J Paleolimnol (2007) 38:597–600
DOI 10.1007/s10933-007-9137-7

REPLY

Was there ice along the shore of the Sea of Galilee during the last 12,000?—Reply to a comment by Prange et al. (2007) and a comment by Friedman (2007)

Doron Nof · Ian McKeague · Nathan Paldor

Received: 20 April 2007 / Accepted: 4 July 2007 / Published online: 2 October 2007

Abstract Prange et al. (2007) question our reconstruction of the Sea of Galilee (Lake Kinneret) paleoclimate and argue that a "careful" analysis of the paleoclimatic analysis leads to much smaller cooling events than we have considered. By and large, their "careful" analysis is based on correlating the paleotemperatures of the Lake with those of the northern Red-Sea that (geographically) is much closer to the Lake than the two Mediterranean cores that we used. Ironically, their argument contradicts Friedman's (2007) statements (the second comment on our original paper), which are based on still-closer cores and *support* our larger cooling choices. This issue alone would be enough to dismiss the uniqueness of PAL argument but there is another issue with their work that we wish to comment on. In support of their own small cooling argument, PAL present winter correlation maps that indeed show a stronger correlation of the northern Red-Sea SST to the lake SST than the correlation of Mediterranean SST with the lake SST. This seemingly correct correlation argument of PAL is totally false (for both daily and millennial time scales) because it has no climatological basis. On the daily time scale, all the storms that reach the Lake originate in the Mediterranean Sea (to the west of the lake), not the Red-Sea (which lies 700 km south of the lake). Also, although the lake and the Red-Sea are only 700 kilometers apart, their climates are very different because they are subject to two totally different air masses. While the climate of the Red-Sea region is desert-like, the climate of the region surrounding the lake is a typical wet Mediterranean climate. Seasonal correlation maps (and even monthly maps) such as those presented by the authors *filter out the storms* that control the winter climate in the lake region because these storms occur on a daily scale. With this filtering, all that one is left with is the low frequency first baroclinic mode, which merely reflects the Rossby radius scale (measured from the lake). On the millennial time scale, cold events in the lake regions (from an earlier period) have been attributed to Bond cycles and Heinrich events both of which are global and not local processes. As such, they are probably forced by variability in the solar radiation rather than a local process implied by PAL. Overall, all that the PAL correlation shows for both daily and millennial time scales is that changes in the

D. Nof (✉)
Department of Oceanography, Florida State University, Tallahassee, FL 32303, USA
e-mail: nof@ocean.fsu.edu

D. Nof
Geophysical Fluid Dynamics Institute, Florida State University, Tallahassee, FL 32303, USA

I. McKeague
Department of Biostatistics, Columbia University, New York, NY, USA

N. Paldor
Department of Atmospheric Science, The Hebrew University of Jerusalem, Jerusalem, Israel

temperature in the Red-Sea occur at *the same time* as they do in the Lake. But this does not say anything about the dynamics in question and does not imply that it is better to use records from the Red-Sea (which does not lie within the path of the zonal winds reaching the Lake). Neglecting this issue (as proposed by PAL) distorts the physics and reminds us of the classical statistical example for the limitations involved in the interpretation of correlation—the incidence of lung cancer is strongly correlated with the incidence of carrying matches in ones pocket even though the matches do not cause the cancer and the cancer does not force one to carry matches.

Keywords Salt springs · Plumes · Lake freezing · Convection · Paleoclimate

Introduction

We thank Prange et al. (2007, PAL, hereafter) for their examination of our work and for drawing attention to the fact that the interpretation of paleolimnological records is not a straightforward matter. One does not need to go very far to find support to this statement. Ironically, even the two comments which this reply addresses contradict each other in their major statements—while PAL argue that the temperature variations in the Red-Sea during the Holocene are an order of magnitude smaller than what we concluded, Friedman (2007) argues that his independent assessment makes it clear that they are of the same order as ours.

In their attempt to show that we overestimated the cooling events, PAL focused on four different aspects that are not necessarily related to each other. Their first and most important issue is that the Red-Sea is closer to the Sea of Galilee (Lake Kinneret, hereafter, referred to as the "Lake") than the Mediterranean cores that we used and, therefore, the Red-Sea records (constructed on the basis of a core taken near Ras Muhammad) which show small cooling events should have been used instead. Second, they argue that our alignment of the Emeis et al. (2000) core with zero temperature change 2,000 years ago is perhaps debatable. Third, they argue that our ocean–atmosphere connection model neglects the latent and sensible heat fluxes between the ocean and the air and contradicts the third law of thermodynamics. Fourth, they say that they are "skeptical" about our statement that the core south of Cyprus was probably contaminated by cold fresh water from the Nile and, therefore, cannot easily be used.

In what follows we shall show that the first and third points are totally wrong (not a little bit wrong, but entirely wrong), the second point is valid but is actually discussed in the original paper, and the fourth point cannot really be proven one way or another and because of this uncertainty the safe approach is to not consider this core's data. We shall take these four issues one-by-one.

Correlation with Red-Sea

For historical and biblical reasons, the climate of Israel is often mistaken by the layman to be desert-like. In reality, much of the country and the Lake enjoy a moderate climate with a significant amount of rain. Conditions do change rapidly when one moves southward and the climate becomes desert-like about two hundred kilometers south of the Lake, near the latitude of Be'er Sheva. Accordingly, even though the Red-Sea region (next to the tip of the Sinai Peninsula) and the Lake are only 700 km apart, their climates are not at all the same and, more importantly, the air masses in the two regions are of completely different *origin*. While the Red-Sea region is desert-like with very little rain (30–40 mm a year) and low humidity, the Lake region enjoys 400–800 mm a year and very high humidity. The main difference between the two air masses is that the source of moisture, the North Atlantic and the Mediterranean Sea, lies within the path of the prevailing winds (and the storms track reaching the Lake) whereas the Red-Sea region lies *outside* this route. Namely, while the air masses over the Lake originate in the North Atlantic and the Mediterranean (on all time scales, days, to thousands of years), the air masses over the tip of the Sinai Peninsula are of much lower-latitude origin. There is, of course, some connection between the Lake and the tip of the Sinai Peninsula through the Jordan Valley and the associated geological rift, but connection is not of major consequence to the climate of the region.

Since the beginning of reliable meteorological records, hundreds of storms have been observed to dump their cold air and rain over the Lake. All originated in the Atlantic and the Mediterranean and

none in the Red-Sea. By the time that the synoptic-scale storms reach the Lake, the temperature in the area immediately to the west has returned back to normal, so that, on a monthly or seasonal time scale, the correlation appears to be small. Dynamically, the Rossby radius is, of course, the controlling scale so all correlation maps show high correlation in regions of that distance away from the Lake. It is clear that seasonal correlation maps filter out the daily time scale and, therefore, have no relevance to the dynamics governed by storms.

For the millennium time scale (our cooling events) the annual and seasonal correlation maps presented by PAL are also irrelevant. Using proxies from ancient Lake Lisan, earlier variations on this time scale have been traced to Bond Cycles (Bond et al. 1997) and Heinrich events (Prasad et al. 2004), both of which are quasi-global processes which are probably induced by solar variations, not the Red-Sea. All that the PAL correlation maps imply is that processes on the annual and seasonal scale occur in both places at the same time. In contrast to what the authors want us to believe, just like the cancer example given in the abstract, the Lake climate cannot possibly be the direct result of the Red-Sea climate. Incidentally, when we stated in our original article that there are no records closer to the Lake than those that we used, we meant closer *within the route of the prevailing winds* (i.e., the Mediterranean), not in general. We were well aware of the Red-Sea records but deemed them irrelevant because they do not lie within the path of the winds reaching the Lake.

Emeis et al. (2000) record for the last 1,000 years

This record shows wild fluctuations for the most recent 1,000 years out of total 16,000 years shown. Also, if taken to be valid to present day (as suggested by PAL), the record appears to be inconsistent with the (near-by) record of Chaco et al. (2001). Hence, we questioned whether the top of the extracted core was affected by near-bottom storms that forced scouring (and deposition) during the last 1,000 years, or by the coring device itself. We attempted to get an answer to this question via emails to the authors but, by and large, these emails were left unanswered. Correctly or not, we took this lack of response to mean that the authors themselves did not know for sure how reliable the top of the core was. To resolve this issue, we eliminated the beginning of their core and aligned their record with the (admittedly debatable) historically based record of Reale and Dirmeyer (2000) implying that 2,000 years ago the temperature was the same as today. We did the same with Chaco et al (2001) record that does not extend to the present day. This procedure is, of course, not ideal but, in our mind, is far better than attempting to determine the lake temperature from the unrelated Red-Sea record or relying on a wildly fluctuating record.

Our coupled air-sea model

PAL must have misunderstood our model. It is a heat-flux conserving model that, in contrast to what they state, does not ignore sensible and latent heat fluxes, nor does it violate the third law of thermodynamics. It only ignores the absorption of long-wave radiation emitted from the lake by clouds higher than the atmospheric Ekman layer and radiation back to space. Neither of the two is critical to our estimate. Furthermore, PAL modeling-based statement that the relation between the SST variability and the SAT variability is 1:1 contradicts observations showing a 1:4 ratio in high latitudes (see Bard 2002). Also, their plot (Fig. 3) shows relatively large scatter and the elimination of merely one point from their record is sufficient to change the slope to 1:2 or 1:3.

The neglect of the core south of Cyprus

Without saying why, PAL states that they are "skeptical" about our rejection of that particular core, which peculiarly shows *warming* for the same period that the other records show cooling. Thinking that our reasoning in the original paper was perhaps not clear, it is given in more detail here. The rejection is based on the commonly held idea that cooling causes increased aridity, not the other way around. (Many records, including the Red-Sea record frequently referred to by PAL, demonstrate this.) Bar-Matthews et al. (2003) speleotheme record clearly shows *increased* aridity for the period in question

suggesting cooling rather than warming. By sharp contrast, the Cyprus core shows warming in that period so we looked for an explanation for how an increased aridity can cause warming instead of cooling. We ultimately came up with the Nile as the possible culprit because most rivers are *cooler* than the bodies of water into which they empty. An increased aridity implies reduced river flux that, in turn, implies less cooling which, in the core record, will show up as *warming*. Given the proximity of the Nile outflow to the core in question, we rejected that record on this basis.

In summary, we hold to our views that our cooling estimates are valid, and, hence, argue that the frequency of storms allows freezing during the cold events. Friedman's analysis supports our choices and PAL correlation analysis with the Red Sea is irrelevant. To re-capture the issue involved in the correlation analysis, consider correlating the temperature of New York City (NYC) with regions around it. New York itself will obviously get the value 1 and this value will fall-off as one proceeds away from it. In a perfectly symmetrical stochastic world, the correlation map will be a perfect circle. The direction of the winds reaching NYC as well as the distribution of land and water and other imperfections will distort the circle but if one goes far enough (i.e., zoom away from NYC) the resolution is decreased and the high correlation map will ultimately look like a circle again. This circle will exclude the most important information involving the origin of the prevailing winds reaching NYC. A statistical analogy to PAL interpretation of the correlation is that the sales of both computers and athletic shoes increased sharply in recent years and there is a strong correlation between the two even though they are not at all related to each other.

Having said that, we should also state that, like many others before us, we recognize that the interpretation of paleoclimatological data is not trivial and will probably always be subject to some debate. Someone who wants to find a discrepancy between one work and another will probably find it if she/he is willing to look hard enough. This reflects perhaps the general weakness of the field, but not the weakness of a particular study.

Acknowledgements Gideon Eshel, who is an expert on Mediterranean climate, has helped us with the interpretation of the PAL correlation. Nof's work is supported by the National Science Foundation Grants OCE- 9911324 and OCE-0241036, the National Aeronautics and Space Administration Grants NAG5-7630 and NGT5-30164 and the Binational Science Foundation grant BSF 96-105.

References

Bar-Matthews M, Ayalon A, Gilmour M, Matthews A, Hawkesworth CJ (2003) Sea-land oxygen isotopic relationships from planktonic foraminifera and speleotherms in the Eastern Mediterranean region and their implications for paleorainfall during interglacial intervals. Geochim Cosmochim Acta 67:3168–3199

Bard E (2002) Climate shock: abrupt changes over millennial time scales. Phys Today 55:32–38

Bond G, Showers W, Cheseby M, Lotti R, Almasi P, deMenocal P, Priore P, Cullen H, Hajdas I, Bonani G (1997) A pervasive millennial-scale in North Atlantic Holocene and glacial climates. Science 272:1257–1266

Chaco I, Grimalt J, Canals M, Sbaffi L, Shackleton NJ, Zahn R (2001) Variability of the western Mediterranean Sea surface during the last 25000 years and its connection with the Northern Hemisphere climatic changes. Paleoceanogr 16:40–52

Emeis KC, Struck U, Schulz HM, Rosenberg R, Basconi S, Erlenkeuser H, Sakamoto T, Martinez-Ruiz F (2000) Temperature and salinity variations of Mediterranean Sea surface waters over the last 16000 years from records of planktonic stable oxygen isotopes and alkenone unsaturation ratios. Palaegeogr Palaeocl 158:259–280

Friedman GM (2007) On 'walking on water' not the geoscientist's fear of social controversy. J Paleolimnol, doi:10.1007/s10933-007-9135-9

Prange M, Arz H, Lamy F (2007) Comment on "Is there a paleolimnological explanation for 'walking on water' in the Sea of Galilee?" J Paleolimnol, doi:10.1007/s10933-007-9136-8

Prasad S, Vos H, Negendank JFW, Waldmaan N, Goldstein SL, Stein M (2004) Evidence from Lake Lisan of solar influence on decadal- to centennial-scale climate variability during marine oxygen isotope stage 2. Geology 32:581–584

Reale O, Dirmeye P (2000) Modeling the effects of vegetation on Mediterranean climate during Roman classical period part I: climate history and model sensitivity. Global Planet Change 25:163–184