Identifying GLEON's sites recording annually-resolved sediments over the last centuries

JENNY Jean-Philippe[1], FRANCUS Pierre[1], NORMANDEAU Alexandre[2], PERGA Marie-Elodie[3]

Contact: jphilippe.jenny@gmail.com

1 INRS, Centre Eau Terre Environnement, Université du Québec, Canada ;
2 Département de géographie, Université Laval, Québec, Canada ; 3 INRA, Université de Savoie, UMR CARRTEL, Thonon les Bains, France

* All references can be found on www.inra.fr/iper_retro

Location of sites with annually-resolved sediments

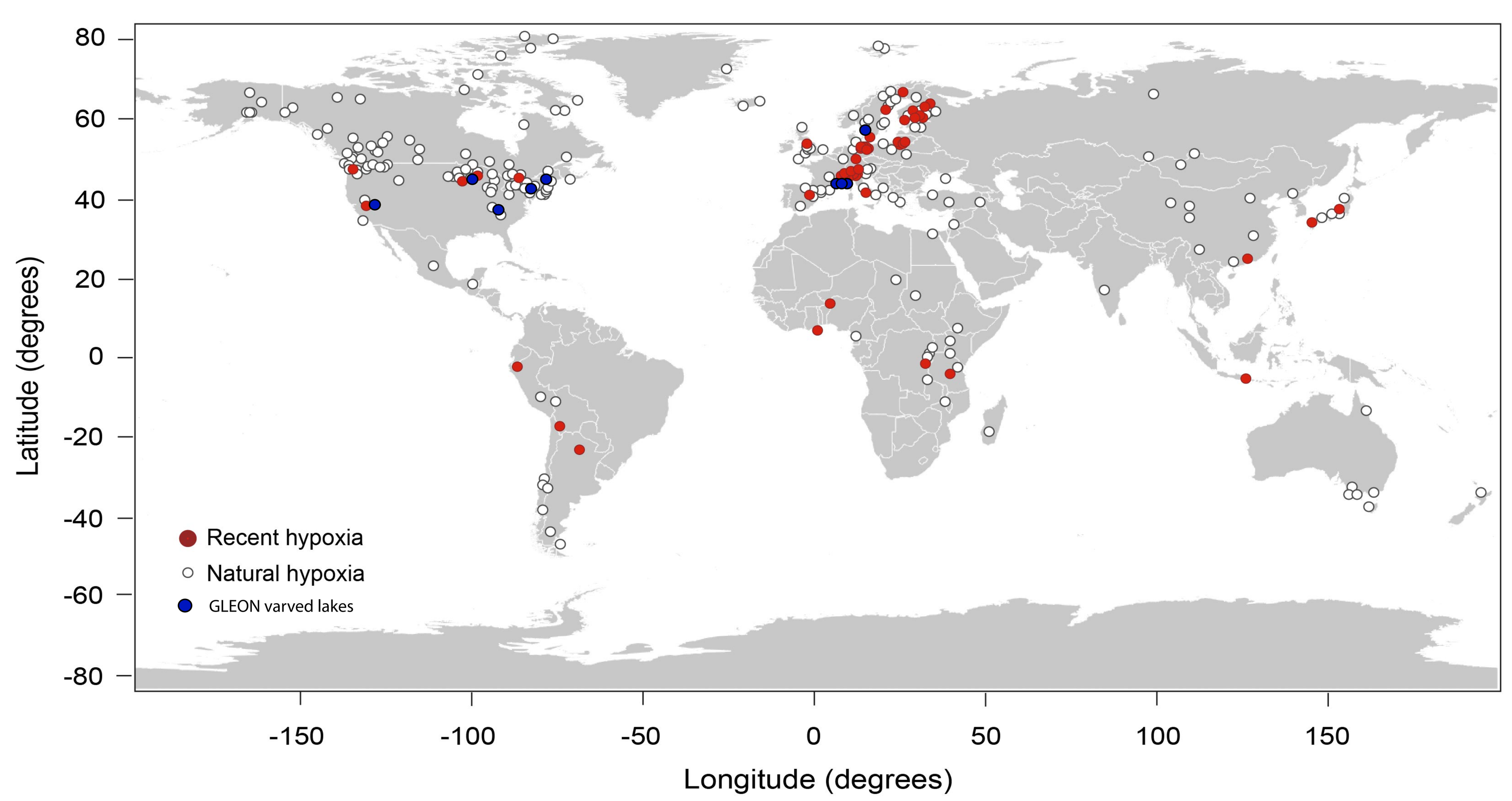

Fig. 1 Localisation of the 365 sites recording natural and recent hypoxia in continental waters

Global climate change and widespread occurrence of eutrophication have increased the intensity, duration and extent of natural hypoxia, threatening aquatic ecosystem functions, services and biodiversity. When annual oxygen concentrations fall below a critical point (combining time and intensity) macro-benthic life disappears, therefore stopping bioturbation and related sediment mixing. This threshold is well recorded through the formation of laminated sediments in general and «varves» when they specifically track annual deposition.

Here, we compiled published records of laminated and varved sediments from 1,246 lakes distributed on the six continents in order 1) to depict the dynamics of global hypoxia for freshwaters over the last 300 years and 2) to locate high potential archives that recorded past environmental conditions with annual resolution, and those related to GLEON's sites.

Achieving high time-and- space resolution on 3 GLEON's sites

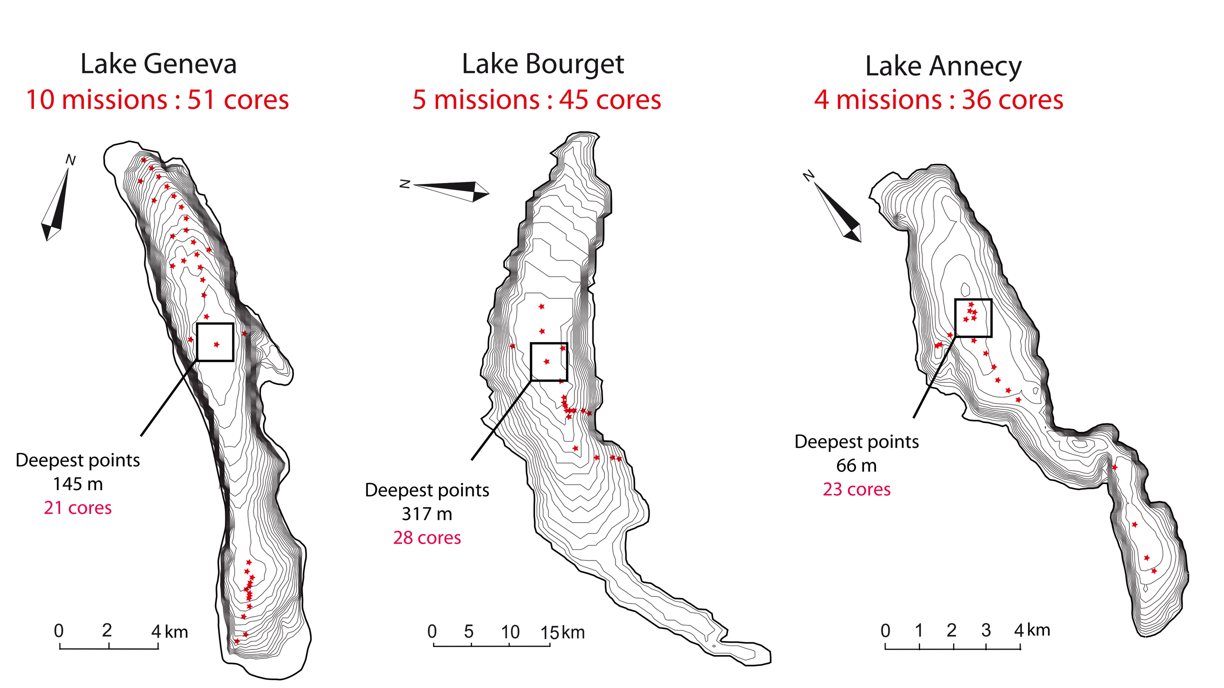

Fig. 2 Annual dating of core samples based on varves counting

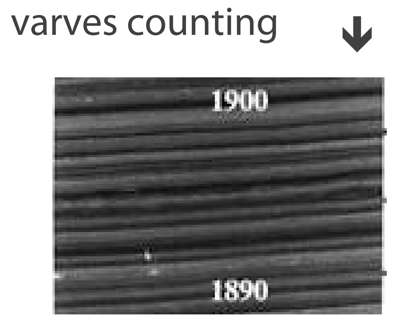

Fig. 3 Location of the 122 cores collected to reconstruct annual changes in hypoxia volumes

Lakes Geneva, Annecy and Bourget (France) are three deep, peri-alpine lakes which anthopization has been increasing from the beginning of the 20th century. As a consequence, they all underwent eutrophication by the end of the 1970s. Although P abatment measures have been successful, monitored data indicate hypoxia ([O]< 2mg L-1) remains in bottom waters, causing habitat reduction of benthic macro-organisms and fishes.

Global dynamic of hypoxia in continental freshwaters reconstructed from annually-resolved sediments

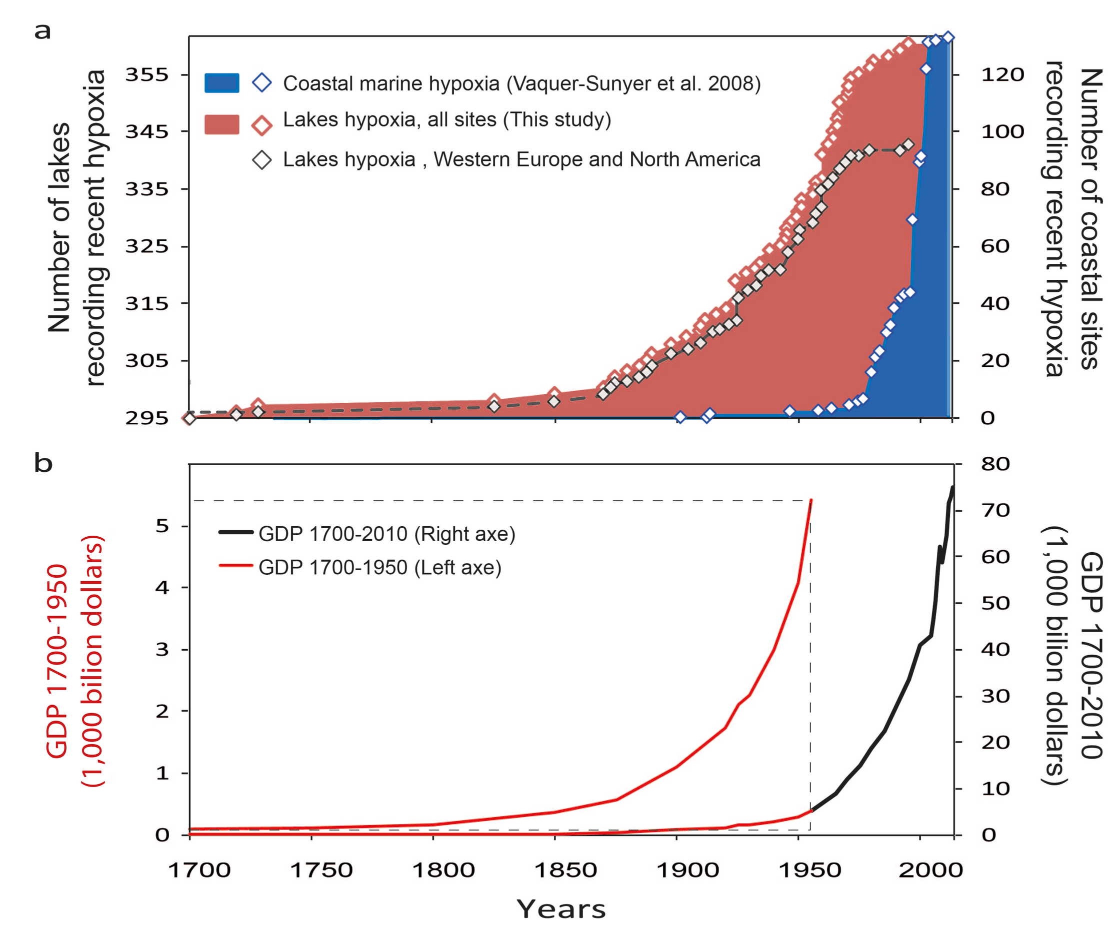

Fig. 4 Temporal changes in terrestrial and marine hypoxia over the last 300 years (Jenny et al. submitted)

In marine environments, instrumental analysis showed that the number of hypoxic coastal sites has increased exponentially since the 1950th. However, long-term monitoring in continental zones remains challenging, preventing global reconstructions of hypoxia's dynamic so far.

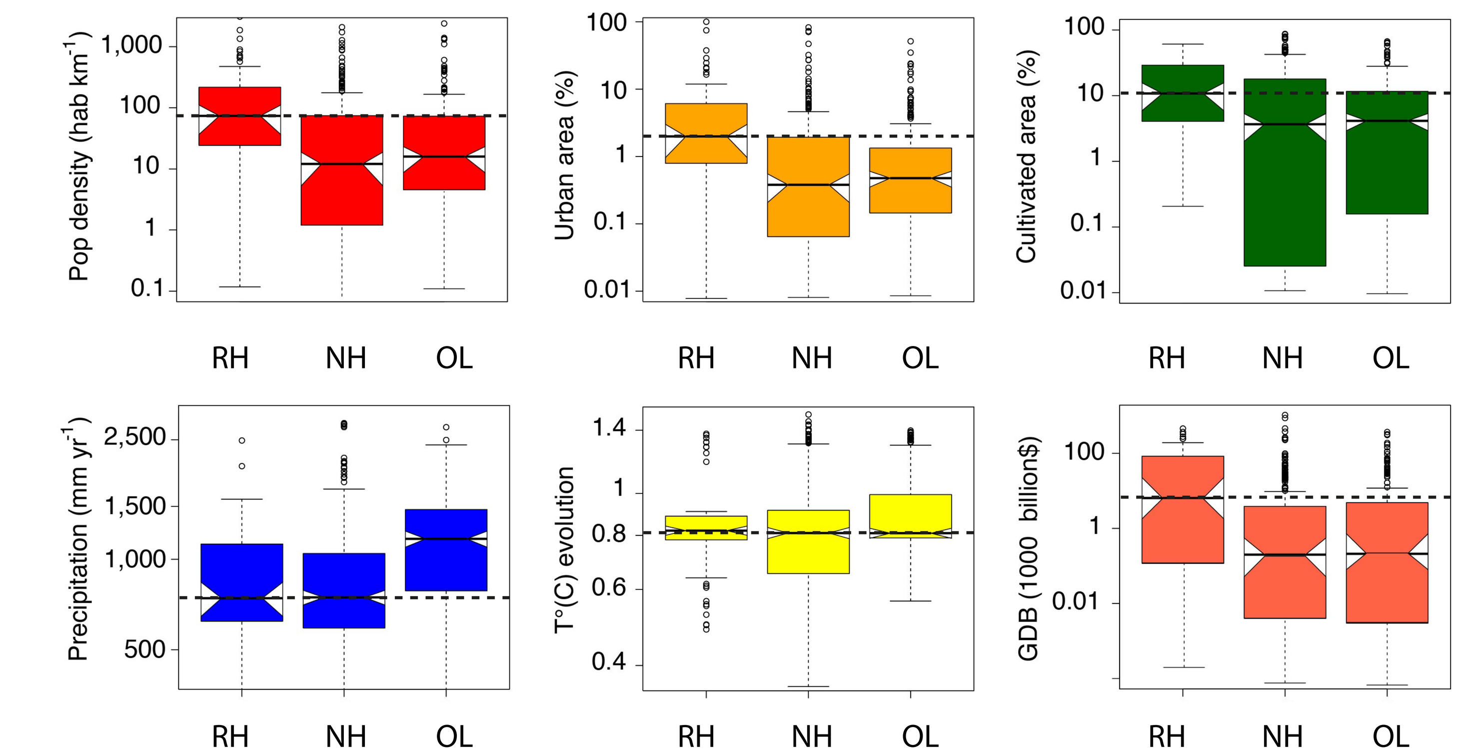

Fig. 5. Box plot describing proportion of anthropogenic, climatic and land use characteristics in the watershed of hypoxic and oxygenated sites. RH: Recent hypoxic lakes; NH: Naturally hypoxic lakes; OL: oxygenated lakes (Jenny et al. submitted)

Statistical population analysis suggests that only anthropogenic factors affected the recent development of hypoxia (Fig. 5). Overall, lakes from urban and agricultural regions or with higher human population density (>80 hab.km-2) and higher GDP, are more likely to develop recent hypoxia (Fig. 5, $p<0.005$).

Local dynamic of hypoxia from 4D analysis of annually-resolved sediments

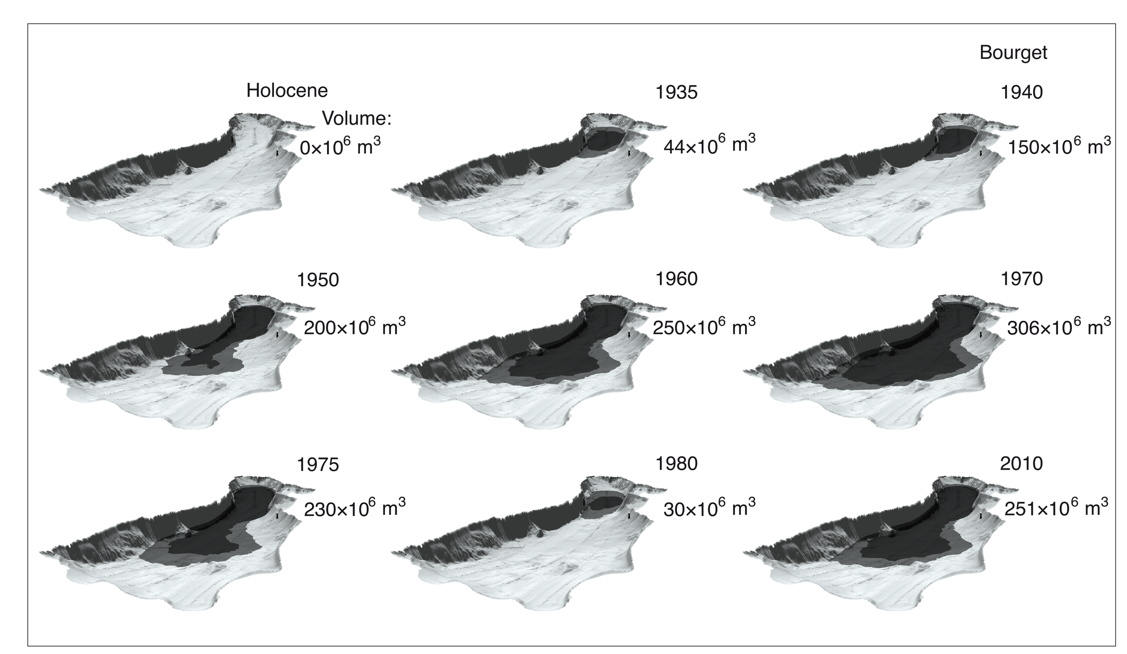

Fig. 6 Spatio-temporal extension of lake oxygen depletion in Lake Bourget as reconstructed from 4D varves preservation (Jenny et al. L&O ; 2013)

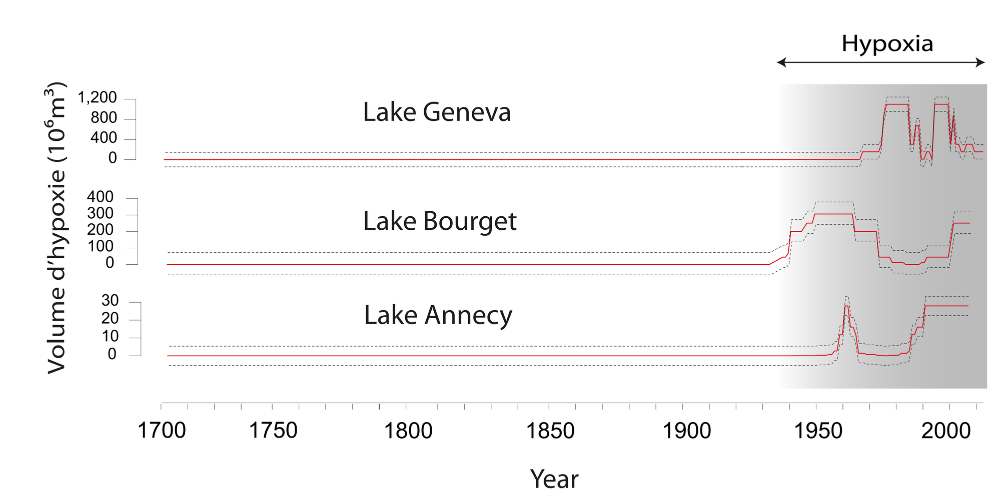

Fig. 7 Temporal evolution of lake oxygen depletion in the 3 lakes indicates an unpressedent ecological shift in the mid- 20th century (Jenny et al. GBC ; accepted)

Conclusion

This research contributed to the reconstruction of hypoxia dynamics worldwide and to the identification of the actual causes of lake hypoxia, compensating the lack of monitoring data by using paleo-approaches at high time-and space resolution

This analysis shows that continental anthropogenic hypoxia has been spreading worldwide since the turn of the 1900th. Therefore, spreading of terrestrial hypoxia has preceded by 50 years that in marine environments, which indicates how reactive and vulnerable are smaller sites, closer to anthropic sources. However, the persistence of hypoxia, well after the implementation of remediation programs in industrialized countries, shows that both marine and terrestrial systems are not responding so far to nutrient emissions reduction.

Paleolimnological investigations can further extend in time the long term instrumental records of lake oxygen regime, compensating for the lack of past monitoring datasets, and address the complexity of the oxygen dynamics in continental waters.

Jenny, J.-P. et al. A spatiotemporal investigation of varved sediments highlights the dynamics of hypolimnetic hypoxia in a large hard-water lake over the last 150 years. Limnol. Oceanogr. 1395–1408 (2013).