Growth Conditions for Mougeotia sp. in Lake Geneva
Damien Bouffard, EPFL Physics of Aquatic Systems Laboratory
Orlane Anneville, INRA UMR CARRTEL
Frédéric Rimet, INRA UMR CARRTEL

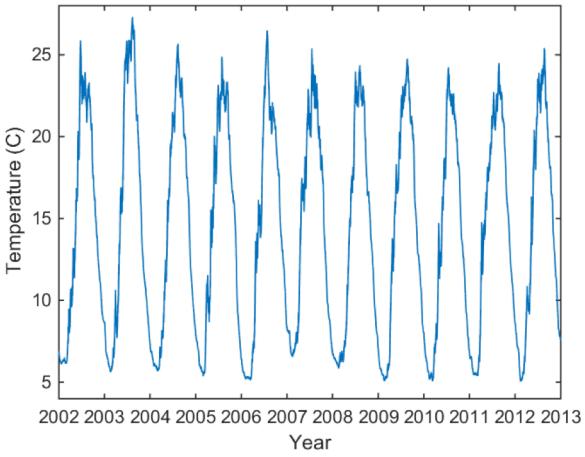
Growth Conditions for *Mougeotia sp.* in Lake Geneva

Lake Geneva (89 km3, 580 km^2), the largest freshwater body in Western Europe, has been recovering from eutrophication since the 1980s. The excessive load of nutrients has led to a total phosphorus concentration of up to 0.092 mg/L in the eighties but active political restoration plans including construction and improvement of waste water treatment plants, ban of phosphorus in textile washing products have gradually improved the trophic status of the lake. Nowadays, the lake is back to a mesotrophic state but still far from its targeted phosphorus goal (0.010 – 0.015 mg/L).

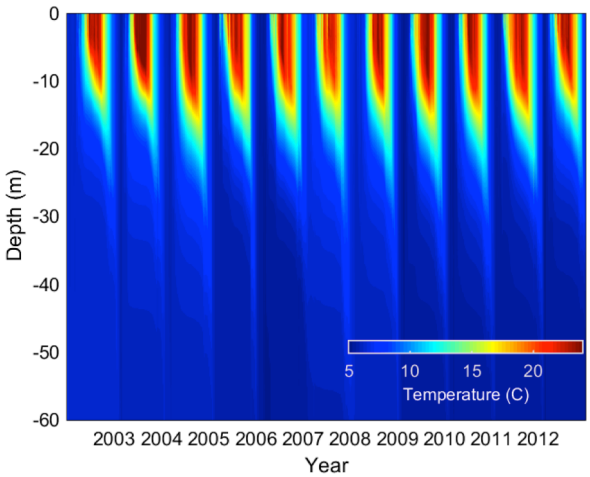
The Lavaux on the northern shore of Lake Geneva is a famous wine land and World Heritage site.

Baseline Conditions from Environmental Monitoring

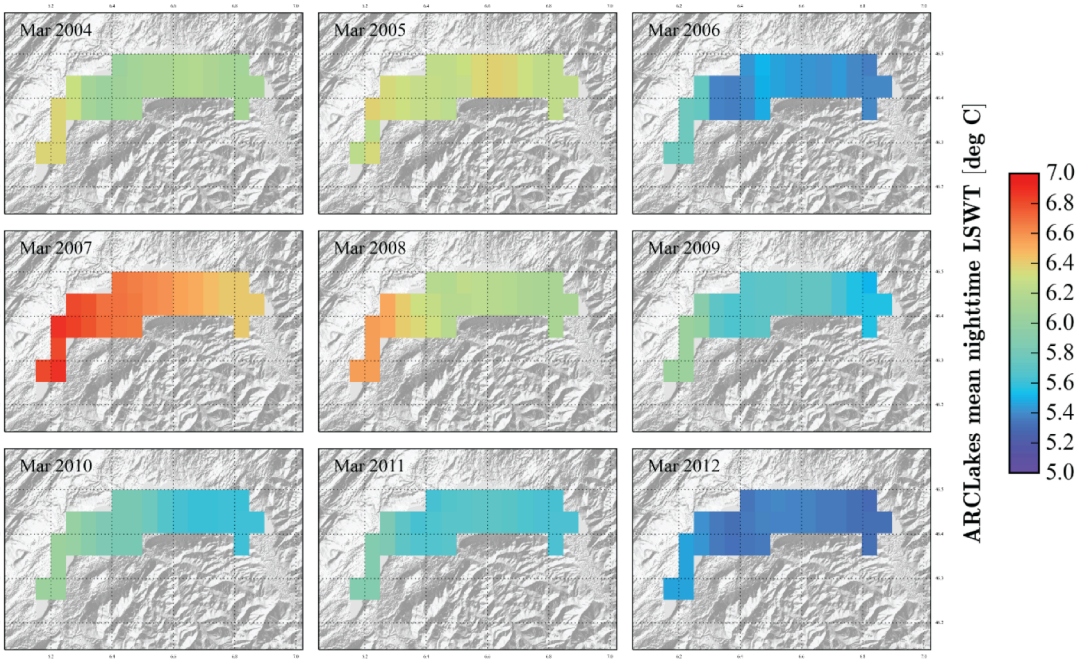
Since 1957, the Commission Internationale pour la Protection des Eaux du Léman (CIPEL) has been coordinating the monitoring of Lake Geneva. Nowadays, in situ measurements are carried out with a monthly to bimonthly sampling period over two locations and the data are stored in the SOERE OLA database (INRA – UMR CARRTEL Thonon les Bains, France). Such unique database allows among others to evaluate the biological response to the recent change in nutrients concentrations and to the dynamic of the water column. In Lake Geneva, a typical biological years starts in winter with a partial or total mixing of the water column depending on the winter, which redistributes the nutrients through the water column. The following warming of the superficial water in spring triggers the onset of the phytoplankton activities with a first peak typically followed by a clear water period (drastic reduction of phytoplankton abundance in mesotrophic lakes) due to zooplankton grazing. The second part of the year is characterized with warm surface water but limited nutrients supply due to the presence of a sharp thermocline limiting vertical fluxes.



Modelled surface temperature for the period 2002-2012. Note the comparatively warm winter 2007.

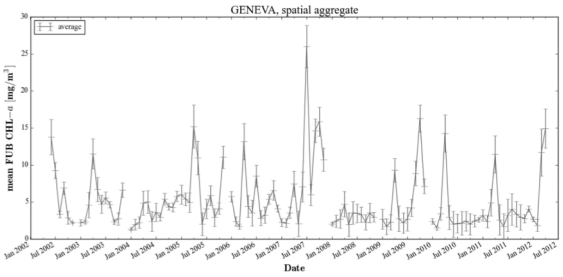


Modeled temperature over the water column for the period 2002-2012 showing a classical seasonal evolution of the thermic structure. The section below 60 m is not shown here.



Monthly nighttime mean surface temperature in March for the period 2004-2012 as a final product from Diversity II. Note the comparatively warmer surface temperature in March 2007.

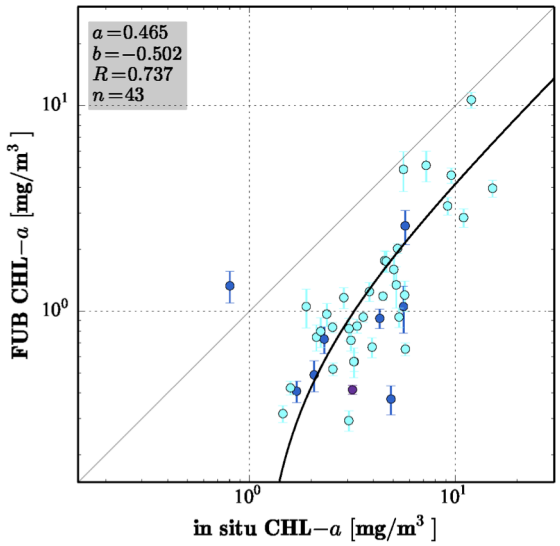
In-situ time serie of chlorophyll-*a* concentrations were used to calibrate the monthly averaged FUB chlorophyll-*a* concentrations in Diversity II. The fit is based on 43 matchups and the correlation is insured by a coefficient of determination of 0.74. The analysis of the time serie of FUB data shows a strong seasonal variability of the phytoplankton with concentration reaching up to 30 mg/l in summer 2007. Over the studied ten years period, we observe a slightly decreasing trend (27 % over one decade) in the time serie of chlorophyll-*a* concentrations. This trend is also observed in the 20 years averaged chlorophyll-*a* concentrations (Kiefer et al., submitted).



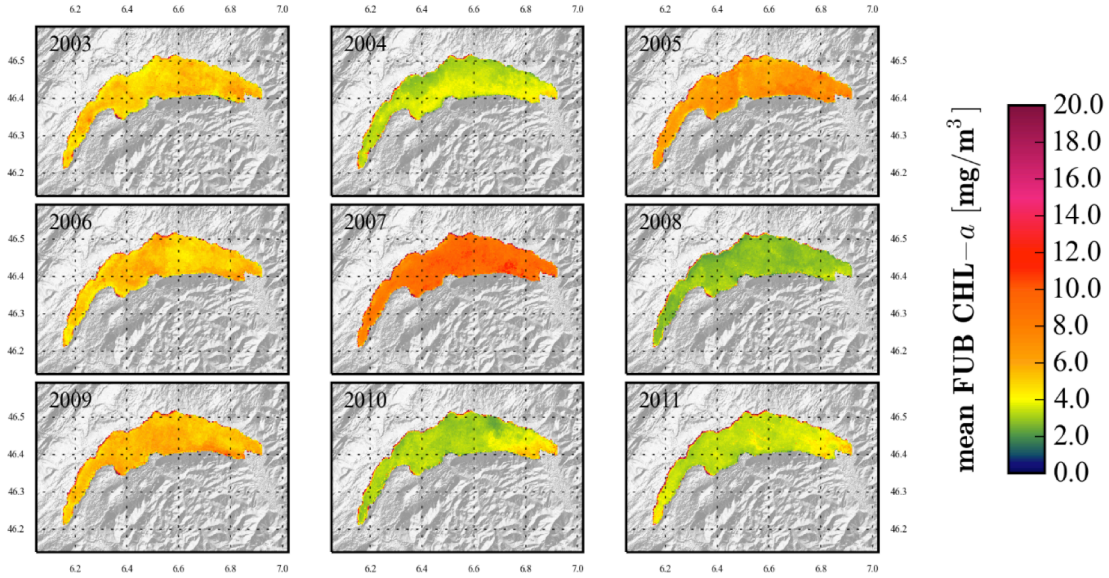
Time serie of remotely observed chlorophyll-a concentration for the period 2002-2012.

The 2007 algal bloom

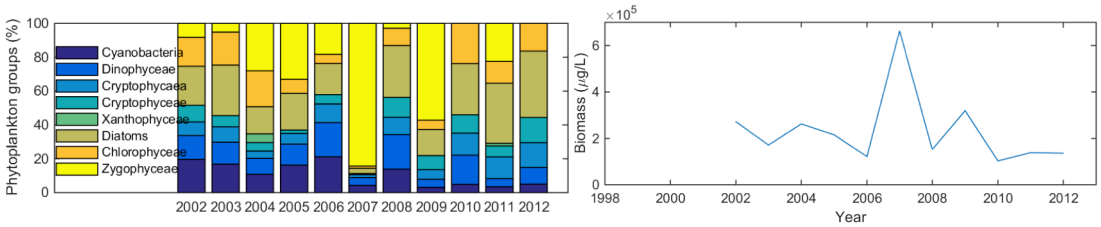
Beside the decreasing trend, the high peak of chlorophyll-*a* in year 2007 deserves more investigation. The specific elevated biomass conditions related to the year 2007 are clearly noticeable with the yearly averaged chlorophyll-*a* concentration maps from Diversity II. Rimet (2014) showed with an algal functional group analysis that the species contribution to the total phytoplankton biomass carried out by the CIPEL was significantly different from other years. The 2007 algal peak was



Correlation between the remote sensing chlorophyll-a estimates and the in-situ observation (in log-log scale). The best fit R = 0.737 is given by CHLa_FUB = 0.465 CHLa_in_situ -0.502.



Yearly averaged chlorophyll-a product from Diversity_II for the period 2003-2011 in Lake Geneva.



Annual mean phytoplankton groups and biomass in Lake Geneva. Data from Rimet (2014).

finally associated with an unusual bloom of *Mougeotia sp.* (Zygophyceae). The circumstances leading to such blooms are still the focus of active research but some factors favouring the blooms have already been identified. (Tapolczai et al., 2015) suggested among other factors that *Mougeotia sp.* can efficiently take benefit from:

- a warmer winter than the average (the coldest daily temperature for 2007 being 6.5 °C and mean coldest daily temperature for the 2002-2012 period being 5.2 °C),
- an early onset of the thermocline in spring (12 days earlier than the average),
- and, a slightly warmer average temperature in the upper layer (0.4 °C) over the summer compared to the reference period 2002-2012.

Conclusions

The year 2007 is characterized by a mild winter and an early thermocline development, which are consistent with an earlier growth of *Mougeotia sp*. This analysis shows the strong relationship between the dynamics of the water column and specific algal growth. Interestingly, the possibility for this phytoplankton species to growth at deep depth may have prevented satellite observations to remotely capture its apparition but the chlorophyll-*a* final product from Diversity II has clearly identified the year 2007 as unusual with a much higher averaged chlorophyll-*a* concentration than for the other years.

Further development in improving the coupling between analyses of field data, satellite observations and 3D modelling, will lead to better knowledge of processes occuring in lakes and better understand the drivers of phytoplankton dynamics.

Further reading

Kiefer, I., Bouffard, D., Odermatt, D., Anneville, O., and Wüest, A. (submitted). Application of remote sensing for the optimization of in-situ sampling for monitoring of phytoplankton a-bundance in a large lake. Sci. Total Environ.

Rimet, F. (2014). The phytoplankton of Lake Geneva (Thonon-Les-Bains, France: INRA UMR CARRTEL).

Tapolczai, K., Anneville, O., Padisák, J., Salmaso, N., Morabito, G., Zohary, T., Tadonléké, R., and Rimet, F. (2015). Occurrence and mass development of Mougeotia spp. (Zygnemataceae) in large, deep lakes. Hydrobiologia *745*, 17–29.