Great Lakes Ensemble

April 2017 - April 2018 Progress Report

en·sem·ble
A group of items viewed as a whole rather than individually.

The Great Lakes Ensemble is a collection of climate projections and expert knowledge, guidance, and synthesis of those projections. The goal of the Ensemble is 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 research results.

Outreach Activities

3.30.2017 - Ensemble Update & Vision for the Scientific Advisory Committee

- Presented an update of GLISA's analysis of the Great Lakes in the CMIP5 models.
- This meeting included a lot of useful discussion around how the Lakes are represented in the models and helped shape our evaluation going forward. We learned that the land-sea mask in the models is not an indicator of lakes - it only indicates where the land vs ocean component model is active. Lakes, which are simulated within the land model, would appear as land in the land-sea mask which was not previously realized.
- Knowledge gained from our advisors helped us revise our investigation of the Lakes in climate models, which is foundational to the credibility of the Ensemble.

9.26.2017 - Michigan Climate Coalition

- Presented an overview of the Ensemble project to MCC members. This group is very interested in our work and two of the members have since joined our Stakeholder Working Group.

12.11.2017 - American Geophysical Union Fall Meeting | Conference Session: Using New Data and Technology to Better Understand Freshwater and Lake Systems: End-to-End Remote Sensing and Regional Modeling Approaches

- Convened this session at AGU to present Ensemble project to an international audience and gather feedback from colleagues in the field. About 50 attendees were present.
- Presented early results of CMIP5 representations of the Great Lakes.
- Showed the breakdown of information coming from the ocean and land component models and how some models have information gaps or conflicting model information over the Great Lakes.

3.21.2018 - Ensemble Stakeholder Working Group Meeting

- This meeting was an introduction to the Ensemble project for a group of 10 members who accepted a role in our Stakeholder Working Group.
- Working group goals were outlined:
  1. Provide feedback on existing GLISA products
  2. Co-develop new products with GLISA
  3. Investigate how to scale products to larger audiences and increase usability across the region
  4. Provide feedback on GLISA's overall program direction
- A list of Working Group Members is on the last page of this report.

Scientific Activities

CMIP5 Great Lakes Representations

Investigated the representation of the Great Lakes in 54 CMIP5 models

- Identified which models have active ocean components versus active land components over the Great Lakes using the land area fraction variable.
- **First Finding**: Some land area maps suggest the ocean component is responsible over the Great Lakes but there exist no ocean data (sea surface temperatures and sea ice) in the Region. Figure 1 depicts this finding where blue grid cells over Lake Erie in the left map would suggest the ocean model is active (blue = 0% land) but when sea surface temperatures are mapped for the region (right map) there are no data over Lake Erie. It is unclear how the surface of Lake Erie is represented since neither the ocean or land model appear active in this region. Only four CMIP5 models have consistent information about the Great Lakes being treated as oceans (HadCM3, IPSL CM5A-LR, IPSL CM5A-MR, IPSL CM5B-LR), and none capture all five Great Lakes.

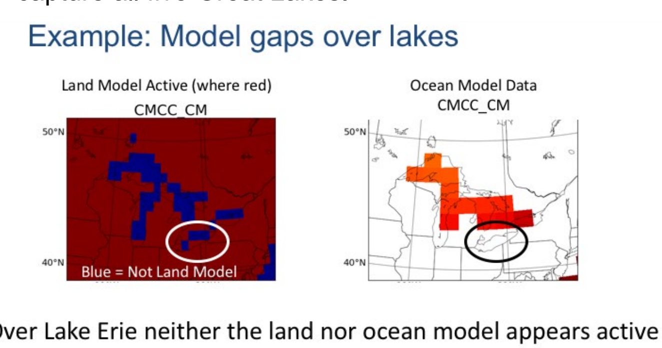

Figure 1. Example of a model that indicates the ocean model is active over Lake Erie (left map indicated by oval around blue grid cells of 0% land) but no ocean data exist for that region (map on right indicicated by oval showing white = no data)

- **Second Finding**: Some of the models appear to have both the ocean and land components active in the same grid cell, which raises concerns about how these components are coupled to one another. Figure 2 depicts that the land and ocean components are both active over Lakes Huron, Erie, and Ontario in the INM CM4.0 model. This finding leads us to believe there are conflicting representations of the Great Lakes in the models as oceans and land (possibly including lakes).

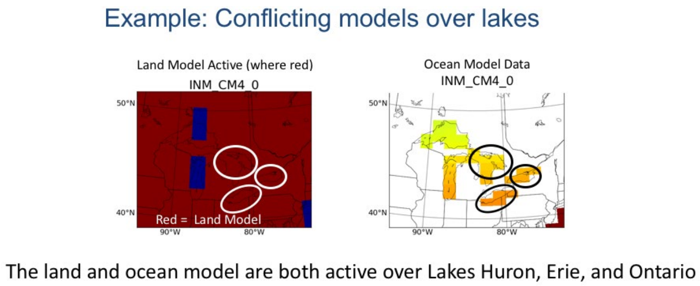

Figure 2. Example of a model that indicates the land model is active over Lakes Huron, Erie, and Ontario (left map shown using ovals outlining grid cells representing 100% land in red) but the ocean component model is also active over the same region (map on right indicicated by colored grid cells inside ovals)

- **Third Finding:** Of the models that definitely do not have ocean data representing the Great Lakes, some may actually treat the Lakes as lakes within their land component models. There is no "lake" variable within the land component models, so identifying which models treat the Lakes as lakes is not straightforward. Even if the land model documentation is found and the treatment of lakes identified, there is no guarantee that the Great Lakes are included. Instead, we searched for a "signature" of the lakes in surface temperature data over the Region. We investigated whether surface temperatures were colder (warmer) over the Lakes compared to surface land temperatures during summer (winter). We also limited our search to those models whose spatial resolution was finer than 1.25-degrees to find models that provide meaningful information about the lakes - resolutions coarser than 1.25 degrees represent each lake with only a few grid cells, which don't provide enough spatial detail for many of our stakeholders. Seven CMIP5 models have a signature of the Great Lakes in their surface temperature data (BCC-CSM1-1m, CCSM4, CESM1-BGC, CESM1-CAM5, MIROC4h, MIROC5, MRI-CGCM3) and may actually represent the Lakes as lakes. Current work is focusing on these seven models and investigating their land component documentation to further uncover the treatment of the Great Lakes.

Evaluating and Integrating Dynamically Downscaled Great Lakes Projections into GLISA Products

Dynamically downscaled projections for the Great Lakes region, developed by researchers at the Center for Climatic Research at the University of Wisconsin - Madison, were acquired, assessed, and used in several future climate summaries and scenarios GLISA developed over the last year. We consider these projections the first set of reliable downscaled data to include in our Ensemble. Special thanks to Dr. Michael Notaro for all of his help in acquiring and working with the data.

- We investigated precipitation in the models and compared it to observations (Univ. of Delaware) to get a sense for model bias. We found:
  1. Most models have a larger mean precipitation than the observations when averaged over the region (95 W to 71W and 38N to 52N) by season.
  2. Downscaled CNRM and GFDL models have the closest spatial distribution and amount of seasonal precipitation over the region compared to observations.
- These data have allowed us to start exploring ways to evaluate lake-effects in the models. Our goal is to quantify the strength of the lake-effect so we can compare across models (including the CMIP5 models that have lakes).
- We started with a few simple methods to investigate lake-effect precipitation in the models and observations:
  1. Use geographic "boxes" (Figure 3) in lake- and non-lake-effect regions to compare the statistical distribution of seasonal precipitation within each box. The boxes were arbitrarily drawn with the goal of investigating lake-effects in Boxes 2, and 4-6, and Box 1 and 3 represent areas where precipitation was more homogeneous outside and within the observed lake-effect zone, respectively. We plotted the distribution of mean winter (DJF) precipitation within each box for the historical period (1978-1999) (Figure 4). We found

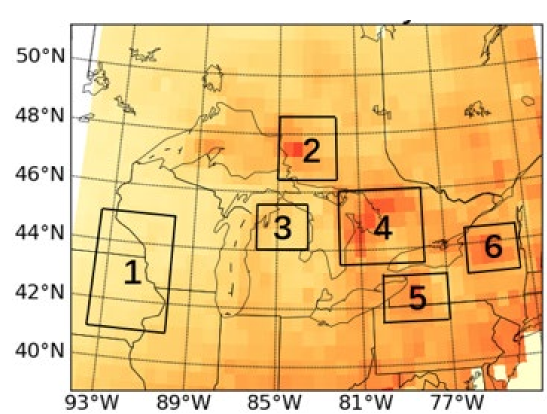

Figure 3. Map showing regions ("boxes") used in the analysis of seasonal precipitation

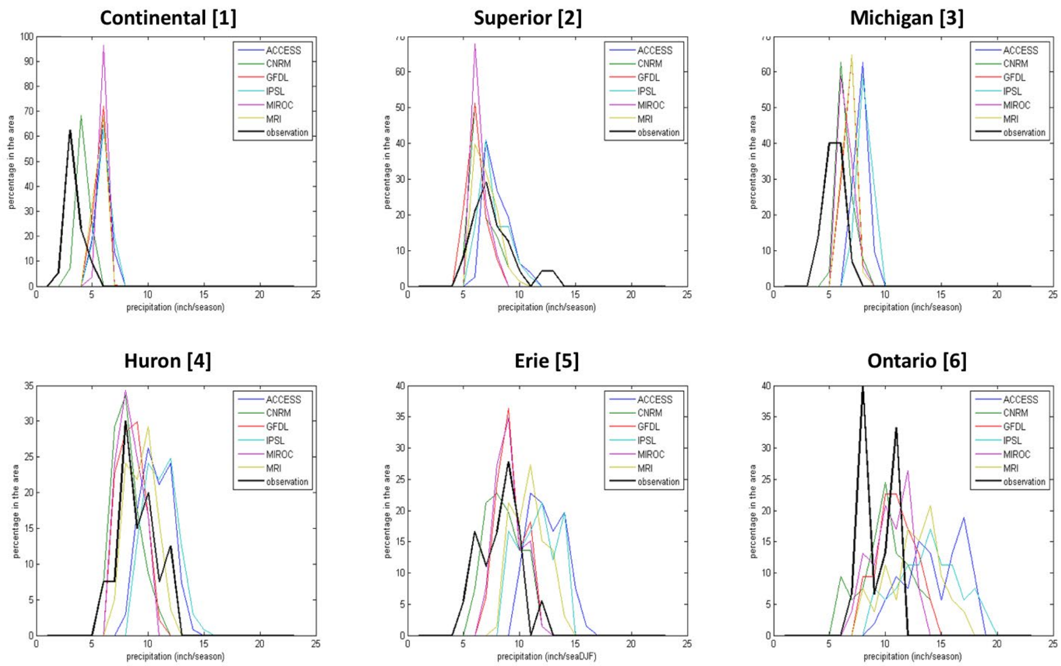

Figure 4. Statistical distributions of mean winter (DJF) precipitation with each "box" defined in Figure 3. Models are marked by colored lines; Observations are marked by the black line.

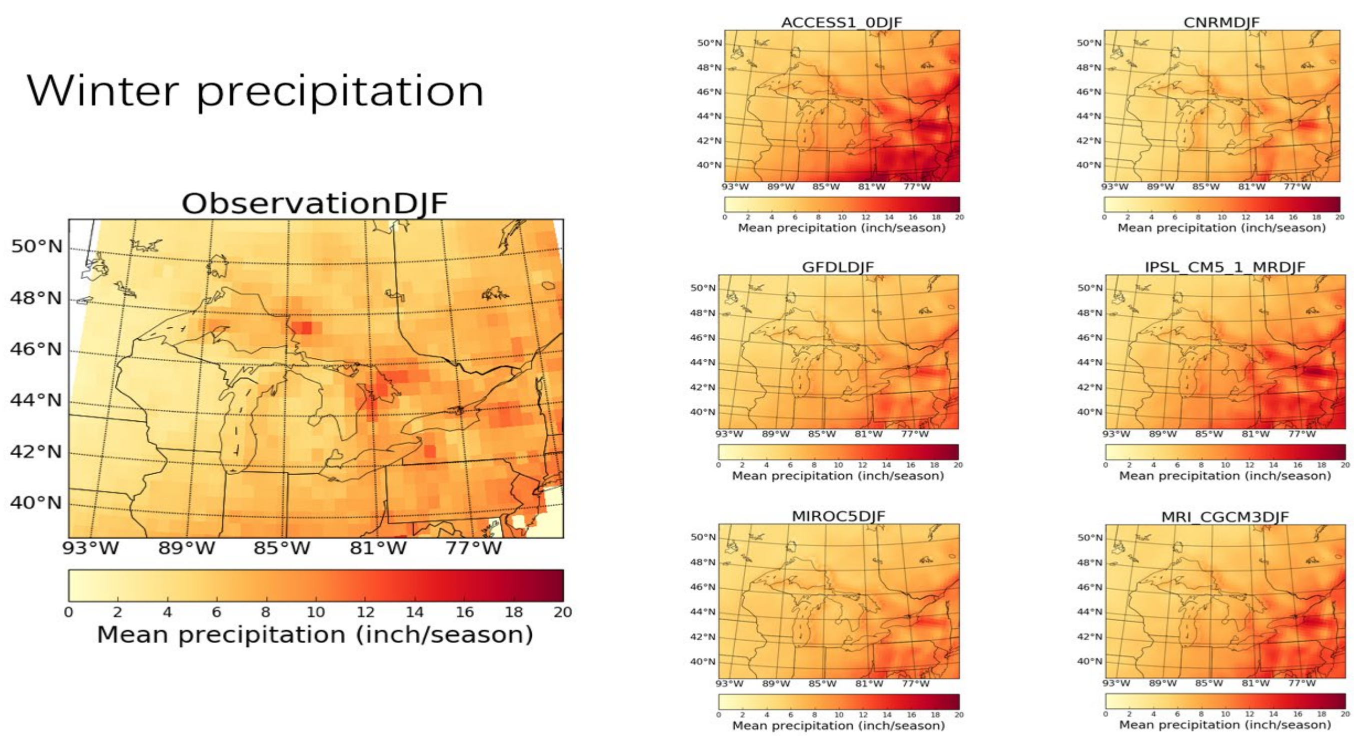

Figure 5. Maps of mean winter precipitation (inches) in the observations (left) and models (set of 6 maps on the right) for the period 1978-1999.

the statistical distribution of winter precipitation within Box 1,2, and 3 has a similar shape to the observations but is shifted towards higher amounts of precipitation. The models in the remaining boxes are in less agreement with the observations for the shape of the distribution. Most models tend towards higher amounts of precipitation.

2. We are also interested in more precisely defining the boundary of the lake-effect zone for our analysis. Our initial step was to divide a 1-degree boundary around the lakes into lake- and non-lake-effect segments primarily based on east-west orientation (Figure 6).

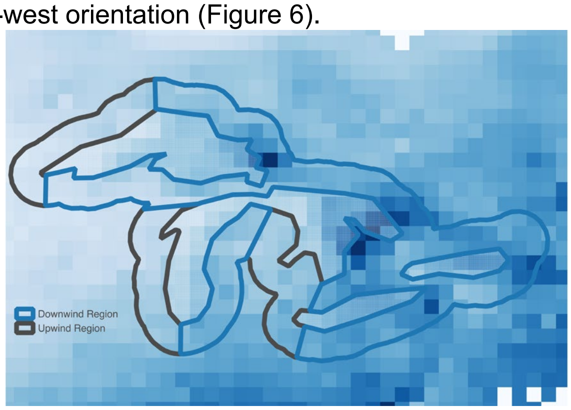

Figure 6. Map showing winter precipitation totals overlayed with a 1-degree buffer around the Great Lakes designated as lake-effect (blue) and non-lake-effect (gray) segments.

We aim to improve this boudnary definition by investigating precipitation gradients across the Region to allow the data to define the lake-effect zones (Figure 7). By mapping the gradient of precipitation we can start to see areas characterized by strong increases/decreases.

$$\text{Precipitation Gradient} = \frac{dp}{dx}i + \frac{dp}{dy}j$$

1	2	3
4	5	6
7	8	9

$$\text{Gradient at position } 5 = \sqrt{\left(\frac{6-4}{2dx}\right)^2 + \left(\frac{2-8}{2dy}\right)^2}$$

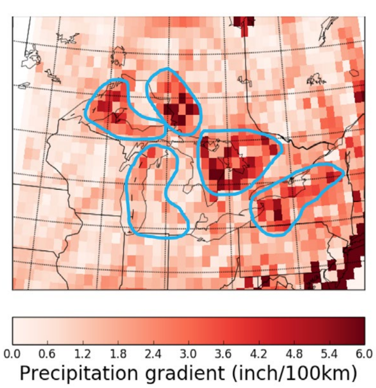

Figure 7. Map showing gradient of precipitation with outlined (blue) regions indicating lake-effect zones.

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

Scientific Advisory Committee

- Joe Barsugli | NOAA Earth System Research Laboratory
- Drew Gronewold | NOAA Great Lakes Environmental Research Laboratory
- Glenn Milner | Ontario Climate Consortium
- Biljana Music | Ouranos
- Michael Notaro | University of Wisconsin - Madison
- Peter Snyder | University of Minnesota

Stakeholder Working Group Members

- Tim Boring | Michigan Agribusiness Association
- Devon Brock-Montgomery | Bad River Band of Lake Superior Chippewa Tribe
- Eric Clark | Sault Ste. Marie Tribe of Chippewa Indians
- Ankur Desai | University of Wisconsin-Madison
- Rebecca Esselman | Huron River Watershed Council
- Edmundo Fausto | Amec Foster Wheeler
- Elizabeth Gibbons | American Society of Adaptation Professionals
- Christopher Hoving | Michigan Climate Coalition/ Michigan Department of Natural Resources
- Greg Mann | National Weather Service-Detroit
- Michele Richards | Michigan Climate Coalition/Michigan Army National Guard

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