The influence of the season on the levels of activities in crops following a short-term deposition of radionuclides to agricultural land

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Seminar

"Expert Programme of Environmental Management and Prognosis of Nuclear Emergencies"

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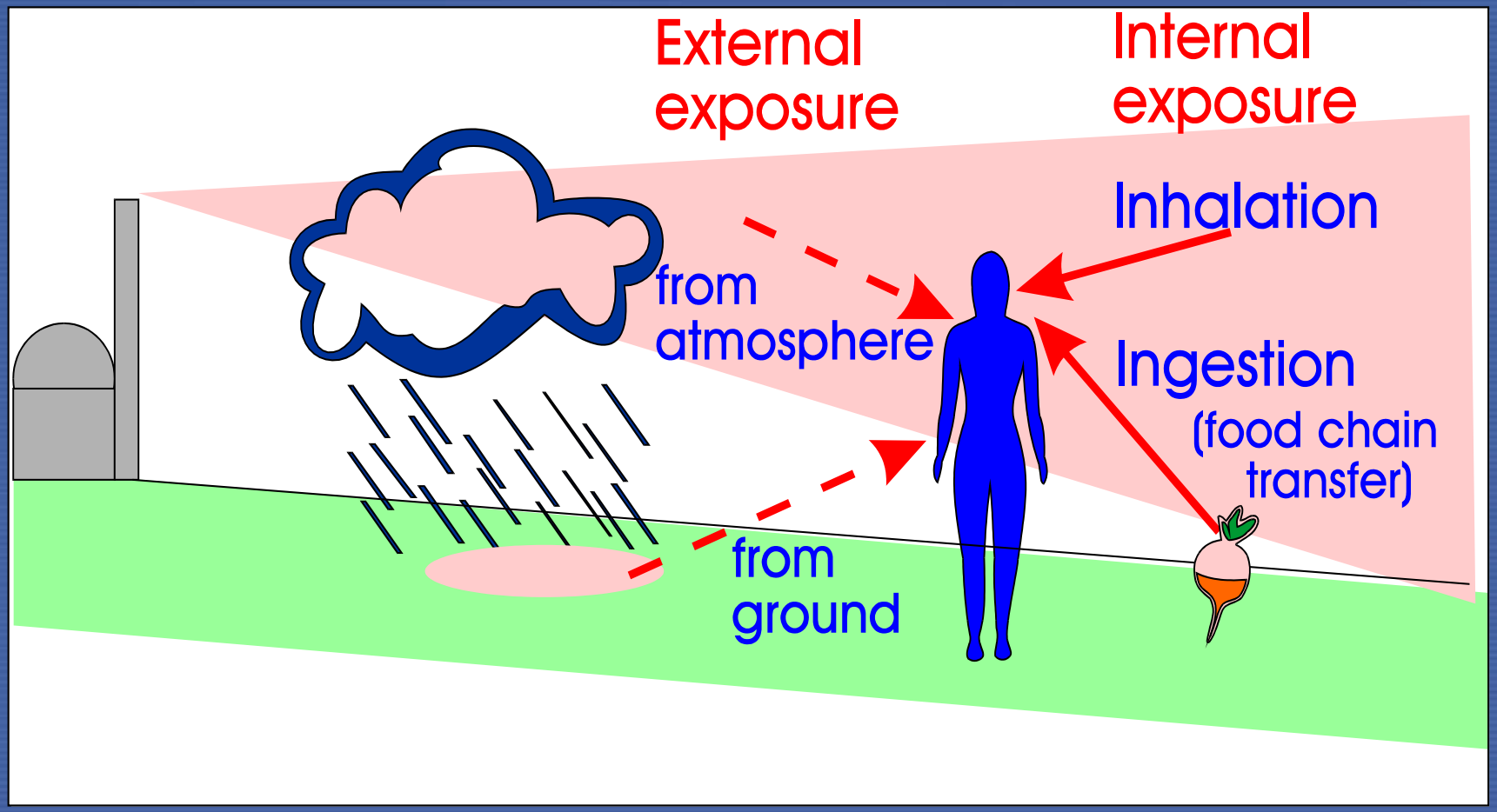
International Atomic Energy Agency

Exposure to people from releases of radionuclides to the environment



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Contamination routes for plant products

A Short-term

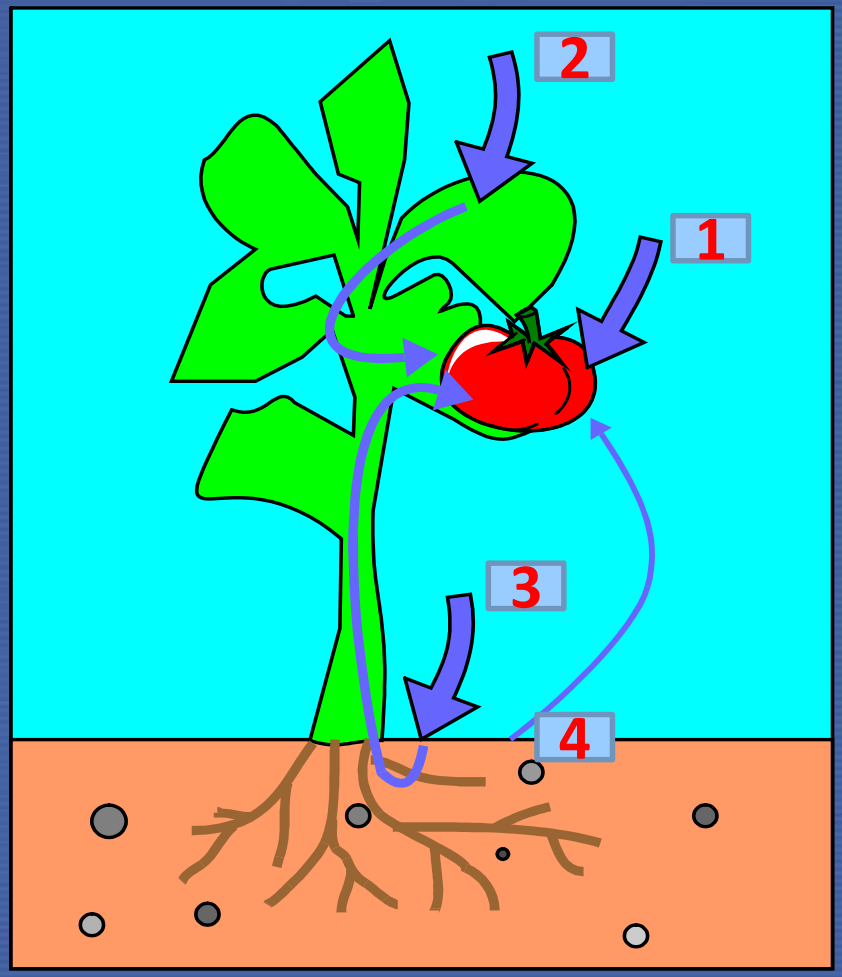
1 Direct deposition onto edible parts of plants

2 Deposition onto leaves -> transport to the edible parts

B Long-term

3 Deposition on soil and uptake through the roots

4 Resuspension of dust and re-deposition on leaves and fruits



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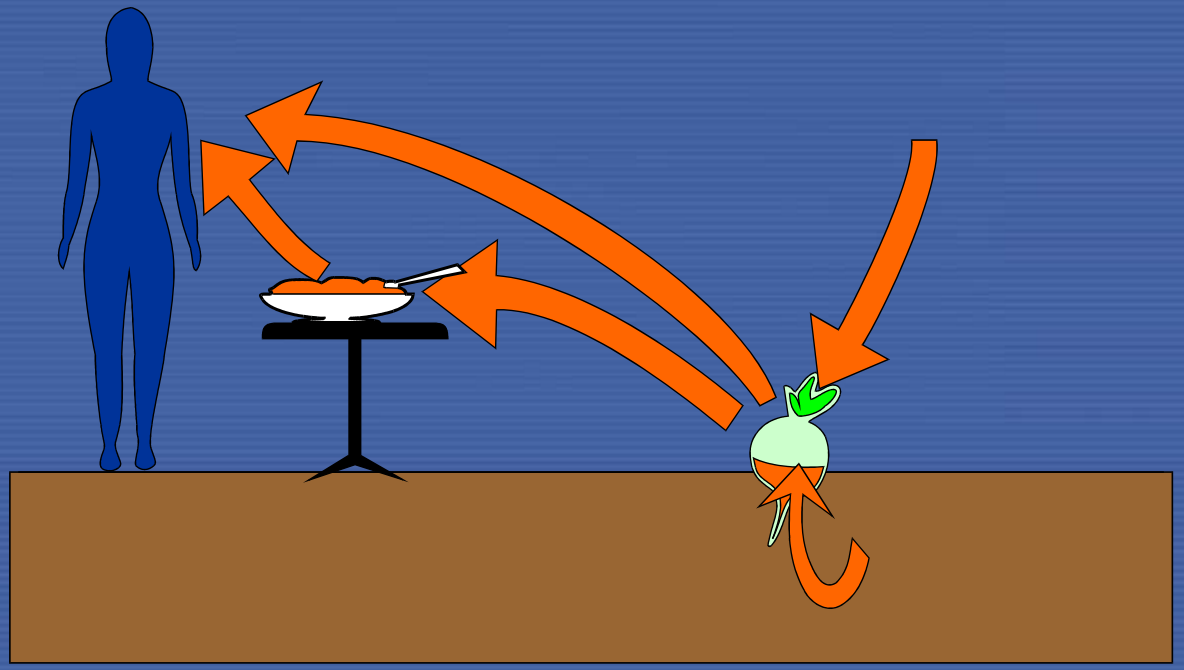
Food processing and preparation

- Crops can be directly ingested
  - Leafy vegetables:
  - Fruit vegetables (tomato, cucumber, etc.)
  - Fruit (peach, apples, pear plum)
- Products may be processed
  - Cereals -> bread
  - Milk -> butter, cheese



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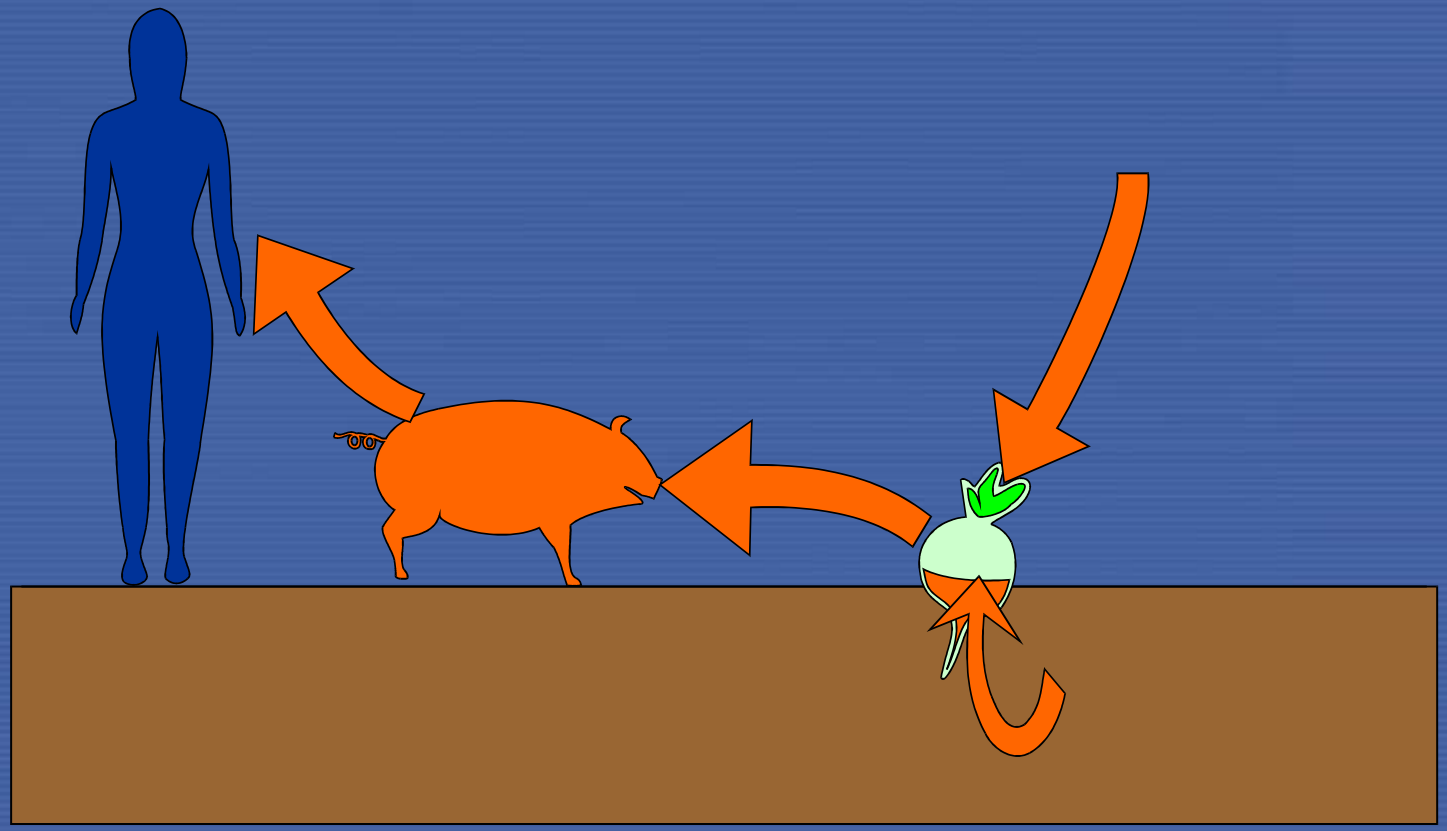
Transfer to animal products

- Use of contaminated fodder
- Transfer to meat, milk, eggs



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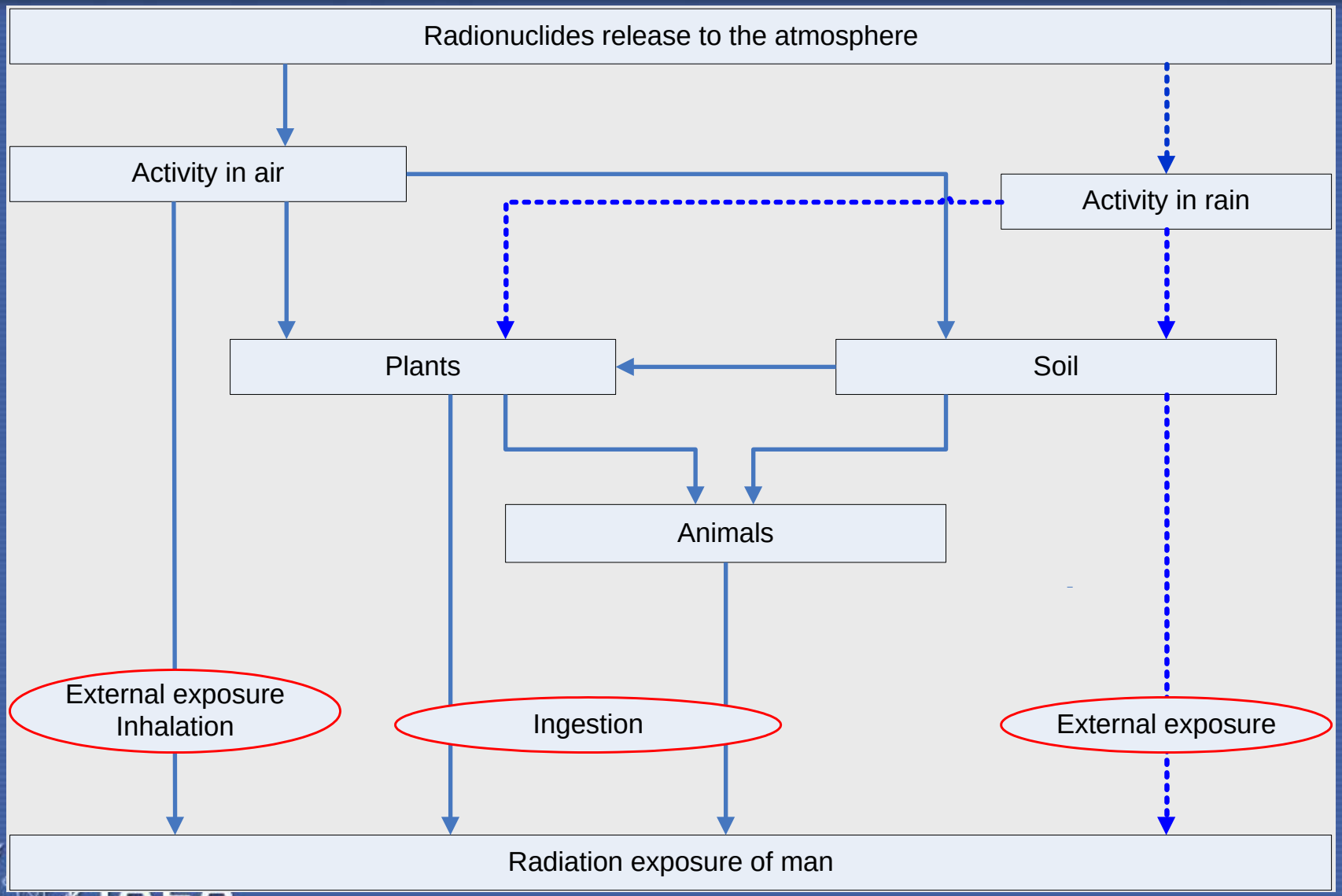
Radioecological model



Purpose of radioecological model: What do we want to know?

Activity levels in environmental media and related exposures

- Air
  - Exposure through inhalation of radionuclides
- Soil
  - Long-term uptake of radionuclides by crops
  - External exposure from radionuclides deposited on the ground
- Plants
  - Internal exposure through the intake of plant food products
  - Intake of radionuclides by domestic animals
- Animals
  - Internal exposure through the intake of plant food products

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Which factors are determining the exposure ?

Radiological characterization

- Radionuclides deposited,
- Deposition per unit area
- Dry deposition or deposition with rain

Environmental characterization

- Ability of soils to sorb/fix caesium
- Agricultural practice (e.g. use of fertilizer)
- *Season of the deposition*

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Which factors are determining the exposure (cont.)?

Life style and economic situation

- Do people produce their own food ?
  - If yes, to which extent?
- Where does the food come from?
  - From the region?
  - From the own country?
  - From global suppliers?
- Spectrum of foods
  - Aquatic food
  - Terresstrial food

Information

- Publication of results of food monitoring
- Provide information on radiation risks

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Model processes and parameters

- **Key processes following direct deposition on the leaves (1st year)**
  - Dry deposition of radionuclides to soil and vegetation
    - Leaf area
  - Interception of wet deposited radionuclides by vegetation
    - Leaf area
    - Amount of rainfall
  - Growth dilution and weathering loss from vegetation
  - Transport of radionuclides in plants to the edible parts

- **Key processes following deposition on soil (following years)**
  - Uptake of radionuclides by plants from soil
  - Migration and fixation of radionuclides in soil
  - Intake of radionuclides by domestic animals
  - Transfer of radionuclides to meat, milk and eggs
  - Modification of activity levels in foods during processing and culinary preparation.

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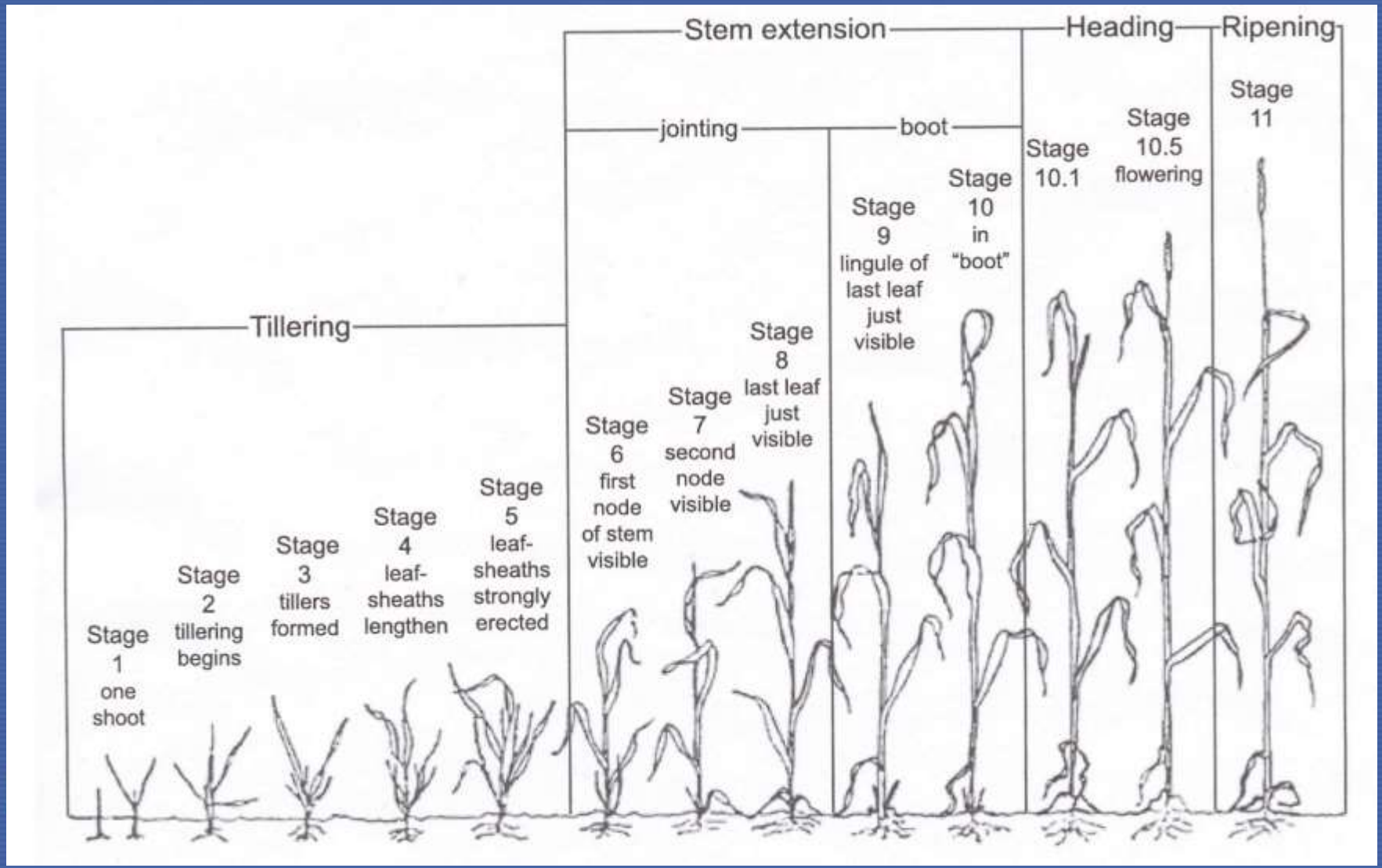
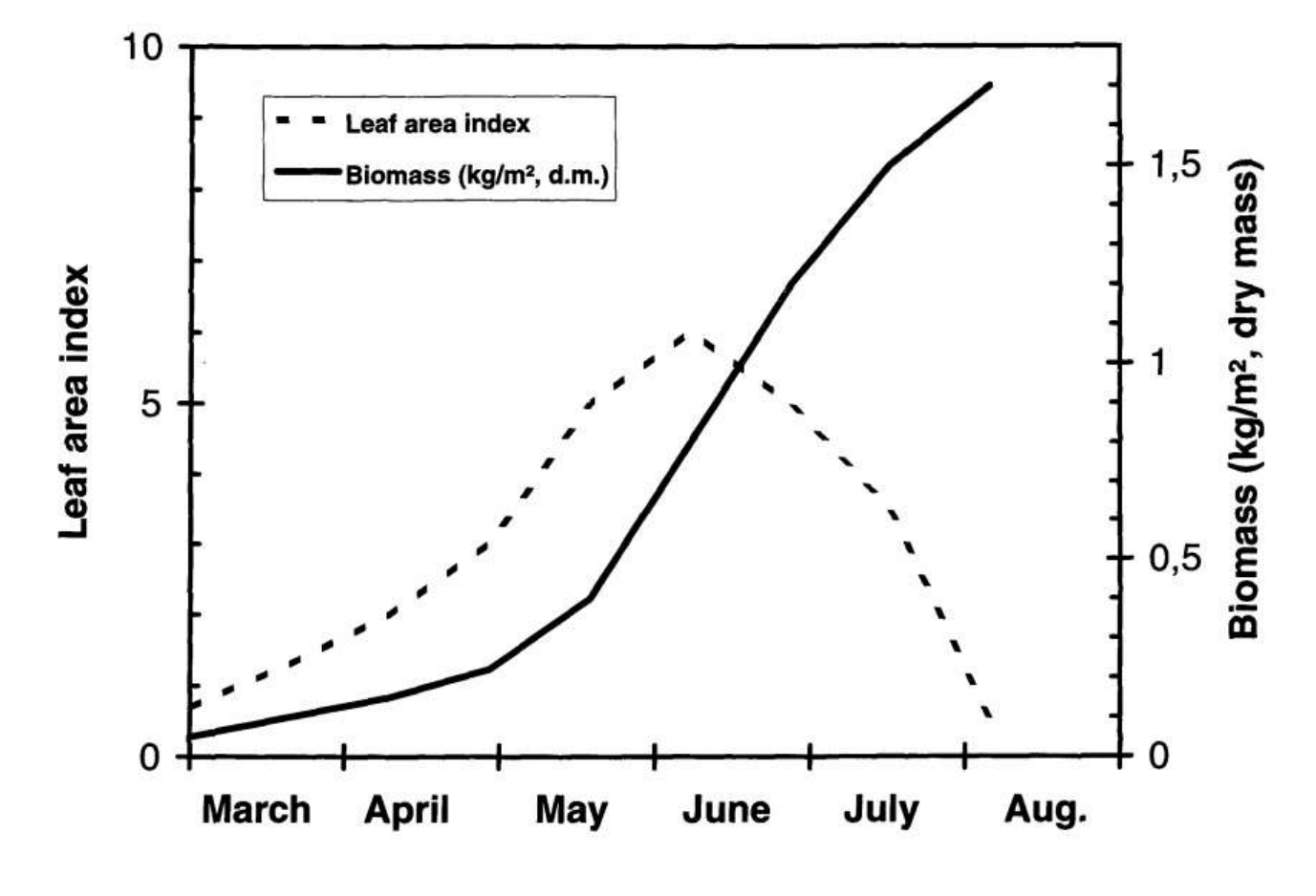
Seasonality of growth: Development of wheat



Development of leaf area and biomass



MÜLLER, H. PRÖHL, G., ECOSYS 87: A dynamic model for assessing radiological consequences of nuclear accidents, Health Phys. 64 (1993) 232-252.

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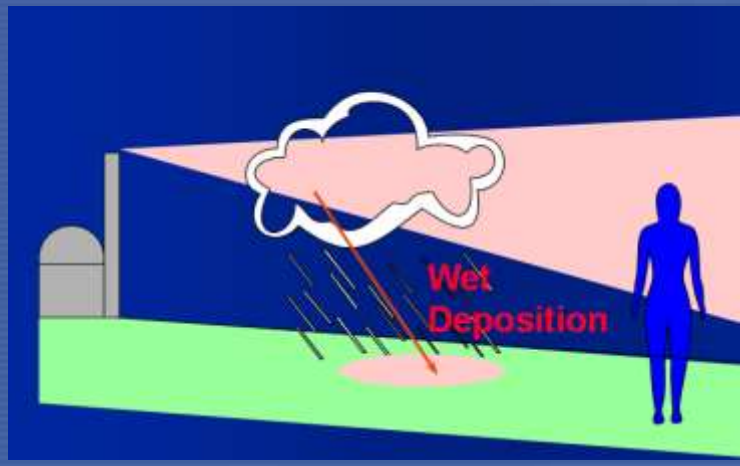
Rainfall and deposition

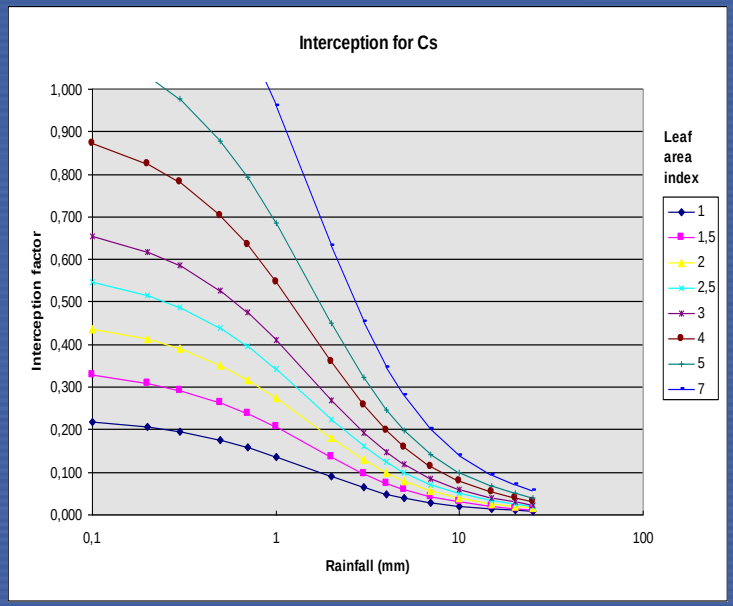
Rainfall during the passage of the plume

- Increase of deposition to the ground due to washout
- Increase of deposition with increasing rainfall (intensity)



Fraction of activity retained by crops (interception) …

- … decreases with amount of rainfall
- … increases with the development of crops
- … highest during the peak season



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Comparison of foliar and root uptake of caesium

Root uptake:

- Deposition: 10000 Bq/m^2
- Ploughing depth: 0.25 m
- Soil density: 1400 kg/m^3

- => **Activity (soil)** = $\frac{Deposition}{Ploughing\ depth * soil\ density} = \frac{10000\ Bq/m^2}{0.25\ m * 1400\ kg/m^3}$ = **29 Bq/kg**

- Transfer factor soil plant: 0.01 Bq/kg plant per Bq/kg soil

- **Activity (plant)** = *29 Bq/kg * 0.01 Bq/kg plant p. Bq/kg soil* = **0.29 Bq/kg**

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Comparison of foliar and root uptake of caesium II

Foliar uptake by cereals (wheat, rice, etc.)

- Deposition: **10000 Bq/m²**
- Deposition date (in this example): **4-8 weeks before harvest**
- Interception: Fraction of activity deposited which is retained by the plant
  - **1) Dry deposition: ~ 1 (equivalent to 100%)**
  - 2) **Wet depostion: ~ 0.1 for a rainfall of 10 mm (equivalent to 100%)**
- Translocation: Fraction of caesium which is transported from the leaves to the grain (@ 4-8 weeks before harvest): **~ 10%**
- Yield: **0.5 kg/m²**

- **Activity (wheat)** = $\frac{Deposition * Interception\ factor * Translocation\ factor}{Yield}$ =
  - $\frac{10000\ \frac{Bq}{m^2} * \mathbf{1} * 0.1}{0.5 kg/m^2}$ = **2000 Bq/kg (dry deposition)**
  - $\frac{10000\ \frac{Bq}{m2} * \mathbf{0.1} * 0.1}{0.5 kg/m2}$ = **200 Bq/kg (wet deposition@10 mm rainfall)**

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Comparison of foliar and root uptake of caesium II

Quantity	Uptake through leaves, Deposition: 10000 Bq/m^2 6 weeks before harvest 1st year		Uptake from soil Deposition: 10000 Bq/m^2 Following years
	Dry deposition	Wet deposition, 10 mm rain	
Activity in cereals	2000 Bq/kg	200 Bq/kg	0.3 Bq/kg

The values are rough estimates:

- Real values depend on the actual circumstances.
- The comparison illustrates the importance of the contamination process .

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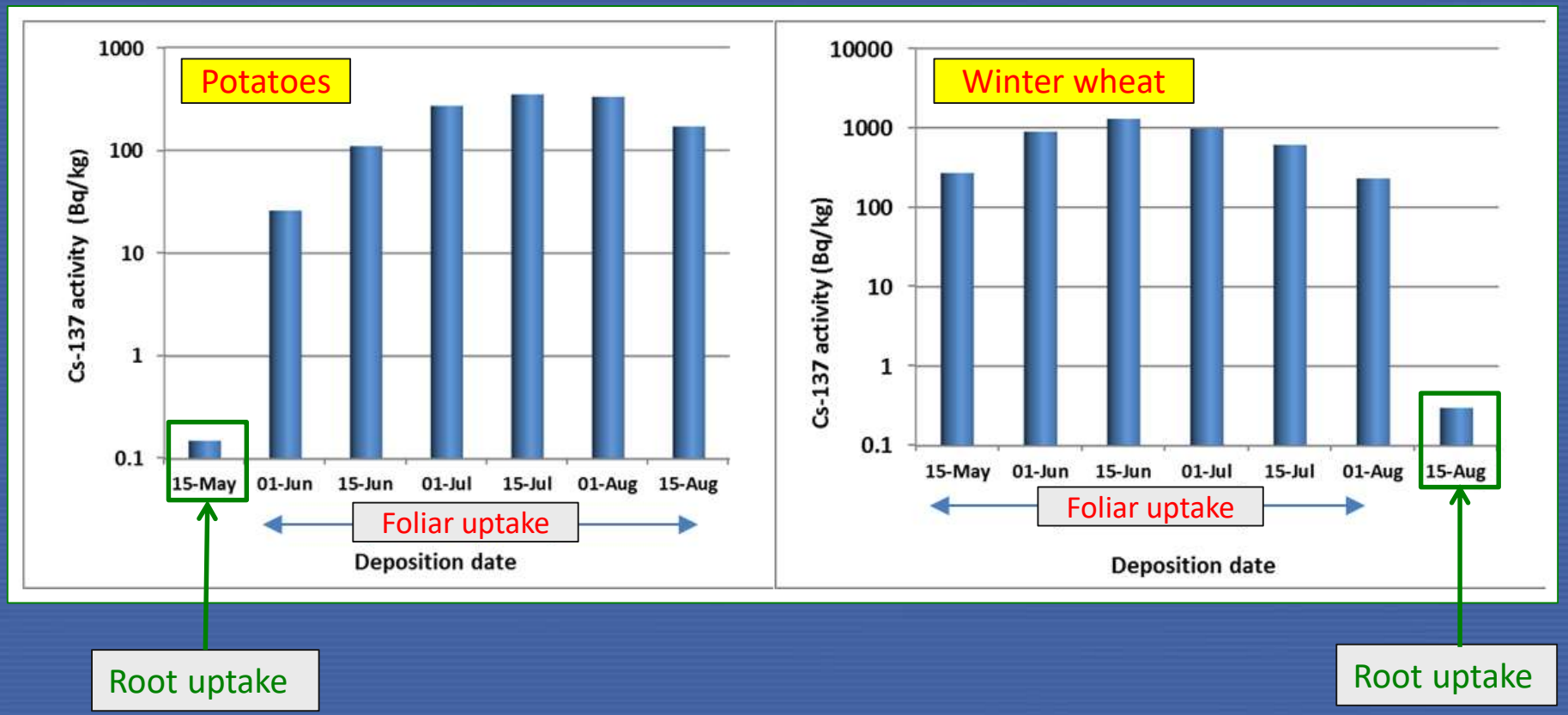
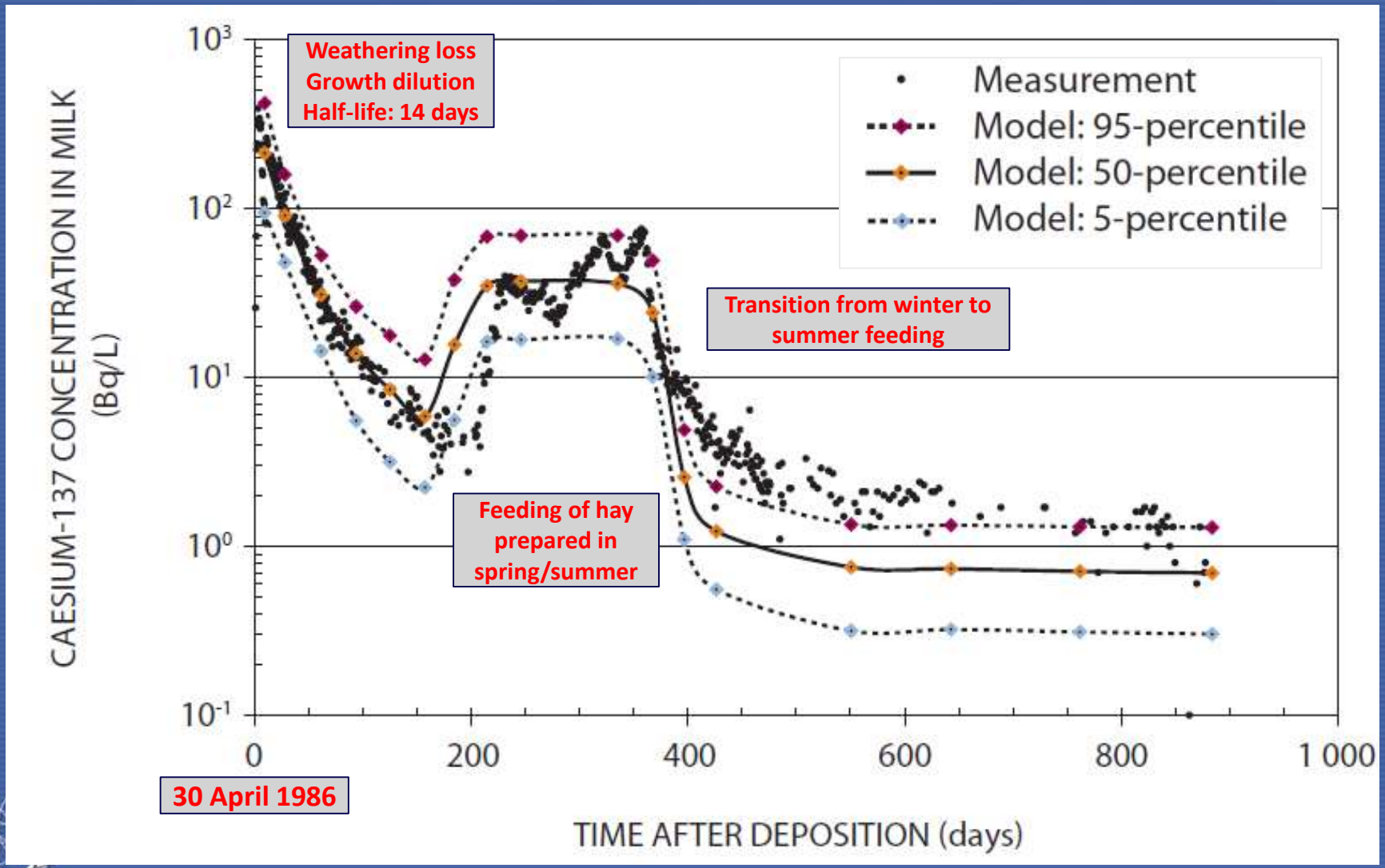
Comparison of activities in potatoes and wheat following different dates of deposition



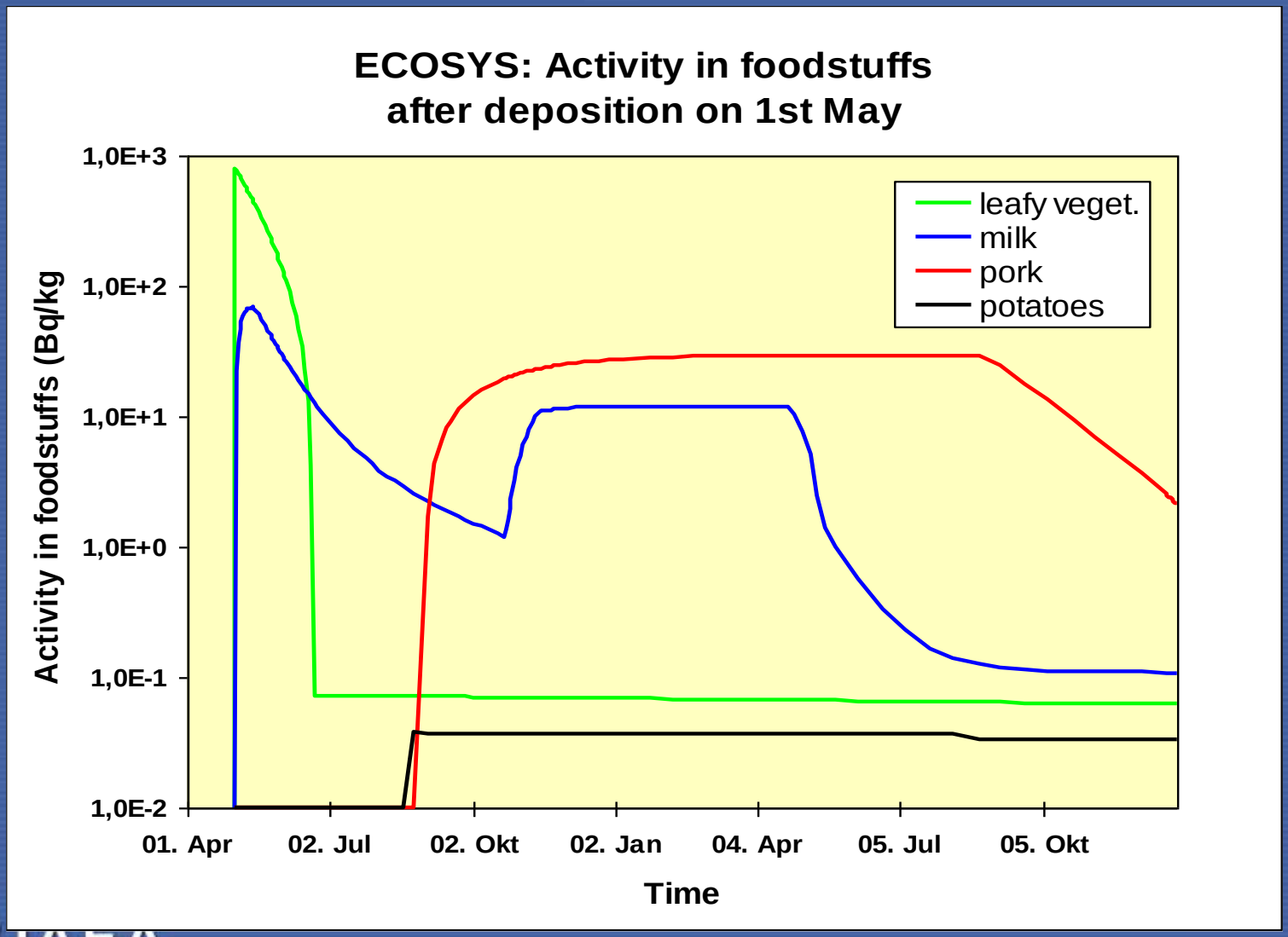
Starting point of the simulation is a **time-integrated Cs-137 activity in air of 1000 Bq h/m^2**.
Depending on the actual stage of development, this leads to a
deposition on the foliage of ca. 4000-7000 Bq/m^2.

Seasonality of Cs-137 in milk following the Chernobyl fallout in spring

(UNSCEAR 2008, dairy farm near Munich, Germany)



Result: time-dependent activity in foodstuffs



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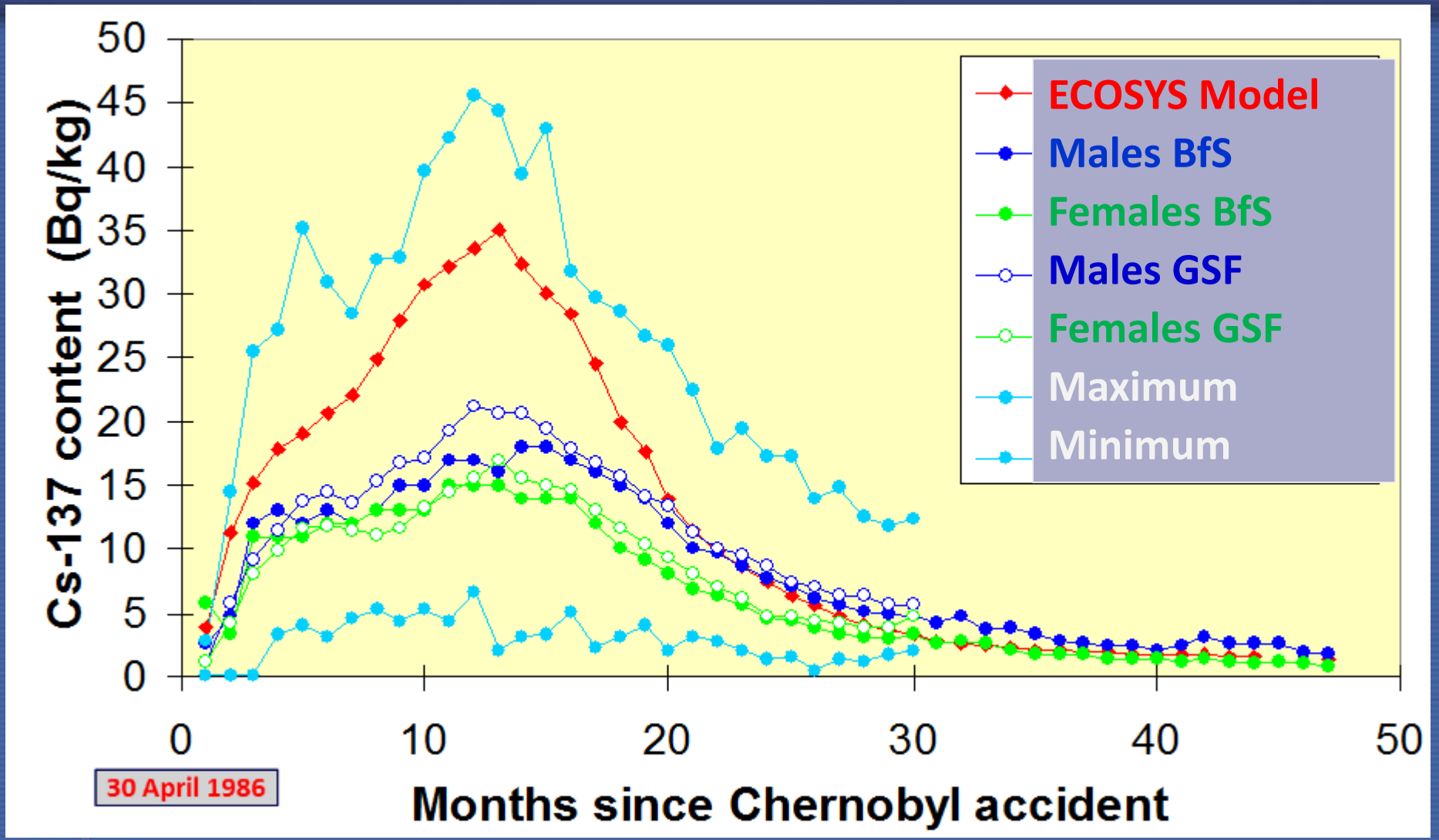
Cs-137 whole body counting (near Munich)



Müller, H, and Pröhl, G., The radioecological Model ECOSYS: Concept and Applications, Proc. Intern. Workshop on Improvement of Environmental Transfer Models and Parameters, Tokyo, Japan, 5-6 February, 1996

Summary

- **The uptake of radionuclides through leaves may be very effective**
  - Subject to pronounced seasonal variations in the plants' development stage
  - The uptake through leaves is much more effective than uptake through the roots.
- **Crops grow during different time slots within the overall vegetation period**
  - Activity levels in different products may vary substantially, because the crops may be affected at very different stages of development.
- **The radiological evaluation of radionuclide depositions occurring during the vegetation periods requires**
  - The careful characterization of the environmental conditions of the affected areas
  - The growing periods of crops cultivated in the area
  - The use of crops as food or feedstuffs
  - The agricultural practices in animal husbandry

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Conclusions – What does this mean?

1000 Bq/kg Cs-137

- Levels in **food other than infants foods** for international trade as provided by the Codex Alimentarius

10000 Bq/m^2 Cs-137-deposition during the peak season

- Cereals: 10000 Bq/m^2 (10 kBq/m^2) would cause
  - Dry deposition: 2000 Bq/kg
  - Wet deposition (10 mm rain): 200 Bq/kg

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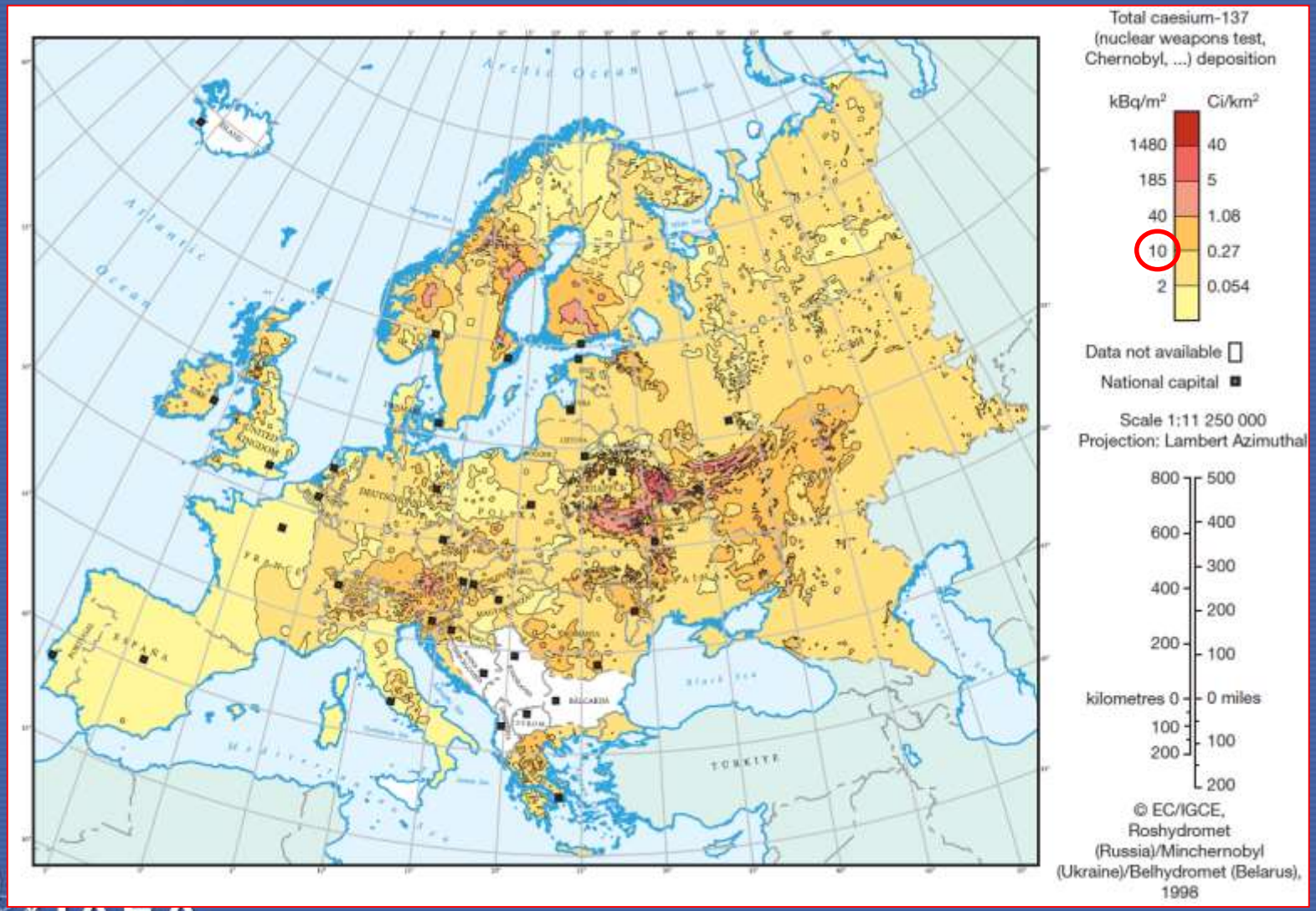
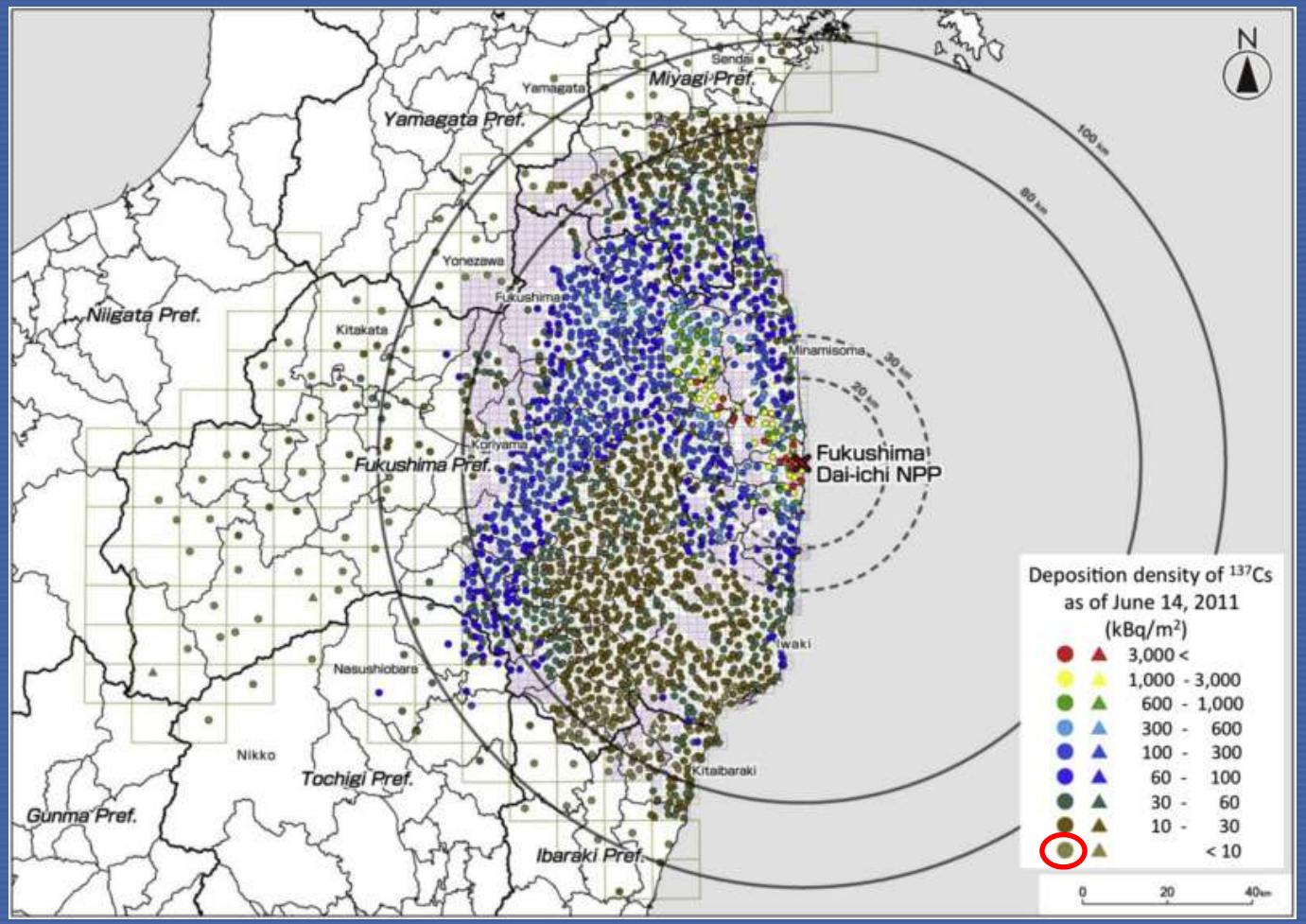
Total Cs-137 deposition in Europe



Deposition density map for Cs-137



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Kimiaki Saito, et al: **Detailed deposition density maps constructed by large-scale soil sampling for gamma-ray emitting radioactive nuclides from the Fukushima Dai-ichi Nuclear Power Plant accident,** Journal of Environmental Radioactivity, Volume 139, 2015, 308–319

Conclusions (cont.)

The Chernobyl and the Fukushima accidents occurred early in the year, during the transition of winter to spring:

- Only few crops were affected by direct deposition of radionuclides.
- Implications for agriculture and trade remained relatively little.

Large-scale depositions during the peak growing season could have much larger radiological implications

- Activity levels in crops would be much larger
- Areas potentially affected by restrictions would be much larger (if the same radiological criteria are applied)
- Implications may need to be explored to elaborate solid grounds for contingency planning.

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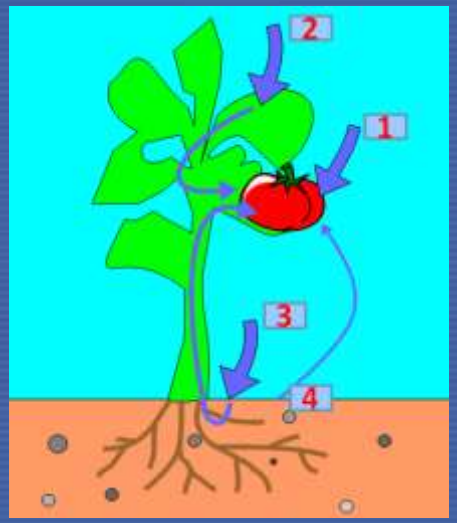
Conclusions (cont.)

The Chernobyl and the Fukushima accidents occurred early in the year, during the transition of winter to spring:

- Only few crops were affected by direct deposition of radionuclides.
- Radiocaesium was taken up by the crops in most cases through the roots only.
  - Caesium levels in food and feed remained relatively low, even in the years 1986 and 2011 respectively
- Implications for agriculture and trade remained relatively little



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