EMRAS-II PROJECT
Urban Working Group

Seville (Spain) 8-10 June

Modelling mid-range radionuclide dispersion and deposition from an hypothetical NPP accident

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- The calculations were performed with RASCAL 3.0.3 (Radiological Assessment for Consequence Analysis for Windows).
- RASCAL was developed for use by U.S. Nuclear Regulatory Commission.
- RASCAL estimates:
  - atmospheric transport, diffusion, and deposition of effluents from the accidents,
  - doses from exposure to the effluents.

Transport, diffusion

- RASCAL 3.0 uses Gaussian models to describe the atmospheric dispersion of radioactive effluents from nuclear facilities.
- A straight-line Gaussian plume model, TADPLUME, is used near the release point where travel times are short and plume depletion associated with dry deposition is small.
- A Lagrangian-trajectory Gaussian puff model, TADPUFF, is used at longer distances where temporal or spatial variations in meteorological conditions or depletion of the plume due to dry deposition may be significant.

TADPLUME Transport

- TADPLUME is a straight-line Gaussian model. As this name implies, the model assumes straight-line transport based on the wind direction at the time and place of release. TADPLUME rounds the wind direction to the closest 10° as it calculates the transport direction to ensure that the axis of the plume passes directly over receptors.
- As is common in straight-line Gaussian models, transit time is not considered in determining when material arrives at receptors; material arrives at receptors at the time of release.

TADPLUME Transport

- Transit time, calculated using the wind speed at the release height, is used to calculate the decay of radionuclides between the source and the receptors.
- It is also used to calculate depletion of material in the plume due to wet deposition. Decay calculations are performed at 5-min intervals; depletion is calculated for the full transit time.

TADPUFF Transport

- TADPUFF explicitly accounts for transit time in all calculations because the model tracks the movement of individual puffs and calculates concentrations and doses based on puff positions.

- Decay and ingrowth of radionuclides and depletion of the puffs as a result of wet and dry deposition are calculated at 5-min intervals.

- The movement of puffs is controlled by the wind at the center of the puff as the puffs move through the model domain. The spatial variation of winds is represented in TADPUFF by two-dimensional fields of vectors that give the direction and speed of puff movement. These fields are updated at 15-min intervals based on the available wind data.

Dispersion parameters

- The horizontal dispersion parameters used in TADPLUME and TADPUFF are based on the results of a large number of dispersion experiments.
- Dispersion parameters have been summarized in many forms. Perhaps the best known summary is the set of dispersion parameter curves called the Pasquill-Gifford curves (Gifford 1976).
- In RASCAL 3.0, dispersion parameters are estimated using the same basic algorithms that are used in other NRC codes.

Dispersion parameters

- The basic dispersion parameter relationships used in the NRC codes are:

$$\sigma_y = a_y x^{0.9031} \qquad \sigma_z = a_z(x) \cdot x^{b_z(x)} + c_z(x)$$

x = the distance from the release point, in meters,

a_y = a function of stability class,

a_z, b_z, e c_z = functions of stability class and distance.

Table 4.1 Constant Values for Calculation of Atmospheric Dispersion Parameters

		Stability Class						
	Distance Range (m)	A	B	C	D	E	F	G
a_y	all x	0.3658	0.2751	0.2089	0.1471	0.1046	0.0722	0.0481
a_z	x < 100 m	0.192	0.156	0.116	0.079	0.063	0.053	0.032
	100 m < x < 1000 m m	0.00066	0.0382	0.113	0.222	0.211	0.086	0.052
	1000 m < x	0.00024	0.055	0.113	1.26	6.73	18.05	10.83
b_z	x < 100 m	0.936	0.922	0.905	0.881	0.871	0.814	0.814
	100 m < x < 1000 m	1.941	1.149	0.911	0.725	0.678	0.74	0.74
	1000 m < x	2.094	1.098	0.911	0.516	0.305	0.18	0.18
c_z	x < 100 m	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	100 m < x < 1000 m	9.27	3.3	0.0	-1.7	-1.3	-0.35	-0.21
	1000 m < x	-9.6	2.0	0.0	-13.0	-34.0	-48.6	-29.2

PARAMETERS

- **Release data**

Source	
Isotopes	Bq/h
I-131	3,69E+12
Cs-137	6,43E+11

Release height and time	
Effective release height	50 m
Simulation time	10 hours

Meteorological data

- Only a limited number of wind vectors provided in the files trillostuv.dat and trillonsuv.dat are used.
- The topographic data of the file trillo.xvz were not using.

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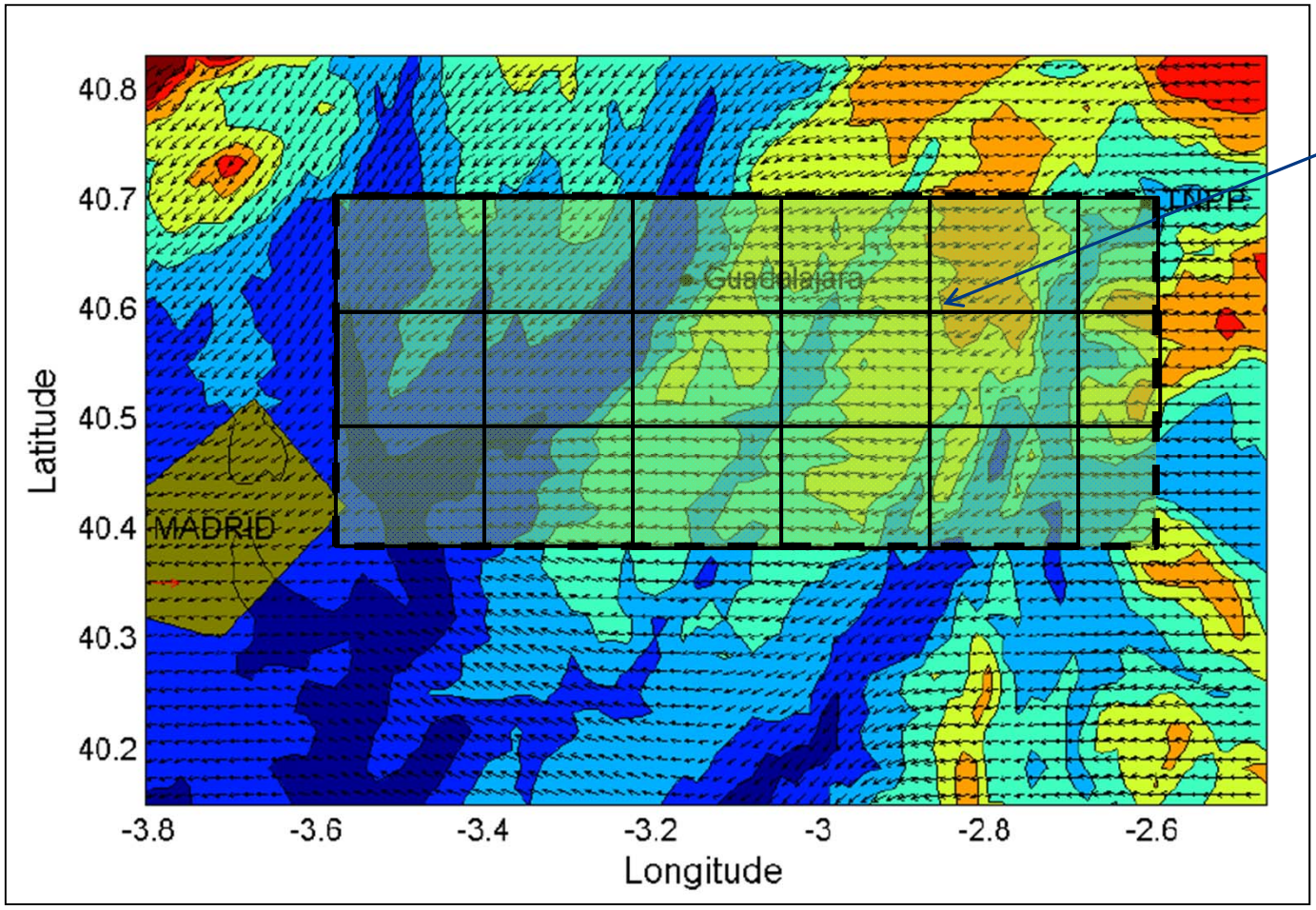
mid-range (NPP) scenario

wind vectors



Meteorological data

Situation 1 - Stability class: E

Wind vectors:

W	N	u	v	W	N	u	v	W	N	u	v	W	N	u	v
-3,598	40,401	0,25	0,41	-3,203	40,401	1,96	0,13	-2,807	40,401	1,59	0,59	-2,495	40,401	1,6	0,04
-3,598	40,498	1,15	0,81	-3,203	40,498	2,15	0,05	-2,807	40,498	1,4	0,56	-2,495	40,498	1,72	0,04
-3,598	40,595	1,12	1,23	-3,203	40,595	1,62	0,77	-2,807	40,595	1,8	0,51	-2,495	40,595	2	0,1
-3,598	40,692	1,2	1,57	-3,203	40,692	1,43	1,35	-2,807	40,692	1,96	0,32	-2,495	40,692	2,31	0,05
-3,4	40,401	1,64	0,1	-3,005	40,401	2,14	0,18	-2,593	40,401	2,18	0,23	-2,593	40,692	1,95	0,12
-3,4	40,498	1,7	0,54	-3,005	40,498	2,05	0,07	-2,593	40,498	1,84	0,01				
-3,4	40,595	1,9	0,92	-3,005	40,595	1,93	0,35	-2,593	40,595	2	0,08				
-3,4	40,692	2,16	1,16	-3,005	40,692	2,18	0,52	-2,593	40,692	1,95	0,12				

Meteorological data

Situation 2 - Stability class: D

Wind vectors:

W	N	u	v	W	N	u	v	W	N	u	v	W	N	u	v
-3,598	40,401	-3,05	-0,61	-3,203	40,401	-3,3	-0,86	-2,807	40,401	-3,3	-0,5	-2,495	40,401	-3,3	-0,36
-3,598	40,498	-2,97	-0,68	-3,203	40,498	-3,27	-0,44	-2,807	40,498	-3,04	-0,57	-2,495	40,498	-2,99	-0,42
-3,598	40,595	-2,92	-0,89	-3,203	40,595	-3,39	-0,3	-2,807	40,595	-2,86	-0,62	-2,495	40,595	-3,13	-0,4
-3,598	40,692	-2,93	-1,04	-3,203	40,692	-3,21	-0,5	-2,807	40,692	-3,02	-0,62	-2,495	40,692	-3,23	-0,33
-3,4	40,401	-3,32	-0,36	-3,005	40,401	-3,03	-0,83	-2,593	40,401	-3,13	-0,45	-2,593	40,692	-3,37	-0,33
-3,4	40,498	-3,21	-0,58	-3,005	40,498	-3,28	-0,56	-2,593	40,498	-3,24	-0,47				
-3,4	40,595	-3,21	-0,75	-3,005	40,595	-3,3	-0,43	-2,593	40,595	-3,13	-0,35				
-3,4	40,692	-3,3	-0,86	-3,005	40,692	-3,22	-0,52	-2,593	40,692	-3,3	-0,31				

SIMULATION RESULTS - Stability class: E

- **Contour map of deposited activity (Bq/m^2)**

The results are provided for points of topographic data except for distances over 50 miles. The code does not allow the calculation over this distance

Deposited activity (Bq/m^2)		
	Cs-137	**I-131**
IP01	0,00E+00	0,00E+00
IP02	1,74E+02	9,64E+02
Guadalajara	1,66E+02	9,22E+02
downtown Madrid	N. C	N. C.

SIMULATION RESULTS - Stability class: E

- **Contour map of time integrated air activity (Bq/m^3)×min.**

The code provides results only for I-131 with the units (Bq/m^3)xsec

Time integrated air activity – ^{131}I		
	(Bq/m^3)×sec	**(Bq/m^3)×min**
IP01	0,00E+00	0,00E+00
IP02	3,74E+05	2,24E+07
Guadalajara	4,17E+05	2,50E+07
downtown Madrid	N. C.	N. C.

SIMULATION RESULTS - Stability class: E

➢ Time series of activity concentrations in air (Bq/m^3)

The activity concentrations in air are provided with a temporal resolution of 15 minutes only for ^{131}I.

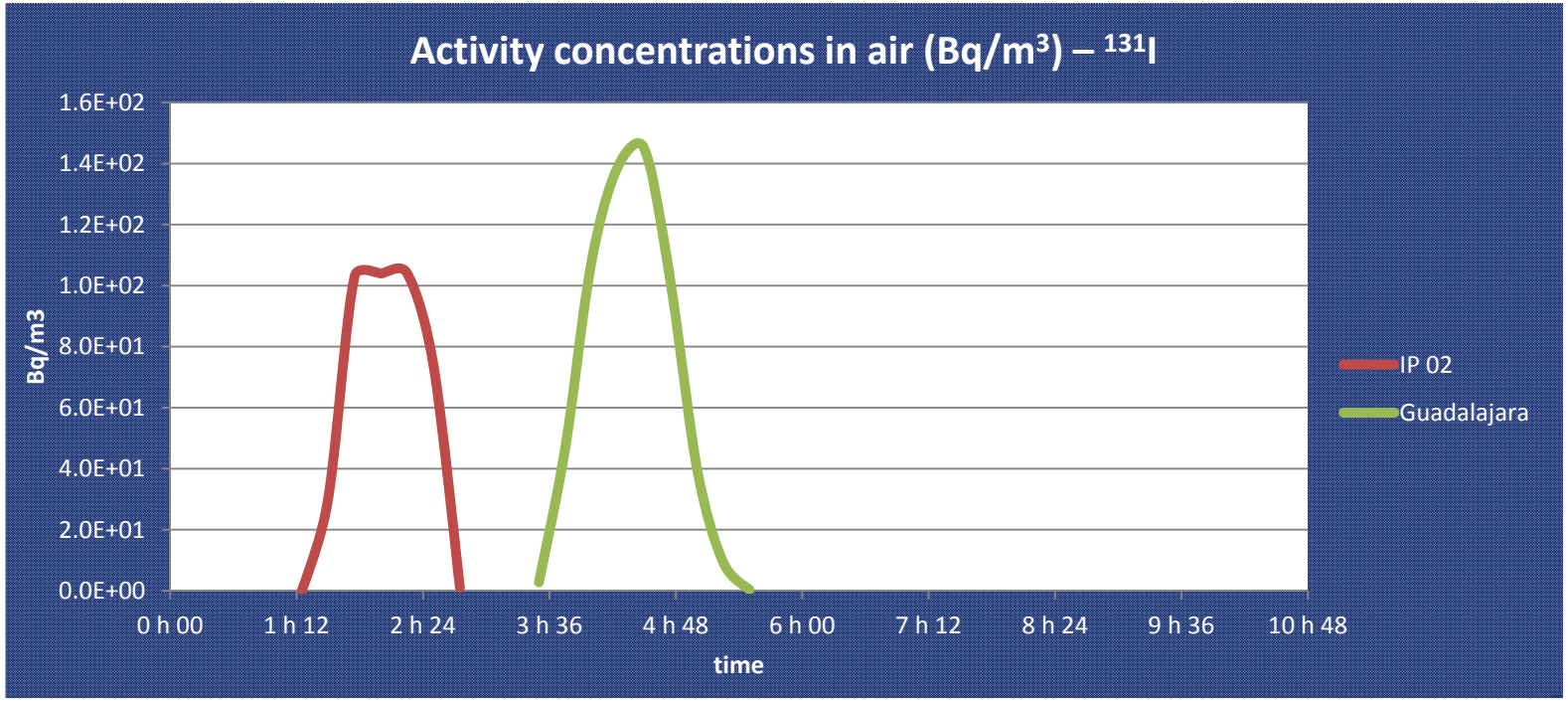
I-131 (Bq/m^3)	
time	IP02
1 h 30	3,03E+01
1 h 45	1,03E+02
2 h 00	1,04E+02
2 h 15	1,04E+02
2 h 30	7,37E+01
2 h 45	1,04E+00

I-131 (Bq/m^3)	
time	Guadalajara
3 h 30	2,82E+00
3 h 45	4,68E+01
4 h 00	1,08E+02
4 h 15	1,39E+02
4 h 30	1,45E+02
4 h 45	1,01E+02
5 h 00	4,02E+01
5 h 15	9,31E+00

SIMULATION RESULTS - Stability class: E

- **Time series of activity concentrations in air**

The activity concentrations in air are provided with a temporal resolution of 15 minutes only for ^{131}I.



SIMULATION RESULTS - Stability class: D

- **Contour map of deposited activity (Bq/m^2)**

The results are provided for points of topographic data except for distances over 50 miles. The code does not allow the calculation over this distance

Deposited activity (Bq/m^2)		
	Cs-137	**I-131**
IP01	2,67E+02	1,48E+03
IP02	6,98E+01	3,89E+02
Guadalajara	1,22E+02	6,77E+02
downtown Madrid	N. C.	N. C.

SIMULATION RESULTS - Stability class: D

- **Contour map of time integrated air activity (Bq/m^3)×min.**

The code provides results only for I-131 with the units (Bq/m^3)xsec

Time integrated air activity – ^{131}I		
	(Bq/m^3)×sec	**(Bq/m^3)×min**
IP01	5,22E+05	3,13E+07
IP02	1,42E+05	8,52E+06
Guadalajara	2,63E+05	1,58E+07
downtown Madrid	N. C.	N. C.

SIMULATION RESULTS - Stability class: D

- **Time series of activity concentrations in air (Bq/m³)**

The activity concentrations in air are provided with a temporal resolution of 15 minutes only for ^{131}I.

I-131 (Bq/m³)	
time	IP01
0 h 15	2,07E+01
0 h 30	1,03E+02
0 h 45	1,45E+02
1 h 00	1,45E+02
1 h 15	1,24E+02
1 h 30	4,23E+01

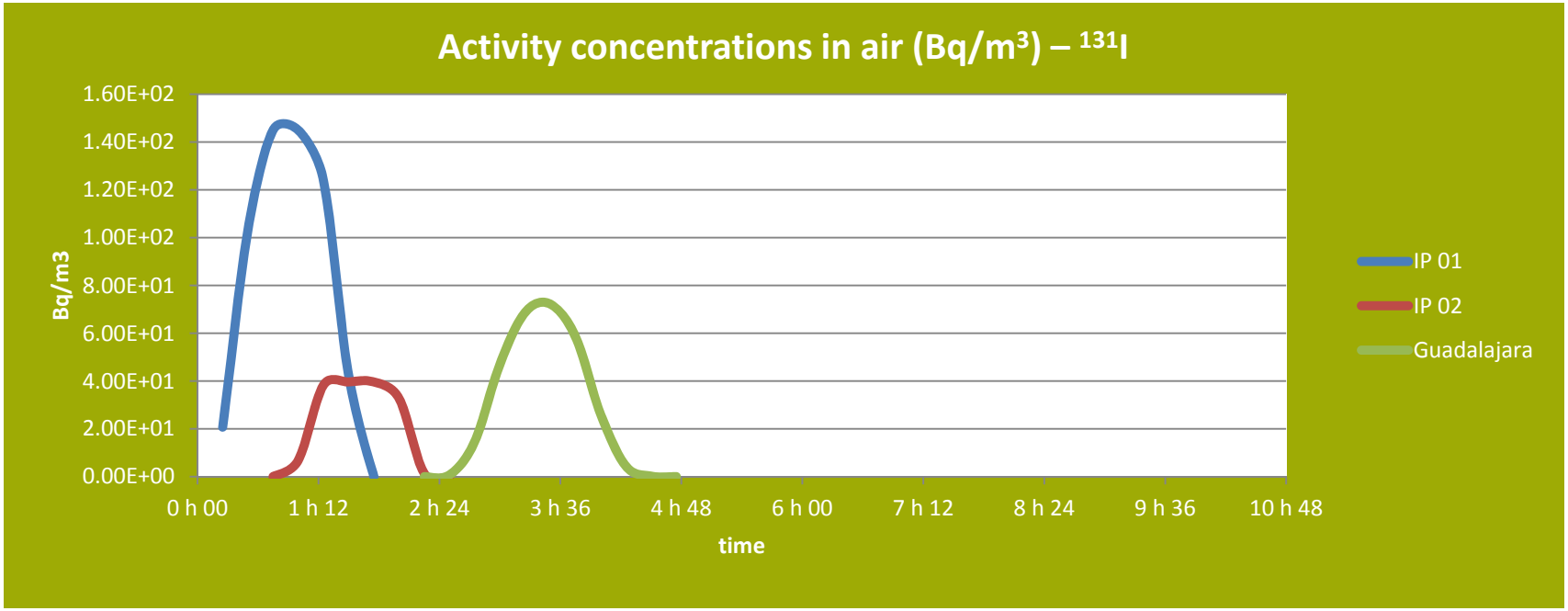
I-131 (Bq/m³)	
time	IP02
1 h 00	6,81E+00
1 h 15	3,83E+01
1 h 30	3,96E+01
1 h 45	3,96E+01
2 h 00	3,27E+01
2 h 15	1,25E+00

I-131 (Bq/m³)	
time	Guadalajara
2 h 30	6,77E-01
2 h 45	1,46E+01
3 h 00	4,70E+01
3 h 15	6,87E+01
3 h 30	7,22E+01
3 h 45	5,85E+01
4 h 00	2,61E+01
4 h 15	4,36E+00
4 h 30	1,82E-01

SIMULATION RESULTS - Stability class: D

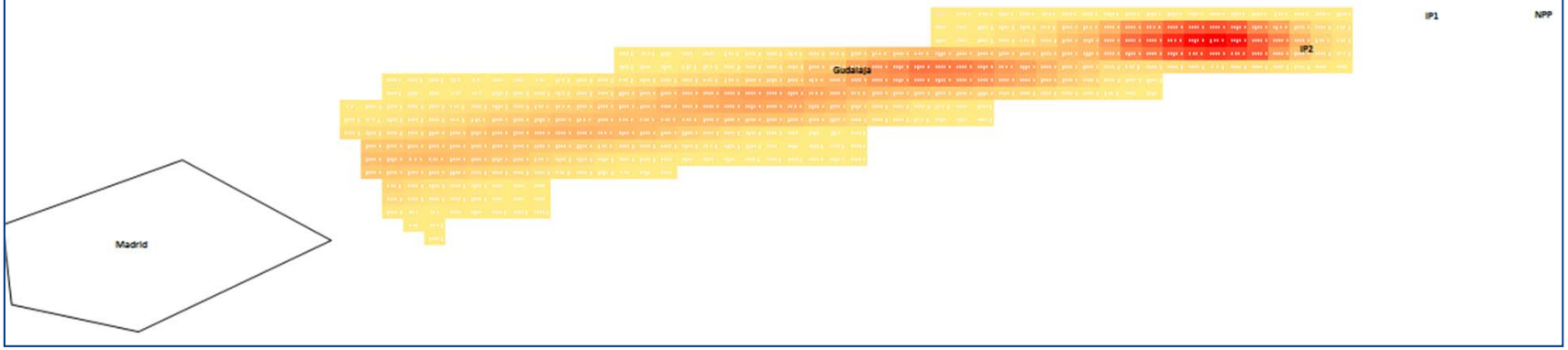
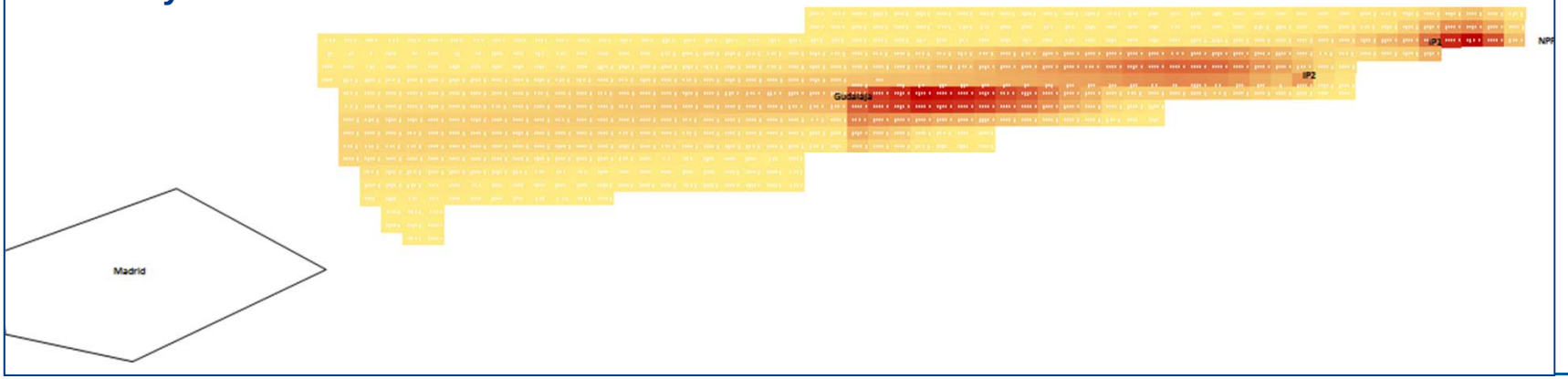
- **Time series of activity concentrations in air**

The activity concentrations in air are provided with a temporal resolution of 15 minutes only for ^{131}I.



SIMULATION RESULTS - ^{137}Cs deposited activity (Bq/m^2)

Stability class: E



Stability class: D