Parallel measurements to study inhomogeneities in daily data

http://tinyurl.com/DailyDataBudapest

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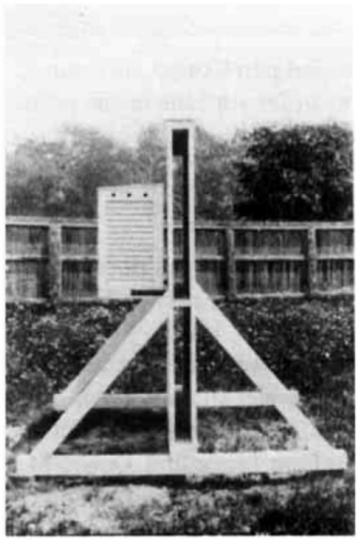
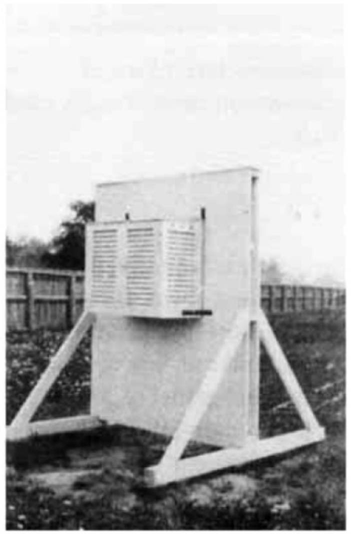
Motivation: daily data

“[Inhomogeneous data] affects, in particular, the understanding of extremes, because changes in extremes are often more sensitive to inhomogeneous climate monitoring practices than changes in the mean.”





Trenberth, K.E., et al., 2007: Observations: Surface and Atmospheric Climate Change. In: Climate Change 2007: The Physical Science Basis. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

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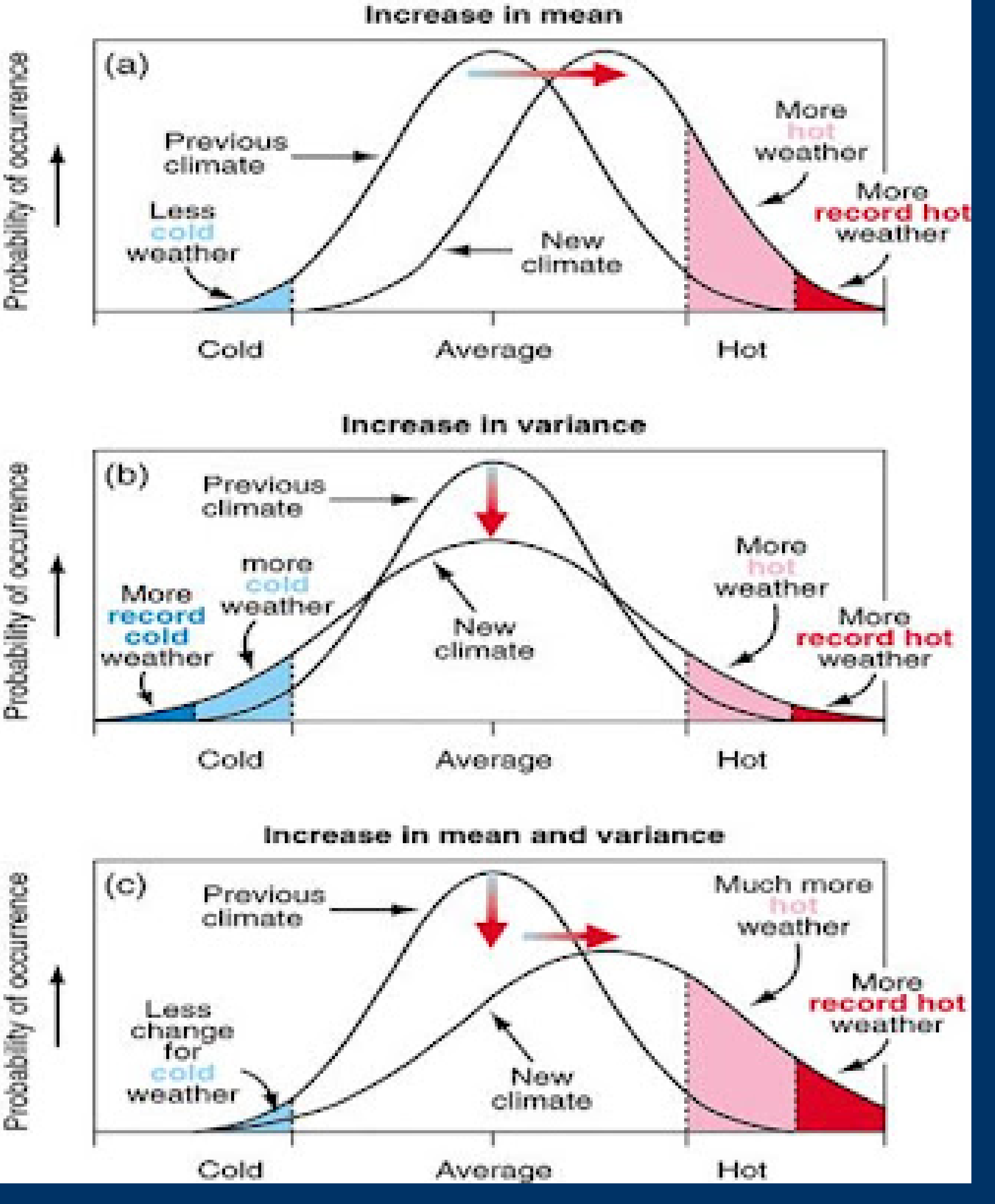
Content

- Motivation: Much recent interest in daily data
  - Changes in extremes: mean or weather variability
  - Variability around mean is added value of daily data
- Inhomogeneities
  - Physical causes of inhomogeneities
  - What do we know from parallel measurements?
- Correction methods
- Homogeneity daily datasets
- Conclusions
- Outlook
  - Homogenization of daily data
  - Study of parallel measurements

Extremes, mean and variability



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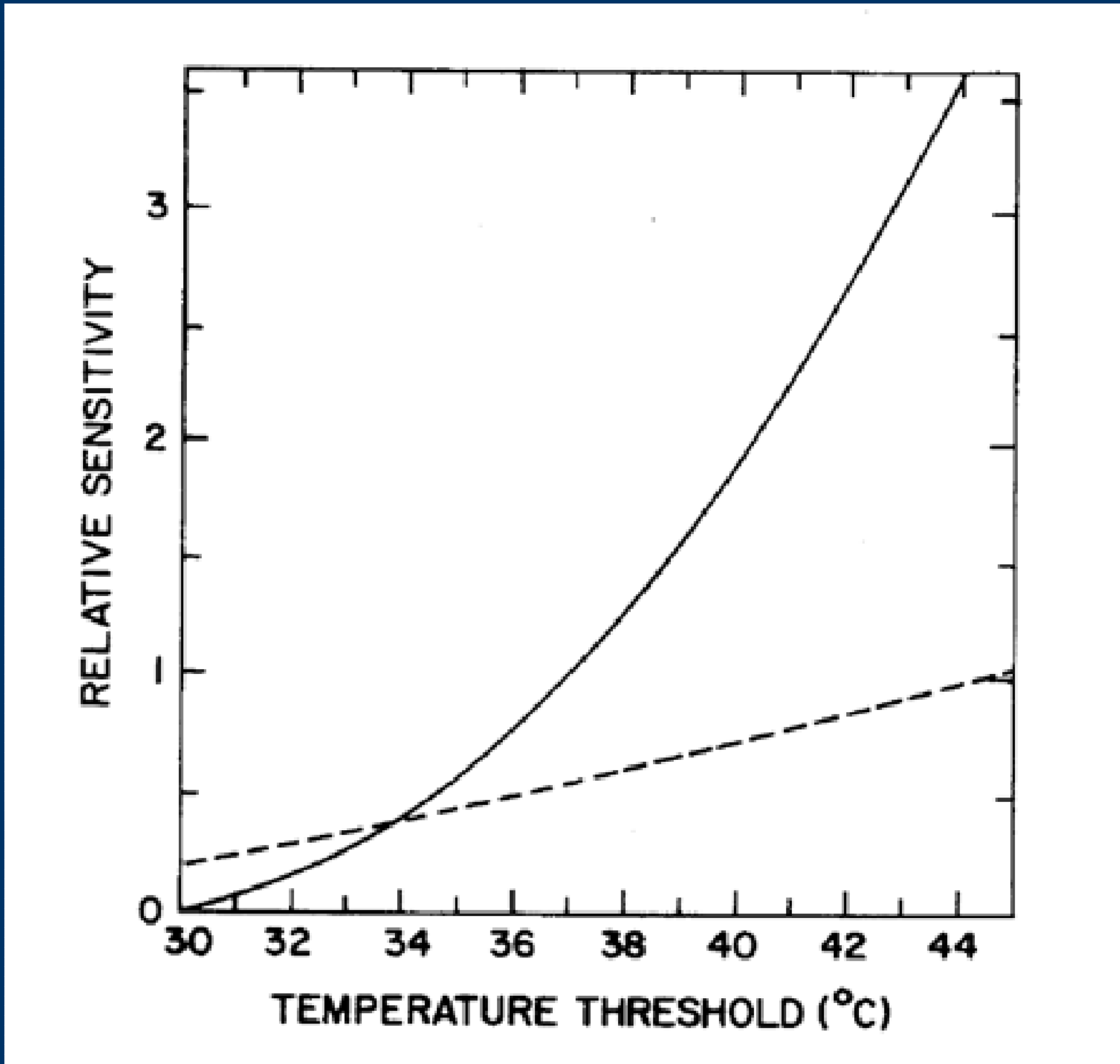
Importance changes in variability and mean



*The relative sensitivity of an extreme to changes in the **mean (dashed line)** and in the **standard deviation (solid line)** for a certain temperature threshold (x-axis). The relative sensitivity of the mean (standard deviation) is the change in probability of an extreme event to a change in the mean (or standard deviation) divided by its probability. From Katz and Brown (1992).*

Station data, heat waves

- Della-Marta et al. (2007)
  - Trends in station data over the last century of the daily summer maximum temperature (DSMT)
  - Increase in **DSMT variance** over Western Europe and central Western Europe is, respectively, responsible for approximately **25%** and **40%** of the increase in **heat days** in these regions.
  - Variance decreasing on the Iberian Peninsula
    - partially due to remaining inhomogeneities.
- They also studied trends in the 90th, 95th and 98th percentiles.
  - Only changes in the mean:
    - Estimates would have been between **14 and 60% lower**

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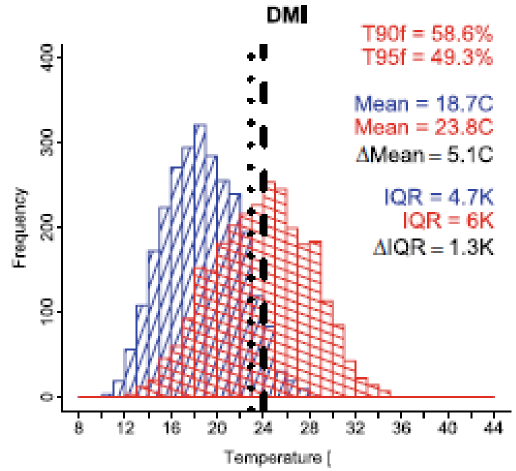
PRUDENCE RCM ensemble dataset

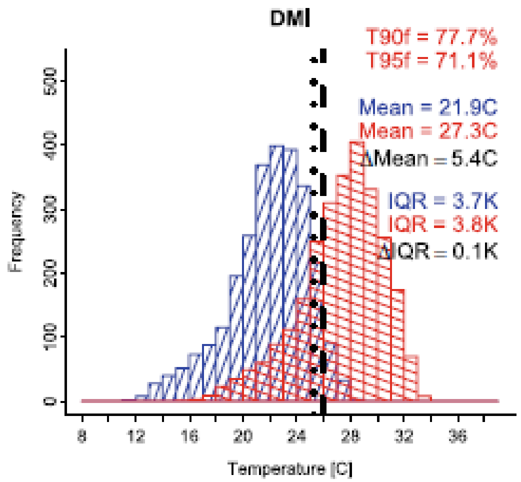
- PRUDENCE dataset (a European downscaling project) that for the coming century
  - Fischer and Schär (2009)
  - Strongest increases in the 95th percentile are in regions where *variability* increases most (France)
  - **Not** in regions where the mean warming is largest (Iberian Peninsula).

- DMI model
  - CTL (1961–1990, blue)

SCN (2071 2100, red)



France



Iberian Peninsula

2003 extreme heat wave

- Heat wave in Western Europe of 2003
- Schär et al. (2004) report that the 2003 heat wave is extremely unlikely given a change in the mean of a normal distribution only
- Suggests: change in variability
- Large consequences
  - Summer mean temperature anomalies above 3°C (up to 5 standard deviations) for a large region around the Alps (Schär et al., 2004)
  - Resulted in over 70 thousand additional deaths (Robine et al., 2008)
  - Wild fires, damage to forest and fresh water ecosystems, reduced crop yields
  - Largely enhanced demands for electricity in France, while simultaneously forcing some power plants to shut down (Jones et al., 2008)

Importance changes in variability and mean

- Not much known yet
- Limited evidence fits to the Katz and Brown theorem
  - Weather variability important for *moderate* extremes
  - Weather variability paramount for *extreme* extremes
- IPCC (2012) special report on extremes:

"Projecting future changes in extremes we need to consider changes in the variability and the shape of the probability distribution."

What do we know about inhomogeneities in daily data from parallel measurements?

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Parallel measurements

- WMO recommendation: several years of parallel measurements in case of change in observation
- Experiments with parallel measurements
  - WMO studies for operational instruments
  - Climatological studies with historical instruments
- Typically analysed for change in mean only
- Three studies on temperature distribution
  - Australia, relocation:
    - Trewin, B. A daily homogenized temperature data set for Australia. *Int. J. Climatol.,* doi: 10.1002/joc.3530, 2012.
  - Austria, north wall and Stevenson screen:
    - Böhm, R., P.D. Jones, J. Hiebl, D. Frank, M. Brunetti and M. Maugeri. The early instrumental warm-bias: a solution for long central European temperature series 1760–2007. *Climatic Change*, **101**, pp. 41–67, doi 10.1007/s10584-009-9649-4, 2010.
  - Spain, French screen to Stevenson screen:
    - Brunet, M., J. Asin, J. Sigró, M. Banón, F. García, E. Aguilar, J. Esteban Palenzuela, T.C. Peterson and P. Jones. The minimization of the screen bias from ancient Western Mediterranean air temperature records: an exploratory statistical analysis. Int. J. Climatol., DOI: 10.1002/joc.2192, 2010.

Australia: Albany airport and town

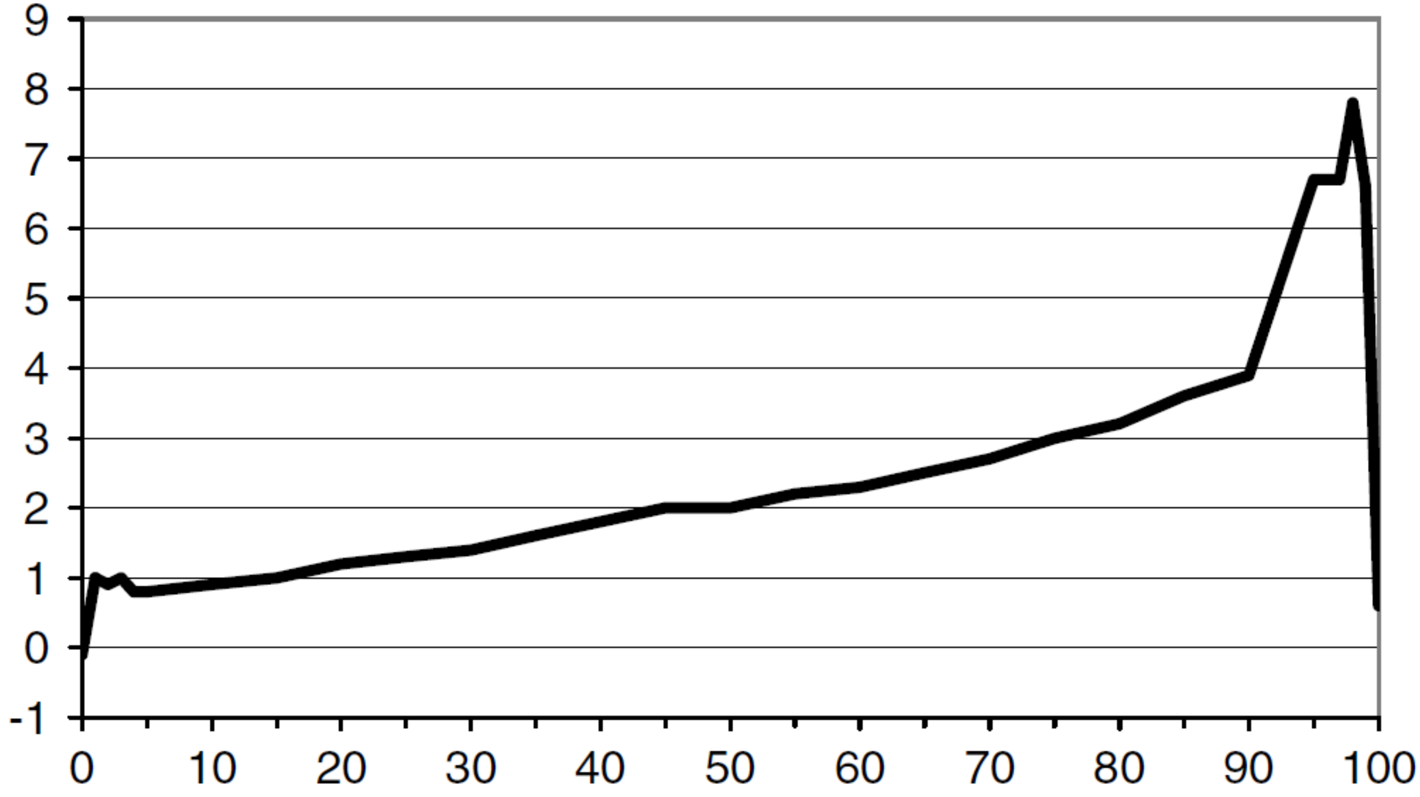

Figure 1. Differences (°C) between percentile points of summer maximum temperature at Albany airport (009741) and Albany town (009500) during the overlap period (2002–2009). The 0th and 100th percentiles indicate the lowest and highest values recorded during the overlap period.

Trewin (2012)

Parallel measurements – Kremsmünster

Böhm et al. (2010)

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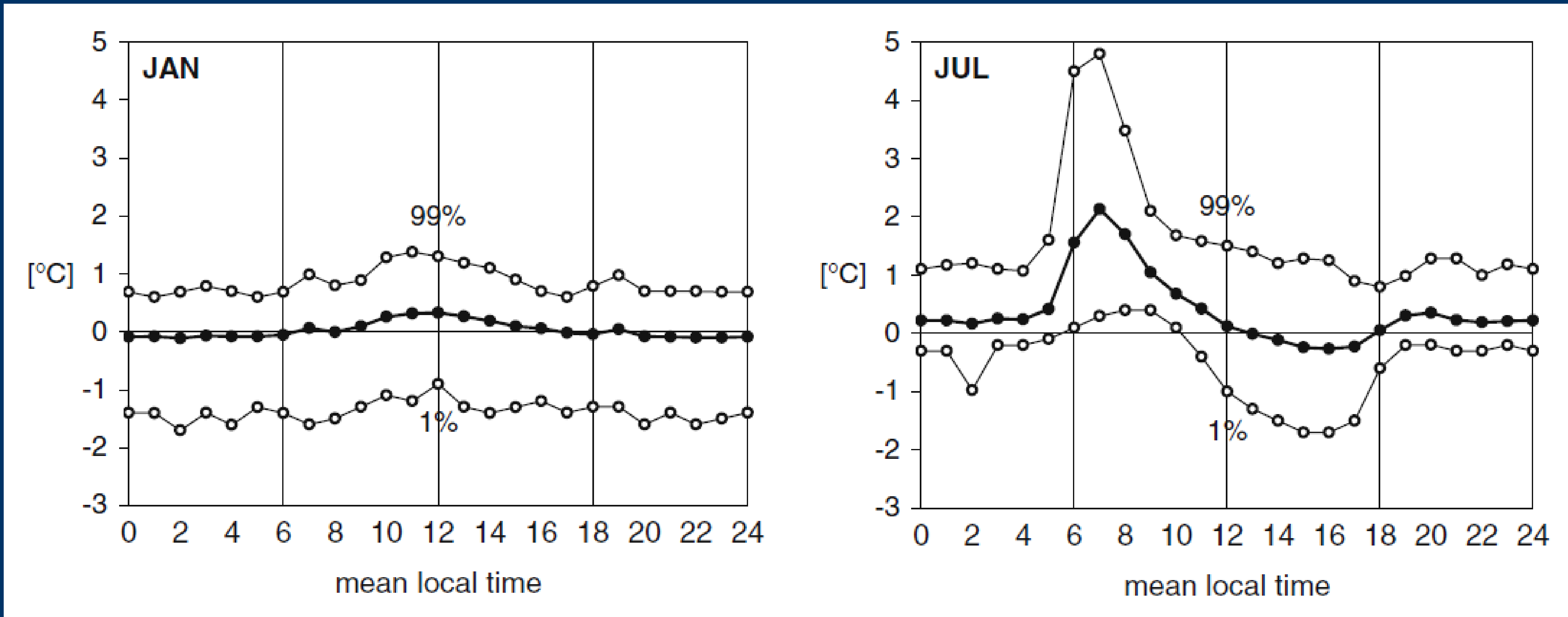
Kremsmünster – percentiles difference

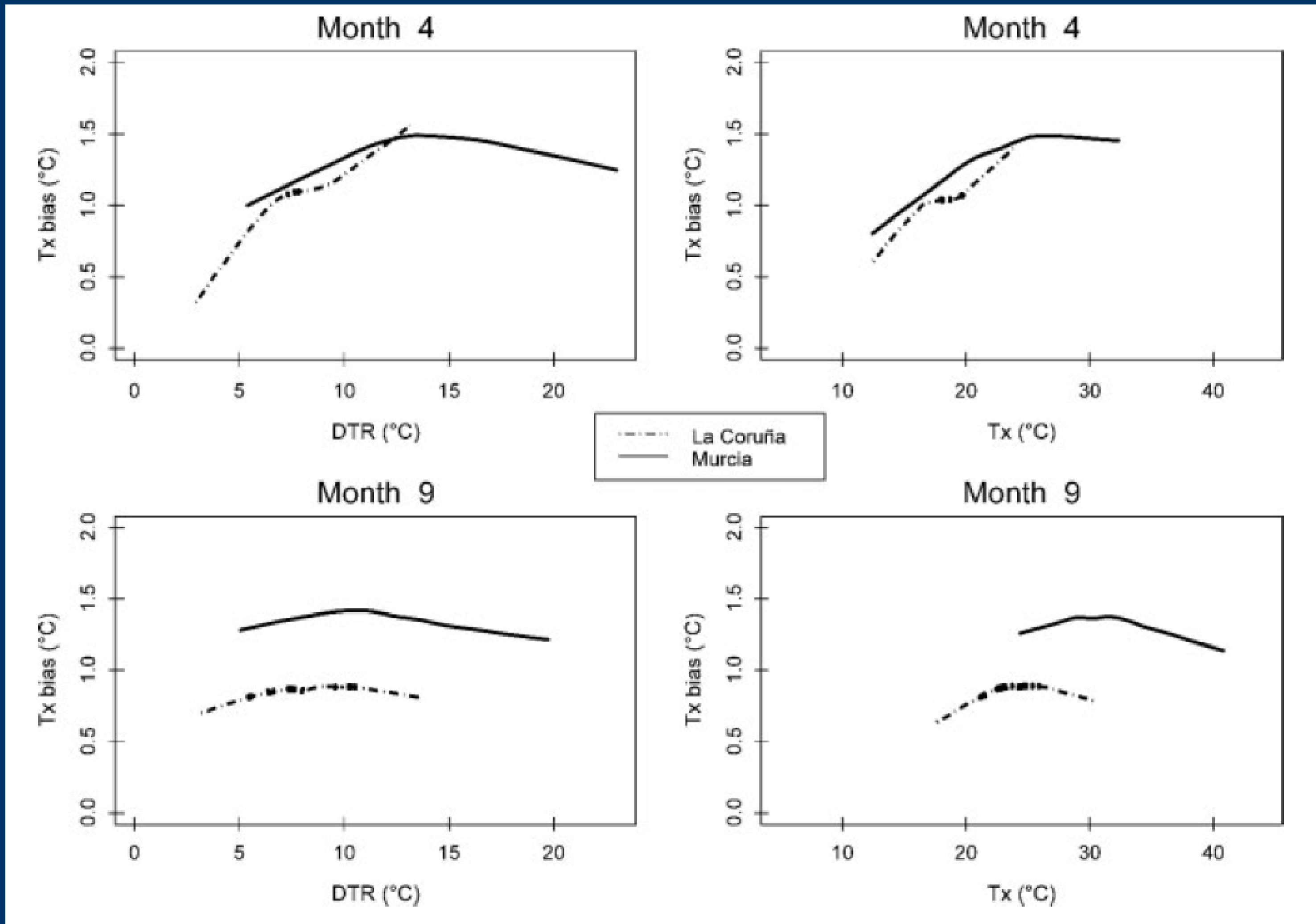


Böhm et al. (2010)

Spain: Montsouri screen, Stevenson observations, Stevenson automatic

Montsouri vs. Stevenson: difference as function of Diurnal Temperature Range and Tmax

Murcia: South East Spain, Mediterranean.
La Corunia: North West Spain, Atlantic.



April

September

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Montsouri vs. Stevenson: difference as function of Diurnal Temperature Range and Tmax

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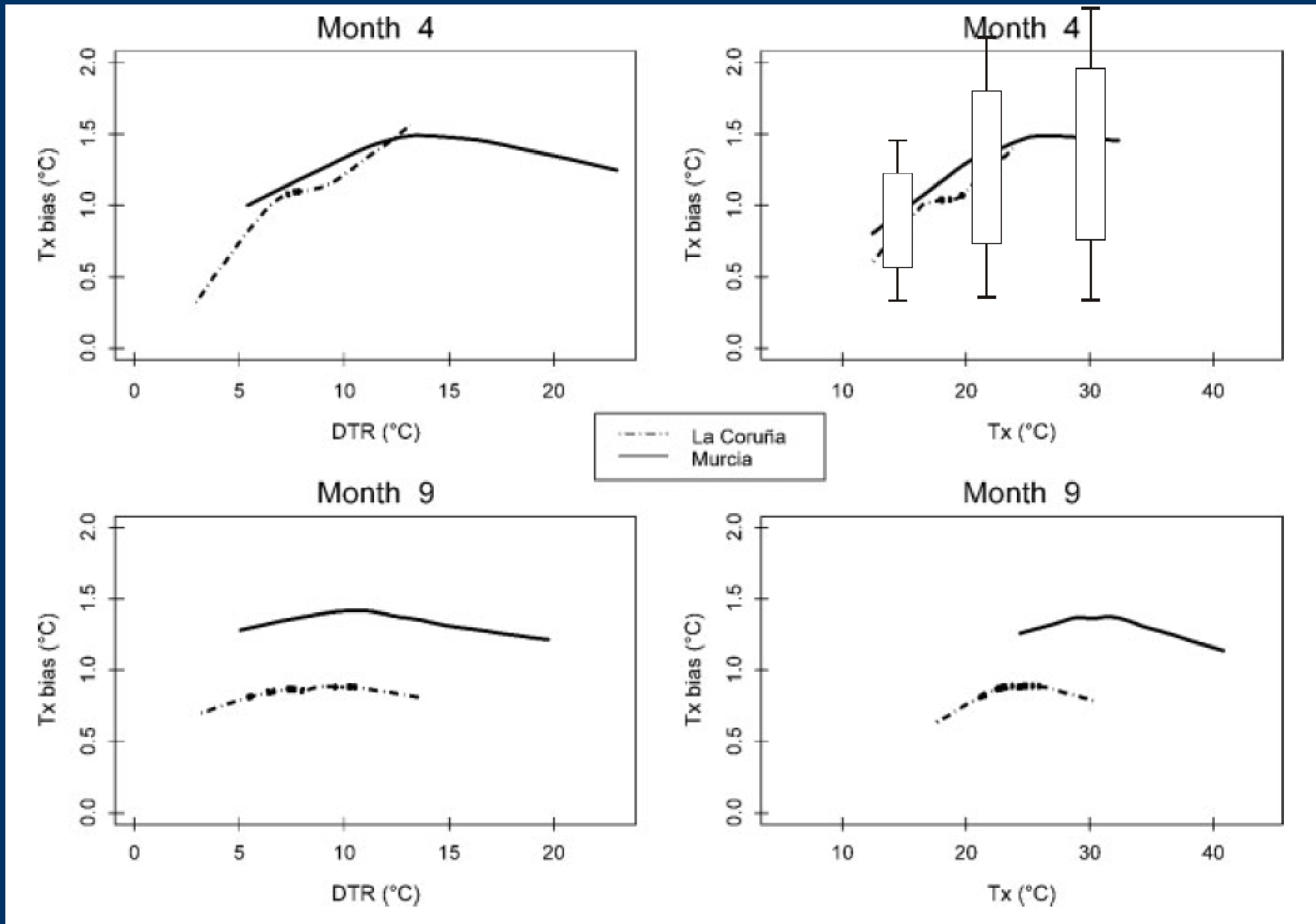

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Physical causes of inhomogeneities
Mean or variability?

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Physical causes of inhomogeneities

- Shelter type, exposure
  - Radiation & wetting protection
  - Natural or forced ventilation
  - Snow cover
  - Plastic screen: insolation on hot days
- Relocation of station
  - City-> airport, suburbs, lower heights
  - Deurbanisation of network
- Instrument
  - Response, integration time
  - Zero drift, shrinking glass initial years
  - Calibration errors
  - Temperature out of range
  - Quicksilver thermometers: T < -39°C
- Change surrounding
  - Urbanization, growing vegetation, irrigation

- Definitions
  - Computation daily means
- Measurement procedures
  - Reading times
- Maintenance procedures
  - AWS: Icing, damage detection
  - Painting & cleaning schedule
- Digitisation & database
  - Minus sign forgotten
  - Station names mixed up
  - Pre-homogenised data

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Mean shift

Tail shift (indirectly also mean)

Mean and tail shift

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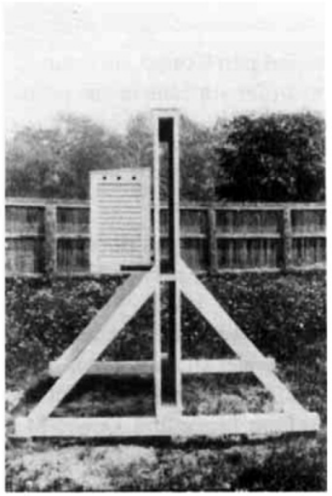
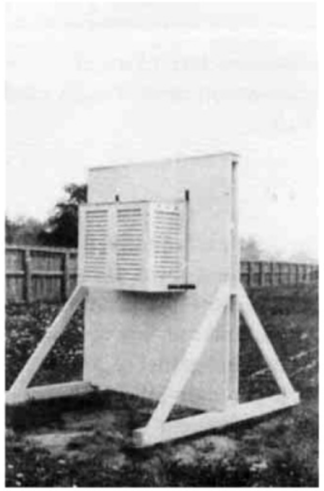
Exposure

- Insolation
  - Sun, hot ground, scattered radiation
- Humidity and clouds
  - Infrared radiative cooling
- Wind
  - Heat exchange
- Design
  - Size sensor
  - Shielding
  - Mechanical ventilation





Daily homogenization methods

Daily detection methods

- Rienzner & Gandolfi (2013)
  - Subtract seasonal cycle as first step
    - Breaks in seasonal cycle (ACMANT)
    - Could be corrected with platform break pairs
- GAHMDI: Toreti et al. (2012)
  - Designed for monthly
  - Takes autocorrelations into account, could be extended
- Future research
  - Advantages of daily over monthly detection
  - Detection on variability measures, not just mean
  - Autocorrelations as AR process (LRD?)
  - Similarity of reference stations

- Rienzner, M. and C. Gandolfi, 2013: A procedure for the detection of undocumented multiple abrupt changes in the mean value of daily temperature time series of a regional network. *Int. J. Climatol.*, **33**, pp. 1107–1120. doi: 10.1002/joc.3496.
- Toreti, Andrea, Franz G. Kuglitsch, Elena Xoplaki, Jürg Luterbacher, 2012: A Novel Approach for the Detection of Inhomogeneities Affecting Climate Time Series. *J. Appl. Meteor. Climatol.*, **51**, 317–326.

Daily correction methods

- No correction
  - Determine trends on homogeneous subperiods
- Correct the mean
  - Monthly adjustments smoothed to daily, Vincent et al. (2002)
- Correct the distribution
  - HOM, SPLIDHOM, HOMAD, QM, PM, WHM (wavelet)
  - One break after another (error accumulation)
  - One station as reference (except PM; Trewin, 2012)
- Weather-dependent correction
  - Using co-variates
  - Wild → Stevenson screen: Auchmann & Brönnimann (2012)

- Auchmann, R., and S. Brönnimann. A physics-based correction model for homogenizing sub-daily temperature series. *J. Geophys. Res.*, **117**, D17119, doi:10.1029/2012JD018067, 2012.
- Trewin, B. A daily homogenized temperature data set for Australia. *Int. J. Climatol.*, **33**, pp. 1510–1529. doi: 10.1002/joc.3530, 2013.
- Vincent, L.A., X. Zhang, B.R. Bonsal, and W.D. Hogg. Homogenization of daily temperatures over Canada. *J. Climate*, **15**, no. 11, pp. 1322-1334, 2002.

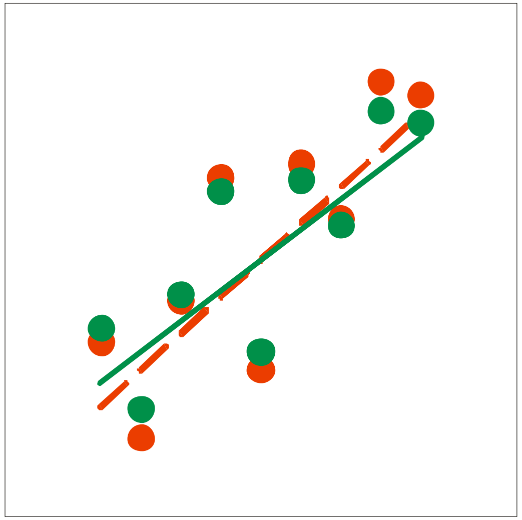
Quality of correction

- Percentile Matching (PM; Trewin, 2012)
  - Improvements if cross correlations (ρ) > 0.6
- Higher order moments method (HOM; Della-Marta and Wanner, 2006), rule of the thumb:
  - ρ > 0.9: Mean, standard deviation, skewness useful
  - ρ < 0.9: Better use adjustment of means
  - Mainly depends on amount of data, likely similar for other methods
- No information: other moments & indices

- Della-Marta PM, Wanner H. 2006. A method of homogenizing the extremes and mean of daily temperature measurements, *J. Clim.*, **19**, pp. 4179-4197, doi: 10.1175/JCLI3855.1.
- Trewin, B. A daily homogenized temperature data set for Australia. *Int. J. Climatol.*, **33**, pp. 1510–1529. doi: 10.1002/joc.3530, 2013.

Correction methodology - inflation

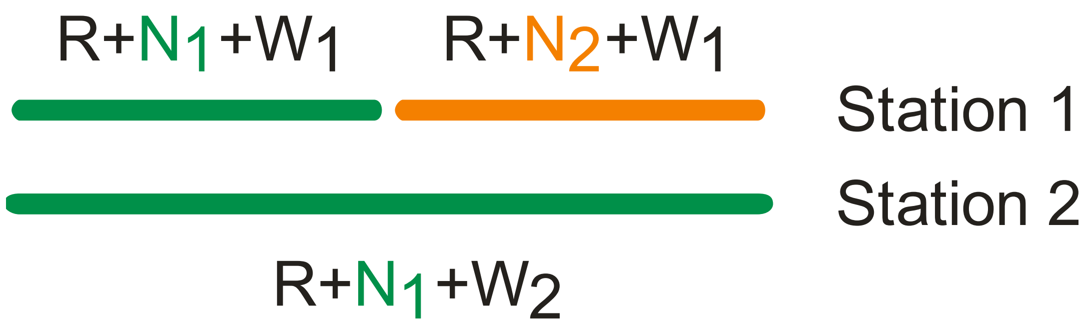
- Corrections have deterministic (explained variance) and stochastic (unexplained) component
- Downscaling: problems deterministic corrections
  - Variance inflation (Von Storch, 1999)
  - Quantile Matching (Maraun, 2013)
- Correct unexplained variance with noise
- Unintended change trend in mean
  - Homogenization: Trend in difference TS is small



- Maraun, D. Bias correction, quantile mapping, and downscaling: revisiting the inflation issue. *J. Clim.*, 26, pp. 2137-2143, doi: 10.1175/JCLI-D-12-00821.1, 2013.
- Von Storch, H. On the Use of ''Inflation'' in Statistical Downscaling. *J. Clim.*, 12, pp. 3505-3506, 1999.

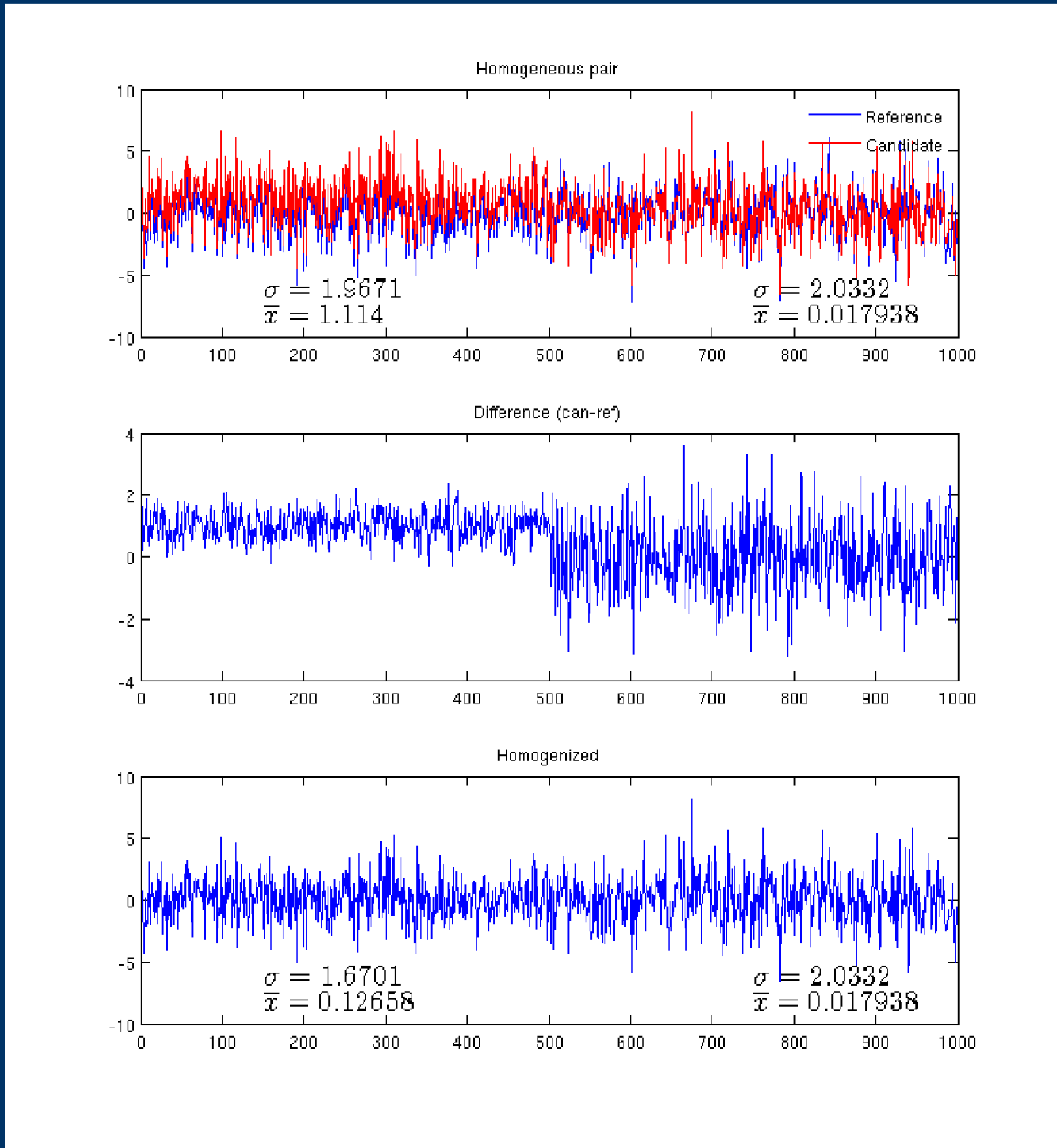
Correction – change in noise source

- Change in cross-correlation
  - Relocation, change in noise source
- Simple example
  - $|N_1| = |N_2|$
  - No inhomogeneity in distribution
  - Jump in difference time series



R Regional climate signal
N Instrument specific error
W Station specific weather

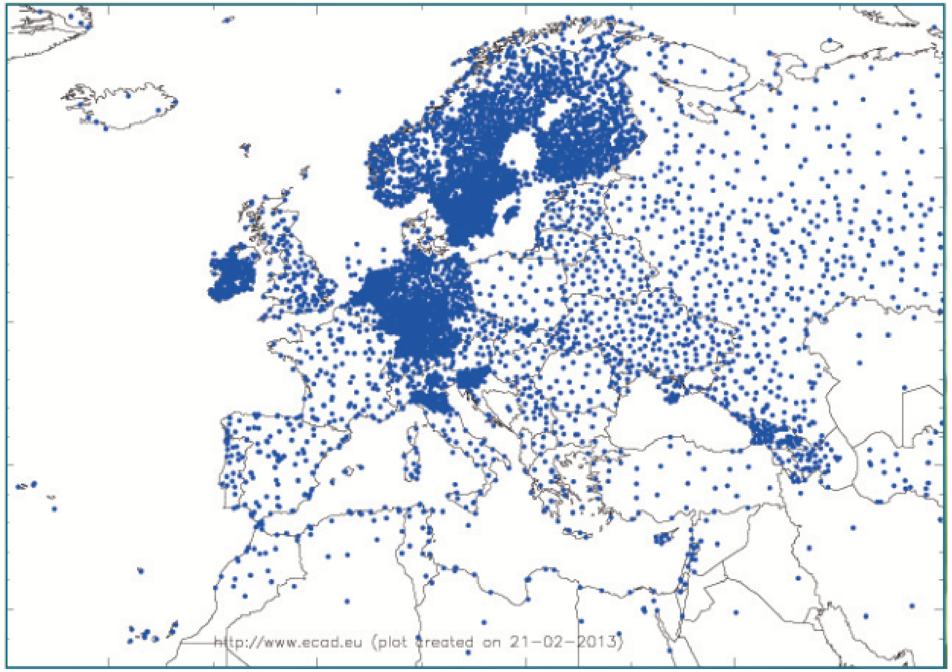
Correction – change in noise source



Daily dataset and their quality

Not homogenized datasets

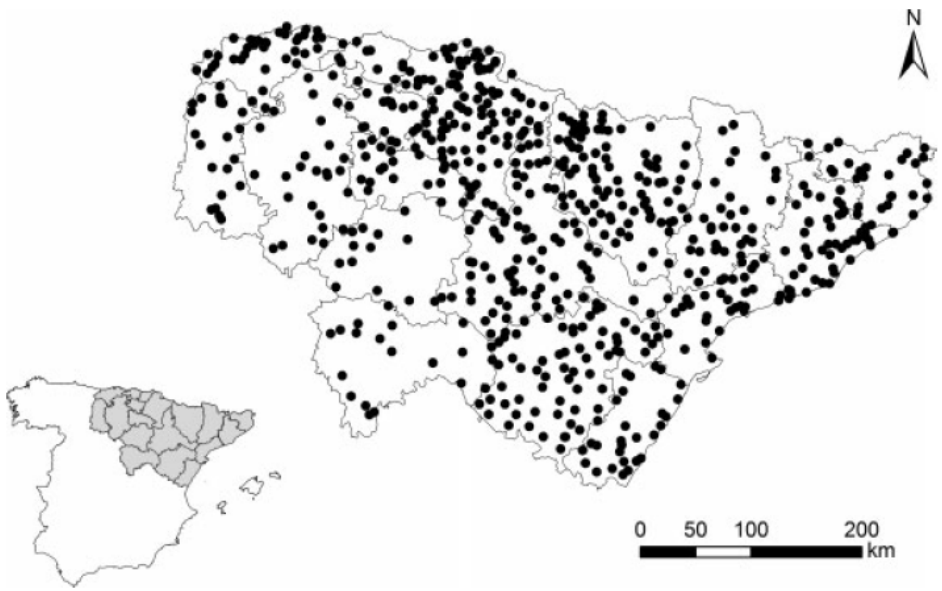
- European Climate Assessment & Dataset
  - Homogeneity assessed (useful, doubtful, suspect)
- Global Historical Climatology Network – Daily



- Introduction: Klein Tank, et al. Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. *Int. J. Climatol.*, **22**: pp. 1441–1453. doi: 10.1002/joc.773, 2002.
- Update: Kolk, E.J. and A.M.G. Klein Tank. Updated and extended European dataset of daily climate observations. *Int. J. Climatol.*, **29**, pp. 1182-1191, doi: 10.1002/joc.1779, 2009.
- Homogeneity assessment: Wijngaard, J.B., A.M.G. Klein Tank, and G.P. Können. Homogeneity of 20th century European daily temperature and precipitation series. *Int. J. Climatol.*, **23**, pp. 679-692, 2003.
- Dataset: Menne, M.J., I. Durre, R.S. Vose, B.E. Gleason, and T.G. Houston. An Overview of the Global Historical Climatology Network-Daily Database. *J. Atmos. Oc. Technol.*, **29**, pp. 997-910, 2012.
- Quality control: Durre, I., M.J. Menne, B.E. Gleason, T.G. Houston, R.S. Vose. Comprehensive Automated Quality Assurance of Daily Surface Observations. *J. Appl. Meteor. Climatol.*, **49**, 1615–1633, 2010.

North-Eastern Spain – mean temperature homogenised

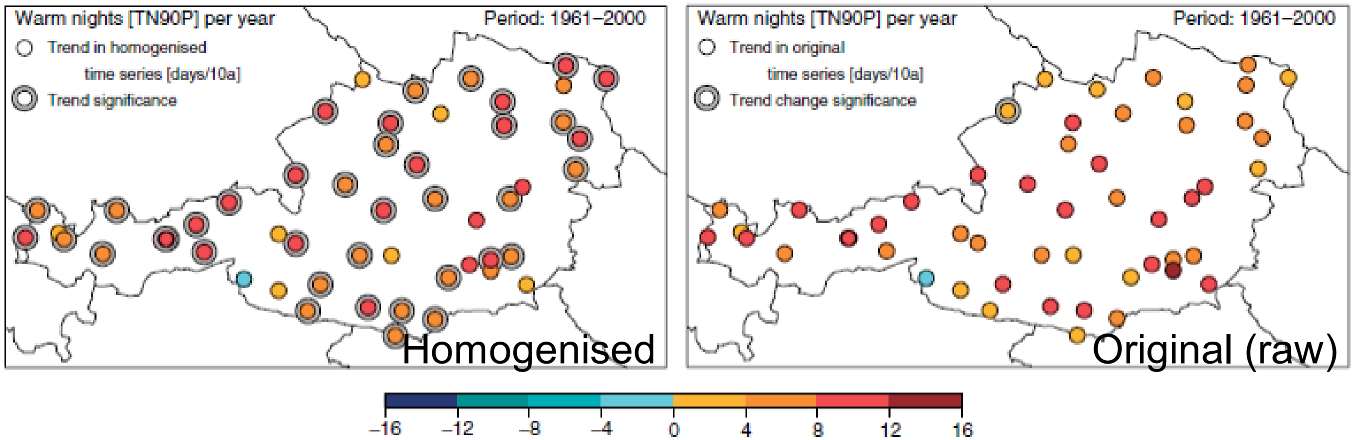
- Detection
  - SNHT, TPR, Vincent (1998)
- Correction
  - Monthly mean corrections are smoothed to daily corrections
    - Vincent (1998)
    - Much applied method



- Vincent LA, 1998: A Technique for the Identification of Inhomogeneities in Canadian temperature Series, *J. Clim.*, 11, pp. 1094-1104.
- El Kenawy, A., López-Moreno, J. I., Stepanek, P. and Vicente-Serrano, S. M. An assessment of the role of homogenization protocol in the performance of daily temperature series and trends: application to northeastern Spain. *Int. J. Climatol.*, **33,** pp. 87–108. doi: 10.1002/joc.3410, 2013.

Austria – Distribution homogenised

- Austria: 1948-2009, 57 Tmin & 54 Tmax stations
- Detection: PRODIGE, metadata
  - Annual, winter and summer means
- Correction: SPLIDHOM (trust the skewness)
  - Significance testing by bootstrapping



- Description dataset: Nemec, J., Ch. Gruber, B. Chimani, I. Auer. Trends in extreme temperature indices in Austria based on a new homogenised dataset. *Int. J. Climatol.*, doi: 10.1002/joc.3532, 2012.
- Download dataset: http://www.zamg.ac.at
- QC: Schöner W, Auer I, Böhm R, Thaler S. 2003. Qualitätskontrolle und statistische Eigenschaften ausgewählter Klimaparameter aus Tageswertbasis im Hinblick auf Extremwertanalysen. StartClim Endbericht. Available from http://www.boku.ac.at/austroclim/startclim/ bericht2003/StCl01.pdf

Conclusions

- A lot of current research
- More needed to study changes in extremes & variability
- Inhomogeneities change the distribution
  - Physical reasoning and parallel measurements
    - Strong inhomogeneities in tail
  - Biases in the trends of extremes/variability are expected
- First correction methods for distribution
  - Need dense network
  - Are labour intensive
- Many widely-used dataset are not homogenised

Outlook

- Urgently need to study non-climatic changes in distribution for severe weather studies
- Uncertainty estimates lacking
- Lack in understanding
  - Physical and statistical properties of daily breaks
  - How much tails are affected
  - Not just the distribution at daily scale
  - Changes in spatial and temporal correlations

Outlook

- More work on detection needed
  - Added value over monthly
  - Breaks in variability
- Correction
  - Multiple breakpoint methods missing
  - Weather dependent corrections
  - Stochastic corrections
  - Correct indices time series?
  - Analysis on HSP requires new statistical tools?
- Close collaboration between climatologists and homogenization specialists

Research on parallel data

- Large database with parallel measurements needed to study daily inhomogeneities
- Study statistical and physical properties of daily inhomogeneities
  - Dependence on local weather and regional climate
  - Most studies are currently about mid-latitudes
- Develop daily correction methods
  - Weather dependent
  - Stochastic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Research on parallel data

- Large database with parallel measurements needed to study daily inhomogeneities
- Generate benchmark data with realistic inhomogeneities
  - For example, second cycle of ISTI
- Validate detected inhomogeneities

Parallel Data Initiative

- Produce an open database
- Initially data is restricted to contributors
  - Incentive to contribute
  - Until first joint paper(s) by contributors are written
- First action: Inventory of parallel datasets
  - https://ourproject.org/moin/projects/parallel
  - Dozens of datasets available
- More information
  - http://tinyurl.com/paralleldata
  - Victor.Venema@uni-bonn.de

E-mail list on homogenisation of climate data

- **Goal**
  - Strengthen communication and co-operation

- **Suggested uses of the list are**
  - Conferences, workshops, etc.
  - Important papers
  - Discussions
  - Job opportunities
  - New projects started
  - Requests for data, information, and cooperation partners
  - ...

- **Subscribing**
  - You can join the mailing list by sending an e-mail to Victor.Venema@uni-bonn.de
  - For more information: http://tinyurl.com/HomList

Questions?

These slides can be found under

http://tinyurl.com/DailyDataBudapest

Parallel data initiative

http://tinyurl.com/paralleldata

Homogenization distribution list

http://tinyurl.com/HomList

Modelled changes in variability

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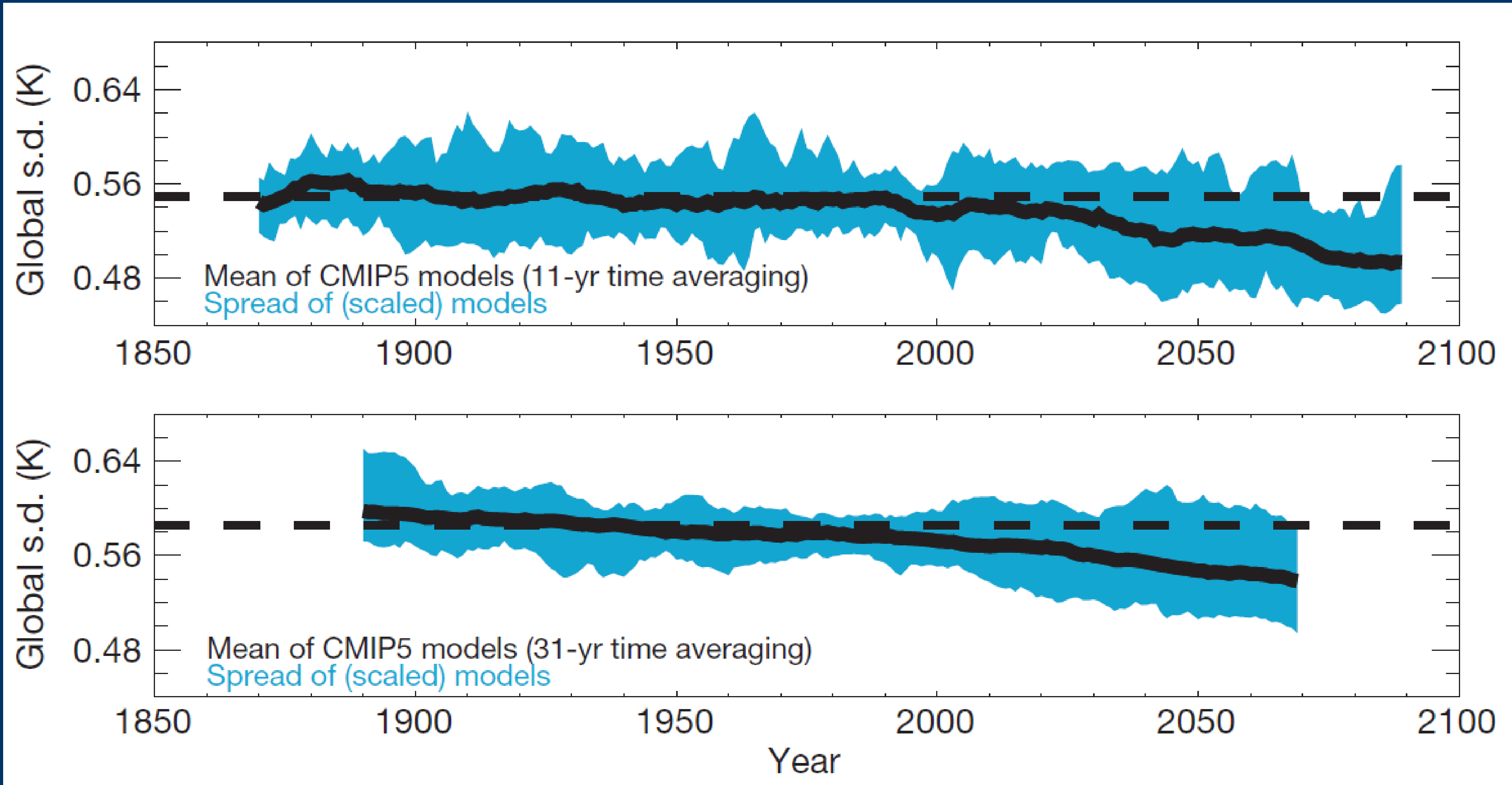
Global annual mean temperature variability



The global standard deviation of the annual temperature derived for two window sizes to compute the anomalies: 11 years (top) and 31 years (bottom). The black line shows the average, the blue area the spread of the ensemble of 17 climate models with historical-plus-RCP8.5-scenario simulations in the CMIP5 database.

PRUDENCE project for Europe

- **Increases** for the **summer temperature variability** at various temporal scales (from daily to intra-seasonal)
  - Fischer and Schär, 2009
  - The increases are seen in the average variability over all of Europe
  - Especially strong in the **Transitional Climate Zone** (TCZ), the region between the Mediterranean and the Nordic countries
- Beniston (2004) finds an increase in variability
  - **Mean** summer maximum temperature increases by only **5°C** in the Southwest of France at the end of this century
  - **Extremes** increase by **6 to 8°C**
- Striking differences
  - **Temporal resolution**
  - Difference in the temporal extend (annual vs. summer)
  - Region considered (global vs. Europe)
  - Methodological differences small

Importance of annual cycle

- Ballester et al. (2010)
  - Find that changes in the *warm percentiles* are mainly determined by the *mean* temperature
  - Do find the variance and skewness to be important to explain changes in the *cold tail* of the temperature distribution
- Difference previously mentioned studies
  - Annual cycle included
  - Variance is mainly determined by annual cycle
  - In the other studies variance was mainly the day to day variance

Model variability validation

- Little studies found
- Fischer and Schär (2009)
  - Models overestimate the total daily summer variability and the interannual variability by up to a **factor 2**
- Lovejoy et al. (unpublished 2012)
  - GCM runs against observations, reanalysis data and multi-proxy reconstructions.
  - Scaling: variability changes (temporal scale)
  - At small scales the relationships are relatively good, at larger scales they can even have the wrong sign
  - Could be both data or models

Model variability validation

- Schindler et al. (2012)
  - Seasonal cycle of extreme precipitation in the UK in the ENSEMBLE dataset
  - Mixed results depending on region
- Frei et al. (2006)
  - Alpine region
  - RCM model biases for extremes are comparable to or even smaller than those for wet day intensity and mean precipitation
  - The model differences are well explained by differences in the precipitation frequency and intensity process (Frei et al., 2006)

Variability

- Upper and lower scale
  - Length of periods and the size of regions considered (extent)
  - Spatial and temporal averaging scale (grain, resolution)
- Accurate separation of scales
  - Strong annual and diurnal cycles
- Moderate extremes to extreme extremes
  - Variance, difference 25 and 75 percentile, difference 1 and 99 percentile
- Natural variability, measurement and modelling uncertainties, sampling and errors