Indian J. Met. Hydrol. Geophys. (1978), **29**, 4, 671-674

551.590.21 : 550.386 : 551.524 (540)

Possible linkage between solar and geomagnetic activity and upper atmospheric phenomena

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(*Received 20 April 1977*)

ABSTRACT. Solar flare effect on the upper atmosphere has been studied by examination of the geopotential height changes of 500, 300, 200 and 100 mb levels over Delhi and Trivandrum, following 9 solar flares of importance $\geqslant 2$ in the winters of 1971 and 1972. There is a change in the geopotential height in low latitudes following a solar flare. Temperature height profiles derived from the meteorological rocket observations over Thumba reveals that a major flare of 2 August 1972 caused a temperature change of nearly 18°C in the height range of 66 to 78 km. Geopotential height changes in the different constant pressure levels over Delhi and Trivandrum following enhanced geomagnetic activity with $\Sigma K_p > 20$, suggest that this effect is manifest even in low latitudes. Cross spectrum analysis of the 10·7 cm solar flux and 100 and 50 mb temperatures over Delhi and Trivandrum do not indicate any relationship between the cyclicities in the solar flux and atmospheric parameters.

1. Introduction

A large number of papers have been published during the last 100 years on the subject of influence of solar activity on weather. Schuurmans (1965) computed the change in height of 500 mb level associated with 53 flares of importance 2. He found a symmetric change in height with reference to geomagnetic rather than to geographic pole. In his subsequent paper Schuurmans (1969) made an exhaustive study by considering the effect of solar fluxes on the geopotential height changes at levels from 500 to 200 mb and found a maximum height rise near tropopause in mid and higher latitudes. Cole (1975), Stranz (1959) and Rasool (1961) correlated the height of tropopause to solar activity at a number of low latitude stations. Mikhnevich *et al.* (1976) examined the change in geopotential height of 10 mb level in northern hemisphere including low latitudes in relation to geomagnetic activity.

The situation to day is that there are no generally accepted conclusions nor has any working mechanism been proposed that can be considered physically sound. In the present paper an attempt has been made to investigate the possible tropospheric effects of solar and geomagnetic activity in low latitudes, in the Indian region.

2. Atmospheric effect of solar flares

A selection has been made of 9 solar flares (Table 1) of importance $\geqslant 2$ observed beteween Longs 0° and 140°E in the interval 0 to 12 UT in the winter months of 1971 and 1972. From the radiosonde observations, the geopotential heights of the constant pressure levels 500, 300, 200 and 100 mb over Delhi (28°38′N, 77°13′E) and over Trivandrum (8°33′N, 76°52′E) have been computed for all flare days and for **3** days before and after the flares.

Trivandrum and Delhi have been chosen in this study, as at these locations we have the radiosonde observatory in the lowest and highest latitudes in Indian region and Srinagar observations were not very regular. As the 12 UT observation is the one that immediately follows the occurrence of the flare, only 12 UT observations are considered here, so that diurnal variation is eliminated; for if the 0 UT observations are also taken in the computation, the temperature variation in the upper atmosphere from 12 UT to 0 UT which normally takes place as part of the diurnal variation, vitiates the temperature effect due to the flare. The 24-hr geopotential height changes $(\triangle H)_n$, where n takes the values −3, −2, −1, 0, 1, 2 and 3 are computed (n=0 being the flare day). Here observations pertaining to each value of n, precedes the observation 24 hr later and thus succeeds the 24 hr earlier observation. Mean $\overline{(\triangle H)}_n$ is computed for the seven values of n, taking the effects of all the flares. Fig. 1 plots $\overline{(\triangle H)}_n$ for different millibaric levels over Trivandrum and Delhi.

It is seen from Fig. 1 that the heights of 500 and 300 mb levels are reduced by 12 gpm over Delhi

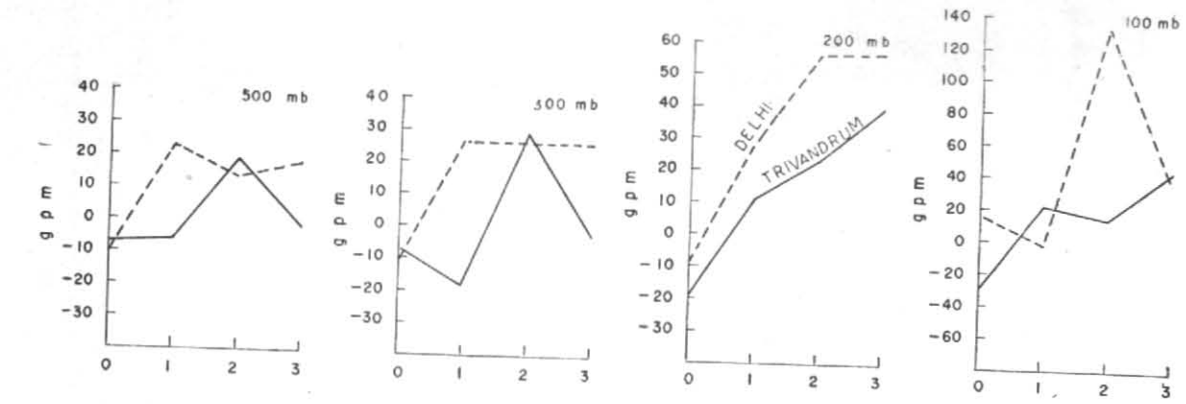

Fig. 1. Mean 24-hr geopotential height changes between the first observation at 12 UT after a flare and the observation 24 hr earlier of the 500, 300, 200 and 100 mb levels on the day of the solar flare and on 3 days after solar flare

TABLE 1

Characteristics of 9 selected flares of importance ≥2

Date	H_α flare			Importance	Source
	Start	End	Max.		
16 Jan 1971	0804	1050	0830	3F	Solar Geophysical data
2 Nov 1971	0428	0608	0504	2F	Do.
3 Dec 1971	0125	0230	—	2N	Do.
18 Dec 1971	0235	0600	0305	2B	Do.
14 Jan 1972	0626	0655	0636	2N	Do.
22 Jan 1972		0613	0545	2B	Do.
13 Feb 1972	0329	0906	0832	3B	Do.
15 Feb 1972	0331	0454	0415	3B	Do.
17 Feb 1972	1054	1107	1054	2B	Do.

Time in UT

and 8 gpm over Trivandrum. At 200 mb the decrease is 9 gpm over Delhi and 20 gpm at Trivandrum, but at 100 mb over Delhi there is an increase while at Trivandrum there is a decrease. The changes in heights between 500 and 100 mb levels were reported by Schuurmans (1969) to be between 5 and 45 gpm which are higher and may be due to latitudinal effect.

The flare effect changes sign on subsequent days over Delhi, the $(\overline{\triangle H})_n$ is positive for days $n=1$, 2 and 3 for all levels and for Trivandrum it is confined to 200 and 100 mb levels. The maximum positive height change is seen after one day over Delhi and after 2 days over Trivandrum for levels 500 and 300 mb. For 200 and 100 mb it is on the second and third day respectively.

3. Atmospheric effect of a "major flare"

On 2 August 1972 there were two flares of importance 3 N and 2 B between 03 and 08 UT (Hakura 1976 and Simnett 1976) but one observed at 0315 UT (Rao 1976) was declared a major flare of importance 3 N with X-ray and energetic particle emission. This big flare was also accompanied with major radio outbursts (Hakura 1976) and high energy flux and mass ejection (Dryer *et al.* 1976). The proton burst was detected on the earth as well on board the satellite pioneer 9, in two energy ranges $E_p > 10\mu$ and $>60\mu$. It was of a slowly developing type, rich in low energy protons (Hakura 1976 and Rao 1976). Fortunately, on that day there was a weekly meteorological rocket launching over Thumba in

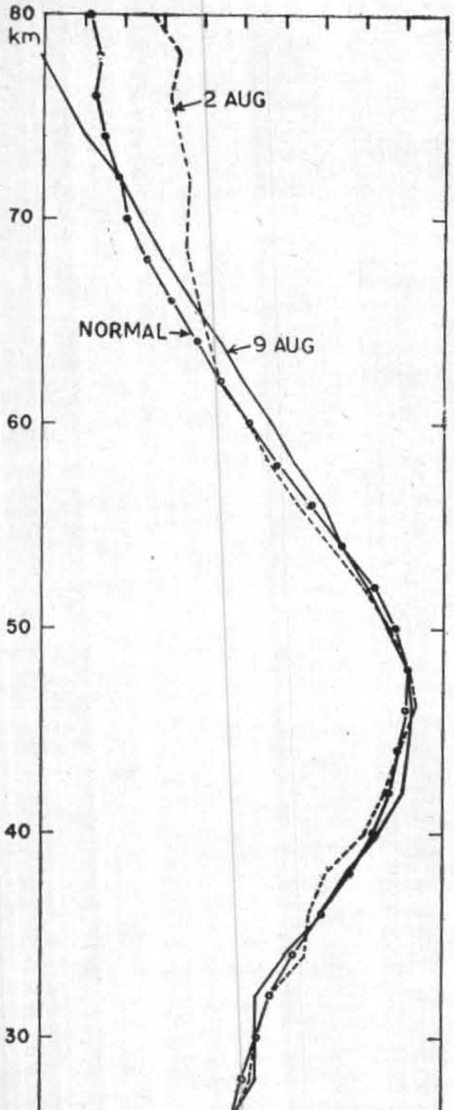

Fig. 2. Vertical profiles of temperatures from 10 to 80 km on the day of a major flare, 7 days after the flare and average profile for the month

the evening. Taking all rocket observations of tem peratures in August during 1971 and 1972 an average height profile of temperature has been constructed. Fig. 2 depicts this height profile on 2 August 1972, the day of the flare, 9 August for the first available observation just after the flare and the average profile. All the profiles are similar up to 66 km. Beyond this height the temperature on 2 August increases with a maximum increase of 18°C above normal at 78 km.

4. Tropospheric effect of geomagnetic activity

The possible linkage between the geomagnetic activity and upper atmospheric height changes has been examined by considering the height changes for 5 consecutive days before and 5 consecutive days after a day of significant geomagnetic activity. The day of significant geomagnetic activity is taken a day on which the planetary magnetic Index $\Sigma K_p > 20$. The height changes for levels 500, 300, 200 and 100 mb have been computed, by superposed epoch method for 36 geomagnetic storms. Fig. 3 plots these height changes for 5 days before and 5 days after key day.

Over Delhi ($\triangle H = -10$ gpm) the effect is seen after 3 days of the key day, but over Trivandrum ($\triangle H = +4$ gpm) it is seen after 2 days at 500 mb. It indicates that even at 8°N, there is some, though small, response from the upper atmosphere. The change increases with altitude.

5. Spectral analysis

In order to see if any cyclic variation in solar activity induces a cyclicity in the upper atmospheric changes, a cross spectral analysis was made of the solar 10·7 cm flux and the 100 mb and 50 mb temperatures over Delhi and Trivandrum. No positive result was obtained.

6. Conclusion

The following conclusions are made based on the observational evidence presented in this paper :

(*i*) Solar flares with intensity $\geqslant 2$ and geomagnetic storms with $\Sigma K_p > 20$ produce changes in the upper atmosphere in the low latitude also.

(*ii*) Large changes in the mesospheric temperatures are observed in association with a 'major' flare having X-ray and energetic particle emission.

(*iii*) Cross spectral studies of solar 10·7 cm flux and upper atmospheric temperatures reveal no relationship.

The results presented in our paper are in agreement with what Schuurmans has reported.

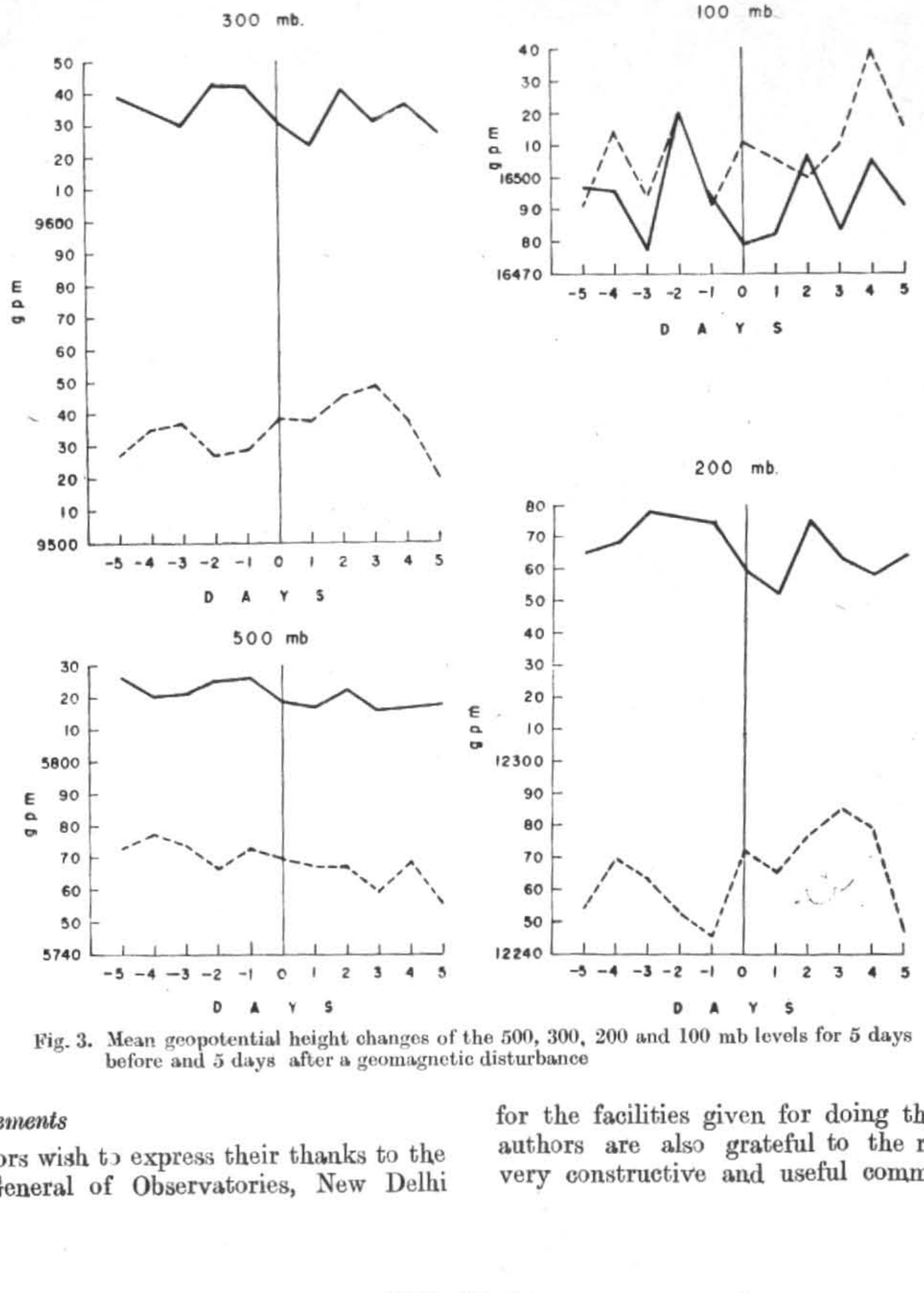

Fig. 3. Mean geopotential height changes of the 500, 300, 200 and 100 mb levels for 5 days before and 5 days after a geomagnetic disturbance

Acknowledgements

The authors wish to express their thanks to the Director General of Observatories, New Delhi for the facilities given for doing this work. The authors are also grateful to the referee for his very constructive and useful comments.

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