Supporting Information (SI) for "Temporal and spatial dynamics of large lake hypoxia: Integrating statistical and three-dimensional dynamic models to enhance lake management criteria"

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Introduction

The supporting information material provides additional information used in the main paper and is organized in the tabled form consisting of four tables and two figures.

Overview of supporting tables (see specific table caption for more detailed information): **Table S1** summarizes some selected concentration thresholds for the dissolved oxygen (DO) and their effects on aquatic organisms. **Table S2** shows reduction in growth rate of some selected salmonid and nonsalmonid fish at various DO concentrations expressed as the median value in tests with each species. **Table S3** provides a summary of statistical measures of fit used for a model skill evaluation. **Table S4** provides details of the quantitative characterization of the vertical structure of the observed and modeled metalimnion.

Overview of the supporting figures (see specific figure legend for more detailed information): **Figure S1** shows the map of Lake Erie with 13 different meteorological forcing zones used in the model (a), and locations of the land-based meteorological stations and in-lake meteorological buoys (b). **Figure S2** shows time series of the simulated basin-average daily surface and bottom temperatures, basin-average horizontal wind speed averaged over two days, and basin-wide hypoxic extents for different DO thresholds (a); and, two-day average values for the Schmidt stability, buoyancy frequency and surface wind shear stress calculated for the station ER78 (see Fig. 1), as well as the basin-wide hypoxic extents for different DO thresholds (b).

Table S1. Summary of concentration thresholds for the dissolved oxygen (DO) and their effects.

DO ($mg\ L^{-1}$)	Reported effect for the areas with	Literature source[$]
< 8	Threshold for embryos and alevins to survive well	*Phillips and Campbell*, 1961 (as cited by *Bjornn and Reiser*, 1991)
< 6 – 6.5	Cause stress and mortality in developing embryos and alevin	*WDOE*, 2002
< 6	A generally recognized criterion for protecting the most sensitive aquatic life	*ODEQ*, 1995
< 5 – 6*	Avoidance by all salmonid species*,**	*WDOE*, 2002
< 5	Suboptimal for fish	*Welch and Jacoby*, 2004
	Low salmonid embryo survival; a generally recognized level for protecting the less sensitive warm-water fish species as crappie and bass	*ODEQ*, 1995
< 4.2	Avoidance response by adult Chinook salmon	*Hallock et al*., 1970
< 4	Acute mortality limit for invertebrates	*USEPA*, 1986
< 3.9	Acute lethality for all salmonid species*	*WDOE*, 2002
< 2 – 4	Avoided by fish	*Klumb et al*., 2004; *Ludsin et al*., 2009; *Vanderploeg et al*., 2009a
< 3	Avoided by fish in Lake Erie	*Vanderploeg et al*., 2009a, 2009b
< 2	Lethal for most fishes	*Vanderploeg et al*., 2009a
< 1.2	Avoided by most mesozooplankton	*Vanderploeg et al*., 2009a
< 1	Substantial mortality of juvenile fish	*Shimps et al*., 2005
< 0.3 – 1	Lethal for daphnids and copepods	*Weider and Lampert*, 1985; *Stalder and Marcus*, 1997; *Lass et al*., 2000

[$]For the literature written in italics see the list of references in the supporting information (this document); * annual lowest single daily minimum oxygen concentration; ** annual lowest single daily average concentration.

Table S2. Percent reduction in growth rate of some selected salmonid and nonsalmonid fish at various dissolved oxygen (DO) concentrations expressed as the median value in tests with each species [calculated from *JRB Associates* (*1984*) as cited in *USEPA* (*1986*)].

DO (mg L^{-1})	Species (number of tests)					
	Salmonids			Non-Salmonids		
	Rainbow Trout (2)	Brown Trout (1)	Lake Trout (2)	Northern Pike (1)	Largemouth Bass (6)	Channel Catfish (1)
9	0	0	0	0	0	0
8	1	0	0	1	0	0
7	5	1	2	4	0	1
6	9	6	7	9	0	3
5	17	13	16	16	1	7
4	25	23	29	25	9	13
3	37	36	47	35	17	20
2	--	--	--	--	51	29
Median Temp (°C)	12	12	12	19	26	25

For the literature written in italics please see the list of references in the supporting information (this document).

Table S3. Summary of statistical measures of fit used for a model skill evaluation.

#	Measure name	Formula
1	Root mean squared error	$RMSE = \left(\frac{1}{N}\sum_{i=1}^{N}(O_i - S_i)^2\right)^{1/2}$
2	Percent bias	$PBIAS = \left[\frac{\sum_{i=1}^{N}(O_i - S_i) \cdot 100}{\sum_{i}^{N} O_i}\right]$

Abbreviations: O_i, the *i*-th observation of the constituent being evaluated; S_i, the *i*-th simulated value for the constituent being evaluated; *N*, the number of observations.

Table S4. Characterization of the metalimnion layer vertical structure (mean depth ±SD) in central Lake Erie in 2008 based on the observations and numerical simulations for the locations of ten USEPA index stations (Fig. 1; Table 1). The simulated values were compared to observations (measured temperature profiles) collected during five cruises in 2008 (June 24-25; July 12-13; August 10-11; August 30-31; and, September 12-13). Number of observations is *N*.

#	Vertical structure of metalimnion:	Observed depth: (m) *N* = 50	Simulated depth: (m) *N* = 50
1.	Thermocline (maximum change in water density)	15.9 ±2.2	15.9 ±3.1
2.	Upper boundary	14.7 ±2.5	12.8 ±2.8
3.	Lower boundary	17.0 ±2.1	18.2 ±2.5

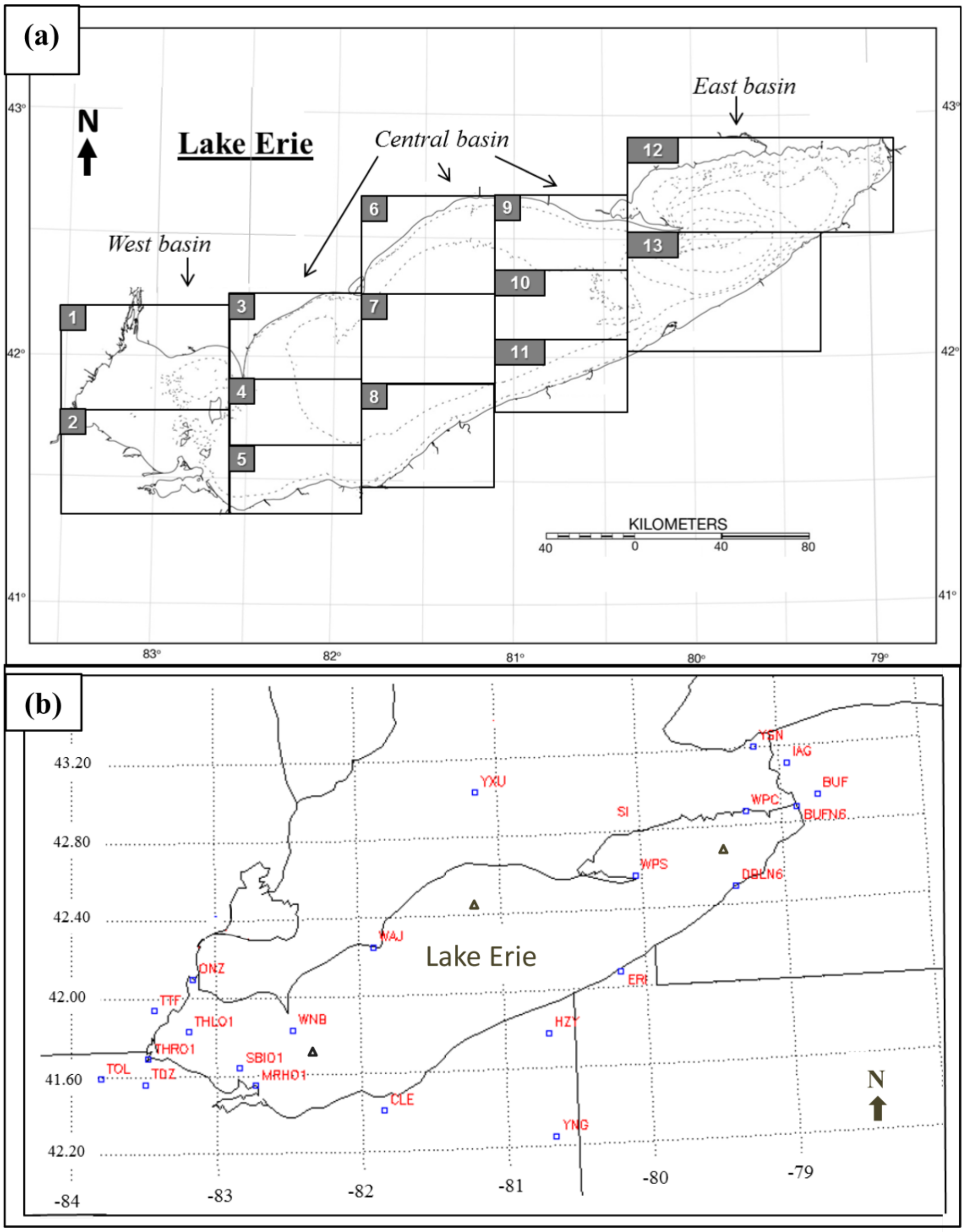

Figure S1. (a) Map of Lake Erie showing the division of the lake domain into 13 different meteorological forcing zones; (b) Map depicting locations of the fixed land-based meteorological stations (open blue squares) with their ID abbreviations indicated in red, as well as in-lake meteorological buoys (open black triangles).

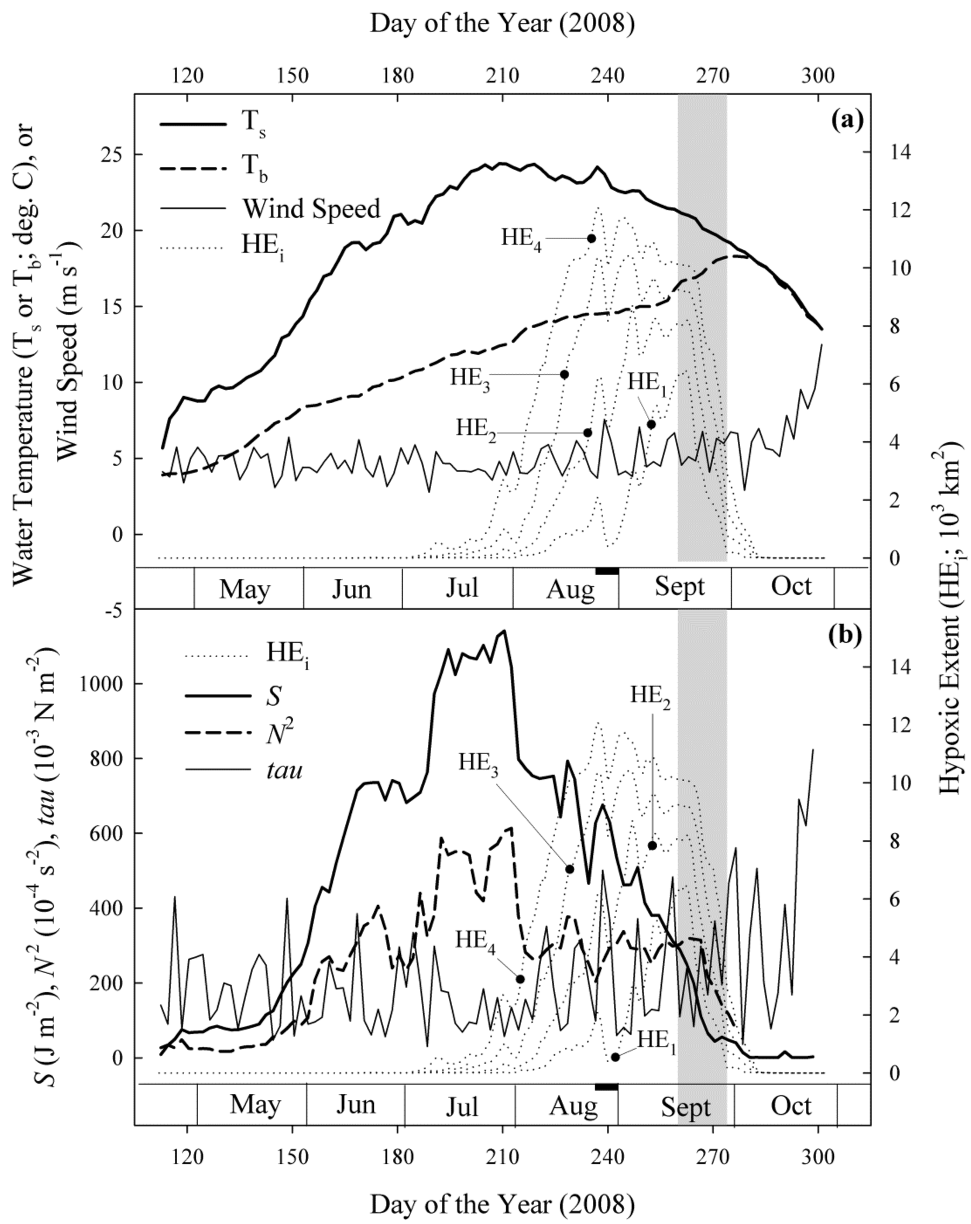

Figure S2. Time series of: (a) simulated basin-average daily values for surface and bottom (in the zone > 20 m deep) temperatures (T_s and T_b), basin-average horizontal wind speed at 10 m above water surface averaged over two days (wind speed), and basin-wide hypoxic extents (HE_i) for different DO thresholds (HE_1, HE_2, HE_3, and HE_4); (b) two-day average values for Schmidt stability (*S*), stability of water column (N^2) and surface wind shear stress (τ or *tau*) calculated for the station ER78 (see Fig. 1), and basin-wide hypoxic extents (HE_i) for different DO thresholds (HE_1, HE_2, HE_3, and HE_4). The vertical grey bar indicates time of the dissipation period for hypoxia. The horizontal black bar indicates timing for the occurrence of strong wind event (August 26-31, 2008) discussed in the text.

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