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Ships' Log-Books, Sea Ice and the Cold Summer of 1816 in Hudson Bay and Its Approaches

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ABSTRACT. Descriptions of sea ice in Hudson's Bay Company ships' log-books and trading post journals are used to reconstruct sea ice conditions in Hudson Bay, James Bay, and Hudson Strait in the summer of 1816. The results demonstrate that exceptionally late sea ice dispersal occurred in James Bay, southeastern Hudson Bay, and at the western extremity of Hudson Strait. A relatively intense flow of ice in the Labrador current occurred at the eastern extremity of Hudson Strait. These patterns of ice behaviour are indicative of the prevalence of northwesterly atmospheric circulation over this region in the summer of 1816.

Key words: sea ice, Hudson Bay, Hudson Strait, 1816, ships' log-books

RÉSUMÉ. Les archives de La Compagnie de La Baie d'Hudson ont été consultées pour reconstruire les conditions des glaces de mer. En particulier, les anciens livre de bord et les journaux quotidiens offrent les descriptions des glaces de la baie d'Hudson, la baie James et le détroit d'Hudson pour l'été de 1816. Les résultats démontrent que le dispersement des glaces était tardif dans la baie James, le sud-est de la baie d'Hudson et l'extremité ouest du détroit. Une condition des glaces relativement intensive c'est développée dans le courant du Labrador à l'extremité est du même détroit. Tout ceci indique la prédominance de la circulation atmosphérique nord-ouest dessus cette région pendant l'été de 1816.

Mots clés: glaces de mer, la baie d'Hudson, le détroit d'Hudson, 1816, livres de bord

Traduit par Guy R.J. Joubert, The University of Manitoba.

Р Е З Ю М Е

Описание морского льда в судовых вахтенных журналах компании "Хадсон Бэй" и дневниках факторий используются, чтобы воссоздать состояние морского льда в Гудзоновом заливе, в заливе Джеймса и в Гудзоновом проливе летом 1816 года. Результаты показывают, что необычайно позднее расхождение морского льда имело место в заливе Джеймса, в юго-восточной части Гудзонова залива и в западной оконечности Гудзонова пролива. Довольно интенсивный поток льда в Канадском течении имел место в восточной оконечности Гудзонова пролива. Эти образцы поведения льда указывают на преобладание северо-западной атмосферной циркуляции над этим районом летом 1816 года.

Translated by M. Fishman, The University of Manitoba.

INTRODUCTION

Hudson Strait is the gullet between Baffin Island and the Labrador peninsula through which Hudson Bay drains into the Atlantic Ocean. In winter the strait is closed to shipping by pack ice, which lingers late into the summer, posing a hazard to vessels enroute to the port of Churchill on the west coast of Hudson Bay (Fig. 1). The shipping season through the strait is a mere three months, since the port of Churchill is open only from 23 July to 20 October. The commercial viability of this brief shipping route stems from the strategic location of Hudson Bay in the interior of Canada. Today the significance of the location accrues from the proximity of Churchill to the grain fields of the prairies, but the important aspect historically was the intrusion of the Bay into the heart of the fur-rich boreal forest. The world's oldest surviving chartered joint stock company was established by Charles II in 1670 to exploit the fur resource and, from its inception, transatlantic shipping played a pivotal role in the activities of the Hudson's Bay Company.

Commencing with the voyage of its first ship, the ketch *Nonsuch*, to Hudson Bay in 1668-69, the Company regularly dispatched a flotilla of ships from England to the Bay. The ships' log-books dating back to 1751 are preserved in the Company's archives, giving the Hudson's Bay Company title to the claim of the world's longest corporate history of oceanic shipping. This record is the more remarkable since it relates to shipping through the perilous waters of Hudson Strait.

Prior to 1892 all vessels deployed on this route were sailing ships and the Company was compelled to establish a routine in which its ships sailed westward through the strait in late July and early August. This allowed time for the ships to conduct their business and return to England before the strait became impassable. Because of this practice the ships encountered hazardous ice conditions during the westward passage through the strait, and the log-books written during these passages abound with references to sea ice. The descriptive information in the log-books has been analyzed to yield annual indices of summer sea ice severity in Hudson Strait for the period 1751-1870 (Catchpole and Faurer, 1983).

This study reveals that the highest index of summer sea ice severity occurred in 1816 (Fig. 2), a finding of general significance because evidence from western Europe and eastern North America demonstrates that exceptionally cool weather was widespread in the summer of 1816 (Hoyt, 1958; Post, 1977). Stommel and Stommel (1979) have characterized

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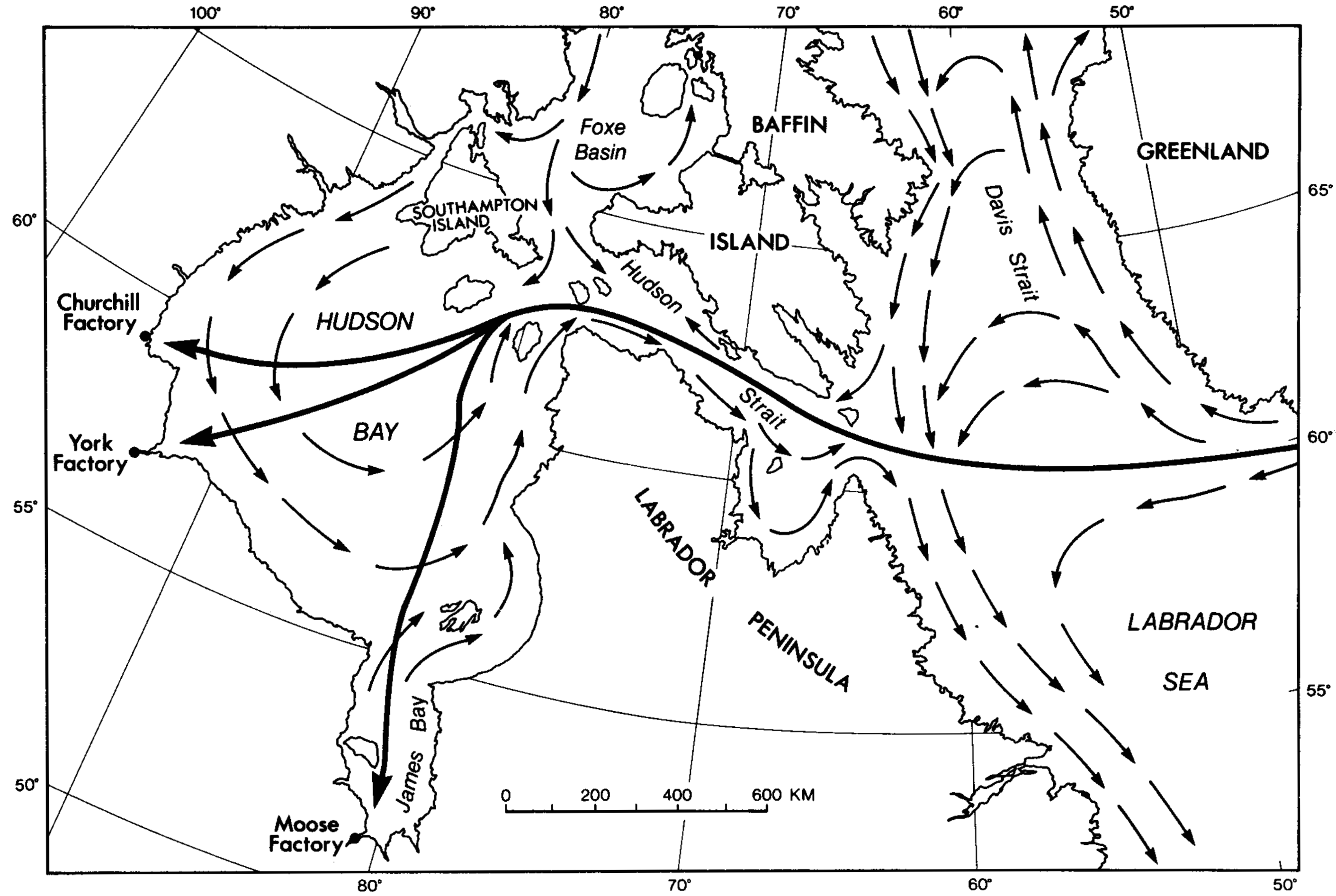

FIG. 1. Location map showing sea currents and the Hudson's Bay Company sailing route.

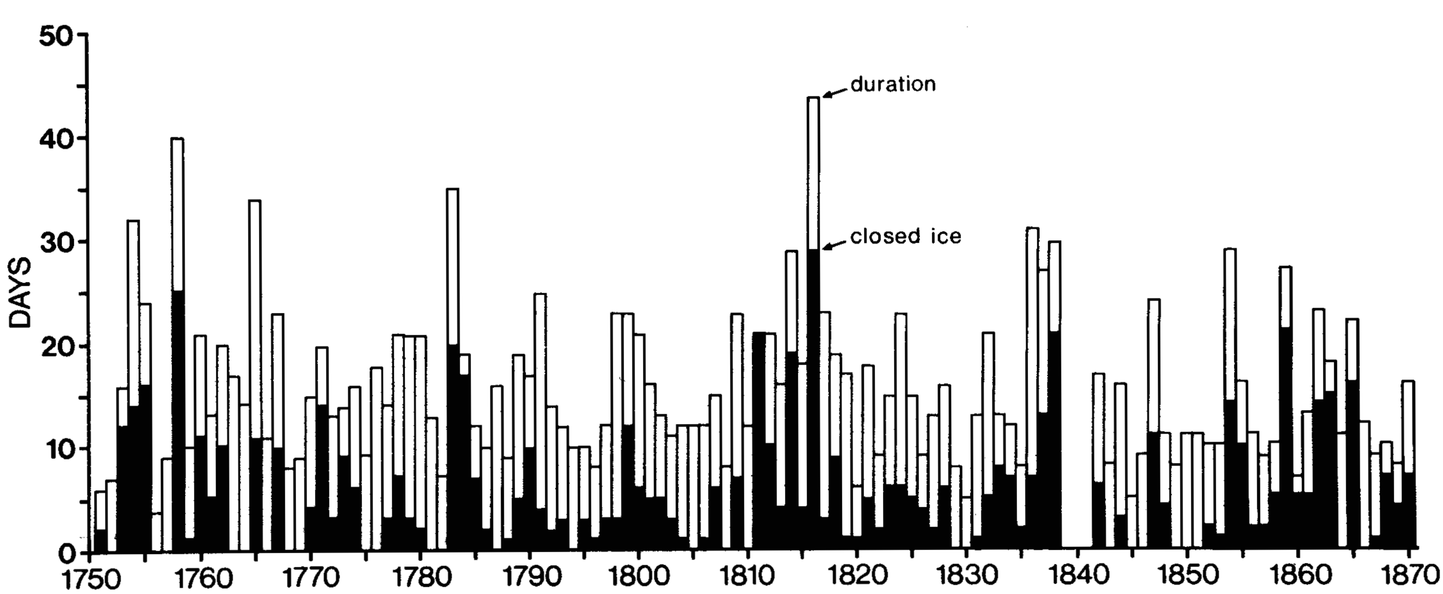

FIG. 2. Annual indices of summer sea ice severity in Hudson Strait, 1751-1870. These indices are based on (a) the annual durations (days) of the westward passages of the Hudson's Bay Company ships through the strait, and (b) the annual frequencies of occurrence (days) of closed-ice conditions during these westward passages. These data are corrected for the effects of seasonal changes in ice severity arising from variations in the dates of commencement of the westward passages (Catchpole and Faurer, 1983). The interruption in 1839-41 is due to missing log-books.

1816 as "the year without a summer" and Post (1977) attributed the "last great subsistence crisis in the western world," namely the crop failures of 1816-19 in Europe and North America, to the coincident coldness. General interest in the summer of 1816 is fuelled by speculation that this coldness was caused by the dust veil emitted into the stratosphere by the eruption of Mount Tambora in 1815. The exceptional nature of this eruption is revealed by its great explosivity (Newhall and Self, 1982); by the high concentrations of acid deposited from its veil in Greenland (Hammer, *et al.*, 1980); and by the high concentrations of particulate matter deposited from its veil in Antarctica (Thompson and Mosley-Thompson, 1981).

The objective of this paper is to examine the available evidence of sea ice conditions in Hudson Strait and Hudson Bay in the summer of 1816. The evidence is drawn from several diverse sources, including the log-books of the ships sailing into or overwintering in Hudson Bay in 1816 and daily journals kept on a coastal sloop and at trading posts on James Bay. The information from these sources is assembled to provide a fragmentary reconstruction of sea ice distribution in Hudson Strait and along the eastern margin of Hudson Bay. With the aid of present-day analogues of the controls of summer sea ice dispersal, inferences are made regarding atmospheric circulation over Hudson Bay in the summer of 1816.

SOURCES

The autumn of 1815 was an anxious period for Joseph Berens, Jr., the governor of the Hudson's Bay Company in London. This was the season in which the Company's ships usually returned from the Bay with their harvest of furs, but the voyage of 1815 was truncated by Hudson Strait pack ice, which prevented the return of the ships *Eddystone* and *Hadlow* through Hudson Strait into the Atlantic Ocean. Faced with the prospect of overwintering in the Bay, both vessels sailed to the comparatively safe anchorage of Strutton Sound in James Bay (Fig. 3) and were to remain there, ice-bound, until 12 August of the following year. The governor of the Company, being unaware of the fate of the *Eddystone* and *Hadlow*, dispatched the 1816 flotilla of ships on 12 May — almost three weeks earlier than the usual departure date. Under normal circumstances, an early entrance into Hudson Strait presaged an arduous, prolonged passage through severe pack ice, but in 1816 the brig *Emerald* and ship *Prince of Wales* encountered exceptional ice congestion in the strait. The two vessels finally entered Hudson Bay on 6 September, 51 days after entering the strait and 119 days after leaving London.

The major source used in this study is the log-book of the *Emerald* kept between 17 July 1816, when the brig first entered Hudson Strait, and 21 October 1816, when it finally returned to James Bay after unsuccessfully attempting to navigate the ice-bound entrance to Hudson Strait on its homeward voyage to England. This log yields ice information along the longitudinal axis of Hudson Strait and the eastern margin of Hudson Bay.

The log-book of the *Eddystone* is a minor source, since it is descriptive of ice conditions at a single location in James Bay,

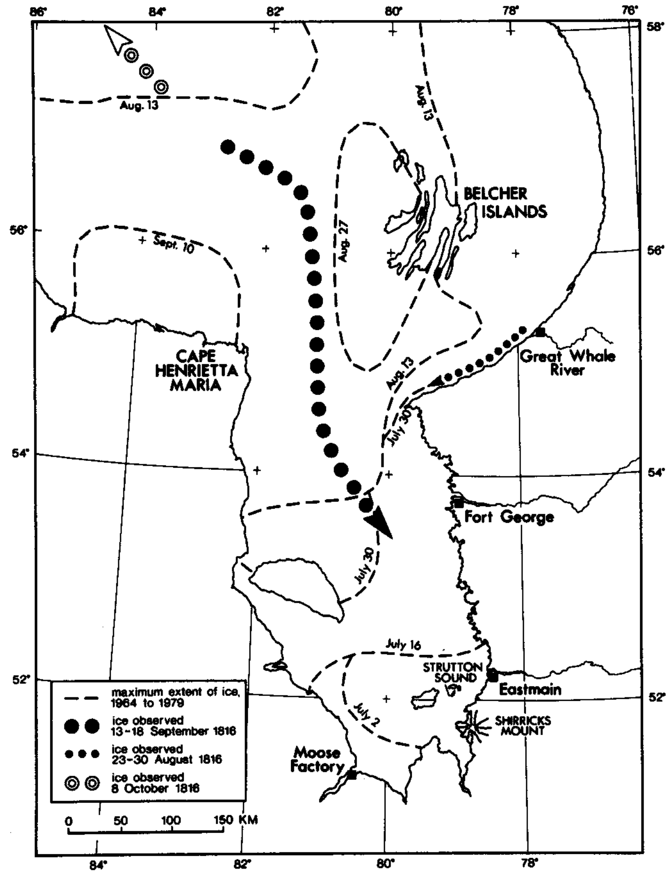

FIG. 3. Sea ice on southeastern Hudson Bay and James Bay. Maximum ice extents (Sowden and Geddes, 1980) are estimated at two-week intervals and defined as the area where, on the given date, ice has existed at least once in the period 1964-79. The dates are plotted on the ice-covered sides of the boundaries. The 1816 ice information is partly derived from the log-book of the *Emerald* during its southward passage in September and its northward passage in October. Ice information for 1816 is also taken from a journal kept on a sloop sailing from Great Whale River to Fort George in August.

but its utility is enhanced by the availability of other sources in the James Bay region. These are daily journals kept at the Company's trading posts located on estuaries draining into Hudson Bay and James Bay. The journals were kept by the Company's post factors in compliance with specific instructions received from the governor in England. The journals lack the rigid, tabular format of the ships' log-books and have the style of descriptive narratives. As such they make detailed references to the events and circumstances at the trading posts, and environmental descriptions are prominent. This study uses sea ice descriptions contained in the Great Whale River and Eastmain post journals (Fig. 3). The former includes descriptions written both at the Great Whale River post and also on a sloop sailing along the coast from Great Whale River to Fort George in August and September 1816.

OPEN AND CLOSED ICE

A previous study of the Hudson's Bay Company ships' log-books kept in Hudson Strait between 1751 and 1870 has shown that the ice conditions encountered by sailing ships can be classified into two categories, *open* and *closed* (Catchpole and

Faurer, 1983). These terms are borrowed from adjectives commonly used in the log-books to describe ice, but their application here is based upon the sailing maneuvers undertaken by sailing ships confronted by ice. Open ice is defined as the condition in which ice was present but sufficiently dispersed to allow the ship to make headway by tacking. Closed ice prevented the ship from making headway through the ice. In some cases this was because the ship was entirely confined by ice and was described in the log-books as being *beset by* or *fast in* ice. Alternatively, the ship would not make headway if the captain judged the threat of ice to be so serious that cables should be used to *grapple* the ship to an ice floe. The nature and purpose of this maneuver is apparent from the journal of Lieutenant Edward Chappell R.N., an officer on H.M.S. *Rosamond*, which escorted the Hudson's Bay Company flotilla in 1814:

> . . . we . . . endeavoured to force our way forward [through Hudson Strait] among the ice; until, from its increasing consolidation, we were again obliged to lash to a large piece of it. This operation is called *grappling*; and it is performed by running the vessel alongside of the piece of ice to which it is intended to make her fast: two men then leap on the ice: the one runs, with a sort of pick-axe, to dig a hole in it, using the precaution to stand with his back to the ship; and the other man follows the first, with a serpent-like iron on his back, having a strong rope affixed to one end of it: this serpent (or ice-anchor, as it is termed) is hooked into the hole on the ice, and the rope is fastened on board the ship. Other ice-anchors and ropes are then hooked in different parts of the piece of ice; and the number of ropes is varied according to the state of the weather. In a gale of wind, we had generally five anchors a-head; and with a moderate breeze, not more than two. The whole manoeuvre of grappling is generally accomplished in five minutes; and although the ship be lashed to windward of a clump of ice, yet the action of the wind on a vessel's masts, yards, &c. turns the ice round, and she will consequently soon be under the lee of it, with water as smooth as a mill-pond. (Chappell, 1817:121-122.)

The hazards of grappling are illustrated by a water-colour by Peter Rindisbacher (Fig. 4), which shows the Swiss settler ship *Lord Wellington* imperilled by an iceberg while grappling with ice in foggy, rainy weather in eastern Hudson Strait. During this incident, an accompanying ship, the *Prince of Wales*, was stove in by a large "isle of ice." The log-book of the *Prince of Wales* describes this incident:

> Thursday 24 July [1821], Laying at Grappling to a field of Ice Consorts fast to the piece. At 3 am it blowing a fresh breeze foggy with Rain, we perceived the Ship drifting on an Isle of Ice close to us, began to haul the Ship away to clear it, the Ship drifting so very fast with the wind and Current we was not able to get clear, and it took us in the midships and stove the Starboard side from the Bends upwards (The Eddyston and Lord Willington on each [side] of us just escaped).... (Hudson's Bay Company, log-book of ship *Prince of Wales*, cl/794, enclosure, 24 July 1821.)

The result of this collision was that the *Prince of Wales* shipped water at an alarming rate, and to lighten the vessel its cargo was transferred to the *Eddystone*. This enabled temporary repairs to be undertaken as the damaged timbers emerged above the waterline.

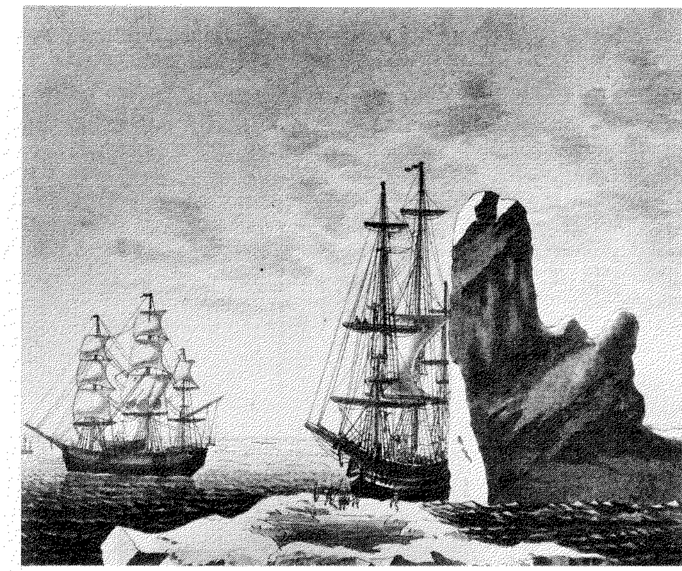

FIG. 4. The Swiss settler ship *Lord Wellington* in danger of being crushed by ice in July 1821 while accompanied by the Hudson's Bay Company ships *Prince of Wales* and *Eddystone*. From the water colour by Peter Rindisbacher. (Public Archives of Canada, C-1915.)

SEA ICE IN HUDSON STRAIT

On 17 July 1816 Captain Benjamin Bell, master of the *Emerald*, sighted Resolution Island and thus anticipated the imminent entry of his vessel into Hudson Strait. At this point, however, the flotilla encountered closed ice moving rapidly southward, and for 15 days the ships drifted helplessly (Fig. 5). This drift carried the flotilla for 130 km, past the northern tip of the Labrador peninsula, where sea ice poses a particularly severe hazard to shipping. Two years earlier Lieutenant Chappell had been apprised of this hazard by the Hudson's Bay Company pilot assigned to the *Rosamond*:

> Entering *Hudson's Straits*, it is a necessary precaution to keep close in with the northern shore; as the currents out of *Hudson's* and *Davis' Straits* meet on the south side of the entrance, and carry the ice with great velocity to the southward, along the coast of *Labrador*. (Chappell, 1817:40-41.)

It was from this perilous location that the *Emerald* was extricated on 31 July, to escape northeastward into open ice. By 2 August open water was regained in the Labrador Sea. The following day this flotilla repeated its approach to Hudson Strait, but its progress was again interrupted by ice to the south of Resolution Island. Virtually no progress was made during the next five days, as the ship drifted haphazardly off the island's south coast, grappling with or fast in closed ice.

Captain Bell's log-book finally reported steady westward progress in open ice on 9 August, but after sailing only 70 km closed ice was again encountered and this persisted for the next nine days. This ice was rapidly moving westward into the strait roughly paralleling the south coast of Baffin Island. It is noteworthy that this closed ice did not extend north to Baffin Island. Indeed, the log-book described the presence of broad expanses of open water in the vicinity of Baffin Island.

By 19 August the flotilla had drifted 130 km westward to 68°W longitude and there encountered open ice that extended

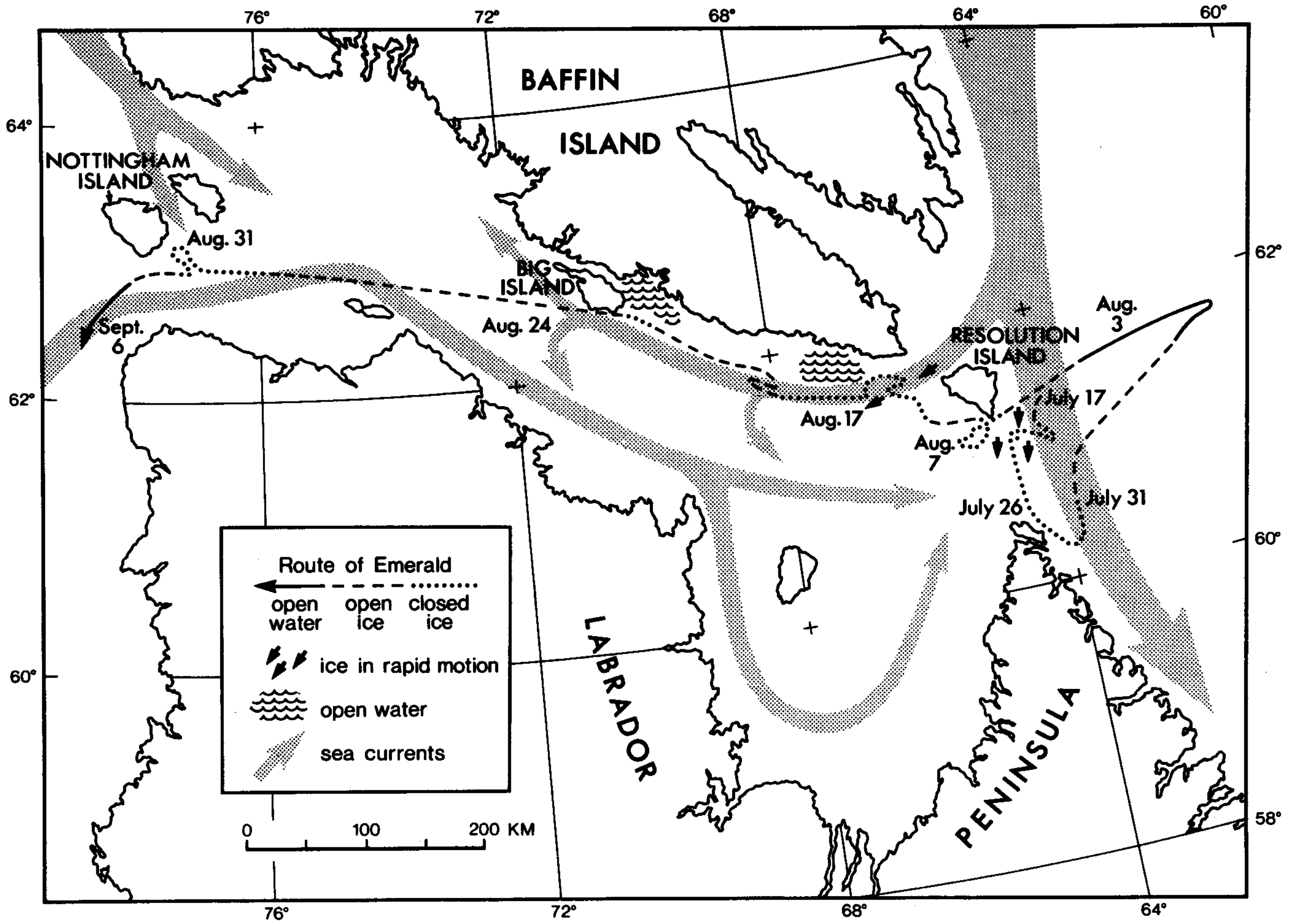

FIG. 5. Westward passage of the *Emerald* through Hudson Strait in 1816. The reconstruction of this passage commences with the first sighting of Resolution Island on 17 July.

400 km to 75°W longitude. This distance was traversed in eight days along the direct shipping route through the strait. At the exit from the strait on 27 August closed ice was again encountered and the ships drifted aimlessly for nine days before emerging into open ice south of Nottingham Island on 5 September. In only two other years (1758 and 1783) during the period 1751-1870 was closed ice encountered here at such a late date in the season (Faurer, 1981). The open water of Hudson Bay was finally reached on 6 September.

Taken in isolation, the 1816 passage of the Company's ships through Hudson Strait is little more than a saga of endurance and peril. The physical significance of this passage emerges when it is compared with the historical records of similar passages made between 1751 and 1870. These records have been examined by Catchpole and Faurer (1983) in a study that analyzed the factors determining annual variations in the duration of the westward passages through Hudson Strait. The major determinant of these durations was found to be annual variations in the incidence of closed-ice conditions along the shipping route through the strait. Both the longest duration of the westward passage and the greatest incidence of closed-ice conditions occurred in 1816 (Fig. 2). The duration of the westward passage in that year (51 days) exceeded by seven standard deviations the mean duration ($\sigma=4.7$ days; $\bar{x}=17.7$ days) for the period of record. Catchpole and Faurer (1983) concluded that the most severe summer sea ice congestion in Hudson Strait between 1751 and 1870 occurred in 1816.

SEA ICE IN HUDSON BAY AND JAMES BAY

Hudson Bay lacks an index of annual changes in summer sea ice severity between 1751 and 1870, so the significance of 1816 ice conditions described in the historical sources must be judged against the yardstick of modern records. This is unfortunate, since these records span a period of only 20 years (1964-84). In this study the significance of descriptions of sea ice conditions in 1816 is assessed in relation to a spatial analysis of the latest dates on which ice has been observed in the Bay in the period 1964-79 (Sowden and Geddes, 1980). The evidence of ice conditions in 1816 is presented in chronological order. Descriptions of ice at the southern extremity of James Bay are examined first, since the earliest clearing of ice occurs in these waters. Information in the logbook of the *Emerald* is presented last, since the ship's route was through those parts of Hudson Bay where the last remnants of sea ice normally occur.

In southeastern James Bay in the vicinity of 52°N, the last ice during the period 1964-79 was observed on 2 July (Fig. 3).

Information from two sources indicates that severe ice conditions persisted here beyond this date in 1816. The Hudson's Bay Company post journal kept by James Russell at Eastmain reported on 10 July 1816 that:

> ... about Noon Mesticoosk and tribe (8 canoes) arrived from the Northward Goose Tent ... they have been prevented arriving here sooner owing to the immense quantity of Ice that extends all round this Coast from Shirricks Mount to the Southward and as far to the Northward as the Indians have been, it is not a mile from the Shore. (Hudson's Bay Company, Eastmain journal, B.59/a/96, fol. 2, 10 July 1816.)

The reference to Shirricks Mount indicates that the pack ice extended along the coast to a point 55 km south of Eastmain (Fig. 3). Later references to sea ice in this vicinity are found in the log-book of the *Eddystone* kept by John Turner at the ship's anchorage at Strutton Sound. The pack ice in the sound first broke up on 27 May 1816, and thereafter the log-book makes frequent reference to moving ice in the sound that occasionally moved forcefully enough to imperil the ship. Even the last reference to ice, on 30 July 1816, reports that:

> Much Ice came into the Sound with the Ebbtide — Got another Cable end to the Shore, to make the Ship more secure. (Hudson's Bay Company, log-book of ship *Eddystone*, cl/302, fol. 82, 30 July 1816.)

The coastline extending from Great Whale River to Fort George has, during the modern record, experienced last ice on dates ranging from 30 July in the north to 16 July in the south. However within 25 km of this coast, last ice has been observed as late as 13 August. Descriptions of sea ice along the coastline in the summer of 1816 are included in a post journal kept by Thomas Alder at Great Whale River and also on a sloop sailing from Great Whale River to Fort George. On 5 August 1816, Alder reported that:

> ... in the morning went out [from Great Whale River] with four hands into the Offing; landed and went to the top of a very high hill, but with a good Telescope it appears one solid body of Ice except a very small spot of open water to the Northward; this at present renders it impracticable for a Vessel to proceed to Sea. (Hudson's Bay Company, Whale River post journal, B. 372/a/3, fol. 27, 5 August 1816.)

By 23 August ice conditions had ameliorated sufficiently to allow Alder to embark on a coastwise voyage to Moose Factory via Fort George. After eight days the sloop had advanced 100 km southwestward along the Hudson Bay coast, but throughout this period sea ice posed a severe hazard. Thus, on 30 August 1816:

> ... just at daybreak we drifted amongst very heavy Ice, from the heavy surf broke up ye Larboard Chain plates, against the Ice. Evansen was in imminent danger of being left on the Ice; hove him a rope which he fastened round him, and was hauled on board thro' the water ... tho' I've been 20 years coasting along the different shores, I never knew a more miraculous escape. (Hudson's Bay Company, Whale River post journal, B. 372/a/3, fol. 30, 30 August 1816.)

When Captain Bell finally sailed the *Emerald* into Hudson Bay on 6 September 1816, he might well have expected an ice-free passage to Moose Factory. None of the Company's ships had previously entered the Bay at this late date. Whatever his expectations, the master of the *Emerald* reported open ice on 13 September in the latitude of the Belcher Islands, and this persisted throughout the next 400 km, until open water was eventually reached on 19 September at 53°N.

On 20 September the *Emerald* reached Moose Factory, offloaded and reloaded with the haste appropriate to the lateness of the season, and then embarked on its return voyage. During the northward passage open ice was encountered on 8 October between 57° and 58°N, though not in quantities sufficient to retard the ship's passage. However, closed ice blocked the entrance to Hudson Strait in the vicinity of Mansel Island on 14 October, compelling the *Emerald* to return to James Bay for the winter.

In the period of the modern record large spatial variations in the date of last ice occur in the area between the southern part of James Bay, Cape Henrietta Maria, and the Belcher Islands (Fig. 3). The interpretation of the significance of the ice described in the log-book of the *Emerald* for September and October 1816 must therefore be undertaken cautiously. During its southward passage between Cape Henrietta Maria and the Belcher Islands, the *Emerald* encountered ice in mid-September in an area where it has not been observed after 13 August in the modern period. However, ice has recently been observed as late as 10 September in the area immediately to the west of this route. Two features of the ice distribution in the path of the *Emerald* in 1816 appear to have no present-day counterparts. The first is the ice observed on 16-18 September in James Bay and the second is the ice encountered to the northwest of the Belcher Islands on 8 October. In each of these cases the ice occurrence in 1816 was more than one month later than the modern date of last ice.

DISCUSSION

This study seeks to reconstruct 1816 ice conditions in waters not easily probed even by the full array of modern satellite surveillance, aerial reconnaissance, and ground truth surveying. The evidence is taken from the ostensibly reliable journals and log-books of sailing ship mariners whose livelihood and security depended upon highly acute perceptions of sea conditions. The quality of this evidence is, however, degraded by its geographical scatter, temporal dispersion, and substantive diversity. A comprehensive reconstruction of sea ice patterns is, therefore, not feasible, and the study can only yield fragmentary information on sea ice in eastern Hudson Bay and its approaches.

Summary of Findings

The exceptional features of sea ice distribution that have been identified can be summarized into two general categories relating to conditions in Hudson Strait and to those at the southern extremity of Hudson Bay. (1) Along the sailing route through the strait, closed ice posed obstacles to navigation at the extremities of the strait at a time when open ice predominated within the interior of the strait and open water was observed off the Baffin Island coast. When compared with ice conditions throughout the period 1751-1870, the ice at the eastern extremity was exceptionally severe in terms of the southward drift imposed on the Company's ships. Similar comparisons indicate the occurrence of exceptionally late closed ice at the strait's western exit. (2) The extreme ice conditions at the southern end of the Bay are assessed in relation to modern ice observations in the period 1964-79. This comparison indicates that in 1816 open ice lingered more than one month later than present-day last-ice dates in Hudson Bay to the northwest of the Belcher Islands and also in the northern half of James Bay.

These results are consistent with findings obtained in a study of summer sea ice conditions in the Labrador Sea during the nineteenth century (Newell, 1983). Historical evidence from the Labrador coast north of 55°N shows that the most severe summer ice conditions in this region throughout the nineteenth century occurred in 1816. An historical study of sea ice in Davis Strait in the nineteenth century made no reference to conditions in 1816 but did note the prevalence of comparatively severe ice conditions in 1817 (Speerschneider, 1931).

Controls of Summer Sea Ice Dispersal

The interpretation of these findings requires a knowledge of the factors determining summer sea ice behaviour and distribution in the Bay and its approaches. Ice data gathered in these waters by aerial reconnaissance and satellite surveillance have been synthesized in weekly ice summary charts by the U.S. Navy Hydrographic Office for the period 1954-63 and by the Canadian Atmospheric Environment Service for 1964-74. However, few recent studies have used these raw data and summary charts in studies of ice processes. A general survey of sea ice behaviour in Hudson Bay and Hudson Strait is given in sailing directions for Labrador and Hudson Bay (Canada, 1983). Regionally focussed studies were published by Danielson (1971) for Hudson Bay, by Crane (1978) for eastern Hudson Strait and adjacent waters in the Labrador Sea, and by Jacobs and Newell (1979) for Foxe Basin, Baffin Bay, and Davis Strait. This work is augmented by studies conducted elsewhere in the eastern Canadian Arctic (Dunbar, 1972; Keen, 1978; Newell, 1979; Dey, 1980; Markham, 1981). The general findings are that the summer dispersal of sea ice in subarctic waters is a response to several thermal and dynamic factors and that at the regional and hemispheric scales (Walsh, 1983) a major control is exercised by atmospheric circulation systems.

Over eastern Canada the atmospheric circulation is dominated by a mean tropospheric trough generally located at 70°-75°W longitude, which persists throughout the year, though it weakens in summer. Over short periods the axis of the trough is displaced longitudinally in response to changes in the strength of the hemispheric westerlies. Recent studies of sea ice behaviour in the Baffin Bay–Labrador Sea region have attributed changing rates of summer ice dispersal to longitudinal changes in the position of the trough axis (Barry, 1981). A westward displacement of the axis fosters early ice dispersal, presumably by steering southwesterly surface winds into the Baffin Bay–Labrador Sea region. This causes warm air advection and frictional resistance to the southward drift of ice in the Labrador current. By contrast, an eastward displacement of the trough axis allows northwesterly winds to prevail over the region. Cold air advection then retards melting while surface friction increases the southward drift of ice, and the effect is retarded summer ice dispersal. These relationships have been identified by Keen (1978) in Baffin Bay and by Crane (1978) in the Davis Strait–Labrador Sea region. The latter study extended westward over Hudson Strait.

Comparable studies of relationships between the position of the tropospheric trough and summer ice dispersal have not been described for the Hudson Bay–Foxe Basin region. Nevertheless there are grounds for assuming a link here between the meridional component of surface wind direction and rates of summer ice dispersal. Jacobs and Newell (1979) have described a tendency for Foxe Basin to have lighter ice conditions in summers having more frequent southerly air flow. This tendency arises from the great *in situ* melting related to advective heating. A study of present-day analogues indicates that persistent northwesterly and northerly winds increase the outflow of ice from Foxe Basin into Hudson Strait in summer (Catchpole and Faurer, 1983). Within Hudson Bay, summer sea ice normally clears southward from Southampton Island in the west and northward from James Bay in the east (Danielson, 1971). The pattern of clearing in the west is determined by the counterclockwise sea currents in the Bay and by the prevalence of northwesterly winds circulating cyclonically into the Icelandic low-pressure cell. The northward clearing from James Bay reflects the northward progression of radiative and advective heating and is likely to be retarded in summers dominated by outbursts of arctic air.

Inferred Atmospheric Circulation in Summer 1816

The features of 1816 sea ice distribution identified in this study are consistent with those ice-behaviour patterns that are today associated with northerly or northwesterly winds and an eastward displacement of the mean tropospheric trough. The severe ice congestion and rapid ice movement at the extremities of Hudson Strait are possibly attributable to exceptional wind-driven southward ice flow in the Labrador current and in the current emerging from Foxe Basin (Fig. 5). Likewise, there is a general tendency for open water to develop early along the Baffin Island coast when the sea ice is driven offshore by northerly and northwesterly winds (Canada, 1983).

Other studies of the 1816 summer weather anomaly provide evidence of meridional atmospheric circulation over eastern North America. This evidence comprises both meteorological observations and indirect indices of weather conditions such as spatial patterns of crop destruction. Daily temperatures observed in New England in the summer of 1816 demonstrate that this summer was punctuated by episodes of exceptional cold. A series of cold waves was described as follows:

> The first of three unseasonably cold waves moved eastward into New England early on June 6. The cold wind lasted until June 11, leaving from three to six inches of snow on the ground in northern New England. A second killing frost struck the same areas on July 9 and a third and fourth on August 21 and

30, just as the harvest of twice-ravaged crops was about to begin. The repeated summer frosts destroyed all but the hardiest grains and vegetables. (Stommel and Stommel, 1979:176.)

Instrumental measurements of air temperature and visual observations of wind speed, wind direction, and general weather conditions were made in summer 1816 at several Hudson's Bay Company posts. Wilson (1983) has reconstructed the daily synoptic weather situation on 6 June 1816 over eastern Canada and postulated that the cold wave that invaded New England on that day was directed southward by an anticyclone over western Hudson Bay and a low-pressure cell over the eastern Labrador peninsula. These pressure cells maintained a meridional surface circulation over eastern Hudson Bay. The mean surface pressure pattern for July 1816 in the North Atlantic region was reconstructed by Lamb and Johnson (1966). This analysis identified a meridional pressure pattern steering a northerly air flow over eastern North America in July 1816.

Proxy evidence of anomalous surface atmospheric circulation is provided by spatial variations in crop destruction in the summer of 1816. The crop destruction described by Stommel and Stommel (1979) was apparently not uniform in its intensity over eastern North America. Severe losses occurred in New England and southward along the Atlantic seaboard, but regions to the west of the Appalachians were less affected (Post, 1977). A similar feature was observed in the pattern of crop destruction experienced in the vegetable gardens kept at Hudson's Bay Company posts in the Bay region. Severe crop destruction occurred in the gardens located to the southeast of the Bay, but these effects were not described in the journals of posts located elsewhere (Catchpole, 1985). These patterns of crop loss are indicative of a regionally selective cooling influence rather than a general hemispheric cooling and point to cold waves steered by long waves in the upper westerlies along the eastern margin of the continent.

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REFERENCES

BARRY, R.G. 1981. The nature and origin of climatic fluctuations in northeastern North America. Géographie physique et Quaternaire 35:41-47.

CANADA. 1983. Sailing Directions — Labrador and Hudson Bay. 5th Edition. Ottawa: Department of Fisheries and Oceans. 450 p.

CATCHPOLE, A.J.W. 1985. Evidence from Hudson Bay region of severe cold in the summer of 1816. In: Harington, C.R., ed. Climatic Change in Canada 5. Critical Periods in the Quarternary Climate History of North America. Syllogeus 55. Ottawa: National Museums of Canada. 121-146.

______ and FAURER, MARCIA-ANNE. 1983. Summer sea ice severity in Hudson Strait, 1751-1870. Climatic Change 5:115-139.

CHAPPELL, E. 1817. Narrative of a Voyage to Hudson's Bay in His Majesty's Ship Rosamond. London: J. Mawman. 279 p.

CRANE, R.G. 1978. Seasonal variations of sea ice extent in the Davis Strait - Labrador Sea area and relationships with synoptic-scale atmospheric circulation. Arctic 31:434-447.

DANIELSON, E.W. 1971. Hudson Bay ice conditions. Arctic 24:90-107.

DEY, B. 1980. Seasonal and annual variations in ice cover in Baffin Bay and northern Davis Strait. Canadian Geographer 24:368-384.

DUNBAR, M. 1972. Increasing severity of ice conditions in Baffin Bay and Davis Strait and its effect on the extreme limit of ice. In: Karlssen, T., ed. Sea Ice. Proceedings of an International Conference, National Research Council of Iceland, Reykjavik. 87-93.

FAURER, MARCIA-ANNE. 1981. Evidence of sea ice conditions in Hudson Strait, 1751-1870, using ships' logs. Unpublished M.A. thesis, Department of Geography, The University of Manitoba, Winnipeg, Manitoba. 148 p.

HAMMER, C.V., CLAUSEN, H.B., and DANSGAARD, W. 1980. Greenland ice sheet evidence of post-glacial volcanism and its climatic impact. Nature 288:230-235.

HOYT, J.B. 1958. The cold summer of 1816. Annals, Association of American Geographers 48:118-131.

HUDSON'S BAY COMPANY. Eastmain journal, B. 59/a/96, fol. 2, 10 July 1816.

______. Log-book of ship *Eddystone*, c1/302, fol. 82, 30 July 1816.

______. Log-book of ship *Prince of Wales*, c1/794, enclosure, 24 July 1821.

______. Whale River post journal, B. 372/a/3, fol. 27, 5 August 1816.

______. Whale River post journal, B. 372/a/3, fol. 30, 30 August 1816.

JACOBS, J.D., and NEWELL, J.P. 1979. Recent year-to-year variations in seasonal temperatures and sea ice conditions in the eastern Canadian arctic. Arctic 32:345-354.

KEEN, R.A. 1978. The response of Baffin Bay ice conditions to changes in atmospheric circulation patterns. In: Muggeridge, D.E., ed. Proceedings, Fourth International Conference on Port and Ocean Engineering under Arctic Conditions. Memorial University, St. Johns. Vol.II:963-971.

LAMB, H.H., and JOHNSON, A.I. 1966. Secular variations of the atmospheric circulation since 1750. London: Her Majesty's Stationary Office, Meteorological Office, Geophysical Memoirs 110:57.

MARKHAM, W.E. 1981. Ice Atlas: Canadian Arctic Waterways. Atmospheric Environment Service. 198 p.

NEWELL, J. 1979. The influence of meteorological factors on the clearing of sea ice from Baffin Bay. Unpublished M.A. thesis, Department of Geography, University of Windsor, Windsor, Ontario. 231 p.

______. 1983. Preliminary analysis of sea-ice conditions in the Labrador Sea during the Nineteenth Century. In: Harington, C.R., ed. Climatic Change in Canada 3, Syllogeus 49. Ottawa: National Museums of Canada. 108-129.

NEWHALL, C.G., and SELF, S. 1982. The volcanic explosivity index: an estimate of explosive magnitude for historical volcanism. Journal of Geophysical Research 87:1231-1238.

POST, J.D. 1977. The Last Great Subsistence Crisis in the Western World. Baltimore: The Johns Hopkins University Press. 240 p.

SOWDEN, W.J., and GEDDES, F.E. 1980. Weekly Median and Extreme Ice Edges for Eastern Canadian Seaboard and Hudson Bay. Ottawa: Ice Climatology and Applications Division. 56 p.

SPEERSCHNEIDER, C.I.H. 1931. The state of the ice in Davis-Strait 1820-1930. Meddelelser 8. Copenhagen: Danske Meteorologiske Institut. 55 p.

STOMMEL, H., and STOMMEL, E. 1979. The year without a summer. Scientific American 240:176-186.

THOMPSON, L.G., and MOSLEY-THOMPSON, E. 1981. Temporal variability of microparticle properties in polar ice sheets. Journal of Volcanology and Geothermal Research 11:11-28.

WALSH, J.E. 1983. The role of sea ice in climatic variability: theories and evidence. Atmosphere-Ocean 21(3):229-242.

WILSON, C.V. 1983. The summer season along the east coast of Hudson Bay during the nineteenth century. Part II: The little ice age on eastern Hudson Bay: summers at Great Whale, Fort George, Eastmain, 1814-1821. Report No. 83-9. Unpublished manuscript. Downsview, Canadian Climate Centre. 88-91. [Available from Applications and Impacts Division, Canadian Climate Centre, 4905 Dufferin Street, Downsview, Ontario M3H 5T4.]