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# Characterization of Xe-133 background at the IMS stations in the East Asian region: insights based on known sources and Atmospheric Transport Modelling

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# Outline

- Introduction
- Methodology
- Results
- Conclusions

# Introduction

- Radioxenon can be produced with a high fission yield during a nuclear explosion, making it an important tracer to demonstrate the nuclear origin of an explosion. For this reason, it is continuously monitored by the CTBTO as part of the verification regime.

- Radioxenon can however be emitted by nuclear facilities, like nuclear power plants (NPPs) or isotope production facilities (IPFs), providing significant contribution to both the regional and global background.

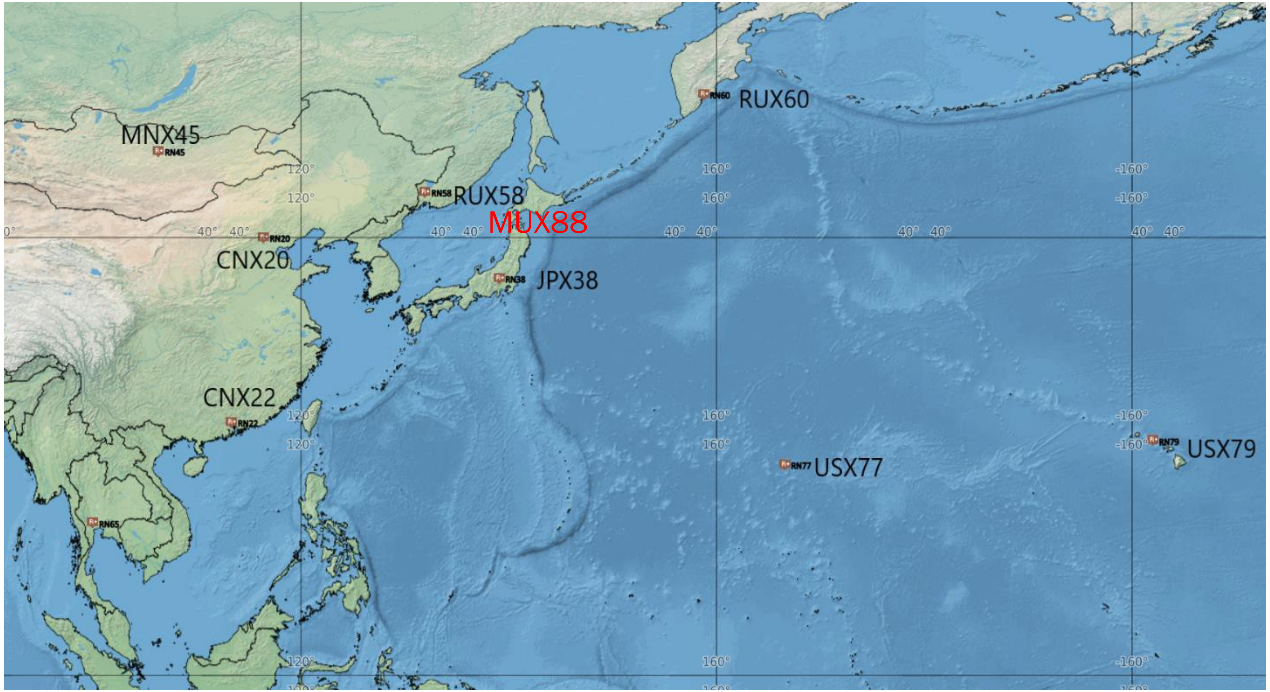
- Since the radioxenon background is highly variable, the discrimination between CTBT-relevant events and the local background is a challenging task.

- This presentation will discuss the preliminary results related to Xe-133 background at the IMS stations in the East Asian region based on known sources and Atmospheric Transport Modelling

# Introduction

## Region of Interest

The radioxenon background was studied at the following IMS stations: JPX38, RUX58, RUX60, CNX20, CNX22, MNX45, USX77 and USX79.




Map showing IMS noble gas stations located in East Asia. The temporary measurement system in Mutsu, MUX88, is indicated in red.

For this presentation, the study is extended to include the temporary measurement system in Mutsu, MUX88.

# Methodology

- The radioxenon background in the Northern Hemisphere was estimated using the results of Atmospheric Transport Modelling (ATM) for a period of 6 months, from June to November 2014, as specified by the 3rd ATM Challenge.
- Forward simulations were used to estimate the contributions from major IPFs and all NPPs in operation in 2014.
- The time resolution of NPPs is in accordance with their shut-down periods assuming continuous release over the operational periods. For certain IPFs at large distances, high time resolution reproduces the operational release pattern, whereas for the IPFs in Asia continuous emission are assumed.
- All emissions from these facilities, were tracked individually.
- The simulated station samples were generated by summing over the individual contributions at each IMS station.

# Results: main contributors

The results show that independently of the covered seasons, NPPs are the main $^{133}Xe$ contributors to simulated detections.

To quantify the NPPs contribution to the total simulated activity concentration from all known sources (NPPs+IPFs), the following ratio was used:

$$k=\frac{NPP}{NPPs+IPFs}x100\%$$

During summertime, i.e. June-August, NPPs contributions may reach 80%, or in some cases 100%, of the total simulated activity concentration. During the same period the observed concentrations are going through a minimum in the seasonal variations.

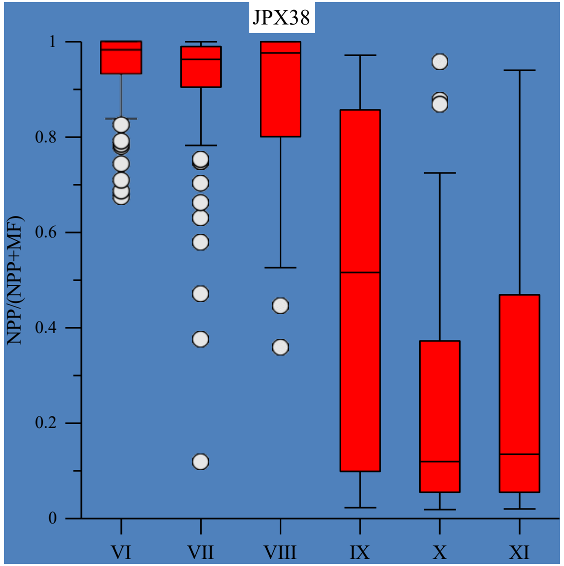
# Results: main contributors

NPPs contribution: $k = \frac{NPP}{NPPs+IPF}$

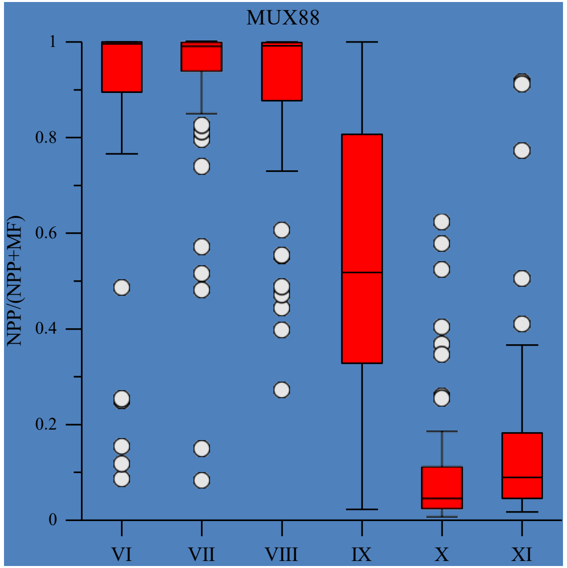
0.7≤k ≤1.0 NPPs dominated

0.3≤k ≤0 IPFs dominated

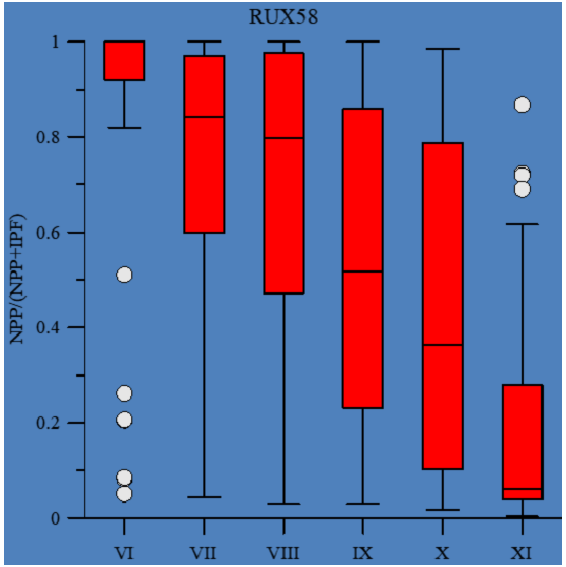
JPX38




MUX88




RUX58



# Results: main contributors

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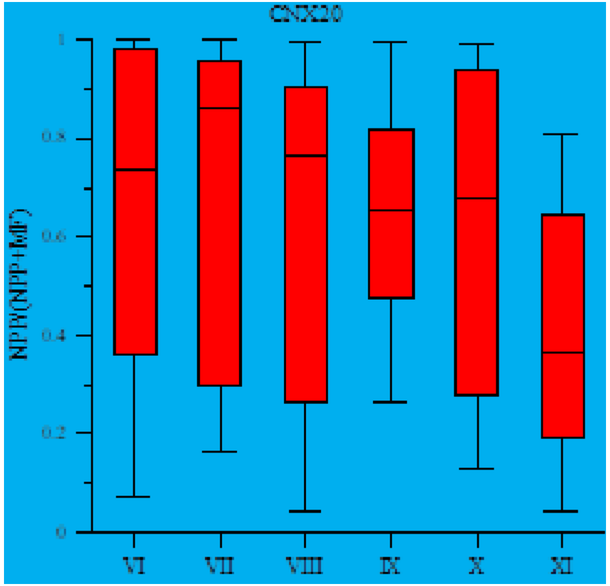
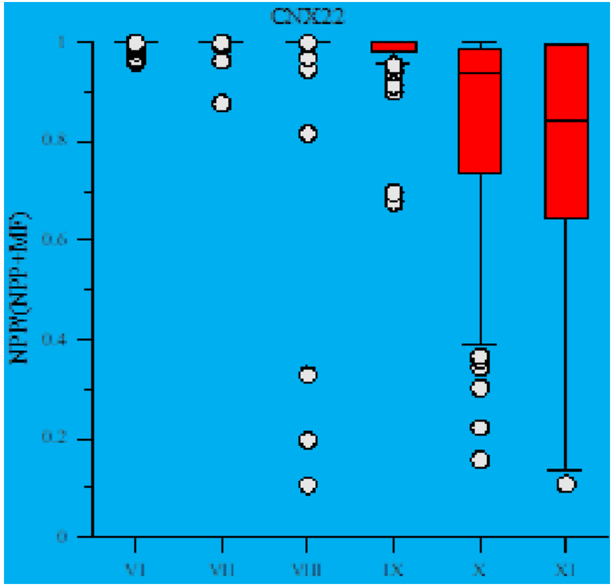
## NPPs contribution: $k = \frac{NPP}{NPPs+IPF}$

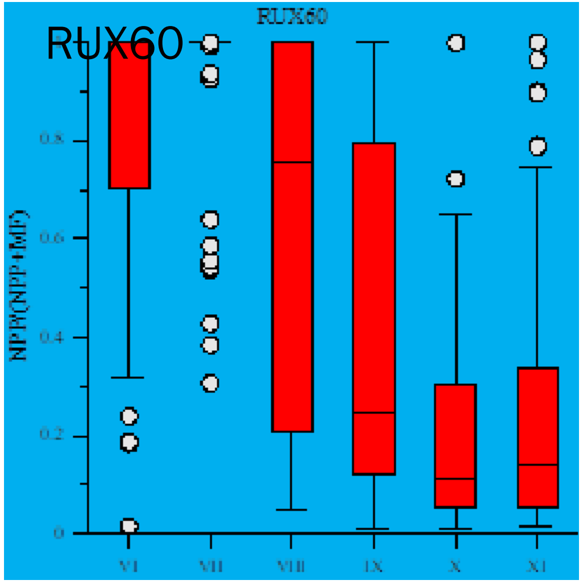
CNX20




CNX22



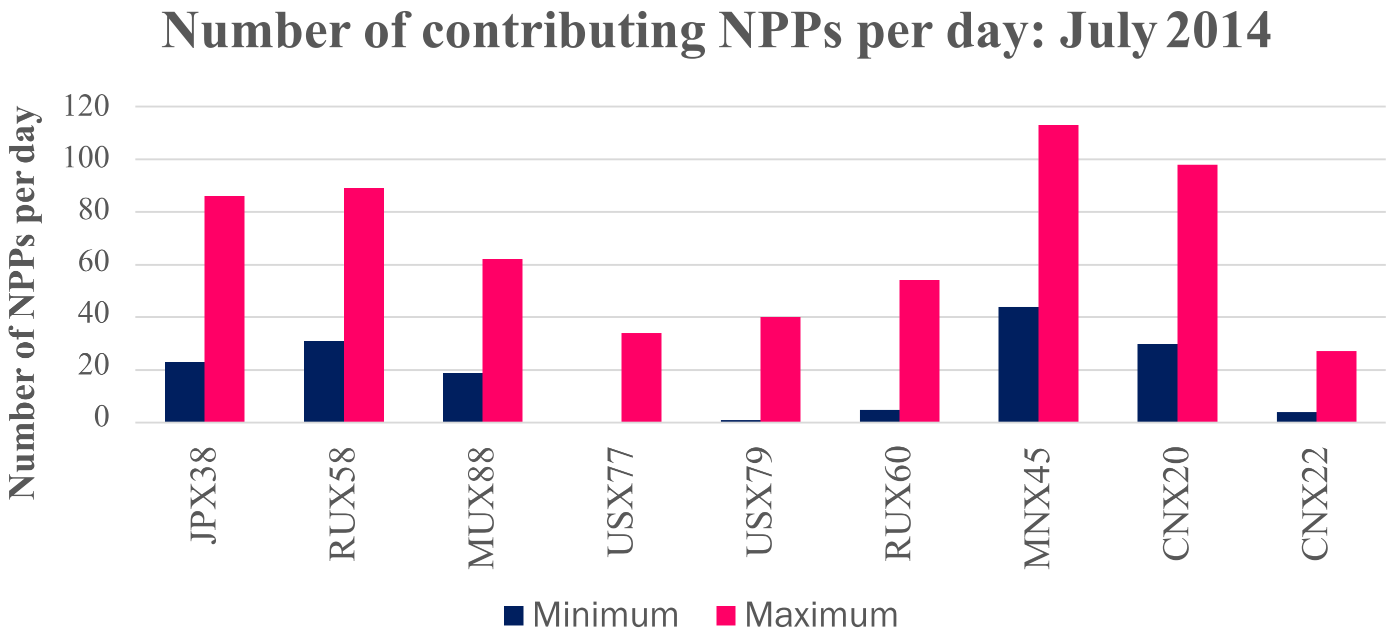

RUX60



# Results

## Number of contributing sources per day

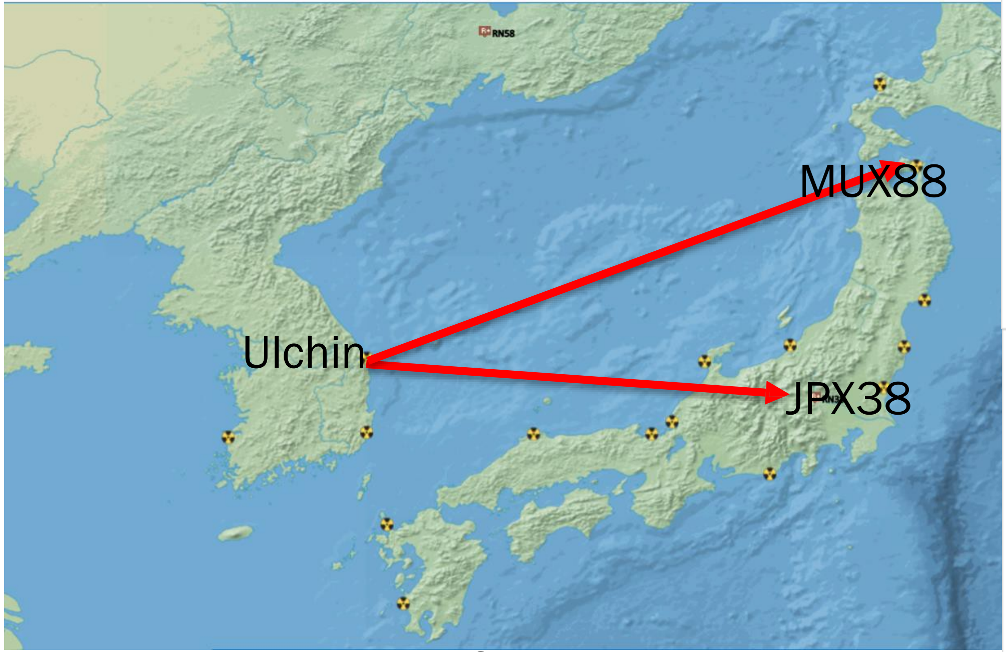
One single sample at JPX38 or RUX58 may include contributions from more than 80 sources. Even if each single NPP will contribute with a low emission assumed to be continuous rather than as puff emission, a combination of many weak sources can lead to a measurable result.



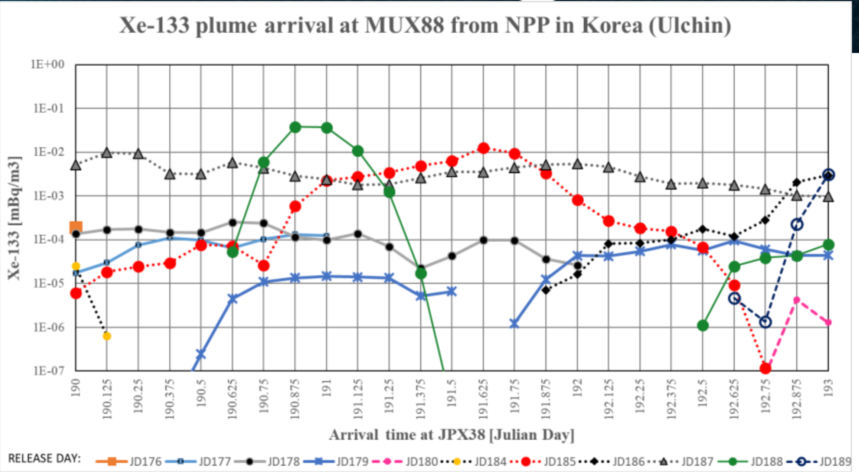
# Results: Plume arrivals at JPX38 & MUX88 during the selected collection time

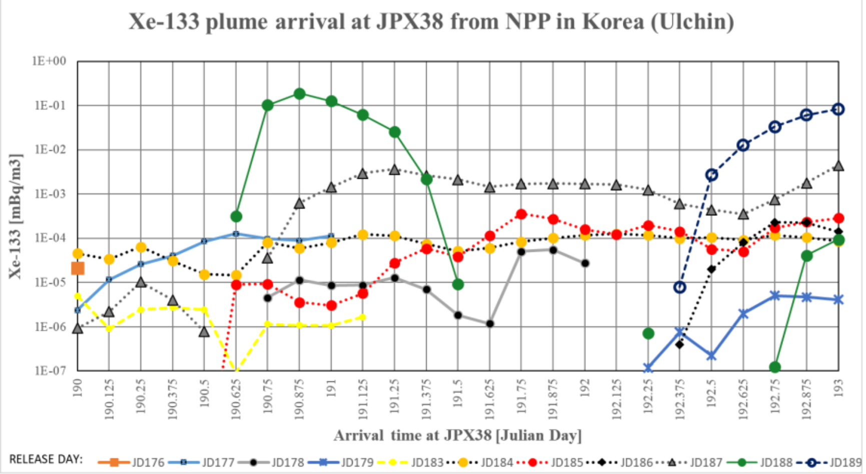


## JPX38, 9-13 July 2014




The shortest travel time from NPP Ulchin is about 2 days to JPX38 and ~2.5 days to MUX88 (the green-dot line)



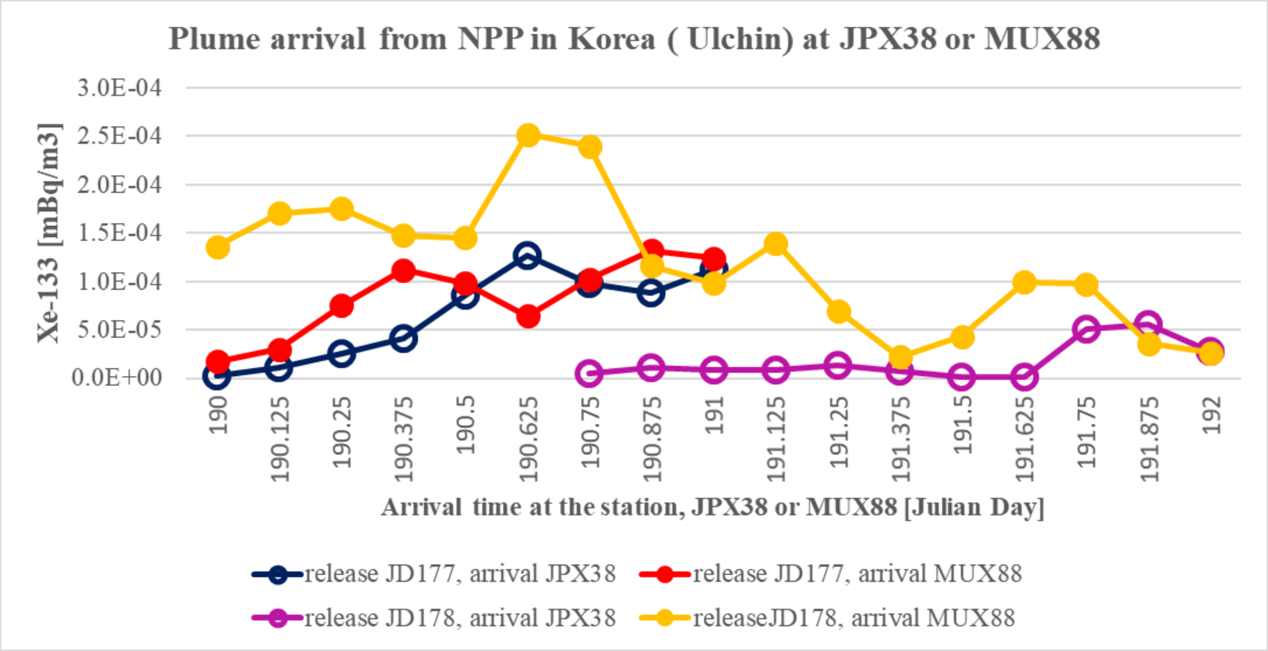



# Results

## Plume arrivals at JPX38 & MUX88 during the selected collection time

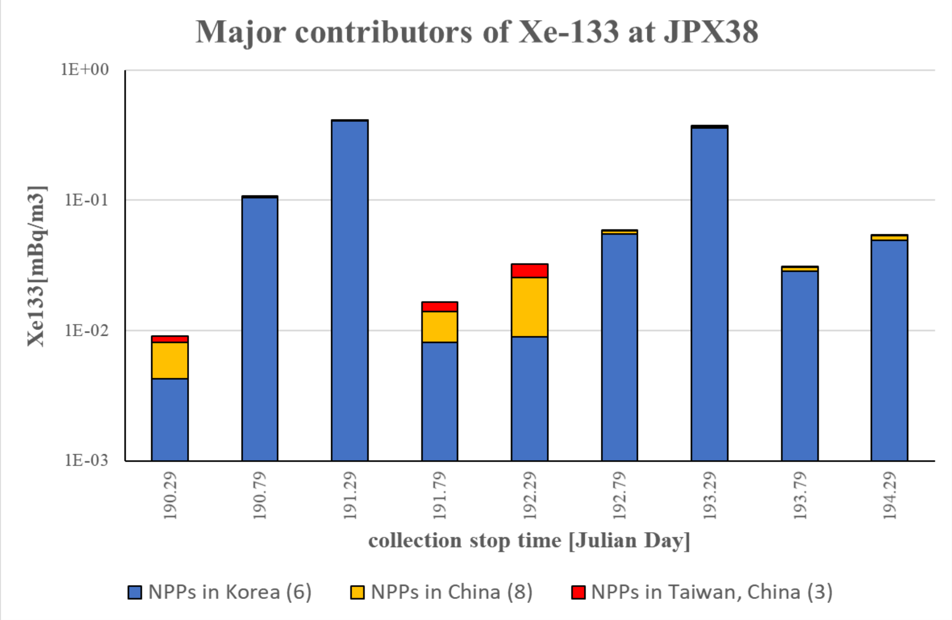
Plume released from NPP in Korea (Ulchin) may arrive:

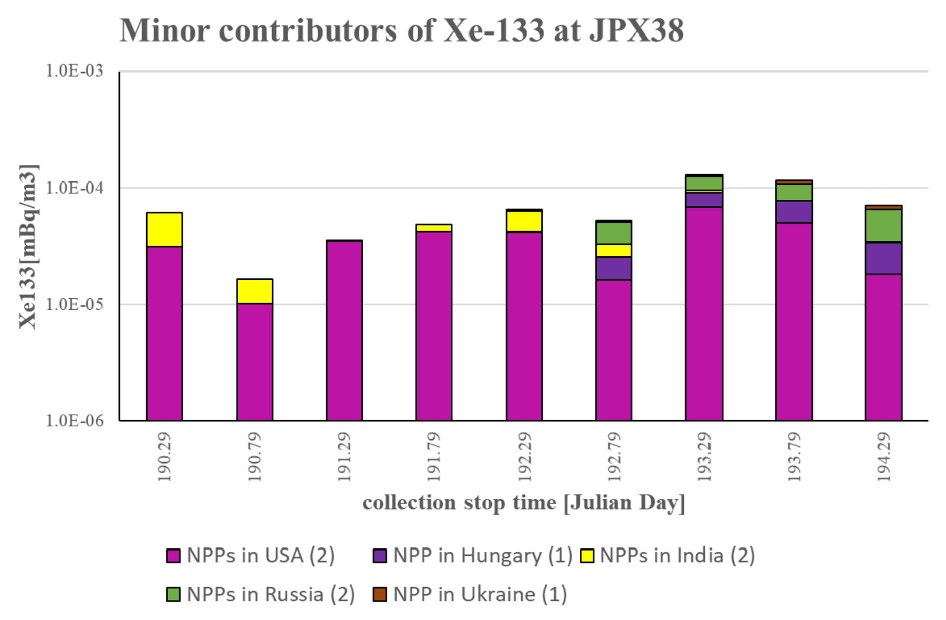
- to JPX38 and MUX88 at the same time (Figure below, *dark blue and red color*)
- first to JPX38 and later to MUX88
- first to MUX88 and later to JPX38 (Figure below, *yellow and violet color*)
- only to JPX38
- only to MUX38
- to none of them



# Results Contributions from NPPs

## JPX38, 9-13 July 2014



# Results Simulations vs measurements

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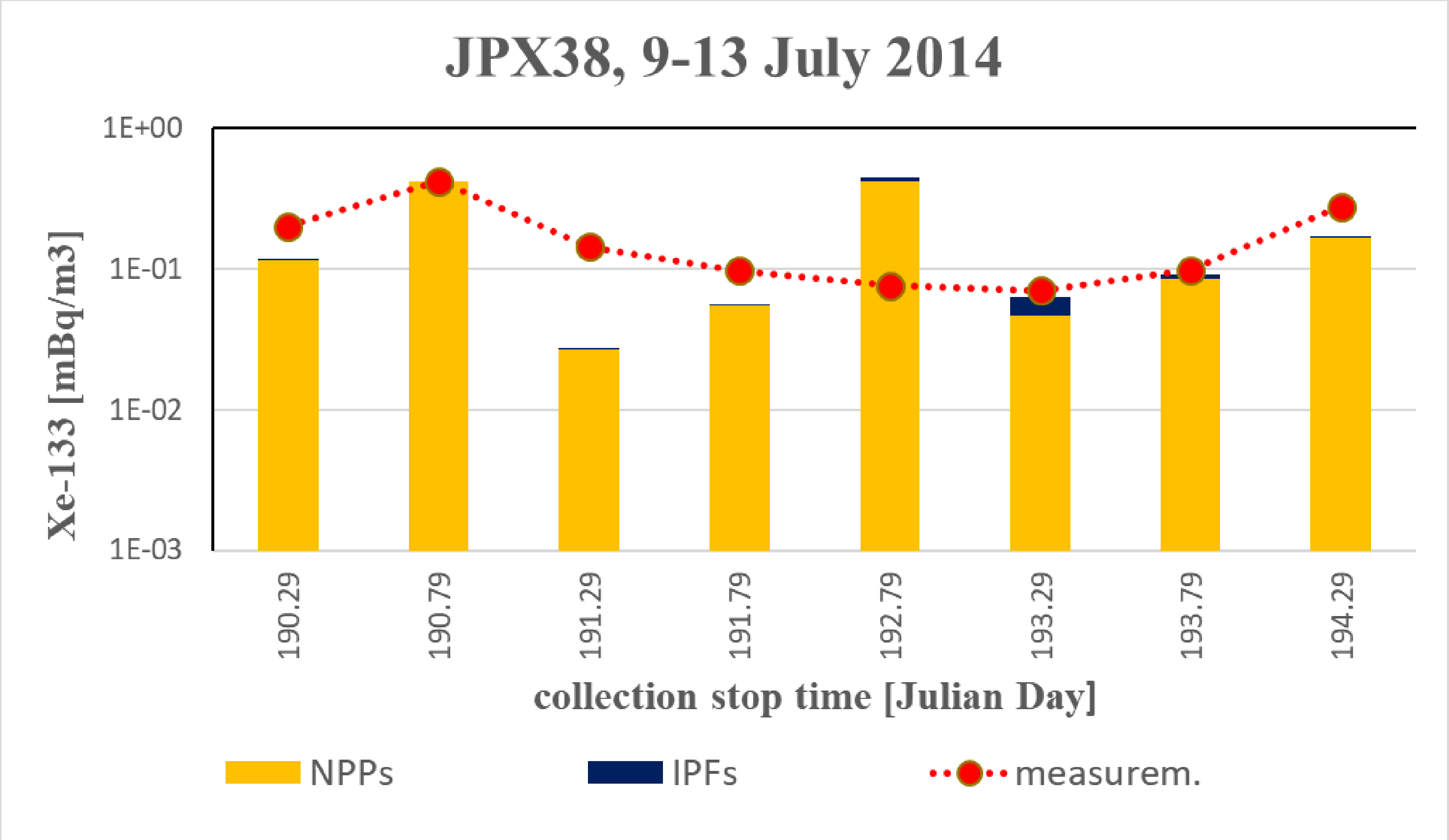
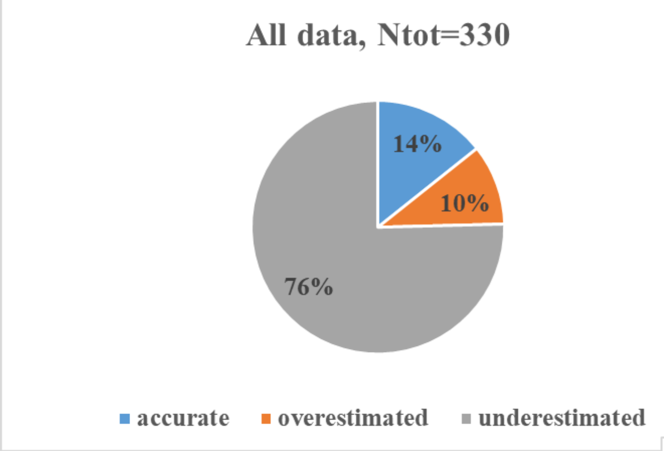
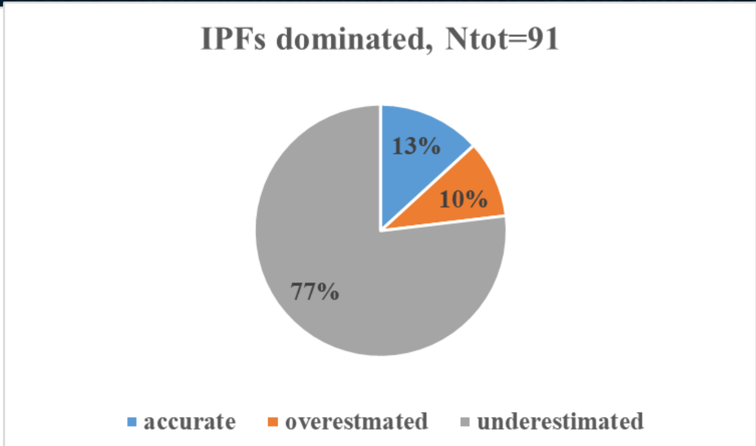


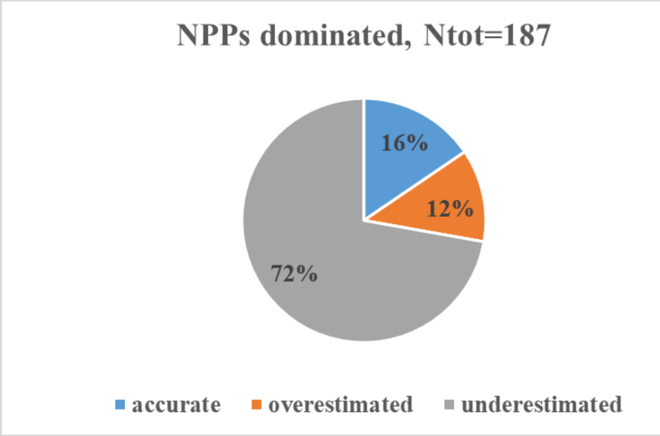
# Results

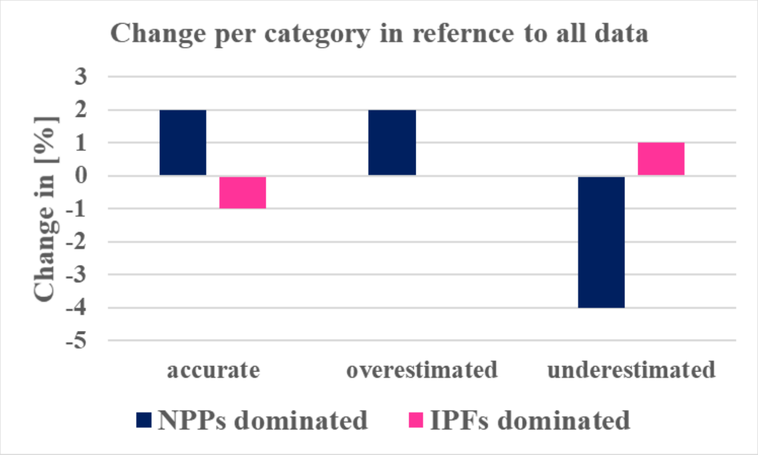
## Statistics






$k = NPPs/(NPPs+IPFs)$

NPPs dominated

$0.7 \leq k \leq 1.0$

IPFs dominated

$0.3 \leq k \leq 0$

accurate:

$$\delta = \left| \frac{meas - simul}{meas} \right| \leq 0.2$$

overestimated:

$\delta > 0.2$ &

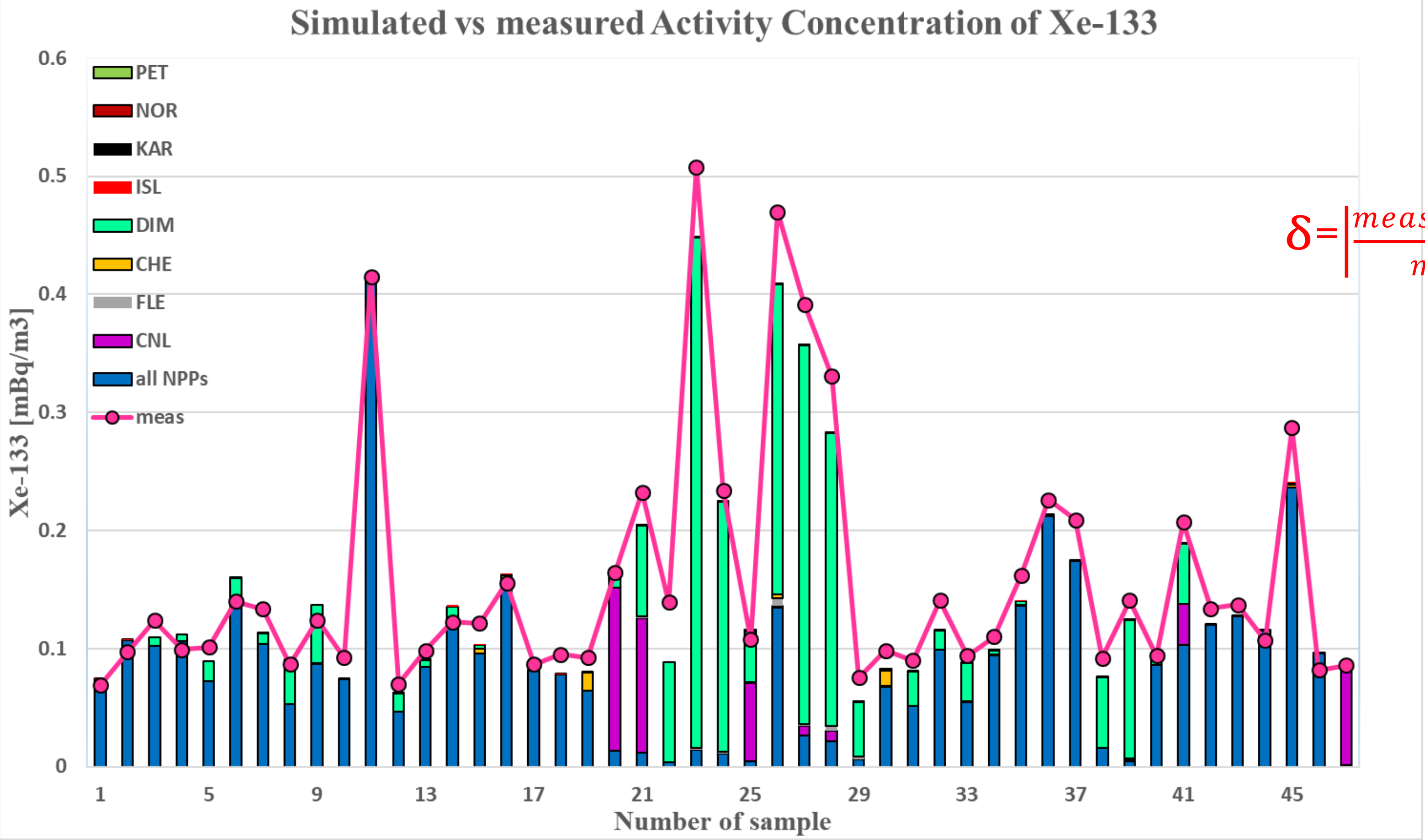
$meas\text{-}simul < 0$

underestimated:

$\delta > 0.2$ &

$meas\text{-}simul > 0$

# Results: Example of a good agreement




$$\delta = \left| \frac{meas - simul}{mea} \right| \leq 0.2$$

~14% of data

# Results

## Statistics

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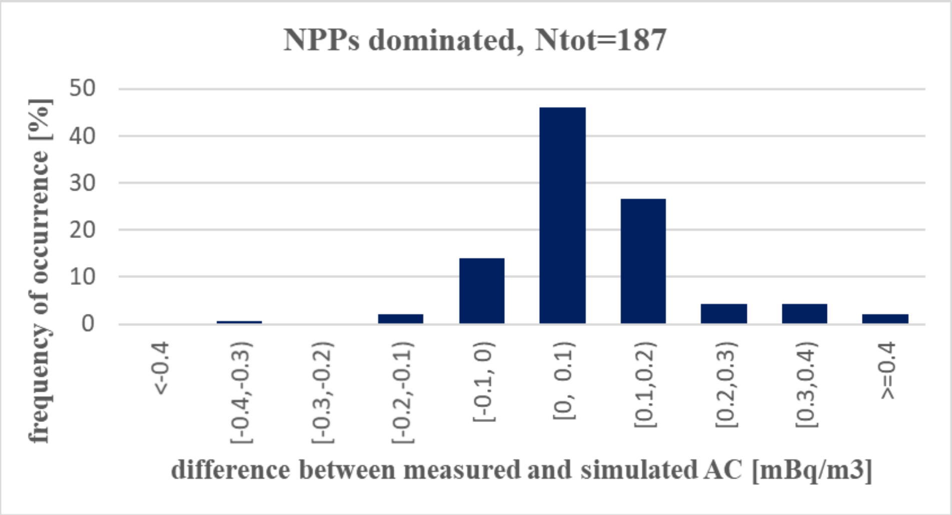


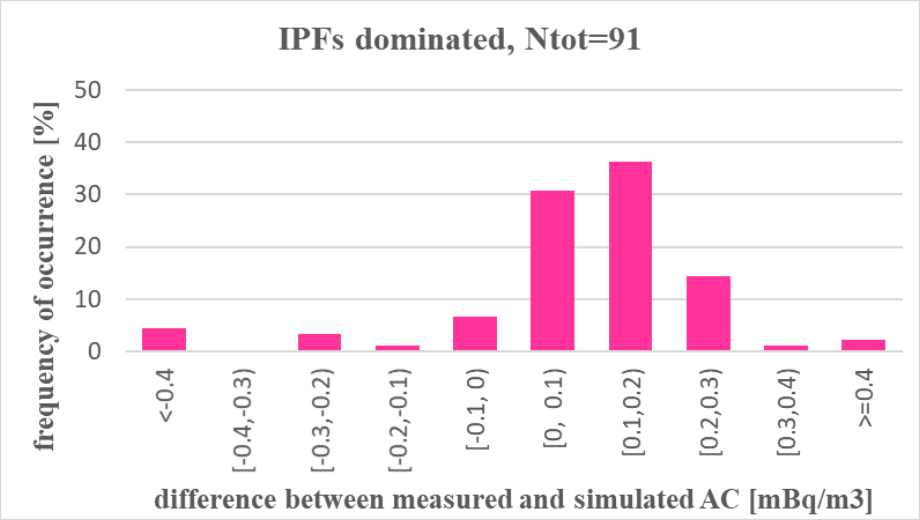

# Conclusions (1)

1)The results show that independently of the covered seasons, NPPs are the main Xe-133 contributors to simulated detections.

2)During summertime, i.e. June-August, NPPs contributions may reach 80%, or in some cases 100% of the total simulated activity concentration. During the same period the observed concentrations are going through a minimum in the seasonal variations.

3)One single sample at JPX38 or RUX58 may include contributions from more than 80 sources. Even if individual NPPs have low (but continuous, rather than puff) emissions, the combination of such weak contributions can lead to a measurable (non-negligible) result.

4)Available measurements and simulations for the stations at JPX38, RUX58 and MUX88 were combined in one data set of 330 pairs. It is demonstrated that:

- about 14% of measurements were accurately estimated i.e. the relative error didn’t exceed 20%,
- 10% was overestimated i.e. a difference between measured and simulated value was positive,
- and 76% was underestimated i.e. a difference between measured and simulated was negative.

# Conclusions (2)

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5)The underestimation for data dominated by NPPs contributions is about 5% lower than for data dominated by IPFs. It is worth noting that insufficiently characterized facilities (e.g. the one in Dimitrovgrad) may have a non-negligible (but not quantifiable) contribution on the Xe-133 background in that region.

6)One of the possible explanation of the noted underestimation is that the assumption of continuous operation (instead of pulses) leads to such discrepancies. It is also possible that there are other unknown sources not included in this study.

7)Even if the knowledge about the NPPs' emissions is lacking an appropriate time resolution, the agreement between the simulated and measured values was good in many cases, despite a general underestimation of the values.

8) More details will be included in the follow-up publication.

# Thank You