THE RELATIONSHIP BETWEEN AIR PRESSURE AND SEA LEVEL IN THE BALTIC

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The study of the relationship between air pressure and sea level has old traditions in the Baltic. In fact, the first paper on this problem was published by GISSLER in 1747 (1) (*). During the first part of the nineteenth century the work was continued, covering not only the Baltic, but also other seas. Although a solid base was thus laid for continued studies and the theoretical relationship between air pressure and sea level, a fact well-known for centuries, there has appeared in the course of the years a great number of papers dealing with the actual numerical ratio between the two factors. In some cases, the ratio between sea level and air pressure (the former expressed in centimetres, the latter in millimetres) was found to be larger than the theoretical value, —1.36, in other cases, the results seemed to indicate that this ratio was considerably less. These apparently confusing results show distinctly the significance of additional factors.

The effect of the wind, reinforcing as a rule the influence of air pressure, cannot be neglected, especially along the coasts. A recent study of the causes of the seasonal cycle in sea level showed that only in the open central parts of the oceans, where there were no pronounced currents, two main factors : namely density of sea water and air pressure, suffice for the interpretation of the general features of this seasonal cycle. Additional causes, for instance seasonal changes in the direction and velocity of the wind, must be taken into account along the coasts (3). This example proves the significance of the wind, when average data are concerned. In individual cases this effect may be expected to be still more pronounced.

In seas like the Baltic, connected with the oceans only by comparatively narrow straits, the inflow and outflow of water may frequently regulate the sea level in a way that counteracts the effect of air pressure. It is therefore self-evident that the theoretical relationship cannot be expected to be valid in these cases, and a more comprehensive study for a few particular tide gauge stations may reveal a number of interesting characteristics.

The following results are based on the tidal records of three Finnish stations : Degerby, Helsinki and Vasa. These stations were selected as the most representative for different parts of the Finnish coasts. Degerby is, without doubt, the best possible choice for the northern part of the Baltic proper, Helsinki is characteristic of the middle parts of the Gulf of

(*) Numbers between brackets refer to the bibliography at the end of the article

Finland, and Vasa is situated in the narrow and shallow sea known as the Quark, that connects the two larger areas into which the Gulf of Bothnia is divided. A special advantage of the three sea level stations is the fact that air pressure observations are made within a reasonable distance from the tide gauges.

The computations are based on the 15-year period 1932-1946. At Degerby and Vasa there were unfortunately several interruptions in the observations. Only twelve years are complete for the former station. For the latter station the number of years with uninterrupted records is fourteen.

Daily and monthly averages were used. These averages can be studied from two different points of view. We have, of course, the well-known, traditional way of determining the linear relationship of the departures from the average data of sea level and air pressure by using the method of least squares. In the Baltic this method may, however, result in a continued accumulation of the effect of the water transport through the Danish Sounds, the consequence being, at least in some cases, a considerable distortion of the actual conditions. In order to avoid this cumulative effect, day to day changes in the two factors were determined and their ratio computed by the method of least squares. In this connexion it may be pointed out, that a certain error is introduced in the results by the fact that the sea level averages are based on six daily readings, while air pressure means are computed from three daily observations. This discrepancy may, however, be significant only in extreme cases. These cases are, as a rule, not very frequent, but their influence being fairly pronounced they may, of course, sometimes affect the final result.

Figure 1 reproduces the ratio between sea level and air pressure for the three stations as a function of the particular years which are given at the bottom of the figure. The curves in the upper part of this figure are based on the departures from mean data, while those in the lower part refer to day to day variations. The difference between the two sets of curves is quite remarkable. On considering the disparities, the difference between the three stations is not very pronounced. The general trend of the curves is on the whole similar, and it may be noted that the mean values for the whole period of 15 years do not deviate appreciably, being for Helsinki —0.96, for Vasa —0.84 and for Degerby —0.74. Individual years show, on the contrary, a considerable discrepancy, the amplitude of the variations reaching about 0.8.

Concerning day to day variations, the diagram reveals fairly different characteristics. In this case, the amplitude of the oscillation is considerably less and the particular effect of any given years is by no means the same for the three stations. Moreover, the averages for the whole period are in this case considerably less than in the former case and they deviate much more from each other, being at their highest, namely —0.74, for Vasa, 0.50 for Helsinki, and as low as —0.37 for Degerby. Thus, we realize that results based on day to day variations are more representative for the stations concerned, while the departures from the average data give a more general picture for a large area.

Although the departures from the mean data approach the theoretical

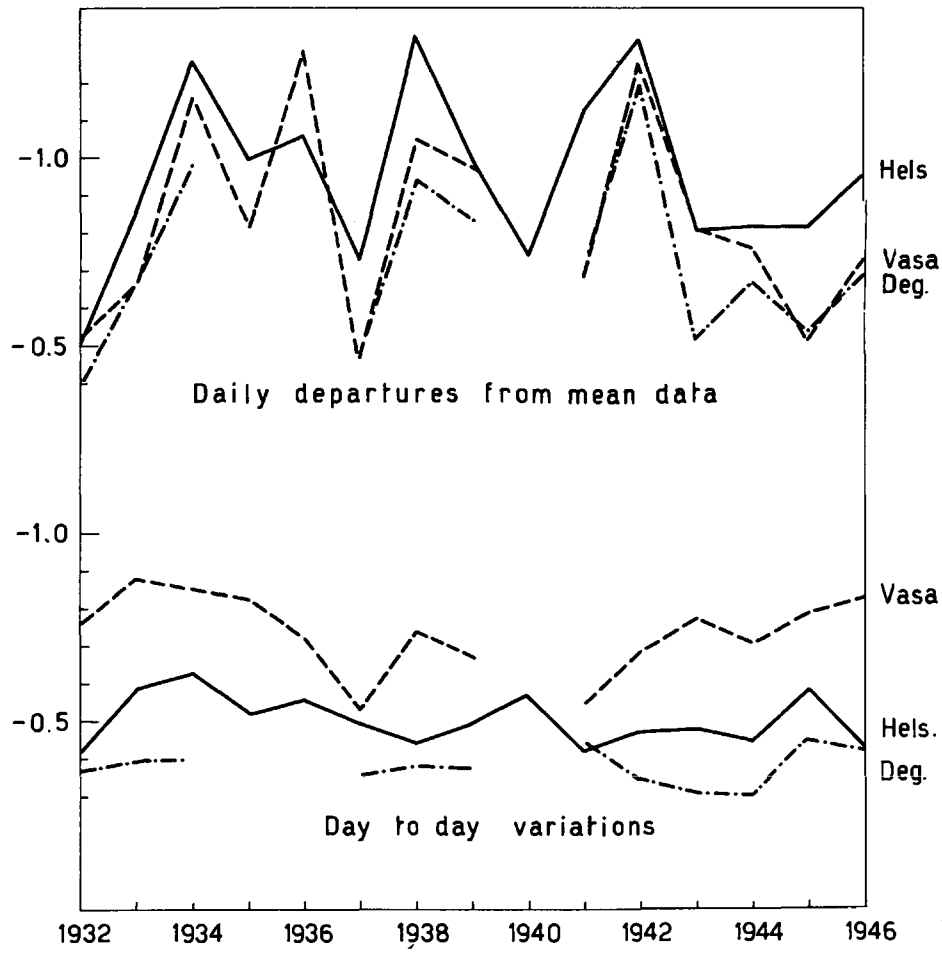

FIG. 1. — The ratio between sea level and air pressure during different years.

value much more closely than day to day variations, the latter method seems to be in many respects preferable. The yearly deviations being less marked, the results represent better the actual average conditions at every station. The pronounced differences of the mean values for the whole period seem also to be well established. At Degerby where piling-up of the water produced by the wind is at a minimum, we have the lowest value. At Helsinki, and especially at Vasa, it is considerably higher indicating distinctly an additional wind effect. These results do not mean that the theoretical relationship between air pressure and sea level is not valid, but that supplementary factors counteract the effect of air pressure, thereby resulting in a lower value. In this connexion, we must also keep in mind the fact that the barometric situation is, as a rule, continually changing, the consequence being that the sea level has not always time to adjust itself to new conditions.

It may also be emphasized that earlier studies showed that the local atmospheric pressure is a factor of minor significance in sea level variations in the Baltic (2). In cases with a more or less stationary distribution of

atmospheric pressure the influence of this pressure may be estimated to 25 per cent of the total amplitude of sea level oscillations, while in cases with extremely large and rapid changes in sea level it may amount only to 10 per cent of these changes. Moreover, a regional study of the influence on sea level variations caused in the Baltic by local factors as opposed to the widespread effect, represented by the water transport through the Danish Sounds, revealed that, at Degerby, an average of about 25 per cent of the changes are of local origin, while the corresponding percentage at Helsinki and Vasa may be estimated at 45 per cent. These data are approximately of the same magnitude as the relationship between the mean values for the whole period and the theoretical value, which is for Degerby 0.27, for Helsinki 0.37, and for Vasa 0.54.

In order to compare in another way the advantages of the two methods used the annual curve of the linear relationship between air pressure and sea level is presented in figure 2. The upper part of this figure reproduces once more the results computed on the basis of the daily departures from the average data, the lower part is again characteristic of day variations. There is no doubt that the lower set of curves is more interesting and more relevant for our purpose than the upper set. While, with the exception of a certain similarity in the curves, no general conclusion can be drawn from the upper part of the figure, the lower part shows, on the contrary, a well defined annual curve. There is evidently a certain discrepancy between particular stations, but at least the curves for Degerby and Vasa reveal the fact that the lowest values are reached in spring and summer, the highest in autumn and winter. At Helsinki this feature is less marked, the trend seems, however, to be the same. This result again shows the contributory effect of the wind, which generally reaches its highest velocity in autunm and winter.

When studying for different purposes the relationship between air pressure and sea level, the monthly averages are used much more frequently than the daily means. Our results computed on the basis of the two methods reveal for the monthly averages a rather different picture of this relationship. While the theoretical value for the daily means was never reached, the monthly averages indicate a ratio between sea level and air pressure that, as a rule, is higher than the theoretical one, showing the complexity of the problem. For the montlhy departures from the average data, the ratio between sea level and air pressure is for Helsinki and Vasa —2.02, and for Degerby —1.85. The principal characteristic of these values is that they do not deviate appreciably from each other. Thus we note that the monthly departures give, at least approximately, the same result within a fairly large area. For month to month variations we get, on the contrary, more individual results. The ratio is for Helsinki —1.73, for Vasa —1.57 and for Degerby —1.32. Although owing to the large dispersion of the results during the separate years too much stress cannot be attributed to these values, they seem, however, to represent the theoretical conditions considerably better than all previous results. For Degerby, where the wind is a factor of minor significance, the theoretical value is practically reached, but for Helsinki and Vasa it is augmented by the additional wind effect. The problem as a whole is, however, by no means solved by a study of a

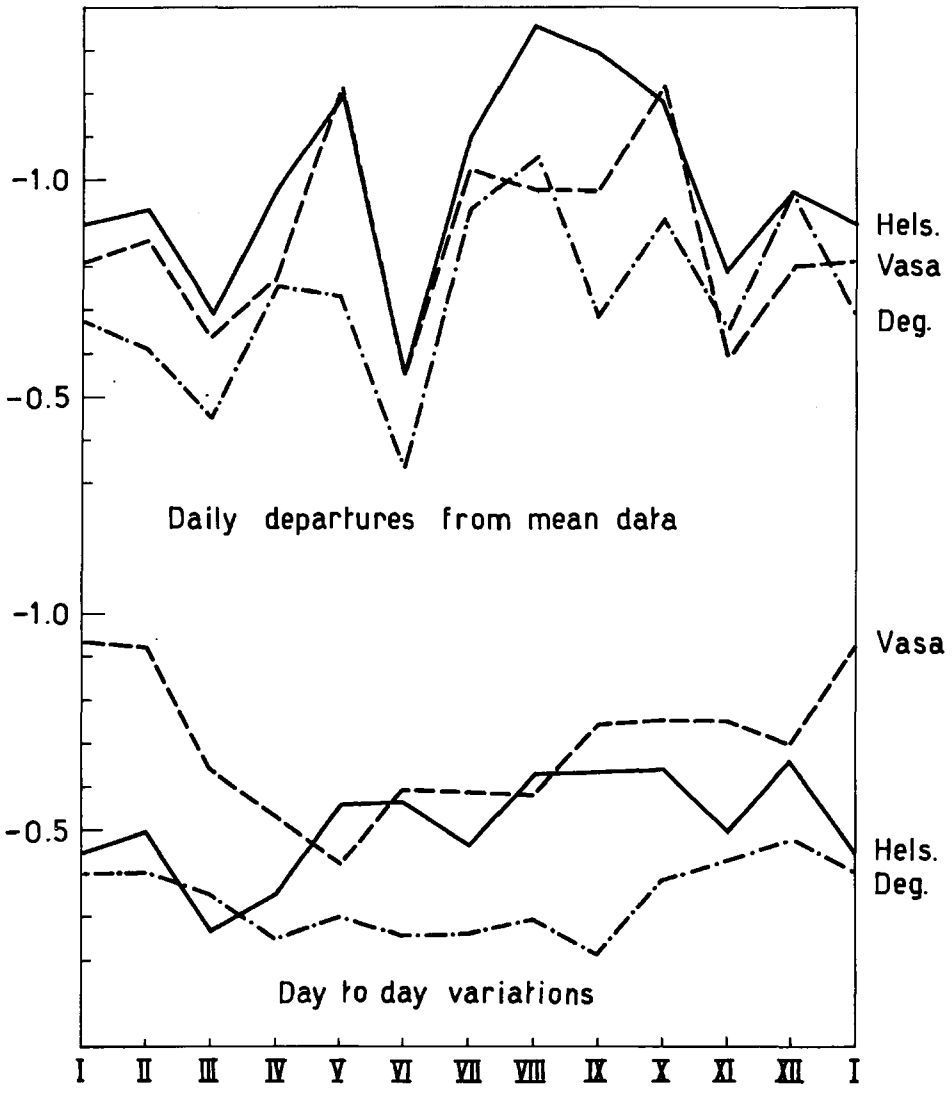

FIG. 2. — The seasonal trend of the ratio between sea level and air pressure.

few stations and research must continue on a larger scale and as assidiously as before.

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