Mixing mechanisms and hydrodynamics of Passaúna Rerservoir

One year of continuous measurements of temperature and dissolved oxygen helped us to identify the key physical mechanisms that govern the mixing processes and also the influence of the Buffer on the reservoir.

Context

River inflows, rich in nutrients and organic matter, can enter the reservoir as underflows along the bottom of the reservoir, favoring the deposition of particles on the sediment. If the inflowing water is lighter (warmer) than the water in the reservoir, it enters as an overflow, delivering nutrients to the photic zone and thus promote phytoplankton growth. Further, the lack of deep-water renewal by underflows and weak vertical mixing promote the formation of hypoxic or anoxic conditions in deeper layers of the stratified reservoir. Oxygen depletion triggers the formation of toxic substances, such as hydrogen sulfide, causes enhanced release of phosphorus and promotes the production and potential emission of the greenhouse gases methane and nitrous oxide. Therefore the comprehension of reservoir hydrodynamics is essential for successful mitigation of adverse effects of reservoir construction, for achieving good water quality and drinking water safety, as well as for predicting future changes.

Objectives/Goals

- Understand the main hydrodynamic processes and drivers of density stratification
- Comprehension on the importance of the Buffer on reservoir hydrodynamics

Method nad Equipment

The measurements were made between February 2018 and February 2019. We measured water temperature in the Passaúna River, after the buffer region and at 11 depths (1 m vertical spacing) in front of the intake station. Two optical oxygen sensors were deployed with the thermistor chain to measure dissolved oxygen concentration near the water surface (at 1 m water depth) and near the bottom (at 2 m above the bed), respectively (Fig. 1).

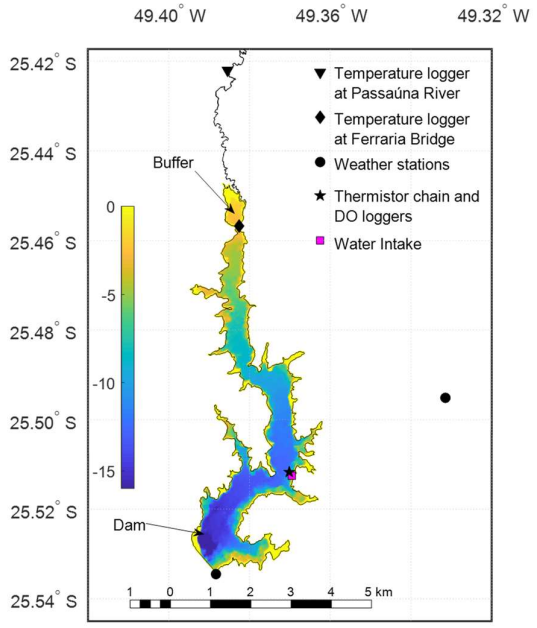

Figure 1 : Map of the study site picturing Passaúna Reservoir, Passaúna River, Buffer and Dam. Locations of monitoring points are indicating in the legend and the colormap shows the depths in meters.

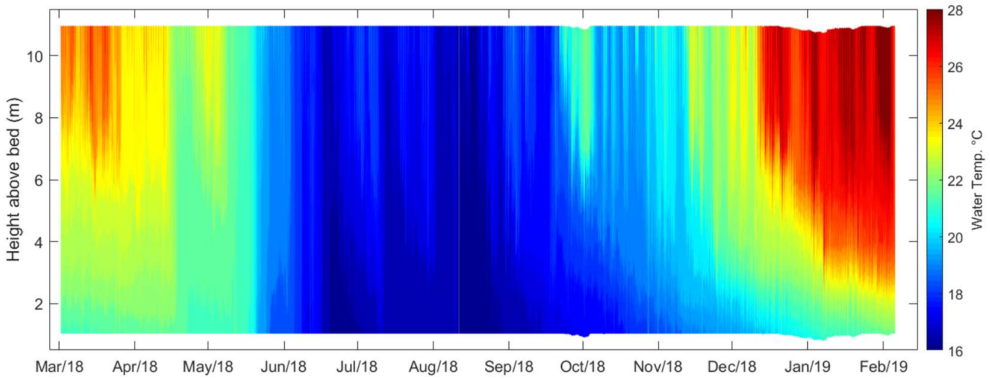

Figure 2: Time series of the measured temperature with the thermistor chain at the Intake region

Results

- Passaúna reservoir was continuously stratified during spring and summer, while frequent mixing and episodic stratification periods were observed during autumn and winter Fig. 2).
- 95 days were mixed from a total of 343 monitored days, representing 72%.
- Observed mixing regime can be classified as discontinuous warm polymictic, it is characterized by more than one mixing period throughout the year and stratified periods lasting for days to weeks.
- Density stratification was particularly strong, related to the strong temperature dependence of density at high temperature.
- Even during shorter periods of stratification during the mixing season, dissolved oxygen concentration near the bottom decreased rapidly (Fig. 3).
- In addition to meteorological forcing, stratification was affected by lateral flows related to river inflow, mainly due to the addition of colder water at the bottom with underflows (Fig. 4).
- The Buffer influences the inflow temperature, and consequently the flow paths into the reservoir.
- For the hypothetical case that the Passaúna River would flow directly into the main reservoir, without passing through the Buffer, the flow path changes towards more frequent underflow situations and lack of overflow (Fig. 4).

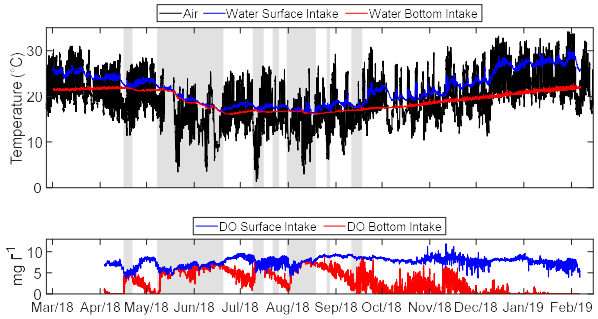

Figure 3 : upper pannel time series of air and water temperatures at the Intake. Lower pannel time series of dissolved oxygen concentrations at the Intake. Grey patches indicate the mixed periods and white areas are stratified.

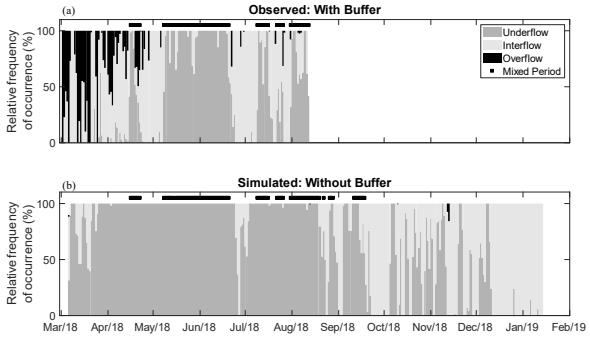

Figure 4: Stacked bar graphs showing the relative frequency of occurrence of different inflow characteristics (flow paths) of the Passaúna River into the main reservoir. (a) Based on observed temperature at Ferraria Bridge. (b) Simulations based on river water temperature measured upstream of the buffer. Data are presented as daily averages of the relative contribution of different flow paths. Square symbols above both panels mark time periods classified as mixed, while during the remaining periods the reservoir was stratified.

Innovation/Outlook

- ✓ High resolution data improved the understanding of reservoir hydrodynamics.
- ✓ Comprehension of the importance of the Buffer for reservoir stratification.
- ✓ Changing inflow conditions without the Buffer, lead to increasing stratification and reduction of the frequency and duration of mixing events. However, bottom water renewal may also reduce the anoxic period's duration.
- ✓ The simulation of inflow dynamics without Buffer can guide the long-term planning for the reservoir operator, as the Buffer is subject to ongoing siltation.

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