On the Inter-year Variation of the Annual and the Semi-annual Oscillations of the Atmosphere

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(Manuscript received 15 December 1960)

Abstract

The inter-year variations of the annual and the semi-annual pressure oscillations are discussed, special emphasis being placed upon the relationship between the amplitude and the phase. The inter-longitude variations along the latitudinal circles are also touched. In both variations, the phase and the amplitude seem to be under a certain relationship. The effects, on the monthly-mean pressure values, of intense storms seem to be serious in many cases. In order to avoid such effects, it is desired that the monthly-mean pressure value be computed from "quiet day" pressures alone.

1. Introduction

The atmospheric lunar tide has been known to change its phase and amplitude of the surface pressure systematically through the course of a year (S. Chapman, 1951). One of the possible cause was proved to be seasonal variations of the mean vertical temperature profile, especially that around the mesopeak and the ionospheric temperature (R. Sawada, 1954 and 1956).

With these results in mind, the annual and the semi-annual oscillations of the atmosphere are analyzed in this paper. The phase and the amplitude of these oscillations vary from year to year considerably, but these inter-year variations seem to follow a certain phase-amplitude relationship.

This is a preliminary report on the analysis of the surface pressure oscillations and that of the 500 mb surface oscillations. The result of analysis will be presented on the phase-amplitude diagram which is a deformation of the harmonic dial.

The examples given in what follows give rather clear idea on the relationship which is similar to that of the atmospheric lunar tides, if not the same for their causes. This result suggests that the inter-year variation of the annual and the semi-annual oscillations may have its principal cause in the corresponding inter-year changes of the mean state of the atmosphere.

This clear relationship between the amplitude and the phase, however, is not always seen for other places or for other periods. The dots on the diagram sometimes scatter so much that no clear relationship is observable. The cause of this scattering should be found not only in the error of original data, but also in the complexity of the inter-year variations of the mean state of atmosphere and also in the effect of intense cyclones which pass nearby the station to affect seriously the monthly-mean pressure values. It seems quite necessary for us to have the monthly-mean value computed only from the "quiet day" values.

2. Characteristics of inter-year variations of the surface pressure oscillation

The amplitude and the phase angle of the annual and the semi-annual surface pressure oscillations change considerably from year to year. As a clearer example, the result of harmonic analysis for Maizuru (35° 28' N, 135° 23' E) is presented here. The annual and the semi-annual oscillations are computed for the period of 1948 through 1957 by harmonic analysis of 12 monthly-mean values for each year. Since these values include the progressive variation caused by climatic changes of longer periods, the variation was eliminated before the analysis (Conrad, V. and L.W. Pollak, 1950).

Fig. 1 Amplitudes of the surface pressure oscillations as functions of the annual mean surface pressure. Each dot represents the amplitude and the annual mean pressure of corresponding particular year.

The result shows that the amplitude of the oscillation is closely connected to the annual mean surface pressure. Fig. 1 shows this fact rather clearly both for the annual and the semi-annual oscillations. It is interesting to notice that in the year of higher mean surface pressure the annual oscillation predominates, and the semi-annual oscillation does not develop. It is in the year of lower mean pressure that the semi-annual oscillation develops and becomes very important. The amplitude increases from 1 mb to 2.5 mb as the mean surface pressure decreases from 1016 mb to 1014.5 mb, while the annual oscillation decreases its amplitude from 6.8 mb to 5.0 mb. The ratio of the intensities of both oscillations varies quite sensibly in response to the change of the annual mean surface pressure, thus causing fluctuations in the type of annual pressure variation from year to year. It remains, however, unknown to what extent the result represents the real oscillations of these long periods. It is quite possible that severe storms passing by the station affects the monthly-mean pressure value considerably. These storms are of shorter periods and of smaller scales in nature, and should be eliminated beforehand.

The oscillation is usually better presented on the harmonic dial. Here, however, the rectangular-coordinate phase-amplitude diagram is used instead, in order to save space on the dial. Each dot in the diagram shows

Fig. 2 Phase-amplitude relationship for the semi-annual surface pressure oscillation. The curve in the figure does not represent any physical meaning, but just shows a general trend of the relationship.

the amplitude and the phase at the same time as in the harmonic dial.

Fig. 2 represents the semi-annual surface pressure oscillation, each dot corresponding to a particular year. The curve in the figure is drawn just to show a general tendency, but not to represent any physical meaning. In spite of the considerable scattering of dots in the left-side part of the figure, it is seen that the amplitude decreases as the phase

angle increases, range of the phase variation being some 20 days. The corresponding result for the annual oscillation which is not reproduced here shows also a relationship between the phase and the amplitude, but with much more scattering of dots.

3. Phase-amplitude relationship for 500 mb surface oscillation

The annual and the semi-annual oscillations

Fig. 3 Phase-amplitude relationship for the annual 500 mb surface oscillation. The curve shows just a general trend of the relationship.

Fig. 4 Phase-amplitude relationship for the semi-annual 500 mb surface oscillation. The large amount of scattering of dots in the left hand side of the figure seems to be due to data No. 11.

of the 500 mb surface are computed for the point located at lat. 30°N and long. 130°E , just south off Kyusyu, for each year from 1947 through 1959, use being made of data published by Japan Meteorological Agency (1959). Fig. 3 represents the result for the annual oscillation. As in other figures, a curve, almost circle in this case, is drawn to show just a general trend, but not any physical interpretation. The relationship is quite similar to that found theoretically for the atmospheric lunar tides, in which case

this type of relationship could be explained as a result of variations of the mean vertical temperature profile. It seems possible that the inter-year variations of the oscillation be due to the corresponding inter-year variations of the mean state of the whole atmosphere.

The corresponding result for the semi-annual oscillation (Fig. 4) shows a similar relationship, but with much more scatterings. The point No. 11 prevents one from drawing any curve further leftward.

Fig. 5 Phase-amplitude relationship along the circle of 20°N for the annual 500 mb surface oscillation of 1947.

Fig. 6 Phase-amplitude relationship along the circle of 20°N for the annual 500 mb surface oscillation of 1948.

Fig. 7 Phase-amplitude relationship along the circle of 30°N for the annual 500 mb surface oscillation of 1947.

Fig. 8 Phase-amplitude relationship along the circle of 30°N for the semi-annual 500 mb surface oscillation of 1948.

4. Inter-longitude variations of the oscillations

The harmonic analysis shows that the phase and the amplitude are not homogeneous along the latitudinal circle, but vary in a considerably wide range from place to place. It is interesting, however, to find that the phase-amplitude relationship is quite similar to that found for the inter-year variations. Fig. 5 and Fig. 6 represent the annual oscillations of 500 mb surface for 1947 and 1948 respectively, along the circle of 20°N. The phase

and the amplitude were computed for every other 30 degrees along the circle of 20°N, thus 12 dots in all are put on each diagram. Similar computations for the year of 1947 along the circle of 30°N resulted in Fig. 7. Finally, Fig. 8 shows the result for the semi-annual oscillation during the year of 1948, along the circle of 30°N. Scatterings of dots in these figures are remarkable especially in the region of smaller phase angles. Nevertheless, the general relationship between the phase and the amplitude is clearly observed.

5. Discussion of results

The results presented above show that both the annual and the semi-annual oscillations of the atmospheric pressure change their amplitudes and phases considerably from year to year. Moreover, the oscillations are not zonal. It seems that both inter-year and inter-longitude variations are under control of certain physical laws, but not simply due to errors. The error, however, is not very small, but seems sometimes to affect seriously. The analysis was done for published monthly-mean values, excepting that the progressing variations due to longer-period climatic changes were eliminated beforehand. The results of the analysis suggest that the data should be controlled to be free from any disturbance of shorter periods and of smaller scales. In order to do this control, it is highly desired to have the monthly-mean pressure values computed from "quiet day" pressures alone.

Finally, it is expected that there will still remain some kind of scattering of dots on

the harmonic dial, which would possibly be connected with the complex nature of variations of the annual mean state of the atmosphere.

The author wishes to thank Mr. A. Matsu-shima and Miss. Y. Sato for their works on harmonic analysis. Thanks are also due to the Ministry of Education for a Science Research Fund grant.

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大気の年振動および半年振動の経年変化について

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気圧の年振動および半年振動の経年変化はかなり著しいが、その振幅と位相は、大気の潮汐振動の場合に似た、明瞭な関係を保っている。これらの振動は帯状ではないが、経度変化にも経年変化に認められると同様な関係がある。場所と時期によつては、これらの関係が認められないことも多いが、それは(1)観測値の誤差(500 mbの場合)や、(2)調和分析に用いた月平均値が短周期で小規模の強い低気圧の影響に敏感であることなどによる。特に(2)の影響を除くためには、“静穏な日”の観測値だけから計算した月平均値を使う必要がある。