SHORTER CONTRIBUTIONS

THE SEMI-ANNUAL PRESSURE OSCILLATION, ITS CAUSE AND EFFECTS

By Werner Schwerdtfeger and Fritz Prohaska

Servicio Meteorológico Nacional, Buenos Aries

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The detailed analysis of the mean annual pressure variation proves that the semi-annual oscillation is of decisive importance to the formation of the mean annual pressure curve in large regions of the world. Therefore, it is related to some characteristic details of the annual variation of the general circulation of the atmosphere. That is true especially for the middle and polar latitudes of the southern hemisphere.

With reference to the northern hemisphere, Reuter [1] and Schumann and van Rooy [2] have already published maps of the phase and amplitude of the semi-annual oscillation. A map of the amplitude, including parts of the southern hemisphere, was also given by Wahl [3] in his detailed study of the annual oscillation of pressure. He has furthermore shown that there does not exist a direct relation between the phase angles of annual and semi-annual oscillations. Also Reuter has included minor parts of the southern hemisphere, though basic data analyzed by him can hardly be regarded as adequate for such a representation, and its interpretation, therefore, cannot give a satisfactory result.

Reuter, and Schumann and van Rooy, as well as Conrad [4] and Ekhart [5], maintain, what at first sight may appear obvious, that the semi-annual oscillation has its origin in the equatorial belt, as only there the incoming radiation from the sun reaches two maxima in the course of the year. But it should be taken into account that the difference between maximum and minimum of insolation is small even at the upper limit of the atmosphere over the equator, and that the amplitude of the semi-annual pressure oscillation in the tropical zones (not amounting to values of 1 mb) is much less than in middle and polar latitudes, where it locally reaches values of 5 mb or more. The latter is shown by the latitudinal means, r_2, contained[1] in table 1. The row $r_2 \cos \varphi$ is added to show, to a first approximation, in which latitude belt the semi-annual oscillation brings about the greatest displacement of mass. In any case, the amplitude increases from the equator to the westerlies of the middle latitudes. The last line of table 1 gives the quotient of the latitudinal averages of the amplitude for the half-yearly and yearly oscillation, r_2/r_1, demonstrating the relative importance of the semi-annual oscillation.

In view of these facts, the principal cause of the half-yearly pressure oscillation should rather be sought in middle and subpolar latitudes, and presumably not on the surface of the earth, but at higher levels, as has already been suggested by the regional analysis of Conrad [4]. Therefore, in seeking a possible cause for these phenomena, we believe that a sound hypothesis could be based on *the different solar heating of different latitude belts.* This means that the meridional differences of the insolation, in its annual

[1] The values for the northern hemisphere have been computed from [2, table 5]. Those of the equatorial zone and the southern hemisphere have been obtained by analyzing all available data series, including those derived from the maps of the mean monthly pressure distribution over the oceans — in all, some 200 series.

TABLE 1. Latitudinal means of amplitude (mb) of semi-annual pressure oscillation (r_2), and quotient of semi-annual and annual mean latitudinal amplitudes (r_2/r_1).

φ:	90°N	80	70	60	50	40	30	20	10	0	10°S	20	30	40	50	60
r_2:	1.70	1.28	1.11	1.19	1.12	1.21	1.08	0.67	0.39	0.4	0.4	0.5	0.8	1.5	1.8	1.8
$r_2 \cos \varphi$:	0	0.22	0.38	0.59	0.72	*0.93*	0.93	0.63	0.38	0.4	0.4	0.5	0.7	1.1	*1.2*	1.0
r_2/r_1:	0.71	37	23	25	20	23	24	20	36	38	19	12	22	63	71	65

TABLE 2. (1): Daily totals of solar radiation (cal/cm²) at equator. (2): Meridional differences of the totals between 40 and 70°S. (3): Same between 50 and 80°S. (Valid for upper limit of atmosphere and solar constant of 2 cal cm^{-2} min^{-1}, according to Milankovitch [6].) D_1 = Difference between principal maximum and principal minimum. D_2 = Difference between secondary maximum and secondary minimum.

Date:	13.I	4.II	26.II	21.III	13.IV	6.V	29.V	22.VI	15.VII	8.VIII	31.VIII	23.IX	16.X	8.XI	30.XI	22.XII
(1) Equator:	881	905	*924*	923	900	863	829	814*	825	856	890	912	*913*	897	877	869*
							$D_1 = 110, D_2 = 44$									
(2) 40–70:	35	173	298	391	*421*	402	339	306*	338	398	*419*	386	296	171	35	−22*
							$D_1 = 443, D_2 = 113$									
(3) 50–80:	−28	116	328	*433*	414	285	199	170*	198	282	410	*428*	324	115	−28	−78*
							$D_1 = 511, D_2 = 258$									

variation, should be related to the intensity and other characteristics of general zonal atmospheric motion and, by interaction of the latter, to the annual pressure variation. These meridional differences of incoming radiation have a well pronounced half-yearly oscillation.

As already mentioned, up to now the semi-annual oscillation of the daily totals of the incoming radiation in the equatorial zones was considered the cause of the semi-annual pressure oscillation. Table 2 shows that the amplitude of this oscillation of incoming radiation is considerably less than the corresponding oscillation of the differences between middle and polar latitudes. Even more pronounced, the same holds true if we take into account a turbid atmosphere, *e.g.*, a transmission coefficient of 0.8 instead of 1.0. It can be demonstrated that the maxima of the semi-annual pressure oscillation over the southern hemisphere (where presumably the entire phenomenon appears more clearly marked, as greater continental areas do not exist) *occur in the latitude of nearly 40 deg during the equinoctial months, while simultaneously the minima occur south of 60 deg.* Therefore, we are inclined to conclude that the increase of the meridional differences of incoming radiation contributes to the intensification of the great tropospheric zonal currents, a circumstance involving opposite pressure variations at middle and polar latitudes.

The existence of such a relation can also be substantiated by a negative correlation of the intermonthly pressure variation at 40°S and at Little America, which is not due to chance.

Furthermore, Scherhag, in his well known work [7], remarks that the difference of the heights of the 500-mb level at Catania (Sicily, 37°N) and Tromsoe (Norway, 70°N) has two well pronounced maxima in the course of the year, *i.e.*, in April and October. Likewise, the vertical cross-sections worked out by Kochanski [8] are supporting evidence for an important semi-annual variation in subpolar latitudes, although the writer does not refer to it in his text. In figs. 1 and 2 of his article, we see that the westerlies in the upper troposphere extend considerably farther north in April and October than in January and July, in accordance with the results of Scherhag. Similar conditions may be found in the southern hemisphere, as the present writers have noted in an analysis of the resultant wind vector at 300 and 200 mb over Malvinas (Port Stanley, 52°S). With further reference to Kochanski's article [8] it may be assumed that the frequency and position of the jet stream are related to the half-yearly pressure oscillation, particularly in view of the fact that in figs. 1 and 2 the northern center of the westerly jets of middle latitudes shifts polewards in the equinoctial months. It may also be mentioned that the subtropical maxima of easterlies at heights over 25 km shows a semi-annual variation in its intensity. The writers believe that this phenomenon cannot be correctly interpreted until the cross section is extended also to those heights over the southern hemisphere.

Nevertheless, we feel that the ideas set forth herein, regarding the possible cause (table 2, rows 2 and 3) of the semi-annual oscillation of the zonal currents in the troposphere and of atmospheric pressure, may be useful for an adequate interpretation of several pecularities of the general circulation and the annual pressure variation over vast regions of the southern hemisphere. This problem will be treated in detail in a separate paper.

This note is presented in the hope of stimulating interest on the part of colleagues elsewhere, who have easy access to the voluminous upper-air data of recent years, with regard to the aerological aspect of the problem. Therefore, the writers suggest the preparation of meridional cross-sections of temperature, zonal currents, *etc.*, for *all* months of the year, not only for two or four months which are not representative of extreme conditions at all levels of the atmosphere and in all regions of our planet.

REFERENCES

1. Reuter, F., 1936: Die synoptische Darstellung der halbjährigen Druckwelle. *Veröff. geophys. Inst. Univ. Leipzig*, **7**, 257–295.
2. Schumann, T. E. W., and M. P. van Rooy, 1950: *Continentality and the analysis of atmospheric pressure over the northern hemisphere.* (W.B. 15), Pretoria, Weather Bureau, 21 pp.
3. Wahl, E., 1942: Untersuchungen über den jährlichen Luftdruckang. *Veröff. meteor. Inst. Univ. Berlin*, **4**, No. 4, 71 pp.
4. Conrad, V., 1938: Der Höheneinfluss auf die Jahresschwankung des Luftdrucks. *Meteor. Z.*, **55**, 429–435.
5. Ekhart, E., 1940: Die ganzjährige Periode des Luftdrucks auf der Nordhalbkugel. *Ann. Hydrogr. mar. Meteor.*, **68**. 158–163.
6. Milankovitch, M., 1930: *Mathematische Klimalehre. In Handbuch der Klimatologie.* (Vol. I, Part A), Berlin, Gebr. Bornträger, p. 176.
7. Scherhag, R., 1948: *Neue Methoden der Wetteranalyse und Wetterprognose.* Berlin, Springer, 424 pp.
8. Kochanski, A., 1955: Cross sections of the mean zonal flow and temperature along 80° W. *J. Meteor.*, **12**, 95–106.