Anonymous Referee #1

RW1: This paper presents new data from 4.2ka from a part of the world where data from this time are lacking. The data collection (e.g. purification of diatom samples) and the treatment of uncertainty in the age model is thorough and allows us to have more confidence in the results. The introduction presents a good hypothesis based on the previously produced proxies to test in this paper with the d18Odiatom data. However, my main concern is regarding the interpretation of the (slight) increase in d18Odiatom around 4.2ka as primarily a water balance signal (i.e. indicating a shift to drier conditions).

But, and the authors acknowledge this at points, a change in precipitation source could also account for some of the isotope shift. In fact, potentially it could account for all of the isotope shift. Also, a decrease in snow (with its very low d18O) around 4.2ka with everything else staying the same could account for the d18Odiatom rise. While your argument about temperature not being the main driver if valid, more thought and caution needs to go in to your interpretation.

There are only a couple of modern day lake water isotope values, but even the summer one is fairly low, so how evaporatively-driven is the isotope system? While I agree that something definitely happened in the lake 4.2ka as the d18Odiatom changes are outside of uncertainty and other proxies show changes too, with so few d18Odiatom data points and the relatively small magnitude of the change means it is difficult to unequivocally say that a change to drier conditions, rather than a change in precipitation source, or decrease in snow, or a combination of these factors, was responsible for the d18Odiatom change.

Therefore, I think the argument of the driver(s) of d18Odiatom needs to be more cautious and more thought through.

Nevertheless, this is a valuable new dataset that is robustly analysed and adds to our knowledge of what was going on in the Mediterranean region around 4.2ka, so I support its publication if my points are addressed.

AC: We thank reviewer#1 for these very constructive and meaningful comments concerning the interpretation of the $\delta^{18}O$ record. The factors that may have controlled the $\delta^{18}O_{lake\ water}$ and $\delta^{18}O_{diatom}$ signatures at 4.2 ka cal. BP are reviewed more thoroughly by reorganizing the discussion section as follows:

1) **A statement on the parameters that may control the present day $\delta^{18}O_{lake\ water}$ is made:**

Water inflows to Lake Petit consist of direct precipitation (rain and snow) and intermittent streams that form during the spring snowmelt. There is no groundwater input into the lake and no glacier is present in the watershed, the last period of active glacier advances in the Maritimes Alps being recorded during the Little Ice Age (Ribolini et al., 2007).

The outlet of Lake Petit is an intermittent surface outlet and is non-active when the lake level drops by 1 meter. Therefore, the hydrological regime alternates between two states: an open system when the outlet is active during snow melt and a closed system during summer months when most water losses are due to evaporation. The 2011 one off $\delta^{18}O_{lake\ water}$ measurements indicate that from the beginning of the unfreezed season to the end, the lake water gets heavier by 1.1 ‰. This ^{18}O-enrichment may come from the inputs of heavy summer precipitation fed by the Mediterranean Sea (weighted annual mean of -4 ‰ in the Alps compared to -8‰ for precipitation originated from Atlantic) and from evaporation of the lake water. The decrease in water depth during the same time supports a strong evaporation. However, in a δD *vs* $\delta^{18}O$ diagram, the lake water samples plot on the regional meteoric water line, which suggests that evaporation has a limited effect on the isotope composition of the lake water. The 1.1‰ shift may also be explained by the drastic decrease of meltwater input at the end of spring. The oxygen isotope composition of meltwater is controlled by $\delta^{18}O$ precipitation, which is lower during winter as the water vapour originates above the Atlantic Ocean (weighted annual mean of -8 ‰ in the Alps), and post-depositional fractionating processes (including evaporation, sublimation, ablation, meltwater percolation and drifting) leading to ^{18}O enrichment of the snow. However, because the Lake Petit watershed is small (area of 6 km^2) and located under the mountain crest, these post-depositional processes are expected to be of minor importance on the $\delta^{18}O$ of meltwater (Stichler and Schotterer, 2000).

Finally, although only two $\delta^{18}O_{lake\ water}$ measurements are available, they suggest that in the context of current climate conditions, seasonal changes in precipitation sources (i.e. winter Atlantic source vs summer Mediterranean source) leading to significant changes in $\delta^{18}O$ precipitation may control the seasonal shift in $\delta^{18}O_{lake\ water}$.

2) **The $\delta^{18}O_{diatom}$ record around 4.2 ka cal. BP is interpreted in light of i) the modern behavior of the lake, ii) the other climate proxy data from the same core (Cartier et al., 2015) and iii) previous climate reconstructions from the Mediterranean area.**

The 4400 to 3900 cal. BP period is characterized by the highest $\delta^{18}O_{diatom}$ values recorded over the last 4800 years in Lake Petit sediments. These values are about 3 ‰ higher than the modern one (27.8 ‰ in 1986 AD) but correspond to a 1.6 ‰ increasing shift from 4800 to 4400 cal. BP and a 1.5 ‰ decreasing shift from 3900 cal. BP. $\delta^{18}O_{diatom}$ depends on the $\delta^{18}O_{lake}$ and the temperature at which silica polymerizes. The $\delta^{18}O_{lake}$ value is itself influenced by the $\delta^{18}O_{precipitation}$ (rainfall or snow). $\delta^{18}O_{precipitation}$ is controlled by the isotope composition of the vapour source and Rayleigh fractionation during the vapour transport (i.e. the continental and altitude effect) and air temperature at the locality where precipitation forms. Changes in these parameters may combine to account for the high $\delta^{18}O_{diatom}$ values observed from 4400 to 3900 cal. BP at lake Petit. They are reviewed below, in light of the other climate proxy data from the same core (Cartier et al., 2015) and previous climate reconstructions from the Mediterranean area.

Shift in lake water temperature

Polymerization of the siliceous frustule from the lake water occurs at equilibrium and the resulting isotope fractionation is thus thermo-dependent. Diatom blooms in alpine lakes occur mainly after the snowmelt in spring season and during autumn. However, sediment traps placed in a lake in Switzerland located at 2339 m a.s.l have evidence that some diatom species (e.g. *Achnanthes*, *Fragilaria* spp.) can continue to grow under the ice when the lake is frozen (Rautio et al., 2000; Lotter and Bigler, 2000). In the following discussion, we assume that the isotopic signal from Lake Petit sediments is an annual signal even if most of the diatom production most likely occur during the ice-free season.

The equilibrium fractionation coefficient previously measured for different silica-water couples range from -0.2 to -0.4 ‰/°C (synthesis in Alexandre et al., 2012; Sharp et al., 2016). According to this range, a 1.6 ‰ shift in $\delta^{18}O_{diatom}$ only controlled by a lake water temperature change would require a mean annual water temperature shift of 4 to 8°C. Reconstruction of temperature based on chironomids and pollen assemblages from the Swiss Alps and Europe suggest that air temperature variations (likely larger than water temperature variations) did not exceed 2 °C during the Holocene (Davis et al., 2003; Heiri et al., 2003).Thus, although a decrease in mean annual temperature may have contributed to the 4400/3900 cal. BP increase in $\delta^{18}O_{diatom}$, it cannot be the only factor explaining this change. According to studies on speleothems in central Italy (Isola et al., 2018), a cooling during the 4.2 ka BP event in response to a positive North Atlantic Oscillation (NAO) is plausible in central Mediterranean. The recent synthesis of Bini et al. 2018 also suggest the presence of a cooling anomaly but temperature data are sparse and not uniform. In the Alps, moraine dated around 4200 cal. BP showed moderate glacier advances in northern and central western Alps but not in the Maritime Alps (Le Roy, 2012; Ivy-Ochs et al., 2009).

Shift in $\delta^{18}O_{lake\ water}$

An increase in the contribution of ^{18}O-enriched Mediterranean precipitation during the ice-free season, or a ^{18}O-depleted winter snow deficit may explain an increase in $\delta^{18}O_{lake\ water}$ at Lake Petit at 4400 cal. BP. High terrigenous inputs from 4400 cal. BP support the increase of ^{18}O-enriched precipitation during the ice-free season. Sedimentological data from the same core (Brisset et al., 2013), allowed to reconstruct before 4400 cal. BP a period of low detrital supply and high chemical weathering from acid soils developed on the slopes. The terrigenous inputs were interpreted as resulting from the dismantling of these weathered soils. The high representation of very low-dispersal alpine meadow pollen (e.g. *Botrychium*) in the sediment additionally argued for an intensification of runoff on the catchment slopes. Similar detrital events were recorded between 4500 and 3000 cal. BP in the Alps, for example at Lake Bourget (Arnaud et al., 2005; 2012). Moreover, a cluster of dated landslide events in the Southern Alps around 4200 cal. BP was interpreted as increasing intense fall precipitation (Zerathe et al., 2014).

A winter ^{18}O-depleted winter snow deficit can also be suggested. But a oxygen isotope record from speleothems record in Italian Apenin, at Corchia Cave, suggest reduced advection of air masses from the Atlantic during winter from ca. 4.5 to 4.1 ka cal. BP.

An evaporation, higher than the modern one, may also account for a ^{18}O enrichment of the surficial water at Lake Petit. However, on an annual basis, the effect of the previous summer's evaporation might be partially or (greatly) offset by the runoff from snowmelt (Ito et al., 2018), as evidenced today.

At least, an increase of air temperature may have led to the increase of the $\delta^{18}O$ of precipitation feeding the lake water. However, as previously discussed, this is not in agreement with other reconstructions from the Mediterranean area that rather argue for a cooling anomaly, although data are scarce (Bini et al. 2018).

Finally, the shift in $\delta^{18}O_{diatom}$ between 4400 and 3900 cal. BP rather suggests an increase in the contribution of ^{18}O enriched Mediterranean precipitation to Lake Petit during the ice-free season. This is in line with increased erosion in the watershed and increased terrigenous inputs to the lake. This does not exclude winter snow deficit and/or summer evaporation and/or on an annual basis, general drier conditions as suggested by Isola et al. (2018). A decrease in annual temperature of the lake water may also have played concomitantly. However, the record from Lake Petit does not allow to further discuss the relative weight of these parameters.

References

Bini, M., Zanchetta, G., Persoiu, A., Cartier, R., Català, A., Cacho, I., Dean, J. R., Di Rita, F., Drysdale, R. N., Finnè, M., Isola, I., Jalali, B., Lirer, F., Magri, D., Masi, A., Marks, L., Mercuri, A. M., Peyron, O., Sadori, L., Sicre, M.-A., Welc, F., Zielhofer, C., and Brisset, E.: The 4.2 ka BP Event in the Mediterranean Region: an overview, Clim. Past Discuss., in review, 2018.

Isola, I., Zanchetta, G., Drysdale, R. N., Regattieri, E., Bini, M., Bajo, P., Hellstrom, J. C., Baneschi, I., Lionello, P., Woodhead, J., and Greig, A.: The 4.2 ka BP event in the Central Mediterranean: New data from Corchia speleothems (Apuan Alps, central Italy), Clim. Past Discuss., in review, 2018.

Ito, E., Yu, Z., Engstrom, D. R., & Fritz, S. C. (1998). Is paleoclimatic interpretation of oxygen isotope records from glaciated Great Plains possible. Abstracts, AMQUA, 15, 119.

Lotter, A. F., & Bigler, C. (2000). Do diatoms in the Swiss Alps reflect the length of ice-cover? Aquatic sciences, 62(2), 125-141.

Rautio, M., Sorvari, S., & Korhola, A. (2000). Diatom and crustacean zooplankton communities, their seasonal variability and representation in the sediments of subarctic Lake Saanajärvi. Journal of Limnology, 59(1s), 81-96.

Ribolini, A., Chelli, A., Guglielmin, M., & Pappalardo, M. (2007). Relationships between glacier and rock glacier in the Maritime Alps, Schiantala Valley, Italy. Quaternary Research, 68(3), 353-363.

Stichler, W., & Schotterer, U. (2000). From accumulation to discharge: modification of stable isotopes during glacial and post - glacial processes. Hydrological Processes, 14(8), 1423-1438.