Hydrol. Earth Syst. Sci. Discuss., 12, C6674–C6681, 2016
www.hydrol-earth-syst-sci-discuss.net/12/C6674/2016/

Hydrology and Earth System Sciences Discussions
Open Access

HESSD

12, C6674–C6681, 2016

Interactive Comment

Interactive comment on "Hydrological, chemical and isotopic budgets of Lake Chad: a quantitative assessment of evaporation, transpiration and infiltration fluxes" *by* C. Bouchez et al.

C. Bouchez et al.

bouchez@cerege.fr

Received and published: 10 February 2016

We are very grateful to our colleague S.P. Good for his insightful comments on our paper. All the issues raised are addressed below.

1- P11175-L2: Why not just write 20th century?

This is corrected in the revised manuscript.

2- P11175-L7: Lake surface AREA oscillations?

This is corrected in the revised manuscript.

Full Screen / Esc
Printer-friendly Version
Interactive Discussion
Discussion Paper

3- P11175-L19: Does endorheic not mean that there is no outlet?

This sentence is indeed ambiguous. It should be corrected such as "Althought it is the terminal lake of an endorheic basin dominated by evaporation, Lake Chad waters remain surprisingly fresh."

4- P11182-L25: According to eq (2) delta_E is a calculated value, not an input. Humidity and delta_A are inputs?

This is true, delta_E should not appear in the list of input variables while humidity and delta_A should appear. This is corrected in the revised manuscript.

5- L11183-L8: Is this not four locations? Kaloma and Kirenowa not shown on fig 1.

These two locations have been added to Figure 1 for the revised manuscript.

6- P11184-L13: What happened to figure 2 and 3? Something is out of order.

It is true that Figure 4 is called before Figure 2 and 3. The figure numbering is corrected.

7- P11189-L12: Shouldn't the Q_SN be positive into the north? Also check eq6 and 7

Indeed,there are mistakes in the sign of Q_SN in equations 6 and 7. The equations are corrected.

8- P11191-L11: Did you consider the effects of high salt concentration on fractionation during evaporation? There is some uncertainty about different kinetic fractionation factors, how was this addressed?

Lake Chad is a fresh water lake with salinity below 1g/L while salinity has effects on fractionation when concentrations exceed those of seawater (Gat, 1995). High concentrations are only simulated during episodes of drying of the Archipelagos that account for less than 1% of the whole time period. Although the isotopic model is probably too rough during these episodes, we did not focus on this extreme situation, neither in

HESSD

12, C6674–C6681, 2016

terms of results nor in the discussion, as we do not have data to constrain it.

It is true that there are uncertainties on kinetic fractionation factors, especially on the value of the θ parameter and it is an important issue also raised by J. Gibson in his review. The θ parameter is commonly set to 0.88 for lakes (Gat et al., 1994). However, because the evaporative conditions of Lake Chad are closer to the conditions of the eastern Mediterranean Sea than to those of the Great Lakes, we chose a value of 0.5 (Gat et al., 1996). Since the θ parameter drives the proportion of kinetic fractionation on total evaporative fractionation, for both isotopic species, it also controls the slope of the evaporation line. The value of θ= 0.5 yields a slope of 5 for the evaporation line, which matches the observed slope (see Figure below), while θ=0.88 would lead to a lower slope value (4). Moreover, we have evaluated the sensitivity of the model to this parameter and there is a clear impact of the choice of the kinetic parameter on the isotopic budget as it leads to an increase of 3‰ of the d18O in the Northern Pool and in the Archipelagos, where the evaporative flux is dominant. However, the calibration of FE using θ=0.88 yields greater ratios of T/ET in the three pools with a ratio of 55% in the Northern Pool which is not consistent with an open water body with few vegetation such as the Northern Pool between 1968 and 1970. Therefore, the chosen kinetic fractionation factors lead to more realistic results for Lake Chad.

We propose to add the following paragraph in the manuscript: (p. 11181 line 6) ”Few studies have focused on the determination of the θ parameter. Its value is generally lower than 1 for water body whose strong evaporation flux perturbs the atmospheric boundary layer (Horita et al., 2008), with a value of 0,88 estimated for the Great Lakes (Gat, 1994), and commonly used elsewhere. Nevertheless, a lower value (θ = 0.5) has been estimated for the Eastern Mediterranean (Gat 1996), attributed to the high contrast between the air column above the sea surface and the advected air masses. Thus, since low values may be expected when humidity is not measured near the lake surface (Gat et al., 1996), and because the Lake Chad evaporative conditions are closer to the conditions of the eastern Mediterranean Sea than to those of the

Great Lakes, we chose a value of 0.5. The choice of the θ value is also supported by the simulated slope of the evaporation line. Indeed, as the θ parameter drives the proportion of kinetic fractionation on total evaporative fractionation, for both isotopic species, it also controls the slope of the evaporation line. The value of θ= 0.5 yields a slope of 5 for the simulated d2H-d18O line, which fits the observed slope (see Section 6.2, and Figure below), while θ=0.88 leads to a lower slope value (4)."

Finally, the d2H-d18O cross plot showing the comparison between the observed evaporation line in Lake Chad and the simulated linear regression between d2H and d18O will be added to the manuscript (Figure below).

9- P11199-L13: Please discuss here (or elsewhere) the implications of a constant F_I and F_E. It is possible that infiltration is linked to surface area or lake depth. Similarly, there may be seasonality in vegetation abundance that influences transpiration rates. F_I, F_E and F_T are indeed defined as constant ratio but in the mass balance calculations they are multiplied both by ETI and the pool surface area to obtain volumetric fluxes. Therefore, simulated evaporation, infiltration and transpiration follow the climatic seasonality of ETI (defined in the paper as the seasonality of evaporation) and the hydrologic seasonality of the surface area variability.

This conceptualization is realistic for evaporation, which is the dominant proportion of ETI. For transpiration, it does not consider the possible seasonal changes of vegetation abundance. We should notice that this assumption is also underlying the chemical simulations based on vegetation at steady state. This is largely discussed in Paragraph 7.2 of our paper and we conclude that, if this assumption is worth being questioned for the peculiar area of Archipelagos, it should be realistic for the northern and southern pools.

According to this comment, we propose to add the following sentence to the discussion of the manuscript: (p.11201, line 18) "We made the assumption of a constant F_T ratio and no salt exportation associated to transpiration. However, this relies on a constant vegetation cover with a steady state turnover, corresponding to the natural vegetation cycle with no human exportation."

Regarding the infiltration flux, we agree that the choice of a constant ratio (F_I) multiplied by ETI and by the surface area to calculate infiltration needs to be better discussed. Indeed, since the lake and the quaternary aquifer are connected, a simple Darcy formulation indicates that infiltration should theroretically depend on the perimeter of the lake, on the saturated thickness and on the hydraulic gradient at the shoreline. Because of the huge surface variations characterizing the shallow Lake Chad, and the associated subsequent displacement of lake banks, Darcy's flux is presumably (at first order) mostly controlled by the geometry of the lake (i.e. its perimeter or surface area through a relashionship between surface area and perimeter). Therefore, alternatively to Darcy's calculation and for the sake of simplicity, we considered an infiltration flux proportional to the lake surface. It is roughly representative of the physical processes because the lake surface influences all the components of a Darcy's flow calculation in the same manner (variations of the lake perimeter at first order, hydraulic gradient and saturated thickness at second order).

The calibration of F_I and F_T provides a general good fit between observed and simulated chemical and isotopic values (Fig. 7) and a good simulation of the observed seasonality, which support the relevance of these parameters as defined in our model. However, there are still some discrepancies between simulations and observations that are above uncertainty ranges (Fig. 7). This was not discussed in our paper but could be related to the representation of F_I and F_T as constant values.

According to this comment, we thus propose to add the following discussion in the revised manuscript: (p.11199 line 24) "Despite uncertainty ranges on observed data, some discrepancies remain between the geochemical simulations and the observations, especially on the chemical simulations during the lake shrinking (between 1974 and 1978, Fig. 7). This could be linked e.g., to the use of a constant value of F_I, because the assumption of an infiltration flux only proportional to the lake surface area, although convenient, is an approximation of the Darcy's flux variations simultaneously dependent on lake level, perimeter and shorelines variations."

10- F1: What does the elevation colorbar correspond to? An outline of the Lake Chad Basin would be helpful on A.

The elevation colorbar corresponds to the altitude given by the MNT, this is added in the caption. The outline of Lake Chad is also added to figure 1.

11- F8: Why is the lake level upside down?

This representation could indeed lead to misinterpretation and the Figure is changed according to your advice.

Camille Bouchez, on behalf of all co-authors

Supplementary References Gat, J.R., Bowser, C.J., Kendall, C., 1994. The contribution of evaporation from theGreat Lakes to the continental atmosphere: estimate based on stable isotopedata. Journal of Geophysical Research 21 (7), 557-560, DOI: 10.1029/94GL00069

Gat, J.R., Stable isotopes in fresh and saline lakes, 1995, in Physics and Chemistry of Lakes, 139-165

Gat, J.R., Shemesh A., Tziperman, E., Hecht, A., Georgopoulos, D., Basturk, O., 1996.The stable isotope composition of waters of the eastern Mediterranean Sea. Journal of Geophysical Research Oceans 101 (C3), 6441-6451, DOI: 10.1029/95JC02829

Horita, J., Rozanski, K., Cohen, S., 2008. Isotope effects in the evaporation of water: astatus report of the Craig-Gordonmodel. Isotopes Environ.Health Stud. 44, 23-49.

Caption of the Added Figure : d2H-d18O cross plot showing the comparison between the observed evaporation line in Lake Chad in blue (according to Fontes et al., 1970b) and the simulated linear regression between d2H and d18O in Lake Chad in red. In

HESSD

12, C6674–C6681, 2016

Interactive Comment

addition, average isotopic compositions are showed for atmospheric moisture (purple) and simulated evaporates (green) above each pool (SP: southern pool, AR: archipelagos, and NP: Northern pool).

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 11173, 2015.

HESSD

12, C6674–C6681, 2016

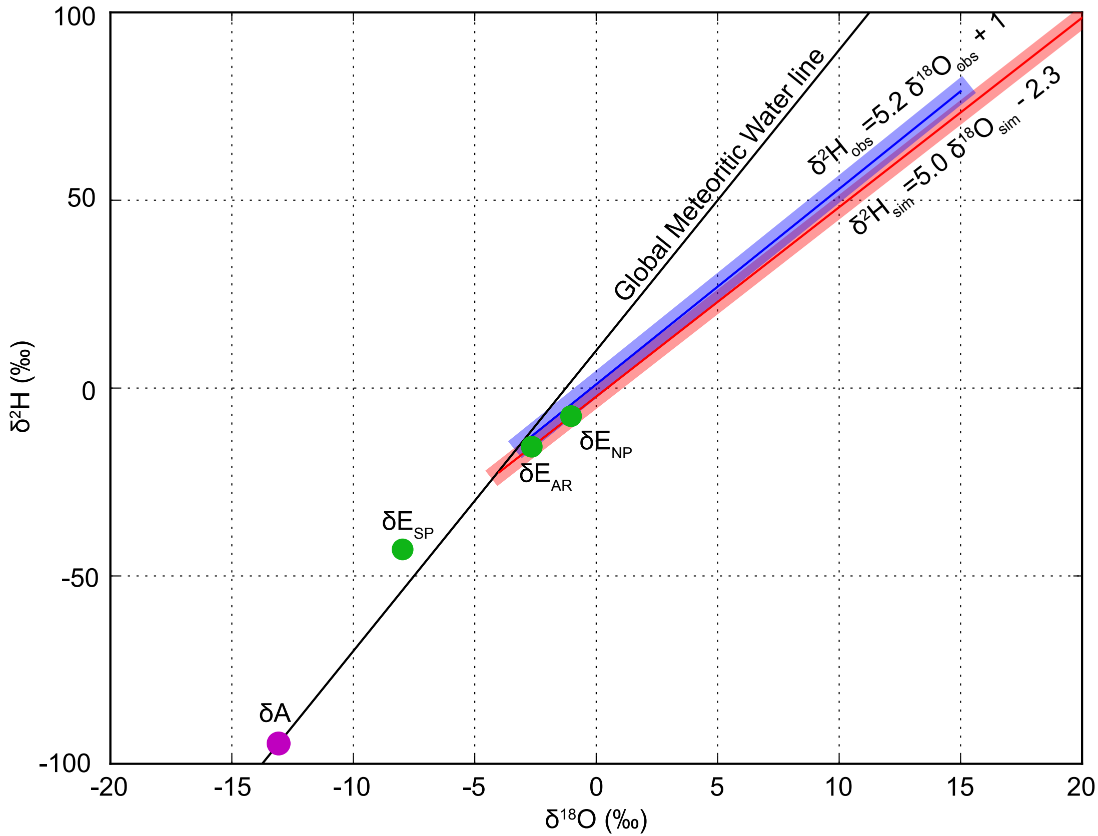

Fig. 1.