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ANURE project: Towards the implementation of a nuclear risk assessment methodology

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4th NERIS Workshop
Dublin, 25-27 April 2018

Outline

1. ANURE project: Framework and objectives

2. ANURE's activities

3. First results

4. Achievements and Future steps

ANURE project: Framework and objectives

Collaboration Agreement (13th January 2016)

Specific Agreement (21st February 2017)

- Nuclear fuel research, developing and testing,
- Nuclear data for reactor and other applications,
- Nuclear reactor safety,
- **Emergency preparedness and radioprotection,**
- Nuclear infrastructures: development and access to facilities,
- Nuclear security and nuclear safeguards.

Project: *Assessment of the Nuclear Risk in Europe - A case study in the Almaraz Nuclear Power Plant (Spain). (February 2017-August 2018).*

Objectives:

- To assess the **off-site radiological consequences of severe NPP accidents** taking into account the meteorological conditions that influence the dispersion and deposition of radionuclides, their accumulation in soils and transfer to plants according to soil parameters that influence soil vulnerability;
- To **develop and test a methodology** to establish the geographical distribution of the risk caused by severe accidents in European NPPs.

ANURE’s activities

Project: Assessment of the Nuclear Risk in Europe - A case study in the Almaraz Nuclear Power Plant (Spain)

1. Meteorological, geographical and socioeconomic characterization of the study area;

2. Definition of the source term;

3. Simulations and modelling outputs;

ANURE’s activities

Project: Assessment of the Nuclear Risk in Europe - A case study in the Almaraz Nuclear Power Plant (Spain)

1. **Meteorological, geographical and socioeconomic characterization of the study area;**
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ANURE’s activities

Meteorological, geographical and socioeconomic characterization of the study area

Study area

Source: World Nuclear Association

Reactor type: **PWR WH 3LP**

Gross Capacity: **1049 MWe**

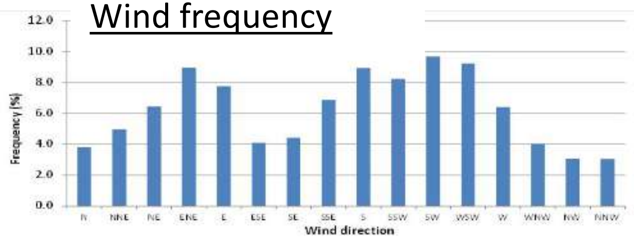
Thermal Capacity: **2947 MWt**

Construction started: **July 1973**

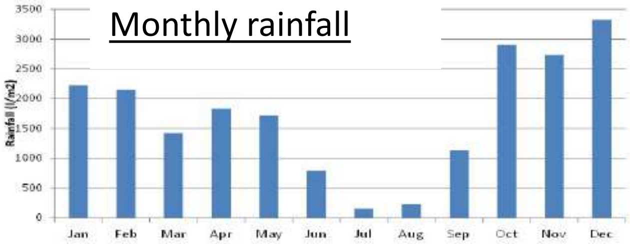
First Grid connection: **May 1981**

Load factor: **85.8%**

Wind frequency



Monthly rainfall



(*Data obtained from Almaraz NPP meteorological stations*)

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ANURE's activities

Meteorological, geographical and socioeconomic characterization of the study area

Density map from air mass trajectories (NERIS 2017, Lisbon [1])

Air mass forward trajectory

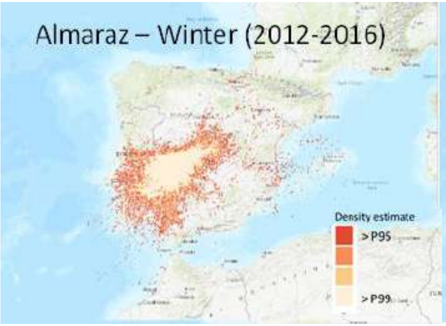
Estimate the path of an air mass from a starting time and place onwards

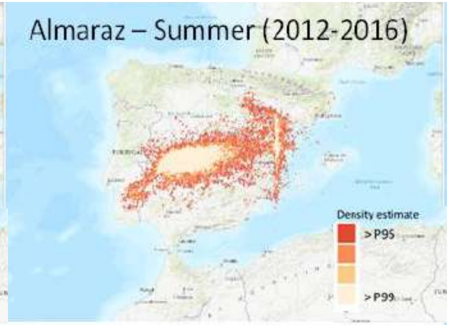
Density maps

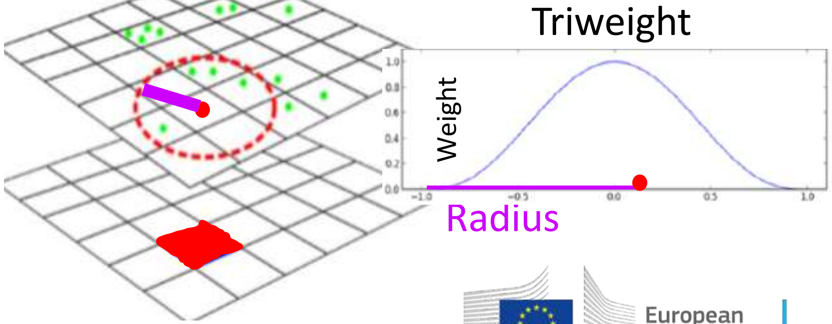
to show where points or lines may be concentrated in a given area.

- HYSPLIT model
- GDAS meteo files (0.5° spatial resolution)
- 100 meters of initial height
- Four per day (00, 06, 12, 18)
- 96 hours of displacement (1 hr of time step)

Kernel density estimation: Controls the rate at which the influence of a point within the radius decreases as the distance from the centre increases.





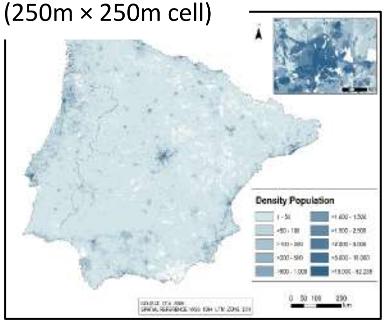


ANURE’s activities

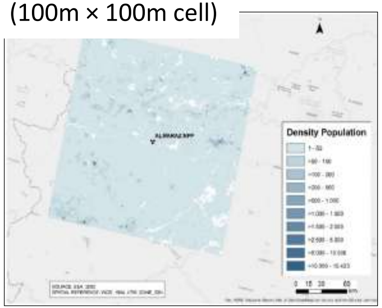
Meteorological, geographical and socioeconomic characterization of the study area

Density Population

(250m × 250m cell)

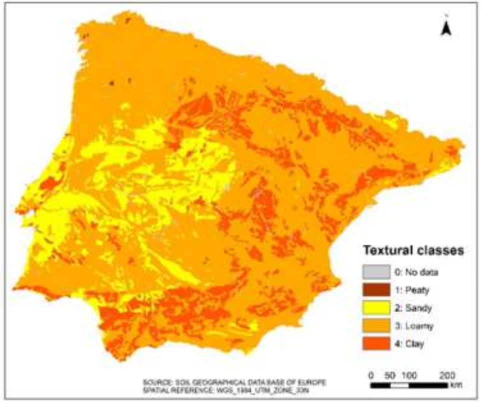


(100m × 100m cell)

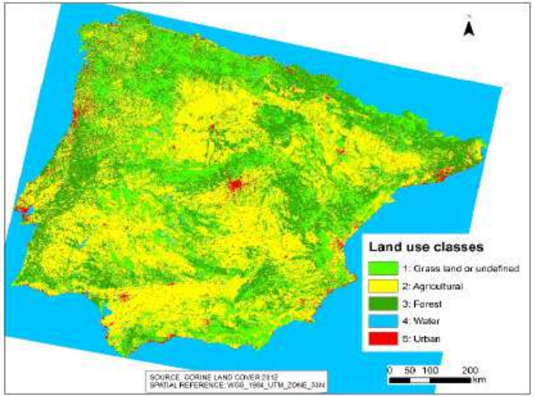


Source: Environmental European Agency (EEA)

Textural soil map (250m × 250m cell)



Land use (250m × 250m cell)



Source: Corine Land Cover European vector map

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ANURE's activities

Project: Assessment of the Nuclear Risk in Europe - A case study in the Almaraz Nuclear Power Plant (Spain)

1. Meteorological, geographical and socioeconomic characterization of the study area;

2. **Definition of the source term;**

3. Simulations and modelling outputs;

ANURE’s activities

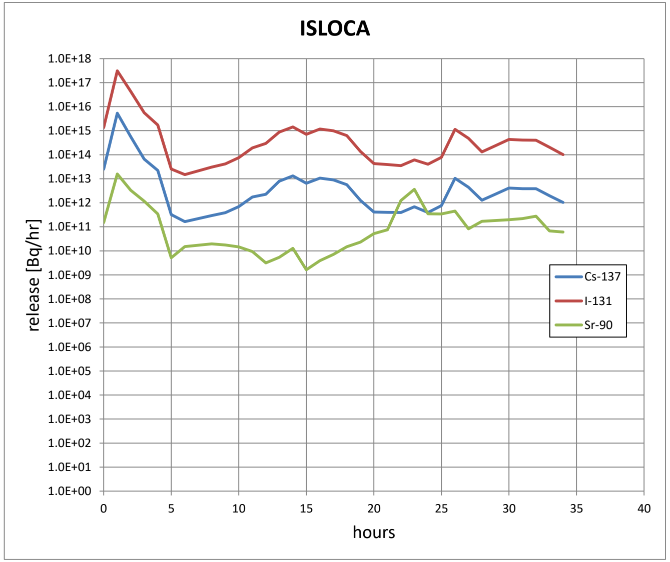
Definition of the source term

The source term determines the timing and magnitude of the radioactive material release. Under ANURE:

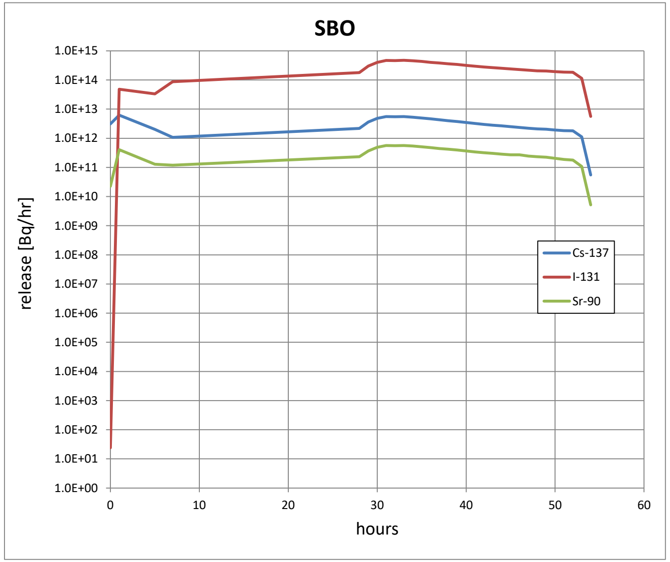
1. Information derived from existing studies (SOARCA [2]);
2. Surry NPP (Virginia, USA) as surrogate for source term estimation;
3. Two accident sequences:
    - **ISLOCA** (Interfacing Systems Loss-Of-Coolant Accident)→ initiated by an internal event caused by an unisolated rupture of lowhead safety injection piping outside containment, with 35 hours of offsite radionuclide release and,
    - **LTSBO** (Long-Term Station BlackOut) → initiated by an external event resulting in loss of offsite and outside AC power, with 55 hours of offsite radionuclide release.
4. Source term calculation:
    - Release fractions grouped on an hourly basis to which the inventory of **^{131}I, ^{90}Sr, ^{137}Cs** of Almaraz, included in the JRODOS database, have been applied.

ANURE's activities

Definition of the source term



Estimated source term for Almaraz is still a theoretical exercise, and the results cannot be used in applications that require an accurate analysis of plant's specific characteristics. However, since we wish to develop a methodology for assessing off-site radiological consequences, these considerations are good enough.



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ANURE's activities

Simulations and modelling outputs

Simulation of the radioactive material released from the Almaraz NPP:

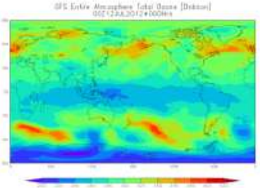
a) Period: Five years (2012-2016);

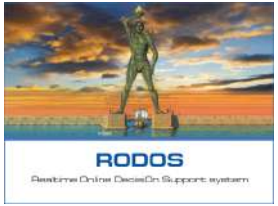
b) Model: RIMPUFF atmospheric dispersion model included in JRODOS [3][4];

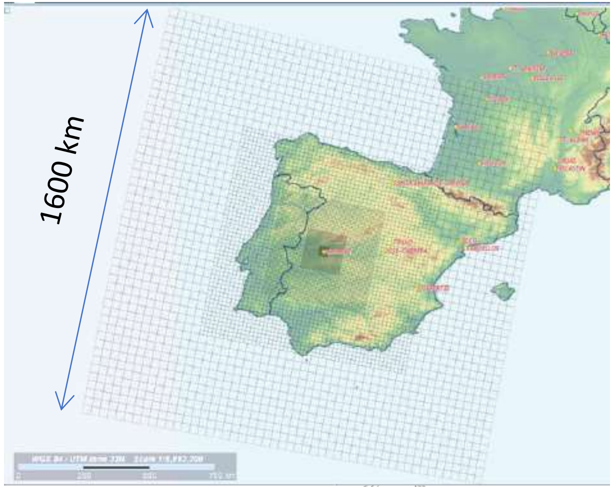
c) Meteorological files: Global Forecast System (GFS) from NOAA* (0.5° × 0.5°) [5][6][7]

d) Grid: variable resolution.

- 5 concentric squares: side 100, 200, 400, 800 and 1600 km
- Minimum resolution: 5 km







*US National Oceanic and Atmospheric Administration

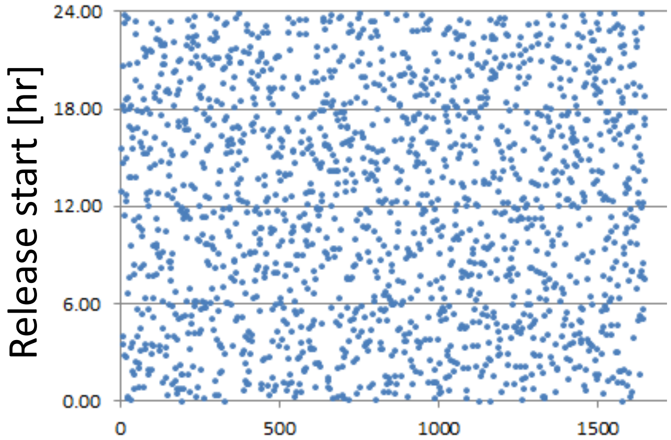
ANURE's activities

Simulations and modelling outputs

Simulation of the radioactive material released from the Almaraz NPP:

e) Number of simulations: 1825 plumes for each source term (one release/day)

- ISLOCA → 83 hours = 35 hours of release + 48 hours for deposition purposes
- LTBSO → 103 hours = 55 hours of release + 48 hours for deposition purposes



1) to equally sample the different seasons or months of the year,
2) to equally sample the different times of the day
3) not to have too much variability in the time intervals between subsequent releases.

ANURE’s activities

Simulations and modelling outputs

Modelling outputs

For each simulation and for each source term:

- Total Deposit (dry + wet) for ^{131}**I**, ^{90}**Sr**, ^{137}**Cs** (Bq/m^2)
- Total Potential effective dose (mSv)

Data flow: From JRODOS to database

1. Jrodos’ output exported as csv files;
2. Reading and parsing simulations in csv files and storing them in **Excel**;
3. Analyses using **VB macros** and creation of needed shapefiles with **QGIS**;

Simulation hours

Grid cell code	1	2	3	4	5	6	7
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	0.0	523.9178
7	0.0	0.0	0.0	0.0	0.0	0.0	5116.3
8	0.0	0.0	0.0	3138.3362		3138.762	
9	0.0	0.0	0.0	6816.246		10018.187	
10	0.0	0.0	0.0	350.74847		12937.649	
11	0.0	0.0	0.0	0.0	539.0034		1272.197
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0
13	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23	0.0	0.0	0.0	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	1090.859
27	0.0	0.0	0.0	8.780846		8.780846	
28	0.0	0.0	35.374146		4797.5815		4797.581
29	0.0	0.0	0.0	8538.891		8755.257	
30	0.0	0.0	0.0	2645.0645		12571.697	
31	0.0	0.0	0.0	1.6723329		2029.8191	
32	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	0.0	0.0	0.0	0.0	0.0	0.0	0.0
36	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	0.0	0.0	0.0	0.0	0.0	0.0	0.0
38	0.0	0.0	0.0	0.0	0.0	0.0	0.0
39	0.0	0.0	0.0	0.0	0.0	0.0	0.0

First results

Probability maps of depositions → Areas more affected → Where and how much?

ISLOCA → ^{137}Cs

P > 0. Bq/m^2

…

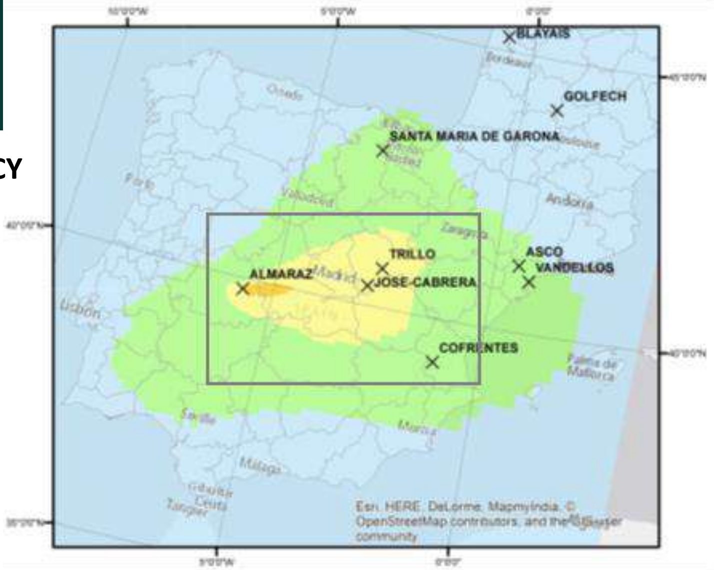
P > 1.e^6 Bq/m^2

First results

ST: **ISLOCA**
Deposit: ^{137}Cs

DEPOSITION FREQUENCY

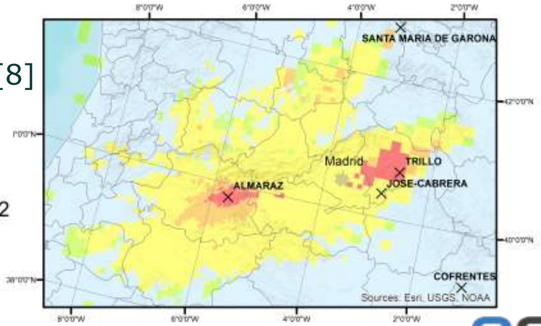
Probability of occurrence of a ^{137}Cs deposition event out of the total launches

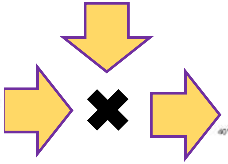


DEPOSITION INDEX:
More Frequent Deposition Bin

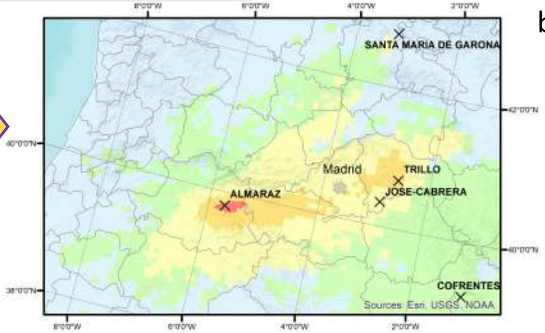
Nordic Deposition Limits [8]

1: <10 kBq/m2
2: 10 - 100 kBq/m2
3: 100 - 1.000 kBq/m2
4: 1.000 - 10.000 kBq/m2
5: >10.000 kBq/m2





WEIGHTED DEPOSITION INDEX :
deposition frequency multiplied by deposition index



Severity Deposition Index

1: Min. Severity
2: Low Severity
3: Med. Severity
4: High. Severity
5: Max. Severity

First results

WEIGHTED DEPOSITION INDEX
Deposition Index weighted
by the deposition frequency

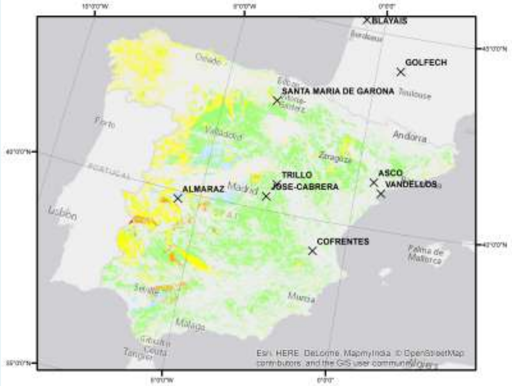
VULNERABILITY INDEX
based on the Soil to Plant Transfer Factor

- ^{137}Cs to rainfed cereals
- TF adjusted considering:
  - K and clay topsoil content
  - Soil texture

(Poster presented
at ICRER 2017)

Vulnerability Index (Cs137 Transfer Factor)

- 1: Min. Vuln. (<0,02)
- 2: Low Vuln. (0,02-0,12)
- 3: Med. Vuln. (0,12-0,5)
- 4: High Vuln. (0,5-0,6)
- 5: Max. Vuln. (>0,6)

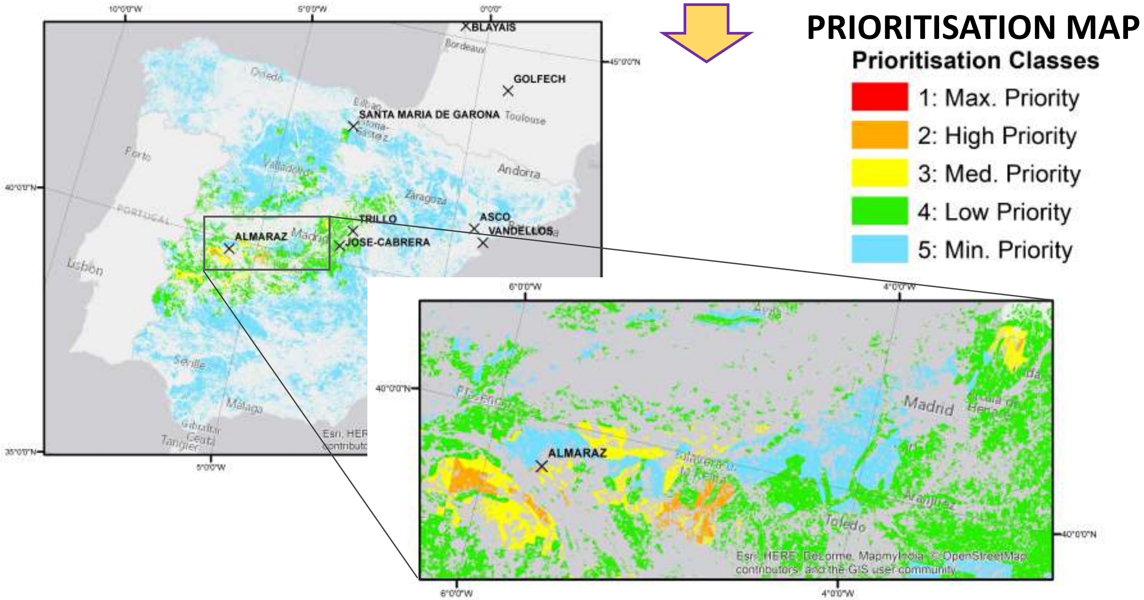


COMBINATION

Deposit Index Weighted \ Vulnerability Index	Min. Vuln.	Low Vuln.	Med. Vuln.	High Vuln.	Max. Vuln.
Min. Severity	5	5	5	5	5
Low Severity	5	5	4	4	4
Med. Severity	5	4	4	3	3
High Severity	5	4	3	2	2
Max. Severity	5	4	3	2	1

Possible combinations

PRIORITISATION MAP



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Achievements and future steps

Achievements

- Development of a methodology to assess the nuclear risk in Europe based on the use of accurate information of soil vulnerability, food chain impact, and the deposition probability of radionuclides released following and accident derived using a large number of real weather situations.

- A very rich source of data has been created;

- A set of flexible tools has been developed.

Achievements and future steps

Next steps

- Extend analysis of the modelling outputs;
- Extend the combinations of depositions' probability maps with soil vulnerability and food chain → Risk map;
- Analyse results by grouping them into meteorological scenarios (seasons, rainfall – no rainfall,…);
- Use modelling outputs to perform analysis of network optimization.

References

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