J. Indian Inst. Sci. 62 (B), Feb. 1980, Pp. 35–41


# Mesospheric influences on linkages between solar activity and lower atmospheric phenomena

RAMANI SESHAMANI*
Department of Aeronautical Engineering, Indian Institute of Science, Bangalore 560 012, India.

Received on November 9, 1979.

**Abstract**

Analyses of rocket data at mid- and high-latitude locations over the American Continent show a solar activity-dependent mesospheric heating effect in the 60 to 90 km altitude region. A study of the altitude dependence of the effect shows that the heating and associated processes propagating downwards through the mesosphere do not cause discernible effects, below the 50 to 60 km layer. At Thumba, a significant short-term heating effect attributable to varying solar ultraviolet fluxes causing variable heating of atmospheric ozone is observed. This effect does not seem to propagate downwards into the upper stratosphere.

**Key words :** Sun-weather relationships, solar activity, mesosphere, upper stratosphere.

## 1. Introduction

The existence of linkages between solar activity and lower atmospheric phenomena has been substantially confirmed by several analyses and observations (see, *e.g.*, King[1], Wilcox[2], for reviews). Such investigations of sun-weather relationships have been carried out for decades now[3], and the growing body of literature on the subject presents practically irrefutable or undeniable evidence of the existence of such relationships. The impetus of investigations and interest in the subject has grown more in recent times, as borne out by the four conferences organised since 1972 on the subject, starting with the Moscow Conference on 'Solar-Atmospheric Relationships in the Theory of Climate and Weather Forecasting'.

One of the suggested[4] mechanisms regarded as a contributory factor in sun-weather effects is downward propagation, through the mesosphere, of the heating effects and

* Present address : ISRO Satellite Centre, Bangalore 560 058.

disturbances from the lower thermosphere which is a strong heat source varying with solar activity. It has been postulated[4] that this variable heating could propagate downwards through the mesosphere and manifest itself within the mesosphere.

The present paper examines whether downward propagation of solar activity-induced disturbances through the mesosphere provides a significant input to the observed solar activity-related lower atmospheric phenomena and variations. This has been studied by analyses of rocket sounding data at three locations: (i) Point Barrow (71° N, 157° W), a high latitude station; (ii) Wallops Island (38° N, 75° W), a mid-latitude station, and (iii) Thumba (8° N, 77° E), an equatorial station.

## 2. Analysis

The analysis was carried out using the correlation method described earlier[5]. An extensive description of the method has been given by the author[6].

The solar activity index considered in the present study is the daily $F_{10.7}$ index. This is based on the 2,800 MHz solar radio flux measured at the Algonquin Radio Observatory, Ottawa and tabulated in the Solar-Geophysical Data Reports[7].

Mesospheric temperatures obtained from several rocket soundings at each location, were taken for the correlation and regression analyses. The data for Point Barrow and Wallops Island have been tabulated in a series of NASA reports by Smith *et al*[8], for 64 soundings over the years 1965–72 at Point Barrow and 121 soundings during 1958–72 at Wallops Island respectively. In the case of Thumba, data were taken from 51 M-100 rocket soundings during the period 1970–71.

The calculation of the correlation and regression coefficients between the temperatures at various altitudes, and the $F_{10.7}$ indices, over a range of time lags relative to the launches, was carried out based on the method described in earlier publications[5,10]. The details are not presented here as they have been described adequately in earlier papers by the author (see, *e.g.*, ref. 11).

The results of the analyses are presented and discussed below.

## 3. Results

Figures 1 to 3 show the variation of the regression coefficient $\Delta T/\Delta F_{10.7}$ in °K $W^{-1}$ $cm^2$ $Hz^{-1}$ over the mesospheric altitude region, 50 to 90 km at Point Barrow, Wallops and Thumba. The black dots represent the $\Delta T/\Delta F_{10.7}$ values, in narrow layers centred at their mid-points, while the horizontal line through each point represents the standard deviation of that value. The figures have been taken for the day relative to the launch at which the corresponding $T$–$F_{10.7}$ correlation was a maximum.

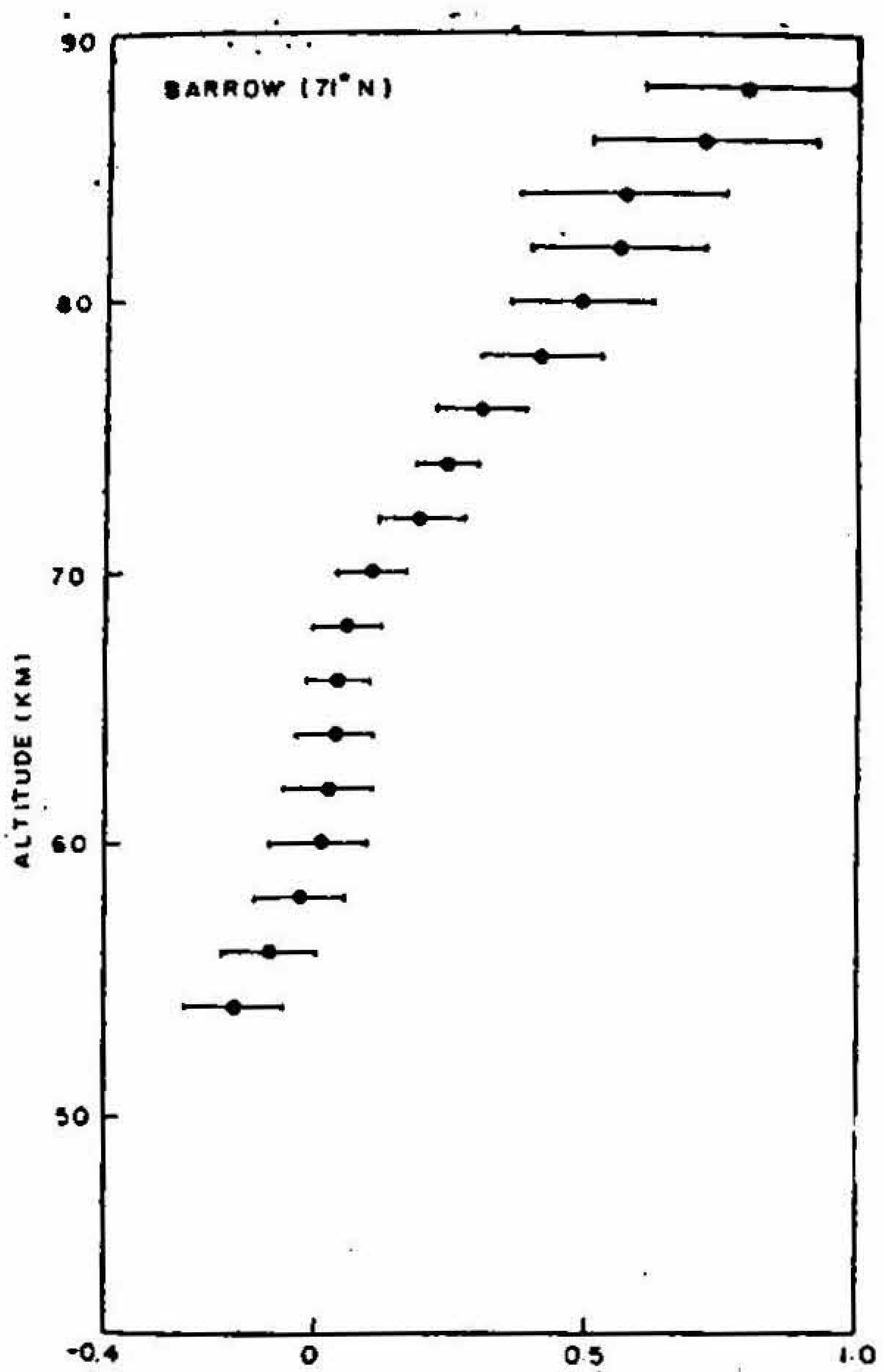


FIG. 1. Altitude variation of the Regression Coefficient $\Delta T/\Delta F_{10.7}$ (° KW$^{-1}$ cm$^2$ Hz$^{-1}$) on D–1 day at Point Barrow (71° N, 157° W).

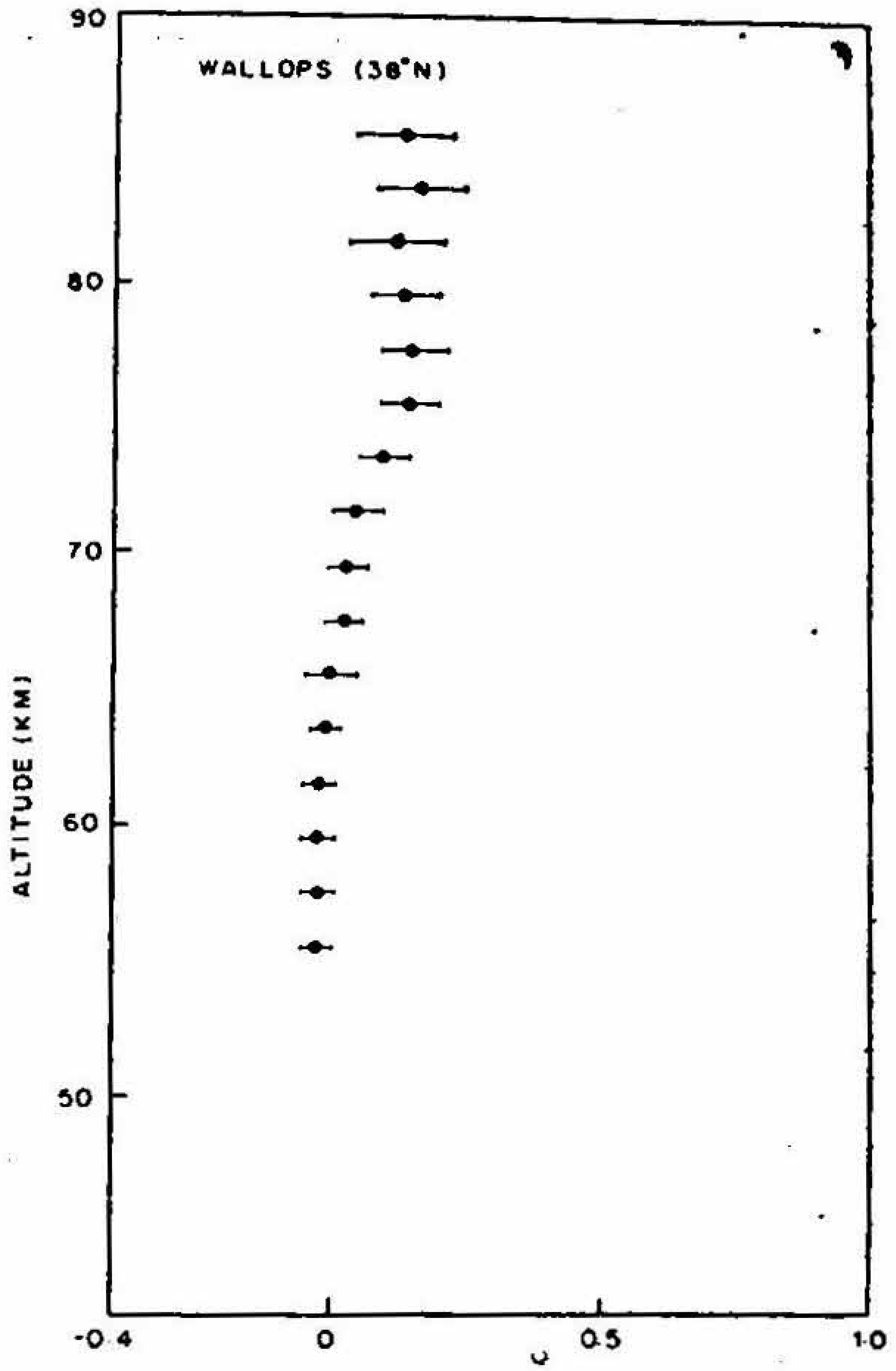


FIG. 2. Altitude variation of the Regression Coefficient $\Delta T/\Delta F_{10.7}$ (°KW$^{-1}$ cm$^2$ Hz$^{-1}$) on D–4 day at Wallops Island (38° N, 75° W).

A common feature in all the figures is the altitude variation of the regression coefficient, from a maximum at high altitudes near the mesopause around 70 to 90 km, reducing to insignificant values in the lower mesospheric region around 50 to 60 km.

*(i) Point Barrow*

Point Barrow (71° N) shows the highest values of $\Delta T/\Delta F_{10.7}$, which were observed to occur at D–1, indicating a time lag of around one day between the time of $F_{10.7}$ enhancement and the subsequent increase in mesospheric temperature. The value is nearly 1° KW$^{-1}$ cm$^2$ Hz$^{-1}$ at around 90 km, and reduces steeply to around 0·2° KW$^{-1}$ cm$^2$ Hz$^{-1}$ at 70 km, below which it drops to near-zero values.

There is also a shift to negative values below 58 km altitude.

*(ii) Wallops Island*

In the case of Wallops Island (38° N), the effect, represented by $\Delta T/\Delta F_{10.7}$ is (*a*) much less than at Barrow, and (*b*) maximises on D–4 day, *i.e.*, with a time lag of around

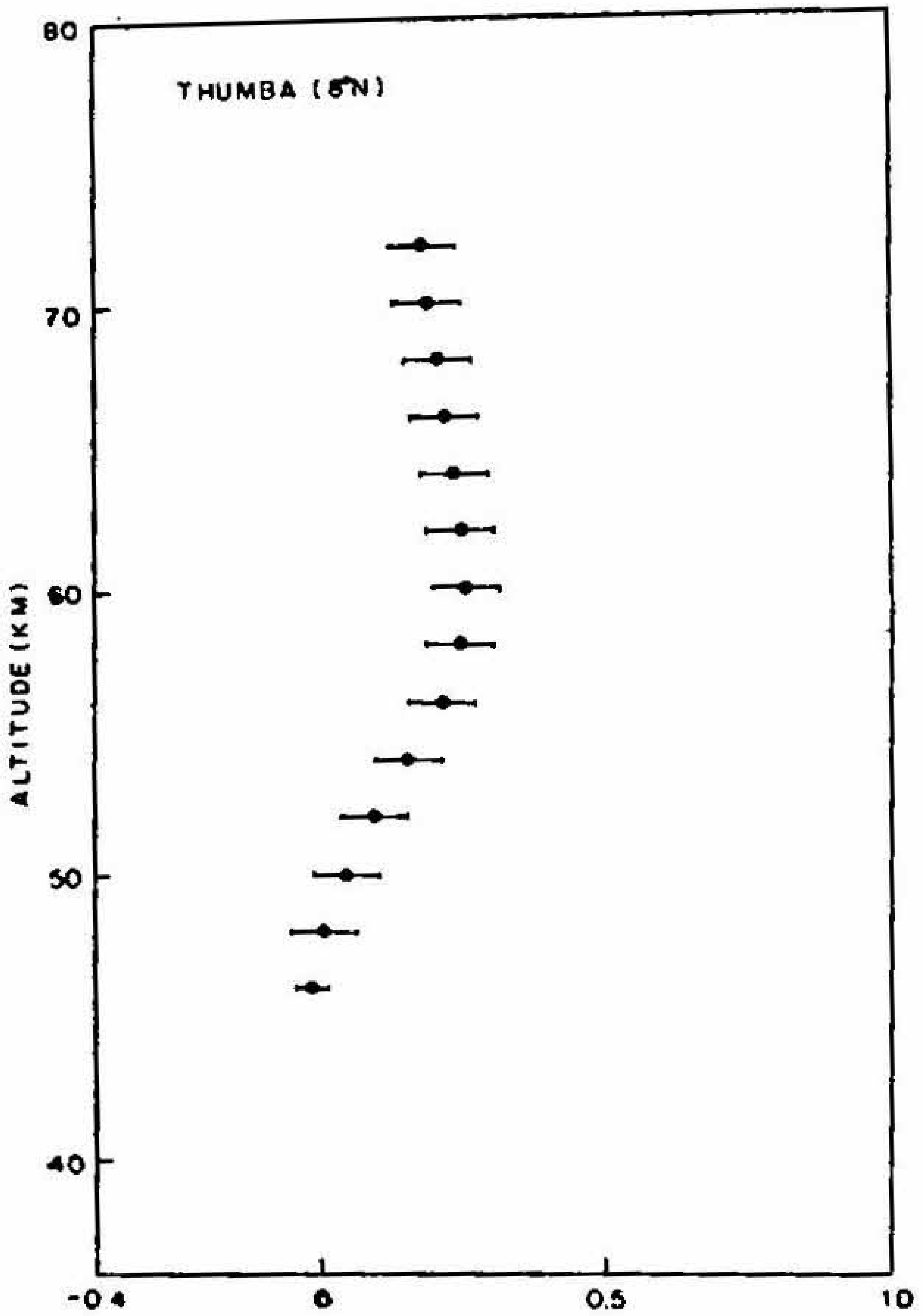


FIG. 3. Altitude variation of the Regression Coefficient $\Delta T/\Delta F_{10\cdot 7}$ (° $KW^{-1}$ $cm^2$ $Hz^{-1}$) on D day at Thumba (8° N, 77° E).

4 days between the day of $F_{10\cdot 7}$ enhancement and the subsequent mesospheric heating.

The maximum value is around 0·2° $KW^{-1}$ $cm^2$ $Hz^{-1}$ at the highest altitudes (85 km) and reduces very gradually to practically a zero value below 60 km.

It is relevant to note here that Point Barrow is a polar latitude station, lying under the auroral electrojet (see for example, Akasofu and Chapman[12]) which is known to intensify substantially in solar-active periods. It is therefore possible to attribute the larger heating effect at Barrow to the nearness of this region to the auroral electrojet current flow, while in the case of Wallops, it being at mid-latitude, situated farther away from the auroral electrojet, the heating effects are weaker and take a correspondingly longer time to occur.

### (*iii*) *Thumba*

At the equatorial station, Thumba (8° N), several differences appear to be present : (*a*) the altitude profile of $\Delta T/\Delta F_{10\cdot 7}$, has a different pattern, with a peak occurring in the middle of the mesospheric region, at around 60 km, and reducing both above and below this altitude, (*b*) the day of maximum heating effect is seem to be the day of launching itself, that is, the major effect is apparently occurring in the same region rather than being caused by transport from the auroral latitudes equatorwards. In the latter case, the time lag should be progressively larger towards the equator, whereas it is less than a day, in the equatorial case while at the mid-latitudes it is 4 days and (*c*) the maximum values are larger than in the case of Wallops Island. All these suggest a different type of effect possibly attributable[6,13], to variable heating due to the absorption of ozone by varying solar ultraviolet fluxes in the wavelength range 2000–3000 Å. The effect also does not appear to be significant below 48 km.

An intercomparison of the three figures shows that the Thumba profile reflects an effect occurring in a different, lower altitude region (50 to 70 km) than that at Point Barrow and to a lesser extent at Wallops Island (70 to 90 km). The lower range of altitudes at Thumba is due inherently to the different sounding method, which gave data in this altitude range—the thermistor method, which is known[10] to develop large inaccuracies above 70–75 km, while the method used at Point Barrow and Wallops Island was the rocket grenade method which is accurate up to 100 to 110 km.

However, in all the cases, the $\Delta T/\Delta F_{10.7}$ value tends to be similar at around 70 km within the range 0–0·2° $KW^{-1}\ cm^2\ Hz^{-1}$. Again, in all the cases, the value tends to become zero or slightly negative, at the lower end of the range of values. It therefore appears that there are two different types of solar activity-induced effects operating at high latitudes and equatorial latitudes. In the former case, the effect being mainly due to the auroral electrojet heating[6,12] the heating effect is propagated downwards into the mesosphere but becomes small below 60 km. Other effects, appearing to give negative values of $\Delta T/\Delta F_{10.7}$ below 56 km, also seem to be present.

In the equatorial region, the effect seems to be an *in situ* type, caused by variable solar ultraviolet heating of ozone in the region. However, even in this case, the effect does not seem to be significant below 48 km altitude.

The results of the present analysis thus seem to indicate that the phenomena of sun-weather relationships are, most likely, caused by *in situ* mechanisms in the stratosphere and troposphere, such as those suggested by Roberts and Olson[14], Markson[15], Hines and Halevy[16], Dickinson[17] and, recently by Herman and Goldberg[18], rather than by solar activity-induced disturbances propagating downwards through the mesosphere into the lower atmosphere.

## 4. Conclusions

The role of the mesosphere as a connecting link for propagation of disturbances downwards from the mesosphere into the lower atmosphere has been examined in this paper. An analysis of the mesospheric temperature response to solar activity, from rocket sounding data at three (high, middle and equatorial latitude) stations has shown the presence of heating effects in the mesosphere due to solar activity.

In the high and mid-latitude cases, the effect seems to be linked to the intensity of heating in the auroral electrojet region, the heating being significant only in the 70 to 90 km region and not below this layer. In the equatorial latitudes, the effect appears to be linked to the variable solar ultraviolet heating of atmospheric ozone and is significant only in the 50 to 70 km layer.

While further light would no doubt be thrown on the question of the propagation of these effects into the stratosphere, the results available at present seem to indicate that the observed sun-weather relationships are more probably due to effects occurring *in situ* in the stratosphere and troposphere.

## Acknowledgements

Thanks are due to the authorities of the Indian Institute of Science for providing facilities for the work and to the referees for their useful suggestions.

## References

1. KING, J. W. — *Astronaut. Aeronaut.*, 1975, **13**, 10–19.
2. WILCOX, J. M. — *J. Atmos. Terr. Phys.*, 1975, **37**, 237–256.
3. SHAPLEY, A. H. AND KROEHL, H. W. — *Solar-terrestrial physics and meteorology: working document II*, SCOSTEP, Washington, D.C., 1977.
4. KELLOGG, W. W. — In *Possible relationships between solar activity and meteorological phenomena* (W. R. Bandeen and S. P. Maran, eds.), NASA Report No. X-901-74-156, 1974, pp. 365-382.
5. RAMAKRISHNA, S. AND SESHAMANI, R. — *Planet. Space Sci.*, 1973, **21**, 1447-1453.
6. SESHAMANI, R. — *Ph.D. Thesis*, Indian Institute of Science, Bangalore, 1976 (unpublished).
7. U.S. Department of Commerce — *Solar-Geophysical Data—Prompt Reports*, 1961-1972. (Prior to 1966 titled as CRPL Reports).
8. SMITH, W. S. *et al.* — *NASA Tech. Rept. Nos. TR R*-211 (1964), -245 (1966), -263 (1967), -288 (1968), -316 (1969), -340 (1970), -360 (1971), -391 (1972), -416 (1974).
9. FEDINSKY, A. V. AND PISHAROTY, P. R. — Paper presented at the XIV COSPAR Meeting, Seattle, 1971.
10. RAMAKRISHNA, S. AND SESHAMANI, R. — *J. Atmos. Terr. Phys.*, 1973, **35**, 1631-1641.
11. SESHAMANI, R. — *Space Research XVIII*, Pergamon Press, Oxford, 1977, pp. 141-146.

12. Akasofu, S. I. and Chapman, S. — *Solar Terrestrial Physics*, Clarendon Press, Oxford, 1972.

13. Ramakrishna, S. and Seshamani, R. — *Space Research XVII*, Pergamon Press, Oxford, 1977, pp. 135–139.

14. Roberts, W. O. and Olson, R. H. — *J. Atmos. Sci.*, 1973, **30**, 135–140.

15. Markson, R. — In *Possible relationships between solar activity and meteorological phenomena* (W. R. Bandeen and S. P. Maran, eds.), NASA Report No. X-901-74-156, 1974, pp. 272–285.

16. Hines, C. O. and Halevy, I. — *Nature*, 1975, 258, 313–314.

17. Dickinson, R. E. — *Bull. Am. Met. Soc.*, 1975, **56**, 1140–1248.

18. Herman, J. and Goldberg, R. — *Weather and Climate*, NASA Special Publication, SP-426, 1978.

19. Pittock, A. B. — *Rev. Geophys. Space Phys.*, 1978, **16**, 400–420.