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Long-term simulations of dissolved oxygen concentrations in Lake Trout lakes

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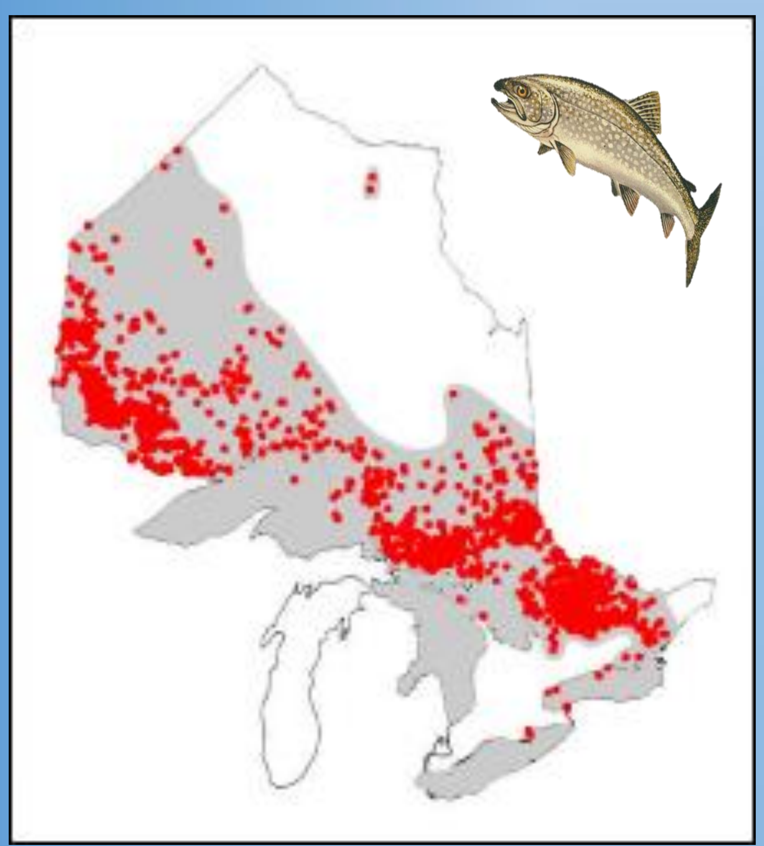
INTRODUCTION

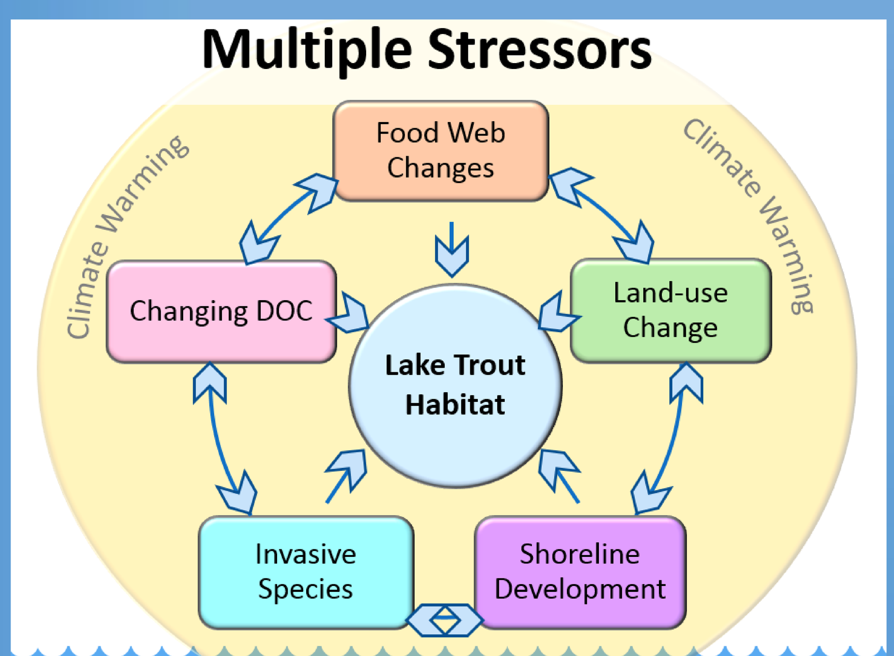
Lake Trout are a rare and valuable natural resource that are threatened by multiple environmental stressors. With the added threat of climate warming, there is growing concern among resource managers that increased thermal stratification will reduce the habitat quality of deep-water Lake Trout lakes through enhanced oxygen depletion. To address this issue, a three-part study is underway, which aims to: analyze sediment cores to understand the past, develop empirical formulae to model the present and apply computational models to forecast the future. This presentation reports on the computational modeling efforts for two Lake Trout Lakes: Harp Lake and Eagle Lake.

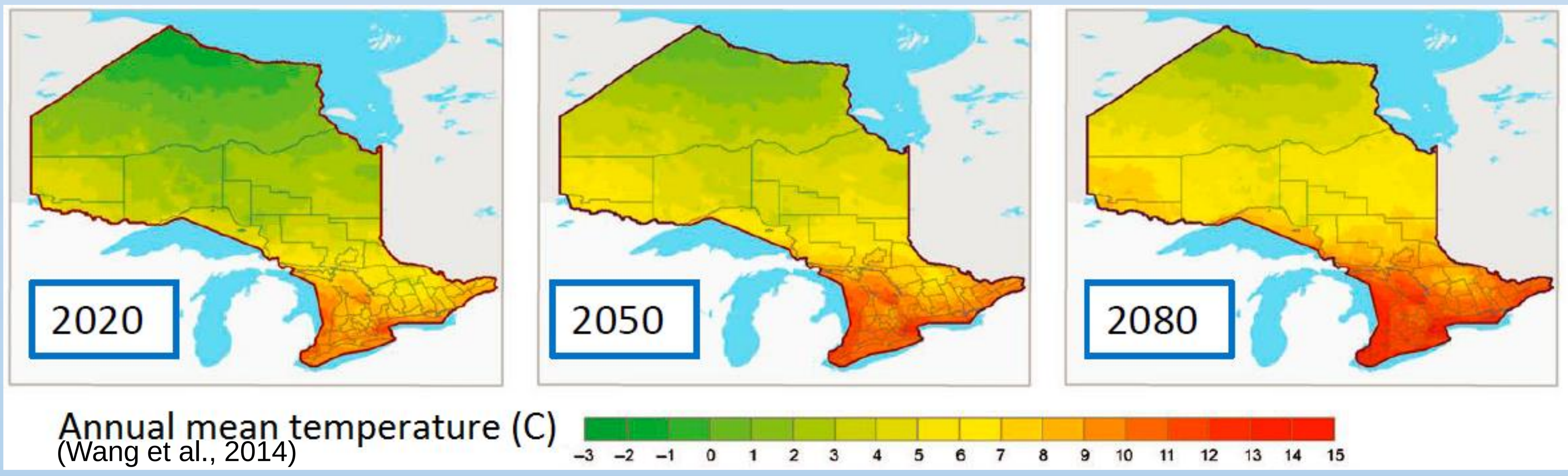


Lake Ontario, Lake Huron, Lake Superior and across the deep, cold lakes of the Canadian Shield (www.ontario.ca)

Lake Trout

Length: 30-80 cm, weight: 1-5 kg.
Relatively rare: only 1% of Ontario lakes contain Lake Trout. 20-25% of Lake Trout lakes are in Ontario. Narrow physiological tolerances for temperature and dissolved oxygen (DO): T: 6-15°C; DO: 9-12 mg/L
Vulnerable to many stresses including climate warming.

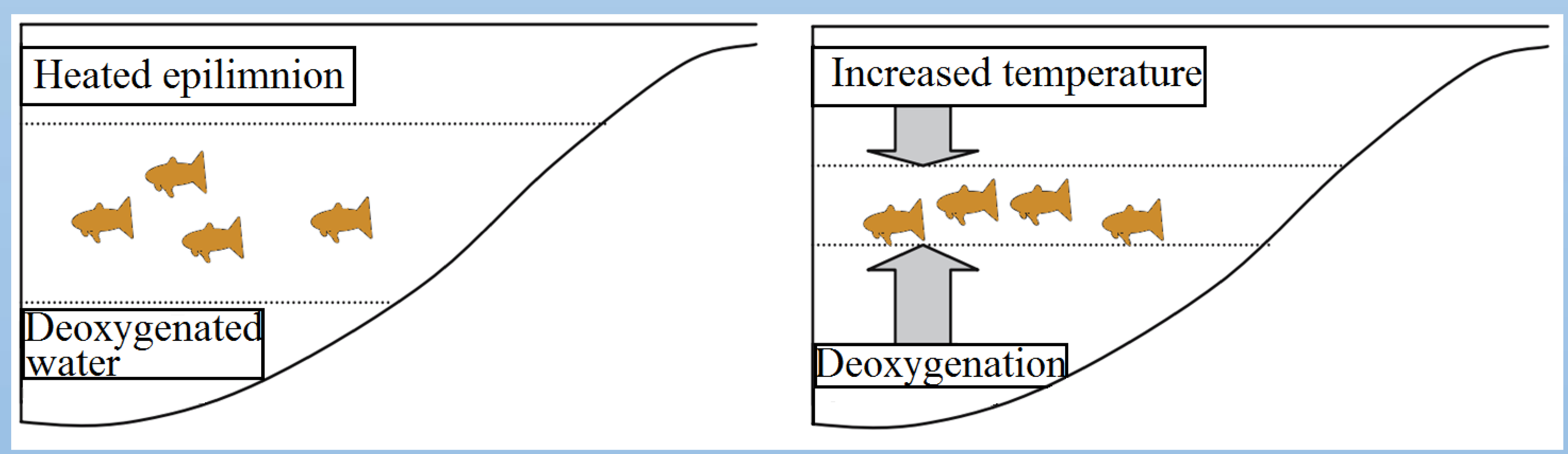




Climate changes ⇨ lower water levels ⇨ less hypolimnion volumes ⇨ severe hypoxia

Kling et al. (2003):

Higher air temperatures ⇨ longer and stronger summer thermal stratification period ⇨ increase the duration of DO depletion in the hypolimnion & decrease the vertical DO flux



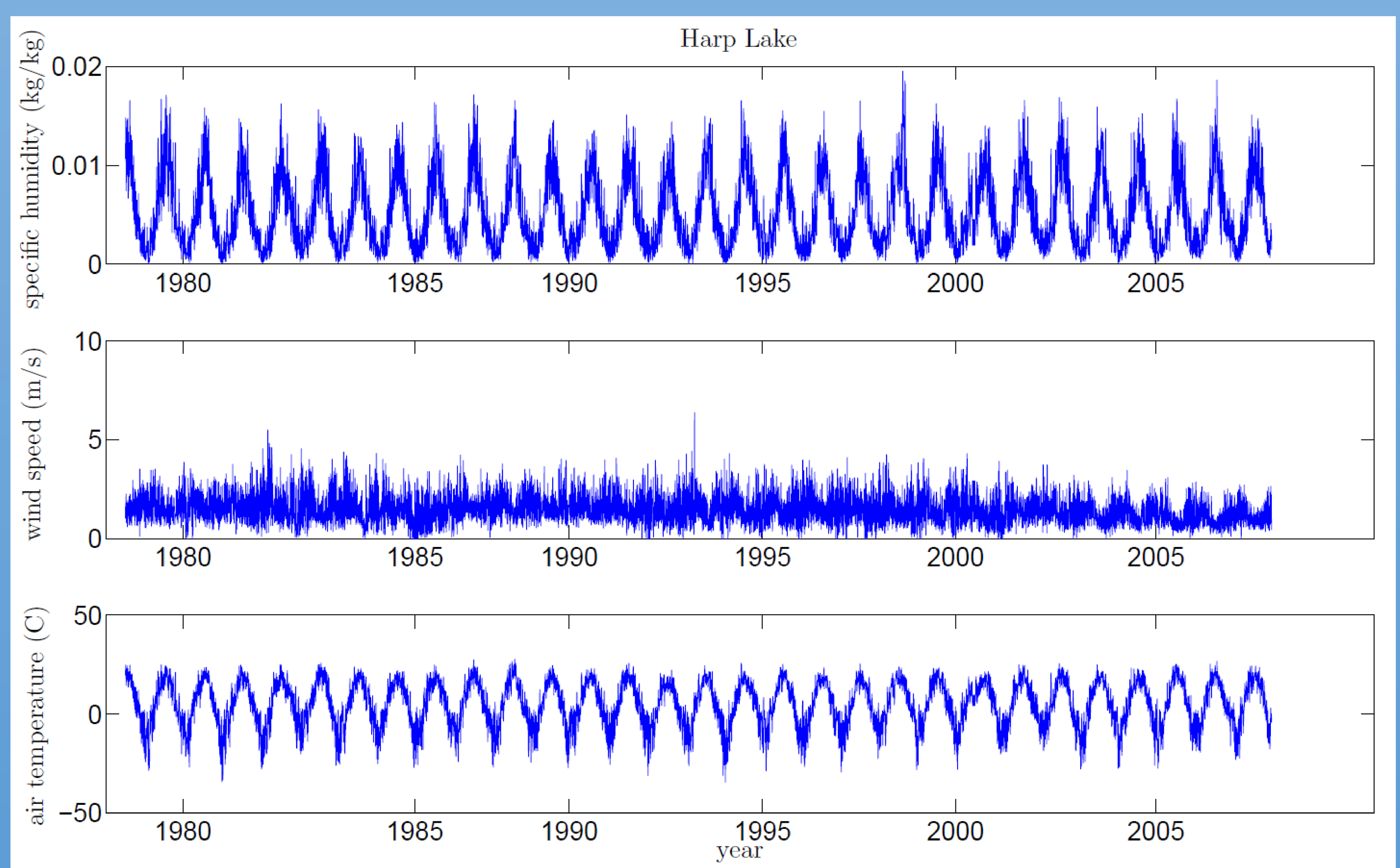
Effect of climate change on restriction of pelagic habitat availability for Lake Trout (Ficke et al., 2007)

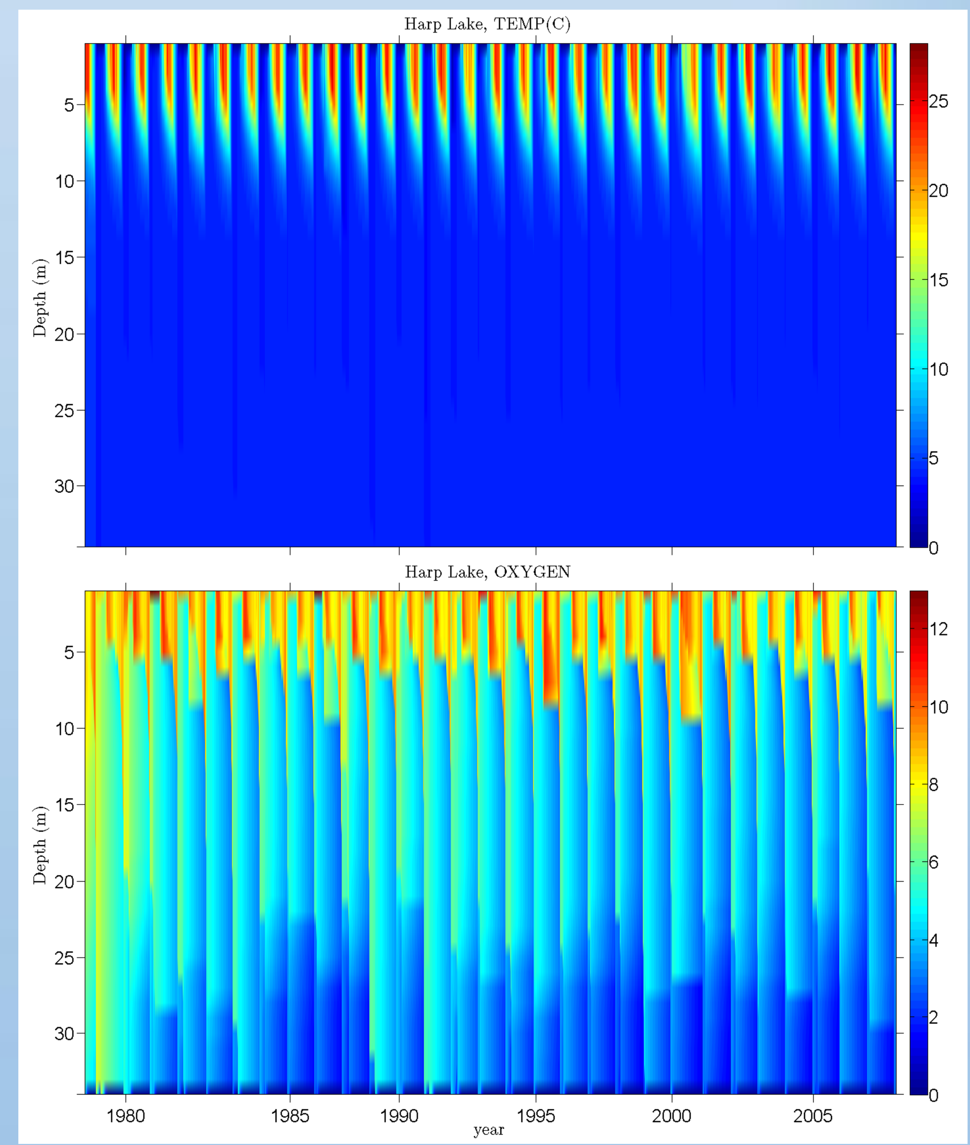
Computational modeling

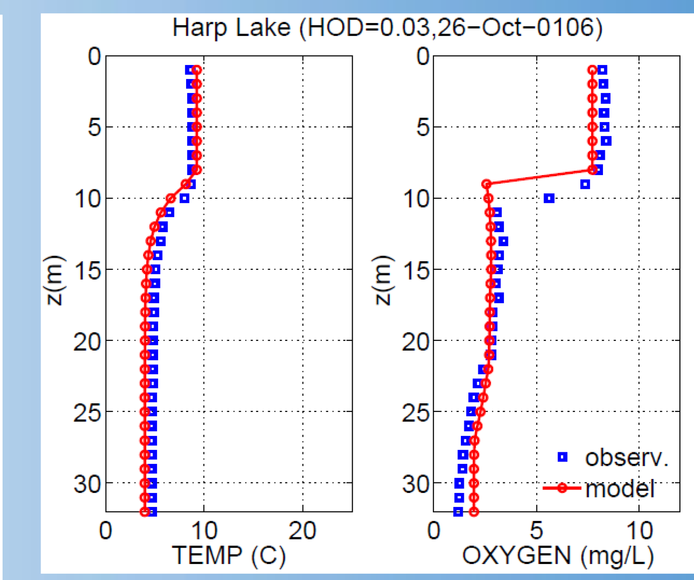
A simple DO sub-model has been embedded in the 1D bulk mixed-layer thermodynamic Canadian Small Lake Model (CSLM). This model is currently being incorporated into the Canadian Land Surface Scheme (CLASS). The model can simulate physics and biogeochemistry over timescales relevant to climate change. Here the model has been calibrated and validated by hind-casting Temperature and DO profiles from 2 Lake Trout lakes: Harp Lake & Eagle Lake

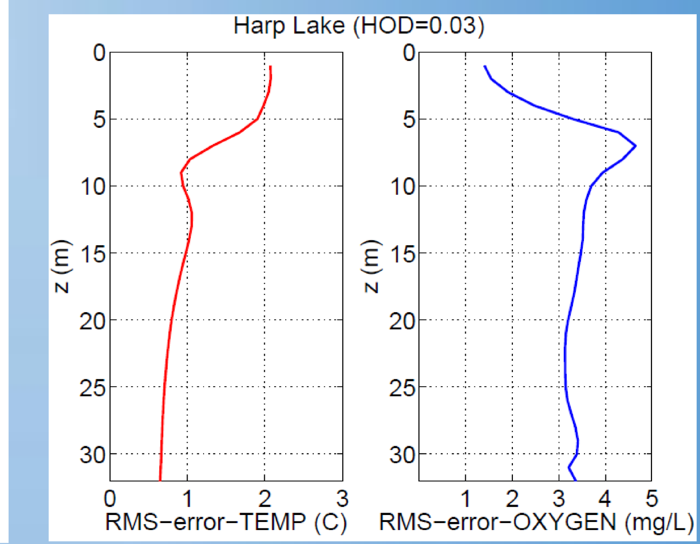
Simulations: Harp Lake

Maximum depth: 34 m, Square root of the surface are: 843 m
Extinction coefficient: 0.5 1/m, Simulations time: 1978-2008
Optimum HOD: 0.03, Grid spacing: 1 m, Time steps: 10 min



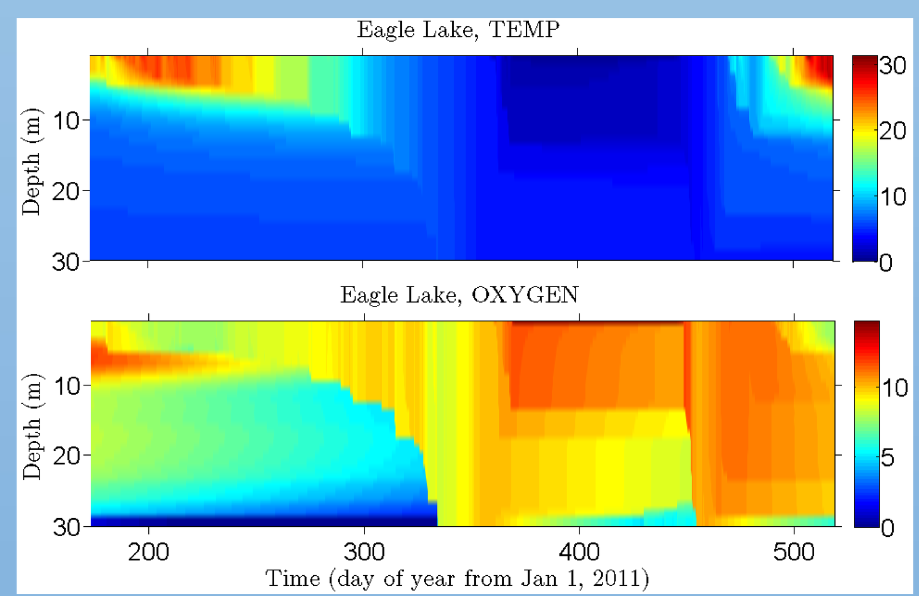


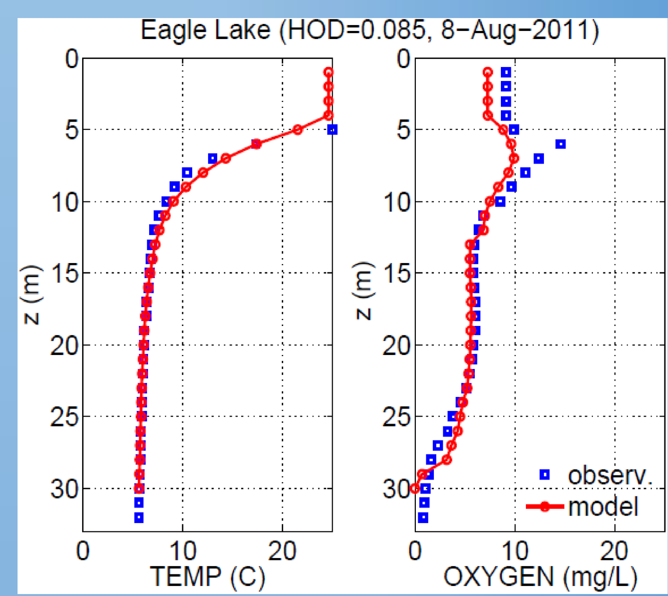


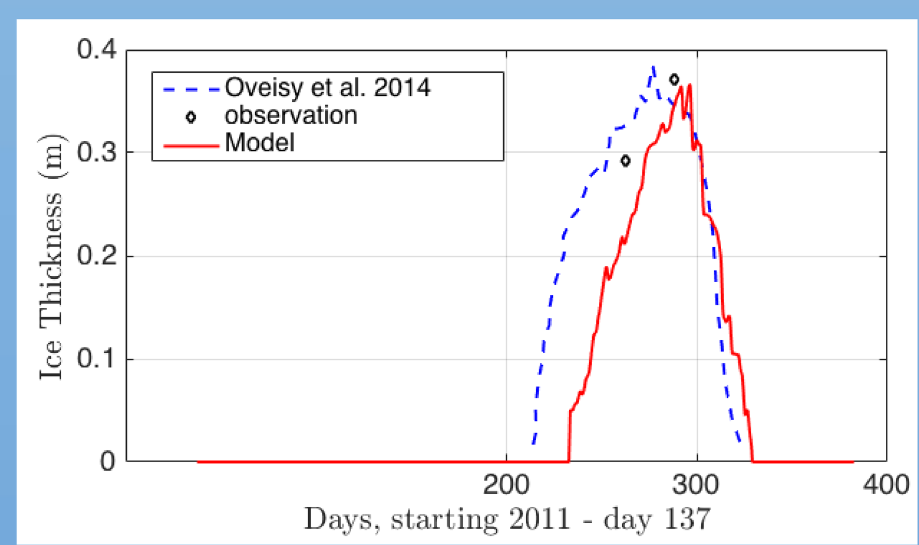


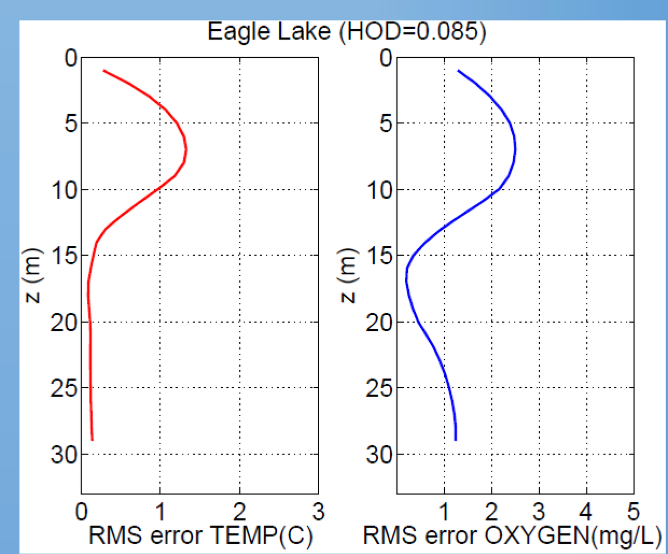
Simulations: Eagle Lake

Maximum depth: 30 m, Square root of the surface are: 250 m, Extinction coefficient: 0.3 1/m, Simulations time: day 173-328, 2011, Optimum HOD: 0.085, Grid spacing: 1 m, Time steps: 10 min









Conclusions and future work

The oxygen model was calibrated and validated by hind-casting temperature and dissolved oxygen profiles from two Lake Trout lakes on the Canadian Shield. These data sets include 2 years of high-frequency (10 s to 10 min) data from Eagle Lake and 30 years of bi-weekly data from Harp Lake. Initial results show temperature and dissolved oxygen was predicted with root mean square error <1.5 °C and <5 mgL^{-1}, respectively. Ongoing work is validating the model, over climate-change relevant timescales, against dissolved oxygen reconstructions from the sediment cores and predicting future deep-water temperature and dissolved oxygen concentrations in Canadian Lake Trout lakes under future climate change scenarios. This model will provide a useful tool for managers to ensure sustainable fishery resources for future generations.