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Bulletin climatologique

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Contributors should submit manuscripts to Alexander H. Paul, editor, CLIMATOLOGICAL BULLETIN, Department of Geography, University of Regina, Regina, Saskatchewan, S4S 0A2. All manuscripts should be typed double spaced on one side of good quality white paper, 28 cm x 21.5 cm, or its nearest equivalent. The abstract, list of references, tables, and a list of figure captions should be typed doubled spaced on separate sheets. Comments (including book reviews and opinions) and news items should not exceed 1 500 words. Furnish an original and three copies if possible, in the order listed below.

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Publication de la Société canadienne de météorologie et d'océanographie, le Bulletin climatologique offre un moyen d'information sur la climatologie. Le comité de rédaction encourage en particulier la soumission de manuscrits sur la climatologie appliquée (comme l'agriculture, le commerce, l'énergie, l'environnement, la pêcherie, la sylviculture, la santé, les loisirs, les transports, et les ressources en eau), les changements et la variabilité du climat, la prospective climatologique, les applications des modèles du climat (inclus la climatologie physique), et les études régional (inclus les océans). Il est publié grâce à une subvention accordée par le gouvernement canadien par l'intermédiare du Conseil de recherches en sciences naturelles et en génie.

Les auteurs peuvent choisir de soumettre leurs manuscrits aux "Articles", "Notes de Recherches", ou "Nouvelles et Commentaires". Ils doivent l'indiquer sur la lettre d'accompagnement du manuscrit. Les articles de recherche et les "Notes" sont indépendamment soumis à l'examen d'au moins deux appréciateurs anonymes. Le rédacteur en chef examine les "Nouvelles et Commentaires" conjointement avec le comité de rédaction. On accepte les articles soit en français, soit en anglais. Il faut envoyer un résumé, de préférence en français et en anglais.

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Vol. 23, No. 3, December/décembre 1989

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Foreword / Avant-Propos

This is the final *Climatological Bulletin* of the 1980's. It looks as though the 1990's will be a critical decade for the environment, of which climate is a key sector. The climate community in Canada is growing, and the *Bulletin* should play an increasing role as an outlet for climate research. We continue to receive manuscripts on a diverse array of subjects, but the flow remains uneven. Six in the past three months is a lot more encouraging than the solitary one which arrived in the second quarter of the year. Good manuscripts on climatological research are always welcome, and more are needed if the *Bulletin* is to fulfil its potential.

C'est le dernier *Bulletin climatologique* des années quatre-vingts. Plusieurs prétendent que les années quatre-vingt-dix seront une décennie critique pour ce qui est de l'environnement, dont le climat s'annonce très significatif. La communauté climatique canadienne accroît actuellement et le *Bulletin* devrait jouer un rôle croissant comme revue de recherche en climat. Il continue à recevoir des manuscrits sur une gamme énorme de sujets, mais ils arrivent irrégulièrement: six les derniers trois mois, mais un seul en deuxième quart de l'an. On accueille toujours de bons manuscrits portant sur des recherches climatologiques, et l'écoulement doit se maintenir si le *Bulletin* va atteindre son potentiel.

Alec Paul
Editor/Rédacteur en chef

An Operational Agrometeorological Information System for the Canadian Prairies

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ABSTRACT

A set of weekly crop-specific Agrometeorological Bulletins and Outlooks for the Prairies is being produced by the Winnipeg Climate Centre, Environment Canada. Separate Bulletins and Outlooks are produced for at least one cultivar in each major class of Prairie crops – cereals (wheat and barley), oilseeds (canola), row crops (corn) and perennial forages (alfalfa). A sixth Bulletin contains heat units correlated with the phenology of certain insect pests (grasshoppers, corn borers, etc.) and the moisture status of fallowed fields.

All of the synoptic, daily and weekly reporting sites in the agricultural areas of Alberta, Saskatchewan, Manitoba and northwestern Ontario are listed in the Bulletins and Outlooks. The one exception is the row crop information which only covers Manitoba. The Agrometeorological Bulletins and Outlooks are available in tabular form via conventional and electronic mail services. Soil moisture maps are disseminated by telephone-facsimile.

RÉSUMÉ

Le Centre climatologique de Winnipeg (Environnement Canada) s'occupe actuellement de la rédaction d'une série hebdomadaire de "Bulletins et perspectives agrométéorologiques" (Prairies). Des "Bulletins et perspectives" distincts s'appliqueront à au moins un cultivar dans chacune des classes principales des cultures des Prairies, à savoir : céréales (blé et orge), oléagineux (canola), cultures en lignes (maïs) et plantes fourragères vivaces (luzerne). Un sixième bulletin renferme les unités de chaleur qui sont en corrélation avec la phénologie de certains insectes ravageurs (sauterelles, pyrales du maïs) et la teneur en eau des terres en jachère.

Tous les lieux diffusant des renseignements synoptiques, quotidiens et hebdomadaires qui sont compris dans les régions agricoles de l'Alberta, de la Saskatchewan, du Manitoba et du nord-ouest de l'Ontario sont listés dans les "Bulletins et perspectives". Les renseignements sur les cultures en lignes est la seule exception a cette disposition

puisqu'ils ne couvrent que le Manitoba. Les "Bulletins et perspectives agrométéorologiques" se présentent sous forme de tableaux et sont transmis par courrier ordinaire et électronique. Les cartes de teneur en eau du sol sont diffusées par télécopieur (fac-similés).

1. INTRODUCTION

This paper describes the Winnipeg Climate Centre's Agrometeorological Bulletins and Outlooks. The near real-time climate monitoring procedures, the foundation for the agrometeorological products, are briefly outlined in Section 2. The "generic model" used to transform the basic weather data into proxy agrometeorological parameters is sketched in Section 3. The tabular Bulletins and Outlooks and the geographical mapping of selected elements are also described. Section 4 outlines some Manitoba field measurements of soil moisture and the use of these data to adjust the model's "tracking" of actual conditions. Section 5 is a brief summary.

Agrometeorological information systems may be categorized as:

i. Farm Weather Forecasts – These forecasts include predictions for weather elements which have an impact on selected crops or cultural practices. The rural format for Public Forecasts, employed by Environment Canada since 1985, is an example of this type of information system.

ii. Agroclimatic Risk Assessments – The probability or risk-of-occurrence of selected climatic conditions is provided based on an analysis of historical weather records. An example is given in the Manitoba Agriculture publication, *Southern Manitoba's Climate and Agriculture* (Dunlop and Shaykewich, 1982).

iii. Agrometeorological Bulletins and Outlooks – The current growing season's weather is monitored in near real-time to provide, via simulations, proxy data for selected biometeorological elements such as growth-stage and moisture-stress for specific crops, and the phenology of certain insect pests and diseases. Outlooks project the state of the biometeorological elements at a future date or crop-stage (Raddatz, 1987a). The Weekly Weather and Crop Bulletin, produced jointly by the United States Department of Agriculture and the National Weather Service, and Agriculture Canada's Soil Moisture Evaluation Project, are examples of this form of agrometeorological information system.

iv. Agrometeorological Advisories – Specific advice about emerging or anticipated agricultural problems is offered to farmers based on a consideration of biological survey data and proxy data from biometeorological simulations. The British Meteorological Service's Agricultural Disease and Pest Warnings are one example.

Thus, it can be seen that Agrometeorological Bulletins/Outlooks are but one type of agrometeorological information system; however, they may be the most important. They allow an assessment of the current growing-season against the yardstick of climatic risk and they are a major building block of agrometeorological advisories. Operational agrometeorological systems of this type, according to Baier (1977), interpret current and immediate past weather in terms that are meaningful in weather-sensitive agricultural situations.

The set of Agricultural Bulletins and Outlooks for the Canadian Prairies routinely produced at Environment Canada's Winnipeg Climate Centre and distributed to various agri-businesses and agencies is described here. Each of the recipients has a requirement to monitor crop growth and vitality. Application areas range from yield forecasting for processing, marketing and equipment sales, to integrated pest management, to the provision of agricultural extension advice, to drought monitoring.

2. NEAR REAL-TIME CLIMATE MONITORING

What was last week's weather across the Prairies? What has the growing-season been like to date? In order to answer these sorts of questions with a higher spatial resolution than that provided by the synoptic weather network, temperature extremes and daily precipitation observations are collected at daily or weekly intervals from a sub-set of the climatological network during the late-winter, spring and growing-season (i.e., February through October). There are approximately 150 sites, a four-fold increase over the synoptic network alone, resulting in an average spacing, $\bar{d}$, of about 100 km. Currently, volunteer climate observers phone their data to a nearby weather station operated by the Atmospheric Environment Service. These weather stations function as hubs – each station collects the observations from a number of climate sites and then forwards this information to the Winnipeg Climate Centre via existing data collection circuits. The near real-time network also includes a few automatic sites with data-loggers. These sites are polled and their observations are assembled into pseudo-synoptic reports by the regional computer. In Winnipeg, the data messages, regardless of type, are automatically decoded and computer assisted quality-control screening is undertaken.

2.1 *Spatial Representativeness of Data and Bogusing*

The Prairie climate is semi-arid; precipitation is adequate to support plant growth with more falling during the height of the growing season (May through August) than during other seasons (Longley, 1972). Summer rainfall, the region's most critical and most highly variable climatic element, is produced by three scales of atmospheric disturbances – synoptic cyclones, organized frontal lines and localized convection. These perturbations have horizontal dimensions of the order 1 to 10^3 km (Holton, 1972).

Barnes' (1964) interpolation technique is used to estimate missing daily precipitation amounts. The scheme, which is consistent with the linear perturbation conceptualization of atmospheric fields, estimates missing data by a weighted average of all observations within a specified radius of influence, $R = 1.6\,\bar{d}$. The weights fall off exponentially with distance. This technique represents completely the effects of atmospheric perturbations with half wavelength $L \geq 4\bar{d}$, partially represents disturbances with $\bar{d} < L$ $4\bar{d}$ and filters perturbations with $L \leq \bar{d}$. Applied to the near real-time precipitation network on Canada's Prairies, where the average station spacing is about 100 km, this means that, in the main, only the spatial variations of rainfall due to disturbances with horizontal dimensions of 10^2 to 10^3 km are included in interpolated point values or in maps of the precipitation field. This includes synoptic cyclones and organized frontal lines but not local convective activity.

Raddatz and Kern (1984) determined the probable magnitude of errors associated with interpolating precipitation values from the near real-time network to an ungauged point or with the construction of the continuous precipitation field. Three sampling periods were considered – a growing-season, a month and one day. The interpolation error as a percentage of the concurrent area average or the coefficient of variation decreases as the sampling period increases. Growing-season precipitation totals can be approximated to within 20%; for summer monthly amounts, the error is about 45%; for daily totals, it is generally over 100%.

It follows that, even for cumulative fields such as season-to-date precipitation and soil moisture, the current near real-time network can, at best, provide site-specific information and represent the agrometeorological conditions on a regional scale.

The Barnes interpolation scheme is also used to fill in missing daily maximum and minimum temperatures. These display less spatial variability than daily summer rainfall amounts. Mapped temperature fields thus have greater spatial representativeness than that exhibited by rainfall analyses.

3. AGROMETEOROLOGICAL BULLETINS AND OUTLOOKS FOR THE PRAIRIES

Specific Agrometeorological Bulletins and Outlooks are published for at least one cultivar in each major class of Prairie crops – cereals (wheat and barley), oilseeds (canola), row crops (corn) and perennial forages (alfalfa). A sixth Bulletin is tuned to the phenology of selected insect pests (grasshoppers, corn borers, etc.) and the moisture status of fallowed fields. Each Bulletin lists weekly rainfall totals plus season-to-date accumulations, with normals, of precipitation and an appropriate heat unit. Modelled weekly actual evapotranspiration and moisture stress (i.e., available water supply minus the crop's demand), and the current available soil moisture values are also listed (Table 1). Each Outlook tabulates season-to-date heat units (the BMT column in Table 2), the current available soil moisture and the accumulated moisture stress. The date of maturity for each crop, the projected total water-use (i.e., total evapotranspiration) and the accumulated moisture stress at

TABLE 1. Sample Bulletin
Environment Canada – Winnipeg Climate Centre
Agrometeorological Bulletin for Manitoba for Wheat

Biometeorological-Time and Moisture Status

For the period May 30 to June 5, 1988

Crop		Period				Season-to-Date		
Dst	Location	ET	PCPN	STRS	Planted	BMT (%N)	PCPN (%N)	SOIL (%C)
1	Turtle Mtn. 11	29.8	11.0	0	May 9	2.1(112)	39(65)	152(76)
	Pierson	26.0	0.0	0	May 16	1.9(17)	3(7)	119(60)
2	Brandon	25.5	2.6	−2	May 16	2.0(125)	5(12)	98(49)
	Cypress River	30.9	24.0	0	May 9	2.1(111)	32(55)	157(79)
	Virden	25.3	0.0	0	May 16	1.9(116)	7(20)	103(68)
3	Birtle	27.3	7.1	0	May 16	2.0(126)	24(62)	108(72)
	Neepawa Water	26.5	2.0	0	May 16	2.0(114)	12(32)	101(67)
	Oakner	27.4	0.0	0	May 16	2.0(123)	11(29)	102(68)
4	Rossburn	17.3	10.6	0	May 23	1.4(103)	11(38)	124(83)
	Russell	17.9	4.0	0	May 23	1.5(115)	5(21)	119(79)
5	Swan River	18.3	1.2	0	May 23	1.5(118)	12(45)	124(82)
	The Pas	12.1	0.0	0	May 30	1.0(113)	0(0)	126(84)
	Pine River	17.7	Tr.	0	May 23	1.5(116)	4(11)	123(82)
6	Dauphin	16.0	26.6	0	May 23	1.4(107)	28(96)	213(95)
	Wilson Creek	25.4	1.8	0	May 16	1.8(111)	5(8)	150(75)
7	Gladstone S.	27.7	2.8	0	May 16	1.9(111)	8(17)	147(73)
	Grass River	27.1	7.6	0	May 16	1.9(118)	16(36)	129(74)
	Portage Man.	32.4	1.2	0	May 9	2.2(114)	6(9)	130(65)
	Starbuck	32.6	Tr.	−4	May 2	2.1(102)	36(45)	116(46)
8	Altona	35.4	0.0	−1	May 2	2.3(111)	35(49)	132(53)
	Baldur	30.6	6.0	0	May 9	2.1(114)	20(37)	93(62)
	Deerwood	33.6	14.6	0	May 2	2.3(109)	44(51)	147(65)
	Emerson	36.2	0.2	0	May 2	2.4(112)	39(53)	135(54)
	Morden CDA	34.2	0.0	−1	May 2	2.3(111)	21(26)	113(50)
	Plum Coulee	34.6	0.0	−2	May 2	2.3(106)	27(32)	95(48)
	Pilot Mound 2	29.2	7.0	0	May 9	2.0(110)	18(30)	137(69)
9	Steinbach	33.6	0.0	−2	May 2	2.3(113)	48(62)	97(48)
	Winnipeg	35.5	0.2	0	May 2	2.3(109)	30(37)	141(56)
	Ostenfeld	29.1	0.0	0	May 9	1.9(106)	47(75)	92(61)
	Glenlea	35.2	0.2	0	May 2	2.3(112)	43(57)	165(66)
10	Pinawa WNRE	30.6	4.0	0	May 9	2.0(108)	45(71)	141(71)
	Sprague	31.0	0.0	−4	May 2	2.1(108)	40(55)	63(42)
	Bissett	25.0	25.8	0	May 16	1.7(103)	52(109)	235(94)
	Zhoda	28.6	0.0	−8	May 2	2.3(109)	25(34)	55(37)
11	Stony Mountain	35.4	0.5	0	May 2	2.2(104)	33(42)	107(54)
12	Broad Valley	24.7	26.2	0	May 16	1.8(116)	38(86)	184(92)
	Gimli	26.9	16.0	0	May 9	2.0(101)	27(46)	165(82)
	Lundar	26.3	4.0	0	May 16	1.9(115)	8(22)	104(69)

BMT – Biometeorological-Time
– Season-to-date BMT for wheat
0 – Planting 1 – Emergence 2 – Jointing
3 – Heading 4 – Soft dough 5 – Ripe
ET – Estimated evapotranspiration (mm)
PCPN – Precipitation (mm)
STRS – Moisture supply minus crop water demand (mm) (zero = nil stress)
SOIL – Modelled available soil moisture reserve (mm)
%N – Percent of normal
%C – Percent of available water holding capacity

Normals used in percentage calculations are for the period 1951–1980.

TABLE 2. Sample Outlook
Environment Canada – Winnipeg Climate Centre
Agrometeorological Outlook for Manitoba for Wheat

Biometeorological-Time and Moisture Status

Crop Dst	Location	Season to June 5, 1988 Planted	BMT (%N)	SOIL (%C)	STRS	Season to Ripe (5) OTLK	ET	STRS
1	Turtle Mtn. 11	May 9	2.1(112)	152(76)	0	Aug. 6	306	−20
	Pierson	May 16	1.9(117)	119(60)	0	Aug. 10	271	−69
2	Brandon	May 16	2.0(125)	98(49)	−2	Aug. 10	265	−69
	Cypress River	May 9	2.1(111)	157(79)	0	Aug. 5	315	−16
	Virden	May 16	1.9(116)	103(68)	0	Aug. 10	277	−51
3	Birtle	May 16	2.0(126)	108(72)	0	Aug. 13	297	−37
	Neepawa Water	May 16	2.0(114)	101(67)	0	Aug. 8	271	−32
	Oakner	May 16	2.0(123)	102(68)	0	Aug. 12	285	−45
4	Rossburn	May 23	1.4(103)	124(83)	0	Aug. 22	309	−16
	Russell	May 23	1.5(115)	119(79)	0	Aug. 21	276	−44
5	Swan River	May 23	1.5(118)	124(82)	0	Aug. 18	287	−35
	The Pas	May 30	1.0(113)	126(84)	0	Aug. 30	270	−20
	Pine River	May 23	1.5(116)	123(82)	0	Aug. 30	324	−34
6	Dauphin	May 23	1.4(107)	213(95)	0	Aug. 20	319	−6
	Wilson Creek	May 16	1.8(111)	150(75)	0	Aug. 11	299	−22
7	Gladstone S.	May 16	1.9(111)	147(73)	0	Aug. 10	292	−44
	Grass River	May 16	1.9(118)	129(74)	0	Aug. 10	287	−45
	Portage Man.	May 9	2.2(114)	130(65)	0	Aug. 1	287	−25
	Starbuck	May 2	2.1(102)	116(46)	−4	Aug. 3	298	−52
8	Altona	May 2	2.3(111)	132(53)	−1	Jul. 28	289	−34
	Baldur	May 9	2.1(114)	93(62)	0	Aug. 7	299	−40
	Deerwood	May 2	2.3(109)	147(65)	0	Jul. 29	303	−13
	Emerson	May 2	2.1(102)	135(54)	0	Jul. 27	297	−27
	Morden CDA	May 2	2.3(111)	113(50)	−1	Jul. 28	277	−39
	Plum Coulee	May 2	2.3(106)	95(48)	−2	Jul. 28	282	−50
	Pilot Mound 2	May 9	2.0(110)	137(69)	0	Aug. 10	310	−28
9	Steinbach	May 2	2.3(113)	97(48)	−2	Jul. 30	290	−43
	Winnipeg	May 2	2.3(109)	141(56)	0	Jul. 31	298	−28
	Ostenfeld	May 9	1.9(106)	92(61)	0	Aug. 12	311	−43
	Glenlea	May 2	2.3(112)	165(66)	0	Aug. 1	317	−17
10	Pinawa WNRE	May 9	2.0(108)	141(71)	0	Aug. 11	313	−20
	Sprague	May 2	2.1(108)	63(42)	−4	Aug. 8	309	−58
	Bissett	May 16	1.7(103)	235(94)	0	Aug. 17	336	−1
	Zhoda	May 2	2.3(109)	55(37)	−8	Aug. 1	280	−54
11	Stony Mountain	May 2	2.2(104)	107(54)	0	Aug. 1	274	−64
12	Broad Valley	May 16	1.8(116)	184(92)	0	Aug. 15	317	−17
	Gimli	May 9	2.0(101)	165(82)	0	Aug. 9	293	−14
	Lundar	May 16	1.9(115)	104(69)	0	Aug. 8	272	−45

BMT – Biometeorological-Time
– Season-to-date BMT for wheat
0 – Planting 1 – Emergence 2 – Jointing
3 – Heading 4 – Soft dough 5 – Ripe
SOIL – Modelled available soil moisture reserve (mm)
OTLK – Projected date-of-maturity
ET – Estimated evapotranspiration (mm)
STRS – Moisture supply minus crop water demand (mm) (zero = nil stress)
%N – Percent of normal
%C – Percent of available water holding capacity

Normals used in percentage calculations are for the period 1951–1980.

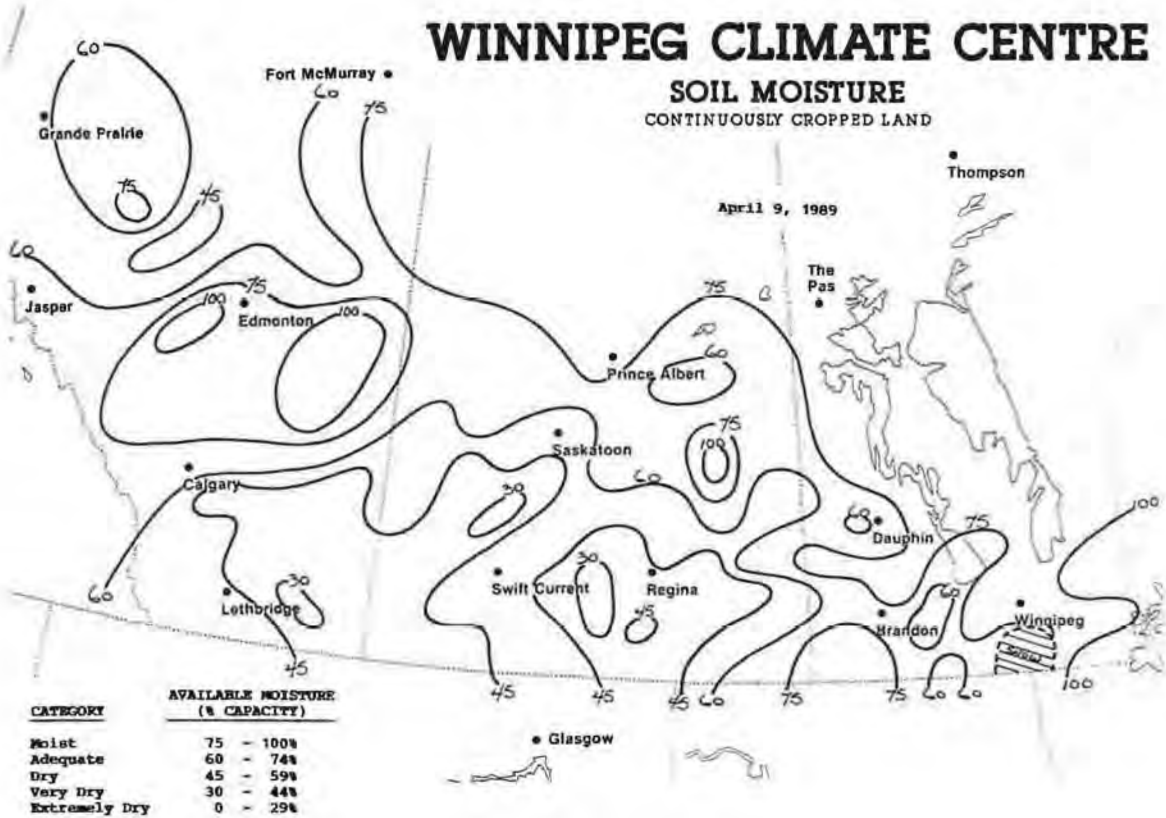

FIGURE 1. Soil Moisture Map

maturity are estimated for each location by assuming that the future weather will be normal (Table 2).

Soil moisture values (percent of available water holding capacities) are routinely analyzed for cereals on continuous cropped fields; Figure 1 is an example of the Prairie-wide maps. A similar analysis is performed for perennial forages and pastures. An objective analysis scheme using the Barnes interpolation technique or "hand" analysis is employed.

The range of possible soil moisture values varies from site to site due to differences in soil textures and the associated available water holding capacities. This precludes a meaningful analysis of soil moistures in absolute units such as millimetres of water. This impediment is, however, removed by changing to a relative scale. Only soil moisture values expressed as a percentage of the sites' available water holding capacities, which limits values to 0–100%, are mapped.

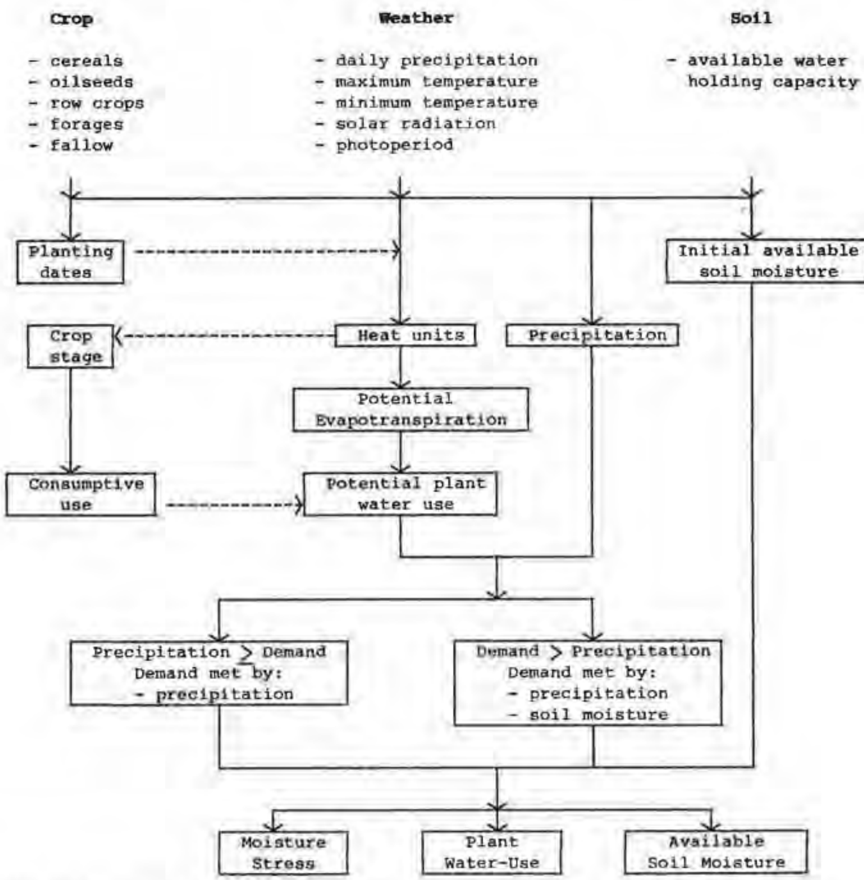

FIGURE 2. Generic Model Flow-Chart for Growing-Season Phase of Agrometeorological Bulletins and Outlooks

3.1 *Generic Model*

Water balance accounting procedures are followed in modelling evapotranspiration (ET), available soil moisture (SOIL) and moisture stress (STRS). The modelling approach of Dunlop and Shaykewich (1982), a conceptualization similar to the Versatile Soil Moisture Budget (Baier *et al.*, 1979), was adopted as the starting point for the building of the Winnipeg Climate Centre's operational model. This type of model compromises on the rigour of the ET estimate to allow the calculation to be performed for climatological sites which only observe maximum temperature, T_x, minimum temperature T_m and daily precipitation P_d. Spatial representativeness is thereby maximized.

The operational model is run on a daily time-step with Bulletins and Outlooks produced weekly – a time interval deemed appropriate for agrometeorological parameters. The model is termed "generic" as parallel procedures are followed for each crop. A Flow Chart for the growing-season phase of the model is included, Figure 2.

3.1.1 *Non-Meteorological Inputs*

The daily photo-period and total solar energy at the earth's surface in the absence of the atmosphere, Q_0, are calculated from astronomical considerations (Robertson and Russelo, 1968).

Site specific available water holding capacities for the top 120 cm of soil at each near real-time climate station were abstracted from maps generated by DeJong and Shields (1988) from soil texture information. For most of the Manitoba sites, the available moisture capacities have subsequently been adjusted to more closely match field measurements obtained in 1989.

For the annual crops, crop and site specific planting dates are abstracted each spring from the provincial agriculture department's and grain companies' crop reports. For perennial forages, an active growth date is established based on the first five consecutive days after April 1 which all have growing degree days, base 5°C, greater than zero (Dunlop, 1981).

3.1.2 *Modelled Physical Processes*

i) *Evapotranspiration, Plant Stage and Stress*

The daily latent evaporation, E_L, at each site is calculated from the daily extreme temperatures and the incident solar radiation in the absence of the atmosphere using Baier and Robertson's (1965) regression equation I. The daily potential evapotranspiration, ET_p, is then obtained from a relationship between E_L and Penman's E_p, the evapotranspiration rate from an extensive short grass cover completely shading the ground and adequately supplied with water (Baier, 1971). The daily ET_p is then converted to actual evapotranspiration, ET, using crop specific consumptive-use curves (Hobbs and Krogman, 1968; Dunlop and Shaykewich, 1982) and a root zone drying function (Johnstone and Louie, 1984).

For each crop, the consumptive-use factor, the ratio of the evapotranspiration demand to potential evapotranspiration, varies with growth-stage which is estimated from the planting or active growth dates and the accumulated heat input. Growing degree days, base 5°C, are used to estimate the growth-stage of oilseeds, specifically canola, (Morrison *et al.*, 1989) and perennial forages, specifically alfalfa (Selirio and Brown, 1979). The growth-stage of row crops, specifically corn, is based on corn heat units (Brown, 1969). The more rigorous biometeorological-time which incorporates photo-period along with a non-linear response to temperature is used to estimate the growth-stage of wheat (Robertson, 1968). A comparable but separate biometeorological-time scale is used for barley (Williams, 1974).

The actual evapotranspiration represents a crop's daily use of water. The water budgeting procedure employs a two-layer conceptualization of the soil (Johnstone and Louie, 1984). Each day's moisture input from rain or snow-melt is considered to enter the soil and to be readily available to meet that day's evapotranspirative demand. This attempts to represent the rapid wetting and drying of the surface soil layer. The daily demand that is not met by that day's moisture input is supplied, at least in part, by soil moisture. A root zone drying function is used to simulate the increasing difficulty that plants experience in extracting moisture from the soil as it becomes drier. For available soil moistures at or above 60% capacity, the moisture demand not met by the daily input is completely supplied by soil moisture. The portion of the demand that is met drops off linearly where available soil moisture is below 60% capacity, becoming zero at 0% capacity (Johnstone and Louie, 1984). The unsatisified demand is termed moisture stress.

The concept of available soil moisture, the difference between field capacity and permanent wilting point, is employed in budgeting water. Water that is surplus to the daily evapotranspiration and also surplus to the moisture required to return the soil to field capacity is assumed to be lost through drainage and/or runoff.

ii *Snow Storage and Melt*

Precipitation occurring during the growing season from April 1 to October 31 is classified as rain for the purpose of the model computations. The water equivalent of the precipitation falling from November 1 to January 31 is accumulated as snow. During the late winter and early spring, precipitation occurring on days with mean temperatures less than −1°C adds to the snowpack; at higher temperatures it is classified as rain. The snow-to-water ratio is assumed to be 10:1 for climate sites while actual measurements are provided by synoptic stations.

Wind redistribution and sublimation losses result in only a portion of the water stored in the over-winter snowpack being available to add to field soil moisture each spring (Steppuhn, 1981). An attempt is made to account for these losses by the incorporation of a "blow-off" factor which is a function of the ground cover during the winter. It is assumed that stubble fields only retain 40% of the snow that falls on them while more substantial perennial forage stands retain 50%. During the freshet period the snowpack is decreased daily by an amount equal to ⅓ ET_p as it can be treated as a freely evaporating surface (Baier *et al.*, 1979).

McKay (1964) correlated the daily rate of snowmelt for the Prairie region with the maximum temperature and the Julian day, a proxy for the intensity of solar radiation. Four of McKay's snowmelt curves for the maximum temperature ranges 0–2.8, 2.9–5.6, 5.7–8.3 and above 8.3°C are used to simulate the daily snowmelt on days without rain (Baier *et al.*, 1979). The daily snowmelt on days with rain is calculated using a relationship between daily mean temperature, daily rainfall amount and melt rate developed by the U.S. Corps of Engineers and employed in the Canadian Climate Centre's Water Budget Model (Johnstone and Louie, 1984).

Obviously, the melt water is limited to the total moisture in the snowpack. The snowpack is also considered capable of reabsorbing 10% of its volume, so that the water from minor melting does not reach the soil (Baier *et al.*, 1979).

iii *Infiltration*

To simulate heavy rainfall events where runoff occurs even though there is unfilled field capacity, daily precipitation, P_d, is partitioned between soil moisture recharge and runoff. On days with $P_d \leq 25.4$ mm, the amount of water infiltrating the soil is limited only by its field capacity. When $P_d > 25.4$ mm, infiltration is calculated as a function of P_d and the soil moisture level (Baier *et al.*, 1979). In both cases, excess water becomes runoff. This same infiltration restriction is applied to the total daily water input from snowmelt plus rainfall in the spring.

Saturated soils, when frozen, form a concrete-like barrier reducing infiltration to near zero. However, some infiltration may be expected under most moisture and temperature conditions (Gray *et al.*, 1970; Steppuhn, 1981). In this application, soil temperatures are approximated by the average of the maximum air temperatures over the previous ten days – simulating the well known soil-air temperature lag. The soil is considered frozen when its temperature is less than or equal to 0°C (Street *et al.*, 1986). Infiltration is then reduced by subtracting a portion of the water which is available for soil moisture recharge in direct proportion to the soil moisture level.

4. VERIFICATION AND TRACKING OF SOIL MOISTURES

Soil moisture is one of several agrometeorological parameters published in the Bulletins and Outlooks. While the various heat unit accumulations provide information on the growth-stages of selected crops and the life-stages of some insect pests, and projected total water-use and accumulated moisture stress are indicators of potential yields, soil moisture, a residual between the inputs and outputs, remains the pivotal model parameter. It is both an indicator of the state of the agro-climate and a summary measure of model performance.

The Winnipeg Climate Centre's model is an operational application of concepts and procedures pioneered and verified by others. The requirement for objective field testing is, therefore, greatly diminished. The Bulletins and Outlooks were moved from the experimental to the operational category in 1989 on the basis of a subjective assessment. In particular, field staff of Manitoba Agriculture have found the estimates of soil moisture to be an accurate reflection of actual conditions on a regional basis (Webster, 1988).

Field measurements not only provide an opportunity to verify model simulations, they also provide a means of keeping the modelling "on track". To this end, Manitoba Agriculture's Soils and Crops Branch established soil moisture measurement sites in the vicinity (2 to 30 km) of 32 of the near real-time climate stations in Manitoba. Three replicate cores from each site were sampled to obtain bulk densities and texture information for five layers to a depth of 120 cm. Average layer compositions were used as input to regression equations developed by Shaykewich and Zwarich (1968) to estimate field capacities, permanent wilting points and available water holding capacities.

Manitoba Agriculture regional personnel collected a second set of three replicate samples from cereal stubble fields at each site between May 14–16, 1989. Following processing to assess the percent moisture by weight and finally the amount of moisture as a percentage of the available water holding capacity (i.e., percent capacity) at each site, these field measurements were compared with modelled soil moisture values for May 14th. Reasonable agreement was obtained. At 10 of the 32 sites the modelled values were within $\pm$ 15% or within one moisture category (as defined in Figure 1) of the measurements; a total of 20 sites were within $\pm$ 30% and 28 sites were within $\pm$ 45%. The average absolute error was 26%. The model exhibited a dry bias, in that 26 of the 32 measured values were above the modelled soil moisture levels, and the average bias was −11%.

The dry bias might logically be attributed to the timing of the measurements and the model's failure to process soil moisture above field capacity. The samples were taken in the spring when the frost-line was just retreating below the 120 cm line. In all likelihood, the soil did not have time to drain thoroughly in some areas as many of the measurements were above the estimated field capacities.

Another potential source of significant error is the substantial distances between many of the soil moisture sites and the climate stations – separations which can lead to major differences in rainfall amounts (Raddatz, 1987b).

The Manitoba sections of the Agrometeorological Bulletins and Outlooks have subsequently been adjusted to bring them into line with the observed 1989 spring soil moisture values. Future fall and spring field measurements may be conducted by Manitoba Agriculture as a means of ensuring that the modelling continues to track the actual moisture conditions. Hopefully, similar field measurements will be available from Saskatchewan and Alberta in the not too distant future, so that the verification and tracking can be extended into these two provinces.

5. SUMMARY

A set of weekly crop-specific Agrometeorological Bulletins and Outlooks for the Prairies is being produced by the Winnipeg Climate Centre, Environment Canada. Separate Bulletins and Outlooks are published for at least one cultivar in each major class of Prairie crops – cereals, oilseeds, row crops and perennial forages. A sixth Bulletin tabulates heat units that are correlated with the phenology of certain insect pests (grasshoppers, corn borers, etc.) and the moisture status of fallowed fields.

All of the synoptic, daily and weekly reporting sites (approx. 150), grouped by Statistics Canada Crop Districts, in the agricultural areas of Alberta, Saskatchewan, Manitoba and northwestern Ontario are listed on the Bulletins and Outlooks. The one exception is the row crop information which only covers Manitoba.

The Agrometeorological Bulletins and Outlooks are available via conventional and electronic mail services. Soil moisture maps are disseminated by telephone-facsimile. Readers wishing further information should write to the author at the address given at the head this article.

ACKNOWLEDGEMENTS

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LIMEX-85: 1. Processing of Data Sets from an Alberta Mesoscale Upper-Air Experiment

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ABSTRACT

The *Li*mestone *M*ountain *Ex*periment (LIMEX-85), conducted by the Alberta Research Council Hail Project (AHP) over the foothills and mountains of southwestern Alberta during July 1985, was one of the first true mesoscale upper-air experiments carried out in Canada. LIMEX experiments were focused on mesoscale convective processes, orographic effects, and interactions with synoptic processes, with particular emphasis on forecasting applications.

Archived data from LIMEX-85 include two-hour soundings from nine upper-air sites with an average spacing of 50 km, continuous SODAR profiles, research aircraft soundings at 20-km intervals, radar data, surface data from eight automated systems, full hourly surface observations from all sounding sites, and an extensive cloud photography component. All synoptic surface and upper-air data for northwestern North America were also processed, and are included in the LIMEX archive. In addition, the archive contains upper-air data from several precursor experiments, such as LIMEX-80 and the Capping Inversion Study (CIS-82). This paper briefly describes the scientific goals and technical logistics of the LIMEX experiments of 1980–85, and provides information on the availability of data. A few preliminary analyses of the LIMEX data are also presented.

RÉSUMÉ

L'*ex*périence *Li*mestone *M*ountain (LIMEX-85), conduite par le projet de grêle (*H*ail *P*roject) du Conseil de Recherche de l'*A*lberta (AHP) dans les piedmonts et les montagnes de l'Alberta du sud-ouest en juillet 1985, a été une des premières expériences véritables en altitude d'échelle moyenne au Canada. Les expériences LIMEX ont porté sur des procédés convectifs d'échelle moyenne, des effets orographiques, et des rapports avec des procédés synoptiques, en portant une attention particulière sur les prévisions météorologiques.

Les données archivées du LIMEX-85 comprennent des observations de neuf sites de sondage des couches d'air en altitude à intervalle de deux heures, des profils continus de SODAR, des sondages aériens à tous les 20 km, des données de radar, des données en surface de huit systèmes automatisés, des observations en surface complètes à chaque heure à chacun des sites de sondage, et une couverture assez complète des photos des nuages. Toutes les observations synoptiques en surface et en altitude du nord-ouest d'Amérique du Nord ont été également inclues dans l'archive LIMEX. De plus, l'archive contient des données en altitude de plusieurs expériences précédantes, telles que le LIMEX-80 et l'étude *C*apping *I*nversion (CIS-82). Cet article décrit brièvement les buts scientifiques et l'organisation technique et logistique des expériences LIMEX de 1980–85 ainsi que la disponibilité des données. Quelques analyses préliminaires des données LIMEX ont été également inclues.

1. BACKGROUND

Until recently, efforts to improve our understanding of mesoscale processes have been restricted by the lack of special mesoscale data sets to provide basic upper-air thermodynamic and wind data for research. Thus, an extensive surface and upper-air mesoscale experiment was carried out by the Alberta Research Council (ARC) Hail Project (AHP) during a two-week period in July 1985. This experiment, LIMEX-85, was the culmination and most detailed of a series of such studies, collectively called the *Li*mestone *M*ountain *Ex*periments (LIMEX), which were initiated in 1980. The experiments centred on Limestone Mountain, simply because Alberta has a high frequency of hailstorms which form over or near foothills peaks such as this, and particularly because Limestone Mountain was within range of detecting first echoes with the AHP radar. The LIMEX-85 data set is unique in that it includes the only upper-air data set in Canada to date suitable for mesoscale spatial analysis of convective storm processes.

This paper briefly describes the available LIMEX data sets and presents some results of analyses to date. It first outlines the original goals of the LIMEX experiments, since these provide the raison d'être for the design of the various data networks employed, the types of data collected, and the type of data processing used.

2. LIMEX GOALS

The LIMEX experiments were part of a larger study by the author dealing with interactions between synoptic, mesoscale, and fixed orographic processes which lead to convective storms. The overall goal of LIMEX was to improve forecasting capabilities during the DAY-1 forecast period. Therefore, unlike most other convective studies, data collection was not concentrated solely on the mature-storm period, nor was it confined to cases of the most severe storms, although the latter typically provide the best data sets for describing physical processes. These experiments, in fact, focussed primarily on the pre-storm period, such that much of the data are from late-morning periods.

A conceptual model of synoptic-scale processes which control the genesis and life cycle of thunderstorms was developed prior to the first LIMEX experiment (LIMEX-80). This model hypothesizes a downscale transfer of eddy kinetic energy to the mesoscale during synoptic-scale cyclolysis, and that it is this energy which leads to mesoscale convergence and ascent favourable for storm initiation. Orographic forcing and convective processes from differential surface heating contribute to the strength of the mesoscale dynamics. Either process can be dominant at a given time, but in this conceptual model, synoptic processes exert the major control, even when not the strongest dynamics. This hypothesis was expanded and tested using SESAME[1] data from Oklahoma, while similarities between the convective storms of Oklahoma, Alberta, and elsewhere were noted (Strong, 1983, 1986). The predominant characteristics for such storms in all areas seem to be the approach of a synoptic-scale low pressure system, usually in a state of decay, and the high frequency of a moist boundary layer capped by a stable potential-temperature inversion during the pre-storm period. The inversion of potential temperature is referred to as the "*capping lid*".

The lid is usually present prior to the formation of a 'severe' storm, often 24 hours or more before. It weakens over the potential storm region 1–6 hours in advance of the storm in time and space in the case of Oklahoma and Alberta storms, and probably of those in other regions as well. The lid is not always detected with 'synoptic network' soundings because often, though not always, it is confined to the immediate *region of influence* of the potential storm.

Given these commonalities between convective storms in the immediate lee of the Rockies, and probably in other regions of North America, and the ultimate goal to improve forecasting capabilities, several LIMEX field experiments were planned (Strong, 1985a) with primary and secondary technical goals as follow:

1. to obtain accurate surface and upper-air data of high spatial and temporal resolution over the Alberta foothills during days exhibiting a capping lid;
2. to test existing forecasting techniques, including the Synoptic Index of Convection (Strong, 1979, 1986; Strong and Wilson, 1983), with high-resolution surface and upper-air data.

3. LIMEX FIELD EXPERIMENTS

Three main and several smaller LIMEX field experiments were carried out during 1980–85 with the above objectives in mind. All were conducted over the foothills

[1] SESAME refers to the *S*evere *E*nvironmental *S*torms *A*rea *M*eteorological *E*xperiment, involving six 24-hour case studies, centred on Oklahoma, and conducted over the southern U.S. plains during 1979.

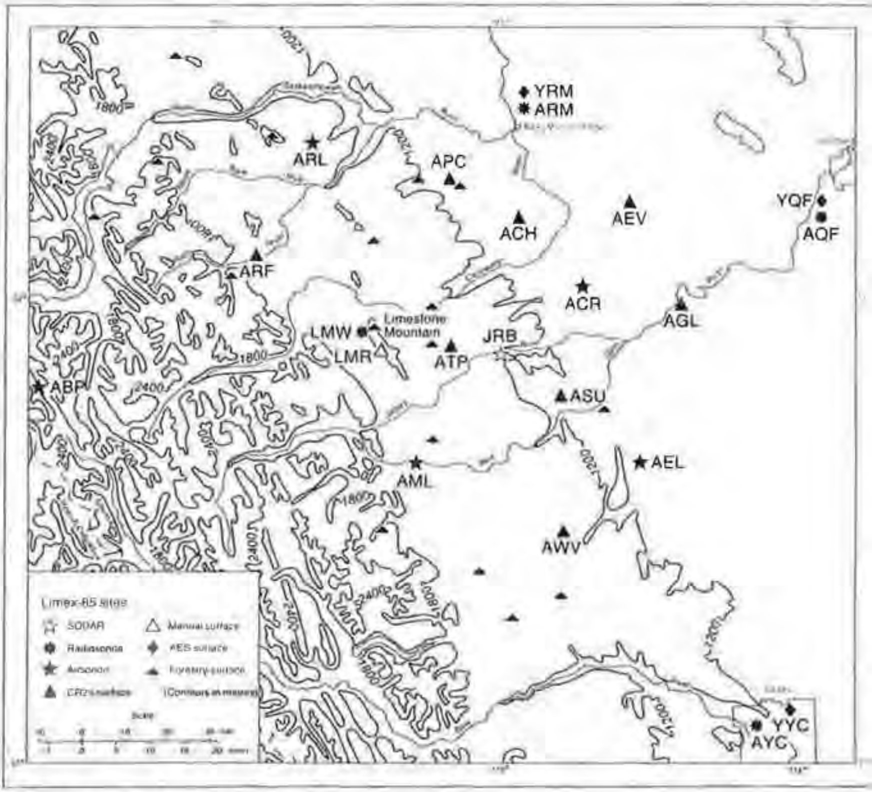

FIGURE 1. Regional topography, and surface and upper-air sites employed during the Limestone Mountain Experiments of 15–17 July, 1980 (LIMEX-80), and 08–23 July, 1985 (LIMEX-85).

and mountainous regions of southwestern Alberta shown in Figure 1. Figure 2 provides a photographic description of the region immediately around Limestone Mountain, the focal point of these experiments. The three primary experiments are now described briefly.

a. *LIMEX-80:*

This was a 3-day experiment carried out on 15–17 July, 1980. The specific goal was to measure thermodynamic responses to orographic subsidence near the main mountain barrier and over the foothills of southwest Alberta. Subsidence warming was thought to combine wth large (synoptic) scale subsidence in creating and maintaining the capping lid.

During LIMEX-80, radiosondes were released at three-hour intervals, commencing at 1400 UTC (Universal Coordinated Time, or 0800 MDT), in a 10-km wide valley west of Limestone Mountain, adjacent to the main mountain barrier (see Figures 1 and 2a), in order to measure the maximum response to orographic subsidence. Radiosondes were also released at three-hour intervals at

FIGURE 2. Views from Limestone Mountain Ridge (LMR, at 2121 m MSL) towards: (a) Limestone Valley and the main mountain barrier southwest; (b) Limestone Mountain peak (at 2252 m) and mountains northwest; (c) foothill peaks northeast.

(c)

Rocky Mountain House 65 km northeast of the Limestone site, and at Red Deer Airport, some 110 km east-northeast, in an attempt to detect the creation and pre-storm breakdown of any lid.

These sites and the general topography of the region are indicated in Figures 1 and 2. Strong orographic subsidence was detected on all three days, and a major hailstorm formed over the region on 16 July. The LIMEX-80 data, consisting of 36 soundings, have been added to the LIMEX archive, but not in fully processed form.

b. *CIS-82:*

The *C*apping *I*nversion *S*tudy field experiment of 01–29 July, 1982 (CIS-82) was designed to measure the sequence of low-level thermodynamic changes near an *existing* capping lid prior to the formation and/or approach of a severe storm complex. CIS-82 involved three *mobile* sounding units (airsondes) directed by radio to various sites during an operational day, as well as serial radiosonde releases from fixed sites at Red Deer Airport and Calgary. The various mobile and fixed sites used are indicated in Figure 3.

In all, 124 airsonde and 43 radiosonde soundings were collected during 16 operational days of CIS-82. A complete listing is provided in Deibert (1982). Excellent storm data were obtained during three severe hailstorm days, 14, 21, and 29 July. However, it was, at best, difficult to deploy mobile sounding crews to the most favourable locations (usually the right flank of a storm). During particularly busy days, mobile personnel often discovered that the storm of interest had passed by them and they were unable to catch up.

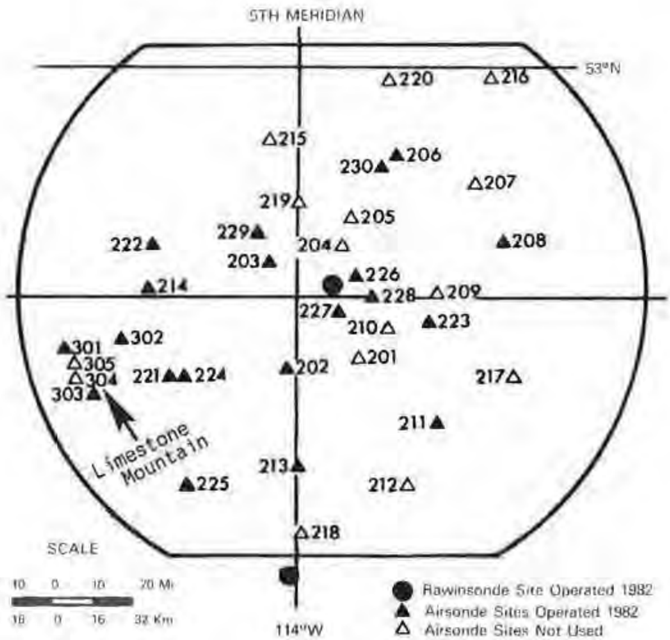

FIGURE 3 Sounding sites surveyed and used during the Capping Inversion Study (CIS-82), 01–29 July, 1982. The quasi-circular region indicates the 130-km radius AHP operations area over central Alberta.

c. *LIMEX-85:*

This was, by far, the most intense data collection phase of the LIMEX experiments. LIMEX-85 involved nine fixed upper-air sites along with several other data platforms, and was conducted during 08–23 July, 1985. Station information and the types of data collected at each of the upper-air and special surface data sites are provided in Table 1. The LIMEX-85 data archive includes hourly surface observations from each sounding site, eight CR-21 autostations, plus additional surface data provided by the existing AES and Alberta Forestry networks. The special data networks are indicated in Figure 1. The schedules of operating logistics used are available in Strong (1985b).

d. *Other Experiments:*

Some related field-experiment data are not currently included in the LIMEX archive, but are available in raw archived form elsewhere. These are as follows.

CCOPE-81 – the *C*ooperative *Co*nvective *P*recipitation *E*xperiment conducted in southeastern Montana during May–August, 1981; involved five radiosonde units operated by Texas A&M University and two ARC sounding units (mid-June through mid-July only) in a 40-km triangular grid, described briefly in Deibert (1981).

TABLE 1. Upper-air and surface data sites used during LIMEX-85, 08–23 July, 1985.

Legend of Observations Types

uR – upper air, Rawinsonde
uA – upper air, Airsonde
SD – SODAR
sM – surface observations, Manual
sC – surface observations, CR-21 autostations
ph – still and/or time lapse photography
XX – alternate site, not used or used just briefly

Upper Air Sites:

STN. I.D.	NO.	LEGAL LAND LOCATION	LAT.	LONG.	ELEV. (m ASL)	NAME	Type OBS.
CAQF	718781	SW13-37-28-4	52.18	113.90	900.	Red Deer	uR,sM
CARM	719281	SE14-40-07-5	52.43	114.92	988.	Rocky Mtn House	uR,ph
CAYC	718771	NW36-24-02-5	51.08	114.13	1114.	Calgary UofC	uR
CLMW	99301	SW27-34-11-5	51.95	115.48	1506.	Limestone Mtn W	uR,sM,ph
CWEG	71119	NW05-53-01-5	53.55	114.10	766	Edm. Stony Plain	uR (00,12Z only)
CABP	99331	NE02-33-19-5	51.81	116.58	1710.	Bow Pass	uA,sM,ph
CACR	99320	SE06-36-05-5	52.03	114.42	1068.	Caroline	uA,sM,ph
CAEL	99317	SW16-31-04-5	51.66	114.51	1130.	Elkton	uA,sM,ph
CAML	99328	SW13-31-10-5	51.66	115.29	1441.	Mountainaire Ldg.	uA,sM,ph
CARL	99329	SW27-34-11-5	52.34	115.65	1294.	Ram Lookout East	uA,sM,ph

SODAR and Special Surface Data Sites:

STN. I.D.	NO.	LEGAL LAND LOCATION	LAT.	LONG.	ELEV. (m ASL)	NAME	Type OBS.
JRR	99232	NE01-34-08-5	51.89	115.00	1198.	James River Ranger	SD
JRB	99231	NE01-34-08-5	51.89	115.00	1204.	James River Bridge	XX
AEV	99331	SE31-37-04-5	52.22	114.55	1009.	Evergreen	sC
AGL	99327	SW09-35-03-5	51.99	114.38	1012.	Glennifer Lake	sC
APC	99319	NE16-37-10-5	52.18	115.36	1406.	Prairie Creek	sC
ARF	99500	SW18-36-13-5	52.09	115.85	1618.	Ram Falls Ranger	sC
ASU	99325	NE33-32-06-5	51.79	114.79	1167.	Sundre West	sC
ATP	99313	SE11-34-09-5	51.90	115.16	1380.	TeePee Pole Creek	sC
AWV	99326	NE21-29-05-5	51.50	114.64	1313.	Water Valley	sC
BCH	99322	NW11-37-07-5	52.17	114.90	1090.	Cheddarville WB	sC
ACH	99321	SE15-37-07-5	52.18	114.91	1088.	Cheddarville WK	XX
LMR	99304	SE07-34-10-5	51.90	115.40	2121.	Limestone Mountain Ridge (field base)	sM,ph

STRESS-81 – the *S*patial and *T*emporal *RES*olution *S*tudy of upper-air data was designed to determine the optimum spatial and temporal resolution of soundings for resolving mesoscale circulations associated with convective weather; sondes were released at 1½-hour intervals at five sites spaced 40 km apart in straight lines over central Alberta, in order that maximum information on gradients could be obtained. Results have been discussed by Sackiw and Strong (1983) and Sackiw (1986). Operational logistics are discussed in Deibert (1981).

LIMEX-83 – a pre-LIMEX-85 field experiment on 07–08 July, 1983, primarily to test field logistics and sounding frequency interference; this included three airsonde systems in the vicinity of Limestone Mountain, plus six radiosonde releases from Rocky Mountain House.

LIMEX-84 – a second pre-LIMEX experiment, conducted on 19–20 July, 1984, which entailed a total of 20 releases, from three airsonde sites in the vicinity of Limestone Mountain, and from the Rocky Mountain House radiosonde site.

4. LIMEX-85 DATA SETS AND ARCHIVING FORMATS

a. *Balloon Sounding Data:*

The LIMEX-85 field operations plan centred on daily upper-air operations, commencing at 1400 UTC (0800 MDT), with subsequent releases at two-hour intervals until 0200 UTC, or until operations were called off due to lack of convective weather. Exceptions were at Red Deer Airport and Calgary, where the first sounding was at 1300 UTC (to provide support for AHP forecasting operations), while crews at two airsonde sites over the foothills (alternating pairs of sites each day) performed an additional sounding at 1300 UTC, in order to determine whether a capping lid was present, and to provide early indications on how long to continue operations for the day. Operations were controlled by radio and radio-telephone from a field site situated on top of Limestone Mountain, since this was the only available location where radio communications to all sites were possible. When communications with a site were lost, the default was to continue soundings at that site until 0200 UTC, regardless of local weather conditions.

A total of 421 soundings were obtained from the nine special upper-air sites during LIMEX-85. All but one of the sites (Red Deer) involved manual tracking for winds, so that the short interval between soundings (1–2 hours) necessitated a cut-off at 600 mb in many instances, acceptable since the sub-cloud layer (below 700 mb) was of primary interest. Despite this, many of the soundings exceed 200 mb. A detailed inventory of LIMEX-85 sounding releases for each site is available from the author. These include the twice-daily soundings from the regular (AES) synoptic site at Stony Plain (CWEG) near Edmonton, merged, processed, and archived in the LIMEX format. Note that soundings from all other synoptic sites in northwestern North America are also included in the LIMEX archive, but have not been merged into the LIMEX format as have the CWEG soundings.

TABLE 2. Typical partial output formats for LIMEX upper air data.

a) "*Significant-Levels*" output file.

CAQF 71878 820721 1215 IO
52 18 113.90 900.00 Red Deer (ARC) UpperAir, Alberta IO

0.00	900.0	914.3	10.0	9.7	0.0	0.0	-500.0	-500.0	290.5	314.1	8.3	98.0	-500.0	-500.0	-500.0	W
0.00	900.0	914.3	10.0	9.7	180.0	0.0	0.0	0.0	290.5	314.1	8.3	98.0	0.0	-500.0	-500.0	T
0.25	990.0	904.5	9.4	8.9	-500.0	-500.0	-500.0	-500.0	290.8	313.6	8.0	96.6	-500.0	-500.0	-500.0	W
0.70	1152.0	887.0	8.4	7.5	-500.0	-500.0	-500.0	-500.0	291.4	312.5	7.4	94.0	-500.0	-500.0	-500.0	T
0.74	1167.1	885.4	8.5	7.2	-500.0	-500.0	-500.0	-500.0	291.7	312.5	7.2	91.6	-500.0	-500.0	-500.0	W
1.20	1322.4	869.0	10.0	4.2	-500.0	-500.0	-500.0	-500.0	294.8	312.2	6.0	67.0	-500.0	-500.0	-500.0	T
1.25	1340.9	867.1	9.9	4.1	-500.0	-500.0	-500.0	-500.0	294.8	312.3	6.0	67.2	-500.0	-500.0	-500.0	W
1.75	1515.4	849.1	8.8	3.4	-500.0	-500.0	-500.0	-500.0	295.5	312.4	5.8	68.7	-500.0	-500.0	-500.0	W
2.25	1690.8	831.4	7.7	2.7	170.9	9.6	-1.5	9.5	296.1	312.6	5.6	70.3	1062.0	322.2	40.3	W
2.76	1868.7	813.5	6.6	2.0	182.8	11.1	0.5	11.1	296.8	312.8	5.4	71.9	1345.6	330.8	38.9	W
2.80	1883.8	812.0	6.5	1.9	183.1	11.1	0.6	11.1	296.8	312.8	5.4	72.0	1370.6	331.5	38.8	T
3.24	2048.5	795.9	5.0	3.4	186.3	11.2	1.2	11.2	297.8	315.1	6.2	89.6	1642.8	337.8	37.6	W

b) "*Interpolated-*" or "*Mandatory-Levels*" output file.

CAQF 71878 820721 1215 IO
52 18 113.90 900.00 Red Deer (ARC) UpperAir, Alberta IO

0.00	900.0	914.3	10.0	9.7	0.0	0.0	-500.0	-500.0	290.5	314.1	8.3	98.0	-500.0	-500.0	-500.0	INT
0.11	939.8	910.0	9.7	9.3	-500.0	-500.0	-500.0	-500.0	290.6	313.9	8.2	97.4	-500.0	-500.0	-500.0	INT
0.37	1031.8	900.0	9.1	8.5	-500.0	-500.0	-500.0	-500.0	291.0	313.3	7.8	95.9	-500.0	-500.0	-500.0	INT
0.62	1124.1	890.0	8.6	7.7	-500.0	-500.0	-500.0	-500.0	291.3	312.7	7.5	94.4	-500.0	-500.0	-500.0	INT
0.89	1218.3	880.0	9.0	6.2	-500.0	-500.0	-500.0	-500.0	292.7	312.4	6.8	83.5	-500.0	-500.0	-500.0	INT
1.17	1312.9	870.0	9.9	4.4	-500.0	-500.0	-500.0	-500.0	294.6	312.2	6.1	68.5	-500.0	-500.0	-500.0	INT
1.45	1409.8	860.0	9.5	3.8	-500.0	-500.0	-500.0	-500.0	295.1	312.3	5.9	67.0	-500.0	-500.0	-500.0	INT
1.72	1506.6	850.0	8.9	3.4	-500.0	-500.0	-500.0	-500.0	295.5	312.4	5.8	68.6	-500.0	-500.0	-500.0	INT
2.01	1600.0	840.0	8.2	3.0	-500.0	-500.0	-500.0	-500.0	295.8	312.5	5.7	69.5	-500.0	-500.0	-500.0	INT
2.29	1703.8	830.0	7.6	2.6	172.0	9.7	-1.4	9.6	296.2	312.6	5.6	70.4	1082.8	322.8	40.2	INT
2.57	1803.4	820.0	7.0	2.3	178.7	10.5	-0.2	10.5	296.5	312.7	5.5	71.3	1241.4	327.6	39.4	INT
2.86	1905.0	810.0	6.3	2.1	183.5	11.1	0.7	11.1	296.8	313.1	5.5	74.3	1405.7	332.3	38.6	INT
3.13	2006.5	800.0	5.4	3.0	185.4	11.2	1.0	11.2	296.9	314.5	6.0	85.1	1573.4	336.2	37.9	INT

c) "*Tabular*" output with headings.

CACR (99320) – Caroline, Alberta
at 52.03 N latitude, 114.42 W. longitude
station elevation 1068.0 m (MSL)

1804 UTC, 11 July 1985

E-time (min)	Height (gpm)	Pressur (mb)	Tempera (dg C)	Dew Pt (dg C)	Dir (deg)	Speed (m/s)	U-comp (m/s)	V-comp (m/s)	Theta (dg K)	Theta-E (dg K)	Mxg Rat (g/kg)	Rel Hum (%)	Range (m)	Azimuth (deg)	Elevati (deg)
0.0	1068.0	894.1	19.8	10.4	300.0	3.1	2.7	-1.5	301.7	328.2	8.9	56.8	-500.0	-500.0	-500.0
0.3	1107.4	890.0	18.6	8.7	323.4	4.5	2.7	-3.6	301.6	325.5	8.0	52.2	-500.0	-500.0	-500.0
0.8	1204.4	880.0	17.0	8.9	336.8	6.5	2.6	-6.0	301.0	325.3	8.1	58.2	277.0	160.4	40.1
1.2	1302.0	870.0	16.3	9.1	342.8	6.5	1.9	-6.2	301.2	326.2	8.4	61.9	459.8	159.2	33.1
1.7	1400.4	860.8	15.4	9.1	342.6	6.3	1.9	-6.1	301.3	326.4	8.4	65.5	625.8	160.5	32.1
2.1	1498.6	850.0	14.6	9.1	339.6	7.0	2.4	-6.5	301.4	326.9	8.5	68.9	824.1	160.7	31.4
2.7	1599.9	840.0	15.0	9.5	333.1	7.5	3.4	-6.7	302.9	329.4	8.9	69.2	1064.3	159.7	29.3
3.3	1701.6	830.0	15.8	1.1	321.7	7.0	4.3	-5.5	304.7	320.1	5.0	38.4	1320.8	157.0	27.5
3.9	1804.6	820.0	16.4	-2.9	306.6	6.0	4.8	-3.6	306.4	318.2	3.7	26.1	1540.8	153.6	26.7
4.8	1908.9	810.0	16.4	-3.3	282.7	4.6	4.5	-1.0	307.6	319.1	3.7	25.2	1704.3	147.9	26.9

In addition to a '*raw data*' archive, all soundings were also archived in two similar '*processed*' forms. All data were processed using the ARC UPPERAIR Software facility. Table 2 provides examples of the two main processed formats, significant-level and mandatory-level data. The significant-wind level data include interpolated thermodynamic data, and vice versa. The mandatory-level output provides data interpolated to 10-mb levels up to 700 mb, and in 50-mb levels thereafter. All interpolated levels were computed linearly with respect to pressure height. While these interpolated data will suffice for most purposes, the ARC UPPERAIR facility can be easily employed to change the interpolated levels as desirable.

The data for each sounding, in either format, are contained in separate files, and each file contains all station information required for an analysis. Each filename is composed of the 4- or 3-letter station identifier, the date and release time (UTC) of the sounding, and the format of the data processing. For example, the file CAQF8507111605.INT would contain interpolated data (file extension ".INT") for Red Deer Airport (CAQF) for 11 July, 1985 (850711), for a sounding released at 1605 UTC.

Relevant flags are included in the archive files to indicate the type of sounding system, sonde frequency, whether a data level is a significant thermodynamic level, a significant wind level, or an interpolated level, etc.

All synoptic upper-air data for northwestern North America were also processed and are included in the 'raw' LIMEX archive. Processing of these synoptic data in the same format as the special sounding data has not been completed to date.

b. *Aircraft Soundings:*

An important component of LIMEX-85 was a series of soundings at 20-km intervals obtained through the sophisticated data-collection facilities of the Intera/ARC research aircraft, as described in Deibert (1981). Aircraft soundings were obtained during six morning flights, each 2–4 hours duration, with the aircraft

TABLE 3. Research aircraft flights in support of LIMEX-85.

	TIMEs (UTC)		FLIGHT
DATE	TAKEOFF	LANDING	HOURS
July 10	16:40	19:36	2.9
11	15:48	18:58	3.2
16	16:46	19:35	2.8
22	18:47	21:55	3.1
23	16:36	18:19	1.7
August 04**	16:57	19:21	2.4

** The LIMEX upper air network was not in operation at this time. However, additional rawinsonde and airsonde soundings are available for CAQF and CAYC on this date.

continually ascending and descending between 850 and 600 mb. These are summarized in Table 3. Where time allowed, the usual aircraft track (reference Figure 1) was from YQF to YRM, to Limestone Mountain by way of the Clearwater River, following lines parallel to the mountains from Limestone Mountain southeast to the Bow River, then northwest from north of YYC to YRM, and finally back to YQF.

This valuable portion of the LIMEX data set has yet to be processed from the ARC raw aircraft data archive for 1985. Hopefully, this will be accomplished in the near future, since these represent an important additional source of LIMEX soundings. It is anticipated that these data will be processed in the same format as the balloon sounding data.

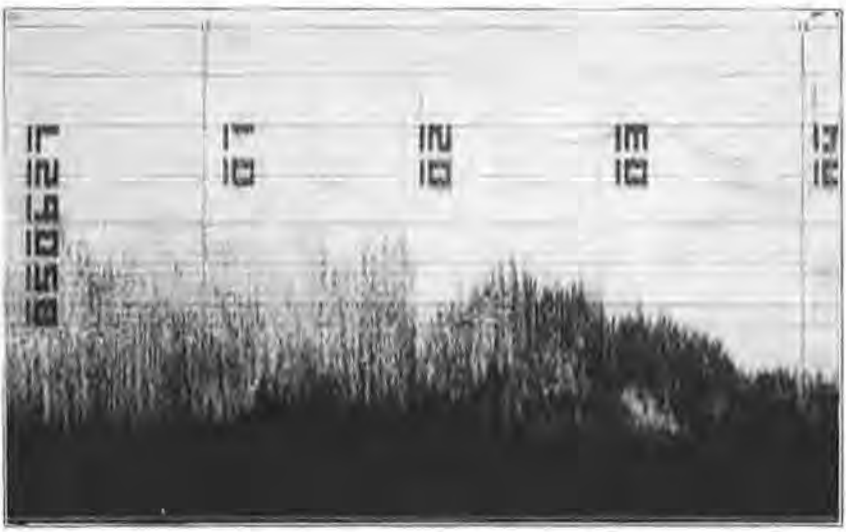

FIGURE 4. Typical portion of a chart record for the SODAR sonic sounding unit at James River Bridge (JRB in Figure 1) during LIMEX-85.

c. *SODAR Profiles:*

The sounding program also included a sonic sounding unit (SODAR), provided by the University of Calgary, in the centre of the network (at James River Bridge, JRB in Figure 1), providing a continuous boundary layer record of capping lids. Data for this system consist of several chart records, which have not been extracted and processed to date. Figure 4 shows a typical portion from the SODAR chart record.

d. *Surface Data:*

The LIMEX "raw" surface data set consists of five different types of surface data from five different sources as follows:

1. manual hourly surface observations, with some specials from seven of

the nine LIMEX upper-air sites (exceptions are CARM and CAYC), and from the field operations centre, Limestone Mountain Ridge (LMR);

2. five-minute averaged surface data from the eight(8) LIMEX automated CR-21 autostation sites (no pressure data);
3. raw teletype archive of hourly and special surface synoptic data from [WEATHER], the ARC Meteorological Data Facility;
4. twice-daily observations from Alberta Forestry Lookout sites (no pressure data);
5. "other" unplanned data sources; e.g., autostation data from an Alberta Forestry site at 40-Mile Flats (F40), with only one observation per day, at noon-hour.

The CR-21 autostations used during LIMEX-85 were located between sounding sites (see Figure 1). Data were averaged and stored over five-minute intervals. Because of unstable power supplies at these remote sites, some data were lost due to power interruptions.

All "raw" surface data, referred to as "Level-1" data, were merged and processed to a "Level-2", in one common format in files by date. Each line of Level-2 data includes a "pressure indicator" to identify whether the raw pressure variable was missing (e.g., no pressure for CR-21 sites), whether it was station pressure (e.g., at LIMEX upper-air sites), or was MSL-reduced pressure (e.g., synoptic data). A humidity indicator designates whether the raw humidity value was missing, or whether it was provided as a wet-bulb temperature, relative humidity, or dewpoint temperature. All weather, cloud, and rainfall information, or other observer's remarks were retained at Level-2, and appear at the end of the line as text.

The format of each line in LEVEL-2 files is

IIII BBnnn yymmdd hhmm Pin P T Hin HUM ddd ss gg TEXT

where the variables represent, in order, the 3- or 4-letter station ID, block and station number, the year-month-day, the time of observation in hours and minutes (UTC), pressure indicator, pressure value, temperature, humidity indicator, humidity value, wind direction, wind speed, and peak wind gust in a set format, ending with all remarks in text form with no fixed length. Example lines of data are:

CLMR 99304 850711 1403 1 790.3 15.7 1 10.2 065.0 15.5 25.8 LN TCU NW-NE, CB TP N, RW--

CAQF 72878 850711 1400 2 1003.2 22.5 3 11.8 09.0 6.4 0.0 CB TPS NW

A further processing of the Level-2 data to "Level-3" was planned, but has not been carried out to date. Level-3 data would have included additional computed variables such as both station and MSL pressure (estimated if missing), potential, equivalent, and pseudo-adiabatic potential temperatures, mixing ratio, and u- and v-components of the wind.

e. *Other Data sets:*

AHP *radar data* are archived separately in the regular AHP radar data archive at ARC facilities in Edmonton. A hard-copy archive of processed PPI analyses at 15-minute intervals for special days is currently included in the LIMEX archive. Specific radar data processing can be carried out using the ARC Radar Software facility.

Hail size data from the extensive AHP telephone surveys, with spatial resolution down to several kilometres, and *daily rainfall totals* from the AHP climatology network are also available in separate data archives.

An extensive *cloud photography* program was carried out during LIMEX. Personnel at each upper-air site were provided with several rolls of 35 mm print or slide film and asked to take photos of significant weather events or interesting operational pictures. In addition, a limited series of *time lapse movies* of cloud formations was obtained in 16 mm format at the LIMEX field control site on Limestone Mountain Ridge (site LMR).

Plans to include a *GOES satellite data* set in the archive, and to complete the above-mentioned data processing, were forestalled due to funding problems. However, there is a limited hard-copy set of NOAA (polar-orbiting) high-resolution satellite images available to the archive.

5. PRELIMINARY ANALYSES AND DISCUSSION

This section provides some preliminary analyses of LIMEX data, commencing with sounding analyses relating to the original primary objective of LIMEX, to map the spatial and temporal variability of the capping lid. On 11 July 1985, a severe hailstorm formed north of the LIMEX network during late afternoon, and tracked eastward across the AHP operations area between Red Deer and Edmonton. A strong low-level inversion (capping lid) had formed over the foothills region during the previous night, and persisted in a wide band east of and parallel to the main mountain barrier.

Figure 5 shows the storm evolution on NOAA satellite images (a,b) and a Red Deer radar PPI (c). We note a large cluster of weak convective cells during mid-afternoon (2134 UTC), contributing to a moderate size convective system northwest of Red Deer during the evening (0300 UTC). The radar PPI (Figure 5c) shows a storm north of Red Deer with maximum reflectivity exceeding 60 dBZ. Figure 5a suggests strong orographic subsidence near the main Rocky Mountain barrier (indicated by the arrow in Figure 5c). Smaller-scale convection is evident over the LIMEX network, including a small thunderstorm just north of Caroline (Figure 5c) with reflectivities exceeding 50 dBZ.

Figure 6 illustrates the effects of subsidence warming helping to create the lid and allow the buildup of latent instability (through increasing moisture and surface heating). This is followed by low-level adiabatic ascent which cools and/or lifts the lid, eventually allowing free convection to occur. In this case, the sounding for the previous day (2209 UTC, Figure 6a) shows strong subsidence

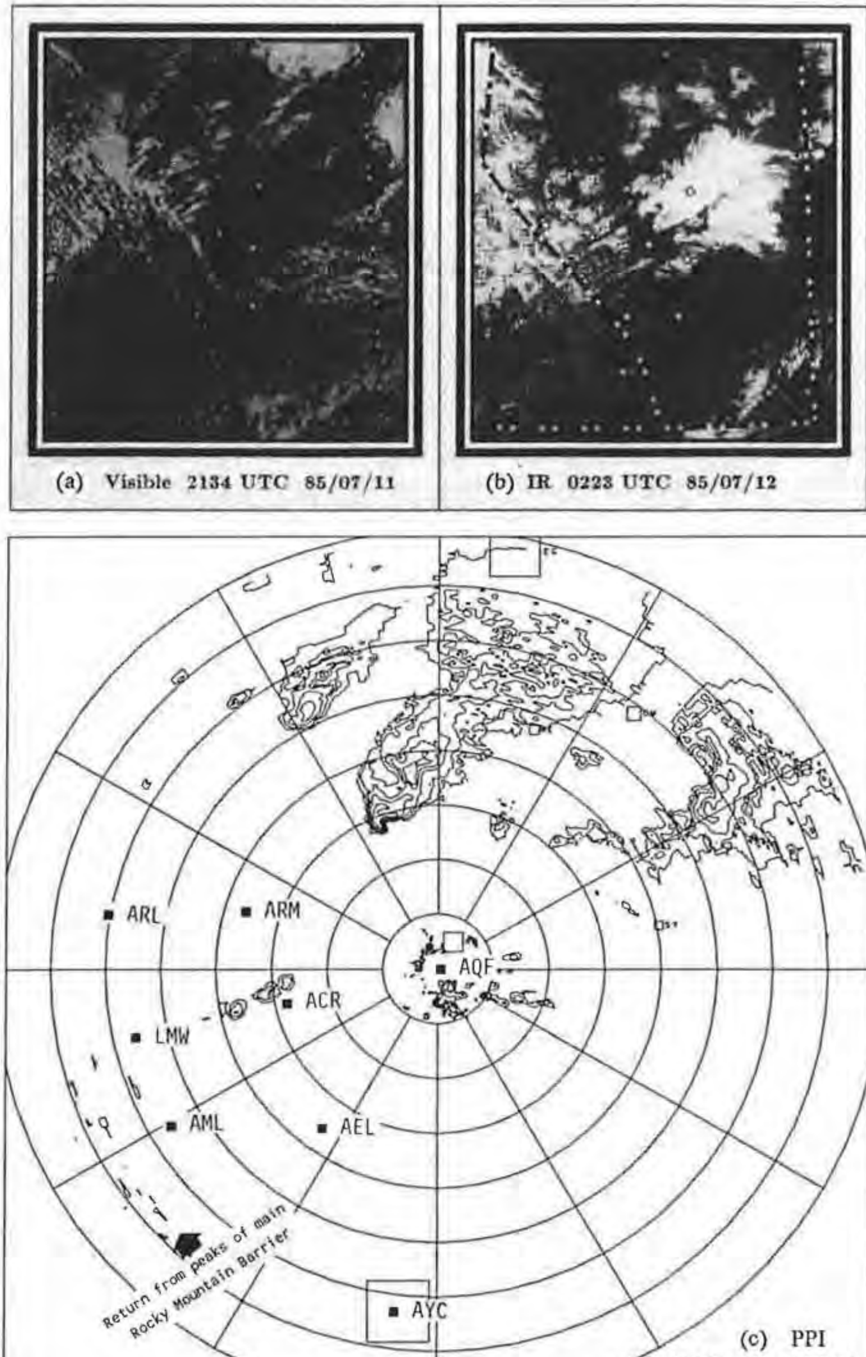

FIGURE 5. NOAA satellite images of southern Alberta and Red Deer radar PPI, 11–12 July, 1985: (a) visible image at 2134 UTC; (b) infrared image at 0223 UTC; (c) 1.5-degree S-Band PPI reflectivity contours with 20-km range rings at 0300 UTC, with 10 dBZ contours starting at 20 dBZ. (Reproduced from Honch, 1989.)

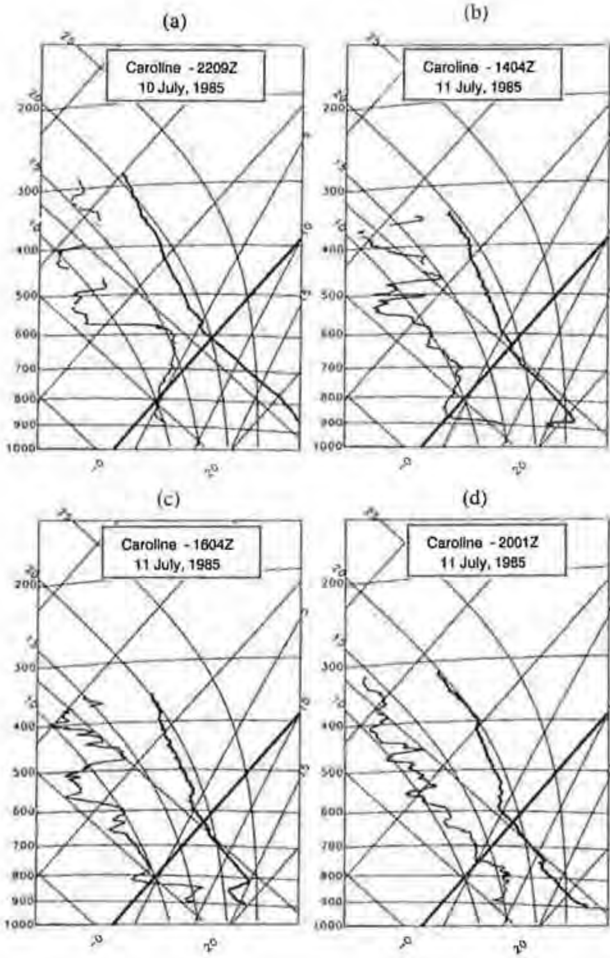

FIGURE 6. Temporal variation in soundings at Caroline (CACR), showing the creation and breakdown of the *capping lid* due to low-level subsidence and ascent respectively on 10–11 July, 1985.

warming and surface heating giving a well-mixed layer with dry adiabatic lapse rate up to 600 mb. By 1404 UTC (Figure 6b), radiational cooling overnight has produced a very shallow moist boundary layer. Late-morning and early-afternoon low-level convergence and ascent (see Figure 10) start to cool the lowest layers, raising the lid (Figure 6cd), while the convergence leads to a deeper layer of moisture. The lid rises to 750 mb and all but disappears by 2001 UTC, providing a much deeper, well-mixed layer of moisture for the convective storm noted in Figure 5.

Figure 7 demonstrates the spatial change in the capping lid from southwest to northeast across the LIMEX-85 network during the late morning of

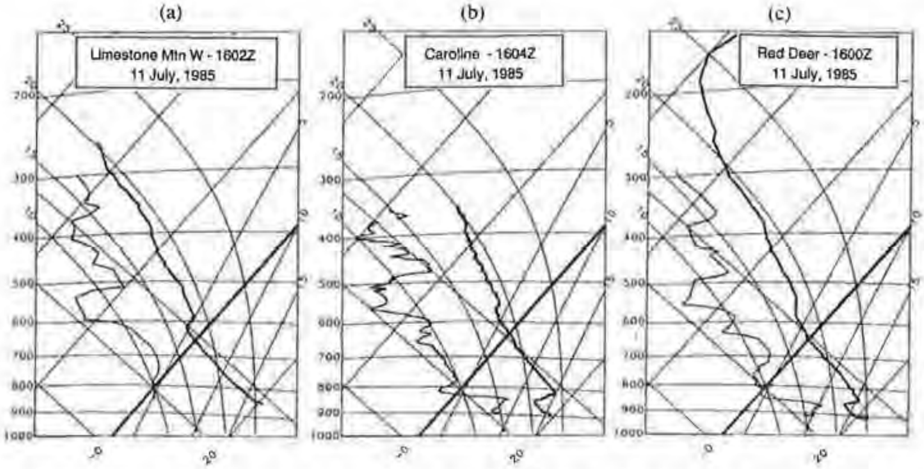

FIGURE 7. Series of soundings illustrating the spatial variability in the low-level capping lid across the LIMEX-85 network, from (a) southwest (west of Limestone Mountain peak, CLMW) to (c) northeast (Red Deer, CAQF) on 11 July, 1985.

11 July 1985, prior to any significant convection. Red Deer (CAQF), at the eastern edge of the capping-lid zone, has a moist boundary layer 500 metres thick below the lid (Figure 7c). The moist layer is slightly deeper to the southwest at Caroline (CACR), near the centre of the lid zone (Figure 7b). However, the lid is non-existent at the Limestone Mountain West site (CLMW), where the strongest subsisidence warming appears to extend down to ground level. Limestone Mountain is one of a series of foothills peaks just east of the main mountain barrier.

One of the objectives of LIMEX was to test the hypothesis that the lid normally remains east of these foothill peaks, and that convective storms frequently are initiated on their eastern slopes due to a combination of synoptic and orographic ascent weakening the lid, thereby allowing free convection of the moist boundary layer air. Figure 7 and other analyses support this hypothesis.

Figure 8 shows the strong subsidence warming effect at the eastern edge of the main Rocky Mountain barrier, at CLMW, just west of the Limestone Mountain peak. This persists with little change from 1800 UTC of 10 July through 1812 UTC of 11 July, except for a very shallow nocturnal inversion at 1409 UTC due to surface radiation.

The next series of figures attempts to relate the mesoscale dynamics during LIMEX-85, specifically 11 July, to the observed convective storms. These figures are reproduced from a recent MSc thesis with the kind permission of the author (Honch, 1989).

Figure 9 depicts the 800 and 750 mb mesoscale vertical motion fields for 1700 and 1900 UTC, 11 July over the LIMEX-85 network. These fields were computed from the upper-air data set by Honch (1989), using a modified version of the adiabatic technique (Strong, 1986). Figure 10 shows comparable analyses of

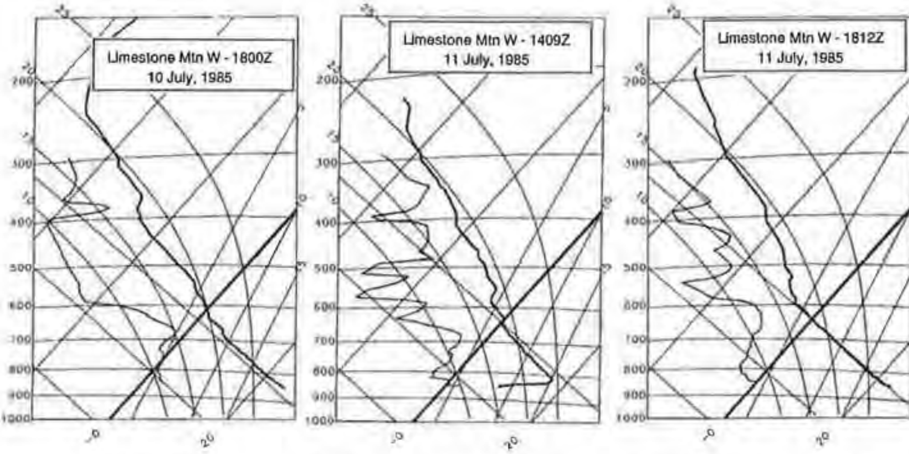

FIGURE 8. Demonstration of the strong subsidence warming effect at the eastern edge of the main Rocky Mountain barrier, at CLMW, just west of the Limestone Mountain peak, 10–11 July, 1985.

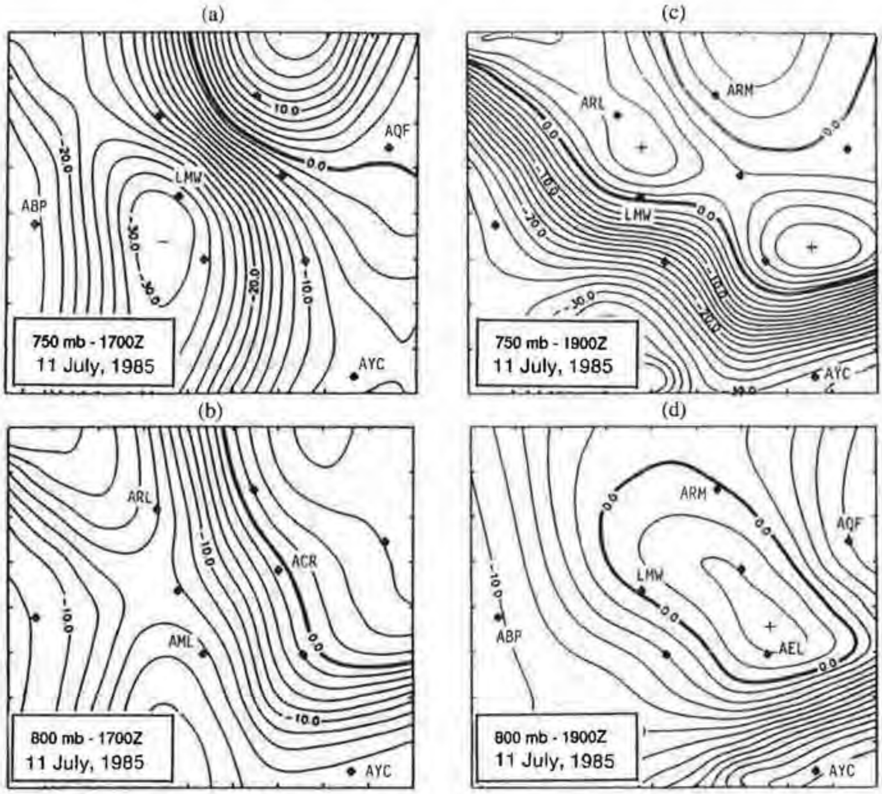

FIGURE 9. 800 and 750 mb mesoscale vertical velocity fields at 1700 and 1900 UTC, 11 July, 1985. Contour intervals are 2 cm s^{-1}, and the indicated grid length is 25 km. (Reproduced from Honch, 1989.)

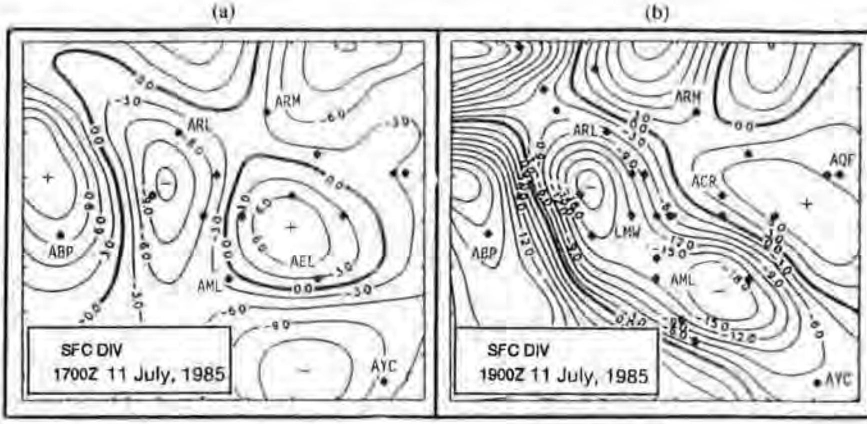

FIGURE 10. Mesoscale surface divergence fields at 1700 and 1900 UTC, 11 July, 1985. Contour intervals are in 10^{-5} s^{-1}, and the indicated grid length is 25 km. (Reproduced from Honch, 1989.)

the 1700 and 1900 UTC surface divergence fields, computed from the surface data set. In Figure 9, *positive* values of vertical motion represent *ascent*, while in Figure 10, *negative* values of divergence of course represent surface *convergence*.

While Figures 9 and 10 reflect similar processes, the use of surface convergence fields has two operational advantages, in that surface data are more readily available, while the spatial and temporal resolution of the data is much higher. In these analyses, the surface data include regular synoptic data (roughly 120-km average resolution), Alberta Forestry data, data from the automated (CR-21) sites, and surface data from the upper-air sites.

Convective storms formed during mid- to late afternoon (Figure 5), after the lid weakening had taken place (Figure 6). A '*weakened lid region*' allows boundary layer moisture, channeled into the region beneath the lid through underrunning, to be released suddenly as latent heat energy. Mesoscale ascent, such as that indicated in Figure 9, is hypothesized to result, at least in part, from a downscale transfer of energy from a decaying synoptic-scale system (Strong, 1986). Topographic forcing also plays an important role, especially when synoptic conditions impose an easterly flow in the boundary layer beneath the lid. Related to these conditions is the strengthening of convergence in the boundary layer beneath the lid (Figure 10). The region of strong convergence at 1900 UTC (Figure 10b) is of course directly related to the low-level ascent in Figure 9cd, computed from entirely different data bases.

6. SUMMARY AND RECOMMENDATIONS

These preliminary analyses barely scratch the surface of these valuable LIMEX data sets. The LIMEX field experiments were well conceived, with clear objectives, and an overall goal to contribute in various ways to convective forecasting applications. The demise of the ARC Hail Project during 1986–87 severely curtailed the data processing and scientific analysis. Most of the data, with the exception of the research aircraft soundings and the SODAR data, have been processed and quality-controlled to a reasonable degree. Diagnostic and modelling studies are continuing at several institutions, even though some data-processing tasks remain uncompleted until funding and time become available. The author welcomes any assistance in this area.

It is therefore recommended that funding support be arranged to have the remaining data-processing tasks completed. Furthermore, it would be useful to have the LIMEX data, and possibly the software specifically developed at ARC for processing such data, added to AES data archives, where the additional facilities would allow greater access by all interested scientists. Finally, the existing instrumentation and computing facilities, professional expertise, and the built-in infrastructure for mesoscale research at ARC, should not be overlooked in the event of future mesoscale research experiments in Canada.

7. ACKNOWLEDGEMENTS

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PROXDAYS – An Algorithm for Generating Realistic Normal Sequences of Daily Rainfall from Monthly Climate Normals

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ABSTRACT

A procedure called PROXDAYS was developed for synthesizing a sequence of daily rainfall data which can be used with crop growth and water use models. Taking account of historical dry periods between rain days is a major concept in the procedure. Inputs to the procedure are restricted to readily available monthly climate normals so that it remains computationally simple, uses few inputs and may be applied on a broad-area basis. The reliability of the synthesized rainfall data was evaluated by using them as input to the Versatile Soil Moisture Budget computer model, whose resulting output of monthly actual evapotranspiration correlated well with output of the same model, run with thirty years of actual daily weather observations.

RÉSUMÉ

Un procédé qui se nomme PROXDAYS a été développé afin de synthétiser une séquence de données des chutes de pluie quotidiennes, lesquelles sont utilisables dans des modèles du rapport entre l'accroissement des récoltes et l'utilisation d'eau. Ce procédé tient compte de façon particulière des périodes sèches entre les jours de pluie. Il se limite à l'utilisation des normales climatiques mensuelles toujours disponibles, donc il est peu compliqué en ce qui concerne les calculs et son application à des aires étendues. La précision des données synthétisées de chutes de pluie a été vérifiée par comparaison des résultats du modèle Versatile Soil Moisture Budget de l'évapotranspiration réelle mensuelle selon premièrement, la séquence synthétisée, et deuxièmement, trente ans de donées météorologiques quotidiennes réelles. Les résultats correspondent bien.

INTRODUCTION

This paper describes PROXDAYS, a computer based synthesizer of daily rainfall patterns designed to provide input normal climate data to models of crop growth and soil moisture which operate on a daily time step. Applications of such computer models can be real-time, near real-time or historical. The main real-time application is to monitor current growing conditions (Edey, 1980). An example of a near real-time application is in crop insurance, where evaluations of perennial forage yield estimates following the growing season are required (Selirio and Brown, 1979). There are many historical uses of daily soil moisture analysis ranging from trafficability studies (Dyer, 1980; Dyer *et al.*, 1978) to crop biomass estimates (Dyer *et al.*, 1984) and drought studies (Dyer *et al.*, 1981; De Jong and Bootsma, 1988). A combination of real-time and historical soil moisture estimates is used in prediction of soil moisture reserves in spring in western Canada (Dyer, 1984, 1988).

The most appropriate approach to determining normal crop growing conditions based on soil moisture reserves is through historical analysis from several decades of actual daily weather records. Examples are provided by Dyer *et al.* (1984) and by Sly (1982). De Jong (1985) considered that the historical approach provides the true agroclimatic normal with which estimates produced in other ways should be compared. However, it is difficult and time-consuming to carry out over wide areas, because 30 or 40 years of daily weather records from many sites must be processed and analyzed. Under present technology, broad-scale application of the historical approach cannot be done on desk-top computers and is difficult and expensive with any size of computer.

Another possible approach involves the use of sequences of daily weather generated from long-term climate parameters through the so-called "weather generator" algorithms (Woolhiser and Pegram, 1979; Zucchini and Adamson, 1984). Such weather generators are based on combinations of daily events with probabilities conditional on previous events. They require a random number generator to operate, and produce a complete probability distribution of typical sequences of daily weather. Agroclimatic normals can be derived from the resulting probability distribution when crop water-use computer models are run with the generated daily weather values. These agroclimatic normals are based on many years, rather than on a single representative average year. Due to the need for large numbers of computations which must usually be stored at least temporarily, this approach again is impractical for broad-area climate analysis, where normal agroclimatic potentials are required at many sites.

In practice, the effective determination of long-term crop growing conditions from monthly normals (Williams, 1973) has been limited solely to the use of empirical relationships. However, Stewart (1981) moved towards the use of the soil moisture model in this context when he worked from monthly normals to generate hypothetical daily rainfall by assuming that an average amount occurred every day. The approach was promising but the assumption was inappropriate. De

Jong (1985) has shown that discrepancies between the synthetically generated normal weather sequences, such as those used by Stewart, and actual historical weather records severely affect the daily estimates of crop water use in the computer models of soil water balance. The most important discrepancy is due to the assumption of continuous distribution of small amounts of rain over all days, which is almost never found in actual weather observations. Furthermore, crop growth and crop water use are as sensitive to the sequence of occurrence of daily rainfall as they are to the amount of rain per day.

Therefore, a synthetic series of days used to run a daily soil-moisture computer model must represent an expected periodicity, as well as the typical amount of daily rainfall. PROXDAYS addresses these issues by generating more realistic sequences of daily rainfall amounts, and the fact that it uses readily available monthly normals allows its wide application in agroclimate studies.

METHODOLOGY

PROXDAYS, the algorithm described here, does not generate probability distributions of typical daily weather events. Instead, it takes readily available climate normals and generates from them a single synthetic season of daily precipitation values. (Since the analysis does not apply to winter the terms "rain" and "precipitation" are used interchangeably here, although the climate normals employed are for precipitation rather than rain.) These values can be used in soil-moisture based models to give reliable mean monthly totals of actual evapotranspiration (AE), which are assumed to be indicators of biomass growth rates (Dyer *et al.*, 1984; Wallis *et al.*, 1983).

Daily potential evapotranspiration (*PE*), which is a required input to the soil moisture model, is assumed to be much less variable than daily rainfall, so that an adequate value for *PE* can be obtained by relating monthly *PE* to each day and smoothing from month to month. Therefore, daily rainfall is the only variable whose periodicity must be taken into account. Periodicity is used here to describe the expected period of time between days with measurable precipitation. It is a function of the number of days with rain (or "rain days") per month, which is a standard published climatic normal in Canada (AES 1982).

Six benchmark sites across Canada, Prince George, Lethbridge, Swift Current, Ottawa, Lennoxville and Fredericton, were used to develop the statistics on periodicity and amount which characterize the day-to-day variability in precipitation in PROXDAYS. The normal amount of rain on days with rainfall can be estimated by dividing the normal monthly rainfall by the number of rain days per month. However, frequency distributions of rainfall amounts on rain days are generally very skewed (as shown in Table 1). Therefore, actual daily rainfall which is typical may be very different from the normal daily rainfall computed as just described. The effect of skewness in the distributions on both periodicity and daily amounts of precipitation requires further modification to the computation of normal daily rainfall on days with rain. The first modification tried was to

TABLE 1. Statistical analysis for precipitation amounts on days with recorded precipitation for six months over 35 years at six sites across Canada.

	No. of Rain Days	Mean Daily Rain (mm)	Std. Dev. (mm)	Skewness	Median Daily Rain (mm)	Lowest Quartile Daily Rain (mm)
			Prince George, British Columbia			
April	287	2.9	3.3	2.3	1.5	0.5
May	362	3.9	4.5	1.8	2.3	0.8
June	427	4.7	5.5	2.5	2.8	1.0
July	381	4.7	5.1	1.7	2.5	1.0
August	396	5.2	5.8	2.3	3.0	1.3
September	398	4.4	5.2	2.4	2.5	0.8
			Lethbridge, Alberta			
April	257	4.8	6.6	3.7	2.5	0.8
May	298	4.9	6.4	3.2	2.5	0.8
June	317	7.4	10.8	3.3	3.6	1.0
July	241	4.9	6.8	3.0	2.4	0.8
August	246	5.8	10.5	5.0	2.3	0.8
September	220	5.0	6.5	2.8	2.5	0.8
			Swift Current, Saskatchewan			
April	258	3.3	4.1	2.4	1.8	0.8
May	272	4.4	5.9	2.6	2.3	0.8
June	376	6.0	8.3	3.1	2.9	1.0
July	269	5.2	6.9	2.4	2.3	0.8
August	244	5.2	6.7	2.0	2.4	0.8
September	229	4.5	6.5	2.8	2.0	0.8
			Ottawa, Ontario			
April	332	6.0	6.6	2.1	3.8	1.1
May	339	6.0	6.7	2.2	3.6	1.3
June	370	6.5	8.2	2.8	3.5	1.0
July	358	7.1	8.9	2.3	3.8	1.1
August	329	7.7	9.9	2.2	3.8	1.3
September	369	6.5	8.3	2.3	3.0	1.0
			Lennoxville, Quebec			
April	407	5.8	6.5	1.8	3.3	1.3
May	426	6.2	6.7	1.9	3.8	1.3
June	409	7.3	8.6	2.3	4.3	1.5
July	422	7.6	8.8	1.9	4.3	1.3
August	399	8.2	10.0	2.2	4.3	1.3
September	399	6.7	8.2	2.3	3.6	1.0
			Fredericton, New Brunswick			
April	351	7.1	8.7	3.0	4.5	1.3
May	388	6.8	9.6	4.5	3.3	1.3
June	385	6.9	9.2	3.0	3.6	1.3
July	362	7.5	9.8	2.7	4.1	1.3
August	349	7.4	9.4	2.2	4.1	1.2
September	307	8.7	11.7	2.8	4.1	1.3

substitute the median for the mean (or normal) value of monthly rainfall. The second modification involved both skewness in the distribution of daily rainfall amounts and the tendency for rain days to cluster and entailed lengthening periodicity to take clustering into account. Clustering refers to the tendency toward sequences of consecutive rain days with prolonged dry spells between these sequences. Based on these two modifications, four versions of the PROXDAYS model were tested.

Version 1 defined the periodicity (P) and the normal daily amount on rain days (D) from the normal monthly rainfall in mm (M), the total number of calendar days per month (C) and the normal number of days with rain per month (N). For each month, the two basic calculations in PROXDAYS were as follows:

$$P = C/N \tag{1}$$

$$D = M/N \tag{2}$$

In Version 2, the normal (or average) periodicity was replaced by the effective periodicity (Pe) which was taken as twice the normal P, thus fulfilling the second modification for clustering defined above:

$$Pe = 2 \times P \tag{3}$$

D must reflect the effective periodicity and must also be doubled to account for an equivalent monthly amount of rain. D in the second version is calculated as:

$$D = 2 \times (M/N) \tag{4}$$

The justification for the doubling of P and D is given later in the paper. In Version 3, the normal (or average) monthly total rainfall (M) was replaced by the median monthly total (Mm), such that:

$$D = Mm/N \tag{5}$$

Periodicity in the third version was calculated as P in eq 1, rather than as Pe in eq 3.

In Version 4, three modifications were made in all relative to Version 1. Effective periodicity was computed as in the second version (eq 3) so that D took into account the change in periodicity as follows:

$$D = 2 \times (Mm/N) \tag{6}$$

Furthermore, the fourth version of PROXDAYS assigns D amount of rainfall to the first of every Pe days, with no rain on the other days. Since Pe is rounded to the nearest whole number, a modification is also required for D. The modification is to multiply D by the ratio of the rounded Pe to the unrounded Pe.

In order for the modified versions of the PROXDAYS model to be widely applicable, it must be possible to estimate Mm and Pe from readily available data. Hogg and Carr (1985) showed that a set of constant relationships between the mean monthly rainfall and those values of monthly rainfall which represent thresholds for various probability levels can be established across

Canada. They computed the 50% probability rainfall (the median, *Mm*) by subtracting 0.164 times the standard deviation of monthly rainfall from the monthly rainfall (*M*). The standard deviation of the monthly precipitation total is also published in the AES climate normals (AES, 1982).

Statistical analysis of daily rainfall amounts was carried out to establish the effective period between rain days (*Pe*). The most effective estimate of periodicity should take into account the difference between the amounts of rain over all days with recorded precipitation and the amounts on only those days with rainfall significant for crop water use.

The first analysis, therefore, included only the monthly distributions of those days with recorded rainfall. These rain days (column 1 of Table 1) were accumulated over 35 years for each of the six months April to September at each of the six benchmark sites, and the average (*D*), standard deviation (*SD*), skewness (*Sk*), median and lowest quartile value of rainfall (mm) on rain days were found. The median and the bottom quartile were determined by sorting the distributions. Skewness was computed from the cubes of the difference of each individual rain day rainfall amount (*Di*) from the mean daily amount on rain-days (*D*) as follows:

$$Sk = \sum_{i=1}^{Xn} [(D-Di)^3/Xn]/SD^3 \qquad (7)$$

(after Arkin and Colten, 1976)

where Xn = total number of rain days in the month over 35 years. *Sk* is calculated from eq. 7 for each of the six months analyzed. Both positive skewness and variability were found to be very high in these distributions with most *Sk* values between 2 and 3, and all *SD* values exceeding the means. The mean value of *Di* was approximately twice the median and more than four times the lowest-quartile value. More important is that these latter values are generally less than 1.5 mm which is close to being insignificant with respect to crop water use. Therefore, the number of days with effective rainfall for crop purposes is significantly lower than *N*, the climatological normal number of days with rain, making the *P* calculated in eq 1 a low estimate of the mean length of effective dry periods.

The second analysis was of the periods between rain days. Frequency distributions for the length of time in days between rain days were determined for each month and site over 35 years. Selected statistics from these distributions are shown in Table 2 for the same six benchmark sites used in Table 1. Column 1 of Table 2 gives the number of intervals of all lengths between rain days including the occurrence of no dry days between two rain days. The average, standard deviation and skewness values for the periods between rain days are also shown. Skewness was calculated as in eq 7, except that *D-Di* was replaced by differences between the durations of individual dry periods and of the mean dry periods during the month, and that *Xn* was replaced by the total number of intervals between rain days

TABLE 2. Statistical analysis for dry periods (intervals between days with precipitation) for six months over 35 years at six sites across Canada.

	*No. of Dry Periods	*Average Dry Period (days)	Std. Deviation (days)	Skewness	Number of Dry Periods of Duration 0 Day	1 Day	Maximum Dry Period (days)
			Prince George, British Columbia				
April	325	2.0	3.0	2.2	148	50	17
May	363	1.5	2.8	3.1	212	56	20
June	436	1.1	2.3	4.1	259	80	20
July	375	1.6	3.2	3.6	216	60	28
August	396	1.2	2.5	2.8	264	35	14
September	370	1.3	2.4	2.7	211	59	15
			Lethbridge, Alberta				
April	289	2.5	4.2	2.6	141	31	26
May	298	2.1	3.2	2.0	158	30	19
June	308	1.8	3.0	2.1	163	46	16
July	241	3.0	4.6	2.5	113	22	28
August	239	3.1	5.8	3.7	101	34	45
September	203	3.4	4.5	1.7	82	22	23
			Swift Current, Saskatchewan				
April	301	2.3	3.9	2.4	151	32	24
May	270	2.3	3.5	2.2	118	43	20
June	366	1.3	2.1	2.6	185	75	15
July	294	2.5	3.7	2.6	124	33	29
August	244	2.7	4.0	2.2	100	32	27
September	204	3.6	5.6	2.6	82	23	33
			Ottawa, Ontario				
April	339	1.9	3.0	2.4	166	49	17
May	336	1.7	2.5	2.2	163	52	17
June	374	1.4	2.2	2.6	189	69	15
July	343	1.8	2.6	2.1	160	60	16
August	340	1.7	2.1	1.4	151	54	9
September	351	1.5	2.2	2.1	162	68	13
			Lennoxville, Quebec				
April	435	1.2	2.1	2.4	245	72	14
May	413	1.2	2.0	2.5	238	60	12
June	413	1.2	1.9	2.5	218	75	13
July	416	1.2	1.9	2.3	219	77	11
August	389	1.4	1.8	1.5	180	72	9
September	387	1.3	1.9	2.3	188	76	12
			Fredericton, New Brunswick				
April	382	1.5	2.4	2.3	199	50	18
May	421	1.2	1.9	2.2	238	56	14
June	357	1.4	2.2	2.4	178	59	16
July	379	1.5	2.1	2.0	172	74	11
August	339	1.7	2.2	1.7	153	46	11
September	311	1.9	2.6	2.3	123	54	15

* Includes periods of length 0 days (i.e. between consecutive rain days)

(including intervals of no dry days between rain days) for the month over 35 years. The median intervals between rain days were found by sorting. The last three columns of Table 2 show the numbers of periods of zero days and one day, and the duration of the maximum dry period over the 35 years. Separate sorting and skewness calculations were carried out for each month. In cases where an interval between rain days extended to the following month, that interval was attributed to the month in which the first rain day occurred.

The periods between rain days also exhibit highly variable and skewed distributions. The standard deviations exceed the mean values. The mean periods range from just over one day in eastern Canada to between three and four days during some months at the two Prairie Province sites. Skewness is positive, ranging from 2 to 3 during most months. The frequencies of zero-and one-day period lengths (columns 5 and 6 in Table 2) suggest that 40 to 50% of all rain days occur in sequence with other rain days, while another 10 to 20% of rain days are separated from each other by only one day. The high frequency of cases with zero days between rain days is consistent with other studies such as by Borgman and Brooker (1961) which have demonstrated that rain days show persistence, i.e. the chances for a rain day increase if the previous day has had rain, as compared to weather events on the previous day being unknown. The remaining periods (roughly 40%) are distributed over a wide range of values, as demonstrated by the maxima oberved (Table 2).

This analysis suggests that true dry spells (intervals longer than one day) are significantly longer and less numerous than would be computed by starting from the climatological normal number of days with precipitation as is done in Versions 1 and 3 of PROXDAYS. With nearly half the rain days occurring in direct sequence with at least one other, i.e., with no dry days between, the remaining dry periods would, on average, be nearly twice as long as the intervals computed in eq 1. Therefore, the modification of eq 3, which is used in Versions 2 and 4, should provide a reasonable estimate of expected periodicity. Given the tendency of rain days to cluster and given the high frequency of days with very light rainfall (see Table 1), the doubling of the expected daily amount in eq 4 is also a reasonable modification.

PROXDAYS was tested as follows. The Versatile Soil Moisture

TABLE 3. Selected sites across Canada used to test PROXDAYS against historical daily weather data as a basis for estimating mean monthly actual evapotranspiration

Prince George, B.C.*	Ottawa, Ontario*
Lethbridge, Alberta*	Montreal, Quebec
Medicine Hat, Alberta	Lennoxville, Quebec*
Swift Current, Saskatchewan*	Fredericton, New Brunswick*
Brandon, Manitoba	Kentville, Nova Scotia
Kapuskasing, Ontario	Charlottetown, P.E.I.
London, Ontario	

* Sites used to evaluate daily rainfall amounts and periodicity

Budget model (VSMB) of Baier and Robertson (1966) as revised by Dyer and Mack (1984) was run continuously for 30 years of actual daily records (1951–80) at the 13 sites listed in Table 3. Control coefficients were selected to represent a perennial forage in clay loam soil. Using the same control coefficients, the same VSMB model was run using synthetic daily rainfall sequences generated by PROXDAYS from 30-year climate normals (1951–80) at the same 13 sites. All four versions of the PROXDAYS model described above were run. Linear regression was used to compare monthly totals of actual evapotranspiration (AE) from the PROXDAYS-driven VSMB simulations to the 30-year historical

TABLE 4. Results of regression analysis of simulated monthly actual evapotranspiration using input data from PROXDAYS (X) against simulations using 30 years of actual historical rainfall records (Y)

4a) Coefficient of Determination (R^2)

	Version Number			
Months	1	2	3	4
April	.704	.801	.757	.857
May	.874	.904	.909	.899
June	.868	.894	.852	.872
July	.879	.860	.804	.855
August	.928	.936	.897	.924
September	.942	.952	.921	.939

R^2 above .813 are significant at .01 level
.729 are significant at .05 level.

4b) Slope (Y = f(X))

	Version Number			
Months	1	2	3	4
April	.751	.831	.780	.855
May	.503	.556	.456	.510
June	.388	.591	.378	.618
July	.378	.582	.413	.648
August	.569	.797	.578	.816
September	.728	.850	.711	.846

4c) Y – Intercept (mm water)

	Version Number			
Months	1	2	3	4
April	3.4	1.7	3.0	1.5
May	24.5	22.1	29.3	26.8
June	37.8	26.1	41.0	28.2
July	42.1	30.6	43.8	30.5
August	22.3	13.3	25.3	16.1
September	10.5	7.9	13.1	10.1

simulations of monthly AE using the VSMB with actual daily records. Months are an appropriate time frame for verification since inputs to PROXDAYS are monthly statistics.

RESULTS

The regression results comparing historically based simulations to each of the four PROXDAYS-based simulations of monthly AE are shown in Table 4. For June, August and September, the second version of PROXDAYS gave the highest coefficients of determination (R^2) (Table 4a). R^2 values for the fourth version, where both periodicity and the daily amount were modified for skewness, were also generally high, but R^2 values for Version 2 were consistently higher over the five growing-season months (May-September) than those of Version 4. This suggests that modifying periodicity, which also increased the daily amount of rain, was the most important refinement in PROXDAYS. Version 3 improved on Version 1 only during April and May. Overall, both Versions 2 and 4 were improvements. The fourth version produced correlations significant at the 0.01 level during all six months, although the second version appears to be the better model during May to September.

The four versions of PROXDAYS were also evaluated in terms of the regression coefficients (slope and Y-intercept) between PROXDAYS-driven VSMB simulations and historically driven VSMB simulations of monthly AE. A one-to-one relationship would be considered ideal. Such a relationship exists when the regression analysis results in a slope close to one and a Y-intercept close to zero. Tables 4b and 4c give the slopes and Y-intercepts respectively for all four versions of the PROXDAYS model.

For four of the six months, the fourth version gives a slope closer to one than the second, with only a slightly higher Y-intercept. This suggests that Version 4 is slightly better than Version 2, in spite of the lower correlation, because it introduces less bias in estimating the historical average AE. According to the monthly AE totals aggregated over all 13 stations in Table 5, all four versions overestimate the historical averages of AE prior to August. The use of median monthly rain instead of mean monthly rain to calculate D in the third and fourth versions compensates for the over-estimation of AE by reducing the total amount of rainfall. Correlation is slightly reduced because the median D is computed from the mean. The difference between Mm and M of any station was assumed to be a constant function of the standard deviation (Hogg and Carr, 1985).

The comparison of the average monthly and seasonal AE totals derived for all four versions of PROXDAYS with AE totals based on the historical VSMB simulations for all 13 sites combined (Table 5) shows that the first version overestimates the historical values for all six months. For the first three months, the fourth version provides the best results. For July, the second version is closest to the historical average. For the last three months, both the second and third versions are closer than the fourth to the historical averages. The seasonal total of

TABLE 5. Averages of 13 weather stations of simulated AE using 30 years of historical data as input to the VSMB model and simulated AE using the four versions of PROXDAYS to provide input data to the VSMB model for each month and for the season.

Months	Historical	PROXDAYS Version Number			
		1	2	3	4
	mm	mm	mm	mm	mm
April	30.4	35.9	34.6	35.1	33.8
May	62.3	75.0	72.2	72.4	69.6
June	72.0	88.0	77.6	81.7	70.8
July	71.7	78.2	70.5	67.4	63.5
August	60.7	67.5	59.4	61.2	54.5
September	42.9	44.5	41.2	41.9	38.7
Season Total	340.0	389.1	355.5	359.7	330.9

the historically based AE simulations, however, is most closely matched by the fourth version (last row of Table 5).

CONCLUSIONS

On the basis of the coefficients of determination and the linear regression coefficients (Tables 4a to 4c), it is difficult to choose between Versions 2 and 4 of PROXDAYS as the ideal model for the whole growing season, but both are superior to Versions 1 and 3. Given that the seasonal total for AE simulations using Version 4 is the closest to the historical total (Table 5), this version could be argued to be the best overall PROXDAYS model. Using the median rather than the mean monthly rainfall reduces the impact of occasional very heavy rainfalls. Such extreme rainfalls have more influence on the mean monthly totals than on soil moisture or AE calculations, because runoff losses are taken into account in the VSMB.

There are applications where using the median rather than the mean monthly rainfall is more appropriate. An example is the projection process described by Dyer (1984) as a means of extrapolating from present soil moisture reserves based on current weather analysis to several months into the future. That extrapolation is based on selected years of historical weather records retrieved from files of daily weather to represent normal climate. The replacement of these selected weather records with data generated by PROXDAYS would increase the flexibility of that system of projection.

PROXDAYS will be a useful tool for increasing the flexibility of weather-based crop monitoring systems in Canada. A major problem in crop weather monitoring is that computer simulation procedures must remain relatively rigid in order for real-time estimates to be normalized (i.e. current estimate expressed as percent of normal). PROXDAYS could be substituted for the historical analysis in generating the agroclimatic normals against which the real-time simulations would be normalized, resulting in significant savings of both computation time and data storage space. An easier process by which changes in the normals-based estimates could be made in response to changes in the real-time analysis would mean more flexibility in the current weather simulation procedure. The addition of new weather stations to a network presently being monitored by systems like SMEP (Edey, 1980) and FoDEWS (Dyer, 1984, 1988) would also be easier.

The main goal of this study was to develop a computationally simple synthesizer of daily rainfall sequences which can be applied to many climate stations at once across Canada. Since PROXDAYS is simple, as well as being based on readily available climate information (normals), it has a potential role in normalizing near real-time weather based estimates of crop-growing conditions. It also has a potential application in providing input data for complex crop-growth simulation models, such as that developed by Stewart (1981), to derive agroclimate normals on a broad-area basis. Further testing is needed, however, before PROXDAYS can be considered a general technique. Flexible control coefficients for the Versatile Soil Moisture Budget (Dyer and Mack, 1984) allow that model to reflect a wide range of crop and soil patterns which should be used to assess PROXDAYS. Similarly, other crop simulation models which also require daily weather records could be used to assess the general applicability of PROXDAYS. Furthermore, the analysis described above for periodicity and skewness in daily precipitation should be carried out for winter months.

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News and Comments
Nouvelles et commentaires

CMOS/R.S.C.'s *Canada and the Changing Atmosphere*

The Canadian Meteorological and Oceanographic Society and the Royal Society of Canada have recently sponsored production of a bilingual document entitled *Canada and The Changing Atmosphere/*
Le Canada et l'Atmosphère en Évolution. Prepared by the well-known scientist Dr. F. Kenneth Hare, Chairman of the Canadian Climate Program Board, the document provides a message for Canadians in all walks of life about the implications of anticipated changes in our climate. Its twenty-two fascinating and well-illustrated pages are "must" reading for all in the climate business as well as for politicians, administrators and the broader public.

Dr. Hare's introduction is the best advertisement for this brochure. He says:

> Extremes of weather have always been a challenge for Canadians. The pioneers had to endure severe cold, summer drought and damaging storms. They learned to survive in a difficult environment, and even to profit from it. Above all they learned to be ready, to be on the alert for signs of change in the weather.
>
> Today, Canadians face a new challenge – an altered atmosphere, expected to cause unprecedented changes in our weather patterns over the next half-century. Some of these changes will be welcome, but others will impose severe stresses on our economy and society. We must be prepared for them, as we are for the shifts in current weather to which this country is so subject.
>
> To be prepared for both kinds of change – day-to-day variations in weather, and long-term climatic changes – we shall have to make good use of Canada's scientific and technical skills.
>
> A highly effective national meteorological service has long been in place. The sciences of the atmosphere and ocean are expanding rapidly. New technology has transformed our ability to monitor weather and climate, and to predict change. If we can see change coming, we can adapt more readily.

Regrettably, the comprehensive forecast and warning information available from the national meteorological service is underused in the country's economic affairs. Canadians remain only partially aware of what they can learn from the nearly three billion weather records now on file, and of how to protect themselves against changes.

This brochure outlines how meteorology and related sciences, especially oceanography, serve the national need for such information. Through coping effectively with the unwelcome parts of our present climate, we shall be better equipped to face climatic change.

COLLOQUE DE L'ASSOCIATION DE CLIMATOLOGIE DU QUÉBEC

L'ACLIQ organise annuellement, depuis 4 ans, un colloque portant sur des sujets d'actualités qui touchent de près les problèmes en climatologie. Ces colloques sont, depuis 3 ans, intégrés dans le programme de l'Association Canadienne-Française pour l'Avancement des Sciences (ACFAS) afin de permettre à un plus grand nombre de personnes d'y participer. Lors du 58e Congrès de l'ACFAS, qui se tiendra à Québec du 14 au 18 mai 1990, le colloque portera sur "Le climat en évolution et ses impacts les secteurs de l'énergie, de l'agriculture et des forêts". Quatre conférenciers invités feront part a) de la situation climatique actuelle et de son évolution réelle au Québec et b) des inquiétudes et des problèmes pratiques associés à cette évolution, ceci dans les trois secteurs d'activités mentionnés. Des intervenants des milieux gouvernementaux, privés et universitaires seront présents et des tables de travail et de discussions sont prévues au programme. Une séance plénière clora cette session et tous les travaux du colloque seront publiés ultérieurement sous forme de "proceedings" une invitation est lancée à tous.

Jacynthe Lacroix
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Call for Papers
CANADIAN SOCIETY OF AGROMETEOROLOGY 1990 TECHNICAL SESSION

The Canadian Society of Agrometeorology (CSAM) is planning a one-day technical session for Tuesday July 24, 1990. The meeting will be part of the Agricultural Institute of Canada (AIC) 1990 Annual Conference to be held at the Convention Centre in Penticton, British Columbia. The CSAM technical session provides an opportunity for members to meet and exchange information on research, extension, and service activities from micrometeorology to climatology. The theme of this conference is Agri-Resource interfaces. You are encouraged to share your information and experiences, and invited to attend the other AIC sessions from July 22–26 to better understand what is happening in the agricultural industry in Canada.

Poster presentations and equipment or instrumentation displays are invited. Please send a proposed title of your paper(s) by December 31, 1989 and a 200 word abstract with the finalized title by March 1, 1990 to:

R.J. Williams, Agricultural Climatologist
B.C. Ministry of Environment
1873 Spall Road, Kelowna, B.C. V1Y 4R2
(604) 861-7211

TROISIÈME ATELIER DE TRAVAIL SUR LA MÉTÉOROLOGIE OPÉRATIONNELLE

Cet atelier de la SCMO aura lieu à l'Université du Québec à Montréal, 2–4 mai 1990. Renseignements de:

Pierre Bourgouin, Section de formation/SEA
100 blvd. Alexis-Nihon, #300, Saint-Laurent (Qué.) H4M 2N8
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ERRATA

Simple Guidelines for Estimating Wind Speed Variations due to Small-scale Topographic Features – An Update
J.L. Walmsley[1], *P.A. Taylor*[2] and *J.R. Salmon*[3]

The authors would like to point out the typographic errors in Equation (7) of their recent paper, Walmsley *et al.* (1989). The correct form of the equation should have been:

$$U_g/u_* = ((\ln(u_*/fz_o)-b)^2 + a^2)^{1/2}/\varkappa \qquad (7)$$

where $x = 0.4$, $a = 4$ and $b = 2$. The corresponding equation in our "Guidelines" software was and is correct.

In the references of the paper, the spelling of Tampieri was incorrect.

We would like to thank Tsoi-Ching Yip for spotting the missing power of 2 on the constant, a.

REFERENCE

Walmsley, J.L., P.A. Taylor and J.R. Salmon, 1989: *Climatol. Bull.*, 23(1), 3–14.

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AUSTRALIAN WORKSHOP ON BUSHFIRE METEOROLOGY AND DYNAMICS

The topic of "Bushfires: Meteorology and Dynamics" was the subject of a workshop held in Canberra, Australian Capital Territory (A.C.T.), on September 28–29, 1989. The Australian National University (ANU) was the venue. Close to 75 people attended the workshop which was held in conjuction with the Simulation Society of Australia's (SSA) Eighth Biennial Conference.

The workshop, which was preceded by the three-day conference, was sponsored by the Australian Meteorological and Oceanographic Society, the Australian Mathematical Society, and the National Bushfire Research Unit (NBRU) of the Commonwealth Scientific and Industrial Research Organization (CSIRO). Dr. Tom Beer, CSIRO Division of Atmospheric Research, Private Mail Bag No. 1, Mordialloc, Victoria 3195, served as the workshop's principal organizer.

The workshop was designed to bring together meteorologists, mathematicians and fire modellers. Furthermore, it aimed to act as a forum for the discussion of future analytical, theoretical and experimental requirements for a better understanding of the dynamics of bushfires, the effects of meteorology on fires and the effects of fires on meteorology.

Fifteen presentations were made during the two-day workshop. Preprints for nine of the papers and abstracts for three others were made available to registered participants on arrival in the form of an appendix to the SSA conference proceedings printed by ANU. Authors had approximately 30–40 minutes for presentation of their papers. The program was arranged to allow ample time for discussion on each paper. The workshop concluded with an open forum on research needs in bushfire meteorology and dynamics. The editor of the Pergamon Press journal *Mathematical and Computer Modelling* has agreed to a special issue

CORRIGENDUM

Australian Workshop on Bushfire Meteorology and Dynamics

Thanks to Marty Alexander for pointing out that on the third line of p. 136 of Vol. 23(3), December 1989, the word "above" should be substituted for the word "below". Information on this Workshop is available from Dr. Tom Beer, CSIRO Division of Atmospheric Research, Private Mail Bag No. 1, Mordialloc, Victoria 3195, Australia, and not from the Northern Forestry Centre in Edmonton.

containing the papers presented at the workshop. Papers for this special issue will be subject to the normal peer review process. For further information, contact Dr. Beer at the address given below.

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ASSOCIATION INTERNATIONALE DE CLIMATOLOGIE, COLLOQUE DE LANNION-RENNES EN JUIN 1990

L'Association Internationale de Climatologie a pour but le développement des relations et de la solidarité entre des climatologues de diverses formations (géographes, physiciens de l'atmosphère, agronomes, statisticiens . . .) et de nationalités différentes par:

- des activités scientifiques communes pluridisciplinaires ou non.
- des colloques et la publication de travaux scientifiques.
- des échanges d'informations, de méthodes d'enseignement et de vulgarisation des problèmes climatiques actuels.

La langue de travail est le français. L'association regroupe actuellement une certaine de membres représentant une quinzaine de pays.

Le troisième colloque de l'AIC aura lieu à LANNION (France, Côtes du Nord) et à Rennes, du 20 au 22 juin 1990 avec le concours de la Météorologie Nationale française, de l'ORSTOM, et de l'université de Rennes II. Le programme est le suivant:

20 juin: Ateliers "Satellites et climatologie" animés par M. GUILLOT (ORSTOM), avec les thèmes: extraction de paramètres physiques à partir des mesures prises par satellites météorologiques, estimation des températures de la mer, des précipitations et de l'évaporation, végétation et risques naturels.

21 et 22 juin: séances de communications et d'affichages sur la climatologie zonale, la topoclimatologie, etc.

Pour s'inscrite au colloque, pour présenter une communication (résumé à envoyer avant le 15 janvier 1990) ou pour adhérer à l'association, prière d'écrire au secrétariat:

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