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Abstract

A new technique based on spectra summing is developed at the CTBTO International Data Centre with the aim of improving analysis results in special verification situations.

The tool has been successfully tested on beta-gamma coincidence Noble Gas data and HPGe detector based particulate sample spectra of the CTBTO International Monitoring System.

The ultimate goal is to integrate this new technique in a CTBTO Expert Analysis Toolkit.

Introduction

An opportunity for improved detection sensitivity and reduced statistical uncertainty in analysis results from the CTBTO International Monitoring System (IMS) radionuclide stations might get of particular importance when dealing with special CTBT monitoring situations.

The radionuclide monitoring in the aftermath of the DPRK announced nuclear test in January 2016 triggered the development by the CTBTO International Data Centre (IDC) of a new approach based on summation of consecutive spectra under the assumption that all samples represent detection of the same plume from a single release event and therefore can be grouped.

The method is implemented in a software tool prototype and handles data from both HPGe and beta-gamma coincidence based detection technologies as operated at IMS stations.

This poster describes the methodology of the spectra summation approach with examples on application cases.

Methodology

The standard processing pipeline of the International Data Centre (IDC) handles sample spectra from the IMS on individual basis. The analysis results are stored in the operational database.

In order to further lower down the detection limit for samples over a timeframe of interest, a new software tool is developed at the IDC to be used on ad-hoc basis. The algorithm is based on the summation of spectral data, channel by channel after energy gain matching:

- For particulates data, spectra counts are added-up after correction for gain-shift, as appropriate;
- For beta-gamma coincidence based Noble Gas data, the summation is applied to counts of coincidence histograms;
- Sample parameters (collection time, volume, acquisition) are also combined in appropriate way.

Resulting summed-up spectra are then processed in offline mode, using the same software tools as in IDC Operational pipeline (*bg_analyze* for beta-gamma and *autoSaint* for particulates).

Case study

Elevated concentrations of Xe-133 have been observed at the IMS Noble gas system JPX38 (Takasaki, Japan) in five consecutive samples (12h cycle duration) from 17 to 19 Feb. 2016 (Kalinowski et al., 2017):

DETECTOR	COLLECTION STOP	CONC., mBq/m3	MDC, mBq/m3
JPX38_001	17-FEB-2016 08:35	1.76 ±0.09	0.14
JPX38_004	17-FEB-2016 20:35	1.79 ±0.09	0.16
JPX38_001	18-FEB-2016 08:35	1.44 ±0.09	0.17
JPX38_004	18-FEB-2016 20:35	1.30 ±0.08	0.15
JPX38_001	19-FEB-2016 08:35	0.67 ±0.07	0.17

However, data analysis of the sample spectra in focus didn't show any evidence of Xe-131m detection. The MDC for this isotope increased when elevated activities of Xe-133 was observed due to their spectral interference. Figure 1 and 2 show 2-month snapshot of activity concentration along with categorization parameters of Xe-133 and Xe-131m, respectively.

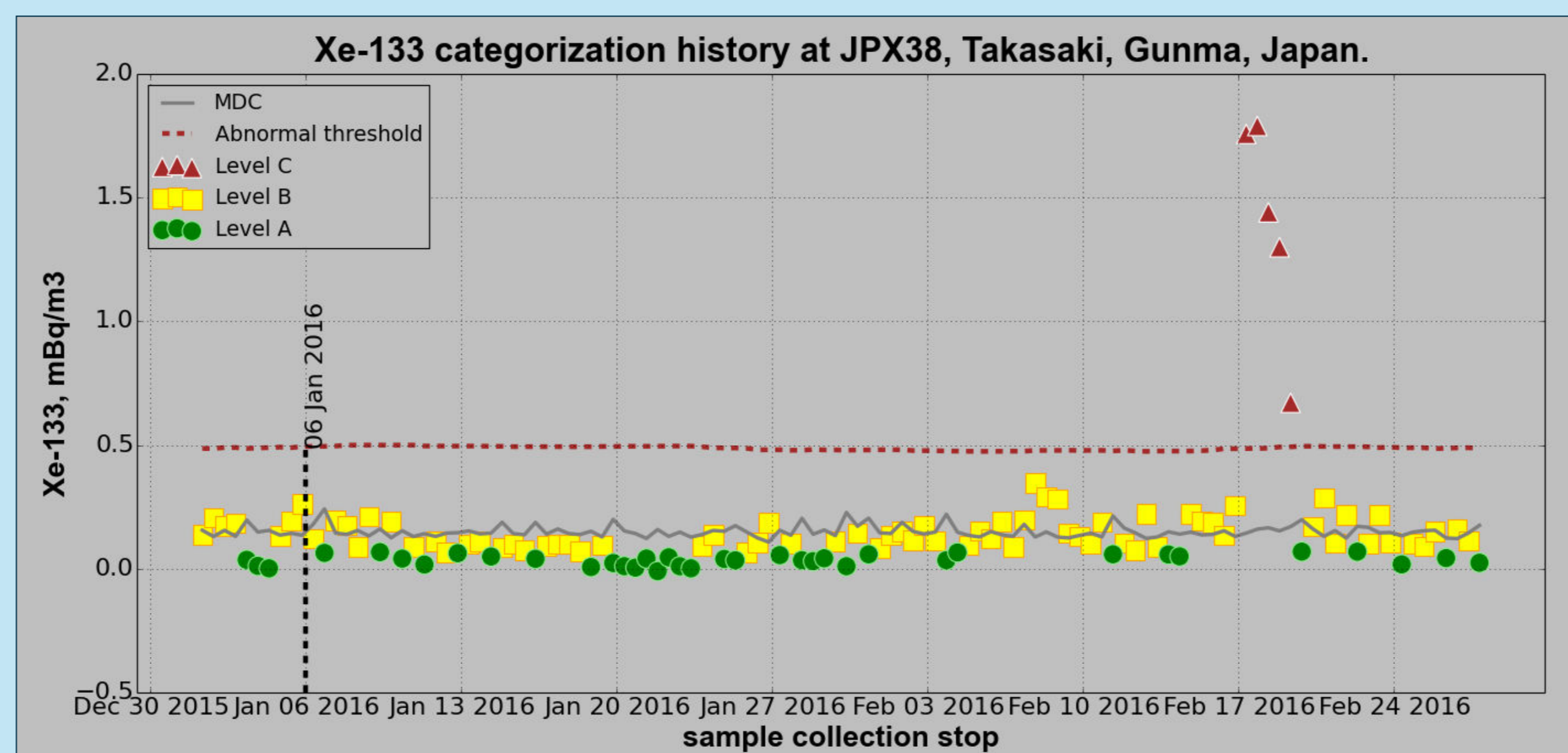


Figure 1. Categorization parameters of Xe-133 at JPX38

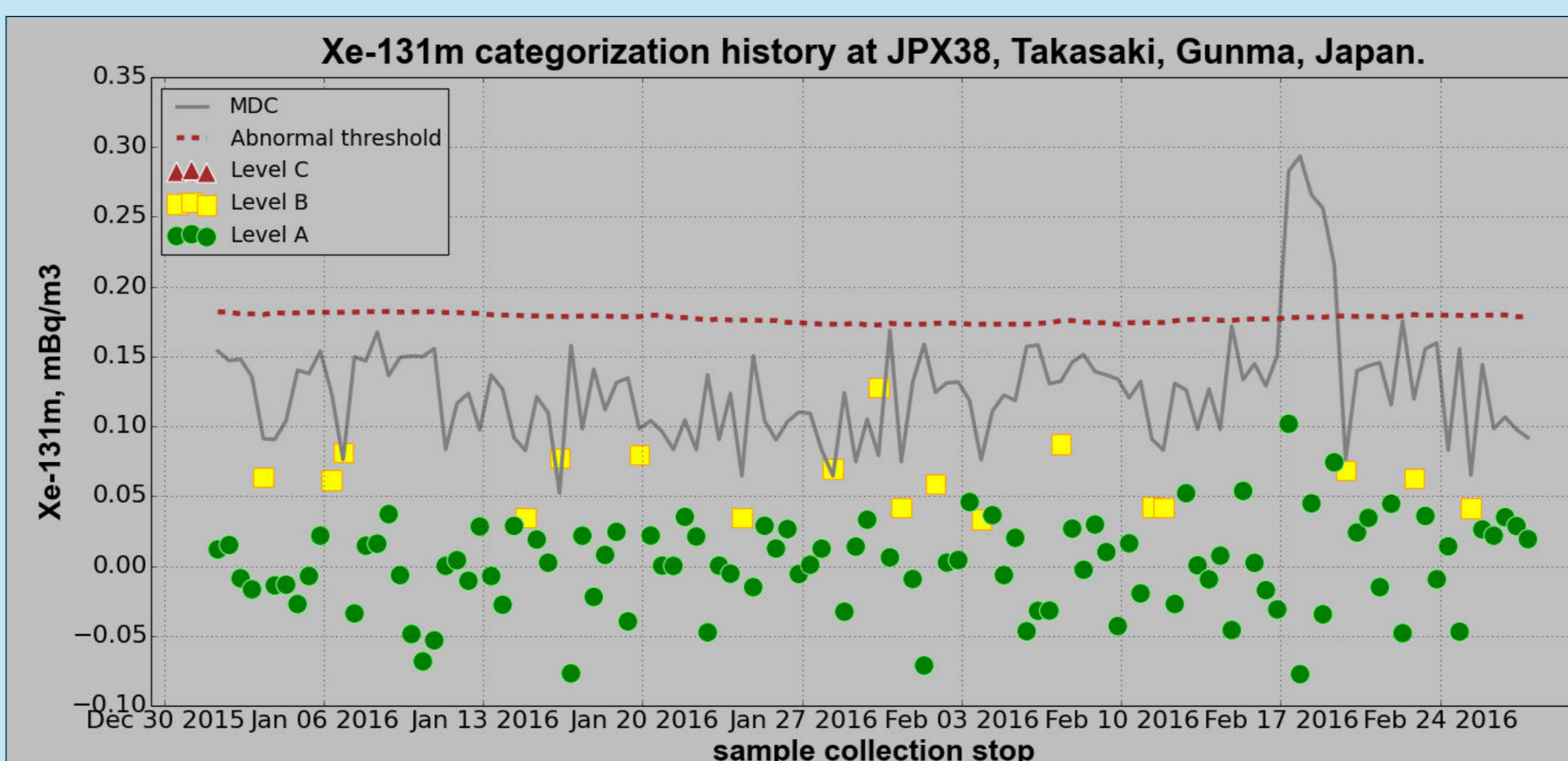


Figure 2. Categorization parameters of Xe-131m at JPX38

Based on Atmospheric Transport Modelling (ATM) as in (Kusmierczyk-Michulec et al., 2017), it was determined that the air collected during these five sampling periods would contain traces of a hypothetical short-term release from the DPRK test site. This offers the opportunity to apply the spectrum summing method that lowers down the sensitivity (MDC) for Xe-131m detection. This is highly relevant because of the high importance of radionuclide isotopic ratios in the CTBT event discrimination process. The five sample spectra in focus are summed-up into two combined spectra:

- The two sample spectra of detector JPX38_004, on one hand;
- The three sample spectra of detector JPX38_001, on the other hand.

Results

As illustrated in Figures 3 and 4, summed-up spectra resulted in improved MDC, compared to real single sample spectra. Achieved MDC for detector JPX38_001 (0.13 mBq/m3) with three summed-up spectra is lower than JPX38_004 (0.17 mBq/m3) with two summed-up spectra.

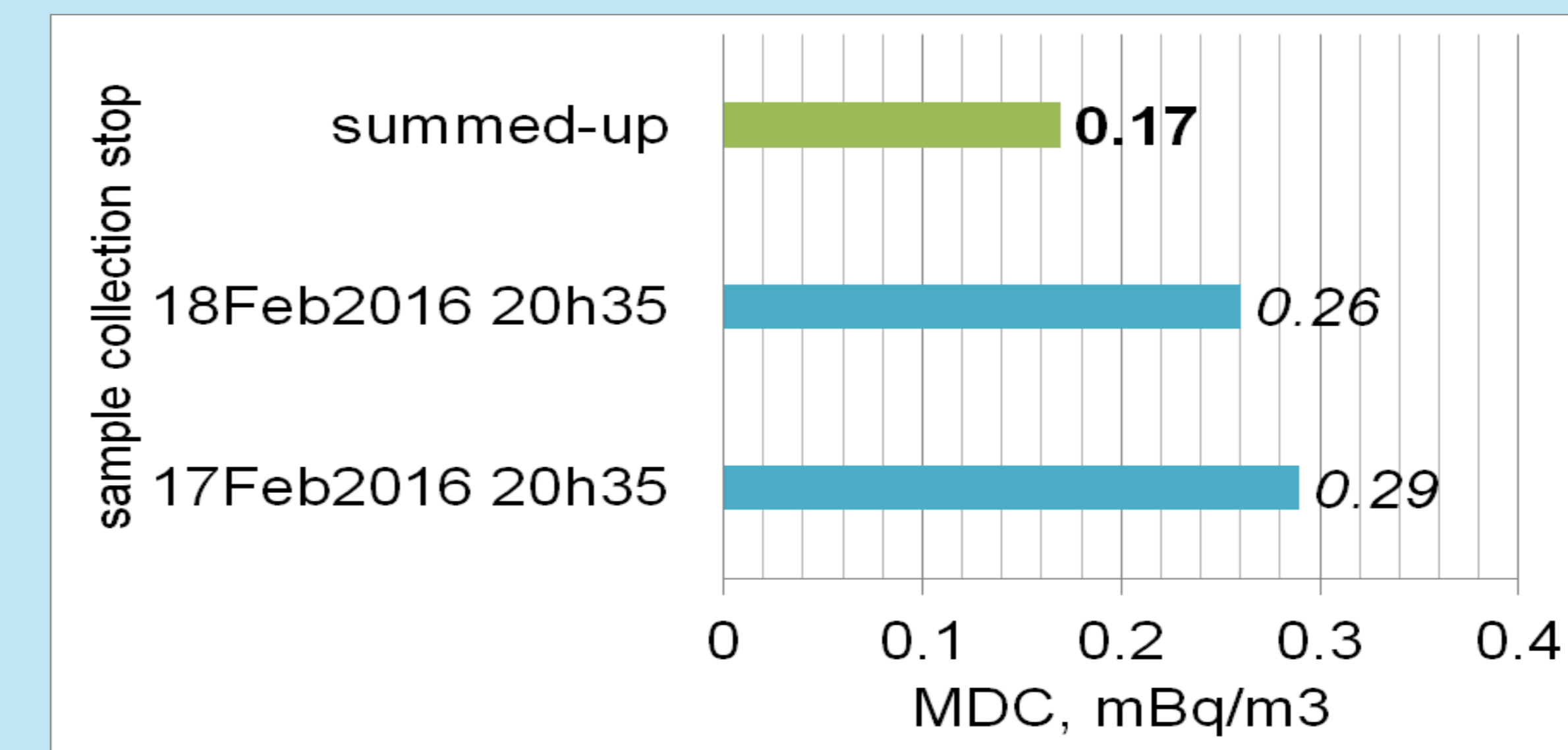


Figure 3. MDC of Xe-131m at detector JPX38_004

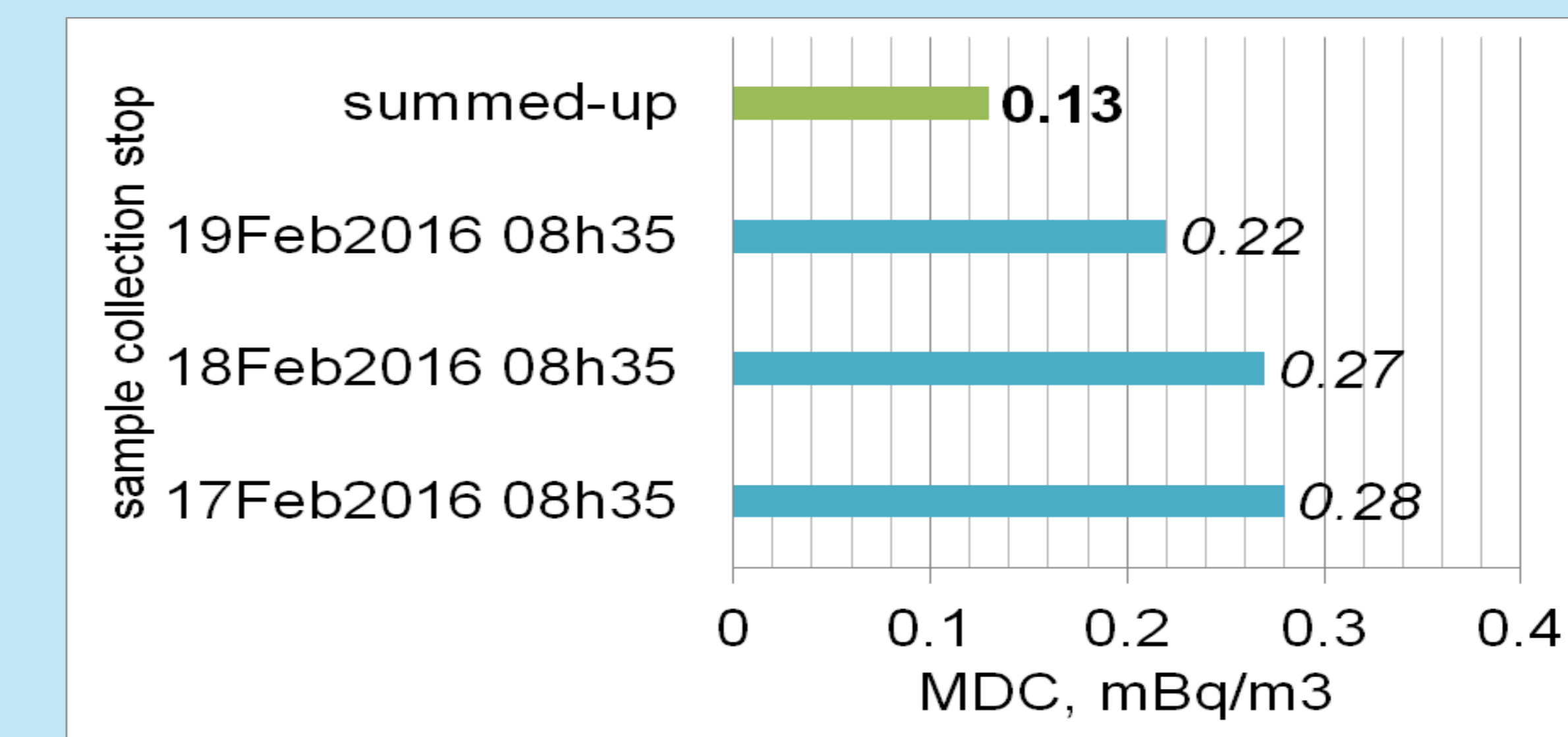


Figure 4. MDC of Xe-131m at detector JPX38_001

The analysis of summed-up spectra reduced the MDC (and LC) by ~40% for summing two samples and by a factor of two for three samples. Nevertheless, it didn't reveal any Xe-131m above the so improved LC values (0.08 mBq/m3 for JPX38_004 and 0.06 mBq/m3 for JPX38_001).

In addition, I-131, a volatile fission product of high significance among CTBT relevant radionuclides was also considered in this special analysis. I-131 was not detected in sample spectra of the collocated particulates station JPP38. With the aim of detecting an I-131 peak or at least improving the MDC for this radionuclide, the summation tool is applied to the three overlapping particulates sample spectra (collection stop 17, 18 and 19 Feb. 2016; 24h cycle duration). Still no I-131 is detected. Figure 5 displays the achieved MDC reductions.

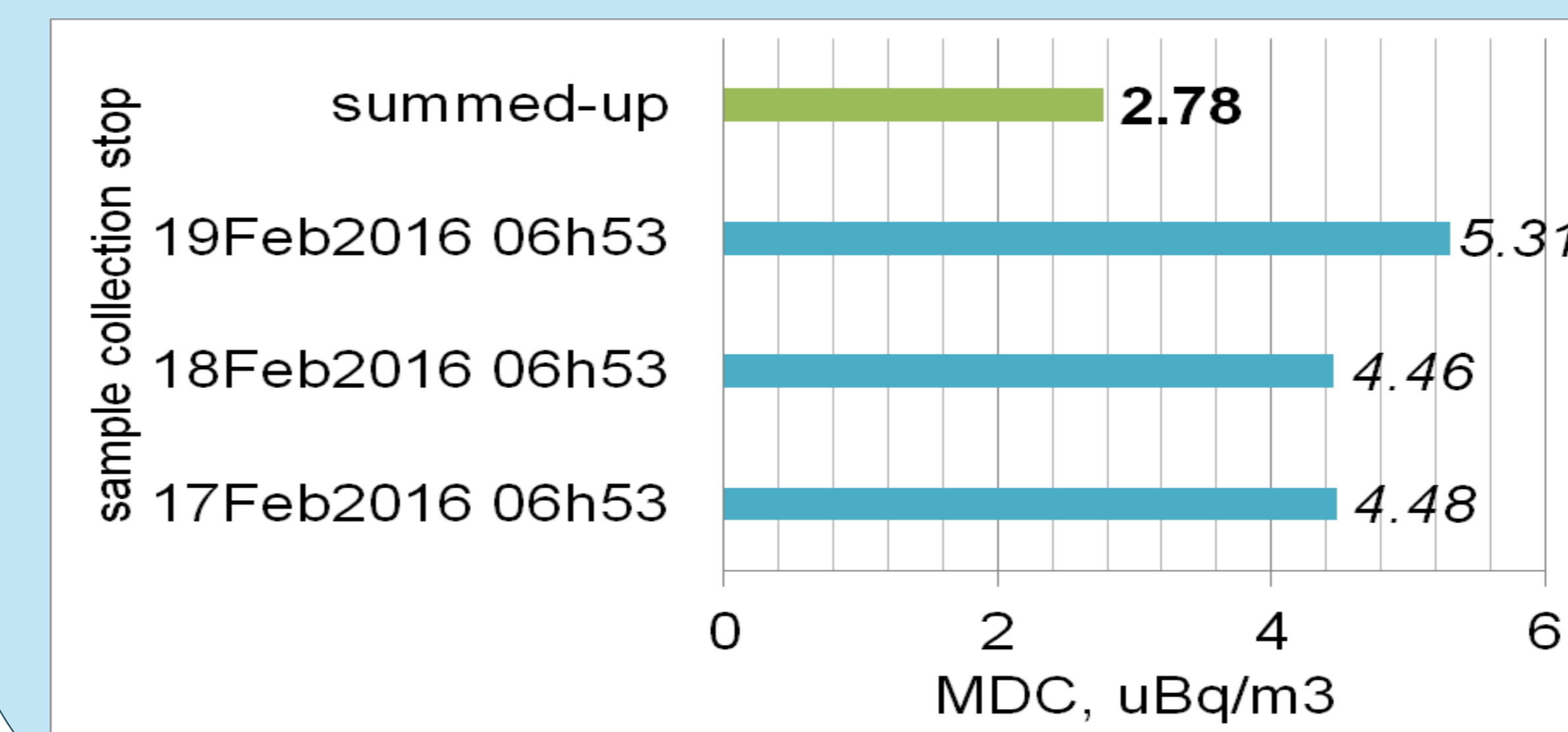


Figure 5. MDC of I-131 at station JPP38

Summary

- Spectra summation technique was successfully applied to improve detection sensitivity of Xe-131m in spectra from the IMS Noble Gas system RN38, Japan, following an episode of Xe-133 observations in February 2016.
- The technique was also extended to data of collocated IMS particulates station for improving the detection sensitivity of iodine isotopes over the time frame of interest.
- The preliminary results demonstrated clear improvement in MDC of both radionuclides in Noble Gas data and iodine in particulates sample data.
- The underlying algorithm for selecting proper sample spectra to be summed-up, based on ATM calculations, will be further tested and validated.

References

- Kalinowski et al., (2017), "IMS Radionuclide Monitoring after the Announced Nuclear Tests of the DPRK on 6 January and 9 September 2016", *SandT2017 Conference, poster T2.1-P11*
- Kusmierczyk-Michulec et al., (2017), "Atmospheric Transport Modelling for Radionuclide Monitoring after the Nuclear Tests of the DPRK on 6 January and 9 September 2016", *SandT2017 Conference, poster T2.1-P6*