To estimate the amplitude of the semiannual oscillations, Reed's results and the results of the White Sands study were combined in Fig. 1. The amplitude of the 6-month component was plotted and analyzed as a function of altitude and latitude. The increase in amplitude with increasing altitude and decreasing latitude is obvious. From Fig. 1 it does not seem too unreasonable to assume that amplitudes of 5 deg may exist between 40–45 km near the equator. At 15N a seasonal variation as large as 6 to 8 deg in the upper stratosphere may be reasonable.

With these estimates the annual variation at 15N would be twice as large as the summer–winter difference between 30 and 50 km attributed to Cole and Kantor's subtropical atmosphere.

At this time there are insufficient data to support either a theory of small seasonal temperature variations or the large semiannual temperature variations suggested here. However, it seems somewhat premature to conclude that the upper stratosphere near 15N has little seasonal variability, particularly since such a conclusion is based on nine observations at 14N, all in November, and one observation at the equator in May.

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Reply

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27 May 1963

The seasonal variation of mean monthly hemispheric temperature for 15N, given in our paper, "Tropical and Subtropical Atmospheres," applies only to altitudes below 30 km. The original manuscript contained a figure presenting the variation from the mean annual temperature-height profile between 10 and 30 km. This figure was eliminated in the revision that was made to reduce the paper to acceptable size. The variation of 2 to 3 deg Centigrade, to which Mr. Batten refers in his first sentence, is a mistake in our text which we gratefully acknowledge. The correct values of 3 to 5C, for the annual range below 30 km, are given in our Research Note, AFCRL 62-899, September 1962. We agree with Mr. Batten that between 30 and 50 km semiannual temperature variations over the equatorial region, where the sun passes overhead two times per year, probably are larger than over other regions. However, we see no reason to believe that the sum of the semiannual and annual variations should be greater at 15N than at 30N. An extrapolation of this condition northward would imply that variations at 60N should be less than at either 15 or 30N, whereas Churchill observations indicate greater variability at 60N than at 30N.

The subtropical atmospheres (30N) are not intended to represent extreme mean monthly conditions at all altitudes and for all parameters. At most levels below 25 km the warmest and coldest temperatures occur in July and January, respectively. Between 30 and 50 km, indications are that the warmest temperatures occur in May, June, and possibly April. Our estimates of the maximum variability, the difference between warmest and coldest month at these levels are based on White Sands (32N) data and scattered observations from the Atlantic (28N) and Pacific (34N) missile ranges. They are roughly 4 deg at 30 km, increasing up to 8 deg at about 40 km, then decreasing and reaching a minimum near 60 km. Above 60 km, temperatures appear to be coldest in July. Sufficient data are not available for determining the warmest month. Consequently, a range cannot be given at these altitudes.

The amplitude of the semiannual temperature component, 2.1C, given for 45 km in Table 1 and Fig. 1 of Mr. Batten's comments, is not in agreement with the value of 1.2C given in Fig. 4 of his RAND report (his footnote 2). The sum of the annual and semidiurnal amplitudes given there increases up to 40 km and decreases above, which agrees with our analysis. The estimated magnitudes of the variation from the warmest to coldest month at 40 km, however, are considerably different. Although both studies are based on essentially the same data, the thermistor temperature observations were weighted differently. Batten finds a maximum mean monthly range of 14C versus our 8C at 40 km. It is unfortunate that this type sensor has not been flown concurrently with others. The few comparisons that were made at Wallops Island with grenades were nullified when the thermistors being used were declared obsolete due to RF heating of the bead. It would be advantageous to the large group of researchers working in this area to sponsor tests comparing bead thermistor with other type temperature sensors used between 30 and 60 km.

In our paper we did not attempt quantitative estimates of temperature variability above 30 km at 15N because of inadequate observational data. We did postulate that the range is smaller at 15N than at higher latitudes, a conclusion which appears to be well borne out by latitudinal extrapolation. We do not believe Batten has refuted this fact. In the preparation of the 15N atmosphere, the annual range of temperature at other latitudes was considered, along with thermal and geostrophic wind equations. The apparent levels of minimum density variability at 90 km and minimum temperature variability near 60 km also served as a basis for an estimated mean annual temperature-height profile at 15N. Earlier estimates (Murgatroyd, 1957; Batten, 1962; and others), based on similar techniques and even less data, have been used to arrive at seasonal values for temperatures and wind at this latitude.

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