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Perturbation in VLF/LF signals from ground-based and satellite observations during strong seismic activity

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Data from VLF/LF station in Petropavlovsk-Kamchatsky and data from the ICE receiver collected on board the DEMETER satellite were used for the analysis of three periods of strong seismic activity occurred in the Far East region in: a) November 2006, b) June-July 2008, c) January 2009. For the DEMETER data we analyze signal in the part of night orbits passing above the earthquake area. The zone of analysis has a width 25° that provides one orbit every day. Time averaging of the dynamic spectrum is about 2s, and the space resolution along the orbit is about 10-15 km. The ground and satellite data were processed by a method based on the difference between the real signal in nighttime and the model one. The model for the ground observation was the monthly averaged signal of amplitude and phase calculated for the quiet days of every month. For satellite data a two-dimensional model of the signal distribution over selected area has been constructed. Specific perturbations in the amplitude of VLF/LF signals have been found several days before the earthquakes in ground and satellite observations.

a) November 2006

The monitoring of the VLF/LF signals was carried out from the 1st of October 2006 to the end of January 2007. The very strong earthquake with M=8.3 took place near the Simushir island of the Central Kuril region (Russia) in November 15, 2006. Follow to this, the series of strong aftershocks (M=5-6.5) was observed during several months.

The earthquake epicenter was in the sensitivity zone of wave paths JJY-Petropavlovsk-Kamchatsky, JJI- Petropavlovsk-Kamchatsky and NWC- Petropavlovsk-Kamchatsky. A comparison of results of the satellite and ground observations is presented in Fig.1. Here we use the differences averaged over night time for the ground reception and differences averaged along the part orbit crossing the seismic area for satellite data. We notice an evident decrease in the amplitude of VLF/LF signals both in the ground and in the satellite data in association with seismicity. Amplitude anomalies are always negative both for magnetic storms and seismic activity because of loss of a signal in ionosphere irregularity during propagation. Phase anomalies can be both positive and negative. It depends on the length of the path. In the present case, the anomalies in the phase of the JJY signal are positive.

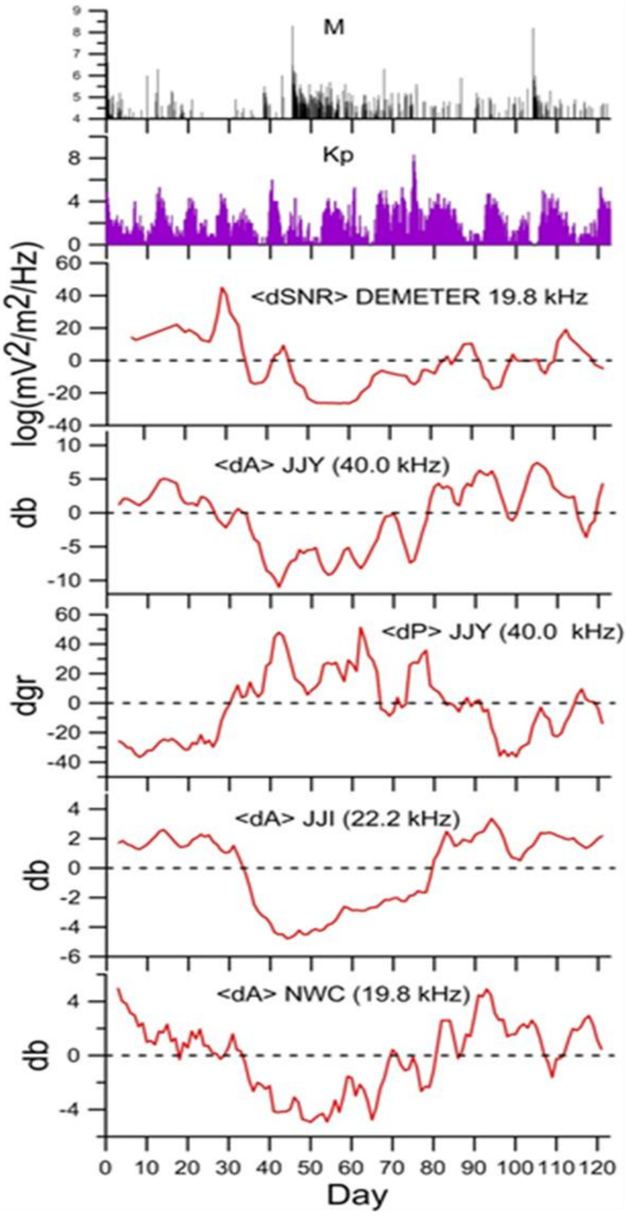

Fig 1. Comparison of ground and satellite observations during October 2006 – January 2007. For the satellite observations averaged along part of the orbits VLF signal differences from the reception of NWC transmitter signal are shown. For ground observations averaged through night time VLF/LF signal differences are shown for the wave paths: JJY-Petropavlovsk-Kamchatsky (amplitude and phase), JJI-

Petropavlovsk-Kamchatsky and NWC- Petropavlovsk-Kamchatsky. Axis X shows the days beginning from the 1st of October 2006. Two upper panels represent earthquake magnitude and Kp index of magnetic activity.

b) June-July 2008

The period of analysis was from the 1st of June to the end of August. Two strong earthquakes occurred during this period in Honshu region of Japan. The first earthquake with magnitude 6.9 took place on June 13, 2008 and the second earthquake with M=7.0 happened on July 20, 2008. The epicenter of the first earthquake was in sensitivity zone of the path JJI-Petropavlovsk-Kamchatsky, the epicenter of the second earthquake was outside sensitivity zones for any path for ground observations.

Results of the satellite and ground observations are presented in Fig.2. As in the previous case we use here the differences averaged over night time for the ground reception and differences averaged along the part orbit crossing the seismic area for satellite data. Decrease of the signal is observed 1-2 days before the earthquakes.

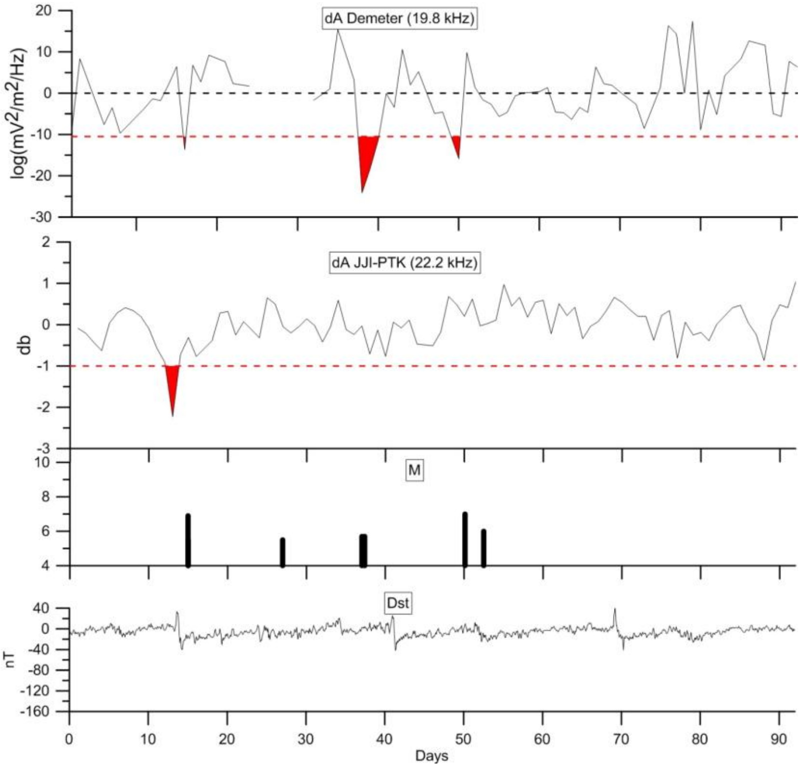

Fig 2. Satellite and ground observations during June –August 2008. For the satellite observations averaged along part of the orbits VLF signal differences from the reception of NWC transmitter signal are shown. For ground observations averaged through night time VLF signal differences are shown for the wave path JJI-Petropavlovsk-Kamchatsky. Axis X shows the days beginning from the 1st of June 2006. Red dotted lines show the 2σ level. Two bottom panels represent earthquake magnitude and Dst index of

magnetic activity.

c) January 2009

The period of analysis was from the 1st of December, 2008 to the end of February 2009. Several earthquakes occurred during this period in Kuril-Kamchatka region. The strongest earthquake on January 15 has magnitude 7.4. The epicenters of all the earthquakes were outside sensitivity zones for any path for ground observations.

Results of the satellite observations are presented in Fig.3. Decrease of the signal is observed 1-2 days before the earthquakes.

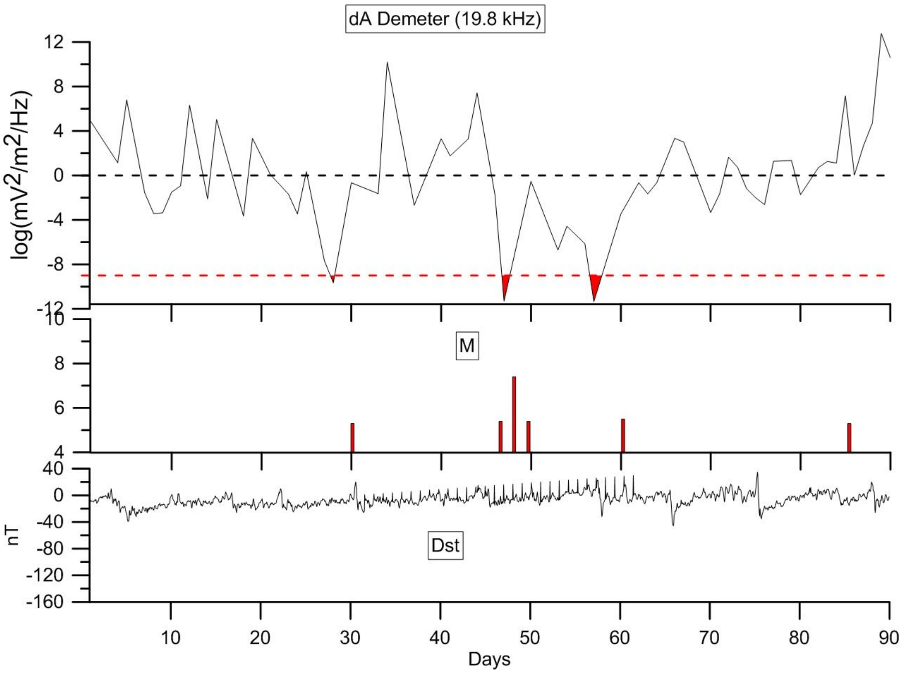

Fig 2. Satellite observations during December 2008 –February 2009. Averaged along part of the orbits VLF signal differences from the reception of NWC transmitter signal are shown. Axis X shows the days beginning from the 1st of December 2006. Red dotted lines show the 2σ level. Two bottom panels represent earthquake magnitude and Dst index of magnetic activity.

An analysis for three periods of seismic activity has been made. A comparison of ground and satellite observation demonstrates good coincidence results. Such simultaneous analysis provides cross validation of the results and can be more reliable in earthquake precursor study. As a mechanism of the observed effects, we suggest that the initial agent is an upward energy flux of atmospheric gravity waves (ACW) which are induced by gas-water release from earthquake preparatory zone. Penetration of AGW waves into the ionosphere leads to the modification of natural (background) ionospheric turbulence.