A Study On The Change In Formation Of D-Layer Of The Atmosphere Of Grindavik, Iceland For 2015 Using A Signal Of 37.5 Khz

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Abstract: The D-layer is the lowest layer of the ionosphere which is capable of reflecting Very Low Frequency (VLF)/Low Frequency (LF) waves. In this work, we analyze the VLF/LF waves of 37453.125 Hz transmitted from two VLF/LF transmitting towers in Grindavik, Iceland which was received in the Kiel Longwave Monitor, Germany for the year 2015. We did a graphical analysis of the variation of the intensity of the field associated with the VLF/LF of the respective frequency along with time. We recorded the Sunrise terminal time, the Sunset terminal time and compared the VLF/LF day and normal day, which is an indicator of the state of the formation of the D-layer. The comparison of sunrise and D-layer formation times with the standard 2σ lines was done. For several months such as January, February and March of 2015, intense anomalies were observed in both the sunrise terminator times and d-layer formation times. This gives us a possibility that the changes in these timings might be associated with intense volcanic activity which was observed in Iceland which stated off in Bardarbunga in August 2014 and ended only on 27th February 2015. Along with the volcanic activity, large amount of earthquakes were associated with the volcano. The magma released from the volcanoes along with huge amount of Radon gas released from the earthquakes might have caused these anomalies.

Index Terms: VLF/LF, D-layer, volcanic activity, sunrise terminator time, Sunset terminator time, VLF day,

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1 INTRODUCTION

The D-layer exists at an altitude of 100 km during the night and cascades down to almost 60 km during the day [1]. The height of the D-layer and the density of the electrons in the D-layer is subject to variation in cases of Sudden Ionospheric Disturbances (SID) [1]. The VLF/ LF waves travel as spherical waveguides to the ionosphere [2]. The interference pattern between the ground wave and the sky wave can be analyzed through one hope, wave model, or two hop wave model and so on up n hop wave models[3],[4], [5].VLF/ LF waves have been used in various fields such as global communications, lightening geolocation, ground to satellite communication, communication with submarines, meteorological information broadcasting, radio navigation signals, radio broadcasting, satellite protection, subterranean mapping etc. [6], [7], [8]. Apart from this, extensive studies of whisters, trimpi and tweeks are also burgeoning [9], [10], [11], [12]. In several scientific studies, it has been found that the sunrise and sunset terminator times shift abnormally a few days before the onset of an earthquake[13], [14, [15].

2 The Transmitters and the Receivers

The VLF/LF recording system of KLM consists of mainly three parts; one receiving antenna, one receiver/amplifier, and one computer. In the setup of KLM, the computer is a Thin-Client one.

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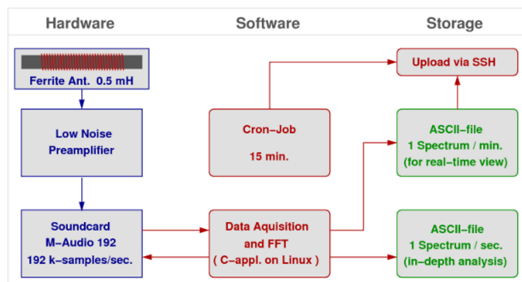

Fig 1: Block diagram of Kiel Longwave Monitor

The receiving antenna can be of two types, namely, the magnetic loop or B-field antenna which receives the magnetic component of the VLF/LF signal and the electric field or E-field antenna which receives the electric component of the VLF/LF signal. The E-field antenna picks more electrical noise and the loop antenna is dependent on the ambient environment. The ferrite loop antennae used at the Kiel Longwave Monitor (KLM) is identical, running at a constant location in a constant direction. The antenna nulls at 50 and 230 degrees. The receivers are broadband of 10-90 KHz running 90 Fast Fourier Transforms (FFT) per second. The B-field probe is located at Kiel Germany at the location of 54°23'46"N and 10°03'13"E [16]. Grindavik is bearing 314° from Kiel, which is close to the maximum of the Northwest directional response pattern of the antenna. The great circle propagation path length is 2106 km, running almost completely over salt water. The data was recorded in a receiver built in 2009 which a broadband is running approximately 90 FFT (Fast Fourier Transforms) per second. Each data used in this case was a one minute spectrum was an average from approximately 5000 raw spectra. The two transmitting towers are located in Grindavik, Iceland. The data are obtained is automatically stored in the computer as an ASCII file.

3 RESULTS and DISCUSSIONS

3.1 Sunrise Terminator Times

We analyzed the particular signal 37.5 KHz for 2015. We noted the sunrise and sunset terminator times. A typical graph of the intensity (dB) plotted against time is given sown in figure 1. The major dip of the intensity was noted as the sunrise terminator time and the second major dip was noted as the sunset terminator time and the difference between the two gave us the length of the VLF day.

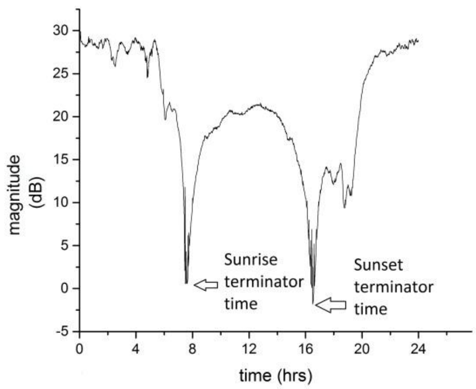

Fig 2: a typical intensity profile of the data[March 10, 2015].

The results of the variation of sunrise terminator time for the month of January isshown in Fig.3:

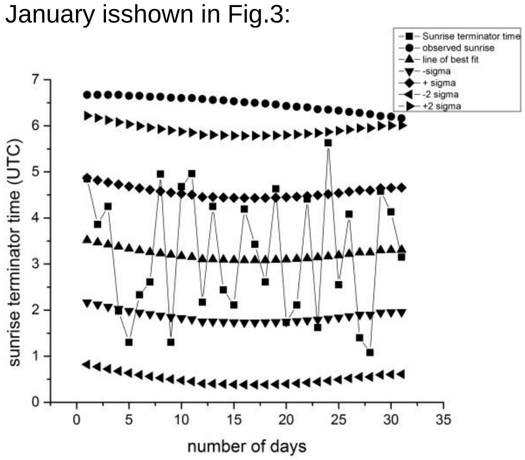

Fig 3: Sunrise terminator time for Grindavik, Iceland using the signal of 37.5 KHz for 2015

Figure 3 shows that less than 68% of the data lays between the 1σ lines. This can only mean that there were major terrestrial events that affected the formation of the D-layer of the atmosphere. Infact, there were some days where Sunrise terminator times were teetering on the edge of the 2σ lines too. The terrestrial event that did affect the D-layer of the atmosphere, and thereby the sunrise terminator times was the Bardarbunga volcano in Iceland that started off in August 2014 and well into 2015. Almost 40 earthquakes were recorded in January 2nd as per the Icelandic Meteorological Office[17]. Even on the 31st of January, 30 earthquakes were recorded with the largest being M4.1 in magnitude. The volcanic activity was relentless too as 31st January was the 152nd day of the continuous eruption[17].

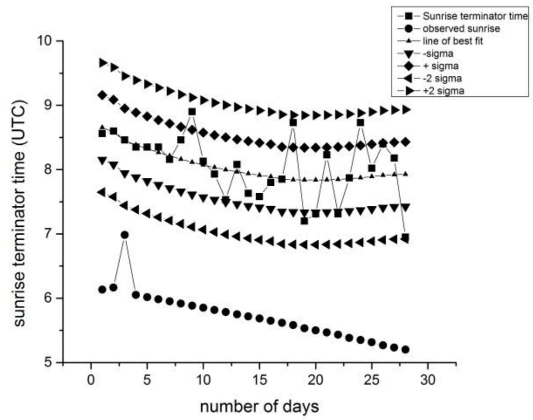

Fig 4: Sunrise terminator times for the month of February

Figure 4, the sunrise terminator times for the month of February shows that the discrepancies in the sunrise terminator times have subsided but not to a great extent. There are a few days where the sunrise terminator times are still edging towards the 2σ lines. This has also got to do with the terrestrial activities of Bardarbunga as the magma flow volcano completely subsided only in the 27th of February 2015[18]. As of 28th February 2015, the gas emissions continued and higher values of pollutant gases were expected [18]. The seismic activities subsided too with time as earthquakes got smaller in the month of February, not only in magnitude but also in its seismic strength [18].

3.2 VLF Day vs Normal Day

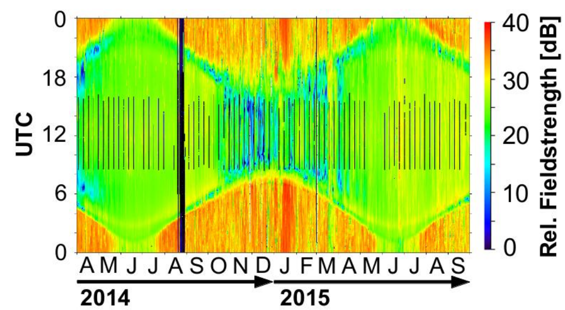

Fig 5: cylindrical projection of diurnal amplitudes of 37.5 KHz over 18 months.

Figure 5 is an outline map demonstrating yearly variation of relative field strength of the signal with time. We also compared the length of the VLF day with the length of the day as measured through local sunrise and sunset timings. The nature of the graph was of particular interest. Although we did expect that the

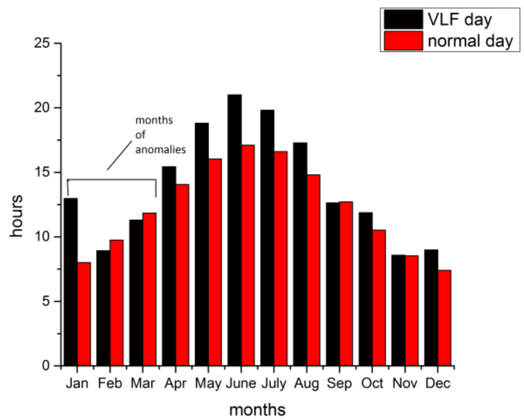

Fig6: Comparison of the VLF day with conventional day

histogram comparing the VLF day with a normal day to be Gaussian in nature as the length of the day gets to a maximum in June in the northern hemisphere and to taper off at the ends for the winters, we noticed an abrupt change in the length of the day for the first three months of the year i.e. January, February and March. This acted as a source of reification of our suspicions that there were dramatic changes in the D-layer of the atmosphere during the respective months where the volcanic and seismic activities acted in unison to produce such discernible effects.

3.3 D- Layer Formation Time

The effects which caused the perturbations in the plot of the sunrise terminator times and the plot of comparison of VLF and normal day was palpable in the plot of the D-

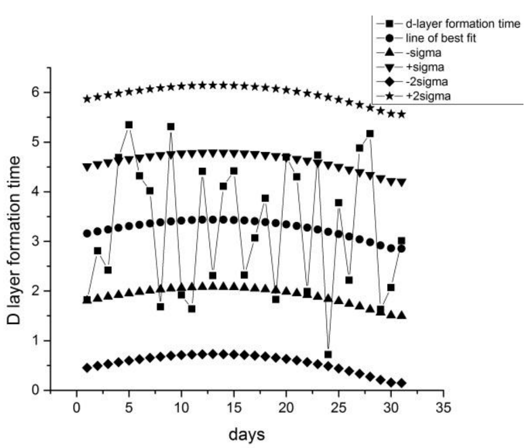

Fig 7: D-layer formation time for the month of January

Layer formation times too. Figure 7 shows that the D-layer formation time for the month of January varied with the same amount of similacrum that the sunrise terminator times varied for the respective month. The other peculiar inference we were able to draw from the graphs was the unusually large amount of time taken for the formation of the D-layer of the atmosphere in the month of January. Generally, the D-layer takes about 30 min- 45 mins to completely set. However, in January the amount of time taken exceeded well beyond the theoretically expected conventional values. Therefore the amount of radiation produced in the atmosphere, firstly by the release of Radon gas during the earthquakes and secondly by the amount of gas emissions from the volcano must have coupled strongly to give rise to such a phenomena. From Figure 8, we can draw a similar conclusion for the month of February too.

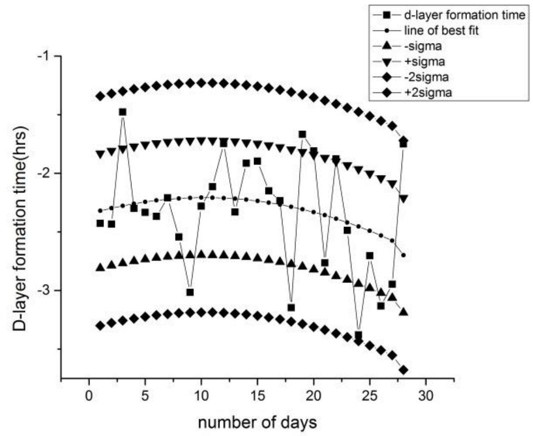

Fig8: D-layer formation time for February

The nagative values for the D-layer formation time is quite intersting in nature. Conventionally, we expect the D-layer to be formed only after sunrise when there is ample amount of ionizing materials coming from the Sun. However, Fig: 8 suggests that there might have been a pre- existing D-layer in the atmosphere. As the volcano drew closer and closer towards the end, more radiation and polluting gases must have produced such effects. This followed out into the month of March as well where a pre-existing D-layer was present.

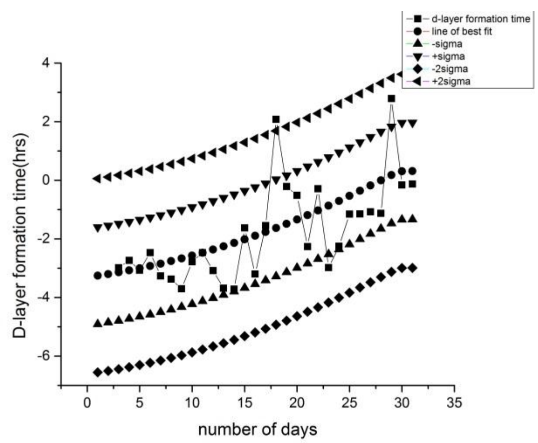

Fig: 9 D-layer formation time for March

Figure 9 which shows the D-layer formation time for the month of March shows the exact trails of the the pattern left off by the month of February in terms of the D-layer formation time. After the flow of the magma stopped completely, the Icelandic Meterological Scientific committee expected even higher doses of polluting gases than in the previous weeks[19]. This can be seen in Fig: 8 where the D-layer formation time dipped into its lowest values for the first two weeks after which the values did come to a state of apparent normalcy. In dealing with the D-layer formation times of the remaining months of the year as demonstrated by Fig 6, an additional factor that could have had its effect would be the formation of auroras in Iceland. Since, auroras can be extensively be formed in Grindavik, and for a prolonged period of time too, this factor cannot be discounted.

4 CONCLUSIONS

Thus the complex geology of Iceland gave us extremely different insights into the study of the VLF/LF waves where the volcanic, seismic and auroral activities in the region caused significant deviations in the sunrise terminator times, d-layer formation times and length of the VLF waves too. A more rigorous study of the sunset terminator times would give allow us for a further understanding of the volcanic activities of Barbdurbunga. Also a study of the same events through VLF/LF waves of different frequencies can be matched to get a more concrete result. Based on this result, however, we can fairly say that the study of the VLF/LF waves can gives us a better understanding of the seismic and volcanic activities in a particular region and maybe used for the short term prediction of such activities.

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