On the Problem of Atmospheric Perturbations

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The following short paper was read by Dr. Baur at the Edinburgh Meeting of the Meteorology Association of the International Geodetic and Geophysical Union in July 1936; it gives his views on two of the Themes (A and B) on the Agenda of the meeting (see Bulletin, Feb., 1936, p. 53-4). Dr. C. F. Brooks and Mr. I. I. Schell have rendered the translation from the original German MS, loaned us by Mr. R. H. Weightman of the U. S. Weather Bureau, Washington. Appended to the article are some abstracts and comments on Dr. Baur’s paper on the importance of the stratosphere in the broad-weather situations in Western Europe published in 1936 (Met. Zts., p. 237) which shows the same ideas used in application to long-range (10-day) forecasting. We print the article with the kind permission of Dr. Baur. See also Dr. Baur’s latest paper in Met Zts., Dec. 1937.

DEFINITION OF PERTURBATION

The idea of perturbation implies the existence of a normal, mean state. The more or less large departures from this mean state are the perturbations. The mean state may differ, depending upon whether it is averaged over a short or a very long period of time. Also the durations of perturbations can be very diverse. Consequently, without regard to the diversity of the causes, there are different kinds of perturbations which must be defined unambiguously and differentiated sharply in order that their nature be scientifically understood.

I suggest a division of perturbations into three groups with the following definitions.

1. Climatic Perturbations are departures of several-year mean values of the meteorological elements from their long-term (at least 30-year) mean values, in so far as they are not caused by single large departures but during the period considered were prevalingly of the same sign... [Here the departure of ten-year means are compared with 50-year normals at individual stations and at a group of ten stations.]

2. Macro-Perturbations are notable departures from the normal state of the atmosphere which maintain the same sign over large areas of the earth’s surface during many (at least three) days and, under certain circumstances, during many weeks... [An example is given for a period of about three weeks when high pressure lay near and west of Ireland.]

The difference between macro-perturbations and climatic perturbations lies in the fact that in case of the former the departures from the normal are of the same sign throughout the entire period, at the most suffering very slight breaks, while the cli-
matic-perturbation underlies the macro-perturbations and only becomes visible in the mean values of a long period of time. The macro-perturbations are differentiated from weather perturbations (infra) not only in duration, but also in that, with the former, the normal "fundamental state" is disturbed for a long time over one and the same area while the latter wander.

(3). Weather-Perturbations are the pressure and temperature waves with a period of 12 hours to 5 days, and the phenomena related to these, the wandering rising and falling areas of pressure [isallobaric highs and lows] and the moving cyclones and anticyclones. The weather-perturbations are termed "Weather" ("Wetter"), the macro-perturbations "larger features of the weather" or "broad-weather situations" ("Grosswetter"), and the climatic variations "Weather trend" ("Witterung"). (F. Baur, "Die Bedeutung der Stratosphäre für die Grosswetterlage", Meteorologische Zeitschrift, 1936, 237-247; abstracted in Quart. Jn. Roy. Met. Soc., Oct. 1937, and reprinted at end of this article below.

ORIGIN OF ATMOSPHERIC PERTURBATIONS

The above-named three groups of perturbations should next be defined purely by their form of appearance. This division seems of value also when one considers the causes of the perturbations. Of the causes of the climatic-perturbations we know very little today. So much, however, appears rather certain: we have to do here chiefly with the effect of influences lying outside of the atmosphere (for example, qualitative and quantitative variations of solar radiation).

The macro-perturbations are apparently caused partly by outside influences and partly by fluctuations which are peculiar to the inner nature of the system of the atmosphere plus the earth's surface. These latter fluctuations, which one, in the wider sense, can designate as "free oscillations", are in the ultimate analysis phenomena of inertia. They disclose themselves on the one hand as pendulations of the general atmospheric circulation about their own equilibrium and on the other hand as fluctuations in the vertical structure of the atmosphere, about an equilibrium determined by radiation and gravity.

The weather-perturbations, finally, are only atmospherically conditioned. They have their origin in the existence of surfaces of instability in the atmosphere.—Sept. 1, 1936.


"In his first section Baur discusses the difference between the schools of Bergen and of central Europe. According to the former the waves on the polar front which produce cyclones may set up waves on the tropopause; according to the latter the prime cause lies in disturbances at the tropopause or in the lower stratosphere, which produce pressure variations at the ground. Baur admits the apparent difficulty that at a polar front there are sudden jumps in temperature and wind, while at the tropopause the discontinuity lies merely in the gradients of these elements, but points out that, according to V. Bjerknes, at a polar front there is a region of continuous, though rapid transition, not a true discontinuity." ... . . . "The picking out of the exact boundary between the stratosphere
and the troposphere is a matter of convention; and it would appear arguable that when... there is a marked inversion this would make a satisfactory boundary, and should be called the tropopause. Quite naturally Baur suggests that the wave formation occurs in the equatorial front rather than at the tropopause. He makes the further interesting suggestion that instead of regarding either the polar front or the equatorial front as the origin of cyclones, the waves on each of them should be looked upon as produced by the constitution of the atmosphere as a whole, with its west-east streams and its contrast of north-south temperature gradients in the stratosphere and troposphere."

"Baur's second section provides the real foundation for his forecasts. "We know that on the average the pressure gradient in the stratosphere, like the temperature gradient in the troposphere, points northward, and Stüve drew attention to some effects of the deviations from the arrangement which occur from time to time. Baur examines how far a moderate S-N pressure gradient, say 1 mb in 111 km at 10 km will extend downwards when there is below it a considerable temperature gradient, say 1° in 111 km in the same direction. He finds that the S-N pressure gradient will persist downward through a layer 6.8 km thick to within 3.2 km of the ground. So the velocity of most of the air in the troposphere will be parallel to the gradient wind in the lower stratosphere, and this holds though the gradient may be only moderate and may be opposed by a considerable temperature gradient. The observations made since Dines's important paper have shown the close-ness of the relation between pressure at 5 km and the air temperature below that. Out of 458 highs at 5 km... only two had cold air between 4 and 5 km, and out of 452 lows only four had warm air. Thus the pressure gradients in the lower stratosphere and the temperature gradients in most of the troposphere tend to be similar."

"The direction of motion of regions of rise and fall of pressure. For changes in 24 hours at ground level the control by pressure at 5 km is very complete, and is called steering by the Frankfurt school. The changes of pressure in 3 hours are less under control because they depend on the motion of the warm and cool air masses of the lower troposphere, so that the changes do not persist for 24 hours." [In the figures of the original article we can readily see that the motion of the isallobaric centers at sea level suffers a decided steering by the pressure at 5 km instead of by the pressure at sea level. Examples of northerly steering, steering around a trough, double steering (see below), and even one of an E to W steering when the usual N-S gradients of pressure and temperature were reversed; in this latter case the Bergen map showed fronts far away over the ocean, none over Europe, so that Baur concludes that any wave formation controlling the weather must have been high up.—R. G. S.]"

"That these examples of steering are representative may be inferred from the table on p. 243 [in M. Z.] showing that the first three months of 1935 were made up of 15 periods of pressure gradients at 5 km; in 14 of them the steering obeyed the rule, and in one case there was no definite direction of motion. Baur states that the continuation of this table through 1935 and 1936 leads to the same conclusion."

"Double steering. So far we have used pressure at 5 km as a substitute for that in the stratosphere; but this will not be legitimate if the latter is very feeble, in which case the winds in the stratosphere and upper troposphere may be essentially different from those in the middle and lower troposphere. The difference may last several days and in such a case we must apply the principle of double-steering..." [In Fig. 14] the isobars at 5 km show a ridge of high pressure, and do not suggest the motion of the 24-hour isallobars [Fig. 17], which was from W to E both at sea level and at 5 km. The last is in agreement with the westerly winds obtaining every day, as far as observations show, at 8 and 10 km. [Fig. 17]. Thus the 24-hour isallobars agree with the winds of the stratosphere, while the 3-hour isallobars [shown in Fig. 15] agree with the winds of the lower troposphere [Fig. 16] and the pressure distribution there. Baur accepts
the theory that lows are due to waves on a surface of discontinuity and therefore here remarks that double steering can only be explained by supposing that waves develop on the tropopause or the equatorial front as well as on the polar front."

"The reality of broad-weather conditions. Since the pressure gradient in the lower stratosphere, the average gradient of temperature in the troposphere, the general flow (Grundströmung), and the steering fit together and last some days, it is reasonable to regard them as constituting the broad-weather situation."

"While at any time there is weather, the factors that determine the broad situation may be inconsistent or may be changing; and these departures from rule are of deep significance in forecasting the broad-weather. Also while the pressure distribution in the lower stratosphere determines it, we cannot deduce that this is in reality the prime cause of weather."

"Baur's experience is that:
(1) The mean duration of a broad situation is 5½ days.
(2) On the average there are in central Europe 5 of these situations in a month, the intermediate days being transitional.
(3) The longest durations are of west steering when central Europe is under a region of high pressure in the stratosphere and is therefore not crossed by areas of rise and fall of pressure.
(4) The most frequent directions of steering are W (18 per cent), NW and SW each 17 per cent; quite rare is SE; and very rare NE and E."

"The outlook. When forecasting for 5 or 10 days the broad situation is obviously very important, and for it the formation and breaking down of stratospheric highs and lows replaces the problem of ordinary highs and lows in daily weather work. The broad-weather must be governed by outbreaks of air from the high pressure belt in the stratosphere; and must be dependent on variations in the balance of radiation, themselves depending on long lasting variations in cloud and humidity."

"An account of the methods of forecasting employed will be found in the Bulletin of the American Meteorological Society, 17, 1936, pp. 148-153, 252-254."

[Sir Gilbert then quotes at length from the 1936 papers of Baur in the Bulletin. He remarks, however, that on p. 153 of May, 1936, Bulletin Baur gives an impossible example, and that on his stating so to Baur in a letter, Baur replied that some words had inadvertently been omitted. "The passage should state that the effect upon temperature of an E-W gradient of temperature depends on the N-S pressure gradient. This is true enough; for a wind from a hotter region sends up the temperature by an amount proportional to \( gg' \cos \theta \), where \( g, g' \) are the gradients of pressure and temperature and \( \theta \) is the angle between them. If we call this expression \( q \) we can presumably work out a linear repression equation with \( q \) as one of the variables."].

The Measurement of Humidity at Low Temperatures

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RECENTLY, during a period of low temperature and low humidity, some indoor comparisons of psychrometers and hair-hygrometers were obtained at Blue Hill through a wide range of relative humidity, and a measurement of the effect of temperature on hair-hygrometers, first made in 1903, repeated under more favorable conditions.

The instruments compared were three Weather Bureau sling-psychrometers, two single-hair Koppe hygrometers and one Richard hair-hygrograph. All were in good condition although the hair in the Koppe hygrometers had not been changed in at least 30 years. The extremes of humidity during the comparisons were 13% and saturation, the latter