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Canadian Meteorological and Oceanographic Society

La Société canadienne de météorologie et d'océanographie

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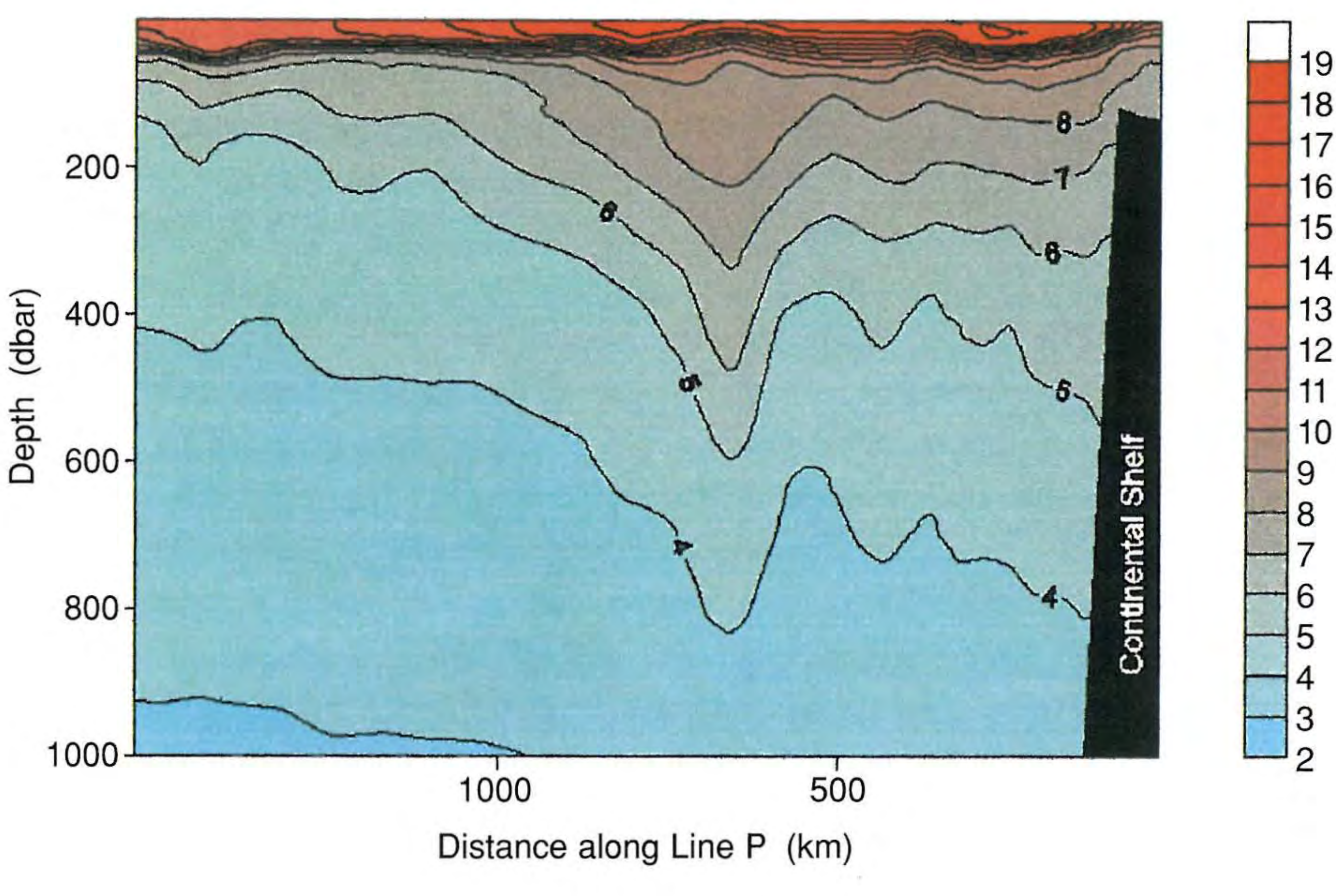
Temperature Field, August 1998

Cruise 9829



CMOS Bulletin SCMO
"at the service of its members
au service de ses membres"

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Cover page: Temperature field along Line-P in the North-East Pacific Ocean as measured in August-September 1998 (Cruise # 9829) from the Canadian Coast Guard Ship J/P Tully. To find more about the feature shown here, read the article on page 54.

Page couverture: Champ de temperature le long de la ligne-P dans l'océan du Pacifique nord-est tel que mesuré en août-septembre 1998 (numéro de croisière 9829) par le navire de la Garde Côtière du Canada, le J/P Tully. La profondeur est exprimée en décibar et la distance le long de la ligne-P en kilomètre. Pour en savoir plus sur le phénomène présenté ici, lire l'article en page 54.

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....from the President's Desk

The federal budget at the end of February contained quite a bit of good news for science, not the least of which was the announcement of $60M for CMOS to establish a new granting agency, The Canadian Foundation for Climate and Atmospheric Sciences. Suffice it to say that this development opens up a whole new role for CMOS, a first for a scientific society and something that will have to be carefully designed and managed. Preliminary work to establish the Foundation has been a major preoccupation of the Executive and Council in February and March. The Foundation will be up and running some time this spring and will disburse the $60M in research grants spread over a six-year period. It is hoped that additional funding can be obtained to expand the program and extend it in time.

There were several other elements of the budget that are significant for science in general and our sciences in particular. In the latter category is the announcement of extended funding of $210M for the Climate Change Action Fund that will extend its life from three years to six. In the first phase, about 10% of the fund was available to support climate science. Hopefully this will continue. A new Sustainable Development Technology Fund of $100M will stimulate new environmental technologies. The budget provides $900M over five years through the granting councils to establish and sustain 2000 Canada Research Chairs by 2004-2005. University departments of meteorology and oceanography will be challenged to take advantage of these. On the research infrastructure side, the budget provides a further $900M to the Canada Foundation for Innovation to support awards out to 2005. Finally, tax assistance to students and new funding for scholarships and study grants will make it easier for students in all disciplines to continue their studies.

Toutes les bonnes nouvelles mentionnées ci-dessus visent à supporter la recherche dans les universités. Par contre, il ne faudrait pas oublier la recherche faite au sein du gouvernement qui supporte la prestation des services au public et l'élaboration des politiques. Le gouvernement est aussi responsable pour les observations systématiques et l'échantillonnage des variables environnementales, la gestion des données, etc., activités qui sont à la base de nos sciences. Le budget contenait peu de mesures destinées à renforcer la capacité scientifique des ministères. Le Partenariat en faveur des sciences et de la technologie (PAGSE-PFST) a, depuis quelques années, fait des représentations dans ce sens, mais jusqu'à présent sans beaucoup de succès. Le temps est peut-être arrivé pour les membres de la SCMO de parler publiquement de la nécessité de réinvestir dans les ministères scientifiques du gouvernement.

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Inside / En Bref

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Further to the NSERC Reallocations Exercise issue discussed in the previous Bulletin, I can now report that Vice-President Peter Taylor will make a presentation to the GeoCanada2000 meeting on behalf of CMOS. The Scientific Committee under Chairman Charles Lin will draft a CMOS position paper that will be made available for comment in April and finalised following GeoCanada2000 and a special session on a vision for the atmospheric and oceanic sciences to be held at our Congress in Victoria. The paper will be submitted in June to the Earth Sciences Liaison Committee (ESLC) as a contribution to improving the Vision Statement to be drafted by the ESLC for the earth sciences group. Everyone will have a chance to contribute, either at the session in Victoria or through the CMOS web-site.

Back in early February, Past-President Bill Pugsley, Executive Director Neil Campbell and I were granted a meeting with Environment Minister David Anderson. The question of CMOS establishing CFCAS was not discussed but it was an opportunity to put forward a number of points of CMOS concern. We suggested that the current exercise of rethinking the role of the Meteorological Service of Canada would be an opportunity to reconsider the recommendations of the Alternative Service Delivery Study and to address some policy issues of concern. We pointed out that there is significant frustration within the meteorological and oceanographic private sector with the commercial service activities of MSC. We also mentioned the need for more resources for government monitoring and research in support of climate and weather concerns, including problems with automation of weather observing and the slowness of implementing the Doppler weather radar network. We noted our dissatisfaction with the responses of the Canadian Radio and Television Commission and the Canadian Association of Broadcasters to the position put forward two years ago by John Reid and Bill Pugsley that broadcasters should be required by law or regulation to promptly disseminate weather warnings.

Ian D. Rutherford, President / Président
CMOS / SCMO

Announcement

New Knowledge and Solutions for Forest Management
June 5-8, 2000
Sagimeo Lake Wilderness Lodge,
near Detour Lake, Ontario

Hosted by the Lake Abitibi Model Forest

Expert presenters will deliver practical solutions to sustainable forest management challenges, including the refinement of forest management guidelines, biodiversity considerations, harvesting impacts, non-timber forest products issues, policy alternatives, and the incorporation of aboriginal values.

Participants will learn about and discuss a variety of topics related to two sub-themes: I: Landscape- and Stand-level Research: Practical Applications to Forest Management; and II: Integrating Policy and Socio-Economic Perspectives into Contemporary Forest Management.

This workshop will appeal to anyone having an interest or active role in forest management, particularly in the boreal region of Ontario and Quebec. Registration fee: $350 (including accommodations and meals).

For complete Program details, please contact the LAMF at (705) 258-4278, e-mail: workshop@lamf.net, or visit www.lamf.net

Next Issue - Prochain Numéro

Next issue of the *CMOS Bulletin SCMO* will be published in June 2000. Please send your articles, notes, reports or news items at the earliest to the address given on page ii. We have an **URGENT** need for your articles.

Le prochain numéro du *CMOS Bulletin SCMO* paraîtra en juin 2000. Prière de nous faire parvenir au plus tôt vos articles, notes, rapports ou nouvelles à l'adresse indiquée à la page ii. Nous avons un besoin **URGENT** d'articles.

News Release

McGill University's Lawrence A. Mysak, a specialist in ocean and climate dynamics, has been elected a Fellow of the American Geophysical Union for

"Having attained acknowledged eminence in one or more branches of geophysics".

The number of Fellows elected each year is limited to no more than 0.1% of the total membership of AGU. The presentation of his Fellow's Certificate will be made at the Fall Meeting of AGU in San Francisco.

Professor Mysak holds the Canada Steamship Lines Chair of Meteorology in the Department of Atmospheric and Oceanic Sciences at McGill University in Montréal. He is past founding director (1990-96) of McGill's Centre for Climate and Global Change Research, and is also a past president (1993-96) of the Canadian Academy of Science, the largest of the three academies that comprise the Royal Society of Canada. During his academic career, which spans three decades, he has supervised 60 graduate and postdoctoral students.

Last year Professor Mysak was elected a Fellow of the American Meteorological Society (October 1999) and also named an inaugural Fellow of the Canadian Meteorological and Oceanographic Society (June 1999). With his recent election as Fellow of AGU, he is the only Canadian to hold fellowships in all three North American organizations which relate to his fields of research and teaching.

Letter to the Editor

In response to Paul LeBlond's call (Shackleton's encounter with a "lava-like flow of tumbling ice": what was it?, *CMOS Bulletin SCMO, Vol.27, No.5, October 1999, p. 149*) for an explanation for the "lava-like flow of tumbling ice" referred to in notes from the Shackleton Expedition: - I submit that this must have been a "sea-ice" tsnuami created by either calving of a nearby ice sheet / iceberg, an earthquake or a sea bottom turbidity slide. A tide rip explanation would have this phenomenon occurring on a very regular basis.

Best regards,

Charles O'Reilly
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Canadian Disasters: An Historical Survey

by Robert L. Jones[1]

Résumé: On identifie selon la cause et le type les désastres canadiens importants de 1500 à maintenant. On définit les critères généraux pour les désastres. Vingt morts simultanées ou plus est le critère principal. L'autre critère important est que l'événement doit avoir eu lieu à l'intérieur du Canada ou de la limite économique côtière de 200 milles. On exclut les événements tels que guerres, épidémies et batailles entre autochtones et colons européens durant la colonisation. Ces critères ont pour effet de réduire les événements à un nombre traitable. On présente les résultats d'une recherche étendue de références et on donne une brève description de certains des désastres. On se place d'un point de vue historique en vue d'illustrer les désastres qui étaient communs au début de l'histoire du Canada, de même que ceux qui se sont produits en temps modernes. On tire des conclusions quant aux types de désastres narurels et anthropogéniques qui sont susceptibles de se produire au Canada à l'avenir.

Methodology

The first task was to define a disaster for analysis purposes. This was followed by an intensive literature search. Implications of weather- and/or climate-related phenomena were also noted and recorded during the search. All disasters appeared in at least one reference, with recent events taken from newspaper coverage. Finally, conclusions were drawn about the weather-related disasters as compared to the other disasters found in the references.

In order to limit the number of events to be included in the survey, the primary disaster criterion was defined as *a single event, occurring at one time (no more than the order of a few days), within Canadian territory out to the 200-mile economic zone offshore, in which loss of life was 20 or more persons*. The search identified and counted all such events except wars and epidemics. The early colonization battles with aborigines and the war of 1812 with the United States were excluded. Several major epidemics were found but not counted in the primary list. The worst of these were the influenza epidemic which killed between 30,000 and 50,000 Canadians in the last five months of 1918, and the smallpox epidemic of 1885 which killed almost 6,000 in Montreal. In all, 157 disasters were identified which met these criteria.

In a short communication such as this, the scope cannot hope to extend to comparisons of Canadian disasters with those in other countries. Further, the scope did not include economic or property loss criteria.

Discussion and findings

1) Major Findings

Table 1 (a to c) lists the 157 Canadian disasters which met the above criteria and which were found in the references, listed inTable 5 at the end of the paper. Thirty-seven of these disasters occurred prior to Canada's Confederation in 1867. It is felt that there may be several unidentified disasters in that early period but, on the other hand, the period from 1867 to date may well include most of the events where at least 20 persons lost their lives. It is worth noting that the significant loss of life in the large number of marine disasters in the period around the time of Confederation was the catalyst which caused the federal government to found the Canadian Weather Service with a grant to Professor George T. Kingston in 1871.

Table 2 lists 52 disasters which did not meet all the criteria, but were reported in the references, often several times. Several were just short of the 20-death criterion, but were spectacular in nature. Others happened outside the 200-mile limit, but had distinctive "Canadian" characteristics such as the 1985 Air India crash over the North Atlantic Ocean. Still others met the criteria, but occurred over periods of time from a few months to a decade or more. All epidemics are listed in Table 2.

Given sets of data such as Tables 1 and 2, many conclusions can be inferred. Dealing with the weather-related factor first, 50% of the disasters were found to be weather-related, whether or not they met the criteria. Of the other half, 43% were not weather-related and the effect of the weather could not be determined from 7% of the disasters found. A strict definition of the weather-related factor is not possible in this examination. Based upon each event description in the references, a subjective decision was made on this factor, depending on the way the incident was described.

[1] Nepean, Ontario; e-mail: jonesb@igs.net

Table 1a: Canadian Disasters Meeting Criteria (before 1900)

#	Description of Disaster	References	Year	Deaths	Weather Factor
1	Wreck of "Delight" off Sable Island	HATB	1583	85	yes
2	Fleet of Ships Run Aground in Fog, Québec City, QC	HAT	1711	884	yes
3	Wreck of "Catherine" off Sable Is., NS	Ca	1737	98	yes
4	Four French Warships Sink near Sable Is., NS	B	1746	200-300	yes
5	Hurricane Hits Grand Banks Area, NF	T	1775	4,000	yes
6	Sloop "Ontario" Sinks in E. Lake Ontario	T	1783	190	yes
7	"Francis" Sinks in Storm off Sable Is., NS	B	1799	40	yes
8	Schooner "Speedy" lost off Newcastle, ON	U	1807	20+	yes
9	"Hamilton" and "Scourge" Sink in L. Ontario	CT	1813	53	yes
10	Wreck of "Sovereign" on St. Paul's Is., NS	C	1814	799	yes
11	"Harpooner" Aground at St. Shotts, NF	PaGm	1816	206	yes
12	Miramichi, N.B. Fire in Hot, Dry Summer	HAT	1825	200-500	yes
13	Brig "Dispatch" Runs Aground S of Newfoundland	W	1828	50	yes
14	"Lady Sherbrook" Lost Near Port-Aux-Basques, NF	Gm	1831	273	yes
15	Two Rafts Sink in Gale on Lac St-Pierre, QC	Ga	1836	25	yes
16	Rockslide onto Lower Quebéc City - I	HA	1841	32	no
17	Hurricane-force Winds on L. Ontario & L. Erie	T	1844	200	yes
18	Hurricane Hits Newfoundland	T	1847	300	yes
19	Steamer "Commerce" Collision in Lake Erie	By	1850	37	no
20	P.E.I. Gale Sinks 70 U.S. Fishing Vessels	T	1851	150-300	yes
21	"Atlantic" Collides with "Ogdensburgh" L.Erie	M	1852	130	no
22	"Ocean Wave" Burns Near False Duck Island, Lake Ontario	GI	1853	36	no
23	"Arctic" Collides with "Vesta" off C. Race	A	1854	285-351	no
24	Trains Collide, Chatham, ON	HAW	1854	52	no
25	Irish Ship "Pallas "Runs Aground, St. Paul's Is, NS	CTr	1856	82	yes
26	"Northern Indiana" Burns 5 mi. off Point Pelee, ON (# passenger list lost in fire)	GI	1856	30-56#	no
27	"Lord Ashburton" Sinks in Bay of Fundy	LorM	1857	21	yes
28	"Welsford" Wrecked off Cape Race NF	MPa	1857	27	yes
29	Steamer "Montreal" Fire Near Québec City, QC	H	1857	253	no
30	Canal Train Bridge Collapse, Hamilton, ON	S	1857	60	no
31	Sinking of "Monasco" with Passengers Locked in Cabins, Corbin (Burin), NF	Pa	1857	50	no
32	Wreck of U.S. Brig "Argo" off Sable Is., NS	B	1860	30	yes
33	Wreck of "Hungarian" off Cape Sable, NS	TPa	1860	205	yes
34	Wreck of "Anglo-Saxon" near Clam Cove, Cape Race, NF	APaGm	1863	238	yes
35	"Water Witch" Founders in SW Gale off Sable Point in Lake Huron	GI	1863	28	yes
36	Richelieu River Bridge Train Wreck, QC	HAW	1864	99	no
37	St-Lawrence R. Floods, Sorel & Trois-Rivières, QC	T	1865	45	yes
38	"City of Boston" Disappears in Storm off NS	T	1870	191	yes
39	"Imperial" Grounded on Moira Rocks, Bay of Fundy	Fi	1870	23	yes
40	"Bavarian"Sinks off Whitby Light, Lake Ontario	Fi	1873	20	*no
41	"August 24 Gale" Sinks 330 Ships in the Atlantic Provinces	TE	1873	360-380	yes
42	Wreck of "Atlantic" in Fog off Prospect, NS	HA	1873	535-585	yes
43	Coal Mine Fire & Explosion, Westville, NS	HA	1873	60	no
44	Steamer "George S. Wright" Lost in Snowstorm, Queen Charlotte Sound, BC	Fi	1873	30	yes
45	"Calcutta" Sinks North of Grindstone Island in Heavy Weather	Fi	1875	23	yes
46	S.S. "Pacific" Sinks near Victoria, BC	PA	1875	236	no
47	Steamer "Waubino" Sinks in Georgian Bay Gale	Ar	1879	24	yes
48	Drummond Coal Mine Explosion, Stellarton, NS	H	1880	44	no

Table 1a: Canadian Disasters Meeting Criteria (before 1900) (Continued)

#	Description of Disaster	References	Year	Deaths	Weather Factor
49	Ferry "Victoria" Flips Over Near London, ON	SHAT	1881	182	no
50	Forest Fires near Lake Huron after Dry Spell	T	1881	500	yes
51	"Jane Miller" Disappears in Gale near Colpoy's Bay, Georgian Bay, ON	GI	1881	30	yes
52	"Asia" Sinks in Georgian Bay Gale	TM	1882	120-126	yes
53	"Mary Ann Hulbert" Sinks Under Tow in Lake Superior Near Thunder Bay, ON	GI	1883	20	yes
54	CPR Ship "Algoma" Sinks in L. Superior	T	1885	48	yes
55	October Gale Sinks 89 Ships off Labrador	Mc	1885	70	yes
56	Great Fire of Vancouver	SHP	1886	30-40	yes
57	Nanaimo Mine Disaster - I	P	1887	148	no
58	Nanaimo Mine Disaster - II	P	1888	77	no
59	Champlain Street Rockslide, Québec City - II, QC	HA	1889	45	no
60	Springhill Mine Disaster - I	SHA	1891	125	no
61	Schooners "Maggie Foote", "George Foote" and "Reason" Lost in August Gale, S. Coast NF	Pa	1892	32	yes
62	Streetcar Falls from Bridge, Victoria, BC	HAP	1896	55	no
63	"La Bourgogne"/"Cromartyshire" Collision off NS	AB	1898	545	yes
64	"City of Monticello" Founders off Yarmouth NS	L	1899	36	yes

x Indicates the same storm; * Indicates weather-related factor uncertain from description.

Table 1b: Canadian Disasters Meeting Criteria (1900 - 1949)

#	Description of Disaster	References	Year	Deaths	Weather Factor
67	"Planet Mercury" Disappears off NS Coast	L	1900	45	*yes
68	Tanker "Heligoland" Aground St. Shotts NF	Pa	1900	35	yes
69	Coal Creek Mine Explosion, Crowsnest AB	Cr	1902	128	no
70	Grand Trunk Railway Collision, Wanstead, ON	Ra	1902	28	no
71	Frank Slide, Turtle Mtn., Frank, AB	SHATRF	1903	70	no
72	Wreck of "Valencia" off Vancouver Island	T	1906	126	yes
73	First Quebec Bridge Collapse	SHAR	1907	75	no
74	Sealers from "Greenland" Freeze on Ice off NF	Mc	1908	48	yes
75	Avalanche in Rogers Pass, BC	HACT	1910	62	yes
76	CPR Derailment, (Spanish R.) Sudbury, ON	HMW	1910	43	no
77	Bellevue Mine Explosion, Crowsnest Pass, AB	FCr	1910	30	no
78	Montreal Herald Building Collapses (June 14)	Ga	1910	32	no
79	Forest Fire, Porcupine, ON	RT	1911	73	yes
80	Regina Tornado	STR	1912	28	yes
81	"SS Florence" Hits Cliffs near Mariner's Cove, NF	Pa	1912	20	yes
82	Thirty-four Ships Sink in Great Lakes Storm	ST	1913	270	yes
83	Coal Dust Explosion, Hillcrest, AB	HAFCr	1914	189	no
x84	"Southern Cross" Vanishes in Storm off NF	H	1914x	173	yes
x85	Four Seal Ships Caught in Ice off NF	HST	1914x	77	yes
86	"Empress of Ireland"/"Storstad" Collision off Rimouski, QC	SHATR	1914	1,014	yes
87	Britannia Mine Avalanche, Howe Sound, BC	C	1915	57	yes
88	Forest Fire, Cochrane/Matheson, ON	SHA	1916	233	yes
89	Halifax Explosion	SHATGR	1917	1,963	no
90	Coal Mine Explosion, Dominion, NS	H	1917	65	no
91	Coal Dust Explosion Michael Mine E. Crowsnest, AB	Cr	1917	34	no
92	Schooner "Mina Swim" Disappears Enroute from Burin to Grand Banks, NF	Pa	1917	23	*no
93	"Princess Sophia" Runs Aground off Northern BC	SHATB	1918	343	yes
94	HMCS "Galiano" Sinks in Heavy Seas off Queen Charlotte Islands, BC	Vi	1918	36	yes

Table 1b: Canadian Disasters Meeting Criteria (1900 - 1949) (Continued)

#	Description of Disaster	References	Year	Deaths	Weather Factor
95	"SS Florizel" Aground, St. John's, NF	Pa	1918	94	yes
96	Allan Mine Explosion, Stellarton, NS	H	1918	88	no
97	"Inkermann", Newly-built French Minesweeper Sinks in Storm in mid-Lake Superior	Gl	1918	38	yes
98	Forest Fire, Haileybury, ON	R	1922	44	yes
99	"Sylvia Mosher" and "Sadie Knickle" Sink off Sable Is. NS	B	1926	60	yes
100	"Laurier Palace" Theatre Fire in Montréal, QC	SHAR	1927	77	no
101	Nine Schooners (including "Joyce M. Smith"; "Columbia") lost off NF and NS in August 24 Gale	PaB	1927	87	yes
102	Naval Sloop "Acorn" Sinks off Halifax, NS	A	1928	115	*no
103	Tsunami Hits Burin Peninsula, NF	HAT	1929	27	no
104	"John B. King" Explodes and Sinks in St. Lawrence R. after Lightning Strike	T	1930	30	yes
105	Loss of "Viking" off St. Barbe Island, NF	Mo	1931	25+	yes
106	Schooners "Alsatian" and "Arthur D. Strong" Disappear in March Storm, Grand Banks, NF	Pa	1935	33	yes
107	Train hits Farm Truck at Level Crossing, Louisville, QC	HOc	1936	22 or 23	no
108	Schooner "Partanna" Wrecked near St. Shotts, NF	Pa	1936	25	yes
109	Three Great Lakes Ships Wrecked in Storm	T	1940	69	yes
110	Arsonist Sets K of C Hostel Fire, St. John's, NF	HARMc	1942	99	no
111	Troop Train hits Stopped Train, Almonte, ON	W	1942	36	no
112	"Truxton" & "Pollux" Aground off NF	ATMc	1942	204	yes
113	"Fanad Head' & "Flora Alberta" Collide off NS	Pr	1943	21	no
114	RCAF Liberator Bomber Crash, Saint-Donat, QC (airmen travelling on leave)	H	1943	24	no
115	December 11 Snowstorm in Southern Ontario	StT	1944	21	yes
116	Dugald Train Wreck, E. of Winnipeg, MB	S	1947	40	no
117	"Noronic" Burns in Toronto Harbour	SHA	1949	118	no
118	Bomb Explodes on Quebec Air DC3 *see Note, Table 3)	HA	1949	23	no

x Indicates the same storm; * Indicates weather-related factor uncertain from description.

Table 1c: Canadian Disasters Meeting Criteria (1950 to date)

#	Description of Disaster	References	Year	Deaths	Weather Factor
119	US Transport Plane Lost over Yukon	M	1950	44	*no
120	Trains Collide, Canoe River, BC	H	1950	21	no
121	Bus Plunges into Williamsburg Canal, Morrisburg, ON	HOc	1953	20	no
122	Hurricane Hazel, Ontario	SHATR	1954	83	yes
123	TCA Northstar Crash onto Mt. Slesse, BC	DM	1956	62	yes
124	Springhill NS Mine Disaster - II	SHAR	1956	39	no
125	Maritime Central Airways DC4 Crashes at Issoudun, QC (40 km SW of Québec City)	M	1957	79	*no
126	Springhill NS Mine Disaster - III	SHAR	1958	75	no
127	22 Fishing Boats Sink, Storm, Escuminac, NB	HR	1959	35	yes
128	Northwest Air DC7 Crash off BC Coast	A	1963	101	*no
129	TCA DC8 Crash, Sainte-Thérèse, QC	SHATDM	1963	118	*no
130	Severe Winter Storm Hits Maritimes	T	1964	23	yes
131	Apartment Fire, La Salle, QC	A	1965	28	no
132	Granduc Mountain Avalanche, Stewart, BC	CT	1965	26	yes
133	CP Air DC6B Explodes and Crashes near 100-Mile House, BC	M	1965	52	no
134	Nineteen Teenagers and Bus Driver, Level (Train) Crossing, Dorion, QC	Oc	1966	20	no
135	Ore Carrier "D.J. Morrell" Sinks in L. Huron	T	1966	28	yes
136	Ilyushin Turboprop Crash, Gander, NF	D	1967	33	no

Table 1c: Canadian Disasters Meeting Criteria (1950 to date) (Continued)

#	Description of Disaster	References	Year	Deaths	Weather Factor
137	"Cape Bonnie", "Polly & Robbie" and "Iceland II" Sink in Storm off NS	Pa	1967	35	yes
138	Nursing Home Fire, Notre-Dame-du-Lac, QC	A	1969	54	no
139	Air Canada DC8 Crash at Toronto Airport	SHADM	1970	109	no
140	Crater Opens During Rainstorm, St-Jean-Vianney, QC	HA	1971	31	yes
141	"Blue Bird" Bar Fire in Montréal	A	1972	37	no
142	Pan Arctic Electra Crash, Rea Point, NWT	HM	1974	32	*no
143	Wreck of "Edmund Fitzgerald", Lake Superior	AT	1975	29	yes
144	Cell Block Fire, Saint John, NB	A	1977	20	no
145	Bus Plunges into Lac d'Argent, QC	HAOc	1978	41	no
146	PWA 737 Crash, Cranbrook, BC	D	1978	42	yes
147	Social Club Fire, Chapais, QC	HA	1979	44	no
148	Tanker Truck/Bus Collision, AB/SK Border	Oc	1980	22	no
149	Drilling Rig "Ocean Ranger" Sinks off NF	SHAT	1982	84	yes
150	Charter "Arrow" DC8 Crash, Gander, NF	HATDM	1985	256	*no
151	VIA/CN Trains Collide, Hinton, AB	HA	1986	26	no
152	Edmonton Tornado	HA	1987	27	yes
153	Air Ontario Crash, Dryden ON	DAM	1989	24	*yes
154	"Johanna B" & "Capitaine Torres" Sink in Gulf of St. Lawrence	MOc	1989	39	yes
155	Westray Coal Mine Explosion, Plymouth, NS	MOc	1992	26	no
156	Truck/Bus Crash Lac Bouchette, QC	MOc	1993	20	no
157	"Gold Bond Conveyor" Sinks off Yarmouth NS	MOc	1993	33	yes
158	Bus Plunges into Ravine, St. Joseph-de-la-Rive, QC - II	MOcSu	1997	43	no
159	Ice Storm Ravages Eastern Canada	CMOcSuT	1998	25-35	yes
160	Freighter "Flare" sinks Southwest of Newfoundland	MOc	1998	21	yes
161	Swissair MD11 Crashes off Peggy's Cove NS (Flight 111)	MOcSu	1998	229	no

x Indicates the same storm; * Indicates weather-related factor uncertain from description.

Table 2: Canadian Disasters Which Do Not Meet Criteria

#	Description of Disaster	References	Year	Deaths	Weather Factor
1	Genocide of Newfoundland Aboriginals (Beothuk Indians)	S	1600-1825	1,000	no
2	Pestilence Aboard 8 French Armada Ships Anchored in Bedford Basin, NS After Surving Storm off Sable Is.	B	1746	1000+	no
3	Royal Navy Warship Lost in Storm E. Lake Ontario off Oswego NY	GI	1780	172-350	yes
4	Two Quebec City Fires, May and June	H	1845	23	yes
5	Typhus Epidemic on Partridge Island Quarantine Station Near Saint John, NB	Sj	1847	1000s	no
6	Loss of Franklin Expedition, NWT.	H	1847-48	129	yes
7	Schooner "Katie" Flounders Enroute Port Hawkesbury, NS to Boston	Fi	1876	68	yes
8	Great Fire of Saint John, NB	AT	1877	18-100	yes
9	Lake Ontario Flash Flood	T	1883	18	yes
10	Thames River Flood of West London, ON	Lo	1883	17	yes
11	Smallpox Outbreak, Montréal	H	1885	5,864	no
12	"Titanic" Hits Iceberg S. of Grand Banks	ATG	1912	1,523	no
13	"SS Erna"Disappears Enroute Glasgow to St. John's NF	Pa	1912	51	*no
14	Second Quebec Bridge Collapse	SHA	1916	13	no
15	Influenza Epidemic (last 5 months of year)	Ba	1918	30 K - 50 K	no
16	Longest, Most Severe Summer Heat Wave	T	1936	780	yes
17	Runaway Mine Tractor, Sydney, NS	M	1938	16	no
18	"Dirty Thirties" in Prairie Provinces	S	1930-39	??	yes

Table 2: Canadian Disasters Which Do Not Meet Criteria (Continued)

#	Description of Disaster	References	Year	Deaths	Weather Factor
19	Lake St. Clair Tornado	T	1946	17	yes
20	Red River Flood, MB	HTR	1950	1	yes
21	MacGregor Mine Explosion, Stellarton, NS	Oc	1952	19	no
22	Freighter Sinks in High Winds in L. Superior	T	1953	17	yes
23	Polio Outbreaks Prior to Salk Vaccine	H	1953-54	638	no
24	Bus Truck Collision, Yamachiche, QC	SuOc	1954	15	*no
25	CF100 Crashes into Convent Near Ottawa	OcM	1956	15	no
26	Radiation Sickness from NF Fluorspar Mine	S	1957-78	75	no
27	Second Narrows Bridge Collapse, Vancouver	SHAR	1958	18	no
28	Gas Explosion in Store, Windsor, ON	A	1960	11	no
29	Bus - Station Wagon Collision E. of Ottawa, ON	Oc	1960	11	no
30	Students Die in School Bus -Train Level Crossing Crash, Lamont, AB	SuOc	1960	17	no
31	Chemical Plant Fire, La Salle, QC	A	1966	11	no
32	CP Air DC8 Crashes on Seawall, Tokyo, Japan	D	1966	64	yes
33	Victoria Hotel Fire, Dunnville, ON	A	1969	13	no
34	60-hour Snowstorm Dumps 70 cm. on Montréal	T	1969	15	yes
35	Bus - Truck Chain Collision, Hwy 400, Barrie, ON	SuOc	1973	12	yes
36	Bus Plunges into Ravine, St. Joseph-de-la-Rive, QC - I	MOc	1974	13	no
37	"Go" Train - Bus Collision, Toronto, ON	MOc	1975	10	*no
38	Transport Truck - Bus - Pickup Collision, Nanaimo, BC	MOc	1977	11	no
39	Bus Crashes into Overpass, St. Hyacinthe, QC	MSuOc	1979	11	yes
40	Mississauga Derailment, Toronto	S	1979	0	no
41	Fire Aboard Air Canada DC9, Cincinnati, Ohio	D	1983	23	no
42	Tornado Outbreak in/near Barrie, ON	HAT	1985	12	yes
43	Air India 747 Crash off Ireland	HA	1985	329	no
44	Trawler "Hosanna" Sinks 400 km off C. Race	T	1987	34	yes
45	"Athenian Venture" Burns 600 km off C. Race	MOc	1988	29	no
46	Logging Truck Hits Hayride in NB	MOc	1989	13	no
47	Gunman Kills Women at École Polytechnique (U. of M)	MOc	1989	16	no
48	"Protektor" Disappears 400 km E. of NF	MOc	1991	33	yes
49	Collision of Transport Truck and Van, Cobalt, ON	MOc	1991	11	no
50	"Salvador Allende" Sinks 900 km S. of NF	MOc	1994	29	yes
51	Gunman Kills Family & Self, Vernon, BC	MOc	1996	10	no
52	Saguenay Floods, QC	MOc	1996	10	yes

* Indicates weather-related factor uncertain from description; 1883 (July 11) Lightning struck the Imperial Oil Co. refinery in London East, completely destroying the plant. The preceding torrential rains had also swollen the Thames River causing the great flood of West London which killed 17 people and causing major damage to buildings.

2) Marine Events

There were interesting findings regarding marine disasters. Over 40% of all the disasters occurred at sea, or on the Great Lakes, and 80% of these were weather-related. As expected, many of these marine disasters did not occur in modern times and, to a degree, aviation disasters are beginning to replace the ship/marine disasters. Clearly, when the number of aviation, train and bus accidents are added, transportation in all forms has been, and still is, a frequent cause of major disasters.

3) Dates of Disasters

An attempt was made to examine the rate of change with time of the numbers of people dying each decade in major disasters. It is evident that, although the nation's population has been rising steadily since colonization, the number of people killed in major disasters has been gradually dropping. The very large anomaly in the 1911-1920 decade was caused by the 1917 explosion of a munitions ship in Halifax Harbour and by the collision of two ships off Rimouski. Addition of the 1918 influenza epidemic, makes this decade Canada's deadliest by far in terms of disasters at home.

Table 3: All Canadian Disasters by Category and Frequency

Disaster Category	Occurrences in Tables 1 & 2
Shipwrecks / Sea Waves	83
Land Transportation	26
Fires / Explosions	21
Air Transportation *	18
Mines	16
Weather / Climate	14
Disease / Epidemics	6
Bridge Collapses	5
Mass Murders *	5
Landslides	4
Floods	4
Snow Avalanches	3
Icebergs / Sea Ice	3
Building Collapses	1
Tsunamis	1
Storm Surges	0
Earthquakes	0
Volcanoes	0
TOTAL:	210

* Canada's first successful bombing of a passenger airliner (Quebec Air, 1949), while earlier considered as an Air Transportation disaster, has been moved to the Mass Murders category, given that the bomber was convicted and executed.

4) Categories of Disasters

The "Journal of Natural Hazards" recognizes the following hazards: atmospheric (weather / climatological), earthquakes, erosion, floods, droughts, landslides, man-made / technological, oceanographic (waves / storm surges), snow/avalanches/ice, tsunamis and volcanoes.

It is interesting to note that Canada has experienced at least one disaster in each of the categories listed in the Journal, with two exceptions: storm surges and volcanoes, and that the two of the three most common Canadian disasters do not fall exactly into any of the classifications listed. They are shipwrecks and fires. Obviously, the shipwrecks are, in many cases, the result of marine (wave) hazards, but the fires do not seem to have a place in the hazards phenomena. A classification for fire should be added. One new disaster category, "Building Collapses", has been added in the updates to this paper. Table 3 lists the disasters by category and frequency.

5) Geographical Distribution

The geographic nature of the disasters was examined. Table 4 shows their distribution by Canadian province. Only 16 events could not be assigned to a specific province. Generally, the locations reflect the population density with the many disasters occurring along the East Coast and in the St. Lawrence River area. On land, they were centred near the large population centres of eastern Canada. Manitoba, Saskatchewan and Prince Edward Island are the provinces with the fewest disasters.

Table 4 - Distribution of All Disasters by Canadian Province / Territory

Newfoundland	38
Nova Scotia	30
Prince Edward Island	1
New Brunswick	8
Quebec	35
Ontario	48
Manitoba	2
Saskatchewan	1
Alberta	8
British Columbia	20
Northwest Territories	2
Yukon Territory	1
Could not be determined or more than one Province	16
TOTAL (Tables 1 & 2)	210

Manitoba had a train wreck at Dugald in 1947 which caused 40 deaths and the Red River Floods which had high economic losses but very few fatalities. Saskatchewan's only disaster was the 1912 Regina tornado which killed 28 persons. The Regina tornado and the 1987 Edmonton Tornado, which resulted in 27 deaths, are the two Canadian tornado events with the highest death tolls. Major Canadian cities which have never had a disaster are Ottawa, Saskatoon and Calgary.

There were only three occurrences in the Canadian Arctic found in the references:

- the Rea Point NWT Pan Arctic Electra crash in 1974 in which 32 oil and gas workers lost their lives;
- the loss of the Franklin expedition when 129 officers and crew of "HMS Erebus" and "HMS Terror" perished over the two-year period 1847 to 1848; and
- the loss, over the Yukon in 1950, of a U.S. military transport plane with 44 persons aboard.

6) Other Findings of Interest

■ Canada's best known and worst disaster in terms of lives lost at one time is undoubtedly the Halifax Explosion of 1917. It had the highest death toll (nearly 2,000), was documented in six of the references and was the only disaster meeting the criteria to appear in the Guinness Book of Records.

■ In terms of total loss of life, the 1918 influenza epidemic which claimed between 30,000 and 50,000 Canadians in five months is Canada's worst disaster (although epidemics were excluded from the disaster criteria of this paper).

■ Only two other disasters meeting the criteria killed over 1,000 people. These are the collision of the ships "Empress of Ireland" and "Storstad" near Rimouski in 1914, and a 1775 storm off Newfoundland that reportedly killed 4,000, presumably in the large number of ships which were lost. Unlike the Rimouski collision, the 1775 event is not well documented, being referenced only in the Weather Trivia Calendar.

■ A few disasters recurred at the same place. There were six wrecks near Sable Island, NS; two or more disasters at coal mines in Nanaimo and Springhill; in Lower Quebec City due to rock falls, at the site of the Quebec Bridge, and in the Crowsnest Pass area of Alberta (landslides and mines).

■ In another coincidence, senior citizens died in almost-identical bus crashes on the same steep hill near St. Joseph-de-la-Rive, Quebec; 13 deaths in 1974; 43 deaths in 1997.

■ Twenty-seven people were killed in 1929 when a tsunami struck Newfoundland's Burin Peninsula following an earthquake in the Grand Banks area. This event was Canada's only tsunami or earthquake disaster.

■ While there have been many lightning strikes which kill one or two people at a time, there was only one major disaster directly caused by lightning (not including forest fires). The Weather Trivia Calendar reports that a freighter, "The John B. King", loaded with explosives was struck by lightning in the St. Lawrence River in 1930. Thirty crewmen died in the resulting explosion.

■ While no mine disasters have been placed in the weather-related category, following the Westray, NS accident in 1992, studies of ambient atmospheric pressure in the areas of mine entrances indicate changing atmospheric pressure may be a contributing factor involved in the build-up of methane gas in mines. Methane gas is believed to be the major cause of several coal mine disasters reported in this paper.

■ Many of the disasters were reported in several of the references. Many of these are the most familiar "household word" disasters. In order of date, the ones recorded in **four or more** of the references are:

1) Wreck of the "Delight" off Sable Island (1583) - the earliest recorded disaster;
2) Sinking of the Ferry "Victoria" near London, Ontario (1881);
3) The Frank Slide, Turtle Mountain, Alberta (1903);
4) First Quebec Bridge Collapse (1907);
5) Rogers Pass Avalanche (1910);
6) "Empress of Ireland" and "Storstad" Collision near Rimouski (1914);
7) Coal Dust Explosion at Hillcrest, Alberta (1914);
8) Halifax Explosion (1917);
9) "Princess Sophia" Grounding off BC (1918);
10) Laurier Palace Theatre Fire and Panic in Montreal (1927);
11) Arson at the Knights of Columbus Hostel in St. John's, Newfoundland (1942);
12) Hurricane Hazel (1954);
13) Two most recent Springhill Mine Disasters (1956 and 1958);
14) Vancouver's Second Narrows Bridge Collapse (did not meet criteria, 18 workmen killed in 1958);
15) Ste. Thérèse DC8 Air Crash (1963);
16) Toronto DC8 Air Crash (1970);
17) "Ocean Ranger" Sinking (1982);
18) "Arrow" DC8 Crash at Gander, Newfoundland (1985);
19) Great Ice Storm in Eastern Canada (1998).

Summary

Despite the various events uncovered during this research, it is evident from comparisons to other countries that Canada gets off rather lightly in major disasters. Canada has not been subject to the disastrous earthquakes, volcanic eruptions, cyclones, typhoons and floods which still regularly take thousands of lives in countries like China and Bangladesh. Even the United States has more weather-related disasters because its larger population is subjected to far more hurricanes than Canada, and the USA is the most tornado-prone country in the world.

Update Notes

Since the final acceptance for publication of this paper in 1991, 63 new disasters meeting the criteria have been added to Table 1 and 21 new disasters have been added to Table 2.

The Great Ice Storm of January 1998, which affected Ontario, Quebec and the Maritime provinces, has been identified by media and other commentators as the worst Canadian natural disaster. In the first 10 days following the storm, which deposited from 50 to 100 mm. of ice on hydro wires, trees and outdoor structures, at least 25 persons died directly as a result of the storm. Most of these deaths were caused by effects of long periods without electricity, such as carbon monoxide poisoning from heaters or hypothermia.

Web sites are increasingly quoted as references. Several are now linked in this web version of the paper. The author is aware of the transient nature and unreliability of material placed on the World Wide Web; therefore, as much care as possible is being taken before accepting Web references.

Robert C. Parsons of Grand Bank NF has authored several books detailing many East Coast marine losses. In 1999, twelve new items from his books were added, eleven of which met the criteria (Reference Pa).

Many of the other recent additions to the tables have been due to work by a colleague, Dr. John D. Reid, who is studying historical meteorological events. Dr. Reid's additions included several dozen more marine events that met the criteria and occurred mainly in the 19th century.

Although the paper has been reorganized since being published, no major changes in abstract, findings or conclusions have been made. It is hoped that the latest available information will ensure that the paper is as complete as possible.

The time of last update for the tables is March 9, 2000.

Note from the Editor: Bob Jones is the webmaster of the CMOS website.

Table 5: References and Source Code Identification

Author / Date	Name of Publication	Code
Yates, S.: 1987	*The Canadian World Almanac and Book of Facts*, Global Press, Agincourt, Canada, pp. 473, 474, 477, 478.	A
Flatt, J.D.: 1985	*The World Almanac and Book of Facts*, Canadian Edition, Newspaper Enterprise Association Inc., New York, USA, pp. 687, 690-692.	A
-	Archeological and Historic Sites Board of Ontario - Printed on Plaque in Parry Sound Ontario (near recovered anchor, 1959)	Ar
*Armstrong, Bruce.: 1981	*Sable Island (NS) - History*, Doubleday Canada Ltd, Toronto and Garden City, New York	B
Bacic, Jadranka: 1999	*The Plague of the Spanish Flu: The Influenza Epidemic of 1918 in Ottawa*, Bytown Pamphlet Series No. 63	Ba
-	*Bytown "Packet"*, May 11, 1850	By
-	*The Canadian Geographic Magazine*, The Royal Canadian Geographic Society: August-September 1983, p. 41; February-March 1983, pp. 24, 25; March-April 1992, pp. 64, 65; March-April 1998, p. 41.	C
*Campbell, Lyall: 1994	*Sable Island Shipwrecks: Disaster and Survival at the North Atlantic Graveyard*, Nimbus Publishers, Halfax, NS	Ca
-	Canadian Museum of Rail Travel , Cranbrook, BC Web Site, subsection Crowsnest Pass - *Early Coal Mining Disasters*	Cr
-	*Department of Transport Aviation Accident Records*, Aviation Safety Bureau, Aviation Group (AABB), Transport Canada, Ottawa, Canada	D
Allaby, E.: 1973	*The August Gale, A List of Atlantic Shipping Losses in the Gale of August 24*, 1873, Seascope Series 1 NB Museum, Saint John, NB	E
-	*Fact Sheets*, Alberta Government, Culture and Multiculturalism Dept.	F
-	*Annual Report of the Department of Marine and Fisheries*, Ottawa Canada,1868 - Ceased publication in 1914; National Library of Canada, AMICUS No. 7350777	Fi

Table 5: References and Source Code Identification (Continued)

Author / Date	Name of Publication	Code
McFarlan D. and McWhirter N.: 1989	*The Guinness Book of Records*, Guinness Publishing Ltd., p. 213.	G
-	*Montreal Gazette*, disaster lists and clippings, various dates	Ga
-	*Web Site Database of Great Lakes Shipwrecks*, http://www.oakland.edu/boatnerd/swayze/shipwreck/ with multiple sources for each item listed	Gl
*Galgay, F. & McCarthy, M.: 1987	*Shipwrecks of Newfoundland and Labrador*, H. Cuff Publications, St. John's NF	Gm
Hurtig, M.: 1985 & 1988	*Canadian Encyclopedia*, Hurtig Publishers, Ltd., Edmonton, Canada, First Edition, 1985, pp. 496, 497; and 1988, Canadian Encyclopedia, Second Edition, pp. 601-603.	H
*Lawson, J. Murray: 1902	*Yarmouth Past and Present*, Vol. I-II (2), Yarmouth Herald Printers	L
Smelser, Cheryl: 1997	*London's Early Disasters and Hard Times*, Historical Web Site by Ms. Smelser, webname "Chaos" http ://www.real.on.ca/~chaos/disaster.html	Lo
Lorimer, John G.: 1876	*History of the Islands and Islets in the Bay of Fundy*, Charlotte County, NB, St. Stephen, NB	Lor
-	*Globe and Mail*, disaster lists and clippings, various dates; including when this paper was called "The Globe" in the 1800s	M
*MacKenzie, M.: 1973-8	*It Happened Yesterday & Reflections of Yesteryear*, Robinson-Blackmore Printing & Publishing, Grand Falls, NF	Mc
*Mowat, Farley: 1958	*The Grey Seas Under*, Little, Brown, Boston, MA	Mo
-	*Ottawa Citizen*, disaster lists and clippings, various dates	Oc
*Pethick D.: 1978	*British Columbia Disasters*, Stagecoach Publishing, Langley, Canada	P
*Parsons, Robert C.: 1992-1998	*Lost at Sea*, Vols. 1 & 2; *Wake of the Schooners; Toll of the Sea and Survive the Savage Sea*, Creative Publishers, 1992; 1993; 1995; and 1998, St. John's, NF. Web Site: http://www.stemnet.nf.ca/Users/rparsons	Pa
Pritchard, Gregory: 1993	*Collision at Sea*, Lancelot Press, Hantsport, NS	Pr
*Raskey, F.: 1970	*Great Canadian Disasters*, Longmans, Don Mills, Canada.	R
-	Canadian Railway Telegraph History Newspaper Accounts; Web Site: http://web.idirect.com/~rburnet/art58.html	Ra
*Schmidt, R.: 1985	*Canadian Disasters*, Scholastic TAB Publications Ltd., Richmond Hill, Canada.	S
-	City of Saint John NB Web Site (History) http://www.city.saint-john.nb.ca/historye.htm	Sj
-	*Toronto Star*, disaster lists and clippings, various dates	St
-	*Ottawa Sun*, disaster lists and clippings, various dates	Su
Phillips, D.W.: 1985-1989	*The Canadian Weather Trivia Calendars*, Minister of Supply and Services, Ottawa, Canada. Includes David W. Phillips personal references.	T
Trace, Mary Kearns: 1998	*Traces from the Past - Canadian Immigration Finding Aids*; Web Site (web site now defunct; trying to find new one)	Tr
-	*History of the Settlement of Upper Canada*, Dudley & Burns Printers, Victoria Hall, 1869	U
Whiffen, Bruce: 1998	Column, "Weatherwise", St. John's Evening Telegraph	W

* Indicates whole Book References, most pages referenced.

A Multi-Scale Conceptual Model of Severe Thunderstorms

by G.S. Strong[1]

Résumé: Cet article décrit un modèle conceptuel à multi-échelle pour les orages qui se forment sous le vent le long des Rocheuses, depuis les Territoires du nord-ouest, en descendant vers le sud par l'ouest de l'Alberta, le Colorado, l'Oklahoma jusqu'à l'ouest du Texas. Ce modèle s'inspire abondemment des études publiées dans les années 1940-1970, et donne un scénario de la façon dont l'écoulement à grande échelle crée les pré-conditions pour un orage violent et déclenche ensuite un orage au moyen de courants ascendants à grande échelle et de refroidissement de la couronne supérieure. Dans un article à venir, nous testerons diverses parties de ce modèle conceptuel avec des données de l'Oklahoma et de l'Alberta.

1. Introduction

The conceptual model discussed here was initiated in a much earlier article (Strong, 1982), then extended in the author's Ph.D thesis (Strong, 1986). This work was also the subject of a series of field experiments carried out in the 1980s by the Alberta Hail project, collectively called the Limestone Mountain Experiment (Strong, 1989). The model borrows heavily from results of several studies of the 1940s to '80s period; in particular, Byers and Braham (1949), Beebe and Bates (1955), Lowe and McKay (1962), Longley and Thompson (1965), Chisholm and Renick (1972), Kung and Tsui (1975), Lemon and Doswell (1979), Maddox (1980), and Carlson et al. (1983). We begin by summarizing a few key studies on which the model is based, although not all of the above will be summarized here.

2. Early Conceptual Models of Convective Storms

Very little field research on thunderstorms was carried out until after World War II. In-flight encounters with such storms by allied pilots during the war, frequent severe tornadic storms over the American mid-west, the war-time development of radar, and the availability of such radar and numerous aircraft following the war, prompted a series of field experiments in the late 1940s called simply the Thunderstorm Project (Byers and Braham, 1949).

One of the results reported by Byers and Braham was the recognition of three distinct phases in the life-cycle of a thunderstorm:

1) the cumulus stage, characterized by updrafts throughout the cumulus cell, initially very weak, but which eventually attain speeds as high as 50 ft/sec (55 kph);

2) the mature stage, when updrafts can no longer maintain the increasing water and ice particles inside the cloud, so that this stage begins with the first occurrence of precipitation at the ground, accompanied by an associated downdraft within the storm. This is the most violent stage, when updrafts reach their maximum velocity, attaining speeds of 50 to in excess of 100 kph, while the downdraft often combines with large hail, heavy rain, strong surface winds, and sometimes the formation of tornadoes.

3) The dissipating stage essentially begins when rainfall at the surface becomes light or ends altogether, while updrafts within the cell decrease significantly and eventually all vertical motion is downward. This stage is also identified by the distinctive anvil top forming on the thunderstorm, when only small ice crystals remain at cloud top and are blown downwind. Each of these three stages persists for only 15-30 minutes.

Beebe and Bates (1955) tried to relate large-scale processes to thunderstorms through a kinematic model which described how synoptic scale ascent might change a previously stable sounding into the type observed in the vicinity of severe thunderstorms. This sounding signature, reproduced in Figure 1, has become known as the capping lid, and is characterized by a moisture-laden boundary layer of 500-2000 metres depth, capped by a strong inversion of temperature (the 'lid') and a dry, unstable atmosphere above this.

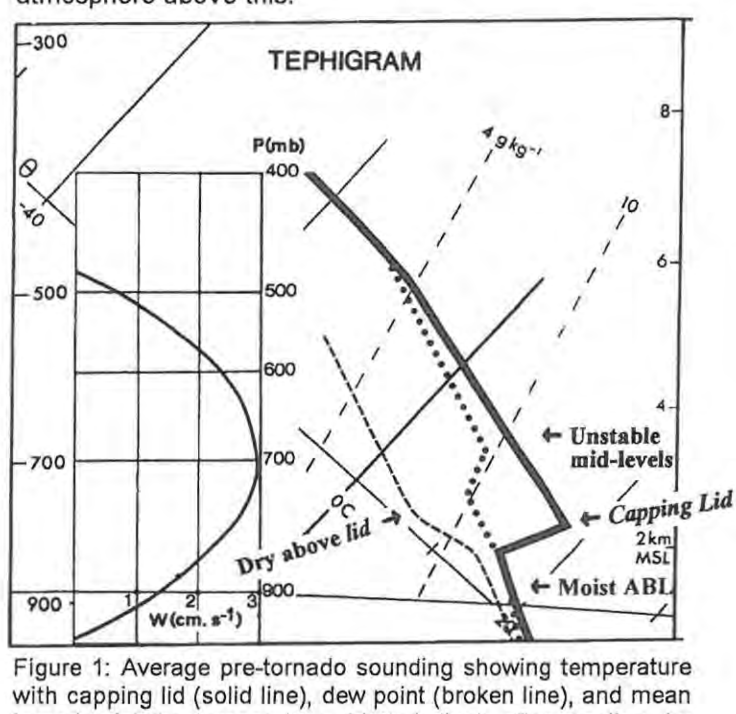

Figure 1: Average pre-tornado sounding showing temperature with capping lid (solid line), dew point (broken line), and mean tornado-vicinity temperature (dotted line) after cooling by synoptic scale ascent as shown on left. Typical upper/lower jet couplings for such cases are also indicated. (After Beebe and Bates, 1955.)

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They also described from known large-scale dynamics how ascent at low- to middle-levels is favoured beneath the left exit region of a cyclonically-curved jet stream (that is, where there is divergence aloft in advance of an upper trough) or in the right entrance region of an anti-cyclonically-curved jet. The ascent results in adiabatic cooling of the lid, allowing the sudden release of latent instability which we observe visually as a rapidly-developing thunderstorm.

This concept of a single storm cell, while still somewhat valid, is far too simplistic, and studies in the early-1970s showed how most storms involve many such cells in various stages of development, so that the collective thunderstorm can survive for many hours; e.g., see Marwitz (1972) or Chisholm and Renick (1972). The recognition of highly-organized multi-cellular storms, and the patterns of synoptic-scale dynamics and the more localized capping lid at the mesoscale are the common factors relating severe storms of west Texas to those of Alberta and elsewhere along the lee of the Rocky Mountains.

3. Pattern Recognition

A) Synoptic-Scale Patterns for Alberta Convective Storms

During the 1960s, a number of studies raised awareness of the preference for severe hailstorms and tornadoes to occur in the presence of particular synoptic weather patterns, and Canadians figured prominently in this evolution. Lowe and McKay (1962) related upper flow patterns with the occurrence of tornadoes over Saskatchewan and Manitoba, while Longley and Thompson (1965) related similar synoptic patterns to severe hailstorms over Alberta. Such climatological studies were helpful in identifying pattern recognition techniques for forecasters predicting convective storms. Thus, for no significant convection, one looks for an approaching upper ridge with anti-cyclonic flow at the surface, which translates to mid-level subsidence and low-level divergence, both negating factors for convective storm development. This pattern and resulting lack of convective weather is demonstrated for Alberta in Figure 2a, which shows similar patterns for specific non-convective days of 1981, 1982, and 1983 (from Strong, 1986). The reverse pattern, with an upper trough approaching and cyclogenesis occurring over southern Alberta, is a typical synoptic pattern for severe hailstorm development during summer, as it was in the three July cases for the same three years shown in Figure 2b, with larger than golfball-size hail reported in each incident. An interesting feature of these severe Alberta storm cases is that, above the boundary layer, dynamic features of the cold front have usually passed through the region before the storm forms over the foothills, although the shallow boundary layer and light surface winds often make this difficult to detect except in post-analysis. Closer analysis of Longley and Thompson's study reveals the same pattern; in other words, that severe Alberta storms tend to be post-cold-frontal, unlike those of Saskatchewan or Manitoba.

During the 1970s, meteorologists began to recognize a hierarchy of scales of motion in the atmosphere (e.g., see Orlanski, 1975), and studies dealing with dynamic relationships between weather systems at different scales was accelerated, especially that between thunderstorms and synoptic weather systems. Multi-scale energy budget studies involving convective storms were carried out (e.g., Kung and Tsui, 1975), as well as field studies on the structure of air flow in the immediate vicinity of and in the mesoscale region around thunderstorms (e.g., Lemon & Doswell, 1979). Conceptual models began to incorporate some of these extra-storm dynamics such as the model of flow around and through storms described by the latter, implying that the storm partially blocks the environmental flow. Later, Maddox (1980) identified mesoscale convective complexes (MCCs) on satellite imagery, involving large, highly organized regions of convection of several hundred kilometres across, and which can incorporate several families of thunderstorms. These are of meso-α scale in Orlanski's terminology (200-200 km wavelength). In Alberta and other parts of Canada, we are more familiar with a smaller (meso-β) scale convective complex (20-200 km), which are in essence the multi-cell and super-cell storms of Chisholm and Renick (1972). Still smaller (meso-γ) scale convection (2-20 km) includes individual cumulus clouds, the single cells of Byers and Braham (1949).

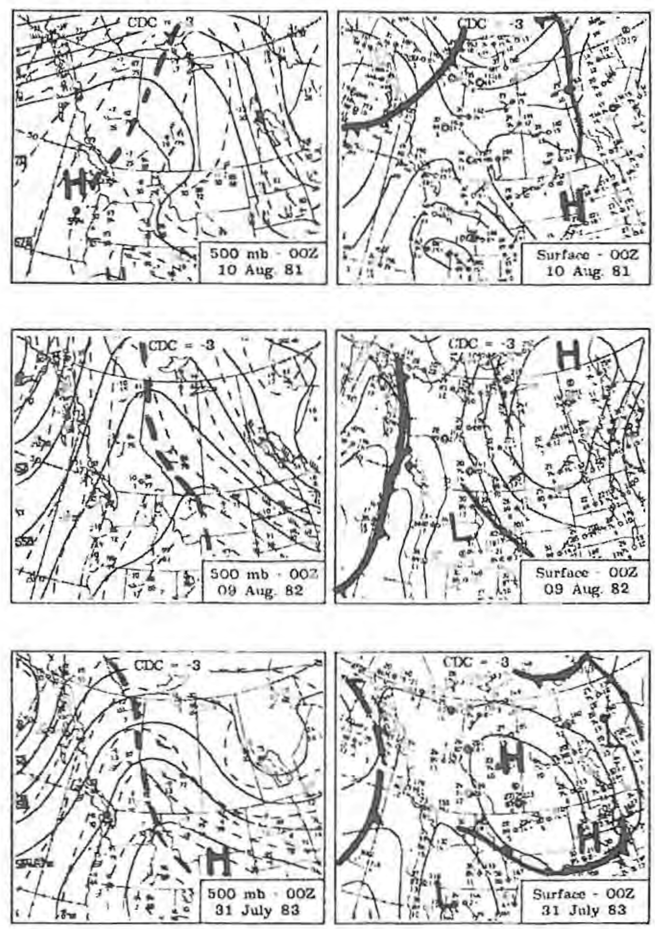


Figure 2a: 500 mb and surface isobaric patterns for non-convective summer days for 1981, 1982 and 1983.

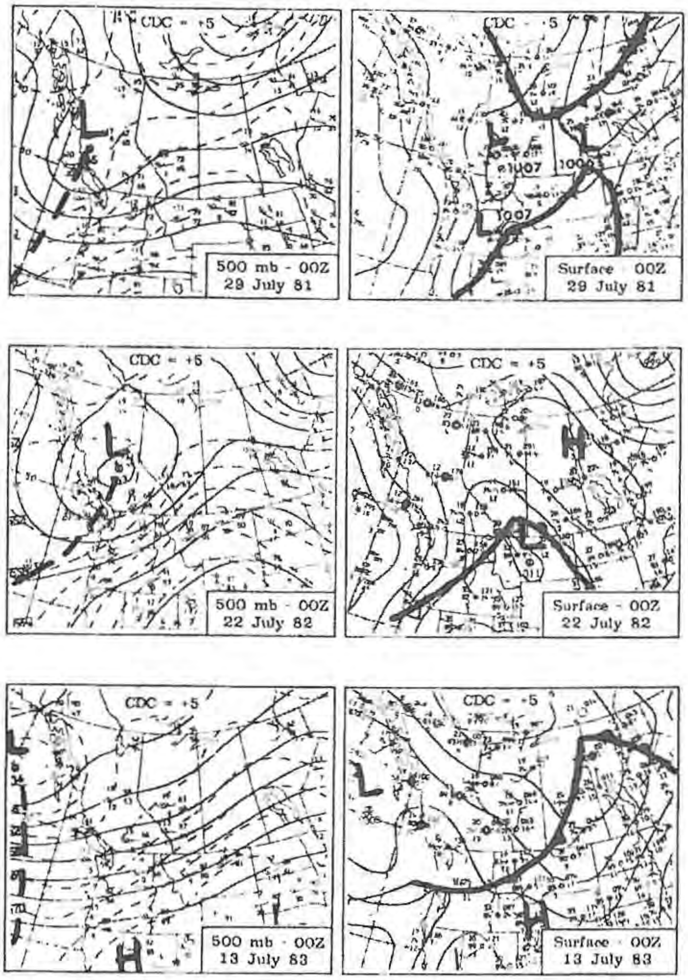


Figure 2b: 500 mb and surface isobaric patterns for most severe hailstorm days in central Alberta for 1981, 1982, and 1983.

B) Meso-γ (Cloud-) Scale Patterns for Convective Storms

It is worthwhile exploring some important and identifiable patterns at the meso-γ (cloud) scale which will signal either an impending thunderstorm development or no significant convection. These patterns, listed as either positive or negative factors, are not sufficient alone to predict a storm or no-storm, but can be used in conjunction with other factors; a few examples, not meant to be exhaustive, include the following:

Positive - Observations of alto-cumulus castellanus (ACC) clouds, especially towards the west or southwest. *Negative* - Observations of alto-cumulus lenticularis (ACSL) clouds, especially towards the west or southwest.

Positive - Evidence of an unstable air mass; this requires a graphical plot of temperature and humidity versus height or pressure (a tephigram), such as exhibited in Figure 1. A forecaster looks for a well-defined, moist atmospheric boundary layer (ABL) of 500-1000 m depth, capped by an inversion of temperature near 850-800 mb, the *capping lid*. The ABL becomes well-mixed with daytime heating, and often gains moisture through evapotranspiration and moisture convergence; i.e., develops a constant mixing ratio with height. Mid-levels above the *lid* will often show a distinctly drier but unstable lapse rate.

Positive - Wind directions veering from light easterly (or northeast) at the surface to southwesterly above the ABL, and increasing speed with height.

Positive - In Alberta, there is a strong tendency for storms to form over the foothills, and less frequently over the plains or over the higher mountains west of the foothills. During the Alberta Hail Project (AHP) cloud seeding operations of the 1970s and 80s, first radar echoes of the most severe storms were frequently recorded over the foothill peaks such as Limestone Mountain, approximately 110 km west-southwest from Red Deer Airport (Strong, 1986, 1989). This is demonstrated partly by hailswath maps produced by AHP, the last of which (for 1985) is reproduced in Figure 3. The arrows indicate the location and direction of hailswaths put down by the summer hailstorms, and one can assume that the storms involved initiate somewhat upstream from the hailswath start. The semi-circular area between Edmonton and Calgary is the old AHP operations area. The eastern edge of the foothills is approximately at the centre of the western half of this AHP area. Most of the hailswaths indicated originate over these foothills. This will be verified in the next section.

4. Multi-Scale Conceptual Model of Convective Storms

Based on the foregoing patterns and other material in severe storm literature, a conceptual model of thunderstorms incorporating all scales of atmospheric motion is now presented, with special emphasis on Alberta storms. This is presented as a sequence of events, using hypothetical diagrams of upper air and surface flow patterns (Fig. 4), and a schematic vertical cross-section of dynamic and thermodynamic features (Fig. 5).

1. The pre-conditions for a severe convective storm are usually prepared a day or two before the storm. An upper shortwave ridge (Fig. 4a - top) initiates the process at least one day prior to the storm, providing large-scale subsidence warming at middle levels of the atmosphere, while also maintaining anti-cyclonic conditions at the surface (Fig. 4a - bottom).

2. The subsidence warming at middle levels, combined with cool air in the boundary layer results in the beginning of the capping lid (Fig. 5 - top).

3. As the upper ridge moves over central Alberta overnight, mid-level winds back from northwest into southwest (Fig. 4b - top), enhancing the subsidence through orographic downslope flow in a relatively narrow band just east of the main mountain barrier, generally over the foothills.

4. Clear skies overnight allow for surface radiation cooling, strengthening the capping lid effect. When surface humidities are high, fog patches are

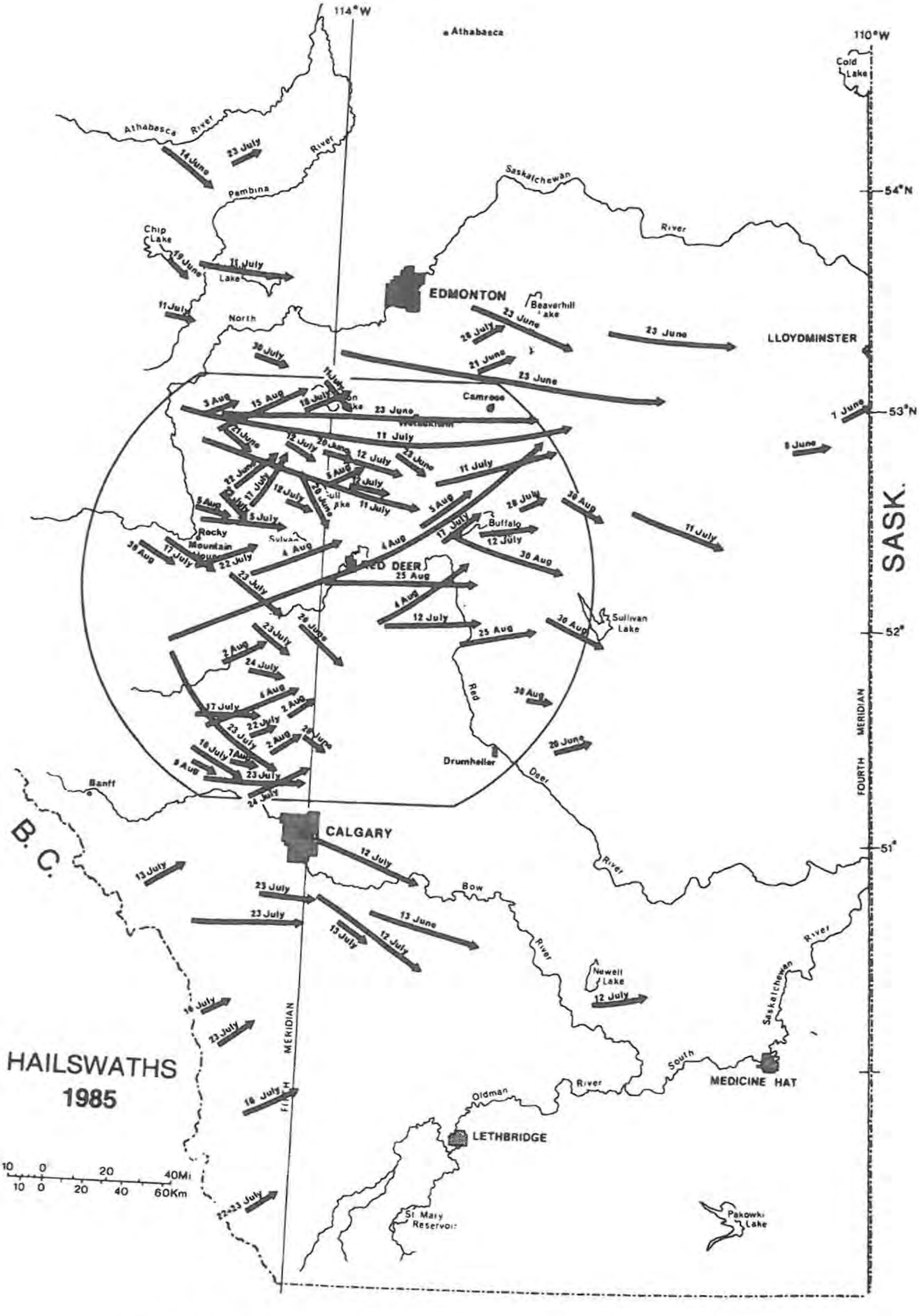
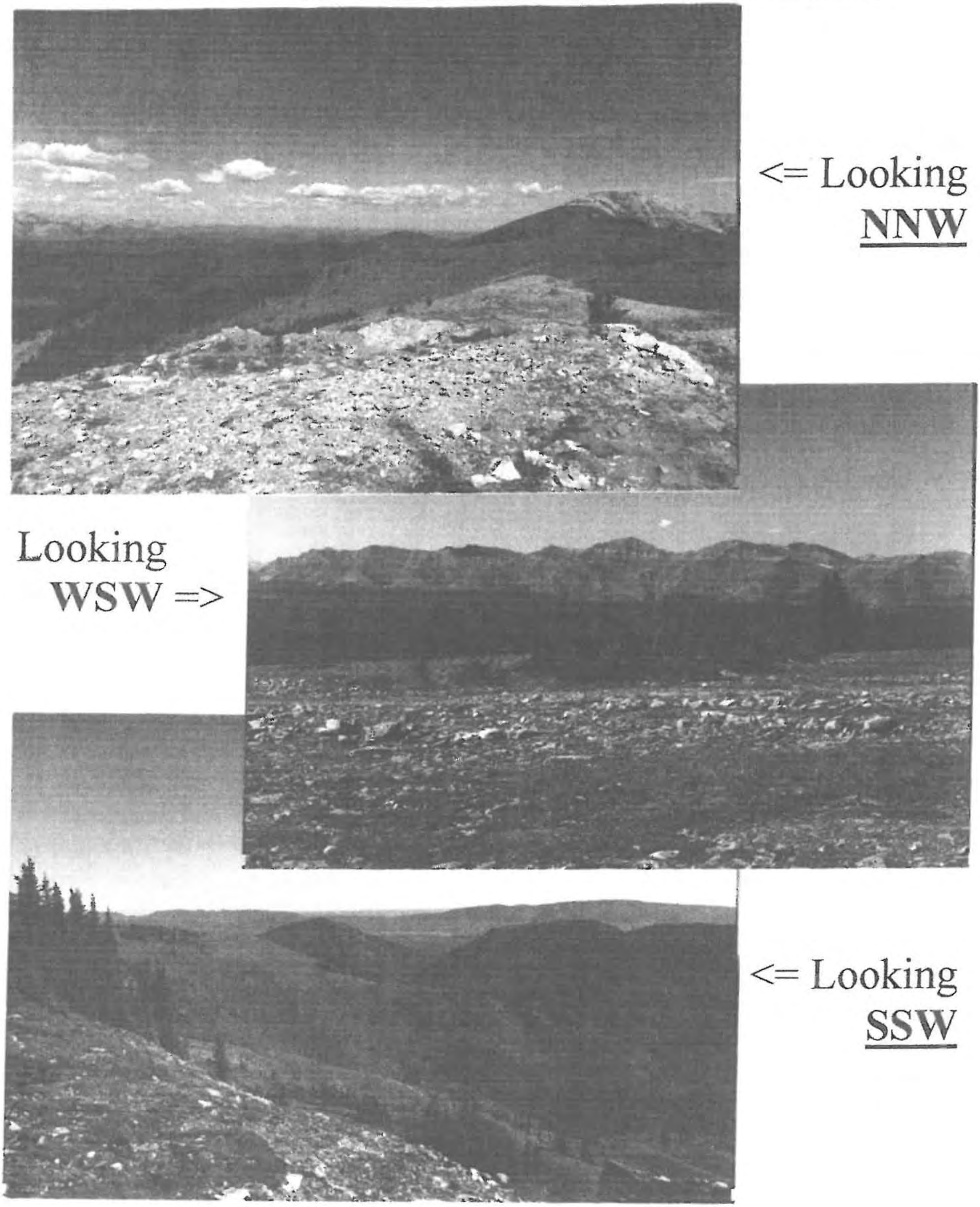


Figure 3: Alberta hailstorm tracks during 1985 (after Deibert, 1985).

Views from Limestone Mountain, July/85



<= Looking NNW

Looking WSW =>

<= Looking SSW

Figure 4:View of main Rocky Mountain barrier from the foothills, in this case, Limestone Mountain ridge looking north-northwest, west-southwest, and south-southwest.

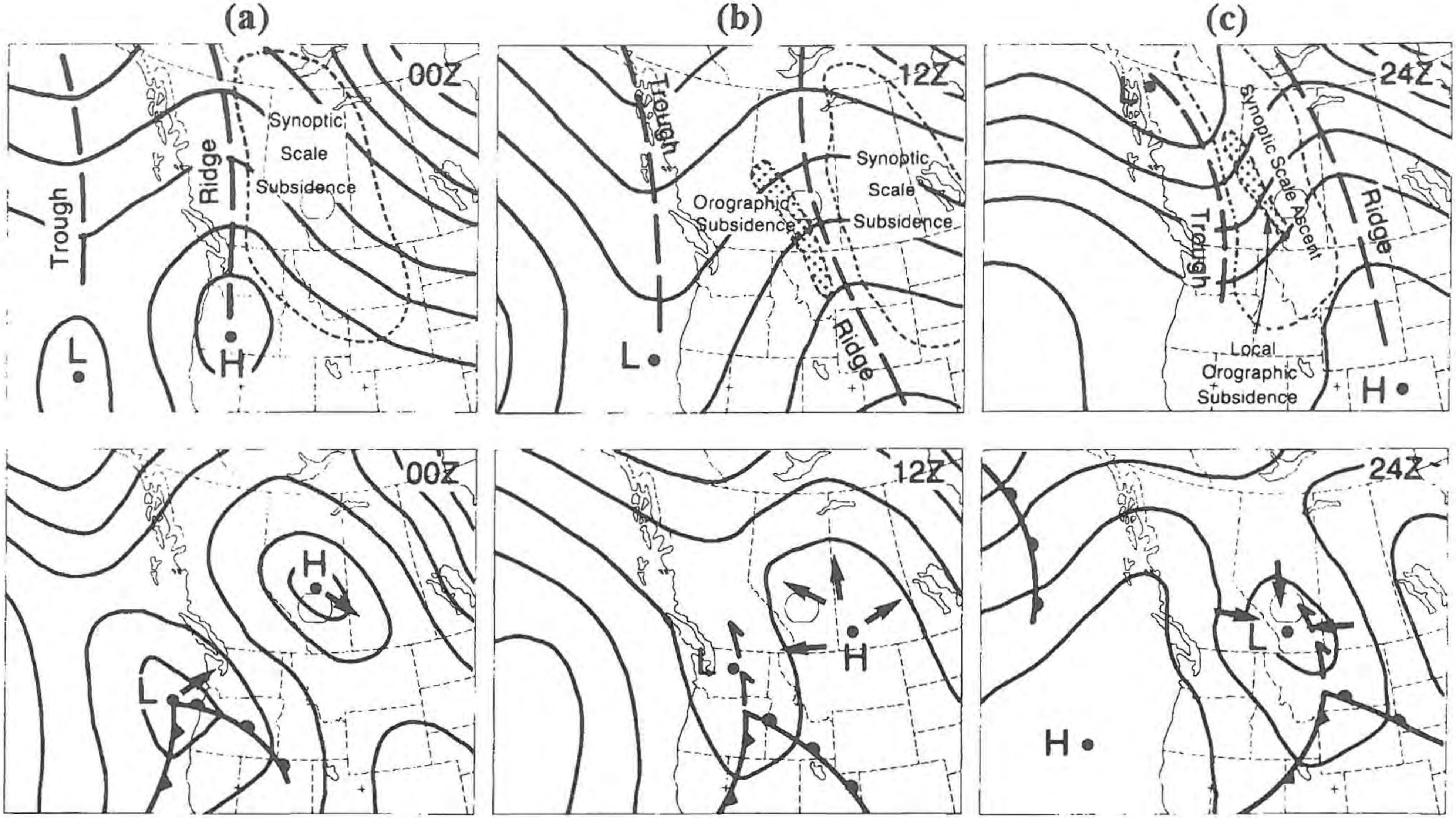


Figure 5: Hypothetical upper air and surface charts leading to the formation and subsequent breakdown of a capping lid over southwest Alberta due to synoptic scale and orographic dynamics, and subsequent severe thunderstorm.

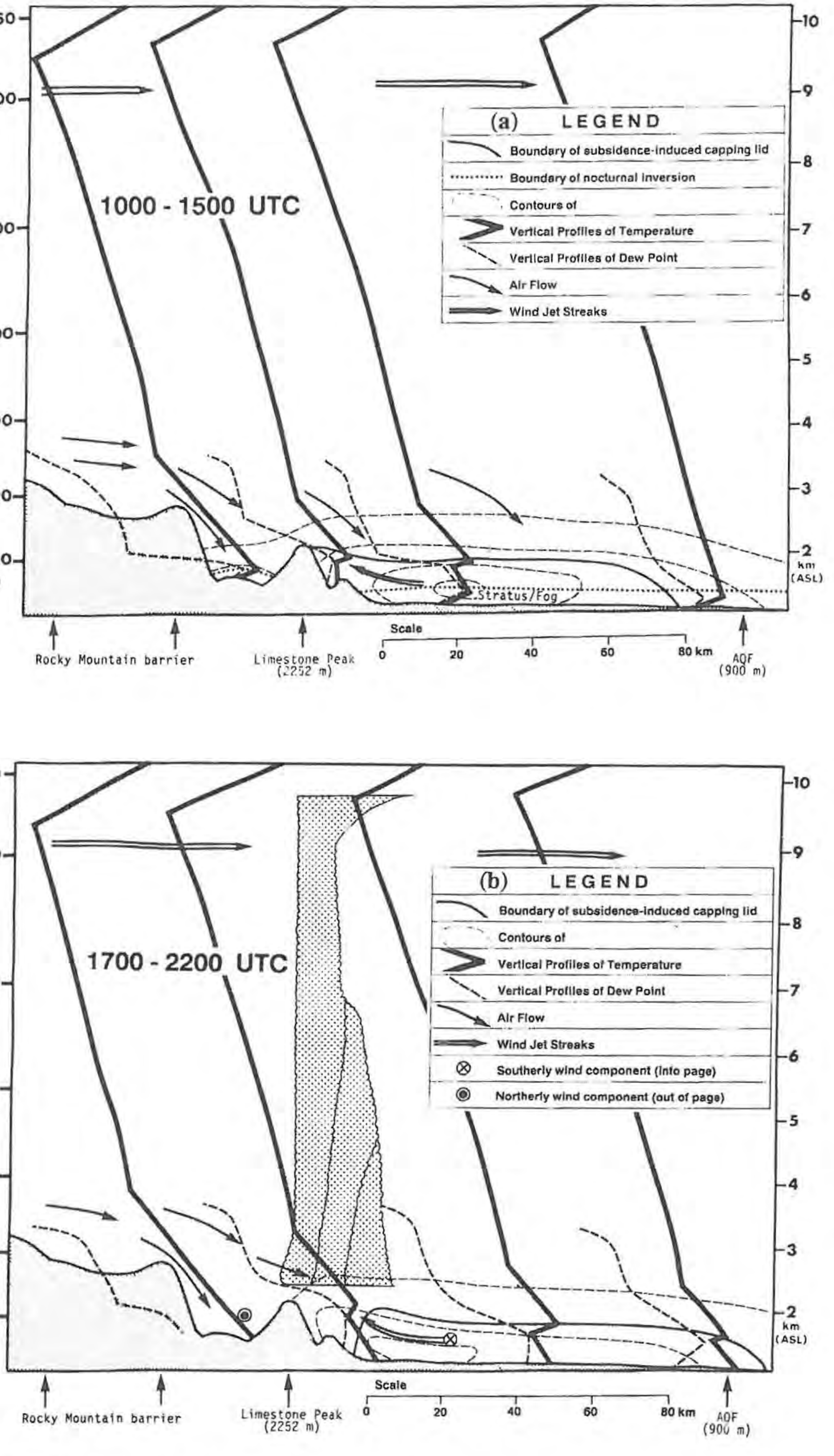


Figure 6: Schematic vertical cross-section illustrating the formation of the capping lid through synoptic scale and orographic subsidence, then breakdown of the lid through boundary layer ascent, followed by rapid development of a severe thunderstorm.

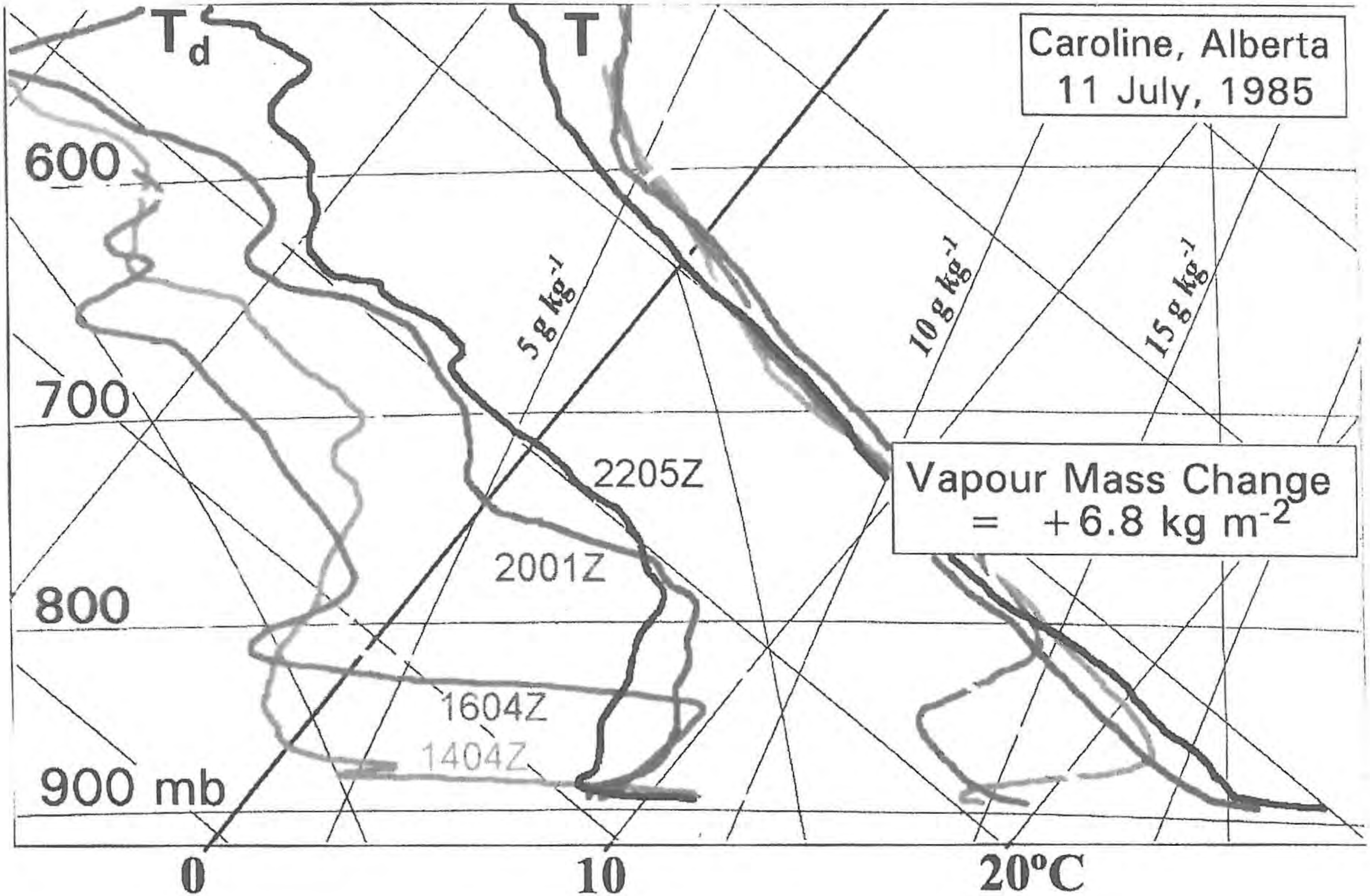


Figure 7: Daytime evolution and breakdown of the capping lid: example from LIMEX-85, 11 July, 1985.

a common occurrence near dawn in these instances (Fig. 5 - top). The fog becomes an additional source of moisture for the later storm.

5. Clear skies under the surface high later in the morning (Fig. 4b - bottom) allow surface heating to start warming the boundary layer (Fig. 5 - bottom). The foothills will tend to warm more rapidly through differential heating caused by the angle of sunshine onto the elevated slopes.

6. By mid-day, the next upper shortwave trough is approaching Alberta from the BC coast (Fig. 4c - top), and this initiates surface cyclogenesis (low pressure) over the southern Alberta plains region (Fig. 4c - bottom), with subsequent ascent in the boundary layer and an increasing easterly component of wind and moisture convergence over the foothills.

7. Meanwhile, orographic subsidence continues close to the main mountain barrier, with subsidence warming often extending down to near ground level close to the mountains (Fig. 5), while the capping lid can intensify over the foothills during this period due to the beginning of ascent and resulting cooling of the boundary layer.

8. Over the plains region, grain crops, with a shallow root zone (mostly in the upper 10 cm of soil), contribute significant amounts of moisture daily to the atmosphere through evapotranspiration, and this is often a contributing factor in moisture convergence over the foothills.

9. By early afternoon, this moisture convergence and easterly winds over the eastern slopes of the foothills results in upslope flow along a narrow band (Fig. 5). This enhanced ascent begins to work at breaking down the capping lid over the foothills by gradually cooling the top of the lid, creating 'preferred lid weaknesses' at select locations depending on the degree of ascent.

10. Below the lid, daytime heating has continued to warm up the boundary layer, and together with continued evapotranspiration and moisture convergence, these increases in sensible and latent heat continue to raise convective instability beneath the lid over the foothills.

An example of this is demonstrated in the actual temperature and dew point temperature profiles from LIMEX-85 (Limestone Mountain Experiment - see Strong, 1989) shown in Figure 6.

11. The final breakdown of the lid over the foothills occurs quite rapidly in the more severe convective cases. Storms form within minutes where previously there may have been almost clear skies. Because of the capping lid, convective potential is released suddenly and with great fury, rather than latent heat being dissipated slowly throughout the day.

12. Such thunderstorms, when all of these factors combine, tend to be quite severe with frequent lightning, heavy precipitation, large hail, and long hailswaths; tornadoes are not uncommon in these situations. The major Calgary hailstorm of 28 July, 1981 (at that time the most expensive natural disaster in Canadian history), and the Edmonton tornado of 28 July, 1987 (which exceeded it in damage) had virtually all of these factors in place.

13. The breakdown of the lid over a narrow band along the foothills effectively explains why Alberta storms tend to form there, and once formed, the propagation of the storm and its hailswath track becomes a vector result of the upper winds and boundary layer moisture convergence. The latter was so strong during the 1981 Calgary hailstorm, that the storm propagated about 90° to the right of the southwest upper winds right through Calgary.

14. The role of local evapotranspiration over the grain fields to the east of the foothills has not been fully quantified, but the effect is thought to be significant, and helps explain why Alberta hailstorms drop off rapidly in frequency and severity by mid-August, since grain crops have then 'headed out' and no longer draw much soil moisture.

15. Finally, following a major thunderstorm, ground moisture left from high precipitation rates often provides the seed for a second storm day in succession, if other environmental conditions are favourable.

5. Concluding Discussion

A multi-scale conceptual model of Alberta thunderstorms has been presented here, based on the author's Ph.D dissertation (Strong, 1986). This model is thought to be valid throughout the North American plains region near the Rocky Mountains, and undoubtedly in similar locations in the world in the lee of a significant mountain range. A future article will provide test analysis results of various aspects of this model using data from Alberta, Colorado, and Oklahoma.

6. Acknowledgement

This work is derived from the author's Ph.D thesis, completed in 1985 while a member of the Alberta Research Council Hail Project (AHP). Funding for this research, as well as the Limestone Mountain Experiments, was provided exclusively by AHP.

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Eddies in the Gulf of Alaska

by Bill Crawford and Frank Whitney[2]

It was in mid-September 1998 that we met over coffee to discuss Frank's Line-P cruise on the Coast Guard Vessel J.P. Tully. While senior scientist on board ship the previous three weeks, Frank had found a huge, warm, fresh water mass more than 200 km wide and 1000 m deep, partway along the Line-P oceanographic stations, about 600 km west of Vancouver Island. (See Figure 1 on cover page).

"Do you see this feature in the TOPEX data?" he asked. TOPEX, or more accurately TOPEX/Poseidon, is a satellite that measures sea surface height. Bill and colleague Josef Cherniawsky of IOS had been processing TOPEX data for several months to look for sea level rise in coastal waters, as part of the El Niño event the previous winter.

Josef Cherniawsky had found a new web site that posted near-real-time TOPEX images. Bill signed on and entered the latitude and longitude range of the Gulf of Alaska, and the cruise date, and there it was: a red bull's-eye of water whose core rose 30 cm above its surrounding ocean, at the same place and diameter as Frank's warm, fresh water mass. (See Figure 2 on back cover). He had just found a web site that posted, for free, the most up-to-date, accurate information on these eddies.

Bob Leben of the University of Colorado had posted this web site only three weeks before to enable the public to find their own eddies. He combined TOPEX altimetry data with similar observations by the ERS-2 satellite that had been launched and tracked by the European Space Agency. He then applied spatial filters to enhance the ocean eddies and suppress large-scale seasonal signals. He developed this tool for his own studies in the Gulf of Mexico, but by putting all the data on his web site, he provided digital eyes to the world.

Bill quickly used this web site to plot images of the eddy over the previous seven months, and continues to track this eddy in November 1999. The images showed the eddy to form in winter along the West Coast of the Queen Charlotte Islands. He labelled it Haida-1998, after the First Nations of the region and its year of formation.

The web site showed Haida-1998 to be one of an annual supply of eddies that transport fresh water and nutrients into mid-gulf from the Alaskan Panhandle and the Canadian West Coast. The unusually high elevation of the eddy core marks it as one of the largest eddies observed in this region. Haida eddies belong to a class of anti-cyclonic,

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[2] Fisheries and Oceans Canada, Institute of Ocean Sciences, Sidney, B.C.

coastal-generated eddies noticed by Tabata (1982) in water property data near Sitka, Alaska at 57° N. Our observations identify another preferred generation region between 51° N and 54° N, off the West Coast of the Queen Charlotte Islands. Over the years 1994 to 1999 he found that three to five large eddies formed along the Alaskan Panhandle and Canadian West Coast in any one winter.

Frank's salinity and temperature measurements in August 1998 showed it to be to be fresher and warmer than surrounding waters below 100-m depth (Figure 1). Above 100 m, both salinity and temperature were slightly lower. Our dynamic height calculations (0/1000dbar) reveal that sea surface in the core of this eddy was 30 cm higher than outside the eddy, matching the altimetry measurements. Nutrient levels in its thermocline were substantially higher than in surrounding waters. The ocean water type of this eddy matches that found near the Queen Charlotte Islands in winter (53° N 133° W).

In February and June 1999, Bill sent the web-generated images to Frank at sea on the J.P. Tully, to direct him to its location for sampling. These measurements in September 1998, February 1999 and June 1999 show the steady erosion of the nutrient excess in the eddy waters, and enhancement of phytoplankton in the September 1998 samples. The eddy provides nitrates to a nitrate-starved region of the Gulf of Alaska first described by Whitney, Wong, and Boyd (1998).

Melsom et al. (1999) find Sitka and Haida eddies to be frequently set up in their numerical simulations of wind-driven currents along this coast. They believe it is baroclinic instability of the coastal flow that triggers the set up of eddies. A competing mechanism at the southern tip of the Queen Charlotte Islands may be the formation of gyres in the outflow jets past Cape St. James.

Based on calculations of dynamic heights of the 100-m surface relative to the 1000-m surface, using archived water property data, two of the highest-elevation eddies were Haida-1998, and Haida-1983, both generated in severe El Niño winters. This finding supports the study by Melsom et al. (1999) that suggests these eddies are larger in El Niño winters when northward, along-shore currents are stronger.

Thomson and Gower (1998) noticed a line of these eddies in a series of infrared images of sea surface temperature taken by one of the NOAA satellites in March 1995. Five eddies spanned the continental margin between Cape St. James and the extreme northern arc of the gulf. Such images are rare due to the prevailing cloud cover in winter. The skies open a bit in summer, but the ocean surface waters heat nearly uniformly in spring and summer, hiding these eddies from infrared eyes.

Radar sensors on altimeter satellites easily penetrate clouds. Indeed Gower and Tabata (1993) observed several of these eddies in the Geosat altimeter record between 1986 and 1989, and picked out their main features: anti-cyclonic rotation, formation at the continental margin and westward drift. TOPEX/ERS imagery generally confirms this westward drift with a few notable exceptions. Sitka-1998 and Haida-1998 both drifted southwards between April and November 1998, then turned toward the southwest. Several eddies that formed at the most northern extent of the Gulf of Alaska drifted mainly southwards, and often stalled completely.

The web site performance degrades on continental shelves where tides are big. Tides of 8 to 14 metres range sweep through the eddy-spawning regions along the Canadian Northwest Coast and the Alaskan Panhandle These signals must be removed before the eddies can be resolved accurately. We rely on global tidal models to provide the local tidal features, but these models degrade on continental shelves, especially where tides exceed 5 metres. Josef Cherniawsky et al. (submitted) have analyzed the TOPEX/Poseidon data to calculate tidal constituents along the satellite tracks in the NE Pacific, and have reprocessed T/P data sent by Richard Ray and Brian Beckley of the Goddard Space Flight Centre with these constituents. The new analysis shows that the formation of Haida-1998 actually began in early January 1998, or even late 1997. Bill and Josef have turned their attention to the eddies that drift along the Alaskan Stream from the Kenai Peninsula to the Aleutian Islands and beyond. These eddies can reach 70 cm in height, and survive for three years or more (Crawford, Cherniawsky and Foreman, submitted.) The T/P record provides a good view of their entire life history.

Michael Foreman et al. (submitted) have developed a numerical model that simulates the tidal heights of the Gulf of Alaska. The model uses almost 100,000 triangular elements for the region, with smallest elements on the continental margin to resolve the rapidly changing tides in shallow waters. Once completed, the simulated tides will improve the accuracy of altimetry signals from the complete satellite set: Geosat, Geosat Follow-on, TOPEX/Poseidon, ERS-1 and ERS-2, and also the proposed series of Jason satellites that will carry on the observations by TOPEX/Poseidon.

We are presently using the same models to determine the average seasonal height of the sea surface along the Canadian margin of the gulf (Foreman et al, 1998). Once combined with all satellite altimetry data, we will be able to determine absolute sea surface heights, and use them to compute northward flow of surface currents along our coast.

To see for yourself, visit his site at:

http://www-ccar.colorado.edu/~realtime/global-real-time_ssh/

Appendix:

Altimeters on satellites

An American-French program launched TOPEX/Poseidon in 1992, and released the first data from it in October that year. It senses sea surface height along a 20-km-wide swath, on an orbital track that repeats about every ten days. Each ten-day sample is denoted a "cycle". "TOPEX" refers to the American dual-frequency radar sensor that is turned on for nine of ten cycles. "Poseidon" is the French radar unit that samples on the tenth cycle. Early studies showed the rms accuracy of TOPEX/Poseidon sea surface height measurements, after all corrections, to be about 5 to 7 cm.

Physical oceanographers usually want to know the sub-surface pressure gradient in the ocean rather than the sea surface height. This gradient is formed by the weight of sea water plus atmosphere above. Therefore, as part of the processing prior to release of data, the inverse barometer correction is applied using the best estimate of sea surface air pressure along the T/P track. Both the European and American global weather models provide air pressure records for this "correction". This calculation assumes the ocean responds to air pressure changes as a perfect inverse barometer. Uncertainties in the air pressure above the T/P tracks and in the oceanic response to changes in air pressure make up some of the larger errors in the T/P calculations of sea level. Obviously, any scientist comparing T/P measurements of sea level and float gauge measurements at shore should remember the former are "pressure compensated", whereas the latter are not.

Most studies of T/P and other satellite data look at anomalies from a long term record. The T/P record now exceeds seven years and embraces the 1997/98 El Niño, so this anomaly record is interesting by itself. To compute absolute sea surface height requires knowledge of the geoid, or of the ocean currents along the T/P tracks. In most regions the geoid is too poorly known to be of use. Several Canadian efforts, (Keith Thompson and Ross Hendry on the Atlantic coast, and Mike Foreman, Josef Cherniawsky and Bill Crawford on the west coast) are in progress to develop dynamical ocean models to compute seasonal sea surface elevations in Canadian waters of the Pacific and Atlantic. The combination of these models and T/P observations will produce a more accurate geoid over the ocean, and permit calculations of absolute currents in these regions from T/P data.

Acknowledgements

Marie Robert prepared Figure 1. Bill Crawford is employed by the Canadian Hydrographic Service, and this research is also funded by the Panel for Energy Research and Development, project 24110. Frank Whitney is funded by the Ocean Climate Program, Fisheries and Oceans Canada. He is a scientist in the Ocean Science and Productivity Division of DFO. TOPEX/Poseidon is entirely supported by federal agencies in the United States and France, who provide both raw and processed sea level data to scientists and public for free. Both American and French agencies support Jason-1, the successor to TOPEX/Poseidon, due to be launched in the fall of 2000.

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Fellow of AMS

Jim Bruce was elected a Fellow of the American Meteorological Society during the 80th Annual Meeting of the AMS held January 9 - 14 in Longbeach, California.

Dr. Rudolph A. Treidl

1923 - 2000

Dr. R.A. Treidl, known to his many friends and colleagues as Rudi, passed away on February 17th. He had suffered for many years from Alzheimer's Disease.

He graduated with a doctorate degree from the University of Vienna in 1951. He was married and emigrated to Canada the same year. He obtained an M.A. degree in Physics (Meteorology) from the University of Toronto in 1953.

He was elected member of the Royal Meteorological Society (Canadian Branch) in 1959 and continued as a member of the CMS and CMOS until 1999.

He served as a weather forecaster at Gander (1953-1956) and at Toronto (Malton, 1956-1959). In 1959 he won a position as an instructor in the Research and Training Branch at meteorological service headquarters. For many years he taught Dynamic Meteorology to post-graduate Meteorological Officer (M.O.) Courses and took part in teaching M.A.Lab Courses and Refresher Courses.

Dr.Treidl moved to the Climatology Branch in the late sixties and became head of the Agriculture and Forest Meteorology Section. He served as the AES representative on the Canadian Committee on Agrometeorology from 1974 to 1978. During the same period he headed the Canadian delegation to the fifth session of the WMO Commision for Agricultural Meteorology (CAgM V,1971) in Geneva and the sixth session (CAgM VI, 1974) in Washington. Subsequently he was one of 3 Rapporteurs appointed by CAgM-VIII.

Among several technical papers he authored or co-authored were the Handbook on Agricultural and Forest Meteorology (Fisheries and Environment Canada, 1978) and Climate Aspects of Forage Provisions and Animal Production (WMO, 1989). In his work as an agricultural meteorologist he established close working relationships with colleagues in the federal and provincial Departments of Agriculture and international agencies.

His hobbies included travel, model trains, gardening and classical music but his special interests were philosophy, languages and English literature. After his retirement from the AES in 1983 one of his projects was translating the works of Ovid from the original Latin into English.

He is survived by his wife Trudi, son Bernard and daughter Karen.

Lives Lived

Tragically short life of a brilliant scientist

Short essay written by Bob Jones[1]

Tertia Mary Clemency Hughes

Atmospheric and ocean scientist, extraordinary graduate student. Born in Ottawa July 24, 1967. Died in Woodstock, Ont. on November 23, 1998.

She was named Tertia because she was the third child in her family. At the age of six weeks, she moved to Quebec City where she spent her childhood and high school years. In November 1978, her younger brother, the only boy in her family, was killed by a motorist who disregarded the flashing lights on a school bus. This loss was a lasting sorrow for Tertia who discussed her brother's death with a friend the week before she herself died - last November - 20 years later!

As a child Tertia was an avid reader. She asked for Alice Through the Looking Glass for her fifth birthday because she enjoyed Alice in Wonderland and had read about the sequel at the back of the book. When she was seven, her parents overheard her giving her younger brother a clear explanation of the theory of evolution: "So you see, that's how we are related to mermaids".

In 1983, upon graduation from high school, she entered CEGEP Champlain Regional College in Ste-Foy, Québec. Clearly a gifted student, Tertia graduated at 17, the youngest in her class. She received her Diplôme d'Études collégiales along with a prestigious award for academic excellence, and a Université Laval entrance scholarship where she completed first year.

In 1986, Tertia returned to her birthplace and in 1989 was awarded an Honours BSc in Physics and Mathematics at the University of Ottawa, with great distinction. She also won the science faculty's silver medal for academic excellence, given to the student with the top marks in all areas of science. Her transcript shows why she received this: 28/28 first class marks, 22 of these being an A+.

In 1987 and 1988, she worked with Dr. Michel Leclerc at the Institut National de la Recherche Scientifique-Eau (INRS) of Université du Québec. Dr. Leclerc reminisced enthusiastically about Tertia's work, recalling her as a very special student: "the kind you try to attract to do graduate work". Dr. Leclerc was honoured by INRS for his pioneering work on the hydrodynamics of fish habitats in salmon rivers and, at a 1998 awards ceremony, he mentioned the

[1] Bob Jones is the webmaster for the Canadian Meteorological and Oceanographic Society.

support he had enjoyed from his students, including Tertia.

Tertia arrived at McGill University in 1989 holding an NSERC (Natural Sciences and Engineering Research Council) postgraduate fellowship, after refusing a McGill Women's Centennial Fellowship because she felt that gender discrimination should never be a factor in academic achievement. She studied numerical methods in atmospheric and oceanic sciences, and Prof. Lawrence Mysak, who taught her three graduate courses, said "she was a remarkably talented student, exceptionally bright, yet very modest".

Once her MSc course work was completed, Tertia undertook research on the temperature and salt circulation of the Indian Ocean, and completed her thesis in record time (about six months). The external examiner for her MSc thesis, Prof. Mike Foreman, found her research outstanding and nominated her for the Canadian Meteorological and Oceanographic Society's (CMOS) Graduate Student Prize, which she was awarded at the Society's 1991 annual congress.

She immediately started PhD research in the Department of Atmospheric and Oceanic Sciences of McGill, and began by writing a literature review on the role of the oceans in climate. Her instructor, Prof. Andrew Weaver, was so impressed by this review that he asked her to join him as a co-author for a follow-up paper, recalling she was more like a colleague than a student. At McGill, she received the top marks in every MSc and PhD class.

In 1992, Tertia moved to the University of Victoria's School of Earth and Ocean Sciences where Prof. Weaver had accepted a faculty position. With support from major national fellowships, Tertia examined ocean circulation and atmosphere-ocean interactions, completing her thesis in 1995. She became so respected that, even as a PhD student, she began to review manuscripts for scientific journals. She remained at UVic as a Research Associate for nine months, collaborating with many scientists in national institutes.

During her years at UVic, Tertia developed many close and lasting friends who enjoyed her warmth and kindness. She was an active organizer of social events such as going-away parties, baby showers and birthdays. Prof. Weaver says that Tertia was one of the most remarkable persons he has ever worked with. She was extraordinarily bright and energetic, easily accomplishing the work of several people. He and his colleagues who knew Tertia have seldom known anyone so cheerful and enthusiastic for the scientific problems under discussion. Her sense of humour was a real delight and her scientific contributions were truly outstanding.

In January 1996, Tertia moved to Princeton University to work with Prof. Jorge Sarmiento. She immersed herself in her new job with the same enthusiasm, energy and dedication that she had shown in her graduate and undergraduate days. She developed a deep understanding of the ocean carbon cycle and became the lead investigator in a project to study the effect of this cycle on climate warming. This included a major contribution towards the development of the next generation of computer models used to study ocean circulation, climate change and global warming.

When the Associate Dean of the Faculty read Prof. Sarmiento's last evaluation of her work, he wanted to raise her salary even more than the high level that had already been recommended. This was a rare event as the salary situation is normally the opposite: the supervisor wants to raise the salary, and the dean wants to lower it!

Upon hearing the news of Tertia's death last November, the response from scientists around the world was overwhelming. Because she died so young, her further successes were lost and will be missed by the world scientific community.

Tertia will be remembered by three initiatives launched by her friends and colleagues. The Department of Atmospheric and Oceanic Sciences and the Centre for Climate and Global Change Research at McGill University held a public symposium in her honour on November 23, 1999. The Canadian Meteorological and Oceanographic Society (CMOS) has named its Graduate Student Prize "The Tertia MC Hughes Memorial Graduate Student Prize" in her honour. The Prize will include a financial award from contributions received from friends and CMOS members. The first award will be made at the 2000 CMOS congress in Victoria. The University of Victoria has set up a memorial web site with the following address:

http://wikyonos.seos.uvic.ca/people/hughes/hughes.html

Charitable Functions of CMOS

CMOS now has five different and distinct charitable donation funds which are:

i) Student and Teacher Travel Bursaries
ii) Rube Hornstein Fund and the J.P. Tully Fund
iii) Tertia M.C. Hughes Memorial Scholarship
iv) The Development Fund
v) The CMOS - Weather Research House Scholarship Fund

that have been approved by Revenue Canada and qualify for tax deductible receipts. Over the years our charitable activities have expanded, but not everyone is aware of what we do with your money.

Student and Teacher Travel Bursaries

CMOS provides funding for student travel to Congresses through the Local Arrangements Committee (LAC) of each Congress. The contribution set by the Society is about $5000 in total and set up to cover the travel costs of approximately ten students who are judged to be presenting high quality papers at the Congress.

The teacher travel bursary is one-of-a-kind in that we share the award with the Canadian Council for Geographic Education (CCGE). CMOS and the CCGE share the responsibility of covering the travel costs of a selected High School Teacher to attend the AMS-NOAA "Project Atmosphere Workshop" in Kansas City, Missouri. It is a two-week workshop offered annually by AMS and NOAA without cost to the attendee except for travel costs. The course is designed in such way that teachers, on leaving, have the necessary training and teaching materials for course instruction in meteorology, weather and climate for students and fellow teachers. AMS offers a teacher slot to CMOS and we use the teacher network of the CCGE to reach high school teachers in Canada.

CMOS does not solicit donations for any of these bursaries but we do register our contributions to recipients as part of our annual Charitable Status report to Revenue Canada.

Funds for the Rube Hornstein Medal in Operational Meteorology and the J. P. Tully Medal in Oceanography

For many years CMOS has requested financial support from members to sustain the Rube Hornstein Prize and the J.P. Tully Medal. The older of these two awards is the Rube Hornstein Prize, and in 1998 it was decided to cast a medal to honour Rube in a more substantive way. The J.P. Tully medal was created in 1983 from funds donated by former colleagues and students of Dr. Tully and since then donations have sustained both awards to the point that by combining and balancing the two funds they can be invested and provide for medals in their honour in perpetuity. As a consequence, there is no further need to seek contributions from members for these two awards. When Mr. Hornstein was informed of this proposal, he asked that any surplus funds and all further contributions be put towards a CMOS scholarship.

The Tertia M.C. Hughes Graduate Student Memorial Prize

Just over a year ago Council agreed to rename one of the Graduate Student Prizes the "Tertia M.C. Hughes Memorial Prize", and in so doing, it allowed Andrew Weaver and others to solicit donations from friends of the late Tertia Hughes in support of creating an endowment fund in her name. The first award is expected to be made this year in Victoria, BC to a deserving graduate student in either atmospheric or ocean sciences.

To date, slightly over $10,000 has been raised, largely from contributions outside the membership of CMOS. It is intended to leave the fund open for additional donations, but after the Victoria Congress no further formal solicitation for this fund is anticipated. The intention of the Society is to bring this fund to a level where it can sustain a $500 annual graduate student scholarship in perpetuity.

The Development Fund

The CMOS Development Fund is of longstanding duration and has not been well-defined as to its purpose. It has been used in non-operational projects and more lately to fund our contribution to InterMET, Project Atmosphere and, most recently, for CMOS sponsorship of workshops, conferences and the like. Financial support for non-CMOS conferences is limited to $500 per event. The Development Fund has been well-supported by members despite the fact the funds are not earmarked for any particular CMOS program. The Development Fund stands at about $18,000. The only major draw on it was the funding of $10,000 for the InterMET project.

The CMOS Weather Research House-NSERC Supplement Scholarship

The CMOS Weather Research House-NSERC Supplement Scholarship is so named because half of the funding comes from a single company and is awarded by CMOS as a supplement to an NSERC postgraduate scholarship. Two awards are made annually, one for the second year of tenure and the other to a new applicant, for a total of $10,000. CMOS is fortunate to have two major sponsors of this award, namely Weather Research House and Seimac. Members are encouraged to support this Scholarship to ensure that the Society can sustain this investment in postgraduate students.

Members' Charitable Donations

An annual appeal for donations is made at membership renewal time by the President. The contributions raised vary substantially, some well below $5.00 and others over

$100. Tax deductible receipts have been issued to all donors no matter what amount has been contributed. This year a new business policy is coming into effect. Starting in June 2000 tax deductible receipts will not be issued for any contribution less than $5.00. Plans are also under way to augment the annual appeal by asking members to consider participating in a regular donation-giving program. CMOS is also planning to recognize major donors in a special honour roll.

Without the need to solicit further charitable donations for the Homstein, Tully and the Tertia M.C. Hughes Memorial Funds, there is an opportunity to consider establishing an undergraduate scholarship as described and proposed below by Dr. Peter Taylor, our incoming CMOS President for 2000/2001. Your support for this undertaking will be solicited at the Annual General Meeting, in Victoria on May 29, 2000.

Neil J. Campbell
Executive Director

CMOS Undergraduate Scholarship

Purpose

To encourage undergraduate students to select courses in meteorology and oceanography as the focus of their final undergraduate year's study.

Value

The value of the scholarship is targeted at $2000 as a contribution to University fees. The value of this scholarship will depend on the availability of funds and university fee structures.

Eligibility

Students who are completing their third year and have been accepted in their fourth and final year of an Undergraduate Honours or Major Degree Program at a Canadian university are eligible to apply. The proposed final year course selection must include at least 40% (two full courses of a five-course full load) of 3rd or 4th year level courses in atmospheric science, physical or chemical oceanography, limnology, climatology or hydrology.

Application

The application deadline is April 15 and must include a transcript of all university courses, including the third year, and letters of recommendation from two CMOS members. The applicant is required to provide a calendar copy or equivalent of the courses planned for the fourth year and a personal statement of career goals.

Selection

The award selection will be made by the CMOS University and Professional Education Committee, in consultation with the Prizes and Awards Committee. Announcement of the award winner will be made at the CMOS Congress Banquet or Awards Luncheon.

Peter Taylor
CMOS Vice-President

Fonctions de bienfaisance de la SCMO

La SCMO possède cinq fonds de dons de charité distincts et différents:

i) Bourses de voyage pour étudiants et enseignants
ii) Fonds Rube Hornstein et fonds J.P. Tully
iii) Bourse d'études commémorative Tertia M.C. Hughes
iv) Fonds de développement
v) Fonds de bourses d'études SCMO - Weather Research House

Ces fonds ont reçu l'approbation de Revenu Canada et sont admissibles à des reçus pour déduction aux fins d'impôt. Au cours des années, nos activités de bienfaisance ont pris de l'ampleur, mais bien des gens ne savent pas où va cet argent.

Bourses de voyage pour étudiants et enseignants

La SCMO subventionne des bourses de voyage pour les étudiants et les enseignants se rendant aux congrès, par l'entremise du comité local d'organisation de chaque congrès. La contribution établie par la Société est d'environ 5000 $ au total et couvre les coûts de déplacement d'approximativement dix étudiants dont les communications ont été évaluées d'assez grande qualité pour être présentées au congrès.

La bourse d'études pour enseignant est unique puisque qu'elle est remise conjointement avec le Conseil canadien de l'enseignement de la géographie (CCEG). La SCMO et le CCEG partagent la responsabilité de défrayer les coûts de voyage de l'enseignant au secondaire sélectionné qui assistera au "Project Atmosphere Workshop" de l'AMS-NOAA tenu à Kansas City, Missouri. Il s'agit d'un atelier annuel d'une durée de deux semaines offert par l'AMS et la NOAA sans coût au participant à part les coûts de déplacement. Le cours a été conçu de façon à ce que les enseignants repartent de l'atelier avec une formation suffisante et les outils pédagogiques en main pour pouvoir élaborer un programme d'enseignement sur la météorologie, le temps et le climat pour leurs étudiants et leurs collègues enseignants. L'AMS réserve une place d'inscription à la SCMO et la SCMO utilise le réseau d'enseignants du CCEG pour rejoindre les enseignants du secondaire au Canada.

La SCMO ne sollicite pas de dons pour ces deux bourses, mais elle inscrit les bourses remises aux récipiendaires dans son rapport annuel pour dons de bienfaisance de Revenu Canada.

Fonds pour le Prix de météorologie opérationnelle Rube Hornstein et la Médaille J.P. Tully en océanographie

Pendant de nombreuses années, la SCMO a demandé l'aide financière des membres pour assurer la subsistance du prix Rube Homstein et de la médaille J.P. Tully. Le prix Rube Hornstein est le plus ancien des deux et il a été décidé en 1998 qu'une médaille serait fabriquée afin d'honorer Rube plus concrètement. La médaille J.P. Tully a été créée en 1983 à partir des dons d'anciens collègues et étudiants du D^r^ Tully. Depuis, les dons ont permis d'assurer la survie des deux prix, à tel point qu'en les combinant et les équilibrant, le placement permettra d'offrir à perpétuité des médailles en leur honneur. Par conséquent, il n'est plus nécessaire de tenter d'obtenir des contributions des membres pour ces deux prix. Lorsque M. Horstein a été avisé de cette proposition, il a demandé que tous fonds excédentaires ou contributions supplémentaires soient alloués aux bourses d'études de la SCMO.

Le prix commémoratif pour étudiants diplômés Tertia M.C. Hughes

Il y a de cela un peu plus d'un an, le conseil a accepté de renommé un des prix pour étudiants diplômés le " prix commémoratif Tertia M.C. Hughes " et ainsi permettre à Andrew Weaver et aux autres de recueillir des dons des amis de la regrettée Tertia Hughes pour permettre la création d'un fonds de dotation en son nom. Le premier prix devrait être remis cette année à Victoria, C.-B., à un étudiant diplômé méritant, soit en sciences atmosphériques, soit en sciences océaniques.

Jusqu'à présent, un peu plus de 10 000 $ ont été amassés, pour la plupart de non-membres de la SCMO. Il a été prévu que le fonds demeurera ouvert pour des dons additionnels, mais qu'après le Congrès de Victoria, aucune sollicitation formelle pour ce fonds n'est prévue. La Société a l'intention d'amasser assez de fonds pour assurer, à perpétuité, une bourse annuelle pour étudiant diplômé de 500 $.

Le fonds de développement

Le fonds de développement de la SCMO date d'un bon nombre d'années et son objectif n'est pas très bien défini. Il a été utilisé lors de projets hors exploitation, et plus particulièrement pour financer InterMET, Project Atmosphere et, dernièrement, le parrainage par la SCMO d'ateliers, de conférences et d'activités semblables. L'appui financier pour les conférences autres que celles de la SCMO est limité à 500 $ par événement. Le fonds de développement a toujours reçu un bon appui des membres malgré le fait que l'argent ne soit pas destiné à un programme de la SCMO en particulier. Environ 18 000 $ se trouvent dans le fonds de développement. Le seul retrait d'importance de ce fonds a été pour le projet InterMET, où 10 000 $ ont été nécessaires.

Le supplément de bourse d'études SCMO Weather Research House-CRSNG

Le supplément de bourse d'études SCMO Weather Research House-CRSNG est nommé ainsi parce que la moitié des fonds proviennent d'une seule entreprise et que la SCMO en fait l'attribution comme supplément à la bourse d'études supérieures du CRSNG. Deux prix sont remis annuellement, un pour un étudiant de seconde année et l'autre pour un nouveau demandeur, pour un total de 10 000 $. La SCMO est privilégiée d'avoir deux commanditaires principaux, soit Weather Research House et Seimac. Nous encourageons les membres à appuyer cette bourse d'études afin que la Société puisse assurer cet investissement aux étudiants de deuxième et troisième cycles.

Dons de charité des membres

Un appel annuel aux dons est présenté par le président lors du renouvellement de l'adhésion. Les contributions amassées varient grandement, d'aussi peu que 5 $ à bien au-delà de 100 $. Des reçus pour fins d'impôts sont expédiés à tous les donateurs, quel que soit le montant contribué. Cette année, la Société instaure une nouvelle politique. À partir du mois de juin 2000, des reçus pour fins d'impôts ne seront pas envoyés pour des contributions de moins de 5 $. Il est aussi question de demander aux membres lors de l'appel annuel d'examiner la possibilité de participer au programme régulier de don. La SCMO projette également un tableau d'honneur spécial en reconnaissance des grands donateurs.

Maintenant que plus aucun don de charité ne sera sollicité pour les fonds Hornstein, Tully et commémoratif Tertia M.C. Hughes, il est question de mettre sur pied une bourse d'études pour étudiant de premier cycle, tel que proposée et décrite ci-dessous par le D^r^ Peter Taylor, notre président entrant de la SCMO pour 2000-2001. Votre appui à ce projet sera sollicité lors de l'assemblée générale annuelle le 29 mai 2000 à Victoria.

Neil J. Campbell,
Directeur exécutif

Bourse d'études SCMO pour étudiant de premier cycle

But

Encourager les étudiants de premier cycle à sélectionner plus particulièrement des cours en météorologie et en océanographie lors de leur dernière année d'études au premier cycle.

Valeur

La valeur ciblée de cette bourse d'études s'élève à 2 000 $ versée directement aux frais de scolarité. La valeur de cette bourse dépendra de la disponibilité des fonds et du barème des frais de scolarité.

Admissibilité

Sont admissibles à l'adhésion, les étudiants qui complètent leur troisième année et qui ont été acceptés à leur quatrième et dernière année du programme de diplôme de premier cycle avec spécialisation ou avec majeure d'une université canadienne. La sélection des cours proposée pour la dernière année doit comprendre au moins 40 % (deux cours complets d'une session de cinq cours) des cours de troisième ou quatrième année en science de l'atmosphère, en océanographie physique ou chimique, en limnologie, en climatologie ou en hydrologie.

Inscription

La date limite d'inscription est le 15 avril et cette dernière doit être accompagnée d'un relevé de notes de tous les cours universitaires, y compris ceux de la troisième année, et de lettres de recommandation de deux membres de la SCMO. Le requérant doit fournir une description des cours ou l'équivalent pour la quatrième année et un exposé personnel des ses objectifs de carrière.

Sélection

La sélection du récipiendaire se fera par le comité d'éducation professionnelle et universitaire de la SCMO, en collaboration avec le comité des prix et honneurs. Le nom du récipiendaire du prix sera annoncé au banquet de la SCMO ou au repas de remise des prix, lors du congrès.

Peter Taylor
Vice-président de la SCMO

Status of the Global Climate in 1999

WMO has just released its annual statement on the Status of the Global Climate in 1999. Globally, the 1990s were the warmest decade on record, and 1999 was the 5th warmest year in the period between 1860 and 1999 (+0.33°C with respect to the 1961-1990 normal). The warmest year on record was 1998 (+0.58°C). In the Northern Hemisphere (NH), 1999 was 5th warmest (+0.45°C) and in the Southern Hemisphere (SH), the 10th warmest (+0.20°C). While the 1999 globally averaged land-surface air and sea-temperature did not top that of 1998, 1999 temperatures in latitudes poleward from 30°N and 30°S were very similar to those of 1998. The 1999 combined land-ocean temperature for the tropics was cooler than that observed in 1998, due mainly to the effect of the La Niña episode, which persisted throughout the year.

Numerous devastating weather extremes occurred across the world in 1999. The year was marked by a particularly high number of floods, particularly in the latter half of the year. Millions of people were left without homes, food and drinking water, and many lost their livelihoods. According to reports from humanitarian relief agencies, the worst disasters in terms of lives lost were in Venezuela, India and Vietnam and other parts of Asia. Other significant events included intense tropical cyclones in Australia, the USA and Asia; heavy snow, avalanches and windstorms in Europe; and drought and tornadoes in the USA.

Dr. Vilho Vaisala Award

The "Professor Dr. Vilho Vaisala Award" was awarded on February 15, 2000 to three scientists including two Environment Canada researchers "for their important contribution to an international project of the World Meteorological Organization (WMO)". Canada played a lead role and these scientists have improved methods of measuring snow creating more accurate data for climate change and meteorological science. Professor Godwin Obasi, Secretary-General of the WMO, presented these awards to Dr. Barry Goodison and Mr. Paul Louie. Dr. Daqing Yang, currently at the University of Alaska, is the third recipient of this award.

Canada and Japan Join Forces in Climate Change and Oceans Research

Dr. John Davis, Assistant Deputy Minister of Science at Fisheries and Oceans Canada (DFO), and Mr. Masato Chijiya, Executive Director of the Japan Marine Science and Technology Center (JAMSTEC), recently signed a Memorandum of Understanding on climate change research cooperation. The partnership aims at developing joint projects in areas of shared interest, involving DFO institutes and JAMSTEC.

The collaborative activities will begin with:

- Observing and modeling ocean climate variability in the upper 200-300 m layer of the Arctic Ocean;
- Observing and modeling physical, chemical and biological processes of the shelf/basin interaction;
- Determining the freshwater and chemical budgets of the Bering, Chukchi and Beaufort Seas; and
- Monitoring and modeling the evolution of ice-thickness variability in both shelf and offshore domains.

To address these science issues, researchers will develop, test and apply new technologies (e.g. ice-drift buoys, sub-ice moorings, autonomous underwater vehicles) and share resources (e.g. Canadian ice-breakers, other ships, instrumentation, science personnel).

DFO climate science programs and their interaction with Japanese counterparts will include strong linkages with university partners to maximize research strength and return to all parties. Mutual access by both agencies to each other's research programs and infrastructures will be very beneficial to both countries.

The support of the Canadian Coast Guard icebreakers and the extensive ocean observation capabilities in the high latitude regions are some of the unique DFO contributions valued by JAMSTEC research teams. The Institute of Ocean Sciences in Sidney, B.C. and the Freshwater Institute in Winnipeg, the headquarters of DFO's Central and Arctic Region, will lead the Department's research efforts.

JAMSTEC is the key marine research agency in Japan responsible for advancing the understanding of global warming and climate change. The JAMSTEC FY2000/01 budget for their Frontier Observational Research System for Global Change (FORSGC) program is about C$30 million (60% increase from last year, while the overall budget for JAMSTEC only experienced 18% increase). The FORSGC program carries out observational activities to monitor variations of the global environment over large-scale temporal and spatial periods. A new research center, scheduled to open early next year, will be equipped with the "Earth Simulator" which is 1000 times faster than the supercomputer now located at JAMSTEC, and will be the most powerful system in the world. The estimated cost of the computer system alone is C$571 million. The Earth Simulator will be partly dedicated to atmospheric and oceanographic science. Furthermore, JAMSTEC plans to deploy 20 TRITON buoys, 18 in tropical regions and 2 in the mid-latitude regions of the North Pacific, as part of Japan's contribution to CLIVAR (Climate Variability and Predictability), a major component of the World Climate Research Programme. The TRITON buoy system will be coordinated with the ARGO Program. The Japanese budget for ARGO is about C$8.57 million for FY2000/01.

To mark the growing collaboration, JAMSTEC's largest research vessel, the Mirai and the Canadian Coast Guard vessel, John P. Tully, managed to work out their availability to rendezvous this August, at the Port of Victoria. An open house on board the ships is planned to communicate to the public the climate science research activities of this partnership. Scientists would also take the occasion to hold planning meetings on the implementation of joint projects.

Photo for the DFO-JAMSTEC MOU signing ceremony, from left to right: Keiji Osada (Assistant Manager/JAMSTEC), Masato Chijiya (Executive Director/JAMSTEC), Wayne Wouters (DM/DFO), John Davis (ADM/Science/DFO), Bill Doubleday (Special Advisor/DFO), Peggy Tsang (Senior Scientific Advisor/DFO)

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L'influence de l'océan Pacifique sur le climat et le temps

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CANADIAN METEOROLOGICAL AND OCEANOGRAPHIC SOCIETY

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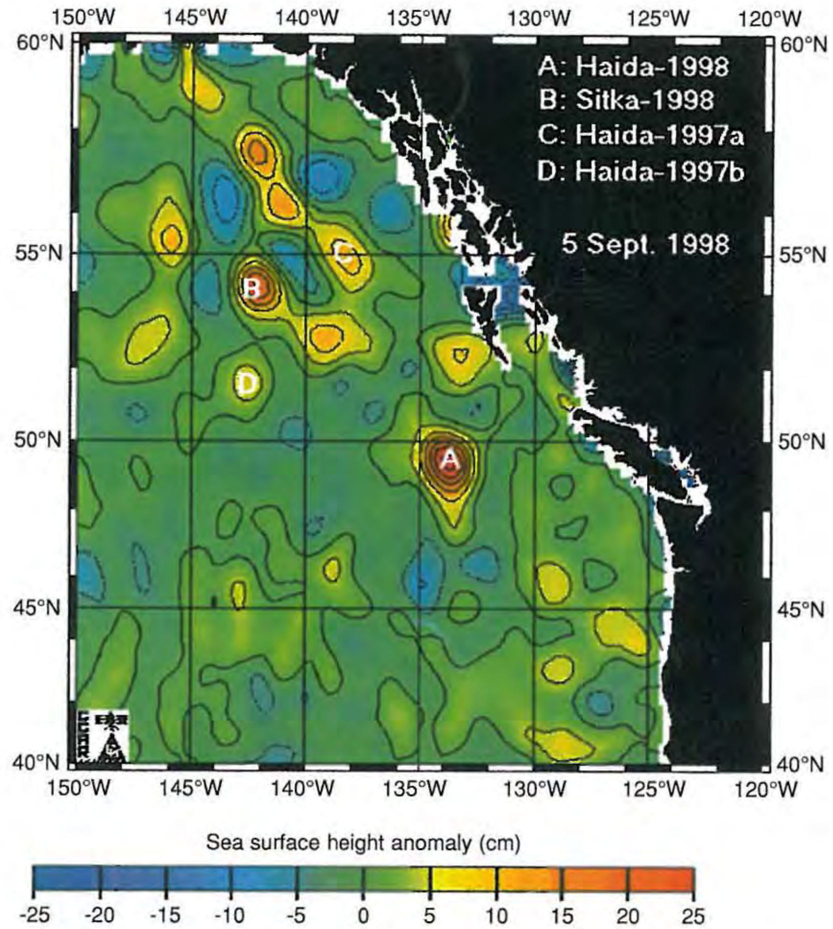

Figure 2. Contours of sea surface height from ERS-2 and TOPEX altimeters, as displayed on the web site www-ccar.colorado.edu/~realtime/global-real-time_ssh.