# An Introduction to International Xenon Monitoring

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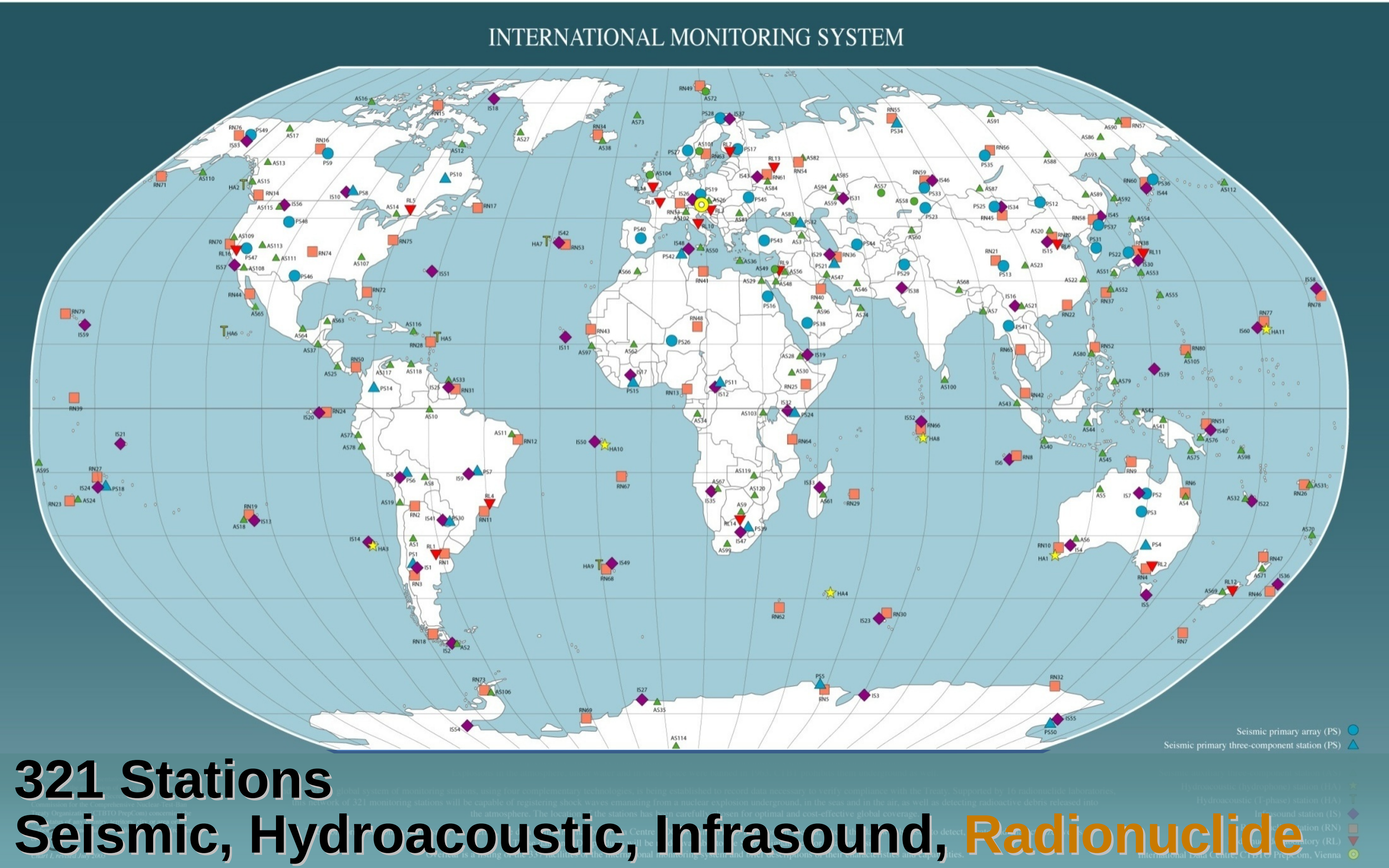
# Overview

- IMS Description
- Range of Xe emissions into the atmosphere today
- IMS sensitivity to production emissions today and the future
- How can medical isotope production emissions be distinguished from explosion debris?
- Current ideas to improve discrimination
- Success stories to date
- Collaborative experiments planned
- Summary

# The International Monitoring System has 80 Radionuclide Monitoring Locations to Monitor CTBT Compliance




**321 Stations**

**Seismic, Hydroacoustic, Infrasound, Radionuclide**

# IMS Xenon Technology

SAUNA
- Adsorbent separation
- Beta-gamma detection

SPALAX
-Membrane separation
-Germanium gamma-spec

- Xenon is relatively 'new'
  - Several automatic sampler-analyzer systems have been developed
- Four isotopes of xenon are important
  - $^{133}$Xe T½ = 5.3 d
  - $^{133m}$Xe T½ = 2.2 d
  - $^{131m}$Xe T½ = 11.9 d
  - $^{135}$Xe T½ = 9.1 h
- Sensitivity: ($^{133}$Xe)
  - ~300 microBq/m$^3$
  - Or ~5000 atoms

# Sources of radioxenon in the atmosphere

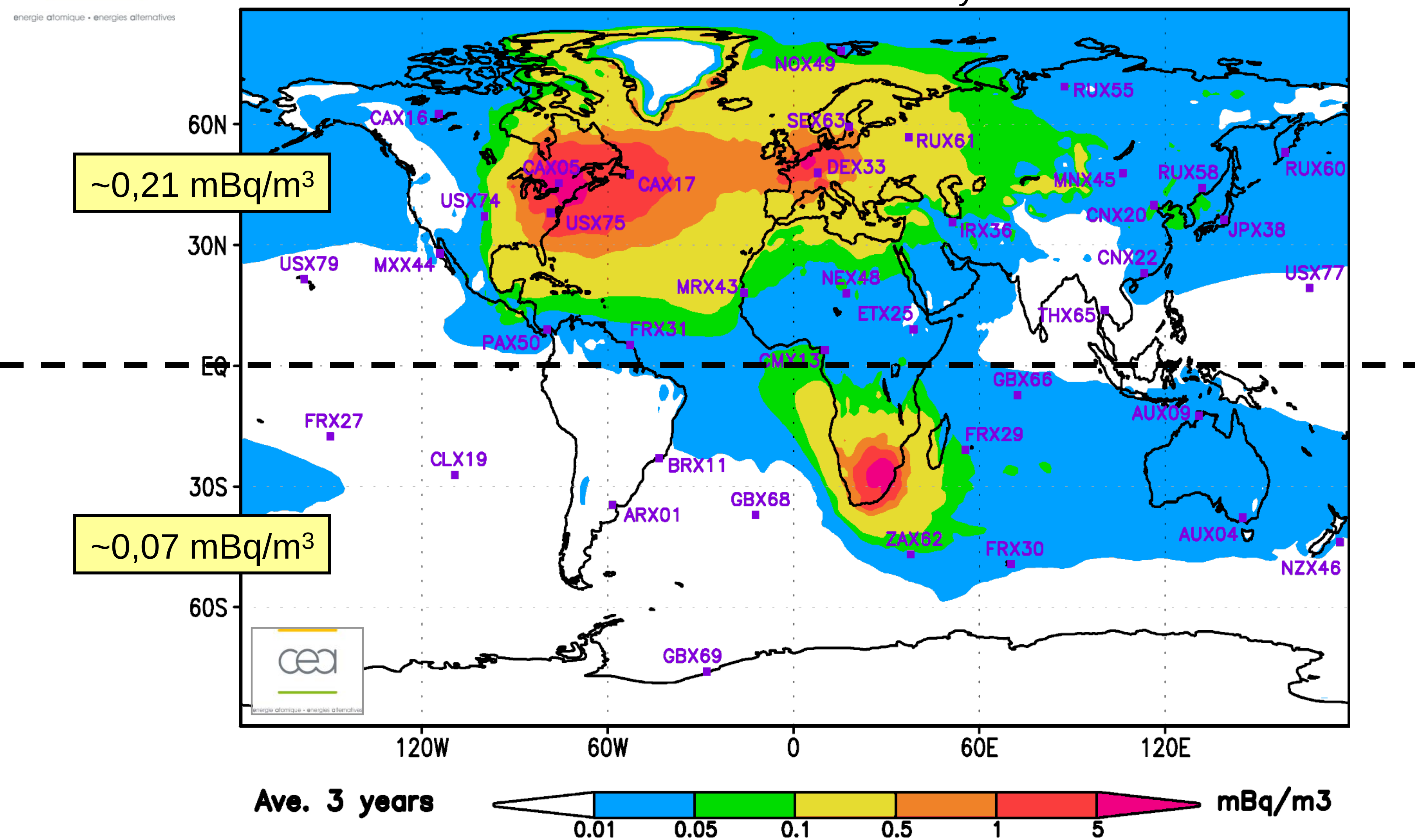
| Source | Order of magnitude of radioxenon release |
|---|---|
| Hospitals | ~ $10^6$ Bq/d |
| Nuclear power plants | ~ $10^9$ Bq/d |
| **Radiopharmaceutical plants** | **~ $10^9$-$10^{13}$ Bq/d** |
| 1kTon nuclear explosion | ~$10^{14}$-$10^{16}$ Bq |

Produced: $10^{16}$ Bq
Released: in 2006, perhaps 0.1%

Production of $^{99}$Mo from irradiated uranium targets ($^{99m}$Tc is most widely used radionuclide for nuclear medicine procedures in the world (>80% of all procedures).)

| Producer | Country | Production [%] | | Average release/day [Bq] |
|---|---|---|---|---|
| | | **$^{99}$Mo** | **$^{131}$I** | |
| MDS Nordion | Canada | 38 | None | 1.6 $10^{13}$ Bq |
| Tyco Healthcare | The Netherlands | 26 | None | 2.5 $10^9$ Bq |
| IRE | Belgium | 16 | 75 | 4.6 $10^{12}$ Bq |
| NTP | South Africa | 16 | 25 | 1.3 $10^{13}$ Bq |

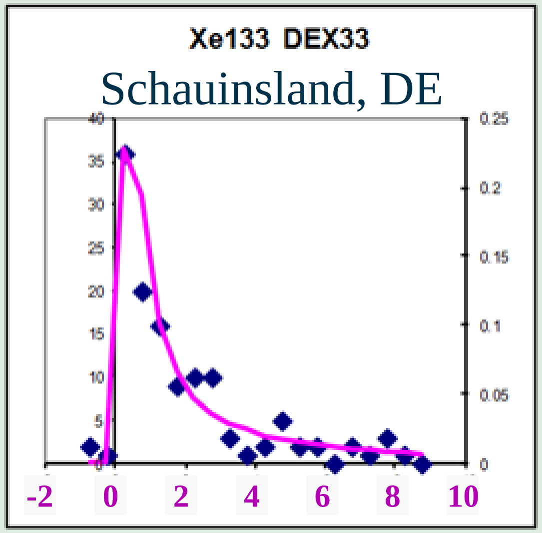
## Contribution of IPFs only

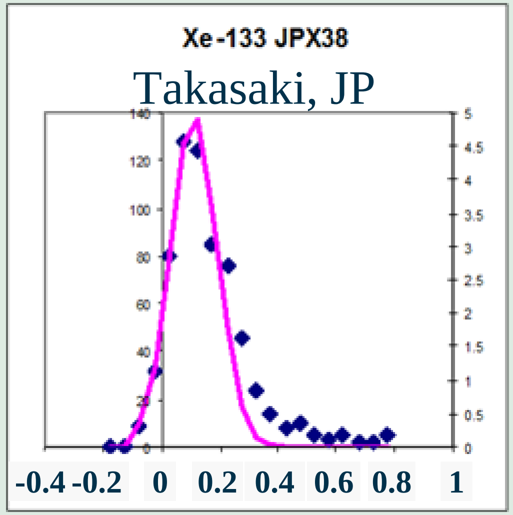




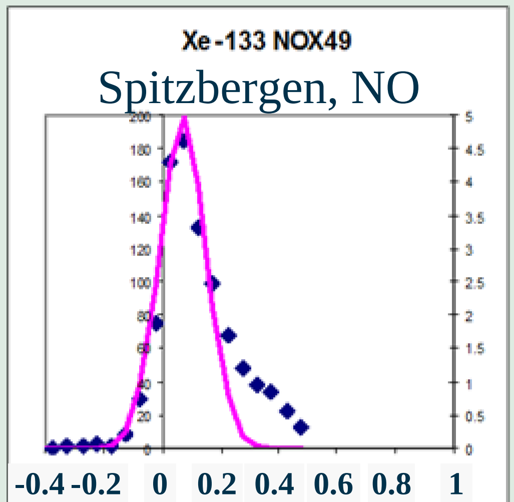

P. Achim, et al, CEA

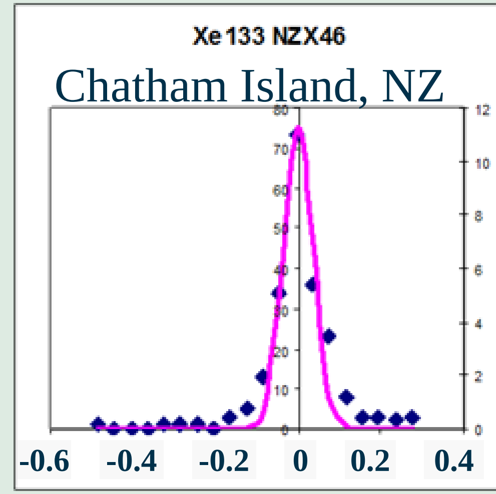
# Detection frequency for a few locations




Zaehringer et al, EGU meeting 2008, PTS




A: Lognormal distribution, isotope often (> 75%) detected

B: Normal distribution with tail, isotope regularly detected (25%-75%)

C: Normal distributed with mean ~ zero

# Notional Model

## *Existing and Possible Future $^{99}$Mo Production*

| Source (Bq/event) | Location | Country | Status |
|---|---|---|---|
| $1.85\times10^{13}$ | MDS Nordion | Canada | Existing |
| $3.15\times10^{9}$ | Mallinckrodt Medical | The Netherlands | Existing |
| $7.63\times10^{12}$ | IRE | Belgium | Existing |
| $1.51\times10^{13}$ | NTP | South Africa | Existing |
| $8\times10^{12}$ | CNEA Ezeiza | Argentina | Existing |
| $8\times10^{12}$ | ANSTO | Australia | Existing |
| $8\times10^{12}$ | Islamabad | Pakistan | Existing |
| $8\times10^{12}$ | Saskatoon, Saskatchewan | Canada | Media Announcement |
| $8\times10^{12}$ | Rabat | Morocco | Media Announcement |
| $8\times10^{12}$ | Otwock | Poland | Media Announcement |
| $8\times10^{12}$ | Inshas | Egypt | Media Announcement |
| $8\times10^{12}$ | Tehran | Iran | Media Announcement |
| $8\times10^{12}$ | Jakarta | Indonesia | Media Announcement |
| $1.85\times10^{12}$ | Yongbyon | North Korea | Media Announcement |
| $8\times10^{12}$ | Itaguaí | Brazil | Media Announcement |
| $8\times10^{12}$ | Dimitrovgrad | Russia | Media Announcement |
| $8\times10^{12}$ | Charlottesville, Virginia | United States | Hypothetical Location |
| $8\times10^{12}$ | Idaho Falls, Idaho | United States | Hypothetical Location |
| $8\times10^{12}$ | Columbia, Missouri | United States | Hypothetical Location |

Source per release event for $^{133}$Xe and $^{135}$Xe
Source of $^{133m}$Xe is assumed at 10% of $^{133}$Xe
Unknown sources for $^{133}$Xe are set to $8 \times 10^{12}$ Bq

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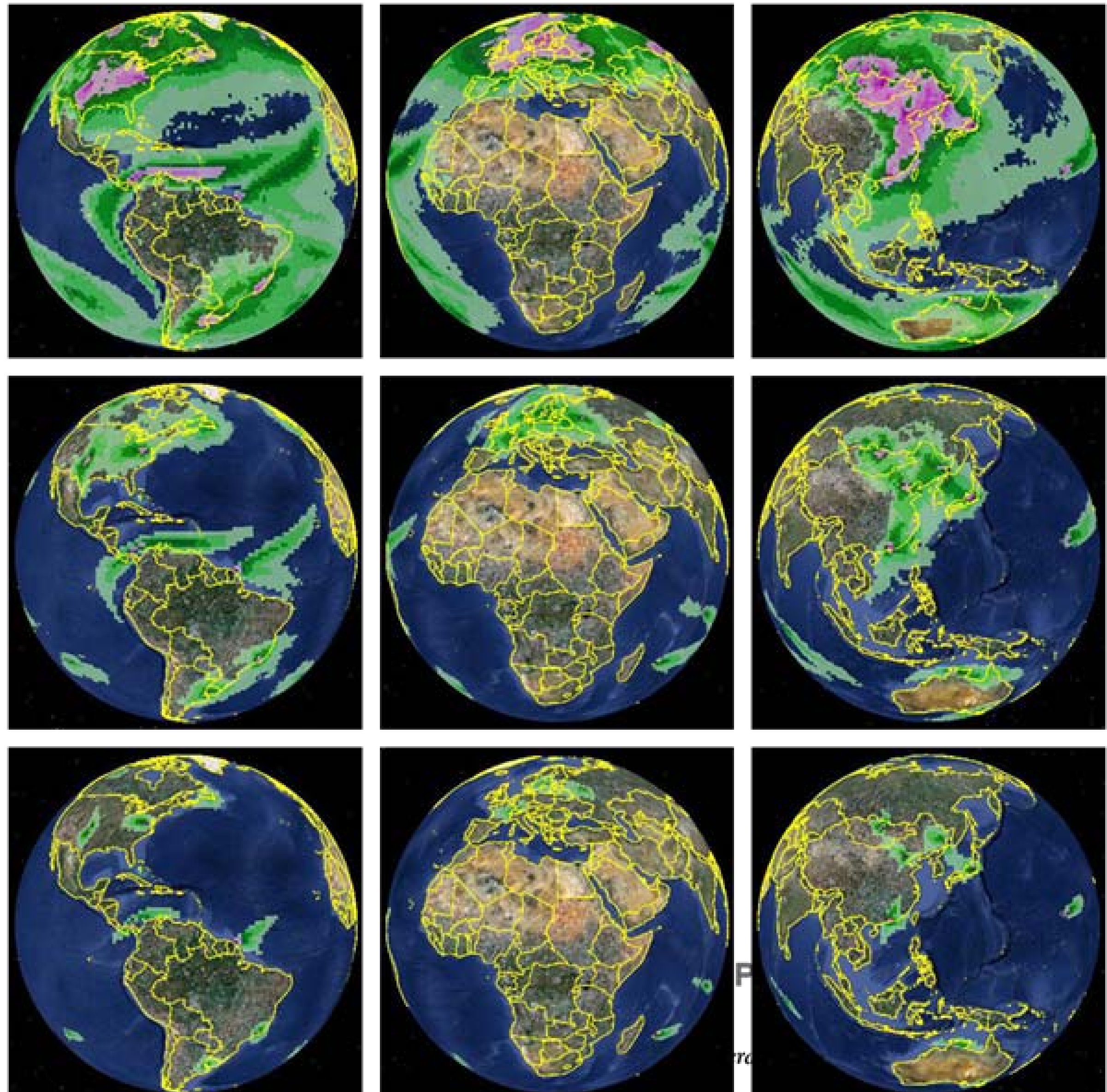
McIntyre et al, S&T 2011

# Coverage for Current IMS Network (27 stations) for Release Magnitudes Compatible with $^{99m}Tc$ Production

Xe-133
Release $8 \times 10^{12}$ Bq
MDC 300 $\mu$Bq/m$^3$

Xe-133m
Release $8 \times 10^{11}$ Bq
MDC 100 $\mu$Bq/m$^3$

Xe-135
Release $8 \times 10^{12}$ Bq
MDC 600 $\mu$Bq/m$^3$



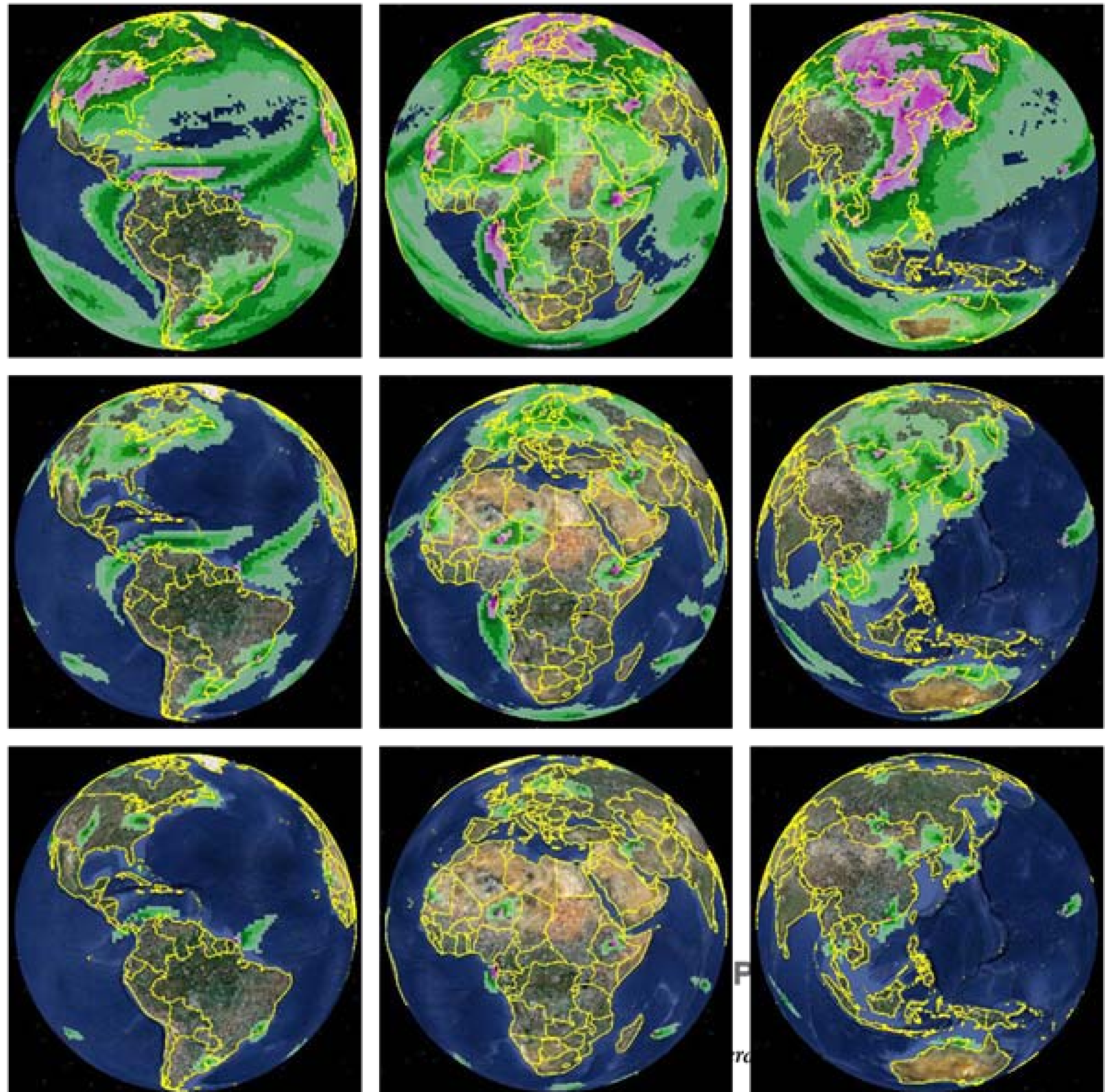
Coverage limited to the 27 stations currently certified or operational.

# Coverage for Planned IMS at EIF (40 Stations) for Release Magnitudes Compatible with $^{99m}$Tc Production

Xe-133
Release $8 \times 10^{12}$ Bq
MDC 300 $\mu$Bq/m$^3$

Xe-133m
Release $8 \times 10^{11}$ Bq
MDC 100 $\mu$Bq/m$^3$

Xe-135
Release $8 \times 10^{12}$ Bq
MDC 600 $\mu$Bq/m$^3$



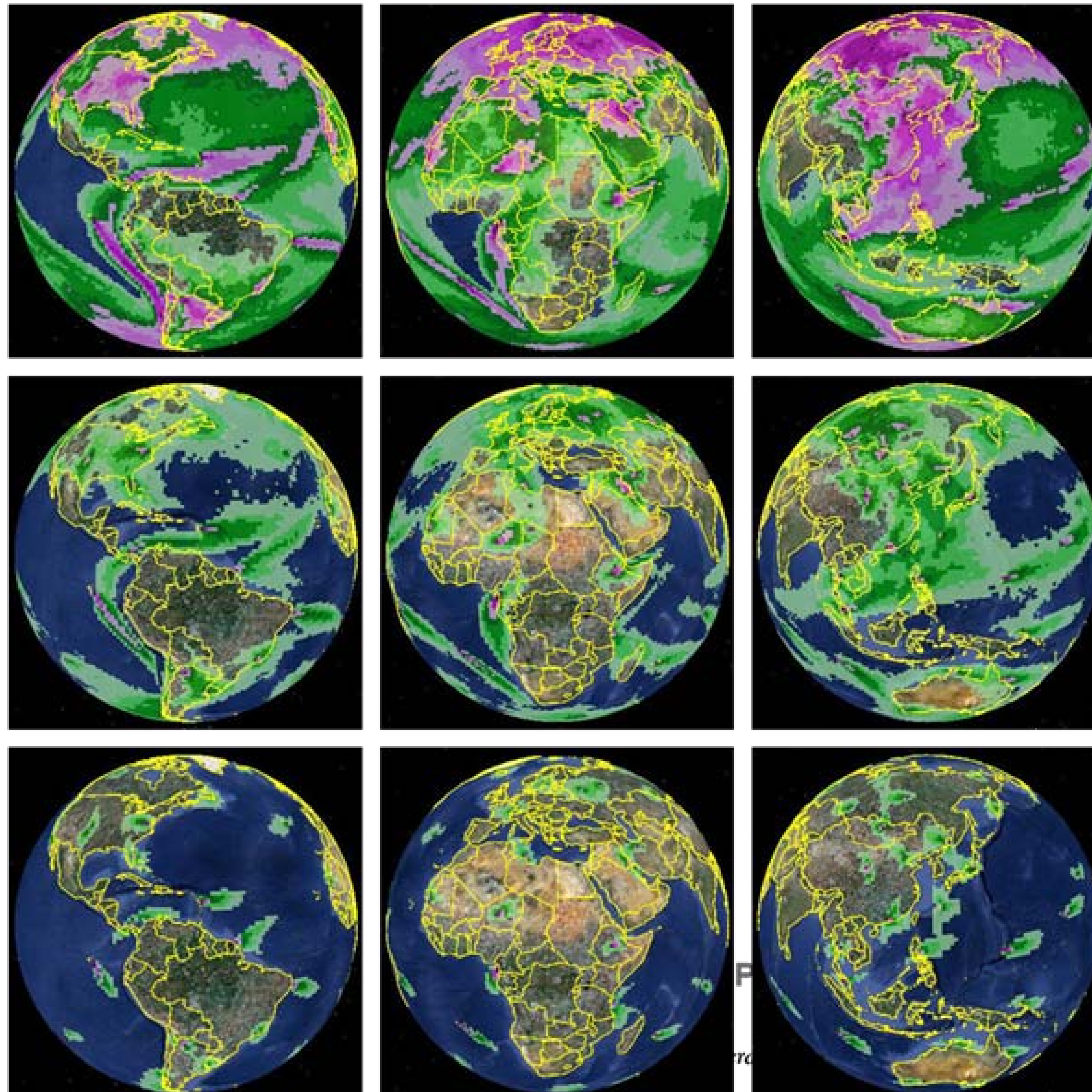
Only 39 stations modeled because coordinates for RN35 have not been established

# Coverage for Eventual IMS Network (80 Stations) for Release Magnitudes Compatible with $^{99m}$Tc Production

Xe-133
Release $8 \times 10^{12}$ Bq
MDC 300 $\mu$Bq/m$^3$

Xe-133m
Release $8 \times 10^{11}$ Bq
MDC 100 $\mu$Bq/m$^3$

Xe-135
Release $8 \times 10^{12}$ Bq
MDC 600 $\mu$Bq/m$^3$

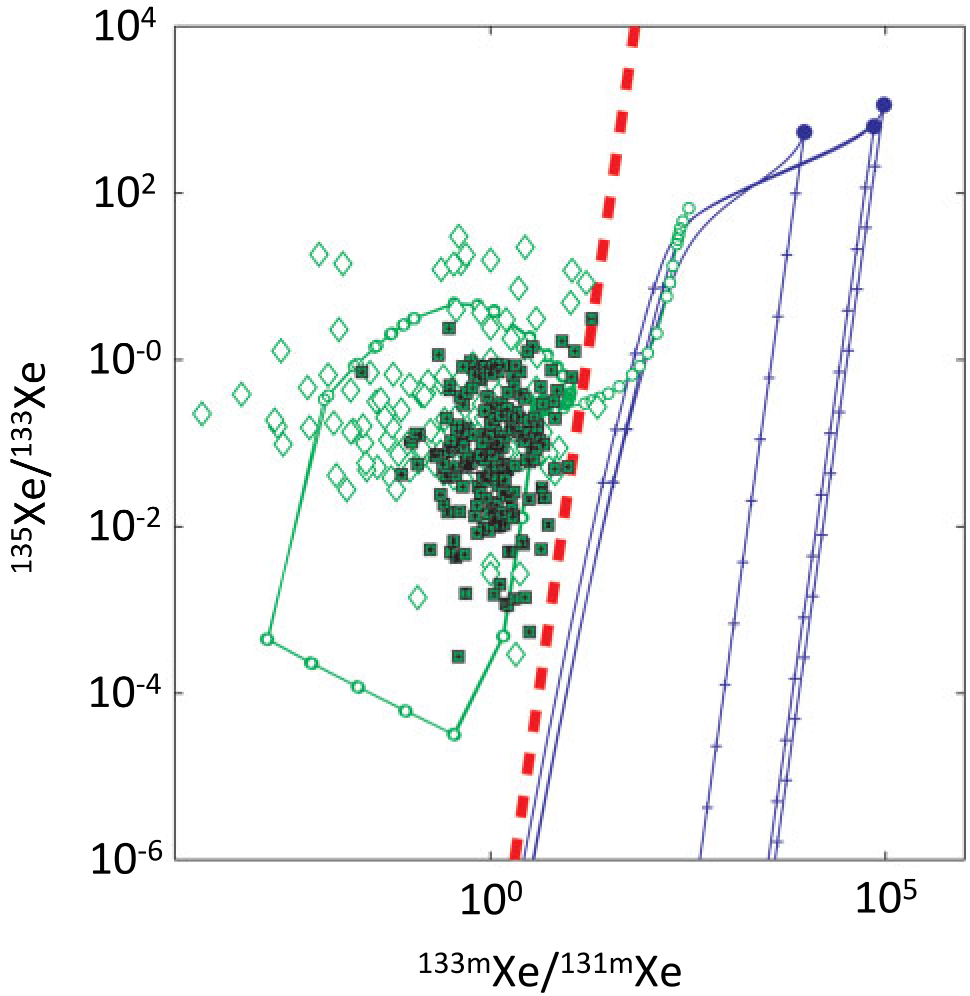


Only 79 stations modeled because coordinates for RN35 have not been established

# Discriminating Civilian from Explosion Signals

*Kalinowski or Multi-Isotope Ratio Chart (MIRC)*

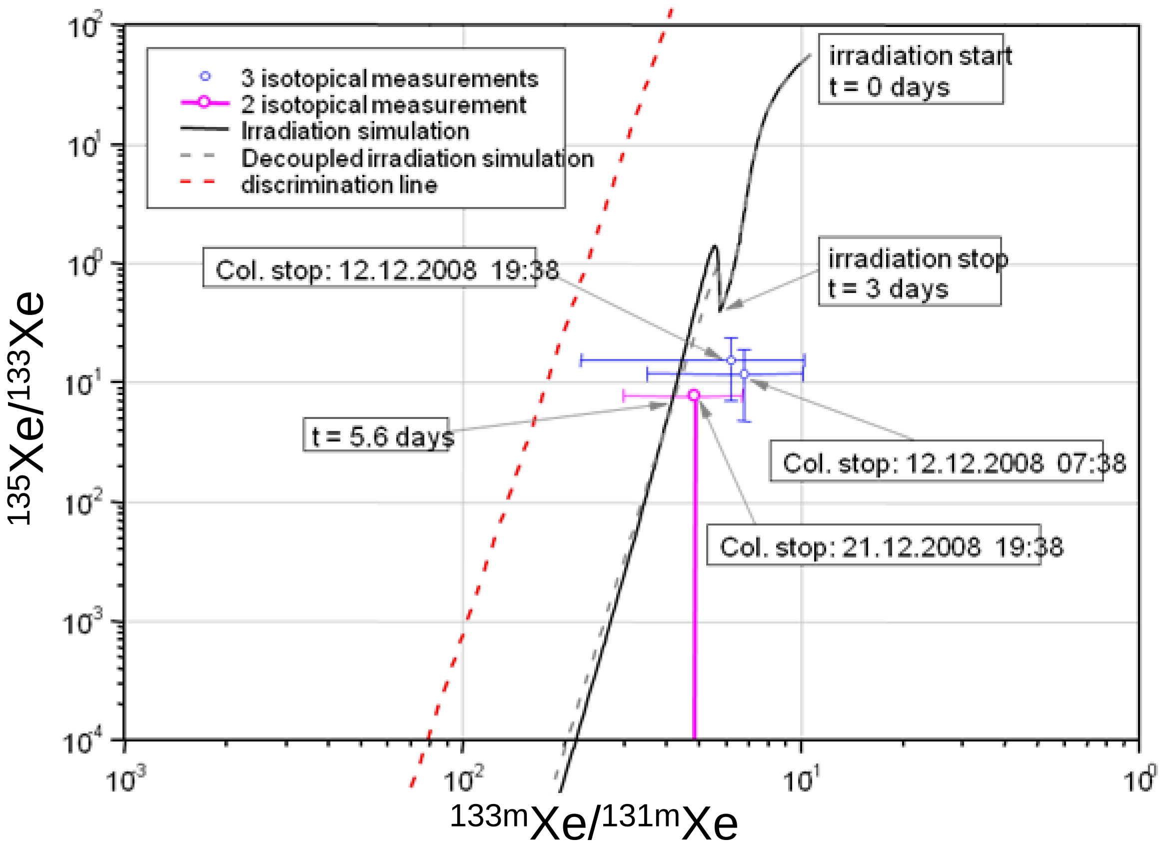
Reactor Ratios
oreactor fuel life cycle model
▪reported releases
◊inferred releases




Fission Yield Ratios with & without Iodine vs Time

Kalinowski et al, 2008
http://onlinelibrary.wiley.com/doi/10.1002/cplx.20228/pdf

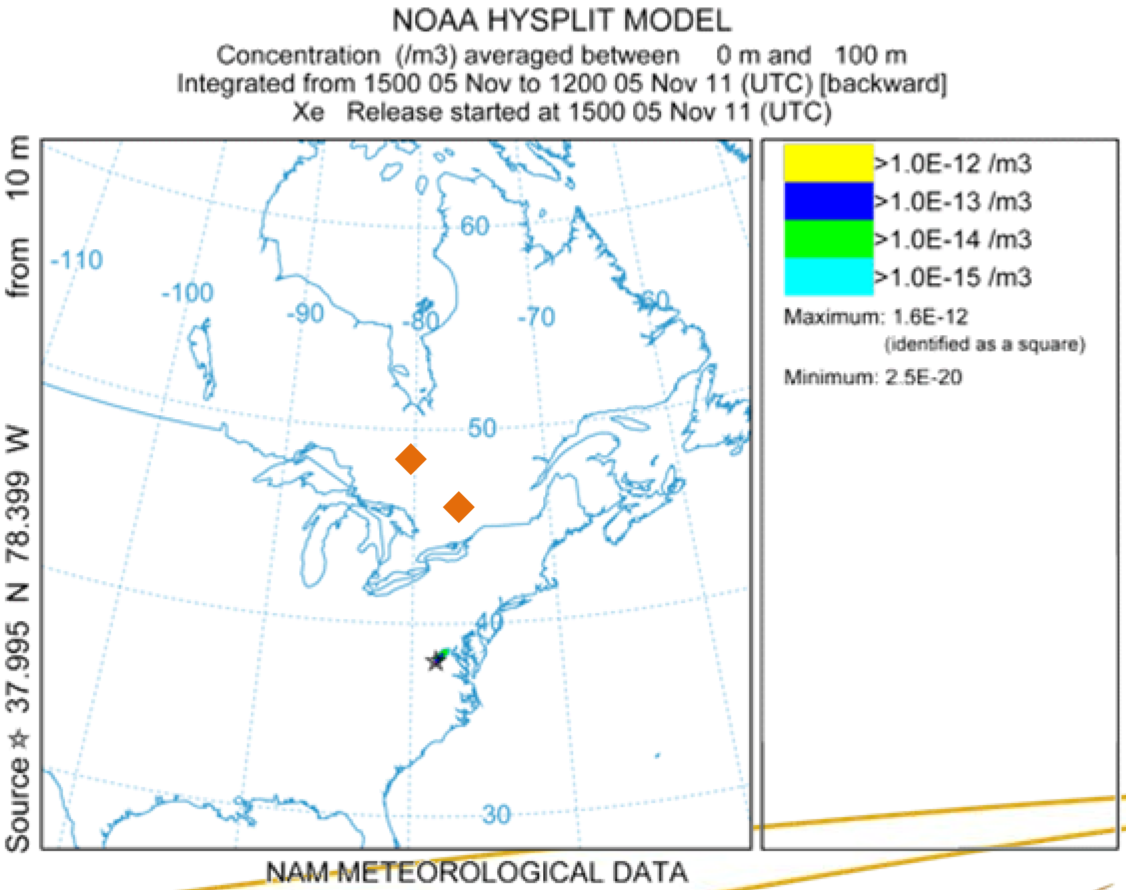
# Measurements compared to simulations
# 3 isotope-plot (ANSTO)




- First radioxenon isotopes were measured at the IMS station in Melbourne, Australia late 2008. This coincides with the start-up of the renewed RPF in Lucas Heights, Sydney, Australia.
- The measurements fit also well with the simulations.

# ATM-based Discrimination
## *Recent Charlottesville Event*

A recent detection at USX75 (Charlottesville, VA) exceeded 700 mBq/m³. Backtracking makes us reasonably confident that it was a medical isotope release.

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# Ideas in the Community

Improve discrimination

- Share stack monitor data, by isotope if possible
- Collaborate to understand the isotopic and temporal nature of production emissions

Reduce emissions

- Improve existing plants within the possible/economic
- Establish emissions to XXX Bq/day per new processing plant (to be no higher than a reactor)

# Collaborative Progress to Date

- WOSMIP meetings to foster collaborations
  - Workshop on Signatures of Medical Isotope Production
- Reductions at several facilities
  - IRE, ANSTO
- Collaborative experiments planned
  - ANSTO stack monitor
  - IRE calibrated release
  - SCK-CEN Close-in Telerad stations

# Summary

- IMS sensitivity is very good
- Even small Xe emissions are an important background
- Some scientific techniques are already in use to discriminate civilian releases from explosions
- Planned experiments will test and improve these methods
- Reduced emission is better than improved discrimination
  - Perhaps more important and efficient for future producers then current producers

# Acknowledgements


- Achim et al: INGE 2010 Presentation
- Kalinowski et al: http://onlinelibrary.wiley.com/doi/10.1002/cplx.20228/pdf
- McIntyre et al: S&T 2011 presentation: http://www.ctbto.org/fileadmin/user_upload/SandT_2011/presentations/T3-O9%20P_Eslinger%20Figure%20of%20merit%20for%20choosing%20Xe%20background%20study%20locations.pdf
- Saey et al: http://www.sciencedirect.com/science/article/pii/S0265931X09000150 and others
- Zaehringer EGU 2008: http://meetings.copernicus.org/www.cosis.net/abstracts/EGU2008/08595/EGU2008-A-08595.pdf