On the usability of event zero time determinations using xenon isotopic activity ratios given the real atmospheric background observations

Kassoum YAMBA[1, 3] ; Martin B. KALINOWSKI[2] ; Oumar SANOGO[3]

[1]LPCE- UO Ouagadougou, Burkina Faso ; [2]CTBTO Vienna, Austria ; [3]NDC– (IRSAT/CNRST) Ouagadougou, Burkina Faso

Corresponding author: yamba.kassoum@yahoo.com

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Introduction

This work focuses on the usability of event zero time determinations using xenon isotopic activity ratios.

One key parameter when IMS facilities of CTBTO detect radionuclides is the origin time of release. The activities of certain pairs of isotopes reported in IMS measurements are usable for event time calculation. In theory, event dating works well under the assumption of a nuclear explosion scenario. For the radioxenon isotopes, the operational challenge is to understand results of event dating applied to the normal background. The routine IMS atmospheric background observations result from normal operational releases of nuclear facilities. The goal of this study is to estimate the usefulness of the timing equations in light of the real observations. It aims at characterizing conditions under which reasonable origin times can be determined and under which discrimination between nuclear test signatures and normal atmospheric background might work.

IMS: International Monitoring System

NPP: Nuclear Power Plant

MIPF: Medical Isotopes Production Facilities

Reference points for NPP and MIPF release

Reported local observations of batch xenon data release from NPP and MIPFs sites are used. The findings are considered as reference points (lower limit, median value and upper limit) for a Nuclear Power Plant (NPP) release (see fig 1. below). The NPP median values are used in Figures 3.

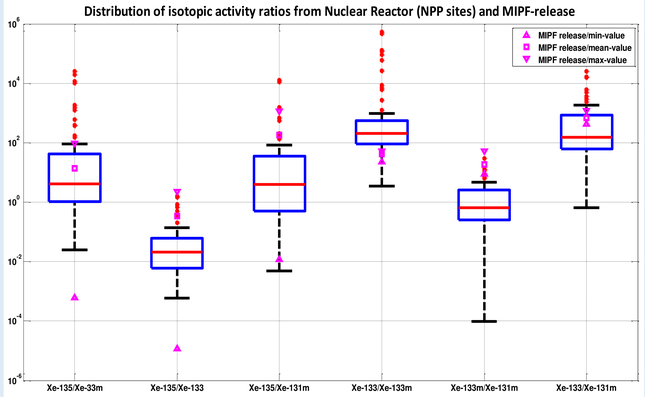

Figure 1

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Comparison of nuclear event timing precision

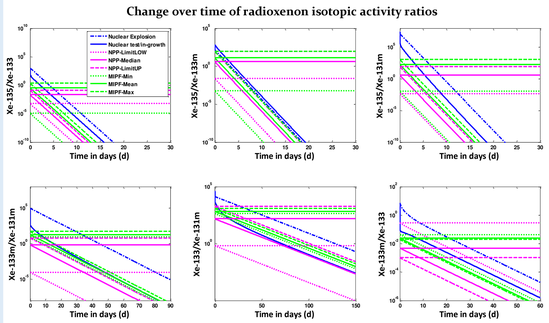

Figure 2: For each isotopic ratio, an event origin time can be calculated. However, the result depends on the assumption of a certain source type.

This figure shows for nuclear explosions, NPPs and MIPFs what range of isotopic ratios can be expected at time zero and how this range develops with time progressing due to decay and –for nuclear explosions – due to in-growth. The constant lines apply if the origin is arbitrary.

Figure 3: Distribution of the evaluated age precisions using three data sets:

Figure 3.a: Nevada underground nuclear test detections from 1962 to 1992.

Figure 3.b: Fukushima debris detections in 2011.

Figure 3.c: IMS data detections in April 2013 following North Korea nuclear test in February 2013.

In Figure 3, the time precision is compared to 1 so that a nuclear event having a time precision closer to 1 is considered as the most probable. Please, note that a decision on source type based on a comparison of the precision values is possible only if the hypothetical age of both types is available (nuclear explosion and nuclear reactor release). The result of cases a and b is that the time precision distribution confirms the kind of the nuclear release.

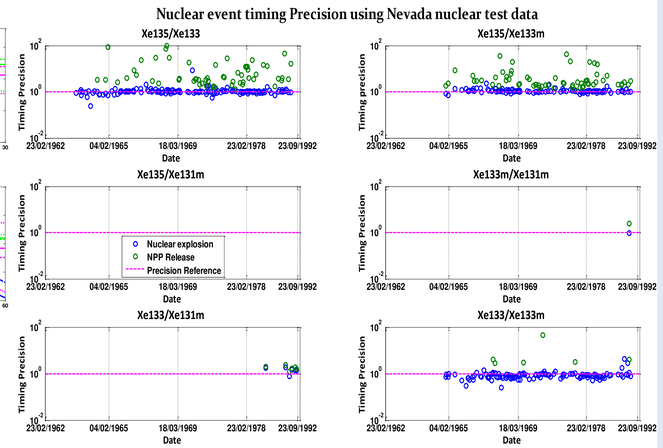

Figure 3. a

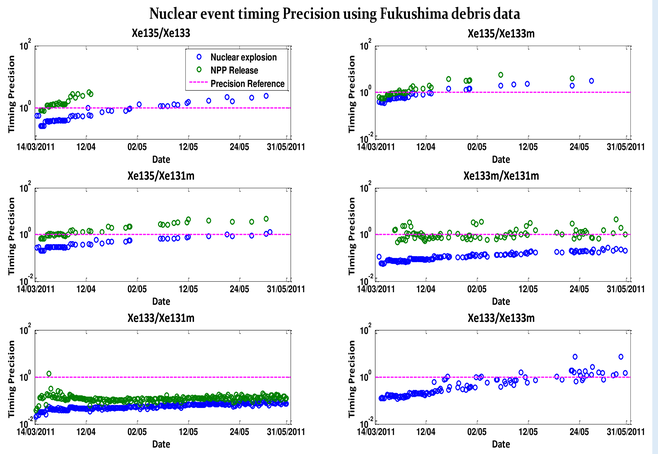

Figure 3. b

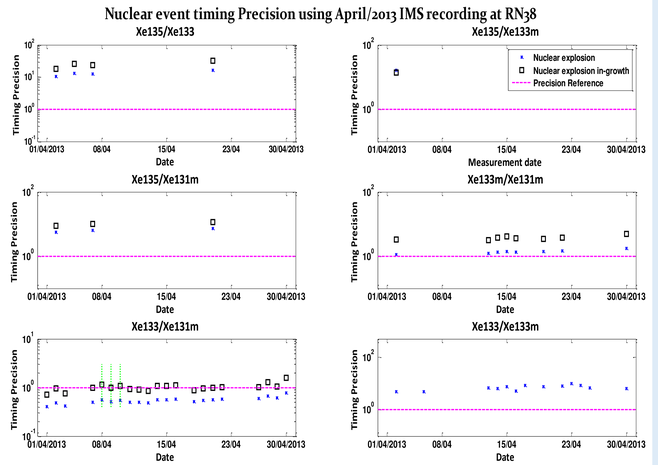

Figure 3. c

Discussion & Conclusion

The age precision is calculated by making the ratio between the true age (real age of a nuclear event) and evaluated age (age calculated using measured radioxenon activity ratios), and the result is compared to 1.

- The use of observations data at the Nevada test sites (figure 3.a) indicates the event is more probable a nuclear test than a nuclear reactor release with a good precision in favor of a nuclear test.
- The result using Fukushima debris (figure 3.b) indicates that data from the first release (thirst week release for March 2011) are in accordance with a nuclear reactor release (not a nuclear test!).
- One month IMS recording in April 2013 at the radionuclide station RN38 gives a good result in favor of a nuclear explosion release, as displayed in Figure 3.c. Others works were carried out using these IMS data highlighted in Fig.3.c with green segments (Ringbom, A. et al. (2014), Carrigan,C.R et al. (2016)).

This approach for age precision determination can then be helpful and used for nuclear event characterization.

In conclusion, this work shows that the nuclear event zero time determination can be successfully applied. The power to distinguish between different source types is validated with Nevada and Fukushima data. Also the age of the late release from DPRK 2013 can be reproduced. The age calculation appears to be a promising tool for screening between nuclear reactor sources and nuclear test by assuming a certain standard NPP and MIPF release and a suspected date related to a nuclear event. The remaining challenge is to deal with the fact that the release time of nuclear facilities can be anytime.

Acknowledgments

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