Global temperature trend biases and statistical homogenization methods

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Outline talk

- Early warming (1850 to 1920, red rectangle)
  - Warming estimates of the main global datasets
  - Non-climatic temperature changes
  - Other early climatic changes
- Cooling biases in the instrumental record
- Performance of homogenisation methods
  - Annual means

Global temperature changes

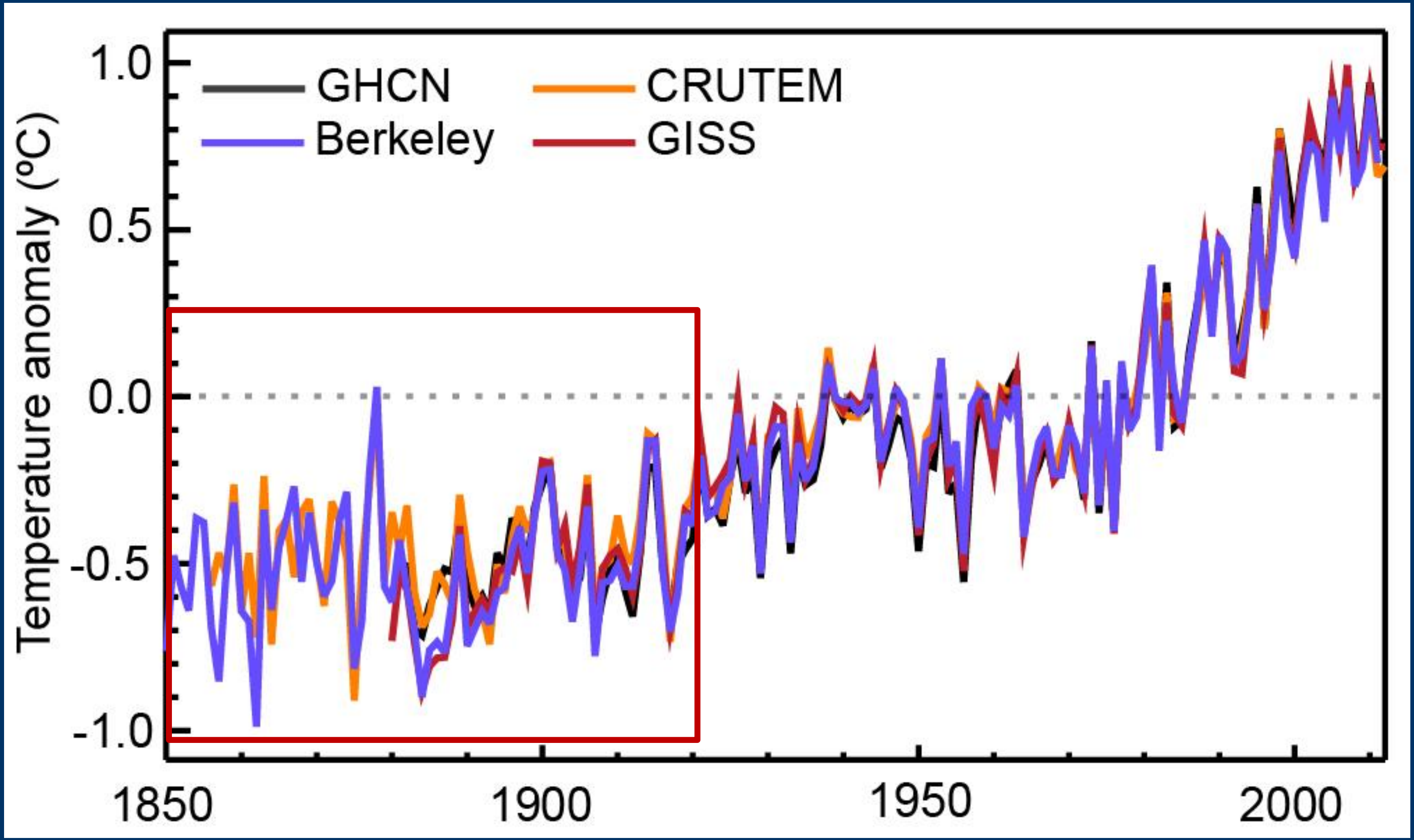
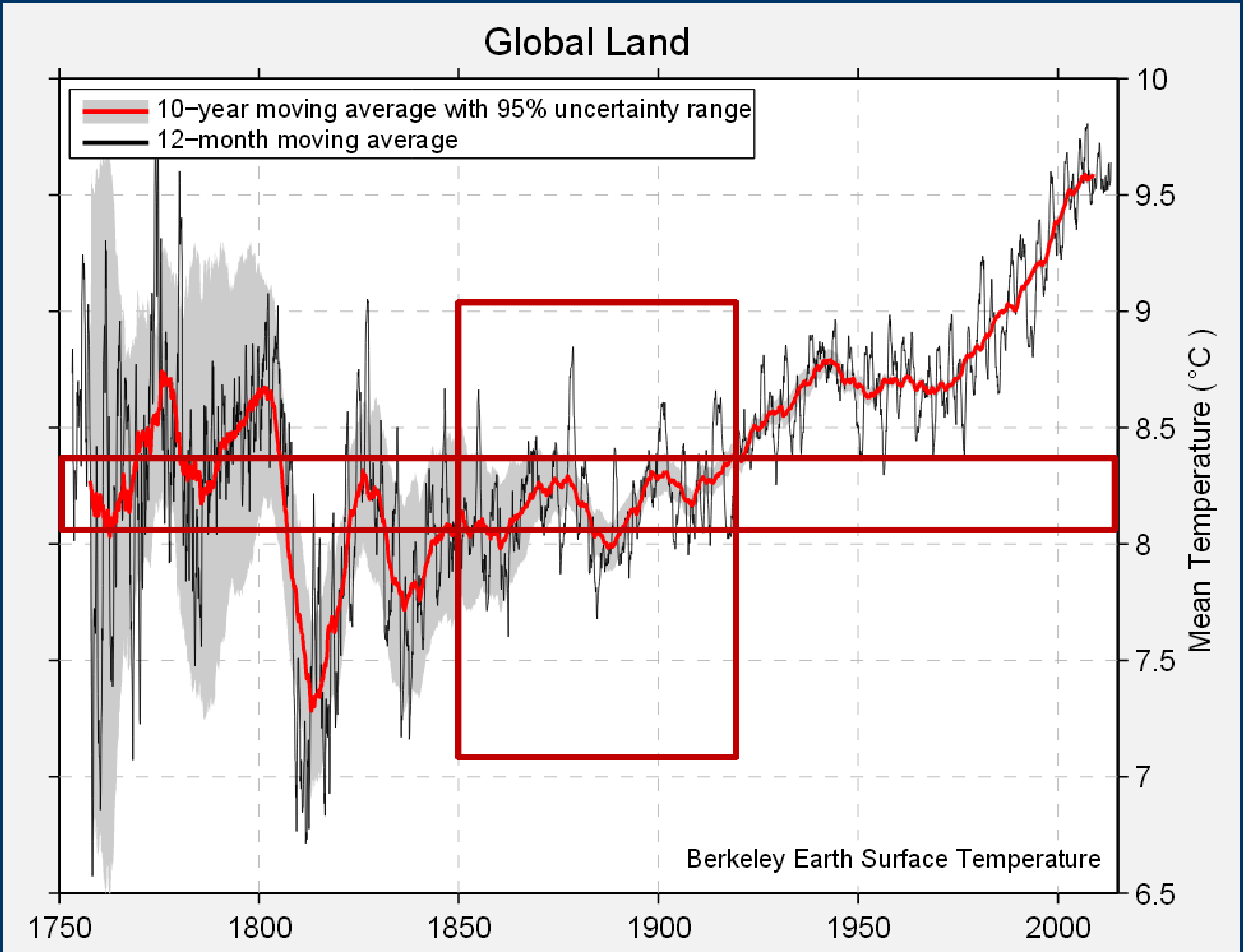
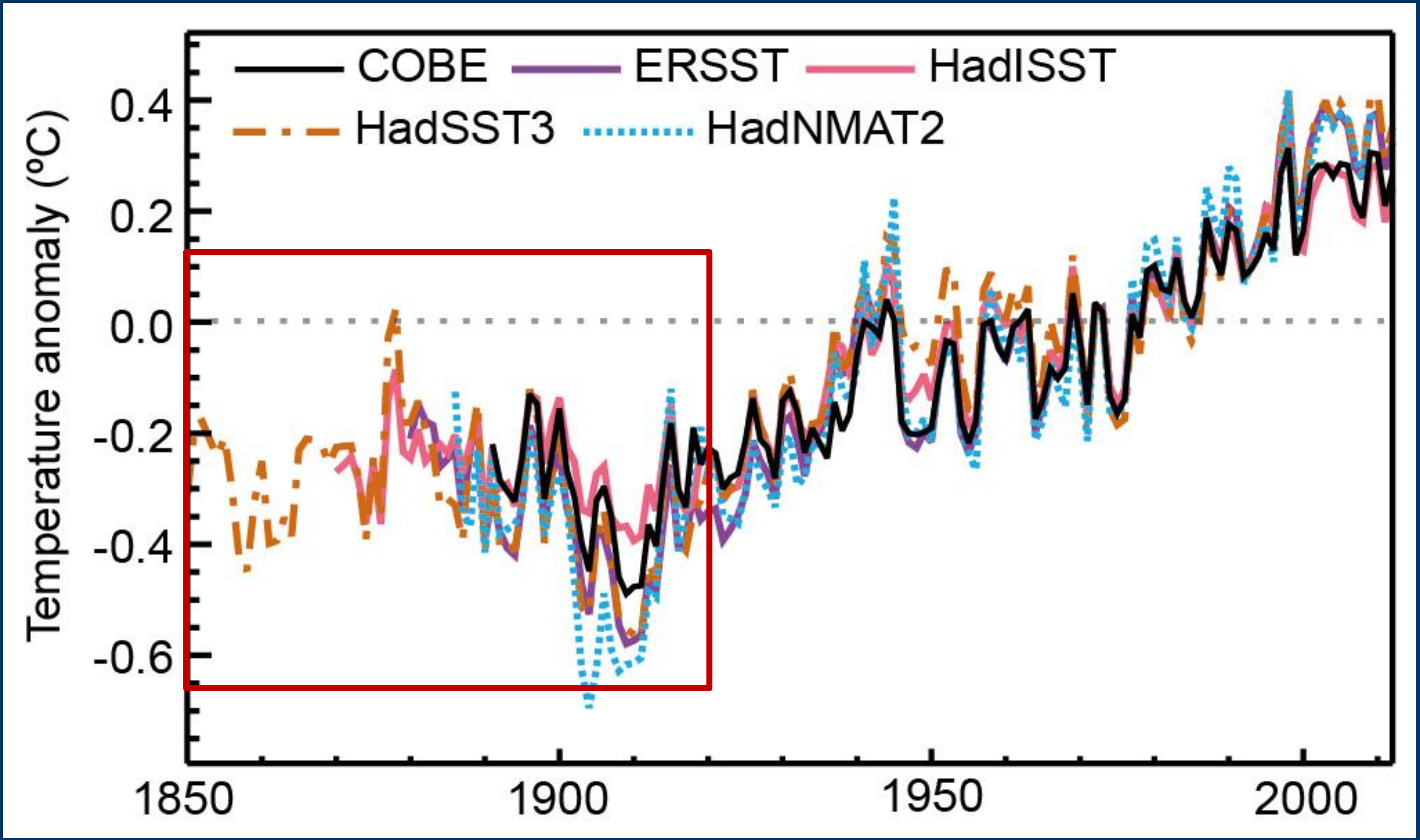


Figure: IPCC (2013)

Berkeley Earth – global land temperature



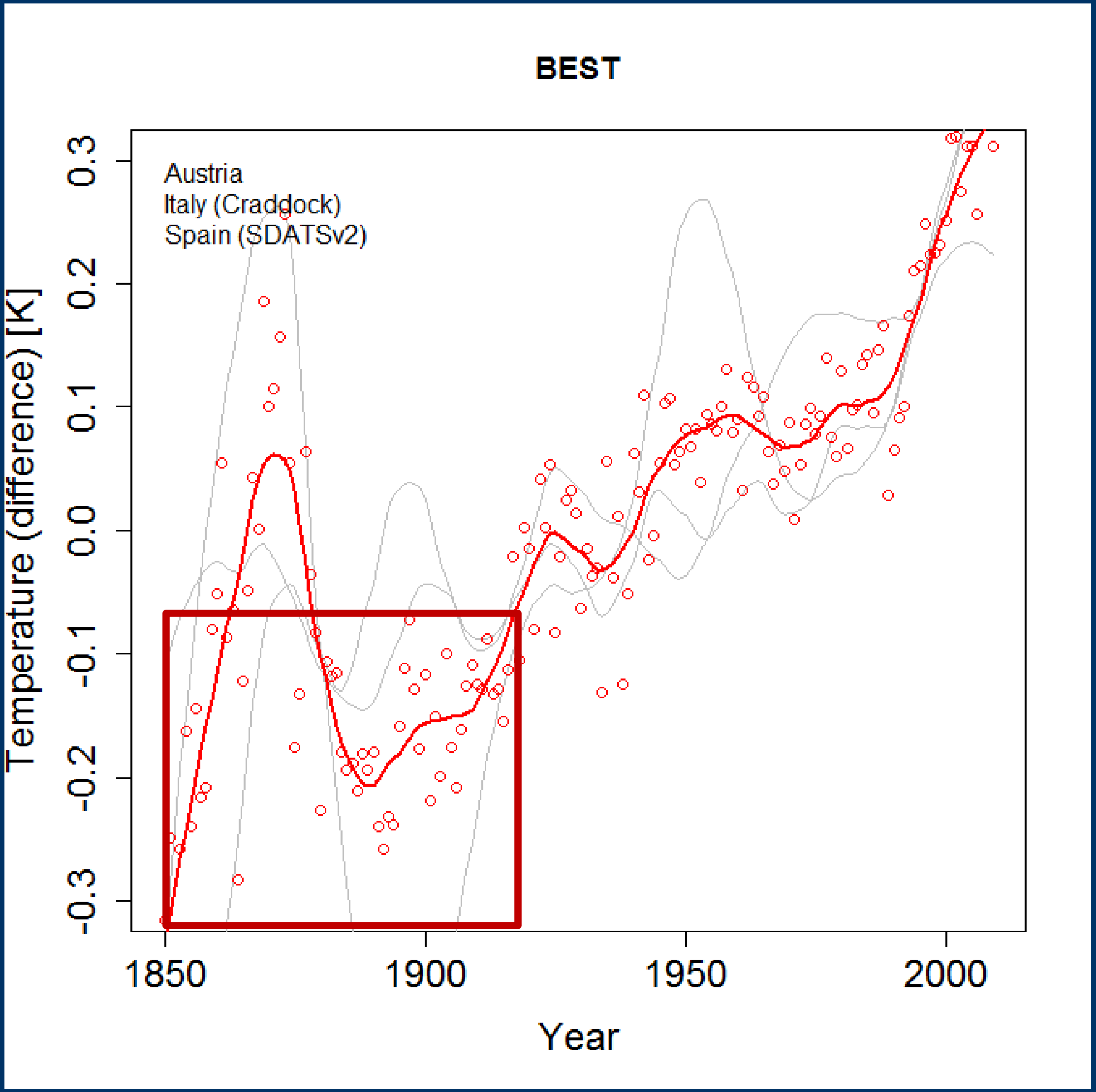
Sea Surface Temperature (AR5)



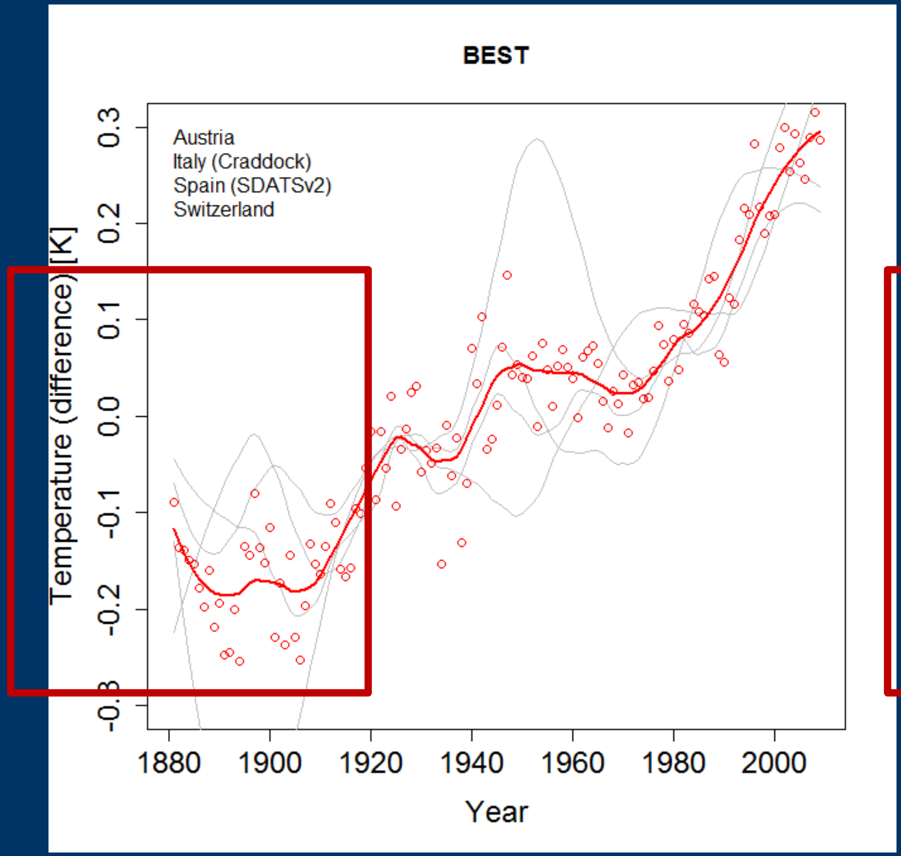
Indications of more early warming

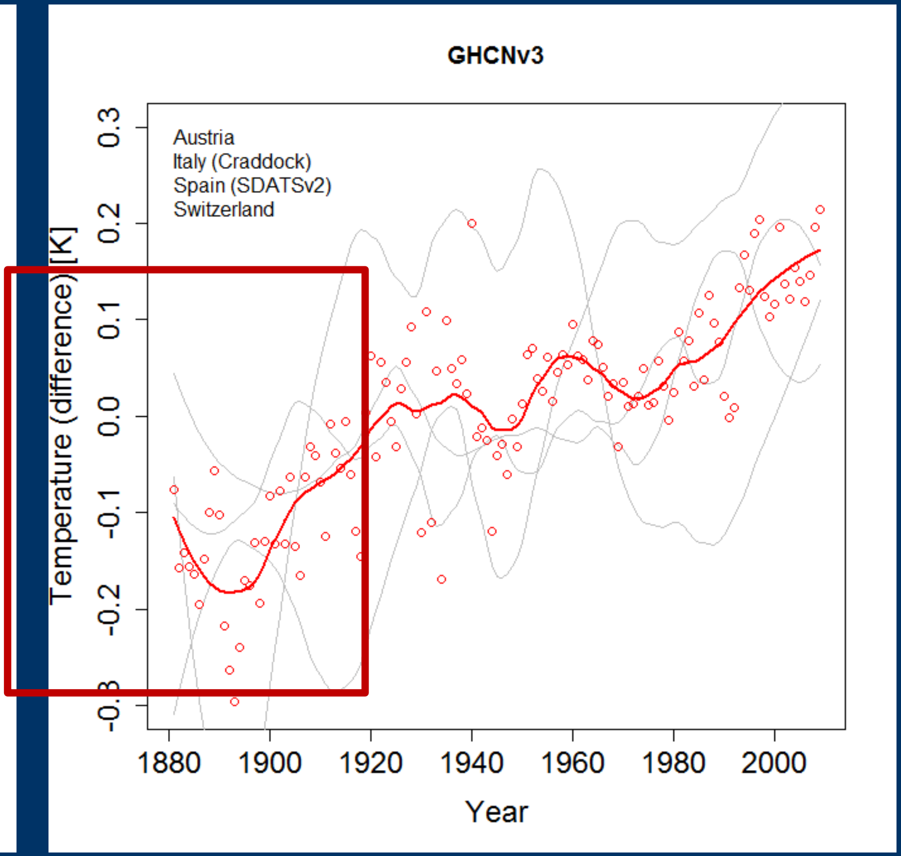
- Inhomogeneities in temperature observations
  - Well-homogenized national dataset see more warming up to 1920 than global datasets
  - Transition to Stevenson screen
    - old data too warm
  - Small adjustments for this transition in GHCNv3

Temperature difference series – 3 countries



Temperature difference series – 4 countries





Physical reasons: Radiation errors

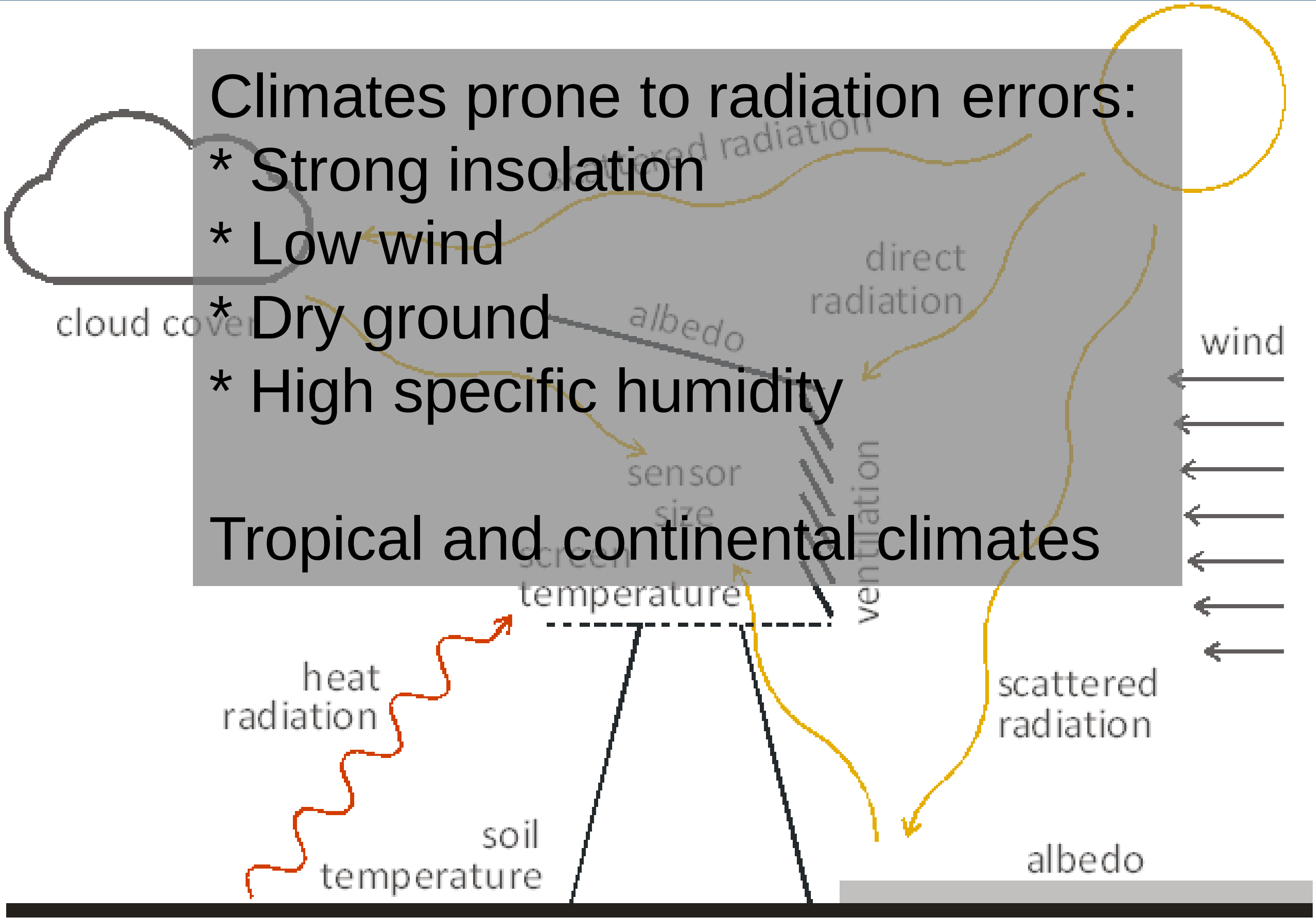
Montsouris/French screen (in Spain)

Photo: URV, Tarragona, SCREEN experiment

Radiation error

Climates prone to radiation errors:
* Strong insolation
* Low wind
* Dry ground
* High specific humidity

Tropical and continental climates



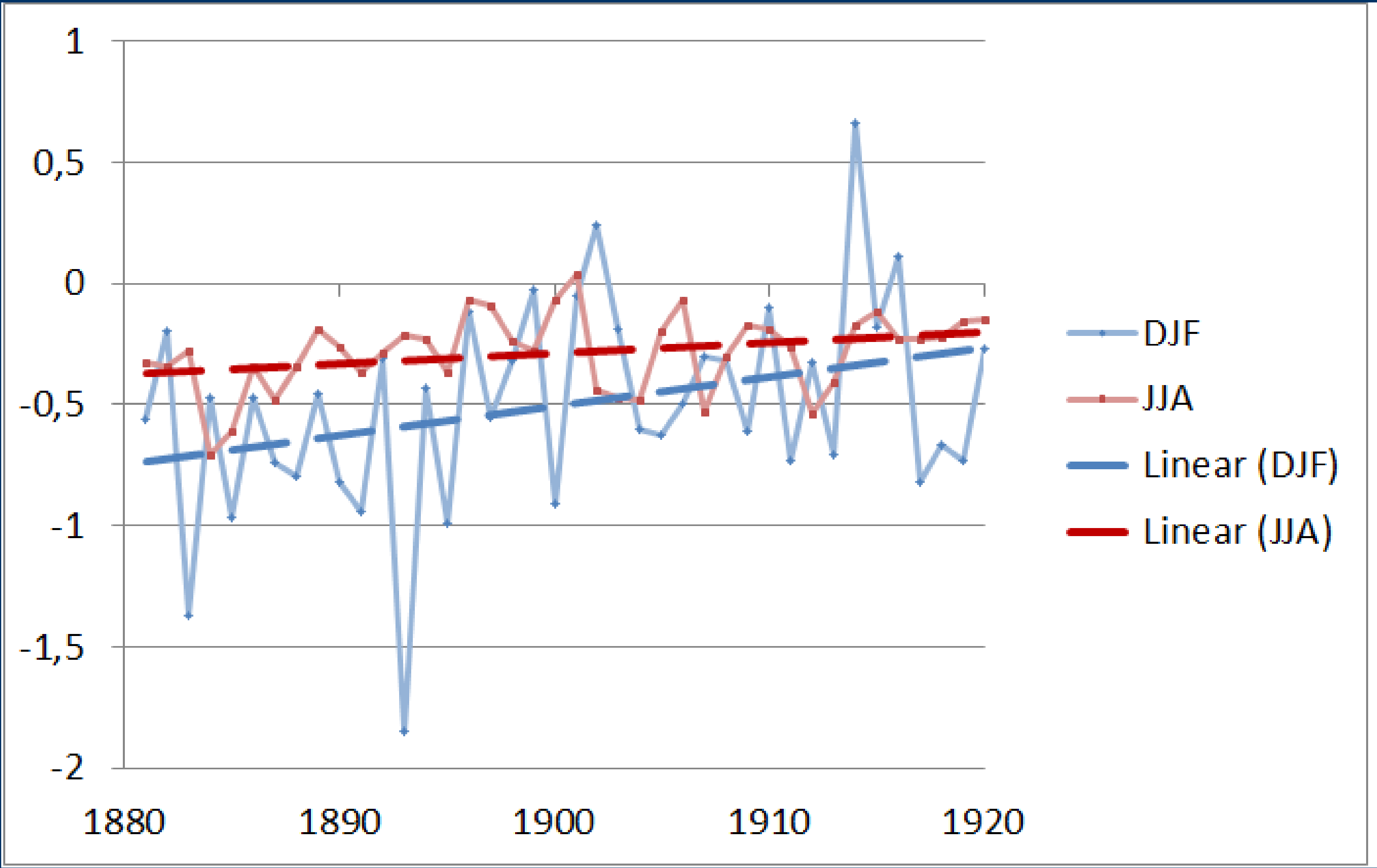
Parallel measurements
Transition to Stevenson screens

- North-West Europe: < 0.2°C (Various, Parker)

- Basel, Switzerland: ~0 (0.25)°C (Wild screen)
- Kremsmünster, Austria: 0.2°C (North-wall)
- Adelaide, South Australia: 0.2°C (Glaisher stand)
- Spain: 0.35 (0.5)°C (French screen)

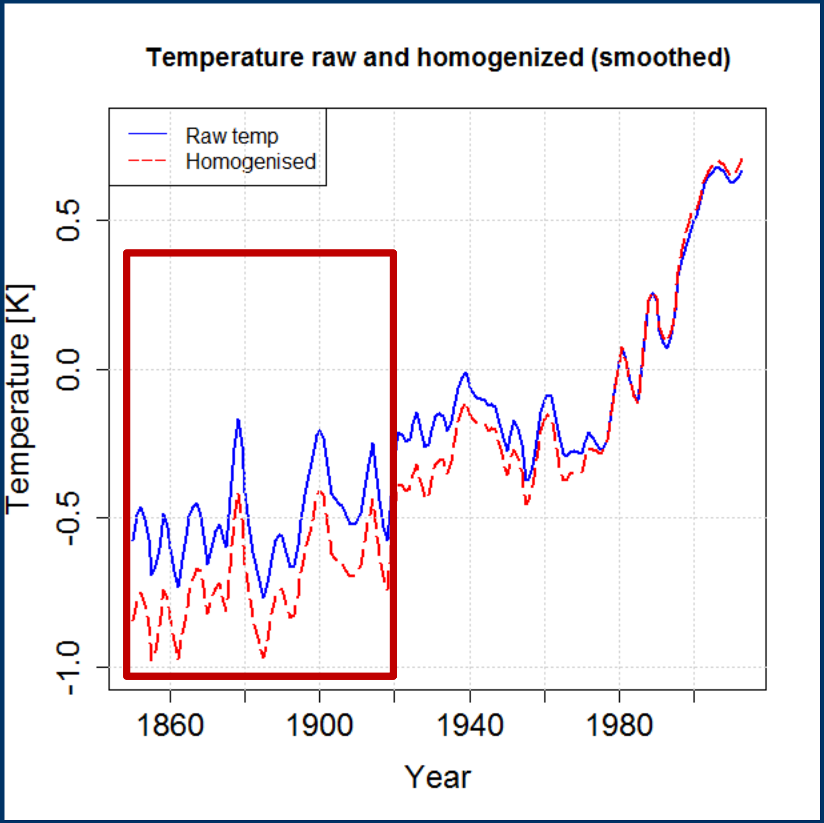
- Sri Lanka: 0.37°C
  (Tropical screen)
- India: 0.42° (Tropical screen)

Winter and summer trend

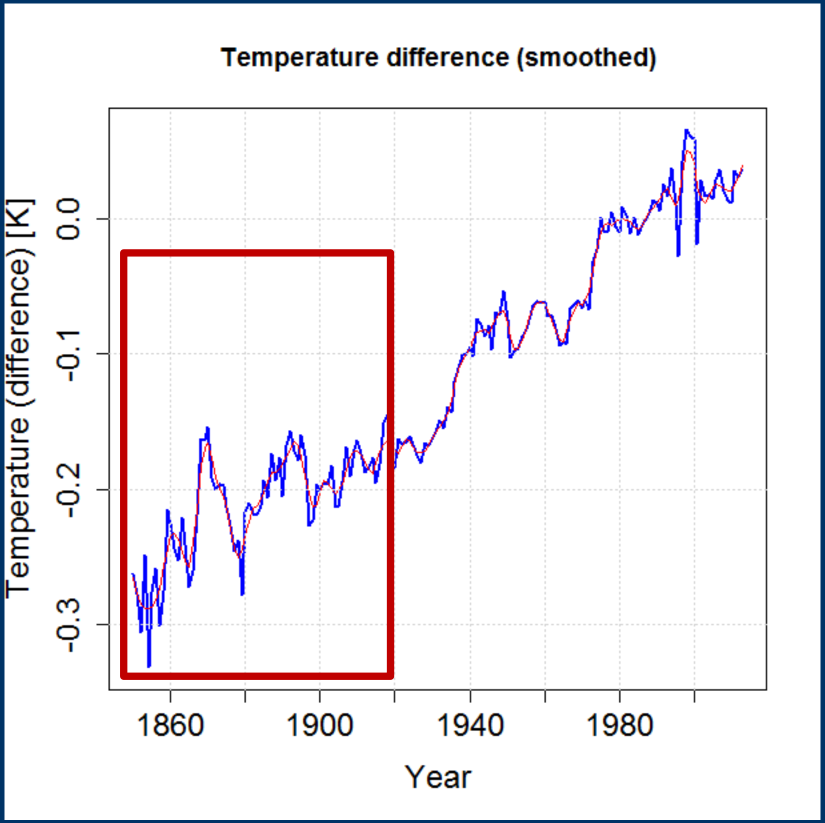


Inhomogeneities in GHCNv3

Global Land Surface Temperature



Adjustments

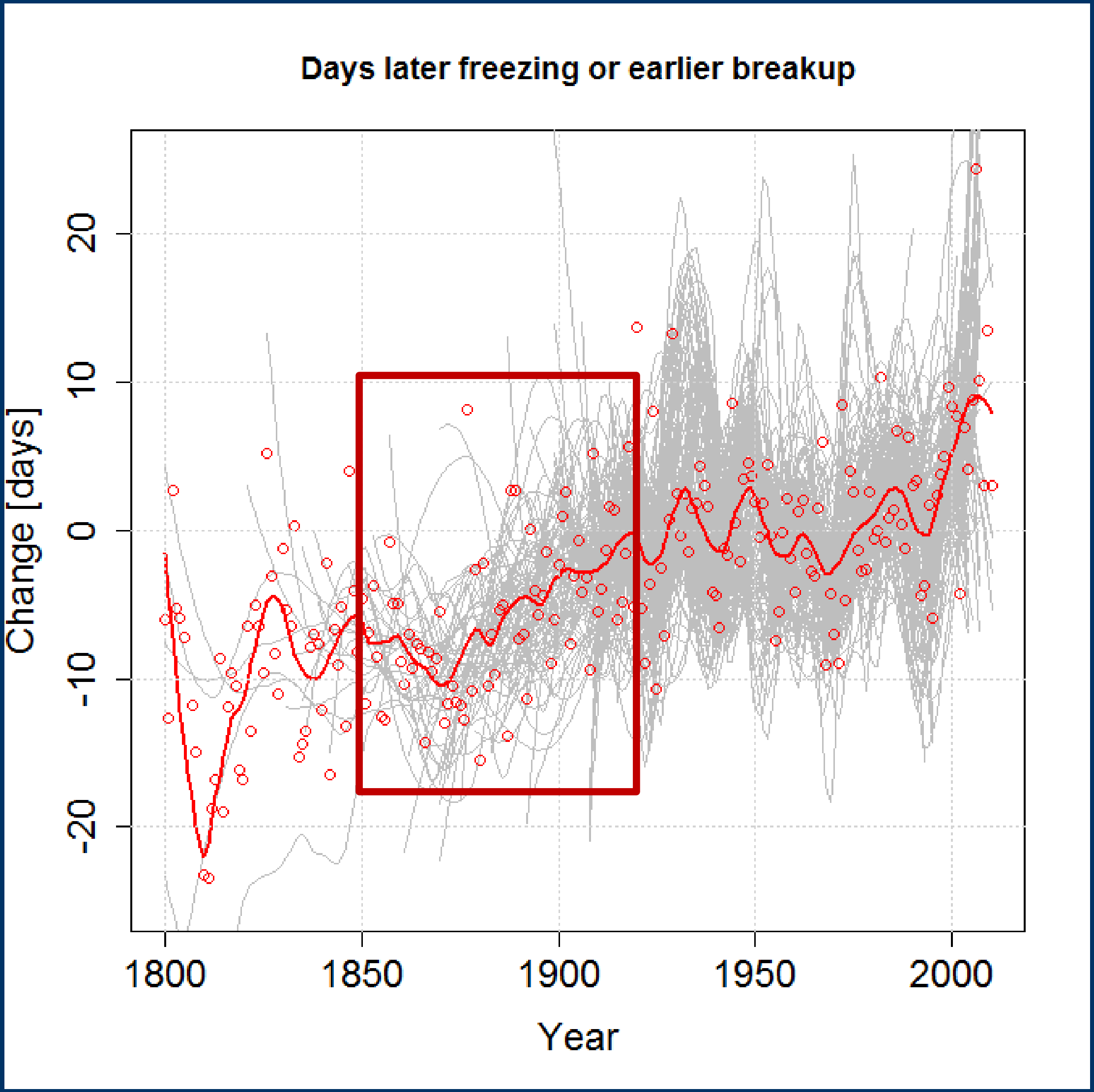


Averaging: Zeke Hausfather
Data: GHCNv3

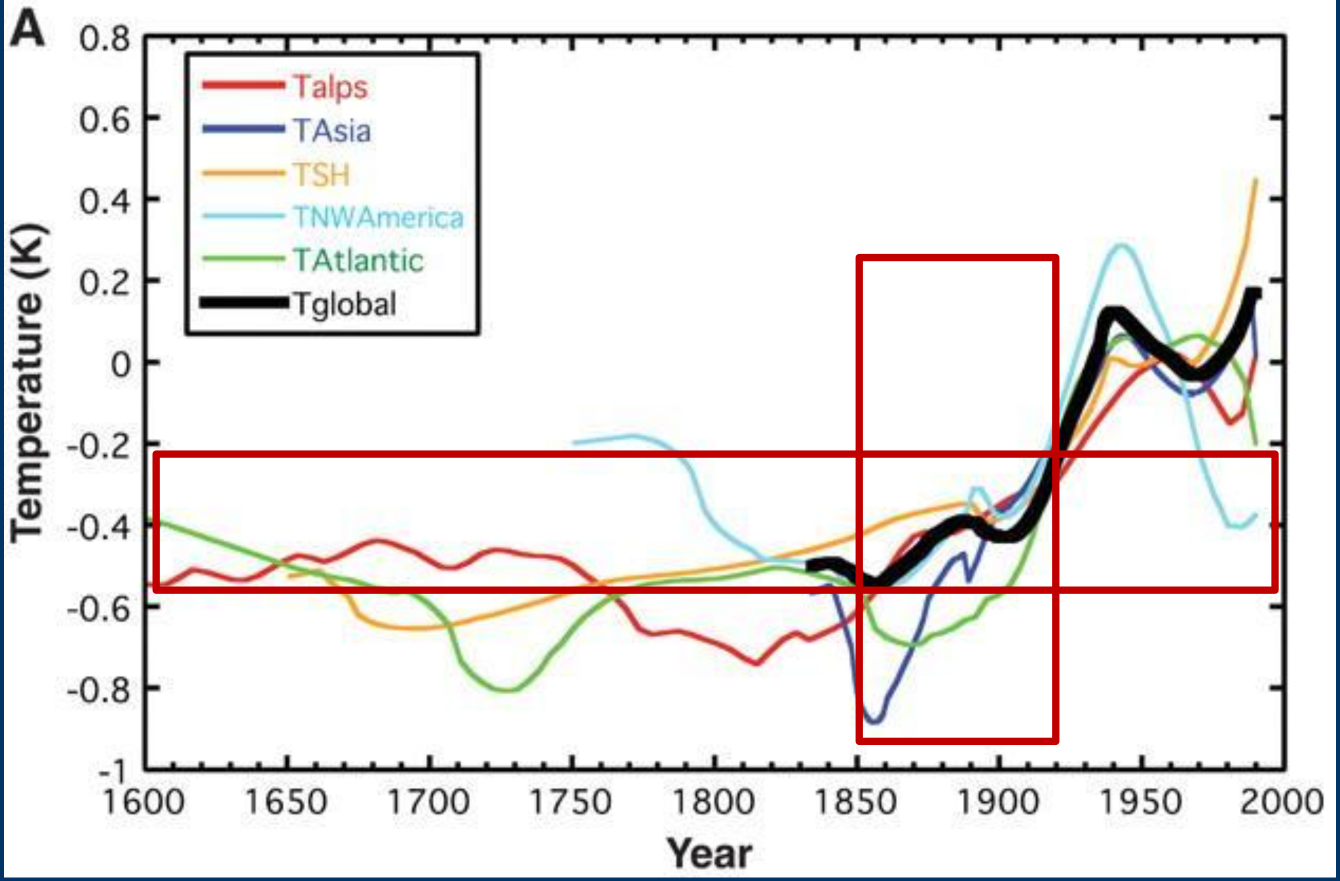
Climatic changes in 19th century

- Trend in lake temperatures, ice season shorter
  - http://tinyurl.com/lake-temp
- Glacier retreat
- Sea level rise

Lake and river freezing

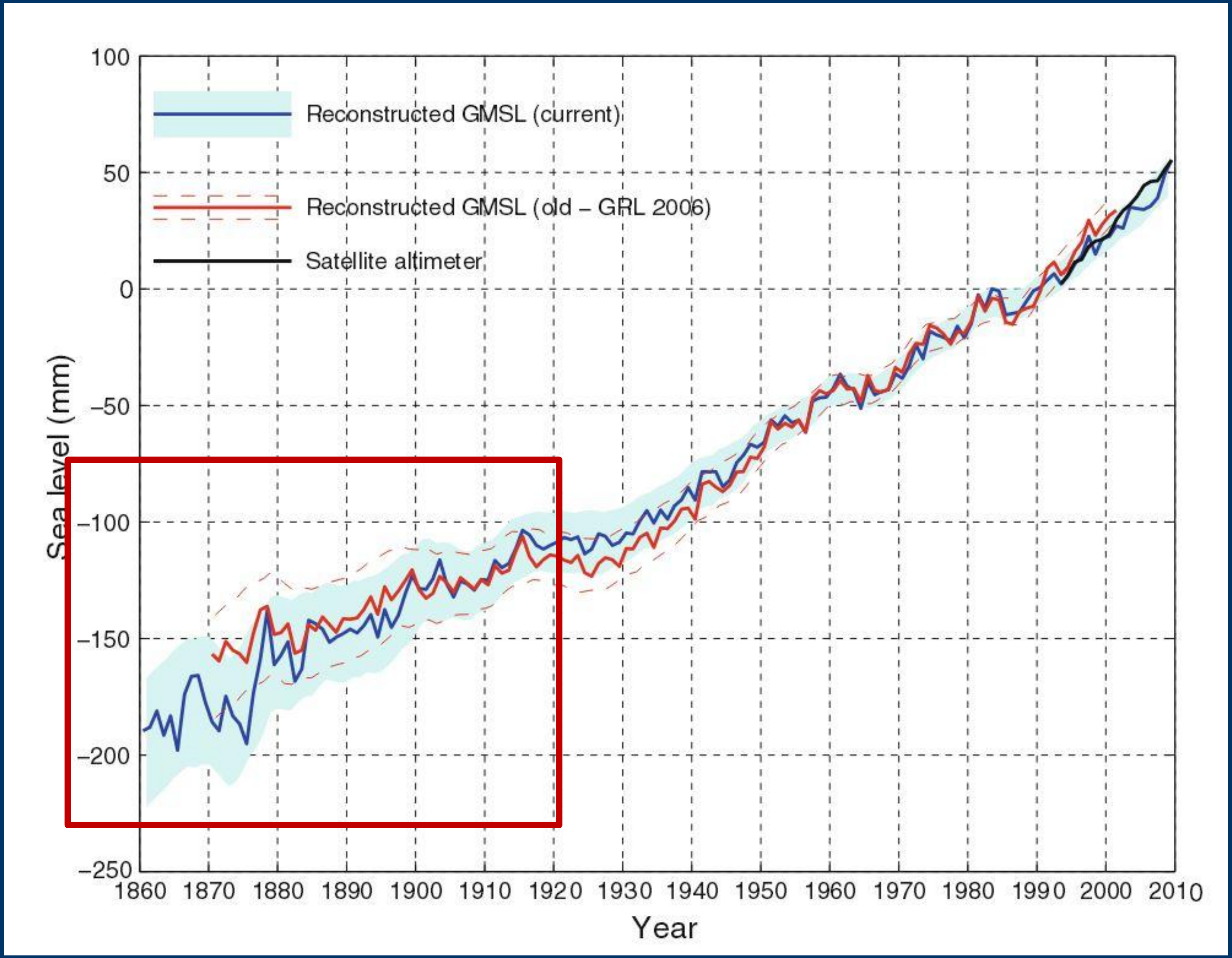


Temperature reconstruction from glaciers



Oerlemans, J., 2005: Extracting a Climate Signal from 169 Glacier Records. *Science*, **308**, no. 5722, pp. 675-677.

Sea level rise



Church & White, 2011

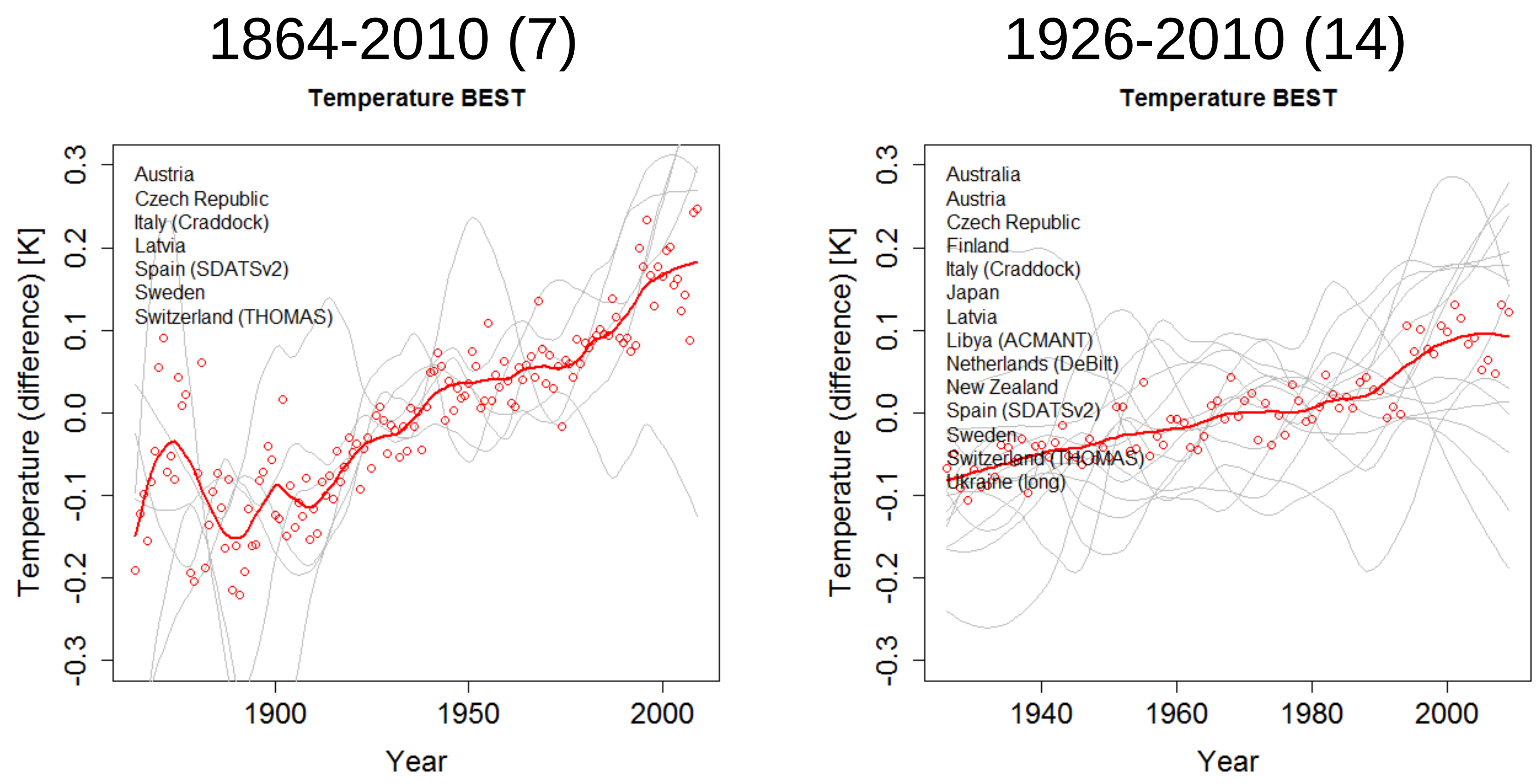
Conclusions – early warming

- A warm bias in the early instrumental data
  - Parallel data suggest clear bias
    - Transition to Stevenson screens
  - Corrections GHCNv3 small and early
  - Winter trend stronger than summer trend
- Large differences between global and national datasets
- Station data is just one line of evidence

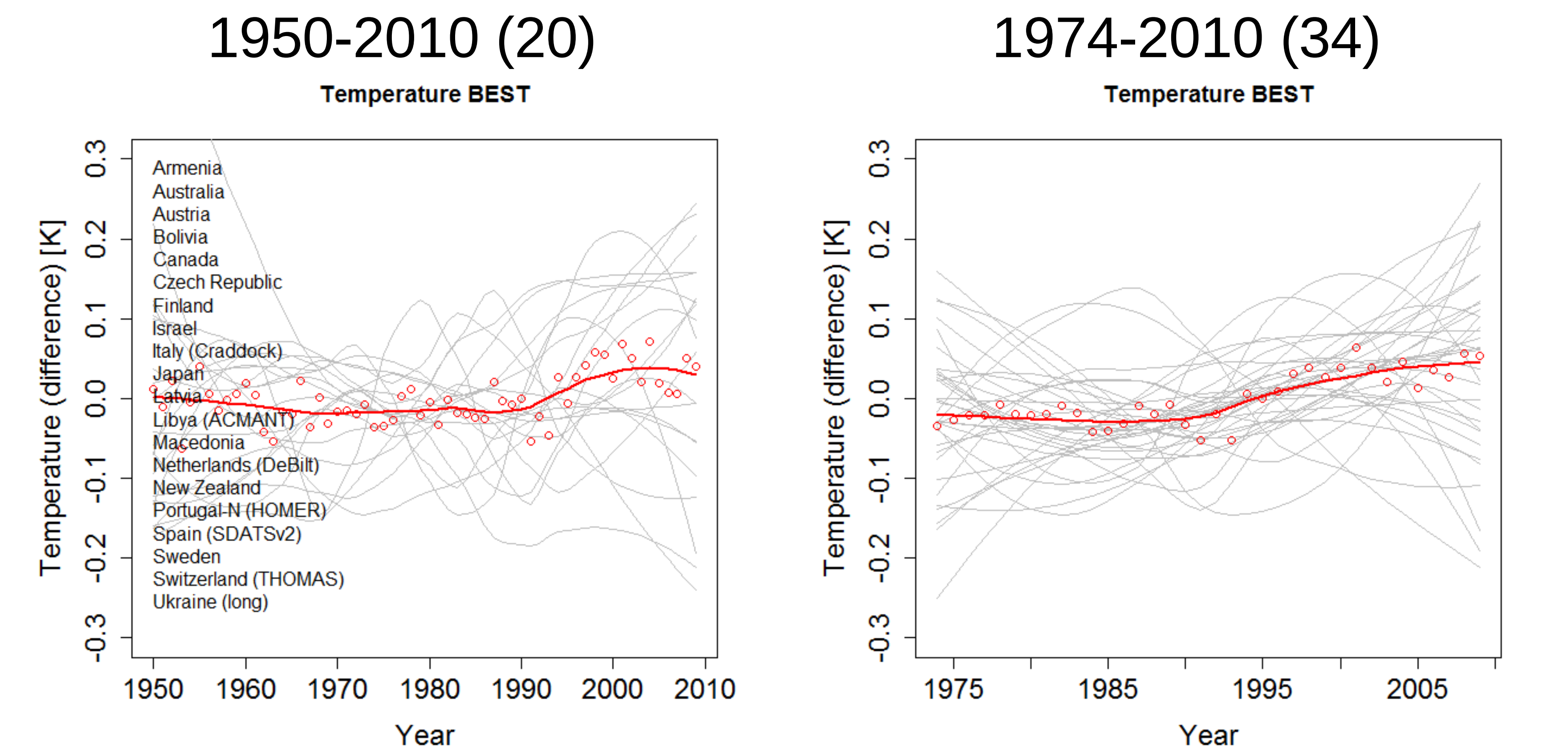
Conclusions – early warming

- Warming
  - River and lake freezing
  - Glaciers
  - Proxy data
  - Sea level rise
- More than expected?
  - Needs quantitative study
    - Berkeley Earth shows some warming over land (Arctic)
  - Would need colocation of datasets
    - Much of the evidence is from cold climates
  - Another indication of a remaining warm bias
- http://tinyurl.com/earlywarming

Difference (national – BEST)



Difference (national – BEST)



Sources of global temperature trend bias

- Details: http://tinyurl.com/reasons-temp-bias

- Transition to Stevenson screens
- Transition to Automatic Weather Stations

- Urbanization
  - Urban Heat Island and relocations
  - Relocations to airports
- Station siting quality
  - Centre of villages to current location outside

- Irrigation & watering

Relocations

- Cooling relocations based on relative statistical homogenization:

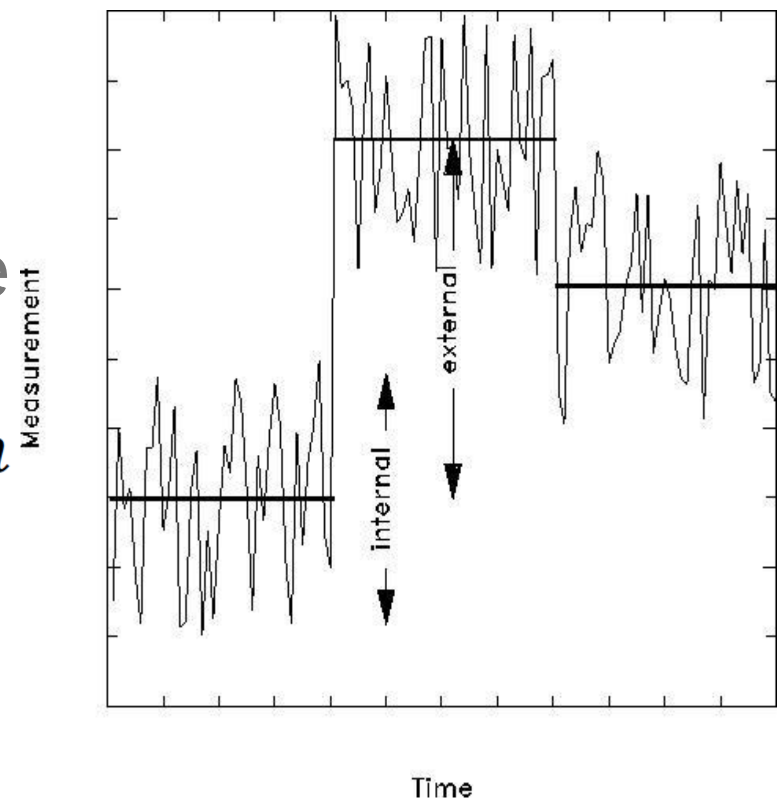
Beijing	-0.75°C	Yan et al. (2010)
Hefei	-0.7°C	Yang et al.(2013)
China	-0.2°C	Xu et al. (2013)
Bulgaria	~0°C	Syrakova et al. (2009)
Nordic+UK	-0.11°C	Tuomenvirta (2001)

Multiple breakpoint problem
More is different

- Decomposition difference time series
  - Break signal + Noise
  - Causinus & Mestre (2004)
- Maximise break variance
- Penalty term to determine

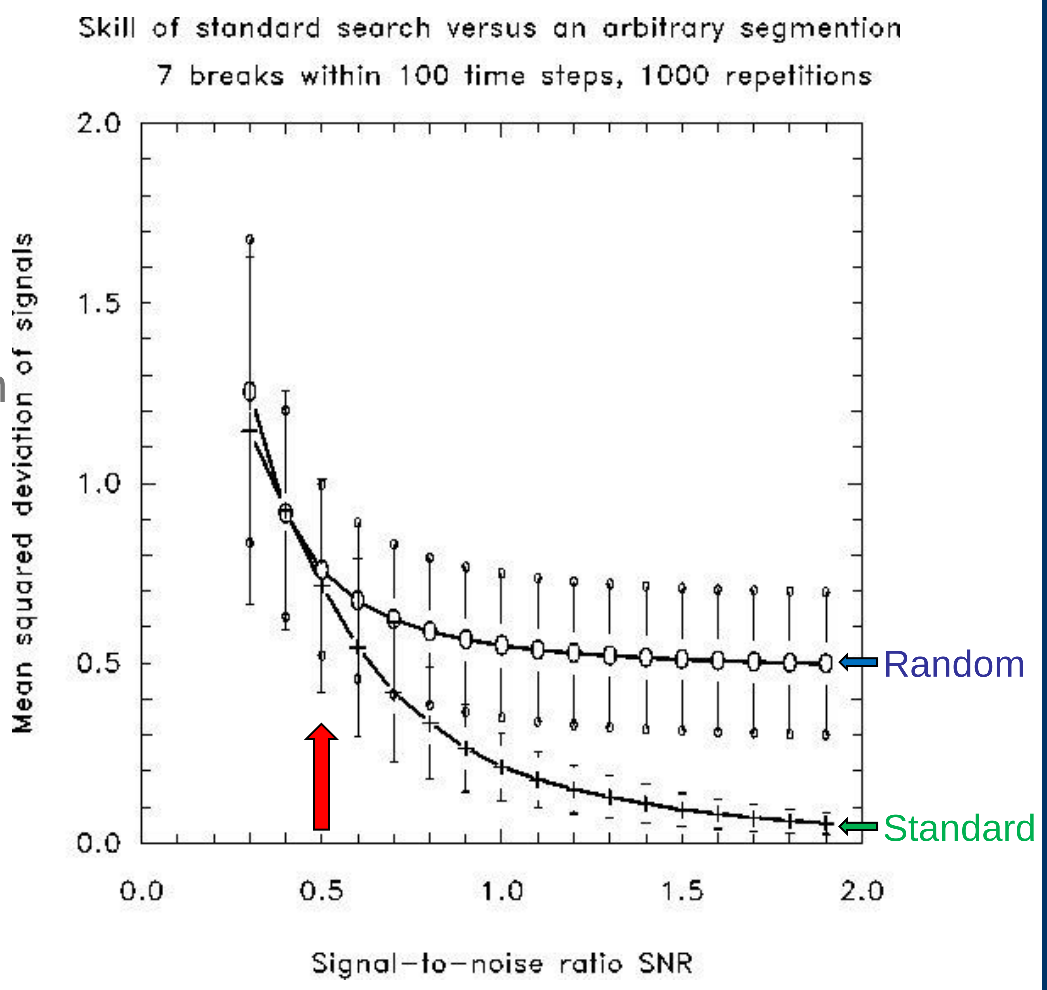
$$ln(1 - v) + \frac{2\, ln(n)\, k}{n - 1} = min$$

- Penalty term not optimal: Lindau & Venema (2013)

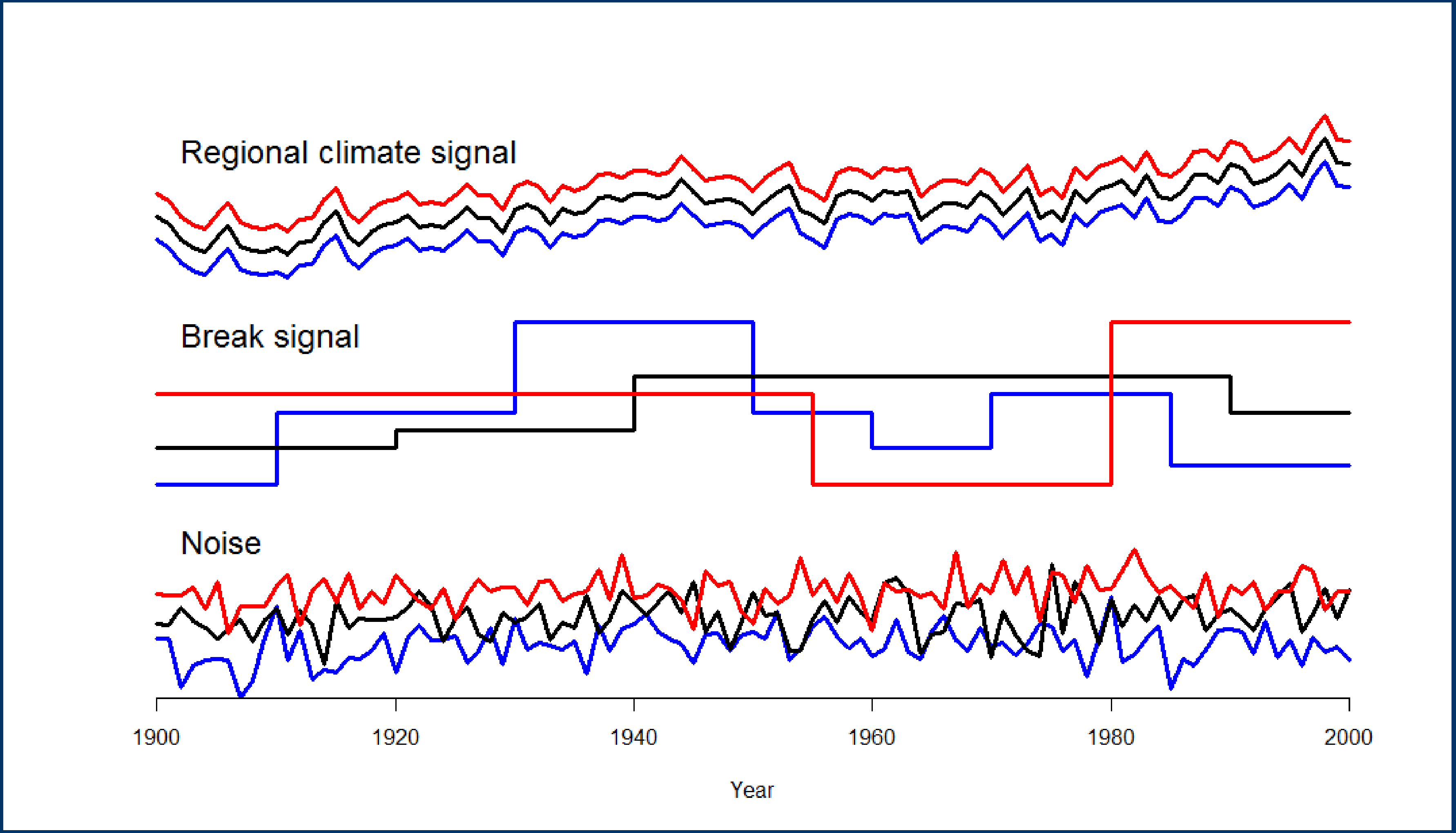


Break detection and SNR

- SNR = Break variance / noise variance
- RMS skill for:
  - 0 Random segmentation
  - + Standard search
- Mean square deviation of signals
  - Inserted (true signal)
  - Computed adjustments
- Lindau & Venema (2016) to be submitted



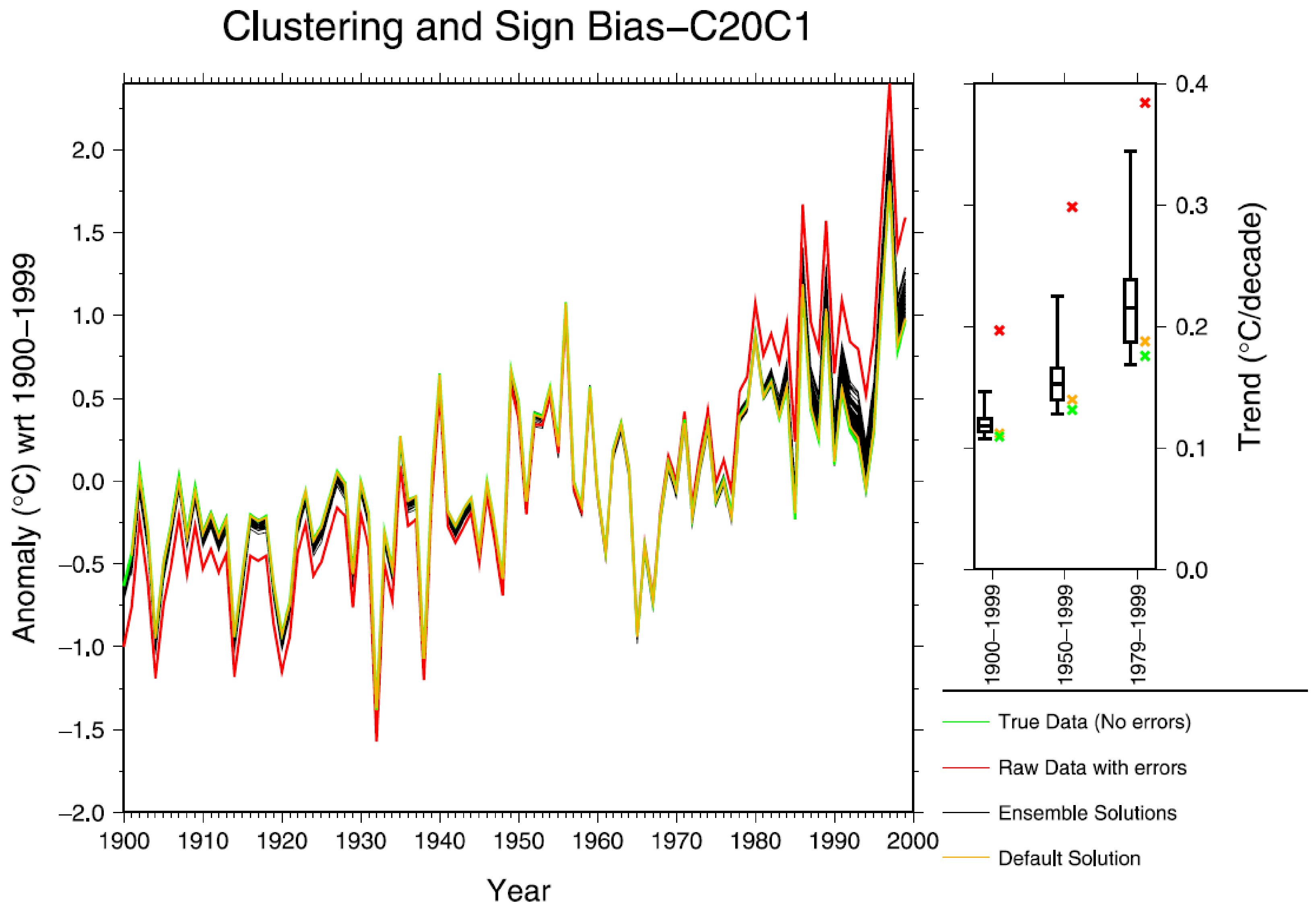
Correction by decomposition



Undercorrecting trend biases

- Computing the adjustments is a regression
  - Predictors: break positions (+ station temps)
  - Predictands: adjustments (+ regional signal)
- Numerical test (all breaks are known)
  - ANOVA adjustments are unbiased (but noisy)
- Imperfect predictors (break positions)
  - Break variance is underestimated
    - Trend biases will be undercorrected
  - All breaks detected, but error in position of 2 year:
    - 18% of trend bias remains
    - Artificial, but gives idea of the order of magnitude

NOAA validation study for USA



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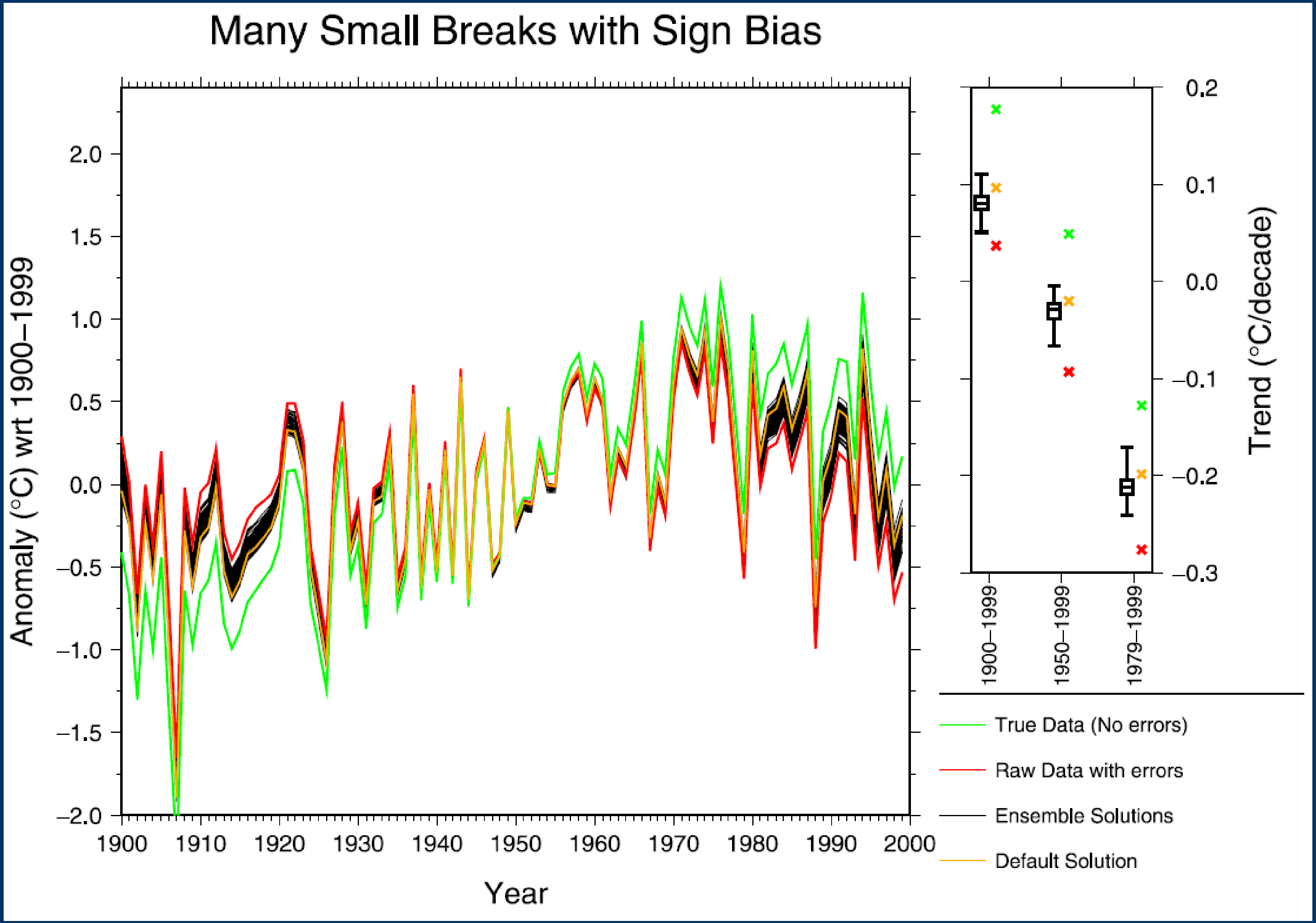
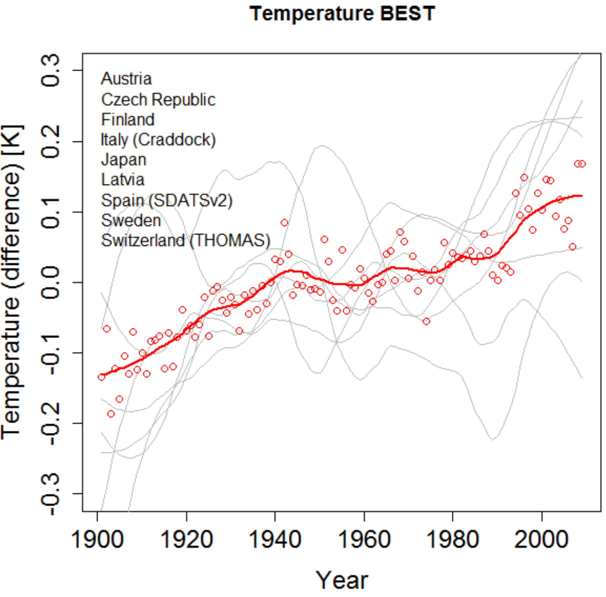
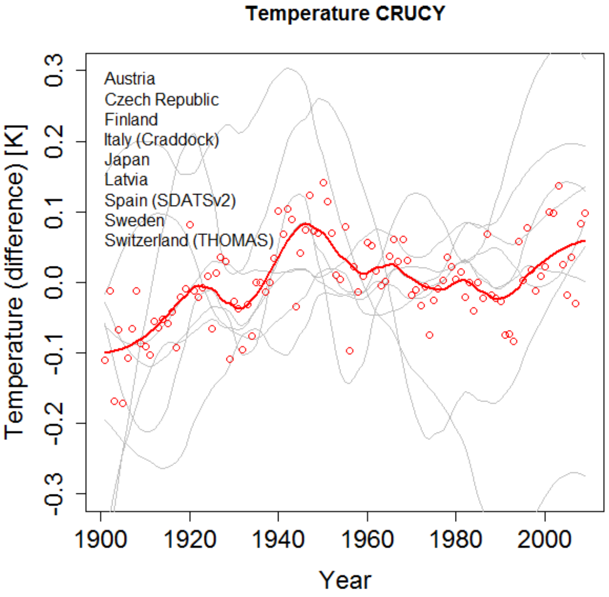


Difference BEST, GISS, CRUCY (1901-2010)

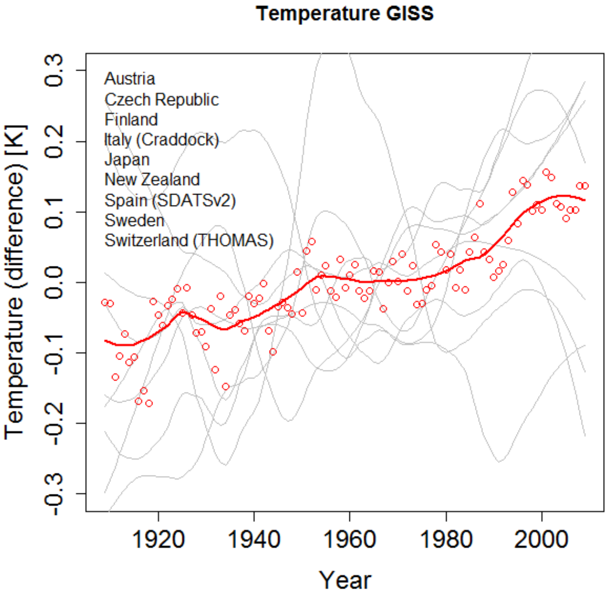
BEST



CRUCY

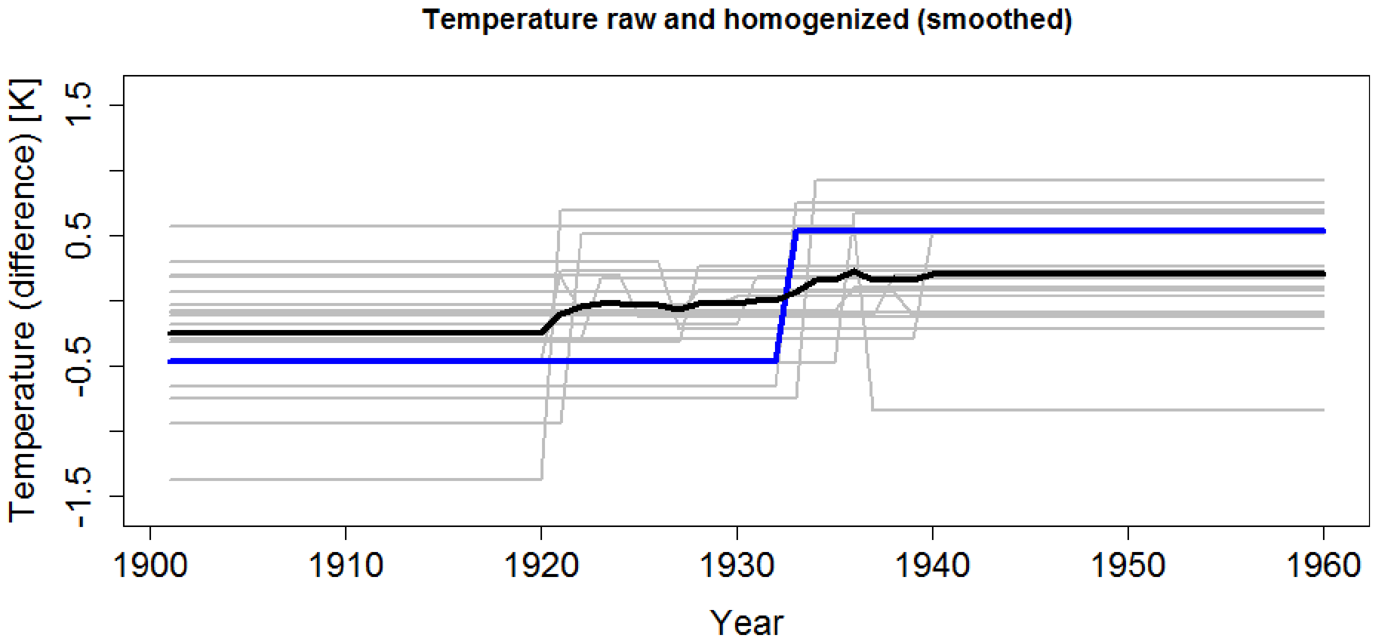


GISTEM



Regional trend bias correction

- A small bias in breaks can lead to large-scale temperature trend errors
- Correction with composite reference
  - Reference has the same bias



Conclusions

- Trend difference between well-homogenized datasets and global collections
  - Land surface temperature
- Relative homogenization: cooling bias data
  - Trend bias likely undercorrected
- Physical understanding of cooling bias poor
  - Transition to Stevenson screens seems undercorrected
- Many other changes in climate system fast
- Climatology urgently need a major investment in homogenization research

Future research - Homogenization

- Need better mathematical understanding of how well trend biases can be removed
  - Numerical understanding: ISTI global benchmarking
- Need better homogenization methods
  - Multiple breakpoint methods
    - Low signal to noise ratio
    - Determination of optimal number of breaks
    - Joint detection
    - Noise reduction of difference time series
  - Apply them to global datasets
- Need to exchange more data & metadata

Future research – Physical reasons

- Understanding of cooling biases is poor
  - Reduction radiation errors
  - Relocations, better siting
  - Irrigation and watering near weather stations
- Large global parallel dataset can help (ISTI-POST)
  - Transition to AWS
  - Transition to Stevenson screen
  - Relocations
  - Changes in weather variability and extreme weather
    - Poster
  - Precipitation, humidity, wind(?)

Future research – Other climatic changes

- Need to study other climatic changes in the light of possible temperature trend biases
  - If trend in other parameters do not fit with models, temperature trend bias often not considered
  - Other changes that go faster/slower than expected?
    - Permafrost?
    - Ground temperatures?
- Station record is just one of many
  - Consilience of evidence