Lightning? Above 70 Degrees North? It's More Likely Than You Think: A Comparison of Two High-Latitude Thunderstorm Outbreaks

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Introduction

- Thunderstorm outbreaks occur above the Arctic Circle, but there are fewer extensive records of these outbreaks because the area is largely unpopulated ((thus there are fewer direct observation sites).
- Two outbreaks on record include one in north-central Canada, which began at about 00:00 UTC on July 24th, 2014 (18:00/19:00 LST on the 23rd) and one in northwest Alaska, which began at about 13:00 UTC on June 27th, 2024 (05:00 LST) .
- Both outbreaks had thousands of lightning strikes detected, as well as indicators of severe strength including severe thunderstorm warning issuance and overshooting tops on satellite imagery.
- The Canadian outbreak was previously studied by Brown et al. (2020).
- **This study is a comparison of primarily synoptic scale features between the two events as well as between these outbreaks and their midlatitude counterparts.**

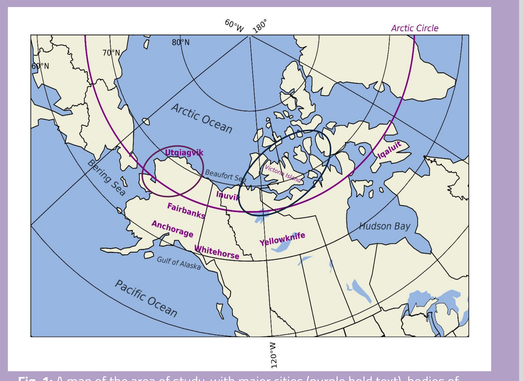


Fig. 1: A map of the area of study, with major cities (purple bold text), bodies of water (grey italics), the Arctic Circle line and location of Victoria Island (purple italics), and approximate locations of the Canadian case (blue oval) and Alaskan case (purple oval) provided for reference.

Methods

- ERA5 reanalysis data was used to create maps of multiple parameters (geopotential height at 850 and 500 hPa, temperature at 2 meters, 850 hPa, and 500 hPa, dew point temperature at 2 meters, and lifted index are included in the poster) in 6-hour intervals for the duration of both events as well as 3 days prior.
- All parameters were directly available from ERA5 except for lifted index, which was calculated from temperatures and dew point temperatures at 1000, 850, and 500 hPa using the calc.lifted_index function from the metpy python package.
- The reanalysis maps were supplemented by NCEP/NCAR reanalysis anomaly data, archived GFS initialization fields, and The Hybrid Single Particle Lagrangian Integrated Trajectory (HYSPLIT) model version 4 (Stein et al. 2015), and satellite imagery from NOAA's Suomi NPP and Aqua satellites.

Results

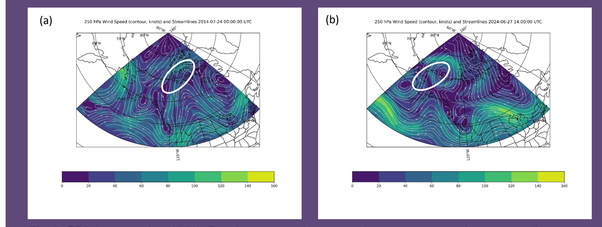


Fig. 2: ERA5 reanalysis of 250 hPa wind speed with streamlines at the approximate start times of the Canadian (a) and Alaskan (b) outbreaks. There is a right jet exit region over Victoria Island and a jet streak located over northwest Alaska at their respective start times.

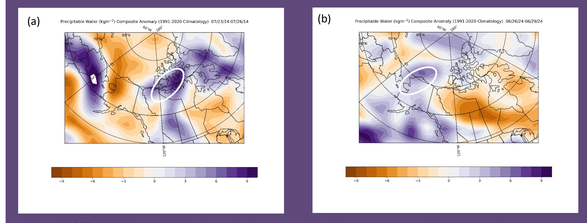


Fig. 4: NCEP/NCAR reanalysis of total column precipitable water anomaly (compared to 1991-2020 climatology) for the four-day period centered around the Canadian (a) and Alaskan (b) thunderstorm events. Precipitable water was higher than average in both cases, but there was a stronger anomaly in the Canadian case.

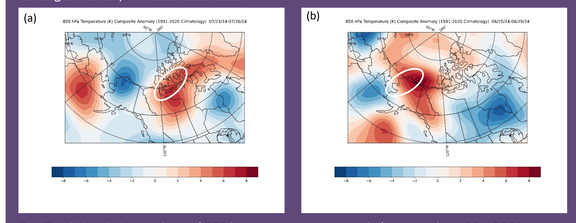


Fig. 5: NCEP/NCAR reanalysis of 850 hPa temperature anomaly (compared to 1991-2020 climatology) for the four-day period centered around the Canadian (a) and Alaskan (b) thunderstorm events. 850 temperatures were anomalously warm in both cases, but the Alaskan case had a larger anomaly.

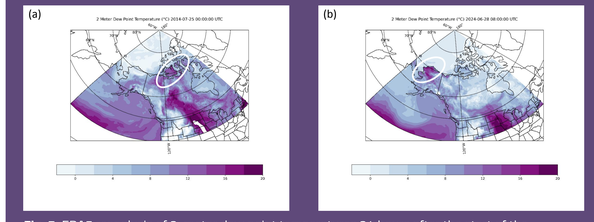


Fig. 7: ERA5 reanalysis of 2-meter dew point temperatures 24 hours after the start of the Canadian outbreak (a) and 19 hours after the start of the Alaskan outbreak (b). Both cases have dew points approaching, if not exceeding, 20 °C.

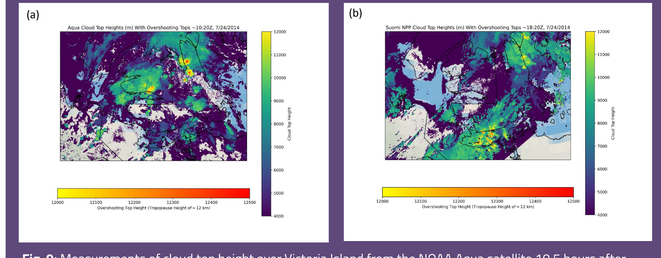


Fig. 9: Measurements of cloud top height over Victoria Island from the NOAA Aqua satellite 10.5 hours after the start and from the NOAA Suomi satellite 18.5 hours after the start of the Canadian outbreak. Overshooting tops are visible in both satellite flyovers.

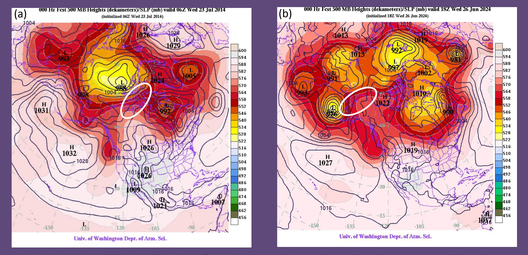


Fig. 3: Archived GFS initialization of 500 hPa heights and sea level pressure valid 18 hours before the Canadian (a) and 19 hours before Alaskan (b) storms begin. While an omega block is present in both cases, the Canadian outbreak area is almost directly above the ridge axis while the Alaskan outbreak area is to the west of the ridge axis.

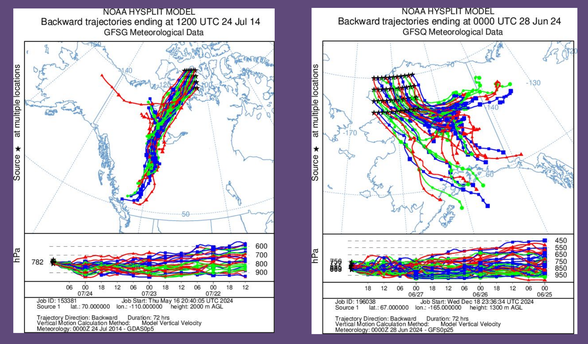


Fig. 6: HYSPLIT model trajectories showing an influx of air from southwestern British Columbia at various levels ending at 782 hPa over Victoria Island 12 hours after storm initiation (a) and air from the gulf of Alaska at various levels ending at approximately 700 hPa over northwest Alaska 11 hours after storm initiation (b).

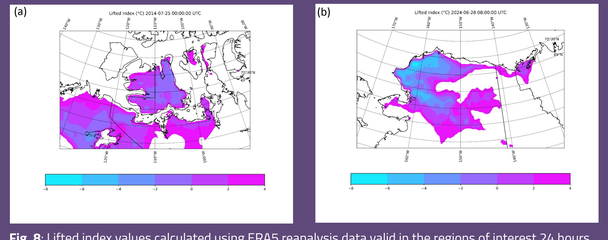


Fig. 8: Lifted index values calculated using ERA5 reanalysis data valid in the regions of interest 24 hours after the first storms break out in Canada (a) and 19 hours after the first storms break out in Alaska (b). Both outbreaks had calculated lifted index values at or below -6 , which is typical of severe convection in the midlatitudes.

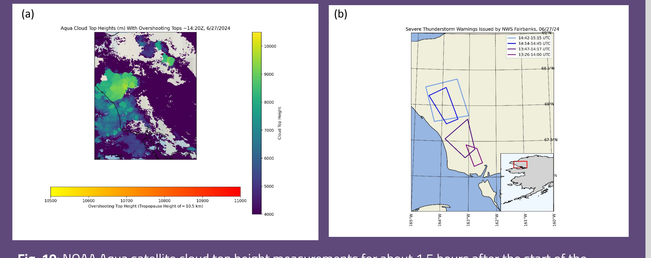


Fig. 10: NOAA Aqua satellite cloud top height measurements for about 1.5 hours after the start of the Alaskan outbreak (a). At about the same time, the National Weather Service office in Fairbanks issued a series of four severe thunderstorm warnings for radar-indicated quarter-sized hail (b) (inset image in 10b provided as reference for both subfigures).

Similarities and Differences

Similarities:

- An omega block pattern was present preceding storm initiation.
- Anomalously high air temperatures, dew points, and precipitable water values were recorded.
- There were fires in the vicinity after the outbreaks, though evidence that these storms specifically started fires is inconclusive.
- The outbreaks occurred in the summer months while the regions were experiencing polar day.
- Both storms displayed multiple characteristics associated with severe convection in the midlatitudes, including overshooting tops, lifted indices of at least -6 and warranting severe thunderstorm warnings.

Differences:

- The upper-level jet pattern in the Canadian case featured a right jet entrance region, while the pattern in the Alaskan case featured a jet streak.
- Even though an omega block was present in both events, storms developed north of the ridge axis in the Canadian outbreak while the developed to the west of the ridge axis in the Alaskan case.
- As the upper-level air pattern progresses, the pattern above northern Canada shifts from a ridge to a trough while the ridge pattern in Alaska encounters a closed low.
- The evidence to warrant a severe thunderstorm classification comes in the form of overshooting tops visible in satellite imagery in the Canadian case and in the form of multiple severe thunderstorm warnings issued in the Alaskan case.
- The outbreak in Canada began during the evening hours (18:00/19:00 LST) while the outbreak in Alaska began in the early morning (05:00 LST). Note that due to polar day, it was light out in both cases.

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