Publikationen (Auswahl):

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (in press)
Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/joc.1377

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

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Received 2 November 2005
Revised 9 May 2006
Accepted 16 May 2006

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

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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.

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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Received 30 March 2004
Revised 25 October 2004
Accepted 25 October 2004

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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INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **25**: 1855–1880 (2005)
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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Received 30 July 2004
Revised 13 May 2005
Accepted 13 May 2005

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

IL NUOVO CIMENTO VOL. 29 C, N. 1 Gennaio-Febbraio 2006
DOI 10.1393/ncc/i2005-10216-0

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.

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

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Received 22 April 2005; revised 4 August 2005; accepted 20 October 2005; published 13 January 2006.

[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/.

Citation: Efthymiadis, D., P. D. Jones, K. R. Briffa, I. Auer, R. Böhm, W. Schöner, C. Frei, and J. Schmidli (2006), Construction of a 10-min-gridded precipitation data set for the Greater Alpine Region for 1800–2003, *J. Geophys. Res.*, *111*, D01105, doi:10.1029/2005JD006120.

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 111, D11107, doi:10.1029/2005JD006674, 2006

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

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Received 14 September 2005; revised 17 January 2006; accepted 15 February 2006; published 7 June 2006.

[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.

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

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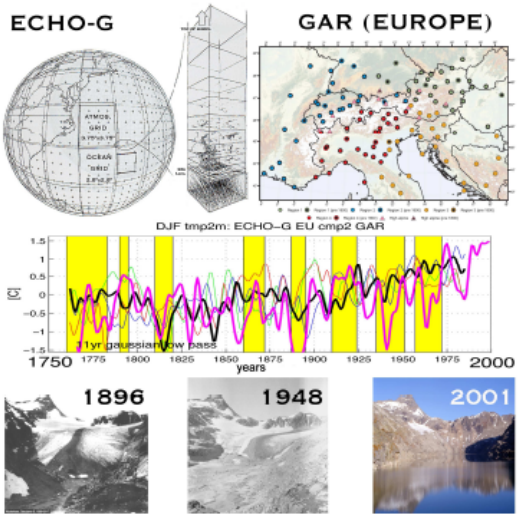
22th April 2005



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.

HISTALP Publikationsliste Abstracts von HISTALP Anwendungen (Auswahl)
1.) für die internationale Klimaforschung

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. (in press)
Published online in Wiley InterScience
(www.interscience.wiley.com) DOI: 10.1002/joc.1411

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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

Received 16 November 2005; Revised 9 June 2006; Accepted 11 July 2006

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **26**: 345–381 (2006)
Published online 25 January 2006 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1251

TEMPERATURE AND PRECIPITATION VARIABILITY IN ITALY IN THE LAST TWO CENTURIES FROM HOMOGENISED INSTRUMENTAL TIME SERIES

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Received 7 February 2005
Revised 5 May 2005
Accepted 30 June 2005

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. Copyright © 2006 Royal Meteorological Society.

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

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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Received 7 July 2003
Revised 4 November 2003
Accepted 4 November 2003

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. Copyright © 2004 Royal Meteorological Society.

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

HISTALP Publikationsliste Abstracts für HISTALP Anwendungen (Auswahl

2) für Tree-ring Forschung

Climate Dynamics (2005) 25: 141–153
DOI 10.1007/s00382-005-0028-1

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.

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1 Introduction

Reconstructions of longer term, regional temperature variability (e.g., Cook et al. 2003; Esper et al. 2003a; Luckman and Wilson 2005) are key to develop larger scale networks (e.g., Briffa 2000; Cook et al. 2004; Esper et al. 2002; Mann et al. 1999), assess spatial patterns of climatic change (e.g., Wanner et al. 1997), and study the influence of natural and anthropogenic forcings on temperature variations (e.g., Crowley 2000; Houghton et al. 2001). In Central Europe, significant progress has been made in reconstructing climatic variations over recent centuries (e.g., Jacobeit et al. 2003) including analyses of long instrumental records (Böhm et al. 2001; Camuffo and Jones 2002; Jones and Lister 2004; Moberg et al. 2003), documentary evidence (Brázdil 1996; Glaser 2001; Pfister 1999), tree-ring records (Briffa et al. 2002a, b) and multi-proxy compilations (Casty et al. 2005; Luterbacher et al. 2004). For the Alps, several dendroclimatic studies assessed temperature signals in local tree-ring chronologies (Carrer and Urbinati 2001, 2004; Meyer and Bräker 2001; Rolland et al. 2000; Wilson and Topham 2004) and regional scale networks (Briffa et al. 1988; Frank and Esper 2005a, b; Rolland 2002; Schweingruber and Nogler 2003) spanning the past couple of centuries. However, a millennial-long, high-resolution Alpine temperature reconstruction that could potentially place the recent warming trend in a longer term context, and would allow a comparison with conditions during the putative medieval warm period (Lamb 1965) is broadly missing.

INTERNATIONAL JOURNAL OF CLIMATOLOGY
Int. J. Climatol. **25**: 1437–1454 (2005)
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/joc.1210

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

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Received 21 June 2004
Revised 10 April 2005
Accepted 18 April 2005

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. Copyright © 2005 Royal Meteorological Society.

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

New Phytologist

Research

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

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Received: *17 October 2005*
Accepted: *29 January 2006*

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.

New Phytologist (2006) **doi**: 10.1111/j.1469-8137.2006.01703.x

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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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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Introduction

Tree-ring analyses provide empirical evidence on how trees respond to internal (biotic) and external (abiotic) forcings (e.g., Fritts 1976). Identifying high- to low-frequency wavelengths embedded in long, annually resolved ring width series contributes to a better understanding of past terrestrial ecosystem productivity, e.g., mountain regions (Beniston 2003; Keller et al. 2000; Kienast et al. 1998), with high elevation vegetation being particularly sensitive to temperature changes (e.g., Büntgen et al. 2005a; Frank and Esper 2005a; Schweingruber 1996), and low-elevation vegetation being particularly sensitive to precipitation changes (e.g., Cook et al. 2004; Stahle and Cleaveland 1994; Woodhouse and Overpeck 1998). However, due to the interaction of several climatic forcings (e.g., Nemani et al. 2003), and a complex plant physiology (e.g., Tranquillini 1964), the discrimination of growth response to a single controlling parameter often fails (e.g., Fritts 1976; Schweingruber 1996; Tessier 1989). In the upper and northern timberline ecotone, a thermal boundary for tree growth is generally given (e.g., Körner 1998; Esper and Schweingruber 2004). However, when temperatures are already high, water availability during the relatively short vegetation period becomes key for tree growth (e.g., Anfodillo et al. 1998; Carrer et al. 1998; Masson-Delmotte et al. 2005; Tranquillini 1964).

With ~74% abundance, Norway spruce (*Picea abies* (L.) Karst.) is the dominant tree species in the Alps, commonly found in montane and subalpine forests (Ellenberg 1996). Recent publications describe the growth/climate response of high-elevation Alpine spruce trees from annual

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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

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THEMA

Forschungsinstitut für Wildtierkunde und Ökologie
der Veterinärmedizinischen Universität Wien

Schwarzwild: Hintergründe einer Explosion

Der Blick in die Geschichte und über Österreichs Landesgrenzen hinaus zeigt es: Die enorme Zunahme des Schwarzwildes ist ein europaweites Phänomen, das wesentlich durch die Klimaerwärmung angeheizt wird.

Univ.-Prof. Dr. Walter Arnold

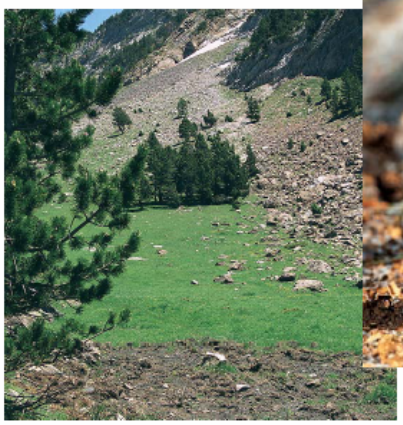
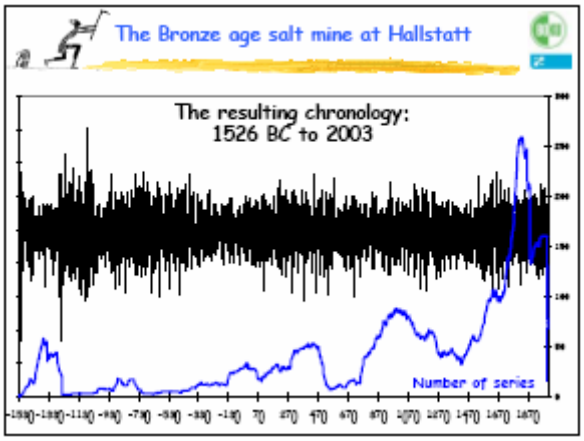


Foto Univ.-Prof. Dr. Walter Arnold


Foto WEIDWERK-Archiv/Schiersmann

Großflächig umgebrochene Wiesen und Schäden an landwirtschaftlichen Kulturen machen insbesondere in den letzten Monaten eines Jahres deutlich, dass es Schwarzwild heute in einer Dichte gibt, die noch vor 20 Jahren völlig undenkbar schien. Selbst für Nichtjäger und damit für eine breite Öffentlichkeit ist mittlerweile unübersehbar, dass Wildschweine in so hoher Zahl in unseren heimischen Wäldern und Fluren leben, wie seit Menschengedenken nicht. Die unvermeidliche Folge sind Wildschäden, die so



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