Indian J. Met. Hydrol. Geophys. (1977), 28, 2, 247-250

551·58 : 338.5

Correlation of historic climate with historic prices and wages

LEONA MARSHALL LIBBY

University of California, Los Angeles, California, U.S.A.

(Received 10 May 1976)

ABSTRACT. Excursions of average annual air temperature measured by mercury thermometers from 1650 to 1950 show a significant correlation with excursions of annual prices of wheat and a better correlation with wheat prices which have been normalized to the price of sterling to correct for inflation of money.

A similar correlation is found between measured air temperatures and the quantity, wages of labour divided by price of wheat, namely the amount of wheat which a labourer's daily wage could buy.

The price of wheat normalized in either of these ways correlates fairly well with what is known as historic climate excursions derived from all various climate indicators for the time span from 1250 A.D. to the present.

From the price of wheat normalized to the price of sterling, a temperature scale for the last 650 years has been devised for England.

1. Introduction

The rapid decline of today's climate (Alexander 1974) which is the basic cause of increasing drought and famine in the countries between the north and south tropics and of the onset of decreasing agricultural yields in temperate countries, leads us to look for new ways to deduce climate excursions which have occurred in the past, before there were thermometer records of air temperatures. If such ways can be developed, and thereby historic climate weather records evaluated, it is conceivable that periodicities in historic climate may be deduced, which information may allow us to predict how far the present climate is going to decline and when the turn-around towards improvement will occur. These predictions obviously would be of great importance to finding ways to achieve national and world energy sufficiency, food being a form of energy, and modern agriculture being heavily dependent on other forms of energy such as petroleum.

Agriculture is the largest of the world industries. Clearly it is exceedingly sensitive to climate, both to annual air temperatures, to late springs, cool summers, early falls and also to rainfall. Palynology studies (Frenzel– *see* Ref.) show some correlation of cold climate with dry climate, although there is no broad agreement by meteorologists on this point. Nevertheless, the northern hemisphere is largely affected by both colder and dryer climate in increasing measure at present.

Therefore, in hopes of eventually being able to evaluate climate periodicity, we propose to study historic records of prices of the basic crop, wheat, for indications of historic climate excursions.

2. Data and methodology

Economists agree that there exists a definite relation between the market price of a commodity such as wheat and the quantity available (Samuelson 1970). Here we are concerned with the relation of wheat price to the quantity available both in times of plenty and times of short supply, so that we are dealing with a large range of values of both price and supply. Without hypothecating what the relation is, we examine the data.

In the present paper are discussed prices and wages from 1250 A.D. to the present, and average air temperatures from 1650 to the present. The population has been increasing and money has been losing value during this time span. Thus it is necessary to make corrections for such effects.

In Fig. 1 are shown the prices of wheat in England, Netherlands, France and northern Italy since 1250 A.D., in units of guilders per 100 kg. These are our basic data. In all four countries there are many-fold increases in prices at around 1600 and 1800 A.D. caused therefore by something more general than local political or economic maneuvering.

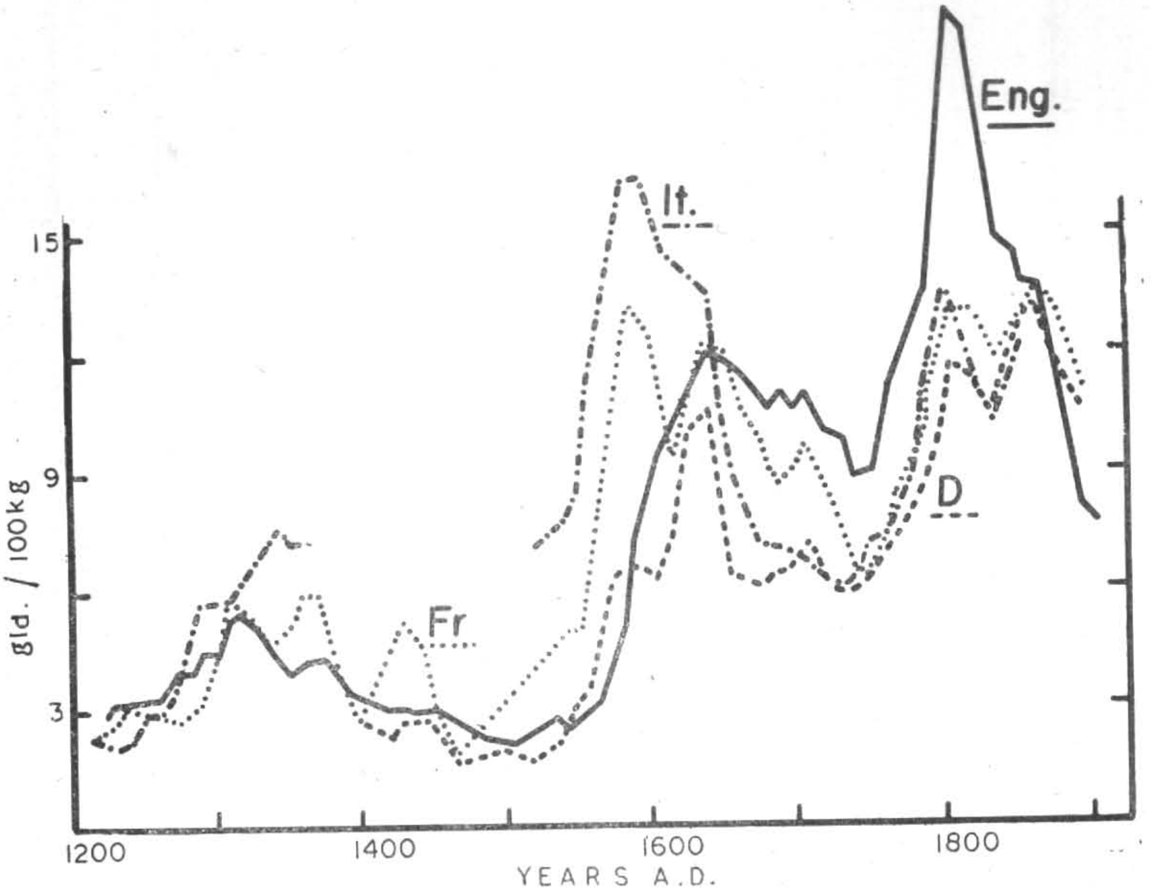

Fig. 1. The price of wheat (tarwe) *vs* time from the 13th to the 20th century in England, France, Netherlands, and North Italy, taken from "De Landbouw in Brabants Westhoek in Het Midden Van de Achttiende Eeuw" Agronomisch Historische Bijdragen, H. Veenman & Zonen, Wageningen, Netherlands. Units are gilders/100 kg.

In Fig. 2 are shown the prices per troy ounce for sterling silver (90 per cent pure) and for fine (pure) gold, in English money, since 1250 A.D. Sterling prices are more basic, because sterling was the only official coin of the realm until 1774. One way of normalizing grain prices to take into account inflation is to compute the ratio R_s of wheat prices to price of sterling, and we have done this.

A second way of normalizing is to compute the amount of grain which a labourer's daily wage can buy; namely R_w, the ratio of labour's daily wage to wheat price. R_s and R_w are shown plotted in Fig. 3. R_s has been computed from data in Figs. 1 and 2 and R_w has been taken from Meredith (1939) and Steffen (1901-4). The third part of Fig. 3 shows a 25 year running average computed from Manley's data on the winter air temperatures in England (Manley 1974), for the months of January, February and March.

We have made a 25 year running average of the temperature means in order to smooth the large year to year fluctuations (the "noise") and in this way make more apparent the major long term temperature excursions. We have used mean temperatures of January, February and March because they show the largest effect in these excursions (the mean temperatures for the other months and therefore for the total year show similar behaviour with smaller amplitude).

The warming-up trend between 1800 and 1930 is a general phenomenon displayed in temperature records of Holland, Edinburgh, Stockholm, Vienna, Berlin, Copenhagen, Greenland, Ukraine, Siberia Basel, Geneva; in the United States in New Haven, Philadelphia, St. Paul, St. Louis, and Washington D.C., as summarized by Ladurie (1971); the amplitude of the change varies locally around 1°-2°C.

In particular the warming of the entire northern temperate zone is estimated at 0.64–0.70°C,

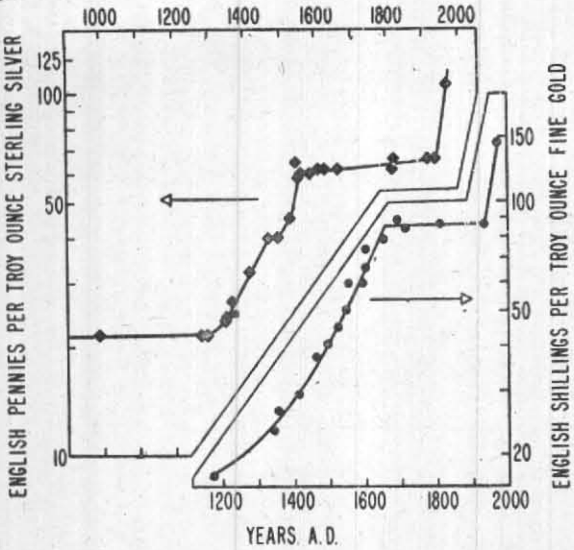

Fig. 2. Cost per ounce of sterling and gold in units of English pennies and shillings respectively, for the last several hundred years. Note log scale.

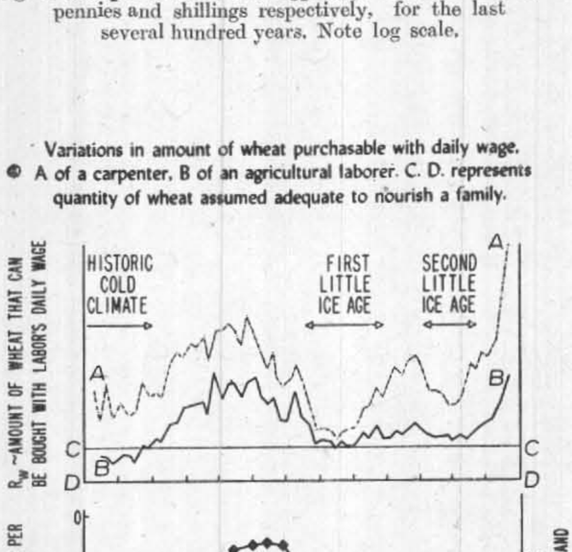

Fig. 3. Labourer's daily wage divided by price of wheat, units unknown, curves *Rw vs* time; price of wheat normalized to price of sterling, *Rs* [gld oz/(100 kg) penny], *vs* time; temperature T of winter months in England *vs* time, 25 year running average. All scales are linear. Temperature scale computed in Table 1 is shown on right hand abscissa of R_s. R_s has been computed from Figs. 1 and 2.

(*see, e.g.* Ladurie 1971 p. 86) for the entire period. Both R_w and R_s as shown in Fig. 3 start declining at about 1760, reach a minimum at around 1800 as did the temperature, and thereafter increase into the 1900's in agreement with the rising temperature curve. This period, from 1760-1860, is known as the Second Little Ice Age. The civilian hardships of this period have been extensively documented (*see*, discussion and bibliography—Ladurie 1971).

Likewise both R_w and R_s show major declines to minima at $\sim$1630 A.D. This earlier period, 1550-1700, the First Little Ice Age, is famous for its famines killing millions of people, cold summers, bitter winters, failed harvests, wars and civil unrest. Of the time of earliest minima at $\sim$1300 shown by R_w and R_s in Fig. 3, Lamb remarks as follows (Lamb 1974).

> "Well marked wet and presumably cloudy phases in northern Europe in 1250 to 1300, bringing the sharpest deteriorations and being the most widely registered."

It is our purpose here to try to estimate past temperature differences using R_w and R_s from Fig. 3, as shown in Table 1. Our purpose is to further calibrate an isotope thermometer method of climate determination which extends in principle many thousands of years back in time (Libby and Pandolfi 1974). We have measured $\triangle R_w$ (from curves A and B), $\triangle R_s$, and $\triangle T$, from peaks to valleys in the time since 1700 A.D. for which T is known [The temperatures from 1650 to 1700 A.D. are less well known (Manley 1974) and those before 1650 are unknown]. From these, we compute temperature coefficients, $\triangle T/\triangle R_j$ (where $j=wA$ and wB, and s). Then multiplying the $\triangle R$ values measured from the peak at 1750 to the valleys around 1650 and 1300 A.D. by $\triangle T/\triangle R_j$ we obtain estimates for $\triangle T$ between these times. As shown in Table 1, the temperature coefficients computed from the curves R_{wA} and R_{wB} differ from each other in each case by factors of 3-4, an unsatisfactory situation; in order to estimate temperature differences before 1750 we have used averages of the two coefficients obtained in each case. We do not know enough about how R_w has been computed to be able to suggest the source of these discrepancies. But because it has been computed by a separate author (Meredith 1939) and yet shows the same major signals as R_s computed by us we feel it has significant value as corroboration.

The two estimates of $\triangle T/\triangle R$ obtained for R_s agree with each other, so that one has somewhat greater confidence in the temperature differences

TABLE 1

Computation of temperature coefficients for curves R_w and R_s in Fig. 1

Time interval (Years)	ΔR_{wA} (cm)	ΔT (°C)	$\frac{\Delta T}{\Delta R_{wA}}$ (°C/cm)	ΔR_{wB} (cm)	$\frac{\Delta T}{\Delta R_{wB}}$ (°C/cm)	ΔT (°C)	ΔR_s (cm)	$\frac{\Delta T}{\Delta R_s}$ (°C/cm)	ΔT (°C)
1800-1900	—	+·45	—	—	—	+·45	6·8	·066	+·45
1800-1875	6·0	+·27	·045	1·9	·14	+·27	4·1	·066	+·27
1745-1800	2·8	—·40	·143	0·9	·44	—·40	5·9	·068	—·40
1650-1745	4·0	(+·38)	—	1·3	—	(+·38)	1·7*	—	(+·11)
1500-1745	1·5	(—·14)	—	2·3	—	(—·67)	3·2	—	(—·21)
1300-1745	3·0	(+·28)	—	2·0	—	(+·59)	2·9	—	(+·19)

Average estimated $\Delta T/\Delta R_{wA} = 0{\cdot}094$ °C/cm (average of ·045 and 0·14)

Average estimated $\Delta T/\Delta R_{wB} = 0{\cdot}29$ °C/cm (average of 0·14 and 0·44)

Average estimated $\Delta T/\Delta R_s = 0{\cdot}066$ °C/cm (average of ·066 and ·066°C/cm and ·068)

N.B. — The scales of R_{wA}, and R_{wB}, and R_s are different, so that their temperature coefficients should not be equal to each other, Values of ΔT in parentheses have been computed from $\Delta T/\Delta R$ multiplied by values of ΔR measured from Fig. 3. Values of ΔT not in parentheses have been read from Fig. 3.

computed therefrom for the times before 1750. The resultant temperature scale is shown on the right hand ordinate of the curve of R_s *vs* time in Fig. 3.

3. Conclusion

We have calibrated the ratio R of English wheat prices divided by the price of sterling from 1250 to 1900 A.D., by comparison with the measured air temperature of England. With the temperature coefficient so obtained we have constructed a temperature scale which, when applied to R from the years 1250 to 1900 A.D., gives a measure of air temperatures for the last 650 years. Our purpose is to devise sensors of climate from historic records in order to study periodicities of past climates as a key to predicting the air temperatures to be expected in the near future, and in particular to test isotope thermometers in wood previously calibrated only to 1700 A.D. The presently suggested calibration method appears promising. Its credibility may be substantiated by pursuing the method further. Appropriate wood samples have been collected spanning this interval and will be measured; the temperatures deduced from historic wages and prices will be compared with the measured isotopic ratios.

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