Analysis of Swarm Satellite Magnetic Field Data before and after the 2015 Mw7.8 Nepal Earthquake Based on Non-negative Tensor Decomposition

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In this paper, based on the Non-negative Tensor Decomposition (NTD), we analyzed the Y-component ionospheric magnetic field data as observed by Swarm Alpha and Charlie satellites before, during and after the 2015 (Mw=7.8) Nepal earthquake (April 25, 28.231°N 84.731°E). All the observation data were analyzed, including the data collected under quiet and strong geomagnetic activities. For each investigated satellite track, we can obtain a tensor, which is decomposed in three components. We found that the cumulative number of the inside anomalous tracks for one component of decomposition components (i.e., hs1, whose energy and entropy are more concentrated inside the earthquake-sensitive area, shows an accelerated increase which conforms to a sigmoid trend from 60 to 40 days before the mainshock. After that till the day before the mainshock, the cumulative result displays a weak acceleration trend which obeys a power law trend and resumed linear growth after the earthquake. According to the basis vectors, the frequency of the ionospheric magnetic anomalies is around 0.02 to 0.1 Hz, and by the skin depth formula the estimated depth of the mainshock is similar to the real one.

In addition, we did some confutation analysis to exclude the influence of the geomagnetic activity and solar activity on the abnormal phenomenon of the cumulative result for the hs1 component, according to the ap, Dst and F 10.7 indices. We also analyzed another area at the same magnetic latitude with no seismicity and find that its cumulative result shows a linear increase, which means that the accelerated anomalous phenomenon is not affected by the local time or due by chance.

At lithosphere, the cumulative Benioff Strain S also shows two accelerating increases before the mainshock, which is consistent with the cumulative result of the ionospheric anomalies. At the first acceleration, the seismicity occurred around the boundary of the research area not near the epicenter, and most of the ionospheric anomalies offset from the epicenter. During the second acceleration, some seismicity occurred closer to or on the mainshock fault, and the ionospheric anomalies appeared nearby the two faults around the epicenter, as well.

Furthermore, we considered combining with other studies on Nepal earthquake. Therefore, we
noticed that the ionospheric magnetic field anomalies began to accelerate two days after the subsurface microwave radiation anomaly detected by Feng Jing et al. (2019). The spatial distribution of some ionospheric anomalies is consistent with the atmospheric Outgoing Longwave Radiation (OLR) anomalies found by Ouzounov et al. (2021). The latter occurred around two faults near the epicenter and the atmospheric anomalies occurred earlier than the ionospheric anomalies.

Considering the occurrence time of the anomalies in different layers, the abnormal phenomenon appeared in lithosphere, then transferred to the atmosphere, and at last occurred in the ionosphere. These results can be described by the Lithosphere Atmosphere Ionosphere Coupling model.

All these analyses indicate that by means of the NTD method, we can use all observed multi-channel data to analyze the Nepal earthquake and obtain a component whose anomalies are likely to be related to the earthquake.