

# Transient Effects in Atmosphere and Ionosphere Associated with 2018 Mw 7.5 Sulawesi Indonesia Earthquake and Triggered Tsunami and Volcano Activities

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We analyze retrospectively the transient variations of four different physical parameters of atmosphere/ionosphere during the time of M7.5 on Sept 28, 2018 in Indonesia namely: (i) thermodynamic properties in the lower atmosphere, (ii) outgoing earth radiation (OLR) at the TOA, (iii) GPS/TEC and (iv) the very-low-frequency (VLF/LF) signals at the receiving station in Petropavlovsk-Kamchatski (RTK, Russia). We found that in the second part of September 2018 a rapid augment of satellite observed earth radiation in the atmosphere and the anomaly located in close vicinity to the future M7.5 epicenter reached the maximum on Sept 21-22. The GPS/TEC data analysis indicates an augment and variation in electron density reaching a maximum value during the Sept 26-27 periods. Two VLF/LF crossing wave paths - NWC-RTK and JJY-RTK, have shown abnormal behavior of signals during on days Sept 26-28 two days before the earthquake. Our results show coherence between the appearance of pre-earthquake transient effects in atmosphere and ionosphere (with a short time-lag, from hours up to a few days) and the occurrence of 2018 M7.5 in Indonesia. Traveling ionospheric tsunami disturbances (TITDs) in the total electron content (TEC) induced by tsunami waves of the 28 September 2018 Mw 7.5 Sulawesi Indonesia earthquake are detected by of seven ground-based receivers of the global positioning system (GPS) in South Asia, Oceanic, Pacific areas. It is found that the origin is about 100 km North of the epicenter and the horizontal speed is of about 187 m/s.

The pre-earthquake nature of the signals in atmosphere and ionosphere were revealed by simultaneous analysis of satellite, GPS/TEC and VLF/LF observations and suggest that they follow a general temporal-spatial evolution pattern, which has been seen in other large earthquakes worldwide.

Keywords: earthquake, tsunami, volcano, precursor, GPS/TEC, thermal anomaly