



Workshop on Signatures of
Man-made Isotope Production

WOSMIP IX | December 4 - 7, 2023

InterContinental Santiago
Hotels & Resorts | Av. Vitacura 2885, 7550023 Las Condes
Region Metropolitana, Chile



CTBTO
PREPARATORY COMMISSION

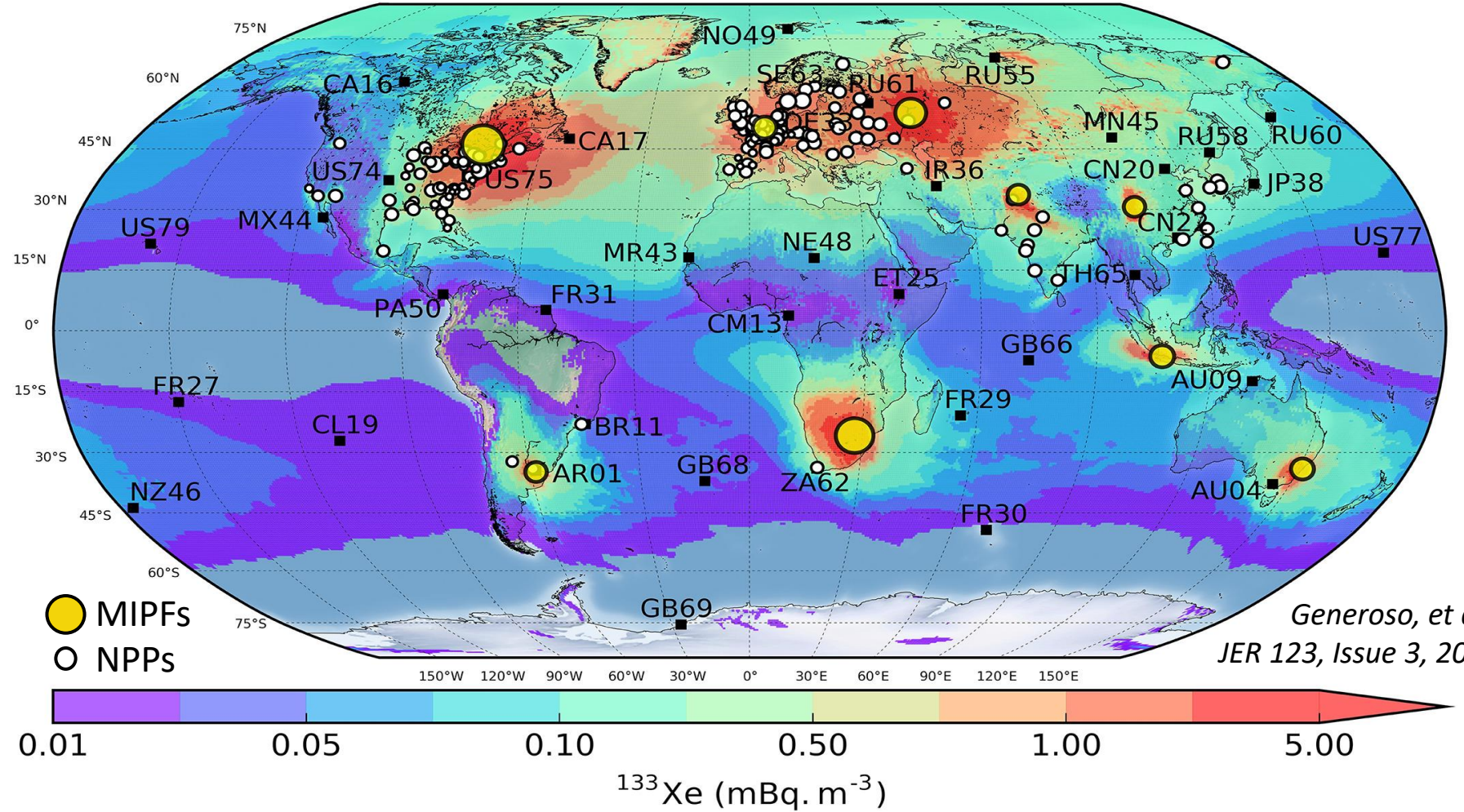
COMPREHENSIVE
NUCLEAR-TEST-BAN
TREATY ORGANIZATION

A Software Tool for Exploring Scientific Methods to Estimate the Radioxenon Background with more Confidence

Robin Schoemaker, Yuichi Kijima, Anne Tipka, Joshua Kunkle, Boxue Liu,
Jolanta Kuśmierczyk-Michulec, Martin Kalinowski, Mark Prior

The views expressed in this presentation are those of the authors and do not necessarily reflect the views of the CTBTO Preparatory Commission

The persistent presence of up to **four** non-naturally occurring CTBT-relevant radionuclides in a highly dynamic atmosphere makes a positive association of an IMS detection with a nuclear test challenging.



- ^{131m}Xe (11.96 days)
- ^{133m}Xe (5.244 days)
- ^{133}Xe (2.198 days)
- ^{135}Xe (9.143 hours)

*Generoso, et al.,
JER 123, Issue 3, 2018*



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Introduction

What / how to solve

Frontrunner XeBET

What / when to expect

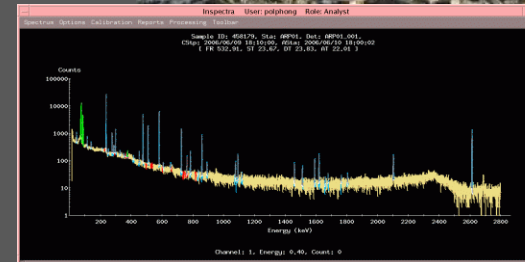
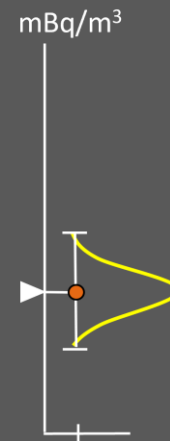
Compute the **influence** of specific **xenon sources** on IMS observations by associating the **stations' sample data (receptor)** with **data from emissions (source)** through **source-receptor sensitivity ATM data (transport)**.

With more confidence

Data (products) from the CTBTO

IMS RN **stations**: noble gas (NG) sample data for detection

- Globally collected high-quality samples.
- Data with statistics inside (Gaussian)
 - Quantity: **Activity concentration (mBq m⁻³)**
 - Space: Point source, locations fixed
 - Time: Every 6, 12, or 24 hours (depending on sample system version)



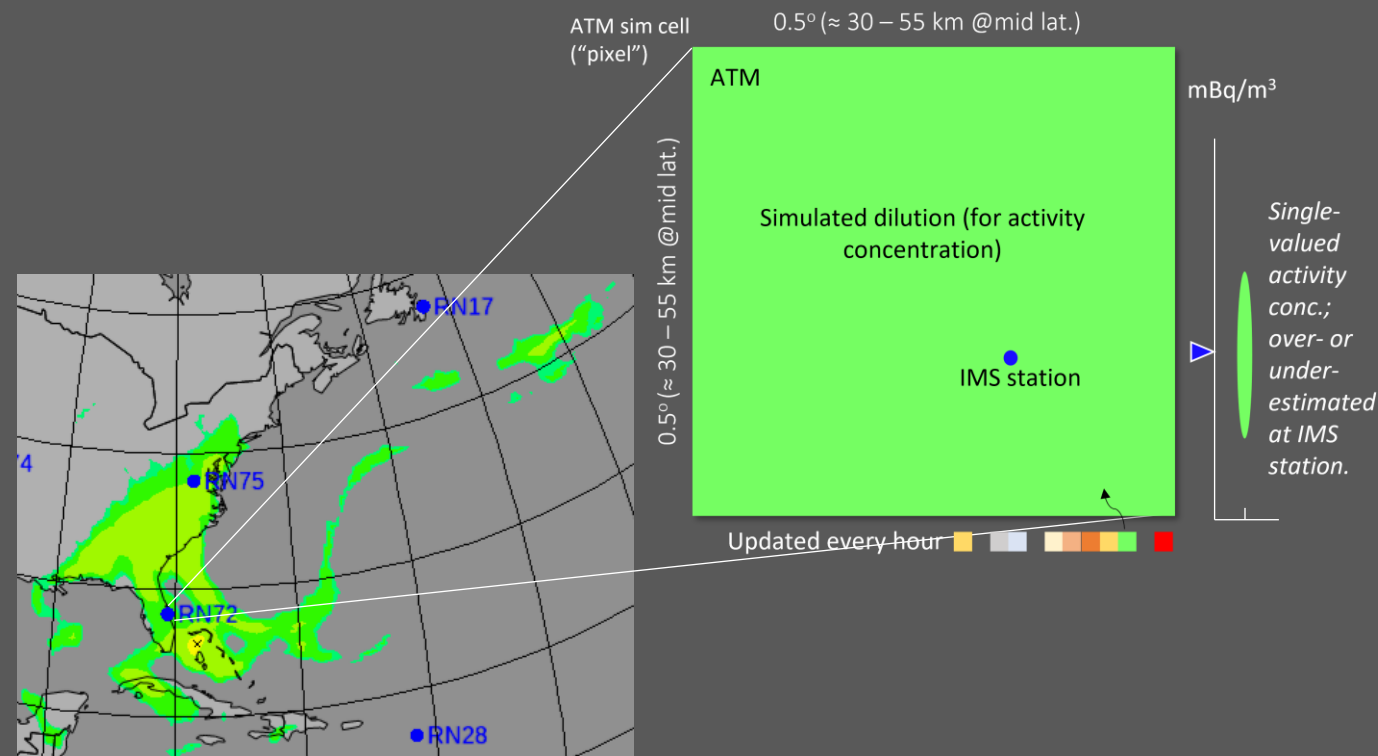
Compute the **influence** of specific **xenon sources** on IMS observations
by associating the **stations' sample data (receptor)** with **data from emissions (source)**
through **source-receptor sensitivity ATM data (transport)**.

With more
confidence

Data (products) from the CTBTO

ATM pipeline: atmospheric **transport** modelling data

- Using high-quality global weather data to link radioisotope detections at IMS stations with nuclear explosions (and v.v.).
- Data with no statistics inside:
 - Quantity: Dispersion of tracers given as a **dilution (m^{-3})** or **activity concentration ($mBq m^{-3}$)**
 - Space: $0.5^\circ \times 0.5^\circ$
 - Time: 1 hour





Compute the **influence** of specific **xenon sources** on IMS observations by associating the **stations' sample data (receptor)** with **data from emissions (source)** through **source-receptor sensitivity ATM data (transport)**.

With more confidence

Non-CTBTO data

Established noble gas sources (emissions from MIPFs, NPPs, and NRRs)

- Quantity: **Activity (Bq)**
- Space: Point source, locations fixed
- Time: **Fragmented** timeframes and averages; low and high granularity
 - mean day course;
 - weekly source variation (difference between days of the week);
 - monthly / seasonal source variation (difference between weeks/months of the year);
 - an annual average?;
 - downtimes of the facility (times with zero emissions).



Current *background estimation* efforts at the IDC

- **Background estimation**
- Source term estimation – *background as input*
- **Data fusion – *implicitly (future)***

Optimization and probabilistic approaches/methods:

- Inverse modelling; linear regression
- **Bayesian inference**
- **Monte Carlo**

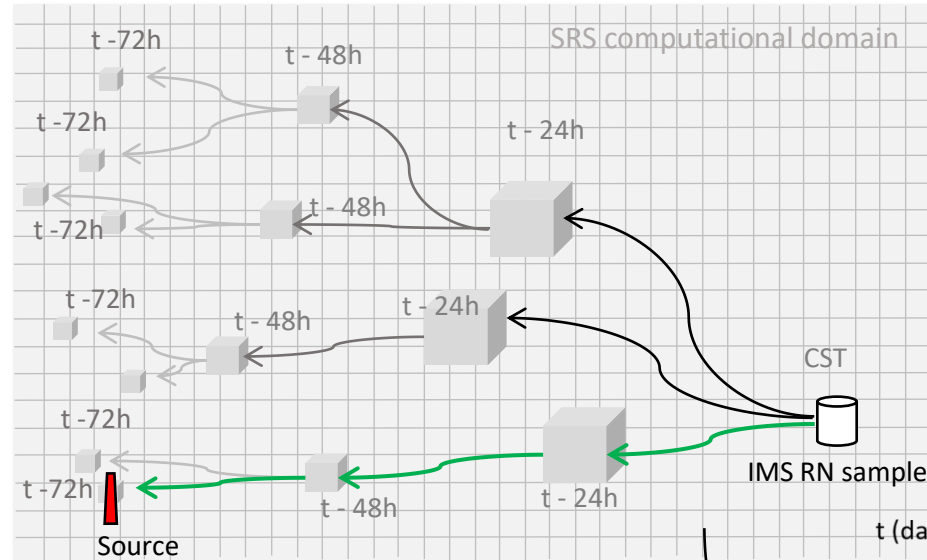
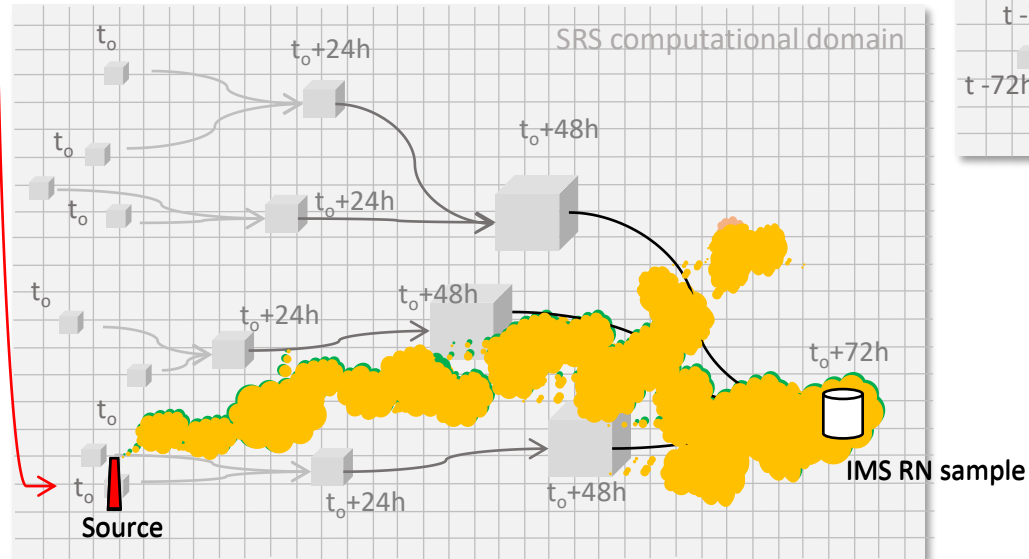
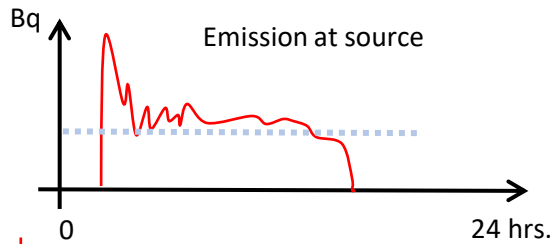
- ✓ **Joshua Kunkle, et al.**, *Evaluation of methodologies for forming a global view of radionuclide release events and their application to the data fusion pipeline at the CTBTO*, WOSMIP IX 2023.
- ✓ **Yuichi Kijima, et al.**, *Investigating the radioxenon probability density function at IMS stations using a Monte Carlo approach for background estimation*, WOSMIP IX 2023.

“Integrate a flag in the operational environment; update Reviewed Radionuclide Report according to its outcome.”

Monte Carlo methods
Stochastically obtaining numerical results for optimization, numerical integration, or generating draws from a probability distribution.

We compute the probability density of the ATM predicted activity concentration for one sample by generating daily draws from an emission probability density function and scaling them by deterministic source-receptor sensitivity values over a 14-day transmission window.

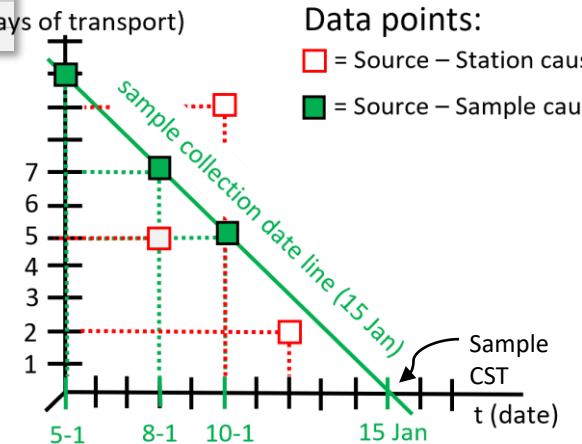
t_0+24h

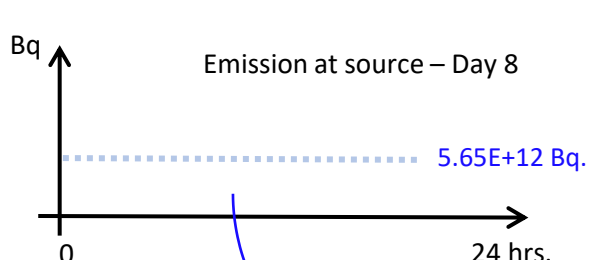


ATM in backward mode is used to **identify the origin of the associated air masses** if an IMS station detects an elevated level of radionuclides in a particular day and station.

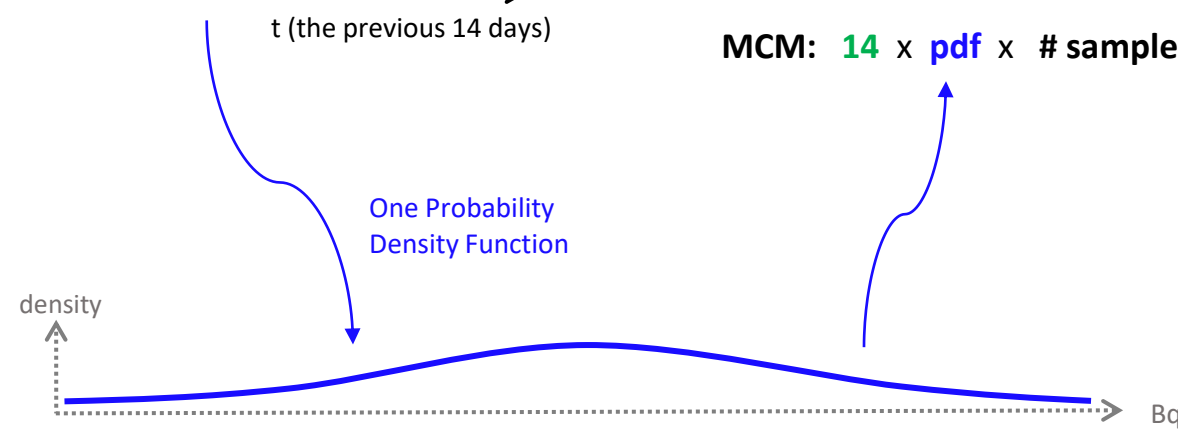
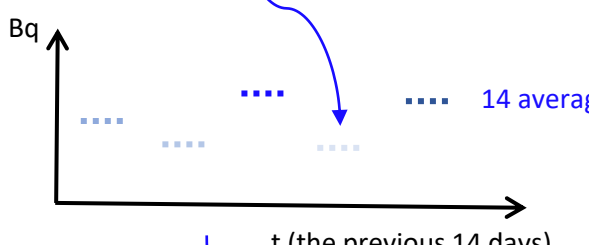
Standard IDC product:
14-day backward SRS

Data points:
□ = Source – Station causality
■ = Source – Sample causality

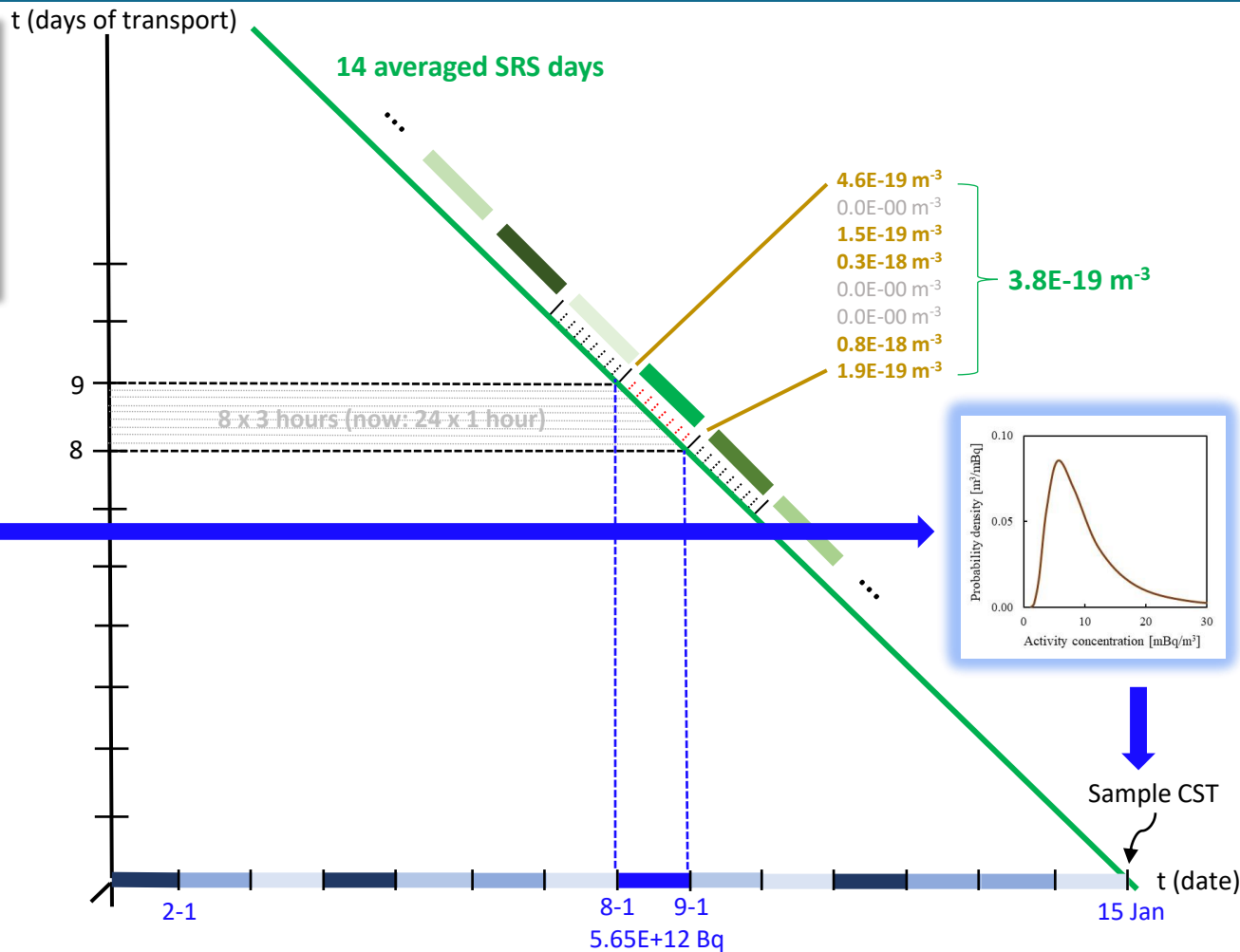




Measurement start	Measurement stop	Emission Xe133 (Bq)	sigma
2014/02/18/00	2014/02/19/00	7.14E+13	1.86E+13
2014/02/19/00	2014/02/20/00	4.42E+13	
2014/02/20/00	2014/02/21/00	2.58E+13	average
2014/02/21/00	2014/02/22/00	4.81E+13	2.87E+13
2014/02/22/00	2014/02/23/00	2.05E+13	
2014/02/23/00	2014/02/24/00	1.15E+13	LN ave
2014/02/24/00	2014/02/25/00	2.52E+13	30.99
2014/02/25/00	2014/02/26/00	5.65E+12	
2014/02/26/00	2014/02/27/00	5.07E+13	LN sigma
2014/02/27/00	2014/02/28/00	3.51E+13	0.43
2014/02/28/00	2014/03/01/00	2.96E+13	
2014/03/01/00	2014/03/02/00	1.08E+13	
2014/03/02/00	2014/03/03/00	5.47E+12	
2014/03/03/00	2014/03/04/00	1.72E+13	



MCM: 14 x pdf x # samples



Frontend layer (GUI):

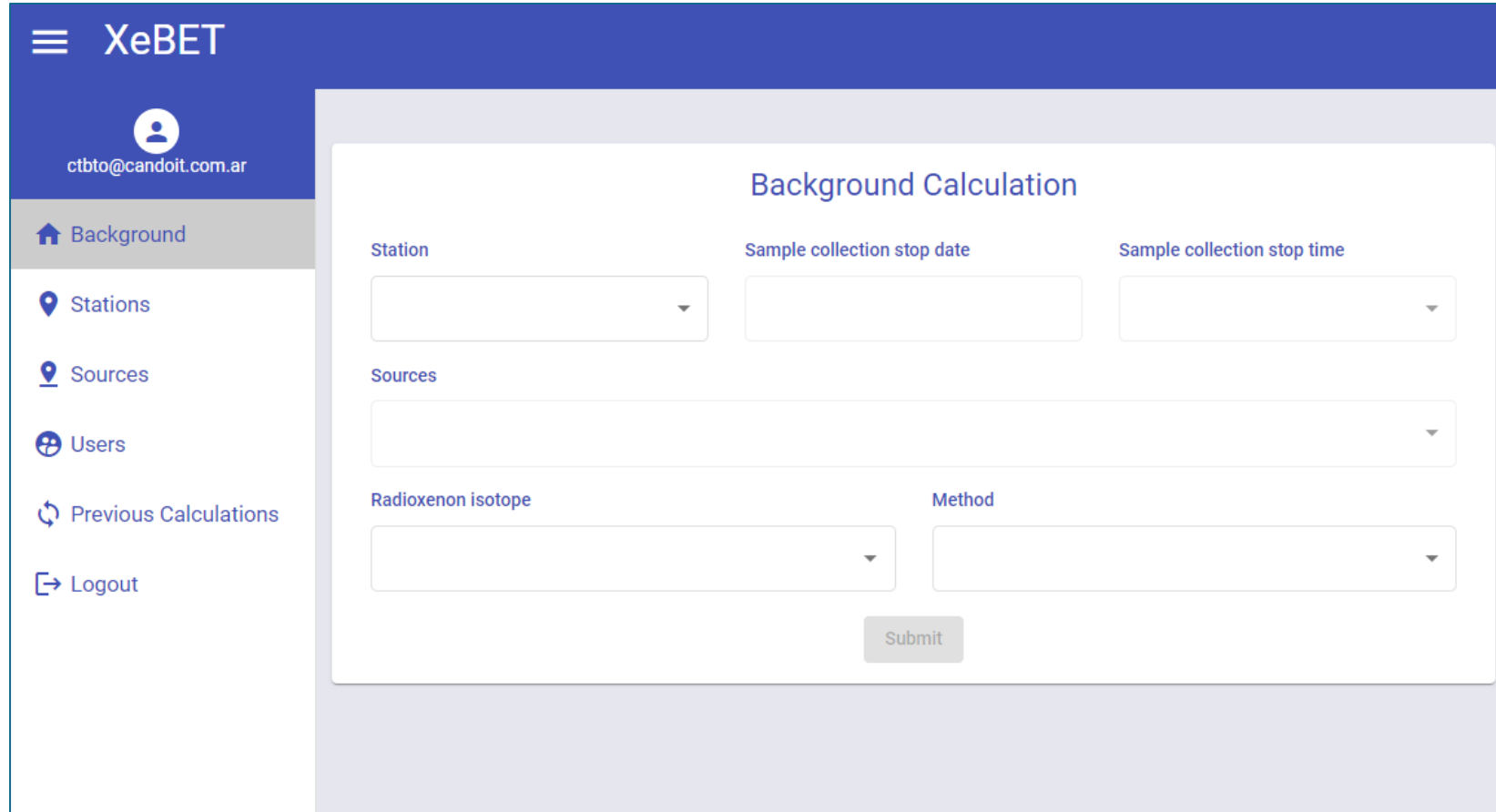
- Station and sample: *date/time*
- Known source(s): for 14-day prior
- Emission strength: *PDF (time)*
 - ✓ 2014 data set
- Radionuclides
- Method

Functional layer (methods):

- Monte Carlo method**

Backend layer (data):

- IMS RN (NG) detections database
- ATM SRS files
- Any emission data available



The screenshot displays the XeBET web application interface. The header includes the XeBET logo and the email address ctbto@candoit.com.ar. A sidebar menu on the left contains options: Background (selected), Stations, Sources, Users, Previous Calculations, and Logout. The main content area is titled 'Background Calculation' and contains the following form fields:

- Station: A dropdown menu.
- Sample collection stop date: A text input field.
- Sample collection stop time: A dropdown menu.
- Sources: A dropdown menu.
- Radionuclide isotope: A dropdown menu.
- Method: A dropdown menu.
- Submit: A button.

* XeBET: Xenon Background Estimation Tool

** Kijima, Y. et al., *Using a Monte Carlo Approach to Determine the Radionuclide Probability Density Function at an IMS Station for Background Estimation*, WOSMIP IX 2023.



The screenshot shows a web browser window with the URL <https://xebet-frontend.candoit.com.ar/home>. The application header is dark blue with the 'XeBET' logo and a user profile icon for 'ctbto@candoit.com.ar'. A left sidebar contains navigation links: 'Background', 'Stations', 'Sources', 'Users', 'Previous Calculations', and 'Logout'. The main content area is titled 'Background Calculation' and contains a form with the following fields:

- Station:** A dropdown menu with a search filter and a list of options: CAX17, USX75, CAX16, SEX63, and DEX33.
- Sample collection stop date:** A text input field.
- Sample collection stop time:** A dropdown menu.
- Method:** A dropdown menu.
- Submit:** A button at the bottom of the form.



Browser address bar: <https://xebet-frontend.candoit.com.ar/home>

XeBET

ctbto@candoit.com.ar

- Background
- Stations
- Sources
- Users
- Previous Calculations
- Logout

Background Calculation

Station: CAX17

Sample collection stop date: 3/3/2014

Sample collection stop time: [dropdown]

Sources: [input field]

Radioxenon isotope: [input field]

Calendar overlay: 3/15/2014, MAR, 3 selected



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XeBET

ctbto@candoit.com.ar

- Background
- Stations
- Sources
- Users
- Previous Calculations
- Logout

Background Calculation

Station: CAX17

Sample collection stop date: 3/3/2014

Sample collection stop time: 2014-03-03 18:00

Sources: [Empty]

Radioxenon isotope: [Empty]

Method: [Empty]

Submit



Browser address bar: <https://xebet-frontend.candoit.com.ar/home>

XeBET

ctbto@candoit.com.ar

- Background
- Stations
- Sources
- Users
- Previous Calculations
- Logout

Background Calculation

Station: CAX17

Sample collection stop date: 3/3/2014

Sample collection stop time: 2014-03-03 18:00

Sources

- Point Lepreau
- Blayais
- Columbia
- Chalk River Canada
- Civaux
- Chinon



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XeBET

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- Background
- Stations
- Sources
- Users
- Previous Calculations
- Logout

Background Calculation

Station: CAX17

Sample collection stop date: 3/3/2014

Sample collection stop time: 2014-03-03 18:00

Sources: Chalk River Canada

Radioxenon isotope: Xe133 Xe135

Method: [Empty]

Submit



Browser address bar: <https://xebet-frontend.candoit.com.ar/home>

XeBET

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- Background
- Stations
- Sources
- Users
- Previous Calculations
- Logout

Background Calculation

Station: CAX17

Sample collection stop date: 3/3/2014

Sample collection stop time: 2014-03-03 18:00

Sources: Chalk River Canada

Radioxenon isotope: Xe133

Method: MCM ATM

Submit

Demo

*Use case 1**: 3 March 2014

One source contribution to CAX17:

- Chalk River (CNL)

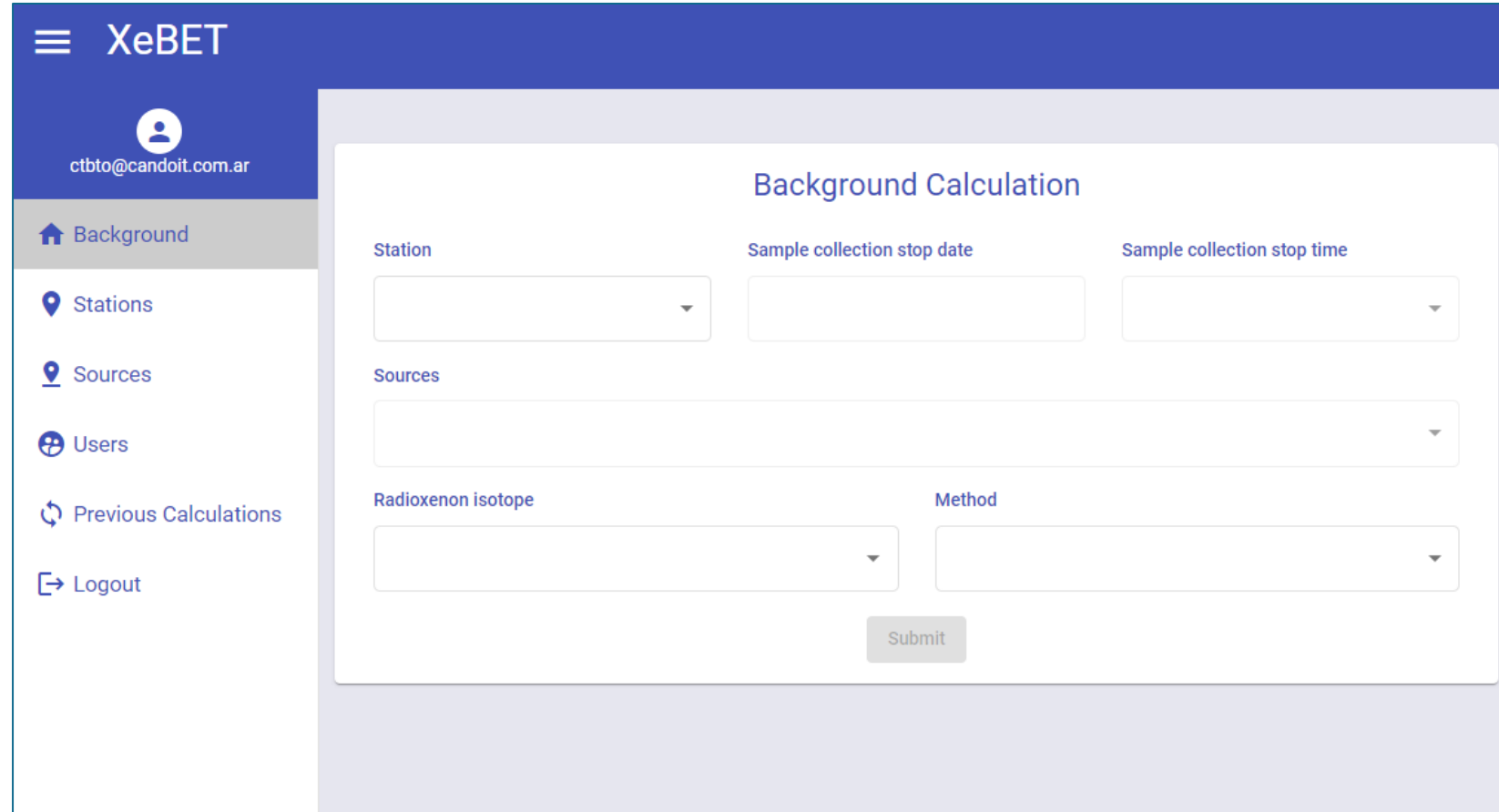
*Use case 2**: 26 January 2014

Multiple source contributions to USX75:

- Chalk River (CNL)

- LaSalle County Generation Station

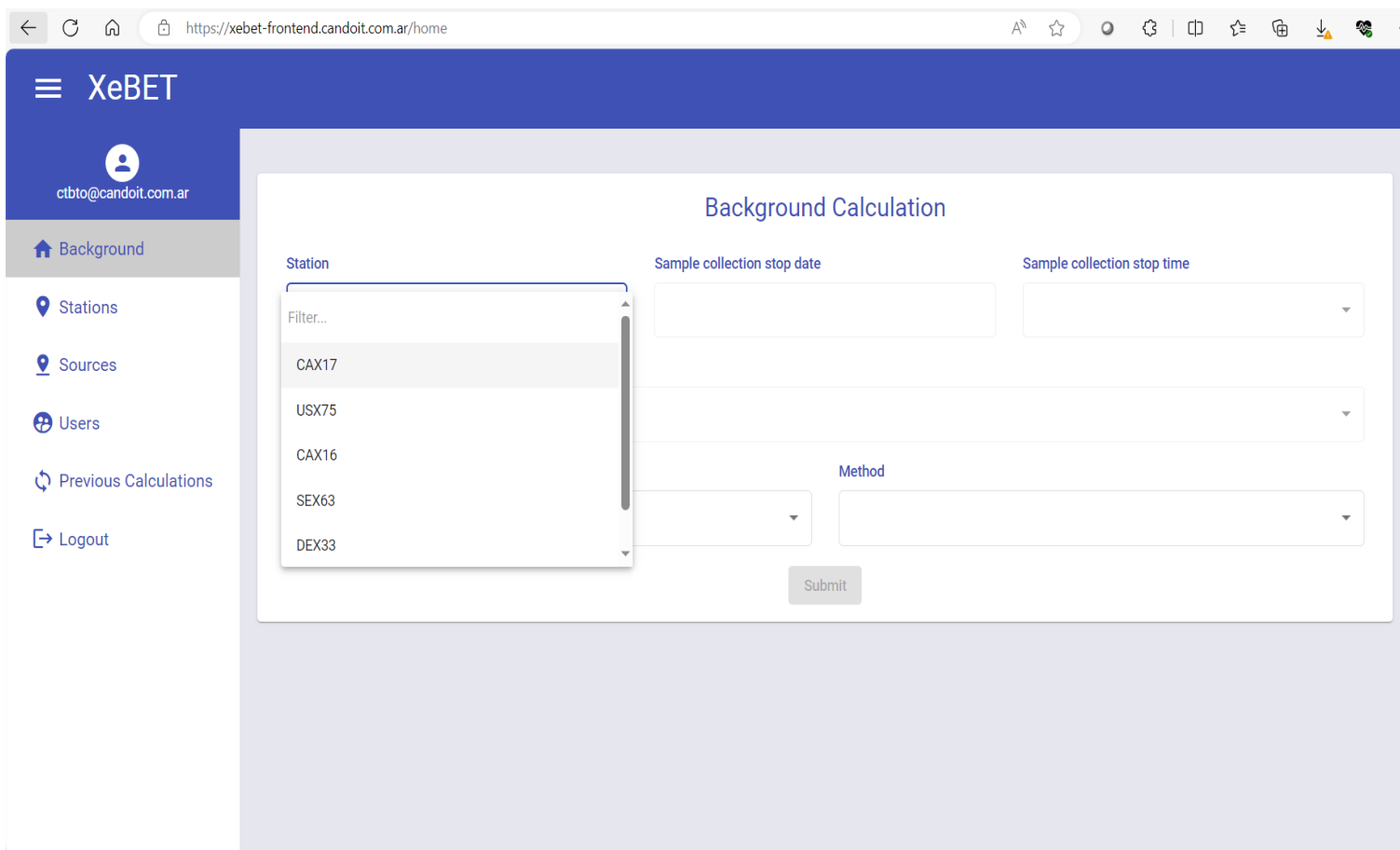
- ?



The screenshot displays the XeBET web application interface. The header includes the XeBET logo and the email address ctbto@candoit.com.ar. A sidebar menu on the left contains the following items: Background (selected), Stations, Sources, Users, Previous Calculations, and Logout. The main content area is titled "Background Calculation" and contains the following form fields:

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- Sources: A dropdown menu.
- Radioxenon isotope: A dropdown menu.
- Method: A dropdown menu.
- Submit: A button.

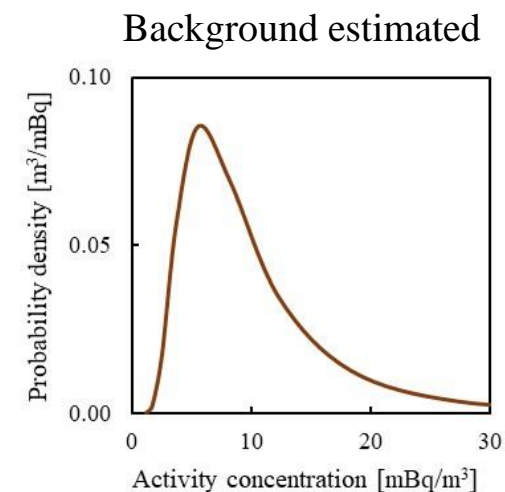
* Kijima, Y. et al., Using a Monte Carlo Approach to Determine the Radioxenon Probability Density Function at an IMS Station for Background Estimation, WOSMIP IX 2023.



The screenshot shows the XeBET web application interface. The main content area is titled "Background Calculation" and contains the following fields:

- Station:** A dropdown menu with a "Filter..." input field. The list includes CAX17, USX75, CAX16, SEX63, and DEX33. CAX17 is currently selected.
- Sample collection stop date:** An empty text input field.
- Sample collection stop time:** A dropdown menu.
- Method:** A dropdown menu.

A "Submit" button is located at the bottom right of the form.



* "The mean value of the background for CAX17 (in St. John's, Canada) on 3 March 2014 is 7.3 mBq/m³. On the other hand, the measured activity concentration is 8.3 mBq/m³."

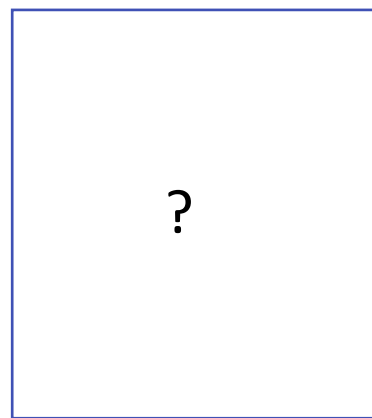
Use case 1*



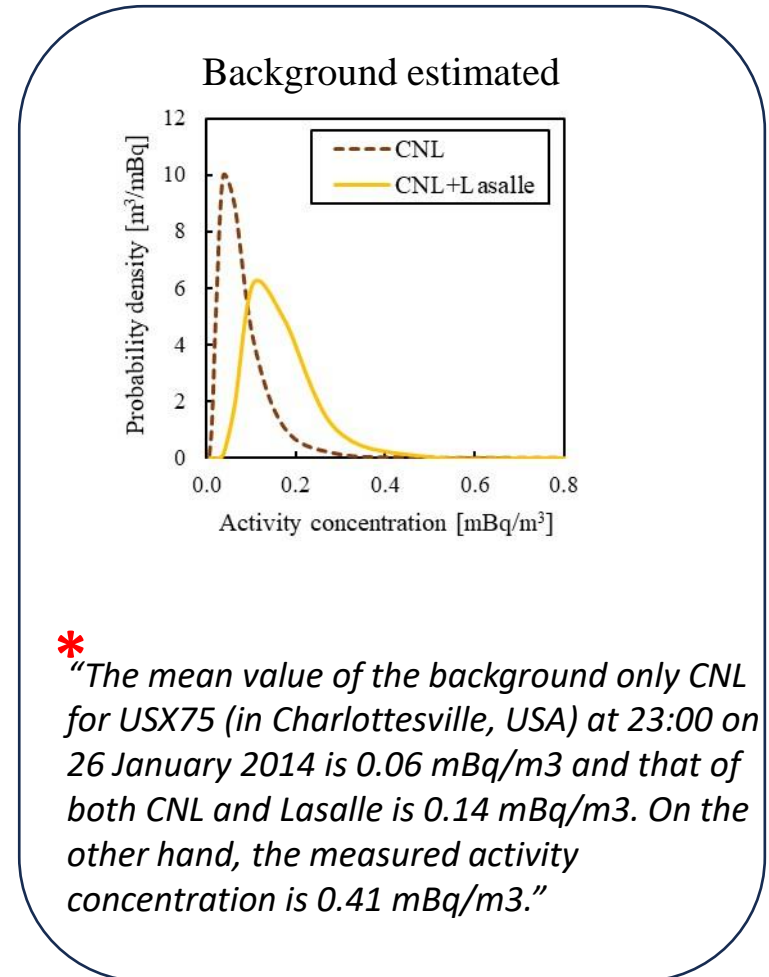
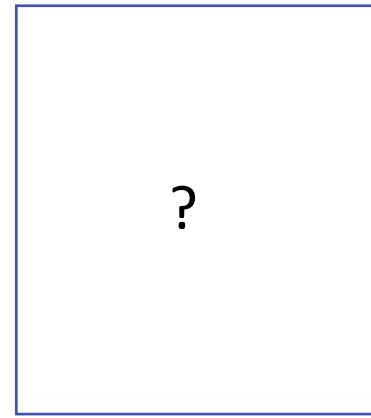
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+



+



* "The mean value of the background only CNL for USX75 (in Charlottesville, USA) at 23:00 on 26 January 2014 is 0.06 mBq/m³ and that of both CNL and Lasalle is 0.14 mBq/m³. On the other hand, the measured activity concentration is 0.41 mBq/m³."

Use case 2*

* Kijima, Y. et al., Using a Monte Carlo Approach to Determine the Radioxenon Probability Density Function at an IMS Station for Background Estimation, WOSMIP IX 2023.

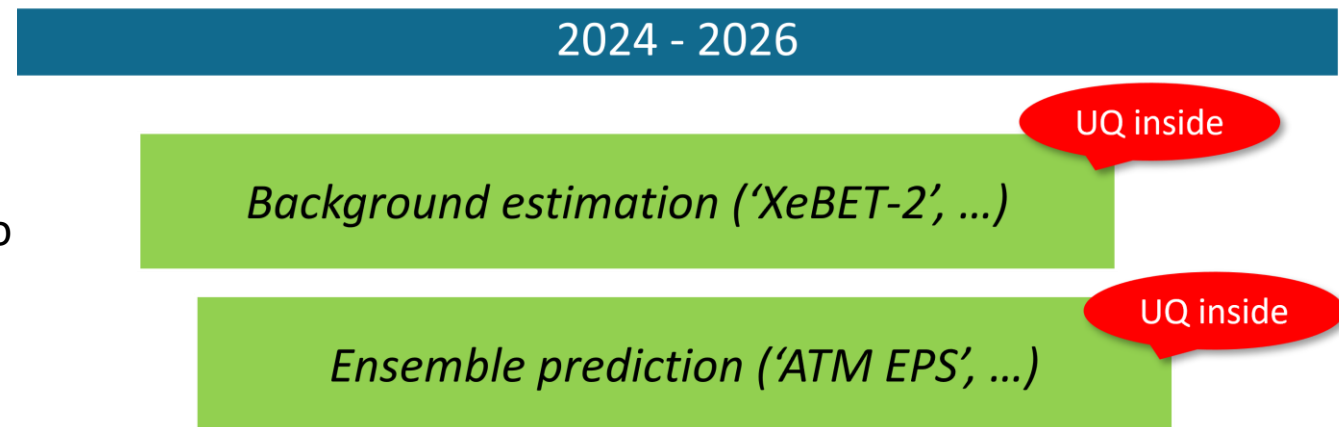
Near future efforts at the IDC for background estimation

Common denominator: **UQ (uncertainty quantification)**

- Identification and assessment of prospective data-driven scientific methods.
- Development of an uncertainty quantification related to each prospective scientific method (and combinations thereof).

Data and methodologies

- IMS RN data : ✓
- Emission data : Fragmented, we use what's available . . . as a prior to optimization
- ATM data : Focus!
 - ✓ Ensemble prediction (**UQ** prospect)
 - ✓ High-resolution ATM
 - ✓ Other: current SRS file utilization
(spatio-temporal nudging of emission database to best fit IMS observations, ...)



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