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Biogeosciences Discussions

Interactive comment on "Climate-driven enrichment of pollutants in peatlands" *by* A. Martínez Cortizas et al.

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Response to the comments made by the referees

Anonymous Referee 1

The general point of this referee is that the evidence for a climatic control of carbon dynamics and peat geochemistry is weak. This argument is developed in three specific comments:

1. Links to climate change:

a) the climate reconstruction is not indenpendent of other records and we used a circular reasoning in our manuscript (climate is reconstructed using geochemistry, variations in the biological proxies are assigned to the climate periods, and then the climate is used back to explain elemental concentrations)

In a paper published in 1999 (Science 284: 939-942, 1999) we presented the relationship between Hg thermal stability in peat and climatic conditions in a record from the blanket bog of Penido Vello (PVO), located in NW Spain. In this paper we established a strong dependency of the accumulation of Hg and its thermal stability on past temperatures, and from this we made a reconstruction of the evolution of temperatures for the last 5,000 years. In the same paper a secondary control on intermediate stability Hg forms was suggested to be exerted by humidity (bog surface wetness linked to variations in precipitation), but the idea was not further developed.

In the 2006 paper (RPP 141: 203-223, 2006) we studied biological proxies from another two bogs of the area (BLL and PDC) and found that some non-pollen palynomorphs (NPPs) varied according to wetness conditions. This conclusion was drawn from the ecology of the NPPs and not from other properties of the peat records of these two bogs. In the same paper we compared the records of biological proxies of BLL and PDC to the geochemical proxy for wetness (the secondary source of control on Hg stability) of the PVO bog. A statistical analysis showed a 93

We don180;t find this to be redundant. The geochemical record and the biological reccords do not belong to the same peat sections, nor to the same bogs. The correlation between both types of proxies was stablished based on the independent chronology of each bog record (supporter by several radiocarbon age datings and non-linear age/depth models).

b) Changes in peatland surface wetness are not necessarily indicative of changes in climate but to water-table depth, which may be affected by other factors than climate alone (peat growth). Peatland surfaces are heterogeneous and their spatio-temporal dynamics are complex.

We agree with the referee on this comment. Nevertheless, in our previous work we compared records from different bogs in the area and didn't base our interpretation in a single record. The three bogs are located in mountain tops, with increasing distance

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to the coast and increasing elevation from 600 to 970 m a.s.l. (BLL > PVO > PDC), following also a gradient of increase in present precipitation (see Science of the Total Environment 292: 33-44, 2002; The Holocene 15: 698-706, 2005; RPP 141: 203-223, 2006; and also the chapter in Developments in Earth Surface Processes 9: 85-110, 2006). Due to their specific location the only source of water for these bogs is rainfall (see also the comments to the second referee), so most of the variations in water-table depth and oxygen availability must be due to variations in rainfall. Since the records are independent and show synchronicity in the changes of the wetness proxies the three bogs were subjected to the same external forcing, i.e. changes in precipitation. The effect of the complex spatio-temporal dynamics of the peatlands surface may have had indeed some influence on the response, but this seems to have been of minor importance. A discussion of the differences in the wetness records of the bogs and their sources can be found in our RPP paper (section 3.3 Evidence for changes in past climate, pages 218-219). For the present work we choose the PDC bog because it is located at higher altitude, at the sector of the gradient with higher rainfall, and seems to have been the most sensitive to changes in rainfall.

2. Data analysis: time series analysis should be used to detect relationships among variables.

We also agree with the referee that peat records do have chronologies, but they are not true time series in a statistical sense. Time series statistics assume that the time interval between consecutive samples is constant, which is not the case is most bogs. In the PDC bog the 2 cm slices in which the core was sectioned represent a minimum of 30 and a maximum of 100 years. This imposes limitations to the interpretation of time series statistics as cross correlation. But the main point of the paper is to established a link between climate (i.e surface wetness controlled by precipitation) and the geochemical response of the peat, so we believe a less sophisticated approach is sufficient four the paper purposes.

3. Export of pollutants: the proposed link is purely speculative. This estudy does not

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present any evidence. It would be helpful to discuss some of the studies which have examined controls on Hg release into pore waters.

Yes, this is a speculation which is a projection of our results on present and future scenarios of peatlands response to climate change. This is why it is included at the end of the paper, in the conclusions, because it is open to more research to confirm this projection. This comment is also based on our previous work on the relationship between the degree of peat decomposition and the geochemical records, which we have been developing during the last years (see for example Environmental Science and Technology 37: 32-39, 2003; Environmental Science and Technology 38: 1984-1991, 2004; or our recent critical review on Hg accumulation, Environmental Science and Technology 41: 4851-4860, 2007). The idea has been now extended discussing other related investigations.

Anonymous Referee 2

This referee is of the opinion that the manuscript is an important contribution to demonstrate the effect of variable peat accumulation on the accumulation of elements in peat, which challenges the simplistic, straightforward interpretations made in previous studies. But the referee also points to some problems we ought to consider:

1. The studied site is not representative for ombrotrophic mires, because of its southern location in the limit of temperate peatlands distribution. No information is giving on present vegetation, but the referee got the impression the site has not the degree of ombrotrophy as other bogs in Europe.

There is no doubt the bog is ombrotrophic. This has been demonstrated in previous work, which is given as reference in our manuscript (and references in point 1.b of response to referee 1; also the book edited in 2001 by Martínez Cortizas García-Rodeja, on mountain mires from NW Spain, which is in Spanish). The vegetation composition is described in these references. Indicators of bog ombrotrophy: 1) it is located on a blanket mire complex of almost 8 km2 which covers the top of a mountain

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range (Xistral Mountais) at elevations of 800-1060 m a.s.l., PDC located at 970 m a.s.l.; 2) very smooth microtopography, with humocks of less than 10 cm; 3) ash contents of 1-4

Because the nature of the bog was published in previous papers in this manuscript we focused on the main objective, and perhaps failed to give more convincing evidence of some aspects to the reader. For a more in depth discussion we refer the readers to the mentioned papers and book chapters.

As for the the location of the bog we took it as an advantange and not as a constraint. Because of its location on the fringe of the mid latitudes distribution of ombrotrophic mires, bogs from NW Spain are under more temperate and humid climatic conditions than those in northern areas, and were also subjected to the swings of Holocene climatic changes. For Europe in particular, the wet and dry phases controlling peat degradation have been in phase between southern and northern Europe through the Holocene (see for example Magny et al, 2003). So we think that in terms of peat degradation and geochemical behaviour they can be an analogous for peatlands in the northern colder areas under a warming climate scenario. Although this is, of course, debatable.

2. The referee considers that we assume that peat accumulation was lower during dry periods, but other processes (i.e. changes in plant productivity) may also affect peat accumulation. The climate records should be compared to others from Southern Europe to indicate whether the detected changes are contemporary and thus regional.

Along the manuscript we avoided to talk about peat accumulation but instead concentrated in peat degradation. It may follow that as peat degrades the rate of accumulation is affected but, in agreement with the referee, we think peat accumulation is a much more complex process resulting from a balance between primary production, plant decomposition, compaction, smearing, release of dissolved of organic matter and -to some extent- the content of inorganic matter (deposited dust). Degradation changes

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the chemical nature of the peat and affects its ability to store elements, and we think this is more relevant for the cycling of elements than the actual estimated amount of mass in the peat sections. In previous papers we have dealt with net accumulation rates (EST 37: 32-39, 2003; EST 38: 1984-1991, 2004).

Although the objective of this work is not to stablish the validity of the peat proxies to reconstruct climatic variations (which we think was already done in previous papers) we have included a brief reference to other records from Southern Europe, for comparison -as sugegsted by the referee. The comparison indicates that the PDC record shows the same chronology found in other studies in Spain but opposite to those of central Europe. This agrees with Magny's hypothesis (Magny et al., 2003, QSR 22: 1589-1596).

3. We argue for a preferential mineralization of N to explain the C/N ratios. Other studies have found that N mineralization in litter and peat is negligible in ombrotrophic bogs and the C/N ratios are controlled by C loss. But in minerotrophic mires, particularly if pH is relatively high, decay conditions are more complex and prone to a more intense N mineralization. In his/her opinion the record of the N isotopic composition and the high N concentrations of the studied bog point to a more minerogenic nature.

The referee is right in pointing that other work has shown C/N ratios variations controlled by C loss rather than N. Here we don't argue that in all ombrotrpohic bogs C/N ratios are controlled by N mineralization (which is not tthe topic of the paper), but offer an explanation for their actual variations in the PDC bog. Other studies developed in ombrotrophic bogs, as those refered to in this section of the masnucript, have found similar results to ours. Here C/N ratios are used as a proxy for peat decomposition. We have included a comment to cope with these two possible controls (preferential N versus C mineralization). But we would like the referee to be more specific when saying that many studies demonstrate in different ways that N mineralization is negligible in ombotrophic bogs.

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4. Factors other than peat degradation (i.e plant cover) may affect element depostion rates. This should also be taken into consideration.

We also agree with the referee in this point; even in the sense that this is not of the main cause of the variations. Nevertheless, other possible sources of variation in elements concentrations should be consider as a possibility in the manuscript.

Interactive comment on Biogeosciences Discuss., 4, 2095, 2007.