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Combined effects of Geomagnetic storm and regional Earthquake on low latitude VLF radio signals: A case Study

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Key Points

- Modulation of Low latitude Very Low Frequency (VLF) radio signals of two propagation paths (VTX, NWC) Were observed at a low latitude station , Cooch Behar (CHB) during a combined occurrence of Moderate Earthquake and Geomagnetic storm Of maximum Kp = 6 from 10 September to 12 September, 2018

- The epicenter of the earthquake was very near (80 km) to the VLF receiving station so that the shaking due to earthquake was sensed by local community at the station. VLF electric field amplitude fluctuates beyond ±3σ range (σ = standard deviation) Prior, during or after the Seismic and geomagnetic event.

- To correlate the Earthquake, Geomagnetic storm and VLF signal disturbances we obtained VLF day length from VLF diurnals and average Kp value of each days from 5^{th} September to 14^{th} September, 2018

- Linear correlation coefficient s (r) between the VLF Day Length and Geomagnetic storm Index Kp have been obtained for two propagation paths. For NWC-CHB path value of r = 0.47 And for VTX-CHB r= 0.28.

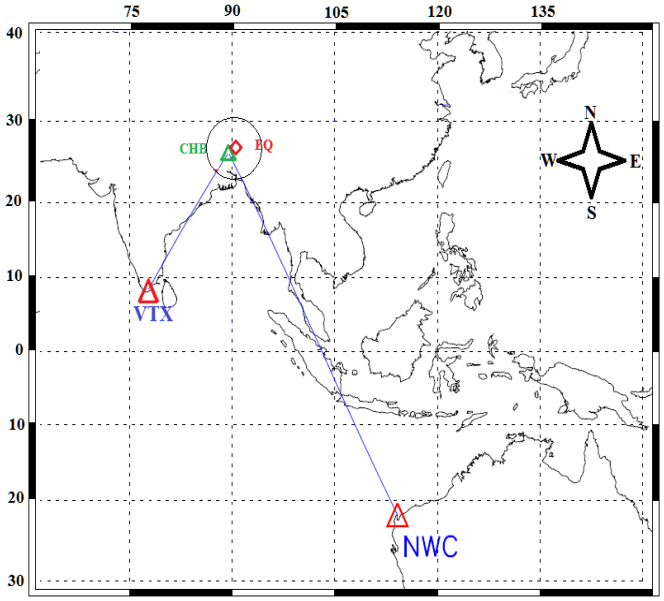
- So the geomagnetic index is showing mere correlation with the VLF signal disturbances. The effects are more likely due to the moderate earthquake.

Introduction

- Earthquake (EQ) is possibly a lithosphere-atmosphere-ionosphere coupling phenomena effecting the electromagnetic wave propagation . Due to the extreme complexity of the earth's structure, the goal of predicting the location and time of occurring of a seismic event is still in search.

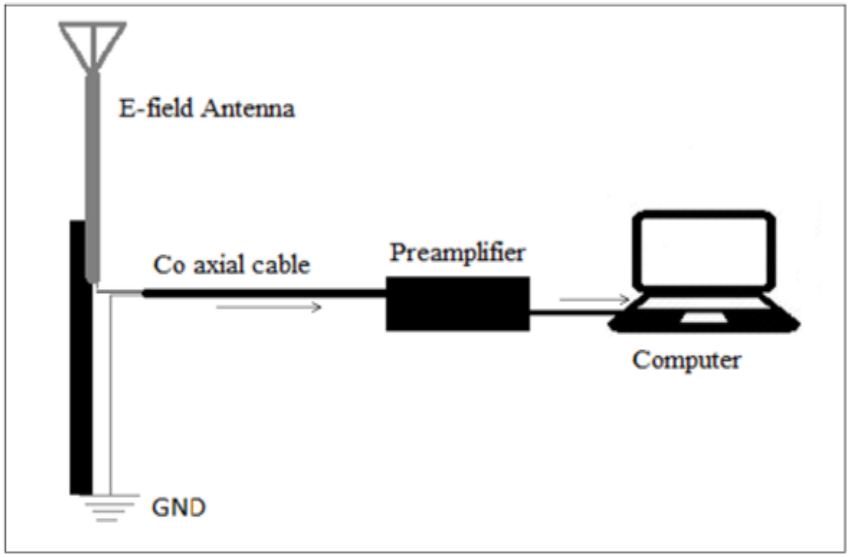
- Space weather conditions causes sudden variations in the Earth's magnetic field and occurrence of geomagnetic storm takes place, which has a possible direct connection to the occurrence of earthquake.

- During a geomagnetic storm the Ionospheric D-region electron density changes which reflect as a fluctuation in the VLF signal amplitude. The geomagnetic activity affects not only the high and mid latitude but it could take place in low latitude also.



➢ *VLF radio ignal Receiving station, VLF transmitters with Great Circle Paths, EQ epicenter and the EQ preparation zone (circle)on global map. The blue lines are the VTX-CHB and NWC-CHB propagation paths.*

Experimental Setup, Data and Methodology



➢ *Schematic diagram of the VLF signal receiving system.*

- VLF antenna (vertical) connected to the receiver by a 75 Ohm Co-axial cable. The negative terminal of the receiver (or sound card) is grounded using a 2m iron rod. It is mainly a two-stage amplifying system which uses two numbers of LF356 OPAMP. The output of the preamplifier system is taken out through an audio transformer (1300:8 Ohm) and fed to the Microphone input of the PC soundcard.

- VLF radio signals obtained from our station have been used as a key tool to diagnosis the anomaly created by seismic and geomagnetic events. EQ and geomagnetic storm information are obtained information are obtained from the following web services:
  a) https://www.usgs.gov/natural-hazards/earthquake-hazards
  b) http://wdc.kugi.kyoto-u.ac.jp/index.html respectively.

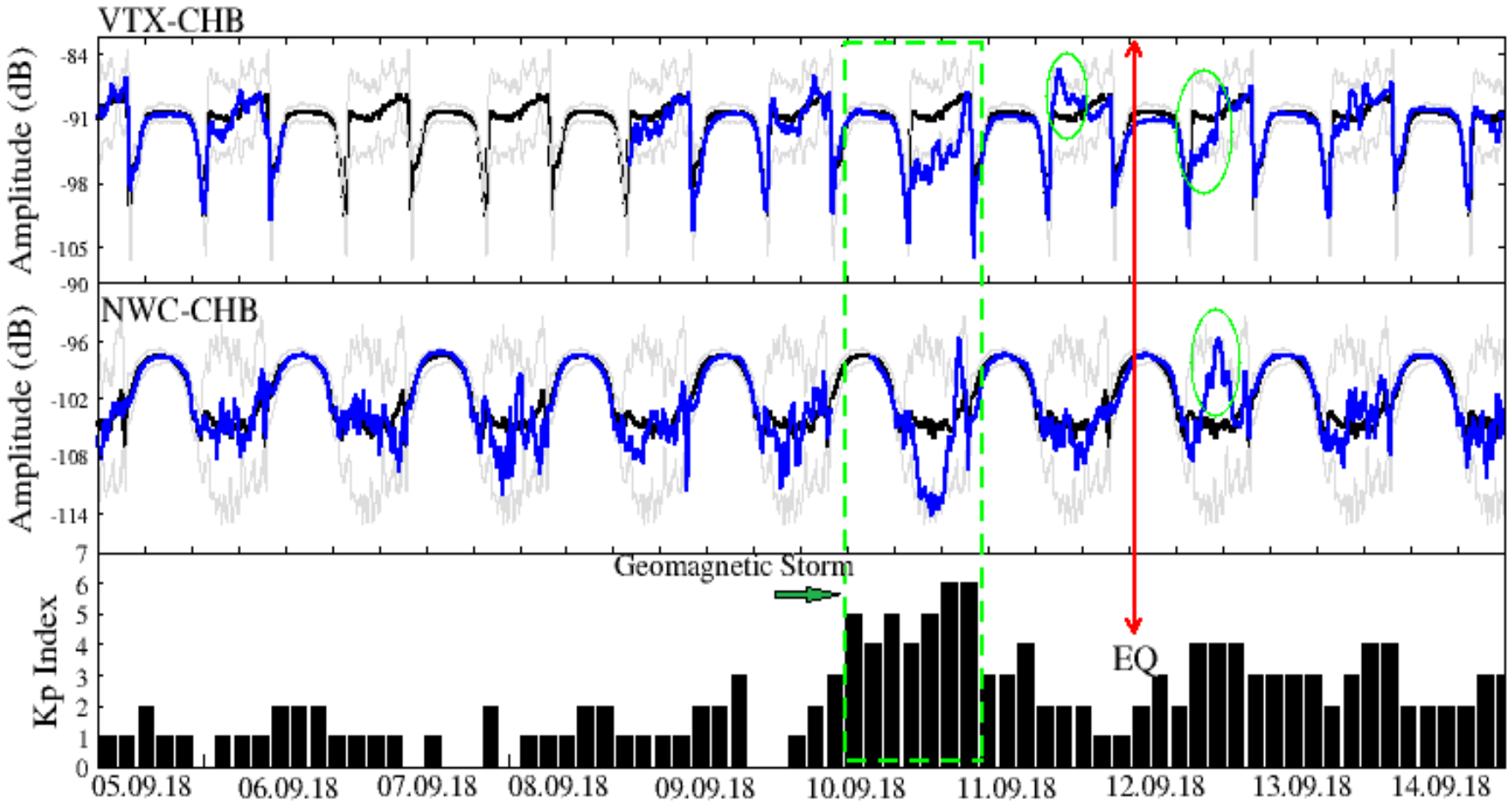
- In this paper we have presented the fluctuations in the VLF signals of VTX (18.2 kHz) and NWC (19.8 kHz) during an earthquake of M5.4 triggered just after the geomagnetic storm having Kp≥6. The Earthquake (EQ) event was on 12th September, 2018 at 10:20:46 (UT+5:30) and the epicenter [26.374^{o}N, 90.165^{o}E] was at 7 km NE of Sapatgram, Assam, India. The epicenter was just 84 km away from the VLF receving station Cooch Behar [CHB, 26.345^{o}N, 89.448^{o}E] and the shaking was felt by local community at VLF receiving station.

- There was no earthquake event ±15 days before or after the said event, according to the information provided by United States Geological Survey website. On the other hand the geomagnetic activity of Kp=5 was started at 20:30:00 (UT+5:30) on 10th September and increased upto Kp=6 at 14:30:00 (UT+5:30) on 11th September, 2018.

- We have checked the VLF day length before, during and after the EQ and geomagnetic storm period. The geomagnetic Kp index is then correlated with VLF day length

Results and Discussion

VLF amplitude Fluctuation



- *Red vertical line shows the EQ day. Green box represent the geomagnetic storm period. The upper panel showing VTX-CHB VLF amplitude, middle panel is for NWC-CHB amplitude compared with ±3σ (gray lines) and average (black line), lower panel are the Kp index. All these data from 05.09.2018 to 14.09.2018*

- To identify the anomaly in the VLF signal amplitude of both the VTX-CHB and NWC-CHB path we have calculated the average diurnal variation of the month of September, 2018, taking 10 quite days with respect to natural phenomena. The ±3σ of those 10 days are also calculated and compared with the each day signal amplitude from 05.09.2018 to 14.09.2018. The Kp index for the same duration were also checked to correlate with the earthquake.

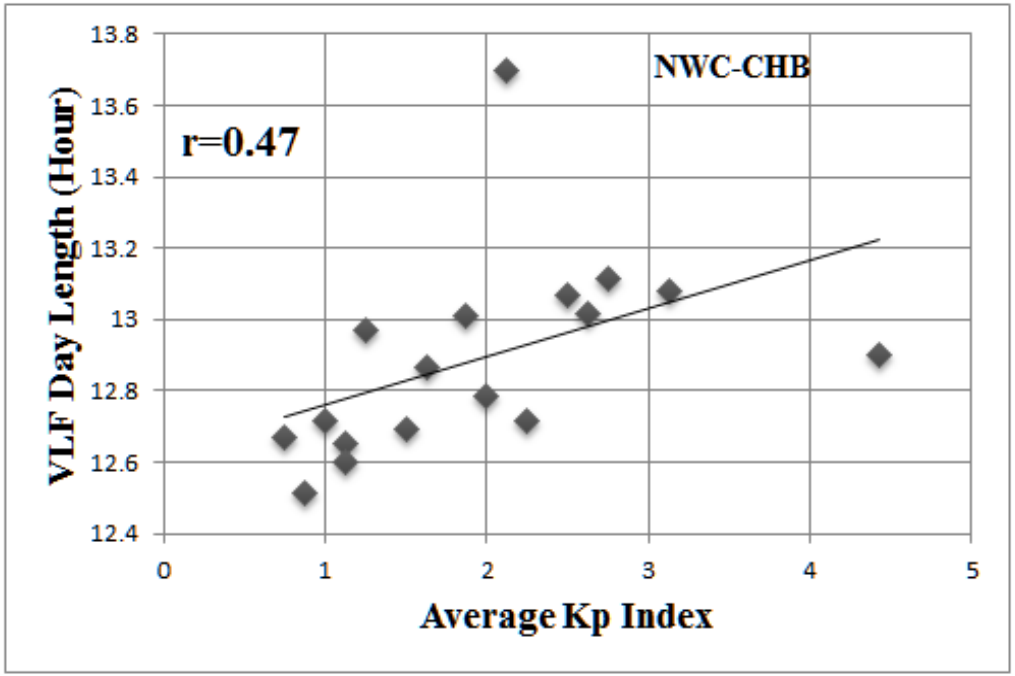
Variation of VLF Day Length

- The VLF Day Length is the time duration from morning terminator to evening terminator of a particular diurnal variation for 24 hour. VLF Day lengths of each day are obtained to establish the correlation between the VLF signal and Geomagnetic storm effect.

- .For VTX-CHB path one significant observation is, on 9^{th} September we see insignificant contraction of day time sensed by VLF signal. On the other hand on 10^{th} September we see an elongation of day time traced by VLF signal.

- The correlation coefficient between VLF Day length and Average Kp index are obtained for both VTX-CHB and NWC-CHB path. A good correlation between VLF day Length and Average Kp value for NWC-CHB path is established (r=0.47), although for VTX-CHB the value is low (r=0.28).

- The analysis shows actually a complicated effect of both the occurrence of geomagnetic storm and the earthquake. The terminator time and amplitudes of each VLF diurnal signal for both the path are also checked and it is found that pre-seismic effects possibly are there. As there was a geomagnetic storm the pre-seismic effect may exists in a complicated way with the effects due to storm.



➢ *Correlation co-efficient graph between VLF Day length and Average Kp index along NWC-CHB path.*

- Studies regarding geomagnetic storm induced disturbances in the ionospheric D-region as well as in the VLF amplitude have been revealed earlier, similar to our case.

Conclusion

- There are sufficient supportive studies which include the fact that geomagnetic can trigger an earthquake. In our case we see both pre-seismic and post seismic effects and a geomagnetic storm before the EQ. So the pre-seismic effects are not only due to earthquake but it is mixed with geomagnetic activity induced influence.

- Looking at the correlation between VLF Day Length and Average Kp index we see nearly no correlation for Short VLF propagation path (VTX-CHB) but for the same we see significant contraction and elongation of Day Length. Again for long VLF propagation path (NWC-CHB) we see a moderate value of R = 0.47. So effects are mainly due to earthquake but geomagnetic storm influence are there.

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Thank You