Climate Change, Lake Ecosystem Dynamics and Lesson Plan

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Literature Review: Climate Change Through the Years (millennial to annual)

Natural Cycles-The Milankovitch Theory

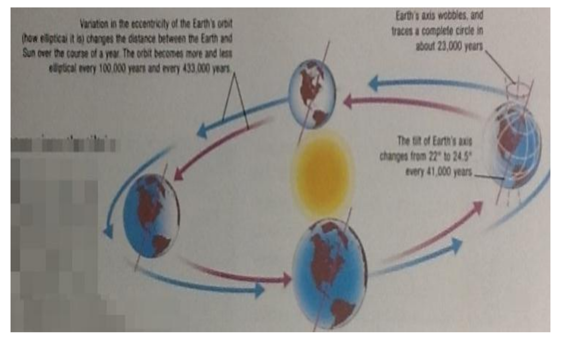

Figure A: Diagram showing images of earth's tilt and orbit and how they relate to the Milankovitch Cycles (Ochoa et al 2005)

- Cyclical changes in paleorecords of Earth's climate occur in synchrony with the earth's orbit around the sun that change cyclically (Ochoa et al 2005).
- The Earth's axis wobbles on its axis in a circle about every 23,000 years (Ochoa et al 2005).
- The tilt of the Earth's axis changes from 22° to 24.5° every 41,000 years (Ochoa et al 2005).
- The eccentricity of earth's orbit changes every 100,000 and 430,000 years (Ochoa et al 2005).

Climate in Continental and Marine Sediment cores: thousands of years:

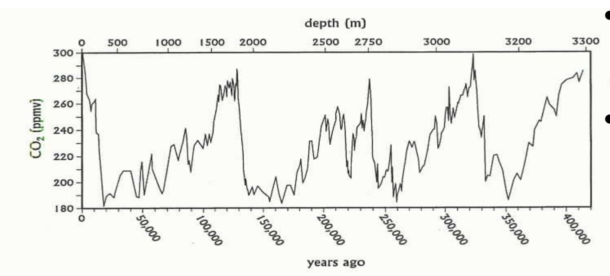

Figure B: Atmospheric CO_2 concentrations during the past 420,000 years determined using ice core data from Vostok Antartica (Petit et al.1999).

- Ratios in ice and sediment cores can serve as paleothermometers for Earth's past climate.
- The greenhouse-gas record in the ice-cores shows that present day levels of Carbon Dioxide and Methane are unprecedented throughout the last 420,000 years (Petit et al., 1999).
- CO_2 concentrations shown in ice and sediment cores match with the periodicity of Milankovitch cycles.

Mann's Hockey Stick Model: A Look at Centuries:

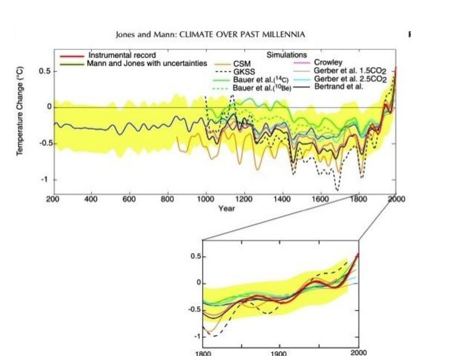

Figure C: Hockey stick Model The zero line shown in Figure 3 shows how all the models have been aligned vertically to have the same mean during the common time range of all the models (1856-1980) (Jones and Mann 2004).

- Twentieth century warming defies the millennial-scale cooling trend that is supposed to be occurring if keeping in step with long-term Milankovitch cycle trends (Mann et al 1999).
- Even warmer intervals in the model's reconstructed climate over the last two millennia, pale in comparison to the rise in temperature and Carbon Dioxide concentrations during the last two centuries following the agro-industrial revolution (Mann et al 1999).
- Yearly, seasonal and daily data are important in studying even as broad of a topic as climate change.

Climate Tracked by Instruments: Keeling Curve and the Last 50 years

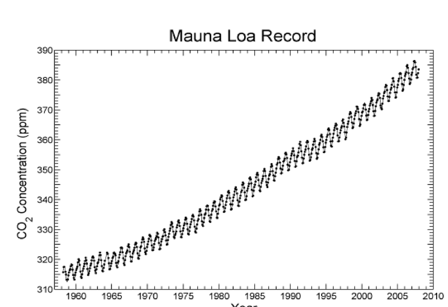

Figure D: Keeling Curve (CO_2 readings from Mauna Loa): http://scrippsco2.ucsd.edu/program_history/keeling_curve_lessons.html

- The natural baseline of CO_2 prior to the industrial revolution was 280ppm, and the values by the end of the millennia surpassed 365ppm, nearly a 30% increase since 1950 (Ruddiman 2001).
- The main carbon increase is due to anthropogenic effects, and the two main factors include deforestation and the burning of fossil fuels (Ruddiman 2001).
- The Keeling Curve is not only used to view 50-year change, but to track annual cycles as well.

Climate Change in the Great Lakes

Climate Change in the Great Lakes region can lead to:

- A decrease in the number of extremely cold days, an increase in extremely hot days, and an overall increase in precipitation including significant precipitation events (Sousounis and Grover 2002).
- Warming temperatures in the winter leading to a decreased freeze period, heating in the summer leading to an increase in lake water heat storage, a net decrease in lake basin water supply due to changes in monthly precipitation, evaporation, and runoff, and soil moisture deficits during the growing season (Hare and Cohen, 1988)
- Thermal stratification and limited availability of nutrients (Brooks and Zastrow 2002).

Research Project: Using Time-Series Data to Understand Lake Dynamics

Abstract

The observatory located in Muskegon Lake, MI collects real-time data on many environmental variables that are key to understanding lake dynamics. Using observatory data collected in 2012, air temperature, water temperature (at 5m), Photosynthetically active radiation (PAR), dissolved oxygen (at 5m), and Chlorophyll (at 5m) data was analyzed to monitor daily and inner-annual cycles to gain insight into larger time scale climate that drives climate change. Data was used to configure daily averages for the year 2012, hourly averages for four typical months, and trends from a typical day in each of those four months. It is important to monitor daily, seasonal, and yearly cycles in lakes to gain an understanding of the pulse of the lake and understand the effects of anthropogenic change.

Introduction

A drowned river-mouth estuary, Muskegon Lake is designated by the US EPA as an "area of concern", thus an ideal location for the lake observatory. When looking at lake time series data, several key questions can be asked: (1) What drives lake production, (2) How are daily cycles mirrored in seasonal cycles, and (3) why are lakes sentinels for climate change? If scientists can answer these key questions, we can better address the effects of anthropogenic activity in the Muskegon watershed to maintain and improve water quality and availability.

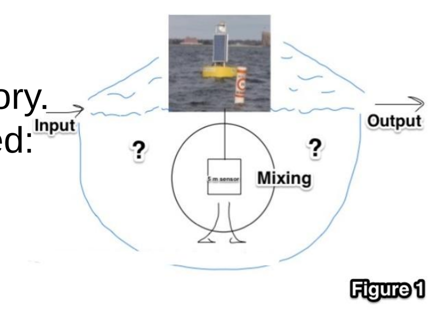

Figure 1

Materials & Methods

Data is collected from the observatory every 15 minutes and transmitted to an on shore computer Data collected from the buoy deployed on Muskegon Lake (Figure 1) collects the following data at various depths: wind speed/direction, air temperature, barometric pressure, precipitation, humidity, dissolved oxygen, conductivity, water temperature, pH, turbidity, photosynthetically active radiation (PAR), nitrates, Chlorophyll a, phycocyanin, colored dissolved organic matter (CDOM), and water velocity/direction (Biddanda, 2012). Data analyzed in this particular study was done with data from the 5m sensor as it yields the most integrated pulse of the lake. All of these variables are important for determining productivity and ecosystem health.

Results

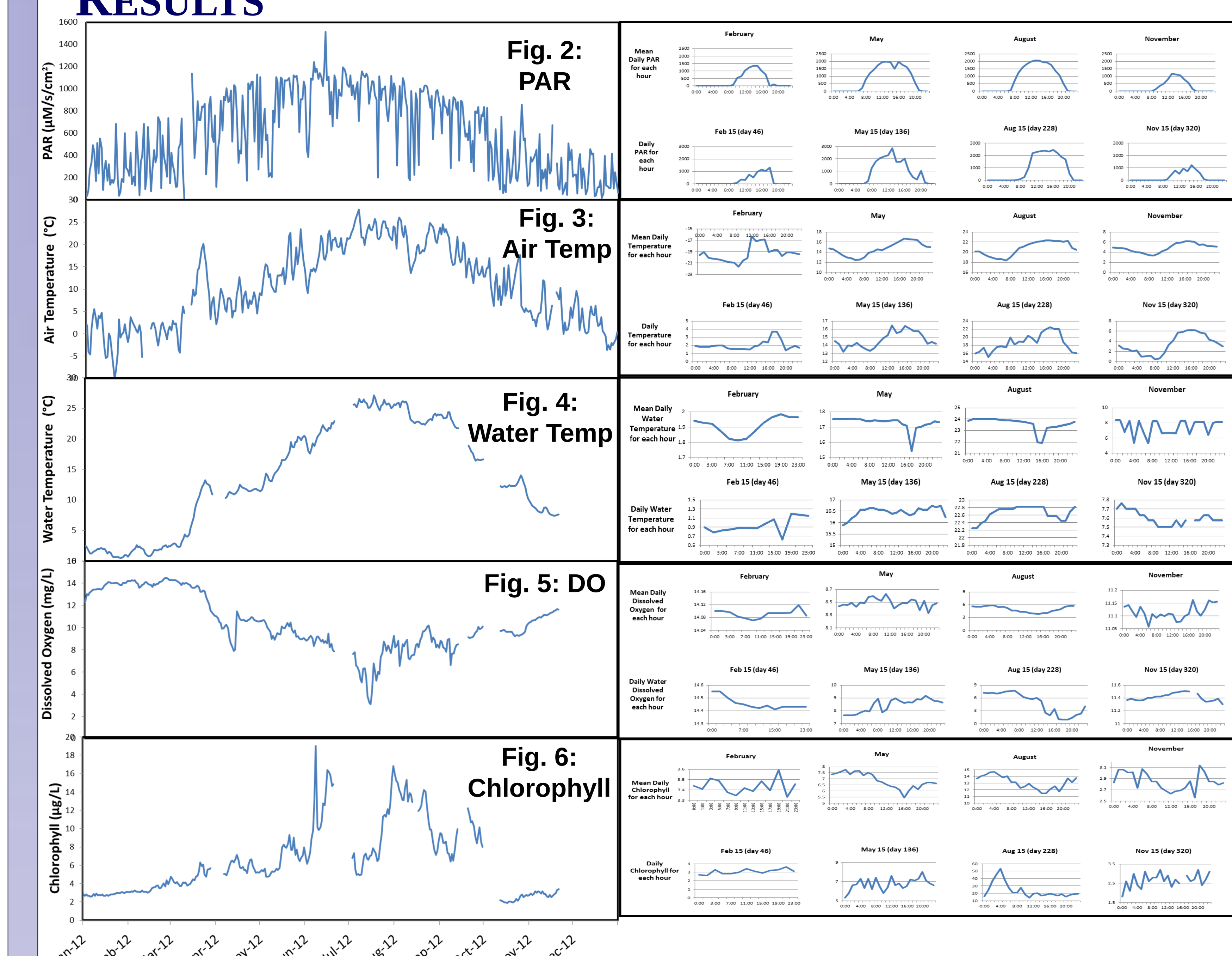

Figure Legends:

Figure 1: Schematic diagram of lake showing observatory and sensor. Question marks represent driving questions (1) What drives lake ecosystems? (2) What objectives/standards can be met using lake studies and observatory data in the K-12 classroom? Figures 2-6 (left panel) show mean daily values and the right panel shows average time of day graphs for a representative month in the winter, spring, summer, and fall (top) and a single representative day for each month shown in the bottom graph) showing daily variability.

- **Air Temperature:** Trends observed are typical to what is expected with increasing warmth in the spring and summer, and cooling in the fall into the winter (Figure 3).
- **Water Temperature:** Trends observed are typical to what is expected with increasingly warmer water temperatures in spring into summer, and cooling in the fall into the winter (Figure 4).
- **Photosynthetically Active Radiation (PAR):** PAR values follow anticipated trends increasing through the spring and summer and decreasing in the fall with the length of the day due to Earth's position relative to the sun (Figure 2).
- **Dissolved Oxygen (DO):** The yearly trend of dissolved oxygen (DO) shows a higher amount in the winter months and a lower amount in the summer months (Figure 5).
- **Chlorophyll:** The general trend for mean Chlorophyll measured at 5m in 2012 shows an increase in the spring, a peak in the summer, and a decrease in the fall; however, there are some anomalies to this trend (Figure 6).

Discussion

- *What controls lake production?*
  Temperature and sunlight. Chlorophyll and PAR show a positive relationship (r^2=0.3393 January-June, and 0.2478 July-December). Temperature and Chlorophyll also shows a positive relationship (r^2=0.5677 January-June, and 0.3915 July-December).
- *How are daily cycles mirrored in a season? Seasonal cycles in a year? Yearly cycles on a large scale?*
  As shown in Figures 2-6, daily snapshots, mirror daily average measurements of each hour, and ultimately those show seasonal trends and a better understanding for what makes up the yearly trend.
- *How do lakes serve as useful sentinels of environmental change?*
  Lakes integrate signals from their air and water sheds, are very sensitive to ecosystem changes, and can be the "canary in the coal mine" as one of the very early indicators of climate and environmental change (Biddanda, 2012). Lakes exist all over the world in many different types of climate and ecosystems (Williamson, 2009).

Conclusion

- Monitoring lake dynamics is key to understanding the effects of human activity and anthropogenic change as lakes act as sensitive sentinels for climate change.
- Temperature and sunlight drive lake productivity dynamics.
- Annual, seasonal and daily cycles of Muskegon Lake follow trends that are seen all over the world in lake ecosystems and others.
- The Mauna Loa observatory's CO_2 measurements mirror Muskegon Lake's Dissolved Oxygen trend indicating that even Mauna Loa far from anthropogenic effect shows an increase in global climate change.

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Lesson Plan: What Time-Series Data can Tell us about Climate Change and Lake Ecosystems

Copy of lesson plan is available upon request

Acknowledgments

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