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Magnetic storm and solar flux effects on IEC in American zone

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Abstract : The variations of ionospheric electron content (IEC), obtained by Faraday rotation measurements of 136 MHz transmissions at Palehua (20.7°N, 203.7°E), Boulder (40°N, 254.7°E) and Anchorage (61.2°N, 210.1°E) have been studied during magnetic storms for the low solar activity period 1984. It has been observed that the variations of IEC occur in both positive and negative phases of magnetic storm for all the three locations. They do not bear any clear relationship either with the magnitude of the geomagnetic storm or with the main phase onset (MPO) of the storm. Often variations of IEC are observed before MPO and it shows maximum variation at low latitude (Palehua) while this is less pronounced at mid latitude (Boulder) and high latitude (Anchorage). Effect of Sa (solar flux) on maximum IEC (IEC_{max}), shows the increase of IEC_{max} with respect to Sa at all three stations. This increase in IEC_{max} is more pronounced during the equinoxial months.

Keywords : Ionospheric electron content, solar flux, magnetic storm.

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Ionospheric storm effects have been studied by many workers [1–4] using foF_2 and ionospheric electron content values. It is reported that in association with geomagnetic storm especially during the main phase onset, large variation in IEC are observed. These observations referring to middle and high latitudes are generally interpreted in termss of electric field and neutral winds of polar and auroral region [5]. However, the response of the ionosphere to an individual geomagnetic storm in the case for which sudden storm commencement (SSCs) or MPOs occurs during day time, would be a positive phase in the afternoon of the same day followed by a negative phase and these storm would be termed as a regular storm. If SSC or MPO occur after dusk, either no positive phase is seen or only a negative phase is seen could be termed as 'No' storm and if the positive phase is delayed and seen next day afternoon termed as 'Deleyed' positive storm [6].

Kane [7–8] showed that there are considerable variation from storm to storm, so much so that the average pattern claimed *viz.* decreases at the mid latitudes and increases at low latitudes, is violated more often. No one wonders whether there is any systematic behavior at all. This study has been designed to investigate the response of the ionosphere at low, mid and high latitudes to the severity (explained by the horizontal component of the earth magnetic field *H*) of the ionospheric storm.

In the present study, the IEC data taken at Palehua (20.7°N, 203.7°E), Boulder (40°N, 254.7°E) and Anchorage (61.2°N, 210.1°E) through Faraday rotation method using 136 MHz transmission are used for few selected geomagnetic storms that occurred during 1984. For this purpose, we have considered the storm which occurred on 28th March, 24th May, 20th Oct and 28th Dec. ΔN_T daily variation pattern against universal time (U.T.) have been studied for the three stations over a period of 5 days commencing a day before the MPO and lasting for four days subsequent to the MPO of the storm. The ΔN_T is the deviation of the IEC from monthly median. We have also

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shown corresponding AE (auroral electrojet index) value and Dst (disturbance storm time index). The MPO has been indicated by an arrow. For convenience of expressions, the day of MPO will be denoted by day-0 and subsequent day as day-1, day-2 *etc.* The effect of *Sa* on maximum IEC (IEC_{max}) has been studied for all the three locations during 1984.

Storm of 28th March 1984 :

Figure 1(a) shows the variation of ΔN_T for 27-31st March, 1984, the MPO occurred on 28th March at 2200 hrs U.T., on day-0 a large positive of IEC variation is observed at Boulder around 2200 hrs, after MPO occur it shows a large positive phase variation in IEC. Palehua shows a negative phase followed by positive phase while Anchorage shows a negative phase. On day-1 Palehua show a negative peak around 0100 hrs and later a positive peak around 0600 hrs, while value of N_T at Boulder remains positive till 1400 hrs, and Anchorage shows a negative phase. On day-2 and day-3 at Palehua large positive peaks have been observed. Before MPO Boulder, Anchorage and Palehua show positive phase variation in IEC.

Storm of 24th May 1984 :

Figure 1(b) shows the plot of ΔN_T for23-27th May 1984, the MPO occurred on 24th May around 1000 hrs U.T. On day-0 ΔN_T shows a positive phase till 1800 hrs while later negative phase has been observed at palehua and Anchorage. IEC values remain in positive phase at Boulder On day-2 a large positive phase at Palehua is observed around 0200 hrs U.T., which more or less remains same in magnitude after going down at 1500 hrs and it again shows a large positive peak around 0200 hrs U.T. on day-3. Before MPO Palehua shows positive phase while Boulder and Anchorage show negative phase.

Storm of 18th October 1984 :

Figure 2(a) shows the plot of ΔN_T for 17-21st Oct. 1984; on the day-0 the MPO occurred at around 1052 hrs U.T After MPO a negative phase is observed at all three stations, which is very small at Anchorage and large at Palehua. After attaining normal values around 0400 hrs U.T. On day-1, the ΔN_T again shows large negative phase at Palehua around mid-night of day-1, which comes to normal value around 0400 hrs U.T. A positive phase of ΔN_T values has been observed at Palehua on day-2 around 1800 hrs U.T. Before MPO Palehua and Boulder show large negative variation while Anchorage shows first a positive and then negative variation in ΔN_T.

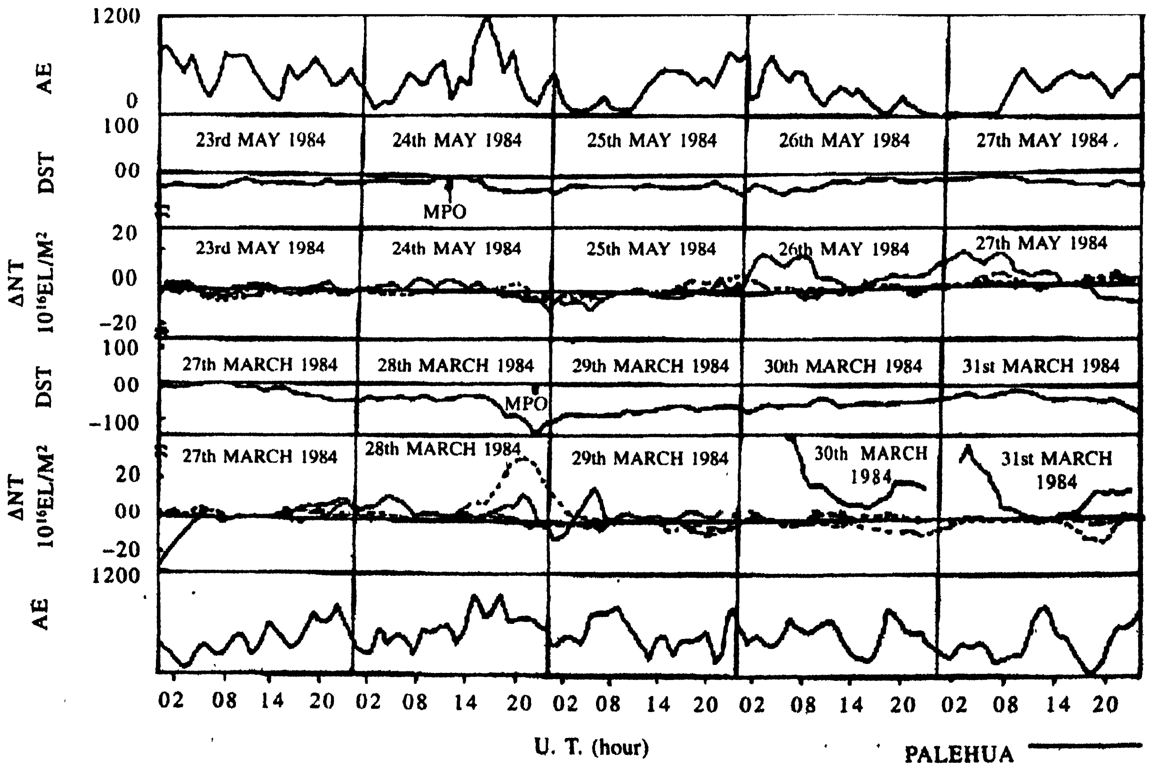

Figure 1. Variation of ΔN_T (a) for 27-31 March 1984 and (b) for 23-27 May 1984

Storm on 26th December 1984 :

Figure 2(b) shows the plot ΔN_T of for 25-29th Dec. 1984. The MPO occurred at around 0800 hrs U.T. On day-0, the ΔN_T variations at all three locations remain normal till 1800 hrs U.T. At around 2000 hrs U.T., a large positive phase of ΔN_T has been observed at Palehua, which is comparably less pronounced at Boulder and Anchorage. On day-1 and day-2 not much significant variation is observed. Before MPO Palehua shows large positive variation.

The following points are noteworthy during all four-storm days described above :

(i) During all the four storm days mentioned above, the IEC values at Palehua are generally observed with large negative or positive phase variations. Except on storm on 28th March 1984 when Boulder IEC values shows a quite large positive phase variation compared to other two stations.

(ii) After the MPO, the AE index has been found to show the maximum peak, except on 28th March storm when the Boulder IEC shows a large positive peak.

(iii) On 18th October 1984, storm Palehua shows positive peaks around midnight of day-0, day-1 and day-2. On 26th December 1984 storm Palehua shows the positive peaks at around midnight before MPO and on day-0 and on day-1.

During all the four storm day, low latitude station shows large variation of IEC except on 28th March whereas it shows minimum at high latitude.

The variation of diurnal maximum IEC (IEC_{max}) with 10.7 cm solar flux has been studied for all the three stations during 1984. Figure 3 and Figure 4 show the diurnal IEC_{max} observed at these stations plotted against 10.7 cm solar flux of the same day measured in W/m²/cycle/sec. The Summer, Equinox and Winter values have been shown by dots, cross and triangles respectively. Season wise variations of *Sa* and corresponding variation of IEC_{max} for 1984 at all the three stations can be inferred from Table 1. The main features are :

(i) The IEC_{max} has been found to increase at all the three stations in all the seasons with *Sa*.

(ii) The increase is more pronounced during equinoxial months at all the stations.

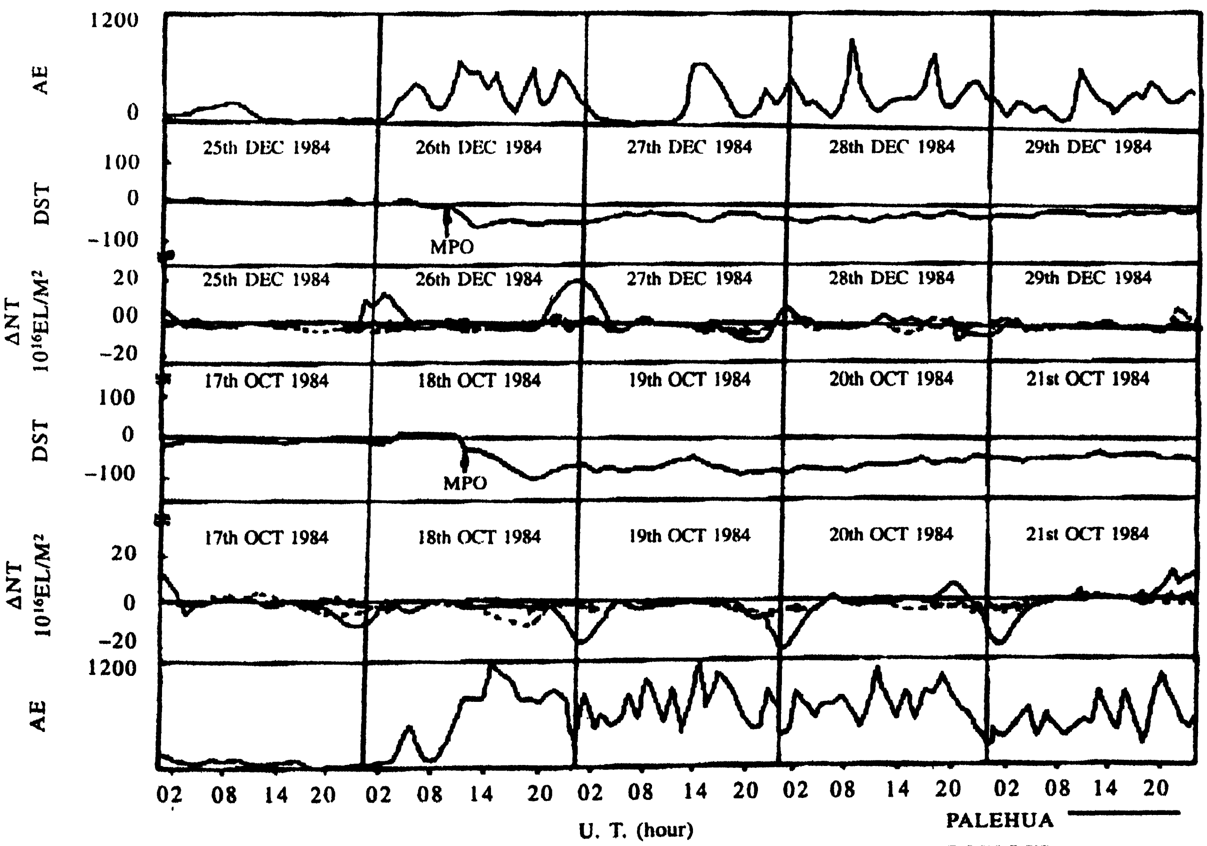

Figure 2. Variation of ΔN_T (a) for 17-21 October 1984 and (b) for 25-29 December 1984

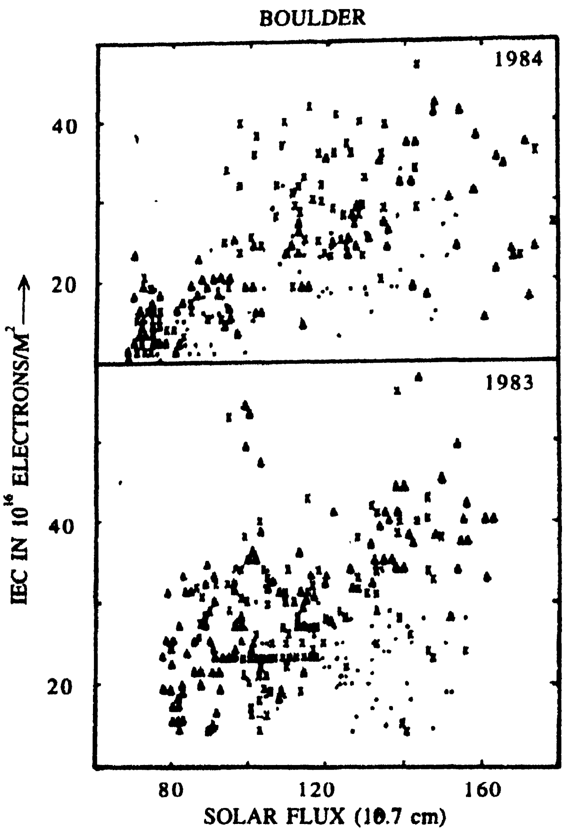

Figure 3(a). Variation of IEC with 10.7 cm SOLAR FLUX

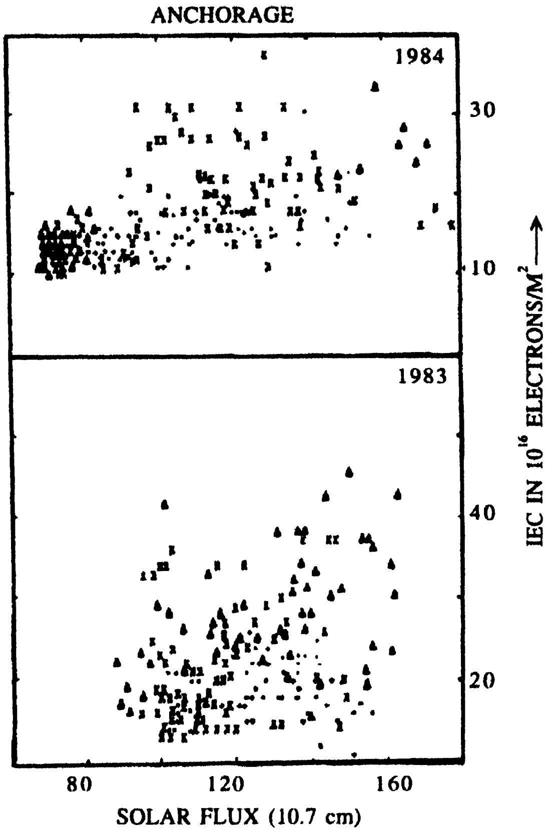

Figure 3(b). Variation of IEC with 10.7 cm SOLAR FLUX

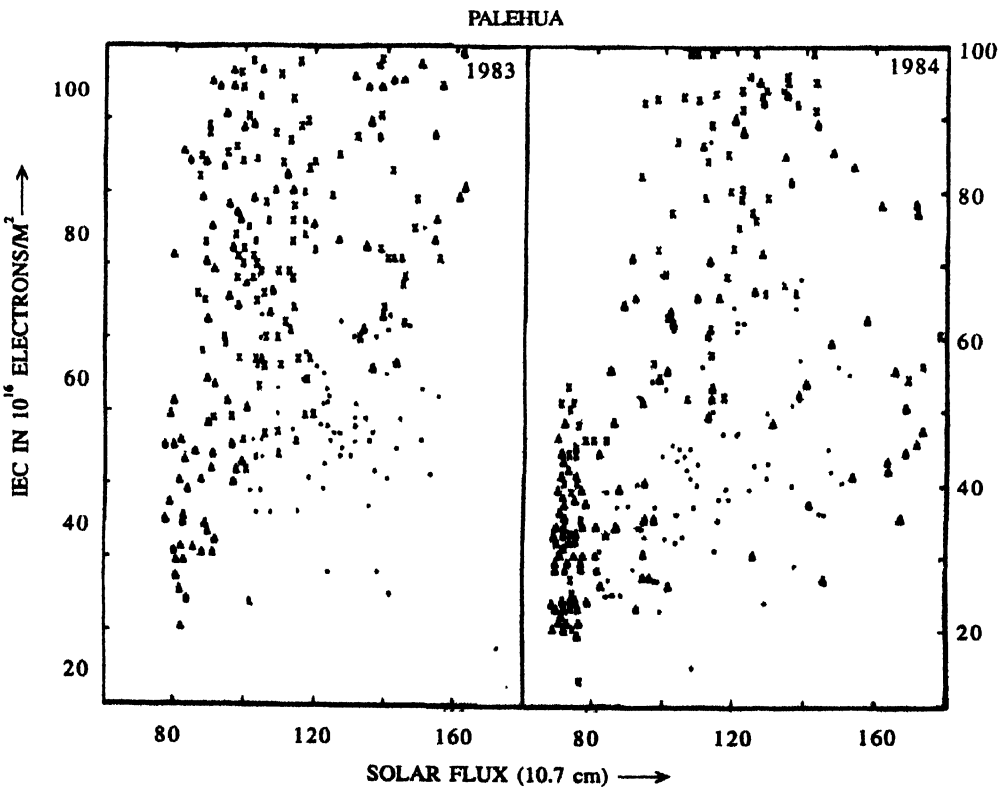

Figure 4. Variation of IEC with 10.7 cm SOLAR FLUX

(iii) Since the plots include IEC_{max} on disturbed days also, there is a scatter variation in IEC_{max} for the same solar flux and season (Table 1).

(iv) The variation of IEC_{max} with *Sa* is more pronounced at low latitude than at high latitude.

(v) The correlation coefficients of IEC_{max} and *Sa* at Palehua, Boulder and Anchorage have been calculated seasonally (Table 1). It may be inferred from table that the correlation are less than 0.3 and it connot be considered good, but the variation of correlation coefficient is in good agreement at all three stations, while in summer the values are poorer.

Table 1. Season wise variations of *Sa* and corresponding variation of IEC_{max} for 1984.

Seasons	*Sa* 1984			Year	Variation of IEC_{max} 10^{16}el/m^2			Correlation coefficient		
	Palehua	Boulder	Anchorage		Winter	Summer	Equinox	Winter	Summer	Equinox
Winter	103	103	103	1984	19–95	15–48	13–99	0.27	0.17	0.24
Summer	78	78	78	1984	10–42	10–34	10–50	0.30	0.15	0.28
Equinox	112	112	112	1984	10–33	10.5–31	10–37	0.31	0.09	0.23

It has been difficult to develop any unique theory that can explain the ionospheric responses at all latitudes for storms in general. Electrodynamical drifts, meridional winds, rapid changes in atmospheric heating and thermal expansion *etc.* have been invoked [9–12] with different degrees of success to suit particular events. We have noticed that positive or negative effects may or may not occur as per the expected average pattern [13]. There is no doubt that ionospheric storm effects do have positive as well as negative effects. Normally, the Polar Regions are supposed to be sources of large-scale neutral wind blowing towards equator during storms. These polar neutral winds have considerable random component which causes complications in the ionospheric dynamics of the equatorial region not only in conjugation with gemomagnetic storms but even during geomagnetically quiet periods through the turbulent neutral winds are produced independently in low latitudes and connection with geomagnetic storms is not at all obvious either qualitatively or quantitatively.

During geomagnetic storm, IEC is generally believed to show an evening increase for stations lying on shells within the plasmasphere and several mechanisms are proposed as explanations [14]. Thermospheric composition and temperature changes during geomagnetic disturbances will result in altered production and loss rates of ionization. In particular, an increase in molecular constituents, upon which the loss process depends, is through to contribute to main phase decrease an electron density [15]. A storm time electric field E causes the ionospheric plasma to drift at a velocity $E \times B/B^2$, where B is the geomagnetic main field. An upward electrodynamics drift for example, tends to increase the height of the F layer and at midlatitudes, it can result either an increase in electron density because of the lower rate of higher altitudes [16] or a reduced density at night because of loss of plasma to the plasmasphere [17]. Tyagi [18,19] showed that for less than 100 units, the IEC variations are more or less independent of solar flux. By constructing plots of 2400 hrs, mean electron content averaged over 30 days against the 183 mean of 10.7 solar flux were able to obtain the average dependence of the electron content on solar flux for all parts of the year [20].

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