fig. 248 8). 249



Supplementary Figure 6: **Dupelim output information from ICOADS Release 1, 1800-1899**. Segments of the circle are coloured by data source (ICOADS DCK or HSST) and the connecting chord is colored by the retained source. Data sources contributing to fewer than 1000 matches have been combined into a single category (other). **a** Visualisation of number of pairs; **b** log of number of pairs; **c** key to data sources.



Supplementary Figure 7: **Dupelim output information from ICOADS Release 1, for 1900-1945**. Data sources contributing to fewer than 200k matches have been combined into a single category (other). **a** Visualisation of number of pairs; **b** log of number of pairs; **c** key to data sources.



²⁵⁰ 5 Ocean warming constrained by land warming and paleoclimate reconstructions using

50-year trends

Supplementary Figure 8: Ocean warming constrained by land warming and paleoclimate reconstructions, shown for 50-year trends. a. Land and ocean warming on multi-decadal time scales is closely linked across CMIP6 models (trends over 50 years for different historical periods). b. Constraints from land air temperature (CRUTEM5 and Coastal Hybrid SST) and paleoclimate reconstructions (PAGES 2k and Ocean 2k) show reduced ocean cooling in the 1871-1920 period due to a less pronounced early twentieth century cold anomaly. This period is followed by more moderate 1901-1950 warming compared to HadSST4 data.

252 6 Supplementary Tables

Supplementary Table 1: Overview of global mean temperature reconstructions by source and train-

ing dataset.

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	Target metrics	Source dataset Training dataset + mask		Training un-	Further notes
				certainties	
	GMST, GMSST, GMLSAT, IO, WP,	CRUTEM5	CMIP6 LSAT &	CRUTEM5	Standard land-based reconstruction
	WA	(LSAT)	CRUTEM5 mask		
	GMST, GMSST, GMLSAT	Berkeley Earth	CMIP6 LSAT &	CRUTEM5	-
		Land (LSAT)	CRUTEM5 mask		
	GMST, GMSST, GMLSAT, TMSST	HadSST4 (SST)	CMIP6 SST & HadSST4	HadSST4	Standard ocean-based reconstruc-
			mask		tion
	GMST, GMSST, GMLSAT	COBE-SST2	CMIP6 SST & HadSST4	HadSST4	-
254		(SST)	mask		
201	GMST, GMSST, GMLSAT	ERSST5 (SST)	CMIP6 SST & HadSST4	HadSST4	-
			mask		
	GMST, GMSST, GMLSAT	HadSST4-unadj	CMIP6 SST & HadSST4	HadSST4	Unadjusted HadSST4 dataset
			mask		
	GMST, GMSST, GMLSAT	HadSST4-MR	CMIP6-MR SST &	HadSST4	global mean removed from each
		(SST)	HadSST4 mask		grid cell for each time step
	GMST, GMSST, GMLSAT	Cowtan-	CMIP6 SST & HadSST3	HadSST3	SST dataset with coastal correc-
		Hybrid36 (SST)	mask		tions to match LSATs
	GMST, GMSST, GMLSAT	ClassNMAT	CMIP6 MAT & ClassN-	ClassNMAT	Reconstruction based on night-time
		(NMAT)	MAT mask		marine air temperatures

Dataset	Long name	Variable	Reference	URL	Notes
short					
name					
CRUTEM	Climatic Research Unit temperature	LSAT	Osborn et al. (2021)	https://www.metoffice.gov.uk/	incl. error estimates
5.0.1.0	version 5			hadobs/crutem5/data/CRUTEM.5.0.	(CRUTEM5) and bias ensemble
				1.0/download.html	extracted from HadCRUT5
HadSST	Met Office Hadley Centre SST data	SST	Kennedy et al. (2019)	https://www.metoffice.gov.uk/	incl. error estimates and bias
4.0.1.0	set version 4			hadobs/hadsst4/data/download.	ensemble from HadSST4
				html	
ClassNMAT	Climate Linked Atlantic Sector Sci-	NMAT	Cornes et al. (2020)	https://catalogue.	incl. ClassNMAT error estimates
1.0.0.0	ence (CLASS) night-time marine air			ceda.ac.uk/uuid/	
	temperature			5bbf48b128bd488dbb10a56111feb36a	
BEST-	Berkeley Earth Land	LSAT	Rohde and Hausfather	https://berkeleyearth.org/data/	-
Land			(2020)		
ERSSTv5	Extended Reconstructed Sea Surface	SST	Huang et al. (2017)	https://psl.noaa.gov/data/	-
	Temperature, Version 5			gridded/data.noaa.ersst.v5.html	
COBE-	Centennial In Situ Observation Based	SST	Hirahara, Ishii, and Fukuda	https://psl.noaa.gov/data/	-
SST2	Estimates of the Variability of SST		(2014)	gridded/data.cobe2.html	
	and Marine Meteorological Variables				
	(COBE)				
Coastal-	Coastal SST corrected dataset	SST	Cowtan, Rohde, and	https://www-users.york.ac.uk/	
HybridSST			Hausfather (2018)	~kdc3/papers/evaluating2017/	

Supplementary Table 2: Overview of gridded observational datasets used for reconstructions

Dataset	Long name	Variable	Reference	URL	Notes
short					
name					
HadCRUT5	Hadley Centre/Climatic Research Unit global	GMST	Morice et al. (2021)	https://www.metoffice.gov.uk/	-
	surface temperature dataset			hadobs/crutem5/data/CRUTEM.5.0.	
				1.0/download.html	
BEST	Berkeley Earth Global Monthly Land + Ocean	GMST	Rohde and Hausfather	https://berkeleyearth.org/data/	-
			(2020)		
CW2014	Cowtan and Way kriging-interpolated Had-	GMST	Cowtan and Way (2014)	https://www-users.york.ac.uk/	-
	CRUT4			~kdc3/papers/coverage2013/	
CW2014-	Cowtan and Way kriging-interpolated COBE2	GMST	Cowtan and Way (2014)	https://www-users.york.ac.uk/	-
COBE2				~kdc3/papers/coverage2013/	
JMA-	Japanese Meteorological Agency Global Aver-	GMST	Hirahara, Ishii, and Fukuda	https://ds.data.jma.go.jp/tcc/	-
GMST	age Surface Temperature Anomalies		(2014)	<pre>tcc/products/gwp/temp/ann_wld.</pre>	
				html	
NOAA	NOAA Merged Land Ocean Global Surface Tem-	GMST	Vose et al. (2021)	https://www.ncei.noaa.gov/	-
GlobTemp	perature Analysis			products/land-based-station/	
5.1				noaa-global-temp	
NASA-	GISS Surface Temperature Analysis 4	GMST	Lenssen et al. (2019)	https://data.giss.nasa.gov/	-
GISTEMP				gistemp/	
Pages 2k	PAGES 2k multi-proxy GMST reconstructions	GMST	Emile-Geay et al. (2017)	https://www.ncei.noaa.gov/	-
GMST		(from	and Neukom et al. (2019)	access/paleo-search/study/26872	
		proxies)			
Ocean 2k	Ocean 2k Tropical sea surface temperature re-	GMST	Tierney et al. (2015)	https://www.ncei.noaa.gov/	-
	constructions			access/paleo-search/study/17955	

Supplementary Table 3: Overview of GMST datasets and paleoclimate reconstructions

ACCESS SCM2 ACC 3 5 ACCESS SCM2 ACC 3 40 AWI-ESM-1-HR AWI 0 5 AWI-ESM-1-HR AWI 0 1 BCC-CSMPAR BCC 0 3 BCC-CSMPAR BCC 0 3 CAMS-CSM-0 CBS 2 3 CESM2-WACCM CES 2 3 CORC-WARSTS CMC 0 1 CORC-WARSTS CMC 0 1 CORC-WARSTS CMC 0 1 CORC-WARSTS CMC 0 1 CORC-CAWSTS CMC 0 1	Model name	Model abbrev. ^a	# Ens. Members in Training	# Ens. Members in Analysis
ACCESS ESM -5 ACC 3 40 AWI-CM -11-MR AWI 0 1 AWI-CM -11-LR AWI 0 1 BCC-ESM BCC 3 3 BCC-ESM BCC 3 3 BCC-ESM BCC 3 3 CESMS-WACCM-FV2 CES 2 3 CESMS-WACCM CES 2 3 CESMS-WACCM-FV2 CES 2 3 CESMS-WACCM-FV2 CES 2 3 CESMS-WACCM-FV2 CES 2 3 CESMS-WACCM-FV2 CES 2 3 CMCC-GWAS-FRA CMC 0 1 CMCC-SMS-SFRS CMC 0 1 CMCC-STAR CMC 0 1 CMMC-SMS-1+R CNR 0 1 CMMC-SMS-1+R CA 3 3 CAMS-SMS-1+R CA 3 3 CAMS-SMS-1+R CA 3 3	ACCESS-CM2	ACC	3	5
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AWIE SWI-1-LERAWI01BCC-CSM-RRBCC03BCC-CSM-RABCC33BCC-ESM1-0CAM33CESM2-WACCM-V2CES23CESM2-WACCM-V2CES23CESM2-WACCM-V2CES211CIESM2CES211CIESM3CIE03COC-CM2-HPACMC01CIESM4CMC01CIESM2CIE03COC-CM2-HPACMC01CIESM3CMC01COMCC-CM2-HPACMC01COMCC-CM2-HPACMC01COMCC-CM2-HPACMC01COMCC-CM2-HPACMC01COMCC-CM2-HPACMC01COMCC-CM2-HPACMR300COMC-CM2-HPACMR300COMM-FSM5Can365E3SM-1-1CAS01CamESM5Can365E3SM-1-1-ECAE3S01E3SM-1-1-ECAE3S01CE-Earth3-Veg-LREC-28EC-Earth3-Veg-LREC-28EC-Earth3-Veg-LREC-28EC-Earth3-Veg-LREC-28EC-Earth3-Veg-LREC-28EC-Earth3-Veg-LRGIS01GISS-E2-LG-CCGIS01 </td <td>AWI-CM-1-1-MB</td> <td>AWI</td> <td>0</td> <td>5</td>	AWI-CM-1-1-MB	AWI	0	5
BCC-CSM2-MR BCC 0 3 CGMS-SCM1-0 CAM 3 3 CEMS-FV2 CES 2 3 CESM2+VACCM-FV2 CES 2 3 CESM2-VACCM-FV2 CES 2 3 CESM2 CES 2 3 CESM2 CES 2 3 CESM2 CES 2 3 CMCC-CM2-HR4 CMC 0 1 CMCC-CM2-SR5 CMC 1 1 CMCC-CM2-SR5 CMC 1 1 CMCC-CM2-SR5 CMC 1 1 CARMA-CM6-1 CNR 3 30 CARMA-CM6-1+HR CNR 1 1 CARMA-CM6-1 CNR 3 4 CESM2+VACM6 CAR 3 4 CESM3 3 4 1 CEARTM2-VAGLA EGS 0 1 CESM2+0 CAR 3 6 ESM-1	AWI-ESM-1-1-I B	AWI	0	1
BCC : ESMI BCC : S 3 CAMS.CSMI-0 CAM S 3 CESM2:WACCM CES 2 3 CESM2:WACCM CES 2 3 CESM2:WACCM CES 2 3 CESM2:WACCM CES 2 3 CESM4:WACCM CES 2 11 CIESM CES 2 11 CIESM2 CMC CM2:R4 CMC 0 1 CMCC-CR2:R5 CMC 3 11 CMCC-SM2:R4 CNMC-CSM2 CMC S 3 30 CNMM-CM6:1-HR CNR 3 11 CARESM5-CanOE Can 3 30 CamESM5 Can 3 4 E3SM-1-1 E3S 0 1 EC-Earth3-AcOthem EC- 2 3 EC-Earth3-Veg-LR EC- 2 23 FGOALS-g3 FGO 3 3 FGOALS-g3 FGO	BCC-CSM2-MB	BCC	ů 0	3
DOMECRIN 0 DOM 3 3 3 CESN2+WACCM-FV2 CES 2 3 CESN2+WACCM CES 2 3 CESN2+WACCM CES 2 3 CESN2+WACCM CES 2 3 CESN2 <waccm< td=""> CES 2 3 CCSN2+WACCM CES 2 3 CMCC-CM2+R4 CMC 0 1 CMC-CM2-SR5 CMC 0 1 CMM-MSM2-1 CNR 3 30 CMM-MSM2-1 CNR 3 30 CMM-MSM2-1 CNR 3 31 CantSM5 Can 3 65 E3SM-1-1-ECA ESS 0 1 CE-Earth3-Veg-LR EC- 2 3<!--</td--><td>BCC ESM1</td><td>BCC</td><td>2</td><td>3</td></waccm<>	BCC ESM1	BCC	2	3
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CIESM CIE 0 3 CMCC-CM2-HP4 CMC 0 1 CMCC-CM2-SR5 CMC 3 11 CMCC-CM2-SR5 CMC 0 1 CMCC-CM2-SR5 CMC 0 1 CMCC-SM2 CMC 0 1 CMCC-CM2-SR5 CMC 0 1 CMCC-CM2-SR5 CMC 0 1 CMCC-CM2-SR5 CMC 0 1 CMCC-CM2-SR5 CMC 3 30 CMR4M-CM6-1 CNR 3 30 CMR5MS-CanCE Can 3 3 CanESMS-CanCE Can 3 4 ESSM-1-0 E3S 3 4 ESSM-1-1 E3S 0 1 EC-Earth3-VegLR EC- 2 3 EC-Earth3-VegLR EC- 2 3 FGOALS-13-L FGO 3 3 FGOALS-13-L FGO 3 3	CESM2	CES	2	11
CMCC-CM2+HP4 CMC 0 1 CMCC-CM2+FR5 CMC 0 1 CMCC-ESM2 CMC 0 1 CMRM-GM6-1HR CNR 3 0 CNRM-CM6-1 CNR 3 0 CORRM-ESM5-CanOE Can 3 65 E3SM-1-0 E3S 3 4 CanESM5 CanC 0 1 E3SM-1-1+ECA E3S 0 1 E5-Farth3-Arc/Chem EC- 2 3 EC-Earth3-Veg_LR EC- 2 23 EGALS-G4 FGO 3 6 FIO-ESM-2.0 FIO 0 3 GALS-G4 FGO 3 3 FIO-ESM-2.0 FIO 0 3 GISS-E2-1-G GIS 0 11 GISS-E2-1-G GIS 3 40 GISS-E2-1-G GIS 0 1 GISS-E2-1-G GIS 0 1	CIESM	CIE	0	3
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CNRM-CM6-1+IR CNR O 1 CORM-CM6-1 CNR 3 30 CNRM-SM2-1 CNR 3 31 CanESMS-CanOE Can 3 3 CanESMS CanO 3 4 E3SM-1-0 E3S 3 4 E3SM-1-1-ECA E3S 0 1 E3SM-1-1-ECA E3S 0 1 EC-Earth3-AerChem EC- 0 1 EC-Earth3-Veg-LR EC- 2 8 EC-Earth3-Veg EC- 2 8 EC-Earth3-Veg EC- 2 8 EC-Earth3-Veg EC- 2 8 EC-Earth3 EC- 2 8 FGOALS+G3 FGO 3 3 GASE21-G GIS 0 1 GISS-E21-G GIS 0 1 GISS-E21-G GIS 3 10 GISS-E22-G GIS 0 1	CMCC-ESM2	CMC	0	1
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Carlesonis Carlesonis Solution Solution	CarleSIVIS-CarlOE	Can	3	5
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EC-Earth3-Veg EC- 2 8 EC-Earth3 EC- 2 23 FGQALS-G3 3 3 FGOALS-G3 FGO 3 3 FGDALS-G3 FGO 3 3 GISS-E2-1-G-CC GIS 0 1 GISS-E2-1-G-CC GIS 3 40 GISS-E2-1-G-CC GIS 3 40 GISS-E2-1-G-CC GIS 3 40 GISS-E2-1-G GIS 3 40 GISS-E2-1-G GIS 0 11 GISS-E2-1-G GIS 0 5 HadGEM3-GC31-LL Had 2 4 INM-CM4-8 INM 0 1 INM-CM5-0 INM 3 10 IPSL-CM6A-LR-INCCA IPS 0 1 IPSL-CM6A-LR IPS 3 33 KACE-10-G MIR 2 3 MIROC-ES2H MIR 2 3	EC-Earth3-Veg-LR	EC-	2	3
EC-Earth3 EC- 2 23 FGOALS:43:1 FGO 3 3 FGOALS:43:1 FGO 3 6 FIO-ESM-2:0 FIO 0 3 GISS:42:1-G-CC GIS 0 1 GISS:21:1-G-CC GIS 3 40 GISS:22:1-G-CC GIS 3 25 GISS:22:1-G GIS 3 25 GISS:22:1-H GIS 0 11 GISS:22:2-H GIS 0 11 IMM-CM4:3 INM 0 1 HadGEM3:GC31-LL Had 2 5 HadGEM3:GC31-MM Had 2 4 INM-CM4:8 INM 0 1 INM-CM4:8 INM 3 10 IPSL-CM6A-LR-INCA IPS 0 1 IPSL-CM6A-LR IPS 3 33 KACE:1-0-G KAC 0 3 MIROC-ES2H MIR 2 3 <td>EC-Earth3-Veg</td> <td>EC-</td> <td>2</td> <td>8</td>	EC-Earth3-Veg	EC-	2	8
FGOALS-13-L FGO 3 3 FGOALS-g3 FGO 3 6 FIO-ESM-2-0 FIO 0 3 GFDL-ESM4 GFD 3 3 GISS-E2-1-G-CC GIS 0 1 GISS-E2-1-G GIS 3 40 GISS-E2-1-G GIS 3 40 GISS-E2-1-G GIS 0 11 GISS-E2-2-G GIS 0 11 GISS-E2-2-H GIS 0 5 HadGEM3-GC31-LL Had 2 4 IMM-CM4-8 INM 0 1 INM-CM5-0 INM 3 10 IPSL-CM6A-LR-INCA IPS 0 1 IPSL-CM6A-LR IPS 3 33 MIROC-ES2H MIR 2 3 MIROC6 MIR 2 31 MPI-ESM1-2-HAM MPI 2 31 MRES 0 5 5 N	EC-Earth3	EC-	2	23
FGOALS-g3 FGO 3 6 FIO-ESM-2-0 FIO 0 3 GFDL-ESM4 GFD 3 3 GISS-E2-1-G-CC GIS 0 1 GISS-E2-1-G GIS 3 40 GISS-E2-1-G GIS 3 25 GISS-E2-1-H GIS 0 11 GISS-E2-2-H GIS 0 11 GISS-E2-2-H GIS 0 5 HadGEM3-GC31-LL Had 2 4 INM-CM4-8 INM 0 1 INM-CM4-8 INM 0 1 IPSL-CM6A-LR IPS 0 1 IPSL-CM6A-LR IPS 3 33 MROC-ES2H MIR 2 31 MIROC-ES2L MIR 2 31 MPI-ESM1-2-HAM MPI 2 30 MPI-ESM1-2-LR MPI 2 30 MPI-ESM1-2-LR MPI 3 3 <td>EGOALS-f3-L</td> <td>FGO</td> <td>3</td> <td>3</td>	EGOALS-f3-L	FGO	3	3
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Supplementary Table 4: Overview of CMIP6 models used in the analysis.

^a Model abbreviation indicates the models that stem from the same model variant and are used in the training step.

255 References

- ²⁵⁶ Chan, D. et al. (2019). "Correcting datasets leads to more homogeneous early-twentieth-century
- sea surface warming". In: *Nature* 571.7765, pp. 393–397.
- ²⁵⁸ Cornes, R. C. et al. (2020). "CLASSnmat: A global night marine air temperature data set, 1880–2019".
- In: *Geoscience Data Journal* 7.2, pp. 170–184.
- ²⁶⁰ Cowtan, K., R. Rohde, and Z. Hausfather (2018). "Evaluating biases in sea surface temperature
 ²⁶¹ records using coastal weather stations". In: *Quarterly Journal of the Royal Meteorological*
- 262 Society 144.712, pp. 670–681.
- ²⁶³ Cowtan, K. and R. G. Way (2014). "Coverage bias in the HadCRUT4 temperature series and its
 ²⁶⁴ impact on recent temperature trends". In: *Quarterly Journal of the Royal Meteorological* ²⁶⁵ Society 140.683, pp. 1935–1944.
- ²⁶⁶ Cowtan, K. et al. (2018). "Statistical analysis of coverage error in simple global temperature esti ²⁶⁷ mators". In: *Dynamics and Statistics of the Climate System* 3.1, dzy003.
- Embury, O. et al. (2024). "Satellite-based time-series of sea-surface temperature since 1980 for
 climate applications". In: *Scientific Data* 11.1.
- Emile-Geay, J. et al. (2017). "A global multiproxy database for temperature reconstructions of the
 Common Era". In: *Scientific Data* 4.1, p. 170088.
- ²⁷² Freeman, E. et al. (2017). "ICOADS Release 3.0: a major update to the historical marine climate
- record". In: *International Journal of Climatology* 37.5, pp. 2211–2232.

274	Gulev, S. K. et al. (2021). Changing state of the climate system. In Climate Change 2021: The
275	Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of
276	the Intergovernmental Panel on Climate Change. IPCC Sixth Assessment Report.
277	Hirahara, S., M. Ishii, and Y. Fukuda (2014). "Centennial-Scale Sea Surface Temperature Analysis
278	and Its Uncertainty". In: Journal of Climate 27.1, pp. 57-75.
279	Huang, B. et al. (2017). "Extended Reconstructed Sea Surface Temperature, Version 5 (ERSSTv5):
280	Upgrades, Validations, and Intercomparisons". In: Journal of Climate 30.20, pp. 8179-8205.
281	Instructions to Marine Meteorological Observers (1925). Tech. rep. Circular M, Fourth Edition.
282	Washington, US: US Weather Bureau.
283	Instructions to Marine Meteorological Observers (1929). Tech. rep. Circular M, Fifth Edition.
284	Washington, US: US Weather Bureau.
285	Instructions to Marine Meteorological Observers (1938). Tech. rep. Circular M, Sixth Edition.
286	Washington, US: US Weather Bureau.
287	Kennedy, J. J. et al. (2019). "An Ensemble Data Set of Sea Surface Temperature Change From
288	1850: The Met Office Hadley Centre HadSST.4.0.0.0 Data Set". In: Journal of Geophysical
289	Research: Atmospheres 124.14, pp. 7719–7763.
290	Kent, E. C. and J. J. Kennedy (2021). "Historical Estimates of Surface Marine Temperatures". In:
291	Annual Review of Marine Science 13.1, pp. 283–311.
292	Kent, E. C. et al. (2017). "A Call for New Approaches to Quantifying Biases in Observations of Sea
293	Surface Temperature". In: Bulletin of the American Meteorological Society 98.8, pp. 1601-
294	1616.

- Lenssen, N. J. L. et al. (2019). "Improvements in the GISTEMP Uncertainty Model". In: *Journal of Geophysical Research: Atmospheres* 124.12, pp. 6307–6326.
- ²⁹⁷ Morice, C. P. et al. (2021). "An Updated Assessment of Near-Surface Temperature Change From
- 1850: The HadCRUT5 Data Set". In: *Journal of Geophysical Research: Atmospheres* 126.3,
 e2019JD032361.
- Neukom, R. et al. (2019). "Consistent multidecadal variability in global temperature reconstruc tions and simulations over the Common Era". In: *Nature Geoscience* 12.8, pp. 643–649.

³⁰² Osborn, T. J. et al. (2021). "Land Surface Air Temperature Variations Across the Globe Updated to

- 2019: The CRUTEM5 Data Set". In: *Journal of Geophysical Research: Atmospheres* 126.2,
 e2019JD032352.
- ³⁰⁵ Page, J. (1906). Instructions to the Marine Meteorological Observers of the U. S. Weather Bureau.

Tech. rep. Washington, US: US Weather Bureau.

³⁰⁷ Rohde, R. A. and Z. Hausfather (2020). "The Berkeley Earth Land/Ocean Temperature Record".

³⁰⁸ In: *Earth System Science Data* 12.4, pp. 3469–3479.

- Sippel, S. et al. (2020). "Climate change now detectable from any single day of weather at global
 scale". In: *Nature Climate Change* 10.1, pp. 35–41.
- Smith, S. R. et al. (2022). *The International Maritime Meteorological Archive (IMMA) Format*.
 Tech. rep. ICOADS.
- Tierney, J. E. et al. (2015). "Tropical sea surface temperatures for the past four centuries recon-
- structed from coral archives". In: *Paleoceanography* 30.3, pp. 226–252.

- Vose, R. S. et al. (2021). "Implementing Full Spatial Coverage in NOAA's Global Temperature
 Analysis". In: *Geophysical Research Letters* 48.4, e2020GL090873.
- ³¹⁷ WMO (1985). Users's Guide to the Data and Summaries of the Historical Sea Surface Temperature
- ³¹⁸ Data Project. Tech. rep. WMO/TD-No. 36. Geneva, Switzerland: Secretariat of the World
- 319 Meteorological Organization.