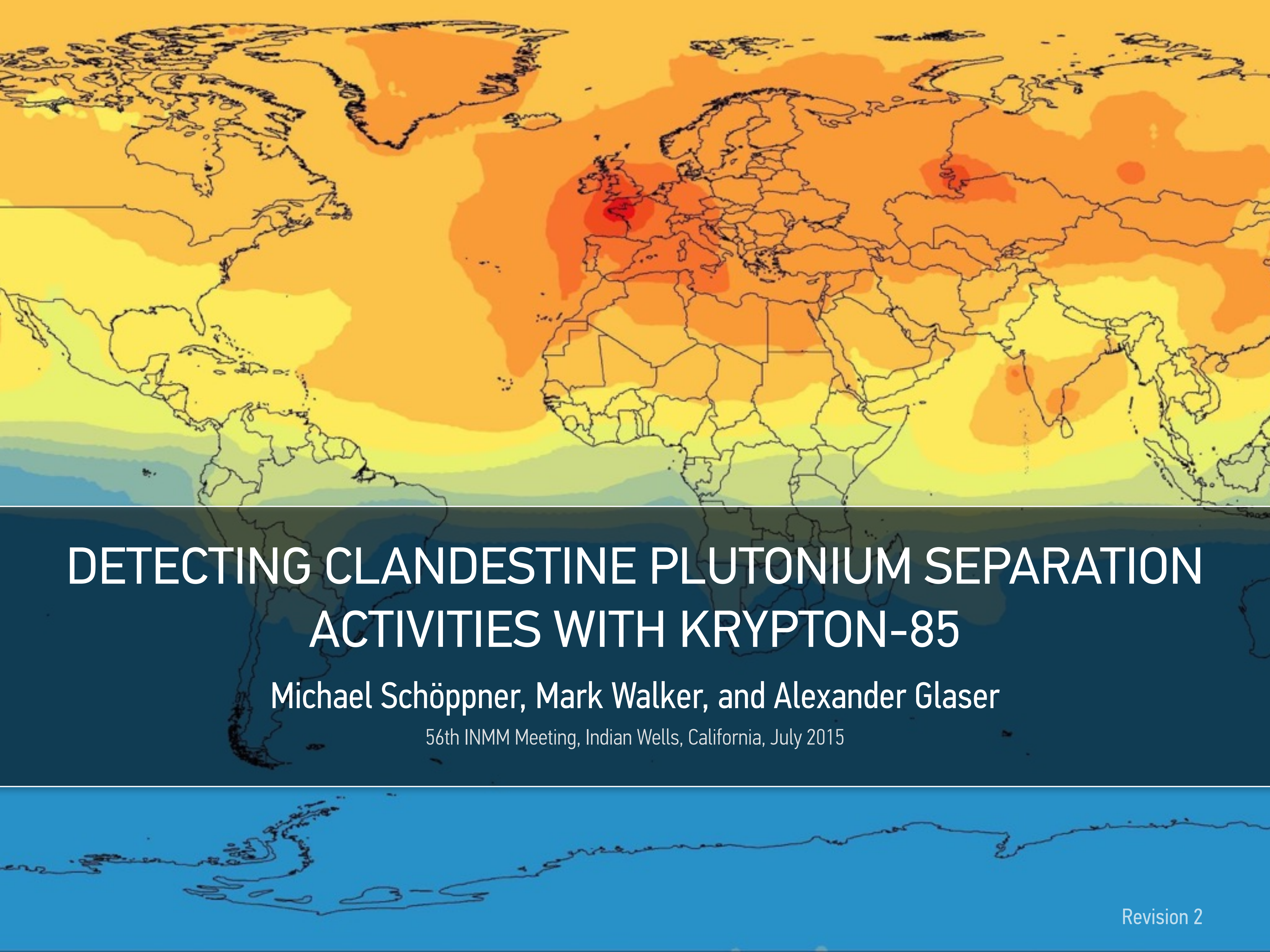


DETECTING CLANDESTINE PLUTONIUM SEPARATION ACTIVITIES WITH KRYPTON-85

Michael Schöppner, Mark Walker, and Alexander Glaser

56th INMM Meeting, Indian Wells, California, July 2015

Revision 2

BACKGROUND AND MOTIVATION

DETECTING CLANDESTINE SEPARATION OF PLUTONIUM

- Precedents exist for attempts to make plutonium in undeclared facilities
- Concern of "Simple, Quick Processing Plant" (Oak Ridge, 1977)
- Challenge for NPT verification; also relevant for future FMCT verification
- Atmospheric (krypton) sampling appears most promising ("STR-321")

FINDINGS AND RECOMMENDATIONS FROM "STR-321" (1996–1998)

- The cost of operating a WAES network "could be high and would be strongly dependent on: the type of facility ...; the target region to be covered; and the acceptable probability of detection and false alarm rate"
- Recommended additional work includes: "Refining evaluation of the variability in background levels of target signatures"

Ned Wogman, *History of STR 321: IAEA Use of Wide Area Environmental Sampling In the Detection of Undeclared Nuclear Activities (1996–1998 Multi-country Effort),* PNNL-SA-75565, November 2010

BASIC CHALLENGE

AN AIR-SAMPLE IS TAKEN SOMEWHERE ON THE GLOBE:

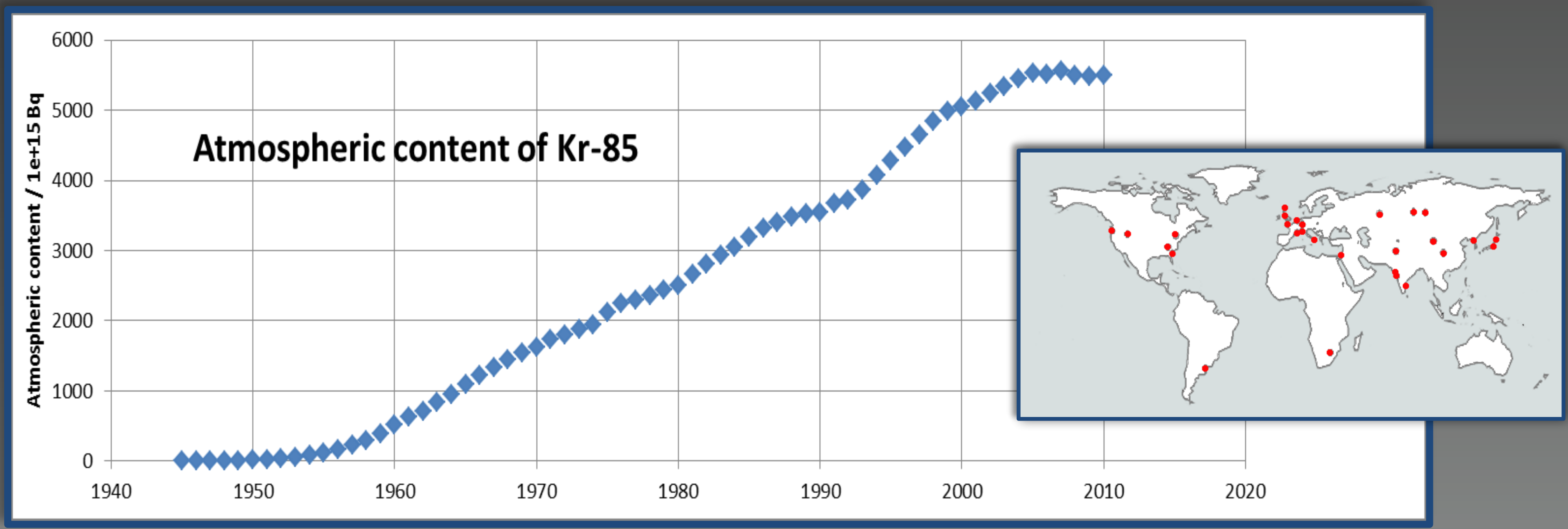
IS THE MEASURED KR-85 CONCENTRATION
FROM A KNOWN OR FROM AN UNKNOWN PLANT?

CHARACTERIZING THE GLOBAL KRYPTON BACKGROUND

CHARACTERIZING THE GLOBAL KRYPTON-85 BACKGROUND

PART 1: HISTORIC BASELINE

70 years of nuclear fuel reprocessing, 10.7-year half life (compare to Xenon-133, 5.2 days)

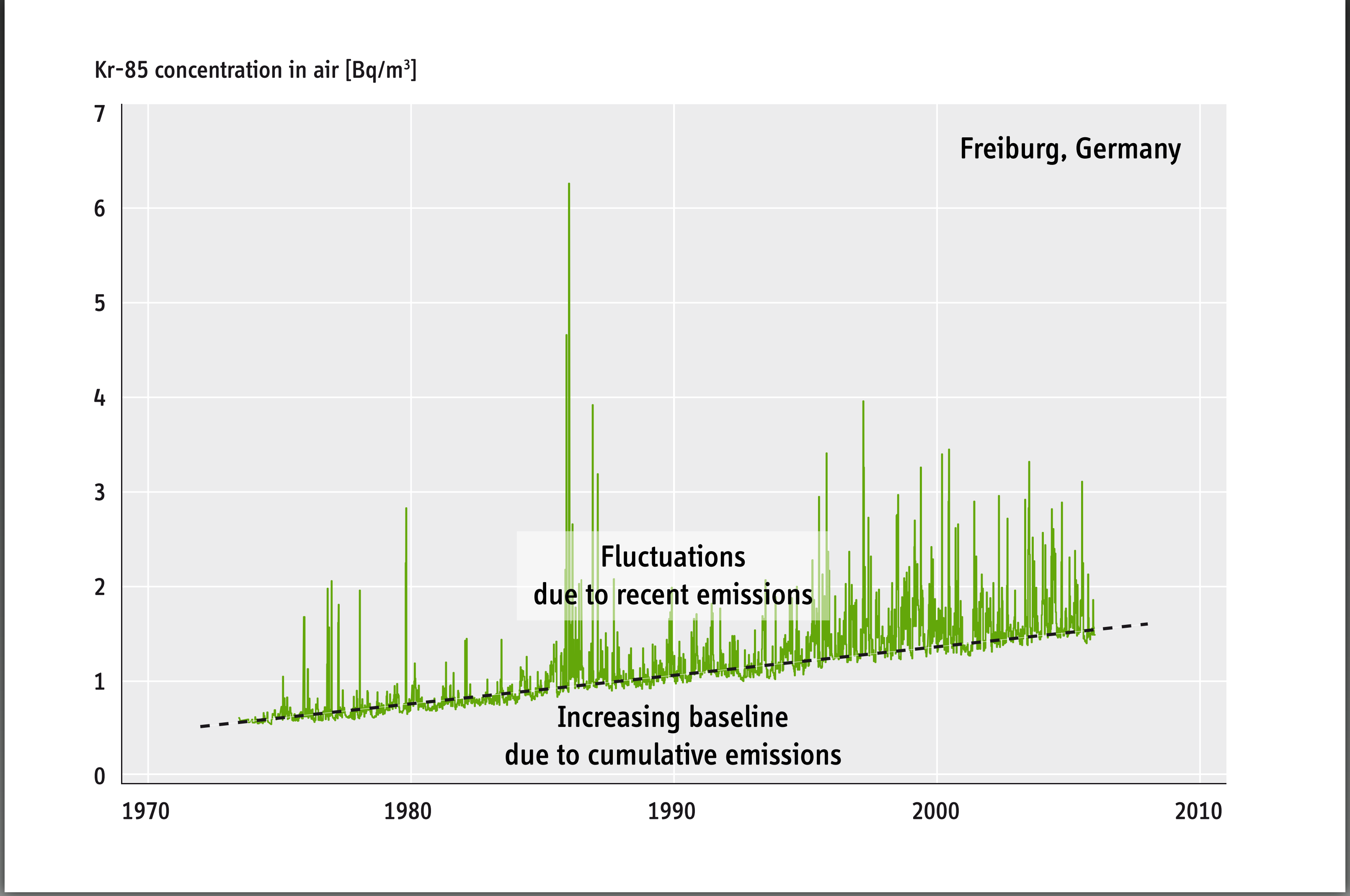


Background today: ≈1.5 Bq/m³ in the Northern Hemisphere and ≈ 1.3 Bq/m³ in the Southern Hemisphere)

Jens Ole Ross, *Simulation of Atmospheric Krypton-85 Transport to Assess the Detectability of Clandestine Nuclear Reprocessing*
PhD Thesis, University of Hamburg, February 2010

CHARACTERIZING THE GLOBAL KRYPTON BACKGROUND

PART 2: EMISSIONS FROM DECLARED REPROCESSING PLANTS



Martin B. Kalinowski and R. Scott Kemp, "Detection of Clandestine Fissile Material Production"
Chapter 9 in G*lobal Fissile Material Report 2007,* International Panel on Fissile Materials, Princeton, NJ, October 2007

SIMULATING EMISSIONS FROM KNOWN FACILITIES

LACK OF LIVE STACK EMISSION DATA:
ASSUME CONTINUOUS EMISSIONS FROM TEN REPROCESSING FACILITIES ACTIVE IN 2010

Country	Facility	LAT	LON	Emissions
China	Lanzhou	36.2	103.5	2.24E+14 Bq/a
France	La Hague	49.4	−1.5	2.26E+17 Bq/a
India	Kalpakkam	12.3	80.1	1.12E+16 Bq/a
India	Trombay	19.0	72.6	8.00E+15 Bq/a
Israel	Dimona	31.0	35.1	5.76E+14 Bq/a
Japan	Tokai	36.3	140.4	1.00E+15 Bq/a
Pakistan	Nilore	33.4	73.2	1.92E+14 Bq/a
Russia	Mayak	55.4	60.1	4.86E+16 Bq/a
Russia	Zheleznogorsk	56.2	93.4	1.00E+16 Bq/a
United Kingdom	Sellafield	54.3	−3.3	4.53E+16 Bq/a

Facility list based on *Global Fissile Material Report 2013,* International Panel on Fissile Materials, Princeton, NJ, October 2013

MODELING APPROACH

CODE

Flexpart (FLEXible PARTicle dispersion model) v8.2.3

www.flexpart.eu

DATA

National Centers for Environmental Prediction (NCEP) meteorological data

www.ncep.noaa.gov

0.5 degree x 0.5 degree resolution (about 260,000 gridpoints)

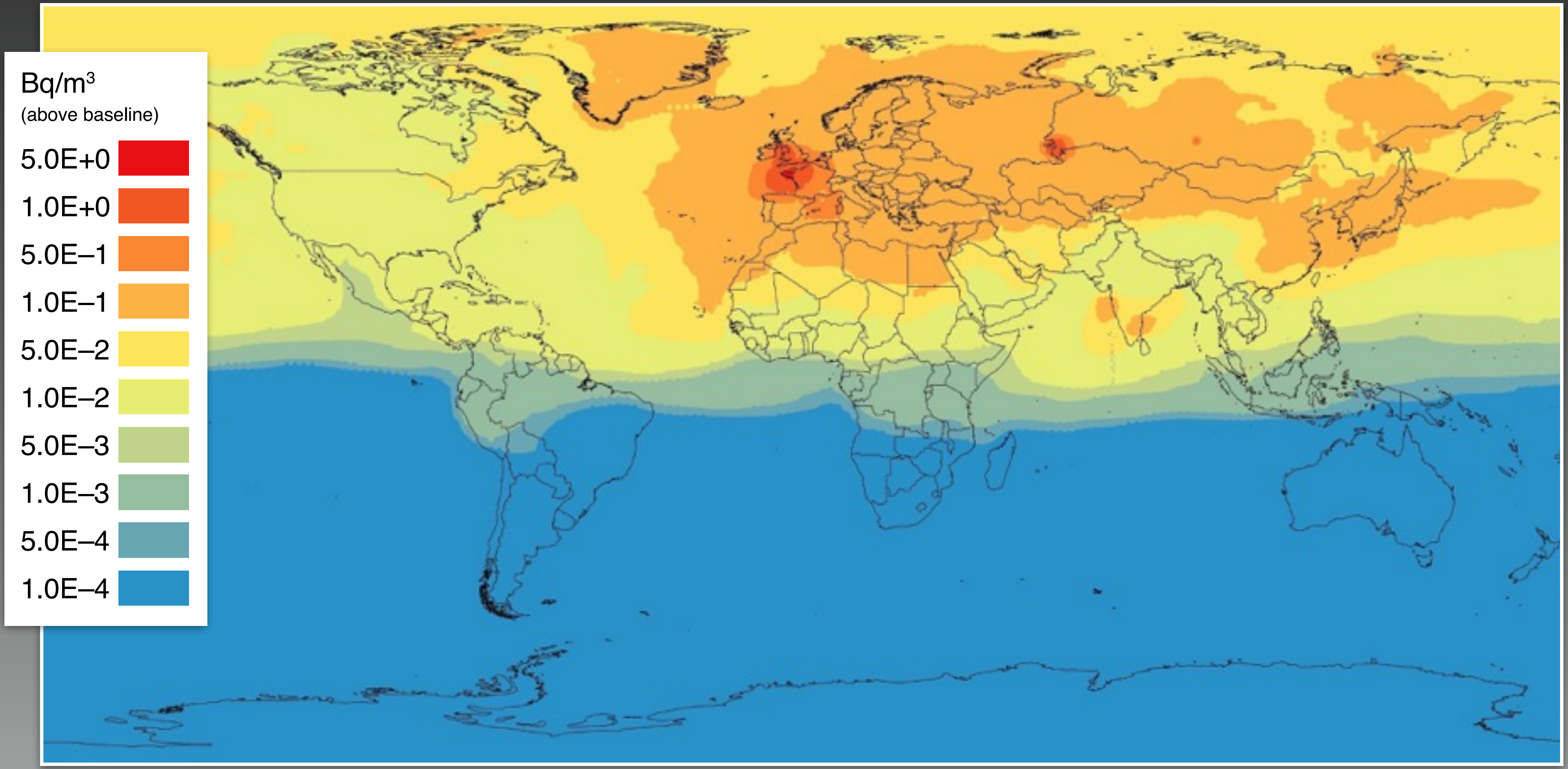
2010, day-by-day emissions from ten plants, all tracked for four weeks

(At that point, puff effectively disappear in the background)

RESULTS

GLOBAL KRYPTON-85 VARIABILITY

$\mu_1 + \sigma_1 \approx 84.1\%$ of local samples are within indicated upper concentration limit <u>above</u> (quasi-constant) baseline μ_0

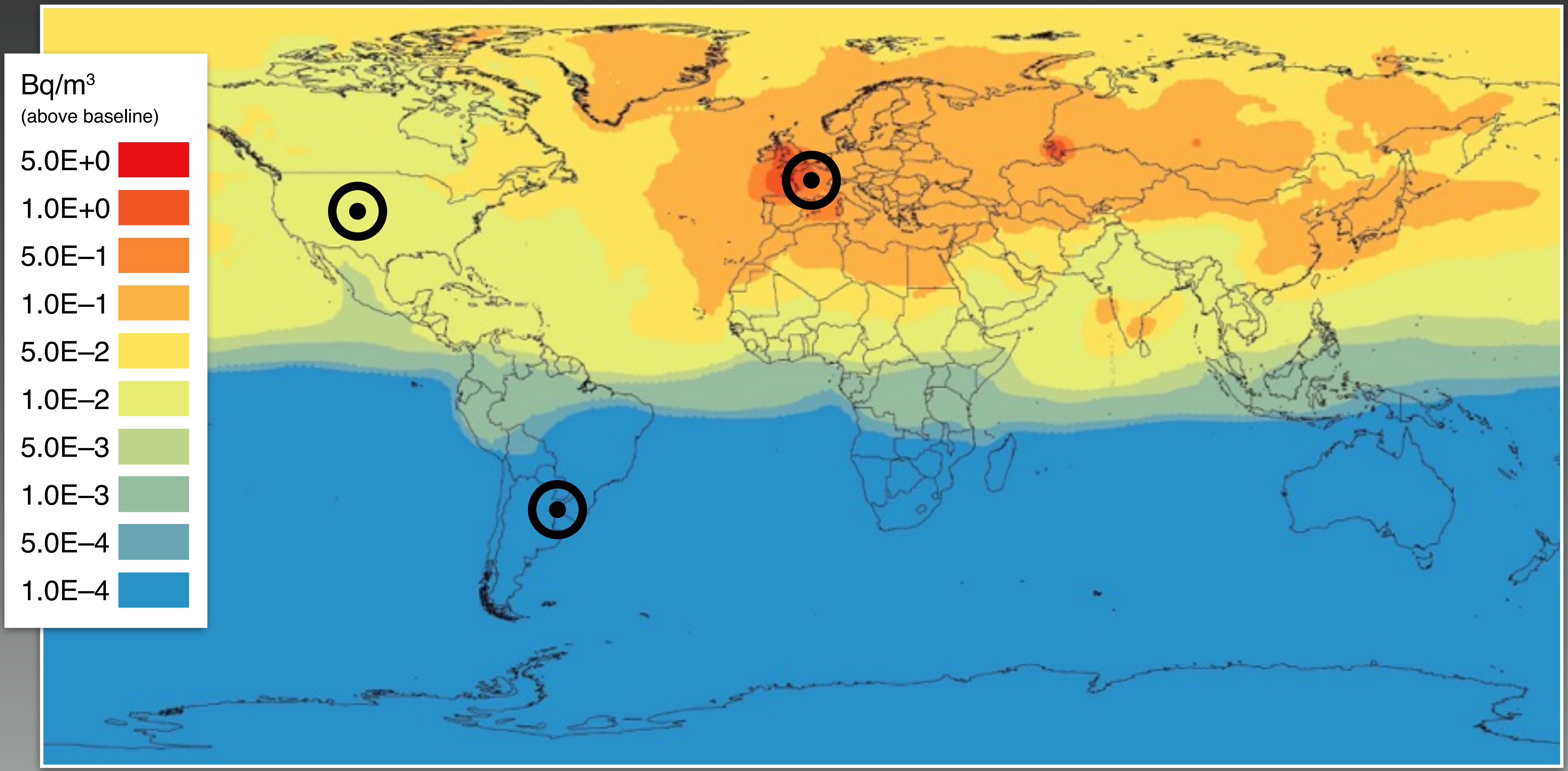


SCENARIOS

RANDOMLY-PLACED UNDECLARED REPROCESSING PLANTS
(IN AREAS WITH LOW, MEDIUM, AND HIGH LOCAL KRYPTON VARIABILITY)

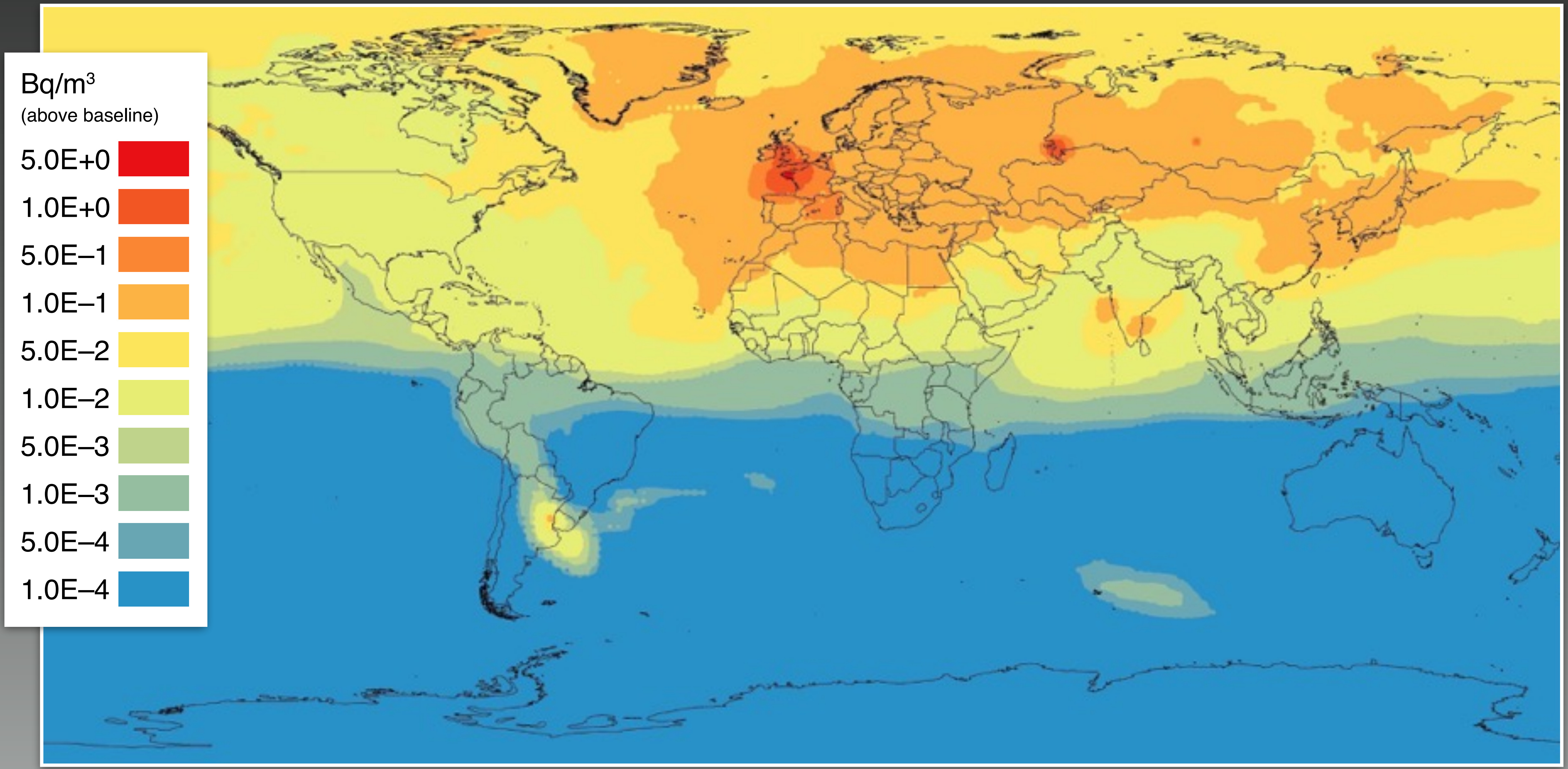
RANDOMLY-PLACED FICTIONAL REPROCESSING PLANTS

(IN AREAS WITH LOW, MEDIUM, AND HIGH LOCAL KRYPTON VARIABILITY)



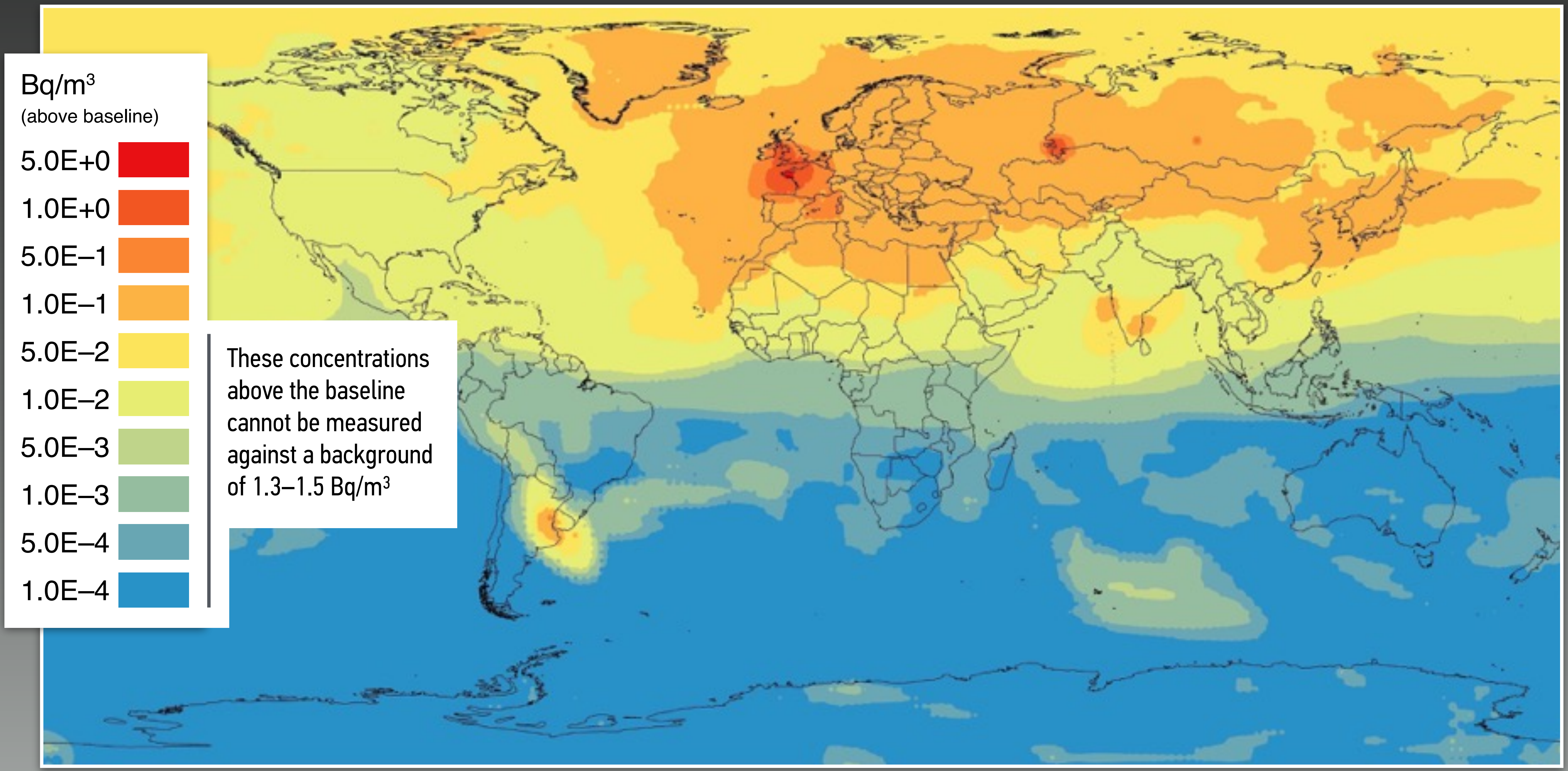
LOW-VARIABILITY SCENARIO

FICTIONAL PLANT IN SOUTH AMERICA
SEPARATING 8 KG OF PLUTONIUM PER MONTH



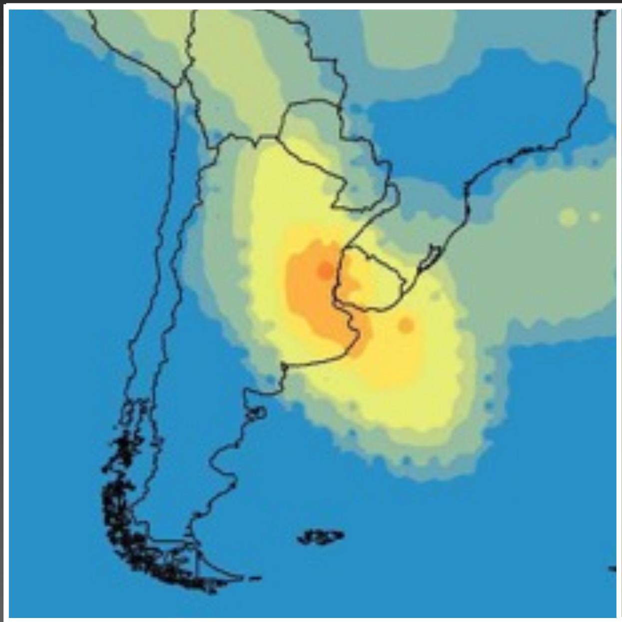
LOW-VARIABILITY SCENARIO

FICTIONAL PLANT IN SOUTH AMERICA
SEPARATING 8 KG OF PLUTONIUM PER WEEK



LOW-VARIABILITY SCENARIO

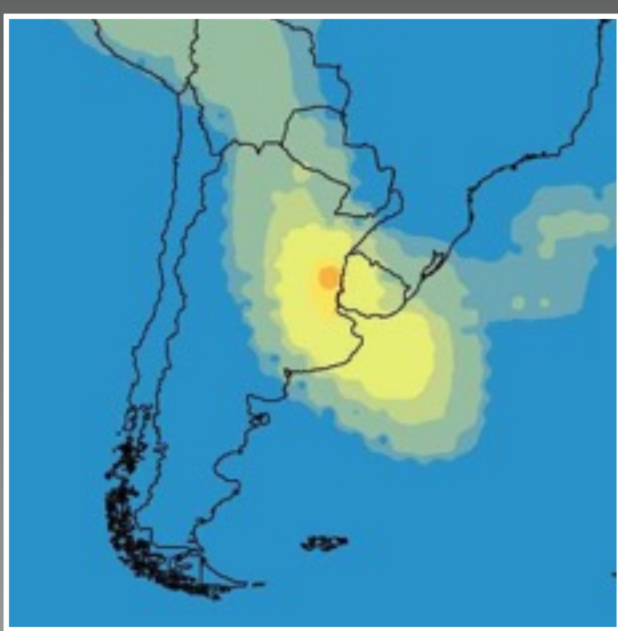
ANALYSIS



PLANT SEPARATING 8 KG PER WEEK (c. 40 tHM/yr)

Earth's landmass: 149,000,000 km^2
Region of detectable emission signature: about 175,000 km^2
About 0.1% of landmass

Detection probability for 1000 random samples: $1 - 0.999^{1000} \approx 63\%$
Detection probability for 100 random samples: $1 - 0.999^{100} \approx 10\%$



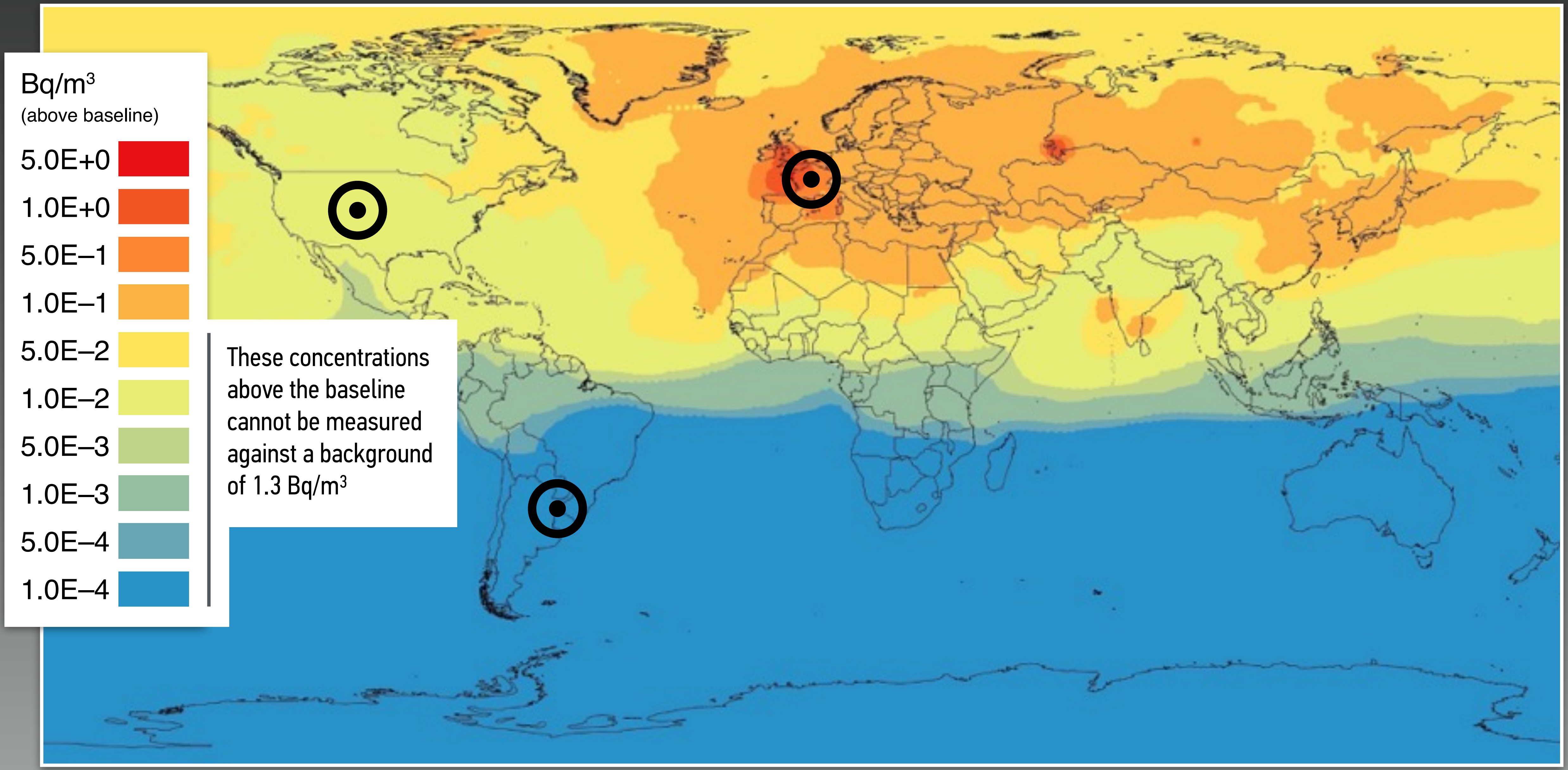
PLANT SEPARATING 8 KG PER MONTH (c. 10 tHM/yr)

Earth's landmass: 149,000,000 km^2
Region of detectable emission signature: about 25,000 km^2
Less than 0.02% of landmass

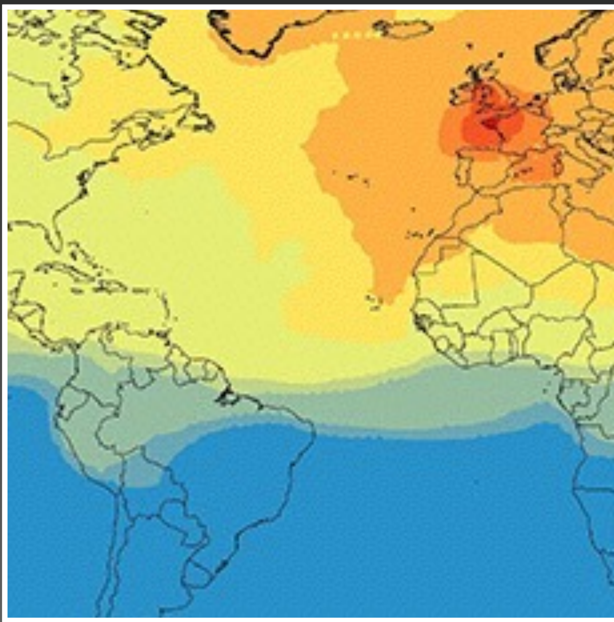
Detection probability for 1000 random samples: $1 - 0.9998^{1000} \approx 15\%$
Detection probability for 100 random samples: $1 - 0.9998^{100} < 2\%$

RANDOMLY-PLACED FICTIONAL REPROCESSING PLANTS

(IN AREAS WITH LOW, MEDIUM, AND HIGH LOCAL KRYPTON VARIABILITY)



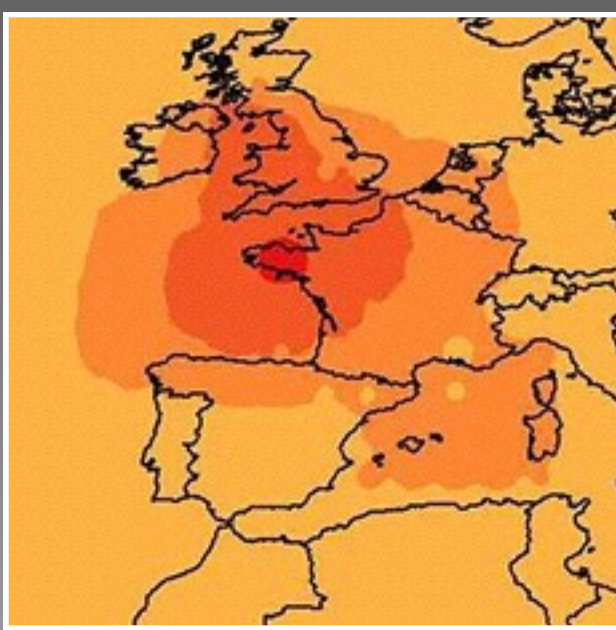
SUMMARY AND FINDINGS



WHAT WAS NEW HERE ?

Decomposition of krypton background into two components (historic baseline + daily emissions from operational reprocessing plants) allows for new, efficient modeling technique

Updated map of global krypton variability



FINDINGS

Northern Hemisphere: Detectability of clandestine facilities inhibited by variability of background due to ongoing emissions from existing reprocessing plants (not only in Europe!)

Everywhere: Fixed (ground-based) monitoring network most likely impractical due to high krypton-85 baseline; mobile options could be more useful

WHAT COULD BE DONE?

OPTIONS TO IMPROVE THE VALUE OF WIDE-AREA KRYPTON MONITORING

1. DAILY DECLARATIONS OF STACK EMISSION DATA

This would significantly improve the value of atmospheric modeling, especially in the Northern Hemisphere, to correlate detected peaks with declared emissions — and to isolate “unaccounted” peaks

2. STOP KRYPTON-85 EMISSIONS INTO THE ATMOSPHERE

- Cryogenic removal of krypton-85 prior to emission

  Stabilizes krypton-85 inventory; quick die-away of fluctuations in baseline
  Technologies for efficient krypton removal exist, but are expensive

- Ending reprocessing altogether would be equivalent

For illustration purposes only; Source: www.vrv.com