

Blended global temperatures versus global surface air temperature: *a view from reanalysis*

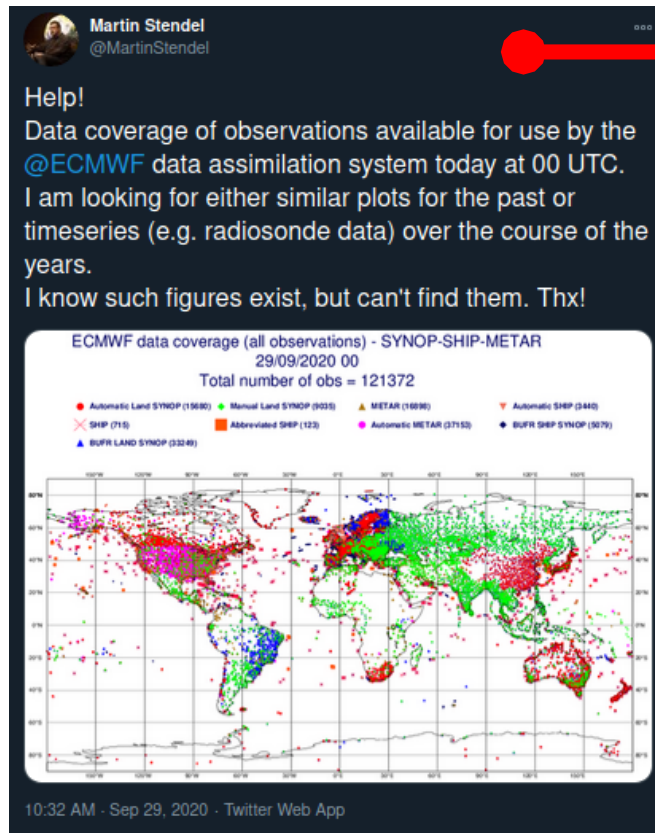
Taylor, M.^{1*}, Osborn, T.¹

¹ Climatic Research Unit, University of East Anglia

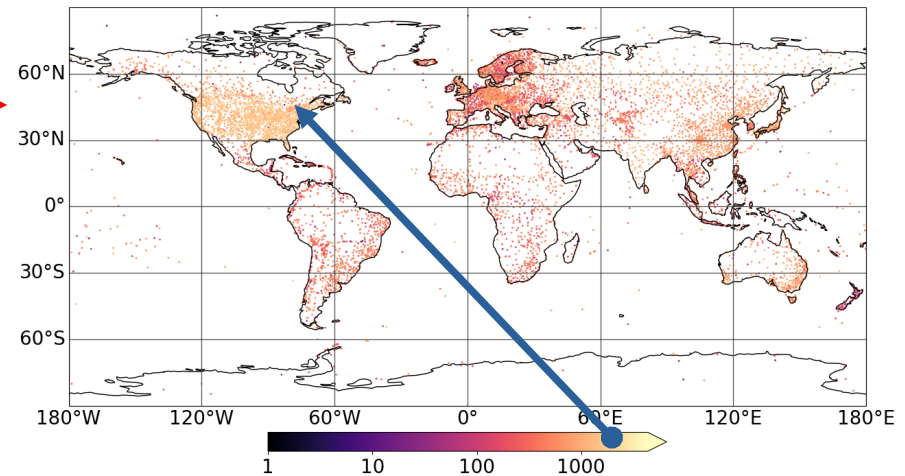
* michael.a.taylor@uea.ac.uk

A GloSAT story:

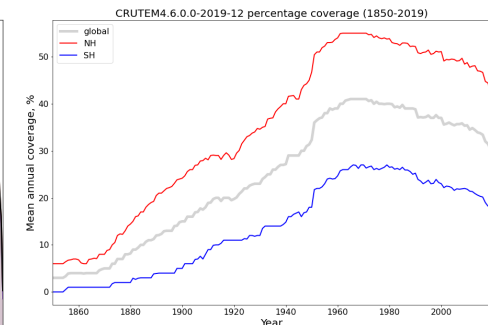
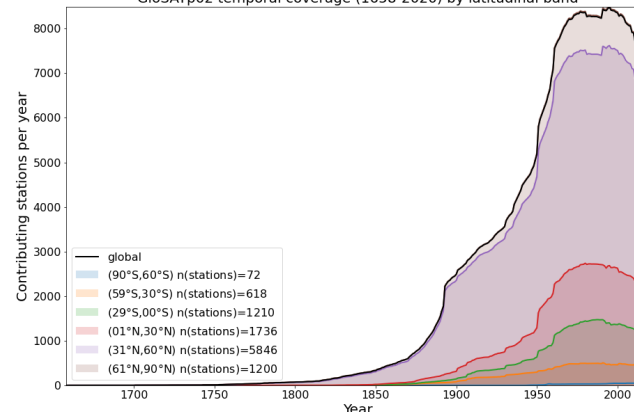
Part I (land obs spatial coverage evolution)



Number of months (1658-2020) with at least 1 observation



GloSATp02 temporal coverage (1658-2020) by latitudinal band



2020 NH coverage ~ 40%
2020 SH coverage ~ 20%

A GloSAT story: Part II (land obs get us part of the way there)

“ There are significantly fewer measurements of the weather - experts warn of the consequences ”

“ Growing fear of global warming, but we take the global temperature less ”

- Observations every hour
- Observations, but they are not good enough
- Outdated and unstable measurements - not good enough
- Observation records that do not provide data

“How the temperature of the globe is measured”



Der er markant færre målinger af vejret - eksperter advarer mod konsekvenserne

En 12 år gammel sønsg kan have været borte. Den 12-årige sønsg er blevet fundet i en sø. Den 12-årige sønsg er blevet fundet i en sø. Den 12-årige sønsg er blevet fundet i en sø.

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Indblik KLIMA

Voksende frygt for global opvarmning, men vi tager klodens temperatur mindre

Siden afslutningen på Den Kolde Krig er antallet af vejrobservationer i verden faldet markant. Ekspert advarer om, at det kan blive værre, at forudsigt farligt vejr og fremtidens klima. Ligesom det kan blive vanskeligere at udpege områder, hvor mennesker bør slås ned eller holde sig væk fra.



Måske har du hørt, at der er færre målinger af vejret. Det er rigtigt. Men det er ikke kun i Danmark, der er færre målinger. Det er over hele verden. Det er især i de udviklingslande, der er færre målinger. Det er især i de udviklingslande, der er færre målinger. Det er især i de udviklingslande, der er færre målinger.

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HER MÅLES VEJRET I VERDEN - VEJROBSEVATIONER

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Indblik KLIMA

Coronakrisen har ramt verdensgigten

Den enormt store verdensgigt under coronakrisen står på hold. Mange af verdensgigterne er lukket ned. Det betyder, at der er færre målinger af vejret. Det er især i de udviklingslande, der er færre målinger. Det er især i de udviklingslande, der er færre målinger.

Verdensgigten er lukket ned

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BØRNEBRILLER HOS THIELE

Indblik KLIMA

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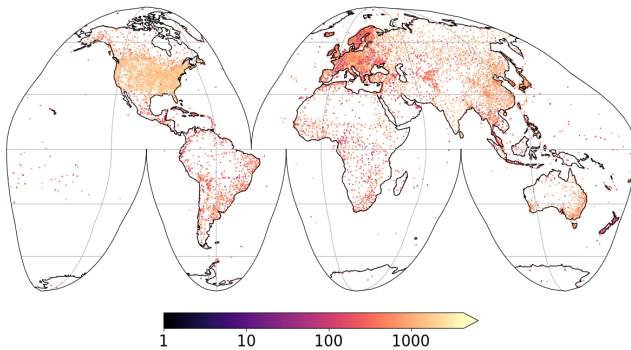
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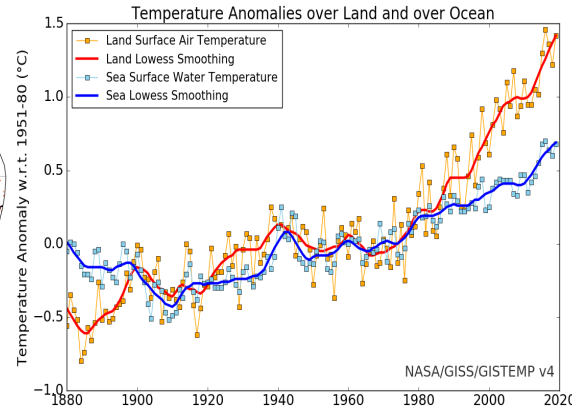
Observations and coverage:

The actual picture is more like this

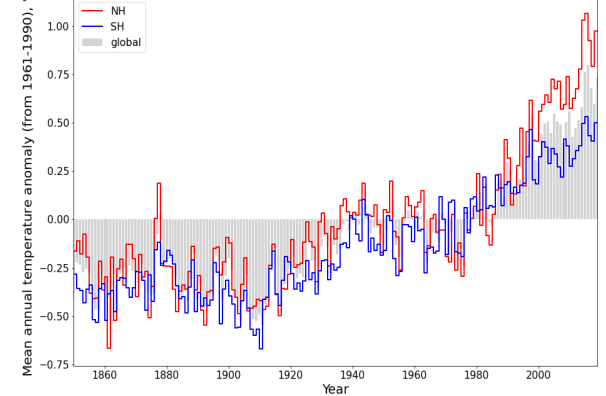
Number of months (1658-2020) with at least 1 observation



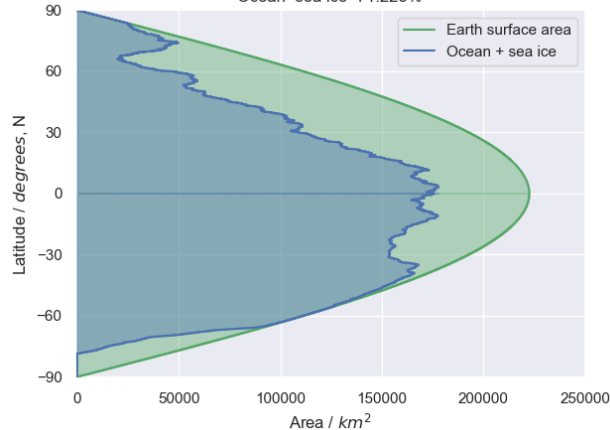
Temperature Anomalies over Land and over Ocean



HadCRUT4.6.0.0 temperature anomalies (1850-2019)

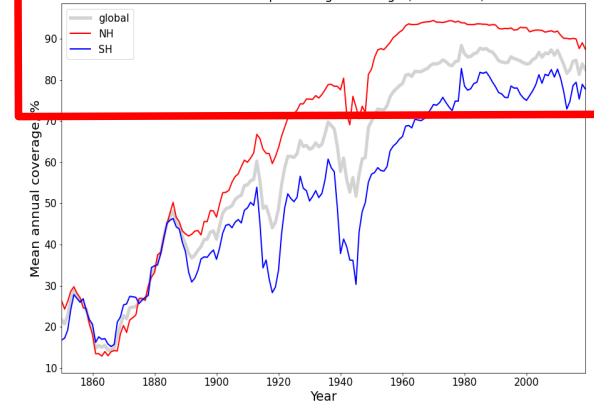


Ocean+sea ice=71.228%



NB: cosine-weighted
average of grid cells
which are bigger in the
tropics

HadCRUT4.6.0.0 percentage coverage (1850-2019)



WMO Data Conference 16-19 Nov 2020:

GloSAT and data rescue efforts will help a lot

WMO DATA CONFERENCE
EXCHANGE OF EARTH SYSTEM DATA
IN THE 21ST CENTURY
16 - 19 NOVEMBER 2020
VIRTUAL CONFERENCE
#WMOData

Summary of Key Statements from Day 3: "Filling the Gaps in Global Data Coverage," 18 Nov. 2020:

Preliminary workshops in Fall 2020 made the case for development of the Global Basic Observing Network (GBON) and the Systematic Observation Financing Facility (SOFF) and extension to climate, ocean and atmosphere composition, including GHG monitoring in support of the Paris Agreement on climate change.

- Other important ways forward - Co-design, connecting with stakeholder communities, work politically (EEZs, PA, ...)
- GBON defines minimum requirements for a global observing system supporting global numerical weather prediction and climate monitoring as the basic infrastructure for many weather and climate related services.

Audio Settings - Chat - Raise Hand - Q&A - Erik Andersson

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#WMOData

Summary of Key Statements from Day 3: "Filling the Gaps in Global Data Coverage," 18 Nov. 2020:

- SOFF is a commitment of the Alliance for Hydromet Development, will provide technical and financial assistance in new ways to support SIDS and LDCs to become GBON compliant.
- Importance of global Numerical Weather Prediction (NWP) for WMO and for prediction. It underpins all other application areas, and is a truly global endeavor, requiring a global approach.
- NWP centers have tools to monitor current observations, measure their current impact, and also estimate potential future impact - including the socio-economic impact.
- Gaps are filled by first sharing all existing observations, ensuring these shared observations can be used (e.g. by providing necessary metadata), next by funding new observations – e.g. via the SOFF - where needed.
- Earth System Aspect: need to evaluate gaps across all components.

Audio Settings - Chat - Raise Hand - Q&A - Erik Andersson

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Summary of Key Statements from Day 3: "Filling the Gaps in Global Data Coverage," 18 Nov. 2020:

- **TAHMO's** experience in Africa shows:
 - Few buyers for data, but people are eager to pay for services.
 - Information technology shortfalls create an important and often overlooked bottleneck in global data coverage.
 - Long-term engagement is very important.
 - "Nobody wants to pay for data"; they want to pay for services;
 - Need to move away from project-driven development toward sustaining the observing networks;
- **RA-I:** Very strong message regarding the importance of free and unrestricted exchange of data, and the need for support to Members, including through increasing their access to improved observations and new types of data.

Audio Settings - Chat - Raise Hand - Q&A - Erik Andersson

Models (and satellite EO) rely on observations (and vice-versa)

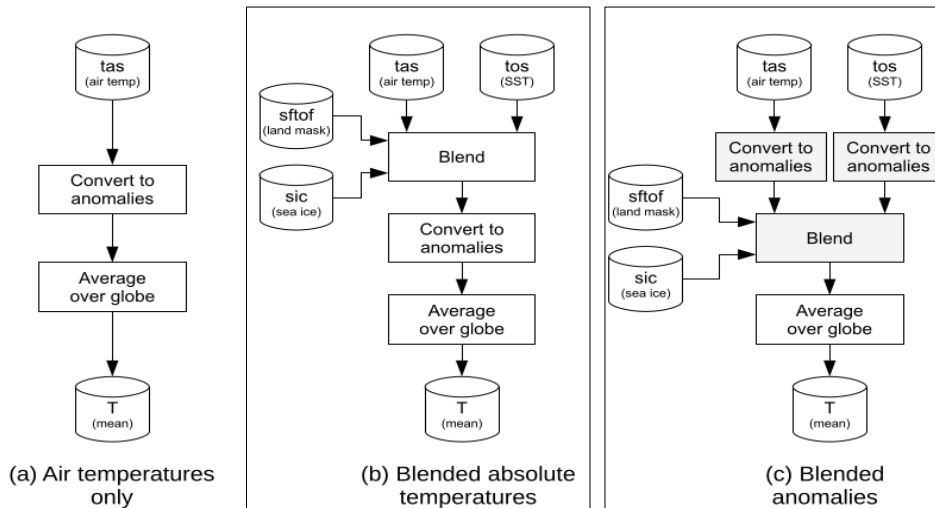
Big issue in some of the poorest countries in Africa and large sea areas in the southern hemisphere like the Indian Ocean and in the Pacific where there are large areas with few or no observations

Big issue in regions affected by extreme weather

Big issue in regions where climate tipping points need careful monitoring

Blending of temperatures

Kevin, Ed & colleagues have shown how to compare obs with climate models by calculating **global mean surface temperature (GMST) anomalies** (from 1961-1990) by **blending air temp over land (TAS)** with **SST over oceans (TOS)** for various **sea-ice concentration (SIC)** and **land/sea mask (SFTOF)** configurations



+

HadCRUT calculation:

No sea-ice: $TOS(SIC > 0.05) = NaN$

Trim to land: $TAS(SFTOF > 0.99) = NaN$

Downscaled to 5x5 grids

NB: may also mask by incomplete geographical coverage of observations (some datasets interpolate to fill in the gaps)

Air temp over sea-ice is usually estimated from obs over land

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2015GL064888

Key Points:

- There is a systematic bias in model-observation comparisons from blending air and sea temperatures
- A further bias arises from using anomalies in regions where the sea ice boundary has changed
- Correcting these accounts for a quarter to half of the discrepancy between models and observations

Supporting Information:

- Supporting Information S1

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kevin.cowtan@york.ac.uk

Citation:

Cowtan, K., Z. Hausfather, E. Hawkins, P. Jacobs, M. E. Mann, S. K. Miller, B. A. Steinman, M. B. Stolpe, and R. G. Way (2015), Robust comparison of climate models with observations using blended land air and ocean sea surface temperatures, *Geophys. Res. Lett.*, 42, 6526–6534, doi:10.1002/2015GL064888.

Robust comparison of climate models with observations using blended land air and ocean sea surface temperatures

Kevin Cowtan¹, Zeke Hausfather², Ed Hawkins³, Peter Jacobs⁴, Michael E. Mann⁵, Sonya K. Miller⁶, Byron A. Steinman⁶, Martin B. Stolpe⁷, and Robert G. Way⁸

¹Department of Chemistry, University of York, York, UK, ²Energy and Resources Group, University of California, Berkeley, California, USA, ³National Centre for Atmospheric Science, Department of Meteorology, University of Reading, Reading, UK, ⁴Department of Environmental Science and Policy, George Mason University, Fairfax, Virginia, USA, ⁵Department of Meteorology and Earth and Environmental Systems Institute, Pennsylvania State University, University Park, Pennsylvania, USA, ⁶Department of Earth and Environmental Sciences, Large Lakes Observatory, University of Minnesota, Duluth, Duluth, Minnesota, USA, ⁷Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland, ⁸Department of Geography, University of Ottawa, Ottawa, Ontario, Canada

Abstract The level of agreement between climate model simulations and observed surface temperature change is a topic of scientific and policy concern. While the Earth system continues to accumulate energy due to anthropogenic and other radiative forcings, estimates of recent surface temperature evolution fall at the lower end of climate model projections. Global mean temperatures from climate model simulations are typically calculated using surface air temperatures, while the corresponding observations are based on a blend of air and sea surface temperatures. This work quantifies a systematic bias in model-observation comparisons arising from differential warming rates between sea surface temperatures and surface air temperatures over oceans. A further bias arises from the treatment of temperatures in regions where the sea ice boundary has changed. Applying the methodology of the HadCRUT4 record to climate model temperature fields accounts for 38% of the discrepancy in trend between models and observations over the period 1975–2014.

Blending using reanalysis

Q. How well do blended (and masked) global mean surface temperatures (**GMST**) from **reanalysis** agree with observations of global surface air temp (**GSAT**) ?

Q. What is the effect of masking by observational coverage ?

Q. What is the effect of variable sea-ice coverage ?

Reanalysis datasets: **ERA5** (incl. BE) 1950-2020 & **JRA-55** 1958-2019 re-gridded at 5x5 and 1x1 using CDO and NCO

Temperature datasets: HadCRUT.4.6.0.0, CRUTEM.4.6.0.0 and HadSST.3.1.1.0 from 1850-2020

Scenarios:

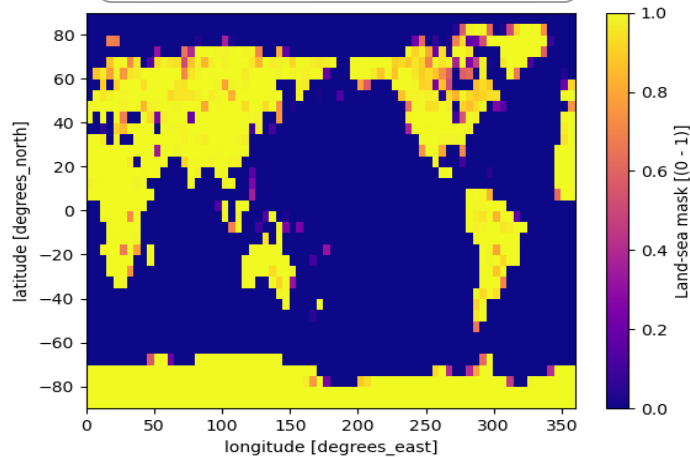
- 1) Reanalysis with **land/sea mask** and variable **sea-ice conc**
- 2) HadCRUT with **separate masks** from CRUTEM and HadSST

Stats: bootstrap calculation of **CI on the GSAT / GMST ratio**

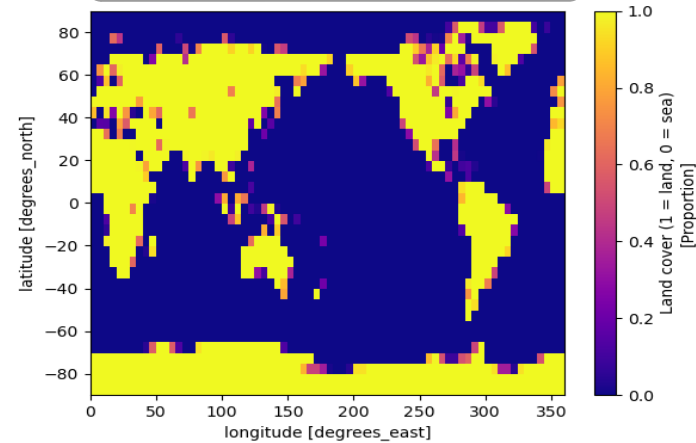
Reanalysis inputs:

Land/sea masks and sea-ice boundary changes

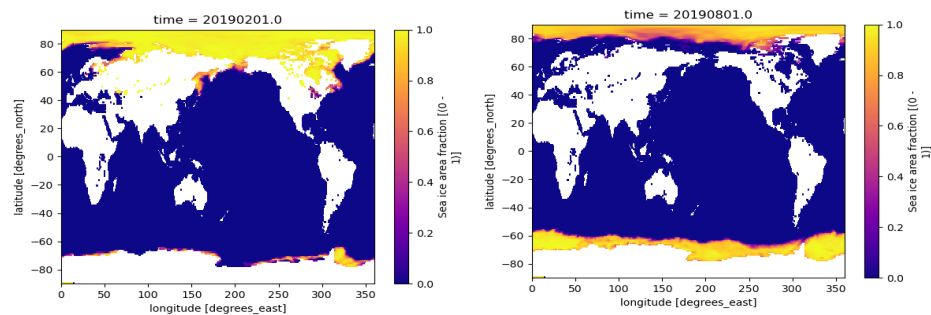
ERA5: sftof 5x5



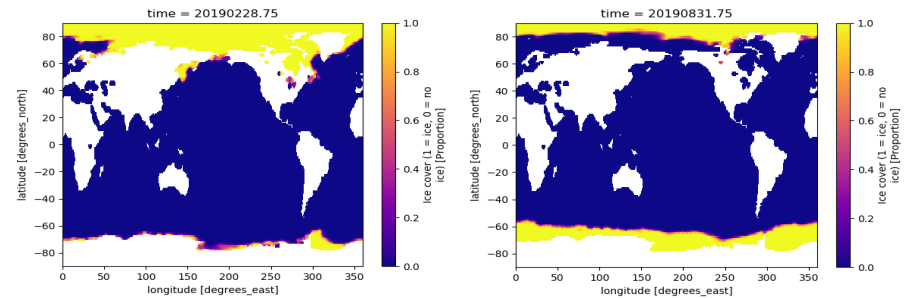
JRA-55: sftof 5x5



ERA5: sic 1x1

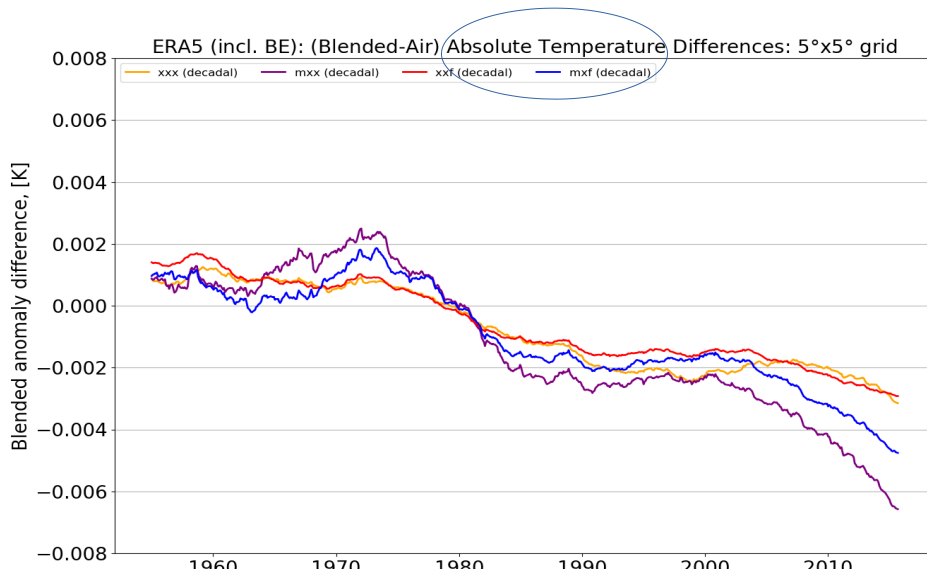


JRA-55: sic 1x1

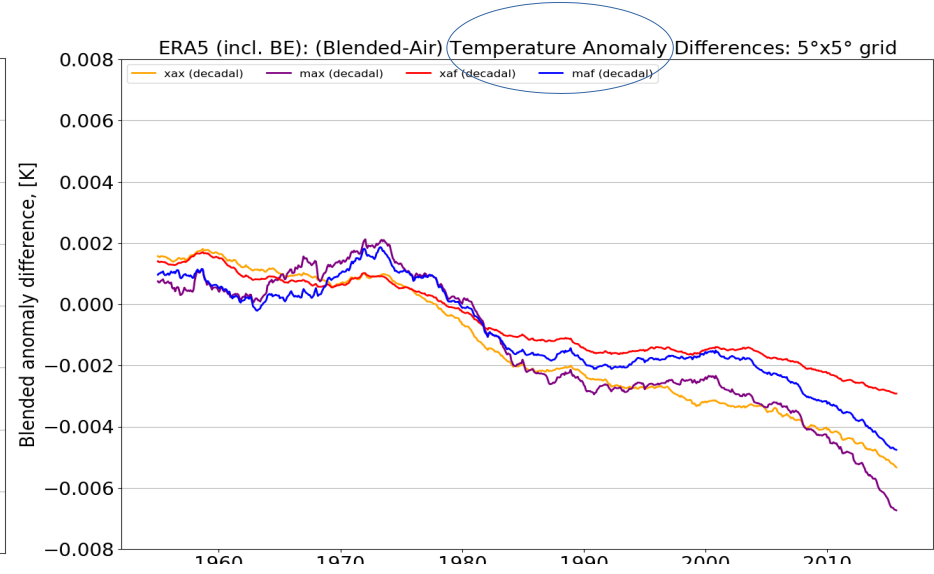


Analysis:

ERA5 (blended-air) scenario effects < 0.01K



xxx - unmasked, blended abs temp, **variable ice**
xxf - unmasked, blended abs temp, fixed ice
mxx - HadCRUT-masked, blended abs temp, **variable ice**
mxf - HadCRUT-masked, blended abs temp, fixed ice

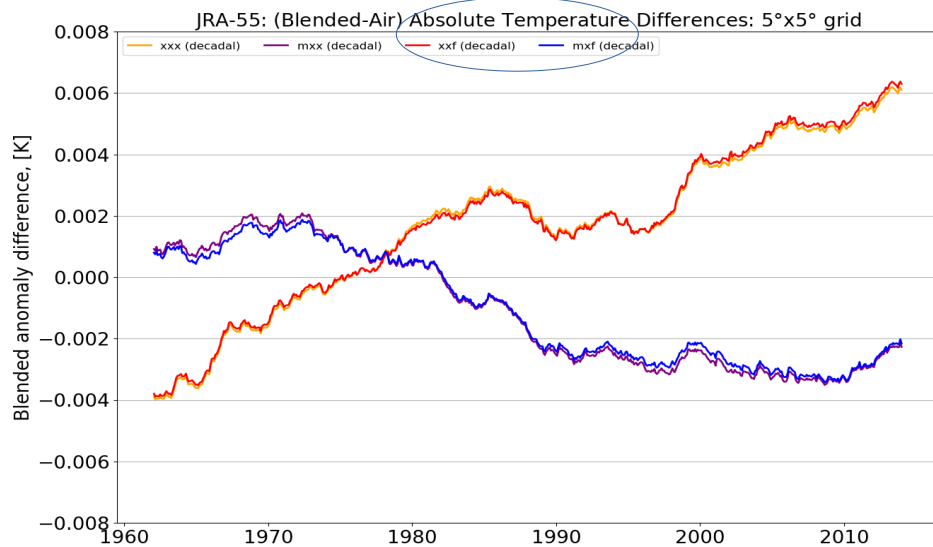


xax - unmasked, blended anomalies, **variable ice**
xaf - unmasked, blended anomalies, fixed ice
max - HadCRUT-masked, blended anomalies, **variable ice**
maf - HadCRUT-masked, blended anomalies, fixed ice

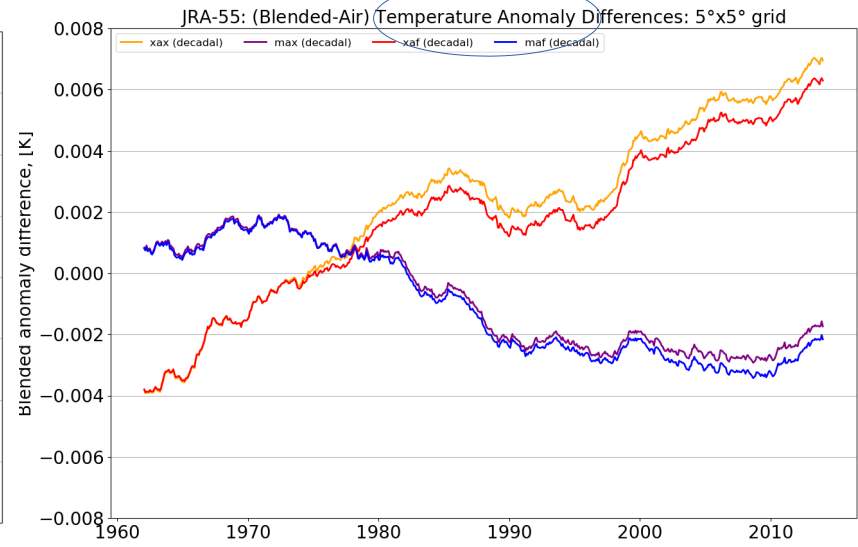
Similar overall trends
Sensitivity to variable ice
Crossover ~ middle of 1961-1990 baseline

Analysis:

JRA-55 (blended-air) scenario effects < 0.01K



xxx - unmasked, blended abs temp, **variable ice**
xxf - unmasked, blended abs temp, fixed ice
mxx - HadCRUT-masked, blended abs temp, **variable ice**
mxf - HadCRUT-masked, blended abs temp, fixed ice

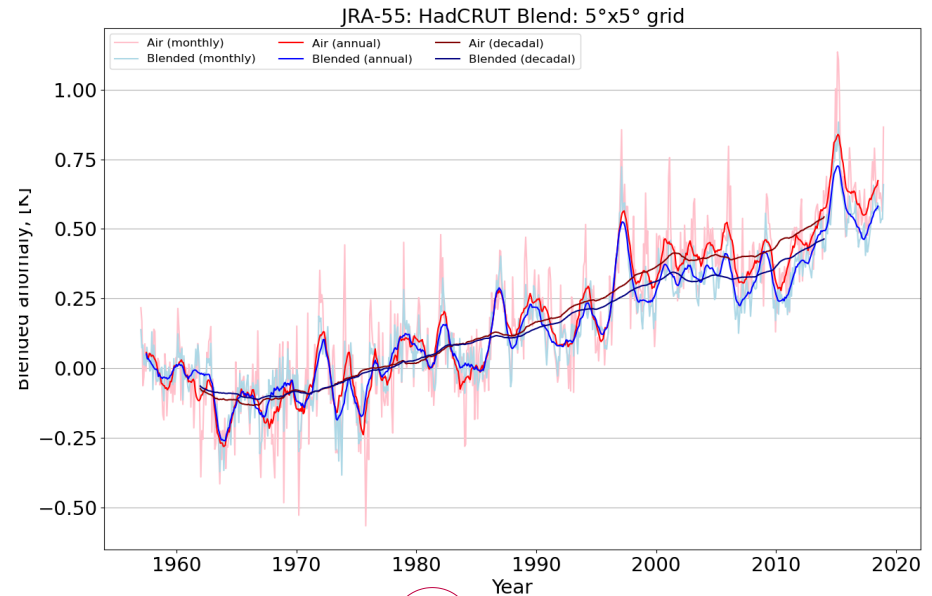
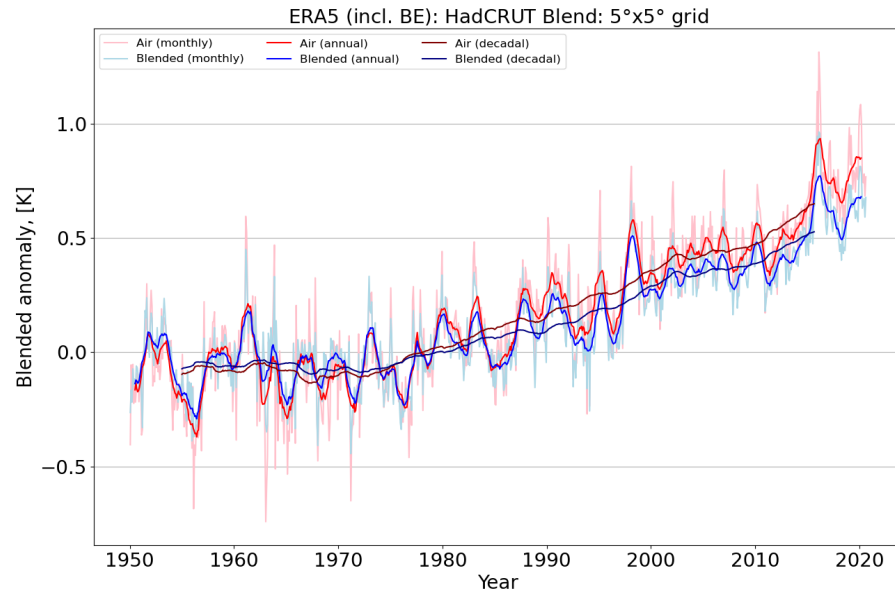


xax - unmasked, blended anomalies, **variable ice**
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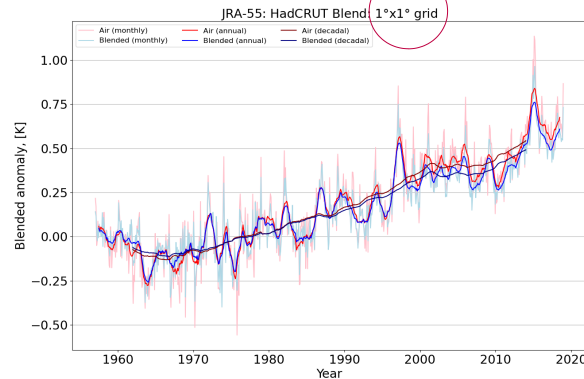
Similar overall trends
(but different to ERA5)
Sensitivity to variable ice
(arguably less than ERA5)
Crossover ~ middle of baseline

Analysis:

The HadCRUT calculation (separate land & sea masks)



GSAT has a large discrepancy from the **GMST** obtained when the reanalysis is blended using a separate land mask from CRUTEM and sea mask from HadSST and rises to ~0.1K by 2020

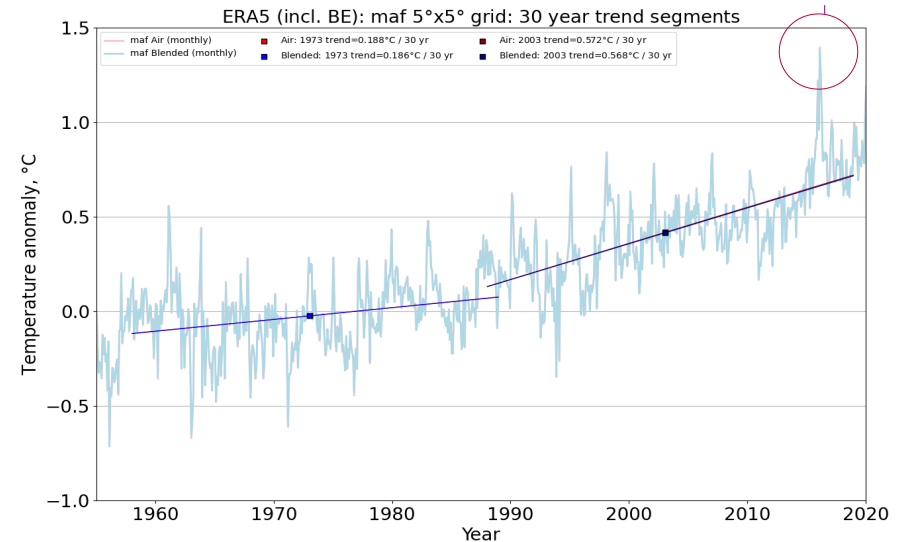
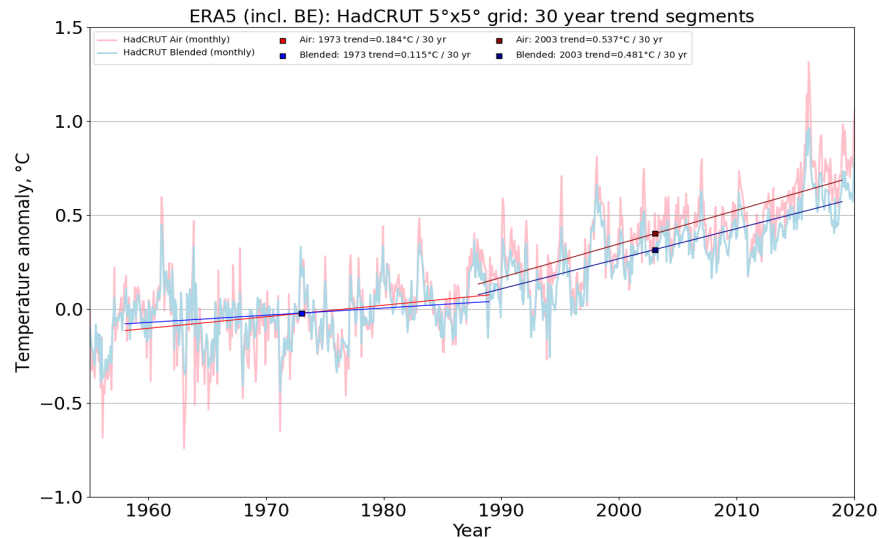


Not a resolution issue – it's still there at 1x1 (maybe slightly less)

Analysis:

Sea-ice resolves the HadCRUT calculation discrepancy

Discrepancy is barely visible



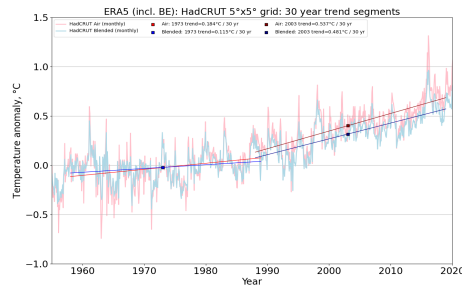
HadCRUT calculation: **no sea-ice**

maf - HadCRUT-masked, blended anomalies, **fixed ice**

GSAT discrepancy from GMST obtained when the reanalysis is blended the HadCRUT mask and known sea-ice seems to resolve this problem

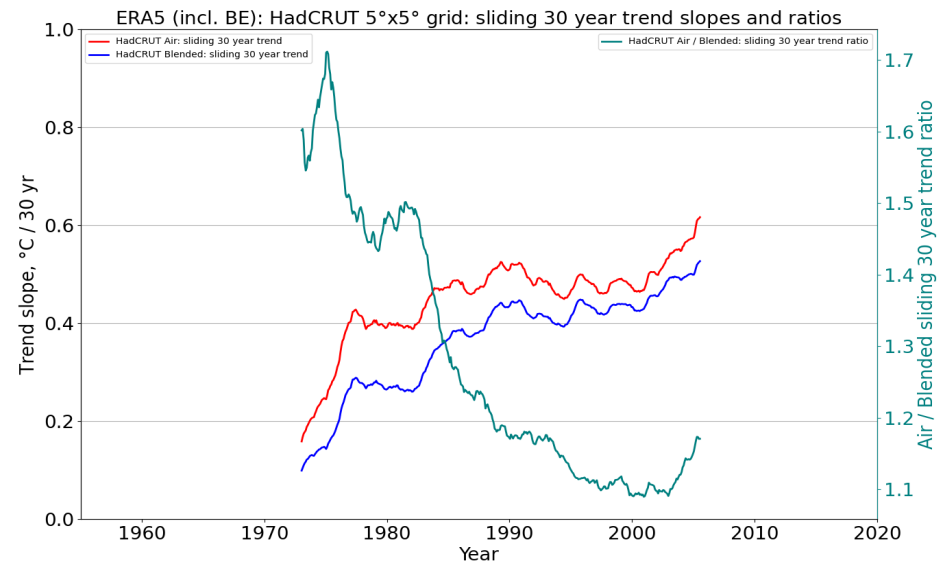
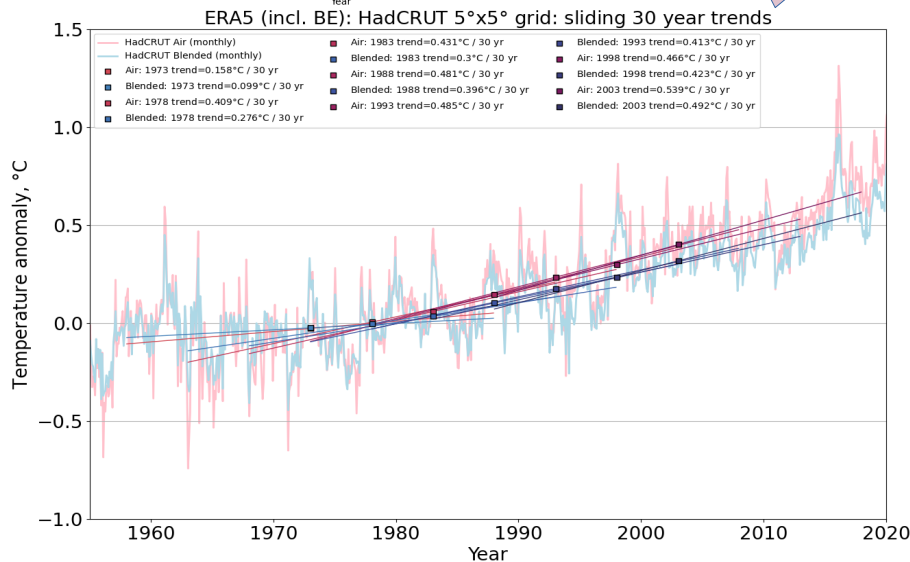
Analysis:

General GSAT/GMST blended cases – sliding trend ratios



GSAT / GMST Ratio = Air / blended

We generalise from 30-yr trend blocks to 30-yr sliding trends for air and blended
This smooths out the ratio (a bit)

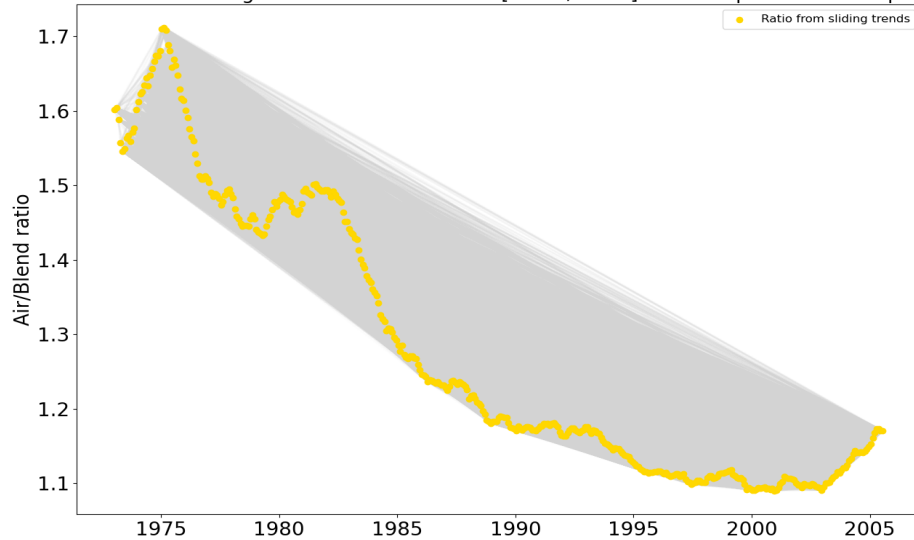


Although the anomaly discrepancy is ~ 0.1K, the impact on the GSAT / GMST is large e.g. a ratio of 1.7 translates to 70% increase over the blended anomaly value
Q. Does repeating this analysis using LOESS fits (30-yr span) change things ?

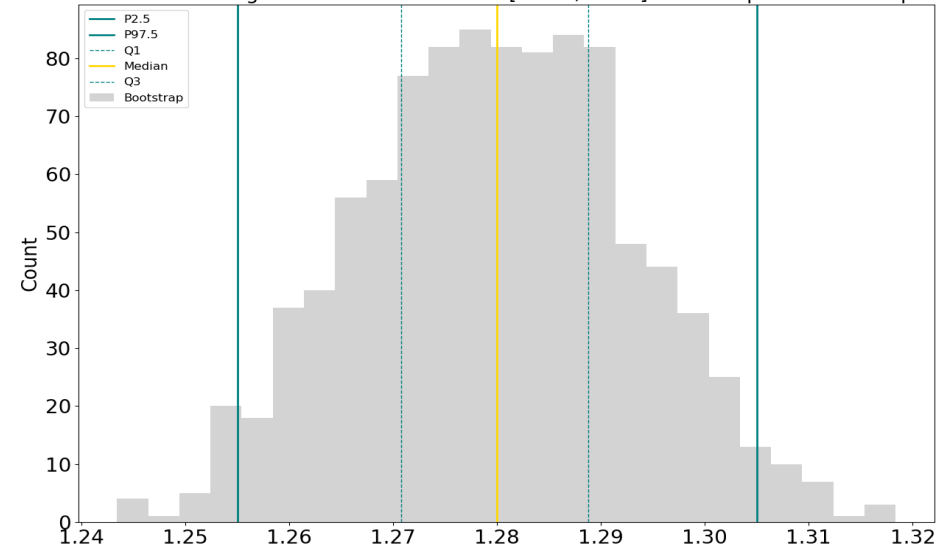
Analysis:

General GSAT/GMST blended cases – bootstrap CI on ratio

HadCRUT: 5°x5° grid: 95% likelihood of CI [1.255,1.305]: bootstrap N=1000 samples



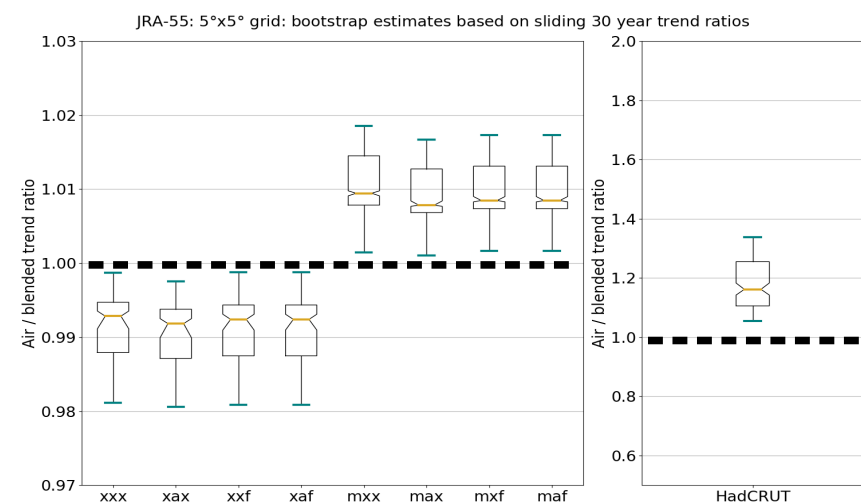
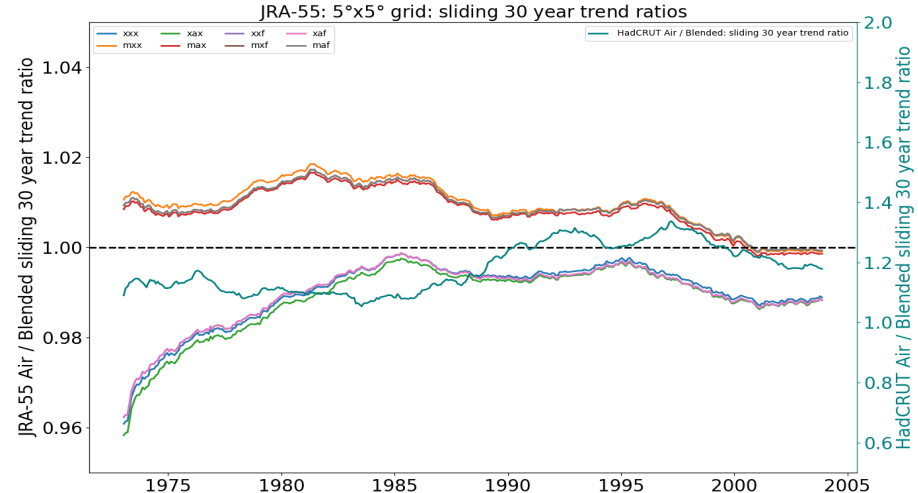
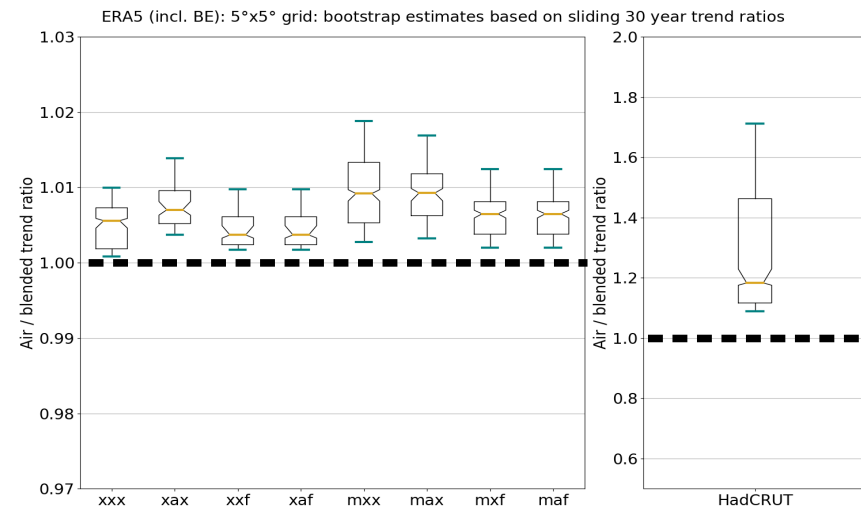
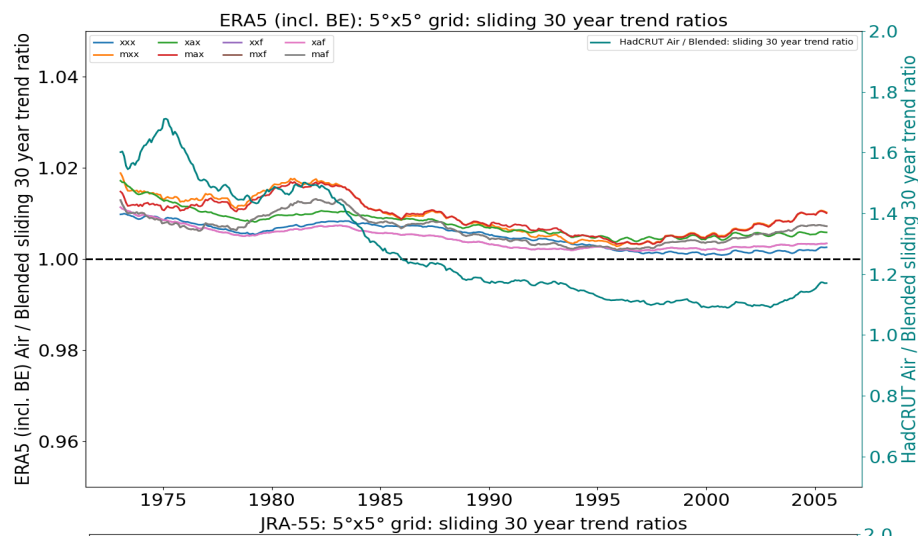
HadCRUT: 5°x5° grid: 95% likelihood of CI [1.255,1.305]: bootstrap N=1000 samples



We then bootstrap to find the likelihood of the 5-95% bounds on the confidence interval (CI) for the ratio
We do this for all cases (including the HadCRUT calculation)

Analysis:

Blended ratio bounds~[0.99,1.01] (HadCRUT case ...)



Conclusions

This study reiterates the value of the **blending approach for robust comparisons**:

A. Blended (and masked) temperatures from **reanalysis** agree well with 'true' GMST observations (some minor difference between **ERA5** & **JRA-55**)

A. Using separate **land/sea coverage masks** and no sea-ice has the strongest impact ~ **0.1K** (the HadCRUT calculation)

A. Variable **sea-ice** and HadCRUT mask effect ~ **0.01K**

Robust statistics can be obtained from sliding trends and **bootstrapping** to determine the 5-95% likelihood of **CI on the GSAT / GMST ratio: [0.99,1.01]** depending on reanalysis

A GloSAT story:

Part III (nice collaborations and rescued obs)

Daily Record, 1 July 1776-10 January 1777

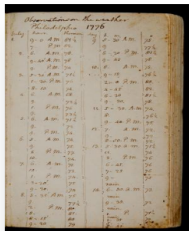
Massachusetts Historical Society: Coolidge Collection of Thomas Jefferson Manuscripts, 1705-1827. Other Volumes, 1766-1824. Memorandum Book, 1776-1778.

5 pp., bound at the end of a volume with Timothy Telescope [Robert Aitken], *The Philadelphia Newest Almanack, for the Year of Our Lord 1776* (Philadelphia, 1776), 70 pp. of Jefferson's cash accounts, and 2 pp. of miscellaneous memoranda.

Printed in *Memorandum Books*, 1:432-5; see also 1:xxxix.

At head of first page: "Observations on the weather / Philadelphia 1776." Headings of first column on first page: "July. | hour. | thermom."; and second column: "day | h | m | °. |."

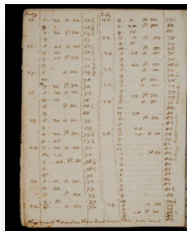
At 17 July 1776, Jefferson put an asterisk in front of his evening observation and put a note at the foot of the page: "this mark * denotes there had been rain previous." He employed the asterisk in other entries in this record up to 26 August 1776.



Daily Record, 1 July
1776-10 January 1777.
page 128

1 July 1776 - 14 July 1776

[View Page](#)



Daily Record, 1 July
1776-10 January 1777.
page 127

15 July 1776 - 29 July
1776

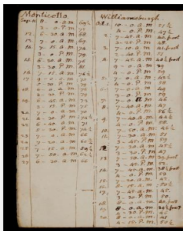
[View Page](#)



Daily Record, 1 July
1776-10 January 1777.
page 126

30 July 1776 - 3
September 1776

[View Page](#)




Daily Record, 1 July
1776-10 January 1777.
page 125

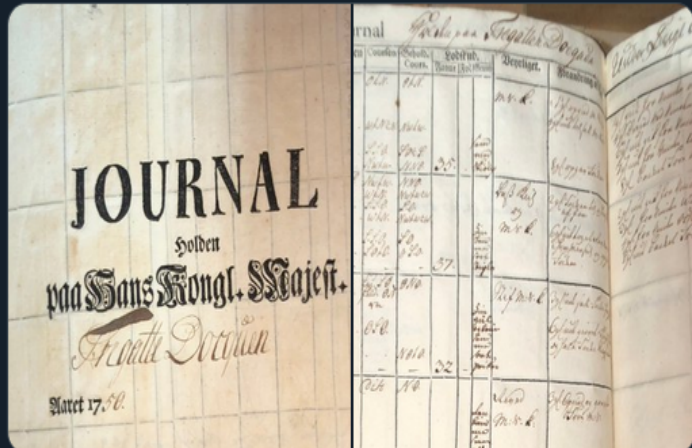
11 September 1776 - 20
October 1776

[View Page](#)

Rescuing land air temp observations

 **Martin Stendel**
@MartinStendel

In the Danish National Archives, @Rigsarkivet, 3 centuries of Danish ship logbooks are kept, offering an invaluable wealth of information about temperature, pressure, wind and weather. @isterbandit, @ed_hawkins and I are building a consortium to digitize ~3 million pages. @dmidk



1:55 PM · Oct 13, 2020 · Twitter Web App

Rescuing marine air temp observations

Many thanks

Kevin Cowtan

For providing python blending code and guidance:

<https://www-users.york.ac.uk/~kdc3/papers/robust2015/methods.html>

NCAR/UCAR & JMA

For providing JRA-55 reanalysis data 1958-2019 and NCO:

<https://rda.ucar.edu/datasets/ds628.1>

C3S CDS / ECMWF

For providing ERA5 (incl. BE) reanalysis data 1950-2020:

<https://cds.climate.copernicus.eu/#!/search?text=ERA5>

UKMO / Hadley Centre

For providing HadCRUT.4.6.0.0 and HadSST.3.1.0.0 anomaly data 1850-2020:

<https://www.metoffice.gov.uk/hadobs>

CRU / UEA

For guidance and inspirations and huge effort providing CRUTEM4.6.0.0 anomaly data 1850-2020:

<https://crudata.uea.ac.uk/cru/data/temperature/>

GloSAT / NOC Team & JASMIN / CEDA

For super project support + GWS access

<https://www.glosat.org/>