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Interactive Comment

Interactive comment on "Climate warming and vegetation response at the end of Heinrich event 1 (16 700–16 000 cal yr BP) in Europe south of the Alps" *by* S. Samartin et al.

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Referee 2

General remark: Samartin et al. present a good and well written paper. The main question (clearly) addressed in this paper is the link between the early afforestation south of the Alps, and a climate warming that possibly occurred 1500 years before the onset of the Bolling. Samartin et al. used a powerful approach: the reconstruction of summer temperature independently of pollen from the Lake Origlio subfossil chironomid record. Temperatures were inferred using an expanded transfer function recently developed by Heiri et al. (2012). The temperature reconstruction inferred from the chironomid record unambiguously showed a climate warming of nearly 2-2.5 °C at ca 16 000 cal BP. As concluded by Samartin et al., this would suggest that the early afforestation south ofthe Alps is climatically driven. From these results obtained at Origlio, Samartin et al. ïňĄnally discussed the pattern of the Late Glacial climate change over Europe and theMediterranean realm. I am conïňĄdent with the results produced in this study. I agree with what is said in the discussion and conclusion. That why I recommend this paper for publication in CPD. Nevertheless, I would recommend moderate changes before deïňĄnitive publication, especially in the Discussion section. As stated by the authors, this study provides the ïňĄrst evidence for an early warming occurring at ca 16 000 cal BP south of the Alps. A similar warming was also found from continental archives in South-West France, Turkey and Israel. Therefore, the results presented by Samartin et al. are of great importance for the understanding of climate and vegetation history in Europe. Given this importance, I think the reliability of the temperature reconstruction is not sufïňĄciently assessed in the present form of the paper. The author should add a sub-section dealing with this issue (the reliability of the temperature reconstruction) in the Discussion section.

Response to general remark: The referee indicates that the reliability of the temperature reconstruction has not been sufficiently assessed in the present form of the paper and that a subsection dealing with this issue should be added. We are convinced that the reconstruction has been adequately evaluated in this article (see section 3.5 "Evaluation of the inferred temperatures" as well as section 4.2 "Reconstructed temperatures"), and that most relevant points have been addressed in the manuscript. Please find our detailed comments regarding the reliability of the reconstruction below.

Remark 1: The early warming corresponded to the Biozone ORE-2. This key biozone is composed of only 6 samples (with one sample with counts less than 50 head-capsules). Furthermore, samples were not taken contiguously along the core (?). According to what is said in the "coring and sediments "sub-section, I suppose that samples were 1 or 2 cm thick (see speciïňĄccomments). ORE-2 is 33 cm thick. In other words, only ca 40 % of the sediment were analyzed (6samples*2cm)/33cm). Is this sampling design well suited to provide representative material (and data) for the whole unit?

Response 1: We thank the reviewer for the very careful review. Her or his criticism is partly correct, unfortunately due to the multiproxy nature of our study, we only had parts of the sediment available along the whole core and especially in zone ORE-2. This is the main reason why we only analyzed 6 samples and why some of them were not taken continuously. Nevertheless we think that these samples provide representative data points for the whole zone ORE-2. Furthermore, it is apparent that our sampling strategy has managed to capture major faunistic patterns in this section of the record: Zone ORE-2 is clearly identified as a period of relatively low taxonomic turnover by the applied numerical zonation techniques. Furthermore, the major changes in DCA axis 1 scores just preceding ORE-2 (Figure 4a) indicate that the period of largest variations in chironomid assemblages happened before the beginning of this zone. Independently, pollen and plant macrofossil data from lowland sites in Southern Switzerland and Northern Italy provide evidence that temperatures must have been significantly higher than during the previous zone ORE-1 (forested vs. unforested steppic tundra environments). The two lines of evidence are in excellent agreement, average temperatures were 11.6°C in zone ORE-2, which is considered to be sufficient to allow forest growth, whereas in zone ORE-1 temperatures were on average 10°C, which usually limits forest growth (Lang, 1994).

Lang, G.: Quartäre Vegetationsgeschichte Europas: Methoden und Ergebnisse, G. Fischer, Jena, 462 pp., 1994.

Remark 2: In the sub-section “Interpretation of faunal trend”, the authors discussed the main changes in chironomid assemblages and their possible forcing factors. In their discussion (biozone by biozone), the authors identiïňĄed several possible forcing factors according to the ecology of taxa: lake-level (profundal versus littoral taxa), température (cold versus warm-adapted taxa) and trophic level (oligotrophic versus mesotrophic taxa). The remaining questions which are not addressed in the discussion are: Is temperature the main forcing factor of changes in chironomid assemblages ? This is the pre-requesite for a relevant temperature reconstruction. What about the possible inïňĆuence of possible confounding factors? Is there a risk for biases induced when inferring temperature from Origlio chironomid ? Could the disappearance of profundal taxa (with cold optima) and the appearance of littoral taxa (with warm optima) characterizing ORE-2 be explained at least in part by a lake lowering? Please note that in a previous study of record from Lake Accesa (Tuscany, Italy,Magny et al. 2006) evidenced a strong lake lowering before the onset of the Bolling. It was the main driving factor of the chironomid assemblages (Millet et al. 2007).

Response 2: In the subsection 4.1 “Interpretation of faunal trends” we discuss main changes in chironomid assemblages and possible influencing environmental factors. Chironomid assemblages changed from cold-adapted profundal taxa (in ORE-1, low temperature) such as for instance Stictochironomus rosenschoeldi-type, Paracladius and Heterotrissocladius grimshawi-type to warm-adapted littoral taxa (in ORE-2, high temperature optima) such as for instance Dicrotendipes nervosus-type, Pseudochironomus and Tanytarsus pallidicornis-type 2. Profundal cold-adapted taxa, for example Micropsectra insignilobus-type, Tanytarsus lugens-type and Chironomus anthracinus-type, are still present in zone ORE-2, they do not completely disappear. We therefore assume that warm-adapted littoral chironomids were not responding to lake-level changes but to increasing temperatures. Furthermore, warm-adapted chironomids have high temperature optima in both the Swiss and Norwegian training set and cold-adapted chironomids have low temperature optima in both training sets. We further discuss the role of oxygen in the distribution of chironomids. Chironomus anthracinus-type for instance, a taxon tolerant of low oxygen concentration, is often abundant in the profundal of deep stratified lakes. Enhanced lake stratification is possibly a result of warmer climatic conditions, as pointed out in the manuscript. Oxygen and trophic status might have slightly influenced our reconstruction, but the bias induced by these factors is part of the prediction error of the reconstruction (sample-specific error of prediction ± 1.5°C). The trainingset used to estimate the prediction error of the transfer function includes lakes with a wide range of oxygen and nutrient conditions and both shallow, unstratified, as well as stratified lake ecosystems. Variations in chironomid-inferred temperatures well exceed the sample specific errors for the reconstruction (Fig. 6) and, therefore, temperature changes can be expected to have been one of the major drivers of variations in chironomid assemblages across the time window of interest.

Remark 3: In their presentation of the vegetation history (p1619), author stated "This vegetational change stabilized the soils and the shift from sandy silt to silty gyttja shows that the erosional input into the lake signiïňĄcantly reduced". The change in vegetation cover at ca 16000 cal BP induced a change in lake sediment (erosional input and probably OM type and amount). Can these changes in the watershed and induced changes in the lake sediment be a cause for chironomid changes independently of climate? OM analysis would be helpful: Are these data available?

Response 3: This shift of sediment and vegetation occurred long before the period of interest. The sediment composition changed at the following positions: change from sandy silt to silty gyttja at around 18,000 cal yr BP (not in diagram), from silty gyttja to slightly silty gyttja at around 14,900 cal yr BP (1338 cm) and from slightly silty gyttja to gyttja at 13,600 cal yr BP (1318 cm). Between 16,000-14,900 cal yr BP, when warm-adapted chironomid taxa started to increase and early Late Glacial forests expanded south of the Alps, no change in sediment composition has been recorded at Origlio. Unfortunately no "Loss-on-ignition" data are available from Origlio, so we do not know if subtle changes in organic matter content occurred between 16,000-14,900 cal yr BP. Nevertheless, it seems that chironomid assemblages did not strongly respond to changes in sediment composition at 14,900 cal yr BP and 13,600 cal yr BP suggesting that they were mainly controlled by temperature. Additionally, changes in DCA axis 1 do fit changes in temperature giving further evidence that chironomids were primarily responding to temperature and not to changes in sediment composition.

Remark 4: In the “results” section, Samartin et al. presented in a sub-section “Evaluation of the inferred temperatures” a detailed description of the reconstruction diagnostics. What do these results tell us about the reconstruction? Are there some speciïňĄc parts of the record where we must be less conïňĄdent with the reconstruction? This issue is brieïňĆy discussed p1630, line 3: “However, a disagreement of ca 3_C is within the method inherent reconstruction error (+ 1.5-1.6_C SSPE)”). 2.5_C was also the amplitude of the shift in temperature between ORE-1 and ORE-2 which is the key result of the paper and also stays “within the method inherent reconstruction error”. Is the change in reconstructed temperature between ORE-1 and ORE-2 really signiïňĄcant?

Response 4: The reliability of our inferred temperatures is briefly discussed in section 3.5 “Evaluation of the inferred temperatures” and further discussed in the section 4.2 “Reconstructed temperatures”. The presented reconstruction diagnostics (modern analogues, residual distances to CCA axis 1, number of rare and absent) are conventionally shown together with chironomid-based temperature reconstructions in order to allow the reader an assessment of whether the calibration data include assemblages resembling chironomid samples in the downcore record, and whether samples exist with a large proportion of rare taxa or taxa which do not occur in the training set. For the Origlio record, our analyses indicate a similar analogue situation as apparent for other late Pleistocene chironomid records (e.g. Heiri et al., 2007; Ilyashuk et al., 2009; Samartin et al., 2012). Some individual samples are characterized by assemblages with no close analogues or a poor fit with temperature. However, there are samples in all the zones and all climatic periods we discuss with close analogues and samples with acceptable goodness-of-fit statistics. As we indicate in the manuscript the lowermost samples of the Origlio chironomid record (age > ca. 16,300 cal yr BP) contain a relatively high amount of rare taxa. However, all the major climatic transitions in the record are covered by chironomid assemblages that are dominated by taxa that are well represented in the applied transfer function. Since the diagnostic statistics do not indicate that the Origlio record is more problematic than other Lateglacial temperature reconstructions published to date, we refrain from discussing them in more detail. How-

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ever, we do write in the manuscript text that the lowermost samples are dominated by a taxon rare in the calibration data.

In respect to the question of whether the temperature rise between ORE-1 and ORE-2 is significant: As described in the manuscript, our conclusion that the temperature shift is relevant is based on several lines of evidence: (1) Although the temperature shift at ca. 16,000 cal yr BP does not exceed two estimated standard errors of prediction it is still large in the context of the prediction error. With ca. 2-3 °C it is equivalent to ca. 133 to 200 % of the standard error. (2) Our statistical analyses show that the shift in chironomid assemblages towards warmer conditions (boundary ORE-1 to ORE-2) is statistically significant if assessed using the broken-stick approach (Bennett, 1996). (3) On the basis of the multiproxy record from Origlio and other sites elsewhere in Southern Switzerland and Northern Italy we are certain that this climatic shift was of paramount importance for the ecosystems, since it coincided with a wide-scale change from steppe-tundra to boreal forests (within a range of > 500 km, see Vescovi et al. 2007). The evidence of afforestation at ca. 16,700-16,000 cal yr BP includes well-dated high-resolution macrofossil series and is thus unambiguous. We believe this evidence clearly indicates that a major temperature shift affected terrestrial ecosystems in the southern Alpine forelands ca. 16,700-16,000 cal yr BP.

Bennett, K. D.: Determination of the Number of Zones in a Biostratigraphical Sequence, New Phytologist, 132, 155-170, 1996. Heiri, O., Cremer, H., Engels, S., Hoek, W. Z., Peeters, W., Lotter, A. F.: Lateglacial summer temperatures in the Northwest European lowlands: a chironomid record from Hijkermeer, the Netherlands, Quaternary Science Reviews, 26, 2420-2437, 2007. Ilyashuk, B., Gobet, E., Heiri, O., Lotter, A. F., van Leeuwen, J. F. N., van der Knaap, W. O., Ilyashuk, E., Oberli, F., Ammann, B.: Lateglacial environmental and climatic changes at the Maloja Pass, Central Swiss Alps, as recorded by chironomids and pollen, Quaternary Science Reviews, 28, 1340-1353, 2009. Samartin, S., Heiri, O., Vescovi, E., Brooks, S. J., Tinner, W.: Lateglacial and early Holocene summer temperatures in the southern Swiss Alps reconstructed using

fossil chironomids. Journal of Quaternary Science, 27, 279-289, 2012.

Remark 5: The reliability of the temperature reconstruction derived from the Origlio chironomid record is supported by the good concordance with d13C record from Southwest of France (and Turkey). Nevertheless, a temperature reconstruction derived from chironomid record of a lake in the Western Pyrenees (Ech paleolake) has been recently published (Millet et al. 2012). This record covered the last ca 18 000 years. There is no trace of such an early warning in this temperature reconstruction. This is in apparent discrepancy with the speleothem record from south-west France (Genty et al 2006). Genty et al. favour the biogenic control for the observed calcite d13C variations (changes in the soil (microbial activity) and vegetation (plant root respiration) above the cave). The d13C variations are indirectly related to changes in climate. Other climate parameters than summer temperature may be involved in the d13C variation in speleotherm (seasonality, moisture . . .).

Response 5: The chironomid-inferred temperature reconstruction from Ech paleolake in the West-Central Pyrenees (710 m a.s.l., Millet et al., 2012) is very interesting. However, as the reviewer correctly states, it lacks any chironomid-based evidence of warming prior to the onset of the Bølling/Allerød interstadial. The Ech pollen record however shows a significant expansion of Juniperus (probably shrublands or open forests) at ca. 17,000-16,500 cal yr BP, which coincided with a marked and abrupt increase of organic material in the sediment (LOI increase 550 °C). These changes may point to a local environmental response to early warming at ca. 16700-16000 cal yr BP that was perhaps too small to influence the chironomid record. Alternatively, it may be possible that climatic parameters other than summer temperature are responsible for this change in organic matter deposition and preservation and in the regional vegetation at Ech. Today Ech is significantly cooler than Origlio (17 vs. 21 °C July means) and it is likely that this climatic difference also occurred during the Late Glacial. Indeed Ech is located 300 m higher than Origlio and, together with its location north of the Pyrenees (while Origlio is situated in the Mediterranean Sea catchment south of the Alps), this difference fully explains why Ech could have had cooler conditions throughout the past 20,000 years. It also explains why Ech could have been more exposed to North-Atlantic influences (see remark to reviewer 3) than Origlio in the Adriatic Sea catchment. On the basis of this reasoning we assume that ecologically Ech is comparable to sites at >800 m in the Southern Alps. These locations were afforested only during the Bølling/Allerød interstadial (Vescovi et al. 2007).

Millet, L., Rius, D., Galop, D., Heiri, O., and Brooks, S. J.: Chironomid-based reconstruction of Lateglacial summer temperatures from the Ech palaeolake record (French western Pyrenees), Palaeogeography, Palaeoclimatology, Palaeoecology, 315–316, 86–99, 2012. Vescovi, E., Ravazzi, C., Arpenti, E., Finsinger, W., Pini, R., Valsecchi, V., Wick, L., Ammann, B., and Tinner, W.: Interactions between climate and vegetation during the Lateglacial period as recorded by lake and mire sediment archives in Northern Italy and Southern Switzerland, Quaternary Science Reviews, 26, 1650–1669, 2007.

Minor remark 1: It would be useful to have more basic information about the sediment sampling: what was the thickness of the samples? Were they taken contiguously?

Response to minor remark 1: We tried to take the samples continuously but it was not always possible due to the lack of sediment. The sample slices were 1 cm thick (included into section 2.4 "Sampling and analysis of fossil chironomids")

Minor remark 2: It should be better to estimate the average 95% coniňĄdence interval of the calibrated ages taking into account the density of radiocarbon dates and the distribution of dated levels (e.g. by using CLAM).

Response to minor remark 2: Because this is a follow-up study, we strongly prefer to use the same age-depth model which has been previously used and published in Tinner et al. (1999) and Vescovi et al. (2007). This also facilitates chronological correlations between the vegetation history records elsewhere (e.g. Vescovi et al., 2007) and the new chironomid record of Origlio. However, this age-model has been adjusted by re-calibration to take into account the new calibration curve (calib 6.0) and we provide the two sigma confidence intervals of the calibrated ages.

Tinner, W., Hubschmid, P., Wehrli, M., Ammann, B., and Conedera, M.: Long-Term Forest Fire Ecology and Dynamics in Southern Switzerland, Journal of Ecology, 87, 273–289, 1999. Vescovi, E., Ravazzi, C., Arpenti, E., Finsinger, W., Pini, R., Valsecchi, V., Wick, L., Ammann, B., and Tinner, W.: Interactions between climate and vegetation during the Lateglacial period as recorded by lake and mire sediment archives in Northern Italy and Southern Switzerland, Quaternary Science Reviews, 26, 1650–1669, 2007.

Minor remark 3: p1626, line 8: I suppose the right sentence is “In many of the YD (ORE-4) and early Holocene (ORE-5) samples.

Response to minor remark 3: We changed the sentence accordingly.

Interactive comment on Clim. Past Discuss., 8, 1615, 2012.