Dendroclimatological spring rainfall reconstruction for an inner Alpine dry valley

W. Oberhuber and W. Kofler

With 4 Figures

Received December 18, 2000
Revised May 28, 2001

Summary

Estimates of spring precipitation for the inner Alpine dry valley of the upper Inn (Tyrol, Austria) are made back to A.D. 1724 using a ring width chronology of Scots pine (Pinus sylvestris L.) as predictor. A highly significant agreement in year-to-year ring width changes exists between several chronologies along the dry valley. The dendroclimatic model used for climate reconstruction is a simple linear transfer function that estimates April–June precipitation from current tree-ring width. All verification statistics commonly used in dendroclimatological research are significant ($p < 0.01$) and indicate that the reconstructed time series provides valuable information on past spring precipitation variability. Reconstructed spring rainfall deficiencies and surpluses $\geq 20\%$ compared to the long-term mean in 1819, 1832, 1834, 1865, 1885, and in 1780, 1782, 1821, 1853, 1910, respectively, are also documented by local historical records. Furthermore, a comparison is made with an independent climate reconstruction based on historical weather indices valid for the northern side of the Swiss Alps. A fairly good agreement is found between both spring rainfall reconstructions at low frequency intervals during 1755–1862 and 1919–1981. This preliminary study shows that tree-rings can be used to reconstruct spring rainfall variability for inner Alpine dry valleys.

1. Introduction

Annual rings of trees are most valuable and long-term climate proxy-data at an annual or even sub-annual resolution (for reviews see Fritts, 1976; Hughes et al., 1982; Schweingruber, 1996). Palaeoclimatologists have been using tree-ring series extensively, particularly in the semiarid, boreal and alpine zones, for the purpose of reconstructing climate and extract information about climatic trends. At alpine treelines summer temperature was found to be the predominant growth factor limiting tree growth and making these sites particularly suited for dendroclimatological reconstructions (e.g. LaMarche and Fritts, 1971; Eckstein and Aniol, 1981; Nicolussi, 1994). Due to prevailing humid conditions precipitation plays usually an insignificant role in controlling tree growth (Tranquillini, 1979). At extreme sites within inner-Alpine dry-valleys, however, precipitation may limit tree growth during the first part of the growing season (Lingg, 1986; Kienast et al., 1987; Oberhuber et al., 1998).

There are indications that drought is an important environmental factor triggering temporary growth declines or tree mortality, even in temperate forests (Innes, 1994). Two recent observations may indicate an aggravation of the already water stressed dry forest sites due to increased evapotranspiration rates: First, Tsonis (1996) reported increases in low-frequency variability of global precipitation over the past century and second, the 20th century increase in surface air temperature over the Northern Hemisphere has been greater in spring than in any other season (Groisman et al., 1994).
Scots pine (*Pinus sylvestris* L.) growing at inner Alpine dry valley sites of the upper Inn (cf. Fliri, 1975; Ozenda, 1988) have shown utility for reconstructing spring rainfall variability. Previous work has shown that growth was primarily influenced by spring precipitation (April–June) and climate variables explained up to 65% of the tree-ring width variance (Oberhuber et al., 1998; Oberhuber and Kofler, 2000).

The purpose of this study was to prove the quality of tree-rings to reconstruct rainfall variability for an inner Alpine dry valley. Furthermore, the agreement of the reconstructed spring rainfall with local documentary climate records (Fliri, 1998) and an independent spring rainfall reconstruction from the northern side of the Swiss Alps, which is based on historical weather indices (Pfister, 1985, 1993), was evaluated.

### 2. Study site and methods

#### 2.1 Study area

Scots pine trees (*Pinus sylvestris* L.) were selected from three sites located in the inner Alpine dry valley of the upper Inn (Tyrol, Austria). Mean annual rainfall during 1911–1995 ranged between 663 mm (Nauders) and 902 mm (Innsbruck) with spring being the driest season in more than 30% of years (Fliri, 1975). From the Swiss borderline to Innsbruck the entire Inn-valley extends almost 100 km (Fig. 1).

The first site (K139) was located within a postglacial rock-slide area, the two other sites (K101 and K115) were located on south-exposed slopes, approximately 40 km west and east from the first site. Vegetation and soil type were similar on all three sites: Spring Heath-Pine habitat (*Erico-Pinetum typicum*; Ellenberg, 1988) with *Juniperus communis* L. covering less than 5% of the area. The soil was of protoendicz type, i.e. rendzic and lithic leptosols according to the FAO classification system (*Soil Map of the World*, 1988), and consisted of unconsolidated, coarse-textured materials with low water holding capacity (Kuntze et al., 1994).

#### 2.2 Field collection and sample preparation

Dominant trees were selected at the sites by extracting two cores at breast height (1.3 m) from opposite sides. Air-dried cores were mounted on wooden holders and the surface prepared with sharp razor-blades (Pilcher, 1990). Total ring widths and latewood widths were measured to the nearest 0.01 mm using an incremental measuring table. The correct dating of tree-ring series was checked again recently developed Scots pine chronologies (cf. Oberhuber et al., 1998). The program COFECHA (Holmes, 1994) helped to identify segments within each ring series showing erroneous crossdating. Due to individual growth characteristics about 15% of total sample size could not be cross-dated accurately and were omitted from the analysis. Missing rings occurred in less than 1% of measured rings and did not occur on both tree radii of a given year.

#### 2.3 Chronology development

A two-stage detrending procedure was chosen using the program ARSTAN to remove most of the low-frequency variability that is assumed to be unrelated to climate. While low-frequency variation is thought to be mostly related to tree aging and forest-stand development, the high-frequency portion should contain mostly climate signals (Cook, 1987; Cook and Briffa, 1990). In the first step a negative exponential curve or a linear regression line was fit to the ring-series. The