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In This Issue...

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In Focus: Water Resource Management in a Changing World

The fear over "global warming" is less about a couple-degree change in global air temperature (albeit a significant issue) than about how it affects climate and water on a local scale: changes in precipitation, storms, droughts, streamflow, water temperature, ice, sea levels, etc. Whatever your view of the causes and trends for climate change, as a profession we are obligated to assess, plan, and design for the potential consequences.

In 2008 Chris Milly and his co-authors in *Science* made the bold statement that "stationarity is dead," and that our efforts in water resource management need to consider that climate is and will continue to change. It is no longer appropriate for hydrologists, engineers, businesses, and water managers to operate under the assumption that climate is stationary. Rather, we are now living in an age when climate is changing, and along with that come changes in precipitation, evapotranspiration, streamflow, and most every other hydrologic process. Humans must plan for and adapt to these changes, but knowing how and when to do so remains a daunting task.

Storms and flooding are the most visible concerns to the public, but the impacts of climate change on water resources extend not only to these episodic events but also to water availability, habitat changes, ecology, and water quality. LimnoTech scientists are researching these issues to help clients plan and design for impacts of climate variability on water resources.

This edition of the newsletter highlights a number of recent projects related to the impacts of climate on aquatic ecosystems, adaptive management of Great Lakes water levels, and water use for electric power generation.

The impacts of climate change on water are far-reaching—from the timing of snowmelt and water availability to Great Lakes wetland habitat, Arctic lake hydrology, water intake temperatures, extreme events, and harmful algal blooms. LimnoTech continues to expand its work in these areas to help clients adapt to changes in climate and to understand the ecosystem impacts of these changes. Through cutting-edge research, applied science, and effective adaptive management, we are working to protect water resources for people, businesses, and the environment, and helping society become more resilient to our ever-changing climate.

We hope that you will find the topics in this newsletter interesting and informative. Please contact us with any questions or comments you may have about these articles.

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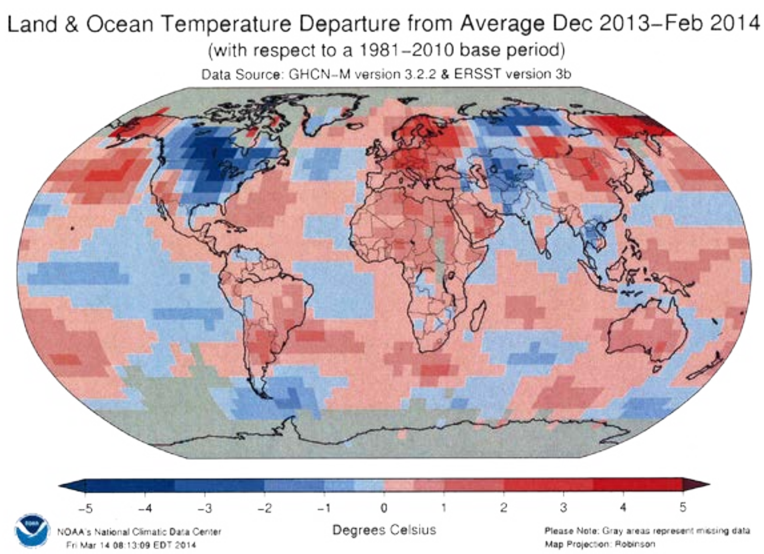
The Winter of 2013-2014: What Happened to Global Warming?

Those of you who live in the U.S. Northeast, Midwest, and especially the Great Lakes region, endured a long and harsh winter this past year. You probably heard this phrase many times in recent months: "What happened to global warming?" It's hard to imagine a warming world when you've just lived through one of the coldest winters you can remember. As it turns out, however, other parts of the world lived through the *warmest* winter in recent memory.

I started writing this article on my way from Michigan to Alaska, where LimnoTech is working with other scientists on a National Science Foundation (NSF) project to monitor the impacts of climate change on Arctic lakes. At that time in Anchorage, they had just hit a record *high* temperature of 68°F for May 3. In contrast, it was 48°F in Ann Arbor, Michigan, at our home office. Occasional record highs are, of course, "normal," but for the winter as a whole, Alaska was abnormally warm. Confusing to say the least, but can we make sense of this?



While colder-than-normal winters in specific regions may seem to contradict global warming, global warming needs to be considered as its name implies—globally.

The figure shows a global map of departure-from-normal air temperatures during the winter of 2013-14 (December-February), with blue denoting colder and red warmer. You probably recall the numerous visits the U.S. and Canada had this winter from the "polar vortex," shown by the blue bulls-eye on the map. These large dips in the jet stream bring incursions of cold air from polar regions—in our case, the Arctic. But in doing so, they generally leave behind warmer conditions in places like Alaska. So while we experienced a cold winter, Alaska was unusually warm. As a result, the Arctic lakes that we've been studying near Barrow, Alaska, had about 20-30% thinner lake ice than in previous years. This is in contrast to the Great Lakes, where Lake Superior ice was not only unusually thick and widespread this winter, but was still abundant through April and May; lake temperatures will also continue to be colder than normal well into August.

As is evident on the map, Alaska was not the only region with a warmer-than-normal winter. Much of Europe and eastern Russia were well above normal, as were parts of East Asia, Africa, South America, and Australia. A few other land areas were colder than normal, but when you tally it all up, it turns out that—on a global average—the winter of 2013-14 was 1°F warmer than the 20th-century average. Only six other winters in history have been warmer than 2013-14, and they all occurred after 1997. This means that approximately 96% of the winters on this planet (since 1880) have—on a global average—been *colder* than this past winter.

So despite the impression you may have gotten from looking in your own backyard, from a global perspective this winter was unusually warm. Therein lies the answer to the question, "What happened to global warming?" It's still a concern. But it means that we need to think outside our own backyard. In other words, we need to appreciate the difference between current local weather and global climate change. There is a reason, after all, that it's called "global" warming and not "Michigan" warming.

When engaging the public in discussions about climate change, it is often difficult to separate our thoughts about climate from our personal experiences with weather. For comparison's sake, do any of you remember the winter of 1978-79? If you're 40 years of age or younger, you probably don't. I was a 10-year-old kid growing up in Holland, Michigan, and we received a whopping amount of lake-effect snow that winter. The temperatures were frigid, and the Great Lakes were heavily ice covered, similar to this past winter and spring. As a kid, I thought the snow was great. Although I'm sure all the cold and snow were a hassle for adults, I don't recall people making much of a fuss, unlike the apocalyptic media stories we read this winter about the polar vortex. After all, this was Michigan, and we were used to it, right?

But maybe that's part of the problem—we're no longer accustomed to "normal" winters, because *normal is changing*. How would a 10-year-old kid or a 30-year-old adult react to this past winter, when they've seen nothing like it in their lifetime? Not surprisingly, they might react with shock. They might wonder if our climate is actually getting colder, rather than warmer, and these would be understandable reactions if it weren't for the fact that we have long-term data to show that winters like the recent one have happened before. In fact, they used to happen regularly. Case in point: The ten coldest global winters on record all occurred before 1914.

The point is that our thoughts, discussions, and actions need to be driven not by individual observations from any particular season or location, but by long-term global data. However you might feel about causality, the data clearly show that climate change and global warming continue to be a concern, and our society, our governments, our businesses, and our researchers need to factor this into our short- and long-term planning.

Climate Trends and Challenges of the Energy-Water Nexus

Most power generation facilities rely on a significant quantity of water, primarily for cooling. The most recent USGS water use survey (2005) reports that thermoelectric power accounts for approximately 41% of total freshwater withdrawals in the United States—more than any other water-use sector. Although most water use for this sector is not highly consumptive (less than 5% of national freshwater consumption budget), projections indicate possible increasing thermoelectric power consumption caused by a shift from "high-volume, low-consumption" once-through cooling plants toward closed-cycle cooling plants that withdraw less water but consume almost twice as much per unit of power produced.

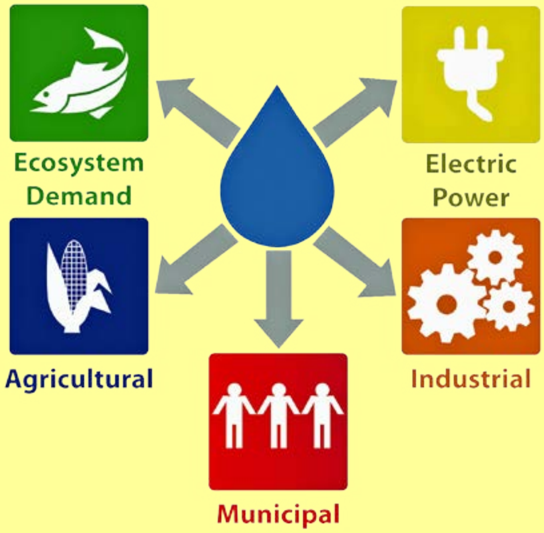
Many electric power generators report high-priority water resource problems related to reduced water availability and/or increased water temperatures. These situations of physical water risk have led plants to temporarily shut down, reduce power generation, or make structural modifications to access cooling water. Situations of physical water risk can lead to increased reputational risk (perception of being a "water hog"), regulatory risk (violation of thermal discharge permits), or financial risk (investor concerns and higher-cost replacement power).

LimnoTech conducted a study for the Electric Power Research Institute (EPRI 2010) to investigate the importance of reliable water supplies to the electric power industry and to identify relevant trends in water quantity and quality. This study found that water resource trends are complex: they can be influenced by a range of controllable and noncontrollable factors, and often reflect the integrated effects of natural and anthropogenic drivers such as climate variability, landscape change, water use, and regulations.

The LimnoTech study noted that trends in precipitation and temperature can influence hydrology and water temperature over decadal and multi-decadal scales. In the U.S., the greatest influences appear to be occurring in the Southeast, Northwest, and Southwest, and include decreasing precipitation, increasing air temperature, decreasing snowpack, earlier snowmelt, and increasing drought. It is not just climate variation, however, that influences water resource trends and makes the past a poor predictor of the future. Society's alteration of the landscape, and the capture, movement, consumption and regulation of water can influence water availability and quality. Landscape changes such as increased impervious surfaces, wetland drainage, damming of rivers, and water diversions can alter the volume, timing, magnitude, and quality of surface water, and can also affect groundwater. These factors may relate to trends of decreasing base flows and/or increasing stream temperatures. Some drivers of water resource trends are not easily controlled, such as variable climate, landscape changes that occurred long ago (e.g., wetland draining, river impoundment, land development), and increasing regional populations. Other drivers such as water use, regulation, and future landscape changes are controllable, and may present an opportunity to positively influence water resources.

It is not a steady-state world, and electric utilities are increasingly in a position where it is imperative to understand and adapt their water resources management. Power plants must adapt to a wider range of climate and water resources variability under which they can operate without excessive water risk.

In regions where benefits can be justified, electric utilities should, and often must, consider solutions that promote water conservation and use efficiency (in-plant reuse, reclaimed water sources, water banking, dry or hybrid cooling systems). It is important for all water stakeholders to be proactively involved in science and technology research and integrated water planning. Continued exploration of synergies among the water, industry, agriculture, and energy sectors will build bridges among water users, and allow for development of collaborative and innovative solutions. We as a society have the power to positively influence water sustainability by promoting green infrastructure, improving water use efficiency, controlling withdrawals and consumption through regulation, and collaboratively planning to reduce competition.



Multi-sector collaborative planning and innovative solutions can help ease the water risk and competition caused by climate variability and water resource trends.

Understanding and Managing the Effects of Climate Change on Aquatic Ecosystems

There is mounting evidence that climate-change-induced extreme events are expected to adversely affect the aquatic ecosystems and ecosystem services that they provide. To address this need to understand how climate, aquatic ecological, and social systems interact and how to manage these coupled systems, LimnoTech is participating with a large team of researchers (from Stanford University, the University of Michigan, Heidelberg University, University of Toledo, Grace College, and the Great Lakes Observing System [GLOS]) in a National Science Foundation (NSF)-funded Water Sustainability and Climate Project to examine the following question: "*What are the possible effects of climate-change-induced extreme events on water quality and ecology in the GL system, and what management strategies would be effective to address these changes?*"

The project team is investigating and examining the interactions among various components of the whole problem, including atmospheric modeling of climate change, effects of extreme events on watershed sediment and nutrient loading, in-lake response to extreme event-driven changes in atmospheric and nutrient loading conditions, socioeconomic responses and adaptation to environmental changes, and education/outreach on this problem (as depicted in the diagram below).

The project will use the Maumee River Watershed and the western basin of Lake Erie as a case study and test bed for the prediction and adaptive management tools that are being developed. As an active partner and co-investigator in this project, LimnoTech's role is the development and application of the Western Lake Erie Ecosystem Model (WLEEM), which simulates the *in-lake* harmful algal blooms in response to climate-induced changes in atmospheric boundary conditions and watershed nutrient loading. We have already applied WLEEM to demonstrate that high spring flows and associated nutrient loads from the highly agricultural Maumee Watershed, predicted by climate models to become more frequent in the future, are the primary driver of harmful algal blooms in the Western Basin of Lake Erie. We are now in the process of using the model to develop a load-response relationship that will allow managers to establish a loading target for reducing the blooms, even in the face of exacerbation of the problem by climate change.

In 2011, the Western Basin of Lake Erie experienced the largest harmful algal bloom in Lake Erie's recorded history, with peak intensity over three times greater than any previously observed bloom. That occurrence provided an excellent opportunity for the NSF project team to investigate the contributing cause-effect relationships for this extreme event. This part of the overall study led to a peer-reviewed publication entitled, "Assessing the Effects of Climate-Change-Induced Extreme Events on Water Quality and Ecology in the Great Lakes" in the Proceedings of the National Academy of Sciences. The findings of the paper, posted on the National Science foundation website (http://www.miseagrant.umich.edu/nsf/), suggest how weather extremes contributed to the large bloom and why this type of occurrence may become more likely in the future.

This study will advance scientific understanding of coupled human-climate-water quality systems, and inform and influence future decision-making in the Great Lakes region.

Managing Great Lakes Water Levels Adaptively in Response to Changing Climate Conditions

The Laurentian Great Lakes contain an abundance of fresh water, collectively representing approximately 20% of the fresh surface water available globally. Despite the enormity of this resource, water levels and flows in the Great Lakes are subject to fluctuations caused by changing climate conditions that have cascading impacts on the coastal ecosystem and the regional economy. Proactive management of this freshwater resource has become increasingly important as we have observed recent changes in regional climate in the Great Lakes, and we anticipate the potential for even greater changes to occur in the future.

Within the past 15 years, the International Joint Commission (IJC) has conducted major studies on the Lake Ontario/St. Lawrence River and the Upper Great Lakes systems to evaluate the impact of water level regulation on the ecosystem and a range of economic interests, including commercial navigation, hydropower, and recreational boating. Early on, these evaluations focused primarily on the impact of current and potential alternative water level regulation plans relative to *historical* water level conditions. It was quickly realized, however, that these plan evaluations must take into consideration the range of potential water level conditions that may result from even minor shifts in the climate of the Great Lakes region.

LimnoTech has been at the forefront of assessing ecological impacts in the Great Lakes in response to changing climate and lake water level and flow conditions since the early 2000s. We have worked closely with the Ecosystem Technical Working Groups and the Study Boards commissioned for each IJC study to synthesize complex biological research into an integrative modeling framework that can be used to support management decisions with respect to coastal ecosystem impacts. The resulting "Integrated Ecological Response Model" (IERM) that we have developed in collaboration with several dozen U.S. and Canadian researchers represents the state-of-the-science with respect to evaluating the impact of Great Lakes basin climate and hydrology on coastal ecosystem health, including indicators of wetland habitat availability and fish and wetland bird populations.

As the results of the IJC water level studies continue to be evaluated and synthesized, it has become clear that an "adaptive management" approach is needed to track and respond to changes in Great Lakes climate and hydrology over the coming years and decades. An adaptive management approach for the Great Lakes involves leveraging the modeling tools developed under the original water level studies to identify key areas where additional data must be collected to further our understanding of the system. Additional data collected to address these needs can then be fed back into the modeling tools to improve our ability to forecast ecological and economic impacts resulting from shifts in water level conditions.

LimnoTech is continuing to work with the U.S. Army Corps of Engineers and Environment Canada to actively support adaptive management needs. Our recent and ongoing work has included modernizing the IERM software and advising on approaches for integrating newly collected wetland habitat data into the model. These enhancements represent the next step in adapting the IERM to support adaptive management, and will result in improved capability for forecasting coastal ecosystem impacts in response to changing climate conditions in the Great Lakes.

LimnoTech has been a leader in assessing ecological impacts in the Great Lakes in response to changing climate and lake water level and flow conditions since the early 2000s.

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LimnoTech is Growing!

LimnoTech is Growing! LimnoTech has added four new employees this year. Julie Padilla joined our Ann Arbor office in February with a Master's degree in environmental engineering from Michigan Technological University. Chelsie Boles came on board in March, again in our Ann Arbor office, by way of Purdue University. Most recently, Ben Crary joined our Washington, DC office, and Craig Taylor joined our Minneapolis-St. Paul region office. Ben graduated with a Master's degree in Civil/Environmental Engineering from the University of Wisconsin, and Craig graduated with a Master's degree in Civil Engineering from the University of Minnesota, Twin Cities. Welcome, all!

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