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Climate of the Past Discussions

Interactive comment on "Millennial-scale climatic variability between 340 000 and 270 000years ago in SW Europe: evidence from a NW Iberian margin pollen sequence" *by* S. Desprat et al.

S. Desprat et al.

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1- COMMENTS SHARED BY REFEREES.

1.1- Nomenclature of MIS 9.

B. Martrat and L. Dupont point out that 1) confusion arises in the last part of the introduction from the mixed use of marine oxygen isotope event numbers and marine isotope stage classification and 2) both notation systems are not interchangeable as oxygen isotope events refer to points and marine isotope substages to intervals. We acknowledge the misuse of the term "substage" to qualify the isotopic events 8.5 and 8.6 and we have made the necessary corrections along the text. The initial choice to refer at the same time to both notation systems (marine oxygen isotope event numbers and marine isotope stage classification) was made in order to inform the reader about the different labels used to ascribe the isotopic stratigraphy to the same interval. Indeed, there is a confusion in the literacy because the classical isotopic event notation of Prell et al. (1986) allocates the events 8.5 and 8.6 to MIS 8 while the marine isotopic stage (MIS) notation used for the SW Iberian record, in particular, consists of including them in MIS 9a and 9b, respectively. In addition, as the latter MIS notation is not fully accepted, we needed to explain in more detail why we choose to use it. Therefore, we have modified the last paragraph of the introduction to clarify it in respect to the referee's comments. And p.377, l.22, we have deleted: "(MIS 8.6 or 9b)" from "the interval 310-290 kyr ago (MIS 8.6 or 9b)" and p.395, l.4: "during MIS 9b (8.6, ~290-310 kyr)" replaced by "the MIS 9 interval ~290-310 kyr (designated as MIS 8.6 section in Siddall's paper)"

1.2- Outline of the manuscript.

The anonymous referee and B. Martrat have requested to improve the structure of the manuscript in particular in adding more subheadings to clarify the discussion section. We have consequently structured the results and discussion section as following: 4- The NW Iberian margin record: Results and interpretation. 4.1- The forest periods in NW Iberia. 4.2- The major open vegetation intervals in NW Iberia. 5- Discussion. 5.1- Climatic variability at orbital scale: the major warm periods. 5.2- MIS 9 millennial-scale climatic variability in the Iberian region. 5.2.1- Sequence of terrestrial and marine abrupt events in the Iberian region. 5.2.2- Degree of the abrupt climatic changes. 5.3- Climatic implications of the MIS 9 millennial-scale variability. 5.3.1- Suborbital climatic variability versus ice volume minimum. 5.3.2- Possible factors modulating the millennial climatic changes. 5.4- Similar millennial-scale variability during MIS 3 and MIS 9?

1.3- Figure and table changes.

- Figure 2: We have represented by shaded areas the forest stages and the maximum forest expansion intervals of Pontevedra and Bueu by a dark grey bar. We have also

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added the arboreal pollen percentage curve and the arrows indicating the forest reduction events which are displayed in the following figures and named them following our new nomenclature (cf. response to B. Martrat).

- Figure 3: We have modified this figure as suggested by B. Martrat. We have represented the bars indicating the forested intervals on the right of the ubiquist herb curve and moved the marine isotope nomenclature on the left of the N. pachyderma s. percentage curve to facilitate the land sea correlation discussion. However, we kept the arrows highlighting the abrupt vegetation and climatic changes in NW Iberia. In addition, to help the clarity of this figure, we have only represented the herbaceous and Poaceae pollen curves instead of the major herbs component curve.

- Figures 4 and 5: We have added: the forested period names from MD01-2443 pollen record (Roucoux et al., 2006), the Mediterranean percentages as suggested by L. Dupont (although we did not take out the oak curve as oak is the main component in the NW Iberian forest). We recognize the redundancy of the MD03-2697 profiles between Fig.4 and 5 but we present too many curves to merge these figures, as suggested by the referee B. Martrat, without a loss in clarity. We have replaced the MD01-2443 pollen curves in Fig.4 by new ones traced from the original data set provided by Katy Roucoux. Finally, we have changed the order of Fig.4 and 5 to match their appearance in the text, and add more precise reference of these figures in the text as required by B. Martrat.

- Figure 6: We have added Figure 6 to illustrate the comparison between climatic changes during MIS9 and 3 as requested by the L. Dupont and B. Martrat.

- Legend captions: As recommended by B. Martrat and the anonymous referee, we have specified the taxa included in the different ecological groups in the legend captions of Fig. 3 and 4 and replaced "Temperate forest" by "Temperate and humid forest" in all the figures.

- Table 1: As requested by L. Dupont and B. Martrat, we have: 1) specified the depth, age and number of sample for each pollen zone described, 2) clarified the text and added a column to indicate the forest reduction events included in each pollen zone and another one to propose equivalences between the forest reduction events from core MD03-2697 and the IMS from the MD01-2443 Uk 37-SST profile (Martrat B., et al., 2007).

2- REFEREE L. DUPONT.

- This referee suggests going into more detail discussing the evidence of the NADW reduction p. 283. The proxies used are not common knowledge and rather complicated to interpret. We have defined the proxies in the caption of Fig. 4. However, discussing in more detail the MD01-2443 record does not appear necessary to us since a description of the proxies and their interpretation is widely given in Martrat et al. (2007).

- This referee says that the statement p. 283 that "prominent abrupt SST drops [...] are preceded by decreases in both C26OH and benthic d13C" is not substantiated by the corresponding curves in Figure 4. This statement represents the main result of Martrat's study on the millennial hydrological and SST changes at the Iberian margin during the last 450 kyrs. Martrat et al. (2007) stated that such deep water hydrological changes (decrease of NADW contribution and increase of ventilation by AABW) are characteristic of the prominent SST changes 3IMS-7, 8, 9 and 10. Although some changes in the C26OH ratio are small, we agree in general with Martrat's observations from the MD01-2443 record presented in Fig. 4.

3- ANONYMOUS REFEREE #1.

The main referee's concern about the paper is related to the discussion. She/he finds the section very confusing and requested to write it more clearly. As this referee suggested, we have: 1) enhanced the structure with more subheadings; b) drew out the key points and implications to each comparison, c) added a figure (Fig. 6).

Specific comments:

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- p.382, l.20 to 23: We agree with the referee's statement that all the warm substages of MIS 9 are not interglacial in the strict sense and replaced "each interglacial substages of stage 9 (MIS9e, 9c, 9a)" by "each low ice volume intervals, i.e. substages 9e, 9c and 9a". The referee also asked to give a definition of the temperate forest periods and temperate forest. We have used these terms to define the periods characterized by a development of the temperate and humid forest. To avoid confusion, we have replaced "temperate forest periods" by "forest period" or "forest stage" as in Tzedakis et al., 2004 and Roucoux et al., 2006, and specified "temperate and humid" to characterize the forest or the tree populations in NW Iberian, all along the manuscript.

- p.383, l.13: As requested, we substituted "Latecomer trees" by late successional although this expression is also commonly used in previous papers. This referee also asks for a more detail discussion concerning the climatic implications of the arrival of the late-succession trees. In the new version of the manuscript, we have thoroughly discussed this and added the following paragraph: "The late expansion of these trees, considered as late successional, probably reveals a temperature decrease on the continent rather than the result of migration time and competition (see Prentice et al. 1991 for discussion) because the planktonic foraminifera assemblages indicates concomitant 3°C summer SST drop and d18O values increase. This change is also contemporaneous with the end of the benthic isotopic plateau suggesting an initial accumulation of glacial ice in the high latitudes."

- p.385, l.15 to 22: This referee has found confusing that earlier on (p.383, 7) we describe the occurrence of a "climatic optimum" within the Pontevedra forest period, while here we refer to Pontevedra in its entirety as representing the climatic optimum of the whole of MIS 9. We have therefore replaced: "Forest character and extent of the different periods assign the first major forested period (Pontevedra) as the climate optimum of MIS 9 in NW Iberia" by "As the development of deciduous oak and Mediterranean plants reaches a maximum extent during Pontevedra, this forest stage therefore represents the warmest period of MIS 9 in NW Iberia. In particular the warmest conditions

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are reached during a 2 kyr-long interval (˜333-331 ka) corresponding to the climatic condition optimum."

- p.385, l.25 to 387, 4: This reviewer requests for re-arrangement and rewording in this section to clarify the important points. Consequently, we have modified the section with the following outline: 1) as on land, the warmest interval is detected by all North Atlantic SST records within MIS 9e plateau and it corresponds to a period of strong deep water formation in the North Atlantic. 2) in contrast to the European pollen sequences, the North Atlantic SST records do not show that the warm period associated with MIS 9c is cooler than that of MIS 9a. These records give different information on the relative warmth. 3) a final comparison with other available MIS 9 records farther away, is made to draw the final conclusion that relative degree of climatic amelioration during the different MIS 9 warm periods appears strongly regional dependent.

- p.388, l.26: As suggested by this referee, we have indicated that the expansion of Poaceae could indicate drier as well as colder conditions.

- p.389, l.1: She/he further suggests that given the uncertainty in the alignment of the cores, the decrease in AP% in MD01-2443 at ˜316 ka could be related to the drop we observe in MD03-2697 at 315 ka. We acknowledge the possibility of correlation considering the age uncertainties. However, in the MD01-2443 record, this forest reduction event (AP%decrease at ˜316 ka in MD01-2443) and the previous AP% peak which is minor, occur before the beginning of the forest stage Queluz, during the stadial 3IMS-14 (Roucoux et al., 2006). This makes the correlation of the AP decrease improbable with the NW Iberian forest reduction 3NWI-fr4 since this event follows the major forest expansion of Sanxenxo stage.

- p.390, l.13 to 15: This referee says that "the trouble with arguing that suborbital climate oscillations are [damped] during periods of low ice volume, is that one must still account for the pronounced (i.e. not damped) decline in tree populations recorded in MD01-2443 during MIS 9e. It is not clear that millennial scale oscillations are [somehow

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scarcer] during times of low ice volume". In the new version of the manuscript we have discussed the climatic conditions that would have produced the forest collapse in SW Iberia bringing to an end the Lisboa forest stage (MD01-2443 record). We have also tempered the statement in specifying that the climatic changes appears dampened and scarcer during low ice volume conditions considering the temperature decreases and the available records: "Effectively, suborbital climatic changes, namely cooling events, during MIS 9 happened whatever ice volume extent but during low ice volume conditions the climatic oscillations seem dampened (cf. events 3NWI-fr1 fr4 and fr10) and somehow scarcer as far as the available records can tell."

- p.391, l.17 to p.392, l.4: This referee states: "in this section there are several distinct ideas about mechanisms, which either need to be split into separate paragraphs, or linked more clearly to make the argument more coherent." We have modified the section as following:

"Bond et al. (2001) interpreted the Holocene millennial variability as the result of atmospheric circulation changes forced by solar irradiance variability and put forward that solar-forced millennial-scale variability is a persistent feature of the past interglacials. The MIS 9e suborbital event could be the particular expression of such variability. However, there is no consensus on the forcing mechanisms for millennial climatic changes during interglacial periods; in particular the solar origin has been lately challenged by a Holocene subpolar North Atlantic record (Came et al., 2007).

Regardless of the origin, suborbital events within MIS 9e ice volume minimum but also those occurring during MIS 7e and MIS 5e, strikingly mark the premature end of the interglacial climatic optimum in southern Europe and off Iberia. In addition, these events appear coeval with the abrupt declines in methane concentrations recorded in Vostok ice core, indicating evidence of a global modification in climate conditions (Tzedakis et al., 2004b). Tzedakis et al. (2004b) introduced the challenging idea that duration of interglacial periods may be dictated by millennial-scale variability. The new records presented here suggest, however, that suborbital variability would determine the duration

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of the climate optimum of the interglacial period. The observed marine and terrestrial cooling trend following the interglacial climatic optimum is generally considered as a response to the orbital forcing and associated feedback mechanisms, further initiating the glacial inception (Crucifix and Loutre, 2002; Kageyama et al., 2004). We can wonder to which extent the millennial-scale climatic variability and the astronomical forcing played each a role in the duration of the interglacial climatic optimum, the interglacial demise and, further the glacial inception."

- p.392, l.18: This referee questions about the inferences made on the muted millennial variability during the forest stages of MIS 7 in comparison with Sanxenxo. The main point of this section is to show that large amplitude suborbital events (more particularly cooling) are more frequent during Sanxenxo than during forested stages of other climatic cycles. Indeed, the SW Iberian pollen record shows variability during the Cascais forest stage (related to MIS 7c) but the millennial forest reductions are actually of smaller degree than during Queluz. And as the alkenone SST does not present cold events during the whole MIS 7c interval, it is possible that the forest oscillations are mainly the response to change in moisture availability and at the most to weak cooling events. We have, however, added "or at least the smaller magnitude of the forest changes in SW Iberia".

- p.394, l.1 to 8: This referee says: "The contrast between minor continental ice accumulation, minor offshore cooling, and major forest contraction (suggesting major cooling/drying on land) requires a clearer explanation. Why is the offshore SST change so minor in comparison with the extent of forest collapse?" We have added the following paragraph in section 5.2.2 to discuss this question: "Surprisingly, during the 3NWI-fr1 event within MIS 9e, the SW Iberian pollen record displays a pronounced decline of the tree populations in favour of Compositae Liguliflorae and steppe plants. According to Roucoux et al. (2006), this vegetation change would indicate pronounced cooling and aridification in SW Iberia. However, the temperature and the precipitation change cannot be easily deciphered from the SW Iberian pollen record. In the light of the northernmost pollen records (MD03-2697 and Praclaux) showing both a weak forest reduction, and in the lack of SST reversal off Iberia, a weak cooling at the most appears likely but it cannot account for the SW Iberian forest collapse. Taking into account that aridity is one major limiting factor for tree growth in the Mediterranean region, a weak cooling associated with strong moisture deficiency in winter seems a more parsimonious explanation for the vegetation change observed in this region."

- p.394, l.15: She/He says "Bottom water temperatures could indeed affect benthic d18O at the Iberian margin, but the ice volume component remains an important part of the signal. It is mainly the timing of changes (especially at deglaciations) that are affected by deep water temperature changes". Indeed, ice volume component remains an important part of the benthic d18O signal and the long-term trend of ice volume changes is well represented by this benthic proxy (Skinner and Shackleton, 2006). However, it is widely acknowledged that changes in deep-water temperature and local or regional hydrography can strongly influence the foraminiferal benthic d18O signal, in particular during terminations (timing of changes) but also in association with millennial scale variability of the last glacial period (Shackleton, 2000; Waelbroeck et al., 2002, Skinner and Shackleton, 2006; Skinner et al., 2003). For example, Shackleton et al. (2000) showed that the reconstructed component of foraminiferal d18O attributable to changes in Pacific deep-water temperature can reach 1 per mil and they stated that "The benthic marine d18O record is heavily contaminated by the effect of deep-water temperature variability". So far, no study is available providing a constraint of the non-glacioeustatic component of the benthic d18O signal at the Iberian margin during MIS 9. Therefore, we explain in the manuscript that the foraminiferal benthic d18O variability observed in the Iberian records, could not always accurately represent ice volume variations. It is why we discussed the sea-level reconstructions in addition to the Iberian benthic d18O curves.

- p.392, l.28: This referee states "When you say that MIS 9 shows variability of particularly high amplitude, which other interval(s) are you comparing it to, and which parameters show this pattern?" This assertion is clearly and directly linked to the previous paragraph showing that the interval from MIS 9d to 9b, including the forest stage Sanxenxo, presents particular recurrent high amplitude variability in the pollen and SST records in comparison with other interglacial periods.

- p.394, l.26-27: According to this reviewer, two points here are not clear: "when ice sheets were reorganizing" and "reached a significant size". She/He askeds "What does re-organizing mean, in terms of ice sheets? What size is significant size; are you able to put a number on that (e.g. 3.5 per mil)?" We have specified more clearly: "when ice sheets were decaying and in particular when they were building up and reached a significant size (c.f. 3.5 per mil threshold)".

- p.395, l.5 and onwards: Finally, this referee suggests including justification for the comparison of MIS 3 and 9b. We have added the following paragraph: "Identifying intervals which display similar rapid climatic changes even though boundary conditions are divergent, is a helpful approach to decipher the potential mechanisms controlling the amplitude and frequency of the millennial-scale variability. The last glacial period is well-known for its millennial-scale dramatic climatic oscillations which have been first identified in the temperature records of Greenland ice cores (Dansgaard et al., 1993; Grootes et al., 1993) and later on in numerous marine or continental paleoclimate records (Bond et al., 1993; Bond and Lotti, 1995; Grimm et al., 2006; Allen et al., 1999; Sanchez Goñi et al., 2000). Recently, Siddall et al. (2007) have shown that millennial-scale variability is strikingly similar during the ˜290-310 kyr MIS 9 interval (designated as MIS 8.6 section in Siddall's paper) and the ˜ 30-55 kyr MIS 3 interval. The frequency (in terms of "Bond cycles") and amplitude of the millennial changes from both intervals parallel according to a comparison between MIS 3 and MIS 9 deuterium and methane profiles from Vostok ice core as well as between the MIS 9 model-estimated Greenland temperatures and GISP d18O (Siddall et al.; 2007). However, the putative similarity between the MIS 3 and MIS 9 millennial variabilities in the Northern Hemisphere needs to be tested using actual high-resolution paleorecords such as those of the Iberian margin which offer vegetation and SST records for both time periods."

4- REFEREE B. MARTRAT.

The referee's specific comments 1 & 3 were answered in the first section of the response, as shared with the other reviewers.

Specific comments 2) A precise, transparent description of every event is needed.

A) Comment S219-221: To clarify which event is referring to, use the MD03-2697 pollen zones.

As requested by the referee, we have changed the notation of the events detected by the NW Iberian pollen record to avoid using inappropriately the nomenclature determined by Martrat et al. (2007) from the MD01-2443 Uk 37-SST profile. This referee suggested that we use the pollen zone names to label the forest reduction events. However, as we have explained in the manuscript, this is not achievable because a forest reduction event identified on the basis of a decrease in the pollen percentages of the temperate a humid forest, does not always correspond to a distinct pollen zone. Actually, a change in the pollen assemblages can be no strong or long enough to unambiguously define a new pollen zone and then infer a vegetation formation shift. For example, there is a clear forest reduction event at ˜3225 cm (cf. Fig.2, 3NWI-fr9) which is marked by AP-Pinus and oak percentage minima (a 10 to 15% decrease in comparison with the previous peak at 3040 cm), although the inferred vegetation formation remains "Open temperate and humid forest with heathland" on the whole pollen zone MD97-12 (3045-3020 cm, cf. Fig.2, Table 1). Therefore, in the revised version, we have defined and named the millennial events corresponding to forest reductions as 3NWI-fr plus number (North Western Iberian forest reduction during the third climatic cycle) and proposed a correlation with the Iberian margin stadials from the SST record (Table 1 and discussion). In this way, the new events detected by the NW Iberian pollen record which were not identified in the SST profile by Martrat et al. (2007) are not named IMS-15a, 13a and 8a anymore but 3NWI-fr 1, 4 and 10. In addition, as recommended by B.

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Martrat, we have modified the text to avoid using ages to refer to a specific event. We acknowledge that with the arrow representation the boundary of the millennial events are not fully constrained but the resolution of our pollen analysis is not sufficient to do so.

We have made changes to avoid using expression such as "MIS 9e forest period" which according to the referee could lead confusion on the different timing of forest and isotopic stages. Although we stated clearly in the submitted version that Tzedakis et al. (2004b) showed the asynchrony of the forest period and isotopic substage boundaries during MIS 9 in the MD01-2443, we have added some inferences about the leads and lags between the boundaries of NW Iberian forest stages and the isotopic substages displayed by our land-sea correlation.

We have changed the name "Sanxenxo-B" to "Sanxenxo-C" as it was defined in Desprat et al. (2007). Further, there are other differences between Desprat et al. (2007) and this present manuscript mainly because, the MIS 9 record was a composite record from cores MD03-2697 (covering MIS9e to 9c) and MD01-2447 (from MIS 9b to 8), as clearly explained in Desprat et al. (2007), while in this manuscript we present the pollen analysis from core MD03-2697 covering the whole interval. In addition, the new record has a time-resolution twice more important than the previous composite one, which allowed us to give a much more detailed description of the vegetation variability in NW Iberia during MIS 9. This is why the number and nomenclature of the pollen zones described in the current paper were different to those of Desprat et al. (2007) and why we were able to define millennial vegetation changes not identified before.

B) Comment S222-S224: To clarify the comparisons and the structure of the discussion.

B. Martrat recommended using the MD03-2697 pollen analysis as the basic reference in the comparisons with the marine proxies in the same MD03-2697 strata or with the indicators from cores ODP site 980, MD01-2443 or EPICA-Dome C and to describe

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and discuss the events as time progressive in respecting the proper nomenclatures. We have applied these suggestions to each comparison made in the discussion.

As requested by the referee, we have detailed the outline of the manuscript in order to clarify the discussion (as presented in section 1 of this response to referee's comments). This allowed us to make clearer the thread of arguments and conclusions. Even though we did not use the subheading proposed by B. Martrat, our outline broadly corresponds to what she proposed.

In addition, the reviewer recommends modifications or points to discuss in each section:

- We have split the results and interpretation section as she has proposed (1/ Forest intervals; 2/ Open vegetation intervals).

- As suggested by the referee, we have added comments on moisture availability changes in NW Iberia from the pollen record all along the text and in particular the following paragraph in section 4 "Results and interpretation": "Afforestation in NW Iberia generally began with Betula (birch), and deciduous Quercus (oak) followed by Alnus (alder), Corylus (hazel), Carpinus betulus (hornbeam), Fagus (beech), Taxus (yew) or Pinus (pine). These trees are the dominant components of the temperate and humid forests established in Europe during the current interglacial. These forests are developing in the temperate regions where the moisture availability is not restricted. In NW Iberia, colder climatic conditions influence the vegetation cover by promoting forest opening. In our pollen record, increase of Ericaceae (heath) or dry-grassland taxa (mainly Poaceae, Taraxacum-type and semi-desert plants such as Artemisia, Ephedra distachya-type, Ephedra fragilis-type and Chenopodiaceae) at the expense of the tree taxa, characterizes the vegetation response to cold and cool events. More particularly, lower value of deciduous oak with heathland expansion suggests a cool and moist climate while the dominance of dry-grassland indicates cold and drier climate."

- In the first section of the discussion, the referee recommends to clearly explain how we define from the pollen record the climatic optimum and the degree of warming of each forest stages in NW Iberia. In the revised version of the manuscript, we have specified that the climatic optimum correspond to the warmest interval (highest winter and summer temperatures) within a warm period and we have modified the section p.385 as following: "The relative degree of climatic amelioration between these periods can be inferred from the forest character and extent, in particular according to the expansion of deciduous oak forest and Mediterranean plants. As the development of deciduous oak and Mediterranean plants reaches a maximum extent during Pontevedra, this forest stage does represent the warmest period of MIS 9 in NW Iberia. In particular the warmest conditions are reached during a 2 kyr-long interval (~333-331 ka) corresponding to the climatic condition optimum. Because of a moderate deciduous forest expansion, Sanxenxo appears as a period of intermediate climatic amelioration between the forest stages Pontevedra and Bueu occurring during MIS 9e and MIS 9a, respectively. As mentioned earlier, although Bueu period presents a striking prominent expansion of deciduous trees as large as Pontevedra, the virtual absence of most of the Mediterranean taxa during the maximal expansion of deciduous oak and the large development of Fagus and Carpinus, indicate that Bueu climatic amelioration is weaker than that of Pontevedra."

- She also recommends to label all warm pollen zones as interstadials (e.g. MD97-I1, MD97-I2, MD97-I3), and then discuss whether, due to their intensity, duration or particular taxa, some interstadials could be considered as interglacials. We have taken into account this comment in adding in the manuscript inferences to interglacial or interstadial for defining the forested periods. However, the terms interstadial and interglacial which have been defined by Jenssen and Milters in 1928 (almost half a century before the paper Mangerud et al., 1974 cited by B. Martrat) identify particular types of non-glacial climatic conditions in temperate northwestern Europe as indicated by vegetational changes. The difference between an interglacial and an interstadial is strictly based on the completeness of the sequential tree succession marking the development of temperate deciduous forest in NW Europe (Jenssen and Milters, 1928).

Indeed, an interstadial is defined as a period which was either too short or too cold to permit the development of temperate deciduous of the interglacial type in the region concerned (West, 1978). Therefore, based on these definitions, Pontevedra, Sanxenxo and Bueu intervals can be defined as interglacials in NW Iberia because of the observed long-term completeness of the sequential tree succession and the large temperate and humid forest expansion. In contrast, during the following MIS 8 period the interval corresponding to pollen zone MD97-16 shows the increase of deciduous Quercus and Betula indicating a minor warm and wet event that we define as an interstadial. However, after these vegetation-based definitions, a forest stage can be defined as interglacial in NW Iberia but interstadial in NW Europe if the vegetation is not complete in this northern region. Consequently, as the three major forested periods in NW Iberia during MIS 9 are all defined as interglacial, this does not allow us to determine the relative degree of warming of each period which is the purpose of the first discussion section. It is why we did not discuss in great detail this interglacial/interstadial topic in the manuscript.

- We have clarified the comparison of the Iberian direct land-sea correlations in section "5.2- MIS 9 millennial-scale climatic variability in the Iberian region". This section includes now: *a first part in which we clearly present the correlation of events between the NW Iberian pollen sequence and the SW Iberian pollen and SST record *a second part with the discussion about the magnitude of the climatic changes inferred from the different events recorded by the Iberian records and a categorization of the events from severe to weak as suggested by B. Martrat. We also clarified how we made this categorization.

- And finally, we have corrected the typing error 'summer' from p. 386, l.17-18 and p.388, l.19-22.

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