LONG PERIOD VARIATIONS IN THE MEAN SEA LEVEL ON THE FRENCH COAST.

(Extract from a Memorandum presented by Messrs. CH. LALLEMAND and E. PRÉVOT at the meeting of the Paris *Académie des Sciences*, 29th May, 1929).

The mean sea level, to which, in principle, the heights of the bench marks in the main national levellings are referred, is not invariable, as might be supposed.

In course of time it undergoes slight alterations the effect of which on the mean value will, it is true, gradually diminish as the period over which the observations are taken is increased.

In France, two stations are outstandingly suitable for the study of these phenomena. They are :

1st. On the Atlantic Ocean, Brest, where a Naval Hydrographic Service self-recording tide-gauge has been working since 1851.

2nd. On the Mediterranean, Marseilles, where, since 1885, regular and very accurate observations have been taken by means of an automatic totalling tide-gauge and of several mean sea-level recorders fitted in this harbour or in its vicinity.

At first sight the results obtained in these two regions appear to show a regular rise of about three-quarters of a millimetre per annum (1) in the mean annual level due, it was thought, to a slow subsidence of the land.

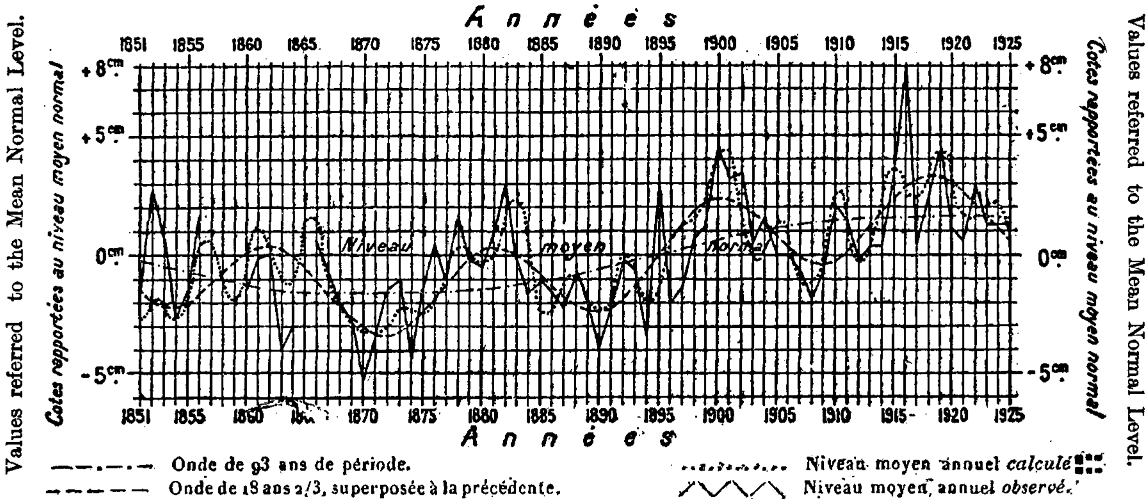
In order better to elucidate the matter, Mr. E. PRÉVOT had the idea of comparing the diagram of the heights of the annual mean level of the Mediterranean at Marseilles for the period 1885-1925, with the record of the heights of the mean sea level at Brest during the period 1851-1906.

Between the data collated at the two stations there is for the common period (1885-1906) a systematic discrepancy of 26 $^{m}\!/\!_{m}$ due, without doubt, to the inevitable errors in the levelling which connects the two harbours.

Eliminating this difference, the variations of the annual mean sea level on the French

(1) *See Report on the work of the French general Levelling Service from* 1922 *to* 1924, *submitted to the second Congress of the International Geodetic and Geophysical Union, Report* 7*b, Madrid*, 1924.

coast, during the period under consideration of three-quarters of a century (1851-1925), are shown in the following diagram by a continuous zig-zag line.



——·——·——Wave of 93 year period. ....*Calculated* mean annual level.

— — — — —Wave of 18 2/3 year superimposed on the above. /\ /\ /\ *Observed* mean annual level.

Variation of the mean annual sea level on the French coast from 1851 to 1925

An analysis of this graph gives evidences of, not as was at first imagined, a regular subsidence of the land, but a complex oscillatory movement, the result of the superposition of several waves of cosmic origin shown in the following table :

TABLE OF THE WAVES WHICH CAUSE THE SLIGHT OSCILLATORY MOVEMENT OF THE SEA.

	Presumed origin of each of the component waves.	*Characteristic Elements* — *Period.* p. Years.	*Amplitude* 2a (*Prov.*[l] *calculation*) m/m
1.	Revolution of the line of the nodes of the moon's orbit	18.6	35
2.	Quarter harmonic of the preceding wave..................................	4.65	12
3.	Fivefold harmonic of the same wave corresponding to 93 revolutions of the Earth in its orbit (93 tropical years of 365. 242 days)..	93	33
4.	Periodic variation of the Earth's magnetism and of the latitudinal change of position of sun spots	11.1	10
5.	Half harmonic of the preceding wave.......................................	5.55	8
6.	Revolution of the perigee of the moon's orbit	8.85	10
7.	Half harmonic of the preceding wave.......................................	4.425	10

For foretelling the annual mean level a long time in advance Mr. Prévot proposed the following formula :

$$\mu = C + \sum \alpha \frac{\sin 2\pi (B - A)}{p}$$

where μ is the required height of the annual mean level for the year B.

C is a local constant = 21 m/m for Marseilles.

47 m/m for Brest.

α and p are respectively the half amplitude and the period of each of the seven component waves.

A is one of the years in which the ascending branch of the component wave under consideration intersects the axis of this latter.

The *dotted line* represents the annual variations of the mean level from 1851 to 1925 worked out by this formula. The differences between this dotted line and the hard line give some idea of the degree of accuracy of the forecast.

The remaining discrepancies are probably due to meteorological influences.

To sum up, it seems to be established that *the increase in height of sea level, observed on the French coast during the course of the last three-quarters of a century, is not, as previously imagined, on account of a slow subsidence of the land but is due to cosmic phenomena of a periodical nature.*

The total amplitude of the regular oscillation seems to be about 7.5 c/m.

Tne precessional lunar wave (18.6 years) appearing, after a study of the diagram, to be the best determined of all the waves in question, it is interesting to compare its actual observed amplitude with the theoretical amplitude m deduced from the formula :

$$m = 0.066 \qquad R\,\alpha_m\,(l - \frac{3}{2}\cos^2 l)$$

formerly proved by Mr. Ch. LALLEMAND, in which

R is the mean terrestrial radius = 6357 km.

l is the latitude of the place under consideration.

αm, $(= \frac{1}{11{,}600{,}000})$, the compression which the geoid would take up assuming the Earth to be quite rigid and subject to the attraction of the moon assumed to be at its mean distance from it.

For Marseilles ($l = 43°3$), $m =$ 7 m/m

For Brest ($l = 48°3$), $m =$ 12 m/m

These amplitudes are obtained on the supposition that the Earth is rigid but if it is admitted, as appears to be accepted now-a-days, that our Earth is elastic and its rigidity is only comparable to that of steel, the values in question should be reduced by one-third which brings them down to about 5 m/m for Marseilles and 8 m/m for Brest, *i.e.* to a seventh and to a quarter respectively of the corresponding actual amplitude (35 m/m) as calculated above.

The same causes, which sometimes considerably amplify the semi-diurnal wave, appear to affect, o a certain extent, ocean waves of very long period also.