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Climate of the Past Discussions

Interactive comment on "Climate changes since the mid-Holocene in the Middle Atlas, Morocco" *by* M. Nourelbait et al.

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Response to reviewer #1

1) References to major works are missing in the introduction. The authors mention a long list of works showing variations in lake level from France, Italy, Spain and even the Dead Sea but they did not cite recent works on Central Mediterranean such as the synthesis of Magny et al. (2013 CP). In addition, excepting one pollen record from southern Spain, only continental pollen records from the Middle Atlas are cited. The authors should have taken into account pollen-based vegetation and climate reconstructions from the nearby marine sites from the Alboran Sea (Combourieu Nebout et al., 2009 CP; Fletcher et al., 2008 QSR; Fletcher et al., 2013 The Holocene). In addi-

tion, the synthesis paper of Fletcher et al. (2011 Catena) on rapid climate changes in the western Mediterranean region and impact on landscape should have been considered.

== Thank you for this comment. We have remodeled the introduction accordingly and included ad hoc citations.

2) Chronology:

a- Which CALIB software version was really used? CALIB 6.0 is indicated in the text (p.4012, l.16) and CALIB 7.0 in the table caption, with a different reference.

== We have re-calibrated the 14C dates using Calib 7.1 and the differences are very minor with the Calib version used previously (6.0). We have made the correction in the ms.

b- Information on the calibration curve used and the material dated (charcoal, shell, bulk sediment. . .?) should be indicated.

== The dated material is bulk. It is now mentioned in Table 1.

c- Presentation of the calibration results in Table 1 does not follow recommendations given in the CALIB manual (in particular indication of 2 sigma cal age ranges and relative area under distribution).

== Table 1 now follows the Calib recommendations and each column is properly titled.

d- In Table 1, what are SD1 and SD2

== These were the standard deviations. We have corrected this in table 1.

e- and does "Calibrated age" stand for median probability?

== It corresponds to the median probability provided by Calib. This has been corrected in Table 1

3) Methods:

a- References for all methods used should be given.

== References are now provided in this version of the ms.

b- p. 4101:

- l. 16: “stable isotopes of delta 13C” must be replaced with “carbon stable isotopes” or “delta 13C isotopic ratio”.

== This sentence is now replaced by “delta 13C isotopic ratio”.

- l. 18: “Pollen was” or “Pollen grains were” should be used.

== This has been corrected.

- l. 23: Justify why Cyperaceae pollen from this site is included in aquatic plants.

== Cyperaceae pollen percentages are included in the aquatic plants because they originate mainly from the genus Cyperus which often grows around the lakes.

- l. 26: replace “the fine grains (< 2 mm) of the sediment” with “the sediment fraction < 2 mm”.

== This has been corrected.

c- p. 4102:

- l. 3: Sentence meaning is unclear.

== We agree. This sentence has been re-written.

- l. 14-15: the method used for delta 13C measurements should be described.

== We have provided a full description of the method.

- l. 15: “University of Bordeaux”.

== Done.

- l. 21 & 26: “annual precipitation” instead of “annual amount of precipitation”.

== We agree.

d- p. 4103 :

- l. 2: give information on the database (name, reference, area covered. . .).

== The database of georefenced plant species has been set up by R. Cheddadi from the following two plant distribution atlases: Hulten and Fries (1986) and Flora Europaea (Jalas et al. 1972, 1973, 1976, 1979, 1980, 1983, 1986, 1989, 1991, 1994). These references are now cited in the manuscript. The database is a local one and its coverage corresponds to the two cited atlases.

4) Pollen data:

*The description of the pollen diagram is very short and uncomplete. In contrast to the author’s statement, other taxa than Pinus and Cedrus, such as Poaceae and Quercus, present strong variations which are not described or interpreted. The authors do not give a clear description of the pollen diagram and do not present a comprehensive history of the vegetation changes at the site. Only the replacement of pine by cedar at 3750 cal yr BP is pointed out while for instance, two important forest opening episodes are clearly recorded, the first one preceding the cedar expansion and the second one between 2500 and 2500 cal yr BP marked by a drastic cedar reduction.

== Thank you for this remark. In order to make an efficient and useful presentation of our data, we now provide a detailed description in a new table. This makes the main features of the pollen diagram easily accessible to the reader without overwhelming the manuscript with unnecessary details.

*In the discussion, the vegetation changes recorded in the Hachlaf sequence are not compared to the other records from the Middle Atlas (only cited in the introduction) and the Alboran Sea.

== Thank you for this comment. We have added a new section that compares the aridity trend after 6ka in both the Mediterranean area and within other records outside the study area as well. This, indeed, provides a wider view of our work.

5) Pollen-based climatic reconstructions:

* The reconstructed climate changes should be discussed in the context of the vegetation variations as recorded by the pollen diagram. Is the increase in precipitation seasonality in the second half of the record supported by the vegetation changes?

== Thank you for this point. The precipitation seasonality increase coincides with substantial changes in the ecosystems around the studied site. The main observed changes are the increase of the taxonomic diversity along with an expansion of the cedar populations and the retreat of the pine forest. Mediterranean areas are known for their high species diversity and for their sclerophyllous tree species that may withstand pronounced annual rainfall seasonality. Since both the annual amount of precipitation and the winter temperature have not changed substantially, we believe that the observed vegetation changes in Hachlaf may be explained by increase of the winter-summer contrast in precipitation.

- Is Quercus taxon including evergreen or deciduous oak pollen, or both?

== Yes it does because the distinction between the two types was rather random during the pollen analyses. We decided not to use dubious assignments of the pollen identifications.

- And which pine and oak species are taken into account in the database used for the climatic reconstructions?

== For the climate reconstruction we have assigned Pinus pollen grains to P. halepensis and those of Quercus to Q. coccifera.

- Are cedar ecological requirements supporting higher rainfall seasonality?

== A study of drought thresholds influencing the growth and photosynthesis was performed on different cedar stands and species (C. atlantica, C. libani, C. brevifolia & C. deodora) of different origins (Aussenac & Finkelstein, 1983). This study shows that among many conifers, cedar trees may keep a sustained photosynthesis activity even when drought is very high. Thus, strong precipitation contrast between summer and winter may not affect the cedar's overall growth as long as the total amount of rainfall is sufficient (higher than 600 mm/year) and the winter temperature is low enough for the bud burst (Larcher, 2000).

Aussenac, G., & Finkelstein, D. (1983). Influence de la sécheresse sur la croissance et la photosynthèse du cèdre. Annales Des Sciences Forestières, 40(1), 67–77.

Larcher, W. (2000). Temperature stress and survival ability of Mediterranean sclerophyllous plants. Plant Biosystems, 134(3), 279–295.

- Which pine species are developing in the Middle Atlas and to which climatic characteristics are they associated with?

== Currently two pine species are developing in the Middle Atlas; Pinus pinaster and Pinus halepensis up to 2600m asl. Although these two species are rarely associated (Benabid, 2000).

[Figure 1]

This plot, based on plant species distributions and their related climate variables archived in our database, shows the climatic niche (annual precipitation versus January temperature) of the two species. The median annual precipitation for P. halepensis and P. pinaster is 927 mm/yr and 991 mm/yr, respectively. The median January temperature for these two species is 4.2°C and 4.5°C, respectively. There is a clear overlap of their climatic niches. Therefore, assigning P. halepensis or P. pinaster to Pinus pollen grains will not affect the climatic reconstruction of neither their annual precipitation nor the January temperature.

- p. 4105, l.25: “water persisted in the lake during the summer season which allowed the presence of aquatic plants (which flower during late spring and summer)”: Could the authors relate this assertion to the pollen diagram?

== The occurrence of aquatic plants (>20%)in the pollen record (figure below) requires a sustained presence of water. All the identified taxa in the fossil record (Potamogetonaceae, Cyperaceae, Typha angustifolia,Typha latifolia, Ranunculaceae, Myriophyllum, Juncaceae) flower during the summer season in a lake (or marshy) environment.

[Figure 2]

- p.4016: the authors state “After 3750 cal BP, Atlas cedar spread noticeably around the site while the pine forest strongly regressed. During this ecosystem transition we do not observe any major change in the reconstructed amount of annual rainfall or in winter temperature.” However, we can see in Fig.3 that Pann become noticeably lower and Tjan more regularly higher when cedar percentages increase.

== Actually, the overall change that we observe in the amount of annual precipitation over the last 6000 years is about 50 mm and the amplitude of change in January temperature is about 2°C. These changes may not be considered as high. However, as the precipitation index shows it, if the 50 mm/yr represent an additional difference between summer and winter seasons then that may affect the ecosystems because it increases the seasonal contrast which is already quite pronounced (3 to 4 times more precipitation in winter than in summer, please see figure 4). Thus, both summer and winter amount of precipitation decrease (since Pann decreases) but the decrease affects more the summer than winter. Such pronounced winter-summer contrast may explain the regression of pines at the elevation of our site (1700m asl) and the expansion of Atlas cedars.

*The obtained climatic reconstructions are not discussed in comparison with previous pollen-based climatic reconstructions available in this region (Cheddadi et al., 2009; Combourieu Nebout et al., 2009). This would have been interesting to note that recon-

structions based on the MAT from Cheddadi et al. (2009) are not consistent to those presented in this manuscript and try to explain this contrasting pattern. Is it related to the method or to an actual different climate pattern?

== Thank for this remark and we will make such necessary comparison in the manuscript.

As a matter of fact, the climatic reconstruction presented in Cheddadi et al. (2009) are based on the pollen records from 3 sites. Two of them are from the Middle Atlas in Morocco (lake Ifrah and lake Tigalmamine) and the third site is from Algeria (Chataigneraie). The record from lake Ifrah does not cover the last 5000 years which prevents from a direct comparison with our data. The climatic data from lake Tigalmamine have already been published by Cheddadi et al. (1998). These data (with an age model based on uncalibrated 14C dates) which cover the Holocene do not show any major conflict with the data of this manuscript (based on calibrated 14C dates). Indeed, they both show a rather decreasing trend of the annual amount of precipitation (figure 4A in Cheddadi et al., 1998) after 6ka. The main "discrepancy" concerns Tjan (figure 4C in Cheddadi et al., 1998). However, if we focus only on the period of interest (the last 6ka) the reconstructed amplitude of change from both pollen records (lakes Hachlaf and Tigalmamine) is about 2°C and in both cases the reconstructed absolute Tjan is between 3 and 5°C.

- The authors only state p. 4104: “Besides the low range, both Pann and Tjan show consistent trends. Pann decreases progressively since 6000 cal BP which is in line with the aridity trend that has been observed in other records from the Mediterranean borderlands (Risacher and Fritz, 1992; Brooks, 2006; Hastenrath, 1991; Anderson and Leng, 2004; Umbanhowar et al., 2006).” None of these works deals with records of the Mediterranean region but to Bolivia, tropics, Greenland and USA records.

== Thank you for this remark and we agree with it. Indeed, there are records that show the aridity trend after 6ka outside the Mediterranean (Risacher and Fritz, 1992;

Brooks, 2006; Hastenrath, 1991; Anderson and Leng, 2004; Umbanhowar et al., 2006) and other records in the Mediterranean as well (Pons and Reille, 1988 ; Julià et al., 1994a, b, 1996 ; Davis, 1994 ; Burjachs et al., 1997; Yll et al., 1997 ; Valino et al., 2002) and in Northern Africa (Ben Tiba and Reille, 1982; Ritchie, 1984; Ballouche et al., 1986; Lamb et al., 1989). We have cited all these studies now properly in the manuscript.

*The reconstructed increasing trend in precipitation seasonality is also opposite to conclusions of other papers such as Fletcher et al. (2008), dealing with Western Mediterranean pollen records. It is also counterintuitive regarding the orbital forcing which favors a decrease in seasonality along the Holocene. Can hypotheses be proposed for explaining that contrast?

== If we may, the reference proposed above, is probably Fletcher and Sanchez-Goni (Quaternary Research, 2008) rather than Fletcher et al. (2008) as we didn't find any Fletcher et al. (2008). If this is correct then, Fletcher & Sanchez-Goni (2008) have not presented any climate reconstruction in their work and ultimately haven't stated any seasonality trend for the mid-Holocene. In their conclusions they state the following: "Changes in the seasonality of insolation (precession) also had an important pervasive influence on vegetation development over the last 48,000 yr, influencing both the amplitude and composition of forest development in this Mediterranean region."

While we do agree with this overall statement, we still are unable to compare our data for the last 6000 years with those of Fletcher & Sanchez-Goni (2008).

We must add that the relationship between precipitation trends and the orbital forcing is more complex than that of temperature. Reconstructed annual precipitation at 9ka, 6ka and 3ka show major spatial differences in Europe (Guiot et al. 1993) which makes their direct relation with the insolation, probably difficult. While some areas recorded more than 400 mm/yr, others received 400 mm/yr less than today (please see figure 8 in Guiot et al. 1993). The temperature trends seem to provide more coherent patterns

with the long-term insolation changes (Davis et al., 2003).

Having made these statements, we would like to add that concerning our data one should analyse the total amount of annual rainfall (Pann) and the seasonality index (SI) at the same time. Pann shows a decreasing trend (of about 50 mm/yr over the studied period). SI shows that the winter amount is 3 times higher at 6ka and 6 to 7 times higher today than the summer amount. These results tend to indicate that the overall amount of annual rainfall decreases which makes the summer season even drier today than at 6ka.

Davis, B. A. S., Brewer, S., Stevenson, A. C., Guiot, J., & Contributors, D. (2003). The temperature of Europe during the Holocene reconstructed from pollen data. Quaternary Science Reviews, 22, 1701–1716.

Guiot, J., Harrison, S. P., & Prentice, I. C. (1993). Reconstruction of Holocene precipitation patterns in Europe using pollen and lake-level data. Quaternary Research, 40, 139–149.

* Rapid climatic changes are presented in the introduction as a characteristic of the Holocene. Could the event at $\sim$ 5 ka be discussed in this context?

== Thank you for this remark. Although the thermal amplitude during the Holocene is lower than 4°C in the temperate latitudes (including the Mediterranean), there are indeed short and abrupt changes between 2 and 4°c which took places in a few decades (or even less). We will discuss these issues in the manuscript.

- Does it correspond to some regional changes?

== As stated above, there are climatic events that have been recorded during the Holocene (Rohling and Pälike, 2005; Berger and Guilaine, 2008; Kaniewski et al., 2008). And they have causal relationship with some societal changes in the Mediterranean (Ben Tiba and Reille, 1982; Ritchie, 1984; Ballouche et al., 1986; Pons and Reille, 1988 ; Lamb et al., 1989; Julià et al., 1994a, b, 1996 ; Davis, 1994 ; Burjachs et al., 1997; Yll et al., 1997 ; Valino et al., 2002). We will include mention these regional changes in the manuscript.

- P. 4105, l.11-15: instead of guessing in a complex sentence that summer rainfall is probably decreasing because annual rainfall is decreasing and seasonality index increasing, why not showing the Psum curve in Fig.3? - p. 4105, l.21-23: Same, why not showing the Pwin curve in Fig.3?

== Thank you for this suggestion. We will add the summer and winter precipitation in figure 4.

[Figure 4]

6) Minor comments:

- The authors repeatedly refer to the “stability” of the Holocene climate (abstract, introduction and discussion). This is somehow clumsy because since more than a decade a large number of works demonstrated that the Holocene climate is far from stable, at orbital and millennial/centennial timescales. And this is also something well known from marine and terrestrial sequences of the Mediterranean region.

== We have stated that the Holocene climate is "stable" in the sense that the overall recorded temperature changes (in different proxies) is estimated between 2 and 4°C, including the little Ice Age, the Medieval Warm Period and other abrupt events such as the 8.2 ka. This "stability" is made in comparison to other time periods and mainly the post-glacial one. However, it is right that the 8.2, for instance, was abrupt and some authors made a remarkable similarity with the Younger Dryas. In our "stability" statement we meant a low amplitude of change. we will make this point more clear in the manuscript and we will mention that the Holocene climate recorded, indeed, some abrupt changes.

- p. 4099, l.6: Holocene climate fluctuations are not only related to “internal variability of the climate system”. Major forcing such as volcanic eruption and solar forcing are

external to the climate system.

== Thank you for this comment. Indeed there are other major forcings and we will mention them properly in the manuscript.

- p.4099, l.9: “known”.

== Done.

-p.4099, from l. 13 to l.17: what about the influence of the subtropical high and Westerlies on the seasonal climate of the western Mediterranean region?

== The subtropical high and the westerlies are major components for the Mediterranean climate. We will discuss their impact on our reconstructed climate data.

- wrong numbering of the figures, ex. a call to Fig. 4 is missing, and it is should appear in the first paragraph of the “Results” section, i.e. before Fig. 3 first call.

== Thank you. This will be corrected in the submitted version.

- p.4100, l. 10: delete “years”.

== Deleted.

- p.4103, l.11: “dominating” – dominant.

== OK.

- p.4015 (p.4105), l.13: sentence unclear, “difference” instead of “amplitude”?

== Thank you, yes.

- p. 4106, l.18: delete “was”.

== "was" will not be deleted because the sentence was truncated; to complete it we must add this: “was important but part of the TOC originated from the terrestrial biomass.”

- p; 4107, l.3-17: First sentences repeated twice.

== Indeed, the first sentence was repeated twice. We will delete it.

- The last paragraph of the discussion has to be rewritten. It is repetitive and unclear.

== The last paragraph has been rewritten.

- p.4117: TN curve is not shown in Fig. 3 while it is described in the text and mentioned in the figure caption;

== TOC and TN are highly correlated (0.99). The shape of the two curves is very similar, that is why we plotted only the TOC curve. We have added it to Fig. 3 (as below) and changed the legend accordingly.

[Figure 3]

- what is the red line?

== The red line will be deleted as it concerned a previous interpretation which no longer appears in the manuscript

- p.4105, l.4: "a SI".

== "an" will be replaced by "a".

- p.4118: in Figure 4, a curve showing the taxonomic diversity and a hierarchical clustering tree are displayed but not mentioned in the caption. In addition, the method and software used for implementing the hierarchical clustering should be described in the main text or indicated in the figure caption.

== Here's a new caption for Fig. 4: "Diagram showing the percentages of the main pollen taxa identified in the Hach-I core. Cyperaceae and Juncaceae were grouped within aquatic taxa. The dashed black curves show an exaggeration (×7) of the percentages of some taxa. On the right, pollen zones with their boundaries are set up using a constrained hierarchical clustering (R Development Core Team, 2013). The

taxonomic diversity is computed using a rarefaction analysis."

- What is the red line?

== Here it's the same; the red line will be deleted as it concerned a previous interpretation which no longer appears in the manuscript.

- Is the taxa Quercus corresponds to deciduous or evergreen oak, or both?

== Quercus pollen grains include both deciduous and evergreen oak as their assignment may often be dubious and/or not reproducible by another pollen analyst.

Interactive comment on Clim. Past Discuss., 11, 4097, 2015.

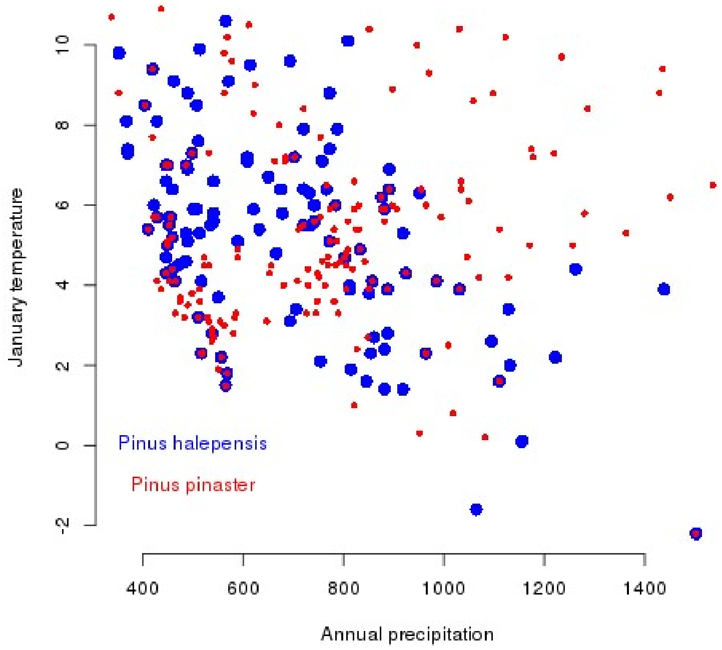
January temperature
Annual precipitation
Pinus halepensis
Pinus pinaster
-2
0
2
4
6
8
10
400
600
800
1000
1200
1400

Fig. 1.

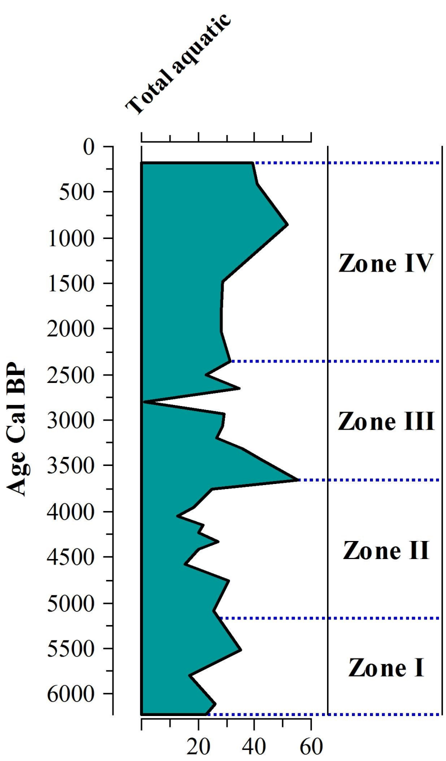
Total aquatic
Age Cal BP
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
20
40
60
Zone IV
Zone III
Zone II
Zone I

Fig. 2.

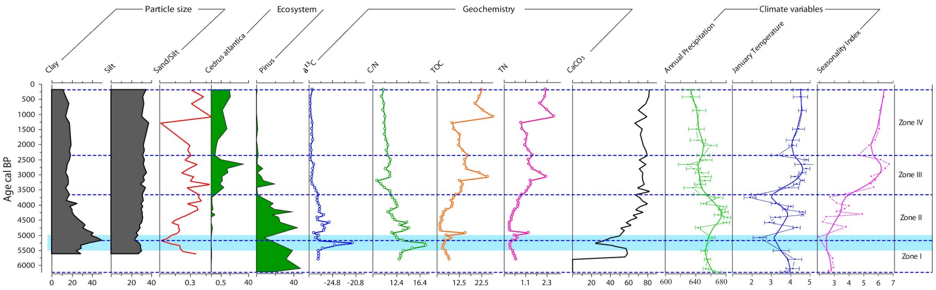
Particle size
Ecosystem
Geochemistry
Climate variables
Clay
Silt
Sand/Silt
Cedrus atlantica
Pinus
$\delta^{13}C$
C/N
TOC
TN
$CaCO_3$
Annual Precipitation
January Temperature
Seasonality Index
Age cal BP
Zone IV
Zone III
Zone II
Zone I

Fig. 3.

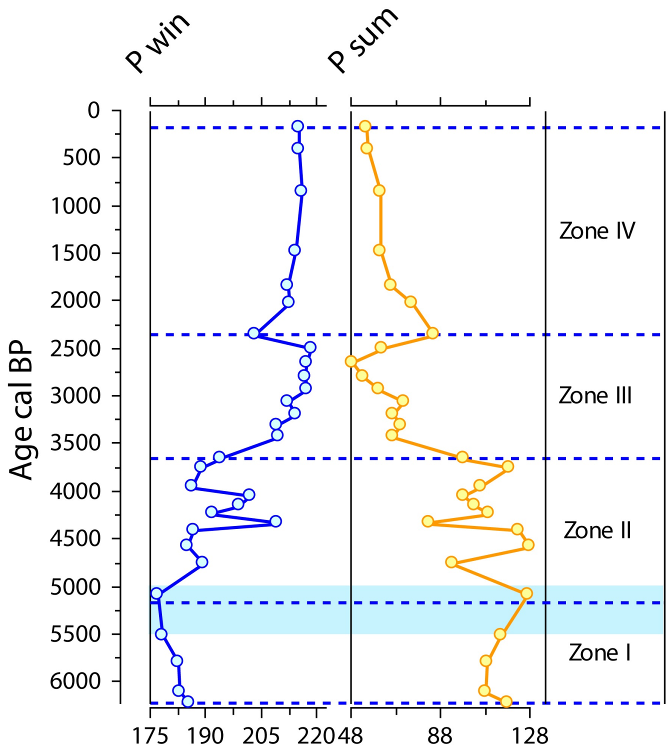
P win
P sum
Age cal BP
Zone IV
Zone III
Zone II
Zone I

Fig. 4.