# JRODOS
# Real-time On-line Decision Support system

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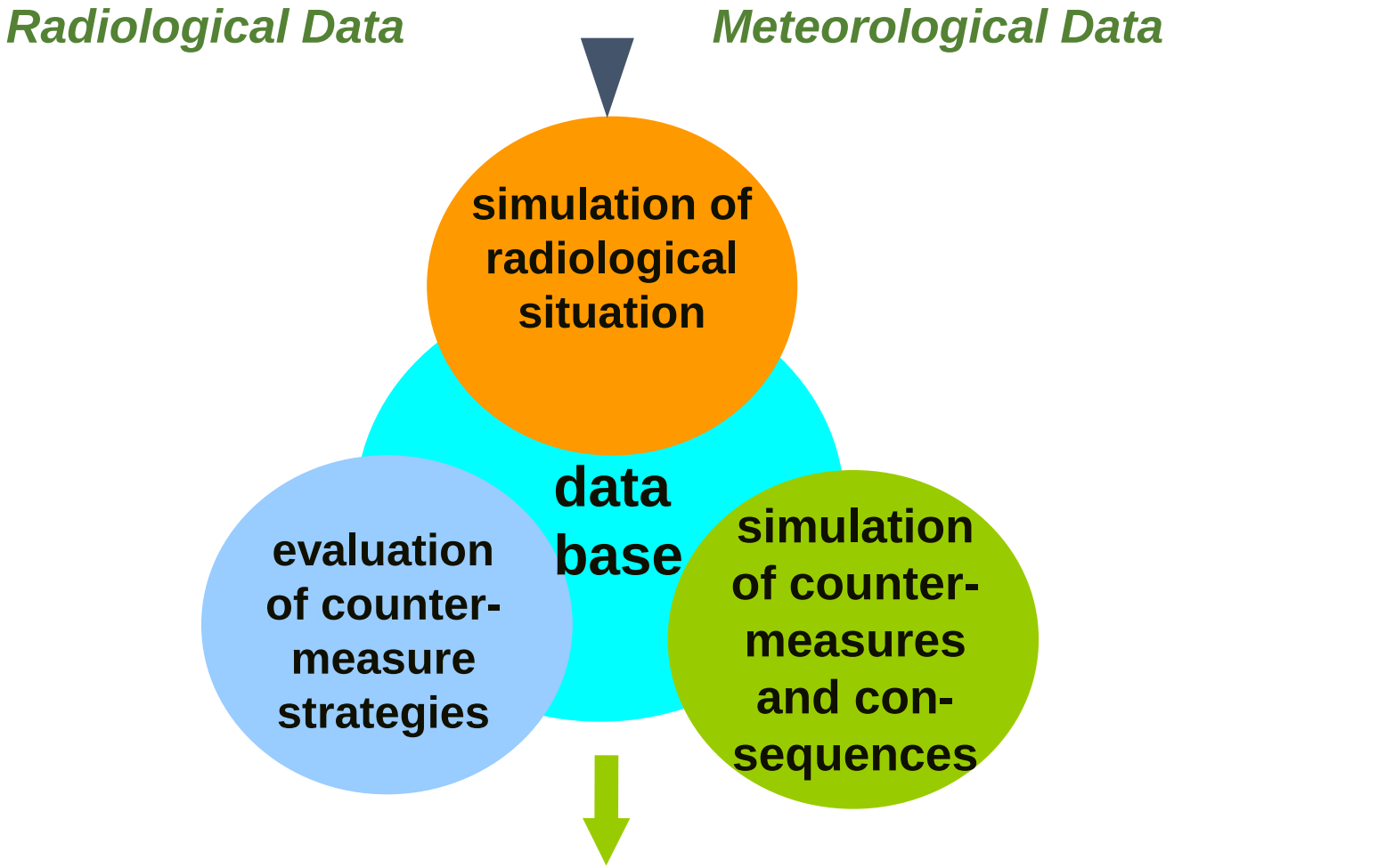
# JRODOS

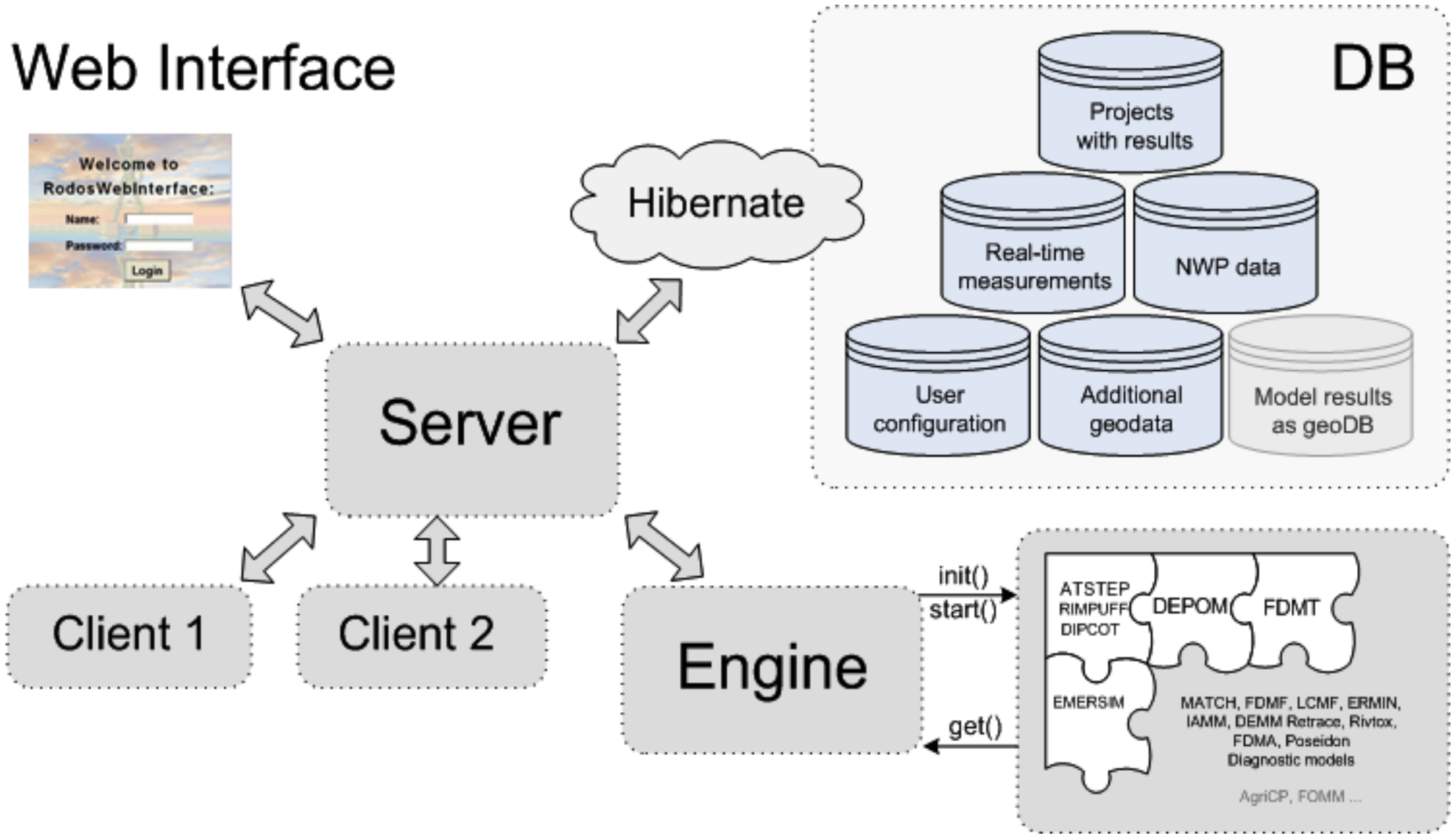
## Real-time On-line Decision Support system

1. JRodos is system for emergency management following releases of radioactive material into the environment
2. Contains detailed simulation models for predicting and analysing the resulting contamination
3. JRodos is a non-commercial system with an active user community that aims to extend and development of the system
4. Multi-user operation system can be used in national or regional emergency centres
5. Provide consistent and comprehensive information
   - on local, national, regional and European scales,
   - It can be used for all stages of an accident (i. e., before, during and after release),
   - it can be used for all emergency actions and countermeasures (i.e., sheltering, relocation, evacuation, distribution of iodine tablets, food restrictions),
   - The current version of the system has been installed in national emergency centers of several countries, such as Germany, Finland, Spain, Portugal, Austria, the Netherlands, Poland, Hungary, Slovakia, Ukraine, Slovenia, Czech Republic, Switzerland, Russia, Hong Kong and China
6. Applicability - Microsoft Windows, Linux and Mac
7. Mainly developed by Karlsruhe Institute of Technology (KIT)

# JRODOS: Tasks, input data, output



# JRODOS software structure



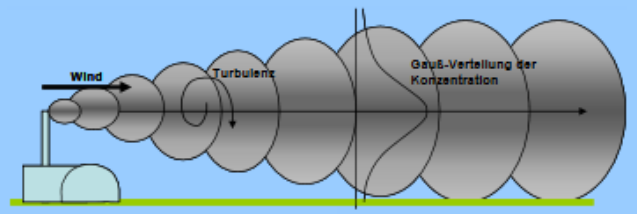
# System architecture - EMERGENCY chain models

**Released activity (Measurement / User)**

**Meteorological data (Measured / Prognostic / User)**

**Further data (from JRodos Data bases)**

**LSMC: Atmospheric dispersion and deposition, local scale (up to several 100 km)**

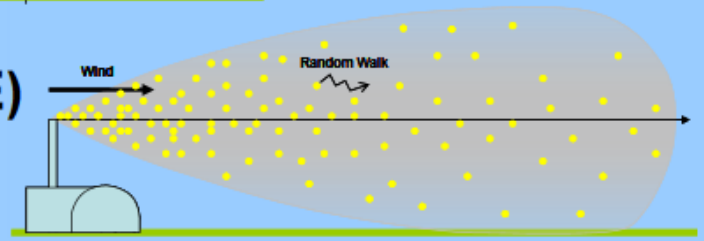



**Rimpuff (DEN)**

**Atstep (IKET)**

**Dipcot (GRE)**

**Lasat (GER)**




## Calculated results

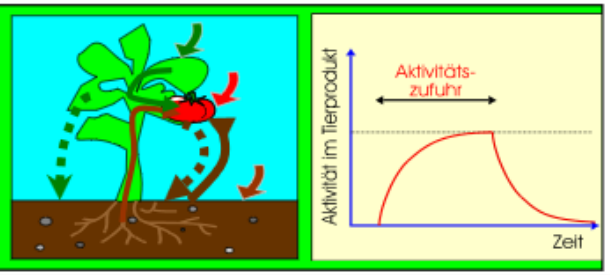
- Contamination of air, ground, vegetation; food- and feedstuffs
- Doses without countermeasures
- Potential countermeasure areas
- Organ doses with/without actions, health effects, effort, effectiveness

**Current dose rate and dose calculation**

**Early countermeasure simulation**

**Health effects and costs**

**Food chain and dose model, terrestrial FDMT (GER)**



# Assessment of radiological situation (diagnostic and prognostic)

Input data

- Numerical weather measurements and prognostic data
- radiological measurements and prognostic data

Near-range model chain

- Meteorological pre-processor
- Several models for atmospheric dispersion and deposition in the near range (*LSMC + EMERSIM + DEPOM + FDMT )*

Far-range model chain

- Meteorological pre-processor
- LASAT model
- MATCH model

# Near-range atmospheric dispersion models in JRODOS

## LSMC - Local Scale Model Chain

- RIMPUFF: Gaussian Puff Model; (Risø, Roskilde, Denmark)
- DIPCOT: Lagrangian Particle Models; (Demokritos, Athen, Greece)
- LASAT: Lagrangian Particle Models; (official reference German model)

## Early countermeasure model

EMERSIM - consists of a combination of the three single actions sheltering, evacuation and the distribution of stable iodine tablets. In addition, EmerSim allows assessing relocation areas

## Deposition Module

DEPOM - assessment of deposition of radionuclides onto soil and all kinds of agricultural crops. Deposition calculations for FDMT

## Food Chain and Dose Module

FDMT - Food Chain and Dose Module

# Near-range atmospheric dispersion models in JRODOS - FDMT

**The task of the food and dose module FDMT in the JRODOS system is to give an assessment of the present and future radiological situation**

## FDMT - Food Chain and Dose Module INPUT

**Results from atmospheric dispersion models - LSMC**

- concentration of radionuclides in the near ground atmosphere
- activity deposited on various crops and on soil
- effective dose rates for adults from radionuclides in the atmosphere
- time of the year when deposition occurs

**geographical data base**:

- radioecological regions (for each location)
- number of inhabitants (for each location)
- amount of foodstuff production (for each location)
- soil type category (for each location)

**Model parameters** describing the food chain transfer for each radioecological region:

- growing and harvesting times for different agricultural crops
- animal feeding diets
- food consumption rates

# Near-range atmospheric dispersion models in JRODOS

## FDMT - Longer term doses, results

**Exposure pathways**

- cloud , ground, inhalation, resuspension
- ingestion, skin exposure, and the sum over all
- pathways except ingestion and including ingestion

**Age groups**

- adults
- children of 1, 5, 10 and 15 years

**Organs**

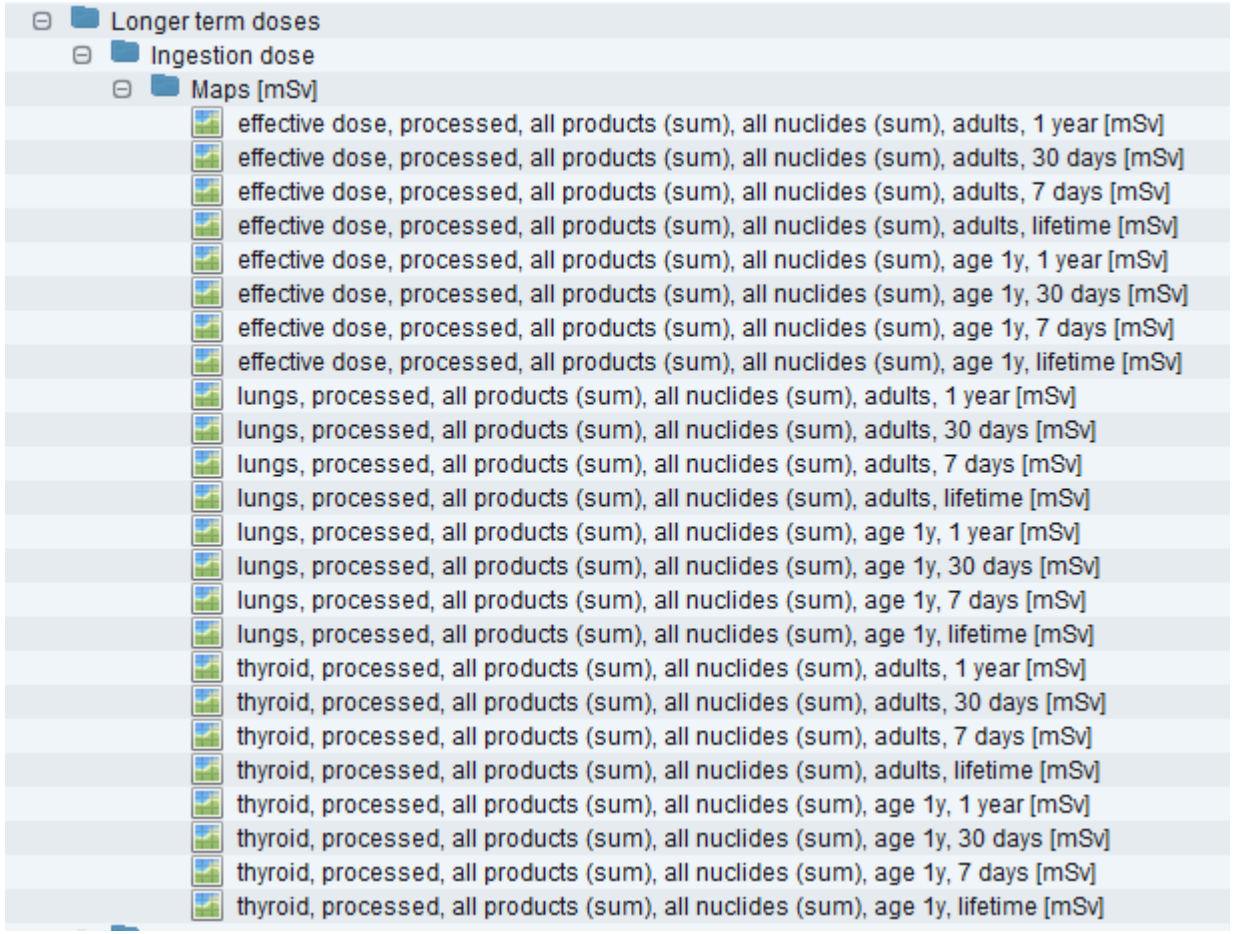
- lungs, read bone marrow, thyroid, uterus
- effective, skin, bone surface, breast, colon
- stomach, liver, pancreas

**Integration times**

- 7 days, 14 days, 30 days, 3 months, 6 months
- 1 year, 2 years, 5 years, 50 years, lifetime

# Near-range atmospheric dispersion models in JRODOS

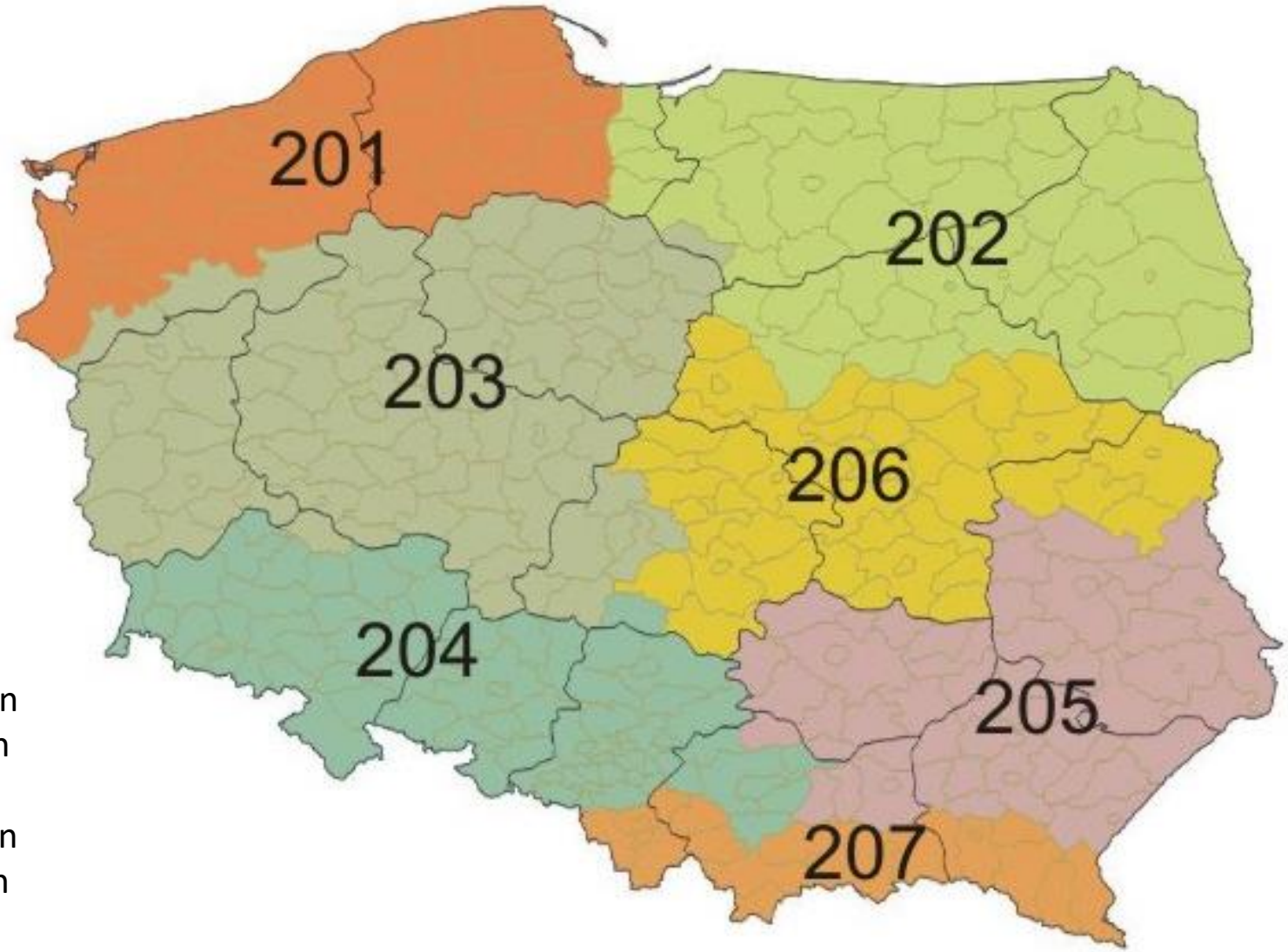
## FDMT - Longer term doses, results



# Far-range model chain
# MATCH

- **MATCH** (**M**ulti-scale **A**tmospheric **T**ransport and **CH**emistry model) is the long-range transport model in the JRODOS system.
- A necessary requirement is access to numerical weather prediction HIRLAM or ALADIN (not free).
- New version JRodos  contains a command line tool for converting LSMC suitable GRIB1 or GRIB2 NWP (Numerical Weather Prediction ) data for use in MATCH Free downloading of GRIB2 Files  from the NCEP NOMAD Server
- MATCH is an Lagrangian grid model.

# Implementation of radioecological regions in Poland




Region 201 - Poland North-western
Region 202 - Poland North-eastern
Region 203 - Poland Western
Region 204 - Poland South-western
Region 205 - Poland South-eastern
Region 206 - Poland Eastern
Region 207 - Poland South (mountains)

# Implementation of radioecological regions in Poland

1. The basic parameters defining regions:
   - vegetable products,
   - animal products,
   - food products,
   - feed products,
   - mean annual precipitation,
   - mean annual temperature

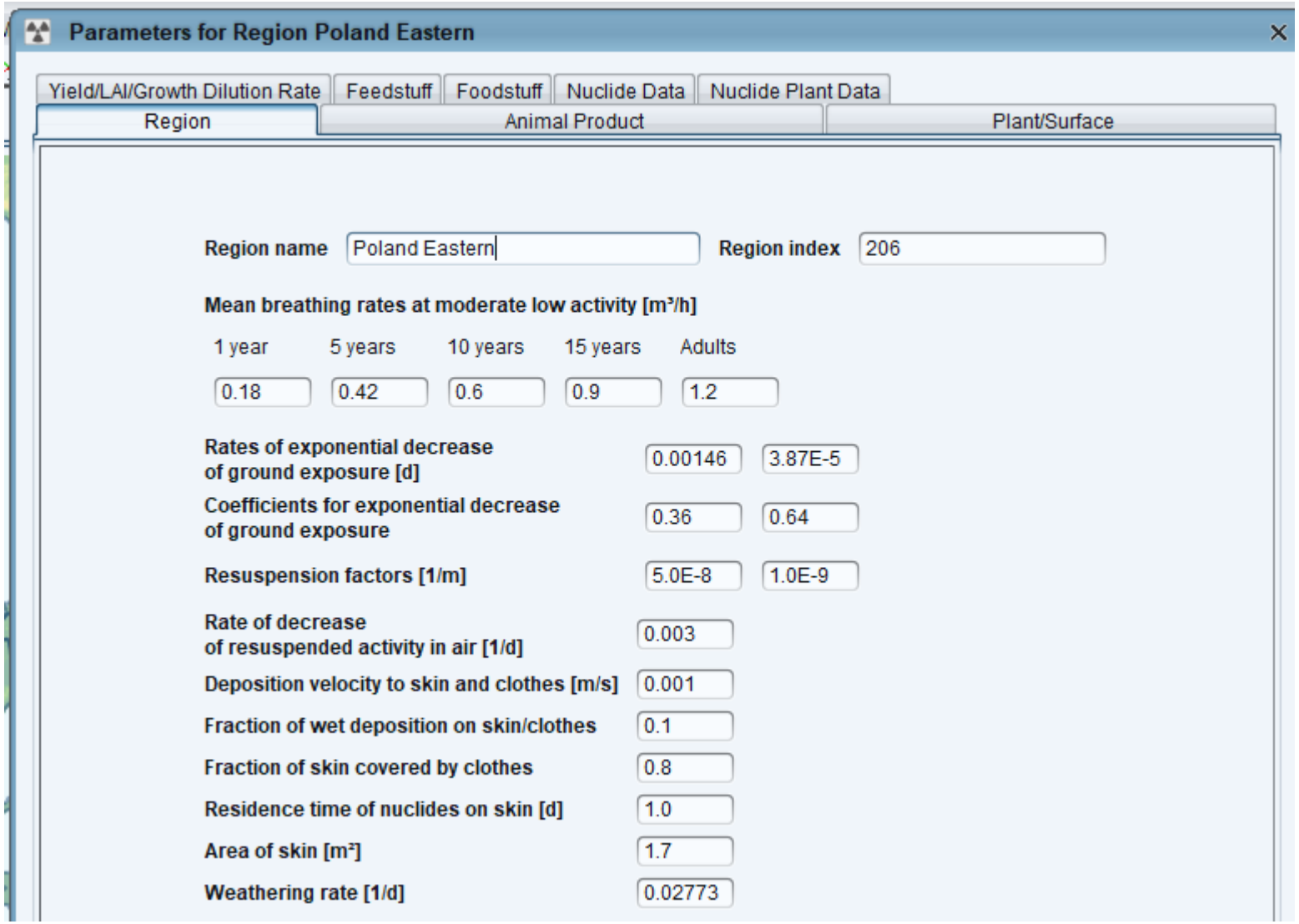
2. The parameters for the Food Chain and Dose Module (FDMT):
   - soil bonitation index,
   - soil type and vegetation data,
   - the growth rate of plants,
   - human diet,
   - feeding farm animals,
   - type of human settlements and housing.

3. Data for macroregions were obtained from:
   - Central Statistical Office (GUS), SGGW, CLOR,
   - Institute of Soil Science and Plant Cultivation (IUNG) - Puławy,
   - Production data have been entered for all counties.

# Characteristics of radioecological regions in Poland

| Parameter | Macroregion | | | | | | |
|---|---|---|---|---|---|---|---|
| | 201 | 202 | 203 | 204 | 205 | 206 | 207 |
| Mean soil bonitation index (soil quality) | 0.8 | 0.68 | 0.84 | 0.83 | 0.91 | 0.67 | 0.88 |
| Mean annual precipitation [mm] | 540 | 572 | 500 | 566 | 550 | 512 | 600 |
| Mean annual temperature [°C] | 9.5 | 7.9 | 9.5 | 9.0 | 8.5 | 9.0 | 8.6 |
| Mean annual length of vegetation period [days] | 298 | 271 | 293 | 291 | 275 | 286 | 276 |

# Characteristics of radioecological regions in Poland



# Characteristics of radioecological regions in Poland

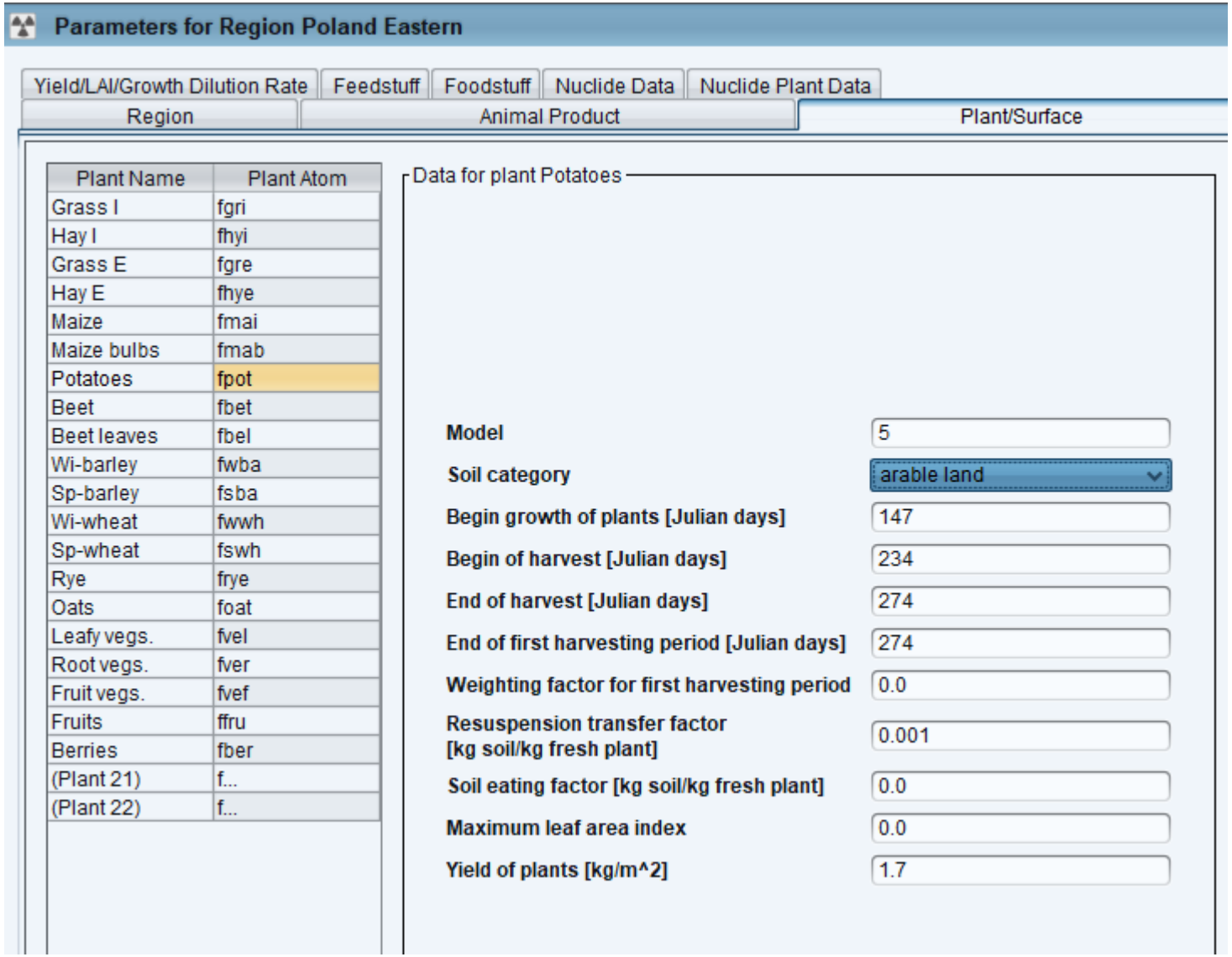
| Soil mass per area [kg/m²] | Arable land | Pasture intensive | Pasture extensive |
|---|---|---|---|
| | 350.0 | 140.0 | 140.0 |

| Limits of the population density for deriving housetype [man/m²] | Low/Medium shielding | Medium/High shielding |
|---|---|---|
| | 100.0 | 250.0 |

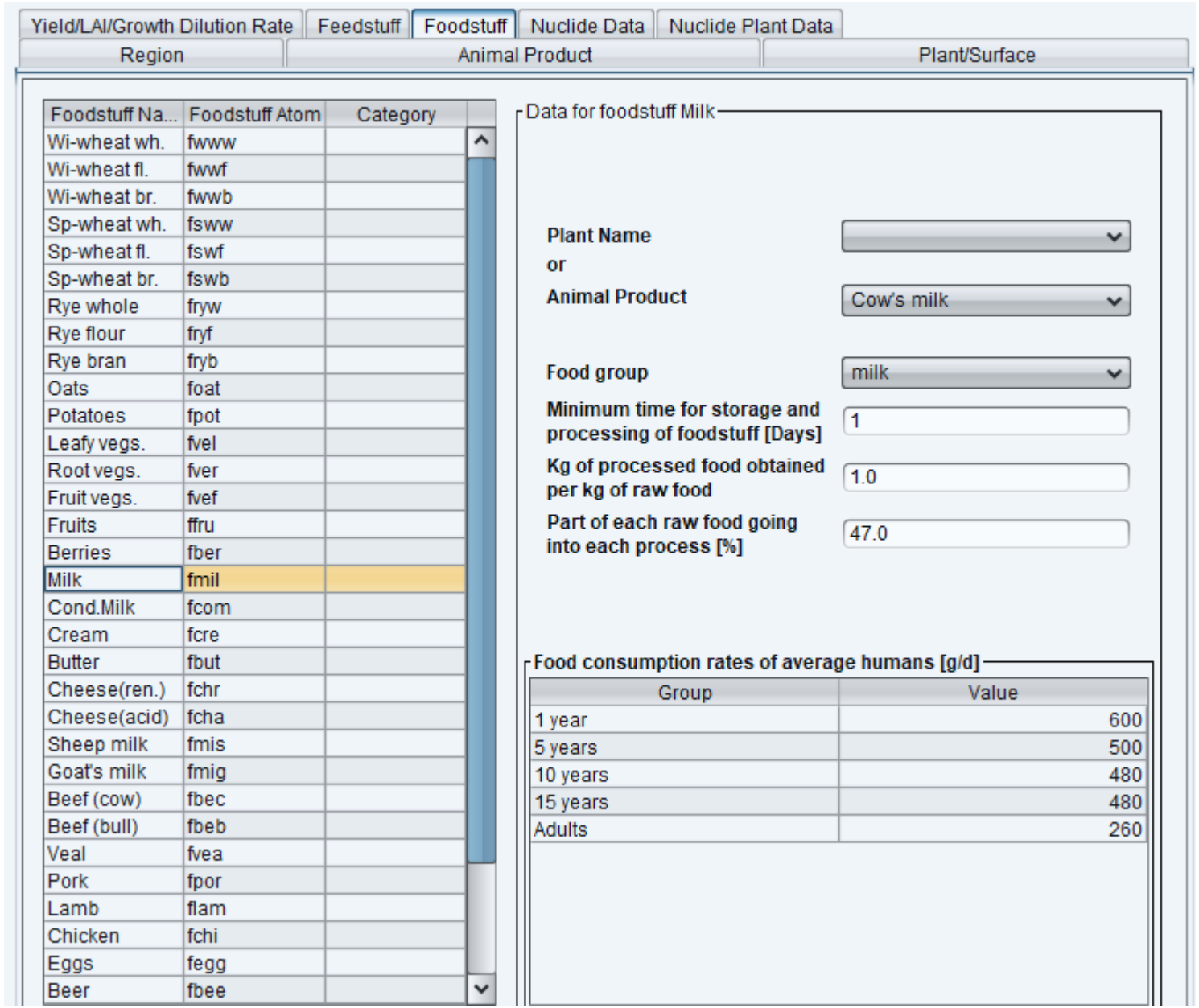
| Occupancy factor (average rate of time spent indoors) | |
|---|---|
| | 0.8 |

| Location factors | Low shielding | Medium shielding | High shielding | Outdoors |
|---|---|---|---|---|
| Groundshine long term | 0.5 | 0.1 | 0.01 | 1.0 |
| Groundshine short term | 0.5 | 0.1 | 0.01 | 1.0 |
| Cloudshine | 0.8 | 0.5 | 0.2 | 1.0 |
| Inhalation | 0.5 | 0.5 | 0.5 | 1.0 |
| Resuspension | 0.5 | 0.5 | 0.5 | 1.0 |

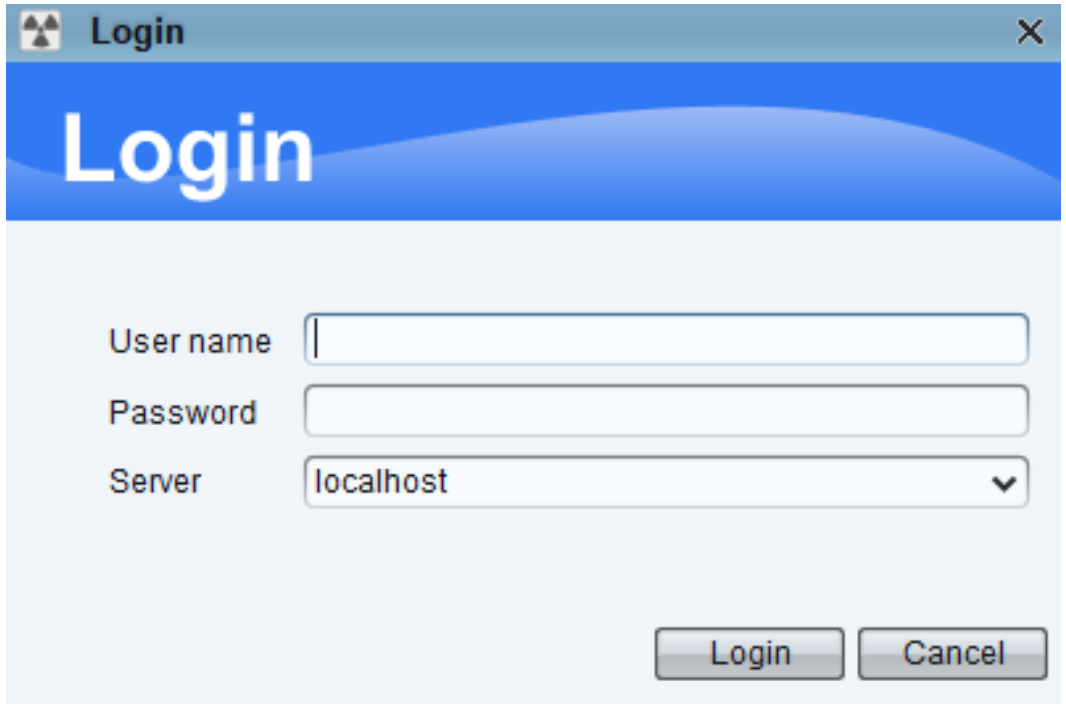
# Characteristics of radioecological regions in Poland



# Characteristics of radioecological regions in Poland



# Example of operation in the JRODOS system



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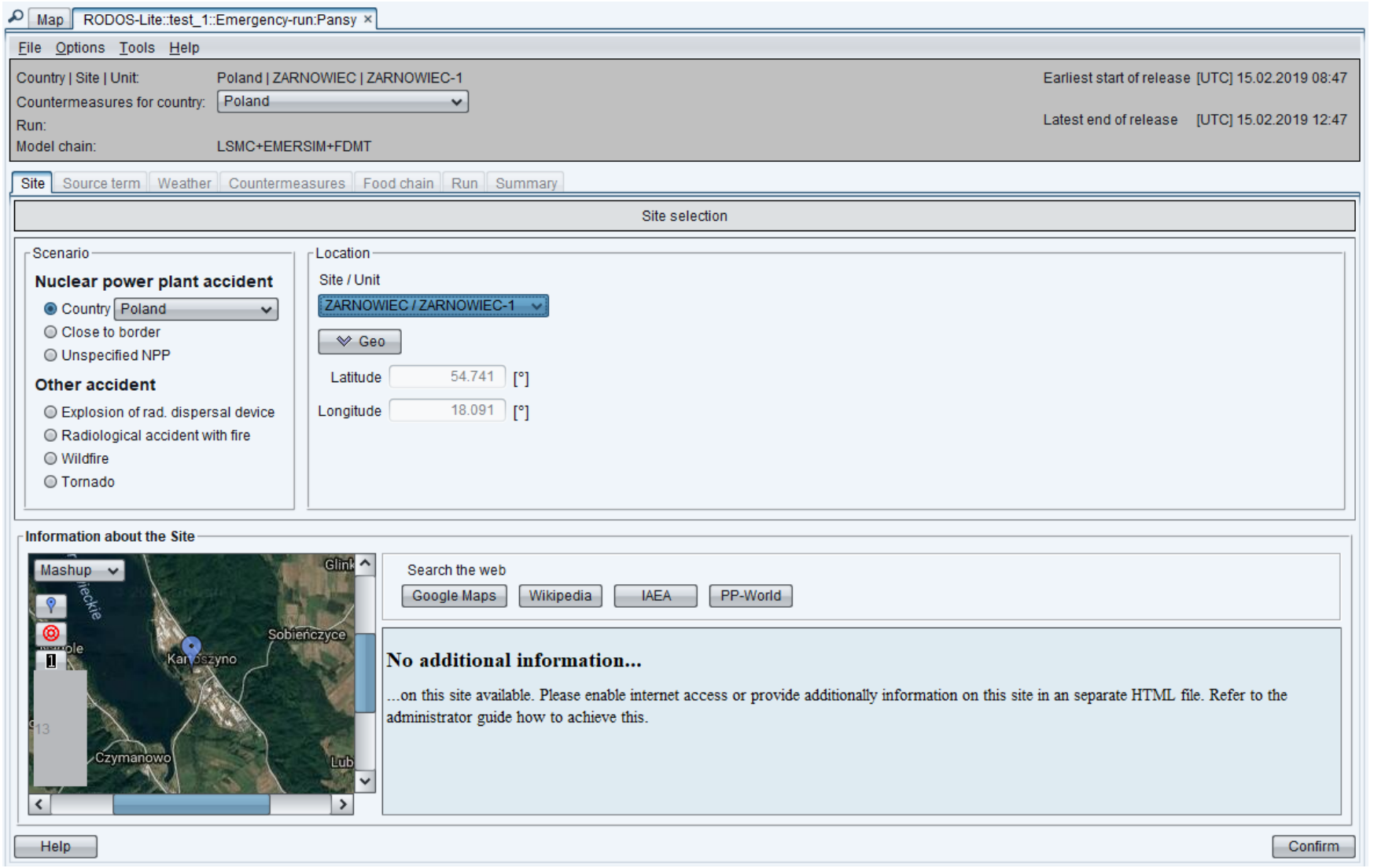

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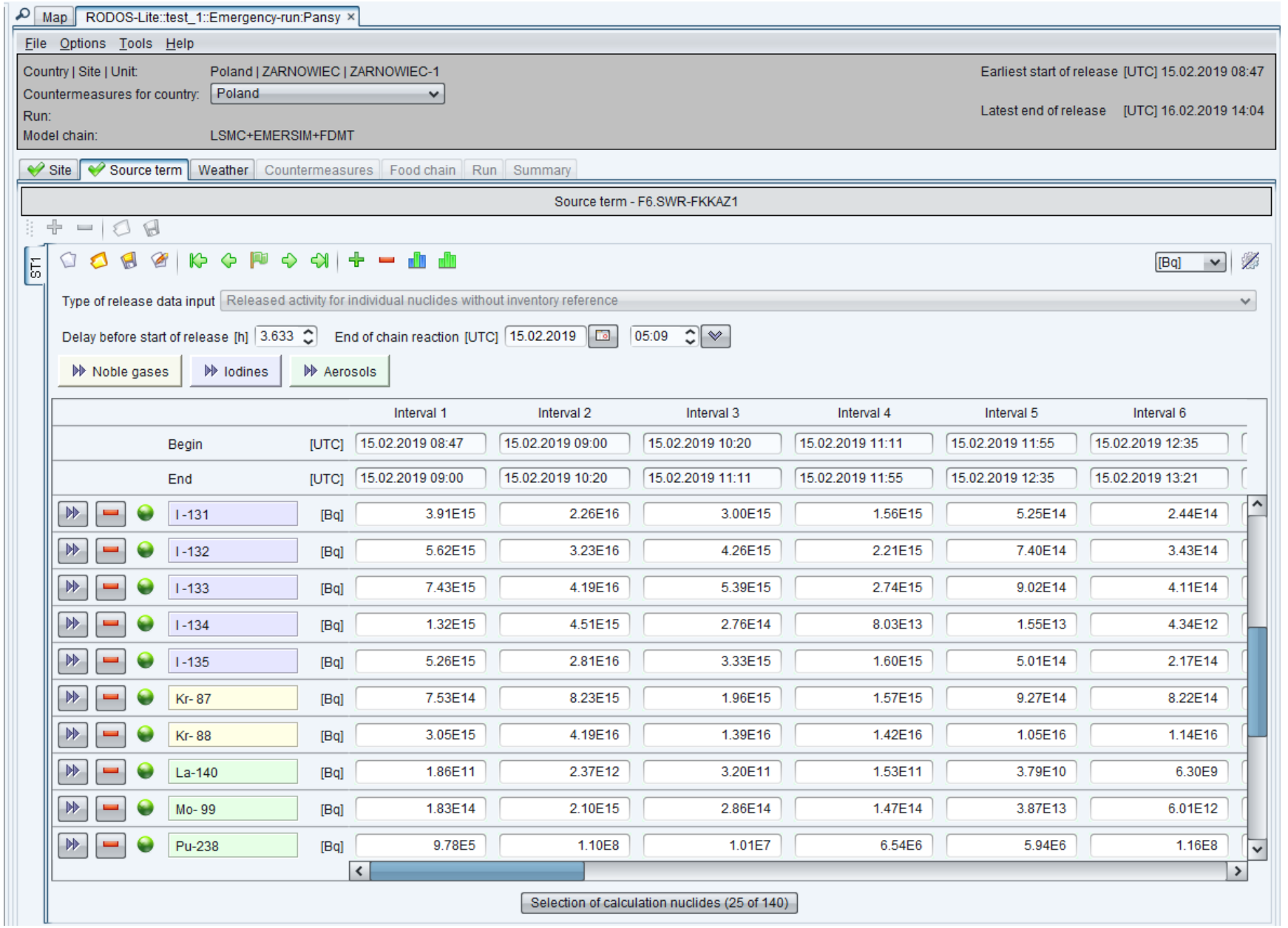
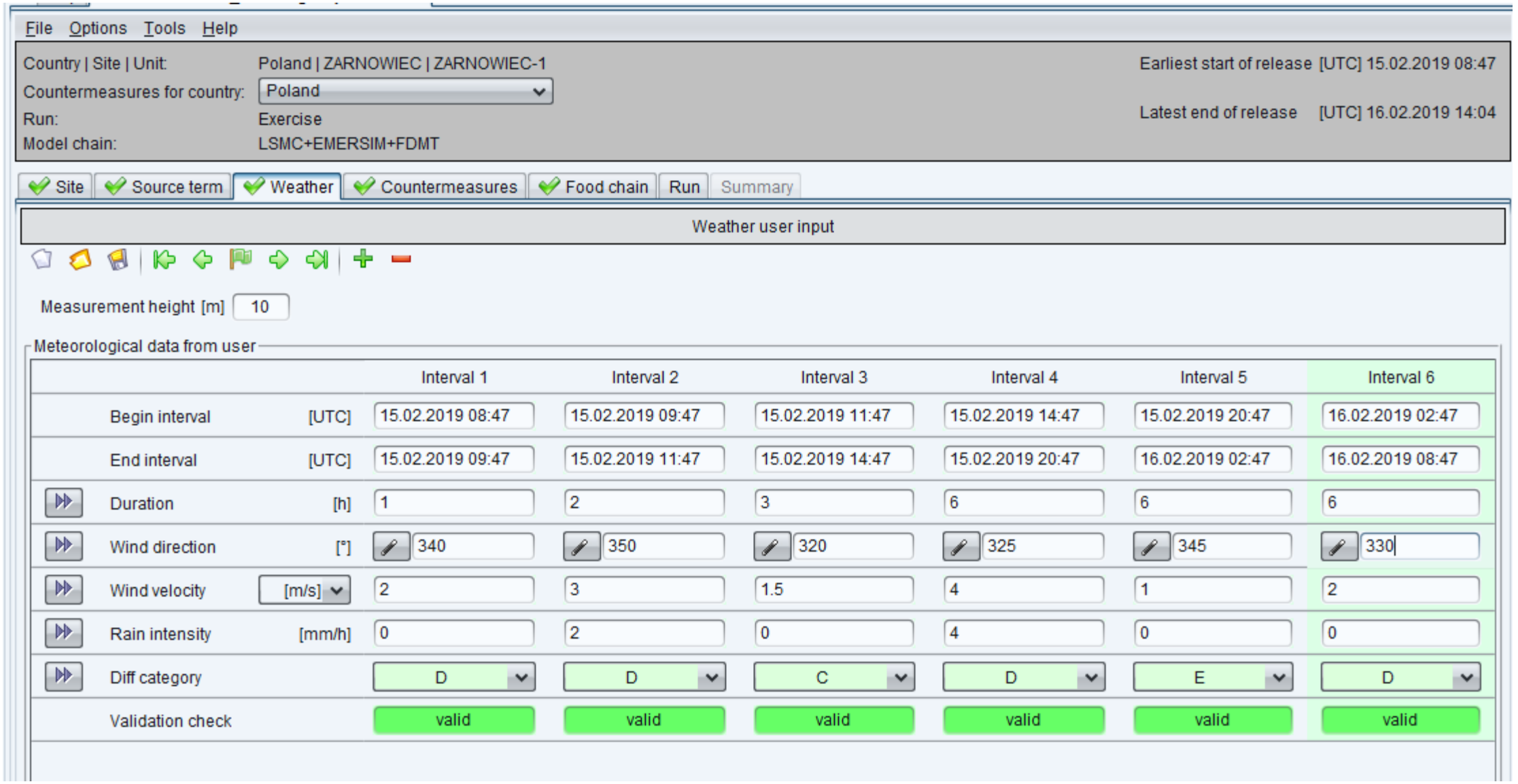



| | | Interval 1 | Interval 2 | Interval 3 | Interval 4 | Interval 5 | Interval 6 |
|---|---|---|---|---|---|---|---|
| Begin | [UTC] | 15.02.2019 08:47 | 15.02.2019 09:00 | 15.02.2019 10:20 | 15.02.2019 11:11 | 15.02.2019 11:55 | 15.02.2019 12:35 |
| End | [UTC] | 15.02.2019 09:00 | 15.02.2019 10:20 | 15.02.2019 11:11 | 15.02.2019 11:55 | 15.02.2019 12:35 | 15.02.2019 13:21 |
| I-131 | [Bq] | 3.91E15 | 2.26E16 | 3.00E15 | 1.56E15 | 5.25E14 | 2.44E14 |
| I-132 | [Bq] | 5.62E15 | 3.23E16 | 4.26E15 | 2.21E15 | 7.40E14 | 3.43E14 |
| I-133 | [Bq] | 7.43E15 | 4.19E16 | 5.39E15 | 2.74E15 | 9.02E14 | 4.11E14 |
| I-134 | [Bq] | 1.32E15 | 4.51E15 | 2.76E14 | 8.03E13 | 1.55E13 | 4.34E12 |
| I-135 | [Bq] | 5.26E15 | 2.81E16 | 3.33E15 | 1.60E15 | 5.01E14 | 2.17E14 |
| Kr-87 | [Bq] | 7.53E14 | 8.23E15 | 1.96E15 | 1.57E15 | 9.27E14 | 8.22E14 |
| Kr-88 | [Bq] | 3.05E15 | 4.19E16 | 1.39E16 | 1.42E16 | 1.05E16 | 1.14E16 |
| La-140 | [Bq] | 1.86E11 | 2.37E12 | 3.20E11 | 1.53E11 | 3.79E10 | 6.30E9 |
| Mo-99 | [Bq] | 1.83E14 | 2.10E15 | 2.86E14 | 1.47E14 | 3.87E13 | 6.01E12 |
| Pu-238 | [Bq] | 9.78E5 | 1.10E8 | 1.01E7 | 6.54E6 | 5.94E6 | 1.16E8 |

# Example of operation in the JRODOS system



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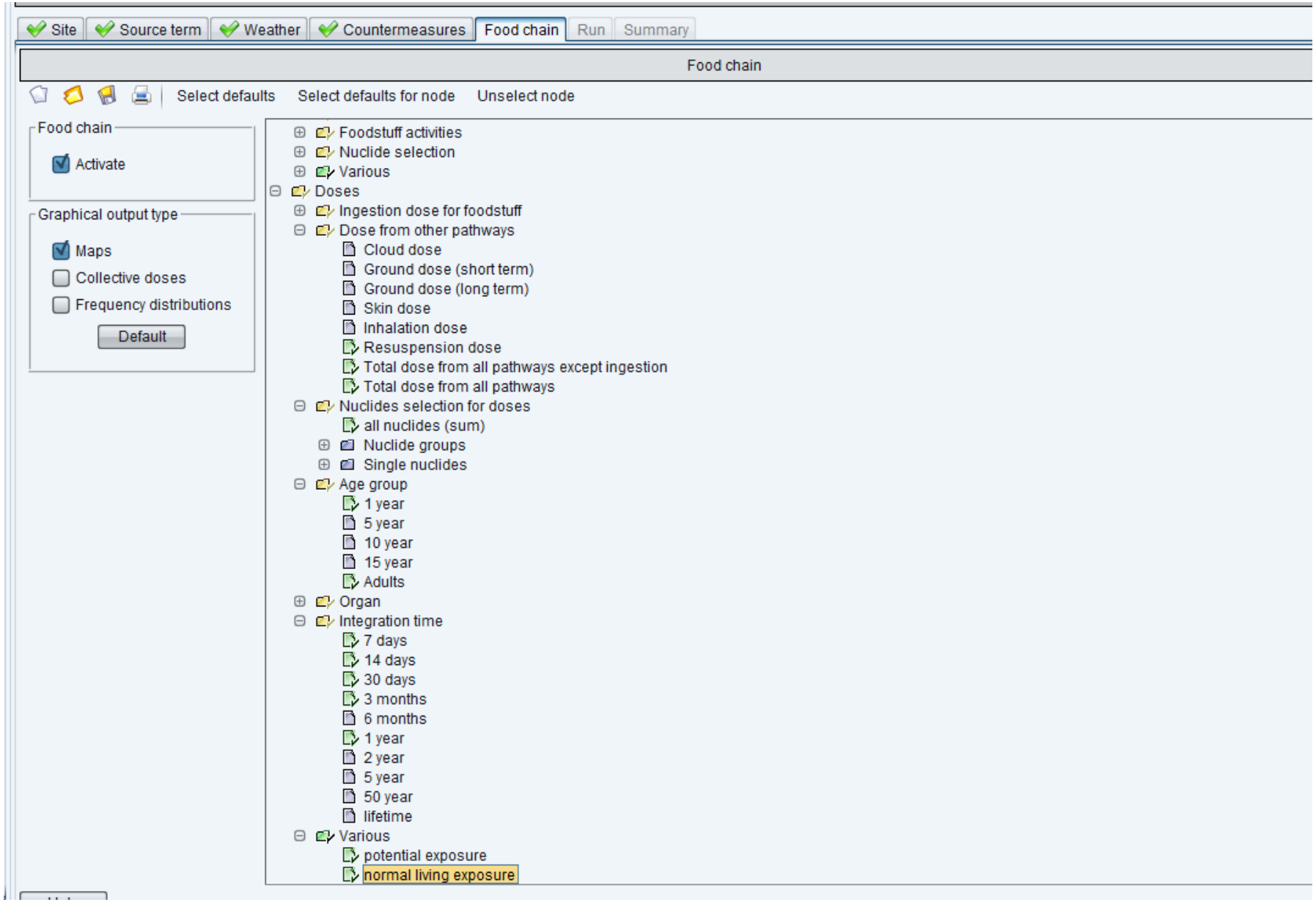
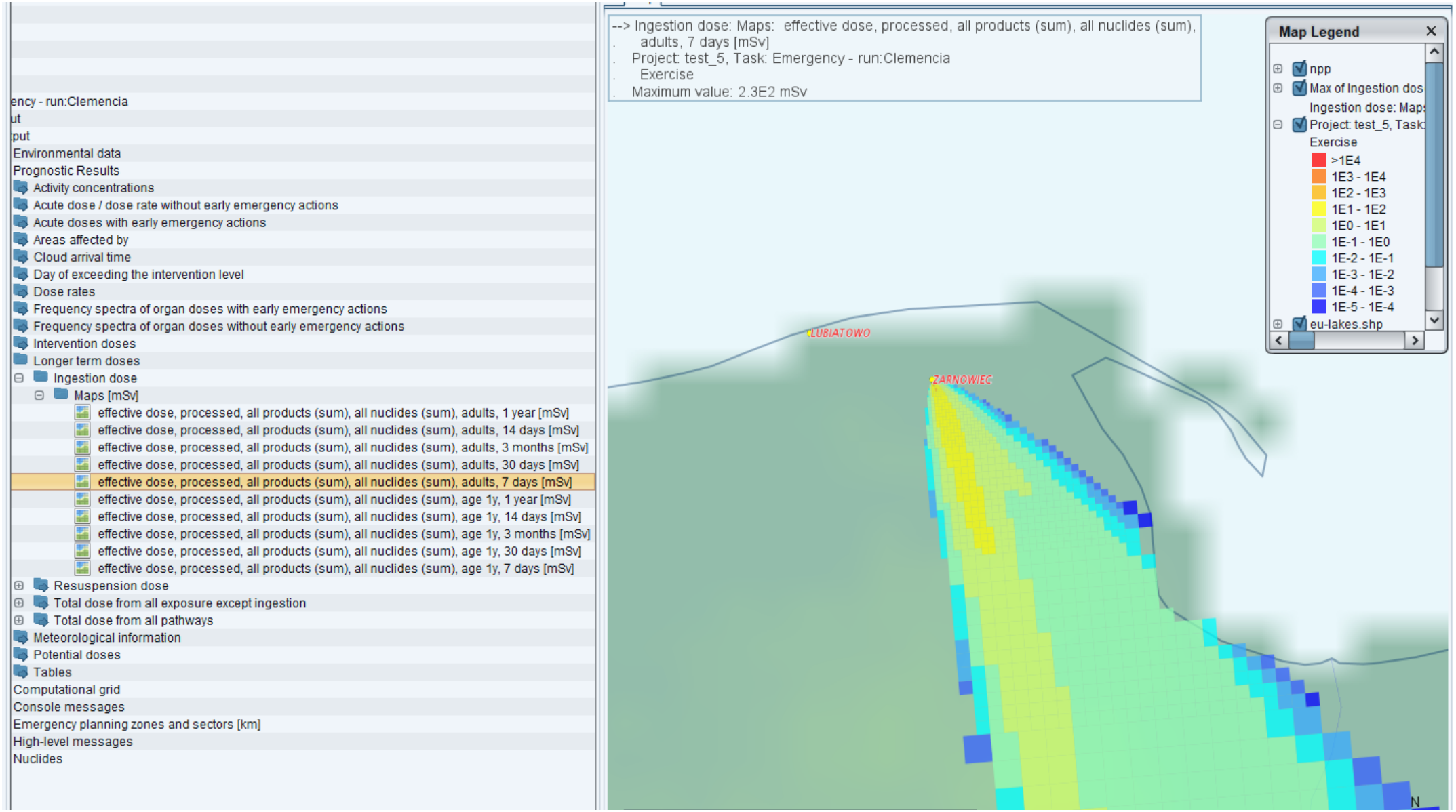


# Example of operation in the JRODOS system



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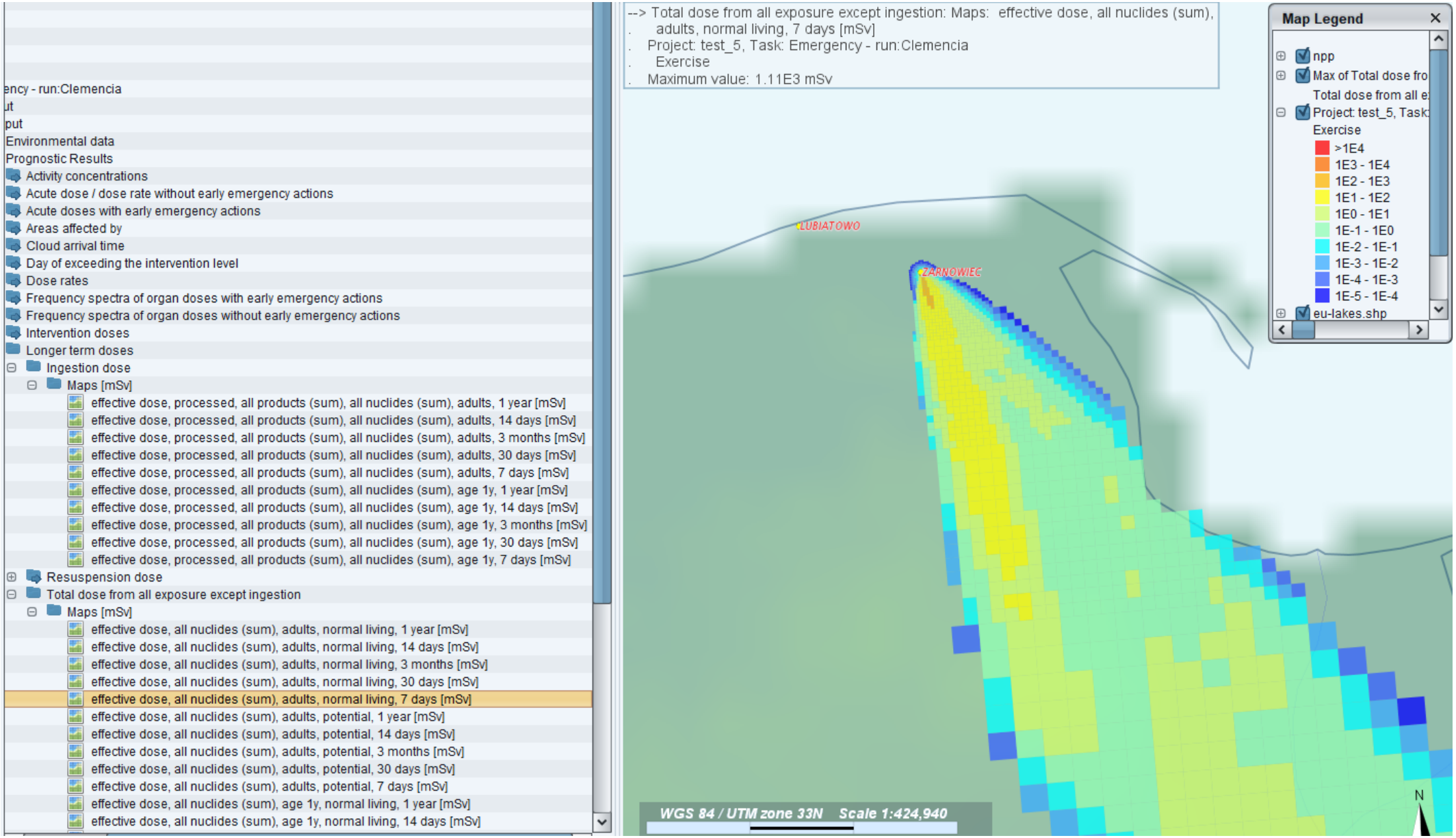
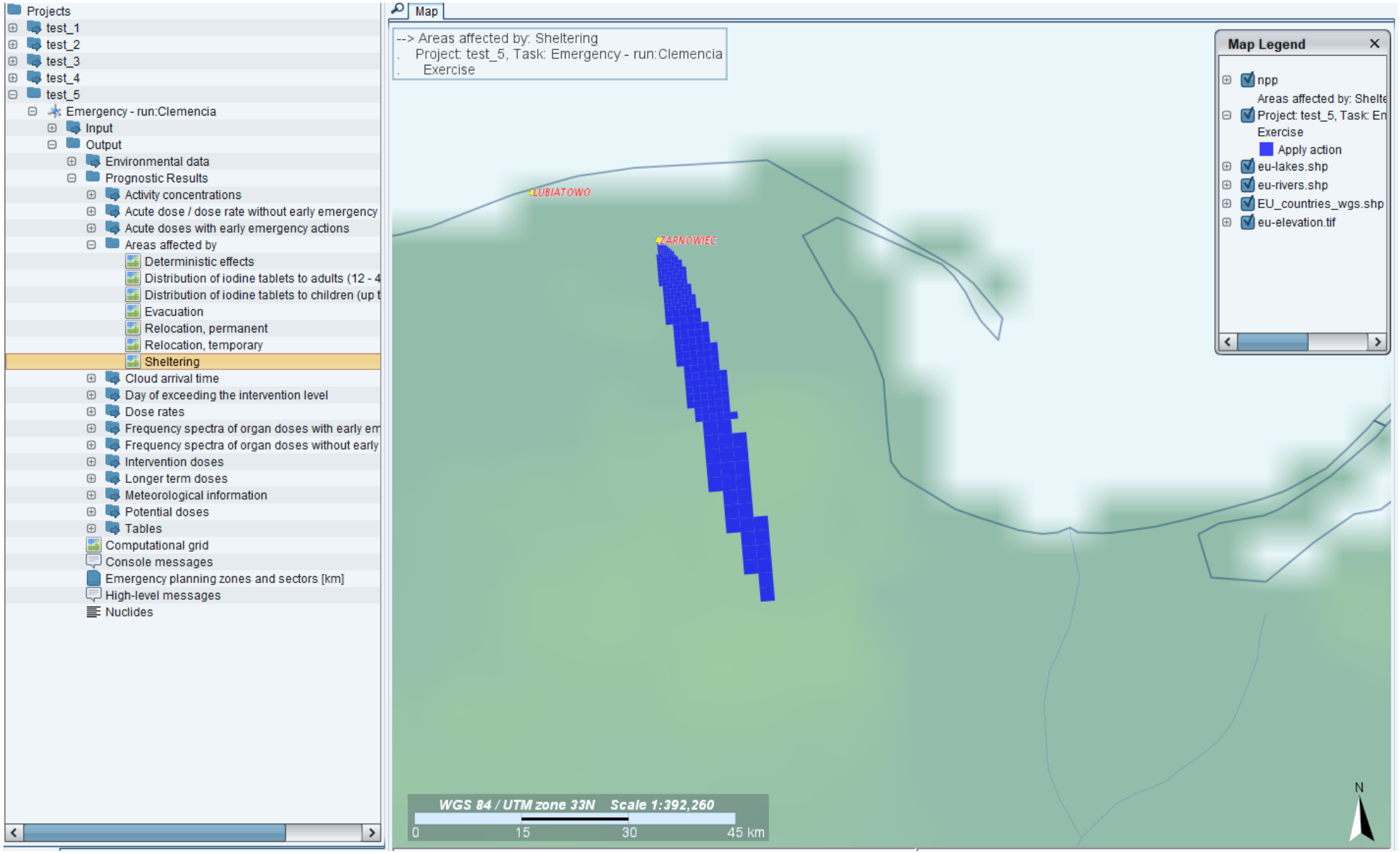


# Example of operation in the JRODOS system



# Performing simulations of the dispersal of radioactive contamination in atmosphere using the JRODOS system for five technologies of nuclear reactors

1. The calculations were made for two locations in Pomerania: Lubiatowo-Kopalino and Żarnowiec.
2. Five technologies are taken into the process calculation (EC6-Candu, AP1000, EPR, APR1400, ABWR).
3. Criteria for calculations were provided by the PGE EJ1 customer.
4. The following meteorological sequences data was used for the calculations:
   - data from the whole year 2010 (it gave the largest exposition and deposition)
   - data from 2005 (the most common occurrence of inversion)
   - data from 2012 (the most frequent strong winds)
   - In total, 115 weather sequences were selected for calculations
5. For this purpose, the JRODOS decision support system has been applied as the main tool for calculating possible human doses for different meteorological conditions.
6. The calculations were carried out for the following criteria:
   - determine of a restricted use area,
   - determine of emergency planning zones
7. The simulation results were presented in the form of a report submitted to PGE EJ1

# Calculation criteria

## *CRITERIA FOR RESTRICTED USE AREA*

**OOU1**: Annual effective dose received from all exposure pathways in normal operation period
zone limiting value: 0.3 mSv/year
**OOU2**: Annual effective dose received from all exposure pathways in case of accident without core melt
zone limiting value: 10 mSv
**OOU3**: In case of design basis accident: 2-days effective dose received from all pathways except of ingestion
zone limiting value: 10 mSv
**OOU4**: In case of design basis accident with extended conditions: 7-days effective dose from all pathways except of ingestion
zone limiting value: 100 mSv
**OOU5**: In case of design basis accident with extended conditions:
**OOU5a:** lifetime dose (50 adults, 70 children) effective dose received from all pathways except of ingestion
zone limiting value: 1 Sv, or
**OOU5b**: if 30-days effective dose received due to from all pathways except of ingestion
does not decrease below 10 mSv during first 2 years from the occurrence of radiation accident

# Calculation criteria

***CRITERIA FOR EMERGENCY PLANNING ZONES***

**Internal zone**: for external exposure
**SPA1**. Absorbed radiation dose in internal human organ (bone marrow, lung, intestine, gonads and thyroid) and eye lens: $D_{red\ marrow}$ = 1 Gy in 10 hours.
**SPA2**. Absorber radiation dose for fetus: $D_{fetus}$ = 0,1 Gy in 10 hours.
**External zone**:
**SPA3**. Effective dose: E = 100 mSv – received, during 7 consecutive days from the beginning of exposure.
**SPA4**. Equivalent dose for fetus: $H_{fetus}$ = 100 mSv – received, during 7 consecutive days from the beginning of exposure.

# Calculation process

1. Creating databases for different meteorological sequences
2. Preparation and configuration of computers to carry out simulation
   - 2 computers running Linux – CENTOS
   - 1 computer with Windows 10
   - installation of the JRODOS system
3. Development and writing of software in Python language that generates calculation files in the "xml" format for the JRODOS system
4. Preparation of "xml" files for calculations in batch processing
5. Performing calculations for each technology (time of calculations without breaks - 7 months)
6. The use of MATLAB software for the presentation of results

# Run JRODOS in batch mode

- Prepare „xml”  input files
- Run JRODOS server
- Put xml files to Automatic directory  (batch processing)
- The use of MATLAB software for the presentation of results

# JRODOS „xml” input file

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```

# JRODOS output text file

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| 1 | 310594.44 | 6067503.5 | 6.25E4 | 0E0 |
| 2 | 310844.44 | 6067503.5 | 6.25E4 | 0E0 |
| 3 | 311094.44 | 6067503.5 | 6.25E4 | 0E0 |
| 4 | 311344.44 | 6067503.5 | 6.25E4 | 0E0 |
| 5 | 311594.44 | 6067503.5 | 6.25E4 | 0E0 |
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| 7 | 312094.44 | 6067503.5 | 6.25E4 | 2.04E0 |
| 8 | 312344.44 | 6067503.5 | 6.25E4 | 1.24E1 |
| 9 | 312594.44 | 6067503.5 | 6.25E4 | 5.03E1 |
| 10 | 312844.44 | 6067503.5 | 6.25E4 | 1.25E2 |
| 11 | 313094.44 | 6067503.5 | 6.25E4 | 1.98E2 |
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| 14 | 313844.44 | 6067503.5 | 6.25E4 | 1.08E2 |
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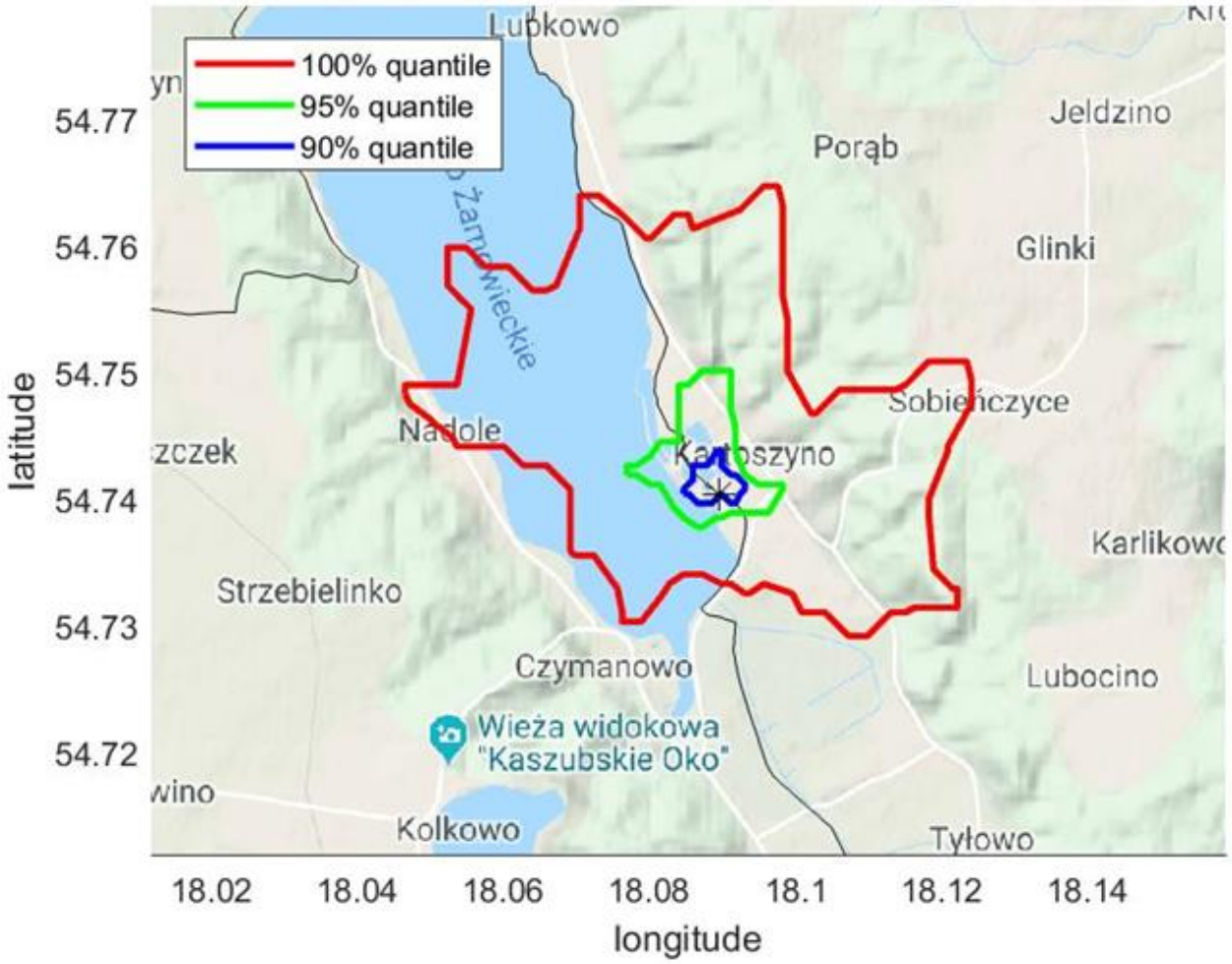
| 23 | 311094.44 | 6067753.5 | 6.25E4 | 0E0 |
| 24 | 311344.44 | 6067753.5 | 6.25E4 | 0E0 |
| 25 | 311594.44 | 6067753.5 | 6.25E4 | 0E0 |
| 26 | 311844.44 | 6067753.5 | 6.25E4 | 0E0 |
| 27 | 312094.44 | 6067753.5 | 6.25E4 | 1.53E0 |
| 28 | 312344.44 | 6067753.5 | 6.25E4 | 1.16E1 |
| 29 | 312594.44 | 6067753.5 | 6.25E4 | 5.45E1 |
| 30 | 312844.44 | 6067753.5 | 6.25E4 | 1.43E2 |
| 31 | 313094.44 | 6067753.5 | 6.25E4 | 2.21E2 |
| 32 | 313344.44 | 6067753.5 | 6.25E4 | 2.18E2 |
| 33 | 313594.44 | 6067753.5 | 6.25E4 | 1.53E2 |
| 34 | 313844.44 | 6067753.5 | 6.25E4 | 8.51E1 |
| 35 | 314094.44 | 6067753.5 | 6.25E4 | 4.13E1 |
| 36 | 314344.44 | 6067753.5 | 6.25E4 | 2.12E1 |

# Calculation process

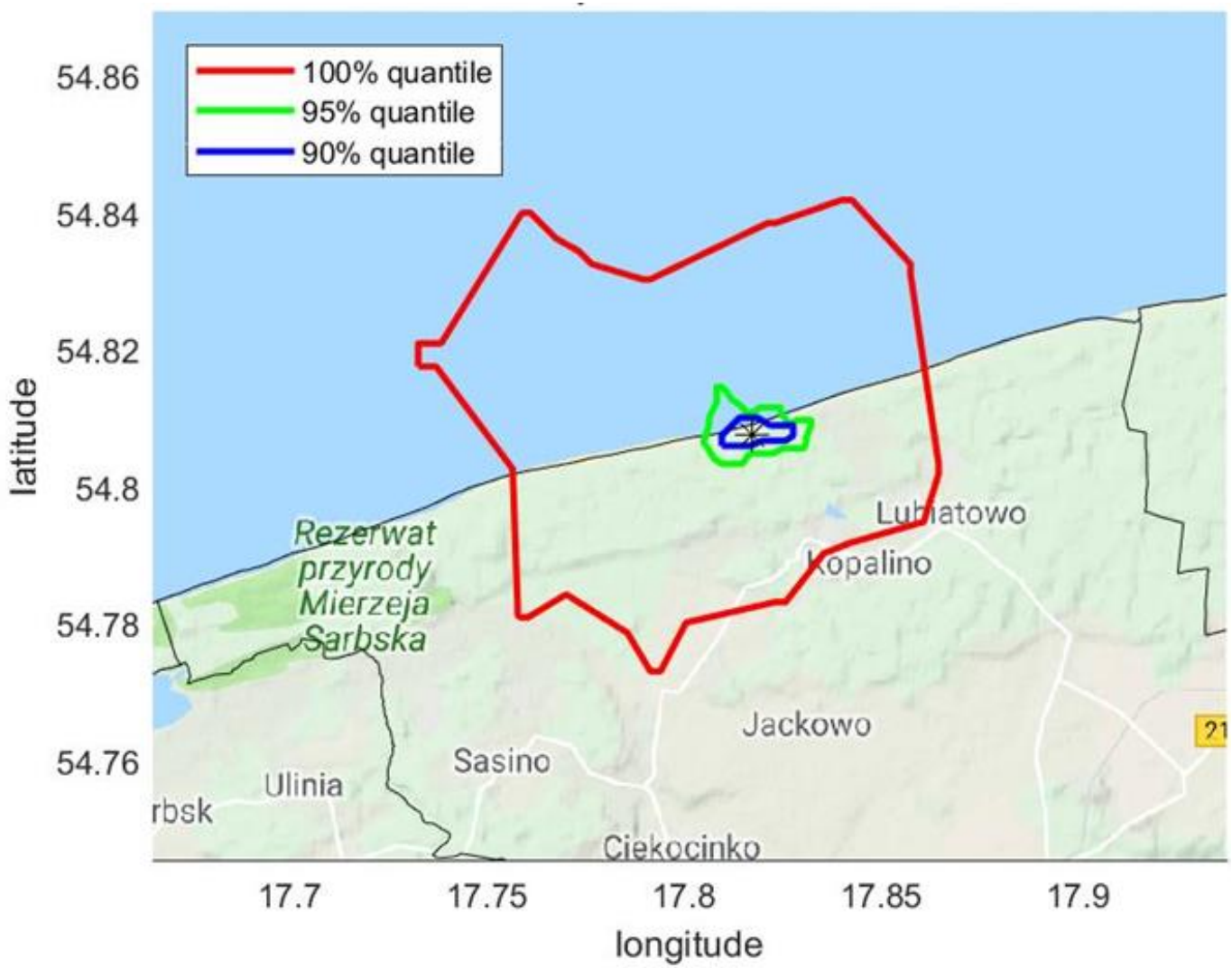
| | | Lubiatowo | | | Żarnowiec |
|---|---|---|---|---|---|
| | XML | Output files | | XML | Output files |
| EC1-candu | 628 | 18 788 | | 681 | 19 880 |
| AP1000 | 628 | 16 475 | | 628 | 16 460 |
| EPR | 1 203 | 31 786 | | 1 203 | 31 783 |
| APR1400 | 1 363 | 54 308 | | 1 362 | 54 307 |
| ABWR | 860 | 30 952 | | 858 | 30 952 |
| | **4 682** | **152 309** | | **4 732** | **153 382** |

# Example calculation




Limits of the restricted use zone obtained for the criterion for limit failure in the category of sequences submitted under extended design conditions in the case of release at 10m high (dose from all routes of exposure). Location Żarnowiec. Zone limit: 10 mSv /a.

# Example calculation




The boundaries of the restricted use zone in case of a severe failure included in the extended design conditions in the Lubiatowo-Kopalino location. 7-day effective dose. Zone limit - 100 mSv

# Thank you
# for your attention