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## CLIMATE OF THE LAST MILLENNIUM IN EASTERN NORTH AMERICA AND IMPACTS ON THE VEGETATION

*Abstract:* The Little Ice Age, Medieval Warm Period and similar century-scale climate fluctuations had significant impacts on the vegetation of eastern and northern North America. These can be detected by high-resolution pollen diagrams, especially if precise dating is provided by laminated sediments. A series of high-resolution pollen diagrams from the Great Lakes eastward show alternating cool and warm periods during the past millennium. Quantitative calibration of these curves suggests differences in mean temperature of 0.5°C. Further north, at treeline in north-western Quebec, several high-resolution pollen diagrams also show impacts of the Little Ice Age on spruce populations. These results indicate that vegetation responds rapidly to century-scale climate changes and that these can be determined by high-resolution analyses of pollen in lake sediments, either from laminated or non-laminated sediments.

*Key words:* pollen analysis, Little Ice Age, Holocene, climate change, eastern North America.

### 1. Introduction

For the period before instrumental records, proxy-climate data provide the only information about climate change that is available. One important source of proxy-climate records is the fossil pollen in lake sediments. Interpreting climate changes from the fossil record is a two step process. First, it must be demonstrated that the particular variability present in these records is caused by climate. Next, these must be calibrated. This paper will concentrate on fossil pollen, but the methodology also applies to other proxy-climate data, such as paleolimnological fossils.

A typical pollen diagram exhibits variability of several scales. There are many potential causes for this variability, including fires and other disturbances, vegetation succession and climate variability. Separating these causes is not easy, but one important consideration is that climate changes are large-scale and would be expected to impact ecosystems across a large area.

In some regions, high-resolution pollen diagrams have been produced from lakes with laminated sediments. The presence of annual laminations means that the dating precision is better than typical sediments, which must be dated by radiocarbon. There is considerable evidence that pollen diagrams developed from lakes with laminated sediments can be used to interpret century-scale climate variations such as the Little Ice Age (Gajewski 1993; Gajewski 1998). But there is also evidence that these rapid climate variations can be interpreted from lakes without laminations. Some preliminary results will be discussed in this paper.

## 2. Methods

Pollen data were obtained using standard methods and are discussed in the papers listed in the reference list.

## 3. Results

Results will be presented from two regions. In the region from New England to the Great Lakes, several pollen diagrams are available from lakes with both laminated and non-laminated sediments. At treeline in northern Québec, several lakes have been analysed at high resolution. Although the sediments are not laminated, the sample resolution is high enough to be able to resolve century-scale climate variations.

### Conifer-Hardwood Forest region:

Seven pollen diagrams are available from across the Great Lakes–St Lawrence region of North America. Complete pollen diagrams have been published elsewhere (Gajewski 1987, 1988; Gajewski et al. 1987). In all cases, the sediments are varved and the dating accuracy should be accurate to a few percent. Gajewski (1987) argued that century-scale climate variations in the region were significant enough to impact the vegetation of the region and cause a change in the composition of the forests of the region. This was shown by performing a principal components analysis on the individual diagrams. The components separated changes in the original pollen diagrams by scale, and all diagrams showed a long-term trend, medium frequency fluctuations and higher frequency changes. The medium frequency fluctuations are of interest to us here, as they are in phase at all sites and correspond to known climate fluctuations such as the Little Ice Age. Other high-resolution pollen diagrams from the region (e.g. McAndrews, Boyko-Dikanow 1989) also record the Little Ice Age. This analysis demonstrated the coherency of the century-scale climate variations, and Gajewski (1988) calibrated the changes using regression techniques. Gajewski (1987, 1998) discussed this in more detail.

### Northern Québec treeline:

Several pollen diagrams have previously been published on a transect from the boreal forest to the shrub tundra (Gajewski et al. 1993, 1996; Gajewski, Garralla, 1992). To study in more detail the last 1000 years, new samples were counted from sites for which we had suitable sediment (Fig 1). The sediment is dated by radiocarbon, which has an error of up to 100 years in this time period. In addition,

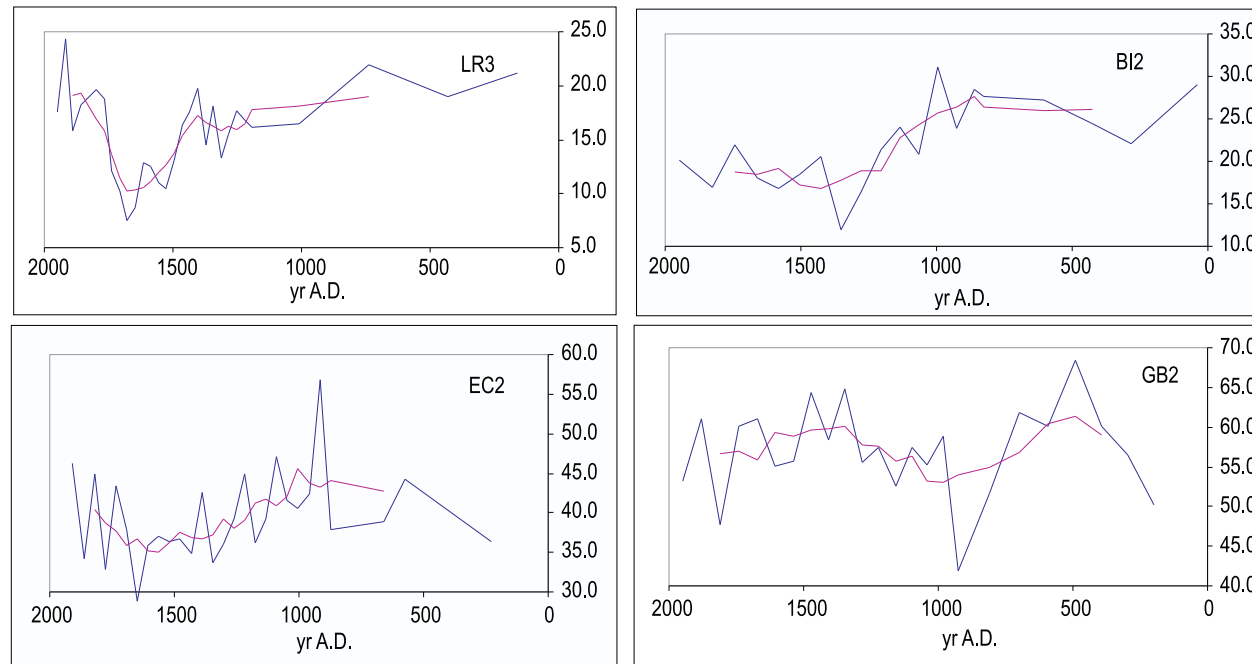


Fig. 1. *Picea* (spruce) pollen percentages from 4 sites spanning treeline in northwestern Québec. Site LR3 is located in the tundra to the north of the present-day treeline, and BI2 is also in the tundra, just to the west of the spruce limit. Site EC2 is in the present-day forest-tundra and GB2 is in the boreal forest. The smoothed curve is a 5-point running mean.

there is some error associated with estimating dates in the relatively unconsolidated uppermost sediments.

In sites LR3, BI2, and EC2 there is a decrease in spruce pollen beginning around AD 1000, dated slightly later in LR3. Given the errors in the dates, these could all be reasonably considered synchronous. Sites LR3 and BI2 are found to the north of the tree limit, and EC2 is in the forest-tundra. This suggests a decrease in *Picea* pollen production in the forest tundra and a decrease in pollen transport into the tundra during the Little Ice Age. This is reasonable if there were more northerly wind during this time period. *Picea* pollen production seems to have been more constant at GB2.

#### 4. Discussion

These results present clear evidence of the impact of century-scale climate fluctuations on the vegetation of this region. Quantitative estimates of temperature and precipitation indicate that these fluctuations are on the order of a half to one degree in magnitude. One important conclusion of these results is that vegetation responds quickly to climate variations, in contrast to conclusions of Davis and Botkin (1985), Campbell and McAndrews (1993) and Overpeck et al. (1990). Another result is that laminated sediments are not needed to interpret these changes, if the sampling interval is fine enough in radiocarbon-dated pollen diagrams.

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