Local expectation from Kriging to aid with LSAT station homogenization and estimation of normals

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Outline

- LEK outputs
- LEK-driven changepoint detector
- LEK-driven adjustments
- Spot-checking app
- Building global outputs
- Issues
- Summary

Local expectation Kriging (LEK) output

LEK (by Kevin) calculates monthly normals and expectation variance for each station

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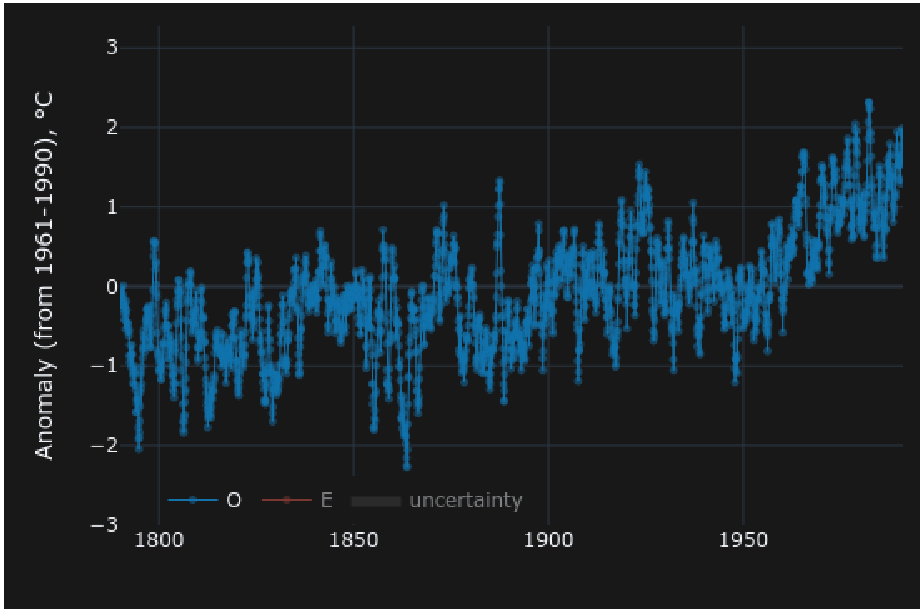

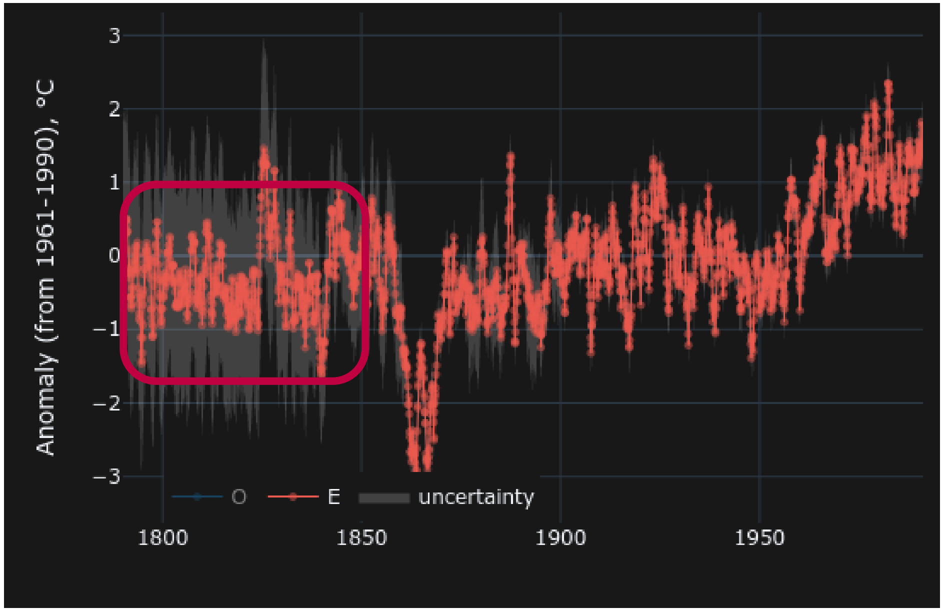

observations
(monthly means)

local expectation (E)
± LEK uncertainty

LEK uncertainty (SD) can be large
(especially pre-1850) e.g. ~ ±1°C

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LEK-driven changepoint detector

STEP 1: from the difference O-E we calculate the cumulative sum (CUSUM)

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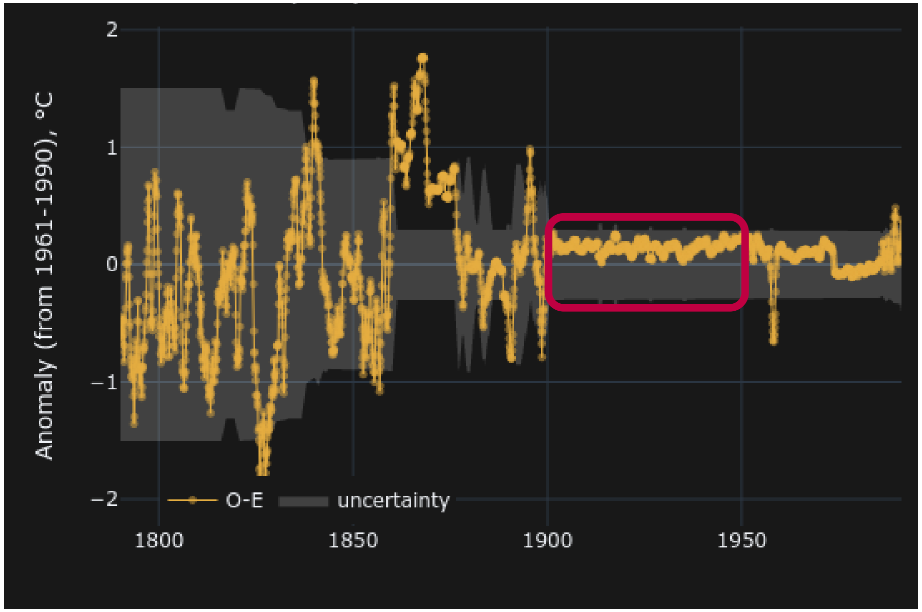

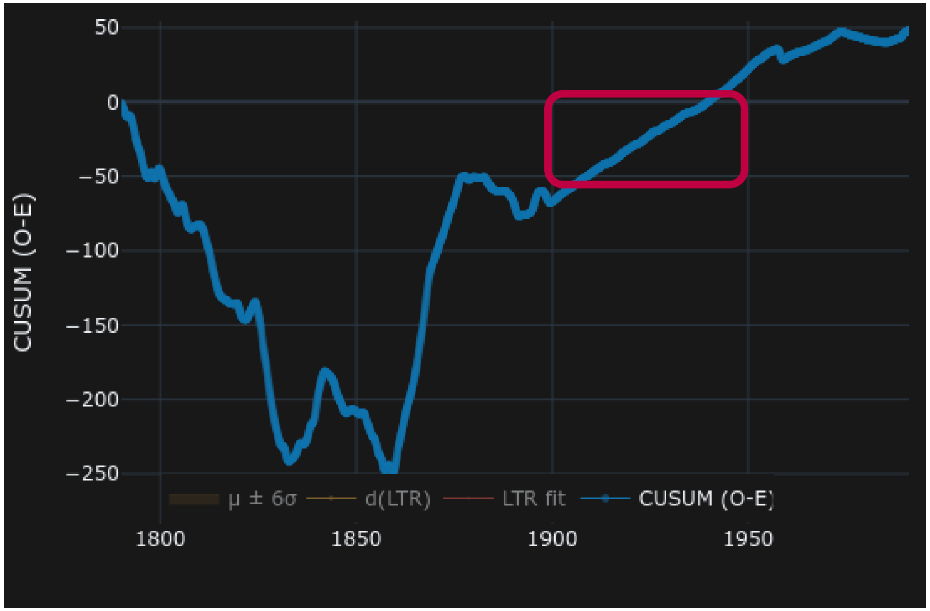

O-E & LEK uncertainty

CUSUM (O-E)

e.g. average O-E = 0.1 over 50 years →
CUSUM = 50 x 0.1 x 12 = 60

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LEK-driven changepoint detector

STEP 2: we do ML linear tree regression (LTR) and calculate change in slope

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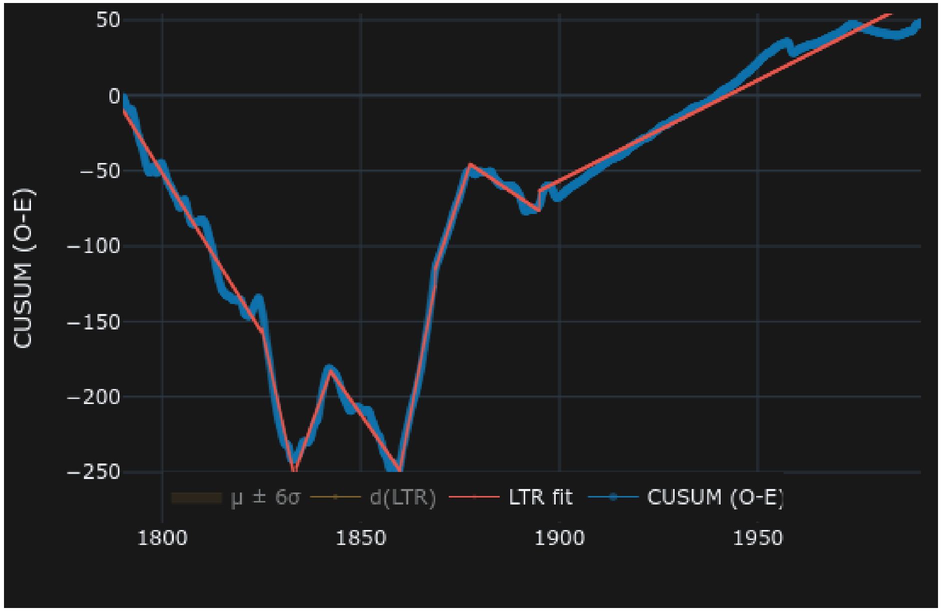

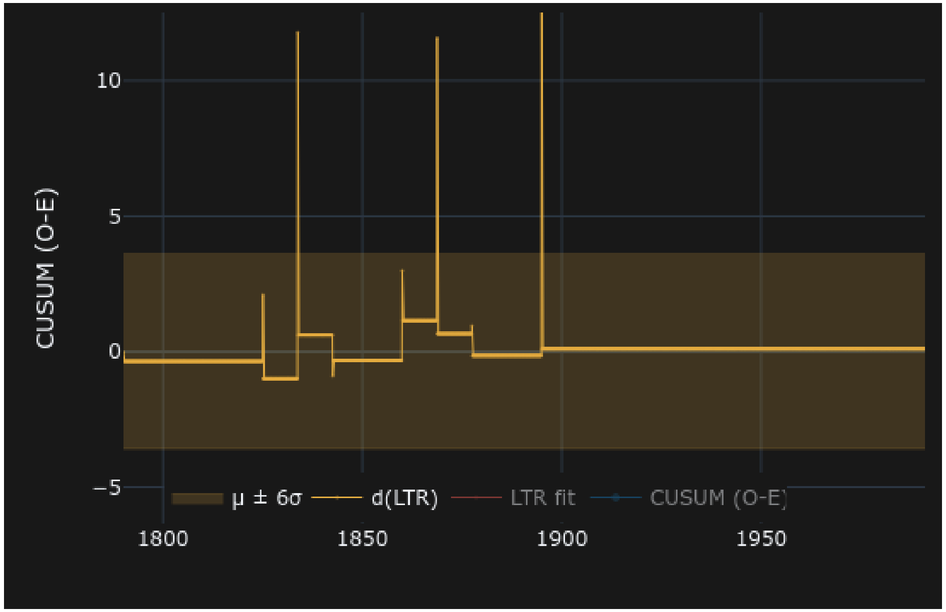

LTR fit to CUSUM

1st difference of LTR fit & μ ± 6σ band

number of linear fit segments (‘fragments’) is determined by decision tree depth (next slide)

absolute exceedences of the mean + 6 sigma level are taken as significant for changepoints

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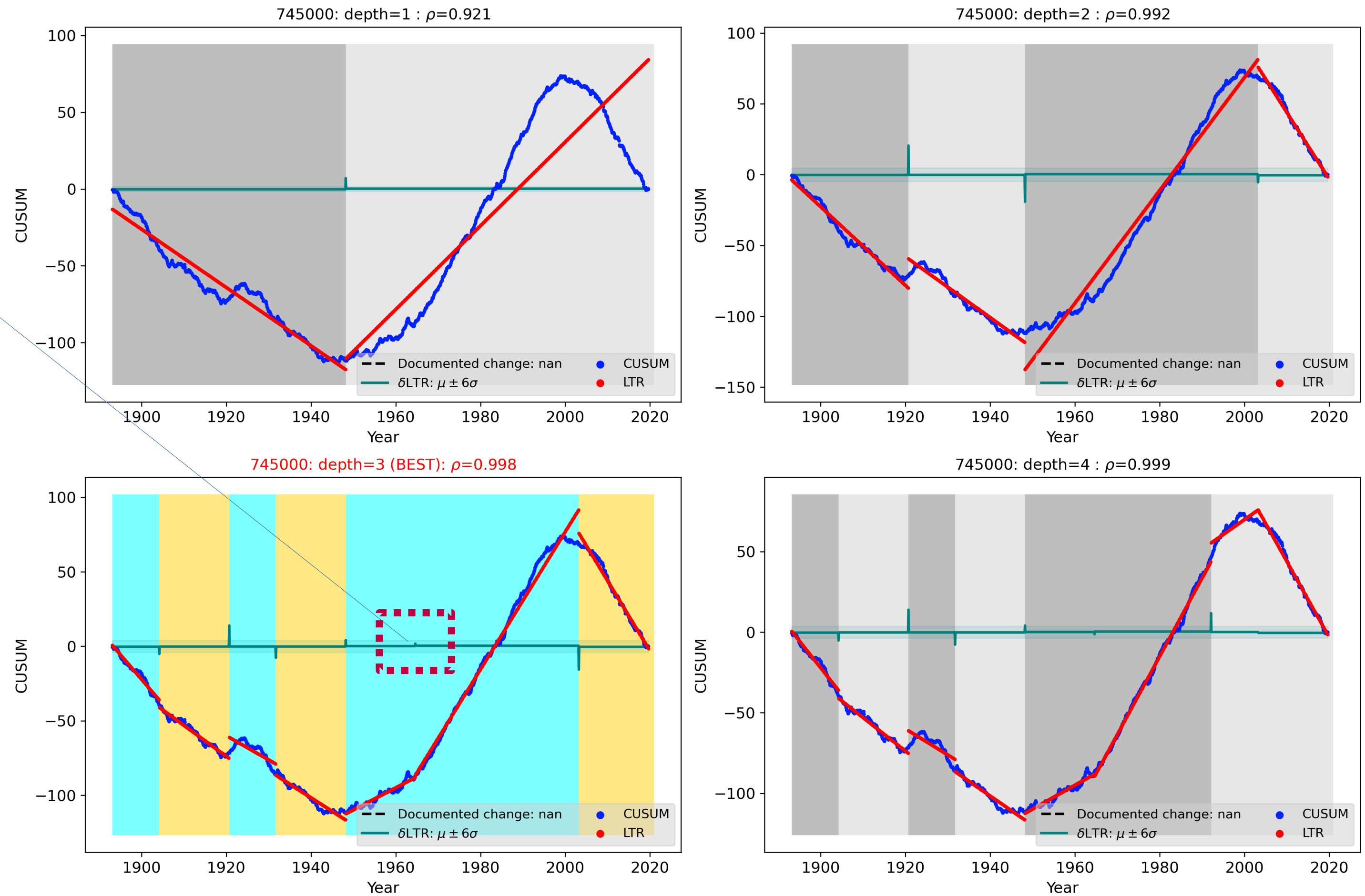
Linear Tree Regression (LTR) changepoint detection

Algorithm (closer look)

non-significant break



0	1904.2
1	1920.7
2	1931.7
3	1948.2
4	2003.2

Stop condition (decision tree depth): corr coeff (LTR vs CUSUM), ρ >0.995
Breakpoint significance condition: | δLTR | > μ (δLTR) + 6σ (δLTR)

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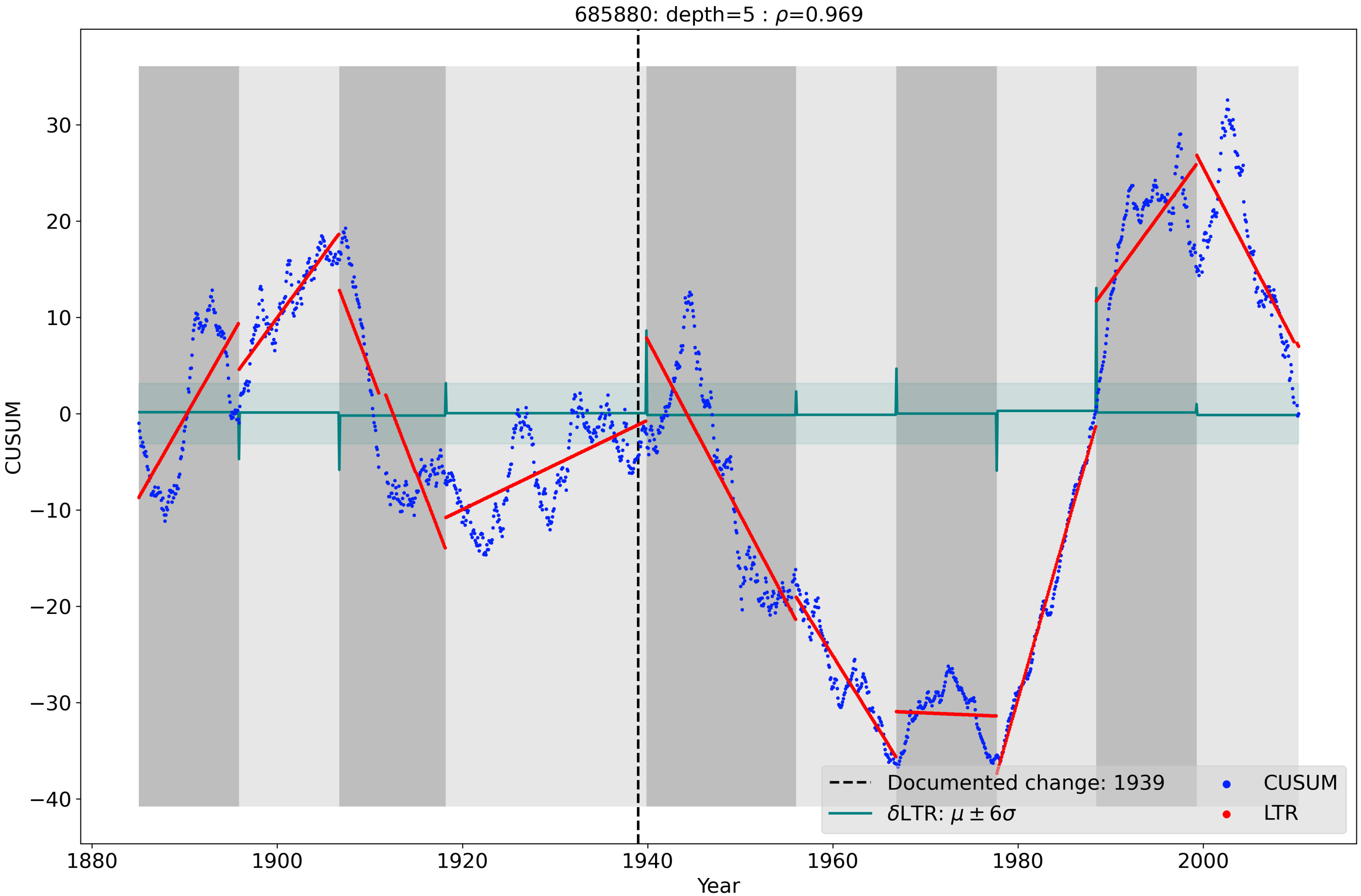
‘Blind’ testing against documented instrument changes

Based on metadata analysis performed by Emily Wallis



0	1895.9
1	1906.7
2	1911.7
3	1918.2
4	**1939.9**
5	1956.0
6	1966.9
7	1977.7
8	1988.5
9	1999.3
10	2010.1

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‘Blind’ testing against documented instrument changes

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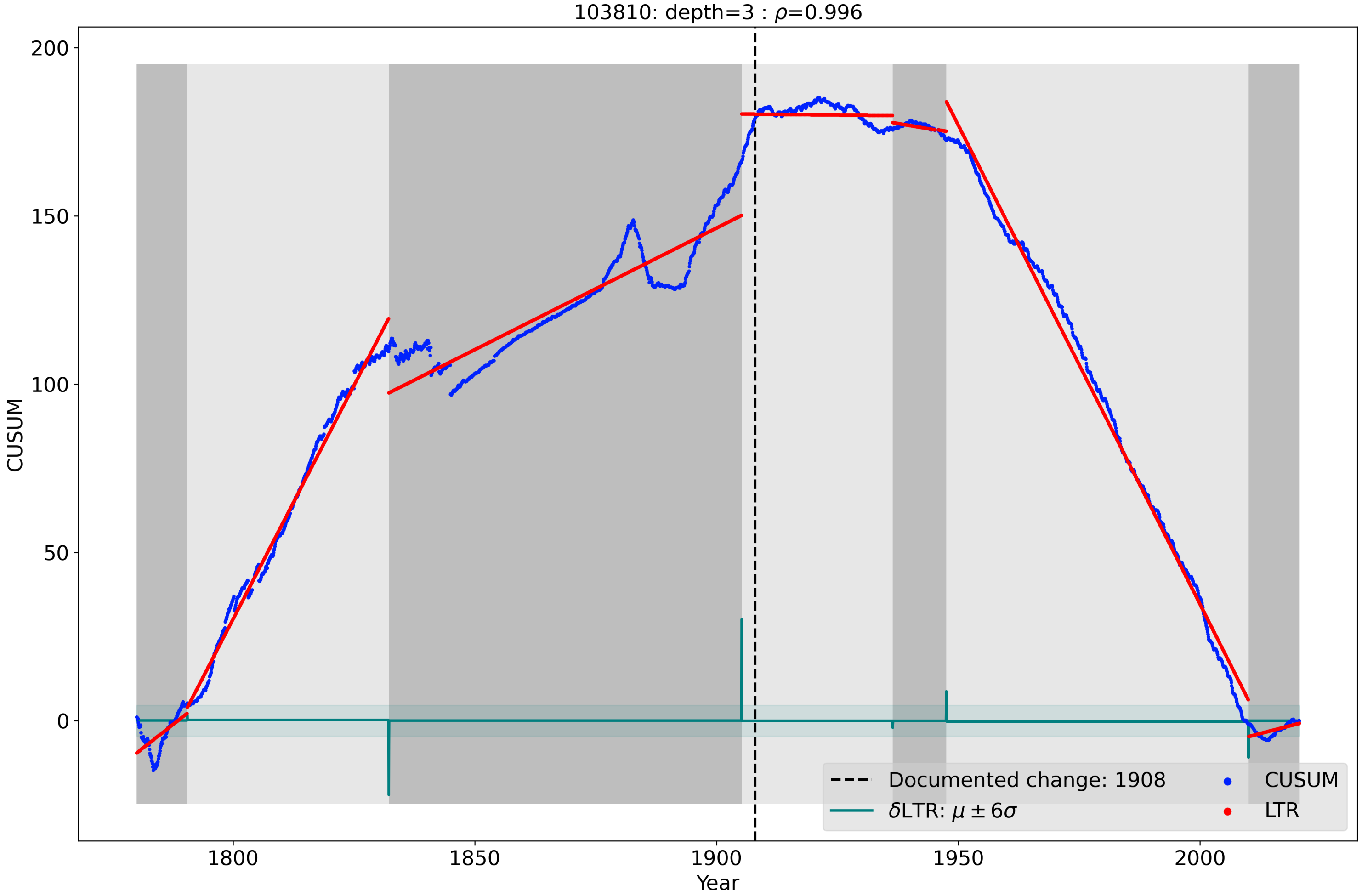

	breakpoint
0	1790.5
1	1832.2
2	**1905.2**
3	1936.5
4	1947.5
5	2010.0

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LEK-driven adjustments

STEP 3: we apply shifts from inter-changepoint mean(E) - mean(O)

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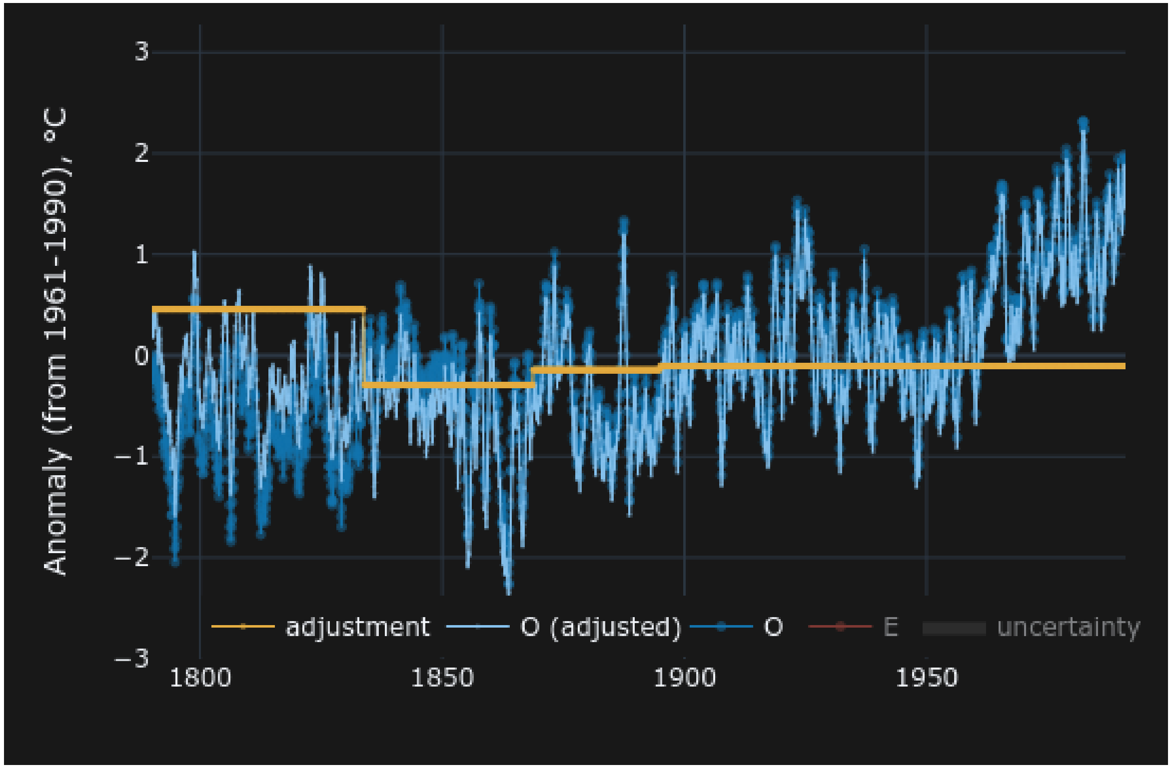

Breaks, O & adjusted O

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+ve shifts warm the observations and -ve shifts cool them

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LEK-driven adjustments (continued)

STEP 4: we place this in context of the local expectation and its uncertainty

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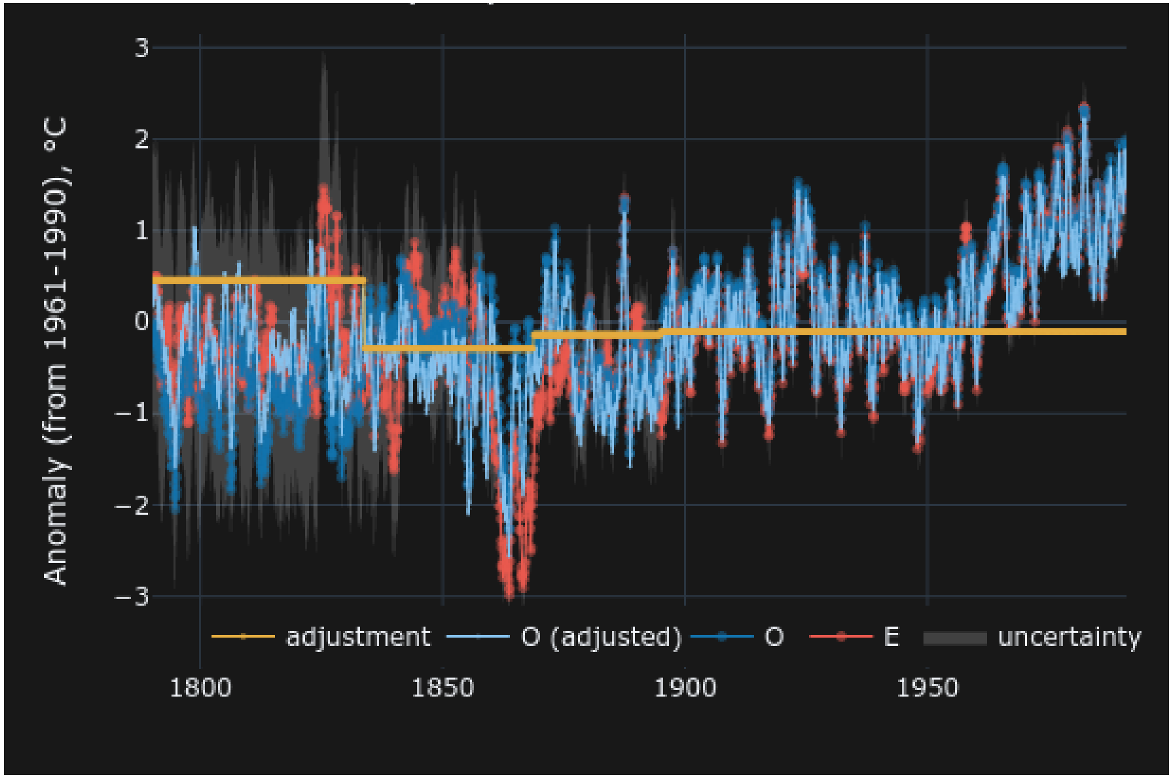
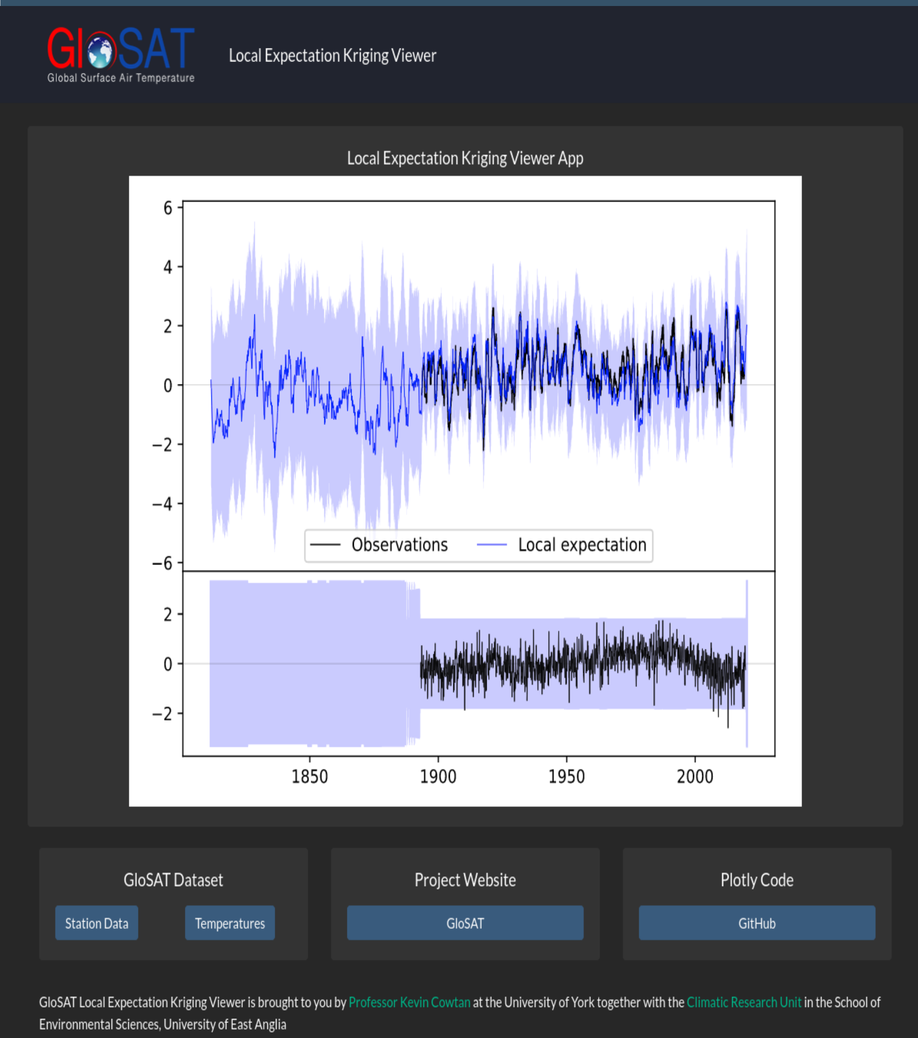


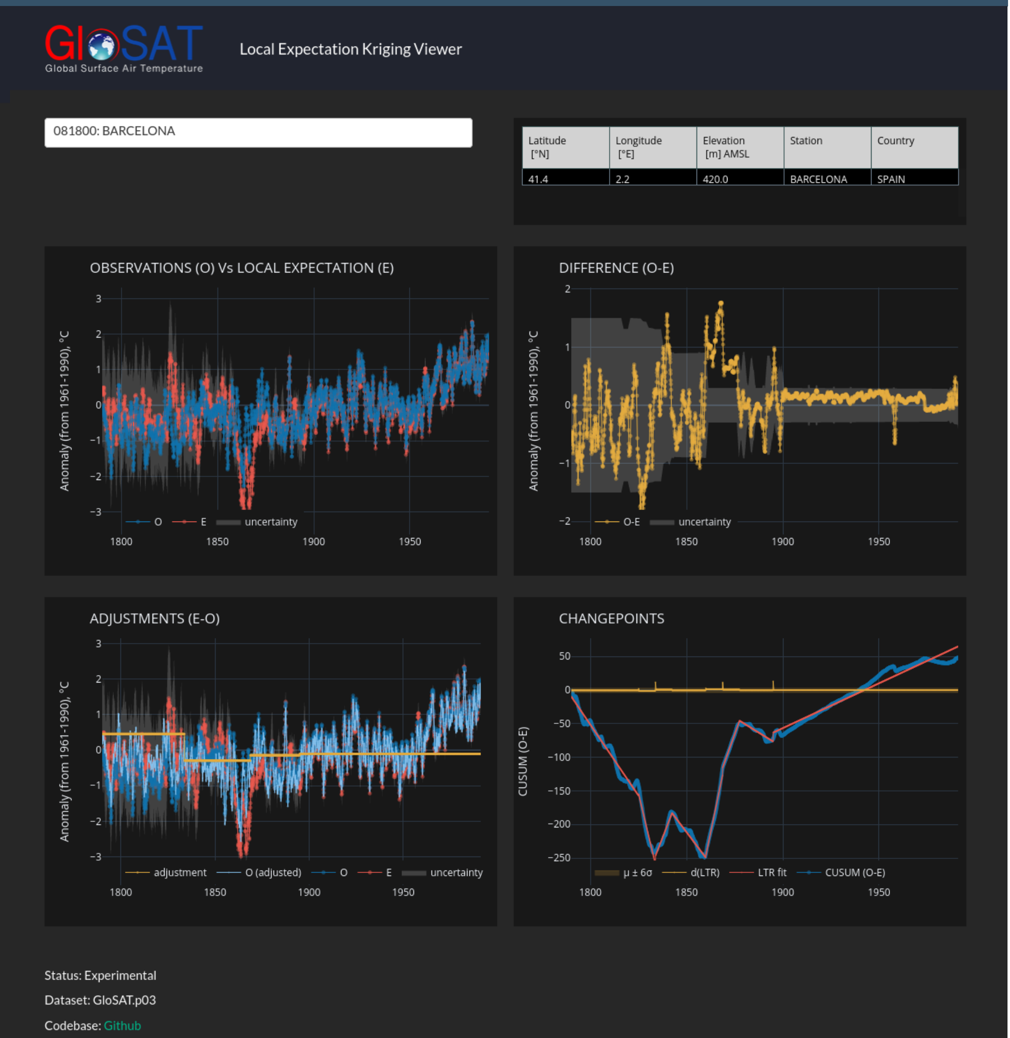
adjusted O & E ± LEK uncertainty

we still need to assess how valid shifting based on mean fragment differences is when CUSUM is nonlinear

App for spot-checking stations

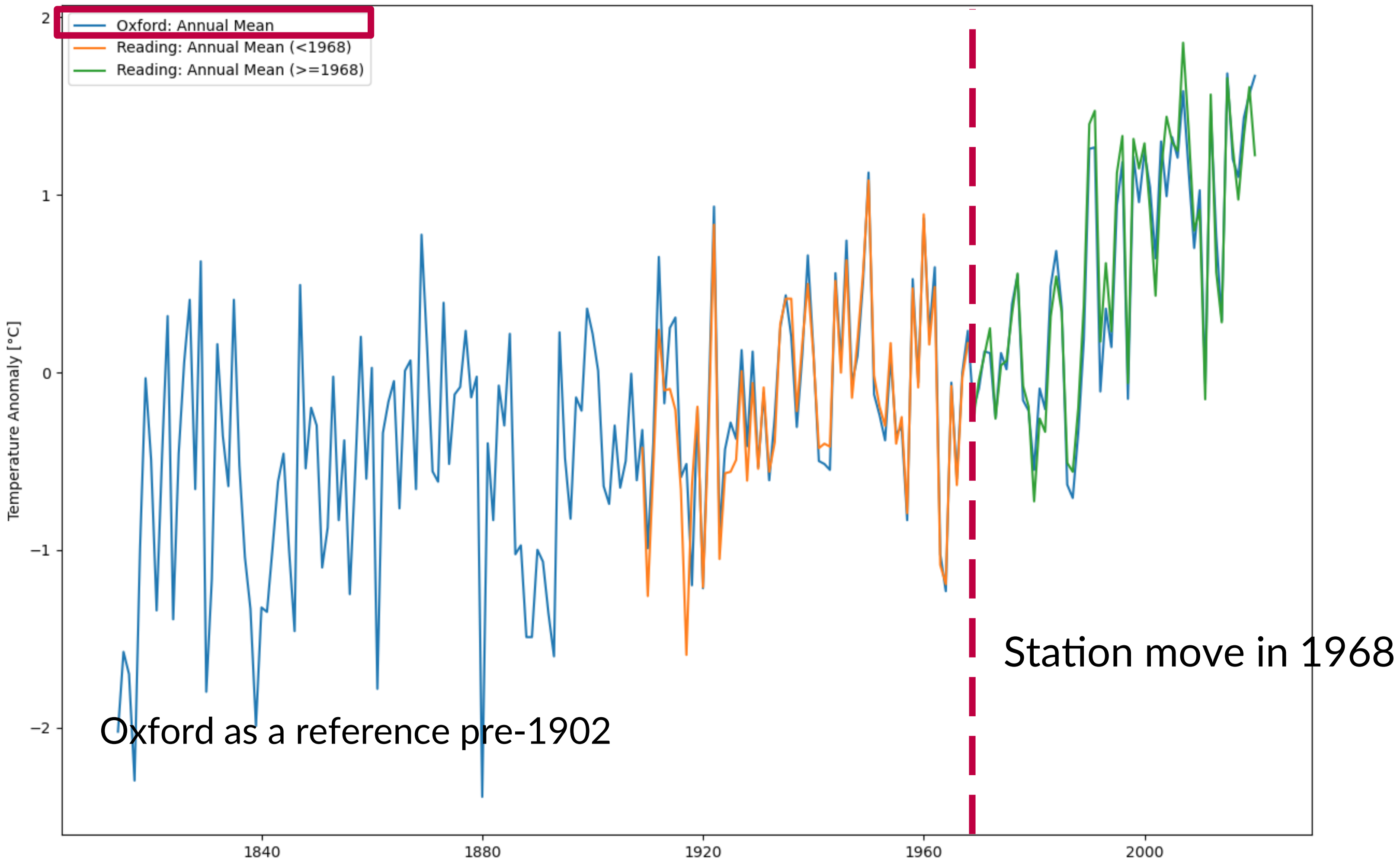
Includes all LEK-processed stations from GloSAT.p03 (10488 stations)





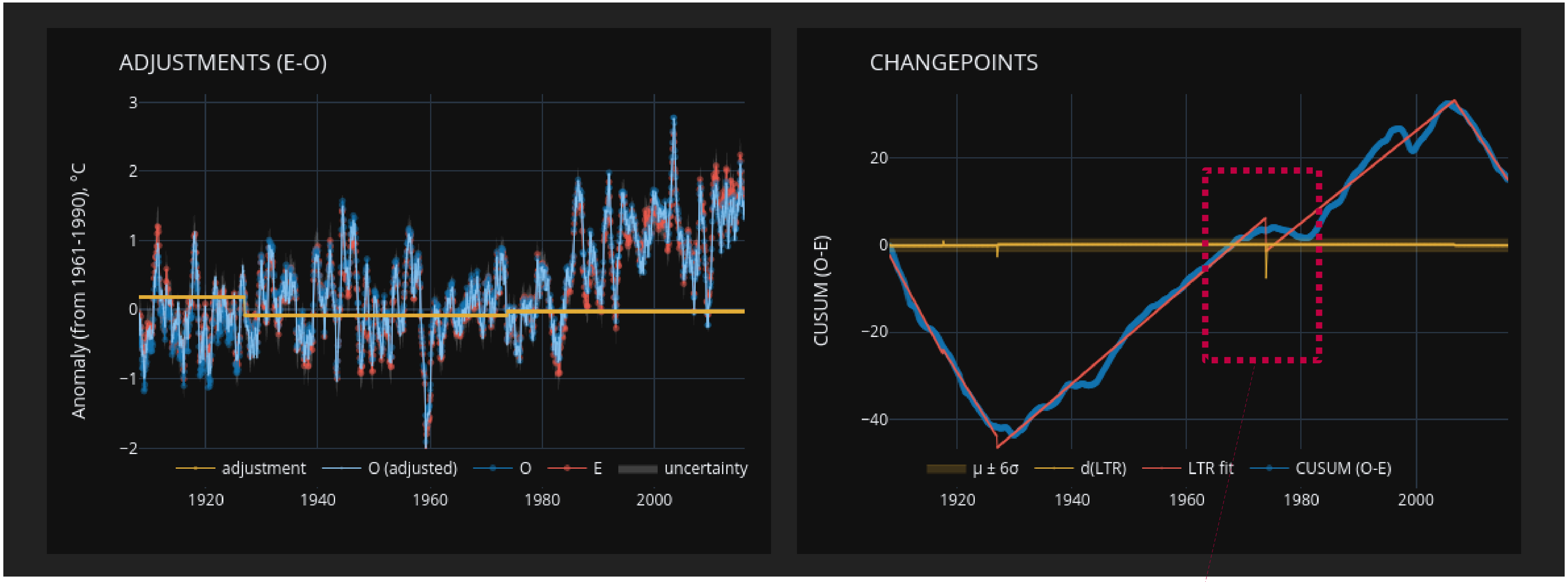
App for spot-checking stations

Test: Reading University (change in location 1968)



App for spot-checking stations

Test: Reading University (change in location 1968)



LEK finds a break 5 years late (not good) but magnitude of adjustments relative to Oxford reference level looks OK

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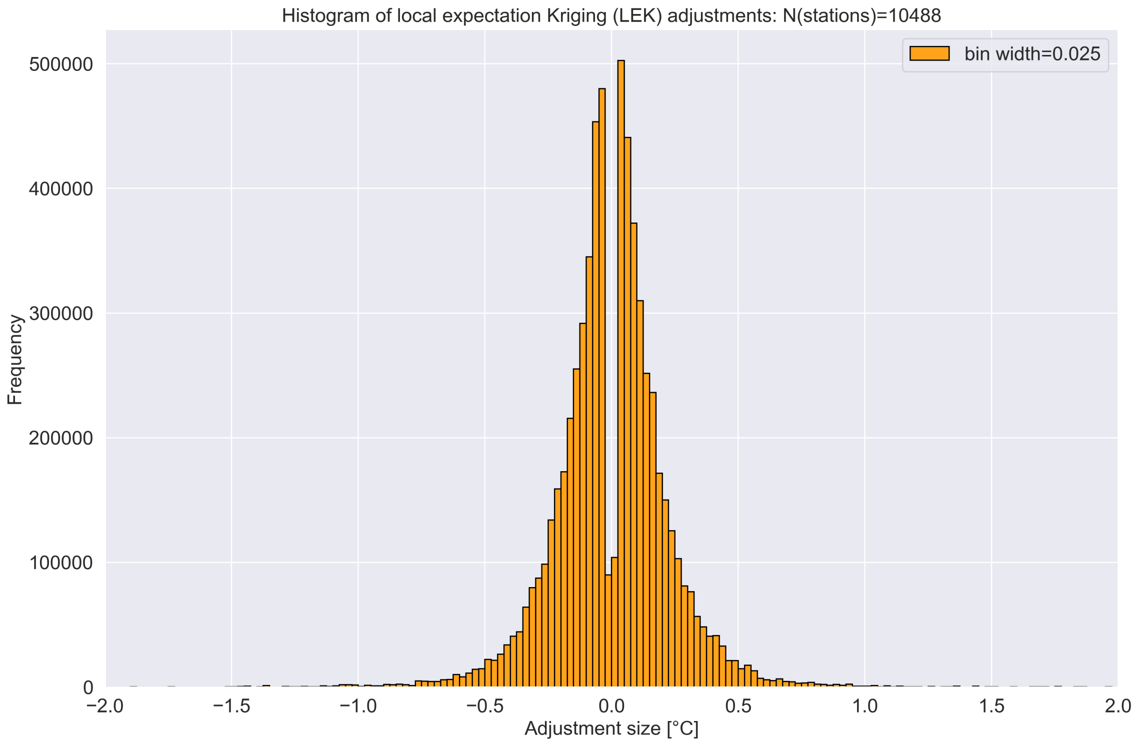
Global adjustments

Accumulating LEK-driven adjustments over all stations



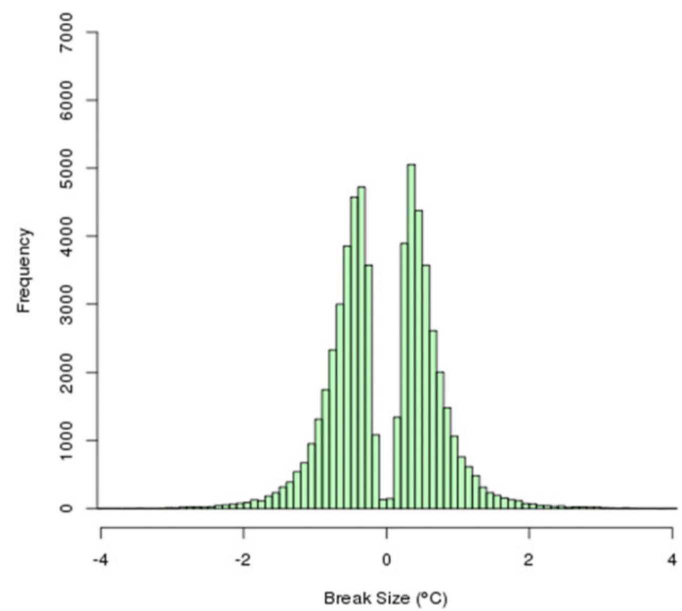


FIG. 3. Histogram of the distribution of shifts identified by the PHA.

Distribution has 'missing middle' but looks narrow (likely due to stations in GloSAT.p03 already being well adjusted)

Menne, M. J., Williams, C. N., Gleason, B. E., Rennie, J. J., & Lawrimore, J. H. (2018). The global historical climatology network monthly temperature dataset, version 4. Journal of Climate, 31(24), 9835-9854. https://doi.org/10.1175/JCLI-D-18-0094.1.

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Other jigsaw pieces emerging – potential issues

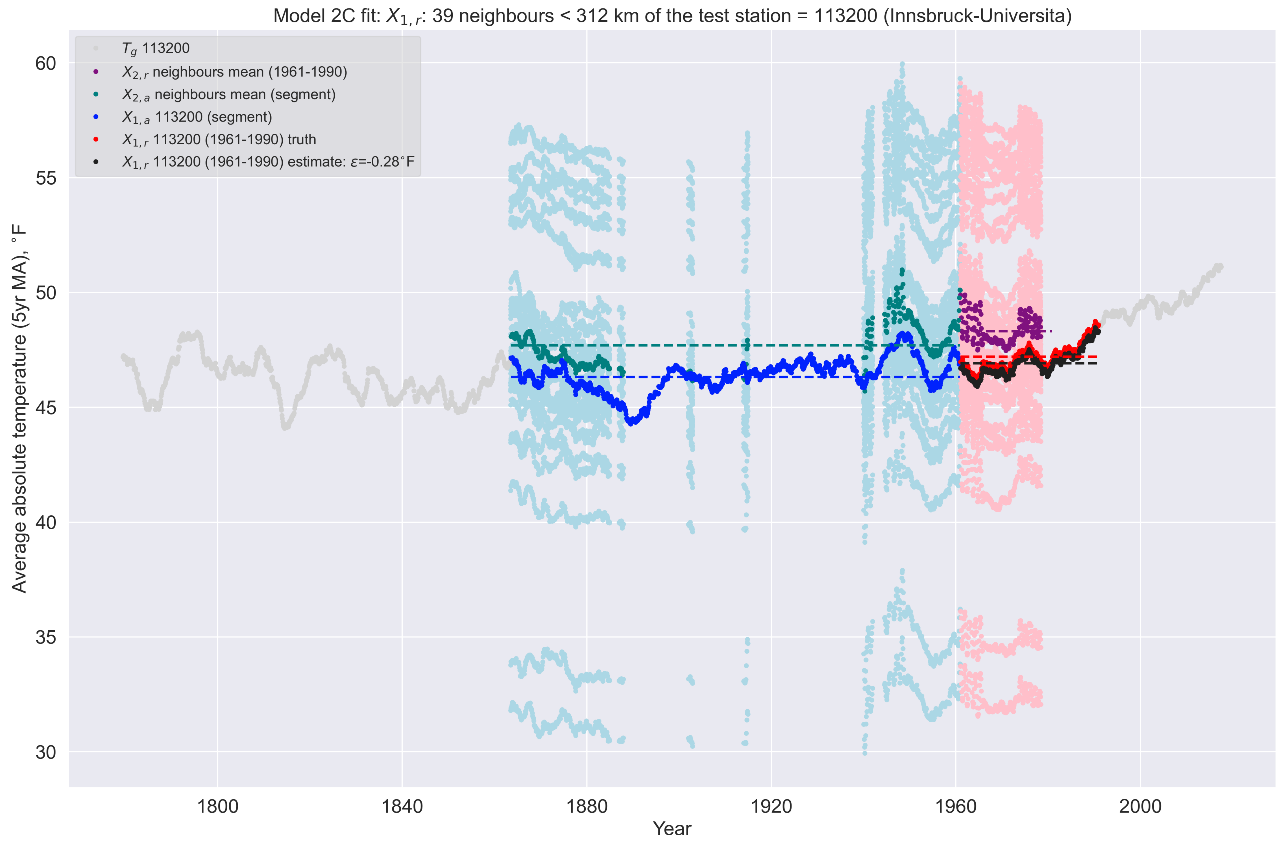
Piece 1 – neighbouring station(s) / reanalysis can help estimate normals → anomalies

PIECE 1

Neighbouring station(s) and/or reanalysis extracts with 1961-1990 data can be used to estimate monthly normals for ‘no baseline’ series with gaps in remote regions

BUT …

As we go back in time before 1850 there is the question of how valid the early proxy data itself is



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Other jigsaw pieces emerging – potential issues

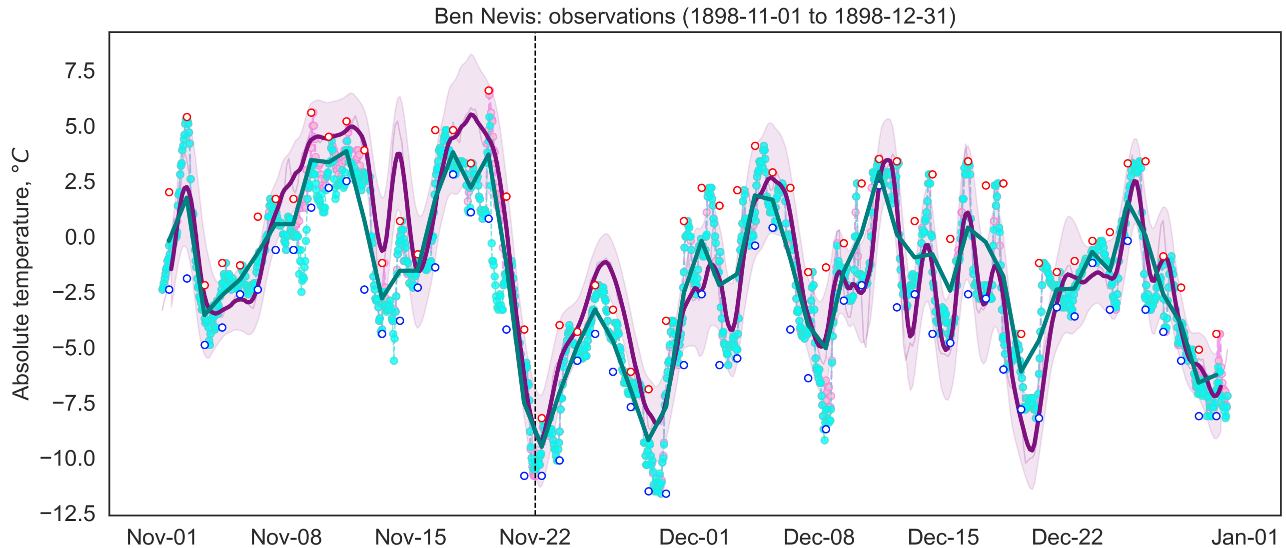
Piece 2 – using reanalysis at high elevation stations looks OK

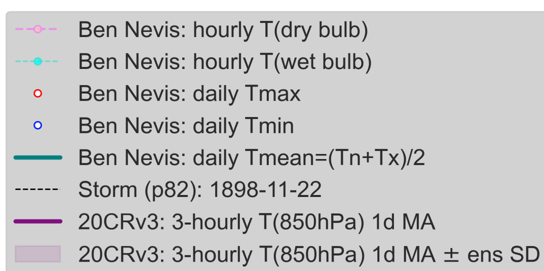
PIECE 2

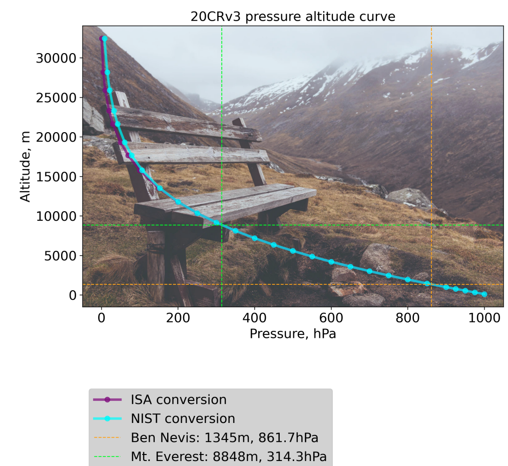
20CRv3 reanalysis can be a good proxy in high elevation data sparse regions back to 1806

BUT …

we should use the closest pressure level







Many thanks to Stephen Burt and Ed Hawkins + the citizen scientists for rescuing 1883-1904 daily and sub-daily observations:

Burt, S., & Hawkins, E. (2019). Near-zero humidities on Ben Nevis, Scotland, revealed by pioneering 19th-century observers and modern volunteers. International Journal of Climatology, 39(11), 4451-4466.

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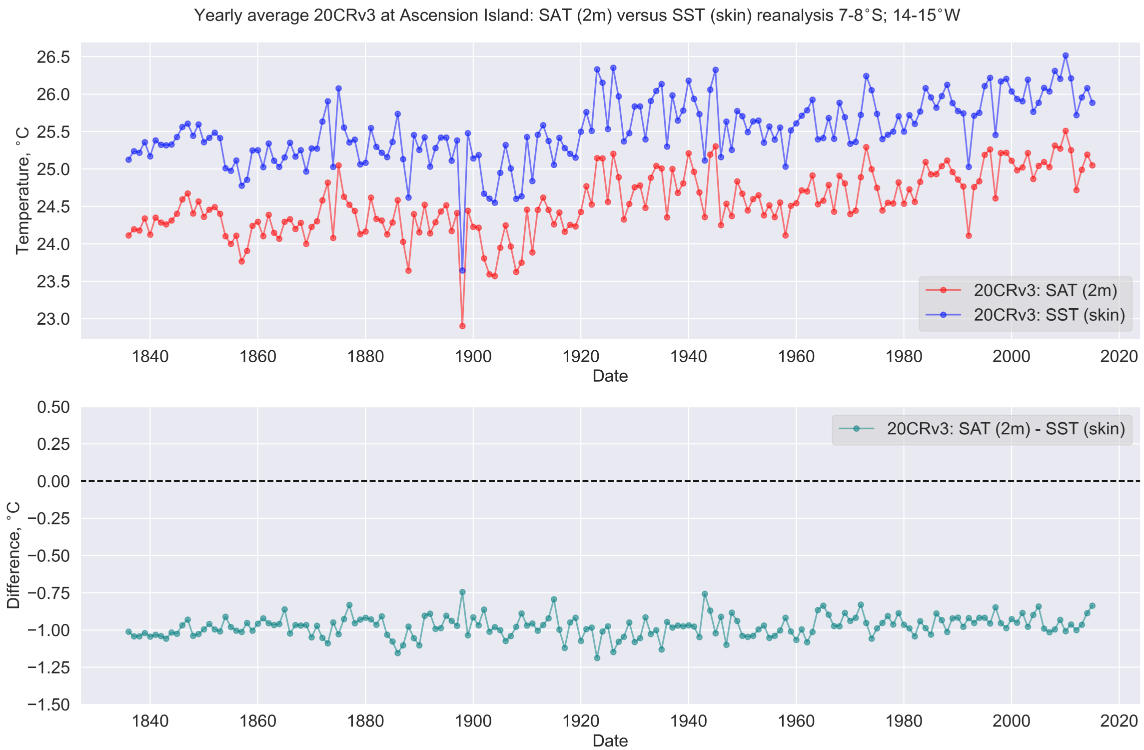
Other jigsaw pieces emerging – potential issues

Piece 3 – use of reanalysis as a proxy for remote small islands ?!

PIECE 3

20CRv3 reanalysis appears to also be a stable proxy for LSAT relative to SAT at remote small islands back to 1806 → supports suggestion by Iain Gillespie et al (2021) that 20CRv3 can be used for homogenisation in remote locations

Gillespie, I.M., Haimberger, L., Compo, G.P. and Thorne, P.W.(2021) Assessing potential of sparse-input reanalyses for centennial-scale land surface air temperature homogenisation. International Journal of Climatology, 41, E3000–E3020 https://doi.org/10.1002/joc.6898



BUT ...

how well does a bias-corrected LSAT from reanalysis compare with observations → see issues in Ascension Island paper

Jones, P. D., & Lister, D. H. (2021). The development of long temperature and precipitation series for Ascension Island. International Journal of Climatology. https://doi.org/10.1002/joc.7314

Summary

1. **Local expectation Kriging (LEK)** using weighted averages over correlation lengths of 900 km looks great for estimating normals and expected uncertainty for early data series (e.g. 1781-1850)
2. **LEK-driven changepoint detection based on the CUSUM of the O-E difference** in a ML (linear tree regression framework) looks promising for comparing breaks and shifts against e.g. piecewise homogenisation algorithms (PHA) on benchmark data & unadjusted GCHNMv4 data (please see Kevin's talk for more)
3. LEK-breakpoints are close to **documented instrumental changes from metadata analysis** being performed by Emily
4. The **distribution of global adjustments** (showing a 'missing middle') looks narrow (presumably due to the majority of stations in GloSAT.p03 already being adjusted)
5. Normals can be tested against those obtained from a single short and / or gappy overlapping neighbouring station using Tim's **no-baseline method**
6. **Reanalysis** may be able to help set the correct level for remote stations (including at high elevation) as well as remote islands for 1806+ (see Iain Gillespie et al's proposals)
7. Next steps ? Cross-method inter-comparions on common station groups ? Varying correlation lengths ? Adding noise to the Kriging kernel (covariance matrix) ?

Many thanks for listening

NOAA PSL
20CRv3 gridded monthly 2m air temperatures:
https://portal.nersc.gov/project/20C_Reanalysis/

CRU / UEA & UKMO HadObs
CRUTEM5.0.1 land surface air temperature instrumental data 1781-2020:
https://crudata.uea.ac.uk/cru/data/temperature/

GloSAT project
https://www.glosat.org/

Codebase:
https://github.com/KCowtan/glosat-homogenisation/tree/main/local_expectation_krig
https://github.com/patternizer/glosat-homogenisation
https://github.com/patternizer/glosat-homogenisation-app
https://github.com/patternizer/glosat-breakpoint-analysis
https://github.com/patternizer/glosat-station-pressure-altitude
https://github.com/patternizer/glosat-ben-nevis-reanalysis

EXTRA SLIDES