Assessment of possible consequences from severe accidents at nuclear power plants in Europe

Petra Seibert[1], Delia Arnold[2], Nikolaus Arnold[3], Klaus Gufler[3], Radek Hofman[4] Helga Kromp-Kolb[1], Gabriele Mraz[5], Anne Philipp[4], Steven Sholly[3]

[1]Institute of Meteorology, BOKU, Austria
[2]Central Institute of Meteorology & Geodynamics, Austria
[3]Institute for Security and Risk Sciences, BOKU, Austria
[4]Department of Meteorology and Geophysics, University of Vienna, Austria
[5]Austrian Institute of Ecology, Austria

NERIS Workshop 2015, April 27, 2015

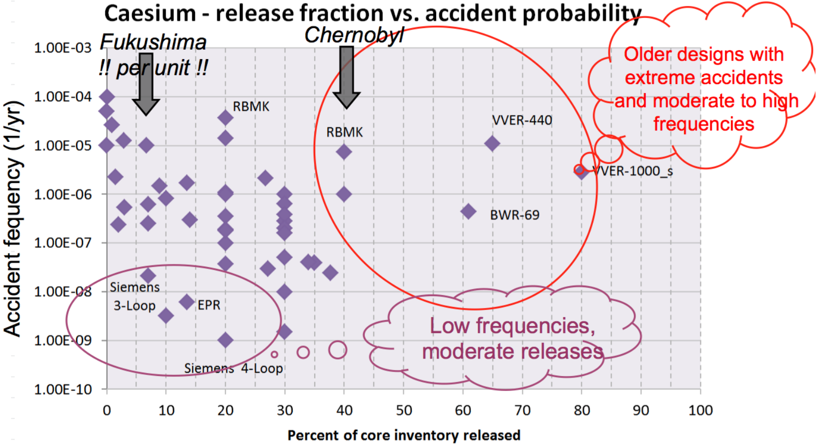
The flexRISK project

- 2009-2012, interdisciplinary
- Main goals:
  - Demonstrate the overall geographical distribution of the risk caused by severe accidents in nuclear power plants in Europe
  - Show the contribution of different nuclear power plants according to type and geographical location
  - Study the effects of phase-out scenarios
- Methods:
  - Collect data for all 228 NPPs in Europe + Akkuyu (TR), Bushehr (Iran)
  - Identify severe accident with inventories, release fractions, release frequencies for each plant
  - Perform Europe-wide dispersion & dose calculations for 2788 cases
  - Produce **single-case maps** and various **aggregated risk** parameters

Accident data

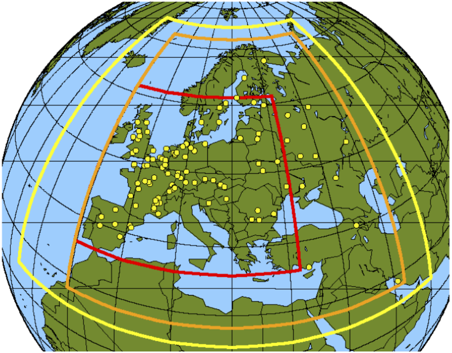
- Limited data available (nuclear industry business secrets)
- Grouping of NPPs into similar types
  - 13 groups for release shapes (duration and effective height)
  - 24 groups for release fractions (of inventory being released)
  - Where available (public), plant-specific data used
- Different types of severe accidents considered, e.g.
  - Steam generator tube ruptures (late)
  - Core melt accident with failure of containment isolation (early)
  - Interfacing Systems Loss-Of-Coolant Accident (early)
  - Core power excursion — RBMK (early)
  - Loss of carbon dioxide coolant — GCR (late)

Release fractions & accident frequency



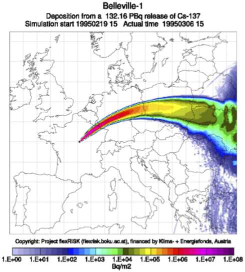
- Most accidents considered release 10-30% of inventory of volatile nuclides, some up to ca. 60%
- Frequencies span 5 orders of magnitude!

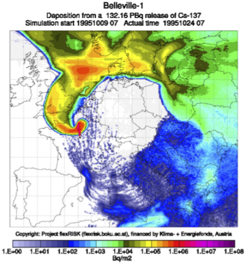
Dispersion calculations

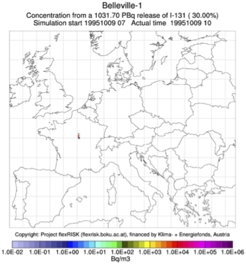


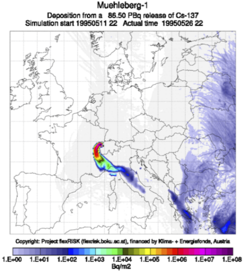
- Lagrangian dispersion model FLEXPART, dry and wet depo
- Fine output domain 10 km (red), Coarse output domain 1 deg (orange), Calculation domain (yellow)
- ERA-Interim 70 km meteo input data for 1995, 2000-2009, 3-hourly, **2788** cases (real weather situations)
- 2 weeks in VSC-2 Vienna supercomputer, 2.5 TB compressed output

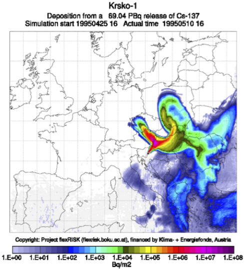
Ground contamination & concentration examples

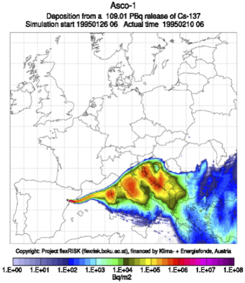








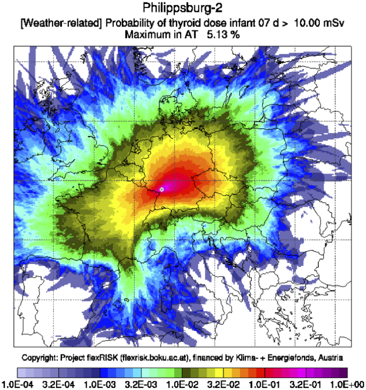




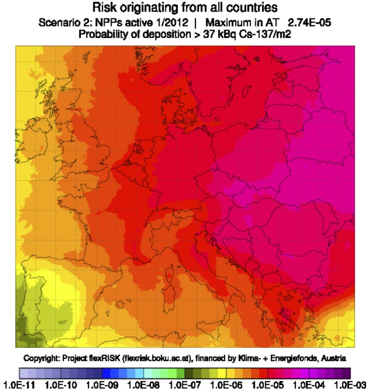
Risk definition and calculation

- Risk is taken as probability of exceeding a threshold contamination or dose
- Justification: intervention measures only above certain levels
- Emergency preparedness needs to know a (nearly) "worst case", not a mean value
- Thus we need to simulate a large number of cases
- $P = P_{\mathrm{acc}}(\text{accident happens}) \times P_{\mathrm{met}}(\text{gridpoint affected})$
  - P_{met} is the meteorological risk, determined by transport and deposition properties of the atmosphere in combination with release shape (duration and height of release)

Risk maps examples



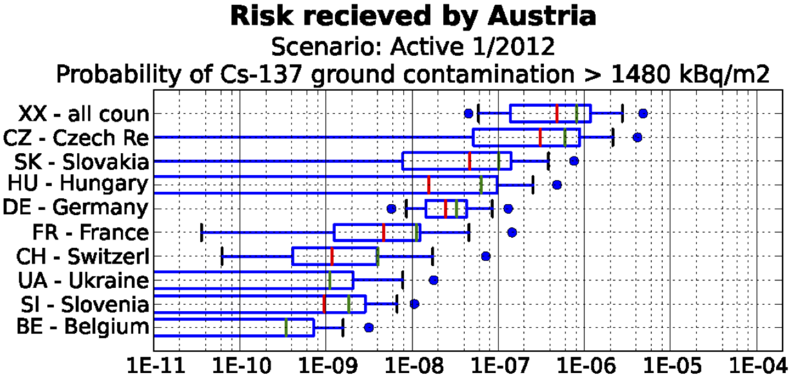
Intervention level for iodine prophylaxis of children in Austria (10 mSv 7 day inhalation dose): weather-related probability of exceeding the intervention level for Philippsburg 2



Distribution of total risk: Probability of exceeding the 37 kBq/m2 Cs-137 IAEA threshold for all active NPPs (met. frequency x frequency of accident in each NPP unit)

Risk originators for Austria

- Contribution of each NPP country to Austria's risk of receiving a contamination over 1480 kBq/m2 on the part of the country indicated in the box-and-whisker



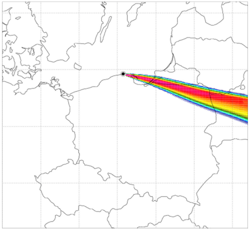
- Risk for Austria is dominated by Czech NPPs

Application of flexRISK methodology to Lubiatowo case

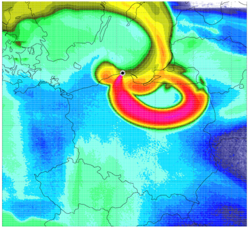
- Possible off-site consequences for three reactor designs (*Hitachi ABWR*, *Areva EPR*, *Westinghouse AP1000*) proposed for new Polish NPP were examined
- For each design, two accident sequences were assumed, with intact and bypassed containment respectively
- Dispersion of releases resulting from each sequence were simulated using Flexpart
  - **revised wet deposition scheme** with more complex parametrization: in cloud and below cloud scavenging
  - 86 real meteorological conditions from 1995 (overall 516 simulations), output on grid 3×3 km
- Evaluated radiological quantities were: time integrated deposition $(\mathrm{Bq/m^2})$, time integrated concentration $(\mathrm{Bq\ s/m^3})$ and various types of doses for infants and adults (mSv)
- Expected doses and countermeasures for selected scenarios were evaluated in Gdańsk, Gdynia and Warsaw respectively

Application of flexRISK methodology to Lubiatowo case

- Variability of meteorological condition
  - Trajectory of the plume and intensity of deposition are governed by prevailing meteorological conditions
  - Three contamination patterns for the same source term and different meteorological conditions:



7 Feb 1995 11:00



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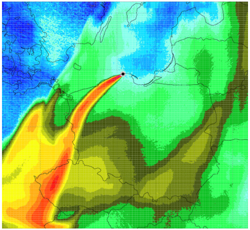

13 Apr 1995 11:00

- Various meteorological conditions can results in complicated contamination patterns and severe contamination of Polish territory or territories of other countries

Application of flexRISK methodology to Lubiatowo case

- Results show that under adverse meteorological conditions, severe consequences are likely far beyond emergency planning zone for all three reactor designs
- Simulations revealed possibility of exceeding intervention limits for iodine prophylaxis all over the Poland and even further. Limits for sheltering and temporary relocation were exceeded in distance range including Gdańsk and Gdynia
- These extreme situations, although unlikely, must be also considered
- The possibility of very large releases, even with extremely small probabilities, leads to correspondingly serious potential consequences
- Comprehensive overview of all cases is available online at `http://www.univie.ac.at/theoret-met/flexrisk_pl/`

Conclusion

- Risk pattern reflects site density, NPP type and climateMaxima: E. Central Europe, parts of FR, around large sites in UA and RUMinima on N European Atlantic coasts and in Mediterranean
- Substantial consequences (intervention measures) possible for distances up to 500-1000 km, more frequent / severe for up to 100-300 km.
  - That's in agreement with Chernobyl experiences, but many didn't want to fully face these consequences
- **Emergency planning presently focussing on too small areas.** In reality, almost all of Europe should be prepared for nuclear disaster
- Risk distribution depends on level of damage: high damage is more concentrated, lower damage spreads over long distance
- Risk distribution also depends strongly on accident frequency, but this parameter is highly uncertain

Extensive project web site

- http://flexrisk.boku.ac.at
- http://www.univie.ac.at/theoret-met/flexrisk_pl/