Response to Reviewer 1

The authors have adequately addressed most of the comments, and the manuscript has improved as a result. I appreciate the authors' additional explanations and clarifications regarding the definitions of OD, CD, and NP. I find the revised descriptions much clearer and easier to understand. The revised Tables 2 and 3 provide a detailed comparison of how different methods and definitions affect the projection results, which is appreciated.

I have only one remaining concern. I still believe that a quantitative evaluation of the performance of these methods in reproducing the historical period is also necessary. For example, statistical metrics such as the correlation coefficient and RMSE could be used to assess the agreement between simulations and observations.

Evaluating model performance over the historical period is essential for assessing the reliability of future projections. If the models cannot adequately reproduce historical climate characteristics, the credibility of their future projections remains uncertain. At least, the authors should demonstrate that the models and methods employed can reasonably capture the long-term trends in the region of interest and discuss the reliability of the resulting projections accordingly.

We are glad that we addressed your previous comments, and we really appreciate the time you took to review the revised manuscript.

Thank you for this comment. Model performance over the historical period is already covered in Section 3.2 (Bias Assessment of CMIP6 Models). Climate models do not reproduce the exact timing of natural variability seen in observations, so correlation or RMSE are not suitable measures here. Instead, we need to build a distribution from the model results and check whether the observed values fall within it (Figures 5 and 6 of previous manuscript). Looking year to year, fully coupled model simulations should capture what the observations could have been, not what they were. However, over multiple decades, for which natural, internal variability in the climate system gets averaged out, accurate simulations ought to produce averages and long-term climate change trends that match the observations. Since we only had comparison to the long-term average in the manuscript at first, we have now added a similar trend comparison.

We revised the manuscript accordingly:

Turning to long-term change, we also examined trends over the longest period the data allow (1979-2024), following Stroeve et al. (2024). Individual CMIP6 model trends largely fall within the observational uncertainty range, especially for the Churchill to Labrador Sea route. The multi-model mean is a good match to the observed trends except for the Churchill to Chesterfield Inlet route / low-risk definition, where it underestimates the trend (Supplementary Figure S9).

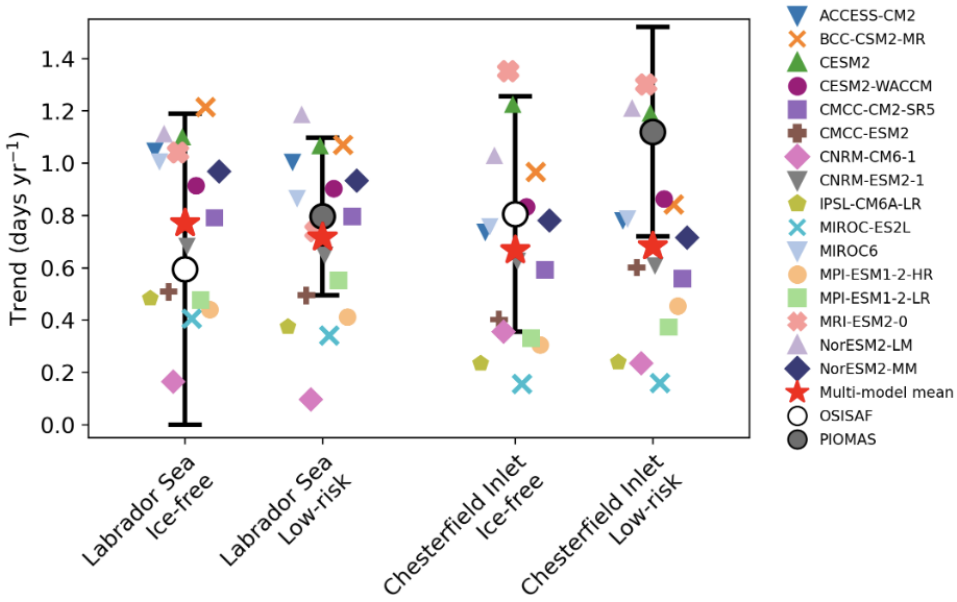


Fig. S9. Historical trends (days yr^{1}) over 1979-2024 from each CMIP6 model, the multi-model mean, and the OSISAF and PIOMAS observations for the ice-free and low-risk definitions for the Labrador Sea and Chesterfield Inlet routes.

We have also revised the Discussion section to include the following:

Line 571: With respect to long-term trends, the underestimation of the observed long-term trend by the multi-model mean for the Churchill–Chesterfield Inlet route under the low-risk definition suggests comparatively lower confidence in the projected magnitude of change, as opposed to the ice-free definition or the Labrador Sea route.

Reference:

Stroeve, J., Crawford, A., Ferguson, S., Stirling, I., Archer, L., York, G., Babb, D., and Mallett, R.: Ice-free period too long for Southern and Western Hudson Bay polar bear populations if global warming exceeds 1.6 to 2.6° C, Communications Earth & Environment, 5, 296, 2024.

Thank you for all your helpful comments and suggestions throughout the revision process. We appreciate your time and constructive feedback, which have helped us improve the quality of the manuscript.

Response to Reviewer 2

Minor Comments

- Paper's title and contents focus on the navigability of Hudson Bay but the shipping route in figure 1 shows Hudson Strait, so it might be worth it to change the text from "Hudson Bay" to the larger "Hudson Bay System" like in Hochheim and Barber (for example https://www.tandfonline.com/doi/full/10.1657/1938-4246-46.1.66) or "Hudson Bay complex" as seen in Barber's work. Thank you for your suggestion, we changed it to "Hudson Bay Region".
- In the abstract, not sure if SIC and SIT need to be spelled out or if they are considered common enough to be able to use it without definition. Thank you, we spelled them out.
- May need to write "(CIS)" on line 55 since the authors use it in 2.2.2 without prior definition, I think? Thank you, we defined CIS on line 55.
- Although 2.6 has been significantly shortened, the wording is confusing. For example, "The OD is the day after the last day prior to September 1 for which the route is closed." Thank you for your feedback.

We revised the manuscript: For each route and year y, we classified each day as open (navigable) or closed (not navigable) and searched for the main navigable season from 1 January of year y to 30 April of year y+1. We defined the median closed day in January to April of year y (mxd1) and year y+1 (mxd2), and the median open day in August to November of year y (mnd). The OD is one day after the last closed day between mxd1 and mnd, so short spring openings are skipped. The CD is the first closed day after mnd, up to mxd2. The navigable period (NP) is the number of days between them (NP = CD − OD). Routes with no closed day in January to April of both years were classified as open year-round (NP = days per year; OD and CD = NaN), and routes with no open day in August to November as closed year-round (NP = 0; OD and CD = NaN). If no closed day was found before mnd, the route starts the year open (OD = NaN; NP = CD − 61), and if none was found after mnd, it stays open (CD = NaN; NP = 365 + 61 − OD). The constants 61 and 365 + 61 correspond to about 1 March of years y and y+1, so NP is truncated at those dates. Figure 4 shows the schematic definition of the OD, CD and NP for a route in year y, together with the special cases where OD or CD cannot be determined.

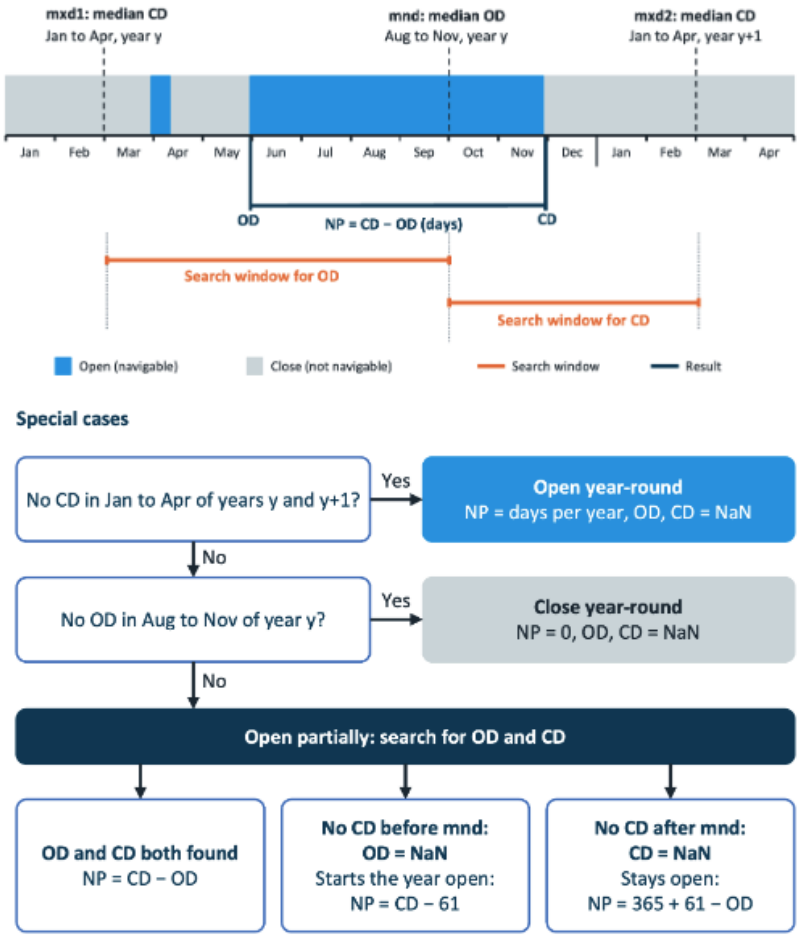


Fig. 4. Schematic definition of the opening day (OD), closing day (CD) and navigable period (NP) for a route in year y and the special cases where OD or CD cannot be determined.

On the use of CIS charts (2.2.2)

- The **digital version** of daily CIS ice charts are only available from 2006 (paper format goes back further).
- Regional CIS charts are available further back (begins around 1970) but authors could state they don't have the desired temporal resolution (since change in this paper is reported in days, not weeks) although the magnitude of change could be reported in weeks, so should be able to pick up the signal from regional charts.
- While I agree that "availability and resolution vary over time" this does not mean that the chart quality itself is unreliable over time.
- "Their accuracy is also affected by atmospheric conditions" is relevant for the optical spectrum but the CIS relies on SAR as the primary data source, which avoids cloud cover
- Although "ice-type classifications may become less reliable after the ice-growth season," the human/analyst interpretation of the SAR imagery is still considered to be more reliable than automated classification of these ice types so arguably there is actually *more* uncertainty around other data sources.
- Authors write "these factors introduce additional uncertainty into long-term trend analyses" but the paper by Tivy et al. show that trend analysis from the charts are still valid

(https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2009JC005855)

So in short summary—I would argue that the use of PIOMAS over CIS should be due to temporal resolution (reporting in days rather than weeks) while still spanning the time frame of interest. POLARIS guidelines rely on ice typing, which normally come from charts but it's not a strict requirement. So the authors' use of PIOMAS can be substituted but ideally there would be a check to show the two datasets correspond well in thickness/ice type category or in risk index values.

Thank you for your comment. We revised the text accordingly:

However, the daily digital CIS charts are available only from 2006 onward. Regional CIS charts extend back to approximately 1970, but they are issued at a coarser temporal resolution than the daily timescale on which changes are reported here. Although the magnitude of change could be expressed in weeks, the daily resolution of PIOMAS allows changes to be reported in days. PIOMAS is therefore used for its daily, continuous temporal coverage over the study period rather than as an operationally superior alternative to CIS charts. Because POLARIS requires ice type or thickness information but not specifically chart-derived inputs, PIOMAS-derived ice characteristics can be substituted.

On Type E Vessels

The paper still focuses heavily on type E vessels throughout: "Type E vessels are the primary focus of this study because they historically have been the dominant commercial vessel class operating at the Port of Churchill (Andrews et al., 2016)." I think there's possibly a misinterpretation going on. Type E under the Canadian Polaris system ***can*** include pressure crafts but is not ***restricted*** to pleasure crafts. And so, this category captures all non-ice-strengthened or minimally ice-strengthened vessels, in which pleasure crafts are a subset. The authors may want to read the paper by Copland on vessel classes for further description https://www.sciencedirect.com/org/science/article/pii/S2371167121000466. So perhaps change throughout the paper "Type E (pleasure craft)" to "Type E (non-ice-strengthened or minimally ice-strengthened vessels). The use of "Type E (pleasure craft)" was confusing because it made it seem like the entire study was ***only*** done on pleasure crafts.

Thank you for bringing this to our attention. We changed "Type E (pleasure craft)" to "Type E (non-ice-strengthened or minimally ice-strengthened vessels).

The authors may want to expand the final sentence in the abstract to then include what their figure 9 supports, which is that the navigable season extends for all vessel types (due to changing ice conditions, but legal, insurance, other restrictions still apply).

Thank you. We revised the text to reflect that:

Findings demonstrate that navigable season extends for all vessel types and year-round shipping would require ice-strengthened vessels throughout the 21st century even with a high-end warming scenario.