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CLIMATOLOGY— A USEFUL BRANCH of METEOROLOGY

H.E. Landsberg

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by

H.E. Landsberg

Chief Climatological Services Division
United States Weather Bureau

An address presented to the Royal
Meteorological Society, Canadian Branch
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by H.E. Landsberg

After accepting your very kind invitation to address you this evening I had a few twinges of conscience. It suddenly seemed that I might find myself in the unenviable position of carrying "owls to Athens." After all, you have had Dr. Griffith Taylor, one of the paragons of comparative climatology, in your midst for so many years. There have also been many progressive contributions to climatology from members of the Canadian Meteorological Service. But I chance to recall some of these fine papers to you, mindful that perhaps even in this case the biblical saying that "a prophet is not without honour, save in his own country, and in his own house" (Matth. XIII, 57), may have some bearing.

Just twenty years ago the prototype of a climatological study applied to Aeronautics appeared here. It is that fine pamphlet by W.E.K. Middleton on the Climate of the Gulf of St. Lawrence (1). I believe it inaugurated the series of Canadian Meteorological memoirs. Many similar studies prepared in other countries, have followed this example.

In more recent years the work done by the Building Research group of your National Research Council under Dr. Legget (2,3) have been followed on our side of the border with much interest. In particular the joint effort of your Meteorological Service with the National Research Council culminating in the Climatological Atlas for Canada has found our admiration and - to a considerable degree - our envy (4,5,6).

It cannot be our purpose here to give you a bibliographical review of all the recent contributions to climatology from your country. However, we were glad to see so many climatological papers cited in Dr. Thomson's annual progress report on meteorology and climatology published a short while ago in the Canadian Geophysical Bulletin (7). Let me just make one brief reference which I cannot suppress. This concerns Longley's admirable booklet on the Climate of Montreal (8). If nothing else, the presentation and art work in it should dispell the notion that climatology is a subject matter which only invites sound sleep.

Tonight I would like to set forth two theses:

(1) Climatology is a part of meteorology, and
(2) It is useful both in itself and to its parent science of meteorology.

For some time climatology was regarded by some meteorologists as a slightly mongrelized discipline with considerable affinity to descriptive geography. To them the acme of climatological performance seemed to be the presentation of mean values of various meteorological elements in areal distribution or as a time series. When, upon reflection, it had to be conceded that extreme values or yet some combinations of various factors was an undeniable feature of even the most routine climatological publications, it became grudgingly accepted that climatology is a type of statistical meteorology. The meaning of "statistical" in this connection was essentially that of an unsophisticated amassing and digesting of large quantities of figures. It is quite correct that climatology has a little of the musty smell of archival work around it. It has even been described as the morgue and graveyard of the meteorological observations which are primarily collected for synoptic purposes. We shall shortly see what can be done for the resurrection of this material. There is even some hope that climatology will still be around in 2000 A.D. Dr. McIntyre spoke before you in his extremely interesting presidential address in a vein that one might interpret that climatology would be by the end of the century completely absorbed or amalgamated into meteorology (9).

Actually, one of the most important tasks of applied climatology is to make use of the accumulated climatological data for weather forecasting. These data contain the historical record. Weather sequences are not haphazard events. Hence the experience, available over periods far exceeding any forecaster's memory, should prove to be useful to him. The use of correlations between antecedent and subsequent weather events has been somewhat ambitiously called objective forecasting (10). We are really only dealing with a systematized weather memory. The past well-known efforts have usually selected one or more observed elements at a given time. These were related by an empirical formula or by a series of alignment charts with the value of a meteorological element at a later time or with the occurrence or non-occurrence of a subsequent event. The larger the historical material, the more refined will be the procedure. In particular it is possible with a large sample to characterize the probability with which the predicted event or value can be expected to occur.

In some of the past work the precursor elements which have been successful as antecedent or predictor quantities were upper air pressures or gradients. Their future values are now being predicted by the modern numerical techniques. These predictions are not yet weather forecasts. Such elements of practical importance as spot occurrence of low ceilings, fog, frost, and specific temperatures will for considerable time to come remain in the province of the human forecaster. It should be of considerable help to him to have available correlations of the type mentioned before. These should cover various time lags including zero lag. The latter for the case when perfection of upper air pattern forecasts is reached by the numerical prediction techniques. The availability of the past record in a form suitable for modern machine processing methods, such as punched cards, will be of great help in preparing such forecasting aids.

In another problem of interest to the forecaster the climatic data will enable us to sift out the truth. Our reference is to the so-called singularities. There is considerable evidence on hand that these calendar-bound events are not entirely the figments of imagination or folklore. The recent papers by Wahl on the January thaw in New England and the October cold spell* attest to that (11,12). A recent paper by Bryson and Lowry (13) shows another singularity in the summer rainfall of Arizona. It is very likely that more of these "spells" and perhaps some of the underlying causes can be detected. Dr. Wahl of the Air Force Cambridge Research Center with cooperation of the Weather Bureau and the U.S. Navy weather people is now analyzing daily pressure values for the whole hemisphere derived from the 40-year historical map series for occurrence of such singularities. Any positive findings will at least be helpful to the forecasters in alerting them to watch for these events. The singularities are apparently tied to regular seasonal variations in the general circulation, such as latitudinal migration of the jet stream. Their occurrence is not a certainty each year but the past record can yield the probability of their occurrence.

One could go on at considerable length in discussing the various "back feed" mechanisms through which climatological records can be useful to the weather forecaster. Let me rather proceed now with a few examples of what we may call the "bread and butter" applications of climatology. In most instances they are essentially predictions in their own right. The underlying assumption is that certain atmospheric events or values of measured elements will occur in the future, by and large, with the same frequency as in the past. Answers based on this reasoning are usually adequate for questions coming from various branches of engineering. Engineers are accustomed to treat various factors of the natural environment as calculated risks. This is exactly the type of information the climatologist can furnish for the atmosphere. Climatic data can enter singly, in varying combinations, or as derivative quantities into the planning.

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*Footnote: In 1946 at a meeting of the District of Columbia Chapter of the American Meteorological Society I had first opportunity to call attention to the October singularity. It was particularly noticeable in the maximum temperatures which are more affected by general than local weather circumstances. More data have since become available. For the 35-year period 1920-1954 the following picture develops:

Washington, D.C., Mean Daily Maximum Temperatures

October	10	11	12	13	14	15
°F	69.7	70.9	72.0	67.9	68.9	70.8

The sharp drop of 4.1°F in mean from the 12th to the 13th is the highest interdiurnal change in October. In the 35 years there were 23 when a negative change occurred between these two dates; no change took place in 2 years and 10 years had a rise. This means 2:1 odds in favour of a negative change. None of the other 16 days in October with negative change show the high odds. Incidentally, all of the positive changes were smaller too.

A few examples will illustrate the point. In heating engineering the capacity of heating plants and fuel storage has to be geared to the heat requirements. These are generally expressed as degree days. The rate structure for steam furnished from central heating plants, and gas delivery costs are also based on degree day statistics. Annual values as well as daily values of heating degree days follow very nicely the normal distribution of statistics. These can be very easily interpreted for construction plans or for rate schedules.

Equally simple is the use of climatic data in agricultural engineering when it comes to broad general decisions about land utilization. In many regions the critical rainfall months for crops are in summer. Mean values of rainfall can be very misleading but a frequency distribution can readily be used to ascertain the risks for various crops, provided their respective water requirements are known. In recent years this approach has been extended to daily precipitation values and sequences. Probabilities obtained from punched cards have been used for the planning of irrigation schedules and, conversely, for hay drying (14, 15).

Climate may play an important part in locating a plant. Some of the operating costs depend on climate, e.g., those for heating and cooling. Some industries have outdoor operations and there may be critical limitations imposed by the atmospheric environment. It is, of course, well known that the efficiency of workers depends upon the cooling power. But the manufacturing process itself may depend upon the climate. This is the case in the U.S. industrial practices in aircraft and railroad car manufacture. In both of these industries, open air activities are hampered by air temperatures below 40°F or wind speeds exceeding 15 to 18 miles per hour. These limit the use of paint spraying equipment and also cause difficulties with close tolerances in assemblies. Climatic data readily permit selection of areas with least occurrence of the critical conditions. Similar criteria can be established for other industries.

A particularly important limit in many outdoor activities is freezing temperature. The construction industry and agriculture are prominent examples. Hence the duration and magnitude of subfreezing temperatures have been very profitable targets for applied climatology. They affect commerce too. Just think of sales campaigns for antifreeze and winter clothing. Lacking precise long range forecasts, there is presently no better substitute than a bet on odds based on past performance. The same holds for planning sale of seeds, shipment of plants from nurseries and guidance for gardening in the spring.

The low temperatures are equally important for laying of pipelines and the dispatching of gas, gasoline and oil through them. Obviously, direct observations of soil temperatures would give the best statistics for these purposes but such data are collected at a few stations only. But it has been empirically established that a derivative of air temperature can be satisfactorily substituted. It is the freezing index. This is a degree day value obtained by algebraically adding the departures of the mean daily temperatures from 32°. This index for the freezing period is a good indicator for frost penetration into the soil. It can be applied to individual seasons, extreme seasons, or seasonal means.

At this time the most widely required climatic information pertains to major weather risks. There is hardly any major structure going up now without a careful assessment of dangers arising from atmospheric extremes. Buildings, hangars, tall towers, bridges, dams, turnpikes are planned with weather hazards in mind. The statistics of extreme values - only a decade ago still largely a theoretical subject - have become a common tool in applied climatology. Temperature, flood stages, extreme wind speeds have been successfully analyzed by several available procedures (Grumbel, 16; Thom, 17). In the United States the extreme wind problem has, unfortunately, gained considerable prominence by the recent hurricanes. Insurance companies are re-evaluating their risks. Climatic data play a prominent role in the assessment of realistic premiums. One can readily appreciate that when losses from hurricanes, floods, and tornadoes begin to run into Billion dollar figures a "painful reappraisal" cannot be avoided. You had a taste of it here when "Hazel" struck her last blow around here just a year ago. We can only point to the very large "market" for climatological data in the insurance underwriting business, be it against damages from hail, wind, rain, lightning or other weather factors.

One of the statistics which will soon be in large demand is information on solar radiation. Even at this early stage of the game it is safe to say that this large amount of free energy will compete in the future, probably quite successfully, with nuclear energy to supply mankind's needs. Our data for this purpose are woefully deficient, - as are many which are not by-products of the synoptic observations. I venture to say that some day when synoptic meteorology has made the transition from kinematic to energetic concepts, the forecasters, particularly those concerned with longer periods, will find the radiation data interesting too.

You will probably agree with me that the enumerated applications of climatology are useful. They are not very glamorous. In fact, I suspect that many of our meteorological colleagues will miss the scientific challenge in this pursuit. Yet climatology has a fair share of problems which require more than a statistical approach. They are definitely in the realm of a physical science. In these questions we are not dealing with stochastic relations but with definite causes and quantitative effects. Many of them are in the field of microclimatology. Here is one of these problems. What is the climate at a point for which no observations are available but which is within reasonable distance from an established meteorological station? This falls into the framework of what Thornthwaite called topoclimatology at the Toronto Meteorological Conference (19). The effects of concave and convex land forms have been well studied. The influence of various types of vegetation and of small water bodies are reasonably well known. We can safely give accurate information on temperatures. We can make some good guesses on humidities, winds, inversion, fog, and even precipitation amounts. The use of micro-climatic principles, except in very rugged terrain is quite permissible for distances of a few miles from a meteorological station. As the distances grow one will want at least some observations. These need not cover months and years. A judicious sample often suffices. This is one of the primary applications of a procedure which can properly be called synoptic climatology. The key observations are made on days which represent the major synoptic situations in the region. If the frequency of these patterns is known or can be determined from a series of synoptic maps a very good approximation of many climatic conditions can be established. These include even cloudiness, ceilings, visibilities and low level aerological characteristics. Annual variations can often be established from observations of stations at considerable distance within the same climatic province. The availability of calendars of synoptic types for past years is a most desirable and useful tool for these procedures.

One can drive these techniques even a step farther. This is the case in which we attempt the prediction of climatic changes which will be caused by a radical change in landscape. This is important for planning. Just remember what changes are wrought by lumbering, by ploughing and what modern bulldozers can accomplish. Where forest and fields were yesterday, we find cities and suburbs today. Conversely, what changes can foresting and shelter belt planting bring about?

We know quite well the changes urbanisation has brought about in climate, as can be seen from the following table:

AVERAGE CLIMATIC CHANGES PRODUCED BY A TYPICAL LARGE INDUSTRIAL CITY

	Element	Change Compared to Rural Environment
Pollution:	condensation nuclei	about 15 times more
	gross dust particles	about 10 times more
	SO_2	about 15 times more
	CO_2	about 10 times more
	CO	about 25 times more
Radiation:	Total sum	-15 to -20%
	Ultraviolet (winter	-30%
	(summer	- 5%
	Illumination	-10 to -40%
	Fog (winter	+100%
	(summer	+ 30%
Smoke:		several 100%
Atmospheric Small Ions:		-50 to -75%
Electricity:	large ions	10 times more
	potential gradient	+100%
Precipitation:	amounts	+10%
	days with 0.2 inches	+10%
Temperature:	annual mean	+1 to +1.5°F.
	winter minima	+2 to +3°F.
Relative Humidity:	annual mean	-6%
	winter	-2%
	summer	-8%
Cloudiness:		+5 to +10%
Wind Speed:	mean	-25%
	extremes	-20%
	calms	+5 to +20%

This knowledge can help in preventing some of the most undesirable effects by proper planning of new communities. The climatologist can also advise on improvements of urban and rural microclimates. In horticulture this is actually quite an old art.

As a natural sequence to the man-made climatological changes it seems proper to make a few statements on the topic of natural climatic changes. Obviously, within this framework we can raise only a few points. One of them is intimately related to the artificial changes. It pertains to our old and long records. In the United States - and I suspect elsewhere - many stations have been located in growing cities. The records thus become afflicted, more or less, by the artificial changes. In many instances the stations have been shifted from one site to another. In rural areas, too, where reliance is primarily placed on voluntary observers, the stability of records leaves much to be desired. A recent survey of our stations manned by civil service personnel shows that within a decade about 64 per cent have either changed their site or appreciably moved their major instrumental equipment. Only 1 per cent has a completely homogeneous record for over 50 years. In the cooperative network, about 74 per cent had a change in 10 years. But here again 1 per cent had a stable record for more than 50 years. Of course, we can attempt to make adjustments by statistical regressions and obtain reasonably homogeneous records. However, if we are looking for some of the very small and subtle long-term trends these discontinuities may be masking the very changes we are trying to establish.

This has led us to the establishment of a number of climatic bench mark stations. These are stations which already have a good long record and which we hope can be kept in perpetuity. They are far from disturbing influences. They have now, and are likely to keep, excellent observers. Most of them are on grounds in the public domain, such as National or State Parks, college campuses, and Agricultural Experiment Stations. It will take some time to analyze the data which are already available from these stations but we hope to get insight into the magnitude of recent climatic changes without requiring adjustments for city influences or station shifts.

The problem of these changes in climate over periods of decades, rather than on a geological time scale, are of extraordinary practical importance. If at all possible we need to discern their causes and predict their future course. There has been some speculation that these climatic trends in recent years have been due to or at least associated with a marked shift in the general circulation. Concomitantly there has been the suspicion of a change in the frequency and tracks of tropical cyclones. In view of the devastating results of these storms and the insurance problems, we have to search for the best possible answers, quite aside from the extraordinarily interesting scientific aspect of this puzzle.

Recent observations from the Arctic have even led some optimists to anticipate an open polar ocean within a few generations. I have no hypothesis to offer. We hope to have soon more facts which will permit more than speculation. But I want to leave the thought with you - that in climatology we have scientific frontiers as challenging to creative minds as in any other field of meteorology.

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