Chinook

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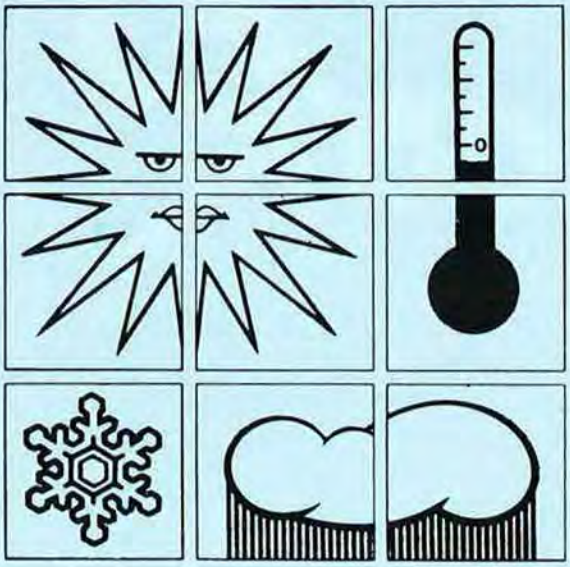

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FROM THE EDITOR'S DESK

Two years ago this July the CMOS Executive approved the nominations of the members of the first Editorial Board of *Chinook*. In October of 1984 the Board held its first meeting, when the Terms of Reference were discussed and approved, but more importantly the aims and objectives of the publication.

It has been the Society's intention – from the beginning – that the publication be aimed at increasing public awareness of meteorology and oceanography, and at stimulating the public interest and the understanding of matters relating to the atmosphere-ocean environment.

The readership that we intended to target were primarily those groups and individuals who through work, study or interest are in one way or another affected by weather, climate or the oceans. Specifically, the emphasis was on such groups as secondary schools, colleges and universities, aviators, marine, recreation and a host of other weather and ocean specialists or enthusiasts.

To date, after some efforts by the CMOS Centres, our subscriptions have *not* increased significantly, in fact the numbers are only slightly higher than they were two years ago. Efforts on behalf of the CMOS to obtain funding from the Federal Public Awareness Program for the purpose of promoting the magazine across Canada have been unsuccessful on two occasions.

The CMOS, however, remains committed to the goal of the magazine and this year at the Regina Congress has given its vote of *confidence* to the Editorial Board.

We believe that we have a good product; we also believe that it can be more relevant to our target audiences. We further believe that we can increase our number of subscriptions, but we feel that *we need your help*. You the subscriber and reader can help us in

Continued on page 82

COVER

Icebergs in the eastern waters of North America. For further details see the article on page 64.

COUVERTURE

Les icebergs dans les eaux de l'Est de l'Amérique du nord. L'article de la page 64 donne de plus amples details.

Chinook

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ICEBERGS OFF CANADA'S EAST COAST

by Jerry E. Salloum

Ice on the earth's land surfaces occurs mostly in Antarctica and Greenland. Of the two, Antarctica's ice-cap far exceeds Greenland's in area, volume and thickness, possessing by itself about 90% of the world's ice. So enormous is the accumulation of land ice in these two locations that if it were all to melt, the world sea-level would rise some 40 m.

The formation of these giant "ice-cubes" occurs if the total annual snowfall exceeds total annual melt. The result is an annual residue of snow. Over many years of accumulation the pressure of snow on snow creates ice from snow and, aided by a sloping surface, the ice begins an imperceptibly slow migration. Migrations that terminate in the sea produce one of nature's most spectacular phenomena – the iceberg.

The following study provides a comprehensive package of information about Greenland's icebergs, their development, drift and deterioration, and their impact on offshore human activity along Canada's East Coast. The study is made purposefully simple in places and more complex in others to permit use of part or all of the material at a variety of grade levels. Teachers will recognize its usefulness to courses in Canadian Geography, Physical Geography, Environmental Hazards, Oceanography and Marine Transportation.

Figure 1 Greenland, indicating the major iceberg-producing glaciers and surrounding bays, basins and seas.

ICEBERG FORMATION

Greenland, the largest island in the world, with a coastline as long as the earth's equator, is dominated by a massive ice sheet that covers all but narrow segments of the island's coastal perimeter. This ice sheet, estimated to contain some 2.6 million cubic kilometres of ice, covers 84% of the surface of the island and has thicknesses in excess of 3400 m.

From above, the island appears as a wedge that extends 2670 km from Cape Farewell (60°N) to Cape Morris Jessup (84°N) (Figure 1). At its widest latitude (about 70°N), it is 1050 km from east to west. In cross-section, Greenland appears as a bowl whose centre is below sea-level and whose rim, though absent in places, serves largely to contain the ice mass.

Despite the structure, ice is slowly released. In some coastal areas such as Kane Basin and Melville Bay the ice sheet comes in direct contact with the sea along very wide fronts. In others, tongues of ice exit the bowl through much narrower geological conduits following valleys that terminate at the heads of long steep-sided fiords. The width of the terminus of the tongue of ice upon reaching the sea is one of the principal factors in determining the initial size of the calved or broken-off chunk that becomes the iceberg.

Thus, *ice sheets* (Figure 2) generate icebergs. In the Northern Hemisphere it is estimated that the annual production rate of icebergs is some 280 cubic kilometres. While glaciers on islands such as Ellesmere, Bylot, Devon and Baffin in Canada's northern archipelago, plus other source regions in the Alaskan Panhandle, Coburg Island, Spitzbergen and Franz Josef Land, contribute to this rate, their combined berg production is miniscule when compared to that of Greenland. We note that, by comparison, Antarctica shows a similar overwhelming predominance as the major iceberg producer in its hemisphere discharging annually to the seas around it approximately 1800 cubic kilometres of ice.

The release of ice from Greenland into adjacent waters shows considerable spatial variation. In east Greenland, iceberg production is greatest in the south between Cape Farewell and Scoresby Sound. North of Scoresby Sound, production rates decrease. In west Greenland, Disko Bay is the area with the most prolific production of icebergs, while the region of Melville Bay up to Cape York has the greatest concentration of bergs. With over 100 berg-producing glaciers along that coast, annual production rate estimates run as high as 40,000 and production is considered to be double that found along the east Greenland coast.

To the north are the massive Humboldt and Petermann glaciers. The latter, the largest in our hemisphere, produces this hemisphere's largest bergs. Known as *ice islands* these flat-topped giants are similar to, but much smaller than, the tabular bergs that regularly calve off Antarctica's Ross and Filchner ice shelves.

The Jakobshavn Glacier, whose bergs traverse a 50-km fiord to enter Disko Bay, is one of the world's fastest. Galloping on at almost 1 m/h, it contributes by itself 20 cubic kilometres of ice or potentially about 4800 five million tonne icebergs. South of Disko Bay, though there are many glaciers, discharges of ice tend to occur into long and narrow inlets thereby tending to produce smaller ice chunks. Called *bergy bits* or *growlers* (Figure 3), these miniature bergs frequently melt before reaching open water. At the present time, of all the bergs reaching North Atlantic waters, about 10% come from east Greenland and 85% from west Greenland. The remaining 5% come from Ellesmere Island and, to a lesser extent, Baffin Island.

SIZE AND SHAPE OF ICEBERGS

Icebergs are floating chunks of land ice whose visible portion (or sail) exceeds 5 m in height. Chunks of ice whose sail is

Figure 2 Ice sheet.

Figure 3 Bergy bit or growler.

Figure 4 Large iceberg.

less than 5 m but greater than 1 m are known as "bergy bits" while those whose sail is under 1 m are called "growlers". Bergy bits are about the size of a house while growlers are the size of a small room.

"Large" icebergs are any whose mass exceeds 2 million tonnes and whose length exceeds 120 m (Figure 4). "Small" bergs weigh less than 100,000 tonnes and are less than 60 m in length. In Baffin Bay, observed berg heights have exceeded 200 m and lengths have exceeded 2 km. The most massive bergs have been estimated to be in the order of 40 million tonnes.

While no two bergs look alike, a few shapes appear common and serve as a basis for classification. Shape categories include tabular, pinnacled, wedge, domed and drydock forms. The size and shape characteristics reflect both a berg's initial calving as well as the manner in which it deteriorates.

Figure 5 Tabular berg.

Figure 6 Pinnacled berg.

ICEBERG BUOYANCY

According to Archimedes, an object will sink into a liquid until it has displaced a volume of liquid whose weight is equivalent to its own. Ice is frozen water. Since one kilogram of ice occupies a larger volume than one kilogram of water, an ice-cube does not have to use its entire volume to displace an amount of water equivalent to its mass. As a result part of it remains out of the water. Depending on the amount of air trapped in the ice and the salinity of the water in which it sits, the block of ice will assume a position of stability when approximately one eighth of its volume is above the water-line and seven eighths is below.

Frequently when observing icebergs people confuse volume dimensions with linear dimensions. One eighth of the iceberg above water refers to its volume, not its height of sail. The depth of the berg, or its draft (D), relative to its height, or its sail (H), is often expressed as a ratio – D/H. While the volume ratio among bergs remains relatively constant at roughly 7 to 1, the linear ratio can vary greatly depending on berg shape. A tabular berg (Figure 5), resembling a relatively uniform elongated block, would have one of the largest D/H ratios. A pinnacled berg (Figure 6), with much of its sail distributed vertically, would have a much reduced D/H ratio, possibly approaching 1 and in some cases falling below 1. In general, the larger the D/H ratio the more stable the berg and the less likely it is to roll.

ICEBERG DRIFT

If the water depth in which a berg is calved exceeds the normal draft of that berg, the berg will float and begin a leisurely drift away from the glacier's calving front. Since draft often exceeds water depth, many bergs must sojourn at or near their points of calving until appreciable erosion has reduced their draft enabling them to float.

The actual drift path of an iceberg in open water is indeed complex, affected by a multitude of variables that include current, wind, tide, ocean bottom bathymetry, sea surface slope and Coriolis effect. Note the following:

- Ocean currents are the most dominant influence governing iceberg drift.
- Wind is influential when it is strong, when it blows in the same direction for an extended period of time, and when iceberg size is small.
- High and low atmospheric pressures above the sea surface affect the surface topography of the water. With the passage of a low pressure system, a small but significant increase in water level is created whose amount is proportional to the pressure drop. The steepness of the slopes on all sides of this liquid "hill" is directly related to the atmospheric pressure gradient above it. Effects of this on berg speed and direction, though slight, are nevertheless measurable.
- The Coriolis effect is related to the motion of the earth under the moving berg. The result is a deflection of the berg to the right of its path of motion with a magnitude proportional to its latitude.
- Locked in pack-ice or grounded in

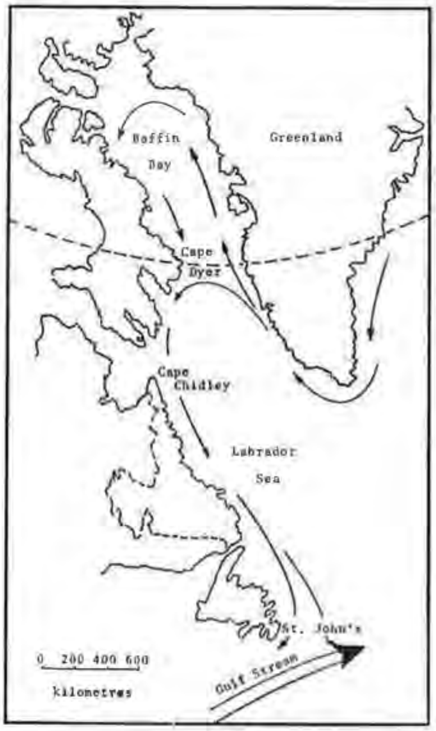

Figure 7 Predominant iceberg paths in Baffin Bay and the Labrador Sea.

shallow water, an iceberg may remain stationary for an extended period of time. Free of these encumbrances and in a current of water, average speeds are in the order of 8–10 nautical miles per day.

With all the variables operative, the drift path of an iceberg is in constant flux. Seldom is its trajectory straight. To produce an accurate model for purposes of drift prediction requires a thorough knowledge of the effect of each variable on iceberg motion.

Icebergs calved from Greenland and nearby Canadian islands enter a circulatory system that renders them capable of lengthy transport before destruction (Figure 7). Bergs calved off east Greenland are carried south and west around Cape Farewell by the East Greenland Current. Here they enter a northward-moving flow along the west Greenland coast. As they approach Davis Strait some curve westward toward Baffin Island, then southward to enter the main body of the Labrador current. Others continue northward into Baffin Bay. Traversing the west coast of Greenland the icebergs follow the dominant current as it loops counterclockwise past Cape York, along the east coast of Baffin Island past Cape Dyer to eventually link up with the Labrador current on its southward journey.

Table 1 Monthly average number of icebergs crossing each latitude from Newfoundland to Cape Dyer. Statistics are based on 1963-69 data after C.J.F. Anderson (Proceedings of the Canadian Seminar on Icebergs, 6–7 December 1971, Halifax, N.S., Dept. Nat. Defence, pp. 52–61).

Flux Across	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
67°N	134	118	147	143	155	156	165	161	128	123	128	139	1,697
66°N	134	117	150	137	153	154	165	154	120	110	117	139	1,651
65°N	134	117	142	140	152	153	163	154	126	102	104	137	1,624
64°N	134	117	141	138	149	152	161	153	113	99	97	130	1,584
63°N	134	117	139	137	147	149	157	146	107	95	91	123	1,542
62°N	107	95	139	135	145	134	124	84	61	53	57	93	1,227
61°N	106	95	134	135	145	138	122	86	60	49	49	87	1,206
60°N	103	95	128	131	144	142	124	87	51	40	40	74	1,159
59°N	97	94	122	130	142	141	129	90	53	26	36	59	1,119
58°N	87	92	115	129	139	140	135	95	62	21	26	43	1,084
57°N	73	88	112	128	132	137	127	99	56	20	16	31	1,019
56°N	49	77	112	112	133	134	122	106	68	28	10	19	966
55°N	31	59	99	105	126	130	120	118	75	35	11	10	909
54°N	17	39	82	98	116	118	91	81	49	32	15	6	744
53°N	12	30	73	93	111	107	64	54	33	23	11	2	613
52°N	9	23	62	89	106	102	42	34	22	14	9	0	512
51°N	4	14	40	76	86	67	37	11	2	5	5	0	347
50°N	3	8	35	66	75	32	22	5	1	2	3	0	263
49°N	2	5	25	53	67	29	15	1	0	0	0	0	197
48°N	0	5	18	46	57	23	8	0	0	0	0	0	157

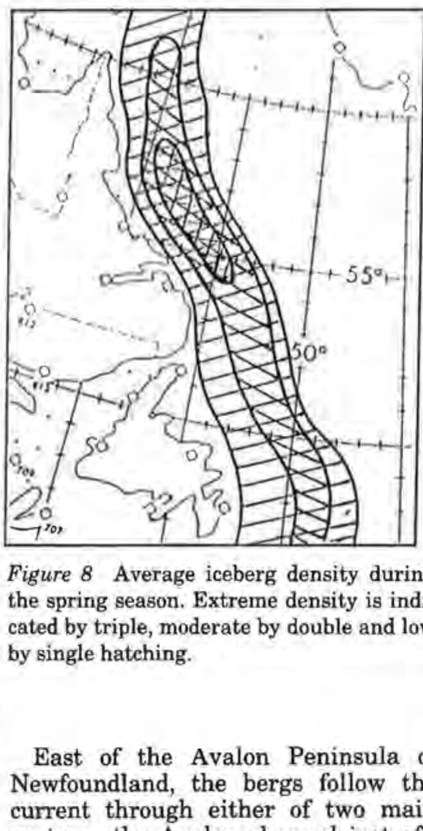

Figure 8 Average iceberg density during the spring season. Extreme density is indicated by triple, moderate by double and low by single hatching.

East of the Avalon Peninsula of Newfoundland, the bergs follow the current through either of two main routes – the Avalon channel just offshore or the Flemish Pass (between the Grand Banks and the Flemish Cap) on the eastern edge of the Grand Banks. South of this at about latitude 45°N the Labrador Current meets the Gulf Stream and ice migration is abruptly terminated due to rapid melt (Figures 7 and 8).

ICEBERG DETERIORATION

The number of icebergs that actually traverse the entire distance described above is very small (Table 1). Most small bergs melt before they exit Baffin Bay. Very large bergs ground in shallow peripheral waters and become severely eroded before moving on. Still others divert into the many bays along the coast and are permanently separated from the main flow. Regardless of their route, the sojourn in water is relatively brief. While the residency periods of ice chunks are a few thousand years inside the ice-cap on land, they are a few days to a few years in water.

The deterioration of icebergs in water is accomplished through processes of melting and calving. Note the following:

- Ice melts faster in water than in air of the same temperature because the rate of heat transfer from water to ice is greater than from air to ice. Also, since ice is a poor conductor of heat an iceberg maintains its initial internal temperature well past the time of initial calving.
- Rates of berg erosion are very temperature-dependent. It is estimated that a large berg in 2°C water will melt in approximately 5 weeks while the same berg in 8°C water will melt in just under 2 weeks.
- Since, especially in the summer months, water temperature decreases with increasing depth, the iceberg surfaces that are just below the waterline tend to melt fastest. The resulting erosion severely undercuts portions of

the sail creating spectacular calving, a repositioning of the berg's centre of gravity, a reduction of iceberg draft, and an increase in the surface area of ice exposed to the melt process.

- Wave action accelerates berg erosion. In addition to promoting calving, it also ensures a continuous circulation of warmer water into the region of the ice-water interface.
- Rates of erosion of bergs imbedded in pack-ice are virtually zero since both temperatures and destructive wave activity are reduced.
- As winter becomes spring and spring becomes summer throughout Canada, an increase in water temperatures gradually progresses northward reaching maxima of 10–15°C off the Grand Banks, 5–10°C off Labrador, and up to 5°C in Baffin Bay. Since both the values and durations of these higher water temperatures are greater in the south a definite decrease in berg size and population is evident from north to south (Figure 9). Annual berg sightings at Cape Dyer are about 1700. At latitude 48°N the average is 370. Since during the summer season many of the bergs melt in the northern latitudes while at the same time their southerly drift rates are so slow, it is not surprising that icebergs do not appear around the Avalon Peninsula in appreciable numbers until well into April and May of the next year. In fact, that area experiences over 90% of its icebergs from March 1 to June 30 of each year (Table 1; Figure 8).
- Given the slow rate of transport of ice in Baffin Bay – 3 to 5 nautical miles per day before freeze-up – icebergs should arrive at Cape York in October and Cape Dyer by mid-January in order to traverse the remaining distance to the Grand Banks by May. As one moves progressively farther south from Cape York past Melville Bay the probability of a berg being at these locations at the right time to eventually enter Grand Banks waters decreases. As a result the only bergs from Disko Bay and south of it that survive are either very large or ones that take the short cut directly across to Cape Dyer.

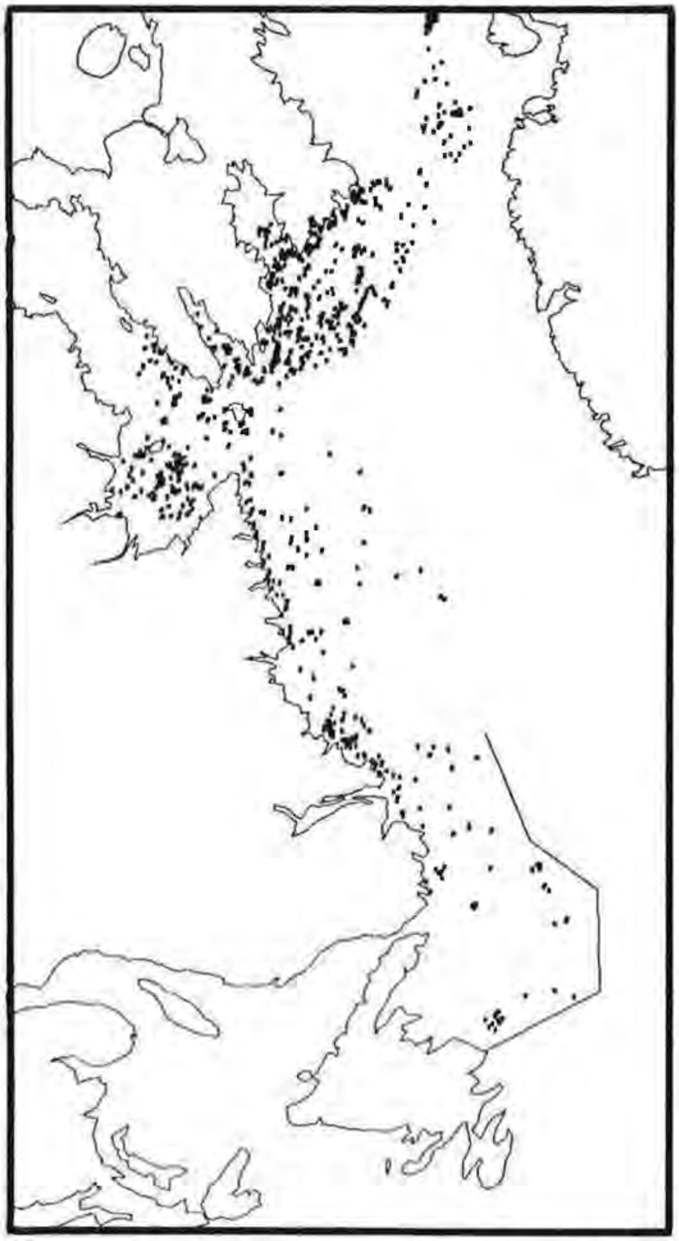

Figure 9 Computer printout of the total number of icebergs reported on September 3, 1986, from ship and aircraft observations, and shore sightings. The line extending northeastward from Newfoundland indicates the iceberg outer limit. This printout is a product of the Atmospheric Environment Service Ice Centre's (Ottawa) Iceberg Analysis and Prediction System (BAPS).

ICEBERGS AND OIL RIGS

On April 14, 1912, at 41°46′N, 50°14′W, a massive block of ice moving at a speed of roughly 1 knot collided with a smaller and brand new passenger liner, the RMS *Titanic* (Figure 10). The ship was moving at an unbelievably dangerous 21½ knots in fog in iceberg-infested waters at night. With extensive leakage below its water-line, the ship sank and 1513 people died.

Ever since this famous tragedy, man's knowledge of the characterisics and behaviour of ice has virtually exploded. Present-day detection equipment is very sophisticated. Our surveillance is regular and systematic. And the destructive capability of ice is both acknowledged and respected.

While most transatlantic great-circle sailing routes lie on the southern margin of iceberg waters or completely out of them, oil exploration sites off Labrador and Newfoundland sit well within them (Figures 8 and 9). Unlike a ship at sea an oil rig is a stationary target. Safe operation of drilling rigs in these waters requires constant and accurate monitoring of ice conditions in the vicinity to ensure the lead time needed to respond safely to any emergency.

The exploration for and the recovery of hydrocarbons from the ocean sediments off Canada's East Coast is both costly and dangerous and involves problems quite different from those facing developers in the Beaufort Sea and the High Arctic. In addition to the iceberg menace the area is "invaded" by

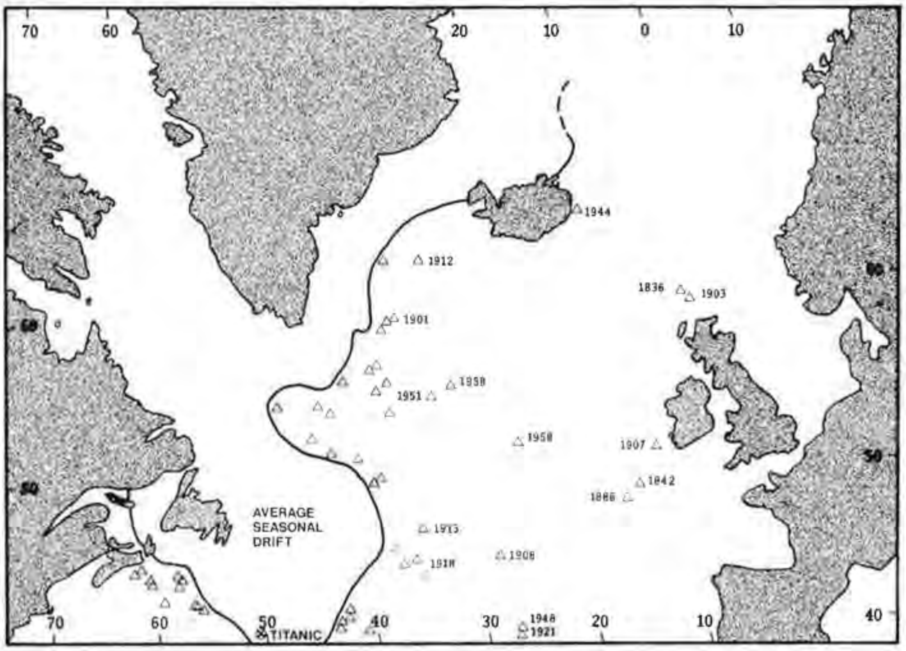

Figure 10 Positions of unusual iceberg sightings in the North Atlantic for the years indicated. Note the approximate location of the *Titanic*.

sea ice from the north, severe atmospheric depressions from the southwest, as well as fog from the south.

ICEBERGS AND SEA FLOOR SCOURING

The hardness of ice within an iceberg is inversely related to its temperature while the momentum of the iceberg is the product of its mass and velocity. Collisions involving icebergs and surface installations invariably destroy the weaker structure. The same is true for installations on the sea floor.

Research into iceberg scouring of the ocean bottom reveals that icebergs possess sufficient hardness and momentum to scour the sea floor over very long distances (Figures 11 and 12). Icebergs of course do not scour when their draft far exceeds water depth or when water depth far exceeds their draft. However, if a berg's draft is about equal to the water depth, its base is known to excavate long and deep channels. Such activity in regions of oil exploration would have devastating effects on seafloor installations such as well-heads, and greatly stimulates further research into the physics and mechanics of ice.

Figure 11 Sonograph showing a complex criss-crossing pattern of iceberg plough marks in about 380-m water depth on the uppermost continental slope west of Norway. Sonograph obtained using the IOS 31/37 kHz hull-mounted side-scan sonar system. Length of sonograph is 16.5 km, width 1.2 km (Courtesy: Institute of Oceanographic Sciences, Wormley, Surrey, United Kingdom).

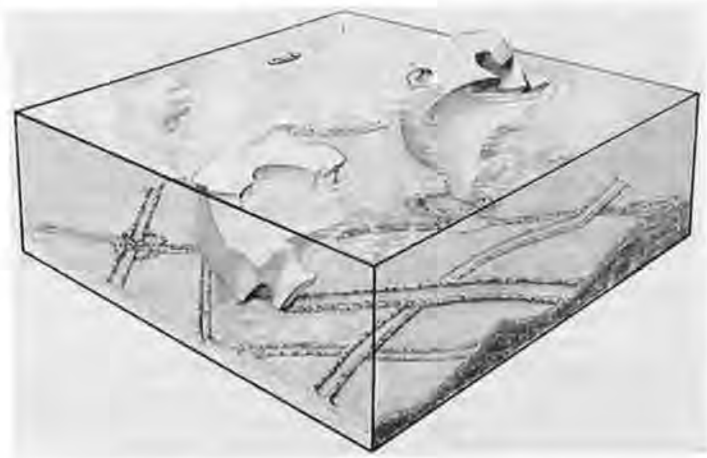

Figure 12 Block diagram illustrating how grounded icebergs can plough into the sea floor to produce distinctive patterns (drawn by N.R. Satchel and courtesy: Institute of Oceanographic Sciences, Wormley, Surrey, United Kingdom).

A "WORD" ABOUT SEA ICE

Salt water freezes below 0°C at a temperature that is determined by its salinity. The result is sea ice. Freezing begins at the surface and proceeds downward, gradually insulating the deeper waters from the cooling effects of the air above. Wind and wave activity can crack the ice and pile it on top of itself, and result in very serious hazards to ships. Similarly old sea ice (4 m thick) produces a similar dangerous hazard.

Sea ice develops from north to south off the east coast of Canada either through southerly drift or through local freeze-up. Off Labrador it appears in December. By April it reaches its most southerly latitudes, off the east coast of Newfoundland. Yearly fluctuations in thickness and distribution are significant. As summer enters each latitude from the south, sea ice melts northward toward Baffin Bay releasing trapped bergs and opening up waterways for various economic pursuits. Since the Newfoundland waters are the last to become ice-infested and the first to be ice-free, drilling can be year-round, especially in and around the Hibernia sites. However, off Labrador, drilling operations are restricted to a few months of the year.

Sea-ice strength relates to its mass, temperature and salt content. As ice ages, its salt crystals leach out by means of gravity. Consequently, it becomes less saline and harder. Colour changes from an initial grey to grey-white to white. Sea ice moves with the water current, is affected by wind and wave activity, and is severely cracked when the energy in an ocean swell passes through it. Sea ice reduces ocean wave activity, acts as a refrigerator for icebergs trapped within it, and is home to a variety of large mammals including the walrus, seal, and the occasional polar bear.

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Jerry Salloum is a Geography Teacher at Don Mills Collegiate in the City of North York. He has been in the teaching profession for more than twenty-two years and has a great interest in curriculum development with particular emphasis on exposing Canadian students to the existing developments on Canada's environmental frontiers. This article is the result of a study carried out with support from the AES (Atmospheric Environment Service) Ice Branch and numerous other organizations involved in offshore development activities.

Photograph credits: Figures 2, 3 and 5 – AES Ice Branch; Figures 4 and 6 – Bedford Institute of Oceanography.

COVER PICTURES

Upper Left Icebergs grounded in Middle Cove, north of St. John's, Newfoundland.

Upper Right An iceberg of 800,000-tonnes mass and 96-m draft drifting on the Newfoundland-Labrador Shelf off the Strait of Belle Isle, June 25, 1983. Erosion by waves has carved grooves at the water-line some of which have been exposed by tilting as the balance of the berg changes. Overhanging ice above the grooves has fallen off to leave chiselled cliffs and towers up to 32 m high (above the sea surface), and a channel or "drydock" through the middle of the berg has been carved by wave erosion (Photograph courtesy of Stuart D. Smith, Bedford Institute of Oceanography).

Lower Left A small iceberg of 69,000-tonnes mass and 60-m draft on the Grand Bank northeast of St. John's, Newfoundland, on June 12, 1984. Grooves cut by waves mark former water-lines, while the chiselled upper portion gives evidence of the breaking off of chunks of ice (Photograph courtesy of Stuart D. Smith, Bedford Institute of Oceanography).

Lower Right The CSS *Hudson* entering Melville Bay, Greenland, in September 1978, at the conclusion of *Hudson* cruise 78-026. The photograph, taken from one of the vessel's survey launches, shows numerous bergy bits in the water, and the high cloud associated with a front moving into the area (Photograph courtesy of Roger Belanger, Bedford Institute of Oceanography).

RÉSUMÉ *La présentation de cet article est telle qu'il peut servir en tant qu'instrument d'études en classe. On y décrit et explique en détail la distribution des icebergs au large du littoral de l'est canadien, et on désigne les types différents d'icebergs, leur position, leur mouvement et leur évolution. Tout particulièrement, on donne une explication détaillée du processus de formation des icebergs en provenance des glaciers du Groënland.*

Sont mis en évidence les caractéristiques des icebergs : dimension et forme, notion de flottabilité, dérive, désagrégation et interaction complexe avec l'environnement océanique.

Les icebergs sont en permanence dans la région de la baie de Baffin et du détroit de Davis et dans l'océan Atlantique, au large de Terre-Neuve et du Labrador. Le mouvement des icebergs est un important sujet de préoccupation en ce qui concerne les activités actuelles d'exploitation pétrolière au large des côtes et le transport maritime.

CRITIQUES / BOOK REVIEWS

LA MÉTÉO. Le temps et la vie quotidienne. Par Pierre Kohler. Hachette Jeunesse, Echos Encyclopédie, 1985; 78 pages, 4,95 $.

Ce livre s'adresse aux jeunes étudiants puisqu'il est publié dans une collection destinée à ceux de 10 ans et plus; il contient assez de faits pour intéresser les élèves du niveau secondaire 1 ou 2.

Le livre est constitué de cinq chapitres intitulés : comment se fait le temps; prévoir le temps; les caprices du temps; quand le temps devient mauvais; la météo d'hier et de demain.

Dans le premier chapitre l'auteur présente, en quelques pages, les masses d'air, la mousson et les systèmes météorologiques. Au deuxième chapitre, il présente les principaux instruments puis il parle de la prévision tout en présentant des éléments historiques d'intérêt. Dans les deux chapitres suivants, l'auteur discute des relations entre la météo et les sports, la santé, le transport, l'agriculture, la famine, l'histoire, etc.; puis il présente les ouragans, les tornades, les orages, la sécheresse, les avalanches, et ainsi de suite. Le volume termine par quelques pages sur les climats du passé et la modification du climat.

La lecture est agrémentée par une abondance de croquis, photos, dessins tous en couleur dont plusieurs sont pleine page. Ceci rend le volume attrayant et sous cet aspect, il plaira sûrement aux jeunes lecteurs. L'auteur a réussi à présenter de façon simple et intéressante l'importance de la météo dans la vie de tous et c'est là son point fort. Les notions de météorologie sont présentées très sommairement, mais c'était sans doute l'intention de l'auteur.

Ce volume constitue un ajout intéressant à la bibliothèque d'une école secondaire et il viendra bien compléter les ouvrages de classe.

Richard Leduc

Continued on page 75

The following items came from Newsletter Number 2, July 1986, of the International Education Committee for School and Popular Meteorological Education.

AUSTRALIA

Australian Science in Schools Week – Weather Day

Australian Science in Schools Week is an initiative of the Australian Science Teachers Association. Each year there are designated theme days and in 1985 they were:

Monday : AIR day
Tuesday : SUN day
Wednesday : INFLATION day
Thursday : STRUCTURES day
Friday : WEATHER day

On INFLATION day, balloons with name tags were launched from schools throughout Australia. The Education Subcommittee of the Australian Branch of the Royal Meteorological Society supplied a map of Australia-wide winds on INFLATION day. The map was published in a national newspaper the following day. Then on WEATHER day various projects were conducted on weather, including studies related to where the balloon tags were or might have been found.

UNITED KINGDOM

Weather Packs for Primary Schools

"Endeavours to improve public weather awareness and literacy should be aimed largely at children. The emphasis should be upon exciting curiosity about the weather, developing an enquiring mind, encouraging observations and generating a sense of wonder at atmospheric behaviour" *(Weather Education,* page 248)

In Northamptonshire, a county in the English Midlands, three groups of teachers have been hard at work since September 1985 designing packs of resource materials for use in teaching children up to 13 years of age about weather. The packs will include definitions and basic information about weather phenomena and atmospheric behaviour, guidance on recording techniques and the making of observations, and advice on experiments and projects. The teachers are collaborating with members of the Royal Meteorological Society's Education Committee, and in due course the packs will be available from the Society.

There is clearly a lot of interest in the weather among children and teachers in British primary schools (those catering for pupils of 5 to 11 years of age), judging by the number of enquiries the Royal Meteorological Society receives from young children. As was mentioned in *Weather Education,* pages 12 and 13, a letter typically begins with: "Dear Sir, I am nine years old and I am doing a project on the weather", and it frequently continues with something like: "Please will you tell me all you know"! The Northamptonshire weather packs are intended to help such youngsters and their teachers and also to help improve public weather awareness and literacy through the education of young children.

If you would like to learn more about the work of the Northamptonshire teachers you should write to the Education Secretary of the Royal Meteorological Society (James Glaisher House, Grenville Place, Bracknell, Berkshire, RG12 1BX, UK) or to Mrs. Marion Ilsley (Senior Lecturer in Earth Science, Nene College, Moulton Park, Northampton, NN2 7AL, UK). Mrs. Ilsley is overseeing and coordinating the work of the teachers. She is also involved in other activities concerned with weather education in primary schools, including courses, for teachers. For details of these activities, please write to Mrs. Ilsley.

Public Understanding of Science

The committee appointed by the Royal Society to enquire into the state of school and popular science education in the United Kingdom published its report in the autumn of 1985. Entitled *The Public Understanding of Science,* it can be obtained from the Publication Sales Department, The Royal Society, 6 Carlton House Terrace, London, SW1Y 5AG, UK, price £6.90. A four-page summary, entitled *Science is for Everybody*, was also published. Here are two quotations from the report:

"Scientists must learn to communicate with the public, be willing to do so, and indeed consider it their duty to do so. All scientists therefore need to learn about the media and their constraints, and to learn how to explain science simply, without jargon and without being condescending."

"Improving the general level of public understanding of science requires concerted action from many sections of society, including most importantly the scientific community itself."

Micros in Weather Education

This was the title of a conference that took place in London on Saturday September 28, 1985. The conference attracted 100 participants. During the morning session, papers were presented, one on the possibilities and limitations of using microcomputers for teaching meteorology, one on the uses of micros for displaying weather radar and satellite images, and several on the linking of meteorological instruments to microcomputers. During the afternoon session, participants were free to inspect commercial software packages, demonstrate their own programs and explore the possibilities of using the micro as an interface/terminal. A report of this conference has been published in *Weather,* 1986, Vol. 41, pages 163 and 164.

School Supplements

A series of articles of interest to school teachers and their pupils was published in *Weather* from September 1985 to April 1986. The series includes articles on sources and types of weather data available to schools, the work of a weather centre, the use of a BBC microcomputer in an automatic weather station, the uses of weather radar and weather satellites for improving rainfall forecasts, weather on other worlds, and forecasting for civil aviation. It is hoped that another series will begin in September 1986.

USA

Snippets From the USA

At the Florida Creative Science and Technology Center in Hollywood, Florida, a program to enhance the science skills of school-aged children is being supported by the Board of School and Popular Meteorological and Oceanographic Education of the American Meteorological Society (AMS).

A *resource guide* to enhance tropical cyclone public information and education is being developed as part of the World Meteorological Organization's Tropical Cyclone Programme. The project is jointly sponsored by WMO, the Office of the United Nations Disaster Relief Coordinator and the League of Red Cross Societies.

The use of "mini-grants" is being developed at Miami-Dade Community College to stimulate interest in meteorology and meteorological education in local schools. Grant-supported activi-

Continued on page 75

DON'T KICK THAT BUCKET

Gordon A. McKay

Into everyone's life some rain must fall. That applies to buckets as well – or, for that matter, to any receptacle that is exposed to the weather elements. You can observe rainfall amounts with good accuracy simply by looking about and seeing what nature has left in tins, pails, dishes, etc. And that information can be quite valuable – such as in knowing how much additional water you should put on your lawn or crop, or in providing valuable information about storms (flooded basements, utilities or communities) to those concerned with assistance or remedial action. A Saskatchewan contractor who had the foresight to measure rainfall where he was constructing an earthen dam was able to show that nature, not his crew, was responsible for the lengthy delay in completion and thereby avoided costly penalties that might have led to bankruptcy. Storm rainfall data can be of great value in determining the optimum size of ditches and culverts, and in designing dams and drainage systems. Rainfall information may also be used in defining assistance payments and in assessing the tractionability of soils for operational activities. Remember, rainfall can be highly variable even over very small distances. Official observations tell what was measured at an official observing site but that may be quite different from the measurement in your area of interest. A bucket can give you fairly precise, local information that could be much more useful in understanding and solving your problem.

Figure 1 Atmospheric Environment Service tipping-bucket rain gauge.

Figure 2 Flowerpot in a backyard vegetable garden, which caught 69 mm of rain during an August thundershower in southern Ontario.

Figure 3 A wheelbarrow will provide a mathematical challenge to anyone calculating the actual rainfall amount.

Rain gauges are hollow cylinders that are open at one end. They can have different shapes and sizes (Figure 1). Buckets and tins are very similar. They, too, have diverse shapes and sizes, and that must be taken into consideration in estimating the depth of rain that has fallen into them (Figure 2). Rainfall is measured as the vertical depth of water falling on a horizontal surface. Gardeners use straight-walled tin cans to measure how much irrigation water they have applied to their gardens or lawns. If the bucket or other receptacle is not perfectly cylindrical and level, geometric corrections can be applied to obtain a good rainfall estimate. The volume of water in a wheelbarrow (Figure 3) or canoe is accumulated over the total collecting surface. Divided by

Figure 4 Test-tube gauge in a south Saskatchewan farmyard as part of the agricultural volunteer-observer network.

the area, it provides a rough estimate of rainfall. Understandably, meteorological services go to great pains to ensure their rainfall measurements are precise and as representative as possible. Still, at times, even they must rely on the lowly bucket, tin cans and test-tube gauges (Figure 4) that are found on many farms. Properly exposed, the test-tube gauge gives remarkably good measures. After major rainstorms meteorologists and water engineers frequently undertake surveys of rainfall amounts in such containers to acquire detailed information on rainfall amounts to define precisely what happened. Those data are used for scientific purposes as well as to assist the community in evaluating damage and planning to mitigate future storm hazards.

Most people have seen thunderstorms that produce rain on one side of a street and not on the other. Thunderstorm rainfall can vary markedly over short distances. Knowing that variation can be very important – particularly to farmers, water engineers, contractors, and insurance assessors. A common observation is: We had a downpour in our neighbourhood, yet the weather office recorded only a trace of rain. Rainfall over mountainous terrain can also differ markedly over short distances and knowing those differences is important in the design of water supply, drainage and sewage systems. If communities are to plan defences against damaging rainstorms like Hurricane *Hazel* or those that inundate Saskatoons's underpasses they must have

Figure 5 Different type of test-tube gauge made available to farmers by farm-support agencies in Saskatchewan.

much more detailed rainfall information than is provided by official weather observing networks. Cooperative observers supply extremely valuable additional information but, depending on the problem, even the combined weather and cooperative networks cannot provide adequate detail on major rainstorms. The intense shafts of damaging thunderstorm rainfall frequently move across the countryside without being detected by these networks.

That is when "bucket" surveys of rainfall come into play. Thanks to popular interest in rainfall, test-tube-type rain gauges are found on many farms (Figure 5). Other useful containers such as grease buckets, old crocks and tin cans are other prime sources of information. A bit of geometry helps in converting the volume of water they contain into millimetres of rain. But other logic must be used. Did the rain in the barrel come directly from the clouds? Or was it diverted into the barrel by branches, a wall or a roof? Was the amount reduced by screening by trees or buildings. Was the barrel leaky or did it overflow? Was there water in the barrel before the storm? Every bit of evidence must by carefully scrutinized to ensure that observations and conclusions are indeed reasonable and valid.

Official measurement rules have to be bent a bit during an areal bucket survey. Road and river conditions following a major storm are often less than ideal (Figure 6), and the observer's arrival at the scene is often quite late. Much detective work and common sense are required. The information sought is primarily depths, rates and timing of the rainfall, but information about damage and flooding is also carefully documented. The bucket surveyor is equipped with a map, a ruler, a device to measure volumes of water, a camera and a gridded note pad in which specifics as to location, gauge types, dimensions, tilt and exposure are entered. Eye-witness descriptions of times of start and ending, changes in intensity, and other features of the storm rainfall are noted. Verbal accounts must be carefully weighed against physical evidence and reconciled with information provided by neighbours. A sharp lookout should be kept for flooding, high water marks, soil erosion, and other factors that may indicate the areal character of the rainfall.

Figure 6 Typical flood conditions as the result of intense storms (Regina, Saskatchewan, August 1955).

For example, a record storm at Buffalo Gap, Saskatchewan, (July 1964) was investigated because engineers noted extremely high water marks on streams flowing out of the area. The rates of rainfall near the centre of the storm were estimated from the experience of the Saskatchewan Wheat Pool operator who knew when he had emptied his overflowing small gauge on three different occasions during the storm. The peak rainfall was measured in a grease pail weighted down by a monkey wrench. The conclusions: Buffalo Gap had been devastated by an all-time record of 266 millimetres (10.5 inches) of rain in 70 minutes!

A similar intense rain and hail storm in southwestern Saskatchewan is illustrated in Figure 7. The Lafleche storm occurred during the evening and early morning hours of June 12 and 13, 1962. An intensive bucket survey (sites identified with open circles) and information from provincial and private agencies' observation networks provided for a surprisingly detailed analysis of the total amount of rain from this intense storm.

The standard precipitation gauge is basically a tall can, the height of which differs in many countries. Lore has it that gauges were made sufficiently tall as not to be disadvantaged by neighbourhood dogs – another hazard in Meteorology. A tin can or other straight-walled container can serve just as well. The professional observer takes care that the rain gauge is not too exposed to the winds, or sheltered in a way that influences its catch, and that its orifice is in the horizontal plane. Surrounding objects should not be closer to the gauge than four times their heights.

You can easily mount a metal, glass or plastic receptacle on your lawn in a way that meets those requirements. Readers of the British magazine, *Weather,* will know that thousands of Britons maintain their own rain gauges as an inexpensive hobby or for practical purposes. You, too, can have high-grade observations of your rainfall using the simplest of instruments – a tin can and a ruler. Some 4-H clubs have made their own rain gauges to official specifications and mapped the variation of rainfall over lands within their community. Why not obtain a small rain gauge for your own use? Many organizations provide these as promotional items. Gauges commercially available include wedge-shaped, plastic gauges that amplify the reading scale for more precision in reading small rainfall amounts.

Much useful information is available – just for the looking. Don't kick that bucket until you've checked how much

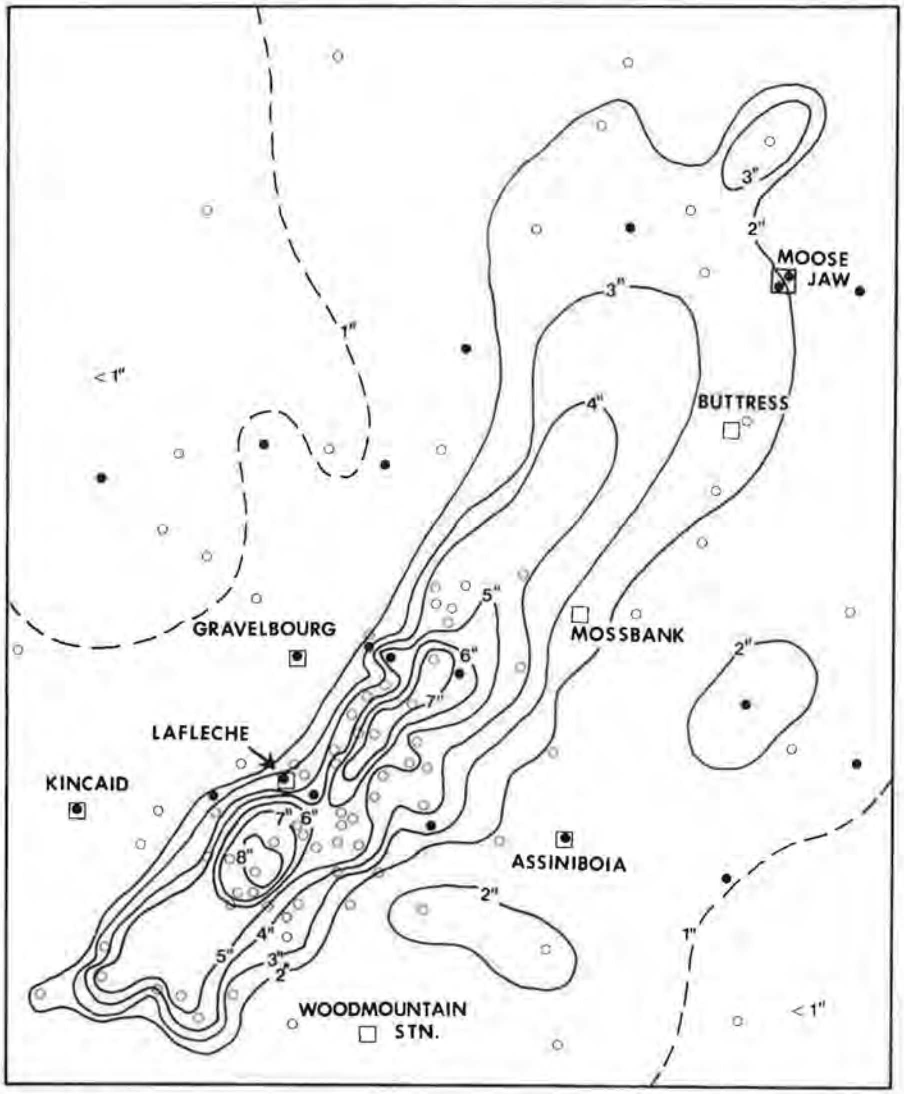

Figure 7 Rainfall analysis of the Lafleche, Saskatchewan, storm, June 12–13, 1962. Total precipitation amounts are in inches (1 inch = 25 mm).

• Routine observations from climatological, provincial or private networks.

○ Observations from gauges that are not part of a formal network, and "bucket estimates".

SAMPLE BUCKET-SURVEY REPORTS OF THE LAFLECHE RAINSTORM OF JUNE 12–13, 1962 (NOTE: 1 inch = 25 mm)

- **No gauge. Rain started 5:00 p.m. – off and on all night. No hail. Neighbour towards town had 4.37 inches of rain.**
- **Water on highway to within 2 inches of car radiator for 2 miles on road to town.**
- **Six inches in grease pail in back of truck. Light hail at start, pigeon-egg size.**
- **Gauge overflowed – over 7 inches.**
- **Gauge overflowed. Crock – good exposure, caught 6.5 inches.**
- **Over 6 inches in pail with straight sides.**
- **5.5 inches in lard pail.**
- **Estimates 7 inches, 6 inches caught in well of truck. No gauge.**
- **Gauge overflowed – capacity 5 inches.**
- **Gauge overflowed – total catch 7.4 inches. Emptied and caught 3 inches second time. Test-tube type.**
- **Over 5.2 inches. Gauge – a tobacco can on post. Overflowed, emptied and caught 0.2 inch more. Gauge is 5 inches deep.**

rain it caught during that storm. You might be destroying valuable information.

Gordon McKay is the former Director of the Climatological Applications Branch of the Canadian Climate Centre. Mr. McKay is a distinguished Canadian and international expert in the climatological applications field. He was a pioneer in hydrometerology and is currently engaged in various consultation activities.

RÉSUMÉ *Les données pluviométriques peuvent être bien utiles, en fournissant les informations nécessaires aux nombreux usagers de données météorologiques, tels que les cultivateurs, les entrepreneurs et les scientifiques, les municipalités et les compagnies d'assurance. Les réseaux pluviométriques officiels fournissent dans certains cas des informations vraiment limitées au sujet de la hauteur totale ou de l'étendue réelle des précipitations résultant d'une tempête intense. Il est possible d'obtenir d'autres données pluviométriques à partir de relevés dits de « seaux », c'est-à-dire de l'estimation du contenu de récipients tels les bottes en fer blanc, les seaux, les plats, les brouettes ainsi que d'autres réceptacles que l'on puisse trouver dans une arrière-cour de maison ou dans une cour de ferme.*

Les informations ainsi obtenues peuvent fournir aux ingénieurs, aux météorologistes et aux hydrologistes une image détaillée d'une tempête de pluie intense. Ces informations peuvent alors servir à des fins scientifiques, de même qu'à aider les localités à évaluer les dommages infligés et à planifier les stratégies pouvant atténuer les effets d'une tempête future. On présente plusieurs exemples types de « seaux » et une analyse détaillée, à partir de relevés de « seaux », des précipitations résultant d'une tempête violente survenue en 1962 dans le sud-ouest de la Saskatchewan.

THE SCHOOL NOTEBOOK

Continued from page 71

ties are expected to involve high school and community college science clubs.

A program, *The Everyday Weather Project*, is being developed at the State University of New York at Brockport. The project seeks to upgrade weather literacy by encouraging teachers to teach from the perspectives of real weather and weather as it happens. Instructional materials emphasize the study of the atmosphere using information acquired with sophisticated technology and disseminated to the public at little or no cost. Six independent educational modules treat weather topics that can be integrated into existing science courses.

A program to enhance science and mathematics instruction in the elementary schools of Missouri is in progress. A significant portion of this effort is directed toward meteorological education.

A "Weather Phone" has been established at Central Connecticut State University to enhance weather awareness for the public.

Gifted science students at several schools throughout the United States have been given opportunities to work with meteorologists and others. The program encourages students to prepare projects in the atmospheric sciences for science fair programs. Students are also encouraged to consider careers in the atmospheric sciences.

The Inner City Marine Program, a joint effort of the Dade County Public Schools, the University of Miami, and the National Oceanographic and Atmospheric Administration's Atlantic Oceanographic and Meteorological Laboratory, has completed its second year of operation. The program provides training opportunities and work experience under the direct supervision of senior scientists or science teams in a research environment. It also promotes an awareness of careers in the marine and atmospheric sciences for minority students of inner-city schools in the Miami area.

BOOK REVIEWS

Continued from page 70

GREAT LAKES CLIMATOLOGICAL ATLAS. Edited by Andrej Saulesleja. Environment Canada, Toronto, 1986; 145 pages. Available from the Canadian Government Publishing Centre, Supply and Services Canada, Ottawa, Ont. K1A 0S9, Catalogue No. EN 56-70/1986; $9.95 (outside Canada, $11.95).

Worth double the price, this Atlas is mandatory for anyone with an interest in the Great Lakes. Mariners, weekend sailors, yacht clubs, power squadrons, cottagers, marinas, shipping agencies, marine insurance companies will all be interested in this unique publication, which was over a decade in the making. The information that the Atlas contains – wind, waves, ice cover, fog, thunder, freezing spray, air and water temperatures, etc. – covers the entire Great Lakes, not just the Canadian portions, and can be found nowhere else because this Atlas is the first of its kind.

Attractively produced on quality paper, it presents the information in the form of easy-to-read maps and graphs. The data have been gathered from many sources. The majority were obtained from the network of voluntary observers operating on ships in the Great Lakes, but was supplemented by data observed by instrumented weather buoys, as well as survey aircraft and satellites. It is organized in two ways; first the areal variation of the climatic elements is shown by month or season, and secondly the monthly variation of the elements is given for each of the Great Lakes.

The Editor has taken care to point out the various errors and biases that exist in the data, and clearly a considerable effort has been made to quality control the data. If I may be allowed to carp a little about an otherwise excellent publication, it would have been useful to show the actual period of years covered by the map of each element rather than just for those showing ice cover. Also, one is left wondering why the maximum wave heights on Lake Superior appear to be lower than those on some of the other Great Lakes.

Not being a sailor myself, but rather a landfast cottager on Georgian Bay, I found myself noting contentedly that my planned vacation in July promises the least precipitation during the year, the calmest and warmest water, and the warmest air temperatures. A highly recommended publication for Great Lakes mariners on both sides of the international border!

M.J. Newark

THE WEATHER REPORT

Norman McLellan

On June 16, 1986 a weather disturbance moved through south-central Ontario and an associated cold front pushed cooler air southward across the lower Great Lakes. In the moist and unsettled air ahead of the front several lines of showers and thundershowers developed during the day. Norman McLellan, a Hamilton, Ontario, amateur weather watcher and student in meteorology, observed one of the more phenomenal storms that day. The following is his report, which is illustrated with a set of fifteen sequential photographs and supported by two satellite pictures (Figures A and B, courtesy: AES Satellite Data Laboratory).

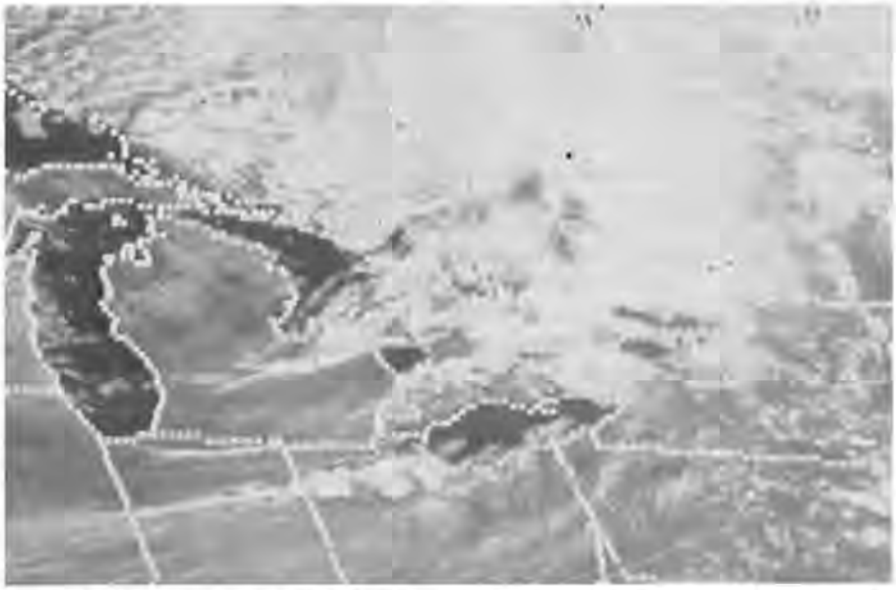

Figure A Visual image of the U.S. NOAA Geostationary Satellite for June 16, 1986, at 1600 EDT (2000 GMT). This visual photograph clearly shows several generally east-west lines of well developed thunderstorms: through the Bruce peninsula; Sarnia–Barrie (note the shadows of the anvil tops of the cumulonimbus clouds); through northern Indiana–Ohio; and a set of storms over the Niagara Peninsula and western Lake Ontario.

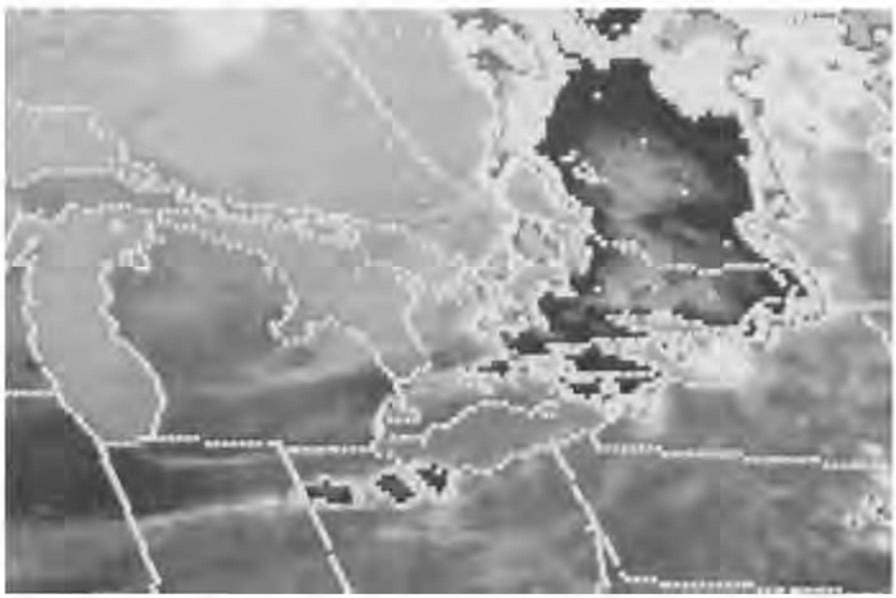

Figure B Infrared image of the U.S. NOAA Geostationary Satellite for June 16, 1986, at 1601 EDT (2001 GMT). The dark areas over the Hamilton–Toronto area are those of thunderstorm tops. Also note the storm cells south of Detroit.

"In Hamilton at 2:00 p.m. rapid development of large cumulonimbus was observed to the west and northwest on Monday June 16, 1986. A severe thunderstorm warning was issued at 2:30 p.m. for Hamilton-Wentworth, Peel, Halton and Wellington Counties. At 2:45 p.m. I drove northwest along Highway Six. A mature thunderstorm cell was observed to the northeast, near Carlisle, Ontario, at 3:30 p.m. Further thunderstorm activity was occurring to the west and northwest but as the Carlisle cell was closest I headed that way to intercept and then follow it. I turned onto the Flamborough-Puslinch townline road and was under the south end of the cell.

About six kilometres northeast of Carlisle the rain stopped and one kilometre ahead rotation was observed on the cloud base. A good vantage point was located 500 metres down the road and this is where photo one was taken. Photo two was taken a few seconds later and shows further development of the wall cloud. Photos three and four show the continued development of the wall cloud but now it was at a better angle for photographing. The next nine photos show the funnel that appeared about ten seconds after photo four was taken. The pictures were shot about five seconds apart. The funnel was rotating counter-clockwise at a speed of about 40–50 km/h. It was 100–150 metres away at its closest point. Direction and speed would be from northwest to southeast at roughly 60 km/h. The funnel descended to approximately 75 metres from the ground. Surface winds that day were from the southwest at 45 km/h, but during the time the funnel appeared there was a dead calm, and it was very quiet, no sound could be heard from the funnel. The funnel disappeared after the final photo.

The storm cell that produced the funnel developed ahead of the cold front that crossed the region shortly after. At the cold front a line of intense thunderstorms was observed. Photos fourteen and fifteen shows the line squall as it passed through the Halton area at 4:15 p.m. No further tornadic activity was observed in these cells in this area."


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SPRING OF 1986 – A REVIEW

by Alain Caillet

Spring was generally warm in the central and eastern parts of the country, from the Rockies to the St. Lawrence Valley, but it was cool in the northwest and the Arctic. Numerous absolute temperature records were set across the country, and there were devastating storms in Quebec and the Maritimes.

Winter, which had seen above-normal temperatures in the West, far above-normal temperatures in the northwest and the Arctic, and below-normal temperatures in most of Ontario and Quebec, maintained its grip on much of the country for the first few weeks of spring. At the beginning of March, spring was in the air for the opening of the winter games in Whitehorse. On the Prairies, several maximum temperature records were set, while in Quebec and the Maritimes some minimum records for the month were established. Later in March, the situation changed dramatically.

Hailstones (three-quarters life size) that pounded Montréal's south shore on May 29, 1986 (Photograph courtesy of Marc A. Gélinas).

ATMOSPHERIC CIRCULATION

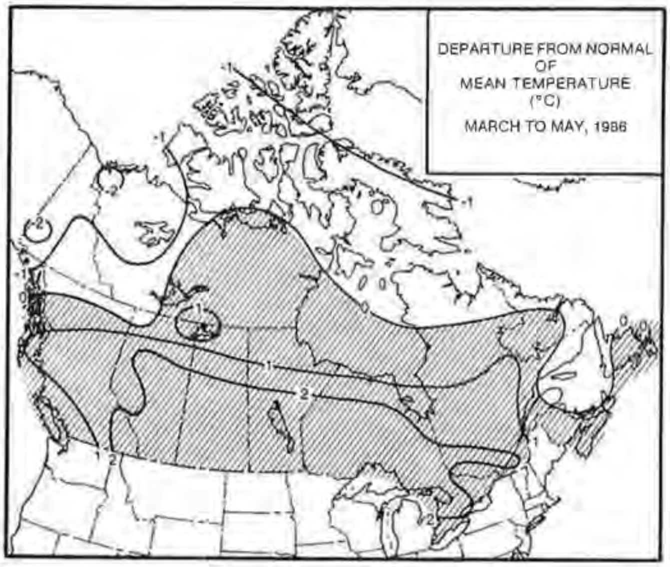
The general weather pattern at the upper levels in the atmosphere, which was characterised by a strong ridge from the Yukon to Greenland, weakened over the polar area resulting in the establishment of the more normal upper ridge over western Canada and a pronounced trough over Baffin Bay that extended into Quebec.

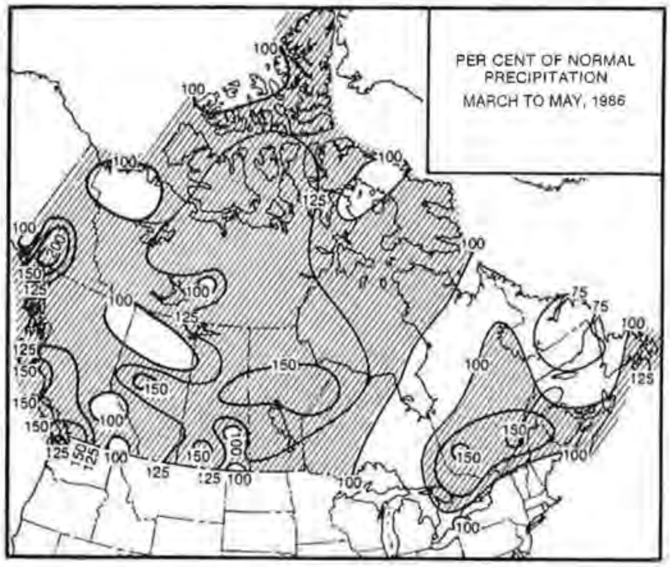
Circulation changes continued as the western ridge moved toward the centre of the country, and the trough moved out over the Atlantic. During the last two months of spring, April and May, Canada's weather was mainly controlled by two persistent features in the mean circulation field throughout the period: in the West, a trough of cold air near the Pacific coast; in the centre and the East a ridge or the filling of the previous trough. This unusual mean circulation pattern brought with it unusual weather. In the Yukon, record minimum temperatures were established and it was very windy. In British Columbia, a succession of frontal systems brought numerous storms, which produced generally rainy and gloomy weather, with high winds (sometimes exceeding 100 km/h) and cool temperatures. The sky was overcast for the opening of EXPO 86. On the Prairies, and in Ontario and Quebec, mean temperatures were generally above normal, but there were large day-to-day temperature fluctuations caused by changing air masses that came from the north or the south, depending on the position of the ridge. Record temperatures were also reached in the Maritimes, where the weather was generally mild, sunny and rather dry, although a few storms left a trail of destruction behind them.

TEMPERATURE

Spring is a transitional season, when temperature reflects better than any other element the fluctuations, sometimes extreme, that can occur at this time of year, as a result of the general warming of the atmosphere. At the beginning of March, the West was still enjoying the unusually mild temperatures that had prevailed during winter. Monthly maximum temperature records were set at Kelowna (20.3°C) and Vancouver (18.1°C). On the Prairies, a maximum temperature of 22°C was recorded at Estevan. In the East, normal winter weather persisted. Southern Ontario experienced an outbreak of cold, Arctic air on March 19, later than in any year since 1967. At Blanc Sablon in Quebec, and in several towns in Newfoundland, the mercury plunged to record March lows.

The first signs of a significant warming appeared in late March. In southern Ontario, the warmest March temperatures since 1946 were experienced over





the Easter weekend. Soon after, record April minimums were recorded in the Yukon; and Vancouver experienced the latest frost ever on April 30. In the East, under the alternating influences of arctic and maritime air masses, temperatures went from one extreme to the next. On April 27 and 28, temperatures at Timmins and Val-d'Or reached 30°C and 28°C, respectively; and between the 23rd and the 26th exceeded 22°C at St. John's, Gander and Stephenville. However, the temperatures at Val-d'Or plunged to −3°C just four days after the new monthly maximum temperature record had been set on the 28th. By the end of April, the seasonal heating trend was generally established across the country, despite a short period of frost that damaged buds and fruit seedlings in Nova Scotia, and the rather cool weather in the Yukon and British Columbia.

PRECIPITATION

The influx of frequent low-pressure systems in the West brought copious precipitation. In the Yukon, the snow cover was much deeper than normal. The total March snowfall in Whitehorse exceeded the previous record of 38.9 cm set in 1967. In British Columbia, record amounts of snow on the ground were observed at Kelowna, Terrace and Williams Lake. The total April B.C. precipitation was above normal, including twice the normal snowfall along the coast. A late storm dropped 34 cm of snow on the north in mid-May. On the Prairies, the precipitation pattern was more varied. In many southern and northern areas that had been relatively dry in early spring, the shortfall was quickly made up. Numerous storms deposited record amounts of precipitation. On April 30, Winnipeg had 44.1 mm of rain, a new 24-hour record for April. It was also the second wettest April ever in eastern Saskatchewan. The same situation continued into May. A 24-hour record was set at Regina, with 60.4 mm. It was the third wettest May ever at Regina and Swift Current, with over 115 mm of rain. Hail the size of golfballs was reported at MacGregor, and a tornado occurred near Borden, Manitoba.

Farther to the east, the amounts of precipitation were less extreme. North-central Ontario, northern Quebec, Labrador and most of Newfoundland failed to receive their normal accumulations. However, numerous storms and violent thunderstorms occurred, especially in Quebec and the Maritimes. A storm covered a large part of Ontario with a thick layer of ice on March 9. In early April, a storm that left southern Ontario under a blanket of snow, paralysed Quebec and the Maritimes. Several snowfall records were set: 44.4 cm in 24 hours at Sept-Îles; a record 65.2 cm of snow during April at Val-d'Or. Charlo, N.B., was buried under a record 75 cm of wet snow on April 10. Several other storms, accompanied by high winds and sometimes hail, caused damage in the Maritimes on March 14, 15 and 19, in southern Ontario on April 22 and at Trois-Rivières on April 18. On May 29, Montréal had the worst hailstorm since 1969. On the south shore of the St. Lawrence, the stones were up to 7 cm in diameter, almost the size of a baseball.

SIGNIFICANT WEATHER

All these extreme conditions did not happen without any direct or indirect social and economic consequences. The abnormally mild temperatures in early March in British Columbia created hazardous snow conditions in the mountains, and four people lost their lives in an avalanche in Yellow Head Pass. The succession of frontal systems and storms frequently brought abnormally high winds to the B.C. coast, and a fishing boat sank off Savary Island leaving ten dead. Low temperatures and cloudy skies delayed agricultural activities for at least two weeks. On the Prairies, some wind erosion of soil resulted from the lack of snow and dry weather in early March. Meltwater associated with a sharp temperature rise in northern Ontario forced the evacuation of the community of Winisk on the shore of Hudson Bay, which was flooded and in the end demolished by ice flows. In the East the storms and thunderstorms caused a lot of damage and upset community life as trees, hydro poles and telephone lines were brought down by winds exceeding 100 km/h. At Montréal, hailstorms on May 29 inflicted damage estimated in the millions of dollars. In the Maritimes, the storms were scattered and did not prevent numerous fires from starting as a result of the dry, mild weather prevailing there. By mid-May there were no less than 100 forest fires burning; 40,000 hectares of woodland were destroyed in New Brunswick, 25 times more than last year. In Newfoundland, 81,000 hectares of forest were consumed.

As summer began, there was good reason to believe that the May situation of cool temperatures in the West and milder readings in the North and East would continue.

Alain Caillet is a meteorologist with the Canadian Climate Centre and is a member of the editorial team of *Climatic Perspectives*.

The Role of Carbon Dioxide and Other Greenhouse Gases in Climate Variations

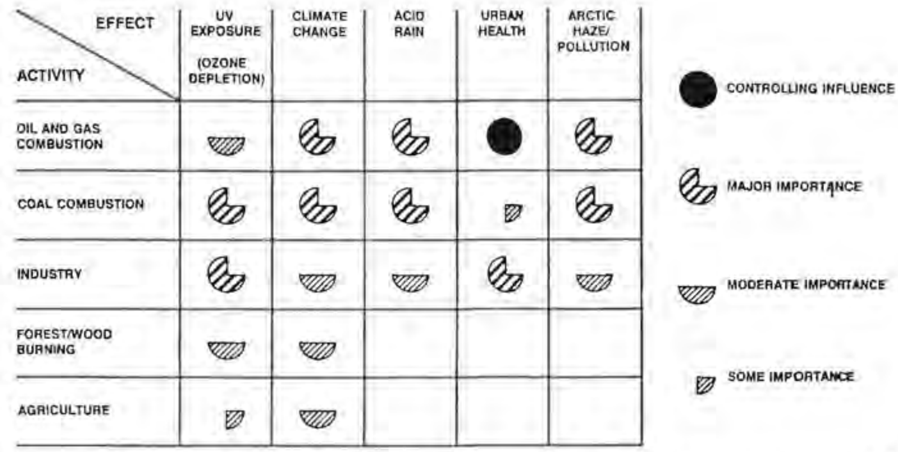
A joint conference, convened by the United Nations Environment Programme (UNEP), the World Meteorological Organization (WMO), and the International Council for Scientific Unions (ICSU), brought an invited group of about 100 scientists and policy analysts from 29 countries, to Villach (Austria) October 9–15, 1985.

The Conference's main purpose was to assess the role of increased carbon dioxide and other radiatively active constituents of the atmosphere (collectively known as greenhouse gases and aerosols) on climate changes and associated impacts. The other greenhouse gases reinforce and accelerate the impact due to CO_2 alone. As a result of the increasing concentrations of greenhouse gases, it is now believed that in the first half of the next century a rise of global mean temperature could occur that is greater than any in man's history.

Five aspects of the issue were addressed by working groups: energy scenarios and CO_2 emissions; prediction of greenhouse gas concentrations; atmospheric models and prediction of climate effects; effects on terrestrial and marine ecosystems; and socio-economic responses.

Two major background documents, prepared by Dr. B. Bolin of the International Meteorological Institute of Stockholm and Dr. W. Clark of the International Institute of Applied Systems Analysis were circulated to invited participants. These provided basic references for the conference discussions. The Bolin report was a comprehensive overview of the present state of scientific understanding of the CO_2 climate issue and its implication for global vegetation. Dr. Clark's essay, on the other hand, examined the manner in which the scientific community should address the question "So what?" and was designed to stimulate further discussion on international and govermental response.

A final conference document will contain background paper summaries, edited working group reports and a summary statement. The latter is intended to bring home to policy makers throughout the world the importance of this issue and the political implications for international agencies and governments.



Interaction between man and environment illustrating the common origins of environmental effects and the multiple environmental implications of human activities. Adapted from Clark, W.C., 1985: On the Practical Implications of the Carbon Dioxide Question, IIASA WP-85-43, background working paper for 1985 Villach meeting of experts.

The statement has three main conclusions for society:

1) Many important economic decisions (about structures, water projects, etc.) are being made today based on the assumption that future climate will be the same as that of the past 100 years, now unlikely to be correct. This demands urgent attention to better predictions of the magnitude and timing of changes.
2) The "greenhouse gases" and climate change form an important environmental issue closely linked to acid deposition and threats to the stratospheric ozone layer. These are all due to man's activities in contaminating the global atmosphere. In several instances solutions of one of these problems will help solve one or more of the others.
3) The rate of change of greenhouse gas concentrations and climate are highly dependent on national and international policy decisions concerning energy production, control of chloro-fluorocarbons (CFCs) and other radiatively active gases.

These conclusions are based on the following consensus of current basic scientific understanding:

- The amounts of some trace gases in the troposphere, notably carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) ozone (O_3) and CFCs are increasing. These gases are essentially transparent to incoming short-wave solar radiation but they absorb and emit long-wave radiation and are thus able to influence the earth's climate.
- The role of greenhouse gases other than CO_2 in changing the climate is already about as important as that of CO_2. If present trends continue, the combined concentrations of atmospheric CO_2 and other greenhouse gases would be radiatively equivalent to a doubling of CO_2 from pre-industrial levels possibly as early as the 2030s.
- The most advanced experiments with general circulation models of the climatic system show increases of the global mean equilibrium surface temperature of between 1.5 and 4.5°C for a doubling of the atmospheric CO_2 concentration, or equivalent. Because of the complexity of the climatic system and the imperfections of the models, particularly with respect to ocean-atmosphere interactions and clouds, values outside this range cannot be excluded. The realization of such changes will be slowed by the inertia of the oceans; the delay in reaching the mean equilibrium temperatures corresponding to doubling the greenhouse gas concentrations is expected to be a matter of decades.

- While other factors such as aerosol concentrations, changes in solar energy input, and changes in vegetation may also influence climate, the greenhouse gases are likely to be the most important cause of climate change over the next century.
- Regional scale changes in climate have not yet been modelled with confidence. However, regional differences from the global averages show that warming may be greater in high latitudes during late autumn and winter than in the tropics, annual mean runoff may increase in high latitudes, and summer dryness may become more frequent over the continents at middle latitudes in the Northern Hemisphere. In tropical regions, temperature increases are expected to be smaller than the average global rise, but the effects on ecosystems and humans could have far-reaching consequences. Potential evapotranspiration probably will increase throughout the tropics whereas convective rainfall could increase in moist tropical regions.
- It is estimated on the basis of observed changes since the beginning of this century, that a global warming of 1.5 to 4.5°C would lead to a sea-level rise of 20-140 centimetres. A sea-level rise in the upper portion of this range would have major direct effects on coastal areas and estuaries. A significant melting of the west Antarctic ice sheet leading to a much larger rise in sea-level, although possible at some future date, is not expected during the next century.
- Based on analyses of observational data, the estimated increase in global mean temperature during the last one hundred years of 0.3–0.7°C is consistent with the projected temperature increase attributable to the observed increase in CO_2 and other greenhouse gases, although it cannot be ascribed in a scientifically rigorous manner to these factors alone.
- Based on evidence of the effects of past climatic changes, there is little doubt that a future change in climate of the order of magnitude obtained for climate models for a doubling of the atmospheric CO_2 concentration could have profound effects on global ecosystems, agriculture, water resources and sea ice.

The statement also provides some recommmendations, addressed to national governments and international agencies, on responses to this situation, even with the uncertainties, and on directions for research to reduce the uncertainties.

This report is adapted from Environment Canada's CO_2/CLIMATE REPORT (Winter 1986), a periodic newsletter devoted to current events in CO_2 climate research. The material was in part prepared and made available by Henry Hengeveld, the Atmospheric Environment Service advisor on carbon dioxide related matters.

Le rôle du gaz carbonique et des autres gaz à effet de serre dans les variations climatiques

Une conférence convoquée en commun par le Programme des Nations Unies pour l'environnement (PNUE), l'Organisation météorologique mondiale (OMM) et le Conseil international des unions scientifiques (CIUS), et réunissant des spécialistes de 29 pays développés et en développement, a eu lieu à Villach (Autriche), du 9 au 15 octobre 1985. On y a évalué le rôle que joue l'augmentation de la teneur de l'atmosphère en gaz carbonique et en autres constituants radiativement actifs (connus collectivement sous le nom de gaz à effet de serre et d'aérosols) sur les modifications du climat et les incidences correspondantes. Les gaz à effet de serre autres que le gaz carbonique renforcent et accélèrent les effets causés par celui-ci. À l'heure actuelle, on considère que l'accroissement de la concentration des gaz à effet de serre entraînera, au cours de la première moitié du siècle prochain, une augmentation de la température moyenne dans le monde, supérieure à tout ce que l'on a connue jusqu'alors dans l'histoire de l'humanité.

La conférence a adopté trois conclusions principales pour la société :

1) Aujord'hui, on prend de nombreuses décisions économiques importantes (sur les structures, les projets hydrauliques, etc.), en supposant que le climat futur sera le même que pendant les cent dernières années, supposition qui risque maintenant fort d'être incorrecte. Il faut traiter cette question de toute urgence pour mieux prévoir l'ampleur et la date d'apparition des changements.

2) Les « gaz qui sont à l'origine de l'effet de serre » et le changement climatique constituent une importante question environnementale étroitement liée aux dépôts acides et aux menaces à la couche d'ozone stratosphérique. Ces faits résultent tous de l'activité humaine qui contribue à contaminer l'atmosphère du globe. Dans plusieurs cas, des solutions à un de ces problèmes aideront à résoudre un ou plusieurs des autres.

3) La vitesse du changement du climat et des concentrations de gaz provocant l'effet de serre dépend beaucoup des décisions d'orientation nationales et internationales sur la production d'énergie, la réduction des chlorofluorocarbones et d'autres gaz à rayonnement actif.

Ces conclusions reposent sur plusieurs constatations, dont celles-ci : Il se produit un réchauffement graduel qui portera sans doute la température mondiale moyenne de la Terre, d'ici la première moitié du prochain siècle, à une valeur jamais atteinte dans l'histoire de l'homme ; l'effet de serre attribuable au seul gaz carbonique est grandement intensifié sous l'effet d'autres gaz radiatifs comme les chlorofluorocarbones, le méthane, les oxydes d'azote et l'ozone à faible altitude, ce qui contribue à accélérer le changement climatique ; la hausse du niveau des mers (en hausse de 25 à 140 cm d'ici à l'an 2030) risque fort de compter parmi les conséquences les plus menaçantes d'une Terre plus chaude.

INDEX – VOLUME 8

AUTHORS / AUTEURS

ARTICLES

EDITORIAL / NOTES DU RÉDACTEUR

NEWS AND NOTES / AILLEURS

THE SCHOOL NOTEBOOK

COVERS *(Chronological Order)*

Winter / Hiver Intense thunderstorm development over southwestern Ontario
Spring / Printemps Low water in the Bay of Fundy area
Summer / Été Fair weather cumulus cloud streets near Frenchman's Bay on Lake Ontario
Fall / Automne Icebergs in the eastern waters of North America

Continued from page 63

promoting the publication by showing it to friends, taking it into schools and colleges and local libraries or to anyone interested in weather, climate and the oceans. *We also need to hear from you.* Again we have received few letters. It is nice to hear the good things, but it is also important to hear about those areas where we are not doing well. Your contributions as articles, notes or reports about some specific observed atmospheric-ocean phenomenon (including pictures) are welcome and will be published, if relevant.

In short, it is *your* publication and in order to remain a viable entity we must increase in numbers. It is important to remember that without a meaningful circulation few, if any, advertisers will come on board. Advertising is important to the financial base of *Chinook's* operation.

This fall we have approached all the Canadian School Boards, asking them for subscriptions for their High Schools. We need a lot of assistance to reach some of the other groups. *Please help us!*

In this last issue of 1986 we have included an article on icebergs. As you will notice the author is an enthusiastic and involved High School teacher, very much committed to leading his students to the frontier of environmental sciences and its related activities and problems. You will also notice that Jerry Salloum is one of our new Editorial Board members along with Barry Grace. Both members bring valuable experience in secondary and college education to the Board. This is also an appropriate time to thank the three retiring members of the Board: Morley Thomas, Jay Heierman and Tom Murphy.

The issue also has something for the amateur weather observer. The article on the "bucket survey" points out that all of us can be part of the ongoing observation and study of weather phenomena. Indeed, there are many keen amateur weather and ocean enthusiasts in this great and varied country of ours. *Please help us reach them.*

Hans VanLeeuwen

PROFESSIONAL AND BUSINESS DIRECTORY

CALL FOR PAPERS

Second (AES/CMOS) Workshop on Operational Meteorology
October 14–16, 1987, Halifax, Nova Scotia, Canada

The theme for the workshop will be Marine Meteorology. Papers on the following topics are solicited:

- marine meteorology (e.g., near-shore forecasting, cyclogenesis, forecasting marine elements)
- mesoscale meteorology and local forecast problems
- data acquisition and remote sensing
- nowcasting and forecast tailoring
- data management, analysis and display systems
- using weather services and verification

Studies using data sets from the Canadian Atlantic Storms Program (CASP) or the Genesis of Atlantic Lows Experiment (GALE) are anticipated.

The workshop will comprise submitted and invited papers, panel discussions and laboratory sessions. A poster session is planned for the evening of October 14.

Titles and abstracts of 200–400 words should be sent by **March 31, 1987** to the Program Chairman, J.D. Abraham, Maritimes Weather Centre, 6th Floor, 1496 Bedford Highway, Bedford, N.S. B4A 1E5. Authors should indicate their preference for presenting their papers either orally in a regular session or in a poster session. Abstracts will be evaluated on their relevance to operational meteorology and weather services, as well as on their quality.

Authors will be notified by **May 1, 1987** regarding acceptance of their abstracts, and will be furnished with instructions on the format of the papers.

Complete camera-ready papers of no more than 8 pages, including diagrams, must be received by the program chairman no later than **July 31, 1987**. A preprint volume will be prepared and distributed to workshop registrants. Papers and abstracts may be in English or French.

Chinook

THE CANADIAN MAGAZINE OF WEATHER AND OCEANS

WHAT? *Chinook* is a popular magazine concerned with two major components of the Canadian environment – the atmosphere and the oceans. It is published quarterly by the Canadian Meteorological and Oceanographic Society (CMOS).

Features in *Chinook* include articles, weather summaries, interpretations of satellite and other photographs, and news and notes. These appear in the language submitted (English or French). In addition, summaries of all articles appear in the other language.

WHY? The aims of *Chinook* are

- to increase public awareness of meteorology and oceanography in Canada and of their modern scientific and technological aspects and achievements
- to stimulate public interest in and understanding of the impact of climate, weather and oceans on Canadian society and economics
- to inform Canadians about the education, information and interpretative services available to them on climate, weather and oceans

WHO? Features in *Chinook* are chosen to appeal particularly to

- secondary school and community college students
- farmers, fishermen and foresters
- marine-recreation, sports and tourism operators and enthusiasts
- aviators
- amateur observers of natural phenomena
- specialists in other sciences
- environmentalists

HOW? Subscriptions to *Chinook* may be ordered using the handy form above.

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LA REVUE CANADIENNE DE LA MÉTÉO ET DES OCÉANS

QUOI? *Chinook* est une revue de vulgarisation qui traite de l'atmosphère et des océans – deux des importants éléments qui composent l'environnement canadien. *Chinook* est publié tous les trois mois par la Société canadienne de météorologie et d'océanographie (SCMO).

On retrouve dans *Chinook* des articles, des sommaires du temps, des interprétations de photos satellitaires et autres, des articles d'actualité et des notes. Ces articles paraissent dans la langue originale, le francais ou l'anglais; tous les résumés sont rédigés dans l'autre langue.

POURQUOI? *Chinook* vise à :

- éveiller la curiosité du public en ce qui a trait aux aspects de la météorologie et de l'océanographie au Canada et à l'informer des réalisations scientifiques et technologiques d'aujourd'hui;
- stimuler l'intérêt du public et l'aider à mieux comprendre les effets du climat, du temps et des océans sur la société et sur l'économie du Canada;
- renseigner les canadiens sur les services d'éducation, d'information et d'interprétation qui leurs sont disponibles et qui traitent du climat, du temps et des océans.

QUI? Les articles choisis pour *Chinook* vise à intéresser notamment :

- les étudiants d'écoles secondaires et de collèges communautaires
- les agriculteurs, pêcheurs et agents forestiers
- les exploitants d'établissements de nautisme, de sports et de tourisme, et les amateurs des ces activités
- les aviateurs
- les observateurs amateurs de phénomènes naturels
- les spécialistes d'autres sciences
- les environnementalistes

COMMENT? On peut s'abonner à *Chinook* en envoyant le formulaire ci-contre.

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