Finding Great Lakes Climate Change Educational Resources

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Abstract: This presentation surveys the development of climate change educational resources in general and identifies specific resources that might be useful in teaching climate change in the Great Lakes region.

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1. Development of climate change as an educational topic in National Science Standards and Benchmarks

For many of us the reality of climate change and the role of atmospheric greenhouse gases from human sources has become scientifically incontrovertible. Conveying this reality to diverse audiences is however hampered by the complexity and subtlety of the observational evidence, the range of science and social disciplines involved in understanding it as well as the political and economic pressures to not tell the story.

Another factor is the historic focus in US science education - as represented by the national benchmarks and standards - on the STEM (science, technology, engineering and mathematics) disciplines to the exclusion of more integrated geoscience and environmental science curriculum.

The arc of influential publications of Project 2061, from the American Association for the Advancement of Science,

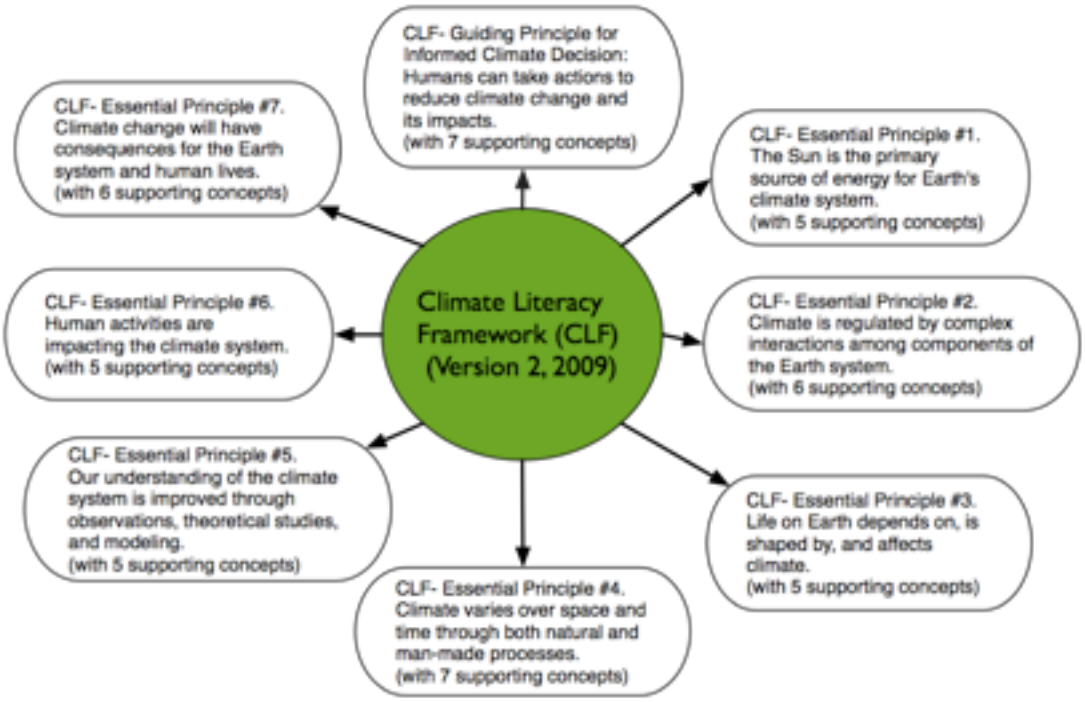
takes us from Science for All Americans (1989), Benchmarks for Science Literacy (1993) to the large two volume folio of the Atlas of Science Literacy (2001, 2007) and its digital form in the NSDL Science Literacy Strand Maps. The National Science Education Standards (NSES) (1996), published by the National Research Council, have shaped virtually all state science standards for the last decade or more.

In recent years several geoscience communities have been developing ocean, climate, atmosphere and earth science literacy frameworks to extend the traditional STEM disciplines in the National Science Education Standards content standards. These geoscience literacy frameworks include Oceans For Life (2002), Ocean Literacy (2005), Climate Literary (2007, 2009), Atmospheric Science (2008), Earth Science (2008), Great Lakes (2010) and Lake Erie (2011).

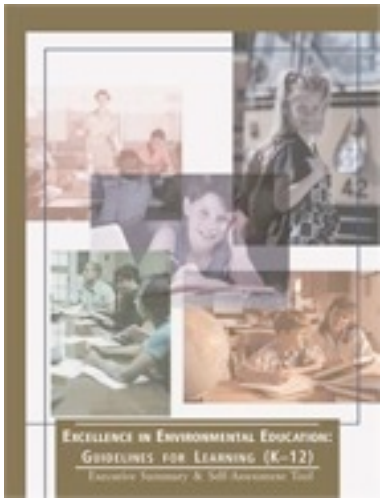
Like the older content standards these new geoscience literacy frameworks have focused on K-12 education although they are also of value for informal education and general public audiences.

These geoscience literacy frameworks potentially provide a more integrated and less abstract approach to science literacy that may be more suitable for non-science major students that are not pursuing careers in science research or education. They provide a natural link to contemporary environmental issues - e.g., climate change, resource depletion, species and habitat loss, natural hazards, pollution, development of renewable energy, material recycling.

Of particular importance to us is the Climate Literary framework with its one Guiding Principle for Informed Climate Decision-making, seven Essential Principles and many supporting concept statements. The 2009 revision of this document was endorsed by all the major federal agencies involved in climate change and has already influenced research, funding and curriculum development priorities and been a tremendous help in introducing topics like climate change into formal classrooms.



We are seeing several new developments that should bring geoscience and environmental education (esp. the teaching of climate change topics) into national science education standards:



The North American Association for Environmental Education (NAAEE) Guidelines: Excellence in Environmental Education - Guidelines for Learning (K-12) (revised 2010) offers a vision of environmental education and promotes progress toward sustaining a healthy environment and quality of life. They are organized into four strands -- Strand 1: Questioning, Analysis and Interpretation Skills; Strand 2: Knowledge of Environmental Processes and Systems; Strand 3: Skills for Understanding and Addressing Environmental Issues; Strand 4: Personal and Civic Responsibility -- that show how concepts/skills develop across the grade levels (4th, 8th, and 12th) They support state and local environmental education efforts by demonstrating how environmental education can be used to meet standards set by the traditional disciplines and to give students opportunities to synthesize knowledge and experience across disciplines.

The development of the New Generation Science Standards (NGSS) is a two-step process. The first step was the building of a framework that identified the crosscutting concepts, disciplinary core ideas, and practices in natural sciences and engineering that all students should be familiar with by the time they graduate. In July, 2011, the National Research Council released *A Framework for K-12 Science Education*, developed by a committee representing expertise in science, teaching and learning, curriculum, assessment and education policy. It represents a

strong alignment with the Common Core Language Arts Standards focused on disciplinary literacy and an emphasis on a developmental approach that leads to deeper understanding of a few big ideas in science.

The second step is the development of a set of high quality, college- and career-ready K–12 *Next Generation Science Standards* ready for state adoption based on this *Framework*. The 20 Lead State Partners (including several Great Lakes states - Michigan, Minnesota, New York, Ohio) will work with the education policy organization, Achieve, to guide the standard writing process, gather and deliver feedback from state-level committees and come together to address common issues and challenges. The Lead State Partners also agree to commit staff time to the initiative and, upon completion, give serious consideration to adopting the Next Generation Science Standards. Drafts of the science standards will be made available for public input at least two times during the NGSS development process. The NGSS should be completed by the end of 2012.

The Senate's reauthorization and revision of the *No Child Left Behind* Act, the new Elementary and Secondary Education Act (ESEA), currently includes environmental education as a subject eligible for funding under Title IV of ESEA.

2. Climate Science in the Science Standards for the Great Lakes States

The depth, breadth and timeliness of science standards vary widely over the region. All have been influenced in part by the NSES 1996 Content Standards. Some more recent revisions appear to be take into account the new geoscience literacy frameworks. Hopefully the recent national developments in geoscience and environmental education will speed up the introduction of climate science topics into Great Lakes classrooms and informal science centers.

The following table provides links to the relevant state standards websites as well as rough indication of some places where climate science (as represented by the Climate Literacy Essential Principles and Fundamental Concepts) appears in the standards and benchmarks.

State	Standards Websites	Climate-Related Standards
Illinois	General: http://www.isbe.state.il.us/ils/Default.htm Science (K-12): http://www.isbe.state.il.us/ils/science/standards.htm	STATE GOAL 12: Understand the fundamental concepts, principles and interconnections of the life, physical and earth/space sciences STATE GOAL 13: Understand the relationships among science, technology and society in historical and contemporary contexts.

State	Standards Websites	Climate-Related Standards
Indiana	General: http://dc.doe.in.gov/Standards/AcademicStandards/index.shtml Science (6-12): http://dc.doe.in.gov/Standards/AcademicStandards/PrintLibrary/science.shtml New Science Standards were adopted in 2010 K-8 Science Standards: http://dc.doe.in.gov/Standards/AcademicStandards/PrintLibrary/docs-Science/2010-K-8ScienceStandards.pdf Earth and Space Science I: http://dc.doe.in.gov/Standards/AcademicStandards/PrintLibrary/docs-science/2010-science-earthspace.pdf	Earth and Space Science I: Standard 4: The Atmosphere and Hydrosphere
Michigan	General: http://www.michigan.gov/mde/0,1607,7-140-28753_38684---,00.html Science: http://www.michigan.gov/documents/mde/Complete_Science_GLCE_12-12-07_218314_7.pdf High School Content Expectations - Earth Science http://www.michigan.gov/documents/mde/Earth_HSCE_9-15-09_292351_7.pdf	EARTH SCIENCE/ Earth Systems K-7 Standard E.ES LIFE SCIENCE Organization of Living Things / Ecosystems (Fourth Grade) K-7 Standard L.EC High School Content Expectations - Earth Science STANDARD E2: EARTH SYSTEMS STANDARD E4: THE FLUID EARTH STANDARD E5: THE EARTH IN SPACE AND TIME E5.4 Climate Change
Minnesota	General: http://education.state.mn.us/MDE/Academic_Excellence/Academic_Standards/index.html Science: http://education.state.mn.us/MDE/Academic_Excellence/Academic_Standards/Science/index.html Academic Standards: Science K-12 (2009) - Adopted version 5.24.10 (http://education.state.mn.us/mdeprod/groups/Standards/documents/Publication/013906.pdf) The 2009 Revision of the Minnesota Academic Standards in Science was put into rule effective May 24, 2010.	9.3.2.2.1: Explain how Earth's rotation, ocean currents, configuration of mountain ranges, and composition of the atmosphere influence the absorption and distribution of energy, which contributes to global climatic patterns. 9.3.2.2.2: Explain how evidence from the geologic record, including ice core samples, indicates that climate changes have occurred at varying rates over geologic time and continue to occur today. 9.3.4.1.2: Explain how human activity and natural processes are altering the hydrosphere, biosphere, lithosphere and atmosphere, including pollution, topography and climate. *For example:* Active volcanoes and the burning of fossil fuels contribute to the greenhouse effect.

State	Standards Websites	Climate-Related Standards
New York	General: http://www.p12.nysed.gov/ciai/standards.html Science: http://www.p12.nysed.gov/ciai/mst/sci/ls.html Earth Science: http://www.p12.nysed.gov/ciai/mst/pub/earthsci.pdf	STANDARD 4: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science. Science Learning Standard: Physical Setting / Earth Science: PERFORMANCE INDICATOR 2.2: Explain how incoming solar radiation, ocean currents, and land masses affect weather and climate. Science Learning Standard: The Living Environment Key Idea 7: Human decisions and activities have had a profound impact on the physical and living environment.
Ohio	General: http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEPrimary.aspx?page=2&TopicRelationID=1696 Science: http://www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEPrimary.aspx?Page=2&TopicID=1696&TopicRelationID=1705 The State Board of Education adopted the Model Curriculum on March 15, 2011. Grades PreK-8 Science Revised Standards and Model Curriculum (March 2011) (http://www.ode.state.oh.us/GD/DocumentManagement/DocumentDownload.aspx?DocumentID=107333)	Grade 7 Earth and Space Science (ESS) Topic: Cycles and Patterns of Earth and the Moon Content Statements The hydrologic cycle illustrates the changing states of water as it moves through the lithosphere, biosphere, hydrosphere and atmosphere. Thermal-energy transfers in the ocean and the atmosphere contribute to the formation of currents, which influence global climate patterns. The atmosphere has different properties at different elevations and contains a mixture of gases that cycle through the lithosphere, biosphere, hydrosphere and atmosphere. High School Advanced Sciences Physical Geology Syllabus and Model Curriculum Environmental Science Syllabus and Model Curriculum

State	Standards Websites	Climate-Related Standards
Pennsylvania	General: http://www.education.state.pa.us/portal/server.pt/community/state_academic_standards/19721 Science and Technology (K-12): http://www.portal.state.pa.us/portal/server.pt/gateway/PTARGS_0_123531_707476_0_0_18/ScienceandTechnologyStandards.pdf Academic Standards for Science and Technology took effect upon their publication in the *Pennsylvania Bulletin* on January 5, 2002 Environment and Ecology: http://www.portal.state.pa.us/portal/server.pt/gateway/PTARGS_0_123531_891012_0_0_18/EEStandards.pdf Academic Standards for Environment and Ecology took effect upon their publication in the *Pennsylvania Bulletin* on January 5, 2002	3.5.10. GRADE 10 3.5.10.C. Interpret meteorological data. • Analyze information from meteorological instruments and online sources to predict weather patterns. • Describe weather and climate patterns on global levels. • Evaluate specific adaptations plants and animals have made that enable them to survive in different climates. 3.5.12. GRADE 12 3.5.12. C. Analyze atmospheric energy transfers. 4.8. Humans and the Environment 4.8.7. GRADE 7 4.8.7.B. Explain how people use natural resources. • Explain how climate and extreme weather events (e.g., drought, flood) influence people's lives. 4.8.7.C. Explain how human activities may affect local, regional and national environments. • Describe what effect consumption and related generation of wastes have on the environment.

State	Standards Websites	Climate-Related Standards
Wisconsin	General: http://www.dpi.state.wi.us/standards/stds.html Science: http://www.dpi.state.wi.us/standards/sciintro.html **Common Core State Standards for Literacy in all Subjects** (http://www.dpi.state.wi.us/cal/pdf/las.pdf) adopted in September 2011 **Science, Standard E: Earth and Space Science** **Performance Standards - Grade 8** (http://dpi.wi.gov/standards/scie8.html)	Science, Standard E: Earth and Space Science Performance Standards - Grade 8 E.12.4 Analyze the benefits, costs, and limitations of past, present, and projected use of resources and technology and explain the consequences to the environment. Science, Standard F: Life and Environmental Science Performance Standards - Grade 12 THE INTERDEPENDENCE OF ORGANISMS F.12.8 Using the science themes, infer changes in ecosystems prompted by the introduction of new species, environmental conditions, chemicals, and air, water, or earth pollution Science, Standard H: Science in Personal and Social Perspectives Performance Standards - Grade 8 H.8.1 Evaluate the scientific evidence used in various media (for example, television, radio, Internet, popular press, and scientific journals) to address a social issue, using criteria of accuracy, logic, bias, relevance of data, and credibility of sources

This is the context for those teaching climate change in the Great Lakes region.

3. Where are the top sources of general climate change educational resources?

Federal agencies

Several federal agencies have developed strong websites of educational material -- based on data or media they have developed as part of their missions. This can be a problem at times -- with some resources not being particularly strong pedagogically and having a focus on the promotion of their data collection efforts.

Source	Website	Comments
National Aeronautics and Space Administration (NASA)	http://climate.nasa.gov/	a particularly polished and continuously refreshed website, the Climate Time Machine is a highlight.
Environmental Protection Agency (EPA)	http://www.epa.gov/climatechange/	
National Oceanic and Atmospheric Administration (NOAA)	http://www.climate.gov/#education	
Department of Energy (DoE)	http://www1.eere.energy.gov/education/index.html	
United States Global Change Research Program (USGCRP)	http://www.globalchange.gov/resources/educators	includes the national assessments; also see for example, the Climate Change Wildlife and Wildlands Toolkit.

Federally-funded Projects

As a result in part of the development of the geoscience literacy frameworks, three federal agencies (NASA, NOAA and the National Science Foundation (NSF)) have developed funding programs that support the development of environmental (and especially, climate) literacy. The tri-agency webpage contains a document with many of these federally funded projects. There is also a shorter list at http://cleanet.org/cln/ccep.html. We can expect new educational materials to continue to come from these projects over the next few years.

The following table contains links to important collections of educational materials developed with federal funds.

Source	Website	Comments
Earth Science Teachers Association	http://www.windows2universe.org/	
Center for Ocean Science Education Excellence - Ocean Systems	http://cosee.umaine.edu/climb/oci/	
Science Education Research Center (SERC)	http://serc.carleton.edu/serc/site_guides/climate.html	
National Geographic	http://education.nationalgeographic.com/education/multimedia/?ar_a=1&ar_r=1	site for videos; many however failed under CLEAN review.

PBS	http://www.pbs.org/teachers/stem/professionaldevelopment/	
Teacher Domain (WGBH Educational Foundation)	http://www.teachersdomain.org/browse/?fq_hierarchy=k12.sci.ess.watcyc.climate	they have collected a number of important resources
NBC Learn - Changing Planet	http://www.nbclearn.com/portal/site/learn/changing-planet	(including a segment on Lake Temperatures - with a focus on Lake Superior - see below)

Advocacy Groups

Material from advocacy groups and their websites (e.g., the Union of Concerned Scientists, RealClimate, Sierra Club, Nature Conservancy , Wilderness Society, Environmental Defense Fund) often have strong political and advocacy viewpoints. This can sometimes make them hard to use in formal or informal settings. However if used with care they can be useful in addressing current news items (advocacy groups/website usually respond much faster than educational resource developers).

RealClimate is a commentary site on climate science by working climate scientists for the interested public and journalists. It aims to provide a quick response to developing stories and provide the context sometimes missing in mainstream commentary. The discussion is restricted to scientific topics and will not get involved in any political or economic implications of the science. All posts on this moderated forum are signed by the author(s), except 'group' posts which are collective efforts from the whole team.

Teachers

Many teachers develop their own educational resources and are generally willing to share them with other teachers. They need to be used with caution since they often lack full scientific reviews, transferrable pedagogical designs and ongoing support that materials from agencies and research group projects have. On the other hand they are often innovative and practical.

4. How do you know what resources are good?

With all these educational resources being developed, what was needed was a comprehensive process of review -- with a standard set of review criteria and a rigorous multi-step science and pedagogical review process -- relative to the content identified in the climate literacy essential principles and the various national standards/benchmarks.

The **CLEAN Pathway Project** was developed by the same group that developed the *Climate Literacy: The Essential Principles of Climate Science* document (mostly members of the Climate Literacy Network. Funded by the National Science Foundation in 2010, in the year before the National Science Foundation's Climate Change Education Partnership - Phase I grants were awarded, it is currently finishing up its second year with one final year to go.

The CLEAN Collection consists of systematic reviews of current online materials of different resource types (e.g., learning activities, videos, static visualizations/figures, animations, simulations/interactives, short demonstration/experiments - with full courses and curriculum coming soon). The review criteria consist of focused questions about scientific accuracy, pedagogical effectiveness and technical ease of use with some variation in the questions depend on the nature of the resource.

The review process (from which a resource can be dropped at any time) consists of the vetting of submitted materials (where its match to climate literacy principles/concepts and the scope of the collection is considered), two full reviews (one by an educator resource collector and a scientist resource collector), review by a mixed team of reviewers (including educators/ scientists outside the regular resource collection process) and expert science review (if needed).

For resources that pass this process, annotations are developed, cataloguing completed and an individual resource webpage is put up on the CLEAN website with
- a URL to the online resource,
- authors,
- short description (including the time and materials required),
- notes from the reviewers on teaching tips, science, pedagogy and technical details/ease of use, and
- a link to a general and resource-specific discussion boards.

The Collection can be searched by resource type, climate and energy topics, grade level, climate literacy principles, energy awareness principles (soon to be replaced by the new energy literacy principles), AAAS Benchmarks for Science Literacy and the NAAEE's Guidelines for Learning (coming soon).

Recent reviews have identified those resources that have a regional focus. CLEAN has used the same regional classification as the US Global Change Research Program National Climate Assessment reports. While the Great Lakes are not covered explicitly they are of course included in the Midwest and Northeast regions.

The CLEAN Resource Collectors looked at between 5-7,000 resources with 1652 (as of November 6, 2011) receiving substantial reviews. The overall impression is that there are a lot of poor resources available on the web and, in this rapidly changing field, older resources are often seriously out of date. More modern resources are generally better since they are often refinements of older resources and frankly have more time and money being spent on them.

Currently the CLEAN Collection consists of 281 resources with about 40 more by end of November as their processing is finished. There are gaps in the coverage of the topics included in the Climate Literacy Essential Principles that the team will attempt to fill in the next year from existing web resources. The CLEAN Pathway project team is just now opening up discussions with selected developers to improve resources that failed the initial review process.

Before the project ends in 2012 at least 500 resources in total are expected in the Collection. The intention is to move this Collection to www.climate.gov and to maintain and improve the collection as more materials appear. Many new resources are expected from recently-funded projects.

4. What special characteristics of the Great Lakes region should be reflected in educational materials used here?

The 2000 Great Lakes Regional Assessment report indicated that the main impacts of climate change in the Great Lakes would be on the "levels of the Great Lakes, streamflow, aquatic and terrestrial ecosystems, agriculture, and quality of life."

In the 2009 Global Climate Change Impacts in the United States gave this more detailed summary of the impacts (in the Midwest and Northeast regional summaries):

- During the summer, public health and quality of life, especially in cities, will be negatively affected by increasing heat waves, reduced air quality, and insect and waterborne diseases. In the winter, warming will have mixed impacts. (Midwest regional summary)
- Extreme heat and declining air quality are likely to pose increasing problems for human health, especially in urban areas. (Northeast regional summary)
- Significant reductions in Great Lakes water levels, which are projected under higher emissions scenarios, lead to impacts on shipping, infrastructure, beaches, and ecosystems. (Midwest regional summary)
- Severe flooding due to sea-level rise and heavy downpours is likely to occur more frequently. (Northeast regional summary)
- The likely increase in precipitation in winter and spring, more heavy downpours, and greater evaporation in summer would lead to more periods of both floods and
- water deficits. (Midwest regional summary)
- The projected reduction in snow cover will adversely affect winter recreation and the industries that rely upon it. (Northeast regional summary)
- While the longer growing season provides the potential for increased crop yields, increases in heat waves, floods, droughts, insects, and weeds will present increasing challenges to managing crops, livestock, and forests. (Midwest summary)
- Agricultural production, including dairy, fruit, and maple syrup, are likely to be adversely affected as favorable climates shift. (Northeast regional summary)
- Native species are very likely to face increasing threats from rapidly changing climate conditions, pests, diseases, and invasive species moving in from warmer regions. (Midwest regional summary)

One of the presentations later in the workshop will discuss recent research that challenges some of these findings.

5. What climate change educational resources do Great Lakes educators have to work with now?

There are two kinds of educational resources collected below:

1. general background materials about the Great Lakes and climate change that do not contain specific teaching activities, videos, etc.; and

2. Great Lakes-specific educational resources from CLEAN and the other topic websites

Since the web links are live in this document, I recommend that you click on the links to the resources and examine them on your own.

A word of caution: In this rapidly changing field, you should look first at the most recent publications. In the CLEAN Review process, background materials and educational older than the 2007 IPCC report were viewed with extreme caution. You may however find some insights in some of the older publications that might suggest ways of presenting the material.

For example, recent research suggests that "Climate change probably won't reduce Great Lakes water levels as much as experts have predicted and might even cause them to rise slightly" (http://online.wsj.com/article/AP059f252dd3b74781a22351af776eed47.html)

5.1 Background Materials

In mostly reverse chronological order here are several general background materials resources:

Lake Erie Literacy Principles *Spring 2011* (http://www.ohiodnr.com/lakeerieliteracy/)

Brochure and Website: The Lake Erie Literacy Principles and Concepts adapted the Ocean Literacy: The Essential Principles and Fundamental Concepts to Lake Erie. After being first presented at an international conference in 2009, the Lake Erie Literacy Principles were used to develop the Great Lakes Literacy Essential Principles and Fundamental Concepts, which were finalized in the summer 2010. After further revisions based on feedback from scientists, researchers and educators, the Lake Erie Literacy Principles and Concepts were finalized in spring 2011.

Great Lakes State and Provincial Climate Change Mitigation and Adaptation: Progress, Challenges and Opportunities *September 2010 (http://www.glc.org/climate/GLCIssue-02-GLClimateChange.pdf)*

This paper examines the state of climate change policy among the Great Lakes states and provinces based on a literature and internet review and interviews conducted with lead climate change staff in the states of Illinois, Michigan, Minnesota, New York and Pennsylvania.

Great Lakes Literacy Principles *July 2010* (http://greatlakesliteracy.net/)

Brochure and Website: The Great Lakes Literacy effort had its origins, as did the other geoscience literacy frameworks, in Ocean Literacy Campaign, a volunteer effort by many scientists and educators to develop a concise framework for conveying the most important science principles and interconnected concepts that all Earth citizens should know. The Great Lakes Principles mostly parallel those of Ocean Literacy. They however include an eighth principle: *The Great Lakes are socially, economically and environmentally significant to the region, the nation and the planet.* This addition allows for greater inclusion of the environmental history of the lakes and their role in the development of the region's history, economy, and regional identity.

US Global Change Research Program - Global Climate Change Impacts in the United States (2009) (http://www.globalchange.gov/what-we-do/assessment/previous-assessments/global-climate-change-impacts-in-the-us-2009)

Midwest (http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/midwest) and Northeast (http://www.globalchange.gov/publications/reports/scientific-assessments/us-impacts/regional-climate-change-impacts/northeast)

Website: A facts sheet or chapter that teachers could have students read to learn about possible impacts that climate change will have on the region of the country they live in.

The Great Lakes at a Crossroads: Preparing for Climate Change (2/25/2009)

Factsheet: Find out what is happening in the Great Lakes and how it can impact your daily life. Learn how climate change in the Great Lakes differs from other regions.

US Global Change Research Program - Preparing for a Changing Climate: The Potential Consequences of Climate Variability and Change in the Great Lakes Region, October 2000 (http://www.geo.msu.edu/glra/assessment/assessment.html) prepared by the Great Lakes Regional Assessment Group for the US Global Change Research Program

Website and Report: One of the regional reports included in the first U.S. National Assessment of the Potential Consequences of Climate Variability and Change

Preparing for Climate Change in the Great Lakes Region (Michigan Sea Grant)

A workshop and report identifying policy changes that will enable Great Lakes communities to adapt, and strategies for implementation.

US Global Change Research Program - US National Assessment of the Potential Consequences of Climate Variability and Change

Educational Resources Regional Paper: Great Lakes (Updated 12 October, 2003) (http://www.usgcrp.gov/usgcrp/nacc/education/greatlakes/greatlakes-edu-refs.htm)

Website: Collection of old educational resource references

Material from the Great Lakes Region Assessment Group (Updated 11 October, 2003) (http://www.usgcrp.gov/usgcrp/nacc/greatlakes.htm)

Website: Collection of media coverage, workshop reports, etc. related to the October 2000 report

Union of Concerned Scientists - Great Lakes (http://www.ucsusa.org/greatlakes/)

Website: based in part on their 2003 report (done with the Ecological Society of America) called *Confronting Climate Change in the Great Lakes Region*, by George W. Kling et al. (http://www.ucsusa.org/greatlakes/glchallengereport.html). It includes short state and solutions summaries. The executive summary for this report was updated in 2005 (see http://www.ucsusa.org/assets/documents/global_warming/gl-exec-summary-update-05-doc.pdf). There are also several climate change interactives that are discussed below.

Climate Change and Water Quality in the Great Lakes Basin Report of the Great Lakes Water Quality Board to the International Joint Commission August 2003 (http://www.ijc.org/php/publications/html/climate/)

The Great Lakes Atlas - Third Edition, 1995 (http://epa.gov/greatlakes/atlas/index.html)

Website: This is an online version of the text, *The Great Lakes: An Environmental Atlas and Resource Book*. Taking an ecosystem approach, the Atlas helps readers understand the Great Lakes and other natural resources in the Great Lakes region as an interdependent system across an international border. Its purpose is to demonstrate how the Great Lakes are affected by use and to increase public appreciation for the importance of these lakes as a North American and global resource.

Here are a number of other organizations and websites that have Great Lakes-relevant background materials.

Finding Great Lakes Climate Change Educational Resources

Organization	Website
NOAA - Great Lakes	http://www.regions.noaa.gov/great_lakes/climate.html and more specifically http://www.regions.noaa.gov/great_lakes/climate_ready.html
NOAA - Great Lakes Environmental Research Laboratory	http://www.glerl.noaa.gov/
Journal of Great Lakes Research	http://www.iaglr.org/jglr/journal.php
Center for Ocean Sciences Education Excellence (COSEE) - Great Lakes	http://coseegreatlakes.net
Great Lakes Observing System	http://glos.us
Ohio State University Climate Change Outreach Team A partnership among Ohio State University departments that develops and communicates research and resources to localize the climate change issue for residents of Ohio and the Great Lakes region.	http://changingclimate.osu.edu/
Midwestern Regional Climatic Center	http://mcc.sws.uiuc.edu/climate_midwest/mwclimate_change.htm#
Great Lakes Commission A binational agency that promotes the orderly, integrated and comprehensive development, use and conservation of the water and related natural resources of the Great Lakes basin and St. Lawrence River	http://www.glc.org/ http://www.glc.org/climate/GLCIssue-02-GLClimateChange.pdf http://www.glc.org/policy/documents/Adaptation%20Policy%20in%20 the%20Great%20Lakes%20-%20FINAL%206-20.pdf http://www.glc.org/coast/documents/5-Schroeck-climate-change.pdf http://www.glc.org/announce/07/pdf/Bierbaum.pdf http://www.glc.org/announce/07/pdf/Lofgren.pdf http://www.glc.org/coast/documents/4-GlobalWarm.pdf http://www.glc.org/tributary/documents/meetings/June10/NOAA_GLRI_Brochure.pdf
International Joint Commission The International Joint Commission prevents and resolves disputes between the United States of America and Canada.	http://www.ijc.org/en/home/main_accueil.htm http://www.ijc.org/php/publications/html/climate/

Organization	Website
Ontario Centre for Climate Impacts and Adaptation Resources (OCCIAR) A university-based resource hub for researchers and stakeholders searching for information on climate change impacts and adaptation. The centre communicates the latest research on climate change impacts and adaptation; liaises with partners across Canada to encourage adaptation to climate change and aids in the development of tools to assist with municipal adaptation.	http://www.climateontario.ca/
U.S. Environmental Protection Agency, Great Lakes National Program Office Information about Great Lakes programs coordinated by the U.S. Environmental Protection Agency's Great Lakes National Program Office.	http://www.epa.gov/glnpo/http://epa.gov/greatlakes/atlas/index.html http://www.epa.gov/glnpo/iatf/index.html http://www.epa.gov/greatlakes/solec/index.html http://epa.gov/greatlakes/glri/index.html
Environment Canada	http://www.ec.gc.ca/grandslacs-greatlakes/default.asp?lang=En&n=BB02C773-1
Great Lakes Regional Integrated Sciences and Assessments Center (GLISA) A joint initiative between Michigan State University and the University of Michigan to improve the nation's ability to adapt to climate variability and change	www.graham.umich.edu/centers/glisa.php
Great Lakes Information Network A partnership that provides one place online for people to find information relating to the binational Great Lakes-St. Lawrence region of North America. GLIN offers a wealth of data and information about the region's environment, economy, tourism, education and more.	http://www.great-lakes.net/
International Association for Great Lakes Research (IAGLR) A scientific organization comprised of researchers studying the Great Lakes, other large lakes of the world, and their watersheds, as well as those with an interest in such research. IAGLR is committed to sharing its collective expertise with the media, policymakers, and the general public to inform public policy and decision-making that will protect the environmental health of large lakes and their watersheds.	http://www.iaglr.org

5.2 Collections of Educational Resources

Here are some current collections of educational resources:

The Education And Curriculum Home (TEACH) site (http://www.great-lakes.net/teach/index.html):

Website of educational resources for elementary through high school:
TEACH is a new component of the Great Lakes Information Network, with a focus on advancing Great Lakes-related educational materials for the broad audience of educators and students in the Great Lakes region and beyond. TEACH features mini-lessons on Great Lakes topics: environment, history and culture, geography, pollution, careers, and business. Geared for elementary through high school students, the modules are continually expanded and updated and include links to a glossary to help explain scientific terms and acronyms. Also included is a section for questions and answers, and education links. Specific topics within the site include: Great Lakes native flora, water levels on the Great Lakes, native peoples of the Great Lakes region, Great Lakes law and policy, introduction to the Great Lakes, how the lakes were formed, Great Lakes shoreline geology, non-native species, and urban sprawl.

Teaching with Great Lakes Data (http://greatlakeslessons.com/)

A collection of free Great Lakes lessons and activities, data sets and tools. They can be incorporated into curriculum to explore climate, weather, water quality and fish habitat; encourage students to develop higher-level thinking skills using real data and enhance teaching skills through guided inquiry methods.

Climate Change Webinar Series
(http://changingclimate.osu.edu/webinars/)

Ohio Sea Grant and Ohio State University developed an ongoing series of webinars bringing climate research and resources to residents of Ohio and the Great Lakes.

and several older collections of educational resources:

ACES (Activities for a Changing Earth System) 1993 (http://earthsys.ag.ohio-state.edu/project/pubs/ACES.html)
This older module is being updated.

ES-EAGLS (Earth Systems - Education Activities for Great Lakes Schools)
(http://earthsys.ag.ohio-state.edu/project/pubs/ES_EAGLS.html)
These 67 activities for students in middle and high cover five major topic areas:

Land & Water Interactions in the Great Lakes (117 pages, 13 activities)

Great Lakes Climate and Water Movement (96 pages, 13 activities)

Great Lakes Environmental Issues (180 pages, 18 activities)

Great Lakes Shipping (86 pages, 11 activities)

Life in the Great Lakes (118 pages, 12 activities)

Great Lakes Instructional Materials for the Changing Earth System (GLIMCES), 1995 (Ohio Sea Grant College Program) (http://earthsys.ag.ohio-state.edu/project/pubs/GLIMCES.html)
GLIMCES provides a packet of scientific scenarios of how global warming could affect the Great Lakes region, a review of climate models, and methods of teaching about those changes in secondary science and social studies classes. It is in the process of being updated by Ohio Sea Grant so that the activities reflective of the most recent climate science.

Global Change in the Great Lakes Scenarios (http://earthsys.ag.ohio-state.edu/project/pubs/SCENARIO.html)

5.3 Educational Resources

In exploring the CLEAN Collection and the other websites we find that there are only a few Great Lakes-specific educational resources. There are many opportunities to supplement the following list:

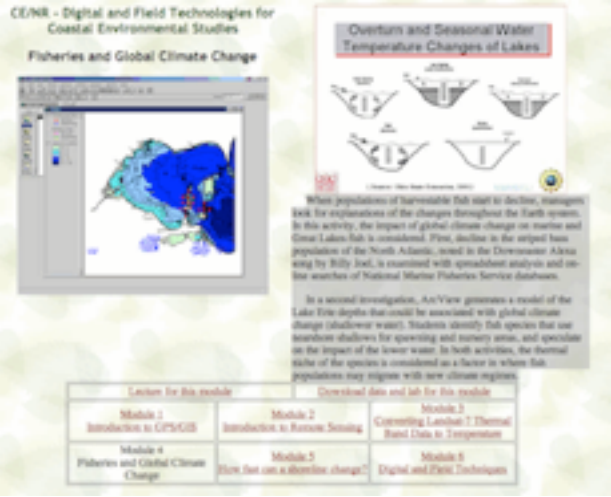
Will Steger Foundation. Minnesota's Changing Climate.
(http://classroom.willstegerfoundation.org/)

Website: In its curriculum and online classroom, *Minnesota's Changing Climate* explores Minnesota's unique biomes and what a changing climate will mean for the state. Specifically, it examines how climate has already, and is projected to change in Minnesota; how these changes may impact agriculture, forests and wildlife, aquatic ecosystems, our economy, as well as tourism and recreation; and how citizens can help reduce these potential impacts and help your biome adapt to a changing climate. The standards alignment to language arts, arts ed, geography, social studies, technology is provided at the beginning of all of the lesson plans.

Great Lakes Image Collection
(http://epa.gov/greatlakes/image/index.htm)

Website: The image collection of the US EPA Great Lakes National Program Office captures the magnitude and awesome beauty of the Great Lakes and its surroundings. These lakes offer beautiful waterfalls, pristine lakes and rivers, canyons forged out of volcanic rock, varied and abundant wildlife, while supporting vigorous economies, major urban centers and large-scale agricultural operations. The image collection was developed as a Cooperative Agreement project with Minnesota Sea Grant, originally called Visualizing the Great Lakes -Images of a Region and was the starting point for the current collection. The Great Lakes Image Collection is in the public domain and cannot be copyrighted.

Fisheries and Global Climate Change
(http://hcgl.eng.ohio-state.edu/~cenr797/module4.html)



Website, Teaching Activity for High School (9-12), College (13-14), College (15-16): When populations of harvestable fish start to decline, managers look for explanations of the changes throughout the Earth system. In these two activities, the impact of global climate change on marine and Great Lakes fish is considered. In the first activity the decline in the striped bass population of the North Atlantic is examined with spreadsheet analysis and on-line searches of National Marine Fisheries Service databases. In a second investigation, ArcView generates a model of the Lake Erie depths that could be associated with global climate change (shallower water). Students identify fish species that use nearshore shallows for spawning and nursery areas, and speculate on the impact of the lower water. In both activities, the thermal niche of the species is considered as a factor in where fish populations may migrate with new climate regimes.

Making Climographs (http://www.eram.k12.ny.us/education/components/docmgr/default.php?sectiondetailid=17511&fileitem=620):

Teaching Activity for Middle (6-8), High (9-12): Students use weather data and spreadsheet software to create climographs (a graph that shows monthly average temperature and precipitation for some location) for any location in the United States and compare their results to those of other students. Instructions and a link to weather data are provided.

Rising Temperature in Large Lakes (http://www.windows2universe.org/earth/climate/lake_temp_rising.html):

Article (for Middle (6-8), High (9-12)): This article is about the impact of global warming on large lakes with special emphasis on invasive species and Lake Superior.

Changing Planet: The Warming of Our Large Lakes - Reasons for Concern (http://www.windows2universe.org/teacher_resources/warming_lakes.html):

Teaching Activity (for Middle (7-8), High (9)): Students observe models of water stratification related to density differences to understand the mechanisms of thermal stratification. Students then analyze and interpret temperature profile data from the Great Lakes in order to locate key thermal layers in the water column and determine whether lake mixing has occurred. They apply their interpretations to the lake ecosystem.

Changing Planet: Warming Lakes
(http://www.windows2universe.org/earth/changing_planet/warming_lakes_intro.html or http://www.nbclearn.com/changingplanet/cuecard/52116):

Video for Intermediate (3-5), Middle (6-8), High (9-12): discusses impact of rising lake temperature on large lake with a focus on Lake Superior.
Included in CLEAN Collection as Resource 42956.

Climate Change Wildlife and Wildlands: A toolkit for formal and informal educators
(http://www.globalchange.gov/resources/educators/toolkit):

Website for Intermediate (5), Middle (6-8), High (9-10): focuses on the impacts that climate change will have on different regions of the United States. One part of the website is devoted to the Great Lakes http://www.globalchange.gov/resources/educators/toolkit/explore/great-lakes). There is a case-study an activity where students build a bottle habitat and model the effects of global warming and an activity where students explore possible impact of climate change on Great Lakes water levels.

Migrating Climates
(http://www.ucsusa.org/greatlakes/glimpactmigrating.html):

Interactive Visualization: Provides a dramatic way of visualizing the effects of climate projections by estimating where Ontario and selected Great Lakes states will have "moved" climatically over the next century. These analyses are based on projections of seasonal average temperature and precipitation and do not consider the extremes or

variability in projected climate changes. They also do not reflect the effect that major topographical features may have upon local climate.

Climate Change Impacts on Water Resources (http://www.ucsusa.org/greatlakes/glimpactwater.html):

Interactive Visualization: A rapidly changing climate will alter water availability and quality, not only in the Great Lakes but also in the region's groundwater and in the hundreds of thousands of smaller lakes, streams, and wetlands that dot the area. Click on these two interactive features to explore the changing water picture in the Great Lakes region. One explains how the water cycle works and what added pressures we humans place on fresh water, while the other explains the changes residents might expect to see in the future.

Climate and Weather - Lesson 1: Source and Sink
(http://greatlakeslessons.com/mod/resource/view.php?id=199, http://greatlakeslessons.com/mod/resource/view.php?id=200)

Activity (from COSEE-Great Lakes) for Grades 5-8: One of the principles of water is that it absorbs and releases heat easily. When there is a basin of water, like the Great Lakes, the ability to hold onto and release heat can have a significant impact on the coastal areas. This lesson explores the affects of temperature change and water on the surrounding areas.

Climate and Weather - Lesson 2: Fruit Belt
(http://greatlakeslessons.com/mod/resource/view.php?id=237, http://greatlakeslessons.com/mod/resource/view.php?id=238)

Activity (from COSEE-Great Lakes) for Grades 5-8: -Students investigate how the properties of the Great Lakes support fruit growing regions.

Climate and Weather-Lesson 3: Lake Effect Snow

(http://greatlakeslessons.com/mod/resource/view.php?id=241, http://greatlakeslessons.com/mod/resource/view.php?id=242)

Activity (from COSEE-Great Lakes) for Grades 5-8: Students investigate lake-effect snow in the Great Lakes region.

6. Questions

Are there other sources of educational resources that you know of?

Have you had experience with some of these resources? Did they work well for you? Do you have some "teacher tips"?

What great lakes-specific topics need to be addressed in the development of new educational resources

Besides (earth and space) science classes, in what other classes can aspects of climate change be taught?

How do you approach teaching material that is at times considered controversial?

What is most useful to you - full curricula, a single teaching activity or "useful bits" (i.e., short video, figures, animations, simulations, interactives) that can be incorporated into your own lessons?

7. Other Resources

The following additional resources were identified during the online workshop and focus group:

Exploring the Great Lakes: A Logbook of Adventures

Book by Patricia Westfield & Nan Soper(River Road Publications, March 2003). Used to introduce information regarding the Great Lakes. There is a small section on weather and climate.

Climate News, Research Projects, Products Website (Illinois-Indiana Sea Grant)

A variety of climate change resources

Videos on Great Lakes issues including boating safety and other weather-related concerns

Topical videos on Great Lakes climate change from New York Sea Grant)

American Meteorological Society. (AMS)
(http://www.ametsoc.org/amsedu/ECS/home.html)
the American Meteorological Society. SUNY sponsors a Water, Ocean, Atmosphere, and Climatology course that have great resources on a global level.

also AMS datastreme classes

"Mysteries of the Great Lakes: A science north production"
An IMAX video is also available on DVD (http://sciencenorth.ca/mysteriesofthegreatlakes/)

My World Creature Cards, from Alliance for the Great Lakes.

http://www.greatlakes.org/Document.Doc?id=803

Beautiful teaching cards about Great Lakes species,that can be used for species identification, to talk about biodiversity or do a foodweb activity. If you assign each person a card and then create a string "foodweb" connecting predators and prey, it is easy to demonstrate the impact of the loss of any species due to climate change, invasive species, overfishing, etc.

Ohio Sea Grant is facilitating a webinar series on climate change across the GL region

http://changingclimate.osu.edu

Dr. Art's Guide to Planet Earth (by Art Sussman) is an easy to read, grade-level appropriate resource as an overview of climate change (from a systems approach). It was published in 2000, but I find it very useful at the 7-12 level. Here is the site as well:

http://www.planetguide.net/

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wonderful EPA website for climate change education: http://www.epa.gov/climatechangekids/basics/index.html

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The Will Steger Foundation
http://www.willstegerfoundation.org

Website has materials for educators, blogs, curriculum to download, videos, etc.

The online classroom just launched this fall focuses specifically on Minnesota's Changing Climate, but has a biome focus.
http://classroom.willstegerfoundation.org

All of their Summer Institutes for Climate Change Education are archived with presentations to download and videos. They can be found at:
http://www.willstegerfoundation.org/summer-institute

Global Warming 101 Lesson Plans for Grades 3-6
These five lesson plans are interdisciplinary in nature, standards-based, help students master the requisite background information on global climate change processes and how to communicate about the issue using communication strategies, and are free for download.
http://www.willstegerfoundation.org/educator-resource-binder/grades-3-6

Minnesota's Changing Climate Curriculum and Online Classroom for Grades 3-8
In the curriculum and online classroom, we explore and learn about Minnesota's unique biomes and what a changing climate will mean for the state. Specifically, we examine how climate has already, and is projected to change in Minnesota; how these changes may impact agriculture, forests and wildlife, aquatic ecosystems, our economy, as well as tourism and recreation; and how you can help reduce these potential impacts and help your biome adapt to a changing climate.

Curriculum Download: http://classroom.willstegerfoundation.org/materials/curriculum-a-handouts/curriculum-download-a-preview

Kristin Poppleton of the Will Steger Foundation teaches a

Course Syllabus for 2 credit course I teach at Hamline University each fall, Teaching Climate Change.
Course Description
The goal of this course is to provide educators from a variety of backgrounds with an overview of the fundamentals of environmental education and climate literacy and introduce them to the knowledge and skills necessary to effectively communicate the topic of climate change in their educational setting. An "effective" environmental educator is one who develops a citizenry that is able and willing to help solve current environmental problems, such as climate change, and help prevent future environmental problems. To achieve this goal students will learn about theories and pedagogy in environmental education and climate literacy, as well as resources for communicating about climate change. Please note this course will provide resources for those looking interested in a deeper understanding of climate science, but assumes participants have some baseline understanding of the drivers and impacts of climate change.

Encyclopedia of the Earth - Climate Change

http://www.eoearth.org/climatechange

Beyond Weather and the Water Cycle - We Depend on Earth's Climate - is now available at http://beyondweather.ehe.osu.edu.

Antarctica's Climate Secrets is available at www.andrill.org/flexhibit. It includes a 200+ page book of hands-on activities appropriate for upper elementary to high school, posters and videos.

Andrill also has a new set of climate change materials still in draft form, but will soon be available at www.andrill.org/education/elf. The draft materials are located at http://andrill.org/education/c2s2/Welcome.html then click on "ELF Activity Book" in the nav bar.

Both sets of materials have activities that are easily related to Great Lakes climate change.

A nice set of fact sheets from Michigan Sea Grant

Climate Variability and Climate Change: What's the Difference?
http://www.miseagrant.umich.edu/downloads/climate/11-703-Climate-Variability-and-Climate-Change.pdf

Weather and Climate: What's the Difference?
http://www.miseagrant.umich.edu/downloads/climate/11-702-Weather-and-Climate.pdf

Preparing for Extremes: The Dynamic Great Lakes
http://www.miseagrant.umich.edu/downloads/climate/11-701-Preparing-Coasts-for-Extremes.pdf

Preparing for Variable Lake Levels: The Dynamic Great Lakes
http://www.miseagrant.umich.edu/downloads/climate/11-700-Preparing-for-Variable-Lake-Levels.pdf

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Diagnosis Earth

A thought-provoking piece pulling risk assessment into personal context by comparing climate change (issues, expertise and response) to medicine.

Diagnosis Earth The Climate Change Debate.pdf

An assessment of teens Climate knowledge...

http://cires.colorado.edu/blogs/mccaffrey/2011/04/21/teens-tilted-climate-knowledge/

The presentation by John Pickle: Using Digital Earth Watch (DEW) Software
(for Lifelines for High School Climate Change Education, 2011 June 14)

http://www.lawrencehallofscience.org/gss/lifelines/archive
You can fast-forward and random-access in the archive.