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Interactive Comment

Interactive comment on "Holocene weak summer East Asian monsoon intervals in subtropical Taiwan and their global synchronicity" *by* K. Selvaraj et al.

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Referee 1

The manuscript attempts to address an important paleoclimate question related to Holocene East Asian monsoon and its global teleconnections using a lake record from Retreat Lake in Taiwan. However, there are several major problems with the manuscript, including the inadequate proxy interpretations and unsupported conclusions, and potential duplicated publication. Here I just list some of these concerns.

Question 1: Proxy interpretations - The authors claim that TOC and C/N ratios from lake sediments can be used as a proxy of EAM intensity; but provide no adequate explanations and evidence in this manuscript and in the previous paper (Selvaraj et al., 2007) on the same data set. In this manuscript, the authors indicate that "The content of TOC and C/N ratio in lacustrine sediments are valuable indicators of monsoon changes because climate, nature of lake catchments vegetation (C3 versus C4), and lake morphology largely control these parameters" (e.g. Meyers and Lallier-Verges, 1999). Since the lake is situated directly on the moisture-carrying southeasterly down-winds of EAM from the WTP, higher contents of TOC and C/N ratio are indicative of vascular plants dominance and, in turn, strong summer monsoon (Selvaraj et al., 2007) (page 933, lines 10-16). In the Selvaraj et al. (2007) paper, a similar simplistic statement was made "High TOC value and C/N ratio, and associated higher negative carbon isotope (δ^{13}C) values, for example, are interpreted to reflect vascular plant (C3) dominance due to increased monsoon precipitation during periods of warm/wet climate". "Why TOC and C/N ratios would indicate EAM change? Are there C4 plants in the catchment? Any reference? Why any contributions of C4 plants to lake organic matter or TOC would result in carbon isotope values from about -31 to -27 per mil from the same core as presented in Fig. 1 of Selvaraj et al. (2007)? Could high TOC and high C/N ratio reflect more inwash of terrestrial organic matter into the lake during heavy storms that may be associated with stronger monsoon? If so, then why didn't the lake produce its own organic matter within the lake in a subtropical setting? I don't think that the authors made their case in their proxy interpretations based on modern-process studies or on sound ecology and geochemistry.

Total organic carbon (TOC) is considered as an indicator of ameliorating environment and directly proportional to the lake's organic input because TOC depends primarily on catchment's vegetation. Lake sediment's carbon : nitrogen (C:N) ratio and δ^{13}C values also help to identify the sources of sedimentary organic matter (e.g., Meyers and Lallier-Verges, 1999; Routh et al., 2004). Atomic C/N ratios of >20, for example, indicate vascular plant contribution whereas lower C/N ratios (<20) indicate a mixture of cellulose-free (algal and C3 plant) organic matter sources. Based on these ideas, the late Holocene paleoclimate changes have been discussed in Taiwan where the TOC content and C/N ratio were utilized as crucial proxies (Lou and Chen, 1997, Lou

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et al., 1997). Similarly, TOC proved to be very effective proxy to reconstruct Holocene summer monsoon strength even in dry Dali Nor area, Inner Mongolia, China (Wang et al., 2004). It also indicated the sharp hydrological changes in southern China where this proxy revealed the Holocene monsoonal fluctuations in a swampy set-up (Zhou et al., 2004). The TOC content and C/N ratio are thus indicative of past environmental changes in humid and arid parts of China which in turn reflect the changes in the amount of precipitation and vegetation; thereby, characterize the East Asian monsoon strength in Taiwan and China.

Alpine and subalpine regions of Taiwan predominantly consist of C3 plants. Therefore, in the present as well as our previous studies, we interpret the sediment TOC content as an indicator of C3 organic matter. The following three points can explain why TOC content and C/N ratio would indicate EAM change in Taiwan:

(1) Analysis of wood materials found 110 cm of the studied core show C/N ratios of up to 75 and most of the values are above 40. C4 plants can not produce such high C/N ratios and can synthesize an organic matter with δ^{13}C values that range from -10 to -15 per mil. Our results rather show extremely depleted δ^{13}C values similar to -26 to -32 per mil and enriched values are associated with minerogenic sediments of early Holocene. These values strongly support the dominant organic input from C3 plant sources.

(2) As part of source materials investigation, a number of plant debris collected from the lake water column in NE Taiwan show a range of δ^{13}C from -26 to -29 per mil with high content of TOC between 25 and 46

(3) A recent study from NE Taiwan indicates the dominance of C3 plant trees, including *Scheffera octophylla, Machilus thunbergii, Litsea acuminata* and *Oreocnide pedunculata* (Huang et al., 2007). They found C4 grasses, such as *Miscanthus floridulus* and *Setaria viridis*, mainly along the stream bank but grasses cover relatively a small area. Their data further show that among vascular plants, C3 plants were depleted in ^{13}C

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(-30.6per mil) and C4 plants were highly ^{13}C enriched (-12.4 per mil). Isotopic values of coarse particulate organic matter also depleted in δ^{13}C (averaged -30.3 per mil) and this value is consistent from those of fresh leaves collected from riparian C3 plants and thus indicating that the particulate organic matter was mainly derived from terrestrial C3 plants.

Based on these results, we can say that nothing is wrong in the proxy interpretations as doubted by the reviewer.

Question 2: Dating and chronology - It is difficult to evaluate and understand the dating and chronology of the core without seeing and discussing sediment lithology. The two dates/ages of 8599 and 8640 cal yr BP are identical statistically. As such, the derived chronology of about 20-30 cm sediment deposition within apparently 41 years is unjustified. Why the lake has such a rapid sediment accumulation rate? Could this be simply a single event caused by a landslide or underwater slope failure? Without presenting and discussing lithology, it is very difficult to evaluate this. Therefore, the rapidity around 8600 cal yr BP as claimed by the authors could just be a dating artifact and not a real pattern. Also, how deep is the lake in causing the desiccation and hiatus at 4-2 ka? I don't find such information from both papers. Did I miss anything?

Actually, it is a rapid accumulation of organic matter and nothing to do with underwater slope failure or landslide because the latter mechanisms can produce minerogenic sediments. Almost all parameters studied in this core, including magnetic susceptibility, show a rapid transition from low to high values and/or vice versa within the duration of around 40 years. Such a change is consistent with the onset of Holocene optimum climate in Taiwan and China.

We also included the following details of sediment lithology and chronology of core R appropriately in the revised version:

Retreat Lake is located in remote, subalpine region of NE Taiwan. Because of its high altitude (2230 m), we assume that sedimentation into the lake is entirely from moun-

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tains (60 m above the lake), comprising slate, argillite and phyllite rocks of Tertiary age, that surrounding the lake. The lower 15 cm (170-155 cm) of the gravity core consists of fine-grained, light-colored (white), minerogenic, organic-poor sediments that reflects the sedimentation into a lower lake water level during the early Holocene (Figure 2, panel a in the revised manuscript). The transition to overlying darker (black), organic-rich, peaty sediments was very abrupt 155-130 cm, implying that the water level during that period was likely increased due to Holocene optimum inception of summer EAM, which enhances the growth of terrestrial vegetation in the surrounding mountains. This is confirmed by the dramatic increase of TOC content and C/N ratio, and persisting high until the late Holocene onset at

ca. 4.5 kyr BP. This long, high precipitation event of Holocene optimum represented by peaty sedimentation between 155 and 38 cm (8.6-4.5 kyr BP) was interrupted by the deposition of wood materials from ca. 115 to 108 cm, perhaps due either to a short period of decreased monsoon or an effect of strong typhoon, which in general responsible for up-rooting trees in the subalpine region. Sedimentation of lighter (less whiter than the sediments of early Holocene), minerogenic, organic-poor sediments from the underlying organic-rich, darker portion was resumed ca. 4.5 kyr BP and this top 38 cm of sediment comprises most of the properties, except higher TOC (likely reason for less white), that are very similar to the sediments deposited during the early Holocene.

The abrupt sedimentation changes at two depth intervals, 155-130 cm (early to mid-Holocene transition-EHMT, white to dark sedimentation change) and 38-35 cm (mid-to late Holocene transition-MLHT, dark to white sedimentation change) in the core R are clearly visible in Figure 2, panels a and b (included in the revised version). It is apparent, where our AMS (8 samples) and bulk ^{14}C (2 samples) dates are plotted as a function of depth, that sedimentation in the lake was highly variable with an overall less-linear (R^2=0.894) mean Holocene sedimentation rate of 16.8 cm/kyr due to relative variable inputs of organic and detrital materials (Figure 2, panel c). C-14 dating (4 dates

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only) especially of mid-Holocene section shows higher (29 cm/kyr; Figure 2, panel d) and less-linear (R^2=0.887) sedimentation rate as a consequence of large amount of organic input from terrestrial plants (C/N ratio = >20) in the lake surroundings. The resulting model of sediment accumulation was, however, almost linear (R^2=0.997) for the organic-poor, early and late Holocene sections, resulting in an combined, average sedimentation rate of 14.4 cm/kyr (Figure 2, panel d). Moreover, 2.3 millennia sedimentation epresented by just 3 cm interval (38-35 cm) around warm, mid-Holocene to dry, late Holocene transition led us to postulate a sedimentation hiatus (Figure 2 in the revised version) due to total drying out of this shallow lake (maximum water depth: 1.5 m) between 4.5 and 2.1 kyr BP.

Question 3: Explanation and conclusions - If the chronology and proxy interpretation were acceptable, the authors fail to discuss why the EAM at their site shows a sudden change in intensity at 8.6 ka, while most other monsoon records in the region (e.g. Dongge as cited in their 2007 paper) show much earlier increase in EAM intensity? What causes this difference? Also, the identification of weak monsoon events in the manuscript is subjective at best, e.g., events at 8.2 ka and 2-1.6 ka. Also, the proposed correlations with other records are weak to non existent. The arguments presented cannot support the proposed connection and synchronicity. For example, how would C/N ratios have any connection with atmospheric CO2 concentration as implied in Fig. 3b? Correlation (they look similar) doesn't necessarily mean causation!

Most of the paleoclimate records show evidence for an increase of monsoon activity at around 10.5 kyr BP, including pollen records from central Taiwan (Liew et al., 2006). Unfortunately, our record extends up to 10.3 kyr BP (10250 yr BP) and this might be one of the reasons why our record did not show the real onset very concurrent with other records. However, the clear representation of our proxy records for vegetation change and concurrent shift from erosion to weathering dominated lake catchments at ca. 8.6 kyr BP (Selvaraj et al., 2007) can be regarded as an onset of Holocene optimum (maximum precipitation/temperature) in subtropical Taiwan and is very consistent with

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the onset of Holocene optimum in the Loess Plateau (An et al., 2000) and the timings (9-7.3 kyr BP) of enhanced heat and moisture transport in the marginal seas of the western tropical Pacific (Wang et al., 1999; Jian et al., 2000) within the Holocene. For some more information, please refer our reply to Referee 1 comments.

This shift can also be substantiated as follows: From the available records of Asian monsoon, one can easily distinguish two intervals of abrupt increase in summer monsoon precipitation ca. 11-12 and 8-9 kyr BP in Asia. The former period correlates with the Northern Hemisphere solar radiation anomaly at ca. 12 kyr BP and corresponds to the tropical Indian monsoon index, i.e. the difference in sea-level pressure (hPa) between ocean and land covering 45 to 120 E Longitude and 45 N to 15 S Latitude) (An, 2000). The latter period correlates with another solar radiation anomaly at ca. 9 kyr BP and corresponds to the East Asian monsoon index, i.e. the difference in sea-level pressure between 160 to 110 E Longitude and 25 to 50 N Latitude. The precipitation increase between roughly 12 and 11 kyr BP widely evident in the monsoon records from Oman, India, and SW China were mainly attributed to the former condition. With 2-3 kyr time lag, the summer EAM attained a rapid increase in Taiwan and this delayed abrupt strengthening was likely related to an inception of climatic optimum from the glacial boundary conditions, including remnant ice sheets and the lowered atmospheric CO2 (see Figure 3 in original version) that delayed the development and advance of summer monsoon in East Asia, and the associated low air-temperature decreased the water vapor content to the atmosphere (An, 2000). They reiterated that these conditions had relatively less influence on the tropical Indian monsoon mainly because of the warming effect of Tibetan-Himalayan Plateaus. A detailed review of Holocene effective moisture changes in Asia largely supports the occurrence of Holocene optimum precipitation during the early Holocene in Indian monsoon region but such a condition has prevailed during the mid-Holocene in the EAM region (Herzschuh, 2006). The rapid increase of summer EAM around 8.6 (between 8.6 and 7.7 kyr BP) apparent in Figure 3 is consistent with the Holocene climate records from East Asia and tropical Pacific, especially the WPWP where the sea surface temperature record showed the

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culmination of postglacial SST similar to 8.5 kyr BP (Gagan et al., 2004). Furthermore, the influence of Indian monsoon in Taiwan has never been invoked as like in Dongge Cave, southern China. The integrated influence of Indian and East Asian monsoon in China and asynchronous behavior of Holocene optimum precipitation (e.g. An et al., 2000) are believed to be determining the timings of postglacial increase or inception of Holocene optimum precipitation in East Asia.

We may accept that the some of the proposed correlations are weak and thus we removed some of the related information in the revised text. The basic idea behind the comparison of C/N ratio with atmospheric CO_2 was that the distribution of C3 and C4 plants is a function of pCO_2 and temperature (Ehleringer et al., 1997). Therefore, we considered the C/N ratio as a proxy for subtropical vegetation and interpreted the long-term decrease of C3 plants for the past 8 kyr as an effect of reduced summer monsoon.

Question 4: Potential duplicated publication - This manuscript presents almost identical data as in the paper by the same authors (Selvaraj et al., 2007). Only difference is the slightly higher resolution data for TOC. All other curves for correlation were presented in the previous paper. Also, there are no new interpretations and conclusions supported by these existing and new data.

The differences between one published in GRL and the present manuscript are given in the beginning of this reply material. We have also included a new data set, water content and dry bulk density, from other core Rd collected from the same lake in the revised version of the manuscript. We present the time series of these two variables between 169 and 335 cm of core Rd. According to 3 AMS ^{14}C dates obtained, we inferred the weak and strong monsoon intervals within the Holocene optimum and their link with solar activity.

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