Correlation of VLF/LF variations with cyclones and typhoons

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ABSTRACT

Our main aim is selection of the very low and low frequency (VLF/LF) signal perturbations related to earthquakes, tsunami and volcano eruptions from other external forcing both from above and from below. In this work we use signals recorded in Petropavlovsk-Kamchatsky (PTK), Yuzhno-Sakhalinsk (YSH) and Yuzhno-Kurilsk (YUK) stations (Fig. 1) to study meteorological effects in the lower ionosphere. The region under consideration is characterized by active winter cyclonic activity in midlatitudes and strong summer and autumn typhoon activity in low latitudes. Correlation analysis demonstrates sensitivity of the VLF/LF signals to variations of atmosphere pressure, wind velocity, humidity and temperature (Fig. 2). An example of the anomalies observed in the amplitude of the signals recorded at the PTK station during two cyclones in January 2013 is shown in Fig.3. The disturbances in the signals during 9 tropical cyclones (TC) of different intensity in 2010-2013 were analysed. The TCs were selected for intervals with quiet geomagnetic conditions. Negative night time amplitude anomalies of the signals that are most probable caused by TC activity are revealed for 7 events (examples Fig.4-5). Anomalies are observed when TCs pass the sensitivity zones of the subionospheric paths. No correlation between TC intensity and magnitude of the signal anomalies is found. The cause of variations of the VLF signal observed during 2 TCs is not clear (Fig. 6). It can be due to the TCs influence or to seismic activity. Spectral analysis made for the typhoon-induced disturbed VLF/LF signals reveals the maximum of spectra energy in the interval of periods of about 7-16 min and 15-55 min (Fig. 7). This result corroborates the theory of penetration into the lower ionosphere the typhoon-generated internal gravity waves.

RESULTS

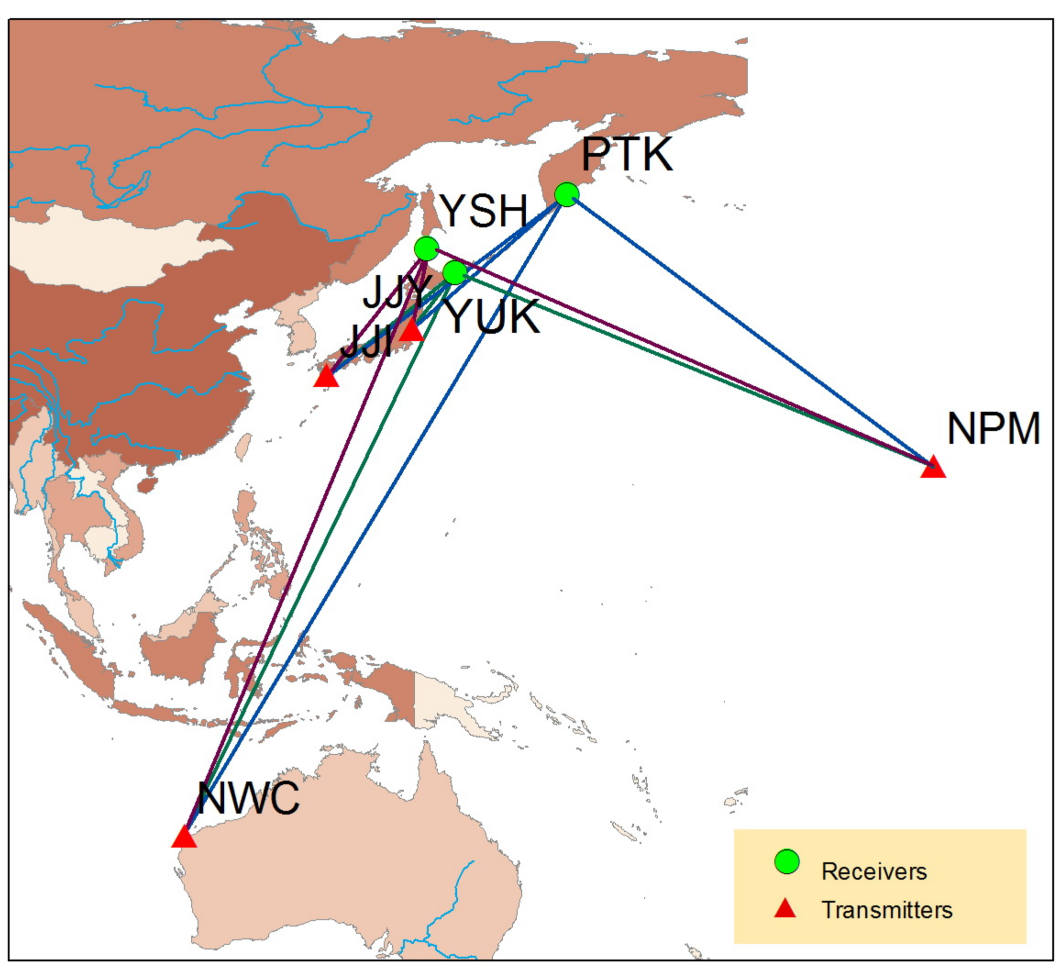

Fig.1 A map showing the position of the receivers in Petropavlovsk-Kamchatsky (PTK), Yuzhno-Sakhalinsk (YSH) and Yuzhno-Kurilsk (YUK) together with the position of the transmitters JJI (22.2 kHz), JJY (40 kHz), NWC (19.8 kHz) and NPM (21.4 kHz).

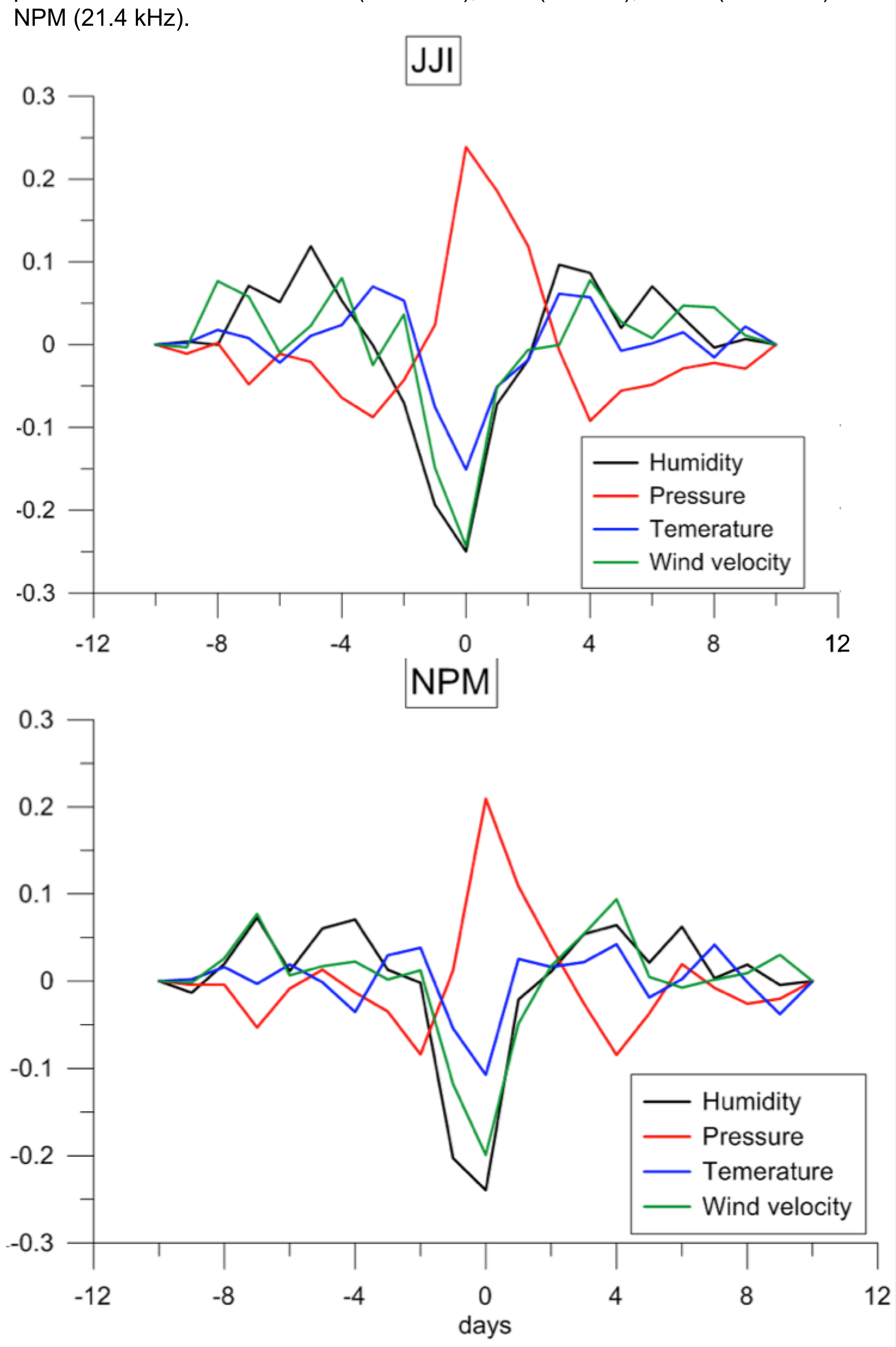

Fig. 2. Cross-covariance functions for the average residual amplitude in nighttime of the JJI signal (top) and NPM signal (bottom) received in Yuzhno-Kurilsk and meteorological parameters from the local weather-station during 2012. The ordinate (axis Y) is the correlation coefficient.

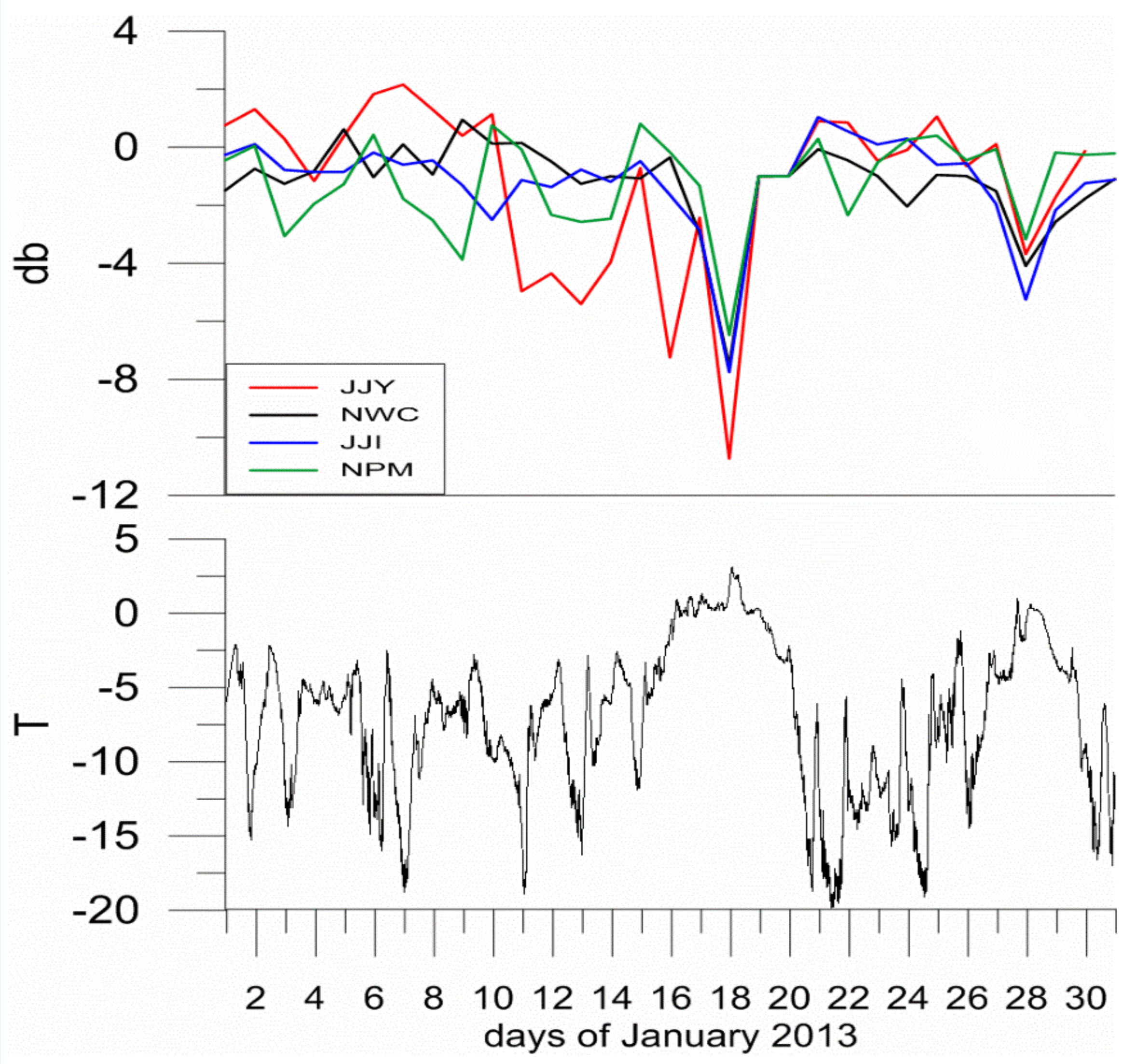

Fig. 3. An example of the anomalies observed in the amplitude of the signals recorded at the PTK station during two cyclones in January 2013. The top panel shows the average residual amplitude of VLF/LF signals in nighttime, while the bottom panel refers to the temperature (°C).

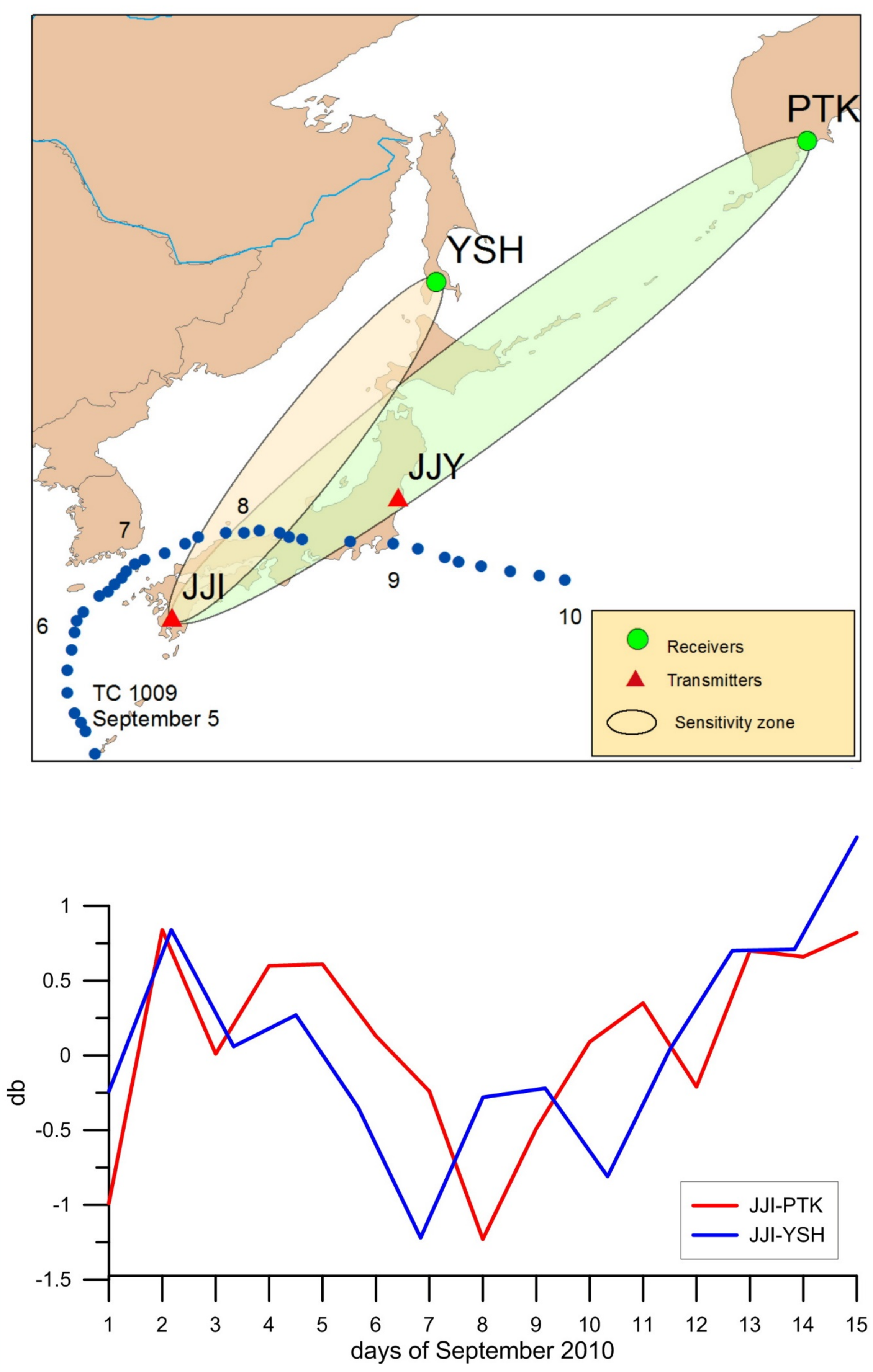

Fig. 4. The anomalies in the JJI signal recorded at the PTK and YSH stations during the passage of the TC Malou (1009), bottom panel. Blue solid circles at the top panel show the position of the TC centres on September 5-10, 2010.

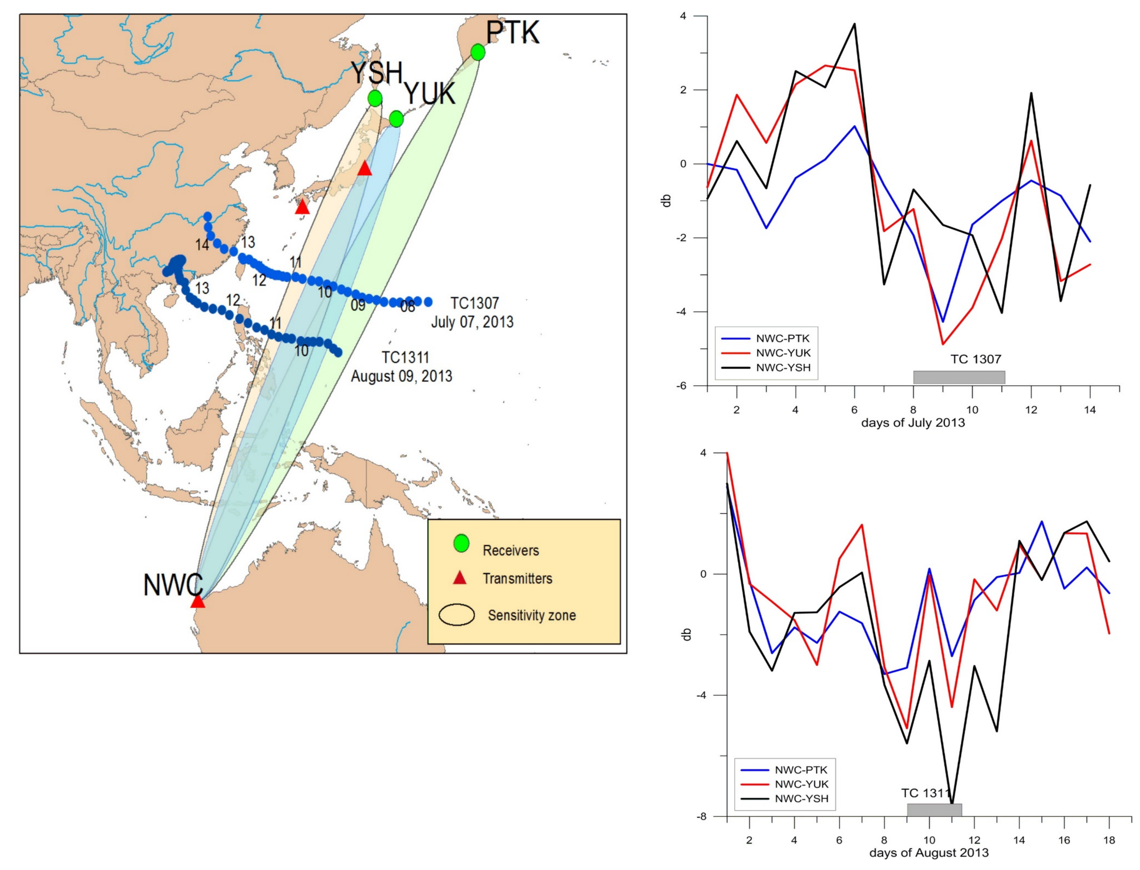

Fig. 5. The anomalies in the NWC signal recorded at three stations during the passage of the TC Soulik (1307) (the top right panel), and the TC Utor (1311) (the bottom right panel). Horizontal grey bars on the abscissa show the periods when the TCs crossed the sensitivity zones of the paths under consideration. The positions of the TCs centres are shown in the left panel.

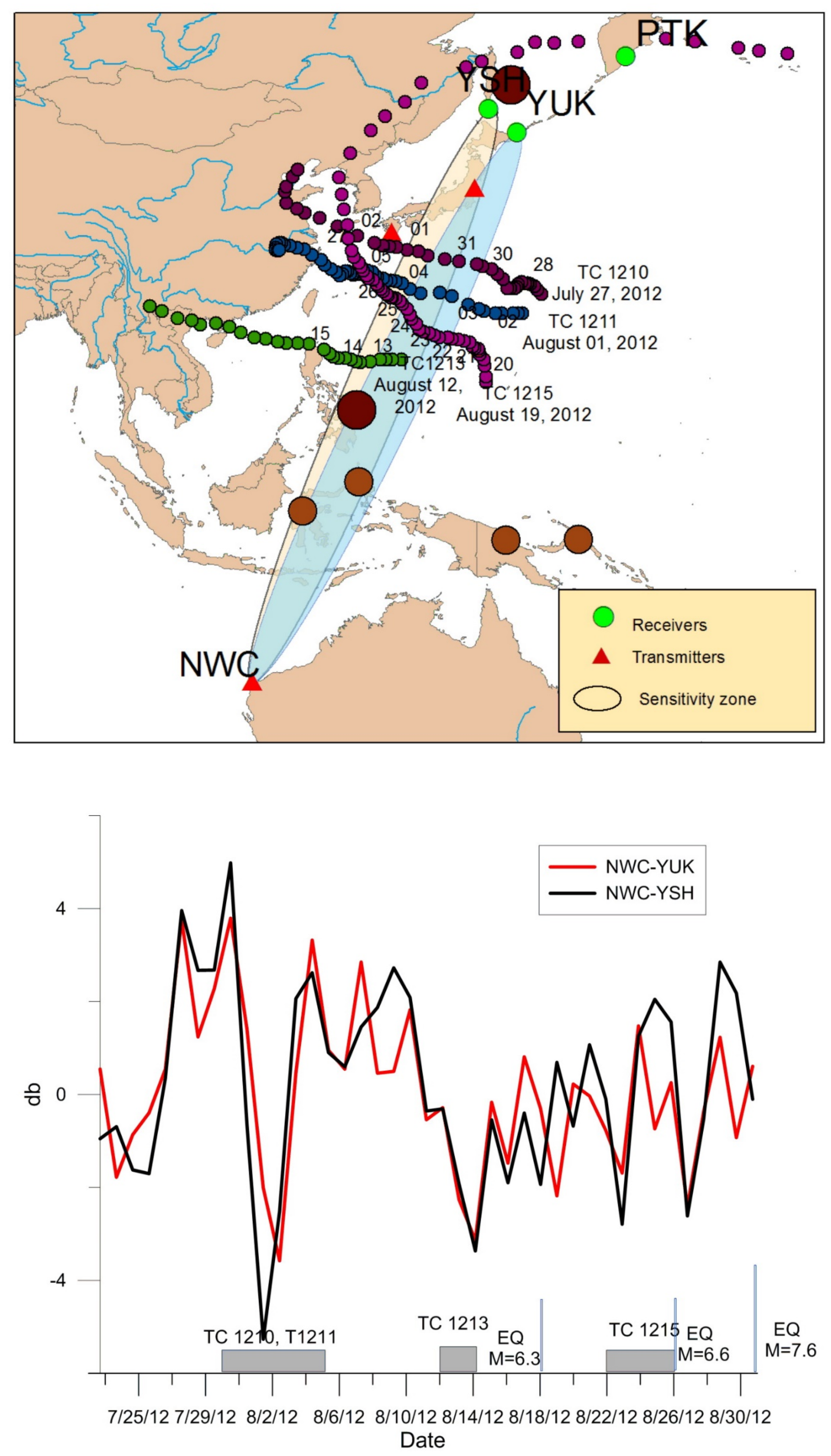

Fig. 6. The anomalies in the NWC signal recorded at the YSH and YUK stations during the passage of several TCs in August 2012 (the bottom panel). Horizontal grey bars on the abscissa show the periods when the TCs crossed the sensitivity zones of the paths under consideration, and blue vertical bars refer to the times of the earthquake occurrences. The epicenters of earthquake with M>6, which took place in the Pacific region during the period of analysis, are shown in the top panel by large solid brown circles.

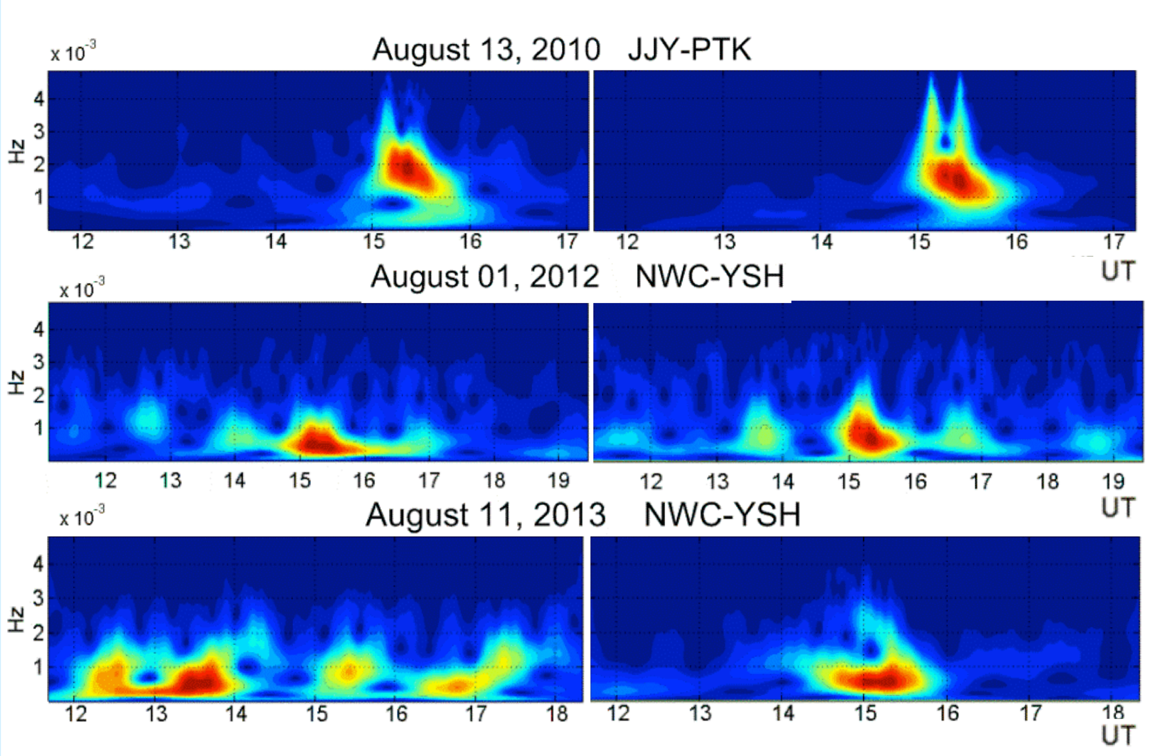

Fig. 7. Examples of the wavelet spectra of the filtered (0.2-15 mHz) typhoon-induce disturbed amplitudes (left) and phases (right) of the VLF/LF signals.

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