To the Editor,

October 8, 2023

Please find attached the revised manuscript ‘A major midlatitude hurricane in the Litte Ice Age.’

The submission is intended to be the draft considered for publication and a ‘marked up’ version is attached. To that end, Table 2 showing prevailing winds offshore Nova Scotia for the second half of September 1757 has been added, and Table 3 summarizing the Louisbourg Storm on September 25 (ship time) recommended by both reviewers has been added.

Additional independent evidence for the storm slowing over Nova Scotia at landfall is clear from a reassessment of Figure 3 which shows hurricane force winds over the ships on the coast for 15 hours and severe conditions for 9 hours. Modern hurricanes and extratropical cyclones took between 3 and 5 hours to cross Nova Scotia.

Specific recommended corrections were made. The reference section has been improved to be consistent with journal guidelines. Inclusion of the detailed complications of researching, locating, reading and translating historical logbooks is provided at a high level and interested readers are encouraged to peruse the considerable references that drill deeper into methodology.

In these corrections I have also taken seriously the comments, however critical, of Michael Chenowith. Unfortunately, his comprehensive reassessment of Atlantic hurricanes was not as comprehensive as it might have been since he seems to have stopped assessing this storm past the US border and missed the impact of this storm.

A more climatologically defensible approach to establishing atmospheric circulation patterns than hoping to locate historical weather records from a low population region more than 250 years ago was met by interpreting the 1757 storm from the context of the established climatology for tropical cyclones in Canadian waters during hurricane season in fall. The model of Hart and Evans (2001) is based on the analysis of every tropical cyclone in the North Atlantic for over a century, including European storms. We use proxy and historical data to describe contemporary temperature data to show that the seasonal weather variability needed to increase the sea surface temperatures that fuel hurricanes existed in the summer of 1757.

Specific Review Comments:

<u>Antoine LaChance</u>

Recommendations to review critical comments of Michael Chenowith were taken into consideration and the approach recommended is substandard to working with the established climatology for how Atlantic tropical cyclones behave in the northern midlatitudes (off New England and Canada) was seen be a superior approach than attempting to patch together Atlantic circulation patterns from historical records that largely no longer exist, having already consulted the Public Archives of Nova Scotia collections for relevant records. The historical records we did locate took considerable effort and provide land-based records for Halifax and inland at Fort Cumberland as well as St. Esprit and Fortress Louisbourg during the

storm. We have far more contemporary records for 1757 than were used in any of the various eighteenth-century compilations.

Besides, this work for the entire eastern seaboard of North America was already done and published by Chenowith (2006) in a 'comprehensive' re-assessment of Atlantic tropical cyclones that assessed the 1757 storm as a hurricane (reference included in the ms). This work has already been done, though the re-assessment did not cross 40 N latitude, which is where our detailed analysis begins.

General Comments:

1. Recommending that the claim that this storm was one of the most powerful ever recorded in the region be highlighted in a more prominent way in the Abstract, Discussion and Conclusion has been done with some rewriting of these sections
2. Restructuring to consolidate methodologies that had been spread through different parts of the paper into the comprehensive methodology section was done
3. The methodology section is, as a result, more complete/comprehensive as stated

Specific Comments (references to specific lines refer to original ms):

Fig. 1 amended to include Fort Cumberland, St. Esprit and Louisbourg

Line 24: unfinished sentence corrected

Lines 56-59: references included as recommended

Line 62: modern system rewritten for clarity

Methodology

Including a table outlining each historical document is untenable and defeats the purpose of outlining the nature and source of each record used in the methodology and references. The details in question are known to those interested in this facet of the study, and to others it is covered in the methods and references which interested parties can explore further.

Information related to estimating storm metrics has been consolidated in the methodology section.

The Little Ice Age (LIA)

The title has been amended to reflect the focus on LIA storminess

This is largely how the section was structured but it has been rewritten to improve clarity

No information on the period prior to the LIA (Medieval Warm Period) has been included but, again, the section has been rewritten for improved clarity to remove any information unrelated to the LIA

Reference to the role the Labrador Current plays in extratropical transition has been amended as outlined.

Lines 118-120 rewritten for better clarity

The inclusion of Table 3 and rewriting to more clearly outline the position of the French and English ships has been done. It is, however, noted at the start that all of the French ships were at moorings in

Louisbourg Harbour which is a very small geographic area shown in Fig. 2. Table 3 will allow the reader to go between the table and the more description of the storm; both follow a time sequence that can also be compared readily to Fig. 3 (plot of wind speeds); colours have been coordinated between Table 3 and Fig. 3) for consistency.

'More reference to historical documents' would add considerably to the length of Section 5 (The Louisbourg Storm) without adding much value. Instead, a superior approach of noting the references and sources in methodology allows the reader to know that reference to a specific ship includes information derived from that specific ship's log (or associated documents pertaining to damages). Again, the requirements of translating historical records to empirical data mean a longer manuscript; the approach used does not leave any doubt in the reader's mind as to the source of the information.

Results

Figure 3 is now cited more in the text

Mee to meet (corrected)

Mislabelled Figure is corrected and is now Figure 6a and 6b

Figure 5a (again, corrected by change to 6a and 6B)

A comparative table with metrics for the 1757 storm and modern analogs has been created and included as Table 4.

Discussion

The discussion has been rewritten to tie back ideas discussed in the previous sections and ties in cyclogenesis under the accepted climatology of Hart and Evans (2001) which allows the conditions of the LIA to drive enhanced intensity with only an incremental change to the model that is inherent to the climate differences of the LIA (earlier onset of much colder continental westerlies than seen today while tropical intensification at the height of hurricane season continues unchanged) .. the result is a much higher temperature gradient shift, increased baroclinic conditions that trigger extratropical transition. In fact, the conditions associated with the Louisbourg Storm have the highest probability of occurring south of Cape Breton where the 1757 storm landed.

The uncertainty aspect of this study has been addressed earlier in the paper. Uncertainty related to ship position was addressed by clarifying that logs referred to known landmarks that were visible to the ships during the storm, allowing triangulation for far greater accuracy than other eighteenth century navigational methods.

<u>William Pretel</u>

Comments provided by Michael Chenowith were considered. He described the 1757 hurricane first seen off Florida as a hurricane (tropical) in his compilation, and inadvertently provided a timeline for its encounter with HMS Winchelsea off North Carolina which ties in perfectly with records for New England and then Nova Scotia. Chenowith's denial that it was a hurricane is curious claim since his own 2006 analysis includes a reassessment of the compilation of Poey (1855) and others. We searched out the original reference to this specific storm to establish translation rates that allow us to interpret synoptic circulation patterns that may have affected storm intensity. We also included broader circulation pattern

research that provides NAO and ENSO indices for 1757 that show strong support for hurricane generation in the North Atlantic during a La Nina year.

Chenowith provided an excerpt from the log of HMS Winchelsea impacted by the same storm that would lead to the conclusion that this was not a significant storm, yet it is unclear where the vessel lay in respect to the storm structure and there are no clear indications of vessel bearing relative to storm motion which we were able to recreate for the British fleet off Louisbourg by using coastal landmarks. We were able to discern that the location of Winchelsea at that time of year puts the storm over the Gulf Stream.

The key take-away from Chenowith is that we do not necessarily assume this to be a fully tropical cyclone at landfall and have instead focused on processes inherent to tropical cyclones tracking into Canadian waters in the fall. The addition of Table 2 showing prevailing winds supporting the overarching climatology of Hart and Evans (2001) helps set the stage for this in the discussion.

Abstract (rewritten for improved clarity and to set the stage for the structure and content of the paper)

A brief explanation of the Seven Years' War has been included to provide better context

The uncertainty and ambiguity associated with logbooks has been more clearly defined in the paper, but the factors Pretel notes apply in general rather than in this specific case. For example, the ship positions were triangulated in to known coastal landmarks noted in the logs and refer to bearing and distance. Also, smaller faster vessels sailing with large fleets were used to regularly measure distances from the fleet to the coast so the Admiral could understand how much 'sea room' he had to move so many ships as one.

More detail outlining how navigational limitations of the day were addressed has been included in the paper. For example, multiple officers taking sightings with sextants provided comparative analysis.

To improve readability, the addition of three tables and restructuring the paper to consolidate methodology scattered throughout into one section has been done. Again, reference to specific logbooks was structured so that the reader necessarily knows a reference to a specific ship comes from that ship's logbook (hence their incorporation in the study) unless otherwise stated, as in the observation of Tilbury's location (since that ship was wrecked and no logbook exists).

Surge was included within methodology but consolidated as part of the broader analysis of the storm and in the discussion.

The reference to temperature comparisons misses our inclusion of historical references to the heat wave of the summer of 1757 in UK and Europe (records not broken until 2003), a historical reference to an unusually hot day in Halifax that coincides with the middle of the European heat wave, onshore weather and observations recorded by Knox at Fort Cumberland over the period of the storm. Reference to areas much farther away, considering the northern midlatitude onset of fall westerlies, may describe regional atmospheric conditions unrelated to the storm system or the prevailing westerlies to the north. However, we reference proxy data from a study that shows North America was warmer on average than usual in the mid eighteenth century despite longer colder winters, implying hotter, shorter summers.

Morre detail us provided to explain the Virot et al. model. Engineering models are standard practice for interpreting applied forces. The fact that the Invincible was under sail with a steady bearing relative to

winds helped ensure that wind vectors (speed plus direction) were steadily applied to the mast, allowing a consistent wind vector that needed to be sustained for only one minute to be compared to the Saffir Simpson scale. The comparison of ship construction between various navies is not directly applicable to our focus on the structural integrity of a single mast made from one tree. The fact that masts were made from single trees makes this a particularly relevant comparison. The isolation of a ship on the sea avoids complicating factors such as interference from multiple trees in a stand or forest, and the height of impact on the mast above the ocean surface is comparable to the height used on land to estimate wind speed for modern hurricanes.

Ship measurements include both metric and imperial measures. The latter was included since historic British ship dimensions are in Imperial units, and the NHC (NOAA) which is arguably the single most significant scientific center studying cyclones, documents hurricane metrics in Imperial units (wind speed in mph, wave height in feet, surge in feet).

The references have been written according to the specifications required by the journal. Chenowith's 2006 compilation is a reassessment of earlier compilations, which are specifically mentioned there. The same references were used, and not one of them included a single one of the 63 warship logbooks or ancillary historical records such as letters or weather records in diaries, newspaper articles and other sources used in this study.

Pretel's request for more information on historical sources is already addressed in methodology which outlines exactly where British naval records are kept relative to captain's and master's logs versus lieutenant's logs. The French naval records were originally drawn from the French archives in Paris but this project benefited from a rigorously reviewed secondary source that published excerpts, translated to English, from specific ships at Louisbourg during the storm. These records primarily serve to describe conditions from a stationary location as the fleet was moored.