# Great Lakes Ensemble

## March 2016 - March 2017 Progress Report

GLISA
A NOAA RISA TEAM

The Great Lakes Ensemble project is an effort to provide the highest quality climate data and information for the Great Lakes region in a way that is valuable to end users. The Great Lakes Integrated Sciences and Assessments program (GLISA) is the project lead, but partners include regional experts from both the scientific and climate information user communities. For a more detailed project description, please visit our online project page.

The purpose of this report is to provide an update of Ensemble outreach and scientific activities to our partners and other interested parties. Much of this report is more technical in nature, focusing on climate model evaluation and our early research results.

## Outreach Activities

*3.2.2016 - Scientific Advisory Committee Meeting*
Main Discussion Takeaways:

- A very basic CMIP3/5 inter-comparison for the purpose of identifying main differences may be useful.
- Model evaluation should include investigating the seasonal cycle of extreme rainfall, net basin supply, lake temperatures, and lake ice cover.
- Models should incorporate minimally a 1-D lake model for projections to be worth considering for the Great Lakes region (except for CMIP which are included for comparison).
- Evaluation should be conducted on original data in order to reveal “red flags” that may be corrected in bias-corrected versions. Additional guidance on the impact of bias correction may be needed.
- Canadian partnerships will be important and should be further pursued to help with the adoption of the Ensemble and additional regional expertise.

*6.7.2016 - International Association of Great Lakes Research | Conference Session: Interactions Between Large Lakes and Regional Climate*

- Presented early results of CMIP5 representations of the Great Lakes and regional summertime precipitation

*10.6.2016 - Great Lakes Adaptation Forum (GLAF) | Working Group Session: Practitioner Partnerships for Great Lakes Ensemble*

- The focus was on gaining knowledge about practitioners’ climate information needs and gauging interest for participation in a Stakeholder Advisory Committee.
- Administered survey focused on individuals’ experience, knowledge, and use of climate information. 10 responses were collected in person and another 36 online after the meeting. Online responses available here.

Here is a summary of the 46 responses:

- Most responders self identified as having an intermediate (i.e., have used climate information in some way) understanding of climate models and data, but there were beginner and advanced responders as well.
- The majority of responders require or have used an intermediate level of climate data in their work (i.e., customized information in the form of location-specific thresholds/indices and/or scenarios).
- In response to how well climate data/information needs are being met, responses were split between somewhat and adequately. No one indicated “not at all” and six responded “very well.”
- Most responders indicated climate models and data need more guidance for end-users.
- Overwhelmingly, responders find both qualitative and quantitative uncertainty information valuable.
- The majority of responders want to stay engaged in the Ensemble work and are willing to help define and evaluate the usability of products.

*2.9.2017 - GLISA Team Ensemble Update | Identification of Needs and Goals*

- Needs: Fill data acquisition and organization role; formalize a model evaluation strategy; identify other data sets to evaluate next (aside from Notaro data).
- Near-Term Goals: Review stakeholder survey from GLAF; Form a Stakeholder Advisory Committee; Develop a strategic plan for integrating end users into Ensemble product development.

*2.17.2017 - Great Lakes Water Quality Agreement Annex 9 Meeting | Introduction to the Ensemble*

- Provided a 10 minute introduction to our Ensemble work.
- Connected with Canadian researcher, Biljana Music at Ouranos, to look for potential ways to partner with her in the future. Her research areas intersect nicely with our work (regional climate modeling, lake level modeling). We continue to talk about a partnership.

## Scientific Activities

### Setting up an Evaluation Framework

*Developed a set of minimum requirements for a model to be considered for the Ensemble:*

- Gridded data are available for the region defined by any state that touches a Great Lake and southern Ontario.
- A 20th century run is provided for comparison with observations.
- Data are available at a daily time step.
- A 1-D lake model is used to represent the Great Lakes (except for CMIP GCMs which are included for comparison).
- Model documentation is publicly available.
- Downscaling and bias-correction documentation is

available (when applicable).

*Developing a model evaluation framework:*

- Standard Statistical Measures (i.e., Mean, Standard Deviation, Percentiles, etc.)
- Adaptation Metrics (i.e., Hot/Cold Days, Freeze-Thaw Cycles, Growing Season Length, etc.)
- Representation of Physical Processes (i.e., Seasonal cycle of lake temperatures, lake ice, extreme rainfall, net basin supply, etc.)
- Model Components (i.e., Are there lakes in the model? Does lake ice form?)
- A complete description is available online.

## CMIP5 Model Evaluation Research

*Investigated the geographic representation of the Great Lakes in 54 CMIP5 models*

- 12 models have a fraction of at least one grid cell over the Great Lakes that is defined by a surface other than land (presumably water).
- 8 of those models simulate sea surface temperatures for at least part of one Great Lake.
- 7 of those models also simulate lake ice.
- Only 1 model simulates surface temperatures and ice cover for all five Great Lakes.
- Geographically, the representation of water and surface temperatures/ice cover data are not necessarily co-located (Figure 1). Water may exist in regions where there are no surface temperature/ice data and vice versa. It is unclear how information about water on the atmospheric grid is coupled to information about SSTs/ ice on the ocean grid. INM-CM4 is the only model that represents all five lakes on its ocean grid.
- Only INM-CM4 uses a 3D model for lakes (similar to ocean model).
- At best, other models treat the lakes as oceans or a wet soil layer.

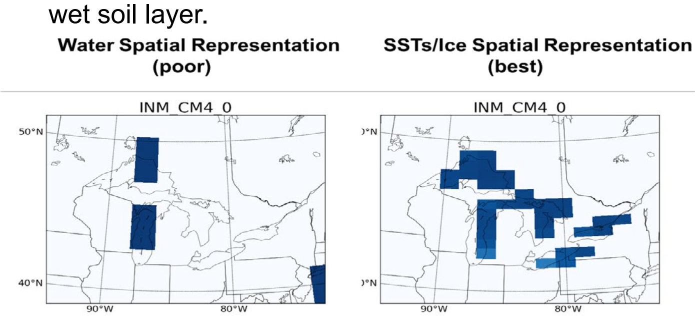
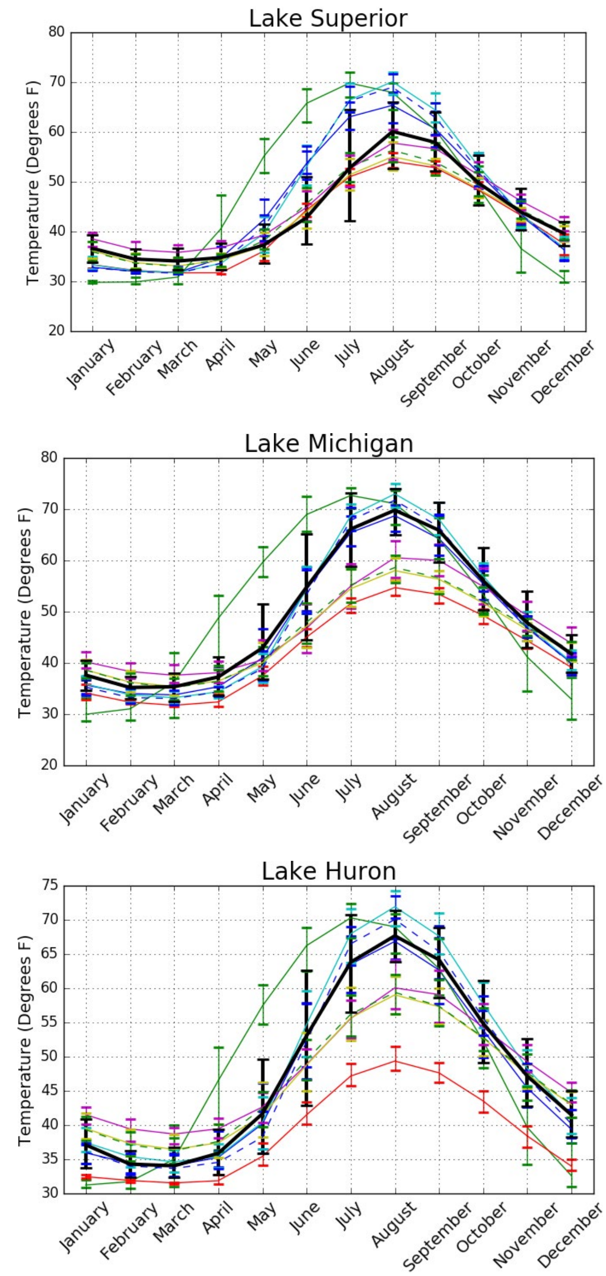



Figure 1. INM-CM4 model's geographic representation of land area fraction (left) and sea surface temperatures/ice cover (right) for the Great Lakes Region.

*Investigated the monthly historical representation of lake surface temperatures for the Great Lakes*

- Compared historical monthly lake surface temperature (°F) means and variability (5th to 95th percentiles) for the CMIP5 models representative of the lakes (1976-2005) and observations (1995-2015) by lake.
- Observations consist of monthly lake wide average lake surface temperature data from GLERL (not available prior to 1995).
- Each lake has at least one model that falls within the range of the observations during most months.
- The models generally simulate temperatures closer to the observations during the winter compared to the summer.
- INM-CM4, the only model with all five lakes, simulates an earlier shift to warmer temperatures in the spring and colder temperatures in the fall.
- The models under-represent intra-monthly variability.

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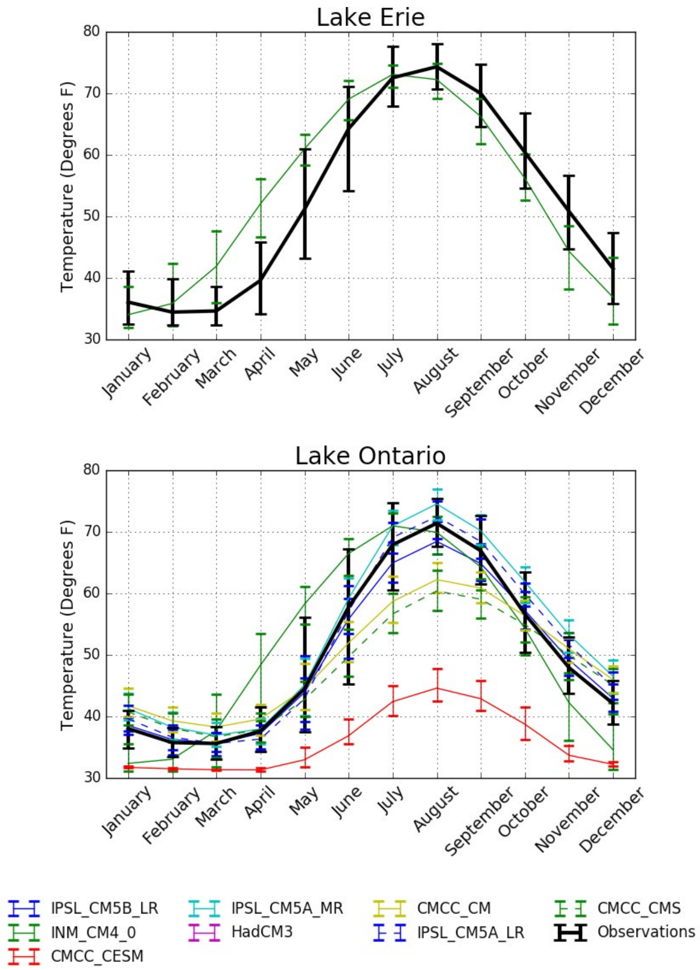
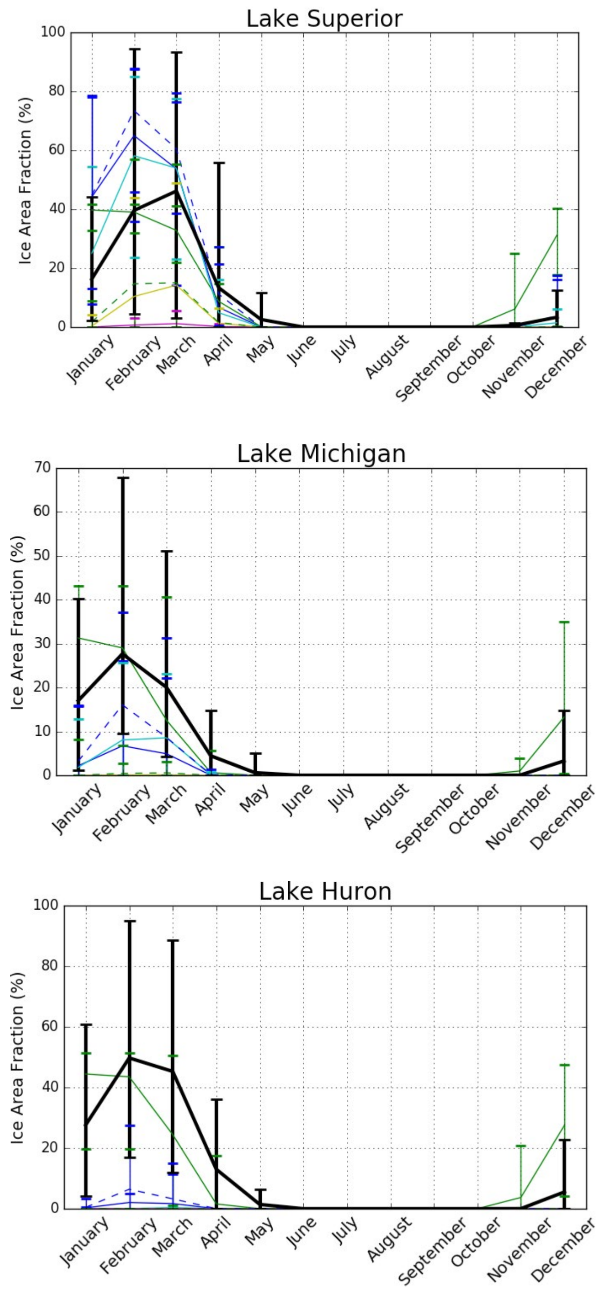



Figure 2. Monthly climatological mean lake surface temperatures (°F) for the CMIP5 models (1976-2005) and observations (1995-2015) by lake. Vertical lines represent the 5th to 95th percentile of the monthly data for the historical period. The thick dark line represents the historical observations.

*Investigated the monthly historical representation of lake ice cover for the Great Lakes*

- Compared historical (1976-2005) monthly ice cover (%) means and variability (5th to 95th percentiles) for the CMIP5 models representative of the lakes and observations by lake.
- Observations consist of monthly lake wide average ice cover data from GLERL.
- INM-CM4, the only model with all five lakes, simulates mean monthly ice cover percentages closest to the observations during most months (except January).
- INM-CM4 has a smaller range of variability during January-April compared to the observations for every lake except Ontario.
- INM-CM4 consistently overestimates ice cover during December and January for every lake except Erie.
- The remaining models generally underestimate mean ice cover for Lakes Michigan and Huron, and for Lake Superior half of the models underestimate and half overestimate ice cover.

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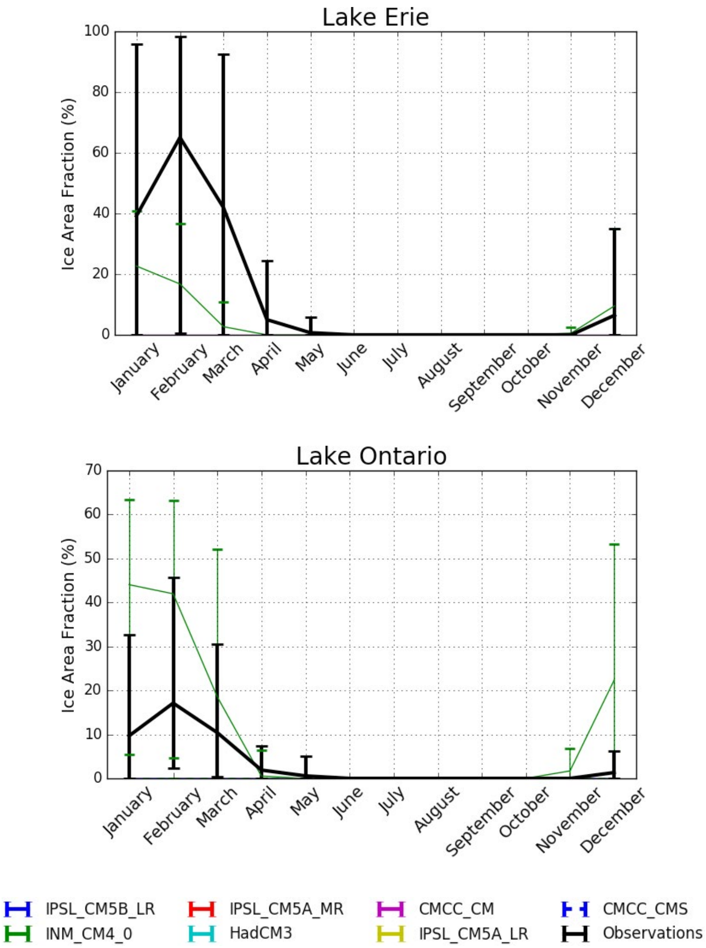
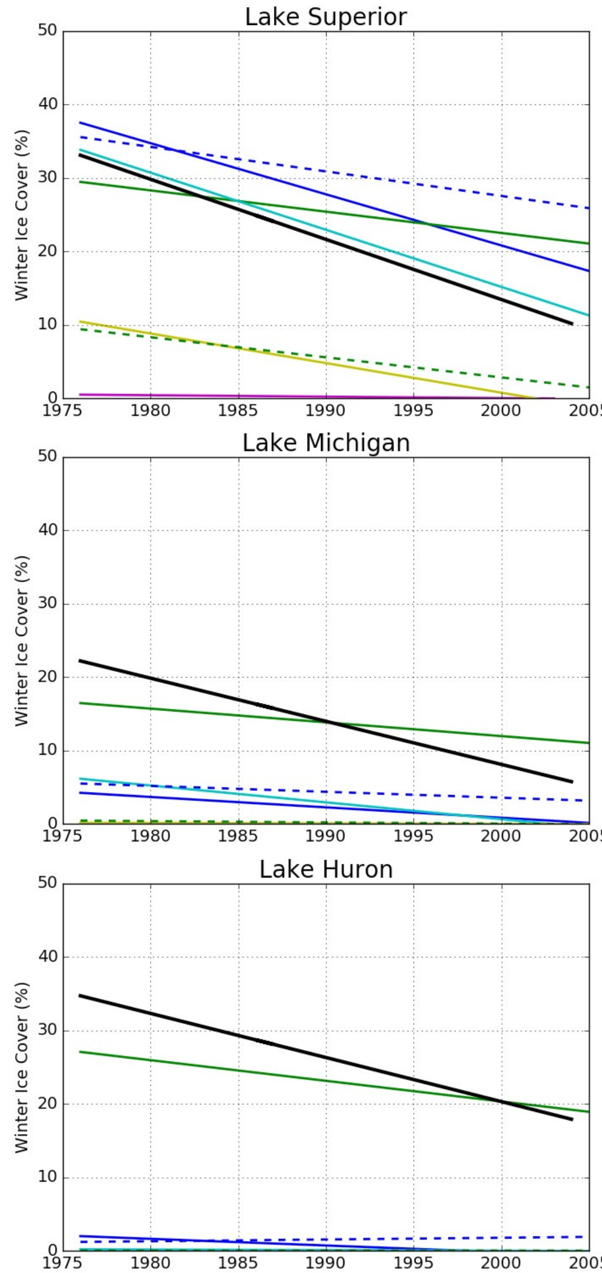



Figure 3. Monthly climatological (1976-2005) lake wide ice cover (%) for the CMIP5 models and observations by lake. Vertical lines represent the 5th to 95th percentile of the monthly data for the historical period. The thick dark line represents the historical observations.

*Investigated the historical annual trend of lake ice cover for the Great Lakes*

- Compared historical (1976-2005) linear regressions of annual (November-April) ice cover (%) for the CMIP5 models representative of the lakes and observations by lake.
- Observations consist of monthly lake wide average ice cover data from GLERL, which was aggregated to annual (November-April) average ice cover.
- Several models capture similar rates of ice cover decline (slope of the regression) compared to observations for Lake Superior, but only a few models simulate accurate amounts of initial ice cover on Lake Superior.
- The remaining lakes do not have any models that simulate both the correct initial amount of ice cover and rate of decline.

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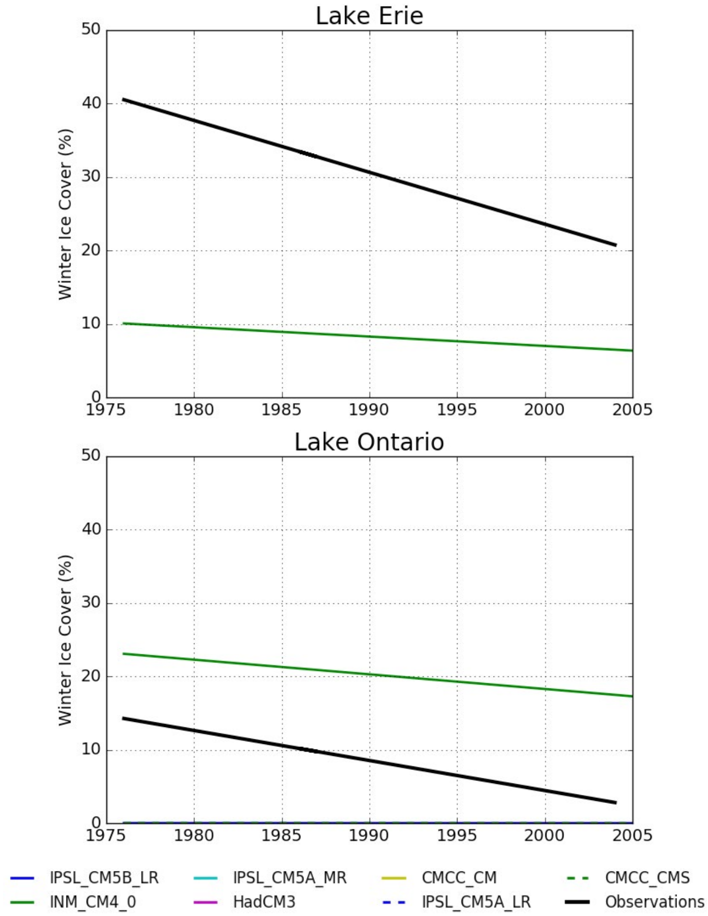


Figure 4. Linear regression lines of lake wide annual (November-April) mean ice cover (%) from 1976 to 2005 in the CMIP5 models and observations (dark line) by lake.

CMIP5 Lake Temperature and Ice Cover Summary

- The model with the best spatial representation of the lakes (INM-CM4) does not translate to the best temporal representation of lake temperatures and ice.
- Only INM-CM4 has a 3D model for lakes (similar to its ocean model)
- At best, other models treat the lakes as oceans or a wet soil layer.
- No single model accurately captures the historical magnitude, timing, variability, and recent trends of surface temperature and ice cover observations for every lake.
- A publication of these results will be submitted in 2017.

## Lake Level Modeling

*An Applied Climate student working with GLISA and NOAA's Great Lakes Environmental Research Laboratory investigated model biases in net basin supply for the GFDL CM3 model downscaled using WRF.*

- Biases in net basin supply remain large
- Bias correction makes large adjustments to the components (precipitation, runoff, and evaporation) which likely dominates any determination of changes in lake levels

## Weather and Climate Thresholds and Indices for Decision Making

*GLISA partnered with the Western Michigan Sustainable Business Forum, as part of a GLISA-funded small grant, and helped identify climate information needs and co-produced a customized climate summary for four businesses in the Grand Rapids, MI area.*

- Identified several weather and climate thresholds and indices that businesses find valuable in their planning
- Established a formal methodology for calculating indices
- Gained experience working with the business sector

## Online Model Inventory

The Model Inventory was developed to collect information about the models being considered for the Ensemble. Each model has its own page in the Inventory where contributors can share model documentation, guidance on how to acquire the data, and meta data about the variables. Pages have been populated for the CMIP3 and CMIP5 models as well as Michael Notaro's Dynamically Downscaled Projections for the Great Lakes Region.

The Inventory has also emerged as an inter-comparison tool, where contributors can upload figures and additional details related to evaluation. For example, when investigating the spatial geography of how the Great Lakes were represented in the CMIP5 models, additional sections were added to each model page for users to contribute figures showing the land-sea fractions, sea surface temperatures, and ice cover. Information about the number of Great Lakes represented in the model was also collected. An inter-comparison page was created using the inventory to quickly display these pieces of information across the CMIP5 models.

## Ensemble Links

Main Project Description: http://glisa.umich.edu/projects/great-lakes-ensemble

GLISAclimate.org project collaboration space (collection of relevant resources, research results, guidance pages, etc): http://www.glisaclimate.org/projects/1581

Model Inventory: http://www.glisaclimate.org/model-inventory

CMIP5 inter-comparison of spatial geography of lakes: http://www.glisaclimate.org/ensemble/intercomparison/lakes?f[0]=field_ensemble%3A643

Stakeholder Survey (includes responses):
https://docs.google.com/forms/d/1AurJvOI44yEOfRq1i8OZaOy5mbSNJR7beuKVU_nMQAQ/edit?usp=sharing

## Scientific Advisory Committee

Drew Gronewold (NOAA Great Lakes Environmental Research Laboratory)
Michael Notaro (University of Wisconsin - Madison)
Peter Snyder (University of Minnesota)
Joe Barsugli (NOAA Earth System Research Laboratory)
Edmundo Fausto (Ontario Climate Consortium)
Glenn Milner (Ontario Climate Consortium)

## Ensemble Contact Information

Richard Rood rbrood@umich.edu
Laura Briley auraell@umich.edu
Frank Marsik marsik@umich.edu