

## **Infrasound signals from events at the DPRK test site: observations and modeling results**

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Over the last ten years North Korea announced underground nuclear test explosions at its Punggyi-ri test site in October 2006, May 2009, February 2013 as well as in January and September 2016. For the test in February 2013 infrasound arrivals are clearly seen in recordings at IMS station IS45 in Russia. These have been associated to the event in the Reviewed Event Bulletin (REB) along with an arrival for IMS station IS30, which appears hidden in the background noise of the waveforms. Even before these infrasound arrivals were detected, there have been reports from infrasound signals observed at a network of national infrasound stations in South Korea for the May 2009 events. These stations subsequently were also reported to have detected the 2013 event acoustically. More recently it was found for IS45 that it may have detections from the January 2016 underground nuclear explosion.

Based on these reports we undertook a comprehensive study and searched for infrasound arrivals in the data of two IMS stations, IS30 and IS45, that could have originated from near-source conversion near the primary nuclear explosion source. For all events analyzed using the frequency-wavenumber (F-K) technique, we find infrasound signals, except for the events in 2009 and September 2016, that can be attributed to the source at the test site, in terms of appropriate arrival directions and apparent velocities. For the 2009 event we find a late acoustic arrival at IS45 corresponding to a previously observed arrival arriving early at South Korean stations, which are located in the opposite direction of IS45. We apply propagation modeling using ray tracing and parabolic equation calculations in order to verify all observed infrasound detections at the IMS stations as well as reported arrivals from a station in South Korea. Finally we also examined the case of the 12 May 2010 event, for which we find weak or spurious detections, but which we can model sufficiently well, so that we can not rule out their existence.