Great Lakes Integrated Sciences and Assessments Center

2016

Annual Report on the activities of the Great Lakes Integrated Sciences and Assessments Center (GLISA) covering the period of June 1, 2015 – May 31, 2016.
Award Title: GREAT LAKES REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS CENTER - NOAA-OAR-CPO-2015-2004099

Annual Report

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GREAT LAKES REGIONAL INTEGRATED SCIENCES AND ASSESSMENTS CENTER - NOAA-OAR-CPO-2015-2004099

Performance Period
June 1, 2015 – May 30, 2016

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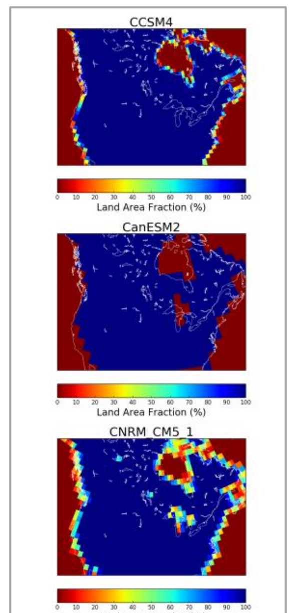
NEW AREAS OF FOCUS AND PARTNERSHIPS

GREAT LAKES ENSEMBLE – Team Lead: Richard Rood, Laura Briley
In 2015, GLISA formally started the development of an Ensemble of future climate projections for the Great Lakes region. This project is motivated by the need for *high-quality* climate projections for use in climate change adaptation work. Previous evaluation of a subset of models for the region revealed strong inconsistencies between observed and simulated physical processes of lake-land-atmosphere interactions—the U.S. Great Lakes are known for their impact on local and regional weather and climate, however, the processes responsible for producing lake-effects and lake-induced modifications of weather are often poorly represented or missing from climate models.



Maps for three CMIP5 models show whether Great Lakes are represented as land, water, or a combination

To address the need for high-quality climate projections for the Great Lakes region, the Ensemble work will:
1) Develop an evaluation framework, specifically tailored to the Great Lakes region, to provide a regional perspective on the quality of information coming from the models.

2) Apply the evaluation framework to several climate model data sets—including regional modeling efforts—to provide expert guidance regarding the limitations, shortcomings, and appropriate uses of the data.
3) Integrate projections from the models that "pass" our evaluation framework into GLISA's existing products (i.e., regional climatologies) to provide narratives and visual representations of future climate change information to stakeholders.

In our first year of work, GLISA convened a scientific advisory committee with representatives from the climate modeling community, regional climate experts, and extension specialists, to start the development of the evaluation framework. Details regarding the framework can be found here.

In addition, we have developed an online inventory to store metadata about the models we are evaluating (i.e., links to where model documentation can be found, instructions on how to download data, etc.) and our evaluations of them (i.e., figures, maps, narratives, etc.). One of the most useful and simple evaluations we have performed on our initial set of CMIP3/5 models is producing maps of their land-sea fractions to show which models define the Great Lakes by water versus land. Using our online inventory, we can quickly compare results across models (i.e., land-sea maps intercomparison).

Expanding Agricultural Reach - USDA/ARS – Team Lead: Jeff Andresen, William Baule

Through the 2014 GLISA Climate Assessment Grants program we initially engaged with a coalition of researchers from Purdue University and the United States Department of Agriculture Agricultural Research Service at Ohio State University. This group of researchers is interested in evaluating the effects of climate change on the efficacy and potential benefit of on-farm water recycling systems and their utility as a climate change adaptation strategy for drained agricultural land. This engagement included three key components: 1) Evaluate potential benefits of on-farm water recycling systems under climate change scenarios using historical field data, climate data, and climate projections; 2) Acquire knowledge about past experiences/knowledge of on-farm water recycling systems from farmers, drainage specialists, contractors, extension agents, agency staff, and irrigation dealers; and 3) Examine impacts of on-farm water recycling systems under historical and future climate conditions using a soil drainage model (DRAINMOD). Continuation of this work has been written into the USDA-ARS Drainage Unit 5-year strategic plan in the form of a USDA-NIFA project focused on irrigation in the larger Midwest. This expansion of our work into the agricultural sector in the Great Lakes region will allow increased focus on sustainable agricultural practices in the face of climate variability and change. Lessons and strategies learned from this work will be transferable to other regions and groups working on issues involving agricultural water management and sustainability.

BUSINESS COMMUNITY – WEST MICHIGAN SUSTAINABLE BUSINESS FORUM – Team Lead: Richard Rood, Laura Briley

Through the 2015 GLISA Climate Assessment Grants program we began a new partnership with the West Michigan Sustainable Business Forum (WMSBF). This organization is a non-profit, regional network supporting business, government, non-profits and academic institutions and it is dedicated to promoting business practices that demonstrate environmental stewardship, economic vitality, and social responsibility. Through our engagement with WMSBF we are working with four entities representing the education, pharmaceutical, health care, and hospitality industries. Over the next year this project will develop resources for the WMSBF adaptation toolkit. This toolkit will lead resiliency champions through a vulnerability assessment—informed by predicted industry impacts and historical climate data and projections—and establish systems to monitor and respond to identified threats and opportunities, as well as communicate with internal and external stakeholders. By working with representative organizations from the four identified business sectors, this project will generate replicable case studies and serve as illustrative examples to other organizations in their industry networks and the community in general, encouraging use of the adaptation toolkit and awareness of climate risk among relevant decision-makers.

EXPANDING ENGAGEMENT WITH TRIBES – Team Lead: Richard Rood, William Baule; Non-GLISA Partners: Kyle Powys Whyte, Frank Marsik, and Adaptation International

1854 Treaty Authority

GLISA joined with the consulting firm, Adaptation International, in developing the Climate Adaptation Plan for the 1854 Treaty Authority and three Bands of Lake of Superior Chippewa tribe. The 1854 Treaty Authority is an inter-tribal natural resource management organization that manages the off-reservation hunting, fishing and gathering rights of the Bois Forte Band of Chippewa and Grand Portage Band of Lake Superior Chippewa in the territory ceded under the Treaty of 1854. Through our contract with Adaptation International GLISA developed localized climate resources for the vulnerability assessment and adaptation plan, served on regular team calls, and provided facilitation support at both a vulnerability assessment workshop in October 2015 and a climate adaptation strategies workshop in May 2016. The final report features regional and local climate information, climate vulnerability assessments for 33 resources, and detailed climate adaptation strategies for 10 individual resources and species.

Nottawaseppi Huron Band of the Potawatomi

GLISA entered a new engagement the Nottawaseppi Huron Band of the Potawatomi. Working with Kyle Whyte, PI on a 2013 GLISA Climate Assessment grant, GLISA supported two graduate students through the summer of 2015 to provide climate resources which could be integrated into the activities of the band on their reservation in south central Michigan. The resources included localized historic climate information, regional future climate projections, and advice on building climate into conversations and resources designed for natural resource managers, public health staff, educators, and members of the tribe.

Grand Traverse Band of Ottawa and Chippewa Indians and Little Traverse Bay Bands of Ottawa Indians

GLISA entered a new engagement with the Grand Traverse Band of Ottawa and Chippewa Indians and Little Traverse Bay Bands of Ottawa Indians focused on climate adaptation planning for a broad range of tribal interests on their reservation and managed lands in the lower peninsula of Michigan. This work included analysis of historical and projected climate information localized to the area of interest, consultation of GLISA's past experiences working with tribes, and application to planning processes for development of tribal lands for various enterprises.

New or Tailored Climate Services being Used by States

Previews (first page) of each item discussed in this section are available in the Appendix.

1854 Treaty Authority – Tailored Climate Products

Using NCEI climate divisional data, in-situ climate station data, and regional climate projections, our team provided guidance on historic, current, and future climate considerations to the Treaty Authority. In addition to delivering locally tailored climate information, our team also provided input on the vulnerability assessment of over 33 resources and species and applied understanding of projected change to generate a sensitivity score, which later contributed to overall vulnerability ranking of each resource or species.

New York – Climate Scenarios for Lake Ontario Basin

Through our 2014 Climate Assessment Grant to New York Sea Grant (NYSG), GLISA assisted the development of scenario planning resources for watershed managers in the Lake Ontario Basin and for input to the Lake Ontario Lakewide Management Plan (LaMP). These resources bring together information about potential future precipitation scenarios with other aspects of economic, population, ecosystem, and land-use shifts to demonstrate four different planning futures. These scenarios were the focus of a regional workshop that brought together scientists and stakeholders to investigate potential barriers, opportunities, and ultimately provide recommendations to decision makers in the Basin. The outcomes of the workshop were presented and discussed in two public forums where the general recommendations were validated and additional areas for inquiry were identified. The body of work was also presented to the NY Great Lakes Basin Advisory Council and will inform the LaMP update in the fall of 2016.

The Maumee Watershed (Ohio, Michigan, and Indiana)

Crop Yield Scenarios

Using a combination of historical field experiment data from fields with water recycling systems and control fields, historical in-situ climate data from NCEI, and NASA POWER gridded solar data, the historical impact/efficacy of these systems on crop yields were quantified for the late 20th/ early 21st centuries in the Maumee River Watershed in Northwest Ohio. Using this historical knowledge, data from regional climate projections were implemented to examine the potential benefits of these systems under climate change for the period from 2041-2070. The project team consisted of researchers from Purdue University, USDA-ARS, GLISA co-PI Andresen, and GLISA staff. GLISA provided technical assistance with climate data acquisition/application, programming expertise to analyze the data, and advised the research team on appropriate model selection.

Calibrated Drain Model for Sub-Irrigation Systems

The historical and projected climate data provided by GLISA were also incorporated in DRAINMOD, which is one of the most widely used models to predict and design subsurface drainage systems. This model was set up, calibrated, and validated using the historical field experiment data from Northwest Ohio. This model will allow for more experiments in system design and understanding the sensitivity of the systems to varied forcing.

Michigan

Localized Climate Information for Menominee County

Through our 2014 Climate Assessment Grant to Model Forest Policy Program, GLISA staff worked collaboratively with staff from Menominee Conservation District to develop a localized climate summary incorporating NCEI climate division, in-situ climate station, and regional climate projection data for Menominee County Michigan. In addition to the climate information contained in the report, a discussion of sectorial impacts, already seen and projected, identified by stakeholders was also included. This document provided Menominee Conservation District with baseline climate information as they developed their adaptation plan.

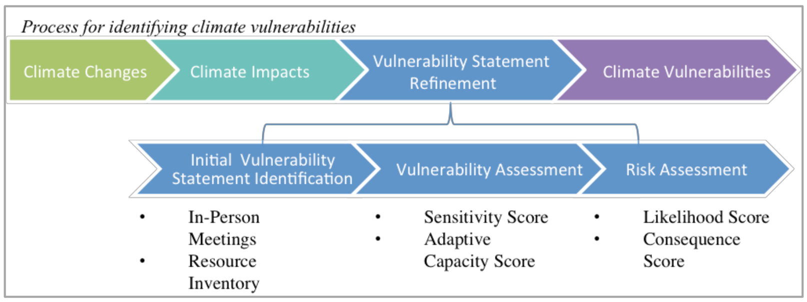
Ohio

Climate Scenarios for Columbus, OH

Through a grant from the Natural Resources Defense Council, our team collaborated with the City of Columbus and Ohio State University to develop climate resources to serve as the foundation for a vulnerability and risk assessment, which the City of Columbus will integrate into its emergency preparedness efforts. This process, adapted from ICLEI's Local Governments for Sustainability "Building Adaptive and Resilient Communities" program, allowed the City to not only better understand its key climate concerns, but provided decision makers with the necessary context to understand what populations, sectors, and resources would be most at risk due to these impacts. Through this partnership the GLISA team led or supported 5 key efforts: 1) Creation and delivery of general historic climate summaries (GLISA Led), 2) Creation and delivery of future climate impact summaries (GLISA Led), 3) Completion of climate resilience document and resource inventory, 4) Vulnerability Assessments, and 5) Risk Assessment.

An initial working group of stakeholders identified over 79 climate impact statements that which were collapsed and refined down to 43 total statements. Vulnerability scores were assigned to each statement, and those exceeding a given threshold (totaling 21 statements) became part of the risk assessment process. In the risk assessment, GLISA staff assigned a "likelihood" score (how likely each impact is by midcentury in the absence of adaptation activity) to each statement and city decision makers and key stakeholders identified "consequence" scores for five different topic areas (Public Health and Safety, Environment and Sustainability, Public Administration, Local Economy and Growth, and Community and Lifestyle). The final risk assessment score for each vulnerability statement was the product of its consequence score and likelihood score.

Of the 21 statements, 14 were identified as the highest priority, and the Core Team reviewed the results and shared them with key stakeholders for final approval in December 2015.



Measurements for Overall Program Impact

GLISA's Small Grant Impacts

GLISA's social science branch is evaluating the impact and flow of resources and information from GLISA to its partner organizations through the small project grants. Understanding that the mission of GLISA's model is to increase the capacity for adaptation, that adaptation comes out of usability and usefulness of the information that boundary organizations receive, we have developed a protocol to understand how receiving a boundary grant from GLISA is creating capacity for adaptation in the region. We focus both the flow of information and resources to understand how GLISA and other producers of climate information will be able to make more-informed decisions about how to communicate climate information to those who use it. We also focus on how different relationships and interactions with stakeholders (embeddedness and complementarities) may influence the outcome of capacity building for adaptation action.

Since April 2016, GLISA has interviewed 20 representatives of the funded projects. The interviews include project participants from 14 of the GLISA-funded small grant projects. More interviews are scheduled throughout the summer.

In addition, we are studying how those funded by GLISA understand the effect the funding has had on their work. In particular, we are focusing on themes of legitimacy within the organization, with interactions with GLISA members, and with members of other organizations. We will compare the network positions (e.g., number of ties, bridging between clusters) of those affiliated with organizations that received GLISA funding with those that did not. These network positions will be defined by participation in events (conferences, group phone calls, documents) concerning climate change in the Great Lakes.

Over the past year a number of partnerships and programs matured and we saw the impact of the GLISA work highlighted throughout the agricultural, urban, health, and tribal communities and sectors.

TRIBAL ENGAGEMENT

We have worked with ten tribes, intertribal entities or bands over the last three years. While we knew these engagements were part of a long-game for our program, over the last year several of these engagements began to bear tangible outputs and outcomes. Through our continued engagement with the Red Lake Band of Chippewa Indians the Climate Adaptation Plan, which emerged from the planning process GLISA supported in 2012-2013, was vetted by a broader group of community members and advanced to the Tribal Council for review and official sanction. Our positive engagement with Red Lake led us to collaborate on the development of Climate Adaptation Plan for the 1854 Treaty Authority, which now has a final draft of a climate vulnerability assessment documenting climate sensitivity, adaptive capacity, and vulnerability for 33 species and resources, and outlining locally relevant, action oriented adaptation strategies for 10 individual resources and species. Our continued engagement with Kyle Whyte, Michigan State University, has led to engagement with additional tribes throughout the Great Lakes region, including the Nottawaseppi Huron Band of Potawatomi, to lay the groundwork for further development of adaptation plans.

AGRICULTURAL WORK

A key goal of this current award period for GLISA is to expand our efforts in agricultural research and outreach. In the past year, GLISA has continued to build ongoing engagements and initiated new engagements and partnerships with a focus on agriculture in the Great Lakes and Midwest. Our continued collaboration with Purdue University/USDA-ARS has resulted in the development of scenarios depicting the benefits of sub-irrigation systems under climate change for corn and soybeans on drain agricultural land and a calibrated drainage model for sub-irrigation systems in Northwest Ohio. Multiple articles are in preparation for peer-reviewed publication, continuations of this work have been proposed in the USDA-ARS Soil Drainage Unit at Ohio State University's 5-year strategic plan, and the research findings are being incorporated into a USDA-NIFA project that involves several project team members. Building upon the success of our engagements with Purdue/USDA-ARS, several new entities were engaged this past year. These engagements included workshops focused on regional collaboration of state mesonets and climate information needs of livestock and specialty crop producers in the Midwest. The overarching goal of these engagements were to gauge the needs of agricultural producers in terms of what climate information would be most beneficial for their operations and to assess vulnerabilities in current agricultural systems.

URBAN ADAPTATION

Great Lakes Climate Adaptation Network

Building on the groundwork laid by the Great Lakes Adaptation Assessment for Cities program, which served as a boundary organization to cities throughout the Great Lakes region, and additional GLISA engagements with municipalities, a group of 18 cities coalesced to form the Great Lakes Climate Adaptation Network or Great Lakes CAN! This network, which is now officially established as a regional partner network of the Urban Sustainability Directors Network, includes in its mission the development and delivery of standardized climate information to cities and municipalities across the Great Lakes Region.

Neighborhood Adaptation Engagement

Our urban adaptation engagement through Macalester College in Saint Paul, Minnesota is a leading example of neighborhood scale, adaptation engagement. Our partnership with Macalester, which began in 2013 matured from an experimental effort to model climate impacts in four neighborhoods and identify potential resources and resource providers, to a city-wide program delivering climate information, planning resources, and funding support for micro-adaptation efforts.

HEALTH

BRACE Meeting and Providing Precipitation Data

One of the primary goals of the Michigan BRACE program is to quantify the historical occurrences of heavy precipitation events and occurrences of waterborne disease across the state of Michigan. In support of this work, GLISA provided an analysis of PRISM gridded precipitation data, which included daily county aggregations of mean precipitation and maximum occurrence of precipitation within each county for the period from 1999-2014 for the state of Michigan. These data were then correlated by the BRACE team with their hospital admissions data on incidences of waterborne disease.

Publication of MI Health Report

GLISA's longstanding partnership with Michigan Department of Health and Human Services was highlighted in the 2016 co-produced Michigan Climate and Health Profile Report. This report is a comprehensive analysis of Michigan's past and future projected climate linked to health vulnerabilities and impacts for the State. This report serves as an excellent example of how to integrate climate science into other disciplines (i.e., health) to produce meaningful information for adaptation planning.

Building Local/Regional Expertise

Synthesizing Existing Information in ways that Increase Utility

Linking Climate Changes to Climate Impacts in Report for Local Health Departments

In GLISA's experience, many stakeholders approach climate adaptation planning wanting to know more about future climate data (i.e., they seek downscaled climate projections), but in reality, climate data do not provide actionable information. GLISA's most "successful" stakeholder engagements, in terms of leaving stakeholders with information they can actually use in decision making, involves 1) linking climate information with the impacts that concern them most, and 2) providing information at a high level of detail that is still applicable to the entire targeted audience. Pathways between the topic(s) of concern (i.e., heat-related morbidity/mortality) and climate variables (i.e., minimum/maximum daily temperatures, consecutive "hot" days) must be established to be able to project future impacts. Descriptions of the linkages are also valuable for stakeholders to be able to localize or customize information to better fit their own needs if they have that capacity. A detailed example of how to link climate data with health related impacts is available in GLISA's co-authored Michigan Climate and Health Profile Report. Although most of the information in the report is generalized for the State of Michigan or for a subset of cities/areas within the State, the detail in the linkages provides a strong foundation for local health departments to be able to filter their local experiences to identify their greatest areas of concern and move forward in adaptation planning.

Preparing Climate Scenarios for New York State/LaMP Decision Makers

GLISA has had the privilege of co-developing several sets of climate change and impacts scenarios, which help provide 1) context around the issues decision-makers are facing and 2) a foundation to move forward in making decisions. In 2016, GLISA co-produced precipitation and population scenarios for New York Sea Grant's climate assessment grant framing future potential climate, economic, population, ecosystem, and land-use conditions. These scenarios were refined and vetted by multiple sets of workshop participants ranging from scientists to stakeholders to the general public. The wide audience invited to critique the scenarios helps garner support and confidence for using the scenarios in decision-making.

Continued Engagement with Tribes

Our work with federally recognized tribes throughout the Great Lakes region has focused on building capacity and expertise in the organizations which we engaged through the development of climate adaptation plans and vulnerability assessments. Our continued engagement with the Red Lake Band of Chippewa Indians this past year was focused on identifying concrete ways/steps that Red Lake climate adaptation plan (developed in collaboration with a 2013 GLISA-funded project) and additional climate resiliency actions could be incorporated into the Tribes' strategic planning process. This project built expertise in climate science and adaptation planning among tribal personnel and band members. Our collaboration with Adaptation International and the 1854 Treaty Authority focused on the development of a climate adaptation plan/vulnerability assessment. This project now has a final draft of a climate vulnerability assessment documenting climate sensitivity, adaptive capacity, and vulnerability for 33 species and resources, and outlining locally relevant, action oriented adaptation strategies for 10 individual resources and species. Expertise was developed in Treaty Authority personnel through a series of workshop that included basic climate change talks and discussions on how these changes are/may be affecting the systems they are responsible for managing.

TRAINING ON SOCIAL NETWORK DYNAMICS IN A BOUNDARY ORGANIZATION

In GLISA's second round of funding to the small-grants project by the Alliance for the Great Lakes, the focus of the project is on engagement with and outreach to private residential landowners and local decision makers associated with the IL/WI ravines of concern. A major component of this work is GLISA's role in helping the project leaders think about the social network dynamics underlying flow of knowledge about climate change in the Great Lakes. This knowledge will help them 1) anticipate gaps in knowledge among stakeholders and policymakers with whom they work; 2) target specific people for professional development; and 3) more carefully consider how they convene events.

TRAINING OF GRADUATE STUDENTS

GLISA's evolving role with the University of Michigan's Applied Climate graduate program and integration of graduate students working with GLISA faculty is preparing future climate leaders and decision-makers to be experts in the field. The educational backgrounds of students that GLISA works with are diverse (i.e., physical scientists, social scientists, business majors, etc.), which mirrors GLISA's effort to collaborate with stakeholders across disciplines. Several students with climate science backgrounds that have worked with GLISA have found employment in the energy industry and will bring along their expertise to this field that obviously has strong intersections with climate.

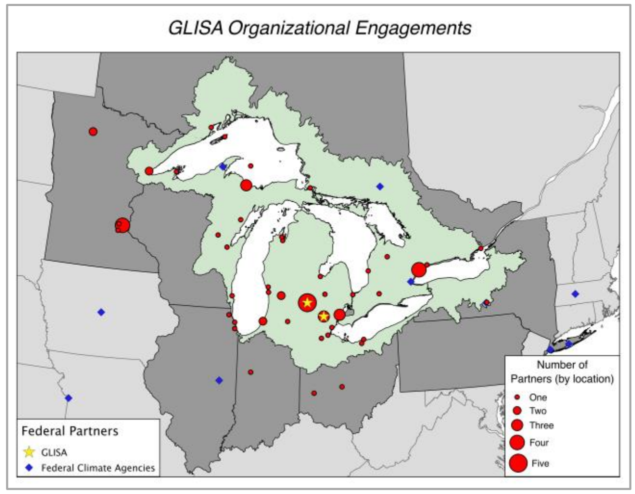
GREATEST ACCOMPLISHMENTS THIS YEAR

REORIENTING GLISA TO PHASE II

As we transitioned into Phase II (2015-2020) we made several decisions to expand our reach, geographically and sectorally, and deepen existing partnerships. These decisions are a product of GLISA's adaptive approach to bringing the most useful and usable climate information to stakeholders in the region.

Expanding Geographically

In our first five years, GLISA was becoming established and known throughout the region, and many partners were coming to us outside of our originally defined geographic scope of Lakes Huron and Erie Basins. We found many partners identified being in the Great Lakes region from Minnesota (west) to New York (east) to southern Ohio. For this reason, we expanded our geographic reach to include the eight Great Lakes states that touch a Great Lake (MN, WI, IL, IN, OH, MI, PA, NY) and Ontario.



GLISA's new geographic engagement scope including the eight Great Lake states (dark gray) and Ontario

Support to the Creation and Working of the Great Lakes Climate Adaptation Network

In Phase I we developed tools, resources, and research through engagement with municipalities across the region. Through this engagement, GLISA played an instrumental role in bringing together the Great Lakes Climate Adaptation Network (GLCAN), a regional network of local government staff and partners representing over 30 members in all. The creation of GLCAN responds to the Urban Sustainability Directors Network's interest in promoting regional networks, by creating a peer-to-peer learning network in order to better understand best practices in addressing climate change by region.

Going into Phase II we seek to strengthen collaborations and engage our network and boundary organization analyses to understand how information is being taken up by cities. We will also engage with cities through GLCAN to develop new decision-support tools (DST) (e.g. updated climatology fact sheets and scenario building) as well as by complementing current DSTs they use by adding and integrating climate related information. Finally, we will strengthen our partnership with GLCAN by exploring integrated funding opportunities to support our work together. In a research/evaluation front will employ a linked chain approach (from the boundary chain model) to analyze how information integrates into city actions, including departmental plans and policies, as well as standard operating procedures.

Advancement of Our Physical Science Agenda via the Applied Climate Program

GLISA has partnered with the University of Michigan's College of Engineering Applied Climate program for the past few years to give master's level students the opportunity to participate in real-world, applied climate projects. This past year the student projects delivered a consistent and coherent message across their various topics that is helping steer GLISA's future research efforts.

In each of the projects, the students were looking at historical observations or model data for the region to investigate past or future trends or to evaluate the quality of information in the various data sets. Each project was designed to support a larger part of GLISA's scientific research agenda. Two common themes among the collective body of student work emerged, and those are 1) differences among observational products warrant further investigation into the quality of individual data sets; and 2) much more analysis of model data is needed for our region to better understand the dynamics—primarily that which is associated with the lakes—that are/are not represented in the models. Additional details about the project findings are provided in the Research Findings section.

Expanding Sectorally

In Phase I we gained valuable insight and experience working with partners that were reaching out to us to collaborate around climate adaptation issues, and in Phase II we also plan to proactively engage sectors that have not necessarily reached the same level of planning—specifically, we have and will continue engaging tribal governments and start working in the field of climate information valuation, which is a priority to many private and public sectors in the region.

In Phase II we also are working to deepen our connection to the agriculture and agribusiness sectors. GLISA is working with the Michigan Agribusiness Association to identify key climate-related issues and needs of agricultural interests in the region and will continue to partner with the Michigan State University Extension.

KEY GLISA RESEARCH FINDINGS

PHYSICAL RESEARCH OBJECTIVES AND FINDINGS FROM APPLIED CLIMATE PROGRAM

GLISA worked with eight graduate students this past year on a variety of projects aimed to provide the students with real-world applied climate experiences. GLISA also provides project-based work for the undergraduate Climate Impacts students at the University. Each student was evaluating or analyzing various observational and model data sets for the Great Lakes region. Research topics included 1) comparison of gridded observational products to station observations; 2) an update to GLISA's Great Lakes freezing rain climatology; 3) producing visualizations of future temperature and precipitation projections for Michigan's Upper Peninsula; 4) comparison of CMIP5 models and their representation of the Great Lakes; 5) investigation into climate adaptation indicators stakeholders are using across the region; 6) investigation into possible correlations between city sewer type, heavy daily precipitation totals, and the frequency of flash flood events; 7) climate change and lake level information for Tribal fisheries management in the Great Lakes region; and 8) Lake Superior ice cover predictions for Apostle Islands National Lakeshore.

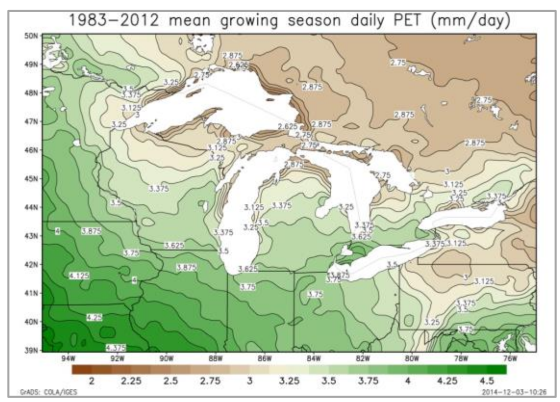
Each of these projects identified common challenges and shortcomings when working with climate data in the Great Lakes region: 1) differences among observational products (i.e., gridded vs station, gridded vs gridded, gridded vs reanalysis) warrant further investigation into the quality of individual data sets; and 2) much more analysis of model data is needed for our region to better understand the dynamics—primarily that which is associated with the lakes—that are/are not represented in the models. To the second point, one of the most interesting findings in the model data was that the CMIP5 models that simulate water in the area of some or most of the Great Lakes (as opposed to placing land in the location of the lakes) have a poorer representation of precipitation in the region. Further investigation into these lake-land-atmosphere relationships in the models is underway as part of our Ensemble work.

TRIBES USE OF CLIMATE INFORMATION – FRAMING SOVEREIGNTY ON LANDS AND EXERCISING TREATY RIGHTS

The work that GLISA has undertaken with tribes throughout the Great Lakes region has mainly been focused on the effects of climate change and variability on natural resources important to the individual tribes and how to best plan for the future in terms of population/resource sustainability and resource access. This is an iterative process of engagement that incorporates knowledge from climate scientists and expertise from resource managers/band members familiar with the system being analyzed. This process has been shown to be effective in both receptions from participants and tribal members, as well as seeing the plans being discussed and developed incorporated into official strategic planning processes, particularly at the department level within tribal government. The goal of most of these plans is to ensure continued resources access for band members, which they are entitled to through their treaties with the Federal government. This is a key aspect of sovereignty over tribal lands and treaty areas.

POTENTIAL EVAPOTRANSPIRATION

A potential evapotranspiration (PET) climatology for the Great Lakes region was developed by co-director Jeff Andresen and his research team at Michigan State University for the period from 1983-2012. It's available at an hourly time step and has a spatial domain of 95°W-75°W and 39°N-50°N. The data set provided satisfactory estimates of PET across the region including lake shore areas, once spatial inconsistencies in the NLDAS-2 forcing dataset were accounted for. Statistical adjustments improved the quality of the estimates but an overall conservative bias remains. The lakes play an important role in describing seasonal and geographical trends observed in the dataset. Overall mean PET tends to decrease in a SW to NE gradient across the region, with relatively lower values near the lakes. Additionally, spatial and temporal variability of PET is relatively high during the spring season. The results suggest greatest potential vegetative water needs are in the southern and western portions of the region, away from the lakes.



Historical climatology (1983-2012) of mean growing season (April-September) daily PET

CREATION AND EMPIRICAL TESTING OF A FRAMEWORK TO EVALUATE THE BOUNDARY CHAINS MODEL

We have been developing a new framework to predict the usability of climate information in the course of GLISA's boundary chain partnerships. In our boundary chain work, multiple boundary organizations play different roles in the course of tailoring climate information for a given set of potential users. We believe that such partnerships can enhance usability if they achieve synergy through attaining two distinct capabilities and constraints: complementarity and embeddedness. Complementarity describes the ability of two partners to deliver more when they engage through bringing two sets of distinctive inputs together. Boundary chains build on each organization's strengths (e.g., in producing scientific information, in facilitation, in having established trust with potential users), to produce partnerships that together increase the potential for improved outcomes. Embeddedness represents the extent of ties that connect the participants in boundary chains. When organizations are embedded, the choices and actions of one side will affect the choices and actions of the other. While these factors are important prerequisites for synergy to develop that enhances the usability of climate information, synergy will only exist if participants are willing to iterate across the boundary chain and are open to change.

ANALYSIS OF DRIVERS OF CLIMATE ACTION IN GREAT LAKE CITIES

GLISA has analyzed the forces underlying the emergence of climate change interventions in cities throughout the eight US Great Lakes states. This research has highlighted the significance of the influence that local governments have on one another for understanding and anticipating the development of climate change policies. Cities in the region make pragmatic decisions about how to "keep up" with their perceived peers and avoid looking like they are falling behind. Whether or not cities in the region have begun addressing climate change in their policies or not is therefore tied into a perceived need to update their approach to economic development and being influenced by other cities nationally and internationally. While this research offers a new approach for thinking about what drives action in particular localities, its main focus is on how action transfers across contexts. Understanding influence is a way in which to understand cascades, or the "scaling up" of behaviors as they proliferate amongst participants. The rapid development of climate change interventions across cities is not just possible, but inevitable, with potential implications for both scholars and society. In particular, the capacity for cities to scale up interventions highlights the importance of developing strategies for outreach that can handle rapidly expanding demands for climate change decision support.

NETWORK DYNAMICS AND PERCEPTIONS ABOUT LAKE LEVELS

After two rounds of surveys taken by stakeholders, scientists, and others within the networks we study, people have not changed overall in their perceptions of long term lake levels, but there is considerable variation – some people reduced their estimates while others increased their estimates. We are investigating how much these changes are a function of specific networks the participants are embedded in and which events they attended. This finding is important in light of the fact that lake levels went up between the administrations of our first and second round of surveys. Therefore, people did not react to immediate changes in lake levels when making their long-term predictions.

Outreach and Communication Activities

Input to Regional Outlooks and Impacts Reports

GLISA is part of a group, coordinated by NOAA Central Region Headquarters and Environment and Climate Change Canada and led by Midwestern Regional Climate Center, that participates in quarterly calls to produce a regional 2-page document for the Great Lakes. This document gives an overview of recent climate conditions/patterns experiences in the last quarter, denotes significant climate events, highlights sectoral impacts across the region, and gives a regional outlook for the upcoming quarter. In all, 16 distinct offices and 9 agencies/organizations participate in the call. During this past winter (2015-16) the regional group was convened approximately every two months during the Fall/Winter to give an update on the ongoing El Niño and the associated climate conditions, impacts, and outlook for the Great Lakes region.

City Climate Fact Sheets

GLISA, in partnership with the Great Lakes Adaptation Assessment for Cities (GLAA-C), has collaborated with multiple cities across the region to develop two-page outlines of the successes and challenges each city faces as it seeks guidance in adapting to projected future climate changes. The City Climate Fact Sheets showcase the efforts being done by various cities around the Great Lakes as they plan for climate change impacts, and each is related to specific goals or projects the cities have identified or undertaken. The following cities are a part of this work: Ann Arbor, MI, Flint, MI, Dayton, OH, Toledo, OH, Columbus, OH, Saint Paul, MN, Minneapolis, MN, Thunder Bay, ON, and Kingston, ON.

Marquette Climate Resilience Toolkit

GLISA built on previous work with Marquette, Michigan and nearby partners by working with the NOAA *Climate.gov* Climate Resilience Toolkit (CRT) Team to demonstrate a 5-step decision-making process and help local managers identify key climate vulnerabilities in the central Upper Peninsula of Michigan. The CRT Team identified Marquette, Michigan as a representative community of the type it aimed to serve: a community with a history of strong interest in climate adaptation with lesser financial resources than other larger cities. GLISA's previous engagements with Marquette provided a foundation for developing localized climate information and presenting it to Marquette's partners. Over three days, the CRT team and GLISA introduced local officials to resources in the CRT, presented them an expanded set of local climate-resources, and guided them through the CRT framework. This work may help demonstrate opportunities for greater RISA-CRT collaboration in the future, as GLISA's focused, regional perspective complemented the CRT team's knowledge of adaptation tools nationwide.

AGU/CGU JOINT ASSEMBLY SESSION

At the Joint Assembly of the American Geophysical Union, the Geological Association of Canada, the Mineralogical Association of Canada, and the Canadian Geophysical Union held in Montreal, QC, Canada in May 2015, GLISA co-convened a session with the Ontario Centre for Climate Impacts and Adaptation Resources focused on the integration of climate data in the Great Lakes. Due to its bi-national nature, data efforts meet unique challenges when attempting to bridge data across the border between the United States and Canada. This session featured 7 speakers focusing on topics from climate modeling in the region to observing networks and observational datasets. Feedback from the speakers and the audience was positive and exposed research to individuals who had not previously seen it.

MIDWEST MESONET AND SPECIALTY CROP WORKSHOP

GLISA participated in a workshop in September 2015 in Champaign, IL, hosted by the Midwestern Regional Climate Center, and USDA Midwest Climate Hub. The focus of this workshop was to bring together climate scientists, extension agents, and producers to discuss climate sensitivities/vulnerabilities in specialty crop and livestock agriculture. An important function of this meeting was also networking between the groups. The discussions at this meeting went on to inform the Midwest NIDIS Pilot development and will inform future meetings focused on the impacts of climate on agriculture in the Midwest. A smaller meeting was held the day prior to start of the livestock/specialty crop meeting. At this meeting, operators of state-run mesonets from across the Midwest came together to discuss their networks and the potential for standardization of measurements and instrumentation across the Midwest. The mesonet effort is being led by the Midwestern Regional Climate Center.

GREAT LAKES CLIMATE CHANGE TALKS

GLISA is positioned as a regional climate expert and is often requested to speak at workshops or meetings on the topic of climate change in the Great Lakes region. For each of these talks, we typically build our presentation from a standard slide deck prepared for general audiences and tailor the talk to any unique information needs or topics not already covered. In the case that a GLISA staff member has been unavailable to present, we have worked with meeting organizers to informally train them on presenting our materials. This type of train-the-trainer exercise is something GLISA is investigating in order to leverage the uptake of information we produce to more audiences. Below is a listing of meetings we participated in over the last year and presented our general "Climate Change in the Great Lakes Region" talk:

- City of Saint Paul (Saint Paul, MN) July 9, 2015
- US Environmental Protection Agency Region 5 Headquarters September 17, 2015
- Northern Climate Network (Marquette, MI) September 18, 2015
- Burnsville, Minnesota Climate Adaptation Planning Kick-Off Meeting September 24, 2015
- Coastal Resilience Planning Project (Macomb County) September 29, 2015

- US EPA Region 5 Green Infrastructure Integration Conference (Grand Rapids, Michigan) October 6, 2015
- Climate Resilience Toolkit Workshop (Marquette, MI) October 22, 2015
- Michigan Watershed and Environment Association (Lansing, MI) December 1, 2015
- Toledo Metropolitan Area Council of Governments (Bowling Green, OH) March 10, 2016
- Chagrin River Watershed Workshops (Willoughby Hills, OH and Pepper Pike, OH) April 18, 2016 and May 12, 2016

GLISA's Influence on Implemented Plans, Tools, Strategies, Etc.

Climate Adaptation Plan for 1854 Treaty Authority

Through two collaborations our program expanded our portfolio of work with tribes throughout the region. Over the past year we joined with the consulting firm, Adaptation International, in developing the Climate Adaptation Plan for the 1854 Treaty Authority and three Bands of Lake of Superior Chippewa tribe. The 1854 Treaty Authority is an inter-tribal natural resource management organization that manages the off-reservation hunting, fishing and gathering rights of the Bois Forte Band of Chippewa and Grand Portage Band of Lake Superior Chippewa in the territory ceded under the Treaty of 1854. Through our contract with Adaptation International GLISA developed localized climate resources for the vulnerability assessment and adaptation plan, served on regular team calls, and provided facilitation support at both a vulnerability assessment workshop in October 2015 and a climate adaptation strategies workshop in May 2016. The final report features regional and local climate information, climate vulnerability assessments for 33 resources, and detailed climate adaptation strategies for 10 individual resources and species.

Climate Vulnerability Assessment for the City of Columbus

Through a grant from the Natural Resources Defense Council, our team collaborated with the City of Columbus and Ohio State University to develop detailed historic and future climate resources for the city's vulnerability and risk assessment process. This process followed Milestone 2 (Research) of ICLEI's Local Governments for Sustainability "Building Adaptive and Resilient Communities" tool. End products included a comprehensive suite of assessments containing 21 key climate impacts of concern that could be organized by primary climate impact (e.g. water quality and availability, flood risk and seasonal precipitation, air quality and extreme heat, and natural resources and growing season) and associated risk scores for each with 14 identified as the highest priority.

Strategic Stakeholder Selection based on Network Analysis

In their second round of GLISA funding, the Alliance for the Great Lakes aims to target local elected officials, land managers, and private landowners in four communities to commit to implementation of policies and practices that increase their adaptive capacity. The project team targeted stakeholders based on the network diagrams we developed with them. In particular, they targeted professional development members of network clusters of resource managers who did not have access to extensive knowledge about climate change within their network cluster. They also deliberately convened those who did not have access to climate change expertise with some climate change experts.

Key GLISA Publications

Peer Reviewed

1. **Laura J. Briley**, Walker S. Ashley, **Richard B. Rood**, Andrew Krmenec, 2015: The role of meteorological processes in the description of uncertainty for climate change decision-making. Theoretical and Applied Climatology. 1-12

doi: http://dx.doi.org/10.1007/s00704-015-1652-2

Abstract Downscaled climate data are available at fine spatial scales making them desirable to local climate change practitioners. However, without a description of their uncertainty, practitioners cannot know if they provide quality information. We pose that part of the foundation for the description of uncertainty is an assessment of the ability of the underlying climate model to represent the meteorological or weather-scale processes. Here, we demonstrate an assessment of precipitation processes for the Great Lakes region using the Bias Corrected and Spatially Downscaled (BCSD) Coupled Model Intercomparison Project phase 3 (CMIP3) projections. A major weakness of the underlying models is their inability to simulate the effects of the Great Lakes, which is an important issue for most global climate models. There is also uncertainty among the models in the timing of transition between dominant precipitation processes going from the warm to cool season and vice versa. In addition, warm-season convective precipitation processes very greatly among the models. From the assessment, we discuss how process-based uncertainties in the models are inherited by the downscaled projections and how bias correction increases uncertainty in cases where precipitation processes are not well represented. Implications of these findings are presented for three regional examples: lake-effect snow, the spring seasonal transition, and summer-time lake-effect precipitation.

Books

2. Gettelman, A. and **Richard Rood**. "Demystifying Climate Models: A Users Guide to Earth System Models." Earth Systems Data and Models 2. (2016)

doi: http://dx.doi.org/10.1007/978-3-662-48959-8

Abstract This book demystifies the models we use to simulate present and future climates, allowing readers to better understand how to use climate model results. In order to predict the future trajectory of the Earth's climate, climate-system simulation models are necessary. When and how do we trust climate model predictions? The book offers a framework for answering this question. It provides readers with a basic primer on climate and climate change, and offers non-technical explanations for how climate models are constructed, why they are uncertain, and what level of confidence we should place in them. It presents current results and the key uncertainties concerning them. Uncertainty is not a weakness but understanding uncertainty is a strength and a key part of using any model, including climate models. Case studies of how climate model output has been used and how it might be used in the future are provided. The ultimate goal of this book is to promote a better understanding of the structure and uncertainties of climate models among users, including scientists, engineers and policymakers.

3. Simpson, C., Dilling, L., Dow, K., Lackstrom, K., **Lemos, M. C**., Riley, R., 2014. "Assessing needs and decision contexts: RISA approaches to engagement research." In Climate in Context: Lessons from NOAA's Regional Integrated Assessments. (2016): 3-26. Eds. A. Parrish and G. Garfin. Wiley.

doi: http://dx.doi.org/10.1002/9781118474785.ch1

ABSTRACT For almost two decades, Regional Integrated Sciences and Assessments (RISA) teams have emphasized iterative engagement with decision-makers. The methodological underpinnings of that approach are the results of years of experiments with applying various methods to understand the complexities of decision-maker needs for climate information and the contexts within which those decision-makers manage resources and plan for the future. RISA teams have used a range of approaches depending on the questions that needed to be answered and the type of data that was required. The selection of methodology also reflects on how to engage with diverse decision-makers from farmers to state agency officials in order to create long-term relationships. This involves taking into consideration such issues as building working relationships, avoiding stakeholder fatigue, and fostering regional networks. This chapter explores the research questions posed and the methods that have been used by four of the RISA teams to further our understanding of these issues.

REPORTS

4. Cameron, L., A. Ferguson, R. Walker, **D. Brown**, & **L. Briley**, 2015: Michigan climate and health profile report 2015: Building resilience against climate effects on Michigan's health. Accessed at: www.michigan.gov/climateandhealth.

Through the 20th and into the 21st century, Michigan's climate has changed in measurable and impactful ways. Since 1951 the average annual temperature has increased by 0.6°F in the southeastern Lower Peninsula, and up to 1.3°F in the northwestern Lower Peninsula. During that same period total annual average precipitation across the state increased by 4.5%, or 1.4 inches. Additional changes include an increased frequency of some types of weather extremes such as heavy precipitation events. These changing climate conditions have had an impact on both environmental and human systems, representing an emerging threat to public health in Michigan. In response, the Michigan Department of Health and Human Services Climate and Health Adaptation Program (MDHHS – MICHAP) in partnership with the Great Lakes Integrated Sciences Assessments Program (GLISA) is using the Centers for Disease Control and Prevention's (CDC) Building Resilience Against Climate Effects (BRACE) framework to build capacity for public health adaptation at the state and local levels. This Climate and Health

Profile Report is the initial step of the BRACE framework, laying the foundation for future assessments of vulnerability, disease burden, and interventions.

Star, J., Fisichelli, N., Schuurman, G., Welling, L., **Rood, R**., **Briley, L,** and **William Baule**. "Climate Change Scenario Planning Workshop Summary." (2016). Accessed at: https://www.nps.gov/apis/learn/nature/upload/APIS-Scenario-Workshop-Report-20160104-FINAL.pdf

This report summarizes outcomes from a two-day scenario workshop for Apostle Islands National Lakeshore, Wisconsin (APIS). The primary objective of the session was (i) to help senior leadership make management and planning decisions based on up-to-date climate science and assessments of future uncertainty. The session was also designed (ii) to assess the effectiveness of using regional-level climate science to craft local scenarios. Finally, it provided an opportunity to (iii) introduce scenarios to participants and further their capabilities in scenario practice.

APPENDIX

Additional Publications

Shulski, M.D., **W.J. Baule**, C. Stiles, and N. Umphlett, 2015. A Historical Perspective on Nebraska's Variable and Changing Climate. Great Plains Research, 25: 109-120.

doi: http://dx.doi.org/10.1353/gpr.2015.0023

Abstract Nebraska is situated at the intersection of the northern and southern GreatPlains, exhibiting a dramatic longitudinal gradient for precipitation and humidity, and benefiting from groundwater resources. The continental climate is highly variable temporally both for temperature and precipitation. Our assessment of long-term meteorological observations shows that over the last century the annual average temperature in Nebraska has warmed approximately 0.6°C, which is similar to the increase in the global average temperature over the same time period. Furthermore, we found minimum temperatures have warmed more than maximum temperatures, and winter and spring show the strongest warming. We found no significant long-term trend in annual precipitation, but seasonal variations exist, namely with wetter springs and falls, and drier winters and summers. The number of days having temperature extremes (both hot and cold) has decreased over time. We found an overall increase in growing season length

Climate Risk Management Special Issue

Maria Carmen Lemos, Christine Kirchoff (former PhD student with Lemos) and Scott Kalafatis led the development of a special issue for the journal Climate Risk Management (peer-reviewed and open-access) that includes GLISA and its boundary chain partnerships at the core of five papers. The special issue puts GLISA's work in conversation with papers discussing similar outreach efforts made by the California Ocean Science Trust and the Alaska Center for Climate Assessment and Policy.

Special Issue Papers:

- **Briley, L.; Brown, D.; Kalafatis, S.E.** (2015) "Overcoming barriers during the co-production of climate information for decision-making." Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.04.004
- **Kalafatis, S.E.; Grace, A.; Gibbons, E.** (2015) "Making Climate Science Accessible in Toledo: The Linked Boundary Chain Approach." Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.04.003
- Kettle, N.; Trainor, S. (2015) "The role of climate webinars in supporting boundary chain networks across Alaska." Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.06.006
- **Kirchhoff, C.J.**; Esselman, R.; **Brown, D.** (2015) "Boundary organizations to boundary chains: Prospects for Advancing Climate Science Application." Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.04.001
- **Kirchhoff, C.J.; Lemos, M.C.; Kalafatis, S.E.** (2015) "Creating synergy with boundary chains: Can they improve usability of climate information?" Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.05.002

- **Kirchhoff, C.J.; Lemos, M.C.; Kalafatis, S.E.** (2015) "Narrowing the gap between climate science and adaptation action: the role of Boundary Chains." Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.06.002
- Meyer, R.; McAfee, S.; Whiteman, E. (2015) "How California is mobilizing boundary chains to integrate science, policy and management for changing ocean chemistry." doi: http://dx.doi.org/10.1016/j.crm.2015.04.002
- Phadke, R.; Manning, C.; Burlager, S. (2015) "Making it Personal: Diversity and Deliberation in Climate Adaptation Planning." Climate Risk Management doi: http://dx.doi.org/10.1016/j.crm.2015.06.005

LOCALIZED CLIMATE INFORMATION
FOR THE 1854 CEDED TERRITORY

Historical and projected climate trends for the 1854 Ceded Territory are summarized in this report. The 1854 Ceded Territory covers portions of two climate divisions[1], most of Minnesota Northeast (NEM) and the northeast corner of Minnesota East Central (ECM) (Figure 1).

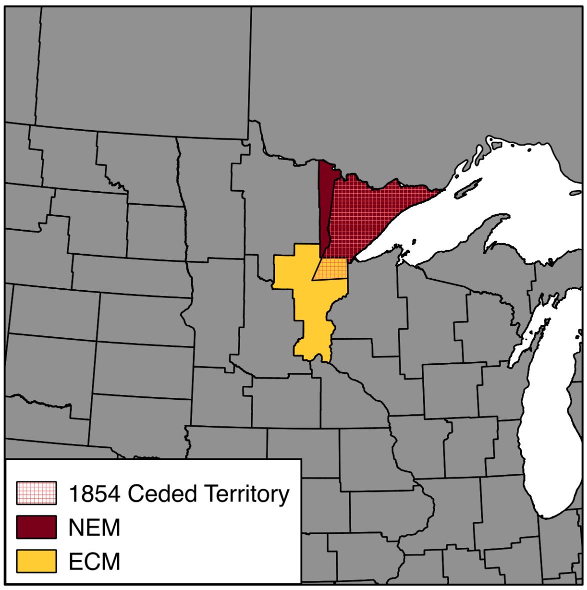


Figure 1. Map of the U.S. climate divisions. With the 1854 Ceded Territory, Northeast Minnesota, Minnesota East Central climate divisions highlighted.

Regional and Local Climate Summary

The area covered by the 1854 Ceded Territory has seen increases in annual temperature. The Minnesota Northeast (NEM) climate division has warmed slightly faster than the Minnesota East Central (ECM) climate division. The increases observed in temperature however, vary between seasons (Table 1). The most significant warming in the region has occurred in the winter and spring. Warming has also occurred in the summer and fall, though less substantial than winter or spring. Annually, minimum temperatures over the area have increased faster than maximum temperatures. The difference in maximum and minimum temperature increase is most pronounced in the winter and summer seasons. During the fall and spring, maximum and minimum temperatures increased at approximately the same rate over the period from 1950-2012.

Table 1: Summary of observed climate change statistics for the Northeast and East Central climate divisions. Changes are for the period from 1950-2012. Precipitation percentage is relative to the base period from 1951-1980.

	Annual	Winter	Spring	Summer	Fall
Minnesota Northeast					
Avg. Temp.	3.7°F	5.8°F	4.5°F	2.1°F	2.4°F
Max. Temp.	3.5°F	4.8°F	4.6°F	1.9°F	2.4°F
Min. Temp.	4.0°F	6.8°F	4.4°F	2.4°F	2.3°F
Precipitation	-2.3%	-12.0%	-11.0%	-5.4%	14.7%
Minnesota East Central					
Avg. Temp.	3.5°F	5.9°F	4.3°F	1.5°F	2.2°F
Max. Temp.	3.2°F	5.0°F	4.4°F	1.1°F	2.1°F
Min. Temp.	3.8°F	6.7°F	4.2°F	1.9°F	2.2°F
Precipitation	6.1%	-2.4%	7.1%	-3.6%	27.2%

Annually, precipitation has decreased slightly in NEM, while it has increased in ECM (Table 1). Seasonally, precipitation has decreased during the winter, spring and summer in NEM. Fall in NEM has seen a moderate increase in precipitation. ECM by contrast has seen slight decreases in winter and summer precipitation; increases have been observed during spring and fall, with the latter being substantial.

Duluth, MN has one of the most complete snowfall/snow depth observation records in the region (climate divisional data for snow are not available)[2]. At Duluth there has been an observed increase in annual snowfall (~+5 inches in the average year since 1950). Seasonally winter and autumn have seen increased total snowfall, while spring snowfall has declined. Average snow depth at Duluth has declined in winter and spring. While autumn snow depth has remained constant. The increases in snowfall seen in Duluth are less than areas directly downwind of Lake Superior in Wisconsin and Michigan (Figure 2). More southern areas in the Midwest have observed decreases in annual average snowfall.

Increases in the intensity of extreme precipitation events (top 1% of all occurrences) have also been observed in recent decades across the much of the Great Lakes region (Figure 3). This is of particular

Crowded Beaches

Drier, Increased Population

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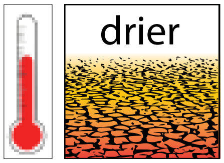
Climate Scenario Details

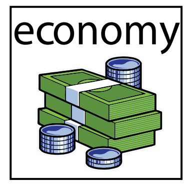


- **Warming** temperatures (especially winter)
- More intense short (seasonal) and long-term (multi-year) **droughts**
- Less snowpack contributes to **summer drought**

Population Scenario Details

- Rapid population **growth** in NY and Ontario
- Increased **crime**

- Increased conversion of land for **urban sprawl** and **mega farms** (with increased water recycling)



- Technology advances have left immigrant and low-wage workers **unemployed**
- Federal/state **stimulus programs** in action
- Shift from historic sportfishing boats to smaller/lighter vessels
- Increased **tourism**
- New **energy** extraction methods

IMPACTED SECTOR	**Precipitation Driver** (Increased Drought)	**Temperature Driver** (Warmer Air Temperatures)	**Population Driver** (High Population)
Land	• Surface soils dry out • Exposed shorelines • Decreased property values from aesthetic changes to lakeshore	• Longer growing season	• More impervious land cover
Water/Lakes	• Lake levels fall • Reduced stream flows • Wetlands dry out	• Warmer lake waters • Less ice cover • More evaporation	• Greater water use, demands • More stormwater runoff
Ecosystem	• Loss of lake and wetland habitat • Fewer fish spawning sites • Increased risk of fire • Increased intensity of Harmful Algal Blooms (HABs)	• Fewer cold refugia • Fewer cold water fish species • Increase in southern invasive species • Lower lake oxygen	• More agricultural pollutants • Increased intensity of Harmful Algal Blooms (HABs) • Increased damage from industrial pollutants
Human	• Greater water use demands/ diminished well water supplies • Increased need for water quality management • Increased need for drought planning and water conservation policy • Economic stress (i.e., crop losses, lake/shoreline industry losses, etc) • Increased risk of fire	• Increased health risks from extreme heat events • Increased urban heat island effects • Increased risk of dangers and damages from freezing rain events	• Increased wastewater treatment and disposal needs • Floodplain/shoreline communities at risk from higher water levels

Sea Grant New York
USGS science for a changing world
Cornell University

Executive Summary

The goal of this project was to begin a process of analyzing the potential for increasing on-farm water storage as a climate change adaptation strategy. To gain understanding of the opportunities and barriers to on-farm water recycling in the Great Lakes region, we talked with drainage contractors, agency staff, farmers, extension specialists, irrigation dealers, and farmers who have and have not installed on-farm water recycling. We used historic yield data together with climate projections to estimate potential yield benefits that could be achieved by the Ohio WRSIS water recycling systems under expected future climate conditions. We have shared this information at drainage workshops, scientific conferences, and meetings and are developing fact sheets describing these systems that provide information that will benefit producer and agency decision-making about this new and promising practice.

Introduction: The need for on-farm water storage and recycling for climate change resilience

Agriculture in the Great Lakes region has benefited historically from regular precipitation patterns. The relatively steady precipitation, coupled with soils with good water-holding ability, has allowed agriculture in the region to become highly productive and a substantial contributor to the region's economy. However, predicted shifts in temperature and precipitation patterns towards warmer and wetter winters and springs, a greater frequency of intense storms throughout the year, and more severe and longer droughts in the summer suggest the potential for decreased crop yields in the future unless ways are found to provide additional water to crops during the growing season, while also being able to quickly remove excess soil water when conditions are wet.

Subsurface (tile) drainage is widely used in crop production in this region, removing excess water, particularly in the spring, to enable timely field operations (Figure 1). While excess water needs to be drained in the spring and other periods of excessive precipitation, crops in drained areas also experience stress from lack of water during the drier summer months at the peak of the growing season. This suggests that storing drainage water on the farm and recycling it through irrigation during summer, when crops experience water deficit, will become more and more beneficial as the pattern of excess water at times and drought at other times is exacerbated by climate change.

Figure 1: Installation of drain tile, a feature of cropland across the Great Lakes region.

The goal of this project was to advance on-farm water recycling as an adaptation strategy, by analyzing data from historical research sites from the perspective of climate change, identifying opportunities for this practice to be implemented more widely in the region, and providing outreach to stakeholders in the region.

Overview of on-farm water recycling on drained cropland

On-farm water recycling is the practice of capturing water drained from fields during high-flow periods, storing it in a pond or reservoir, and irrigating it onto crops later in the season. When this practice captures tile drainage water, we are calling it *drainage water recycling***,** a practice that has two major benefits:

- It will improve **water quality** because drained water, that typically contains nitrate and phosphorus, is diverted into the water storage pond. Storing the water and recycling it onto crops prevents it from causing water quality problems such as algae blooms in Lake Erie or hypoxia in the Gulf of Mexico.
- It will increase **crop yields** because although precipitation in the Midwest is generally plentiful, it does not occur exactly when needed by the crop. Tile drainage occurs mostly in the spring, while crop water use in mid- to late summer may result in periods when insufficient water is available.

Drainage water recycling can be a closed-loop system where the drained water from a field is recirculated onto the same field, or water drained from one field can be used

Localized Climate Information
for Menominee County, Michigan

Historical and projected future climate trends for Menominee County in Michigan are summarized in this report. Menominee County is located in Michigan's West Upper (WUM) climate division.

Regional and Local Climate Summary

The climate division in which Menominee County is contained has seen increases in annual air temperature. While at the same time annual precipitation has decreased. These increases have not been consistent throughout the year. Temperature increases have been largely observed in winter and spring. Summer and fall temperature increases have been substantially smaller.

Table 1: Summary of observed climate change statistics for the West Upper climate division. Changes are for the 1951-1980 to 1981-2010 time period.

	Annual	Winter	Spring	Summer	Fall
Temperature	1.5°F	2.6°F	1.5°F	1.1°F	0.8°F
Precipitation	-2.9%	0.1%	-7.8%	-9.7%	8.1%

Annually, precipitation has decreased in the climate division that includes Menominee County. This decrease has not been evenly distributed throughout the year. Seasonally, precipitation has increased during the fall. Summer and spring have seen decreases in precipitation. While winter precipitation amounts have remained constant, in terms of the amount falling as rain or liquid-water contained in snow.

Lake Michigan water temperatures have risen during the summertime and lake ice levels have declined during the winter, though there is significant interannual variation.[1,2] Increased water temperatures and ice cover declines have the potential to alter the near-shore climate through increased evaporation and potential for increased lake effect snowfall. Though lake event snowfall is less common on the windward side of Lake Michigan.

Future climate information for WUM and Menominee County comes primarily from global and regional climate models (GCMs and RCMs). In the Midwest, the GCMs project a wider range of temperature and precipitation outcomes than the RCMs, so some of the values reported here are beyond what is shown in the RCM-based maps later in this report. No model perfectly simulates the physics that govern global, regional, and local climate, so several models are consulted[3] to describe potential climate changes in the Midwest and Menominee County..

Table 2: Summary of projected climate changes for the Midwest with localized descriptions for Menominee County.[3]

		Short Term (2021-2050)	Long Term (2041-2070)
Annual	Temperature	Midwest ranges from 1.5-4.5°F warming with an average around 3°F.	Midwest ranges from 3-5°F warming with an average around 4.5°F. Warming is consistent across most of the Midwest.
	Precipitation	Midwest ranges from -4% to +7% change.	Midwest ranges from -7% to +12% change. WUM has some of the greatest projected annual increases.
Winter	Temperature	Midwest ranges from 2-5°F warming with an average around 3.5°F.	Midwest ranges from 3.5-7°F warming with the greatest warming in the north. WUM averages warming toward the upper bound of that range.
	Precipitation	Midwest ranges from -3% to +15% change.	Midwest ranges from -3% to +17% change. Projected changes for WUM are an increase in winter precipitation from 10-17%

Climate Changes and Impacts in Columbus, Ohio

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Rising Temperatures

Average Temperature

2.3°F
1951-2012

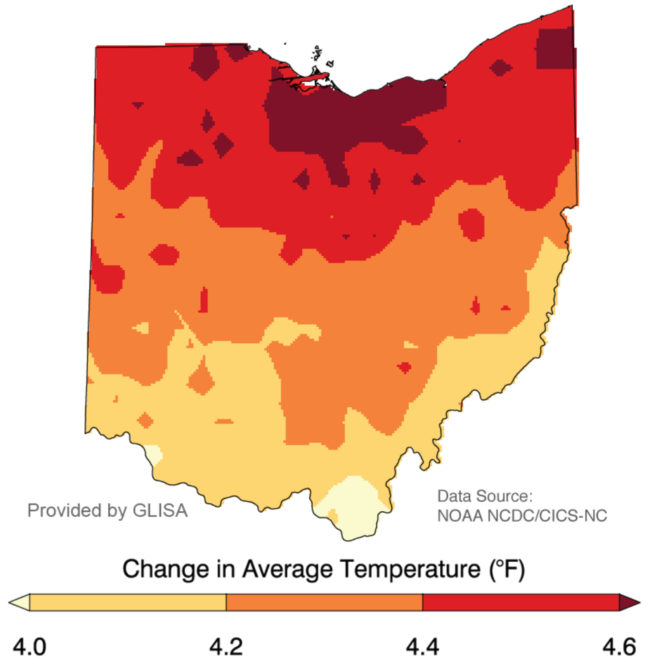
Average temperatures warmed by 2.3°F from 1951 through 2012, faster than the national and global rates. Models project this trend will continue, with temperatures rising approximately 3-5°F by mid-century.

Growing Season

26 Days
1951-2012

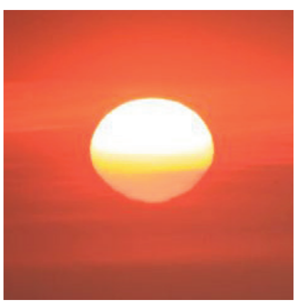
The length of the freeze-free season (growing season) increased by 25.5 days from 1951 through 2012, and is expected to lengthen by an additional 1-2 months throughout the coming century.

Projected Change in Average Temperature
Period: 2041-2070 | Higher Emissions: A2



Average temperatures are projected to increase by 3 to 5°F by the middle of the 21st century, depending on the rate of future greenhouse gas emissions. Shown above are mid-century projections for 2041-2070 that assume greenhouse gas emissions will continue to rise as they have in the recent past (the A2 Scenario).

What Rising Temperatures Mean for Columbus:



Dangerously Hot Days: Rising temperatures increase the potential for extremely hot days. By mid-century, Columbus could see an additional 3 to 7 weeks per year of high temperatures exceeding 90°F, and an additional 1 to 2 weeks exceeding 95°F.

Air Quality: Air quality deteriorates with warmer temperatures, increasing the risk of serious public health consequences. A greater incidence of asthma attacks and other respiratory conditions is anticipated.

Agriculture: Through mid-century, some crop types may flourish in a warmer climate. Beyond mid-century, those benefits will likely be negated by heat stress, more frequent droughts, and a greater risk from pests.

Natural Resources: Rising temperatures will alter the habitats of fish and wildlife, forcing plants and animals to migrate or adapt. Those unable to migrate with the pace of climate change will lose their advantage over other species, reducing ecosystem diversity.