The PREDICT Project – WP3

Model comparison and model uncertainties for nuclear detonation scenarios

Wolfgang Raskob
on behalf of the WP3 partners

NERIS workshop, April 2026

Co-funded by the European Union

Outline

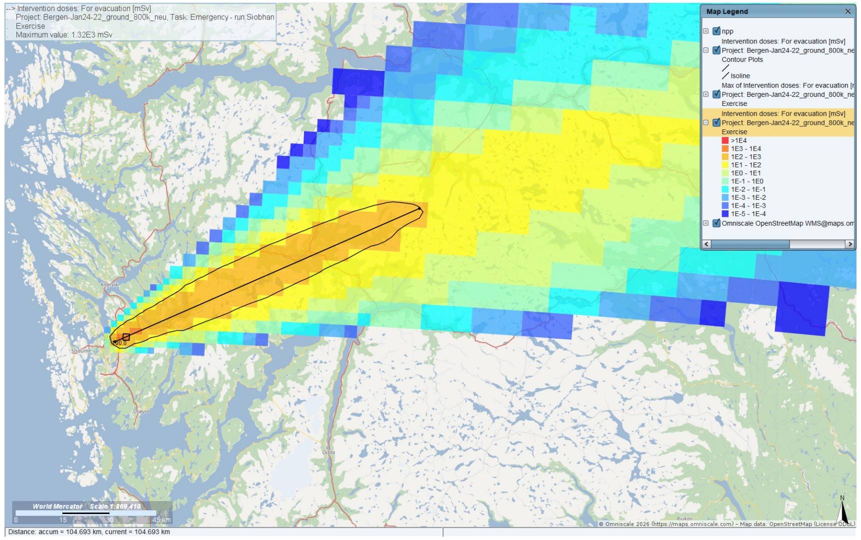
- Short introduction
- Description of work performed in the work package
- Results
- Conclusions

NERIS workshop, April 2026

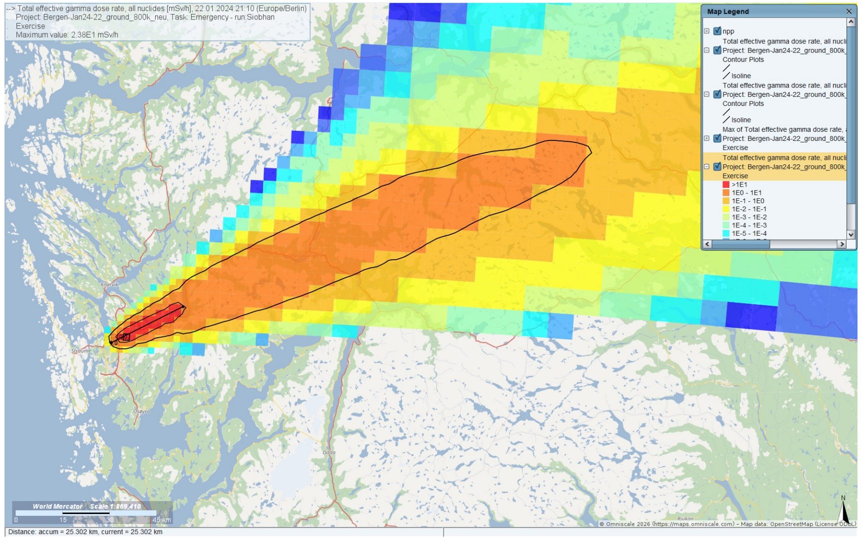
Co-funded by the European Union

The problem (10 kT detonation near ground)

Large evacuation areas (doses > 100 mSv, 7d)
Up to 100km



High dose rates(> 10 mSv/hr, up to 20km
> 1 mSv/hr, up to 150km)



Objectives of Work Package 3

- WP3 aims at quantifying model uncertainties resulting on the one hand from current limited understanding of key model parameters and on the other hand by exploring the consequences of critical weather conditions on the model results such as high precipitation events and weather conditions with changing wind directions and frontal passages
- With the knowledge gained in WP1 and WP2, parameter settings and, if possible, initial model improvements will be applied in our statistical analysis to demonstrate the possible reduction in result uncertainties
- For the operational community, WP3 will provide recommendations on which parametrisations should be applied in the simulation models.

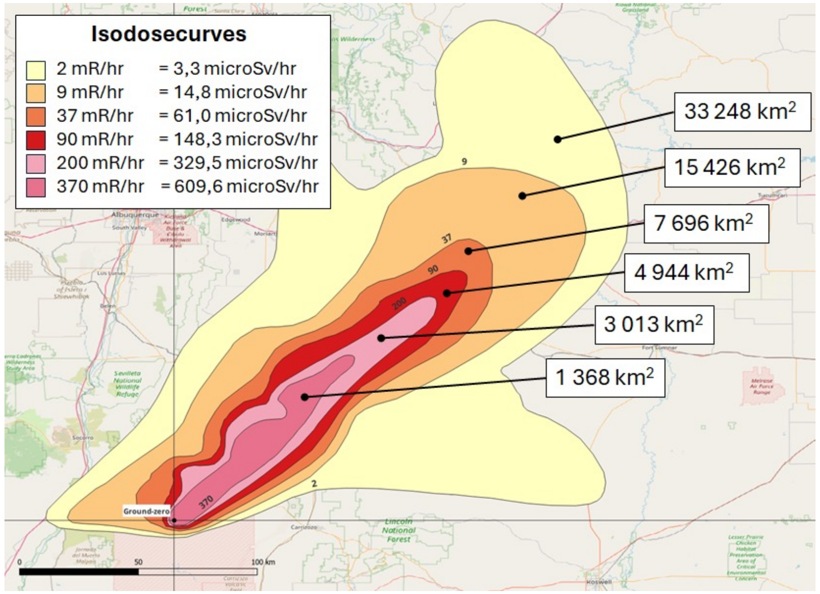
WP3 – Model Comparison

3.1 Model validation with historical contamination data from weapon tests from 1945 onwards (accuracy of the prediction)

To date work performed:

- Identified usable tests (Nancy, Harry, Trinity, Smoky, Small Boy)
- Data sets for all tests digitized
- Simulation performed
- Full comparison of model results from all project partners with all five test scenarios
- Exercise will be repeated towards the end of the project with improved input parameters

Trinity, 16 July 1945



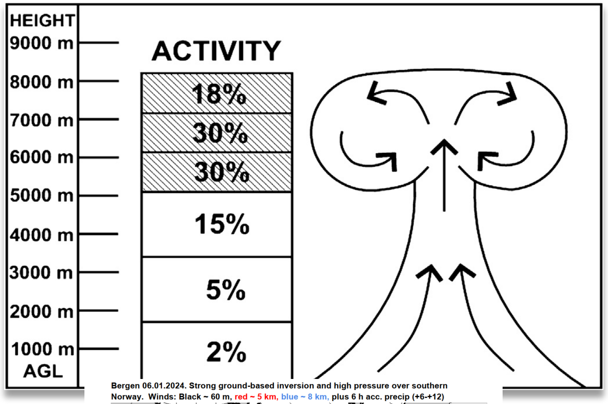
WP3 – Model Comparison

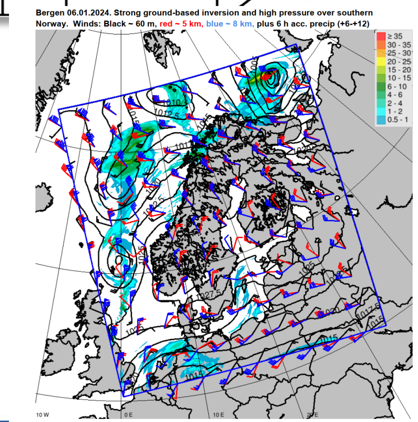
3.2 Sensitivity analysis for key source term parameters:

- Parameter variations for plume height, activity-height distribution, activity-particle size distribution and particle density were derived and applied for the five test cases
- Parameter variations performed for weather statistics but only for one (or two) model(s)

3.3 Sensitivity analysis for key weather conditions:

- Weather situations with simple or complex weather, changing wind directions and precipitation were identified for two locations, Bergen and Emden
- 4 Scenarios per city with low and high level detonation





Co-funded by the European Union

WP3.1 challenges

- We were aware, that information on historic tests is limited in terms of input and result data
- Meteorological input data is course – nowadays ~2 - ~10 km
  - European Medium Range Weather Forecasting (ECMWF) reanalysis numerical weather data, ERA-5, was extracted from the European Copernicus web site with a resolution of 0.25 degrees (~ 30 km) and an hourly time resolution
  - Dose rate data was taken at any time but visualised for 12 hours after detonation

Co-funded by the European Union

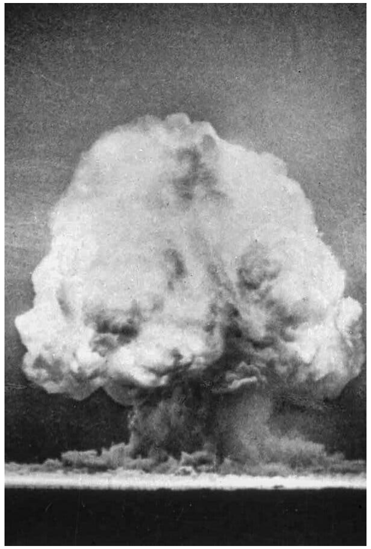
WP3.1 Scenarios

Harry 32kT

Small Boy 1.65kT

Smoky 44kT

Trinity 21kT

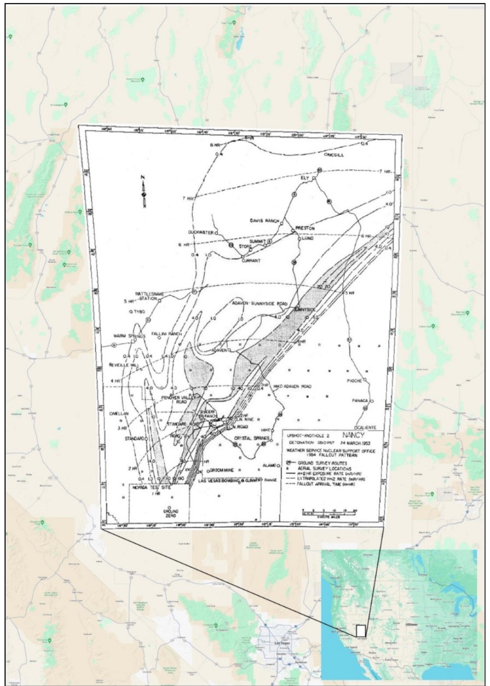


Nancy 24kT

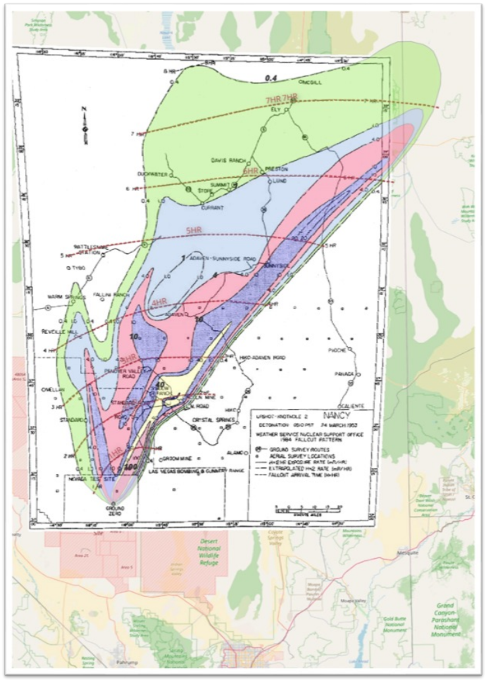
Co-funded by the European Union

WP3.1 Data digitisation

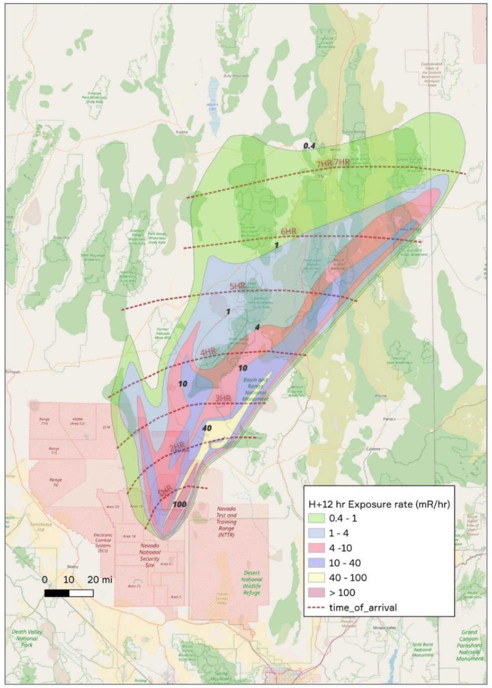
Original data in book



step digitisation



final step conversion in shape



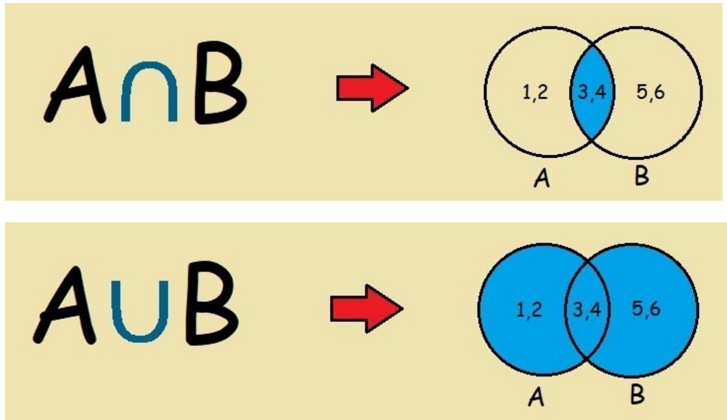
WP3.1 Simulation models participating

- METNO/DSA: Lagrangian particle model (SNAP)
- UKMO: Lagrangian particle model
- KIT: Lagrangian particle model (LASAT)
- BfS: Lagrangian particle model (FLEXPART)
- DEMA: Lagrangian particle puff model
- RIVM: Gaussian puff model (Lagrangian)

Co-funded by the European Union

WP3.1 Evaluation first approach

- Figure of Merit in Space (FMS)
- Problem: All historic data were recalculated to 12h
- We did similar and used dose rate at 48 hours – recalculated to 12 hours
- Conversion H+48 -> H+12 = $\frac{12^{-1.2}}{48^{-1.2}}$ = 5.3)



$$FMS = 100 \cdot \frac{Intersection\ AB}{Union\ AB} = 100 \cdot \frac{A \cap B}{A \cup B}$$

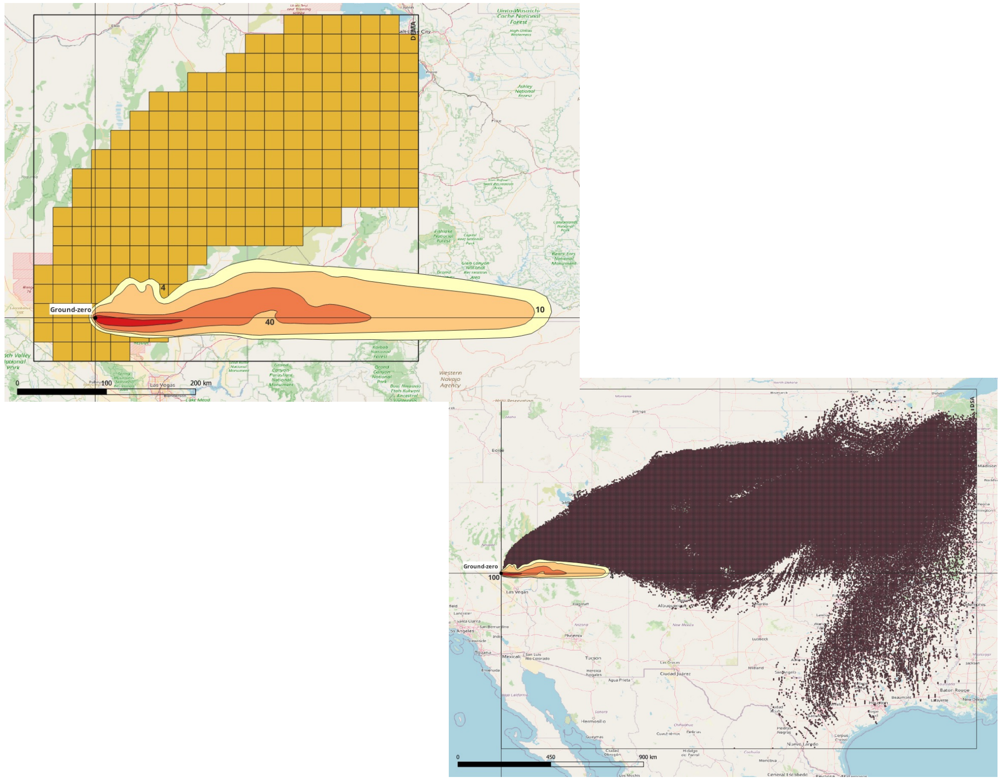
Co-funded by the European Union

WP3.1 Evaluation first approach

- Dose rate considered from 0.4 - 100 mRöntgen/hr
- Isodose areas evaluated for (1 mSv/hr = 607 mRöntgen/hr)
  - 0.4, 1.0, 4.0, 40.0, and 100.0 mRöntgen/hr
- Isodose areas were evaluated with the Figure of Merit in Space approach
- Results were difficult to compare

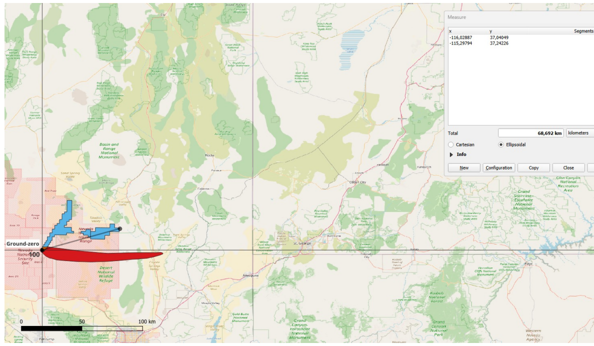
WP3.1 Evaluation first approach

- Issues encountered
  - Weather data might not fit with the monitored data – for what ever reason
  - Parametrisation does not fit reality and therefore, deposition pattern do not fit monitoring information
  - Assessment area very different

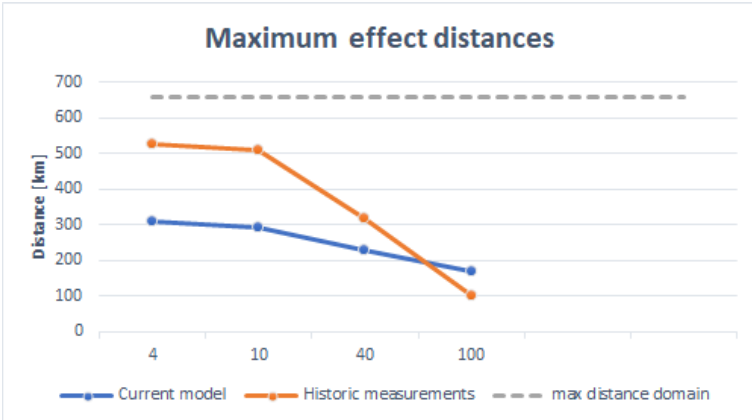


WP3.1 Evaluation second approach

- Consider the isodose area independent of its location as was monitored
- Consider the maximum effect distance
- Consider the FMS as in the first approach



Isocurve 100	
Isocurve area	890 km^2
Model area	606 km^2
Intersection	15 km^2
Distance	69 km



WP3.1 Evaluation third approach

- Shape
- Area comparison (model vs. isodosecurve)
- Distance comparison (model vs. isodosecurve)
- Figure Merit in Space (FMS)
- Conclusion

- For some results we considered also 1000 mRöngten/hr

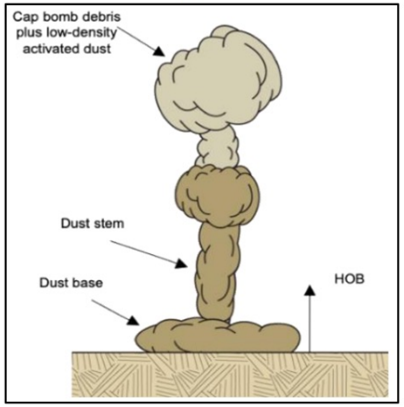
WP3.1 Evaluation third approach

Smoky	Shape	similar	
	Area	underestimation	factor 1-10, increasing with dose rate
	Distance	underestimation	factor 1-4, only factor 4 for 1000 mR/hr
	FMS	range 3-37%	overall good, but only 3% for 500 and 1000
	Conclusion	good agreement	similar shape, high FMS

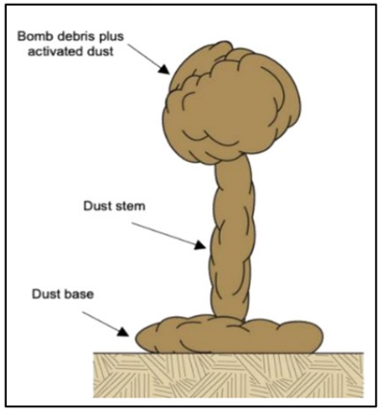
WP3.1 Evaluation third approach

	kT	Height of burst in m							
Nancy	24	91 Regime 5	Reasonable	Inconclusive	Good	Good	Reasonable	Low
Harry	32	91 Regime 4?	Reasonable	Inconclusive	Reasonable	Low	Good	Low
Smallboy	1,65	3 Regime 6	Reasonable	Good	Low	Reasonable	Reasonable	Reasonable
Smoky	44	210 Regime 5	Reasonable	Inconclusive	Good	Good	Good	Low
Trinity	21	30 Regime 6	Reasonable	Inconclusive	reasonable	Reasonable	Good	Reasonable

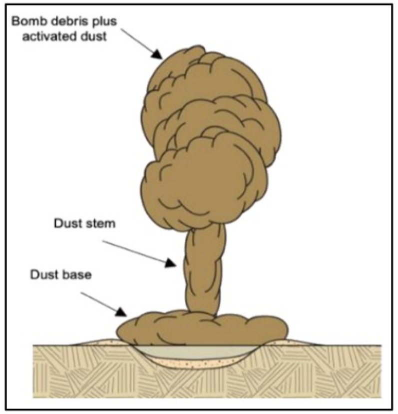
Regime 4



Regime 5



Regime 6



Co-funded by the European Union

WP3.1 way forward

- With the knowledge of the results from the first round and the evaluation of the parameter variations in WP3.2, new simulations with "optimised" model parameters will be performed in the second half of 2026

PIANOFORTE EUROPEAN PARTNERSHIP FOR RADIATION PROTECTION RESEARCH
PREDICT
Co-funded by the European Union

WP3.3

- Objectives: to explore the sensitivity and uncertainty of model results related to variable weather conditions
- Three aspects
  - Numerical weather prediction data used by the different atmospheric transport and dispersion models
  - The atmospheric transport and dispersion model itself
  - Near ground and higher in the atmosphere burst

WP3.3 Participating models

Participant	NWP model/data set	Horizontal resolution	Geographical domain covered	Access to historical data
KIT	ERA5	31 km	Global	1940 to present
RIVM	ECMWF ECMWF Europe Harmonie43 Could also run on MET Norway data	0.25° x 0.25°, 3h 0.1° x 0.1°, 1h 0.018° x 0.029°, 1h	Global 35°–80°N, -12°–60°E 49°–56.002°N, 0 –11.281°E, a larger high-resolution domain could be obtained from KNMI upon request	2024
SSM	ECMWF ECMWF Europe AROME/Harmonie	0.25° x 0.25°, 3h 0.1° x 0.1°, 1h 2.5 km, 1h	Northern Hemisphere Europe (see figure below) Northern Central Europe and Scandinavia (see figure below)	From SMHI upon request From SMHI upon request 2021-01-22 to 2022-01-22 and from SMHI upon request for other dates
DEMA	ECMWF Harmonie	0.1° x 0.1°, 1h 2,5 km, 1h	Global Central, North West Europe and Scandinavia Greenland (see figure below)	From DMI upon request 2023-2024
UK Met Office	ECMWF¨ UK Met. Office Global UKV	0.1° x 0.1°, 1h ~10 km, 3h ~1.5 km	Global Global UK and Republic of Ireland	From June 2013 From July 2017 From July 2013
DSA/MET Norway	ECMWF for EMEP (??) ECMWF AROME/MEPS	0.1° x 0.1°, 1h (3h) 0.1° x 0.1°, 1h 2.5 km, 1h	Europe Europe Same domain as SSM (Northern Central Europe and Scandinavia, see figure below)	1990-2022 No storage, somewhat resource demanding to regenerate 2017-2024
BfS	DWD-ICON	0.0625° x 0.0625° (~ 7 km)	23.5°W – 62.5°E, 29.5°N – 70.5°N	21 days storage, historical data on request to DWD

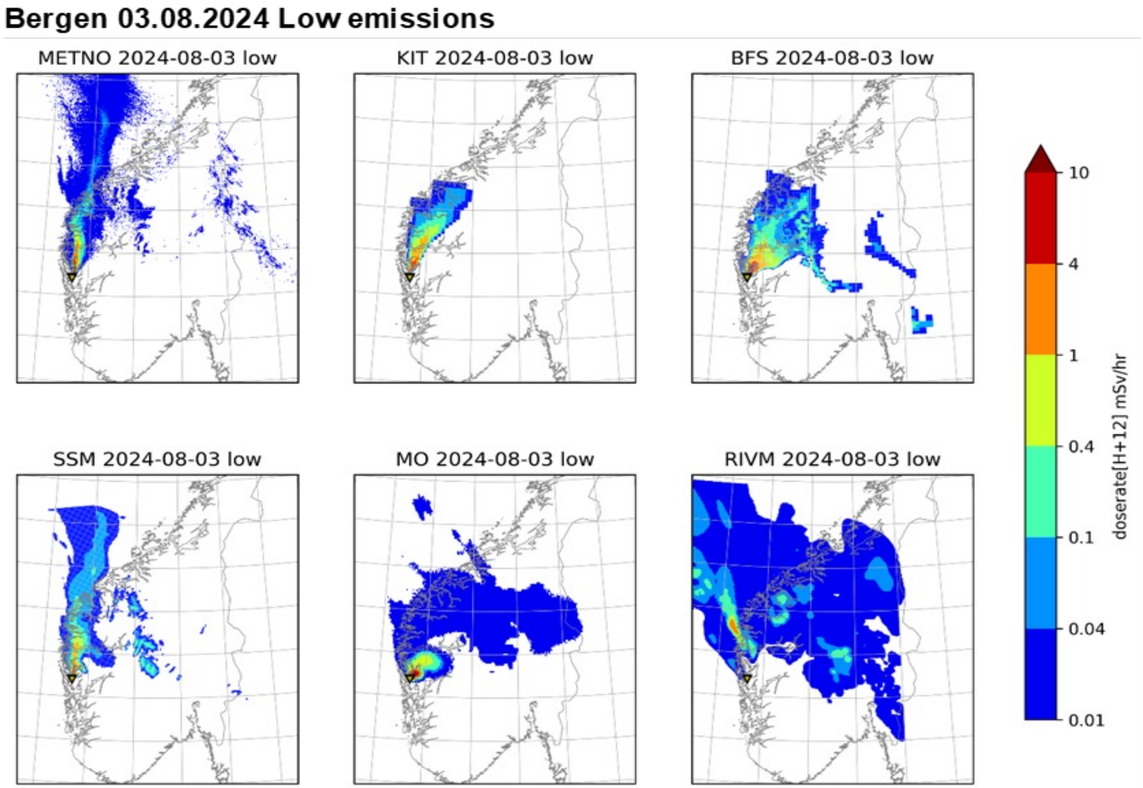
WP3.3 Scenarios

- Bergen:
  - Low pressure passage moving from west to east with variable wind directions and considerable amounts of precipitation.
  - High pressure summertime situation with considerable diurnal variations in boundary layer height, stability etc., no precipitation in bomb area.
  - Summertime unstable case with convection and precipitation
  - Wintertime high pressure situation with ground based inversion and no precipitation in bomb area

WP3.3 Scenarios

- Emden:
  - Low pressure passage moving from west to east with variable wind directions and considerable amounts of precipitation.
  - High pressure summertime situation with considerable diurnal variations in boundary layer height, stability etc., no precipitation in bomb area.
  - Summertime unstable case of slow moving low around Netherlands, UK, Germany including convection, heavy precipitation and low wind speeds near ground
  - Fall/spring case with cloudy and windy conditions (winds from southerly direction), little or no precipitation.

WP3.3 Example results

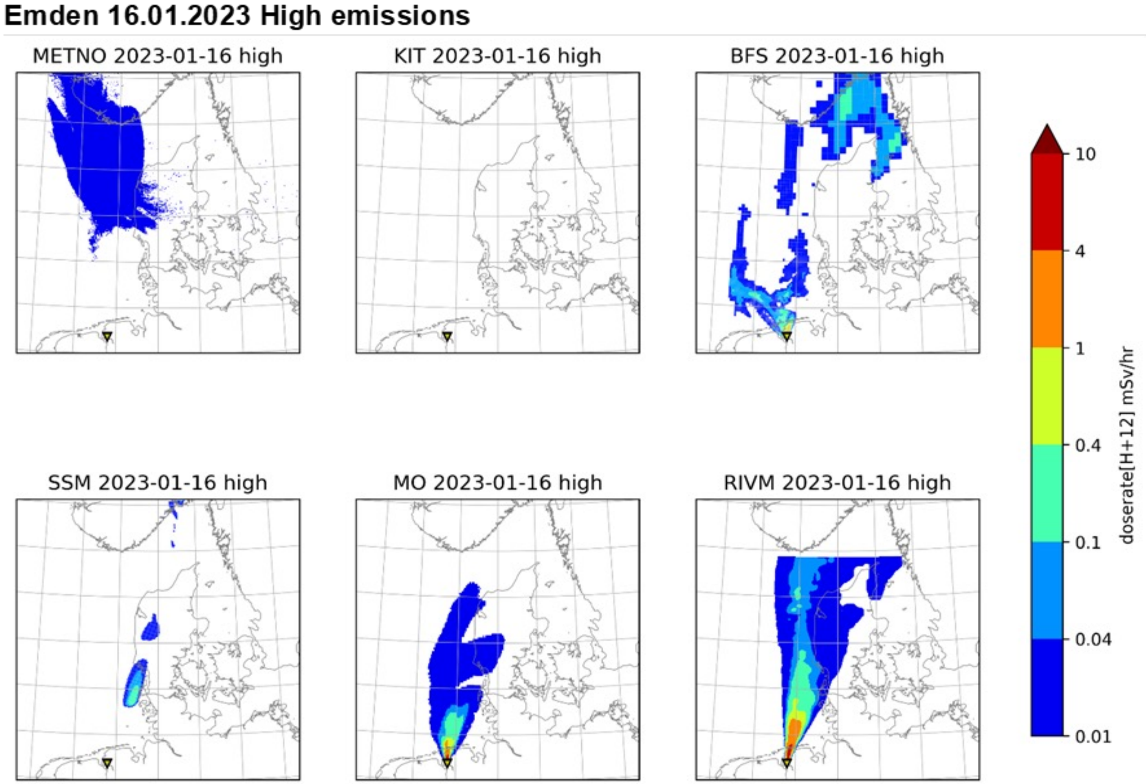


PREDICT

NERIS workshop, April 2026

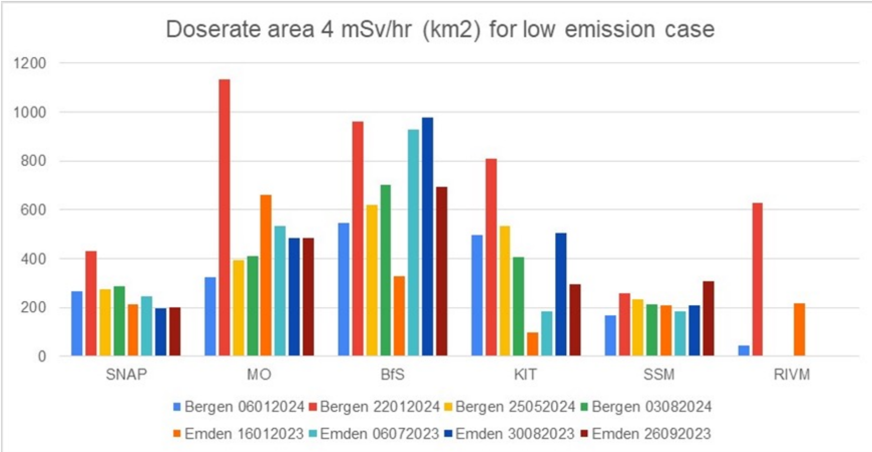
Co-funded by the European Union

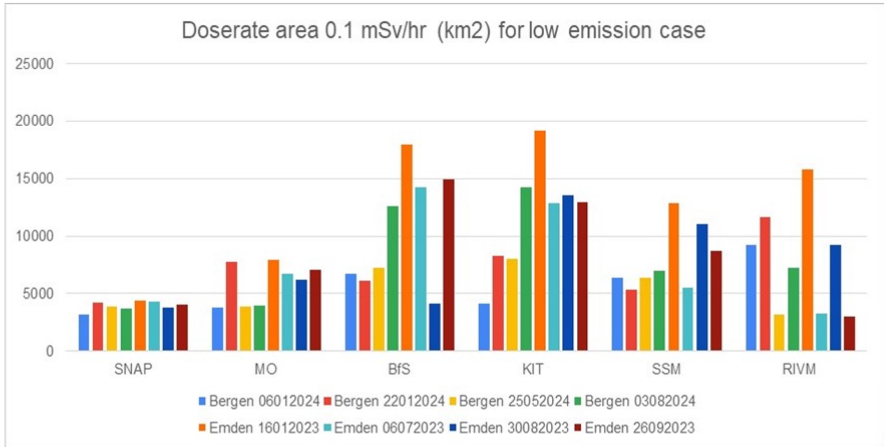
WP3.3 Example results



WP3.3 example dose rate result

- SNAP and SSM use the same weather data, but results differ
- UKMO, BfS and KIT give highest areas for larger dose
- RIVM shows smallest areas for higher doses
- Large area differences are also seen for smaller doses

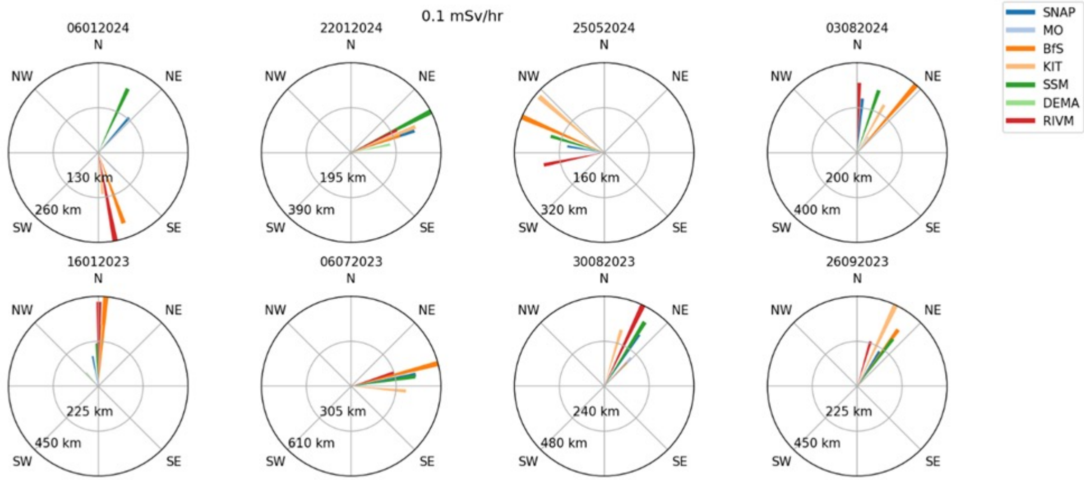




WP3.3 Bearing (°) given as the mean directions of movement of the plume

- In general, the bearings are quite similar for all models for the 8 weather cases
- For 0.1 mSv/hr deviations are largest between the models in the 06.01.2024 case
- During the strong low and frontal case Bergen 22.01.2024 the bearings are quite similar in all models

Upper is Bergen, Lower is Emden



NERIS workshop, April 2026

Co-funded by the European Union

WP3.3 first conclusions

- Different bearings depend on the underlaying weather data – important to consider when comparing results from different countries
- Differences in doses are the result of the atmospheric transport and dispersion models – most probably, but for sure for SNAP and SSM as both use the same weather data
- Different weather conditions show different results in doses and affected areas – however spreading between simulation models is also high

Co-funded by the European Union

WP3.3 way forward

- More detailed evaluation will start in May 2026

Co-funded by the European Union

WP3.2 Statistical analysis

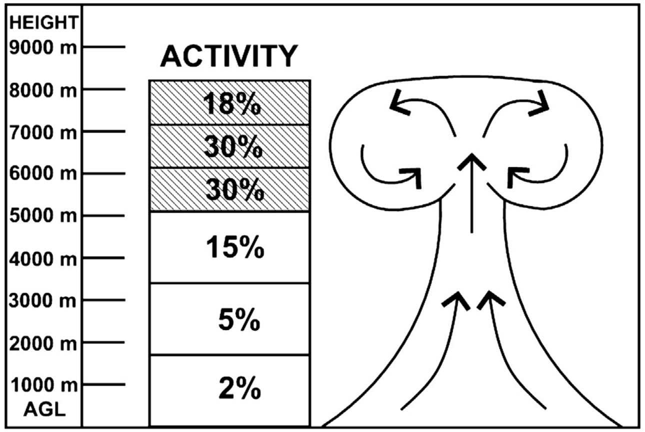
- Initially statistical simulations will be performed using one year of numerical weather data and parameter distributions defined in WP1 and information obtained from WP2
  - This subtask is underway, however with a limited set of participants
  - Aim to assess the variability in results based on key source term input parameters
- In addition, the parameter variations will be applied to the five test cases from WP3.1
  - Added value: comparison with monitoring data!

WP3.2 Scenarios

- 15 scenarios with variations of
  - Cloud geometry (3 cases)
  - Activity height and seize distribution (10 cases)
  - Particle densities (2 cases)
- The five test scenarios from WP3.1 will be considered
- All in all 75 calculations

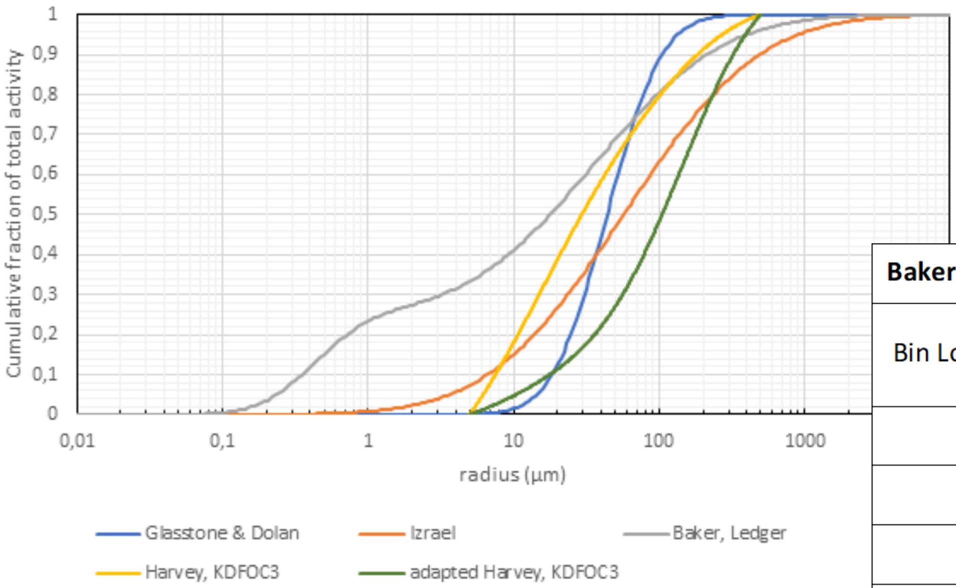
WP3.2 Cloud geometry and activity distribution

Yield	Cap geometry #1 (m) Harvey et al. (1992) /KDFOC3			Cap geometry #2 (m) Glasstone and Dolan (1977)			Cap geometry #3 (m) Anderson (1961)		
	Bottom	Top	Radius	Bottom	Top	Radius	Bottom	Top	Radius
10	5094	8231	2331	3204	5675	1686	3831	8452	1974
100	9150	14370	6230	5758	11767	3280	6167	13605	4529
1.65	2221	4183	1080	1844	3256	912	2609	5755	967
21	7105	10902	3200	3908	7248	2003	4476	9874	2608
24	7261	11162	3387	4045	7574	2062	4602	10152	2740
32	7608	11745	3830	4352	8324	2204	4885	10776	3042
44	8012	12426	4388	4712	9226	2406	5217	11507	3409



Layer	Height		Activity distribution (%)			
			Particle N1		Particle N2	
	Start	End	10 kT	100 kT	10 kT	100 kT
Stem 1	0.00	0.33 CB	11.4	11.8	7.0	7.2
Stem 2	0.33 CB	0.67 CB	17.3	18.0	5.9	6.0
Stem 3	0.67 CB	1.00 CB	23.1	24.2	4.1	4.1
Cap 1	1.00 CB	CB + 0.33(CT-CB)	15.4	14.3	1.7	1.5
Cap 2	CB + 0.33(CT-CB)	CB + 0.67(CT-CB)	9.6	8.8	1.0	0.9
Cap 3	CB + 0.67(CT-CB)	CT	3.2	2.9	0.3	0.3

WP3.2 Particle size distribution



Baker N1 25 % N2 75 %

Bin Low Edge / µm	Bin High Edge / µm	Bin Activity mean radius / µm	Bin Activity fraction
0.1	0.74	0.37	20 %
0.74	9.5	3.5	20 %
9.5	31.5	18.2	20 %
31.5	99.5	54.6	20 %
99.5	> 2000	221.4	20 %

Co-funded by the European Union

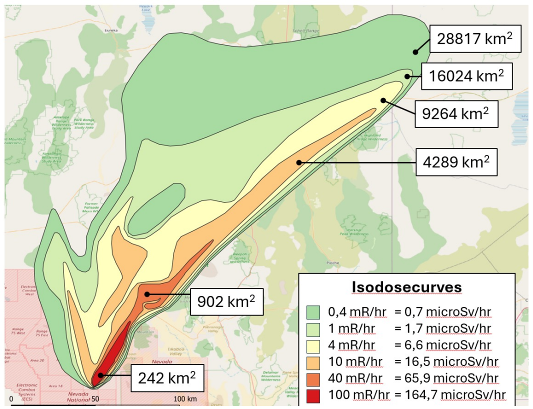
WP3.2 Status

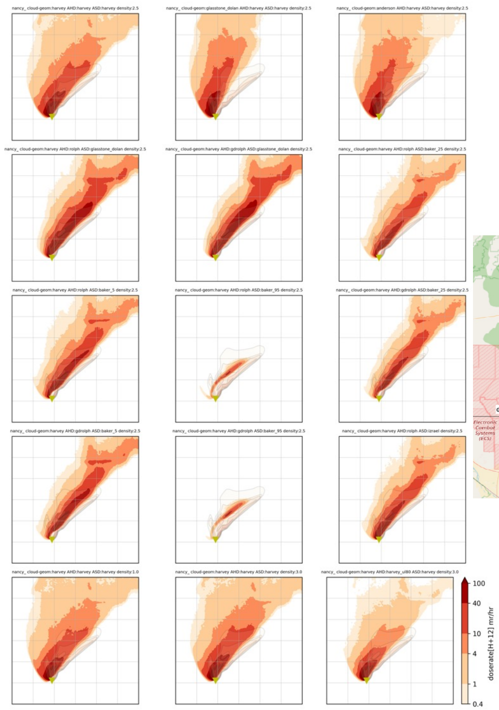
- Calculations are under way
- Evaluation similar as for WP3.1
  - Shape
  - Area comparison (model vs. isodosecurve)
  - Distance comparison (model vs. isodosecurve)
  - Figure Merit in Space (FMS)
  - Time of arrival
- Identification of parameter settings that fits best – for all or for individual test cases

Co-funded by the European Union

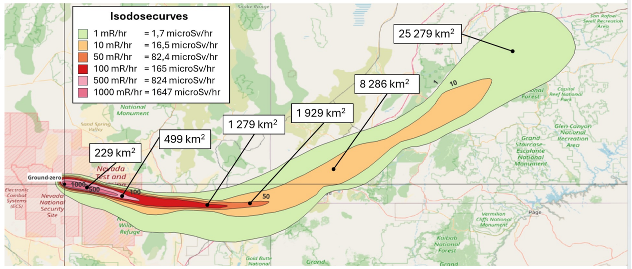
First results Met Norway

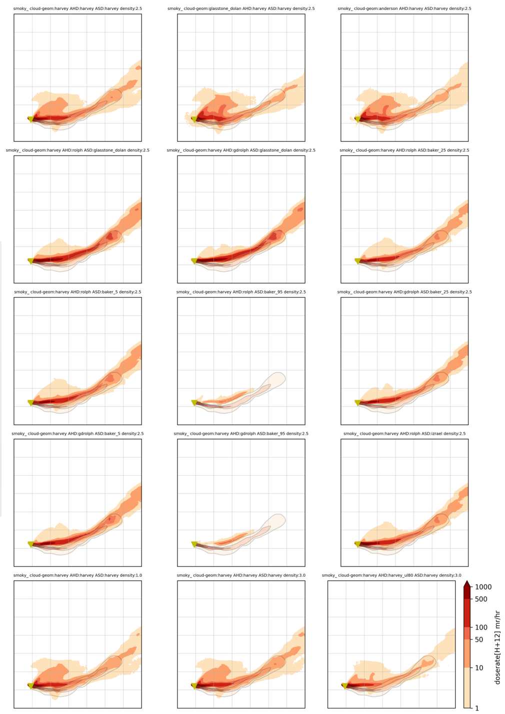
Nancy





Smokey





PIANOFORTE
EUROPEAN PARTNERSHIP FOR RADIATION PROTECTION RESEARCH
PREDICT

NERIS workshop, April 2026

Co-funded by the European Union

Summary and conclusions

- The various test simulations aim to find better parametrisation of our existing simulation models – WP2 aims to improve them
- The first round of simulations for the five test cases demonstrated our capabilities – even limited at the moment
- We are confident to improve our predictions with the statistical analysis
- We will issue recommendations on the parametrisations – possibly dependent on the model and scenario by end of the year – open to all interested in that topic

Co-funded by the European Union