

Simultaneous analysis of ground-based and satellite VLF/LF signal observations for strong seismic activity in the Far East region

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Periods of seismic activity

1. July-September 2005

near Honshu Island (Japan)

July 16 (M=7.2), July 24 (M=6.2) and September 8 (M=6.2)

2. November 2006

near Simushir Island (Central Kuril)

November 15 (M=8.3)

3. May-June 2008

north part of Honshu Island (Japan)

May 7 (M=6.8) and June 13 (M=6.9)

USED DATA

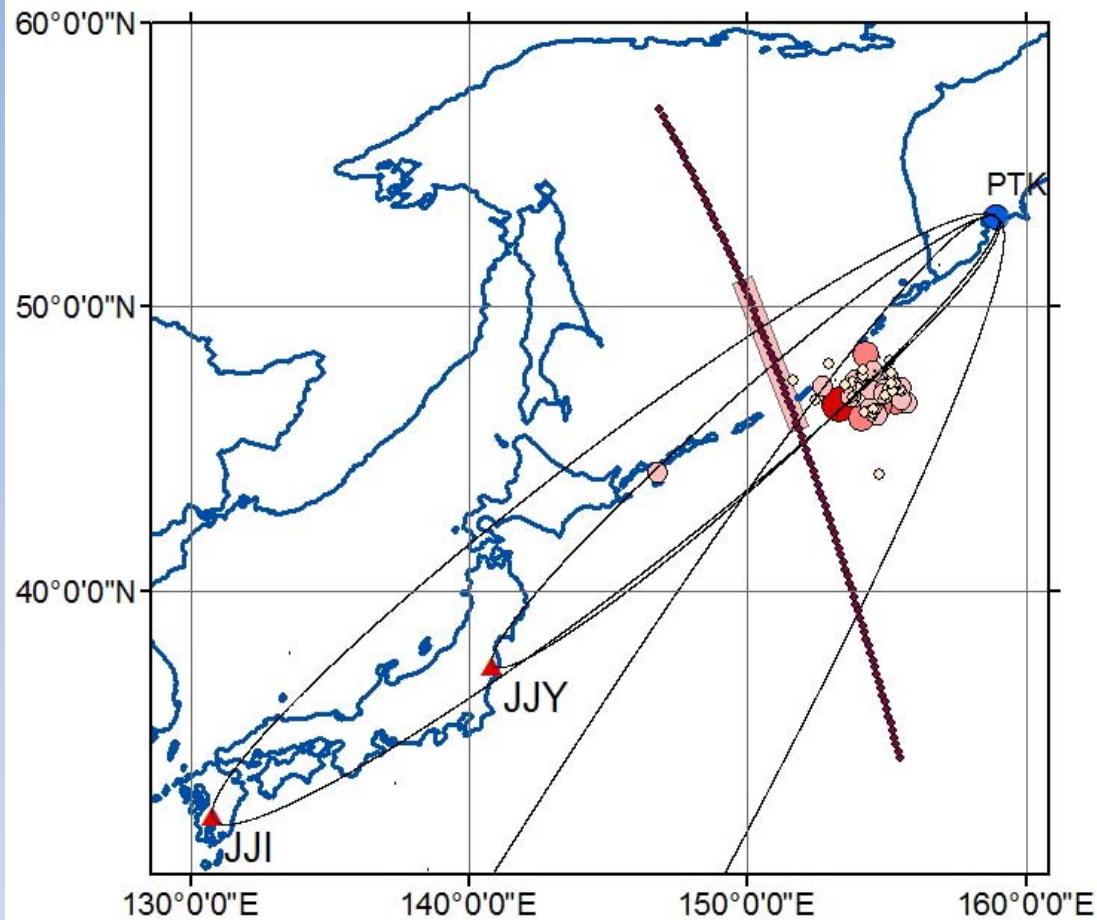
Data from VLF/LF station in Petropavlovsk-Kamchatsky and data from ICE receiver collected on board the DEMETER satellite are used for analysis.

for satellite observations:

- signal from Australian NWC transmitter (19.8 kHz)

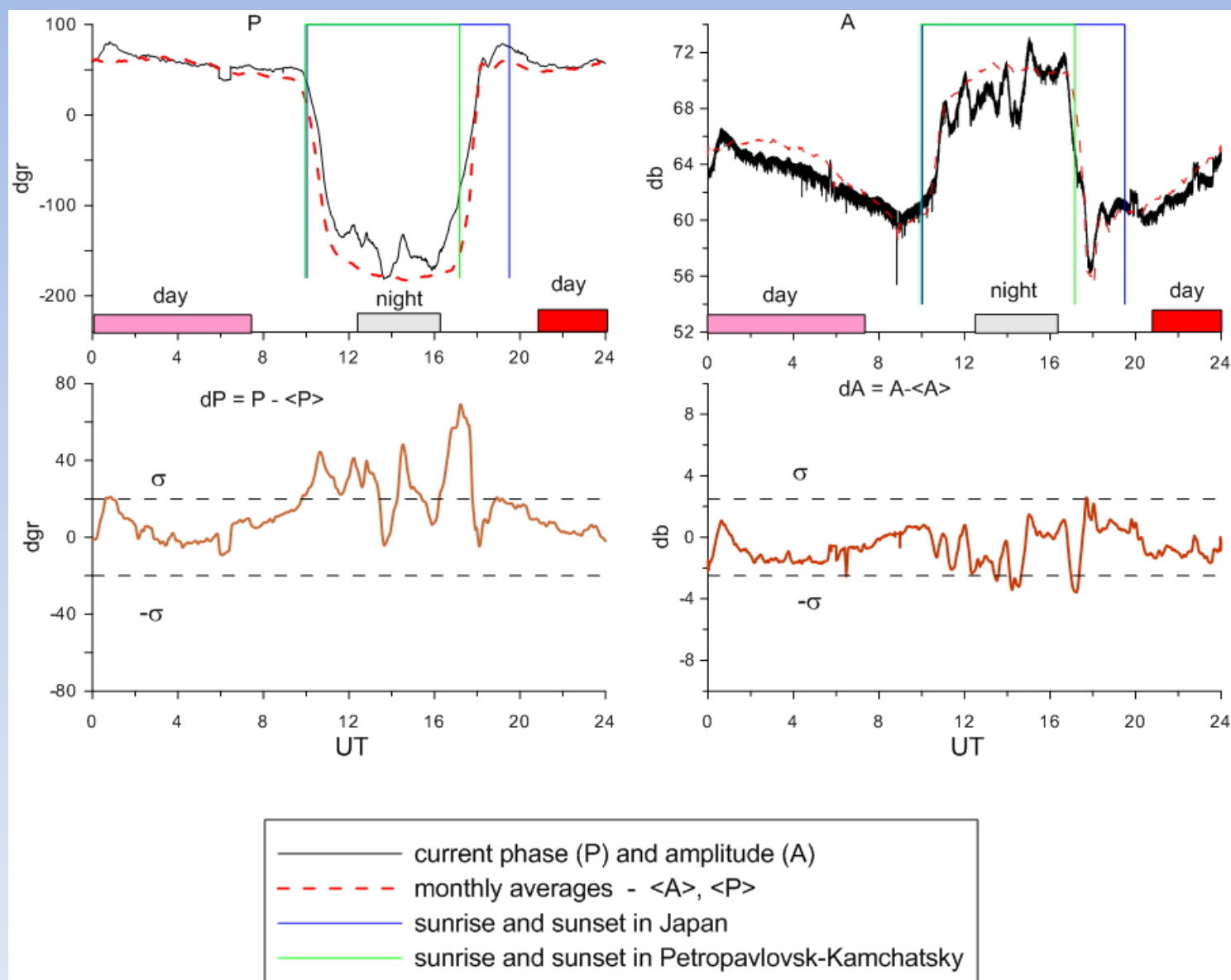
for ground observations:

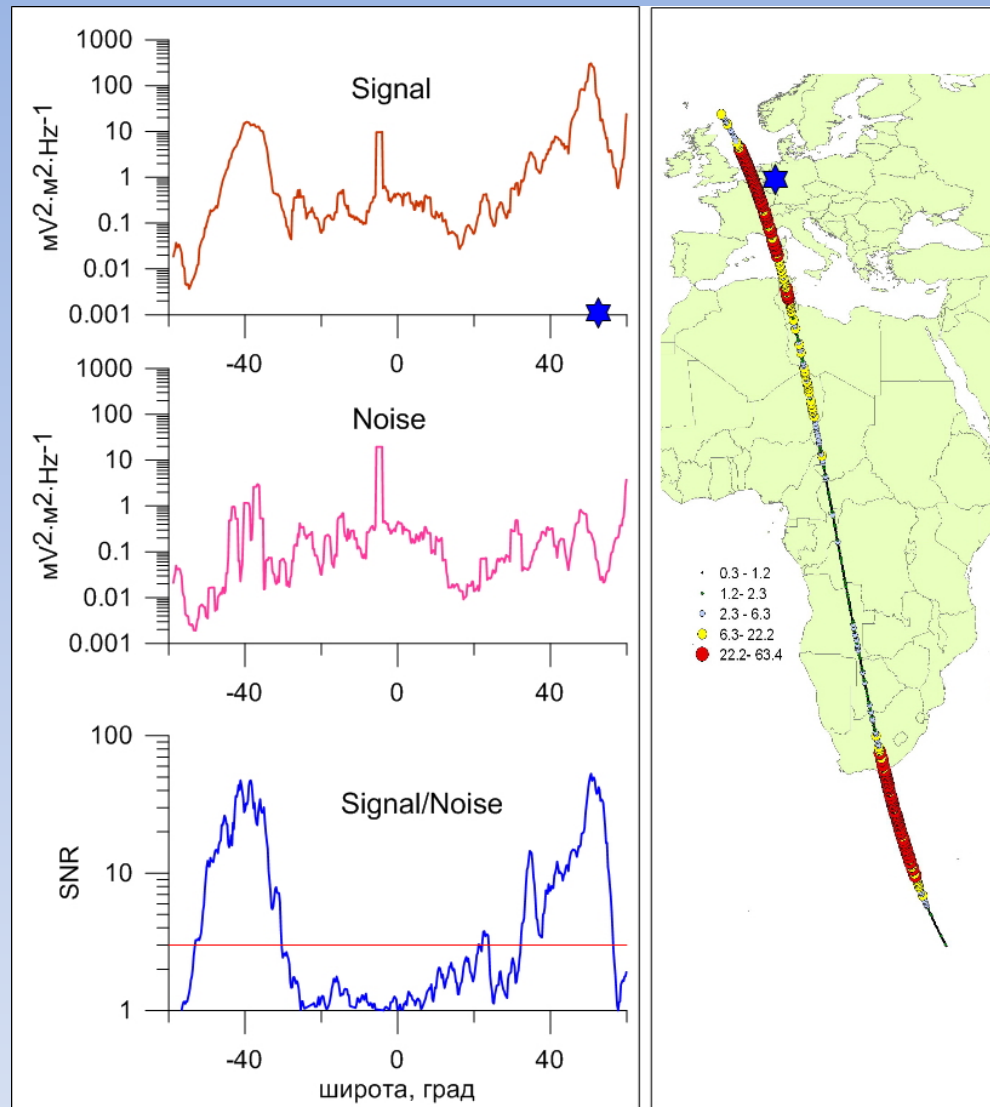
- signal from Australian NWC transmitter (19.8 kHz)
- signal from Japanese JJI transmitter (22.2 kHz)
- signal from Japanese JJY transmitter (40 kHz).



A map showing the position of the station in Petropavlovsk-Kamchatsky (PTK) and VLF/LF transmitters (JJI and JJY) together with epicenter of the earthquake on November 15, 2006 and its aftershocks (catalogue USGS). Ellipses show the sensitivity zones for the transmitters JJI, JJY and NWC. Part of a night orbit passing above the earthquake area is indicated. Pink rectangle is section where effects are observed.

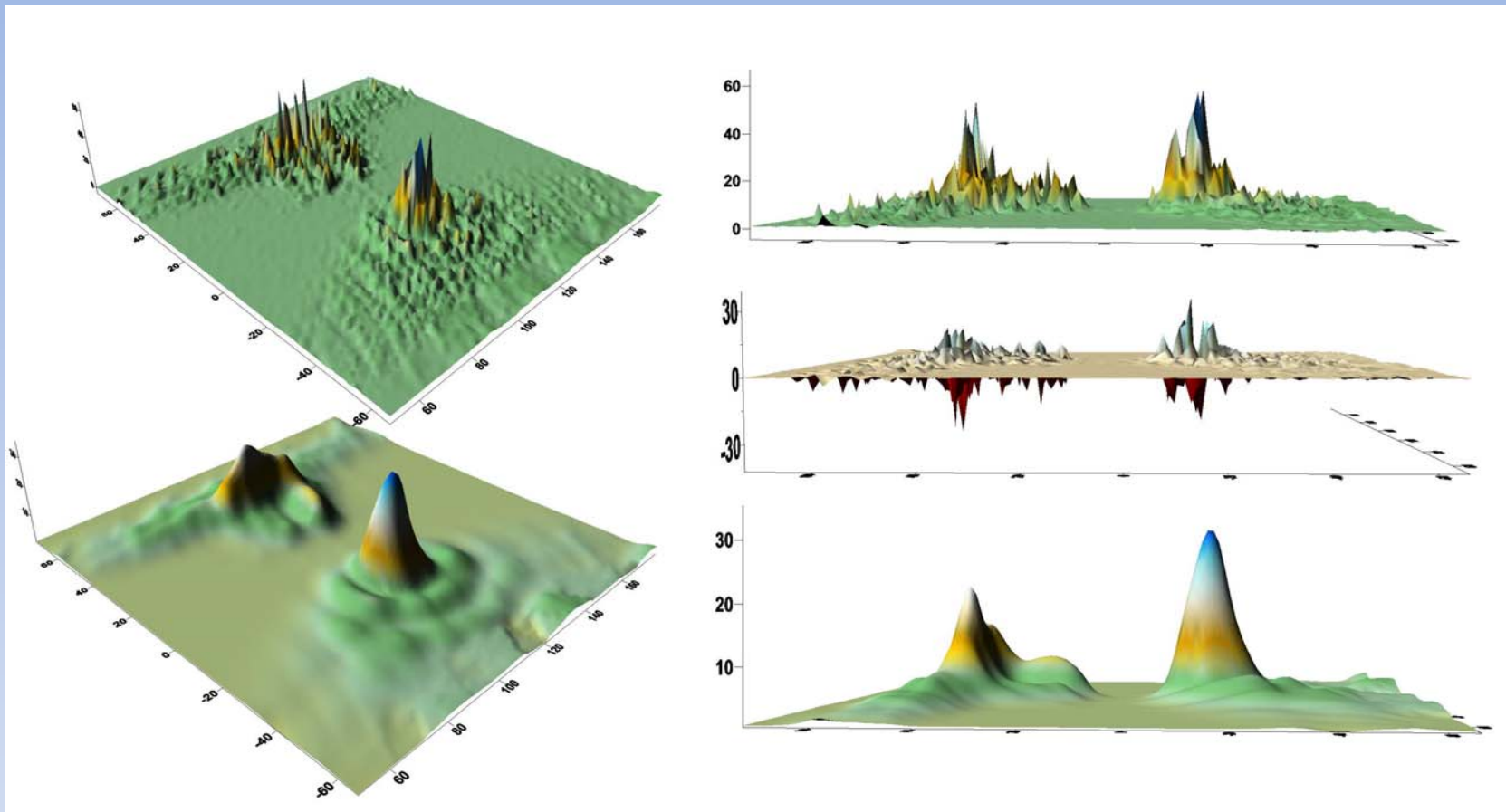
Model for the ground observation



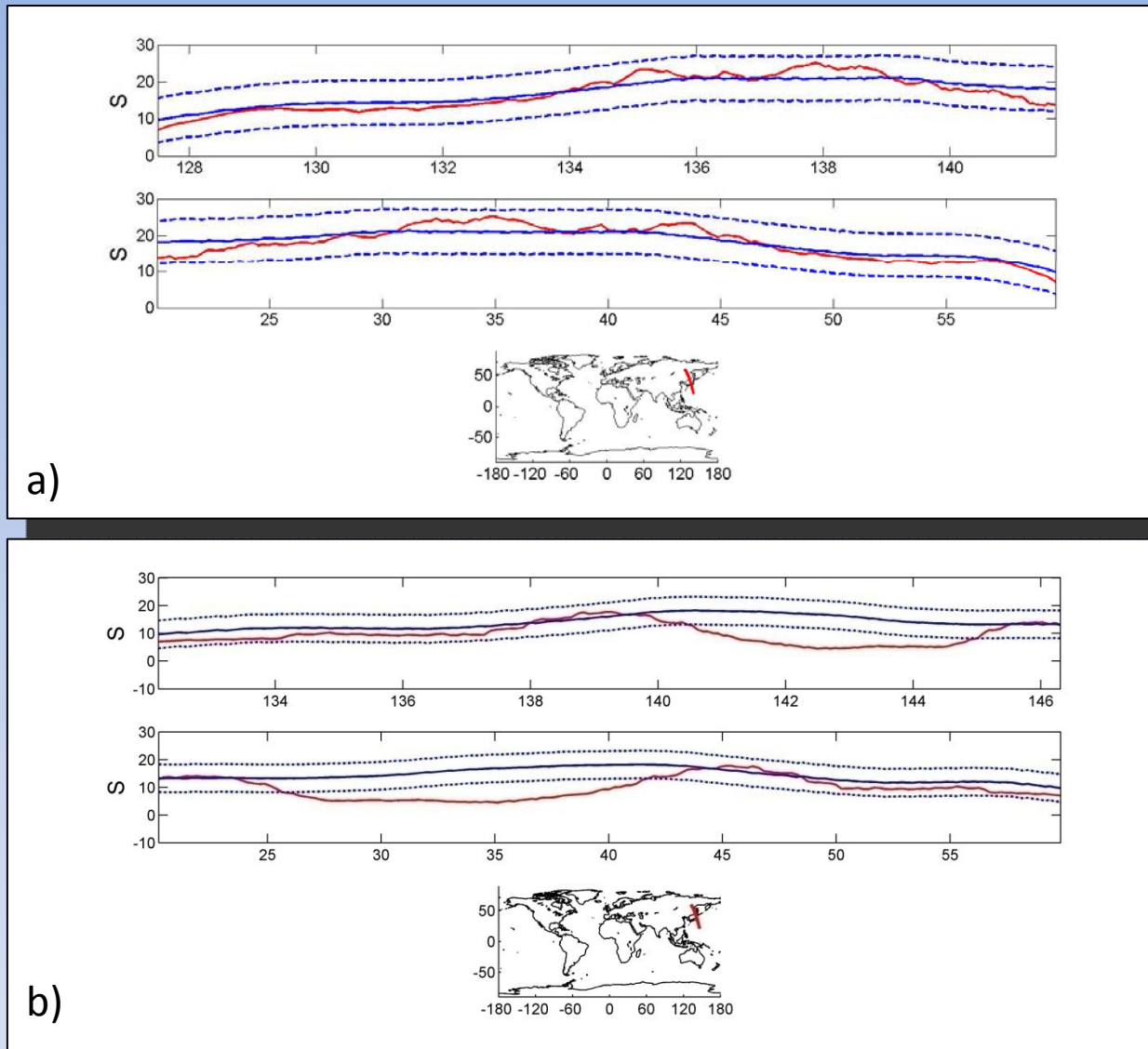


An example of signal/noise (SNR) definition for the night orbit February 12, 2005. Right – position of the transmitter 16.6 kHz and change of S along the orbit, left – graphs of the signal, noise and S.

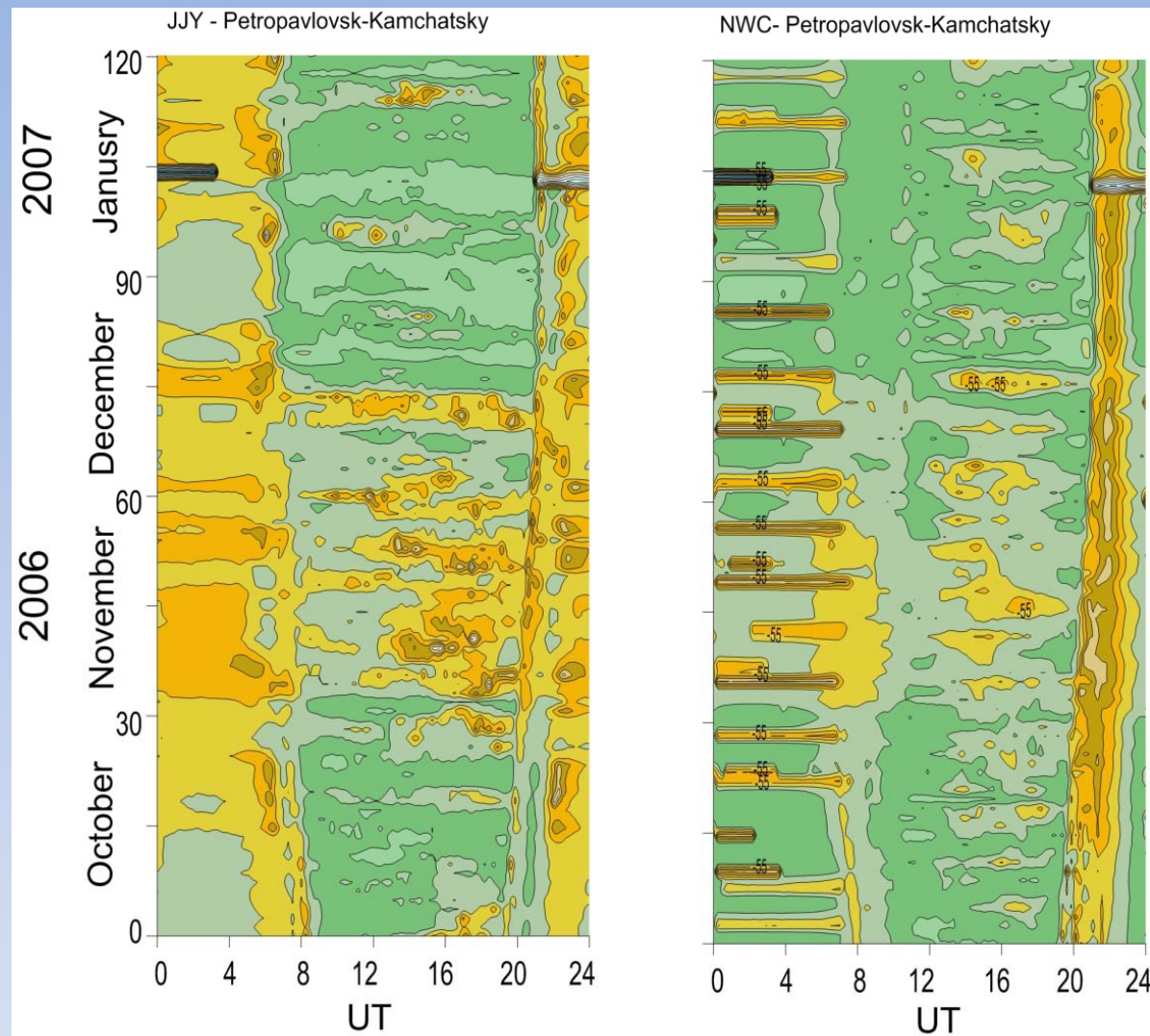
Model for satellite observations



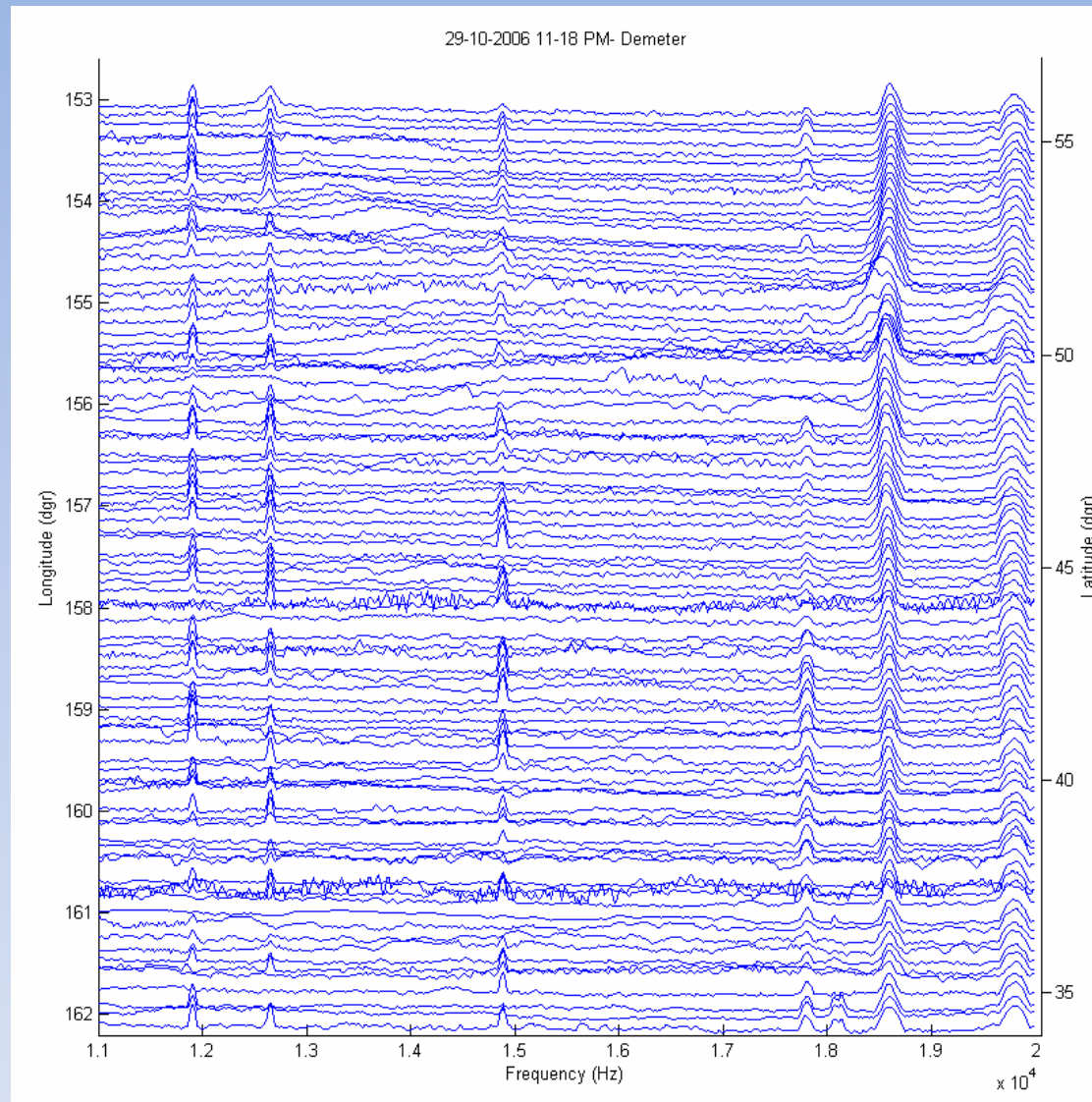
3D image of a model for NWC transmitter for January-March 2005 (day orbits) in different projections. Left – real data (up) and model (down); right - real data, difference between real data and the model, model.



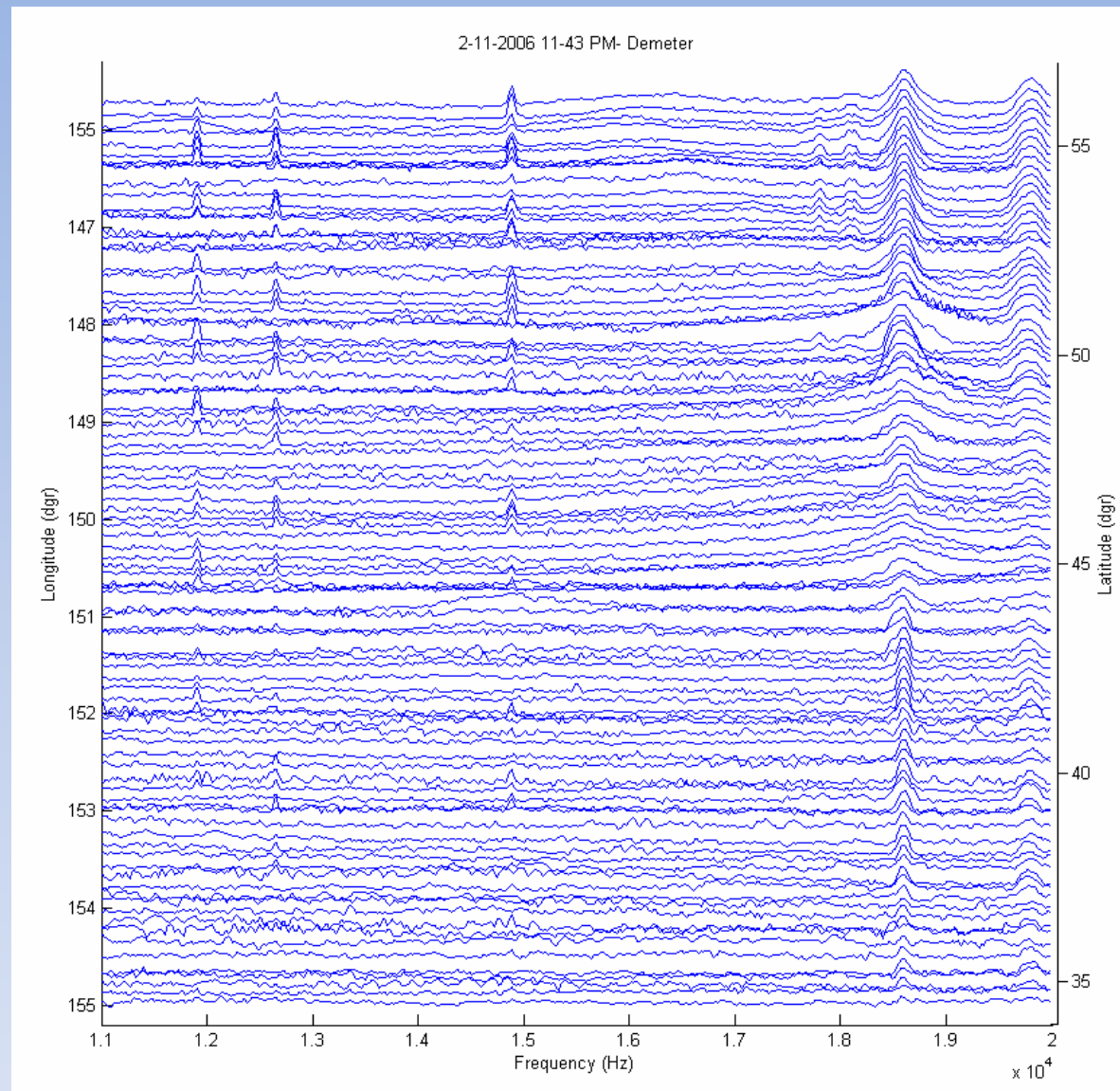
Real (smoothing through 20 points) and model SNR data in a part of the night orbit 56311 for the 2nd of July 2005 as function of longitude (upper panel) and latitude (middle panel). Bottom panel indicates the position of the orbit. Red line is real data, blue one is a model, dotted line is $\pm\sigma$ for the model. The same but for disturbed day August 30, 2005 (orbit 6170).



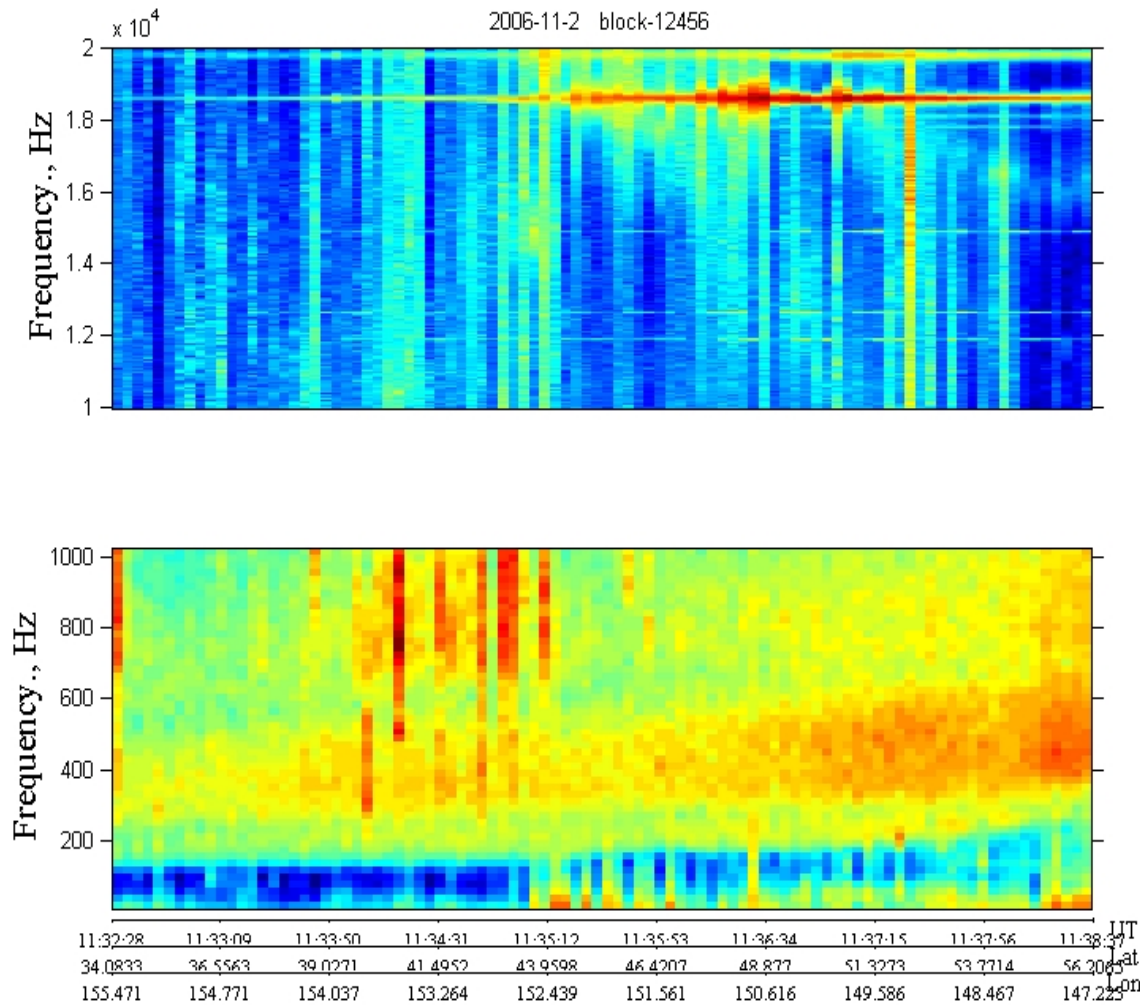
Contour map of the VLF/LF signal amplitude diurnal variations in Petropavlovsk-Kamchatsky during October 1, 2006 – January 31, 2007. Left panel – for the wavepath JJY - Petropavlovsk-Kamchatsky, right panel - for the wavepath NWC - Petropavlovsk-Kamchatsky. Axis X is UT. Local time is UT+10 hours.



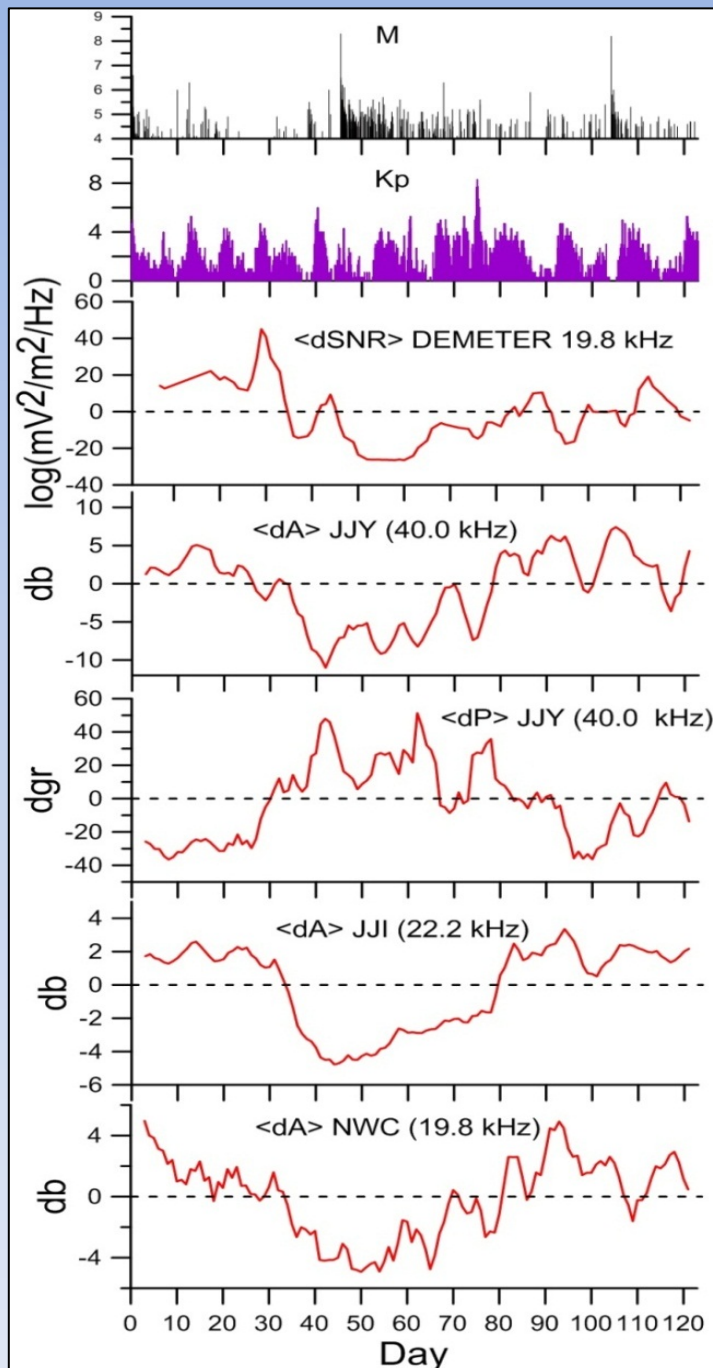
VLF signals variations recorded in the DEMETER satellite along part of orbits for the 29th of October (quiet day). Axes X are coordinate of points.



VLF signals variations recorded in the DEMETER satellite along part of orbits for the 2nd of November 2006 (disturbed day). Axes X are coordinate of points.



Dynamic spectra of VLF signal variations for part of orbit passing above earthquake area. Upper panel – for frequency band 10 – 20 kHz, bottom panel – for frequency band 3-1000 Hz. Disturbed day November 2, 2006 is represented here.



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 is days beginning from the 1st of October 2006. Two upper panels show earthquakes magnitude and Kp index of magnetic activity.

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