Response to the interactive comment by anonymous referee # 1

We thank the anonymous referee for his/her positive comments on our work. We also appreciate his/her thorough comments about our discussion on speleothem record that helped to improve the manuscript. He/she raises four detailed considerations, relating to: (1) the Hendy test, (2) the open nature of the cave and its impact on isotope values (modern - paleo isotope comparison); (3) the difference of the isotopic signal of two speleothems; and (4) the caution of climatic interpretation from growth phase/rate variability. We have carefully revised the manuscript to take into account these comments. We respond to all points item by item bellow with the comments in black and our responses in blue fonts.

Interactive comment on "Evidence of a prolonged drought ca. 4200 yr BP correlated with prehistoric settlement abandonment from the Gueldaman GLD1 Cave, N-Algeria" by J. Ruan et al.

Anonymous Referee #1

Received and published: 3 August 2015

The manuscript is interesting and adds more to the understanding that major climatic events during the Holocene in larger part of the Mediterranean basin are synchronized and that there is a possible link between climatic events and human occupation. The manuscript deals with climate reconstruction based on 2 speleothems from the open Gueldaman cave, in N-Algeria _60 km from the Northern Mediterranean Sea, where well dated speleothems and archeological remains co-exist. The isotopic record of the speleothems was correlated to speleothems from central and eastern Mediterranean Sea. The major conclusions from the comparison of the isotopic record from N. Al-geria with speleothems from Italy and Israel is that synchronicity with major drying at ca. 5600, ca. 5200 and ca.4200 yr BP occur across the Mediterranean basin. The archeological findings in the cave supports their conclusions. The weaker part of the manuscript is the discussion of the speleothems record. This section needs more clarification and re-organization. Hendy tests need to be shown as a figure, and need explanation if they were performed along single laminae or across lamination.

We have significantly revised and re-structured the Discussions part of the manuscript. We added the figure of Hendy tests as Supplement in revised manuscript (Figure 1, below). Our strategy for Hendy tests was to determine the isotopic compositions along visible single lamina, from the apex toward the edge, at the depths of 52 mm, 172 mm and 292 mm. Since the diameter of the drill we used is 0.6 mm and the growth rate at these depths vary from ca. 0.1 mm to 0.3 mm per year, each data point may contain information for ca. 2-6 years. The result showed that the carbon and oxygen isotope values significantly correlate and increase by up to ~1‰ from the apex toward the edge, which suggests non-equilibrium isotopic precipitation.

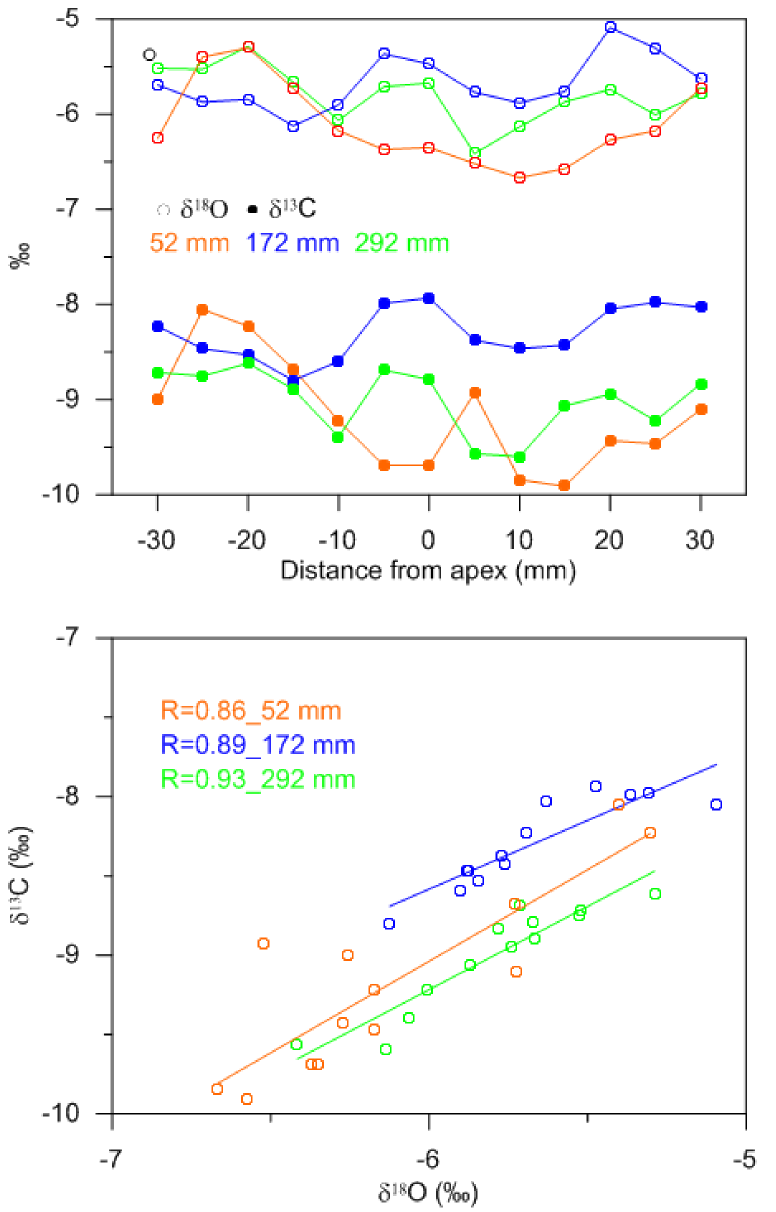

Figure 1. The Hendy test from stalagmite GLD1-stm2

A more in depth discussion is needed regarding the fact that the cave is open and how this can modify the isotopic record? The authors show the present-day values of the speleothems d18O and d13C but they don't discuss why the values fit more the speleothems value pre _5000ka. Is it due to climate change? Can it be associated with the opening of the cave? When was the cave opened?

We agree with the reviewer. It would be helpful to further discuss the impact of open cave on speleothem isotopic values. More comments were added in the Discussions 4.1 of revised manuscript. Briefly, the open cave allows evaporative and kinetic isotopic fractionations, which would amplify the climatic signal imprinted in speleothem isotopes. First of all, variations in Gueldaman GLD1 speleothem isotope are negatively correlated to rainfall to a certain degree. Evaporation and kinetic fractionation processes, due to the open nature and short extension of the cave, further modify speleothem isotope values with an overall increasing effect, which is prolonged/diminished during drier (low rainfall) /wetter (high rainfall) period.

In the manuscript, we compared the present-day isotope values to the paleo-records. We agree that the modern values fit better to the values of pre-5000 yr in stalagmite GLD1-stm4, but this is less clear when comparing them to stalagmite GLD1-stm2. We therefore only suggested (Discussions 4.1) that the current humidity condition is within the range of its Mid-Holocene variability, based on the observation that the present-day isotope values fall in the range of two stalagmites variations.

Radiocarbon dating and archaeological evidence argue that the Gueldaman GLD1 Cave was occupied by ancient human since at least ca 7 ka ago. Besides, there is no clear evidence from previous field investigation of changes in cave geomorphology. These suggest that the cave has probably been open in the last 7 ka. More information was added in the Study Site 2.1 of revised manuscript.

The isotopic events are well observed in GLD1-stm4 whereas in speleothem GLD1-stm2 the record hardly shows any significant change. It is impossible to compare the 4500 Ka event recorded in sample 4, to sample stm-2. The enrichment isotopic trend well observed from 4800-4600 yr BP in sample 4, but is hardly seen in sample 2. The authors need to explain why the isotopic profiles of two speleothems growing close to each other are so different.

Although two stalagmites broadly show similar isotopic variations and the isotopic events discussed in the manuscript (ca.3800-4400 yr, ca.5200 yr and ca.5400-5600 yr) are identical in both stalagmites, we admit that their isotopic profiles significantly differ in regards of the amplitude and stalagmite GLD1-stm2 record shows less clear changes during these events (Fig. 5). The absolute isotopic changes in stalagmite GLD1-stm2 usually are 1/3-1/2 as small as these in stalagmite GLD1-stm4 across these events. Albeit these we notice that the amplitude of stalagmite GLD1-stm2 is more comparable to those of Soreq and Corchia cave stalagmites (Fig. 5). The relatively ambiguous change of stalagmite GLD1-stm2 isotopic profile may suggest that the reservoir feeding GLD1-stm2 is so large that smooths significantly the rainfall signal and/or other site-specific factors also play an important role in controlling the isotope value. On the other hand, the isotopic events are clearly seen in stalagmite GLD1-stm4 possibly because: (1) the reservoir feeding GLD1-stm4 is small and smooths the rainfall signal to a lesser degree; and/or (2) the rainfall signal in GLD1-stm4 is amplified significantly by being suffered from prolonged evaporative and kinetic fractionations. These explanations were added in the Discussion 4.1 of revised manuscript.

As is clearly seen in Fig. 4, there is NO relation between the growth rate and the isotopic profile. Sample 2 shows a striking change in the growth rate at _4800-4600, which is more than twice that of the time periods before and after. This major fast “growth-rate” occurs before the major increase in d18O and d13C in stm4. It does not seem to be related to changes in the isotopic composition, so maybe there is no connection with climate change? Changes in growth rate based on 1 or 2 speleothems are sometimes misleading because they can be associated with internal processes of water dripping mode.

We agree that caution should be taken when interpreting stalagmite growth rate. Because it is likely that two stalagmites have different reservoirs, their growth rate variations would be difficult to compare and their relationships to the isotope profiles might be non-stationary. However, we do not fully agree that there is no relationship between stalagmite growth rate and its isotopic profile. The major fast growth rate in stalagmite GLD1-stm2 ca. 4800-4600 yr BP broadly corresponds to the most negative isotope values; both of which argue for wet conditions.

Sample 4 shows significant isotopic variations at _5800-5500 yr BP, _4600- 4400 yr BP, etc. None of these events is reflected in the growth rate which is more or less constant at this period. The authors argue for a wetter period ca. 4800–4500 yr BP based on the high growth rates of stalagmite GLD1-stm2 and they say that it is not seen in the growth rate change of stalagmite GLD1-stm4 probably due to the lack of dating between 5023 and 4197 yr BP. This is a strange argument. Maybe another dating point is required to solve this inconsistency, or maybe the age model is not absolutely correct.
We agree that the growth rate of stalagmite GLD1-stm4 is relatively constant and its variability seems less sensitive to the isotope change. This may suggest that changes in GLD1-stm4 growth rate might have been affected by other climatic/hydrological processes than those closely associated with isotope variability. We would also like to suggest that the growth rate curve, stimulated from limited U/Th dates by the StalAge program, is less precise and resolved comparing to the isotope profile. This is most apparent for the period of pre- 4197 yr BP in stalagmite GLD1-stm4, where was argued by the referee for the lack of isotope-growth rate relationship.

The authors don't give good explanation to why sample 2, though being the thicker speleothem, ceased to grow at _4100 yr, whereas speleothem 4 continued to grow. They try to suggest a phase of increased aridity, and this explanation fails to explain the continuous growth of speleothem 4. A possible explanation is that sample 2 ceased to grow due to local variations in the dripping position, rather than major climate change. The authors claim that the larger amplitudes of isotopic variations in stalagmite GLD1-stm4 (Fig. 4) can be explained by the likelihood of more evaporative and non-equilibrium enrichments due to lower drip rates, being indicated by its smaller diameters (Fig. 2), but in such case, shouldn't we expect a significant relation between the isotopic composition and growth rate?
We agree with this comment and give more detailed explanations in the Discussion 4.1 of revised manuscript. We suggest that the discrepancy in growth cessation of two stalagmites may be due to different sensitivities of their growths responding to climates, but we do not exclude the possibility that the growth cessation of stalagmite GLD1-stm2 have been caused by shifts in dripping position which eventually might also be linked to deteriorating climates. We also suggest that a significant growth rate – isotope/climate relationship may be blurred due to the lack of substantial U/Th dating from stalagmite GLD1-stm4. Additional dates will help refine the growth rate curve and prove this hypothesis.

Despite these inconsistency between the two speleothems and lack of good explanation for the reasons, one speleothems show a good match with the timing of major drying events in central and Eastern Mediterranean speleothems.