

# Detection patterns for two IMS infrasound stations in the vicinity of the North Korean test site

T1.1-P8

Karl Koch and Christoph Pilger

Federal Institute for Geosciences and Natural Resources (BGR), Stilleweg 2, D-30655 Hannover, Germany.

## 1 Introduction

IMS stations IS30 in Japan and IS45 in Russia at distances of nearly 1200 km and some 400 km, respectively, from the North Korean (DPRK) nuclear test site have been in operation since 2003 and 2008. A corresponding detection catalogue is available, including the detections from the nuclear test in 2013 which were included in the REB. In addition, we have analyzed infrasound data relevant to the North Korean underground nuclear tests since 2006 at these stations and found signals that can be associated to most events, except for the 2009 test and the September 2016 event. Except for the DPRK test in 2013 and the corresponding infrasound signals at IS45, none of these detections can be visually identified in any of the waveform data. This is further the case for the weak signal detections that can be associated to the seismic event of 12 May 2010 on or very close to the test site. Based on the fact that nearly all detections are hidden in the background noise, we assessed the probability for incidental detections from the directions towards the test site.

## 2 Locations of IMS stations IS30, IS45 and seismoacoustic sources

IMS stations IS45 (Russia) and IS30 (Japan) are located to the northeast and southeast with backazimuths of 217° and 308° to the DPRK nuclear test site. Major cities in their vicinity are Vladivostok (at a distance of some 100 km and a backazimuth of ~180° from IS45) and Tokyo (at distances of some 30-100km and a backazimuth range from 270-330° from IS30) (Fig. 1).

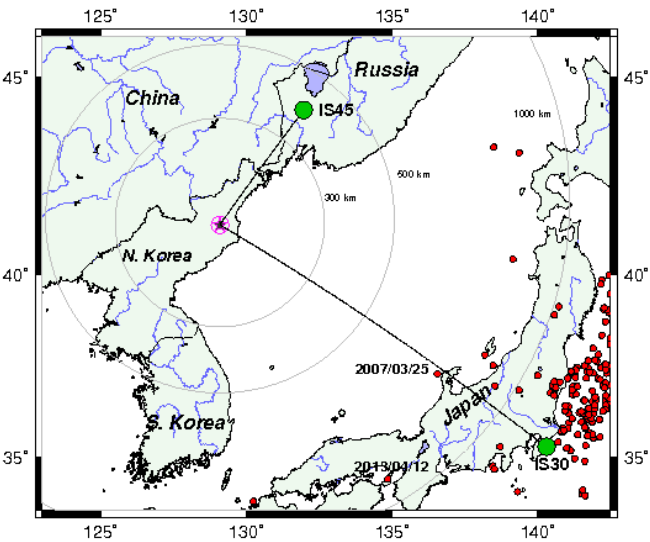


Fig. 1: Map of eastern Asia showing the locations of IMS stations IS30 and IS45 (green dots) together with the great circle paths to the North Korean Nuclear Test Site, depicted by a circled magenta star. Furthermore the shallow seismic sources from the ISC catalogue (reported depths not exceeding 35 km) for the years 2005-2016 with magnitude above mb=6 in this region are shown by the red dots. These (seismoacoustic) sources have a potential for exciting acoustic waves that may be recorded by infrasound stations. For two of these events, one located in the direction towards the DPRK test site and one in westerly direction from IS30, we present signals below, with the corresponding detection from the latter event reported in the REB as well.

## 3 Results of detection processing for IS30 and IS45 using PMCC

The waveform data from infrasound stations IS45 and IS30 have been processed using the Progressive Multi-Channel Correlation (PMCC) technique (Cansi, 1995) in order to find signal detections from seismoacoustic sources. Initially the processing was carried out for frequencies between 0.5 and 5 Hz, but here we limit the data set to the detections in the frequency band from 1 to 5 Hz (Fig. 2) within the six years from 2009 to 2014, for consistency with the frequency-wavenumber (F-K) analysis (Capon, 1969; Stammer, 1993) carried out within this study.

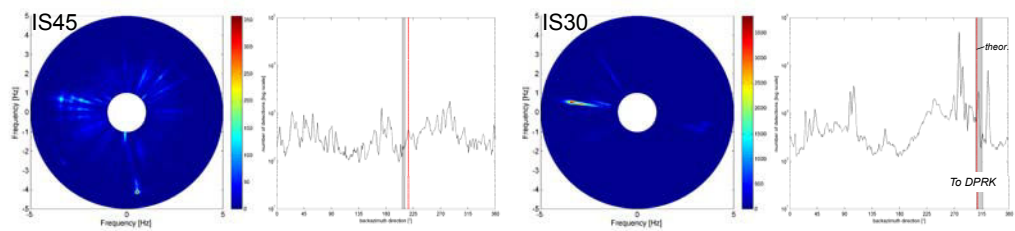


Fig. 2: Detection results from PMCC processing of the data from IMS stations IS45 (left) and IS30 (right) as cumulative frequency plots. The polar diagrams show the cumulative frequency color-coded according to the detection frequency (in Hz), while the azimuth diagrams indicate the preferred directions (backazimuths). Note that the azimuthal cumulative frequency is logarithmically scaled.

## 4 Comparison between PMCC detection processing and F-K moving window analysis

Based on previous studies by Koch & Pilger (2016, 2017), who found infrasound signals associated with most DPRK underground nuclear tests between 2006 and 2016 at the two IMS infrasound arrays closest to the test site using the F-K technique, a moving window analysis (length 80 s, 50% overlap) was carried out over the available 6 years of waveform data and compared to PMCC detection results (Figs. 3 and 4). With this analysis we aim at estimating the probability for chance (or noise) detections from specific azimuth ranges, especially concerning the azimuths pointing towards the DPRK test site.

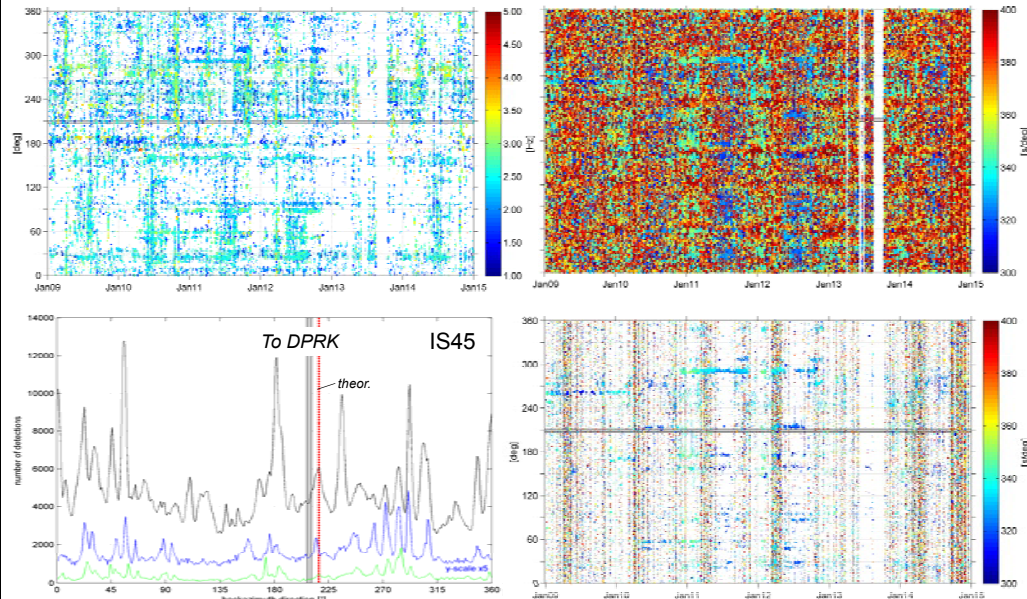


Fig. 3: Comparison of the detection results from PMCC processing (top left) and the moving window analysis by the F-K technique (right) for the years from 2009 to 2014. In these diagrams the expected azimuth range for DPRK test site events is highlighted in grey, based on the results from the detected nuclear events. The lower F-K results plot contains only detections exceeding a specific spectral power level. On the lower left the cumulative frequency vs. azimuth is shown for the different F-K analysis results (black/blue lines) and PMCC processing (green). The backazimuth to the DPRK test site is not particularly significant, but directions towards the south (Vladivostok), however, are.

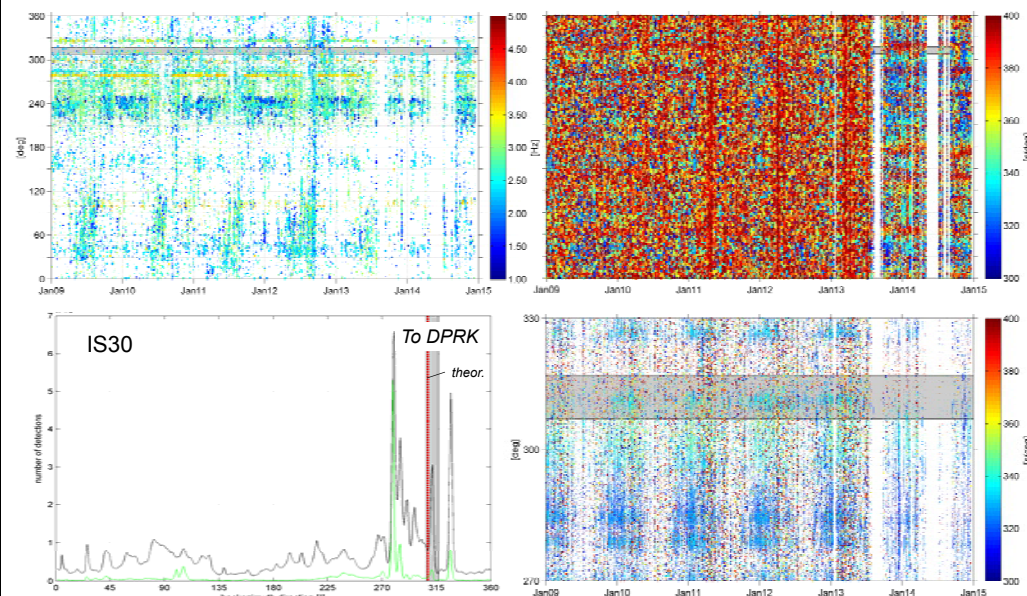


Fig. 4: Comparison results for IS30 (same as Fig. 3), except that on the right the analysis results are presented for all directions and for the azimuth range between 270 and 330 degrees, resp. This range covers the directions to the Tokyo metropolitan area, but also to the DPRK test site. It should be noted that DPRK test site events may be affected only by one of the side maxima near 315° (lower left).

## 5 Seismoacoustic detections at IS30 and IS45 from F-K analysis

Results of Koch & Pilger (2016, 2017) from interactive analysis of infrasound data from IS30 and IS45 using the F-K technique are presented below, firstly, concerning the 2013 underground nuclear explosion at the DPRK test site, and secondly, the weak F-K detections that may be associated to the 12 May 2010 event studied by Zhang & Wen (2015) and Kim et al. (2017). We also searched for additional shallow earthquake sources in the general area and found two events in Japan with data recorded at IS30, one (2007/03/25) near the great circle path to DPRK and one (2013/04/12) to the west-southwest of IS30, with the detection of the latter also being contained in the REB.

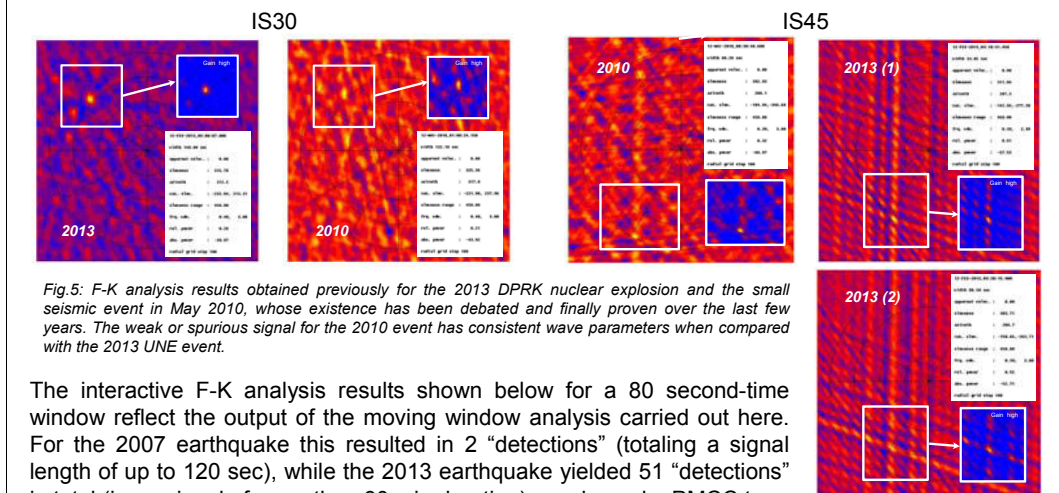


Fig. 5: F-K analysis results obtained previously for the 2013 DPRK nuclear explosion and the small seismic event in May 2010, whose existence has been debated and finally proven over the last few years. The weak or spurious signal for the 2010 event has consistent wave parameters when compared with the 2013 UNE event.

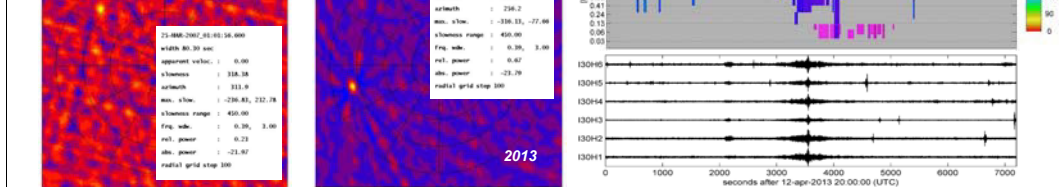


Fig. 6: F-K analysis results for two earthquakes in Japan that were recorded by IS30 at a distance of 400km (2007) and 500 km (2013), resp. (see also Fig. 1). The signal for the 2013 event at IS30 is very prominent in the waveform data (see Fig. 7).

## 6 Summary & conclusions

Processing six years of waveform data with the PMCC algorithm and the F-K technique a number of frequency peaks are found for specific azimuths. For IS45 these peaks are widely scattered, while for IS30 the peaks cluster mainly between 270 and 330°, which could be indicative for a number of acoustic sources within the Tokyo metropolitan region. However this range also includes the direction to the DPRK test site. We conclude from this study:

- From PMCC processing we do not obtain a significant number of detections for IS45 in the relevant azimuth range for DPRK test site events; it applies similarly for IS30.
- For IS45 comparison of PMCC detections and F-K moving window analysis above a certain spectral power level suggests consistent detection patterns for certain directions.
- For IS30 the backazimuth towards the DPRK test site coincides with the azimuth range of the Tokyo metropolitan area – PMCC and F-K produce similar frequency patterns therein.
- The probability for incidental F-K “detections” for events on the DPRK test site, including the small May 2010 seismic event, is very low. This applies in particular for IS45.

### References

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