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MICROMETEOROLOGICAL STUDIES AT MT. KOBAN, B.C.

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METEOROLOGICAL SERVICE OF CANADA, TORONTO

INTRODUCTION

THE PROPOSED SITE FOR THE QUEEN ELIZABETH II TELESCOPE IS A 6200 FOOT RIDGE ON MT. KOBAN BETWEEN OSOYOOS AND OLIVER IN BRITISH COLUMBIA. MT. KOBAN IS SITUATED IN A SEMI-ARID REGION, EAST OF THE COASTAL RANGE BETWEEN THE OKANAGAN AND SIMILKAMEEN VALLEYS. SITE DEVELOPMENT IS UNDER THE DIRECTION OF THE DEPARTMENT OF ENERGY, MINES AND RESOURCES.

METEOROLOGY

A CLIMATOLOGICAL STATION WAS ESTABLISHED IN JUNE 1966 WITH THE ASSISTANCE OF THE DEPARTMENT OF TRANSPORT. THE STATION IS EQUIPPED TO RECORD PRECIPITATION, TEMPERATURE, WIND SPEED AND DIRECTION, PRESSURE, HUMIDITY, AND SNOW DEPTH. A KIPP PYRANOMETER MEASURING GLOBAL SOLAR RADIATION WAS ALSO INSTALLED AND WAS REPLACED BY AN EPPLEY PYRANOMETER IN NOVEMBER 1967. THE NATIONAL RESEARCH COUNCIL, OTTAWA, INSTALLED AN ALL-SKY CAMERA TO STUDY CLOUD COVER. A 200-FT TOWER SUITABLE FOR MEASURING TEMPERATURE AND WIND PROFILES WAS ERECTED ON THE MOUNTAIN, AS SHOWN IN FIGS. 1 AND 2. THE TOWER IS ALSO USED FOR THERMAL TURBULENCE MEASUREMENTS. THE BUILDING HOUSING A 16-INCH TEST TELESCOPE IS APPROXIMATELY 850 FEET SOUTH OF THE TOWER (FIG. 1). IN APRIL, 1967 A SERIES OF STEVENSON SCREENS WERE INSTALLED AT 1000 FOOT HEIGHT INTERVALS BEGINNING IN THE VALLEY AT OSOYOOS AND ENDING AT THE 200 FOOT TOWER ON MT. KOBAN. THE SCREEN'S MAXIMUM AND MINIMUM THERMOMETERS ARE READ DAILY, AND ARE YIELDING INTERESTING INFORMATION ON LOCAL TOPOCLIMATOLOGY.

AS THE RESOLUTION OF EARTH-BOUND OPTICAL TELESCOPE IS INFLUENCED STRONGLY BY PHYSICAL PROCESSES OCCURRING WITHIN THE ATMOSPHERE (TURNER 1968), THE MICROMETEOROLOGICAL UNIT OF THE RESEARCH AND TRAINING DIVISION, METEOROLOGICAL HEAD-QUARTERS, TORONTO, IS ASSISTING IN THE SITE-TESTING OPERATIONS. THERMAL TURBULENCE IN AN OPTICAL PATH PRODUCES RANDOM FLUCTUATIONS IN THE ANGLE-OF-ARRIVAL OF STAR LIGHT. THIS PHENOMENON IS TERMED "SEEING" AND IS OBSERVED AS A DEFOCUSING OF THE IMAGE OR MOTION OF THE IMAGE AS A WHOLE.

THE ORIGINAL 200 FEET TOWER HAVING A CROSS-SECTION OF 18 INCHES WAS INSTALLED EARLY IN THE SPRING OF 1967. DURING JANUARY 1968 RIME ICE BUILT UP ON THE SOUTHWEST EDGE OF THE TOWER TO A WIDTH OF 24 INCHES. THE TOP 130 FEET OF THE TOWER

THEN SNAPPED OFF DUE TO THE ICE LOADING. INSTANTLY THE BOTTOM 70 FEET OF THE TOWER SPRANG BACK TO A PERPENDICULAR POSITION, THE TOP 130 FEET DROPPING VERTICALLY BESIDE IT. THE PRESENT 200 FOOT TOWER WAS INSTALLED IN MARCH, 1968 AND HAS A CROSS-SECTION OF 54 INCHES.

SITE TESTING

THE TURBULENCE GROUP OF THE MICROMETEOROLOGICAL UNIT UNDERTOOK PRELIMINARY MEASUREMENTS OF OPTICAL SEEING AND THERMAL TURBULENCE AT MT. KOBAN IN OCTOBER, 1966. TURBULENT IRREGULARITIES WERE MONITORED BY MEASUREMENTS OF TEMPERATURE FLUCTUATIONS AT THE 50-FOOT AND 100-FOOT LEVELS OF THE TOWER. THE TEMPERATURE SENSORS WERE 0.125 MM COPPER CONSTANTAN THERMOCOUPLES (MC LERNON 1965) WITH TIME CONSTANTS OF 0.25 SECONDS. OPTICAL SEEING OBSERVATIONS WERE PROVIDED CONCURRENTLY BY DOMINION OBSERVATORY STAFF. AT THIS TIME POLARIS WAS MONITORED WITH A QUESTAR TELESCOPE. THE ASTRONOMERS OBTAINED A SEEING ESTIMATE THROUGH USE OF THE DANJON (1926) SCALE. THE TELESCOPE WAS MOUNTED SOLIDLY ON A CEMENT PIER 1.2 METERS ABOVE THE GROUND.

IN OCTOBER, 1967 SITE-TESTING BEGAN AGAIN WITH THE ADDITION OF A POLARIS IMAGE MONITOR INSTALLED BY THE OBSERVATORY STAFF. AS THE INTERESTING ASPECTS OF THERMAL TURBULENCE APPEARED TO OCCUR AT HIGHER FREQUENCIES THAN THAT PREVIOUSLY MEASURED, THE TURBULENCE GROUP CHOSE A MORE SOPHISTICATED SYSTEM FOR FURTHER STUDIES. DURING THE LATE WINTER OF 67-68, SEVERAL FAST RESPONSE (1 MILLISECOND) 1000 OHM PLATINUM RESISTANCE THERMOMETERS OF 2.5 MICRON WIRE WERE BUILT.

MAY, 1968 SAW THE RETURN OF THE TURBULENCE GROUP TO MT. KOBAN. THREE LEVELS OF TEMPERATURE SENSORS AND TWO LEVELS OF WIND SENSORS WERE MOUNTED ON THE 200 FT. TOWER (FIG. 2). THE 1000 OHM, FAST-RESPONSE RESISTANCE THERMOMETERS WERE MOUNTED AT 30, 70, 110, 150, AND 190 FT. OUTPUTS FROM THE THREE TEMPERATURE LEVELS AND TWO WIND LEVELS ARE RECORDED ON ANALOG STRIP CHART RECORDERS. THE FAST RESPONSE RESISTANCE THERMOMETERS ARE RECORDED ON FM MAGNETIC TAPE AND THESE DATA CORRELATED WITH THE DATA FROM THE POLARIS IMAGE MONITOR.

FURTHER STUDIES WILL BE CARRIED OUT DURING AUGUST AND OCTOBER, 1968.

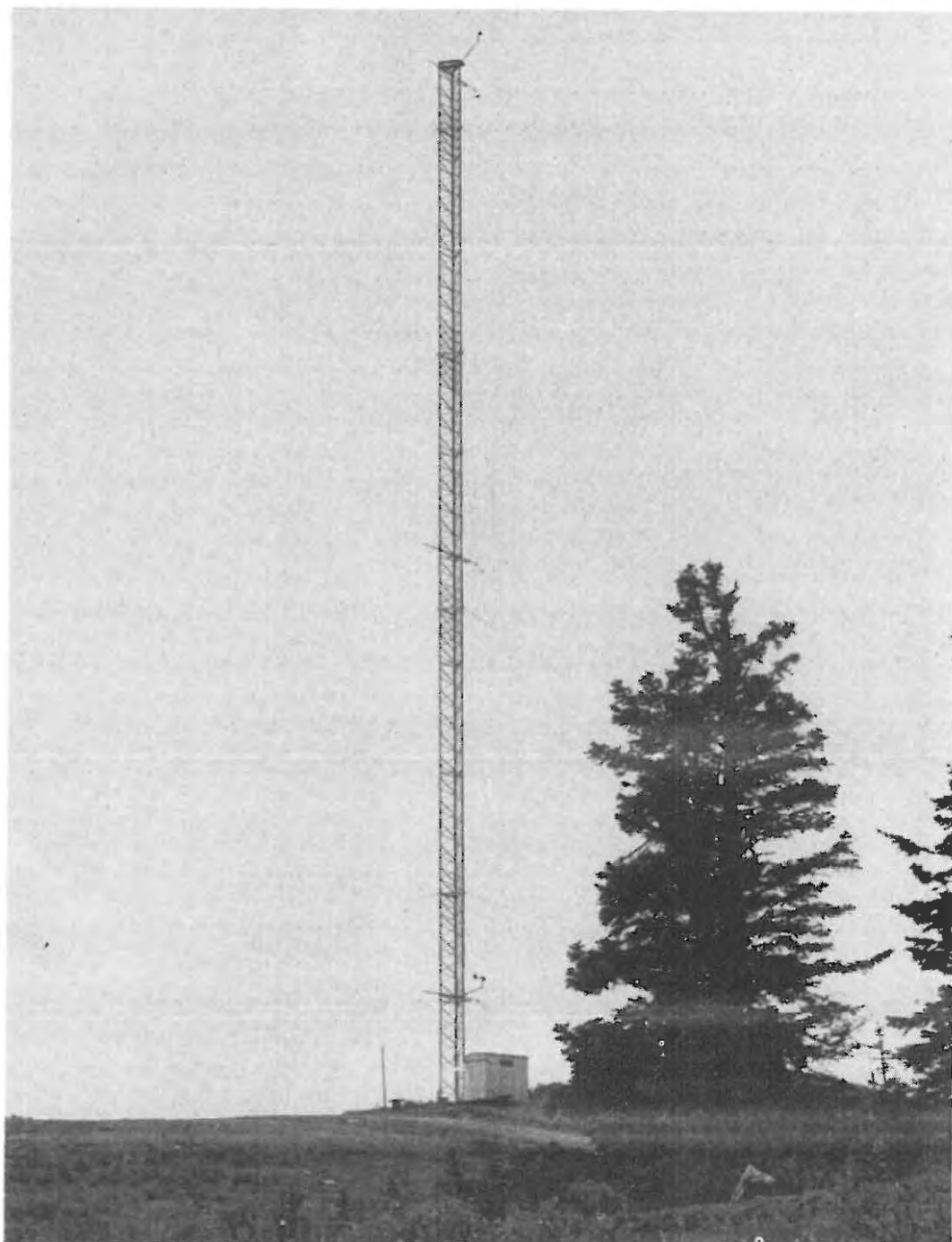
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FIGURE 1. VIEW SHOWING 200 FOOT TOWER, POLARIS IMAGE MONITOR BUILDING, AND 16" TELESCOPE DOME



FIGURE 2. VIEW SHOWING 200 FOOT TOWER, TEMPERATURE AND WIND
PROFILE EQUIPMENT



TWO WARM FRONTAL PASSAGES AT OTTAWA, CANADA

R.E. MUNN

METEOROLOGICAL SERVICE OF CANADA

INTRODUCTION

OBSERVATIONS FROM A 200-FT TOWER IN OTTAWA, CANADA, PROVIDE AN OPPORTUNITY TO EXAMINE THE FINE-SCALE STRUCTURE OF WARM FRONTAL PASSAGES. TWO RECENT CASES (NOVEMBER 12-13, 1964 AND DECEMBER 17, 1964) ARE TYPICAL AND WILL BE OF INTEREST TO THE SHORT-RANGE WEATHER FORECASTER. IN ADDITION, THE VECTOR VERTICAL WIND SHEAR THAT DEVELOPED BRIEFLY MAY BE OF IMPORTANCE TO THE AVIATION INDUSTRY.

SOURCES OF DATA

A 200-FT METEOROLOGICAL TOWER IS LOCATED AT THE CENTRAL EXPERIMENTAL FARM, OTTAWA (FIG. 1). THE SITE HAS A RELATIVELY OPEN LOCAL EXPOSURE, ALTHOUGH THE EXPERIMENTAL FARM ITSELF IS PARTIALLY SURROUNDED BY BUILT-UP RESIDENTIAL AREAS. WINOS ARE MEASURED AND RECORDED CONTINUOUSLY WITH BENDIX AEROVANES AT THE 20- AND 200-FT LEVELS. HONEYWELL MATCHED RESISTANCE BULBS HOUSED IN BECKMAN-WHITLEY VENTILATED RADIATION SHIELDS ARE POSITIONED AT THE 20- AND 196-FT LEVELS. THE RECORDER OUTPUT IS 20-FT TEMPERATURE (SCALED TO THE NEAREST WHOLE DEGREE F) AND TEMPERATURE DIFFERENCE BETWEEN 196 AND 20 FT (SCALED TO THE NEAREST TENTH OF A DEGREE). THE SYSTEM WAS PURCHASED AND IS OPERATED BY THE OCCUPATIONAL HEALTH DIVISION, DEPARTMENT OF NATIONAL HEALTH AND WELFARE, IN CONNECTION WITH ITS AIR POLLUTION RESEARCH PROGRAM.

REGULAR HOURLY SURFACE WEATHER OBSERVATIONS ARE MADE AT THE OTTAWA* UPLANDS AIRPORT, ABOUT FOUR AND ONE-HALF MILES TO THE SOUTH-SOUTHEAST OF THE TOWER (FIG. 1). THE RCAF ROCKCLIFFE AIR STATION NO LONGER RECORDED WEATHER CONDITIONS AT THE TIMES IN QUESTION. HOWEVER, MEASUREMENTS FROM THE NORTHEAST PART OF THE CITY WERE AVAILABLE FROM THE DIVISION OF BUILDING RESEARCH, NATIONAL RESEARCH COUNCIL (INDICATED BY NRC IN FIG. 1). THESE INCLUDED TEMPERATURE FROM A THERMOCOUPLE IN A STEVENSON SCREEN AND WIND FROM A STEP ANEMOGRAPH CONNECTED TO CUPS ON THE ROOF OF THE BUILDING RESEARCH CENTRE.

LOCAL TOPOGRAPHY

THE LAND SLOPES GENTLY DOWN TOWARDS THE OTTAWA RIVER. A FEW HEIGHT CONTOURS ABOVE MSL ARE INCLUDED IN FIG. 1, AND IT CAN BE SEEN THAT THERE IS A DROP OF ONLY ABOUT 200 FT BETWEEN UPLANDS AIRPORT AND THE RIVER. NEVERTHE-

*OTTAWA INTERNATIONAL AIRPORT

FIGURE 1. MAP OF OTTAWA AND VICINITY, INCLUDING A FEW CONTOURS OF HEIGHT ABOVE SEA-LEVEL.

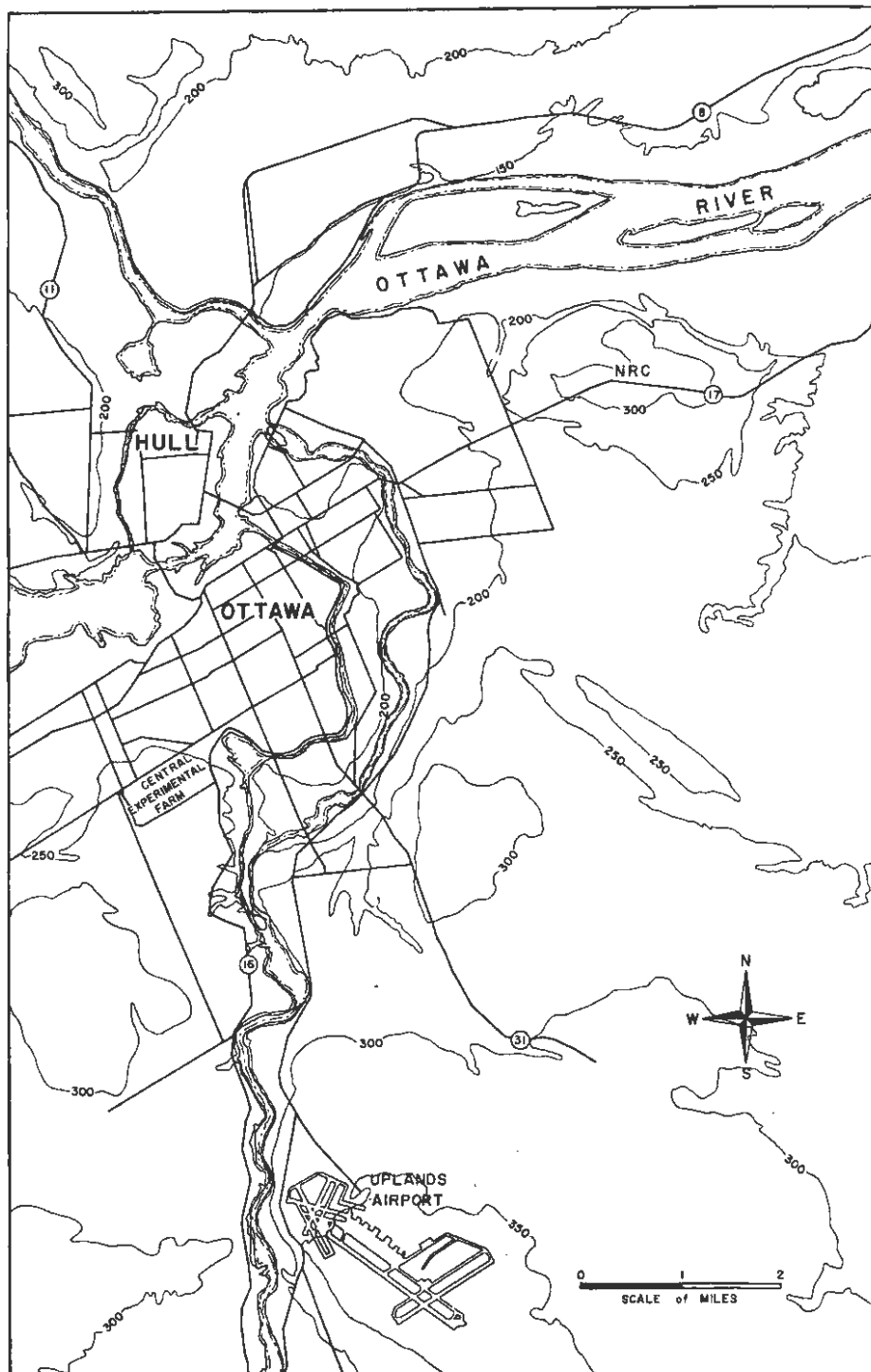
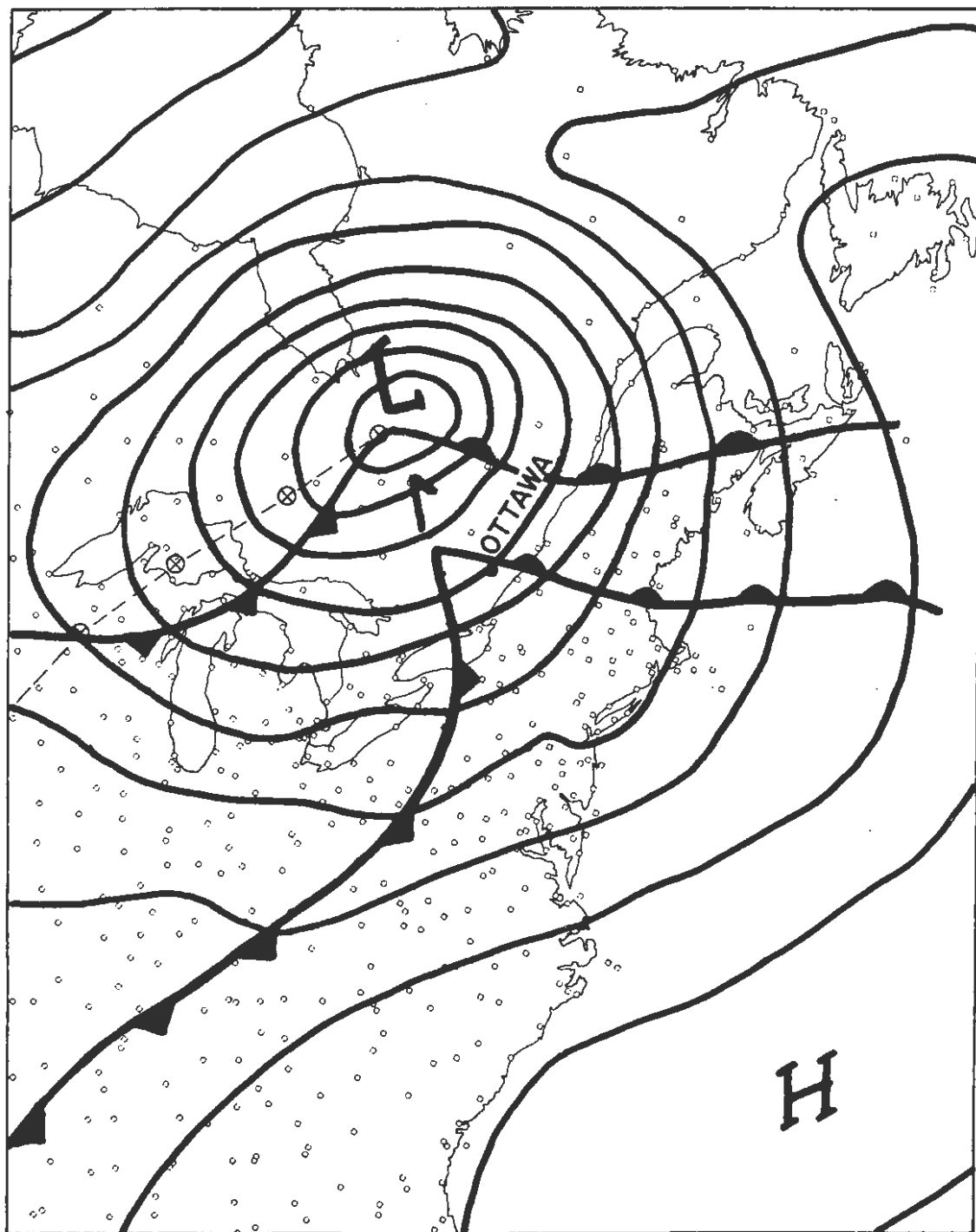


FIGURE 2. SURFACE SYNOPTIC WEATHER MAP, 0600 GMT, NOV. 13, 1964.



LESS, IT IS GENERALLY RECOGNIZED BY FORECASTERS THAT COLD AIR HAS A TENDENCY TO BE "TRAPPED" IN THE OTTAWA RIVER VALLEY.

RESULTS

SOME UPLANDS AIRPORT WEATHER OBSERVATIONS ARE GIVEN IN TABLE 1, WHILE THE RELEVANT SURFACE SYNOPTIC WEATHER MAPS ARE SHOWN IN FIGS. 2 AND 3. IN BOTH INSTANCES THE WARM FRONTAL PASSAGES WERE RELATIVELY SHARP, ALTHOUGH THERE WAS NOT MUCH PRECIPITATION. THERE WAS A 20-DEGREE RISE OF TEMPERATURE AT THE AIRPORT BETWEEN 2300 EST AND MIDNIGHT ON NOVEMBER 12 WITH A WINDSHIFT FROM EAST-SOUTHEAST TO SOUTHWEST. ON DECEMBER 17 THE TEMPERATURE RISE WAS NOT QUITE SO SPECTACULAR BUT NEVERTHELESS THERE WAS A 17-DEGREE INCREASE IN TWO HOURS. THERMOGRAPH AND WIND RECORDS WERE NOT AVAILABLE TO ESTABLISH THE PRECISE TIMES OF FRONTAL PASSAGE.

TABLE 1: HOURLY OBSERVATIONS FROM OTTAWA UPLANDS AIRPORT -- NOVEMBER 12-13, 1964 AND DECEMBER 17, 1964 NEAR TIMES OF WARM FRONTAL PASSAGES

NOVEMBER 12	2200 EST	--XM50 @ 2RW--F	43 41 / 09
	2300 EST	20 @ 50 @ 3F	41 40 -- \ 10
NOVEMBER 13	0001 EST	50 @ 5H	61 49 / 18
	0100 EST	O 8	59 49 / 18
	0200 EST	O 10	58 47 / 17
DECEMBER 17	0700 EST	M38 @ 10	20 15 \ 08
	0800 EST	M26 @ 100 @ 5S--H	28 22 ↑ 10
	0900 EST	M26 @ 100 @ 10SP--	37 26 ↑ / 18
	1000 EST	M22 @ 140 @ 10	38 27 / 18
	1100 EST	16 @ M20 @ 7R--	38 32 / 18

THE METEOROLOGICAL TOWER DATA HAVE BEEN AVERAGED OVER SUCCESSIVE NON-OVERLAPPING 5-MIN. INTERVALS AND ARE PLOTTED IN FIGS. 4 AND 5. WIND DIRECTIONS FOR ONLY EVERY OTHER DATA INTERVAL ARE INCLUDED.

IN THE NOVEMBER 12 CASE, THE WIND SHIFT AT THE 200-FT LEVEL OCCURRED AT 2330 EST. HOWEVER, THE FULL TEMPERATURE RISE INTO THE LOWER SIXTIES DID NOT COME UNTIL 0100 EST WHEN THERE WAS A SUBSTANTIAL INCREASE IN WIND SPEED. AT THE 20-FT LEVEL, THE WIND SHIFT AND TEMPERATURE RISE OCCURRED ABOUT 0100 EST. A TEMPERATURE INVERSION OF MORE THAN 10F DEGREE EXISTED BETWEEN 0050 AND 0105 EST.

A STRONG VERTICAL VECTOR WIND SHEAR WAS OBSERVED BETWEEN 2325 AND 0100 EST. THE EXTREME VALUE OCCURRED AT 2335 EST WHEN THE WINDS AT 20 AND 200 FT WERE NORTH 6 AND SOUTH-SOUTHWEST 14 MPH, RESPECTIVELY.

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WATER BALANCE OF EXTRATROPICAL CYCLONES

REVIEW PAPER PRESENTED OCTOBER 5, 1967

AT THE XIVTH IUGG GENERAL ASSEMBLY
LUCERNE, SWITZERLAND

MAURICE B. DANARD*

THE WATER BUDGET EQUATION FOR A VOLUME ENCLOSING AN AREA OF PRECIPITATION MAY BE WRITTEN

$$-\frac{\partial}{\partial \tau}(W + L) + R = F_W + F_L + F_P + E \quad (1)$$

WHERE W AND L REFER TO THE WATER VAPOR AND LIQUID WATER CONTENTS, R AND E ARE THE RATES OF PRECIPITATION AND EVAPORATION FROM THE UNDERLYING SURFACE, F_W AND F_L ARE THE NET HORIZONTAL INFLUXES OF WATER VAPOR AND LIQUID WATER, AND F_P IS THE NET INFLUX OF WATER SUBSTANCE THROUGH THE TOP.

NOW IF (1) IS AVERAGED OVER THE ENTIRE ATMOSPHERE AND OVER A LONG PERIOD OF TIME, WE HAVE APPROXIMATELY

$$\bar{R} = \bar{E} \quad (2)$$

WHERE THE BAR DENOTES MEAN CONDITIONS. THAT IS, ON THE AVERAGE, PRECIPITATION AND EVAPORATION ARE EQUAL (I.E., NO NET TRANSPORT AT THE EARTH'S SURFACE). HOWEVER, EVAPORATION IS OCCURRING MORE OR LESS CONTINUOUSLY OVER A LARGE PORTION OF THE EARTH'S SURFACE WHEREAS PRECIPITATION IS FALLING ON ONLY A SMALL FRACTION (PERHAPS TWO PER CENT) OF THE TOTAL AREA AT A GIVEN TIME. IF ATTENTION IS RESTRICTED ONLY TO SHORT TIME PERIODS IN AREAS OF PRECIPITATION, E SHOULD BE A SMALL TERM COMPARED TO R . THIS IS SUPPORTED BY CALCULATIONS OF E BY PETTERSSSEN ET AL (1962) OVER THE NORTH ATLANTIC IN DEVELOPING CYCLONES. MAXIMUM VALUES OF E WERE ONLY ABOUT 0.75 MM HR^{-1} WHICH IS SMALLER THAN TYPICAL VALUES OF R . OVER LAND, EVAPORATION RATES WOULD, OF COURSE, BE EVEN LESS THAN OVER THE SEA.

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FURTHERMORE, THE LIQUID WATER CONTENT OF LAYER CLOUDS IS OF THE ORDER OF 0.5 GM M^{-3} (SEE, E. G., MASON, 1962, PP. 36 AND 39). BY COMPARISON, THE DENSITY OF WATER VAPOR IN SATURATED AIR AT 700 MB AND 0°C IS ABOUT 5 GM M^{-3} . THUS, IN LAYER CLOUDS, L IS AN ORDER OF MAGNITUDE SMALLER THAN W AS IS THE TERM F_L COMPARED TO F_W . IN ADDITION, F_p MAY BE OMITTED PROVIDED THE TOP OF THE VOLUME CONSIDERED IS SUFFICIENTLY HIGH (FREQUENTLY TAKEN AS 400 MB).

THUS, (1) MAY BE APPROXIMATED AS

$$R = F_W - \frac{\partial W}{\partial T} \quad (3)$$

SPAR (1953) SUGGESTED USING (3) IN QUANTITATIVE PRECIPITATION FORECASTING. HOWEVER, IF THE CALCULATIONS ARE PERFORMED MANUALLY, THE PROCEDURE IS TOO TIME-CONSUMING FOR OPERATIONAL USE. NEVERTHELESS, IT IS OF VALUE IN RESEARCH. EQUATION (3) HAS BEEN VERIFIED DIRECTLY BY BRADBURY (1957) FOR THREE STORMS (TABLE 1). THE VALUES ARE AREA AVERAGES. SINCE THE AREAS UNDER CONSIDERATION EXTENDED BEYOND THE REGIONS OF PRECIPITATION, THE LOCAL RAINFALL RATES WERE THEREFORE LARGER THAN THE VALUES GIVEN IN THE LAST COLUMN. THE DISPARITY BETWEEN R AND THE OBSERVED PRECIPITATION IS AN INDICATION OF THE ERROR IN (3). FROM TABLE 1 IT IS SEEN THAT $\partial W / \partial T$ IS SMALLER THAN EITHER F_W OR R . THUS, A FURTHER APPROXIMATION IS

$$R = F_W \quad (4)$$

THE NET HORIZONTAL INFLUX OF WATER VAPOR MAY BE EXPRESSED AS

$$F_W = - \frac{1}{G} \int_0^{P_0} \oint q V_N dS dp \quad (5)$$

WHERE G IS THE SPECIFIC HUMIDITY, V_N IS THE OUTWARD COMPONENT OF VELOCITY AT THE PERIMETER S AND P_0 IS THE SURFACE PRESSURE. FIGURE 1 SHOWS THE VERTICAL VARIATION OF $-\oint q V_N dS$ COMPUTED BY PALMEN AND HOLOPAINEN (1962) FOR A CYCLONE OVER THE UNITED STATES. THE IMPORTANCE OF THE CONTRIBUTION FROM THE LOWEST LAYERS IS EVIDENT. FURTHERMORE, IT IS ESSENTIAL TO USE THE ACTUAL RATHER THAN THE GEOSTROPHIC WIND IN THESE LAYERS.

THE ABOVE EQUATIONS HAVE ALSO BEEN USED IN STUDIES OF INDIVIDUAL EXTRA-TROPICAL CYCLONES BY BRADBURY (1958), PALMEN (1958), AND RIEHL AND GRAY (1962).

IT MAY BE SHOWN THAT THE FOLLOWING EQUATION IS EQUIVALENT TO (1) WITH L , F_L AND E OMITTED.

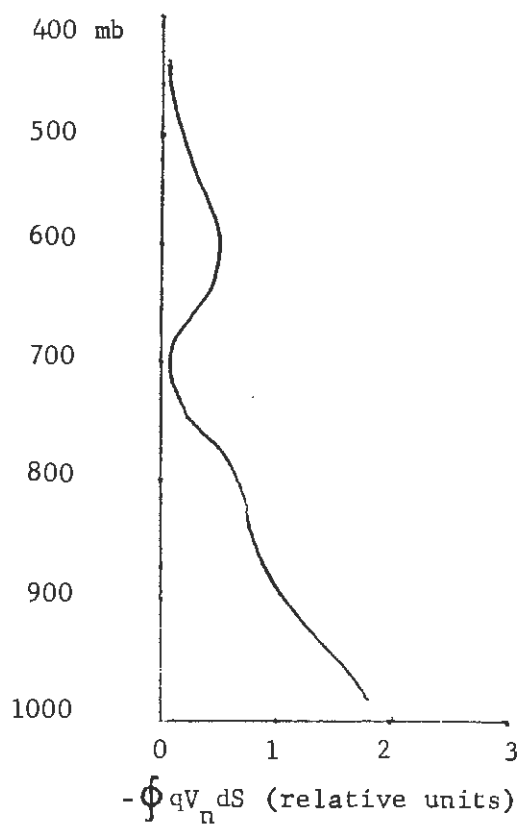
$$R^x = - \int_{P_T} \int_{P_B} \omega \left(\frac{\partial q}{\partial p} \right) \frac{dp}{G} dA \quad (6)$$

THUS, (6) IS APPROXIMATELY EQUIVALENT TO (3). IN (6), P_B AND P_T DENOTE THE

TABLE 1. COMPUTATION OF TERMS IN EQUATION (3) BY BRADBURY (1957)

UNITS: MM HR⁻¹.

STORM	F_W	$\partial W / \partial T$	R	OBSERVED PRECIPITATION
21-22 MAR / 55	0.67	-0.22	0.89	0.67
24-25 NOV / 52	1.34	-0.15	1.49	1.00
23-25 OCT / 56	0.28	0.00	0.28	0.10

FIGURE 1. THE VERTICAL VARIATION OF $-\oint qV_n dS$ (SEE EQUATION (5)) ADAPTED FROM PALMEN AND HOLOPAINEN (1962).

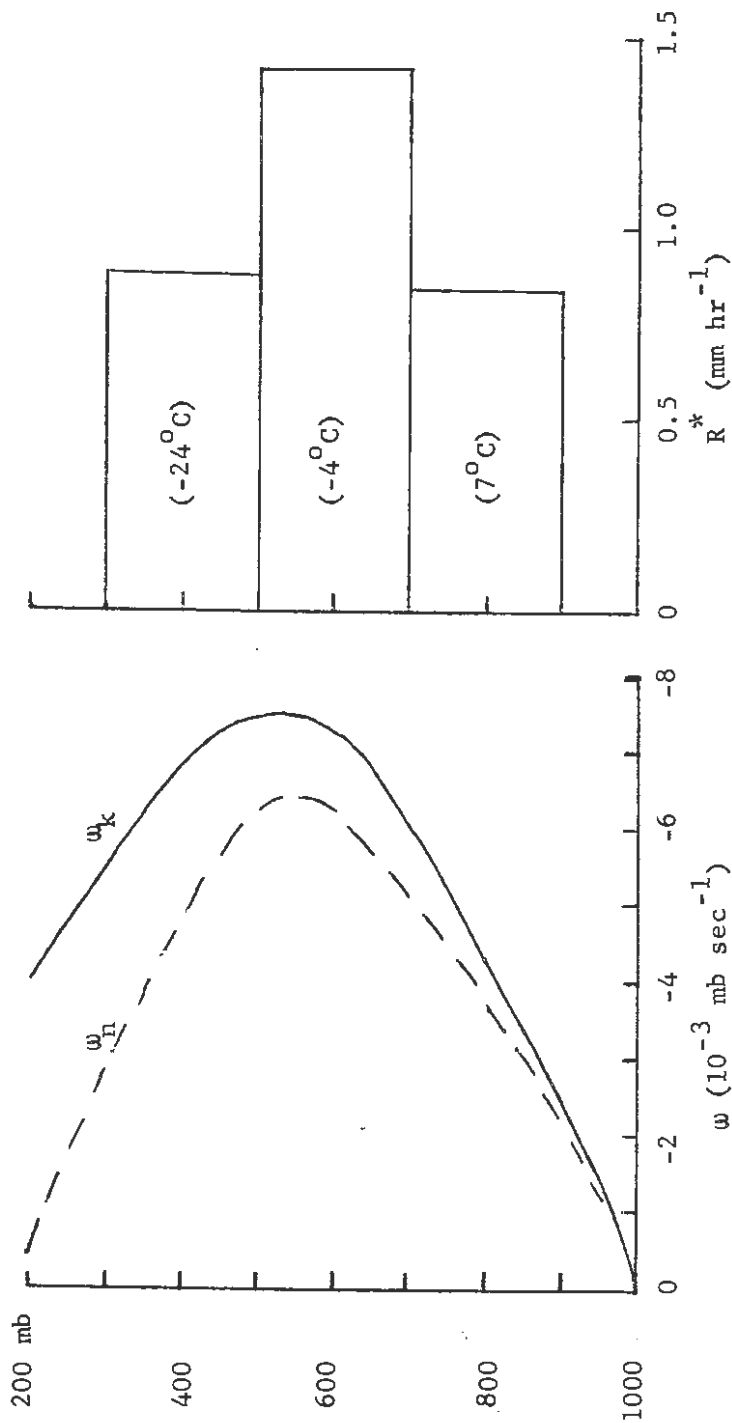


FIGURE 2

LEFT: VERTICAL DISTRIBUTIONS OF ω COMPUTED KINEMATICALLY (ω_K) AND NUMERICALLY INCLUDING RELEASE OF LATENT HEAT (ω_N).

RIGHT: CONTRIBUTIONS TO R^* (SEE EQUATION (6)) FROM 200 MB THICK LAYERS COMPUTED USING ω_K .

SOME NOTES ON RADIATION AND LONG-TERM CLIMATIC VARIATIONS

H. L. FERGUSON

1. INTRODUCTION

MOST OF US HAVE OUR HANDS FULL GRAPPLING WITH DAY-TO-DAY PROBLEMS OF WEATHER AND CLIMATE. HOWEVER, THERE ARE FEW METEOROLOGISTS WHO HAVEN'T AT ONE TIME OR ANOTHER GIVEN SOME THOUGHT TO PRE-HISTORIC CLIMATES AND THE EFFECTS THEY HAVE HAD ON OUR BIOLOGICAL AND GEOLOGICAL HERITAGE. MOST PEOPLE ARE INTERESTED NOT ONLY IN THE GLACIATIONS AND ALTERNATING WARM EPOCHS OF THE PAST, BUT ALSO IN THE CLIMATIC FUTURE OF OUR GLOBAL REAL ESTATE. WILL THE MELTING OF ARCTIC ICE SOME DAY SUBMERGE NEW YORK? WILL SOUTHERN ONTARIO REALLY BECOME A BANANA BELT? IS THE FAMILY OF MARITIME TROPICAL AIR MASSES IMMORTAL?

THE PREDICTION OF FUTURE CLIMATES IS BASED ON THE SAME PRINCIPLES AS EVERYDAY FORECASTING, WITH THE ADVANTAGE THAT THE PROGNOSTICIAN DOESN'T NEED TO WORRY ABOUT THE POSSIBLE EMBARRASSMENT OF FORECAST VERIFICATION. THE FIRST STEP IS TO ESTABLISH THE CAUSE AND EFFECT RELATIONSHIPS BETWEEN PHYSICAL CONTROLS AND CLIMATE. IN THE CASE OF OUR HISTORICAL RECORD THIS TASK IS NOT TOO DIFFICULT. HOWEVER, HISTORY PROVIDES US WITH AN INFINITESIMALLY SMALL DATA SAMPLE FROM THE GEOLOGICAL TIME SEQUENCE AND WE HAVE NO DIRECT OBSERVATIONS OF NATURAL EVENTS FOR MOST OF THE PALEOCLIMATIC "SPECTRUM". WE CAN USE INDUCTIVE REASONING TO STUDY THE POSSIBLE CAUSES OF PAST VARIATIONS IN GLACIATION. A PREDICTION OF FUTURE CLIMATES CAN THEN BE MADE, BASED ON OUR UNDERSTANDING OF PRESENT AND PAST EVENTS.

THIS PAPER GIVES A BRIEF SUMMARY OF MAJOR TEMPERATURE VARIATIONS AND GLACIATIONS OF THE PAST AND DISCUSSES THE PROBABLE INFLUENCE OF RADIATION AS INDICATED BY BUDYKO'S RECENT WORK (1968).

2. PAST VARIATIONS IN TEMPERATURE AND GLACIATION

FOR THE PAST TWO BILLION YEARS, THE CLIMATE OF THE EARTH HAS BEEN CHARACTERIZED BY LONG PERIODS OF MILD WEATHER SEPARATED BY SHORTER PERIODS OF EXTENSIVE GLACIATION, OR GLACIAL EPOCHS, WITH A ROUGH MAJOR PERIODICITY OF A QUARTER OF A BILLION YEARS. TABLE 1 GIVES A SUMMARY OF IMPORTANT GLACIATIONS AND THEIR LOCATIONS ACCORDING TO SELLERS (1965). FIGURE 1 ILLUSTRATES VARIATIONS IN NORTHERN HEMISPHERE TEMPERATURES SINCE THE BEGINNING OF THE CAMBRIAN PERIOD, OVER 500 MILLION YEARS AGO, ACCORDING TO BROOKS (1951). WITHIN THE NARROW DIP OF THE PRESENT QUATERNARY PERIOD THERE HAVE BEEN AT LEAST FOUR SHORT-

TABLE 1. ESTIMATED DATES AND REGIONS OF MAJOR GLACIATIONS (AFTER SELLERS, 1965)

ERA	PERIOD	EPOCH	BEGINNING OF INTERVAL (MILLIONS OF YEARS AGO)	MAJOR GLACIATIONS							
				ANTARCTICA	SOUTH AMERICA	AFRICA	AUSTRALIA	ASIA	EUROPE	NORTH AMERICA	ARCTIC
PRE-ARCHEOZOIC	.....	.....	4,600	...	...	...	...	...	...	...	...
ARCHEOZOIC ...	(KEEWATIN	.....	2,800	...	...	...	...	...	...	X	...
	(TIMISKAMING	.....	.....	...	...	...	...	...	...	X	...
PROTEROZOIC ...	(HURONIAN	.....	1,000	...	?	X	X	...	...	X	...
	(ALGONKIAN	.....	.....	...	...	...	...	...	...	...	...
	(PRE-CAMBRIAN	.....	.....	...	...	X	X	X	X	?	X
	(CAMBRIAN	.....	600	...	...	...	...	...	...	...	...
PALEOZOIC ...	(ORDOVICIAN	.....	500	...	...	...	...	...	...	...	...
	(SILURIAN	.....	430	...	...	...	...	...	...	...	...
	(DEVONIAN	.....	400	...	X	X	...	...	...	...	...
	(CARBONIFEROUS	(MISSISSIPPIAN	350	...	...	...	...	...	...	...	...
	(	(PENNSYLVANIAN	330	...	...	...	...	...	...	...	...
	(PERMIAN	.....	275	?	X	X	X	X	...	...	...
	(TRIASSIC	.....	225	...	...	...	...	...	...	...	...
MESOZOIC ...	(JURASSIC	.....	180	...	...	...	...	...	...	...	...
	(CRETACEOUS	.....	135	...	...	...	...	...	...	...	...
		(PALEOCENE	66	...	...	...	...	...	...	...	...
CENOZOIC ...	TERTIARY	(EOCENE	59	...	...	...	...	...	...	...	...
		(OLIGOCENE	38	...	...	...	...	...	...	...	...
		(MIOCENE	25	...	...	...	...	...	...	...	...
		(PLIOCENE	12	...	...	...	...	...	...	...	X
		(PLEISTOCENE	0.6	X	X	...	X	X	X	X	X
	QUATERNARY	(HOLOCENE	0.01	...	...	...	...	...	...	...	...

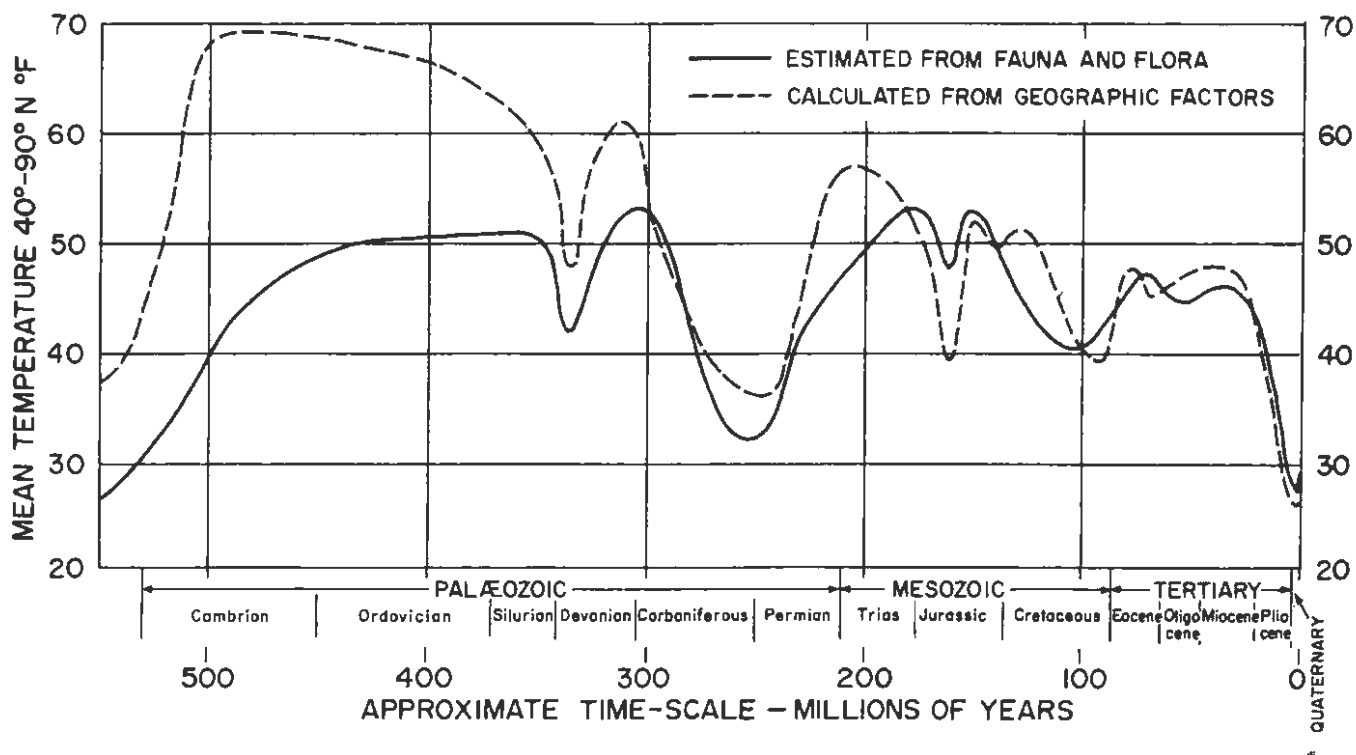


Figure 1. Variations in temperature from the Cambrian period to the present (after Brooks, 1951)

TABLE 2. PRIMARY FACTORS AFFECTING CLIMATE AND GLACIATION

1. EXTRA-TERRESTRIAL	(I)	VARIATIONS OF SOLAR OUTPUT
	(II)	VARIATIONS OF OTHER ASTRONOMICAL FACTORS, E.G. SOLAR DISTANCE
2. ATMOSPHERIC	(I)	VARIATIONS IN ATMOSPHERIC TRANSMISSION AND ABSORPTION:
		VOLCANIC DUST
		NUCLEAR EXPLOSIONS
		CARBON DIOXIDE
		WATER VAPOUR
		CLOUDINESS
3. TOPOGRAPHIC	(I)	VARIATIONS IN SURFACE ALBEDO
	(II)	CHANGES IN EARTH'S SURFACE:
		POLE WANDERING
		CONTINENTAL DRIFT
		MOUNTAIN BUILDING
	(III)	VARIATIONS IN OCEAN HEAT STORAGE OR DIVERSION OF OCEAN CURRENTS

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THIRD INTERNATIONAL CLOUD PHYSICS CONFERENCE

TORONTO, ONTARIO

AUGUST 26-30, 1968

THE THIRD INTERNATIONAL CLOUD PHYSICS CONFERENCE WAS HELD AT THE UNIVERSITY OF TORONTO, AUGUST 26-30, 1968, UNDER THE SPONSORSHIP OF THE INTERNATIONAL ASSOCIATION OF METEOROLOGY AND ATMOSPHERIC PHYSICS OF THE INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS, THE CANADIAN AND AMERICAN METEOROLOGICAL SOCIETIES, THE WORLD METEOROLOGICAL ORGANIZATION AND THE NATIONAL RESEARCH COUNCIL OF CANADA. APPROXIMATELY 330 PARTICIPANTS FROM 23 COUNTRIES ATTENDED THIS CONFERENCE TO DISCUSS 155 PAPERS PRESENTED IN TEN SESSIONS OVER THE FIVE DAYS OF THE CONFERENCE. THIS WAS THE FIRST TIME THAT DELEGATES FROM THE U.S.S.R. HAD ATTENDED ONE OF THE SERIES OF INTERNATIONAL CLOUD PHYSICS CONFERENCES WHICH BEGAN IN AUSTRALIA IN 1961, FOLLOWED BY THE SECOND CONFERENCE IN JAPAN IN 1965, AND THIS FACT CONTRIBUTED GREATLY TO THE SUCCESS OF THE CONFERENCE.

AS BEFITTED AN INTERNATIONAL CLOUD PHYSICS CONFERENCE, THE WEATHER CO-OPERATED BEAUTIFULLY, AND FIVE WARM, SUNNY, LATE SUMMER DAYS ENABLED THE DELEGATES TO FULLY APPRECIATE THE BEAUTIES OF CANADA, INCLUDING AN EXCURSION TO NIAGARA FALLS AND BANQUET SPONSORED BY THE ONTARIO GOVERNMENT. THE UNIVERSITY OF TORONTO ALSO TENDERED A RECEPTION IN HONOUR OF THE DELEGATES.

THE METHOD OF PRESENTATION OF PAPERS AT THIS CONFERENCE WAS SOMEWHAT DIFFERENT THAN THAT NORMALLY USED. WITH SO MANY PAPERS TO BE PRESENTED AND IN ORDER TO AVOID RUNNING CONCURRENT SESSIONS, THE PROCEDURE ADOPTED WAS TO HAVE A KEYNOTE SPEAKER SUMMARIZE THE CURRENT SCIENTIFIC POSITION IN THE FIELD TO WHICH HIS SESSION WAS DEVOTED. TWO OR MORE LEAD SPEAKERS THEN SUMMARIZED AND COMMENTED ON THE PAPERS INCLUDED IN THE SESSION AND THE PAPERS WERE THEN THROWN OPEN FOR DISCUSSION. THE SYSTEM APPEARED TO WORK VERY WELL AND THERE WERE MANY LIVELY AND INTERESTING DISCUSSIONS. ANOTHER FEATURE OF THIS CONFERENCE WAS AN EVENING MEETING DEVOTED TO THE PRESENTATION OF "EXPERIMENTS IN CLOUD PHYSICS FOR PHYSICS STUDENTS". THIS WAS A VERY INTERESTING AND TIMELY SESSION WHICH INDICATED THE MANY POSSIBILITIES WHICH EXIST FOR STIMULATING INTEREST IN CLOUD PHYSICS AMONG UNIVERSITY PHYSICS STUDENTS. AN "OPEN HOUSE" SESSION AT THE UNIVERSITY OF TORONTO CLOUD PHYSICS LABORATORIES ALSO ATTRACTED MANY DELEGATES AND DISPLAYED TO ADVANTAGE THE CLOUD PHYSICS STUDIES BEING CONDUCTED THERE.

THE FOURTH INTERNATIONAL CLOUD PHYSICS CONFERENCE IS TENTATIVELY SCHEDULED FOR LONDON, ENGLAND IN 1972. IN MAKING THIS ANNOUNCEMENT, PROFESSOR B.J. MASON, DIRECTOR-GENERAL OF THE BRITISH METEOROLOGICAL OFFICE, NOTED THAT A NEW APPROACH WOULD BE REQUIRED SINCE THE FIRST INTERNATIONAL CLOUD PHYSICS CONFERENCE DEALT WITH 50 PAPERS IN 15 DAYS, THE SECOND CONFERENCE WITH 100 PAPERS IN 10 DAYS, WHILE THE THIRD COVERED 150 PAPERS IN 5 DAYS. SINCE THE NEXT TERM IN THE SERIES IS 200 PAPERS IN ZERO DAYS, THE NEED FOR A NEW APPROACH IS OBVIOUS.

TORONTO CENTRE

THE FIRST MEETING OF THE TORONTO CENTRE FOR THE 1968-69 SEASON WAS HELD ON OCTOBER 22. THE SPEAKER WAS MR. J.D. HOLLAND OF THE RESEARCH AND TRAINING DIVISION, METEOROLOGICAL BRANCH, WHO SPOKE ON "HAIL SUPPRESSION IN THE U.S.S.R."

PROTECTION FROM HAIL IS PROVIDED ON AN OPERATIONAL BASIS TO ABOUT TWO AND ONE-HALF MILLION ACRES UNDER CROP IN THE CAUCASUS REGION, SIXTEEN PROTECTION CENTRES COVER THE AREA. THE PROGRAM EMPLOYS 800 MEN AND THE CLAIMED COST-BENEFIT RATIO IS ONE TO TEN. ABOUT 100 ARTILLERY GUNS USING 19 MM. SHELLS AND A NUMBER OF ROCKET LAUNCHERS ARE EMPLOYED TO FIRE CHARGES OF SILVER IODIDE INTO HIGH-REFLECTIVITY CLOUD LAYERS OR "ACCUMULATION ZONES" DETECTED BY RADAR. THIS CAN PROVIDE A HUNDRED-FOLD INCREASE IN NUCLEUS DENSITY. AS A RESULT MANY MORE HAILSTONES ARE PRODUCED, BUT THEY AVERAGE ABOUT ONE-QUARTER TO ONE-FIFTH THE SIZE OF NATURAL HAILSTONES AND MAY MELT BEFORE REACHING THE GROUND. THE RUSSIANS CLAIM A REDUCTION IN HAIL DAMAGE TO CROPS OF 80 TO 85 PER CENT OVER THE PERIOD 1964 TO 1968. MR. HOLLAND ILLUSTRATED HIS TALK AND HIS IMPRESSIONS OF THE U.S.S.R. WITH A SERIES OF 35 MM. SLIDES.

DR. ROLAND LIST EXPRESSED ENVY AS WELL AS ADMIRATION ON BEHALF OF THE MEMBERS PRESENT.

ON NOVEMBER 26, 1968, PROFESSOR B.J. GARNIER OF MC GILL UNIVERSITY ADDRESSED THE TORONTO CENTRE ON THE SUBJECT "THE AIMS AND PRACTICE OF GEOGRAPHICAL CLIMATOLOGY". PROFESSOR GARNIER STATED THAT THREE ANALYTICAL APPROACHES ORIGINALLY DEFINED BY KANT COULD BE APPLIED TO EARTH PHENOMENA. THESE ARE THE SYSTEMATIC, HISTORICAL AND GEOGRAPHICAL POINTS OF VIEW. IN APPLYING GEOGRAPHICAL OR SPATIAL ANALYSIS THE PROBLEM OF INTERPOLATION TO OBTAIN MAP PATTERNS IS OF GREAT IMPORTANCE.

THE SPEAKER DESCRIBED HIS WORK IN STUDYING THE ENERGY BALANCE AT THE EARTH'S SURFACE, WHICH EXERTS CONTROLS ON NATURAL VARIABLES SUCH AS AIR TEMPERATURE AND HUMIDITY, VEGETATION AND SOIL MOISTURE. HIS OBJECTIVE IS TO MAP THE PRIMARY RADIATION VARIABLES RATHER THAN THE RESULTANT VARIABLE FIELDS. HE IS CURRENTLY CARRYING OUT FIELD PROJECTS AT KNOB LAKE AND MONT ST. HILAIRE, QUEBEC, AND IN BARBADOS. PROFESSOR GARNIER ALSO DISCUSSED HIS WORK IN DEFINING REGIONAL CLIMATIC ZONES IN NIGERIA, BASED ON STUDIES OF SYNOPSIS WEATHER PATTERNS. HE ILLUSTRATED HIS TALK WITH AN INTERESTING SET OF 35 MM. SLIDES. FOLLOWING A LIVELY DISCUSSION PERIOD, DR. ANDREW THOMPSON THANKED THE SPEAKER.

BURN LOWE PRIZE

"A UNANIMOUS MOTION OF THE 1967 ANNUAL BUSINESS MEETING INSTRUCTED THE EXECUTIVE OF THE WINNIPEG CENTRE OF THE CMS TO ESTABLISH A PRIZE IN METEOROLOGY TO HONOUR THE MEMORY OF THE LATE BURN LOWE. THE AWARD WAS DEFINED AS FOLLOWS:

THE BURN LOWE MEMORIAL PRIZE. TO BE AWARDED ANNUALLY TO THAT PERSON IN THE AREA OF INTEREST OF THE WINNIPEG CENTRE OF THE CANADIAN METEOROLOGICAL SOCIETY ADJUDGED TO HAVE MADE A SIGNIFICANT CONTRIBUTION TO METEOROLOGY.

AT THE 1968 ANNUAL BUSINESS MEETING OF THE WINNIPEG CENTRE, C.C. WARKENTIN, RECENTLY RETIRED METEOROLOGICAL INSPECTOR, WAS NAMED FIRST RECIPIENT OF THIS AWARD.

IN PRESENTING THE PRIZE, MR. S.V.A. GORDON, O.I.C. OF THE PRAIRIE WEATHER CENTRAL, CITED MR. WARKENTIN'S PIONEERING EFFORTS IN METEOROLOGICAL INSTRUCTION AND INSPECTION. MANY TECHNICIANS AND METEOROLOGISTS RECEIVED THEIR EARLY TRAINING FROM HIM, AND A GENERATION OF TRANS-CANADA AIRLINE PILOTS REMEMBER HIM AS 'MR. WEATHERMAN' FROM THE DAYS WHEN THE COMPANY'S HEADQUARTERS AND TRAINING WERE CENTRED IN WINNIPEG. IN LATER YEARS HIS FRIENDLY VISITS WERE AN OCCASION THROUGHOUT THE FAR FLUNG OBSERVING NETWORK, AND MUCH OF THE SUCCESS OF THE VOLUNTEER CLIMATOLOGICAL STATIONS WAS DUE TO THE HIGH REGARD IN WHICH HE WAS HELD. MR. GORDON STRESSED THAT MR. WARKENTIN'S SUCCESS WAS LARGELY DUE TO HIS ABILITY TO ESTABLISH, THROUGH HIMSELF, A PERSONAL LINK BETWEEN PEOPLE AND WEATHER. IT SEEMED VERY FITTING THAT HE SHOULD SHARE THIS ABILITY WITH THE MAN TO WHOM THE AWARD WAS DEDICATED."

R.E. MUNN PRIZE

THE FIRST PRESENTATION OF A NEW BURSARY, NAMED IN HONOUR OF WELL-KNOWN MICROMETEOROLOGIST DR. R.E. MUNN, WAS MADE IN TORONTO ON SEPTEMBER 17, 1968. THIS BURSARY, WHICH WILL BE AWARDED ANNUALLY, AND IS WORTH \$100.00, HAS BEEN ESTABLISHED BY THE TORONTO LOCAL OF THE DEPARTMENT OF TRANSPORT COMPONENT OF THE PUBLIC SERVICE ALLIANCE OF CANADA. IN ESTABLISHING BURSARY, THE LOCAL PAYS TRIBUTE TO THE DEDICATED WORK OF DR. MUNN IN SUPPORT OF STAFF ORGANIZATIONS IN THE PUBLIC SERVICE.

RECIPIENT OF THE FIRST BURSARY WAS NORMAN POULTON, SON OF MR. AND MRS. J. POULTON. HE IS A FIRST YEAR STUDENT IN ARTS AND SCIENCE AT THE UNIVERSITY OF TORONTO AND WILL USE THE BURSARY TO FURTHER HIS STUDIES.

INTER ALIA

SOMAS MEETING 24 OCTOBER, 1968

SOMAS RECEIVED A PRELIMINARY VERSION OF A REPORT FROM THE WORKSHOP ON GARP HELD 7 JUNE, 1968 IN CALGARY. THE REPORT WAS ACCEPTED IN PRINCIPLE. IN FURTHER DISCUSSION, PROFESSOR BREWER, WHO ACTED AS SPOKESMAN FOR THE COMMITTEE THAT ORGANIZED THE WORKSHOP AND WHO HAD DRAFTED THE REPORT, WAS ASKED TO ESTIMATE THE FINANCIAL IMPLICATIONS OF FULL PARTICIPATION BY CANADIANS IN A BALANCED CANADIAN GARP PROGRAM.

SOMAS RESOLVED TO CO-ORDINATE ITS CONSIDERATIONS OF WEATHER MODIFICATION IN CANADA WITH THAT UNDERTAKEN BY THE COMMITTEE ON AGRICULTURAL METEOROLOGY IN THE CANADIAN DEPARTMENT OF AGRICULTURE. SOMAS WILL PAY SPECIAL ATTENTION TO ENSURING THAT ALL MODIFICATION ACTIVITIES HAVE TO BE PUBLICLY REGISTERED.

SOMAS RECEIVED REPORTS ABOUT FOUR METEOROLOGICAL MEETINGS IN CANADA IN 1967-68, AMONG THESE BEING TWO INTERNATIONAL CONFERENCES WHICH PRODUCED THEIR OWN HANDSOME PROCEEDINGS VOLUMES. THE COMMITTEE NOTED THAT AT THESE TWO MEETINGS (RADAR METEOROLOGY AT MCGILL AND CLOUD PHYSICS AT TORONTO, BOTH HELD IN AUGUST 1968) SPECIAL EFFORTS HAD BEEN MADE TO ENSURE AUDIENCE PARTICIPATION AND DISCUSSION, IN SPITE OF THE LARGE NUMBER OF CONTRIBUTIONS THAT HAD BEEN OFFERED. MORE DETAILED REPORTS ON THESE CONFERENCES, INCLUDING THE PROCEDURES ADOPTED BY THEM, ARE AVAILABLE FROM THEIR ORGANIZERS.

SOMAS RECEIVED REPORTS ON MEETINGS IN 1969, INCLUDING A SUMMER WORKSHOP AT STANSTEAD, QUE., CONCERNING ATMOSPHERIC DYNAMICS FROM THE POINT OF VIEW OF GARP, AND THE 2ND CANADIAN CONGRESS ON MICROMETEOROLOGY TO BE ORGANIZED BY A COMMITTEE HEADED BY DR. R.E. MUNN.

W. HITSCHFELD

MONTREAL CENTRE EXECUTIVE 1968-69

DR. P.E. MERILEES	-	CHAIRMAN
MR. M. KUNZAK	-	MEMBER
MR. R. ASSELIN	-	TREASURER
MR. S.F. WORONKO	-	SECRETARY, DEPT. MET, MCGILL UNIVERSITY

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HISTORICAL NOTE - BRISTOL? IN ALASKA?

A MYSTERY OLDER THAN THIS CENTURY RESURFACED RECENTLY. ON PAGE 158 OF THE Q.J.R.M.S. OF 1901 (VOLUME 27) APPEARS, IN PART, THE FOLLOWING NOTE:

"EXTRAORDINARY MIRAGE - WE HAVE RECEIVED, THROUGH MR. F. NAPIER DENISON OF THE METEOROLOGICAL OFFICE, VICTORIA, BRITISH COLUMBIA, A COPY OF THE VICTORIA DAILY TIMES, JANUARY 26, 1901, WHICH CONTAINS AN ILLUSTRATION OF A REMARKABLE MIRAGE KNOWN AS "THE SILENT CITY OF ALASKA". IT IS SAID TO APPEAR EVERY YEAR ON THE GIGANTIC GLACIER OF MOUNT FAIRWEATHER....

THE PHENOMENON IS SEEN BETWEEN 7 AND 9 O'CLOCK BETWEEN JUNE 21 AND JULY 10, AND THE SCENE NEVER VARIES EXCEPT FOR SLIGHT CHANGES IN THE BUILDINGS AND OTHER PROMINENT LANDMARKS. IT IS BELIEVED THAT THE MIRAGE IS A REPRESENTATION OF THE CITY OF BRISTOL, ENGLAND. THAT IT IS A SEAPORT IS SHOWN BY THE MAST OF A VESSEL, WHILE A TOWER, AN EXACT DUPLICATE OF THAT OF ST. MARY REDCLIFF, APPEARS IN THE BACKGROUND...."

IN ANSWER TO A RECENT QUERY REGARDING THIS OLD NOTE, A.F. MCQUARRIE, O.I.C., AT THE GONZALEZ OBSERVATORY WAS ABLE TO GET A COPY OF A STORY FROM THE APRIL 12, 1901 ISSUE OF THE VANCOUVER PROVINCE HEADLINED "MYSTERY OF THE SILENT CITY". THE FOLLOWING INFORMATION CAME FROM THAT ARTICLE.

IN 1897, THE DUKE OF ABRUZZI, WHO CARRIED THE TITLE OF ROYAL POLAR EXPLORER REPORTED "...A SERIES OF STRANGE SHAPES WHICH...UNDERWENT CHANGES BEFORE OUR VERY EYES, ASSUMING THE FORMS OF SPIRES, BELFRIES, MINARETS AND ARCHITECTURAL OUTLINES OF FANTASTIC CATHEDRALS, ALL OF WHICH SLOWLY APPEARED AND DISAPPEARED, TO BE SUCCEEDED BY BUILDINGS OF LESSER HEIGHT, SEVERELY RECTILINEAR.... THE MARVELOUS SPECTACLE CONTINUED THROUGHOUT THE AFTERNOON."

THE CAPTAIN OF A CANADIAN GOVERNMENT STEAMER, J.T. WALBRAN, WAS ONE OF A GROUP WHICH BELIEVED THAT "REFLECTED LIKE A GREAT PHOTOGRAPH FIVE MILES LONG ON THE TOP OF MUIR GLACIER, IS A REPRESENTATION OF THE CITY OF BRISTOL". A PROSPECTOR'S PHOTOGRAPH, TAKEN IN THE TWILIGHT WITH A SHORT EXPOSURE, WAS USED BY OTHERS WHO COULD RECOGNIZE THE CITY OF BRISTOL IN IT, AS FURTHER PROOF.

THERE WERE OTHER STORIES, AND THEORIES. TWO MINERS HIT ON THE IDEA OF POURING A FEW POUNDS OF QUICKSILVER INTO A GOLD PAN. BY PEERING INTO THIS WITH A MAGNIFYING GLASS, THEY COULD "SEE EVERYTHING FOR MILES AROUND REFLECTED INTO THE QUICKSILVER". THEY SAW WHAT APPEARED TO BE "THE RUINS OF A LARGE CITY.... REMAINS OF WALLS, TOWERS AND MANY LARGE BUILDINGS, BUT ALL WERE SEEN IN A WAVERING SORT OF WAY". THEY DECIDED THAT THE CITY WAS ONE AT THE BOTTOM OF THE BAY, SO THEY "SPENT A WHOLE DAY GETTING ON THE TOP OF THE GLACIER AND AT GREAT RISK VENTURED NEAR TO ITS PERPENDICULAR FACE. THERE WE ERECTED A

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ATMOSPHERIC POLLUTION ON THE MOON: A FUTURE PROBLEM?

W. R. FRYERS
MEDLEY, ALBERTA

LUNAR POLLUTION IS BY NO MEANS THE RIDICULOUS PROPOSITION THAT IT SOUNDS. THE VERY FACT THAT THE MOON AS YET HAS NO ATMOSPHERE CREATES THE PROBLEM. THE MOON WILL HAVE A 'POLLUTION POTENTIAL' STARTING WITH THE FIRST ACTIVITIES OF MAN. IN THE ABSENCE OF THE NATURAL CONTROLS PROVIDED BY DYNAMIC WEATHER PROCESSES, POLLUTION WILL BE RELATIVELY PERMANENT, AND MAY BECOME A MAJOR PROBLEM IF NOT UNDER TOTAL TECHNOLOGICAL CONTROL FROM THE OUTSET.

ALL BUT THE MOST TRANSIENT VISITS OF MAN TO THE MOON WILL REQUIRE ELABORATE ARRANGEMENTS FOR SURVIVAL. SUPPLY OF ESSENTIAL EQUIPMENT AND MATERIALS FROM EARTH BY ROCKET VEHICLE WILL BE PROBITIVELY EXPENSIVE AND INEFFICIENT. ONCE PERMANENT OCCUPATION IS UNDERTAKEN, HOWEVER, THE READY AVAILABILITY OF RAW MATERIALS PROVIDED BY THE MOON ITSELF WILL GENERATE THE RAPID DEVELOPMENT OF MEANS OF EXTRACTION AND FABRICATION. ENERGY SOURCES WILL NOT BE A MAJOR PROBLEM. ABUNDANT SOLAR ENERGY IS READILY AVAILABLE FOR NETWORK DISTRIBUTION. EVIDENCE NOW AVAILABLE SUGGESTS THAT VOLCANIC ENERGY WILL BE WIDELY AVAILABLE. AND FINALLY, THE IMPORTATION OF ATOMIC ENERGY UNITS FROM EARTH MAY BE FEASIBLE AND NECESSARY TO STIMULATE THE LUNAR ECONOMY.

GIVEN THEN, THE RAW MATERIALS AND THE ENERGY FOR INDUSTRIALIZATION, TOP PRIORITY WILL GO TO PRODUCTION OF LIFE-SUPPORT SYSTEMS. WATER FIRST, AND AIR-OXYGEN AND NITROGEN. PLANT-SUSTAINING COMPOUNDS AND ENVIRONMENTS WILL RECEIVE EARLY ATTENTION. ON A LOWER PRIORITY, BUT PROBABLY DEVELOPED CONCURRENTLY, WILL COME IMPROVED CONSTRUCTION MATERIALS, TOOLS, VEHICLES, SYSTEMS OF TRANSPORT, AND COMMUNICATIONS, PLUS COMPLEXES FOR SOCIAL LIVING, TRAINING, RECREATION, HEALTH, AND SO ON.

IN THE HOSTILE ENVIRONMENT OF THE MOON, IT SEEMS PROBABLE THAT THE ENERGY CONVERSION REQUIRED FOR SURVIVAL, PER PERSON, WILL BE MUCH HIGHER THAN IN ANY SOCIAL SYSTEM HERETOFORE DEVELOPED ON EARTH. THE BY-PRODUCTS OF THIS DEGRADATION OF ENERGY, BY INDUSTRIAL PROCESS OR BY THE ACTIVITIES OF THE SOCIAL GROUP ITSELF, COULD CONTRIBUTE LARGE-SCALE CONTINUOUS POLLUTION OF THE LUNAR ENVIRONMENT. INITIALLY GASES ONLY - NITROGEN, OXYGEN, CARBON DIOXIDE, AND OTHER EXHAUST GASES OF INDUSTRIAL BIOLOGICAL PROCESSES - WOULD SURVIVE IN DETECTABLE QUANTITIES. EVENTUALLY, SOLID PARTICLES, SUCH AS DUST, MIGHT ALSO CREATE A PROBLEM.

THE MOON HAS SUFFICIENT GRAVITY - ABOUT $\frac{1}{6}$ THAT OF EARTH - TO RETAIN SOME ATMOSPHERE FOR INDEFINITE PERIODS. REDUCTION AND COMBINATION BY CHEMICAL PROCESSES MAY BE EXTREMELY SLOW IN THE ABSENCE OF FREE OXYGEN, EVEN IN THE PRESENCE OF STRONG SUNLIGHT, LOSS TO SPACE WOULD BE NEGLIGIBLE EXCEPT IN TERMS OF GEOLOGIC OR COSMIC TIME.

THE LUNAR SURFACE IS NOW IN EFFECTIVE EQUILIBRIUM WITH THE TENUOUS CONCENTRATIONS OF MATTER IN SOLAR SPACE. THE DETAILED NATURE OF THIS EQUILIBRIUM CANNOT BE KNOWN UNTIL MAN HIMSELF ARRIVES ON THE SCENE TO CARRY OUT PRECISE SCIENTIFIC INVESTIGATION. WITH HIS ARRIVAL, NEW ELEMENTS OF CONTAMINATION WILL BEGIN TO APPEAR AND NEW EQUILIBRIUMS WILL BE ESTABLISHED. LUNAR 'WEATHER' AND 'WEATHERING' WILL COMMENCE. LUNAR METEOROLOGY WILL, PERFORCE, BECOME A MATTER OF CONCERN. BETTER NOW TO ANTICIPATE THE PROBLEMS BEFORE THEY OCCUR. THE PROBLEMS CAN BE CHARACTERIZED AND CLASSIFIED AT THIS TIME BY THE SINGLE TOPICAL WORD: 'POLLUTION'.

ONCE MAN HAS ESTABLISHED HIMSELF ON THE MOON, THERE IS LITTLE DOUBT THAT HIS OCCUPANCY WILL CONTINUE AND EXPAND THROUGHOUT FORESEEABLE TIME, AND THAT HE WILL FIND IN THE FUTURE, AS HE HAS IN THE PAST, INTERESTS BOTH USEFUL AND PLEASURABLE IN THIS HEAVENLY BODY - THE ORIGINAL EARTH SATELLITE.

WHETHER DESIRABLE OR NOT THEN, THE MOON WILL ACQUIRE SOMETHING OF AN ATMOSPHERE, INCREASING WITH TIME. IT WILL BE AN ACTIVE COMPONENT OF THE LUNAR ENVIRONMENT, SUBJECT IN SOME DEGREE TO THE FUNDAMENTAL DYNAMIC PROCESSES WHICH ARE THE LEGITIMATE CONCERN OF THE SCIENCE OF METEOROLOGY. IT IS THEREFORE APPROPRIATE TO DESIGNATE A SPECIAL BRANCH OF THE GENERAL SUBJECT, TO BE KNOWN AS "LUNAR METEOROLOGY", AND TURN OUR ATTENTION TO IT. IT OFFERS UNIQUE PROBLEMS, BUT ALSO UNIQUE OPPORTUNITIES. FOR THE FIRST TIME, ATMOSPHERIC EXPERIMENTS AND PROCESSES WILL BE OBSERVABLE IN RELATIVELY SIMPLE NEAR-LABORATORY CONDITIONS ON A NEAR-PLANETARY SCALE. THE OPPORTUNITY SHOULD NOT BE LOST. IT IS THE FIRST MAJOR CHALLENGE TO BE FACED BY METEOROLOGISTS IN PLANETARY SPACE.

HAVING NAMED THE SUBJECT AND NOTED THE CHALLENGE, IT IS APPROPRIATE TO SCAN THE FIELD FOR THE MAJOR SECTORS OF ACTION.

1. THE PRIMITIVE LUNAR ENVIRONMENT MUST FIRST BE MAPPED AND MEASURED. A START CAN BE MADE ON THIS TASK RIGHT NOW. IT CAN EXPAND RAPIDLY WHEN ON-SITE WORK CAN BE DONE. TO ESTABLISH THE INTERFACE CONDITION AT THE LUNAR SURFACE, CLOSE CO-ORDINATION WITH OTHER SCIENCES SUCH AS GEOLOGY WILL BE REQUIRED.
2. CONTAMINATING AGENCIES MUST BE ANALYZED AND MONITORED. THIS WILL MEAN THAT EVERY PIECE OF EQUIPMENT, EVERY PROCESS PLANNED FOR LUNAR ESTABLISHMENT, MUST BE CRITICALLY EXAMINED AND TESTED - EVEN IN THE PLANNING STAGE - FOR ITS METEOROLOGICAL SIGNIFICANCE.
3. EQUILIBRIUM CONDITIONS FOR ALL CONCEIVABLE CONTAMINANTS IN THE LUNAR

ENVIRONMENT MUST BE TESTED IN ADVANCE AT THE EARLIEST POSSIBLE STAGE, IN THE LABORATORY AT FIRST, LATER IN SITU.

4. OBSERVING SITES AND EQUIPMENT FOR MONITORING THE LUNAR ENVIRONMENT MUST BE PLANNED AND DEPLOYED.
5. PLANNING FOR A CONTROLLED LUNAR ATMOSPHERE SHOULD BE STARTED. THE ROLE OF OXYGEN, FOR INSTANCE, MAY BE CRITICAL, HOWEVER TENUOUS THE ATMOSPHERE, AS A MEANS OF CONTROL OF OTHER CONTAMINANTS. THE DESIRABLE RATIOS OF CONCENTRATION FOR EACH COMPONENT SHOULD BE DETERMINED AND MEANS DEVELOPED FOR THEIR MAINTENANCE.
6. COMPREHENSIVE RECORDS MUST BE PLANNED, MAINTAINED AND PROCESSED IN SUPPORT OF RESEARCH, PLANNING AND DEVELOPMENT. SPECIALIZED PUBLICATION OF RESULTS MAY BE REQUIRED.
7. FINALLY, SPECIALIST TRAINING MUST BE DEVELOPED FOR BOTH THE OPERATIONAL PERSONNEL INVOLVED AND THE PROFESSIONAL SUPPORT LEVELS.

IN COMMON WITH ALMOST ALL SPACE ACTIVITIES, THIS FIELD OF ENDEAVOUR WILL BE A CO-OPERATIVE ONE INVOLVING SEVERAL NATIONS. IN THE SPIRIT OF THE INTERNATIONAL AGREEMENT ON PEACEFUL USES OF OUTER SPACE, WE HAVE A COMMON INTEREST IN THE LUNAR ENVIRONMENT, AND ITS PROTECTION FROM IRREVERSIBLE POLLUTION.

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MIRROR ON A SORT OF TRIPOD, PLACED IT AT ABOUT A HEIGHT OF FIVE FEET, FACING THE BAY, AND USING OUR GLASSES, WE SAW IN IT THE IMAGE OF THE SAME RUINS IN THE QUICKSILVER WHEN WE WERE DOWN ON THE WATER. WE COULD ALSO GET A PART OF THE CITY IN OUR PAN WHEN WE TRIED ON THE SURFACE OF THE GLACIER". IN THIS WAY, THEY SATISFIED THEMSELVES THAT "THE SILENT CITY OF ALASKA", IS IN REALITY A SUNKEN CITY RESTING AT THE BOTTOM OF GLACIER BAY. "

A THIRD EXPLANATION OF THE PHENOMENON IS OFFERED BY A GEORGE KERSHON WHO FOUND A CITY IN ONE OF THE INTERIOR VALLEYS. AT FIRST HE THOUGHT IT MUST BE HIS IMAGINATION ATTRIBUTING CITY STRUCTURES TO ICE AND SNOW ARRANGEMENTS. HOWEVER, HE PUSHED ON TO THE SITE AND SPENT SOME TIME WANDERING THROUGH THE CITY. IT WAS LAID OUT IN STREETS, AND HAD BLOCKS OF STRANGE LOOKING BUILDINGS ENCASED IN ICE. KERSHON SUGGESTED THAT THE MIRAGE WAS OF THIS LOST CITY, A RELIC OF AN ANCIENT ART-LOVING PEOPLE THAT WAS WIPED OUT IN A CATACLYSMIC COLD WAVE THAT TURNED THE ARCTIC INTO A LAND OF ICE AND SNOW. ACCORDING TO THE WRITER OF THE NEWSPAPER STORY, KERSHON TOLD HIS STORY "WITH AN AIR OF TRUTH".

THERE IS LITTLE DOUBT THAT SOMETHING IS REFLECTED IN THE GLACIER. IT WAS SEEN BY TOO MANY PEOPLE OVER TOO LONG A PERIOD OF TIME. IN THE VANCOUVER ARTIST, MENTION WAS MADE OF A SCIENTIFIC EXPEDITION THAT WAS PLANNED FOR JUNE OF 1901 TO INVESTIGATE THE PHENOMENON. NO REFERENCE OF THE RESULTS OF THIS EXPEDITION IS KNOWN TO THE WRITER AT THIS TIME.

WAS IT REALLY A MIRAGE OF BRISTOL? WAS IT THE REFLECTION OF ANOTHER CITY, UNDER THE WATER OR ENCASED IN ICE? WERE THE VIEWERS EITHER "BUSHED" OR "IM-PAIRED"? I DON'T KNOW. DO YOU HAVE ANY IDEAS?

J. MCCULLOCH

PERIOD OSCILLATIONS (AND ICE AGES) WITH A RANGE OF MORE THAN 2°C . THE LAST OF THESE SHORTER-PERIOD REFRIGERATIONS, THE SO-CALLED VALDER'S READVANCE APPEARED TO REACH A MAXIMUM ABOUT 10,000 YEARS AGO. ON A SHORTER TIME-SCALE STILL, LAMB (1966) POINTS OUT THAT EVIDENCE HAS BEEN PUT FORWARD IN SUPPORT OF CYCLICAL VARIATIONS OF PERIODS 11, 22, 80 AND 400 YEARS. RIGOROUS METHODS OF ANALYSIS ARE DESCRIBED IN A RECENT PUBLICATION OF THE WMO (1966). AT PRESENT WE ARE WITNESSING A DECREASE IN THE AREA OF GLACIATION WHICH, HOWEVER, STILL COVERS A CONSIDERABLE PART OF THE EARTH'S SURFACE.

3. THE ROLE OF RADIATION IN CLIMATIC CHANGE

EVIDENCE OF CLIMATIC CHANGE DURING THE LAST CENTURY IS PROVIDED IN FIGURE 2. A GRADUAL RISE IN MEAN NORTHERN HEMISPHERE TEMPERATURE OF ABOUT 0.6°C OCCURRED BETWEEN THE 1880'S AND THE 1930'S. BETWEEN 1940 AND THE MID-1950'S THE TEMPERATURE FELL ABOUT 0.2°C . SHORTER-PERIOD FLUCTUATIONS OCCURRED OF COURSE, THROUGHOUT THE PERIOD. THE OBSERVED VARIATIONS IN DIRECT MID-LATITUDE SOLAR RADIATION UNDER CLEAR SKIES FOR THE SAME PERIOD ARE ALSO SHOWN IN FIGURE 2. THE CURVES OF SECULAR VARIATIONS OF TEMPERATURE AND RADIATION ARE MORE OR LESS SIMILAR. ALSO, THE VARIATIONS IN RADIATION ARE MORE THAN COULD BE SATISFACTORILY EXPLAINED BY CHANGES IN THE SOLAR CONSTANT (GODSON, 1963). THEY MUST THEREFORE BE ATTRIBUTED TO VARIATIONS IN ATMOSPHERIC ATTENUATION. THE CORRESPONDING VARIATIONS IN TOTAL RADIATION (DIRECT PLUS DIFFUSE) FOR ALL SKY CONDITIONS FOR THE PERIOD OF FIGURE 2 CAN BE ESTIMATED WITH REASONABLE CONFIDENCE. IT TURNS OUT THAT A 1°C TEMPERATURE CHANGE OVER THE LONGER TERM CORRESPONDS TO A TOTAL RADIATION VARIATION OF 0.9 PER CENT. THUS, THE MEAN TEMPERATURE INCREASE OF 0.6°C BETWEEN THE 1880'S AND 1930'S CORRESPONDED TO A TOTAL RADIATION RANGE OF BETWEEN 0.5 AND 0.6 PER CENT. THIS APPARENT RELATIONSHIP BETWEEN RADIATION VARIATIONS AND TEMPERATURE IS IN SUBSTANTIAL AGREEMENT WITH THEORETICAL ESTIMATES BASED ON PREVIOUS WORK BY BUDYKO (1963) AND MANABE AND WETHERALD (1967). HOWEVER, IT CAN BE SHOWN THAT WHEN CHANGES IN GLACIATION, WHICH AFFECT THE AVERAGE EARTH ALBEDO, ARE TAKEN INTO ACCOUNT, THE EFFECT OF A DECREASE IN RADIATION ON THE TEMPERATURE REGIME IS EVEN MORE PRONOUNCED. FIGURE 3 SHOWS THE EFFECT OF DECREASED RADIATION ON THE TEMPERATURE DISTRIBUTION, TAKING ACCOUNT OF GLACIATION.

THE ESTIMATED RELATIONSHIPS OF THE THREE VARIABLES OF INTEREST ARE ILLUSTRATED IN FIGURE 4. A DECREASE IN RADIATION OF 1 PER CENT NOW RESULTS IN A MEAN TEMPERATURE CHANGE OF 5°C . A DECREASE OF 1.5 PER CENT RESULTS IN A TEMPERATURE DROP OF 9°C AND PRODUCES AN EQUATORWARD EXPANSION OF ICE AMOUNTING TO ABOUT 18 DEGREES OF LATITUDE. THIS WOULD BRING THE MEAN ICE EDGE IN NORTH AMERICA TO JUST NORTH OF EDMONTON, TROUT LAKE AND GOOSE BAY. BUDYKO'S CALCULATIONS INDICATE THAT A 1.6 PER CENT DECREASE IN RADIATION WOULD PRODUCE EXPANSION TO A "CRITICAL LATITUDE OF 50° , FOLLOWING WHICH THE ICE COVER WOULD SHIFT TO LOWER LATITUDES AS A RESULT OF SELF-DEVELOPMENT". HE ARGUES THAT THIS COMPLETE GLACIATION OF THE EARTH WAS ON THE POINT OF BEING REALIZED IN THE PERIOD OF MAXIMUM QUATERNARY ICE. AT THAT TIME THE ICE BOUNDARY HAD MOVED ABOUT 90 PER CENT OF THE DISTANCE FROM THE PRESENT MEAN LATITUDE (72°) TO THE CRITICAL MEAN LATITUDE.

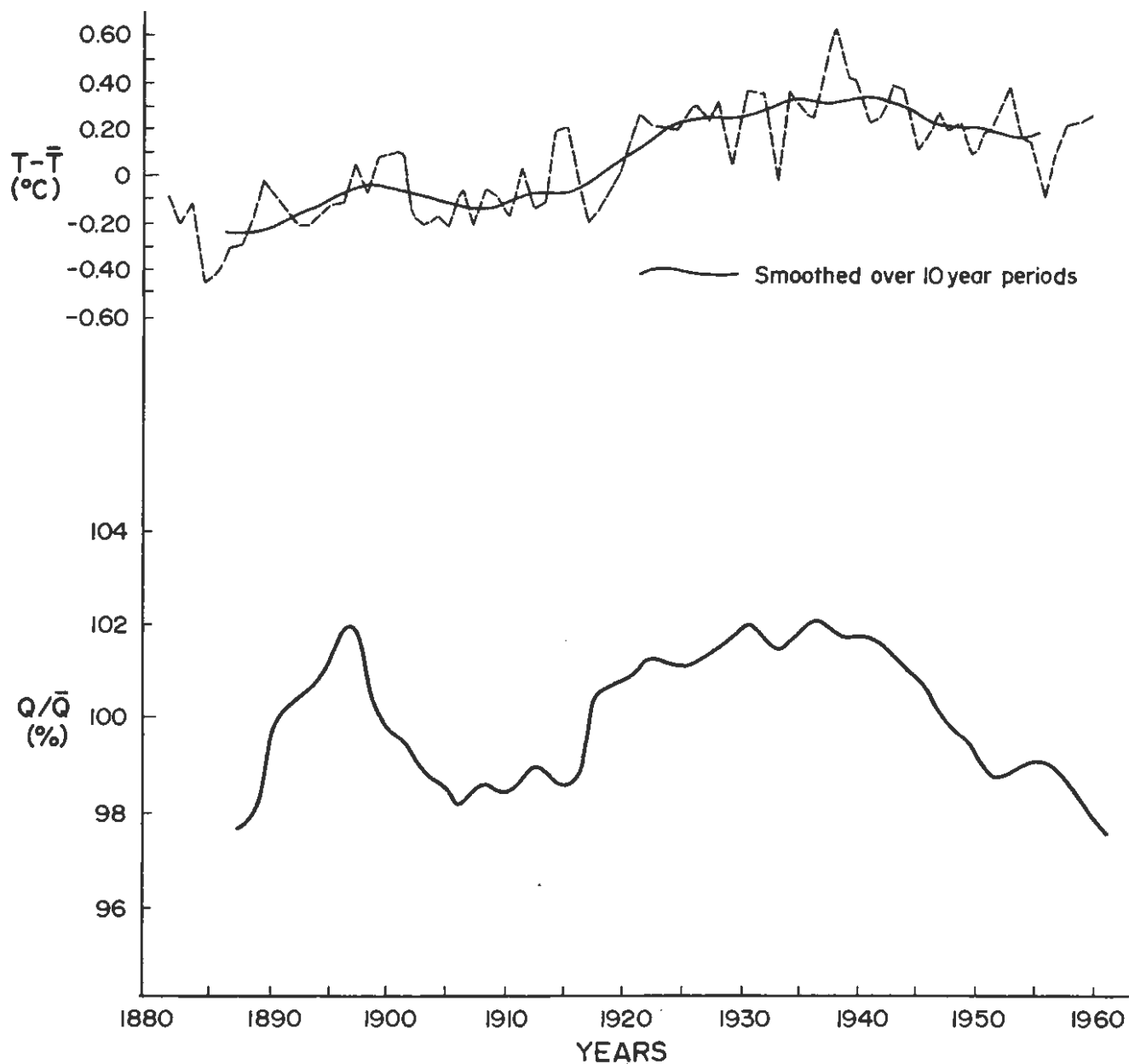


Figure 2. Secular variation of temperature and cloudless sky direct radiation over the Northern Hemisphere (after Budyko, 1968)

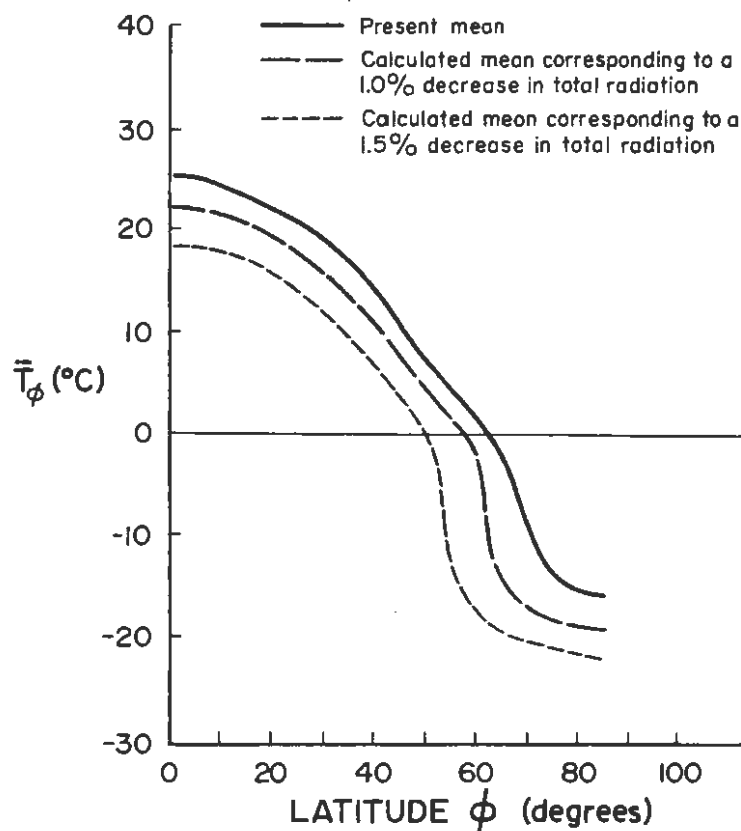


Figure 3. The effect of total radiation changes on mean latitudinal temperature in the Northern Hemisphere (after Budyko, 1968)

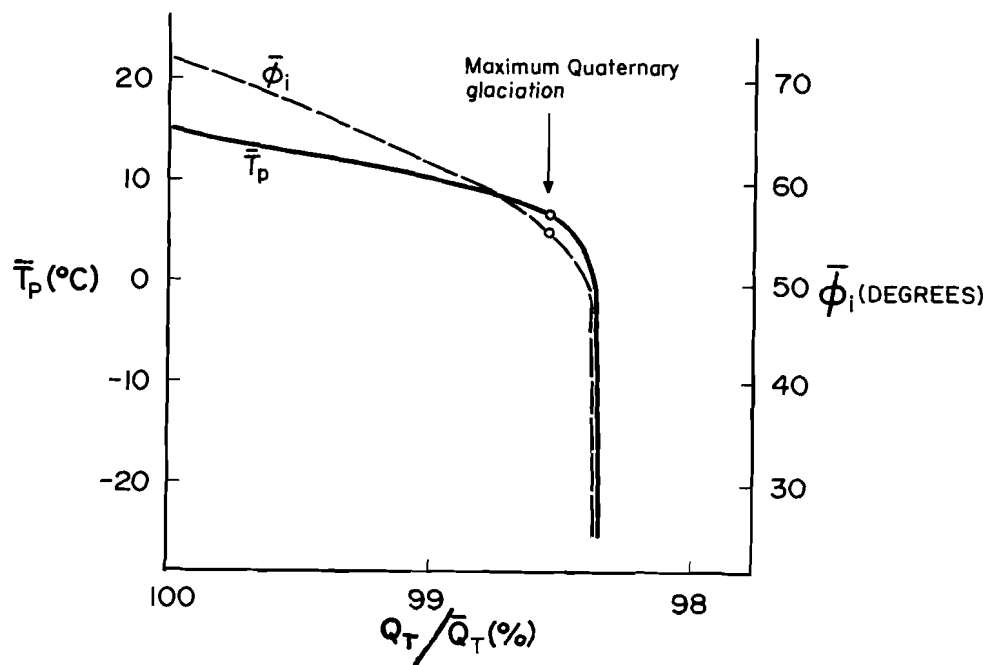


Figure 4. The estimated effect of decreased total radiation on mean planetary temperature $\bar{T}_p$ and mean ice boundary latitude $\bar{\phi}_i$ (after Budyko, 1968)

— CONTINUED ON 151

PRESSURES AT CLOUD BASE AND TOP, $\omega = dp/dt$ IS THE VERTICAL VELOCITY EXPRESSED IN TERMS OF PRESSURE, A IS THE HORIZONTAL AREA AND THE SUBSCRIPT S INDICATES VARIATION ALONG A MOIST ADIABAT. THE MAIN PROBLEM IN EVALUATING (6) IS THE COMPUTATION OF ω . ONE WAY IS KINEMATICALLY USING OBSERVED WINDS AND THE EQUATION OF CONTINUITY

$$\frac{\partial \omega}{\partial p} = -\nabla \cdot \vec{V} \quad (7)$$

FIGURE 2 SHOWS THE VERTICAL DISTRIBUTIONS OF ω COMPUTED KINEMATICALLY (ω_K) AND THE CONTRIBUTIONS TO R^* FROM 200-MB THICK LAYERS AT THE TIP OF A WARM SECTOR IN A DEVELOPING CYCLONE (DANARD 1964). THIS WAS THE REGION OF HEAVIEST PRECIPITATION. NOTE THAT THE LEVEL OF MAXIMUM PRECIPITATION WAS SOMEWHAT LOWER THAN THE LEVEL OF MAXIMUM UPWARD MOTION. THE TOTAL PRECIPITATION (SUM OF THE CONTRIBUTIONS FROM THE THREE LAYERS WAS 3.1 MM HR⁻¹).

USING QUASI-GEOSTROPHIC THEORY IT IS POSSIBLE TO DERIVE AN EQUATION FOR ω AND HENCE FORECAST PRECIPITATION AMOUNTS NUMERICALLY. FIGURE 2 SHOWS THAT VERTICAL VELOCITIES COMPUTED IN THIS WAY TAKING RELEASE OF LATENT HEAT INTO ACCOUNT (ω_N) ARE COMPARABLE TO KINEMATICALLY COMPUTED ONES (ω_K). A SHORT-COMING OF NUMERICAL METHODS IS THE INABILITY TO ACCOUNT FOR CONVECTIVE PRECIPITATION. THIS IS DUE TO TRUNCATION ERROR AND THE FACT THAT THE QUASI-GEOSTROPHIC EQUATIONS ARE NOT APPLICABLE TO SMALL-SCALE MOTIONS. TABLE 2 SHOWS RESULTS OF FOUR 36-HR NUMERICAL PREDICTIONS OF THE TOTAL PRECIPITATION OVER NORTH AMERICA (DANARD 1966 A, 1966 B). NOTE THE CONSISTENT UNDER-ESTIMATE OF TOTAL PRECIPITATION AMOUNTS, DUE, PRESUMABLY, TO THE ABOVE-MENTIONED CAUSES.

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ACKNOWLEDGEMENT

MY JOURNEY TO SWITZERLAND WAS FUNDED BY THE AMERICAN GEOPHYSICAL UNION AND THE NAVAL POSTGRADUATE SCHOOL.

CASE	PREDICTED (P)	OBSERVED (O)	P / O
11-13 FEB / 65	3.4	5.2	0.62
24-26 FEB / 65	5.3	7.4	0.72
16-18 MAR / 65	2.5	5.8	0.43
21-22 JAN / 59	9.1	10.3	0.88
AVERAGE	5.1	7.2	0.72

TABLE 2. TOTAL MASS OF PRECIPITATION IN 36-HR INTERVALS OVER NORTH AMERICA (DANARD 1966 A, 1966B).

UNITS: 10^{16} GM.

THREE QUESTIONS SHOULD BE ASKED:

- (I) IS THE RADIATION VARIABILITY THE DOMINANT FACTOR IN LONG-PERIOD CLIMATIC CHANGE AND GLACIATION?
- (II) CAN RADIATION VARIATIONS OF THE NECESSARY MAGNITUDES AND TIME-SCALES BE EXPLAINED FROM A PHYSICAL POINT OF VIEW?
- (III) ARE SUCH VARIATIONS LIKELY IN THE FUTURE?

IN ANSWER TO THE FIRST QUESTION, THE PHYSICAL FACTORS WHICH COULD THEORETICALLY AFFECT THE EARTH'S TEMPERATURE REGIME CAN BE DIVIDED INTO THREE BASIC CLASSES AS SHOWN IN TABLE 2. IT MIGHT BE POINTED OUT THAT THESE FACTORS ARE THE SAME ONES THAT ARE CONSIDERED IN STUDIES OF THE HEAT BALANCE AND GENERAL CIRCULATION OF THE ATMOSPHERE, AND MANY AUTHORS, INCLUDING GODSON (1963), HAVE DISCUSSED THE CHANGES IN GENERAL CIRCULATION WHICH MUST HAVE ACCOMPANIED THE PALEOCLIMATIC SEQUENCE. ALSO, THESE FACTORS ARE INTERDEPENDENT AND THIS MAKES IT DIFFICULT TO ASSIGN WEIGHTS TO THE IMPORTANCE OF INDIVIDUAL VARIABLES. THERE ARE MANY THEORIES. SINCE, IN MOST CASES, THERE ARE NO DEFINITE "PROOFS" AVAILABLE, THIS IS ONE AREA WHERE THEORETICIANS CAN GIVE (AND HAVE GIVEN) FREE REIGN TO THEIR IMAGINATIONS. FOR MOST SIMPLE, OR SINGLE-CAUSE, THEORIES OF CLIMATIC CHANGE, THERE ARE COMPELLING ARGUMENTS "FOR" AND EQUALLY CONVINCING ARGUMENTS "AGAINST". HOWEVER, MOST EXPERTS NOW AGREE THAT NEITHER EXTRA-TERRESTRIAL NOR TOPOGRAPHIC EFFECTS ALONE PROVIDE A SATISFACTORY EXPLANATION OF PAST CLIMATIC VARIATIONS. MANY BELIEVE THAT ATMOSPHERIC CHANGES AFFECTING THE RADIATIVE BALANCE ARE THE MOST IMPORTANT TRIGGERING AGENTS. BUDYKO'S LATEST WORK EMPHASIZES THE IMPORTANCE AND CRITICAL NATURE OF RADIATION IN LONG-TERM CLIMATIC CHANGE WHILE STRESSING THE SUPPORTING ROLE OF OTHER FACTORS, ESPECIALLY CHANGES IN SURFACE ALBEDO. WHILE MOST EXPERTS AGREE THAT RADIATION PLAYS A SIMILAR VITAL ROLE IN DAY-TO-DAY WEATHER, THIS PARAMETER HAS BEEN SOMEWHAT NEGLECTED IN FORECAST TECHNIQUES AND MATHEMATICAL MODELS, LARGELY BECAUSE OF DIFFICULTIES IN OBTAINING ACCURATE MEASUREMENTS OF NET RADIATION.

IN ANSWER TO THE SECOND QUESTION, A PHYSICAL FACTOR WHICH MIGHT HAVE MODIFIED RADIATION IN SUCH A WAY AS TO PRODUCE THE CLIMATIC AND GLACIAL VARIATIONS OF THE PAST IS THE VARIATION IN VOLCANISM. BUDYKO (1968) STATES THAT THE REQUIRED RADIATION VARIATIONS ARE ONLY "SEVERAL TIMES AS GREAT AS THOSE OBSERVED DUE TO CHANGES IN VOLCANIC ACTIVITY DURING THE PAST CENTURY". IT HAS ALSO BEEN ESTABLISHED THAT THE MAIN EPOCHS OF QUATERNARY GLACIATIONS CORRESPONDED TO PERIODS OF CONSIDERABLE INCREASE IN VOLCANIC ACTIVITY AT LOW LATITUDES. IT SHOULD BE NOTED THAT WE ARE REFERRING HERE TO PERSISTENT VOLCANIC POLLUTION OF THE STRATOSPHERE, WHICH MODIFIES THE EARTH-ATMOSPHERE ALBEDO BY SCATTERING BUT HAS LITTLE DIRECT EFFECT ON MEAN ATMOSPHERIC WATER VAPOUR AND CLOUD CONTENT.

4. THE FUTURE

WHAT ABOUT FUTURE CLIMATIC VARIATIONS? BUDYKO(1968) STATES THAT "THE QUATERNARY HISTORY OF THE EARTH SEEMS TO BE A PERIOD OF COMING CLIMATIC CATASTROPHE DUE TO WHICH THE EXISTENCE OF HIGHER FORMS OF ORGANIC LIFE ON OUR PLANET MAY BE EXTERMINATED". BEFORE WE ALL START SIGNING UP FOR SPACE VOYAGES THERE ARE SOME IMPORTANT POINTS TO CONSIDER. MAN'S ARRIVAL ON THE SCENE HAS ALREADY BEGUN TO MODIFY THE "NATURAL" CLIMATE. THE ADDITION OF CARBON DIOXIDE AND COMBUSTION PRODUCTS TO THE ATMOSPHERE IS CHANGING THE GREENHOUSE EFFECT WHILE AT THE SAME TIME MODIFYING THE HYDROLOGIC CYCLE COMPONENTS SUCH AS EVAPORATION, CLOUDINESS AND PRECIPITATION. ACCORDING TO BUDYKO, THE HEAT PRODUCED BY MAN IN LESS THAN TWO HUNDRED YEARS WILL BE COMPARABLE TO THE ENERGY COMING FROM THE SUN. IT WOULD, INDEED, BE STRANGE IF THE COMBINED EFFECTS OF INDUSTRIALIZATION, POLLUTION AND THE POPULATION EXPLOSION, WHICH WE VIEW TODAY AS MAJOR PROBLEMS AND POTENTIAL DISASTERS, TURNED OUT TO HAVE BENEFICIAL AND CRUCIAL LONG-TERM EFFECTS IN THE PRESERVATION OF MAN.

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IN THE DECEMBER 17 CASE, THE WIND SHIFT AT THE 200-FT LEVEL OCCURRED ABOUT 0900 EST AND THERE WAS AN ASSOCIATED TEMPERATURE RISE. AT THE 20-FT LEVEL, THE WIND SHIFT AND TEMPERATURE INCREASE OCCURRED A HALF HOUR LATER, AT 0930 EST. DURING THE PERIOD 0855 TO 0920 EST, THERE WAS A TEMPERATURE INVERSION OF 8 TO 10 DEGREES. A RELATIVELY LARGE VECTOR WIND SHEAR DEVELOPED WHEN THE FRONTAL SURFACE WAS BETWEEN THE TWO LEVELS. AT 0900 EST, FOR EXAMPLE, THE WINDS AT 20 AND 200-FT WERE EAST-NORTHEAST 5 AND SOUTH-SOUTHWEST 10 MPH, RESPECTIVELY.

THE NRC OBSERVATIONS ARE GIVEN IN TABLE 2. FRONTAL PASSAGES OCCURRED BETWEEN 0200 AND 0300 EST ON NOVEMBER 13 AND BETWEEN 1100 AND 1200 EST ON DECEMBER 17.

TABLE 2 - HOURLY OBSERVATIONS FROM DIVISION OF BUILDING RESEARCH, NRC, NOVEMBER 12-13, 1964 AND DECEMBER 17, 1964 NEAR TIMES OF WARM FRONTAL PASSAGES

		WIND (MPH) (AVERAGE FOR HOUR ENDING AT INDICATED TIME)	TEMPERATURE (°F) (AT INDICATED TIME)
NOVEMBER 12	2200 EST	NE6	40
	2300 EST	NE9	40
NOVEMBER 13	0001 EST	NE4	40
	0100 EST	NE4	40
	0200 EST	SW3	39
	0300 EST	SW8	51
	0400 EST	SW13	54
DECEMBER 17	0700 EST	E5	18
	0800 EST	E4	19
	0900 EST	NE3	21
	1000 EST	SW3	27
	1100 EST	NE1	26
	1200 EST	SW12	37

THE TIMES OF FRONTAL PASSAGE ARE SUMMARIZED IN TABLE 3. FOR UPLANDS AIRPORT, THE TIME CAN BE GIVEN ONLY TO AN HOURLY INTERVAL, WHILE FOR THE TOWER 200-FT NOVEMBER CASE, THERE IS SOME QUESTION AS TO WHETHER THE FRONTAL PASSAGE OCCURRED AT 2330 EST (WIND SHIFT) OR 0100 EST (FINAL TEMPERATURE RISE).

FIGURE 3. SURFACE SYNOPTIC WEATHER MAP, 1200 GMT, DEC. 17, 1964.

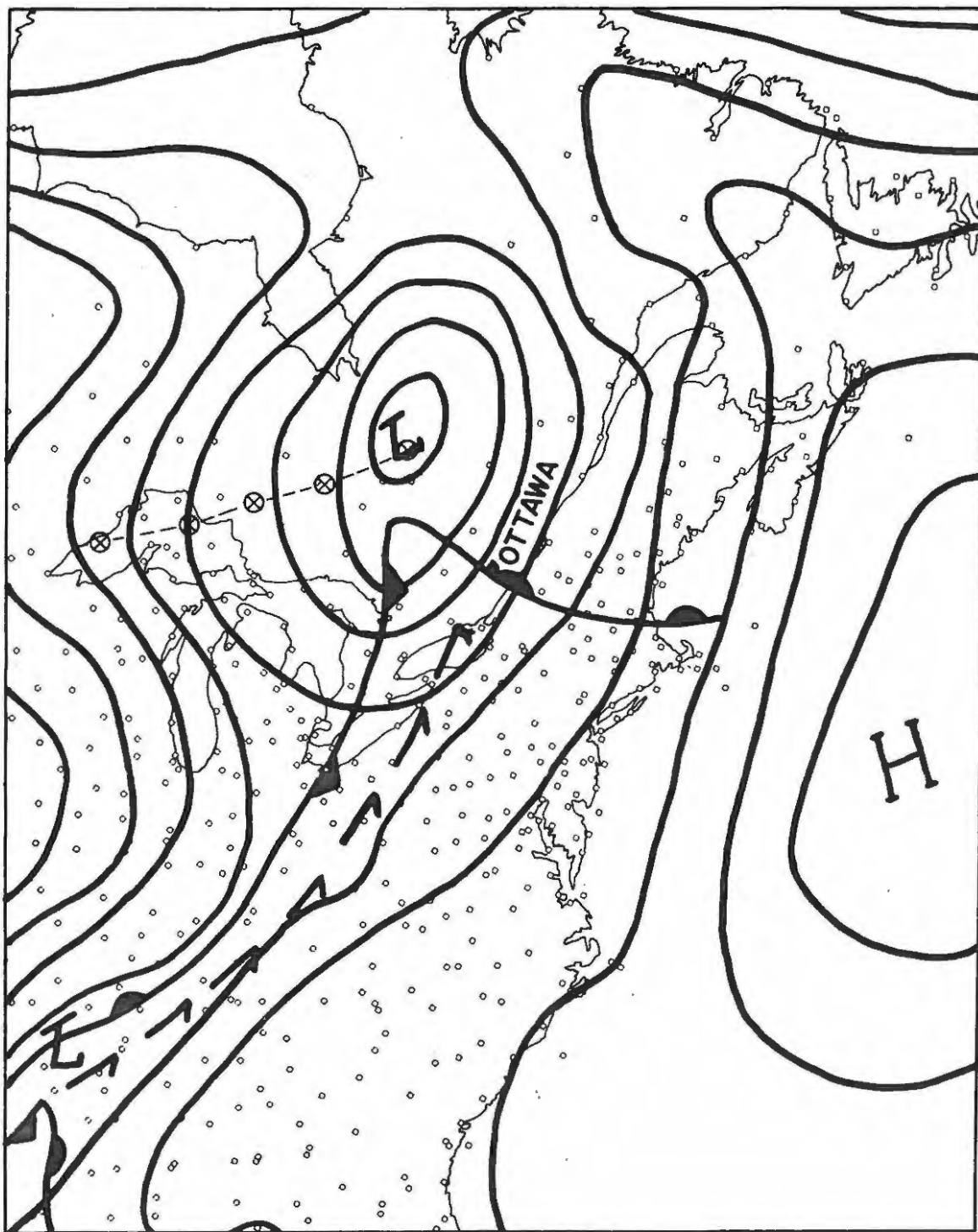


FIGURE 4. CENTRAL EXPERIMENTAL FARM TOWER WIND AND TEMPERATURE DATA,
2200 EST, NOV. 12 TO 0200 EST, NOV. 13, 1964.

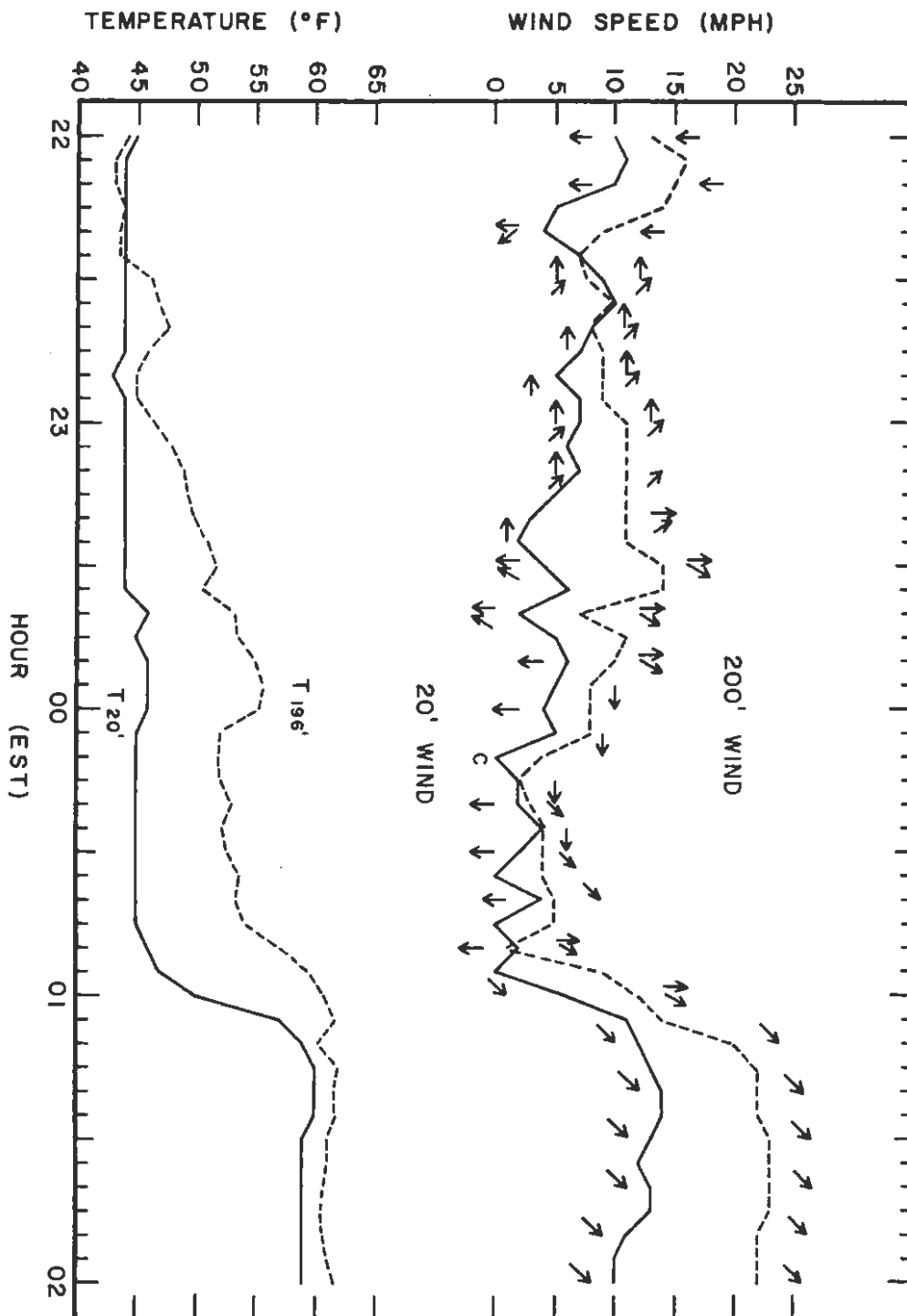


FIGURE 5. CENTRAL EXPERIMENTAL FARM TOWER WIND AND TEMPERATURE DATA,
0700 EST TO 1100 EST, DEC. 17, 1964.

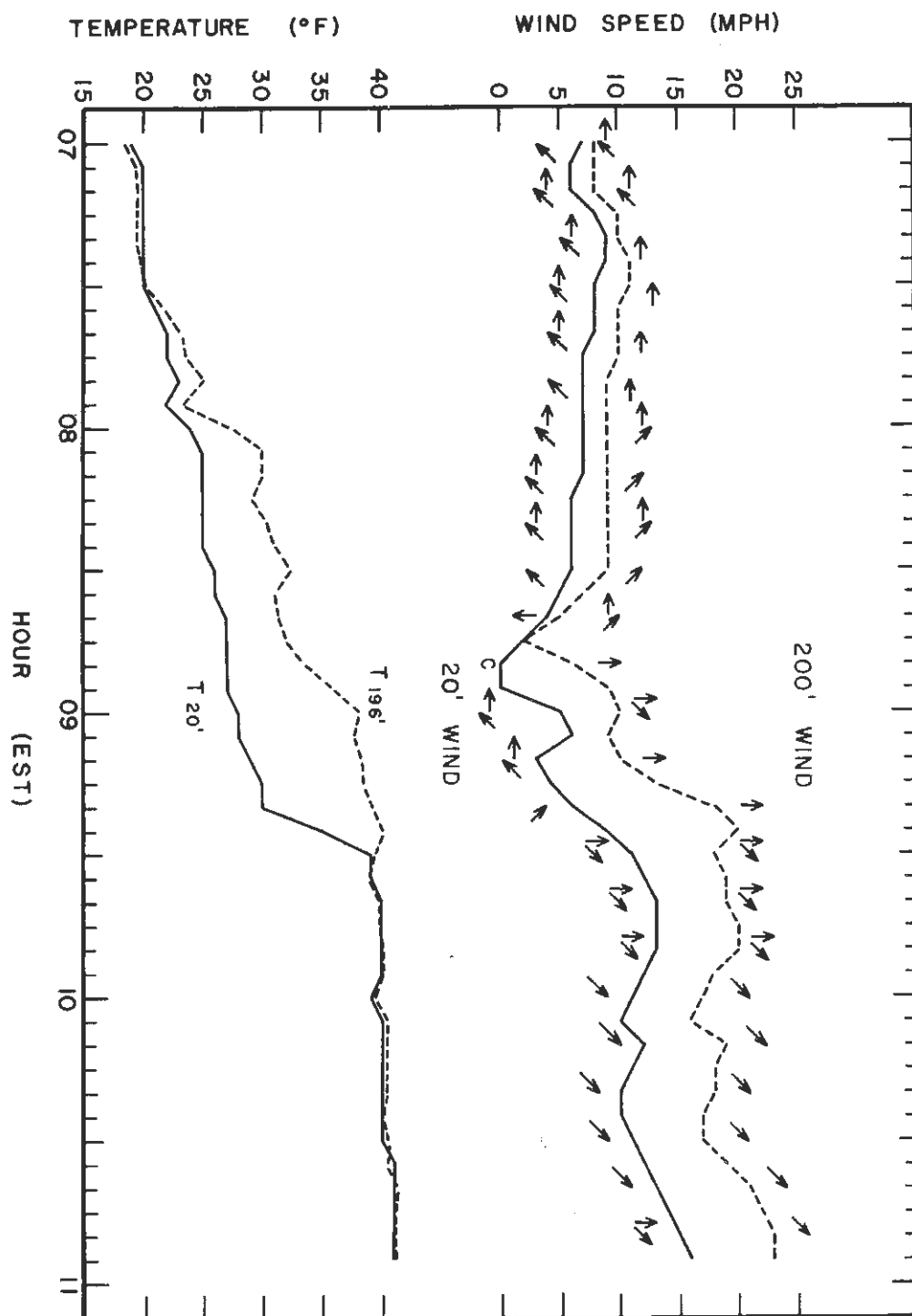


TABLE 3: SUMMARY OF TIMES OF FRONTAL PASSAGES

	NOVEMBER 12-13, 1964	DECEMBER 17, 1964
UPLANDS AIRPORT	2300 TO 2359 EST	0800 TO 0900 EST
TOWER, 200 FT	2330 EST (OR 0100 EST ?)	0 900 EST
TOWER, 20 FT	0100 EST	0930 EST
NRC	0200 TO 0300 EST	1100 TO 1200 EST

WITH BOTH WARM FRONTS ORIENTED IN A NORTHWEST-SOUTHEAST DIRECTION, AND WITH RELATIVELY BRISK SOUTHWEST WINDS IN THE WARM SECTORS, IT WOULD NOT BE EXPECTED THAT THE FRONTAL PASSAGE TIMES AT THE THREE LOCATIONS WOULD DIFFER BY SO MUCH. THE PROBABLE FACTORS OF IMPORTANCE ARE THE DIFFERENCES IN ELEVATION AND THE ADDITIONAL FRICTIONAL DRAG CREATED BY THE URBAN ROUGHNESS.

FINALLY, IT IS OF CONSIDERABLE INTEREST TO NOTE THAT IN BOTH CASES, THE 200-FT TOWER WIND DID NOT STRENGTHEN UNTIL AFTER THE FRONTAL PASSAGE AT 20 FT (FIGS. 4 AND 5). THE PROBABLE EXPLANATION IS THAT THE FRONTAL SURFACE, ACTING AS A VISCOUS-FLUID INTERFACE, CREATED FRICTIONAL DRAG AND REDUCED THE 200-FT WIND SPEED.

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EASTERN SNOW CONFERENCE

THE EASTERN SNOW CONFERENCE IS AN INTERNATIONAL GROUP OF BUSINESSMEN, ENGINEERS, FORESTERS, AND SCIENTISTS FROM EASTERN CANADA AND NORTHEASTERN UNITED STATES WHO MEET ANNUALLY FOR THE INTERCHANGE OF INFORMATION RELATED TO SNOW, ICE, FROST, HAIL, AND OTHER PHENOMENA ASSOCIATED WITH THE WINTER SEASON. MEMBERSHIP IS OPEN TO ALL INTERESTED INDIVIDUALS.

THE 1969 MEETING WILL BE HELD AT THE SHERATON - EASTLAND MOTOR HOTEL IN PORTLAND, MAINE, ON FEBRUARY 6-7TH. TEN TECHNICAL PAPERS ARE SCHEDULED FOR THE 1 $\frac{1}{2}$ DAY MEETING.

FURTHER INFORMATION MAY BE OBTAINED FROM MR. GORDON AYER, SECRETARY, P.O. BOX 948, ALBANY 1, NEW YORK, OR MR. D.N. MC MULLEN, EXECUTIVE MEMBER, E.S.C., CONSERVATION AUTHORITIES BRANCH, 880 BAY STREET, TORONTO 5, ONTARIO.

REVIEW

CLIMATOLOGY AND THE WORLD'S CLIMATES

BY GEORGE R. RUMNEY

NEW YORK

(MAC MILLAN), 1968. 656 PAGES. (\$13.75 CANADIAN)

- M. K. THOMAS -

THIS BOOK'S ANNOUNCED PURPOSE IS "TO INTRODUCE THE READER TO THE NATURE AND DISTRIBUTION OF THE WORLD'S CLIMATES". THE CLIMATES OF THE WORLD ARE DESCRIBED IN DETAIL, BUT ALTHOUGH SOME MENTION IS MADE OF THE VARIOUS ASPECTS OF SYNOPTIC METEOROLOGY AND DYNAMIC CLIMATOLOGY, IN GENERAL THEY ARE NOT DESCRIBED IN TERMS OF THE PHYSICAL METEOROLOGY WHICH PRODUCES THEM. THIS IS A THICK BOOK - PERHAPS TOO THICK, THE TEXT IS REPETITIOUS AND THE CHAPTERS LACK EFFECTIVE SUB-HEADINGS. THERE IS, TO BE SURE, SOME DULLNESS INHERENT IN ANY BOOK DEALING WITH DESCRIPTIVE CLIMATOLOGY, BUT MUCH OF THIS COULD HAVE BEEN AVOIDED BY A LIVELIER STYLE AND THROUGH THE USE OF MORE PICTURES AND ILLUSTRATIONS.

THE BOOK CONTAINS AN ABUNDANCE OF MAPS, ALTHOUGH AS IN MANY AMERICAN TEXTS, COVERAGE OF THIS CONTINENT IS LARGELY LIMITED TO MAPS OF THE CONTINENTAL UNITED STATES. MANY CLIMATIC DATA ARE PRESENTED IN BOTH TABULAR AND GRAPHICAL FORM, THIS REVIEWER, HOWEVER, FINDS SERIOUS FAULTS WITH BOTH. DATA FROM REGIONS OUTSIDE OF THE UNITED STATES AND CANADA WERE OBTAINED FROM OBSCURE PUBLICATIONS INSTEAD OF FROM NATIONAL OR WORLD METEOROLOGICAL ORGANIZATION DATA PUBLICATIONS, AND THE GRAPHS SHOWING THE ANNUAL MARCH OF TEMPERATURE ARE INCORRECT IN MANY INSTANCES BECAUSE OF THE DRAFTSMAN'S FAULTY HANDLING OF DECEMBER AND JANUARY DATA (THAT IS, WHEN AN ANNUAL GRAPH COVERS 14 MONTHS, ONE END OF THE CURVE SHOULD BE THE IMAGE OF THE OTHER).

THE REFERENCES GIVEN AT THE END OF EACH CHAPTER MIGHT WELL HAVE BEEN MORE EXTENSIVE, AND MANY OF THE REFERENCES GIVEN ARE NON-METEOROLOGICAL IN CHARACTER. UNFORTUNATELY, THE REFERENCES GIVEN ARE NOT A SATISFACTORY GUIDE TO THE MANY EXCELLENT CLIMATOLOGICAL BOOKS AND ARTICLES WHICH HAVE NOW BEEN PUBLISHED.

THERE ARE ALSO A FEW OBVIOUS ERRORS IN THE TABLES AND GRAPHS, FOR EXAMPLE, ON PAGE 209, VANCOUVER TEMPERATURES ARE SHOWN AS BEING 10 DEGREES HIGHER THAN THEY ARE, WHILE ON PAGE 344 THE LATITUDE LINES ARE LABELLED INCORRECTLY.

IN SUMMARY: THIS IS A STANDARD DESCRIPTIVE CLIMATOLOGICAL TEXT-BOOK, PERHAPS TO BE RECOMMENDED FOR NON-SCIENCE UNDERGRADUATES, OR AS AN ADDITION TO A LARGE CLIMATOLOGICAL LIBRARY, BUT CERTAINLY NOT AS THE ONLY TEXT-BOOK IN CLIMATOLOGY FOR A METEOROLOGIST'S LIBRARY.

NOVEMBER 11, 1968

MR. J. MCCULLOCH
EDITOR ATMOSPHERE
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TORONTO, ONTARIO

DEAR MR. MCCULLOCH:

IT WAS A PLEASURE TO HEAR AGAIN THROUGH THE PAGES OF ATMOSPHERE FROM MY FELLOW COLLEAGUES IN METEOROLOGY, DR. K.D. HAGE, WITH WHOM I GRADUATED FROM THE UNIVERSITY OF TORONTO IN 1950, AND OR. C. MATEER, WITH WHOM I WORKED AS A FORECASTER AT MALTON. I ENJOYED THEIR COMMENTS REGARDING THE ROSE REPORT WHICH I HAVE SUBSEQUENTLY READ.

I WAS PARTICULARLY INTERESTED IN OR. HAGE'S SECOND LAST PARAGRAPH ON PAGE 13 OF VOL. 6 NO. 1 IN WHICH HE DESCRIBES A NATIONAL CENTRE WHICH SHOULD EMBRACE -----". FROM THIS POINT ON, THE SUBJECT MATTER READS VERY MUCH LIKE MY JOB DESCRIPTION HERE AT ONTARIO HYDRO WHICH I JOINED IN 1953. FOR ANY OF MY FELLOW METEOROLOGISTS WHO MAY NOT KNOW, ONTARIO HYDRO PRESENTLY EMPLOY THREE METEOROLOGISTS WHO HAVE OR ARE WORKING ON STUDIES OF AIR-SEA INTERACTIONS WHICH AFFECT LAKE ERIE ELEVATIONS AND NIAGARA RIVER FLOWS, WATER RESOURCE FORECASTS, ESTIMATES OF SPRING BREAK-UP AND VOLUME OF SPRING FRESHETS, AIR POLLUTION CLIMATOLOGY AND DIFFUSION FOR THERMAL PLANT DESIGN, CORRELATIONS OF WEATHER VARIABLES WITH SYSTEM DEMANDS, FORECASTS AND EFFECT OF ICE ON HYDRAULIC AND THERMAL GENERATING STATIONS, PROVIDE CLIMATOLOGICAL CONSULTING FOR DESIGN OF PLANTS, LINES ETC. AND OF COURSE THE INEVITABLE TAILOR-MADE DAILY FORECASTS FOR HYDRO'S OPERATIONS. SOME OF THESE PROJECTS ARE CARRIED OUT IN CO-OPERATION WITH CIVIL, ELECTRICAL AND CHEMICAL ENGINEERS AND OPERATIONS RESEARCH STAFF. IN ADDITION, HYDRO WAS INVOLVED WITH THE EARLIEST ERA OF WEATHER MODIFICATION IN CO-OPERATION WITH NRC OVER THE FROZEN MUSKES OF NORTHERN ONTARIO IN 1948, AND LATER IN A PROJECT WHICH PRODUCED LIVELY PUBLIC RELATIONS CONSEQUENCES IN 1965. I DID NOT REALIZE UNTIL I READ DR. HAGE'S LETTER, THAT WE HAVE HAD AN INSTITUTE HERE AT ONTARIO HYDRO FOR THE PAST FIFTEEN YEARS!

I ALSO AGREE WITH THE MATEER THEOREM THAT "THE USEFULNESS OF A COMPUTER IS INVERSELY PROPORTIONAL TO THE SQUARE OF ITS DISTANCE FROM THE USER". SCIENTISTS, INCLUDING METEOROLOGISTS, CANNOT SURVIVE WITHOUT READY ACCESS TO COMPUTERS, ACTUAL OR VIA TERMINALS, ANY MORE THAN AN ENGINEER OF 10 YEARS AGO COULD LIVE WITHOUT A SLIDE-RULE.

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I AGREE WITH THE STATEMENT MADE BY MR. CAMERON THAT "THE PROBLEM MAY BE WITH CANADA'S EDUCATIONAL PROGRAM". THERE IS AMPLE REASON WHY MORE METEOROLOGY SHOULD BE TAUGHT FROM GRADE 7 ONWARD - ANYTHING THAT AFFECTS PEOPLE'S LIVES AS MUCH AS "WEATHER" SHOULD BE ANALYZED A LITTLE MORE CLOSELY AT AN EARLY AGE AND CONTINUED INTO UNIVERSITY. I WOULD FURTHER SUGGEST THAT COMPANIES AND GOVERNMENT DEPARTMENTS REQUIRING METEOROLOGICAL ADVICE SHOULD HIRE METEOROLOGISTS, NOT BORROW THEM - THIS IS ONE WAY THAT MR. CAMERON'S PROBLEM OF "LACK OF APPRECIATION OR UNDERSTANDING OF THE APPLICATIONS OF METEOROLOGY" WILL BE SOLVED. IT IS MY OPINION THAT THE METEOROLOGICAL SERVICE HAS PASSED THROUGH THE ERA WHEN THEY COULD PROVIDE EVERYTHING METEOROLOGICAL TO EVERYBODY - INCLUDING PROVISION OF A CONSULTANT SERVICE. IT IS LONG OVERDUE THAT QUALIFIED METEOROLOGISTS OPERATING PRIVATELY, IN COMPANIES OR WITH CONSULTANTS FULFILL THE ROLE OF APPLYING THE RESULTS OF METEOROLOGICAL RESEARCH, CLIMATOLOGICAL DATA, ETC. TO MANY OF THE NEEDS OF SOCIETY - IT IS EXPECTED THAT THIS WOULD STRENGTHEN, NOT WEAKEN, THE METEOROLOGICAL SERVICE BY PROLIFERATION OF THEIR PRESENT KNOWLEDGE AND BY BETTER FEED-BACK FROM THE USERS.

STEALING A LEAF FROM MATEER'S LETTER, I WOULD LIKE TO SUGGEST THE GILLIES' THEORY WHICH HAS DEVELOPED FROM 15 YEARS OF EXPERIENCE WORKING IN AN ORGANIZATION OF OVER 1,000 ENGINEERS AND SCIENTISTS, THAT IS, THE USEFULNESS OF A METEOROLOGIST - RESEARCHER, FORECASTER OR CLIMATOLOGIST - IS INVERSELY PROPORTIONAL TO THE TIME IT TAKES TO FIND ONE TO ANSWER YOUR QUESTION.

APPARENTLY, IT WAS AN OVERSIGHT WHICH LED DR. ROSE'S COMMITTEE TO OMIT REFERENCE TO THE PIONEERING WORK IN WEATHER MODIFICATION (DEVELOPMENT AND USE OF A GROUND LAUNCHED ROCKET) AND IN AIR POLLUTION STUDIES IN MONTREAL CARRIED OUT BY WEATHER ENGINEERING CORPORATION IN MONTREAL. ALSO, THE PRESENCE OF A METEOROLOGIST WORKING ON APPLIED HYDRO-METEOROLOGY, AIR POLLUTION ETC. AT H.G. ACRES ENGINEERING FIRM DESERVES MENTION. IT IS ALSO WORTHY OF NOTE THAT ONTARIO HYDRO HAVE PROVIDED OPPORTUNITY AND TRAINING IN AIR POLLUTION METEOROLOGY TO ONE METEOROLOGIST WHO HAS RECENTLY MOVED INTO A RESPONSIBLE POSITION WITH THE ONTARIO AIR POLLUTION CONTROL SERVICE.

IN CONCLUSION, IT IS HOPED THAT THIS BRIEF REFERENCE TO APPLIED RESEARCH IN METEOROLOGY OUTSIDE THE FEDERAL GOVERNMENT AND UNIVERSITY CIRCLES WILL BE OF INTEREST TO ATMOSPHERE'S READERS. IT IS EXPECTED THAT INCREASING NUMBERS OF GRADUATE METEOROLOGISTS WILL BE AVAILABLE TO FILL THIS EXPANDING REQUIREMENT AND THAT THE METEOROLOGICAL SERVICE OF CANADA WILL FULLY ENCOURAGE AND SUPPORT ITS GROWTH.

YOURS TRULY,

D.K.A. GILLIES
SENIOR METEOROLOGIST
OPERATIONS DIVISION
ONTARIO HYDRO

THE CANADIAN METEOROLOGICAL SOCIETY

LA SOCIÉTÉ MÉTÉOROLOGIQUE DU CANADA

THE CANADIAN METEOROLOGICAL SOCIETY CAME INTO BEING ON JANUARY 1, 1967, REPLACING THE CANADIAN BRANCH OF THE ROYAL METEOROLOGICAL SOCIETY, WHICH HAD BEEN ESTABLISHED IN 1940. THE SOCIETY EXISTS FOR THE ADVANCEMENT OF METEOROLOGY AND MEMBERSHIP IS OPEN TO PERSONS AND ORGANIZATIONS HAVING AN INTEREST IN METEOROLOGY. THERE ARE LOCAL CENTRES OF THE SOCIETY IN SEVERAL OF THE LARGER CITIES OF CANADA WHERE PAPERS ARE READ AND DISCUSSIONS HELD ON SUBJECTS OF METEOROLOGICAL INTEREST. ATMOSPHERE IS THE OFFICIAL PUBLICATION OF THE SOCIETY. SINCE ITS FOUNDING, THE SOCIETY HAS CONTINUED THE CUSTOM BEGUN BY THE CANADIAN BRANCH OF THE RMS OF HOLDING AN ANNUAL CONGRESS EACH SPRING, WHICH SERVES AS A NATIONAL METEOROLOGICAL CONGRESS.

FOR FURTHER INFORMATION REGARDING MEMBERSHIP, PLEASE WRITE TO THE CORRESPONDING SECRETARY, CANADIAN METEOROLOGICAL SOCIETY, P.O. BOX 851, ADELAIDE STREET POST OFFICE, TORONTO 1, ONTARIO.

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