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SHORT COMMUNICATION

Regional maps of rate of change of pollen percentage as a tool for climate change visualization

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Isoline maps of percentage of pollen, obtained for different time horizons through the Holocene, are a typical tool for palaeobotanical studies. In connection with the West Carpathian project the authors have developed the idea of graphically presenting on the map a rate of change of the pollen percentage. Such a map is based on the data from two time horizons. The precision of such a type of map, which shows the %/change/100 yrs, and in which the value can be negative as well as positive, is lower that of a typical isopollen map. However, this type of map gives a direct insight into changes in the plant cover, which are related to climate change.

Key words: isopollen maps, rate-of-change map.

INTRODUCTION

Palaeobotany, especially palynology, serves as a palaeoclimate proxy data source, since the taxonomic assemblages indicate many weather parameters with relative accuracy, such as average or extreme temperatures or precipitation. Regional isopollen maps (Szafer, 1935), produced for time horizons from the Holocene and Late Glacial (e.g., Ralska-Jasiewiczowa et al., 2004), are an almost unique source of geographical insight into the plant cover of the past. Since palynological data consists, as a rule, of full profiles frequently covering a geological epoch, it is typical to have isopollen maps not only for one time horizon (Huntley and Birks, 1983; Hoek, 1997a, b), but also for a series of horizons. It is therefore natural to analyse not only one given map, but two neighbouring maps, in search of some pattern of change of plant cover.

The primary result of such an analysis is information regarding in which areas the amount of pollen percentage of a given taxon rises or falls. The question how well the pollen percentage does in fact represent the vegetation is another matter. That problem will not be discussed here, since many papers considering the subject of isopollen maps have already covered this (e.g., Szafer, 1935; Huntley and Birks, 1983; Ralska-Jasiewiczowa et al., 2004), as have more recent publications (Gaillard et al., 2008).

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THE IDEA OF THE RATE OF CHANGE MAPS

For each selected point on the map, it is simple to calculate the difference in pollen percentage. Let us denote is difference as ΔP (the older P is subtracted from the younger value). The time span ΔT for the two given maps would be of the order of hundreds of years up to 1000 years. The ratio $R = \Delta P/\Delta T$ is simply the rate of change of pollen percentage for a given geographical position.

Pollen percentage values are plotted on the maps, as a rule, making use of the isoline idea, which makes the map more readable. The natural, continuous values of the estimated pollen percentage are categorised into a set of bands; for example 0–0.1%, 0.1–0.2%, 0.2–0.5%, and so on. It is clear that the R (rate of change) should be calculated prior to this categorization. The map of R values runs the same way as do the P-maps and they will also finally be categorised by isolines. The only significant difference, however, is that twice the volume of data is necessary here; namely the P values, for all the sites available, for two time horizons. A necessary, additional data item is the ΔT. This seems to be trivial, being simply ΔT = 500 years, for example; in practice, though, the question of the precision of ΔT is far from simple.

THE MAP CONSTRUCTION

The palynological profiles are radiocarbon dated as well as dated by comparison with other, neighbouring profiles. The second method does not necessarily make the argument circular, since the data are multivariate. Correlation by one taxon imposes the same correlation for all other taxa. However, even the most precise elements of the dating process, namely the radiocarbon dates, are not free of uncertainty. The only solid fact is that the ^{14}C ages have a well defined confidence band (as long as there is no gross error, for example of the type of sam-

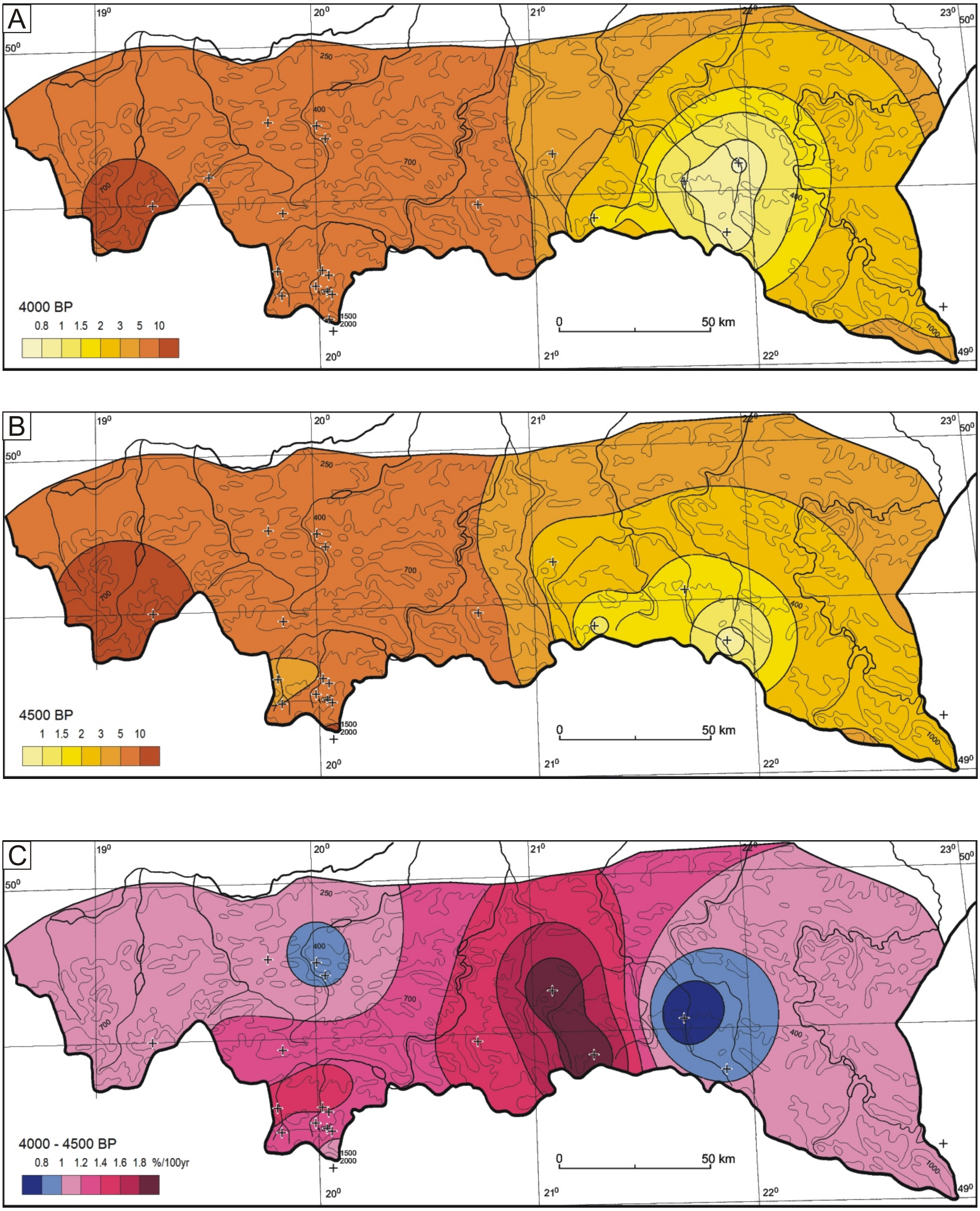

Fig. 1. Two typical isopollen maps (A, B) of the percentage of an example taxon, obtained for time horizons 4000 ^{14}C BP (A), and 4500 ^{14}C BP (B); the third map (C) comprises the information from both the above time horizons showing differences in percentages recalculated to the time unit (100 yrs)

The value range of (A), and (B) is roughly from 1 to 10%, while for (C) it is from –0.4 to +1.0 %/100 yrs

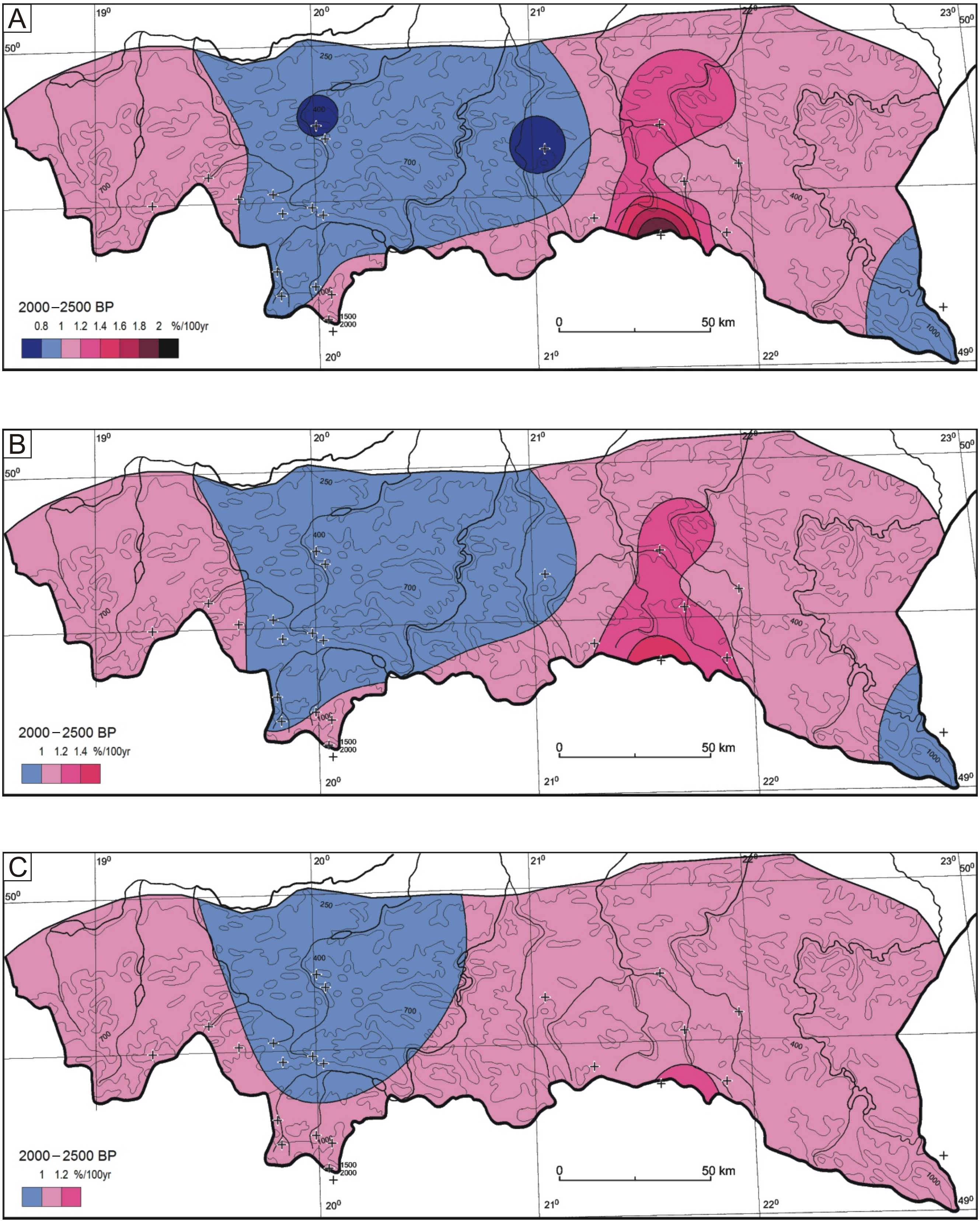

Fig. 2. The examples of different data presentation accuracy

The median (B) map is probably a good trade-off between the loss of valuable information and artificially creating information ple/context). Radiocarbon dates are rare, at least for older profiles, so relative dating is necessary. Finally, interpolation by the subjectively chosen method creates an additional source of uncertainty in terms of unknown statistical features. To produce a map for each profile requires its samples to be dated. It is relatively easy to attach a number of years to the samples, but it is almost impossible to estimate the precision of the dating. Also, this is not the final step. While the map is defined to illustrate the time T (for example T = 4500 yr b2k; Fig. 1B), it is not reasonable to expect to have samples in the profiles of that age label. A further interpolation is necessary. However, taking into account the low time resolution of dating, a Gaussian smoothing of samples from the vicinity of T is applied, instead of a simple (linear) interpolation. The Gaussian weights are defined by the normal distribution bell curve of the mean value equal to T and σ equal to, for example, 200 years. It means that samples of age $T \pm 1\sigma$ are of 61% (not 68%) importance in terms of the T age, and that of age $T \pm 2\sigma$ are of 14% weight, while at $T \pm 3\sigma$ we approach 1%, which is practically zero. However, 3σ means 600 years (in fact ±600 years), if σ is assumed to be equal to 200 years.

The last interpolation is that between sites, in the geographical sense. The final result is the P percentage for each map point. The value of rate of change is calculated as the difference of P's from two maps divided by ΔT. If there are N P-maps (N time horizons), then the total number of R-maps will be N-1. The R-map calculated based on the P-maps for time T and T-ΔT should be interpreted as illustrating the time T-$\Delta T/2$ (Fig. 1C).

From the numerical point of view of computer calculations, it is possible to split up the Holocene into 1 year sections. One can produce over 10,000 maps and even publish them (on the web). This is similar to a movie based on the maps, which require thousands of frames. The map obtained for T = 1234 yr b2k may be reliable enough if calculated with σ no less than, say 100 years. Of course, this does not mean that such a map illustrates precisely that time point. Calculation of R-maps with a too small ΔT is unreasonable. If the two quantities ΔT and σ are interrelated, the relationship would be as simple as $\sigma = \Delta T/2$; however, it would be sensible to also use another factor.

ADVANTAGE OF THE RATE OF CHANGE MAPS OVER THE CONVENTIONAL ISOPOLLEN MAPS

It is clear from the maps in Figure 1A and B that the given taxon is more abundant in the west than the east. However, only a map charting the rate of change makes clear more subtle features connected with the evolution of the taxon cover. In the middle of the given area, there is an evident increase of pollen. That feature can be discovered when inspecting both the (Fig. 1A) and (Fig. 1B) maps in parallel. Similarly, the fall in pollen percentage visible on (Fig. 1C) on the right can be recognized from (Fig. 1A) and (Fig. 1B); however, on (Fig. 1C), it is simply and directly indicated, with its numerical value (between –0.4 and –0.2 %/100 yrs).

Selection of the value of ΔT is a trade-off between the high number of maps obtained for the given database, and of that particular map accuracy (reliability). The second value is very different since it is measured (while the first one is simply a number). On Figure 2 are shown maps with different smoothing (averaging) degrees. The extremes would be: the representation of each site included with its own value; or, on the other hand, one value used right across the map. Such extremes are not presented below. However, the map (Fig. 2A) is probably slightly too precise, in terms of the reliability of the visible features. Map (Fig. 2C), however, seems to be too poor in terms of sufficient detail. The intermediate one (Fig. 2B) is probably a good option.

Appreciation of the quality offered by maps is possible with the application of the bootstrapping method (Walanus and Nalepka, 2009), or by visual inspection of a series of maps by an experienced scientist. The proposed maps of rate of change of the percentage pollen (Fig. 2) are very sensitive to overestimation in terms of the amount of information they convey. This is connected with the fact that twice as much data has been used in their creation than for typical isopollen maps. However, the potential map reader has to bear in mind that in the case of differentiation, data imprecision grows, because it is in summary form, while the data values themselves may easily be close to zero after subtraction. If used with a due amount of care, the rate-of-change maps could be seen, however, as a good tool for determining plant cover change indicators.

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