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Historical sketch of microseisms from past to future

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ABSTRACT

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The paper is a commentary on the theme presented in a poster at Vancouver. After a few words on the discovery of microseisms more than a century ago, their constant relation with swell and the cyclonic disturbances which are the cause of it are recalled. The practical use of microseisms as an index of the cyclonic activity may throw light on the dependence of atmospheric dynamics on solar irradiance variations.

Microseisms were studied physically before earthquakes themselves because the waves from the latter could not be properly separated by the undamped Galileo pendulum (known as a tromometer). This apparatus, however, resonantly revealed these continuous oscillations to Timoteo Bertelli (Fig. 1). They vary in amplitude simultaneously at distant stations, even if the wind does not, as is shown by the extensive array of such apparatus which was established; that apparatus under the direct maintenance of Father Bertelli, first in Firenze and afterwards in Rome, gave a continuous series of observations, the annual means of which shows conspicuous maxima in 1873 and 1886: we will see later the significance of these dates.

Bertelli also emphasized the correlation of the tromometric storms with barometric lows, and suspected the influence of coastal sea waves on these movements (Eva, 1975). This was also discovered on Campbell Island by Bouquet de la Grye. In France, the siting of a tromometer in a coal mine 300 m below ground (the only known experiment of this kind) led to the discovery of the occurrence of a gas emission during a microseismic storm at the same time as a fall in barometric pressure (Chesneau and de Chancourtois, 1888).

It was recognized at an early stage that "microseisms" arose when a cyclonic centre travelled on the sea off a seismic station (Algue, 1900; Kikuchi, 1904; Linke, 1906; Klotz, 1908; Gherzi, 1924; Poisson, 1931), and that extra-tropical lows had the same property when on an oceanic area (Lacoste, 1927; Lee, 1932), apparently bound to the very centre of the isobars (Bernard 1937, see Fig. 2). This was later the basis of the experimental work accomplished by the tripartite method (Ramirez, 1940; Gilmore 1946) but its practical application to meteorological forecasting was successful only irregularly because the bearing of the microseismic waves vary angularly over short periods and the identification of wave trains is difficult at a distance of more than a few hundred meters, which indicate interference of simultaneous waves "perplexing together": indeed, a strong dispersion occurs in the frequency range of microseisms (Sezawa, 1935). Modern analyses of numerous seismographs giving a statistical treatment of microseism velocity appear promising and the detection of a P wave component in microseisms by the installation of a subterranean station under the surface device has been tried in Greenland by Hjortenberg (1972).

The search for a mechanical cause of microseisms has also made great progress since the

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Fig. 1. Timoteo Bertelli (1870) represented at the eyepiece of his tromometer by Texas Instruments Inc.

bringing together by Deacon and Longuet-Higgins of the two-to-one ratio of the respective periods of swell and microseisms and of the calculations of Miche who found a propagation towards the bottom of the sea of second-order pressure fluctuations, unattenuated with depth, when stationary oscillations of the sea level occur. These stationary waves, first attributed to the crossing of opposite wave trains such as those provoked by orthogonal reflection on a linear barrier, are rarely found to have arisen because of meteorological conditions over the ocean except at the centre of depressions, where convergent winds give rise to "pyramidal waves" (Fig. 3) which are usually higher than long crest waves, or in the change in direction of winds which accompanies cold fronts (Grinda, 1972), but the examination of isobaric charts shows that the microseismic effect of circular lows is always stronger than that of fronts.

On the other hand, the reflection of sea waves on a coast referred to above can give rise to a concave mirror effect when the bank presents a circular design so that there is, as in optics, a "caustic area" where the plashing waves are higher. This can be observed on ponds, lakes, or lagunas (Fig. 4) and microseisms originate, for example, from the Great Lakes (Lynch, 1953) or from Lake Baïkal (Tabulevich, 1986). As for the greater periods generated on oceans, case histories can be quoted in the Gulf of Alaska where lows generate microseisms perceptible as far as the Atlantic stations (Carder, 1955), and in the Bay of Biscay, where microseismic storms are duplicated by the arrival of distantly originated cyclonic swells which have earlier been signalled microseismically both in Paris and Hendage (Bernard, 1961).

In shallow waters, "primary" microseisms have the same period as swell. An experiment on the wave canal at Maisons-Alfort (LNHF) has shown that swell arriving against a dam acts as downward pressure on the floor and not as a percussion at the surface level: the movement of the dam is not a backward shift but a tilting toward the crest of the wave (Bernard and Brosselard-Faidherbe, 1972).

The close connection between microseisms and swell has been useful to clarify properties of the latter phenomenon as well as of the former. For example, a field of swell travelling on the ocean has local microseismic effects on the coasts

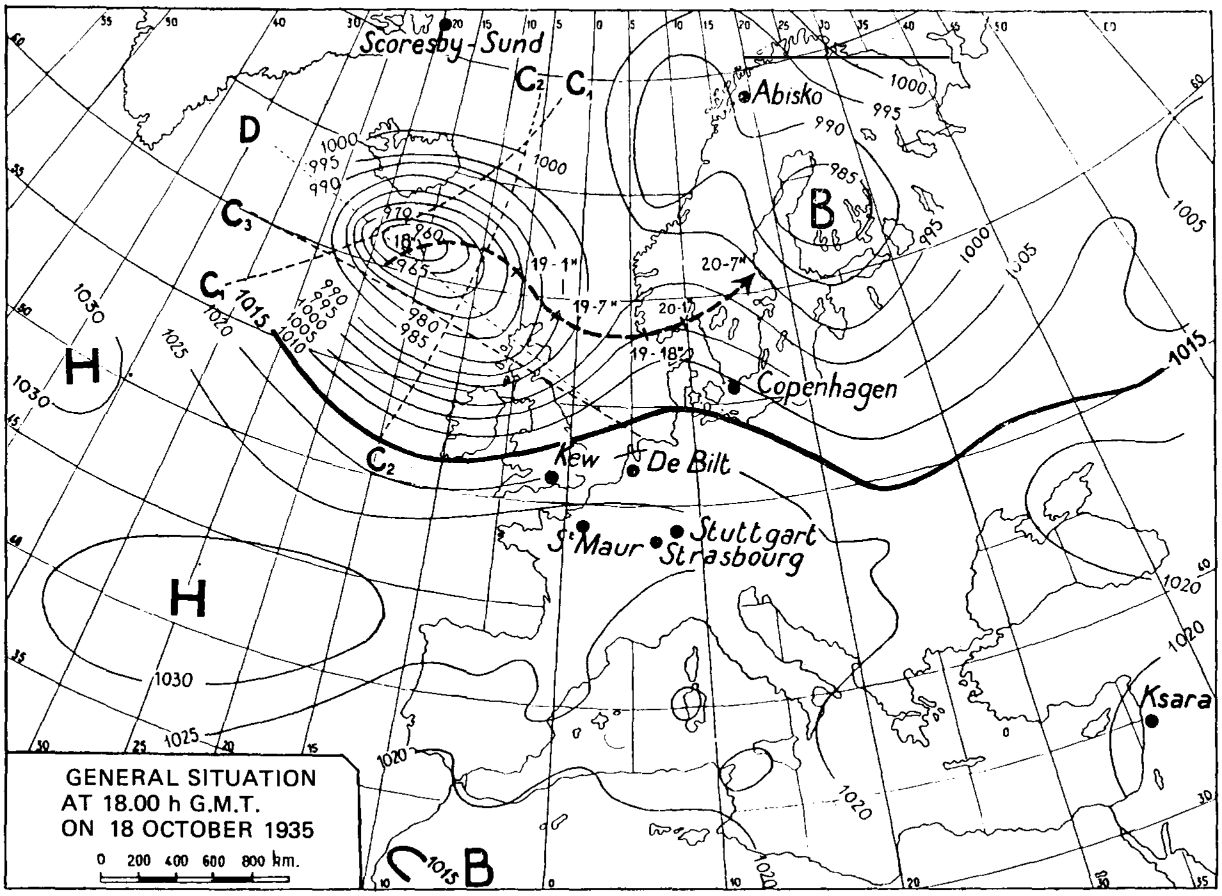

Fig. 2. Application of the hyperbolic method (locus of the difference in times of a sudden increase of microseismic amplitude): curve C_1, between Scoresby-Sund and Ksara; curve C_2, between Abisko and Scoresby-Sund; curve C_3, between Copenhagen and W. Europe as a whole; D, median of the simultaneous stations St. Maur and Copenhagen: all curves pass near the centre of an oceanic barometric low (Bernard, 1941).

reached, and so can be tracked as far as the antipods: the velocity observed does not vary greatly (about 60 km h^{-1}) (Bernard, 1949, 1959) and this figure is used in swell prediction (Gelci, 1952). Microseisms are registered in France 1–3 days before the arrival of swell in Morocco, and in South Africa or Antarctica before its arrival on the coast (Darbyshire, 1973; Smirnov, 1968).

Another important fact is that the amplitude of microseisms is dependent on cyclonic activity, and may therefore furnish an index of it for a large area around each station, on contrast to other meteorological parameters of a local character. It was consequently possible to search for a solution to the much-debated problem of the dependence of meteorology on solar activity and indeed an undecennial variation of microseisms was found on a 70 years composite series of annual means using successive stations, each referred to its own general mean: conspicuous maxima occur in 1910, 1920, 1930, 1940, 1962, and 1972, all dates falling during the decrease of sunspots, as do the years 1873 and 1886 of Bertelli. It is, however, curious that the amplitude of this undecennial period is smallest after the paroxysmal solar cycles of 1948 and 1958 (Fig. 5).

It is remarkable that this lag of microseisms behind sunspot activity is also found in the unde-

Fig. 3. Pyramidal wave photographed at the centre of a cyclone (after Charcot, 1929).

cennial variation of the amplitude of geomagnetic disturbances, as mentioned by Bernard (1948) and confirmed for a period of over 100 years by Simon and Legrand (1989).

Moreover, this research on microseismic monthly and yearly means over long periods led to the observation that variations of the total ozone measured at Mauna-Loa (Garcia et al., 1984)

Fig. 4. Plashing waves near a circular bank on the lagoon at West Palm Beach, Florida.

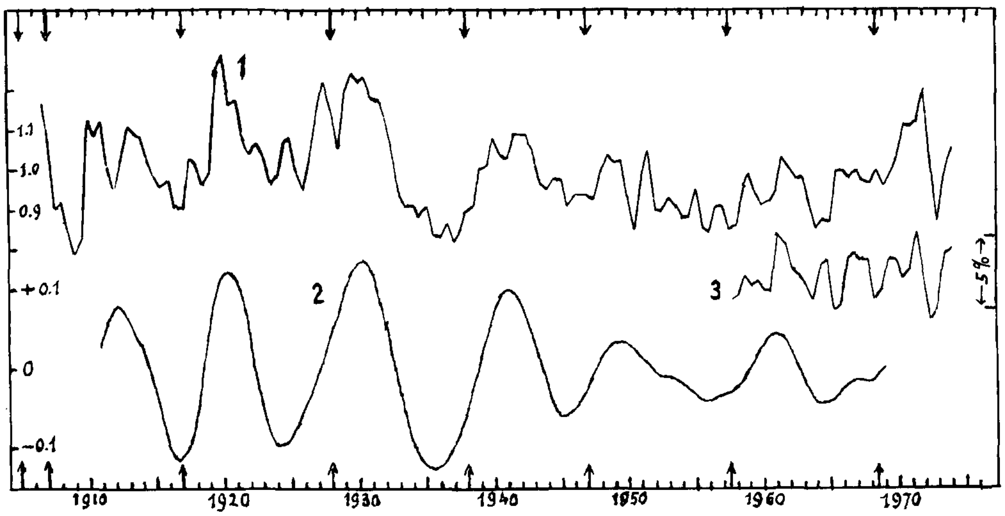

Fig. 5. Curve 1, biannual means on 12 months of relative amplitude of global microseisms (15 overlapping stations). A Labrouste linear filter on these data give the undecennial periodic curve, curve 2. Arrows indicate the solar sunspots maxima. Curve 3, successive annual means calculated, as for microseisms, from January to December and July to June, on total ozone data at Mauna-Loa (after Garcia et al., 1984).

strongly resembled microseisms during their common series of observations; this correlation suggests that the amount of ozone is actually affected by tropospheric disturbances and their mechanical action on the general circulation and equilibrium of the middle atmosphere.

Other stations observing ozone are not known to reveal this undecennial tendency, but it is understandable that an atmospheric effect will be clearer in the centre of an immense ocean than in continental observatories; it is however noticeable that Arosa had a conspicuous maximum in 1940 and 1952 (Dütsch, 1984).

These remarks illustrate the interest of microseisms in a global approach of geophysical phenomena and therefore it is the wish of the author that their routine observations are continued and are treated statistically at a number of well-distributed stations.

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