Analysis of ice safety in the Northern Hemisphere

A Data Management Plan created using DMP Assistant

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Project abstract:

Millions of people rely on lake ice for safe winter recreation. Warming air temperatures impact the phenology (timing of formation and breakup) and quality (ratio of black to white ice) of lake ice cover, both critical components of ice safety. Later formation and earlier breakup of lake ice lead to overall shorter periods of use. However, greater proportions of white ice may further inhibit safe ice use owing to its lower weight-bearing capacity. As ice cover duration decreases and ice quality changes in a warming world, the period of safe ice use will similarly diminish. We use a large ensemble modeling approach to predict ice safety throughout the winter period in the Northern Hemisphere. We used the Community Earth System Model Version 2 Large Ensemble (CESM2-LE) to calculate the period when ice first appears until it is of sufficient thickness for safe use, which depends on the ratio of black to white ice. We conducted this analysis for 2,379 to 2,829 ~1° by 1° grid cells throughout the Northern Hemisphere. We focus on the period between ice formation (≥ 2 cm) to a safe thickness for general human use (i.e., ≥10, ≥15, or ≥20 cm, depending on the ratio of black to white ice). We find that the transition period from unsafe to safe ice cover is growing longer, while the total duration of safe ice cover is getting shorter. The transition period of unsafe ice increases by 5.0 ± 3.7 days in a 4 °C warmer world, assuming 100% black ice. Diminished ice quality further limits safe ice conditions. The unsafe transition period increases by an average of 19.8 ± 8.9 days and 8.8 ± 6.6 days for the ice formation and breakup periods, respectively in a 4 °C warmer world assuming 100% white ice conditions. We show that although many lakes are forecasted to freeze, they will be unsafe to use for an average of 5 to 29 fewer days in a 4 °C warmer world for 100% black and 100% white ice ratios, respectively. This wide range indicates that ice quality has a strong influence on ice safety. This work highlights the need to understand both lake ice phenology and quality to better assess safe lake ice use during the formation and melt periods.

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Project Information

1.1 Name of project or sub-project and project number (if applicable).

Widespread loss of safe lake ice access in response to a warming climate

1.2 Please provide an outline description of the research project and the intended products of the research.

- This research project intends to assess the safety of lake ice in the Northern Hemisphere. Safety is defined as lake ice of an appropriate thickness for basic human use (e.g. recreation, mobility, etc.)
- Lake ice is generally safe for human use when black ice (also called clear ice, blue ice, or congelation ice) is at least 10 cm thick.
- When lake ice is primarily white, the thickness of the ice should be doubled. Therefore, safe lake ice that is primarily white should be at least 20 cm thick.
- We assess the time period when lake ice first forms (at least 2 cm thick) to when lake ice reaches a safe thickness.
- We assess a historical condition for Northern Hemisphere lake ice (1851-1880) and compared it to 1C warming, 2C warming, and 4C warming.

1.3 Please provide details of the project timelines.

- Project start time: November 2022
- Discussion and assessment of available data: November 2022 - May 2023
- Submission of manuscript to Earth's Future: November 2023
- Revision and resubmission of manuscript PLOS ONE: March 2024
- Revision and resubmission to PLOS ONE: August 2024
- Manuscript acceptance: November 2024

1.4 Principal Investigator(s)

Sapna Sharma

1.5 Research data management policies

ArcticNet Data Management Committee (ADMC)

Data Collection

2.1 What types of data will you collect, create, link to, acquire and/or record?

- We made use of downloaded modelled data from the Community Earth System Model - Version 2 - Large Ensemble (hereafter, referred to as "CESM2-LE")
- CESM2-LE data included:
    - Lake ice thickness
        - Daily data for representative years of a historical condition, as well as 1, 2 and 4 degrees Celsius warming
    - Surface air temperatures
        - Daily data for representative years of a historical condition, as well as 1, 2 and 4 degrees Celsius warming
    - Lake ice thickness for validation lakes
    - Snow depth
        - Annual mean
- All data (except validation data) include a value for each 1 degree by 1 degree (latitude and longitude) for the Northern Hemisphere)
- Validation data give a value for the nearest 1 degree by 1 degree grid surrounding a lake with validation data
- Validation data included lake ice thickness data from a collection of lake ice studies throughout the literature.

2.2 What file formats will your data be collected in? Will these formats allow for data re-use, sharing and long-term access to the data?

- All CESM2-LE data is made available as a NetCDF file (.nc).
- All lake validation time series are made available as Comma Separated Variable files (.csv)

2.3 How much data do you anticipate collecting? Include an estimate of how much storage space you will require (in megabytes, gigabytes, terabytes). This estimate should also take into account storage space required for file versioning, backups, and the growth rate over time.

All data requires approximately 0.3 Gb of space.

2.4 Are there are any existing data that you can re-use? If so, please explain how you will obtain that data and integrate it into your research project.

- As described above in section 2.1, data were obtained from the CESM2-LE website: https://www.cesm.ucar.edu/community-projects/lens2
- Validation data were obtained from data availability statements within research articles.

2.5 What conventions and procedures will you use to structure, name and version-control your files to help you and others better understand how your data are organized?

We have made our data available through Figshare: https://figshare.com/

- All data are saved within the data repository for easy accessibility and reproducibility
- Data are saved as either NetCDF or CSV files, both are broadly usable; however, some coding may be necessary to use NetCDF files, as they are multidimensional file formats
- Files are named with the type of data that they are (lake ice, snow, etc) along with the time step (daily, annual, etc), and degree of warming if applicable (1C, 2C, and 4C)
- NetCDF files include metadata within the file to describe what each column, row, and matrix slice contains.

Documentation and Metadata

3.1 What documentation will be needed for the data to be read and interpreted correctly in the future? This includes study-level documentation, data-level description, and any other contextual information required to make the data usable by other researchers.

- We have included two files within the Figshare data repository that explains each data file
  - The file "ReadMeNetCDF" explains the data within each NetCDF file
  - The file "ReadMeCSV" explains the data within each CSV file
- We have also included the code that we used to run all of the data to conduct our analyses and make our figures.

3.2 If you are using a metadata standard and/or tools to document and describe your data, please list here.

- Because we have a combination of NetCDF and CSV files, we have customized the ReadMe files to describe the data.
- They include the information required to understand the data structure and units (e.g., thickness in cm or air temperature in degrees Celsius)

3.3 How will you make sure that documentation is created or captured consistently throughout your project?

- Through the use of a single R Project in conjunction with version control using GitHub, all data manipulation from the original data downloaded from CESM2-LE have been recorded and then preserved in Figshare.

Storage, Access, and Backup

4.1 What are the anticipated storage requirements for your project, in terms of storage space (in megabytes, gigabytes, terabytes, etc.) and the length of time you will be storing it? If applicable, where are hardcopy notebooks and physical samples going to be physically stored?

- No hard copies or physical notebooks exist.
- All data were downloaded either from CESM2-LE in the case of the main analysis data or from individual data repositories or email requests in the case of validation data
  - All information on how to download each data file can be found within the FigShare repository, which also includes a link to the GitHub repository that contains code for reproduction of the analysis and figures.

4.2 How and where will your data be stored and backed up during your research project?

- These data are all available at our Figshare repository
  - Link: https://doi.org/10.6084/m9.figshare.26882467.v1
  - Citation: Culpepper, Joshua (2024). Lake ice safety data. figshare. Dataset. https://doi.org/10.6084/m9.figshare.26882467.v1
- These data will be available in perpetuity as outline through FigShare, which adheres to FAIR principles:
  - Please, see information at https://figshare.com/

4.3 How will the research team and other collaborators access, modify, and contribute data throughout the project? If applicable, how will you ensure that sensitive data is stored securely and only accessible to the research team and other collaborators throughout the project?

- No sensitive data were used. All data are publicly available through CESM-LE, reference literature DOIs or through our FigShare account, which is currently public.
- Any co-author requesting access to modify the FigShare account will be given access. Alternatively, Joshua Culpepper (creator of the FigShare repository -- see section 4.2), will modify the FigShare archive from a request from a contributor.

Sharing and Reuse

5.1 What data will you be sharing and in what form? (e.g. raw, processed, analyzed, final).

- As described in sections 2 and 4, all data we used in this analysis are available publicly through CESM2-LE (https://www.cesm.ucar.edu/community-projects/lens2/data-sets)
- To used the data as we used it, our data is publicly available in perpetuity within the FigShare data repository at https://doi.org/10.6084/m9.figshare.26882467.v1
- Data are shared as NetCDF files as they were downloaded from CESM2-LE.
- R code to conduct the analysis on the data are available as a link to our GitHub repository within the FigShare data page (https://github.com/jculpepper7/ice_safety_2024)

5.2 Where will you deposit your data and provide access at the end of your research project? Is there specific software needed in order to use or interpret your research data collection?

- Our data is publicly available in perpetuity within the FigShare data repository at https://doi.org/10.6084/m9.figshare.26882467.v1

5.3 Please describe whether there will be any restrictions placed on your data when they are made available and who may access them. If data are not openly available, describe the process for gaining access.

- Our data are publicly available and we provide a link to the original data source (CESM2-LE) within the FigShare page as well as a citation within the publication.
- All lake ice data from individual studies within the literature are cited within the manuscript and we give explicit instructions on how to access those data either by linking the data repository or by citing the paper from which we obtained the data because not all data have been made publicly available.

5.4 Have you considered what type of end-user license to include with your data?

- Yes, we are using CC BY 4.0
- Below is a description of the license provided by FigShare:

CC-BY (Attribution)
By licensing your research outputs under CC-BY, Figshare ensures that your research is openly available whilst still ensuring that others give you credit, in the form of a citation, should they use or refer to the research object. This license lets others distribute, remix, tweak, and build upon your work (even commercially) as long as they credit you for the original creation. This is the most accommodating of licenses offered. It is recommended for maximum dissemination and use of licensed materials.

5.5 What steps will be taken to help the research community know that your data exists?

- Our data is made publicly available with minimal restrictions. The only requirement is a citation of our data product and/or manuscript.
- We reference our data product within the manuscript so that access is simple.
- We provide a data availability statement within the manuscript that details the access and use of the data and code.

Preservation

6.1 If the way you store and share data during and after your research project differs from how you will preserve your data long-term, include a brief description of any resources needed to share your data (equipment, systems, expertise, etc.).

- There are no restrictions on the preservation of our data.
- All data will be available in perpetuity via the FigShare servers.

6.2 Which data are selected for preservation and access?

- All data that we used within the analysis of our project have been preserved on FigShare.
- We do not directly include validation data on FigShare because not all data ar made publicly available.
- However, detailed descriptions to download all required validation data are available within the GitHub repository.

6.3 Indicate how you will ensure your data is preservation ready. Consider preservation-friendly file formats, ensuring file integrity, anonymization and de-identification, inclusion of supporting documentation.

- All data are saved as NetCDF files.
- These files are the most commonly used file formats for climate data and have been in consistent use since 1988 as supported by the University Corporation of Atmospheric Research (UCAR).
- Validation files are available as CSV files, which are system and software agnostic.

Responsibilities and Resources

7.1 Identify who will be responsible for managing this project's data during and after the project and the major data management tasks for which they will be responsible.

- Joshua Culpepper will be responsible for maintaining the data
    - He will:
        - Create the data files
        - Create the FigShare repository
        - Create and maintain the GitHub repository

7.2 How will responsibilities for managing data activities be handled if substantive changes happen in the personnel overseeing the project's data, including a change of Principal Investigator?

- If Joshua Culpepper is no longer able to maintain the data, he will transfer ownership of the FigShare and GitHub repositories to Sapna Sharma or another required PI.

7.3 What resources will you require to implement your data management plan? What do you estimate the overall cost for data management to be? What additional resources will you require to implement your data management plan?

- The data management plan has no additional cost besides the personnel to create it.
    - Data used in the project are freely and publicly available (see earlier sections on data acess)
    - FigShare is a free format and requires no additional cost if your project is smaller than 20 GB.
    - GitHub is also a free repository for code.

Ethics and Legal Compliance

8.1 If your research project includes sensitive data, how will you ensure that it is securely managed and accessible only to approved members of the project?

- Our project does not include sensitive data.
- All data are publicly available.

8.2 If applicable, what strategies will you undertake to address secondary uses of sensitive data?

- See 8.1

8.3 How will you manage legal, ethical, and intellectual property issues?

- Legal, ethical, and intellectual property issues will be carried out through consultation with the York University legal department.

Planned Research Outputs

Dataset - "Lake Ice Safety Data"

This repository includes data from the Community Earth System Model Version 2 Large Ensemble (CESM2-LE) and the necessary code to process the data. The code uses the downloaded CESM2-LE data to detect periods of unsafe ice cover throughout the Northern Hemisphere at different warming scenarios as well as ice quality (i.e., black ice:white ice ratios) scenarios.
The model output of CESM2LE is available via: https://www.cesm.ucar.edu/projects/communityprojects/LENS2/data-sets.html.

Planned research output details

Title	Type	Anticipated release date	Initial access level	Intended repository(ies)	Anticipated file size	License	Metadata standard(s)	May contain sensitive data?	May contain PII?
Lake Ice Safety Data	Dataset	2024-08-30	Open	None specified	299 MB	Creative Commons Attribution 4.0 International	None specified	No	No