

SOME GEOGRAPHIC APPLICATIONS OF CLIMATIC INDICES

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THE SUBJECTIVE NATURE OF CLIMATE

We have rainfall gauges, thermometers, evap-
rimeters, anemometers and many more but no "climatometer".
Our derivation of "climate" must depend upon our subjective
selection of data relating to certain climatic elements.

This subjective aspect of climate presents a
difficulty. We are likely to forget that the "climate"
(and so the climatic index or climatic classification)
selected for a particular application is not the total
climate nor necessarily the appropriate "climate" for some
other application. The term climatic index, itself, is
misleading, since it is representative not of climate but
of one or more elements of climate. In practice we find
that almost all of the climatic indices in common usage may
be classified as moisture indices or temperature indices.

WORLD CLIMATIC CLASSIFICATION

The value of a world climatic classification must
be based primarily upon its utility as a teaching device;
upon its ability to orientate the multitude of specific
climatic regions (local climates) of the earth into a
reasonable number of climatic types which repeat themselves
over the surface of the earth and reflect not only the basic
genetic factors but also the broad patterns of other
natural landscape features.

Such a classification must involve a minimum number
of climatic types, each of which is capable of quantitative
delimitation. A classification which is based upon too many
factors (especially if these include local topography) or
which incorporates too many fine distinctions, negates the
very objectives of classification. There is no point in
classifying local climates since this becomes merely the
enumeration of individual climatic "personalities".

METHODS OF CLASSIFICATIONClassifications of Köppen and Thornthwaite

Both define their climatic types by quantitative representation of climatic elements so that each climate can be assigned to its type without subjective judgment; both utilize climatic indices involving precipitation and temperature, but their approach is fundamentally different.

Köppen adopted a frankly empirical approach based upon the matching of climatic data (derived from mean monthly and annual precipitation and temperature) with the vegetation regions of de Candolle.

Köppen saw, in the continuous scales of climatic elements, break points indicated by the disappearance of regional forms of vegetation when certain limiting values of the climatic elements are exceeded. The result is that Köppen used a wide selection of different climatic elements and indices in defining his boundaries. The major types, with the exception of the dry (B) climates, are thermal regions, the first order subdivisions usually indicate the seasonal rainfall regime and the second order subdivisions special features of the temperature regime.

Criticisms and adjustments of the Köppen classification fall into three categories. Trewartha⁵⁷, and others recognizing it as a world classification have simplified it, giving not more than twenty-four climatic types. In this form it is recognized as a useful device for teaching world climatic patterns.

A second group, the "boundary adjusters" have tinkered with the boundaries, especially those of the dry climates, because of their failure to fit the observed soil or vegetation boundaries in this area or that.

Never satisfied with the boundaries of his dry regions, Köppen adjusted the climatic indices a number of times.

The use of an index of the form $I = \frac{P}{K_1 t + k_2}$ was a feature of the 1918 classification and all subsequent classifications, although he modifies the values of the constants k_1 and k_2 in both 1923 and 1931.

Thornthwaite⁵¹ has criticized the Köppen classification for its arbitrary boundaries and empirical approach and for what he with some justification calls a "patchwork of unrelated rules and definitions". He is critical, also, of the use of temperature as the major criterion.

The Earlier Thornthwaite Classification

Thornthwaite has adopted the fate of water falling on the earth as his major criterion and has relegated temperature to secondary rank. On the basis of the mean monthly temperature and precipitation data he has developed "precipitation effectiveness" and thermal efficiency indices as a measure of the ability of climatic elements to support plant growth. He develops five humidity and six thermal types; four degrees of summer concentration of precipitation effectiveness and five of summer concentration of thermal efficiency.

Estimate of the Thornthwaite Classifications for World Climatic Classification

With suitable simplification it would appear that the earlier Thornthwaite classification could be used to elucidate the world climatic pattern, perhaps equally as well as Köppen's. The later Thornthwaite classification⁵² has not yet been applied on a world or continental basis and it is unlikely that it will ever be, in its complete form. Neither classification has been adopted in geographical textbooks. Both lack the direct reflection in landscape which the Köppen classification, with all its inadequacies, gives on a world basis and even with the omission of the fourth element in the classification they may introduce too many fine distinctions. On the other hand, Thornthwaite's Moisture indices, considered as empirical formulae, are probably more satisfactory than Köppen's.

Thornthwaite, in his later scheme, introduces the idea of "potential evapo-transpiration" and a moisture index (I_m) which has a "rational" break-point where $I_m = 0$. The basis of the classification is now too well known to require reiteration, but it is unfortunate that in application and review it has been given undue prestige as a "rational classification". This is too great a claim and in fact Thornthwaite, much later, says "the problem of developing a formulae for potential evapo-transpiration remains unsolved"⁵⁵; the present "formula is empirical and subject to revision"⁵⁶. This does not, however, invalidate his claim that there is a balance between rainfall and evapo-transpiration (with due allowance for run-off, drainage through the soil and soil moisture storage) which affords a "rational" break-point in the continuous scale of values of a suitable moisture index.

It will no doubt be a long time before we can measure potential evapo-transpiration either accurately or in many localities; meantime it must be calculated from an empirical formula. The Thornthwaite formula is based on temperature alone (with corrections for length of day and latitude) but with no allowance for their phase difference. It is quite empirical and must give misleading results when applied in an area in which occur air masses of markedly different relative humidity and similar temperature. This has been shown in both California³¹ and Australia^{5, 62}.

The numerous checks made in middle latitude humid regions indicate that the formula is likely to give substantially correct results there; one or two checks in tropical regions seemed hopeful but recent work by Garnier⁷ indicates there are marked discrepancies between measured and calculated potential evapo-transpiration at Ibadan (Nigeria). He notes that temperature "does not seem to be a crucial element" but that "important factors appear to be strong solar radiation.....and, in particular the comparative dryness of the air. Saturation deficit seems especially significant" in explaining the measured potential evapo-transpiration. Experiments should be directed, he suggests, towards the relationship between potential evapo-transpiration and such elements as "solar radiation, water vapour in the atmosphere, duration and intensity of sunshine cloud cover, intensity, incidence and duration of rainfall".

Attempts to determine a more universally applicable measure of "evaporating power" (potential evapo-transpiration) have been made by Penman² and Halstead¹⁰. The latter's formula shows promising results in several localities in Australia, Ocean Island and New Guinea⁵. It seems, however, that if an index is eventually found to link evapo-transpiration universally with its causative factors, it must be too complex for general application and require climatic data not available in other than limited areas.

The Thornthwaite moisture index seems a useful part of a regional climatic framework, at least in some humid areas of the earth's surface, especially as Thornthwaite is now prepared to admit different values of soil moisture storage 54, p.134. It is a pity that those who have applied it have accepted it without a critical examination of its deficiencies. Generally these applications follow a set pattern - acceptance without question of the validity of the indices for the region concerned, the production of moisture-balance graphs, maps of water surplus and deficiency, and of the four elements of the "classification" shown separately.

Sometimes there is a comparison with the Köppen or de Martonne indices. Garnier⁸ and Howe¹⁴ use only the moisture index, while Burgos² on the basis of that alone claims "almost perfect representation of vegetation". Howe also attempts a correlation with natural vegetation but concludes that "a simple correlation between vegetation types and climatic factors does not exist in Central Africa". Sanderson, who had previously checked calculated values of evapo-transpiration at both Norman Wells and Toronto with limited success, has achieved a useful secondary application in the Canadian North West⁴⁵ but in most cases primary application with perhaps a hint of possible secondary applications within the climatic framework is all that is achieved.

Investigations at the Waite Agricultural Research Institute

Moisture indices developed at the Waite Agricultural Research Institute find their origin in the Meyer and Transeau ratios, and their expression in the concept of "length of growing period". The approach of Davidson, Trumble, Prescott and others has always been consciously empirical. The earlier forms of simple index $\frac{P}{E}$ or $\frac{P}{S.D.}$ have been applied with success in Southern Australia, indicating close agreement with the known limits of vegetation and land use patterns, but the need to adjust the values of these indices in application to Northern Australia suggested the adoption of a more universal index.

The index: $\frac{P}{E^{0.75}}$ or $\frac{P}{S.D^{0.75}}$ was selected

P = mean monthly precipitation

E = mean monthly potential evaporation (tank)

S.D = saturation deficit for the month

and has subsequently provided a useful framework for the comparison of moisture regimes in Australia and Argentina⁴⁰. Maps of the month by month rainfall efficiency in Australia and Argentina in terms of the index $\frac{P}{S.D^{0.75}}$ are presented, in addition to length of growing S.D.^{0.75} season map for both countries on the basis of index values 4 and 8. Also presented are maps showing the number of months for which $\frac{P}{S.D^{0.75}} \geq 12$. This value corresponds approximately, according to Prescott to Thornthwaite's evapo-transpiration, although Thornthwaite has recently written that "atmospheric moisture is not a conservative property of the air. Consequently it is not possible to determine potential evapo-transpiration by considering either relative humidity or saturation deficit"⁵⁵.

With the temperature index, this moisture index undoubtedly provides a useful climatic framework for some regions of the earth's surface. It needs more universal checking and testing by secondary application.

Thermal Indices

Thermal indices have suffered relative neglect, both in development and application. Prescott³⁶ using a simple Fourier analysis, has derived a thermal "index" based on the march of mean monthly temperatures. It reveals mean annual temperature, amplitude (half annual range) and the phase lag of temperature behind solar radiation. The "phase lag" seems to show little more than the measure of continentality.

Thornthwaite⁵² uses his potential evapo-transpiration index which contains a measure of temperature and length of day as a thermal index and defines empirical divisions in the scale. This procedure seems unwise in view of the recent doubts cast upon the validity of the concept itself, its measurement and its calculation from the formula.

It is clear that we have not yet derived a thermal index suitable for general use in a regional climatic framework.

SUMMARY - THE MAIN INDICES FOR REGIONAL CLIMATIC FRAMEWORK

The indices developed by Prescott and Thornthwaite both seem to offer possibilities for the development of a sound regional climatic framework. It would be informative to see the Prescott indices applied more widely and compared with those of Thornthwaite under widely differing climatic conditions. In the Argentine^{40,2} the only region where comparable results are available there are obvious correlations between the two sets of moisture regions. It seems probable that further investigation along these lines will prove more fruitful than the Thornthwaite-Köppen comparisons of the past, since it is clear that both Prescott and Thornthwaite are attempting the same task using different lines of approach.

There is much yet to be done before a universally applicable index for general use is available, indeed, it seems more likely that indices will be developed more and more for specific application rather than general use. It may well be that the universally applicable index, even for a reasonably specific application, is as elusive as the concept "climate" itself.

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