SnT 2023
CTBT: SCIENCE AND TECHNOLOGY CONFERENCE
HOFBURG PALACE - Vienna and Online
19 TO 23 JUNE

Ratio Estimation Based on Activity Concentration Profile and Decay Correction During Sampling for CTBT-Relevant Radionuclides with a Short Half-Life

CTBTO PREPARATORY COMMISSION

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INTRODUCTION

Evolution of isotopic ratios from released activities to activity concentrations in a plume is used for event characterization.

METHODS/DATA

Decay correction during sampling is investigated based on concentration profiles in the plume over an IMS RN station.

START

RESULTS

An activity concentration profile can be estimated by ATM in forward simulations.

CONCLUSION

Decay corrections for Xe-135/Xe-133 and La-140/Ba-140 must be applied due to short half-life.

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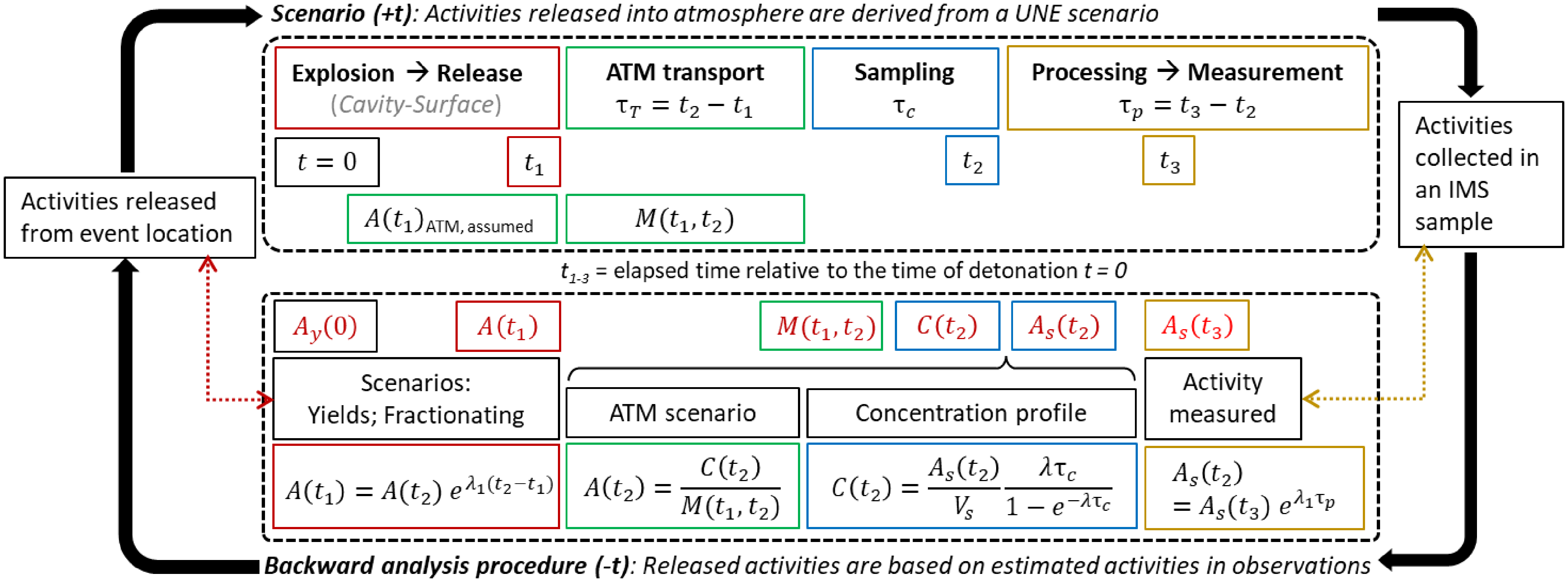
Summary

- An activity evolution model, which goes from the release of an assumed underground nuclear explosion, through the atmospheric transport modelling (ATM), to sample collection and measurements, can be used to link various quantities, including activities released from a nuclear event, activity concentrations in the plume over an International Monitoring System (IMS) station and activities collected in samples.
- Activities collected in a sample are determined by spectrum analysis, then the activity concentrations are estimated based on an assumption on activity concentration profiles in the plume over an IMS station.
- The decay correction on isotopic ratios of activity concentrations in the plume and activities in the sample can be estimated based on the assumption of the concentration profile.
  - Decay corrections for Xe-135/Xe-133 and La-140/Ba-140 must be applied due to short half-life.
- The activity concentration profile at IMS stations can be estimated by ATM forward simulations.
  - Activity concentrations might be changing much larger compared to radioactive decay.
  - The average concentration over the whole sampling duration might not be a good estimate for the radioactive plume passing over the IMS station.

Objectives

The characterization of a nuclear event is based on the evolution of isotopic activity ratios between observations at IMS stations and potential releases of underground nuclear explosion.

- One end is the radioisotope generated by a nuclear explosion,
- The other end is the activity measurements of IMS samples.
- The relationship can be setup through activity concentrations predicted by the atmospheric transport.



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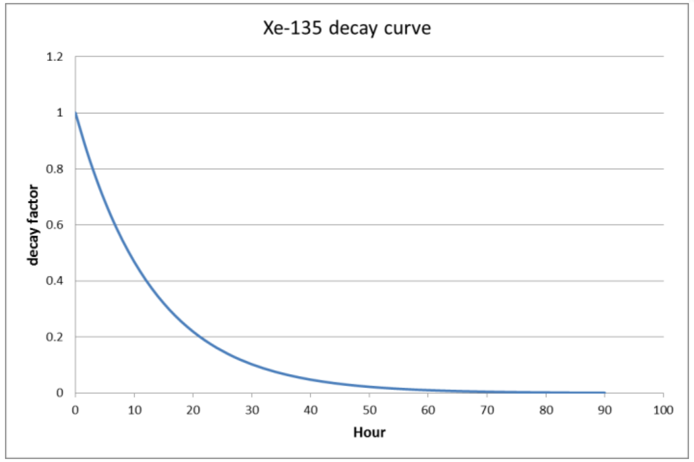
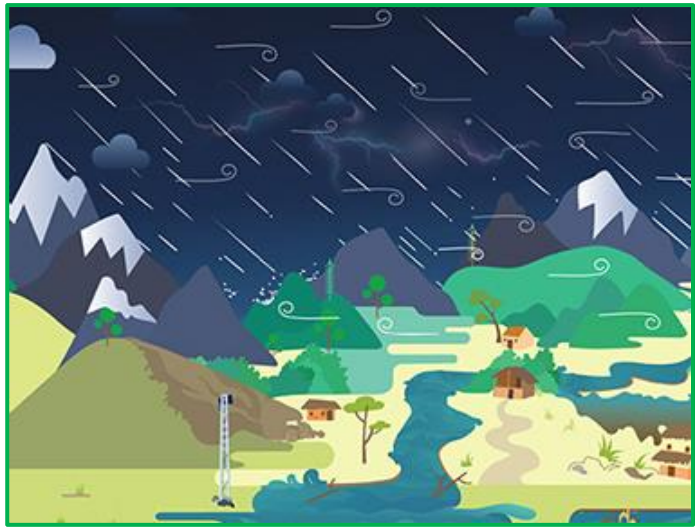
Methods

Two issues pop up regarding activity concentrations during long sampling durations (**12/24 hours**):

1. **Decay**: This is a challenge for isotopes with a short half-life, such as ^{135}Xe (**9.14 hours**).
   - ✓ Constant or decay concentrations
   - ✓ Decay correction factor required



2. **Weather**: Concentrations might highly fluctuate due to dynamic weather conditions (more dilution).
   - ✓ Interval activity concentrations by ATM simulations
   - ✓ Since ATM can deliver activity concentrations with a temporal resolution of 1 or 3 hours, the collection duration can be divided into multiple intervals, each in which a constant concentration is assumed.



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Methods and results

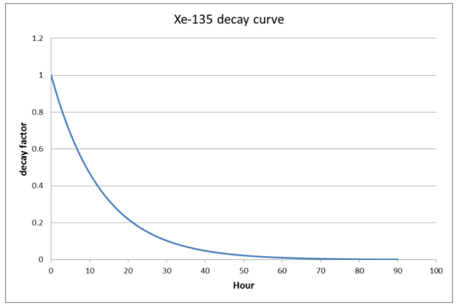
The activity collected in a sample is derived based on ordinary differential equations of activity decay and accumulation in the sample collection duration.

- Relationship between isotopic ratios of
  - Activity concentrations in the plume and
  - Activities collected in the sample
- Ratios of activity concentrations in the plume ($R(t_2)$) is only dependent on decay constants from release site to IMS stations.
- Ratios of activities collected in the sample ($R_s(t_2)$) is dependent on not only decay constants (λ_1, λ_2) but also on collection time (τ_c).

$$R(t_2) = \frac{C_2(t_2)}{C_1(t_2)}$$

$$R_s(t_2) = \frac{A_{s2}(t_2)}{A_{s1}(t_2)}$$

Sampling: Constant concentrations



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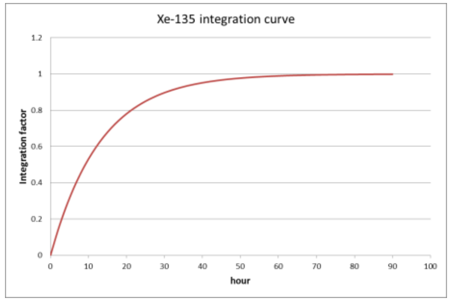

$$R_s(t_2) = R(t_2)\frac{\lambda_1}{\lambda_2}\frac{1 - e^{-\lambda_2\tau_c}}{1 - e^{-\lambda_1\tau_c}}$$

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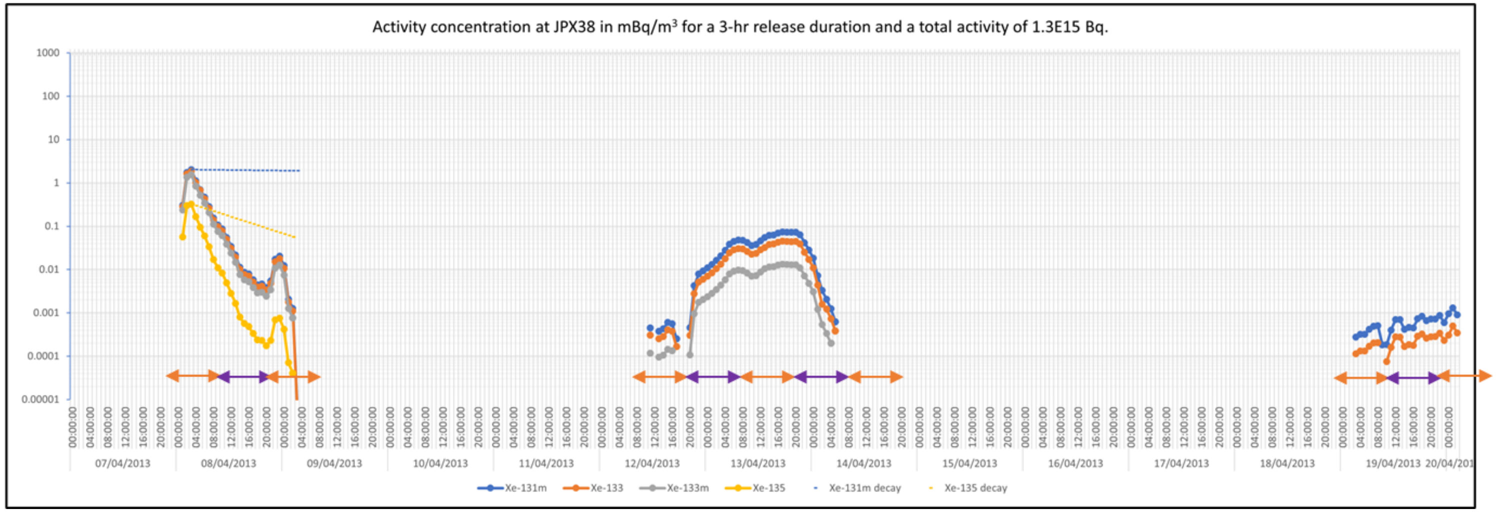
Methods and results

Concentration Profile Using ATM simulations

- Activity concentrations at IMS stations are mainly dominated by plume transport and dilution.
  - ✓ Radioactive decay might be relatively smaller compared to dilution due to plume transport.
- Impact on isotopic ratios by the concentration profile needs to be studied further.
  - ✓ Multiple ATM intervals in the low temporal resolution of the sampling duration
  - ✓ How to estimate the average concentration with respect to the profile.

✓ Release time of the DPRK2013 event was estimated using backward ATM simulations.

✓ Concentration profile at JPX38 was estimated using forward ATM simulations with the intervals of 3 hours.



↔ = sampling cycle 12 h