Extending the GloSAT land surface temperature record

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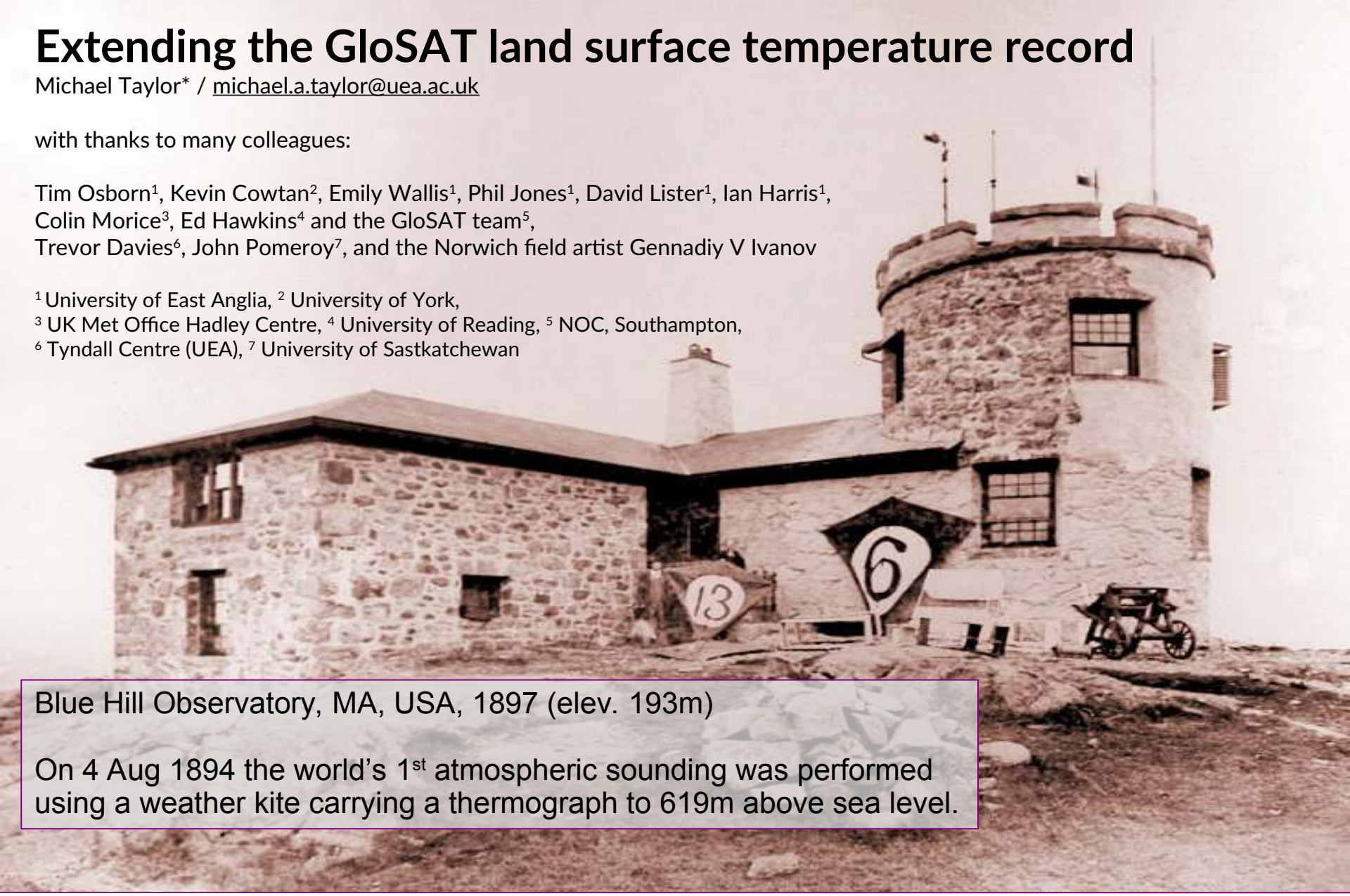
with thanks to many colleagues:

Tim Osborn[1], Kevin Cowtan[2], Emily Wallis[1], Phil Jones[1], David Lister[1], Ian Harris[1], Colin Morice[3], Ed Hawkins[4] and the GloSAT team[5], Trevor Davies[6], John Pomeroy[7], and the Norwich field artist Gennadiy V Ivanov

[1] University of East Anglia, [2] University of York,
[3] UK Met Office Hadley Centre, [4] University of Reading, [5] NOC, Southampton,
[6] Tyndall Centre (UEA), [7] University of Sastkatchewan



Blue Hill Observatory, MA, USA, 1897 (elev. 193m)

On 4 Aug 1894 the world's 1st atmospheric sounding was performed using a weather kite carrying a thermograph to 619m above sea level.

RMetS Data Rescue meeting 11 Oct 2023
Geological Society, Burlington House, London

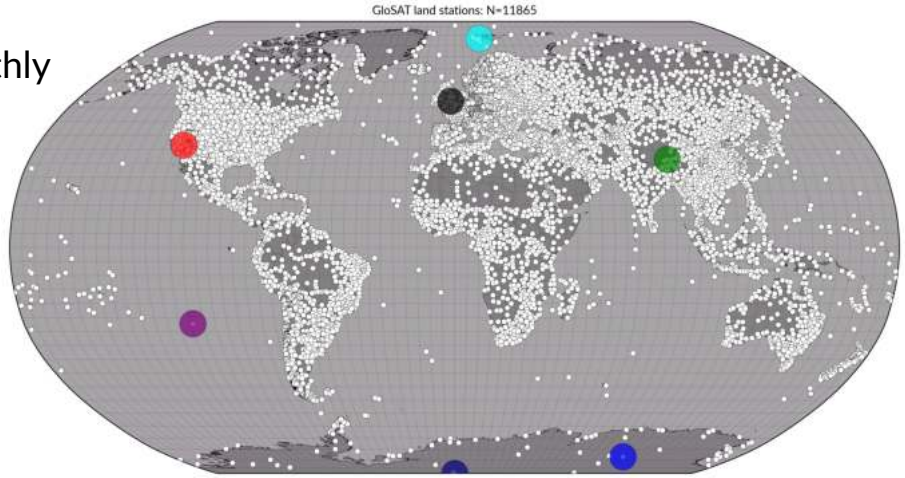
GloSAT LAT_sdb (global land air temperature station database)

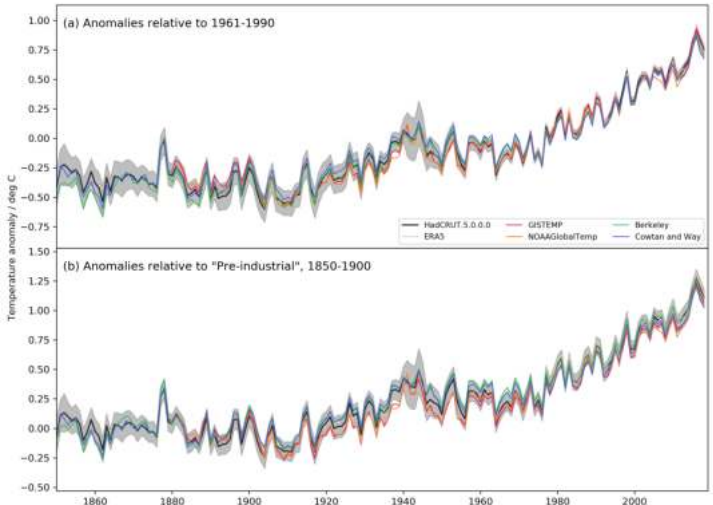
I am helping to update the global station database * of monthly mean land air temperatures at the Climatic Research Unit (CRU) @UEA for the GloSAT project (**www.glosat.org**).

The database comprises 11865 stations 1658-2023 (Aug).

Some of the longer "extreme" station records:

Oldest datum is from CET (Feb 1658) and is the longest series: 1658-2023
Hottest = **42.6°C** (July 2021), Death Valley (36.5°N, 116.9°W): 1895-2021
Coldest = **-75.3°C** (Aug 1987) at Vostok (78.5°S, 106.9°E): 1958-2021
Highest = **4700m** at Bange, Tibet (31°N, 90°E): 1956-2017
Remotest is Mataveri Isla de Pas, Chile (27.2°S, 109.4°W): 1942-2021
Northernmost is Svalbard Lufthavn (78.3°N, 15.5°E): 1898-2015
Southernmost is Amundsen-Scott (90°S, 0°E): 1957-2021





https://www.metoffice.gov.uk/hadobs/hadcrut5/

The 1850-2023 5°x5° land product is CRUTEM5 **.
The 1850-2023 5°x5° ocean product is HadSST4.
The Met Office blends CRUTEM5 with HadSST4 to produce the global dataset HadCRUT5.

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* GloSAT LAT_sdb is a collaborative product of CRU / UKMO-HC & UYork
** CRUTEM5 is a collaborative product of CRU / UKMO-HC & NCAS

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Data Rescue: CRUTEM growing ecology of sources

Keying-in
≈ 10s of stations

e.g. John Dalton (Kendal)

single practitioner consistency

Metadata fixes
≈ 10-100 stations

e.g. Franz-Josef Land

Decadal updates
≈ 100s of stations

e.g. WWR

NMS bulk releases
≈ 100s - ?

Exposure Bias Adjustment

CRUTEM

LEK homogenisation

Station + AWS merges
≈ 100s of stations

e.g. BAS Reader

Digitisation
(citizen sci + AI parsing)
≈ 100s-1000s ?

engagement + edu + capacity

LEK new anomalies
≈ 1000s

(this talk)

X-project merges
≈ 100 -1000s ?

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Recovery (of historical data)
Repair (of erroneous data)
Release (of constrained data)

CRUTEM's approach is to QC all available source data and merge it in with that provided by NMS's

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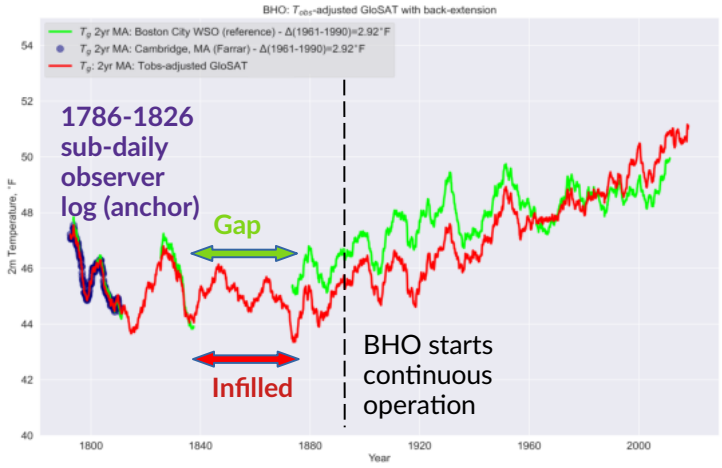
Data Rescue: extending CRUTEM new GloSAT developments

- Back-extension of CRUTEM from 1850 to 1781
- First Reliable Year (FRY) per station
- NMS HOMxx level per station
- New updating composite series

(e.g. Blue Hill Observatory, 1786-2023+)

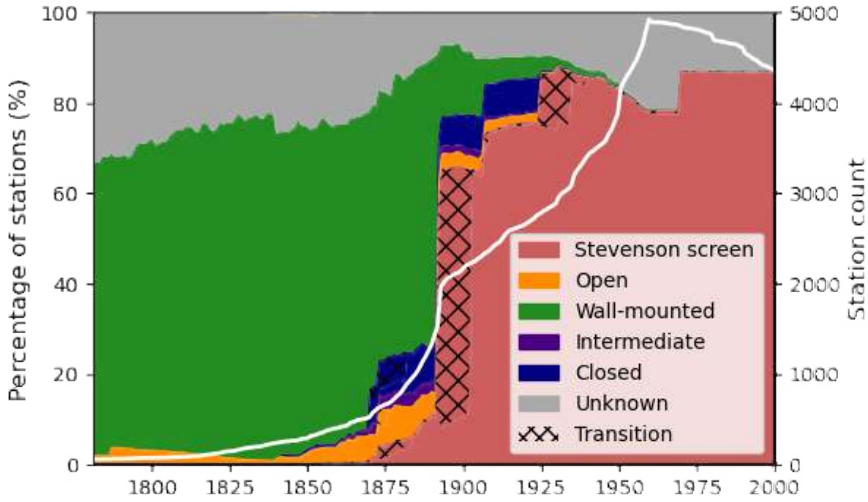


- Exposure bias adjustments for stations transitioning from non-standard thermometer enclosures to Stevenson screens

Wallis et al., 2023, IJoC (in review)

- Rescue of old & new short temperature anomaly series by updating 1961-1990 station reference data

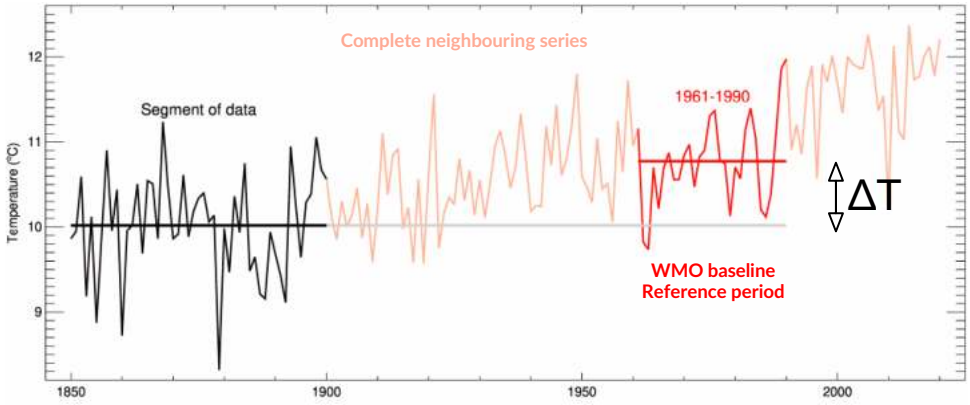
Taylor et al, 2023, Geoscience Data, (in prep)

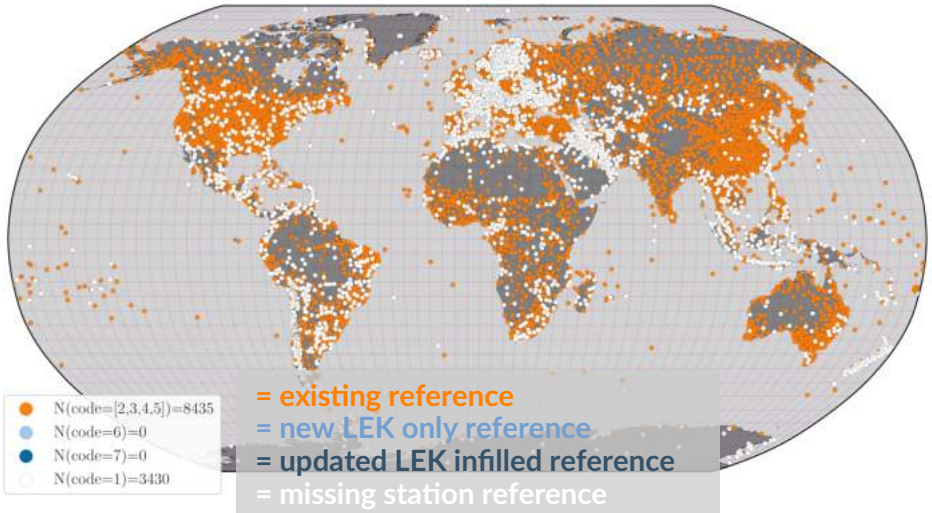


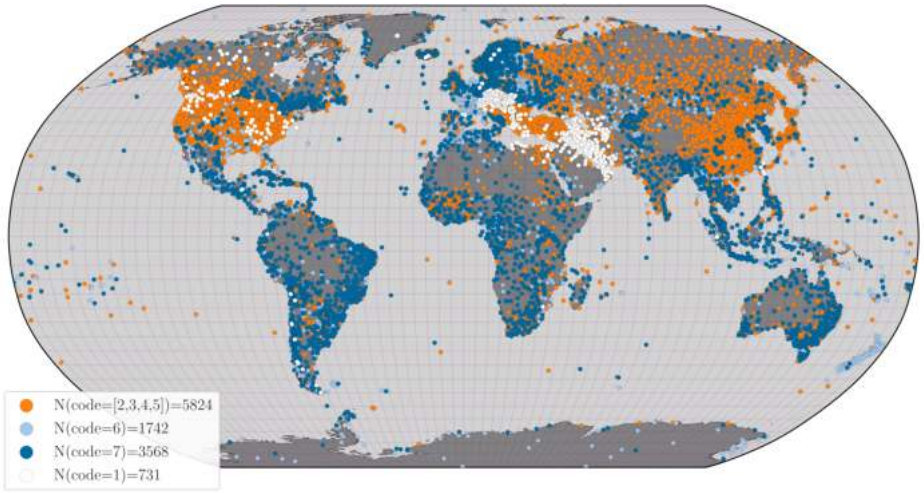
Data Rescue: extending CRUTEM with Kriging

Many (3430) stations have insufficient data in 1961-1990 to compute the baseline averages needed to convert from absolute temperatures to anomalies.

We infer missing data from neighbouring stations using local expectation Kriging (LEK) *







Gains: 1742 new conversions to anomalies and 3568 updated station anomaly series. **Still missing: 731 stations without anomalies ***

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* or Ordinary Kriging with station hold-out
(code dev by Prof Kevin Cowtan at the University of York)

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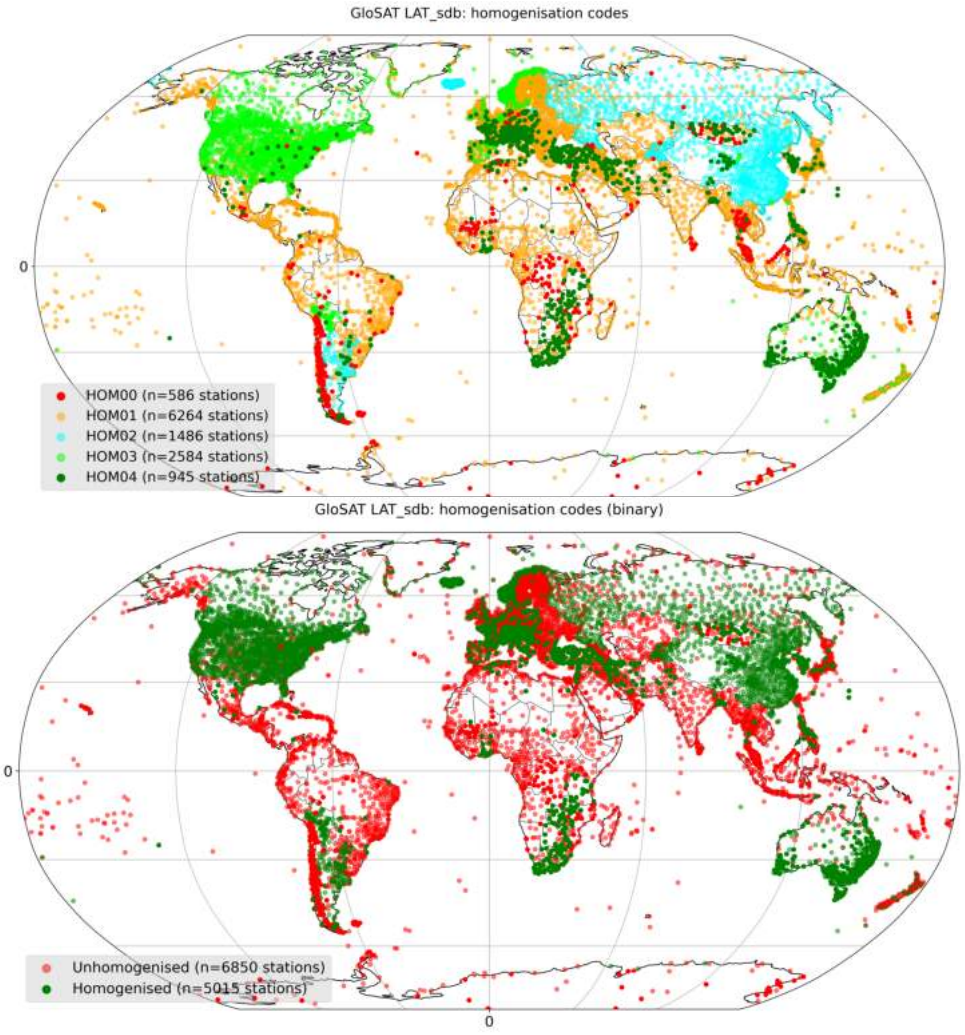
Data Rescue: homogenising CRUTEM with Kriging

HOM00	homogeneity not assessed or unknown
HOM01	homogeneity not assessed but data from reliable source (NMS or WWR)
HOM02	homogeneity assessed and inhomogeneities corrected at source but method unkown
HOM03	homogeneity assessed and inhomogeneities corrected at source via documented methods
HOM04	homogeneity assessed and inhomogeneities corrected by CRU via documented methods

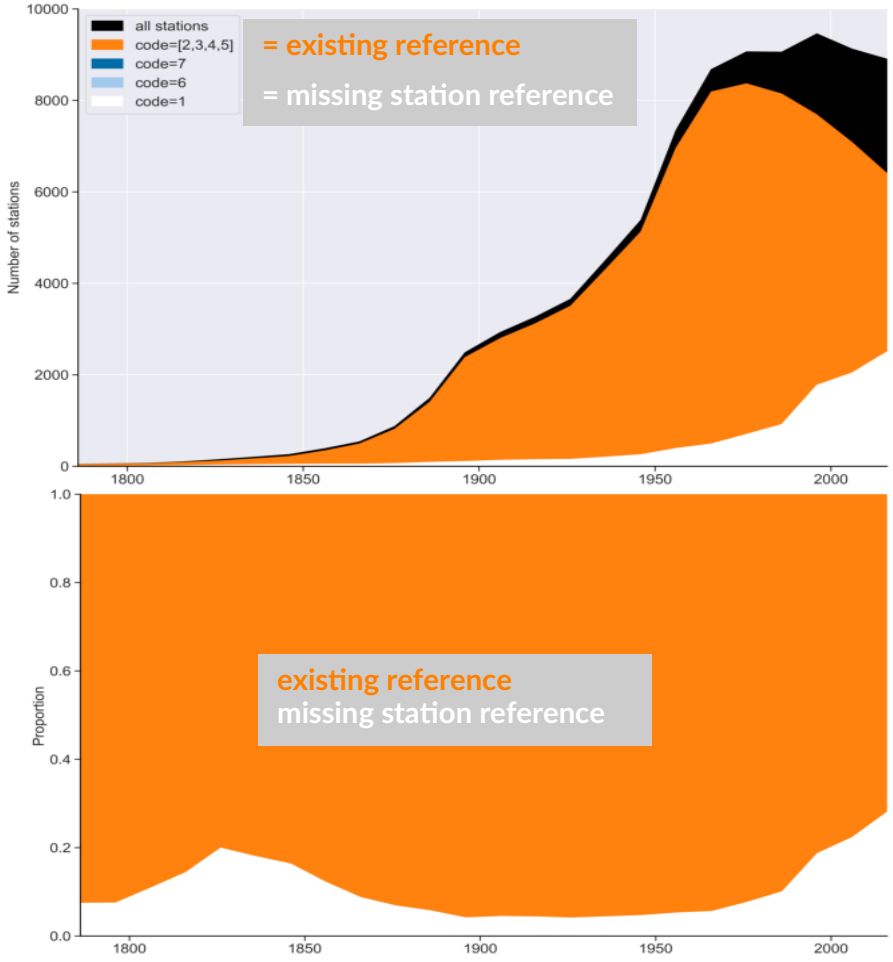


We have found that 58% of the global station database is potentially in need of homogenisation.

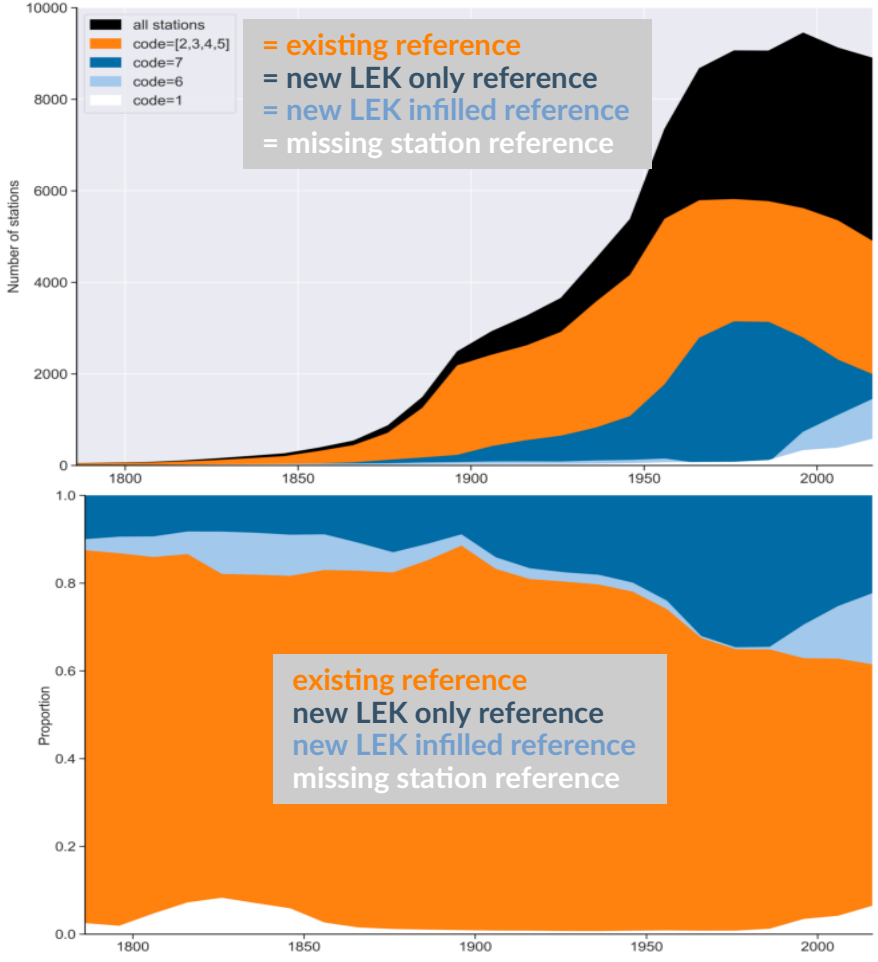
We are in the process of using breakpoint detection and LEK to homogenise these stations *

Data Rescue: missing anomaly series rescued per decade

Before data rescue



After data rescue



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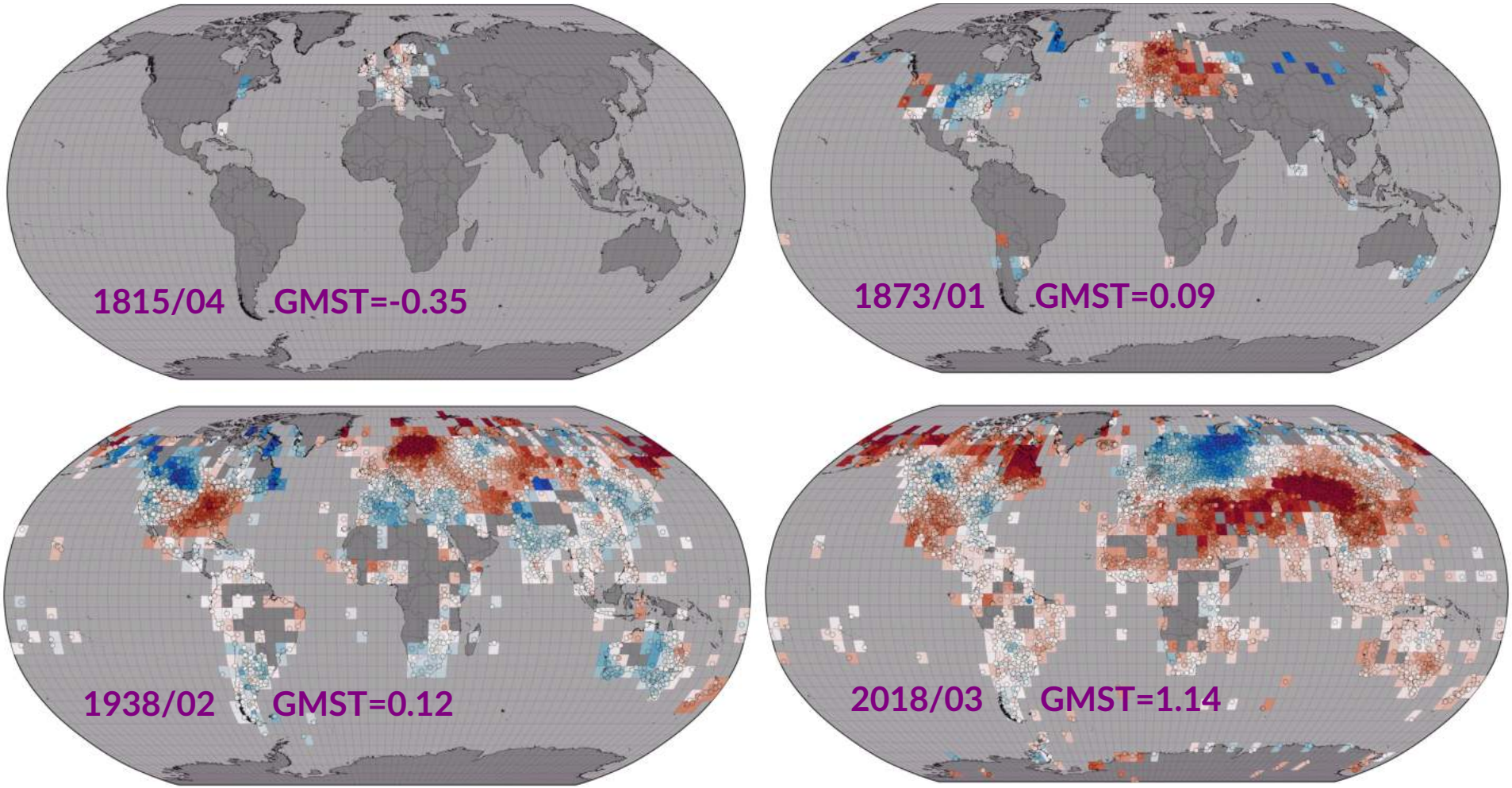
Data Rescue: changing spatiotemporal coverage



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Data Rescue: Guy Callendar's spatially robust computation

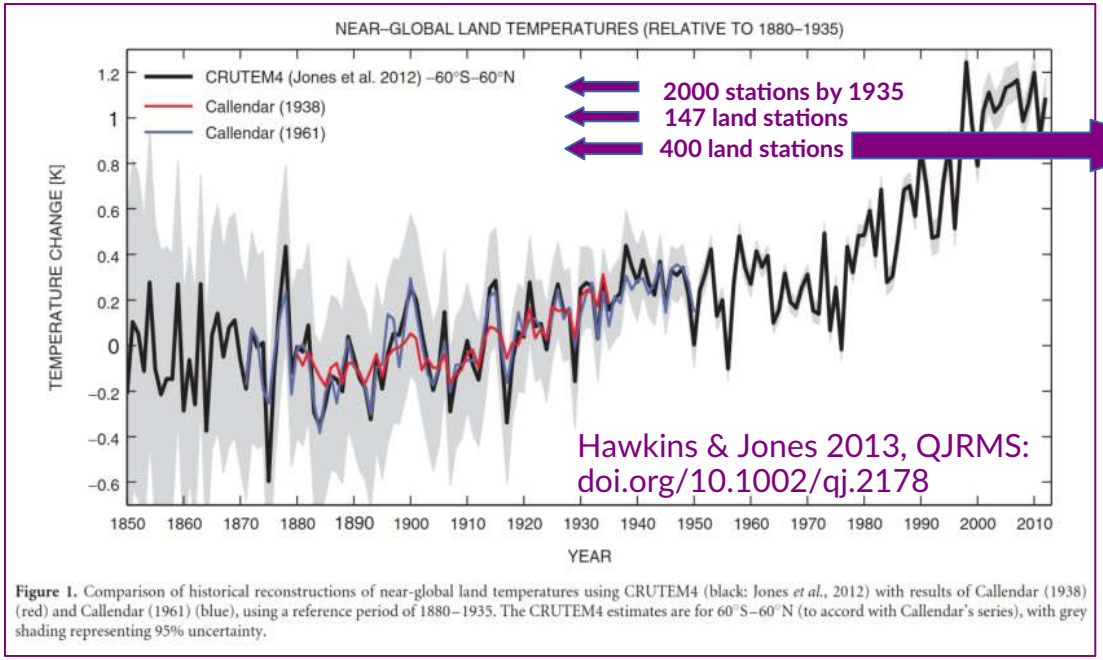
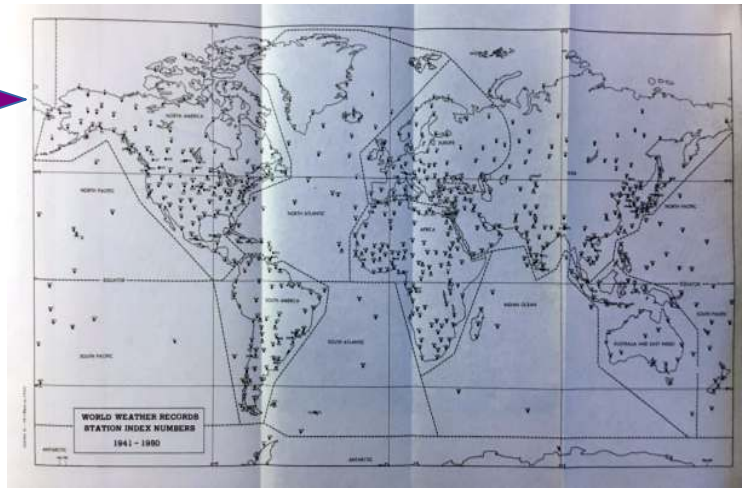


Figure 1. Comparison of historical reconstructions of near-global land temperatures using CRUTEM4 (black: Jones *et al.*, 2012) with results of Callendar (1938) (red) and Callendar (1961) (blue), using a reference period of 1880–1935. The CRUTEM4 estimates are for 60°S–60°N (to accord with Callendar's series), with grey shading representing 95% uncertainty.

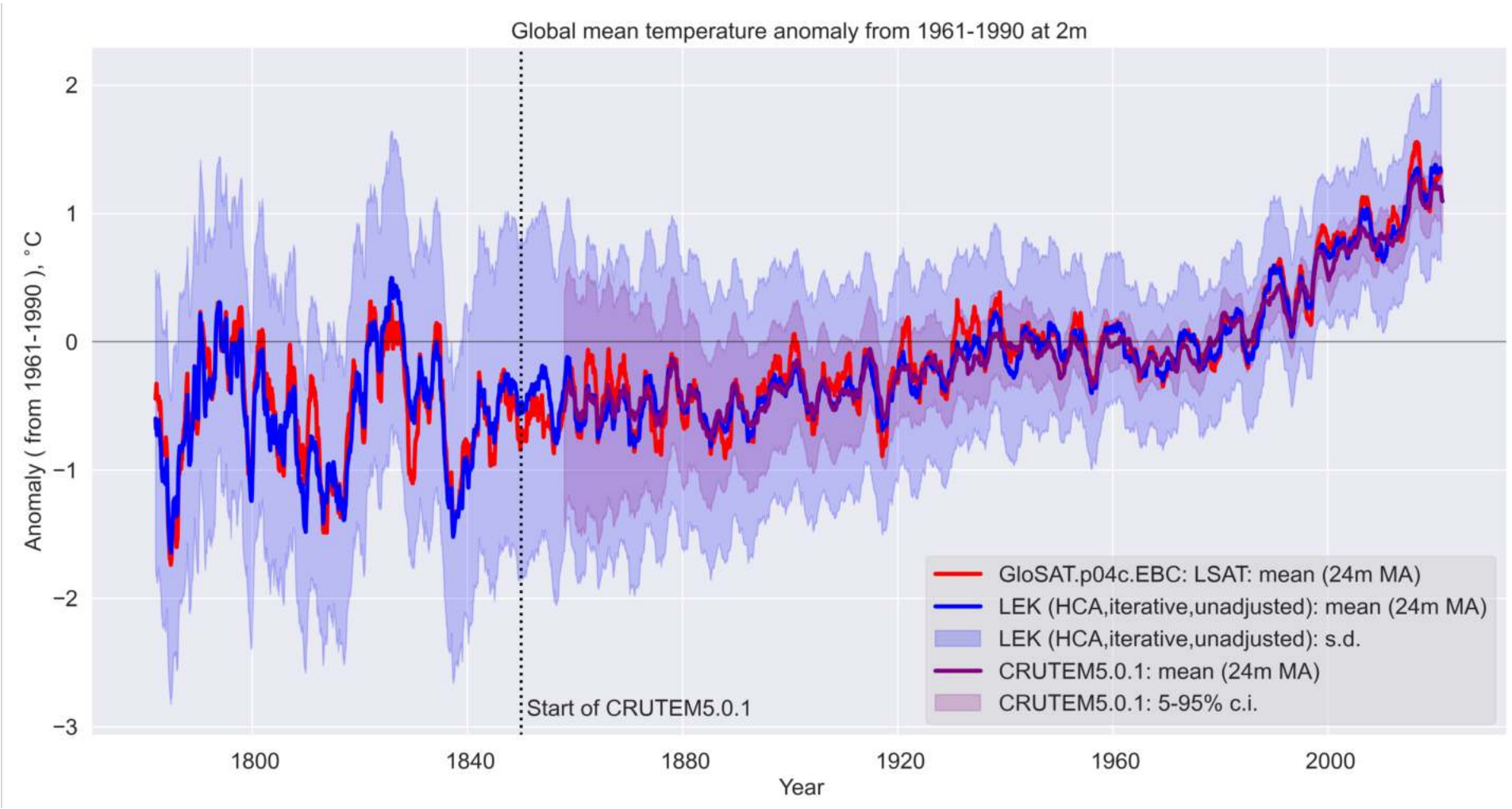
WWR 4th series (1941-1950) published in 1959



QJRMS @ 150 has Callendar's 1938 paper as one of its key 21 papers. His calculations **by hand** match modern CRUTEM data.

Callendar's calculation shows that GMST is spatially robust.

Data Rescue: GloSAT back-extension of CRUTEM *



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* CRUTEM has no SH station data before 1856 → a slightly later than 1850 global timeseries relative to HadCRUT5 which has SSTs

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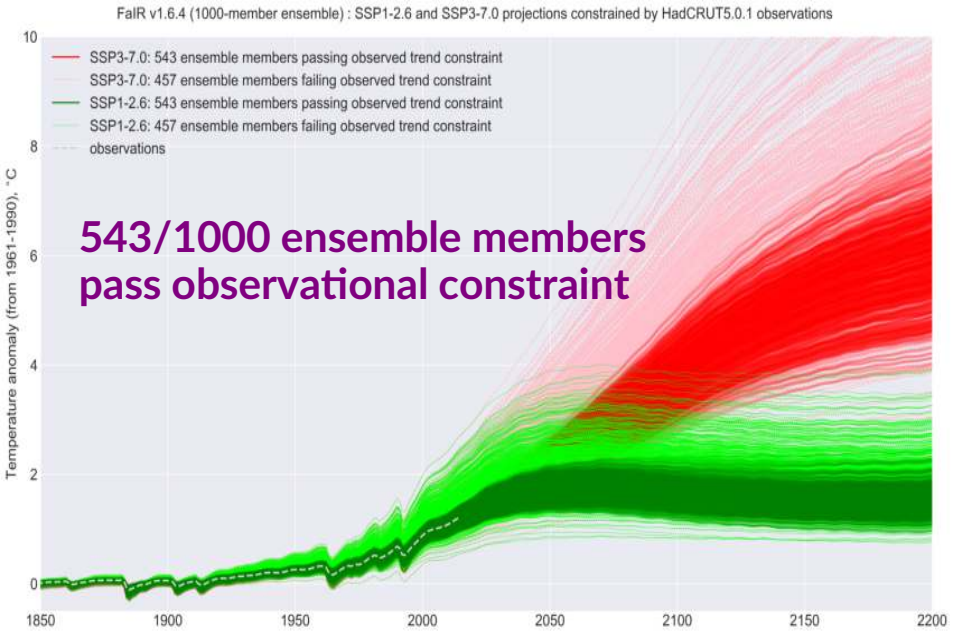
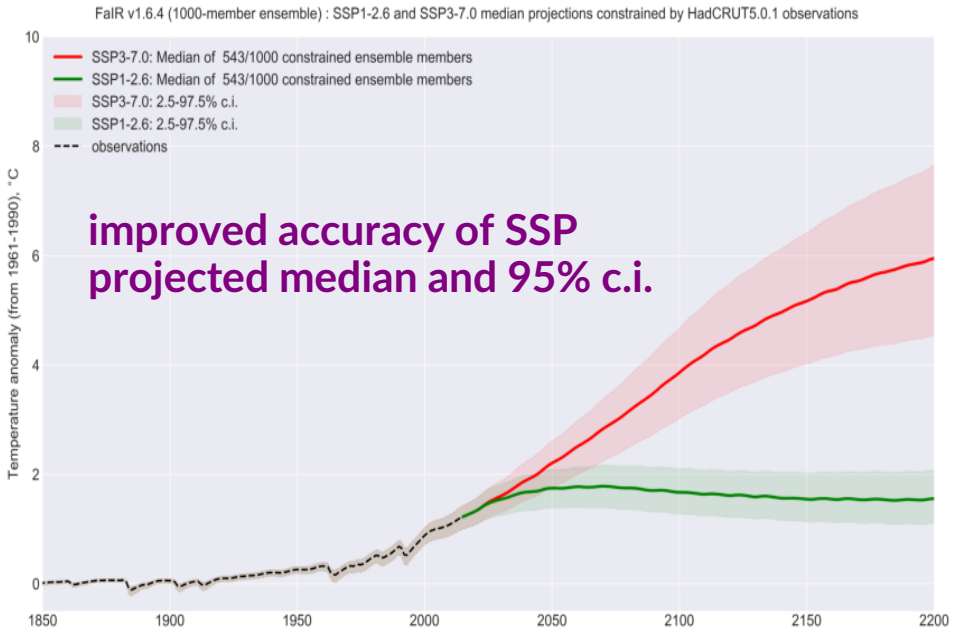
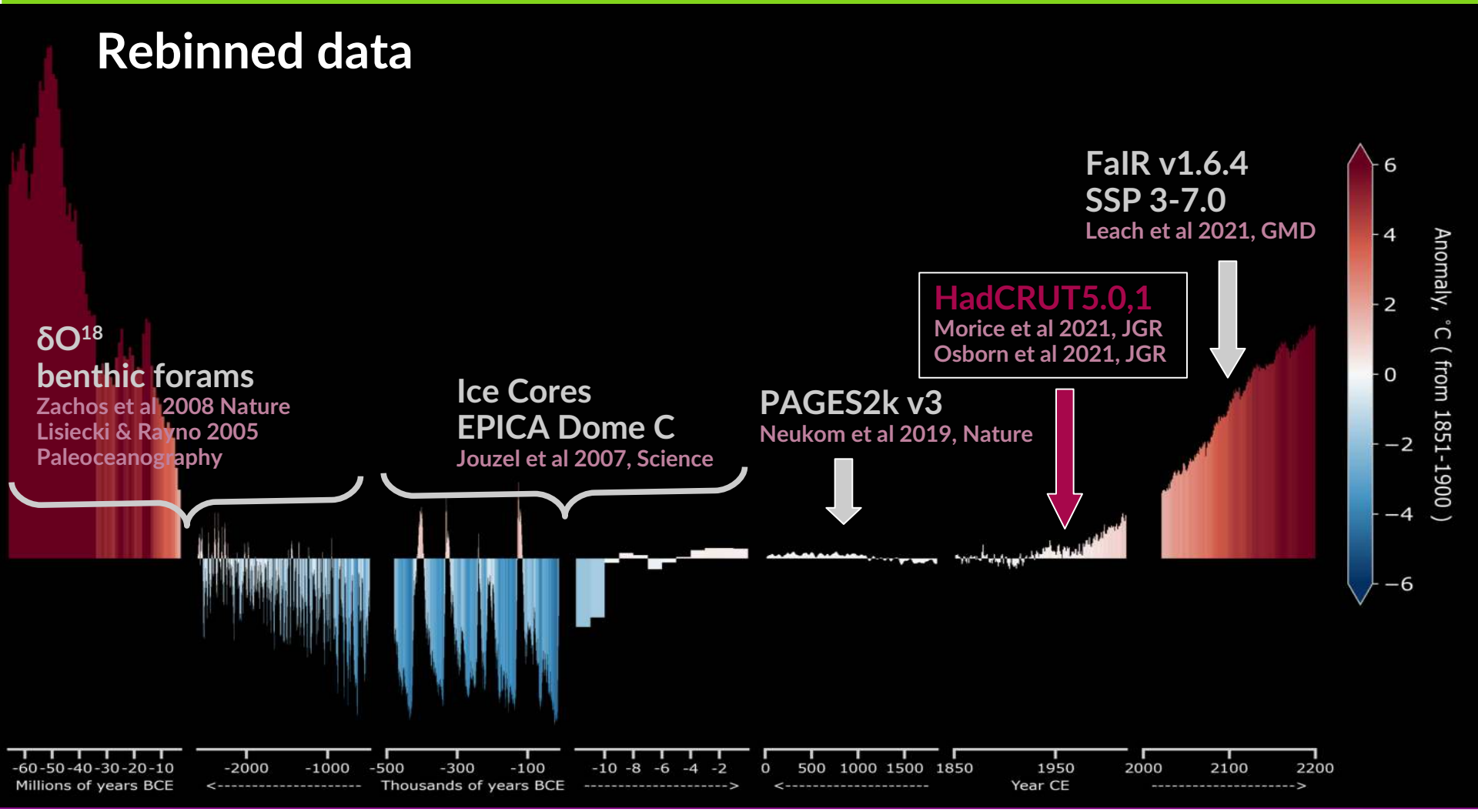
Data Rescue: application – contraining SSP ensembles

We constrain climate model ensemble members to past observations
to eliminate unrealistic model simulations and refine SSP projections:





Data Rescue: application – climate mural *



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* remit from Norwich City Council was to produce 6 panels:

65.5-2.58Ma / 2.58Ma-500CE / 501-1400 / 1401-1850 / 1851-2020 / 2021-2200

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Data Rescue: (climate mural) from observations to art

GMST converted to warming stripes *

δO^{18} | Ice Cores | PAGES2k | Thermometers | FaIR Climate Model runs

6 panel painting by Gennadiy V. Ivanov (10m long)

SSP3-7.0
SSP1-2.6

65.5-2.58 Ma BCE | 2.58 Ma BCE–500 CE | 501-1400 | 1401-1850 | 1851-2022 | 2023-2200

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* Prof Ed Hawkins, University of Reading. To help Gennadiy paint the stripes we used a different colour axis for each panel.

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Data Rescue: (climate mural) outreach *

The Future:

To be painted by schools in Norwich

(19th October teachers' event)

2023-2200

* each panel of the mural has an accompanying easel painting Containing social anthropological and geological elements

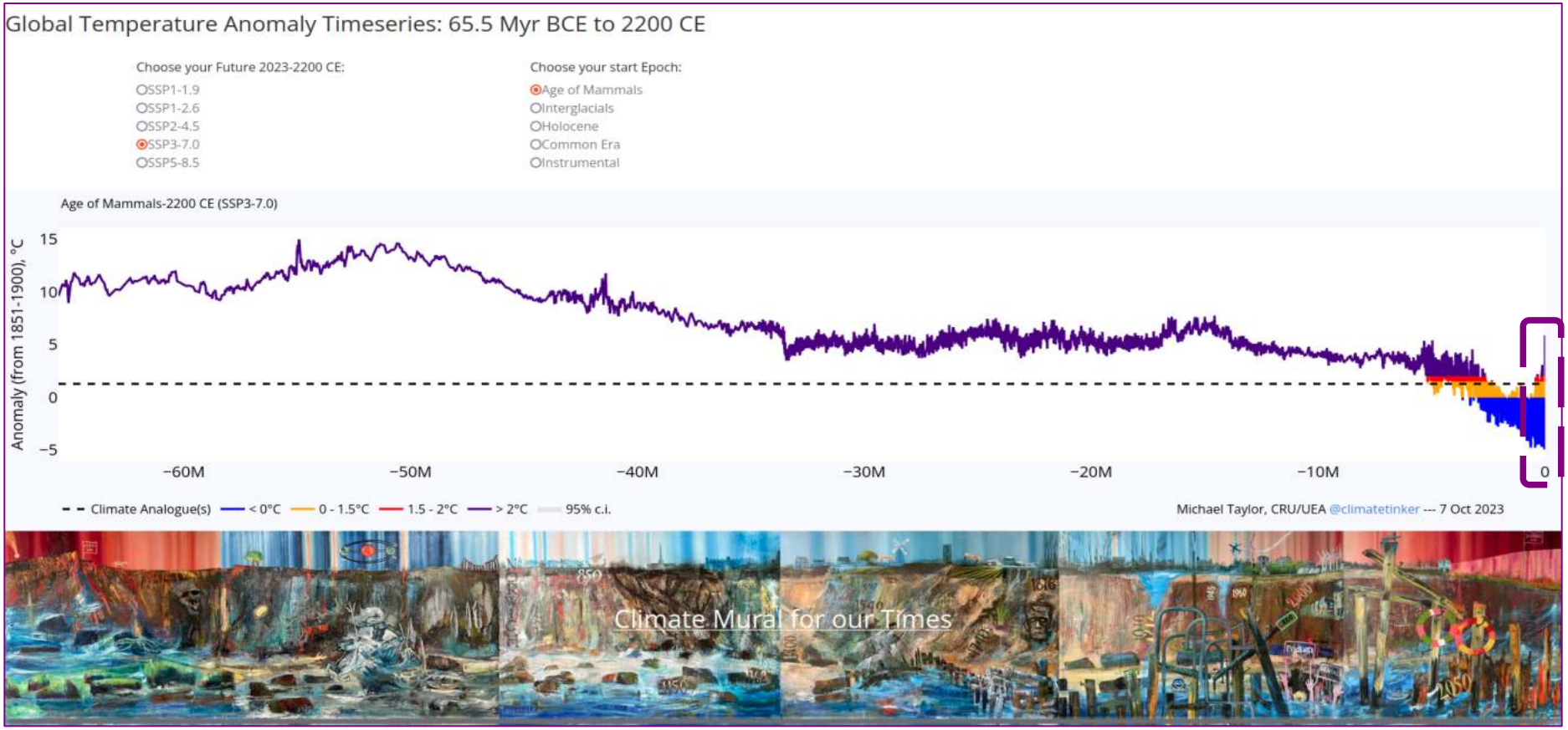
Data Rescue: (climate mural) a constant reminder

"Climate Mural for our Times" *
Unveiling in Norwich City Hall Debating Chamber 25 Nov 2022
(Prof Trevor Davies pictured speaking next to Gennadiy)

* mural website: https://crudata.uea.ac.uk/cru/climate-mural/

Data Rescue: (climate mural) app

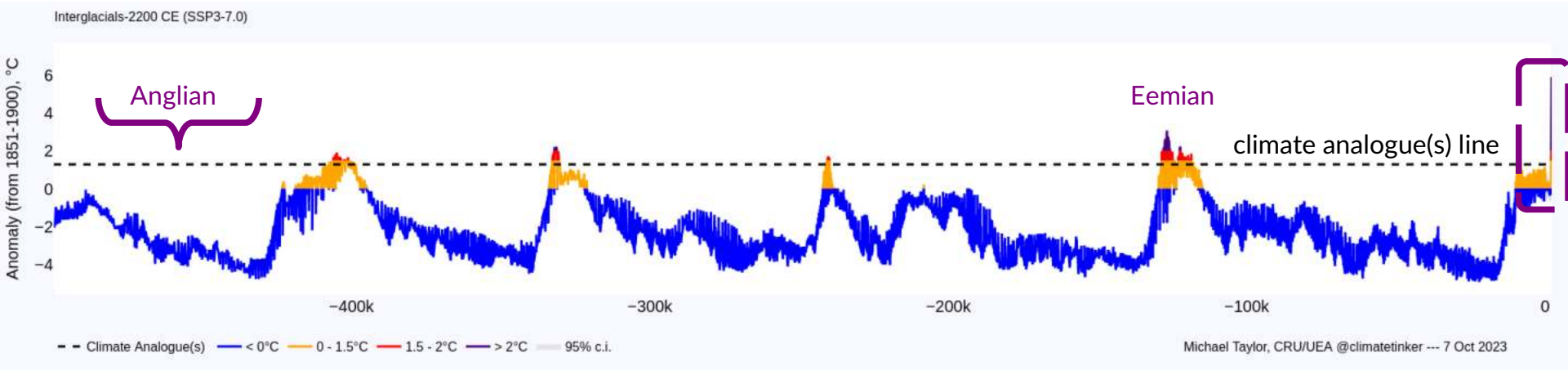
Age of Mammals app to inspect the raw data is online *
https://ncc-stripes-app-99ed067aff9e.herokuapp.com/



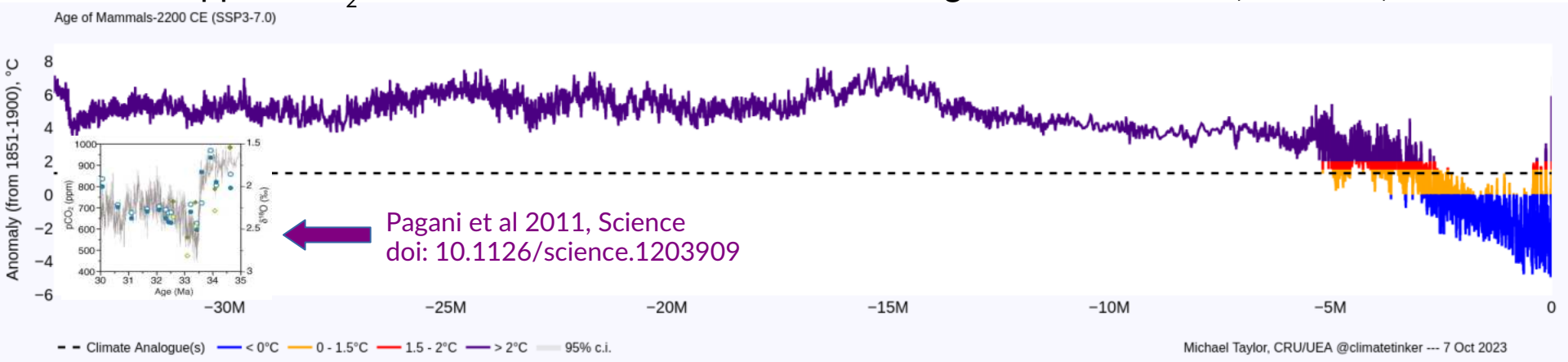
* including HadCRUT5 up to and including July 2023

Data Rescue: (climate mural app) past climate analogues *

By 2200, SSP 3-7.0 will zoom past the interglacials (and the Anglian glaciation)



and at 600 ppmv CO_2 levels will be similar to the Eocene-Oligocene transitions (-33.5 Ma)



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* data rescue is increasing our capacity to predict the future so that we can learn from the past

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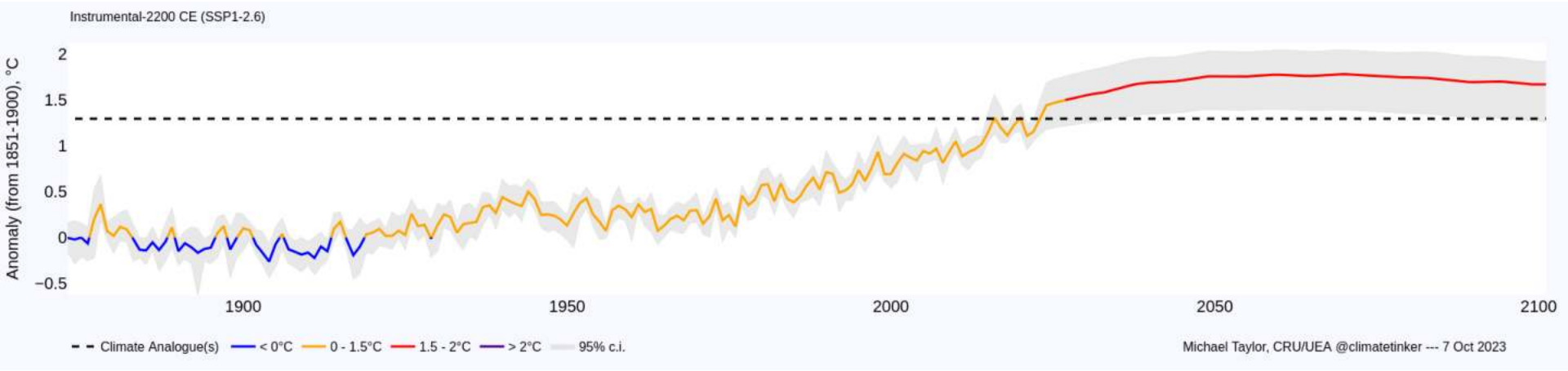
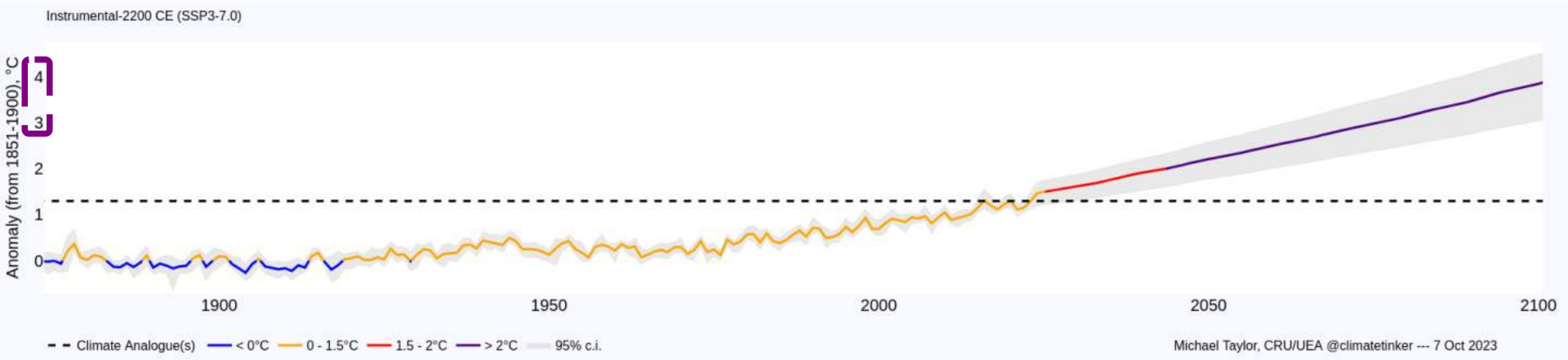
Data Rescue: (climate mural app) 1873*-2023 & future choices

With concerted action to reduce emissions (SSP 1-2.6)



Without concerted action to reduce emissions (SSP 3-7.0)



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* 1873 chosen to celebrate 150 years of the QJ of the RMetS

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Data Rescue: future needs

Now that **we have a way to include short anomaly series** using LEK:

- We need to rescue data from stations (or install new ones) in regions where we don't have them.
- We need digitization of more international historic data from regions where coverage is poor (Africa, South America, Southern Asia, Antarctica) and help countries improve visibility and accessibility of their archives.
- We need to accelerate decolonisation to facilitate two-way benefits and extend series by merging newly digitised pre-independence records with post-independence records held by NMS's.
- We need more funding to support ingestion from large-scale digitisation efforts and cross-project collation of records made available by data rescue.

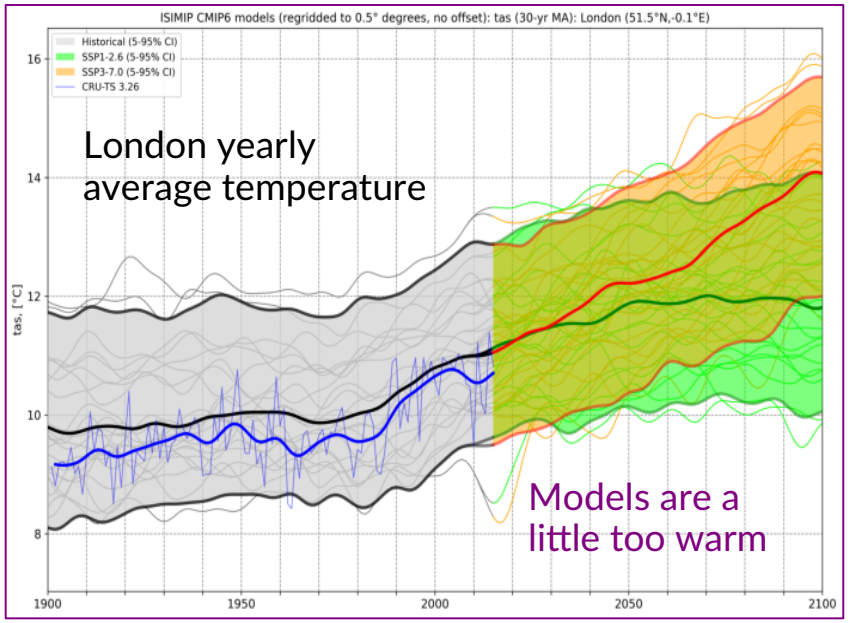
These data rescue steps will significantly improve regional climate understanding and the skill of forecasts.

EXTRA SLIDES

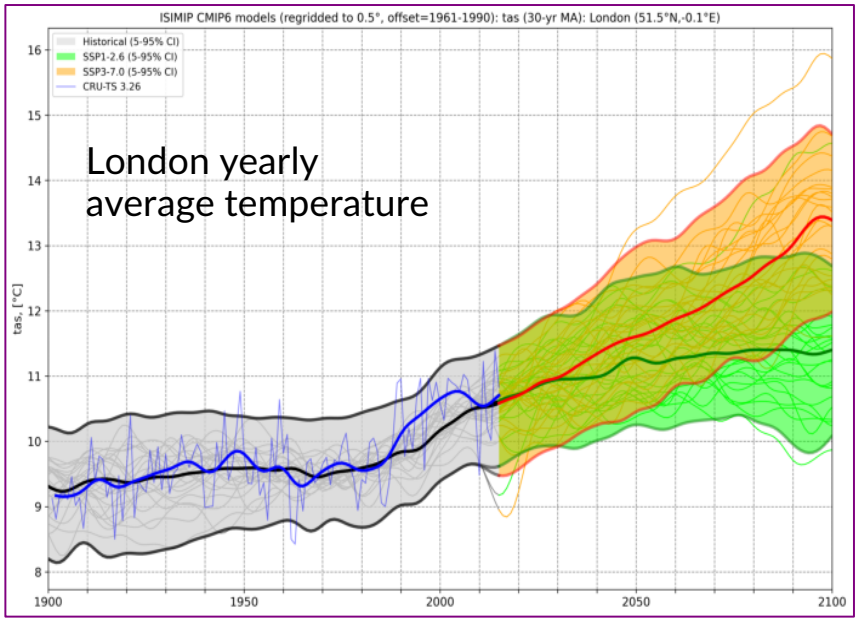
Data Rescue: application – CMIP6 bias-adjustment

I am using 1961-1990 observations from the sister of CRUTEM (CRU-TS 1900-2023) to bias correct CMIP6 model climate indices for the CUSSH project *

Before bias adj of 23 climate models



After bias adj of 23 climate models



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* CUSSH = Complex Urban Systems for Sustainability & Health
https://www.ucl.ac.uk/complex-urban-systems/cussh

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