# ANNEX 2

# ABSTRACT-COLLECTION

of all peer reviewed ALP-IMP project papers

and of

a selection of non reviewed project papers

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**ALP-IMP-rev-01**

*WMO-TD* **1186** *WCDMP* **53,** 53 pages

# GUIDANCE ON METADATA AND HOMOGENIZATION

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## 1 RATIONALE

If we measure rainfall, in order for the data to be useful for future users, we also need to document where and how the measurements were made. Station documentation is information about the data or data about the data: metadata. The word metadata is made up by the addition of the Greek "meta" (beyond) and the Latin "datum" (a given fact). Metadata should reflect how, where, when and by whom information was collected. Ideally, complete metadata should register all the changes a station has undergone during its lifetime, composing what is called the station history.

Supplementary information about the observations, such as type of instrument or exposure, can provide additional insights into interpreting the observed quantities. Sometimes when the instruments change, the observations will show an artificial increase or decrease. Such a jump in the measured amount is an example of an inhomogeneity and adjustments to these data are often applied to account for the effects of the inhomogeneity. If a long-term time series is homogeneous, then all variability and change is due to the behavior of the atmosphere.

Every user and provider of climate data has to deal with metadata and homogeneity to some extent. Many climate researchers throughout the world have developed effective approaches for dealing with the many aspects of metadata and homogeneity. The following document is based on their collective experience and should and is intended to offer guidance to the NMHSs on these matters.

**ALP-IMP-rev-02**

INTERNATIONAL JOURNAL OF CLIMATOLOGY
*Int. J. Climatol.* 24: 437–455 (2004)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.991

# SEA-LEVEL PRESSURE VARIABILITY IN THE PO PLAIN (1765–2000) FROM HOMOGENIZED DAILY SECULAR RECORDS

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## ABSTRACT

A homogenized 236 year daily regional sea-level pressure (SLP) record is constructed for the Po Plain (north Italy) by means of six station records: Bologna, Genoa, Lugano, Milan, Padua and Turin. Station records are subjected to a first homogenization in order to reduce all observations to sea level and to 0 °C and to correct the bias introduced by calculating daily means using different sets of observation hours. A second homogenization is performed by means of comparison with other Italian and European series. After homogenization, the root-mean square error of the yearly station records is evaluated within 0.2 hPa after 1880, whereas for the periods 1834–1880 and 1765–1833 it is estimated as between 0.2 and 0.3 hPa and as around 0.4 hPa respectively. Trend analysis is applied to the annual and seasonal regional records and concerns both SLP and its day-to-day variability. The results show that neither the SLP nor its day-to-day variability have an evident trend when considering the entire 1765–2000 period. However, if the series is divided roughly in two parts, then significant trends can be highlighted. The annual and seasonal regional SLP records are also compared with corresponding regional temperature series. The results show that, especially in spring and in summer, temperature and SLP are in good agreement. 

KEY WORDS: Po Plain; data homogenization; trend analysis; daily air-pressure records; day-to-day variability

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INTERNATIONAL JOURNAL OF CLIMATOLOGY
*Int. J. Climatol.* 25: 139–166 (2005)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1135

# A NEW INSTRUMENTAL PRECIPITATION DATASET FOR THE GREATER ALPINE REGION FOR THE PERIOD 1800–2002

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ABSTRACT

The paper describes the development of a dataset of 192 monthly precipitation series covering the greater alpine region (GAR, 4–18 °E by 43–49 °N). A few of the time series extend back to 1800. A description is provided of the sometimes laborious processes that were involved in this work: from locating the original sources of the data to homogenizing the records and eliminating as many of the outliers as possible. Locating the records required exhaustive searches of archives currently held in yearbooks and other sources of the states, countries and smaller regional authorities that existed at various times during the last 200 years. Homogeneity of each record was assessed by comparison with neighbouring series, although this becomes difficult when the density of stations reduces in the earliest years. An additional 47 series were used, but the density of the sites in Austria and Switzerland was reduced to maintain an even coverage in space across the whole of the GAR. We are confident of the series back to 1840, but the quality of data before this date must be considered poorer. Of all of the issues involved in homogenizing these data, perhaps the most serious problem is associated with the differences in the height above ground of the precipitation gauges, in particular the general lowering of gauge heights in the late 19th century for all countries, with the exception of Italy. The standard gauge height in the early-to-mid 19th century was 15–30 m above the ground, with gauges being generally sited on rooftops. Adjustments to some series of the order of 30–50% are necessary for compatibility with the near-ground location of gauges during much of the 20th century. Adjustments are sometimes larger in the winter, when catching snowfall presents serious problems. Data from mountain-top observatories have not been included in this compilation (because of the problem of measuring snowfall), so the highest gauge sites are at elevations of 1600–1900 m in high alpine valley locations. Two subsequent papers will analyse the dataset. The first will compare the series with other large-scale precipitation datasets for this region, and the second will describe the major modes of temporal variability of precipitation totals in different seasons and determine coherent regions of spatial variability. Copyright © 2005 Royal Meteorological Society.

KEY WORDS: monthly precipitation time series; homogeneity; instrumental period; greater alpine region

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**ALP-IMP-rev-04**

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SCIENCE DIRECT®
Dendrochronologia 22 (2005) 107–121
DENDROCHRONOLOGIA
www.elsevier.de/dendro

ORIGINAL ARTICLE

# Characterization and climate response patterns of a high-elevation, multi-species tree-ring network in the European Alps

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Received 7 April 2004; accepted 15 December 2004

## Abstract

We combine 53 ring width and 31 maximum latewood density data sets from a network of high-elevation tree sites distributed across the European Alps (43–48°N and 6–14°E). This network is analyzed to understand the climate, and in particular, the temperature signal, in terms of geography, species and measured parameter. These analyses will be useful for any subsequent climatic reconstruction. The first Principal Component (PC) of the ring width chronologies explains 20% of the network's variance and correlates significantly with the June–August summer season temperatures, while that of the density chronologies explains 69% of the variance and correlates with the wider April–September season. Of the four species considered, ring width records from *Picea abies*, *Larix decidua*, and *Pinus cembra* tend to show most similar responses to climate, with the *Abies alba* having a more unique response. The climatic signal of the density chronologies is rather independent of species and site ecology. It is quite strong across the network, although possibly weighted towards the higher-frequency domains. In comparison, the ring width chronologies display much greater site- and species-specific components in their climate response, with only elevation found to serve as an indicator for the level of seasonal temperature response. Climatic gradients across the network are shown to exist through spatial correlation and rotated Principal Component Analysis (PCA). These gradients are rather small, but show similar patterns to those observed in PCA of instrumental data. High correlations between temperature and *Latix decidua* are found despite concern over the presence of effects from the larch budmoth on the climatic signal. Similarly, the ring width parameter of *Pinus cembra* showed strong ability to serve as a proxy, notable in the context of this species to have poorer responses to temperature when considering maximum latewood density. The potential for a regional climatic reconstruction, using the networks PCs as predictors exists, as demonstrated by the high and consistent loadings across the network on the first PCs for both the ring width and density chronologies.


***Keywords:*** Dendroclimatology; Temperature; Ring width; Maximum latewood density; Network; Alps

**ALP-IMP-rev-05**

*Zeitschrift für Geomorphologie N.F., Suppl.-Vol.* ***138***. 113-129

# GIS-based modelling of glacial sediment balance

Michael Zemp, Andreas Kääb, Martin Hoelzle and Wilfried Haeberli, Zurich

with 8 figures and 2 tables

**Summary.** In view of ongoing atmospheric warming, there is concern as to whether retreating glaciers uncover a rocky or sedimentary bed. Sedimentary beds are abundant in high-mountain areas and represent, if exposed, a severe hazard potential for outbursts of periglacial lakes or debris flows. Furthermore, knowledge about glacier sediment balance is needed when dealing with climate sensitivity of recent and historical glaciers.

The main factors influencing sediment balance of a glacierised mountain catchment have been organised into an *index* ($I_{es}$) *of glacier erosion and sedimentation*, which distinguishes between glaciers eroding into bedrock and those building up thick sedimentary beds. GIS-based methods were developed to extract the needed $I_{es}$-parameters from Digital Elevation Models (DEM), digitised glacier outlines and central flowlines. These methods were automated and tested on 84 Swiss Alpine glaciers. The results were validated through comparisons with forefield classifications and manually derived index results.

The comparison with classified forefields confirms that the index allows for a rough assessment of the glacial sediment balance. In order to improve the predictability of glacier-bed characteristics, a better understanding of the periglacial debris production is necessary. However, the high overall accuracy of the comparison with the manual glacier-by-glacier investigation shows the potential of using GIS-based modelling with DEM in geomorphodynamics.

**ALP-IMP-rev-06**

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Published online 7 October 2005 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1216

# TEMPERATURE AND PRECIPITATION VARIABILITY IN THE EUROPEAN ALPS SINCE 1500

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## ABSTRACT

High-resolution temperature and precipitation variations and their seasonal extremes since 1500 are presented for the European Alps (43.25–48.25°N and 4.25–16.25°E). The spatial resolution of the gridded reconstruction is given by 0.5° × 0.5° and monthly (seasonal) grids are reconstructed back to 1659 (1500–1658). The reconstructions are based on a combination of long instrumental station data and documentary proxy evidence applying principal component regression analysis. Annual, winter and summer Alpine temperatures indicate a transition from cold conditions prior to 1900 to present day warmth. Very harsh winters occurred at the turn of the seventeenth century. Warm summers were recorded around 1550, during the second half of the eighteenth century and towards the end of the twentieth century. The years 1994, 2000, 2002, and particularly 2003 were the warmest since 1500. Unlike temperature, precipitation variation over the European Alps showed no significant low-frequency trend and increased uncertainty back to 1500. The years 1540, 1921 and 2003 were very likely the driest in the context of the last 500 years.

Running correlations between the North Atlantic Oscillation Index (NAOI) and the Alpine temperature and precipitation reconstructions demonstrate the importance of this mode in explaining Alpine winter climate over the last centuries. Winter NAOI correlates positively with Alpine temperatures and negatively with precipitation. These correlations, however, are temporally unstable. We conclude that the Alps are situated in a band of varying influence of the NAO, and that other atmospheric circulation modes controled Alpine temperature and precipitation variability through the recent past.


KEY WORDS: European Alps; principal component regression; temperature; precipitation; climate variability; reconstructions; North Atlantic Oscillation

**ALP-IMP-rev-07**

Climate Dynamics (2005) 25: 141–153
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Ulf Büntgen · Jan Esper · David C. Frank
Kurt Nicolussi · Martin Schmidhalter

# A 1052-year tree-ring proxy for Alpine summer temperatures

Received: 15 November 2004 / Accepted: 12 April 2005


**Abstract** A June–August Alpine temperature proxy series is developed back to AD 951 using 1,527 ring-width measurements from living trees and relict wood. The reconstruction is composed of larch data from four Alpine valleys in Switzerland and pine data from the western Austrian Alps. These regions are situated in high elevation Alpine environments where a spatially homogenous summer temperature signal exists. In an attempt to capture the full frequency range of summer temperatures over the past millennium, from inter-annual to multi-centennial scales, the regional curve standardization technique is applied to the ring width measurements. Correlations of 0.65 and 0.86 after decadal smoothing, with high elevation meteorological stations since 1864 indicate an optimal response of the RCS chronology to June–August mean temperatures. The proxy record reveals warm conditions from before AD 1000 into the thirteenth century, followed by a prolonged cool period, reaching minimum values in the 1820s, and a warming trend into the twentieth century. This latter trend and the higher frequency variations compare well with the actual high elevation temperature record. The new central Alpine proxy suggests that summer temperatures during the last decade are unprecedented over the past millennium. It also reveals significant similarities at inter-decadal to multi-centennial frequencies with large-scale temperature reconstructions, however, deviating during certain periods from H.H. Lamb's European/North Atlantic temperature history.

**ALP-IMP-rev-08**

МАТЕРИАЛЫ XIII ГЛЯЦИОЛОГИЧЕСКОГО СИМПОЗИУМА
САНКТ-ПЕТЕРБУРГ, май 2004 года

# Worldwide glacier mass balance measurements: general trends and first results of the extraordinary year 2003 in Central Europe

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Рассмотрены тренды баланса массы ледников мира, в частности, за 1980—2001 гг. и для чрезвычайно жаркого и сухого лета 2003 г. в Центральной Европе, которое привело к потере 5—10% объема ледников Альп.

## Introduction

Worldwide collection of information about ongoing glacier changes was initiated in 1894 with the foundation of the International Glacier Commission at the Sixth International Geological Congress in Zürich, Switzerland. It was hoped that long-term glacier observations would give insight into processes of climatic change such as the formation of ice ages. In 1986 the World Glacier Monitoring Service (WGMS) started to maintain and continue the collection of information on ongoing glacier changes, when the two former ICSI services PSFG (Permanent Service on Fluctuations of Glaciers) and TTS/WGI (Temporal Technical Secretary/World Glacier Inventory) were combined [4].

Since its initiation, the goals of international glacier monitoring have evolved and multiplied. Today, the WGMS is integrated into global climate-related observation systems and collects standardized observations on changes in mass, volume, area and length of glaciers with time (glacier fluctuations), as well as statistical information on the distribution of perennial surface ice in space (glacier inventories). Thus, a valuable and increasingly important data basis on glacier changes has been built up over the past century [4].

International assessments such as the periodical reports by the Intergovernmental Panel on Climate Change (IPCC) or the GCOS/GTOS Plan for Terrestrial Climate-related Observation [1] define mountain glaciers as one of the best natural indicators of atmospheric warming with the highest reliability ranking. The Global Terrestrial Network for Glaciers (GTN-G) of the Global Terrestrial Observing System (GTOS), aims at combining (a) in-situ observations with remotely sensed data, (b) process understanding with global coverage and (c) traditional measurements with new technologies by using an integrated and multi-level strategy. This approach, the Global Hierarchical Observing Strategy (GHOST), uses observations in a system of Tiers. These Tiers include extensive glacier mass balance measurements within major climatic zones for improved process understanding and the calibration of numerical models (Tier 2) as well as the determination of regional glacier volume change within major mountain systems using cost-saving methodologies (Tier 3). A network of 60 glaciers representing Tiers 2 and 3 is already established. This data sample closely corresponds to the data compilation published so far by the WGMS with the bi-annual «Glacier Mass Balance Bulletin» [6].

The present contribution gives an overview on presently observed rates of change in worldwide mass balance of mountain glaciers, corresponding trends and regional peculiarities, such as the extremely hot and dry Central European summer of 2003.

**ALP-IMP-rev-09**

IL NUOVO CIMENTO Vol. 29 C, N. 1 Gennaio-Febbraio 2006
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# Reconstructing the climate of the 250 years of instrumental records at the northern border of the Mediterranean (the Alps)(*)

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(ricevuto l'1 Settembre 2005)

**Summary.** — The paper provides a selection of first results based on a newly developed instrumental climate database for the European Alps and their wider surroundings. After an outline on data availability, network density, series durations and quality aspects some examples for the two main climate elements temperature and precipitation show some principal features of climate variability and trends in the region. Regional as well as seasonal differences are discussed. The overview closes with examples dealing with changes of climate variability: For temperature as well as for precipitation (the former stronger, the latter weaker and with regional modifications) inter-annual (-seasonal, -monthly) variability has not increased but decreased during the past two centuries of well-proved instrumental data in the study region.

PACS 92.60.Ry – Climatology.
PACS 92.70.Gt – Climate dynamics.
PACS 92.60.Wc – Weather analysis and prediction.
PACS 01.30.Cc – Conference proceedings.

**ALP-IMP-rev-10**

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# TEMPERATURE RECONSTRUCTIONS AND COMPARISONS WITH INSTRUMENTAL DATA FROM A TREE-RING NETWORK FOR THE EUROPEAN ALPS

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## ABSTRACT

Ring-width and maximum latewood density data from a network of high-elevation sites distributed across the European Alps are used to reconstruct regional temperatures. The network integrates 53 ring-width and 31 density chronologies from stands of four species all located above 1500 m a.s.l. The development and basic climatic response patterns of this network are described elsewhere (Frank and Esper, 2005). The common temperature signal over the study region allowed regional reconstructions to be developed using principal component regression models for average June–August (1600–1988) and April–September (1650–1987) temperatures from ring-width and density records, respectively. Similar climatic histories are derived for both seasons, but with the ring-width and density-based reconstructions seemingly weighted toward carrying more of their variance in the lower and higher frequency domains, respectively. Distinct warm decades are the 1940s, 1860s, 1800s, 1730s, 1660s and the 1610s, and cold decades, the 1910s, 1810s, 1710s, 1700s and the 1690s. Because of the model fitting and the shorter time spans involved, comparisons between the reconstructions with high-elevation instrumental data during the majority of the 1864–1972 calibration period show good agreement. Yet, prior to this period, from which only a few low elevation temperature records are available, a trend divergence between tree-ring and instrumental records is observed. We present evidence that this divergence may be explained by the ring-width data carrying more of an annual rather than warm-season signal in the lower frequency domain. Other factors such as noise, tree-ring standardization, or the more uncertain nature of low-frequency trends in early instrumental records and their homogenization, might help explain this divergence as well. 

KEY WORDS: dendrochronology; dendroclimatology; temperature reconstruction; Alps; instrumental data; tree-ring width; maximum latewood density

**ALP-IMP-rev-11**

INTERNATIONAL JOURNAL OF CLIMATOLOGY
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# TEMPERATURE AND PRECIPITATION VARIABILITY IN ITALY IN THE LAST TWO CENTURIES FROM HOMOGENISED INSTRUMENTAL TIME SERIES

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## ABSTRACT

The Italian monthly temperature (mean, maximum and minimum) and precipitation secular data set was updated and completely revised. Station density and metadata availability were greatly improved and the series were subjected to a detailed quality control and homogenisation procedure. The data homogenisation is described in detail. The bias affecting original data is quantified by studying the temporal evolution of the mean adjustments applied to the series and examined in the light of the stations history. The results stress the importance of homogenisation in climate change studies.

The final data set was clustered into climatically homogeneous regions by means of a Principal Component Analysis. Yearly and seasonal trend analyses were performed both on regional average series and on the mean Italian series. The results highlight a positive trend for mean temperature of about 1 K per century all over Italy; it is generally higher for minimum temperature than for the maximum temperature. The progressive application of trend analysis shows that, in the last 50 years, behaviour is the opposite; the maximum temperature trend being stronger than that of the minimum temperature. This has led to a negative trend in the daily temperature range that for the last 50 years has become positive. Precipitation shows a decreasing tendency, even if low and rarely significant, the negative trend being only 5% per century on a yearly basis. 

KEY WORDS: Italy; data homogenisation; trend analysis; monthly temperature records; monthly precipitation records; minimum and maximum temperature; daily temperature range

**ALP-IMP-rev-12**

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D01105, doi:10.1029/2005JD006120, 2006

# Construction of a 10-min-gridded precipitation data set for the Greater Alpine Region for 1800–2003

Dimitrios Efthymiadis,[1] Philip D. Jones,[1] Keith R. Briffa,[1] Ingeborg Auer,[2] Reinhard Böhm,[2] Wolfgang Schöner,[2] Christoph Frei,[3] and Jürg Schmidli[4]

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[1] A new precipitation data set for the Greater Alpine Region (GAR; 4°E–19°E, 43°N–49°N) has been developed. It provides monthly precipitation totals, for the 1800–2003 period, gridded at 10-min resolution. The new HISTALP 10-min-grid data set is based on 192 long-term homogenized precipitation series from meteorological stations across the study domain and a high-resolution precipitation climatology for the 1971–1990 period. The effective coverage of the data set depends on the observations available in the station network which progressively declines back to the early 19th century (from 192 to 5 stations). To aid the use of these data in other studies, an accompanying data set has also been developed, which provides a measure of the quality of each monthly precipitation estimate over the grid: the explained variance, relative to the 1931–2000 (maximum data availability) period. The computed quality score illustrates the comparatively poorer accuracy of the data set for regions and months with less coherent precipitation fields (i.e., over the Alps and in summer) and when the number of stations is reduced, particularly before 1840. The derived gridded field has also been compared for the whole and geographical subregions with other independently developed data sets and is found to provide a similar description of the precipitation in the GAR for places and periods of common coverage. The data set is publicly available at http://www.cru.uea.ac.uk/.

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**ALP-IMP-rev-13**

ERDKUNDE

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BEGRÜNDET VON CARL TROLL

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# 700 YEARS OF SETTLEMENT AND BUILDING HISTORY IN THE LÖTSCHENTAL, SWITZERLAND

With 5 figures, 3 photos and 1 supplement (II)

ULF BÜNTGEN, IGNAZ BELLWALD, HANS KALBERMATTEN, MARTIN SCHMIDHALTER, DAVID C. FRANK, HENNING FREUND, WERNER BELLWALD, BURKHARD NEUWIRTH, MARCUS NÜSSER and JAN ESPER

*Zusammenfassung:* 700 Jahre Siedlungs- und Baugeschichte im Lötschental, Schweiz

Alle 2.317 gegenwärtig im Lötschental existierenden Gebäude wurden inventarisiert, zeitlich eingeordnet und kartiert. 1.432 von diesen Gebäuden konnten mit Hilfe von Inschriften, Jahrringen und/oder Archivdokumenten jahrgenau datiert werden. 885 Gebäude wurden durch Schätzungen zeitlich in Jahrhunderte eingeordnet. Diese Datierungen dienen als Grundlage für die Erstellung einer Karte, welche erstmals die Gebäudealter eines gesamten alpinen Tales im Überblick darstellt. In der Karte, welche als Ergebnis einer interdisziplinären Untersuchung unter Einbeziehung lokaler Wissenssysteme und Bezeichnungen verstanden werden muss, werden sowohl Wohn- als auch Wirtschaftsgebäude integriert. Zusätzlich wurden 116 lokale Flurnamen aufgenommen und die Gebäudealter zurück bis AD 1299 in einem Histogramm dargestellt.

Die Zusammenarbeit von Historikern, Volkskundlern und Geographen sowie die aus den jahrgenauen Datierungen gewonnenen Erkenntnisse zu geschichtlichen Bauformen und Konstruktionstechniken ermöglichten die zeitliche Einordnung von Objekten. In diesem begleitenden Text beschreiben wir die Datierungsmethoden, wesentliche Bautypen und Konstruktionstechniken und diskutieren alte Siedlungsmuster und ausgewählte Gebäude. Die Ergebnisse werden unter Berücksichtigung des Kulturlandschaftswandels und der die siedlungsgeschichtlichen Entwicklungen steuernden Faktoren wie Lawinen, Dorfbränden und sozioökonomischen Prozessen diskutiert.

*Summary:* All 2,317 current buildings within the Lötschental were registered, chronologically assigned and mapped. Annual construction dates of 1,432 of these objects based on inscriptions, tree-ring dating and/or documentary evidence were derived. Century-resolved construction dates for the remaining 885 buildings were estimated. These dates are utilized to develop a map that, for the first time, provides a full inventory of building ages of an entire alpine valley. Residential and non-residential buildings are shown in a map resulting from an interdisciplinary study, using local knowledge and nomenclature as a basis. Additionally, 116 local area names were added, and the age of all buildings back to AD 1299 graphically displayed.

The joint analysis by historians, social anthropologists and geographers, as well as the knowledge about historic building types and construction techniques derived from the annual dating, allowed the age estimation of buildings. In this supplementary text, we describe the applied dating methods, some relevant building types and construction techniques and discuss former settlement patterns and selected buildings. We also address some factors of cultural landscape transformation relevant for the settlement history, such as avalanches, fire outbreaks and socio-economic processes.

**ALP-IMP-rev-14**

New Phytologist

Research

# Long-term change in the sensitivity of tree-ring growth to climate forcing in *Larix decidua*

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## Summary

• Tree rings are widely used long-term proxy data which, if combined with long-term instrumental climate records, can provide excellent information on global climate variability. This research aimed to determine whether interannual climate–growth responses in Alpine treeline forests are stationary over time.
• We used tree-ring width chronologies of *Larix decidua* (European larch) from 17 sites and monthly temperatures and precipitation data for the period 1800–1999. Climate–growth relationships were assessed with correlation and response functions, and their stationarity and consistency over time were measured using moving correlation.
• Tree-ring chronologies showed similar interannual variations over the last two centuries, suggesting that the same climatic factors synchronously limited growth at most sites. The most sensitive variables showed significant transient responses varying within the time period, indicating a possible deviation from the uniformitarian principle applied to dendroclimatology.
• If these findings are confirmed in future studies on other species and in other regions, we suggest that time-dependent variables should be taken into account to avoid overestimation of treeline advance, future forest carbon storage in temperature-limited environments and inaccurate reconstruction of past climate variability.

**Key words:** climate–growth responses, dendroclimatology, *Larix decidua* (European larch), moving correlation function, tree ring, uniformitarian principle.

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# Synchronous variability changes in Alpine temperature and tree-ring data over the past two centuries

DAVID FRANK, ROBERT WILSON AND JAN ESPER

BOREAS

Frank, D., Wilson, R. & Esper, J. 2005 (November): Synchronous variability changes in Alpine temperature and tree-ring data over the past two centuries. *Boreas*, Vol. 34, pp. 498–505. Oslo. ISSN 0300-9483.

The understanding of extremes and their temporal distribution is useful in characterizing the behaviour of the climate system, and necessary for understanding their social and economic costs and risks. This task is analogous to the study of pointer years in dendrochronological investigations. Commonly used dendroclimatological methods, however, tend to result in an equalization of variance throughout the record by normalizing variability within moving windows. Here, we analyse a larger network of high-elevation temperature-sensitive tree sites from the European Alps processed to preserve the relative frequency and magnitude of extreme events. In so doing, temporal changes in year-to-year tree-ring width variability were found. These decadal length periods of increased or decreased likelihood of extremes coincide with variability measures from a long-instrumental summer temperature record representative of high-elevation conditions in the Alps. Intervention analysis, using an F-test to identify shifts in variance, on both the tree-ring and instrumental series, resulted in the identification of common transitional years. Based on a well-replicated network of sites reflecting common climatic variation, our study demonstrates that the annual growth rings of trees can be utilized to quantify past frequency and amplitude changes in extreme variability. Furthermore, the approach outlined is suited to address questions about the role of external forcing, ocean–atmosphere interactions, or synoptic scale changes in determining patterns of observed extremes prior to the instrumental period.

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Status 2006-10: in press

## Glacier fluctuations in the European Alps 1850–2000: an overview and spatio-temporal analysis of available data

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**Abstract:** Within the framework of the EU-funded project ALP-IMP, which deals with climate change within the greater Alpine[1] region, the World Glacier Monitoring Service (WGMS) compiled an unprecedented Alpine glacier dataset containing fluctuation information dating back to 1850. Here we give an overview of the available data, results of spatio-temporal analyses and discuss the representativity of front variation and mass balance series for the entire Alpine glacierisation. In the 1970's there were approximately 5,150 Alpine glaciers covering an area of 2,909 km$^2$. Overall area loss since 1850 is estimated to be about 35% until the 1970's and almost 50% until 2000. Rapidly shrinking glacier areas, spectacular tongue retreats and increasing mass losses are clear signs of the atmospheric warming observed in the Alps in the last 150 years and its acceleration over the past two decades. However, in the short-term or at a regional scale, glaciers show a highly individual variability. Glacier behaviour depends not only on regional climate but also on local topographic effects which complicate the extraction of the climate signal from glacier fluctuations. The latter are essential for the verification of mass balance and ice flow models, which are needed to quantify these topographic effects. It is of major importance to continue with long-term fluctuation measurements and to extend the existing fluctuation series back in time using reconstructions of former glacier geometries. Additionally, it is necessary to integrate glacier monitoring as well as reconstruction activities into the global framework of the Glacier Land Ice Measurement from Space (GLIMS) project and the WGMS.

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# Alpine-wide distributed glacier mass balance modelling: a tool for assessing future glacier change?

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## Abstract

Distributed glacier mass balance models enable the calculation of the mass balance for each point of a glacier surface from meteorological input data. In view of the observed enhanced down-wasting of Alpine glaciers in recent years, such models become increasingly valuable for assessment of ongoing and future glacier change. However, their potential for large-area application by using gridded input data sets has not been fully exploited yet. In this contribution we describe the major components of distributed glacier mass balance models and apply a model that is based on the calculation of the energy balance to a larger test site (Mischabel region) in Switzerland. We thereby force the model with gridded data sets from annual precipitation, satellite-derived albedo and daily potential solar radiation as well as climatic means of meteorological variables. While the latter can easily be tuned to agree with observed mass balance distributions of specific glaciers, other nearby glaciers get unrealistically high positive or negative balances in the same simulation. Besides a variable sensitivity of individual glaciers, this hints to processes acting on a local scale, that are not yet considered in the model (e.g. snow redistribution by wind). However, the model is well suited for sensitivity studies with the included variables, and the mass balance sensitivities obtained agree well with results from previous studies (e.g. we calculate a 125 m rise of the equilibrium line altitude (ELA) for a 1 °C temperature increase). Once the local processes have been included successfully, we see a large potential of forcing such models with future climate data as computed by regional climate models. The resulting changes in mass balance or ELA on a glacier-specific basis may then be used as an input for further impact models which calculate future discharge or water resources.

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EARSeL eProceedings 4, 2/2005 139

# ON THE IMPACT OF GLACIER ALBEDO UNDER CONDITIONS OF EXTREME GLACIER MELT: THE SUMMER OF 2003 IN THE ALPS

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## ABSTRACT

The extraordinarily hot summer of 2003 caused record-breaking glacier melt in the European Alps (i.e. eight times the long-term average). Multispectral Landsat Thematic Mapper (TM) satellite data of August 2003 clearly shows very dark glacier ablation areas, particularly in the near-infrared. In order to assess the influence of the low glacier albedo and the special 2003 meteorological conditions on glacier mass balance more quantitatively, we have calculated glacier albedo from TM for three distinct years (1985, 1998, 2003) and applied a distributed glacier mass balance model forced by climatic mean as well as the special 2002/03 meteorological conditions. For this purpose, we use the TM-derived albedo for 1998 and 2003 as a surrogate for the background glacier albedo. We observe a large albedo variability from year to year, constant or even decreasing albedo with altitude and much lower albedo values in the ablation area than generally applied (0.15 instead of 0.35). The modelled mass balance reveals a distribution pattern that is governed by the potential solar radiation, increasing glacier mass loss with altitude using the 2003 albedo, and a three times higher mass loss for the meteorological conditions of 2002/03 compared to the climatic means.

**Keywords:** Glacier albedo, mass balance model, summer 2003.

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# The variability and change of Italian climate in the last 160 years(*)

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**Summary.** — The awareness of the importance of data quality and homogeneity issues in the correct detection of climate change has increased rapidly in the last few years. Most of the contributions have been addressed to upper air data, however errors and inhomogeneities also concern surface ones. At surface level it is often assumed that such inhomogeneities have random distribution and that, considering a sufficiently large number of series, average records with negligible bias can be obtained. This assumption is likely to be correct if global or hemispheric averages are considered, but it may not be correct at a regional scale. The aim of the work is a rigorous reconstruction of the Italian climate for the last centuries (the longest series start in the late 1700s), with particular attention to the identification of spurious non-climatic signals introduced by changing instruments and methods in the measurement procedures. A data set of 111 precipitation series, 48 minimum and maximum temperature series and 67 mean temperature series was set up, together with the information about the station history (metadata). The records were subjected to a detailed quality control and homogenisation procedure that was extensively supported by a large metadata availability. The series were grouped by means of Principal Component Analysis and regional average records were obtained and analysed for trends. Trend analysis was performed on seasonal and annual basis by means of the progressive Mann-Kendall statistics and the progressive analysis of the linear regression coefficients. A comparison between the homogenized and the original series and the preliminary results of the analysis are presented. Particular emphasis is given to stress the importance of data homogenisation in the correct detection of long-term trends.

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

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## ABSTRACT

This paper describes the HISTALP database, consisting of monthly homogenised records of temperature, pressure, precipitation, sunshine and cloudiness for the 'Greater Alpine Region' (GAR, 4–19°E, 43–49°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. A systematic QC procedure has been applied to the series and a high number of inhomogeneities (more than 2500) and outliers (more than 5000) have been detected and removed. The 557 HISTALP series are kept in different data modes: original and homogenised, gap-filled and outlier corrected station mode series, grid-1 series (anomaly fields at 1° × 1°, lat × long) and Coarse Resolution Subregional (CRS) mean series according to an EOF-based regionalisation. The leading climate variability features within the GAR are discussed through selected examples and a concluding linear trend analysis for 100, 50 and 25-year subperiods for the four horizontal and two altitudinal CRSs. Among the key findings of the trend analysis is the parallel centennial decrease/increase of both temperature and air pressure in the 19th/20th century. The 20th century increase (+1.2°C/+1.1 hPa for annual GAR-means) evolved stepwise with a first peak near 1950 and the second increase (1.3°C/0.6hPa per 25 years) starting in the 1970s. Centennial and decadal scale temperature trends were identical for all subregions. Air pressure, sunshine and cloudiness show significant differences between low *versus* high elevations. A long-term increase of the high-elevation series relative to the low-elevation series is given for sunshine and air pressure. Of special interest is the exceptional high correlation near 0.9 between the series on mean temperature and air pressure difference (high-minus low-elevation). This, further developed via some atmospheric statics and thermodynamics, allows the creation of 'barometric temperature series' without use of the measures of temperature. They support the measured temperature trends in the region. Precipitation shows the most significant regional and seasonal differences with, e.g., remarkable opposite 20th century evolution for NW (9% increase) *versus* SE (9% decrease). Other long- and short-term features are discussed and indicate the promising potential of the new database for further analyses and applications. Copyright © 2006 Royal Meteorological Society.

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# Precipitation variability and changes in the greater Alpine region over the 1800–2003 period

Michele Brunetti,[1] Maurizio Maugeri,[2] Teresa Nanni,[1] Ingeborg Auer,[3] Reinhard Böhm,[3] and Wolfgang Schöner[3]

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[1] The paper investigates precipitation variability in the greater Alpine region (GAR) (4–19°E, 43–49°N) based on 192 instrumental series of homogenized and outlier checked monthly precipitation and on the 1° gridded version of the same data set. Compared to the previous data sets, the one used in this paper adds a full century of data (earliest series starting in 1800) by exploiting the early instrumental period as much as possible in terms of series length and spatial density. The records were clustered into climatically homogeneous subregions, by means of a principal component analysis, and average subregional series were calculated. The principal component analysis was applied also in T-mode to investigate the most recursive precipitation patterns that characterize the examined area. Yearly and seasonal trend analysis was performed both on subregional average series and on the mean GAR series. It was also applied to moving windows, of variable width ranging from 2 decades to 2 centuries, in order to investigate any trends over decadal to secular timescales. Beside trends in total precipitation, precipitation seasonality was also analyzed as an important indicator of climate changes. Links between precipitation variability in the Alpine region and atmospheric circulation, and the North Atlantic Oscillation in particular, were also studied.

**Citation:** Brunetti, M., M. Maugeri, T. Nanni, I. Auer, R. Böhm, and W. Schöner (2006), Precipitation variability and changes in the greater Alpine region over the 1800–2003 period, *J. Geophys. Res.*, *111*, D11107, doi:10.1029/2005JD006674.

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# Bronce Age dating of timber from the salt mine at Hallstatt, Austria

Michael Grabner, Andrea Klein, Daniela Geihofer, Hans Reschreiter, Fritz E. Barth, Trivun Sormaz and Rupert Wimmer

SUMMARY

The prehistoric salt mine of Hallstatt together with its burial ground is one of the most prominent archaeological sites in Austria, which has also given name for the "Hallstatt period" of human civilisation (800 to 400 BC). Due to the perfect conservation in rock salt a great number of organic materials have been found, among mostly wooden artefacts. Currently, the major archaeological focus is on the Bronze Age salt mining activities with excavations taking place at the historic *Christian von Tusch-Werk, Alter Grubenoffen* mine.

Chronology building started at the Dachstein plateau, in the vicinity of Hallstatt, where tree-trunks were discovered in an alpine lake (Schwarzer See) and after recovery a spruce-larch chronology was compiled that dates back to 1475BC. In addition, at the bog Karmoos, very close to the mining place of Hallstatt, preserved trees were intensively sampled resulting in a spruce chronology reaching even 1523BC.

Over 500 samples were taken at the *Christian von Tusch-Werk, Alter Grubenoffen*. They also included samples from the recently discovered world's oldest wooden staircase. The spectrum of wooden species encompassed Norway spruce, Silver fir, beech, European larch and maple. We were able to synchronize 128 samples, ending in a 282-year long floating chronology. While the staircase dated back to 1344BC, the end year of the floating chronology dated even to 1245BC. Tree felling dates showed clusters within the chronology, providing evidence for archaeologists to find construction phases and usage periods.

The Dachstein-Hallstatt spruce chronology currently holds 840 synchronized series, and includes samples from the lake at the Dachstein, from the Karmoos bog at Hallstatt, from the prehistoric Hallstatt salt mine, and from historical buildings, as well as living trees. The chronology covers the period between 1523BC through 2004AD.

Keywords

Historical dating, dendrochronology, Hallstatt, Bronze Age, salt mine

**ALP-IMP-rev-23**

Leal, S., Melvin, T.M., Grabner, M., Wimmer, R., Briffa, K.R.

in preparation

# Extreme growth years in relation to climate in precipitation sensitive *Pinus nigra Arn*. Trees growing in Austria

**ALP-IMP-rev-24**

submitted to: *Global Change Biology*

# Tree rings of *Pinus nigra* Arn. from the Vienna basin region (Austria) show evidence of $CO_2$-induced change in sensitivity to water availability and temperature

Sofia Leal[1], Derek Eamus[2], Michael Grabner[1], Rupert Wimmer[1], Paolo Cherubini[3]

We used a large sample of *Pinus nigra* Arn. tree-ring series collected within the Vienna basin, in Austria, from trees growing near the ecological limits for the species. Tree rings showed a strong and positive correlation with spring-summer precipitation, indicating a growth dependence on water availability during the growing season. During the late 20th century, tree rings grew wider than expected given the predicted relationship between rainfall and growth rate observed in the early 20th century. Models of the relationship between growth and rainfall, built on the basis of a strong climatic control of growth by spring-summer precipitation, tended to overestimate the precipitation fallen in the late 20th century. During the last quarter of the century the sensitivity of ring growth to spring-summer precipitation disappeared and was replaced by a strong and positive correlation with summer temperature, which had previously been negatively correlated with growth. This change in sensitivity indicates that tree growth was no longer dependent on water availability.

We propose there was an improvement in water-use-efficiency in consequence of the increasing $CO_2$ concentration in the atmosphere, enhanced by a relatively high input of nitrogen due to the proximity of N emission sources. We interpret the recent correlation of growth with temperature as a result of the rise of the temperature optimum for photosynthesis under elevated atmospheric $CO_2$ concentrations.

**ALP-IMP-rev-25**

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# Tree ring-growth variability in the Austrian Alps: the influence of site altitude, tree species and climate

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**Abstract**

We present an extensive new network of ring-width chronologies comprising data from 100 sites within the Austrian Alps made up of multiple tree species. Cluster analysis is used to identify five separate high-frequency tree growth signals from this data. Tree growth variability at these sites is explained by site altitude and species differences which moderate the effects of the annually varying climatic forcing on tree growth. High altitude chronologies suitable for reconstructing temperature and low altitude chronologies suitable for reconstructing precipitation are identified.

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# European Alpine moisture variability for 1800–2003

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Abstract:

Moisture availability for the European Greater Alpine region (GAR) (43 °N–49 °N and 4 °E–19 °E) for the period 1800–2003 is analyzed on the basis of maps of monthly self-calibrating Palmer Drought Severity Index (scPDSI) with a 10′ × 10′ spatial resolution.

To represent the impact of seasonal snow cover on the water budget, a simple snow-accumulation and snowmelt model is added to the water balance calculations on which the (self-calibrating) Palmer Drought Severity Index is based.

Over the region as a whole, the late 1850s into the 1870s and the 1940s to the early 1950s stand out as persistent and exceptionally dry periods, whereas the first two decades of the nineteenth century and the 1910s were exceptionally wet periods. Dividing the Greater Alpine Region into four subregions, with the subregions based on coherence of precipitation variability, we find a large degree of heterogeneity in the behavior of the drought index over the subregions. The driest summers on record, in terms of the amplitude of the index averaged over the Alpine region, are 1865 and 2003. In these years, 75.6% and 85.1% of the region was suffering from a moderate drought (or worse). The areas northwest of the high mountains were affected most severely in the 1865 drought, whereas the 2003 drought impacted all subregions more equally.

By substituting climatological monthly mean temperatures, from the period 1961–1990, for the actual monthly means in the parameterization for potential evaporation, an estimate is made of the direct effect of temperature on drought. It is observed that a major cause for the vast areal extent of the area affected by the summer drought in the last decade is the high temperatures. Temperatures in the 12 months preceding and including the summer of 2003 explain an increase in the area percentage with moderate (or worse) drought of 31.2%. 

KEY WORDS Alpine region; drought; PDSI; waterbalance model

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submitted to:

*Annals of Glaciology* (IGS-Cambridge)

**A statistical mass balance model for reconstruction of LIA ice mass of glaciers of European Alps**

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## ABSTRACT

Stepwise linear regression models for prediction of specific annual net balance and summer balance from climatological and topographical input data were calibrated against measured mass balances of glaciers of Austrian part of the Alps. For estimation of winter mass balance a simple ratio between winter precipitation amount and measured winter balance was used. A ratio with mean value of 2.0 and standard deviation of 0.44 was derived from the sample of measured winter balances. Climate input data were taken from HISTALP data base which offers an outstanding homogenised data source in terms of spatial and temporal coverage. Data from the Austrian glacier inventory was used as topographical input data. From the pool of possible predictors summer air temperature, winter precipitation, summer snow precipitation, temperature continentallity where selected as climate forcing factors as well as lowest glacier elevation and area weighted mean glacier elevation as significant topographical contributors. Summer temperature explains 60% of the variance of summer mass balance and 39% of variance of annual mass balance. Additional factors increases explained variance by 22% for summer and 31% for annual net balance. The calibrated mass balance model was used for reconstruction of mass balance of Hintereisferner and Vernagtferner back to 1800. Whereas the model performs well for Hintereisferner it fails for some sub-periods for Vernagtferner due to complicated flow dynamics.

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# The application of glacier inventory data for estimating past climate-change effects on mountain glaciers: a comparison between the European Alps and the Southern Alps of New Zealand

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## Abstract

This study uses the database from national glacier inventories in the European Alps and the Southern Alps of New Zealand (hereinafter called the New Zealand Alps), which contain for the time of the mid-1970s a total of 5,154 and 3,132 perennial surface ice bodies, covering 2,909 km$^2$ and 1,139 km$^2$ respectively, and applies to the mid-1970s. Only 1,763 (35%) for the European Alps and 702 (22%) for the New Zealand Alps, of these are ice bodies larger than 0.2 km$^2$, covering 2,533 km$^2$ (88%) and 979 km$^2$ (86%) of the total surface area, respectively containing useful information on surface area, total length, and maximum and minimum altitude. A parameterisation scheme using these four variables to estimate specific mean mass balance and glacier volumes in the mid-1970s and in the '1850 extent' applied to the samples with surface areas greater than 0.2 km$^2$, yielded a total volume of 126 km$^3$ for the European Alps and 67 km$^3$ for the Southern Alps of New Zealand. The calculated area change since the '1850 extent' is -49% for the New Zealand Alps and -35% for the European Alps, with a corresponding volume loss of -61% and -48%, respectively. From cumulative measured length change data an average mass balance for the investigated period could be determined at -0.33 m water equivalent (w.e.) per year for the European Alps and -1.25 m w.e. for the 'wet' and -0.54 m w.e. per year for the 'dry' glaciers of the New Zealand Alps. However, there is some uncertainty in several unknown factors, such as the values used in the parameterisation scheme of mass balance gradients, which, in New Zealand vary between 5 and 25 mm m$^{-1}$.

*Keywords: glacier fluctuations, glacier length changes, glacier mass changes, climate change, reconstruction, volume change, area change*

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# Distributed modelling of the regional climatic equilibrium line altitude of glaciers in the European Alps

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## Abstract

Glaciers are among the key indicators of ongoing climate change. The equilibrium line altitude is a theoretical line which defines the altitude at which annual accumulation equals the ablation. It represents the lowest boundary of the climatic glacierisation and, therefore, is an excellent proxy for climate variability. In this study we introduce a simple approach for modelling the glacier distribution at high spatial resolution over entire mountain ridges using a minimum of input data. An empirical relationship between precipitation and temperature at the steady-state equilibrium line altitude ($ELA_0$), is derived from direct glaciological mass balance measurements. Using geographical information systems (GIS) and a digital elevation model, this relationship is then applied over a spatial domain, to a so-called distributed modelling of the regional climatic $ELA_0$ ($rcELA_0$) and the climatic accumulation area (cAA) of 1971–1990 over the entire European Alps. A sensitivity study shows that a change in $rcELA_0$ of ±100 m is caused by a temperature change of ±1 °C or a precipitation decrease of 20% and increase of 27%, respectively. The modelled cAA of 1971–1990 agrees well with glacier outlines from the 1973 Swiss Glacier Inventory. Assuming a warming of 0.6 °C between 1850 and 1971–1990 leads to a mean $rcELA_0$ rise of 75 m and a corresponding cAA reduction of 26%. A further rise in temperature of 3 °C accompanied by an increase in precipitation of 10% leads to a further mean rise of the $rcELA_0$ of about 340 m and reduces the cAA of 1971–1990 by 74%.

**Keywords**: Glacier, Climate at Equilibrium Line Altitude, Climate Change, Geographical Information Systems

**ALP-IMP-rev-30**

GEOPHYSICAL RESEARCH LETTERS, VOL. 33, LXXXXX, doi:10.1029/2006GL026319, 2006



# Alpine glaciers to disappear within decades?

Michael Zemp,[1] Wilfried Haeberli,[1] Martin Hoelzle,[1] and Frank Paul[1]

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[1] Past, present and potential future glacier cover in the entire European Alps has been assessed from an integrated approach, combining in-situ measurements, remote sensing techniques and numerical modeling for equilibrium line altitudes. Alpine glaciers lost 35% of their total area from 1850 until the 1970s, and almost 50% by 2000. Total glacier volume around 1850 is estimated at some 200 $km^3$ and is now close to one-third of this value. From the model experiment, we show that a 3°C warming of summer air temperature would reduce the currently existing Alpine glacier cover by some 80%, or up to 10% of the glacier extent of 1850. In the event of a 5°C temperature increase, the Alps would become almost completely ice-free. Annual precipitation changes of ±20% would modify such estimated percentages of remaining ice by a factor of less than two. **Citation:** Zemp, M., W. Haeberli, M. Hoelzle, and F. Paul (2006), Alpine glaciers to disappear within decades?, *Geophys. Res. Lett.*, *33*, LXXXXX, doi:10.1029/2006GL026319.

**ALP-IMP-rev-31**

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4th Swiss Geoscience Meeting, Bern 2006

# Hypsographic modelling as a tool for assessment of future glacier extent in the Swiss Alps

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The strong reaction of glaciers to small changes in climate (mainly temperature and precipitation) designates glaciers as a unique demonstration object of ongoing climate change for a wide public (Zängl & Hamberger 2004). Under current scenarios of atmospheric warming for this century, many Alpine glaciers are likely to disappear within the coming decades (Zemp et al. 2006). The future evolution of glacier size and volume is of major importance for many purposes, including hydro-power production, run-off (agriculture, transport), tourism or natural hazards (rock fall, lake development). In consequence, there is an urgent need to quantify future glacier evolution on an Alpine-wide scale. As current models for calculation of future glacier length or area require input data that are generally not available for most glaciers (e.g. the bedrock), simpler approaches have to be found. We have developed such a simple modelling scheme that calculates future glacier geometry using digitized glacier outlines and a digital elevation model (DEM) only (Paul et al. in press). The model assumes a steady-state equilibrium line altitude ($ELA_0$) that is based on a constant accumulation area ratio (AAR) for all glaciers (e.g. Maisch et al. 2000) and a constant sensitivity of the $ELA_0$ to temperature changes of 140 m for a 1 °C increase. By calculating a 10 m hypsography within a GIS for all 3062 glacier entities in our sample, we can easily calculate the new accumulation area (and thus total area) for any given shift of the $ELA_0$ (we use six values in steps of 100 m) within a few seconds. In order to account for a certain variability of the $AAR_0$, we run the model with four different $AAR_0$ values (0.5, 0.6, 0.67, and 0.75). The model neglects any changes in glacier thickness, curvature or the size of the accumulation area.

**ALP-IMP-rev-32**

Trees (2006) 20: 99–110
DOI 10.1007/s00468-005-0017-3

ORIGINAL ARTICLE

Ulf Büntgen · David C. Frank · Martin Schmidhalter ·
Burkhard Neuwirth · Mathias Seifert · Jan Esper

# Growth/climate response shift in a long subalpine spruce chronology

Received: 6 June 2005 / Accepted: 29 June 2005 / Published online: 26 October 2005


**Abstract** A new Norway spruce (*Picea abies* (L.) Karst.) tree-ring width chronology based on living and historic wood spanning the AD 1108–2003 period is developed. This composite record combines 208 high elevation samples from 3 Swiss subalpine valleys, i.e., Lötschental, Goms, and Engadine. To retain potential high- to low-frequency information in this dataset, individual spline detrending and the regional curve standardization are applied. For comparison, 22 high elevation and 6 low-elevation instrumental station records covering the greater Alpine area are used. Previous year August–September precipitation and current year May–July temperatures control spruce ring width back to ~1930. Decreasing (increasing) moving correlations with monthly mean temperatures (precipitation) indicate instable growth/climate response during the 1760–2002 period. Crucial June–August temperatures before ~1900 shift towards May-July temperature plus August precipitation sensitivity after ~1900. Numerous of comparable subalpine spruce chronologies confirm increased late-summer drought stress, coincidently with the recent warming trend. Comparison with regional-, and large-scale millennial-long temperature reconstructions reveal significant similarities prior to ~1900 (1300–1900 mean $r$=0.51); however, this study does not fully capture the commonly reported 20th century warming (1900–1980 mean $r$=−0.17). Due to instable growth/climate response of the new spruce chronology, further dendroclimatic reconstruction is not performed.

**Keywords** Alps · Dendroclimatology · Growth/climate response · High–low frequency · Standardization

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**ALP-IMP-rev-33**

# SUMMER TEMPERATURE VARIATIONS IN THE EUROPEAN ALPS, AD 755-2004

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Manuscript ***JCLI-1065*** accepted for publication in ***Journal of Climate***, March 02, 2006

**Abstract** We describe annually resolved summer temperatures for the European Alps. The reconstruction covers the AD 755–2004 period, and is based on 180 recent and historic larch [*Larix decidua* Mill.] density series. The regional curve standardization method was applied to preserve inter-annual to multi-centennial variations in this high elevation proxy dataset. Instrumental measurements from high (low) elevation grid-boxes back to 1818 (1760) reveal strongest growth response to current year June-September mean temperatures. The reconstruction correlates at 0.7 with high elevation temperatures back to 1818, with a greater signal in the higher frequency domain ($r$ =0.8). Low elevation instrumental data back to 1760 agree with the reconstruction's inter-annual variation, although, a decoupling between (warmer) instrumental and (cooler) proxy data before ~1840 is noted. This offset is larger than during any period of overlap with more recent high elevation instrumental data, even though the proxy time-series always contains some unexplained variance. Our reconstruction indicates positive temperatures in the 10th and 13th century that resemble 20th century conditions, and are separated by a prolonged cooling from ~1350–1700. Six of the ten warmest decades over the 755–2004 period are recorded in the 20th century. Maximum temperature amplitude over the past 1,250 years is estimated to be 3.1°C between the warmest (1940s) and coldest (1810s) decades. This estimate is, however, affected by the calibration with instrumental temperature data. Warm summers seem to coincide with periods of high solar activity, and cold summers *vice versa*. The record captures the full range of past European temperature variability, i.e., the extreme years 1816 and 2003, warmth during medieval and recent times, and cold in between. Comparison with regional- and large-scale reconstructions reveals similar decadal to longer-term variability.

**ALP-IMP-rev-34**

Au: Please check that all editorial changes are OK, reword any that you do not like, and answer any questions. If you wish to make any changes to figures, please send a high quality print of the revised figure(s). If this proof is returned by fax, please avoid writing in the outer 1 cm of the page, attach a typewritten list of changes and mail the original. Thank you.

**Tree Physiology** 27, 000–000


# Growth responses to climate in a multi-species tree-ring network in the Western Carpathian Tatra Mountains, Poland and Slovakia

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**Summary** We analyzed growth responses to climate of 24 tree-ring width and four maximum latewood density chronologies from the greater Tatra region in Poland and Slovakia. This network comprises 1183 ring-width and 153 density measurement series from four conifer species (*Picea abies* (L.) Karst., *Larix decidua* Mill., *Abies alba* (L.) Karst., and *Pinus mugo* (L.)) between 800 and 1550 m asl. Individual spline detrending was used to retain annual to multi-decadal scale climate information in the data. Twentieth century temperature and precipitation data from 16 grid-boxes covering the 48–50 °N and 19–21 °E region were used for comparison. The network was analyzed to assess growth responses to climate as a function of species, elevation, parameter, frequency and site ecology. Twenty ring-width chronologies significantly correlated ($P < 0.05$) with June–July temperatures, whereas the latewood density chronologies were correlated with the April–September temperatures. Climatic effects of the previous-year summer generally did not significantly influence ring formation, whereas site elevation and frequency of growth variations (i.e., inter-annual and decadal) were significant variables in explaining growth response to climate. Precipitation increased with decreasing elevation. Correlations between summer temperatures and annual growth rates were lower for *Larix decidua* than for *Picea abies*. Principal component analysis identified five dominant eigenvectors that express somewhat contrasting climatic signals. The first principal component contained highest loadings from 12 *Picea abies* ring-width chronologies and explained 42% of the network's variance. The mean of these 12 high-elevation chronologies was significantly correlated at 0.62 with June–July temperatures, whereas the mean of three latewood density chronologies, that loaded most strongly on the fourth principal component, significantly correlated at 0.69 with April–September temperatures ($P < 0.001$ over the 1901–2002 period in both cases). These groupings allow for a robust estimation of June–July (1661–2004) and April–September (1709–2004) temperatures, respectively. Comparison with reconstructions from the Alps and Central Europe supports the general rule of the dominant influence of growing season temperature on high-elevation forest growth.

**ALP-IMP-rev-35**

submitted to:

*Proceedings of the Royal Society: B*, in review

# Insect outbreak clockwork in the European Alps stops after 1200 years

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**Abstract**

Impacts on ecological disturbance regimes are critical but poorly understood environmental consequences of contemporary climate change. Recurring outbreaks of Lepidoptera common to many temperate forest ecosystems are ideal systems for studying such impacts because they regularly cause massive defoliation of large forested areas and therefore play important roles in nutrient cycling. Unfortunately, long-term data on outbreaks are often lacking and this limits our ability to measure the effects of climate change on these disturbance regimes. Here we introduce a reconstruction of the long-term history of outbreaks by *Zeiraphera diniana* Gn. (the larch budmoth, LBM) feeding on sub-alpine larch in the European Alps derived from a dataset of 47,513 maximum latewood density measurements from tree-rings. With over 1,000 generations represented, this is the longest annually resolved record of herbivore population dynamics, and our analysis demonstrates that remarkably regular LBM fluctuations persisted over the past 1173 years with population peaks every 8.9 years. These regular abundance oscillations recurred until 1981, with the absence of peak events during recent decades. Comparison with an annually resolved, millennium-long temperature reconstruction representative for the European Alps (r = 0.72, correlation with instrumental data), demonstrates that cyclic insect population dynamics occurred despite major climatic changes related to warming during medieval times and cooling during the Little Ice Age. The late 20th century absence of LBM mass-outbreaks, however, corresponds to a period of regional warmth that is exceptional with respect to the last 1000+ years, suggesting vulnerability of an otherwise stable ecological system in a warming environment.

**ALP-IMP-rev-36**

Vol 440|27 April 2006|doi:10.1038/nature04743 nature

LETTERS

# The twentieth century was the wettest period in northern Pakistan over the past millennium

Kerstin S. Treydte[1], Gerhard H. Schleser[2], Gerhard Helle[2], David C. Frank[1], Matthias Winiger[3], Gerald H. Haug[4] & Jan Esper[1]

Twentieth-century warming could lead to increases in the moisture-holding capacity of the atmosphere, altering the hydrological cycle and the characteristics of precipitation[1]. Such changes in the global rate and distribution of precipitation may have a greater direct effect on human well-being and ecosystem dynamics than changes in temperature itself[2,3]. Despite the co-variability of both of these climate variables[3], attention in long-term climate reconstruction has mainly concentrated on temperature changes[4–8]. Here we present an annually resolved oxygen isotope record from tree-rings, providing a millennial-scale reconstruction of precipitation variability in the high mountains of northern Pakistan. The climatic signal originates mainly from winter precipitation, and is robust over ecologically different sites. Centennial-scale variations reveal dry conditions at the beginning of the past millennium and through the eighteenth and early nineteenth centuries, with precipitation increasing during the late nineteenth and the twentieth centuries to yield the wettest conditions of the past 1,000 years. Comparison with other long-term precipitation reconstructions indicates a large-scale intensification of the hydrological cycle coincident with the onset of industrialization and global warming, and the unprecedented amplitude argues for a human role.

**ALP-IMP-rev-37**

# Spatial reconstruction of summer temperatures in Central Europe for the last 500 years using annually resolved proxy records: problems and opportunities

ROBERT WILSON, DAVID FRANK, JOHN TOPHAM, KURT NICOLUSSI AND JAN ESPER

BOREAS

Wilson, R., Frank, D., Topham, J., Nicolussi, K. & Esper, J. 2005 (November): Spatial reconstruction of summer temperatures in Central Europe for the last 500 years using annually resolved proxy records: problems and opportunities. *Boreas*, Vol. 34, pp. 490–497. Oslo. ISSN 0300-9483.

Most palaeoclimate studies in Central Europe, utilizing annually resolved proxies such as tree-ring and documentary sources to reconstruct past temperatures, have focused mainly upon single sites or regional studies. The combined information of published summer temperature reconstructions from the Alpine region show a generally coherent picture of cool conditions for the periods *c.* 1450–1475, 1575–1610, 1660–1710, 1800–1850 and 1875–1925. These reconstructed cool periods can be partly explained by external forcing (e.g. low solar activity and volcanic events). However, these reconstructions, in their present form, cannot be used to comparatively assess spatial summer temperature variability through the region due to methodological differences in their development and the fact that many of them were not originally developed to emphasize spatial patterns. We propose that a network of tree-ring chronologies which have been processed in a consistent way would allow the robust reconstruction of spatial summer temperature variability for high elevations in Central Europe. Unfortunately, most living tree-ring chronologies only go back into the 18th century – so restricting the length of reconstruction. As a possible solution, we introduce a historical database of ring-width series, measured from string instruments, that could be used to extend high elevation spruce chronologies in Central Europe back for at least 500 years.

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**ALP-IMP-rev-38**

Veget Hist Archaeobot (2005) 00
DOI 10.1007/s00334-005-0013-y

ORIGINAL ARTICLE

Kurt Nicolussi · Matthias Kaufmann · Gernot Patzelt ·
Johannes van der Plicht · Andrea Thurner

# Holocene tree-line variability in the Kauner Valley, Central Eastern Alps, indicated by dendrochronological analysis of living trees and subfossil logs

Received: 7 March 2005 / Accepted: 13 July 2005


**Abstract** The altitude of the Alpine tree-line has often been used as proxy for the climatic conditions in the Holocene epoch. The usual approach for establishing a record for this proxy is the analysis of pollen and macro remains. We analysed living trees and subfossil logs from the timberline ecotone in the innermost Kauner valley in the Central Eastern Alps in order to assemble a Holocene dendrochronological tree-line record. Data sets comprising age and height of living Stone Pines (*Pinus cembra* L.) were collected at one site. Sections of 170 subfossil Stone Pine logs from five other sites were dendrochronologically analysed and dated. Besides using dendrochronological analyses, radiocarbon dating served as a means of obtaining the age of some logs. For most of the samples we could provide dendrochronological dates (1-year dating precision, back to 5125 B.C.) or wiggle matched dates (between approx. 7100 and 5040 B.C., dating precision with 95% probability: ±7 years). In the first half of the 19th century the tree-line was located at about 2180 m a.s.l. in the innermost Kauner valley. After approximately A.D. 1860 the altitude of the upper limit of the occurrence of *Pinus cembra* individuals (tree-species-line) and, being closely linked, also that of the tree-line both rose. The current tree-line (trees >2 m) is located at 2245 m a.s.l. due to climatic conditions around 1980. Additionally we observed saplings up to a present (A.D. 2000) tree-species-line at approx. 2370 m a.s.l. The dendrochronologically analysed subfossil logs found at up to 2410 m a.s.l. date from within the last 9000 years (between approx. 7100 B.C. and A.D. 1700). In the space of the last 4000 years the dendrochronological tree-line record is not continuous, probably due to human impact. Tree-line positions similar to or slightly above the 1980 tree-line are established for the time periods approx. 1000 to 640 B.C. and A.D. 1 to 330 respectively. For the time period between approx. 7100 and 2100 B.C. the dendrochronologically analysed logs show nearly continuous evidence of a tree-line above the 1980s limit. Very high elevation of the tree-line, between 120 and 165 m above the 1980s level (2245 m a.s.l.) and even higher than the A.D. 2000 tree-species-line (2370 m a.s.l.), are recorded for the periods 7090–6570, 6040–5850, 5720–5620, 5500–4370 B.C., approx. 3510–3350 B.C. and 2790–2590 B.C. Additionally, a tree-line which was located at least 50 m above the 1980s limit can be shown for the periods 6700–5430, 4920–3350 and 3280–2110 B.C. The dendrochronological record from the Kauner valley, showing high and very high tree-line positions between approx. 7100 and 2100 B.C. with only two gaps (around 6490 B.C. and from 3350 to 3280 B.C.), suggests that summer temperatures as observed in the late 20th century were at the normal or the lower limit of the temperature range which can be assumed for long periods of the early and middle Holocene epoch.

**Keywords** Holocene · Alps · tree line · *Pinus cembra* · dendrochronology

**ALP-IMP-rev-39**

accepted for:

*Dendrochronologia*

*Technical Note:*

# *Time-varying-response smoothing*

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**Summary**

Cubic smoothing splines with a fixed-period response are used widely in producing "expected" growth curves for ring-width and density data in dendroclimatology. A simple modification to the procedure which generates these splines enables the use of a smoothing spline with a user-specified, time-varying flexibility and hence time-varying-response characteristics. The revised procedure is presented here, along with different examples of its application in the context of Regional Curve Standardisation (RCS). The ability to generate a smoothing spline with time-dependent flexibility may have wider application in tree-ring studies.

**Keywords**

RCS method, smoothing spline, dendrochronology, standardisation

**ALP-IMP-rev-40**

Nicolussi K., Pichler T., Kaufmann M., Thurner A

in preparation

# Years of extreme tree-ring growth during the last millennium in the European Alps

**ALP-IMP-rev-41**

Nicolussi K., Böhm R., Briffa K.R., Melvin T., Thurner A

In preparation

# A summer temperature reconstruction for the last 2000 years

**ALP-IMP-rev-42**

Nicolussi K, Kaufmann M

in preparation

# Evolution of the tree line in the central European Alps during the last 2000 years

**ALP-IMP-rev-43**

# Influence of large-scale atmospheric circulation on climate variability in the Greater Alpine Region of Europe

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Submitted for publication in

**Journal of Geophysical Research – Atmospheres**

12 September 2006

**Abstract**

The climatic variability in the Greater Alpine Region (GAR) of Europe has a diverse character: it exhibits differences between winter and summer, and between its individual subregions. The large-scale atmospheric circulation, as expressed by the mean sea level pressure (MSLP) patterns in the wider Euro–Atlantic region, plays a significant role in the climate variability in winter, but less in summer. In winter, high-altitude temperatures are markedly linked with the Northern Hemisphere (NH) zonal circulation, as expressed by the NH annular mode (NAM), whereas the low-level temperature field is associated more with the circulation over the NE Atlantic. The Alpine mountain chain delimits the different winter precipitation regimes between the northern and southern side of the GAR. While a British Isles-centered pressure pattern plays the principal role in influencing northern Alpine precipitation, the North Atlantic Oscillation (NAO), and in particular its Mediterranean component, is the large-scale atmospheric mode affecting precipitation over the southern Alpine region. The impact of the El Niño/Southern Oscillation (ENSO) phenomenon on GAR climate is weak, though it is distinctly manifested within intermittent periods of 2 to 3 decades. In these periods, the late autumn and winter temperature and the winter and spring precipitation exhibit a significant correlation with the ENSO state of the boreal winter, and even more prominently with ENSO state of the preceding autumn and late summer. Signs of ENSO impact on summer temperature are also apparent, especially in the last quarter of the 20th century. The ENSO impact is associated with atmospheric pressure anomaly patterns in the European region indicating modifications of large-scale circulation whose effects are also found in the climates of larger areas of Europe.

**ALP-IMP-rev-44**

# Warmer early instrumental measurements *versus* colder reconstructed temperatures: hemispheric to regional evidence

**David Frank[a*], Ulf Büntgen[a*], Reinhard Böhm[b] Maurizio Maugeri[c] and Jan Esper[a]**

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Submitted to *Quaternary Science Reviews* as Rapid Communication, September 28, 2006

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**Abstract**

Comparison of tree-ring based warm-season temperature reconstructions and their observational target data reveals substantial divergence between (warmer) early instrumental measurements and (colder) proxy estimates. We here detail this systematic misfit for the Northern Hemisphere and European Alps, discuss the homogenization applied to the instrumental data and draw attention to its relevance for understanding recent anthropogenic and past natural forced climate systems.

**ALP-IMP-rev-45**

Brunetti M, Lentini GL, Maugeri M, Nanni T, Auer I, Böhm R, Schöner W

in preparation

# Climate variability and change in the Greater Alpine Region over the last two centuries based on multiple variable analysis

**ALP-IMP-rev-46**

Böhm R, Brunetti M and co-authors

in preparation

# Trends of climate variability in the European Alps in the past two centuries

Preliminary abstract:

Public climate change discussion often claims an “increase of climate extremes” already to be observed. In most cases, the subject it is not precisely defined and therefore not easy to be supported or rejected by scientific analysis. Therefore, the proposed contribution wants to precisely define its topic. We use a new dataset (HISTALP) covering the “greater Alpine region” (GAR). The dataset is based on monthly instrumental climate data, carefully, homogenised and outlier corrected. It is described in a poster in session AC07. For the three leading climate elements, air pressure, temperature and precipitation, many series extend back into the early instrumental period, some into the 18$^{th}$ century. An early series subset is used to analyse the evolution of the range of high frequent variability. To overcome problems related to non Gaussian distributions and in order to exclude any influence of existing climate trends, we used interquantile ranges of detrended series in moving windows of 30 years. To avoid any influence of a variance increase due to decreasing number of series when proceeding back in time, we performed the analysis on each single series and not on regional means.

The results are maybe astonishing for someone not familiar with climate in the early instrumental period. From the 19$^{th}$ to the 20$^{th}$ century there has been a prevailing and significant decrease of temperature variability, independent from the choice of the range (80%, 90%, 95% and the outliers beyond) and stable also in terms of different subregions. For precipitation we found different subregional and seasonal trends, but more decreasing than increasing evolutions. Air pressure takes a position between: a clear dominance of variability decreases, but a strange different winter evolution, which then also influences the annual results due to the much higher variability of air pressure in winter. The results are similar (but as a matter of fact less significant) for the recent decades which may be under anthropogenic influence already.

We clearly state that our study is not dealing with extremes based on daily or subdaily data, for which we regard the still existing and not easily solvable data availability, homogeneity and general quality problems to hamper similar analyses. But we are also convinced that a number of extreme climate events and impacts like hot summers, large scale flooding events, major droughts and others are well captured by monthly data. Therefore we regard our results to be well usable as argument in a topic of main interest in a region to be claimed of high climate sensitivity and vulnerability.

**ALP-IMP-rev-47**

Böhm R, Brunetti M, Jones P, Maugeri M, Ungersböck M

in preparation

# An independent confirmation of past decadal-scale temperature increase by high- and low elevation air pressure series from the European Alps

**ALP-IMP-rev-48**

submitted to:

*Climate Dynamics*

# Evaluation of the Skill and Added Value of a Reanalysis-driven Regional Simulation for Alpine Temperature

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Julie Jones (2), Martin Widmann (3)

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## Abstract

A high-resolution regional climate simulation has been performed with the REMO model for the whole of Europe for the period 1958-1998. The REMO simulation and the driving ERA40 reanalysis are validated against station datasets for 2m temperature over the Greater Alpine Region. The temporal variability, as quantified by correlation, is well represented by both ERA and REMO. However, both models show problems with the bias. For the REMO simulation the bias reaches 3 K in regions known to experience a problem with summer drying in a number of regional models. In winter the bias for the REMO simulation is negligible except for the high-elevation stations, where it is highly negative (-3.5 K) and is probably caused by the comparison of grid box data with station data as the altitude correction applied to the simulated data can not consider all effects related to elevation differences. The difference between the biases of the REMO and ERA simulations dominates the reduction of error, which shows that the added value of the higher resolution regional simulation compared to the reanalysis, where measurements are assimilated, varies between the seasons and regions. In some regions the reduction of error also depends on the selection of stations used for the validation. However, the better representation of REMO in the inner Alpine subregions in summer is a robust feature.

**ALP-IMP-rev-49**

Scheifinger H, Böhm R, Widmann M, Frei Ch

in preparation

# Climatological evaluation of the REMO (REgional MOdel) precipitation simulation over the Greater Alpine Region 1971 – 1999

**ALP-IMP-rev-50**

Jones PD, Briffa K, Melvin T, Böhm R, Schöner W, Büntgen U, Esper J, Frank D, Grabner M, Nicolusi K, Hoelzle M, Zemp M, Haeberli W + co-authors still to be decided

in preparation

Climate variability in the alpine region over the last millennium in a European context

**ALP-IMP-rev-51**

submitted to:

*Hydrological Processes*, special issue: Hydrometeorology and Snow Seasonality in Mountains

# Long term trend of snow depth at Sonnblick (Austrian Alps) and its relation to climate change

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Abstract:

Snow is a significant factor of mountain environments and plays a relevant role for national economies and water resources. Moreover it is an important climatic impact especially in the context of climate change. In this study the extensive snow measurement network of the Sonnblick region (Hohe Tauern, Austrian Alps) is used to describe temporal trends in snow depth as well as its relation to climate change for a high elevated site of the Alps. Spatial representateveness of single snow stakes with readings back to 1928 is derived using a spatially dense snow height probing performed every May since 1987 in the frame of glacier monitoring programme. Long term trends of snow depth show a significant reduction in the contribution of snow accumulation from core winter (1.December to 1.March). Largest values of snow depth were measured in the 1940ies and 1950ies. Relation between snow depth and climate is investigated by means of local climate data of Sonnblick Observatory and by means of the North Atlantic Oscillation Index NAOI. Whereas winter air temperature and therefore fraction of solid precipitation are significantly correlated with the NAOI, for winter precipitation and snow height at 1.May no correlation was found with NAOI. A simple statistical relationship between air temperature and fraction of solid precipitation is used for estimation of temporal trends of fraction of solid precipitation at different altitudes. For summer a decrease of about 1% of solid precipitation per decade was found. Comparison of monthly changes in snow depth with precipitation measurements underlines the high influence of wind processes on snow depth.

**ALP-IMP-rev-52**

Grabner M plus author-consortium from partners 9, 2, 10

in preparation

Temperature reconstruction at the mountain Dachstein, Austria

**ALP-IMP-rev-53**

Grabner M plus author-consortium from partners 9, 2

in preparation

Reconstructing early summer precipitation at Eastern Austria with the help of tree-rings

**ALP-IMP-rev-54**

HYDROLOGICAL PROCESSES
*Hydrol. Process.* **19**, 3425–3444 (2005)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.5979

# Simulation of $\delta^{18}O$ in precipitation by the regional circulation model $REMO_{iso}$

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## Abstract:

The first results of a regional circulation model $REMO_{iso}$ fitted with water isotope diagnostics are compared with various isotope series from central Europe. A 2 year case study is conducted from March 1997 to February 1999 centred over Europe, analysing daily and monthly measurements. Isotope signals over Europe are dominated by the typical isotopic effects such as temperature, continental and altitude effects, both on annual and seasonal scales. These well-known isotopic effects are successfully reproduced by $REMO_{iso}$, using two different boundary data sets. In a first simulation, the European Centre for Medium-range Weather Forecasts (ECMWF) analyses serve as boundary conditions, where water isotopes were parameterized by a simple temperature dependence. In a second simulation, boundary conditions both for climatic and isotopic variables are taken from the $ECHAM_{iso}$ general circulation model output. The comparison of both simulations shows a very high sensitivity of the simulated $\delta^{18}O$ signal to boundary conditions. The ECMWF-nested simulation shows an average offset of $-4{\cdot}5‰$ in mean $\delta^{18}O$ values and exaggerated seasonal amplitude. The ECHAM-nested simulation represents correctly the observed mean $\delta^{18}O$ values, although with a dampened seasonality. $REMO_{iso}$'s isotope module is further validated against daily $\delta^{18}O$ measurements at selected stations (Nordeney, Arkona and Hohenpeissenberg) situated in Germany. 

KEY WORDS stable water isotopes; hydrological/water cycle; regional modelling

**ALP-IMP-rev-55**

under revision at:

*Journal of Climate*

# Simulation of the water isotopes in precipitation over South America: comparing regional to global circulation models

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28th February 2005

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## 1 Introduction

[1] *The case for regional circulation models. Climate archives contain temporally continuous, but spatially discrete information. Circulation models help interprete / synthetise station data in terms of synoptic variations. A better horizontal resolution improves the simulation of local/regional processes, especially in mountain areas. The stable water isotopes (SWI) give further insights on the path of an air parcel, hence its simulation sets further constraints on the correct representation of the water cycle.*

*In order to differentiate ourselves from the comprehensive paper by Vuille et al., highlight our bonuses: REMO, D excess, dipole feature once ENSO variability is cancelled (climatological run).*

**ALP-IMP-rev-56**

Frank D, Büntgen U, Esper J, Pichler T, Nicolussi K

In preparation

# Temperature variability in the Alps: extension and update of the Tyrol dataset

## Preliminary abstract:

The Tyrol dataset is a collection of 71 *Picea abies* ring width measurement series from the Stubaital and Oetztal in Austria. It was sampled in the 1970s (Lamprecht 1978, Siebenlist-Kerner 1984) – the outermost ring is 1975 – and extended back into the 14th century. Despite this limited length, the collection and derived chronologies have been used in recent publications dealing with millennium-long, hemispheric scale temperature variations (D'Arrigo et al. 2006, Esper et al. 2002, Osborn & Briffa 2006), indicating the relevance of these data in reconstructing large-scale climate variability. The data were considered despite the early end date (1975) limiting the calibration period by about 30 years, i.e. recent decades of instrumental data could not be used for climate signal analysis.

We here describe efforts of updating this relevant dataset. These include extending the data back in time and updating it during recent decades. We review the common variance of the various sub-samples combined in the Tyrol collection, and describe some initial assessment of the climate signal. Interestingly, past efforts to reconstruct larger scale temperature variations considered only the tree-ring width (TRW) data fraction of the Tyrol collection. The original and now updated datasets contain both TRW and density measurements, however. So, here we focus on the maximum latewood density (MXD) measurements and compare their climate signal with that found in TRW.

**ALP-IMP-rev-57**

Hoffmann G plus author consortium of partners 6 and 4

in preparation

High-Resolution Modelling of Water Isotopes in Western Europe and the Greater Alpine Region: From day-to-day variability to climatological isotope/temperature relationships

**ALP-IMP-rev-58**

Hoffmann G plus author consortium of partners 6 and 4

in preparation

Using high resolution modelling to construct an archive transfer function for high Alpine water isotope records

**ALP-IMP-rev-59**

IGS Symposium on Cryosphere Indicators of Global Climate Change

Cambridge, 20-25 August, 2006

# Integrated monitoring of mountain glaciers as key indicators of global climate change: the European Alps

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## 1. ABSTRACT

The internationally recommended multilevel strategy for monitoring mountain glaciers is illustrated using the example of the European Alps, where especially dense information has been available through historical times. This strategy combines in-situ measurements (mass balance, length change) with remote sensing (inventories) and numerical modelling. It helps to bridge the gap between detailed local process-oriented studies and global coverage. Since the 1980s, mass balances became increasingly negative with values close to -1 m w.e. per year during the five first years of the 21st century. The hot/dry summer of 2003 alone caused a record mean loss of -2.45 m w.e., roughly 50% above the previous record loss in 1998, more than three times the average between 1980 – 2000 and an order of magnitude more than characteristic long-term averages since the end of the Little Ice Age and other extended time periods of glacier shrinkage during the past 2000 years. It can be estimated that the glaciers in the European Alps have lost about half their total volume (roughly -0.5% per year) between 1850 and around 1975, another 25% (or -1% per year) of the remaining amount between 1975 and 2000, and additional 10 to 15% (or -2 to -3% per year) in the first five years of this century.

**ALP-IMP-rev-60**

*IGS Symposium on 'Cryospheric Indicators of Global Climate Change', Cambridge, 21.-25. Aug 2006*

# Long-term changes in alpine glacier volume obtained by six independent approaches

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## Abstract

Changes in volume of alpine glaciers over longer periods of time are of major interest for several studies, including impacts of climate change, changes in fresh water resources (agriculture, hydro-power), validation of direct mass balance measurements and calculation of contributions to sea level rise. As many glaciers around the world have lost a major part of their volume (up to 50%) from 1850 to the 1970s, an accurate assessment of this loss based on a larger sample is required. The methods to evaluate long-term volume changes can be distinguished into differences of total volumes and direct determination of the change. Large uncertainties arise due to lacking input data and result in the still most popular application of volume-area scaling, although area is physically not the factor controlling glacier thickness. In this study we compare changes in glacier volume from 1850 to 1973 for 59 selected glaciers in the Swiss Alps by means of six independent methods: (1) volume-area scaling, (2) mean thickness from area, (3) the shallow ice approximation, (4) cumulative length changes, (5) polygon bodies from contour lines, and (6) subtraction of reconstructed DEMs. The comparison reveals that volume changes for individual glaciers might differ by a factor of three or more, while relative differences compared to method (2) varies mainly between +100% and -150%. There is no correlation between the differences in total or relative volume change with glacier size. While method (1) and (2) give very similar volume changes, (3) reveals somewhat higher changes and (4) somewhat lower changes than (2) for most of the glaciers, both with a large scatter. Methods (5) and (6) mainly overestimates volume changes with a 40% higher mean. We suggest to average volume changes at least from two independent methods and take an uncertainty range of about +/-25% into account.

**ALP-IMP-nrev-02**

Terra Nostra 2003/6: 6. Deutsche Klimatagung 61

# Der Alpine Niederschlagsdipol – ein dominierendes Schwankungsmuster der Klimavariabilität in den Scales 100 km – 100 Jahre

Reinhard Böhm[1], Ingeborg Auer[1], Wolfgang Schöner[1], Markus Ungerböck[1], Corinna Huhle[2], Teresa Nanni[3], Michel Brunetti[3], Maurizio Maugeri[4], Luca Mercalli[5], Marjana Gajic-Capka[6], Ksenija Zaninovic[6], Sandor Szalai[7], Tamas Szentimrey[7], Tanja Cegnar[8], Oliver Bochnicek[9], Michael Begert[10], Olivier Mestre[11], Jean-Marc Moisselin[11], Gerhard Müller-Westermeier[12] & Zeljko Manstrovic[13]

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**Zusammenfassung**

Das Klimaelement Niederschlag zeigt auf allen der raum-zeitlichen Skalen starke Variabilität, auch im langfristigen Trendverhalten. Ein neuer, räumlich dichter Datensatz von 192 homogenisierten instrumentellen Reihen in monatlicher Auflösung im Großraum Alpen wird hier vorgestellt, der bis zum Jahr 1800 zurückreicht. Erste Analysen deuten auf eine systematische Langfrist-Oszillation zwischen gegenläufigen Trends NW-lich und SE-lich der Alpen hin.

**Summary**

Precipitation shows strong variability on all spatial and temporal scales – also concerning long-term trends. We present a new high density dataset of 192 homogenised instrumental monthly precipitation series in the "Greater Alpine Region", starting in the year 1800. First analyses have detected a systematic long-term oscillation of inverse long-term trends in the NWern vs. the SEern subregions of the study region.

**ALP-IMP-nrev-03**

Terra Nostra 2003/6: 6. Deutsche Klimatagung 375

# Räumliche Dekorrelation von Klimazeitreihen unterschiedlicher zeitlicher Auflösung und ihre Bedeutung für ihre Homogenisierbarkeit und die Repräsentativität von Ergebnissen

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**Zusammenfassung**

Relative Homogenisierungsmethoden setzen voraus, dass ein gewisses Mindestmaß an gemeinsamer Varianz (z. B. 0.5) zwischen benachbarten, zur Homogenisierung verwendeten Stationen, vorliegt. Auf Grundlage dieser Idee soll ein Kriterium der Homogenisierbarkeit entwickelt werden, das es ermöglicht, a priori die Homogenisierbarkeit von Datensätzen festzustellen. In dieser Arbeit werden erste Ansätze dazu vorgestellt. Das räumliche Verhalten der gemeinsamen Varianz von Zeitreihen zweier Temperaturdatensätze werden beleuchtet und gegenübergestellt.

**Abstract**

Relative methods for homogenisation of data sets assume that there exists a minimum of common variance, e.g. 0.5, between neighbouring stations. Based on this idea one might develop a criterion, which makes it possible to figure out a – priori, whether a data set is suited for homogenisation at all or not. Here we present first results of an analysis of the spatial variability of the common variance between station pairs of two temperature data sets.

**ALP-IMP-nrev-07**

*Kartographische Nachrichten* **5** 212-217

# Das neue Schweizer Gletscherinventar 2000: Anwendungen in der Gebirgskartographie

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## ABSTRACT

Im neuen Schweizer Gletscherinventar 2000 wurden verschiedene kartographische Darstellungen von Gletschern und ihren Veränderungen mit Hilfe des GIS Arc/Info realisiert. Neben einem DHM und orthorektifizierten Satellitenbildern verschiedener Auflösung standen dafür eine Auswahl digitaler Gletscherumrisse von 1850 bis heute zur Verfügung. Mit diesen drei Komponenten lassen sich unterschiedlichste Visualisierungen realisieren, die jedoch nicht alle sinnvoll sind. Insbesondere der Verwendungszweck, das Zielpublikum und der gewählte Masstab schränken die Auswahl möglicher Kombinationen ein. Diese werden im folgenden Artikel diskutiert.

**ALP-IMP-nrev-13**

4th Seminar for Homogenization and Quality Control in Climatological Databases, 06-10 October 2003, Budapest, Hungary

# METADATA AND THEIR ROLE IN HOMOGENISING

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## INTRODUCTION

During the last years the question of climate variability and change has moved more and more into the public eye. Although the climate debate aims more to future climate the knowledge of past climate variability is the indispensably solid basis to understand the mechanisms of climate variability for the changes of future climate. In order to achieve this goal historical climate time series have to be analysed, however, inhomogeneities can bias the series and the results will not reflect only natural climate variability. The best way to avoid inhomogeneities in climate time series is to keep the record homogeneous, nevertheless we have to accept that even at present some changes cannot be avoided and the history of a station cannot be changed. In order to ascertain the homogeneity of a series a number of good tools have been developed (comp. Szalai et al, 1999 or Peterson et al., 1998 a.o.) and progress has been going on to improve and refine these methods. Also WMO has stressed its strong interest in this topic. For that purpose WMO initiated that "Guidelines on Metadata and Homogenisation" (Aguilar E et al., 2003) should be worked out. The draft version is available at: http://www.bom.gov.au/wmo/climate/ccl/CCl_HM_250603.doc:

At the Central Institute for Meteorology and Geodynamics in Vienna during the last ten years a number of climate variability projects have been finished or are carried out at present focussing on time series analyses in the Alpine region (ALOCLIM, ALPCLIM, ALP-IMP, CLIVALP). During these projects, apart from the use of homogeneity tests an intensive study of metadata has been performed. The paper intends to put together some results provided by these projects and to underline the importance of metadata studies.

**ALP-IMP-nrev-14**

*TRACE* **3** 141-149

# The effect of power transformation on RCS – evidence from three millennial-length alpine chronologies

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**Abstract** Three multi-centennial tree-ring chronologies from the Swiss and Austrian Alps are aggregated. 229 spruce, 1110 larch and 418 pine samples from living trees and historical timbers were detrended to preserve low frequency, multi-centennial variations, by applying the Regional Curve Standardization (RCS) method. The influences/biases of two different ways of calculating tree-ring indices as part of the chronology development are shown. Specifically, we compare detrending by ratios with detrending by residuals after applying a power transformation. These methods are shown to have a significant impact on growth levels, trends and variability of the resulting chronology. The sensitivity and/or robustness of RCS chronologies to these calculation methods is discussed. We show this to be of significant importance, particularly when tree-ring data are used in climatic and environmental change studies, placing the 20$^{th}$ century warming into a long-term context.

**ALP-IMP-nrev-16**

*GKSS-Report* **2005-04**, 1-115

# Outstanding past decadal-scale climate events in the Greater Alpine Region analysed by 250 years data and model runs

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**Abstract**

Detrended climatic time series are in general not white but show on a multi-annual to decadal timescale significant anomalies, hereafter called 'outstanding periods' (O.P.). Such O.P.s are the central subject/core of the study. Basis of the investigation are two datasets that cover the past 250 years and their consistencies at regional and multi-annual to decadal scales respectively. The first dataset is representative at sub-European to European scale and consists of homogenized time series of several climate elements. This study contributes to its generation. The second dataset covers the whole globe at a rather coarse resolution and results from differently forced climate model simulations.

There is a set of goals achieved by this study. First, to comprehensively describe climate and its variability during the past 250 years within the Greater Alpine Region. Second, the detection of 'outstanding temperature periods' from 1760 onward. Third, the investigation of the linkage/interplay between large scale circulation and regional scale temperature and thereby fourth, making a contribution to the understanding of the interrelation between external forcings and regional scale climate.

The first goal is achieved by creating a homogenized dataset (hereafter called HISTALP) of instrumental monthly series of air temperature, precipitation, air pressure, sunshine duration and cloudiness, that are of sufficient length. These series cover 'the Greater Alpine Region' (hereafter 'GAR'), which extends from 43N4E to 49N19E and some of them start as early as 1760. The HISTALP series have been quality improved in terms of detection and elimination of non climatic inhomogeneities and outliers.

Based on temperature 'outstanding periods', which are multi-annual to decadal sequences of years that exhibit large fractions of stations showing significantly higher or lower values than the detrended long-term course, are detected. The reality of these outstanding periods is shown to be supported by the temporal advancing and retreating of Alpine glacier records. Precipitation records are used to confirm the detection of outstanding periods and series of sunshine-duration and cloud cover help to formulate a hypothesis explaining some model-data mismatches.

During outstanding periods we investigate the synoptic scale behaviour as simulated by the atmosphere-ocean general circulation model ECHO-G. Atmospheric circulation is analysed by an objective decomposition of ECHO-G's SLP, which is done by rotated empirical orthogonal functions. This step helps to achieve the third goal.

The fourth goal is aimed for by the analysis of several ECHO-G model runs driven by different external forcings. Although findings should not be overrated this approach seems to be appropriate for answering questions related to the regional scale impacts of different external forcings. Such comparisons between homogenized historical series and model simulations have the potential to enhance our knowledge about the interaction of the scales and the possible physical-dynamical background. For winter plus the whole year results, achieved by the comparison of large scale simulation and regional scale reaction, are somewhat promising. Results achieved for summer are more difficult to interpret mainly because of summer circulation and a reduced sample size of outstanding periods compared to winter and the whole year.

**ALP-IMP-nrev-32**

*Croatian Meteorological Journal* **40** 106-110

# EXPLORING PAST CLIMATE VARIABILITY IN THE GREATER ALPINE REGION

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**Abstract:** The presentation discusses the potential, the needs and the state of the art of climate variability data quality and analysis in the instrumental period. The greater alpine region is used as an example. Problems and solutions concerning the non climatic noise in time series is discussed (the homogeneity and outlier problem) and some first results based on the new HISTALP datasets are shown

***Keywords:*** climate variability, instrumental period, data quality, Greater Alpine Region

**ALP-IMP-rev-33**

*Croatian Meteorological Journal* **40** 111-113

# A NEW HIGH-RESOLUTION BI-CENTENNIAL (1800–2003) PRECIPITATION DATASET FOR THE GREATER ALPINE REGION

Dimitrios Efthymiadis [1], Philip D. Jones [1], Keith R. Briffa [1], Ingeborg Auer [2], Reinhard Böhm [2], Wolfgang Schöner [2], Christoph Frei [3], Jürg Schmidli [3]

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**Abstract**: A new precipitation dataset for the Greater Alpine Region (GAR; 4°E–19°E, 43°N–49°N) has been developed. It provides monthly precipitation totals for the 1800–2003 period on a 10-min resolution grid. The new 'HISTALP 10-min-grid' dataset is based on long-term homogenized precipitation series from meteorological stations across the study domain and a high-resolution precipitation climatology dataset for the 1971–1990 period. The effective coverage of the dataset depends on the observations available in the station network which progressively decline back to the early 19th Century (from 192 to 5 stations). To aid the use of these data in other studies, an accompanying dataset has also been developed, which provides a measure of quality of each monthly precipitation estimate over the grid: the explained variance, relative to the 1931–2000 (maximum data availability) period. The computed quality score illustrates the comparatively poorer accuracy of the dataset for regions and months with less coherent precipitation fields (i.e., over the Alps and in summer) and when the number of stations is reduced, particularly before 1840. The derived gridded field has been compared with other independently-developed datasets and is found to provide a similar description of the precipitation in the GAR for places and periods of common coverage.

***Keywords*** *– precipitation, spatial interpolation, European Alps*

**ALP-IMP-nrev-34**

*Croatian Meteorological Journal* **40** 593-596

# A HIGH RESOLUTION TEMPERATURE CLIMATOLOGY FOR THE GREATER ALPINE REGION (GAR)

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**Abstract:** The Greater Alpine Region (the GAR) covering the area between 4-19°E and 43-50°N and an altitude range between 0 and more than 4000 m asl. offers a challenging climate worth to be studied in any detail. However, it is surprising that up to now no comprehensive Alpine Temperature Climatology covering the whole region is existing. To overcome this deficiency as a first step we want to produce monthly temperature maps for this region in spatial resolution as high as possible. The period under investigation will be 1961-1990. In this paper we will describe the first steps of our initiative as well as the further plans.

***Keywords*** *- Greater Alpine Region (GAR), monthly Temperature Climatology ,high spatial resolution, 1961-1990*

**ALP-IMP-nrev-35**

*Croatian Meteorological Journal* **40** 597-

# PATTERNS OF PRECIPITATION VARIABILITY IN THE GREATER ALPINE REGION

Michele Brunetti [1], Teresa Nanni [1], Maurizio Maugeri [2], Ingeborg Auer [3], Reinhard Böhm [3], Wolfgang Schöner [3], Keith Briffa [4], Dimitrios Efthymiadis [4], Phil D. Jones [4]

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**Abstract:** A recently set up and homogenised new precipitation dataset for the Greater Alpine Region (GAR) is presented here with some first preliminary analyses. Climate change patterns within the study region are analysed in terms of regionally different evolutions, seasonality, and short to long-term trends. It will be shown that precipitation presents pronouncedly different variability patterns in space as well as in terms of seasonality and at different time scales.

***Keywords*** *– Precipitation, PCA, Trends*

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# THE NEW CENTENNIAL SNOW INITIATIVE FOR THE GREATER ALPINE REGION (GAR). STATUS REPORT AND FIRST RESULTS

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**Abstract:** Snow is a significant element in the climate system and has great impact on ecosystem and economy in the Alps, too. Astonishingly there is still a strong gap between the data potential and the data availability. Caused by the existing deficits we started a digitising, quality evaluation, homogenising and analysing initiative for the Alpine region. For the first time we can present a 21-year (1895-1915) daily, high density dataset that was electronically scanned from historic hydro-yearbooks for recent Austria and additional some surrounding regions in Italy, Slovenia, Croatia and Czech Republic. We hope that our snow initiative will grow to a pan-alpine effort to fill the existing lack of information.

**Keywords** - snow initiative, daily data, greater alpine region, high density dataset

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# COMPARISON OF A HIGH-RESOLUTION REGIONAL SIMULATION AND THE ERA40 REANALYSIS OVER THE ALPINE REGION

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**Abstract:** Within the EU project ALP-IMP a high-resolution regional simulation driven by the ERA40 reanalysis has been performed for the Greater Alpine Region (GAR) for the period 1958 to the present. A comparison of the high-resolution simulation and the ERA40 reanalysis regridded to 1 deg resolution with four different monthly mean temperature datasets for the GAR shows for both very high correlations of around 0.9, and in general slightly higher correlations for the regional simulation. Correlations of the regional simulation and the reanalysis with observations increase with spacial scale. The separation of the GAR into six subregions identifies the Po plain as a region where the high-resolution simulation as well as ERA40 have problems in reproducing the instrumental measurements.

***Keywords*** *- ALP-IMP, high-resolution regional modelling, REMO, ERA40 reanalysis*

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# Effect of uncertainty in instrumental data on reconstructed temperature amplitude for the European Alps

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## Introduction

We compiled two recent high-resolution climate reconstructions (Büntgen et al. 2005a, b) estimating millennial-long temperature variations in the European Alps. These records show similar long-term behavior including the Medieval Warm Period (MWP), Little Ice Age (LIA), and recent warmth (Grove 1988, IPCC 2002, Lamb 1965), however, vary in their estimates of the absolute reconstructed temperature amplitude. Reasons for these amplitude ranges are manifold, including the utilization of differing tree-ring parameters (ring width and maximum latewood density), slightly varying instrumental targets, and differing calibration methods. This regional-scale finding is even more striking for the Northern Hemisphere, where uncertainty in reconstructed amplitudes is in the order of the total variance estimated over the last millennium (Esper et al. 2005a, b).

Herein, we more systematically study the effect of utilizing instrumental target data on the reconstructed Alpine temperature amplitude. We re-calibrate the two temperature reconstructions (Büntgen et al. 2005a, b) against two differing 20th century instrumental datasets representing the same area in the Alps, and test the effect of changing calibration periods and seasonal means on the obtained amplitude. We show that reconstructed amplitude ranges in the order of ~1-1.4°C solely result from scaling against different instrumental target datasets. Further amplitude variations are quantified and their relevance for the 'true' long-term course of Alpine temperature variability discussed.

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# Hypsographic modelling as a tool for assessment of future glacier extent in the Swiss Alps

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The strong reaction of glaciers to small changes in climate (mainly temperature and precipitation) designates glaciers as a unique demonstration object of ongoing climate change for a wide public (Zängl & Hamberger 2004). Under current scenarios of atmospheric warming for this century, many Alpine glaciers are likely to disappear within the coming decades (Zemp et al. 2006). The future evolution of glacier size and volume is of major importance for many purposes, including hydro-power production, run-off (agriculture, transport), tourism or natural hazards (rock fall, lake development). In consequence, there is an urgent need to quantify future glacier evolution on an Alpine-wide scale. As current models for calculation of future glacier length or area require input data that are generally not available for most glaciers (e.g. the bedrock), simpler approaches have to be found. We have developed such a simple modelling scheme that calculates future glacier geometry using digitized glacier outlines and a digital elevation model (DEM) only (Paul et al. in press). The model assumes a steady-state equilibrium line altitude ($ELA_0$) that is based on a constant accumulation area ratio (AAR) for all glaciers (e.g. Maisch et al. 2000) and a constant sensitivity of the $ELA_0$ to temperature changes of 140 m for a 1 °C increase. By calculating a 10 m hypsography within a GIS for all 3062 glacier entities in our sample, we can easily calculate the new accumulation area (and thus total area) for any given shift of the $ELA_0$ (we use six values in steps of 100 m) within a few seconds. In order to account for a certain variability of the $AAR_0$, we run the model with four different $AAR_0$ values (0.5, 0.6, 0.67, and 0.75). The model neglects any changes in glacier thickness, curvature or the size of the accumulation area.

**ALP-IMP-nrev-70**

*TRACE* **4**

# Updating the Tyrol tree-ring dataset

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## Tyrol collection and use in palaeoclimatology

The Tyrol dataset is a collection of 71 *Picea abies* ring width measurement series from the Stubaital and Oetztal in Austria. It was sampled in the 1970s (Lamprecht 1978, Siebenlist-Kerner 1984) – the outermost ring is 1975 – and extended back into the 14th century. Despite this limited length, the collection and derived chronologies have been used in recent publications dealing with millennium-long, hemispheric scale temperature variations (D'Arrigo et al. 2006, Esper et al. 2002, Osborn & Briffa 2006), indicating the relevance of these data in reconstructing large-scale climate variability. The data were considered despite the early end date (1975) limiting the calibration period by about 30 years, i.e. recent decades of instrumental data could not be used for climate signal analysis.

We here describe efforts of updating this relevant dataset. These include extending the data back in time and updating it during recent decades. We review the common variance of the various sub-samples combined in the Tyrol collection, and describe some initial assessment of the climate signal. Interestingly, past efforts to reconstruct larger scale temperature variations considered only the tree-ring width (TRW) data fraction of the Tyrol collection. The original and now updated datasets contain both TRW and density measurements, however. So, here we focus on the maximum latewood density (MXD) measurements and compare their climate signal with that found in TRW.