T2.4-P17

Towards a better noble gas characterization scheme based on ten years of National Data Centers analysis

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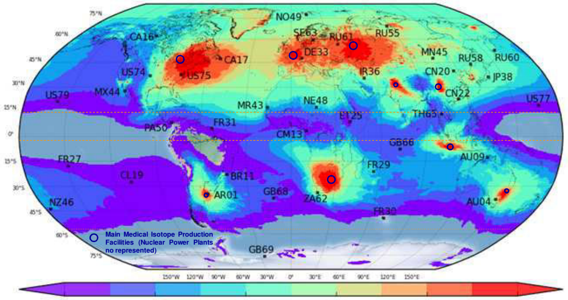
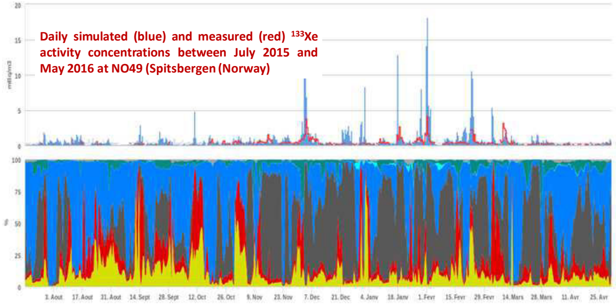
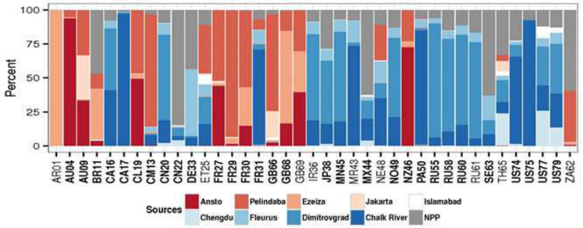
Releases from industrial facilities, mainly Medical Isotopes Production facilities (MIPs) but also Nuclear Power Plants (NPPs), are at the origin of the worldwide radioxenon background and lead to specific activity concentration levels at most noble gas stations of the IMS network (figures A&B). Owing to the tremendous atmospheric dilution, signature of an underground nuclear test in case of a prompt or/and delayed release into the atmosphere can be detected at the IMS stations at the Xe background level. A follow up over years by both IDC and NDCs of the detection time serie can help a lot in the event characterization but only an radioxenon isotopic ratio is likely to give a clear event discrimination. Validation by NDCs of the isotopic ratios, involving three radioxenons ($^{135, 133m \text{ and } 133}$Xe), measured by the IMS noble gas stations over the last decade, allows to efficiently improve the current IDC event characterization scheme.



Contribution of the identified sources to the annual average Xe-133 background simulated at the 39 IMS stations (Data: 2103-2014)





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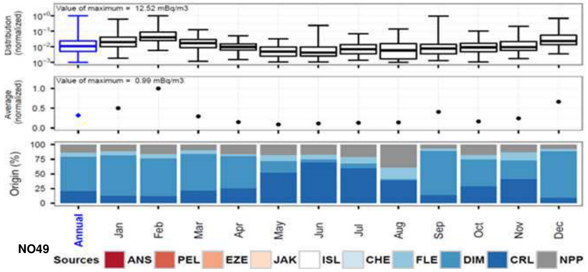
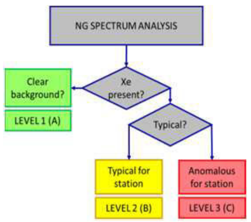


Illustration of the complexity of the worldwide radioxenon background depending on the geo-localisation of the noble gas station. Case of NO49 (Norway): same contributors over the year but with ratios evolving in the time (seasonal effect)

In the framework of the Comprehensive Nuclear-Test-Ban Treaty (CTBT), the International Data Center (IDC) monitors signs of nuclear weapon tests from measurements at stations of the International Monitoring System (IMS), and categorizes relevant signatures, which are analyzed independently by National Data Centers (NDC) of member states. Among the radionuclides of interest, radioxenons are of crucial importance to determine the nuclear nature of an explosion, in particular the isotopic ratios ^{135}Xe/^{133}Xe and especially ^{133m}Xe/^{133}Xe in case of a prompt release. Analysis of multiple detections at the IMS station by French, Swedish and Canadian NDCs over the last decade provide new insights likely to make more efficient the current IDC event categorization scheme. **In particular it was demonstrated that an isotopic ratio ^{133m}Xe/^{133}Xe larger than 0.1 should be considered as a new relevant CTBT threshold as it is beyond the radioxenon background civilian signatures.**



IDC Flags *(current approach)*

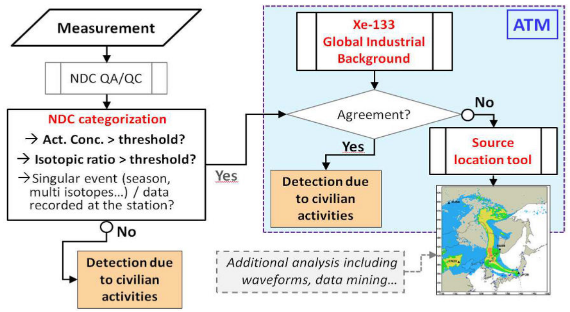
Activity concentration:

- ^{133}Xe, ^{133m}Xe, ^{131m}Xe, ^{135}Xe typical?

Isotopic ratios :

- ^{131m}Xe/^{133m}Xe> 2?
- ^{133m}Xe/^{133}Xe> 0.3?
- ^{135}Xe/^{133}Xe> 5?
- Quality indicators on sample reliability
- Backtracking indicates known sources

Current IDC flags and event characterization scheme



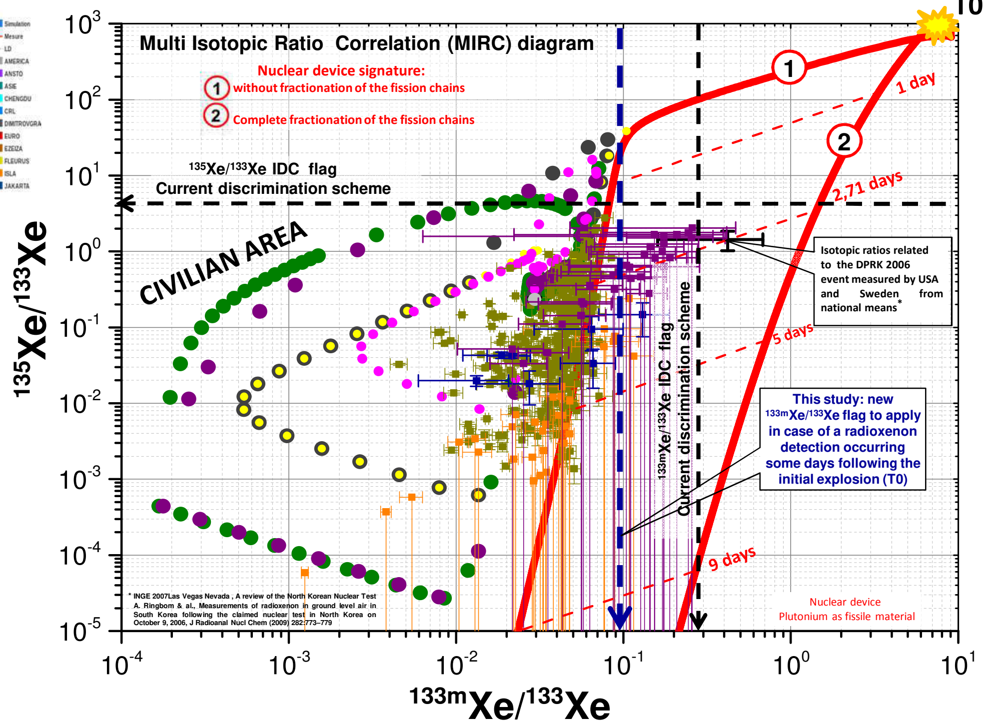
Simplified NDC analysis process to focus on the most "relevant" events

❑ Characterization methodology at French NDC:

- Rely on the station databases to define metrics/indicators based on statistical approaches → Event notification from station-specific triggers (screening out)
- Validation of any relevant measurement rely on an interactive analysis and the coherence between X Rays and gamma rays for metastable isotopes (SPALAX system)
- Comparison with the continuous simulation of the global xenon industrial background (ATM)
- Backward and forward ATM to assess the source location

❑ Characterization methodology at Swedish NDC

- Rn event analysis triggered by observation of anomalous measurements
- Admit only anomalous RN for event analysis; defined by station history and ATM
- RN event analysis cycle
- Select set {R} of event-relevant measurements→ Production hypotheses with {R} yield source time interval {T}, Backward ATM with {T} yield source hypothesis and Forward ATM based on S yields refined set {R'}



Roughly similar neutron flux levels lead to same Xe ratios evolution whatever the fuel reactor type[1]:

- Magnox 1 (UG fuel): 300 days at 2 MW/ton of initial U in the fuel, then 60 days at 0.01 MW/ton, then 300 days at 2MW/ton (300d-2 60d 0.01-300d 2), 1,5E13 n/s/cm²
- PWR1 (14x14-pin 5% LEU): 300d 35 600d 0.01-300d 35, 3.2E13 n/s/cm²
- PWR2: 300d 35 60d 0.01-300d 35
- PWR3: 300d 35 30d low-300d 35
- NRX1 (HEU 93%): 300d 650-30d 0.1-300d 650, 6-9E13 n/s/cm²
- NRX2: 300d 650-30d Low-300d 650 (Low means a power level of 5 order of magnitude lower than the previous one)
- French 950 MW PWR Chinon ½ (measurements at 1 hour following a shutdown)
- Isotopic ratios ^{135}Xe/^{133}Xe (>Lc) versus ^{133m}Xe/^{133}Xe (>Lc) measured by different SPALAX[2] systems
- Isotopic ratios ^{135}Xe/^{133}Xe (<Lc) versus ^{133m}Xe/^{133}Xe (>Lc) measured by different SPALAX systems
- Isotopic ratios ^{135}Xe/^{133}Xe (>Lc) versus ^{133m}Xe/^{133}Xe (>Lc) measured by different SAUNA[2] systems
- Isotopic ratios ^{135}Xe/^{133}Xe (<Lc) versus ^{133m}Xe/^{133}Xe (>Lc) measured by different SAUNA systems

Ten years of IMS noble gas data analysis by NDCs led to new insights for improving IDC flags associated to the IDC event categorization scheme:

- Isotopic ratio ^{135}Xe/^{133}Xe >5 is an efficient underground nuclear explosion (UNE) flag within the range T0-T0+3days,
- **Isotopic ratio ^{133m}Xe/^{133}Xe >0.1 is a strong and univoke UNE flag** (no **significant** value >>0.1 due to civilian origins was found over 10 years of NDCs analysis)
- The measured of the two isotopic ratios ^{135}Xe/^{133}Xe and ^{133m}Xe/^{133}Xe lead to a clear discrimination between a civilian and a nuclear event.

Publications

Ringbom, A. Axelsson, M. Aldener, M. Auer, T.W. Bowyer, T. Fritioff, I. Hoffman, K. Khrustalev, M. Nikkinen, V. Popov, Y. Popov, K. Ungar, G. Wotawa, *Radioxenon detections in the CTBT international monitoring system likely related to the announced nuclear test in North Korea on February 12, 2013*, Journal of Environmental Radioactivity 128 (2014) 47-63

P. Achim, S. Generoso, M. Morin, P. Gross, G. Le Petit, C. Moulin, *Characterization of Xe-133 global atmospheric background: implications for the International Monitoring System of the Comprehensive Nuclear-test-Ban treaty*, JGR Atmospheres, Vol 121, Issue 9 , 2016

1: Calculations performed by FOI using the Scale code from Oak Ridge National Laboratory

2: SPALAX and SAUNA systems were designed by CEA and FOI respectively