551.509.312

The Motion of Surface Pressure Centers in Relation to Upper Mean Maps

by

K. Mørch Jensen and A. Wiin Nielsen

Danish Meteorological Institute, Copenhagen

Abstract

See the report of the Symposium in Helsinki, May 1953, this issue of *Geophysica*, p. 149.

It has been the purpose to investigate the accuracy of two methods for 24-hours-forecasts of the displacements of surface pressure centers. These methods are the common used 50 %-rule, related to the 500-mb map, and a method using the 500-mb space-mean-map as it is defined by R. Fjörtoft (Tellus, Volume 4, No 3, August 1952).

We have directed our intention:

1) to estimate the accuracy with a measure, proper to the case of practical routine forecasting,
2) to measure the discrepancy in the forecasts in a way, practical for the same purpose and with special reference to the possibility of improving the displacement rules.

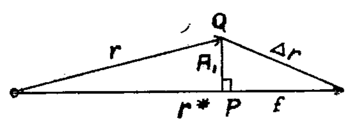
Re 1): If the pressure center actually is displaced the distance r and the distance between the forecasted position of the center and the actually arrived position of it is Δr, we have defined the error F as:

$$F = \frac{\Delta r}{\frac{L + r}{2}}$$

where L is the »wave-length», the distance between two consecutive centers of the same kind. This non-dimensional quantity converges towards the usual relative error, when r is great in relation to $\frac{L}{2}$. Moreover F has the advantage rather than the relative error that it has a definite value $\frac{\Delta r}{\frac{L}{2}}$, when $r = 0$. This combination mentioned above ($\Delta r \neq 0$ and $r = 0$) is rather often observed in practical forecasting, and F deserves, seen from the point of view of interpreting the prognostic chart, rather the significance of an error-index measuring Δr relative to L (or better $\frac{L}{2}$) than an error index measuring Δr relative to r.

In the investigation here carried out we have in all cases put $L =$ 2 400 km.

Re 2): Let us define the curvlinear vectors r and r^* as the actual and the forecasted track of the pressure center during the forecast period. r^* was found as the distance a pressure center would move, if it was travelling with a speed corresponding to 100 % of the gradient wind in the field of displacement. Then the »delay» f and the »derailment» A_1 are defined as seen from the figure:



It is seen, that $\overline{\Delta r} = \overline{f} + \overline{A}_1$.

Furthermore we have defined a quantity A_2 as the potential difference in the field of displacement between the two points P and Q. We have then from our forecasts computed the quantities:

$$A_2, \ \frac{A_1}{|r^*|} \text{ and } \frac{f}{|r^*|}$$

The investigation included:

75 greater cyclones with closed circulation

25 smaller cyclones without closed circulation (smaller frontal-waves and polar-lows).

11 of the 25 smaller cyclones we could follow over a longer period (2 or

3 days). Because of this the number of small cyclone forecasts could be increased to 36.

In the following the error-index F is given as a mean-value and the other quantities as mean-values with their standard-deviations added.

The results were:

1° The actual 500-mb map used as a field of displacement in connection with the usual 50 %-rule (only small cyclones).

$$F = \left(\frac{\Delta r}{\frac{L}{2} + r}\right) = 0.22,$$

$$r = 1\,340 \text{ km}$$

$$\frac{f}{r^*} = -0.3 \pm 0.8$$

$$A_2 = -4.7 \pm 7.0 \text{ dam.}$$

2° The 500-mb space-mean-map used as a field of displacement in connection with a supposed 100 %-rule

2 a. Smaller cyclones.

$$F = 0.32$$
$$r = 1\,290 \text{ km}$$

$$\frac{f}{r^*} = -0.28 \pm 0.23$$

$$A_2 = -5.3 \pm 5.4 \text{ dam.}$$

2 b. Greater cyclones.

$$F = 0.21$$
$$r = 1050 \text{ km}$$

$$\frac{f}{r^*} = -0.19 \pm 0.25$$

$$A_2 = -2.7 \pm 5.1 \text{ dam.}$$

2 c. All investigated cyclones.

$$F = 0.25$$
$$r = 1\,130 \text{ km}$$

$$\frac{f}{r^*} = -0.24 \pm 0.17$$

$$A_2 = -4.0 \pm 3.8 \text{ dam.}$$

These results show, that the centers in mean seem to move somewhat faster than 50 % of the velocity in the actual 500-mb map, and that the supposed 100 %-rule for the space-mean-map cannot hold. The velocity of a pressure center related to the velocity in the space-mean-field of R. FJÖRTOFT is about 75 %.

There seems to be a rather pronounced tendency for the cyclones to deviate to the left of the streamlines in the fields of displacement.

One might think, that there was a linear relation between the quantities A_1, (measured in a length-unit) and r^*, so that the »derailment» A_1 was increased, if r^* was increased. To investigate this we have calculated the correlation coefficient k between A_1 and r^*, and we have found $k = -0.02$. From this it is shown, that the »derailment» is not related to the forecasted distance.

In practical routine forecasting it is often less interesting whether the forecasted position is reached just after 24 hours. The forecaster is satisfied if the position is reached to some other time in the neighbourhood of 24 hours. We have found that our small cyclones, which we could follow with 3 hours interval, arrived nearest to the forecasted orbit in 27.6 ± 6.0 hours, but the error-index was still rather great ($F = 0.28$ and now mostly caused by »derailment»).

The mean of r is then 1 750 km.

After that we have improved our mean-field displacement formula by taking into account the now obtained values of »delay» and »derailment». We have estimated:

$F = 0.18$ for smaller cyclones
and $F = 0.21$ for greater cyclones.

It deserves to notice that although the space-mean-field after correction for »delay» and »derailment» is as a field of displacement for pressure centers only a little better with respect to accuracy than the 50 %-rule used in connection with the actual 500-mb map, it is much more usable than the latter, especially in the vicinity of singularities in the upper-air map. The rather small displacements, most commonly occurring in these cases, are fairly well forecasted with the space-mean-field. It is also our opinion that the accuracy will be still greater if the forecaster uses the formula here quoted for $\frac{f}{r^*}$ over time-intervals on 6 hours or so, because it is possible then to take in view a variable gradient in the space-mean-map. Furthermore, in a weather service using Fjörtoft's method for forecasting the 500-mb map, a part of the computation work must be common to the sea-level and the 500-mb forecasts.