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REGIONAL PRECIPITATION VARIABILITY IN THE EUROPEAN ALPS 1803 – 1998 FROM HOMOGENISED INSTRUMENTAL TIME SERIES

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1. INTRODUCTION

In the frame of the European ALPCLIM project a high quality instrumental climate data base was produced to provide instrumental climate information from the regular measuring network to the high elevation ice core sites (Mont Blanc and Monte Rosa) for the development of climate proxy information.

As the proxy information from the high elevation ice cores could be expected to cover the climate element temperature mainly, the activities initially concentrated on instrumental temperature data. To study also possible systematic biases of the climate information in the ice cores due to the fact that the "ice core calendar" per definition only stores climate information during precipitation episodes, also precipitation was included into the project. To enable studies on spatial representativity of the climate information from the ice core sites it became evident quite soon that a spatially extended dataset was desirable. Previous studies in other regions (e.g. Moberg and Alexandersson, 1997) could show that the existing global datasets (Jones, 1994, Jones et al., 1999, Vose et al., 1993, Eischeid et al., 1991, Hulme, 1992, Hulme et al., 1998) have difficulties to meet the quality demands in terms of homogeneity at regional to local scale. A number of studies (Peterson et al, 1998, Auer et al., 2001, Hanssen-Bauer and Nordli, 1998, HMS-WMO 1997 and 1999 among others), could show that strictness in terms of homogeneity is an non negligible precondition for climate variability studies. Non climatological noise in the original series is as large as or larger than the true climate signal. In the Alps there have been some national attempts to homogenize instrumental time series (e.g. Aschwanden et al., 1996, Auer, 1993, Böhm, 1992, Maugeri and Nanni, 1998) but none covered the whole "Greater Alpine Region" (GAR) and some did not use the whole length and spatial density of the instrumental series in the region (which makes the instrumental GAR data potential unique in the world).

Thus the ALPCLIM community decided in the initial phase of the project to carry out a complete re-analysis of the long-term instrumental temperature and precipitation series in a region extending from 4 to 18 deg E and 43 to 49 deg N – understanding "re-analysis" as a collection of all available long-term series to really use the data-potential in the region in terms of length and spatial density, a common and accurate homogeneity check of the series, an elimination of non climatic inhomogeneities and an interpolation to a regular grid to overcome limitations due to inhomogeneities in spatial coverage.

2. HOMOGENISATION

All series, original and pre-homogenised, were re-analysed for inhomogeneities based on the following system: homogeneity testing, adjusting and gap-closing was performed in a number of regional sub-groups of 10 series each using the MASH-test of Szentimrey (1999) and the HOCLIS procedure (Auer et al., 1999). HOCLIS (and also the system used by Météo-France, Mestre, 1999) rejects the a priori existence of homogeneous reference series. They test each series against other series in sub-groups of 10 series. The break signals of one series against all other series are then collected in a decision matrix and the breaks are assigned to the single series according to probability. This system also avoids trend imports and an inadmissible adjustment of all series to one or a few "homogeneous reference series". For temperature high elevated sites (>1500m asl.) were treated separately in two high elevation subregions, for precipitation no homogenisable high elevation series were available due to the well known difficulties of precipitation measuring at high alpine sites which is strongly biased by wind and a high amount of solid precipitation.

Not all of the 120 temperature and 180 precipitation series met the requirements in terms of homogeneity. A final total of 97 temperature and 157 precipitation series proved to be homogenisable. A total of 1000 breaks were detected in the original, pre-homogenised series. This represents an average of about 4 breaks per series or in other words a homogeneous sub-interval of an

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average series not longer than approximately thirty years. The availability and the quality of the metadata are different for the different regions and, besides stations with very well documented history, the dataset also contains stations for which only limited metadata were available. As a consequence, it was not possible to perform a complete comparison of the identified inhomogeneities with the history of the stations. It is however, worth noticing that a high percentage of the breaks could be explained through metadata where high quality information was available (for details see Auer et al., 2001).

A comparative analysis of the original and the homogenized temperature series confirmed the necessity of the re-analysis in terms of homogeneity, in fact a systematic bias of an under-estimation of the long term temperature trend in the region by the original series of 0.5°K was identify (for details see Böhm et al., 2001).

2.1 Precipitation

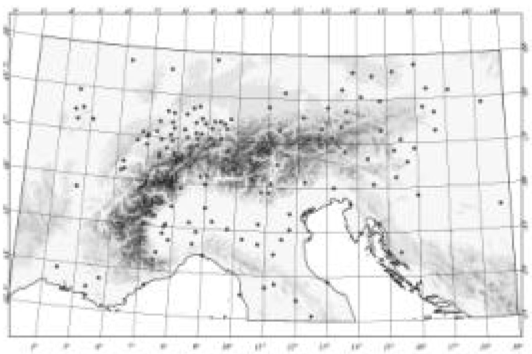

Figure 1. The ALPCLIM-network of homogenised long-term temperature (a) and precipitation (b) time series. Dots: low level series (<1500m asl), triangles: high level series (>1500m asl).

With regards to precipitation, the final 157 station dataset is shown in figure 1.

The temporal coverage of the homogenised dataset runs from 1803 to 2000, but the station density is not uniform along the whole period as shown in figure 2.

Figure 3 shows the logarithm of the mean adjustment curves (obtained by dividing each homogenised series by the corresponding original ones and averaging over all the stations) for the summer and the winter half year and for the entire year plus the standard deviation. The standard deviation range underlines the absolute necessity to homogenise in order to get any reasonable single station series. As the number of stations is limited in the early period (see Figure 2), the adjustment curve shows greater variability before the mid-19th century and reflects single site peculiarities more than general systematic evolutions (before 1831 standard deviations were not calculated due to a sample size less than 10). With the founding of Meteorological Services in the Alpine countries in the 1850s and 1860s, the number of series quickly increased and the adjustment curve becomes less noisy. The average of the adjusted series reveals no significant trend for the 150 years from the mid-19th to the end of the 20th century, allowing us to say with confidence that the inhomogeneities did not add any non climatic signal.

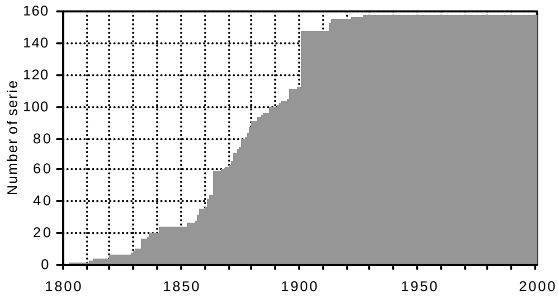

Figure 2. Temporal coverage of the instrumental area in the Alps by homogenised precipitation records.

This is true also considering national subset. Figure 4 shows three examples of national subset – those covering the majority of ALPCLIM series (more than 80%) and also those with the best metadata coverage. The same characteristics observed for the whole ALPCLIM dataset are evident: a noisy behaviour before 1850 and a progressive reduction in standard deviation throughout the last 150 years (before 1866, 1837 and

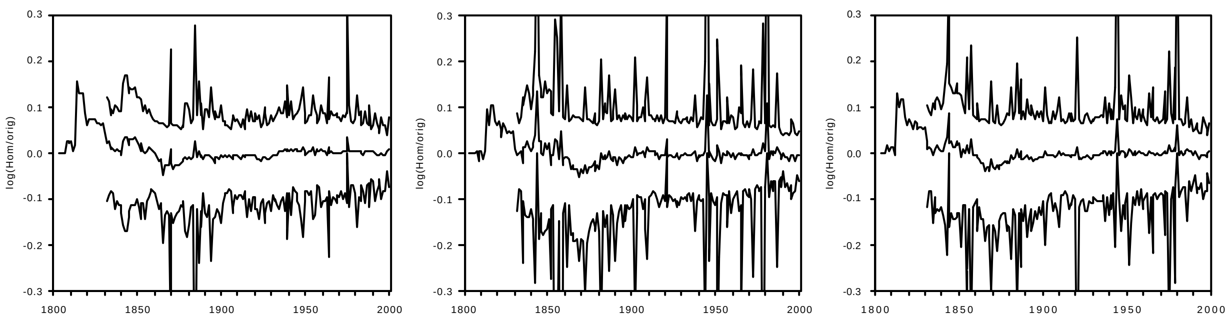

Figure 3. Long-term adjustment curves (homogenised / original) averaged over all 157 ALPCLIM sites for summer-half year (a), winter-half year (b) and year (b).
Bold line: mean, medium lines: standard deviation range, thin lines: absolute range.

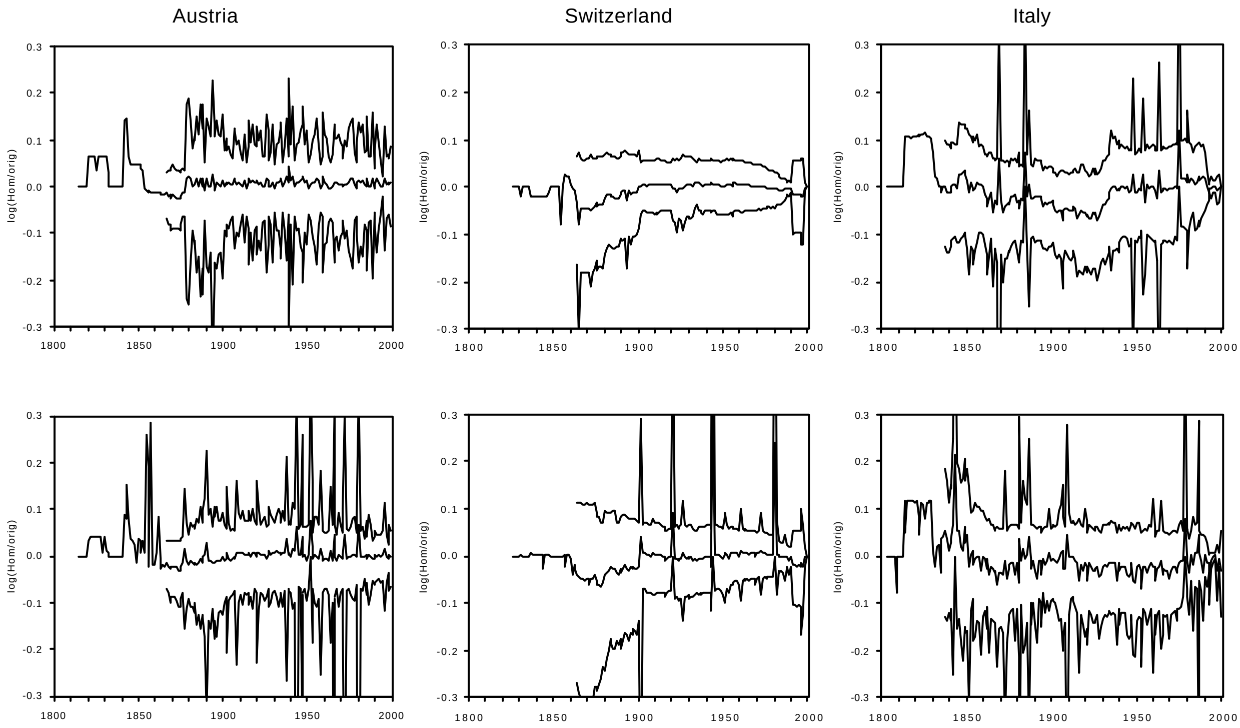

Figure 4. Mean adjustment curves (homogenised / original) for three national ALPCLIM subsets. Top: summer half year (4 to 9), bottom: winter half year (10 to 3).

1864, for Austria, Switzerland and Italy respectively, the standard deviations were not calculated due to a sample size less than 10).

The described homogenising procedure produced 157 instrumental series of total monthly precipitation covering a 682,000 km^2 area. Such a relatively high station density makes the dataset usable for studying not only mean climate variability but also its regional structure and patterns within the region. For easier and more systematic mathematical handling, and to enable a comparison with other gridded datasets, the single series were interpolated to grid points.

3. REGIONALIZATION

Unlike temperature with highly similar long-term variability in the entire study region, precipitation shows considerable spatial differences according to seasonal mean features as well as according to short-term and long-term variability.

Figures 5 and 6 show the regionally different mean annual courses of precipitation in the GAR. The main climatic divide is the Alps with a prevailing Summer maximum north of the Alps and a bimodal annual course in the south. The latter can be sub-divided into three groups – one in Piedmont with the main maximum in Spring, one in the central and eastern south with the main maximum in Autumn and one in the southwest and southeast with an Autumn maximum and very low summer precipitation. The fifth group in the north-east shows a summer maximum and an additional weak Autumn maximum.

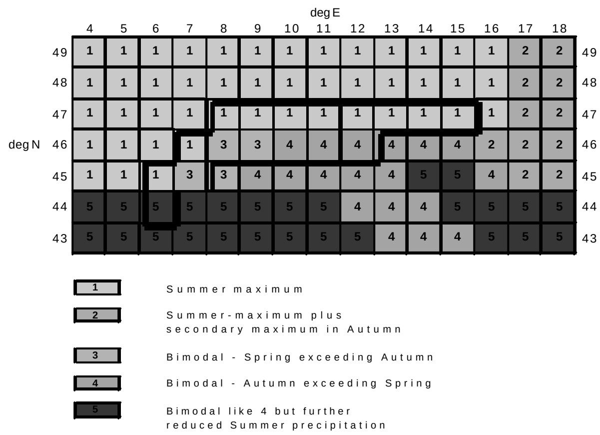

Figure 5. Regionalisation of the study region according to mean annual course of precipitation

A regionalisation in respect to variability patterns was carried out using a principal component analysis for clustering (figure 7). The result is similar but not identical to the regionalisation based on mean annual course. Again the Alps are the main divide. The second variability structure is a meridional one – sub-dividing the region north of the Alps in a western and an eastern part, whereas south of the Alps three sub-regions could be identified.

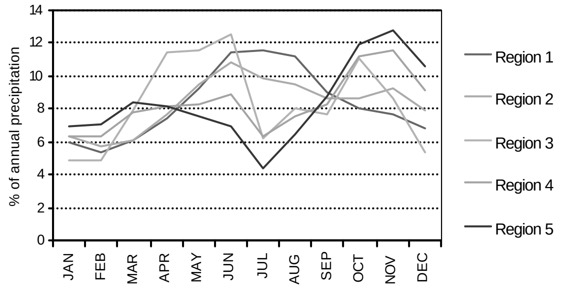

Figure 6 Mean annual course of precipitation in the sub-regions of Figure 5.

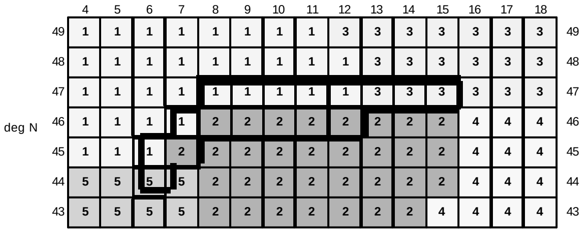

Figure 7. Map of precipitation sub-regions based on Principal Component Analysis clustering.

PCA clustering reflects short term variability rather than long-term variability and does not necessarily mean that the long-term evolutions in the spatial sub-regions are different.

4. CONCLUSION

A re-analysis of the long-term instrumental temperature and precipitation series of the "Greater Alpine Region" (GAR) in terms of eliminating non-climatic inhomogeneities produced two high quality gridded datasets significantly and systematically different from existing global scale datasets.

Temperature variability in the Alps is representative for large parts of Europe, highly representative for a region ranging from northern Germany to northern Algeria and from western France to mid Hungary in Summer, slightly smaller (and more orientated to the West) in Winter.

Precipitation variability shows more complicated spatial patterns – there is no single GAR-precipiation series representative for the whole region.

Both temperature and precipitation gridded data will be widely available without restrictions for scientific research and can be obtained from the authors.

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