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CTBTO's Verification Regime and its Role in Ensuring a Safer World

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Outline of the Presentation

- CTBT and Verification Regime
- International Monitoring System (IMS)
- Radionuclide Monitoring
- Civilian applications: Fukushima detections in the IMS
- CTBT Radionuclide Laboratories

CTBTO

Comprehensive Nuclear-Test-Ban Treaty (CTBT)

- Opened for signature in 1996
- Currently 183 States have signed
- 157 States have ratified
- Will enter into force after 44 States listed in Annex II of the Treaty (operated nuclear research/power reactors in 1996) ratify; 36 have ratified to date

CTBTO

- UN-related intergovernmental organization
- Preparatory Commision
- Provisional Technical Secretariat
- About 250 staff members from over 71 States Signatories

Putting an end to nuclear explosions

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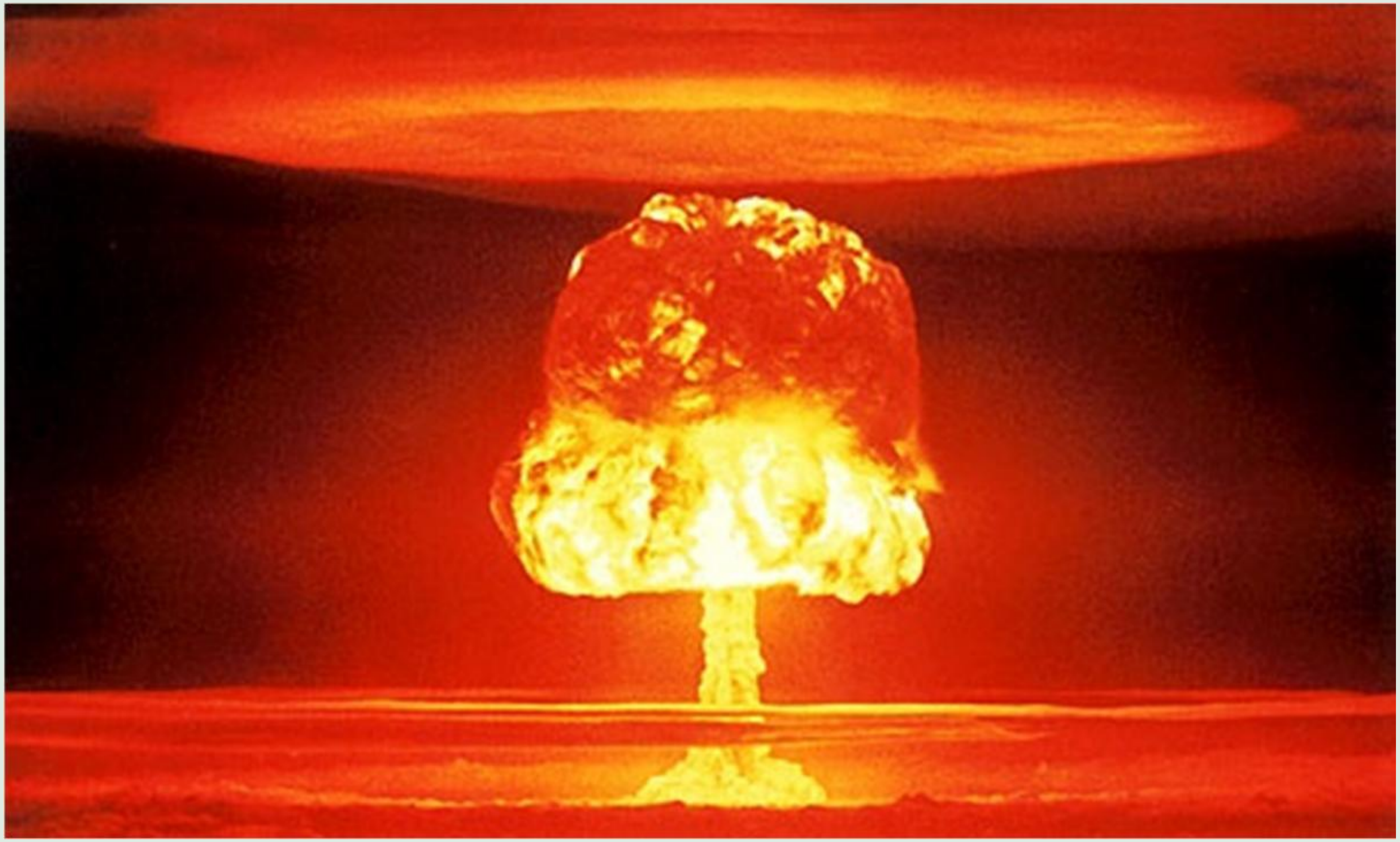

Nuclear weapons explosion over Bikini Atoll
Photograph: U.S. Department of Energy-Nevada/Corbis

Nuclear Test Environments

Atmospheric Tests

- *Infrasound Waves*
- *Possible Seismic/Hydro Coupling*
- *Radionuclide Release (Particulate & Noble Gas)*

Underground Tests

- *Seismic Waves*
- *Possible Infra/Hydro Coupling*
- *Possible Radionuclide Release (Noble Gas)*

Underwater Tests

- *Hydroacoustic Waves*
- *Possible Seismic/Infra Coupling*
- *Possible Radionuclide Release (Noble Gas)*

International Monitoring System (IMS)

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<u>Seismo-acoustic Technologies (Waveform)</u>

- Provide real-time monitoring in underground, underwater, and atmospheric environments
- Determine the time and location of the event

<u>Radionuclide Technology (Spectra)</u>

- Provides confirmatory, forensic evidence of the nuclear nature of any suspicious event
- Based on high-resolution gamma-ray spectrometry of air samples

The IMS Network

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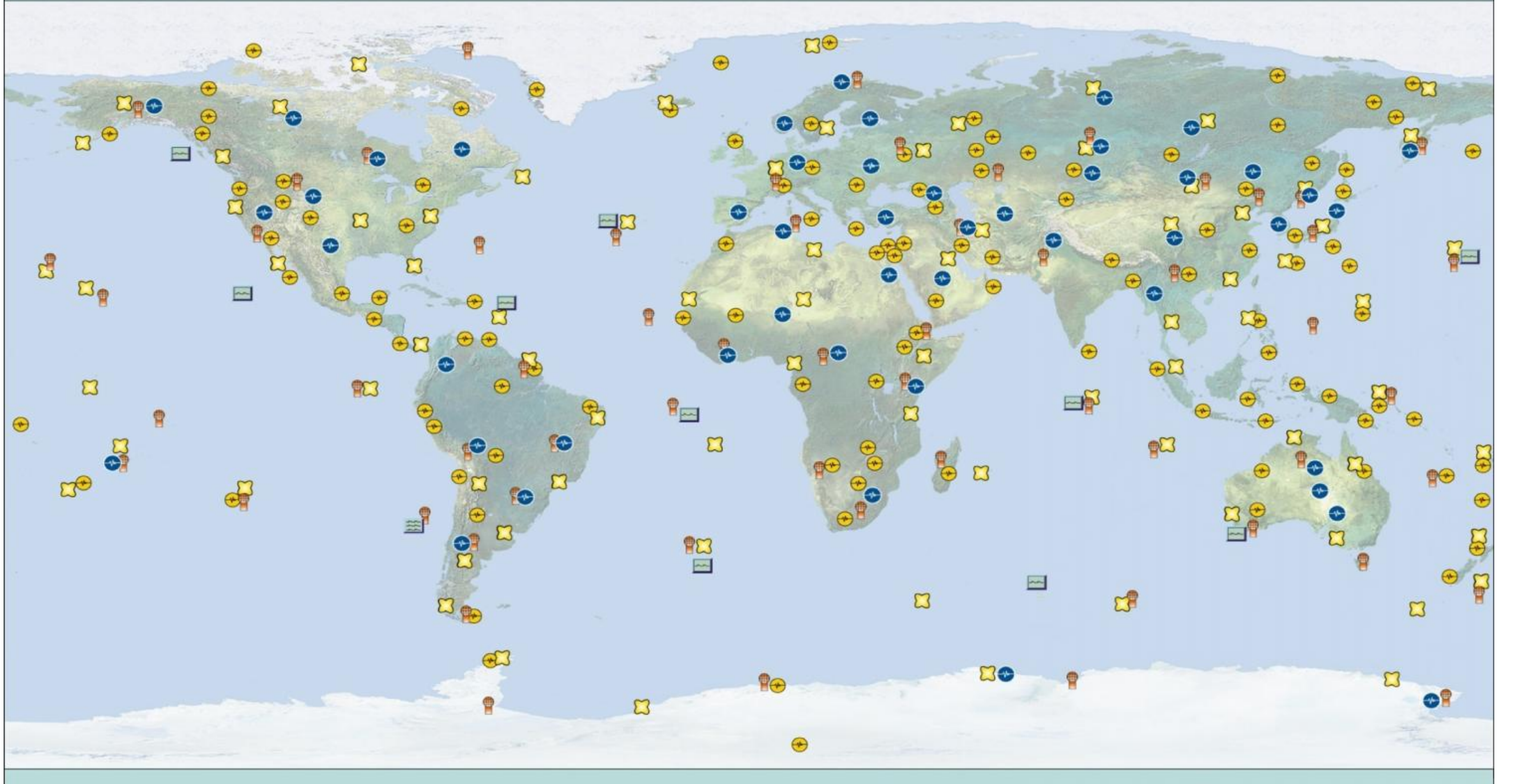
81% of the network is certified (261 out of 321)



Primary Seismic

Auxiliary Seismic

Radionuclide

Hydroacoustic

Infrasound

Stations hosted by UK (12+1)

Auxiliary Seismic Station (1)

Eskdalemuir_55.3 N 3.2 W

Radionuclide Station (4)

BIOT/Chagos Archipelago 7.0 S 72.0 E

St. Helena 16.0 S 6.0 W

Tristan da Cunha 37.0 S 12.3 W

Halley, Antarctica 76.0 S 28.0 W

Radionuclide Laboratory (1)

AWE Aldermaston

Hydroacoustic Station (3)

BIOT/Chagos 7.3 S 72.4 E

Tristan da Cunha 37.2 S 12.5 W

Ascension 8.0 S 14.4 W

Infrasound Station (4)

Tristan da Cunha 37.0 S 12.3 W

Ascension 8.0 S 14.3 W

Bermuda 32.0 N 64.5 W

BIOT/Chagos Archipelago 5.0 S 72.0 E

Data Collection and Analysis

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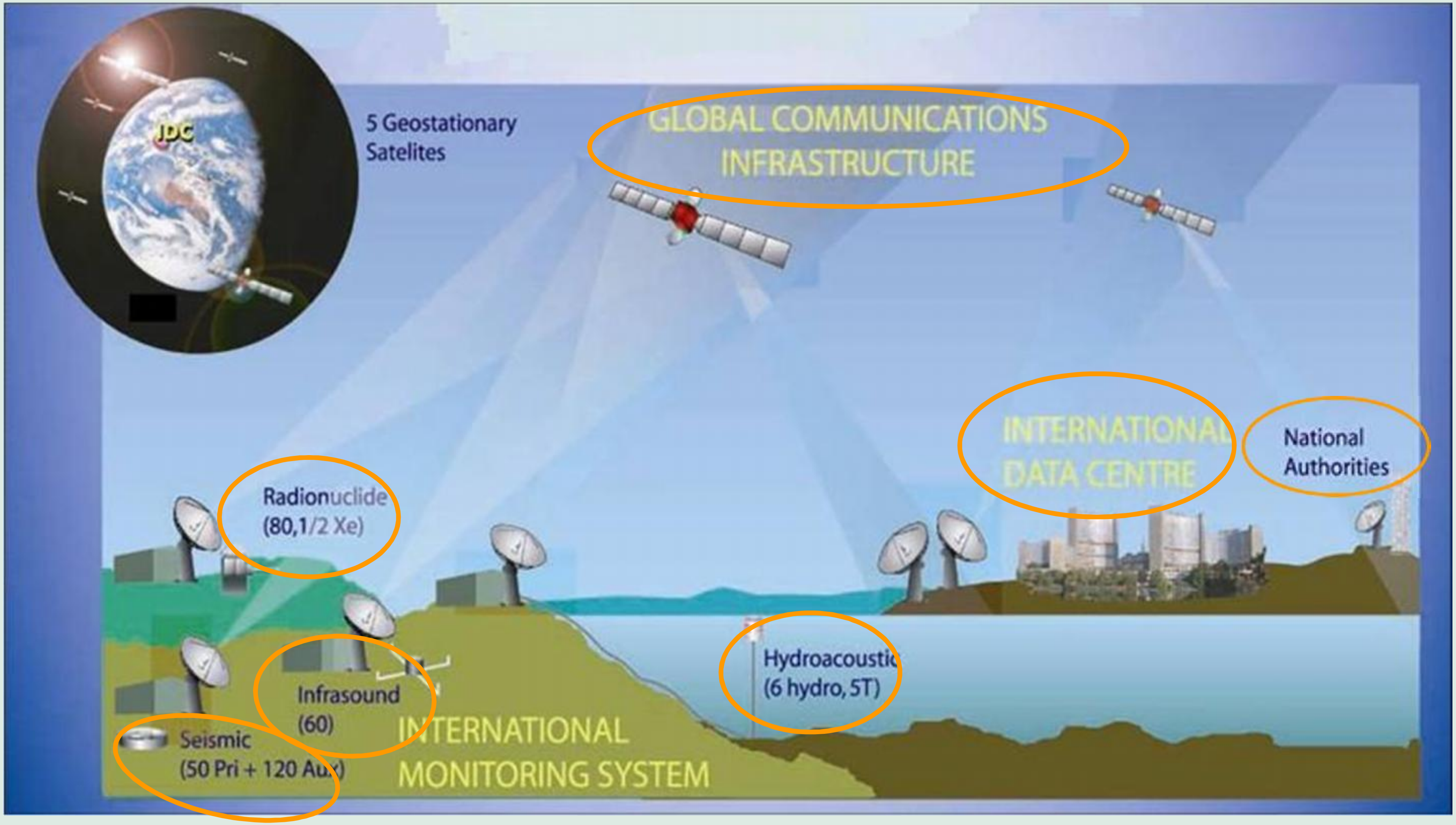

Characteristics of the IMS Network

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- Global coverage
- Secure and centralized data communication
- High detection sensitivity
- Data quality assurance
- High data availability
- Standardization of products

Highly reliable global monitoring network

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Radionuclide Monitoring

Identification and quantification of radionuclides in air

Radionuclide Monitoring Network

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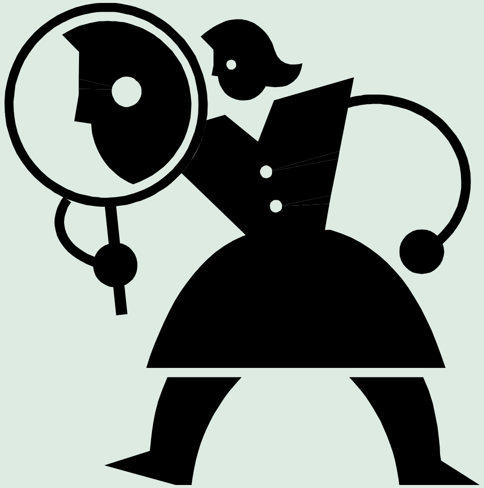
Detection Capability:

Not less than 90% probability of detecting any above-ground nuclear weapon test within 14 days
Explosive Yield = 1 kiloton TNT



Detection of vented noble gases from underground or underwater tests

Types of Radionuclide Stations

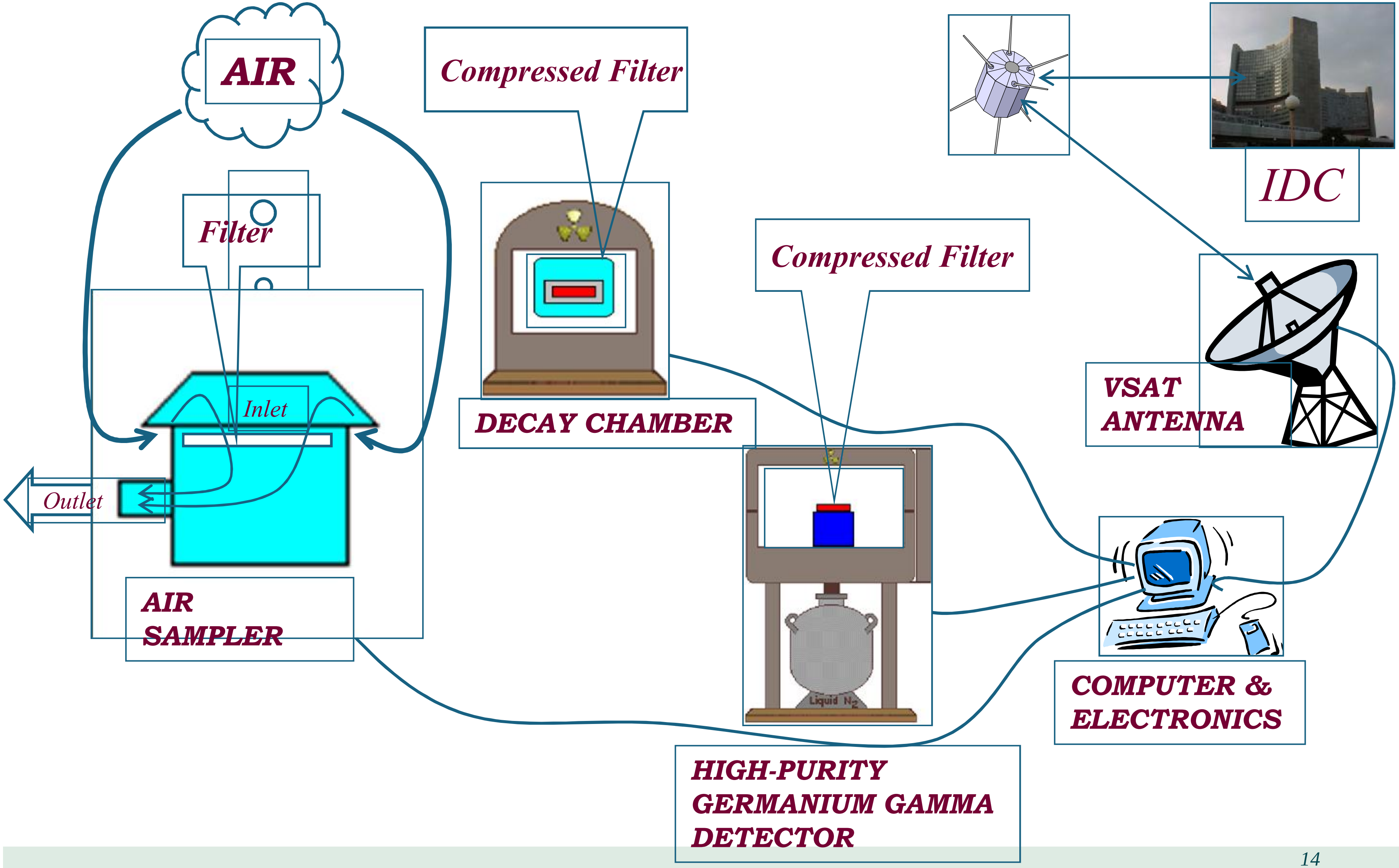
Particulate (80)

- Manual – needs a station operator to perform the daily operations
- Automatic
  - Radionuclide Aerosol Sampler/Analyzer **(RASA)**
  - Automatic Radionuclide Air Monitoring Equipment **(ARAME**)

With Noble Gas Capability (40)

- SPALAX (**S**ystème de **P**rélèvement **A**tmosphérique en **L**igne avec l'**Á**nalyse du **X**énon)
- SAUNA (**S**wedish **A**utomatic **U**nit for **N**oble **G**as **A**cquisition)
- ARIX (**A**nalyzer of **R**adioactive **I**sotopes of **X**enon)

Radionuclide Station Design



Minimum Requirements

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Characteristics	*Minimum requirements*
Air flow	*500 m^3/h*
Collection time	*24 h*
Decay time	á *24 h*
Measurement time	ñ *20 h*
Time before reporting	á *3 days*
Reporting frequency	*Daily*
Particulate collection efficiency	*filter:* ñ *80 % at* Ą *= 0.2 µm,* *global:* ñ *60 % at* Ą *= 10 µm*
Measurement mode	*HPGe High resolution gamma-ray spectrometry*
HP Ge relative efficiency	ñ *40 %*
HP Ge resolution	*< 2.5 keV at 1332 keV*
Base line sensitivity	*10 to 30 $\mu Bq/m^3$ for ^{140}Ba*
Calibration range	*88 to 1836 keV*
State of health	*status data transmitted to IDC*
Communication	*two-way*
Auxiliary data	*meteorological data*
Data availability	ñ *95 %*
Down time	á *7 consecutive days* á *15 days annually*

Radioactive Products of a Nuclear Explosion

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- **Fission radionuclides**

  Of prime importance because released by practically all nuclear weapon types

- **Neutron-activation products**

  Products of interaction of neutrons released during nuclear fission with elements in the device material, fuel and surrounding environment

- **Fuel products**

  Radioactive debris from the nuclear fuel itself.

  There are 42 Fission Products and 41 Activation Products on the List of CTBT-relevant nuclides for particulate samples (CTBT/WGB/TL-2/40)

Radionuclides Most Relevant to CTBT

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- Radionuclides that are monitored include those that are most indicative of a nuclear test.

- Xe-135 and Xe-133 are most abundant in a 1 kiloton nuclear explosion, with activity increasing after a couple of days due to formation of beta-decay chain of precursors

Most abundant radionuclides after a 1 kt explosion.

1-day decay		3-day decay		10-day decay		30-day decay	
Xe-135	11.8 %	Mo-99	9.6%	Xe-133	13.6%	Ru-103	12.2%
I-133	7.8 %	Rh-105	8.3%	Ba-140	7.9%	Ce-141	10.7%
Zr-97	6%	Xe-133	7.3%	I-131	7.0%	Ba-140	9.6%
Rh-105	5.4%	Te-132	6.9%	Mo-99	6.5%	Zr-95	6.3%
Pd-109	4.4%	Ce-143	5.9%	Te-132	6.2%	I-131	4.5%
Ce-134	4.3%	I-133	5.9%	Ru-103	4.8%	Xe-133	3.5%
Mo-99	4.2%	Zr-97	3.1%	Ce-141	4.6%	Nd-147	3.4%
I-135	4.2%	I-131	3.1%	Nd-147	3.3%	Ce-144	1.4%
Te-132	2.8%	Ba-140	2.9%	Zr-95	2.2%	Ru-106	1.4%
Sr-91	2.4%	Xe-135	1.9%	Rh-105	1.2%	Te-129m	0.39%
Ru-105	1.5%	Pd-109	1.4%	Sb-127	0.76%	Te-132	0.32%
Xe-133	1.4%	Ru-103	1.4%	Ce-143	0.69%	Eu-156	0.29%
		Ce-141	1.3%	Xe-133m	0.23%	Xe-131m	0.13
		Xe-133m	0.42%	Xe-131m	0.05%		
		Xe-131m	0.0058%				

IMS Noble Gas Systems

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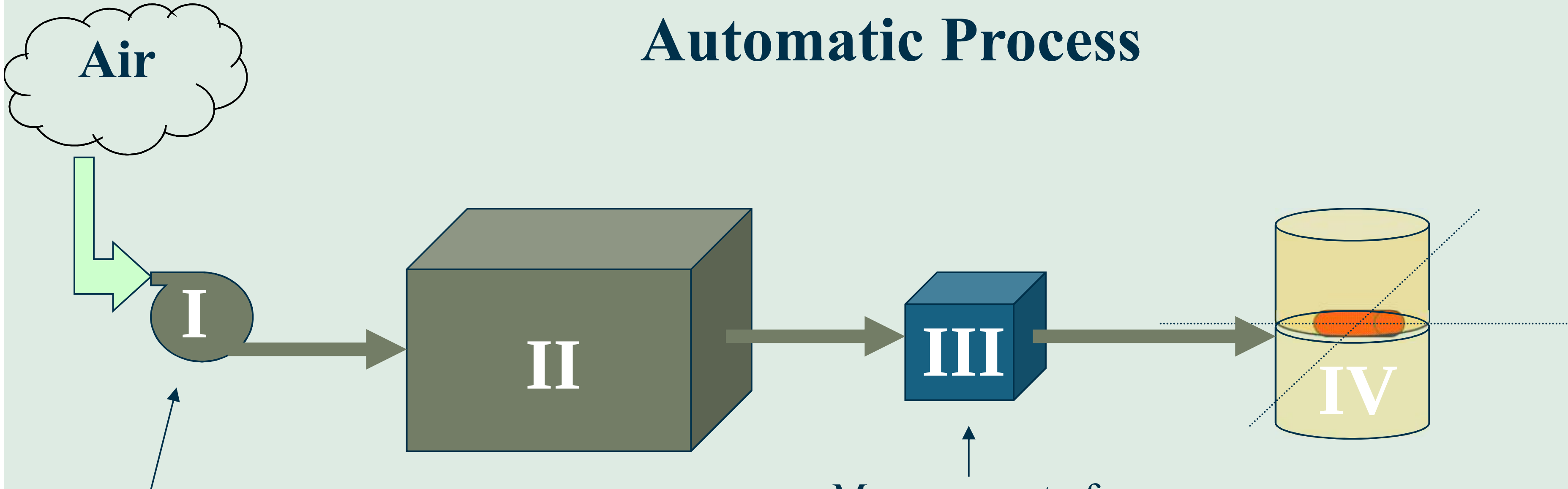
SPALAX

ARIX

SAUNA

Xenon Sampling and Analysis

Automatic Process



Collection of Air

Gas Processing & Sample Preparation:

- Removal of water, O_2, CO_2, Rn
- Creation of final Xe-sample
- Gas transport via carrier gas (He, N_2)

Measurement of sampled Xenon volume (GC, TCD)

Activity Measurement (HPGe or beta-gamma coincidence)

Minimum Requirements for Noble Gas Systems

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Characteristics	Minimum Requirements
Air flow	0.4 $m^3 h^{-1}$
Total volume of sample	10 m^3
Collection time	á 24 h
Measurement time	á 24 h
Time before reporting	á 48 h
Reporting frequency	Daily
Isotopes measured	^{131m}Xe, ^{133}Xe, ^{133m}Xe, ^{135}Xe
Measurement mode	Beta-gamma coincidence or high resolution gamma spectrometry
Minimum Detectable Concentration	1 mBq/m^3 for ^{133}Xe
State of health	Status data transmitted to IDC
Communication	Two-way
Data availability	ñ 95%
Down time	á 7 consecutive days; á 15 days annually

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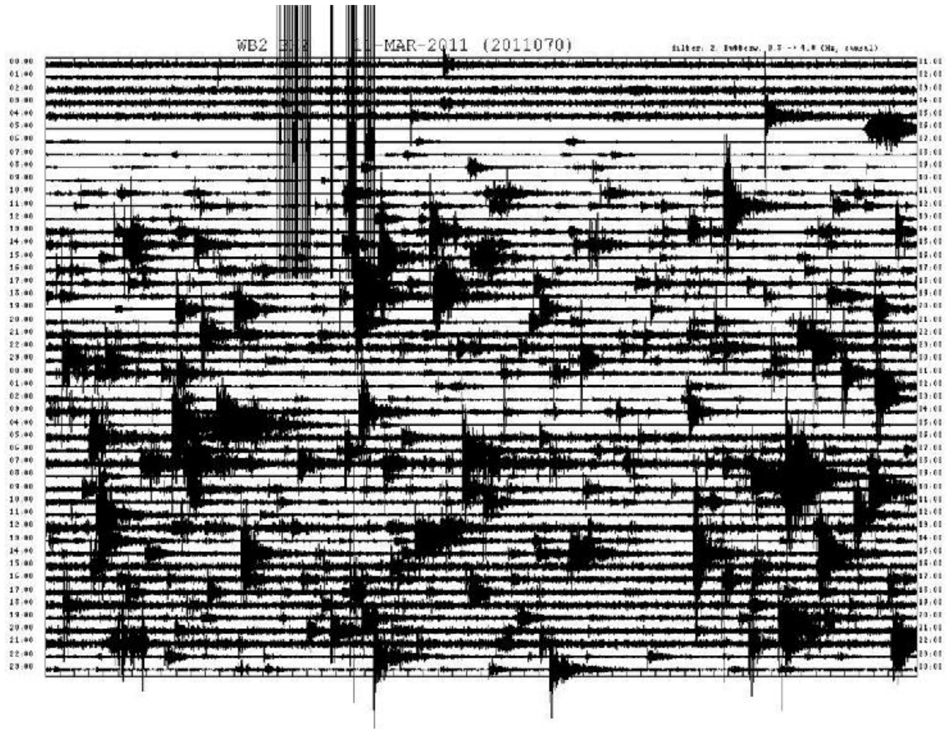
Civilian Applications

- ***Tsunami Warning***
- ***Monitoring radioactivity levels in the event of a nuclear accident***

Tohoku Earthquake and Aftershocks

- On 11 March 2011, the 4th largest earthquake since 1900 occurred off the east coast of Honshu. It was magnitude 9.0
- Fault rupture extended over 100 km
- The earthquake was recorded by each of the 140 IMS seismic stations operating at that time
- There were 800 aftershocks on that day and about 10,000 altogether in succeeding months.



Source: Spiro Spiliopoulos, PTS Tim Hampton Lecture Series

Tsunami Detected by Hydroacoustic Station

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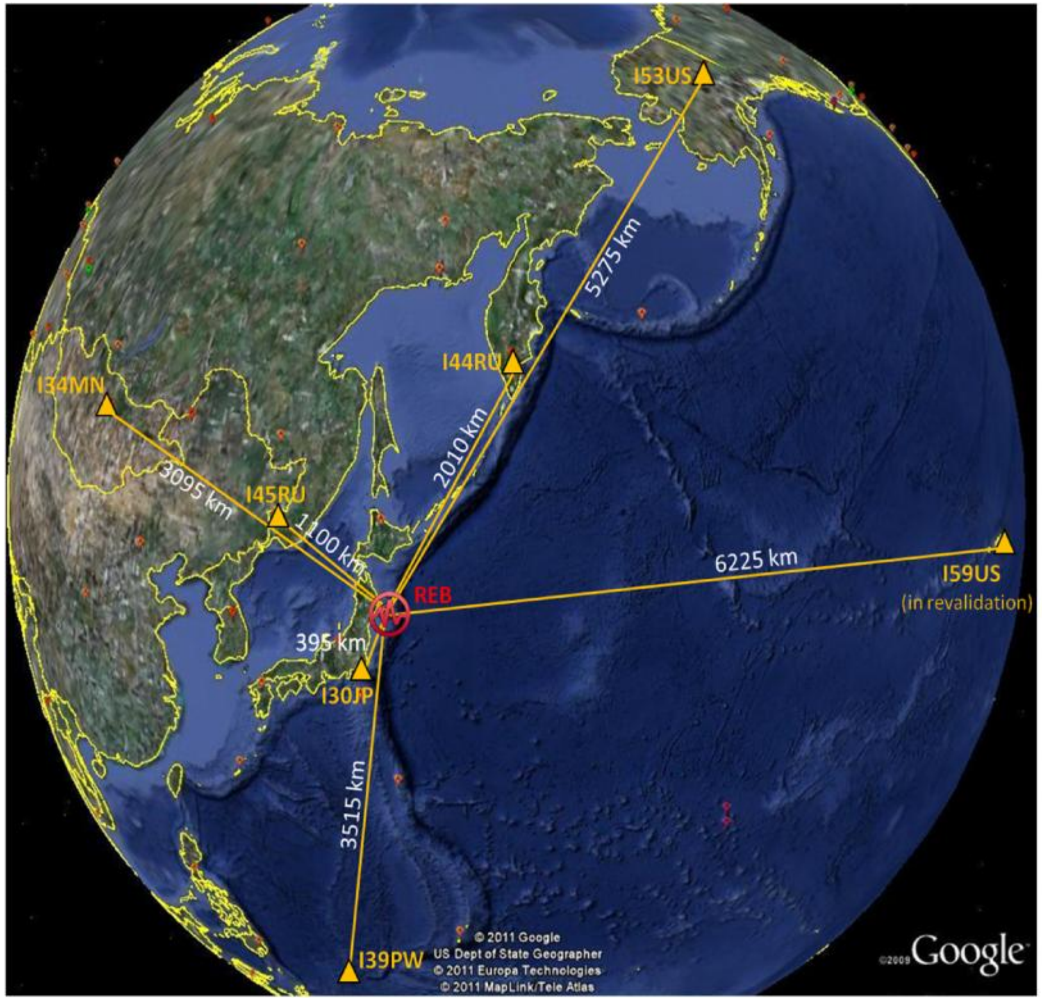
- Fault rupture and subsequent tsunami was detected by the hydroacoustic station at Wake Island, USA, about 3000 km distant from epicenter.
- **In collaboration with the UNESCO/IOC, the CTBTO provides real-time and continuous data to tsunami warning centres.**
- As tsunami goes over hydrophone, water depth changes and pressure recorded by hydrophone changes. Low-frequency waves arrive first because of high propagation speed.

Source: Mark Prior, PTS Tim Hampton Lecture Series

Tōhoku Earthquake – Infrasound

11 March 2011, Mw 9.0



- **7 IMS infrasound stations** detected sound waves generated by the ground vibration during the Tōhoku earthquake.
- Stations to epicenter distances from 395km (IS30, Japan) to 6225km (IS59, Hawaii).
- Most distant stations located in **downwind conditions** that favor the propagation of infrasound waves.

Source: Paulina Bittner, PTS Tim Hampton Series

IMS Radionuclide Network – Status as of March – April 2011

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RN38 (JPP38) Takasaki Automatic Station RASA

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RN38 (Takasaki, Japan)

Collection 12 – 13 March 2011

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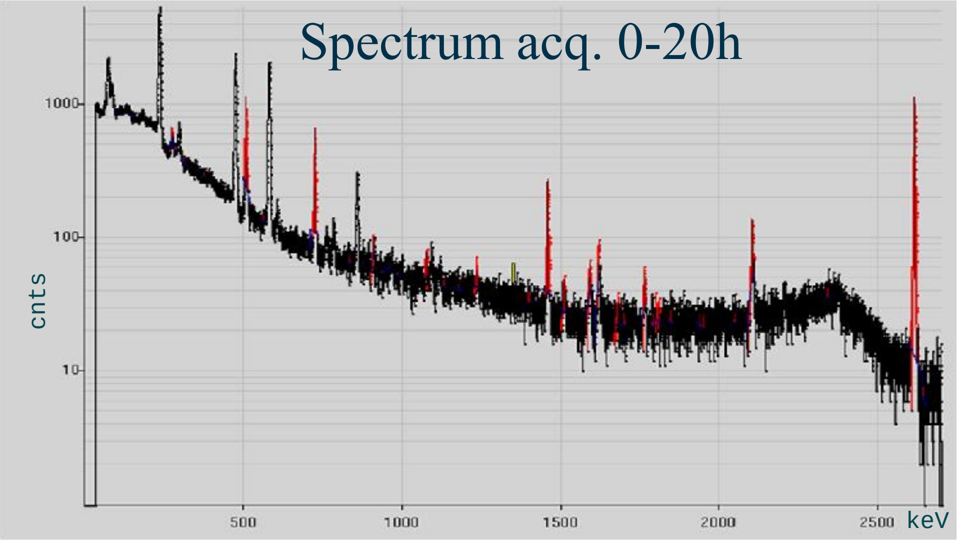

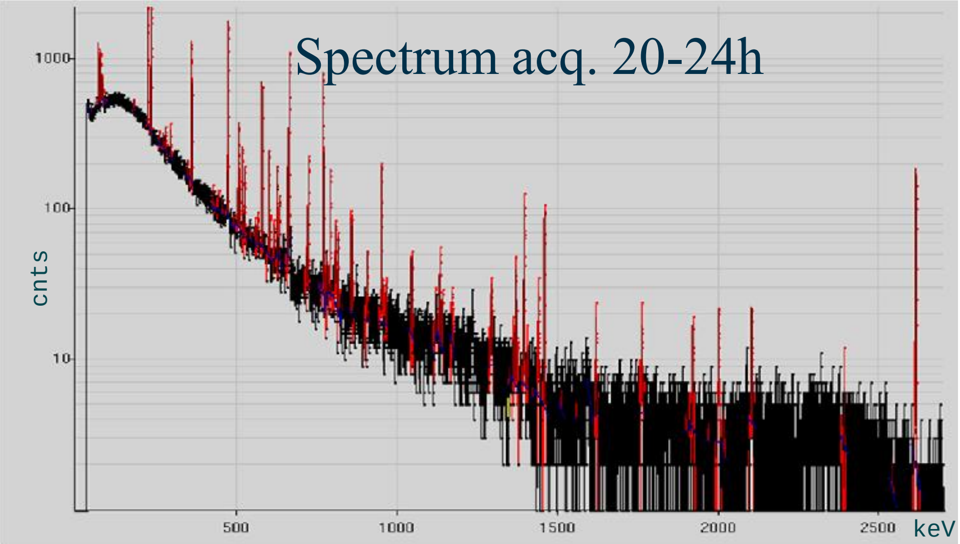

Gaseous fission products were detected. Concentrations are not reliable as these gaseous nuclides infiltrated detector chamber during counting (visible in spectra collected last 4h) but not on the sample. Arrival time of these radionuclides is between 2 and 3 am (UTC) on 15/03.

Multiple fission products were detected.

Nuclide	Relative activity	
Cs-134	15	These values do not represent actual air concentration as the sample was clean during the sampling.
Cs-136	4.9	
Cs-137	12	
I-131	83	
I-132	82	
I-133	44	
Te-132	110	
Ba-136m	4.8	
Xe-133	Detected	

Atmospheric Transport Model, East Asian View

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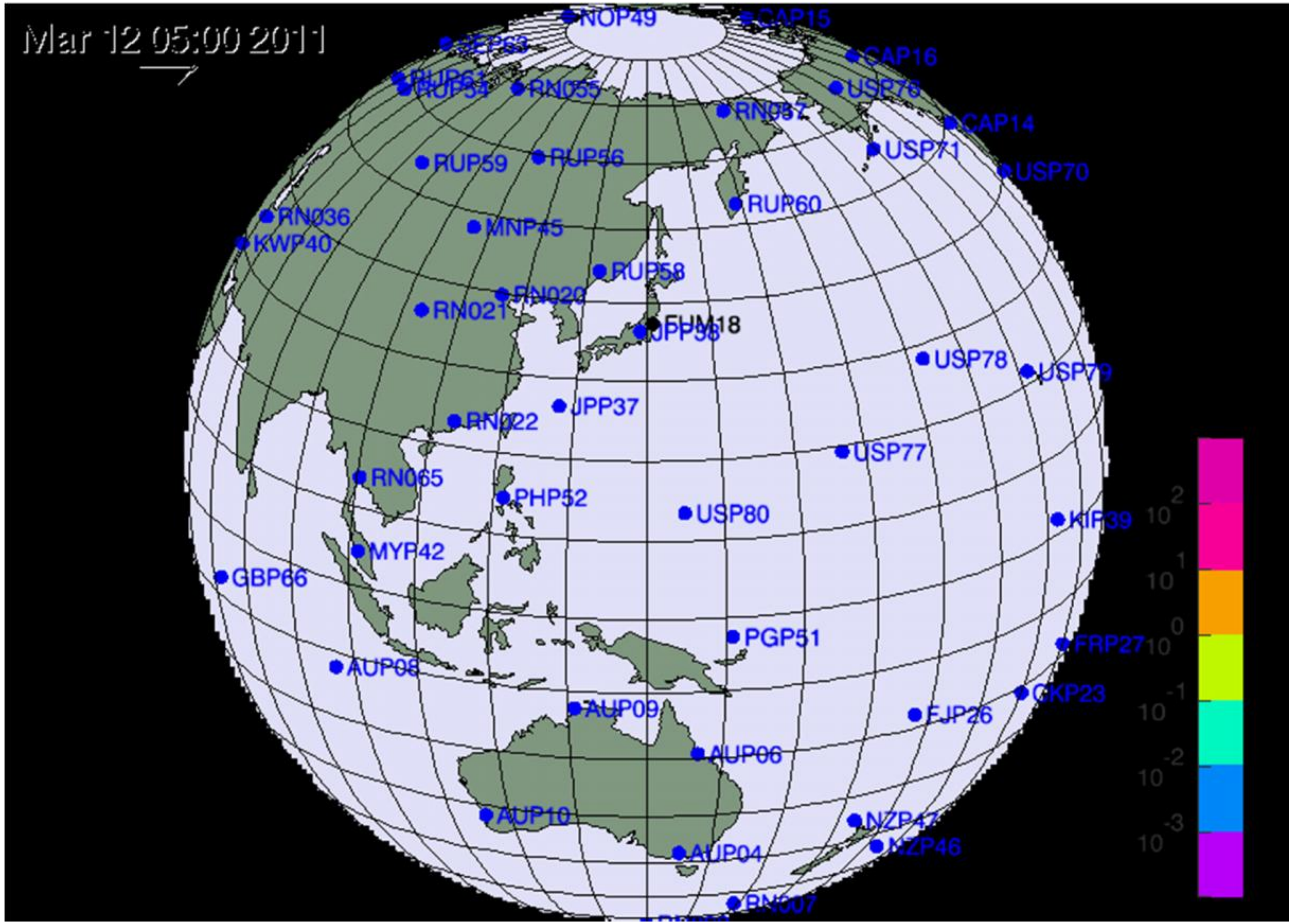
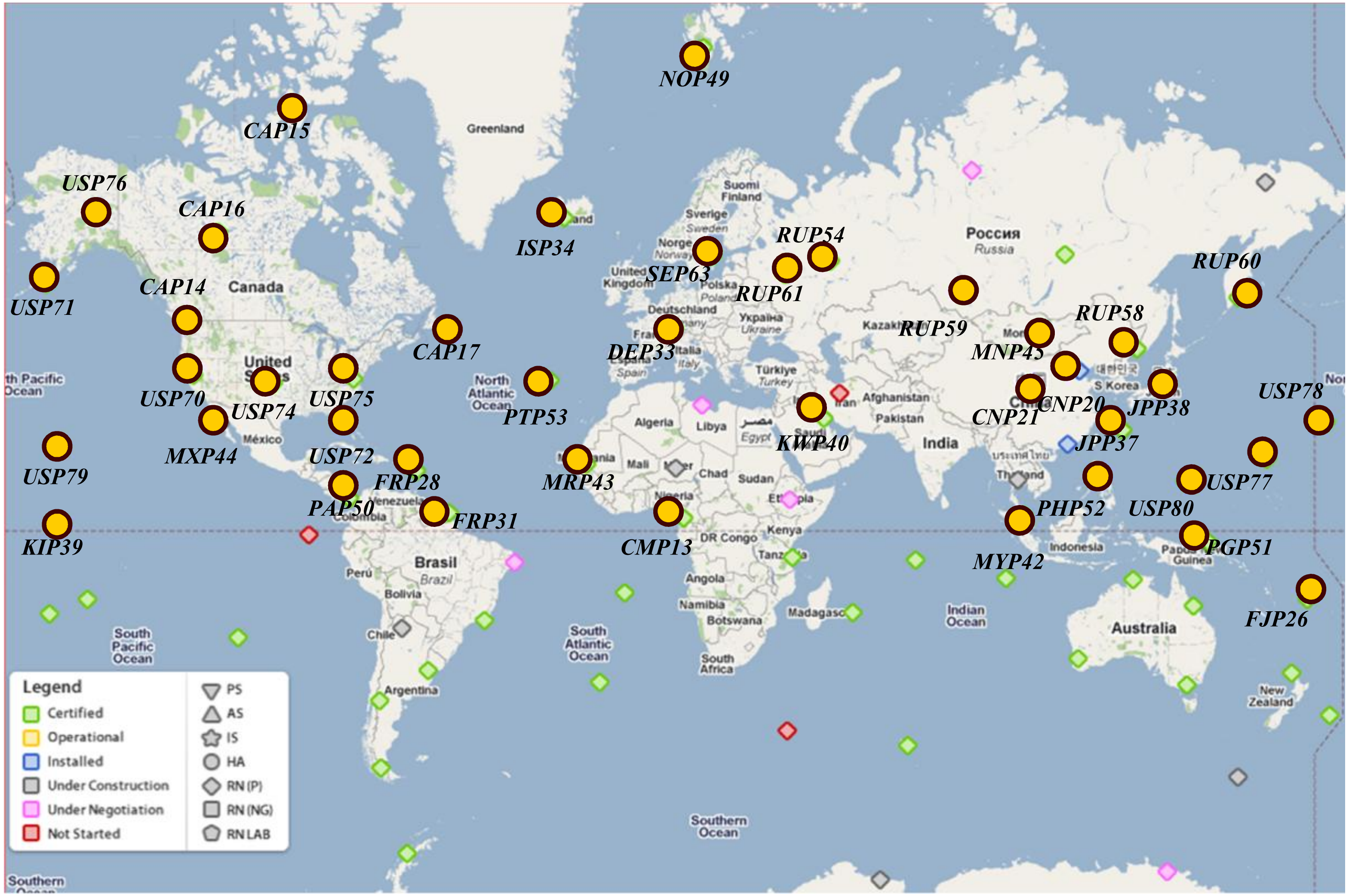


Source: Monika Krysta, PTS

Particulate Network Detections of Fukushima Releases



Network data availability 90-95% (end of March to mid-April 2011)

RN60 (Petropavlovsk-Kamchatskiy Russian Federation)
Collection 13 – 14 March 2011

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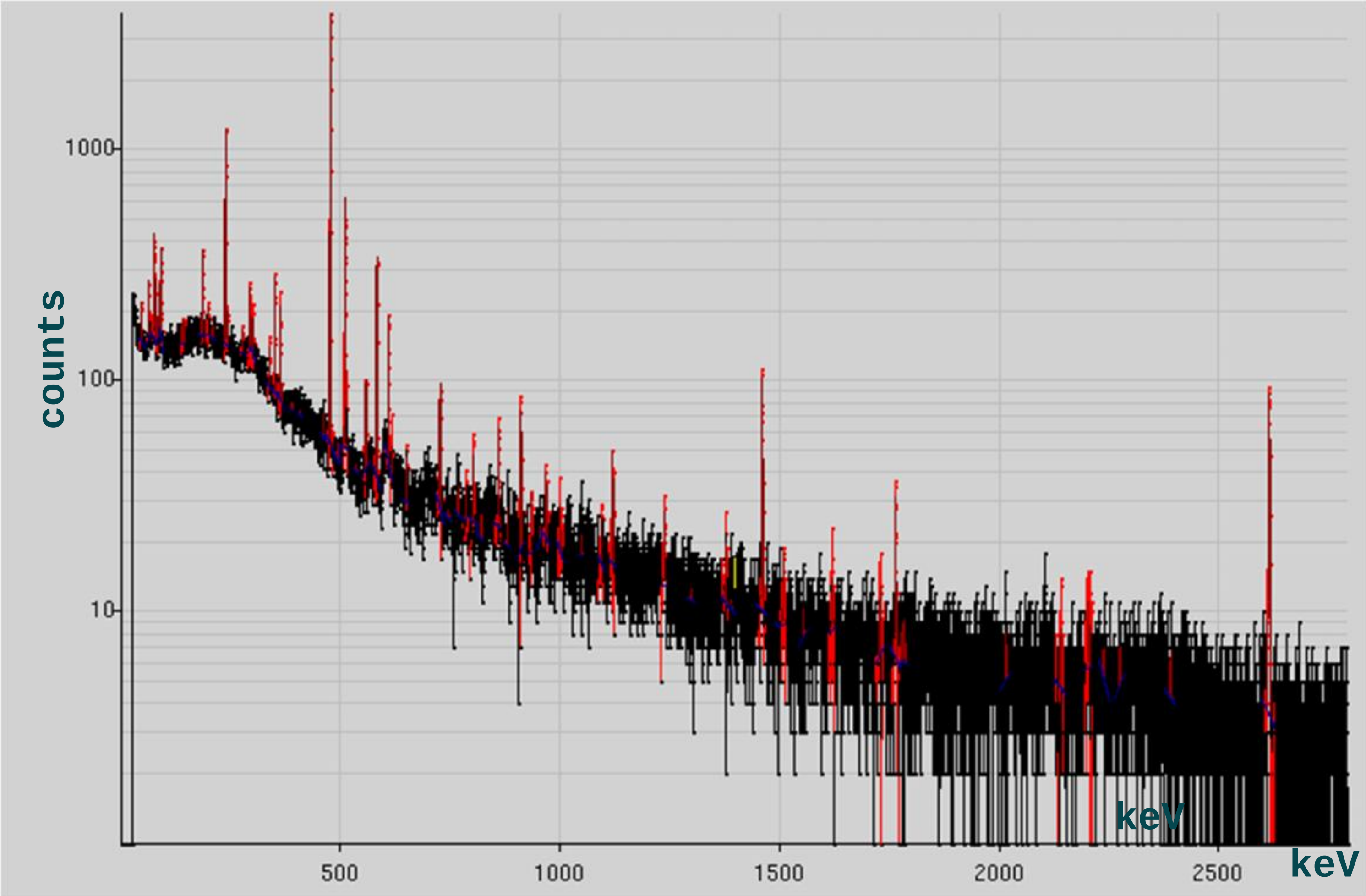
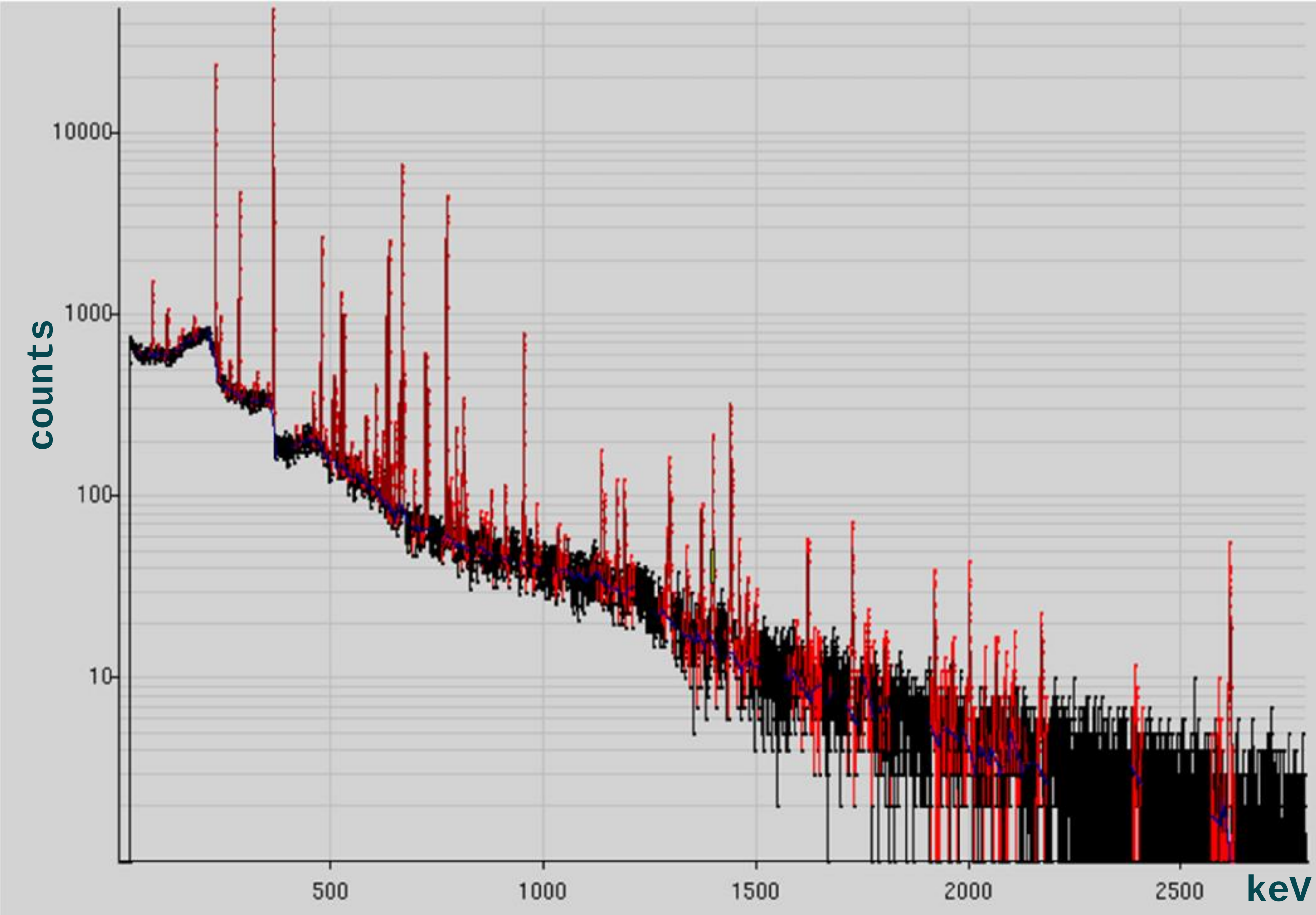


Normal sample, except small amount of I-131 detected (4 μBq/m^3)

RN60 (Petropavlovsk-Kamchatskiy Russian Federation)
Collection 14 – 15 March 2011



Nuclide	Concentration ($\mu Bq/m^3$)
Cs-134	32
Cs-136	6
Cs-137	33
I-131	3300
I-132	1500
I-133	280
La-140	5
Tc-99m	5
Te-129	11
Te-129m	116
Te-132	1285

Similar set of isotopes detected in RN38 Takasaki. Concentrations are reliable.

Multiple fission products were detected.

Nuclide Concentrations RN38 (Takasaki, Japan)

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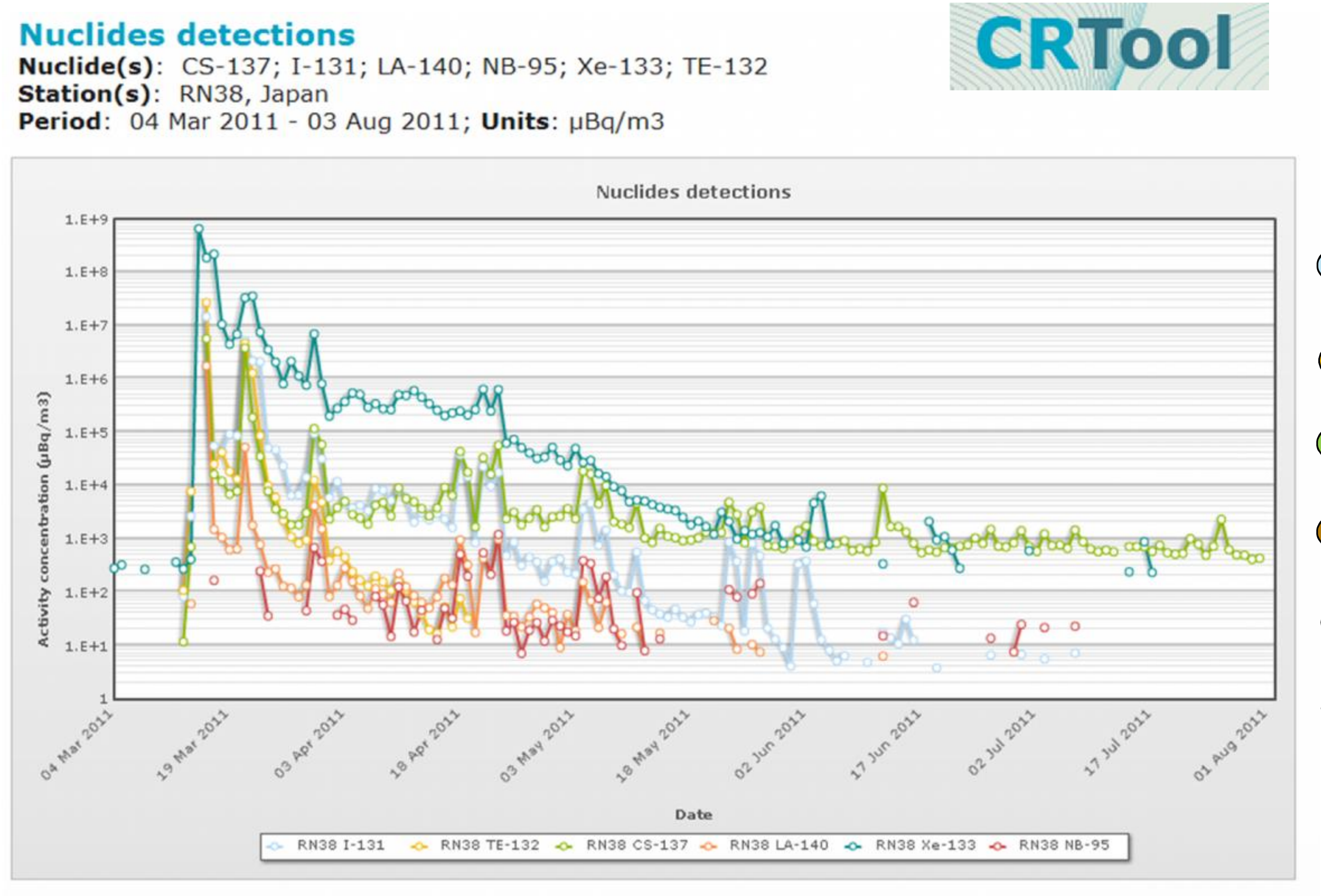

I-131

Te-132

Cs-137

La-140

Xe-133

Nb-95

The radioactivity levels detected are low in the global scale.

Xe-133 Activity Concentrations (mBq/m^3)

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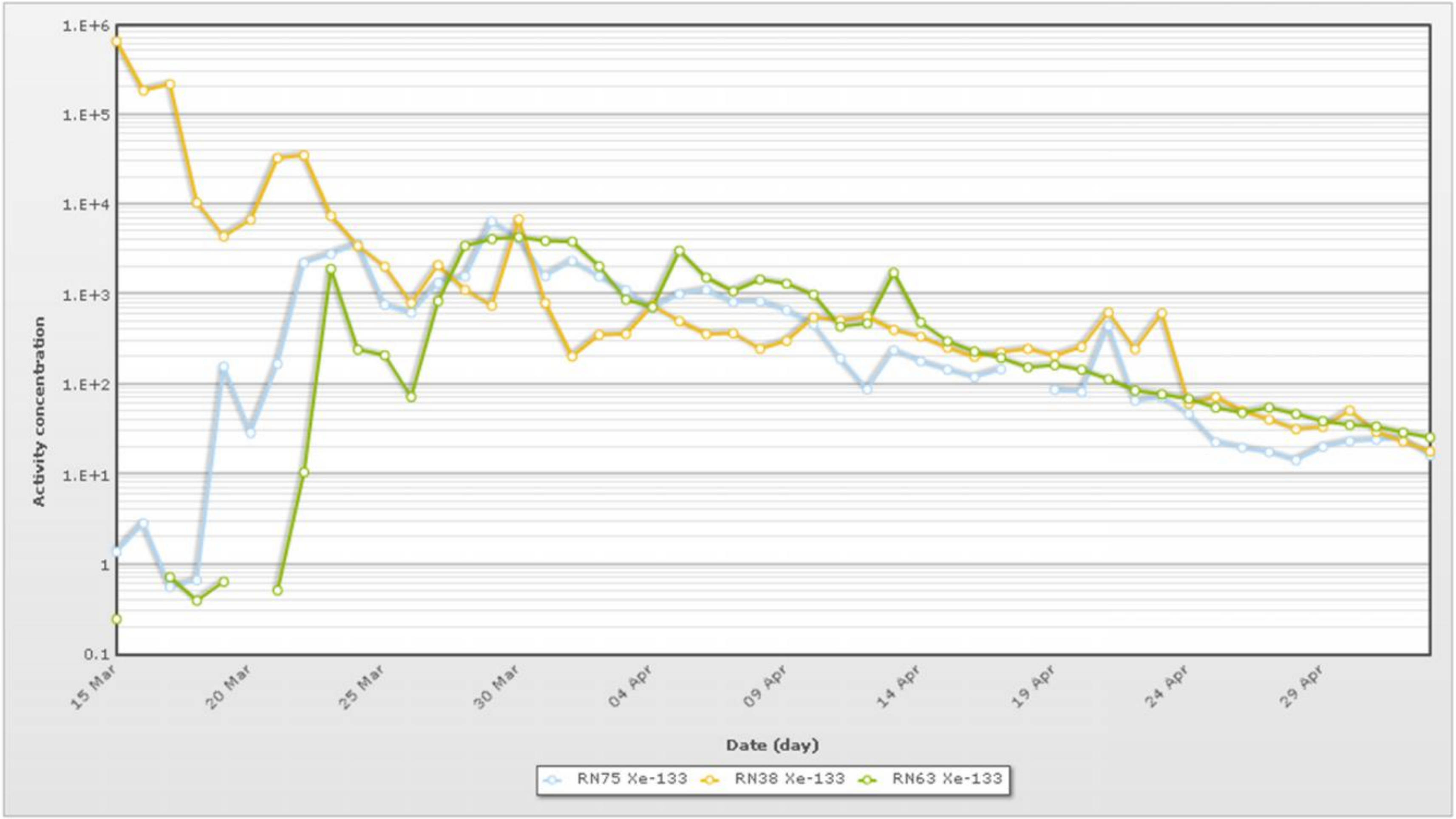
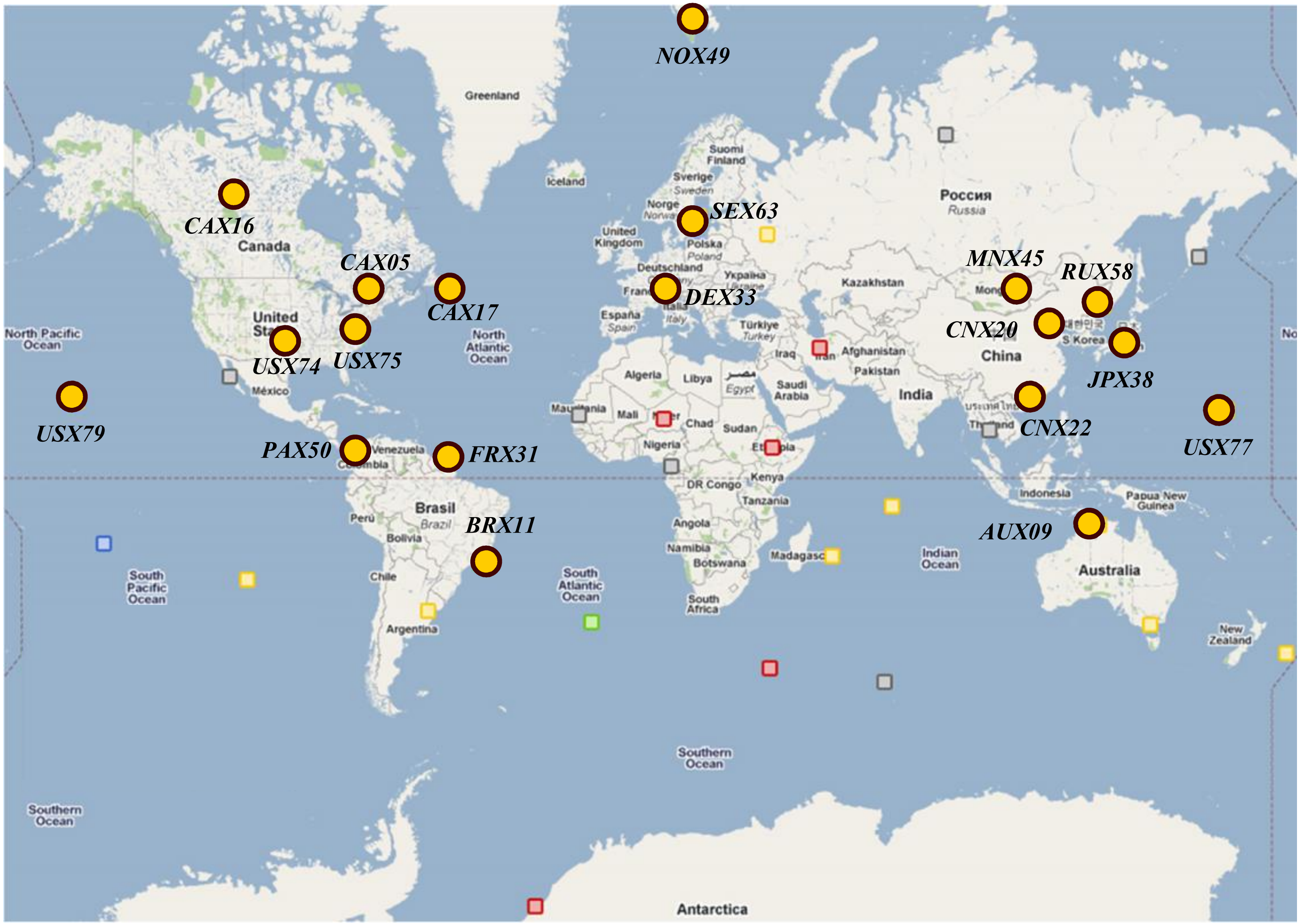


RN38, Takasaki, Japan *RN63, Stockholm, Sweden* *RN75, Charlottesville, USA*

Noble Gas Network Detections of Radioactive Xenon from Fukushima



Network data availability 85-90% (end of March to mid-April 2011)

Levels of ^{131}I Detected

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- In Japan, up to few tens of **Bq/m^3** of ^{131}I was measured.
- In stations outside Japan, the highest was up to few tens of **mBq/m^3** of ^{131}I.
- Data from the network was provided to States Signatories, which they used partly or entirely to determine risks to the public.

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Radionuclide Laboratories

Laboratory Network

Certified Lab

Non-certified Lab

CTBT Radionuclide Laboratories

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- Certified by the CTBTO Provisional Technical Secretariat (PTS) according to management and technical requirements, that are consistent with ISO/IEC 17025
- High-resolution gamma-ray spectrometry using HPGe detector for air samples (all labs)
- Radioactive xenon measurements by gamma-ray spectrometry or beta-gamma coincidence measurements (currently 6 labs).
- Certified labs are required to participate in annual Proficiency Test Exercises as part of ongoing evaluation of lab performance

Lab Re-analysis of Station Samples

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- corroborate the results of the routine analysis of a sample from a CTBTO station (radionuclide network QA/QC);
- provide more accurate and precise measurements;
- serve as back-up of a station when the measurement system of the station is malfunctioning;
- clarify the presence or absence of fission products and/or activation products in the case of a suspect or irregular analytical result from a particular station.

Summary

- The international monitoring system being established by CTBTO serves as a global deterrent against clandestine nuclear weapons testing
- Data produced by CTBTO during the Fukushima crisis were found credible and reliable and thus used by States Signatories in advising their respective governments on radiation protection implications for the public
- In collaboration with the UNESCO/IOC, the CTBTO provides real-time and continuous data to tsunami warning centres
- Radionuclide monitoring provides the forensic evidence that an explosion detected by the waveform technologies is nuclear in nature.
- Radionuclide laboratories provide accurate, confirmatory measurements and contribute significantly to the data quality of the radionuclide network.
- Instrumental methods of analysis, i.e., high-resolution gamma-ray spectrometry using high-purity germanium detector, is used for radionuclide monitoring to identify nuclides and measure their activity concentrations in air. This application demonstrates that chemistry does contribute to a safer and more secure world!

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Thank you!