Regional Distribution of the Continentality in the Climate of the Oceans

by

ILMO HELA

The increase of the annual range of temperature inland is perhaps the most striking effect of the continental surface on climate (CONRAD, 1950). Conversely, the annual range A is taken as a measure of the climatic factor called *continentality*. A general physical correlation seems to exist between the annual range of temperature and the geographic latitude. Therefore, if possible, the range should always be reduced to equality for all latitudes. For this reason, the ratio $\frac{A}{\sin \varphi}$ has been in most cases the measure sought for. JOHANSSON (among others 1926) defines an index of continentality as follows:

(1) $$K = \frac{1.6\ A}{\sin \varphi} - 14$$

where K is the index of continentality (0—100),

A is the annual range of temperature, °C and

φ is the geographical latitude.

The formula given by RAUNIO (1948) has the form

(1′) $$K = \frac{1.57\ A}{\sin \varphi} - 11.7.$$

Another formula (GORCZYNSKI, 1920) now frequently used reads:

(2) $$K = \frac{1.7\ A}{\sin \varphi} - 20.4.$$

These and other similar formulas are based on the principle that a purely oceanic climate would have an index value of 0 and an extremely continental climate one of 100. The constants of the equation are obtained by assigning the values 0 and 100 to two extreme stations. Traditionally, following the procedure given by JOHANSSON, Thorshavn (Faeroe Islands 62.0° N., 6.8° W.) and Verkhoyansk (67.5° N., 133.4° E.) or Jakutsk (62.0° N., 129.7° E.) are used as the two extreme stations.

CONRAD (1946) has emphasized the really weak point in the above formulas: the coefficient of continentality K becomes infinite ($K \rightarrow \infty$) when $\sin \varphi \rightarrow 0$, i.e., in the interior tropical belt. Therefore, all the formulas of type (1) or (2) are no longer valid for low latitudes. This limitation demands a simple modification of the above formula, the suggestion of CONRAD being

$$K = \frac{b A}{\sin (\varphi + \varphi_0)} - c. \tag{3}$$

The addition of a constant angle φ_0 eliminates the absurd values obtained for K within the inner tropical belt. CONRAD assumes »as a first estimate» $b = 1.7$, $c = 14$, and $\varphi_0 = 10°$ so that

$$K = \frac{1.7 A}{\sin (\varphi + 10)} - 14. \tag{3'}$$

hen writing an empirical formula for the continentality, in fact, all the following boundary conditions must, if possible, be taken into consideration: (i) the continentality yielded for a typical continental station of the higher latitudes (Verkhoyansk) must be approximately 100; (ii) the continentality yielded for a typical maritime station of the higher latitudes (Thorshavn) must be approximately 0; (iii) the continentality of typical maritime locations in the interior tropical belt must be 0; (iv) in addition, the continentality of a typical continental station in the tropical belt ought to be approximately 100 if, of course, on the basis of all the facts, the chosen station really seems to be purely continental. Unfortunately, this does not seem possible. (v) The range of the continentality in the middle latitudes must be reliable; i.e., (a) values under 0 or over 100 are impossible, (b) typical maritime locations must have a continentality from the order of magnitude 0 and (c) purely continental stations, if any, must have a continentality being approximately 100.

In the formulas (1) and (2) attention has only been directed to the conditions (i) and (ii). In formula (3') the condition (iii) and, to a certain degree, the condition (iv) is taken into account. As to the condition (iv), it does not seem possible to measure the continentality of the continental areas in the interior tropical belt with the same scale as the continentality of the higher latitudes. For this reason, the continentalities given for the tropical belt will perhaps always be somewhat arbitrary. The additional conditions (v) can be used as a control for the empirically derived formulas. In fact, formula (3′), although according to CONRAD being only a first estimate, seems to fulfill the conditions remarkably well. However, the existence of the Atlas of Climatic Charts of the Oceans (1938) offers a new approach to the determination of the boundary conditions of the formulas used. We have made use of the following procedure.

The regional distribution of the annual range of the temperature is computed for the Atlantic Ocean (Northern hemisphere, Fig. 1). The dashed lines correspond to the minimum influence of the continents upon the climate of the Atlantic Ocean. This minimum annual range of the temperature as a function of the latitude[1]) can be seen in Fig. 2. The

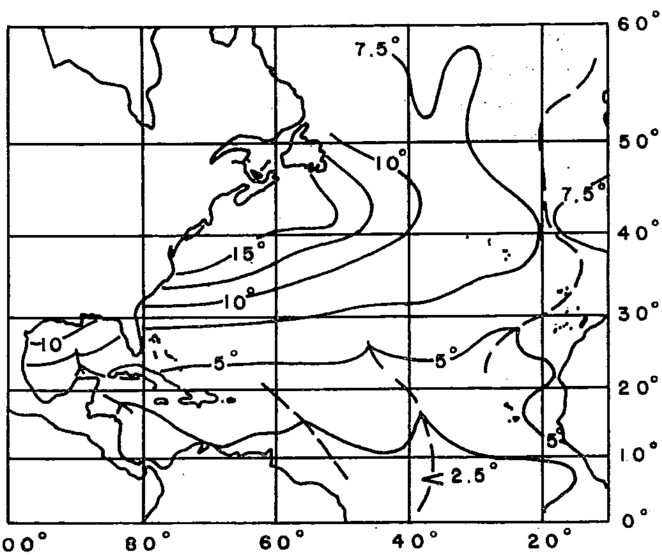

Fig. 1. The regional distribution of the annual range of the air temperature over the northern Atlantic Ocean.

[1]) The curve corresponding to this minimum annual range of the temperature as a function of sin φ, instead of φ, deviates from a straight line far more than the curve of Fig. 2.

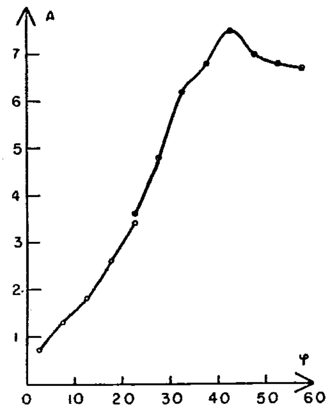

Fig. 2. The minimum annual range of the air temperature over the northern Atlantic Ocean as a function of the latitude.

method of least squares gives the equation $A = 0.13\ \varphi + 0.76$ for a linear relationship between them. From this equation average minimum temperature ranges can be taken, for instance, for the latitudes 50°, 30° and 10°, the ranges being 7.3° C, 4.7° C, and 2.1° C. These three values can be used, together with the original Siberia range for the determination of the constants in the formula which is now assumed to be of the type

(4) $$K = \frac{a\ A}{b + \sin\ (\varphi - \varphi_0)} - d.$$

Thus the formula

(4′) $$K = \frac{2.2\ A}{0.62 + \sin\ (\varphi - 30)} - 16$$

will be obtained.

When using this formula negative, and thence strictly speaking, impossible values of the continentality will be obtained for large ocean areas on both sides of the westerlies, especially in the tropical belt. Therefore, instead of using the method of least squares (Fig. 2), it seems more suitable to take from the curve the minimum temperature ranges appearing at the latitudes 7.5° (1.3° C.), 12.5° (1.8° C.), and 57.5° (6.7° C.) and to use them together with the Siberia value for the final determination of the formula. Thus

$$(4'') \qquad K = \frac{1.97\,A}{0.92 + \sin\,(\varphi - 53)} - 13.3$$

is obtained which certainly fulfills the conditions (i), (ii) and (iii).

In Table 1 the continentality according to JOHANSSON (1), GORCZYNSKI (2), CONRAD (3′), and HELA (4″) is given for Jakutsk and for

Table 1. The Continentality According to Different Authors.

	JOHANSSON	GORCZYNSKI	CONRAD	HELA
Jakutsk $A = 61.6°$ C	105	99	96	100
Thorshavn $A = 7.6°$ C	1	—6	0	0
Elisabethville $A = 7.5°$ C	49	43	25	24
2° 30′ N., 47° 30′ W. $A = 1.2°$ C	33	26	—5	2
27° 30′ N., 132° 30′ W $A = 3.8°$ C	0	—6	—3	3

Thorshavn. In addition, the continentalities of a typical continental station inside the tropical belt, Elisabethville (11° 39′ S., 27° 28′ E.) and of two typical maritime locations, (2° 30′ N., 47° 30′ W.) and (27° 30′ N., 132° 30′ W.), are given. As stated by CONRAD, the improvement gained by introducing the formula (3′) has been essential. As to the formulas (3′) and (4″), it can be stated that the values of continentality yielded are practically the same in all the given cases. There are, however, two differences of principle between them: (i) the continental influence of the continental areas of the middle and low latitudes is emphasized slightly more according to formula (4″) than according to (3′). The greatest differences occur when $\varphi = 30°$. When $A = 30.6°$ C, formula (3′) gives $K = 87$ while formula (4″) gives $K = 100$. (ii) The formula (3′) seems to give negative values more generally in the maritime portion of the tropical belt than the formula (4″). These are the reasons to believe that the formula (4″) is, to a certain degree, more reliable to use also in

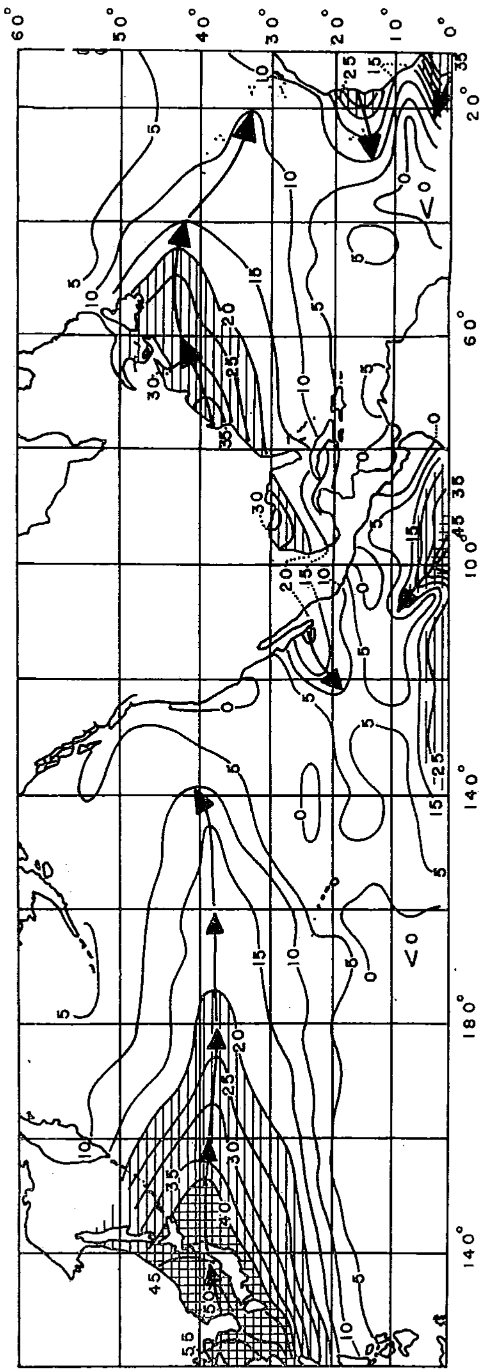

Fig. 3. The regional distribution of the continentality over the Pacific and the Atlantic Oceans.

the tropical belt than the formula (3′), although the real difference between them is, as stated, in most cases unimportant.

Finally, the formula (4″) is used for determining the regional distribution of the continentality of the oceans (Fig. 3). The analogy between the Atlantic and the Pacific can be seen immediately. The profound influence of the westerlies upon the climatic conditions of the oceans is easily seen. The continental influence of Asia on the climate of the Pacific is distinctly more effective than the influence of North America on the climate of the Atlantic. In addition, among others, the influence of the trade winds can be traced.

LITERATURE

CONRAD, V. 1946 Usual Formulas of Continentality and Their Limits of Validity. Trans. Am. Geophys. Union, *27*, 663.

CONRAD, V. and POLLAK, L. W. 1950 Methods in Climatology. Harvard University Press, Cambridge, Massachusetts.

GORCZYNSKI, WL. 1920 Sur le Calcul du Degré du Continentalisme et son Application dans la Climatologie, Geogr. Ann., Stockholm.

JOHANSSON, O. V. 1926 Über die Asymmetrie der Meteorologischen Schwankungen, Soc. Sc. Fenn., Comm. Phys.-Math. *3*, 1, Helsingfors.

RAUNIO, NIILO. 1948 The Effect of Local Factors on the Meteorological Observations at Tórshavn. Geophysica 3. Helsinki.

Atlas of Climatic Charts of the Oceans. 1938. U. S. Weather Bureau, Washington, D.C.