THE EFFECTS OF SALINITY AND RIVER RUNOFF ON IDEALIZED BRACKISH ICE-COVERED LAKES

F. Sharifi[1,2], R. Hinkelmann[2], T. Hattermann[3] and G. Kirillin[1]

[1] Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), Berlin, Germany;
[2] Technische Universität Berlin (TU), Berlin, Germany
[3]The Arctic University of Norway (UiT), Tromsø, Norway

Motivation

- The effects of freshwater river runoff on the dynamics of ice-covered brackish lakes have not been adequately studied to date.
- Compared to freshwater lakes, the circulation patterns in brackish lakes are complicated by non-linear effects of temperature and salinity on density stratification and mixing, and as a result on the ice melt. Quantifying these effects is essential for understanding circulation of large endorheic lakes in cold regions and their ecological and physical characteristics.
- Cabbeling is an inflow-related effect that can occur when there is a notable difference in temperature and salinity between inflowing water and the water beneath the ice cover, causing unexpected changes in density.

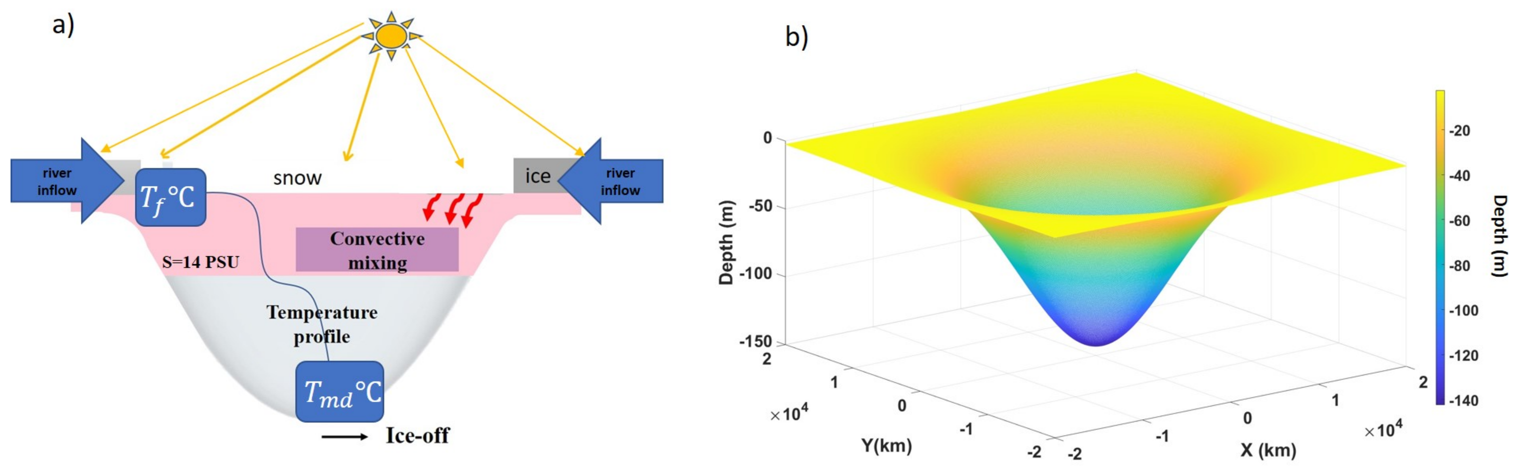

Fig. 1: Schematic representation of the main forces affecting the thermal regime in lakes during ice-off, along with idealized bathymetry of the lake

Methods

- The simulations were run on a modified version of the Regional Ocean Modeling System (ROMS 3.6) [1].
- Our scenarios apply to the axisymmetric idealized lake bathymetry illustrated in Fig. 1b.
- The lake water salinity was set to 14 practical salinity units (PSU). In the initial state, the water temperature increased linearly from the freezing point (T_f) at the surface to the temperature of maximum density (T_{md}), at the bottom, both accounting for the water salinity.
- We defined two freshwater inflows with temperatures equal to T_{md} of freshwater (approximately 4 °C). Average inflow velocities range ≤ 1 m/s, depending on the lake size. The average inflow velocity calculated using:

$$u_{in} = \frac{Q}{(f \times h \times dx)} \quad (1)$$

where dx and h represent cell width and depth, respectively, and Q is the river transport in cubic meters per second (m^3/s). F can change the fractional distribution of the river transport among the vertical cells.

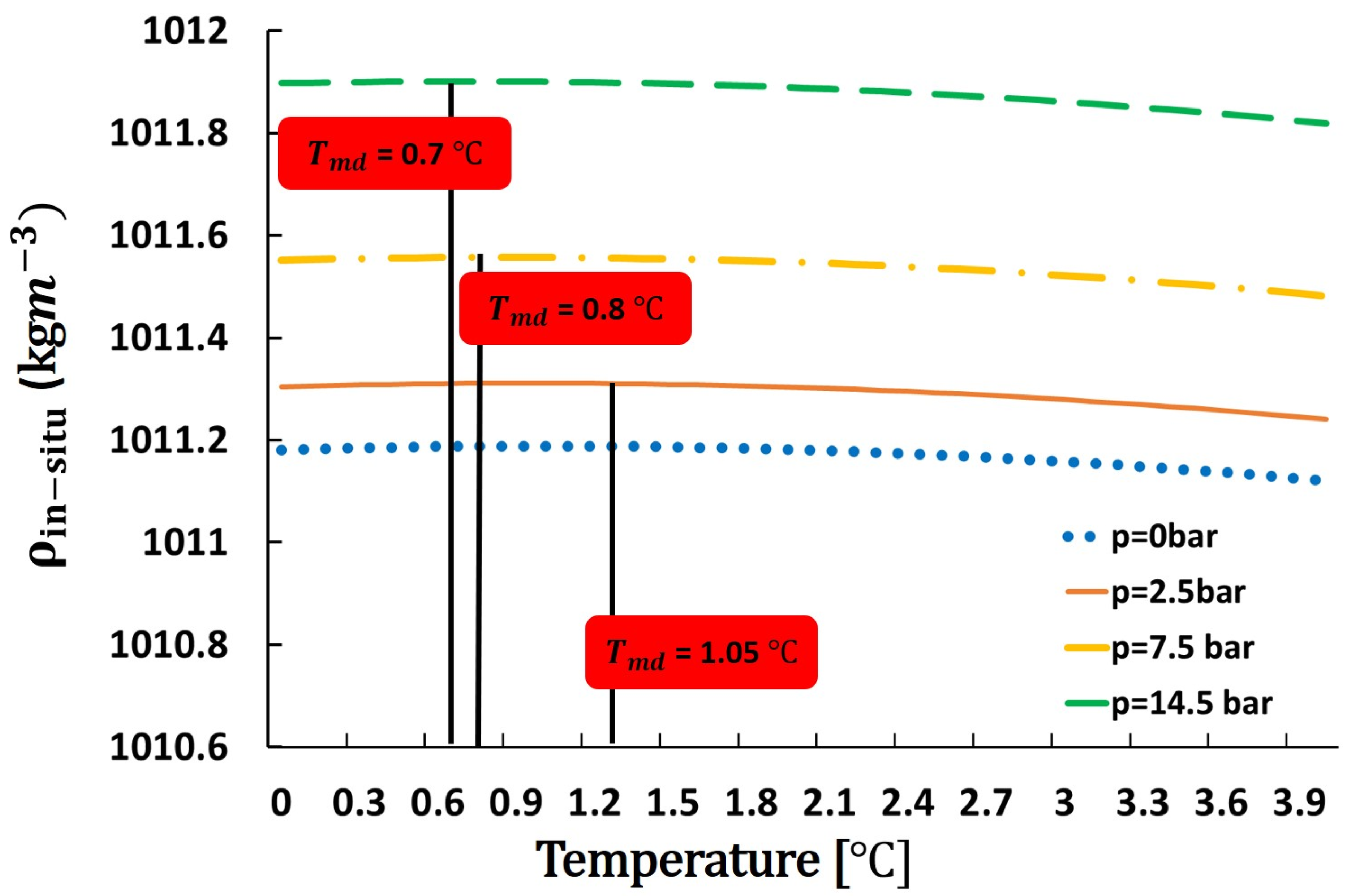

Fig. 2: Estimation of the temperature of maximum density T_{md} for a salinity of 14 PSU

T_{md} and T_f estimation

- In the ROMS model, it is presumed that pressure does not vary along geopotentials, consequently treating pressure and depth as interchangeable. It should be noted that the conversion from bars to meters can be achieved using the equation [2]:

$$pressure(bars) = 0.1 \times depth(meters) \quad (2)$$

- We determined the value of T_{md} (Fig. 2) using the density function ρ(S,θ,P) [2] at different temperatures and pressures while maintaining a salinity of 14 PSU (pressure calculated using Eq. (2)).
- T_f estimated using [4]:

$$T_f = -0.0575.S + 1.710523 \times 10^{-3} S^{3/2} - 2.154996 \times 10^{-4} S^2 - 7.53 \times 10^{-3} P \quad (3)$$

- The salinity-pressure-dependent values of T_{md} were evaluated in comparison to the findings reported by Bluteau et al. (2006) and Cotter (2010).

General characteristics of freshwater river inflows on brackish lakes

Non-linearities in the equation of state lead to the water mass's transformation as a result of cabbeling. It always causes the fluid to sink through a neutral surface [3].

- The vertical flow patterns were complex, revealing features of both viscosity-driven currents and gravity currents due to cabbeling.
- An upward movement persisted along the boundaries compensated by a downward flow immediately close to the river mouth.
- When these currents with different directions faced each other, a jet-like flow formed in the middle of the lake.

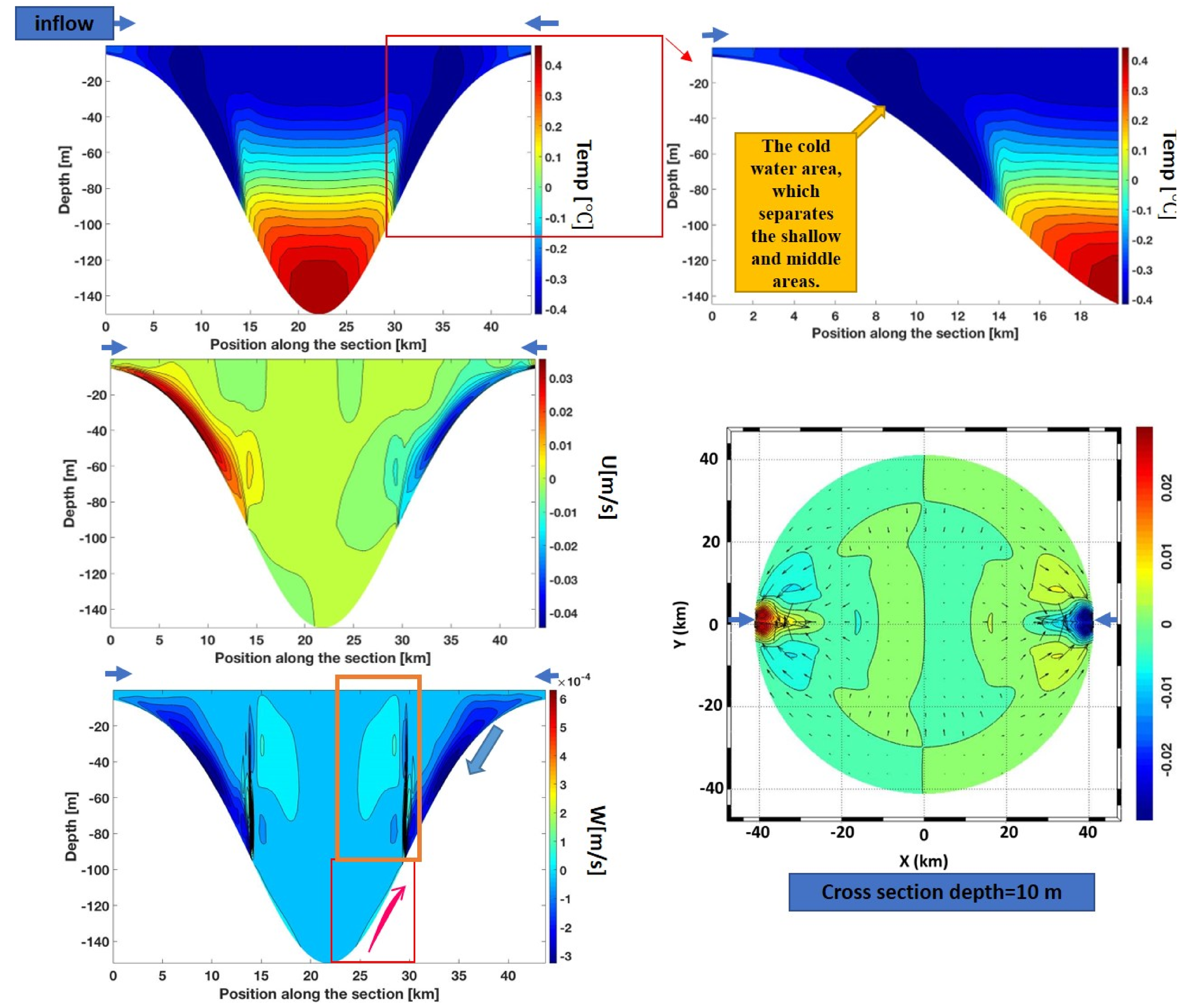

Fig. 3: Summary of river inflow modeling results, including temperature, horizontal and vertical velocity fields near river inflo

- The maximum downward velocity is 3 $\times 10^{-4}$ m/s, while the maximum upward velo is 6 $\times 10^{-4}$ m/s.
- Maximum horizontal velocity are order is $\pm$0.03 m s^{-1}.
- One cold layer separated lake interior stratification and shallow areas. Surface inte temperature increased from -0.7576 °C to -0.4 °C.

Outlook

Further modeling efforts are needed to:

- Understand and summarize the complex circulation patterns in brackish lakes, part larly considering different depth and length scales and inflow temperatures.
- Investigate the potential impact of shallow water depth on the described outcomes.
- Address the issue of shallow areas attaining a maximum salinity of 14.08 PSU, ongoing efforts to resolve it.

References

[1] DMCS, Ocean Modeling Group, ed. *Regional Ocean Modeling System (ROMS)*. https://www.myro org/.

[2] DR Jackett and TJ McDougall. "Stabilization of hydrographic data". In: *J. Atmos. Oceanic Techno* (1995), pp. 381–389.

[3] Trevor J McDougall. "Thermobaricity, cabbeling, and water-mass conversion". In: *Journal of Geophy. Research: Oceans* 92.C5 (1987), pp. 5448–5464.

[4] IWG UNESCO. "The practical salinity scale1978 and the international equation of state of seawater 19 In: *Tenth Report of the Joint Panel on Oceanographic Tables and Standards (JPOTS)* 25 (1981).

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