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

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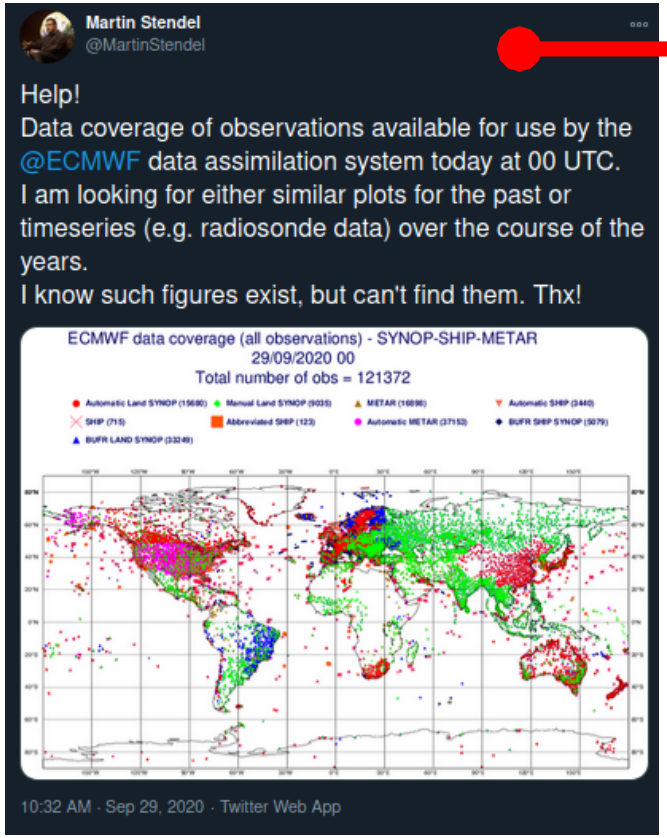
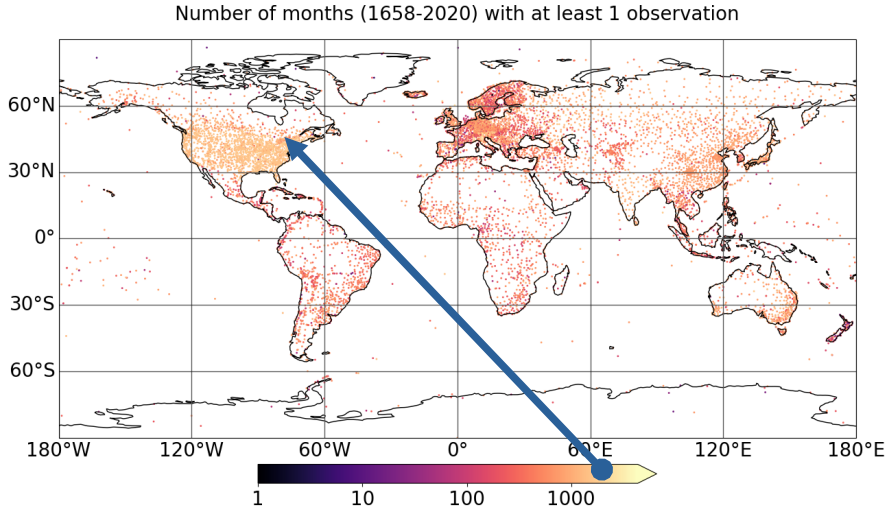
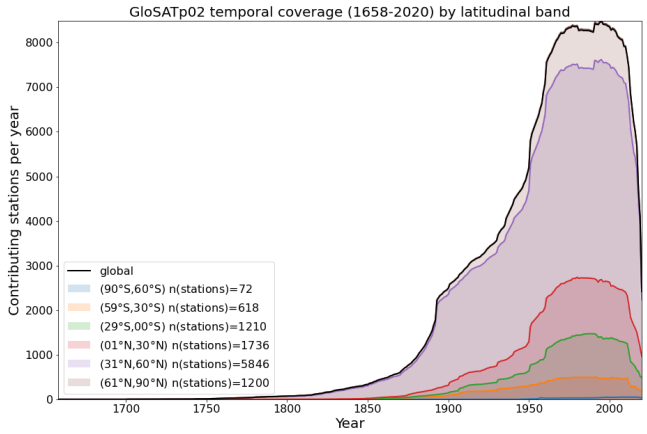
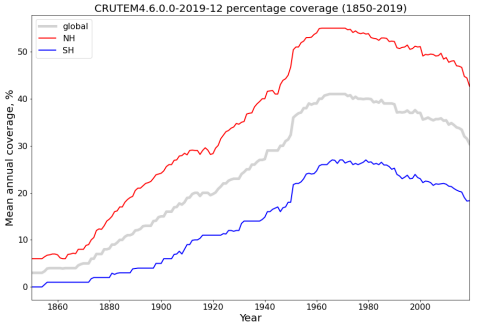
GloSAT Global Surface Air Temperature

A GloSAT story:
Part I (land obs spatial coverage evolution)









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

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GloSAT
Global Surface Air Temperature

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

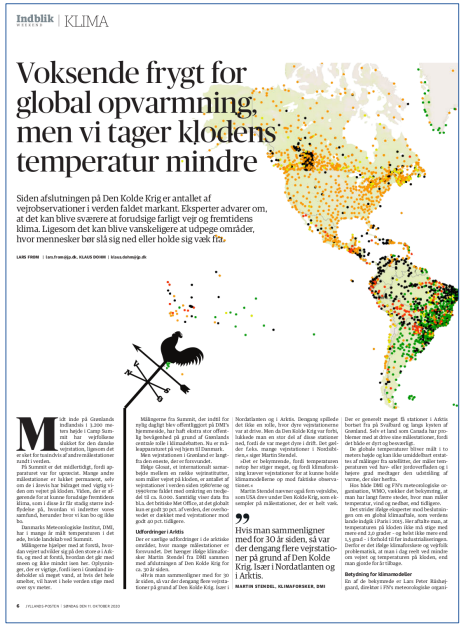
“ There are significantly fewer measurements of the weather - experts warn of the consequences ”

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

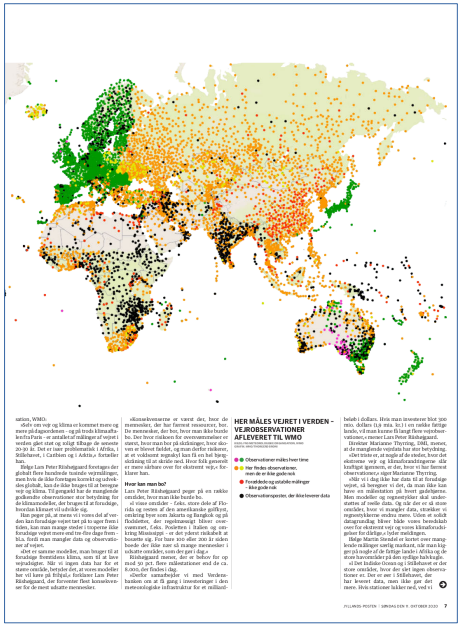
- Observations every hour
- Observations, but they are not good enough
- Outdated and unstable measurements - not good enough
- Observation records that do not provide data

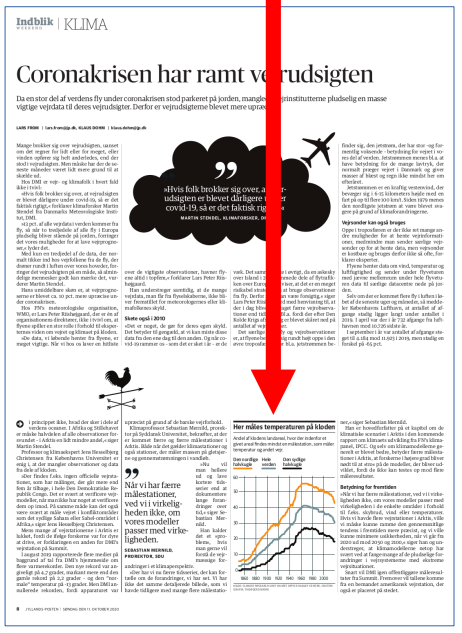
“How the temperature of the globe is measured”

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



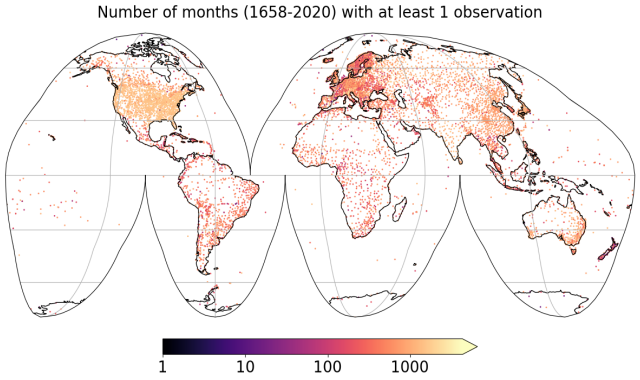
Voksende frygt for global opvarmning, men vi tager klodens temperatur mindre

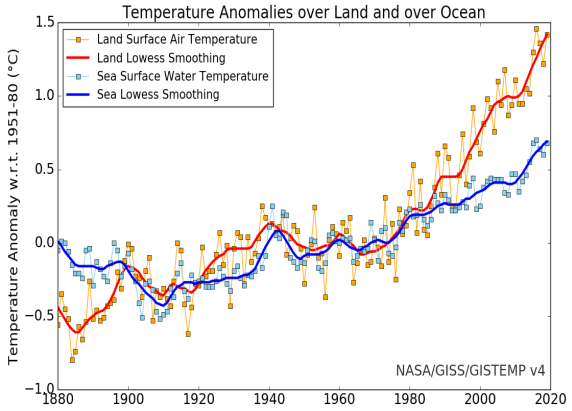


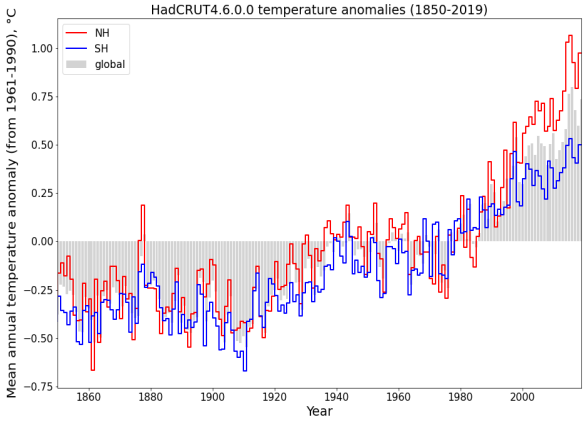


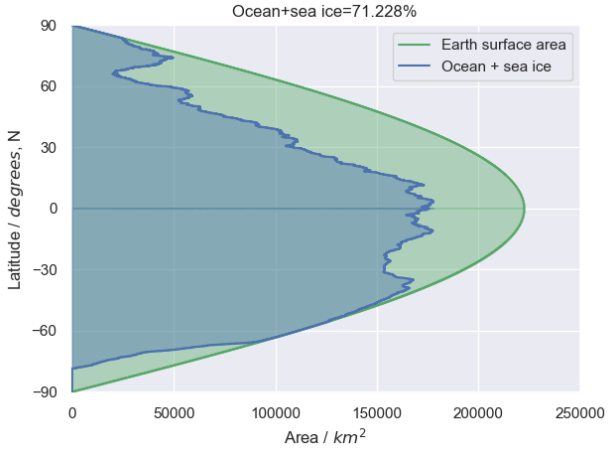
Coronakrisen har ramt vejrudsigten

Observations and coverage:
The actual picture is more like this

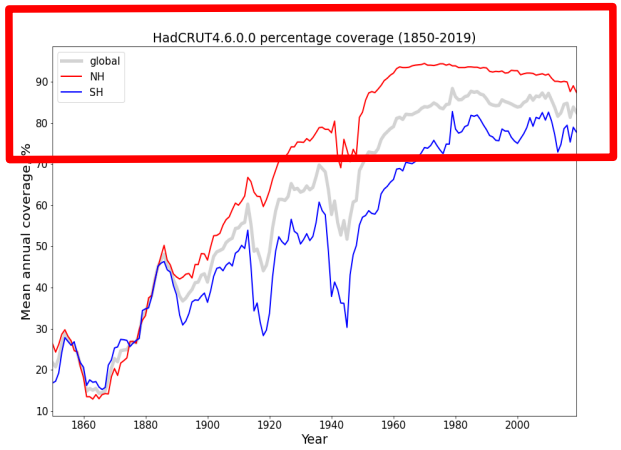




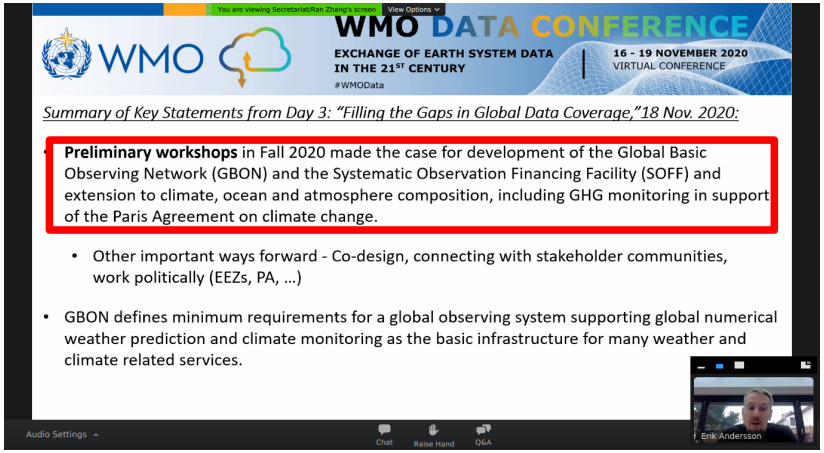




NB: cosine-weighted average of grid cells which are bigger in the tropics



WMO Data Conference 16-19 Nov 2020:
GloSAT and data rescue efforts will help a lot



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

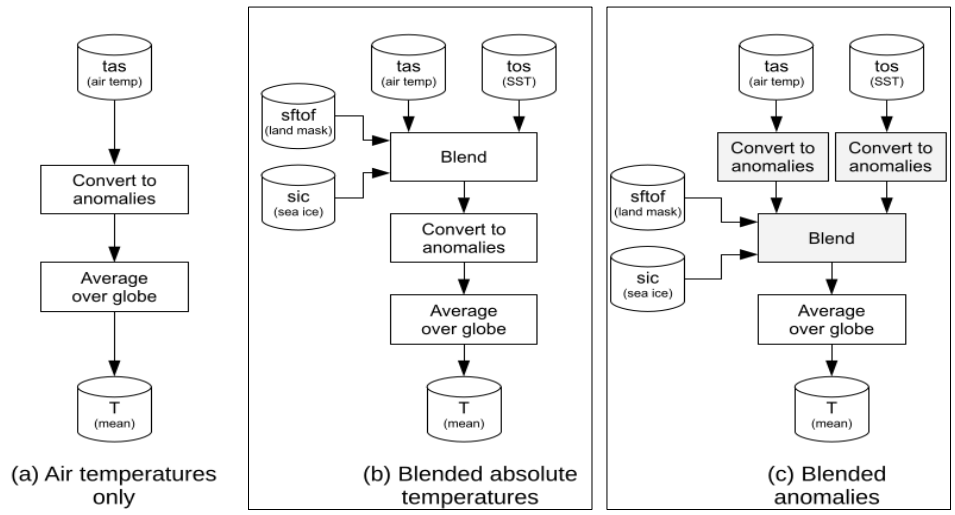
Big issue in some of the poorest countries in Africa and large sea areas in the southern hemisphere like the Indian Ocean and in the Pacific where there are large areas with few or no observations

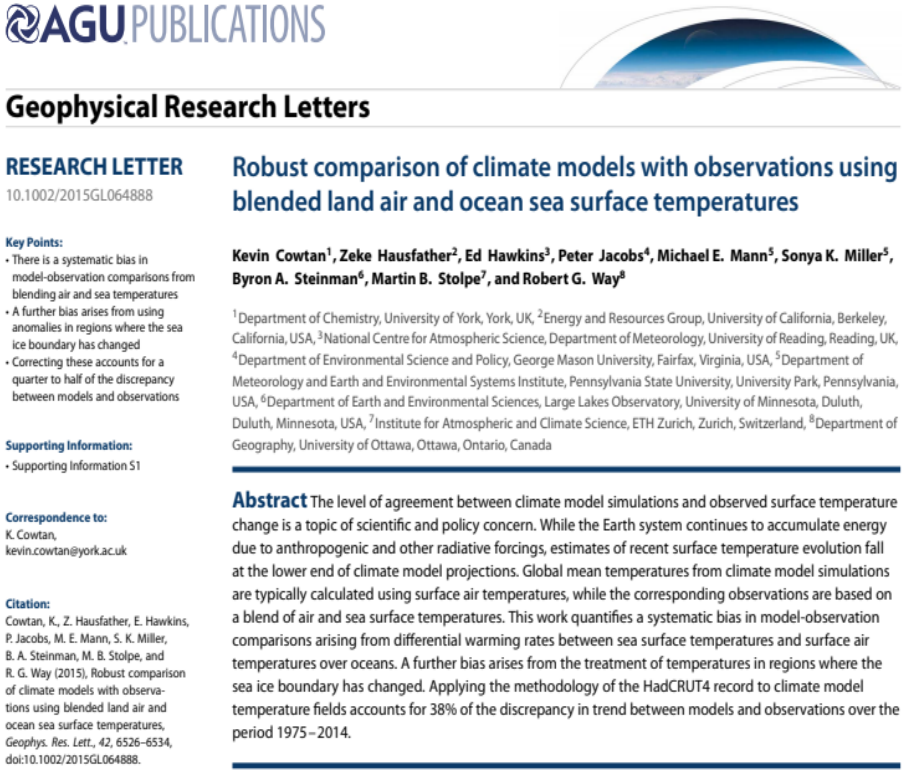
Big issue in regions affected by extreme weather

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





AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2015GL064888

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

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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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.

Kevin Cowtan[1], Zeke Hausfather[2], Ed Hawkins[3], Peter Jacobs[4], Michael E. Mann[5], Sonya K. Miller[5], Byron A. Steinman[6], Martin B. Stolpe[7], and Robert G. Way[8]

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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.

\+

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

Blending using reanalysis

Q. How well do blended (and masked) global mean surface temperatures (**GMST**) from **reanalysis** agree with osbervations 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 ?

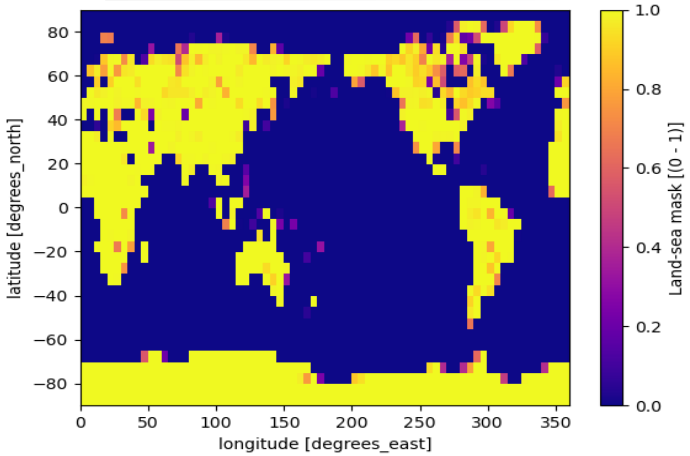
Reanalysis datasets: **ERA5** (incl. BE) 1950-2020 & **JRA-55** 1958-2019 re-gridded at 5x5 and 1x1 using CDO and NCO
Temperature datasets: HadCRUT.4.6.0.0, CRUTEM.4.6.0.0 and HadSST.3.1.1.0 from 1850-2020

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

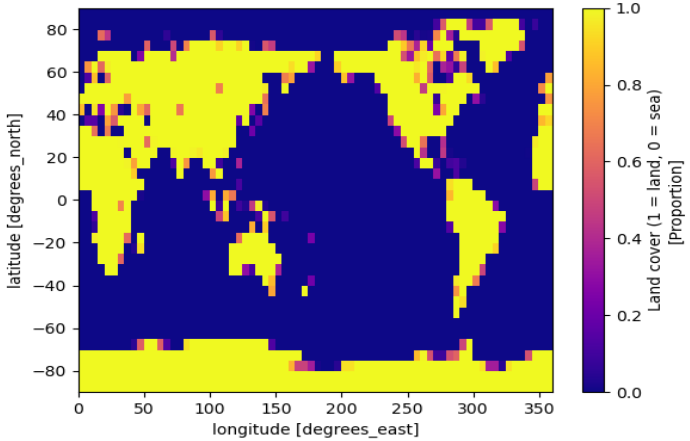
Stats: bootstrap calculation of **CI on the GSAT / GMST ratio**

Reanalysis inputs:
Land/sea masks and sea-ice boundary changes

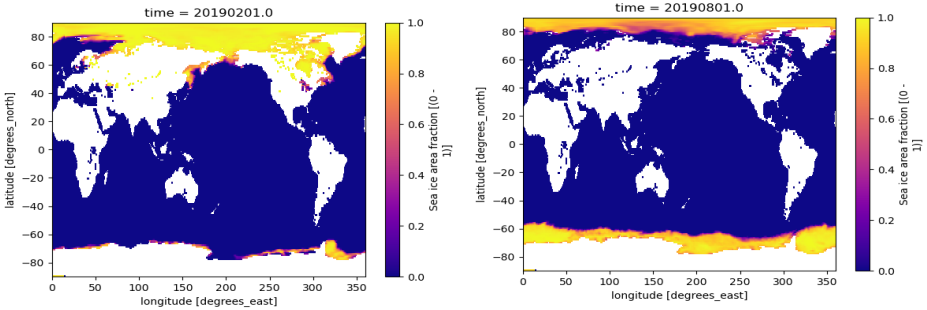
ERA5: sftof 5x5



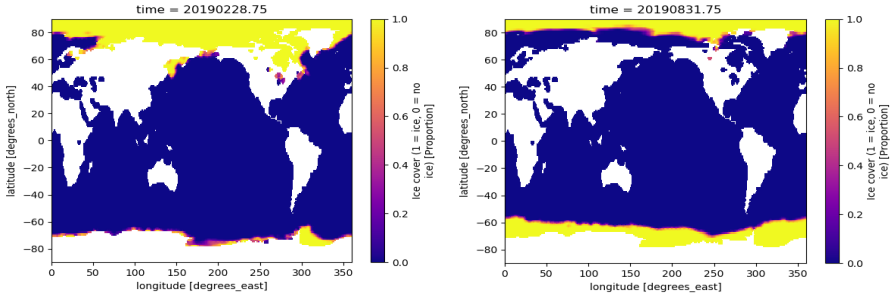
JRA-55: sftof 5x5



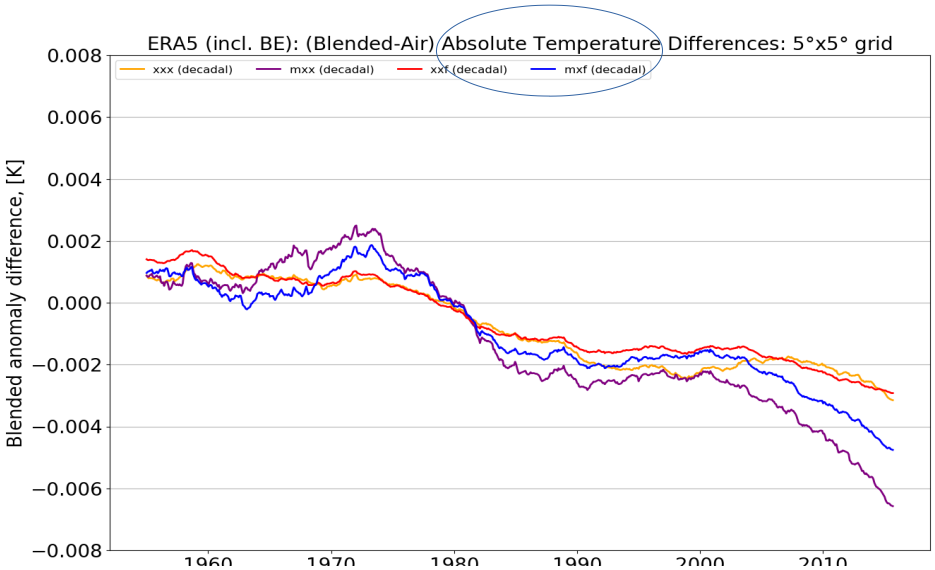
ERA5: sic 1x1

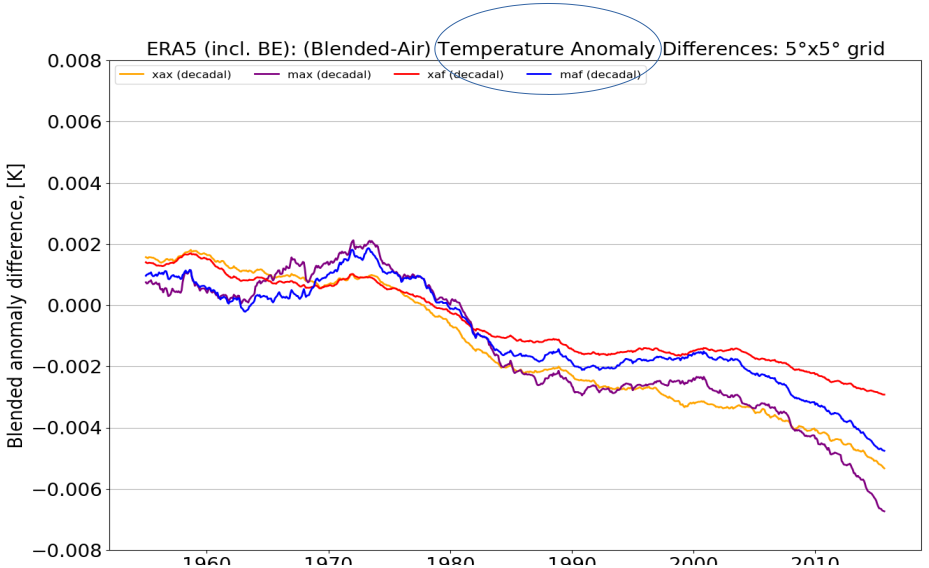


JRA-55: sic 1x1



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

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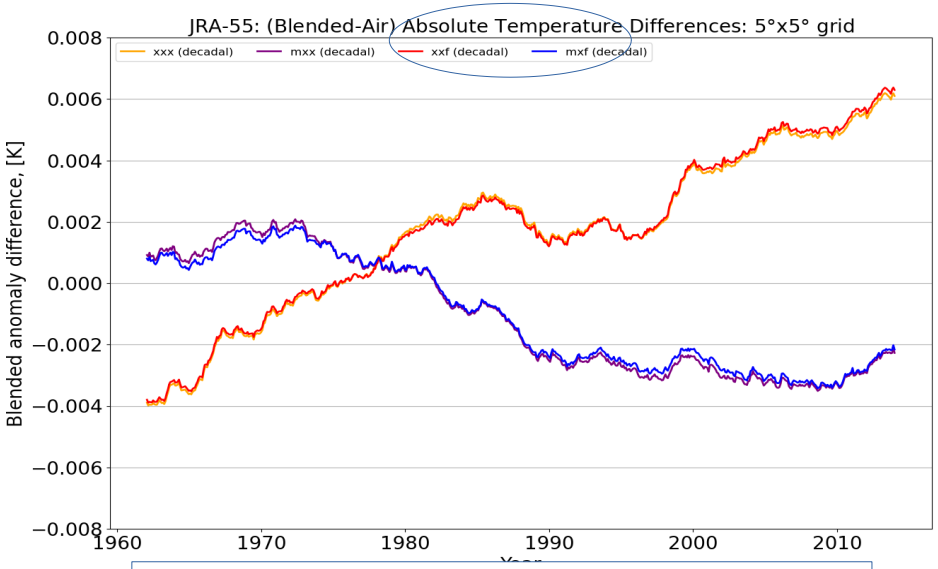
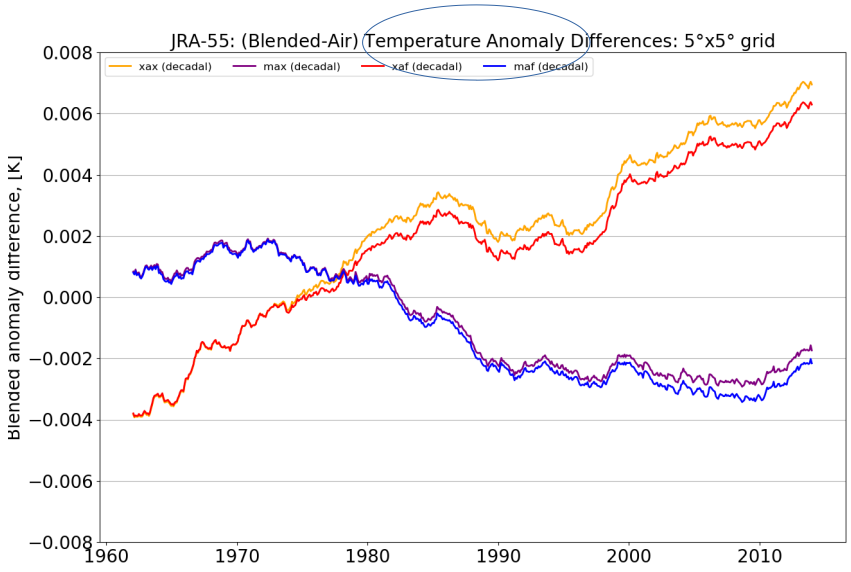
Global Surface Air Temperature

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

Similar overall trends
(<u>but different to ERA5</u>)
Sensitivity to variable ice
(arguably less than ERA5)
Crossover ~ middle of baseline

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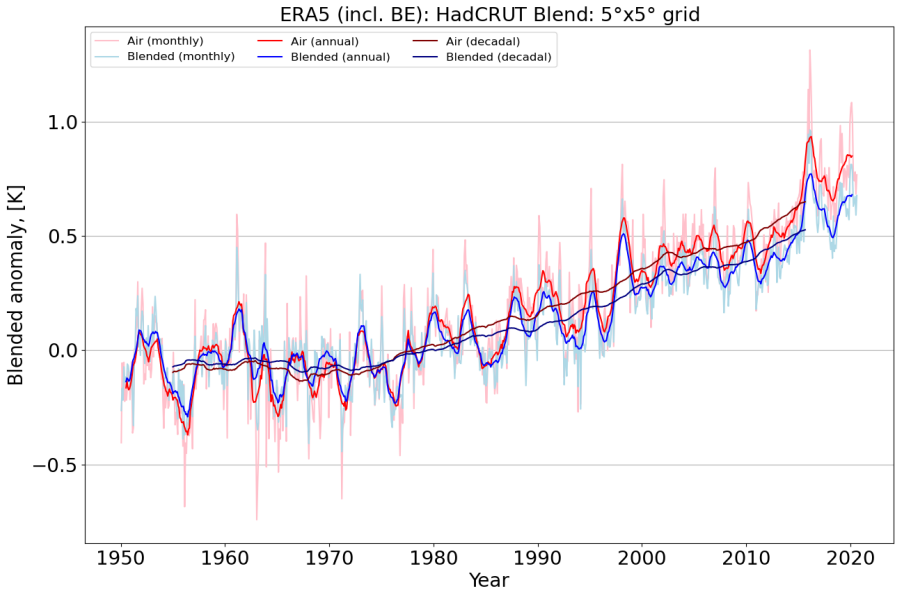
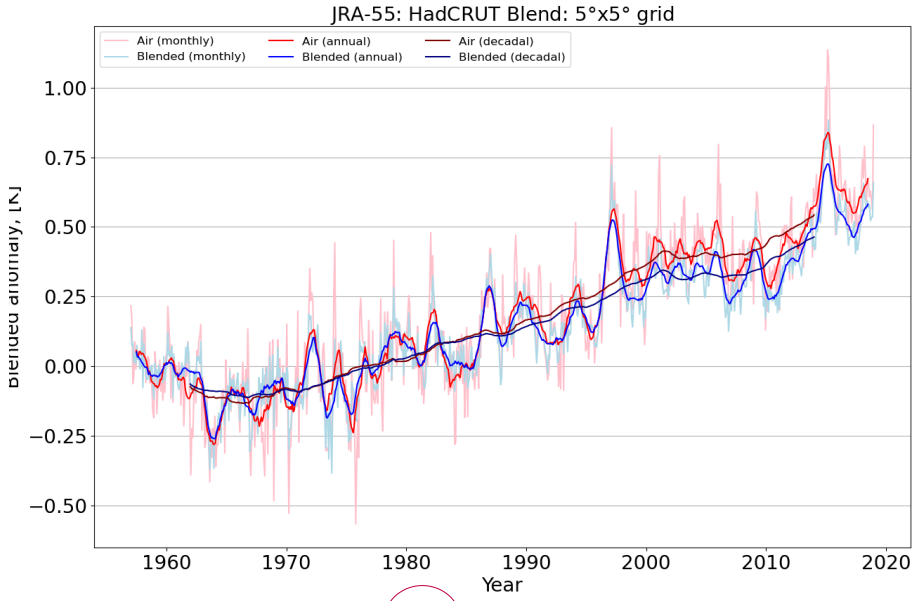
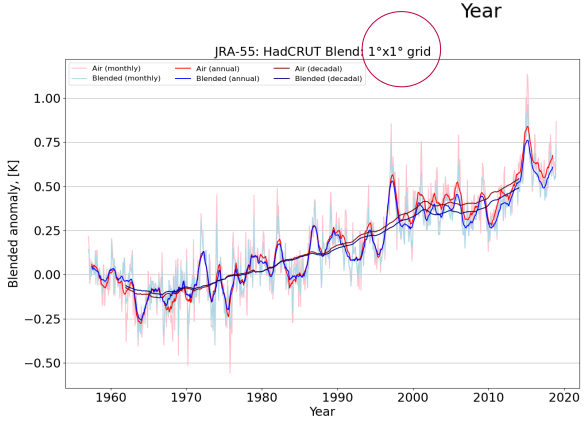
GloSAT
Global Surface Air Temperature

Analysis:
The HadCRUT calculation (separate land & sea masks)





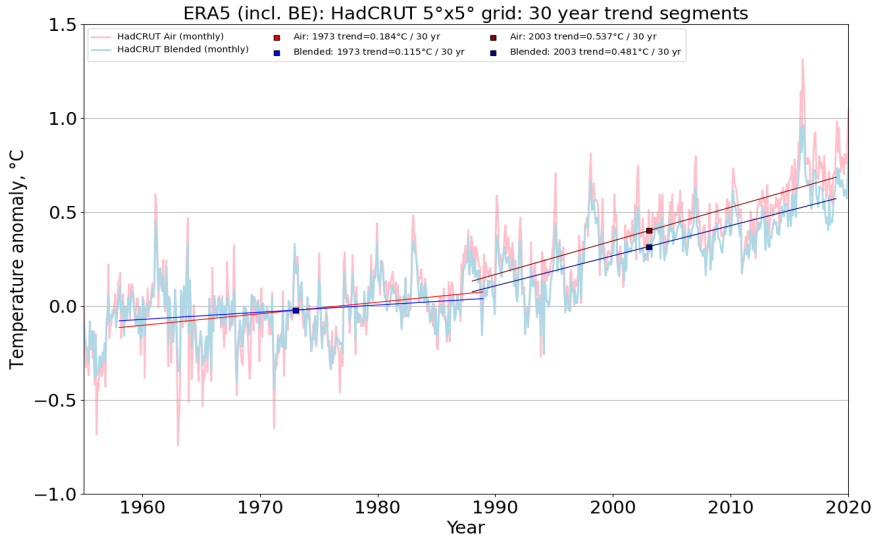


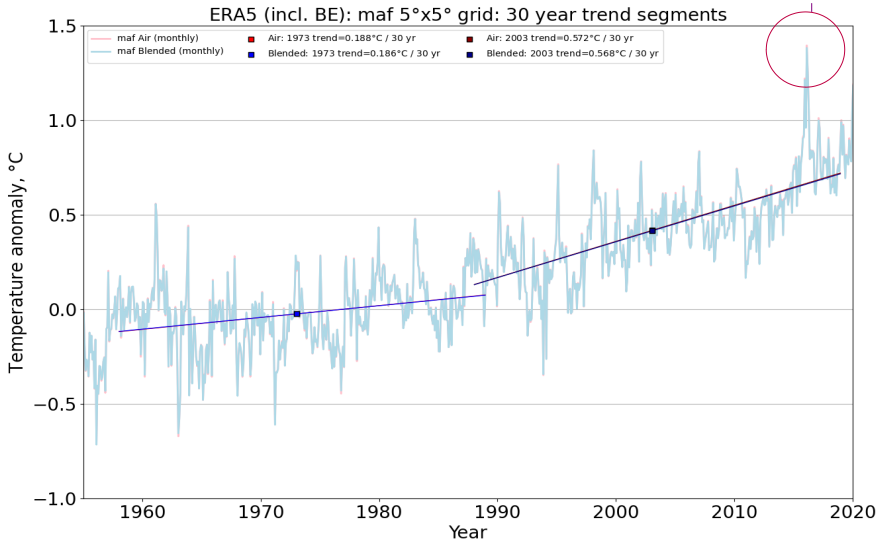
GSAT has a large discrepancy from the **GMST** obtained when the reanalysis is blended using a separate land mask from CRUTEM and sea mask from HadSST and rises to ~0.1K by 2020

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



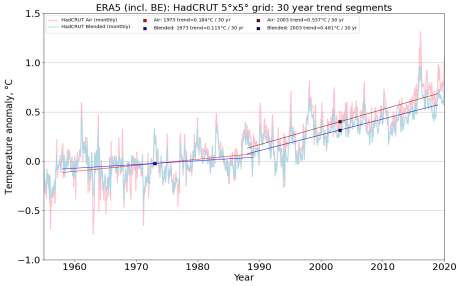


HadCRUT calculation: **no sea-ice**

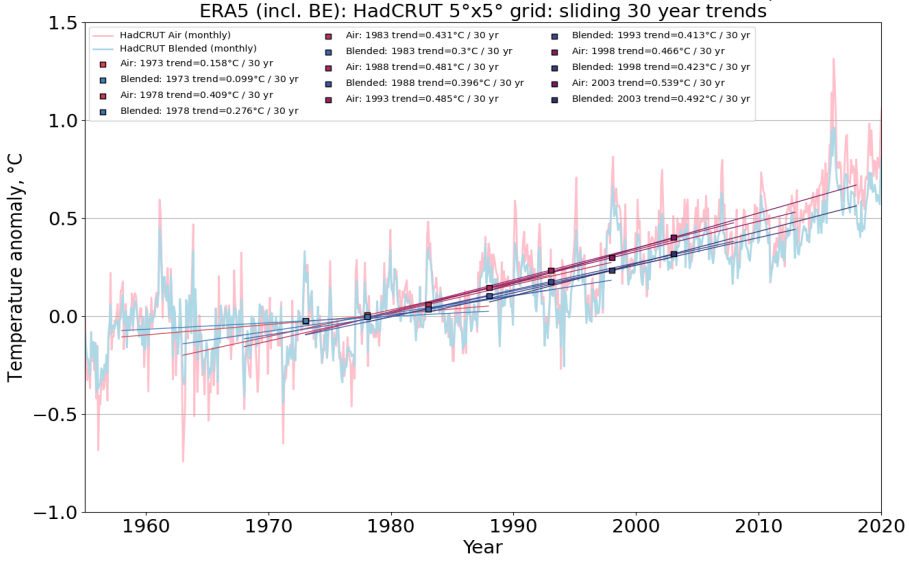
maf - HadCRUT-masked, blended anomalies, **fixed ice**

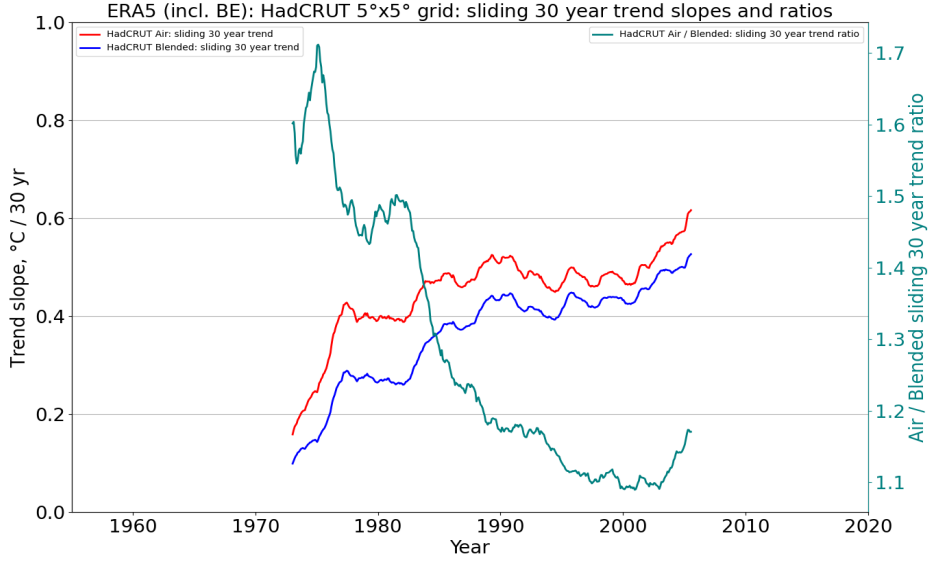
GSAT discrepancy from GMST obtained when the reanalysis is blended the HadCRUT mask and known sea-ice seems to resolve this problem

Analysis:
General GSAT/GMST blended cases – sliding trend ratios



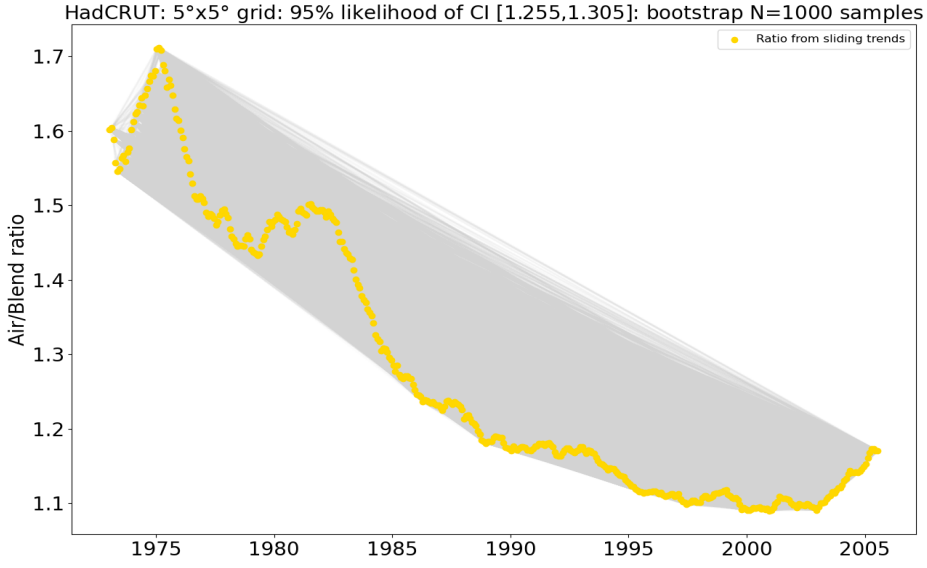
GSAT / GMST Ratio = Air / blended
We generalise from 30-yr trend blocks to 30-yr sliding trends for air and blended
This smooths out the ratio (a bit)

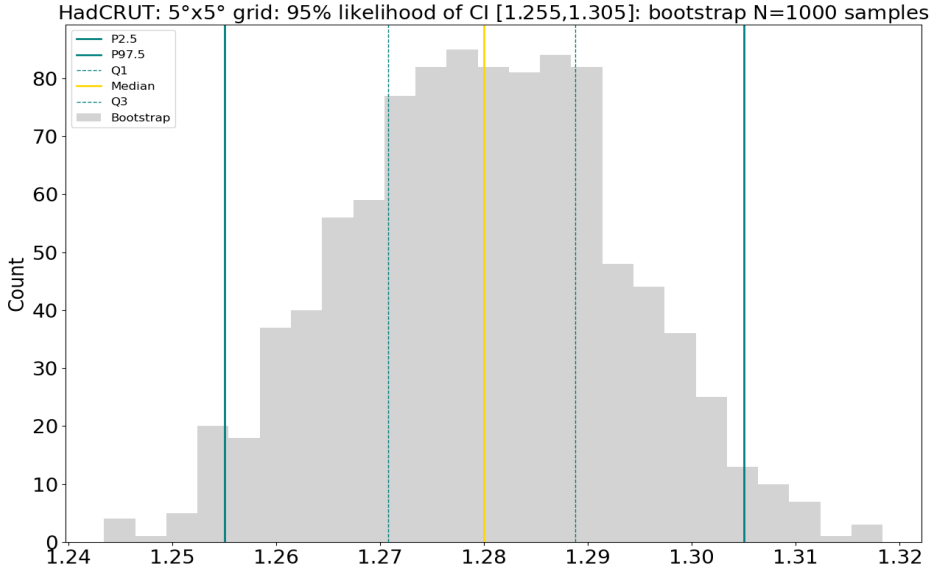




Although the anomaly discrepancy is ~ 0.1K, the impact on the GSAT / GMST is large e.g. a ratio of 1.7 translates to 70% increase over the blended anomaly value
Q. Does repeating this analysis using LOESS fits (30-yr span) change things ?

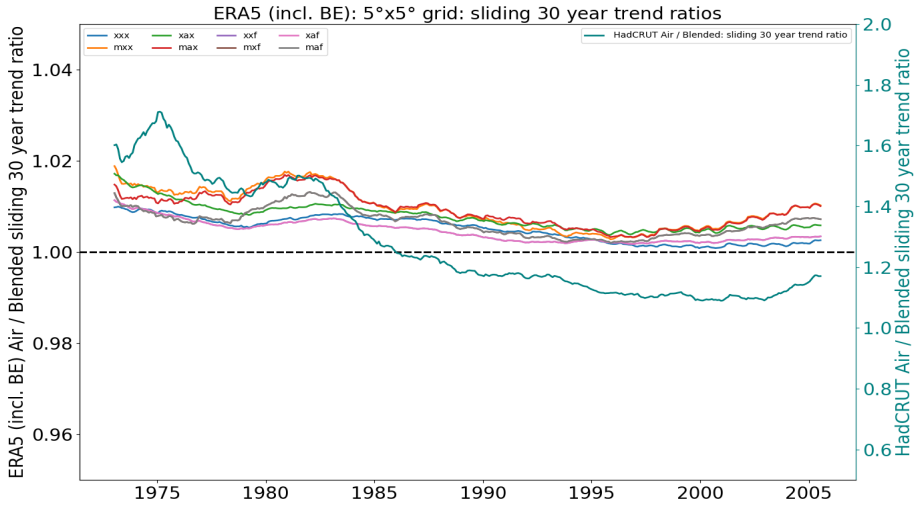
Analysis:
General GSAT/GMST blended cases – bootstrap CI on ratio

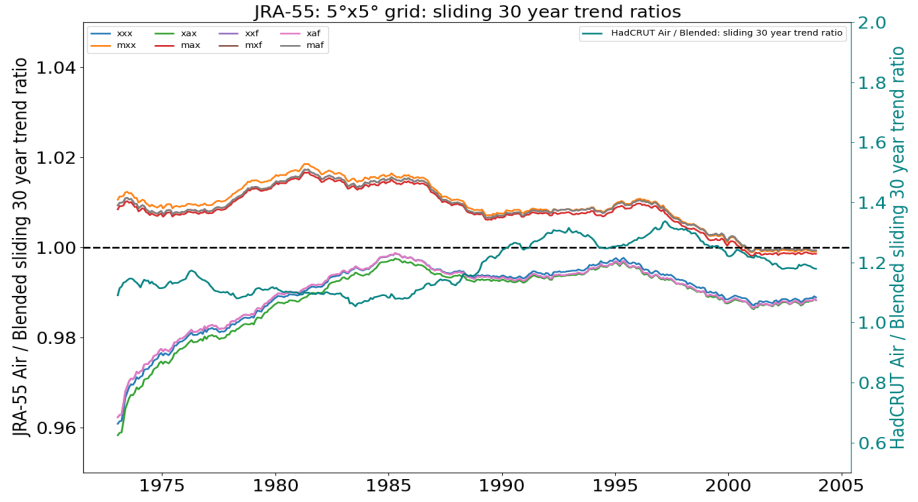


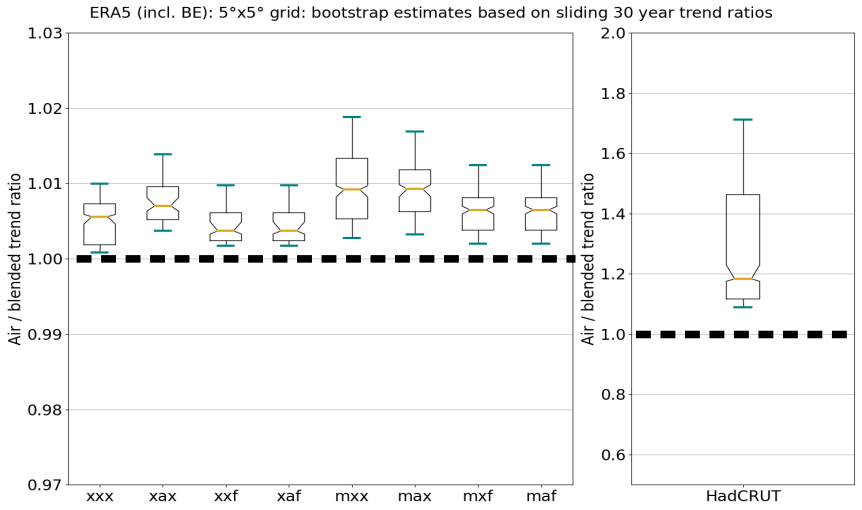


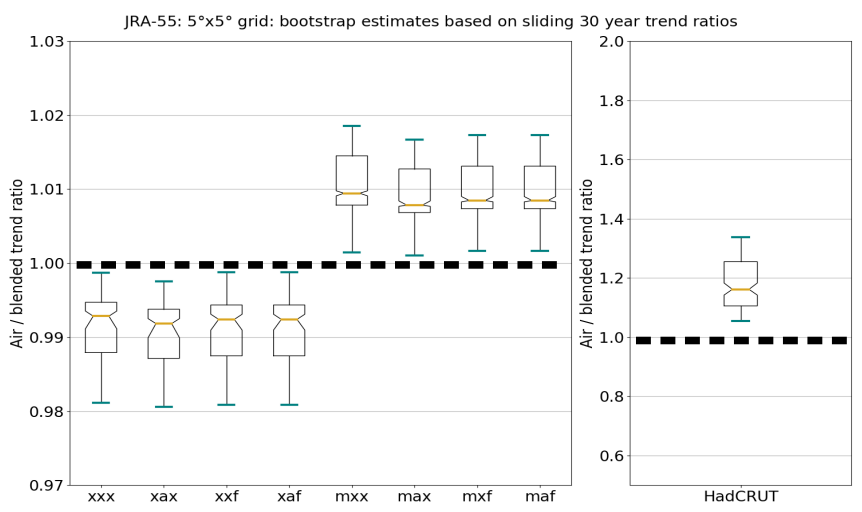
We then bootstrap to find the likelihood of the 5-95% bounds on the confidence interval (CI) for the ratio
We do this for all cases (including the HadCRUT calculation)

Analysis:
Blended ratio bounds~[0.99,1.01] (HadCRUT case …)









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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 l**and/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

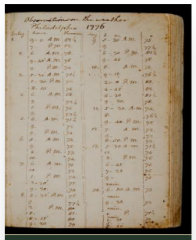
Massachusetts Historical Society: Coolidge Collection of Thomas Jefferson Manuscripts, 1705-1827. Other Volumes, 1766-1824. Memorandum Book, 1776-1778.

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 | ° ."

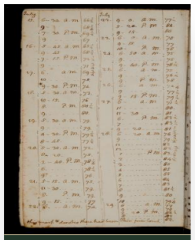
At 17 July 1776, Jefferson put an asterisk in front of his evening observation and put a note at the foot of the page: "this mark * denotes there had been rain previous." He employed the asterisk in other entries in this record up to 26 August 1776.



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

1 July 1776 - 14 July 1776

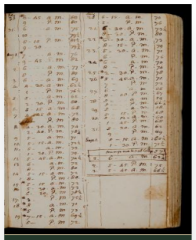
View Page



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

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Rescuing land air temp observations

Rescuing marine air temp observations

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