TOWARD AN INDEX OF HIGH-ATMOSPHERE METEOROLOGICAL ACTIVITY

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ABSTRACT

The author believes that much benefit would derive from a daily numerical index of large-scale meteorological activity as high in the stratosphere as possible, for example at the 10-mb. surface or higher. It would serve as a condensed daily record of conditions there, much as the indices K and C constitute condensed daily records of geomagnetic activity, to meet a need in comparative studies of ionospheric phenomena (including geomagnetic variations) with meteorological conditions in the upper atmosphere. It seems probable that these phenomena of the lower ionosphere, after adequate study, will return high-atmosphere meteorological information of value. A description is given of a proposed index. It is illustrated by its application to the chart of the 10-mb. surface for a series of eight consecutive days.

1. INTRODUCTION

Because of the several different indications of interaction between the lower ionosphere and the atmosphere below, it appears important to undertake a systematic daily comparison of these two regions [3]. A condensed meteorological measure of the state of the upper atmosphere would greatly facilitate such a study. I believe that a daily numerical index of the pattern of large-scale atmospheric circulation as high in the stratosphere as possible (for example at the 10-mb. surface, approximately 30 km.)[1] would be invaluable as a daily record of conditions there, much as the indices K and C constitute condensed daily records of geomagnetic activity.[2]

It seems essential that such an index be derived for each of several parts of each hemisphere (northern and southern), since there is evidence that the conditions of which it is desired to make a comparative study, though of large-scale character, are not planetary in scope. The effects do not register on a world-wide scale, as they do in much of geomagnetic activity. A proposal is made for the construction of such an index for each of several large-scale, equal, longitude-intervals, here sixths, of the Northern and of the Southern Hemispheres. Since at present data are available for the construction of high-level hemispheric charts of pressure and temperature only for the Northern Hemisphere, discussion in the present paper is confined to that hemisphere.

In 1945 such an index was devised [8] and I used this [6] in a comparative study of the geomagnetic daily variation and the large-scale atmospheric circulation. This was carried further by Wulf and Hodge [7]. I feel that a quantity of this general form constitutes a helpful index, although one of a different form might be superior. I believe the matter of real importance is the production of a daily index that may be available to those studying the high atmosphere in the years ahead.

Two principal phenomena, in studies of which such an atmospheric index is already needed, are, I believe, the anomalous absorption (better known as the anomalous winter absorption) of radio wave energy in the D region of the lower ionosphere, and the variable form of the quiet day daily variation of the earth's magnetic field. The meteorological significance of the former of these is clearly brought out in a recent paper by Beynon and Jones [1] concerning meteorological influences in ionospheric absorption measurements, while that of the latter is discussed in the paper just preceding the present one in this journal, and in earlier papers by the present author [3, 4, 5, 6]. It seems very probable that these phenomena, after adequate comparative study, will return high-atmosphere meteorological information of value.

2. PROPOSED INDEX

A portion, such as a 60° longitude interval, of the large-scale height-contour pattern portrayed on a hemispherical chart of a constant pressure surface can be reduced (thought of as on Mercator's projection) to a sinusoidal pattern of wavelength equal to this longitude interval, which can be described by an amplitude and a position angle, and which, though a rough approximation, still retains considerable information concerning the pattern from which it was derived. Three further quantities

[1] The 10-mb. surface lies in about the middle of the stratosphere, and the expression "upper stratosphere" will be used here to denote the middle and high stratosphere.

[2] See for example one of the yearly Bulletins of the series No. 12, entitled "Geomagnetic Data, Indices K and C" of the International Association of Geomagnetism and Aeronomy.

(described below) can helpfully augment these. Required to obtain these five quantities are the values of the height and of the temperature of the constant pressure surface at a grid of systematically placed points in the longitude interval.

The index which I believe would be adequate to establish a beginning in such a program comprises five quantities for each of the six 60° longitude intervals of the hemisphere, four quantities for each daily chart and a fifth that is interdaily in nature. They are obtained, for example for the 10-mb. surface, from the heights and temperatures at a grid of 96 points formed by the intersections of the 25°, 40°, 55°, and 70° parallels of latitude with the 24 standard-time hour meridians beginning with the Greenwich meridian.

If we refer to some one-sixth of the hemisphere, let us say for illustration the sixth centering on 90°W. with boundaries 120°W.←60°W., and for the moment only to the first two quantities of the index, there will be four values of the height for each of the five standard-time hour meridians, repeating the boundary meridians. From these four values, the average height on each of the five meridians is first obtained.

Using these five values of height for the 120°, 105°, 90°, 75°, and 60°W. meridians, which for convenience will be referred to as quantities a, b, c, d, and e, respectively, we can give the description of the pattern, approximated as a sine wave, as a single point on a polar diagram by obtaining the radius vector (which is the range, or twice the amplitude, of the wave) from the expression

$$\rho=\sqrt{(b-d)^2+\left(c-\frac{a+e}{2}\right)^2}$$

and the position of the maximum of the wave from the vectorial angle

$$\theta=\arctan\frac{(b-d)}{\left(c-\frac{a+e}{2}\right)}$$

the correct quadrant being seen by inspection from the signs of the numerator and denominator in the tangent. The position, λ, of the maximum of the approximating sine wave in the longitude interval is then readily determined, which, with the range ρ, constitutes the first two quantities.

This representation possesses the advantage that this approximation to the patterns for a series of consecutive days, for example a month, can be shown, for any one of the six longitude intervals, as points on a single polar diagram. By connecting the points with light arrow lines, some of the change that has occurred over these days can be seen at a glance, as is illustrated for eight days in figure 3. The range, ρ, moreover, gives an indication of the extent to which the air circulation is meridional in the particular longitude interval. I feel that the ease of representation of ρ and λ graphically in polar coordinates for a number of consecutive days contributes considerably to the usefulness of the index.

The third quantity in the index is the average slope, Δ, of the constant pressure surface between the 40° and 55° parallels, taken positive when sloping downward toward the pole, thus an indication of the zonal air circulation from west to east in the longitude interval. It is the average of the five appropriate differences afforded by the five pairs of values of the height on these two parallels.

The fourth quantity in the index is the average temperature, $\overline{T}$, over the respective sixth of the hemisphere, the average of the 20 values for the longitude interval.

These four values refer to a particular synoptic chart. The fifth and last quantity has to do with the change between two consecutive daily charts, and affords an indication of the interdiurnal variability of the temperature, δT. It is the root-mean-square value of the 20 interdiurnal differences in the temperature at the 20 grid points, thus a measure of the degree of unrest of the temperature at this pressure (or, approximately, at this height) in the particular longitude interval.

As an illustration of these indices, values are given in figure 1 for the eight days of February 18 through 25, 1966, at the 10-mb. surface. The values were taken from data obtained through the courtesy of Mr. F. G. Finger of Environmental Science Services Administration by computer interpolation and computation from the daily 1977-point hemispheric grid data [2]. The figure is in the form of a page, the page for February, in an envisioned yearly booklet giving these indices for each month of the year. The values of λ, the position in longitude of the *maximum* of the approximating sine wave, were determined from the computed values of θ for the six longitude intervals. These intervals are hereafter referred to as sectors and designated by the longitude of the central meridian of the sector, e.g., the 0°–60° E. interval will be referred to as the 30° E. sector.

In figure 2 is given, as an illustration, the accompanying table of δT, the seven instances of the interdiurnal variability of the temperature (described above) included in these eight days for each sector.

None of the changes in the hemispherical circulation over the eight days was very large, though over Atlantic and Eurasian longitudes they were not inconsiderable.

Comparing the values in figure 1 with the actual situation on February 18 we find that a High in high latitudes lay to the west of 150° W. (note the value of Δ, −180 meters). From the 150° W. sector eastward, the 10-mb. surface in the main sloped downward toward a high-latitude Low centered roughly in the 30° E. sector (λ=60° E., Δ=+870 meters). Continuing eastward the surface in general rose toward the high-latitude High in the vicinity of 180° longitude (Δ=−190 meters in the 150° E. sector).

The Low that was centered approximately in the 30° E. sector on February 18 changed considerably over these

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180° 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°

Day	ρ	λ	Δ	$\bar{T}$	ρ	λ	Δ	$\bar{T}$	ρ	λ	Δ	$\bar{T}$	ρ	λ	Δ	$\bar{T}$	ρ	λ	Δ	$\bar{T}$	ρ	λ	Δ	$\bar{T}$
1																								
2																								
18	16	158	-18	-44	23	108	+13	-46	15	41	+38	-52	19	60	+87	-53	34	104	+45	-44	14	158	-19	-43
19	13	155	-28	-43	24	107	+16	-46	19	39	+51	-53	17	59	+87	-54	31	104	+49	-45	17	159	-22	-43
20	17	156	-34	-44	17	109	+14	-47	19	43	+55	-53	21	58	+95	-55	34	104	+43	-46	13	160	-28	-44
21	21	162	-24	-46	11	106	+10	-48	18	46	+53	-53	11	2	+83	-54	39	104	+32	-44	10	164	-27	-44
22	17	165	-16	-47	8	100	+ 4	-48	25	50	+50	-52	2	34	+72	-53	31	104	+41	-43	21	160	-25	-43
23	14	165	-16	-47	9	100	+ 2	-48	21	52	+67	-53	4	32	+69	-49	18	104	+41	-42	15	156	-13	-43
24	8	161	-15	-46	10	100	+ 2	-47	18	56	+64	-52	9	12	+65	-49	21	105	+40	-42	11	152	-10	-43
25	8	160	-16	-46	15	98	+ 7	-48	17	2	+64	-51	15	17	+50	-50	17	106	+34	-44	9	154	- 7	-44
26																								
27																								
28																								

FIGURE 1.—Page for February of table of proposed daily index of upper-atmosphere meteorological activity, illustrated here using the 10-mb. constant-pressure surface and the days of February 18–25, 1966. ρ is the range in tens of meters and λ the position in longitude of the maximum of the sine wave approximating the height-contour pattern within the longitude interval (see text). Δ is the average difference in height of the surface in tens of meters between the 40° and 55° parallels of north latitude (see text), and $\bar{T}$ the average temperature of the surface, within the longitude interval. Scale of longitude at top of table.

eight days, spreading mainly westward. The changes that occurred in the 30° W. and 30° E. sectors are in some measure portrayed, as an illustration, in the polar diagram representation shown in figure 3 constructed from the values of λ and ρ. The diagram indicates that the meridional circulation in the 30° E. sector decreased in the first part of this period, increasing thereafter. Between February 22 and 23 the average temperature for the sector rose 4° (fig. 1) and the interdiurnal variability of the temperature was the largest for these eight days (fig. 2). At the end of this period, a high-latitude Low was centered roughly in the 30° W. sector (λ=2° W., Δ=+640 meters), to the east of which the surface in general rose a little (λ=17° E. in the 30° E. sector), falling again somewhat (λ=106° E. in the 90° E. sector) before beginning to rise toward the High near 180°.

These last three paragraphs are only intended to show that the index is of a form that conserves some important characteristics of the synoptic chart to which it refers. Clearly it does not even approximate a complete portrayal of that chart, nor is it, of course, intended to.

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Interday	180-120°W	120-60°W	60-0°W	0-60°E	60-120°E	120-180°E
1-31						
2-1						
19-18	20	23	23	32	32	33
20-19	18	17	25	20	23	31
21-20	34	26	14	22	36	32
22-21	23	21	14	20	30	17
23-22	18	21	34	54	36	22
24-23	27	26	33	23	29	22
25-24	19	14	29	41	21	19
26-25						
27-26						
28-27						

FIGURE 2.—Page for February of table that accompanies the table of figure 1: the interdiurnal variability of the temperature in tenths of a degree (see text), illustrated here using the days of February 1966 included in figure 1.

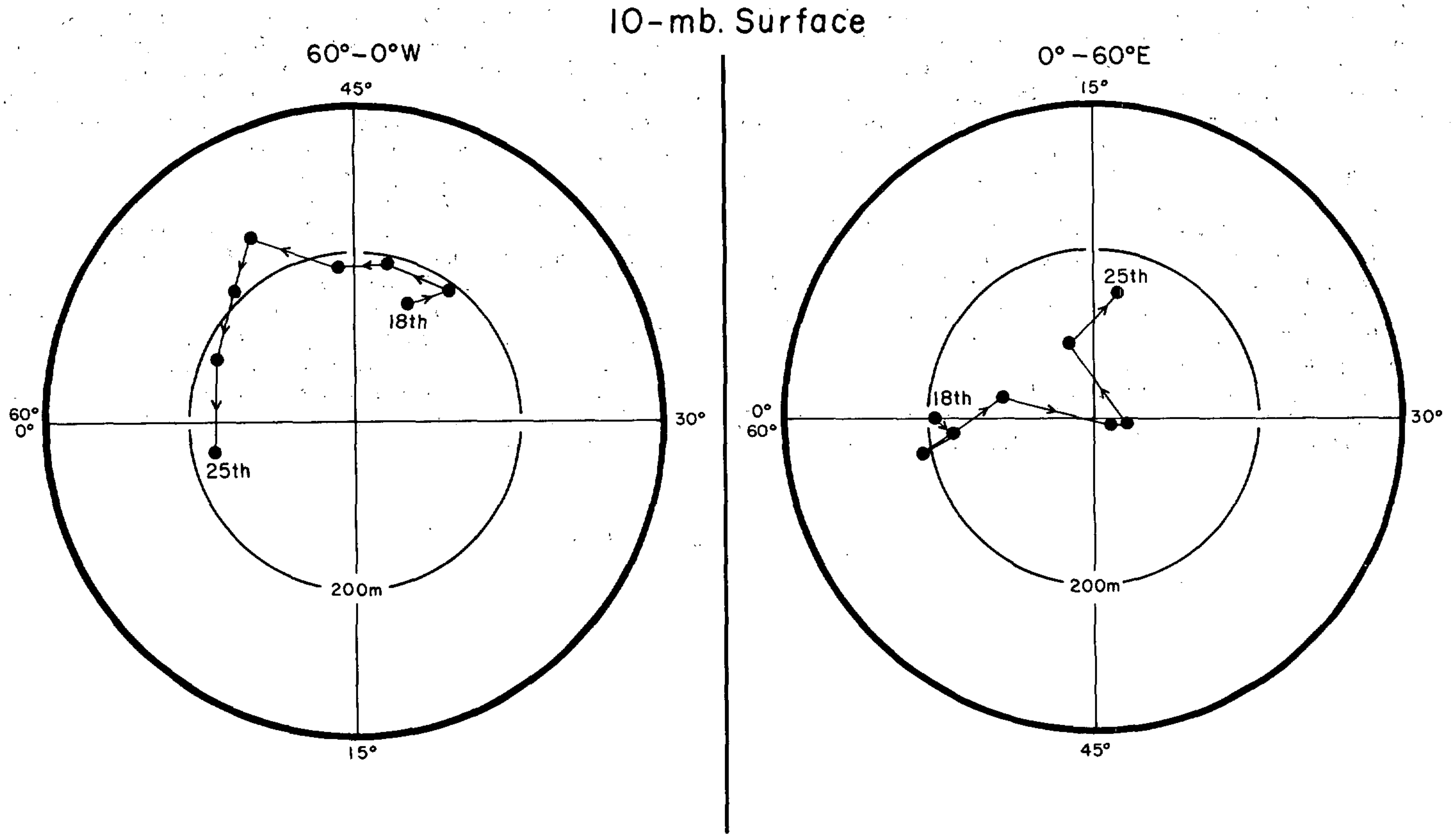

Figure 3.—Polar diagram representation of the change with time of the approximation to the height-contour pattern in two of the sectors for the eight days of February 1966 in the table of figure 1.

3. DISCUSSION

Such indices are ordinarily of use in comparative studies, as in an investigation of a possible relationship between two variables. An example might be a study of geomagnetic activity against solar activity in which the international magnetic character figure and the Zürich sunspot number might be used. These two quantities are daily indices of geomagnetic activity and solar activity, respectively, which have proven of much value. But neither is a detailed statement of the condition of which it is an index. One could not, for example, reproduce a detailed picture of the spottedness of the sun from the sunspot number for that day.

Similarly, there is no implication that the Northern Hemisphere 10-mb. constant-pressure chart for February 18, 1966 could be reproduced from the numbers on the corresponding line of the table in figure 1. But these numbers do concern some significant features of this chart (as illustrated in the preceding section) in a readily usable form, and as such should serve as a helpful index of a geophysical condition that is becoming increasingly important in high-atmosphere research, the large-scale air circulation in the upper stratosphere.

4. CONCLUSION

I believe that there is daily meteorological information concerning the upper stratosphere of much value to research in the lower ionosphere, and that this information would be of greater use if it could be made available as a daily condensed index, in a similar manner as are certain daily geomagnetic and solar data. It seems practicable to put some of the meteorological information contained in charts of the upper stratosphere into the form of a daily index, proposed here, that would be of much help in comparative studies of phenomena of the lower ionosphere with large-scale conditions in the upper stratosphere. The importance of these studies, even to the information that they will probably return concerning meteorological conditions in the lower ionosphere, suggests that such an index would make accessible upper-atmosphere meteorological information in a form for which there would be considerable demand.

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