PNNL-SA-143335

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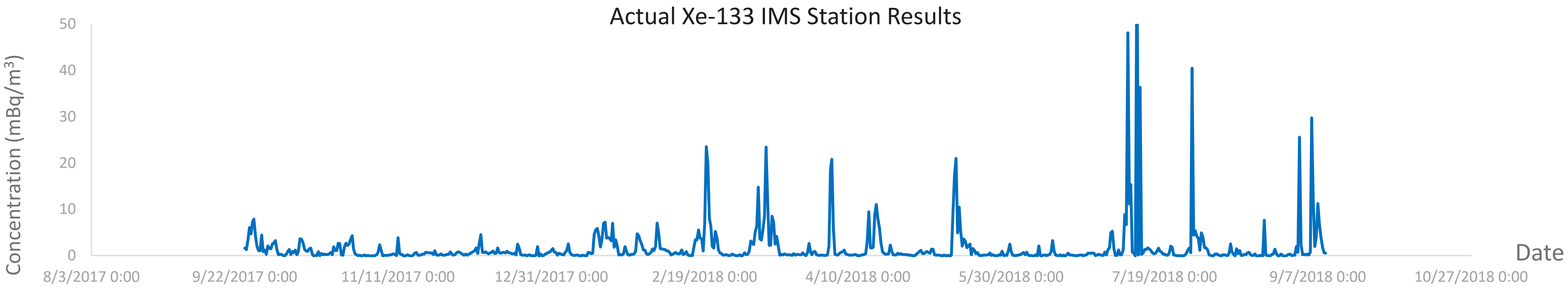
Backgrounds and False Positives

Dealing with RN Detection in 2019 and beyond

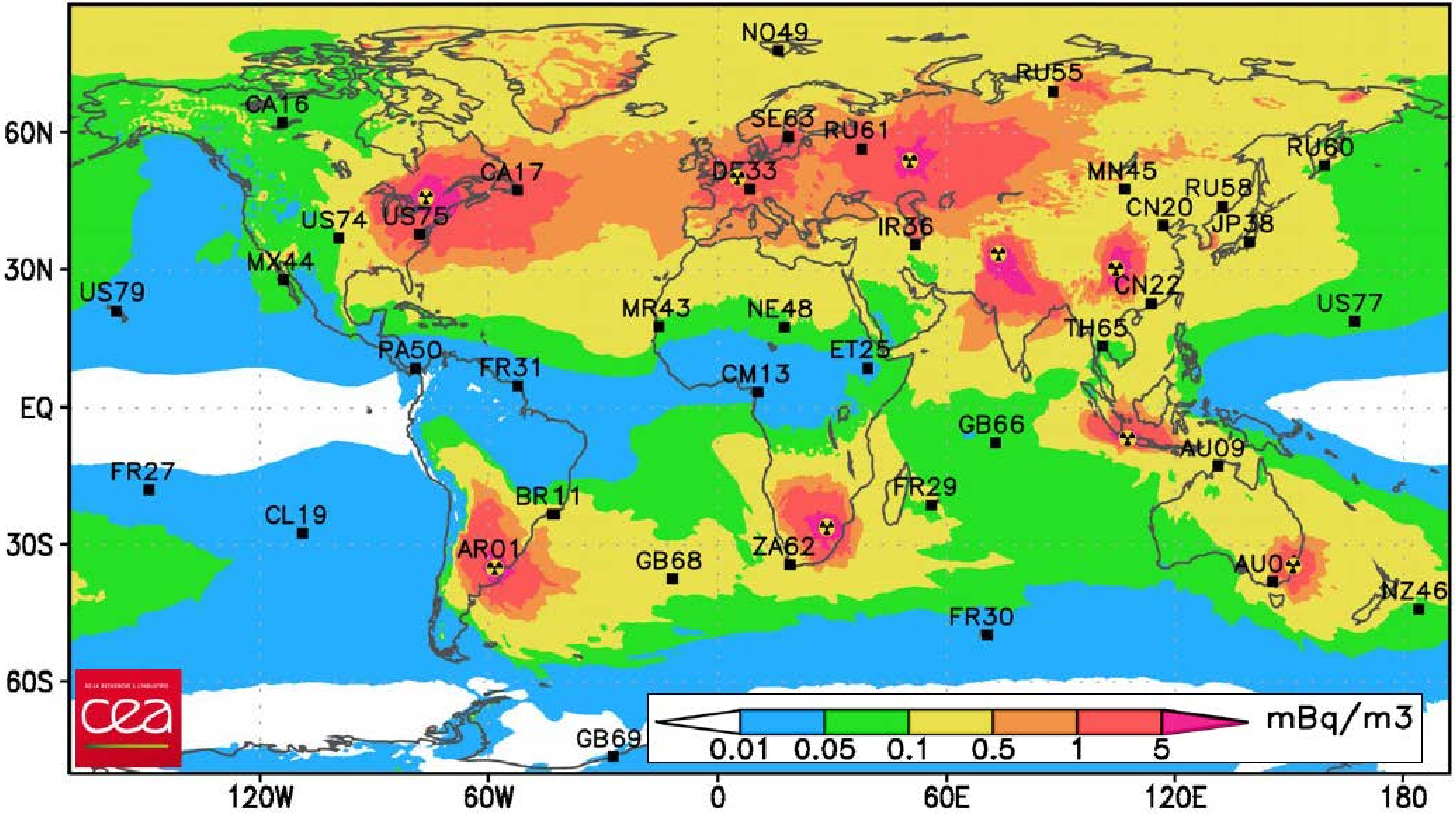
TW Bowyer

What is Background?

- Background refers to the fluctuating concentration of radioactive isotopes in the environment *not associated with a nuclear test*
  - Backgrounds make it difficult to analyze data from IMS stations – sometimes impossible
  - Isotopes that interfere with our measurement or the actual isotopes themselves we measure
  - For example:
    - Xenon-133 is created in man-made processes and that xenon is detected frequently in the IMS



Global view of background (2009)



P. Achim 2009

Backgrounds don’t have stop the show

- Under many cases we can get, or have knowledge of the background
  - Unfortunately, the background at a station can change on daily basis
- Luckily, with additional information, we know how to subtract the effect of the background
  - From our observations we subtract the effect of the background if there is additional information
    - Knowledge of emissions from an industrial process
    - Average local backgrounds and models
    - Average values at the station

Station Backgrounds Can Be Determined With Information the Sources of the Emissions

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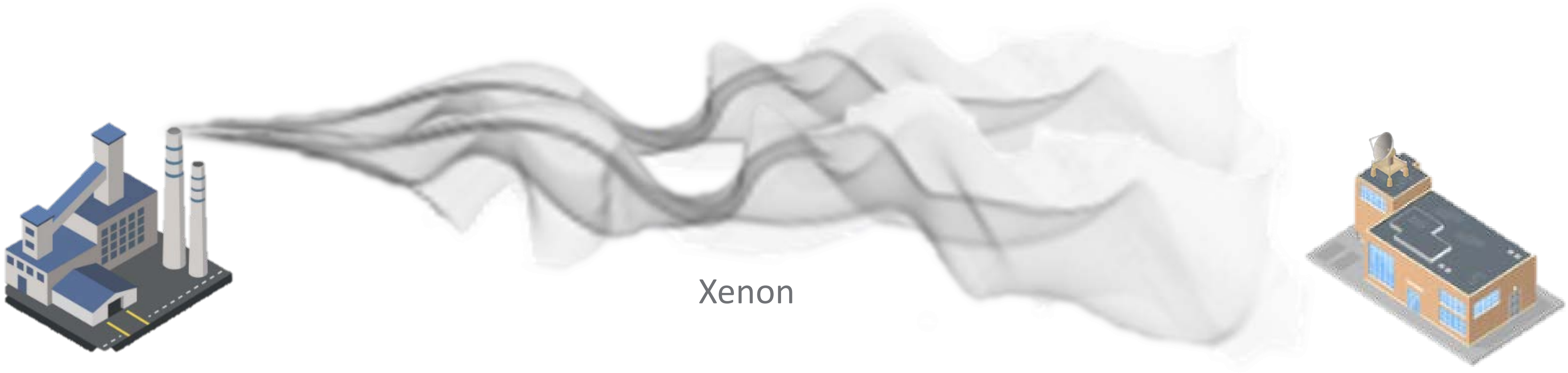
Emission Level
Atoms Released
1,000,000,000,000,000,000 atoms/day

Predictable IMS Station Detection
Atoms Detected
10,000 atoms/day



Emission Source

IMS Station

Subtracting the Effect!

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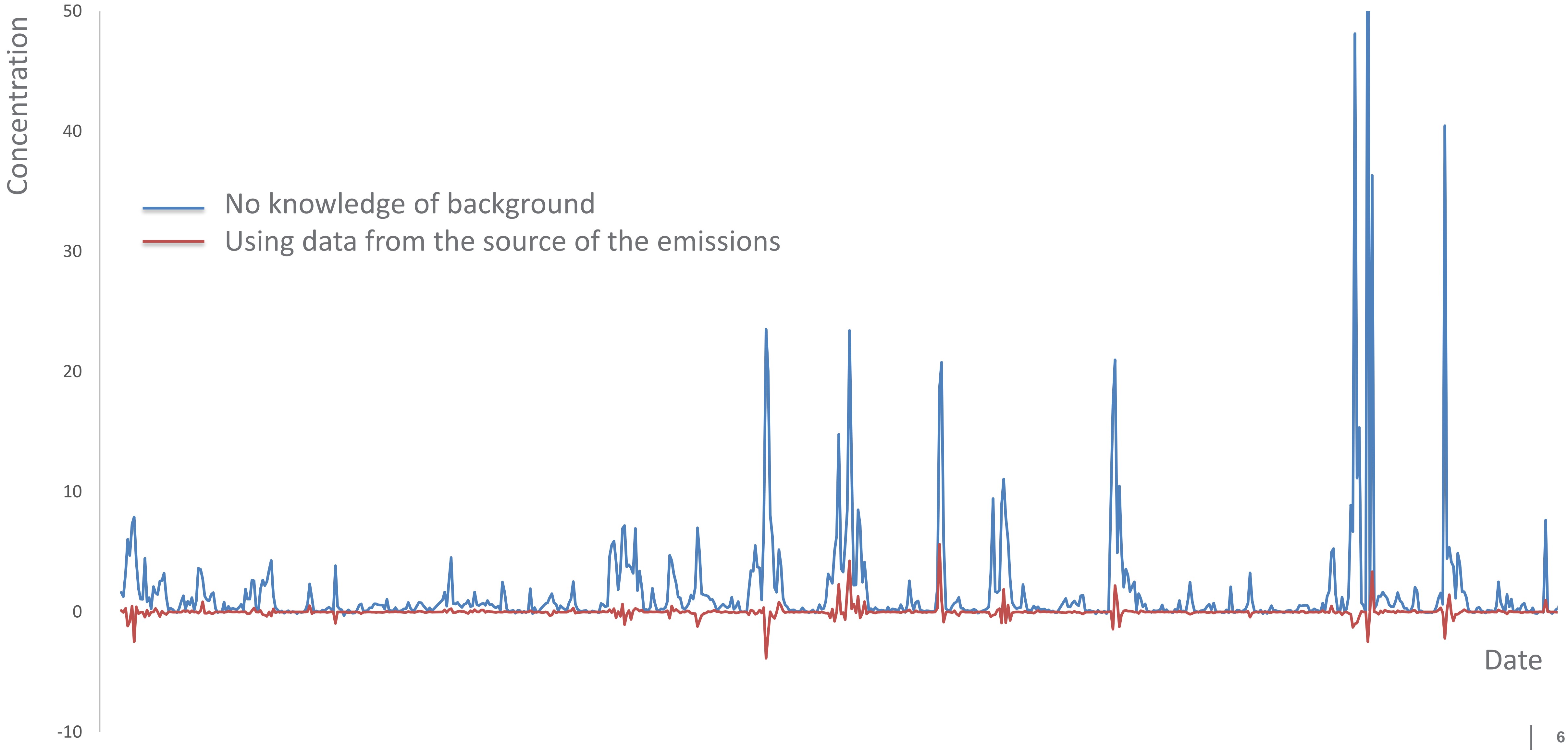

What if we cannot or do not correct for the background?

- Unfortunately, we get
  - False negatives
    - We may miss the detection of a real nuclear explosion
  - False positives
    - We may think a detection is a nuclear explosion when it isn't….

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False Positives

(Accidentally saying it’s a nuclear explosion, when it isn’t)

The *FALSE POSITIVE*

- A false positive may cause significant difficulties for States affected

- Among other things, the ramifications of a false positive are:
  - Additional scrutiny on samples collected in the field and calls for reanalysis of samples
  - Calls for reanalysis of data from IMS stations
  - Could lead to a call for an on-site inspection (OSI)

How might a false positive happen?

- There are tens of 1000's of seismic events per year, most of which are "screened out"
  - However a seismic event happening at the same time and calculated location as an isotope detection could look a lot like a clandestine nuclear explosion
  - We have calculated the probability of this happening at the Nevada Nuclear Security Site

Our premise

- The next few slides present an analysis of a notional situation in which the calculated locations and times of a seismic event and radionuclide event overlap in time

- Disclaimer: Although there are a number of tools we have to lower the chance that the coincidental event looks suspicious, such as sophisticated waveform discrimination techniques and radionuclide ratio analysis they are not perfect and several events have surprised us in the past (i.e., enigmatic events fall near the discrimination lines!)

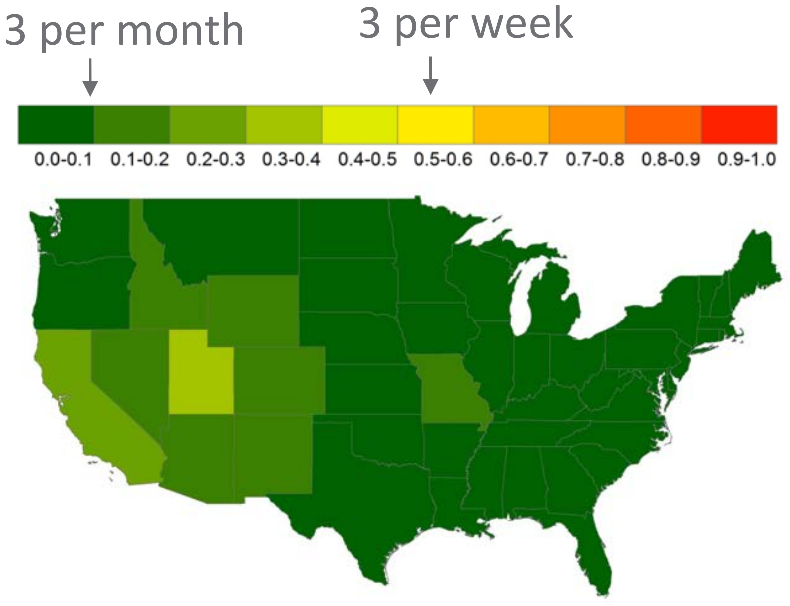
Modeling FALSE POSITIVES

- We simulated medical isotope production occurring in Utah (US), and calculated the expected number of times the calculated field of regard extended over the Nevada Nuclear Security Site (NNSS) and was detected by an IMS station

- Assumptions:
  - 40,000 ATM runs
  - 4 IMS Xe stations in the US
  - 6×10^{12} Bq release of Xe-133 per day
  - MDC = 0.2 mBq/m^3

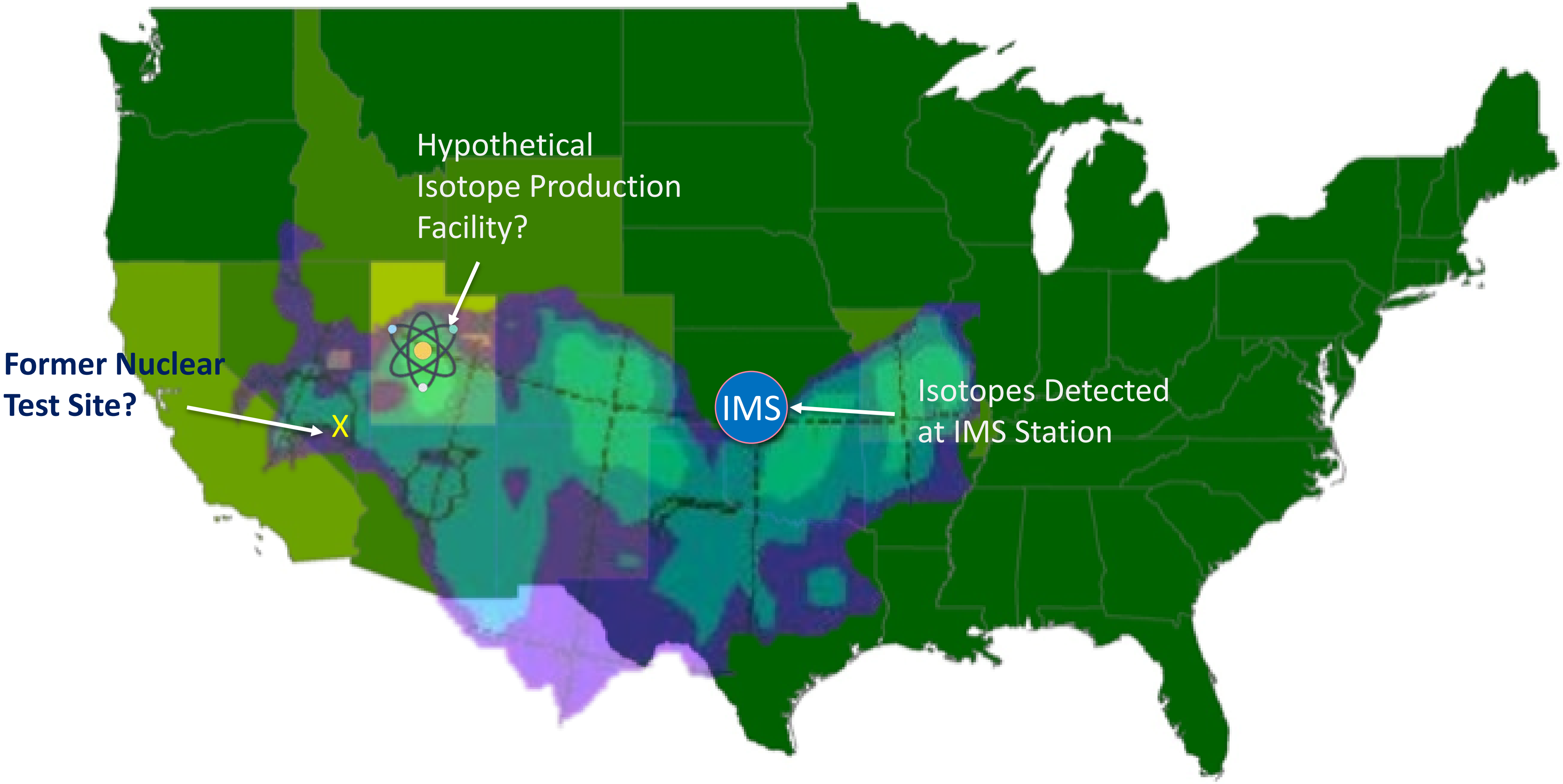
- *Conclusion*

  If there was isotope production in the center of Utah, approximately 10 times per month the calculated emission location would overlap the former nuclear test site (~500 km away)



Probability that we calculate a RN release location to include the NNSS using standard IMS stations

Where was the origin of the event?



Study conclusions

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- Therefore, we can calculate the probability that a shallow earthquake at the NNSS will overlap the field of regard (in time) for detection at one of the IMS stations
  - For isotope production in Utah, the calculated probability of an earthquake at the NNSS overlapping with isotope production and creating a false positive at the NNSS is 84% in any one year
  - If there was production elsewhere in the continental United States, the only state in which there is a small chance (1% or less) of overlap appearing to the NNSS in a year is Maine (~6000 km away)
  - It is very likely that there will be coincident seismic and RN events many times per year, which can lead to false positives. Fortunately there is a solution.

Summary

- The need to characterize backgrounds were anticipated during the writing of, and is incorporated in the Treaty
  - We are actually fortunate that it was anticipated, because backgrounds are much larger than we thought in the 1990s

- Without background subtraction, there is a significant chance of both a FALSE POSITIVE

- By paying attention to the problem, we can largely mitigate the impact of backgrounds at IMS stations

Backup Slides

Why Do We Care About "Background"?

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List of Characterization Parameters for International Data Centre Standard Event Screening (Protocol Annex 2, para 5)

5. For events detected by the International Monitoring System radionuclide component, the following parameters, inter alia, may be used

- Concentration of background natural and man-made radionuclides;
- Concentration of specific fission and activation products outside normal observations; and
- Ratios of one specific fission and activation product to another.

Modalities for subtracting background

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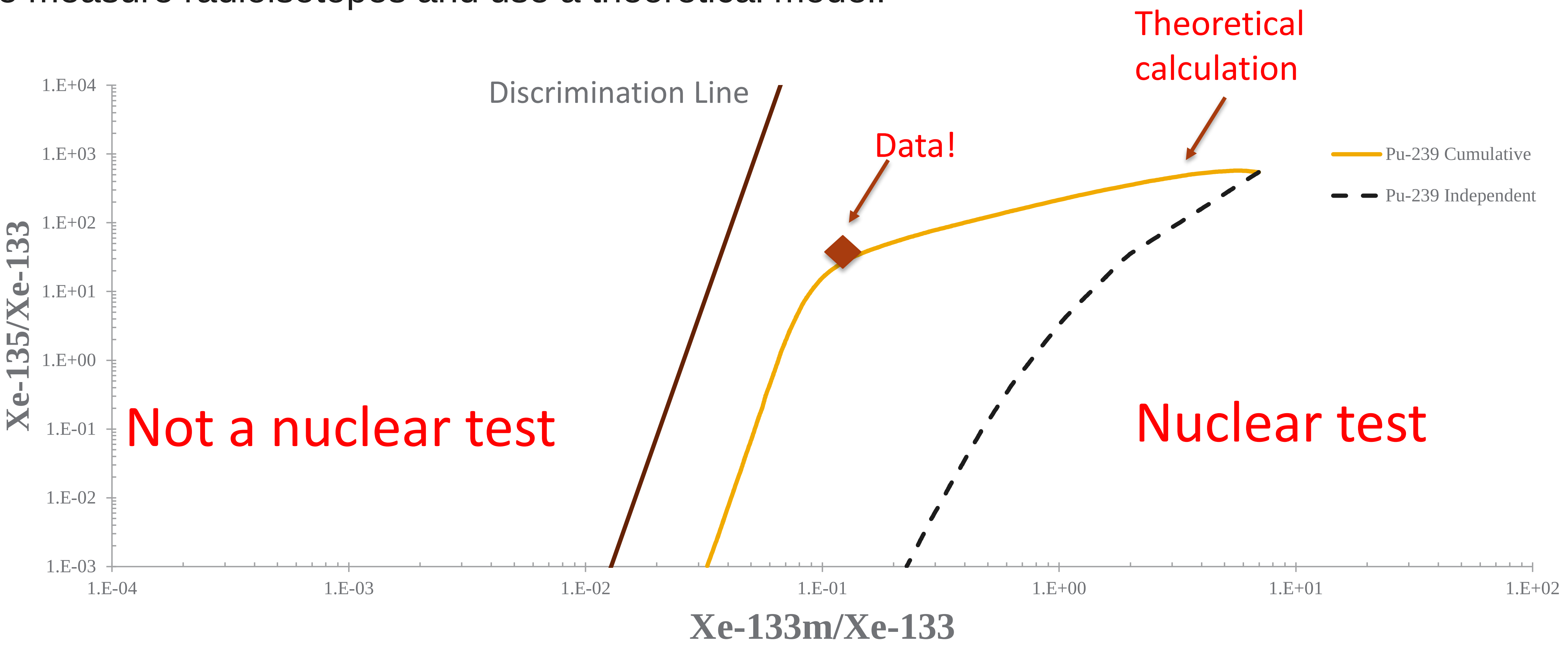
- Knowledge of emissions from known sources causing the background
  - Stack monitoring
- Understanding regional backgrounds and their variations
  - Mobile xenon measurements
- Better knowledge of peaceful sources of relevant radionuclides

How do we tell a nuclear explosion from innocent background?

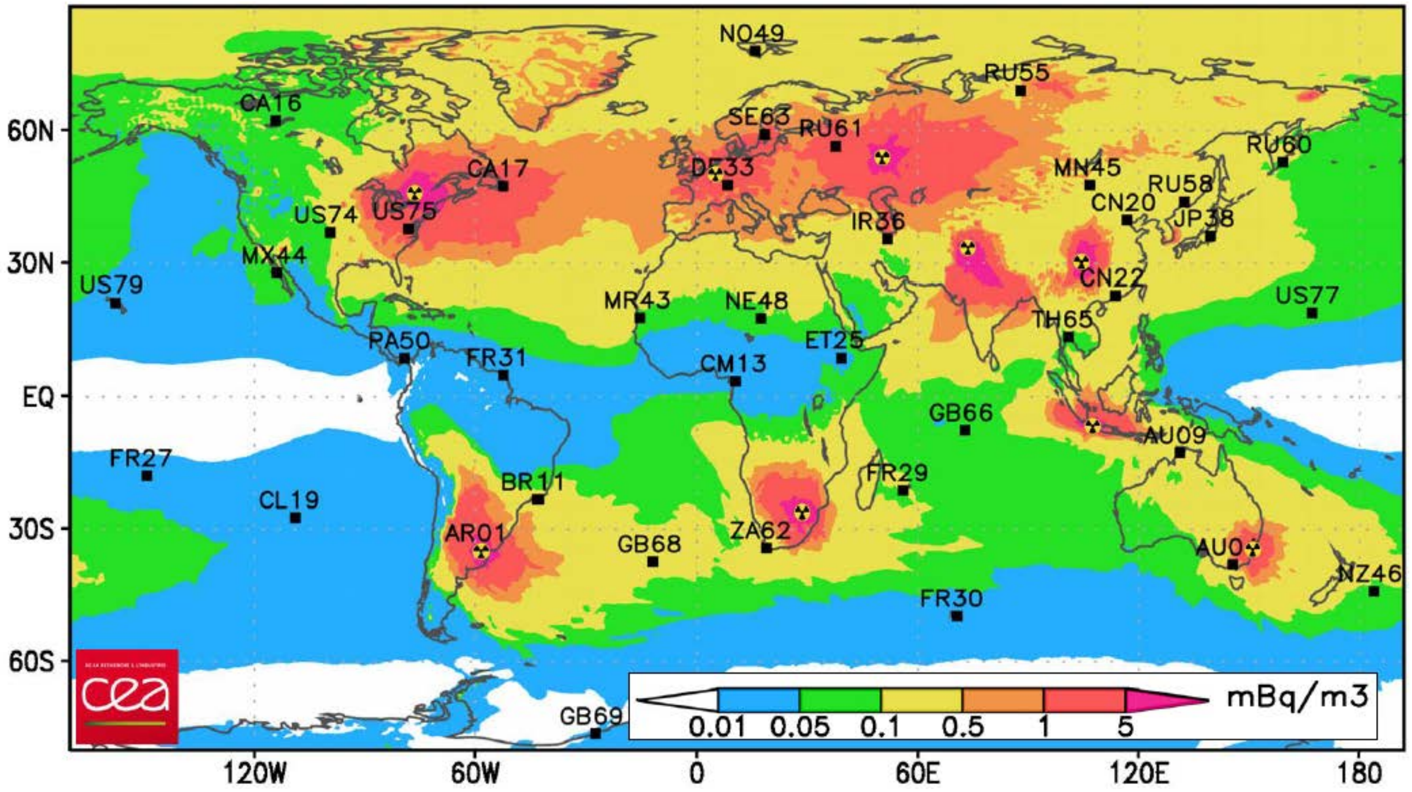
- We measure radioisotopes and use a theoretical model:



The “Holy Grail” of radionuclide detection

- We can, and we should create a model of the atmosphere and emissions that can predict the concentration of xenon (and other) isotopes at a station every day

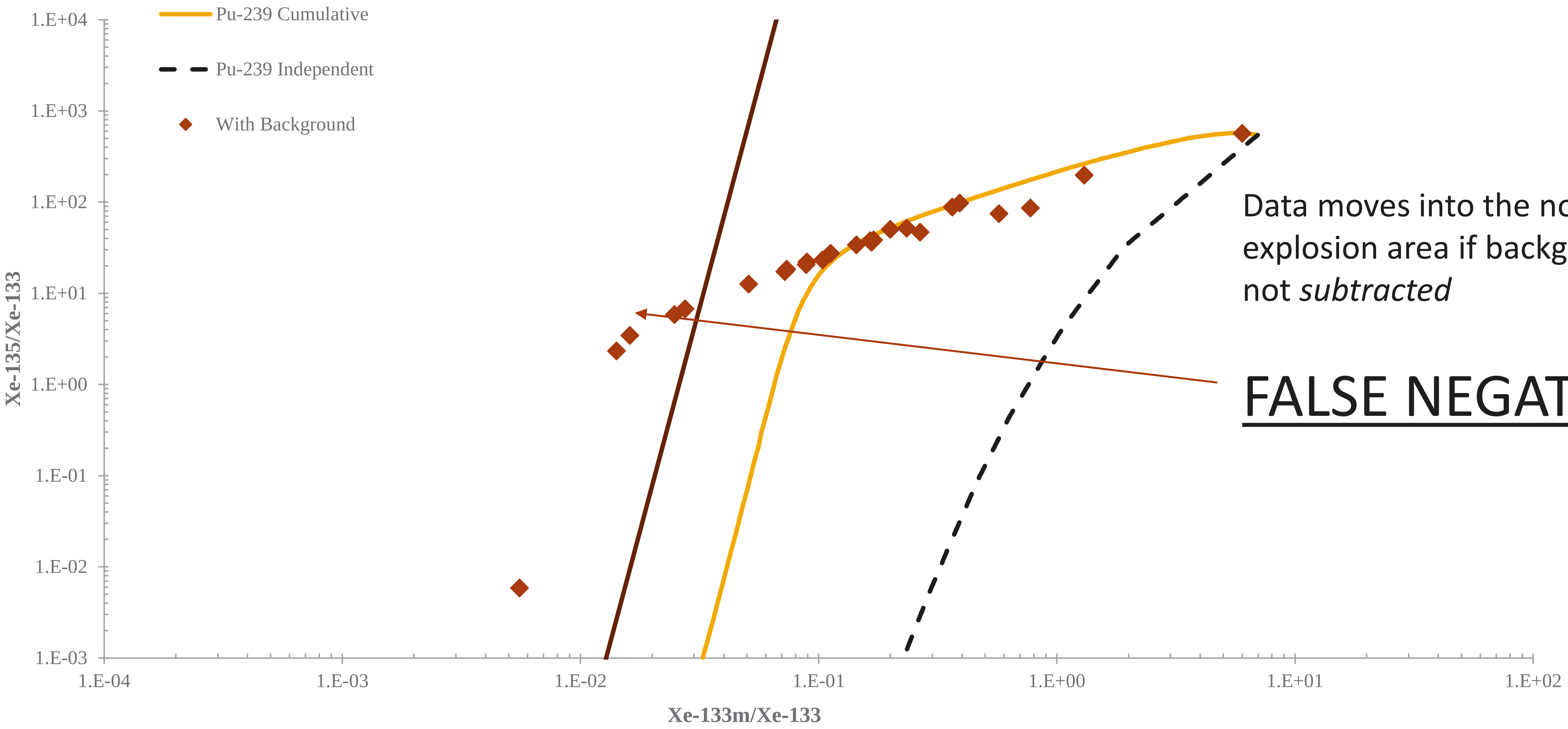
- We have been computationally limited, but the day is closer – maybe we are even there, that we can run the needed ATM code and always know the concentration at a station



False Negatives

(Accidentally missing a nuclear explosion)

Computer simulation of nuclear explosions – Background causes problems

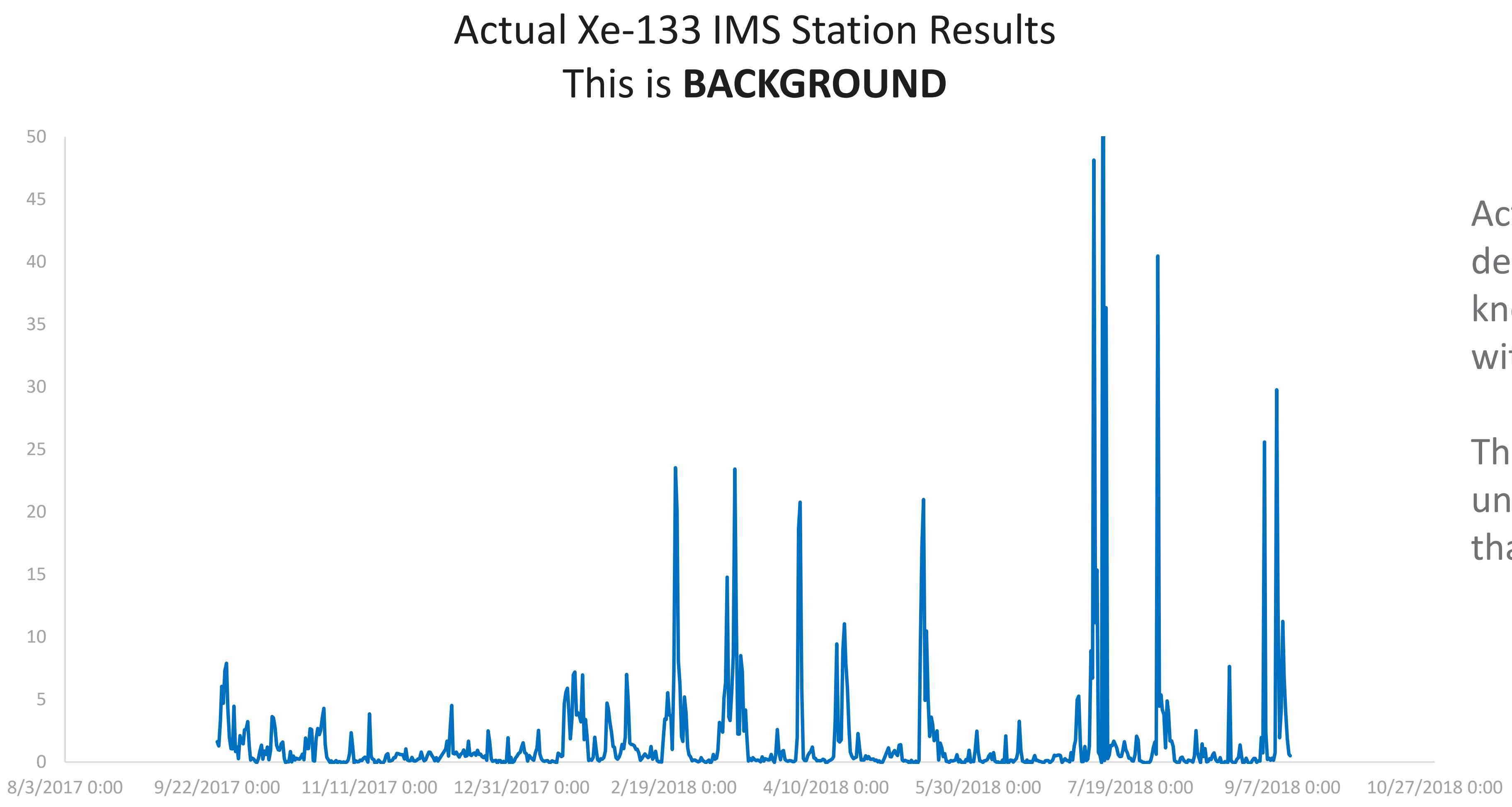


Data moves into the non-explosion area if background is not *subtracted*

<u>FALSE NEGATIVE</u>

Simulation of 1 mBq/m³ background on top of 0.2 mBq/m³ signal

We detect signals all of the time at some stations!



Actual Xenon isotopes detected in the IMS station, known to not be associated with a nuclear test

These detections are an unwanted "background" that can be subtracted out

How can we subtract the background?

Modalities Pros and Cons

Modality	Advantage	Limitations	Net Effect
Stack measurements	• High fidelity measurement • As frequent as needed	• Voluntary reporting	• Can remove effect accurately to within ~10% • Improves detectability of events
Regional measurements	• Used to characterize the background and create accurate models • Will improve interpretation of events	• Moderate fidelity	• Improves interpretation of some events
Station measurements only	• Easy to get information	• Assumes average station effect does not change over time	• Requires intense ATM and other information for interpretation

Subtracting the background (Yes, we can)

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If knowledge of the source creating the background is known, the background can be subtracted. For example:

Measurement at station
A Bq/m^3

Stack measurement of
B Bq/second

ATM predicts at the station
$C \pm \Delta C$ Bq/m^3

$$\text{Net Signal} = A - (C \pm \Delta C)$$

$\Delta = \pm 11\%$*

Δ represents how accurately we can determine the concentration at the station using ATM and stack data

* The ATM challenge showed best calculations were around ±11%

Subtracting background

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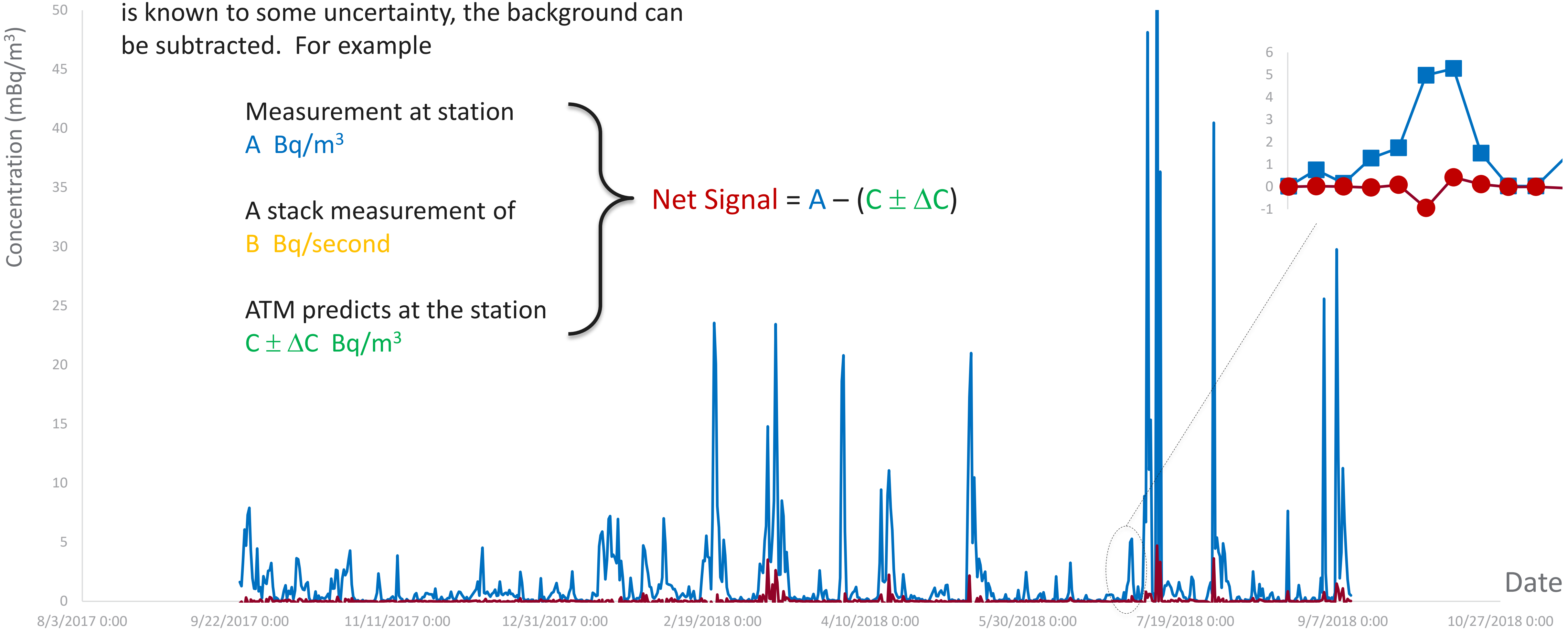
If knowledge of the source creating the background is known to some uncertainty, the background can be subtracted. For example

Measurement at station
A Bq/m^3

A stack measurement of
B Bq/second

ATM predicts at the station
$C \pm \Delta C$ Bq/m^3

Net Signal = A – ($C \pm \Delta C$)



Subtracting background with only a single isotope

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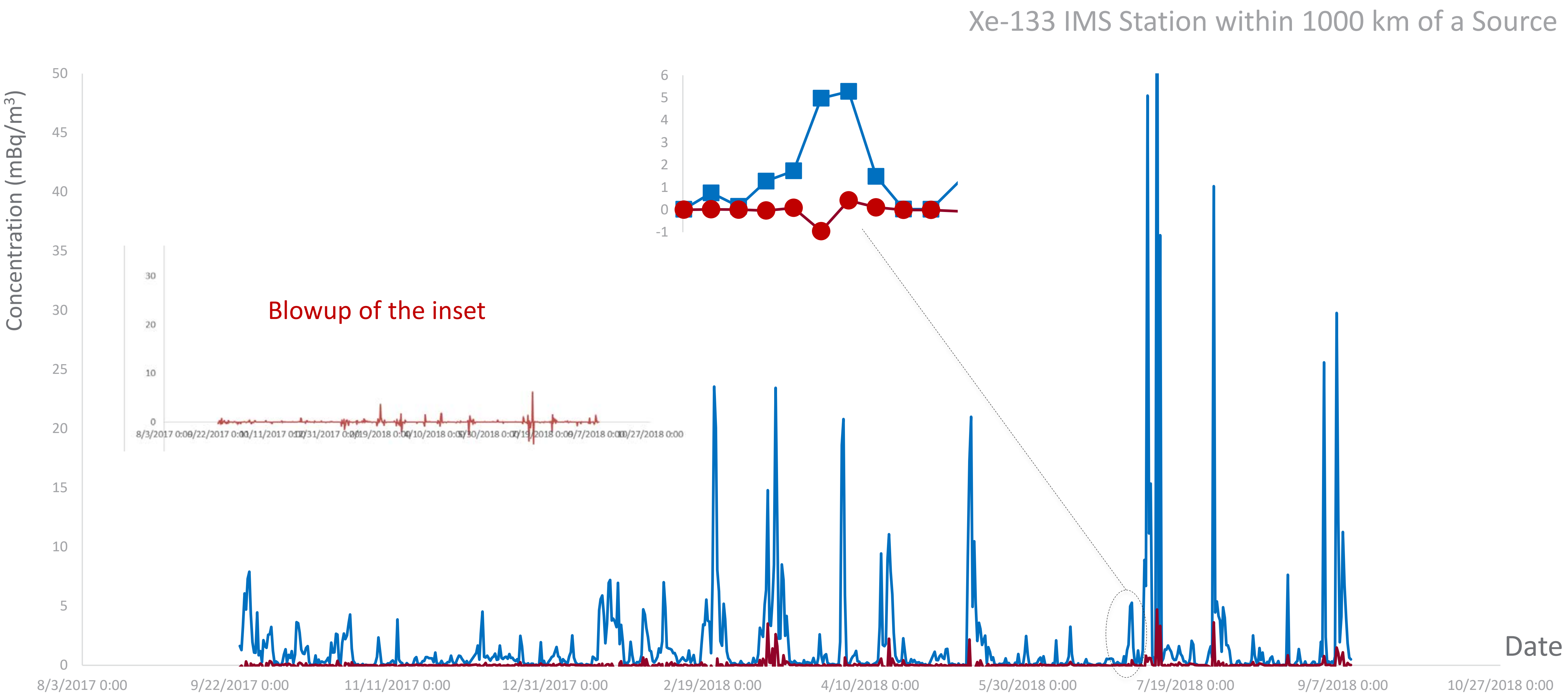
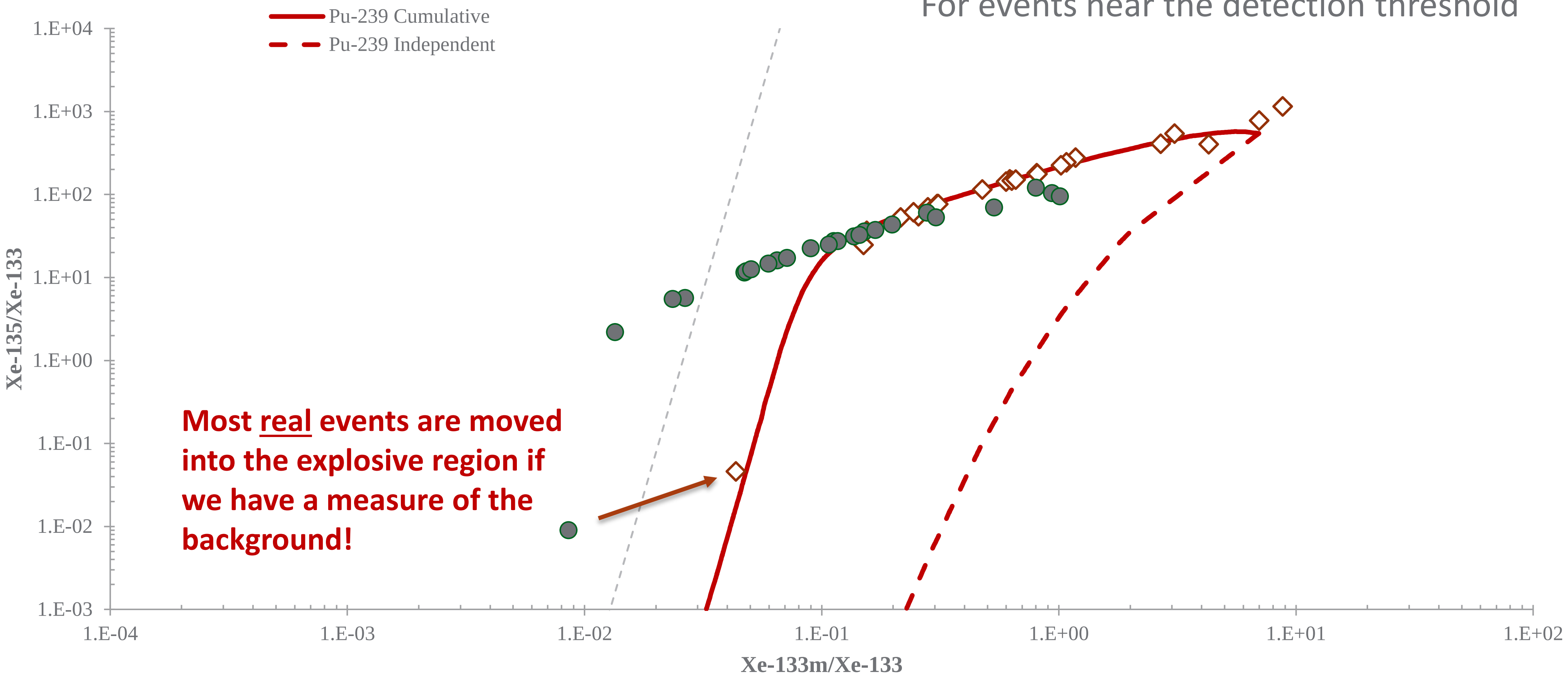


Background measurement helps decrease FALSE NEGATIVES

11% accurate background data
For events near the detection threshold



Effect on innocent sources (reactors)

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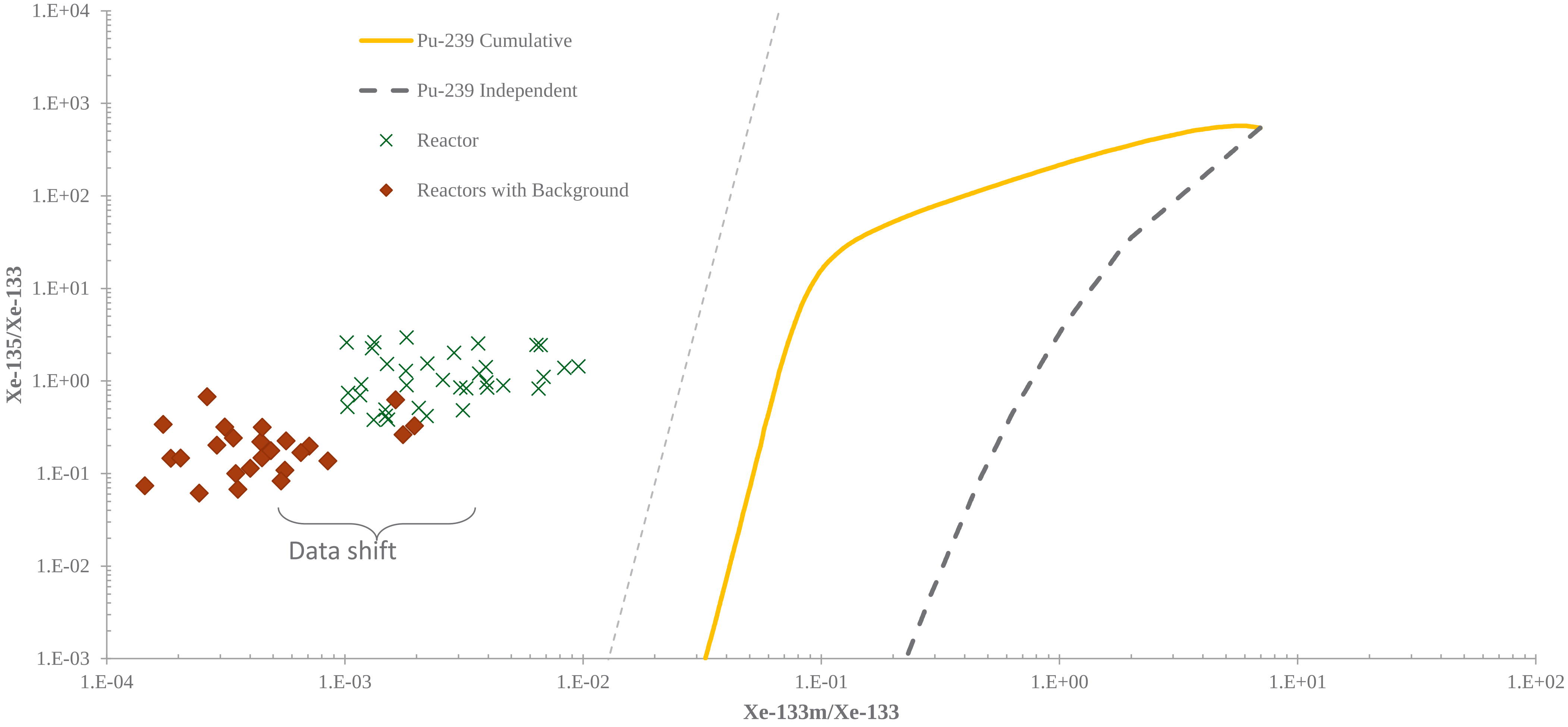
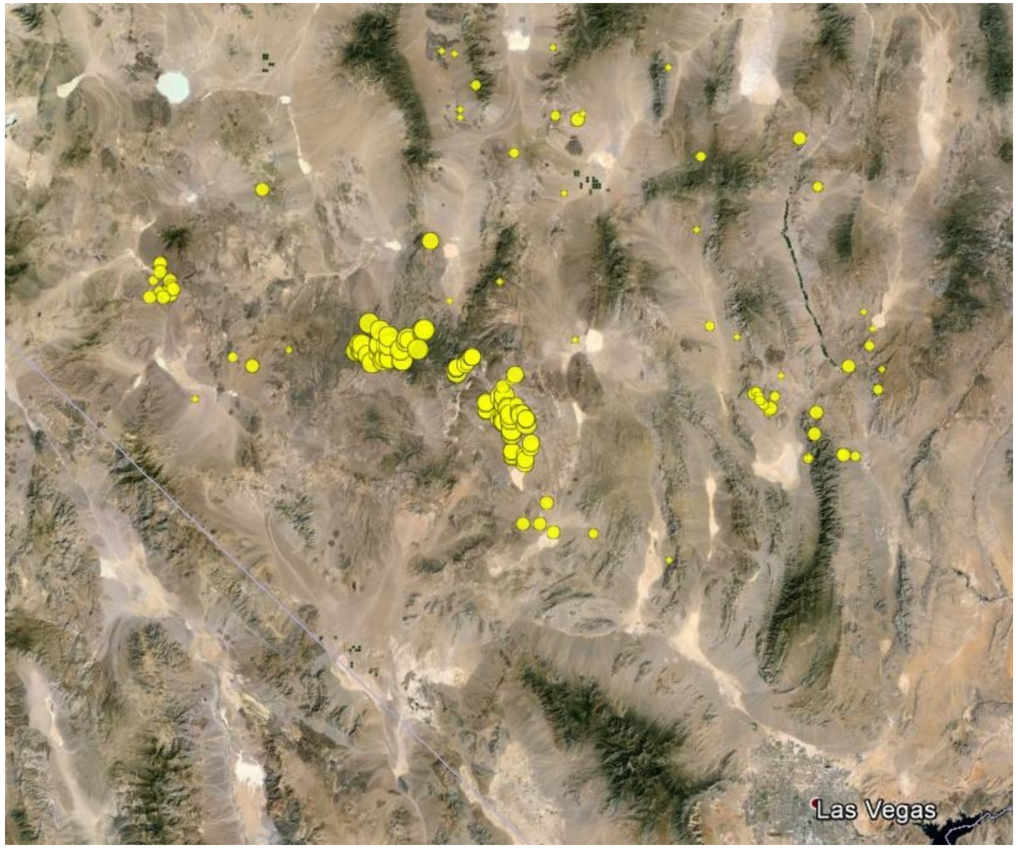


Simulation of 1 mBq/m^3 background on top of 0.2 mBq/m^3 signal

Earthquakes at the NNSS

Data source: U.S. Geological Survey online earthquake data archive



- 154 earthquakes from 1985 through mid 2015*
- An average of 5 per year
- Epicenter within 100 km of the Sudan test crater
- Epicenter depth 2 km or less
- Magnitude 1.5 or more

*We realize that SHI analyses may screen most of these events out