second, "Clayton," I used Clayton's World Weather Records, as, apparently, Mr. Groissmayr had, and obtained, my departures from the Clayton normals, except for 1929 Goya temperatures, when only the departures were available in the Argentine "Resumen Mensual."

Of the 44 winters used by Groissmayr for Winnipeg, the calculated and actual departures were the same in 37, or 84 per cent. The additional five winters show similar correspondence. Droughts in India preceded five of the six warm winters in Groissmayr's series, but only one of the two warm winters in the new series.

In view of the shorter period of years, 36, for Saskatchewan and Alberta, Mr. Groissmayr gives only the larger indications, and shows that for computed departures $\geqq \pm 3°$ F. there is *invariable* agreement of the subsequent winter temperature as to sign. In the new series, the one strong indication of a warm winter was likewise verified.

In the 24 years when India was unusually wet or dry, Groissmayr shows that Saskatchewan and Alberta winters have been, *without exception,* below or above normal in temperature. The year 1922 (January to October) averaged 6 inches below normal and 1925 averaged 6 inches above normal; the following winter temperatures were, respectively, below normal and above normal, breaking the rule. Two-thirds of the excess of rainfall in 1925, however, occurred at but one of the five stations and in a single month.

If the forecasting formula had been applied for the five winters 1921–1926 and the results published in advance of each winter, the forecasts and verifications would have run about as follows:

1921–22: A winter of normal temperature is indicated, possibly slightly below normal in Manitoba and above normal in Saskatchewan and Alberta. Verification: A moderate degree above normal in Manitoba and normal in the other prairie Provinces. *Reasonably successful.*

1922–23: A winter temperature slightly above normal is indicated, with a little greater departure in Saskatchewan and Alberta than in Manitoba. Verification: A little above normal in Manitoba and just under normal in the other Provinces. *Reasonably successful.*

1923–24: A mild winter is indicated, especially for Saskatchewan and Alberta. Verification: Very mild throughout. *Nearly perfect.*

1924–25: A winter of normal temperature is indicated. Verification: Normal in Manitoba, a little below normal in Saskatchewan and Alberta. *Good forecast.*

1925–26: A normal winter is indicated, possibly slightly above normal in Manitoba. Verification: Extremely mild throughout. *Poor forecast.*

In five years: One nearly perfect, two reasonably successful, one good and one poor.

According to criteria published two years ago [2] we may say that this performance is within the limits of being satisfactory for official presentation to the public, and, therefore, that if the winters of 1926–1930 do as well as those of 1921–1926, the physical connections here indicated should be investigated.

THE INFLUENCE OF THE WEATHER FACTORS IN INDIA ON THE FOLLOWING WINTER IN CANADA

By FRED GROISSMAYR, Passau, Germany

(Abstract and excerpts by C. F. Brooks; translation by W. W. Reed, of "Der Einfluss der Wetterfaktoren Indiens auf der Folgewinter Kanadas." *Met. Zeitschr.*, May, 1929, 46:176)

Following the lead of E. W. Bliss,[1] who gives four somewhat useful correlation coefficients indicating winter temperatures for central North America from previous conditions about the Indian Ocean, the author sought higher correlations by adding more tropical elements and localizing the North American end. The factors used by Bliss were pressure at Mauritius, temperature at Batavia, the Nile flood, and Indian rainfall. Since Schostakowitsch had found that over the Indian-Australian region temperature and pressure varied together while precipitation went opposite, the author added Indian temperature and pressure and Batavia and Egypt pressures, and also weather conditions of Argentina, which has long association with other Indian monsoon indicators.

"For the whole area investigated [in central North America] the pressure and temperature of India prove more influential than the monsoon rains of northwest India. With the exception of Montreal, the pressure over central India is more closely connected with the winter temperature of the region under consideration than is the summer of south India. Especially close relations resulted for the winter in Manitoba; also the autumn temperatures of Bombay, and that of Lahore plus Allahabad show uncommonly close correlation with the character of the cold season at Lake Winnipeg."

1876–1920: Δt IX–XI Allahabad plus Lahore with Δt XII–II Winnipeg: $r=0.62$.

1878–1920: Δt IX–XI Bombay with Δt XII–II Winnipeg: $r=0.66$.

After an especially cool autumn —2° F. or more below normal—in northwest India there always followed a severe winter at Winnipeg, and after a warm autumn—2° above—a relatively mild winter.

	1876	1877	1879	1884	1896	1907	1917	1920
Δt IX-XI Allahabad and Lahore	−2.0	+2.5	−2.0	−2.6	+2.7	+2.5	−2.7	+2.6
Δt XII-II Winnipeg	−0.8	+17.9	−6.0	−9.1	+2.2	+9.1	−3.4	+8.8

Such decided relations led to further study of tropical factors with respect to Winnipeg's winters and to the discovery of the additional very notable correlation coefficients: With Nile flood, at Assuan, 1873–1922, $r=-0.52\pm0.07$; with Batavia October pressure departure, 1873–1922, $r=+0.54\pm0.07$; with Batavia October and November temperature departure, $r=+0.60\pm0.06$, and with Goya, Argentina, temperature departure April to July, $r=+0.52\pm0.07$. Pressure over central India proved most closely correlated with the subsequent winter at Winnipeg, especially when advantage was taken of the pronounced tendency of weather in the tropics to maintain an existing departure.

The mean monthly pressure departure at Nagpur from January to October is correlated with the departure of the winter temperature of Canada and of the north central part of the United States, the coefficient for Winnipeg being, $r=+0.77\pm0.04$, "the highest correlation ever

[1] E. W. Bliss, World Weather III, Memoirs, Quar. Jour. Roy. Metl. Soc., vol. II, No. 17, — pp.

[2] Charles F. Brooks, Performance in Long-range Forecasting. MONTHLY WEATHER REVIEW, September, 1927, 55:390–395, including bibliography.

obtained between different weather elements of widely separated stations and at disconnected times. The correlation here exceeds nineteen times the amount of the probable error. Other Indian stations show high positive correlations, for example, Bangalore pressure, January to October with Winnipeg winter temperature, $r = +0.43$. In all cases in which the mean monthly pressure departure at Nagpur for January–October equaled or exceeded 20 (1/1000 inch) the winter temperature at Winnipeg had the same sign of departure." The highest India pressure, of 1877, was followed by the mildest winter at Winnipeg. Pressure maximum in India is associated with winter temperature maxima later over an immense part of Canada and the United States.

"The summer and autumn temperature of the western and eastern coasts and likewise of the interior of India show high correlation of like sign to the winter of North America, from the mouth of the St. Lawrence to Montana and Saskatchewan. Here also Winnipeg holds the record.

"The rainfall of India likewise proves of special significance relative to the region around Lake Winnipeg." Though most of India's rainfall comes in June to September, it appeared advantageous to include all the months, January to October. This element shows negative correlation.

By the method of partial correlations these three elements of India were combined into a regression equation, which gave a coefficient of $r = +0.81$ (1875–1920):

$$\Delta t \text{ XII–II Winnipeg} = +0.21\Delta p \text{ I–X Nagpur} + 1.00\Delta t \text{ VI–VII Madras} - 0.10\Delta N \text{ I–X (Jaipur + Lahore)}/2$$

p stands for pressure (thousandths inch), t for temperature (°F.), and N for precipitation (inches). The mean difference between calculated and observed temperature at Winnipeg is but 2.9° F., which is but 52 per cent of the mean winter temperature anomaly of 5.6° F. All cases of calculated departures of 5° or more (15 of the 46 years) have winters of the same sign; and all warm or cold winters 5° or more from normal agree in sign with the calculated departure. In very many cases there is the possibility of a nearly certain forecast; of the 28 cases of calculated departures of 3° or more, 26 winters have the same sign. Calculated and observed departures of any size agree as to sign for the whole 46-year period in 80.4 per cent of the cases.

"In addition to the weather elements of India the winter of Manitoba is effectively influenced by the October air pressure and the October-November temperature at Batavia; both correlations are positive,"

$$r = +0.54 \text{ and } +0.60, \text{ resp., } 1873\text{–}1922$$

The Nile flood shows nearly the same negative correlation with the succeeding winter at Winnipeg as for that of central Europe.

Central Argentine temperature, at Goya, from April to June, is correlated with the Winnipeg winter, $r = +0.52$ (1877–1920). In all cases where Goya temperature was 1.5° C. or more above or below normal (8 years out of 44) the winter in latitude 50° N. and in longitude 100–105° W. had the same sign.

Egyptian pressure in summer, July at Cairo, has a correlation with the following winter at Winnipeg, $r = 0.44$ (1873–1922).

Cold winters in subarctic continental North America are as a rule snowy, and the mild winters deficient in precipitation; thus it is not particularly surprising to find Nagpur pressure, January-October, correlated with Bismarck winter precipitation, $r = -0.50 + 0.07$. Similar values were found for the other stations.

The winters of central Europe are indicated by the same factors as are those of Canada. These are the weather elements of India and of the Sunda Sea in summer and autumn of the Southern Hemisphere; also, here we have again the interaction of Argentine weather in the autumn of the Southern Hemisphere with the monsoon intensity over the northern part of the Indian Ocean. The weather elements of Egypt are functions of the southwest monsoon, not of the Atlantic Ocean. Stronger southwest monsoon in India brings copious rains, with low pressure and relatively cooler weather in India itself. For cold winters the scheme reads:

Canada	*Central Europe*
$-p$ I–X India.	$-p$ I–X India.
$-t$ VI–XI India.	$-t$ VI–XI India.
$+N$ I–X India.	$+N$ VIII–XI India.
$-t$ IV–VII Argentina.	$-t$ IV–VII Argentina.
$-N$ I–VII Argentina.	$-N$ I–VII Argentina.
$+p$ IV–VI Argentina.	$+p$ IV–VI Argentina.
$-p$ VI–VIII Egypt.	$-p$ III–VIII Egypt.
+Nile VII–X Egypt.	+Nile VII–X Egypt.
$-p$ X Java.	$-p$ X Java.
$-t$ X–XI Java.	$-t$ X–XI Java.

THE DAILY MARCH OF TEMPERATURE AND HUMIDITY [1]

551.524 : 551.571

By V. E. Shelford

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A study of development of the various stages of the codling moth carried out a few years ago (Shelford, 1927), indicated that the evaluation of rates of development must be based upon a combination of temperature and moisture. These two factors vary roughly reciprocally and are quite inseparable for that reason.

In this study experiments were carried out in great detail on the pupa. For this stage a chart was made showing the rate of development at each combination of temperature and humidity under which the pupa would live and develop. The chart is shown in Figure 1. Rates or velocities are given in developmental units per hour, the developmental unit being the difference in amount of development between a given degree of medial temperature and the amount 1° higher. The total is measured in terms of the total number of hours to complete the stage at several medial temperatures. Lines connect combinations of temperature and moisture giving the same rate. The figures at the right of the curve show the developmental units per hour characteristic of each line. Under average conditions the total (°F. and hour) developmental units required to complete the pupal stage is 6,480. One hour at 75 per cent humidity and 54° F. gives 5 units while one hour at 80 per cent humidity and 89° F. gives 37 units. In preparing this chart, variable temperature experiments were introduced. In these chambers the temperature rose during the forenoon when the sun was shining through the glass roof of the room or when large incandescent lamps were turned on during cloudy days. It fell off in the afternoon and was

[1] Contribution from the Zoological Laboratory of the University of Illinois, No. 355.