Management of Climatic Extreme Events in Lakes and Reservoirs for the Protection of Ecosystem Services
European Joint Doctorate Innovative Training Network GA 722518

POLICY BRIEFING NOTE 3

Exploring the effects of climate extremes on lakes: modelling lake stratification

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INTRODUCTION

Changes in the local weather are fundamental drivers of change in lake ecosystems. Recently, however, there has been an increasing focus on the potential effects of climatic extremes, such as storms and heatwaves, on lakes and reservoirs. These extreme events are projected to become even more intense and frequent due to climate change. The EU funded Innovative Training Network (ITN) MANTEL* investigated the potential impacts of such extremes using near real-time data, long-term monitoring data, and lake models. This briefing note describes new advances on the implications of climate extremes for lakes and reservoirs based on modelling work undertaken in MANTEL.

BACKGROUND

- The water column in lakes and reservoirs commonly stratifies into discrete layers during warmer weather, with a layer of warmer water in the upper part of the lake (red in Fig. 1a), and cooler waters below (blue in Fig. 1a).
- Once the lake stratifies, these layers do not generally mix with each other. They are separated by a zone where the water temperature changes rapidly from warmer to cooler, called the thermocline.
- This layering has implications for water quality. For example, toxic algal blooms are more likely to occur when there is strongly stratification. The water in the bottom layer is separated from contact with the atmosphere and can become depleted in oxygen. Storms can also mix sediment and nutrients from lower waters up to the surface.
- Mathematical models of lake thermal structure can be used to investigate changes in lake stratification patterns due to climate change, information that could aid decision making and planning.
- This policy brief describes advances in **modelling changes in lake stratification** based on outputs from MANTEL.

OVERVIEW OF THE ADVANCES IN OUR KNOWLEDGE

There have been **four** outputs from MANTEL researchers and colleagues that have increased our ability to accurately model the impacts of climate extremes on lake and reservoirs and provided new insights into these effects:

1. A study by Mesman and others[1] compared the ability of three models to simulate the effects of storms and heatwaves on lake stratification. It found that the models could reproduce the overall direction and magnitude of change during climate extremes. They did note a higher level of uncertainty associated with model simulations for periods of extreme weather when compared to reference periods which should be considered when interpreting the results of such studies.
2. Modelling studies are often based the outputs of several models rather than on a single model. The suite of models used is referred to as a 'model ensemble'. Setting up and running multiple models, however, can be challenging and time consuming, A new package written in R, LakeEnsemblR, was developed by group that included MANTEL researcher Jorrit Mesman and published by Moore and others[2] This new R package facilitates running model ensembles using five models of lake thermal structure. The package can be accessed at the link provided below.
3. A single site study of the effects of future climate change on lake thermal structure was undertaken at Lake Erken, Sweden, by Ayala and others.[3] The study also compared the use of daily versus hourly data to simulate future changes in lake water temperature and found that a daily time step was sufficient. It estimated that by the late 21st century, surface water temperatures in Lake Erken were projected to increase on average by 1.79 ∘C based on a low greenhouse gas emission scenario, and by 3.08 ∘C based on a medium greenhouse gas emission scenario. This change in temperature led to an increase in the length of the period when the lake was stratified of 13 days for the low greenhouse gas emissions scenario and 22 days for the medium greenhouse gas emissions scenario (Fig. 1).

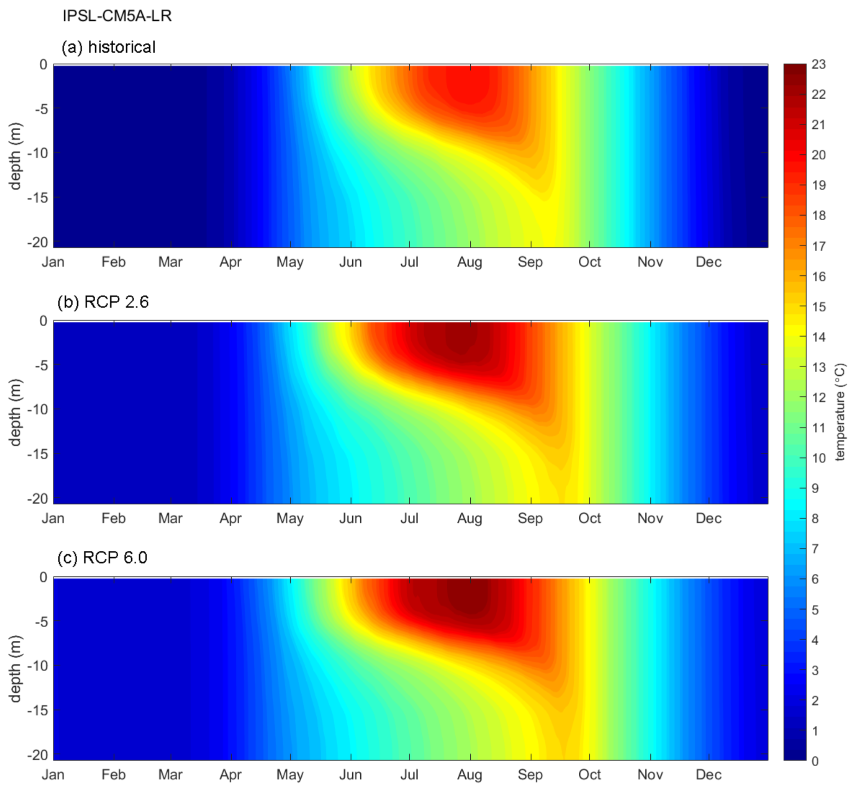

Fig. 1: water temperature over the lake depth and across the year for the (a) historical, (b) low greenhouse gas emissions increase (RCP2.6), and (c) medium greenhouse gas emissions increase (RCP6.0) scenarios for Lake Erken. The plots show the average for modelled daily temperature profiles across all years for each scenario.

4. In a larger scale study, a model ensemble was used by Woolway and others[4] to investigate changes in stratification onset and break-up across the Northern Hemisphere from 1901 to 2099. They found that under the highest greenhouse gas emission scenario, summer stratification would begin 22.0 ± 7.0 days earlier and end 11.3 ± 4.7 days later by the end of this century. It is very likely that this prolonging of the stratification period by 33 days would result in oxygen in lower waters being depleted even more rapidly, and therefore result in more phosphorus being released from lake sediments into the upper waters. These changes in stratification may also result in a misalignment of other lifecycle events in lakes and reservoirs, with possible irreversible changes for these ecosystems.

ABOUT MANTEL

MANTEL (Management of Climatic Extreme Events in Lakes & Reservoirs for the Protection of Ecosystem Services) was an EU funded Maire Skłodowska Curie Action (MSCA) European Joint Doctorate Innovative Training Network (2017-2021, Grant Agreement 722518) that focused on training a cohort of Early Stage Researchers to investigate the effects of the climate extremes on water quality, providing training in state-of-the art technology, data analysis and modelling, and linking to the water management sector.

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