Circulation, Temperature and Dissolved Oxygen in Lake Erie

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Objectives of Field Experiments (2004 & 05)

- Provide hydrodynamic and temperature observations required to assess/predict changes in water quality

- Data base for calibration and verification of hydrodynamic and water quality models

Physical Processes for nutrient status, hypoxia in the lake

- Circulation, horizontal and vertical mixing
- Estimate water and nutrient residence times
- Estimate Inter basin transports on daily scale for model input
- Estimate onshore-offshore exchanges during summer episodic events (upwelling) along the north shore of the central basin
Experimental Set-up (2004)

Deployed: 12-16 April 2004
Refurbished: July & August 2004
Retrieved: First week of October

- 6 RDI-ADCPs for inter-basin transports,
- Sontek Hydra station (+75 cm above bottom) in the central basin for studying the hypolimnion characteristics.
- 5 NOBSKA MAVs for Coastal exchange processes

Temperature
Thermistor chain moorings near all ADCP and Met stations.

Meteorology
3 Meteorological buoys in three basins with Radiation sensors

Water Quality
2 Stations with transmissometers at two depths
3 YSI 6600 (2 in the central basin)
Hydrolab stations in the western basin
International Field Year on Lake Erie

2005- GLERL & NWRI Collaborative Moorings

- More Coverage of instruments & water sampling
- Maintained interbasin transport moorings & High frequency temperature
Nearshore/Offshore Exchanges

2004 Experiment

2007 Experiment

With MOE (Todd Howell)

Central Lake Erie
1. The linear slope shows a depletion of 0.07 mg/L/d.
2. Some stations show anoxic conditions from mid-July to the middle of August.
3. Relation between low hypo volume and DO

- Effects of physical processes on DO
- Differences from time series and ship

• Stratification started from middle of June
• Hypolimnion Volume and DO
Similar Variability in 2005
Influence of Meteorology (Central Basin buoy)

Effect of wind on Heat Fluxes

- a) Atemp-Wtemp
- b) Total HF
- c) SHF
- d) LHF

Wind Rose Summary, Station 2004-01W-017A (Str 084)

Legend:
- 0 - 0.5 m/s
- 0.5 - 1 m/s
- 1 - 2 m/s
- 3 - 4 m/s
- 5 - 10 m/s
- 10 - 20 m/s
- 20 - 30 m/s

Upwelling

East storm
Influence of Vertical Mixing on Hypoxia

- Strong stability in the thermocline
- Secondary thermoclines?
- Inertial shear
- $K_z$ varied from 0.1 to 8 cm$^2$/s
- Higher $K_z$ (surface, bottom and above thermocline)

- Persistence of strong N2
- $K_z < 1$ cm$^2$/s
- This doesn’t explain all
Westerly winds forced upwelling

Summer Episodic Events and DO
Meteorological forcing influences currents/mixing

Surface currents are in the order of 20-30 cm/s.

Bottom currents are as high as 8-10 cm/s.
Horizontal Exchanges in the Central basin

- Difference between the years
- Shear in the u comp is because of inertial oscillations
- Horizontal exchange (0.5 m²/s at the surface to 0.25 m²/s at bottom)
Dissolved Oxygen Balance in the Hypolimnion

Vertical Mixing + low hypolimnion vol + typical SOD do not balance DO variability

Horizontal Transport is also important

\[ \frac{dO_k}{dt} = \frac{K_x}{H_d} \left( \frac{O_z - O_k}{\Delta z} \right) - (SOD + P - R) \]
Currents are mostly barotropic. Mean currents at the north mooring is equivalent of Major inflow.
EC-University (NSERC-SPG) Collaborative Study  
2008 - 2009

NSERC SPG (Kevin Lamb/ U Waterloo- PI, Ralph Smith- U Waterloo, Joe Ackerman- U Guelph, Leon Boegman- Queens University)

Environment Canada (Ram Yerubandi, Sue Watson, David Lam)

Goals:
1. Understand the implications of internal wave induced mixing in hypoxia and other biogeochemical processes
2. High resolution models require detailed field measurements
3. Provide improved understanding on how the nutrients are assimilated from west basin to the central basin (GLWQA & Lake Erie LaMP)
1. 8 High Frequency thermistor moorings (10 sec @ 1m)
2. 3 Hourly temp mooring
3. Multi-level oxygen/Turbidity moorings at several stations
4. High frequency and hourly current profiles (ADCPs, ADVs)
5. Sediment Traps, Meteorology, Waves
6. Water sampling/ Microstructure profiling
Summary

- Large experiments after 20 years in the lake
- Data analysis & Hydrodynamic and water quality modeling ongoing

Results so far!

- Physical limnology and surface meteorology parameters are analysed
- Physical Processes play a major role in the central basin hypoxia (nothing new!)
- Importance of bottom currents and turbulence measurements
- Estimation of horizontal and vertical mixing
- Interbasin and coastal exchanges
- Basin scale and small scale internal oscillations
- New physical limnology experiments in 2008 & 2009 (Lake Erie Surveillance Year)