The Interaction Between Stratosphere and Mesosphere in Winter

KARIN LABITZKE [1]

National Center for Atmospheric Research,[2] Boulder, Colo.

13 March 1972

ABSTRACT

Rocketsonde and rocket grenade data show that stratospheric temperature changes in winter in both low and high latitudes are accompanied by simultaneous changes of opposite sign in the mesosphere, which indicates that the two layers interact.

1. Introduction

Fritz and Soules (1970), using SIRS channel 8 data, pointed out that the stratospheric temperature changes at high and middle latitudes in the winter hemisphere are accompanied by changes of the opposite sign over the tropics and subtropics of both hemispheres. It is the purpose of this note to show that the temperature changes in the winter stratosphere in both low and high latitudes are accompanied by temperature changes of opposite sign in the *mesosphere*.

2. Temperature changes in the upper stratosphere

Although the radiances of the Selective Chopper Radiometer (SCR) are not through final processing, the preliminary values from channel A[3] can be used to define the periods of highest and lowest temperature

[1] On leave from the Free University of Berlin.

[2] The National Center for Atmospheric Research is sponsored by The National Science Foundation.

[3] The radiances of channel A are a measure of a weighted mean temperature of a layer about 20 km thick, centered at about 45 km (Ellis *et al.*, 1970; Abel *et al.*, 1970).

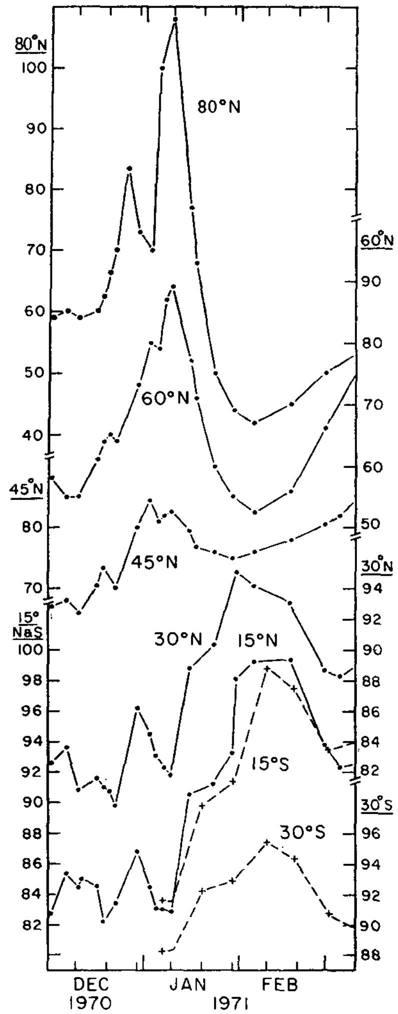


FIG. 1a. March of zonally averaged radiances of channel A of the SCR [mW m^{-2} ster^{-1} (cm^{-1})$^{-1}$] in winter 1970/71. The radiances were kindly supplied by Dr. J. T. Houghton and collaborators at Oxford University before publication, and are not to be regarded as final values.

in the upper stratosphere in the winter of 1970/71. The zonal means are shown in Fig. 1a. Over high and middle latitudes the peak of the stratospheric midwinter warming was reached around 10 January. At the same time low radiances were received from 30N to 30S. During the late winter, cooling north of 40N and the reintensification of the polar vortex, the region between 40N and 50S warmed, reaching its annual maximum.

Whereas no SCR data are available for earlier years, the temperature distribution of the upper stratosphere has been documented for many years by the Staff Upper Air Branch of NOAA (1969, 1970, 1971), in the form of weekly maps. Their 2-mb temperatures at 60N (averaged between longitudes 170E across North America to 20E) are plotted in Fig. 1b for 1967/68 and in Fig. 1c for 1966/67, together with 2-mb temperatures at Ft. Sherman (9N, 80W) for 1966/67, and a mean temperature around 45 km (Meteorological Rocket Network data) for 1967/68, also at Ft. Sherman. The circulations of the two winters were very different, as a major midwinter warming, accompanied by a breakdown of the stratospheric circulation, was observed in 1967/68 (Labitzke and Schwentek, 1968) but only a minor warming occurred in 1966/67. The 1967/68 warming (Fig. 1b) can be compared with that of 1970/71 (Fig. 1a) as regards intensity and time-scale. The maximum occurred around 27 December 1967, the minimum after the breakdown around 24 January 1968. The rocketsonde data of Ft. Sherman indicate a cooling over the tropics simultaneously with the peak of the warming over high latitudes, and a tropical maximum simultaneously with the minimum at high latitudes. The data show clearly that during the major midwinter warmings strong coupling exists between polar and tropical latitudes.

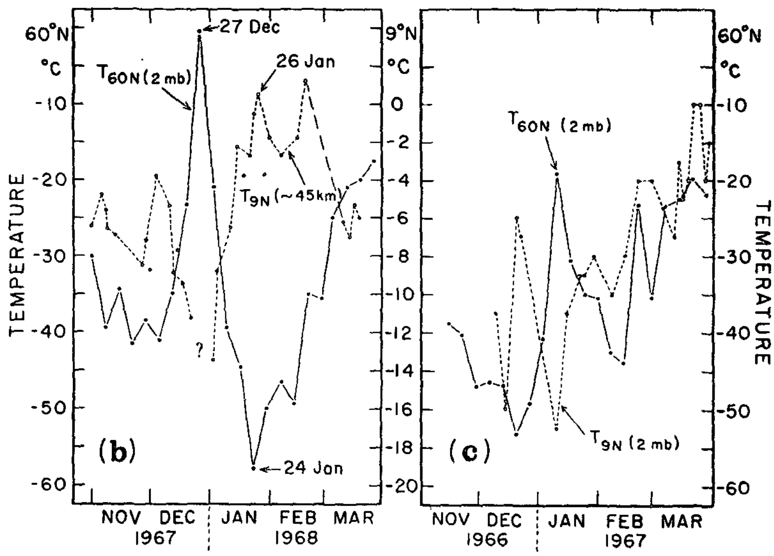
During the winter with a minor warming, 1966/67 (Fig. 1c), cooling over the tropics together with warming over high latitudes was still evident. But as no breakdown of the polar vortex took place, the late-winter cooling at high latitudes was only moderate, and the simultaneous warming in the tropics was not pronounced.

3. Temperature changes in the vertical

The vertical distribution of the temperature changes can be shown by rocketsonde data. For three subpolar stations (Fig. 2a), temperature profiles are plotted for three extreme temperature conditions of the winter 1970/71: I denotes the *early winter* before the beginning of a warming; II, the *peak* of the warming; and III, the late winter *minimum* in February. On the right-hand side the amount and the vertical distribution of the temperature changes between I and II, and between II and III are given. All three stations show a similar pattern with a reversal indicated at 50–55 km.

The corresponding temperature profiles of two tropical stations are shown in Fig. 2b. The temperature changes (right-hand side) are similar for both stations, though different types of rocketsondes were used, and they are opposite to those at high latitudes (Fig. 2a). A reversal of sign at about 55 km is also obvious here.

Further evidence that the vertical changes in Fig. 2 are characteristic for winter with major circulation disturbances is given by Fig. 3. Extreme temperature conditions (I, II, III, cf. Fig. 1b) have been selected as for the winter 1970/71. Two subpolar stations (Fig.



Figs. 1b. and 1c. 2-mb temperatures at 60N (averaged from 170E across North America to 20E) and temperatures around 45 km over Ft. Sherman, Canal Zone (9N, 80W), during the winter 1967/68 (b) and the winter 1966/67 (c).

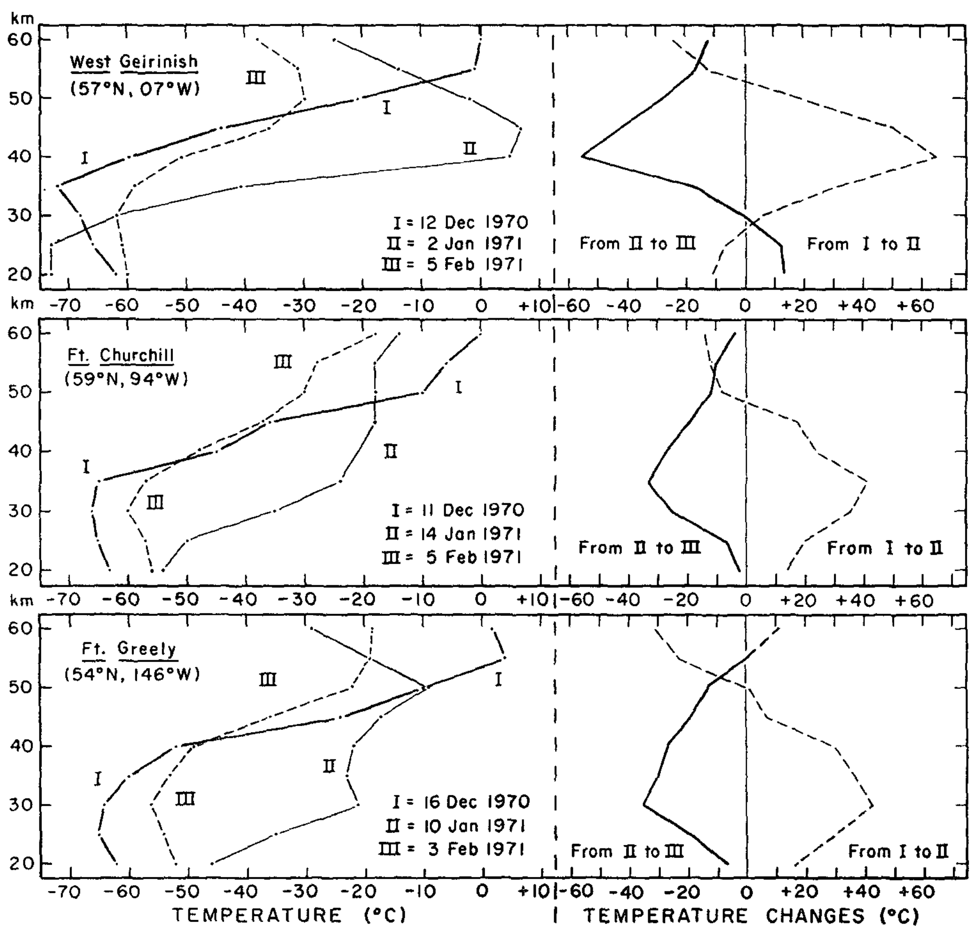


Fig. 2a. Typical vertical temperature profiles at three subpolar stations for the winter 1970/71: I, early winter before the beginning of a warming; II, approximately at peak of warming; III, late winter minimum. Also changes between I and II, and between II and III.

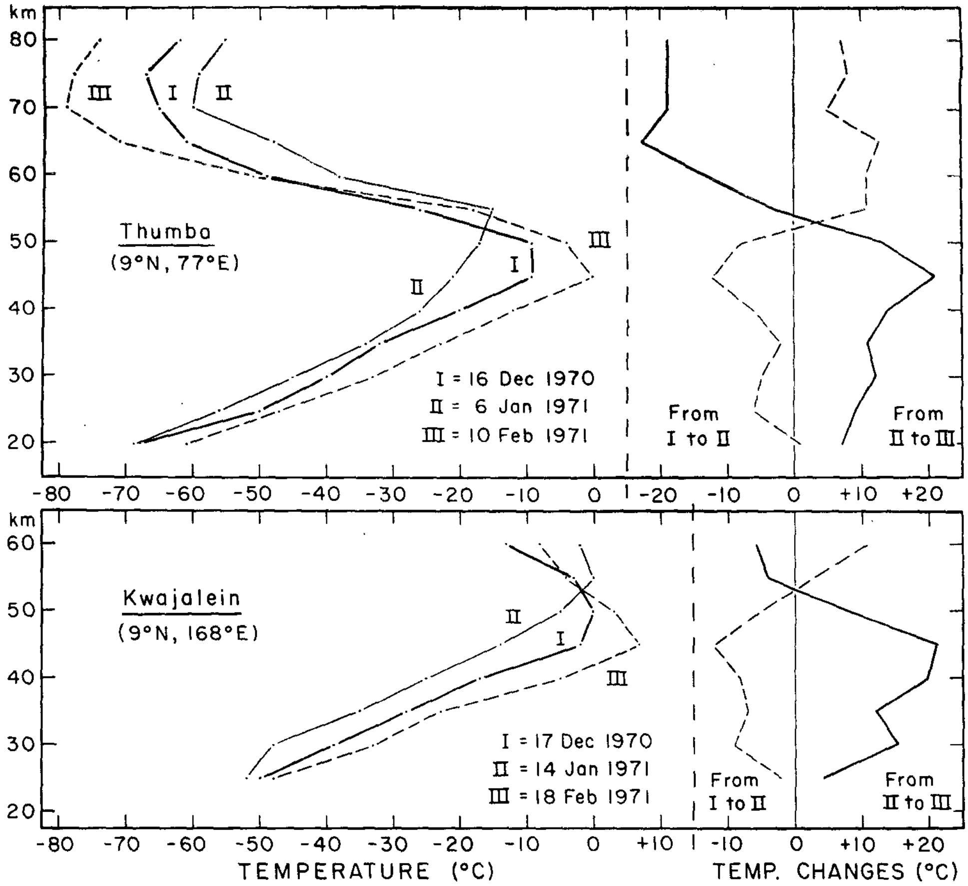


FIG. 2b. As Fig. 2a, but for two tropical stations, Thumba, India (Russian instrument) and Kwajalein, Marshall Islands (American instrument), for the winter 1970/71.

3a and b) are compared with a tropical station (Fig. 3c). The vertical distributions of the temperature changes between the extremes of the winter 1967/68 are similar to those of the winter 1970/71, the opposite trend between high and low latitudes is evident, as well as the reversal of sign at 50–55 km.

4. Comparison with temperature changes in the mesosphere

Most small meteorological rockets reach only heights of about 60 km. But the Russian rockets launched in Thumba, India, and the rocket grenade experiments in Pt. Barrow, Alaska, and Ft. Churchill, Canada, give temperatures for the whole mesosphere.

The three soundings at Thumba from the winter of 1970/71 in Fig. 2b are repeated in Fig. 4b. For higher latitudes in the winter of 1970/71, only the data of one experiment (Pt. Barrow; 71N, 157W) were available. It was, however, carried out on 7 January 1971, which is within the period of maximum warming of the arctic stratosphere. Therefore, this sounding has been used as profile II in Fig. 4a. It clearly shows the cold upper mesosphere postulated by Leovy (1964), Quiroz (1969) and Labitzke (1972). For comparison, an *early winter* profile (20 November 1968) and a late winter profile (1 February 1968) from Ft. Churchill had to be used. These profiles can be assumed to be fairly representative of early winter in general and of the recooling in late winter after a major midwinter warming, as the warming in 1967/68 was comparable in intensity and scale to the one in 1970/71 (Figs. 1a and 1b).

Comparing Figs. 4a and 4b, the opposite changes between stratosphere and mesosphere and between high and low latitudes are apparent. The region of sign changes lies between 50 and 55 km, and this must be the pivotal level for the interaction between stratosphere and mesosphere in winter.

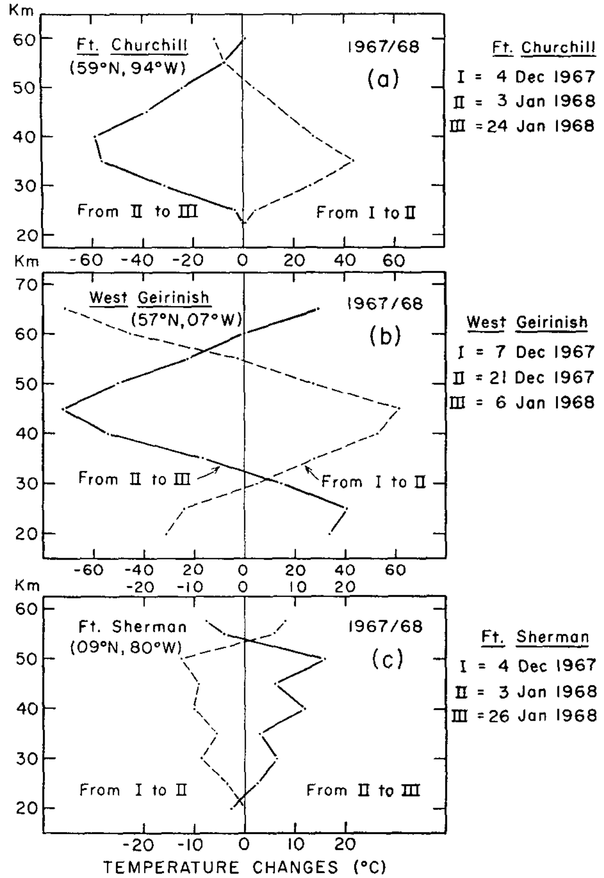


Fig. 3. Vertical distribution of temperature changes at two subpolar and one tropical stations for the winter 1967/68. Same notation as in Fig. 2.

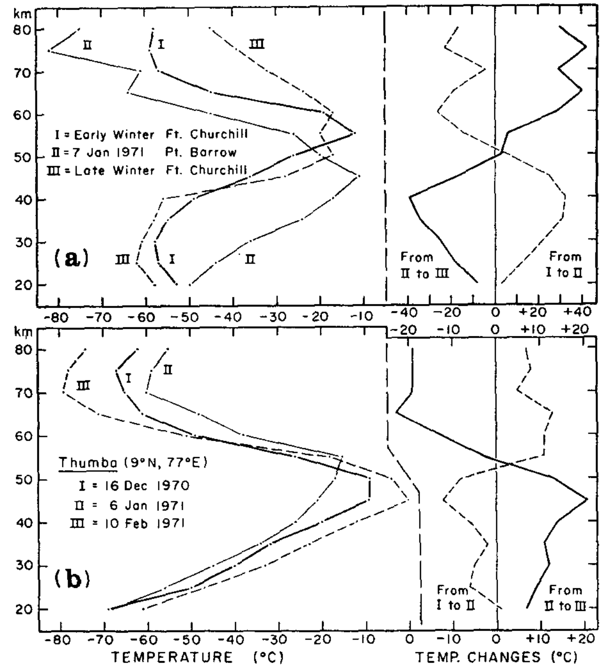


Fig. 4a. Vertical temperature profiles: I, early winter (20 November 1968), Ft. Churchill; II, peak of warming (7 January 1971) Pt. Barrow; III, late winter minimum (1 February 1968) Ft. Churchill. Also the changes between I and II, and between II and III. Fig. 4b. Vertical temperature profiles for Thumba, India, for the winter 1970/71.

REFERENCES

Abel, P. G., P. J. Ellis, J. T. Houghton, G. Peckham, C. D. Rodgers, S. D. Smith and E. J. Williamson, 1970: Remote sounding of atmospheric temperature from satellite, Part II. *Proc. Roy. Soc. London*, **A320**, 35–55.

Ellis, J. P., G. Peckham, S. D. Smith, J. T. Houghton, C. G. Morgan, C. D. Rodgers and E. J. Williamson, 1970: First results from the selective chopper radiometer on Nimbus 4. *Nature*, **228**, 139–143.

Fritz, S., and S. D. Soules, 1970: Large-scale temperature changes in the stratosphere observed from Nimbus 3. *J. Atmos. Sci.*, **27**, 1091–1097.

Labitzke, K., 1972: Temperature changes in the mesosphere and stratosphere connected with circulation changes in winter. *J. Atmos. Sci.*, **29**, 756–766.

——, and H. Schwentek, 1968: Midwinter warmings in the stratosphere and lower mesosphere and the behavior of ionospheric absorption. *Z. Geophys.*, **34**, 555–566.

Leovy, C., 1964: Radiative equilibrium of the mesosphere. *J. Atmos. Sci.*, **21**, 238–248.

Quiroz, R. S., 1969: The warming of the upper stratosphere in February 1966 and the associated structure of the mesosphere. *Mon. Wea. Rev.*, **97**, 541–552.

Staff, Upper Air Branch, NMC, NOAA, 1969: Weekly synoptic analyses, 5-, 2- and 0.4-mb surfaces for 1966. ESSA Tech. Rept. WB-9, 169 pp.

——, 1970: Weekly synoptic analyses, 5-, 2- and 0.4-mb surfaces for 1967. ESSA Tech. Rept. WB-12, 169 pp.

——, 1971: Weekly synoptic analyses, 5-, 2- and 0.4-mb surfaces for 1968. NOAA Tech. Rept. NWS-14, 169 pp.