Third periodic report for RTD-project

ALP-IMP

Multi-centennial climate variability in the Alps based on Instrumental data, Model simulations and Proxy data

EVK-CT-2002-00148

Period covered by the report: May 1st 2005 to April 30th 2006

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SECTION 2:

EXECUTIVE PUBLISHABLE SUMMARY, RELATED TO REPORTING PERIOD 1

(MAY 2005 TO APRIL 2006)

Contract n°	**EVK-CT-2002-00148**	Reporting period:	**2005-05 to 2006-04**
Title	**ALP-IMP: Multi-centennial climate variability in the Alps based on Instrumental data, Model simulations and Proxy data**		

Objectives:

The main tasks of the second reporting period were

- to finalize the 6 data and consistency activities of worktasks 1 and 2
- to concentrate on worktask 3 (synthesis worktask) with the main objective to create an integrative picture

Scientific achievements:

In general, most of the achieved scientific results of the project are already published. The harvest was rich: 101 papers have been written so far and some are still foreseen for the last project phase of 4 extra months which were conceded. 44 ALP-IMP papers were placed in peer reviewed journals, 36 of them already printed, 2 accepted and 6 submitted. 57 non reviewed articles also transported ALP-IMP findings, mostly in conference volumes but also some longer papers. These papers describe in detail the project findings. They are all available as pdfs via the project website, for copyright reasons at the password secured part. The following summary describes the scientific achievements of the 3rd project year.

WP1: The instrumental data activity: has produced a dataset of multiple monthly timeseries of 7 climate elements of hitherto not equalled length, spatial density, vertical dimension, quality in terms of homogeneity and single error elimination. The WP was not closed to allow for an update to 2005-12. The series are available in three modes: station mode, original and homogenised for all 7 elements, grid-mode 1 (1 deg lat-long, anomalies to 1901-2000 average for temperature, precipitation and air pressure) and grid-mode 3 (1/6 deg lat-long, absolute grid-fields for precipitation.

WP2: Tree-ring based long-term climate reconstructions of the Greater Alpine Region: Tree-ring data from the Greater Alpine Region (GAR) were compiled to reconstruct temperature variations of the past centuries to millennium. Networks of numerous of high-elevation ring width and density measurements from trees located near the upper timberline were used to first understand their growth/climate response and then to estimate inter-annual to multi-centennial temperature variations prior to the period of instrumental measurements. Reconstructed summer temperatures indicate warmth in the 10th and 13th century, resembling 20th century conditions, separated by a prolonged cooling from ~1300–1850, only interrupted by a warming around 1400. Six of the ten warmest decades over the 755–2004 period are recorded in the last century. Warm summers seem to coincide with periods of high solar activity, and cold summers *vice versa*. Records capture the full range of past European temperature variability, such as the extreme years 1816 and 2003, warmth during medieval and recent times, and cold in between. Low elevation instrumental data back to 1760 agree with the reconstruction's inter-annual variation, however, a systematic decoupling between (warmer) instrumental and (cooler) proxy data before ~1840 is noted. Comparison with regional- and large-scale reconstructions reveals similar decadal to longer-term climate variability, but the 'divergence problem' remains. Our long-term palaeo-archives further allow the reconstruction of past larch budmoth (*Zeiraphera diniana* Gn) outbreaks. Such work is of high scientific relevance as impacts on ecological disturbance regimes are critical but poorly understood environmental consequences of contemporary climate change. Recurring insect outbreaks common to many temperate forest ecosystems such as the European Alps are ideal systems for studying such impacts because they regularly cause massive defoliation of large forest areas and therefore play important roles in nutrient cycling.

WP3: The isotopic ice core records activity: Essentially dealing with a multi-core approach on "cold glaciers" of the highest Alpine summit ranges (Monte Rosa and Mont Blanc), eventually a set of three complementary records down to bedrock on the isotope temperature index could be retrieved. Thereby the variability of stable isotope of water was obtained from a newly drilled Monte Rosa core dedicated to long term isotope records. Standing out through an extremely low accumulation rate, this core provides now a significantly higher depth resolution in the lower section covering medieval times. Experimental assessment of the related upstream effect, (commonly biasing the centennial scale records) revealed an opposite sign compared to all other flank cores, which may greatly help in considering this important non-temperature interference. The unexpectedly high isotope sensitivity seen in the Alpine cores versus long term temperature changes could be confirmed by isotope analyses of seasonally allocated precipitation, showing a value, which is at least a factor of two lower.

WP4: Glaciers: Glacier and climate information collected during the whole ALP-IMP-project for the Greater Alpine Region (GAR) could be used in the last project year for the development and application of various numerical models. They have different levels of sophistications. On the one hand there are process models, which are mainly based on physical relations. These models are computing the distributed glacier mass balance based on the calculation of the energy balance at the glacier surface in combination with a DEM. On the other hand, we applied simpler models that are based on statistical relationships or simple physical steady-state glaciers. These models are applied over the entire European Alps (i.e. the GAR). All models allow the application of climate scenarios to assess the impact of past and future climate change on glaciers. In particular the latter indicate that many Alpine glaciers might disappear within decades.

WP6: Consistency observed vs. simulated data: A simulation for the Greater Alpine Region (GAR) on 1/6 degree resolution performed with the REMO regional model for the period 1958 to 1998 has been compared to observed temperature and precipitation. During the 3rd report period the temperature evaluation has focussed on the comparison with station datasets on monthly and daily timescales and whether the high-resolution simulation leads to an added value in comparison to the 1.125 degree resolution ERA40 reanalysis which forced the simulation. The results of the two different timescales show only minor differences whereas between the different regions and seasons the results vary strongly. Therefore, an overall conclusion about the added value is not possible. The evaluation of simulated precipitation shows that a number of questions concerning the precipitation climatology can be clarified with additional information from REMO. The results of the REMO simulation are encouraging and a valuable contribution to the Alpine precipitation climatology.

WP7: Internal climate variability in the Greater Alpine Region: The internal climate variability in the GAR has been analysed using the REMO simulation performed in WP6. First, the mesoscale circulation patterns have been determined by an EOF analysis of REMO and ERA40 sea level pressure fields. Those overall circulation patterns are similar in both simulations, but differences in the lee of the Alps show, that the higher resolution of REMO simulates small-scale lee effects that are not included in ERA40. Second, the influence of the mesoscale circulation patterns on 2m temperature and precipitation variability over the GAR was determined by calculating the correlation between REMO temperature and precipitation and the first four PCs for all gridpoints. Both temperature and precipitation signals are dynamically and physically plausible.

WP8 and WP9: are the main integrating, and summarizing activities of the project. They are both well on their way, have produced a new and a better established picture of the instrumental and the pre-instrumental climate variability of the past 250 to 1300 years in the Greater Alpine Region. Their description will be the main part of the final project report, due by the end of October 2006.

Socio-economic relevance and policy implications: will take effect by the end of the project and will be argued then

Conclusions: With a few exceptions (counterbalanced by not planned additional activities), the project is well on its way. The data WPs have produced more than expected and have been already intensively analysed. The remaining 4 project months are going to resume the findings of the analysis WPs to a general picture of past +1000 years of climate variability in the Alps and their wider surroundings, and a spatially highly resolved picture of the past 250 years with additional physical understanding provided by the high resolution multi-annual model runs performed. Some of the findings point at remaining inconsistencies. They will be discussed, clearly described and they will define the remaining research needs for the future.

Keywords: instrumental datasets, homogeneity, tree-ring datasets, isotopic ice-core records, glacier variability, Greater Alpine Region, regional modelling, isotope modelling

Publications (cumulative list): annex 2.1. (ALP-IMP publications list, of 101 scientific papers)

SECTION 3:

DETAILED REPORT ORGANIZED BY WORK PACKAGES INCLUDING DATA ON INDIVIDUAL CONTRIBUTIONS FROM EACH PARTNER

RELATED TO THE REPORTING PERIOD (MAY 2005 TO APRIL 2006)

3.1. WP-1: INSTRUMENTAL RECORDS (reported by partner 1)

WP-1 is a common activity of partners 1 and 5, continuously supported (without costs) by the network of "corresponding project partners" and linked national projects (described in the first project report). Lead and reporting partner is partner 1. Activities of WP-5 (responsible partner 2, CRU) has provided additional instrumental data products and thus contributed to WP-1 as well. The planned deliveries have been produced as reported in the 2nd periodic report (PR2) already and WP-1 can be regarded as successfully closed.

As announced and described in PR2, four activities (not originally planned but recognised as feasible and necessary) have been further pursued: A snow-activity and one to produce a very-high-resolution (VHR) gridded long-term temperature dataset. Two others have also emerged as highly eligible at the end of the 2nd reporting period: a stronger condensing of the higher resolved datasets to a few coarse resolution subregional means and an update of the instrumental database. The motivation for the latter two activities was further supported by numerous respective requests on the part of scientific users as well as such for public use. Both applications show the usefulness of and the demand for WP-1 data and thereby may serve as a good reason for the respective changes of the original project plan.

3.1.1. WP-1 OBJECTIVES

3.1.1.1. Original

- Collect all available monthly long-term instrumental climate data from the GAR
- Reanalysis in terms of general quality and homogeneity
- Standardized re-procession and description for further internal and external use

3.1.1.2. Additional

1.5.1.1. Start an initiative for the creation of a pan-alpine longterm dataset of daily snow series

1.5.1.2. Start an initiative for the creation of a pan-alpine longterm high resolution monthly temperature dataset

1.5.1.3. Create condensed coarse resolution subregional mean series

1.5.1.4. Update all WP-1 series to 2005-12

3.1.2. METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WP-1 INCLUDING CONTRIBUTION FROM PARTNERS

The three original objectives have been successfully met (described in the 2nd report). The four additional ones have been still open in the reporting period:

Additional Objective 1

Snow activity: After intensive QC-work on (as mentioned in the second report: from Austrian plus some surrounding countries), after inclusion of additional data from Tyrol and Burgenland and after gap closing a dataset of daily snow more than 800 series is ready for use for two timeslices (1896-1916 and 1980-2000). Analyses has started on the Austrian subset of 117 sites covering both time slices) concentrating on trends between the early period and the recent one. The statistical evaluation included correlation between altitude and number of days with snow, average altitude of snow cover, min and max of snow cover and others. Interpolation and visualisation of this data was performed with Arc-Gis 9.0. The newly digitised and quality improved data from time-slice 1 (former Austrian Monarchy) have been sent to the recent data providers in Slovenia, Croatia, Czech Republic as well as to the regional ARPAs in northern Italy (Lombardia, Trento, Bolzano, Veneto, Friuli). The ARPAs could be included through a collaboration with the project FORALPS (Interreg IIIB, Alpine Space programme)

Additional Objective 2

VHR-temperature dataset activity: The database of the VHR- 1961-1990 monthly temperature climatologies was quality controlled. Questionable stations had to be eliminated, still existing spatial gaps filled by a new data. The final version now comprises 1735 sites in the GAR. As the different data providers use different algorithms for the calculation of means, the data were all adjusted to a common algorithm. Not adjusted means would have biased national subregions of the dataset with errors up to more than 1 K. This was done with the help of existing datasets with hourly resolution and of T_x and T_n datasets. These were regionalised into homogeneous subregions (low-elevation subregions plus a differentiation into altitude bands) and each a representative set of monthly adjustments was calculated for each subregion. The final dataset was presented, discussed and accepted at a workshop held at 2-3 Feb. 2006 in Vienna (project ECSN/HRT-GAR, announced in the 2nd ALP-IMP report already). The workshop also served to discuss the possibilities and techniques of interpolation to a VHR-grid in the complicated terrain of the Alps. Currently the analysis on the dataset is on the way. The method finally chosen will most likely be a combination of multi-regression (lat-long-alt) modelling in subregions - the latter to be identified through spatial residual analysis after regression.

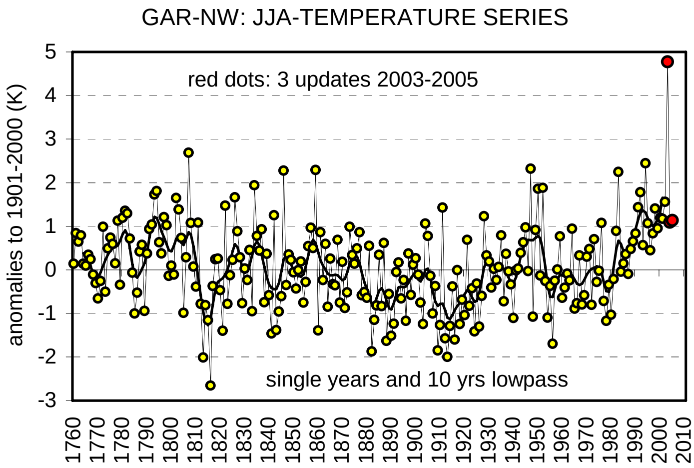
Additional Objective 3

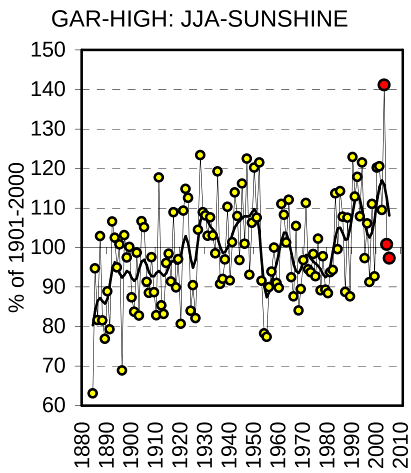
CRSM-mode:

The concept of “coarse resolution subregional mean series” (CRSMs) was realised, the CRSMs were analysed and an extensive paper is in press (publication list ALP-IMP-rev-2-21, details on it in WP-8 description). The CRSM-series are available from the download area of the project-website – together with a description of their structure (CSRM-datafiles.zip).

Additional Objective 4

Update to 2005-12: The updating to 2005-12 makes the instrumental database of the project fit for the final analyses within the project and for post-project application. We undertook not only a simple update (which is time consuming enough due to the patchy situation concerning data providers in the region) but we also used the practical experience gained in the project on the “near to real time availability” of the single sites to shift a number of long-term but not easily updateable series to nearby and quicker available sites for which multi-annual comparative series existed. The updates within the project working period first to 2003 and now to 2005 allowed for an inclusion of some extreme climate events like the hot summer 2003 (2 examples in the following figures).





3.1.3. SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

The socio economic value of WP-1 products and results has been discussed in the two previous regular project reports. The additional activities contribute to intensify it. A concluding respective statement will be part of the final project report

3.1.4. DISCUSSION AND CONCLUSION

The additional ongoing four WP-1 activities have proved to produce an added value to the project as a whole. 1 has set a first benchmarks in the region for future concentration on daily series, 2 is going to produce the necessary precondition for a post project objective (pan alpine high resolution temperature datasets and a further differentiation of the already existing (2nd report) high resolution precipitation dataset into a solid and a liquid subset, 3 has produced a slim and easy to use condensed version of instrumental long-term series of seven climate elements and 4 made the database more timely and has created the basis for quick future updates.

3.1.5. PLAN AND OBJECTIVES FOR THE NEXT PERIOD

In general the workpackage is closed. As already argued in the previous reports its data and findings will be included in the final project work which concentrates on integrative analysis. All data in gridded datamode will be shifted to the public part of the project website as soon as the respective reference publications have passed the reviewing process.

3.2 WP-2: TREE-RING RECORDS (reported by partner 8)

WP 2 is a common activity of partners 2, 8, 9 and 10, with partner 8 as the lead and reporting partner. The Universities of Padua and Ancona (both Italy) act as collaborators.
Our objectives are:
- Assemble best possible 'optimum' set of existing and new tree-ring data for the Greater Alpine Region (GAR) with a focus on identified key regions and tree-growth variables.
- Screen, quality control, and reprocess raw measurement data to form standardized multi-century to millennial site and regional chronologies for different species, using recently developed/improved statistical techniques.
- Undertake systematic detailed identification of climate signals in the chronology data, with emphasis on quantifying time-dependent changes.

1.1. 3.2.1 Methodology and scientific achievements related to WP-2 including contribution from partners

Within the third project year we introduced 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 (Esper et al. in review). Such work is of high scientific relevance as impacts on ecological disturbance regimes are critical but poorly understood for 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.
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.

Based on the internal ALP-IMP tree-ring databank installed at the WSL, a re-assessment of growth trends, climate response and insect defoliation of the European larch (*Larix decidua* Mill.) was launched. We compiled a network of 70 larch site chronologies and 73 spruce reference chronologies from the European Alps and western Carpathian arc. Data were analyzed to better understand growth trends in regard of differing elevation, site ecology and tree-age. The growth/climate response of the 70 site chronologies was systematically explored through comparison with monthly resolved temperature means and precipitation sums from the GAR. For the detection of cyclic insect population dynamics and their spatio-temporal patterns throughout the Alpine arc and past centuries, we used 'non-host' evidence from the 73 spruce reference chronologies and the multi-proxy Alpine summer-temperature reconstruction by Casty et al. (2005).

A detailed comparison of tree-ring based warm-season temperature reconstructions and their targets was performed for the Northern Hemisphere and European Alps. Such analyses revealed substantial divergence between (warmer) early instrumental measurements and (colder) proxy estimates. The homogenization applied to the instrumental data was discussed, and attention drawn to the misfit's relevance for understanding recent anthropogenic and past natural forced climate systems. Since the longest and highest quality instrumental measurements worldwide can be found in Central Europe, with many stations extending to the mid 18th century or deriving from high-elevations (Böhm et al. 2001; Auer et al. 2006), these data allow proxy records to be calibrated over exceptionally long periods and their temporal stability to be tested (Frank and Esper 2005; Büntgen et al. 2006a). Recent palaeoclimatic efforts in the European Alps have resulted in estimations of past temperature variations based on high-elevation tree-ring data, spanning the past centuries to millennia (Frank and Esper 2005; Büntgen et al. 2005, 2006b). A compilation of these reconstructions and their targets, however, revealed a systematic long-term divergence between measured and estimated temperatures.

A maximum latewood density chronology of high-elevation *Picea abies* samples from living trees and historical wood was developed. The majority of wood samples was collected by partner 10 in the Tyrol region (Austria), and processed together with partner 8. The new data compilation includes 227 series of both tree-ring width and density measurements and covers the 1028-2003 period. It is therefore ideally designed for the application of age-related standardization techniques, and allows for the robust reconstruction of past environmental fluctuations. Further analyses including a detailed comparison between differing species (e.g., larch, pine, spruce) and parameters (e.g., width, density) are now possible.

Moreover, a comparative analysis of extreme growth years of wide spread Alpine tree species *Pinus cembra*, *Larix decidua* and *Picea abies* has been carried out. The comparison is based on 2408 tree-ring width series of living trees, historical samples and subfossil logs (Nicolussi et al., in prep.). The results based on Cropper transformation show an unusual high amount of extreme growth years during the 20th century in relation the about 1000 years before.

A comparison of multi-millennial long tree-ring chronologies from central Austria (Dachstein, Hallstatt) and Tyrol was performed using enhanced statistical methods of detrending. First results show similar climate-growth relationships at both high-elevation summer-temperature sensitive sites. A common analysis will be carried out.

Besides our regional-scale Alpine activities preliminary based on high-elevation temperature sensitive tree-ring width and density data (Frank and Esper 2005a, b; Büntgen et al. 2005, 2006a, b), we are currently developing a low-elevation ring-width network for the central Swiss Alps. This data compilation including most likely precipitation sensitive living and historic material from the Valais (sampled between 800-1,500 m asl) is now updated to 2005. The final chronology should allow the development of local precipitation fluctuations during the past centuries.

Additionally, a low-elevation sample-set of *Pinus nigra* Arn. (black pine) tree-ring series was collected within the Vienna basin, Austria. These trees were growing near their ecological limits, and were used to identify changes of their sensitivity to precipitation. Variations in ring width showed a strong and positive correlation to spring-summer precipitation, indicating a growth dependence on water availability during the summer season. During the late 20th century, tree-rings grew wider than expected by the model, observed in the early 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 not 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.

The black pine sample-set originally used by Wimmer et al. (2000) was applied to recalculate ring-width indices, based on improved statistical methods. Additionally old trees were sampled and included. A 600-year long reconstruction of summer precipitation and drought periods, most likely will be developed for eastern Austria (south of Vienna). We further sampled black pine trees in the driest region of Austria, the Weinviertel (north-east of Vienna), to latter on compare and combine both local-scale precipitation reconstructions.

Activities that were in a broader sense related to the ALP-IMP key region, include the development of a multi-species tree-ring width and density network in the western Carpathian arc. We developed a network and analyzed the growth/climate response of 24 tree-ring width and four maximum latewood density chronologies from the greater Tatra region in Poland and Slovakia. The novel network comprises 1,183 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 800-1,550 m asl. Individual spline detrending was used to retain annual to multi-decadal scale climate information in the data. 20th century temperature and precipitation data from 16 grid-boxes covering the 48-50 °N and 19-21 °E region were utilized for comparison. The network was analyzed to assess growth/climate response as a function of species, elevation, parameter, frequency, and site ecology. Twenty ring width chronologies significantly correlate ($p< 0.05$) with June-July temperatures, while the density chronologies reveal strongest response to the wider April-September season. Climatic effects of the previous year summer were generally not found to significantly influence ring formation, while site elevation and wavelength of growth variations (i.e., inter-annual and decadal) were found to be significant variables in explaining growth/climate response. Increasing precipitation response with decreasing elevation is observed. Correlations between summer temperatures and annual growth rates of Larix decidua are lower than for Picea abies. Principal component analysis elucidates five dominant eigenvectors that express somewhat contrasting climatic signals. The first principal component contains highest loadings from 12 Picea abies ring width chronologies and explains 42% of the network's variance. The mean of these 12 high-elevation chronologies correlates at 0.62 with June-July temperatures, while the mean of three density chronologies that load most strongly on the fourth principal component, correlates at 0.69 with April-September temperatures, both significant at $p< 0.001$ over the 1901-2002 period. 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 support the dominant influence of warm season temperatures on high-elevation forest growth. This analysis enabled us to spatially extend our Alpine results towards surrounding mountain systems.
In this regard, we are currently developing a similar data compilation of living and historic high-elevation wood in the southern European Pyrenees.

Moreover, although not directly related to the GAR region, a millennium long oxygen isotope record from tree rings in northern Pakistan proves this novel tree ring parameter to be a promising tool for precipitation reconstruction at sites, where ring widths and densities are currently used for temperature reconstruction (Treydte et al. 2006). The study suggests an intensification of the global hydrological cycle due to global warming, a finding which needs to be empirically verified by the development of more long-term precipitation reconstructions e.g. from alpine areas.

1.2. 3.2.1 Socio-economic relevance and policy implication

The existing GAR (and those from the European surroundings) tree-ring records and their explained local and regional climatic sensitivity currently allow initial interpretation of climate before, at the transition to, and during unprecedently intense anthropogenic activity. Our millennial-long temperature reconstructions point to the recent decade being the warmest over the whole period, but followed by the pre-industrial, medieval warmth about AD 970. Although, reconstructed temperature variations mimic natural forcing agents reasonably well, anthropogenic impact during the industrial period cannot be excluded (Hegerl et al. 2006). Moreover, the obtained Alpine temperature histories denote significant similarities with results derived from surrounding European mountain systems and even match reconstructed NH decadal scale variations and longer-term trends. These findings suggest that the Alpine climate regime is of larger-scale importance.

In future, these data will hence be useful to quantify natural (e.g., solar and volcanic) vs. anthropogenic (e.g., CO_2 and manmade aerosols) forcing in the highly sensitive GAR in a long-term context. Moreover, the data will help enable quantifying long-term spatial and temporal changes of GAR biomass. This will yield information to aid in future valuation of forest resources, and can provide data to help shape, and/or assess compliance with policies seeking regulate the flux and sequestration of carbon.

3.3. WP-3: ISOTOPE ICE CORE RECORDS (reported by partner 4)

The ice core WP 3 comprises joint experimental work covered by partners 4&6 as well as joint evaluation/modelling work to which in addition partners 1, 3, 6 and 7 contribute. The experimental activities are substantially supplemented by external co-operations at no project costs. They include: the KUP of University Berne (field work,),VERA at University Vienna (^{14} C-AWS), the LGGE-CRNS (sample sharing ,field work, stratigraphical dating), the ETH-Zürich(field work, ground penetrating radar)and the German Polar Research Institute (automatic stratigraphical profiling). In charge of WP-3 lead and reporting is partner 4.

3.3.1. WP-3 OBJECTIVES

1) retrieve first multi-centennial isotope profiles in the Mt. Blanc in addition to theMonte Rosa region

2) interlink the long term isotope records by appropriate ice core chronologies

3) identify periods of abrupt changes and long-term trends in isotope summer precipitation signature, representative for high elevation Alpine areas, and

4) provide recent and long term isotope records ready for use in WP6 and WP9

3.3.2. METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WP-3 INCLUDING CONTRIBUTION FROM PARTNERS

Basic methodology :

The isotope ratios (δ^{18}O) or δ D) of ice recovered from ice sheets and non-temperated glaciers are well recognized proxies, which eventually reflect the local temperature variability. While polar ice core studies have extensively deployed this isotope-thermometer back into the past glacial(s), much less studies focussed on the near past (e.g. last millennium)and, particularly on mid-latitude glaciers. The latter ice bodies are however subject to a series of shortcomings (as fragmentary snow deposition, ice flow effects and highly non-linear depth/age relationships), which still deserves basic investigation to reliably explore these climate archives.

Selected target regions for the ALP-IMP ice core studies are the Monte Rosa and Mt. Blanc summit ranges, which offer the most suitable Alpine drill sites for recovering long term and high resolution isotope records, respectively. To enhance and to confirm the climate significance of Alpine isotope records, their spatial and temporal coverage needs to be substantially improved. This attempt is accomplished by establishing isotope records from specifically selected new ice cores including dedicated isotope analyses of fresh snow and from shallow ice core and snow pit samples.

3.3.2.1.Objective 1 (additional records from Mt.Blanc and Monte Rosa drill sites) feature

Within the third year reporting period, continuous isotope analyses of the 100m flank core from Col de Dome (Mt.Blanc) could be extended to bedrock. Due to a similar feature in the surface topography and accumulation rate of this core with respect to the Colle Gnifetti (Monte Rosa) flank ice cores, for the first time a more direct inter-site comparison is now possible.

At the Monte Rosa site, GPR(ground penetrating radar) based prospecting of an appropriate drill position, which should be specifically useful for the reconstruction of long-term climate records at high resolution in the section more than some 100 years old could be successfully evaluated. Drilling down to bedrock at the identified site, which was expected to particularly stand out by a low accumulation rate, provided a 62m core as well as a near by supplementary one of 26m (see contour map of drill site in Fig.1). Deploying the updated KUP-Drill, now 4- inch cores could be recovered, allowing for extensive ice consumption as e.g. needed for age constrains of the deeper core section by radiocarbon dating and cosmogenic isotope analyses. The $\delta^{18}O$ isotope record of this new deep Colle Gnifetti could be continuously analysed already to bedrock, providing a depth resolution between 2 and 20 cm as to broadly compensating for annual layer thinning (Pettinger et al. 2006).

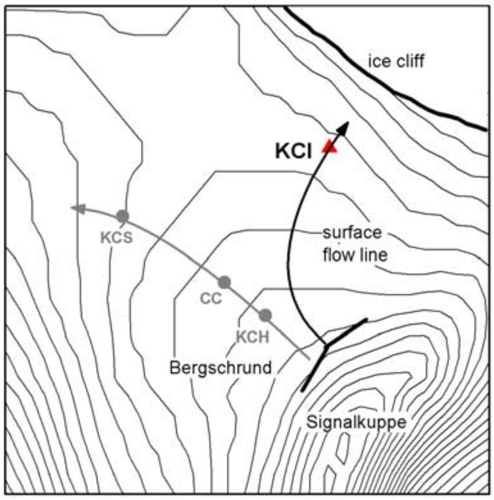


Figure 1: Position of new drilling to bed rock (KCI) in the low accumulation area of Colle Gnifetti (4450 m asl, Monte Rosa). Also shown are the array of already existing deep ice cores, approximate surface flow lines through the boreholes and 10m contour lines.

3.3.2.2.Objective 2 (ice core chronologies)

Based on chemical stratigrapies dating of the Col de Dome flank core could accomplished by annual layer counting back to 1900, while extension to about 1820 was accomplished by a 2D flow model driven by up stream ice velocities(C.Vincent, LGGE, personal comunications). It is shown, that this site experience unexpectedly strong changes in the annual layer thickness, including rapid thinning in the lower core section, which disqualify the isotope records regarding evaluations on the centennial time scale.

A first chronology of the new Colle Gnifetti core revealed a modern snow accumulation rate close to 15 cm water per year (based on tritium reference horizon). This value is by a factor of 1.7 lower than the hitherto lowest accumulation rate, found at the core array of this drill place. Along with a correspondingly larger distance to the commonly disturbed bedrock section, this extremely low accumulation rate is estimated to ensure approximately a factor of 3 higher time resolution for medieval ice. It is also expected to substantially reduce the isotope bias introduced by long term change in the seasonality of the preserved snow, since this fraction is as minor as being almost entirely made up by summer time precipitation. On the other hand temporary accumulation enhancements are more sensitive seen in this core, challenging its stratigraphical dating and coherence with other records on the short time scale.

Again guided by internal GPR reflector tracking in the catchment area of the new Colle Gnifetti core the influence of systematic isotope up-stream effects was investigated by $\delta^{18}O$ analyses from shallow firn core and snow pit samples. Thereby a related $\delta^{18}O$ upstream decline in the order of one ‰ was revealed, corresponding to a respective accumulation increase, and thus showing the opposite sign compared to all other flank cores of the ALP-IMP dataset. The systematic accumulation increase of up to a factor of two seen in the GPR and firn data, (going upstream from that core) will partly compensate for strain thinning, further enhancing the depth resolution in the lower core section.

Along with the visual dust stratigraphy continuous profiles devoted to core dating by matching with the lateral chronologies, were obtained for the entire core, with respect to density at sub-cm resolution and optical transparency(both reflecting melt layer feature, which provide a secondary climate signal being used for core matching as well). Continuous chemical and particle profiling at sub- seasonal time resolution are currently made to validate and back up the preliminary core chronology, which may include the identification of volcanic horizons. Further attempts to constrain the multi-centennial ages of the Colle Gnifetti cores were based on ^{10}Be investigations during sun spot minima. Respective analyses of the prepared AWS targets are delayed however due to failure of the accelerator mass spectrometer at University Vienna. Age constraints via radiocarbon started on chipping material, but failed so far due to extensive contamination by the novel drill equipment.

3.3.2.3 Objectives 3 and 4

(Representative isotope variability and master record of isotope-temperature)

The new Monte Rosa core (KCI) basically confirm the findings of the already existing long term isotope records with respect to the broad (temperature)minimum at turn to the 20th century, the lack of an outstanding LIA signal and no prominent trend to higher isotope values towards mediaeval times. With the first core chronology on hand, the latter feature might however be revised to enhanced isotope levels, after considering here the (inverse) upstream effect. Fig. 2 illustrates the isotope variability of the new KCI core over the instrumental period along with that provided by a relatively well dated core of much higher accumulation.

The significant higher isotope sensitivity obtained from ice core/ long term temperature comparisons versus theoretical prediction or seasonal allocations are confirmed by the newly established ice core records and extensive fresh snow investigations at Colle Gnifetti and Sonnblick Observatory. At the latter site the seasonal based isotope/temperature relationship with respect to $\delta^{18}O$ was found to be close to 0.74‰/°C, which is more than a factor of two lower than the one obtained from long term regressions.

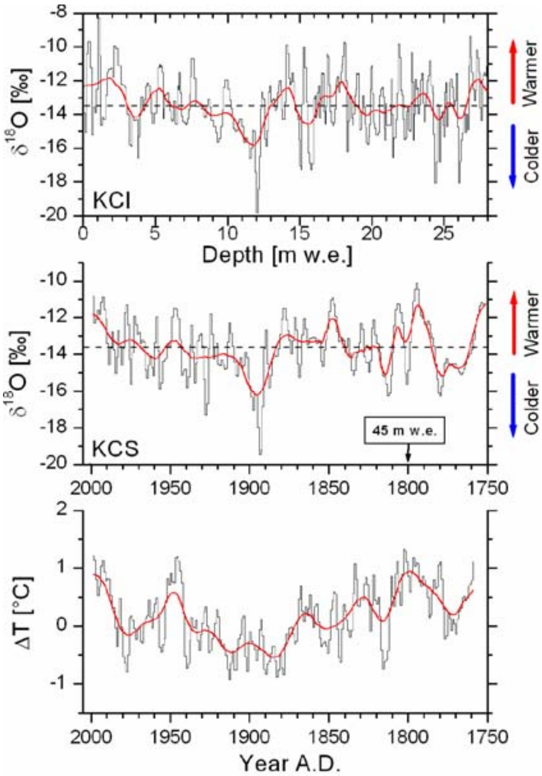


Figure 2: Isotope record of the newly drilled ice core at Colle Gnifetti (upper panel) contrasted to the higher accumulation KCS core (middle panel) and the instrumental WP 3 summer temperature series (lower panel). The water equivalent depth scale of KCI (which is initially linear with age) was adjusted as to become broadly comparable to the below time scale, using the tritium reference horizon. Note that the original temperature data were slightly low passed filtered in order adapt them to the diffusional smoothing already experienced by the isotope data.

3.3.3. SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

Climate proxies derived from high altitude cold glaciers of the Alps offer specific means to better assess the climate variability in Central Europe. Related activities may thus supplement the commonly deployed paleo-climate archives of the European realm in a unique way. The dedicated prospection of these glacier archives, otherwise available in the less climatically explored polar regions or sub-tropical mountains only, constitutes thus an innovative enterprise within the European climate research community.

3.3.4. DISCUSSION AND CONCLUSION

The WP 3 isotope ice core records comprise now almost all relevant glacio-meteorological regimes encountered at appropriate high Alpine drill sites, ranging from:

- seasonally resolved isotope change in the Mont Blanc area reflecting a good deal of the whole year precipitation, but being confined to 20 century only, to
- extremely low accumulation records the Mont Blanc and Monte Rosa regions, being well distinguished by different flow regimes and specifically suited for multi-centennial investigations, though dating precision remains challenging.

Thus the major data material is now available as needed to assess the climate significance of Alpine isotope records and to deploy them accordingly as paleo-climate proxy in the integrated project evaluations. Here, particularly the isotope change in terms of net local temperature effect still awaits explanation of the unexpectedly high isotope sensitivity at the high Alpine sites. This phenomenon(among others driven by the influence of isotopically heavy, convective summer precipitation) has to be specifically investigated in a integrated approach of the final ALP-Imp evaluation. Here the instrumental WP1 dataset backed up by the respective modelling attempts of WP 6 and the isotope data of high Alpine precipitation are the chief ingredients to tackle this question.

3.3.5. PLAN AND OBJECTIVES FOR THE REMAINING PERIOD

Final field work is scheduled to temperature profiling in the newly drilled Colle Gnifetti borehole, (see also chapter 1.2) providing an independent clue to recent warming trends at this site. Although isotope ice core data acquisition is basically finalised in WP 3, key data aimed at the verification and improvement on the respective chronologies will be put forward, still in the final project stage. This attempt, comprising radio isotope constraints and detailed inter-core matching determines among others the comparability of the ice core evidence to concurrent ALP-IMP findings on the centennial time scale. In this context, it deserves together with systematic up-stream effects major concern.

3.4. Workpackage 4: Glacier Proxies

3.4.1 Objectives

3.4.1.1 WP 4 aims

o dense and long term set of glacier variability data within the Greater Alpine Region (GAR)
o uniform structure in terms of data quality
o glacier as an integrated proxy for air temperature, precipitation, radiation, snow cover, atmospheric circulation and its representativity for GAR
o climate impact study on glaciers (use of glaciers as key indicator of climate change)

3.4.1.2 WP 4 deliverables & milestones

Month 13: A quality checked dataset of glacier variability within the GAR (mass balance, front position changes, area changes, volume changes, historical/geomorphological evidences)
Month 16: Representativity of glacier variability data within the GAR
Month 18: Complete GAR glacier dataset plus description ready for use on the project home apge and for transfer to the existing dataset of World Glacier Monitoring Service (WGMS) and World Data Center-A for Glaciology

3.4.2 Methodology and scientific achievements of 3rd reporting period

3.4.2.1 General remarks

In the final project year we focused on the application of various numerical models to assess the impact of past and future climate change on glaciers. Thereby, we developed and applied models that can be driven by gridded meteorological input data to achieve both, the use of the gridded datasets as obtained within the ALP-IMP project and the application to large regions in order to yield a better spatial representativity. Moreover, simple but robust parameterization schemes and statistical relations are applied to the carefully revised glacier data set in order to facilitate a later GAR-wide application.

3.4.2.2 Model 1: Temperature and precipitation at the ELA

Model 1 is based on a statistical relationship between annual precipitation and mean summer temperature at the steady-state glacier equilibrium line altitude (ELA_0). Using a geographical information system (GIS) and a digital elevation model (DEM). 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 corresponding climatic accumulation area (cAA) for 1971–1990 over the entire European Alps (i.e. the GAR).

The sensitivity study shows that for Alpine glaciers, a change in 6-month summer temperature by ±1 °C would be compensated by an annual precipitation change of about 25%. 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%. This latter value is somewhat lower than the loss in glacier area (35%) as yielded from glacier inventory data from 1850 and the 1970s, and suggests that either the model is not perfectly able to reproduce the area loss between 1850 and the 1970s, or that a rise in temperature by 0.6 °C cannot completely explain the corresponding glacier shrinkage.

A 3 °C warming of summer air temperature would reduce the Alpine glacier cover of the reference model run (1971–1990) by some 80%, or down 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 (see Fig. 1).

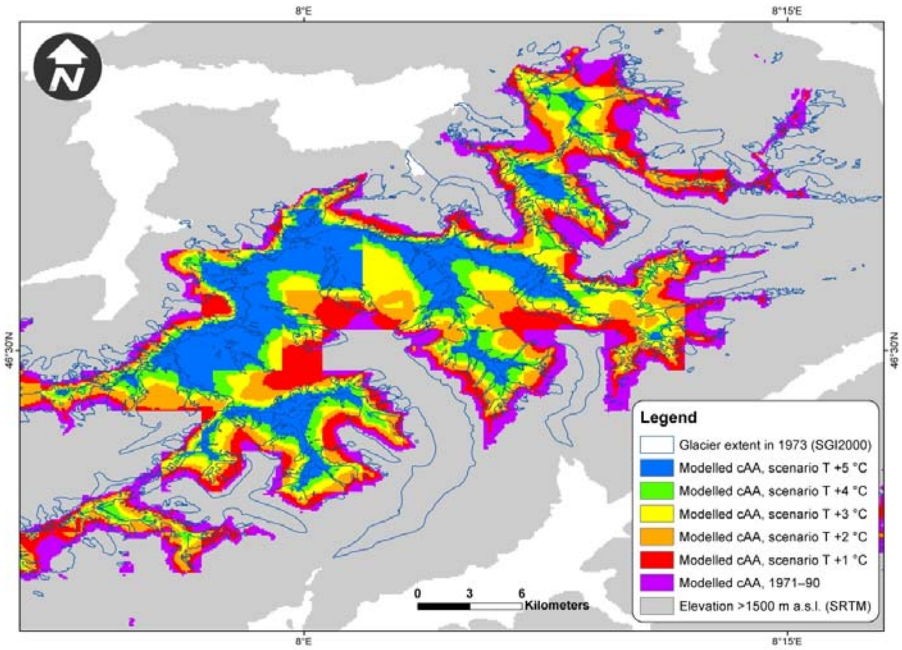


Fig. 1: Modeled climatic accumulation area (cAA) of the reference period (1971–1990) and of scenario runs, assuming a rise in 6-month summer temperature of +1 to +5 °C. The background map shows the Aletsch region with the 1973 outlines from the Swiss Glacier Inventory (SGI2000). Elevations above 1500 m a.s.l. (grey) are computed from the SRTM3 DEM.

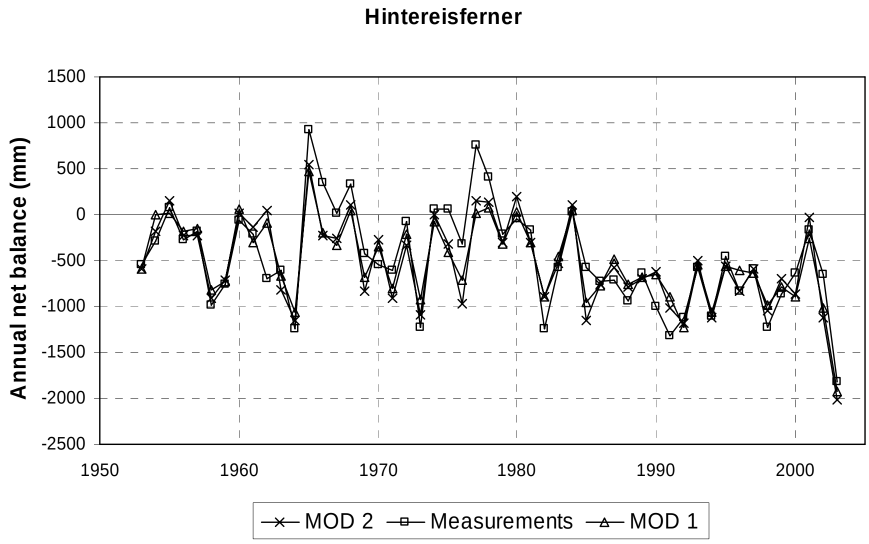
3.4.2.3 Model 2: Distributed energy balance modelling applied to past and current glacier geometries

This approach is a process model, which computes the distributed glacier mass balance based on the calculation of the energy balance at the glacier surface in combination with a DEM. Such mass balance models can either be used to calculate glacier net balance for a specified period (e.g. for model validation) or for a longer period in time using climatic means (e.g. to detect shortcommings of the input data and the model in general). The latter principle has already been applied and detected problematic regions with a too low precipitation in the climatic data set by Schwarb et al. (2001). Moreover, such a distributed model is currently used to test the influence of a changing glacier geometry (i.e. change in glacier thickness at the tongue between 1850 and today) on the resulting mass balance and the related gradients and sensitivities to climate change. This will also hint to a possible change of the accumulation area ratio (AAR_0) for a steady-state glacier with the 1850 geometry (currently a 2:1 ratio is frequently applied for todays as well as past glacier geometries). If no change is found, other more simple models can be applied to 1850 glaciers without changing the sensitivities. The models currently run for mountain ranges which are about 30 by 30 km in size on a 25 m regular DEM, but can in principle be applied to ten-times larger regions using 100 m cells. Publications on the above investigations are in preparation and will be submitted after the end of the project.

3.4.2.4 Model 3: Statistical reconstruction of past glacier mass balance

A statistical model was developed to simulate past glacier mass balances from climate and topographic input data of glaciers. For climate input the HISTALP data of air temperature and precipitation was used. As the current version of HISTALP does not provide absolute series of air temperature these data series were computed by combining HISTALP air temperature anomalies with a new high alpine air temperature climatology with high spatial resolution.

Moreover a statistical relationship (tanh-fit) between air temperature and fraction of solid precipitation was used to compute snow precipitation from air temperature and total precipitation. Topographic input of glaciers was taken from the Austrian glacier inventory 1969. For statistical modelling a stepwise multiple linear regression of climate and topographic input data as predictors was calibrated against measured winter mass balances, summer mass balances and annual net balances, respectively. First results of model validation shows that the model can describe present mass balances of glaciers well but fails in computation of past mass balances back to 1800 in cases of glaciers with complicated topography and ice dynamics (e.g. Vernagtferner). Figure 2 shows measured and modelled mass balances of glaciers Hintereisferner and Kesselwandferner two adjecent glaciers with remarkeble different glacier bahaviour. It can be seen that the model covers the mass balances of both glaciers well. Figure 3 compares computed mass balance of Hintereisferner with measured mass balances and mass balance values from interpretation of maps.



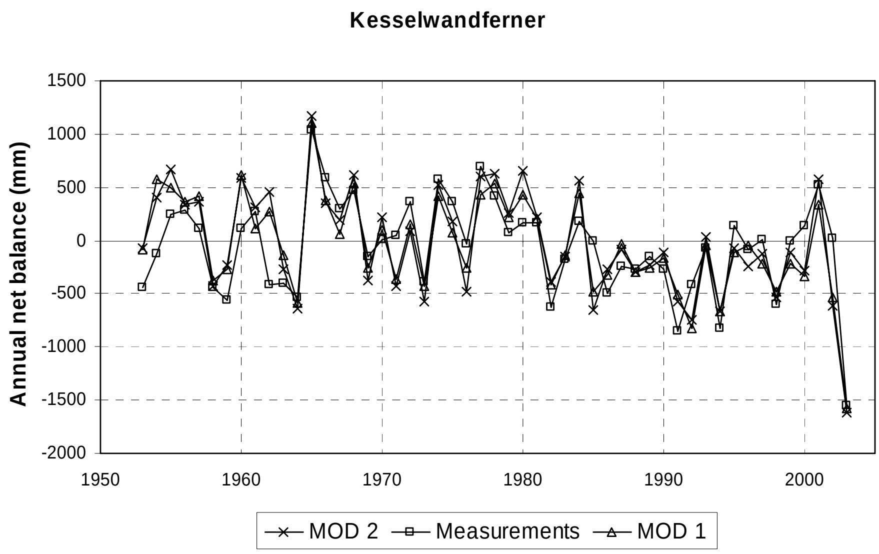


Figure 2: Computed and measured mass balances of Hintereisferner and Kesselwandferner (MOD1 = statistical model of annual net balance, MOD2 = statistical model of annual net balance distinguishing winter and summer balance)

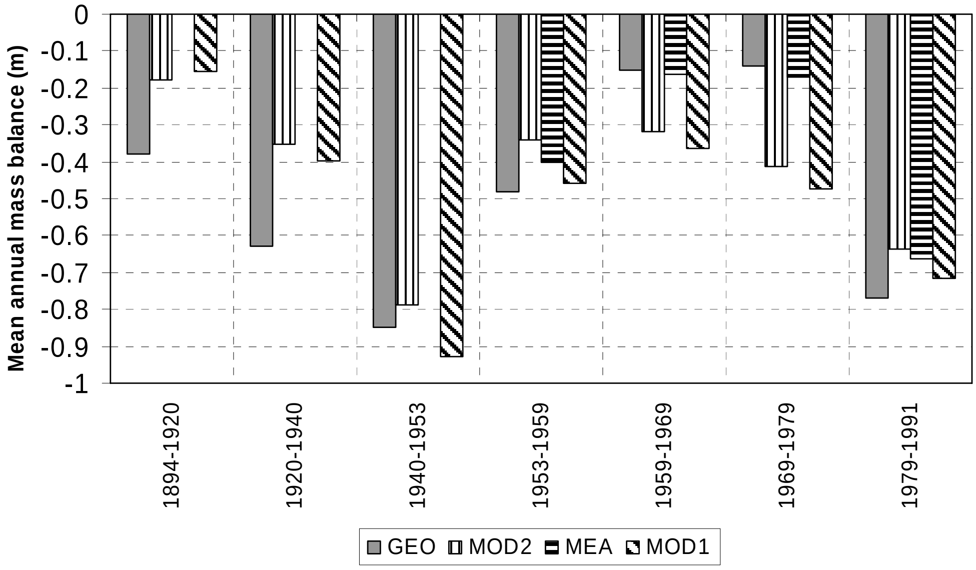


Figure 3: Reconstructed mass balances of Hintereisferner in comparison to measurements and reconstruction from maps (GEO = reconstruction from maps, MEA = measuremnts, MOD1 = statistical model of annual net balance, MOD2 = statistical model of annual net balance distinguishing winter and summer balance)

3.4.2.5 Model 4: Comparison of the GAR glacier data sets with other mountain regions

This study uses the database from the revised glacier inventory in the European Alps and the inventory of 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. Only ice bodies larger than 0.2 km^2 contain useful information on surface area, total length, and maximum and minimum altitude. This reduces the above sample to 1,763 (35%) glaciers for the European Alps and 702 (22%) for the New Zealand Alps, covering 2,533 km^2 (88%) and 979 km^2 (86%) of the total surface area, respectively. A parameterisation scheme using the above 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.

3.4.2.6 Publication of the digitized glacier outlines

Digital glacier outlines from 1850 and 1973 have meanwhile been published as part of the digital ‘Atlas of Switzerland’. Satellite outlines from 1998/99 were transferred to the GLIMS database at NSIDC and will be released within this year. An outstanding issue of glacier coding and identification after splitting up will hopefully be solved during this years GLIMS meeting in Cambridge. Afterwards, it is planned to publish a seperate book with a compilation of all Swiss glacier data from 1850-1973-2000.

3.4.2.7 Worldwide comparison of mass balance trends

Hoelzle et al. (2003) compared mean specific mass balances estimated from long-term measurements of cumulative glacier length change for different mountain regions, ranging from dry, continental-type climate conditions (e.g. Altai) over transitional climates (e.g. Caucasus) to humid, maritime-type conditions (e.g. Western Norway). They found that on average of the worldwide sample, mean specific mass balance since 1900 centres around an average value of about -0.25 m w.e. per year, and that the reconstructed rates of secular mass losses strongly differ between humid, maritime-type glaciers (> -0.5 m w.e. per year) and dry, continental-type glaciers (< -0.1 m w.e. per year). Thus, the sensitivity with respect to secular trends in global warming of maritimetype glaciers is much higher than that of continental-type glaciers, with the European Alps somewhere in between.

Since 1980 continuous mass balance measurements have been available for 30 glaciers in nine mountain ranges (Cascades, Alaska, Andes, Svalbard, Scandinavia, Alps, Altai, Caucasus, Tien Shan). For the time period from 1980–2001, the mean specific net balance of these mountain regions averaged roughly -0.3 m w.e. per year (including polythermal and cold glaciers), resulting in a total thickness reduction of approximately 7 m w.e. since 1980. The corresponding values for the European Alps were about -0.6 m w.e. per year and a total ice loss of almost 13 m w.e. In addition to the Cascade Mountains with a total ice loss of more than 19 m w.e. over this period, the Alpine reference glaciers show the greatest cumulative mass loss after 1980.

3.4.3 Socio-economic relevance and policy implication

Glaciers are recognized as high-confidence climate indicators and as a valuable element of early detection strategies in view of possible man-induced climate change by several international assessments such as the periodical reports of the Intergovernmental Panel on Climate Change (IPCC). Past and present glacier fluctuations do indeed provide important information on ranges of natural variability and rates of change with respect to long-term energy fluxes at the earths surface. The spectacular loss in length, area and volume of mountain glaciers during the 20th century is a major reflection of the fact that rapid secular change in the energy balance of the earths surface is taking place at a global scale. However, glacier change not only has implications on the water cycle at global scale (e.g. sea level rise). Increased impacts are also expected on economic aspects (e.g. tourism, energy production, water irrigation, landscape attraction) and natural hazards (e.g. glacier lake outbursts). It is expected that they will increase on a regional to local scale. Such impacts show the strong socio-economic relevance of the glaciers especially on the local and regional scale within GAR.

3.4.4 Final remarks and future work

All deliverables have been completed. Additionally, more work than previously intended has been accomplished. There are still several ongoing investigations (e.g. related to a diploma thesis) as well as publications that are in prepartion, but which will not be published before the end of the project.

3.6. WP-6: CONSISTENCY OBSERVED VS. SIMULATED DATA

This workpackage is a common activity of partners 3, 4, 5, and 7, supported without costs by partner 1. The lead and reporting partner is partner 3.

3.6.1. OBJECTIVES

- Perform a high-resolution (approx. 17 km) simulation for the greater Alpine region (GAR) with a regional atmospheric model for the last few decades.
- Identify regions, variables, and periods where the simulation and the observations agree and where they do not, and analyze reasons for inconsistencies.
- Identify water vapor sources for the Alps and their influence on water isotopes.
- Deconvolute the isotope signal in a part affected by local climate parameters and in a part affected by large-scale circulation and varying vapor sources.

3.6.2. METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WP-6 INCLUDING CONTRIBUTIONS FROM PARTNERS

3.6.2.1. High-resolution simulation for the last decades and temperature evaluation

In the second report period it became evident that in the high-resolution simulation, which was completed at GKSS (partner 3) at the end of the first report period, the solar constant has been reduced by mistake in October 1989. Therefore, the simulation has been repeated and was completed in May 2005 for the period 1958 to 1998. It became also evident that the ERA40 reanalysis data provided by the DKRZ-CERA database used for the comparison were incorrect.

In the third report period the revised simulation and revised ERA40 reanalysis data were used for the comparison with station datasets of temperature and to analyse whether the higher resolution of REMO leads to an added value in comparison to ERA40.

As it was planned at the end of the second report period REMO and ERA40 were compared to station datasets with different timescales. One is the monthly mean HISTALP station dataset consisting of 131 long temperature series with a maximum length of nearly 250 years (Auer et al., 2005) and the other one is a daily mean temperature station dataset for Austria and Switzerland provided by ZAMG and Meteo Swiss, respectively. This dataset was additionally converted to a monthly mean dataset. A gridded daily dataset for the Po Plain was also provided by the University of Milan but we decided to focus the analysis on the station data. The mixture of gridded and station data made an overall conclusion difficult, as it was difficult to separate out whether differences were due to different regions, or to the interpolation of the gridded dataset.

Together with the precipitation evaluation undertaken by ZAMG (see below) the analysis has been written up as a deliverable report. A paper on the temperature evaluation is in preparation for submission to a peer-review journal.

To summarise the results of the comparison they have been averaged over six subregions defined by Böhm et al. (2001). The analysis shows that both simulations represent the temporal variability of temperature in the Greater Alpine Region (GAR) quite well for all datasets and timescales whereas they are too warm nearly during the whole year except for subregion High Level. REMO has the largest positive bias in summer and autumn (up to 4 to 5 K) for both datasets. In winter the bias is small except for the high elevation stations. The bias of ERA40 is less consistent and shows different results for the regions. Nevertheless, there are still some uncertainties with the altitude correction of the simulated data which might contribute to the bias.

The reduction of error (Fig.1) for the different datasets and timescales does not show a clear added value of REMO in comparison to ERA40 as the results depend on the selection of stations and on the regions. Therefore, despite the very high resolution it is difficult for REMO to represent Alpine temperature better than the reanalysis, which knows the observed values.

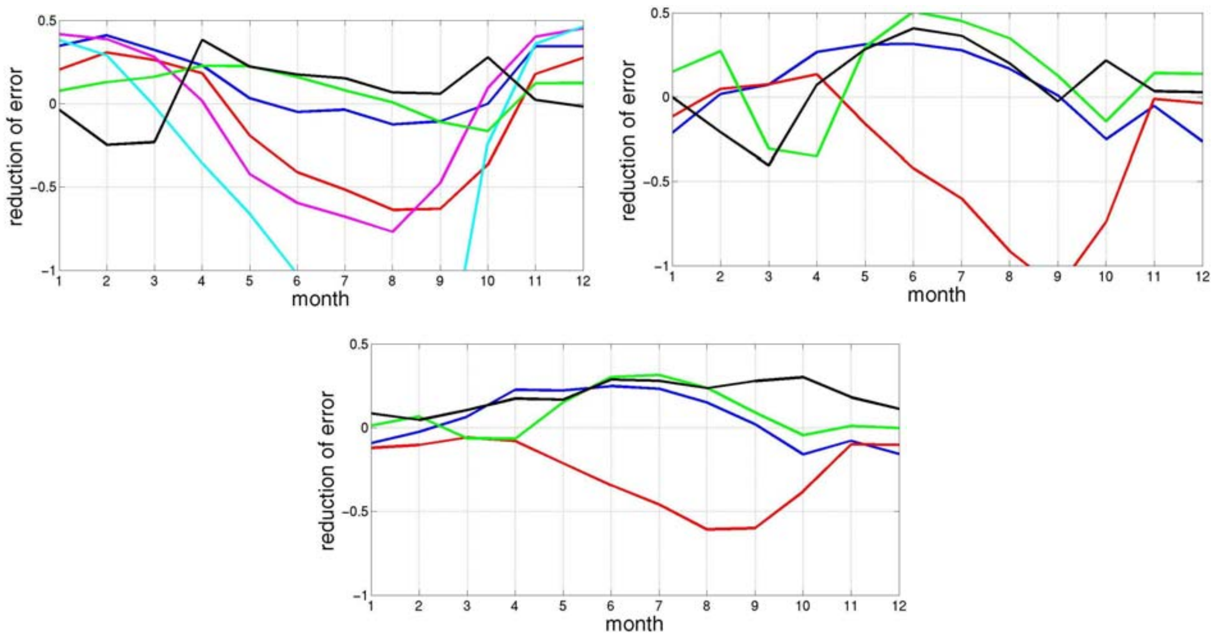


Fig.1: Seasonal cycle of the reduction of error for the subregions West (blue), East (red), South (magenta), Po Plain (cyan), Central Alpine Low Level (green) and High Level (black) derived from monthly HISTALP data (upper left panel), monthly ZAMG and Meteo Swiss data (upper right panel) and daily ZAMG and Meteo Swiss data (lower panel)

As an added value of REMO is expected on smaller spatial scales (Feser and von Storch, 2005), three different approaches of scale separation were applied for temperature and precipitation, namely a kriging filter, an EOF decomposition and a 2-dimensional spectral filter (Feser and von Storch, 2005). For the kriging filter different variograms were estimated but none of them was able to successfully separate temperature over the GAR into small (<200 km) and large (>200 km) scales. The EOF decomposition for the large scales consists of the mean field and the first few EOFs. As the mean field already contains small scale structures the interpretation of the EOF filtered large scales is not clear. To use the 2-dimensional spectral filter of Feser and von Storch (2005) the settings need to be adjusted to the datasets, which is still in progress.

3.6.2.2. Climatological evaluation of the REMO precipitation over the Alps for the period 1971-1999

At ZAMG (partner 1) the ability of REMO to simulate monthly precipitation sums over the GAR has been evaluated by comparison with observations. The evaluation utilizes mostly a gridded analysis of the ETHZ (Eidgenössische Technische Hochschule Zürich) based on high resolution rain gauge data (Frei and Schär, 1998). As explained in the second annual report a special version of the dataset with elevation correction and on the REMO grid was agreed with, and provided by, Christoph Frei from the ETHZ (the original, publicly available dataset has a spatial resolution of about 25km and has no altitude correction). Both versions of the dataset are based on time series from a high density network of about 6700 rain gauges. The ZAMG analysis has also used to some extent the HISTALP (Historical Instrumental climatological Surface Time series of the greater ALPine region) precipitation data set with a monthly resolution.

The hourly REMO and daily ETHZ precipitation sums were added up to monthly sums. The time period considered begins with January 1971 and ends with November 1999. The general spatial distribution of long term mean yearly precipitation sums is simulated with moderate success including features of up- and downwind effects of the topography on the precipitation distribution (Fig. 2). The common spatial variance of the long term mean yearly precipitation sums between ETHZ and REMO is 25%. At the level of individual grid points REMO is not well able to reproduce long term yearly and monthly precipitation sums. A few specific areas can be identified, where the model is unable to come reasonably close to the observed absolute precipitation sums. The topographical effects on the precipitation sums are exaggerated, which means that the precipitation of upwind areas is overestimated and of downwind areas is underestimated. The temporal succession of the seasonal spatial precipitation patterns are largely reproduced by the model.

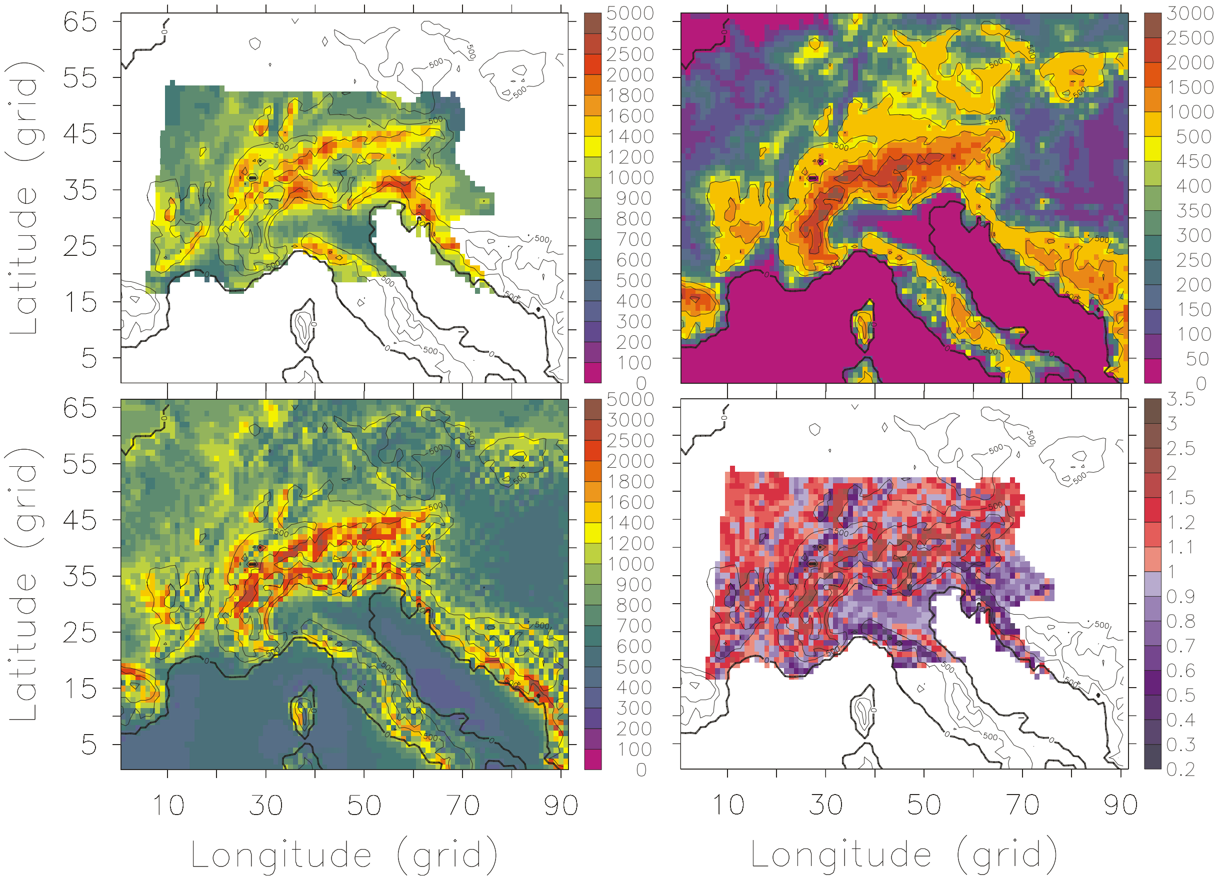


Fig. 2: Distribution of the ETHZ mean yearly precipitation (mm/year, upper left), REMO mean yearly precipitation (mm/year, lower left), the model topography (geopotential in m, upper right) and the ratio REMO/ETHZ (lower right). The time ranges from 1971 –1999.

There is a general desiccation of the model atmosphere to be observed over the simulation period from 1971 – 1999. This general trend towards lower precipitation sums produces a bias on most of the precipitation trends. Apart from this long term bias the spatial distribution of linear trends of the mean yearly precipitation sums is fairly well described by the model. The spatial distribution of the cold season linear trends is also captured by the model to large extent. The spatial distribution of the warm season linear trends is captured by the model only to a minor extent. The same is valid for the extreme precipitation sums in the 10% and 90% percentile ranges. The model reproduces general time - space variance, as summarised by the EOFs, quite well.

3.6.3. SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

The socio economic value of WP-6 products and results has been discussed in the two previous regular project reports. The additional activities contribute to intensify it. A concluding respective statement will be part of the final project report.

3.6.4. DISCUSSION AND CONCLUSION

The comparison between ERA40 and REMO temperature does not allow an overall conclusion about the added value as the results vary between the different regions and seasons. Additionally, they depend on the selection of stations. The still ongoing validation of temperature and precipitation simulated in REMO provides a systematic assessment of the skill of the simulation. The non-clear added value of the higher resolution of the REMO simulation compared to the ERA40 for temperatures, although somewhat surprising, is supported by emerging studies in other regions (e.g. Duffy et al., 2006, Seth et al., 2006). The results of the precipitation evaluation suggest that for a number of above mentioned features of the precipitation fields, REMO can serve as a physically consistent link between the large scale forcings and the local scale precipitation variability.

3.6.5. PLAN AND OBJECTIVES FOR THE NEXT PERIOD

Regarding the evaluation of temperature in the REMO and ERA40 simulations, this work is concluded and during the remaining period the preparation of the publication for submission to a peer-reviewed journal shall be completed. The work on the evaluation of precipitation done so far will be summarised and published, whereby the suggestions of the co-workers and co-authors will be included in the manuscript. A link to the results of the HISTALP precipitation analysis of Brunetti et al. (2006) is to be established.

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3.7. WP-7: INTERNAL CLIMATE VARIABILITY IN THE GREATER ALPINE REGION

This workpackage is a common activity of partners 3 and 5. The lead and reporting partner is partner 3. In the workpackage description in the proposal the following objectives are stated:

3.7.1. OBJECTIVES

- Comparison of the 1/6 degree REMO, 0.5 degree REMO model runs, and the 2.5 degree reanalysis to determine the influence of topography on Alpine flow.
- To determine mesoscale circulation patterns within the GAR domain for the simulated period 1948-present from the 1/6 degree REMO run.
- Use mesoscale circulation patterns in conjunction with long instrumental records to produce a 4-dimensional reconstruction of climate for the GAR for the instrumental period.
- Investigate the mesoscale dynamical causes for decadal and longer-scale variability of surface temperature and precipitation.

3.7.2. METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WP-7 INCLUDING CONTRIBUTIONS FROM PARTNERS

As explained in the previous annual reports, due to the availability of the ERA40 reanalysis, the 1/6 degree REMO simulation has been forced with ERA40 for the period 1958-present. Thus as stated in the proposal, comparison with the 0.5 degree REMO simulation was not undertaken, as this existing run was forced with the NCEP reanalysis. Analysis has therefore been undertaken on the ERA40 reanalysis and the 1/6 degree REMO simulation.

3.7.2.1. Mesoscale circulation patterns over the GAR

To determine the mesoscale circulation patterns over the GAR, EOF analysis (von Storch and Zwiers, 1999) was applied to sea level pressure (SLP) of the ERA40 reanalysis (Uppala et al., 2005) over this region and of the REMO simulation for the four standard seasons. The first three EOFs explain more than 97% of the field together. Therefore, only these EOFs are analysed in detail.

	pc1	pc2	pc3
DJF	**0.85**	0.10	-0.03
MAM	**0.50**	0.02	-0.27
JJA	**0.48**	**-0.31**	-0.11
SON	**0.60**	-0.09	0.19

Table 1: The correlation between the Arctic Oscillation Index and the first three REMO mean sea level pressure PCs. Significant values are bold.

To aid interpretation of these EOFs, the principal components (PCs) of the EOFs were correlated with the Arctic Oscillation Index (AOI), which is similar to the North Atlantic Oscillation (NAO) Index (Table 1). The AO is the major mode of extratropical circulation variability in the Northern Hemisphere, and influences temperature and precipitation in many areas, including Europe (Thompson and Wallace, 1998).

The AOI used in this analysis is based on the PC of the first EOF of extratropical SLP (20°-90°N) based on NCAR/NCEP reanalysis from 1958 to present (Thompson and Wallace, 2000).

As the different EOFs are very similar for all seasons only the first three winter (DJF) EOFs of REMO (Fig. 1) and ERA40 (Fig. 2) are described. The results in more detail can be found in the deliverable report.

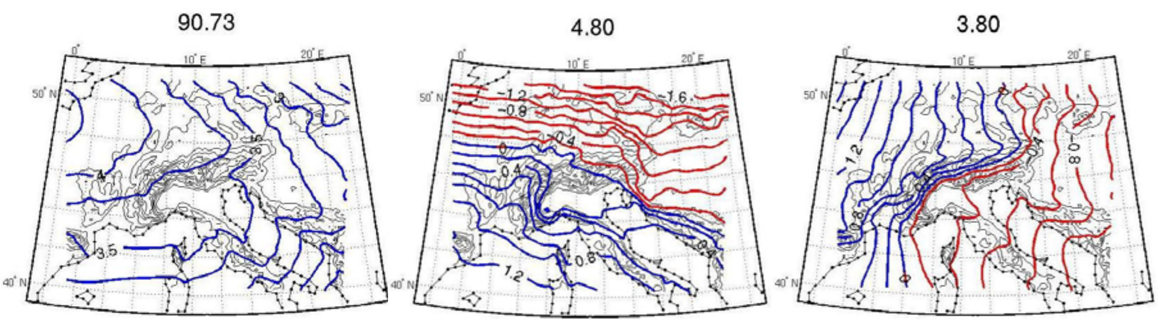

Fig.1: The first three winter (DJF) EOFs of mean sea level pressure of REMO with explained variance in % and REMO topography in the background (contour levels every 400 m). Units of the EOFs are hPa change for 1 standard deviation of the principal component.

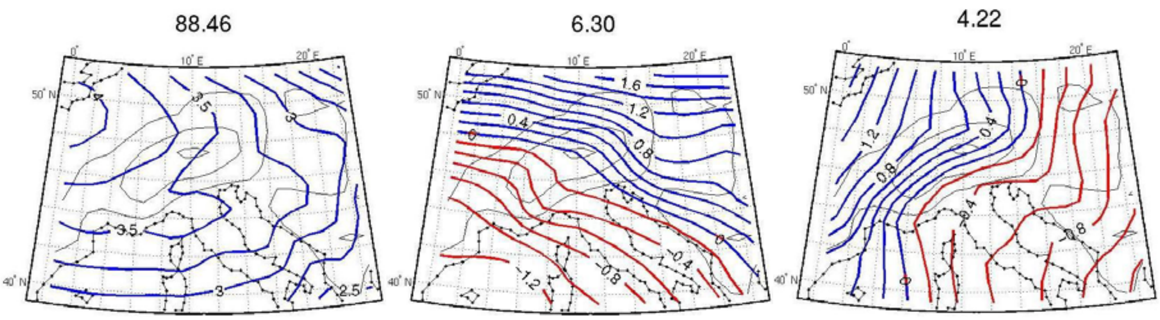

Fig.2: The first three winter (DJF) EOFs of mean sea level pressure of ERA40 with explained variance in % and ERA40 topography in the background (contour levels every 400 m). Units of the EOFs are hPa change for 1 standard deviation of the principal component.

The first EOF has a monopole pattern describing the mean pressure anomaly over the GAR with a very high explained variance (90.73% for REMO, 88.46% for ERA40). The correlations between REMO PC1 and the AOI (Table 1) show that the first EOF is in winter very closely linked to the Arctic Oscillation (r=0.85).

The second EOF describes the north-south pressure gradient, which is associated with westerly flow. The general pattern is very similar for REMO and ERA40 but noticeable differences occur in the Piemont region (northwestern Italy) showing that REMO simulates small-scale lee effects that are not included in ERA40 despite the assimilation of observations in the reanalysis.

The third EOF represents the east-west pressure gradient. Smaller differences exist between REMO and ERA40 than for the second EOF, although the isolines over northern Italy are slightly more complex in the REMO EOF.

3.7.2.2. The relationship between the REMO mesoscale variability patterns and 2m temperature and precipitation over the GAR.

To determine the influence of mesoscale circulation variability on 2m temperature and precipitation, REMO temperature and precipitation for all gridpoints over the GAR were correlated with the first four PCs, for the four standard seasons. All EOFs and correlations are calculated from the mean of the respective season.

The correlations between temperature and the PCs reflect the influence of radiation and advection of warmer or cooler air for all seasons except the correlation with PC1 in winter. As correlations between PC1 and the AO index are high in winter, the correlation map can largely be interpreted in terms of the AO. The Alps are generally in the node of the AO, so would be expected to have a weak AO signal. However a band south of the main ridge of the Alps has high positive correlations with PC1, which are typically not seen in correlation maps with coarse resolution. This might suggest that in the southern part of the Alps, temperature variability is strongly correlated with the (N)AO, whereas in neighbouring areas it is not at all.

For precipitation the correlations reproduce the advection of wetter or drier airmasses and the blocking effect of the Alps. In all seasons the first EOF is associated in most regions with reduced precipitation over the GAR. Together with the at least moderate correlations of the PCs of this EOF with the AO in all seasons, this agrees with Quadrelli et al. (2001), who found a strong negative correlation between Alpine precipitation and the NAO index in winter. However Schmidli et al. (2002) found less strong correlations and instabilities in the correlations between Alpine precipitation and the JFM NAO index through time.

3.7.3. SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

As explained in previous annual reports, the analysis of the high-resolution REMO simulation in WP7 can substantially improve our understanding of the structure and temporal variability of mesoscale circulation variability in the GAR and its links to local climate. Understanding of these links may be important for understanding the dynamical causes of temperature and precipitation changes, and therefore for improving regional scenarios for future climate change. The three-dimensional reconstructions of past climate will help determine the magnitude of past climate variability over the GAR, and thus aid detection and attribution of climate change in this region.

3.7.4. DISCUSSION AND CONCLUSION

The EOF analysis of REMO and ERA40 SLP fields shows that these overall circulation patterns are similar in both simulations, which is to be expected. Nevertheless, some clear effects of the topography are visible in SLP anomalies with the structure of the second EOF, which shows that REMO simulates small-scale lee effects that are not included in ERA40 and thus where perhaps the improved resolution helps.

The influence of the mesoscale circulation patterns on 2m temperature and precipitation variability over the GAR was determined and shows that the temperature signals are dynamically plausible, being a combination of radiative and advective effects. The precipitation signals are also physically plausible. As may be expected the blocking effect of the Alps strongly influences the precipitation distribution over the GAR.

The above work has been written up in more detail as a combined report for deliverables 7/1, 7/2 and 7/4.

3.7.5. PLAN AND OBJECTIVES FOR THE NEXT PERIOD

The final few open questions regarding understanding of the mesoscale circulation patterns, and their signal in 2m temperature and precipitation shall be completed. The interesting apparent (N)AO temperature relationship south of the Alpine main ridge shall be investigated using the HISTALP dataset. The start of the final analysis of the workpackage, statistical upscaling using the 1/6 degree REMO data and the long station records to reconstruct variables such as geopotential height throughout the troposphere, has been somewhat delayed, due to the delay in employing a new staff member described in WP6 of the second annual report. This work shall be started imminently.

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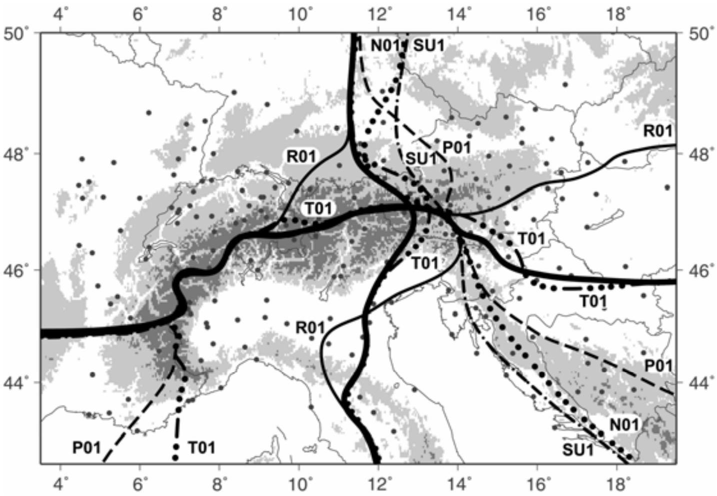
3.8. WP-8: 200 YEARS GAR VERSUS GLOBAL (reported by partner 1)

WP-8 is a common activity of partners 1 and 2, with (unscheduled) contributions of partner 5. Lead and reporting partner is partner 1. It has started its activities in time during the reporting period, mainly based on the deliveries of WP-1. **3.8.1. OBJECTIVES**

- to comprehensively describe the general climate variability features of the greater Alpine region (GAR) as a whole (what is *the* Alpine climate variability like)
- to analyze the representativity of the GAR climate variability features for larger parts of Europe (what do the Alps tell is about other parts of Europe?)
- to understand GAR climate variability in the context of large scale influences (what is the influence of continental to global scale climate variability on the Alps?)

8.8.2. METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WP-8 INCLUDING CONTRIBUTIONS FROM PARTNERS

The project's instrumental dataset (compare WS-1) was analysed and the planned extensive overview paper is in press (publication list ALP-IMP-rev-2-21). It summarizes the creation of the dataset and highlights some of the first analysis results based on the CRSM-mode of the project-data. An additional paper (ALP-IMP-rev-2-22) analyses more in detail one of the seven climate elements present in the dataset – precipitation.



It was possible to find a solution to regionalise the GAR into four low elevation (NW, NE, SW, SE) and one high elevation (H) homogeneous subregions common for the five main climate elements (air pressure, air temperature, precipitation, sunshine and cloudiness. For relative humidity and vapour pressure, data availability restricted the analysis to three of the five subregions (NW, NE and H). There is only very low internal variability within the CSRs – the CSRMs are representative for their areas.

ALP-IMP-rev-2-21describes the analysis as an example of a number of interesting evolutions and co-evolutions in the regions – some of them homogeneous for the entire GAR, some showing significant differences between the CRSs. The table below is (the annual) part of the systematic trend analysis performed on the 25-, 50-, 100-years annual and seasonal climatic trends for 7 climate elements.

LONGTERM CLIMATIC TRENDS IN THE GREATER ALPINE REGION (annual)
in two 100-years, four 50years- and two (recent) 25years subperiods
Trends in units per decade

ANNUAL TRENDS (JAN to DEC)

	AIR PRESSURE hPa			TEMPERATURE degC			PRECIPITATION % of 1901-2000			
1800to1900	0.00	-0.06		**-0.05**	**-0.07**		**-1.9**	-0.6		100 years
	0.00	-0.02	-0.02	**-0.06**	**-0.08**	**-0.06**	-0.9	**-1.1**	**-1.1**	
1900to2000	**0.12**	**0.13**	**0.20**	**0.14**	**0.12**	**0.13**	**0.9**	**-0.8**		
	0.09	**0.09**	**0.11**	**0.13**	**0.10**	**0.12**	-0.1	**-0.9**	-0.2	
1800to1850	0.01	-0.20		**-0.11**	**-0.16**		-1.3	-1.7		50 years
	-0.02	0.00	-0.06	-0.07	**-0.11**	**-0.11**	-1.5	**-2.9**	**-1.9**	
1850to1900	0.03	0.06		-0.04	-0.02	0.06	-0.7	**2.7**		
	0.00	0.00	0.04	-0.02	0.00	-0.02	0.4	-0.4	0.7	
1900to1950	0.13	0.14	**0.31**	**0.19**	**0.12**	**0.18**	-0.4	-1.0		
	0.09	0.12	0.12	**0.16**	**0.11**	**0.15**	-2.3	**-2.7**	-1.6	
1950to2000	**0.20**	**0.25**	**0.45**	**0.25**	**0.21**	**0.24**	1.6	-0.6		
	0.23	**0.22**	**0.22**	**0.23**	**0.17**	**0.21**	-0.2	-0.5	0.1	
1950to1975	0.23	0.25	0.00	-0.04	0.05	-0.05	-1.7	-2.0		25 years
	0.18	0.25	0.22	-0.03	-0.07	-0.02	0.2	-2.0	-1.4	
1975to2000	0.17	0.27	**0.79**	**0.55**	**0.47**	**0.53**	0.5	3.3		
	0.26	0.25	0.23	**0.57**	**0.51**	**0.54**	-3.9	-0.8	-0.1	

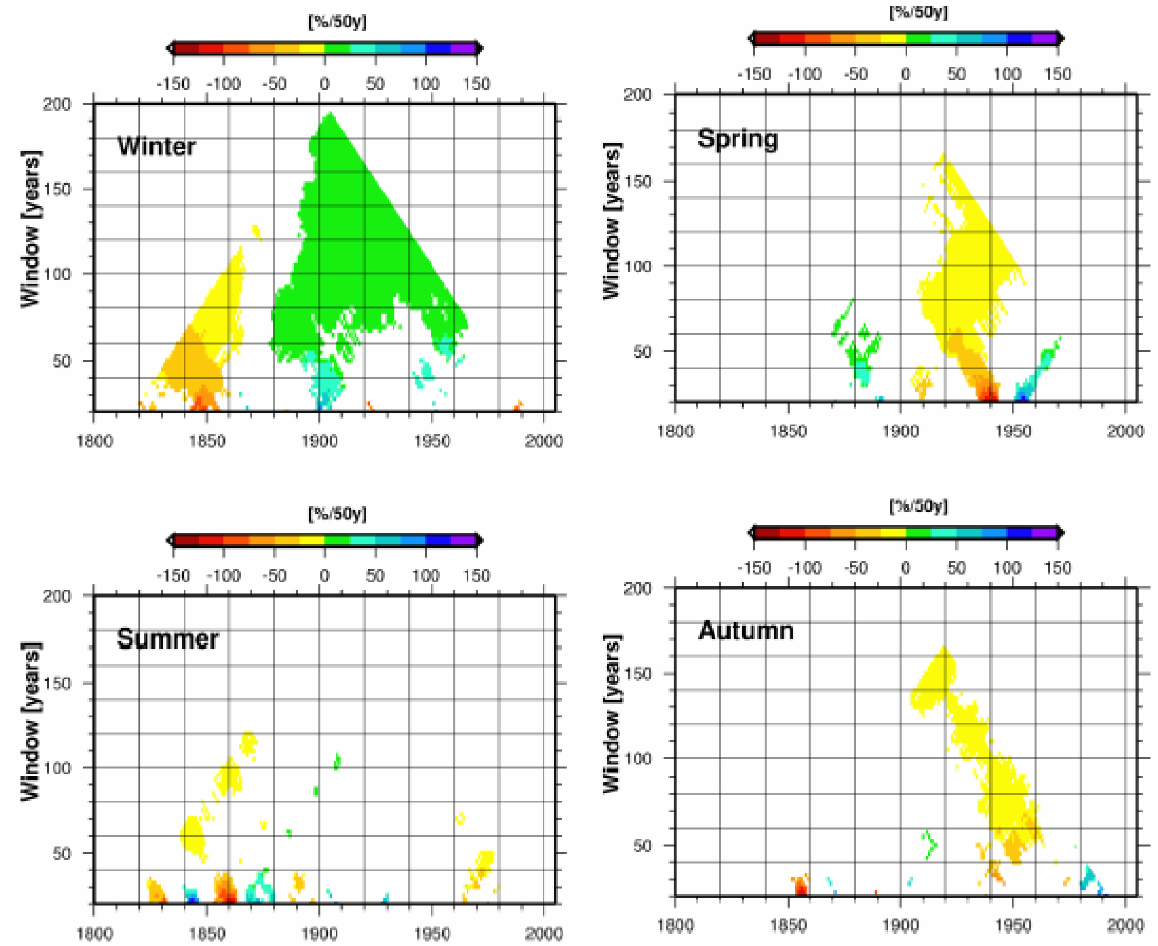
SUBREGIONS:

NW	**NE**	**HIGH**
SW	**SE**	**LOW**

bold: significant at 90% level (Mann-Kendall-trend test)

	SUNSHINE % of 1901-2000			CLOUDINESS % sky coverage			VAP. PRESS. hPa			REL. HUMIDITY %			
1800to1900													100 years
1900to2000	**0.5**	0.0	**1.2**	**0.25**	**-0.29**	**0.30**	**0.07**	**0.04**	**0.05**	**-0.11**	**-0.77**	-0.09	
	0.7	0.0	0.3	0.09	**-0.33**	-0.10		**0.05**			**-0.83**		
1800to1850													50 years
1850to1900					-0.20			**0.07**					
								0.05					
1900to1950	**1.3**	0.3	**3.1**	0.13	**-0.54**	0.30	**0.12**	**0.04**	**0.11**	-0.18	**-0.74**	0.25	
	1.6	0.8	1.0	0.14	-0.13	-0.19		0.01			**-0.45**		
1950to2000	-0.6	0.3	**1.2**	-0.10	-0.06	0.48	**0.11**	0.05	**0.04**	**-0.36**	**-1.30**	**-0.48**	
	-0.6	0.4	-0.1	-0.04	-0.36	-0.12		0.03			**-2.07**		
1950to1975	-2.1	-1.7	0.4	0.26	-0.21	0.13	-0.06	-0.01	-0.03	0.21	-0.25	-0.45	25 years
	-0.9	-2.4	-1.8	-0.23	-0.02	-0.06		-0.02			**-1.47**		
1975to2000	**3.6**	**2.8**	2.9	-0.15	0.15	0.52	**0.36**	**0.25**	**0.15**	**-0.95**	**-1.47**	-0.35	
	3.4	**4.8**	**3.7**	-0.35	**-1.35**	-0.24		**0.17**			**-2.29**		

ALP-IMP-rev-2-22 describes the analysis with the example of the precipitation subset. The PCA-based regionalisation is described and discussed more in detail. An analysis, based on seasonal and annual filtered and non-filtered precipitation-series highlights the existing regionally different short- and longterm variability features. In particular, the existing dipole-like contrary evolutions of the subregions NW vs. SE point to the strong impact of the Alps on the precipitation trends in the region. An innovative method to analyse and visualise climate trends is presented in the form of a "running trend analysis" which allows a quicklook on the existing trends over different subperiods. A final section touches the influence of circulation on GAR-precipitation and its variability in time – this contributing to objective 3 of the WP.

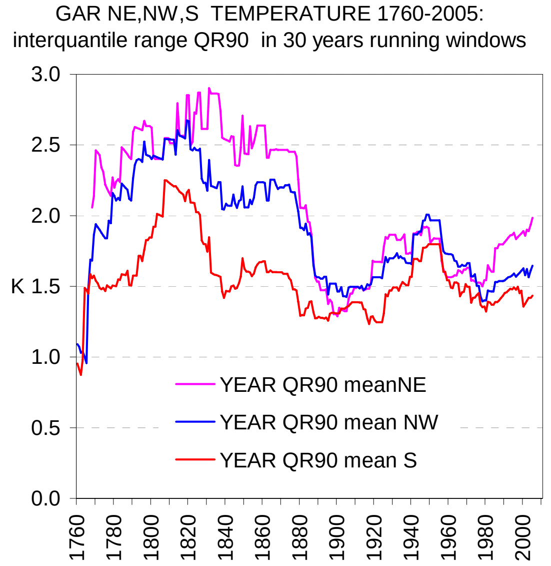


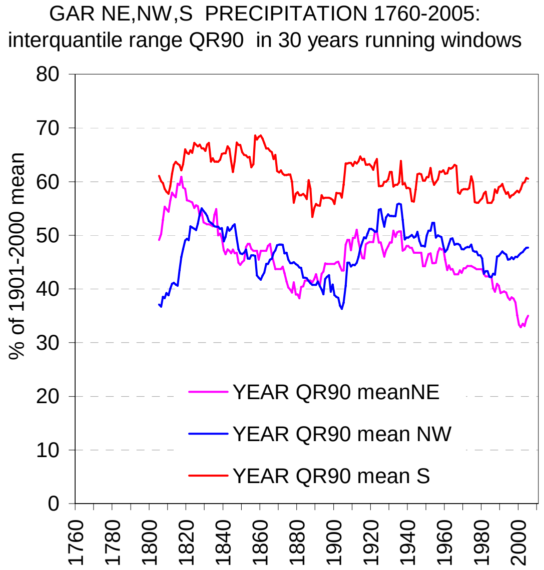
Subregion NW Subregion SE

Example of the running trend analysis plots. The y-axis represents the window width and the x-axis represents the central years of the windows over which the trend is calculated. Non significant trends (90% level Mann Kendall) are masked

In addition to some preliminary respective studies already mentioned in the 1st and 2nd report, all objectives of WP-8 have both been touched by the two papers in press, but there will be additional WP-8 work in the extension period of the project, in close connection with the respective concluding activities of WP-7 and WP-9.

Two other WP-8 analysis are in progress and promises interesting results: The first is a study of the changes of climate variability itself. A subset of the longest monthly, seasonal and annual temperature, precipitation and air pressure series in the GAR were detrended (high-pass filtered) and transferred into series of detrended interquantile ranges (80% and 90%) in moving windows of 30 years. These series are a distribution independent measure for the question whether the widths of the PDFs have changed in the course of the past 200 years. The second looks at the relationships of temperature and precipitation change in the GAR with those more widely across the whole of Europe, and the links to the large-scale atmospheric circulation influences (including the North Atlantic Oscillation and the Southern Oscillation).





Subregional means of 90% interquantile ranges (calculated from high-pass-detrended single long-term series in 30 years moving subperiods). Examples shown are for annual temperature and precipitation. Seasonal and monthly analysis also available

8.8.3. SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

The socio-economic value and the policy implications of the so-far achieved deliverables of WP-8 – are given by a yet unknown real "climate"-variability description (climate to be understood as a linked continuum of different climate elements) of a region highly sensitive to climate impacts. The remaining work to be done in the WP will set the GAR-region's climate variability of the instrumental period in relation to that of larger scales. This is expected to help avoiding one of the major and most frequent biases of the recent discussion on climate change – the simplifying and often incorrect extrapolation of findings to other (larger or smaller) regions.

8.8.4. DISCUSSION AND CONCLUSION

The achieved findings of WP-8 distinguish the study region as one with stronger warming than the global mean, as one with significantly different subregional long term precipitation trends and as one with a number of vertical distinctions of trends and variability features of the seven climate elements present in the project's instrumental datasets. Most of them are influenced or dominated by the orographic effects of the mountain chain of the Alps which tend to steepen the existing continental scale climatic transition zones (Atlantic, Continental, Mediterranean) to relatively sharp climatic borders.

8.8.5. PLAN AND OBJECTIVES FOR THE NEXT PERIOD

The workpackage is well on its way. The extension period of four months will be used complete the variability-changes study and to resume the findings under special attention to circulation topics and comparisons with continental- to global scale climate variability.

3.9: WP-9: 1000 YEARS: GAR VERSUS GLOBAL (reported by partner 2)

WP-9 is a common activity of all partners, with the exception of partner 3. The.lead and reporting partner is partner 2. It has started its activities during and before the reporting period, mainly based on the deliveries of most of the other WPs.

3.9.1. OBJECTIVES

- Integration and analysis of the tree-ring reconstructions
- Extraction of climatic signals from ice cores
- Interpretation of climate forcing of glaciers
- Proxy-proxy intercomparison reconciliation
- Integrated analysis of GAR millennial climate
- GAR vs. global millennial climate
- Description of ALP-IMP findings for public use

3.9.2. METHODOLOGY AND SCIENTIFIC ACHIEVEMENTS RELATED TO WP-9 INCLUDING CONTRIBUTIONS FROM PARTNERS

Objective 1 has partially been reported elsewhere in WP2. The aim in this objective is to bring the various tree-ring reconstructions together and reconcile them with the early instrumental records, particularly for the period prior to about 1830. Various, independent reconstructions (some based entirely on ring-width data, others on combinations of ring-width and ring density data) have now been produced – see WP2. Some initial comparisons have been undertaken and some potential source of biases in one or more, identified as a possible product of the particular (Regional Curve Standardisation) chronology production techniques. These issues are the focus of the 'integrated comparison' of the dendroclimatic evidence of GAR climate for the last 1,000 years, currently underway.

Objective 2 has been delayed due to delays in the analysis of the ice cores. These will be undertaken during the extension period.

Objective 3 is mostly complete. The only additional work to be undertaken is some direct modeling of glaciers using the tree-ring based reconstructions of summer temperatures and winter precipitation. This will be deliberately based on a simple geometric model where glacier volume (and extension) is simulated as a response to temperature and precipitation forcing. Work on the remainder of the project will focus first on the use of instrumental climate inputs, possible back to AD 1800 using the integrated ALP-IMP precipitation and temperature data sets. This result will be compared with evidence of glacier change deduced from WP4 and with the output of the calibrated temperature and precipitation estimates for this period derived from the consolidated tree-ring reconstructions. This will then be extended back for the period prior to AD 1800 (for up to 400 years with dendroclimatic estimates of precipitation and temperature and up to 1000 years based on the integrated dendroclimatic evidence of temperature change alone).

Objectives 4-7 are still ongoing and will be the subject of much discussion at the final project meeting in early July.

Objective 8 will be addressed through the public meeting at the final project meeting.

3.9.3 SOCIO-ECONOMIC RELEVANCE AND POLICY IMPLICATION

The socio-economic value and the policy implications of the so-far achieved deliverables of WP-9 have yet to be fully realised. The remaining work to be done in the WP will set the GAR-region's climate variability of the last millennium in relation to that of larger scales, particularly for more northern areas of Europe (such as Scandinavia and the United Kingdom). This aspect will bear in mind the conclusions of WP8. If for example they show that there is little relationship between the GAR and northern Scandinavia, then it is unlikely to be any stronger in earlier centuries

3.9.4 DISCUSSION AND CONCLUSION

The achieved findings of WP-9 indicate that there has been marked century timescale variability, although this is sometimes out-of-phase with that evident in the north of Scandinavia. The 19th century is crucial to the usefulness of the earlier proxy records, as agreement with the earliest instrumental records gives greater belief in what they are telling us about earlier periods. The integration of the proxies on different timescales is best achieved by using the higher-frequency ones to simulate those at lower frequency via modelling approaches.

3.9.5. PLAN AND OBJECTIVES FOR THE NEXT PERIOD

The workpackage is well on its way. The extension period of four months will be used complete the planned work and bring all the various proxy reconstructions together. The initial results of this will be discussed at the final meeting and presented at the public session at the same final meeting..

Cumulative list of ALP-IMP project papers

All publications listed below available as pdf-files in the member area of the project homepage

(www-zamg.ac.at/ALP-IMP)

under the filenames indicated in column “ALP-IMP-ref-ID” (first column)

So far produced by ALP-IMP: 101 papers

colour code:

black: 1st and 2nd reporting period (unchanged) green: 3rd reporting period

(including those already present as submitted, in review, in press during earlier periods and now having another status and possibly changed contents)

Part 1: PEER REVIEWED PAPERS

So far produced by ALP-IMP:

44 peer reviewed papers

36 already printed, 2 accepted or in press, 6 submitted

ALP-IMP PUBLICATION LIST			PEER REVIEWED ARTICLES		Version June 2005		
ALP-IMP ref-ID	**Reporting Period**	**Authors**	**Date**	**Title**	***Journal***	**Reference**	**availability of pdf**
REPORTING PERIOD 1: 2003-03 to 2004-04							
ALP-IMP-rev-1-1	1	Aguilar E, Auer I, Brunet M, Peterson TC, Wieringa J	Dec. 2003	Guidlines on Climate Metadata and Homogenization	*WMO-TD* **1186** *WCDMP* **53**	51 pages	pdf unchanged
ALP-IMP-rev-1-2	1	Maugeri M, Brunetti M, Monti F, Nanni T	2004	Sea-level pressure variability in the Po-plain (1765-2000) from homogenized daily secular records	*International Journal of Climatology* **24**	437-455	pdf unchanged
REPORTING PERIOD 2: 2004-05 to 2005-04							pdf unchanged
ALP-IMP-rev-2-1	2	Auer I, Böhm R, Jurkovic A, Orlik A, Potzmann R, Schöner W, Ungersböck M, Brunetti M, Nanni T, Maugeri M, Briffa K, Jones P, Efthymiadis D, Mestre O, Moisselin JM, Begert M, Brazdil R, Bochnicek O, Cegnar T, Gajic-Capka M, Zaninovic K, Majstorovic Z, Szalai S, Szentimrey T	2005	A new instrumental precipitation dataset in the greater alpine region for the period 1800-2002	*International Journal of Climatology* **25/2**	139-166	pdf unchanged
ALP-IMP-rev-2-2	2	Frank D, Esper J	2005	Characterization and climate response patterns of a high elevation, multi species tree-ring network for the European Alps.	*Dendrochronologia* **22**	107-121	pdf unchanged
ALP-IMP-rev-2-3	2	Zemp M, Kääb A, Hoelzle M, Haeberli W	2005	GIS-based modelling of glacial sediment balance.	*Zeitschrift für Geomorphologie N.F.*, Suppl.-Vol. **138**.	113-129	pdf unchanged
ALP-IMP-rev-2-4	2 to 3	Casty C, Wanner H, Luterbacher J, Esper J, Böhm R	Apr.05	Temperature and precipitation variability in the European Alps since 1500	*International Journal of Climatology*, published online: (www.interscience.wiley.com). DOI: 10.1002/joc.1216, 2006		pdf of new version exists
ALP-IMP-rev-2-5	2 to 3	Büntgen U, Esper J, Frank DC, Nicolussi K, Schmidhalter M	2005	A 1052-year tree-ring proxy of Alpine summer temperatures.	*Climate Dynamics* ***25,*** 141-153, DOI 10.1007/s00382-005-0028-1, 2005		pdf of new version exists
ALP-IMP-rev-2-6	2	Zemp, M., Frauenfelder, R., Haeberli, W. and Hoelzle, M.	2005	Worldwide glacier mass balance measurements: general trends and first results of the extraordinary year 2003 in Central Europe.	accepted for: *Data of Glaciological Studies,* **98**		pdf unchanged
ALP-IMP-rev-2-7	2 to 3	Böhm R	Apr.05	Reconstructing the Climate of the 250 Years of Instrumental Records at the Northern Border of the Mediterranean (The Alps)	*Il Nuovo Cimento* **29 C** N 1, 13-19 DOI 10.1393/ncc/i2005-10216-0, 2006		pdf of new version exists
ALP-IMP-rev-2-8	2	Frank D, Esper J	2005	Temperature reconstructions and comparisons with instrumental data from a tree-ring network for the European Alps	*Data of Glaciological Studies [Materialy glyatsiologicheskih issledovanii]*, **99**, Moscow, Russia, 3-12.		pdf of new version exists

ALP-IMP-rev-2-9	2 to 3	Brunetti M, Maugeri M, Monti F, Nanni T	2006	Temperature and Precipitation Variability in Italy in the Last Two Centuries from Homogenized Instrumental Time Series	*International Journal of Climatology* **26-3, 345-381** DOI: 10.1002/joc.1216, 2006		pdf of new version exists
ALP-IMP-rev-2-11	2 to 3	Efthymiadis D, Jones PD, Briffa K, Auer I, Böhm R, Schöner W, Frei C, Schmidli J	Apr.05	Construction of a 10-min.gridded precipitation dataset for the Greater Alpine Region 1800-2003	*Journal of Geophysical Research - Atmospheres* **111**, D01 105, doi: 10.1029/2005JD006120, 2006		pdf of new version exists
ALP-IMP-rev-2-12	2	Büntgen U, Bellwald I, Kalbermatten H, Frank DC, Freund H, Schmidhalter M, Bellwald W, Neuwirth B, Esper J	2006	700-years of settlement and building history in the Lötschental/Vallis.	*Erdkunde, 96-112 Beitrag* **2/60**		pdf of new version exists
ALP-IMP-rev-2-13	2 to 3	Carrer M, Urbinati C	Apr.05	Long-term change in the sensitivity of tree-ring growth to climate forcing of *Larix decidua* (L.)	*New Phytologist* **2006**, doi: 10.1111/j.1469-8137.2006.01703.x		pdf of new version exists
ALP-IMP-rev-2-14	2	Frank D, Wilson R, Esper J	2005	Synchronous variability changes in Alpine temperature and tree-ring data over the last two centuries	*Boreas* **34** 2005 DOI: 10.1080/03009480500231443 # 2005		pdf of new version exists
ALP-IMP-rev-2-15	2	Zemp, M., Paul, F., Hoelzle, M. and Haeberli	June 2006: in press	Glacier fluctuations in the European Alps 1850-2000: an overview and spatio-temporal analysis of available data.	In: Orlove, B., Wiegandt, E. and B. Luckman (eds.): The darkening peaks: Glacial retreat in scientific and social context. University of California Press.		pdf of new version exists
ALP-IMP-rev-2-16	2 to 3	Paul, F., Machguth, H., Hoelzle, M., Salzmann, N. and Haeberli, W.	June 2006: in press	Alpine-wide distributed glacier mass balance modelling: a tool for assessing future glacier change?	In: Orlove, B., Wiegandt, E. and B. Luckman (eds.): The darkening peaks: Glacial retreat in scientific and social context. University of California Press.		pdf of new version exists
ALP-IMP-rev-2-17	2 to 3	Paul, F., Machguth, H. and Kääb, A.	Feb.05	On the impact of glacier albedo under conditions of extreme glacier melt: the summer of 2003 in the Alps.	EARSeL Workshop on Remote Sensing of Land Ice and Snow, Bern, 21.-23.2. 2005. *EARSeL eProceedings* **3**, *CD-ROM.*		pdf of new version exists
ALP-IMP-rev-2-18	2	Steier P, Drosg R, Fedi M, Kutschera W, Schock M, Wagenbach D, Wild EM	2005	Radiocarbon determination of particulate organic carbon in glacier ice from the Grenzgletscher (Monte Rosa)	submitted to: *Radiocarbon*		no pdf available
ALP-IMP-rev-2-19	2 to 3	Brunetti M, Maugeri M, Monti F, Nanni T	2005	The Variability and Change of Italian climate in the last 160 years	Il Nuovo Cimento **29 C** N 1, 3-12 DOI 10.1393/ncc/i2005-10215-1, 2006		pdf of new version exists

REPORTING PERIOD 3: 2005-05 to 2006-04							
ALP-IMP-rev-3-1	3	Auer I, Böhm R, Jurkovic A, Lipa W, Orlik A, Potzmann R, Schöner W, Ungersböck M, Matulla C, Brunetti M, Nanni T, Maugeri M, Mercalli L, Briffa K, Jones P, Efthymiadis D, Mestre O, Moisselin JM, Begert M, Müller-Westermeier G, Kveton V, Bochnicek O, Stastny P, Lapin M, Nieplova E, Cegnar T, Dolinar M, Gajic-Capka M, Zaninovic K, Majstorovic Z, Szalai S, Szentimrey T	2006	HISTALP - Historical instrumental climatological surface time series of the Greater Alpine Region 1760-2003	in press: *International Journal of Climatology*		pdf exists
ALP-IMP-rev-3-2	3	Brunetti M, Maugeri M, Nanni T, Auer I, Böhm R, Schöner W	2006	Precipitation variability and changes in the greater Alpine region over the 1800-2003 period	Journal of Geophsical Research **111** in press. Doi: 10.1029/2005JD006674, 2006		pdf exists
ALP-IMP-rev-3-3	3	Grabner, M., Klein, A., Geihofer, D., Reschreiter, H., Barth, F.E., Sormaz, T., Wimmer, R.	2006	Bronze Age dating of timber from the salt-mine at Hallstatt, Austria.	accepted for: *Dendrochronologia*		pdf exists
ALP-IMP-rev-3-4	3	Leal, S., Melvin, T.M., Grabner, M., Wimmer, R., Briffa, K.R.	2006	Extreme growth years in relation to climate in precipitation sensitive Pinus nigra Arn. Trees growing in Austria	submitted to: *New Phytologist*		pdf will follow for final report.
ALP-IMP-rev-3-5	3	Leal, S., Eamus, D., Grabner, M., Wimmer, R., Cherubini, P.	2006	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	submitted to: *Global Change Biology*		pdf exists
ALP-IMP-rev-3-6	3	Leal, S., Melvin, T.M., Grabner, M., Wimmer, R., Briffa, K.R.	2006	Tree ring-growth variability in the Austrian Alps: the influence of site altitude, tree species and climate	submitted to: *Boreas*		pdf exists
ALP-IMP-rev-3-7	3	van der Schrier G, Efthimiadis D, Briffa K, Jones P	2006	European Alpine moisture variability for 1800-2003	submitted to: *International Journal of Climatology*		pdf of reviewed version exists
ALP-IMP-rev-3-8	3	Schöner W and Böhm R	2006	A statistical mass balance model for reconstruction of LIA ice mass of glaciers of the European Alps	submitted to: *Annals of Glaciology* (IGS-Cambridge)		pdf exists

ALP-IMP-rev-3-9	3	Hoelzle M, Chinn T, Stumm, Paul F, Zemp M, Haeberli W	2006	The applicaton of glacier inventory data for estimating past climate-change effects on muntain glaciers: a comparison between the European Alps and the Southern Alps of New Zealand	in press (published online: www.sciencedirect.com) *Global and Planetary Change,* special issue on climate change impacts on glaciers and permafrost.		pdf exists
ALP-IMP-rev-3-10	3	Zemp M, Hoelzle M. and Haeberli W	2006	Distributed modelling of the regional climatic equilibrium line altitude of glaciers in the European Alps.	*in press:* (published online: www.sciencedirect.com) *Global and Planetary Change, special issue on climate change impacts on glaciers and permafrost.*		pdf exists
ALP-IMP-rev-3-11	3	Zemp, M., Haeberli, W., Hoelzle, M. and Paul, F.	2006	Alpine glaciers to disappear within decades?	*Geophysical Research Letters. 2006GL026319.*		pdf will follow for final report.
ALP-IMP-rev-3-12	3	Paul, F. Maisch, M., Rothenbühler, C., Hoelzle, M. and Haeberli, W.	2006	Calculation of future glacier extent in the Swiss Alps by means of hypsographic modelling.	*submitted to: Global and Planetary Change.*		pdf will follow for final report.
ALP-IMP-rev-3-13	3	Brunetti M, Lentini GL, Maugeri M, Nanni T, Auer I, Böhm R, Schöner W	2006	Climate variability and change in the greater alpine region over the last two centuries based on multiple variable analysis	to be submited soon to: JGR, IJC or CCh		pdf will follow for final report.
ALP-IMP-rev-3-14	3	Büntgen U, Frank DC, Schmidhalter M, Neuwirth B, Seifert M, Esper J	2006	Growth/climate response shift in a long subalpine spruce chronology	*Trees - Structure and Function*	20: 99-110	pdf exists
ALP-IMP-rev-3-15	3	Büntgen U, Frank DC, Nievergelt D, Esper J	2006	Summer temperature variations in the European Alps: AD 755-2004	*Journal of Climate*	in press	pdf exists
ALP-IMP-rev-3-16	3	Büntgen U, Frank DC, Kaczka RJ, Verstege A, Zwijacz-Kozica T, Esper J	2006	Growth/climate response of a multi-species tree-ring network in the Western Carpahian Tatra Mountains, Poland and Slovakia	*Tree Physiology*	accepted after revision	pdf exists
ALP-IMP-rev-3-17	3	Esper j, Büntgen U, Frank DC, Nievergelt D, Liebhold A	2006	Insect outbreak clockwork stops after 1200 years	submitted to: *Proceedings of the Royal Society: B*	in review	pdf exists
ALP-IMP-rev-3-18	3	Treydte K, Schleser GH, Helle G, Frank DC, Winiger M, Haug G, Esper J	2006	The twentieth century was the wettest period in northern Pakistan over the past millennium	*Nature*	44: 1179-1182	pdf exists

ALP-IMP-rev-3-19	3	Wilson RJS, Frank DC, Topham J, Nicolussi K, Esper J	2005	Problems and opportunities for the spatial reconstruction of summer temperatures in central Europe	*Boreas*	34: 490-497	pdf exists
ALP-IMP-rev-3-20	3	Nicolussi K , Kaufmann M, Patzelt G, van der Plicht J, Thurner A	2006	Holocene tree-line variability in the Kauner Valley, Central Eastern Alps, indicated by dendrochronological analysis of living trees and subfossil logs	*Vegetation History and Archaeobotany*	14: 221-234.	pdf exists
ALP-IMP-rev-3-21	3	Melvin T., Brifffa K., Nicolussi K., Grabner M.	2006	Time-varying response smoothing	submitted to*: Dendrochronologia*		pdf will follow for final report.
ALP-IMP-rev-3-22	4	Nicolussi K., Pichler T., Kaufmann M., Thurner A		Years of extreme tree-ring growth during the last millennium in the European Alps	in preparation		pdf will follow for final report.
ALP-IMP-rev-3-23	4	Nicolussi K., Böhm R., Briffa K.R., Melvin T., Thurner A		A summer temperature reconstruction for the last 2000 years	in preparation		pdf will follow for final report.
ALP-IMP-rev-3-24	4	Nicolussi K., Kaufmann M.		Evolution of the tree line in the central European Alps during the last 200 years	in preparation		pdf will follow for final report.

Cumulative list of ALP-IMP project papers

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green: 3rd reporting period

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57 non reviewed papers

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ALP-IMP ref-ID	**Reporting Period**	**Authors/Editors**	**Date**	**Title**	**Event**	**Reference**	**Type***	**availability of pdf**
REPORTING PERIOD 1: 2003-03 to 2004-04								
ALP-IMP-n-rev-1-1	1	Böhm R, Auer I, Ungersböck M, Schöner W, Huhle C, Nanni T, Brunetti M, Maugeri M, Mercalli L, Gajic-Capka M et al.	May 2003	Mesoscale patterns of long-term precipitation variability in the greater alpine region	ICAM-03: International Conference on Alpine Meteorology	Binder P, Richner H, Schär Ch (eds): ICAM-03 Extended Abstracts, *Publications of MeteoSwiss* **66** 555	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-2	1	Böhm R.,Auer I, Schöner W, Ungersböck M, Huhle C, Nanni T, Brunetti M, Maugeri M, Mercalli L, Gajic-Capka M, Zaninovic K, Szalai S, Szentimrey T, Cegnar T, Bochnicek O, Begert M, Mestre O, Moisselin JM, Müller-Westermeier G, Majstorovic Z	Sep. 2003	Der Alpine Niederschlagsdipol – ein dominierendes Schwankungsmuster der Klimavariabilität in den Scales 100 km – 100 Jahre *(The alpine precipitation dipole - a dominant climate variability pattern at the scales of 100 km - 100 years)*	6. Deutsche Klimatagung - Klimavariabilität, 22.9. - 25.9.2003, Potsdam (DE) *(6th German climate conference - climate variability)*	Negendank FW, Ristedt H (eds), 2003: *Terra Nostra* **2003/6**, 61-65	proceedings with extended abstracts (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-3	1	Scheifinger H, Böhm R, Auer I	Sep. 2003	Räumliche Dekorrelation von Klimazeitreihen unterschiedlicher zeitlicher Auflösung und ihre Bedeutung für ihre Homogenisierbarkeit und die Repräsentativität von Ergebnissen *(Spatial de-correlation of climate time series of different time-resolution and it's relevance for homogenization and spatial representation of results)*	6. Deutsche Klimatagung - Klimavariabilität, 22.9. - 25.9.2003, Potsdam (DE) *(6th German climate conference - climate variability)*	Negendank FW, Ristedt H (eds), 2003: *Terra Nostra* **2003/6**, 375-379	proceedings with extended abstracts (of a poster)	pdf exists
ALP-IMP-n-rev-1-4	1	Roswitha Drosg, Walter Kutschera, Martin Schock, Peter Steier, Dietmar Wagenbach, Eva Maria Wild	Sep. 2003	Radiocarbon determination of particulate organic carbon in glacier ice	18th International Radiocarbon Conference in Wellington, New Zealand, 1-5 September 2003	Proceedings of the 18th International Radiocarbon Conference (in Press)	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-5	1	Böhm R	Apr. 2004	Systematische Rekonstruktion von zweieinhalb Jahrhunderten instrumentellem Klima in der größeren Alpenregion – ein Statusbericht (*Systematic reconstruction of two and a half centuries of instrumental climate in the greater alpine region - a status report*)	54. Deutscher Geographentag, Bern (CH) 28.9.2003 bis 4.10.2003 *(54th German Geographer's Day)*	Gamerith, W., Messerli, P., Meusburger, P., Wanner, H. (Hrsg.) (2004): Alpenwelt – Gebirgswelten. Inseln, Brücken, Grenzen. Tagungsbericht und wissenschaftliche Abhandlungen, 121-131	extended proceedings with invited contributions (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-6	1	Böhm R, Auer I, Jurkovic A, Orlik A, Potzmann R, Schöner W, Ungersböck M, Brunetti M, Maugeri M, Nanni T, Jones P, Briffe K, Efthimiadis D	Apr. 2004	Die neuen ALP-IMP - CLIVALP Klimadatensätze - Neuerungen, Datenqualität unsd erste Ergebnisse *(The new ALP-IMP - CLIVALP datasets - news, data quality and first results)*	8. Österreichischer Klimatag, 19. und 20.Apr. 2004, Wien (AT) (8th Austrian Climate Day)	http://oegm.boku.ac.at/Veranstaltungen/klimatag08.html	Abstracts and ppt-files of presentations	pdf exists

ALP-IMP-n-rev-1-7	1	Paul, F., Kääb, A., Maisch, M., Kellenberger, T. W. and Haeberli, W.	2003	Das neue Schweizer Gletscherinventar: Anwendungen in der Gebirgskartographie. (*The new Swiss glacier inventory: Applications in mountain catography*)	*Kartographische Nachrichten,* **5**	212-217.		pdf exists
ALP-IMP-n-rev-1-8	1	Haeberli, W., Paul, F., Gruber, S., Hoelzle, M., Kääb, A., Machguth, H., Noetzli, J., Rothenbühler, C.	2004	Effects of the extreme summer 2003 onglaciers and permafrost in the Alps - first impressions and estimations.	EGU 1st General Assembly, Nice, 25-30 April 2004	*Geophysical Research Abstracts* , **6,** 2004, CD-ROM (ISSN: 1029-7006)	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-9	1	Hoelzle, M., Zemp, M., Frauenfelder, R. and Haeberli, W.	2004	Integration of alpine glacier monitoring into the GTN-G network of the global climate observing system (GCOS) by applying the global hierarchical observing strategy (GHOST). A discussion report.	EGU 1st General Assembly, Nice, 25-30 April 2004	*Geophysical Research Abstracts* , **6,** 2004, CD-ROM (ISSN: 1029-7006)	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-10	1	Zemp, M. and Hoelzle, M.	2004	Revision and expansion of World Glacier Monitoring Service's database	EGU 1st General Assembly, Nice, 25-30 April 2004	*Geophysical Research Abstracts* , **6,** 2004, CD-ROM (ISSN: 1029-7006)	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-11	1	Machguth, H.; Paul, F.;Hoelzle, M. and Haeberli, W.	2004	Calculating distributed glacier mass balance over entire mountain groups.	EGU 1st General Assembly, Nice, 25-30 April 2004	*Geophysical Research Abstracts* , **6,** 2004, CD-ROM (ISSN: 1029-7006)	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-1-12	1	Paul, F.; Machguth, H.; Hoelzle, M.; Salzmann, N. and Haeberli, W.	2004	Application of a distributed glacier mass balance model to the western part of the Swiss Alps	EGU 1st General Assembly, Nice, 25-30 April 2004	*Geophysical Research Abstracts* , **6,** 2004, CD-ROM (ISSN: 1029-7006)	abstract (of an oral presentation)	pdf exists
REPORTING PERIOD 2: 2004-05 to 2005-04								pdf exists
ALP-IMP-n-rev-2-1	2	Auer I, Böhm R, Scheifinger H, Ungersböck M, Orlik A, Jurkovic A	Sep. 2004	Metadata and their role in homogenising	Fourth Seminar for Homogenization and Quality Control in Climatological Databases, 6.-10.10.2003, Budapest (HU)	Szalai S, Szentimrey T (eds.), 2004: Proceedings of the 4th Seminar for... *WMO-WCDMP* **56**, *WMO-TD* **1236** 17-23	proceedings with extended abstracts (of an oral presentation)	pdf exists
ALP-IMP-n-rev-2-2	2	Büntgen U, Esper J, Frank DC, Nicolussi K, Schmidhalter M, Seifert M	2005	The effect of power transformation on RCS – case study from 3 millennial-length alpine chronologies	TRACE Dendrosymposium 2004 April 22nd-24th, Birmensdorf, Switzerland	*TRACE* **3** 141-149	extended abstract volume of invited contributions (of an oral presentation)	pdf exists
ALP-IMP-n-rev-2-3	2	Scheifinger H, Böhm R	2004	Räumliche Dekorrelation und Homogenisierbarkeit von Klimazeitreihen	DACH-2004 Meteorologen-Tagung, 7.-10.9.2004, Karlsruhe	Extended Abstracts CD, P12.21	proceedings with extended abstracts (of a poster presentation)	pdf exists
ALP-IMP-n-rev-2-4	2	Matulla C, Auer I, Böhm R, Ungersböck M, Schöner W, Wagner S, Zorita E	Apr.05	Outstanding past decadal-scale climate events in the Greater Alpine Region analysed by 250 years data and model runs		*GKSS-Report* **2005-04**, 1-115		pdf exists
ALP-IMP-n-rev-2-5	2	Leal, S., Melvin T.M., Grabner, M., Wimmer, R., Briffa, K.R.	Sep.04	Tree-ring width variability in the Austrian Alps and its relation with climate	Eurodendro 2004, September 15.-19., 2004, Rendsburg, Germany	Proceedings of the EuroDendro 2004, September 15.-19., 2004, Rendsburg, Germany: 29-30	abstract of a poster	pdf exists
ALP-IMP-n-rev-2-6	2	Auer I, Böhm R, Matulla C, Ungersböck M, Nanni T, Maugeri M, Pastorelli R	Sep.04	Frost occurrence in the European Alps - A view into the future and into the past	4th Annual Meeting of the European Meteorological Society, 26-30 Sept. 2004, Nice	EMS Annual Meeting Abstracts CD Vol.1, 00167, 2004	abstract proceedings	pdf exists

ALP-IMP-n-rev-2-7	2	Böhm R, Auer I, Potzmann R, Schöner W, Ungersböck M, Brunetti M, Nanni T, Maugeri M	Sep.04	Homogenising 192 precipitation time series in the greater alpine region (GAR) - A field report on theoretical and practical problems and solutions	4th Annual Meeting of the European Meteorological Society, 26-30 Sept. 2004, Nice	EMS Annual Meeting Abstracts CD Vol.1, 00168, 2004	abstract proceedings	pdf exists
ALP-IMP-n-rev-2-8	2	Böhm R, Auer I, Schöner W, Brunetti M, Nanni T, Maugeri M, Jones PD, Briffa K, Efthymiadis D	Sep.04	4-dimensional precipitation patterns in the greater alpine region - re-analysed with the new HISTALP dataset	4th Annual Meeting of the European Meteorological Society, 26-30 Sept. 2004, Nice	EMS Annual Meeting Abstracts CD Vol.1, 00169, 2004	abstract proceedings	pdf exists
ALP-IMP-n-rev-2-9	2	Zemp, M., Paul, F., Hoelzle, M., Haeberli, W. and Frauenfelder, R.	Oct.04	Spatio-temporal analysis of 150 years of Alpine glacier fluctuations.	International and Interdisciplinary Workshop on Mountain Glaciers and Society, Wengen, October 6 - 9, 2004.	Proceedings volume not yet available	abstract (of a poster)	pdf exists
ALP-IMP-n-rev-2-10	2	Schöner W, Auer I, Böhm R, Briffa K, Efthymiadis D, Jones PD, Widmann M, Brunetti M, Nanni T, Maugeri M	Oct.04	Long-term gridded air temperature and precipitation for the Greater Alpine Region	Conference on Spatial Interpolation Techniques in Climatology and Meteorology, 25. to 29. October 2004, Budapest	Proceedings volume not yet available	abstract of an oral presentation	pdf exists
ALP-IMP-n-rev-2-11	2	Zemp, M., Paul, F., Hoelzle, M., Haeberli, W. and Frauenfelder, R.	Feb.05	Spatio-temporal analysis of 150 years of Alpine glacier fluctuations.	9th Alpine Glaciology Meeting, Milano, February 24 - 25, 2005.	http://users.unimi.it/glaciol/9agm/zemp.pdf	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-2-12	2	Zemp, M., Hoelzle, M., Paul, F. and Haeberli, W.	Apr.05	Distributed Modelling of Regional Equilibrium Line Altitude in the European Alps: First Results and Discussion Report.	EGU 2nd General Assembly, Vienna, 25-29 April 2005.	*Geophysical Research Abstracts* , 7, 2005, CD-ROM (ISSN: 1029-7006)	abstract (of an oral presentation)	pdf exists
ALP-IMP-n-rev-2-13	2	Zemp, M., Paul, F., Hoelzle, M., Frauenfelder, R. and Haeberli, W.	Apr.05	Spatio-temporal Analysis of 150 Years of Alpine Glacier Fluctuations.	EGU 2nd General Assembly, Vienna, 25-29 April 2005.	*Geophysical Research Abstracts* , 7, 2005, CD-ROM (ISSN: 1029-7006)	abstract (of a poster)	pdf exists
ALP-IMP-n-rev-2-14	2	Hoelzle, M., Chinn, T., Stumm, D., Paul, F., Zemp, M. and Haeberli, W.	Apr.05	Application of inventory data for estimating characteristics of and regional climate-change effects on mountain glaciers: a comparison between the European Alps and the New Zealand Alps.	EGU 2nd General Assembly, Vienna, 25-29 April 2005.	*Geophysical Research Abstracts* , 7, 2005, CD-ROM (ISSN: 1029-7006)	abstract (of a poster)	pdf exists
ALP-IMP-n-rev-2-15	2	Böhm R, Auer I, Jurkovic A, Orlik A, Potzmann R, Schöner W, Ungersböck M	Apr.05	Climate variability changes in the greater alpine region in the past two centuries	EGU General Assembly 2005, 24-29 April 2005, Vienna, Austria	*Geophysical Research Abstracts* **7** 06634 2005 Sref-ID: 1607-7962/gra/EGU05-A-06634	abstract proceedings	pdf exists
ALP-IMP-n-rev-2-16	2	Pettinger M, Keck L, Fischer H, Wagenbach D, Preunkert S, Böhm R, Hoelzle M, Leuenberger M Hoffmann G	Apr.05	Centennial scale isotope thermomentry from Alpine ice core records: shortcomings and challenges	EGU General Assembly 2005, 24-29 April 2005, Vienna, Austria	*Geophysical Research Abstracts* **7** 07941 2005 Sref-ID: 1607-7962/gra/EGU05-A-07941	abstract proceedings	pdf exists
ALP-IMP-n-rev-2-17	2	Arnold W	Jan-2005	Schwarzwild: Hintergründe einer Explosion		Waidwerk **1/2005** 8-11		pdf exists

REPORTING PERIOD 3: 2005-05 to 2006-04								
ALP-IMP-n-rev-3-1	3	Böhm R, Auer I, Schöner W	May.05	Exploring past climate variability in the greater alpine region	28th International Conference on Alpine Meteorology, Zadar, 23-27 May 2005	*Croatian Meteorological Journal* **40** 106-110	proceedings with extended abstracts (of an oral presentation)	pdf exists
ALP-IMP-n-rev-3-2	3	Efthymiadis D, Jones PD, Briffa K, Auer I, Böhm R, Schöner W, Frei C, Schmidli J	May.05	A new high-resolution bi-centenial (1800-2003) precipitation dataset for the greater alpine region	28th International Conference on Alpine Meteorology, Zadar, 23-27 May 2005	*Croatian Meteorological Journal* **40** 111-113	proceedings with extended abstracts (of an oral presentation)	pdf exists
ALP-IMP-n-rev-3-3	3	Auer I, Böhm R, Potzmann R, Schöner W, Müller-Westermeier G, Kveton V, Cegnar T, Dolinar M, Gajic-Capka M, Zaninovic K, Maugeri M, Brunetti M, Nanni T, Carrer M, Mercalli L, Majstorovic Z, Begert M, Moisselin J-M, Ceron J-P, Bochnicek O, Zitari B, Nola P	May.05	A high resolution temperature climatology for the Greater Alpine Region (GAR)	28th International Conference on Alpine Meteorology, Zadar, 23-27 May 2005	*Croatian Meteorological Journal* **40** 593-596	proceedings with extended abstracts (of a poster presentation)	pdf exists
ALP-IMP-n-rev-3-4	3	Brunetti M, Nanni T, Maugeri M, Auer I, Böhm R, Schöner W, Briffa K, Efthymiadis D, Jones PD	May.05	Patterns of precipitation variability in the greater alpine region	28th International Conference on Alpine Meteorology, Zadar, 23-27 May 2005	*Croatian Meteorological Journal* **40** 597-600	proceedings with extended abstracts (of a poster presentation)	pdf exists
ALP-IMP-n-rev-3-5	3	Jurkovic A, Auer I, Böhm R, Debit S, Orlik A, Schöner W	May.05	The new centennial snow initiative for the greater alpine region (GAR). Status report and first results	28th International Conference on Alpine Meteorology, Zadar, 23-27 May 2005	*Croatian Meteorological Journal* **40** 601-603	proceedings with extended abstracts (of a poster presentation)	pdf exists
ALP-IMP-n-rev-3-6	3	Proemmel, K., B. Mueller, M. Widmann, and J. M. Jones	May.05	Comparison of a high-resolution regional simulation and the ERA40 reanalysis over the Alpine region	28th International Conference on Alpine Meteorology, Zadar, 23-27 May 2005	*Croatian Meteorological Journal* **40** 369-372	proceedings with extended abstracts (of a poster presentation)	pdf exists
ALP-IMP-n-rev-3-7	3	Grabner, M., Wimmer, R.	March 06	Dendroklimatologie - Klimainformationen in der Holzstruktur	9. Österreichischer Klimatag, Vienna	http://www.austroclim.at/index.php?id=39	abstract proceedings of a poster	pdf exists
ALP-IMP-n-rev-3-8	3	Geihofer, D., Grabner, M., Gelhart, J., Wimmer, R., Fuchsberger, H.	October 05	New master chronologies from historical and archaeological timber in Eastern Austria	Eurodendro 2005, 29 Sep - 1 Oct. 2005, Viterbo	Proceedings of the EuroDendro 2005 50-51	abstract proceedings	pdf exists
ALP-IMP-n-rev-3-9	3	Grabner, M., Klein, A., Geihofer, D., Reschreiter, H., Barth, F.E., Sormaz, T., Wimmer, R	October 05	First dendrochronological results from the Bronze Age salt mine at Hallstatt, Austria	Eurodendro 2005, 29 Sep - 1 Oct. 2005, Viterbo	Proceedings of the EuroDendro 2005 20	abstract proceedings	pdf exists
ALP-IMP-n-rev-3-10	3	Böhm R.	March 06	Hat die Klimavariabilität im Alpenraum zugenommen? Eine Flash-Studie mit ~200-jährigen HISTALP Daten (Did climate variability change in the Alpine realm? A flash-study based on ~200 years of HISTALP data)	9. Österreichischer Klimatag, Vienna	http://www.austroclim.at/index.php?id=39	pdf-version of the full presentation	pdf exists
ALP-IMP-n-rev-3-11	3	Ingeborg Auer, Reinhard Böhm, Anita Jurkovic, Alexander Orlik, Wolfgang Schöner, Markus Ungersböck	March 06	HISTALP – 250 Jahre instrumentelle Klimareihen im Großraum Alpen – Status und erste Analysen (HISTALP - 250 years of instrumental climate series in the greater Alpine region - status and first results)	9. Österreichischer Klimatag, Vienna	http://www.austroclim.at/index.php?id=40	pdf-version of a poster	pdf exists

ALP-IMP-n-rev-3-12	3	Prömmel,K., M. Widmann, J.M. Jones, and B Geyer	Mar.06	High-resolution simulation for the Alpine climate since 1958 - validation on mothly and daily timescales	Annual WGNE-meeting 2006	WGNE Blue Series, Reprt on WGNE-meeting 2006, Section 5, 46-47	report	pdf exists
ALP-IMP-n-rev-3-13	3	Zemp, M., Hoelzle, M., Paul, F. and Haeberli, W.	2005	Glaciers and climate change – past and present spatial glacier variability within the European Alps.	4th International NCCR Climate Summer School, Grindelwald.		abstract poster	pdf exists
ALP-IMP-n-rev-3-14	3	Zemp, M., Hoelzle, M. and Haeberli, W.	2005	Glaciers and climate change – Distributed modelling of the regional climatic equilibrium line altitude of glaciers in the European Alps.	3rd Swiss Geoscience Meeting, Zurich.		abstract talk	no pdfs available
ALP-IMP-n-rev-3-15	3	Zemp, M., Paul, F., Hoelzle, M. and Haeberli,	2005	Glaciers and climate change – Spatio-temporal analysis of 150 years of glacier fluctuations in the European Alps.	3rd Swiss Geoscience Meeting, Zurich.		abstract talk	no pdfs available
ALP-IMP-n-rev-3-16	3	Zemp, M., Paul, F., Hoelzle, M. and Haeberli, W.	2006	Past, present and future glacierisation in the European Alps.	EGU General Assembly, Vienna.	Geophysical Research Abstracts, Vol. 8, 06556, 2006; SRef-ID: 1607-7962/gra/EGU06-A-06556	abstract talk	pdf exists
ALP-IMP-n-rev-3-17	3	Zemp, M., Haeberli, W., Hoelzle, M. and Paul, F.	2006	Potential sea level rise estimates from the glacierisation of an entire mountain range as exemplified with observations from the European Alps	WCRP Workshop on Understanding Sea-level Rise and Variability		abstract poster	no pdfs available
ALP-IMP-n-rev-3-18	3	F. Paul, F., Kotlarski, S. and Hoelzle, M.	2006	Coupling of a distributed glacier mass balance model to the regional climate model REMO: Down-scaling strategy and first results	EGU General Assembly, Vienna.	Geophysical Research Abstracts, Vol. 8, 06556, 2006	abstract poster	pdf exists
ALP-IMP-n-rev-3-19	3	Paul, F., Rothenbühler, C., Maisch, M., Hoelzle, M. and Haeberli, W.	2006	Assessment of future glacier extent by means of hypsographic and GIS-based modelling	EGU General Assembly, Vienna.	Geophysical Research Abstracts, Vol. 8, 06556, 2006	abstract poster	pdf exists
ALP-IMP-n-rev-3-20	3	Zemp M, Frauenfelder R, Haeberli W, Hoelzle M	2006	Worldwide glacier mass balance measurements: general trens and first results of the extraordinary year 2003 in Central Europe	DGS St. Petersburg, May 2004	Conference proceedings, full articles	pdf-version of the presentation	pdf exists
ALP-IMP-n-rev-3-21	3	Schöner W	2006	Chapters 2 (Klimaänderung in den Alpen-Climate change in the Alps), Chapter 3 (Gletscheränderung in den Alpen - glacier change in the Alps), Chapter 6 (Auswirkungen der Klimaänderung auf den Apinismus - Impacts of climate change on alpinism) of: Auswirkungen der Klima- und Gletscheränderung auf den Alpinismus (Inpacts of climate- and glacier change on alpinism),		text.um 1/06, Umwelt-Dachverband, Vienna, 2006, 96 pages	currently only the printed version available	pfd to be provided soon, paper copies available at final ALP-IMP workshop 2006
ALP-IMP-n-rev-3-22	3	Büntgen U, Frank Böhm R, Esper J	2006	Effect of uncertainty in instrumental data on reconstructed temperature amplitude in the European Alps	In: Heinrich I (ed) *TRACE*	4:38-45	extended abstract	pdf exists
ALP-IMP-n-rev-3-23	3	Nicolussi K., Kaiser K.F., Patzelt G., Schießling P	2006	Precisely dated glacier Glacier advances and retreat periods during the 1st millennium AD in the eastern European Alps	International Glaciological Society – International Symposium on High-Elevation Glaciers and Climate Records. Lanzhou, China, 5.–9. September 2005	In: Price MF (ed): Global Change in Mountain Regions. Sapiens Publishing, UK	Abstract	pdf exists
ALP-IMP-n-rev-3-24	3	Nicolussi K., Kaufmann M., Patzelt G., Plicht van der J., Thurner A	2005	A Holocene tree-line record from the Central Eastern Alps, based on the dendrochronological analysis of living trees and subfossil logs	EuroDendro 2005, 28.September – 2. Oktober 2005, Viterbo	Proceedings of the EuroDendro 2005 60-61	Abstract	pdf exists

ALP-IMP-n-rev-3-25	3	Nicolussi K	2006	Gletscher der Alpen – vom Anwachsen und Abschmelzen	In: Slupetzky H. (Hrsg.): Bedrohte Alpengletscher. *Alpine Raumordnung*	**27**: 47-49		pdf exists
ALP-IMP-n-rev-3-26	3	Nicolussi K., Patzelt G.	2006	Klimawandel und Veränderungen an der alpinen Waldgrenze – aktuelle Entwicklungen im Vergleich zur Nacheiszeit	*BFW-Praxisinformation*	**2006/10**, 3-5.		pdf exists
ALP-IMP-n-rev-3-27	3	Pichler T., Nicolussi K	2006	Zur Bauentwicklung der Obermairalm am Fuchsberg – Ergebnisse dendrochronologischer Analysen	*Der Schlern*	**80/4**, 4-11		pdf exists
ALP-IMP-n-rev-3-28	3	Nicolussi K., Stötter H	2006	Zur Geschichte der Gletscher der nördlichen Ortlergruppe im 19. und 20. Jh.	*Der Schlern*	**80**, in print		no pdf yet available