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Impact of environmental backgrounds on atmospheric monitoring of nuclear explosions

Selected results

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BLUF/Outline/Summary

- Backgrounds are of two types
  1. Radon & progeny impact MDC
     - Pb-212 causes aerosol MDC to vary
     - Xenon MDC less affected
  2. Nuclear activities can emit the *exact NEM signature* we are interested in
     - We define an ANOMALY LEVEL of a 95th percentile to estimate an action threshold
     - Same as MDC for places where background is low.
     - Aerosol – I-131 (few stations can even have a defined anomaly level)
     - Xenon – Xe-133

- Source Term motivation
  - For xenon, use Ringbom 2009 paper
    - ✓ (1% release)
  - For iodine, use release fraction 1e-5
    - ✓ Motivated by Ely et al
- Conclusions
  - Xenon bkg is global and major
    - ✓ Some regions worse than others
  - Iodine bkg is regional and minor
- New: estimate number of reporting stations and samples
- New: identify potential background study locations

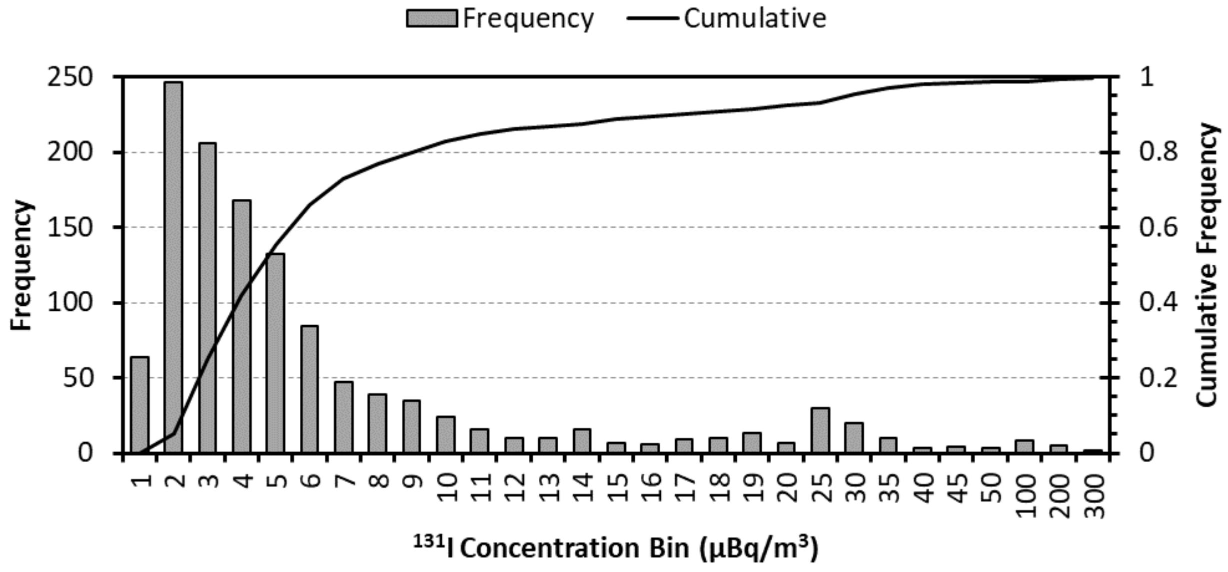
Background

- WP.224 RN design based on
  - ^{140}Ba atmospheric 1 kt
    - ✓ 2×10^{15} Bq of ^{140}Ba
  - ^{133}Xe various scenarios
    - ✓ 10^{15} Bq evasive ATM
    - ✓ 10^{15} Bq UWT
    - ✓ 10^{14} Bq over 12 hrs after UGT
      - *A 17% leak!*
- IRNWG 1998
  - 10% leak at 3 days = 10^{15} Bq ^{133}Xe
- For aerosols, volatile ^{131}I is far more likely to escape
- Volatile ^{131}I has had 1234 detects in the IMS over 9y

Tabulated from DOE/NV-317

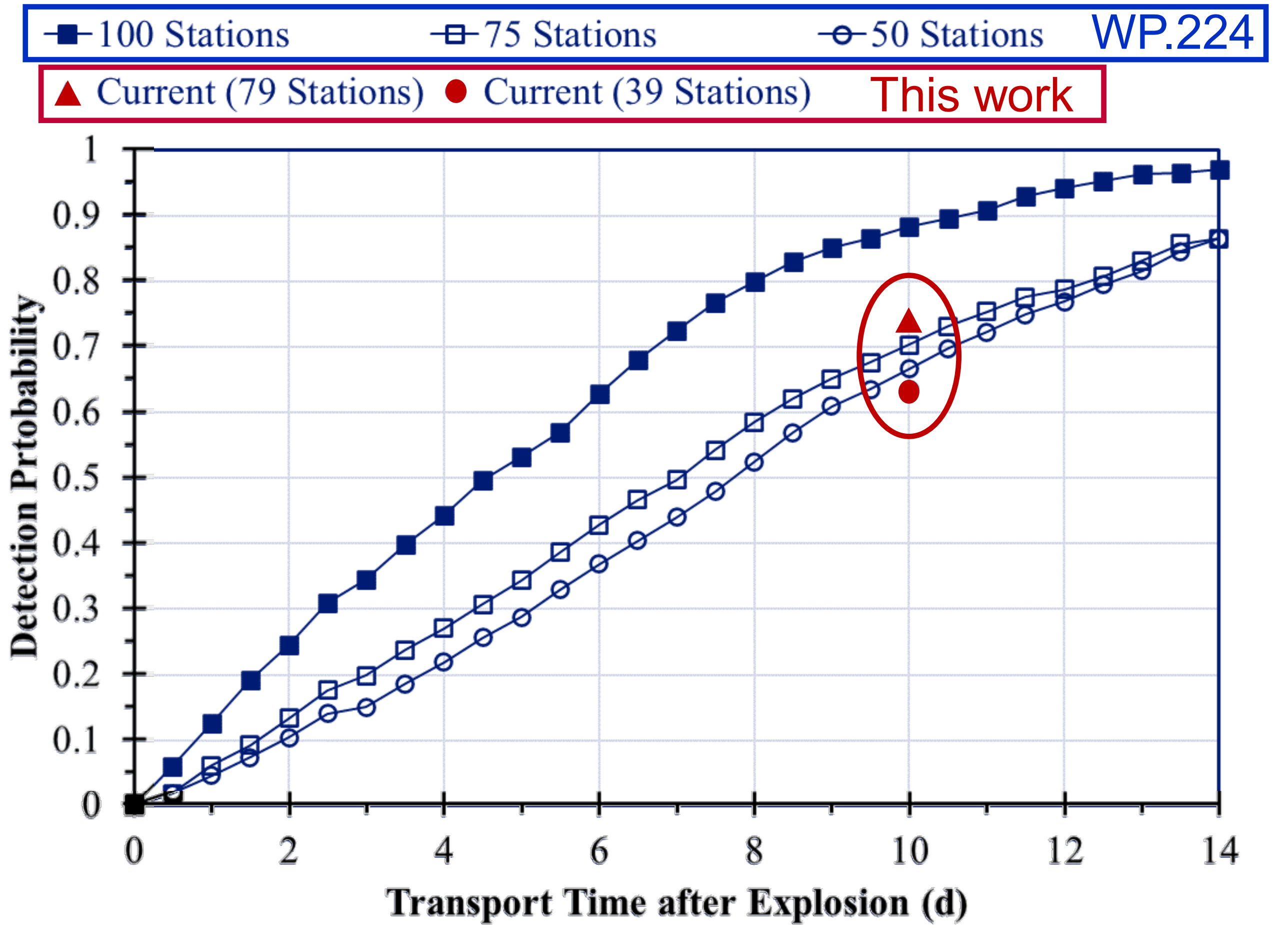
Noble Gas				Volatile above 600° C				Refractory			
Isotope	Number	$T_{1/2}$	Cum. Yield	Isotope	Number	$T_{1/2}$	Cum. Yield	Isotope	Number	$T_{1/2}$	Cum. Yield
^{131m}Xe	10	11.8 d	.0451	^{131}I	131	8.03 d	3.22	^{99}Mo	3	65.9 h	5.94
^{133}Xe	310	5.25 d	6.72	^{132}I	13	2.30 h	4.67	^{99m}Tc	1	6.01 h	5.23
^{133m}Xe	169	2.20 d	0.192	^{133}I	109	20.8 h	6.72	^{139}Ba	6	82.9 m	6.34
^{135}Xe	271	9.14 h	6.60	^{134}I	6	52.5 m	7.64	^{140}Ba	19	12.8 d	5.98
				^{135}I	88	6.58 h	6.30	^{140}La	17	1.68 d	5.98
				^{132}Te	13	3.20 d	4.66				
				^{137}Cs	10	30.1 y	6.22				
				^{138}Cs	29	32.5 m	6.65				
				^{139}Cs	1	9.27 m	6.32				

^{131}I: 45 IMS stations over 9 years



Historical: WP.224 nailed the aerosol performance

- $D(15)_{79}$ to match WP.224
- Our 79/39 calculations with real IMS MDC's bracket their 75/50 calculations
- Why such good agreement?
  - They got the MDC's right
    - ✓ 10 μBq/m3 for ^{140}Ba – WP.224
    - ✓ 9.92 μBq/m3 for ^{140}Ba – avg IMS
  - There were global aerosol measurements in the literature
  - No such record existed for ^{133}Xe

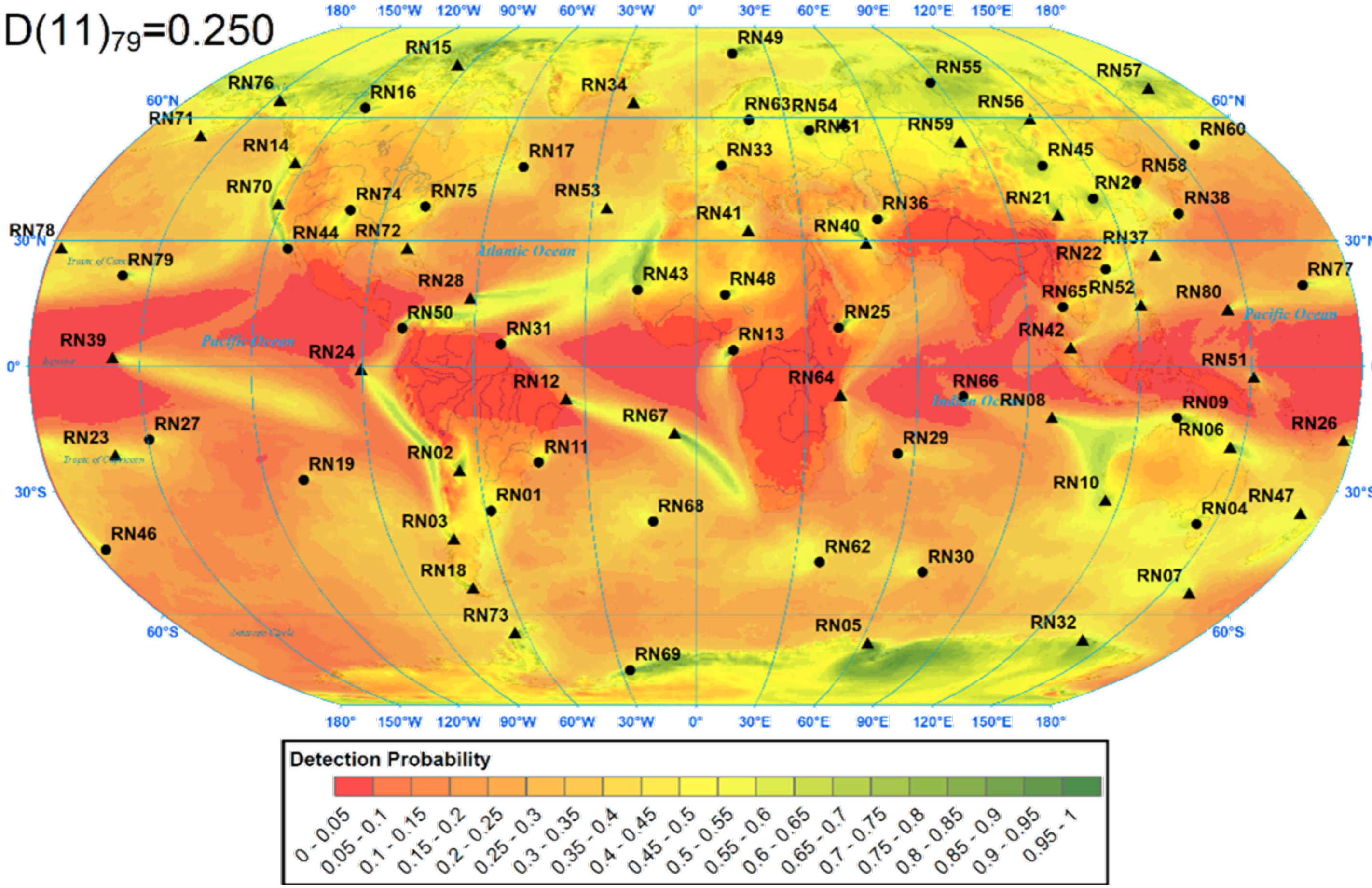


Notation used here

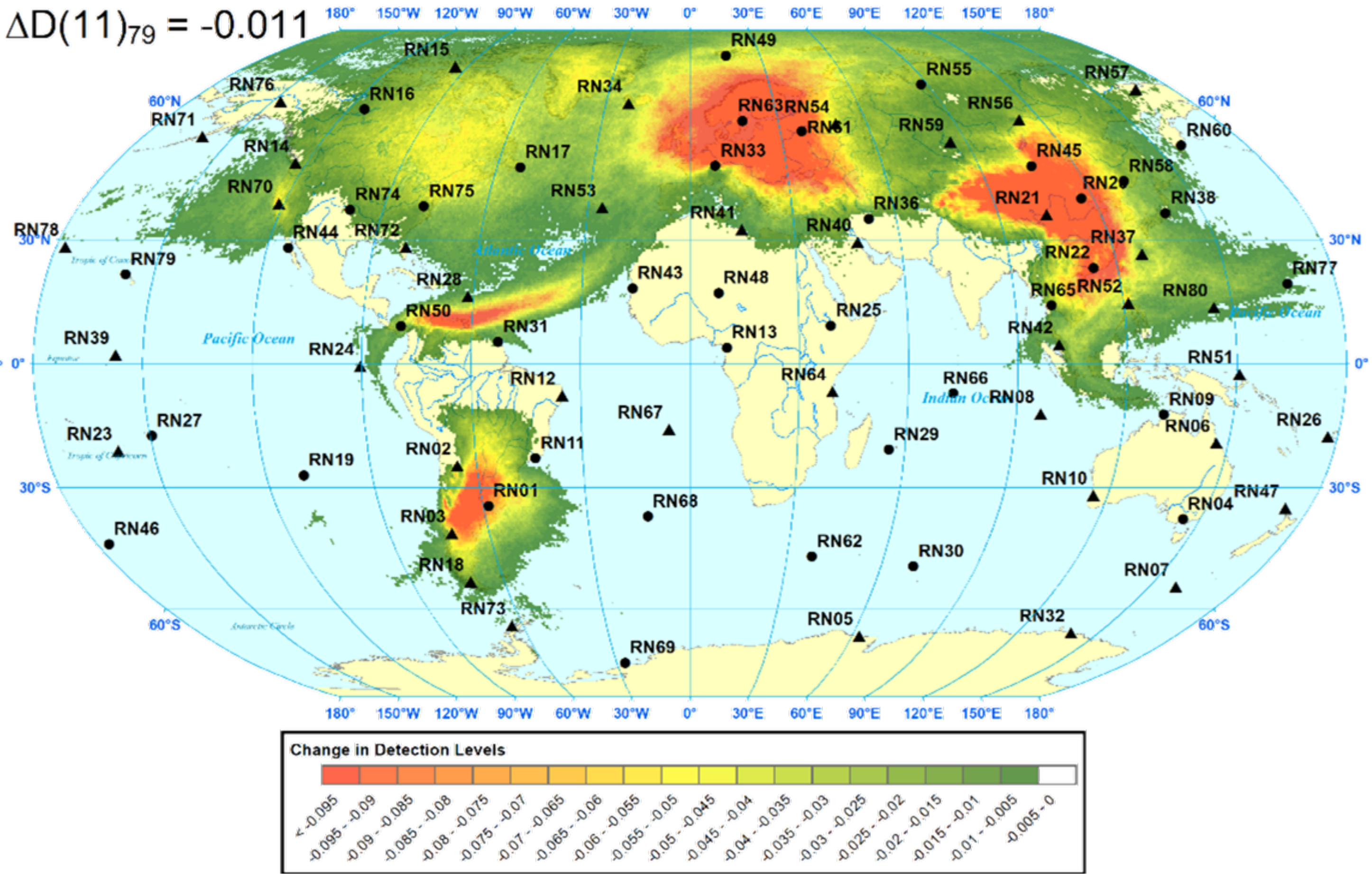
- Detection metric: $D(M)_N$
  - probability of a signal reaching or exceeding Max(MDC, 95^{th} percentile)
  - For a signal magnitude M (order of magnitude of becquerel released
  - For a network with N stations
- $D(11)_{79}$
  - Detection probability, map or single value
  - for 10^{11} Bq released anywhere on Earth
  - in a 79 station network
- $\Delta D(11)_{79}$
  - The change brought on due to backgrounds in the case above
  - Map or single value
- We are also working on a *location metric*, and it will depend on the number of stations and samples involved in a detection

Detection prob: 79-station for a 10^{11} Bq ^{131}I: $D(11)_{79}$ and background-induced $\Delta D(11)_{79}$

$D(11)_{79}=0.250$



$\Delta D(11)_{79} = -0.011$

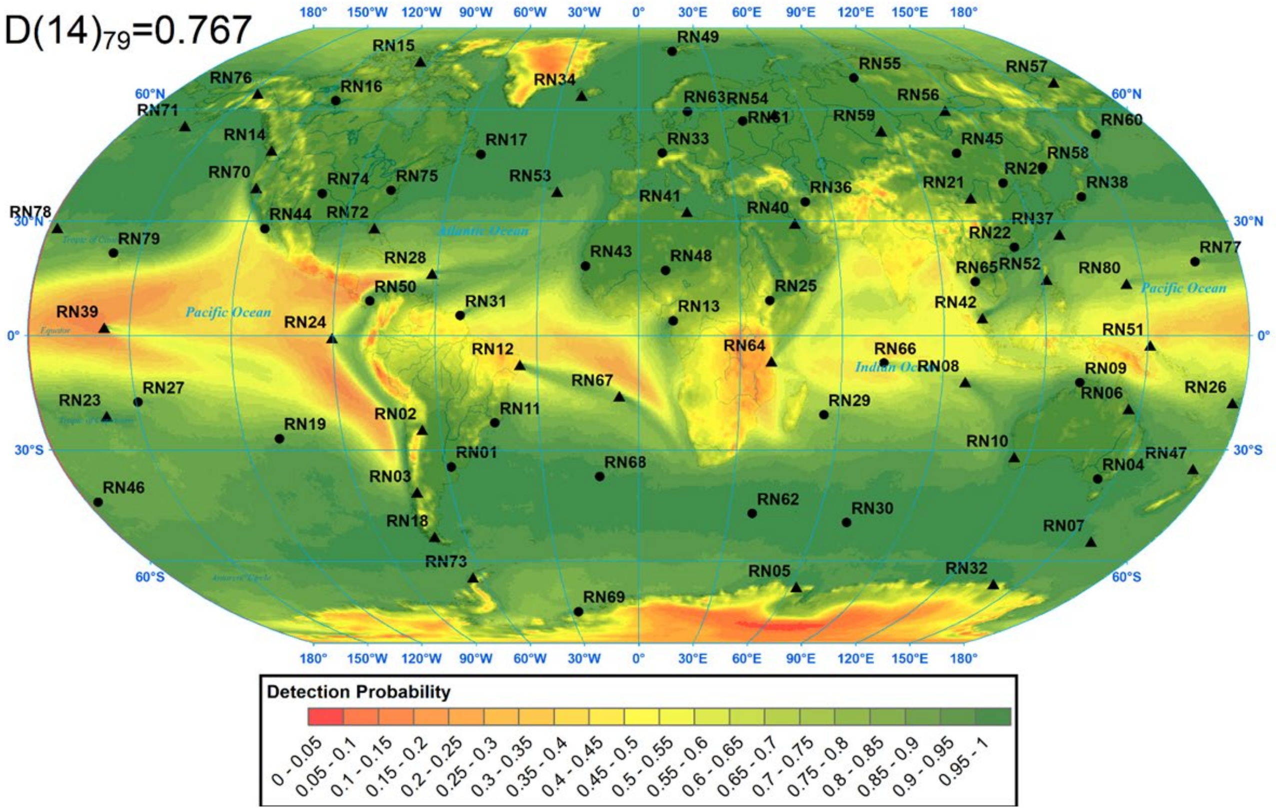


Iodine

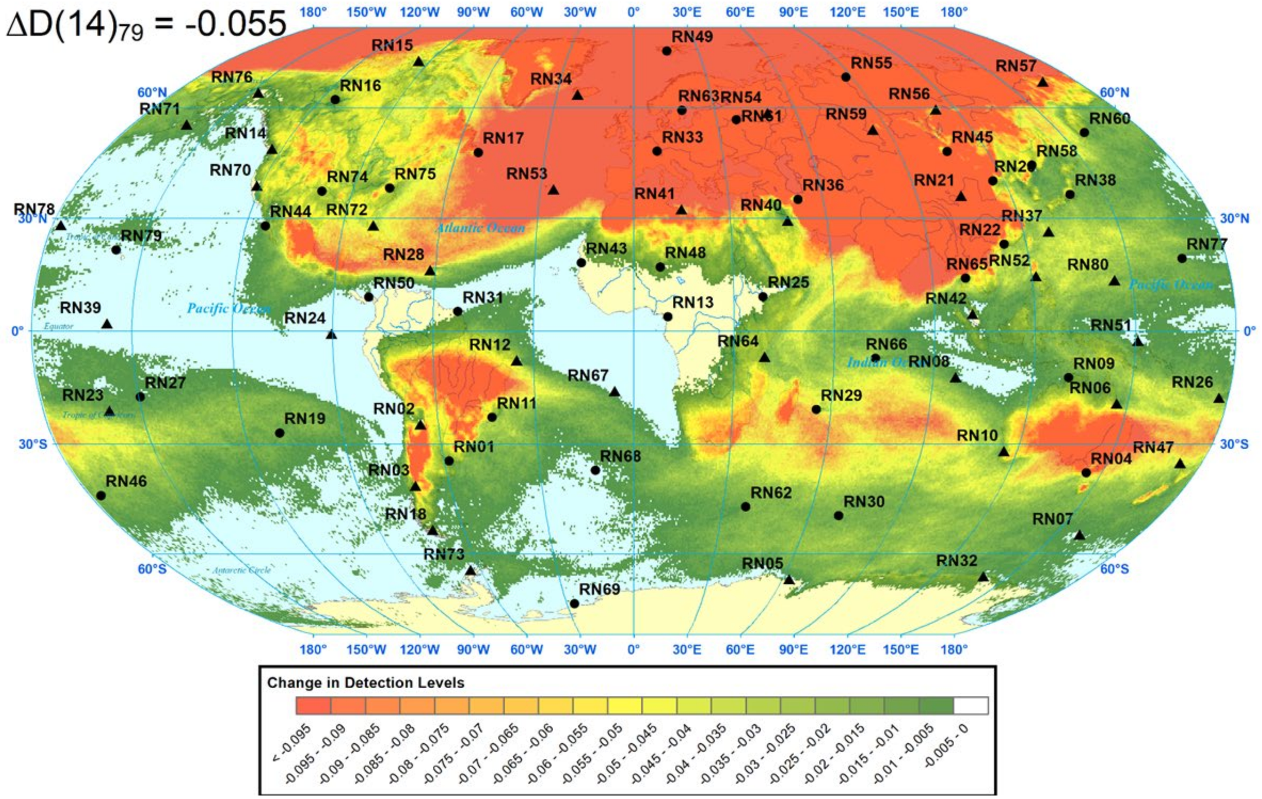
This would be a *smaller* effect at higher signal levels.

Detection prob: 79-station for a 10^{14} Bq ^{133}Xe: $D(13)_{79}$ and background-induced $\Delta D(13)_{79}$

$D(14)_{79}=0.767$



$\Delta D(14)_{79} = -0.055$



Xenon

Excellent coverage, but major impact to large regions.

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Stations with Most Background Impact

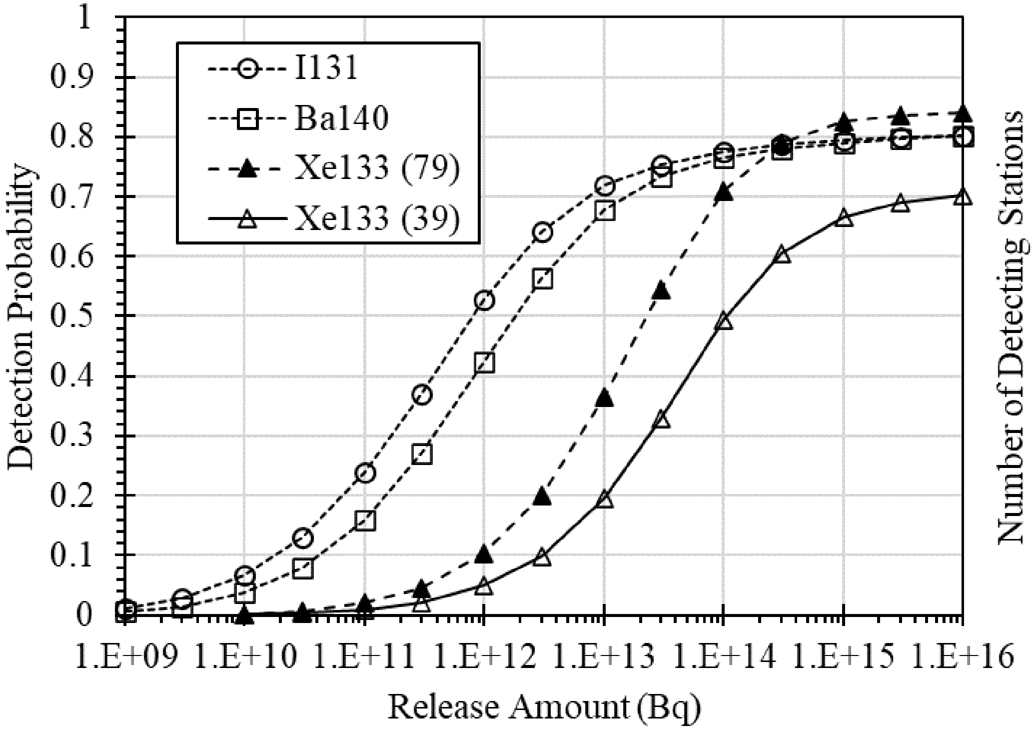
Aerosol

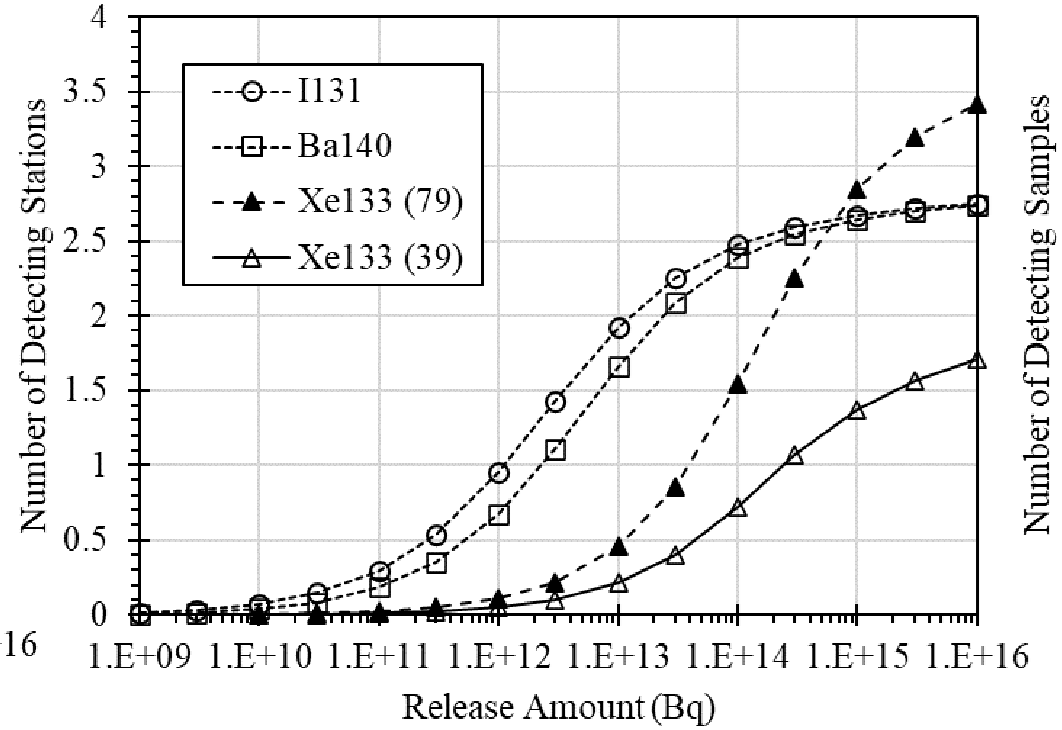
Station	MDC[a] µBq/m³	Detecting Samples	Average µBq/m³	95th Percentile µBq/m³
RN61	2.34	449	9.12	29.85
RN22	5.19	224	10.2	23.35
RN21	5.42	23	11.1	20.21
RN20	4.81	145	6.36	16.92
RN01	3.78	80	4.97	14.92
RN58	4.11	14	3.43	8.07
RN52	1.98	79	2.22	4.21
RN54	2.00	76	1.93	4.18
RN50	1.54	41	1.76	3.68
RN59	3.12	12	1.49	2.99

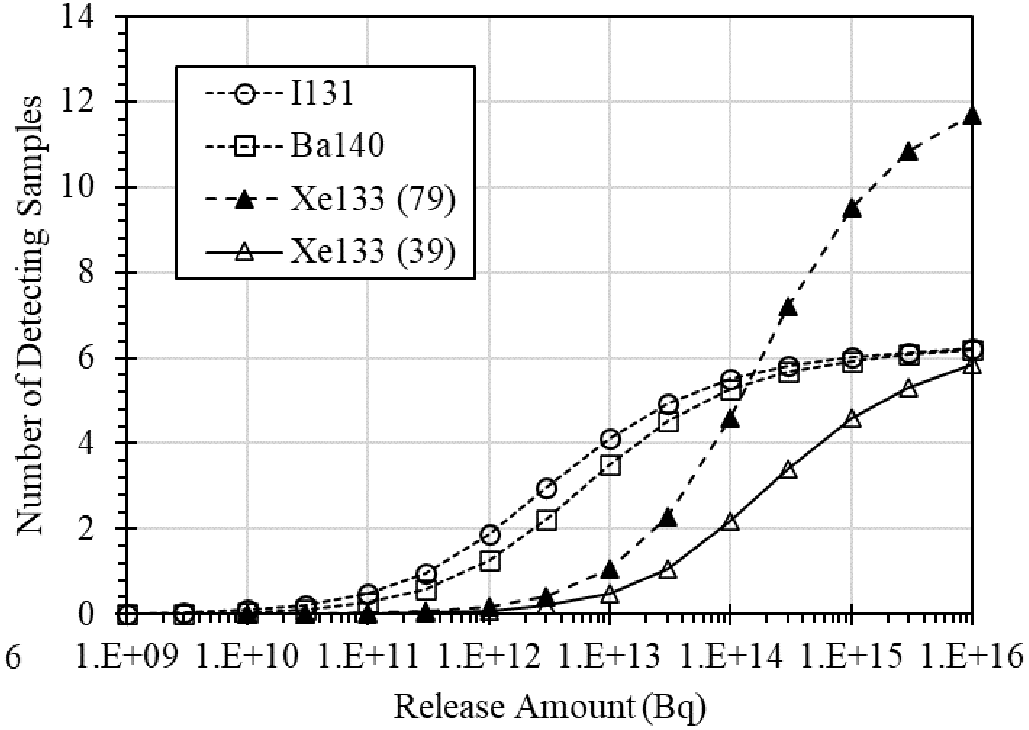
Xenon

Station	System MDC mBq/m³	Median mBq/m³	95th Percentile mBq/m³
RN61	0.5	0.531	50.1
RN54	0.5	0.446	44.7
RN33	0.15	0.221	36.7
RN57	0.5	4.850	20.7
RN21	0.15	0.464	19.3
RN59	0.5	0.081	9.73
RN04	0.2	0.000	9.53
RN63	0.2	0.182	8.26
RN49	0.2	0.001	7.25
RN20	0.15	0.097	7.23
RN01	0.5	0.166	7.07
RN55	0.5	0.003	6.58

Network performance (79), Current Tech Aerosol = 24h, Xenon = 12h







Network (79) Detect Prob vs source strength

Number of Detecting Stations vs source strength

Number of Detecting Samples vs source strength

Not bad, but…
Next Gen systems could improve this markedly!

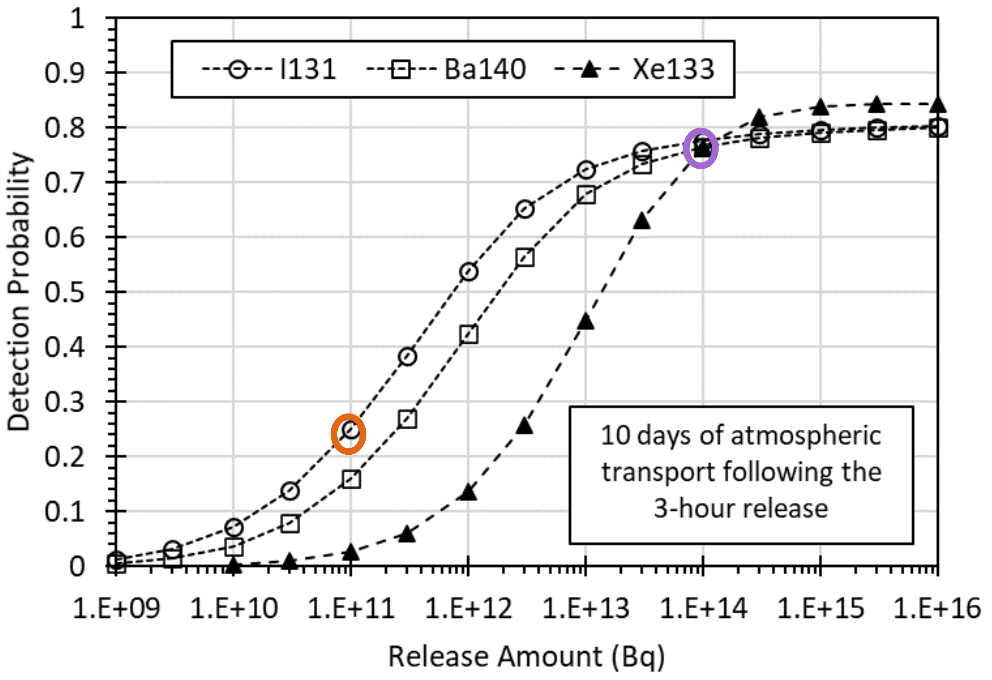
Illustrative 79 Scenario

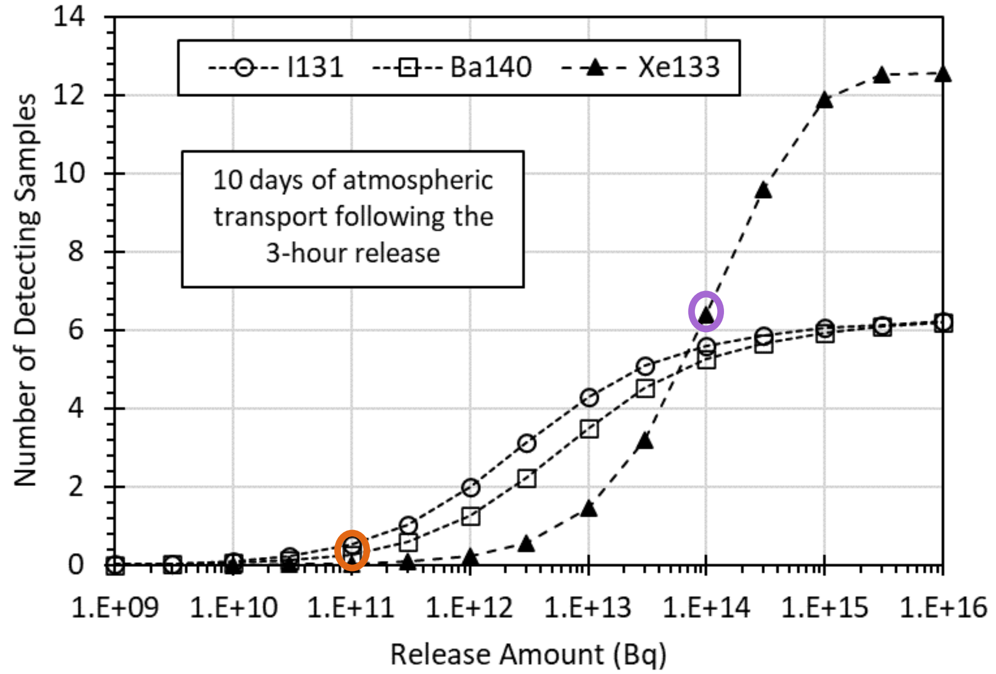
- Imagine a case where 1% of xenon escapes and 1e-5 iodine escapes…
  - 3 orders of mag separation in Bq
- Detection prob
  - Xenon 78%
  - Iodine 26%
- Number of detecting samples
  - Xenon 6.5
  - Iodine 0.5 ?

BUT, xenon and iodine are similar for split 39 - 79 network

The sum isn't too bad!

This helps bolster the case that we need a bit more sensitivity for iodine





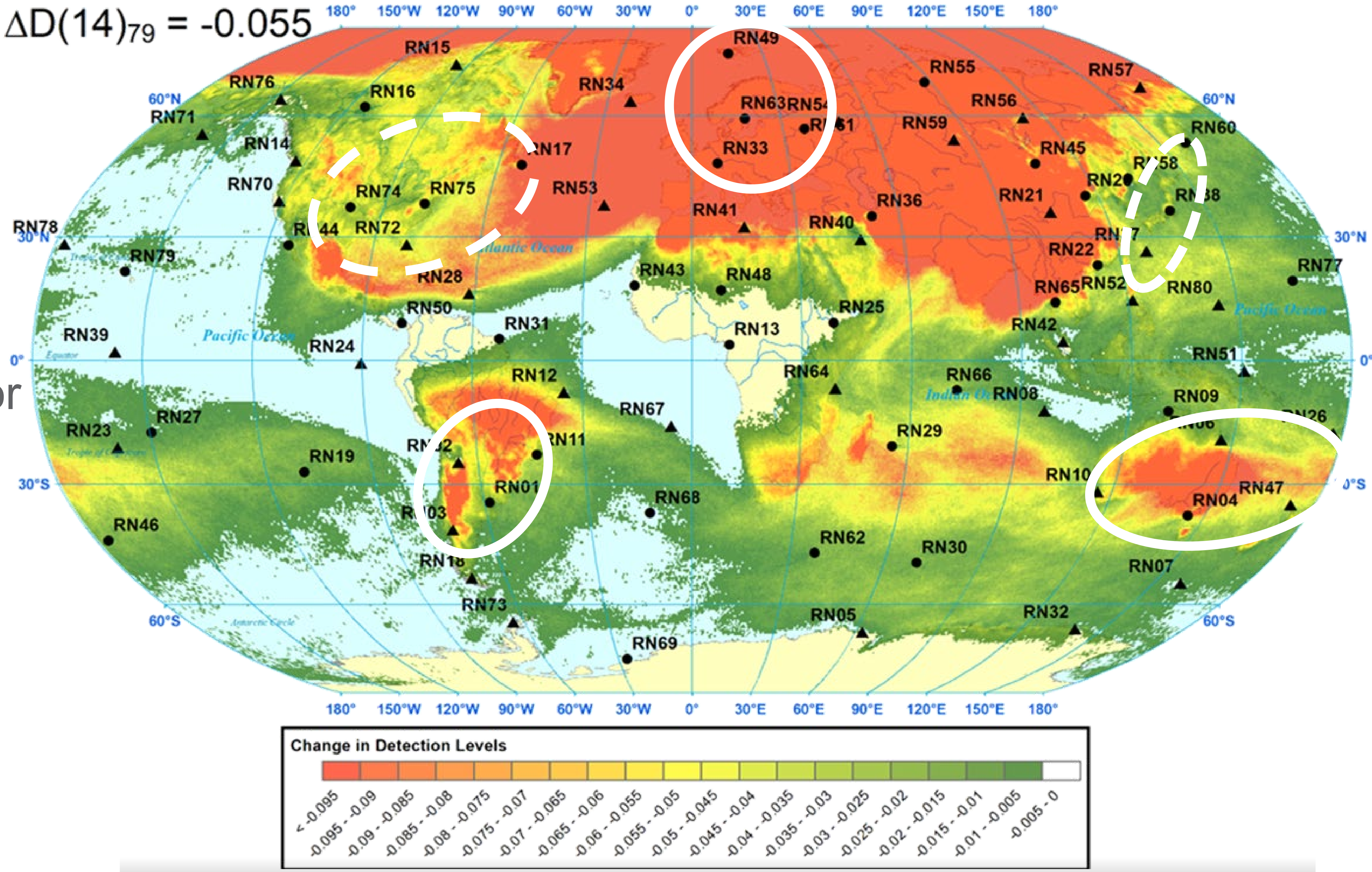
Next Steps: Confirm or Improve with Background Studies

- If background estimates could be made sufficiently accurate, the action level could be lowered substantially.
  - Additional measurements done at IMS stations that do not yet have a xenon system
  - Adding other measurements to constrain backgrounds
    - ✓ Local/regional monitoring data
    - ✓ Stack monitors at participating institutions
    - ✓ Temporary background campaigns
- Develop cross-signature support between aerosol and xenon measurements
  - Could add key confidence for hard-to-detect signals, lowering false positives
- All of the above:
  - Run temporary science experiments that include stack monitors, local/regional measurements, highly impacted stations, Xe and ^{131}I, and IMS stations so far unmeasured

High Value Places for Background Study

- Highest Impacted Stations for Both Xe and I
- 2nd 40 stations (triangles)
- Stack Monitors
  - Belgium
  - Australia
  - Near Future: US Niowave*
  - Near Future: Argentina
  - Future: Chile
  - Future: KJRR*

*New producer



$D(14)_{79}$ for ^{133}Xe

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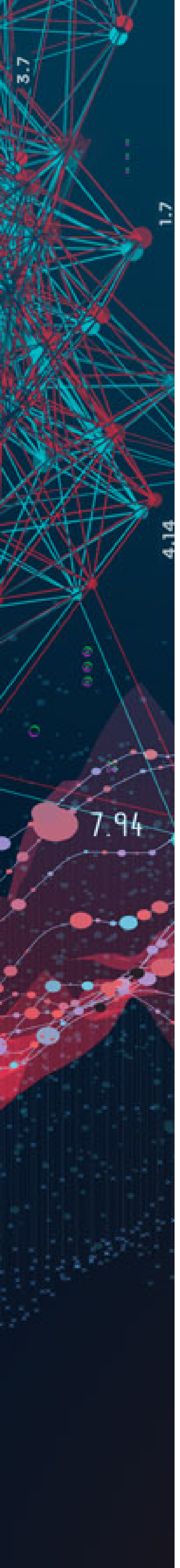
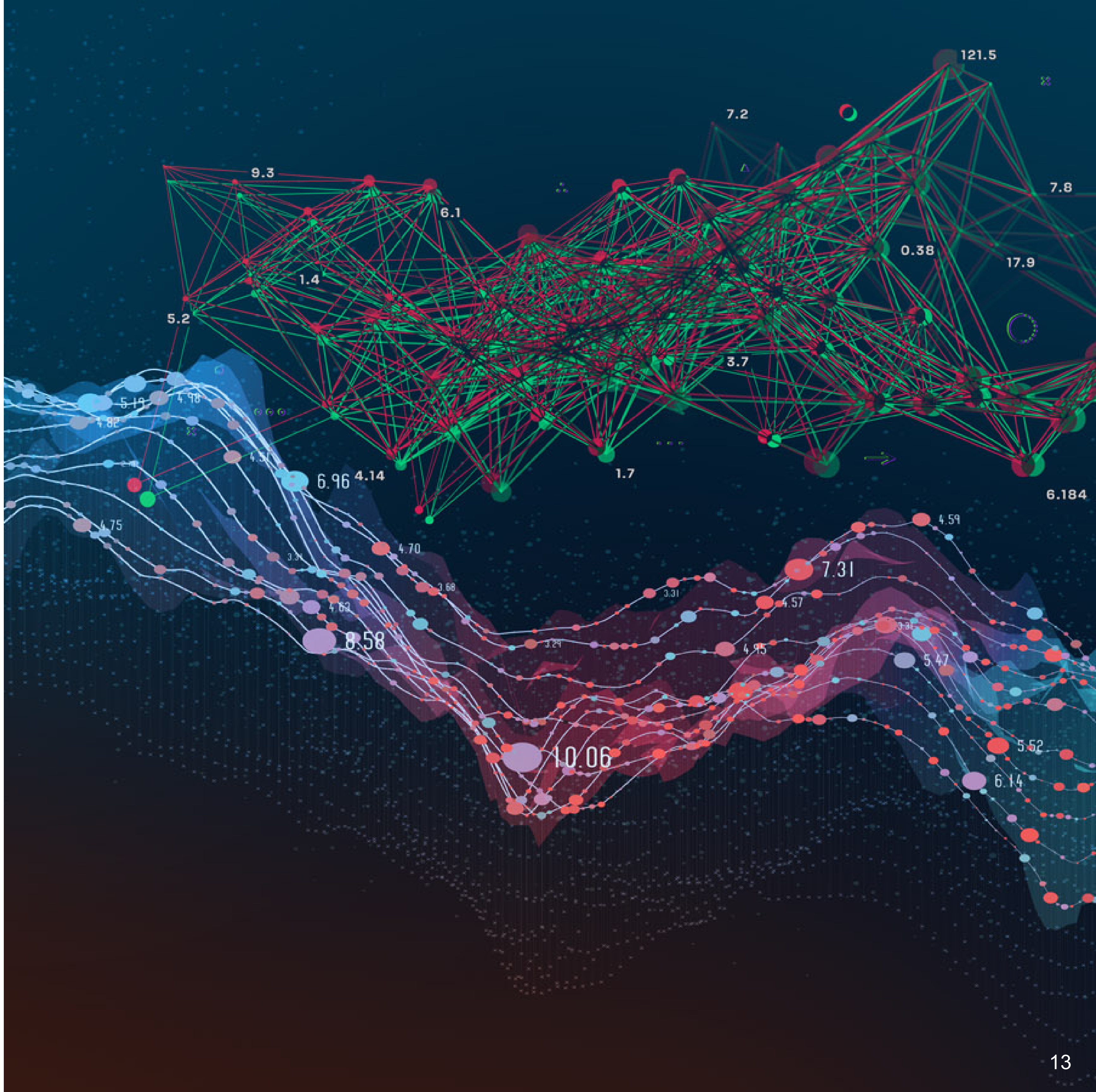
Thank you





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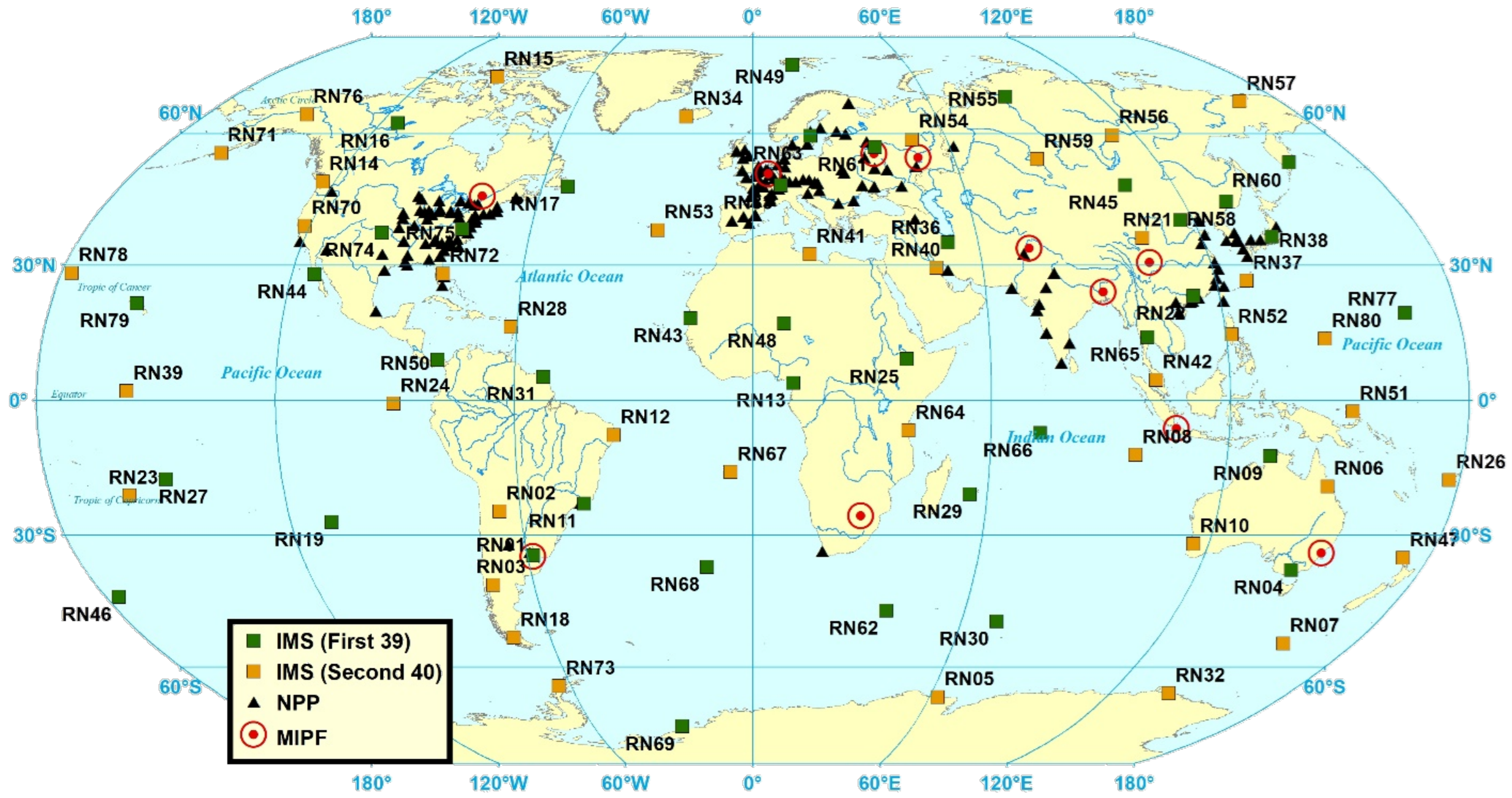
How we simulated Xe backgrounds



Extra: Xenon Growth and Decay

- The ingrowth of 133Xe is fed by 133I and parent isotopes
- If 133Xe is extracted/fractionated at T=0, it is 1000x smaller