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TÍTULO: A PRELIMINARY PROGRAMME FOR ANALYSIS OF THE CLIMATOLOGICAL DATA OF BRAZIL FOR THE YEARS 1961 TO 1970 AND ASSOCIATED RESEARCH

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ABSTRACT

Climatological data of a large number of stations in Brasil for the years 1961 - 1970 are currently being punched for computer processing. These will be analysed and means etc of various elements worked out as required by W.M.O. and as in practice in the Brazilian Meteorological Service, by the latter authority. This note is to suggest some further analysis of the data by INPE in cooperation with the Meteorological Service, particularly keeping in view user interests. The problem of meeting user interests is immense. It is proposed to restrict this report to utilising the above data to the best further advantage, and if possible derive some knowledge of similar information for other areas with scantly data and for areas where no data are available.

INTRODUCTION

Brasil is expanding fast economically. It is an agricultural country, has vast and rich forecast resources and is industrialising rapidly. In all these and consequential economic activities, climate is an important if not controlling factor. The user interest for climatological information can be broadly classified into from categories: (a) designs and specifications, (b) location and operation of a facility or equipment, (c) planning of an operation and (d) relation between climatic and biological processes.

DESIGNS AND SPECIFICATIONS

Climatic facator is very important for this class of problems because it often determines a major capital investment and the end product has to endure for a considerable length of time. The problem confronted is a question about most frequent or extreme conditions; sometimes the whole frequency spectrum involved. Almost always a long series of observations is required. In practice however, when a good series of data is available, it is sufficient for a good estimate of probabilities.

LOCATION AND OPERATION OF A FACILITY OR EQUIPMENT

This problem generally requires a greater degree of sophistication in climatological analysis. The practical question is usually the choice of optimal conditions among several possibilities.

The climatic factors are normally one of the many of equal or of greater importance. The analysis therefore will have to illuminate the various advantages and disavantages which arise from the climatic environment. Frequency distributions, extremes and interrelations of various climatic factors are involved in this problem.

PLANNING OF AN OPERATION

At present there is the greatest demand upon the climatologist from this type of interest for an interpretation of climatic factors that enter into this class of problems. The demand grew out of wartime experiences, when weather conditions affected every military operation. The peacetime applications are as numerous as the military ones. Under this head climatic information is needed for dicisions on where, when ahd how to perform the job best. In simple terms, the climatological problem is one of giving odds are based on past performance of climatic factors. The factors involved always a mixture of elements, some favourable, some unfavourable for the operation. The various elements always cover a range. A prudent planner will want to know all the various contingencies. Therefore, climatological analysis for operational planning purposes will invariably be a composite frequency analysis as well as those based on synoptic material or background. Mean value climatology is most out of place in this field.

RELATIONS BETWEEN CLIMATIC AND BIOLOGICAL PROCESSES

This is both a complex and vast field. Under this head is included topics like agricultural meteorology, agricultural climatology, climatic influence on animal life, influence of climate on human comfort and health, etc, each one of which is a discipline by itself and has vast illuminating literature. Damage to crops, animals, human beings, structures etc due to the vagaries and excesses of weather also come under this grouping. As the need becomes greater for space to accommodate the ever increasing population of the world, this type of investigation remains one of the most pressing tasks of applied climatology. Regions may have to be classified into inhabitable, conditionally inhabitable and uninhabitable regions. The first two categories may be suitable for agricultural (wet or dry inclusive of fruit growing, etc) or for industrial development.

PART I

SCOPE AND GENERAL SCHEME

TECHNIQUES OF CLIMATOLOGICAL ANALYSIS

Three major parameters enter into analysis of climate for every problem:

1. Space - (a) single point, (b) multiple point or area;
2. Time - (a) simple series, (b) complex relation;
3. Climate - (a) single element, (b) multiple element.

In all therefore eight possible combinations exist. For example, insurance against damage by hailsform is a problem of the type 1(a), 2(a) and 3(a). Housing design comes under 1(a), 2(a) and 3(b) since a knowledge of the frequencies of temperature, sunshine, winds and atmospheric moisture properties are involved.

To conclude, applied climatological problems are varied and many. With the data available good many user interests can be served by suitable analysis of these. Climatological mean values will not be sufficient for very many of the purposes. Mean together with standard deviation is also limited in its utility. In the case of extremely skew distribution like daily rainfall etc they have not much usable significance, because many of the statistical tests and ideas are based on normality

of frequency distribution and assumption of independence of observations. Quite a few of the climatological variables are skew in their distribution and the meteorological parameters are not independent either in time or in space. Frequency distribution of various elements, preferably presented in terms of probability will be useful in addition to means and standard deviations where applicable. Combined frequency distribution of certain elements is also necessary.

Two further prblems naturally arise in this connection: (1) Utilisation of short period data to draw conclusions regarding long-term probabilities,and (2) extending the available information in space to areas and localities where no information or scanty information is available. Both these are research-type problems.

How long a period of record is needed to give an answer to a problem within an appropriate safety factor? The question is the same as when does a frequency distribution become essentially stable? Some preliminary investigations have been made, based on a few pilot tests by the Weather Information Branch of the Army Air Forces Headquarters, of U.S.A. and the results, which are tentative, are given in the table below:

APPROXIMATE NUMBER OF YEARS NEEDED TO OBTAIN A STABLE FREQUENCY DISTRIBUTION

CLIMATIC ELEMENT	ISLAND	SHORE	PLAINS	MOUNTAIN
	EXTRATROPICAL REGIONS			
Temperature	10	15	15	25
Humidity	3	6	5	10
Cloudiness	4	4	8	12
Visibility	5	5	5	8
Precipitation amounts	25	30	40	50
	TROPICAL REGIONS			
Temperature	5	8	10	15
Humidity	1	2	3	6
Cloudiness	2	3	4	6
Visibility	3	3	4	6
Precipitation amounts	30	40	40	50

The data of ten years at present being punched are sufficient for most elements except for precipitation, and temperature in extra-tropical regions. As Brasil is mostly situated in the tropical belt, temperature analysis also is not expected to raise serious difficulties.

The problem of extrapolating and interpolating the available information in space and that of arriving at a fairly reliable knowledge from the extrapolated/interpolated values together with a short-period value from a climatic station specially started for the purpose, has not been studied on any broad scale. That is, the latter problem is to reduce the short to the long record. Many standard books on climatological methods deal with this problem. But the nature of reliability with distance and with topography and exposure is still an open question. This problem therefore is a fruitful field for research.

An initial attempt can be made with temperature data. Some possible approaches are indicated later in this report. With some basic relationships established by a study of the available data, normal temperature values can be computed for other areas and locations. The computed field can now be compared with a similar field constructed with data not used earlier to assess the reliability. This is expected guide towards similar studies in more difficult fields.

The classical methods of statistical analysis were developed for genetics and quality control. These are not necessarily universally useful. There is need for the development of better statistical techniques specially adapted for climatological problems. This need is understood and some work is being done in advanced countries like U.K. and U.S.A. INPE may consider sending some of their personnel, say two each time, for study and training in these countries.

PART II

SCHEME OF ANALYSIS FOR DATA OF BRASIL

Meteorological observations recorded at 12, 18 and 24 GMT are available as follows for about 158 stations in Brasil. It is however possible to get earlier or more recent data for an additional 200 and odd stations. These data however may not be as complete.

1. Pressure (mb)
2. Dry bulb temperature (^{o}C)
3. Wet bulb temperature (^{o}C)
4. Maximum temperature (^{o}C) } (recorded once a day at 12 GMT)
5. Minimum temperature (^{o}C) }
6. Relative humidity (%)
7. Wind direction (8 points of compass)
8. Wind speed (mps)
9. Cloud amount
10. Visibility
11. Total daily precipitation } (recorded once a day at 12 GMT)
12. Total daily evaporation }
13. Insolation (hours of sunshine) }

and whenever they occur

14. Snow
15. Hail
16. Thunderstorm
17. Lightning
18. Fog
19. Dust haze
20. Dew
21. Frost

ANALYSIS ALREADY BEING DONE

As seen from the "Climatological Normals (1969)" published by the Meteorological Service, Ministry of Agriculture, monthly and annual normals of the following elements are being worked out and published for every 30 year period as required by W.M.O. recommendations.

1. Pressure, mean of the day
2. Temperature of air, mean of the day
3. Cloudiness, mean of the day
4. Relative humidity, mean of the day
5. Precipitation, monthly total
6. Evaporation, monthly total
7. Insolation, monthly total

As per the "Climatological Atlas of Brasil (1969)" published by the same authority, in addition to the above they are also interested in

1. Number of days of rainfall (greater than 0.1mm) (at present they have published annual normal).
2. Wind roses (without reference to speed), (mean of the day for 4 representative months and for the year).
3. Number of rainy months (rainfall of 100mm or more).
4. Number of humid months (rainfall of 30 to 100mm).
5. Number of dry months (rainfall of 5 to 30mm).
6. Number extremely dry months (rainfall of < 5mm).
7. The three rainiest months.
8. The three driest months.

and in the following derived parameters:

1. Aridity index
2. Effective precipitation (index)
3. Effective temperature
4. Index of oceanity
5. Continentality index
6. Annual range of temperature
7. Precipitation during three hot months
8. Precipitation during three cloud months
9. Annual temperature anamoly from the southern hemispherical mean along latitude circles

10. Annual mean wet-bulb temperature
11. Ratio of rainfall to evaporation
12. Saturation deficit
13. Meyer index

and 14. Köepper classification

Therefore, it will be clear that at present climatological analysis is directed mainly to matters of interest to students of Geography and to a limited extent to agricultural interests. Analysis of data to meet other economic, human, biological and industrial needs is still to be tackled. A scheme of analysis to meet these at least in part, as is feasible with available data, is now discussed.

SOME SUGGESTIONS FOR FURTHER ANALYSIS

Discussion in Part I has brought out that climatological mean values are not sufficient for very many purposes and also that they are unrepresentative in the case of quite a few climatological variables. It has also indicated that frequency distribution of the variate affords more useful information. Information on combined occurrence of more than one parameter is often required for many purposes. The necessity of extrapolating climatological information to areas of sparce data is indicated.

1. SIMPLE FREQUENCY DISTRIBUTION

In the first instance, a simple frequency analysis may be made of all the elements listed in the first paragraph of Part II for all the hours of observation, month by month, suing all the ten years data and covering the full range of the variable. In the case of remperatures the frequencies will be number of days in which various ranges of temperaturewere recorded. Similar analysis will be made for relative humidity, precipitation (total of day), evaporation (total of day), insolation (number of hours in a day) and visibility (various ranges of it). Wind direction will be analysed according to eight points of compass* and wind speed in various ranges of it. In the case of cloud amount, a distinction has to be made between low cloud amounts, medium clouds and high clouds. Total cloud amount also will be analysed. Frequencies of occurrence of rare events will be number of occurrence per month. These frequencies can now be converted into percentage (probability) tables or number of occurrence per month as may suit utility. One more quantity which may usefully be added to the list of variables is the daily range of temperature. Details of the analysis as well as addition or subtraction to the list can be done after a preliminary study of the data and with the experience gained with the progress of work.

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* This is also being done by the Meteorological Service.

2. COMBINED FREQUENCY DISTRIBUTION TABLES

Quite a few interests will require information on combined occurrence of more than one weather elements. For example, measure of humidity of air in association with temperature is of value for air-conditioning of a place. Therefore a combined frequency distribution of dry-bulb and wet-bulb temperatures, as well as dry-bulb and relative humidity will have to be worked out. These will also be useful for Spinning and Weaving industry.

Wind direction analysed with reference to wind speed is necessary occurrence of moderate to heavy rainfall (precipitation) continuously for more than one day is of general interest for very many purposes. Therefore, frequencies of 2-day, 3-day etc. rainfall, as well as number of rainy days, 2-days in a row, 3-days etc. should be worked out. Further additions may have to be made to this class of analysis also in the course of the work.

SOME PROBLEMS OF RESEARCH THAT ARISE IN THIS CONNECTION

The main purpose of research in this field should be with a view to extending the available information in space and time. A preliminary idea and suggestion on a possible approach to extending surface temperature information in space will now be briefly outlined.

Surface temperature (T) at a location is a function of the height above sea-level of the location, its latitude, insularily, continentality, peculiarity of location and a random variation

$$T = F(H, L, C, \ell, \varepsilon)$$

H = height above sea-level

L = latitude

C = insularity/continentality

ℓ = location peculiarity or micro-climatic factor

ε = random variation

Analysing the variate (temperature) with a view to establishing the influence of the various factors on it will be the first step. While it is possible to assess the influence the first three factors may have on the variate, it may not be so for the other two variables. Therefore, one may without committing serious error, take the value of the variate computed using the influence of the first three factos to be representative of the general atmospheric property of the area. Next setp is easy. We may now compute the value of the variate for the other areas. The step after that, namely, that to assess the representative character of the calculated value is a difficult problem, especially as the premise was that there is no data in the area. However, we may perhaps get some information from an old station which is no more functioning or from some new stations which have data but for a few years.

These may be used for an assessement of realibility. With the experience gained similar or different techniques may be appplied to other elements.

Another technique that may be applied to the above problem is to reduce the temperatures at recording stations to the nearest standard level (say, 1.000mb, 900mb) with an assumed lapse rate based on the analysis in the previous paragraph or other wise and use additional information culled out from the climatological charts/data published by various countries like U.S.A., U.K etc. as well as data deduced by using the formula derived as in the previous paragraph for other areas. From these smoothed grid point values may be worked out by polynomial or other fits. An easy and useful method which gives the value of the variable correct to fifth order terms in a Taylor expansion of the field in the neighbouhood of grid point has been suggested by Rao, Y.P. and Ramamurti, K.S. (MS under publication). From these, work back to arrive at the surface values at the various locations. In this case also verification is necessary against actual recorded values of at least some stations at the level under consideration.

An estimate of standard error the calculated value can however be got from a comparison with the data of available stations.

SUMMARY AND CONCLUSIONS

The above is purely a preliminary broad statement of the problem and a few possible modes of analysis of the data. However, it is felt the approach delineated above has promise to more and more useful fields. For example, based on the sucess of the above, aviation interests and Air Force may wish to analyse the current weather and other information available with them towards "planning of operation" studies.

The processed data can be published. Frequency curves, nomograms and charts may also be prepared.

It is well known that supply induces demand. Industries and other institutions may wish to consult on their particular problems. Such consultations are necessary and are to mutual advantage. INPE can make another useful contribution to the economic good and progress of the country.

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