THE INSTRUMENTAL PERIOD IN THE GREATER ALPINE REGION

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Introduction:

ALP-IMP intends to use the unique data potential existing in the "Greater Alpine Region " (GAR) to produce a consistent picture of regional climate variability during the last 1000 years. Instrumental series with a monthly resolution of the last 250 years may contribute to this topic. In regard to this ALP-IMP does not need to start at zero, experiences and knowledge from finished and ongoing projects are available. The following presentation extracts and combines results of the Projects ALOCLIM, ALPCLIM and CLIVALP.

Why is the Greater Alpine Region of special interest? – What additional information can we provide?

Climate variability can be studied within a vertical structure between sea-level and 4000 m above sea-level.
The Alps are a sharp climate divide between Atlantic, continental and Mediterranean influences
Alpine regions have a high climate change sensibility – Alpine ΔT 1890-2000= 2 times ΔT global
The Greater Alpine region offers a high spatial density of stations
Instrumental series go back into the 18th century (since 1760)
Climate variability can be studied in a multiple sense – we are not only investigating into air temperature and precipitation,
The greater Alpine region is highly sensitive for climate impacts (e.g. topographical enhanced water cycle plus steep orography resulting in flooding, debris flows, avalanches, vertical plant migration etc.)

Reliability of long-term series

Whenever we are dealing with instrumental data we first have to question their reliability, especially with data from the former centuries. Historical climate time series carry the information of natural and artificial variability. This means that all artificial biases have to be removed before climate variability can be studied (This is a very hard job, but unavoidable). What are the causes of artificial biases? These are changes concerning the whole network operations as well as individual station-specific changes, and this is a long list. Here, a selection of four examples can be shown.

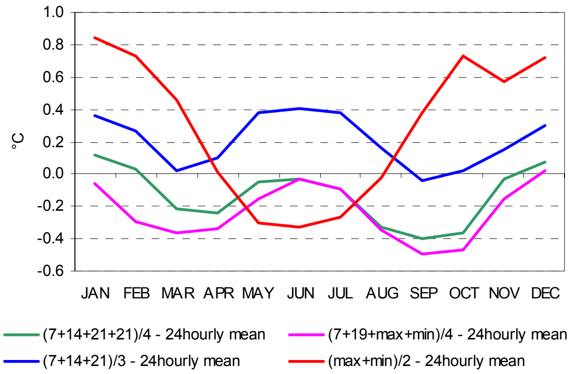


Figure 1 shows the evolution through the year of the difference between different ways of calculating daily mean temperature and the 24hourly average for the inner-alpine station Puchberg in Austria, 1987 –1996. Errors are varying in a range of +0.9 and –0.5 deg C . Data source: Central Institute for Meteorology and Geodyamics, Vienna, Austria.

Figure 1: : Example for inhomogeneities Changes in the formulae of the calculation of mean temperature.

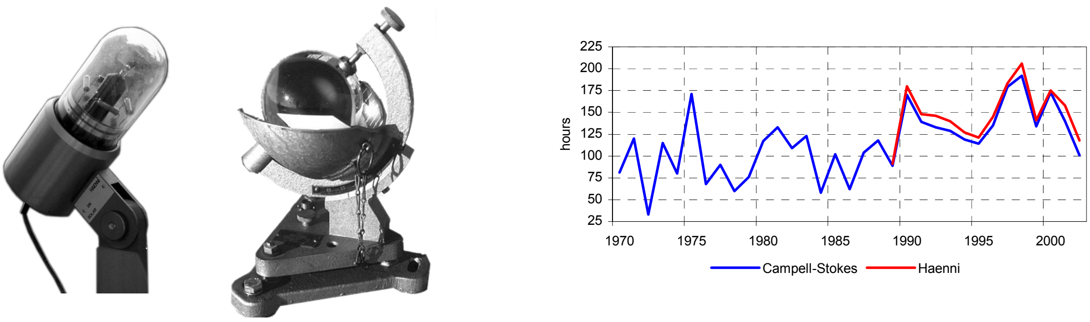


Figure 2: : Example for inhomogeneities: Introduction of automatic weather stations into the network documented by the hours of bright sunshine for February 1971-2002 for the station Graz-University. Data source: Central Institute for Meteorology and Geodyamics, Vienna, Austria.

Figure 2 shows two types of instruments to record sunshine duration: Campbell-Stokes sunshine autograph and Haenni Solar system of automatic weather stations (on the left). Consequences (on the right): time series of hours of bright sunshine for February in Graz-University (366m asl.) since 1970: Campell-Stokes sunshine autograph (blue curve). With the introduction of the automatic weather station a Haenni solar system (red curve) was installed next to the Campbell-Stokes, which in February systematically records an excess of sunshine. Sunshine has increased since 1970: for the unchanged Campbell Stokes 2.13 hours per year, continuing the series with Haenni solar since 1989 the trend would be biased with an excess of 0.45 hours per year.

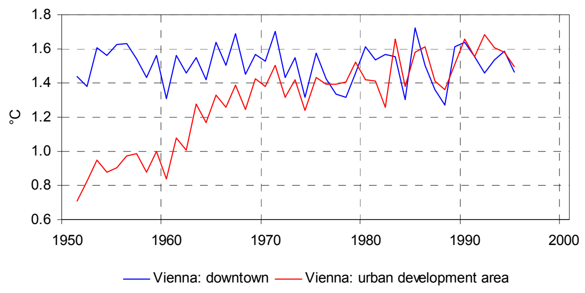


Figure 3: Example for inhomogeneities: Urban bias in long-term series: Data source: Böhm, R.: Urban bias in temperature series – a case study for the city of Vienna. Climatic Change 38: 113-128, 1998.

Figure 3 shows the time series of annual mean urban temperature excess (relative to rural mean) 1951 to 1995based on height reduced temperature records. The station in the densely built-up area shows a stable temperature excess against the rural surroundings, whereas the trend of temperature excess at the station in the urban development area is 0.18 °C per decade.

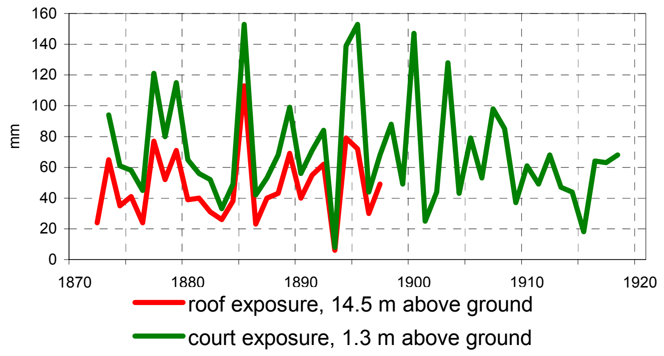


Figure 4: Example for inhomogeneities: Exposure of instruments

Figure 4 shows the precipitation series for April at Pula Monte Zaro (Croatia). Measurements were taken on the roof of the building of the K.K. Hydrograhical Office from July 1871 and also in the courtyard from 1873. The period of parallel measurements lasted from 1873 until 1897. The mean precipitation amount of April at the roof exposure shows a deficiency of 35% compared to courtyard exposure. Data sources: Jahrbücher der k.k. Central-Anstalt für Meteorologie und Erdmagnetismus 1871-1915, Wien, Beiträge zur Hydrographie Österreichs, X. Heft, Lieferung II, Wien and Archivio del Ufficio Centrale di Meteorologia e Geofisica Italiano, Roma.

The question of homogeneity:

These examples demonstrate that normally long-term climatological series have been affected by a number of non-climatic factors that make these data unrepresentative for climate variability studies and can lead to misinterpretations. It is important, therefore, to remove these inhomogeneities and to determine its errors. This should be preferentially done by a combined approach of studying all available metadata and using statistical homogeneity tests. Non-climatic inhomogeneities are not necessarily random! The average of the adjusted air temperature series of the GAR, for example, reveals a general increasing trend of appr. 0.5 K from the mid-19th to the end of the 20th century (Figure 5).

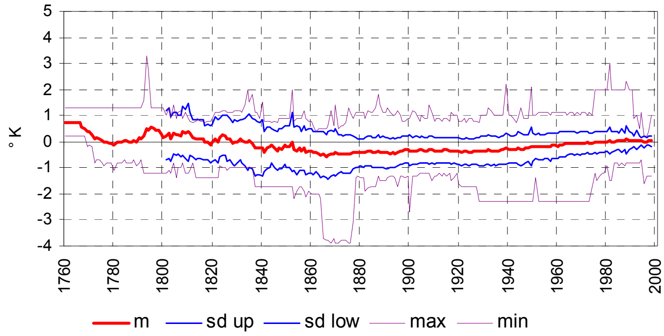


Figure 5: Adjustment curves (homogenised minus original) averaged over all Alpine long-term annual mean temperature series.

Alpine Multiple long-term series

Climate variability is more than the variability of air temperature and precipitation. For that, ALP-IMP will study climate variability out of a pool of multiple-series including also air pressure, cloudiness-sunshine duration, MDR of temperature, relative humidity, vapour pressure and snow.

Moreover, multiple series allow to study the reaction of the other climate elements to the increasing temperature and the potential forcing of other elements on temperature. Such studies have been conducted within the ongoing Project CLIVALP. One example is given for the relationship between mean air temperature and the number of frost days: Based on the daily measurements of 200 stations non linear analytical functions explaining the monthly relationships between mean air temperature and frost days frequencies have been used to investigate into the following topic: Where are the frost sensitive regions in Austria?

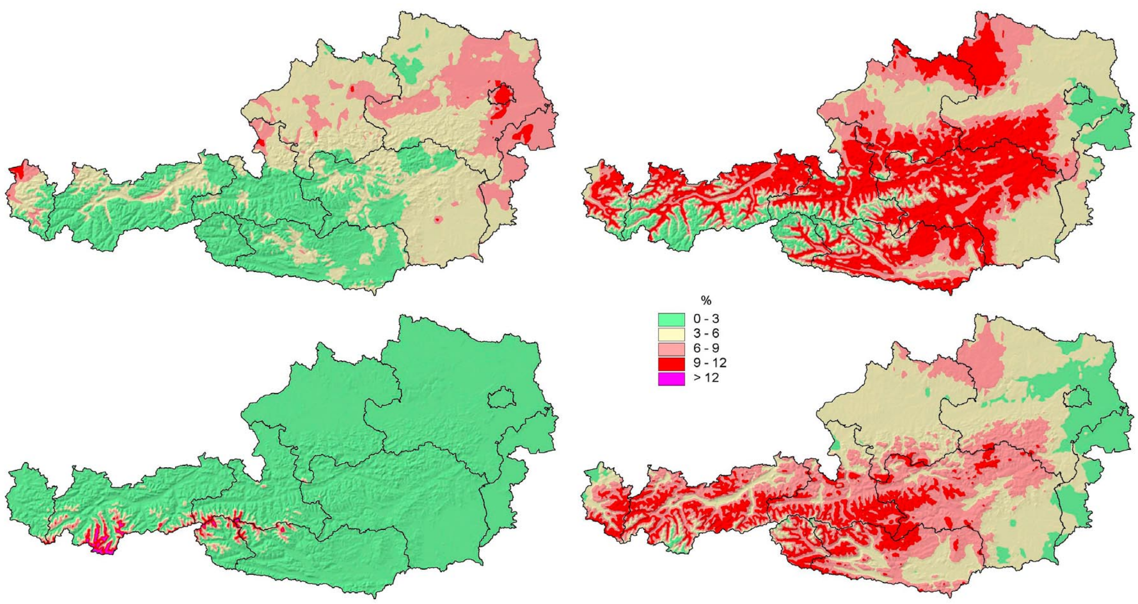


Figure 6: Sequences of maps of Austria showing the sensitivity of frost frequencies in regard to a temperature change of 1 K (in percent of months lengths) during January, April, July and October (from top left to bottom right). Figure from Auer et al., 2003.

Alpine long-term series are objects to study also vertical effects of climate variability:

An impressive example gives us the difference series of the long-term evolution of high level and low level sunshine series. Although the features of the low elevation stations show only minor differences among them, the high elevation curves do differ significantly from the low elevation sites. With their centennial increasing trend of bright sunshine hours, high elevation stations show a strong parallel with temperature curves. In contrast, this similarity is not true for low elevation stations. The second half of the former century is especially characterised by a reduction of sunshine at low elevation sites, a significant trend of 1.6 hours per year of the difference series of high and low elevation stations becomes obvious. The effect is similar in winter and summer. This effect has been the subject of a study (Auer et al., 1998) which discusses an increase of boundary layer turbidity as a potential cause.

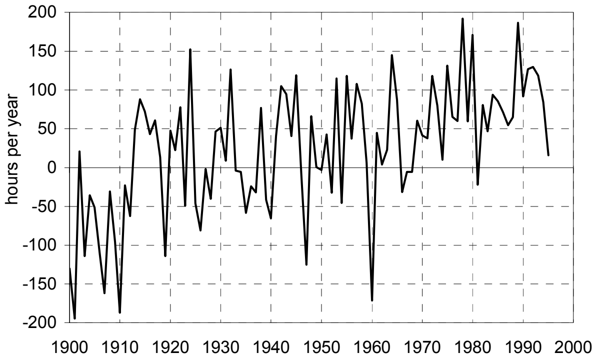


Figure 7:Annual hours of bright sunshine, differences high elevation minus low elevation. Data source ALOCLIM.

What do we know about Alpine temperature?

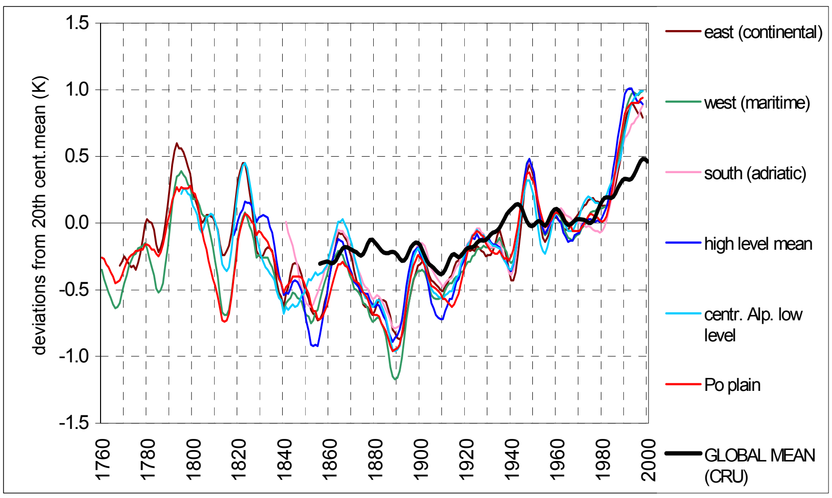


Figure 8: Annual regional mean temperature series in the Alps plus global mean (deviations in K from 20th century mean) smoothed with a 30yrs Gaussian low pass filter

It is evident that the regional temperature anomalies are highly correlated, not only on an annual scale but also on a secular time scale with a range of the filtered curves between +/- 1 K. Prior to 1850, the range gently increases, which might be due to reduced station density in the early parts of the series. In this connection, we are interested in the spatial representativity of temperature measurements. Especially for ALP-IMP, the question about the spatial representation of an ice core taken at a high western Alpine site arises.

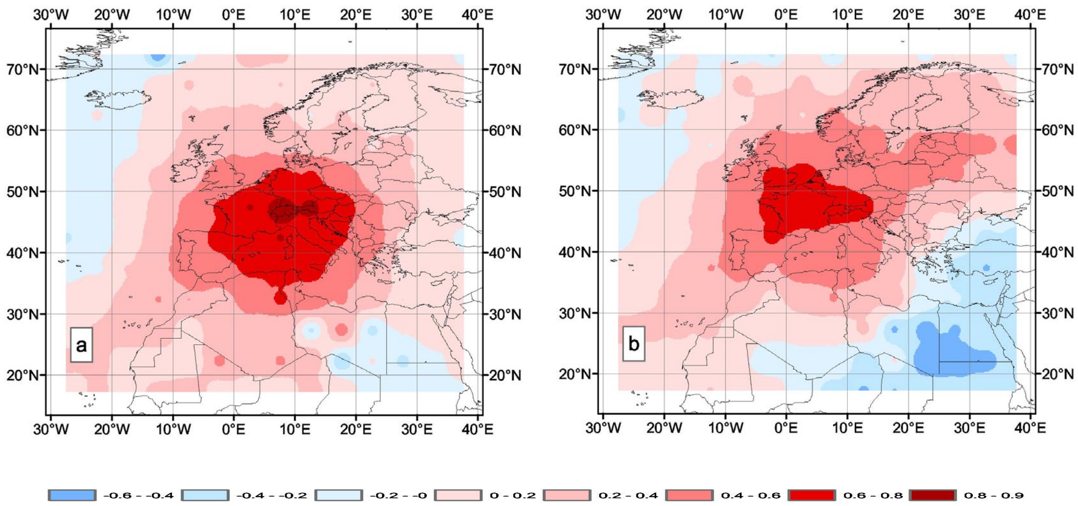


Figure 9: Spatial representation of temperature information from a high elevation western Alpine site for low elevation Europe (left summer, right winter)

What do we know about Alpine precipitation?

The work on the precipitation data set of the GAR consisting of 192 single series is under way. Compared to temperature the precipitation series show significantly different variations on a regional scale. Moreover, the picture becomes more complicated by the effect of different annual courses. In the northern Alpine region the precipitation series show a distinct maximum during the warm season, whereas in the Mediterranean the autumn amounts exceed those of the summer season. For different seasons reverse trends are obvious.

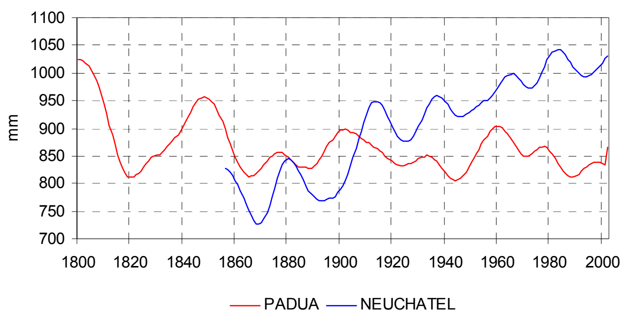


Figure 10: Annual precipitation sums of Padua (Italy) and Neuchatel (Switzerland). The 30yrs. smoothed values show completely different trends.

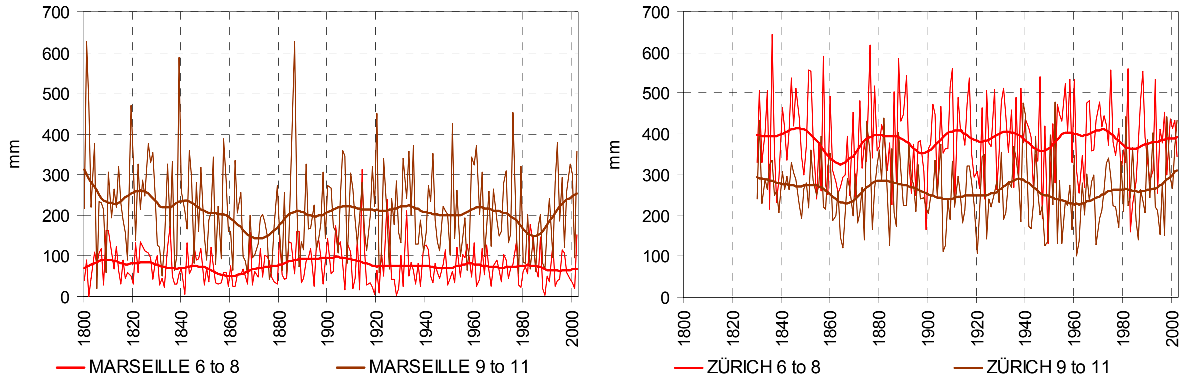


Figure 11: Comparison of seasonal precipitation amount in Marseille and Zürich.

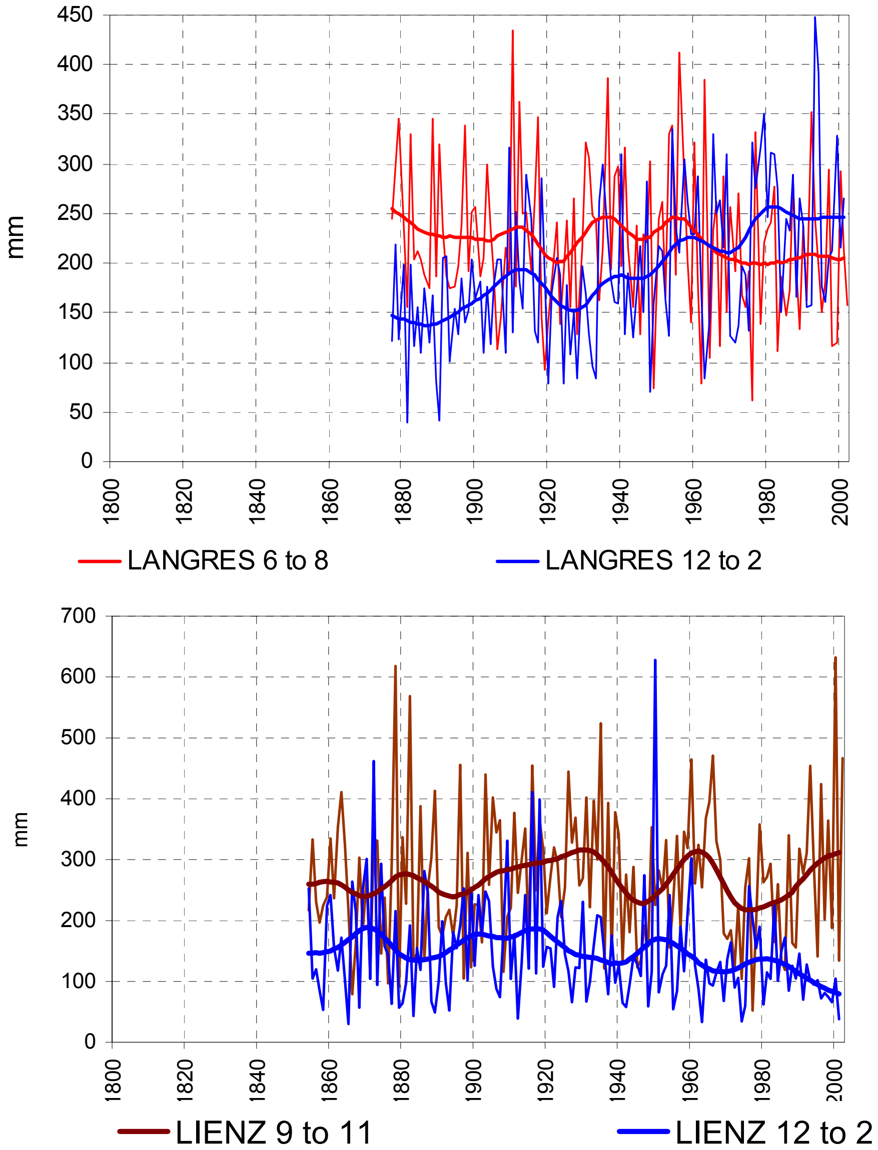
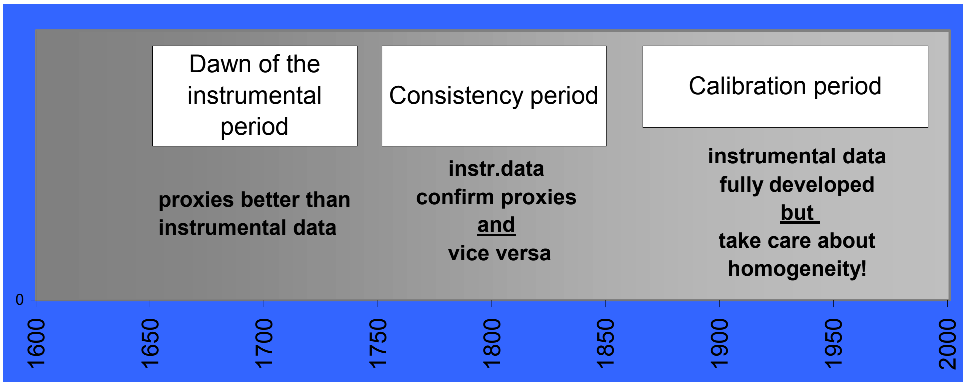


Figure 12 : Two examples of reverse seasonal trends: Summer drying versus winter wetting in Langres (Bourgogne, FR) and Winter drying versus autumn wetting in Lienz (south central Alps),, most pronounced since 1980

Potential of instrumental data for paleo-reconstruction



Conclusions

Homogenising is necessary – otherwise there are not only errors in single series – there are also systematic biases in larger regions

Homogenising should be based on mathematical tests plus metadata

The time series potential in the Alps is high – due to the length of the series and due to network density

Long-term temperature trends (back to 1760) are highly similar in the Alpine region, but there are seasonal differences

Long-term precipitation trends (back to 1800) show strong spatial and seasonal differences

Combined trend analysis (of several climate elements or of climate series in different altitudes) contributes much to a better understanding of the complicated pattern of the climate system

Since 1900 climate variability can be fully described by instrumental series, in earlier parts a vice-versa confirmation of instrumental data and proxies is recommended. For the earliest parts of the series we hope that proxies will confirm the measurements.

References:

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