MODELLING AND SIMULATION OF THE RADIOACTIVE RELEASE DURING THE FUKUSHIMA ACCIDENT

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Topics

- Overview: The ABR in the scope of the Nuclear Power Plant (npp) monitoring system of Baden-Württemberg (KFÜ)
- Modelling of the Fukushima accident
- Results

The NPP Monitoring System in Baden-Württemberg (KFÜ)

- Tool to monitor the operating parameter and emissions of the nuclear power plants by the regulatory body (UM BW).
- Immission monitoring: Surveillance of the local gamma dose rate (ODL) and the administration of the monitoring network.
- Measurement of the local on site meteorology and use of the forecast of the German Weather Service DWD
- Tool for the emergency preparedness for the evaluation of the situation during nuclear accidents
- Atmospheric dispersion calculation to predict the radiation exposure of the population
- Tool to design scenarios and to train people within the authorities and the operating companies

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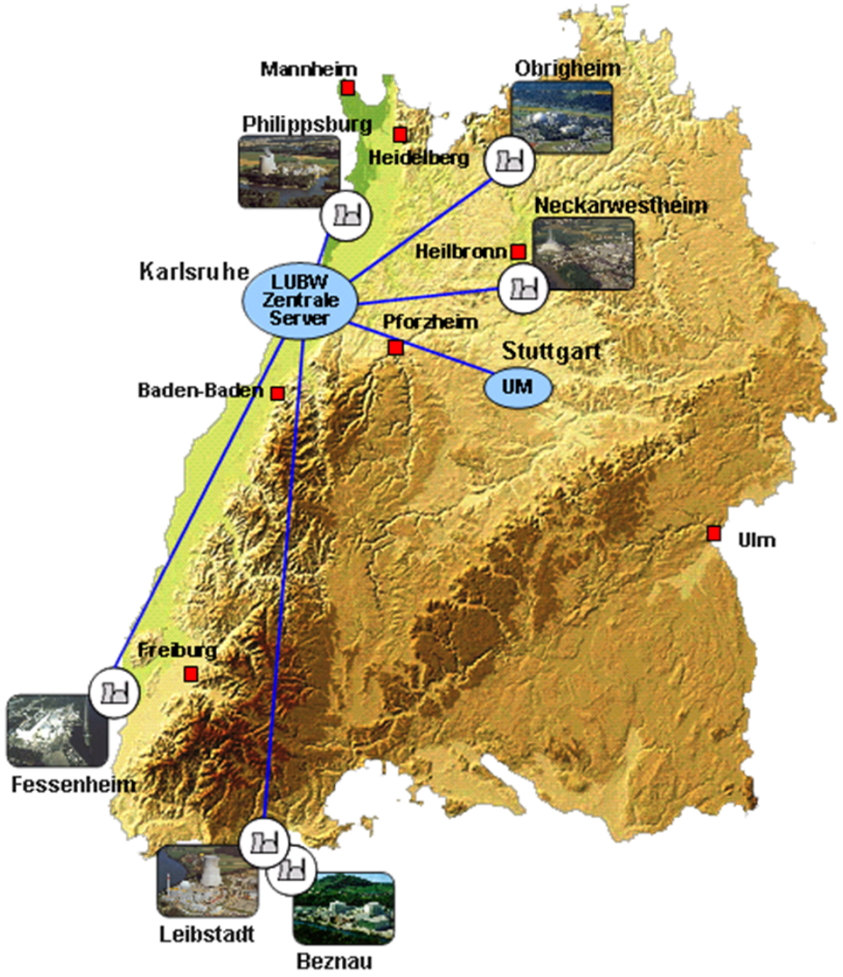
Sites contained in the KFÜ Baden-Württemberg



Philippsburg (KKP)
Neckarwestheim (GKN)
Obrigheim (KWO)

Fessenheim (F)
Leibstadt, Beznau (CH)

Gundremmingen (Bayern)
Biblis (Hessen)

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Components of the Simulation system ABR

- Emission
  - Inventory of the power plant
    - *INVENTAR:*
      - Taking into account the operation history
      - Radioactive decay after reactor shutdown
  - Source term
    - Activity of the nuclide groups
    - Activity of the individual nuclide released
    - Release factor:
      - based on the accident categories defined in the German risk studies Phase A and B and PSA study for GKN
    - *FREI:* considering decay during a release phase

Components of the Simulation system ABR

- Wind field
  - Diagnostic model
  - Stability of the atmosphere
  - Topography
  - ➢ WINDO, MCF
    - WINDO: Calculation using Cartesian coordinates
Divergence free and mass consistent
    - MCF: Calculation using terrain following coordinates
Divergence free and mass consistent

Components of the Simulation system ABR

- Particle transport
  - Transport by wind and diffusion
  - Deposition on the ground
  - Considering wet deposition (wash out)
  - ➢ PAS:
    - Lagrange particle model
    - Advection - diffusion equation
    - 3 layered atmosphere with different diffusion categories
    - Terrain following coordinate system
    - Considering inhomogeneous distributed rain

Components of the Simulation system ABR

- Radiological exposure
  - Gamma cloud radiation (Gamma submersion)
    - ➢ AIRDOS: Considering 30 energy groups using adjoint fluxes
  - Dose
    - Radiation from the ground
    - Organ dose (25 organs)
    - Equivalent dose
    - Effective dose
    - Inhalation
    - For different age groups
    - Local gamma dose rate (ODL)
    - ➢ DOSE: calculation on the basis of weighting factors

Components of the Simulation system ABR

- Assisting modules
  - CRETOPO:
    - Provision of the Topography in Cartesian coordinates
  - KART-GELF, GELF-KART:
    - Conversion between Cartesian and terrain following coordinate system

ABR Models

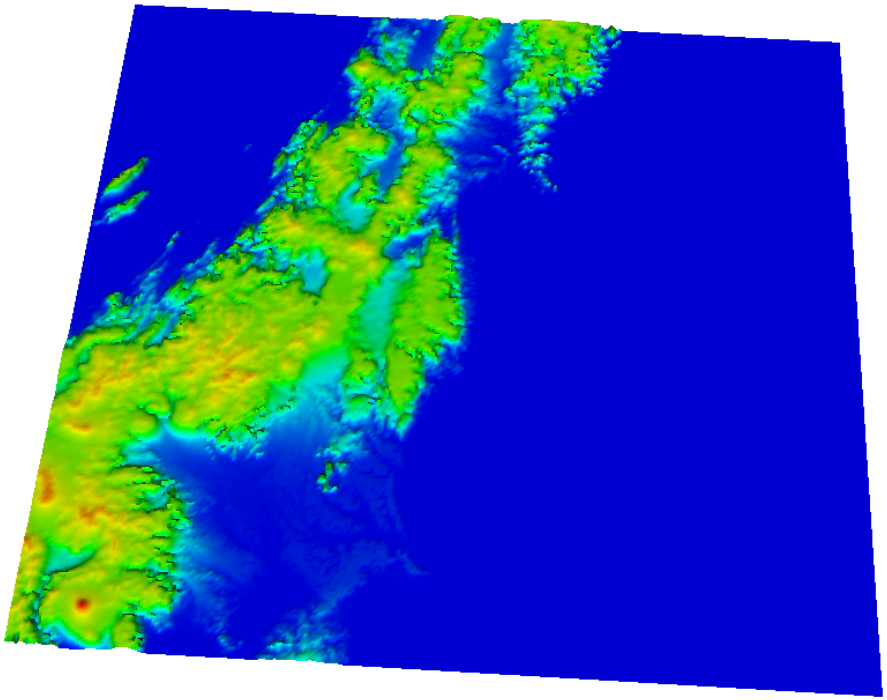
- Source term:
  - FREI: Calculation of the nuclide vector and the released activity rates
- Wind field calculation (3-dimensional)
  - WINDO: Calculation using Cartesian coordinates
Divergence free and mass consistent
  - MCF: Calculation using terrain following coordinates
Divergence free and mass consistent
- Transport and deposition of radioactive particles (3-dim.)
  - PAS: Lagrange-Monte-Carlo method, terrain following, considering inhomogeneous distributed rain
- Dose calculation
  - AIRDOS: Calculation of the cloud gamma dose rate
  - DOSE: Calculation of the ground radiation, Inhalation, thyroid and effective dose
- Topography
  - CRETOPO: Provision of the Topography in Cartesian coordinates
  - KART-GELF: Transformation in terrain following coordinates

Simulation of the accident at Fukushima

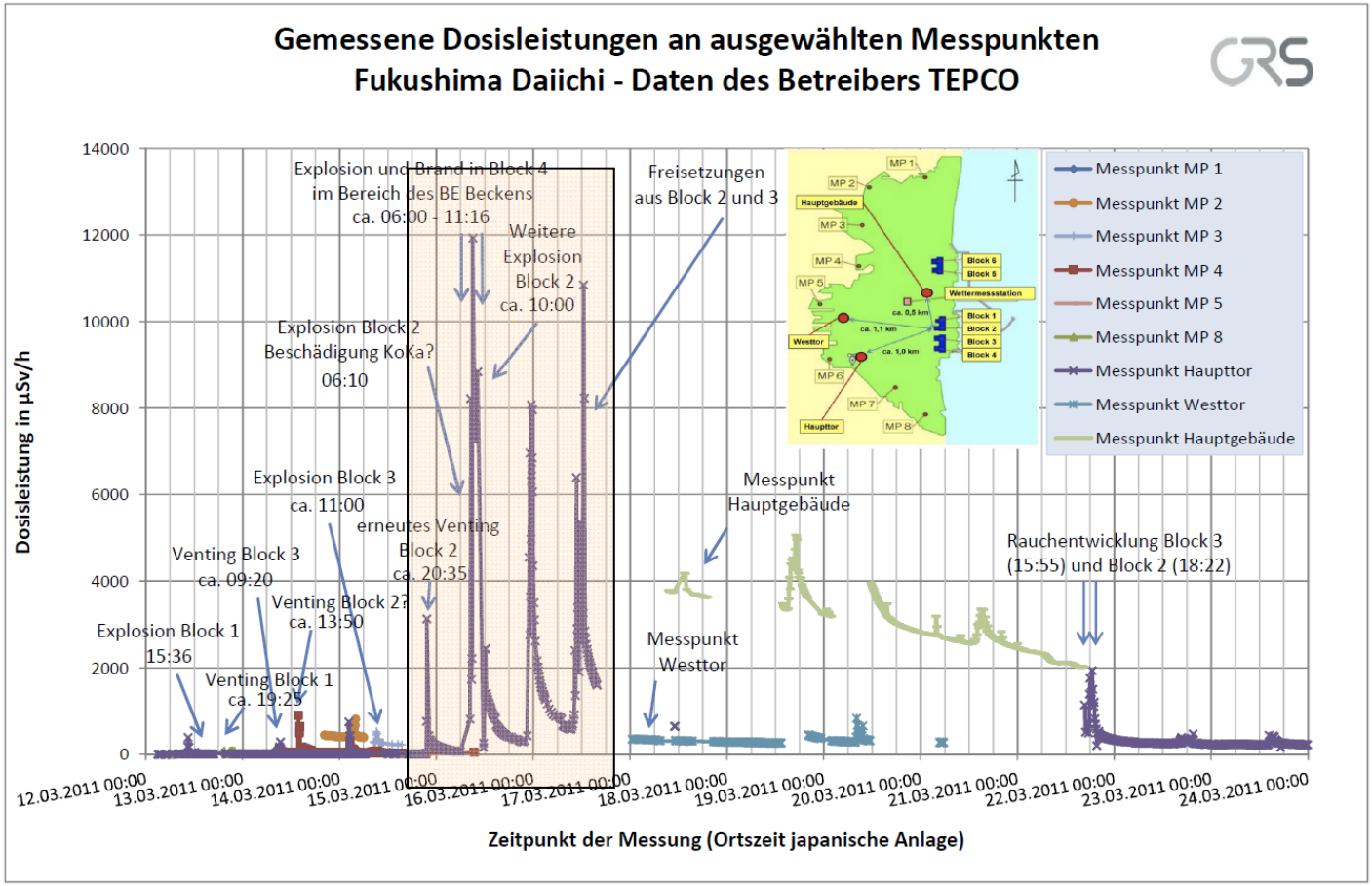
- Starting position
  - **Only few assured Information**
  - Unknown status of the reactors
  - Few measured values due to the failure of measuring devices caused by the station black out
  - Complex accident sequence with several activity release phases
  - Fukushima site not available in the ABR
- Data sources
  - Internet
  - Published data from the operating company TEPCO and the Ministry of Education, Culture, Sports, Science and Technology (MEXT)

Modelling the Fukushima Accident

- Integration of Fukushima as new site
  - Change the coordinate system from Gauß-Krüger to Universal Trans Mercator (UTM) WGS84
  - Increasing the model area
  - Provision of a digital terrain model for the modelling areas:
    - 50 km x 50 km
    - 500 km x 500 km (including Tokio)
    - Basis: *Shuttle Radar Topography Mission data* (*SRTM*) from *February 2000*
  - Maps taken from OpenStreetMap



Accident sequence by means of the release phases



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Modelling

- Only major releases will to been taken into account
  - Releases in the first days of minor impact
    - Later publications discuss the possibility of a partial core melt down accident caused by the earth quake, leading to earlier remarkable releases.
- Simulation starts at 14.03.2011
  - Covering the next 4 days
- Emission point
  - Due to the mesh size of 2 km not all 4 reactor units and the fuel element storage pool can be pinpoint.
  - As a consequence they have been merged into a single emission point and an averaged emissions height

Modelling

Begin and duration of the release phases

Phase	Begin	Duration	Description
1	14.03.2011 13:30	2 h	Venting block 2
2a	15.03.2011 00:00	2 h	Explosion block 2
2b	15.03.2011 00:00	5 h	Block 4 release from fuel element storage pool
3	15.03.2011 14:30	3 h	Release from fuel element storage pool
4	16.03.2011 02:00	4 h	Explosion block 2 and 3

Modelling

- Emission point and emission height
  - Due to the mesh size of 2 km not all 4 reactor units and the fuel element storage pool can be pinpoint.
  - As a consequence they have been merged into a single emission point and an averaged emissions height

Modelling

- Source term estimation
  - Data published by Nuclear and Industrial Safety Agency NISA

Phase	Begin	Noble gas [Bq]	Iodine [Bq]	Aerosol [Bq]
1	14.03.2011 13:30	1.00 E+18	1.14 E+16	1.15 E+16
2	15.03.2011 00:00	1.00 E+18	1.50 E+17	1.00 E+17
3	15.03.2011 14:30	5.00 E+17	5.00 E+16	3.00 E+16
4	16.03.2011 02:00	1.00 E+18	1.00 E+17	5.00 E+16

Modelling

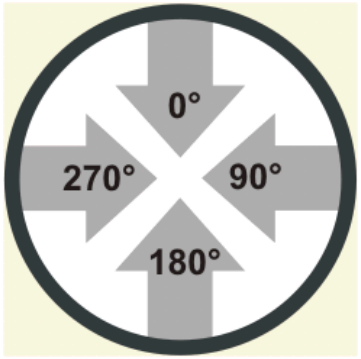
- Source term estimation
  - Estimation of the released activity per nuclide
    - Inventory calculation based on the inventory of German BWR scaled with the power of the Fukushima reactors (per nuclide)
    - Taking into account
      - Duration of full power operation since last maintenance
      - Duration of the last maintenance
      - Radioactive decay since shutdown

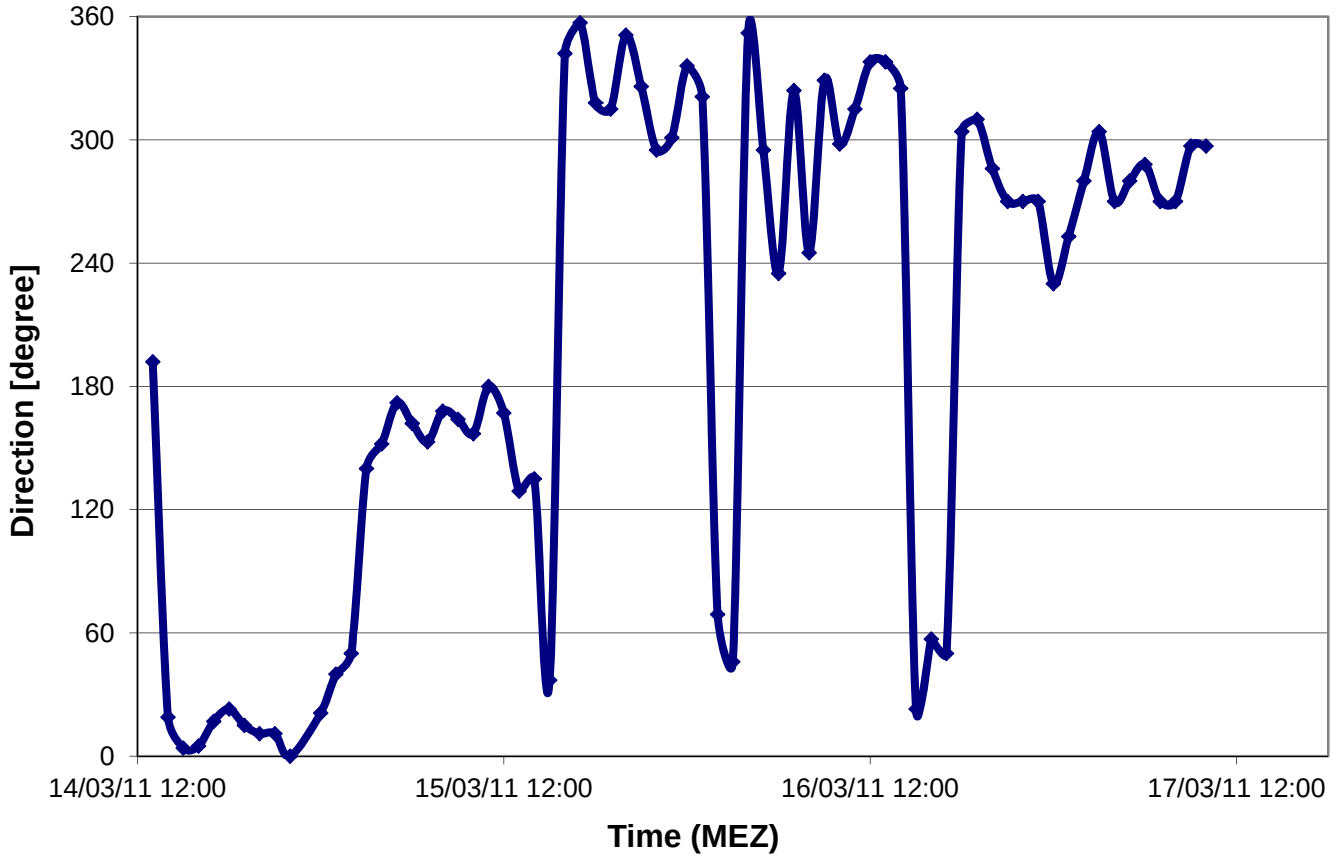
Modelling

- Meteorology:
  - Measured data of the wind direction and speed from different places on the site have been available, however with timely gaps
  - All values of the measurement stations on the site have been vectorialy averaged to a single wind vector
  - A uniform turbulence parameter for the whole modelling area has been used
    - Diffusion category: C (neutral until slightly unstable)
    - Turbulence parameter: Pasquill Guiford Parameter
    - Only dry deposition taken into account (no precipitation)

Modelling

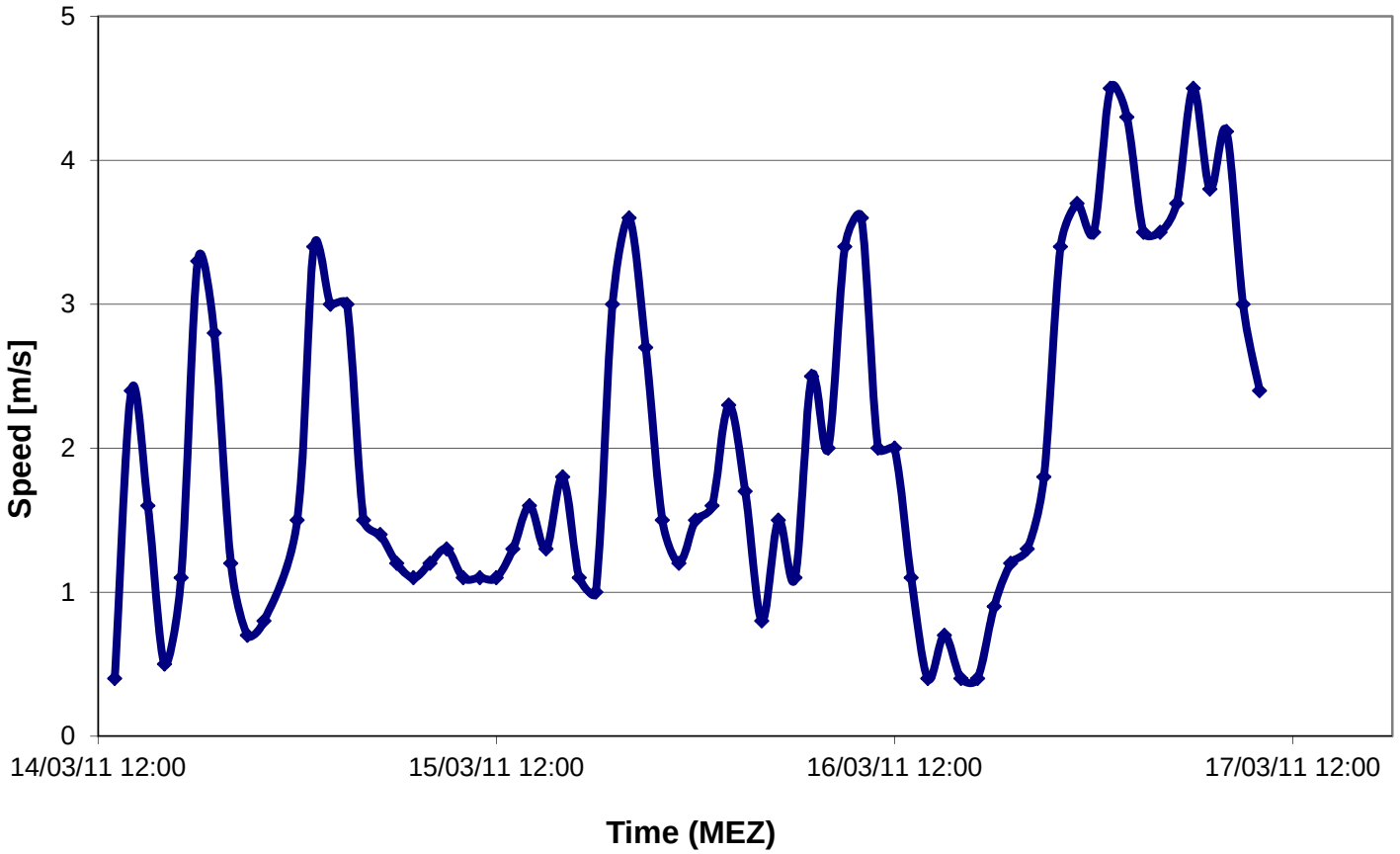
Measured values: wind direction





Modelling

Measured values: wind speed



Results of the dispersion calculation

- Comparing the results with measured values the following has to be taken into account:
  - **High uncertainty also of the measured data**
    - Quality of the measured data is not known
      - Measuring device
      - Measuring method
    - The measurement and emission height had to be assumed
    - The location of measurement points are not known exactly

Results of the dispersion calculation

Local gamma dose rate (ODL) measurement points

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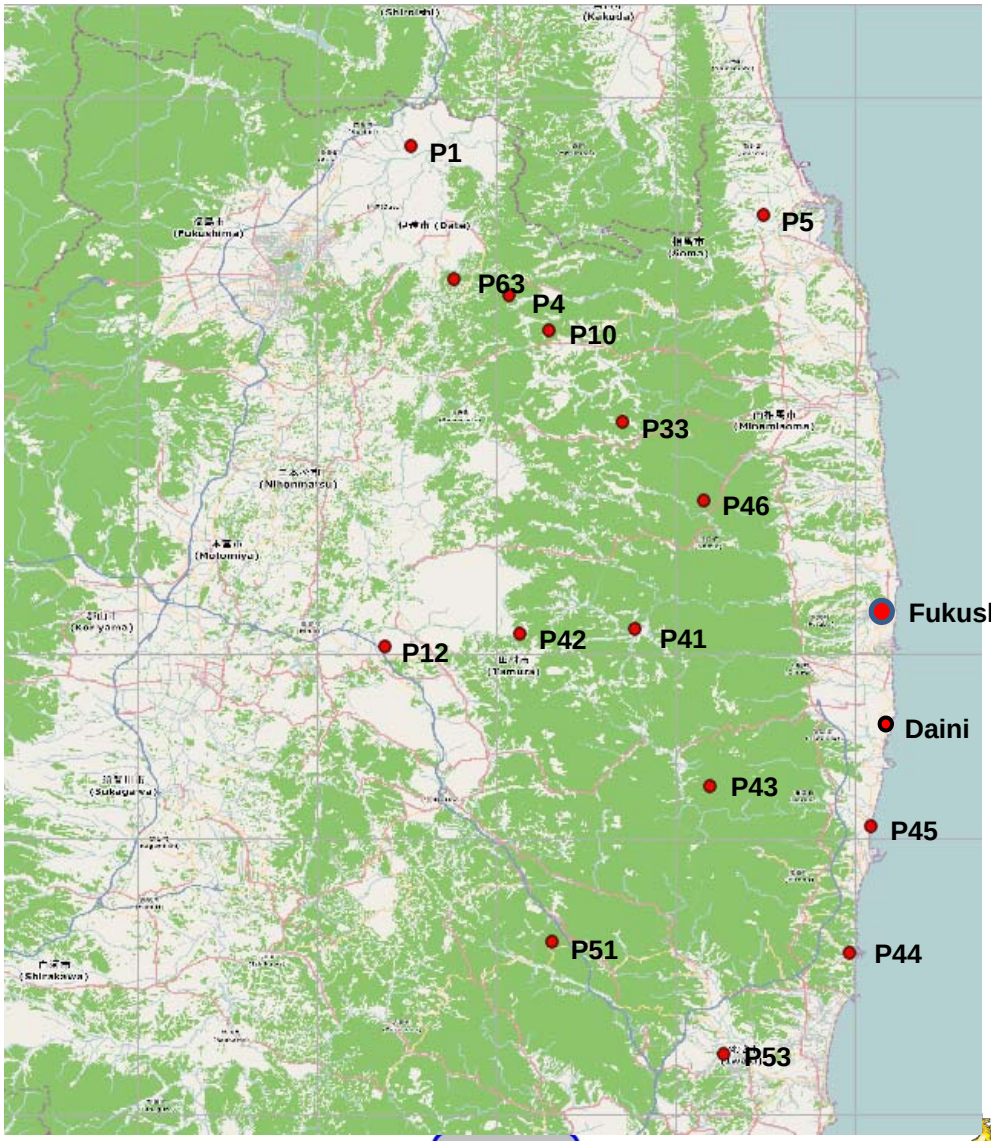
Location of measurement points estimated from:

“Readings at Monitoring Post out of 20 Km Zone of Fukushima Daiichi NPP As of 19:00 March 17, 2011”

Source: Ministry of Education, Culture, Sports, Science and Technology (MEXT



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Slide 23

obr22 woher stammen die Ortsinformationen?)

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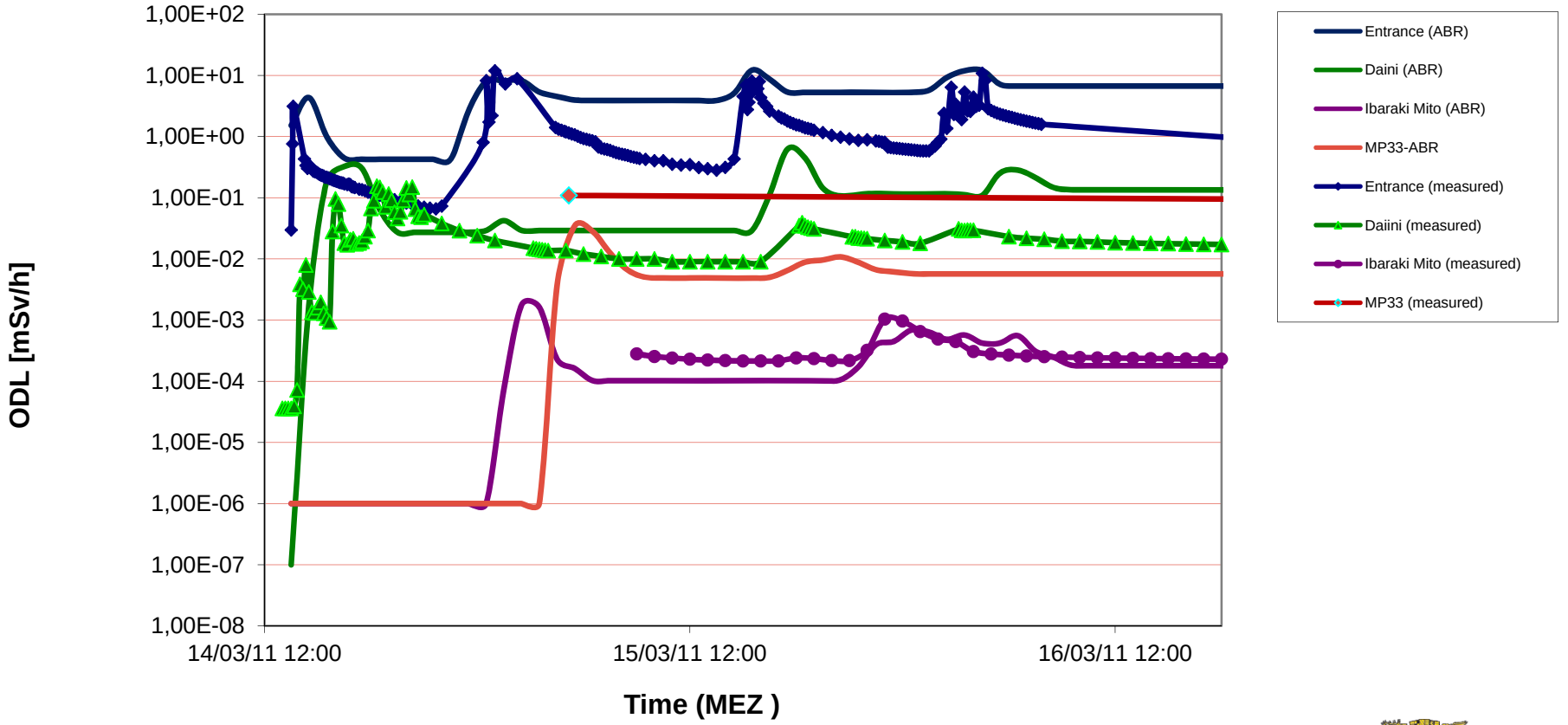
Results of the dispersion calculation

Comparison: measured values / Simulation results of the local gamma dose rate (ODL) at different measurement points



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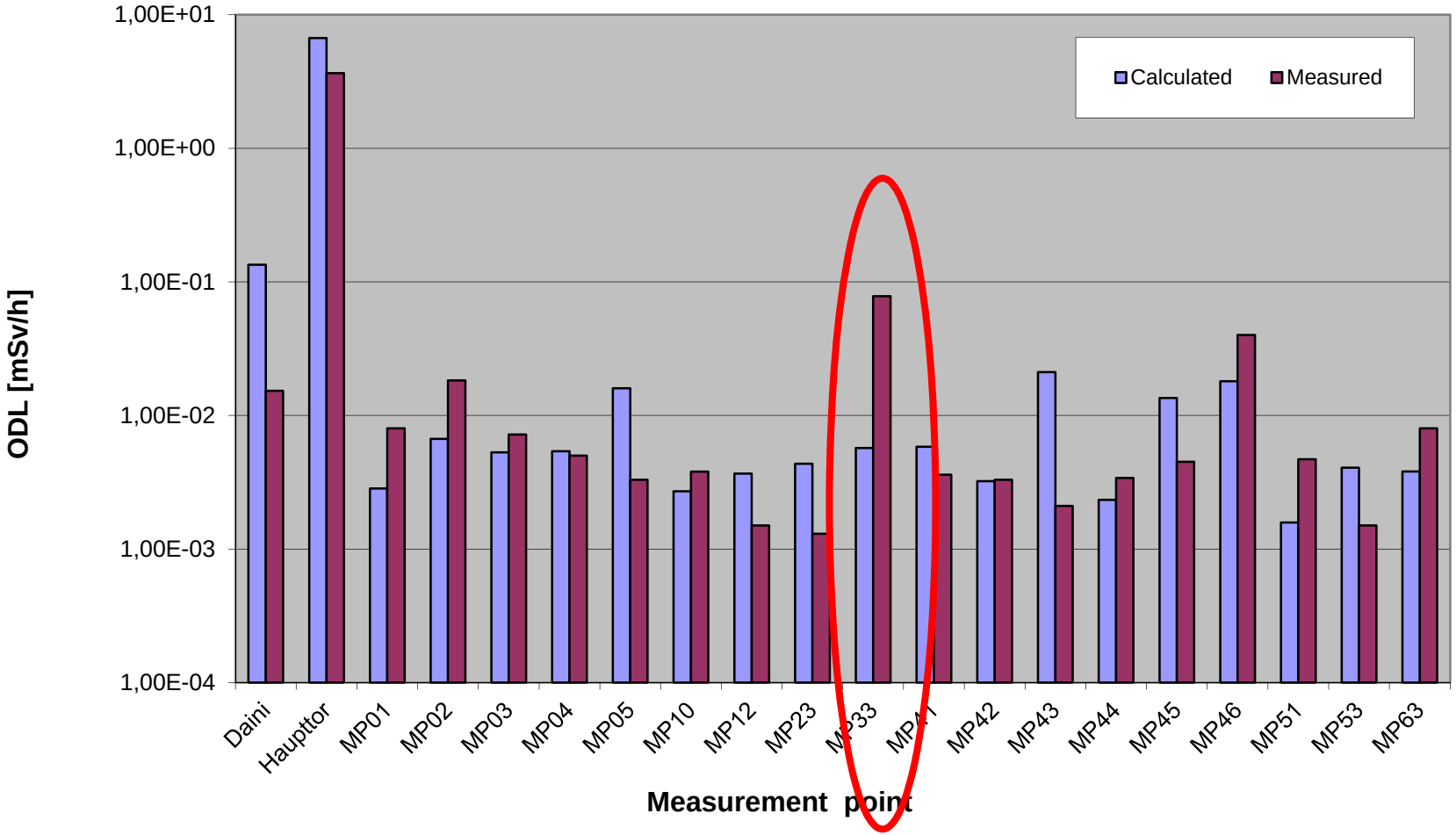
Results of the dispersion calculation



Comparison: Measured values / Simulation results (ODL) after the cloud has left the modelling area at 17.03.2011 18:00 at different measurement points

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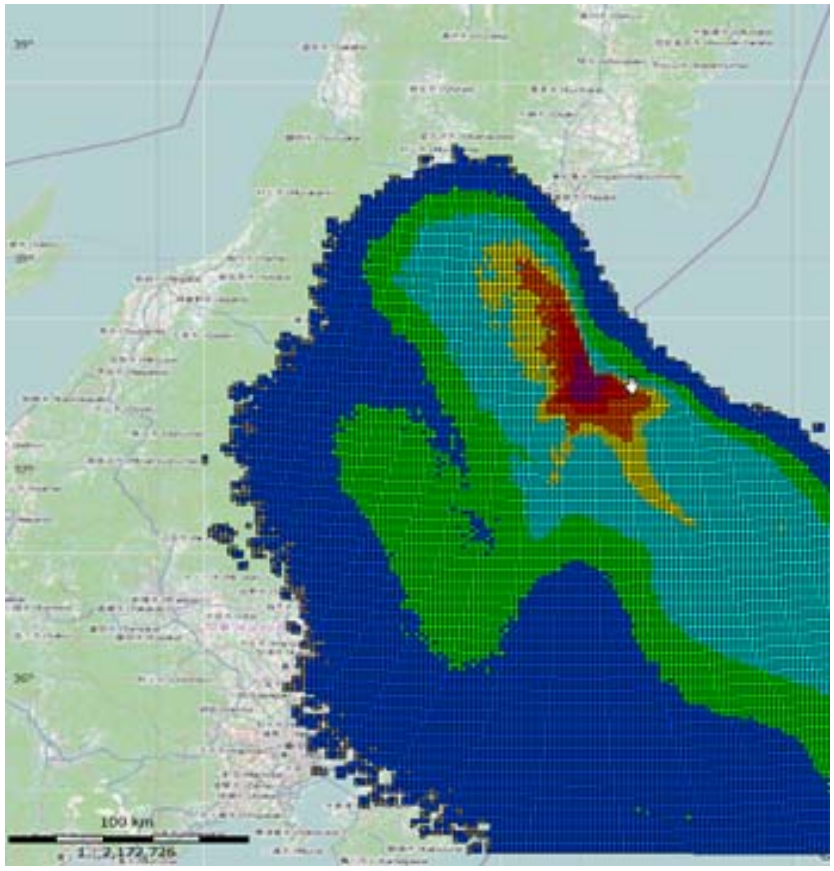
Results of the dispersion calculation

Thyroid exposure

SPEEDI



ABR

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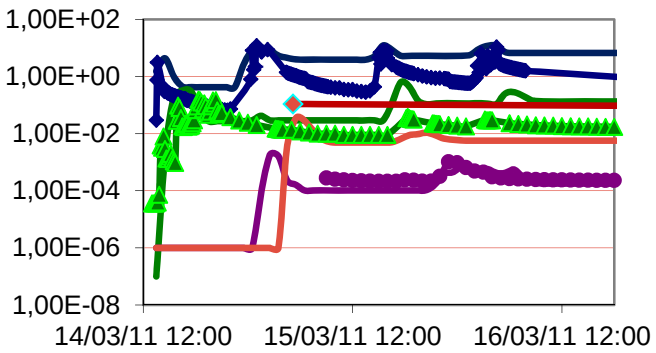

Summary

- Good Agreement of the cloud arrival and value of the local dose rate.
- In the current implementation of the dose rates, the ABR does not consider the radioactive decay during the dispersion phase and of the nuclides deposited on the ground.

Summary

With respect to the question concerning the use and the usefulness of the tools developed after the Chernobyl accident, it can be noticed that the ABR is capable to calculate realistic results.

Although there is still a need for further development and improvement.

Thank you
for your
Attention

Questions ???

Local gamma dose rate