A Study of the Correlation between Enhanced LHR, VLF Turbulences and Earthquakes

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***Abstract*—Lower Hybrid Resonance (LHR) frequency in the ionosphere is influenced by the plasma density and the temperature. Variations in the same two governing factors are indicators of earthquakes. Hence, observing the variations of LHR is important as an indirect precursor of earthquakes. At the same time some correlations were observed with the earthquakes and ionospheric Very Low Frequency (VLF) turbulences. In this work we analyze data collected by the Radio Receiver Instrument (RRI) on the enhanced Polar Outflow Probe (e-POP) for LHR and VLF turbulences and compare our records with the United States Earthquake database.**

I. Introduction

Lower hybrid resonance frequency of the ionosphere depends on the plasma density and the particle temperature [1]. Based on our observations from the Radio Receiver Instrument (RRI) on the enhanced Polar Outflow Probe (e-POP) or Swarm-E, the LHR can vary from 4-10 kHz, depending on the solar and geomagnetic parameters.

In addition, the two main influencers of the LHR, the plasma density and temperature are also considered governing factors of earthquakes [1]. Therefore, the state of the LHR frequency gives additional information on the probability of earthquake occurrences.

A large enhancement in the VLF range is considered a VLF turbulence. Typically these enhancements occur in the vicinity of the LHR frequency. Previous literature has observed a simultaneous occurrence of earthquakes and VLF turbulences [2].

As mentioned in one of our previous publications [3], we observed that the LHR acts as a noise filter, considering the very low frequency (VLF: 3-30 kHz) noise level at frequencies higher than LHR is much higher than the noise level at frequencies below it on a spectrogram. This observations is especially evident with lightning generated whistlers. At every occurrence of the lightning generated ducted or non-ducted whistler an intensification at the LHR frequency was observed, indicating that part of the whistler energy is dissipated at the LHR frequency. This observation is shown in Fig. 1.

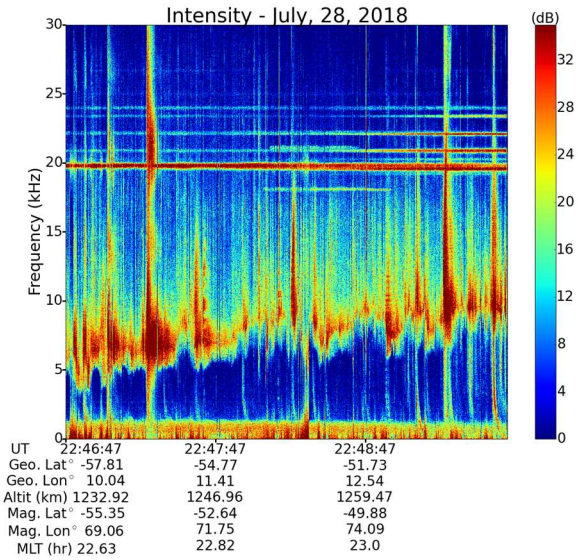

Fig. 1: enhancement of the lower hybrid resonance frequency with each 'hop' of the whistlers, and the presence of high VLF noise level at frequencies higher than the LHR compared to the noise level at frequencies lower than the LHR. Within this satellite observation, LHR varies from 5 kHz to 10 kHz.

We analyze the low frequency data observed by the Radio Receiver Instrument (RRI) on the enhanced Polar Outflow Probe (e-POP) [4] from the year 2014 through 2020, for the frequency variation of the LHR, the occurrence of VLF turbulences and their effect on a subsequent earthquake in the near-region.

II. Data

The data presented in this work is collected using the Radio Receiver Instrument (RRI) on the enhanced Polar Outflow Probe (e-POP) also known as Swarm-E [4].

In this work we analyze the e-POP events from the year 2014 through 2020, where the LHR frequency and the VLF turbulences were observed. Then we compare this record with the United States earthquake database [5] in order to find the occurrence of earthquakes in the near regions within that timeframe.

III. INITIAL RESULTS

Figure 2 below shows an enhanced LHR and a VLF turbulence observed by e-POP RRI on Feb 19, 2014 around 14:30 UT. The geographical location corresponding to that observations is the Alaskan Aleutian islands. According to the United States national database of earthquakes, there had been a series of earthquakes in that region within a timeframe of ±5 hours of the satellite observation are marked white dots in Fig. 3.

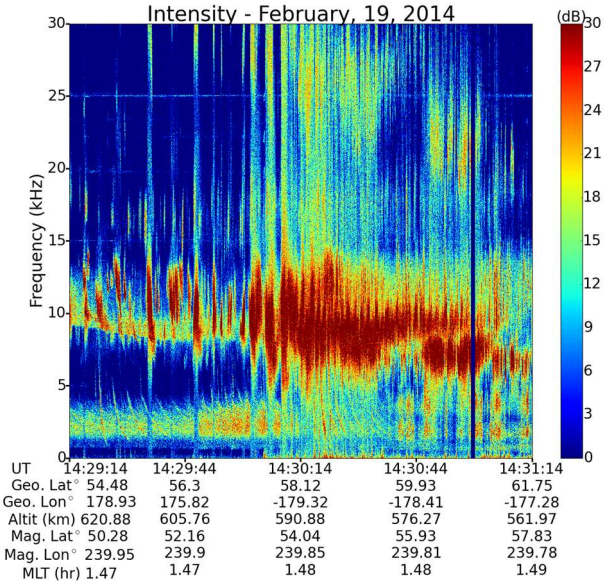

Fig. 2: the enhanced lower hybrid resonance frequency and a very low frequency turbulence observed by RRI, on February 19, 2014. The VLF turbulence was observed at 14:30:14 UT. The LHR frequency is around 10 kHz for the duration of this observation.

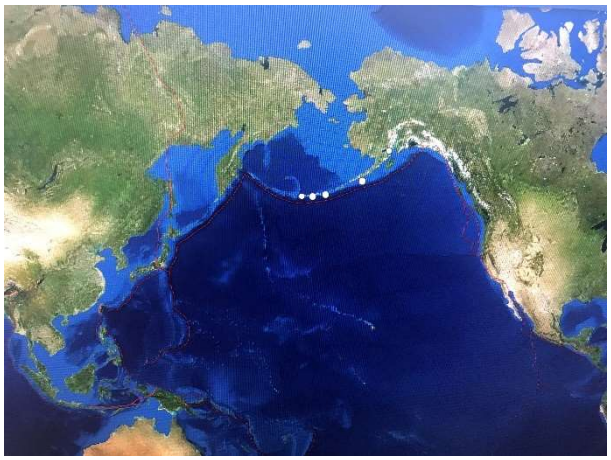

Fig 3: the earthquakes greater than magnitude +2.5 within that region within a time frame of ±5 hours of the satellite observation.

IV. CONCLUSIONS AND FUTURE WORK

Previous work have identified some correlation between earthquakes and VLF turbulences in the ionosphere. In this work our goal is to conduct a detailed analysis of the relationship between ionospheric VLF turbulences and earthquakes. At the same time we analyze the enhancement and variation in the LHR frequency and their relationship to the occurrences of earthquakes.

Further work is necessary to comment on the VLF turbulences being a course of earthquakes.

ACKNOWLEDGEMENT

Authors would like to acknowledge Dr. Andrew Yau the principle investigator of e-POP mission.

REFERENCES

[1] D.I. Vavilov, D.R. Shklyar, E.E. Titova, Michel Parrot. Study of the lower hybrid resonance frequency over the regions of gathering earthquakes using DEMETER data. Journal of Atmospheric and SolarTerrestrial Physics, Elsevier, 2013, 100-101, ff10.1016/j.jastp.2013.03.019ff. ffinsu-01291266f

[2] Alexander Rozhnoi, Maria Solovieva, Michel Parrot, Hayakawa Masashi, Pier Francesco Biagi, et al.. Ionospheric turbulence from ground-based and satellite VLF/LF transmitter signal observations for the Simushir earthquake (November 15, 2006). Annals of Geophysics, Istituto Nazionale di Geofisica e Vulcanologia (INGV), 2012, 55 (1), pp.187-192. ff10.4401/ag-5190ff. ffinsu-01295678fJ. Doe, "Title of paper if known," unpublished.

[3] Maxworth, A.; Hussey, G.; Gołkowski, M. Coexistence of Lightning Generated Whistlers, Hiss and Lower Hybrid Noise Observed by e-POP (SWARM-E)–RRI. Atmosphere 2020, 11, 177.

[4] James, H.G., King, E.P., White, A. et al. The e-POP Radio Receiver Instrument on CASSIOPE. Space Sci Rev 189, 79–105 (2015). https://doi.org/10.1007/s11214-014-0130-y.

[5] US Database for Earthquakes https://earthquake.usgs.gov/, accessed on September 18, 2020.