EUNUPRI2019: The European Nuclear Power Risk Study 2019 – Doctor's warning for energy politicians and civil protection authorities

Climate Crisis - Why nuclear is not helping

GOBAL 2000 Conference Vienna 8.10.2019

Dr. med. Claudio Knüsli,
FMH Internal Medicine / Oncology

Board member of PSR/IPPNW Switzerland
(Physicians for Social Responsibility /
International Physicians for the Prevention of Nuclear War)
www.ippnw.ch

Bern, Switzerland, National Climate Demonstration 28th September 2019 – 100 000 participants

However…


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World Nuclear Industry Status Report 2019*

- **Nuclear power is […] not effective in the effort to battle the climate emergency, rather it is counterproductive…**

- The rather surprising outcome of the analyses is that **even the extended operation of existing reactors is not climate effective** as ***operating costs*** exceed the costs of competing energy efficiency and new renewable energy options and therefore durably block their implementation.

… ***and what about nuclear risks of existing reactors ?***

*Ref. WNISR2019, 24th Sept. 2019 https://www.worldnuclearreport.org/WNISR2019-Assesses-Climate-Change-and-the-Nuclear-Power-Option.html

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European Nuclear Power Risk Study

Title:

***Modelling of a Major Accident** in One of Five Nuclear Power Plants From 365 Meteorological Situations in Western Europe and Analysis of the Potential Impacts on Populations, Soils and Affected Countries*

*Study on the dispersion of 32 radioelements simulated for the **4 Swiss nuclear power plants (NPP)** and **NPP Bugey** **(France)** for the year 2017*

Study link: https://institutbiosphere.ch/wa_files/EUNUPRI-2019v01.pdf

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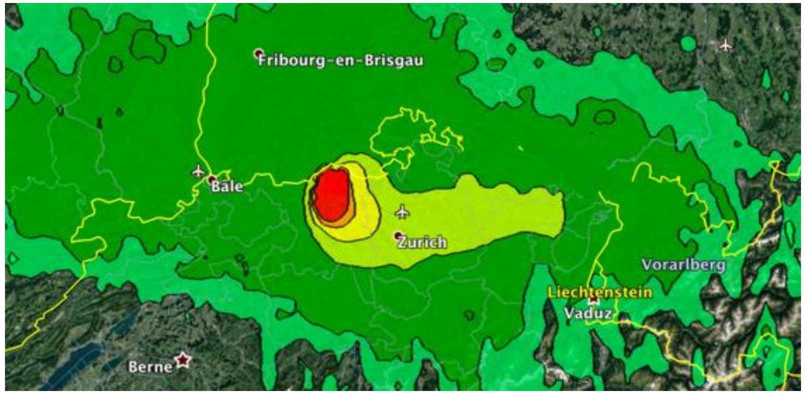
Impact by a major nuclear power plant accident in Europe

Independent study by the *Institut Biosphère, Geneva, Switzerland*, on request of and financed by the NGO *Sortir du nucléaire Suisse romande* published in May 2019 by an **interdisciplinary** team:

- Piguet Frédéric-Paul, Institut Biosphère, Genève (**environmental sciences**)
- Eckert Pierre, Genève (**meteorology**)
- Knüsli Claudio, IPPNW (Suisse), Luzern (**medicine / oncology**)
- Deriaz Bastien, Institut des sciences de l'environnement, University of Geneva (**geomatics**)
- Wildi Walter Department A.F.Forel, University of Geneva (**geology**)
- Giuliani Gregory, Institut des sciences de l'environnement, University of Geneva (**geomatics**)



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European Nuclear Power Risk Study

Study commissioned by NGO Sortir du Nucléaire (SdN) Suisse romande http://sortirdunucleaire.ch/

Poster SdN campaign 2019

Location of Swiss NPP : Swiss «Mittelland»
- 3 regions :
  - canton Bern: NPP Mühleberg
  - canton Solothurn: NPP Gösgen
  - canton Aargau: NPP Beznau (2 reactors)
    NPP Leibstadt

Location of the French NPP Bugey (4 reactors),
- region of Lyon (valley of the Rhône)

impact of a major NPP accident in Europe

Content:

1. Background - existing studies and data
2. Methodology
3. Meteorological simulations
4. Health risks
5. Evacuation of populations
6. Conclusion

«Major nuclear accident: probability and dimension»

- **Analysis of 216 nuclear energy accidents / incidents (Wheatley 2016)** *
- With **388 reactors** in operation worldwide → **50% chance of a nuclear event of the dimension of Fukushima (or +) every 60 – 150 years**
- INES (International Nuclear Event Scale, Categories 1 -7) inconsistent with cost data and radiation released: **«for Chernobyl and Fukushima accidents, INES 11 – 12 (instead of 7) would have been appropriate»!**
- US-Dollar = best severity measure (better than INES «technical standard»):
  - Chernobyl 260 000 Million USD
  - Fukushima 166 000 Million USD

* S. Wheatley, B. Sovacool, D. Sornette: Reassessing the safety of nuclear power; Energy Res & Soc Science 15 (2016) 96-100

What is the probability of a severe accident in the 5 NPPs studied ?

- 9 reactors, 2nd generation, connected in 1969-79 (1984 for Leibstadt/CH)

- IAEA-normative: probability of a major accident ≤ 1/1’000’000 years of operating time
(« very unlikely » according to the IAEA)

- According Wheatley * (2017) and others: The risk amounts to 1.8 major accidents during 100’000 years **(= 18 x IAEA-normative)...** (« improbable » according to IAEA)

→ 0.8 % (≈ 1%) risk of a major NPP accident during 50 years of operation of 5 NPPs
(« possible » according to IAEA)

*Wheatley S. et al. Of Disaster and Dragon Kings: A Statistical Analysis of Nuclear Power Incidents and Accidents Risk Anal. 2017; 37(1) p 99 - 115

NPPs in Switzerland and Belgium represent high risks for their countries

Intrinsic NPP risks increasing (aging NPPs / probability of terrorism, cyber-criminality)

Additionally **high strategic** (social, economic, political) **risks from several NPPs** for their countries (F.P.Piguet *):

→ Strategic environment of **194 NPPs worldwide** (in 31 countries) - vulnerability of population / of territory / distance to urban areas analysed

→ «…***several countries have a very high risk profile,*** including one power plant in ***Armenia,*** two in ***Taiwan*** (out of three), four in ***Switzerland***, and two in ***Belgium***." (**Ranks:** Swiss NPPs - No. **4,5,6,8;** Belgian NPPs - No. **7,9;** of a total of 194 ranks)

* F. P. Piguet, 2015: The Vulnerability of Small Countries in the Event of a Major Nuclear Accident in Their Territory
https://institutbiosphere.ch/crbst_6.html

Major nuclear accident: Early course and source term

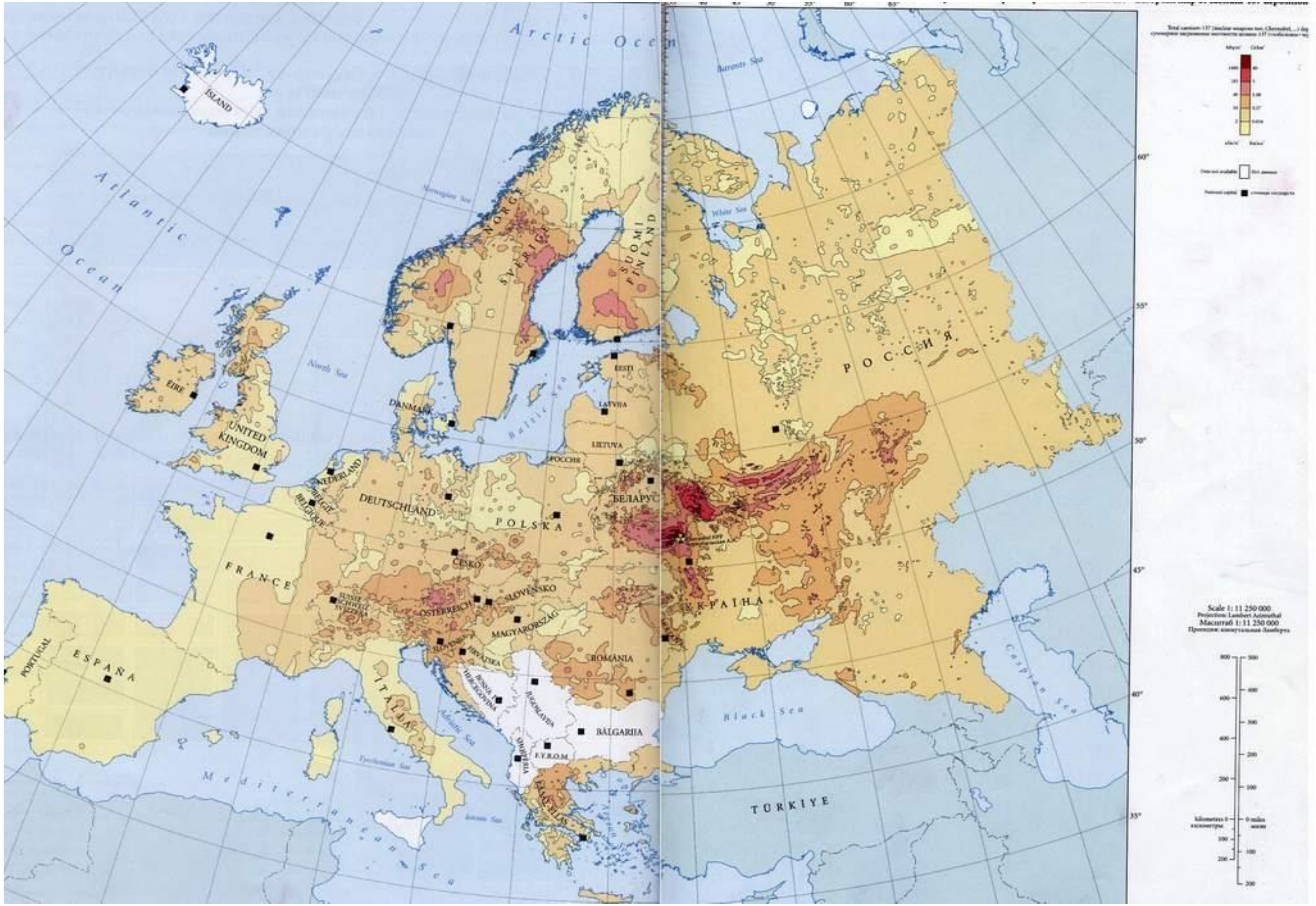
- Emission of **radioactive gases**, especially radioiodine (^{131}J) and **radioactive particles** → **airborne** dispersion according to winds / rain → **radiocontamination of the biosphere by complex meteorological processes** →

- ***Irregular*** **deposition** on **ground** (incl. hot spots) and **water** contamination

- **Amount of Radioactivity (« source term, nuclear inventory »)**
  e.g. **Chernobyl 1986:** 12×10^{18} Bq = 12'000 PBq (Peta-Becquerels)
  = 200 x A-Bombs on Hiroshima and Nagasaki

Europe

Atlas of caesium deposition on Europe 1998 after the Chernobyl accident



How many deaths after a severe nuclear accident ?

- **Epidemiological studies:** Most reliable health risk calculations known for radioinduced **cancer = longterm effect of stochastic (…occurring by chance) nature**, but there are many other health risks *

- **Collective effective radiation dose = individual effective dose x persons exposed**

- Excess **A**bsolute **R**isk (EAR) **for radioinduced cancer mortality: 0.1/Sv = 10%/Sv (according to WHO / UNSCEAR)**

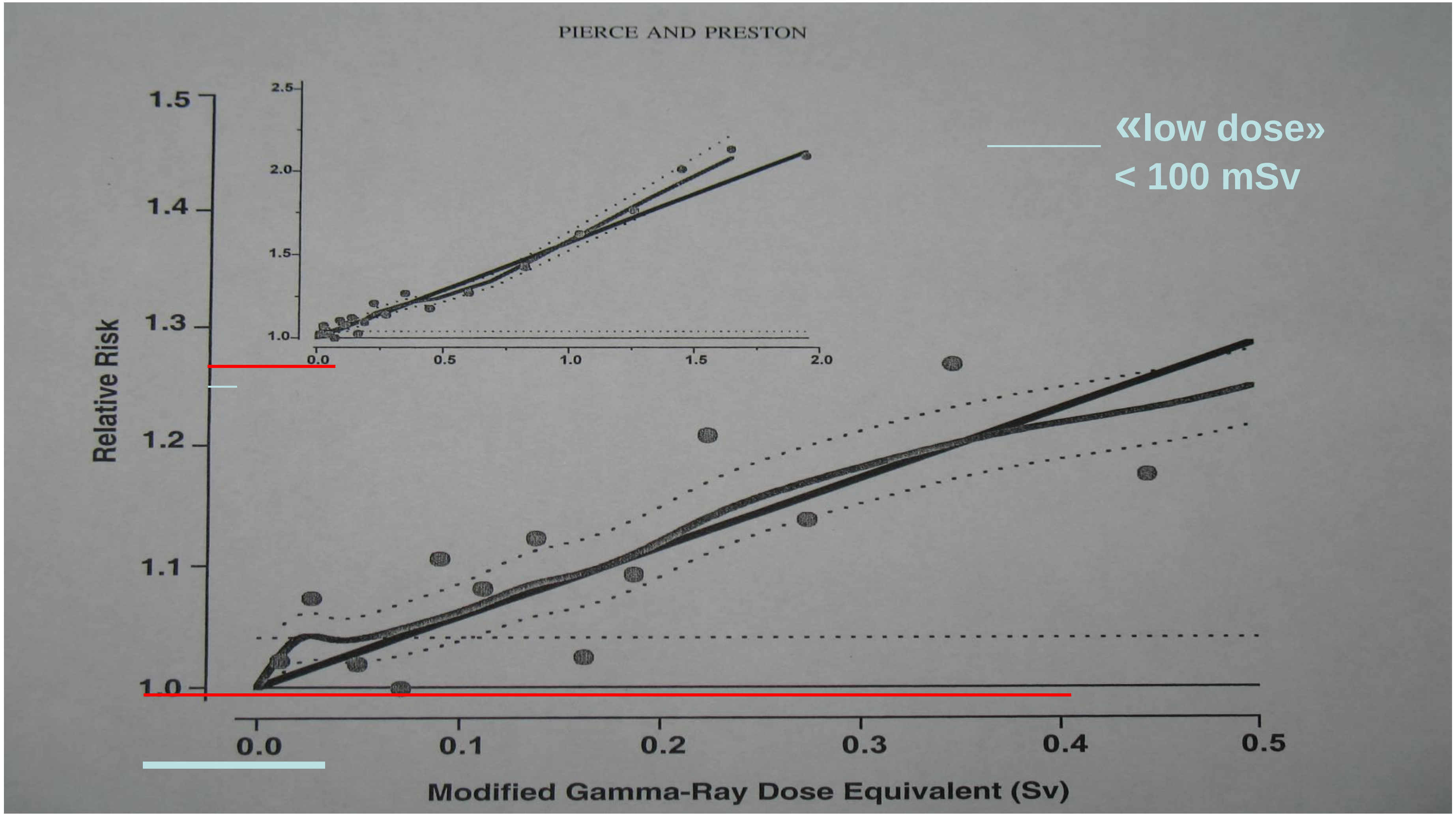
- → e.g.: in 2006 (20 y after Chernobyl): Switzerland 0.5 mSv/person → 7 million inhabitants → collective dose = 3'500 Sv → 350 radioinduced cancer deaths

*IPPNW Germany 2016: ippnw report - 30 years Chernobyl / 5 years Fukushima
http://www.ippnw.de/commonFiles/pdfs/Atomenergie/IPPNW_Report_T30_F5_Folgen_web.pdf

Life span study (LSS): Radiation-related cancer risks at low doses among
Atomic Bomb Survivors; D.A.Pierce, D.L.Preston Radiation Res. 154, 178-186 (2000)

→ No threshold – there is no harmless dose of ionising radiation

→ LNT (Linear No Threshold) model



Studies with statistically significant health effects (solid cancer / leukemia / non-cancer disease / cardiovascular disease) associated with low dose ionising radiation (IR; < to << 100 mSv)

Setting / Criteria	Nuclear workers	Nuclear workers	Chernobyl / Fukushima victims	Indoor radon exposure	Diagnostic CT-exposure in childhood	Diagnostic CT-exposure in childhood	Children, natural background	Children natural background
1st Author; Study	Cardis; Vrijheid; 15 countries	Richardson; Leraud; Gillies; INWORKS	Several authors cited by IPPNW.de	Darby; collabor. 13 case ctrl studies	Pearce	Mathews	Kendall	Spycher
Publication year	2005; 2007	2015; 2015; 2017	2016	2005	2012	2013	2013	2015
Journal(s); Ref. No	BMJ; Rad Res; 1,2	BMJ; Lancet hem; Rad Res; 3,4,5	IPPNW.de; 6,7	BMJ; 8	Lancet; 9	BMJ; 10	Leukemia; 11	Environ Health Perspectives; 12
Persons (N) Cases / Controls	407 391	308 927		7 148 / 14 208	> 176 000 74 B / 135 L	10.9 Mio 680 000	27 447 / 36 793	2 093 660 1782
Country/ Continent	US, EU, Can, Aus, s Korea, Japan	F, UK, US	EU, UDSSR; Japan	9 European countries	England, Wales, Scotland	Australia	Great Britain	Switzerland
Solid Cancer I Incidence / D Death	+ (D) 0.97 / Sv (ERR)	+ (D) 0.48 / Gy (ERR)	+ (especially thyroid)	+ (D, lung) 0.084 / 100Bq / m3	+ (I, brain) 0,023 / mGy	+ (I) brain 0.021 / mGy + other 0.027 / mSv		+ (I, brain) 1.04 / mSv (HR)
Leukemia I Incidence / D Death		+ (D) 2.96 / Gy (ERR)	+		+ (I) 0.036 / mGy (ERR)	+ (I) 0.039 / mGy (ERR)	+ (I) 0.12 / mSv (ERR)	+ (I) 1.04 / mSv (HR)
Non Cancer disease I / D		+ (D) 0.19 / Sv (ERR)	+					
Cardio-vasc. Disease I / D		+ (D) 0.22 / Sv (ERR)	+					
Dose response	YES	Yes (x 4)		YES	YES (x 2)	YES (x 3)	YES	YES (x 2)
Low dose IR	19.4 mSv (mean)	20.9mGy - 25.2mSv	Yes	+/- 100 Bq / m3	50-60 mGy	4.5 mSv	0.8mGy/y (ctrls)	1mSv / y (mean)

1. Cardis M, Vrijheid M, M Blettner M, et al. Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. IARC Lyon, BMJ 9 July 2005: Vol. 331; p.77-80
2. Vrijheid M, Cardis E, Blettner M, et al. The 15-country collaborative study of cancer risk among radiation workers in the nuclear industry: Radiat Res 2007; 167: 361–7
3. Richardson B, Cardis E, Daniels R D, et al., Risk of cancer from occupational exposure to ionising radiation: retrospective cohort study of workers in France, the United Kingdom, and the United States (INWORKS) BMJ 2015; 351 doi: https://doi.org/10.1136/bmj.h5359
4. Leuraud K, Richardson D B, Cardis E, et al., (2015), Ionising radiation and risk of death from leukaemia and lymphoma in radiation-monitored workers (INWORKS): The Lancet Haematology 2(7): e276–e281. http://www.thelancet.com/journals/lanhae/article/PIIS2352-3026(15)00094-0/abstract
5. Gillies M, Richardson B, Cardis E, et al., Mortality from Circulatory Diseases and other Non-Cancer Outcomes among Nuclear Workers in France, the United Kingdom and the United States (INWORKS). Radiation Research 10th July 2017 https://www.ncbi.nlm.nih.gov/pubmed/28692406
6.. https://www.ippnw.de/commonFiles/pdfs/Atomenergie/Health_effects_of_ionising_radiation.pdf
7. http://www.ippnw.de/commonFiles/pdfs/Atomenergie/IPPNW_Report_T30_F5_Folgen_web.pdf
8. Darby S, Hill D, Auvinen A, et al., Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies. BMJ. 2005 Jan 29;330(7485):223. Epub 2004 Dec 21.
9. Pearce MS, Salotti JA, Little MP, et al., Radiation exposure from CT scans in childhood and subsequent risk of leukaemia and brain tumours : a retrospective cohort study. Lancet 2012, 380, 499 – 505
10. Mathews JD ; Forsythe AV, Brady Z, et al., Cancer risk in 680.00 people exposed to computed tomography scans in childhood or adolescence : data linkage study of 11 million Australians. British Medical Journal BMJ 2013, 346 : f2360 12360.doi : 10.1136/bmj.12360
11. Kendall GM, Little MP, Wakeford R, (2013) A record-based case–control study of natural background radiation and the incidence of childhood leukaemia and other cancers in Great Britain during 1980–2006, Leukemia 27, 3 – 9. https://www.ncbi.nlm.nih.gov/pubmed/22766784
12. Spycher BD, Lupatsch JE, Zwahlen M, et al. (2015) Background Ionizing Radiation and the Risk of Childhood Cancer, Environ Health Perspective. https://ehp.niehs.nih.gov/wp-content/uploads/123/6/ehp.1408548.alt.pdf

PSR / IPPNW Switzerland 2018

Chernobyl: how many victims? → how many humans have been irradiated to what extent → how many and which diseases? **We will never know - not even roughly…**

Different populations with different dose levels of ionising radiation (IR)

- 830’000 Liquidators (cleaning up nuclear workers, high IR doses)
- > 350’000 evacuees (30 km-zone and other heavily contaminated regions)
- about 8’300’000 humans in the most exposed regions of Russia, Belarus and Ukraine
- about 600’000’000 humans from other parts of Europe contaminated to a lesser degree

…and different estimates of exposure (…collective doses) and EAR for cancer incidence (0.2 / Sv or 0.4 / Sv ?) – corresponding to 2 x mortality → broad range between

- **11 000 cancer victims** (according to IAEA IR dose estimation)
- **960 000 cancer victims** (according to UDSSR IR dose estimation)

Other radioinduced pathologies

(cf. «Statement of IPPNW from 10th October 2017; Paris ICRP-Meeting» suggesting a revision of the ICRP Publication 103 published in 2007 *)

After exposure in utero and after preconceptual (parental) exposure to ionizing radiation at doses below 100 mSv there is a significant increase of the risk not only for leukemia and solid cancer in the offspring, but – among others – also an increased risk for

- abortions,
- stillbirths,
- low birth weight,
- perinatal and infant mortality,
- malformations (especially of the central nervous system and skeletal system) *and*
- Down's syndrome (Trisomy 21).

Low doses of ionizing radiation increase the risk for the following non-cancer diseases :

- cardiovascular diseases (eg. myocardial infarction, cerbrovascular insults) with an impact on mortality in the range of radiation induced cancer mortality
- benign tumors (e.g. brain)
- blood and immune system diseases,
- pulmonary, urogenital tract, gastrointestinal, endocrine and ocular diseases.

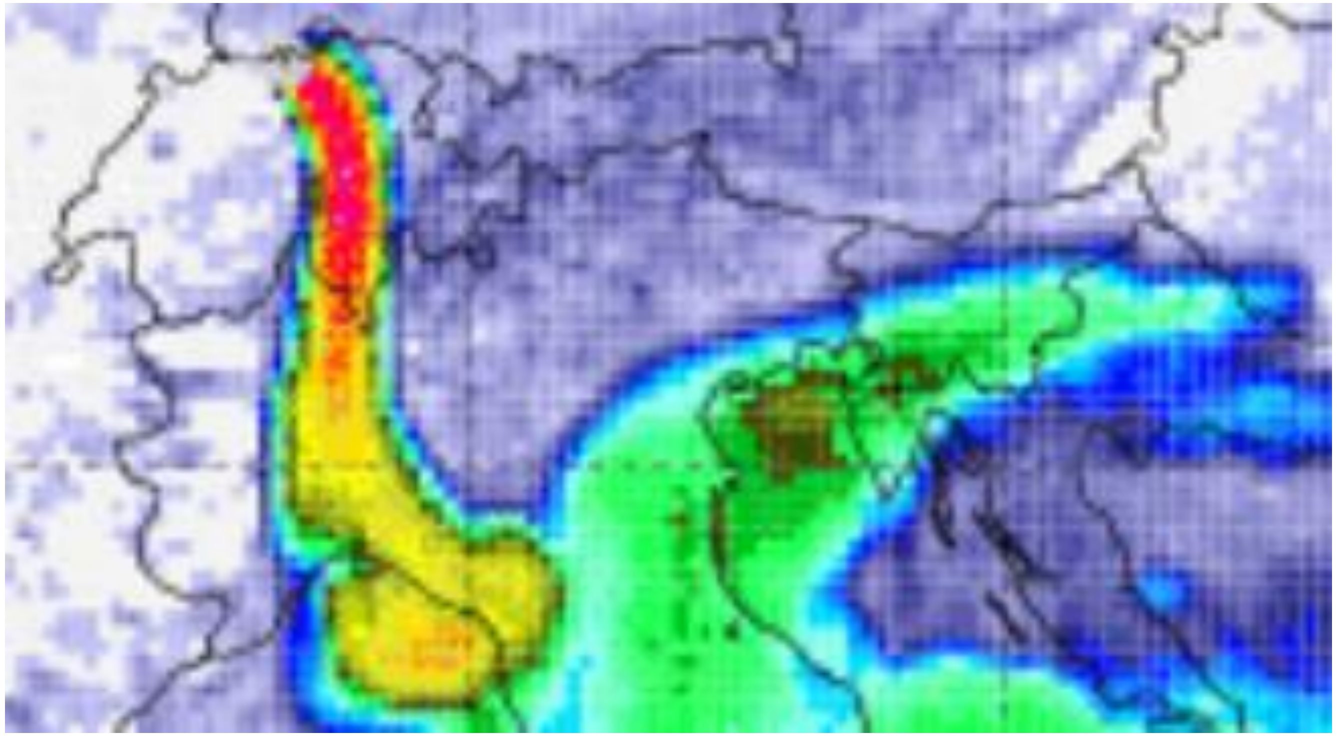
* Recommendations of the International Commission on Radiological Protection (ICRP), Publication 103, 2007.
http://www.icrp.org/publication.asp?id=ICRP%20Publication%20103

Aims of the study:

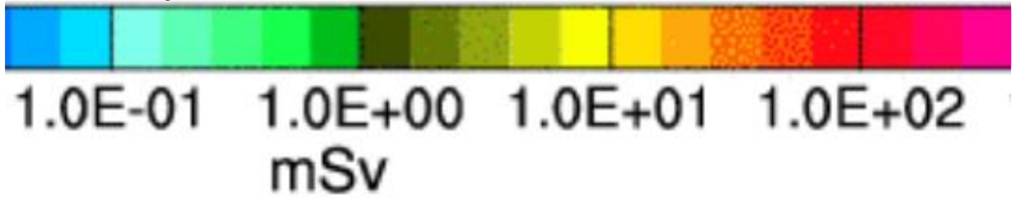
1° Estimation of the health impact of a major accident (one event per NPP) in one of the 4 Swiss NPP (5 reactors) and the French NPP Bugey (4 reactors)

2° Provide an informed dicussion basis with responsible Swiss authorities (Swiss Federal Nuclear Safety Inspectorate ENSI; Federal Office for Civil Protection FOCP / BABS) and for the Swiss Federal Council

- **2012, Flexrisk study, 88 NPP in Europe, 88 meteorological simulation**



NPP Beznau, simulation according to weather situation on 3rd march 1995, radiation dose in an adult person (^{137}Cs) after 1 y



→ Transparent method, however **no collective health risk calculations**

EUNUPRI2019 – first study to cover

- Collective population health risk analysis
- Exhaustive, transparent publication (method, intermediary & final results, references)
- 32 isotopes
- Estimation of the source term (amount of radioactivity) according to the literature: **«scénario A5-A6» (ENSI) – corresponding to ≥ 3 x l'accident de Fukushima (= corresponding to 1/3 of the source term of Chernobyl)**

Dispersion of radioactive substances in the atmosphere

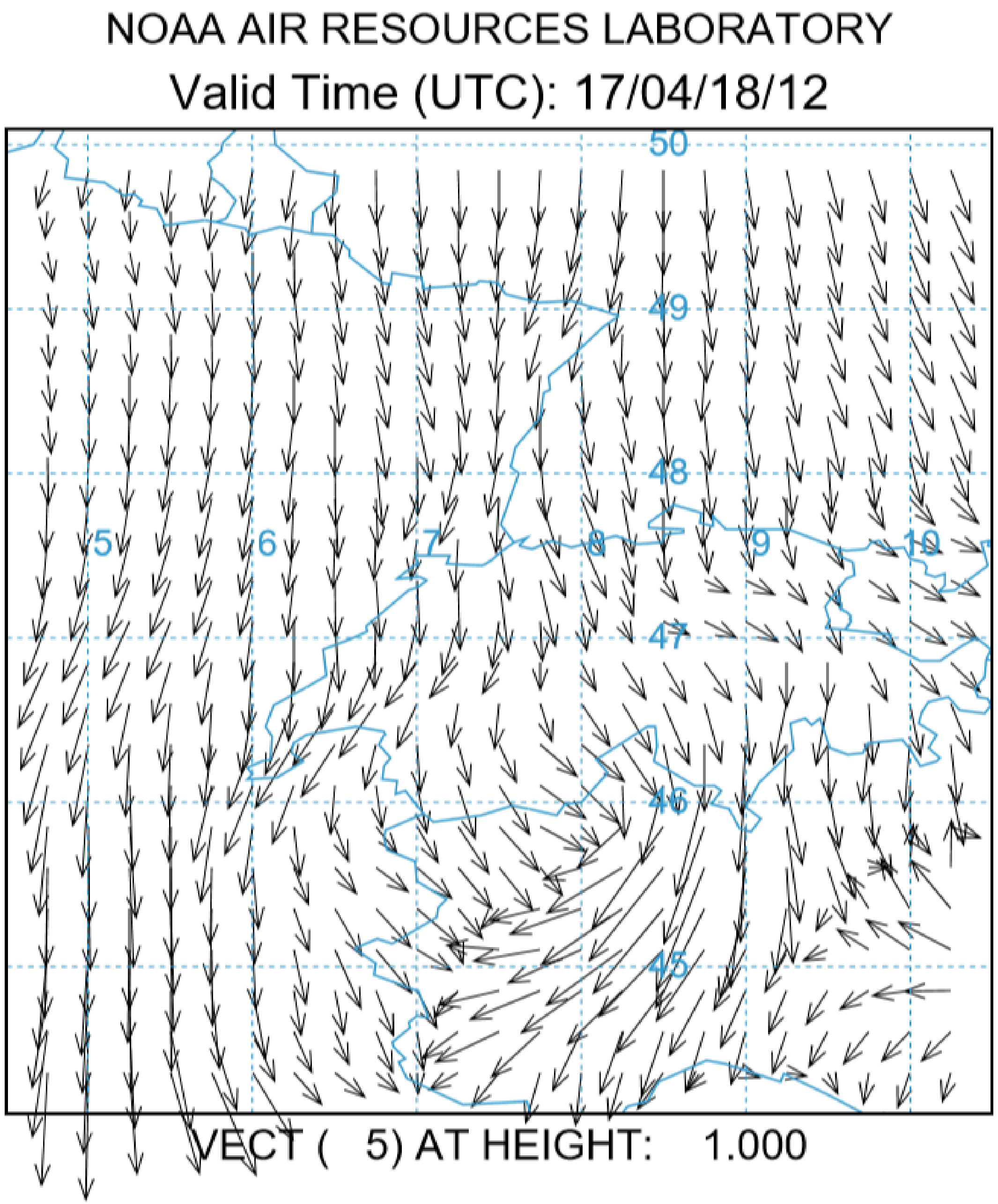
- horizontal and vertical transport by winds → deposition according to weight, rain…

Simulation

- HYSPLIT dispersion model of the *National Oceanic and Atmospheric Administration* (NOAA – developed after Chernobyl and Fukushima)

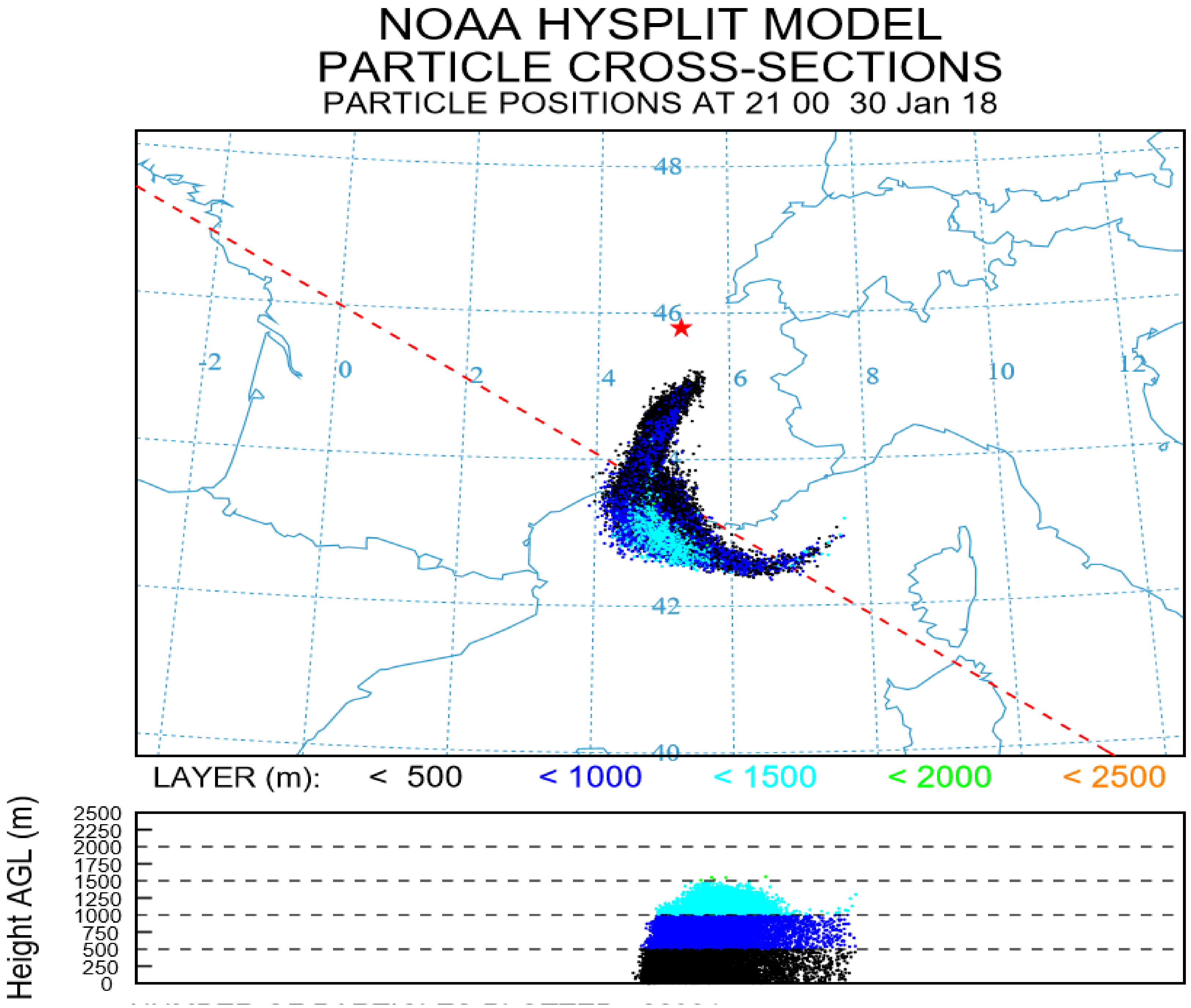
Meteorological simulation

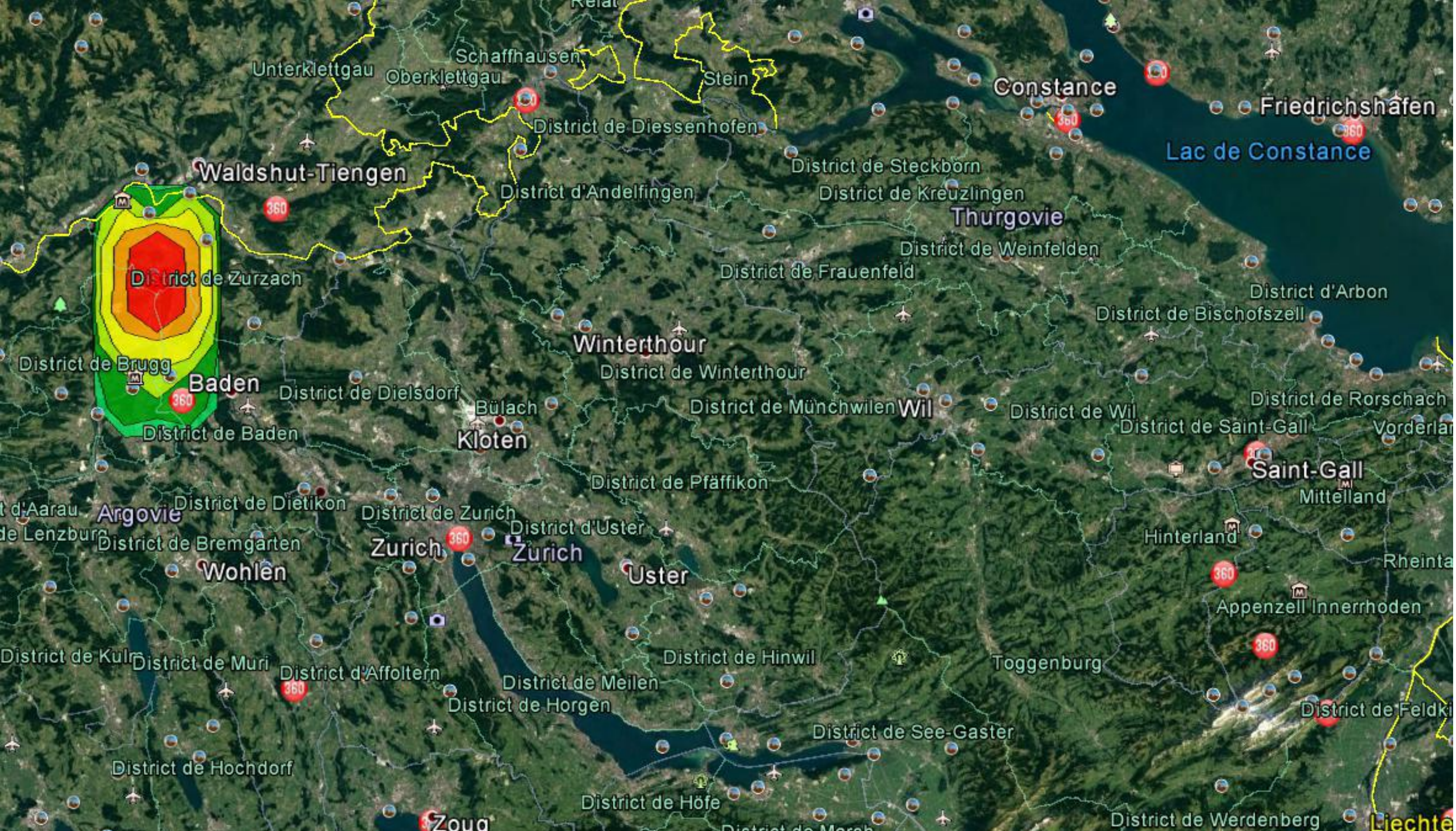
Wind situation at a specified point in time



Meteorological simulation

Three spatial dimensions at a defined point in time

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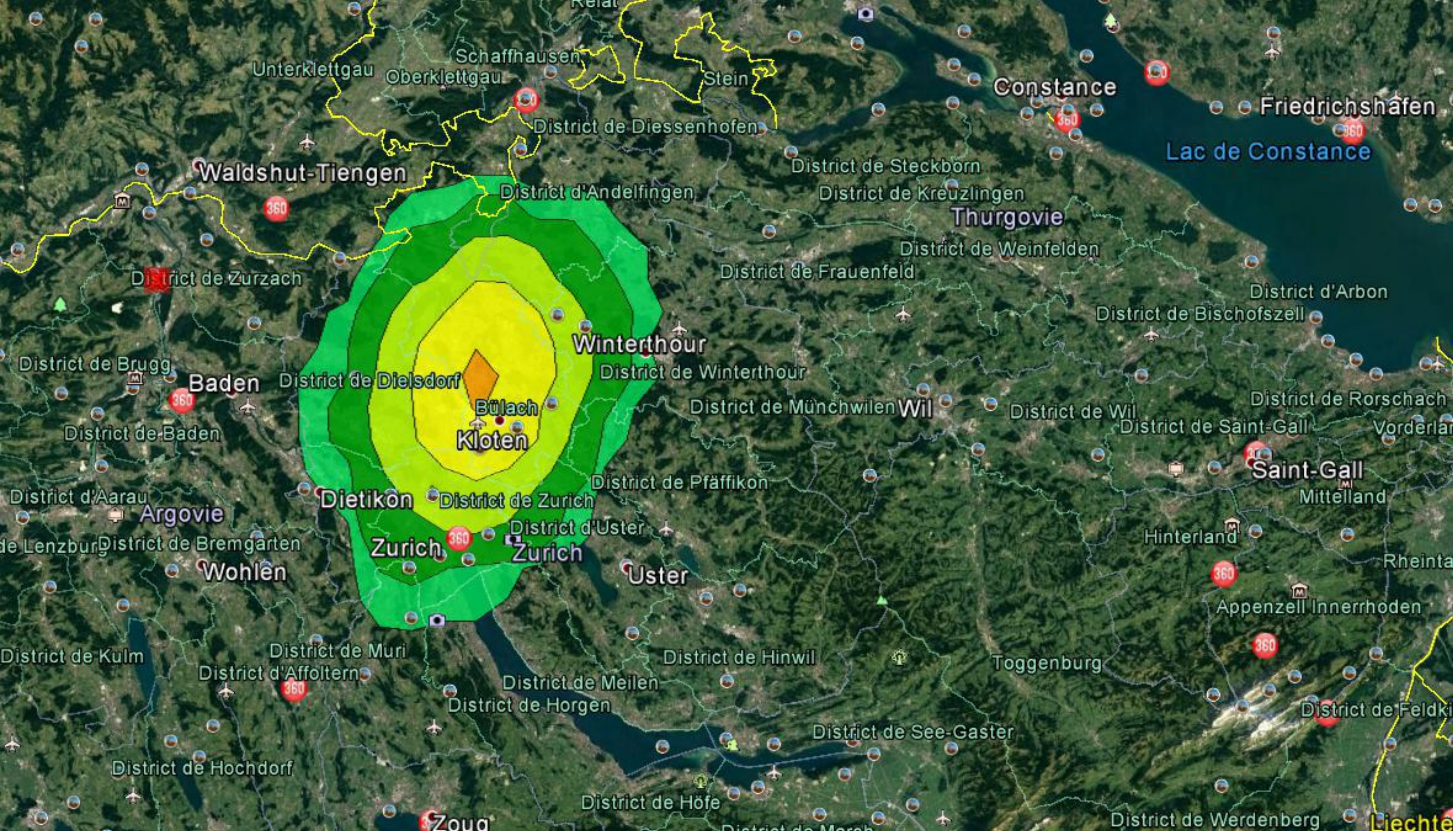

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District de Hinwil
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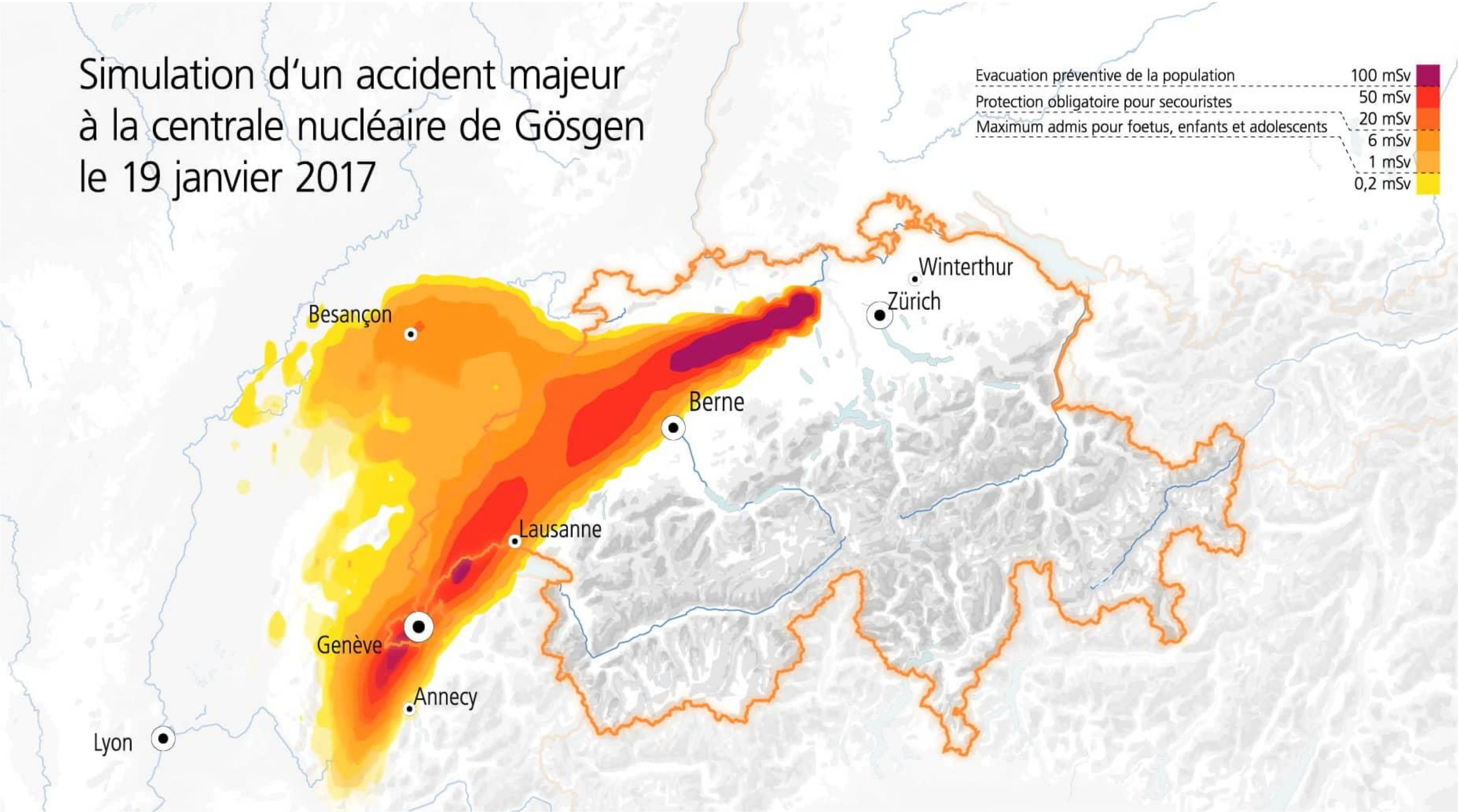
District de Hochdorf
District de Höfe
Zoug
District de Werdenberg

Simulation of an accident at NPP Gösgen 19.1.2017:

https://vimeo.com/335779717?utm_source=email&utm_medium=vimeo-cliptranscode-201504&utm_campaign=28749



At the centre of interest: The collective radiation dose

… addition of all individual radiation doses by:

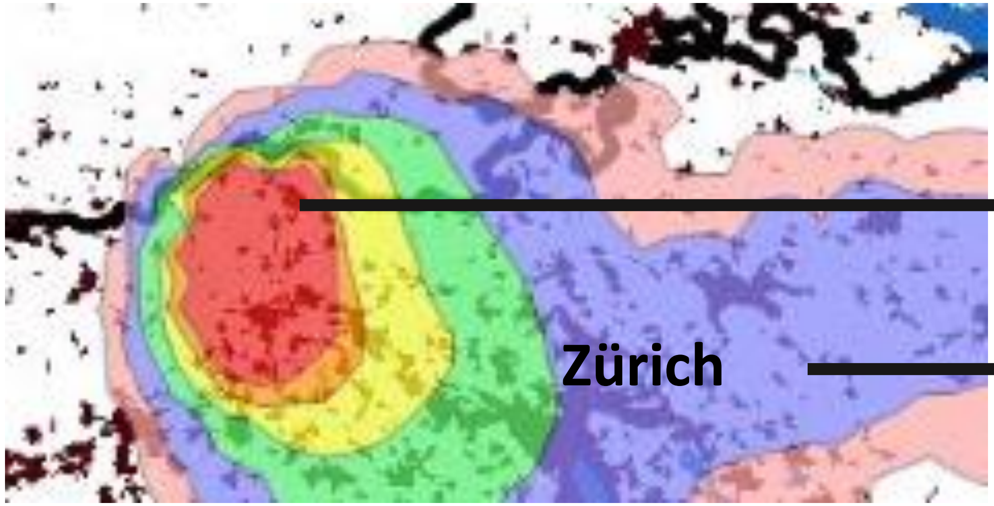
- ext. exposure to rare gas cloud
- inhalation / ext. exposure to aerosol cloud
- inhalation / ext. exposure to refractories cloud
- exposure to groundshine of deposited aerosols (1y)
- exposure to groundshine of deposited refractories (1 y)

→ collective radiation dose in person-Sieverts (PersSv; manSv)

EUNUPRI2019 Meteorological simulation

Technique

- Real weather conditions for 2 x 365 days (2017 et 2018), 5 NPPs
- 3 types of dispersion: Rare gases, aerosols, heavy metals (such as plutonium)
- 10’950 meteo-simulations, overall 73’000 analyses.
- Calculations with GIS (geographic information system): → number of impacted persons, agricultural surfaces, forests, water surfaces (*by Bastien Deriaz MSc, dir. of Dr. Gregory Giuliani – Geneva University)* → → **collective radiation dose**



NPP Beznau (CH) 2017

100 mSv/person x 110’919 persons = 11’091 Sievert («**collective dose**»)

1 mSv/person x 3’917’490 persons = 3’917 Sievert («**collective dose**»)

Collective radiation dose

Addition of all individual radiation doses

→ collective radiation dose in person-Sieverts (PersSv; manSv)

→ calculation of numbers of radioinduced disease cases (incidence and mortality) using an ***EAR (Excess Absolute Risk) - caculation factor***

EUNUPRI 2019: Health effects

Collective radiation dose

Addition of all individual radiation doses

→ collective radiation dose in person-Sieverts (PersSv; manSv)

→ calculation of numbers of radioinduced disease cases (incidence and mortality) using an ***EAR (Excess Absolute Risk) - caculation factor***

Aspects not covered by the study:

1° radiation dose by ingestion (contaminated nutrition, water…)

2° Inhalation and surface exposure by radionuclides resuspended from the air

3° effects do to radiation protection measures (emergency and longterm-evacuation)

4° elevated / high radiation suceptibility of children and adolescents

Results

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Major NPP accident in Switzerland or Bugey (FR):

Estimated collective radiation doses – number of impacted inhabitants in Europe

(72 hours exposure; doses > 0.1 mSv)

NPP / region		NPP Beznau (1 reactor) CH	NPP Bugey (1 reactor) FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	**Collective radiation dose (person-Sievert, persSv)**	**50’580**	**78’198**	**123’439**	**92’991**	**109’973**
Europe	**Radioexposed persons (rounded)**	**16.4 millions**	**24 millions**	**22.9 millions**	**21.3 millions**	**23 millions**

Table 1: Radioinduced health effects due to a major NPP accident – model A, B und C: Number of victims (*incidence*) calculated according to estimated effective collective dose (PersSv). EAR = excessive absolute risk («risk factor» for calculation), Sv = Sievert

Severe radioinduced health damages	ICRP 103	model A	model B	model C
	EAR according to ICRP 103 (2007) **(outdated)**	EAR according to **WHO / UNSCEAR 2013**		
Cancer	0.1 / Sv	**0.2 / Sv**		
Cardiovascular diseases				
Other non-cancer diseases, genetic defects and other reproductive disorders	- Threshold dose 500 mSv for non-cancer diseases - 0.002 / Sv for genetic damages			

Table 1: Radioinduced health effects due to a major NPP accident – model A, B und C: Number of victims (*incidence*) calculated according to estimated effective collective dose (PersSv). EAR = excessive absolute risk («risk factor» for calculation), Sv = Sievert

Severe radioinduced health damages	ICRP 103	model A	**model B**	model C
	EAR according to ICRP 103 (2007) **(outdated)**	EAR according to WHO / UNSCEAR 2013	**EAR based on Cardis 2005 / Körblein 2006 / Little 2012 / IPPNW 2014 / INWORKS 2015 / Hoffmann 2017 / European CVD 2017**	
Cancer	0.1 / Sv	0.2 / Sv	**0.4 / Sv**	
Cardiovascular diseases			**0.15 / Sv**	
Other non-cancer diseases, genetic defects and other reproductive disorders	- Threshold dose 500 mSv for non-cancer diseases - 0.002 / Sv for genetic damages			

Table 1: Radioinduced health effects due to a major NPP accident – model A, B und C: Number of victims (*incidence*) calculated according to estimated effective collective dose (PersSv). EAR = excessive absolute risk («risk factor» for calculation), Sv = Sievert

Severe radioinduced health damages	ICRP 103	model A	**model B**	**model C**
	EAR according to ICRP 103 (2007) **(outdated)**	EAR according to WHO / UNSCEAR 2013	**EAR based on Cardis 2005 / Körblein 2006 / Little 2012 / IPPNW 2014 / INWORKS 2015 / Hoffmann 2017 / European CVD 2017**	**Same EAR as for model B**
Cancer	0.1 / Sv	0.2 / Sv	**0.4 / Sv**	0.4 / Sv
Cardiovascular diseases			**0.15 / Sv**	0.15 / Sv
Other non-cancer diseases, genetic defects and other reproductive disorders	- Threshold dose 500 mSv for non-cancer diseases - 0.002 / Sv for genetic damages			**Semiquantitative estimations (no established “risk factors” for calculations)**

Table 2. Major NPP accident – health effects, model A (WHO/UNSCEAR): Estimate of number of radioinduced cancer cases (incidence) in Europe (mean).

NPP / region		NPP Beznau (1 reactor) CH	NPP Bugey (1 reactor) FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	radioinduced cancer cases	10‘116	15‘640	24‘688	18‘598	21‘995

Table 2. Major NPP accident – health effects, model A (WHO/UNSCEAR): Estimate of number of radioinduced cancer cases (incidence) in Europe (mean). Maximum: NPP Gösgen

NPP / region		NPP Beznau (1 reactor) CH	NPP Bugey (1 reactor) FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	radioinduced cancer cases			24‘688		

Table 2. Major NPP accident – health effects, model A (WHO/UNSCEAR): Estimate of number of radioinduced cancer cases (incidence) in Switzerland (mean)

NPP / region		NPP Beznau (1 reactor) CH	NPP Bugey (1 reactor) FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Switzerland	Radioinduced cancer cases	5‘666	737	16‘879	6’889	14‘388

Table 2. Major NPP accident – health effects, model A (WHO/UNSCEAR): Estimate of number of radioinduced cancer cases (incidence) in Switzerland (mean)

Maximum: NPP Gösgen and NPP Mühleberg

NPP / region		NPP Beznau (1 reactor) CH	NPP Bugey (1 reactor) FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Switzerland	Radioinduced Cancer cases			16‘879		14‘388

Table 2. Major NPP accident – health effects, model A (WHO/UNSCEAR): Estimate of number of radioinduced cancer cases (incidence) in Switzerland (mean); NPP Bugey: → radioinduced cancer cases mainly in France

NPP / region		NPP Beznau CH	NPP Bugey (1 reactor) FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	radioincuced cancer cases		15‘640			
Switzerland			737			
France			11‘073			

Table 3. Major NPP accident – health effects, model B: estimates of the number of radioinduced cancer and cardiovascular cases. Maximum for NPP Gösgen: → Nearly 50 000 cancer cases and more than 18 000 cases of myocardial infarctions (MI) and cerebrovascular insults (CVI) in Europe

NPP / regione		NPP Beznau CH	NPP Bugey FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	Cancer cases	20‘232	31‘279	**49‘376**	37‘196	43‘989
	Cardiovascular diseases	7‘587	11‘730	**18‘516**	13‘949	16‘496

Table 3. Major NPP accident – health effects, model B: estimates of the number of radioinduced cancer and cardiovascular cases (mean). NPP Leibstadt: more radioinduced cancer cases and cardiovascular cases (MI, CVI) in Germany then in Switzerland.

NPP / region		NPP Beznau CH	NPP Bugey FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Switzerland	Cancer cases				13‘778	
	Cardiovascular diseases				5‘167	
Germany	Cancer cases				16‘711	
	Cardiovascular diseases				6‘266	

Table 4: Major NPP accident – impact of weather on numbers of victims, model B (median and deciles)

NPP / region	Weather situations during one year	NPP Beznau CH	NPP Bugey FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	worst 10% (36 days)					
	median					
	most favorable 10% (36 days)					

Maps illustrating the cloud of 17 aerosols on specified weather situations (simulation over 72 hours)

Movies (dispersion of radioactive clouds):
https://www.youtube.com/channel/UC-roJCWGJcH8RpCZ95lz-xA

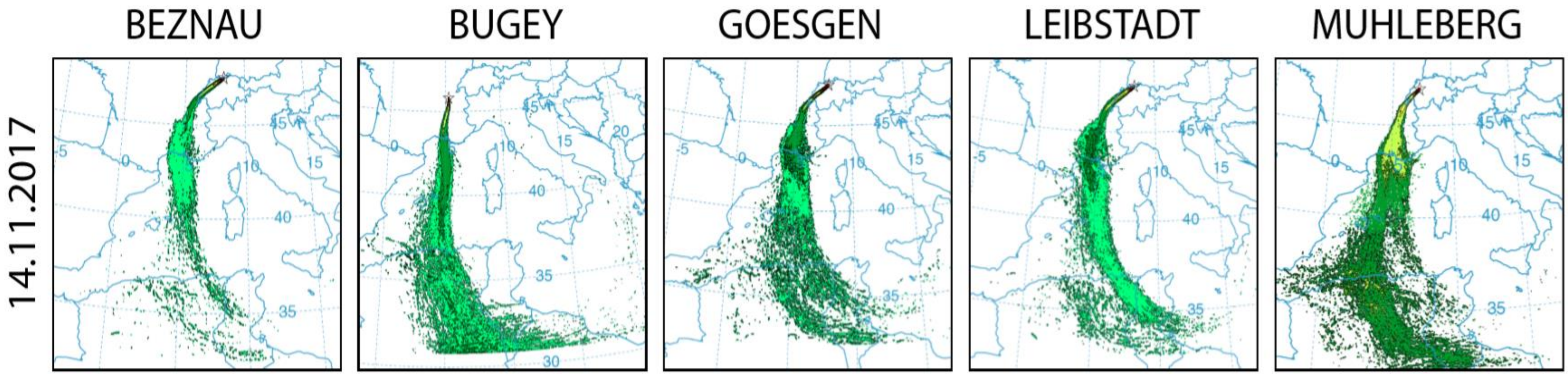
Legend 1. Inhalation and external exposure to the cloud of 17 aerosols

Red	≥ 100 mSv
Orange	≥ 50 mSv
Yellow	≥ 20 mSv
Yellow-green	≥ 6 mSv
Dark green	≥ 1 mSv
Light green	≥ 0.2 mSv

Inhalation and external exposure to the cloud of 17 aerosols

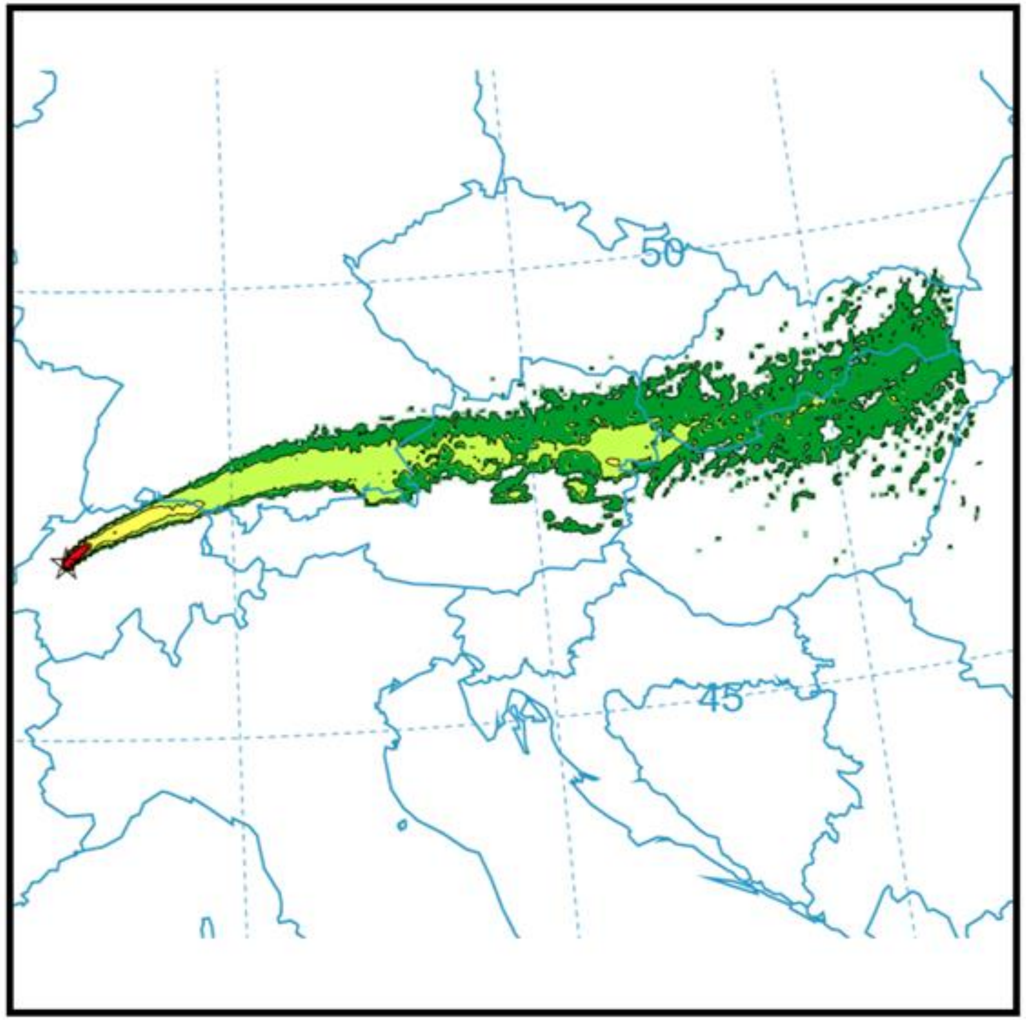
Simulations of a major accident in a NPP (CH, FR): Distribution of radioactive cloud in case of northern winds (example of 14th November 2017) in Europe

→ similar qualitative patterns of dispersion despite different sources (NPPs)



NOAA Hysplit model for cloud dispersion

22nd February 2017: same day, different cloud distribution due to different sources: NPP Mühleberg (CH; left) and NPP Bugey (FR; right)



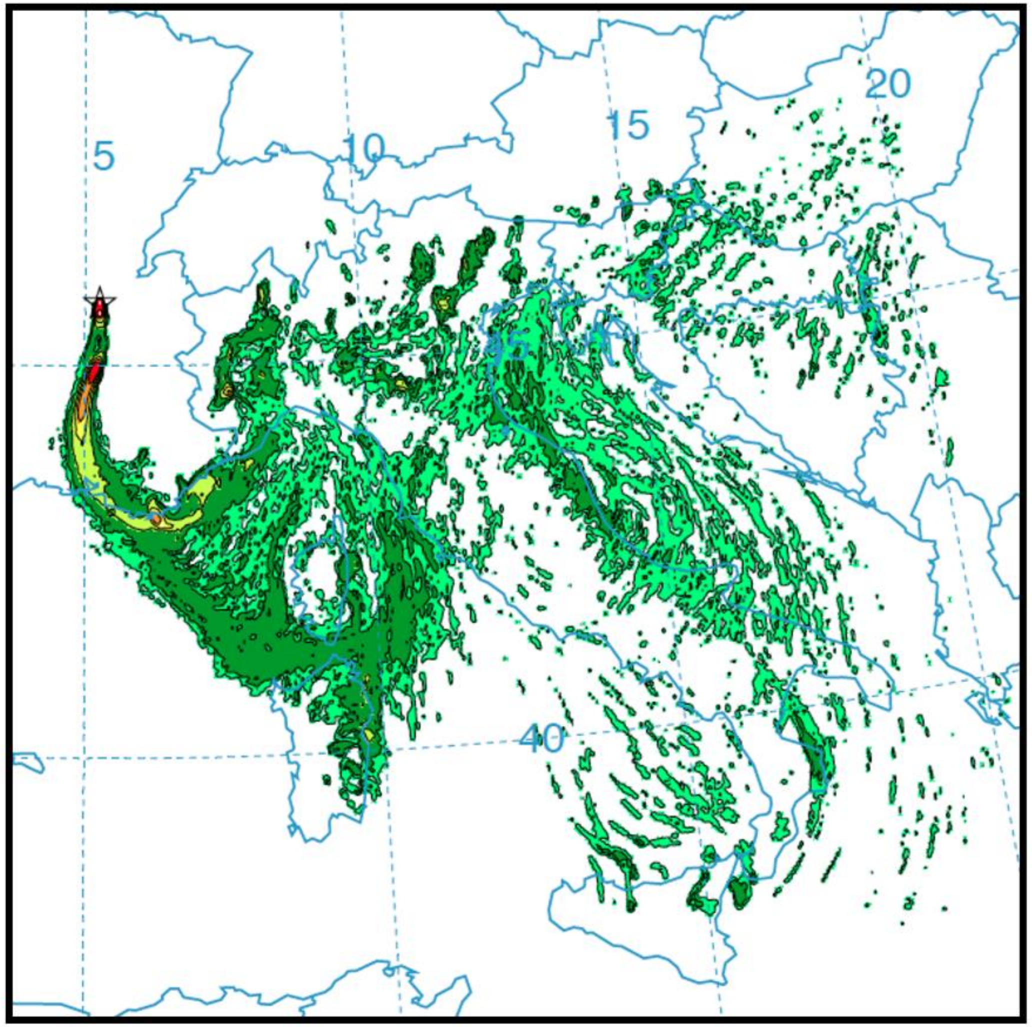
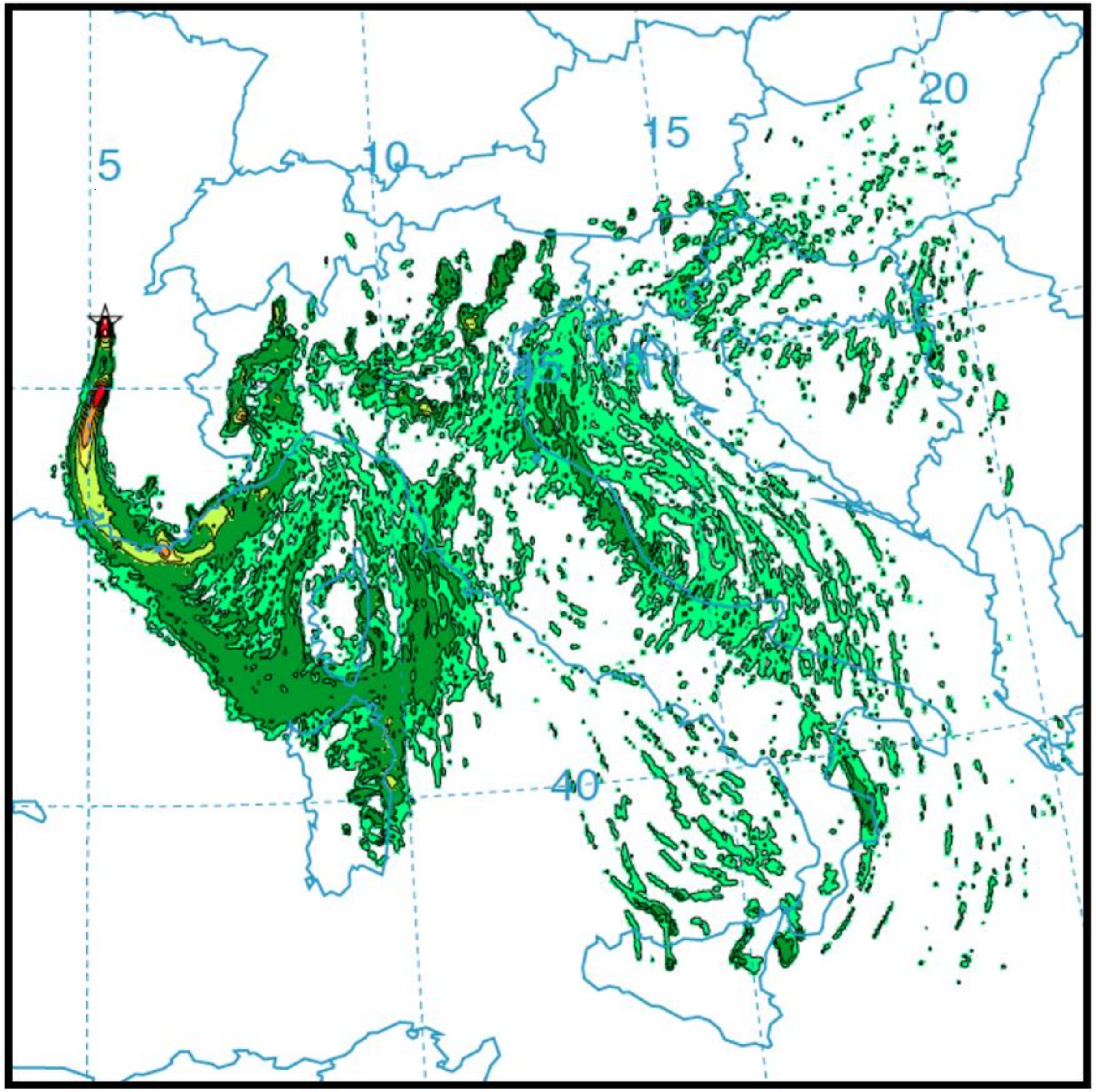


Table 4: Major NPP accident – impact of weather on numbers of victims, Modell B (median and deciles)

NPP / region	Weather situations during one year	NPP Beznau CH	NPP Bugey FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	worst 10% (36 days)					
	median	24’151	37’649	60’881	41’477	57’738
	Most favorable 10% (36 days)					

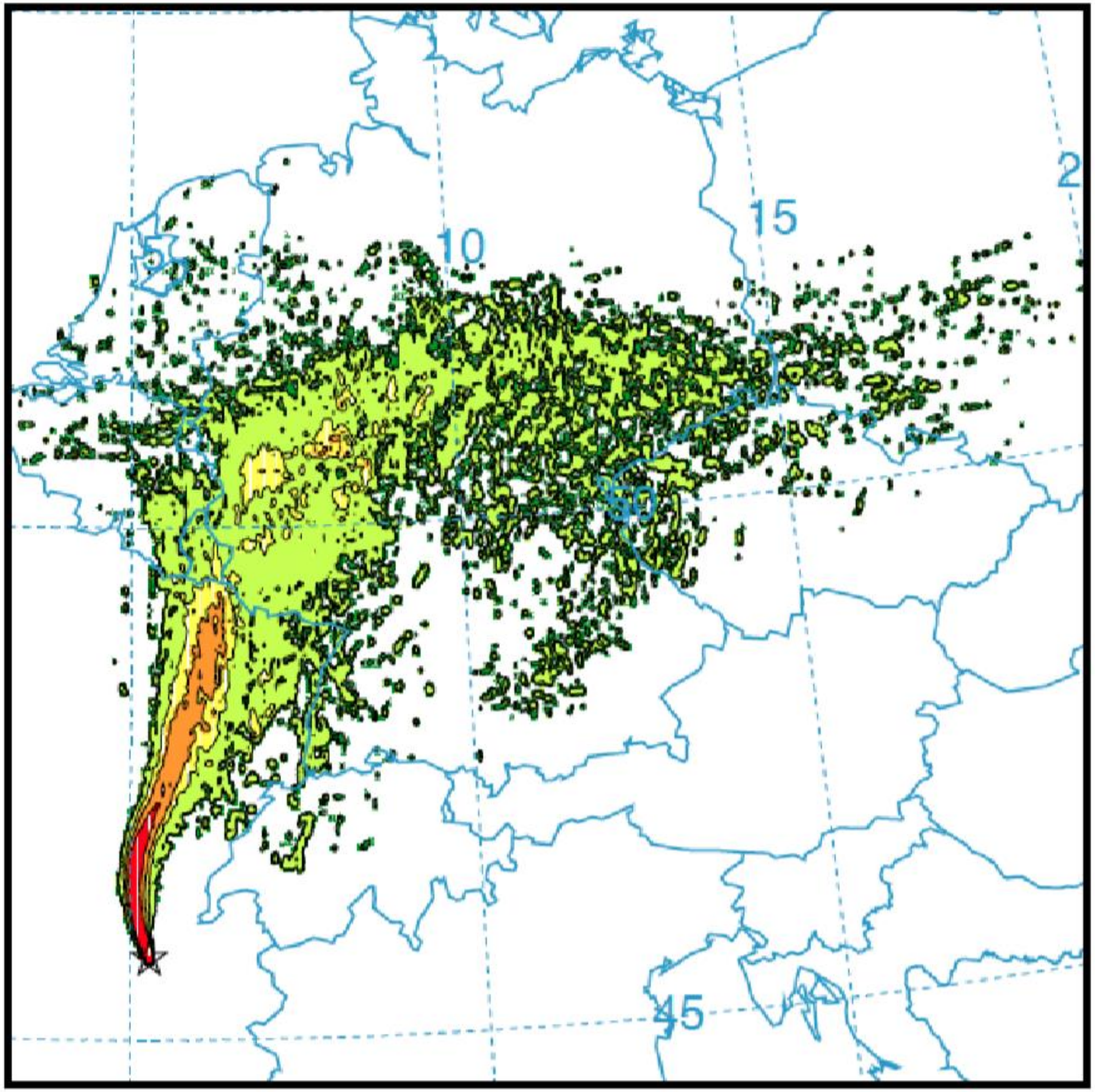


Distribution of the radioactive cloud from NPP Bugey

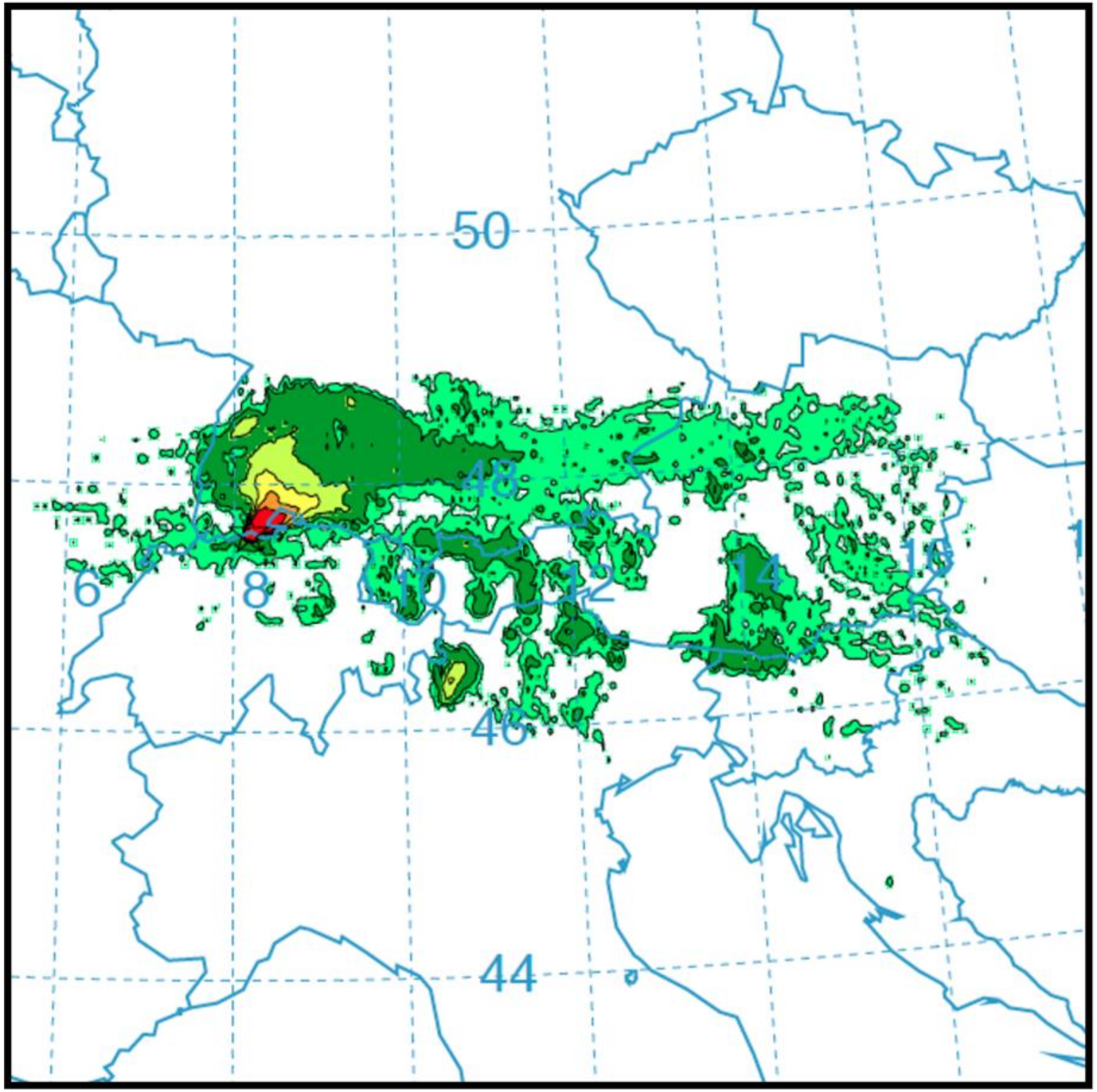
22nd February 2017
northern winds

Distribution of the radioactive cloud from NPP Bugey

27th May 2017, southern winds

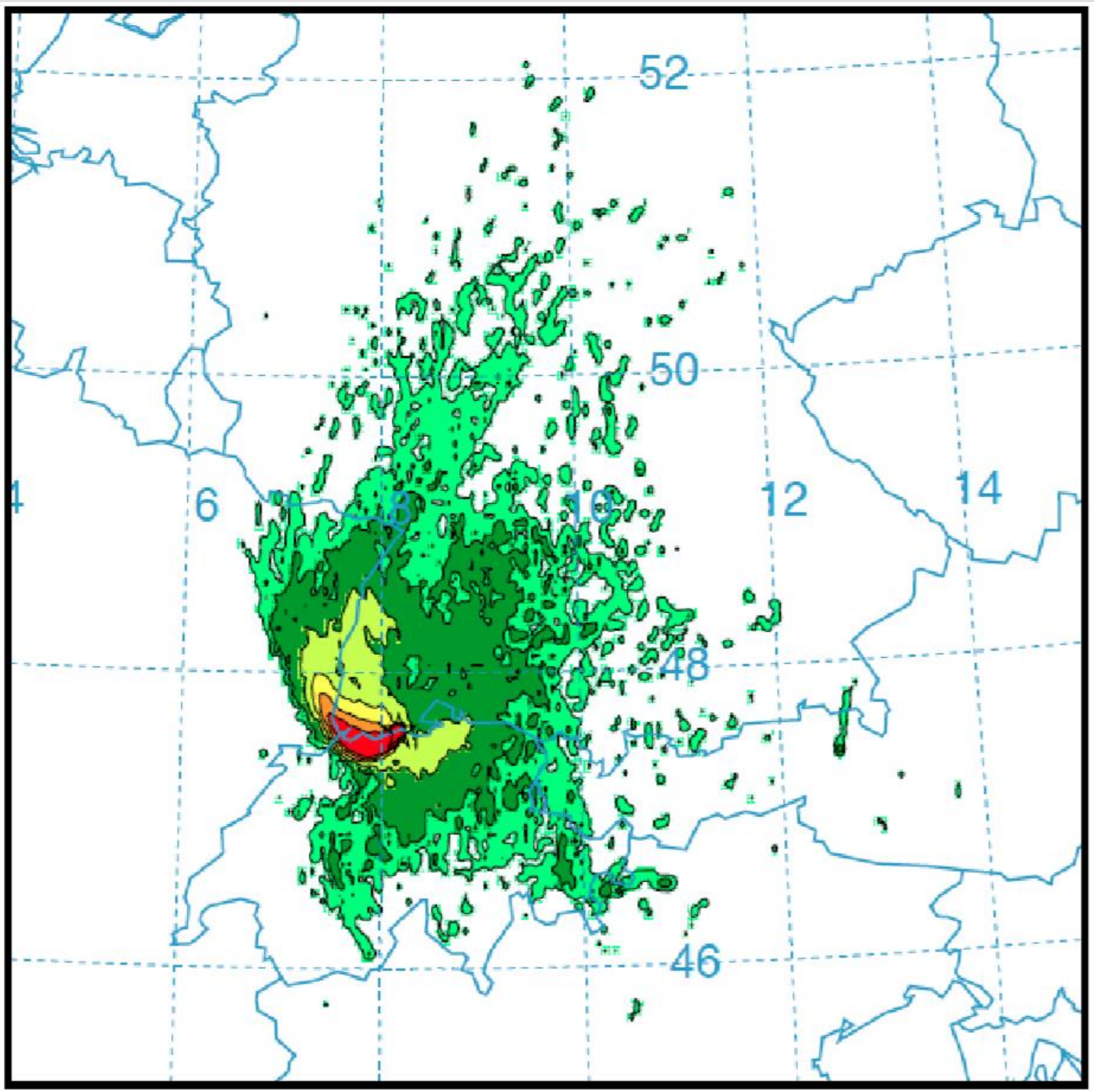


Leibstadt 3rd May 2017
+/- stable, little winds from west



Simulation distribution of the radioactive cloud

Accident NPP Leibstadt 27th May 2017 +/- stable, little winds from south



Simulation sistribution of the radioactive cloud

Accident of NPP Leibstadt 27th February 2017 strong south-western winds

(…→ Nürnberg, Leipzig, Dresden, Berlin, Baltic states, Helsinki)

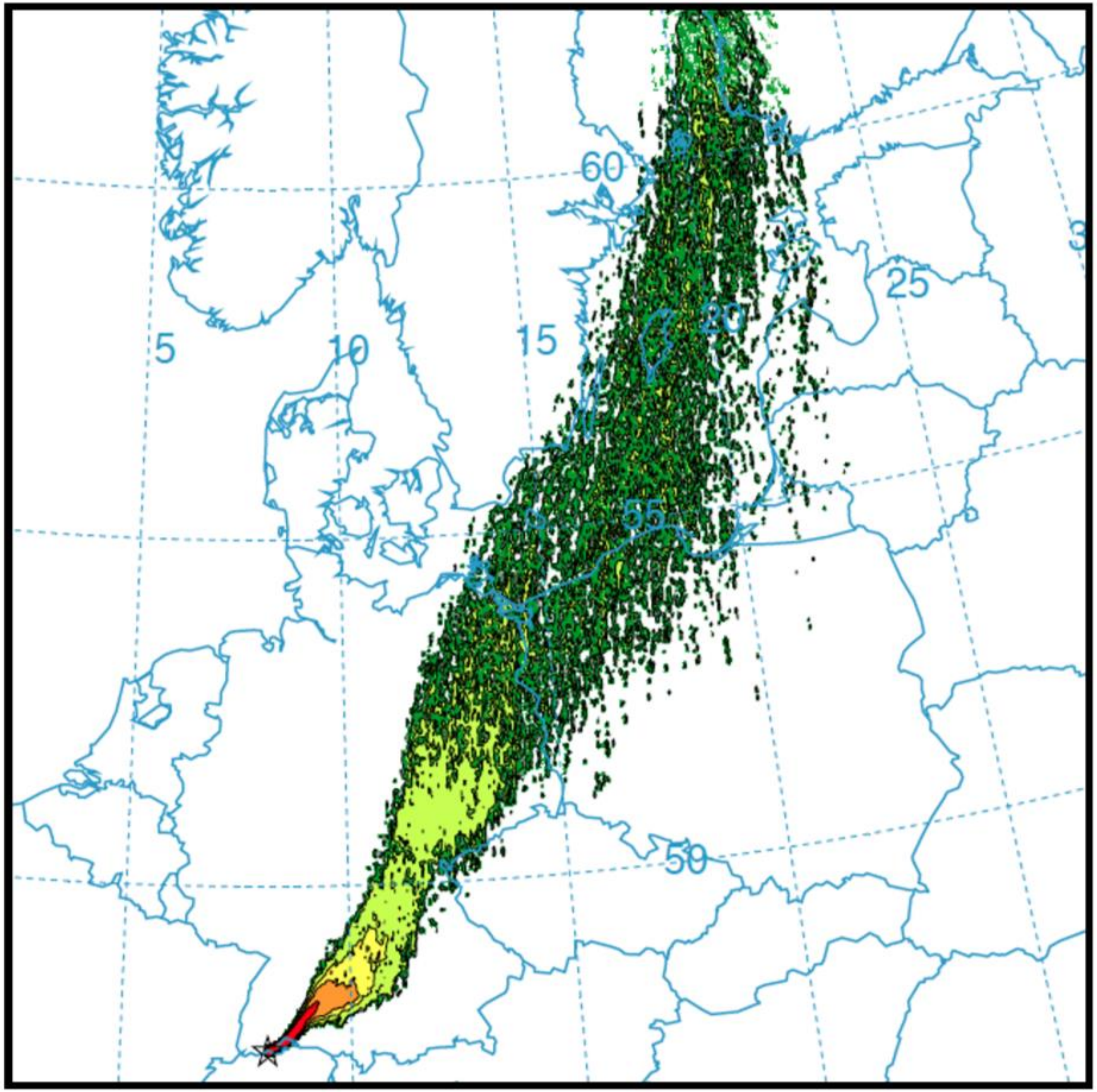


Table 4: Major NPP accident – impact of weather on numbers of victims,

Modell B: bad weather situation on 36 days of the year → nearly doubling of of risk for severe radioinduced diseases (cancer, non-cancer)

NPP / region	Weather situations during one year	NPP Beznau CH	NPP Bugey FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	worst 10% (36 days)	52’191	70’366	109’578	92’320	97’231
	median	24’151	37’649	60’881	41’477	57’738
	Most favorable 10% (36 days)					

Table 4: Major NPP accident – impact of weather on numbers of victims,
Modell B: bad weather situation on 36 days of the year → nearly doubling of of risk for severe radioinduced diseases (cancer; cardio-vascular: MI, CVI)

NPP / region	Weather situations during one year	NPP Beznau CH	NPP Bugey FR	NPP Gösgen CH	NPP Leibstadt CH	NPP Mühleberg CH
Europe	worst 10% (36 days)	52’191	70’366	109’578	92’320	97’231
	median	24’151	37’649	60’881	41’477	57’738
	Most favorable 10% (36 days)	9’299	18’126	32’884	19’305	29’067

Table 5. Major NPP accident – health effects model C: Number of victims due to radioinduced cancer and cardiovascular diseases as for model B; additionally other non-cancer diseases, genetic damages and disturbances of reproduction. Risk factors for calculations not established, however total number exceeding radioinduced cancer cases

Other non-cancer diseases (for cardiovascular diseases see model B.)

- of the digestive tract
- of the lung
- of the hormonal system (thyroid gland, diabetes, hormonal infertility of women)
- of the central nervous systenm (…intellectueal deficits, suicides, psychoses, degeneration of the left half of brain in right-handers) des central nervous system

Genetic damages and disturbances of reproduction

- increase of cases with trisomy 21 (Down's syndrome),
- malformations (especially of the limbs, the face, the brain and of the myelon as well of the heart)
- increase of numbers of abortions,
- increase of numbers of stillbirths,
- Distorted sex odds radio (boys / girls) at birth signalising augmented numbers of early abortions

Long-term evacuation of populations

At Chernobyl, the level of evacuation was set at 555 kBq/m2 de ^{137}Cs (corresponding to 5.6 mSv / y)

Cumulative number of impacted persons living in regions above the critical level of Césium-137 contamination of 1'480kBq/m2 (corresponding to 14.8 mSv / y) - mean impact of 365 meteorological simulations in 2017

2017	Beznau	Bugey	Goesgen	Leibstadt	Muehleberg
^{137}Cs deposition **kBq/m2**		persons	persons	persons	persons
≥ 1'480	**252 251**	**217 879**	**426 871**	**502 596**	**309 555**

Impact on soils

- In case of a possible major accident in NPP Beznau (just as *one* example) about 1'076 km^2 (**1/8 of Swiss agricultural soil**) would receive a radiocontamination of more than 37 kBq / m^2 (corresponding to about 0.4 mSv/y) of 6 isotopes with half lives of more than 6 months (on average) .
- Overall 41'000 km2 of European agricultural soil would receive more than 37 kBq / m^2 (corresponding to about 0.4 mSv/y) of 6 isotopes with half lives of more than 6 months (om average .

To compare with Ref. Piguet 2015, *The Vulnerability of Small Countries in the Event of a Major Nuclear Accident in Their Territory:*

→ Exclusion zone: 2'826 km^2 (30km radius) (for comparison: **For Switzerland, this would be 1/5 to 1/4 of the "high productivity zone"** (…industry, agricultural, urban areas) = roughly 12'400 km2 of a total of CH-surface = 41'300 km2)

Conclusion

a) The **major nuclear accident probability is around 18 times higher** then the IAEA-normative. A major NPP accident in one of the 9 reactors studied is **«probable»** (…around 1% during 50y) in the terminology of the IAEA .

b) A major NPP accident would lead to up to around 100'000 radioinduced cancer cases and severe cardio-vascular diseases – however the true health effects are much larger taking into account the huge number of other radioinduced non-cancer diseases and genetic / reproductive health detriments.

c) Up to **half a million persons would need a longterm evacuation** after a major NPP accident.

d) The protection of the population could be impossible. Presently the Swiss authorites plan for a NPP-accident at the **A4-level** only – the most realistic scenario according to EUNUPRI2019 is **level A5-A6** (**factor 30**)

e) The sanitary + «migratory» + economic + financial + political crisis due to a major NPP-accident could lead to severe societal uproar and may heavily compromise the Swiss federal solidarity

f) The Swiss Federal Council should rely on diversified information sources (… to avoid at least one dimension of «human error» in the nuclear power era.)

Lessons to be learnt from recent NPP accidents – closing general remarks

- ***Chernobyl 1986:***

  A technology causing an accident of a size so big, that even after one generation we still don't know, whether there were 10'000 or 1 000 000 cancer victims, is ***far too risky for mankind and therefore irresponsible***

- ***Fukushima 2011:***

  A technology causing an accident whose dimension for the fate of 50 million humans such as the population of Tokyo just depends randomly on the direction of winds and eventual rain must be declared ***totally unusable and hoplessly out of date***

Protection of the climate is health protection

28th September 2019,
Bern, Switzerland
National Climate
Demonstration

https://klima-gesundheit.ch/