Hydrologic balance of Lake Geneva: insights from hydrogen and oxygen stable isotope compositions of water and carbon isotope compositions of dissolved inorganic carbonate

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With a total surface area of 580 km^2 and a maximum water depth reaching 310 m, Lake Geneva represents Europes largest freshwater reservoir. Given its central European position, large size, and long residence time of water (about 11 years as determined from mass balance of fluvial and precipitation inputs), the sediments and calcareous fossils (e.g. ostracods) in this Lake may represent a unique climatic archive. However, little is known about its past and present water budgets in terms of the mixing processes of its isotopically distinct sources of water nor the changes in loss via evaporation, all of which may have changed in concert with the changes in the regional climate. Sources include (e.g., CIPEL, 2005):
a) rivers from an Alpine catchment partially fed by glacial meltwaters, that is the Rhone which makes up about 70 to 80% of the total input,
b) rivers with a catchment including the Jura mountains and Molasse sequences, e.g. the Aubonne and Versoix, amongst others, which make up about 9 to 11%,
c) the Dranse with a catchment in the forealpine Molasse (about 5 to 7%),
d) direct precipitation with a contribution of about 5 to 8%, and
e) possibly some minor groundwater infiltration (volume unknown).

As a first step to help constrain the water balance of the Lake, six depth profiles have been analyzed during March and July of 2005 for their stable hydrogen and oxygen isotope compositions of water, and for that of carbon from dissolved inorganic carbon (DIC), shortly after a complete overturn of the Lake in March 2005. In addition, the isotopic composition of several rivers feeding the Lake, its outflow, and the local precipitation have been measured several times during the year.

δD and δ^{18}O values of the Lake average –90 and –12.4‰, respectively. These values are identical to those measured in short profiles to depths of about 12 m during the 60's (Fontes and Gonfiantini, 1969). This is surprising as the isotopic compositions of precipitation and rivers in Switzerland have changed by at about +1‰ as a result of changing climate over the course of the last two decades (data from NISOT, 2004). Because the isotopic composition of the Rhone, which itself is partially fed by glacial melt waters, has changed in parallel with the precipitation, larger amounts of glacial melt water contributions cannot account for this constancy in isotopic composition. Instead, mass balance models on the overall budget of the lake indicate that this constancy may well be related to a larger evaporative loss in the past compared to today (from about 5% to 1.5% by volume of the total runoff). Such a decrease in evaporative loss over the past decades runs parallel to an increase in the relative humidity accompanying the rise in mean annual temperature over the same period.

Both δD and $\delta^{18}O$ values are slightly higher in winter (–89 and –12.2‰) compared to summer (–90 and –12.6‰), paralleling the much larger seasonal variation of the Rhone and indicating that the water is quite responsive even to seasonal changes. The profiles also support distinct layering of the lake with a surface layer of 5 to 10 m depth influenced by evaporation, a middle layer between 10 to 90 m influenced by descending, commonly colder waters of the Rhone and other local rivers, and a deep layer of homogeneous isotopic composition.

The DIC also clearly reflects the complete turnover of the lake during winter, with very little to no significant variation in $\delta^{13}C$ values in the depth profiles for the March sample collection campaign. The values average about –7.0‰ to –6.2‰, depending on the location of the profile in the lake. Profiles taken closer to the rivers clearly allow the infiltration of river waters with $\delta^{13}C$ values deviating towards more positive values (Rhone; reaching about –3‰ just in front of the Rhone), or more negative values (down to –10‰; Jura rivers in summer) to be recognized. Similarly, a strong stratification of the lake is indicated during summer where the profiles have $\delta^{13}C$ values of between –4 to –3‰ because of the bioproductivity in the upper water column. In addition, mixing with waters from the Rhone is still well pronounced ($\delta^{13}C$ of up to –5‰) for depths between 10 to 90 meters even within the centre of the lake. For larger depths the profiles again have $\delta^{13}C$ values similar to those for the flat winter profiles of about –7‰. Mass balance calculations also indicate an overall enrichment in ^{13}C of up to 1‰ relative to the total input from the rivers, likely related to an exchange with atmospheric CO_2.

REFERENCES

CIPEL, 2005. Rapport compagne 2005, commission internationale pour la protection des eaux du Léman contre la pollution.
Fontes J.C. and R. Gonfiantini (1969). Composition isotopique et origine de la vapeur d’eau atmosphérique dans la région du Lac Léman. Earth Planet. Sci. Lett. 7: 325-339.
NISOT (Network for isotopes in Precipitation), 2005. Office fédéral de l’environnement (OFEV) et hydrogeology, Confédération Suisse, date d’accès 15.11.2005 (http://www.bwg.admin.ch/themen/geologie/f/sekhg.htm#nisot).