*Lesson Plan*

**Modelling exercises: lakes and reservoirs**

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**Objectives and goals**

The aim of this class is to provide a first-hand experience with hydrodynamic modelling of thermally stratified lake, highlighting the assumptions and limitations that underlie the solutions obtained with Delft3D, helping students gain a sufficient understanding of the complexity of hydrodynamic of thermally stratified lakes and reservoir.

**Subject Matter**

Outline of the class content:

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| Title | | Content |
| Introduction to stratified flows | | Brief introduction of the mechanisms that causes stratification and its implication to currents into the lake interior |
| Governing equation of motion and Delft3D solution | | Brief explanation on how Delft3D-FLOW solves the governing equation of motions considering the influence of thermal and salinity stratification |
| Hypothetical Reservoir | Initializing the vertical profile | Demonstration on how create a vertical stratification profile of temperature, salinity, and constituents |
| Wind shear at stratified closed water body | Demonstration of Poincaré Internal waves induced by wind shear on a thermally stratified lake |
| Exchange of Heat flux at water surface | Demonstration of daily and seasonal variation of lake temperature |
| Discharges | Demonstration of gravity currents evolution induced by discharges waters. |

**Methods**

* Theoretical description (Slides): A brief explanation of the governing equation of motion and transport of dissolved substances, including the transport of salinity and heat fluxes.
* Exercise (Delft3D): One exercise from a hypothetical reservoir used to illustrate the mechanisms observed in thermally stratified lakes/reservoirs (e.g. daily and seasonal variation of temperature stratification and the formation of internal waves and gravity currents).
* Additional exercises (Delft3D): Using the hypothetical reservoir, create a new vertical profile (e.g. continuous thermal stratification), change the wind speed (e.g. duplicate), and change some parameters of the heat flux model (e.g. Secchi depth) and discharge (e.g. flowrate or temperature).

**References**

* Deltares, D., 2013. Delft3D-FLOW user manual. *Deltares Delft, The Netherlands*, *330*.
* Imboden, D.M., 2004. The motion of lake waters. *The Lakes Handbook,*, *1*, pp.115-152.
* de Carvalho Bueno, R., Bleninger, T. and Lorke, A., 2021. Internal wave analyzer for thermally stratified lakes. *Environmental Modelling & Software*, *136*, p.104950.
* de Carvalho Bueno, R., Bleninger, T., Yao, H. and Rusak, J.A., 2021. An empirical parametrization of internal seiche amplitude including secondary effects. *Environmental Fluid Mechanics*, *21*(1), pp.209-237.

**Recommended prerequisites**

* Fluid Mechanics
* Basic concepts of limnology