# Climate Variability in the Greater Alpine Region, ZAMG research based on instrumental series

*Ingeborg Auer*

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# instrumental series - homogeneity



- station specific changes: relocation, instrument changes etc. : tests for break detection – adjustments for correction
- general changes: introduction of weather shelters, ventilation, wind shields, installation height of instruments (precipitation), (could be within only few years)

urbanization (ongoing process)

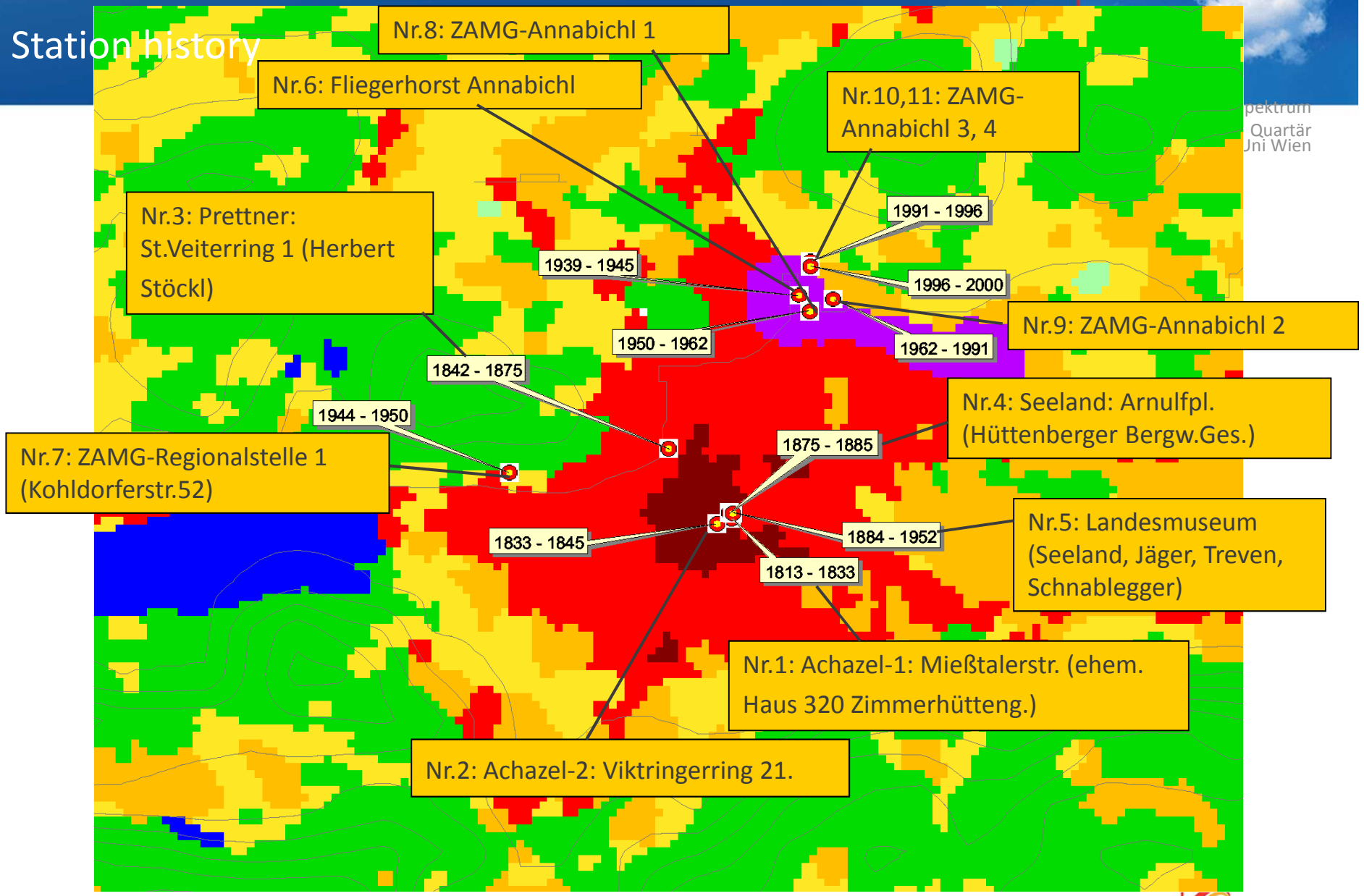
change of observing hours from 9 pm to 7 pm (all stations have this break at the same time)

calculation of mean values

changes in daylight saving times regulations

# KLAGENFURT

## Station history




pektrum Quartär Uni Wien

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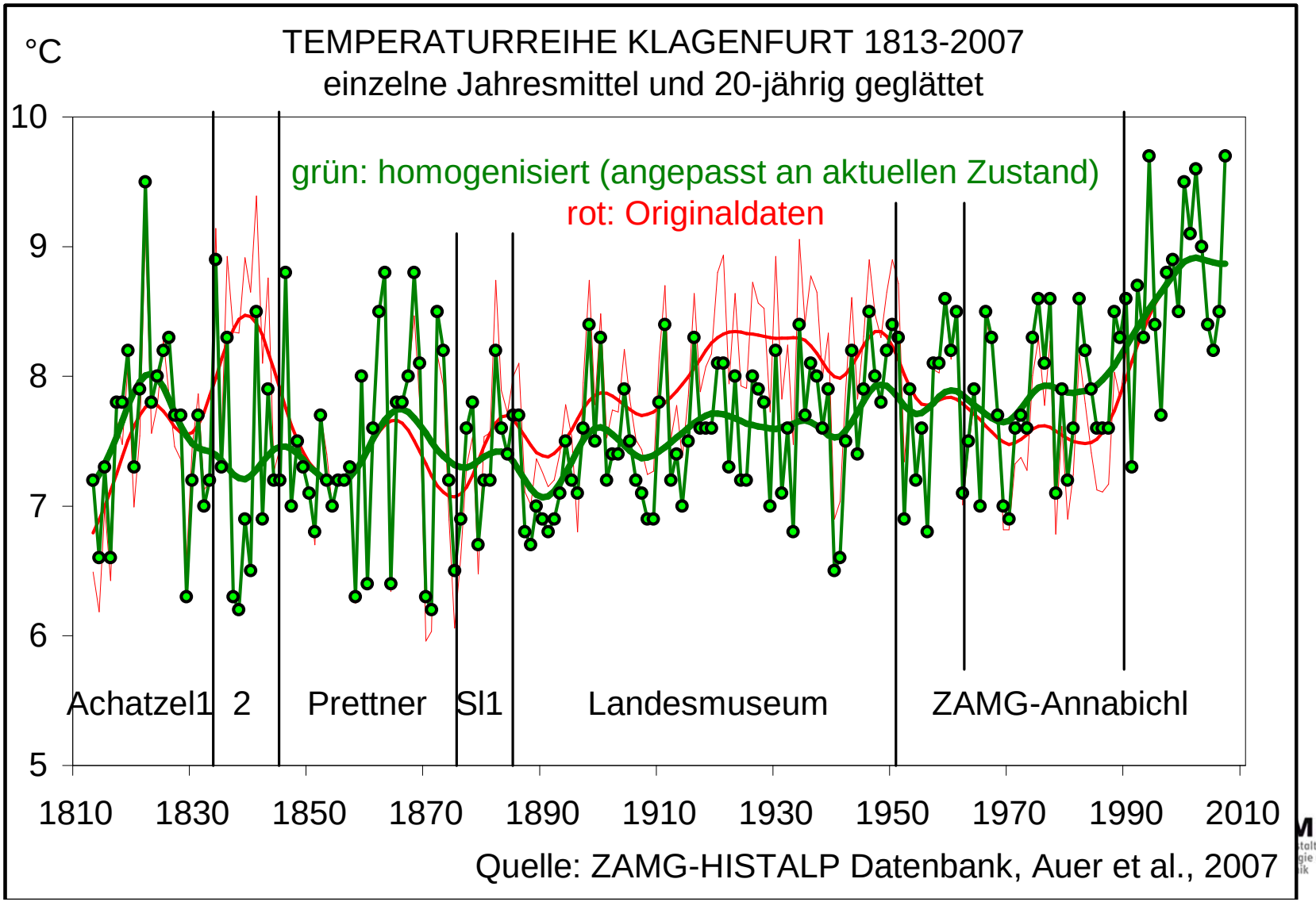
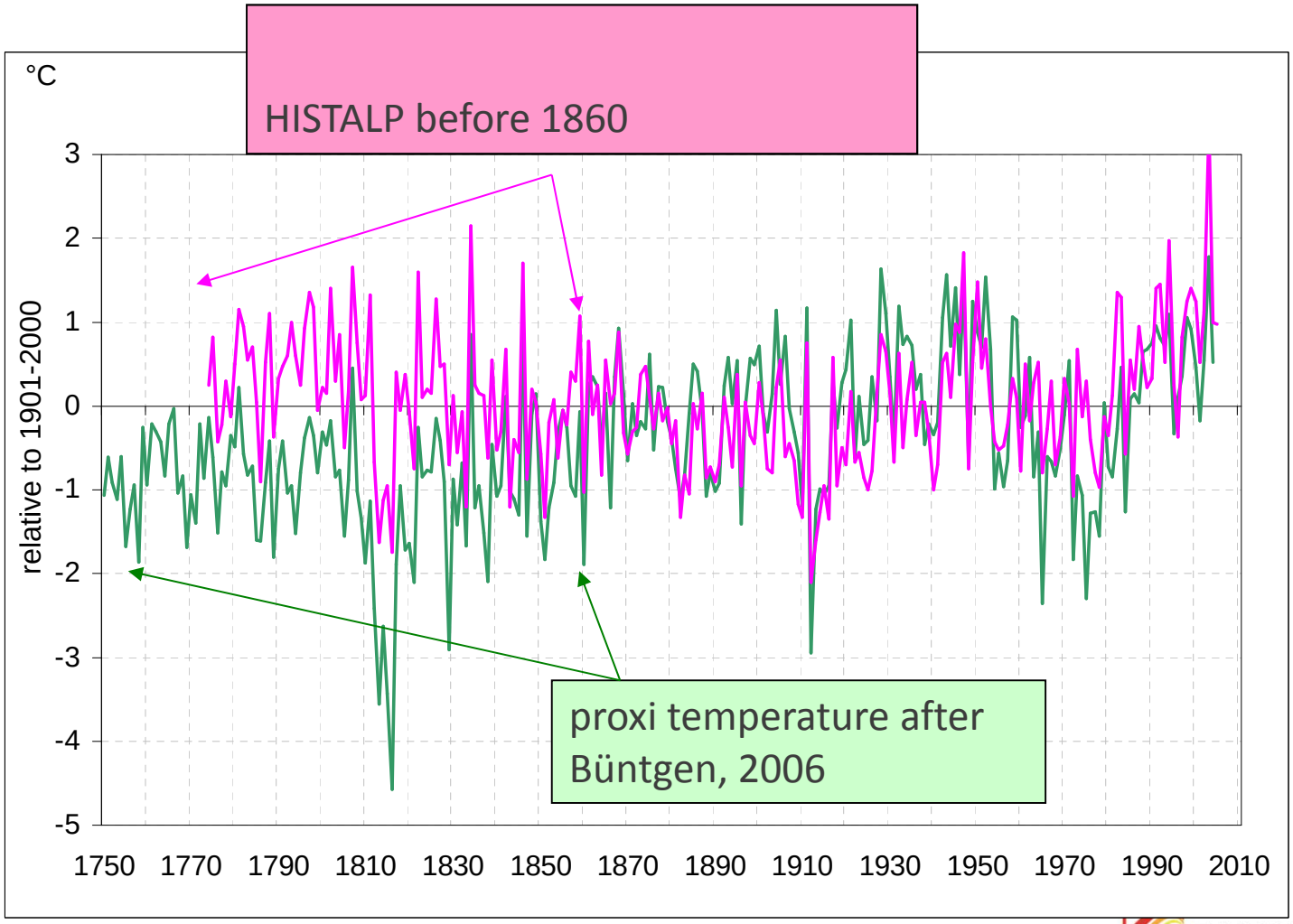
# temperature series KLAGENFURT





# Differences of instrumental measurements and temperature series derived from proxy data before




nach Böhm, 2008

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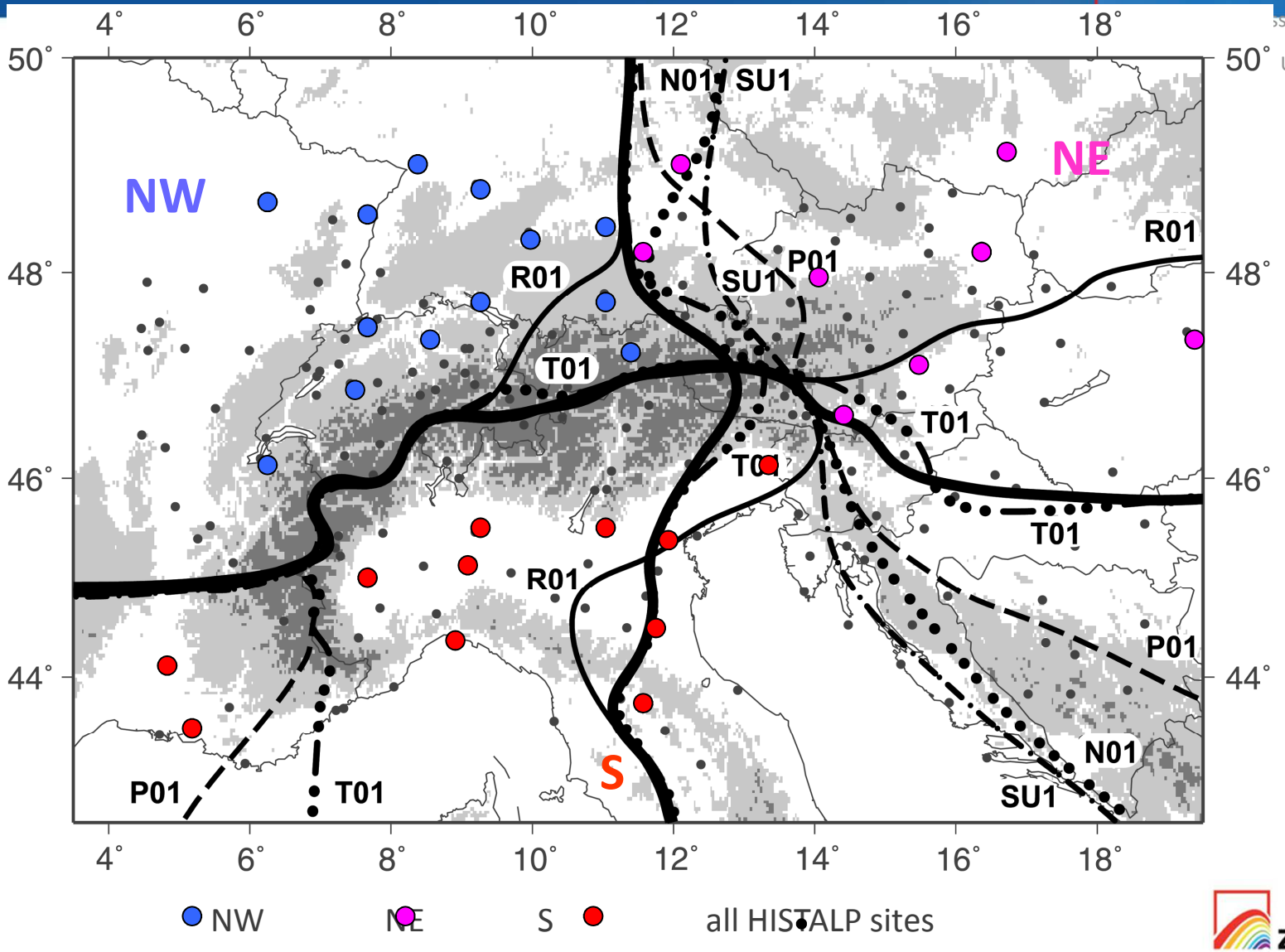
# HISTALP and early HISTALP- stations

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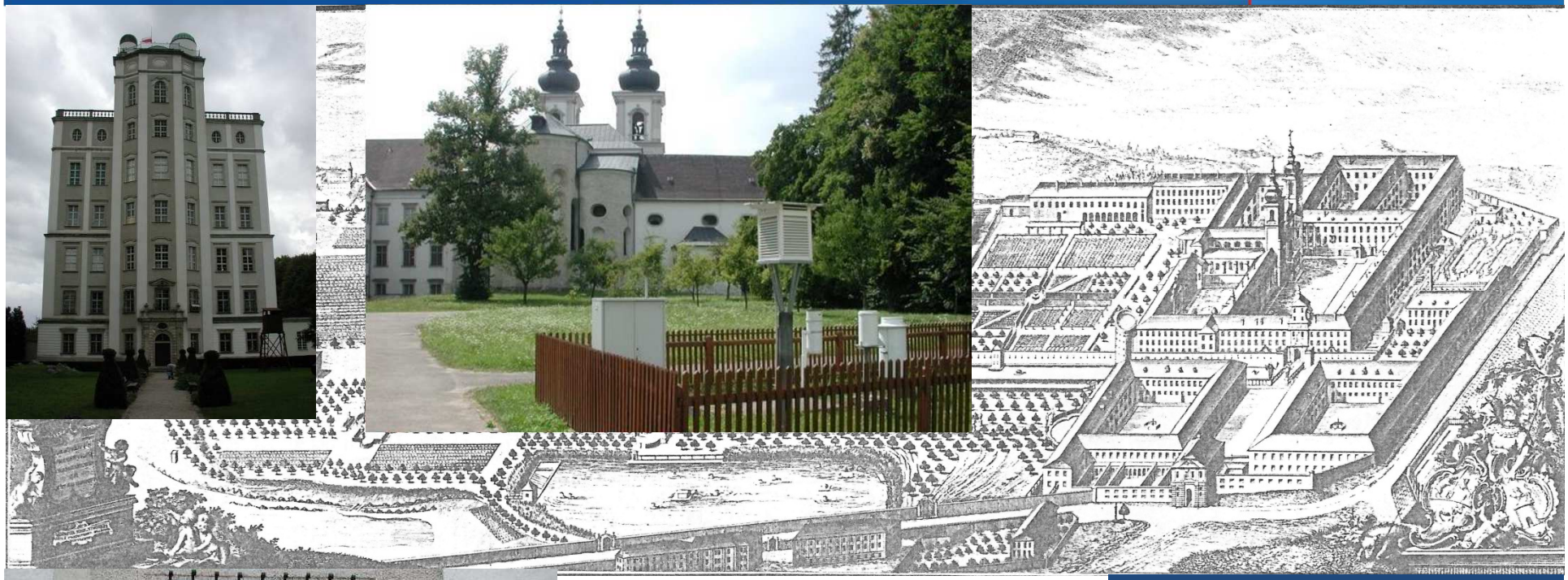
# Kremsmüster, historic measuring site since 1763



Kremsmünster monastery, F. Landerer after F.X.Gürtler, 1778 (from Austaller, 1988).

measurements taken 6 m above ground in window cage oriented to the north, no shelter!

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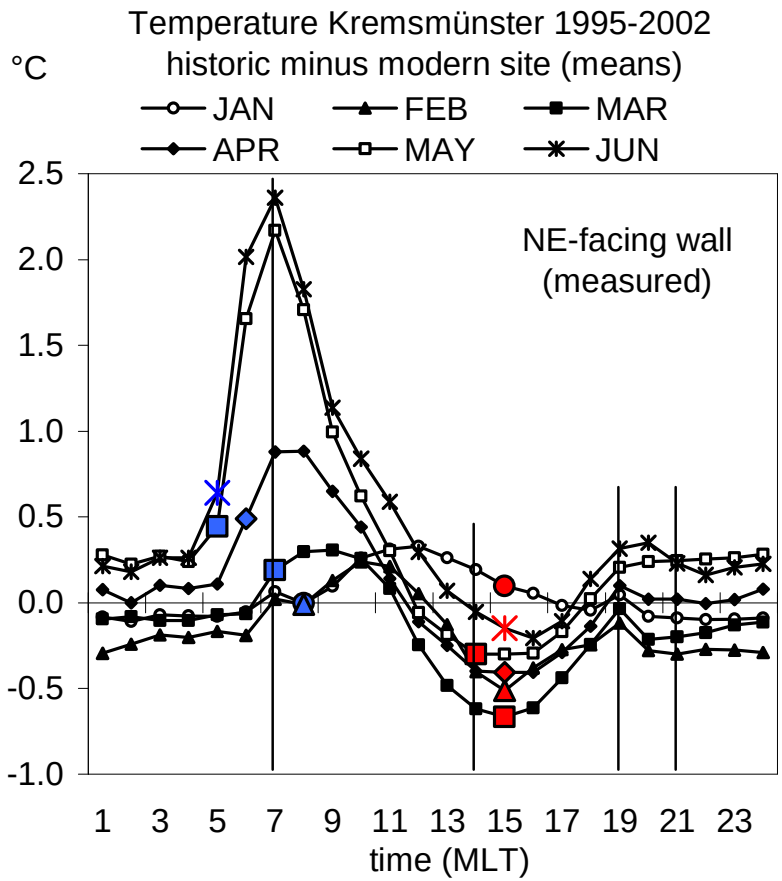
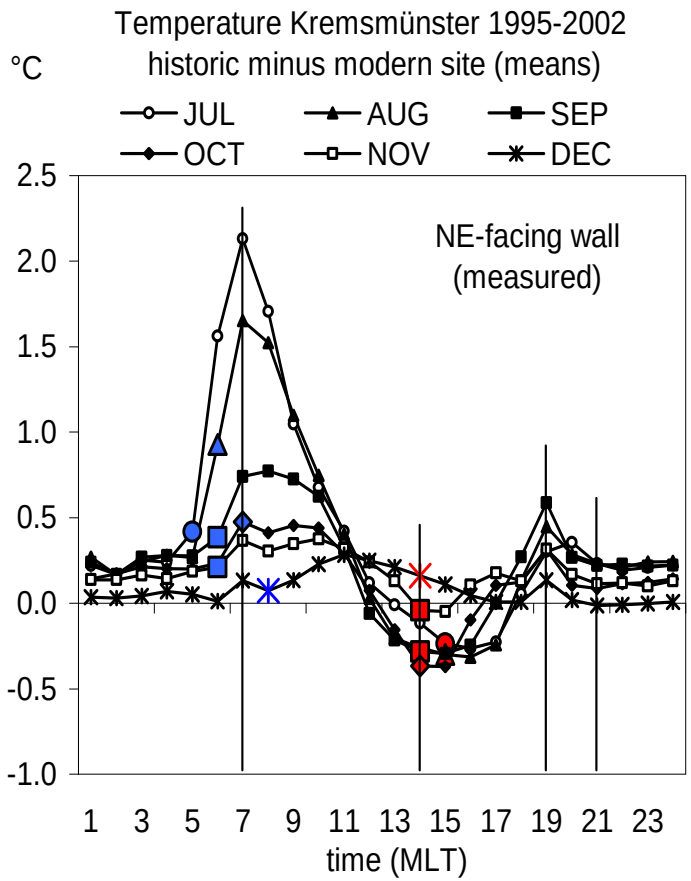
# mean difference of 8 years parallel measurements




1.5 – 2.5 ° from May to August
smaller differences in April and September

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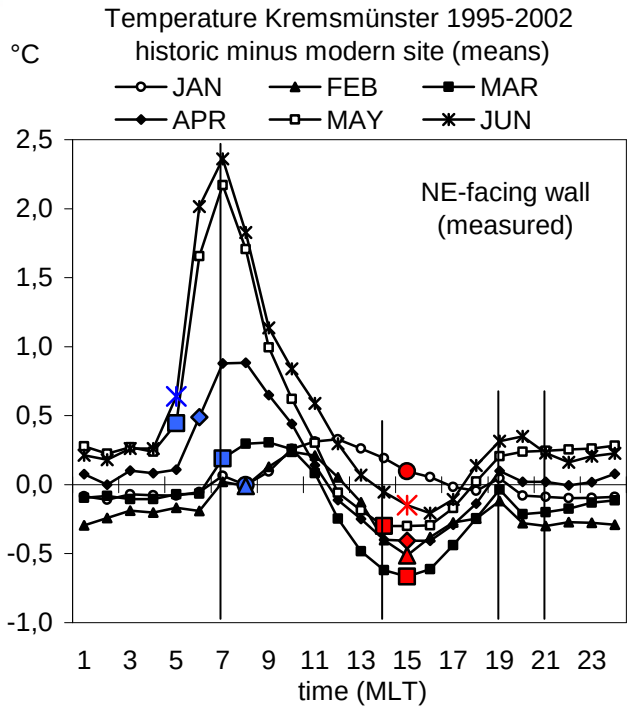
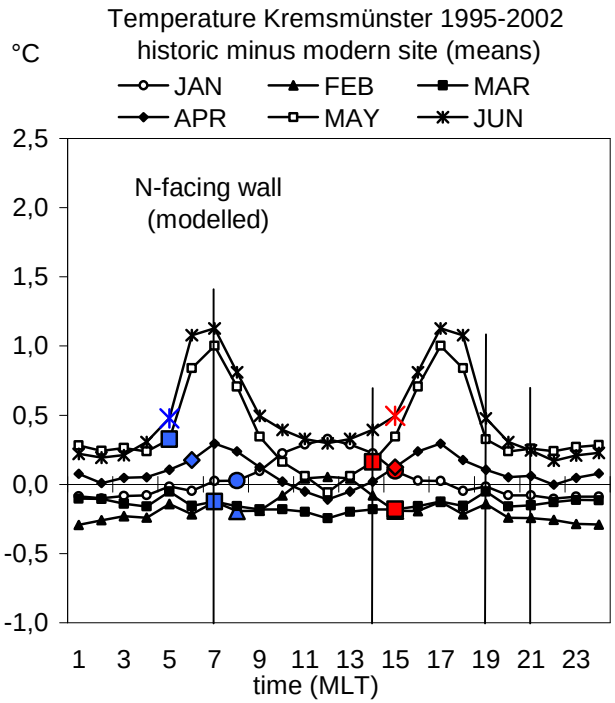
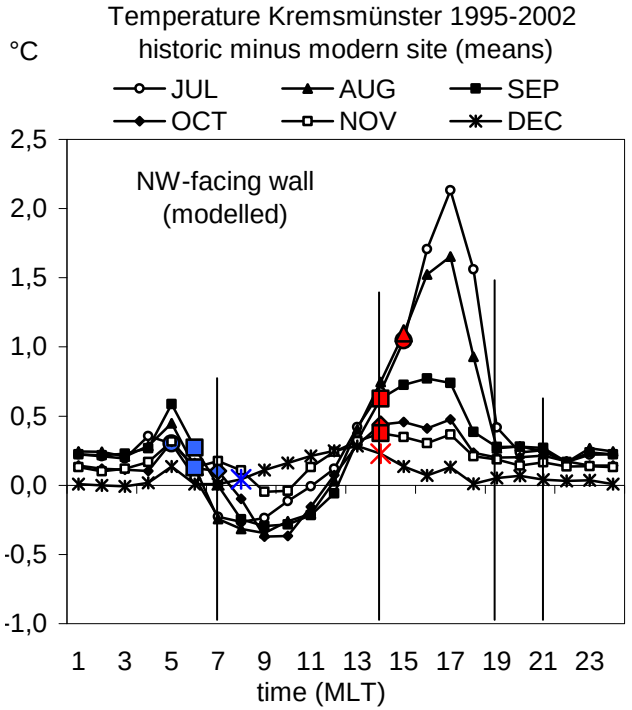
# Model for NW and N windows

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# metadata for the HISTALP region

from – to

observing hours

direction

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 59 | INNSBRUCK | INN | AT | 576 | 2 | 1777-1784 | Jesuiten Colleg Sillgasse (Franz v. Zallinger) | second floor | -9° | 4, 13.30 |
| | | INN | AT | 576 | 2 | 1784-1828 | Kapuziner Kloster, Universitätsstrasse (Franz v. Zallinger) | 8 | 15° | near min, near max |
| | | INN | AT | 590 | 2 | 1828/09-1855/12 | Prämostratenser Kloster Wilten (Prantner) | 8 | -19° | 6, 13.30 |
| | | INN | AT | 590 | 2 | 1856/01-1859/12 | | | | (7+14+2*21)/4 |
| | | INN | AT | 590 | 2 | 1860/01-1870/12 | | | | 6, 14 |
| | | INN | AT | 576 | 2 | 1865/01-1870/12 | Old University-Botanical Institute | 8 | 15° | (7+14+2*21)/4 |
| | | INN | AT | 576 | 2 | 1871/01-1875/07 | | | | 6, 14, 22 |
| | Zallinger F, 1833. Innsbrucker meteorologische Beobachtungen von 50 Jahren. Ferdinandeum, Wagnersche Schriften 107 pages | | | | | | | | | |
| | Auer et al., 2001: ALOCLIM - Austrian long-term climate 1767-2000. Österreichische Beiträge zu Meteorologie und Geophysik 25 147pages plus data and metadata CD | | | | | | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 139 | TORINO | TOR | IT | *) | 4 | 1760-1786 | Ignazio Somis, *)mostly Università, via Po, but also other locations | 10 to 25 | 28° | variable (a) |
| | | TOR | IT | 250 | 4 | 1787-1802/05 | Accademia delle Scienze, biblioteca | 12,5 | 28° | variable (a) |
| | | TOR | IT | 282 | 4 | 1802/06-1802/12/21 | Accademia delle Scienze, specola | 44,2 | 0°? | sunrise, 14, sunset |
| | | TOR | IT | | 4 | 1802/12/22-1851/01/05 | | | | sunrise, 12, sunset |
| | | TOR | IT | | 4 | 1851/01/06-1857/07 | | | | 09, 12, 15 |
| | | TOR | IT | | 4 | 1857/08-1865/06 | | | | (max+min)/2 |
| | | TOR | IT | 232 | 4 | 1865/07-1865/11 | Castello del Valentino | 2,0 | 28° | 08, 16 |
| | | TOR | IT | 276 | 4 | 1865/12-1919/02 | Palazzo Madama | 37,7 | 20° | Tmin, Tmax |
| | di Napoli G, Mercalli L, 2007. Il clima di Torino. Ca.900 pages, in press | | | | | | | | | |

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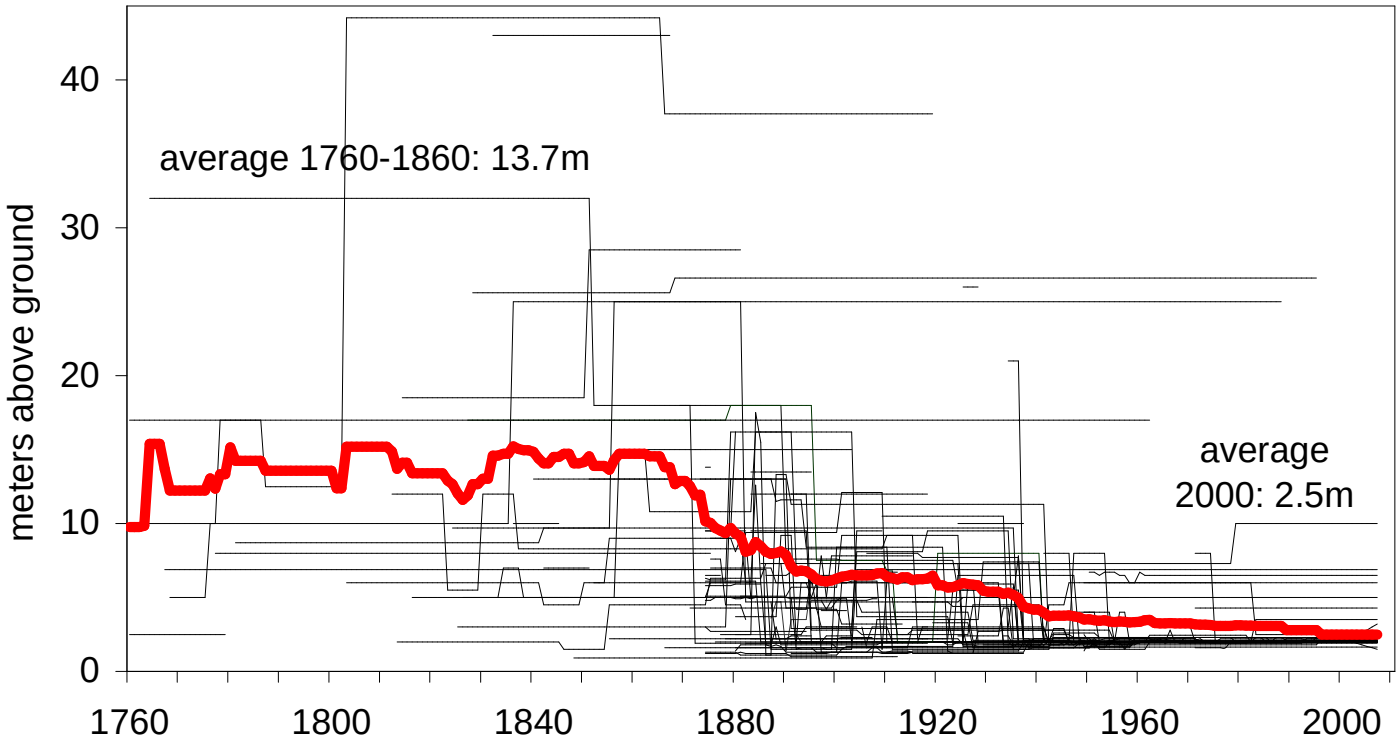
# thermometer heights

**The development from high to low elevated thermometers**
in the climate network of 97 central European sites with sufficient station history documentation




thin: single sites, bold, red: mean

source: ZAMG-HISTALP metadata

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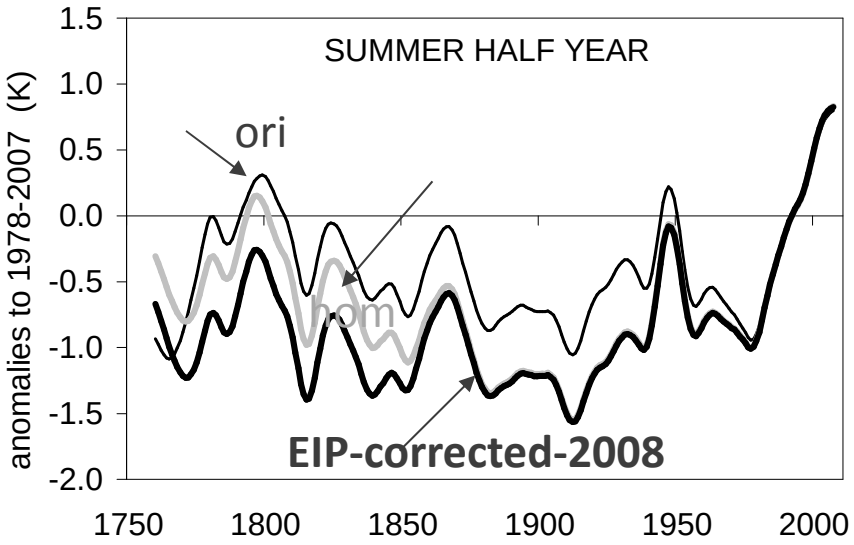
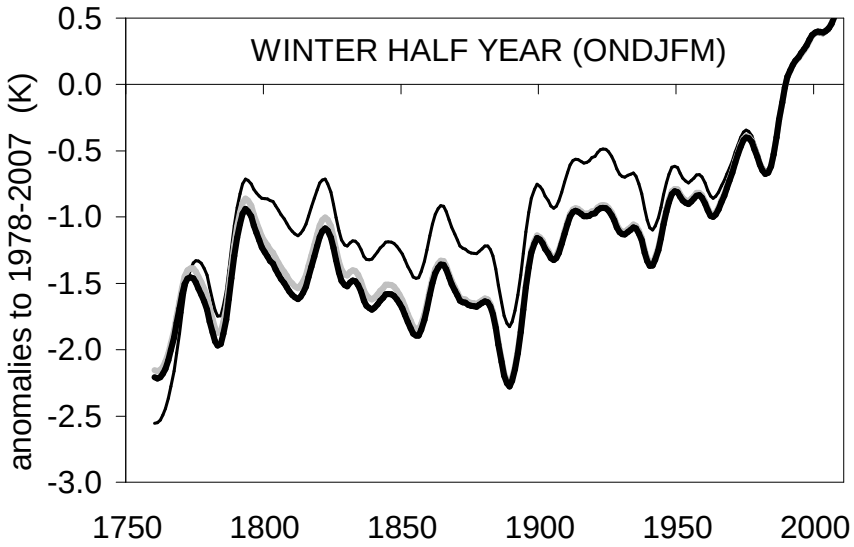
# homogenized early instrumental bias corrected mean temperatures

mean of 32 stations, -0.4°C before 1850




Publikation: Böhm R , Jones PD , Hiebl J , Frank D Brunetti , Maugeri M, The Early Instrumental Warm-bias: A Solution For Long Central European Temperature Series 1760-2007, CLIMATIC CHANGE special issue MILLENNIUM project.

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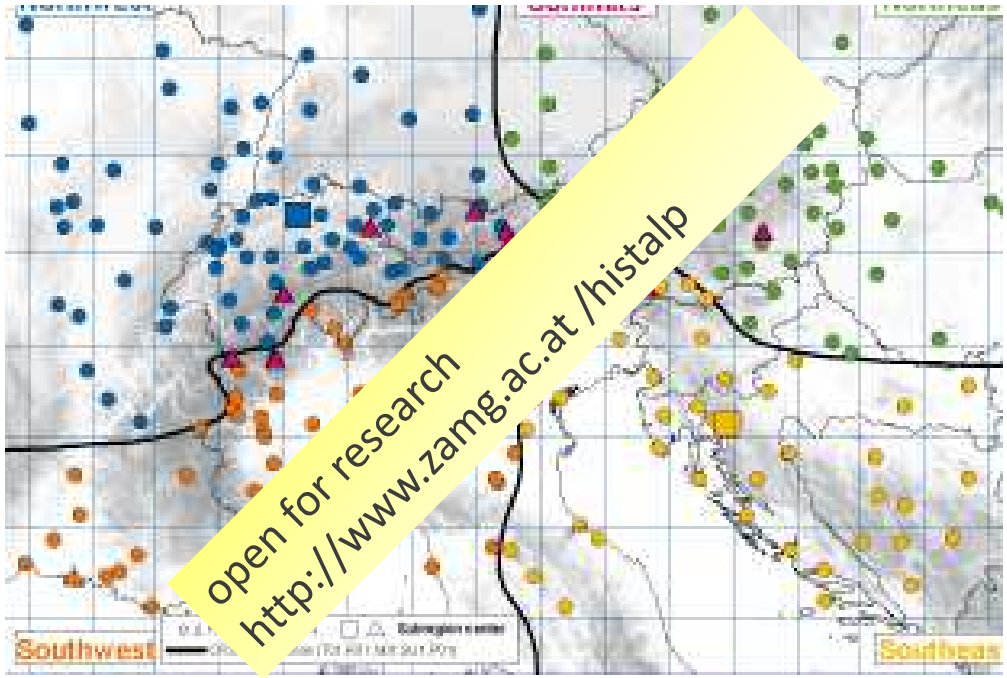
# What is HISTALP?

## HISTORICAL INSTRUMENTAL CLIMATOLOGICAL SURFACE TIME SERIES OF THE GREATER ALPINE REGION

7/29/2015

**sharing of knowledge**: database, consisting of monthly homogenized temperature, air pressure, precipitation and sunshine records for the „Greater Alpine Region“ (GAR, 4-19 deg E, 43-49 deg N, 0-3500m asl).




.

the longest temperature and air pressure series extend back to 1760, precipitation to 1800, cloudiness to the 1840s and sunshine to the 1880s

Collection of climate time series from GE, F, CZ, SK, HU, SI, HR, BiH, IT, A
Stations 0- 3500m,
NMSs and universities

Auer et al., 2007: HISTALP- HISTORICAL INSTRUMENTAL CLIMATOLOGICAL SURFACE TIME SERIES OF THE GREATER ALPINE REGION Journal of Climatology , 27: 17-46 (

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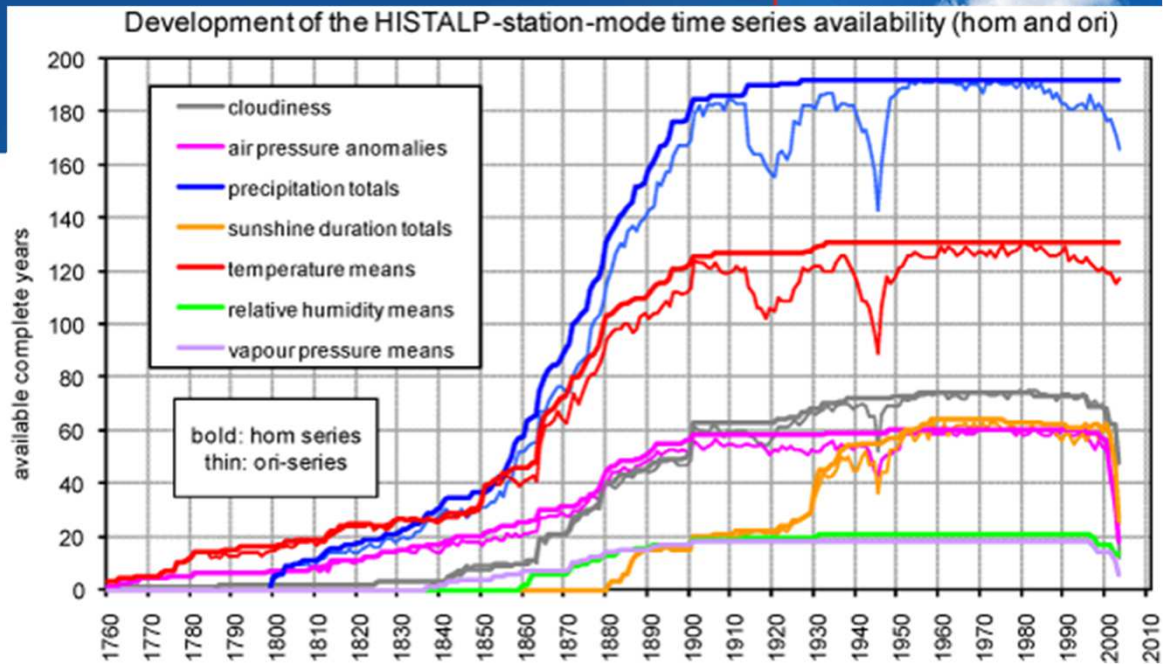
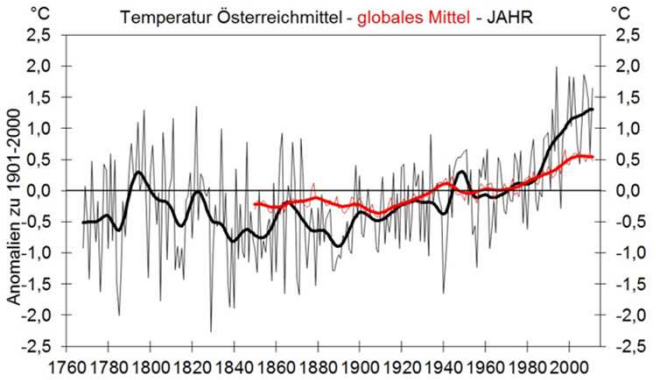
# HISTALP development




| country | Air pressure | precipitation | sunshine | temperature | | sum |
|---|---|---|---|---|---|---|
| | | | | | | |
| Austria | 8 | 45 | 18 | 59 | | 130 |
| Bosnia and Herzegovina | 1 | 9 | 0 | 4 | | 14 |
| Switzerland | 8 | 31 | 15 | 19 | | 73 |
| Czech Republic | 1 | 1 | 0 | 1 | | 3 |
| Germany | 7 | 12 | 9 | 9 | | 37 |
| France | 9 | 27 | 8 | 10 | | 54 |
| Croatia | 4 | 15 | 4 | 7 | | 30 |
| Hungary | 1 | 7 | 2 | 5 | | 15 |
| Italy | 13 | 40 | 1 | 38 | | 79 |
| Slovenia | 1 | 4 | 2 | 3 | | 10 |
| Slovakia | 2 | 2 | 2 | 2 | | 8 |
| | | | | | | |
| | **42** | **193** | **61** | **157** | | **453** |

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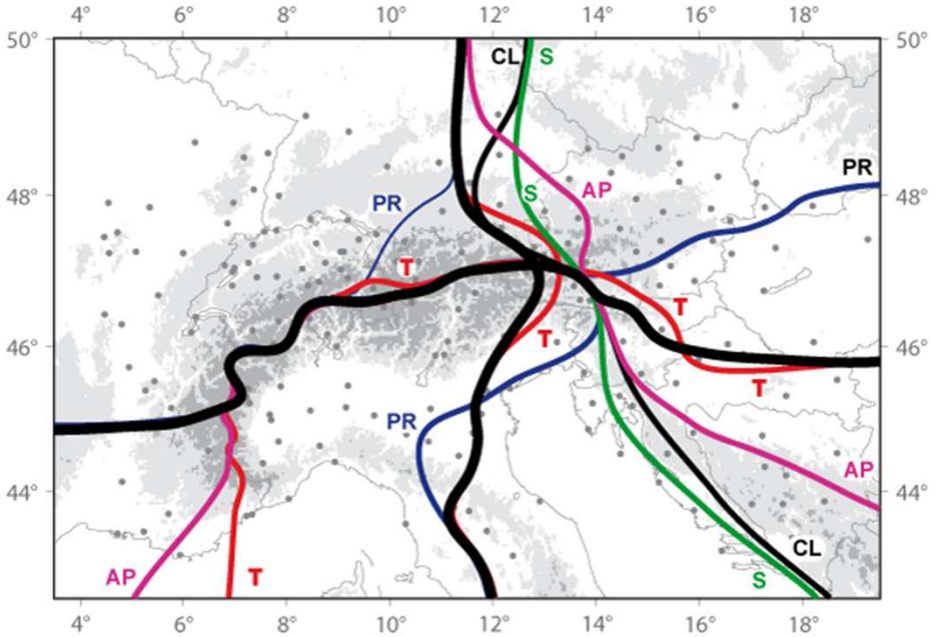
# Regionalization






further simplifications:
nearly identical temperature trends for the whole GAR
for air pressure and sunshine duration only two sub-regions: high alpine and low for valleys and plains
for precipitation: West, inner-alpine, North and Southeast

Results of PCA (based on single element monthly anomalies) for AP air pressure, T air temperature, PR precipitation, S sunshine, CL cloudiness. Bold lines: The CRS (coarse resolution) compromise allowing for intra-elemental comparisons based on equal sub-regions for each climate element

+ 1 vertical sub-region above 1600 m

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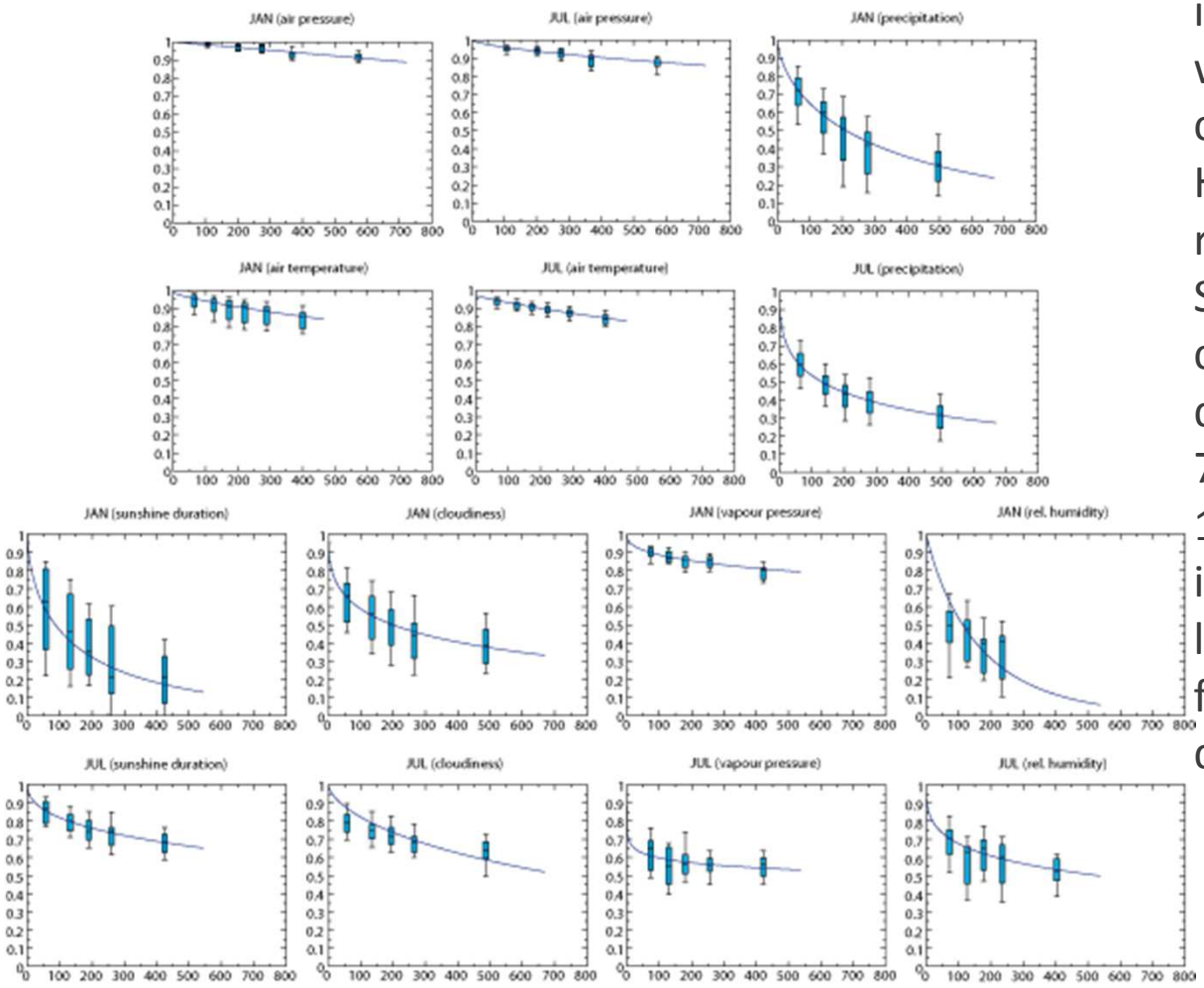
# spatial decorrelation




inter-station de-correlation within Region NE for the seven climate elements present in HISTALP for January and July respectively. Vertical axes: Spearman's correlation coefficient, horizontal axes: distance in km, boxes: medians, 75 and 25 percentiles, whiskers: 10 and 90 percentiles of interstation-distance subgroups, lines: exponential decorrelation fits (calculated from the grouped dataset)



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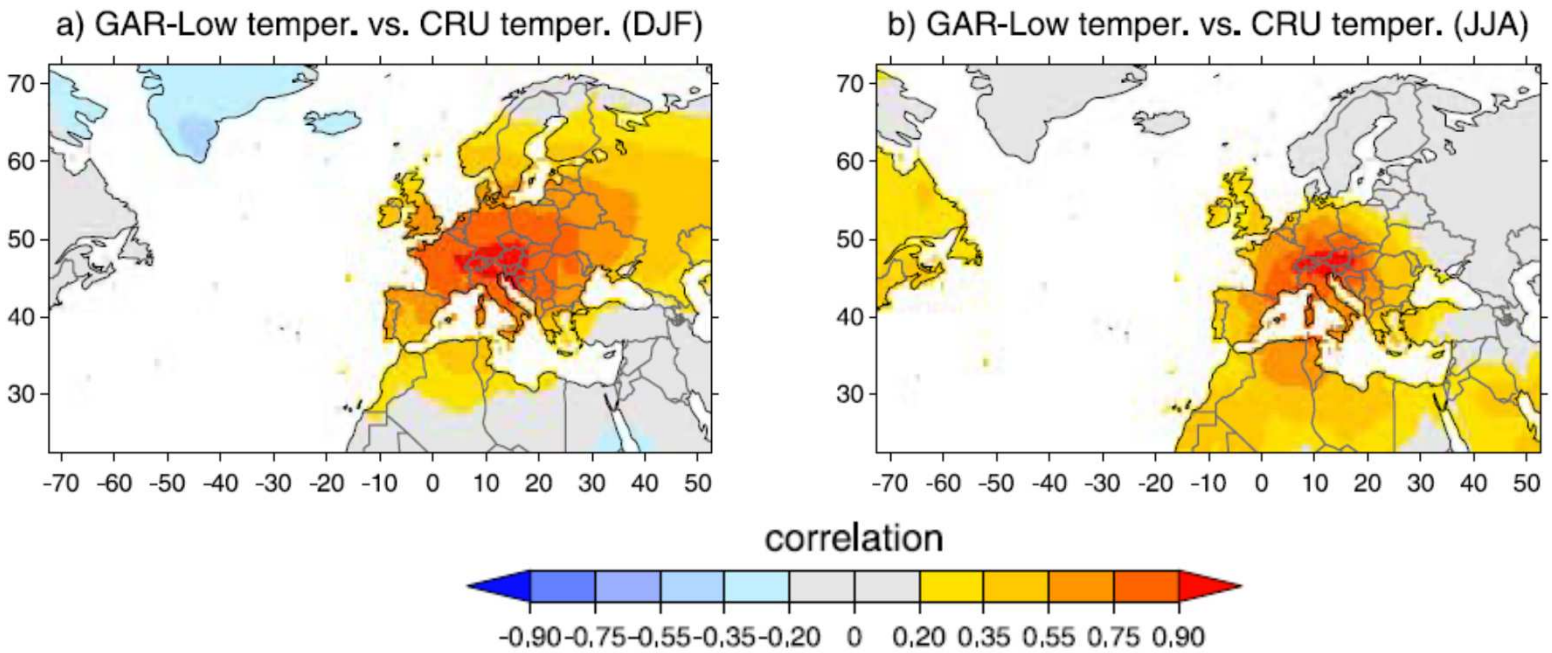
# HISTALP temperature correlation






correlation of the GAR temperature interannual variability with the wider European- North Atlantic land temperature: (a) for the winter (DJF) GAR-low temperature, (b) for the summer (JJA) GAR-low temperature (Efthymiadis et al., 2007)

GAR temperature correlates well with broader European temperatures throughout the year
In winter the coherence has a prominent zonal character which is not observed in summer
In the meridional dimension, stronger correlation with northern Europe is found for winter, whereas links with northern Africa develop in summer.

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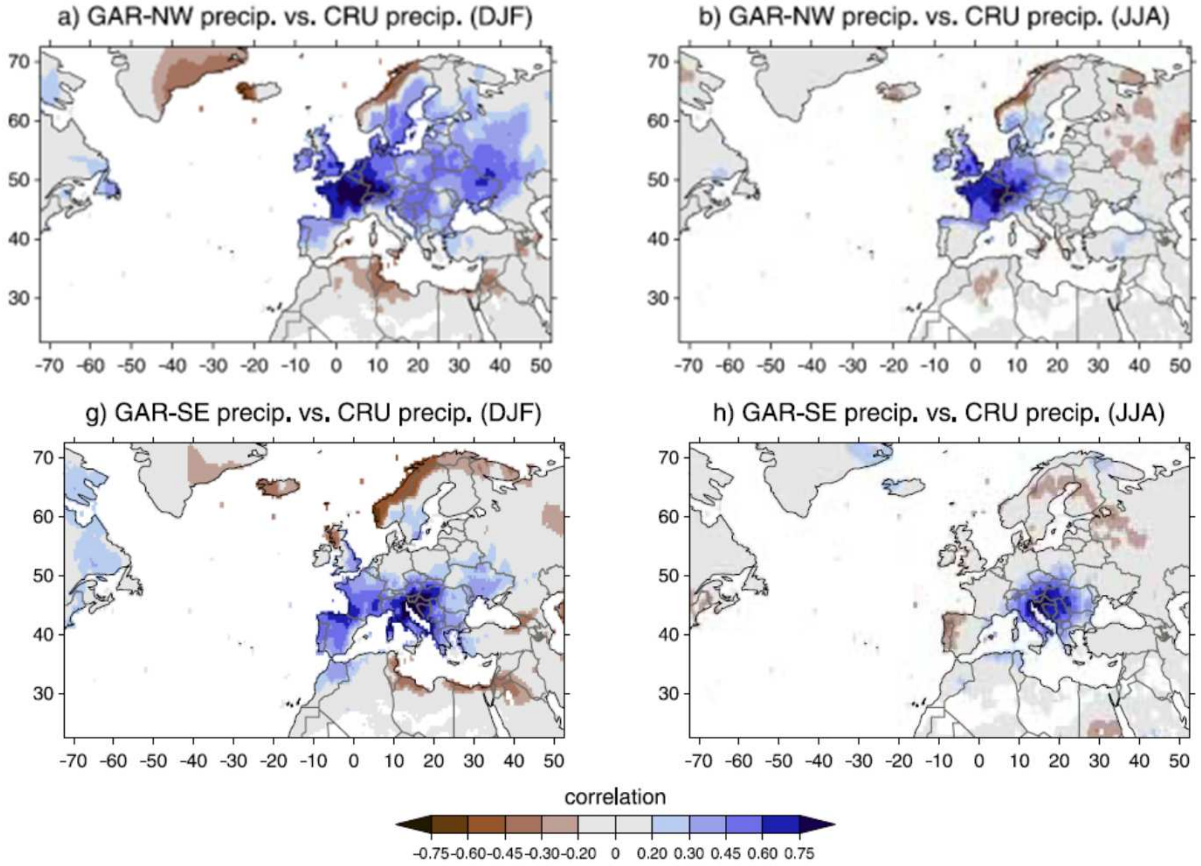
# HISTALP precipitation correlation




correlation of GAR precipitation with the wider European-North Atlantic precipitation: (a) for the winter (DJF) GAR-NW precipitation, (b) for the summer (JJA) GAR-NW precipitation, for the winter (DJF) GAR-SE precipitation, and (h) for the summer (JJA) GAR-SE precipitation (Efthymiadis et al., 2007).

correlation is less strong,
The GAR-NW precip.is related with the precipitation in a broad area of northern continental Europe, extending from France to Poland (Fig 4a).
GAR-SE precipitation is related with southern European precip. the western Mediterranean (Fig. 4g).
In summer, all the correlations are confined to areas close to the Alps (Fig. 4b, 4h).

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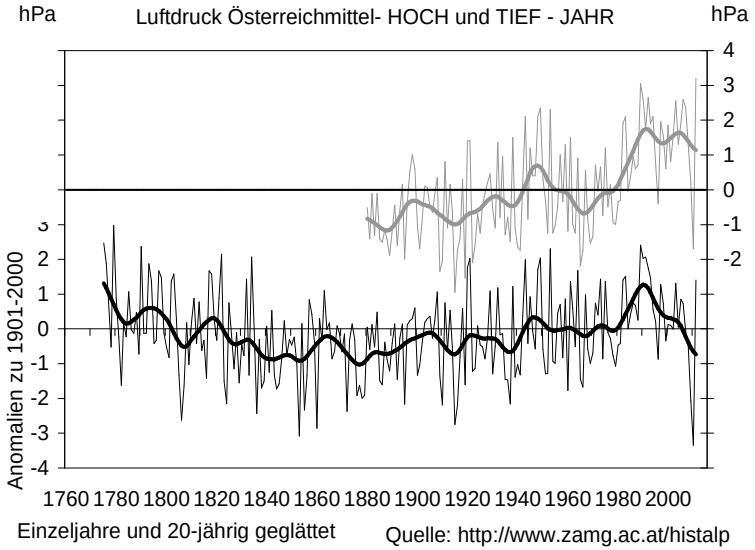
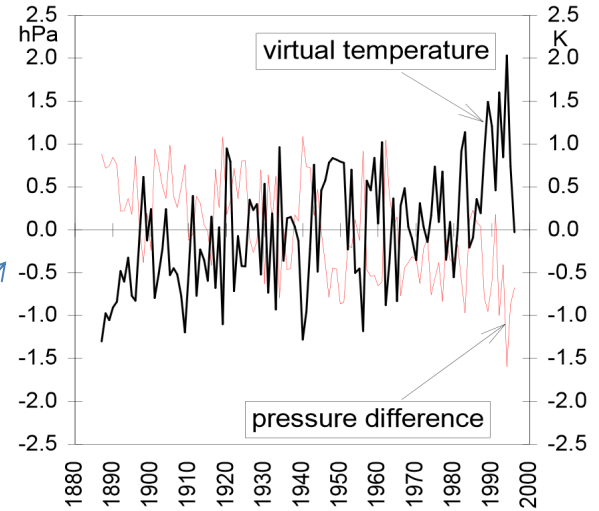
# Air pessure

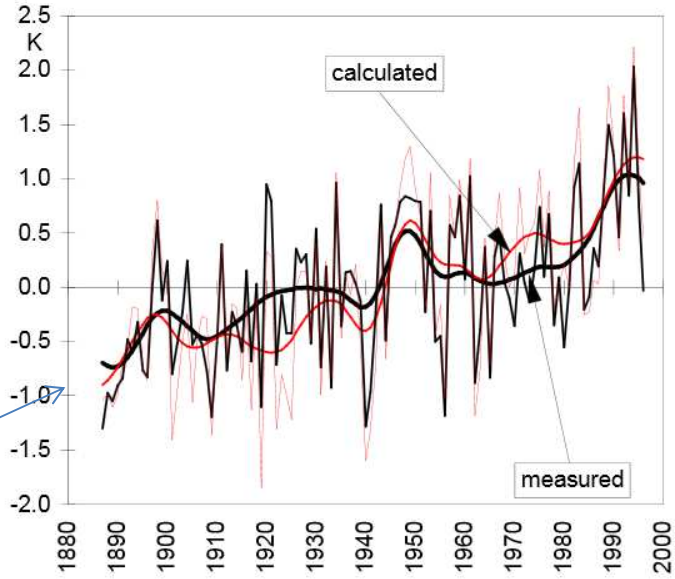



Annual means of air pressure, relative to 1901 – 2000, low: 1775-2011, high: 1880-2011). single years and 20yrs smoothing

Time series of air pressure difference (low level mean minus high level mean) and mean virtual
air temperature of „East alpine standard air column “ (449m to 2855m barometric height extension

Time series of the virtual temperature calculated from air pressure, 1887-1996 and 21 yrs. smoothed all relative to 1887-1998 average (Böhm et al., 1998)

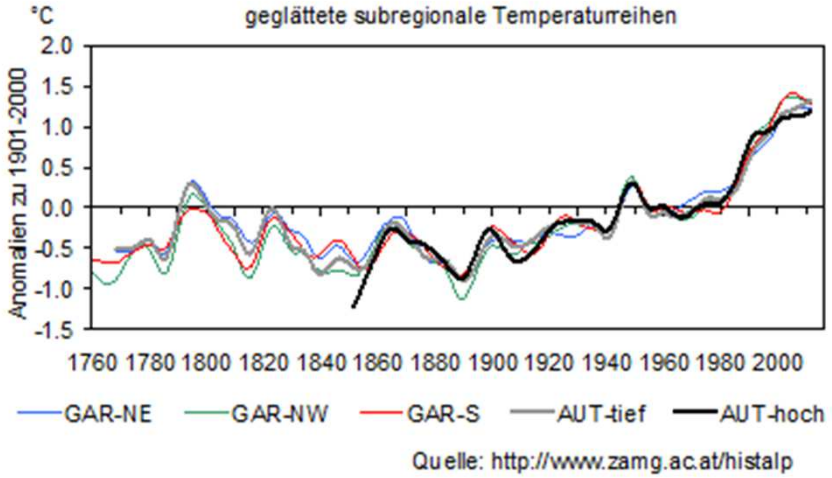


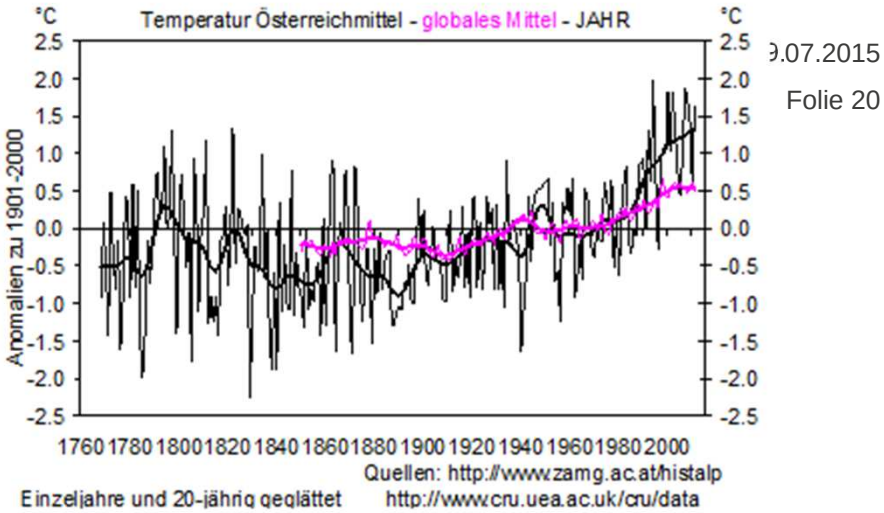

Böhm et al., 1998

Meteorologie und Geodynamik

# air temperature




Anomalies of smoothed temperatures for different GAR sub-regions .




Anomalies of smoothed annual temperature (for Austria and global)



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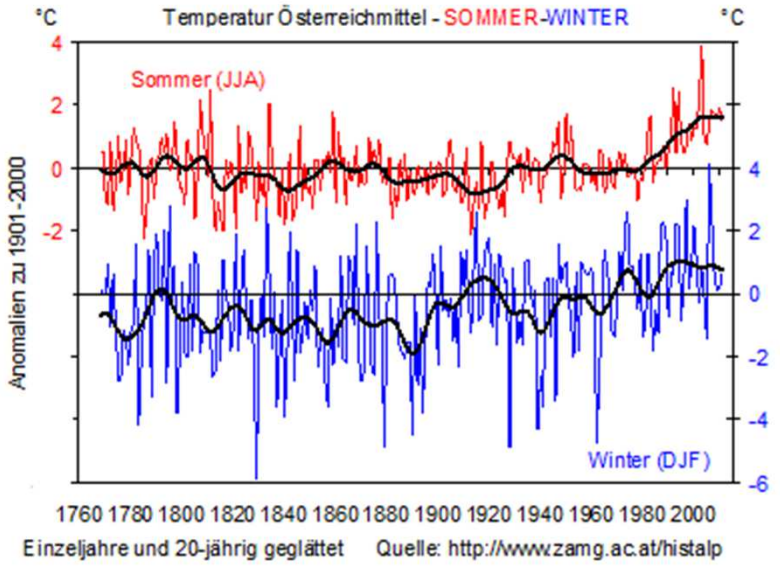
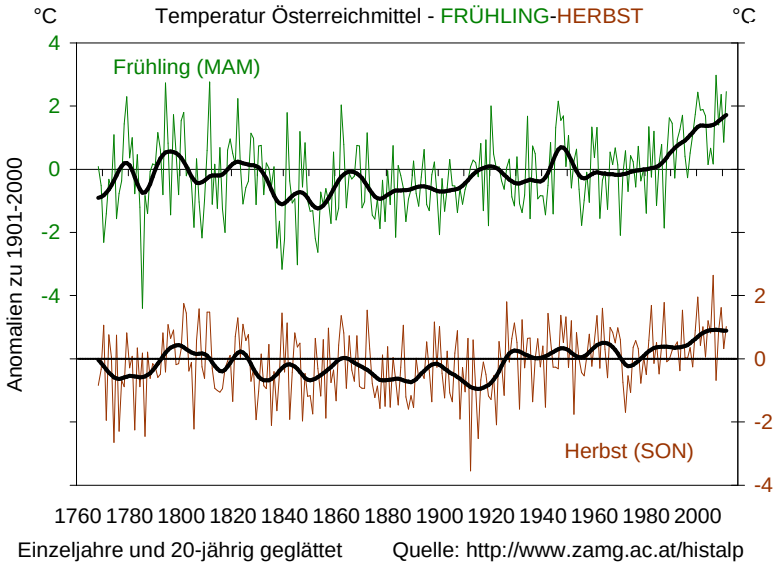
# findings from seasonal temperatures



- Seasonal temperatures can show different evolution
- All seasons show warming since midst 19th century
- Autumn only moderate warming
- During 1910th mild winters and rather cool and humid summers – prominent glacier advances in the Alps with moraines in glaciated areas.
- more continental climate  during 19th century and around 1940.
- The last 30 years: ongoing warming in spring and summer, smaller in autumn and only little warming in winter.

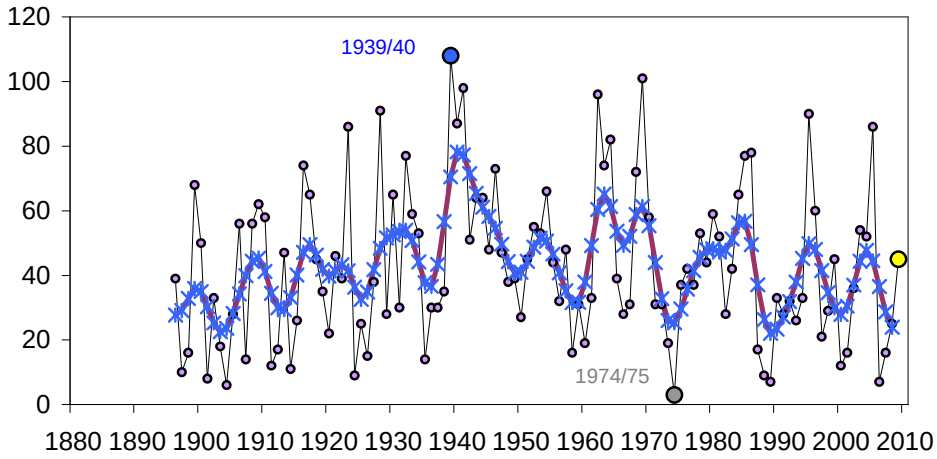


# snow in Vienna

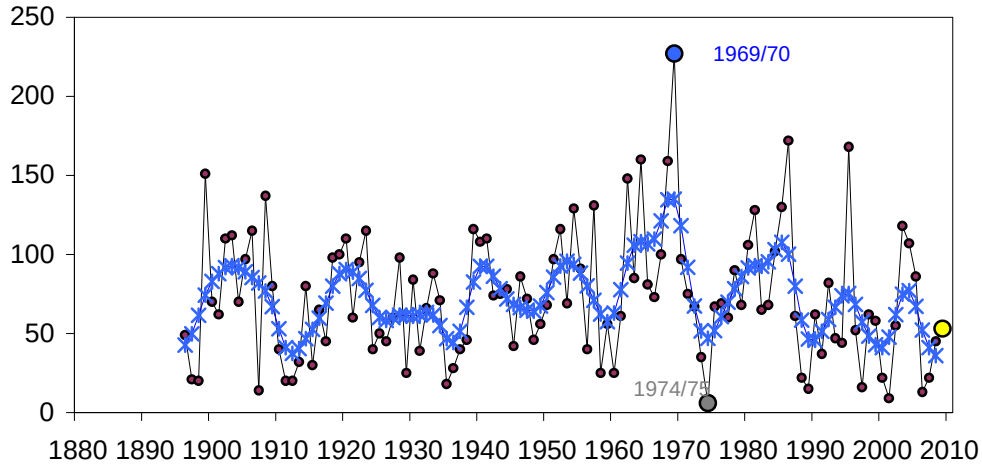


SCHNEEDECKENTAGE WIEN 1896/97-2009/10



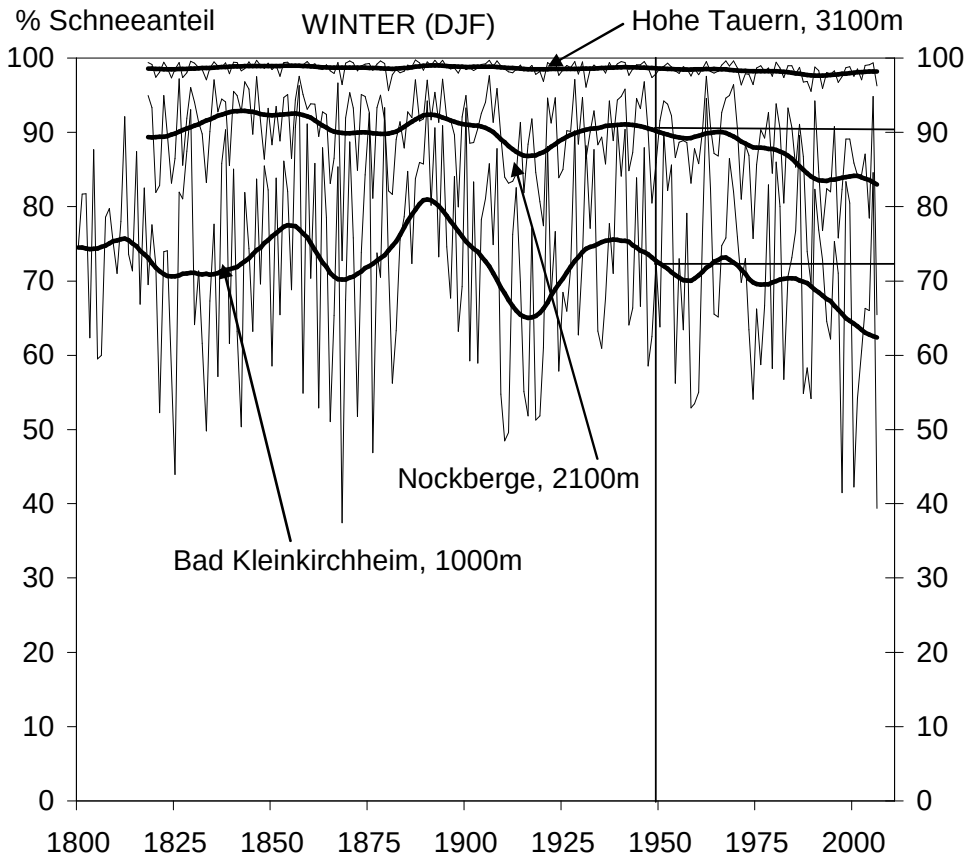

Quelle: HISTALP-Datenbank, ZAMG (http://www.zamg.ac.at/histalp)

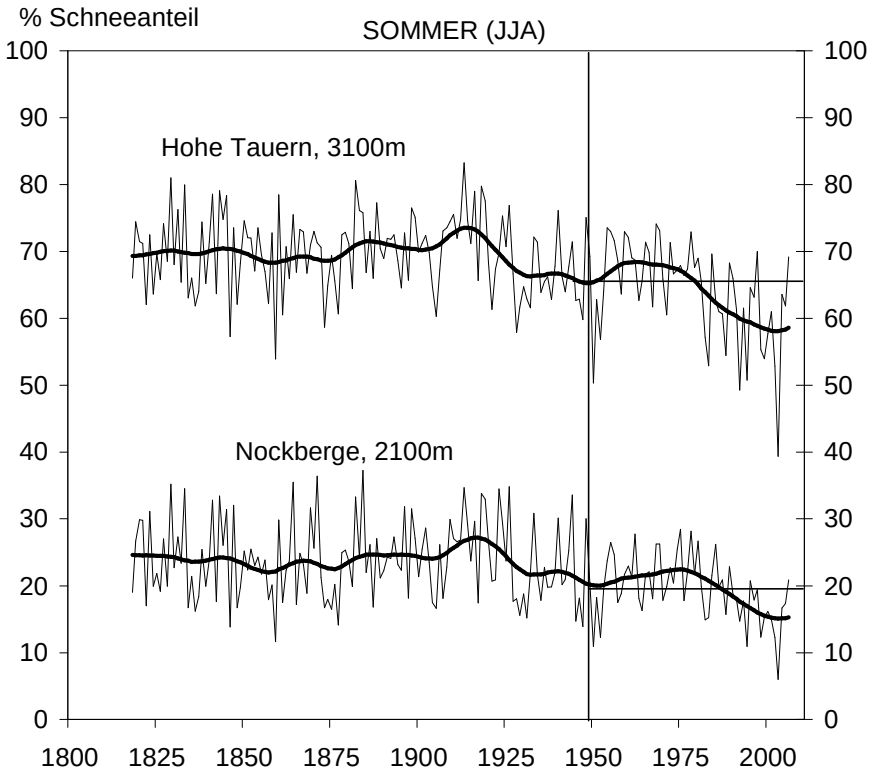
SUMME der NEUSCHNEEHÖHEN WIEN 1896/97-2009/10




Quelle: HISTALP-Datenbank, ZAMG (http://www.zamg.ac.at/histalp)

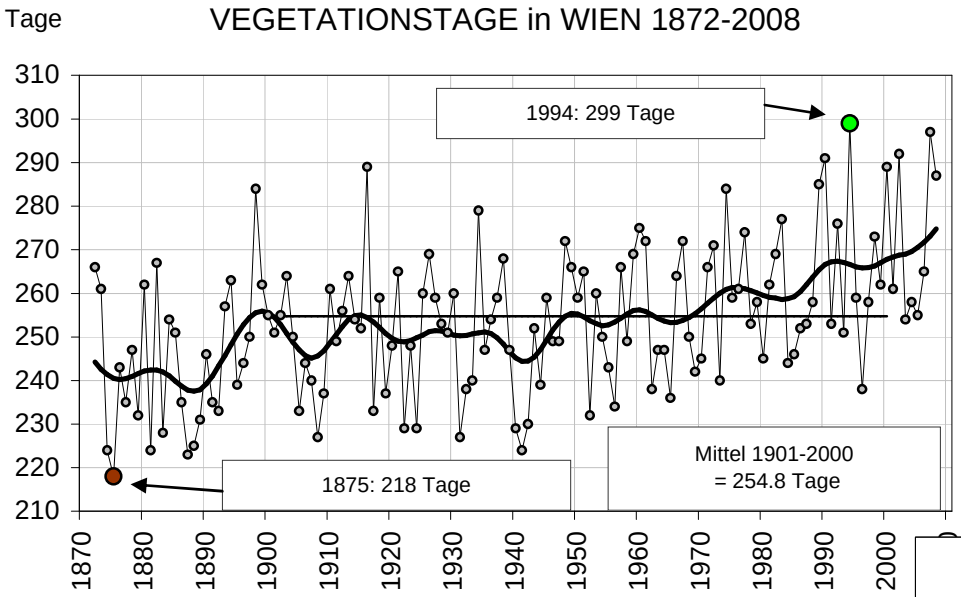
# Snow in the mountains



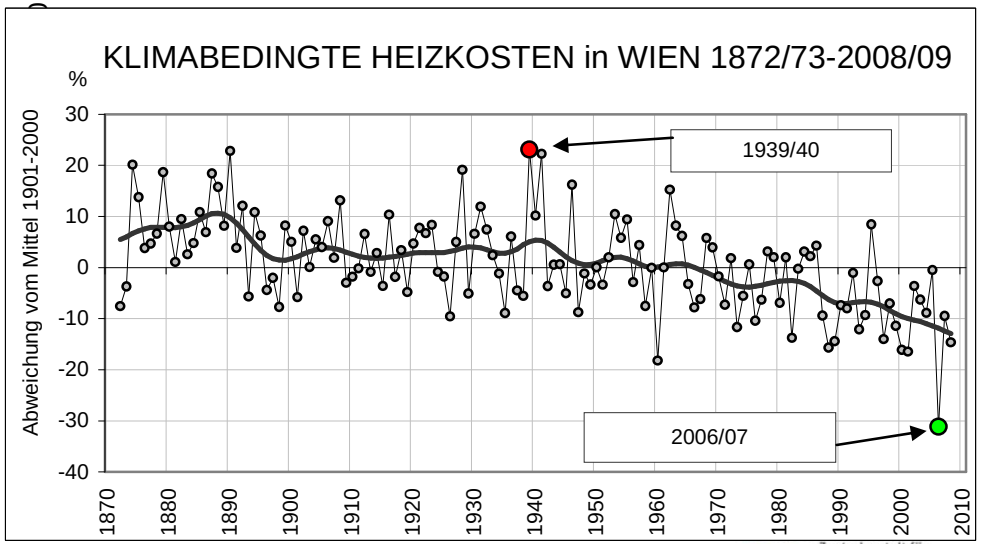
# vegetation days, heating costs



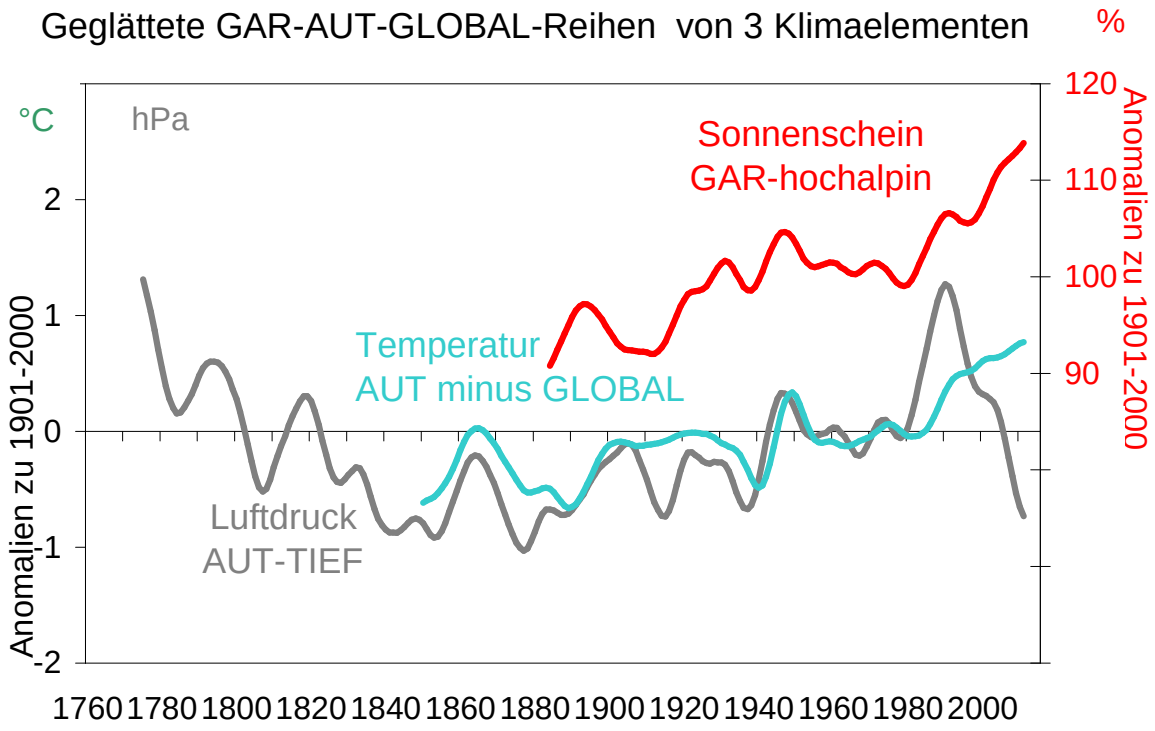



Increase +15 days 1880-1980
+10 days since 1980

decrease: -12 % 1880-1980
-10 % seit 1980



# regional contribution to GAR warming






regional contribution to GAR warming
similarity of temperature, low level air pressure and high alpine sunshine
shift of the subtropical high with increasing sunshine and warming

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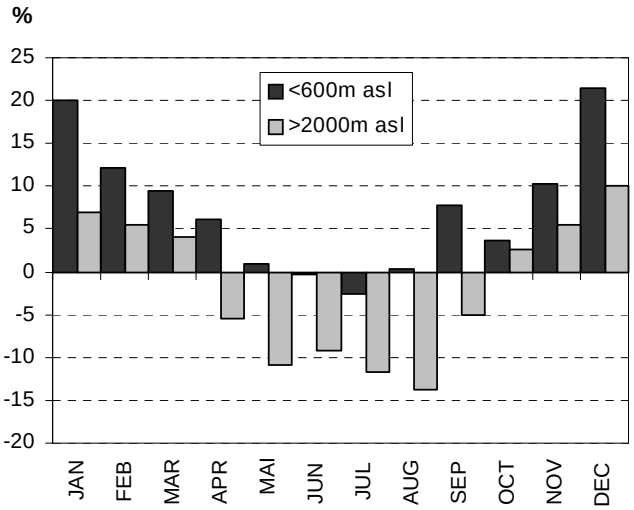
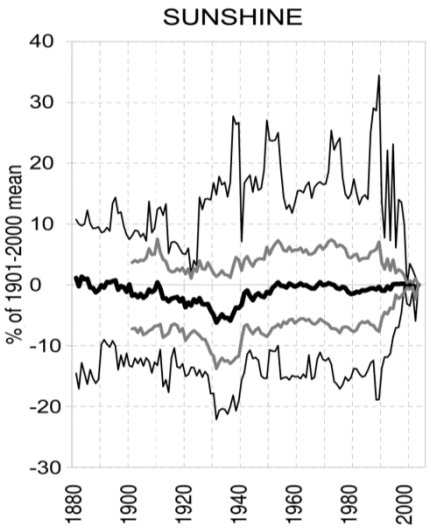
# significant breaks in sunshine series




Mean annual course of the breaks in Austrian sunshine series due a change from the traditional Campbell-Stokes recorders to the Haenni-Solar sensors (new minus old in %, sample 1986-1999, dark: mean of 4 low-level sites, light: mean of 3 high-level sites)

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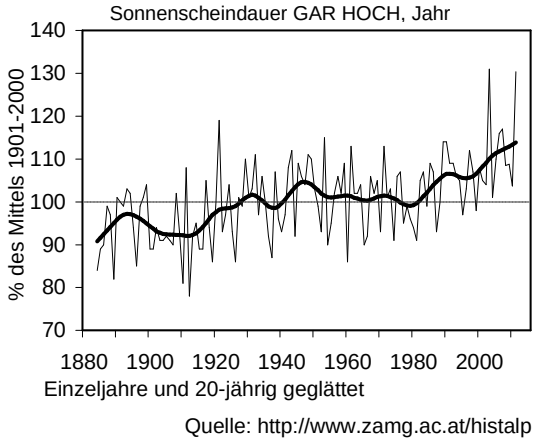
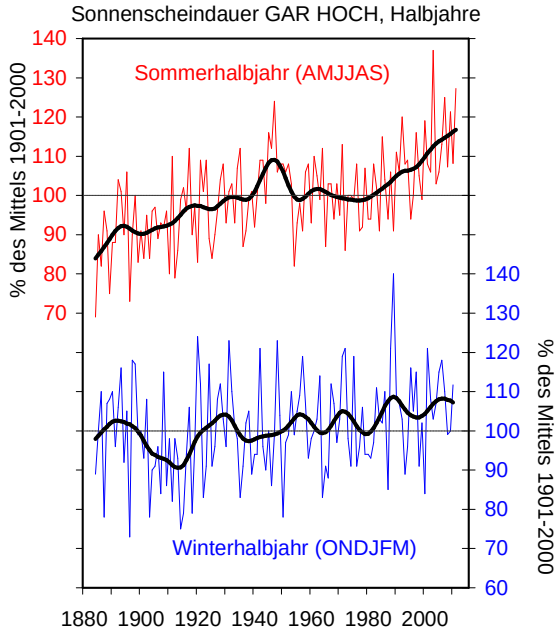
# sunshine (duration)






Quelle: http://www.zamg.ac.at/histalp

Anomalies of sunshine duration – high level stations




Quelle: http://www.zamg.ac.at/histalp

Increase of sunshine duration of ~20% (300 hours for annual sunshine)

most expressed in summer – regional brightening

stepwise increase in summer , around 1950 and after 1980.

sunshine records in 2003 and 2011, (2003) und (1989/90).

explanation for stronger temperature increase

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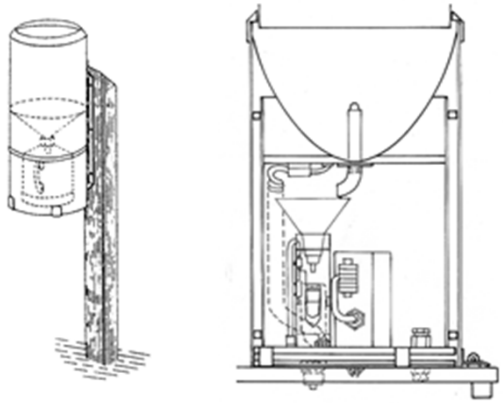
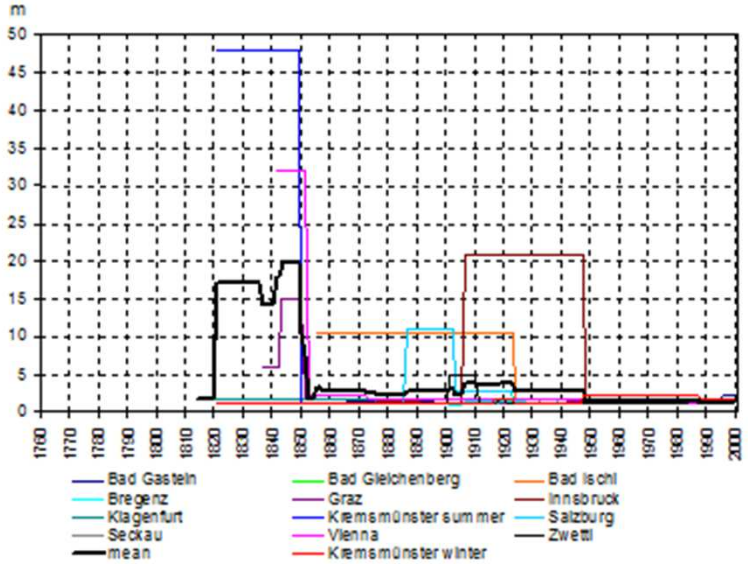
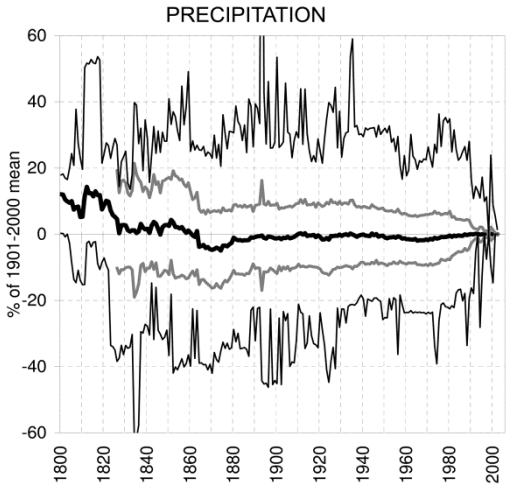
# precipitation

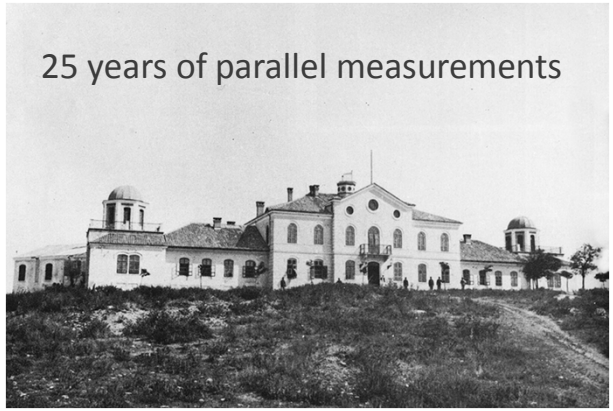


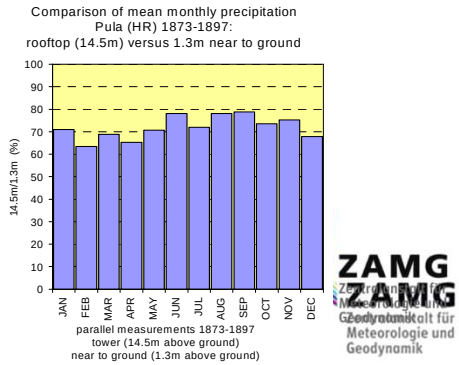





Heights above ground of rain gauges
Thin: single stations, bold: Austrian mean

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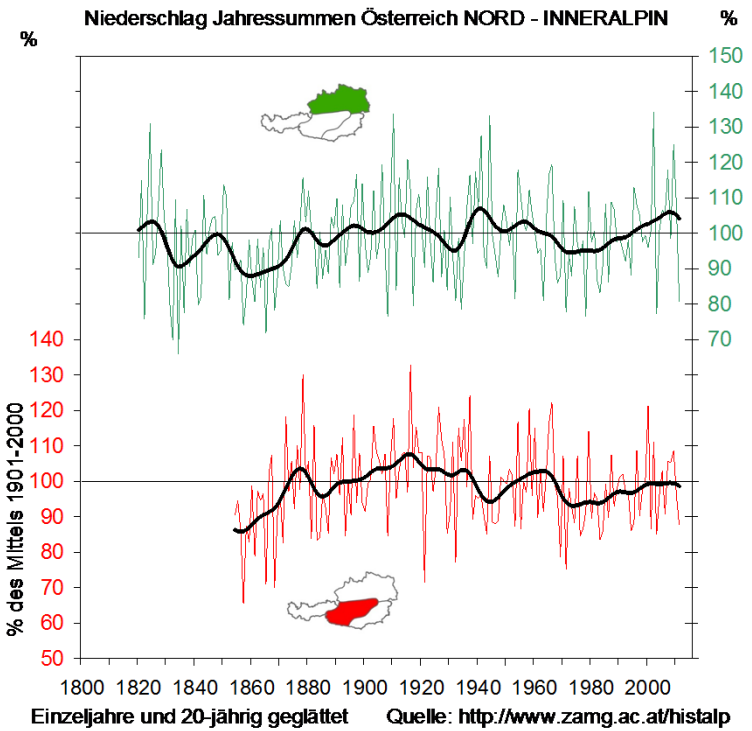
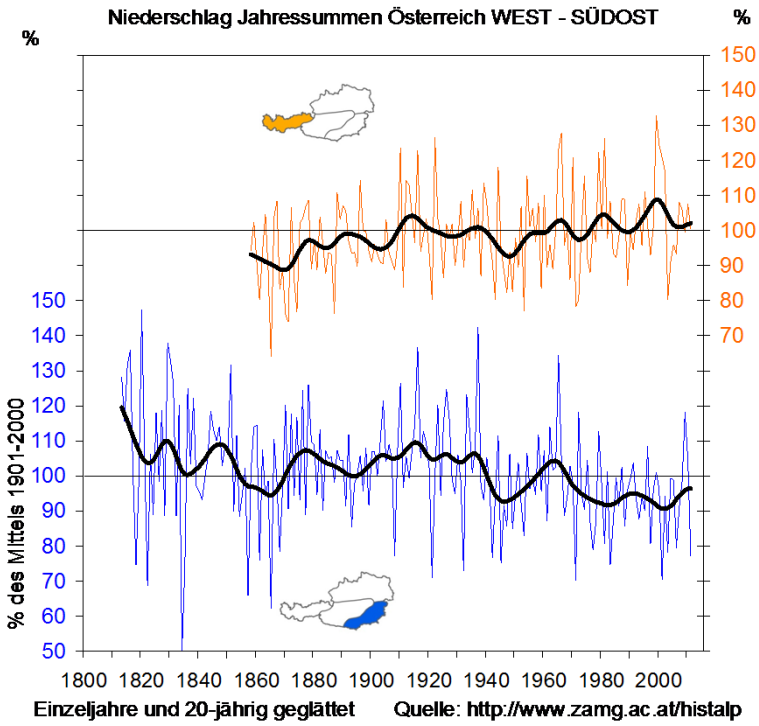
# precipitation






Anomalies of annual precipitation sums

no uniform trends in Austria (GAR), 4 sub-regions for Austria
increase in the West, decrease in the South-East , no long-term trends in the North and inneralpine
prominent minimum around 1860, very dry in the sourth-east 1940 and after 1970
1st half of 19th century very humid (SE), glacier advances in 1810 and 1850.
1900 und 1940 was humid (inneralpine, SE)
increase after the 1970ies in the North and West

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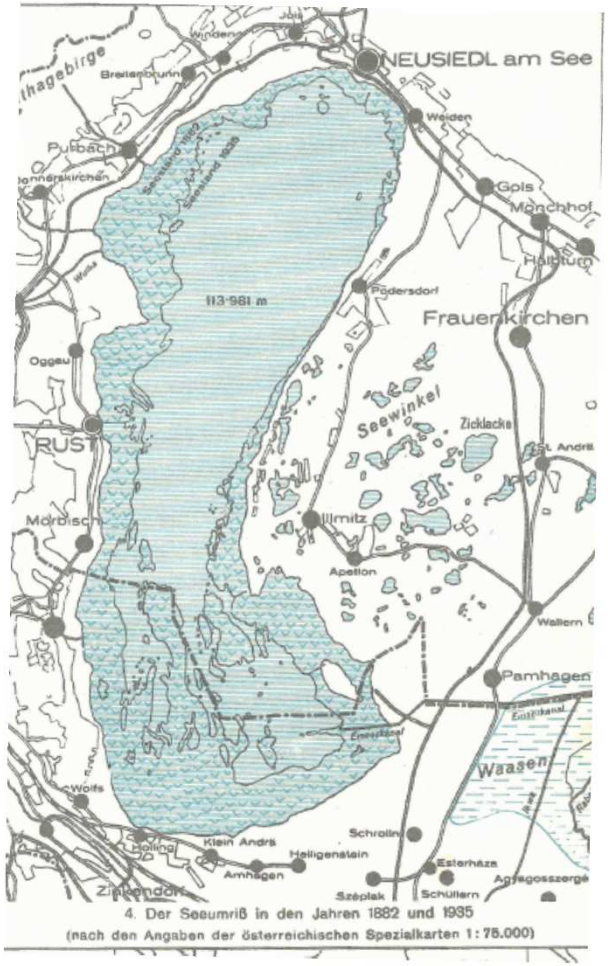
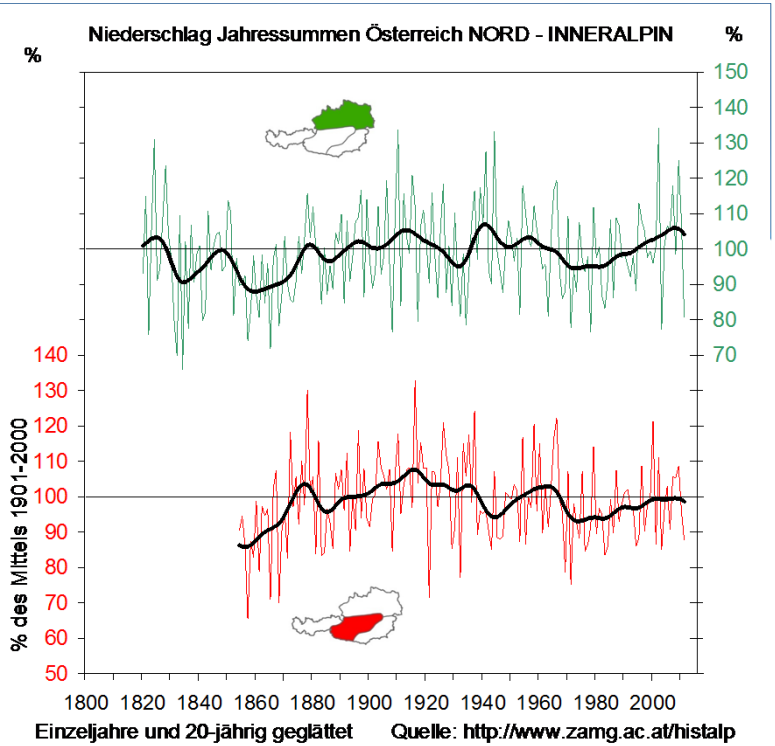
# Neusiedlersee

lake outline in 1882 and 1935



4. Der Seeumriß in den Jahren 1882 und 1935
(nach den Angaben der österreichischen Spezialkarten 1:75.000)




1867 the lake was dried out and disappeared
land segmentation to farmers

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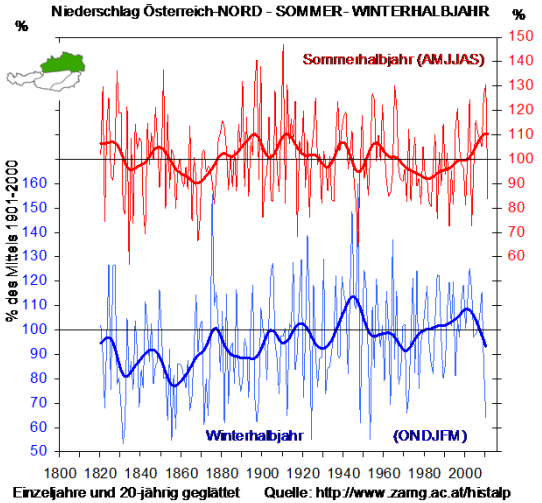
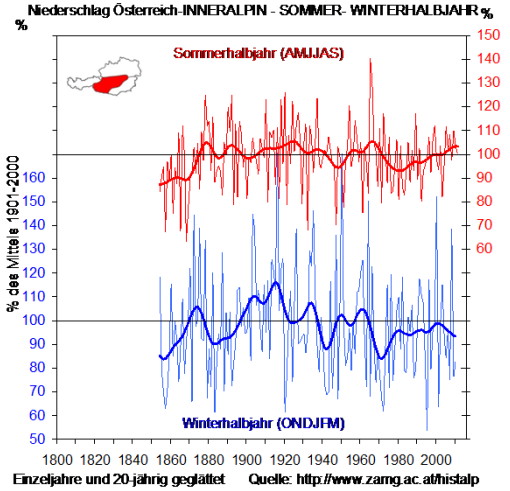
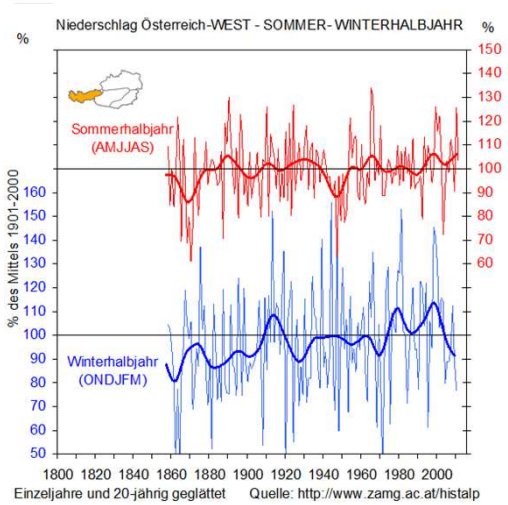
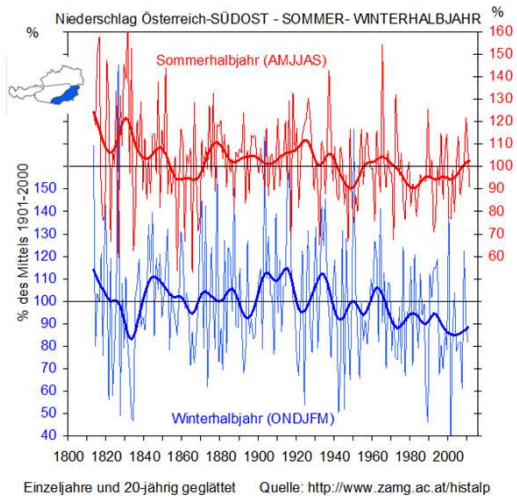
# seasonal precipitation



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# precipitation trends for river catchments since 1801

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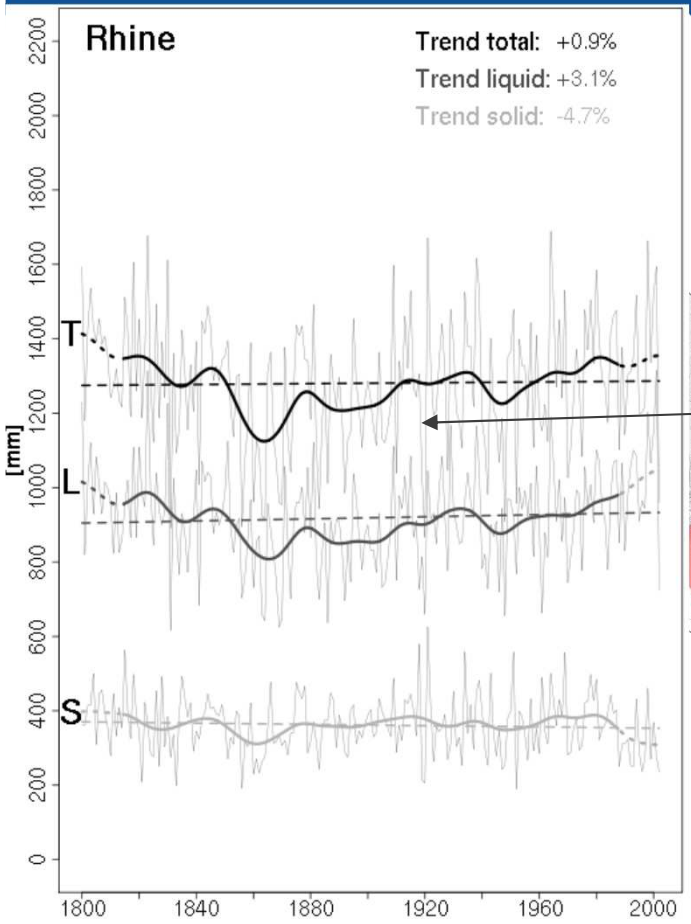
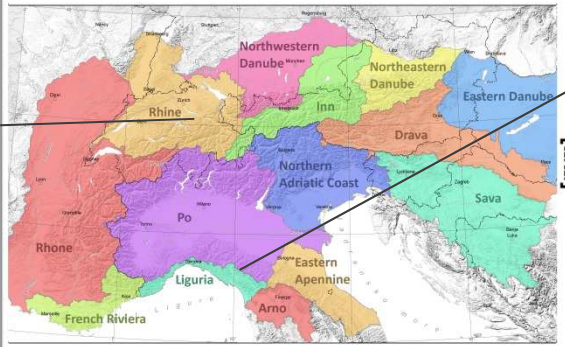
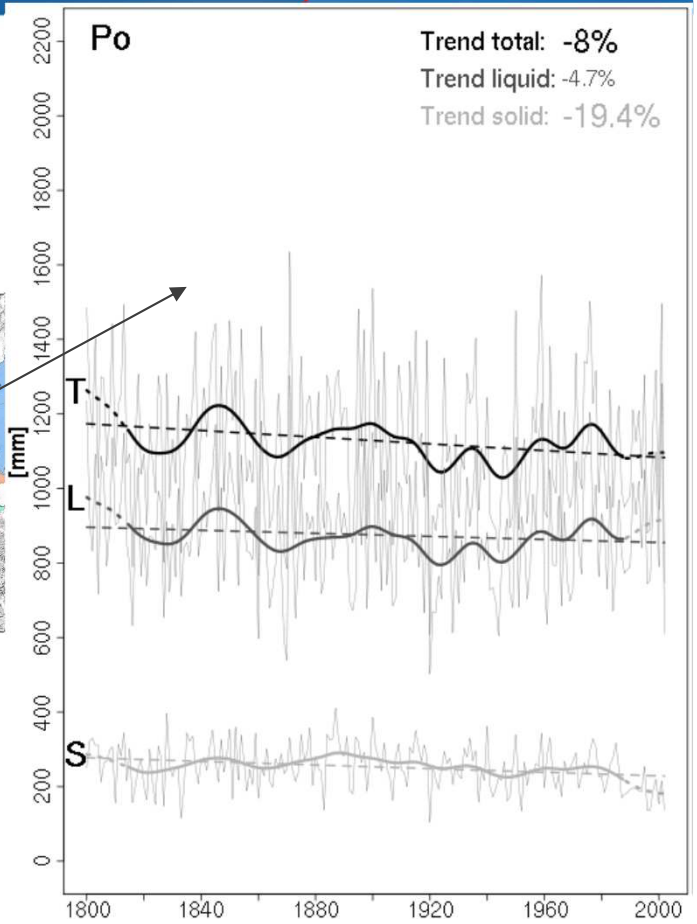



T = total

L = liquid

S = solid

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Chimani, Haslinger, Böhm, 2012

# Danube flooding







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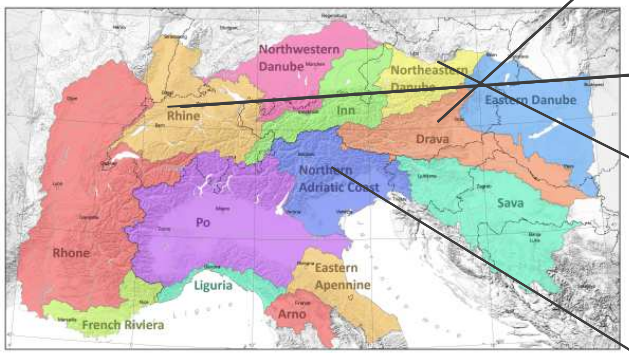
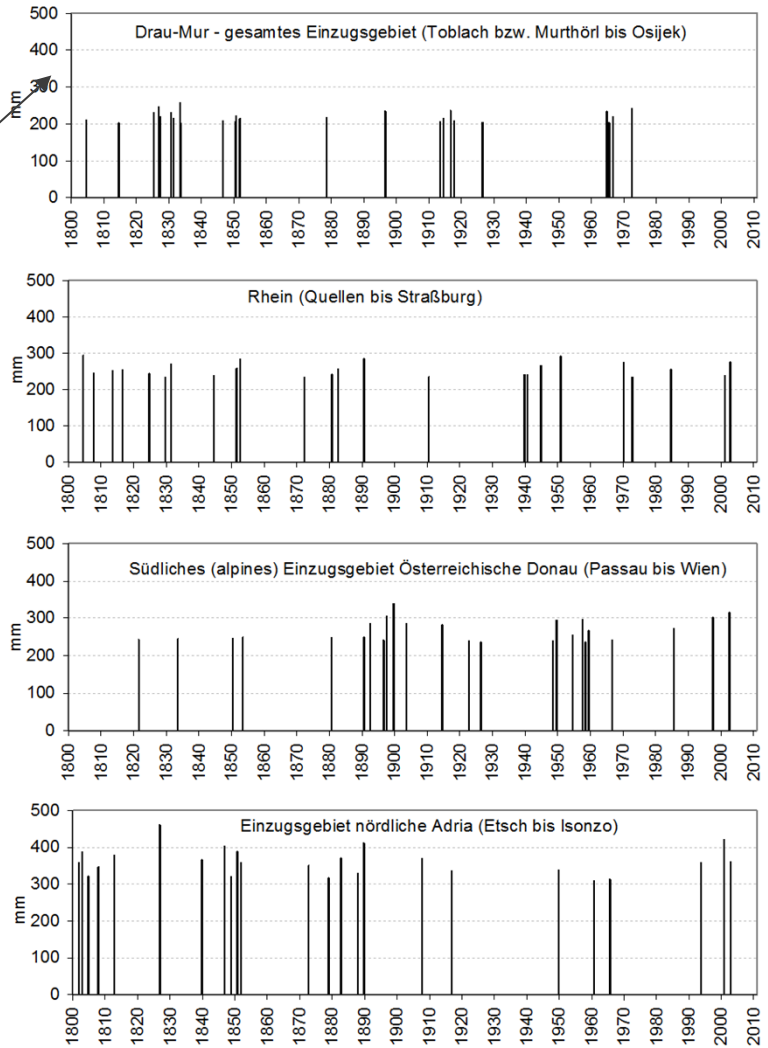
# Time series of 99th percentile monthly prec. in GAR catchment areas

regional differences




Haslinger, Chimani, Böhm, 2011

HISTALP-preciptation grids back to 1800:

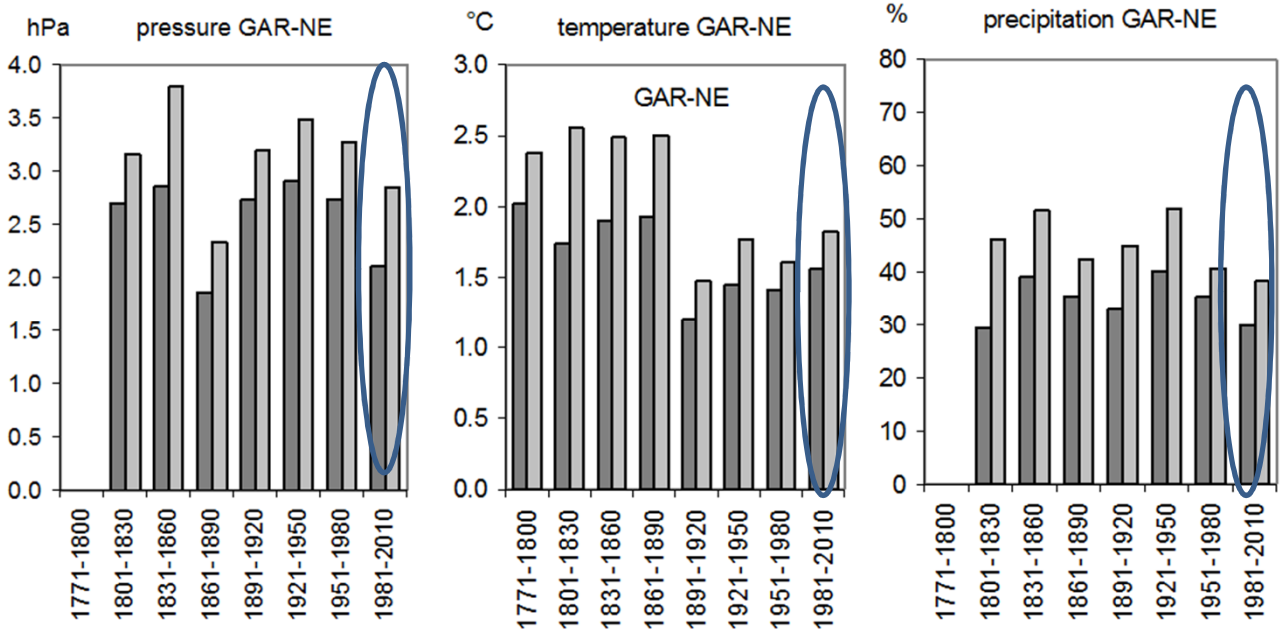



?

# extremes derived from monthly time series -

greater variability in the time series (de-trended)?
analyses for each series of the GAR






80% (dark grey und 90% (light grey ) interdecile range of annual time series in the GAR (NE) in discrete 30 yrs intervals ( Böhm, 2012),

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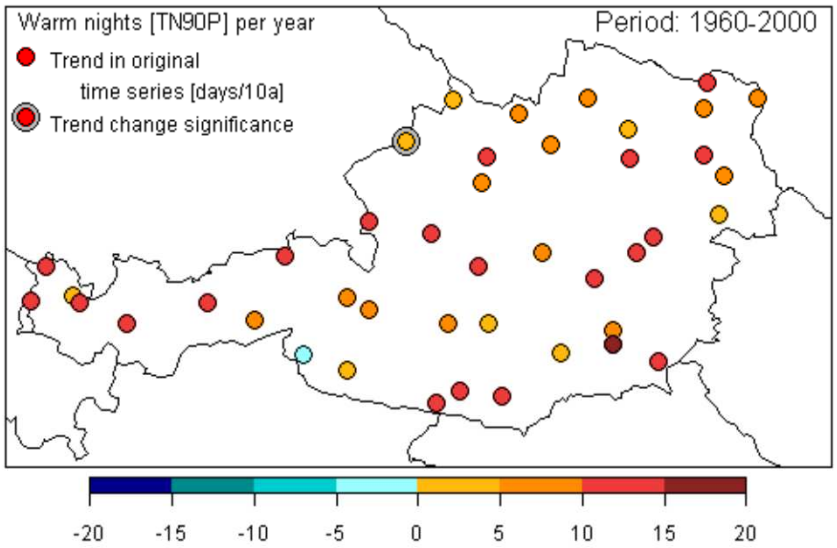
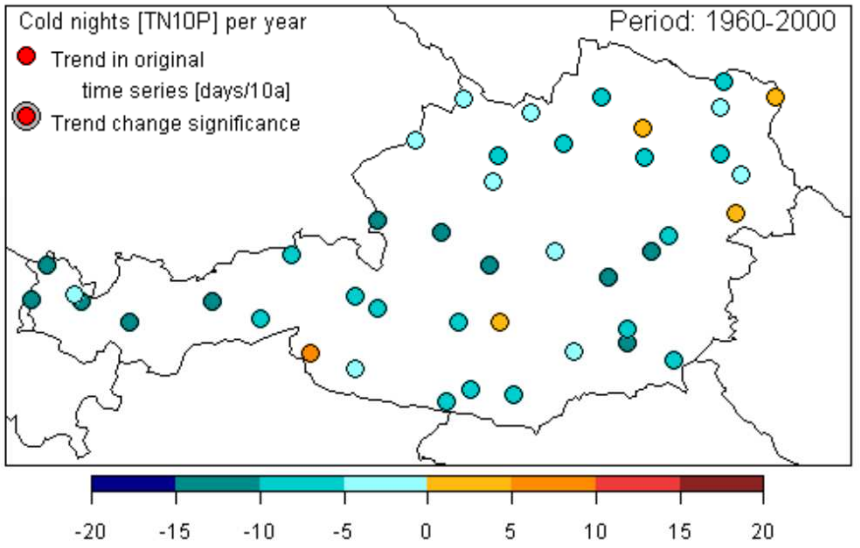
# warm and cold nights – homogenised data




from Nemec et al., 2012

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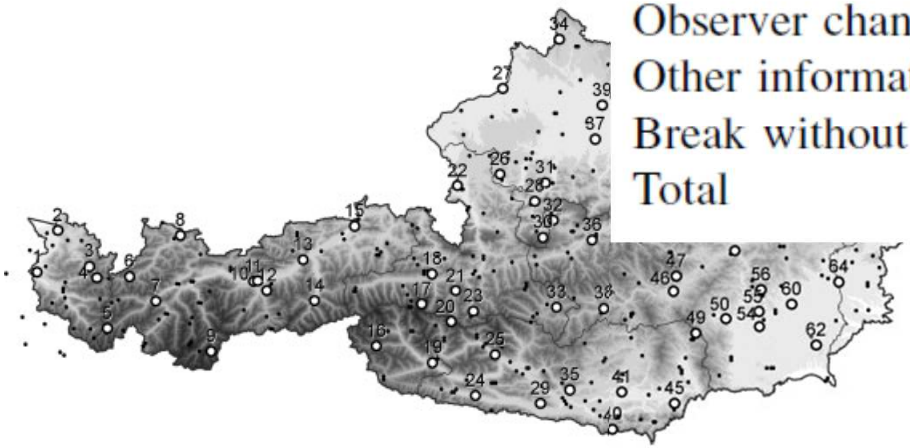
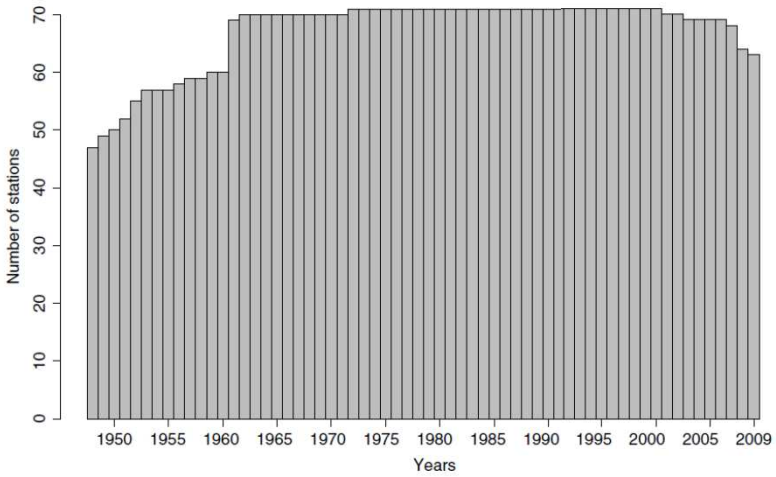
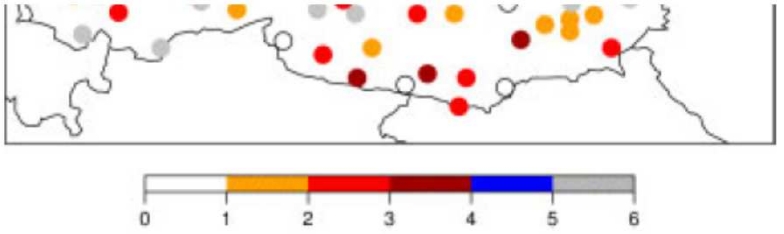
# homogenized daily tem

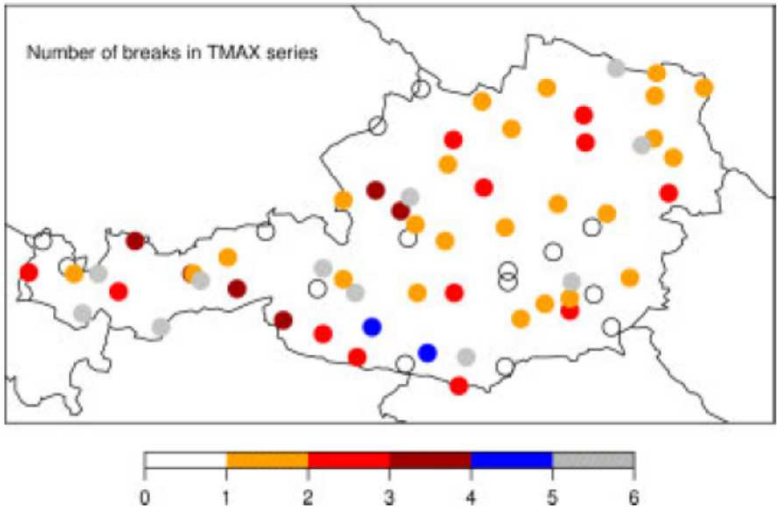
| Metadata event | Number |
|---|---|
| Station relocation | 50 |
| Instrumentation change | 23 |
| Screen shelter change | 16 |
| Observer change | 8 |
| Other information | 6 |
| Break without metadata | 36 |
| Total | 139 |



candidate series and reference series

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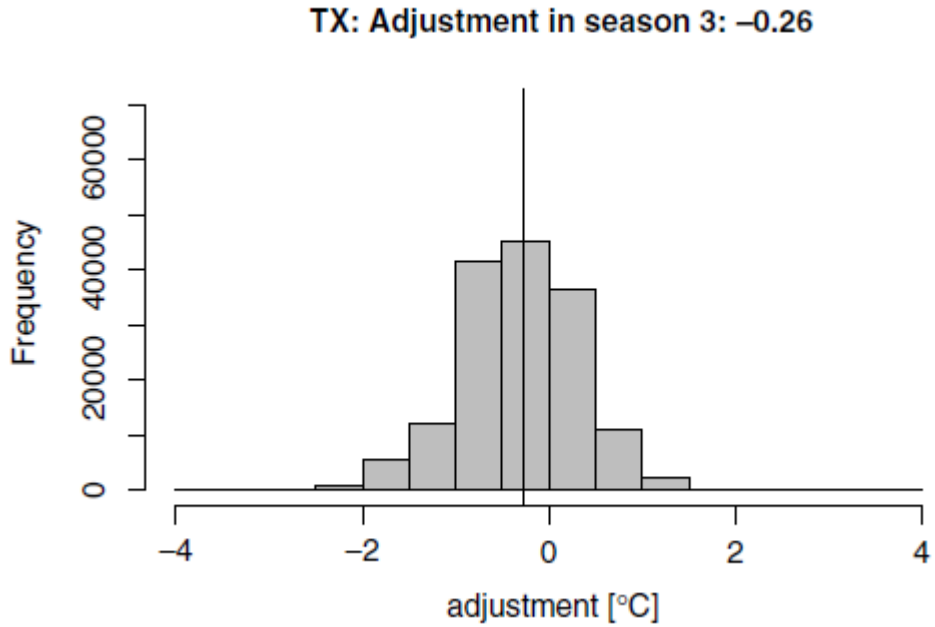
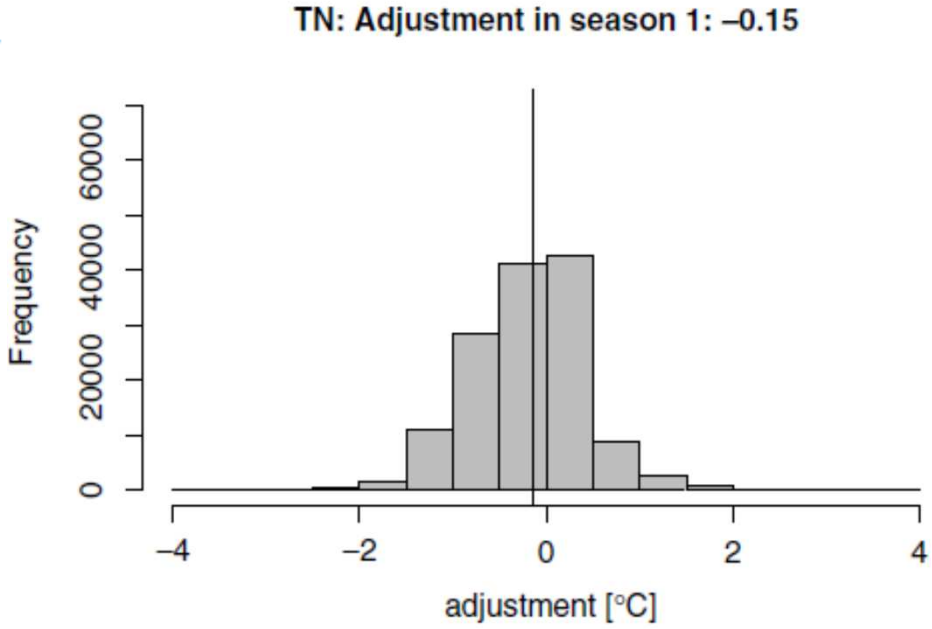
# adjustments

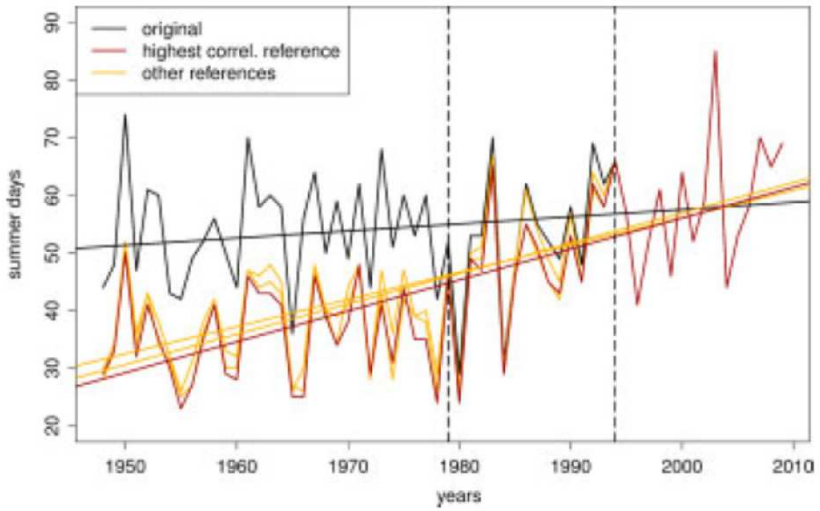




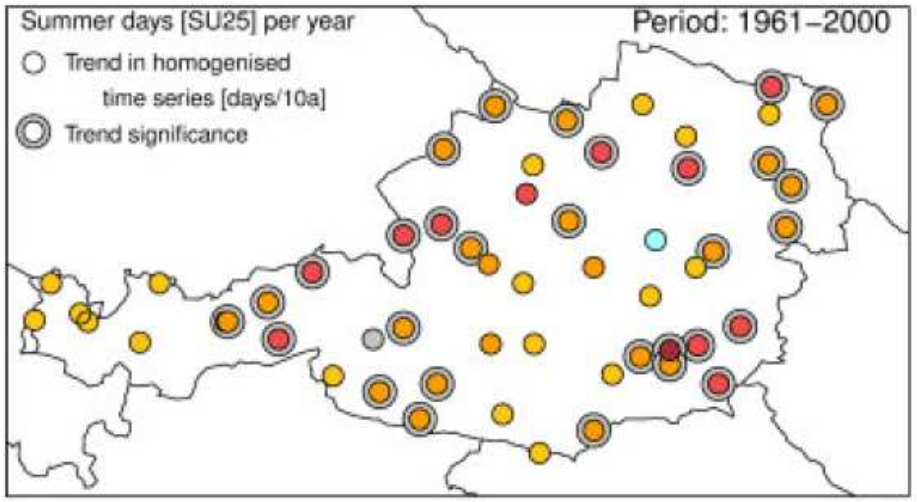

break adjustment for Tx in summer and Tn in winter

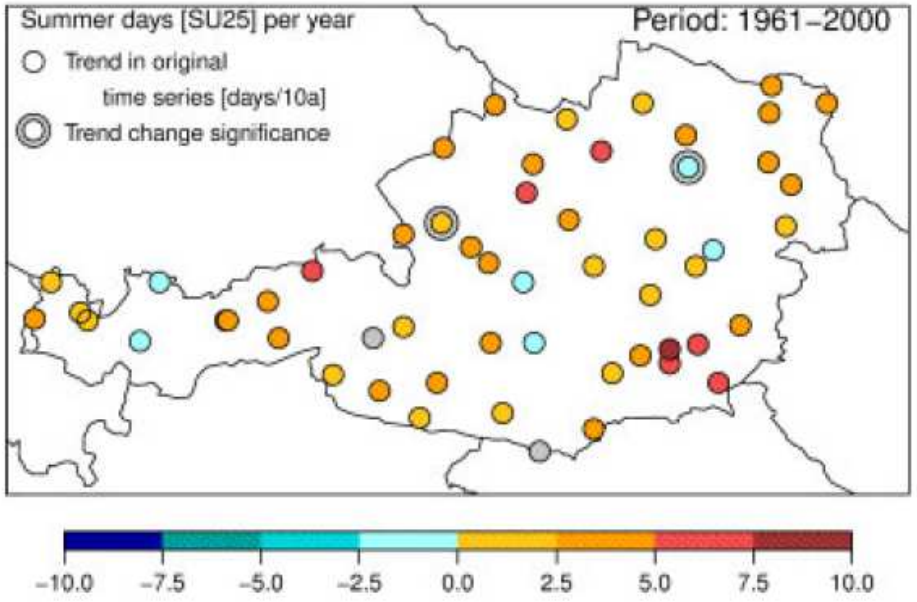


# trends of summer days

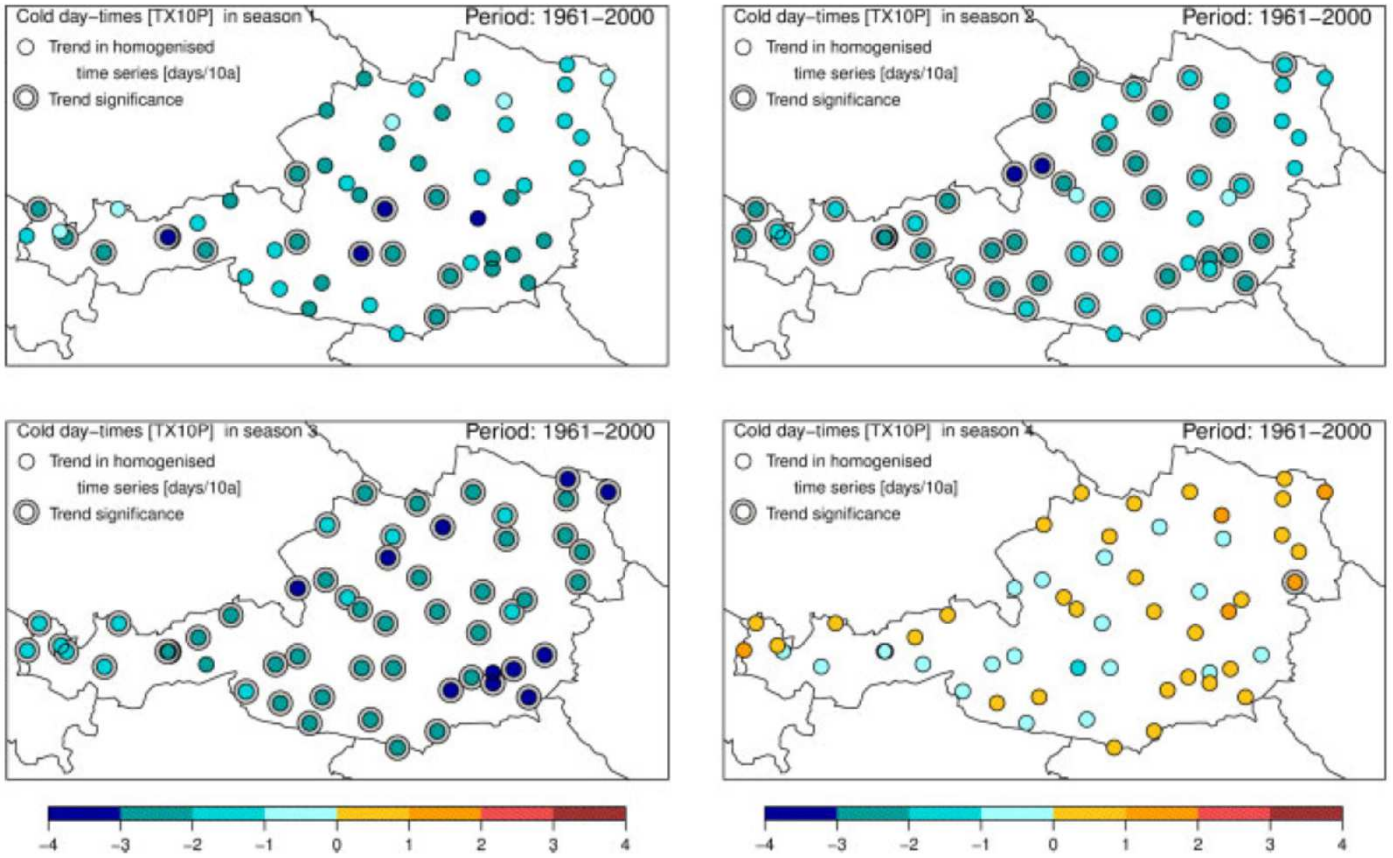



summer days in St. Pölten



# seasonal cold days




cold days, Tmax <10%



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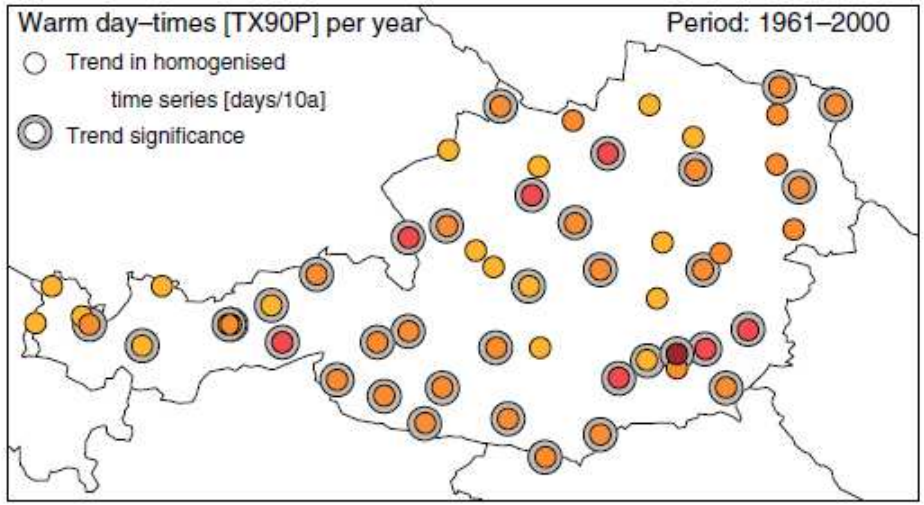
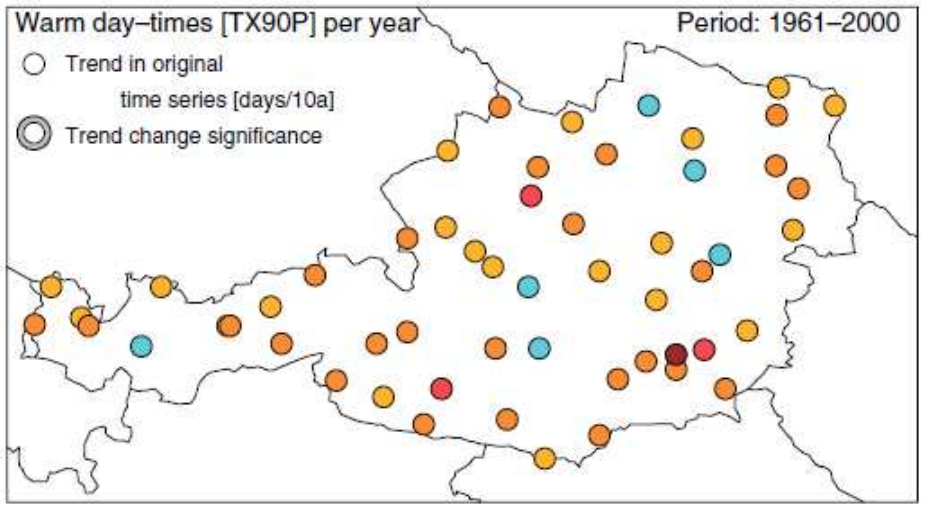
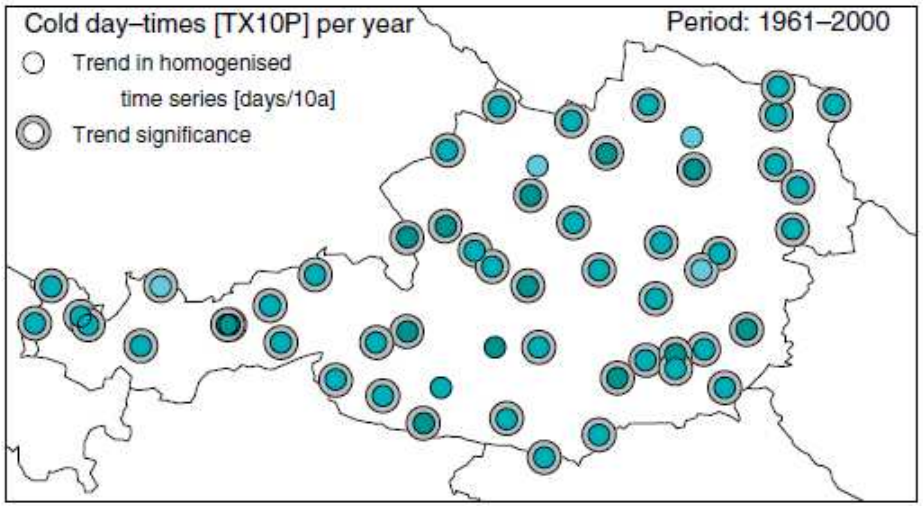
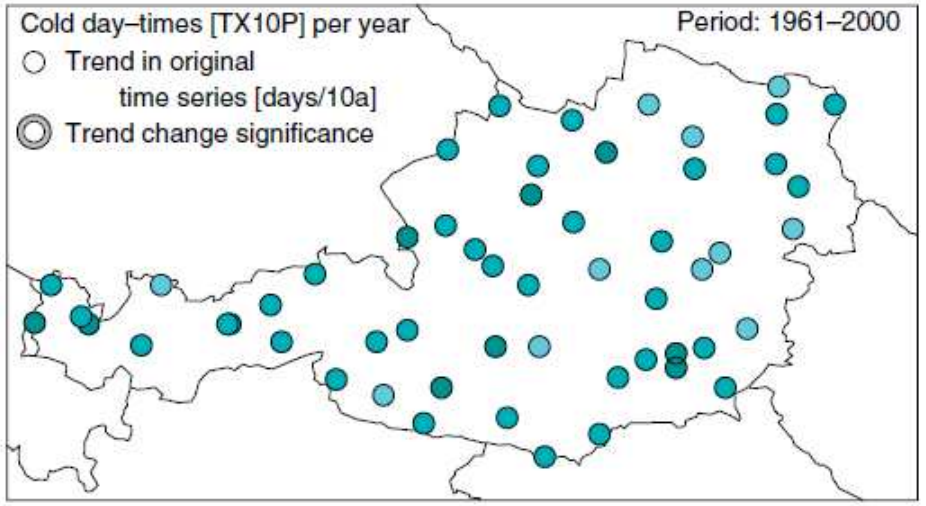
# annual warm and cold days (homogenized and original)

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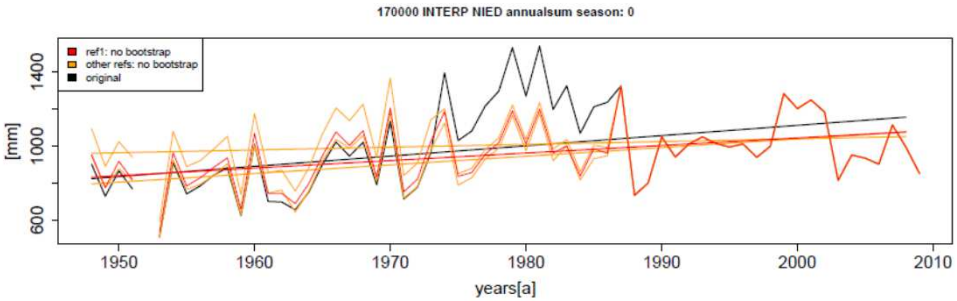
# findings for precipitation

*Statistics of the homogenisation of the precipitation dataset.*



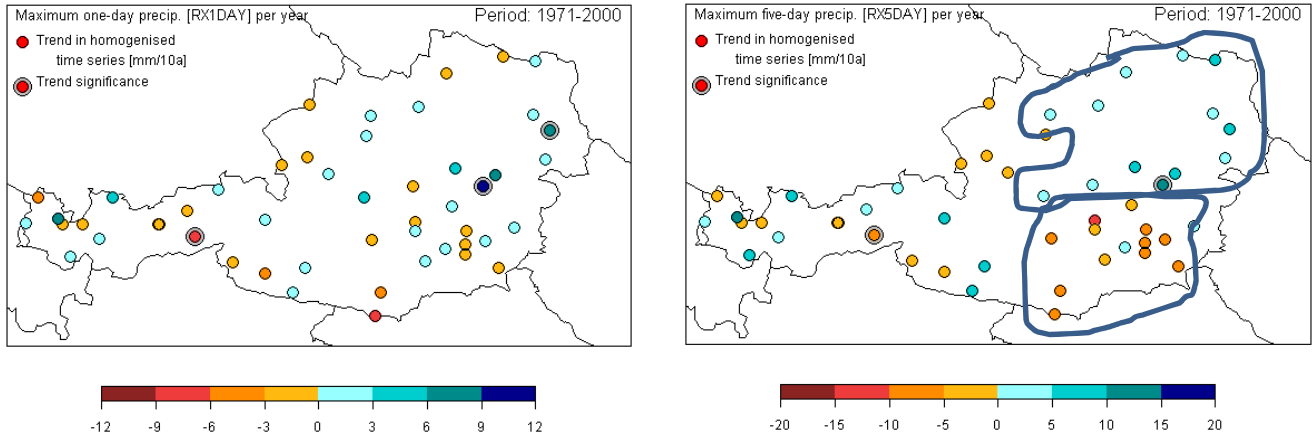
| | number | percentage |
|---|---|---|
| homogeneous | 49 | 69% |
| homogenisation not possible | 11 | 15.5% |
| homogenised | 11 | 15.5% |
| | 71 | 100% |




*Annual precipitation sums [mm] for Galtür (170000). The black line displays the original data, red the applied homogenization and orange the homogenization if one of the other two reference stations would have been used.*

# maximum precipitation





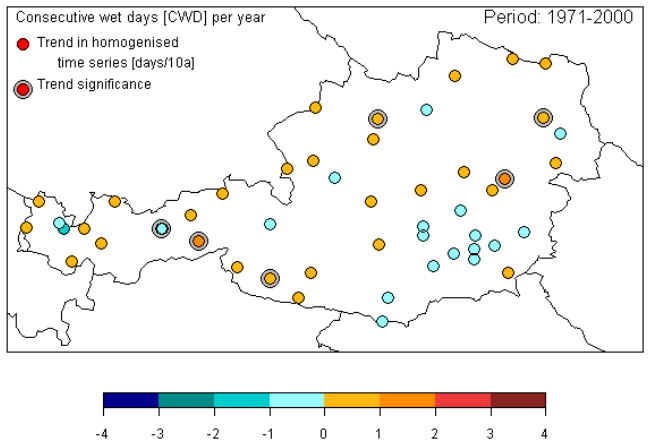

Trend of maximum one-day precipitation for the period 1971-2000 for all homogenised precipitation series in Austria (left). trends of maximum five-day precipitation (right).

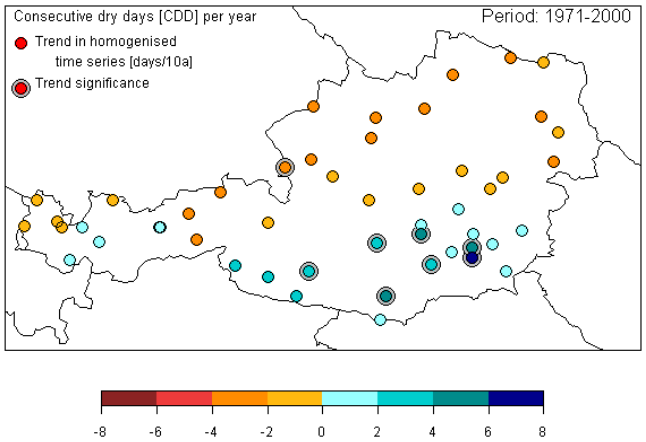
variable behavior of daily precipitation sums related to maximum precipitation

not very significant, towards weaker precipitation events in the southeastern parts of Austria

the northeast experiences a weak intensification of maximum five-day precipitation sums

# consecutive wet and dry days






Left: Trend of number of consecutive wet days (CWD) per year Right: Trend of the number of consecutive dry days (CDD) per year for the same stations and the same period.

South of the alpine divide a trend towards longer dry periods, with most of the trends being significant. In the northern part CDD trends are negative.

However, the apparent CDD pattern is not balanced by reversed trends in the CWD (consecutive wet days) index.

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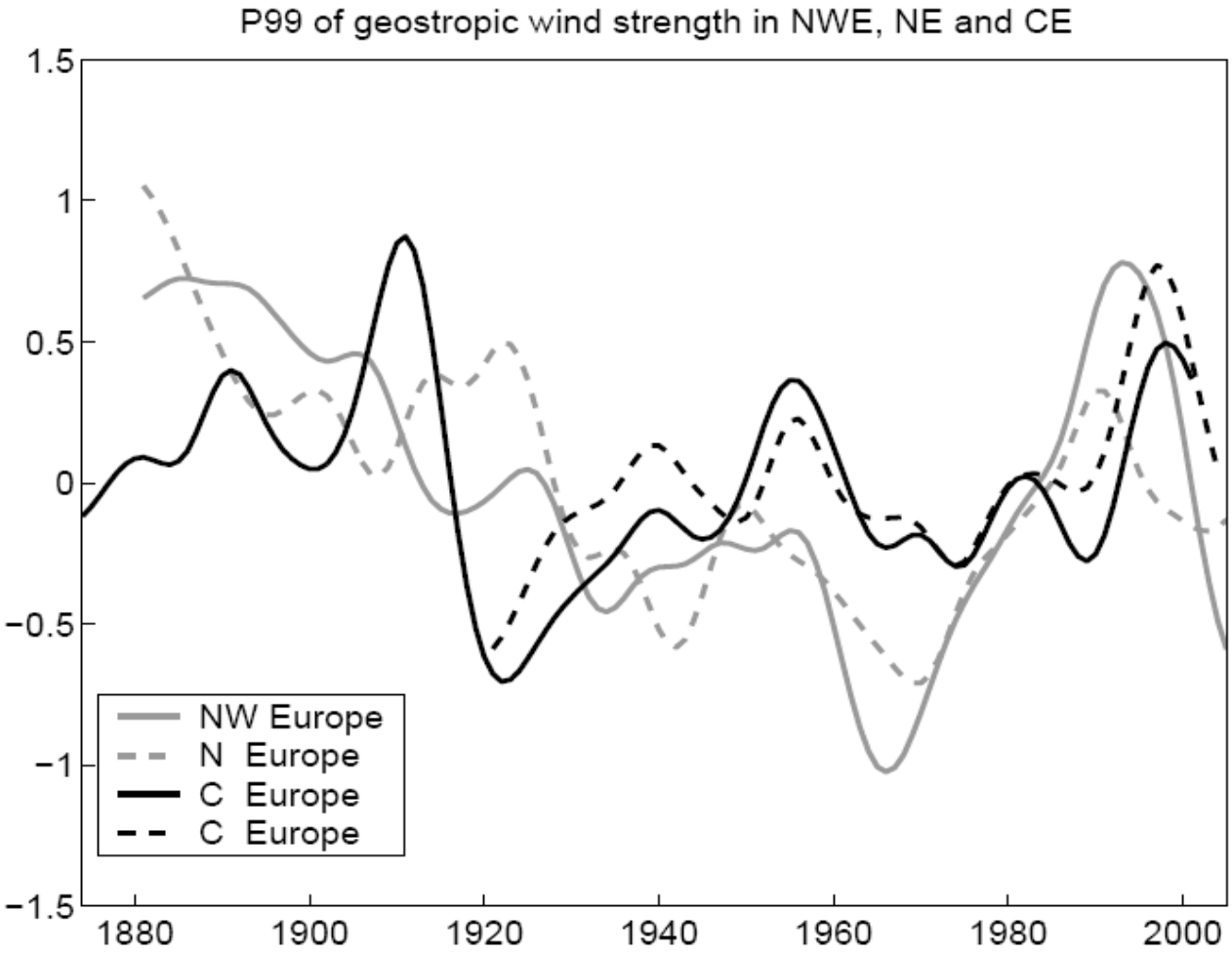
# Storminess – no wind data






Matulla C, Schöner W, Alexandersson H, von Storch H, Wang XL, 2007. European storminess: late nineteenth century to present. *Climate Dynamics* **29**: DOI 10.1007/s00382-007-0333-y

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# climate knowledge – climate services

**CCCA Servicezentrum** since 2012 to provide extensive information and data about climate change and impacts, not at ZAMG



Informationsportal Klimawandel -
http://www.zamg.ac.at/cms/de/klima/informationsportal-klimawandel


120 textmodules: climate of the past, climate future, impacts, climate basics: how climate works and working on climate

# Climate Services

**Standpunkt**
Der hilfreiche Einstieg ins Portal. Neben einem Überblick über alle Artikel finden Sie allgemeine Worte zur Klimawandeldiskussion. mehr ...

**Klimaforschung**
Worauf basieren die Vorstellungen von der Klimavergangenheit und die Annahmen über die Klimazukunft? mehr ...

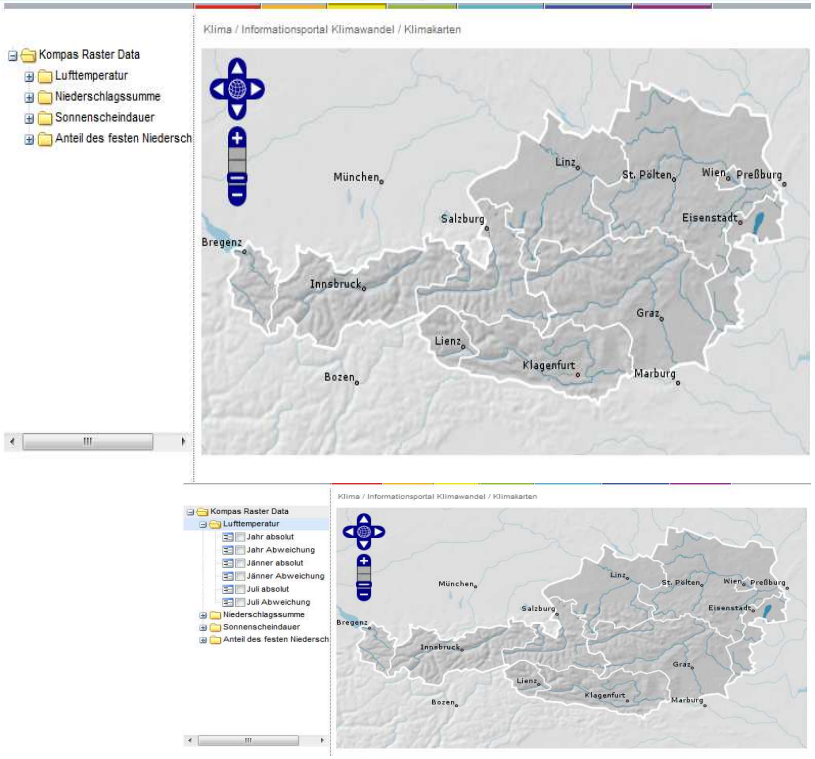
**Klimasystem**
Klimaschwankungen werden durch Antriebe angestoßen, die im vernetzten Klimasystem meist nicht auf direktem Weg umgesetzt werden. mehr ...

**Klimavergangenheit**
Lernen Sie die Phasen der Klimageschichte, vom Tropenklima des Mesozoikums zum pleistozänen Eiszeitalter, richtig einzuordnen! mehr ...

**Klimazukunft**
Hier finden Sie einen Überblick über aktuelle Ergebnisse globaler und regionaler Klimasimulationen mit Fokus auf den Alpenraum. mehr ...

**Klimafolgen**
Klimaänderungen beeinflussen andere Naturbereiche, die wiederum auf das Klima rückwirken. Das prägt den Lebensraum des Menschen. mehr ...

**Klimakarten**
Verfolgen Sie die Entwicklung des Klimas in Österreich vom späten 18. bis zum Ende des 21. Jahrhunderts! mehr ...

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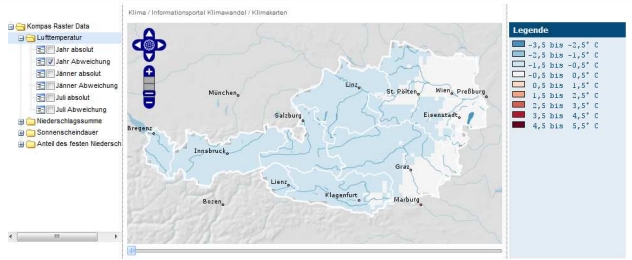
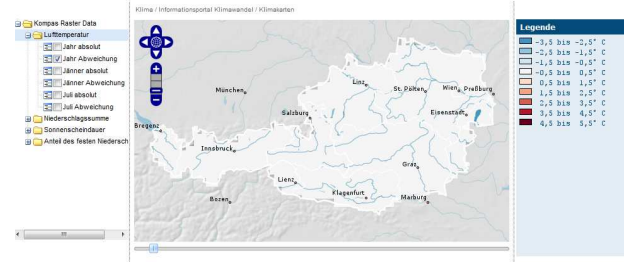
# 1781 - 1900




1791 bis 1800

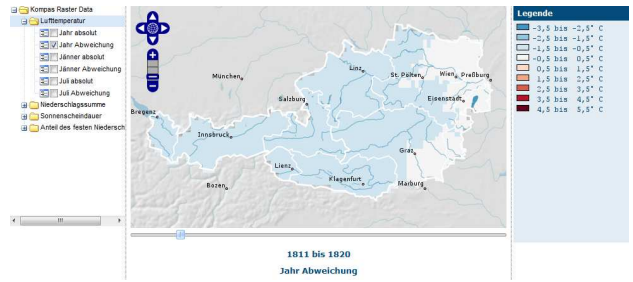
Jahr Abweichung


1801 bis 1810

Jahr Abweichung

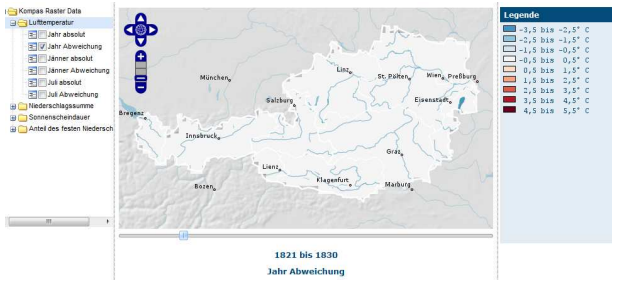
mittlere jährliche Lufttemperatur – Abweichung zum Zeitraum 1971–2000

mehr Information zu Datenerstellung und Interpretierbarkeit (bis 2000 | nach 2001)



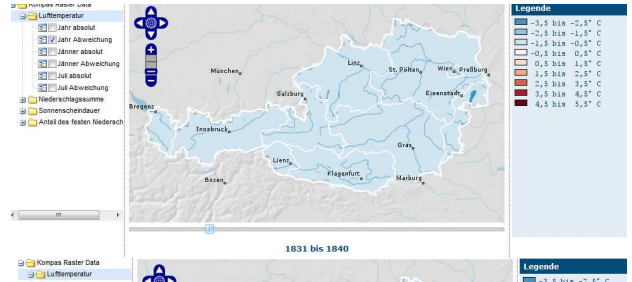

1811 bis 1820

Jahr Abweichung

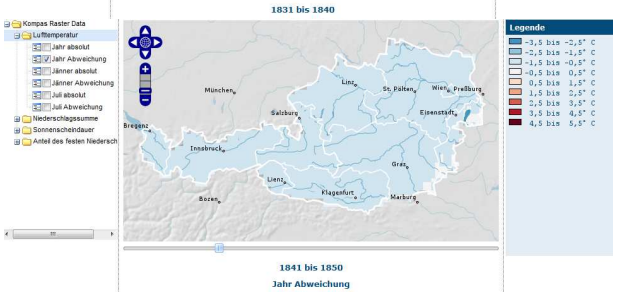



1821 bis 1830

Jahr Abweichung

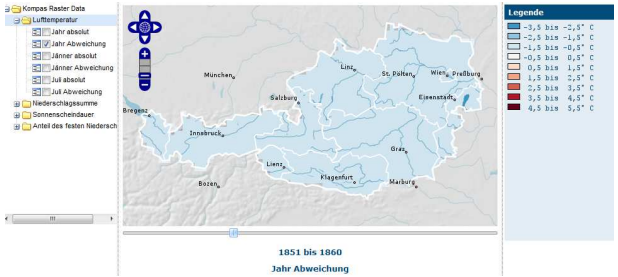



1831 bis 1840



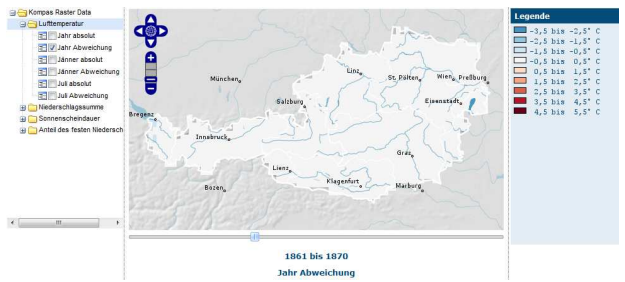

1841 bis 1850

Jahr Abweichung



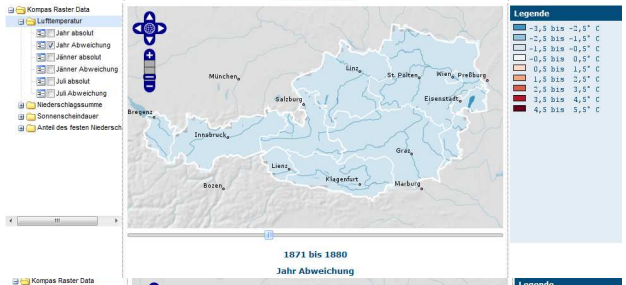

1851 bis 1860

Jahr Abweichung



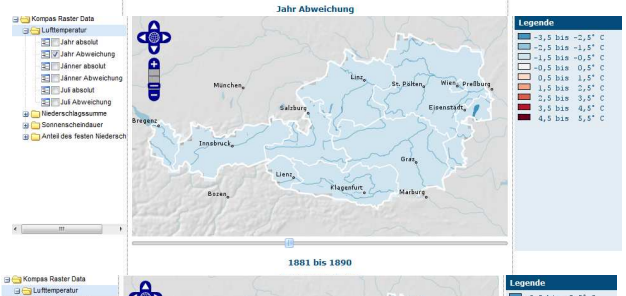

1861 bis 1870

Jahr Abweichung




1871 bis 1880

Jahr Abweichung




1881 bis 1890


1891 bis 1900

Jahr Abweichung

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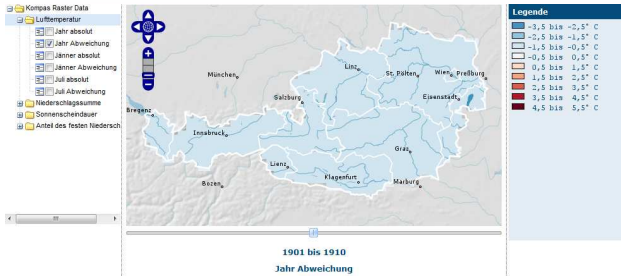
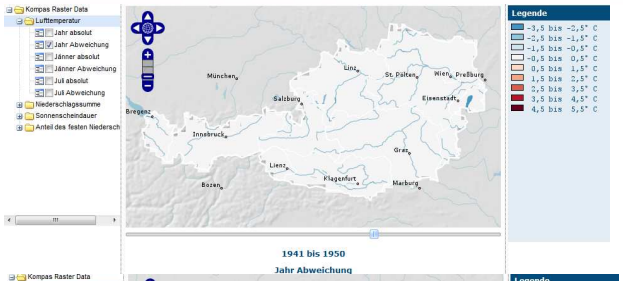
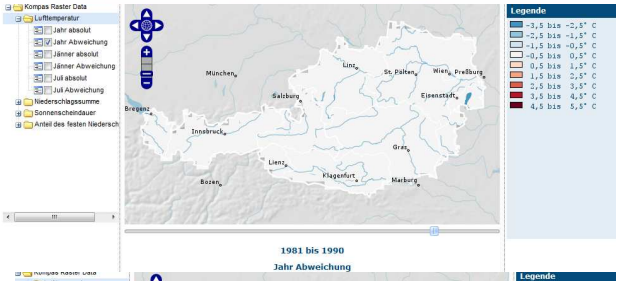
# 1901 – 2000, 2001 – 2030, 2031 - 2060



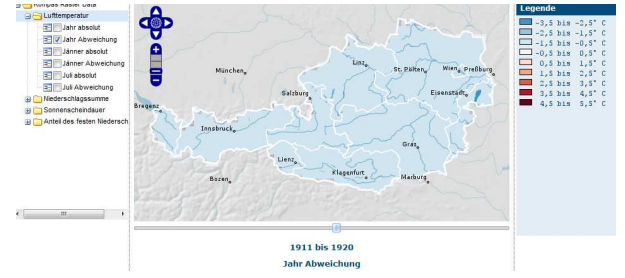

1901 bis 1910
Jahr Abweichung



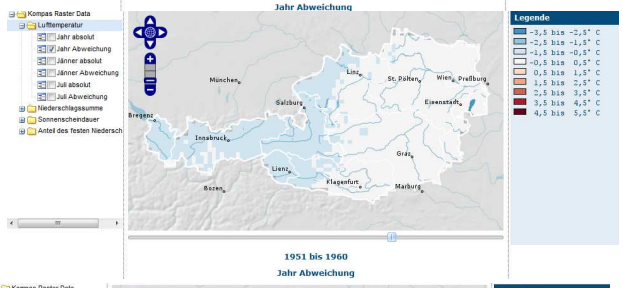

1941 bis 1950
Jahr Abweichung




1981 bis 1990
Jahr Abweichung

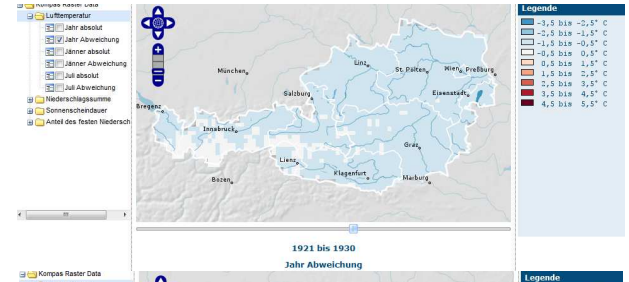



1911 bis 1920
Jahr Abweichung

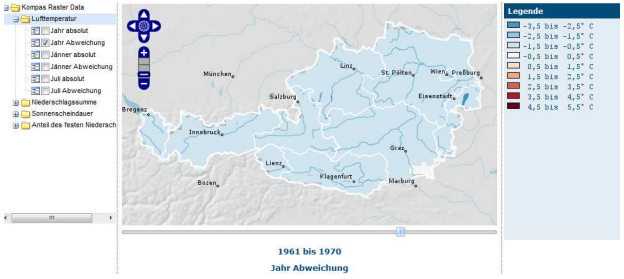



1951 bis 1960
Jahr Abweichung


1991 bis 2000
Jahr Abweichung

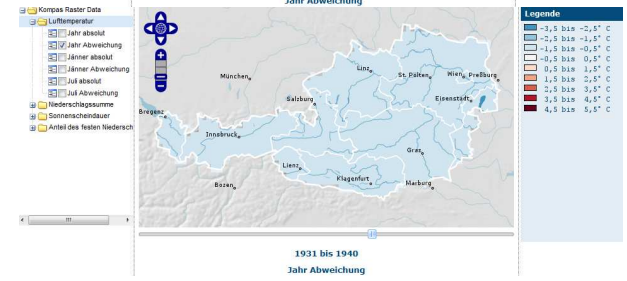



1921 bis 1930
Jahr Abweichung

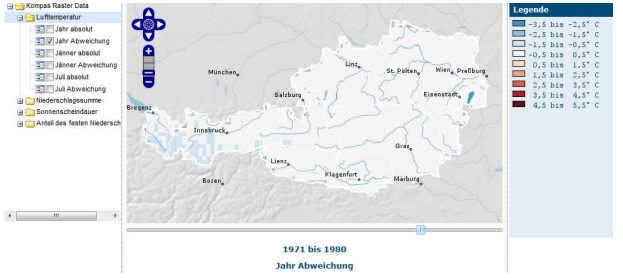



1961 bis 1970
Jahr Abweichung


2001 bis 2030
Jahr Abweichung




1931 bis 1940
Jahr Abweichung




1971 bis 1980
Jahr Abweichung


2031 bis 2060
Jahr Abweichung

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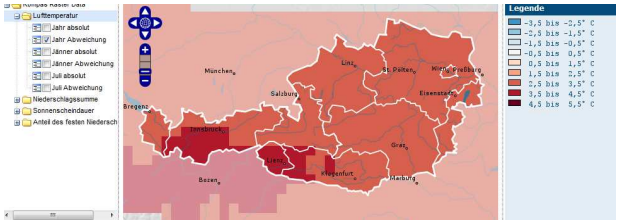
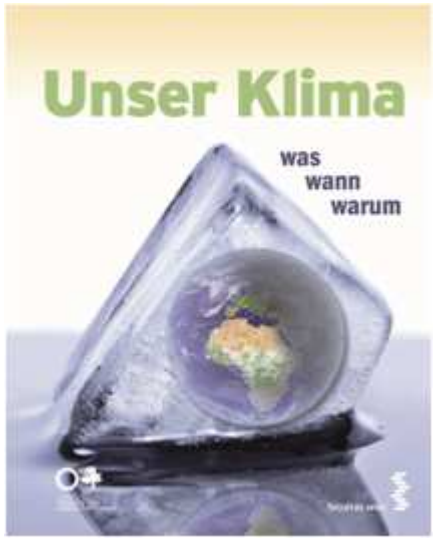
# 2061 - 2090




**FAQ**



**1. Ändert sich das Klima?**
**2. Werden Unwetter häufiger?**
**3. Werden die Sommer heißer und trockener?**
**4. Gibt es in Österreich bald keinen Schnee mehr?**
**5. Verschwinden die Übergangsjahreszeiten Frühling und Herbst?**
**6. Verschieben sich die Klimazonen?**
**7. Verschwinden die Gletscher in Österreich?**
**8. Schmilzt das Eis der Antarktis und Grönlands?**
**9. Wie ändert sich der Meeresspiegel?**
**10. Wie kann man zur Verringerung der Erderwärmung beitragen?**

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# Thank you  for your attention !