Response to Reviewer #1

Reviewer's general comments: *The paper investigates the dominant pattern of Holocene SST variability and its similarity with the dominant mode of modern decadal SST variability in the Atlantic Ocean, which is referred as Atlantic Multidecadal Oscillation (AMO). They investigate also a possible role of the AMO on the 8.2 ka cold event and on the Medieval Warm Period (AD 800-1300). The paper is valuable because it proposes a new interpretation of the dominant pattern of the Holocene SST variability. However there are some points the authors should clarify to convince that the Holocene SST pattern resembles more the AMO-SST than NAO-SST like pattern.*
I have several comments the authors may consider for improving their paper.

Response: See our point-to-point response to your specific comments, as all of your general comments are addressed in it.

Reviewer's comments 1: *A stable pattern which appears in Fig. 3a, which is described also in the papers cited here, is the dipole between eastern Mediterranean/Northern Red Sea and western Mediterranean/eastern North Atlantic. Such a dipole does not appear in any seasonal AMO-SST patterns.*

Response: Firstly, the AMO is typically defined by SST in the North Atlantic Ocean. If a basin-wide SST pattern (e.g. the EOF01, and the 8.2ka event and MWP) occurs in the North Atlantic Ocean, it can be interpreted as an AMO-like pattern. Our interpretation of AMO-like SST pattern in North Atlantic is similar to the interpretation of El Nino/La Nina SST variations in the Pacific Ocean. During the El Nino/La Nina cycle, the SST in the eastern tropical Pacific is usually (but not always) out-of-phase with the SST in the western tropical Pacific Ocean. However, an El Nino/La Nina event is defined merely by the SST in the eastern tropical Pacific Ocean. If the eastern tropical Pacific (e.g. the Nino 3 region) is warm (cold), we say there is an El Nino (La Nina) event no matter whether the western tropical Pacific is cold, warm or in neutral conditions.

Secondly, though the SST variations in the eastern Mediterranean and Red Sea are related to SST variations in the North Atlantic, they are also influenced by other factors (local vs remote factors, e.g. Felis et al., 2000). It is interesting to note that the proxy records in the northern Red Sea were used to reconstruct ENSO and PDO variations in the Pacific Ocean (McGregor et al., 2010). The net effect of North Atlantic influences and all other factors are responsible for the SST variations in the eastern Mediterranean and Red Sea. In other words, teleconnections between SST in the North Atlantic and the eastern Mediterranean and Red Sea may appear or disappear by the impacts of other factors. In fact, many of the well-known teleconnections are unstable because those teleconnections come and go on different periods (e.g. Kumar et al., 1999; Lu and Greatbatch, 2002; Hilmer and Jung 2000). Therefore, it is reasonable that the teleconnection between North Atlantic and the eastern Mediterranean and Red Sea during the Holocene is different from the modern times.

Thirdly, we analyzed simulations made by two fully coupled atmosphere-ocean models. Correlations between the modeled AMO index (averaged SST over 0-60N, 7.5-75W) and the modeled surface temperature showed a reverse relationship between the extra-tropical North Atlantic and the southwest tropical Atlantic (where site 14 is located) and the eastern Mediterranean and Red Sea (see the Figure.R1 below). These results suggest the AMO pattern can indeed demonstrate opposite SST variations in the extra-tropical North Atlantic and the west tropical Atlantic, as well as the eastern Mediterranean and Red Sea. Those model results also suggest that the AMO-like pattern can show such an out-of-phase relationship during the Holocene. We will add Fig.R1 in our discussion to reiterate this point in the revision.

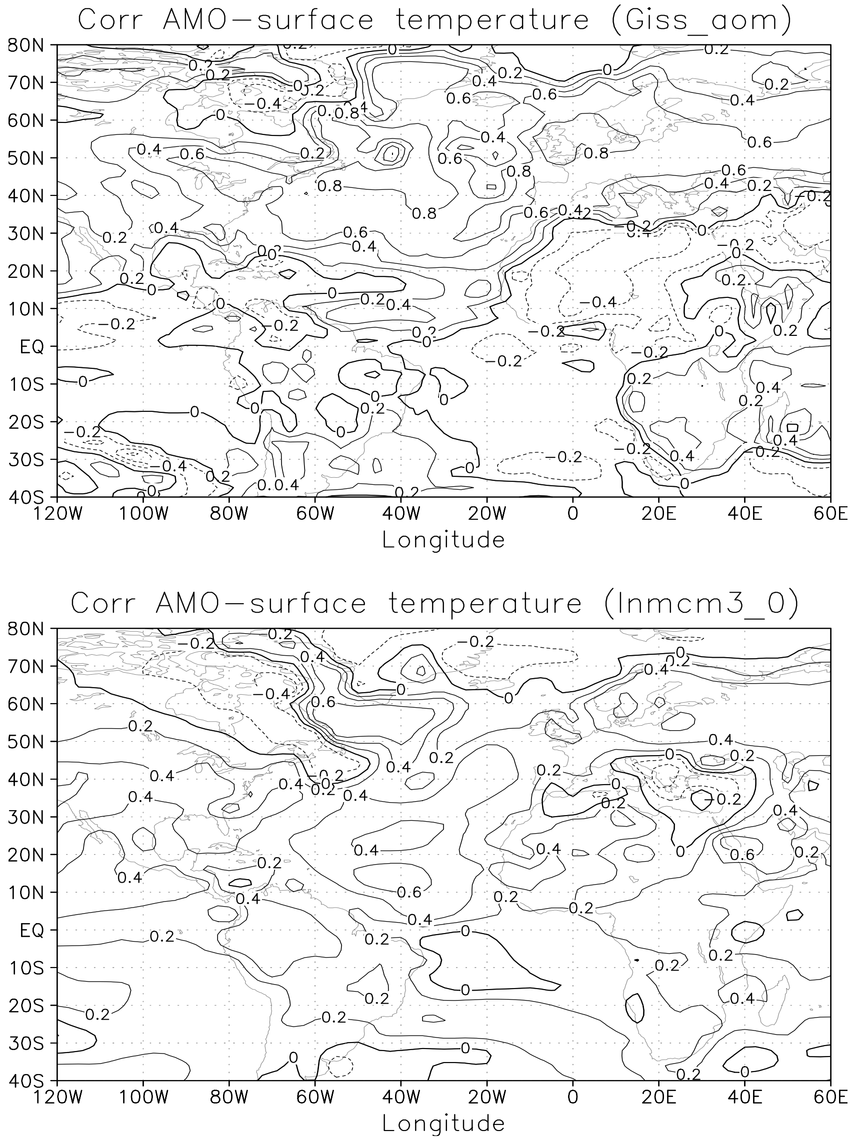

Figure R1. Correlation between annual AMO index (averaged SST over 0-60N, 7.5-75W) and the annual surface temperature (TS) simulated by GISS-AOM (251 years) and INMCM3.0 model (330 years). Both models are fully coupled atmosphere-ocean models. Before calculating the correlation, the data were detrended and smoothed with 19 years running filter.

Reviewer's comment 2: *The Holocene SST dominant pattern (Fig. 3a) does not show a well defined dipole pattern in the Atlantic Ocean, which is a key element of AMO SST pattern identified in the observed SST field. In the South Atlantic there is only one core with anomaly opposite to those from the North Atlantic. The spatial resolution of the South Atlantic SST reconstruction should be improved to clearly emphasize the North-South Atlantic SST dipole.*

In my opinion the spatial resolutions of the Holocene SST-data used in this and previous studies cited here are not high enough to conclude that the dominant mode of Holocene millennial and longer time *scale SST-variability is similar to the modern AMO or NAOSST patterns. This remains an open question until high resolution proxy data as well as simulations with high resolution climate models are available.*

Response: The AMO is usually defined by SST in the North Atlantic Ocean. We also focused on Holocene SST variations in the North Atlantic Ocean because there are very few SST records available in the South Atlantic. Our Fig.3 clearly suggested that there is a basin-wide SST pattern in the North Atlantic, resembling the AMO pattern in the North Atlantic Ocean. Several previous studies argued that the AMO is associated with a dipolar SST pattern between North Atlantic and the mid- and high-latitude South Atlantic Ocean. Your Fig.1 as well as our Fig.3a and Fig. S1 all suggest that, compared to the North Atlantic, the opposing SST variations mainly occur in the high latitude South Atlantic. There are no proxy SST records available in the mid- and high-latitude South Atlantic, so the first EOF of the Holocene SST could not resolve the dipole pattern between the North and South Atlantic. Despite the paucity of SST records from the South Atlantic, we believe it is still reasonable to call the EOF01 of Holocene SST AMO-like because most of the previous studies defined the AMO pattern in the North Atlantic.

Reviewer's comment 3: *Is not very clear how the observed annual fields were filtered. In order to obtain AMO and related patterns the fields have to be linear detrended and filtered in order to isolate decadal variations. A more detailed description of statistics used to produce the observed and proxy patterns would improve the quality of the paper.*

Response: The annual (or seasonal) SST was first detrended and then smoothed using a 9-year equal weight filter, which remove the SST variations shorter than 9 years. The AMO pattern (Fig. 3a and Fig. S1) we referred to is the first EOF of this low-pass filtered SST. The detrended SST minus the low-pass filtered values contains the interannual variations. The first EOF of the interannual SST variations is shown on Fig.6b and Fig.S1. The above information will be added in our section 2 in the revision.

Reviewer's comments 4: *In this study only annual resolution observed fields are used to establish AMO pattern and related teleconnections. Although AMO is the dominant mode of decadal SST variability in all seasons the associated teleconnections may be seasonal dependent. A discussion of seasonal AMO teleconnections during observational period and during Holocene based on AMO reconstruction presented here would be valuable.*

Response: In high latitudes, the variations of alkenone are related to warm season temperature (Vaillencourt et al., 2009). In other regions, the seasonality of the Holocene SST cannot be resolved by the alkenone and Mg/Ca SST reconstructions. The proxy SST records used in this study are commonly interpreted as the annual temperature (Marchal et al., 2002). Therefore, it is appropriate to compare the Holocene SST variations with the observed annual SST variations in the North Atlantic. We agree that a comparison of seasonal teleconnections during the observational period and the Holocene would be very valuable, but outside the purview of our current study. We will take the reviewer's suggestion and certainly include it in our follow-on work.

Reviewer's comments 5: *It is argued that basin-wide monopolar SST variations in the North Atlantic induces dipolar SLP variations in the Atlantic region. Such an atmospheric circulation pattern is similar to the NAO pattern (Fig. 7). However, the dipolar SLP pattern associated to the AMO does not produce dipolar SST pattern in the eastern North Atlantic/western Mediterranean and eastern Mediterranean/northern Red Sea but NAO does. This was the main reason that previous studies associate the dominant mode of Holocene SSTvariability to the NAO.*

Response: Our section 4 and the detailed response to comment 3 of reviewer #2 suggested that it is more appropriate to interpret the Holocene SST in the North Atlantic as an *oceanic* (AMO-like) than an *atmospheric* (NAO-like) pattern. Our Fig.7 as well as modeling studies by others all show that the AMO can induce a dipolar SLP (NAO) pattern in the Atlantic region. Because the NAO leads to an anti-phase relationship between the temperature in the Middle East and the Atlantic, it is thus reasonable to argue that the AMO-related dipolar SLP pattern could induce an anti-phase SST pattern between the eastern Mediterranean and Red Sea during the Holocene. Our reasoning is that the AMO induces a dipolar SLP (NAO) pattern and the NAO then induces the reversed sign SST variations in the eastern Mediterranean and Red Sea. In other words, the NAO atmospheric pattern did play some roles on the Holocene SST variations in the eastern Medeterranean and Red Sea, but the NAO is caused by oceanic (AMO) SST variations. This interpretation could reconcile the AMO-like pattern in this study and the NAO-like SST pattern as suggested in previous studies. We will reiterate this point on our discussion in the revision.

Reviewer's comments 6: *It is argued that physical mechanisms that control SST variations at interannual time scales are different from those operating on decadal and longer time scales. This is true but it is not an argument to consider that processes operating at decadal time scales are the same with those operating at centennial, millennial or longer time scales. The monopolar SST structure in the North Atlantic during Holocene could be due to variations of THC like in the case of the AMO but could be induced by other mechanisms not related to the AMO. Only model experiments could clarify if THC variations or other causes are responsible for the monopolar structure of the dominant pattern of North Atlantic SST at centennial and longer time scales during the Holocene.*

Response: Our Fig.6 and Fig.S1 showed that the AMO is the dominant SST signal on North Atlantic on decadal and longer time scales, while the NAO-SST relationship is dominant on interannual time scales. Because the proxy SST records cannot resolve SST variations on interannual time scales, it is more appropriate to compare Holocene SST pattern with the AMO pattern. In fact, previous studies (e.g. Jung et al., 2004; Yan and Petit-Maire, 1994) frequently compared the observed decadal climate changes with proxy records to understand the underlying physical processes that causing the past climate changes during the Holocene (or the glacial and interglacial).

Reviewer's comments 7: *It is evident from Figure 5 that temperature anomaly in the Atlantic-Mediterranean region is monopolar during 8.2 ka cold event and during MWP event. It matches exactly the AMO pattern which does not show dipolar pattern in the eastern Mediterranean-Northern Red Sea and western Mediterranean and eastern North Atlantic like EOF01 (Fig. 3). Therefore the patterns in Fig 3 (EOF01) and those in Fig 5(temperature anomaly during MWP and 8.2 ka event) are not similar and the physical mechanisms behind them could be different.*

Response: Again, the AMO is typically defined by SST in the North Atlantic Ocean. Our Fig.5 clearly shows a basin-wide cold (warm) pattern in the North Atlantic during the 8.2ka event (MWP), suggesting an AMO-like cold (warm) phase in the North Atlantic during both periods. Though AMO is the dominant signal in the North Atlantic; it is presumably not the dominant signal in the eastern Mediterranean and Red Sea. Other factors (local or remote) may also influence the temperatures in this region. Fig.5 just suggests that other factors such as those of ENSO and PDO (Felis et al., 2000) override the impact of AMO during both periods.

References:

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