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Historical occurrence of Antarctic icebergs within mercantile shipping routes and the exceptional events of the 1890s

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Abstract

A major consideration for maritime activity in the Southern Hemisphere is the northern limit of icebergs, or the Southern Ocean Limit Of Known Ice (SOLOKI). This analysis of historical reports of icebergs during Southern Hemisphere voyages from 1687 to 1933 provides a basis for examination of their geographical and chronological occurrence during ~250 years. The analyses use tabulated data from 742 voyages and other reports from many sources, some including first-person descriptions. While these data are dependent on icebergs being reported by mariners, as well as the variable frequency of voyages, they demonstrate distinct periods of exceptional frequency of icebergs occurring in certain localities, particularly the far South Atlantic. Based upon historical records the evidence suggests unprecedented numbers of icebergs were present in southern shipping channels in the 1890s. When these historical observations are combined with modern iceberg drift trajectories, their possible origin can be elucidated. Owing to the numbers of icebergs seen and their geographical spread, our results suggest that this was possibly the largest near-synchronous calvings in the last 300 years, and the northernmost extent of the SOLOKI.

1. Introduction

A major consideration for maritime activity is the Southern Ocean Limit Of Known Ice (SOLOKI), or northern limit of icebergs. This is because icebergs represent an important shipping hazard, especially as some drift into major shipping lanes. Although monitoring icebergs using satellites has increased in the past 20 years, the period of the satellite record is inadequate for determining the temporal and spatial variability of iceberg drift especially for SOLOKI. In this paper we examine the reports from vessels of icebergs for the period from 1687 to 1933 and how these occurred in the context of shipping activity and events of historical significance. During the 1890s there was a large increase in the number of reported icebergs that is coincident with a decline in the apparent level of maritime traffic. This indicates an Antarctic iceberg calving events of exceptional magnitude and large northward shift in the SOLOKI.

The zone of interest of this paper is that of the usual courses of far southern navigation, known collectively as the southern trade routes. The northern limit is effectively 26°S (Munn, 1911), the most northerly record of an iceberg in the Southern Hemisphere. These data mostly exclude vessels engaged in Antarctic exploration as they proceeded to regions where icebergs are unexceptional, well south of the usual routing of mercantile voyages. The essence of the data is the reports of icebergs, where their presence would be a notable phenomenon and a potential hazard to shipping within the southern trade routes. A pictorial example of a British mercantile voyage eastbound from Melbourne to London encountering icebergs in 1867 can be seen in Figure 1.

Where practicable we excluded observations in the waters covered by the *Antarctic Pilot* published by the Hydrographic Office of the Admiralty, in seven editions, starting from 1930 (Robinson, 2009) as this publication generally covers the region to the south of the usual routes of shipping and areas where there are expected to be icebergs, although there is inevitable overlap. Figure 2a shows a map of the Southern Hemisphere showing locations and analysis regions, with the maximum observed iceberg volume from AltiBerg; an online database which contains satellite detected icebergs less than 3 km in length (Tournadre and others, 2021).

The earliest comprehensive analysis of the occurrence of southern icebergs is a detailed compilation by James Horsburgh, the first East India Company hydrographer. He examined records from over a century of return voyages, during the 1700s, most plied between Britain and India on courses that took them south of Cape Agulhas. The results, with a commentary, were published as two notes in the *Philosophical Transactions of the Royal Society* (Horsburgh, 1830). These may be summarised with Horsburgh's observation that vessels rounding Africa (thus exceeding 42°S) did not see any icebergs in the region during the 18th century: 'The journal of the ships belonging to the East India Company during the whole of the last century, contain no account of Icebergs having been seen in the course of their navigation in the

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Figure 1. 'The *George Thompson* leaving the Icebergs in the Antarctic Ocean'. A British mercantile voyage, eastbound from Melbourne to London, Capt. William Shepherd, was driven southwards by adverse winds, became beset in severe pack ice with many icebergs, then driven to latitude 59°S, between longitudes 136°W and 121°W, 10–20 December 1867. The voyage continued through Drake Passage and was reported in *The Illustrated London News*, 7 March 1868 (ILN, 1868).

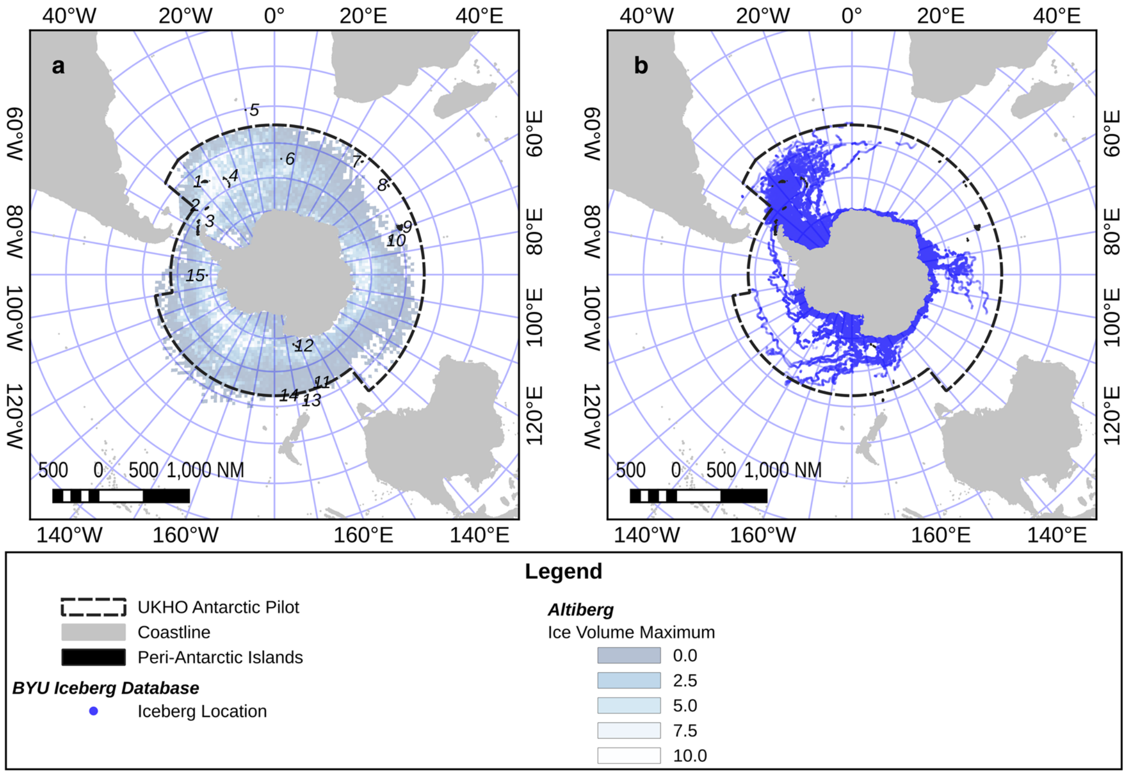

Figure 2. Map of the Southern Hemisphere showing key locations and analysis regions, with (a) maximum observed iceberg volume, in gigatonnes of ice above sea level, from AltiBerg (Tournadre and others, 2021), and (b) tracks of large icebergs from BYU database (Budge and Long, 2018). The names of the Peri-Antarctic islands shown are: (1) South Georgia, (2) South Orkney Islands, (3) South Shetland Islands, (4) South Sandwich Islands, (5) Gough Island, (6) Bouvet Island, (7) Prince Edward Islands, (8) Crozet Islands, (9) Kerguelen Islands, (10) Heard Island, (11) Macquarie Island, (12) Balleny Islands, (13) Auckland Islands, (14) Campbell Island and (15) Peter I Island.

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Southern Hemisphere' (p. 117 in Horsburgh, 1830). However, there was a report of icebergs east of the Cape of Good Hope by HMS *Guardian* in 1789 (Martin, 2023).

During 1828 and 1829 however, icebergs were occasionally encountered relatively close to Cape Agulhas, and throughout subsequent decades such reports became more frequent. Vessels of the East India Company had been trading from 1601 and by the early 1800s sailings had reached a peak of 40–50 ships per year (Farrington, 1999), thus Horsburgh had summarised an abundant amount of information.

In the westbound direction from the Atlantic Ocean early far southern voyages to and from the Pacific Oceans were mainly by Spanish vessels trading with ports of the western coast of South America. These were difficult voyages and much rarer; most plied Drake Passage, 900 km wide south of Cape Horn. Far fewer used the hazardous Magellan Strait between mainland South America and Tierra del Fuego. Early voyage records similarly contain very few observations of ice (del Rosario Prieto and others, 2004). After the American colonies of Spain became independent such voyages became far more frequent, consequently numbers of observations increased from the late 1810s.

2. Compilations of data

This paper utilises several modern and historical sources. These are outlined below.

2.1 Historical sources

To understand the SOLOKI better, and how this may have varied over time this paper brings together (1) historical observations of icebergs from vessels plying the southern trade routes, (2) a database of historical shipping activity and (3) modern databases of satellite observations of icebergs. Each is explained below.

Several compilers, with a variety of interests, have listed records of far southern iceberg observations. Jones (1985), whose extensive maritime notes allowed him to extract records of icebergs for the serial publication *Iceberg Research*. This records 18 voyages with comments about encounters with ice. Kozian (1994) compiled an extensive tabulation of voyages that, until the current compilation, was the most detailed record of historical iceberg sightings. This includes analytical text with contemporary descriptions and observations of many icebergs, and contributed ~370 voyages to our database. Lubbock (1929, 1948, 1958) has sections giving detail and log extracts of encounters with southern ice in several of his many books describing various specialised aspects of shipping. del Rosario Prieto and others (2004) compiled a detailed list of 42 Spanish voyages plying between the Atlantic and Pacific Oceans but only four reported encountering icebergs. Reisenberg (1941) includes many details about Antarctic ice and icebergs involving shipping around Cape Horn for its entire history, including some extensive quotations from logs. Russell (1895, 1897) summarised reports of ice affecting Australasian shipping during the 1890s. His reports included much information from logs, and the observations and accounts of persons aboard. Stommel (1984) published a detailed account of non-existent islands in which a proportion of these, that were reported in the Southern Ocean, may well be explained as observations of icebergs. Swan (1998) included in a dissertation sections on Southern Ocean encounters with ice and non-existent islands including 73 vessels.

Examining these sources, with various others with smaller numbers of records, provided a high degree of corroboration although not without occasional discrepancies. Where practicable these have been reconciled with various newspaper, internet and similar diverse sources, some of which provided illustrations. Searches with a combination of electronically available newspaper scans, especially of Australasian and British publications (*Trove*, https://trove.nla.gov.au/; *British Newspaper Archive*, https://www.britishnewspaperarchive.co.uk/), have been particularly useful by yielding and confirming iceberg observations.

From these above-mentioned sources we have been able to establish an iceberg database of observations from 742 independent voyages transiting the southern trade routes spanning 1687–1933. This database was compiled in a spreadsheet, and converted to point and line Shapefile format for mapping in GIS. Apart from the maritime traffic data, other datasets used including the Brigham Young University (BYU) Iceberg Tracking Database and AltiBerg were sufficiently compact to be stored in vector point ESRI Shapefile format.

Maritime activity during the period of this study can be assessed using the International Comprehensive Ocean-Atmosphere Data Set (ICOADS) dataset (Freeman and others, 2017). This provides records of surface maritime meteorological data from sources including logbooks that have been digitised, to more recent measurements from automatic systems including moored buoys and surface drifters.

ICOADS data were loaded into a PostGIS database, from where it was converted to annual densities of distinctly named reporting vessels, and number of observations, per 300 × 300 km polar stereographic map projection gridcell. Note, the ICOADS data cover only vessels whose records have been digitised and thus may not represent the actual amount of traffic in a particular region. However, the general pattern of traffic of vessels seems realistic for the period.

2.2 Modern sources

The introduction of satellite remote sensing of the environment has significantly improved our ability to monitor the polar regions, with sea ice being a well-studied climate variable. However icebergs, particularly those smaller than several kilometres long, remain difficult to track and the vast numbers emanating from Antarctica means that is yet to be established a comprehensive and effective monitoring even for subjects so critical as maritime safety. Some initial steps in this regard, which provide an overview of likely iceberg distribution but exclude the extremities of range considered here, are the following sources.

2.2.1 AltiBerg

More recently an iceberg volume and extent database has been compiled from the records of satellite altimeters (Tournadre and others, 2021). These sensors primarily monitor sea surface height and ocean waves along orbital transects and have a greater sensitivity to smaller icebergs, down to ~3 km in length. The database also covers the period 1992 to present, and the iceberg volume and extent pattern (Fig. 2a) matches closely that of the concentrations of BYU iceberg tracks.

2.2.2 BYU iceberg tracking database

Large icebergs can be tracked using both passive and active microwave coarse-resolution satellite sensors primarily developed for meteorological applications. The U.S. National Ice Center (NIC) monitors and allocates an alphanumeric identifier to all icebergs >70 km^2 (20 square nautical miles) or with a long axis >18.5 km (10 nautical miles), that consists of a letter determining the Antarctic quadrant of origin and a serial number. Monitoring includes additional positional data from optical and synthetic aperture radar imaging satellites. BYU has expanded on this record with the addition of positional tracking using active microwave scatterometer satellite missions (Budge and Long, 2018). This type of sensor was developed for monitoring ocean winds,

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with the wind speed being derived from the radar reflection from ocean waves. This reflection can also be used to map the extent of contrasting objects, such as sea ice and icebergs. The database covers the period from the earliest NIC record in 1976 to present, and includes the tracks of all large Antarctic icebergs (Fig. 2b). From this 46 year record it can be seen there are three major source areas for large Antarctic icebergs; the Filchner-Ronne, Ross and Amery ice shelves, that calve icebergs into the Weddell Sea, Ross Sea and Prydz Bay, respectively. The database also shows that few large icebergs drift beyond the northern limit of the area covered by the *Antarctic Pilot*.

2.2.3 Shipboard observations

The Scientific Committee on Antarctic Research (SCAR) International Iceberg Database (Orheim and others, 2023b) contains 35 632 observations for the austral summers between 1982–83 and 1997–98. Of these, the 26 601 observations of the Norwegian Polar Institute cover the widest geographical extent, with observations also in the areas where large concentrations of icebergs were observed in the 1890s. Removal of the 6821 observations where the number of icebergs was zero, results in a spatial distribution that is largely within the limits of the satellite observations, with only a few isolated bergs in the northern-most regions of the 1890s event.

A further compilation of modern shipboard observations of icebergs, from the SCAR iceberg database and adding observations collected by Soviet Union vessels between 1947 and 1990, is provided by Romanov and others (2017). In this study figure 3a provides a map of the mean iceberg concentration for the whole dataset. Again, the distribution is consistent with modern satellite observations.

3. Frequency of voyages

Several contemporary authors published reports of vessels encountering icebergs during the 19th and 20th centuries which, when collated, demonstrate various distinct, but brief, periods where voyages report icebergs, sometimes in quite exceptional numbers. When interpreting these sightings, it should be remembered that this will correlate with the frequency of maritime traffic within a region. Geographical and historical observations include the courses taken and consequences of history influencing frequency of far southern voyages. The main southern trading routes are summarised below.

3.1 Southern trade routes involved

3.1.1 Europe to Australasia, the African (eastern) route

The modern discovery of the eastbound route round Africa, passing Cape Agulhas at 42°S, in 1488 was by Bartholomeu Díaz de Novaes from Portugal. Subsequently French (1505), Netherlands (1516), Spanish (1521), British (1580) and various other European exploratory and mercantile voyages to Asian regions plied this route. The main portion of this route is within the region in Figures 2a, b that stretches from 20°W to 160°E and encompasses Africa and Australia.

3.1.2 Europe to eastern Pacific Ocean, the South America (western) route

These voyages through the southern passages of South America from Atlantic regions began from 1520 with the first transit through the Magellan Strait by Fernño de Magalhães (Headland, 2009), and Cape Horn being first rounded in 1616 by Willem Schouten. Subsequent far southern voyages in this direction were sparse, with most Spanish colonial voyages to the Pacific Ocean coasts of the Americas using the African route. As a result iceberg records for this region are few and sporadic until the independence of most of South America, when traffic increased in both directions. The main portion of the route is within the sector in Figures 2a, b that stretches from 20°W to 100°W and around South America.

3.1.3 Australasia to South America, the Pacific route

This is the region of ocean transited eastbound by vessels returning to the Northern Hemisphere from Australasia. The route was used when the vessels were reliant on sail but was greatly reduced after the Panama Canal was opened. It is represented by the sector in Figures 2a, b that stretches from 160°E to 100°W.

3.2 Historical influences

Several political, economic and other factors affect the number of vessels sailing the far southern courses during the two and a half centuries (1687–1933) covered by this dataset. As a consequence, the frequency of iceberg sightings are sporadic and somewhat connected to these historical events. The major ones, chronologically, are the colonialisation of Australasian regions (from 1788), vast increase of trade as South American countries gained independence (from 1810s), Pacific coast guano trade (from 1835), American and other gold rushes (from 1848), publication of Maury's sailing directions (1851), opening of the Suez Canal (1869), Chilean nitre trade (from 1873), opening of the Panama Canal (1914) and the First World War (1914–18). These events affect both the frequency of observations and the courses taken of far southern voyages.

Presently maritime traffic southbound around Africa or South America remains relatively sparse, although occasional closure of the Suez Canal, or drought in Panama, causes its resumption. Only exceptionally specialised cargo vessels currently use Drake Passage and most traffic in these waters is Antarctic bound for research, survey or tourism, with several ships often making multiple return crossings during a summer.

4. Technological factors

Technological factors influenced the number of ships plying these southern trade routes, and safety of navigation steadily improved. The evolution of steam-powered vessels throughout the 1800s led to them slowly displacing sailing vessels, and by the late 1800s these conducted most oceanic voyages, with colliers and bunkering stations of increased importance. Navigation through constrained passages, notably Magellan Strait, became more practicable, but it remained a minor, and dangerous, transit route until after 1896 when a series of lighthouses were built (Beros and Fernández Mallo, 1994).

Towards the end of the 1800s accounts of navigation, and the publication of *Warnings to Navigators* in mercantile and other gazettes, became more common (Headland, 2022). During the late 1800s records of ships not reporting appeared more frequently in *Lloyds List* and similar maritime newspapers, with a large proportion of those, which were never seen again, having been on routings which would have taken them through far southern waters. It is impossible to determine their fates but the circumstantial evidence suggests a collision with icebergs is a distinct possibility.

A consideration when compiling this database is that determining a ship's geographical location, especially longitude, was problematic until the production of reliable chronometers was established in the 19th century (Sobel, 1995). With smaller and less well-equipped vessels the positions of some of the icebergs in the database could be imprecise. In contrast, before the mid-18th-century latitude was accurately determinable through

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the use of a sextant and associated tables, when weather conditions allowed. Thus, although there is confidence in the latitude of iceberg observations, the longitude could be less accurate due to the lack of affordable chronometers for mercantile voyages prior to the late 19th century.

5. Meteorological and geographic factors

The latitudes of southern courses considered in this paper took vessels into and beyond the 'roaring forties' where gale-force, west-to-east winds result from the combination of warm air movements, Coriolis forces and the near absence of landmasses. Voyages rounding Africa have plenty of sea-way to navigate as Cape Agulhas is only 42°S although complex and perilous currents flow along both coasts of southern Africa which may cause storms with hazardous waves. South of Australasia vessels may exceed 48°S passing south of Stewart Island. These waters have hazards to navigation, two bearing indicative names: The Traps and The Snares. Farther south across shipping lanes lie the Auckland Islands which have a notorious record of eight known shipwrecks with probable others (Fraser, 1986).

The farthest southern navigation is around Cape Horn, below 56°S, where winds and currents of the eastbound 'furious fifties' are infamous. The Diego Ramírez Islands centred at 58.5°S and ~100 km south of Cape Horn have a substantial history of shipwreck. A lighthouse was established there in 1951. The sea way through the Drake Passage is also constrained by a reluctance of mariners to go south into waters increasingly likely to be encumbered by ice. The alternative passage, through the sinuous Magellan Strait, is not easy, but does not exceed 54°S, and although it is protected from oceanic swell, is subject to very strong local winds and currents.

During the period covered by this study, although vessels were as prepared as possible for maritime safety hazards given the limitations of the technologies, the risk was much greater, as they ventured into regions where there was little existing information on prevailing conditions, and further impediments to navigation including seasonal daylight duration and fog. Even with modern aids including radar, the small fragments of disintegrated icebergs may be difficult to detect when masked by anything more than a slight sea state. These fragments, 'growlers' if <5 m long and under 1 m high, and 'bergy-bits' for up to 15 m long and up to 5 m high, can still cause significant damage if a vessel collides with them at speed, as was experienced by MV *Explorer* on 23 November 2007 which sank in the Bransfield Strait.

Icebergs are possibly the origin of 'discoveries' of several non-existent Antarctic islands (Stommel, 1984; Swan, 1998). These, on the principle of erring on the side of safety, often appeared on charts. Twenty such islands and rocks are recorded in the database of historical iceberg reports, available at https://doi.org/10.5281/zenodo.8007770. Those relevant to this paper are: *Isla Grande* (46.67°S, 48.58°W), *Swain's Island* (59°S, 90°W), *Macy's Island* (59°S, 91°W), *Burdwood's Island* (54.15°S, 59.60°W), *Nimrod Island* (56.50°S, 158.50°W), *Dougherty's Island* (59.03°S, 120.03°W), *Pagoda Rock* (60.18°S, 4.72°E), *Undine Rock* (58.52°S, 41.80°W), *Strathfillan Rock* (54.68°S, 42.37°W), *Sevilla Rocks* (62.47°S, 23.68°W) and *Trulsklippen* (56.25°S, 23.75°E) (Headland, 2009). Other non-existent 'islands', which were also probably icebergs, have been reported in the Weddell Sea, Ross Sea and Bransfield Strait thus not relevant to this paper.

6. Discussion

The data for the analysis of records of Southern Hemisphere icebergs, derived from the historical sources listed above for 1687–1933, have been standardised and tabulated. A spatial plot of the data is shown in Figure 3, in which most iceberg sightings are displayed as red triangles. Sometimes the sightings are listed over a section of the vessel track, and in these instances the data are displayed as a red line. Non-existent islands, which we interpret as icebergs, are displayed in green.

It can be seen that the majority of observations are in the South Atlantic region to the east of South America. There is also a significant number of observations between Africa and Australia, despite satellite records Figure 2 showing an absence of icebergs in this area. In the rest of the region observations are sparse, but interestingly, many of those between New Zealand and South America are listed with a range of longitudes suggesting that if icebergs are seen in this regions they are likely to be in a groups; possibly indicating they originated from the same calving.

The probability of seeing an iceberg is very much dependent on whether the vessel encounters it during daylight. As mentioned previously, there are several events that affect the spatial distribution of sailing vessels in the higher latitudes of the Southern Hemisphere. To display these trade-driven variations visually, we have provided a decadal spatial 'heatmap' showing shipping data from the ICOADS historical database, with iceberg locations (Fig. 4). The number of distinctly named ships per 300 × 300 km polar stereographic map projection gridcell is displayed as a colour, ranging from light blue (low density of shipping) through to dark blue (high density), with white representing no ships in that region. Again red triangles indicate point sightings of icebergs, and red lines sightings along the course. From this figure we can also see how the number of vessels plying these different trade routes varied from one decade to the next. As the vessels tended to follow routes of near constant latitude rather than the shorter great circle route the icebergs sightings are clustered around these presumed courses. This is due both to it being easier to determine latitude, and avoiding uncharted, potentially ice-infested, waters farther south.

Historical events influenced the number of distinctly named reporting vessels plying the southern trade routes. The main events from 1780 to 1940 are displayed in Figure 5, with the annual number of iceberg sightings, and number of vessels in each of the three sectors. Interestingly, there was a slight increase in ship traffic within the sectors Africa to Australia and South America from 1830 to 1860. For much of the 1860s traffic diminished significantly in all three sectors. From 1870 it began to recover and by the 1880s a significant increase in the number of ships plying the South America, and Africa to Australia, sectors occurred. After 1890 the numbers again diminished significantly, but peaked again in the 1910s before declining after the Panama Canal opened in 1914. The influence of insurance costs is imponderable but might be a consequence of iceberg frequency within the 1890s and the 'perils of the sea'. The First World War reduced the amount of ship traffic generally. In the 1920s to the 1940s the number of ships plying the southern routes increased, albeit with some variability. By far the most frequented route was the South America sector, followed by the Australia to America sector. The South Pacific sector was not utilised as often.

The obvious correlation is between the number of ships plying the southern trade routes varying from one decade to the next, with the number of icebergs sighted. Between 1687 and 1859 very few iceberg sightings were recorded, mainly around the southern extremities of South America and Africa. Interestingly, in the 1860s most of the sightings were in the little-travelled South Pacific sector, where most vessels were eastbound, and many of the sightings there were over a range of latitudes, which suggests icebergs were ubiquitously spread over the region. In the 1870s and 1880s there was a cluster of icebergs to the east of

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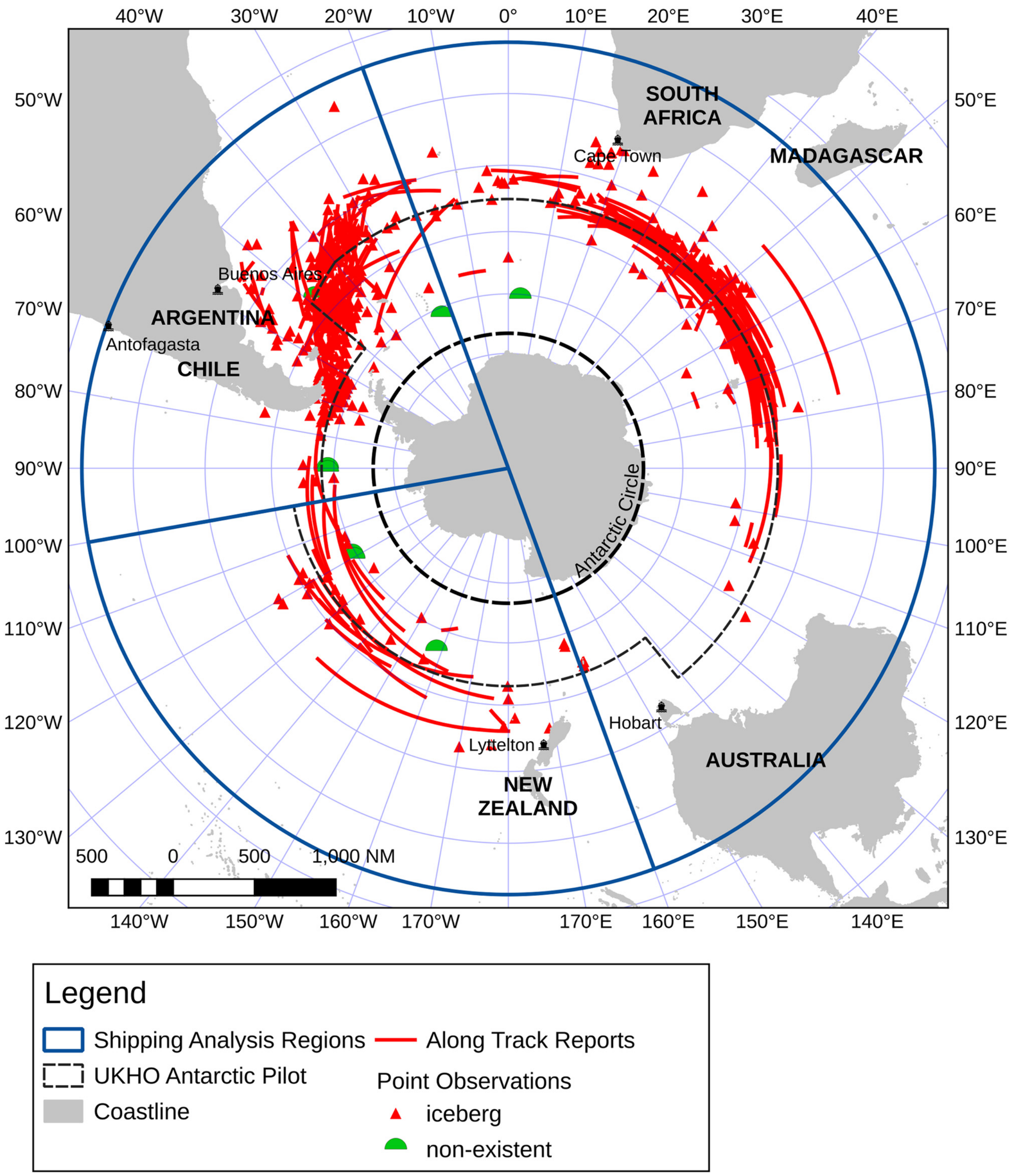


Figure 3. Overview of the iceberg dataset (1687–1933), including red triangles and green half-circles for positional sightings of icebergs and islands that were later confirmed to be non-existent, and red lines for where reports continued along the course of a voyage.

South America, however in the 1890s a significant number of sightings stretched from the South America sector to the Africa to Australia sector. This exceptional decade of iceberg sightings is described in detail below. By the 1900s the number of sightings had decreased significantly, with relatively few sightings during the 1910s and 1920s. The most northerly location for iceberg sightings for each of the three sectors are:

- **Australasia to South America (Pacific Ocean):** 43°S by *Star of England* on 19 October 1892 (Russell, 1895; Taylor, 2006).
- **African (South Atlantic and Indian Oceans):** multiple reports from 35°S in 1893 by the *Nora*, and Australasia bound ships, and in 1895 by the *Imberhorne*, *Bardowie* and *Port Chalmers* (Russell, 1895).
- **South American (South Atlantic and Pacific Oceans):** 26.83°S by *Dochra* on 30 April 1894 (Munn, 1911), the most northern record of a Southern Hemisphere iceberg.

It is noticeable that these most-northerly sightings occur in a 3 year period between 1892 and 1894.

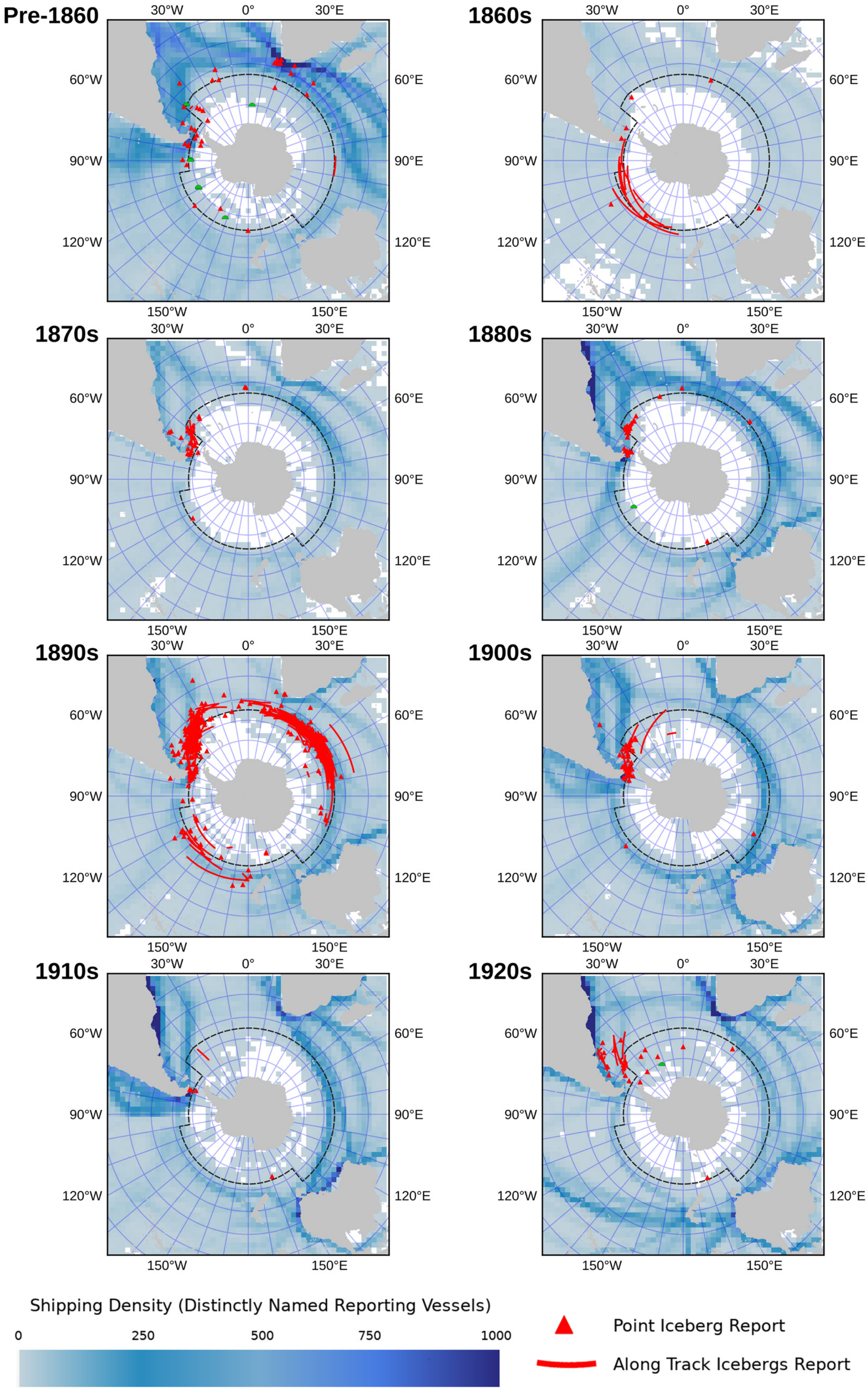


Figure 4. Iceberg observations for the years prior to 1860, and for each decade following, in comparison to the number of distinctly named reporting vessels per 300 km × 300 km gridcell from ICOADS database.

6.1 Exceptional events during the 1890s

Events of the 1890s are of major significance within the period covered by this paper. This decade was an exceptionally severe period for icebergs, with no less than four warnings to mariners published in the *Falkland Islands Gazette*, the only occasion when such announcements were made (Headland, 2022). The edition of 27 June 1894 reproduced *Admiralty Notice* 647 dated

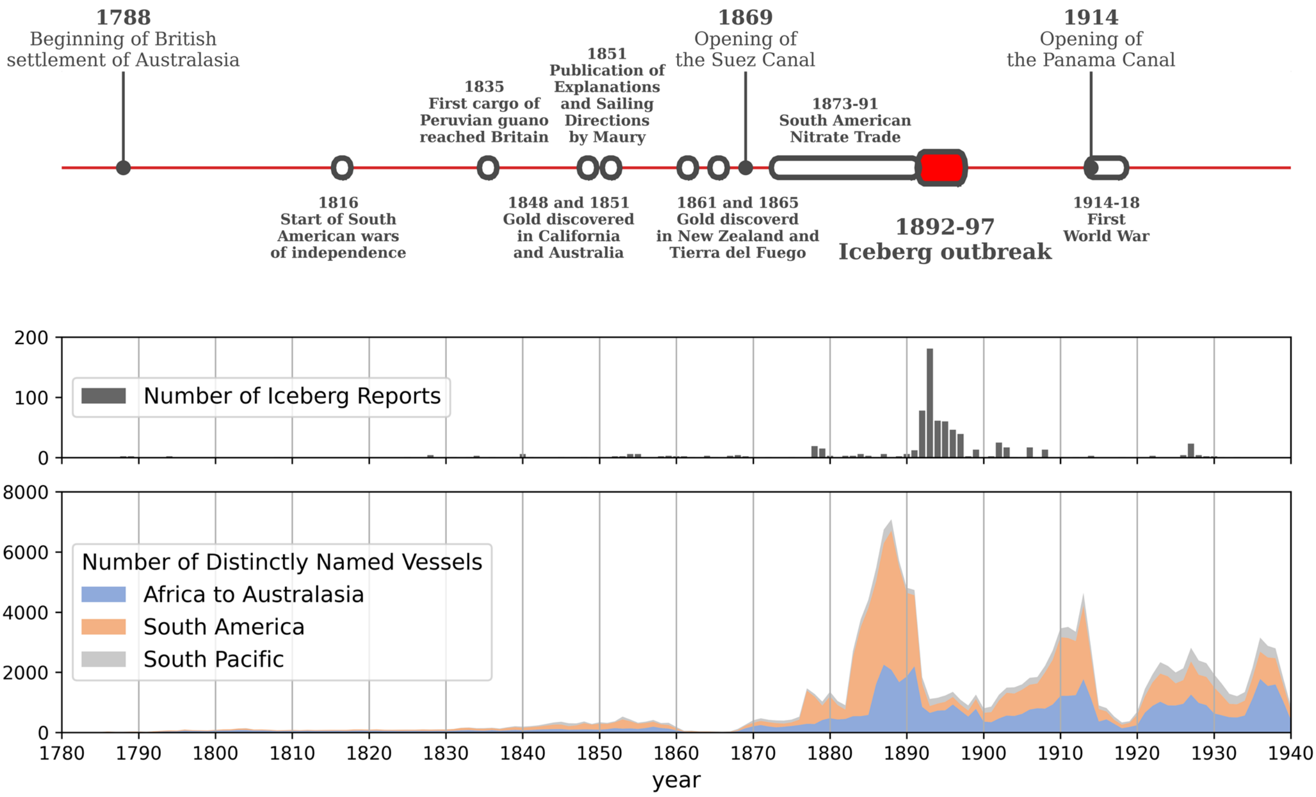
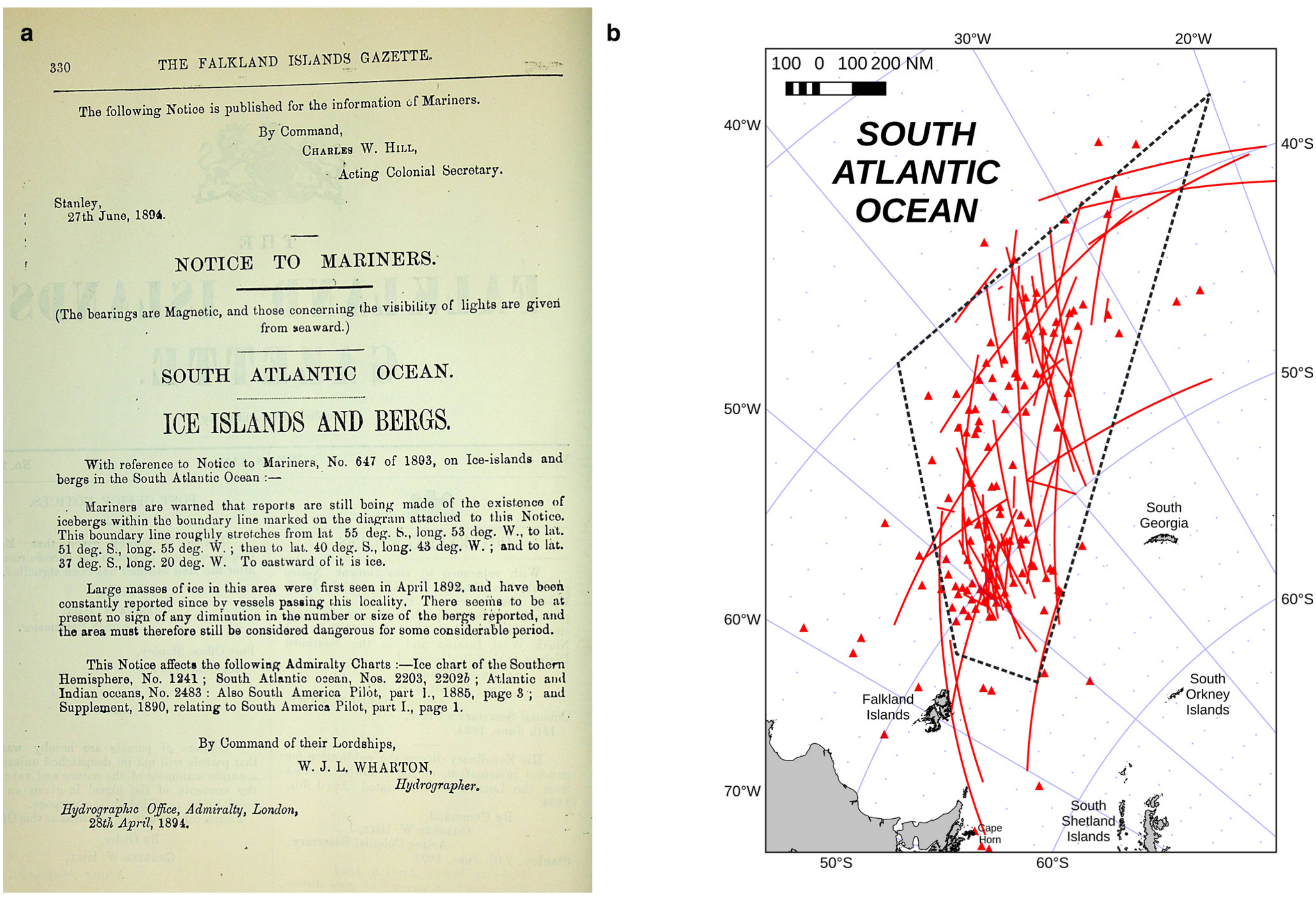


Figure 5. Timeline of notable historical events, the number of iceberg reports and numbers of distinctly named reporting vessels (data source: ICOADS) for analysis regions.


330 THE FALKLAND ISLANDS GAZETTE.

The following Notice is published for the information of Mariners.

By Command,
CHARLES W. HILL,
Acting Colonial Secretary.

Stanley,
27th June, 1894.

NOTICE TO MARINERS.

(The bearings are Magnetic, and those concerning the visibility of lights are given from seaward.)

SOUTH ATLANTIC OCEAN.

ICE ISLANDS AND BERGS.

With reference to Notice to Mariners, No. 647 of 1893, on Ice-islands and bergs in the South Atlantic Ocean :—

Mariners are warned that reports are still being made of the existence of icebergs within the boundary line marked on the diagram attached to this Notice. This boundary line roughly stretches from lat 55 deg. S., long. 53 deg. W., to lat. 51 deg. S., long. 55 deg. W. ; then to lat. 40 deg. S., long. 43 deg. W. ; and to lat. 37 deg. S., long. 20 deg. W. To eastward of it is ice.

Large masses of ice in this area were first seen in April 1892, and have been constantly reported since by vessels passing this locality. There seems to be at present no sign of any diminution in the number or size of the bergs reported, and the area must therefore still be considered dangerous for some considerable period.

This Notice affects the following Admiralty Charts :—Ice chart of the Southern Hemisphere, No. 1241 ; South Atlantic ocean, Nos. 2203, 2202b ; Atlantic and Indian oceans, No. 2483 : Also South America Pilot, part I., 1885, page 3 ; and Supplement, 1890, relating to South America Pilot, part I., page 1.

By Command of their Lordships,
W. J. L. WHARTON,
Hydrographer.

Hydrographic Office, Admiralty, London,
28th April, 1894.

Figure 6. (a) Notice to mariners with the limit of iceberg infested area as published by the *Falkland Islands Gazette* (Wharton, 1894). (b) Map of the quadrilateral mentioned in Figure 6a (black dotted lines), individual icebergs (red triangles) and icebergs occurring along vessel tracks (red lines) reported between 1892 and 1893.

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18 December 1893 that summarised these warnings noting a major zone of icebergs (Wharton, 1894), see Figure 6a.

The map in Figure 6b shows the irregular quadrilateral specified by the Notice to the Mariners (Fig. 6a) with the positions of icebergs from the database from the 2 year period spanning 1892 and 1893 also displayed. During this time the historical iceberg database has recorded 258 independent iceberg locations. To understand this significant iceberg event in detail we have provided maps from 1890 to 1898 showing iceberg reports and shipping density (Fig. 7).

The first report of an unusual amount of ice in this part of the South Atlantic was by Captain Andrew, of the *Cromdale*, in April 1892 (Trove, 1894) and our analysis also suggests that a significant number of icebergs drifted into the shipping lanes to the east of South America later in this year, with a few additional sightings of icebergs in the South Pacific between New Zealand and South America. In 1893 the majority of the South Atlantic icebergs were still east of South America, albeit with them occupying a larger spatial range, from near the South American coast to the seas south of Africa. During this year there was also a significant increase in iceberg sightings in the same vicinity of the South Pacific as was reported the previous year.

The record for 1894–95 is particularly intriguing, as the number of icebergs seen in the South Pacific drops off significantly, as also do the numbers reported to the east of South America. Interestingly, the number of sightings in the south-western Indian Ocean (between Africa and Kerguelen) increased significantly during this year. There is little traffic between the south of South America and Africa (white to light blue colour in Fig. 7), which may be the reason for the lack of iceberg sightings in this sector.

In 1895–96 there are still significant numbers of icebergs reported south-east of Africa, with reasonable numbers distributed within the seas between Africa and Kerguelen. During 1896–97 the nexus of significant numbers of iceberg sighting moved eastwards, towards Kerguelen, but in 1897–98 no evidence of this preponderance is evident and it is assumed that all iceberg remnants have melted. This mass iceberg event, or events, which was first seen in 1892, caused navigational impediments for at least 6 years. From satellite records (Fig. 2) and modern ship observations (Romanov and others, 2017; Orheim and others, 2023b), we can see that there is nothing comparable in the recent records either in the number of icebergs at northern latitudes or their longevity. Such large numbers of icebergs, or indeed icebergs in general, in the seas between Africa and Australia are particularly rare.

6.2 Speculation about the origin of the unprecedented 1890s event

Before we speculate on the origin of the numerous icebergs seen within the 1890s it is worth commenting on the possible trajectories and melt rates of Antarctic icebergs. To do this we take the recent and well-studied example of the A68a iceberg as a test case, which was the sixth largest iceberg ever recorded in satellite observations (Budge and Long, 2018). Braakmann-Folgmann and others (2022) review of the trajectory and disintegration of A68a revealed that it calved off Larsen C in July 2017 with an initial area of $5719 \pm 77\,km^2$. It then resided close to where it calved for over a year before eventually drifting northwards through the Weddell Sea, reaching the Scotia Sea in early 2020, just south of South Georgia at the end of 2020, and by mid-April 2021 it had practically melted away. This general drift of A68a tracks well with other large icebergs that originated in the region, the results of which can be found in the BYU database (see Fig. 2b).

Interestingly, Braakmann-Folgmann and others (2022) estimated that the mean loss rate while A68a was in the Weddell Sea was $200 \pm 82\,km^2\,a^{-1}$, but once A68a drifted into the warmer waters of the Antarctic Circumpolar Current (ACC), via the Scotia Sea, the loss rate increased by an order of magnitude to $2807 \pm 199\,km^2\,a^{-1}$, with basal melting peaking at 7.2 ± 2.3 m month^{-1} (0.23 ± 0.07 m d^{-1}) in the Northern Scotia Sea.

Recently, England and others (2020) proposed a fracturing mechanism for large tabular icebergs which is based on the 'footloose mechanism'. This inclusion of this mechanism in modelled iceberg trajectories provides better agreement with observations. Results suggest this mechanism extends the drift of icebergs from the Weddell Sea to the seas south of western Australia (135°E), see their figure 4c. This new discovery suggests that the icebergs located within the Indian Ocean sector could have originated from the Weddell Sea. It is also interesting to note that this is in agreement with a recent detailed account of the encounter of HMS *Guardian* with an iceberg in 1789, when eastbound in the south-west Indian Ocean. The iceberg was considered to have calved from the Filchner Ice Shelf (Martin, 2023).

In summary, with the new evidence from England and others (2020), we speculate that the origin of the icebergs are most likely originating from the Weddell Sea. Whether these are related to the same event that were seen in the Atlantic Ocean sector is not known. If so, there is a continuous large number of icebergs sightings over 6 years, firstly into the Atlantic Ocean sector and then into the Indian Ocean sector all with an origin in the Weddell Sea.

Based upon these results, with drift tracks from the BYU database, it suggests that icebergs can travel for many years in the Antarctic coastal current, or be grounded at various points around the continent, but once they drift into the ACC their existence is probably less than a year. This conclusion accords with Orheim and others (2023a).

Given this knowledge it is possible that there were a series of major outbreaks, in the 1890s, at different locations around the continent that occurred within a few years of each other. While this, at first, sounds improbable, over the past 60 years at least three near-coincident calvings of icebergs, $>5000\,km^2$, have occurred around the continent. Examples given in Orheim and others (2023b), Table S8, include:

(1) Amery Ice Shelf (1963/1964) AND Fimbulisen (1967).
(2) Larsen Ice Shelf (A20: 1986) AND Filchner-Ronne Ice Shelf (A22: 1986) AND Filchner-Ronne Ice Shelf (A23: 1986) AND Filchner-Ronne Ice Shelf (A24: 1986) AND Ross Ice Shelf (B09: 1987).
(3) Ross Ice Shelf (B15: 2000) AND Filchner-Ronne Ice Shelf (A43: 2002) AND Ross Ice Shelf (C19: 2002).

When interpreting these historical records some of the potential limitations should be remembered. These include: (1) the iceberg observations are at the very southern limit of the shipping lanes, and nothing of the density of icebergs to the south of these observations is known (white regions of Fig. 7), (2) the data within Figure 7 are split by year standing in July and ending in June, which can lead to misinterpretation of these data especially those near the start and end of the consecutive periods, (3) there is the possibility of several ships seeing the same icebergs, thus exaggerating the numbers seen at that locality and (4) the language of the reports can be somewhat qualitative, having originated from mariners with a non-scientific background, and subsequently reinterpreted by journalists.

To provide a flavour of some of these reports, several first-hand descriptions before the 1890s event suggest that encounters with numerous icebergs in a small region are rare, but not uncommon. Examples of notes from observers include: 'constantly in ice and

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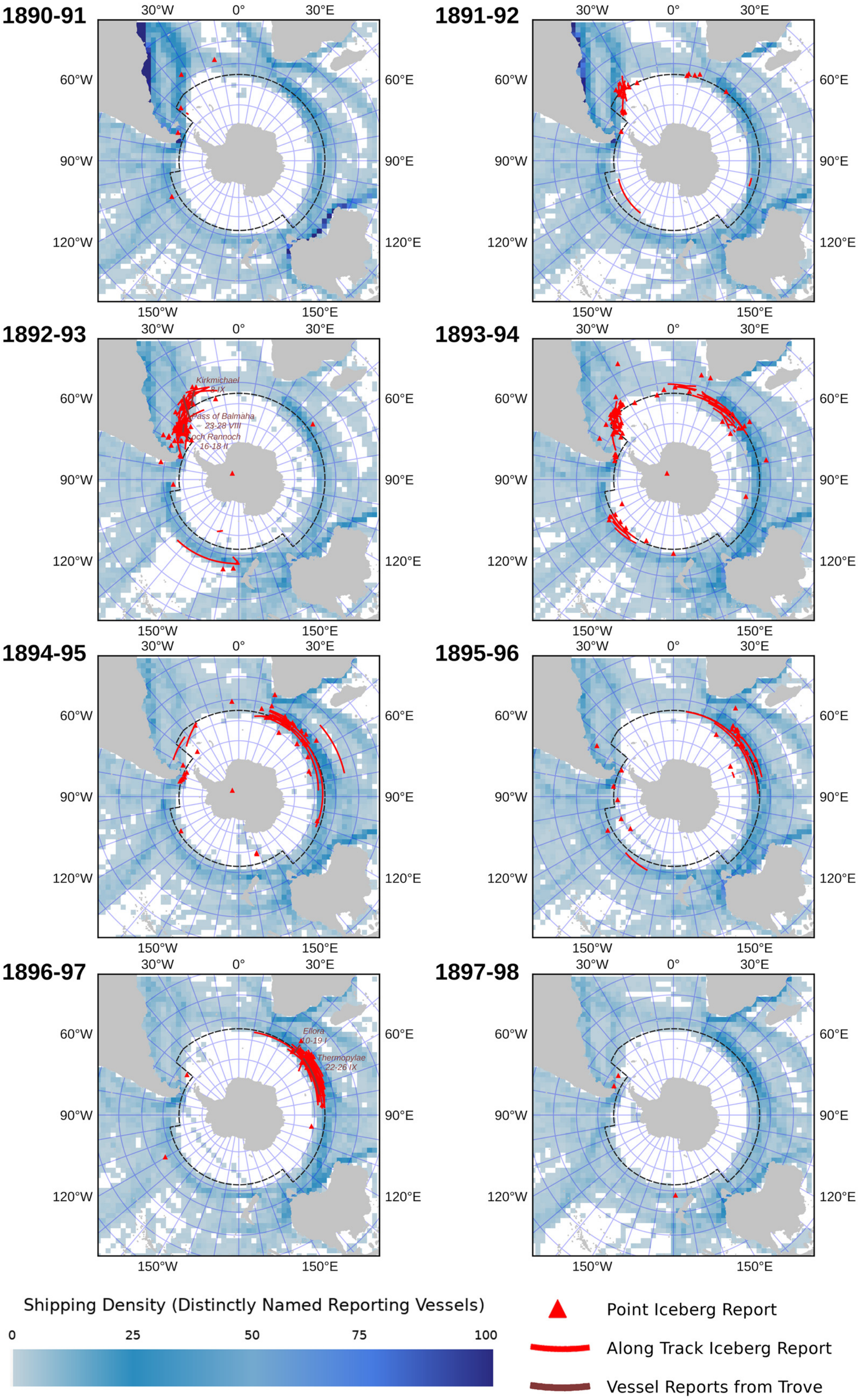

Figure 7. Iceberg observations for July to June for 1890–91 through to 1897–98, in comparison to the number of distinctly named reporting vessels per 300 km × 300 km gridcell from ICOADS database. Voyages of vessels referenced in the text during this period and listed in Table 1 are highlighted in dark red. Note: Years are based upon the austral winter and run from July to June the following year.

bergs until reaching Cape Horn' (*Sirius*, 1788), 'surrounded by bergs and barely escaped destruction' (*Golden Era*, 1854), 'in great danger for 5 d surrounded by huge ice masses' (*Omar Pasha*, 1868).

However, during the 1890s there are significantly more examples, from Kozian (1994), Lubbock (1948) and Swan (1998), as well as appearing in numerous Trove newspaper scans. These describe substantial icebergs and provide some examples of the

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Table 1. Dates and positions of ice-encountering vessels quoted in the text and, for the period 1891–98, shown in Figure 7

Vessel	First ice			Last ice			Type	Reference
	Date	Latitude	Longitude	Date	Latitude	Longitude		
HMS *Sirius*	1788-11-23	57°S	76°W	N/A	N/A	N/A	Unspecified	Swan (1998)
Golden Era	1854-11-DD	63°S	72°W	N/A	N/A	N/A	Unspecified	Towson (1859), Jones (1985), Swan (1998)
Omar Pasha	1868-03-05	54.67°S	120.5°W	1868-03-12	56.53°S	92.4°W	Unspecified	Swan (1998)
Pass of Balmaha	1892-08-23	49.5°S	38.52°W	1892-MM-DD	39°S	34°W[a]	All incl. tabular	Trove (1893a)
Kirkmichael	1892-09-07	43.98°S	32.23°W	1892-09-11	39.12°S	45.13°W	All incl. tabular	Trove (1892)
Loch Rannoch	1893-02-16	51.16°S	49.33°W	1893-02-18	49.22°S	26.85°W	All incl. tabular	Trove (1893b)
Thermopylae	1896-09-22	45.15°S	49.24°E	1896-09-26	46.5°S	75°E	All incl. tabular	Trove (1896)
Ellora	1897-01-10	46°S	41.78°E	1897-01-19	42.06°S	41.17°E	Unspecifed	Trove (1897)

Last ice date and position are not applicable (N/A) for point reports.
[a]Longitude inferred.

vessels, dates and positions that are also listed in Table 1 and shown in Figure 7, with their comments including the *Loch Rannoch*: 'At daybreak on 18th February nothing was to be seen from the masthead, except ice mountains and bergs' (Trove, 1893b) ~375 nautical miles east of the Falkland Islands, and the *Thermopylae* 'Altogether fully 100 bergs, all dangerous to navigation, were seen from the deck of the *Thermopylae* in a space of 1000 miles long by 20 miles broad. Probably as many more were distributed over this area which were not seen in the darkness and during the heavy snow showers' (Trove, 1896) just south of the Antarctic Circle in the southern Indian Ocean to the west-northwest of Kerguelen.

From the *Pass of Balmaha* in the southwest Atlantic Ocean, ~750 nautical miles east of Falkland Islands in August 1892, 'At 7 a.m. as many as 96 bergs could be counted from the deck, some being two miles in length… As far as the eye could see from the masthead nothing could be seen but ice… How far this ice extended east and west it is impossible to say, as from aloft the ends of barrier could not be seen' (Trove, 1893a).

Many experienced observers', such as those aboard *Kirkmichael* on 8 September 1892 ~40°S in south Atlantic and 1100 nautical miles northeast of the Falkland Islands, indicate their astonishment of the quantity, amount of brash ice and lack of open water surrounding the vessels: 'As far the eye could see, there was not anything to be discerned but icebergs all around, far too numerous to count. It was a very clear day, the sun shining brightly. There was not more than half a mile of a passage between any of them, and that always pretty thickly studded with drift-ice, and at other times little more than room for the ship to sail through. Many of the bergs were connected together by boulders of ice' (Trove, 1892).

There are also reports of ships being beset, such as *Ellora* (Trove, 1897) ~1200 nautical miles southeast of the Cape of Good Hope; 'On January 10, when she had reached latitude 40 degrees south, longitude 41 degrees 47 mins. east, at midnight the vessel touched some drift ice and although there was much fog and occasionally heavy rain showers, it was found she was in the vicinity of several icebergs. Next day the vessel was completely beset'.

From Figure 7 it can be seen that there are potentially three major iceberg occurrences that occurred during this period:

(1) Atlantic Ocean sector, occurrence first seen in 1891–92.
(2) Indian Ocean sector, occurrence first seen in 1893–94.
(3) Pacific Ocean sector, occurrence seen only in 1893–94.

6.2.1 Atlantic Ocean sector (seasons 1891–92 to 1893–94)

We speculate that a calving from the Weddell Sea is the probable source, possibly major calving in the vicinity of the Ronne or Filchner Ice Shelf. If we assume that the icebergs were able to freely drift once calved, then it would take about a year to drift into the region where they were a hazard to mariners (see quadrilateral in Fig. 6b). Historical precedent is provided, within two decades of the 1890s, by the drifts of *Deutschland* in 1913 and *Endurance* in 1915 when the ships became beset off the southern shores of the Weddell Sea. Both ships drifted within the pack to its northern extent during 11 months (January–November). The former ship escaped, but the latter was crushed and sank (Shackleton, 1919; Filchner and others, 1922). While icebergs and sea ice do have different drift trajectories, it provides an indication of drift timings for that period.

Based upon modern records, see Figure 2, Schodlok and others (2006) and the commentary on iceberg A68a (Braakmann-Folgmann and others, 2022), icebergs that leave the Weddell Gyre are swept in a northeast direction towards South Georgia. Once they join the ACC they generally continue to drift eastbound. This drift trajectory would place them first into the shipping lanes of the South Atlantic Ocean for about a year before they completely melt. All the while presenting a hazard to navigation, especially prior to radar and similar technologies. It is interesting to note that A68a, the sixth largest iceberg in the satellite era, broke up near South Georgia and did not become a threat to the South Atlantic shipping lanes by entering the quadrilateral shown in Figure 6.

Intriguingly, the South Atlantic region was also infested by icebergs in the following two years, 1892–93 and 1893–94. This could be explained by (1) further calving events in the Weddell Sea region the following year/s, (2) large fragments of the original calving in the Weddell Sea being grounded for a period, or they took a different trajectory, thus arriving one or two years late or (3) the icebergs did not originate in the Weddell Sea.

An alternative potential source for this outbreak is that it originated in the Bellingshausen, Amundsen and Ross Sea. In this sector icebergs drift away from the coast and are swept east towards the Drake Passage. Any icebergs that survive could then drift northwards in the Falklands Current along the Atlantic edge of the South American continental shelf.

There is precedent as in November 2002 an iceberg 700 m long and 50 m high was observed 123 nautical miles (228 km) east of the Buenos Aires seaside resort of Mar del Plata in Argentina at a latitude of 39.39°S (Diario El Día del la Plata, 2002). It is speculated that this iceberg originated from west of Drake Passage before being captured by the Falkland Current. There is some historical evidence of icebergs being within Drake Passage (Fig. 4), with a large number of sightings during 1902–04, but in the contemporary record only one large iceberg, B10a in 1999, has transited through. The increase in sightings in the Pacific Ocean sector in 1893–94, see below, is therefore too late to be linked to the large number of sightings in the South Atlantic from 1891–94. England and others (2020) shows the potential of icebergs from the Bellingshausen, Amundsen and Ross Sea sector to drift through Drake passage (their figure 4c). However, we can only find two other large icebergs that have approached Drake Passage from

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the west, but both disintegrated to a small size which meant tracking was stopped before they reached the area. C19a in 2009 reached 98°W, and B31 in 2018 reached 69°W. Smaller icebergs originating from these potentially transited the Drake Passage, but further study and investigation of the satellite archives would be needed to confirm this.

In summary, we hypothesise that there was a calving that originated in the Weddell Sea prior to 1891, and once they started to drift (1892) the icebergs would have drifted into the seas east of Falkland Islands and the South Atlantic shipping lanes. The icebergs seen in the region in the following two years (1892–94) could have originated from the same outbreak, but were delayed due to grounding and possible trajectory differences. Interestingly, recent large iceberg releases in this area, for example A68 in 2020–21 and A76 in 2022–23, have remained in the seas around South Georgia, and not drifted as far north. Therefore it seems there were exceptional factors affecting the 1891–92 event that allowed a larger number of icebergs to cross the ACC and enter the Falkland Current.

Another exception for this event is its longevity, not only did it inject icebergs into the Atlantic sector from 1891–92 through to 1893–94, but significant numbers were sighted in the Indian Ocean sector, between 1893 and 1896. Below we hypothesise that these too may have come from the Weddell Sea region.

6.2.2 Indian Ocean sector (seasons 1893–94 to 1896–97)

The Southern Indian Ocean occurrence of icebergs was first seen in the 1893–94 season by which time iceberg sightings had extended from the eastern reaches of South Atlantic to south-western regions of the Indian Ocean. The maximum number of sightings in the Indian Ocean sector was a few years later, in the 1896–97 period, which was then followed by no sightings in 1897–98.

Given the magnitude and location of the outbreak, it is difficult to understand where these icebergs could come from, other than being associated with the Weddell Sea. This begs the question, how does a continuous stream of icebergs exit the Weddell Sea for such an extended period?

It is possible that icebergs from a major breakout in the Weddell Sea were delayed through a combination of groundings, along with possible delays due to transits through winter sea ice of the Weddell Sea. It is not unusual for icebergs to be released from the Weddell Sea Gyre further east, a pattern clearly seen in the BYU dataset (Fig. 2b), which would assist them in reaching the Indian Ocean sector. However, breakouts from the Weddell Sea, within the BYU dataset have a maximum easterly limit that lies in the region south of Africa. Although it should be remembered that smaller icebergs cannot be detected by the BYU algorithm, this uses enhanced resolution images with pixel sizes varying between 2.225 and 8.9 km pixel^{-1} (Budge and Long, 2018).

6.2.3 Pacific Ocean sector seen only in 1893–94 season

Although there were some sightings of icebergs in the South Pacific between New Zealand and South America during the seasons 1891–92 and 1892–93 these were not considered unusual. However, it was during the 1893–94 season that significant sightings were made. We speculate that the source of these icebergs was the Bellingshausen, Amundsen or Ross Sea, and not the same source as the icebergs observed in the South Atlantic and Indian Ocean sectors. The pattern of iceberg drift, as shown in the BYU data in Figure 2b, shows some modern icebergs drift into this area. These sightings were only during the 1 year, 1893–94, and consistent with the duration of an iceberg drifting into the ACC.

7. Conclusion

The analysis of historical shipping trade routes in the Southern Hemisphere, with their observations of icebergs demonstrates the sporadic consequences icebergs had when they then drifted into shipping routes.

Our production of a historical iceberg database develops the review of Horsburgh (1830) and extends knowledge between 1687 and 1933. During this period we find only one example of significant numbers of icebergs within the southern shipping channels: the 1890s event. This manifested as numerous icebergs being seen by mariners in the three sectors around the Antarctic: (1) Atlantic Ocean sector (seasons 1891–92 to 1893–94), (2) Indian Ocean sector (seasons 1893–94 to 1896–97) and (3) Pacific Ocean sector seen in the 1893–94 season.

The origin of the icebergs seen in the Atlantic and Indian Ocean sectors was most likely the Weddell Sea. Whether these icebergs were from the same calving event is an open question. Once calved, this armada of icebergs would have drifted in the Weddell Gyre eventually drifting into shipping lanes of the South Atlantic and Indian Oceans. We speculate the source of the icebergs seen in the Pacific Ocean sector, in the 1893–94 season, was from the Amundsen or Ross Sea.

Recent massive calvings from the Ross Ice Shelf, sections of the Larsen Ice Shelf and elsewhere have released numerous icebergs during the satellite period (e.g. Rack and Rott, 2004), but none of these have demonstrated the release of such an unprecedented amount of sightings into the Southern Ocean as that of the 1890s, especially in the waters north and west of the Falkland Islands and the Indian Ocean sector. Furthermore, Horsburgh's (1830) review of the journals for the ships belonging to the East India Company during the 18th century contained no account of icebergs encountered as these ships sailed between Britain and India on courses that took them south of Africa (the Indian Ocean sector). This, and other evidence in the 19th century (Fig. 4), could suggest that there may have been a dearth of calving prior to the 1890s calving events, thus allowing for larger portion of ice shelves to become unstable in the 1890s.

Based upon the historical and modern data, the evidence suggests that the 1890s events were one of the largest efflux of Antarctic icebergs ever recorded within shipping channels. Given the stresses on the Antarctic ice sheet due to climate change, whether these mass carving events from the Ross Ice Shelf, sections of the Larsen Ice Shelf and elsewhere will become more frequent is an open question.

With significant historical newspaper resources coming on-line, such as the Australian Trove repository or the UK's British Newspaper Archive, further detail on iceberg sightings within the shipping lanes of the Southern Ocean in the pre-satellite era are just waiting to be found. A more comprehensive historical iceberg database would provide further clarity to the geographical and chronological occurrence of icebergs in the southern ocean over the last 300 years.

Data. The table of historical iceberg reports, including identification of report sources, can be found in text, spreadsheet and Shapefile formats in the *Operational Polar Remote Sensing and GIS* community repository at https://zenodo.org/communities/polarops and has the DOI https://doi.org/10.5281/zenodo.8007770.

The following openly available datasets were analysed for this study:

AltiBerg database of iceberg detections from satellite altimeters can be found at Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), France at ftp://ftp.ifremer.fr/ifremer/cersat/projects/altiberg/.

Brigham Young University (BYU) database of large Antarctic iceberg tracks (Budge and Long, 2018) is available at https://www.scp.byu.edu/data/iceberg/.

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International Comprehensive Ocean-Atmosphere Data Set (ICOADS) providing marine meteorological observations and historical vessel activity can be found at https://icoads.noaa.gov/.

The Scientific Committee on Antarctic Research (SCAR) International Iceberg Database, as described in Orheim and others (2023b), can be accessed at https://www.scar.org/resources/iceberg-database/.

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