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GWL-Fingerprints in Central European Tree-Rings

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Introduction

Dendroclimatological research often deals with the reconstruction of past climate conditions. Up to now all tree-ring based reconstructions try to extract the signal of one climatic parameter or a combination of different climatic parameters from tree-ring series (Fritts 1976). One important step to be able to use tree-ring series as proxies for climate-reconstruction is the elimination of the non-climatic environmental signals. Further, it is necessary to take into consideration that tree growth can even differ at the same site due to the different demands and sensitivity of the various tree species towards environmental and climate conditions (Schweingruber 1996).

Moreover, in temperate climates it is quite difficult to separate the different climatic parameters, because the correlation between tree-ring growth and these parameters is weak (Glaser 2001). Nevertheless, it is possible to investigate the relation between climatic parameters and radial tree-ring growth in temperate climates if certain conditions, like biogeographical stratification, similar editing and statistical preparation of all datasets, are fulfilled (Schweingruber & Nogler 2003).

This paper presents a conceptual approach for a new dendroclimatological project. The target of the project is to estimate the influence of synoptic circulation conditions on high resolution spatial patterns of variations of radial-growth anomalies for Central European trees at annual resolution from 1901 to 2000. The synoptic conditions will be parameterized by a daily resolved dataset of 29 so called Großwetterlagen (GWL). These GWLs were often called ‘extended-range weather situations’ or ‘weather regime types’ and were introduced first by Baur 1943 and extended by Hess & Brezowsky 1952 (Gerstengarbe 2005, Hess & Brezowsky 1952, Baur 1944). The spatial patterns of radial-growth anomalies will be derived from pointer years, which were expressed by z-transformed Cropper-values (Neuwirth et al. 2006a, b).

Is there a linkage between GWL and spatial patterns of tree-ring growth?

Climate is an important forcing factor for tree-ring growth. Regarding the growth responses to variations in temperature and precipitation, the annual patterns of tree-ring growth in Central Europe could not be explained comprehensively for the time between 1901 to 1971 (Neuwirth et al. 2006b). This is caused by the fact, that, on the one hand, other climatic factors like air moisture or irradiance also can influence tree-ring growth and, on the other hand, the data from meteorological stations do not reflect the real climatic situations in the respective forests.

But, all climatic factors all over Central Europe are caused by the large scale circulation condition over the North Atlantic, which are determined by the situation of the atmospheric control centres Icelandic Low and Azores High, and the topography of the local sites. The situation of the atmospheric control centres determines the basic flow direction towards Europe, which can be classified into three general circulation types: zonal, mixed, and meridional.

Table 1: Classification of the circulation types into 10 synoptic types and 29 GWLs. (Gerstengarbe 2005)

CirculationType	*Synoptic Type*	*GWL Großwetterlagen*
zonal	West	West Anticyclonic (WA), West Cyclonic (WZ), Southern West (WS), Angleformed West (WW)
mixed	South-West	South-West Anticyclonic (SWA), South-West Cyclonic (SWZ)
	North-West	North-West Anticyclonic (NWA), North-West Cyclonic (NWZ)
	Central European High	Central European High (HM), Central European Ridge (BM)
	Central European Low	Central European Low (TM)
meridional	North	North Anticyclonic (NA), North Cyclonic (NZ), North Iceland High Anticyclonic (HNA), North Iceland High Cyclonic (HNZ), British Isles High (HB), Central European Trough (TRM)
	North-East	North-East Anticyclonic (NEA), North-East Cyclonicl (NEZ)
	East	Fennoscandian High Anticyclonic (HFA), Fennoscandian High Cyclonic (HFZ), Norwegian Sea - Fennoscandian High Anticyclonic (HNFA), Norwegian Sea - Fennoscandian High Cyclonic (HNFZ)
	South-East	South-East Anticyclonic (SEA), South-East Cyclonic (SEZ)
	South	South Anticyclonic (SA), South Cyclonic (SZ), British Isles Low (TB), Western European Trough (TRW)

According to the flow direction, the circulation types can be classified into 10 synoptic types and furthermore into 29 GWLs (Tab. 1). The GWLs are accompanied by different air masses which are characterized by distinctive combination of properties in terms of temperature, moisture etc. For example, the GWL WZ (Tab.1) normally comes along with very wet conditions in the north of the study area and drier conditions in the south of the study area. The weather conditions at specific locations are modified by the topographic situation. In the luff of a mountain range, rainfall is stronger than in the lee side, for example. Therefore, it is useful to investigate the growth responses related to the frequency distribution of the GWLs. If it is possible to extract the GWL signal from tree-ring chronologies nearly the complete climatic signal is explainable.

Study area

The research area is located in Central Europe and defined as the area between 5°-15°E / 42.5°-52.5°N (Fig. 1). The triangles in the map show the spatial distribution of dendro-chronological sites representing more than 8,000 trees from all the important Central European tree species (*Abies alba, Fagus sylvatica, Larix decidua, Quercus robur, Quercus petraea, Picea abies, Pinus cembra, Pinus sylvestris, and Pinus uncinata*). The circles in figure 1 mark regions without or only a few sites. These gaps should be closed to get a network with a homogeneous density. A homogeneous density is needed to exclude results and interpretations for the GWL-growth responses, which were affected by inhomogeneties in the site network.

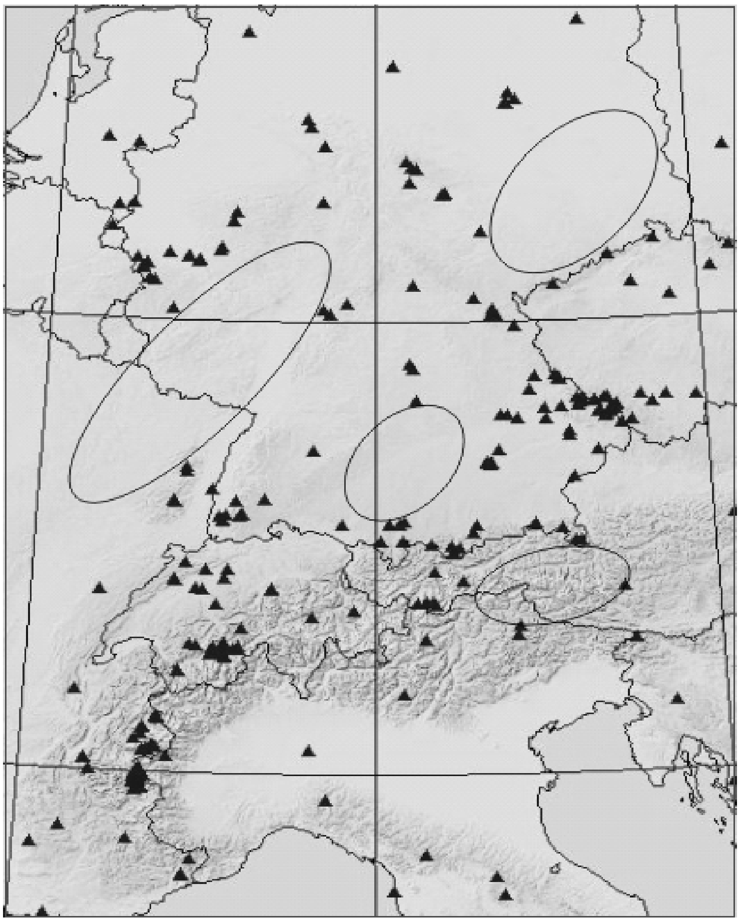

Figure 1: Spatial distribution of dendrochronological sites in Central Europe (modified after Neuwirth, 2005, p. 57). Circles indicate regions without or only few sites.

Procedure

The relations between spatial patterns of tree-ring growth and GWL will be analysed by a dendroclimatological network covering the period from 1901 to 2000. This network is based on a multidimensional data base structure which combines annually resolved dendrochronological time series and their corresponding meta data (site related information) with daily resolved GWL-data. The data bank will be developed by using the object-oriented software package ORACLE 10g.

The dendrochronological part of the network includes ring-width data from more than 500 Central European sites (Fig. 1) and their topographic and site-ecological data. The primary steps for the preparation of the dendrochronological data are:

- data collection,
- editing (quality check, data inputting, encoding, data formatting (Neuwirth 2005)),
- processing (indexation and, if necessary, elimination of the age trend by Regional Curve Standardization RCS (Esper et al. 2003; Cook & Peters 1997)).

The indexed time series will be grouped by using techniques like Principal Component Analyses (PCA) and Cluster Analyses (CA) to gather all sites with similar growth anomalies into one group. Then, the characteristics of the resulting groups will be defined by interpreting those meta data which are common for the group. Finally, for every group the GWL signal on different time scales (extreme years, interannual, decadal, long-time trend) will be evaluated by using pointer-year analyses, time-series analyses, and GIS-analyses (GIS: Geographical Information Systems).

GIS-analysis for the investigation of the growth / GWL- response

Due to the fact that pointer-year analyses (e.g. Neuwirth et al. 2005; Neuwirth et al. 2006b) and time-series analyses (e.g. Frank & Esper 2005; Neuwirth 2005) are quite common, only the GIS-analyses will be presented. During the GIS-analysis GWL-charts and growth maps are analysed and combined. In the left part of figure 2 the pressure chart shows the typical circulation and pressure situation for the most frequent GWL, the so-called ‘West Cyclonic’ (WZ) (Tab.1). The northern part of Central Europe is influenced by low-pressure, the south is influenced by high-pressure. This synoptic situation is linked to wet conditions, especially in the north of the study area and more or less dry conditions in the southern part of the study area.

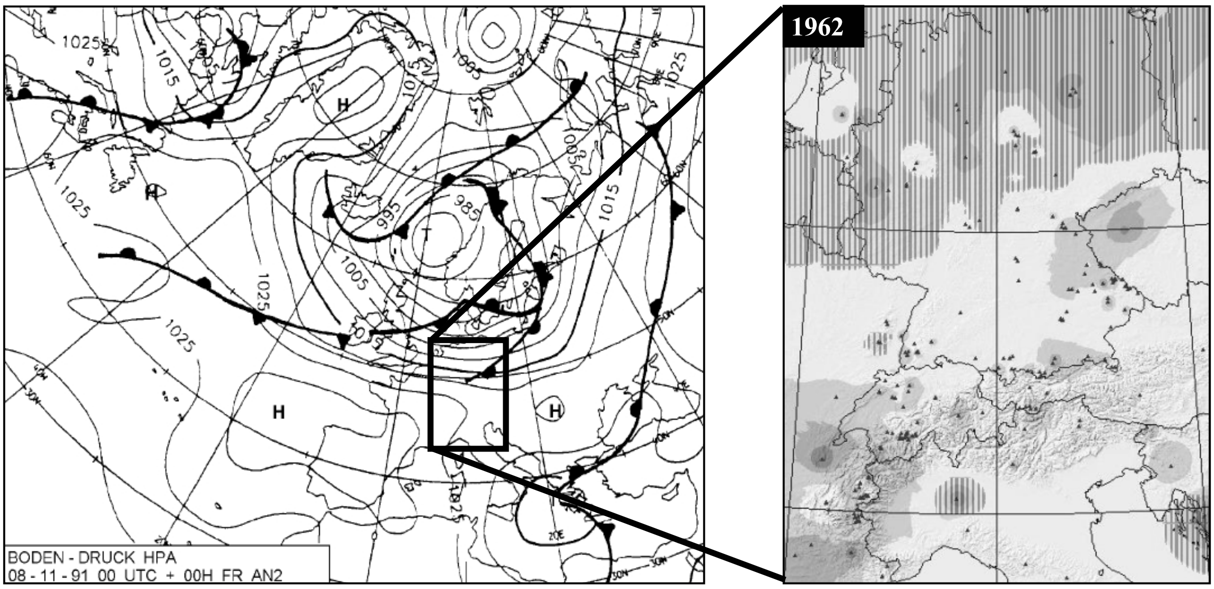

Figure 2: Example for the GIS-analyses. Comparison between the growth map for the year 1962 (source: Neuwirth 2005) and the typical synoptic situation for the GWL WZ which is presented in the pressure chart (source: Gerstengarbe 2005).

On the right side of figure 2, the growth map for the year 1962 is presented. This map reflects the negative (grey colour) and positive (grey vertical lines) growth anomalies derived from z-transformed Cropper-values (Neuwirth et al. 2006b). The vertical grey lines dominate the northern parts of the map, whereas in southern parts negative growth anomalies are dominant.

Within the framework of the GIS analysis it will be endeavoured to link the circulation and pressure situation as represented by a GWL or a combination of different GWLs for a period (month, year, decade) to the spatial distribution of tree-ring growth. Thus, in the pressure chart and in the growth map similar spatial divisions can be observed. Normally, wet conditions lead to positive growth anomalies and dry conditions to negative growth anomalies. Therefore, the chosen synoptic situation fits very well the growth map for the year 1962. To exclude random and to discover systematic relations between GWL and growth reactions, several questions have to be answered.

Questions and aims of the project

The main target of the project is to explain the spatial pattern of tree-ring growth anomalies in Central Europe with the frequency distribution of the GWLs. For the investigation of the linkage between tree ring growth anomalies and GWL it is necessary to answer the following questions using time series-, pointer year- and GIS-analysis.

- Is it possible to establish a link between tree-ring growth and GWL?
- Is it possible to trace back extreme growth responses to a special frequency distribution of the GWLs?
- Are there seasonal differences regarding the influence of the various GWLs on tree-ring growth?
- What is the most important factor for tree-ring growth: circulation type, synoptic type, a combination of different GWLs or even one GWL?
- Is it possible to detect the circulation changes above Central Europe in tree-ring series?

The expected results of this project can be used to reconstruct past climate conditions for Central Europe on a high spatial resolution. The first step for a reconstruction is to understand the link between the spatial pattern of tree-ring growth and the frequency distribution of GWLs in the present. Afterwards it will be possible to reconstruct the frequency distribution of the GWLs of the past. The advantage of a tree ring-based GWL reconstruction is the stability of the climate signal derived from GWL towards topographic and spatial modifications, because all climate elements like precipitation or temperature are modified by the topography but the overall trigger is the GWL.

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