Reply

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Dr. Haurwitz's comments reveal a number of very pointed objections to the hypothesis presented in my paper. Without pretending to dispose unequivocally of these objections (even to my own satisfaction), I should like to discuss briefly each of the points thus raised.

In the derivation of the isallobaric wind equation, inertial forces represented by the terms $u\,\partial u/\partial x$, $v\,\partial u/\partial y$, *etc.*, are neglected. Dr. Haurwitz's study of the neglected terms makes it clear that the isallobaric wind may not be identified with the geostrophic departure. It may, however, be identified with the deviation of the wind from gradient or steady flow, provided the rate of change of the local acceleration is small. Since the divergence associated with the changing pressure distribution is only that required to account for the changes taking place, the isallobaric

[3] E. R. R. Holmberg, "A suggested explanation of the present value of the velocity of rotation of the earth," *Mon. Not. r. astr. Soc., Geophys. Suppl.*, **6**, 325–330, 1952.

divergence appears to offer a reasonable basis for the study of pressure changes.

If the pressure-gradient forces are included in (21), as Dr. Haurwitz suggests they should be, these forces are largely eliminated in obtaining the divergence. In this operation we assume that a term representing the advection of the Coriolis parameter may be neglected. This approximation is consistent with the avoidance of terms involving the advection of the vertical component of the relative vorticity. However, inclusion of the pressure gradient forces in (21) does result in an additional term in (32); this term contains essentially the horizontal shear of the u-component of the geostrophic wind, integrated with respect to time. The significance of this term or its omission is not easily assessed.

Dr. Haurwitz notes that the third and higher harmonics in the series representing the local temperature variation have been ignored. However, my attempt at a quantitative explanation of the pressure wave entails the *spatial* representation of the temperature wave throughout a deep layer of the atmosphere, and in this representation it did not seem worthwhile to strive for accuracy not present in the observational data. It seemed justifiable, in other words, to resort to a method of comparison often necessary in dealing with meteorological data, and to remark that the curves of fig. 10 "resemble each other closely."

It is true that the large scatter of points in figs. 4 and 5 makes it impossible to determine with certainty the latitutdinal variation of amplitude of the temperature wave. Here, again, accurate data on the diurnal variation of temperature in the free air would be a requisite for a thorough investigation of the hypothesis. It may be noted that the latitudinal variation of amplitude of both the diurnal and semi-diurnal pressure waves exhibits considerable scatter.

The standing wave to which Dr. Haurwitz refers might alternatively be explained as the result of differences in the latitudinal variation of amplitude of the semi-diurnal temperature wave over the continents and over the oceans, which in the northern hemisphere are spaced roughly 90 deg long apart. Given these circumstances, one may readily visualize a "polar oscillation" which is in phase with the temperature wave over the continents and out of phase over the oceans, or *vice versa*; as a result, a portion of the pressure departure would have the same sign, at a given Greenwich time, all around the hemisphere.

Finally, despite doubts concerning details of the hypothesis, I believe that the explanation I have given for the daily pressure wave contains a large germ of truth. In simplest terms, this explanation is that the spatial distribution of the temperature change determines quite largely the form of the sea-level pressure variation, an idea in general agreement with thermal theories of pressure change. This idea is also consistent with the findings of Petterssen[1], that the (advective) change of the Laplacian of temperature is an important factor in sea-level development.

[1] S. Petterssen, "A general survey of factors influencing development at sea level," *J. Meteor.*, **12**, 36–42, 1955.