THE RELATION BETWEEN AIR-PRESSURE MICRO-OSCILLATIONS AND CONCURRENT SYNOPTIC PATTERNS

By Walter H. Roschke, Jr.

Saint Louis University[1]

(Original manuscript received 2 January 1952; revised manuscript received 26 February 1952)

ABSTRACT

A detailed investigation of air-pressure micro-oscillations of periods less than one minute, as recorded by the Macelwane electromagnetic microbarographs at Florissant, Missouri, and Ottawa, Canada, shows that a definite relationship exists between these oscillations and the concurrent synoptic pattern.

The typical time sequence, with relative amplitudes, of atmospheric micro-oscillations characteristic of certain synoptic patterns is as follows: (1) small-amplitude oscillations occurring concurrently with an extensive surface high-pressure area, (2) a transition activity of medium amplitude accompanying the flow on the back, or trailing, side of a high, and (3) a period of relative quiescence occurring during the time of passage of a cold front, with maximum-amplitude oscillations existing for a relatively short period of time immediately prior to this in the pre–cold-front interval and for an extended period in the post–cold-front interval.

It is shown that high-velocity flows of cold air are much more efficient mechanisms for producing extended intervals of maximum-amplitude oscillations than corresponding warm-air flows.

1. Introduction

The investigation of air-pressure micro-oscillations of periods much greater than 1 min was initiated by Helmholtz (1889), who hypothesized internal gravitational waves, generated at horizontal discontinuity surfaces in the atmosphere. Many subsequent investigators, including Schmidt (1911), Goldie (1925), Johnson (1929), Namekawa (1934), Suzuki and Oomori (1937), and Mitchell (1949), have substantiated this hypothesis of Helmholtz.

The investigation of micro-oscillations of short period, however, is of rather recent origin. It received its initial impetus from the development of the Macelwane (1938) and Benioff (1939) electromagnetic microbarographs, whose response characteristics emphasize oscillations of periods less than 1 min.

A description of the Macelwane microbarograph will be found elsewhere (Macelwane and Ramirez, 1938). On the original records (*i.e.*, before photographic reduction), a 1-cm trace deflection on the Macelwane microbarogram corresponds, approximately, to a sudden pressure change of 3×10^{-3} mb; and the 3-cm interval between successive time marks on the record represents 1 min of time.

The purpose of the research presented here is to correlate the patterns of air-pressure micro-oscillations of periods less than 1 min, as recorded by the Macelwane electromagnetic microbarographs at Florissant, Missouri (near Saint Louis), and at Ottawa, Canada, with the contemporaneous synoptic patterns, to determine, if possible, the mechanism responsible for these short-period micro-oscillations of air pressure.

2. Micro-oscillations and synoptic patterns

Even a casual examination of the microbarograms shows the complex nature of microbarographic activity, particularly the alternating periods of quiescence and maximum activity, and the appearance of certain isolated impulses. Furthermore, previous investigators have suggested a relation between these micro-oscillations and synoptic patterns. Ramirez (1940) observed that the times of greatest disturbance on the Macelwane microbarograms were not governed by purely local conditions, while both Ramirez (1940) and Gutenberg and Benioff (1941) noted oscillations of large amplitude associated with low-pressure areas.

In view of these facts, it was felt that an investigation of the relation between micro-oscillations and concurrent synoptic patterns, to determine whether a significant percentage of a particular type of microbarographic activity is associated with the occurrence of a particular synoptic pattern and/or air mass, should prove useful in increasing our understanding of the mechanism producing the micro-oscillations of short period.

The various synoptic-pattern and air-mass data discussed were obtained by utilizing ozalid copies of the surface maps of the U. S. Weather Bureau-Air Force-Navy Analysis Center. Four maps, at 6-hr intervals, were available for each day.

Classification of oscillations.—Clark (1950) analyzed and classified the micro-oscillations of air pressure, recorded by the Macelwane microbarograph, according

[1] Submitted as a contribution to a research project on atmospheric micro-oscillations and short-period microseisms, sponsored by the Office of Naval Research under Contract N7onr–408, Task Order I. A portion of a Master's thesis.

to an average hourly period and amplitude. In view of the primary interest of the present investigation to compare the time-duration characteristics of the activity on the microbarogram with the concurrent synoptic pattern, it was deemed unwise to attempt a quantitative classification of these oscillations. Therefore the following, somewhat qualitative, classification of micro-oscillations was selected: (1) *Quiet*—oscillations of minute amplitude, almost straight lines on the record; equivalent to a sudden pressure-change of less than a few ten-thousandths of a millibar, (2) *Transition*—oscillations of medium amplitude; a transition type of activity occurring as a build-up to maximum activity, or a dying-down from maximum to quiet, (3) *Maximum activity*—oscillations of large amplitude, so large that individual wave-periods and -amplitudes are almost indistinguishable due to over-lapping of adjacent lines on the microbarogram; equivalent to a sudden pressure-change greater than 0.002 mb.

An example of each of these three types of microbarographic activity is shown in fig. 1; hereafter these groups will be symbolized by the letters Q, T, and M, respectively.

Oscillations characteristic of extensive surface high-pressure areas and post–cold-front intervals.—After a preliminary study of the surface weather-maps and the concurrent microbarograms, the following two synoptic patterns were chosen for the initial investigation of the relation between synoptic patterns and micro-oscillations: (1) Extensive surface high-pressure area, frequently extending from southeastern Canada over a considerable portion of eastern United States, the major axis being orientated north-south, and accompanied by a cP, cPk or cPw air-mass; (2) Post–cold-front interval, characterized by generally strong northwesterly winds, cyclonically curved isobars, a tight surface pressure-gradient, and a cP or cPk air-mass.

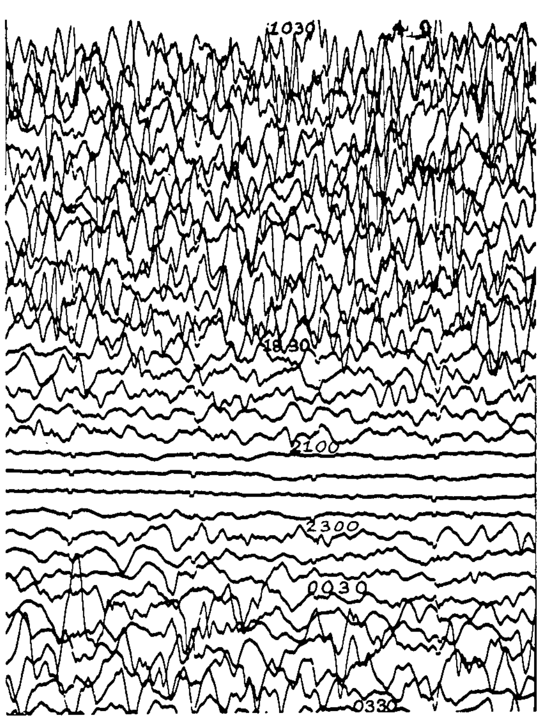

FIG. 1. Portion of typical winter microbarogram at Ottawa, 16–17 January 1949, showing the three microbarographic activity groups: maximum activity (M), 1030–1830 (also 0030–0330); transition (T), 1830–2100 (also 2300–0030); quiet (Q), 2100–2300. (All times are EST; 1 min elapses between time marks.)

TABLE 1. Total number of hours of certain air masses included in synoptic-pattern definitions, and concurrent microbarographic activity.

Air mass	Air-mass hours	Microbarographic activity (hr) Q	T	M	Season
		Florissant			
cP, cPk, cPw*	956.5	455	342	159.5	Winter
cP, cPk, cPw	386	196	152	38	Summer
cP, cPk**	570.5	271.5	184.5	114.5	Winter
cP, cPk	317	165.5	123.5	28	Summer
		Ottawa			
cP, cPk, cPw*	969	480	259.5	229.5	Winter
cP, cPk, cPw	817	406	262	149	Summer
cP, cPk**	825	372	234	219	Winter
cP, cPk	679.5	309	229	141.5	Summer

* Air masses which may accompany synoptic pattern No. 1.
** Air masses which may accompany synoptic pattern No. 2.

The investigation of the extensive surface high-pressure area (synoptic pattern No. 1) includes four months of data with winter conditions prevailing; two months each at both Florissant and Ottawa (December 1948 and January 1949). The study of the post–cold-front interval (synoptic pattern No. 2) includes eight months of data; the identical two-months winter interval for both stations as for synoptic pattern No. 1, as well as a two-months summer interval at Florissant (15 May to 15 July 1949) and also at Ottawa (15–31 July 1948, 15–31 August 1948, 15–30 June 1949, 15–31 July 1949).

Tables 1 and 2 contain a summary of the data; all time intervals were estimated to the nearest half-hour. The following example, taken from lines one of tables 1 and 2, will facilitate a better understanding of the data collected and the analysis performed. The cP, cPk and cPw air-masses (included in the

TABLE 2. Microbarographic activity and synoptic patterns.

Synoptic pattern and season	Station	Pattern hours	% of total air-mass hours	Microbarographic activity (percentages) Q	T	M
No. 1.—Winter	Florissant	196	20.5	40.7	3.1	0.0
No. 1.—Winter	Ottawa	357.5	36.9	60.2	21.8	5.2
No. 2.—Winter	Florissant	199.5	35.0	10.3	37.4	89.5
No. 2.—Winter	Ottawa	326	39.5	15.9	38.5	80.7
No. 2.—Summer	Florissant	138	43.5	34.7	42.9	98.2
No. 2.—Summer	Ottawa	300.5	44.2	19.1	56.2	79.7

definition of synoptic pattern No. 1) occurred 956.5 hr at Florissant in the winter interval (table 1); this total of 956.5 hr is accompanied by 455 hr of Q, 342 hr of T, and 159.5 hr of M. Synoptic pattern No. 1 occurred only 196 hr (table 2), or 20.5 per cent of this total of 956.5 hr; however, these 196 hr, or 20.5 per cent, are accompanied by 40.7 per cent of the total Q, only 3.1 per cent of the total T, and 0.0 per cent of the total M microbarographic-activity hours occurring with the cP, cPk and cPw air-masses listed in table 1.

As is obvious from the tables, a small percentage of maximum activity accompanies an extensive surface high-pressure area, while a large percentage of M is associated with the post–cold-front interval.

The following conclusions were obtained from the data contained in tables 1 and 2: (1) An extensive surface high-pressure area at Ottawa or Florissant in winter, with its major axis orientated north-south, and accompanied by a weak surface pressure-gradient and a cP, cPk, or cPw air-mass, is characterized by a significantly small percentage of micro-oscillations of maximum amplitude, and a rather large percentage of the total quietude; (2) The post–cold-front interval at Florissant and Ottawa, with its strong northerly winds, tight surface pressure-gradients, and a cP or cPk air-mass, is characterized by a significantly large percentage of the micro-oscillations of maximum amplitude, and a rather small percentage of the total quietude. Fig. 2 shows the micro-oscillations characteristic of extensive surface high-pressure areas and post–cold-front intervals.

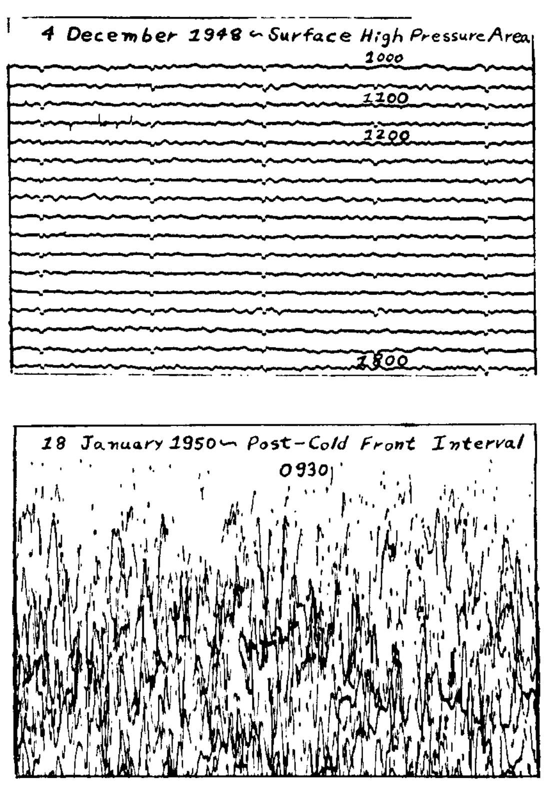

FIG. 2. Selected portions of two Ottawa microbarograms. Top: surface high-pressure area, 1000–1800 EST 4 December 1948. Bottom: post–cold-front interval, 0930–1730 EST 18 January 1950.

A study for December 1948, at Ottawa, re-emphasized the relation indicated above; namely, a tight surface pressure-gradient is generally accompanied by micro-oscillations of large amplitude, while a weak gradient is characterized by oscillations of small amplitude. However, the influence of the horizontal surface pressure-gradient in controlling the amplitude of micro-oscillations is limited; while all extended intervals of large-amplitude oscillations are accompanied by a concurrent steep surface pressure-gradient, not every occurrence of a steep gradient is accompanied by large-amplitude oscillations.

Oscillations characteristic of the back side of a surface high-pressure area.—The previous discussion emphasized maximum and minimum microbarographic activity. Since oscillations of medium amplitude (transition activity) also occur frequently on the microbarogram, an investigation was initiated to determine the microbarographic activity characteristic of the back, or trailing side, of a surface high-pressure area, and the activity occurring before and during a frontal passage.

The discussion of the microbarographic activity characteristic of the back side of a surface high-pressure area has been further divided into two parts, to include strong southerly flows of returning polar air as well as flows of maritime tropical characteristics.

The investigations were restricted to easily analyzed and well-defined synoptic situations, which often occur at Florissant and Ottawa; situations with complicated frontal and air-mass systems were not included. The resulting conclusions are well founded, being based on the large number of cases that occurred during the three winter seasons of 1948–1949, 1949–1950 and 1950–1951; however, only a few representative synoptic-pattern intervals will be listed.

The synoptic situations of 5 December 1948 (1500–2400 EST), 15 December 1948 (0830–2030 EST), 26–28 December 1948 (261230–280130 EST), and 19–20 November 1949 (191130–200130 EST) at Ottawa, as well as those of 10–11 December 1948 (101330–111730 EST) and 28 December 1948 (0730–2130 EST) at Florissant, are examples of representative synoptic-pattern intervals which produced micro-oscillations characteristic of a strong, southerly flow of returning polar air (cPw) on the back side of a high-pressure area, with a steep surface pressure-gradient.

The micro-oscillations occurring concurrently with this particular synoptic pattern were a transition type of medium amplitude, with oscillations of largest amplitude being somewhat smaller and occurring less frequently than those associated with the post–cold-

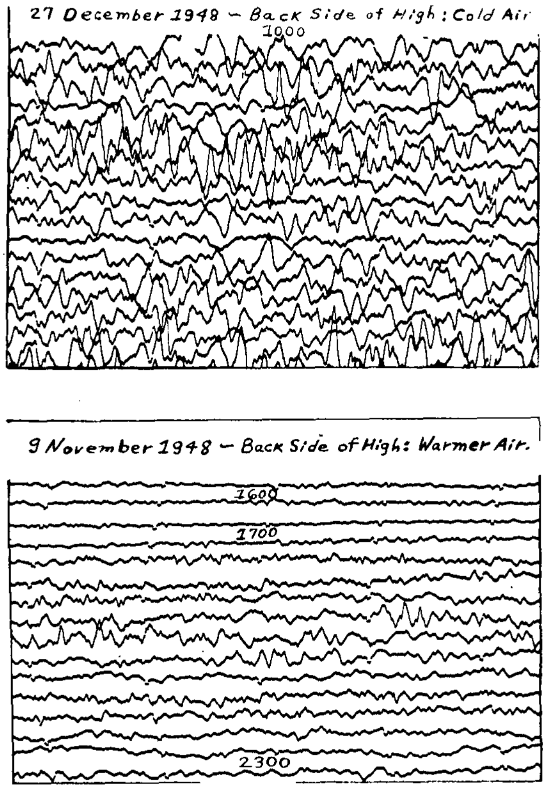

FIG. 3. Selected portions of two Ottawa microbarograms. Top: back side of high-pressure area accompanied by returning polar air, 1000–1830 EST 27 December 1948. Bottom: back side of high with strong southerly flow of maritime tropical air, 1600–2300 EST 9 November 1948.

front interval. Examples of this transition activity are shown in figs. 3 and 4.

After an extended interval of strong southerly flow on the trailing side of a high center, the initial polar air-mass is often replaced by a warmer air-mass of maritime tropical characteristics. The synoptic situations of 9–10 November 1948 (091530–100630 EST) and 6 December 1948 (0000–0600 EST) at Ottawa, and of 14–15 December 1948 (141030–151430 EST) at Florissant, are examples of representative synoptic-pattern intervals which produced micro-oscillations characteristic of strong southerly flows of mT air in a warm sector, on the trailing side of a surface high-pressure area.

The micro-oscillations accompanying this particular synoptic pattern were a "reduced transition" type, *i.e.*, the amplitudes are smaller than those occurring with a southerly flow of returning polar air, but larger than the quietude found with an extensive surface high-center. Examples of this "reduced transition" microbarographic activity are shown in figs. 3 and 4.

The previous investigations indicate that high-velocity flows of cold air are much more efficient mechanisms in the production of micro-oscillations of large amplitude than correspondingly strong flows of warm air. The strong northerly flow of polar air in the post–cold-front interval produces oscillations of

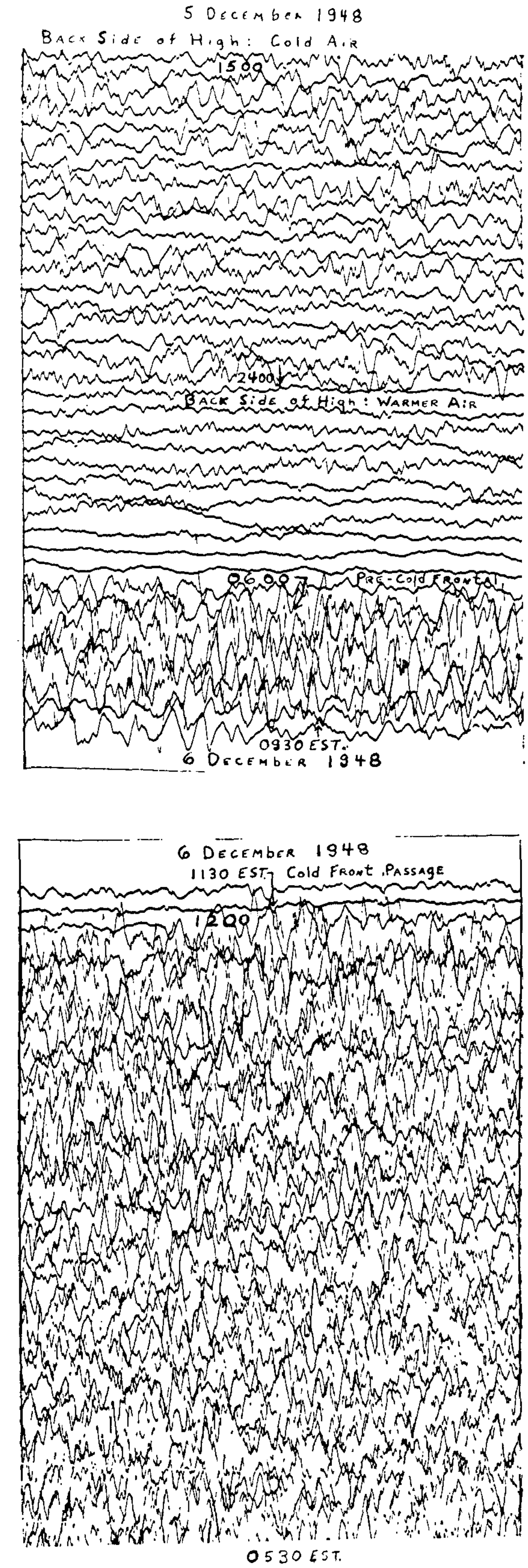

FIG. 4. Selected portions of two Ottawa microbarograms for 5–7 December 1948, showing typical time-sequence and relative amplitudes of micro-oscillations characteristic of back side of high-pressure area, and before, during, and after passage of cold front. (All times are EST.)

maximum amplitude; oscillations of medium amplitude accompany a strong southerly flow of returning polar air on the back side of a high, while a strong southerly flow of maritime tropical air in a warm sector is characterized by oscillations of relatively small amplitude.

However, an additional study of the eight months of data previously collected for synoptic-pattern intervals shows that the occurrence of a particular air-mass at a station does not uniquely determine the characteristics of the microbarographic activity. While micro-oscillations of large amplitude occur more frequently in winter, with its characteristic cold air-masses, than in summer, with its warm air-masses, and while the more frequent occurrence of cold air-masses at Ottawa, as compared to Florissant, results in more frequent occurrence of oscillations of large amplitude at Ottawa, the importance of air mass in controlling the amplitude of the micro-oscillations should not be over-emphasized. While all extended intervals of maximum activity are accompanied by a cold air-mass, such as cPk, not every cold air-mass is accompanied by maximum activity.

Oscillations characteristic of a frontal passage.—An analysis of the nine frontal passages during December 1948 at Ottawa, as well as the cold-front passages of 23 November 1949, 10 January 1950, 16 January 1950, 18 January 1950, 29 January 1950, and 11 April 1950 at the same station, has substantiated Clark's (1950) findings based on one frontal passage; namely, air-pressure micro-oscillations of short period are predominantly of small amplitude, or even absent, during the time of almost all frontal passages. In addition, while almost all cold fronts are characterized by this definite break and decrease in the amplitude of the oscillations during the time of (or just before) the frontal passage, oscillations of maximum amplitude occur for a short interval (approximately 3 to 6 hr in duration) immediately prior to this relatively quiet period, as well as in the post–cold-front interval discussed previously.

The microbarogram of 6 December 1948 (fig. 4) indicates the micro-oscillations characteristic of the passage of a cold front, showing the two maximum-amplitude oscillation intervals surrounding the period of relative quiescence.

This interval of quiescence is so evident from the microbarogram that workers on the microbarograph project have become remarkably proficient at determining from the record that a frontal passage has occurred, before examining the concurrent synoptic data. The micro-oscillations characteristic of a frontal passage are some of the most interesting and may eventually provide a key necessary for understanding the mechanism producing these oscillations.

Typical time-sequence of oscillations.—To facilitate a better understanding of the characteristic microbarographic activity occurring in each of the synoptic pattern intervals previously discussed, consider the typical time-sequence of micro-oscillations for the easily analyzed and well-defined synoptic situations of 5–7 December 1948 at Ottawa. Fig. 4 shows the typical time-sequence of micro-oscillations, as well as the approximate time that the indicated synoptic

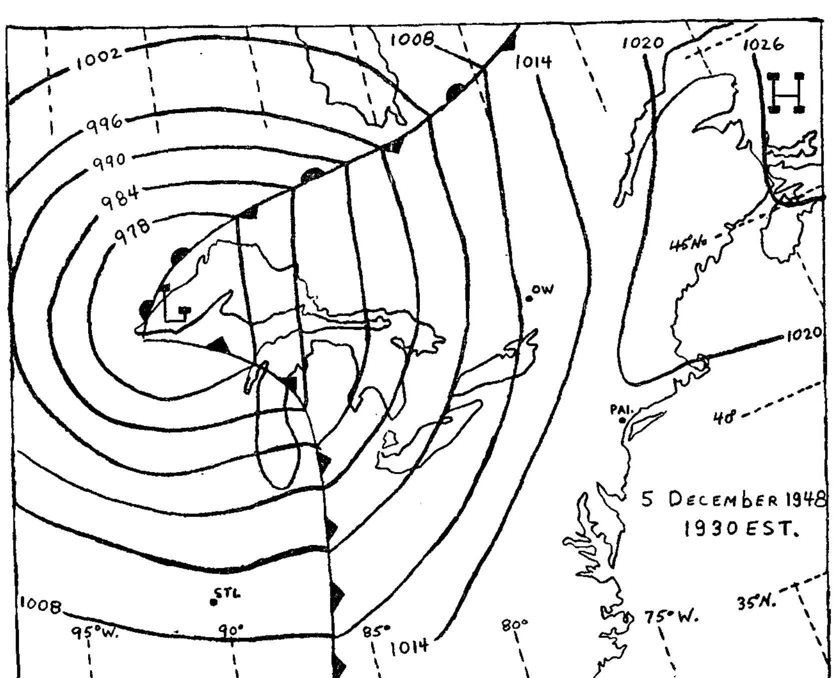

FIG. 5. Synoptic map of 1930 EST 5 December 1948, showing synoptic situation accompanying the typical time-sequence of micro-oscillations in fig. 4.

interval began, while fig. 5 presents the synoptic pattern.

The typical time-sequence and relative amplitudes of air-pressure micro-oscillations characteristic of certain synoptic-pattern intervals in winter, at Ottawa and Florissant, is as follows:

1. Quietude accompanying the extensive surface high-pressure area. (The record trace consists of almost straight lines prior to 0130 EST 5 December 1948.)
2. Transition activity of medium amplitude accompanying the strong southerly flow of returning polar air on the back side of the high pressure area (1500–2400 EST on the 5th).
3. "Reduced transition" activity, of relatively small amplitude, occurring concurrently with the strong southerly flow of air of maritime tropical characteristics on the back side of the high in the warm sector (0000–0600 EST 6 December 1948).
4. Maximum activity of relatively short duration in the pre-cold-front interval (0600–0930 EST on the 6th, cold front 125 mi to west of Ottawa).
5. Quietude, or oscillations of small amplitude, during the time of (or just before) the passage of the cold front (0930–1200 EST; cold front passed Ottawa about 1130 EST).
6. Maximum activity of extended duration in the post-cold-front interval (after 1200 EST on the 6th).

The amplitude of the oscillations again decreases as the surface high-pressure area following the cold front enters the region of Ottawa, thus completing the cycle of this particular time-sequence of micro-oscillations and concurrent synoptic patterns.

While the microbarograms and synoptic patterns of 5–7 December 1948 are typical, not every seemingly identical synoptic pattern will produce oscillations of identical amplitude; often the amplitudes of all the oscillations will be reduced somewhat. Nevertheless, even in such cases, the oscillations maintain the same typical time-sequence and relative amplitudes in relation to each other.

One additional fact, concerning the character of the mechanism producing micro-oscillations, was discerned from this synoptic situation. The meteorological system of 4–7 December 1948 conveniently moved so that first Florissant, and later Ottawa (separated by 875 mi), occupied almost identical positions with respect to the system, permitting a comparison of the amplitudes and time sequences of the oscillations at the two widely separated stations.

The production of almost identical microbarograms (first at Florissant and later at Ottawa), from this particular synoptic system, indicates that the mechanism producing micro-oscillations can maintain its characteristics for considerable time and distance. (The synoptic situation of 10–12 December 1948 also produced similar records at both stations.)

3. Conclusions

A definite relationship exists between the time-duration patterns of air-pressure micro-oscillations of periods less than 1 min, as recorded by the Macelwane electromagnetic microbarograph, and the contemporaneous synoptic pattern.

The typical time-sequence and relative amplitudes of the micro-oscillations characteristic of various synoptic-pattern intervals, in winter at Florissant and Ottawa, are as follows:

Micro-oscillations of negligible amplitude, *i.e.*, almost straight lines on the microbarogram, accompanying an extensive surface high-pressure area, with its major axis orientated north-south, and a concurrent continental polar air-mass;

Micro-oscillations of medium amplitude accompanying a strong southerly flow of returning polar air on the back side of a surface high-pressure area, with the amplitude of the oscillations being relatively smaller during a strong southerly flow of warmer air of maritime tropical characteristics;

Micro-oscillations of maximum amplitude occurring for a relatively short interval, prior to the period of quiescence characteristic of the passage of a cold front;

Micro-oscillations of negligible amplitude occurring during the time of (or just before) the passage of a cold front;

Micro-oscillations of maximum amplitude persisting for an extended period in the post-cold-front interval, with the amplitude decreasing as the high-pressure center following the cold front moves into the region of the recording station.

Certain characteristics of the mechanism responsible for air-pressure micro-oscillations of short period have been determined:

The mechanism can maintain its characteristics for considerable time and distance (Florissant to Ottawa).

Streams of cold air are much more efficient mechanisms in the production of micro-oscillations of large amplitude than corresponding flows of warm air, the oscillations of largest amplitude being relatively smaller and occurring less frequently with the warmer air flows.

Extended intervals of maximum-amplitude micro-oscillations occur concurrently with the combination of a tight horizontal surface pressure-gradient and a very cold polar air-mass; however, the occurrence of either a tight pressure-gradient, or a particular air-mass, does not, of itself, signify a particular characteristic microbarographic activity.

The exact mechanism responsible for short-period micro-oscillations of air pressure is not completely understood at present. Certain of the characteristics discussed above support Clark's hypothesis (1950) of low-level turbulence as the responsible mechanism. The oscillations of negligible amplitude associated with the passage of a cold front (while not necessarily supporting the turbulence hypothesis) may provide the key necessary for completely understanding the micro-oscillation mechanism.

REFERENCES

Benioff, H., and B. Gutenberg, 1939: Waves and currents recorded by electromagnetic barographs. *Bull. Amer. meteor. Soc.*, **20**, 421.

Clark, R. D. M., 1950: Atmospheric micro-oscillations. *J. Meteor.*, **7**, 70–75.

Goldie, A. H. R., 1925: Waves at an approximately horizontal surface of discontinuity in the atmosphere. *Quart. J. r. meteor. Soc.*, **51**, 239–246.

Gutenberg, B., and H. Benioff, 1941: Atmospheric pressure waves near Pasadena. *Trans. Amer. geophys. Union*, **22**, 424–426.

Helmholtz, H. V., 1889: In *Sitzb. Kgl. Preuss. Akad.*, p. 761.

Johnson, N. K., 1929: Atmospheric oscillations shown by the microbarograph. *Quart. J. r. meteor. Soc.*, **55**, 19–30.

Macelwane, J. B., *et al.*, 1948: *Investigation of the nature and origin of micro-oscillations in the atmosphere.* St. Louis, Saint Louis University, 15 pp.

Macelwane, J. B., and J. E. Ramirez, 1938: The electromagnetic microbarograph and its performance. *Trans. Amer. geophys. Union*, **19**, 126–127.

Mitchell, J. M., Jr., 1949. An example of micro-oscillations in pressure, wind, and temperature at Blue Hill Observatory. *Bull. Amer. meteor. Soc.*, **30**, 105.

Namekawa, T., 1934: A study of the minor fluctuations of the atmospheric pressure, Part 1, Theory of the internal gravitational waves in the atmosphere and its application to the waves of pressure recorded by the microbarograph. *Mem. College Sci. Kyoto Imp. Univ.*, A, **17**, 405–430.

Ramirez, J. E., 1940: An experimental investigation of the nature and origin of microseisms at Saint Louis, Missouri. *Bull. seism. Soc. Amer.*, **30**, 35–84, and 139–178.

Schmidt, W., 1911: Atmospheric waves of short period. *Quart. J. r. meteor. Soc.*, **37**, 73–79.

Suzuki, A., and H. Oomori, 1937: On the atmospheric waves. *Gerlands Beitr. Geophysik.*, **49**, 301–318.