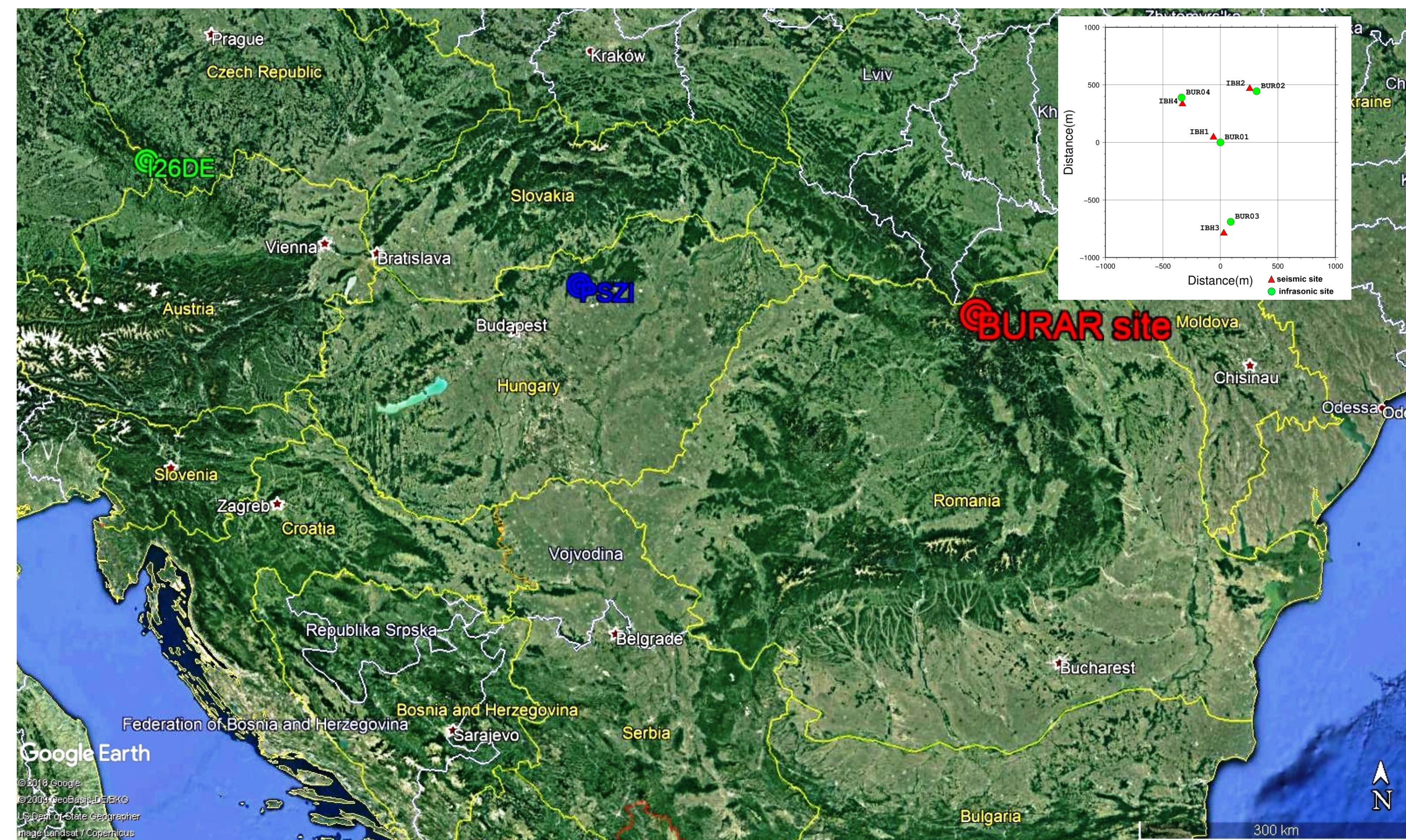


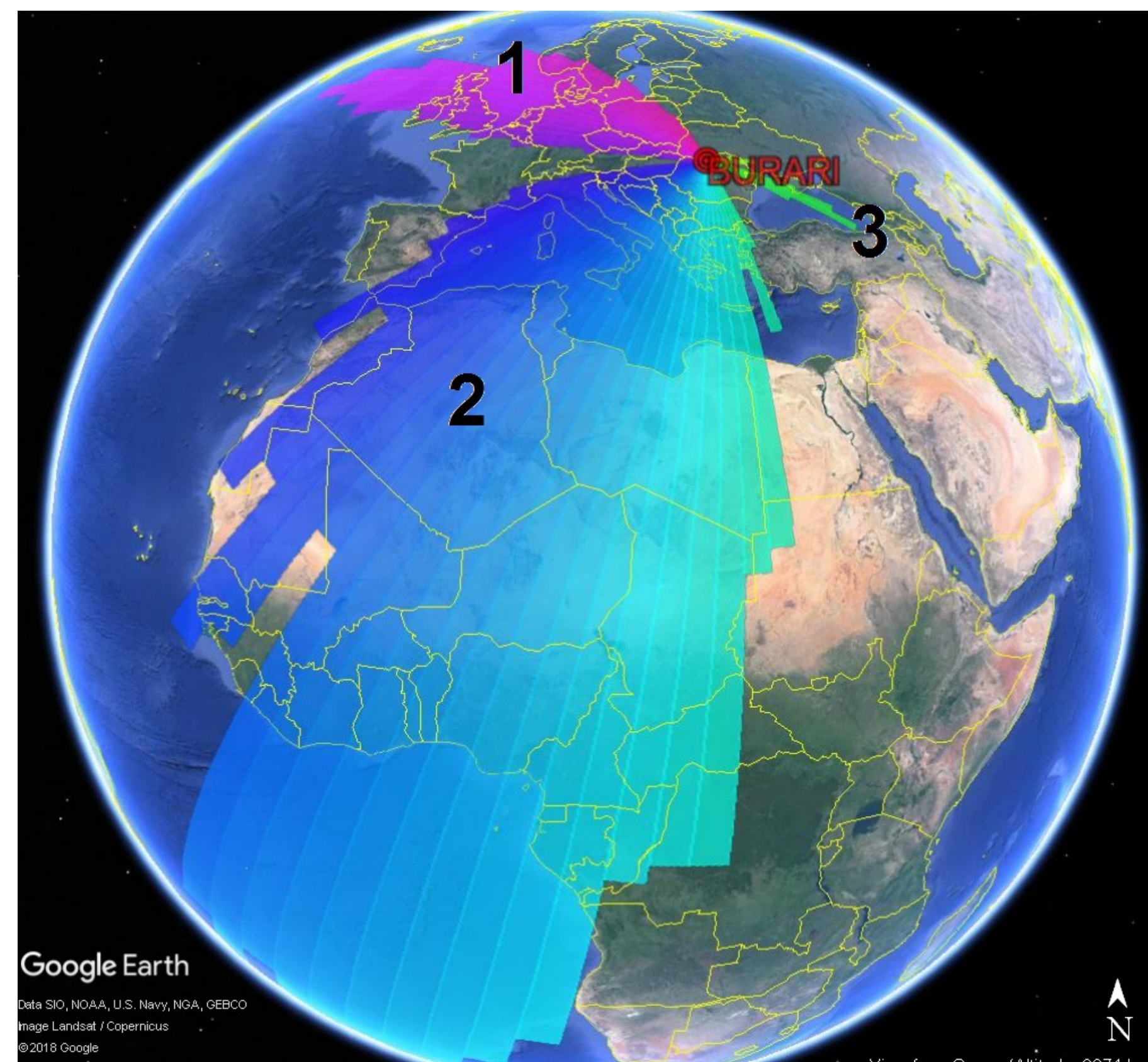
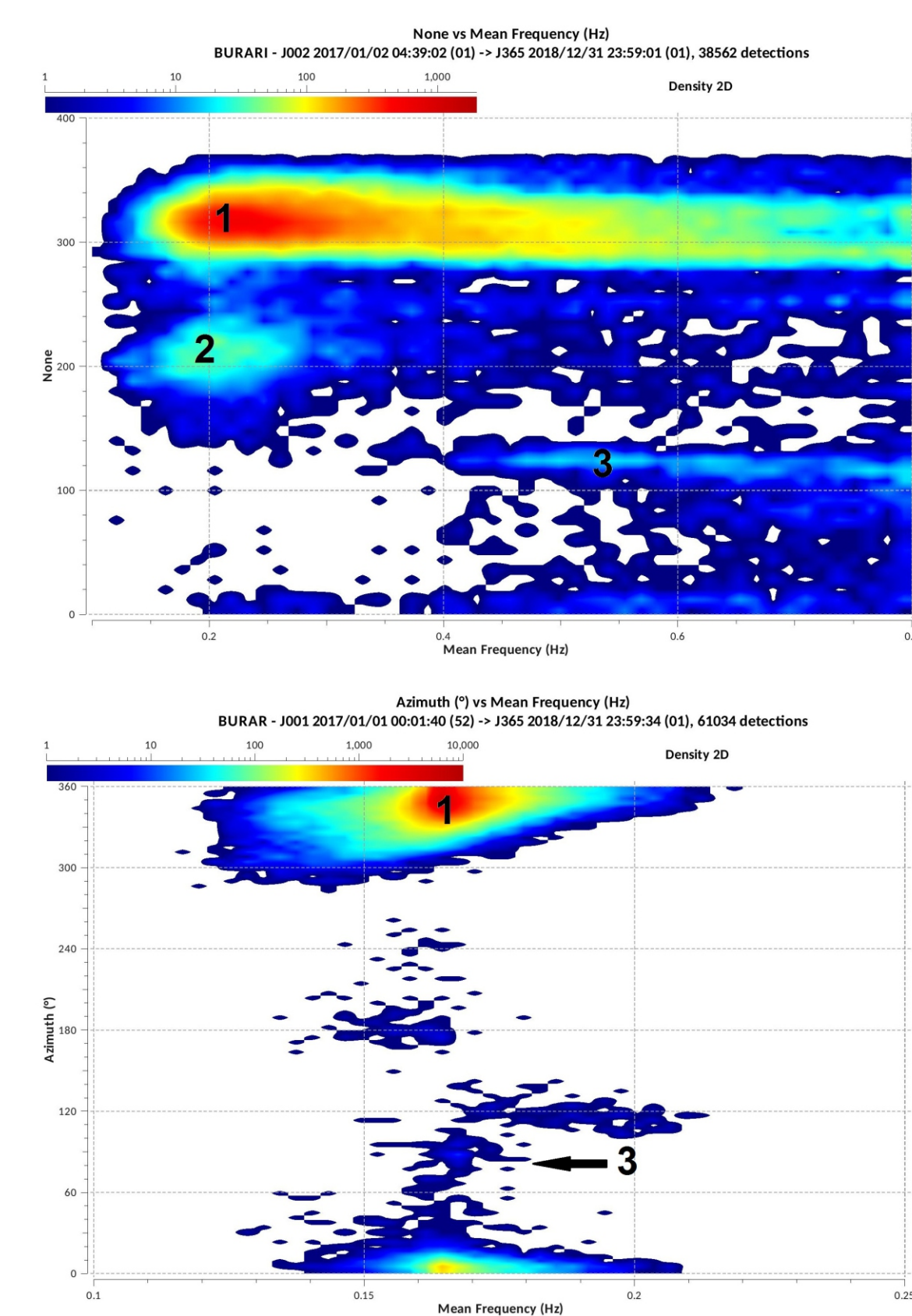
BURAR SEISMO-ACOUSTIC SITE



- Located in the northern Romania, in Bucovina region - Suceava county, at Benea
- Two arrays has been deployed under a joint effort of Air Force Technical Application Center (AFTAC, USA) and National Institute for Earth Physics (NIEP):
 - (1) ten-element seismic array (BURAR) with a total aperture of 5 km, in operation since 2002; for the current study, only the four central elements (BUR01, BUR02, BUR03, BUR04) equipped with 1C-SP GS-21 borehole seismometers are used
 - (2) four-element infrasonic array (BURARI) in operation since 2016; the microbarometers (Chaparral Physics model 21) are located in the vicinity of BURAR four central elements and distributed over an 1.2 km aperture

MICROBAROMS AND MICROSEISMS AT BURAR SITE

- The ambient noise generated by the ocean swell could be observed both atmospheric (**microbaroms** = non-linear interaction with the atmosphere generating infrasound) and crustal (**microseisms** = interaction with the sea floor generating seismic motion)
- The continuous monitoring over two years (2017-2018) at BURAR site showed that the ocean swell can be considered as a significant seismo-acoustic source leaving imprint on both infrasonic and seismic recordings
- Data recorded by BURARI and BURAR arrays have been processed and analyzed in the low frequency bands (0.1Hz to 0.8Hz for infrasonic and 4s to 10s for seismic) using DTK-GPMCC and DTK-DIVA software (CTBTO NDC-in-a-Box); the wave parameters of the signals are calculated with the progressive multichannel correlation method (PMCC) (Cansi, 1995).
- Based on the infrasonic detections, three main directions of arrival (backazimuth), indicating repeating seasonal sources, could be observed:
 - (1) between 280° and 350° (from October to June) - consistent detections, likely originated from ocean swells in the North Atlantic
 - (2) between 180° and 240° (from May to September) - less prominent detections, likely originated from ocean swells in the South Atlantic
 - (3) between 90° and 130° (from May to September) - less prominent detections with higher frequency content, likely originated from wave activity in the Black Sea
- Seismic detections showing almost similar backazimuths could be associated for only two of these sources: (1) North Atlantic and (3) Black Sea



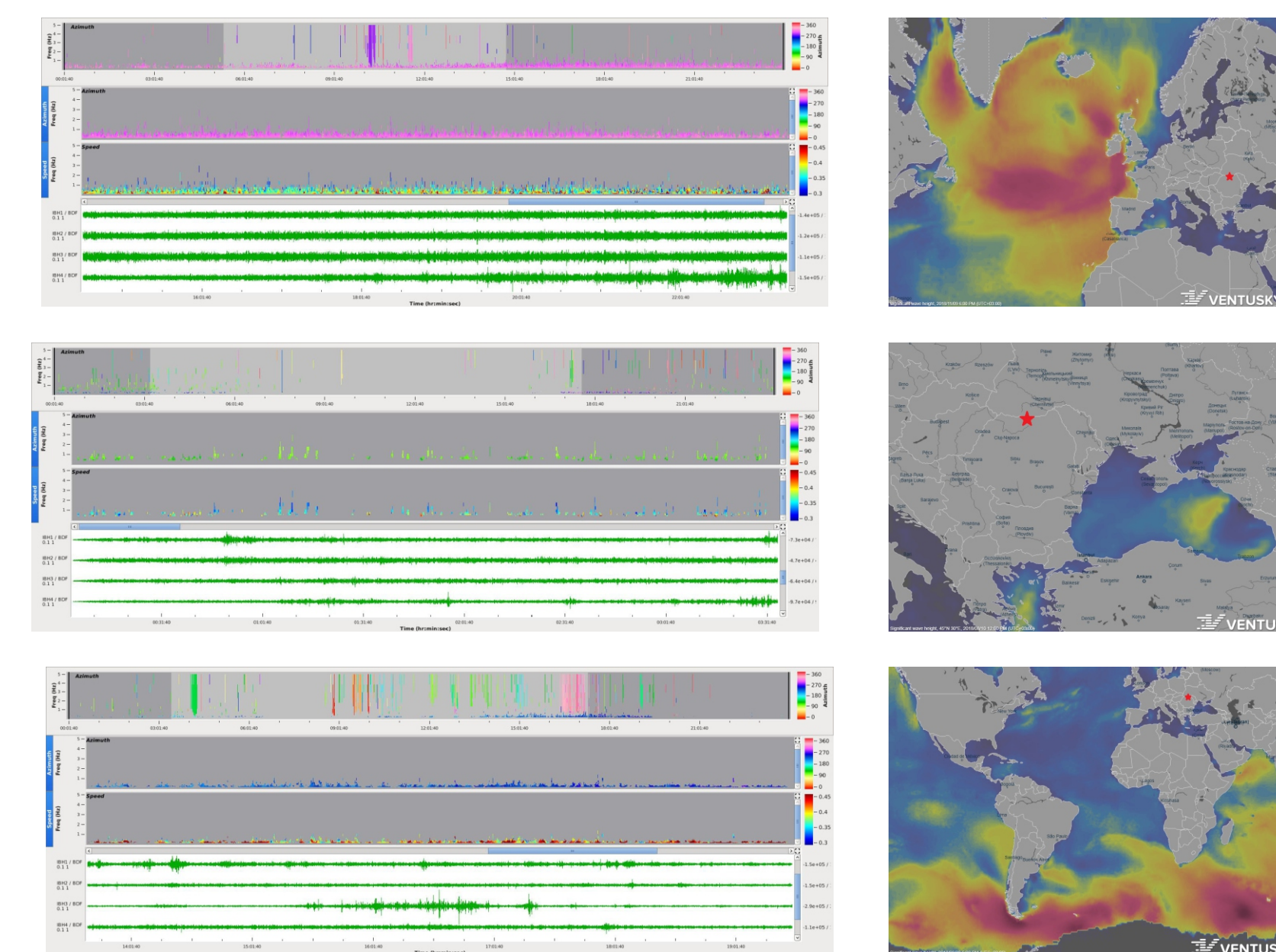
SEISMO-ACOUSTIC ANALYSIS

- One year (2018) of seismo-acoustic observations at BURAR site is analyzed
- Scatter plots of automatic PMCC detections showing the azimuthal variation of both infrasonic and seismic signals from 01 January to 31 December 2018 are displayed
- The low frequency background seismo-acoustic noise recorded at the BURAR site indicates that the sources are most likely located in the North Atlantic and Black Sea
- Whilst the microbaroms originated from ocean swells in the South Atlantic are likely to be detected with BURARI station, the microseisms do not appear to be observed on the BURAR array
- Clear seasonal variation in the infrasonic arrival azimuths are observed; the empirical HWM-93 model can provide a good representation of the general seasonal changes (inversion of stratospheric winds)
- 85% of infrasonic detections are observed during winter season when the stratospheric winds blow westward and the oceanic storms are much frequent in the North Atlantic
- During summer season (Austral wintertime), when the stratospheric winds blow eastward, the interaction between ocean waves in southern hemisphere increases significantly, the swell intensity becoming much larger
- The low frequency observations at BURARI station have been correlated with the performance of two other regional infrasonic stations: **PSZI** (Hungary) (detection bulletins kindly provided by Csenge Czanik, MTA CSFK) and **IS26** (IMS, Germany) (detection bulletins kindly provided by CEA)

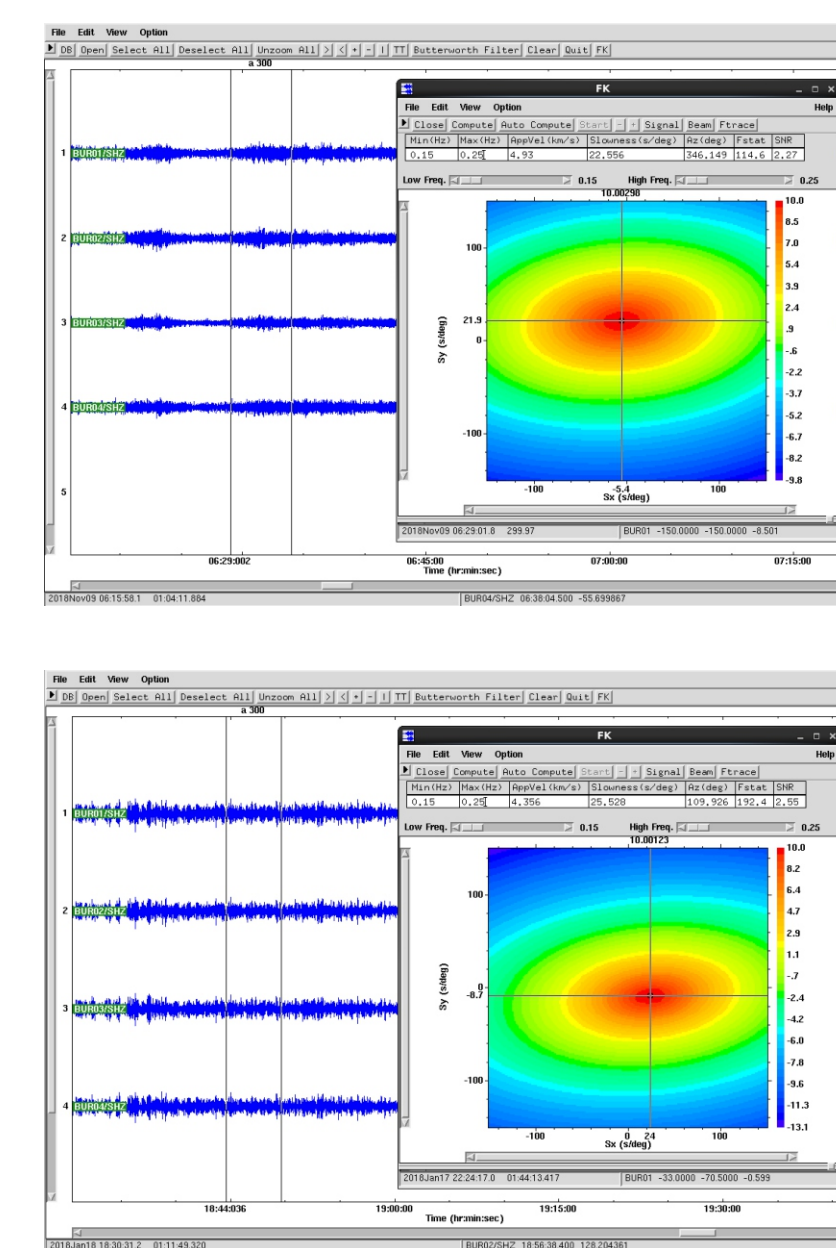
Station	No of elements	Aperture (km)	Distance to BURAR site (km)	Frequency band analyzed (Hz)
PSZI	4	0.4	400	0.1 - 0.8
IS26	8	2.6	860	0.05 - 0.8

- PSZI station shows similar detection behavior to that of BURARI array - all three microbaroms sources mentioned seem to be observed
- With a larger array aperture, IS26 station does not have the capacity to detect microbaroms of low frequency (originated from south hemisphere) (*Le Pichon et al., 2006*)
- When the array aperture decreases (BURARI and PSZI stations), the resolution in characterizing low frequency noise at larger distances increases significantly
- The analysis of the seismo-acoustic data combination allows to connect the microseism and microbarom sources into a complex system which generates both seismic and infrasonic energy
- Both microseisms and microbaroms could be detected by applying PMCC on seismo-acoustic arrays data
- Furthermore, results of f-k analysis applied for seismic data shows backzimuth measurements consistent with two main ocean swell sources likely identified: North Atlantic Ocean and Black Sea
- Detections obtained by applying PMCC algorithm to BURARI infrasonic data, displayed using features of DTK-GPMCC graphical user interface are presented

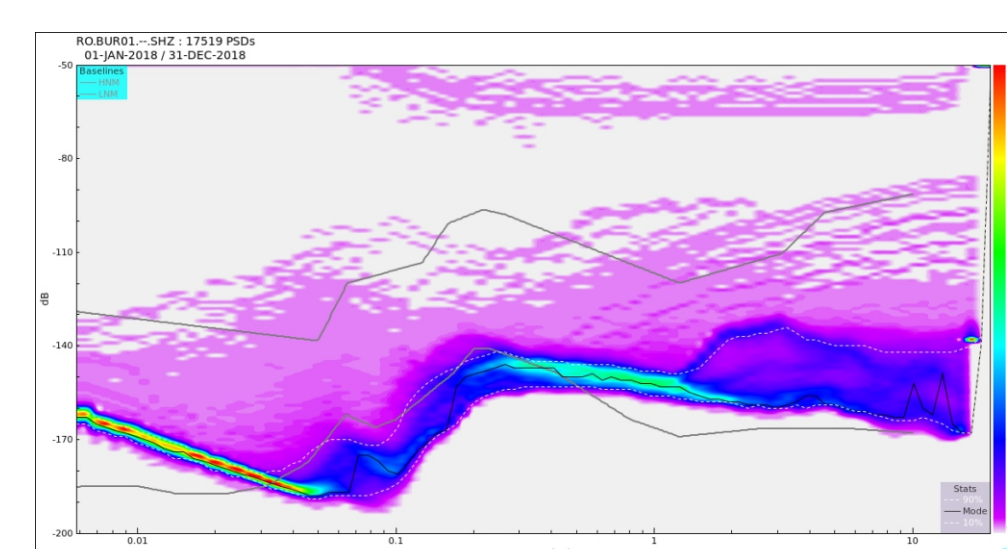
DTK-GPMCC detection results



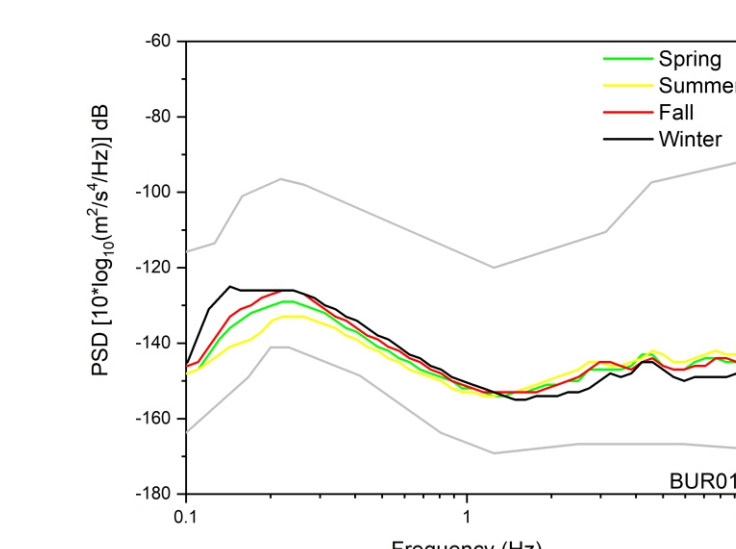
F-k analysis of seismic data



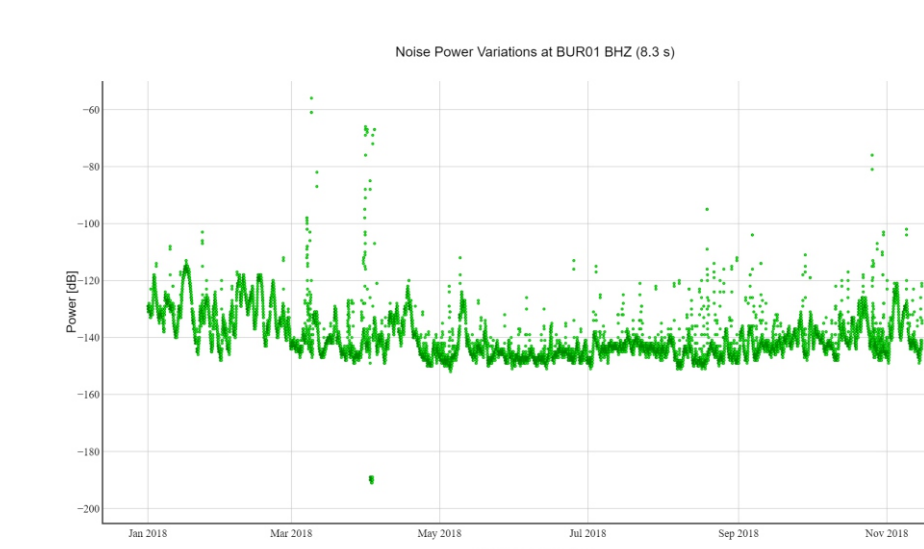
Noise characterization at site



Power Spectral Density Probability Density Function (PSD PDF) for BUR01 seismic element during 2018. The grey lines correspond to the NLNM and NHNM curves



Median of the PSD PDF at station BUR01 computed for three months intervals for 2018



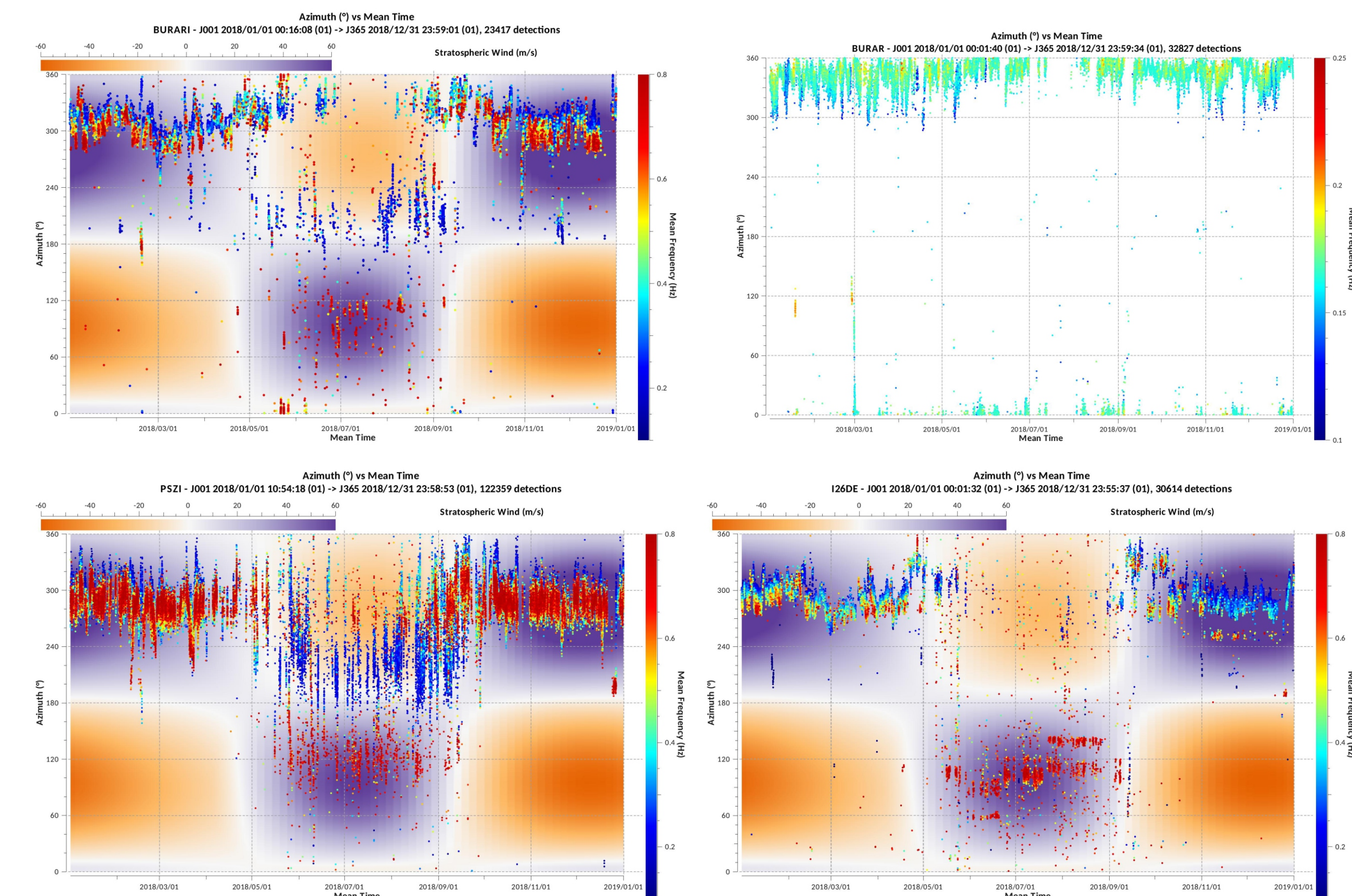
Noise power variations at microseisms periods (8.3 s)

- The high-probability region that corresponds to the background seismic noise level shows very low powers close to the New Low Noise reference Model (NLNM), indicating very good noise conditions at the site
- The noise diurnal variations at the site can be observed for frequencies higher than 1Hz

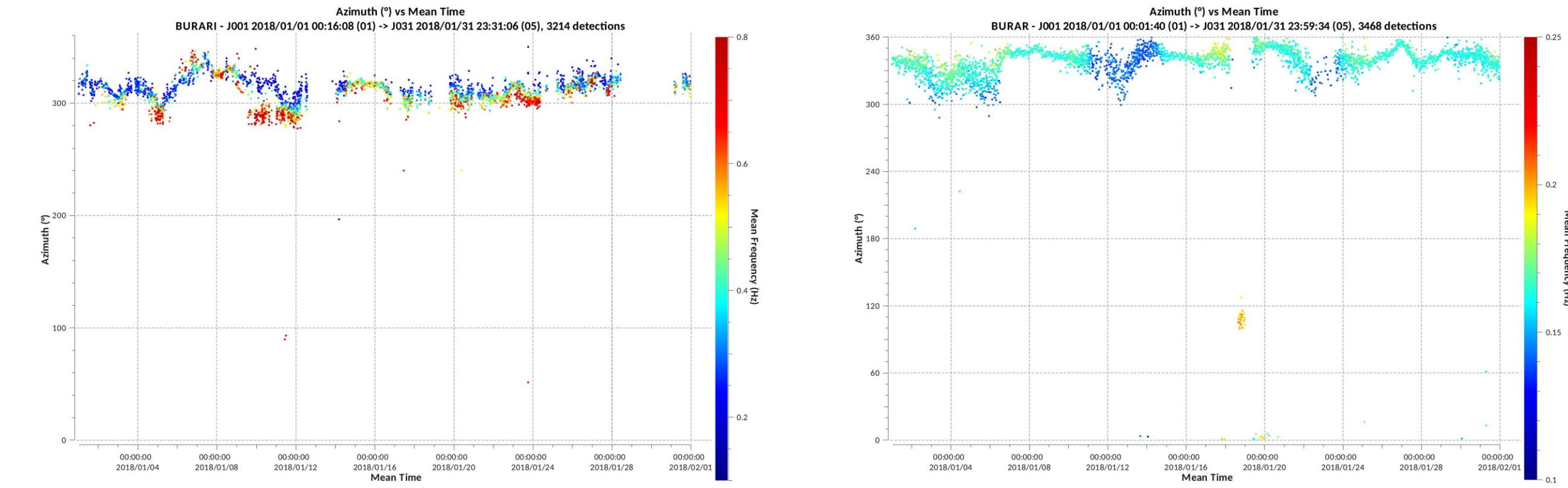
- Increase of the noise power levels in the microseisms band (0.1-0.25 Hz) during the winter and the decrease of the noise levels during summer are shown
- The shift of the Double Frequency Peak (DFP) from smaller frequencies - in summer towards higher frequencies - in winter is observed

- The noise power at 8.3s period computed every 30 minutes for 2018 is shown
- The peaks of the increased noise powers observed during winter months are well correlated with the increase of the wave heights in the North Atlantic

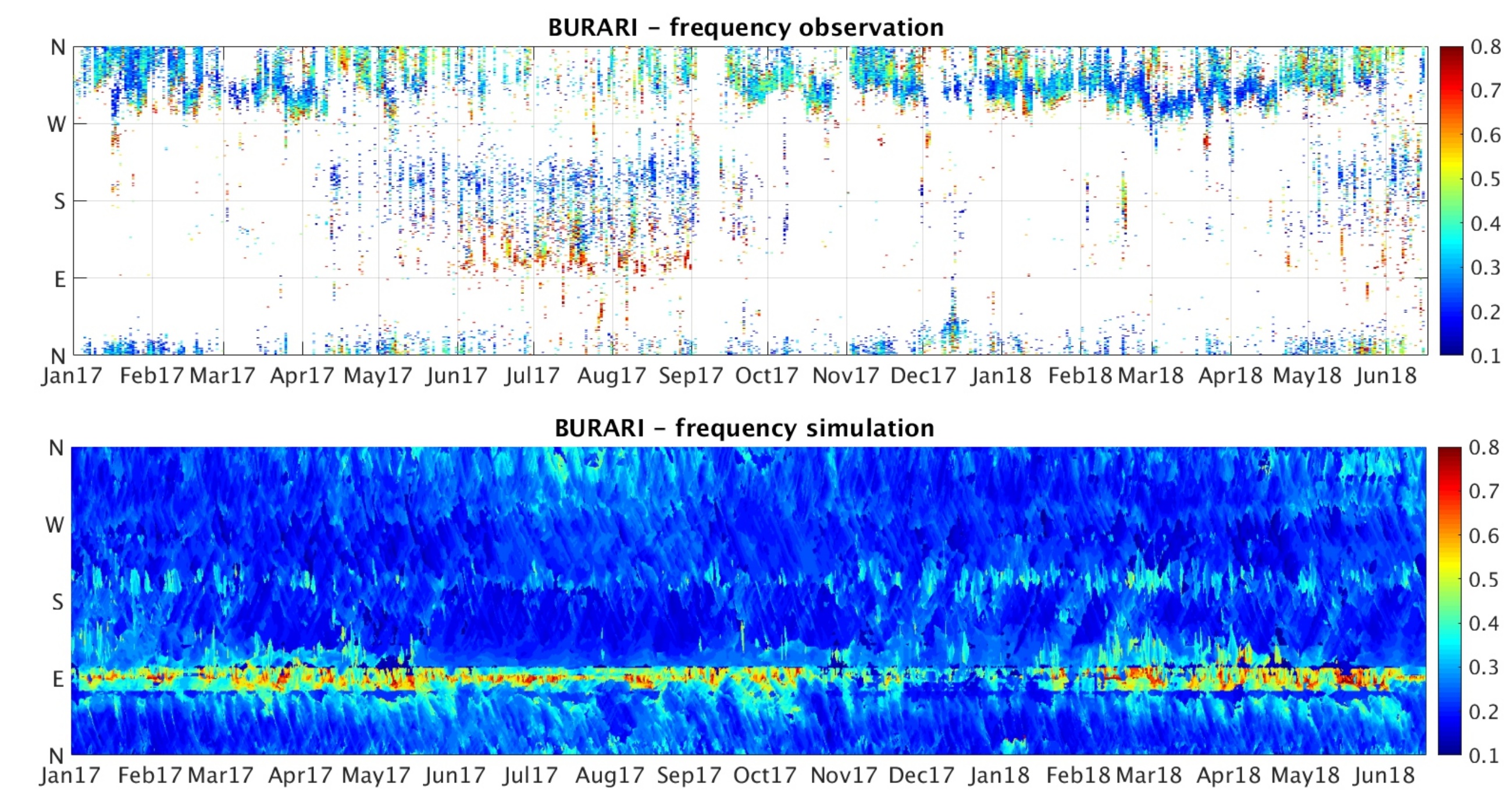
Array detection performance - one year of data



Array detection performance - one month of data (January 2018)



Observation and expectations modeling (kindly provided by Marine de Carlo, CEA)



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- Le Pichon A, Ceranna L, Garcés M, Drob D, Millet C (2006) On using infrasound from interacting ocean swells for global continuous measurements of winds and temperature in the stratosphere, J Geophys Res 111 (D11):D11106, doi:10.1029/2005JD006690

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