



UNIVERSITÉ DE  
VERSAILLES  
ST-QUENTIN-EN-YVELINES



# RadioClimFire

Radioactivity, climate, fire and human health: A second Chernobyl catastrophe about to happen?

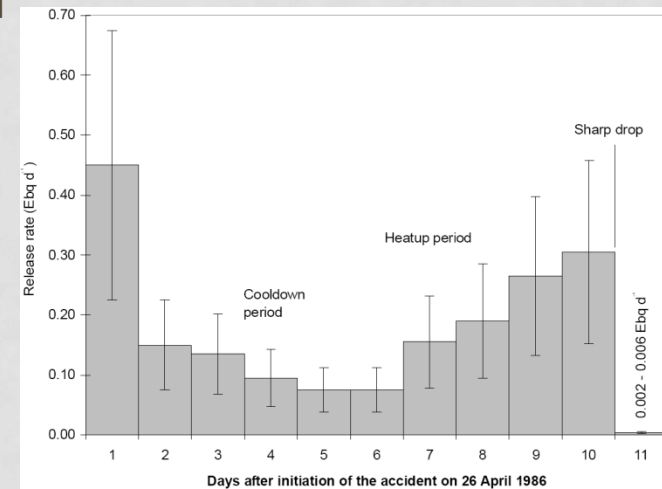
NIKOLAOS EVANGELIOU

# Chernobyl, Ukraine, 26 April 1986

Released radionuclides  
still measurable



- $^{90}\text{Sr}$  :  $0.22 \cdot 10^{18}$  Bq
- $^{137}\text{Cs}$  :  $85 \cdot 10^{15}$  Bq
- $^{239+240}\text{Pu}$  :  $2.1 \cdot 10^{15}$  Bq
- $^{238}\text{Pu}$  :  $1.0 \cdot 10^{15}$  Bq
- $^{241}\text{Pu}$  :  $0.17 \cdot 10^{18}$  Bq



# Regional deposition

Plate 60 Chernobyl zone - Чернобыльская зона

Чернобыльская зона - Chernobyl zone Plate 60

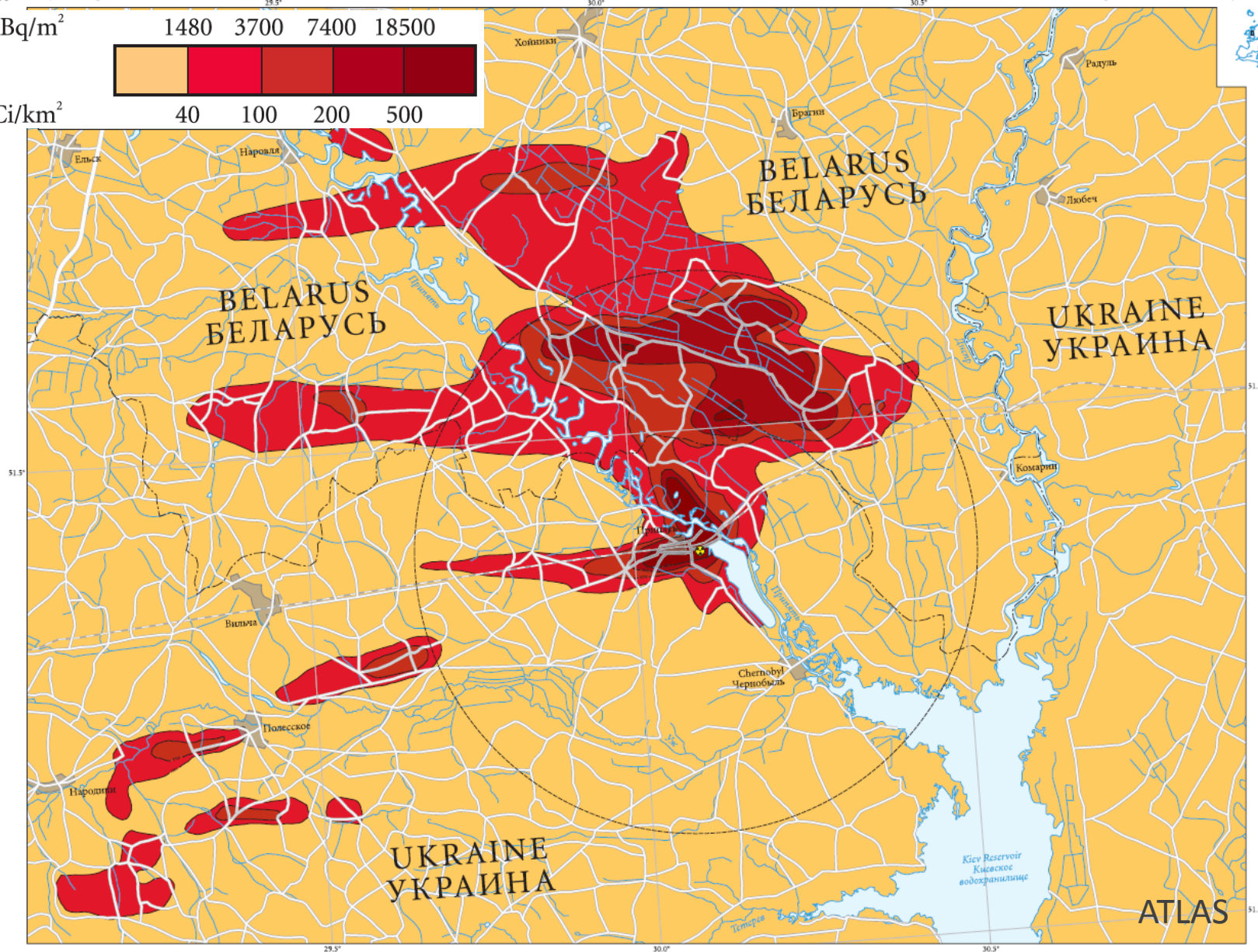
$\text{kBq/m}^2$

1480 3700 7400 18500



$\text{Ci/km}^2$

40 100 200 500



ATLAS

# Vegetation in CEZ

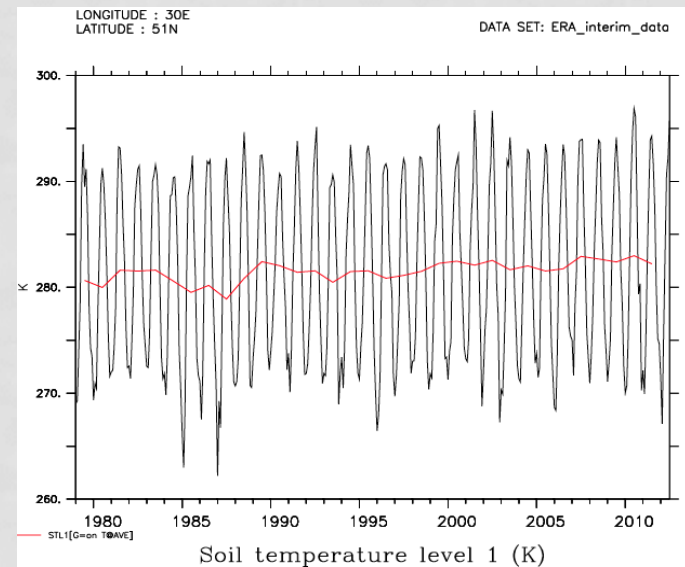
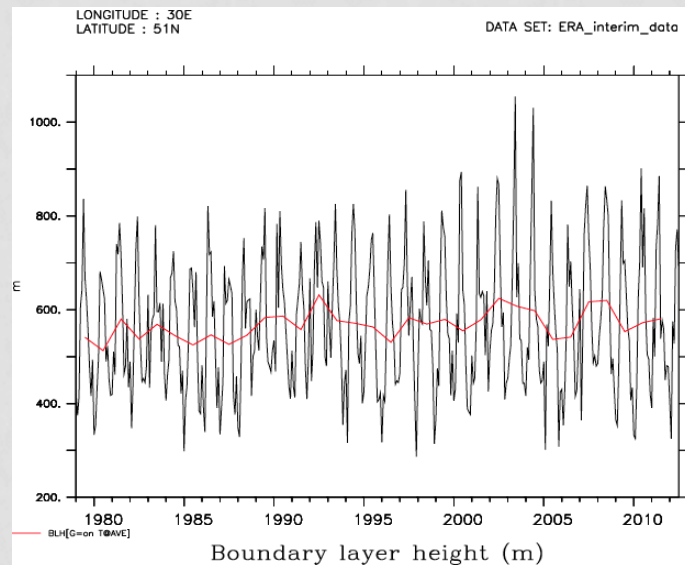
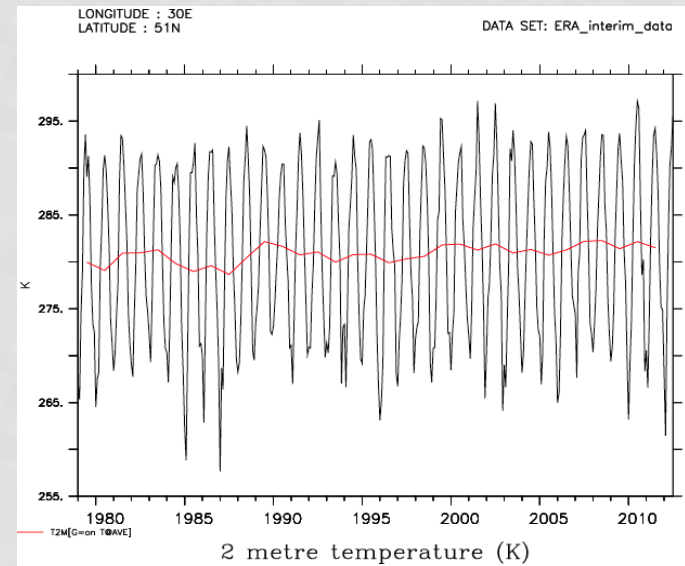
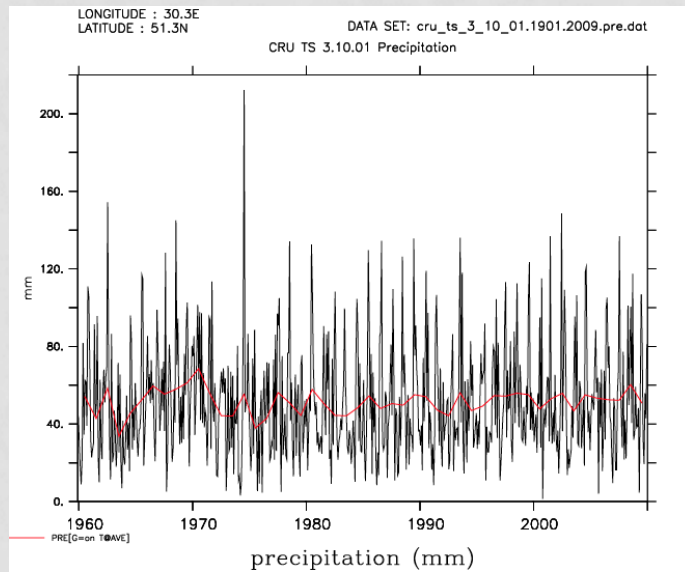


CEZ: 2600 km<sup>2</sup>  
70 % boreal forest (pine trees)  
30 % agricultural land

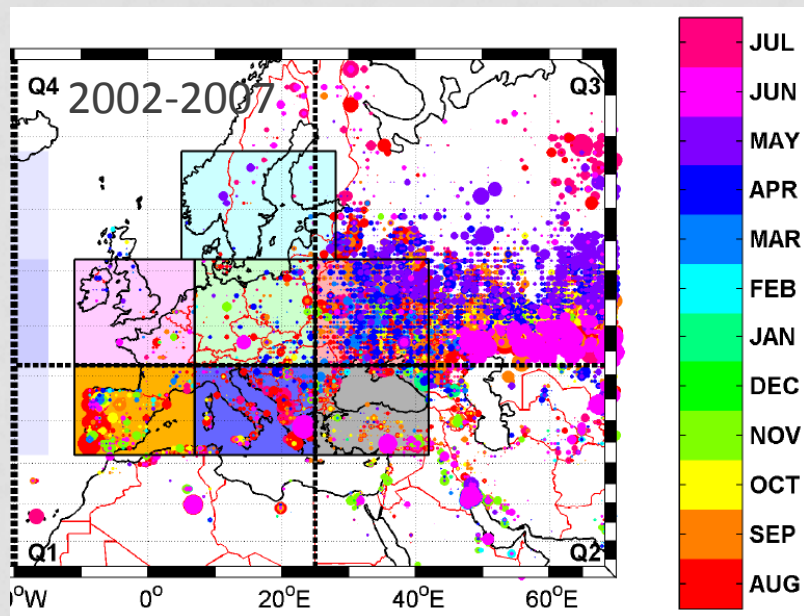


Red forest

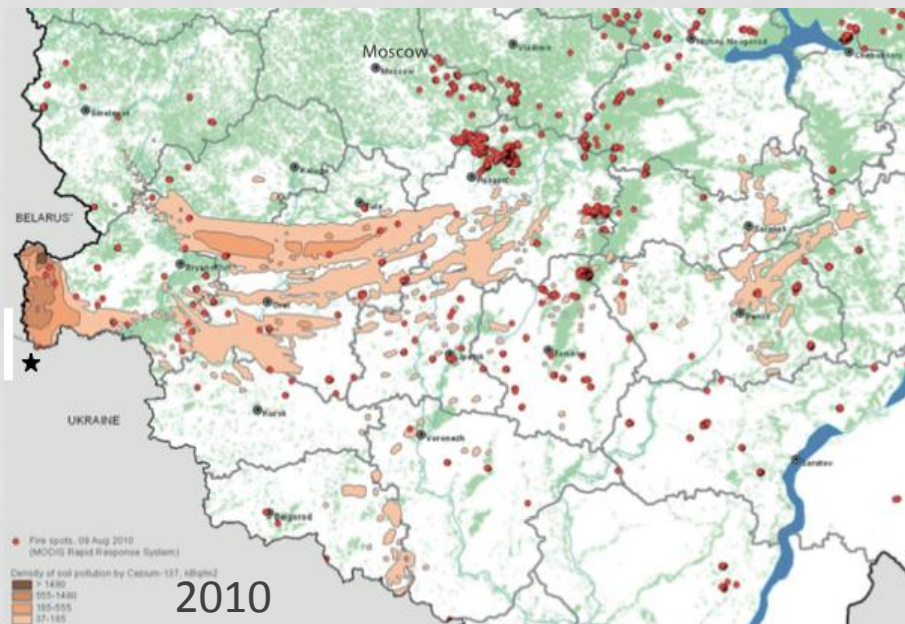
# Precipitation, temperature, BLH in the Chernobyl NPP



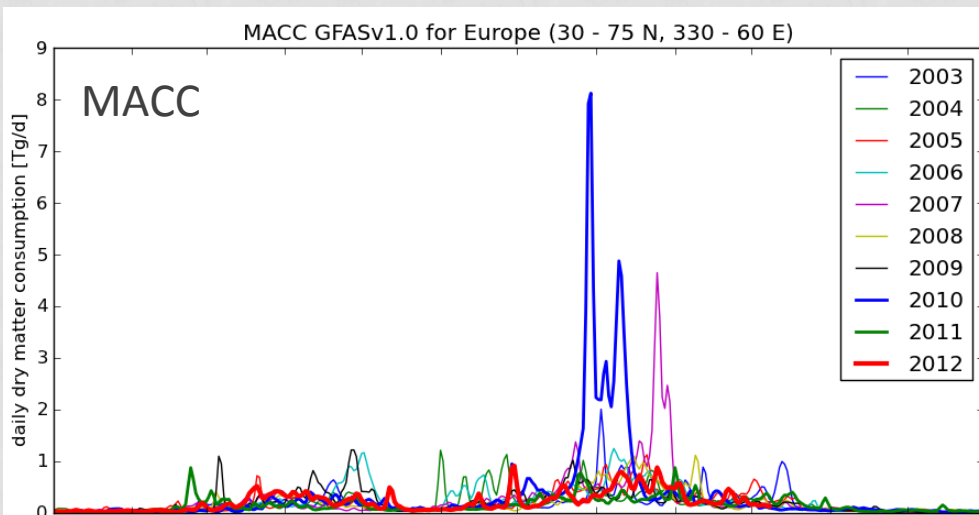
# Fire distribution over Europe



Barnaba et al., 2012



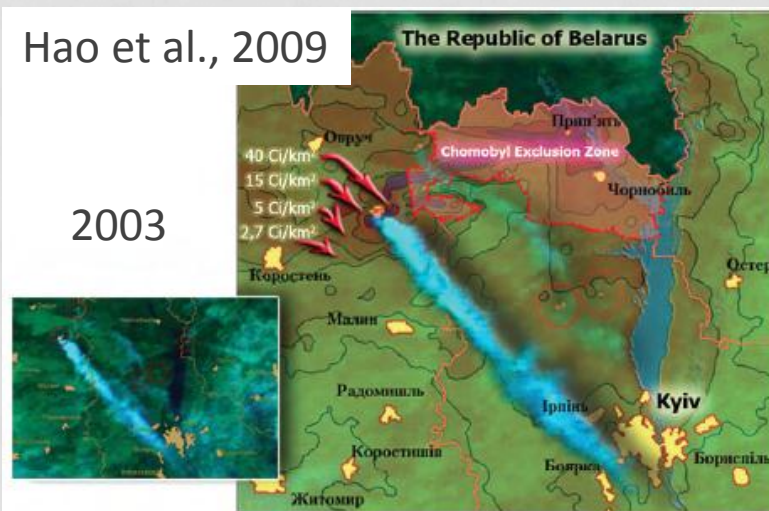
MODIS satellite



MACC

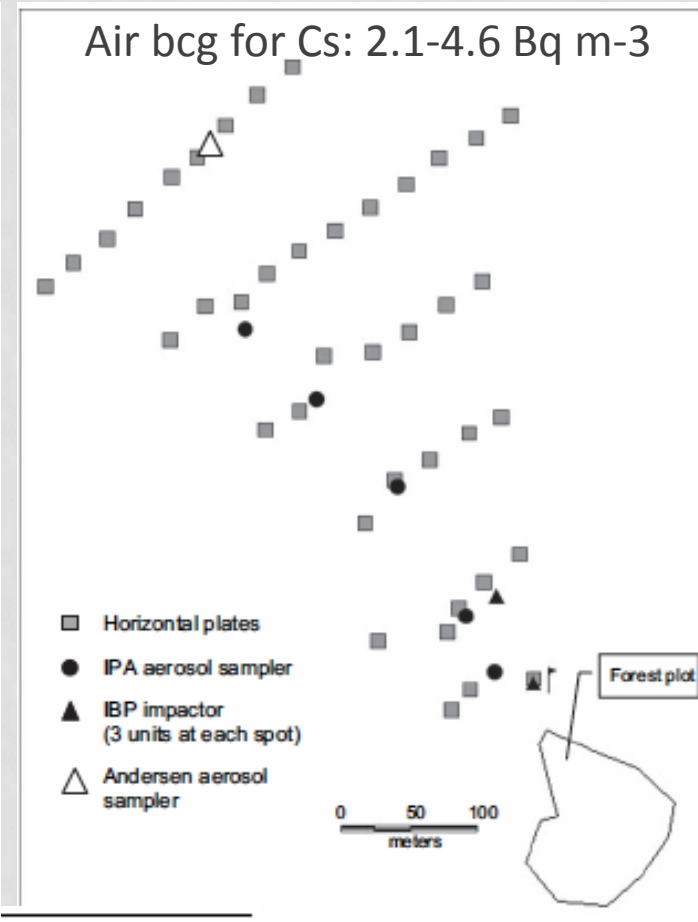
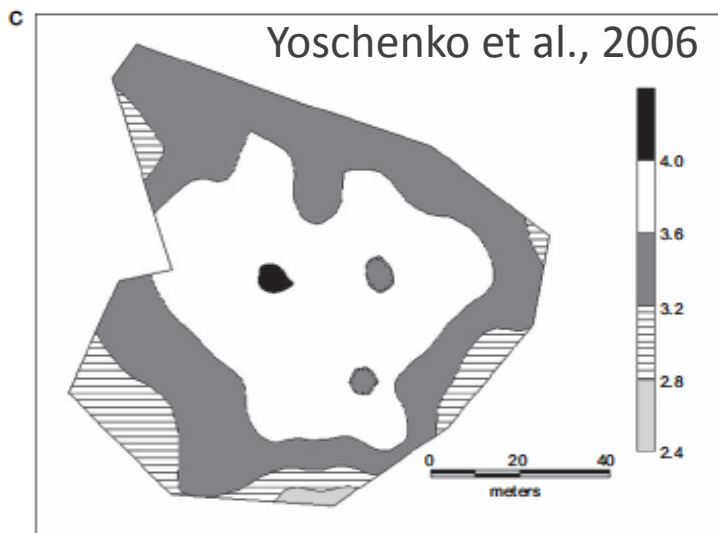
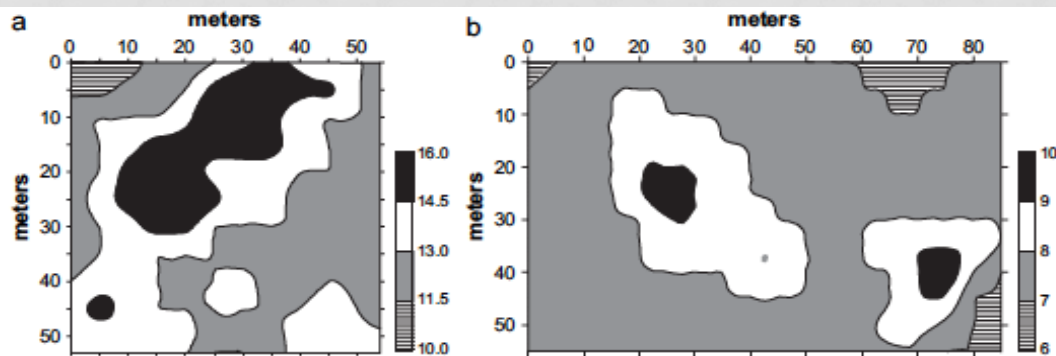
MACC GFASv1.0 for Europe (30 - 75 N, 330 - 60 E)

Hao et al., 2009



2003

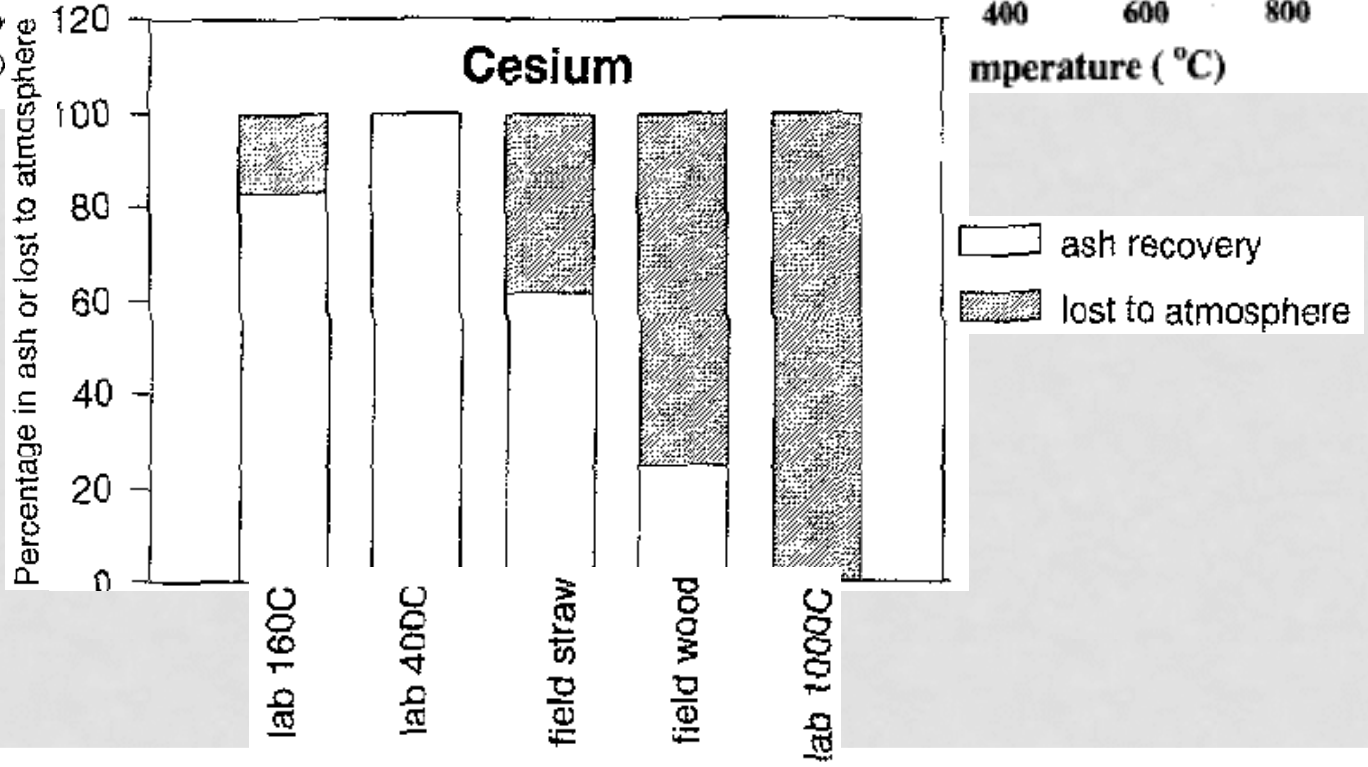
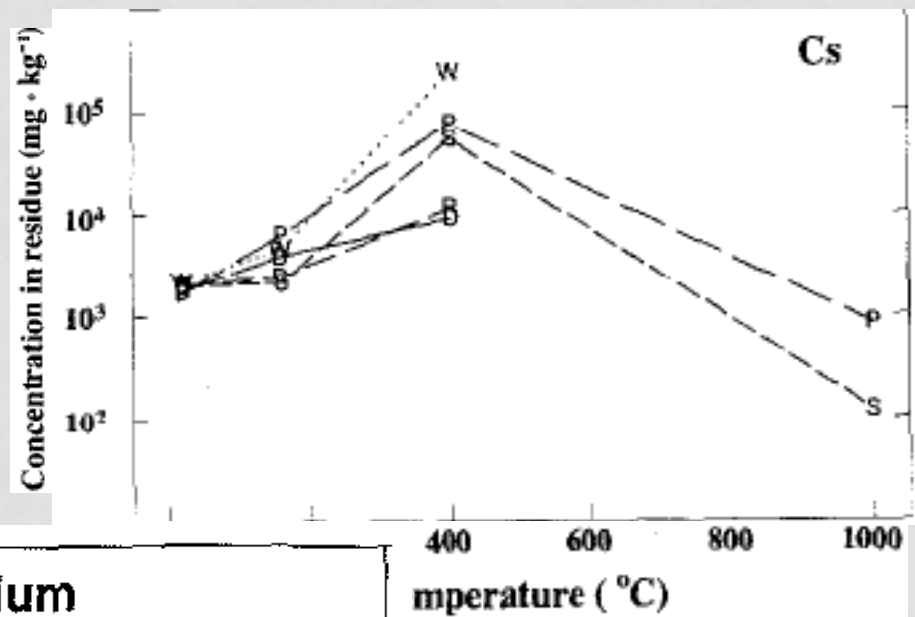
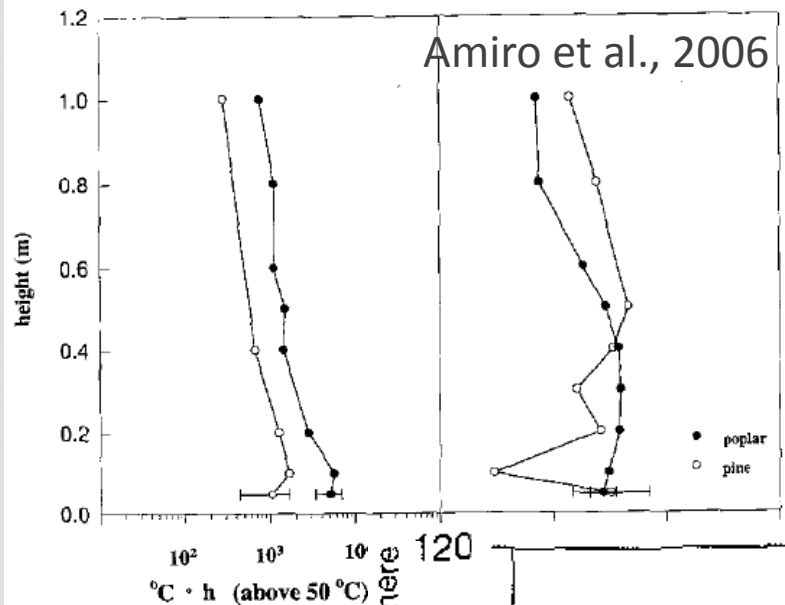
# How much cesium might be redistributed after fires?



	Plot #1	Plot #2	Plot #3
Area (m <sup>2</sup> )	3600	5400	8770
Land type	Wildland (grass)	Wildland (grass)	Forest
Vegetation species	<i>Elytrigia repens</i> (L.)	<i>Elytrigia repens</i> (L.)	<i>Pinus silvestris</i>
	Nevski (85%)	Nevski (85%)	
Vegetation height (m)	0.5	0.2	15
Biomass density (kg m <sup>-2</sup> )	0.4	0.3	24
Litter density (kg m <sup>-2</sup> )	0.7	1.25	2.3
Dose rate range (μGy h <sup>-1</sup> )	10–16	6–10	2–4

Redistribution 4 %

# How much cesium might be redistributed after fires?





## How much cesium might be redistributed after fires?

*'Hot Burn' — Mean Temperature 660°C 48 kg of air-dry heather yielded 0.95 kg of ash (2.05%)*

	<i>Total Bq before burning</i>	<i>Total Bq after burning</i>	<i>Smoke loss %</i>
$^{137}\text{Cs}$	152 000	99 300	39
$^{134}\text{Cs}$	22 000	15 000	35

*'Cool Burn' — Mean Temperature 550°C 50.1 kg of air-dry heather yielded 2.2 kg of ash (4.4%)*

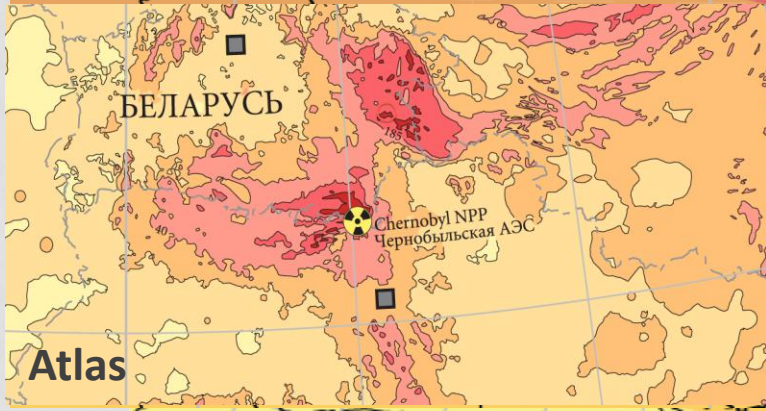
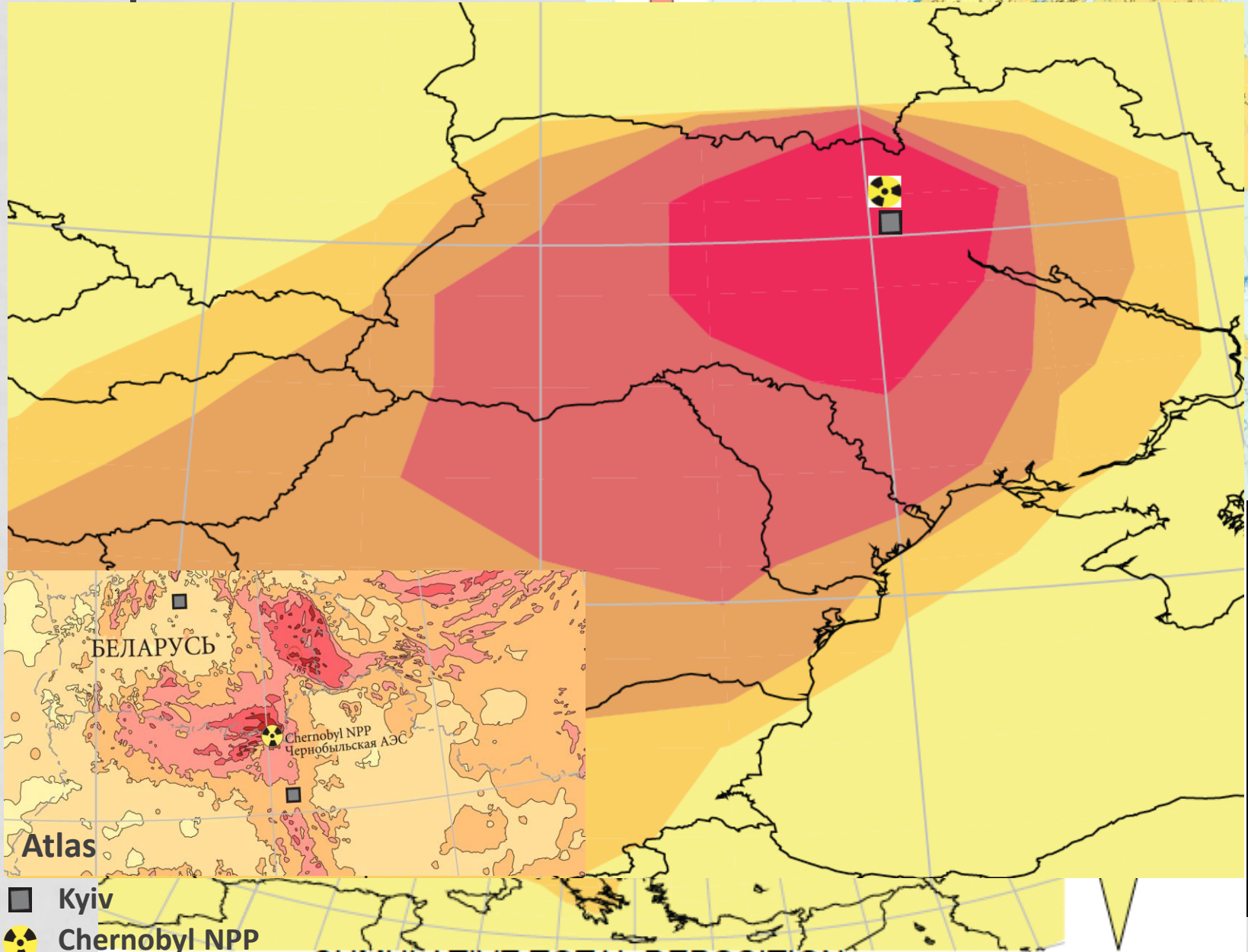
	<i>Total Bq before burning</i>	<i>Total Bq after burning</i>	<i>Smoke loss %</i>
$^{137}\text{Cs}$	120 000	106 000	12
$^{134}\text{Cs}$	23 000	21 000	11

Horill et al., 1995

# How important is the altitude



in PBq



Atlas

- Kyiv
- ☢ Chernobyl NPP

CUMULATIVE TOTAL DEPOSITION

kBq/m<sup>2</sup>

# Goals...

- Assessment of the transport and deposition of  $^{137}\text{Cs}$  after fire scenarios
- Assessment of the risk of contamination of major human urban centers in Ukraine, Belarus and Russia due to contaminated smoke originating from forest fire in contaminated areas
- Assessment of the biological and public health consequences of such contamination.
- Forecast of the risk and areas that are particularly likely to suffer from further contamination due to forest fire
- Report of the risk to human health and the level of morbidity due to increased contamination arising from forest fires
- Address of the effects of increased contamination arising from forest fires on abundance and diversity of animals by using reference organisms inhabiting the area and modeling applications

RadioClimFire

# Mapping the route to the final destination...

End...

Start...

Insert  $^{137}\text{Cs}$   
in the code  
of the model  
2 months  
tests

Study of the  
Chernobyl  
accident  
Validation of the  
results

Build fire  
scenarios  
3 fire scenarios to  
be studied

SPITFIRE use  
a. to account for  
redistribution  
b. Possibility of  
fires in the area

Dose to human  
and non human  
biota  
a. Dose rate  
estimates for the  
population  
(CROM)  
b. Risk  
assessment of  
animals using  
relevant software  
(ERICA Tool)

ORCHIDEE provides  
amount of litter  
per area

SPITFIRE coupled  
with LMDZORINCA

New transport and  
deposition

Consequences

LMDZORINCA

# Model description

LMDz

Laboratoire de  
Météorologie  
Dynamique

INCA

INteractions  
between Aerosols  
and Chemistry

ORCHIDEE

ORganizing Carbon  
and Hydrology In  
Dynamic  
Ecosystems  
Environment

GCM

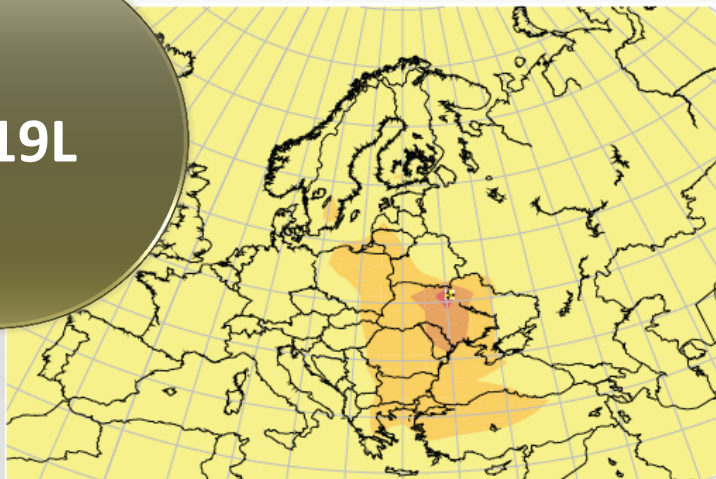
- Offers the possibility of zoom

Chemistry model

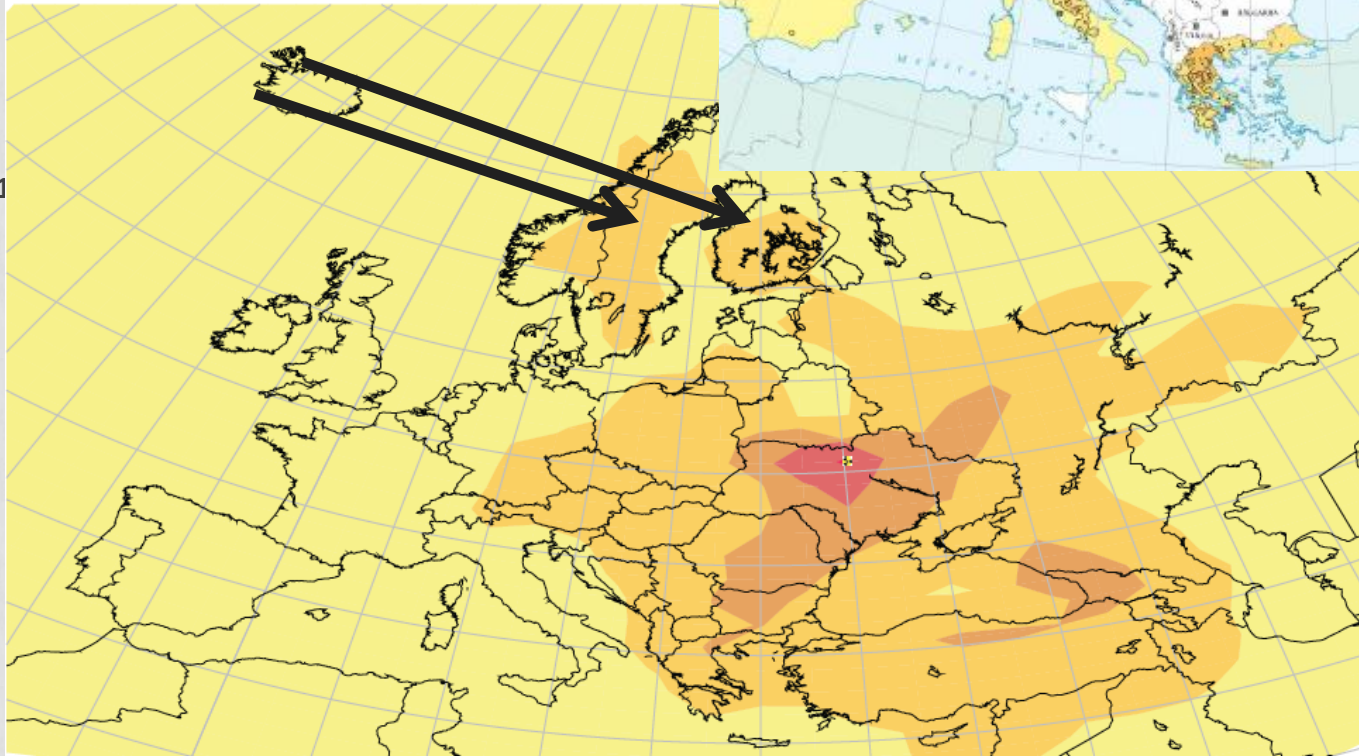
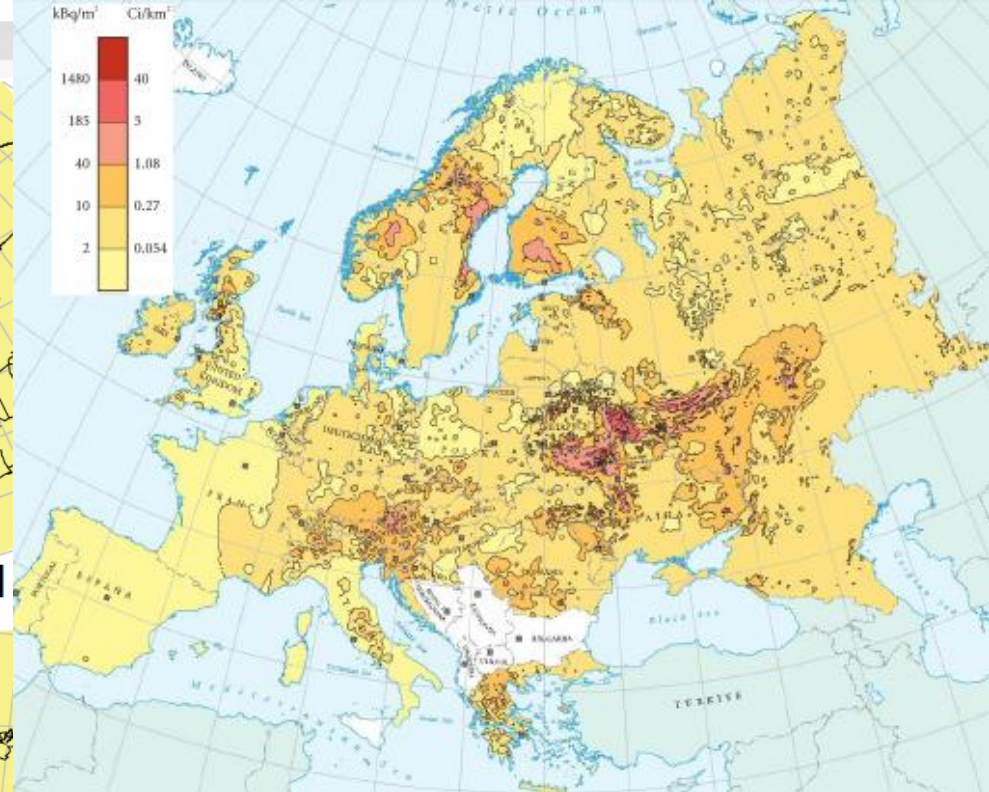
- Can run in nudged mode of ECMWF meteorology

Vegetation model

RG19L

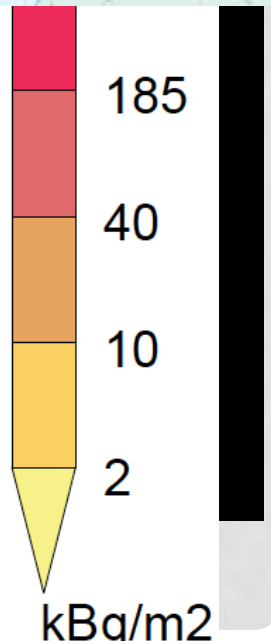


CUMULATIVE DRY DEPOSITION

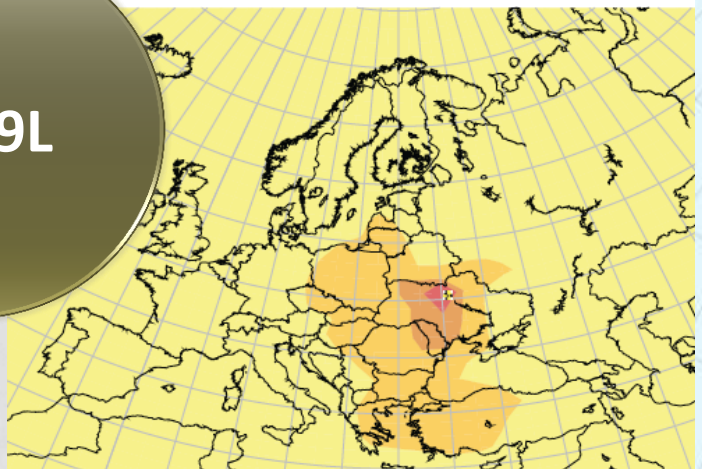


in PBq (10<sup>15</sup>)

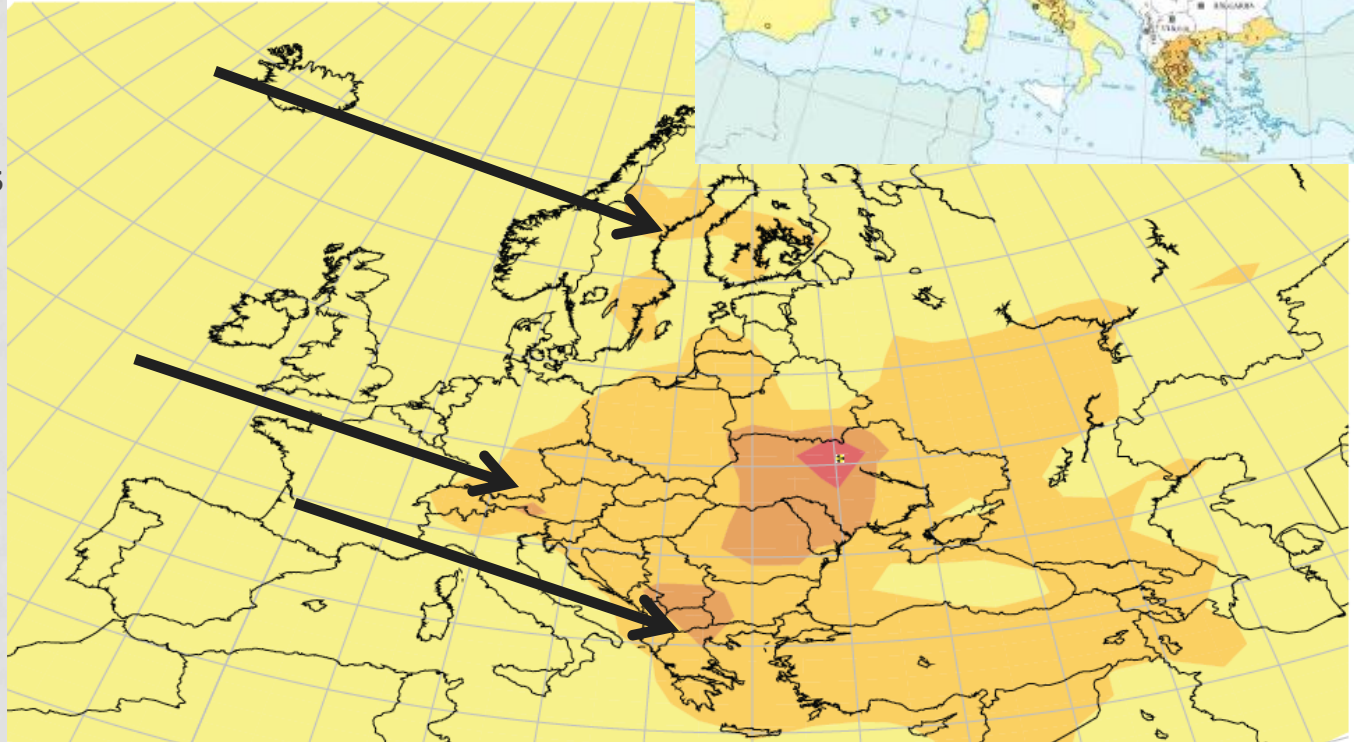
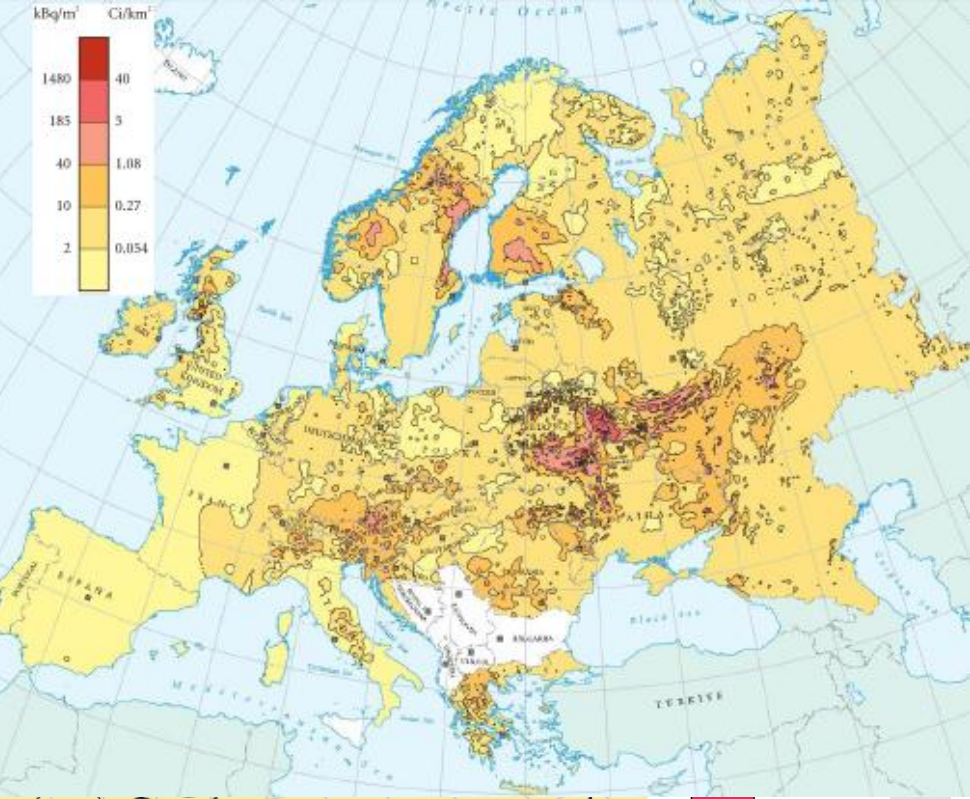
CUMULATIVE TOTAL DEPOSITION



**RG39L**

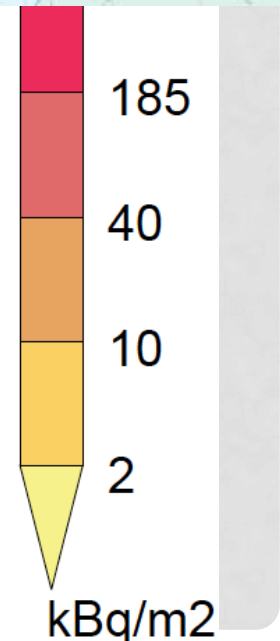


**CUMULATIVE DRY DEPOSITION**

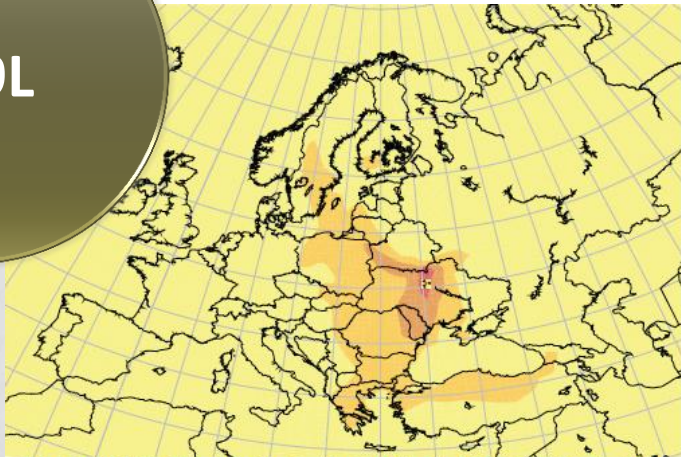


in PBq ( $10^{15}$ )

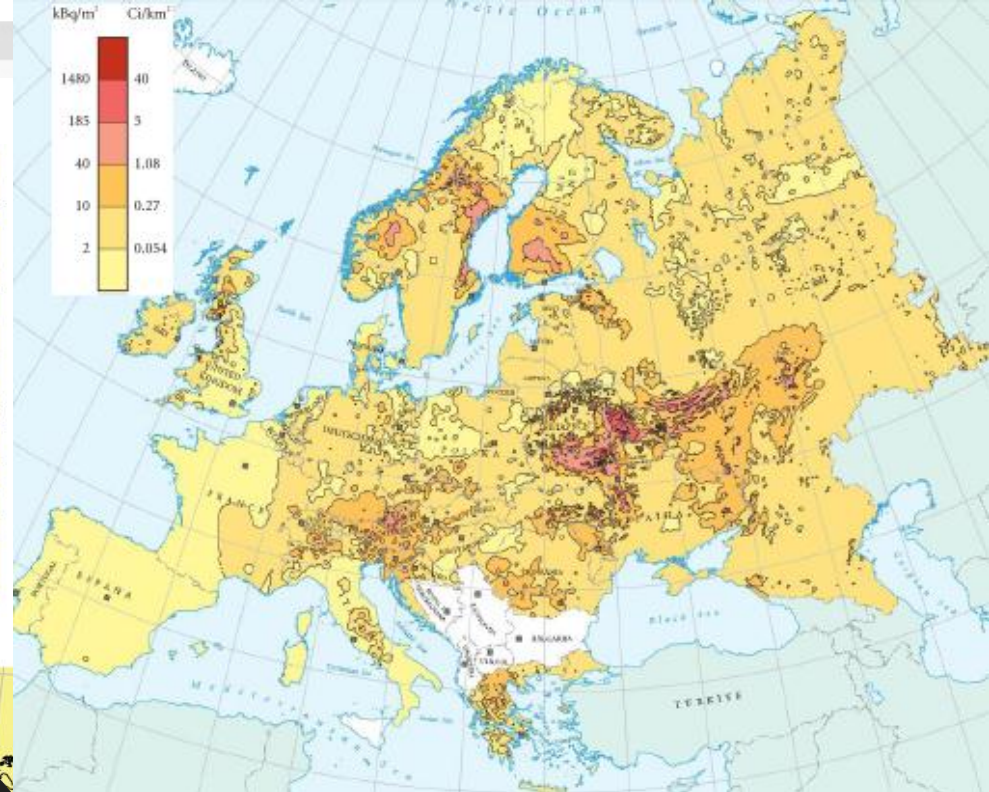
**CUMULATIVE TOTAL DEPOSITION**



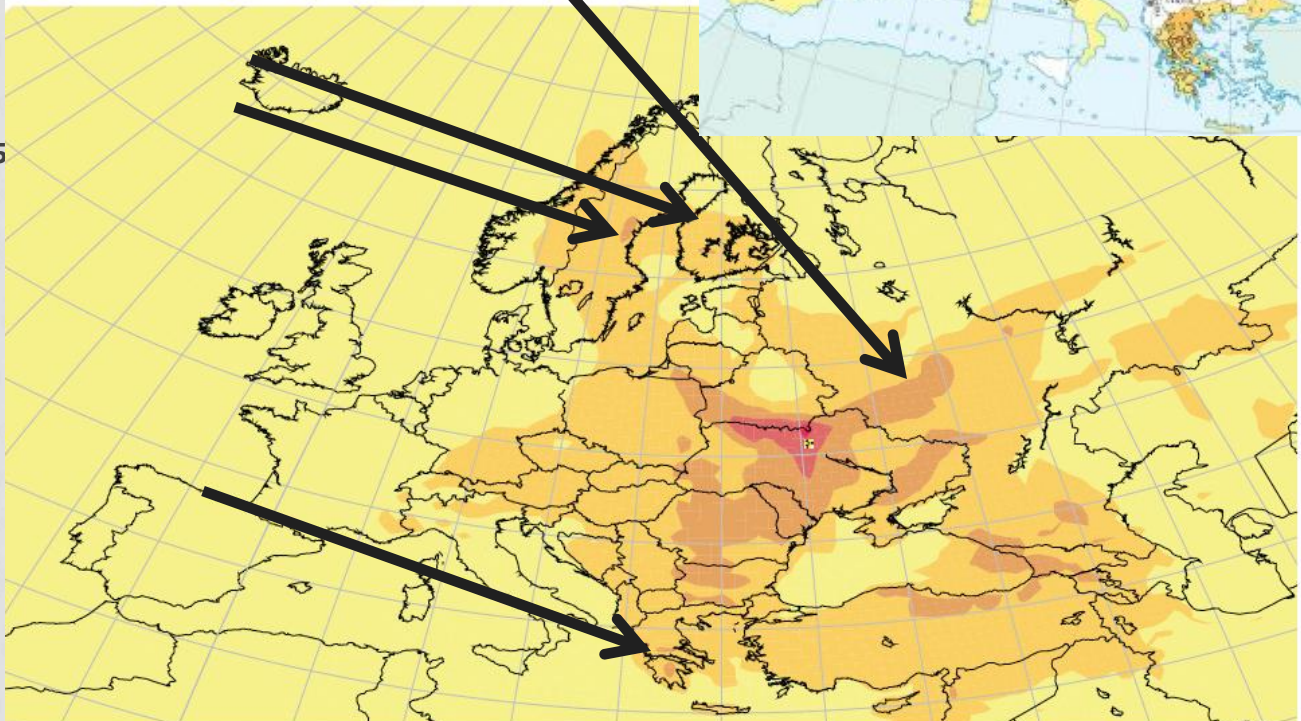
Z19L



CUMULATIVE DRY DEPOSITION

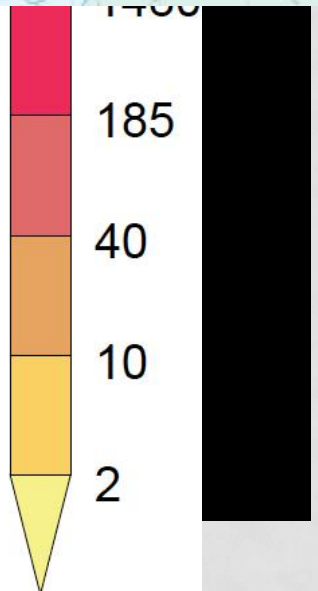


kBq/m<sup>2</sup> Ci/km<sup>2</sup>  
1480 40  
185 3  
40 1.08  
10 0.27  
2 0.054



in PBq (10<sup>15</sup>)

CUMULATIVE TOTAL DEPOSITION

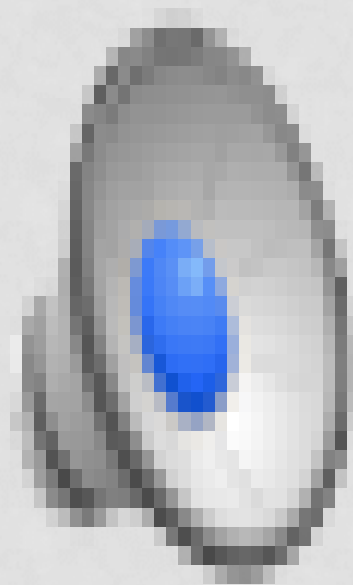


1480  
185  
40  
10  
2  
kBq/m<sup>2</sup>



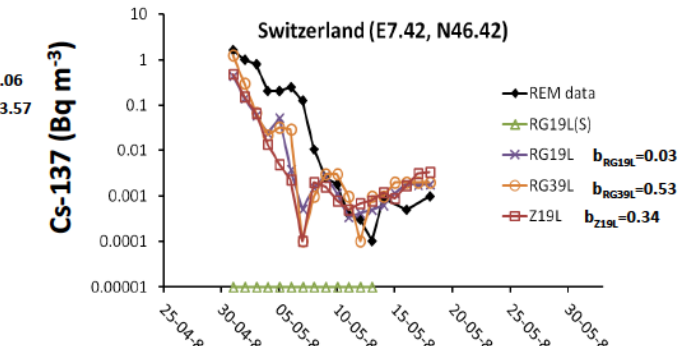
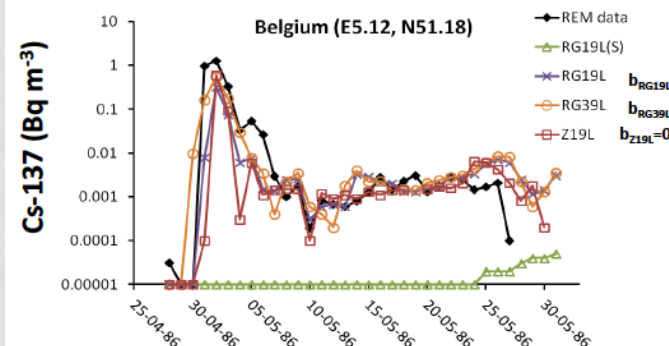
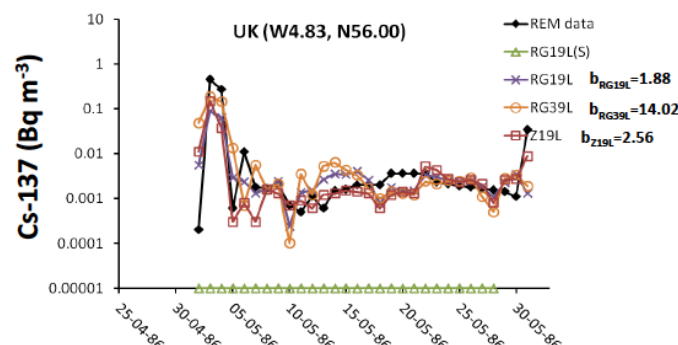
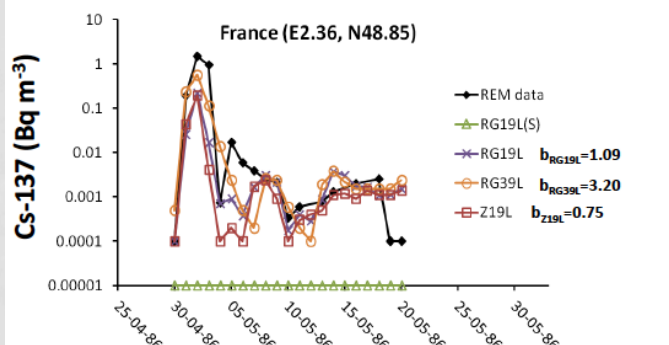
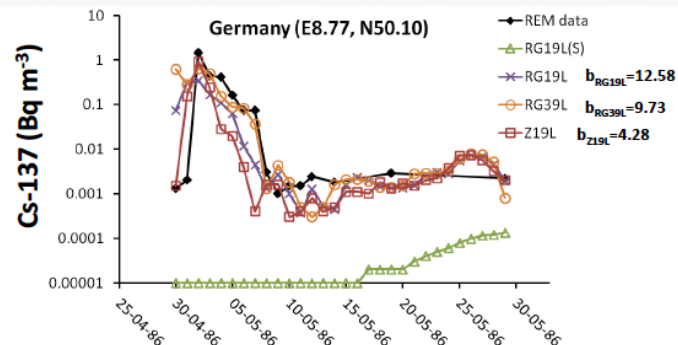
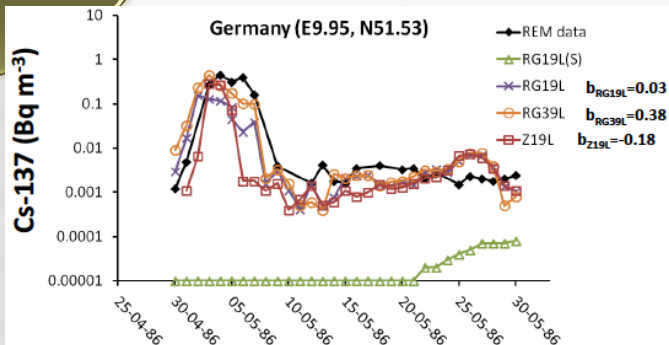
19 levels  
or  
39 levels

# Vertical resolution



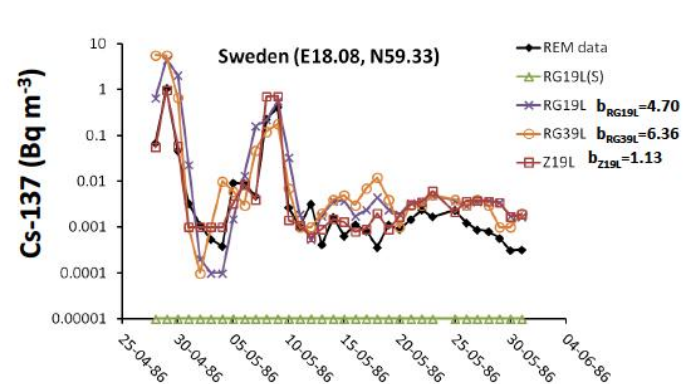
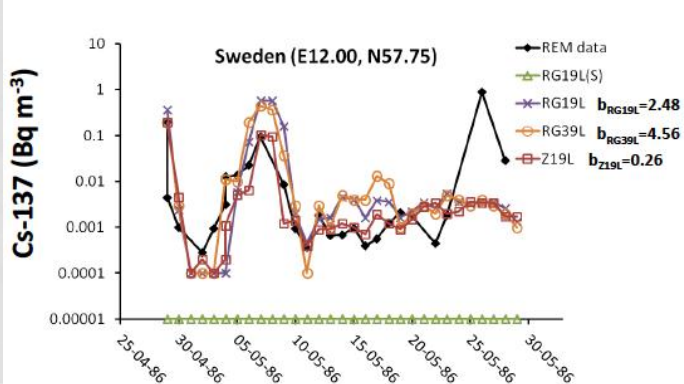
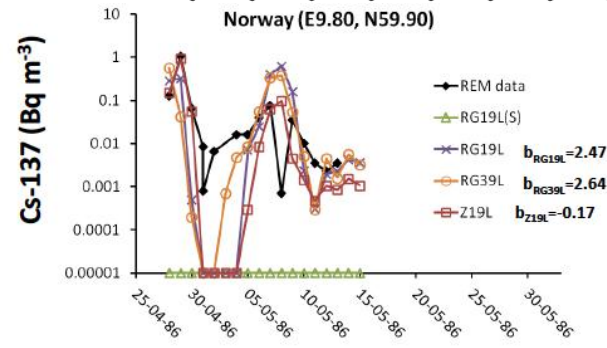
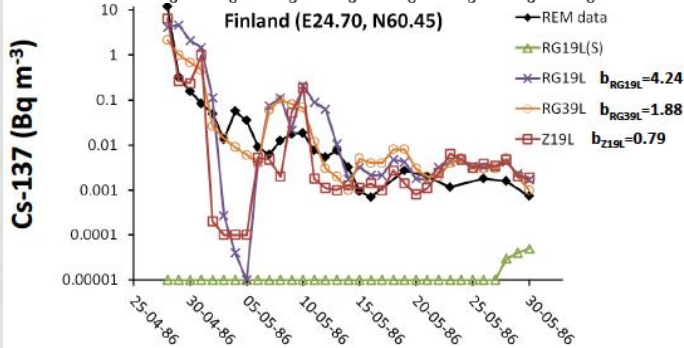
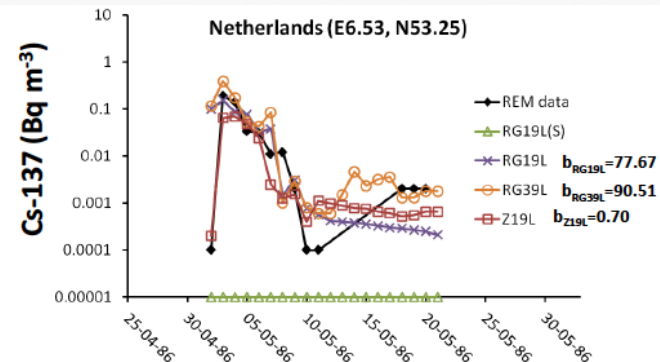
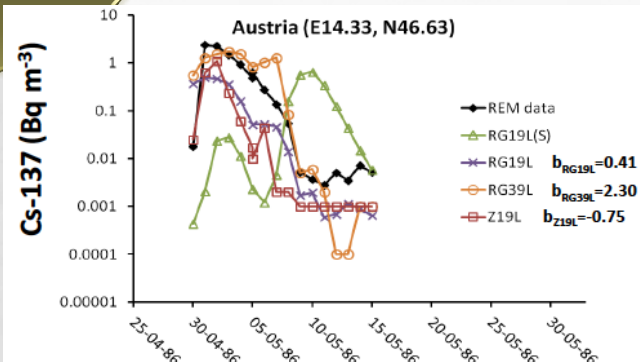
VALIDATION  
OF SURFACE  
ACTIVITY  
CONC.

# Model vs Measurements



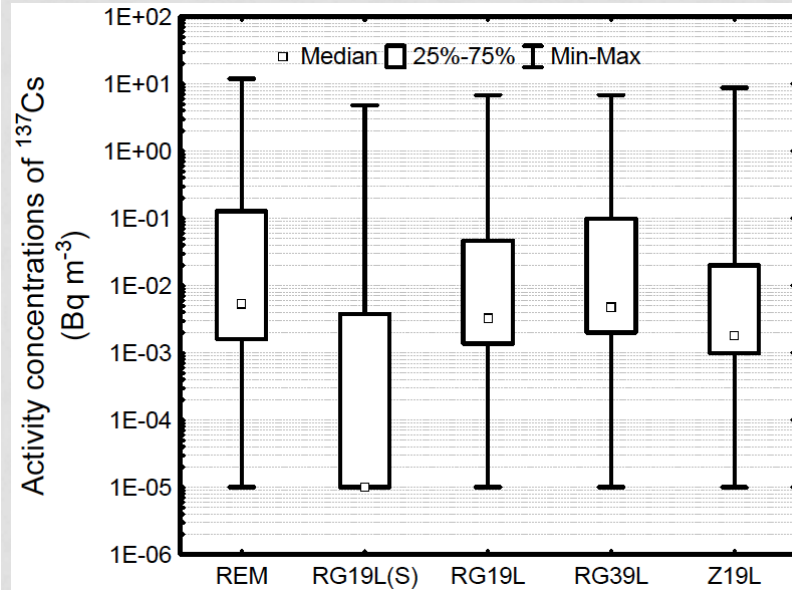
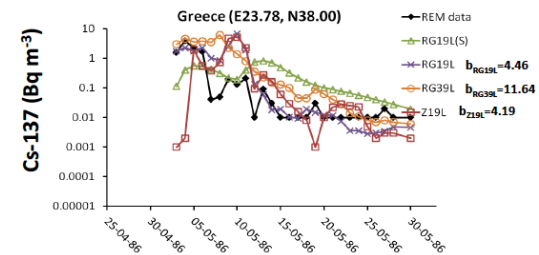
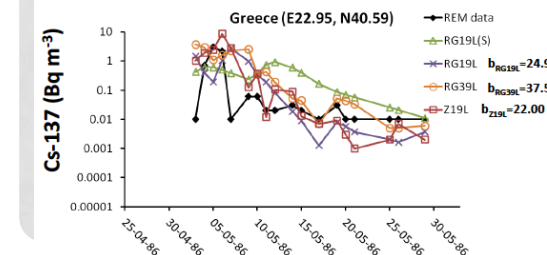
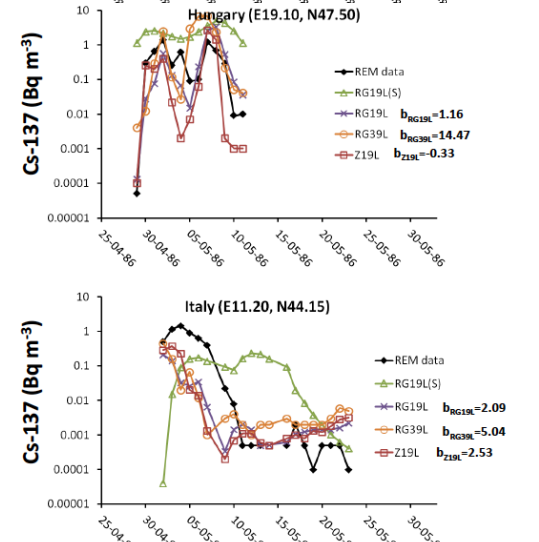
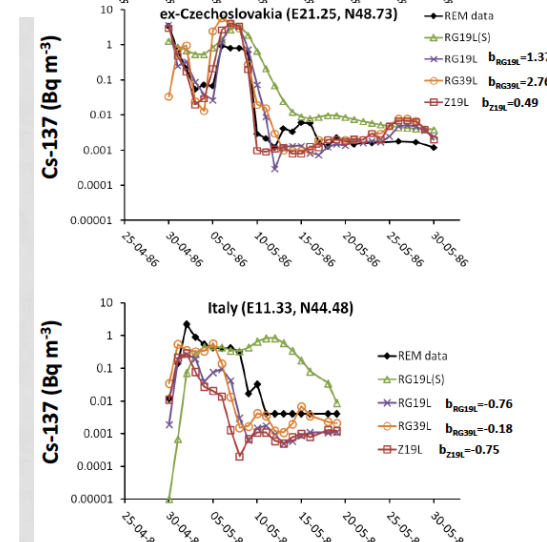
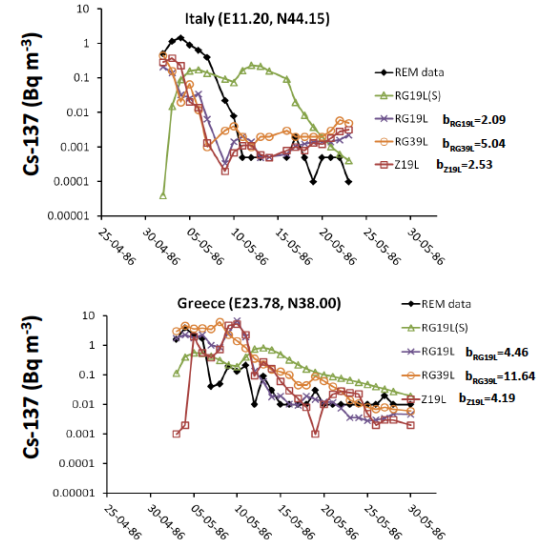
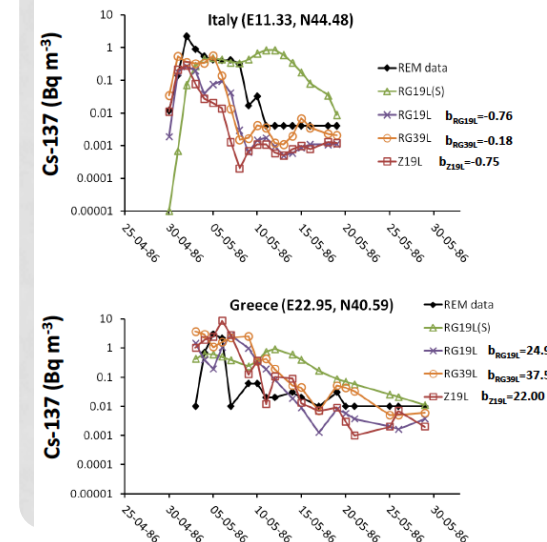
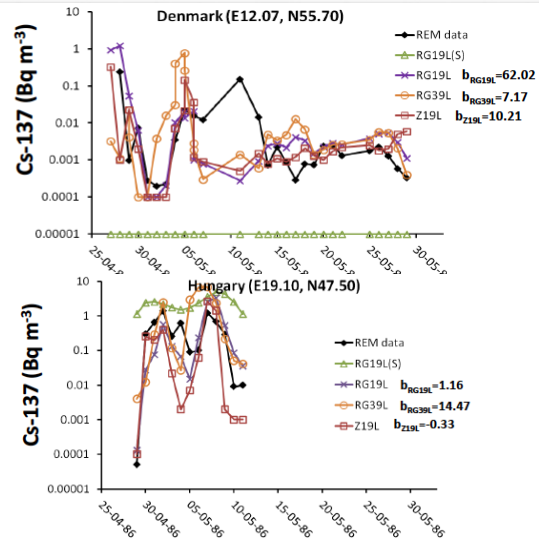
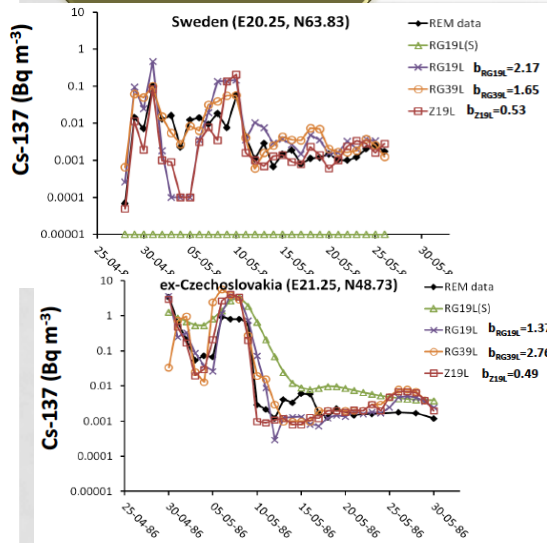
VALIDATION  
OF SURFACE  
ACTIVITY  
CONC.

# Model vs Measurements



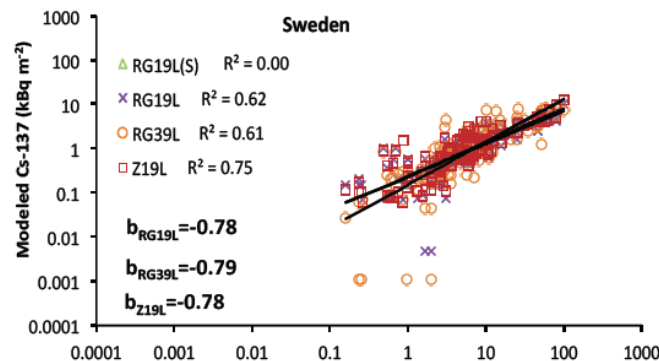
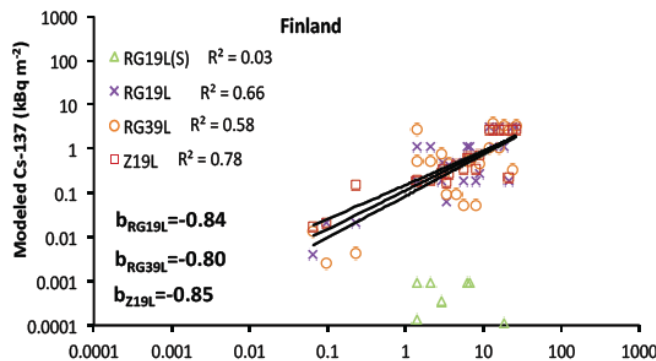
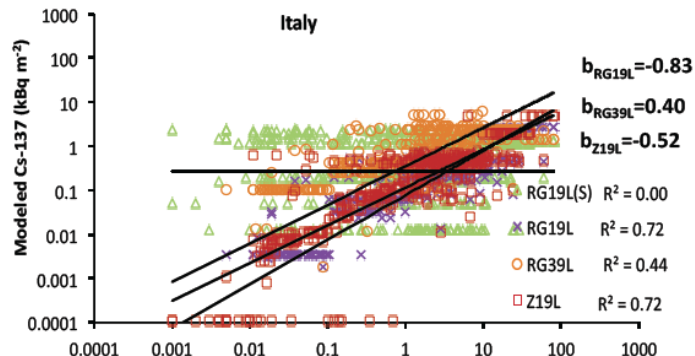
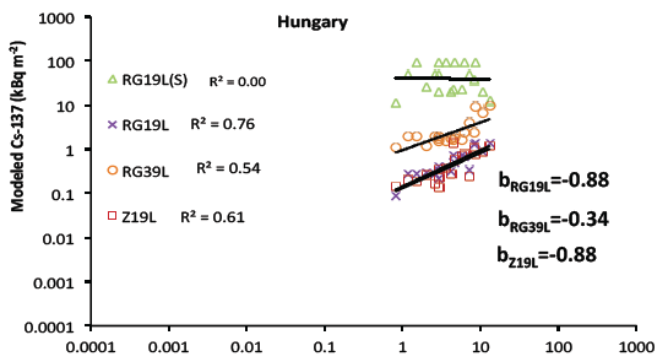
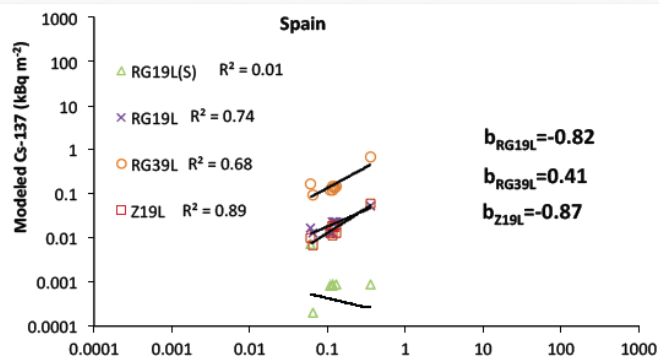
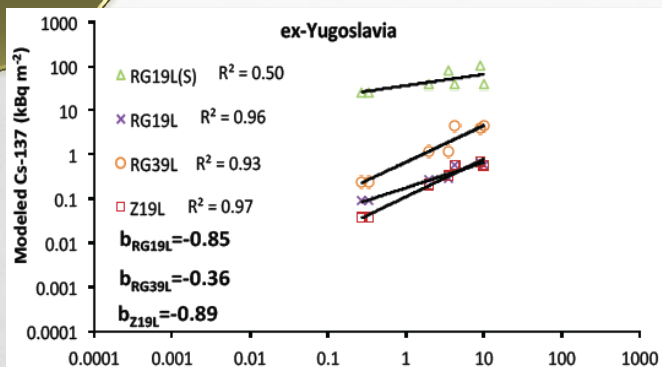
**VALIDATION  
OF SURFACE  
ACTIVITY  
CONC.**

# Model vs Measurements



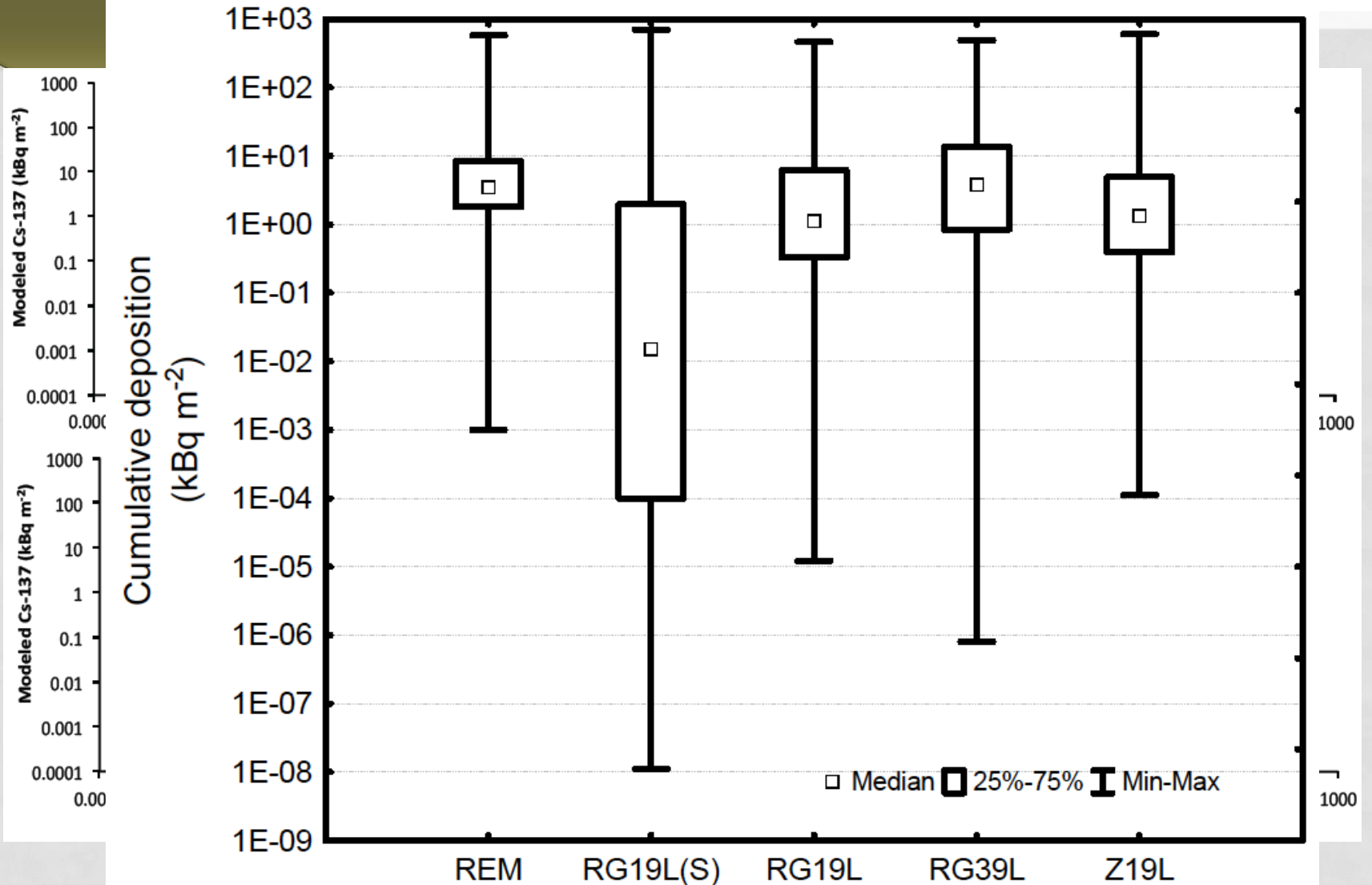
VALIDATION  
OF CUMUL.  
DEPOSITION

# Model vs Measurements



VALIDATION  
OF CUMUL.  
DEPOSITION

# Model vs Measurements



# Assessment of the radiological risk to the population in nearby areas

CROM v6.0.9 - Código de cRiba para evaluaciOn de iImpacto

Date: Datab: Datab: Database Case Options View Help

Case

Case name:  
Cs-137 dispersion after fire

Site name:  
ATM 2 + FOOD

Installation type:  
Nuclear Power Plant

Study by

- Emission rate
- Concentration

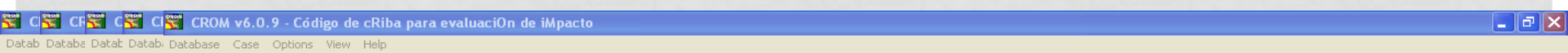
OK

Cancel

It creat

NUM

# Assessment of the radiological risk to the population in nearby areas



**Dispersion in the lee of an isolated point source**

Receptor point:  Distance:  m

Pp - Fraction of time during the year that the wind blows towards the receptor in sector p:

F: Gaussian diffusion factor

Estimation

Value

<< Back Cancel Continue



# Assessment of the radiological risk to the population in nearby areas

**Dose assessment - Internal irradiation data for the critical group: HCG-1**

Diet composition

Units: Q- Food (kg/year)  
Q- Water (m3/year)  
f- Adimensional

Radionuclide:

Product:  Q  Add value

Age group:  f

Products	Q (0 - 1)	f (0 - 1)	Q (1 - 2)	f (1 - 2)	Q (2 - 7)	f (2 - 7)	Q (7 - 12)	f (7 - 12)	Q (12 - 17)	f (12 - 17)	Q (>17)	f (>17)

Inhalation data

Radionuclide: Cs-137

Inhalation rate (m3/year)

Type	F	0 a 1	1 a 2	2 a 7	7 a 12	12 a 17	More than 17
		1043.9	1898	3197.4	5577.2	7336.5	8322

<< Back

Continue

# Assessment of the radiological risk to the population in nearby areas

**CROM/Calculation options**

Case name:  
Cs-137 dispersion after fire

Site name:  
ATM 2 + FOOD

Installation type:  
Nuclear Power Plant


Site location:  
Inland

GRAPHICS


REPORTS


CLOSE CASE


Gaseous discharge


 ATMOSPHERE

Liquid discharge


 RIVERS


 COASTAL WATERS

 ESTUARIES

 LITTLE LAKES AND RESERVOIRS

Food chains and dose assessment

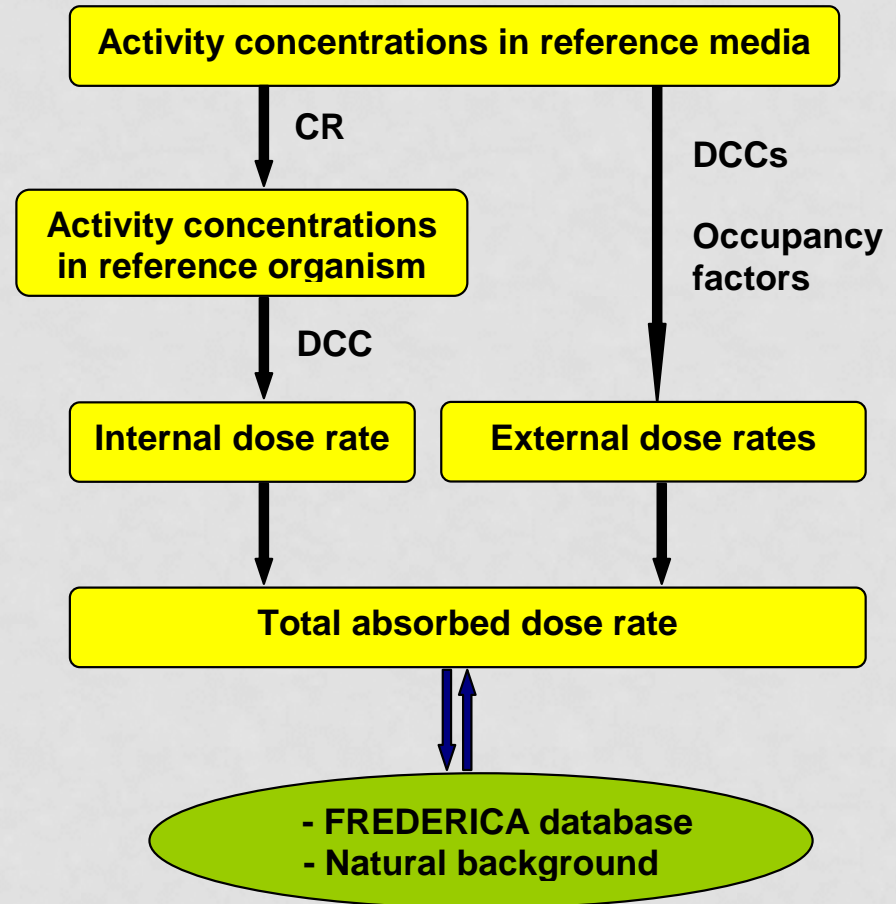
 FOOD CHAINS AND CRITICAL GROUPS

 DOSE

# Dosimetric modeling of the ecosystem (ERICA example)

## ERICA approach

- Transfer to the environment
- Estimates of dose to biota from internal and external distributions of radionuclide
- Establish the significance of the dose rates the organisms are exposed to



# Dosimetric modeling of the ecosystem (ERICA example)

## Reference organisms in ERICA

### ***Terrestrial***

Soil Invertebrate (worm)  
Detritivorous invertebrate  
Flying insects  
Gastropod  
Lichen & bryophytes  
Grasses & Herbs  
Shrub  
Tree  
Mammal  
Bird  
Bird egg  
Reptile  
Amphibian

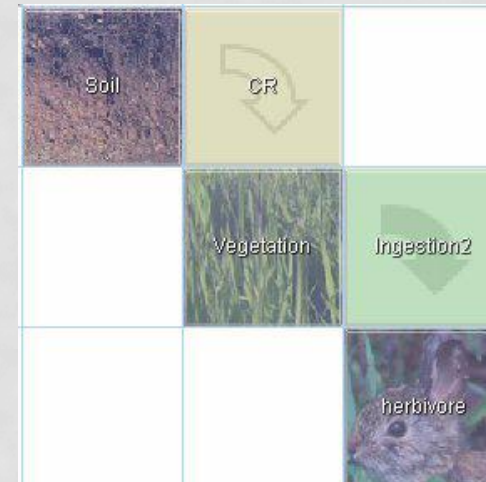
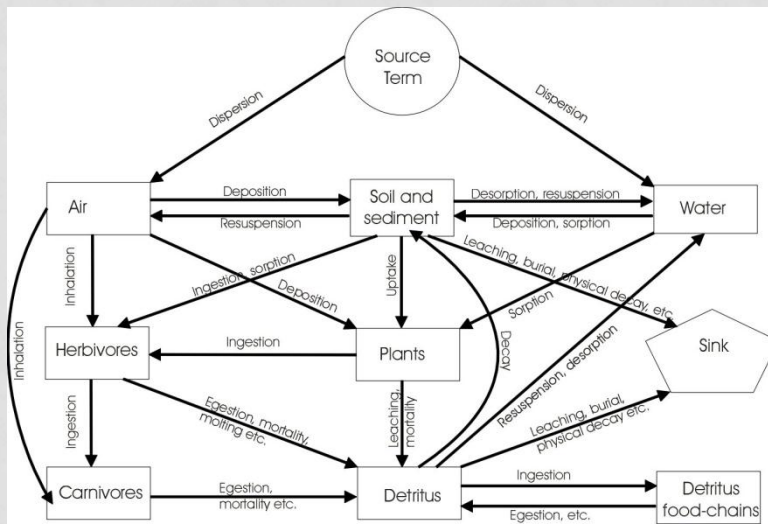
### ***Marine***

Phytoplankton  
Macroalgae  
Vascular plant  
Zooplankton  
Polychaete worm  
Bivalve mollusc  
Crustacean  
Benthic fish  
Pelagic fish  
(Wading) bird  
Mammal  
Reptile  
Sea anemones/true corals

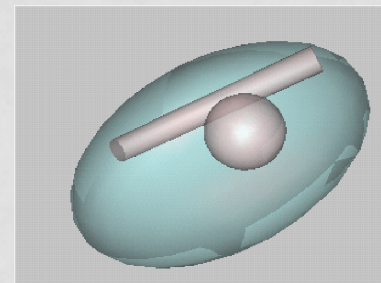
### ***Freshwater***

Phytoplankton  
Vascular plant  
Zooplankton  
Insect larvae  
Bi-valve mollusc  
Gastropod  
Crustacean  
Benthic fish  
Pelagic fish  
Bird  
Mammal  
Amphibian

# Dosimetric modeling of the ecosystem (ERICA example)



$$CR_{b,i} \text{ (dimensionless)} = C_{b,i}/C_{soil,I}$$



$$DCC = \frac{\dot{D}}{A}$$

Dose rate  $\mu\text{Gy/h}$  per unit activity  $\text{Bq/kg f.w.}$

# Dosimetric modeling of the ecosystem (ERICA example)

The screenshot displays the ERICA software interface. The title bar reads "ERICA - Nikos - Tier 2 - Problem Formulation". The menu bar includes "File", "Assessment", "Database", and "Help". The toolbar contains icons for "New", "Open", "Save", and "Help". The left sidebar shows a tree view with a folder named "Nikos". The main content area is titled "Formulate your problem" and includes a breadcrumb trail: "Communication Methods > Problem Formulation > Assessment Context". Below the title, there is a section for "Provide a detailed description of the assessment" with a text input field containing the text: "Dose assessment to non-human biota after redistribution of Cs-137 from fire events in the nearby area of the Chernobyl NPP." Below this is a section for "List the transfer pathways and your assessment endpoints" with an empty text input field. At the bottom, there is a section for "Attach illustration of conceptual model" with a "Browse..." button and a "View" button. The bottom right corner of the interface has "Back", "Next", and "Help" buttons.

ERICA - Nikos - Tier 2 - Problem Formulation

File Assessment Database Help

New Open Save Help

Communication Methods > Problem Formulation > Assessment Context

## Formulate your problem

Provide a detailed description of the assessment

Dose assessment to non-human biota after redistribution of Cs-137 from fire events in the nearby area of the Chernobyl NPP.

List the transfer pathways and your assessment endpoints

Attach illustration of conceptual model

Browse... View

Back Next Help

# Dosimetric modeling of the ecosystem (ERICA example)

**Terrestrial**

**Air**

ERICA - Nikos - Tier 2 - Assessment Context

File Assessment Database Help

New Open Save Help

\*Nikos

Problem Formulation > Assessment Context > Radioecology Parameters

Please select the ecosystem, organisms and radionuclides for your assessment. If you do not have media concentrations, you can select a built-in dispersion model to use instead.

**Isotopes**

Select from	Selected
Ag-110m	Cs-137
Am-241	
C-14	
Cd-109	
Ce-141	
Ce-144	
Cl-36	
Cm-242	
Cm-243	
Cm-244	
Co-57	
Co-58	
Co-60	
Cs-134	
Cs-135	
Cs-136	
Eu-152	
Eu-154	
H-3	
I-125	
I-129	
I-131	
I-132	
I-133	
Mn-54	
Nb-94	
Nb-95	
Ni-59	
Ni-63	
Np-237	
P-32	
P-33	
Pb-210	
Po-210	
Pu-238	
Pu-239	
Pu-240	
Pu-241	
Ra-226	
Ra-228	
Ru-103	
Ru-106	
S-35	
Sb-124	
Sb-125	
Ce-137	

Add Isotope

**Organisms**

Select from	Selected
Amphibian	Bird
Bird egg	Tree
Detritivorous invertebrate	Flying insects
Gastropod	Lichen & bryophytes
Grasses & Herbs	Mammal (Deer)
Mammal (Rat)	
Reptile	
Shrub	
Soil Invertebrate (worm)	

Add Organism

**Ecosystem**

Terrestrial

**Dose rate screening values**

- The ERICA dose rate screening value is 10  $\mu\text{Gy h}^{-1}$ .
- 40  $\mu\text{Gy h}^{-1}$  for terrestrial animal and 400  $\mu\text{Gy h}^{-1}$  for terrestrial plants and aquatic biota. It has previously been suggested that below these values (of chronic exposure) no measurable population effects would occur (IAEA 1992; USDOE 2002; UNSCEAR 1996).
- Custom value [ $\mu\text{Gy h}^{-1}$ ]:

**Uncertainty Factor (UF) [unitless]**

- UF = 3; This will test for 5% probability of exceeding the dose screening value, assuming that the RQ distribution is exponential.
- UF = 5; This will test for 1% probability of exceeding the dose screening value, assuming that the RQ distribution is exponential.
- Custom UF =

Comment on custom value here!

**Media Activity Concentration**

- Use site specific media concentration
- Use IAEA SRS-19 model:

Back Next Help

# Dosimetric modeling of the ecosystem (ERICA example)

Activity Concentration - Rules Selection > Results

These are your results for Tier 2. Click on the tabs to see the assessment details  
To finish click -Record decision- tab and provide a justification.

Risk Background **Effects** Tables Plots Rules Record decision

**This tab contains summarise radiobiological effects data to provide guidance on the types of effects that may be seen at given dose rates.**

Organism  
Bird

Effects

Dose rate range [ $\mu\text{Gy h}^{-1}$ ]	Dose rate [ $\mu\text{Gy h}^{-1}$ ]	Species	Endpoint	Effect
0-50	10.0	Small grouse	MB	No statistically significant effect on weight of birds
	10.0	Large grouse	MB	Increase in infestations with parasites of feather and gastroenterine (no value given)
	30.0	Tree swallow	RC	No statistically significant effect on breeding success measured by clutch size, hatching success, fledg
50-100				Effects reported within this dose rate range have also been reported occurring at lower dose rate bar
100-200				Effects reported within this dose rate range have also been reported occurring at lower dose rate bar
200-400				Effects reported within this dose rate range have also been reported occurring at lower dose rate bar
400-600				Effects reported within this dose rate range have also been reported occurring at lower dose rate bar
600-1000				Effects reported within this dose rate range have also been reported occurring at lower dose rate bar
1000-5000				Effects reported within this dose rate range have also been reported occurring at lower dose rate bar
5000-10000	10000.0	Chickens (Barred Rock)	RC	Severe reduction in the number of oocytes contained within two week old birds when compared with c
> 10000				No data in FREDERICA for effects observed at this dose rate range

Record Decision

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