The Seasonal Reversal of the Stratospheric Circulation

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ABSTRACT

The mean and individual seasonal reversal progressions are described for each of the 11 years of available rocket observations from 80°N to 80°S, and from 20 to 65 km. Isochrone sections were based on the time sections of the preceding paper and on frequencies of east-west wind data.

In the Northern Hemisphere the mean spring reversal starts in early April at highest altitudes and progresses downward and southward. The mean fall reversal proceeds simultaneously both upward from 20 km and downward from 60 km at high latitudes and then southward and downward. Both the onset and direction of the spring reversal are highly irregular from year to year, but the fall process is very uniform and rapid, starting in August and reaching 20 km in the subtropics in two months.

The Southern Hemisphere spring reversal appears to move from low to high latitudes oppositely to that in the Northern Hemisphere, and downward, taking about three months to reach 60°S at 20 km. The Southern Hemisphere fall proceeds to low latitudes and altitudes from both highest subtropical altitudes and lowest polar altitudes. The local nature of spring reversals for individual years is stressed.

1. Introduction

The annual cycle in solar heating of the stratosphere causes a seasonal reversal of the meridional thermal gradient and of the resulting zonal wind field. The seasonal reversals of the stratospheric winter westerlies and summer easterlies, in a restricted sense, can be defined as the dates of change of sign, if any, of the annual wave only. However, the observed mean monthly wind variability contains other components; thus, in more common usage, the reversal dates refer to the observed final seasonal change of sign due to the resultant of all periodic and non-periodic components. In this paper we will adopt the latter definition. Of course, no annual reversal is noted if an annual component, no matter how large, remains always positive or always negative. For example, in the tropical region from about 20°N to 20°S and from 20 to 40 km, the changes of zonal circulation are so irregularly affected by the quasi-biennial oscillation (QBO), that there is no annual reversal and that region will not be considered here. The explanation of the mean observed reversals depends on an understanding of the component waves, and it will be necessary to refer to the latitude-time sections in the preceding paper of this issue (hereafter referred to as B2), and to the amplitude and phase of the long-term cycles in the zonal wind given in Belmont *et al.* 1974a (hereafter referred to as B1). This paper will discuss the mean reversals of the zonal wind as functions of altitude, latitude and month and in terms of the component periodic waves and, for individual years, as determined by particular synoptic circulation features.

Studies of how the stratospheric circulation reverses with season as functions of altitude, latitude and longitude were first based on rawinsonde data and hence limited to below 30 km (Belmont, 1962). As meteorological rocket data became available after 1960, reversals could be described at levels up to 65 km at individual stations for particular years (Miers, 1963; Kats, 1968; Mitchell, 1970; Ebdon, 1972). The process varies widely from year to year and with both latitude and longitude, so that a larger space and longer time scale of this basic seasonal phenomenon is only recently becoming possible.

With the more than 10 years of rocket (MRN) data now available, with the expanded network, and most importantly, the more frequent observations, this study can now examine the altitudes 20–65 km, the years 1960–71, and the range of latitudes 80°N–70°S. This can provide an improved estimate of the average process by which the stratospheric and lower mesospheric circulations change as the seasonal insolation varies.

2. Data and processing

Stations and data are the same as used in B2. Two kinds of summaries of the individual observations were employed: the monthly mean wind from B2, and the prevailing frequency of occurrence of east or west winds at a given station for each monthly period for each year of record as done in Belmont (1962). The prevailing frequency of occurrence of east or west winds at a given station was computed for monthly periods for each 2 km of altitude. Frequencies of north, south and calms were excluded from the data. As the zonal circulation is often so asymmetric with respect to longitude, and as some stations are distributed over a wide sector of the globe, cross sections giving isochrones of reversal times were made separately for stations nearest 80°W, and for the Pacific Ocean area. In the Southern Hemisphere since there are too few stations to separate them by longitude, South American and Australian stations are combined as in a zonal mean, for a first guess.

To obtain reversal dates, height-time sections, by station, giving prevailing percentage frequency of east or west winds for months were used. Reversal isochrones equivalent to the 50% frequency line were analyzed by hand and the corresponding dates were read from the graph, interpolated to the nearest half-month (indicated by 1 and 2) and plotted on height-latitude sections for selected longitudes. A few of the resulting 72 graphs are used in examples of reversals for individual years given below.

The dates of the zero zonal wind in Table 1 (see Appendix) were interpolated by eye to the nearest half-month from the 11-year latitude-time sections (Figs. 1–10 of B2). For the years 1964–68 these were verified and adjusted as necessary using the weekly synoptic rocket network maps, available only for those years (Staff, Upper Air Branch, 1967). Where there were no data, these maps were used to supply values at upper levels in the Northern Hemisphere, by interpolating between the 5, 2 and 0.4 mb levels. These maps provide excellent examples that the reversal dates can sometimes be quite local, depending upon the scale and duration of synoptic-scale patterns. Those regions in the tropics under the influence of the QBO, where no annual reversals can be defined, are omitted in the table and in Figs. 1–8 shading indicates those areas which experience no equinoctial reversal from prevailing easterlies or westerlies.

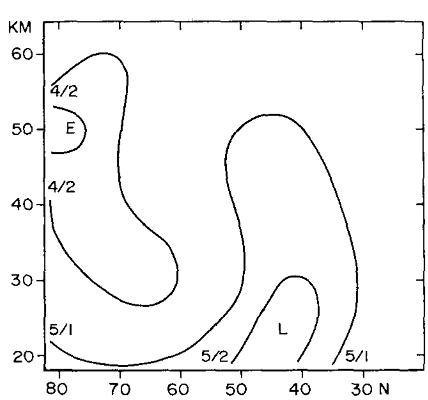

FIG. 1. Isochrones of mean reversal dates in spring, 80°W, Northern Hemisphere (Note: *in all figures the first number is the month, the second the first or second half of the month.*) E, early; L, late.

3. Results

The mean reversal isochrone patterns which follow are displayed in height-latitude sections. Different views of the same data are available in Figs. 6–10 and 11–14 of B2, where the reversal progressions can be understood by inspecting how the boundary of the shaded westerlies changes its north-south direction in time. As the time resolution used here is a half-month, all dates and time intervals are plus or minus two weeks.

a. Mean spring reversal, 80°W

Fig. 1 shows that for this 11-year period, the average spring reversal in the Northern Hemisphere starts in early April at highest latitudes near 50 km and progresses downward and southward, reaching 45°N and 20 km by late May. In the arctic, the reversal reaches 20 km a half-month sooner. Easterlies arrive latest at 20 km near 45°N near the location of the tropospheric westerly jet. In many years, even though the easterly progression begins in the north, easterlies also appear at or below 40 km, near 20°N, often at an earlier date (see discussion of Fig. 5 below), but progress very slowly from that general latitude zone. Table 1a shows the wide annual variations from the mean picture in Fig. 1. In 1961, 1963, 1964, 1966 and 1969 and 1971, final reversals as early as February occurred at 30 km at high latitudes.

b. Mean fall reversal, 80°W

The fall reversal along 80°W (Fig. 2) starts from 20 km, near 55°N, presumably under the influence of strong tropospheric westerlies from which the isochrones extend rapidly northward, upward, and then southward and downward. The main progression also appears to start at highest latitudes and altitudes and descends and moves southward, merging with the first progression. The processes starting in early August at 20 km and in late August at 60 km take only one month to change the easterlies to westerlies at all altitudes north of 50°N. It requires only one month longer to reach 30 km at 30°N. Note also that at 60 km the reversal takes only about two weeks, on the average, from 80 to 30°N. The upward progression to 30 km was shown also by Batten (1959) for the year 1957 and by Belmont (1962) for the years 1957–59, with both studies based on radiosonde data. The mean shown by Kats (1968)

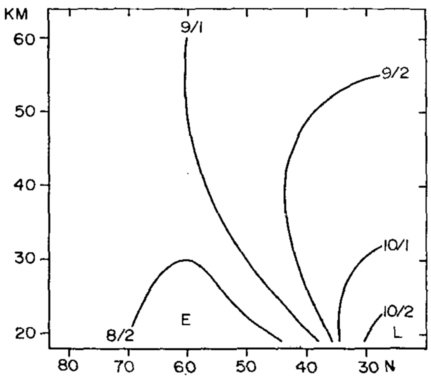

FIG. 2. As in Fig. 1 except in fall.

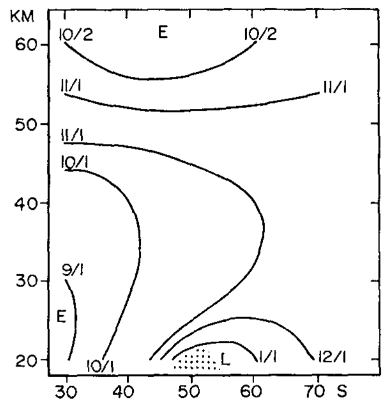

FIG. 3. Isochrones of mean reversal dates from west to east in spring, Southern Hemisphere. Shading represents winds continuously from west.

for 1961-64 MRN data, however, does not show this upward component.

The rapidity of the fall progression with height at high latitudes can easily lead to both conclusions of downward and upward motion, although the very consistent nature of the 11 years of data now available requires recognition of the upward trend. Further, we have been unable to confirm the early data of 8/1 which Kats shows at 65–70 km at all latitudes on his mean isochrone diagram, even for the period of record and stations then at his disposal. It seems most likely at this time that the fall reversal progresses from both above 60 km and from below 30 km merging in the layer between, as suggested also by Batten (1964) in a study based on Churchill and White Sands data. The rapidity of the process in the fall and the semi-monthly resolution used here do not allow a more detailed separation of the progressions. Only more frequent observation in space and time, and especially in the relatively unexplored levels above 65 km, will resolve this point.

The fall reversal is quite different from the spring reversal because of its uniformity in timing and direction, which is likely due to the seasonal radiational cooling acting on a comparatively uniform, stable summer anticyclonic circulation. In contrast, the spring change from the erratic winter migrations and divisions of the polar vortex occur randomly, primarily from instabilities of the circulation, rather than from purely gradual, radiational warming which would bring a gradual increase of the pressure field. The fall reversal starts in late August or early September in each of the 11 years for which data exist, and westerlies usually reach 20 km and 30°N by 15 October.

c. Mean Southern Hemisphere reversals

The Southern Hemisphere spring reversal (Fig. 3) progresses from low to high latitudes, oppositely to that in the Northern Hemisphere, and starts from two regions—the lowest subtropical stratosphere in early September, and the highest mid-latitude stratosphere in early October. The reversal progresses poleward and downward taking about three months to reach 60°S at 20 km. The Southern Hemisphere tropospheric westerly jet extends into the lower stratosphere and is sufficiently strong, in the mean, to persist even through the summer, at 50–60°S, so that no reversal occurs (see Fig. 6, B2). In the Australian sector the spring reversal appears to start one or two months earlier than over the South American sector. In the Southern Hemisphere fall (Fig. 4), it proceeds to low latitudes, both from highest subtropical altitudes and lowest polar altitudes, taking three months at 20 km to reach 30°S from 70°S.

d. Examples of individual reversals

In individual years relatively local displacements of highs or lows or changes in the planetary wavenumber at a given latitude, some of which may be associated with sudden warmings, can cause temporary or even

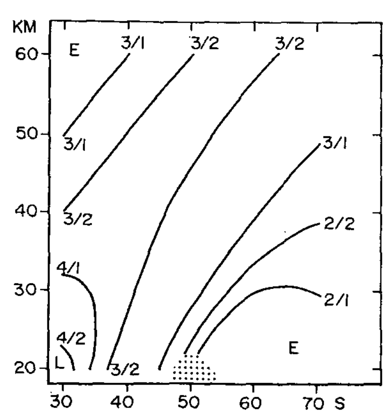

FIG. 4. As in Fig. 3 except in fall from east to west.

extended reversals at a given station. See, for example, a summary of "anomalous" easterly winds in the winter stratosphere (Belmont, 1961; Barbé, 1961).

As an example of the local nature of some reversal dates, the mean monthly data for 1964 in Table 1a show an unusually early final spring reversal at Churchill (60°N) at 30 km in the first half of March, but with dates two months later at both 20 and 40 km. From NMC weekly synoptic analyses (Staff, Upper Air Branch, 1967) this was caused by the Alaskan anticyclone's movement eastward over northern Canada. It persisted at 5, 2 and 0.4 mb (35, 42 and 55 km) from 4 March through 1 April after which time the upper levels at 60°N became westerly as the center of a low moved northward and replaced the anticyclone, which in turn moved toward the Asian side of the pole. At 5 mb, however, the low apparently receded southward before the westerly circulation on its southern side affected Churchill, as far as can be seen from these weekly maps. At 2 and 0.4 mb, and also at stations farther south, the easterlies were interrupted by these westerlies and the circulation did not again become easterly until near May 13, the date of final reversal.

When compared with the maps published serially in *Meteorologische Abhandlungen* at 50 and 10 mb (for 20 and 30 km), the dates in Table 1 may easily vary a half-month because of the greater resolution possible with these daily maps at a given place. However, there is so much variability with longitude on a given day, depending upon location with respect to the circulation of a transient high or low, that the dates from the cross sections can be taken as representative only for North America along the MRN meridians. If a global average date is wanted, one would have to compute zonal means of gridded observed zonal winds. At levels higher than about 30 or 35 km, such global maps do not exist and one must temporarily accept the scattered few MRN data as the best indication at present, realizing that the results can never be expected to apply to all longitudes.

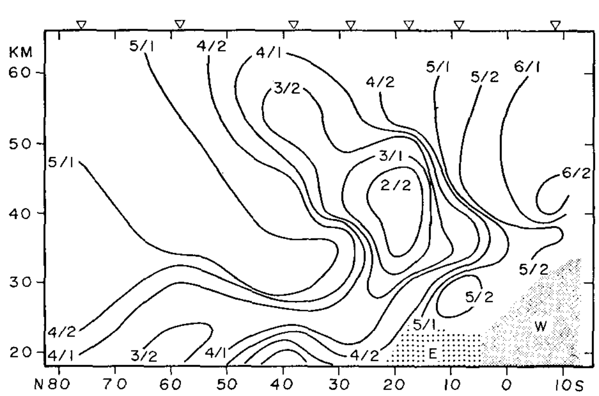

FIG. 5. Isochrones of spring 1971 reversal, 80°W, 80°N to 10°S. (Note: in Figs. 5–8, triangles indicate rocket station locations; E, east winds; W, west winds.)

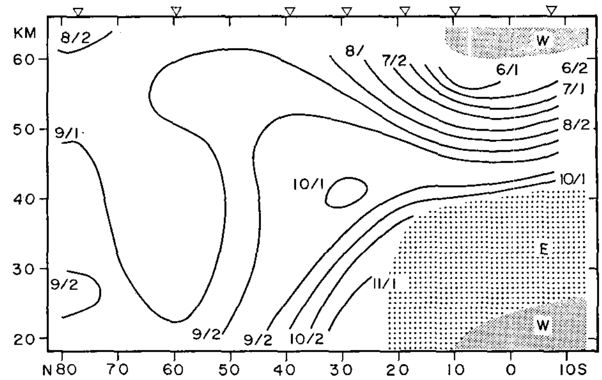

FIG. 6. Isochrones of fall 1971 reversal, 80°W, 80°N to 10°S.

Figs. 5–8 give examples, from the east-west frequency data, of individual reversals along 80°W and over the Pacific area to show differences with longitude and variations from year to year due to synoptic pattern influences. Latitudes to 8°S are included in order to note what actually occurred in the tropics, especially at high altitudes. Regions where there were no changes in wind direction are shaded. Fig. 5 shows an opposite progression to that in Fig. 1, with respect to both latitude and height. The zone of abnormally early reversal near 40 km in 1971 has no counterpart in the mean pattern of Fig. 1. These tropical centers are probably caused by the coincidence of the semi-annual and annual waves together with the long-term mean, and vary from year to year because of the QBO and normal year-to-year synoptic variability (see B1). The last regions to change are always in the lowest stratosphere at latitudes of the mean jet stream which frequently extends its influence on the circulation up to at least 20 km. In the fall, Fig. 6 shows descent of the reversal from highest polar levels to 30°N and 20 km. At all latitudes except 60°N it appears to descend from 60 to 20 km. At 20 km in both the mean in Table 1 and in 1971 a slightly earlier origin is shown near 60°N than at 80°N.

Over the Pacific area (Fig. 7) the spring of 1971 reversal pattern is rather similar to that of 80°W (Fig. 5). In the fall of 1971 Fort Greely data were missing for the Pacific area so 1970 is used (Fig. 8). This shows an early reversal in the subarctic lowest altitudes arriving

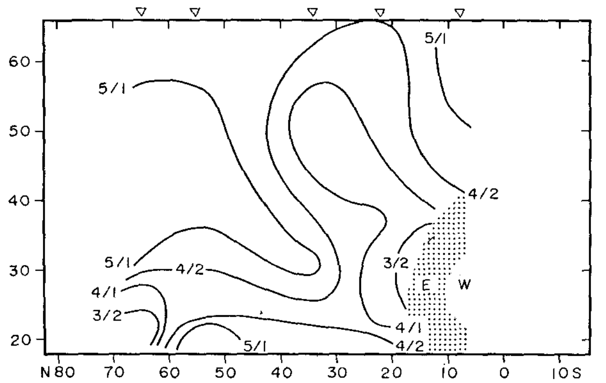

FIG. 7. Isochrones of spring 1971 reversal, Pacific, 70°N to 10°N.

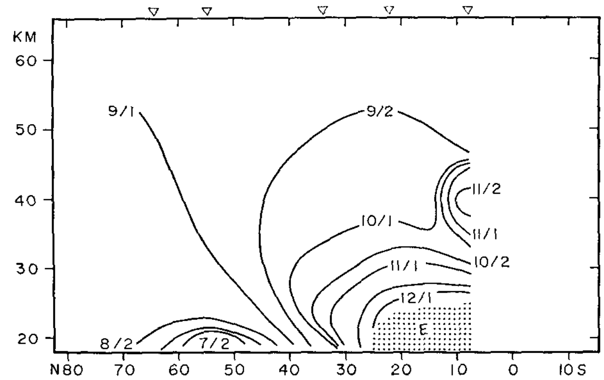

FIG. 8. Isochrones of fall 1970 reversal, Pacific, 70°N to 10°N.

last to the subtropics and lowest altitudes. The 80°W counterpart (Fig. 6, 1971) agrees with respect to the downward progression from high to low latitudes, but lacks the unusually early high latitude center.

As noted previously, definition of an annual reversal in the tropics is difficult as the semi-annual wave and the QBO dominate the annual wave there. The complicated interplay between these component waves can be seen by comparing the tropical regions of Figs. 6 and 8. While a portion of the difference between these figures is likely due to longitudinal variations and to normal synoptic-scale interannual variability, the QBO's irregularity is especially evident below 40 km. There is a reversal at 8°N at 40 km (Fig. 8) in late November 1970, but in 1971 (Fig. 6) it comes in early October, and never reaches 39 km.

An example of the superposition of the mean on the annual and semi-annual waves, and its effect on the average beginning and end of the summer easterlies, is given in Belmont *et al.* (1974b) as are charts which show the longitudinal variations in the amplitude of the semi-annual wave.

4. Conclusions

From these examples it can be said that the spring reversal of the stratospheric circulation is irregular. It is perhaps caused by random accidents of the polar vortex's splitting and shifting along arbitrary longitudes. Until the physical causes of the breakdown are identified and measured it will not be possible to predict these reversal phenomena in either time or space. Possibly the advent of satellite radiance data will enable better global coverage and allow the entire high-latitude thermal field to be examined to high altitudes. To do this at present from rocket measurements is very difficult because of the few observations and the doubtful status of comparing temperatures from different instruments, especially for years past. This is a main advantage of observations taken with a single satellite.

In contrast, the Northern Hemisphere fall reversal starts regularly in August moving both upward from 20 km and downward from 60 km at high latitudes. The fall reversal resembles a stable, gradual, spatially-uniform, radiational cooling process in direct response to decreasing insolation at high latitudes. This difference in behavior implies that the spring reversal is a more dynamically caused process arising from release of potential energy built up by the large and unstable meridional temperature gradients. This is manifested by irregularly spaced and timed eddies, resulting in large-scale mixing and turbulence.

The hemispheres have different reversal patterns. In August, the Northern Hemisphere fall and Southern Hemisphere spring reversals proceed in the same southward direction, but there is no continuity in time across the tropics. In April, the reversal moves in opposite directions, starting at about the same time toward the equator from high latitudes of each hemisphere, and arriving at low latitudes at about the same time.

It is as difficult to describe the mean reversal processes as it is to describe any other aspects of climatology. Spatial and temporal variations are so large that objective, globally-averaged data (if the data existed) would likely give a very unrepresentative view of the behavior of the circulation at any given place. The estimates given here show the large variations with latitude and height and year, even in terms of semi-months.

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APPENDIX

TABLE 1a. Yearly and mean spring reversal dates for the Northern and Southern Hemispheres. First number is month, second number is first or second half of month. W indicates continuous westerlies.

Year	Height (km)	Latitude 80°N	70°N	60°N	50°N	40°N	30°N	30°S	40°S	50°S	60°S	70°S	80°S
1961	60	—	—	—	—	4/2	4/2	—	—	—	—	—	—
	50	—	—	5/2	5/2	5/1	4/2	11/1	—	—	—	—	—
	40	—	6/1	6/1	6/1	5/2	5/1	10/1	—	—	—	—	—
	30	3/2	3/2	3/1	3/1	4/1	4/2	10/2	11/1	11/2	12/1	11/2	10/2
	20	5/2	5/1	4/2	5/2	6/1	5/2	10/1	11/1	W	W	W	W
1962	60	—	—	—	—	5/1	5/1	9/2	9/2	9/2	10/1	10/2	—
	50	—	—	4/2	4/2	5/1	5/1	11/1	11/1	11/1	11/1	11/1	—
	40	—	5/2	5/1	5/1	5/2	5/1	8/1	8/1	8/2	9/2	19/2	—
	30	5/1	4/2	4/2	5/1	5/2	4/2	5/2	10/1	11/1	11/1	11/1	11/2
	20	5/2	5/2	6/1	6/2	6/1	5/1	9/1	9/2	W	11/2	W	W
1963	60	—	—	3/1	4/1	5/1	5/1	11/1	—	—	—	—	—
	50	—	—	4/1	5/1	5/1	5/1	11/1	—	—	—	—	—
	40	—	—	4/1	5/1	5/1	5/1	9/1	—	—	—	—	—
	30	3/2	4/1	4/1	5/1	5/2	4/1	8/1	9/2	11/1	11/2	12/1	12/1
	20	4/2	3/2	6/1	6/2	6/1	5/1	9/1	W	W	W	1/1	W
1964	60	4/2	5/1	5/1	5/1	4/2	4/1	10/1	—	—	—	—	—
	50	4/2	5/1	5/1	5/1	4/2	4/2	10/2	—	—	—	—	—
	40	4/1	4/2	5/1	5/1	5/1	5/1	8/2	—	—	—	—	—
	30	3/1	3/1	3/1	4/2	5/1	5/2	8/2	9/2	10/1	10/1	10/2	11/1
	20	6/1	5/2	5/1	4/2	5/1	5/1	8/2	9/1	12/2	12/1	11/2	W
1965	60	4/1	4/2	4/1	4/2	4/2	4/2	9/2	—	—	—	—	—
	50	4/1	4/1	4/1	4/2	5/1	4/2	11/2	—	—	—	—	—
	40	4/1	4/1	4/2	4/2	5/1	4/2	6/2	—	—	—	—	—
	30	4/1	4/2	5/2	5/2	5/1	4/2	11/2	10/1	11/2	11/2	11/2	11/2
	20	5/1	5/1	6/1	5/2	5/1	4/2	9/1	10/2	11/2	12/1	12/1	W
1966	60	4/1	4/1	4/1	4/1	4/2	4/2	11/1	—	—	—	—	—
	50	4/1	4/1	4/1	4/2	5/1	4/2	10/1	—	—	—	—	—
	40	4/1	4/1	4/1	5/1	5/2	5/1	10/1	—	—	—	—	—
	30	4/1	3/2	4/1	5/2	5/1	5/1	11/1	10/2	10/1	10/1	10/1	11/1
	20	5/1	4/2	4/2	6/1	6/1	5/2	10/1	11/2	12/1	12/1	12/1	12/1
1967	60	4/1	4/1	4/1	4/1	4/1	4/2	10/1	—	—	—	—	—
	50	4/1	4/1	4/1	4/2	4/2	5/1	11/1	—	—	—	—	—
	40	4/1	4/1	4/1	4/2	5/1	5/1	10/2	9/1	—	—	—	—
	30	4/1	4/1	4/1	4/2	5/1	6/1	10/1	9/1	9/1	9/2	10/2	11/1
	20	5/2	4/2	4/2	5/1	5/2	4/2	8/2	9/2	12/1	12/2	12/1	12/1
1968	60	4/1	4/1	4/1	4/2	4/2	4/2	10/2	—	—	—	—	—
	50	4/1	4/1	4/2	4/2	4/2	5/1	11/1	—	—	—	—	—
	40	4/1	4/1	4/2	4/2	5/1	5/1	10/1	11/1	—	—	—	—
	30	4/2	4/2	4/2	4/2	6/1	5/1	8/2	9/1	10/1	10/2	10/2	11/1
	20	5/2	4/2	4/2	5/1	5/1	4/1	9/1	10/1	10/2	11/1	11/2	W
1969	60	—	12/2	4/2	4/2	4/1	4/1	—	—	—	—	—	—
	50	—	2/2	5/1	5/1	5/1	4/2	11/1	11/1	11/1	11/1	11/1	—
	40	—	3/1	3/1	5/1	5/1	5/1	11/2	11/2	11/2	11/1	11/1	—
	30	5/1	4/1	3/2	4/1	5/2	5/2	10/2	10/2	11/1	11/2	11/2	—
	20	4/2	3/2	4/1	5/2	5/2	5/1	9/1	10/2	11/2	W	12/2	12/2
1970	60	—	4/1	4/1	4/1	4/1	4/2	10/1	—	—	—	—	—
	50	—	4/1	4/2	4/2	4/2	4/2	11/1	11/1	11/1	10/2	10/1	—
	40	—	4/1	4/1	4/2	5/1	3/2	9/2	8/2	9/1	10/1	11/1	—
	30	4/1	4/1	4/2	5/2	5/2	4/1	8/1	9/1	10/1	10/2	11/1	—
	20	4/2	4/1	5/1	5/2	5/1	4/1	8/2	9/2	W	12/2	12/1	W
1971	60	—	4/2	4/2	4/1	3/2	3/2	10/2	10/2	10/2	10/2	—	—
	50	—	5/1	5/1	4/2	4/1	3/2	10/2	10/2	11/1	11/1	11/2	—
	40	5/1	4/2	4/2	4/2	4/2	4/1	10/2	10/2	10/1	10/2	11/1	—
	30	6/1	3/2	4/1	5/1	5/2	5/1	9/1	10/2	11/1	11/2	12/2	—
	20	5/1	4/2	5/1	5/1	4/2	4/2	9/1	9/2	11/2	W	W	—
Mean	60	4/2	4/1	4/2	4/2	4/2	4/2	10/2	10/1	10/1	10/2	10/2	—
	50	1/1	4/1	4/2	5/1	5/1	4/2	11/1	11/1	11/1	11/1	11/1	—
	40	4/1	4/1	4/2	5/1	5/1	4/2	9/2	10/1	10/2	11/1	11/1	—
	30	4/2	4/1	4/1	5/1	5/2	5/1	9/1	10/1	10/2	11/1	11/2	—
	20	5/1	5/1	5/1	5/2	5/2	4/2	9/1	10/2	W	1/1	12/1	—

TABLE 1b. As in Table 1a except for fall reversals.

Year	Height (km)	80°N	70°N	60°N	50°N	40°N	30°N	30°S	40°S	50°S	60°S	70°S	80°S
		Latitude											
1967	60	9/1	9/1	9/1	9/2	9/2	9/1	2/1	—	—	—	—	—
	50	8/2	8/2	8/2	9/1	9/2	9/2	2/1	—	—	—	—	—
	40	8/2	8/2	9/1	8/2	9/1	9/2	1/2	—	—	—	—	—
	30	8/2	9/1	9/1	9/1	9/2	10/1	4/1	3/1	2/2	2/2	2/2	2/1
	20	8/2	8/1	8/1	7/2	9/1	10/2	4/1	2/2	2/1	2/1	2/1	1/2
1968	60	8/2	8/2	9/1	9/1	9/1	9/1	3/1	—	—	—	—	—
	50	8/2	8/2	9/1	9/1	9/2	9/2	2/1	—	—	—	—	—
	40	9/1	8/2	9/1	9/1	9/2	10/1	3/2	3/1	—	—	—	—
	30	9/1	9/1	9/1	9/1	9/2	10/2	4/1	3/1	2/2	2/1	1/2	1/2
	20	8/2	8/2	8/1	8/1	8/2	10/1	4/1	3/1	2/2	1/2	1/2	1/1
1969	60	—	8/1	8/2	9/1	9/1	8/2	2/1	—	—	—	—	—
	50	—	8/2	8/2	9/1	9/2	9/2	3/2	—	—	—	—	—
	40	—	8/2	8/2	8/2	9/1	9/2	3/1	3/1	—	—	—	—
	30	9/1	9/1	9/1	9/1	9/2	10/2	4/1	3/2	2/2	1/2	1/2	2/1
	20	9/1	8/2	8/1	8/2	9/1	10/2	4/1	3/1	2/1	1/2	1/2	W
1970	60	—	8/1	8/2	8/2	8/2	8/2	—	—	—	—	—	—
	50	—	9/1	8/2	9/1	9/1	9/2	3/1	3/1	3/2	3/2	3/1	—
	40	—	8/1	8/2	9/1	9/1	9/2	3/2	3/1	3/1	2/2	2/1	—
	30	9/1	9/1	9/1	9/2	10/1	11/1	4/2	3/1	2/2	2/1	2/1	—
	20	8/1	7/2	7/2	7/2	9/1	10/2	4/1	2/2	1/1	W	1/2	1/2
1971	60	—	8/2	8/2	8/2	8/2	8/2	2/2	3/1	3/2	3/2	—	—
	50	—	8/1	8/2	8/2	9/1	9/2	3/2	3/2	3/2	3/1	2/2	—
	40	—	8/2	8/2	8/2	9/1	9/2	4/1	3/2	3/1	3/1	2/2	—
	30	9/2	9/1	9/1	9/2	9/2	10/2	4/2	4/2	4/1	3/1	2/2	—
	20	8/1	7/2	7/2	8/1	9/2	10/2	4/2	3/2	W	1/2	1/2	W
Mean	60	8/2	8/2	9/1	9/1	9/1	9/1	2/2	3/1	3/2	3/2	3/1	—
	50	8/2	8/2	9/1	9/1	9/2	9/2	3/1	3/2	3/2	3/1	3/1	—
	40	8/2	8/2	8/2	9/1	9/2	9/2	3/2	3/2	3/1	3/1	2/2	—
	30	8/2	8/2	8/2	9/1	9/2	10/1	4/1	3/2	3/1	2/1	2/1	—
	20	8/2	8/2	8/1	8/1	9/1	10/2	4/2	3/1	W	1/2	1/2	—
1961	60	—	—	—	—	9/2	9/2	—	—	—	—	—	—
	50	—	—	7/2	8/1	9/1	8/2	3/2	—	—	—	—	—
	40	—	9/2	8/2	8/2	9/1	9/2	—	—	—	—	—	—
	30	8/2	8/2	8/2	8/2	9/1	9/2	4/2	4/1	3/1	2/1	2/1	2/2
	20	9/2	9/1	8/2	8/2	10/2	11/2	5/1	3/1	—	2/1	1/2	—
1962	60	—	—	—	—	9/1	9/1	—	—	—	—	—	—
	50	—	8/2	9/1	9/1	9/2	9/2	3/2	—	—	—	—	—
	40	—	—	8/1	8/2	9/2	9/2	3/2	—	—	—	—	—
	30	8/2	8/2	8/2	8/2	9/2	10/1	4/1	3/1	2/2	2/2	2/2	2/2
	20	9/2	9/1	8/2	8/2	9/2	11/1	5/1	4/1	W	W	W	W
1963	60	—	—	10/2	10/1	9/2	9/2	2/2	3/1	3/2	3/2	3/1	—
	50	—	—	9/2	9/2	9/2	9/2	2/2	3/1	3/1	3/1	3/1	—
	40	—	—	7/2	8/1	8/2	9/1	3/2	3/2	3/2	3/1	2/2	—
	30	—	8/2	8/2	8/2	9/1	9/2	4/1	3/2	2/2	2/2	2/1	2/1
	20	9/2	9/2	8/2	8/1	9/2	11/1	4/1	3/2	W	1/2	W	W
1964	60	8/2	8/2	9/1	9/1	9/1	9/2	3/1	—	—	—	—	—
	50	8/2	9/1	9/1	9/1	9/1	9/2	3/2	—	—	—	—	—
	40	8/2	8/2	9/1	9/1	9/2	9/2	4/1	—	—	—	—	—
	30	8/2	8/2	9/1	9/1	9/1	10/1	4/2	3/1	2/1	2/1	2/1	2/1
	20	9/1	9/1	9/1	8/2	9/1	10/2	4/1	W	W	W	2/1	W
1965	60	9/1	9/1	9/1	9/1	9/1	9/1	3/1	—	—	—	—	—
	50	9/1	8/2	9/1	9/1	9/2	9/2	3/1	—	—	—	—	—
	40	9/1	8/2	8/2	9/1	9/2	10/1	4/1	—	—	—	—	—
	30	8/2	8/2	9/1	9/1	9/2	10/1	4/1	3/2	2/2	2/1	2/1	2/2
	20	9/2	8/2	8/2	8/1	9/1	10/1	4/1	3/2	2/2	2/2	2/1	W
1966	60	9/1	9/1	8/2	9/1	9/1	9/1	3/1	—	—	—	—	—
	50	8/2	8/2	8/2	9/1	9/1	9/1	3/1	—	—	—	—	—
	40	8/2	8/2	8/2	8/2	9/1	9/2	3/1	—	—	—	—	—
	30	9/1	8/2	8/2	9/2	9/2	10/1	4/1	3/1	3/1	2/1	1/2	1/2
	20	8/2	8/2	8/1	8/1	9/1	10/2	4/1	3/2	1/2	1/2	2/1	W

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