Atmospheric Transport Modelling
A refined backtracking and source reconstruction for the noble gas measurements taken in the aftermath of the announced October 2006 event.

Andreas BECKER1, Gerhard WOTAWA1, Anders RINGBOM2 and Paul R.J. SAEY3

1Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization, Vienna International Centre, P.O. Box 1200, A-4040 Vienna, Austria
2Swedish Defence Research Agency (FOI), Defence and Security, System and Technology Division, SE-172 90, Stockholm, Sweden,

Introduction
At 01:35:28 UTC on 9th October 2006, the International Monitoring System being built under the auspices of the Provisional Technical Secretariat (PTS) of the Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) recorded an event with the characteristics of an underground explosion in the Democratic Peoples Republic of Korea (DPRK) located at (41.3119ºN, 129.0189ºE). Six days earlier the public press reported on an announcement of a nuclear test explosion issued by DPRK officials.

Dispersion Modelling of the REB Event in the DPRK
The announced October 2006 event in the Democratic People’s Republic of Korea (DPRK) has been the first real test regarding the technical capabilities of the verification system built up by the Vienna based Provisional Technical Secretariat (PTS) of the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) to detect and locate a nuclear test event. The PTS analysis indicated an explosive nature of the event with a body wave magnitude of 4.1 ± 0.1 that corresponds to an energy release of somewhat less than one kiloton of TNT in hard rock. This comparatively low yield gave rise to many speculations on whether the explosion event was nuclear or not and demonstrated therefore the relevance of the radionuclide (RN) compartment of the IMS comprising a highly sensitive 60 stations radionuclide (RN) network. 40 of these stations are scheduled to measure also radio-xenon (Figure 1). Within a refined backtracking effort compared to previous studies (Saey et al., 2007, Becker et al., 2007) the radionuclide release scenario of the October 2006 event was reconstructed by analysis of the radio-xenon measurements taken at the remote radionuclide station in Yellowknife, Canada, which is part of the PTS International Monitoring System (IMS), and additional measurements taken by a mobile noble gas system deployed quite close to the event location in the Republic of Korea (ROK) by the Swedish Defence Research Agency (Figure 3). Source location methods based on forward (Figure 2) and backward atmospheric transport modelling (Figure 5) with the Lagrangian particle trajectory model FLEXPART 5.1 (Stohl et al., 2005) played a crucial role for the source scenario reconstruction (Figure 4). It is shown that the Xenon-133 measurements in Yellowknife were significantly sensitive to releases from the nuclear explosion during the first three days after the event, while the mobile measurements where rather insensitive to releases during the days 2 to 4 after the explosion.

Results
According to the analysis, the most likely source scenario would consist of an initial (possibly up to 21 hours delayed) venting of 1×10−15 Bq Xe-133 during the first 24 hours, followed by a 2 orders of magnitude weaker seepage during the following 72 hours. The Swedish mobile measurements were crucial to improve the scenario outline and Fortunately served as a substitute of the contribution the IMS radio-xenon network in full operations would have made. According to our calculations this full scale IMS xenon network would have detected the Xe-133 plume at the station in Usuiyiskiy, Russia, within one day and with a strong signal compared to the detection at Yellowknife. So in the final network, there would have been no such monitoring gap that was in 2006 compensated by the mobile measurement. Nevertheless, mobile measurements can play an important role in the verification regime, in particular on-site inspections once the treaty enters into force, or to supplement IMS monitoring capabilities, mainly announced or expected nuclear explosions where the lead time to deploy such systems at a good location is sufficiently long (Becker et al., 2009).

References

Figure 1: Google Maps of the REB event area. A place mark for the REB event of 9 October 2006, 1:35 AM is inserted.

Figure 2: Early stages and 2 weeks evolution of the October 2006 event plume in case of immediate venting as modeled at 0.2 and 1.0 horizontal resolution.

Figure 3, left: Predicted Xenon-133 signal at Yellowknife from a release at the time and place of the 9 October event (lower graph), compared with observations (Saey et al., 2007). The observations indicate a strong xenon signal from a common source (Chalk River Labs, Canada) also observed (grey bars). They are calculated by folding a worst case release assumption with the source-receptor sensitivity fields pertaining to the measurements. Right: Estimated Xenon-133 signal measured at Kansong, ROK based on inversion modeling at 1.0 and 0.2° horizontal resolution applying multiple linear regression (Wotawa et al., 2005).

Figure 4: 2006 DPRK event xenon release scenario reconstruction taking the measurements in Yellowknife (XAS10). Kansong (ROK) separately (top) and jointly (bottom). Obviously the RK3 measurements help to constrain the range of times when the measurements were actually taken place. The most likely scenario consists of both (possibly delayed) strong venting at the first day and a later seepage during the following three days.

Figure 5, top: Field-of-Regard (FOR) for the strongest Xe-133 detection encountered by Ringbom et al. (2007). Bottom: Possible source region (PSR) of the entire 5 detections scenario at Kansong, ROK. In contrast to the vast area the FOR covered for the for the remote Canadian detection (Saey et al., 2007) the much closer detections help to constrain the source region estimates significantly.

The best source location estimates, based on inversion modeling at 0.2° horizontal resolution is 129.7ºE, 40.7ºN at October (day 7), 21-24 UTC, i.e. offset of 90 km and 69 hours to the DPRK event location and time. The SEL3 and REB error ellipses are indicated in the top graph, the latter also in the bottom graph.