NEMO-GSL v1.0: An integrated hydrodynamic and ice-process model for a deep subarctic lake (Great Slave Lake, Canada)
Responses to Referee 3

November 20, 2026

We thank the referee for the positive assessment and the constructive questions, which have led to a clearer justification of the model choice and the parameter values. In response to Referee 2, simulated conservative temperature is now converted to in-situ temperature before comparison with observations, which changed all temperature statistics. The simulations were also rerun without the evaporation scaling factor described below, and all statistics in the revised manuscript are from these simulations. The referee's comments are in black and our responses in blue. Section, figure and table numbers refer to the revised manuscript, and all works cited here are listed in its reference list.

This is a well-written paper that discusses the application of NEMO to Great Slave Lake. I find the model compelling, and the metrics used are within a reasonable range (especially the evaporation rate and the ice timing). Overall, this appears to be a model that captures key features of GSL.

We thank the referee. The referee notes that the metrics are within a reasonable range, "especially the evaporation rate". In revising the evaporation evaluation, however, we found errors in the submitted manuscript that affect exactly this result, and we have corrected them. First, the simulated evaporation compared with the eddy covariance observations at Inner Whaleback Island (IWI) was the lake-wide average, not the value at the IWI location as stated. Second, the simulation applied a constant scaling factor to evaporation (NEMO parameter `rn_efac`). The scaling has been removed, so that evaporation is now computed directly by the COARE 3.6 bulk algorithm, and all simulations have been rerun. The comparison now uses the lake grid cells within 5 km of IWI and the full observation record (June 23–September 26, 1998 and June 9–November 25, 1999), rather than July and August only.

With these corrections, the model reproduces the seasonal increase and the day-to-day variability of evaporation (R = 0.79 over both years; 0.63 in 1998 and 0.84 in 1999), but underestimates evaporation by 30.1% in 1998 and 11.9% in 1999. In 1998, the deficit accumulates mainly in July and early August, when the model simulates near-zero evaporation or condensation on days with small positive observed evaporation. In 1999, it accumulates mainly in October and November, when the largest observed evaporation events are underestimated (Sect. 4.6, Figs. 13 and 14). We discuss the causes of these deficits in Sect. 5.3: errors in the near-surface humidity gradient under stable conditions over the cold lake surface in early summer, and the smoothing of autumn wind and humidity extremes in the reanalysis. The sensitivity simulation with RDRS v2.1 forcing has been rerun and evaluated in the same way (Sect. 4.7). We also corrected the description of the sensitivity experiments: wind speed is the dominant control on the

simulated mixed layer depth, whereas simulated evaporation responds more strongly to air temperature. The Abstract, Sects. 3.3, 3.5, 4.6, 4.7 and 5.3, Fig. 13, the new Fig. 14 and the Conclusions have been revised accordingly. We regret the errors and thank the referee for prompting this closer examination.

That said, there are several points of note that warrant further clarification:

Why NEMO? The Authors comment on it being used for the Great Lakes, though FVCOM is a more commonly applied model in that context. Many of the stated benefits of NEMO are also available with FVCOM and its ice module, which includes ice advection, or ELCOM, which also has an ice module.

We agree. FVCOM is the most widely used model for the Laurentian Great Lakes, and both FVCOM, through the unstructured-grid version of CICE (Gao et al., 2011), and ELCOM (Oveisy et al., 2012) include ice modules; the FVCOM ice module also includes ice advection. We have rewritten this part of the manuscript as a new Sect. 3.1, which reviews FVCOM, MITgcm and ELCOM/AEM3D and their lake applications, and states explicitly that any of them could be configured for Great Slave Lake and that we do not claim NEMO is uniquely suited. Our choice reflects four practical considerations rather than a capability gap in the other models: the ice (SI^3) and passive tracer (TOP) components are developed and versioned together with the ocean core; the partial-step z-coordinate is well suited to the steep slopes of the East Arm; NEMO has been evaluated in the Laurentian Great Lakes, the Baltic Sea and the Salish Sea; and NEMO is the lake and ocean component of Environment and Climate Change Canada's prediction systems. Sect. 3.1 also lists the limitations of the choice, including the absence of local grid refinement, and Sect. 3.3 explains why ice dynamics are not included in the present version. Including ice dynamics is identified as a logical extension of the configuration (Sects. 3.3 and 5.2).

Following this, the Authors note that ELCOM was previously used to model GSL but "was restricted to the West Arm during the ice-free periods (Leon et al., 2007)." What is the significance of that? Is there significant exchange between the West and East Arms? The only comparison to that work states that "Large anti-clockwise gyres form along the shores, showing circulation patterns similar to those reproduced by Leon et al. (2007) using ELCOM." Does that mean that ELCOM would have been equally effective?

Leon et al. (2007) applied ELCOM to the West Arm only, with a closed boundary between the West and East Arms, because reliable bathymetry for the East Arm was not available (Sect. 2). Their simulations covered the ice-free season, so exchange between the arms and the ice season were both excluded. This is why our comparison with that study is limited to the West Arm circulation, and one reason we consider a full-lake bathymetry (Sect. 3.2) necessary.

Our simulations show that the exchange between the arms is wind-dependent and two-layered (Sect. 4.8, Figs. 16–17). In 1998, upper-layer flow through the northern passages was directed from the West Arm into the East Arm, while lower-layer flow in the connecting channel returned towards the West Arm. In 2001, with more variable winds, the flow through the East Arm passages was weaker. Mass conservation also implies a small net outflow from the East Arm, which receives river inflow but has no outflow, but this net flux is small compared with the gross two-layer exchange.

On whether ELCOM would have been equally effective: the similarity of the West Arm gyres in both models indicates that the basin-scale circulation is a robust feature that does not depend on the model, and we expect that a full-lake ELCOM or FVCOM configuration could also reproduce it. To our knowledge, however, no continuous, multi-year, ice-covered simulation of the whole lake has been reported with any model. NEMO-GSL v1.0 is presented as a baseline for such comparisons, and the bathymetry, forcing and evaluation datasets assembled here are independent of the choice of model (Sect. 5.5).

Some of the parameterizations could be better explained. For example:
Light penetration coefficients: Why these numbers? Why not temporally variable? Or spatially variable as noted by the changing turbidity?

The values are the two-band parameters of Paulson and Simpson (1977) for Jerlov water type III (Jerlov, 1968): 78% of the shortwave radiation is absorbed with an e-folding depth of 1.4 m and the remainder with an e-folding depth of 7.9 m. Type III is the most turbid of the open-ocean water types. The NEMO default corresponds to the clearest type I, which would place too much heating below the thermocline in the turbid West Arm, where all profile observations are located. We have also corrected Sect. 3.3, which wrongly described type III as a coastal water type. We agree that turbidity in Great Slave Lake varies in space and time, from the sediment-laden waters near the Slave and Hay river mouths to the clear, oligotrophic East Arm. As stated in Sect. 3.3, a constant attenuation is a compromise made because no spatially distributed water clarity observations are available. In addition, the chlorophyll-based spectral scheme available in NEMO is not suited to attenuation dominated by mineral sediment.

Ice Module: What were the selected ice and snow parameters?

The ice and snow configuration is now described in more detail in Sect. 3.3. SI^3 is run with five ice thickness categories, ten ice layers and five snow layers, using the multi-layer thermodynamics of Bitz and Lipscomb (1999), and without ice dynamics. The snow thermal conductivity is set to 0.25 W m^{-1} K^{-1}, within the range reported for seasonal snow (Sturm et al., 1997), and the albedos of melting snow and bare puddled ice are reduced from the default values to 0.72 and 0.49, respectively. New ice forms with 90% salt rejection, giving an ice salinity of 0.02 g kg^{-1}, and the turbulent exchange coefficients over ice follow Lüpkes et al. (2012). These parameters were adjusted during calibration to reproduce the observed freeze-up and break-up timing.

Selecting a mixed layer depth based on a temperature change is common practice; however, the value of 0.5 was a choice. How sensitive are the results to this value? Based on Figure 6, selecting a value of 0.1 would give a very different story.

We agree that the threshold is a subjective choice. MLD is now computed with thresholds of 0.2, 0.5 and 1.0 °C, applied identically to observed and simulated profiles, together with the threshold-free depth of maximum buoyancy frequency (Sect. 3.5, Table 3). Because MLD is undefined for a fully mixed water column, errors are computed for dates on which both profiles are stratified, and the agreement in stratification state is reported separately. Across the three thresholds, the model and observations agree on the stratification state on 93–94% of dates, the ME ranges from $+0.68$ to -0.70 m and the RMSE from 5.42 to 7.16 m, and the depth of maximum N^2 places the simulated thermocline on average 1.0 m shallower than observed (Sect. 4.4). We also tested a threshold of 0.1 °C. As expected, the MLD decreases with smaller thresholds, particularly at 0.1 °C, where the criterion increasingly captures transient diurnal near-surface stratification rather than the seasonal mixed layer. We therefore use 0.2–1.0 °C, with 0.5 °C as the primary threshold.

I do believe that this paper has merit and is an interesting contribution.

Minor Comments:

Line 82 – Define RDRS here

CaSR v3.2 (Canadian Surface Reanalysis, version 3.2) and RDRS v2.1 (Regional Deterministic Reforecast System, version 2.1) are now spelled out at their first occurrence in the Abstract and Introduction.

Figure 1 – Highlight the simulation domain in this figure as it's unclear how much of the different arms are included.

The simulation domain covers the whole lake, including the North Arm and the East Arm with Christie Bay and McLeod Bay. It is shown by the model bathymetry in Fig. 3, which is now part of the bathymetry methods (Sect. 3.2).

Figure 2 – Most of the discussion on the bathymetry interpolation occurs within Section 3 but we need to wait until Section 4 to see the results. While I agree that the bathymetry is a significant result, consider combining Figures 2 and 4.

We agree that the result should appear with the method. Rather than merging the two figures, which would make both hard to read at the journal's page width, we moved the interpolated bathymetry (Fig. 4 of the submitted manuscript) into the bathymetry methods (Sect. 3.2). It now appears as Fig. 3, directly after the input observations (Fig. 2). The interpolation error assessment remains in Sect. 4.1 (Fig. 5).

Line 199 – What is the bottom friction parameterization?

Bottom friction is parameterized with a quadratic drag law with a drag coefficient of 2.5×10^{-3}, as now described in Sect. 3.3. This replaces the unclear description in the submitted manuscript ("non-linear scaling based on flow velocity").

Line 295 – What interpolation scheme?

Simulated temperatures were interpolated to the observation depths by linear interpolation in depth at the model grid cell nearest to each mooring; this is now stated in Sect. 3.5. For LSWT, the satellite fields are regridded from 1/120° to the model grid by nearest-neighbour interpolation (Sect. 3.5).