

Fukushima: the crisis continues

Dr Ian Fairlie
Consultant on Radiation in the Environment
London, United Kingdom
www.ianfairlie.com



Tsunami hits Fukushima



Tsunami floods Fukushima



March 12: Explosion at Unit 1



March 14 – Explosion at Unit 3



plus 2 more explosions

- On March 15, at 06.10 am, “explosive event” in fuel pond at unit 2, followed seconds later by “explosive event” in spent fuel pond at unit 4, then a fire
- On March 16 at 05.45 am, a major explosion at Unit 4
- No TV video footage as explosions occurred early in the mornings

Damage to Reactors 4,3,2,1



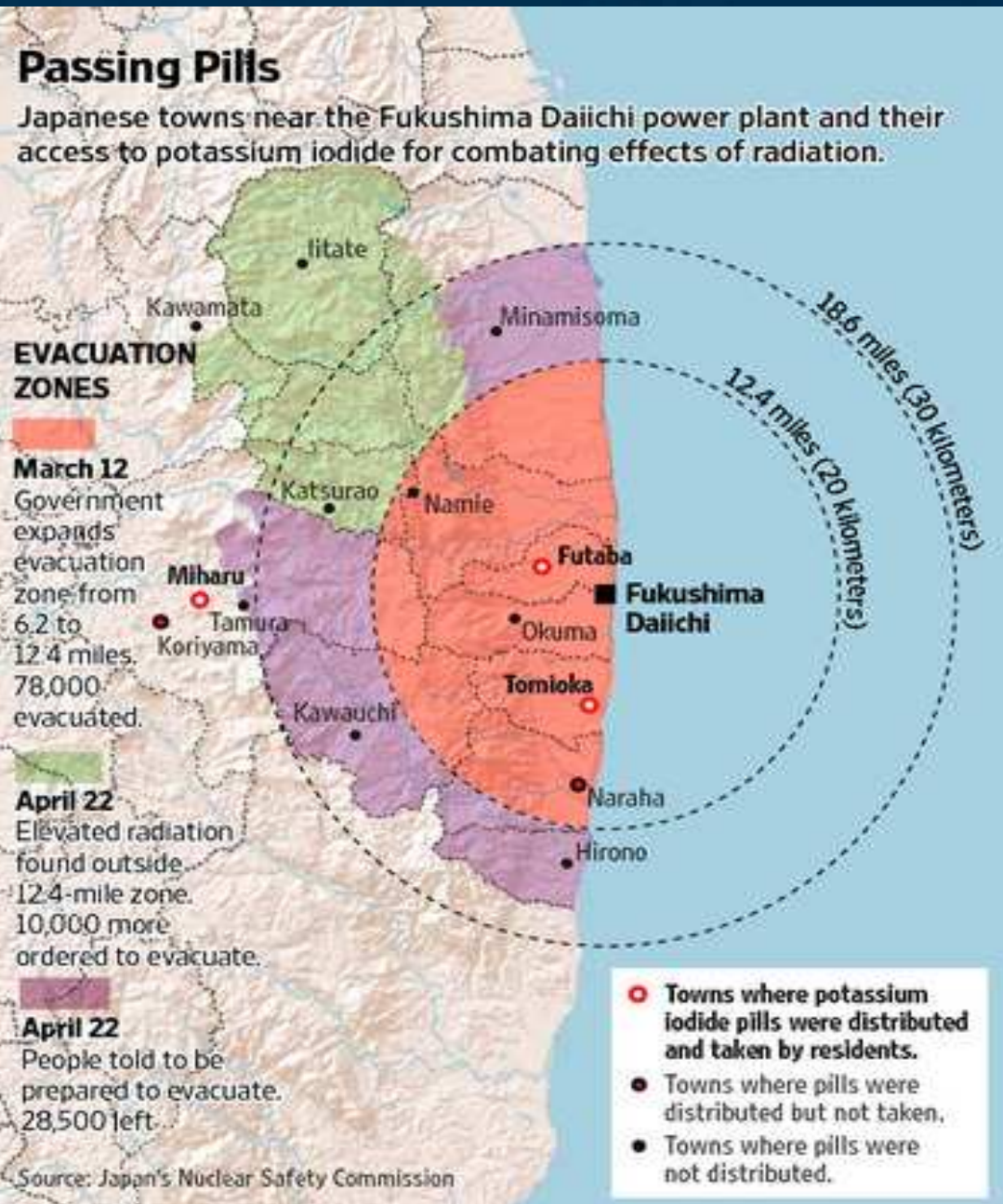
Damage to Units 4,3



What happened

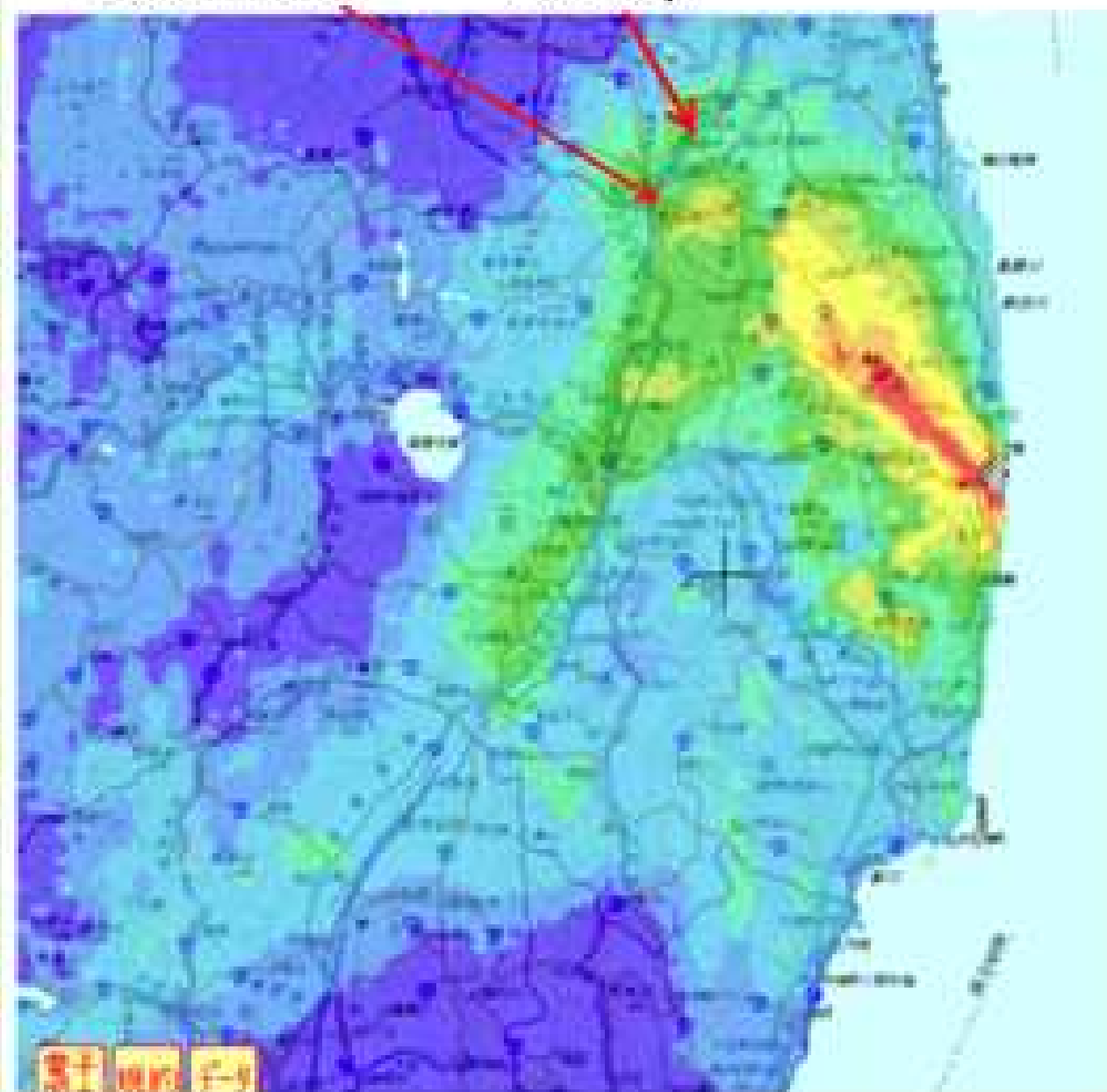
- **four explosions** destroyed the reactors of Units 1, 2, 3, and the spent fuel pond of Unit 4;
- spent fuel stored in Units 1–4 pools overheated as water levels dropped; fuel **fire** at Unit 4 pool
- **three core meltdowns** in reactors 1, 2, 3
- 7 workers/soldiers **killed** by the explosions
- many more workers suffered high radiation **exposures** and had to be evacuated;
- ~140,000 civilians **evacuated**

Evacuation Areas

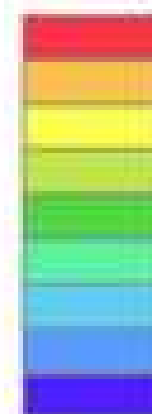


Fukushima city

Kouri city



$\mu\text{Sv/hr}$



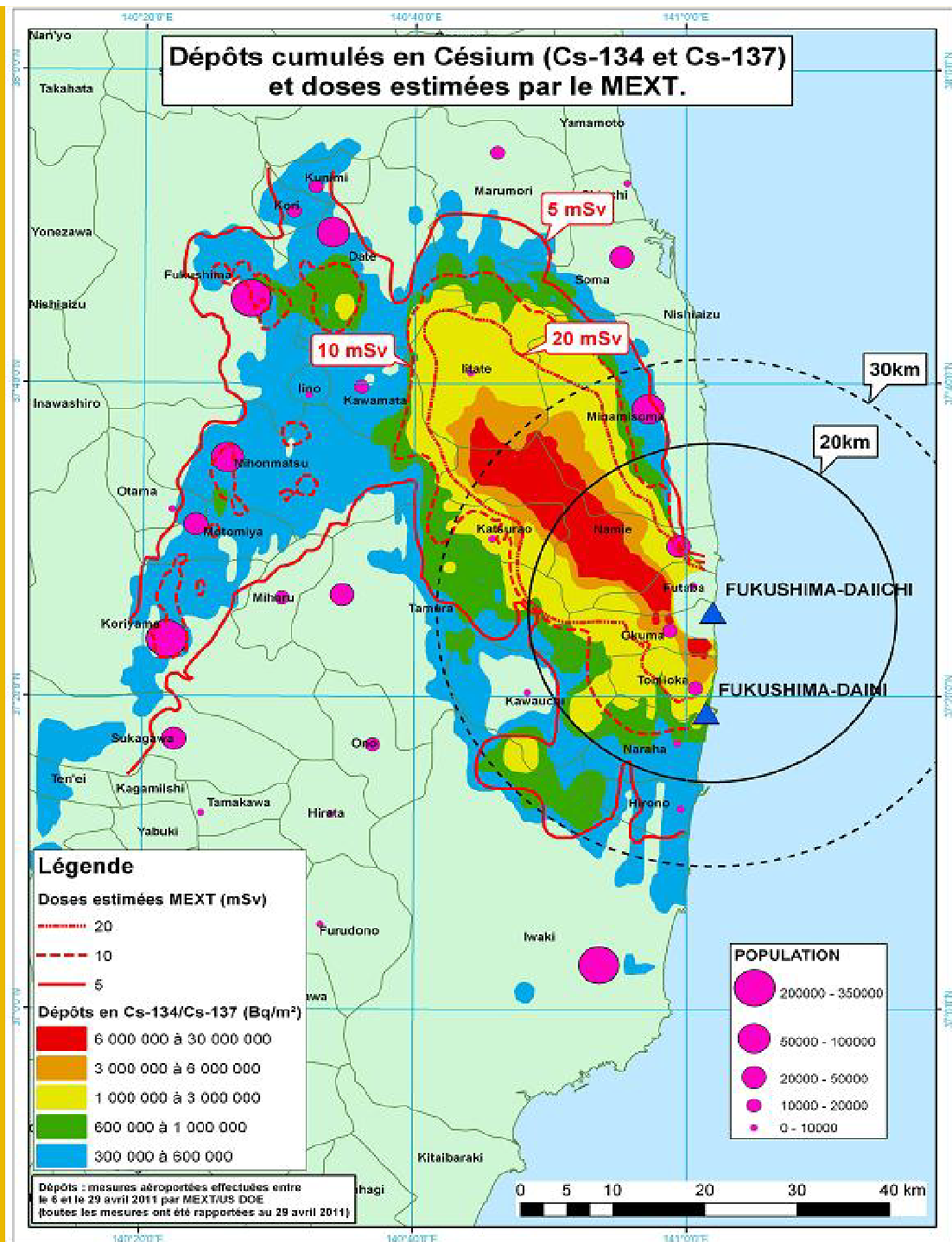
19.0
9.5
3.8
1.9
1.0
0.5
0.2
0.1

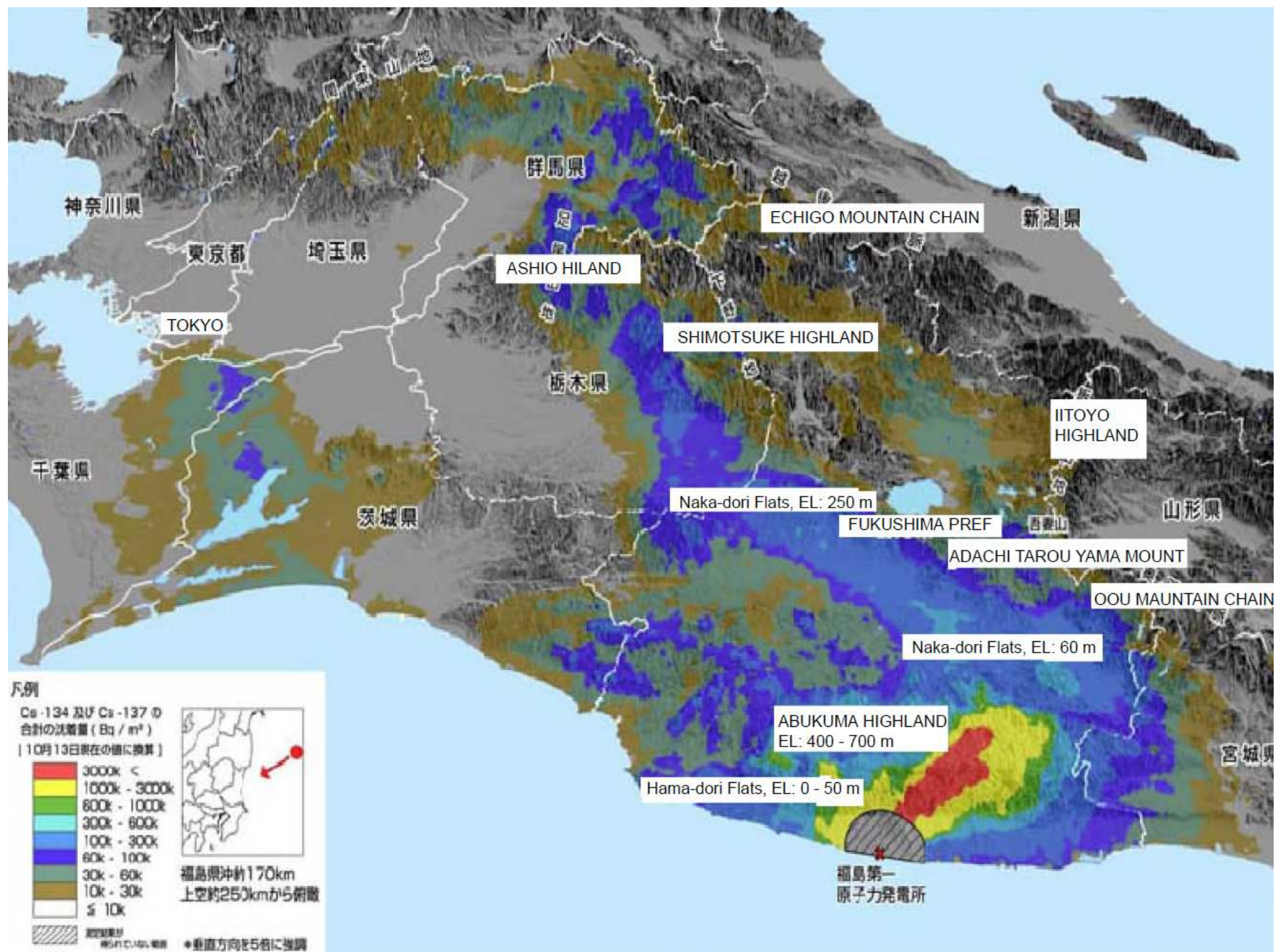
≦ 19.0
≦ 9.5
≦ 3.8
≦ 1.9
≦ 1.0
≦ 0.5
≦ 0.2
≦ 0.1

$\mu\text{Sv/hr}$ → mSv/year

9.5	50
3.8	20
1.9	10
1.0	5
0.5	2.5
0.2	1
0.1	0.5

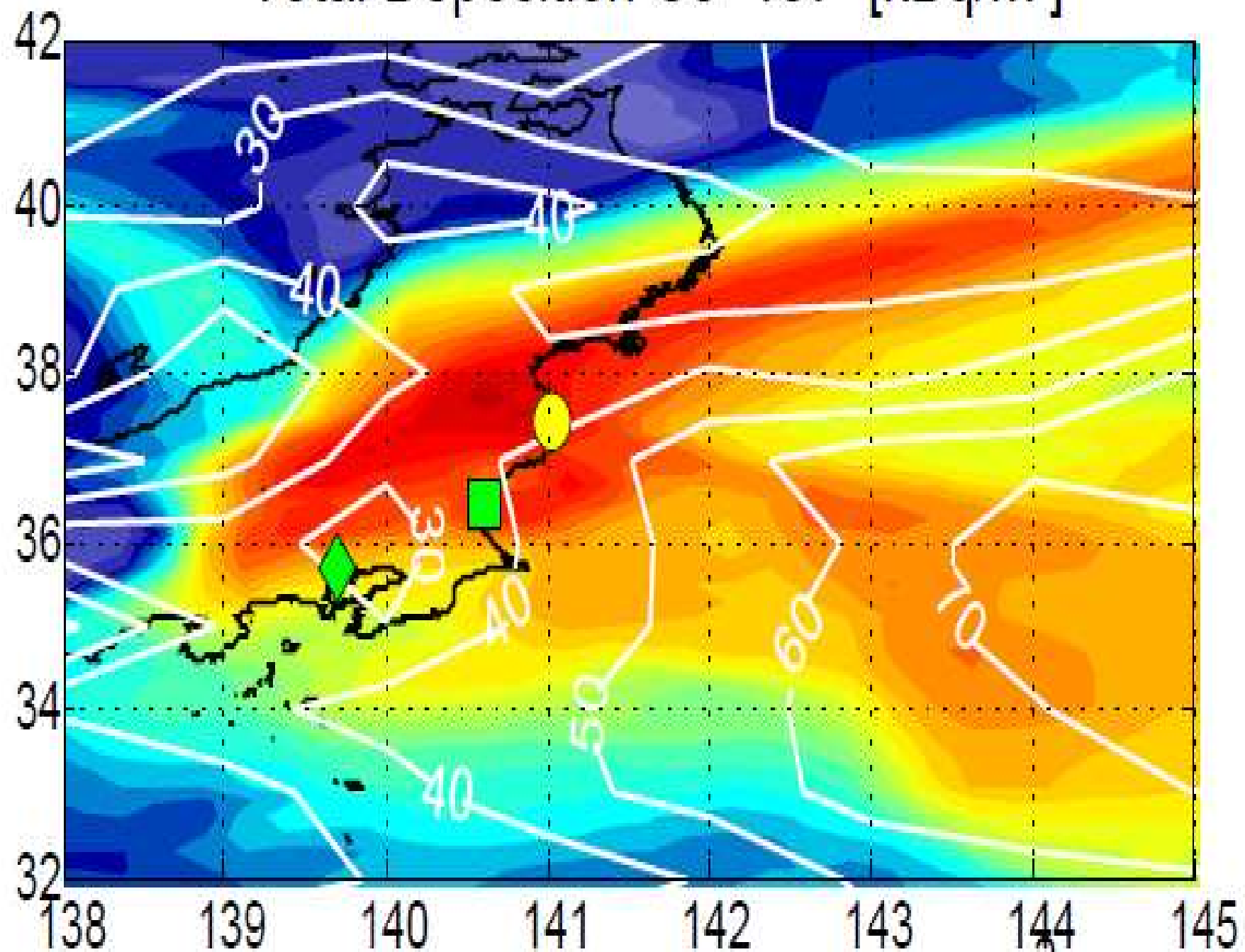
2011 Nov 5th



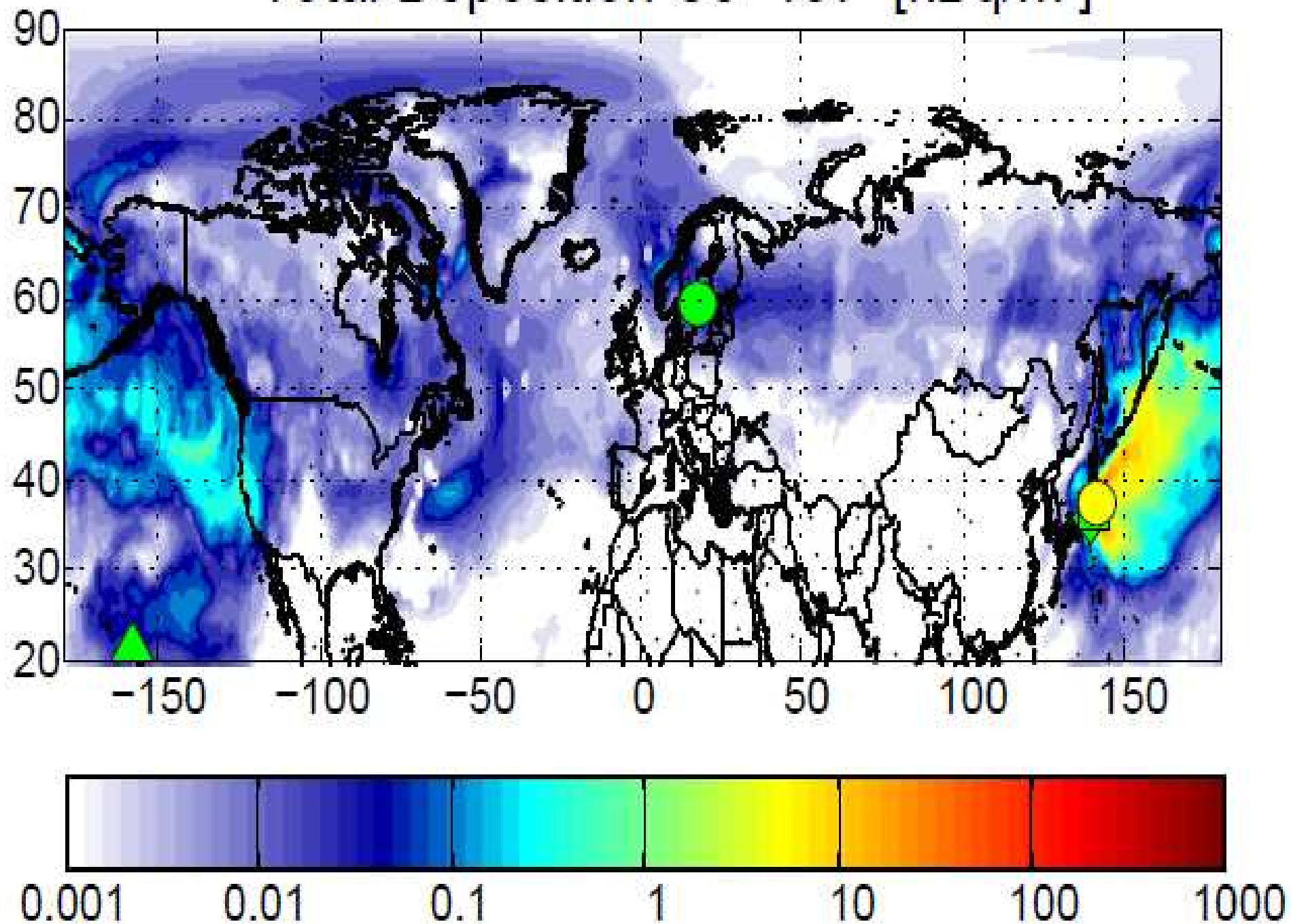


<http://www.youtube.com/v/nQ6lCR71Yik>

Total Deposition Cs-137 [kBq/m²]



Total Deposition Cs-137 [kBq/m²]



FUKUSHIMA - present situation

- Ongoing leaks of contaminated water from reactors to ground and ocean (new well = 54 kBq/L Cs-137 and 22 kBq/L Cs-134) = 600 x Japanese limit for Cs-137 to ocean
http://www3.nhk.or.jp/nhkworld/english/news/20140213_22.html
- unresolved = how to reliably store huge volumes of contaminated water
- massive radioactive wastes produced by decontamination
- plight of ~140,000 evacuees, 12,000 workers
- many exposed to <250 mSv
- Whereabouts of melted reactor cores
- spent fuels in v precarious ponds
- thousands of km² contaminated for many decades

Tanks at Fukushima









300 TONS

of radioactive isotope-contaminated water
is estimated to be leaking into the Pacific-ocean
from the damaged Fukushima power plant every day.

137

Cs

55

Cesium-137

HALF-LIFE: 30.17 yrs

- Enters the environment only from man-made nuclear activities.
- Exposure to radiation results in an increased risk of cancer.

90

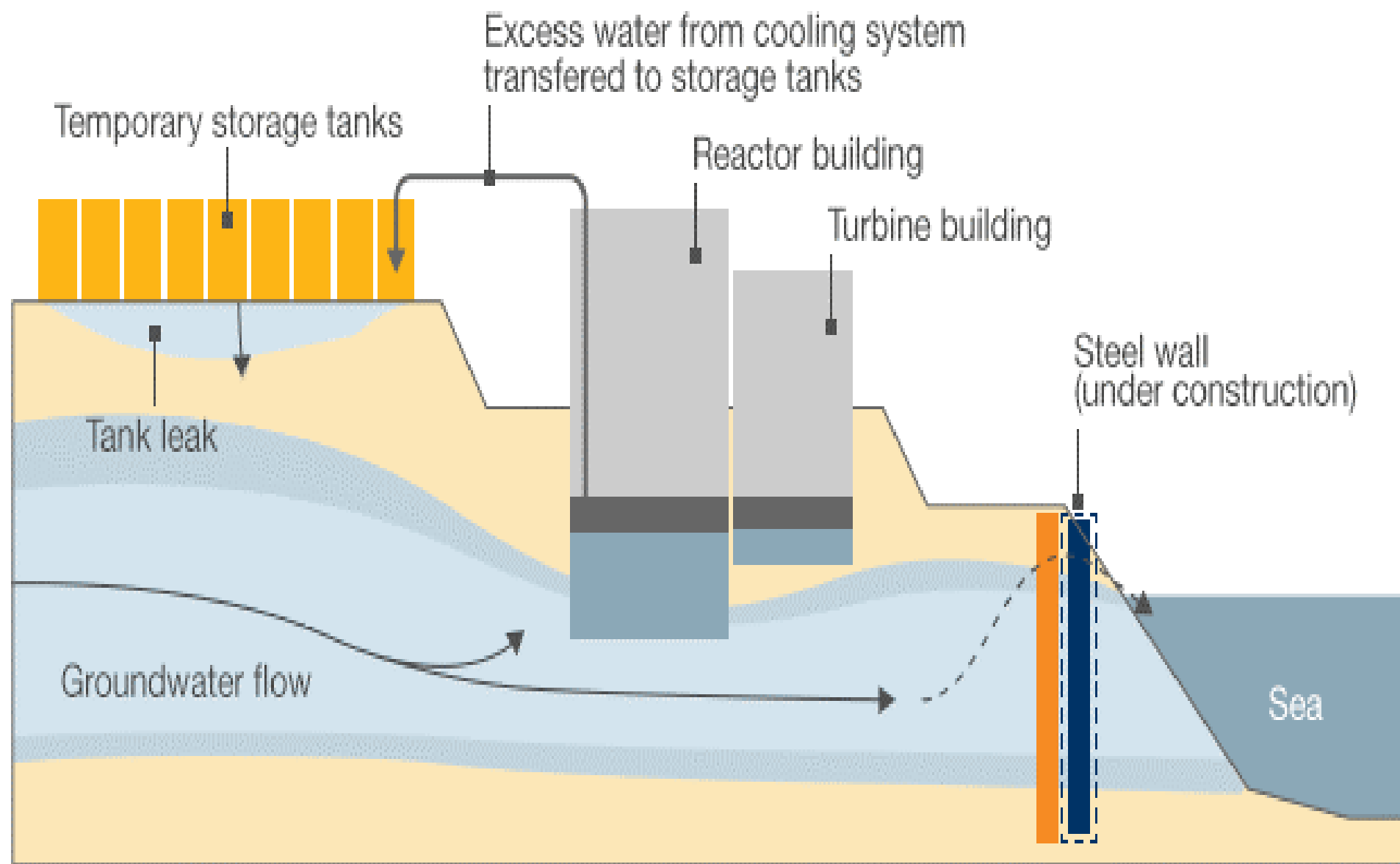
Sr

Strontium-90

HALF-LIFE: 28.8 YRS

- Extremely damaging to your health, as it's difficult to get rid of the body
- Strontium-90 is linked to bone cancer and leukemia.

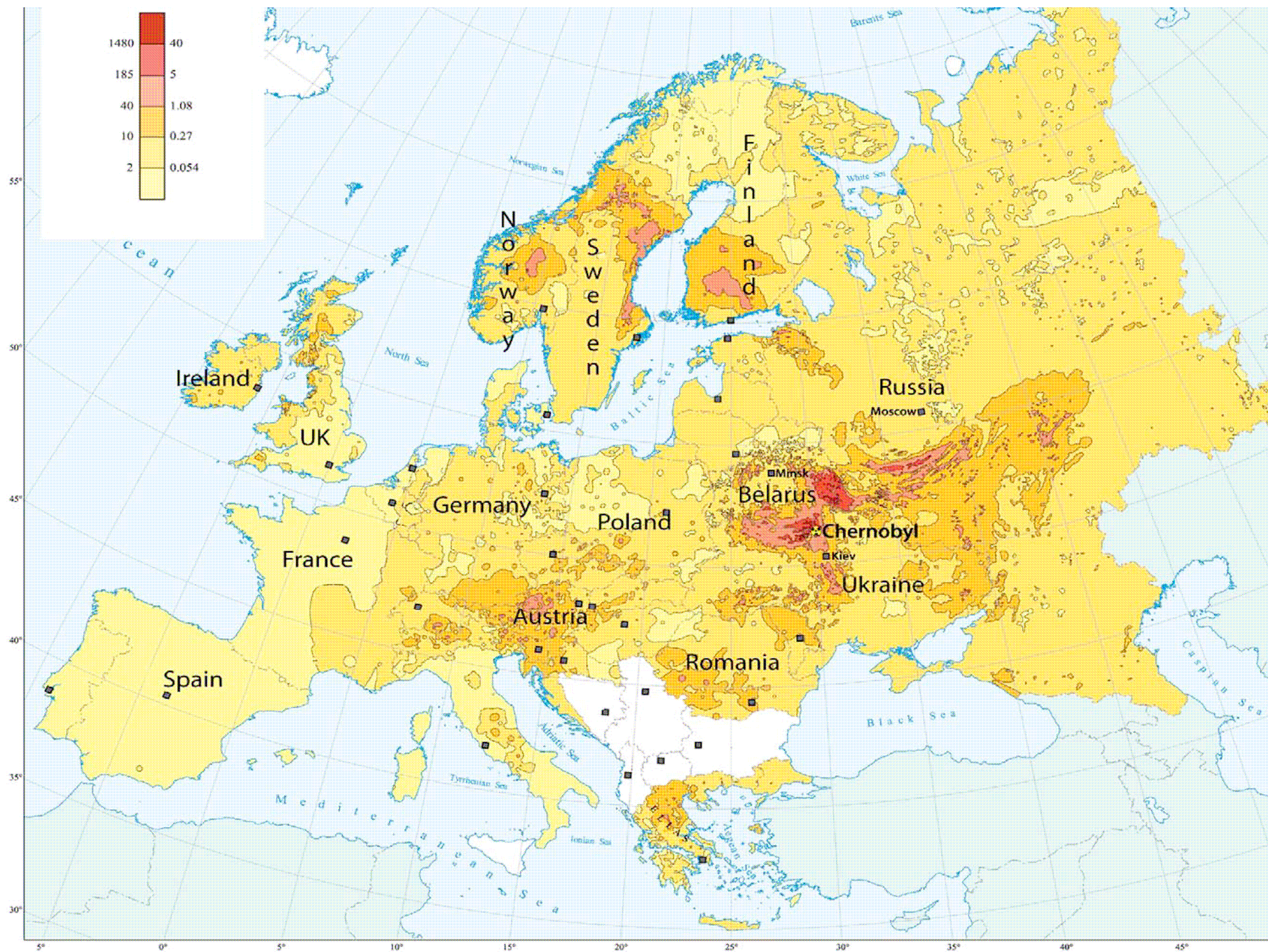
Groundwater contamination at Fukushima

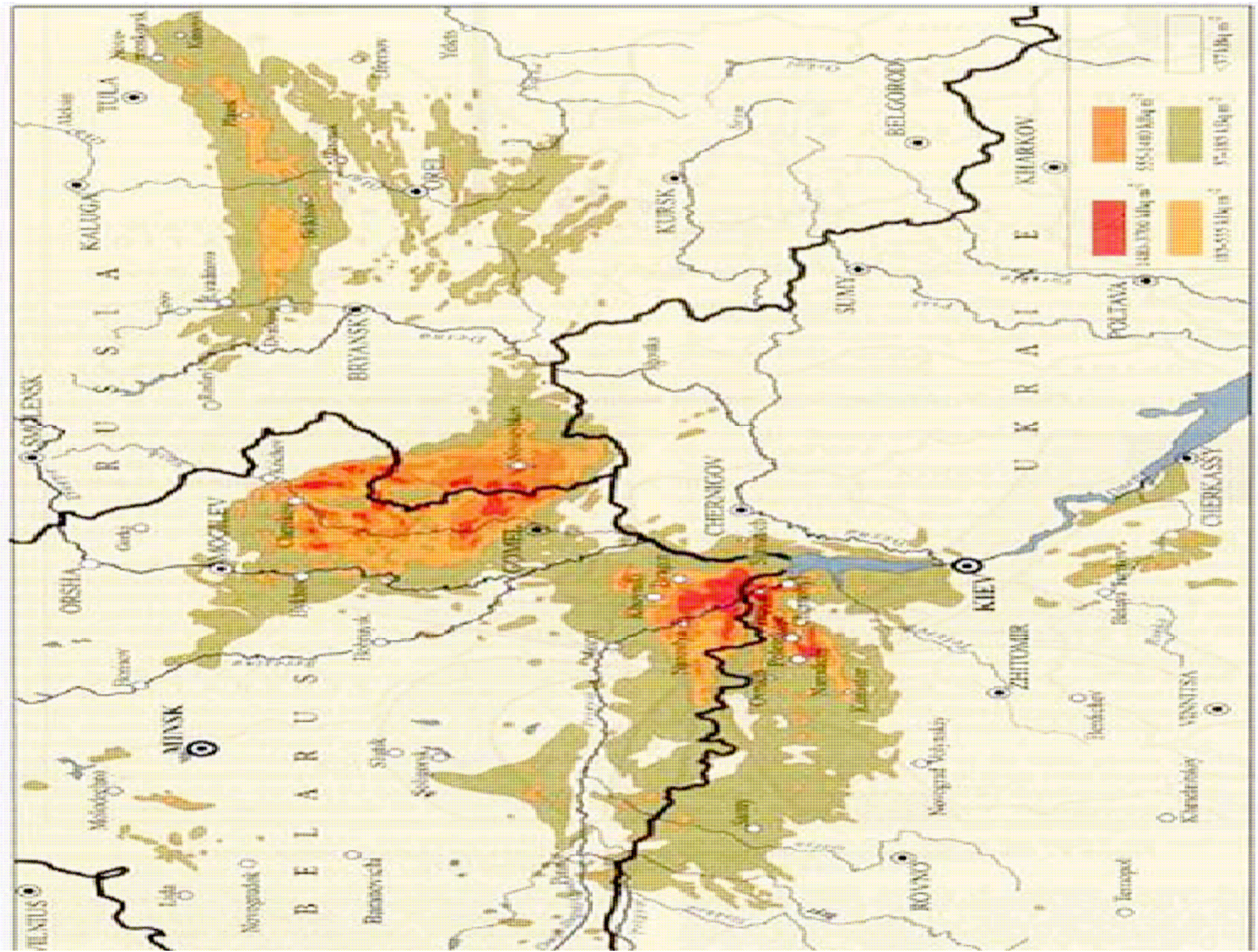


Source: Reuters

Chernobyl

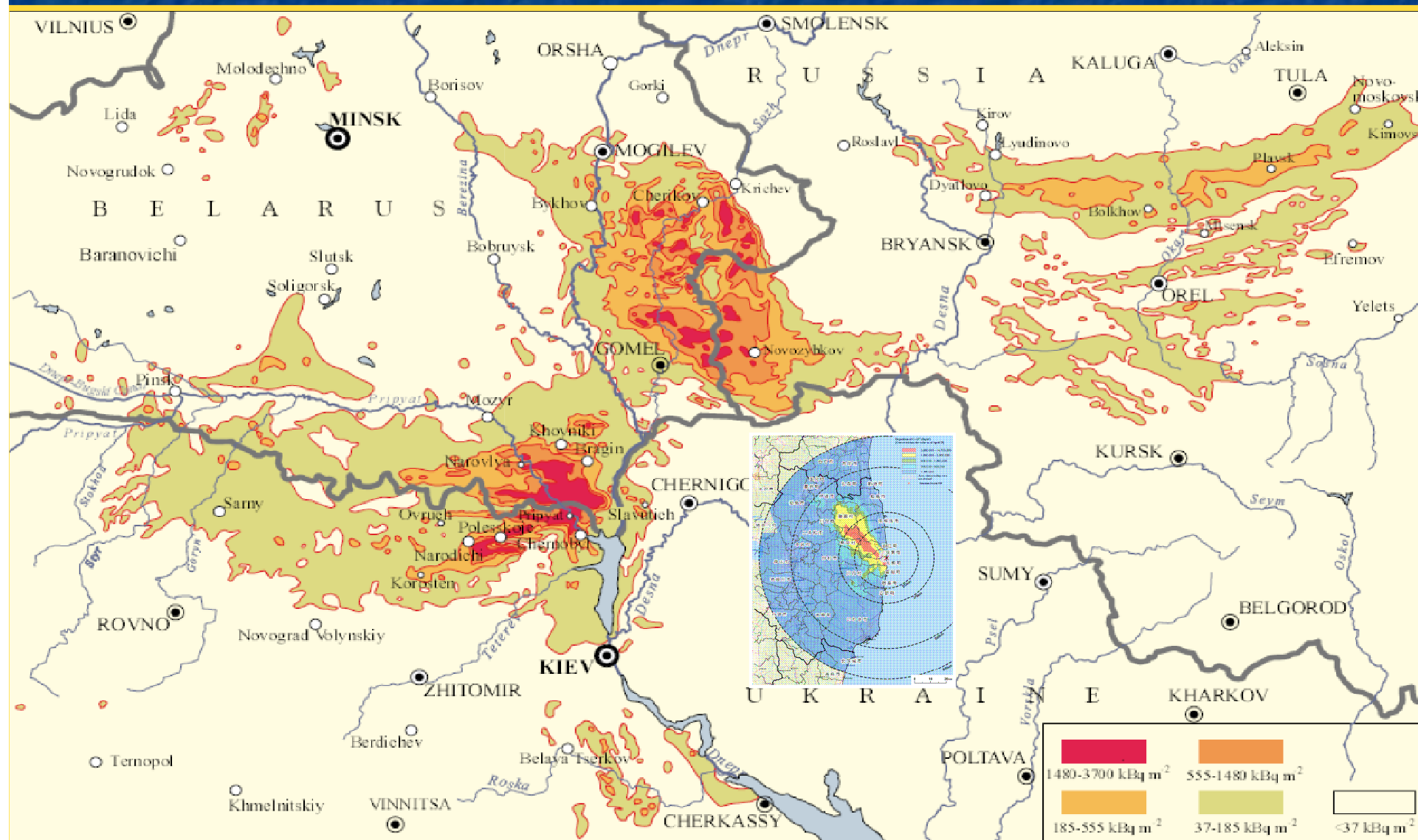
- fallout over much larger area
- over land; not sea
- but lower population densities
- 3 to 5 x larger Cs source terms





^{137}Cs contamination at Chernobyl and Fukushima

The two areas are at approximately the same scale. The yellow/orange/red areas around Chernobyl correspond approximately to the green/yellow/red areas around Fukushima re contamination levels. Thanks to Dr R Wakeford.



Nuclides released to air at Fukushima - PBq

PBq = petabecquerel = 10^{15} Bq, ie 1 quadrillion Bq

Nuclide	Stohl et al 2011*	Chernobyl (TORCH **)	Chernobyl/ Fukushima
Xe-133	16,000	~6,500	x 0.4
I-131	360***	~1,760	x 5
Cs-134	36	~100	x 2.8
Cs-137	36	~100	x 2.8

*Stohl et al (2011) Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. Atmos. Chem. Phys. Discuss., 11, 28319–28394, www.atmos-chem-phys-discuss.net/11/28319/2011/ doi:10.5194/acpd-11-28319-2011

**Torch = www.chernobylreport.org

***ZAMG (2011) Accident in the Japanese NPP Fukushima: Large emissions of Cs-137 and I-131. Austrian Central Institute for Meteorology and Geodynamics (ZAMG), March 24, 2011. www.zamg.ac.at/docs/aktuell/Japan2011-03-24_1600_E.pdf

Nuclides Discharged to Sea

27 PBq (12 - 41) Cs-137
estimated up to July 18 2011

P. Bailly du Bois et al. Estimation of marine source-term following Fukushima Dai-ichi accident Journal of Environmental Radioactivity 114 (2012) 2-9

Radioactive Fish caught near Fukushima NPP

TEPCO statements



- Jan 21 2013, **muraso**i
(254 kBq/kg Cs-137)
~2,500 x legal limit

- March 2 2013, **greenling**
(508 kBq/kg Cs-137)
~5,000 x legal limit

http://www.upi.com/Science_News/2013/03/01/Radioactive-fish-caught-near-nuclear-plant/UPI-91811362176136/

3/1/2012

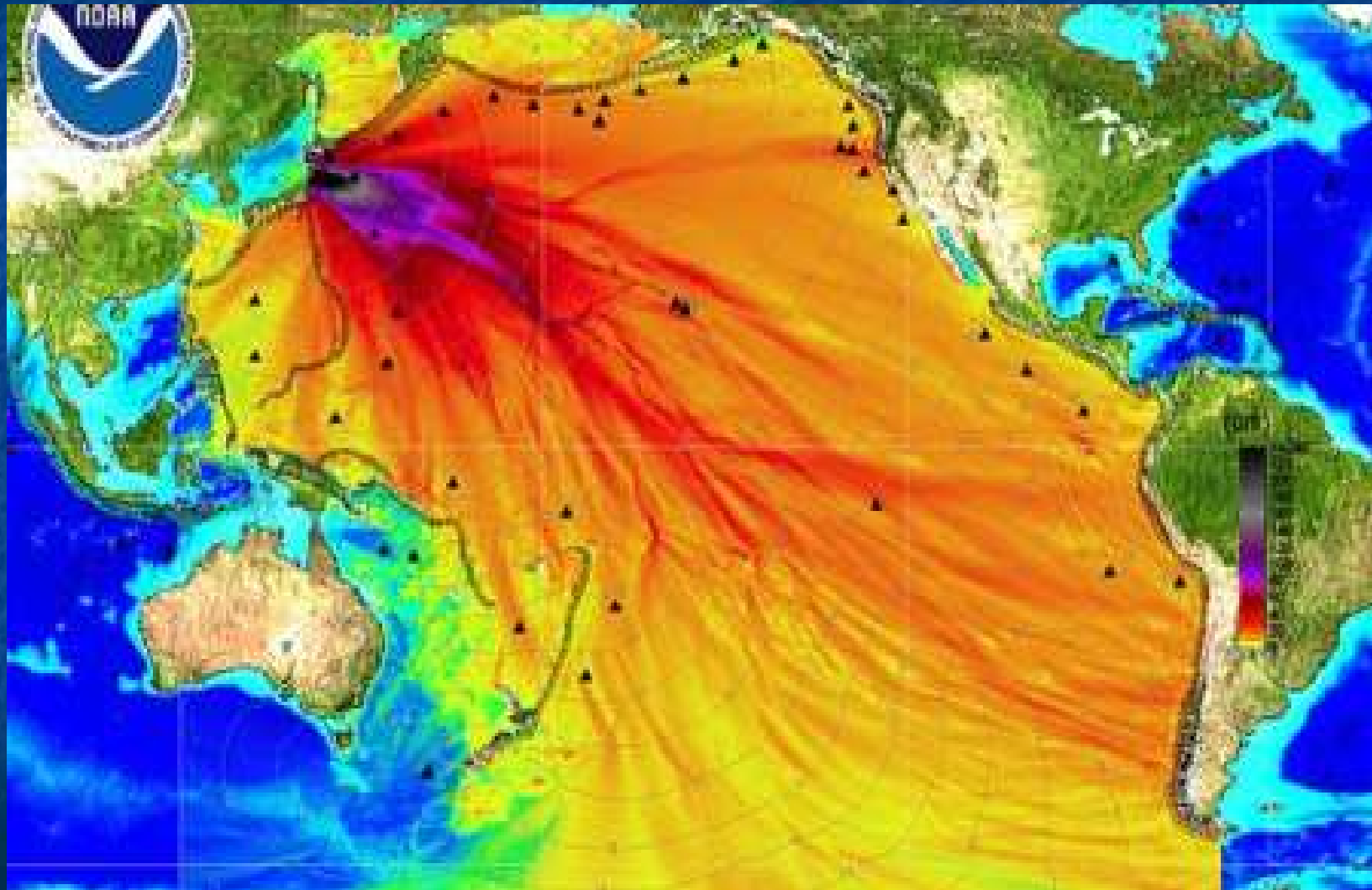
US Dept of State Geographer
Image © 2012 TerraMetrics
© 2012 Google
Data SIO, NOAA, U.S. Navy, NGA, GEBCO

Google earth
[Terms of Use](#)



NOAA

NATIONAL OCEANIC AND
ATMOSPHERIC ADMINISTRATION
UNITED STATES DEPARTMENT OF COMMERCE





year 1 - red
year 2 - orange
year 3 - yellow
year 4 - light blue
year 5 - violet

Data from NOAA, U.S. Navy, NOAA, USFWS
Images © 2011 Panoramio
Images © 2010
Data © 2010 NOAA

Courtesy of J. Charnie

©2004 Google

2013 WHO Risks Report

In the most contaminated area:

- **thyroid cancer**- 70% higher risk in females exposed as infants
- **breast cancer** - 6% higher risk in females exposed as infants
- **leukaemia** - 7% higher risk in males exposed as infants

WHO Risks Report Feb 2013

- for general population in Japan, health risks predicted to be “low”
- no “discernible” increase in health risks expected outside Japan
- one-third of emergency workers estimated to have “increased” risks

Future Consequences

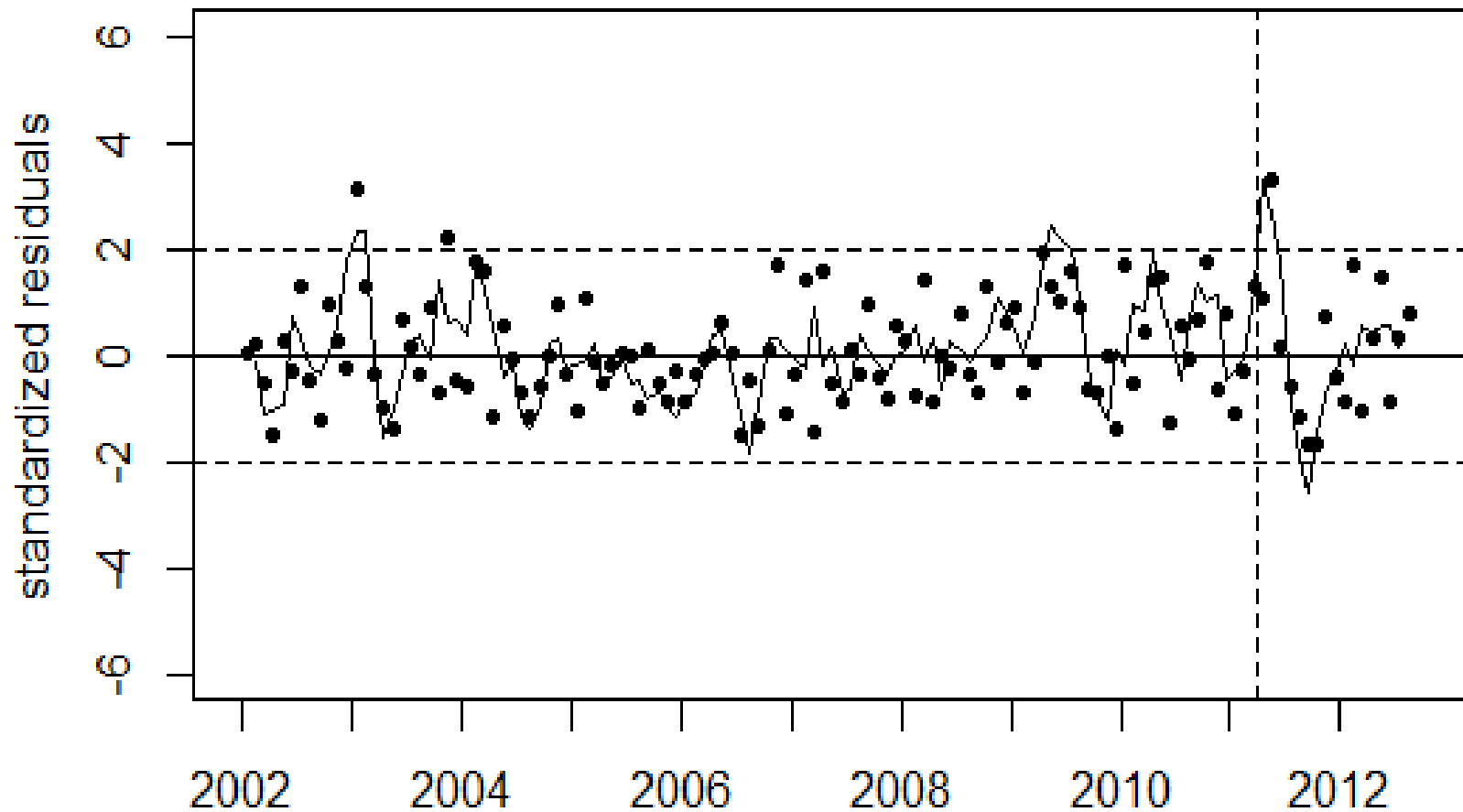
Using Chernobyl as a guide, we can expect

after ~9 months	teratogenic effects <ul style="list-style-type: none">• infant deaths• infant leukemias, and• decline in birth numbers
after ~2 years	leukemias (but hard to pick up)
after ~4 years	thyroid cancers in children and women
after >10 years	solid cancers, cardiovascular effects

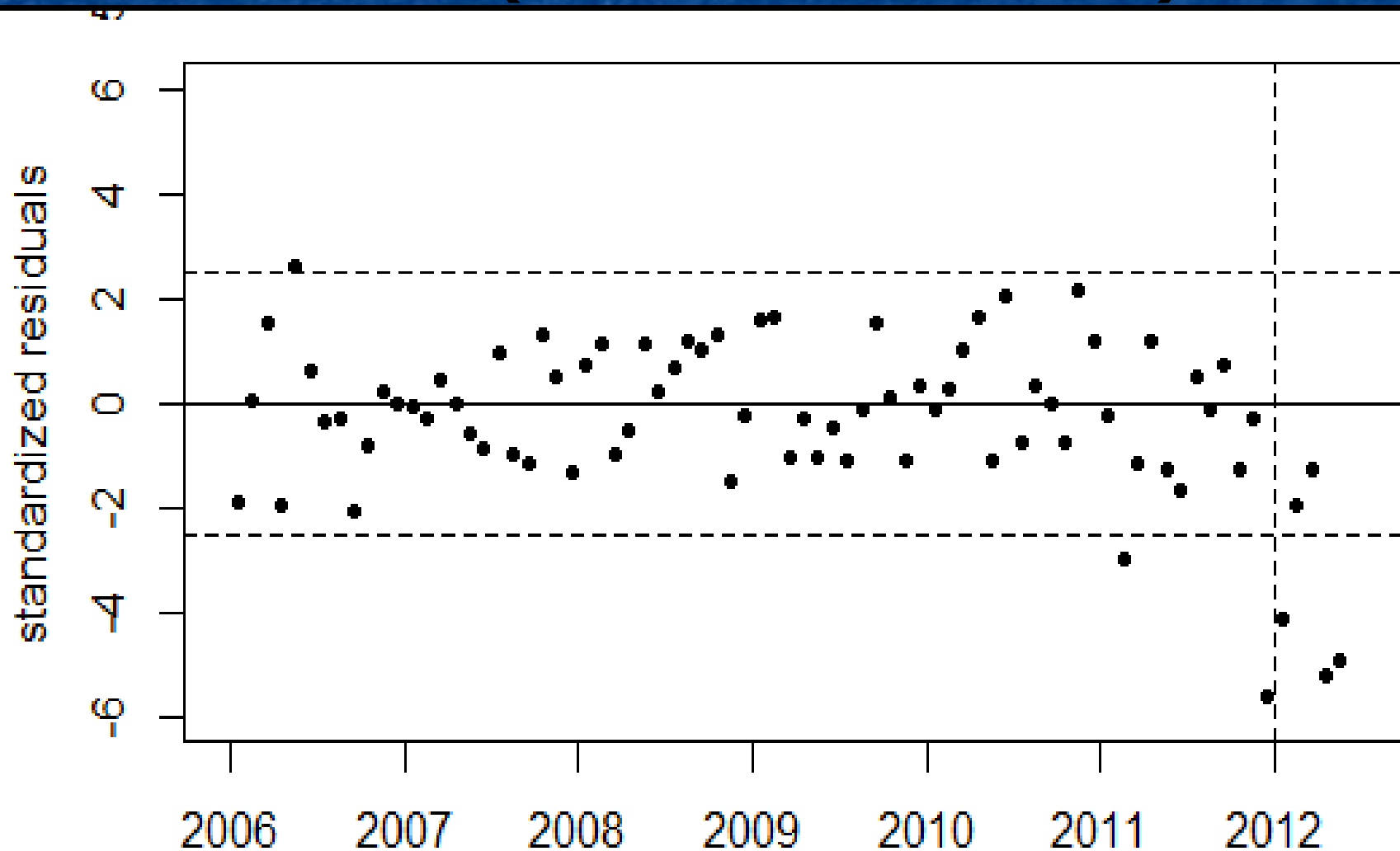
Infant mortality peaks

Deviations of infant mortality rates in Fukushima prefecture, in units of standard deviations
solid line = 3-month moving average

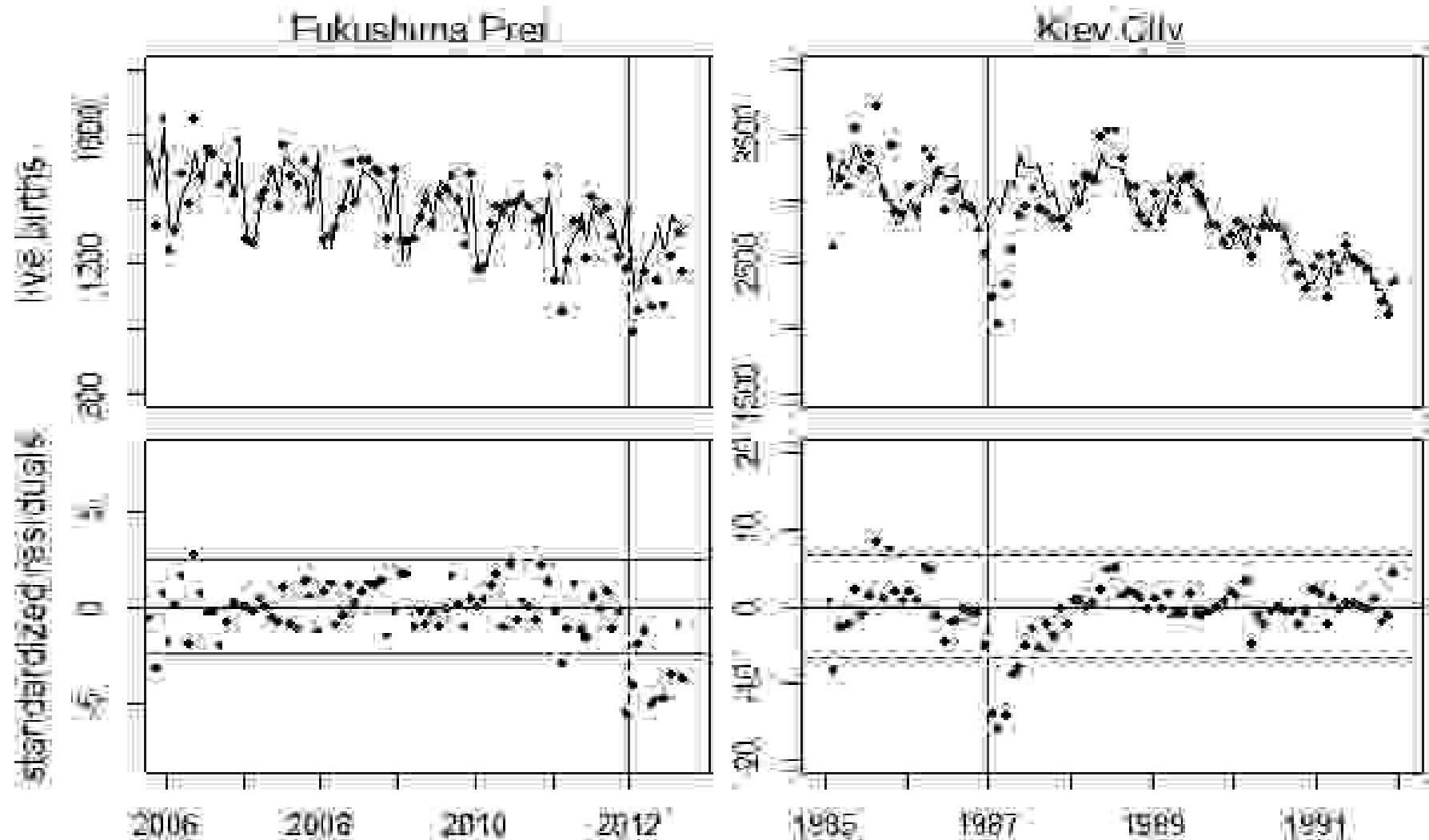
http://www.strahlentelex.de/Infant_mortality_in_Japan_after_Fukushima.pdf



Decreased Numbers of Live Births (9 months after)



Decline in Live-Birth Numbers

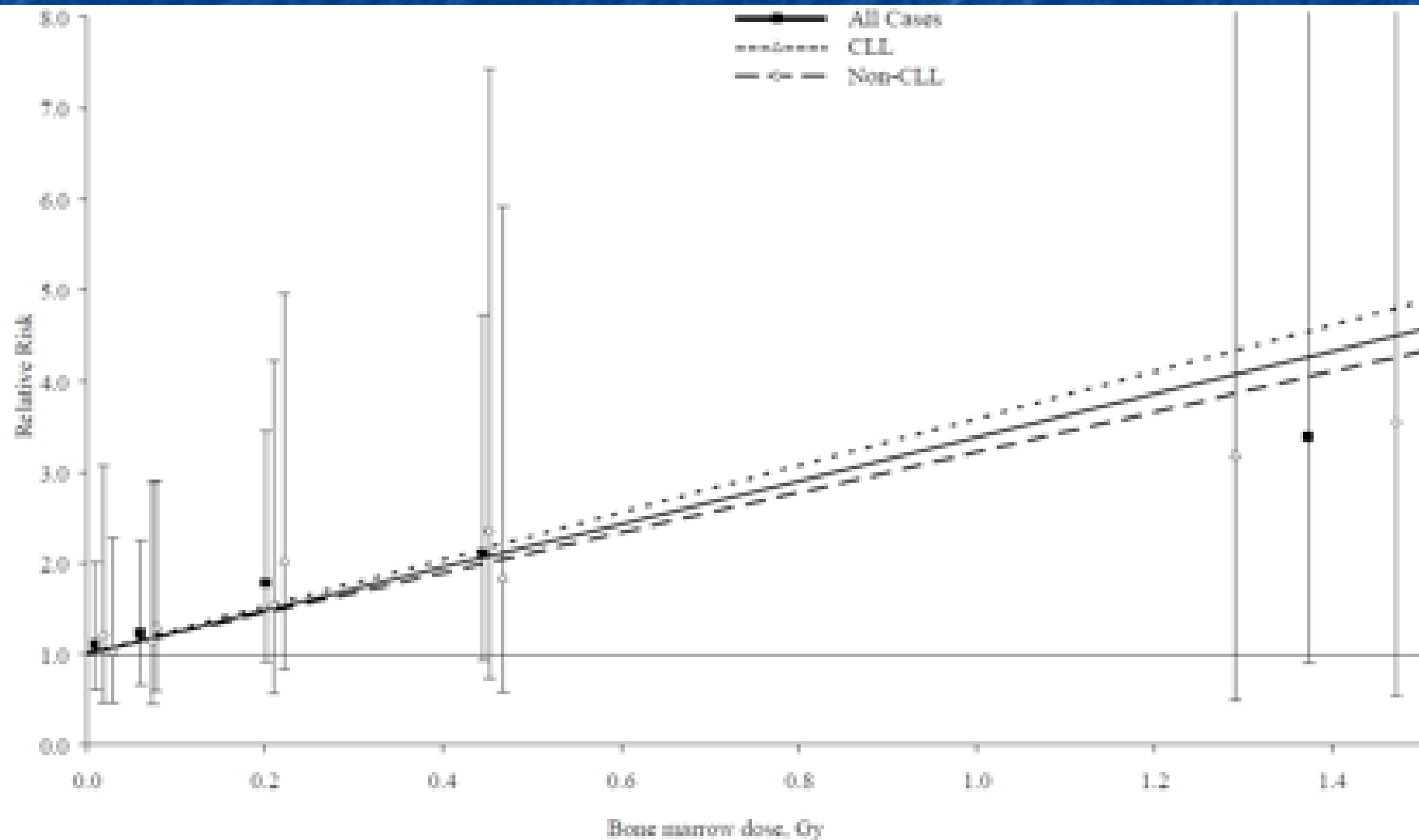


After ~2 years: increased leukemias

- difficult to pick up
- but Zablotska et al in 2013 did in huge study of >110,000 Chernobyl liquidators
- bone marrow doses 5 mGy to >400 mGy
- found a linear dose response
- no study proposed yet in Japan
- Zablotska et al (2013) Radiation and the Risk of Chronic Lymphocytic and other Leukemias among Chornobyl Cleanup Workers. Environmental Health Perspectives. Volume 121, number 1. Pp 59-65. January 2013.
<http://ehp.niehs.nih.gov/2013/01/1204996/>

Zablotska: Increased Leukemias in Chernobyl Liquidators

<http://ehp.niehs.nih.gov/2013/01/1204996/>



Chernobyl: Thyroid Cancers

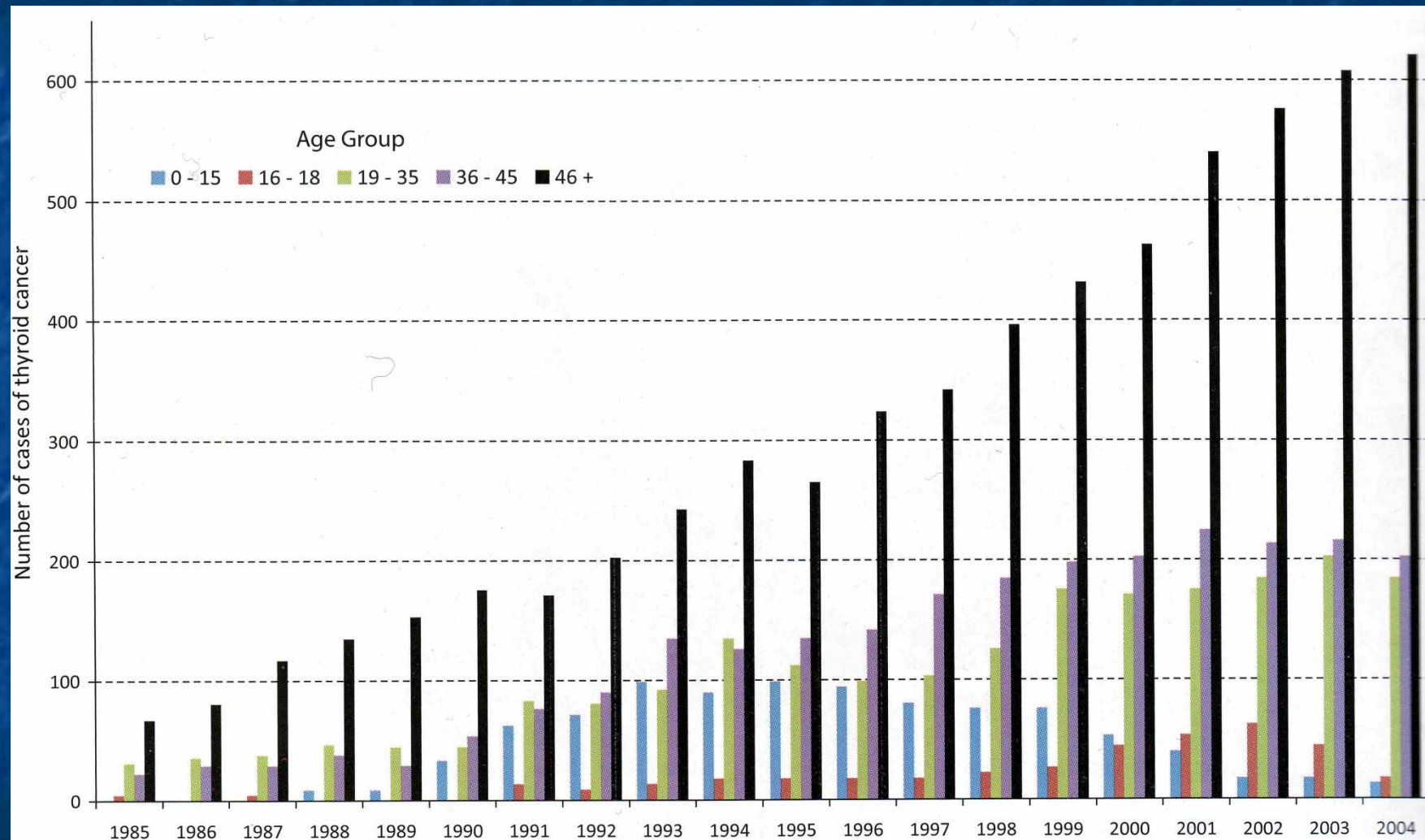


Figure 14.17 | Epidemic of thyroid cancer in Belarus following the 1986 Chernobyl accident. Annual number of cases of thyroid cancer grouped by age at the time of diagnosis. Note that the incidence of thyroid cancer in the youngest group (0–15 years) returned to low levels in 2002 when all the exposed population had graduated into older groups. In the younger groups the death rate due to thyroid cancer has been low. This does not appear to be true, however, for the increasing number of cases among those aged 46 and over. In 2004, this group would have been over 27 at the time of the Chernobyl accident. Source: Bepalchuk et al., 2007.

Population Risks vs Individual Risks

- great emphasis on individual risks
- but we need to estimate doses to Japanese populations
- reverse lottery tickets effectively handed out to 1,000s of Japanese
- real people will die

Future Fatal Cancers – 3 studies

IRSN (2011) Assessment on the 66th day of projected external doses for populations living in the north-west fallout zone of the Fukushima nuclear accident - outcome of population evacuation measures, Report DRPH/2011-10: L'Institut de Radioprotection et de Sécurité Nucléaire <http://www.irsn.fr/EN/news/Documents/IRSN-Fukushima-Report-DRPH-23052011.pdf>

John E. Ten Hoeve and Mark Z. Jacobson(2012) Worldwide health effects of the Fukushima Daiichi nuclear accident Energy Environ. Sci., 2012,5, 8743-8757

Jan Beyea, Edwin Lyman and Frank von Hippel (2013) Accounting for long-term doses in "Worldwide health effects of the Fukushima Daiichi nuclear accident." Energy Environ. Sci., 2013, Accepted Manuscript. DOI: 10.1039/C2EE24183H

Future Fatal Cancers

Near Fukushima (no DDREF applied)

von Hippel (2011)	~1,500
IRSN (2011) draft report	~220 (derived from IRSN data)
Beyea et al (2012)	>700
My study (2013)	~3,000
UNSCEAR (expected Oct 2013)	~3,000

From Chernobyl (no DDREF applied)

Fairlie and Sumner (2006)	60,000
Anspaugh et al (1988)	~48,000
Cardis et al (2006)	16,000 thyroid cancers + 25,000 other cancers

George Santayana
philosopher (1863 - 1952)

governments that are unable to
learn from history
.... are condemned to repeat it

a radioactive future?



or a renewable future...?

