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A study of the radioxenon background and potential sources at the IMS station SEX63, Sweden

Mattias Aldener and Tomas Fritioff

P2.4-551

POSTER

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ABSTRACT

Understanding the radioxenon background at the radionuclide stations in the IMS network is important to improve the verification capability of the network. The background at the IMS station SEX63 in Stockholm Sweden has been studied using data from the IMS SAUNA II system From and a co-located SAUNA III system. Xenon detections have been studied to understand potential sources and their contributions to the detections at the station. Detections have been characterized with respect to concentrations, isotopes detected and wind direction.

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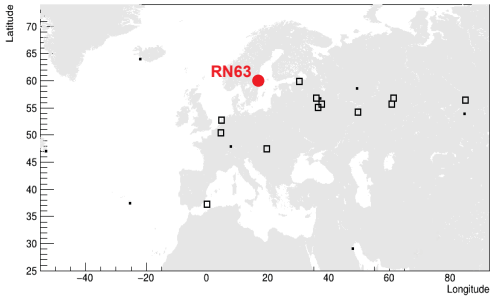
INTRODUCTION

Understanding the radioxenon background at the noble gas stations in the International Monitoring System (IMS) is important. This understanding improves the possibility to discriminate between civilian sources and signals due to a nuclear explosion.



Map showing RN63 station in Sweden and the medical isotope production facilities (MIPFS) in the region (squares). The MIPFS provide the largest sources of radio-xenon but it is also emitted by *e.g.* nuclear power plants (NPP) and hospitals. NPPs are frequent in the region (not shown on map) with the closest to the RN63 station being Forsmark NPP, located 110 km to the north.

Two systems are co-located at the IMS RN63 (left) site in Stockholm, Sweden: SEX63 a SAUNA II system (the IMS station, center picture) and SAX63, the first SAUNA III (right). SEX63 was installed at the site in 2005 and the SAUNA III system started measuring in 2017.

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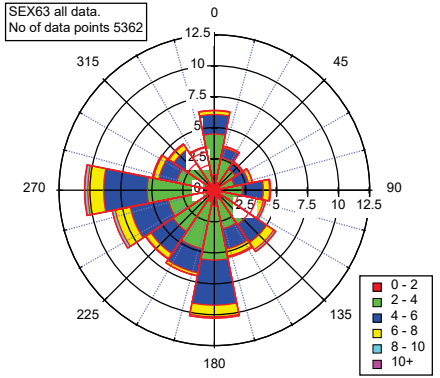
METHODS

- Data has been analysed from the two systems co-located at the IMS RN63 site in Stockholm, Sweden.
- Data has been filtered by removing spikes and samples with poor quality, *e.g.* low xenon volume or high radon activity in the samples.
- To clarify the picture the Minimum Detectable Concentration (MDC) was used as the discriminating level instead of the detection limit (LC) when creating most of the wind rose graphs.
- Different time periods were evaluated for the systems:
  - SEX63 2012-2019
  - SAX63 Feb 2017-2019



- Shown are the wind directions for all 5362 data points for the SEX63 system.
- The graph shows the percentage of time the wind is coming from respective wind direction, during the time periods when the selected samples were collected.
- The dominating wind direction is West or South with modest wind speeds, average is 4 m/s all year. No seasonal variation is observed.
- All wind data is taken from the SMHI (www.smhi.se) weather station located nearby at Bromma airport. The weather station at the site experience problems with turbulence due to the surrounding tall buildings.
- Field of regards (FOR) are calculated at the IDC for every sample in the IMS and these have been used for source location.

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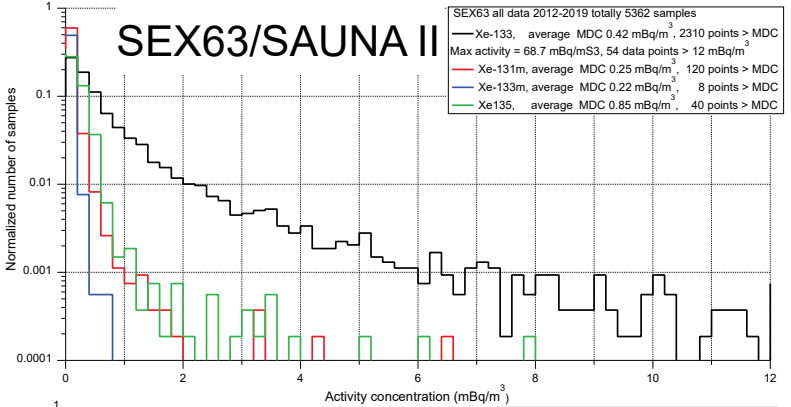
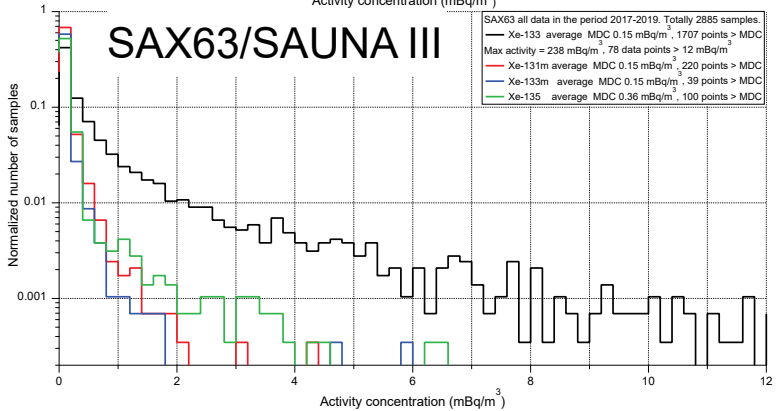
RESULTS





- The RN63 station regularly detects ^{133}Xe, in over 63% of all samples.
- Two or more isotopes are detected in more than 16% of the samples.
- The frequency of detection increases significantly for the SAUNA III system, with better sensitivity and time-resolution. This is especially true when two or more isotopes are detected.
- The geometrical mean in the table below is calculated for all detections, *i.e.* where the activity concentration is above LC.

Isotope	Detections > LC	Geomean (mBq/m3)	Detections > LC	Geomean (mBq/m3)
	SEX63	SEX63	SAX63	SAX63
Xe-133	*63.4%*	*0.75*	*75.1%*	*0.55*
Xe-131m	*15.9%*	*0.16*	*31.3%*	*0.11*
Xe-133m	*6.4%*	*0.10*	*12.6%*	*0.17*
Xe-135	*5.5%*	*0.57*	*13.2%*	*0.33*
2-isotopes	*16.7%*	*N/A*	*36.5%*	*N/A*
3-isotopes	*1.8%*	*N/A*	*12.0%*	*N/A*
4-Isotopes	*0.1%*	*N/A*	*2.8%*	*N/A*

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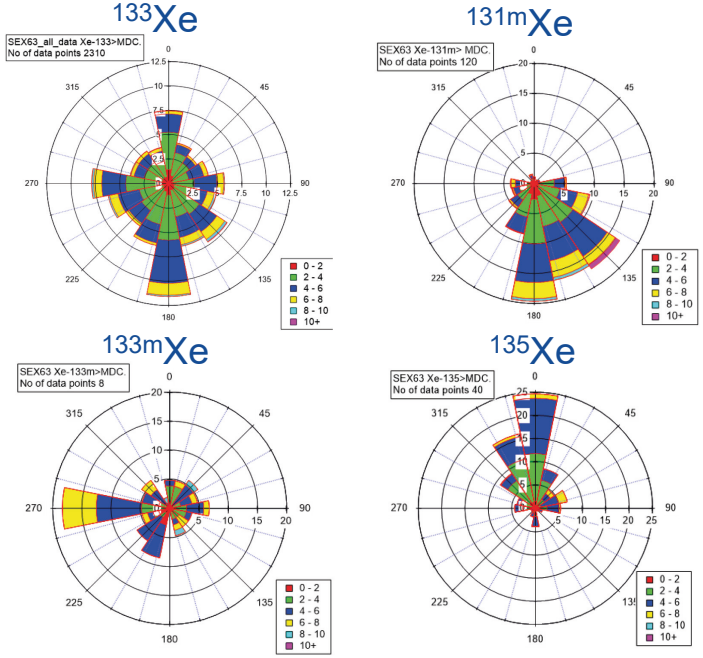
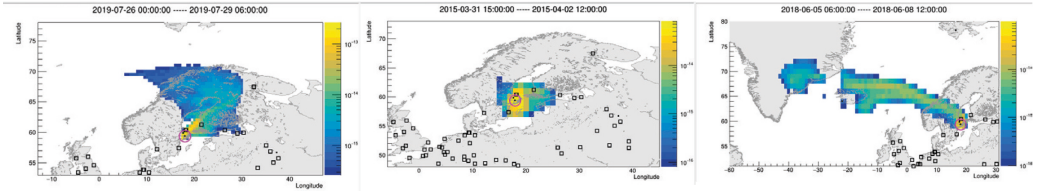
SEX63/SAUNA II



- 5362 data points evaluated for the period 2012-2019.
- ^{133}Xe is detected in more than half of the samples and does not correlate with a particular wind direction.
- ^{131m}Xe is correlated with S-SE winds with a unidentified source, see slide 8.
- ^{133m}Xe is only detected in a few samples over the whole period, potential sources are discussed in slide 8.
- ^{135}Xe has a strong correlation with N wind direction and can usually be attributed to the Forsmark NPP 110 km north, see Ringbom et.al(*).
- The field of regards for ^{135}Xe detections normally overlap with Forsmark NPP, see the three examples below. Due to the short distance ATM benefits from a model run on a more a local scale as done in Ringbom et. al.(*).



(*)Ringbom et.al https://doi.org/10.1007/s00024-020-02425-z

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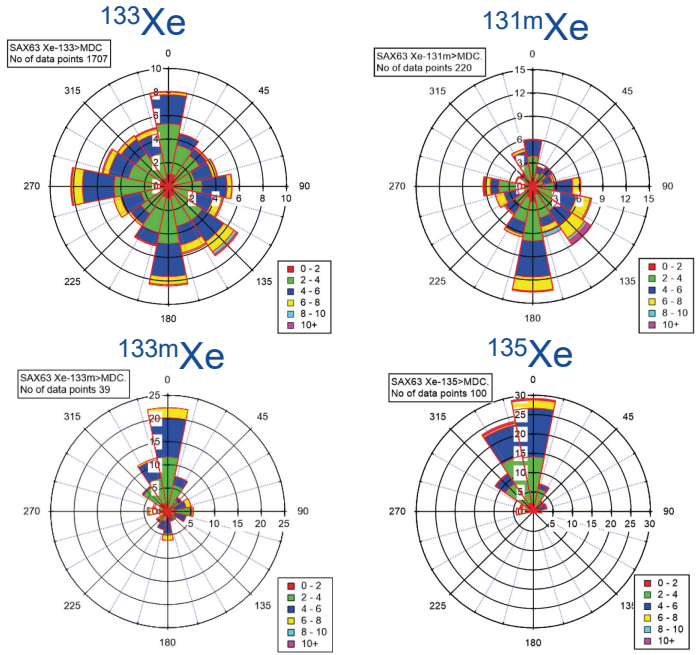
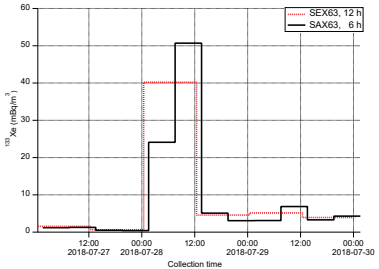
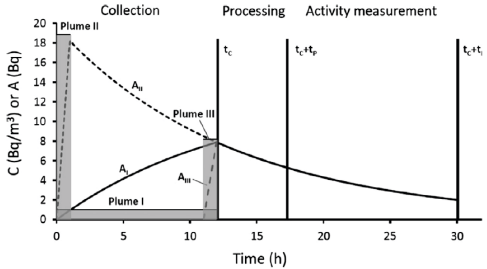
SAX63/SAUNA III



- 2885 data points evaluated for the period 2017-2019.
- The higher time-resolution resolves the temporal resolution of the plumes and detects higher concentrations for many plumes. This indicates that plumes sometimes have a temporal variation that is shorter than the SAUNA II collection time of 12 hours, as seen in the example below (left).
- In the right figure below an example is shown for how three plumes with different time profiles results in the same reported activity concentration, example for ^{135}Xe is taken from Axelsson et. al.(*)
- Similar wind rose pattern as for the SEX63 station, except for ^{133m}Xe. This is due to the better sensitivity which leads to more low-level detections. Most of the ^{133m}Xe detections likely have the Forsmark NPP as the source.





(*)Axelsson et.al https://doi.org/10.1016/j.apradiso.2014.05.020

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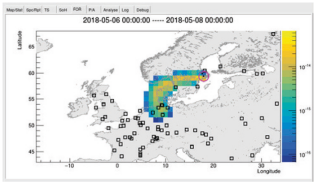
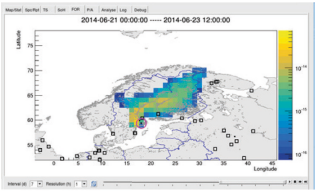
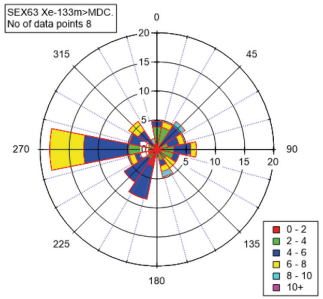
Potential sources, ^{133m}Xe

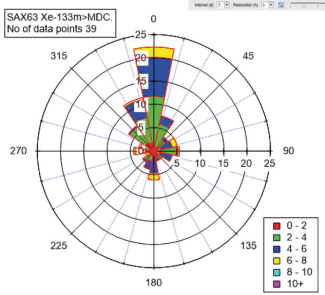
When analysing the FOR (right) for the ^{133m}Xe detections two different main regions can be identified :

- S-SW overlapping with MIPFS in the Netherlands and/or Belgium, (top right).
- NW-N-NE winds where Forsmark NPP plant can not be ruled out as the likely source, (bottom right).



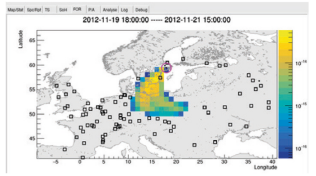


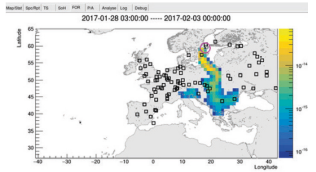


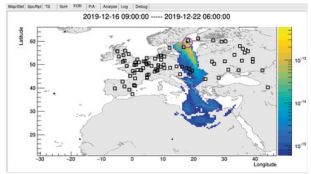


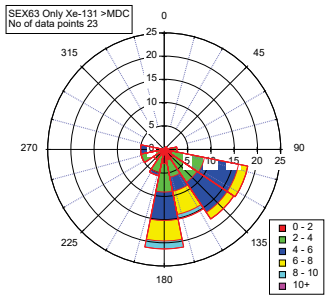
Potential sources, ^{131m}Xe

For SEX63 there are 23 detections where **only** ^{131m}Xe is detected (above MDC). These correlate with a S-SE wind direction. Examining the FOR it is seen that the source region mostly overlaps with eastern Europe. A possible source might be a medical isotope production facility in this region.









Field of regards for three detections where only ^{131m}Xe was detected (above MDC) at the SEX63 station.

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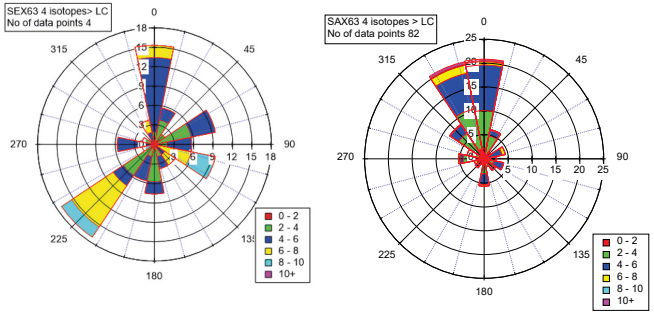
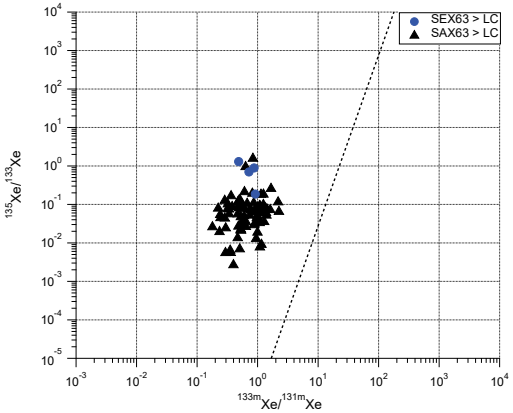
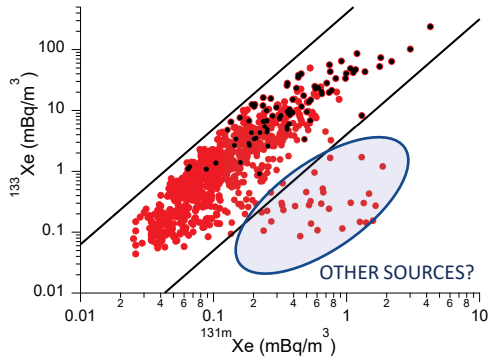
RESULTS

Detection of multiple isotopes



Multi isotope detections can in most cases be associated with the Forsmark NPP, this is to be expected due to its proximity to the station. Most of these detections are close to the sensitivity of the noble gas system so improving the sensitivity radically increases the number of detections.





- More samples with 4 isotopes detected with the SAUNA III system due to the improved sensitivity.
- The frequency of detection increases from 0.1% to 2.8% in the time period studied here.
- All detections are on the civilian side of the discrimination (dashed) line, according to Kalinowski et.al(*).

Shown on the left in red, ^{133}Xe plotted vs. ^{131m}Xe, with the 4 isotope detections marked in black. The isotopic ratio of the most frequently detected isotopes, ^{133}Xe and ^{131m}Xe, seem to fall in a fairly limited range, indicated by the black lines. Many of the detections within this region could probably be associated with a similar source as the 4 isotope detections but ^{135}Xe and ^{133m}Xe would only be detected if the system sensitivity for these isotopes were improved. This can be seen in contrast to the detections in the region marked with the blue oval.

(*)Kalinowski et.al https://doi.org/10.1007/s00024-009-0032-1

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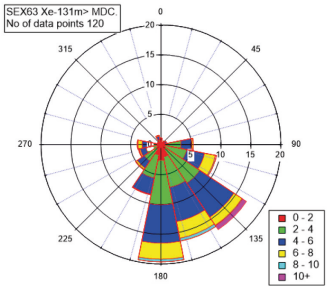
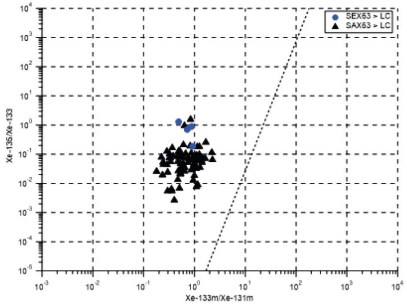
CONCLUSIONS

- The radioxenon background at the RN63 station in Stockholm, Sweden, has been studied in relation to the local wind direction for the period 2012-2019.
- Xenon is detected at the station on regular basis. ^{133}Xe is detected in 63% (75%) of the samples. The higher number is for the more sensitive SAUNA III system, co-located in the period 2017-2019.
- ^{135}Xe has a strong correlation with N wind directions and can usually be attributed to the Forsmark NPP 110 km north, see Ringbom et.al(*).
- ^{131m}Xe is correlated with S-SE winds with a potential source in eastern Europe.
- A more sensitive system increases the frequency of detections with 4 isotopes almost 30 times, significantly increasing the discrimination capacity at the station.
- A more dense network would yield more detections for each release and increase the possibility to localize the source, see SAUNA Q_B poster P3.1-375.
- The SEX63 IMS station will be upgraded to a SAUNA III system during June 2021.





(*)Ringbom et.al https://doi.org/10.1007/s00024-020-02425-z