Met.O. 904

The Marine Observer

A quarterly journal of Maritime Meteorology

Volume XLVII No. 256

April 1977

£1·25 net

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THE MARINE OBSERVER

A QUARTERLY JOURNAL OF MARITIME METEOROLOGY PREPARED BY THE MARINE DIVISION OF THE METEOROLOGICAL OFFICE

VOL. XLVII No. 256 APRIL 1977

CONTENTS

Letters to the Editor, and books for review, should be sent to the Editor, 'The Marine Observer', Meteorological Office, Eastern Road, Bracknell, Berkshire RG12 2UR

Published for the Meteorological Office by

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Report of Work for 1976

(MARINE DIVISION OF THE METEOROLOGICAL OFFICE: VOLUNTARY OBSERVING FLEET AND OCEAN WEATHER SHIPS)

1. Voluntary Observing Ships

At the end of the year the British Voluntary Observing Fleet was composed as follows:

(*a*) 522 Selected Ships, including 10 trawlers, which are supplied with a full set of meteorological instruments on loan and which make observations in code every six hours and transmit them to the appropriate coastal radio station wherever their voyages take them.

(*b*) 41 Supplementary Ships, including 10 trawlers, which make less-detailed observations than Selected Ships and are supplied on loan with only a barometer, air thermometer and screen. They use an abbreviated code for their messages.

(*c*) 56 coasting ('Marid') vessels which make sea-surface temperature observations in UK coastal waters and transmit them in a special code by W/T or R/T. When in the North Sea, the coasting ships include in their messages wind, weather and visibility observations.

(*d*) 13 light-vessels and 1 light-tower which make observations of wind, waves, visibility, air and sea temperatures; all of these send coded reports by R/T. Reports from the Royal Sovereign light-tower and the *Galloper*, *Dowsing* and *Varne* light-vessels are included in the BBC weather bulletins for shipping and all four report barometric pressure, using the precision aneroid. The first two also report barometric tendency.

(*e*) 14 trawlers which make non-instrumental observations only and transmit them by W/T or R/T, using an abbreviated code, to radio stations in the UK, Canada, Iceland, Norway or USSR depending on the area in which they are fishing.

(*f*) 9 Auxiliary Ships which make and transmit visual observations similar to those made by trawlers, with the addition of pressure and air temperature readings from the ships' own instruments (using the 'Shred' code). These ships do this work only when in areas where shipping is known to be sparse.

As the oceans occupy three-quarters of the world's surface, the value of regular weather observations from oceanic areas is obvious both for forecasting and for climatological purposes. With the exception of HM ships, Ocean Weather Ships and research vessels, these surface observations from the oceans are provided entirely voluntarily by the masters and officers of merchant ships and the organization for obtaining them has been, since 1855, the responsibility of the Marine Division. The vessels from which these observations are made form what is termed the British Voluntary Observing Fleet and the ships vary from passenger liners and general cargo ships to coastal vessels and distant-water trawlers. The numerical strength of the UK Voluntary Observing Fleet is about 550 ships and has remained almost static during the year due to the number of recruitments balancing the withdrawals, due to ships being sold or laid up for long periods. The direct administration of the Voluntary Observing Fleet is under the control of the Marine Division and local administration is delegated to its seven Port Meteorological Officers who are stationed at major ports in the UK. These officers are all master mariners with considerable experience of voluntary observing at sea. They are responsible for the recruitment of ships and the supply and replenishment of meteorological instruments which are supplied on loan to the vessels. Port Meteorological Officers maintain personal contact with the masters, deck and radio officers and advise and instruct officers in the techniques of observing at sea. There can be little doubt that the personal touch, bringing goodwill on both sides, has been a major factor in maintaining the high quality of the observations received from these voluntary observers at sea. Throughout their voyage the officers aboard voluntary observing ships record their observations in logbooks in addition to transmitting them by radio, and, at the end of the voyage, these logbooks are returned to the Marine Division for scrutiny and extraction of the data.

The British Voluntary Observing Fleet includes ships of many shipping companies and Table 1 shows the variety of trade routes on which they are engaged.

Table 1. Average number of British Selected and Supplementary Ships on main trade routes to and from the UK

Europe	69	West Indies	25
Australasia	49	South America	17
Far East	78	Pacific Coast of North America	8
Persian Gulf	30	Falkland Islands and Antarctic	2
South Africa	30	World-wide 'tramping'	151
West Africa	12	Near and distant-water fishing grounds	20
North Atlantic	72		

Acknowledgement should once again be made of the valuable service rendered by many Commonwealth and foreign Port Meteorological Officers for their services in the replacement of defective instruments in UK Selected Ships on protracted voyages, and the withdrawal of instruments from British vessels which have been sold abroad to foreign interests. The timely intervention of the foreign Port Meteorological Officers has been of immense assistance to us as the number of vessels ending their British sea-going career in ports abroad has been increasing considerably.

The building program of the the Merchant Navy is directed mostly towards larger and faster ships whilst the whole tendency of seaborne trade is towards the container type vessel, bulk carrier and super-tanker. As these vessels spend less time in port than their predecessors, the number of observations received has increased steadily over the years.

During two typical five-day periods, one in June and one in November, the average daily number of reports from ships received in the Central Forecasting Office at Bracknell from various sources is shown in Table 2.

The policy of installing distant reading meteorological equipment in merchant ships under construction, in order to ease the work-load of the observing officers, continues to receive the whole-hearted support and co-operation of shipowners.

2. Ocean Weather Ships

The World Meteorological Organization (WMO) Agreement for Joint Finances of North Atlantic Ocean Station (NAOS) having only recently come into force, the UK continued the interim agreement and the British Weather Ships, *Weather Surveyor* and *Weather Reporter*, manned station Lima (57° 00′N 20° 00′W) continuously throughout the year thus completing 17 years service as weather ships and completing 32 years since they were commissioned as Castle Class Frigates for the Royal Navy. Arrangements having been completed to refurbish the *Weather Adviser* and *Weather Monitor* to extend their service to about the end of 1981, the ships sailed from Glasgow to Manchester in early July to commence the refit program. It is anticipated that they will return to service early in 1977 and take over station duties from their UK sister weather ships. The refurbishment will consist of improvements

Table 2. Average daily number of reports received at Bracknell by various sources from ships during 1976

	JUNE	*NOVEMBER*
Direct reception from		
British ships in eastern North Atlantic	122	130
Foreign ships in eastern North Atlantic	115	91
British ships in North Sea	19	28
Foreign ships in North Sea	4	2
Ships in other waters	6	4
Total	266	255
Via other countries		
Ships in eastern North Atlantic	409	376
Ships in western North Atlantic	299	288
Ships in Mediterranean	58	63
Ships in North Sea	79	96
Ships in Arctic Ocean	42	47
Ships in North Pacific	603	809
Ships in other waters	363	239
Total	1853	1918

to accommodation, crew recreation spaces, automation of the boiler controls, installation of the new upper-wind finding equipment (NAVAID) and the complete modernization of the communications equipment. The weather ships make hourly surface and six-hourly upper air observations. The following additional observations were made at regular intervals by the two British weather ships: solar radiation, sea temperature and salinity to considerable depths, collection of rain water for analysis by the International Atomic Energy Agency, plankton net hauls made for the Institute of Oceanographic Sciences, samples of sea water at monthly intervals collected for an International Atomic Energy Agency/WMO tritium Survey, sea water samples collected to and from station for monitoring radioactive content, reporting of floating pollutants for the Intergovernmental Oceanographic Commission/WMO pilot project on marine pollution monitoring. Sea and swell records were maintained throughout the year using the Tucker shipborne wave recorder.

3. Ship Routeing

A ship routeing service is provided to advise on North Atlantic and North Pacific passages and to offer advice in regard to the movement of tows. In the case of cargo vessels the object of the service is to select the best course for a ship to steer in order to reach its destination in the shortest time with the least damage to hull and cargo and with the most economical fuel consumption. The vessel's response to various wave fields is determined by extracting sufficient data from the deck logbooks and a ship/wave performance curve is constructed. Wind and sea wave predictions at intervals of 12 hours for up to 72 hours ahead are supplied to the ship routeing officers by forecasters of the Central Forecasting Office and this information is applied to the performance curve to determine the most favourable course for the vessel to follow. Subjective consideration is given to the loading state of the ship, to surface currents, navigational hazards such as shoals, ice and to areas of fog, also to later stages of the voyage. Communication with the vessel is usually by telex before sailing and via pre-determined coastal radio stations when the ship is on passage. The provision of routeing advice to tows which do not have too restrictive weather parameters is similar to that for conventional ships but allowance has to be made for the slower speed of the tow and for their reduced manoeuvrability. In the case of tows with limiting weather factors which may be wave height or period or amount of heel or wind force, the routeing service advises when and where to seek shelter and when to resume passage.

About 300 routeings including tows were made during the year.

4. Services for Marine Activities

During the year the Marine Division conducted a survey within the shipping industry to obtain opinions regarding the meteorological services available to the industry. Response to the questionnaire issued was most encouraging and ranged from brief comment to very full treatment of the subject, the full results of the survey have still to be analysed and the relevant authorities consulted, but it is pleasing to record that it would appear no major changes or improvements have been requested.

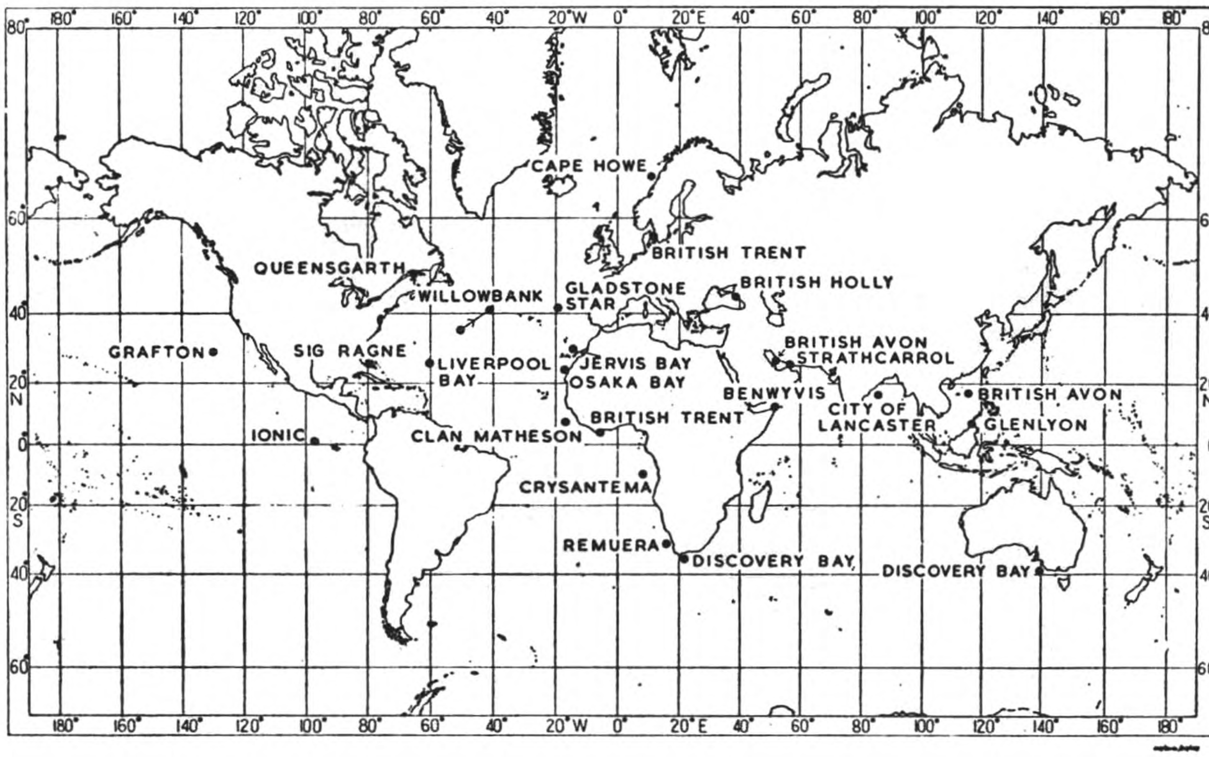
General services to shipping via BBC Radio 2 and the Post Office coastal radio stations continued as in previous years. To meet the growing demand from local fishermen and yachtsmen a new service has been introduced on BBC Radio 3. This service provides an inshore waters forecast every morning for the whole of the United Kingdom and supplements the inshore waters forecast given daily towards the close down on BBC Radio 4. The Marine Division has also sponsored the printing of a new Coastal Waters Plotting Chart to be used onboard in conjunction with the reception of BBC Radio 2 forecasts. Copies of these charts are available from Port Meteorological Offices.

5. Inquiries

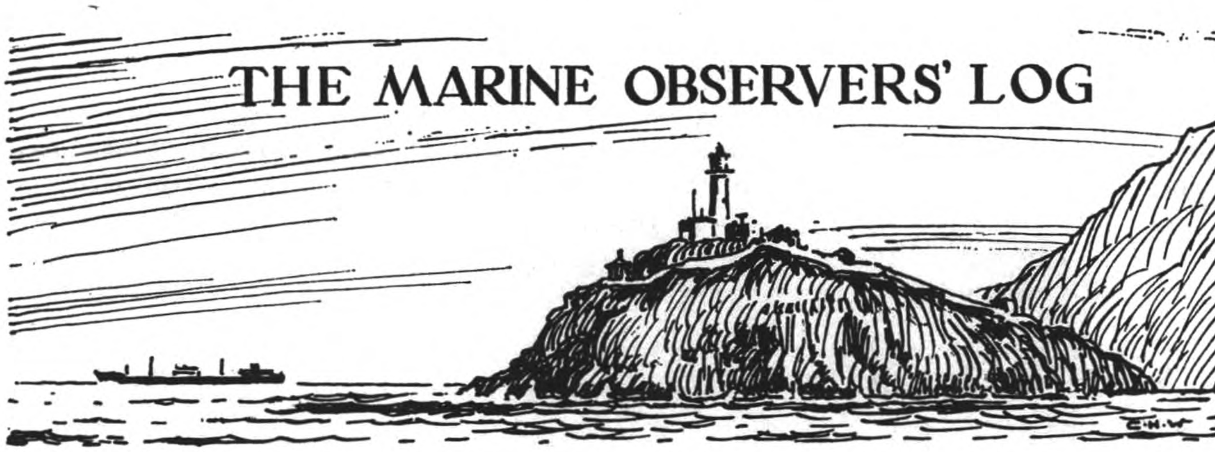
The number of marine enquiries has continued to rise and amounted to 520 during the year. The inquiries are mainly from official organizations, solicitors, insurance companies, shipping interests, universities and industrial firms in the British Isles. The subjects of inquiries are extremely varied and have included a request for the weather conditions at the time of the sinking of HMS *Victory* on 3 October 1744, the sea conditions at the probable abandonment of the *Marie Celeste* between 7 and 25 November 1872 and a more recent event, the weather conditions in the Bay of Biscay on 12 March 1976 when the British container vessel *Frendo Star* developed a heavy list due to the cargo shifting and the crew had to abandon ship.

6. Awards to Voluntary Observing Ships

Awards of books were, as customary, made to the shipmasters, principal observing officers and radio officers who have been responsible for submitting the 100 best meteorological logbooks during the year. Awards were also made to masters and officers of vessels on the short sea trades for their contribution in making sea-surface temperature observations. Trawler skippers and radio officers who had the best records in making and sending non-instrumental observations from the fishing regions also received awards. The books selected for these awards were *The University Atlas*, *Cassell's English Dictionary* and *The Life-giving Sea* by David Bellamy. Barographs were presented to four masters whose long record and consistently good service were considered as deserving of special recognition.



Position of ships whose reports appear in 'The Marine Observers' Log'



April, May, June

The Marine Observers' Log is a quarterly selection of observations of interest and value. The observations are derived from the logbooks of marine observers and from individual manuscripts. Responsibility for each observation rests with the contributor.

Observing officers are reminded that preserved samples of discoloured water, luminescent water, etc. considerably enhance the value of such an observation. Port Meteorological Officers in the UK will supply bottles, preservative and instructions on request.

TYPHOON 'OLGA'

South China Sea

m.v. *Glenlyon*. Captain A. MacKenzie. Brunei to Manila. Observers, the Master and ship's company.

19 May 1976. The vessel left Brunei for Manila via the Balabac Straits. The

weather at the time was good with a SE'ly, force 3 wind. After passing through the Balabac Straits at 0001 GMT on the 20th the wind became SW'ly, force 4 and a steady fall in barometric pressure over the next 16 hours was noted; after this time the pressure became steady at 995 mb.

During the vessel's passage through the Mindoro Straits the wind freshened to become W'ly, force 8 and the visibility was reduced to nil in heavy rain. At 2200 when the vessel was 5 n. mile from Cobra Island, all radar echoes were lost for about half an hour.

When the vessel steamed into Manila Bay we were informed that the port was closed because of Typhoon Olga, or Didang as it was named in the Phillipines; we therefore proceeded to safe anchorage off San Nicholas Shoal Light. The lowest pressure recorded while the vessel was at anchor was 992·1 mb at 0800 on the 21st, after which time the pressure remained more or less steady for the next 24 hours.

Meanwhile Olga was reported to be heading westwards very slowly with winds at the centre up to 50 knots. At 0300 on the 22nd Olga was reported to be in position 16° 12'N, 120° 36'E.

At 0400 on the 22nd the wind decreased to S'W, force 4–5, the port was re-opened at 0500 and the vessel berthed alongside.

At 0800 on the same day Olga was reported to be stationary in position 16° 00'N, 121° 45'E. Winds by this time had increased to force 9, heavy rain continued and the pressure varied from 994–995 mb for the next 32 hours. At 0600 on the 24th Olga was reported to be in position 16° 06'N, 119° 30'E (west of Luzon) moving slowly northwards and having maximum winds of 35 knots. In Manila the wind decreased to force 6 from the SW and barometric pressure began to rise very slowly; rain, however, was still heavy and continuous.

At 0600 on the 25th Olga in position 18° 00'N, 119° 36'E was moving northwards with maximum winds of 40 knots. In Manila the wind remained at SW, force 6, pressure reading was 1002 mb and there were intermittent rain showers.

At 1800 on the 26th, Olga in position 25° 48'N, 125° 48'E, weakened to become a tropical depression moving NE at 15 knots.

Position of ship at 0001 on the 20th: 7° 53'N, 117° 05'E.

STORMY WEATHER

South African Waters

s.s. *Discovery Bay*. Captain J. D. Thomson. Cape Town to Fremantle. Observers, the Master and ship's company.

7 June 1976. At 1930 GMT as the vessel rounded the Cape of Good Hope, very rough seas and heavy swell were encountered.

At 2200 the wind was WSW, force 7–8, the vessel was scending and rolling moderately.

At 0500 on the 8th in position 35° 17'S, 21° 49'E the wind remained force 7–8 from the WSW, the vessel was rolling heavily at times in a rough sea with a steep following swell, cloudy with rain squalls, barometer 1011·1 mb, course 091°T speed 20 knots.

At 1000 in position 35° 09'S, 23° 59'E, wind W, force 10–11, barometer reading 1011·7 mb, vessel rolling violently at times, course 081°T speed 20 knots.

At 1040 speed was reduced to 18 knots, vessel rolling violently, observed rolls of 30°, taking spray and occasional water over the starboard side, estimated maximum height of waves 14 metres.

At 1210 speed was further reduced to 16 knots, wind SW'W, force 11, barometer reading 1011·2 mb.

Course of 085°T was resumed at 1500, speed 16 knots, wind SW to WSW decreasing to force 10, vessel rolling and scending violently, shipping occasional seas over the starboard side, overcast with showers.

At 1900 speed was increased to 17½ knots, wind SW, force 10, barometer 1011·5 mb.

At 0030 on the 9th course was altered to 090°T, wind SW, force 9, barometer 1014·6 mb, vessel rolling heavily at times, very rough sea, steep quarterly swell.

Speed was increased slightly at 0730 by which time the wind had decreased to force 8, vessel now rolling moderately, barometer reading 1013·5 mb, cloudy.

At 1115 full speed was resumed on a course of 090°T, wind SW decreasing slowly, now force 7.

At 2130 wind SW, force 6–7, barometer reading 1012·3 mb, scending and rolling moderately in heavy SW'ly swell.

At 0500 on the 10th in position 34° 48'S, 39° 12'E, course 090°T, speed 20 knots, wind SW, force 5, barometer reading 1011·1 mb, vessel rolling moderately at times in steep SW'ly swell.

During the period 8–9 June the vessel was under the influence of the Agulhas Current and SW'ly gales. Mountainous waves occurred periodically, the heights of which were very difficult to estimate, but were well in excess of 12 metres.

Position of ship at 0500 on the 8th: 35° 17'S, 21° 49'E.

Note. This is another interesting case of the unusually steep and potentially damaging waves that can be experienced when there are strong winds opposing the Agulhas Current (see, for instance 'The unusual waves off south-east Africa' by R. M. Sanderson, *The Marine Observer*, **44**, No. 246, October 1974, pp. 180–183). The phenomenon has been noted particularly off the coast of south-east Africa but may also occur elsewhere when gales blow in opposition to a strong current. Accounts of such waves are welcomed and reporting forms are available from Port Meteorological Officers, see 'Special Reports of Freak Waves' by J. E. Atkins, *The Marine Observer*, **47**, No. 255, January 1977, pp. 32–35.

HAIL

Gulf of Aden

m.v. *Strathcarrol*. Captain B. S. C. Mordaunt. Observers, the Master and ship's company.

7 April 1976. Between 1410 and 1430 GMT an extremely heavy hailstorm was experienced. At 1400 a large cumulonimbus cloud was observed approaching the vessel from astern, the wind at this time was N'W force 3. Ten minutes later when the storm was overhead, the wind increased to force 10, the corrected barometric pressure fell from 1009·6 mb to 1005·4 mb and hailstones ranging from 2 to 6 cm in diameter fell, or rather crashed down, on us. At 1725 the hail was replaced by heavy rain, the pressure rose to 1008·6 mb and the wind eased to force 4.

The 2nd Officer and 4th Engineer were exposed to the hailstorm and both received bruises on the forearms.

When the storm was at its height the radar scanner stopped turning and the main television aerial, made of light alloy, was quite badly bent. The radar scanner functioned properly after the storm.

Position of ship: 25° 42'N, 57° 18'E.

Note 1. m.v. *Strathcarrol* is a Hong Kong Selected Ship.
Note 2. The following is an extract from the *Persian Gulf Pilot*, NP 63, 1967:
'Hail is occasionally reported and is liable to be exceptionally large. Hailstones of 10 to 13 cm have been reported in April.'

DISCOLOURED WATER

North Atlantic Ocean

m.v. *Clan Matheson*. Captain R. M. Bessant. London to Ascension Island. Observers, the Master and Mr C. W. Laycock, 2nd Officer.

18 June 1976. At 1400 GMT the vessel entered an area of sea containing a large number of patches of discoloured water. The vessel passed through many of these patches and the discoloration appeared to be due to the presence of a fibrous substance close to the surface. The most dense patches were orange to rust-red in colour and extended over an area of at least 15 n. mile in one direction. A sample of the water was taken.

Position of ship: 07° 26′N, 17° 02′W.

Note. Dr G. T. Boalch of the Marine Biological Association of the United Kingdom, comments:

'This sample was perfectly preserved with gin and we were able to identify a number of marine diatoms, both oceanic and coastal species. From this mixture we suggest that the sample was taken in an area where the coastal and oceanic waters mix. These areas are often characterized by dense phytoplankton growths.'

UNUSUAL WIND BEHAVIOUR

Arabian Sea

s.s. *Benwyvis.* Captain W. C. Watson. Suez to Penang. Observer, Mr D. A. Hawkins, 2nd Officer.

13 June 1976. At 1130 GMT the vessel encountered a patch of water in which conditions differed greatly from those on either side of it. The patch was about 300 metres wide and was orientated in an 080°–260° direction. The wind dropped from S'ly, force 6 on either side to S'ly, force 1–2, and the swell, which was heavy on either side, was only slight within the patch. There was no evidence of oil on the water.

The observer commented that he would like to have stayed inside the patch as it was much more comfortable there. Alas, however, it was going in the wrong direction for the vessel!

Position of ship: 12° 49′N, 51° 40′E.

Note. The *Benwyvis* probably experienced one of the complex lee effects produced off the NE tip of Somalia during the months of the most pronounced SW Monsoon (June to September). The subject has been investigated and written about by J. Findlater in his paper 'The Strange Winds of Ras Asir' (*Meteorological Magazine,* Vol. **100**, February 1971, pp. 46–54).

That such a phenomenon may be noticed relatively far from land has lately been strikingly illustrated by satellite photographs which show changes in wind patterns on the sea tens of miles to the lee of quite small islands.

DOLPHINS

Southern North Pacific

m.v. *Ionic.* Captain J. J. Rutter. Balboa to Noumea. Observers, Mr R. E. V. O'Donnell, 2nd Officer, Mr R. M. Jones, 3rd Officer and Cadets Mackay, Bassett and Blake.

25 May 1976. At 2145 GMT a disturbance was noticed in the sea to the south-west which appeared to be approaching the vessel. Within minutes the vessel was surrounded by leaping blue-grey bodies and the air was filled with the noise of the dolphins as they performed their marine acrobatics. A conservative estimate of their number would be something like 1000 to 1200. Several small groups provided displays of synchronized swimming whilst the majority played in the bow waves and the south-westerly swell.

The main body departed after about 15 minutes in a north-easterly direction in a roughly circular group about half a n. mile in diameter; isolated groups of up to 50 dolphins stayed behind for a short while.

There appeared to be great excitement among one group about half a nautical mile to the south, they had, no doubt, encountered a shoal of flying fish or tuna, and had stopped for a meal.

By 2215 the area around the vessel was quiet again and to the north-east the last of the dolphins could be seen trailing the main body.

Position of ship: 01° 38′N, 97° 23′W.

SHARK

South Atlantic Ocean

m.v. *Chrysantema*. Captain R. Duggan. Cotonou (Dahomey) to Cape Town. Observers, Mr M. M. Grass, 3rd Officer and Mr P. Fitzgerald, Chief Steward.

9 June 1976. At 1330 GMT whilst the vessel was stopped, the 3rd Officer and the Chief Steward were aft fishing with shark lines (heaving lines with steel-wire traces and barbed meat hooks). One line was baited with bacon and the other with herring.

A shark had been seen in the vicinity of the vessel and after a short while it approached the lines. Twice it took the bait but was eventually hooked by the Chief Steward. It was brought on board with not too much trouble and killed by another member of the crew.

The shark (*see* photograph opposite page 73) was approximately two metres long and weighed between 70 and 90 kilograms, the fins were tipped with white and the teeth varied in shape and size from serrated triangular to needle-point.

Position of ship: 09° 50′S, 08° 10′E.

MARINE LIFE

North Atlantic Ocean

m.v. *Willowbank*. Captain A. S. Haynes. Cristobal to Liverpool. Observers, the Master and members of the ship's company.

9 May 1976. At 1200 GMT jellyfish-like objects were observed floating past the vessel. At first it was thought they were plastic bags with a pocket of air trapped in each corner. When observed through binoculars they were identified as forms of marine life. The shape above the water-line was like that of a segment of an orange, the darker mass below the water-line appeared to resemble a number of short legs. They were frequently observed passing down either side of the vessel throughout the afternoon.

The following morning the creatures were observed once again. Later in the day two specimens were obtained whilst the vessel was stopped and drawings were made, see sketch, and photographs taken.

The creatures were between 90 and 110 millimetres long and 50 millimetres wide. The 'legs' proved to be tentacles, about 20 millimetres long, dark green and resembling coiled springs expanding and contracting, when caught they were in excess of three metres in length when fully extended. It was thought that the tentacles were used to assist the creatures to feed.

On the following morning the creatures were no longer observed.

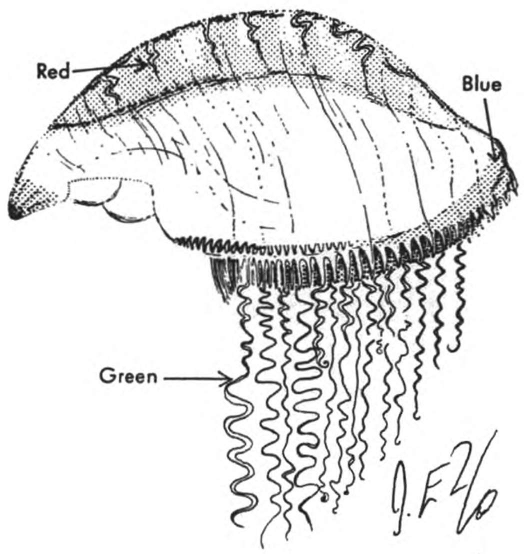
It seemed remarkable that the creatures were observed, not so much in large concentrations, but over such a wide area, approximately 400 to 450 n. mile.

Position of ship at 1200 on the 9th: 35° 04′N, 50° 10′W.

Position of ship at 1145 on the 11th: 41° 24′N, 40° 56′W.

Note. The article by Ailsa McGowan Clark (*The Marine Observer*, 40, 1970, pp. 63–65) identifies the creatures as Portuguese men-of-war (Latin name *Physalia*). This oceanic animal is related to the jellyfish and lives generally within 35°N or S of the equator. It is sometimes observed in extensive shoals.

The name Portuguese man-of-war is thought to have originated from the extensive use of



caravels with fore-and-aft lateen rig by the Portuguese in the fifteenth and sixteenth centuries.

The Portuguese man-of-war consists of numerous individual polyps modified for catching and stinging its prey, or for engulfing and digesting it through its numerous mouths, or for reproducing the species. These polyps are linked together under an inflatable pink- or purple-tinted semi-transparent flotation bladder shaped something like a Cornish pasty.

BIRDS

North Atlantic Ocean

m.v. *British Trent.* Captain R. S. Larking. Lagos to Gibraltar. Observers, Mr D. Jeffcock, 2nd Officer and Mr R. Norton and Mr P. Armitage, 3rd Officers.

18 June 1976. At 0715 GMT a yellow-billed Tropic-bird with a suspected broken wing was caught on one of the accommodation decks. The bird's chances of survival seemed pretty slim if left to its own devices so we decided to take care of it and hoped it would survive.

We established that the left wing was broken and after unsuccessful attempts with a bandage, we secured the broken wing to the body with sticking plaster.

Tins of sardines were procured and attempts were made to feed it but without success; the bird refused to eat and for our pains we suffered sore fingers and bad tempers. However, we did eventually find the knack—one of us held open the bird's bill while another pushed the pieces of fish down the gullet; soon the bird too got the idea and we decided to feed it three small meals each day.

On the second day the bird seemed much more settled and all the previous day's hostility was gone.

We filled a bowl with sea water and the bird showed some enthusiasm to get into the water. However, once in, it showed even more enthusiasm to get out. We lifted it out and tried three times to persuade it to take a swim. By this time we were thoroughly wet and had had enough.

Curiously the bird was never seen to preen itself although it shook itself frequently to clear salt from the bill and oil surplus from the body.

The eyes had an almost opaque inner lid. It could, we thought, see through the lid and used it as protection probably when diving for food.

The bird's shuffling across the deck gave amusement to some and concern to others. We thought that either one or both of the legs were broken or that perhaps we had been overfeeding it.

After three days the bird died and was buried at sea with a small ceremony.

The whole experience proved to be a valuable and interesting, if disappointing, one for us.

The bird's statistics were as follows: length 27 cm from bill to end of primary feathers, bill about 4 cm long and yellow, feet black and legs greyish, a single tail feather 27 cm long and light peach in colour. The white feathers of the body were very lightly tinged with peach on the edges.

Position of ship at 0600 on 18th: 04° 18′N, 05° 36′W.

Persian Gulf

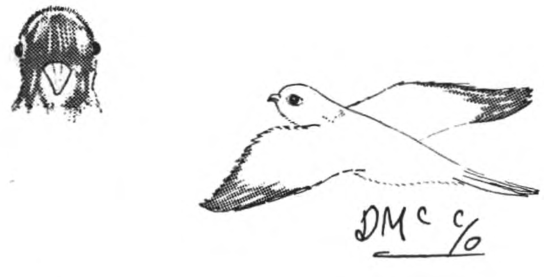
m.v. *British Avon.* Captain I. B. McNaughton. Basrah to Singapore. Observer, Mr D. McCallum, Chief Officer.

2 April 1976. At 1330 GMT seven hawks, see sketch, landed on the vessel. Unfortunately the direction from which they approached was not noted.

The wings and backs of five of the birds were reddish brown with bars of dark brown, the other two birds were lighter in colour with almost sand coloured backs and wings. The undersides of all of the birds were light brown and shaded grey, and this grey colour was seen in the tails when spread for hovering or landing. The ends of the tails and wing tips were dark brown. A very distinctive white throat was observed on one bird which landed on the wheelhouse rails. The overall length of each bird was 25–30 cm. It seemed unusual to see so many hawks together, especially as they all seemed to be adult birds.

An odd feature about their behaviour was their restlessness. Even after dark they were constantly changing position and flying around the foremast which seemed to be the favourite perch. They remained with us for about six hours.

Position of ship: 27° 11′N, 52° 22′E.



Note. Captain G. S. Tuck, Chairman of the Royal Naval Birdwatching Society, comments: 'I consider this to be a flock of kestrels, *Falco tinnunculus.* The grey tail indicates a male bird. The two lighter birds quoted as almost sandy on their backs were probably Lesser Kestrels, *Falco naumarini.* The males of both species have plain grey tails with dark tips. The females have dark spotted backs and tails.'

Editor's note. The following was received from the Chairman of the Royal Naval Birdwatching Society too late for publication in the January edition:

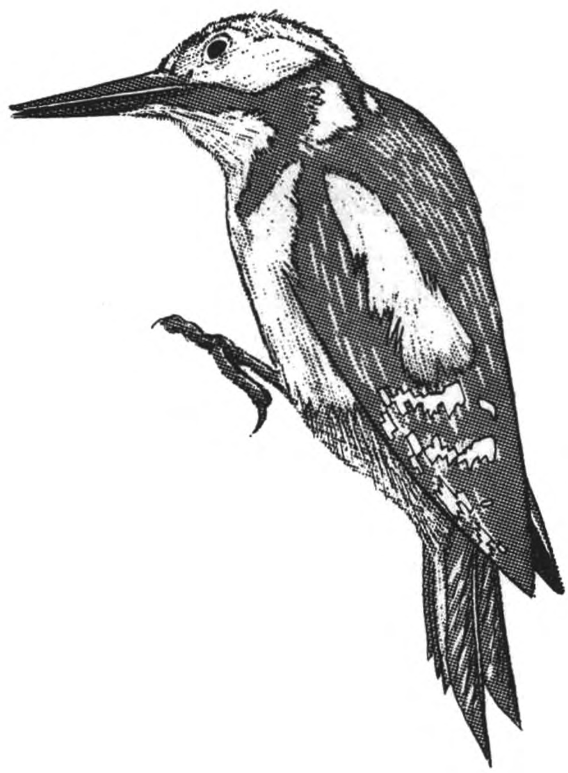
'Captain Tuck wishes to thank all those who have contributed such interesting and valuable information in sea- and land-bird observations at sea during 1976 and sends good wishes for 1977. All observations are plotted as necessary on ocean charts to build up further knowledge of oceanic distribution.'

WOODPECKER

The Kattegat

m.v. *British Trent.* Captain R. Weston. Swansea to Copenhagen. Observer, Mr N. R. Nelms, 2nd Officer.

15 April 1976. While steaming in the Kattegat towards the Sound a great spotted woodpecker, see sketch, landed on deck and took a great deal of interest in a packing case. It spent about an hour on board.



The observer comments that this is an unusual bird to observe in this area as it prefers broad-leaved woodland to coniferous forest.

Position of ship at 0600 GMT: 57° 00′N, 11° 42′E.

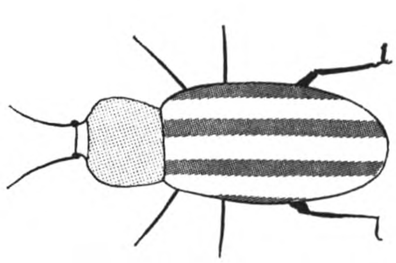
Note. The Great Spotted Woodpecker, *Dendrocopos major*, is to be found in Britain in woodlands, commons, farmlands and parks and does show a greater preference for woodlands. In northern England and Scotland it prefers conifers. It breeds from mid-May to July in deciduous and coniferous woods in Britain and Scandinavia.

FLYING BEETLES

North Atlantic Ocean

s.s. *Liverpool Bay*. Captain M. Lees. Cristobal to Hamburg. Observer, Mr P. F. Robinson, Chief Officer and Mr D. Jordan, Cadet.

11 May 1976. At 0807 GMT two small beetles, see sketch, were discovered on the bridge. These two gave rise to much speculation about a UFO observed on the previous evening, especially as at the time we were some 600 n. mile NE of Puerto Rico.



The 'aliens' were captured and placed in a tobacco tin. Fred and Fanny, as they were named, were about one centimetre long and each had an orange head and black striped body.

Position of ship: 26° 11′N, 60° 02′W.

Note. Mrs S. L. Shute, Department of Entomology, British Museum (Natural History), comments:

'The sketch of the small striped beetle appears to show that of a species belonging to the genus *Disonycha*, family Chrysomelidae, sub family Alticinae. It is not possible to determine a more specific level as most of these species in this genus are striped and of a similar colour.

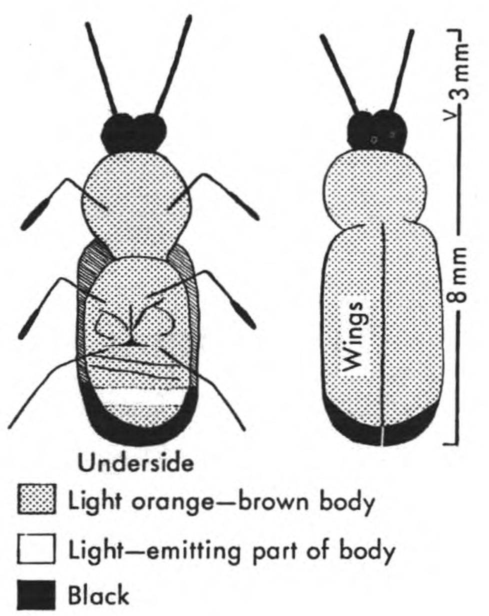
'The genus Disonycha occurs throughout North and South America. All the species are leaf feeders and can be found on a wide variety of plants from small weeds to trees. Very few are pest species.'

FIREFLIES

Bay of Bengal

m.v. *City of Lancaster*. Captain P. E. Harwood. Chalna to Trincomalee. Observers, Mr J. T. Bennett, Chief Officer and Mr C. C. Broadbridge, 2nd Officer.

1 June 1976. At 2030 GMT a small light was observed on the deck of the vessel. Inspection by torch showed it to be coming from an insect, see sketch. A glass jar was collected and by this time another flashing light was observed also on the deck. This second insect was captured and once it realized its predicament its flashing light became brighter. This may have been some kind of warning as the first insect emitted no more light.



The captured insect continued to flash continuously until presumably it became accustomed to its new situation, then, after a while, it flashed only occasionally when agitated.

Position of ship: 16° 21′N, 86° 11′E.

Note. Miss C. M. F. von Hayek, Department of Entomology, British Museum (Natural History), comments:

'The insects found on m.v. *City of Lancaster* were fireflies, family Coleoptera, Lampyridae, it was not possible to identify the species.

'These beetles are related to the glow-worm which is found in this country. In many species both males and females are able to fly. The flashing light enables them to locate each other. It has been found that many species show a characteristic pattern of flashes, like those of different lighthouses, but the pattern is often disturbed when the insects are handled.'

MOTH

Black Sea

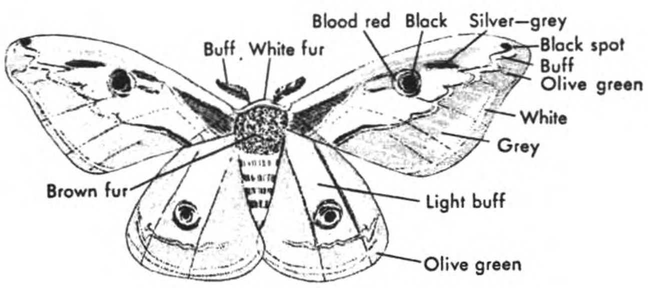
m.v. *British Holly*. Captain N. J. Packard. At anchor off Tuapse. Observers, Mr P. F. St Lawrence, 2nd Officer, Mr D. R. Robinson, 3rd Officer, Mr D. Walker, Radio Officer, Mr A. Pullian, Cadet A. Garnet and Mrs St Lawrence.

19 June 1976. The moth as shown in the sketch was found on the poop deck. It appeared at first to be dead, but on closer inspection and after a few gentle touches with a pen, it responded by flapping its wings slowly.

The specimen had a wing span of 15 cm and the body was 7 cm long.

The top half of the body was covered in a brown fur, the lower half was less furry and was a striped two-tone brown in colour.

The wings were very distinctive, see sketch, and were covered with a thin layer of a shiny transparent liquid.



The moth remained quiet during the day but became active in the evening flying around towards light sources.

Weather conditions at the time were as follows: wind W'ly, force 2–3, air temp. 25·5°C, barometer reading 1017·0 mb.

Position of ship: 44° 04′N, 39° 03′E.

Note. Mrs K. H. Smiles, Department of Entomology, British Museum (Natural History), comments:

'This is most certainly the Emperor Moth, *Saturnia pavonia* Linnaeus. This species is to be found throughout Europe and Russia.'

ABNORMAL REFRACTION

Great Australian Bight

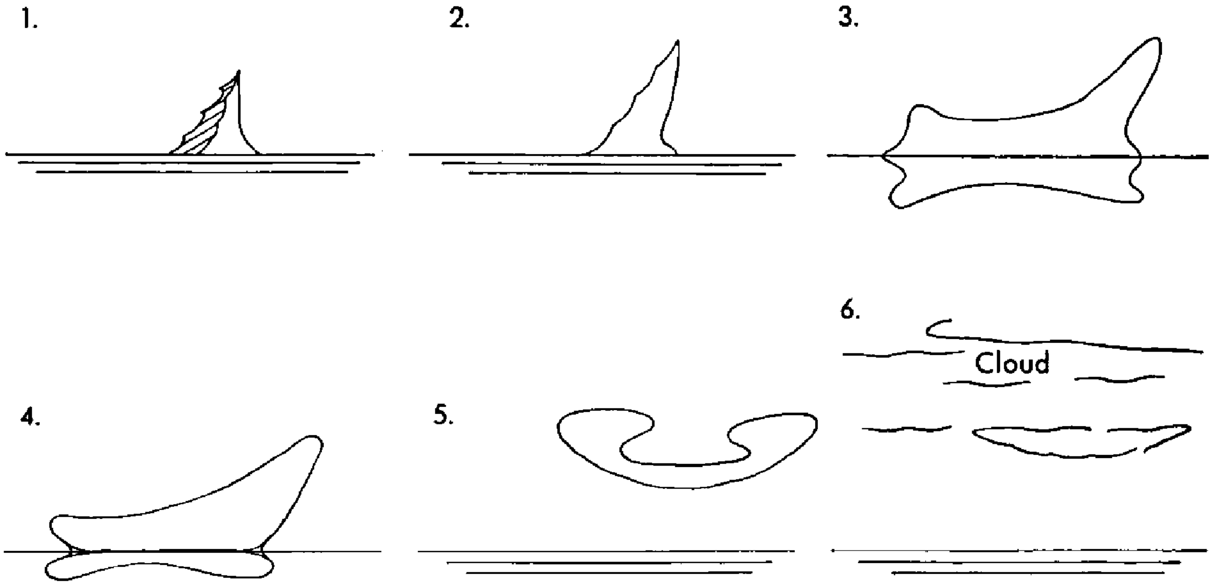
s.s. *Discovery Bay*. Captain J. D. Thomson. Fremantle to Sydney. Observers, Mr P. S. E. Cave, 3rd Officer and Mr G. Rudd.

21 June 1976. At 1647 GMT the moon was observed to rise about two points on the port bow. Its unusual shape immediately aroused the interest of the observers and the following notes, and sketches as illustrated, were made.

The moon first appeared as a triangle of light, bright on one side and merging into the background on the other. A small patch of light was observed to the left (see Figure 1). The right-hand side of the triangle curved outward at the base.

As the moon continued to rise it took on the texture and colour of a ball of fire, the whitish light on the left-hand side disappeared (Figure 2).

When both sides of the moon appeared, an image was formed below the horizon similar to the shape above it (Figure 3). It was considered that this was a reflection but it parted company with the shape above before the lower limb had risen above



the horizon (Figure 4); the image below the horizon disappeared shortly afterwards (Figure 5). The moon then was lost to sight behind the cloud (Figure 6).

Weather conditions at the time were as follows: dry bulb 13·3°C, wet bulb 11·9, barometer reading 1024·8 mb falling unsteadily, seven oktas of stratocumulus.

Position of ship: 38° 24′S, 138° 48′E.

FLAT RED MOON

South China Sea

m.v. *British Avon*. Captain I. B. McNaughton. Singapore to Japan. Observers, Mr J. H. Miller, 3rd Officer and Mr J. Goldie.

16 April 1976. At 1230 GMT a deep-red glow was observed on the horizon bearing 109°T. At first it was thought to be a distress signal because of the colour, but after a few seconds it was seen to be the moon rising. Neither the observer nor the watch keeper had seen the moon such a deep-reddish colour before. This colour persisted until the moon was a full diameter clear of the horizon; at this stage it was oval in shape, the top and bottom edges were apparently flattened. By 1235 the deep-red colour had given way to deep-orange and by 1245 this had given way to the normal yellow colouring. At the time of the observation the atmosphere was clear and the horizon well defined. The only clouds present were a few patches of stratocumulus to the east and clear of the horizon.

The observer suggests that the deep-reddish colour may have been the consequence of greater scattering of light rays by an unusually large concentration of dust particles and asks if any other factors contributing to this phenomenon were involved, also why such pronounced flattening of the top and bottom edges of the moon was observed.

Position of ship at 1230: 16° 33′N, 116° 26′E.

Note. Dust particles redden the colour of the low sun or moon by scattering blue light out of the direct solar (or lunar) beams more effectively than red light.

The apparent flattening of the lunar disc is due to differential atmospheric refraction and is virtually independent of dust content. Near the horizon the light from the lower limits traverses a longer atmospheric path than light from the upper limits and so its path gets bent more and this leads to an apparent flattening. The report of an unusually large flattening needs to be verified by actual measurement.

Large dust concentrations in the tropics usually originate from deserts or volcanoes. It is noted that a volcanic eruption was sighted 1300 n.mile to the SSE of this report sent a year earlier (m.v. *Orenda Bridge*, *Mar Obsvr*, **46**, 1976, p. 19).

GREEN FLASH

North Pacific Ocean

m.v. *Grafton*. Captain J. M. Huke. Panama to Japan. Observer, Mr K. A. Stapleton, 3rd Officer.

31 May 1976. At approximately 0330 GMT while the observer was watching a rather picturesque sunset, a green flash was observed.

The sky was generally cloudy but there was a clear sector to an altitude of 15° over the western horizon, an uninterrupted view of the sunset was therefore obtained. The atmosphere was clear and the horizon distinct.

Just before the moment of sunset the last of the disc was seen to turn a bluey-green colour; the flash was clearly visible to the naked eye. The phenomenon lasted for about one second and was observed by four of the ship's officers.

Weather details at the time were as follows: dry bulb 17·3°C, wet bulb 14·4 and barometric pressure 1022·8 mb.

Position of ship: 29° 00′N, 129° 40′W.

Note. The following is an extract from *The Meteorological Glossary*:

'On some occasions the last glimpse of the sun at sunset, or the first glimpse at sunrise, is a brilliant green—the "green segment"—lasting a few seconds. On still rarer occasions a "green flash" or "green ray", also lasting a few seconds, shoots above the horizon from the upper limb. The explanation is the greater refraction of the short waves (violet, blue, green) than of the long waves (red) of white sunlight, coupled with the greater degree of scattering experienced by the violet and blue rays. In a hazy atmosphere such differential scattering may not be appreciable and the flash may then appear blue or violet. It is probable, though not yet confirmed, that an unusual degree of refraction, such as occurs with a low-level inversion of temperature, is required for the phenomenon.

'Differential refraction of white light is also the cause of the analogous very rare phenomenon of the "red flash" which may occur when the sun's disc appears just below a bank of clouds near the horizon.

'The green flash has been observed in association with the moon and planets on rare occasions.'

METEOR SHOWER

North Atlantic Ocean

s.s. *Jervis Bay*. Captain K. E. Howard. Rotterdam to Fremantle. Observer, Mr A. J. Ball, 2nd Officer.

23 June 1976. At 0100 GMT a meteor shower was observed to the north of the vessel. The shower consisted of five simultaneous meteors, one of them being about twice the brightness of Jupiter, the other four were of about magnitude 1·5. They appeared to be in formation, the brighter one being in the middle and two each of the smaller ones on its port and starboard quarters. This formation gave the impression that the meteors might be part of a large meteor breaking up on entering the earth's atmosphere.

The shower was seen to come from the region of Cepheus, cross Ursa Minor and disappear from view in the region of Ursa Major.

Later, another small meteor shower was observed in the region of Andromeda and Cassiopeia, the direction of these meteors was, however, random.

The atmosphere was extremely clear and there was no cloud.

Position of ship: 30° 10′N, 14° 33′W.

AURORA

Gulf of St Lawrence

m.v. *Queensgarth*. Captain J. P. Waldock. Birkenhead to Seven Islands. Observers, Mr N. Williams, 3rd Officer and Mr D. Nixon, Cadet.

4 June 1976. At 0100 GMT aurora was observed as horizontal white luminous shapes covering most of the western sky. There appeared to be one main patch at elevation of 40° to 45°; smaller patches were observed to the west of the main patch.

After about 40 minutes the patches began to change in shape and size and gradually they moved towards a wave formation. The intensity of luminosity changed continually from a bright to a dull glow; the patches were at their brightest when the shapes covered a greater part of the sky.

After about 1½ hours a shimmering effect was observed to surround the patches, it seemed that someone was turning a strong light on and off at a steady rate behind each patch. This effect continued for only 35 minutes during which time refraction, which was observed at the same time as the aurora, increased. Lights were seen to have three or four images all placed on top of each other.

At 0310 the shimmering effect ceased, refraction decreased and the auroral shapes began to decrease in size. The effect of refraction on the moon as it was setting was to make it appear elongated. The aurora was also observed to decrease in intensity; it finally disappeared from sight at about 0400.

Weather conditions during the period 0100–0400 were as follows: dry bulb varied from 9·1 to 10°C, wet bulb from 8·0 to 8·8, wind WNW, force 3–4, barometer reading from 1022 to 1024 mb and sea temp. remained at approximately 2·5. Cloud cover was negligible, only small patches of cirrus were observed.

Position of ship at 0100: 49° 33′N, 65° 09′W.

MAGNETIC ANOMALY

South African Waters

s.s. *Remuera*. Captain L. E. Howell. Liverpool to Melbourne. Observers, the Master and Mr R. J. McLarty, 3rd Officer.

1 June 1976. At 1915 GMT the vessel was steering 144° T and gyro, 160° Magnetic, and passing through an area of very heavy rain when the wind backed suddenly from NW, force 7 to SW, force 7. There was no apparent electrical interference, i.e. thunder and lightning, but about five minutes later it was noted that the westerly compass error had decreased by about 5° and the Decca Navigator had become very erratic. The vessel was now steering 144° T and gyro, 155° Magnetic. The magnetic compass error increased over the next few hours and the compass was eventually back to 160° at 2240.

Position of ship: 31° 19′S, 16° 05′E.

UNIDENTIFIED PHENOMENON

North Atlantic Ocean

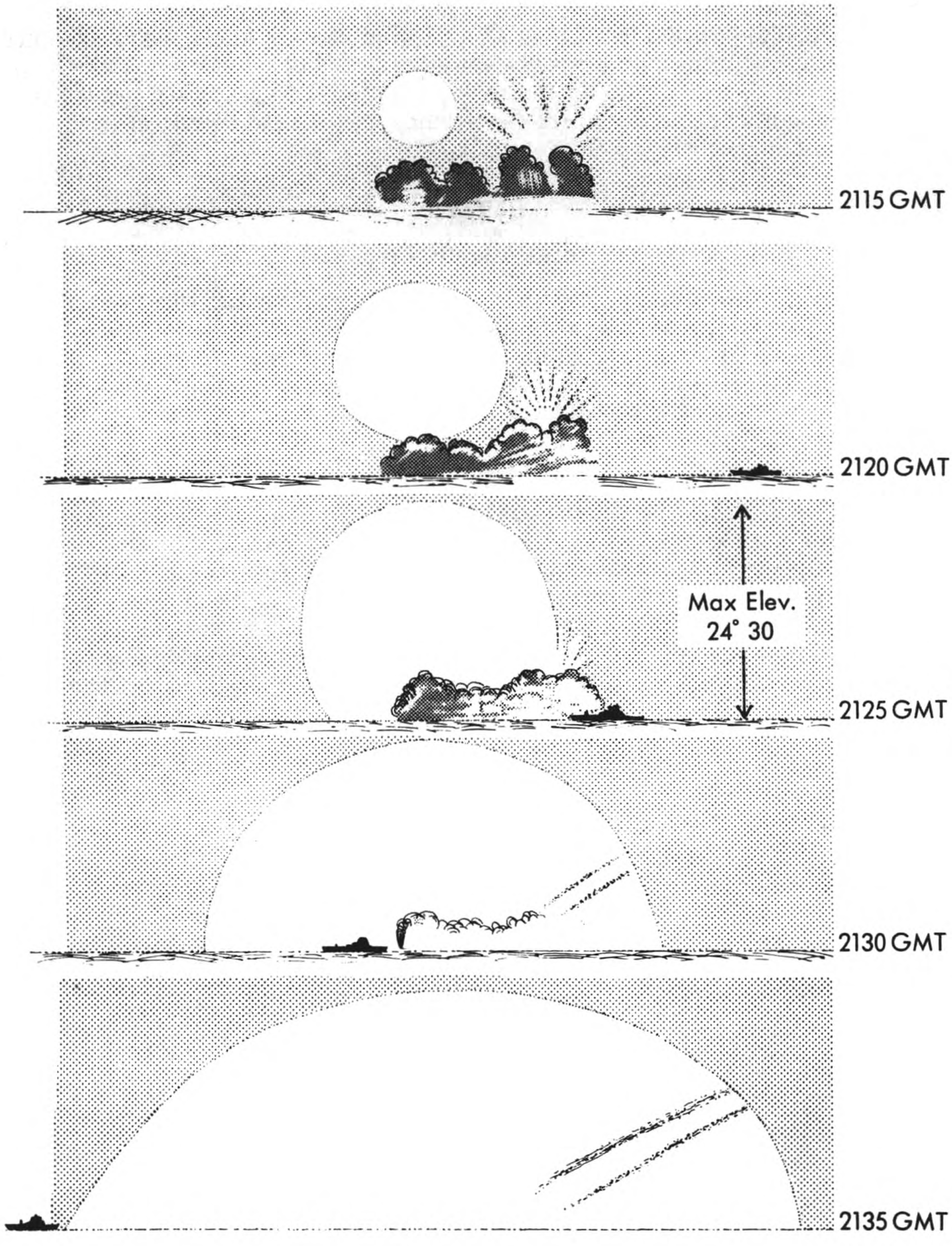
s.s. *Osaka Bay*. Captain R. Moore. Cape Town to Southampton. Observers, the Master, Mr D. M. Illingworth, 2nd Officer and Mr T. Smullen.

22 June 1976. At 2113 GMT a pale orange glow was seen to be coming from behind a bank of towering cumulus to the west.

At 2115 a ghostly white disc, see sketches, was observed at an approximate altitude of 10° and bearing 290°. The glow from behind the cloud persisted.

At 2125 the disc had grown to such an extent that the lower limb was touching the horizon and the upper limb had reached an altitude of 24° 30′; the altitude of the upper limb did not increase any further as the lower limb sank below the horizon. The outer edges were brighter now so giving the appearance of a well-defined globe rather than a disc. Stars were visible through the disc at all times.

By 2130 half of the enlarged disc was below the horizon although its upper limb



was still at an altitude of 24° 30′. The light from behind the cloud was becoming elongated, like a searchlight beam, as the disc sank. This beam of light had grown with the disc.

At 2135, the well-defined edges of the disc had become much fainter but the beam of light maintained its brilliance. The cumulus cloud had by this time gone.

By 2140 the disc had disappeared completely but the beam of light was visible for a further five minutes before it too lost its brightness and disappeared. The western sky maintained a brightness, as it does after the moon has set, for another ten minutes.

Weather conditions at the time were as follows: dry bulb 20·2°C, wet bulb 19·0, barometer reading 1018·0 mb, rising slowly, wind 020° 20 knots, a thin complete covering of cirrostratus cloud was evident at twilight but no cloud apart from the cumulus could be seen at the time of the observation, a slight haze prevailed, visibility was about 12 n. mile. Sunset that evening was at 1956 GMT.

Position of ship at 2115: 24° 25′N, 17° 09′W.

BUOYS

North Atlantic Ocean

m.v. *Gladstone Star.* Captain J. C. King. Sheerness to Panama. Observers, Mr A. Milligan, Chief Officer and Mr N. B. Meek, 3rd Officer.

20 June 1976. At 1940 GMT an orange spherical buoy was sighted. There were no visible markings, but it was thought it may have been a meteorological buoy.

Position of ship: 41° 50′N, 19° 32′W.

Norwegian Sea

m.v. *Cape Howe.* Captain W. Warden. Narvik to Glasgow. Observer, Mr S. A. Budd, Cadet.

28 May 1976. The vessel was steaming on a course of 223°T when an object was sighted on the starboard bow. Course was altered to investigate and the object was seen to be a buoy. The time was noted and a Decca position obtained. Bodo radio was called on VHF and the following description given: red spherical buoy approximately three metres tall, mast, thought to be telescopic, with a square red flag flying

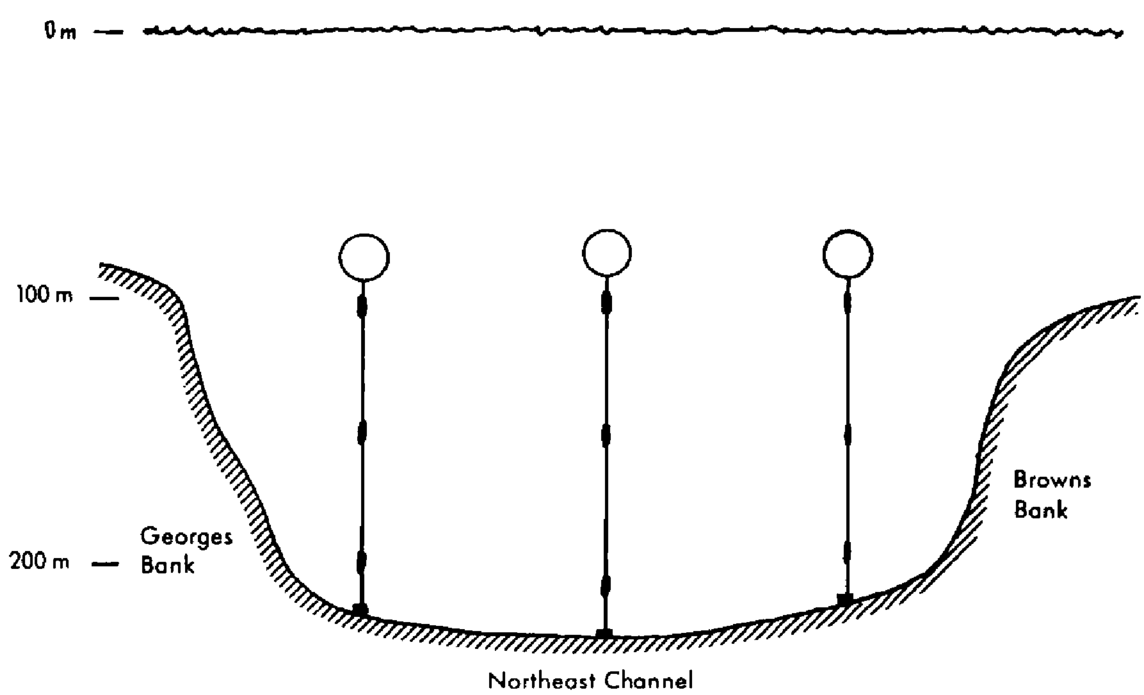


Figure 1. Vertical view of moored array

at top, buoy marked 114 TN. It was floating 'light' in the water and it appeared to be anchored.

Position of ship: 66° 29′N, 10° 15′E.

Note. Current meter, meteorological and other data-acquisition buoys have been established in many parts of the world's oceans. Many of these are moored, sometimes so that the floats are sub-surface, others are free-drifting. Reports of buoy sightings received from the VOF are forwarded to the International Council for the Exploration of the Sea (ICES) who, in

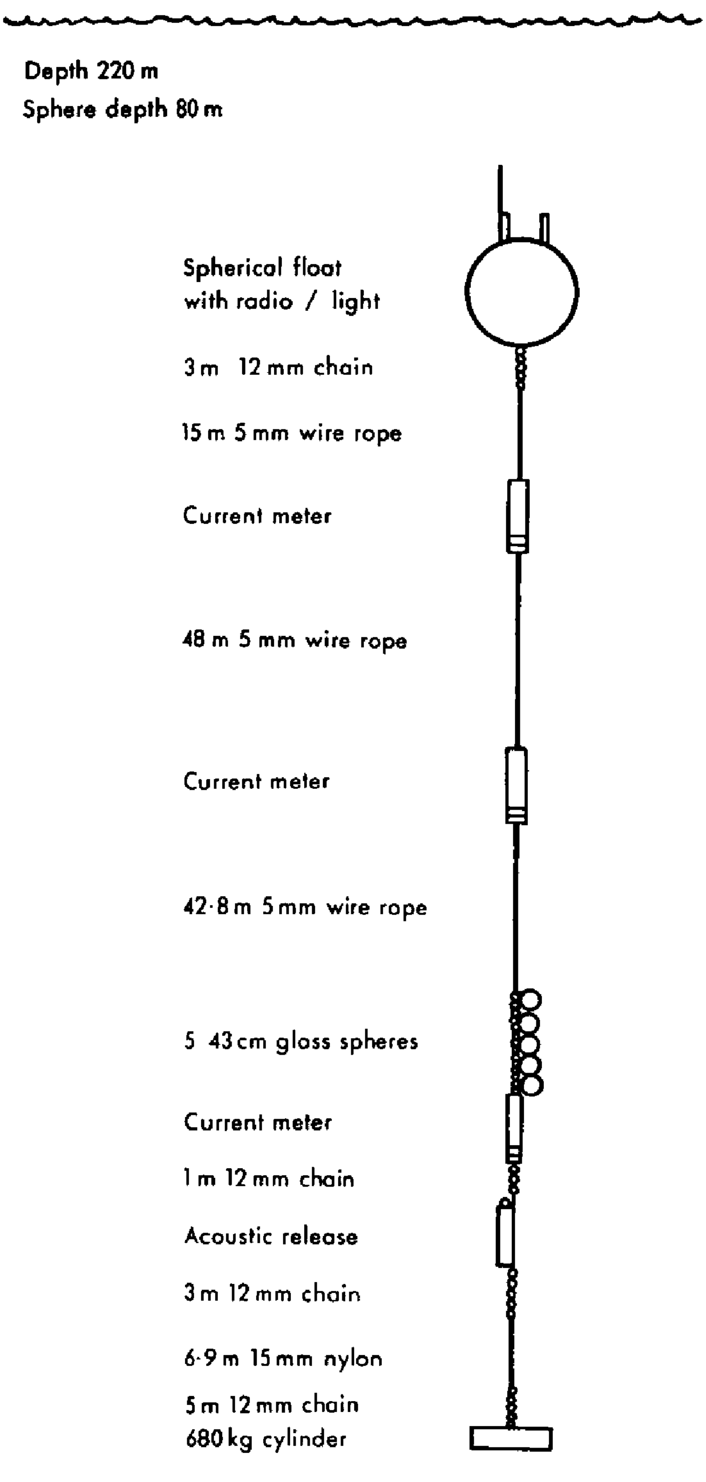


Figure 2. Design of Northeast Channel mooring

turn, inform the National Offices charged with the distribution of information on unattended oceanographic buoys. A buoy sighting may thus lead to the recovery of an expensive piece of equipment which might otherwise be lost.

In September 1976 the US National Marine Fisheries Service established sub-surface current meter buoys in Northeast Channel, an entrance to the Gulf of Maine in the area 42°N, 66°W. There are no surface markers for these, the sub-surface floats being about 80 metres below the sea surface. Figures 1 and 2 show the configuration of these moorings. In the event that a mooring breaks free or is otherwise disturbed, it is requested that the National Marine Fisheries Service, Northeast Fisheries Centre, Woods Hole, Massachusetts be informed.

RESCUE AT SEA

North Atlantic Ocean

m.v. *Sig Ragne*. Captain B. S. McManus. Bilbao to Havana.

29 March 1976. At 0001 GMT a small white cabin cruiser was observed one n. mile fine on the port bow. As we approached the vessel she began to flash SOS by light to us.

The SOS was acknowledged by Aldis lamp and the helm was put over to port as the cabin cruiser passed close by the port beam. A pair of orange oilskin trousers was seen to be flying from her mast.

At 0030 the cabin cruiser was alongside and made fast. The three men on board identified themselves as American citizens. They told us they had been lost since 1700 and had been out of fuel since 2000. They had set out from Bimini in the morning on a fishing trip but deteriorating weather had caused them to lose sight of land and there was no compass on board. The DF and VHF were rendered unserviceable by rain and spray.

The Master decided to take the cabin cruiser on board and to proceed to Miami. After some difficulty, because of the deteriorating weather, the boat was finally lifted on board and secured. We resumed passage at 0148.

At 0530 we met a US Coastguard cutter off Miami sea buoy and our three guests and the cabin cruiser were transferred to the cutter. At 0554 we resumed passage to Havana.

Position of ship at 0010: 26° 06′N, 79° 18′W.

Tsunami—The Great Waves

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The Earth is covered like an armoured reptile with enormous stony slabs which drift on the denser material of the mantle, slabs which are constantly being destroyed and renewed in the processes of 'plate tectonics'. As they drift they push continents together and tear them apart over long stretches of geologic time, and cause the massive accumulations and sudden releases of energy we experience in the form of major earthquakes.

Nowhere are these processes more in evidence than along the belt of frequent earthquakes and volcanic eruptions that rings the Pacific Ocean. This circum-Pacific belt is the Earth's most active seismic feature, a place where myth-sized earthquakes still shake down the fragile things men build.

These earthquakes, the destructive off-spring of larger forces shaping or re-shaping planet Earth, have destructive oceanic off-spring of their own—the great waves of the Pacific.

Every island and coastal settlement in the Pacific Ocean is vulnerable to the onslaught of the great waves. Those of 1868 and 1877 devastated towns in northern Chile and caused death and damage across the Pacific. A series of waves generated by the eruption and collapse of Krakatoa in 1883 killed more than 36 000 persons in the East Indies. Japan lost 27 000 lives to the wave of 1896 and 1000 more to that of 1933. There have been hundreds more whose effects were less spectacular but which took many lives and did much damage.

The 1946 waves which struck Hawaii are a case in point. Also the waves sent out by the 1960 Chilean earthquakes and the Great Alaskan earthquake's sea waves which in 1964 caused damage as far away as California, Hawaii, Chile and Japan.

Some call them 'tidal waves', a name as misleading as it has been persistent. The great waves are not related to the tides. The Japanese, whose islands have felt their destructive power for generations, give us the name used internationally: tsunami, pronounced 'soo-nah-me'.

The Great Waves

The tsunami is a series of travelling ocean waves of extremely great length and period. In the deep ocean their length from crest to crest may be a hundred n. miles or more; their height from trough to crest only a few metres. They cannot be felt aboard ships in deep water and they cannot be seen from the air.

The kinetic energy—the energy of motion—represented by a tsunami is impressive. A tsunami 'feels the bottom' even in the deepest ocean, and it appears that the progress of this imperceptible series of waves represents the movement of the entire vertical section of ocean through which the tsunami passes. In the deep ocean the waves may reach speeds of 600 knots.

As the tsunami enters the shoaling water of coastlines in its path, the velocity of its waves diminishes and wave height increases. The arrival of a tsunami is often, but not always, heralded by a gradual recession of coastal water, when the trough precedes the first crest, or by a rise in water level of about one-half the amplitude of the subsequent recession. This is nature's warning that more severe tsunami waves are approaching. It is a warning to be heeded for tsunami waves can crest to heights of more than 30 metres and strike with devastating force.

Tsunamis are caused by large earthquakes centred under or near the ocean—specifically, by the vertical displacement of the ocean floor caused by such disturbances. These displacements can also be produced by volcanic eruptions and the submarine avalanches along the slopes of the Pacific trenches, events which have been linked to tsunami generation.

But the tsunami-generating process is more complicated than a sudden push against the column of ocean water. The earthquake's magnitude and depth, water depth in the region of tsunami generation, the amount of vertical motion of the sea floor, the velocity of such motion and the efficiency with which energy is transferred from the Earth's crust to ocean water are all part of the tsunami birth equation.

There are other difficult questions. Except for focusing effects on tsunami wave energy, particularly the well-studied tsunamis of 1960 and 1964, not much is known about the relationship between ocean floor configuration and the shape taken by tsunamis there. It is not completely clear, for example, why a tsunami's waves may be of negligible size at one point along a coast and much larger at other coastal points nearby. Tsunami run-up—the vertical distance between the maximum height reached by the water on shore and the mean-sea-level surface—is also impossible to predict at the present time. Nor is it possible to predict whether the destructive component of a tsunami will lie in its powerful surge across a beach or in a gradual rising of sea level followed by a rapid draining back to sea.

The key known characteristic of tsunamis is that their speed varies with the square root of water depth. It is this relationship which permits prediction of tsunami arrival times at all points in the Pacific Ocean area.

The Tsunami Warning System

In the early morning of 1 April 1946 a violent earthquake disturbed the northern slope of the Aleutian Trench and triggered one of the most destructive tsunamis in recent years. Minutes after the earthquake occurred waves more than 30 metres high smashed the lighthouse at Scotch Cap, Unimak Island, killing five. The first wave struck Hawaii less than five hours later. When the tsunami had gone 159 persons were dead and 163 injured and the islands had suffered some 25 million dollars loss in property damage—the worst natural disaster in Hawaiian history.

This was the 36th tsunami recorded in Hawaii in 127 years and the first to do severe damage since 1877. Other major tsunamis struck the islands in 1837 and twice in 1868; they came without warning as the great waves had always come in the Pacific.

But the tsunami of April 1946 would be the last destructive tsunami to surprise Hawaii.

To a group of scientists in what is now the National Oceanic and Atmospheric Administration (NOAA) of the US Department of Commerce, there was nothing inevitable about the 1946 disaster in Hawaii. The victims of the tsunami they believed could have been warned and saved. Tsunamis could be detected and their arrival predicted with sufficient accuracy to provide early warning to the people of Hawaii.

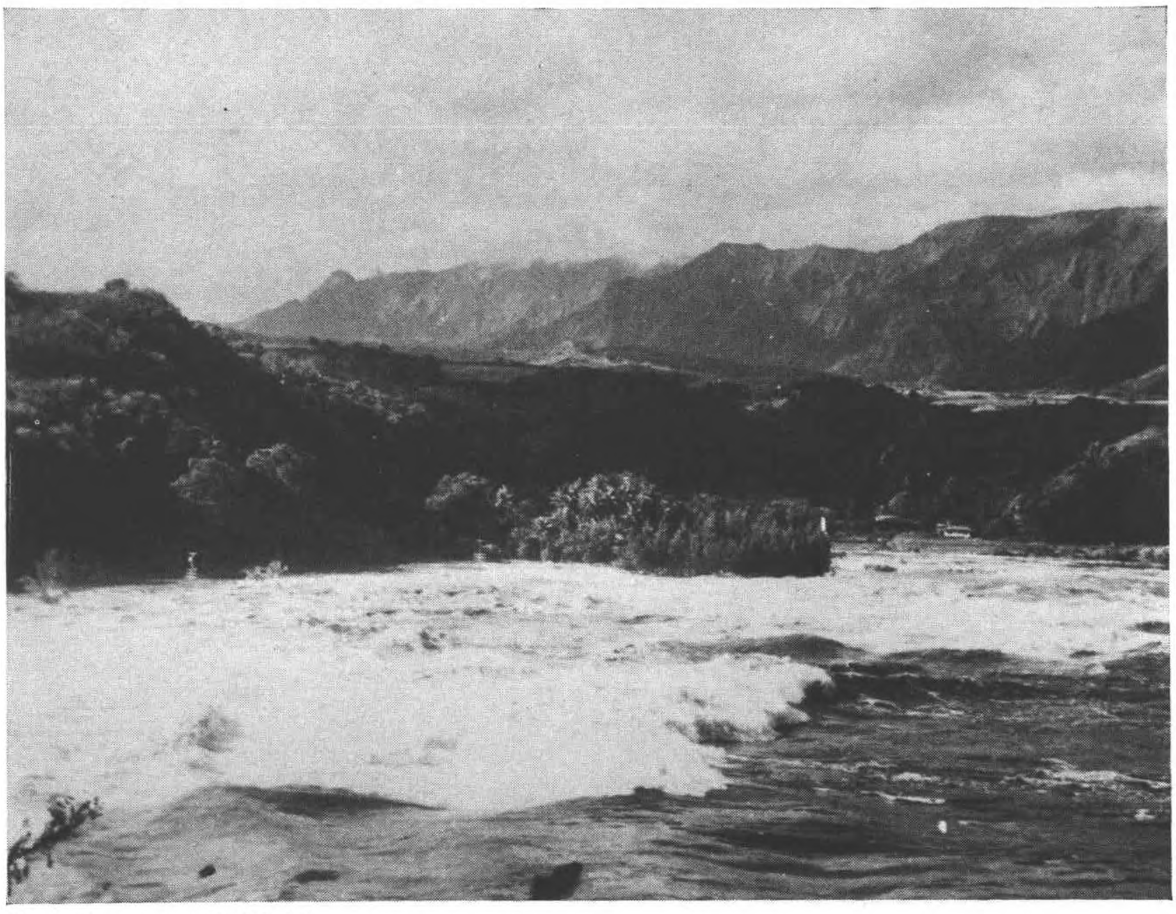
The tsunami warning system they envisaged would use seismographs to detect and locate earthquakes and tide gauges to detect passing tsunami waves. These would be linked by an extensive communications network. It took two years and considerable tailoring of existing instruments and techniques to transform the belief into a functioning reality.

In 1948, what was then called the Seismic Sea-Wave Warning System, was put into operation with its headquarters at the former Coast and Geodetic Survey's magnetic and seismological observatory near Honolulu. During the next four years the system detected many submarine earthquakes but no major tsunamis developed and no full-scale alerts were necessary. Then, on 4 November 1952, a submarine earthquake near the Kamchatka Peninsula generated a tsunami felt across the Pacific. The waves caused some 800 000 dollars worth of damage in Hawaii, but took no lives. The warning system had begun to pay its way.

Until 1964 three major tsunamis had crossed the Pacific since the Kamchatka

(*Opposite page* 72)

Water draining away from the beach as the tsunami trough approaches the shore



Photos by courtesy of NOAA

The onslaught of the wave crest (*see* page 71)

(*Opposite page* 73)

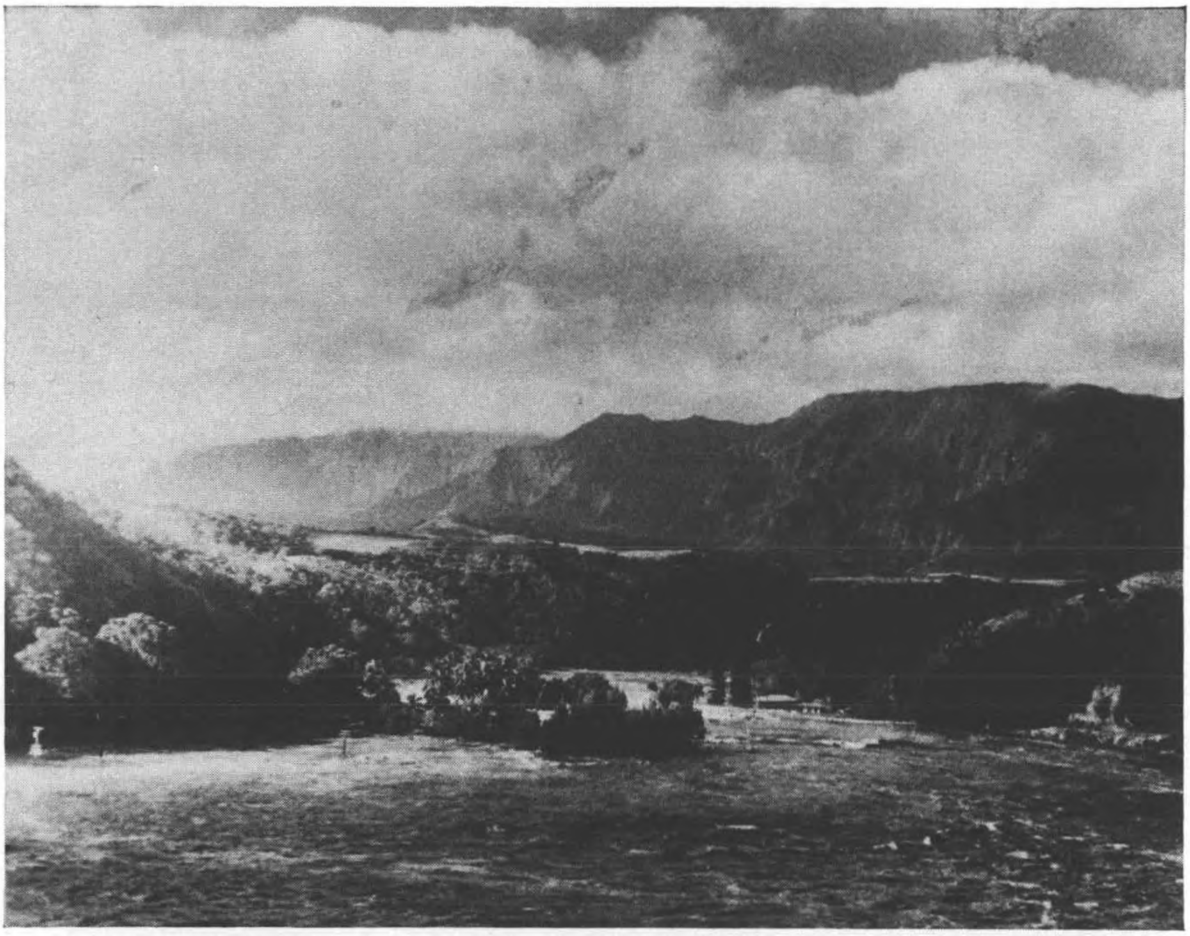


Photo by courtesy of NOAA

The height of the tsunami

(*see* page 71)

Crew member removing hook from jaw of shark

(*see* page 58)

tsunami of 1952. The Aleutian tsunami of 9 March 1957 caused damage in the Aleutians, Hawaii, Japan and along the west coast of North America, but no lives were lost.

The Chilean tsunami of May 1960 was the most destructive in recent history causing deaths and extensive damage in Chile, Hawaii, the Philippines, Okinawa and Japan. Waves 5 to 11 metres high pounded the Hawaii city of Hilo leaving 61 dead and causing 22 million dollars worth of damage to property. But a warning had preceded the waves in Hawaii by six hours; the toll might have been much worse.

In Japan no general tsunami alert was issued for it was not known then that a tsunami of such distant origin could be so destructive. The waves left at least 180 persons dead or missing in northern Japan and Okinawa, 20 dead in the Philippines, caused 500 000 dollars worth of damage along the western coast of the United States and did considerable damage in New Zealand. All Chilean coastal towns between the 36th and 44th parallels were destroyed or severely damaged.

The third large tsunami, which originated off the coast of Peru on 20 November 1960, caused 11 deaths on nearby coasts but did little damage in other Pacific areas.

On 28 March 1964 a magnitude 8·5 earthquake struck the Prince William Sound area of Alaska. Called the Good Friday earthquake, this largest North American tremor ever recorded generated a tsunami that was felt across the Ocean. Considerable damage was done along the coasts of Alaska and Canada and at Crescent City, California. There were casualities, but the number was in tens, not hundreds and not thousands. Warnings make an important difference!

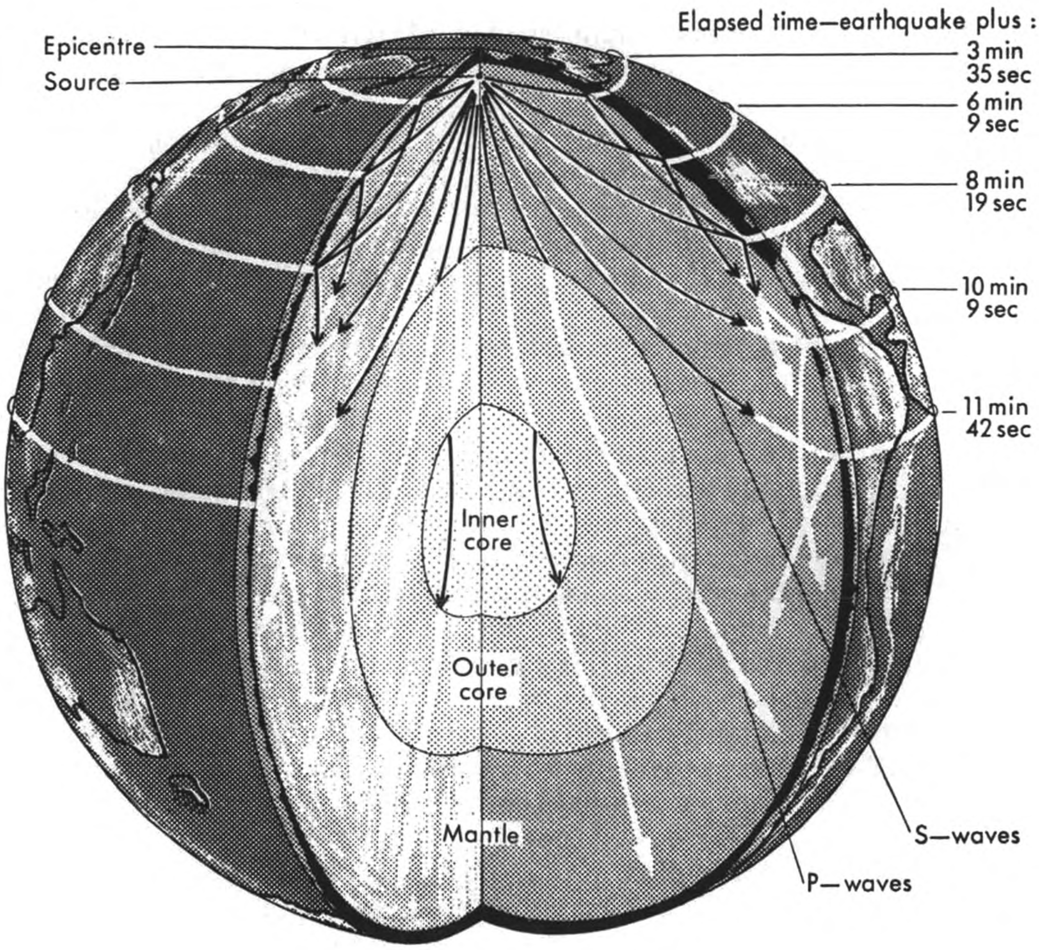
Today's Tsunami Warning System operated by NOAA's National Weather Service is a truly international service providing timely warning to 14 Pacific coastal and island nations and territories including the United States. Honolulu Observatory is headquarters for the Tsunami Warning System and the nerve centre of an ocean-wide network of detectors. Here the 24-hour watch is kept for the first reactions of instruments thousands of nautical miles away.

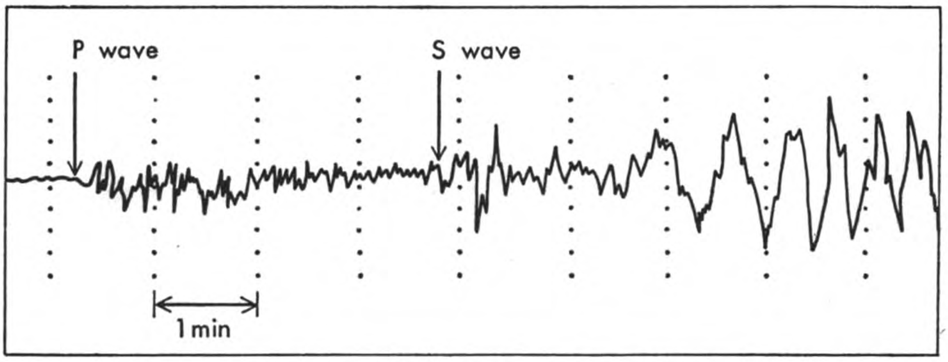
Most earthquakes are caused by slippage along strained faults in the Earth's crust. The sudden release of energy as these faults move towards equilibrium produces a variety of earthquake waves which travel through the Earth and across its surface. At seismograph stations these waves are picked up and translated into electrical signals which are further translated into a written record that becomes the earthquake's 'signature'. From this signature or seismogram seismologists can determine the approximate magnitude of the earthquake and the surface distance between their seismograph station and the source of the disturbance.

A diamond-shaped 'quadripartite' array of seismic detectors on the island of Oahu, linked to Honolulu Observatory, forms the first line of detection for the Tsunami Warning System. The array permits automatic calculations of the surface point of origin (the epicentre) of incoming earthquake waves, earthquake magnitude and something about the tsunami generating potential of the earthquake. (Earthquakes below magnitude 6·5 for example are not considered tsunamigenic, nor are earthquakes occurring in areas characterized by horizontal fault motion.)

In addition a network of seismograph stations around the Pacific contributes data as it comes in and is analysed. Some of these are operated domestically by other government agencies and private institutions and some are the private and governmental seismological observatories of co-operating Pacific nations. When an earthquake of sufficient magnitude to generate a tsunami occurs, each seismograph station equipped with an automatic alarm comes to alert and the watch and warning process begins.

As the computers and scientists at Honolulu Observatory go to work on the developing tsunami emergency, participating seismograph stations begin reporting the local arrival times of earthquake waves. Because the propagative characteristics of earthquake waves are well-established, the time interval between P (compressional, push-pull) and S (up-and-down and side-to-side shaking) waves can be used to





The difference between P and S wave arrival time at each seismograph station can be used to calculate the distance between the source and the seismograph locations. If the source falls near or under the ocean, and the earthquake is large enough, a tsunami watch goes out across the Pacific.

compute the surface distance between each seismograph station and the source of the disturbance. The intersection of these arcs of surface distance—in a computer program or on a world globe—is the earthquake epicentre. If this point falls on or near the ocean, tsunami generation is possible.

On the basis of such seismographic evidence, Honolulu Observatory issues a tsunami watch which tells Tsunami Warning System participants that an earthquake has occurred, and where, and that the possibility of tsunami generation exists.

Estimated times of arrival are also computed and transmitted for each participant's location.

Now the warning system turns to its second line of detection, a Pacific-wide network of tide stations. There, gauges continuously record the cycles of the tides. Passing tsunamis appear on the tidal record, or marigram, as distinctive abnormalities. With the occurrence of a major earthquake, Tsunami Warning System headquarters requests tide observers closest to the epicentre to check their record for 'unusual activity'.

The first positive indication that a tsunami exists usually comes from tide stations nearest the disturbance. When confirmation is received, Honolulu Observatory issues its warning alerting warning system participants to the approach of a potentially destructive series of waves and repeating tsunami estimated arrival times for each location.

Local warning, evacuation and other emergency procedures are then undertaken by designated emergency and relief forces in the regions covered by the warning. Because the main benefit of the Tsunami Warning System is to give participants time to prepare for the waves, transmission of watches and warnings is limited to a single point in each country, territory or state.

Because tsunamis respect no national boundaries, and because close liaison is essential between participating nations in the Tsunami Warning System, an International Co-ordination Group has been established composed of interested member nations in the Intergovernmental Oceanographic Commission. The group helps tie together the three distinct tsunami warnings operations in the Pacific—those of the United States, the Soviet Union and Japan—and generally promotes liaison and information exchange in the areas of tsunami detection and forecasting. It also deals with the establishment and operation of the International Tsunami Information Centre at the Pacific Regional Headquarters of NOAA's National Weather Service and with World Data Centre A for Tsunamis located at the National Geophysical and Solar-Terrestrial Data Centre (of NOAA's Environmental Data Service) in Boulder, Colorado. Nations participating in the International Co-ordination Group include Canada, Chile, Ecuador, France, Guatemala, Japan, Korea, New Zealand, Peru, the Philippines, Taiwan, Thailand, the United States and the Soviet Union.

Into the Space Age

Later in the decade of the 1970s, the first Geostationary Operational Environmental Satellite will be lifted into an earth-synchronous orbit above the International Dateline. This spacecraft, like its geostationary predecessors, will seem to mark time 22 300 miles above a point on the equator, and, like its predecessors, it will provide a relay point for a wide spectrum of fast-moving environmental data including tsunami watches and warnings.

The difference will be that the spacecraft in NOAA's operational series will be able to pass on the questions and answers between a computer at Honolulu Observatory and automated seismic and tide stations around the Pacific. This warning system of the not very distant future will dramatically slice the time between the occurrence of a tsunami generating earthquake and the issuance of watches and warnings by Honolulu and the regional systems.

These and other uses of space age technology have been accompanied by a continuing effort to improve tsunami detection, prediction and theory. The Joint Tsunami Research Effort, a co-operative venture of NOAA's Environmental Research Laboratories and the University of Hawaii, has been pursuing the legion unknowns of the great waves since the mid-1960s.

One reason there are still so many unanswered questions about tsunamis is that they are difficult to observe directly. They leave their tidal record and their mark on coastal communities and that is about all, so that tsunami research has involved a good deal of detective work.

The researchers have set up a volunteer observer program in an effort to get good time-lapse photography and measurements of tsunami water-levels and run-up. This observation program also tries to correlate ground deformation and other effects and eye-witness accounts in the event of a tsunami.

The group had fielded some new tsunami-sensing equipment including the offshore pressure-sensors used in the Hawaiian regional warning system. These measure the changes in the height of the water column above the sensor caused by a passing tsunami or other wave of that amplitude and period. An electromagnetic wave-measuring technique developed there uses the interactions of ocean waves with an electromagnetic field to sense tsunami's wave action offshore; it has also been applied to measuring tides on the open ocean as part of the Mid-Ocean Dynamics Experiment.

One of the key efforts at the laboratory involves the development of mathematical models which simulate the behaviour of tsunamis. By using present models, the NOAA scientists are looking into such unseeable events as tsunami generation, deep-ocean propagation and the relationship between the source of a tsunami and the shape taken by the mature wave series.

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1684: The Coldest Winter in the English Instrumental Record

By Gordon Manley
Coton, Cambridge

(This article is reproduced from *Weather* December 1975, by kind permission of the Editor.)

In England systematic daily meteorological observations with instrumental readings were recommended soon after the foundation of the Royal Society in 1660; the barometer and the so-called 'thermoscope' were known and used a few years earlier. Knowledge of the comparative intensity of heat or severity of cold, so far as it could be registered by thermometers, began to be acquired, and, however imperfect the instruments and techniques of measurement, once one can obtain a sequence of daily entries with wind and weather, standardization can be attempted with the result that a representative sequence of monthly means for England can be carried back to 1659 (Manley 1974), with sources and references—many used in this article.

Not that earlier efforts at comparison were lacking. From early medieval times we find accounts of the length of winter frosts in terms of weeks, or of the Church festivals, e.g. 'a frost from the feast of St Catherine to St Valentine' (25 November–14 February, 1433–34). But we must always question just what was meant by 'frost'. My own inclination is to think that for many it began when night minima in the open country fell, at least for several nights, noticeably below the freezing point, otherwise it is hard to understand such phrases as 'a great frost which lasted for 15 weeks' (1407–08).

Intensity began to be noted for example when 'wine froze' in Scotland in 1435; extent and persistence of ice began to be noted for example when the Thames was frozen and 'bore waggons as far down as Gravesend' in 1435. Sometimes there might be a note on the persistence of lying snow, for example snow is said to have lain at Edinburgh from 18 March to 22 April in 1595. It begins to be possible to estimate the character of winter by comparing the reported dates of formation and break-up of ice on our larger inland rivers on which trade was increasingly important, for example, Trent at Nottingham, Ouse at York, Severn at Worcester, Thames at Oxford or London and we can compare these with similar events in northern France or Belgium. If only we had more records of the freezing of our lakes such as Windermere, or the rarer occasions of ice on Loch Tay, Loch Lomond or even across the head of Loch Fyne, we could compare them with the occasions when the Bodensee (Lake Constance) or the Lake of Zurich were frozen. But as we do not hear of our men of Westmorland and Lancashire organizing a religious procession across their frozen lake as they did between Switzerland and Germany, records are lacking. Occasionally someone notes effects on vegetation, especially the more delicate evergreens (rosemary, lamented by Evelyn in 1684, and near Penzance by Borlase in 1740).

Gradually the documents become more numerous; more men record more facts more precisely. Barker in 1740 noted that his pond at Lyndon froze 3 inches thick overnight, and that this had only once been surpassed in 'the Long Frost' of 1684 when his grandfather (Whiston) recorded 3¼ inches in a night. But we do not know the dimensions of the pond; presumably it was where the stock were watered. In 1740 ice was noted 22 inches thick on the Eden in Cumberland, 'two feet thick' on the tidal Lune at Lancaster, and 26 inches at Leyden in Holland. Ground frozen to a depth of 'three-quarters of a yard' was noted at Northenden near Manchester in 1684 and 'three feet' in Kent; again we could do with more detail. For comparison, ground was frozen 24 to 30 inches deep in a number of places in February 1895 where there was little snow, and ice was noted upwards of 15 inches thick; on the Cambridgeshire fens a measured thickness of 2 feet was reported (Bayard and Marriott 1895).

Much can be learnt about 17th–18th century standards of comfort from the indoor temperatures, frequently observed with the primitive thermometers of the day, some of which were over 2 feet long with bulbs upwards of an inch in diameter. These were understandably precious to their owners and were often hung indoors beside a window or perhaps in a hallway. We can provide approximate Fahrenheit equivalents, and from the early journals we learn that in January 1698 at Oates near Ongar, John Lock, more familiar to us as the philosopher, recorded 38° in his parlour at about 10 am. With big open fires and wide chimneys, one can understand high-backed chairs and footstools. During the phenomenally bitter easterly gale early in January 1740 (Gregorian dating) Jurin observed 34° in his London study at about 9 am, and Short at Sheffield on the same occasion read his instrument on his staircase at 25° and was very properly impressed by the fact that 'even within a nobleman's library' the reading was 29°. Frequently it was recorded that milk froze overnight indoors; more rarely 'it froze beside the fire', and one readily imagines the housewife or one of her maids coming down in the dark morning hoping that she could blow up the embers, and finding a skim of ice on the pan left ready for the cook beside the hearth. At Oxford in 1684 Wood recorded that his bottle of ink froze at the fireside on 12 January.

But in the popular mind the real test of 18th century severity was when the clergy and the more polite travellers were able to record that vessels were found frozen within the bedroom. The forbears of today's outspoken scientists were then to be found among the medical men who were wont to define the vessel with greater precision. Such events indeed are not quite unknown today. In December 1938 we found ice in the bedroom washbowl in a well-built and well-found hotel beside the Great North Road, and in 1947 after a night when the temperature in my fireless study fell to 19°, one of those memorably vigorous ex-service undergraduates came in to the morning's lecture with the news of the ultimate 18th-century event that had just befallen him in his Cambridgeshire village lodging.

In the endeavour to establish for this country the longest representative series of temperatures in the form of monthly means that so far appears practicable, search of many sources enables one to carry a sequence back to 1659. Over England generally, the coldest winter since the beginning of instrumental observation was that of 1683–84, taking as 'winter' the three months December–February (all months and dates here are those of the Gregorian or 'New Style' calendar). It was appropriately known as 'the Long Frost'; at London the Thames remained passable on foot for seven weeks (2 January to 20 February). It does not appear that such persistence prevailed in any of the later renowned winters such as 1740 or 1795. And while each of the three months was not by any means the coldest on record (about nine Decembers, two Januaries and four Februaries were colder) the three together gave an overall mean about one deg F below that of any other winter season in the series. Not the least difficulty in such seasons arose from the stopping of many water-mills; hindrance to working of ships' rigging in the bitter wind and to water transport was a serious matter. We read much of this in 1740 when ships could not leave the frozen Tyne and the price of coal in London multiplied by eight; a further problem was that of getting the laden coal carts up the icy streets rising from the river. For 1684 perhaps the most familiar general account comes from John Evelyn's diary, we read how he 'took coach to Lambeth' along the frozen river.

We have enough in the way of daily weather observations for 1684 to go some way towards a reconstruction of the meteorology. For London we have John Downes' daily notes on the weather with thermometer readings; he was physician to Christs' Hospital. To them we can add the regularly-maintained journals by Gadbury and Ashmole. For Oxford there are the daily observations from 11 January onward by Robert Plot and from the north of England, the valuable daily note of wind and weather kept by Christopher Sanderson of Eggleston in Teesdale, where he had his small estate 700 feet above sea-level. With these we can make use of a good many scattered descriptive notes from various places.

Of the preceding autumn, September 1683 was an average month, unsettled westerly at first, improving and becoming anticyclonic 15th–20th with much cloud off the North Sea, rather warm and thundery 16th–18th in the south-east. Later, anticyclone-margin westerly weather until about 3 October, becoming quiet with cool nights and some morning fog in the south.

4–5 October saw more wind as a low came down with an arctic outburst behind it; in Teesdale snow on 6th with hard frost to follow. From 9th–17th unsettled, cool, mainly north-east to east; moist westerly 22nd–31st with a frosty night or two. As a whole, October was decidedly cooler than average, as it was indeed in 1974, but with very different consequences.

November was unsettled, cool west to north-west at first, snow both in Teesdale and London on 4th, thence unsettled and rather windy in north, quieter in south; brief snowfalls in Teesdale 14th–15th, then frost; sleet on 18th in south, then milder. Fog and frost in south-east at end of month, which as a whole was slightly cooler than average. Some of the general accounts, however, describe 'the frost' as beginning in mid-November.

December began cold and frosty with a cutting east wind and snow showers in the north; early on 3rd there was a northerly blizzard in Teesdale. Thereafter, persistent cold northerly weather in the north. On 7th 'a melting snow all day' in London, on 10th to 11th very windy in Teesdale with 'great thaw and rain', followed on 12th by sudden hard frost and snow most of the night on a strong northerly wind with much drifting. This snow reached London and cold north-east to easterly weather prevailed 14th–21st; London had snow laying 15th–18th with 'pinching hard frost'. Thaw however reached Teesdale 19th–22nd but 'not enough to clear the snow from the higher hills'; these were cold rainy days in the south. And then a brief west-wind spell brought thaw and fair weather in Teesdale 22nd–23rd, cloud and rain in London; but then, snow showers on a north wind ushered in a prolonged spell of fair north-wind weather with hard frost at night, in Teesdale from 24 December to 10 January, with two days on which snow showers fell. How well those who know Durham can picture the sequence today. Further south, Wood reports 'a great deal of snow fell at Oxford' on 25th; perhaps this provided the very heavy 'Lorna Doone snowfall' on Exmoor. Some snow fell on that night in London, but it does not appear to have been heavy. At Bristol on 19th, 'very wet and cold with snow and sleet'.

1–10 January was described in London as 'bitter hard frost, snow lies, some blew mist'; Evelyn has 'the air so very cold and thick'. From 11th–19th, 'hard frost, cloudy, mainly easterly winds'. Indeed in London from 10 January to 13 February the wind is noted as easterly on twenty-two days, north-easterly on eight, northerly on one and south-easterly on one; in Teesdale mainly northerly or easterly. Thaws in Teesdale 21–23 January, in London and Oxford on 20th–23rd give the impression of a low over France bringing in milder air for a time; but on the night of 23rd–24th cold cloudy weather returned with snowfalls on 27th and showers thereafter; about 6 inches fell in Teesdale. 4 February gave heavy snow in Teesdale, 'about 27 inches in the plains', after which the anticyclone built up again with sunshine in Teesdale and fog in London. Frost appears everywhere to have been intense, 2–7 February. Bristol recorded severe cold on 30 January.

On 15 February 'began to thaw' in Teesdale (wind west to south); 'rain and great west wind' in London. We can compare the break-up of the 1947 frost, about 10–17 March, with the Fenland floods, the Furness snowstorm and later the great westerly gale (at Mildenhall for example) while the cold persisted in Scotland. In 1684 the thaw about 15 February saw the break-up of the ice 15th to 16th on the Trent by Nottingham where the bridge collapsed. Cold returned to Teesdale on 17th–19th (north-east wind, with some snow) backing to south-east on 20th with 'renewed thaw and great wind'. But in London and Oxford the 17th–19th gave rainy westerly weather, although 'some rain and snow' fell at Oxford on the night of 19th before the general south-wind thaw on 20th. Such a sequence brings to mind the meteorology of the break-up of the 1947 cold. Ice on Tees broke at Eggleston on 21st, but not till 23rd at Barnard Castle six miles down river, and despite the thaw and rain, Thames was still 'hard' on 19th, although at Nottingham ice had broken on 15th to 16th in the earlier thaw.

According to the daily thermometer readings kept by Dr John Downes, who had studied at Leyden, the greatest cold occurred on 15–16 January and it was almost as cold on 2, 3, 4 and 6 February. His thermometer hung indoors, probably adjacent to a window following the prevailing custom, used a degree whose equivalent was about 2·4°C (4·3°F) and these were read above and below a zero which in 1684 was probably about 48°F. The fact that in mid-January the spirit fell 'within the ball' indicates something of the order of 25°F indoors (mid-morning), and probably below 10°F outdoors. This is of the same order as the lowest daily means recorded at Greenwich (e.g. 15 January 1838, 6·2°F, 20 January 1838, 10·7°F and 8 January 1841, 12·8°F). Lowe, writing in 1870 quotes for 1684 a record of −8°F at 'London' but we do not know the source, the conversion factor or the location of the instrument. For comparison there are reports of −6°F in Marylebone on Christmas Day 1796 and a more acceptable −4°F at Chiswick on 20 January 1838. We can read that in 1684 'large forest trees were split by the frost' near London in Enfield Chase. From a garden at St Boswells in the Tweed basin it was stated that 'large trees were giving off reports like the firing of a gun' in January 1881 when −16°F was observed at Kelso and stagnant cold must have lasted for many hours.

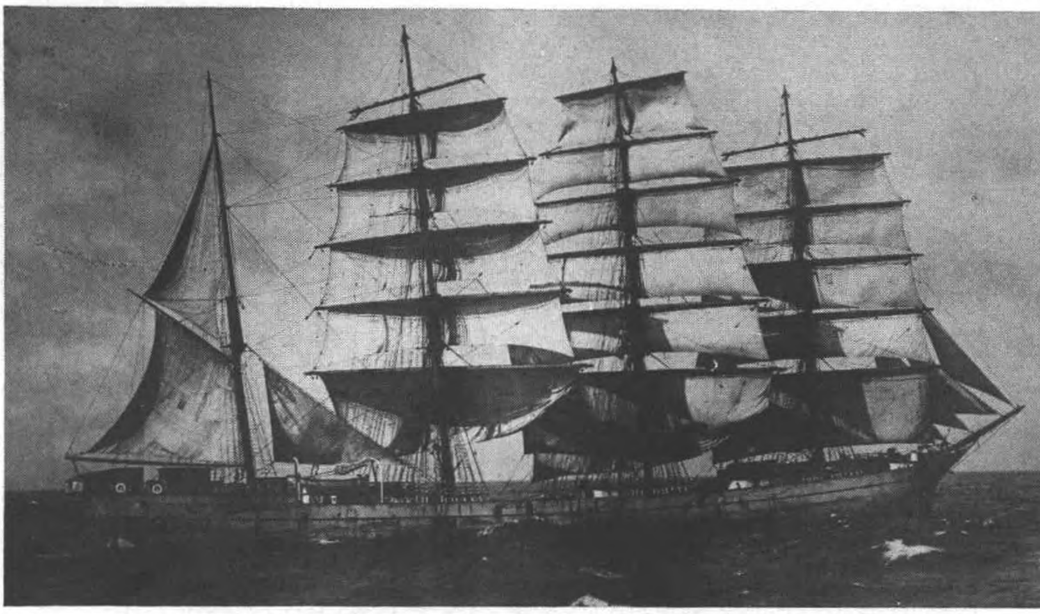
In Teesdale Sanderson noted now and then the thickness of ice formed 'where John Aislaby gets his water'; on 12–13 February ice formed 'two inches thick overnight'. He then adds 'it was in my gazette that at the Downs the water was frozen a mile into the Sea, which was never known before'. This would probably have occurred during the latter part of January. From other sources we learn that for 14 days packet-boats with the mails could not leave the Belgian coast and that 'the sea was frozen for two leagues off Caen'. Near Manchester 'it did freeze ice more than half a yard thick, and some ice continued till 25 March'.

We learn that the cold air was still persisting in the north; on 24 February it became cold again in Teesdale with snow and hard frost at night, although in the south it became a rainy afternoon after morning frost. But from 27 February to 6 March there was persistent thaw with mild winds and a good deal of sunshine; the last of the ice on Tees was carried away on 28th and evidently the ground (at 700 feet) became clear of snow. But it was freshly powdered again on 7 March and thereafter until 26th, north-east winds prevailed with snow showers noted on eight days, a 6-inch fall on 22nd and the Tees frozen over again. Sanderson also noted a violent storm in Yarmouth Roads on 31st; evidently he had news of shipping through Stockton and Yarm. His son, as an undergraduate at Cambridge (St Johns), went by sea to King's Lynn and thence by river.

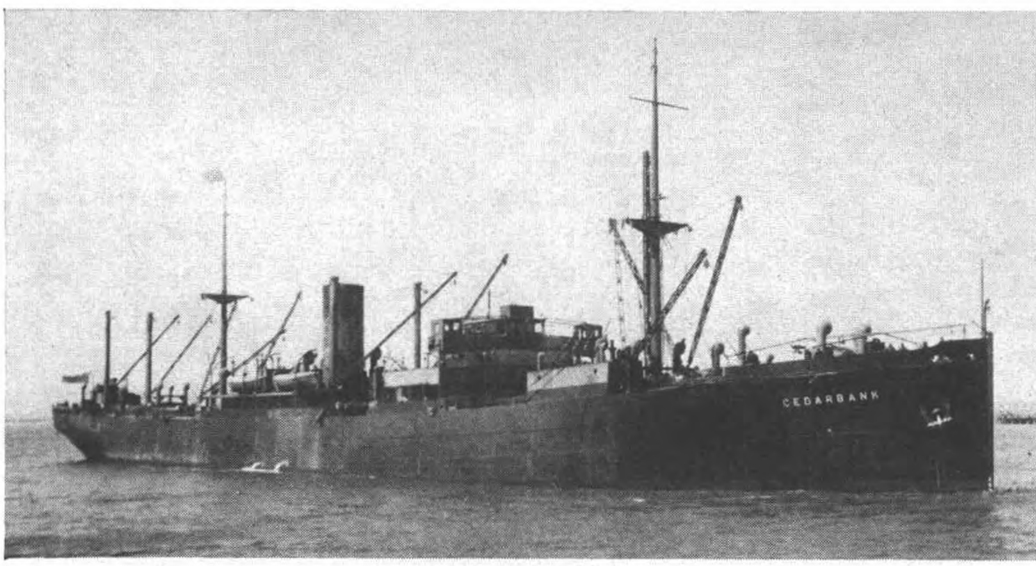
April of 1684 seems to have been a coolish to average month, cold at first then generally mild, though no marked warmth. Teesdale had snow showers on 26th; a quite normal occurrence around the time of what Westmorland knows today as 'the gesling blast'.

Reviewing the season as a whole, over much of the country the mean temperature of October 1683 was fully 4 deg F below the average prevailing in this century; November 2 deg below, December 7 deg below, January 10–11 deg, February 8 deg and March 4 deg below. Towneley's observations near Burnley indicate very little precipitation in December and January as we might expect, followed by a very wet February (Old Style months); but we also cannot be sure how much snow his roof gauge caught, or how far across the Pennines the frequent north-easterly falls carried. From the depth of frozen ground near Manchester there must have been an appreciable period with little or no snow cover, and the account of the intensity of the frost at Lancaster supports the likelihood of a good deal of clear, dry weather west of the Pennines.

We know that severe cold prevailed over much of west Europe, not only the



Cedarbank (1) *Copyright H. H. Morrison*



Cedarbank (2)

Cedarbank (4)

VESSELS OF THE BANK LINE (*see* page 82)

(*Opposite page 81*)

Photograph taken at Bracknell on 22 September 1976 during the Conference of Port Meteorological Officers. Standing, left to right: Mr D. J. F. Southon (Tyne), Mr H. M. Keenan (Clyde), Mr W. G. Cullen (Mersey), Mr J. D. W. Brown (HQ Bracknell), Captain D. R. McWhan (Southampton), Mr P. M. Swan (Humber), Captain J. H. Jones (Bristol Channel), Captain C. R. Downes (HQ Bracknell). Seated, left to right: Miss J. G. Caudrelier (HQ Bracknell), Captain G. V. Mackie (Deputy Marine Superintendent), Captain G. A. White (Marine Superintendent), Dr N. E. Rider (Deputy Director, Meteorological Office), Mr B. F. Bulmer (HQ Bracknell), Captain R. C. Cameron (Thames).

greatest rivers, but the lake of Constance itself was frozen. But in France the winter of 1709 was regarded as more extreme and is so rated by Easton. Moreover Derham recorded in early January 1709 a lower temperature than on any previous occasion in his own observations and thought it colder than on any day in 1684. On the other hand, in 1709 it was particularly noticed that in Cumberland and Scotland the lakes and rivers did not freeze, and at London the Thames was not frozen for anything like the spell in 'the long frost' of 1684.

The weight of the evidence suggests for 1684 a situation like 1963 but developing a little earlier with high pressure at first probably towards Iceland, then developing and forming a 'blocking high' giving clear skies and light northerly winds for that critical fortnight, in late December–early January, when there was a widespread snow cover at least over Scotland and the east and south of England, if not further. During the short-lived anticyclone over Scotland in mid-November 1919 the maximum at Braemar on the 16th was 12°F and the minimum was −10°F, this gives an indication of the possibilities, given quiet weather and clear skies after a snow cover during the period roughly November–February when outgoing radiation is in excess. The anticyclonic cooling over the Midlands in mid-January 1940, although there was no great snow cover, can also be cited. In 1947 the onset of the cold came later in January, the wind throughout February was more persistently easterly and the month was very cloudy. But in a clear-sky interval after snow-fall the minimum of −6°F at Houghall near Durham on 6 March 1947 still stands as the lowest yet recorded for England in that month. We can be fairly confident that temperatures of that order would have occurred in Teesdale in January–February 1684. The Kentish reference to frozen ground is less easy to explain unless the snow was either somewhat lacking compared with the west country, or was much drifted. Undoubtedly too the impression is gained that both the North Sea and the English Channel were somewhat colder than that which we should expect today; but we have yet much to learn about the past vicissitudes of surface temperature over our northern seas.

There is some prospect of making a more-detailed interpretation of the meteorology. The Admiralty archives include log-books, which were sometimes kept in ports, from 1669 onward; hence there might well be some reports from Aberdeen or Leith, Liverpool, Plymouth or Dublin for example. To these it looks as if one might add Dutch, north German and Danish observations. Indeed the meteorology of the whole period from about 1667 to the beginning of the next century appears worthy of careful study, comprising as it did some of the greatest extremes of which we have knowledge. There is still abundant opportunity for the amateur with time, energy and a zest for the archives—not forgetting, as a by-product, the revelation of the personalities of his assiduous forefathers, who in the 17th century lived through what appear to be short-period, wide-amplitude oscillations about which we need to know more.

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LONG ASSOCIATION WITH SHIPOWNERS—BANK LINE LIMITED

Our annual practice of publishing a short illustrated article of a company with whom we have had long connexions continues this year with Bank Line Limited, Baltic Exchange Buildings, 21 Bury Street, London.

The Company was founded by Mr Andrew Weir who was born in 1865 in Kirkcaldy and commenced business as a shipowner in 1885 before reaching his 21st birthday. The first ship acquired by the new Company was the iron barque *Willowbank* of 882 tons, built in Newcastle by Wigham Richardson and Sons. She was the first ship of the Company and the first to be recruited into the Voluntary Observing Scheme under the then Meteorological Department of the Board of Trade.

The business prospered and within a decade Mr Weir was the owner of one of the largest fleets of sailing ships under the British flag. Several of his ships made observations for the Meteorological Office and in addition to *Willowbank* his *Laurelbank*, *Falklandbank* and *Trafalgar* also played their part in the Observing Scheme. In 1899 Lloyd's Register showed that the fleet consisted of 30 sailing vessels and 11 steamers—quite an achievement in the 14 years since the Company was founded.

In the early part of the 20th century Andrew Weir and Company were expanding rapidly. A number of steamships had now been built and accordingly a branch office was opened in Middlesbrough. In 1905 the headquarters of the Company was moved from Glasgow to London. This year also saw the formation of Bank Line Limited and since that date all vessels of the fleet have been named in the name of this Company or in one of its subsidiaries. It is interesting to note that although the venue of its operations was moved to London, the registered office of Bank Line Limited is still Glasgow—thus retaining the links with the birthplace of the Line after which the Company is named.

A portion of the first meteorological logbook of *Willowbank* remains in the Meteorological Office Archives and although the voyage commenced 20 July 1885 and terminated 13 March 1887, the latter part of the book is regrettably missing and it ends on 14 February 1886 whilst on passage from Newcastle NSW towards Rangoon. *Willowbank* sailed from Glasgow under the command of Captain T. Perrin on 20 July 1885 bound for Adelaide, round the Cape of Good Hope, arriving at Adelaide on 31 October 1885 after taking 103 days to complete the passage.

Captain Perrin's voyage appears largely uneventful except for one incident recorded on 15 October at 6.30 pm in approximate position 39°S 104°E. The following entry was made on a page at the beginning of the logbook:

'October 15th at 6.30 pm. Wind about SSW (compass) steering SE by E force 5 to 6, a hail squall force 7 struck the ship the wind Westering about 2 points in it. After the squall had passed over the ship it rose again on the lee bow and recurved directly against the wind towards the ship, coming up from the leeward with great speed, looking very fierce and threatening, seemed to me like a waterspout. When about a mile from us, it shifted its course to the NE and disappeared on the lee-beam. The wind hauled to the Southward again directly afterwards. Was this a waterspout? It looked so bad that I believe had it caught us aback as it threatened to, we should have been dismasted. Barometer 30·08 rising, attached thermometer 59°.'

After arrival at Adelaide it is to be regretted that a number of logbook pages are missing, the next entry being made on 26 January 1886 whilst on passage from Newcastle NSW towards Rangoon. It is only from entries in the front of the book that we know that the *Willowbank* proceeded from Rangoon to Valparaiso and that the period of the logbook ended 13 March 1887.

During the 1914–18 War Bank Line lost 10 of their ships by enemy action—almost a quarter of the fleet. In 1917 Andrew Weir was appointed to the office of Surveyor General of Supply at the War Office as a member of the Army Council and in 1919 he became a member of the Cabinet and Minister of Munitions. For his services in these capacities Mr Weir was created first Baron Inverforth of Southgate.

Extensive building during the 1920s and 30s found the Company entering the Second World War with a large fleet of cargo vessels and seven 'Inver' tankers, 29 of these ships were lost during the war years. The Company also managed a number of *Empire* and *Liberty* ships on behalf of the Ministry of War Transport.

After the war the Company began to increase the size of its fleet by purchasing a number of *Empire*- and *Liberty*-type steamers which were renamed with Bank Line names. Subsequently Bank Line embarked on a steady program of building up the large modern fleet of 43 ships which they have today.

The three photographs opposite page 80 show three of the four Company's ships which have borne the name *Cedarbank*.

The first photograph shows *Cedarbank* (*1*), a steel barque of 2825 gross tons, built in 1892 by Mackie and Thompson. This vessel arrived at San Francisco from Newcastle NSW in 1893 with a fire on board and had to be scuttled. She was later refloated and continued in service.

The second photograph shows *Cedarbank* (*2*) built by Harland and Wolff and delivered in 1924. This vessel was torpedoed on 21 April 1940 by a submarine.

Cedarbank (*3*), not shown, was also built by Harland and Wolff and delivered to Bank Line in January 1955.

The third photograph, *Cedarbank* (*4*) is a single-screw motor vessel built at the new Pallion Ship Factory which was developed by Sunderland Shipbuilders. The vessel was delivered to the Company on 29 June 1976. This ship was recruited into the Voluntary Observing Fleet before her maiden voyage.

At the present time, of their fleet of 43 ships, 22 are members of the Voluntary Observing Fleet. It gives us considerable pleasure to express our gratitude to Bank Line Limited and to all their Masters and Officers who have rendered such valuable service to the Meteorological Office during our 92 years association.

J. D. B.

ICE CONDITIONS IN AREAS ADJACENT TO THE NORTH ATLANTIC OCEAN FROM OCTOBER TO DECEMBER 1976

The charts on pages 85 to 87 display the actual and normal ice edges (4/10 cover), sea-surface and air temperatures and surface-pressure anomalies (departures from the mean) so that the abnormality of any month may be readily observed. (The wind anomaly bears the same relationship to lines of equal pressure anomaly as wind does to isobars. Buys Ballot's law can therefore be applied to determine the direction of the wind anomaly.) Southern and eastern iceberg limits will be displayed during the iceberg season (roughly February to July). In any month when sightings have been abnormally frequent (or infrequent) this will be discussed briefly in the text.

The periods used for the normals are as follows. Ice: 1966–73 (Meteorological Office). Surface pressure: 1951–70 (Meteorological Office). Air temperature: 1951–60 (U.S. Department of Commerce, 1965). Sea-surface temperature: area north of 68°N, 1854–1914 and 1920–50 (Meteorological Office, 1966), area south 68°N, 1854–1958 (U.S. Navy, 1967).

October

West of Greenland winds were more north-westerly than usual giving temperatures which were below average; areas of ice developed quickly and the spread of ice over Foxe Basin and around the coast of Baffin Island into Davis Strait was much ahead of normal. East of Greenland there were anomalous south-easterly winds with temperatures near or above average; by the end of the month there was some deficit of ice over the Greenland Sea with the edge, on the whole, north-west of its normal position. Over the Barents Sea, however, there was an excess of ice associated with an anomaly for northerly winds and lower-than-average temperatures.

November

Over eastern Canada winds were more northerly than normal and temperatures mostly below average. Rapid freezing continued so that by the end of the month most of Hudson Bay was frozen and the whole of Hudson Strait; there was an excess of ice in Davis Strait with a tongue of ice extending further south than usual, along the coast of Labrador. East of Greenland, though, the increase of ice during the month was much less than normal—a feature that cannot be readily explained in terms of the anomaly patterns of temperature and pressure. Over the Barents Sea the excesses of previous months gave way to near normal conditions. The first ice of the season formed in the Baltic and the White Sea, much as normal.

December

The pattern of pressure anomalies was weak over eastern Canada where temperatures remained lower than average. The tongue of ice along the coast of Labrador continued to extend southwards reaching Belle Isle Strait. In the Davis Strait, however, the position of the ice edge changed little during the month and in places the ice even receded somewhat; there was a tendency for southerly winds here, with temperatures above normal. Deficits of ice persisted over the Greenland Sea and near Spitzbergen. Areas of excess or deficit of ice were rather small in the Baltic, the White Sea and near Novaya Zemlya.

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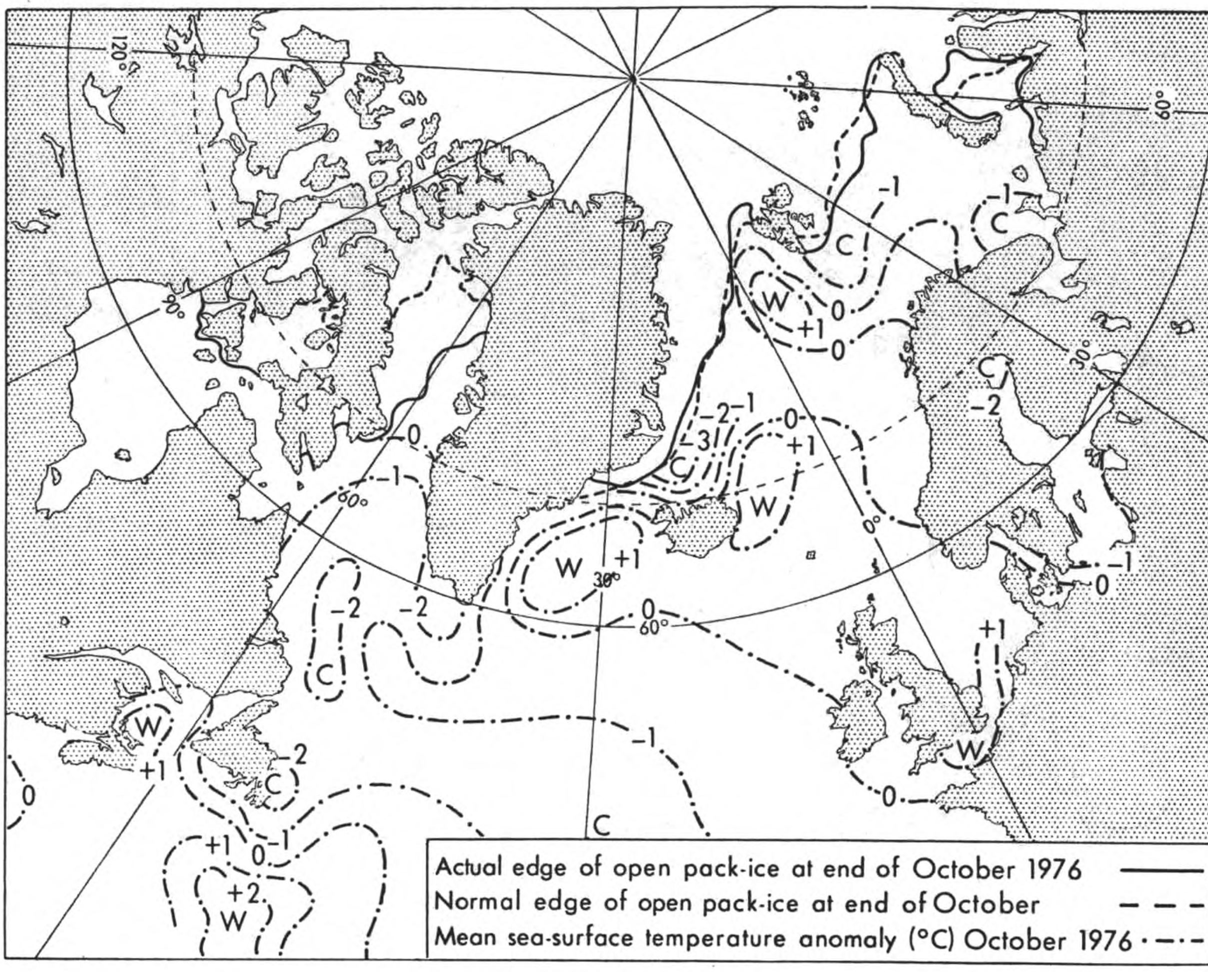
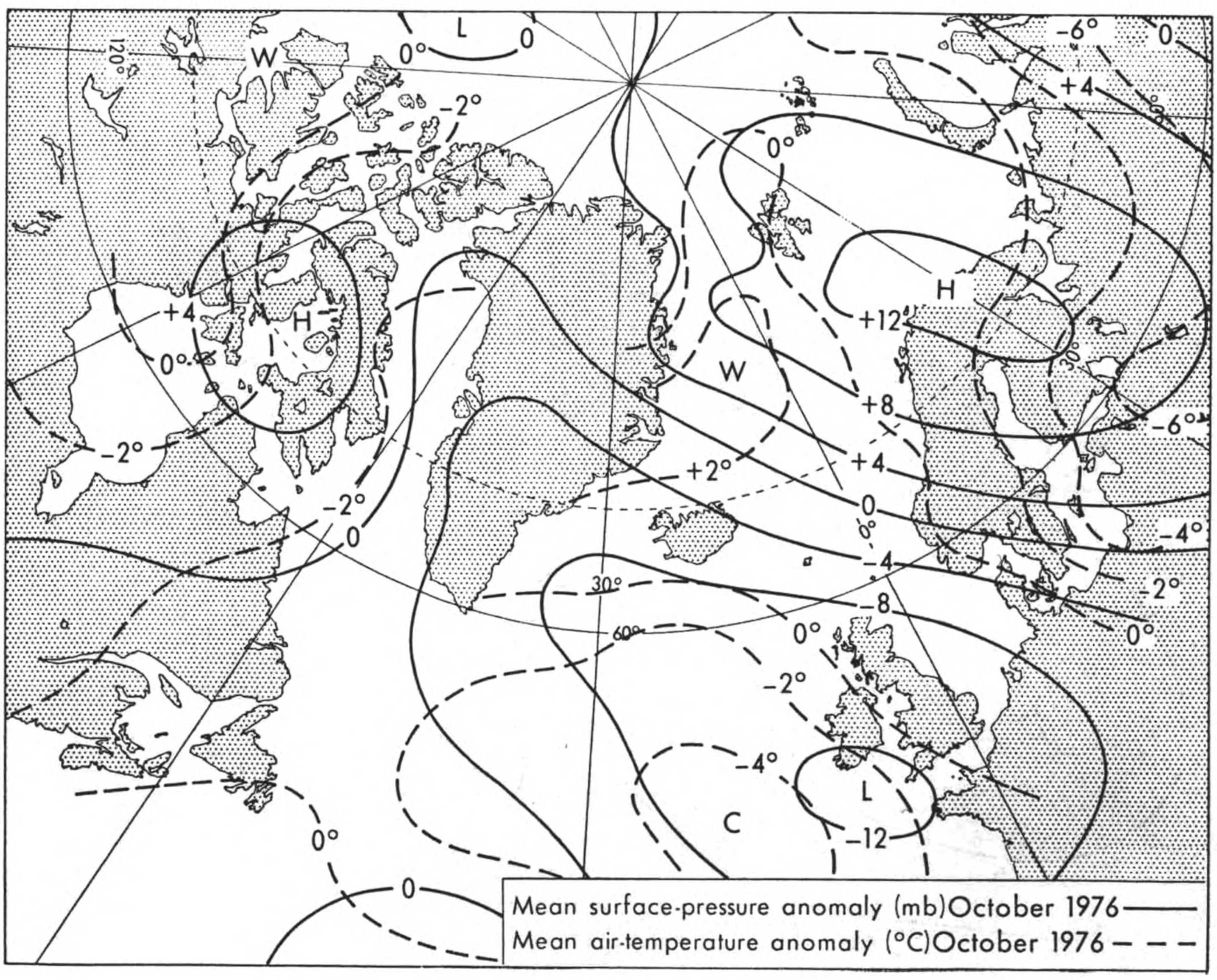
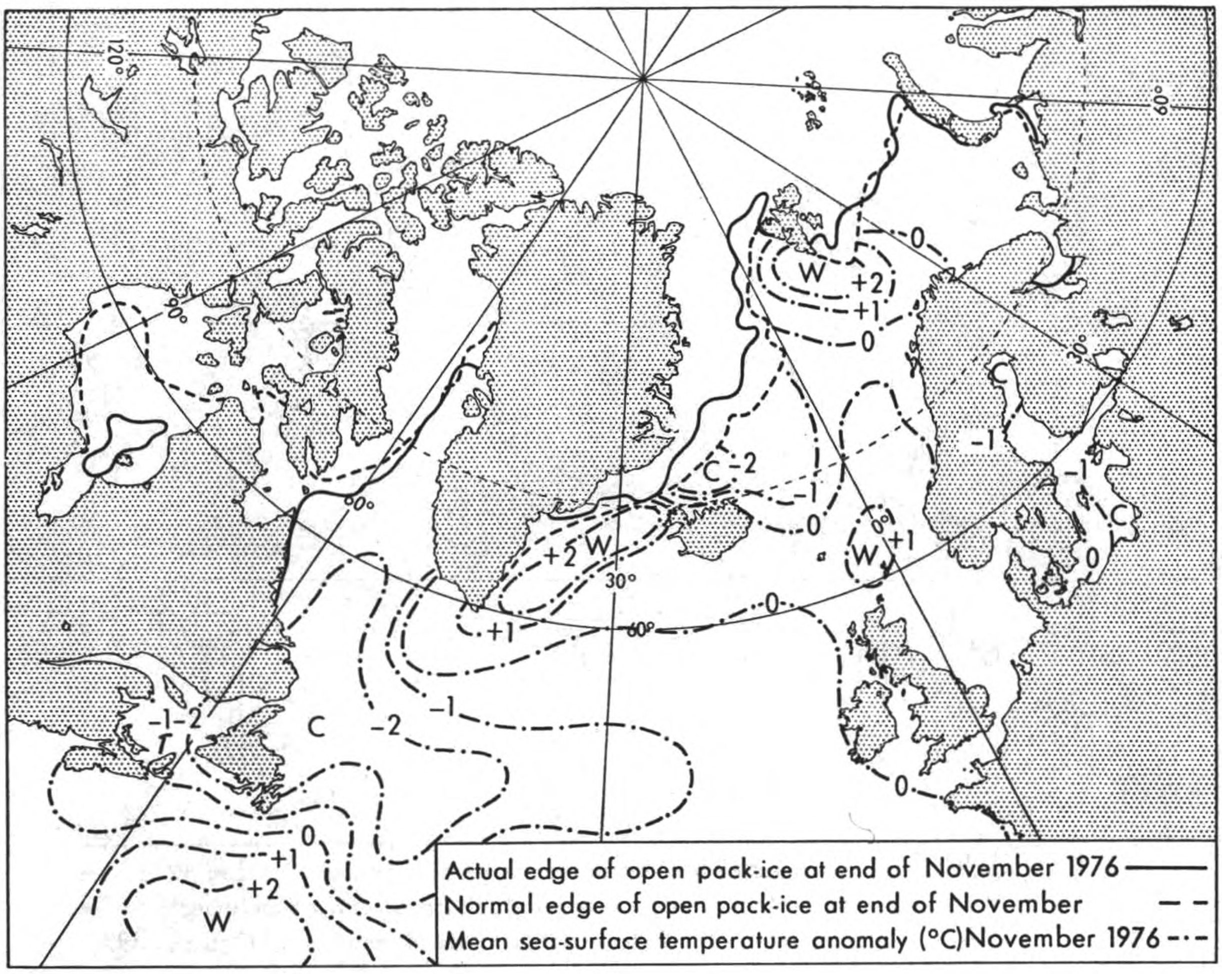
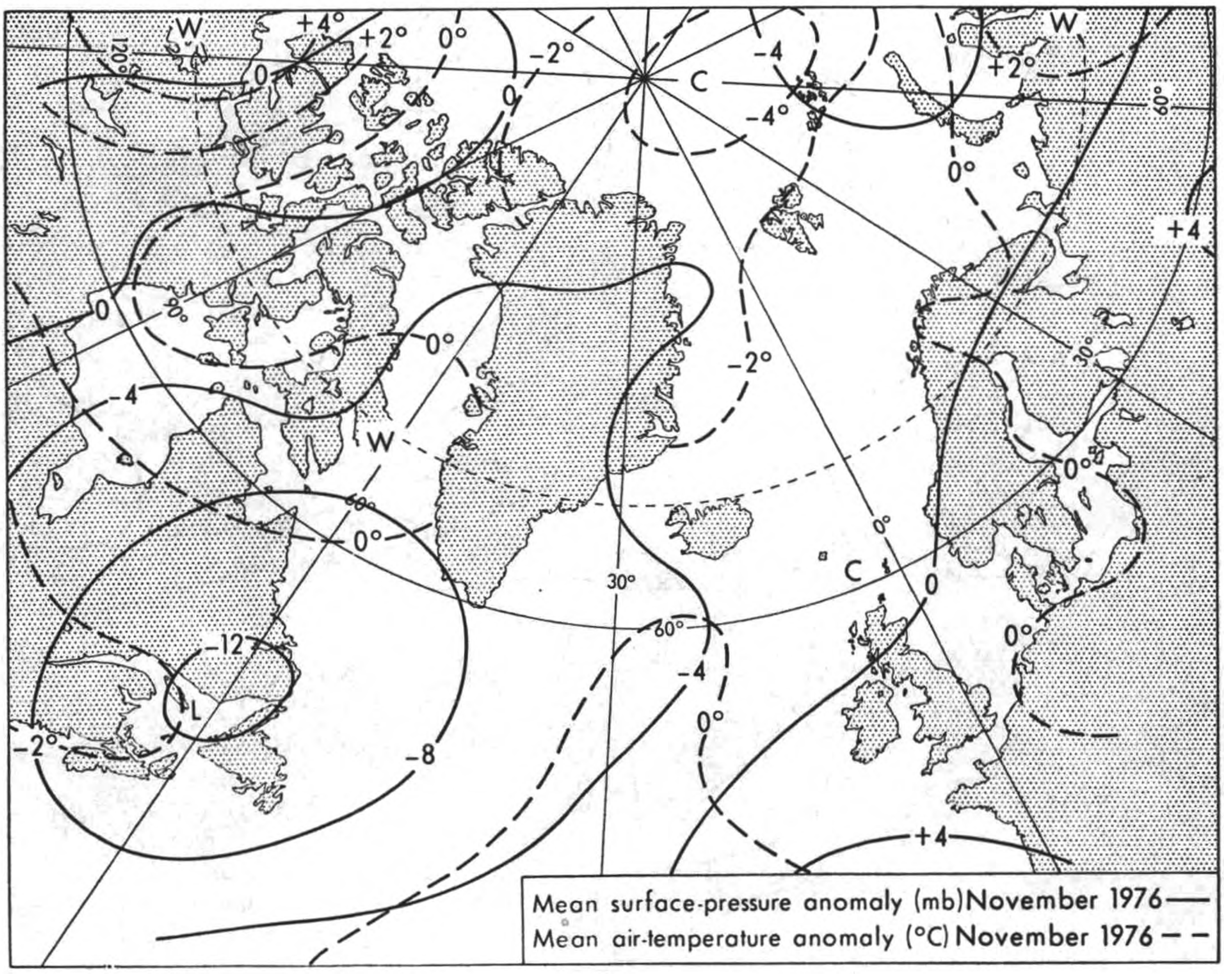
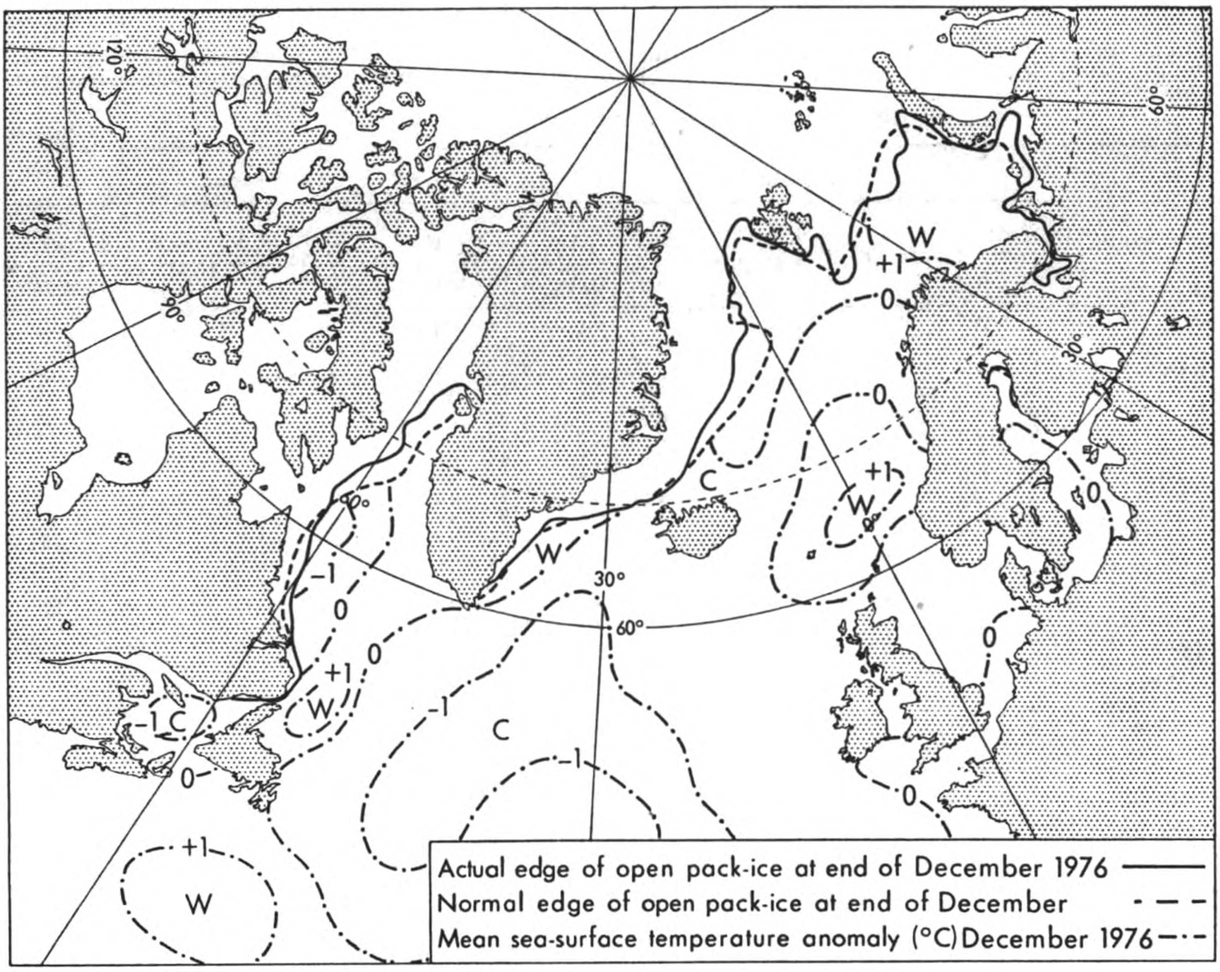
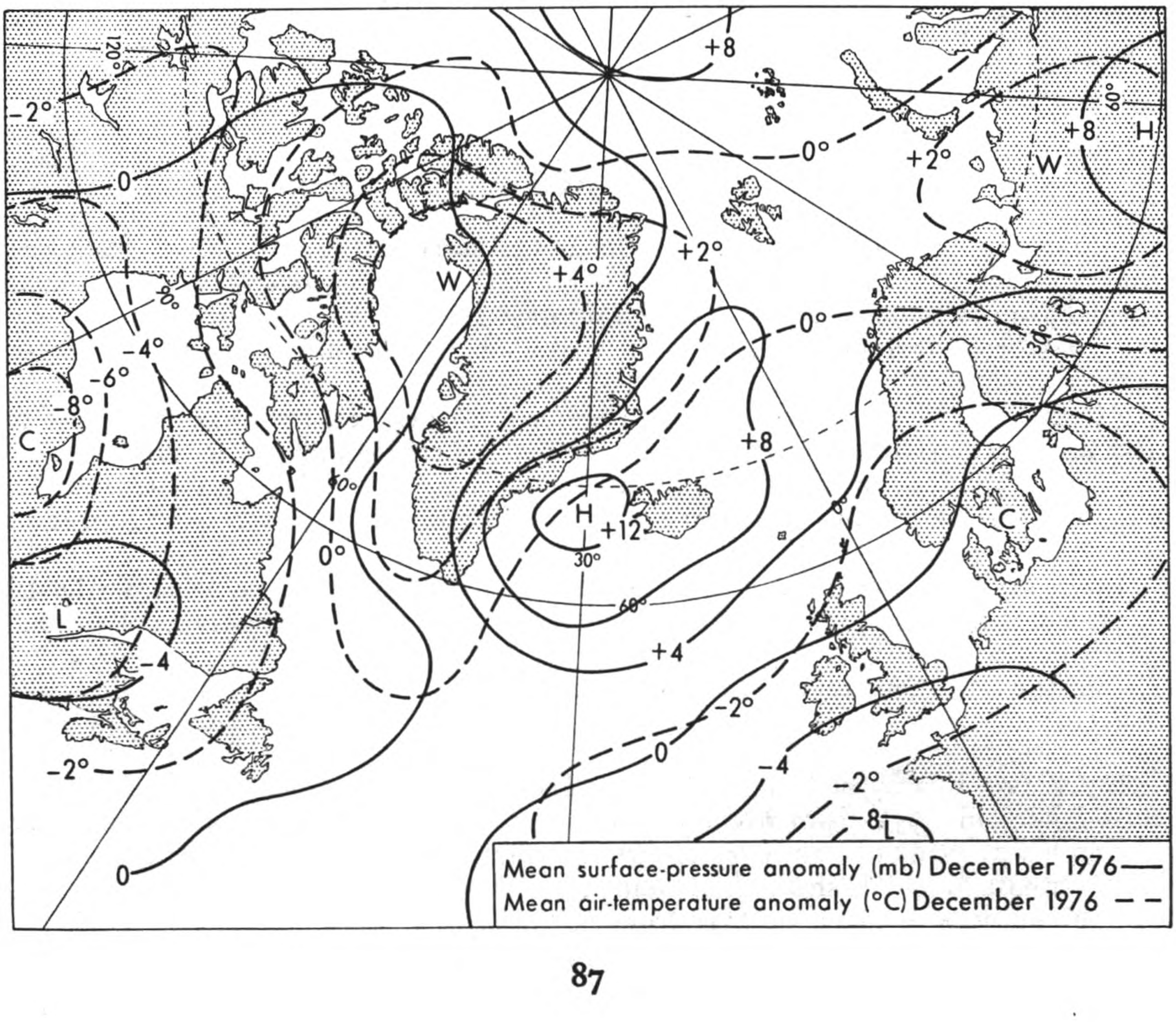

Actual edge of open pack-ice at end of October 1976
Normal edge of open pack-ice at end of October
Mean sea-surface temperature anomaly (°C) October 1976


Mean surface-pressure anomaly (mb)October 1976
Mean air-temperature anomaly (°C)October 1976


Actual edge of open pack-ice at end of November 1976
Normal edge of open pack-ice at end of November
Mean sea-surface temperature anomaly (°C)November 1976


Mean surface-pressure anomaly (mb)November 1976
Mean air-temperature anomaly (°C) November 1976


Actual edge of open pack-ice at end of December 1976
Normal edge of open pack-ice at end of December
Mean sea-surface temperature anomaly (°C) December 1976


Mean surface-pressure anomaly (mb) December 1976
Mean air-temperature anomaly (°C) December 1976

Baltic Ice Summary: October–December 1976

No ice was reported at the following stations during the period: Ventspils, Tallin, Mariehamn, Göteborg, Visby, Bremerhaven, Kiel, Flensburg, Stettin, Gdansk, Stralsund, Rostock, Aarhus, Copenhagen, Oslo, Kristiansandfjord.

No ice was reported at any of the stations in October.

Station	November									December								
	Length of Season		Ice Days			Navigation Conditions			Accumulated Degree Days	Length of Season		Ice Days			Navigation Conditions			Accumulated Degree Days
	A	B	C	D	E	F	G	H	I	A	B	C	D	E	F	G	H	I
Leningrad	5	30	9	0	3	7	0	0	75	1	31	19	4	10	17	1	0	221
Riga ..	0	0	0	0	0	0	0	0	—	30	30	1	0	0	1	0	0	99
Pyarnu ..	0	0	0	0	0	0	0	0	—	27	31	5	5	0	0	0	5	—
Viborg ..	6	30	8	4	0	8	0	0	—	1	31	19	14	1	11	8	0	—
Klaipeda	0	0	0	0	0	0	0	0	—	17	31	10	0	1	5	0	0	—
Helsinki ..	0	0	0	0	0	0	0	0	—	26	31	6	4	0	6	0	0	149
Turku ..	0	0	0	0	0	0	0	0	—	27	31	5	0	1	4	0	0	164
Mantyluoto	0	0	0	0	0	0	0	0	—	27	31	5	0	0	3	0	0	—
Vaasa ..	26	30	5	0	0	0	0	0	44	1	31	21	10	0	10	5	0	207
Oulu ..	15	30	16	15	0	11	5	0	—	1	31	31	31	0	0	31	0	—
Roytaa ..	15	26	2	0	0	0	1	0	—	4	31	23	6	14	0	23	0	—
Lulea ..	14	30	16	12	0	13	0	0	128	1	31	31	31	0	14	17	0	396
Bredskar ..	0	0	0	0	0	0	0	0	—	22	31	5	0	0	5	0	0	—
Sundsvall	0	0	0	0	0	0	0	0	—	28	31	4	0	0	4	0	0	—
Stockholm	0	0	0	0	0	0	0	0	—	24	31	8	4	0	8	0	0	105
Kalmar ..	0	0	0	0	0	0	0	0	—	28	31	3	0	2	3	0	0	—
Skelleftea	0	0	0	0	0	0	0	0	—	17	31	15	8	0	12	3	0	—
Emden ..	0	0	0	0	0	0	0	0	—	31	31	1	0	0	0	0	0	—
Lübeck ..	0	0	0	0	0	0	0	0	—	31	31	1	0	0	1	0	0	—
Hamburg	0	0	0	0	0	0	0	0	—	31	31	1	0	0	0	0	0	—

CODE:
A First day ice reported.
B Last day ice reported.
C No. of days that ice was reported.
D No. of days continuous land-fast ice.
E No. of days of pack-ice.
F No. of days dangerous to navigation, but assistance not required.
G No. of days assistance required.
H No. of days closed to navigation.
I Accumulated degree-days of air temperature (°C) where known.*

* These figures give a rough measure of the first probability of the formation of sea ice, and later the progress of the growth and its thickness. They are derived from daily averages of temperature (00 + 06 + 12 + 18 GMT) and are the sum of the number of the degrees Celsius below zero experienced each day during the period of sustained frost.

SPECIAL LONG-SERVICE AWARDS

Commencing in 1948, in addition to the annual Excellent Awards which have been presented since 1924, the Director-General of the Meteorological Office has made special awards every year to the four voluntary marine observers whose services to the Meteorological Office have been particularly outstanding over a prolonged period.

All officers who have provided us with meteorological records in 15 or more years and who have contributed at least one meteorological logbook in the previous year are considered for the selection of the special awards. Personal cards are scrutinized; length of service combined with the number and quality of their records determines the order of placings.

In the current award year, 1975, there were 112 officers with the necessary length of service; these years are rarely continuous and frequently cover periods of 30 years or more.

The Director-General is pleased to make the special awards to the following shipmasters:

1. Captain P. Lay of P. & O. Lines, whose first meteorological logbook was received here in 1952 from mv *Rangitoto* (New Zealand Shipping Co.), has since, during his 21 years of voluntary observing, provided us with a total of 34 logbooks.

2. Captain J. M. Rushworth of Manchester Liners Ltd, whose first meteorological logbook was received in 1947 from ss *Carnaervon Castle* (Union Castle Line),

has since provided, during a total of 24 years of voluntary observing, a further 46 logbooks all compiled during his service with Manchester Liners.

3. Captain J. L. Downie, Shipping & Coal Co. Ltd, sent in his first meteorological logbook in 1946 from ss *Delilion* (Donaldson Line), and subsequently has contributed a further 45 logbooks during his 23 years of voluntary observing.

4. Captain W. A. Murison, Shaw Savill Line, whose first meteorological logbook was received in 1953 from ss *New Australia*, has supplied us with a total of 29 logbooks over a period of 20 years voluntary observing, all compiled during his service with the Shaw Savill Line.

Following the usual practice, the award will be in the form of an appropriately inscribed barograph, and it is with great pleasure that, once again, we congratulate four shipmasters on this acknowledgement of their many years of zealous voluntary observing at sea on behalf of the Meteorological Office.

The four masters will be advised personally of the award and of the arrangements to be made for its presentation.

J. D. B.

Personalities

OBITUARY.—It is with much regret that we record the death on 12 December 1976 of LIEUTENANT COMMANDER E. R. PULLAN, R.D., R.N.R. in Darwen where he lived since his retirement as Port Meteorological Officer Liverpool in 1973.

Edwin Ronald Pullan was born in Yorkshire in 1911 and after serving his apprenticeship with Hain Steamship Company, he joined Blue Funnel Line with whom he remained until he left the sea in 1949 on medical grounds and commenced his service in the Meteorological Office.

During the war he served as a Royal Navy Reserve Officer in submarines and cruisers. Subsequently he was seconded to the Royal Indian Navy and appointed to command HMIS *Tranvancore* engaged on convoy escort duty in the Indian Ocean.

Lieutenant Commander Pullan commenced his career in the Meteorological Office as Port Meteorological Officer in Southampton and in 1956 was transferred in the same capacity to Hull. In 1967, on promotion to Senior Nautical Officer, he was appointed to Liverpool as Port Meteorological Officer.

We extend our sympathy to his family.

OBITUARY.—It is with great regret that we have to record the sudden and tragic death of MR R. R. WEBB, Assistant Scientific Officer in the Port Meteorological Office at Southampton on 9 December 1976.

'Bob' Webb was educated at Andover Grammar School and, on leaving in 1935, he enlisted in the Royal Navy where he attained the rating of Petty Officer before he retired in 1947.

He then joined the Meteorological Office as Meteorological Assistant and served at Habbaniya in Iraq and at Porton Down before his first posting to Southampton Port Meteorological Office in 1957. In 1958 he did a tour of duty on Christmas Island in the Pacific before being posted to Glasgow Port Meteorological Office where he remained for the next three years. He then saw service in Wildenrath in Germany and on board the Ocean Weather Ships until 1964 when he was posted to the Cardiff Port Meteorological Office. Two years later he was transferred to London and in 1972 he was posted back to Southampton Port Meteorological Office, where he remained until his untimely death.

We extend our deep sympathy to his family.

RETIREMENT.—CAPTAIN R. D. LECKIE retired on 6 January 1977 after serving nearly 45 years at sea.

Robert Leckie commenced his sea-going career as an apprentice with Elders and Fyffes Company in 1932. On obtaining his 2nd Mate's Certificate in 1936, as jobs at that time were difficult to find, he sailed as Quartermaster in the *Franconia* and, later, in the *Laconia* along with other certificated Quartermasters.

He eventually found a 'berth' as 3rd Officer with Strick Line in s.s. *Marsa* and remained with that Company until he obtained his Mate's Certificate. Thereafter he sailed with Kays of London, the Bolton Steamship Company and again with Strick Line.

After being torpedoed off Freetown in 1943 in s.s. *Bandar Shapour*, he joined Moss Hutchison Line in 1945 and remained with them until his recent retirement.

For the last five years of his career Captain Leckie commanded m.v. *Melita* engaged in the UK/Mediterranean trade during which he developed a friendly relationship with Mr Miller of the Israeli Meteorological Service and benefited much from his help and interest.

We received the first meteorological logbook bearing Captain Leckie's name from the *Armarna* in 1970. Since then he has sent us a further 13 logbooks.

We wish him good health and happiness in his well-earned retirement.

RETIREMENT.—CAPTAIN J. K. MARROW M.B.E. retired in May 1976 after over 45 years at sea.

John Kristijan Marrow commenced his career at sea as an apprentice with Silver Line in 1930 and, as was quite common in those days, completed his four years' apprenticeship without returning home. He obtained his 2nd Mate's Certificate in 1934 but owing to the depression spent the next two years serving in tugs, trawlers and colliers. Early in 1937 he obtained a position with Eagle Oil and Shipping Company and remained with them until he obtained his 1st Mate's Certificate in 1939.

Captain Marrow then joined Ellerman's Wilson Line with whom he remained until his recent retirement. In 1943 he joined the so-called 'Ball Bearing Fleet' which was 'running the gauntlet' through enemy waters to Sweden and, with a brief interruption during the D Day landings, remained with them until they were disbanded in 1945.

Captain Marrow was appointed to his first command, the *Salerno*, in 1953. Prior to his retirement he commanded the Ro-ro ship *Hero* jointly owned by Ellerman's Wilson Line and DFDS on the UK–Esbjerg service.

Captain Marrow sent us his first meteorological logbook from the *Bravo* in 1952. Since then we have received a further 21 logbooks bearing his name of which 15 were classed as Excellent. He received Excellent Awards in 1960, 1964, 1965 and 1966.

We wish him a long, healthy and happy retirement.

RETIREMENT.—CAPTAIN B. L. O'BRIEN retired last November after 47½ years unbroken service at sea.

Brian O'Brien was indentured as an apprentice with Manchester Liners Ltd and commenced his first voyage to sea in the *Manchester Regiment* in May 1929. He remained with that Company until October 1937 after which he served for two years with the Lancashire Shipping Company of Liverpool.

In early 1940 he joined Orient Line and thereafter served in the *Otranto*, the *Orion* and the *Oronsay*. Whilst in the latter vessel he was torpedoed by a German U-Boat in October 1942. After spending two weeks in a lifeboat he was rescued by the Flower class corvette, HMS *Armeria*. He received the King's Commendation as a result of this experience.

Captain O'Brien joined Cunard Steamship Company in March 1944 and, apart from a spell of 12 months with L M S Railway ships sailing out of Holyhead, remained with Cunard until his recent retirement. During this period he sailed in nearly all the Cunard liners, including *Queen Elizabeth*, *Queen Mary*, *Aquitania*, *Mauretania*, *Caronia*, *Britannic* and *Georgic*. Whilst serving in the *Queen Mary* in 1944 he acted as Liaison Officer to Winston Churchill and his War Cabinet whilst travelling to and from the Quebec Conference with President Roosevelt.

On 15 June 1976 he commanded the *Atlantic Conveyor* in the rescue of yachtsman Pierre Fehlmann from his yacht *Gauloises* which foundered in mid-Atlantic during a severe gale whilst competing in the *Observer* Single-handed Transatlantic Yacht Race.

We received the first meteorological logbook bearing Captain O'Brien's name in 1948 from the *Queen Elizabeth*. Since then he has sent us a further 23 logbooks.

We wish Captain O'Brien a long, happy and healthy retirement.

Printed in England for Her Majesty's Stationery Office by
William Clowes and Sons, Limited, London, Beccles and Colchester
Dd. 497685 K19. 4/77

ISBN 0 11 724384 1