Italian National Agency for New Technologies, Energy and Sustainable Economic Development

Overview of the MACCS code utilisation to support the ENEA EP&R activities

12th Meeting of the European MELCOR and MACCS User Group, NUBIKI Nuclear Safety Research Institute as a WEBINAR 12-16 April 2021

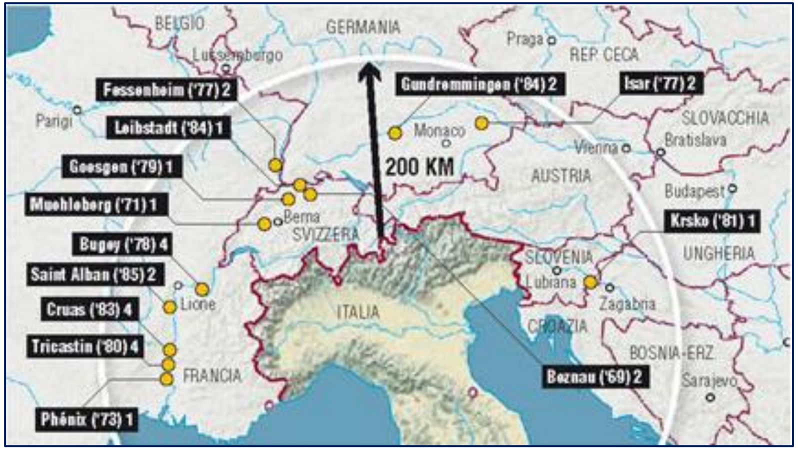
A. Guglielmelli, F. Rocchi, A. Cervone, F. Mascari / ENEA Bologna - Italy

Contents

- Background
- Introduction
- ENEA role in EP&R
- ENEA codes, tools, and capabilities for EP&R
- Examples from past/on-going activities
- MACCS4: Krsko NPP case study

Background

- In the aftermath of **Fukushima**, and taking into account **its aims as TSO**, ENEA decided to strengthen its capabilities in the field of EP&R;
- Italy has **not anymore** active NPPs; however…
- …it is surrounded at less than 200 km from the borders by **26 foreign NPPs.**



Introduction

- Italy should maintain capabilities to perform **independent judgment** on the consequences of SAs to protect citizens and economic assets **abroad;**

- Italy should still also be capable to make assessments also of radiologically non relevant, but psychologically and **socially relevant** cases…

106Ru detected over Europe in 2017.

- …for this reason, ENEA aims to improve its RC forecasting capabilities through the use of dedicated tools such as the MACCS code.

ENEA role in EP&R

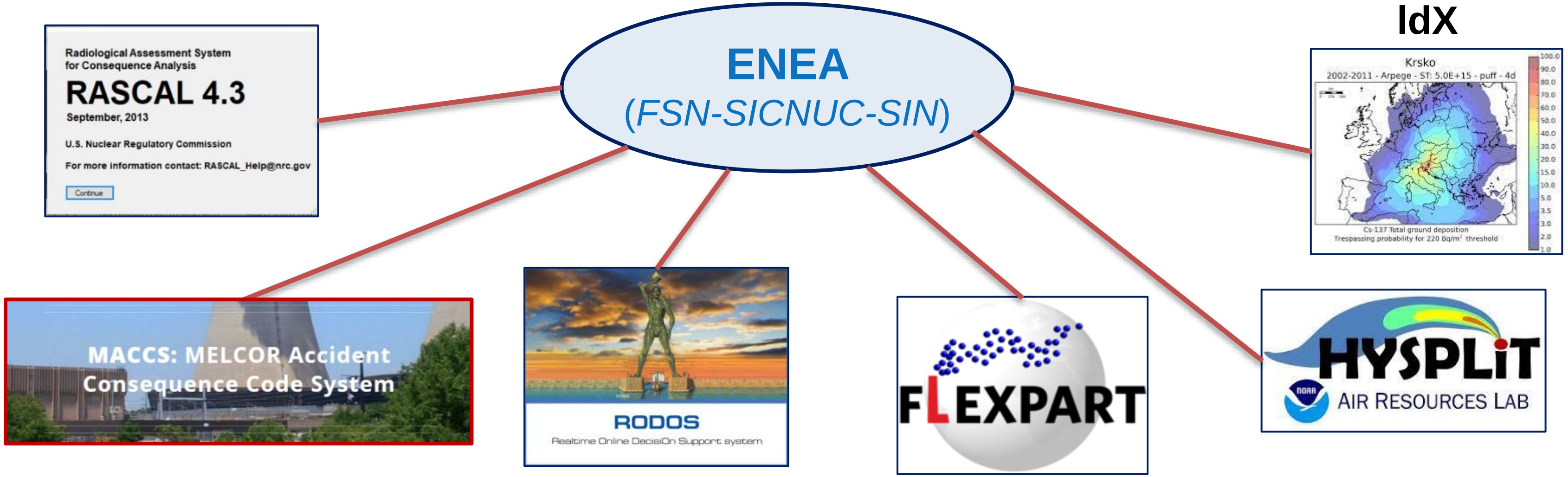
The official mandate of our Division states, inter-alia, that:

«…in cooperation with other Laboratories and Divisions of ENEA, it gives technical support to Competent Authorities for evaluations in the areas of safety and security in the various phases of the fuel cycle, and **it develops and applies previsional models to support the management of emergencies**, also through agreements with Technical Support Organizations (TSOs) and other international organizations…»

«…**it gives support to the National Nuclear Safety Authority** and other institutions dedicated to the **preparedness and response to nuclear and radiological emergencies**…»

Enea codes and tools

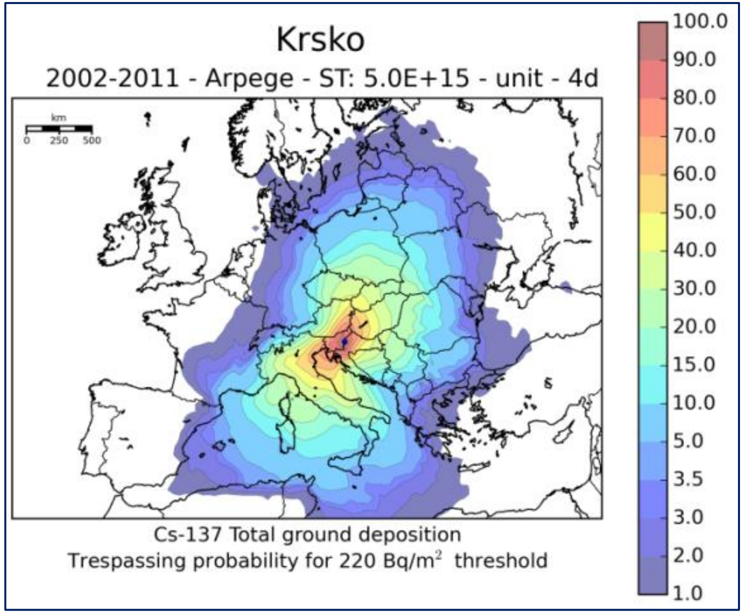
- ENEA started to use the MACCS code in order to improve its capabilities in the field of Emergency Preparedness and Response **(EP&R)** to foresee in real-time the consequences of a SA on Italy.

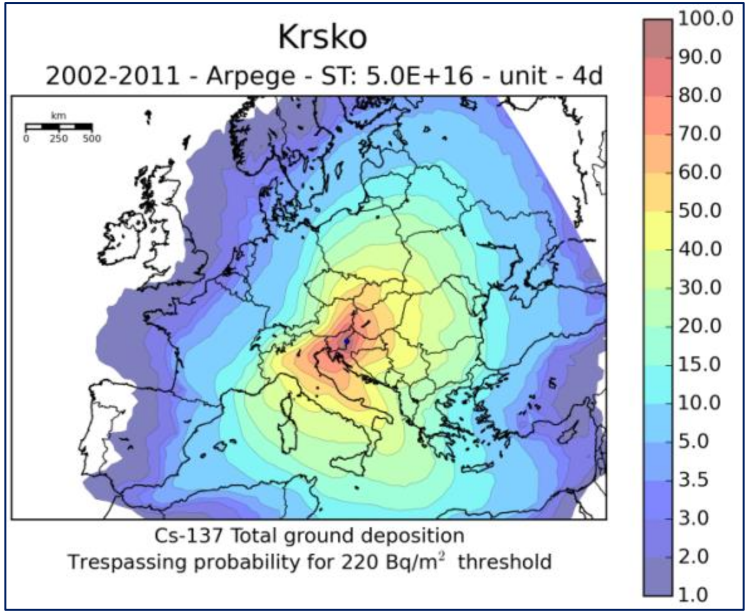


- The continuous improvements on the RC forecasting analysis allowed ENEA to have **the skills needed to provide Technical Support to the Italian National Regulatory Authority** (ISIN).

Codes and tools – IdX

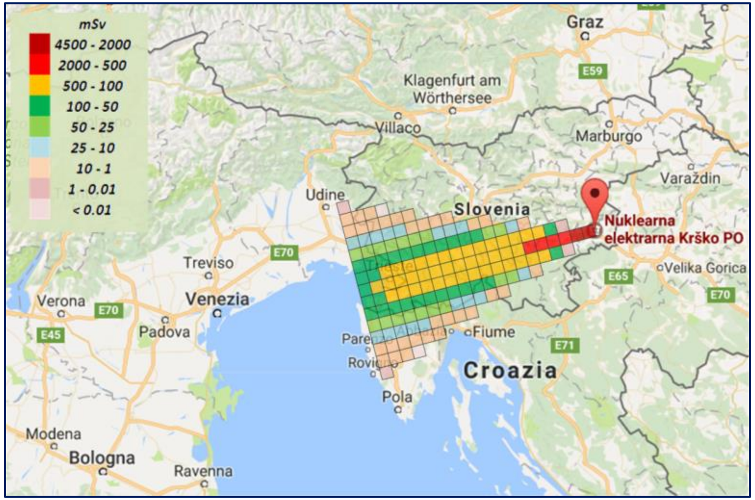
- **IdX** Eulerian transport code is used to **perform statistical consequence analysis**.
- Example: statistical analysis impact of a hypothetical SA event at Krško NPP.

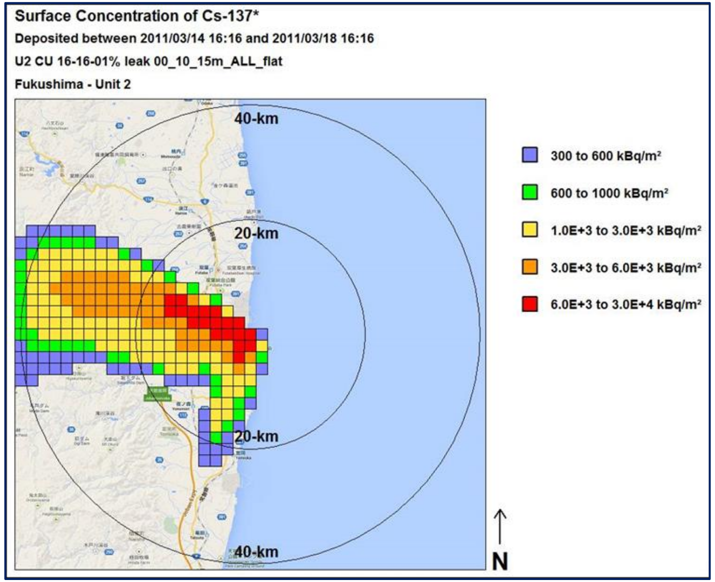




Codes and tools – RASCAL 4.3

- **RASCAL 4.3** is currently used both to **estimate STs** and to **make consequence analysis**.
- Examples: Fukushima analysis (still on-going), Krško analysis, etc.

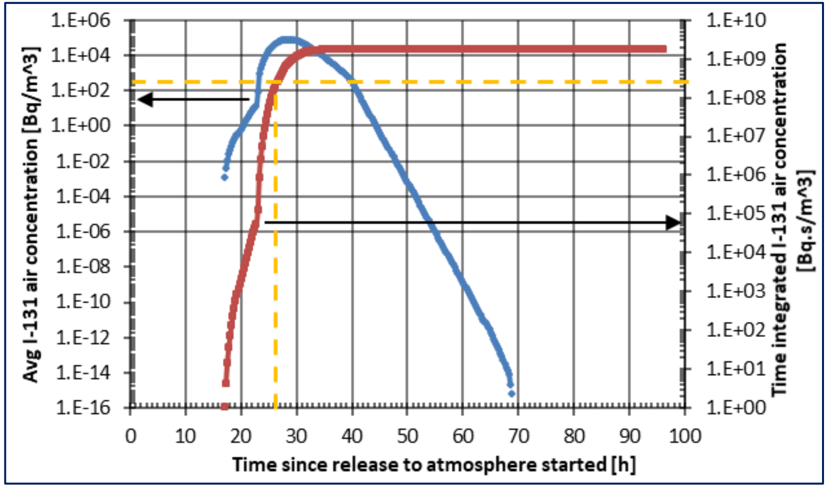




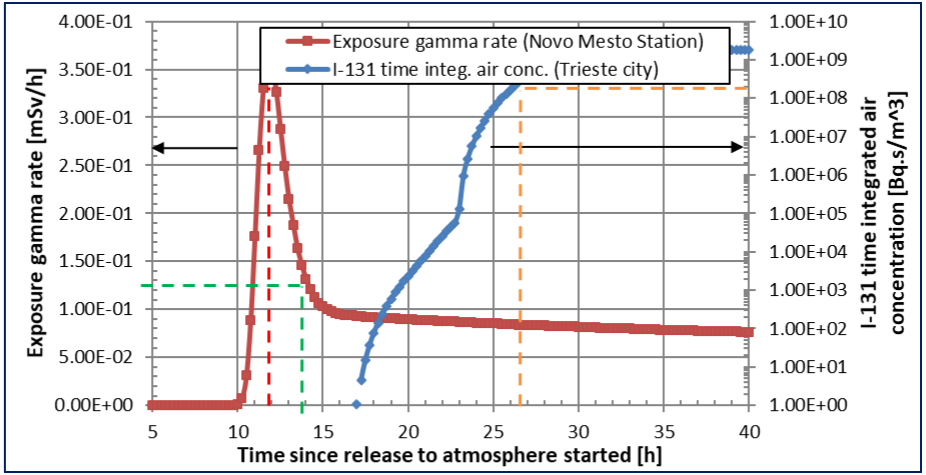
Codes and tools – RASCAL 4.3

- RASCAL is also currently in use to develop an **alert methodology** for the NE part of Italy in relation to SAs at Krško NPP, based on the **EURDEP network** of dose-rate stations

131I air concentration in Trieste area



Relation to Novo Mesto Station Pulse



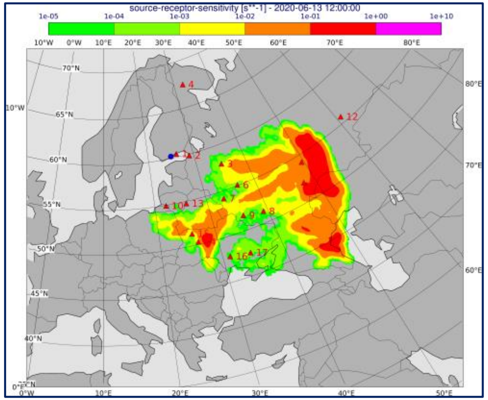
Codes and tools – FLEXPART & JRODOS

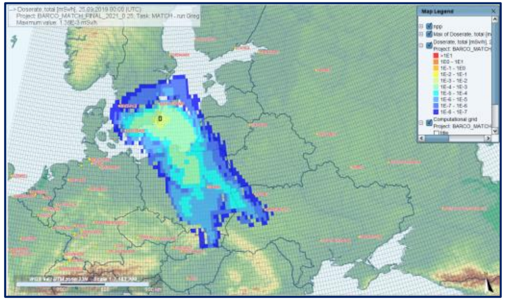
- **FLEXPART** is a Lagrangian open-source code which ENEA uses with high-resolution forecast and re-analysis **ECMWF** data (*) to perform both **forward and backward calculations**.

- In 2021, **ECMWF servers** will be based in **Bologna** and more synergies can be imagined in data utilization.

- **JRODOS** is a consequence code which performs medium range ATM and dose calculation; it is developed and maintained by KIT.

(*) Data are obtained through the Italian Military Aeronautics Weather Service





MACCS2 and MACCS4 activities

- Since 2018 ENEA adopted **MACCS2** code to support Level-3 PRAs and radiological consequence (RC) analysis on Italian territory. The activities carried out are:
  - Get statistical results by **sampling annual meteo data** in order to obtain the probability of occurrence of specific RC scenarios due to a severe accident (SA) event;
  - Get deterministic results by means of **single meteo data** in order to evaluate the most conservative RC scenario date for Italy.
- Since 2020 ENEA adopted **MACCS4** which includes the possibility to couple analyses with the HYSPLIT atmospheric transport code. The planned activities are:
  - Get intercomparison results between Gaussian (1-D) and Lagrangian (HYSPLIT) transport code simulation at the same fixed start date and geographical location for a fictious site.
- All the simulations performed included a conservative early phase (7 days) RC scenario with both no countermeasures, KI model and relocation of the population.

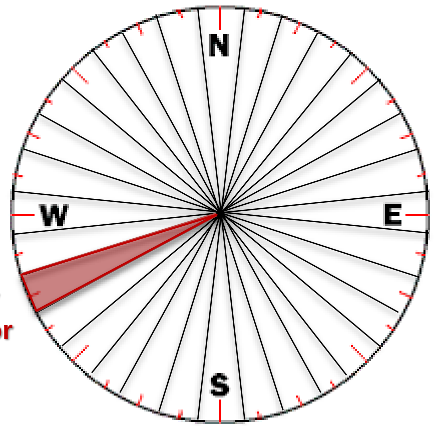
Case study: Krško NPP

- Krško NPP is one of the neighboring sites that are **at less than 200 km** from the national borders.
- Due to the typical meteo conditions and orography Krško site can be considered as one of the most impacting in terms of RC due to a postulated SA.
- MACCS4 analysis:
  - **ST:** simplified for a preliminary impact evaluation [131-I (1.0E+17 Bq) and 137-Cs (1.0E+16 Bq)]. Two ST dynamics: single release of 1 hour duration (PUFF) and 72 consecutive releases of 1 hour each (UNIT)
  - **Spatial grid:** 22 radial directions and 32 compass directions with a linear distance up to about **140 km** from Krško NPP to reach the Italian territory;
  - **Meteorological data:** 1 year of Global Data Assimilation System (GDAS) weather data with a spatial resolution of 0.5° (~ 50 km) and a time step of 3 hrs (ftp://arlftp.arlhq.noaa.gov/archives/gdas0p5).

Krško NPP: polar grid

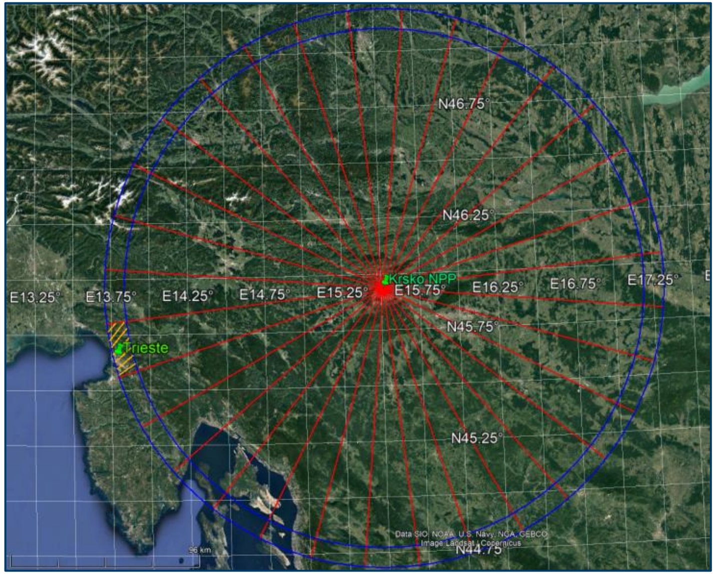
- MACCS4 Computational polar grid subdivision:

32 angular directions



Italy sector

22 radial directions (up to italian area @ 140 km)



[km]	
0.16	MACCS Best Practices
0.52	
1.21	
1.61	
2.13	
3.22	
4.02	
4.83	
5.63	
8.05	
11.27	
16.09	
20.92	
25.75	
32.19	
40.23	
48.28	
64.37	
80.47	
112.65	
130.00	Italy area
140.00	

Krško NPP: ST and Meteorological data

20180101_gdas0p5
20180102_gdas0p5
20180103_gdas0p5
20180104_gdas0p5
20180105_gdas0p5
20180106_gdas0p5
20180107_gdas0p5
20180108_gdas0p5
20180109_gdas0p5
20180110_gdas0p5
20180111_gdas0p5
20180112_gdas0p5
20180113_gdas0p5

GDAS meteo data

MacMetGen tool

```
MET DATA FOR MACCS FR
DAY HR DR SPS RN (JUL
/PERIOD 60
   1  1  5 195  0
   1  2  5 245  0
   1  3  5 285  0
   1  4  5 335  0
   1  5  5 265  0
   1  6  5 205  0
   1  7  6 135  0
   1  8  6 155  0
   1  9  6 175  0
   1 10  6 195  0
   1 11  6  95  0
   1 12 16  25  0
   1 13 20 124  0
   1 14 20 184  2
   1 15 19 254  2
   1 16 19 314  2
   1 17 20 314  7
   1 18 20 314  7
```

MACCS meteo data

+

year	month	day	hour	minute	lat (deg)	lon	ut	vt	precipitation	height1	temp1 (K)	height2	temp2	cloud cover	boundary layer	solar radiation flux
(-)	(-)	(-)	(-)	(-)	(deg)	(deg)	(m/s)	(m/s)	(mm/hr)	(m)	(K)	(m)	(K)	(%)	(m)	(W/m2)
2018	1	1	0	0	45.93813	15.51529	1.37	1.37	0	271.62	277.37	426.84	279.24	47.05	233.98	0
2018	1	1	3	0	45.93813	15.51529	2.4	2.24	0	273.35	278.93	429.44	280.53	99.15	778.81	0
2018	1	1	6	0	45.93813	15.51529	1.04	0.84	0	272.28	279.47	428.68	281.68	100	65.67	0
2018	1	1	9	0	45.93813	15.51529	1.53	1.13	0	274.03	281	431.28	281.63	100	164.25	22.57
2018	1	1	12	0	45.93813	15.51529	-0.69	-0.92	0	300.75	282.03	458.58	280.74	100	116.91	60.22
2018	1	1	15	0	45.93813	15.51529	-1.39	-2.79	0.57	300.6	279.39	456.96	278.15	99.88	538.52	58.86
2018	1	1	18	0	45.93813	15.51529	-1.68	-2.62	1.81	298.02	277.06	453.07	275.86	100	454.23	41.65
2018	1	1	21	0	45.93813	15.51529	-0.48	-1.26	0.91	325.91	277.87	481.42	276.63	100	321.71	0
2018	1	2	0	0	45.93813	15.51529	-0.05	-1.8	1.08	323.44	277.66	478.82	276.59	100	239.45	0
2018	1	2	3	0	45.93813	15.51529	0.53	-1.3	0.01	323.13	277.41	478.38	276.85	100	99.92	0
2018	1	2	6	0	45.93813	15.51529	1.02	0.05	0.04	319.1	275.97	473.54	276.59	100	43.17	0
2018	1	2	9	0	45.93813	15.51529	0.96	0.16	0	284.94	277.92	440.47	276.65	90.25	139.8	56.96
2018	1	2	12	0	45.93813	15.51529	0.91	-0.01	0	283.92	280.31	440.78	278.1	93.92	316.25	137.17
2018	1	2	15	0	45.93813	15.51529	0.73	-0.02	0	283.94	278.73	439.93	278.81	91.98	19.63	139.76
2018	1	2	18	0	45.93813	15.51529	1.31	-0.64	0	249.4	276.12	403.92	278.47	71.84	32	63.97
2018	1	2	21	0	45.93813	15.51529	1.06	-0.72	0	244.39	275.19	398.4	278.04	0.26	0	0
2018	1	3	0	0	45.93813	15.51529	1.21	-0.25	0	239.56	274.49	393.17	277.69	0.13	32	0
2018	1	3	3	0	45.93813	15.51529	0.71	1.2	0	240.7	274.02	394.05	276.41	3.4	16.97	0
2018	1	3	6	0	45.93813	15.51529	0.67	1.14	0	272.64	272.96	425.4	274.83	14.47	35.22	0
2018	1	3	9	0	45.93813	15.51529	1.2	2.16	0	314.03	276.1	468.54	275.72	51.64	195.91	80

Surface data extracted from GADS data

Meteo data

Source: GDAS (Reanalysis)

Year: 2018

Resolution: 50 km

Time step: 3 hours

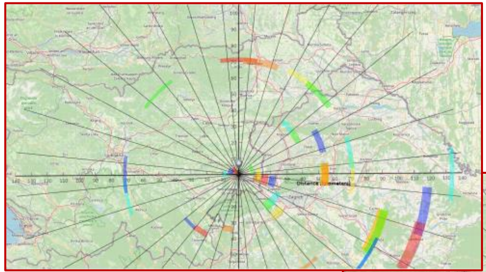
Dynamics & ST

Transport: Gaussian 1-D

Orography: Land/water

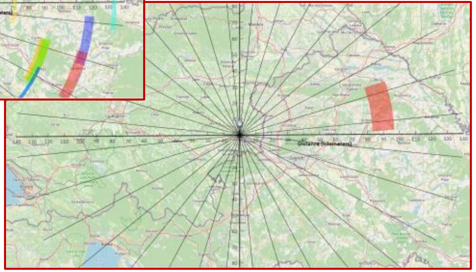
Cs-137: 1.0E+16 Bq

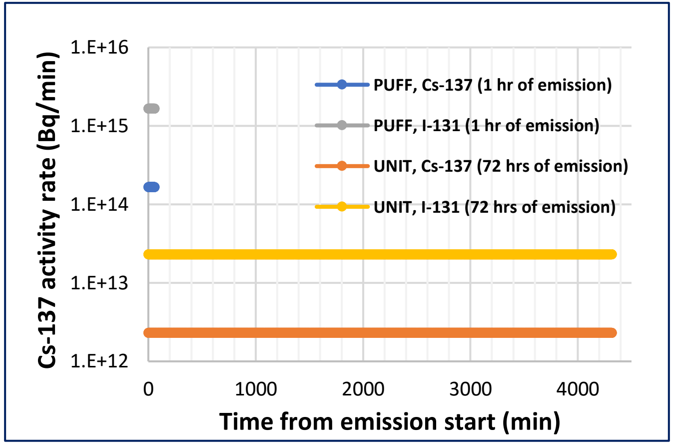
I-131: 1.0E+17 Bq



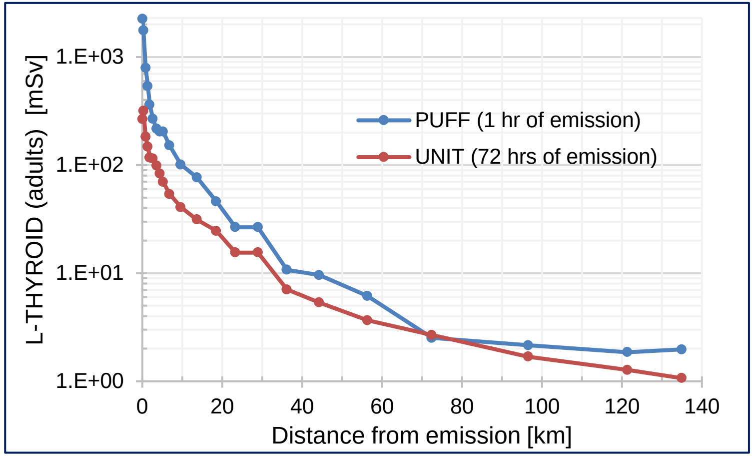
UNIT: 72 hrs of emission

PUFF: 1 hr of emission



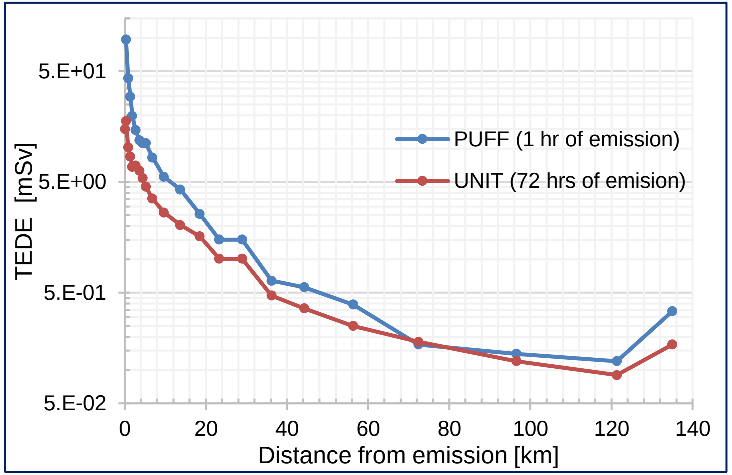


Krško NPP: statistical results



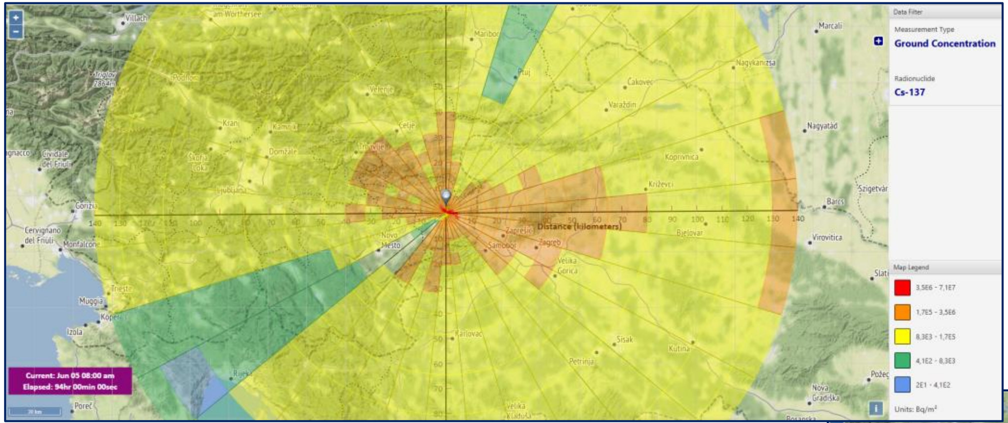
Distance (km)	P/U (-)
0.08	8.5
0.34	5.6
0.87	4.3
1.41	3.6
1.87	3.1
2.68	2.3
3.62	2.2
4.43	2.5
5.23	2.9
6.84	2.8
9.66	2.5
13.68	2.5
18.51	1.9
23.34	1.7
28.97	1.7
36.21	1.5
44.26	1.8
56.33	1.7
72.42	0.9
96.56	1.3
121.33	1.5
135	1.8

- The PUFF vs UNIT differences are:
  - higher than a factor two up to 14 km from the emission point;
  - lower than a factor two from 14 to 140 km.



- PUFF dynamics is an unrealistic scenario but more conservative than UNIT one;
- The results are associated with a probability less than equal to 2%.

Krško NPP: Cs-137 Ground Concentration (PUFF vs UNIT)



Total ground concentration – 4.38E+08 Bq/m^2

UNIT (72 hrs)

- Unit dynamics involves a deposition on almost all polar grid sectors;
- All impacted polar grid sectors have values behond some regulatory threshold limits (i.e., 220 Bq/m^2 for leaf vegetables) **[1]**.

[1] F. Rocchi, et alt., "*Methodological Aspects for the Evaluation of the Radiological Impact of Severe Nuclear Accidents: Codes, Numerical Examples and Countermeasures*", Report RdS/PAR2015/091.

Transport: Gaussian (1-D)

NPP: Krško

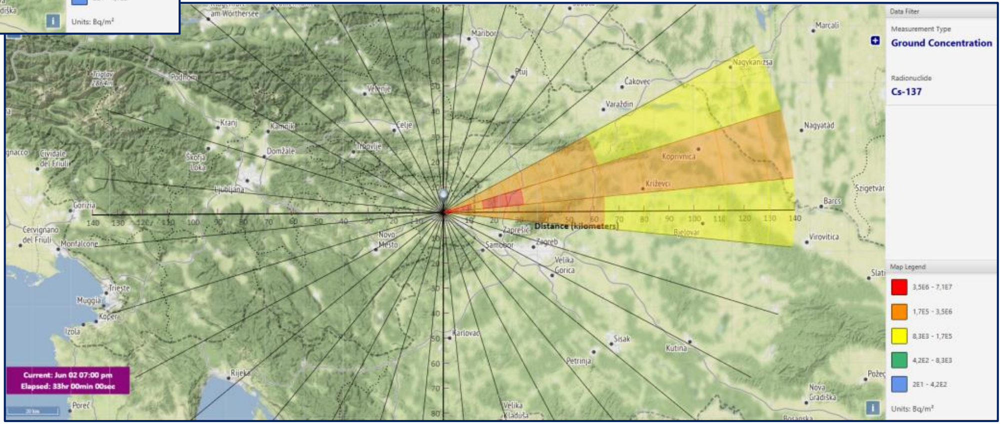
Meteo data: hourly, 2018

ST: 1.0E+16 Bq of Cs-137

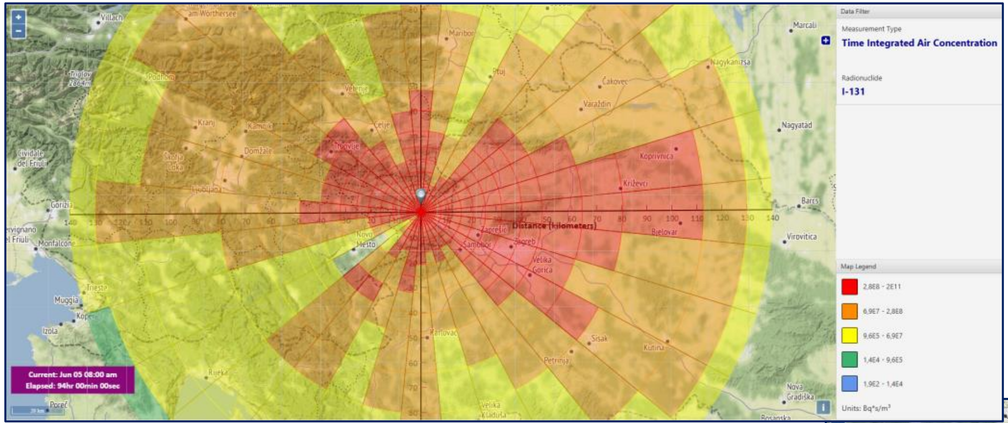
Start of release: 01/06/18 @ 10:00 a.m.

PUFF (1 hrs)

Total ground concentration – 4.11E+08 Bq/m^2



Krško NPP: I-131 Time integrated Air Conc. (PUFF vs UNIT)



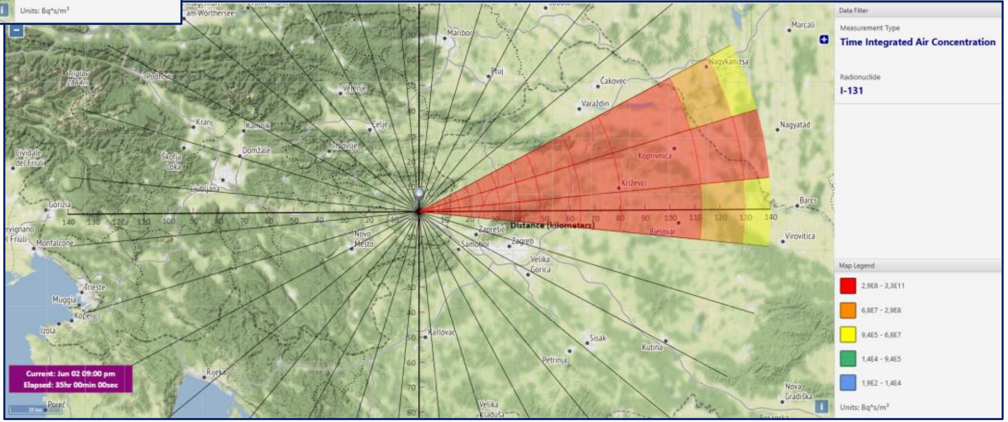
Time integrated air concentration: 1.56E+12 Bq.s/m^3

UNIT (72 hrs)

Transport: Gaussian (1-D)
NPP: Krško
Meteo data: 2018
ST: 1.0E+17 Bq of I-131
Start of release: 01/06 @ 10:00 a.m.

PUFF (1 hrs)

Time integrated air concentration: 1.68E+12 Bq.s/m^3



- The red sectors include an equivalent Thyroid dose to the population (adults) higher than 20 mSv;
- Puff dynamics involve a thyroid dose higher than 20 mSv up to 140 km from the emission point;
- The chosen date **is not conservative for Italy**.

Test case: GAUSSIAN vs HYSPLIT

- 20110311_gdas0p5
- 20110312_gdas0p5
- 20110313_gdas0p5
- 20110314_gdas0p5

GDAS meteo data

GenHysplit tool →

- 2011031100H001.ccd
- 2011031101H001.ccd
- 2011031102H001.ccd
- 2011031103H001.ccd
- 2011031104H001.ccd
- 2011031105H001.ccd
- 2011031106H001.ccd
- 2011031107H001.ccd
- 2011031108H001.ccd

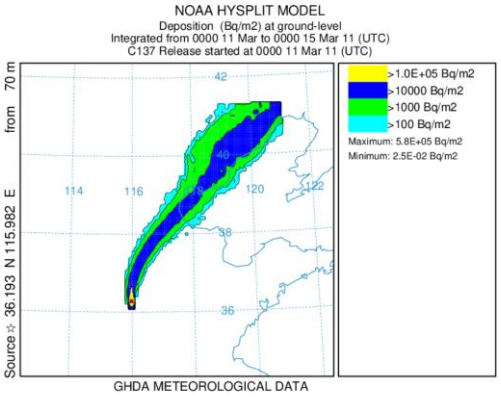
HYSPLIT results (.ccd)

HyGridConvert tool →

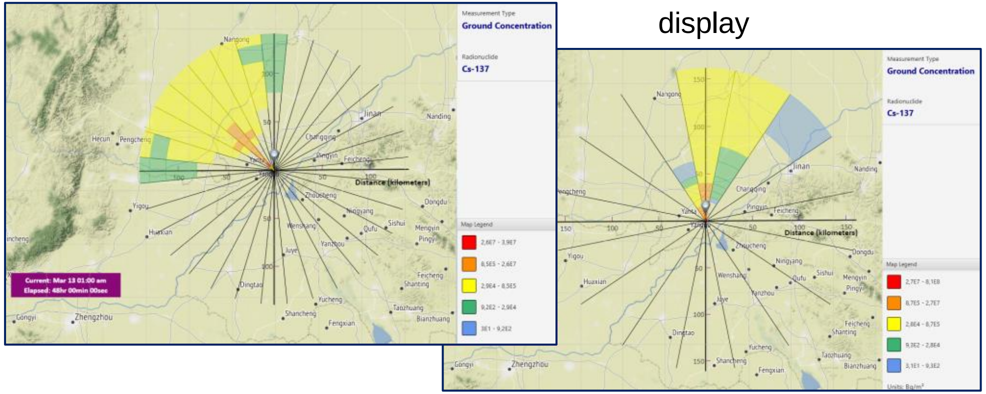
- 2011031100H001.mcd
- 2011031101H001.mcd
- 2011031102H001.mcd
- 2011031103H001.mcd
- 2011031104H001.mcd
- 2011031105H001.mcd
- 2011031106H001.mcd
- 2011031107H001.mcd
- 2011031108H001.mcd

HYSPLIT to MACCS (.mcd)

Hysplit 5.0 display



AniMACCS display



HYSPLIT Parameters

Emission site: fictious

ST & Dinamics: Cs-137 (1.0E+16 Bq), I-131 (1.0E+17 Bq) , 1 hr of emission

Run time: 96 hrs

Time incr. conc. output: 15 min

Output grid size: 165 km

Base grid size: 50 km

Base grid spacing: 10 km

Particles and aerosol (size/minute): 10

Meteo Data

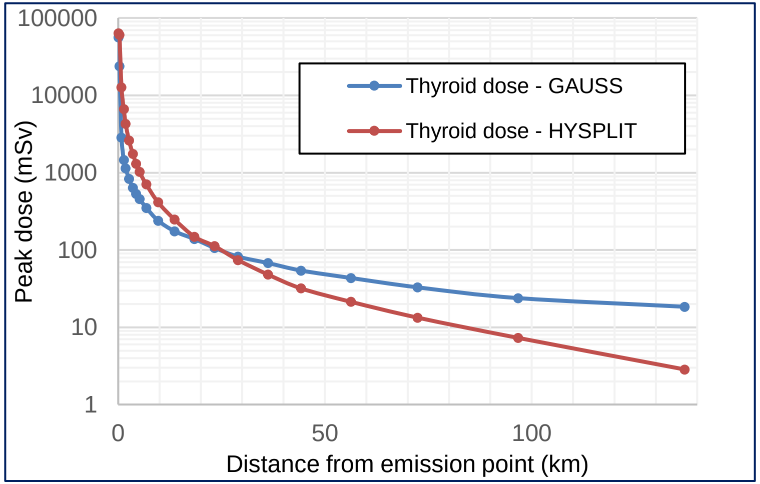
Source: GDAS (Reanalysis)

Time: 11-14/03/2011

Resolution: 50 km

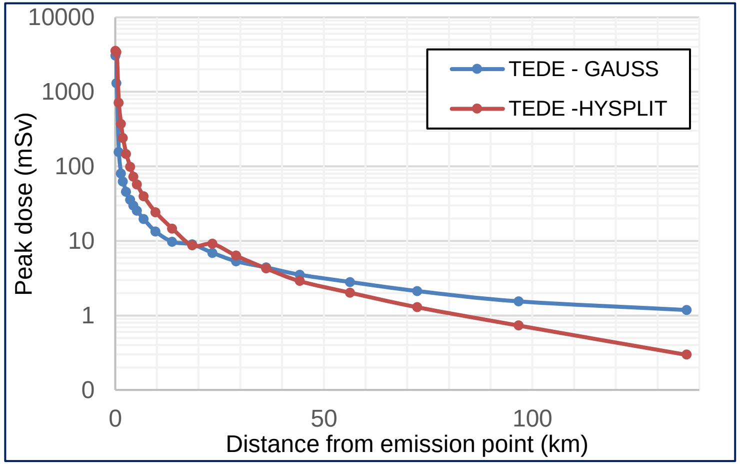
Time step: 3 hours

Test Case: Deterministic results



Distance (km)	G/H (-)
0.1	0.9
0.35	0.4
0.85	0.2
1.4	0.2
1.85	0.3
2.65	0.3
3.6	0.4
4.4	0.4
5.2	0.4
6.85	0.5
9.7	0.6
13.7	0.7
18.5	0.9
23.35	0.9
29	1.1
36.25	1.4
44.25	1.7
56.35	2.0
72.45	2.5
96.75	3.3
137	6.5

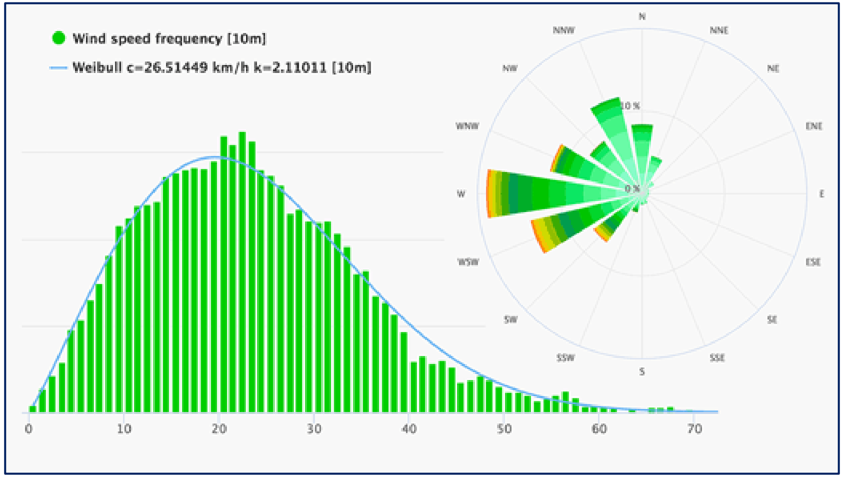
- The HYSPLIT vs GAUSS (G/H) differences are:
  - Less than a factor one up to 23 km (Lagrangian model more conservative)
  - Higher than a factor one from 29 to 140 km (Gaussian model more conservative)



- For EP&R point of view, the scenario performed with a Lagrangian model is more realistic but less conservative with respect to the Gaussian model scenario.

Planned activities with MACCS4

- **Objective:** ENEA intends to further improve the model for Krsko NPP area in order to perform **PSA-3 studies** of the impact over Italy using **HYSPLIT** transport code.
- **ST:** time-dependent radiological relevant nuclide (i.e., 131I and 137Cs)
- **Meteo:** hourly year weather data obtained through U.S. **NOAA meteo database**
- **Distances:** up to about **150 km** from NPP



- **Expectations:** more accurate results given the use of a Lagrangian code and more useful in relation to dose-rate signals measured at EURDEP stations at shorter distances
- **Intercomparison:** with RASCAL "single" results and other codes (i.e., IdX, FLEXPART)

Thank you for your attention!

Antonio Guglielmelli

antonio.guglielmelli@enea.it