COMPARISON OF OPERATIONAL ATMOSPHERIC DISPERSION MODELS IN GERMANY

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Agenda

1. Introduction and scope of the model comparison
2. Simple Scenarios:
   constant wind,
   wind rotation,
   wind shear
3. Realistic weather conditions
4. Recommendations and summary

Introduction: Deployment of models in nuclear emergencies

- Nuclear emergency preparedness and response are characterised by
  - Complex processes and unclear boundary conditions (Source term; Weather, …)
  - Huge potential risk
  - Short time scale
- Decision support systems based on dispersion models have been established since many years

- In emergency preparedness or response, different models are used to recommend measures (evacuation, resettlement, shielding, Iodine blocking)

- After Fukushima: German Commission for Radiological Protection (SSK) started several projects concerning lessons learned in nuclear emergency planning and preparedness

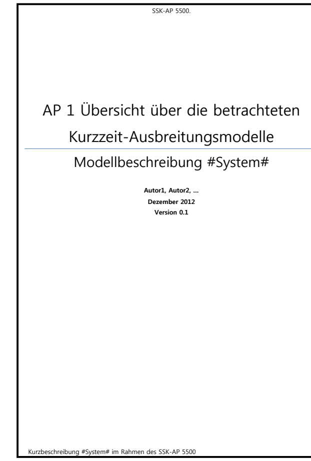
- One of the projects:
  Comparison of operational systems in Germany
  - differences / similarities of the models?

Foto: Reuters

Introduction: Scope of the model comparison

1 Documentation of the operational models includes

- Overview and scope of the system/model
- Modelling area, grid type, grid resolution
- Boundary conditions; input data; parameters; interfaces
- Source term
- Flow model
- Diffusion model
- Dose calculation procedures



SSK-AP 5500.

AP 1 Übersicht über die betrachteten Kurzzeit-Ausbreitungsmodelle

Modellbeschreibung #System#

Autor1, Autor2, …

Dezember 2012

Version 0.1

Kurzbeschreibung #System# im Rahmen des SSK-AP 5500

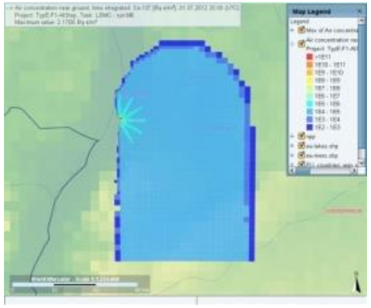
2 Definition of scenarios (from simple to realistic conditions)

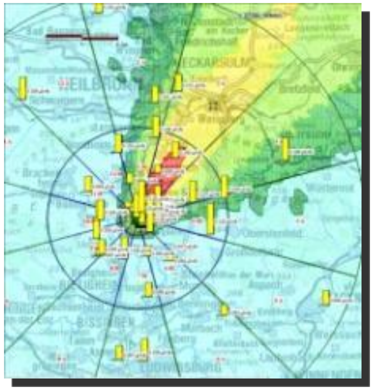
3 Collection and analysis of the results for concentrations, deposition, doses

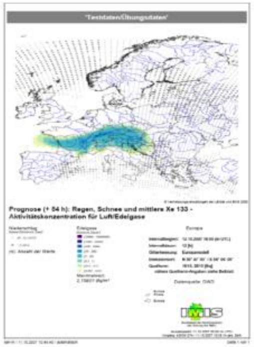
4 Conclusions and Recommendations

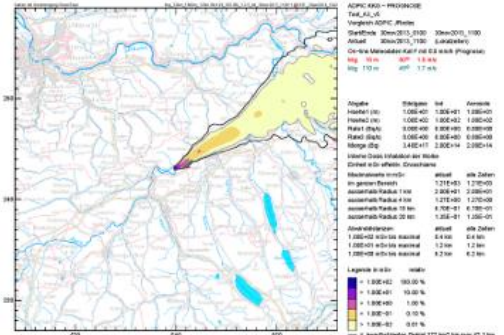
The models/systems included in the project

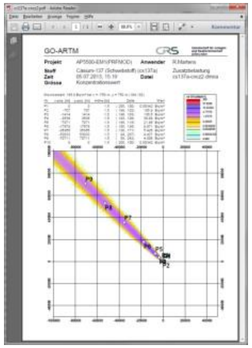
Model or System	Type
SAFER	Gaussian plume model
RODOS-System **RIMPUFF** **ATSTEP** **DIPCOT**	Simulation system with Gaussian puff model Gaussian puff model Lagrangian Particle model with Gauss Kernel method
KFÜ-ABR	Simulation system with Lagrangian Particle model
DWD-LPDM	Simulation system with Lagrangian Particle model: focus large scale
ADPIC	Simulation system with Lagrangian Particle model
ARTM	Simulation system with Lagrangian Particle model; focus long term calculations
LASAIR	Simulation system Lagrangian Particle model; focus short scale (dirty bombs)







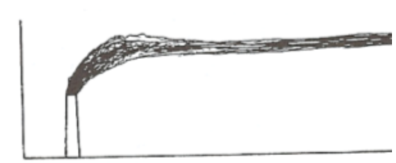




Simple Scenarios E1: Meteorological conditions

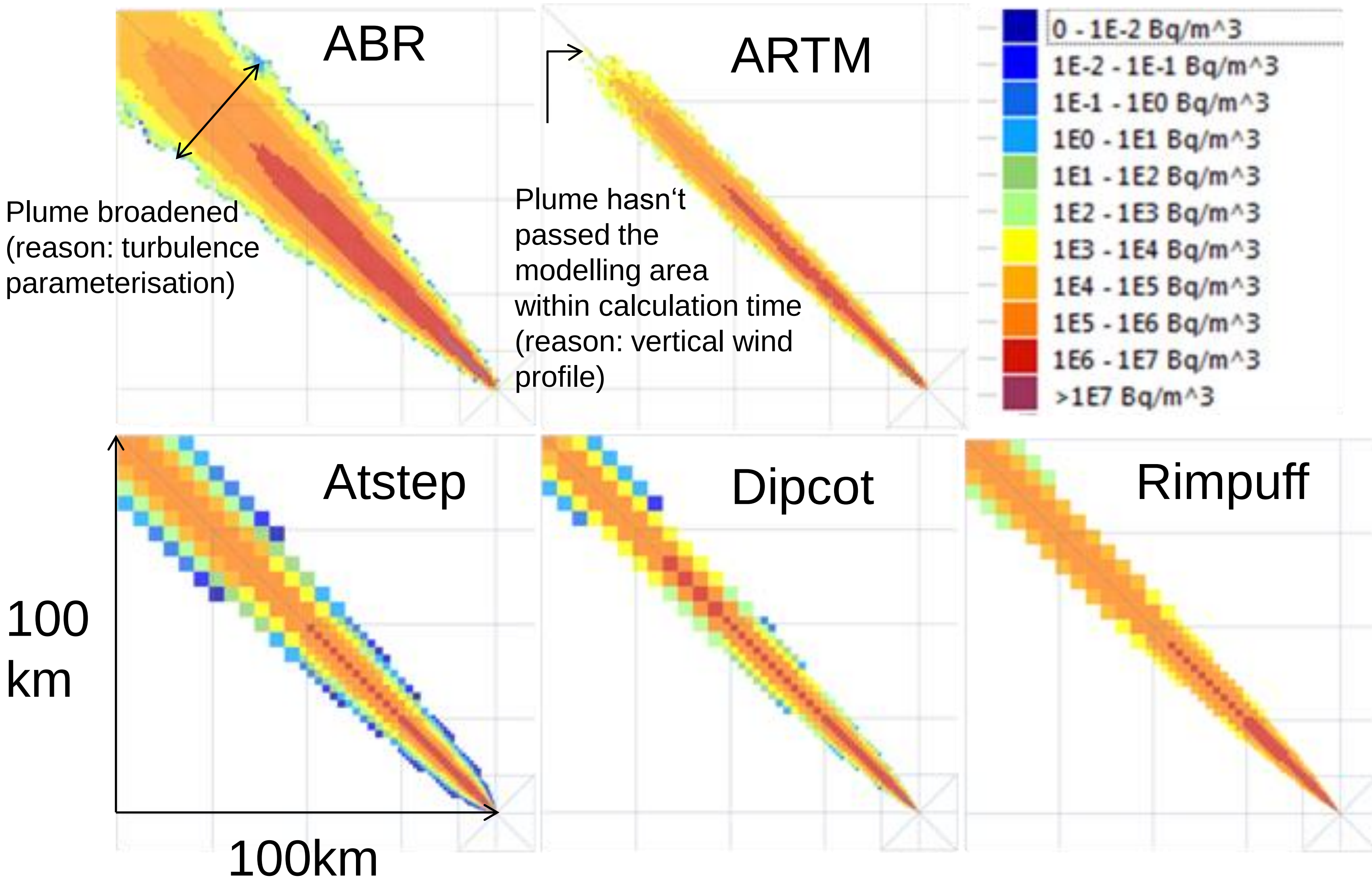
- Constant wind speed and direction (3 m/s, 135° at 10m above ground)
- Variation of
  - Stability
  - Precipitation
  - Topography (roughness)
- Simple Source term:
  - 1E17Bq Xe133, 1Ee15Bq I131 (elementary and organic), 1E13 Bq Cs137
  - Constant emission rate at 150m (2 hours vs. 6 hours calculation time)

	M1	M2	M3	M5	M4
Diffusion category	B	D	D	D	E
Precipititation *(constant over the whole area)*	0 mm/h	0 mm/h	0 mm/h	2 mm/h	0 mm/h
Rougness length	0,1 m	1,5m	0,1m	0,1m	0,1m

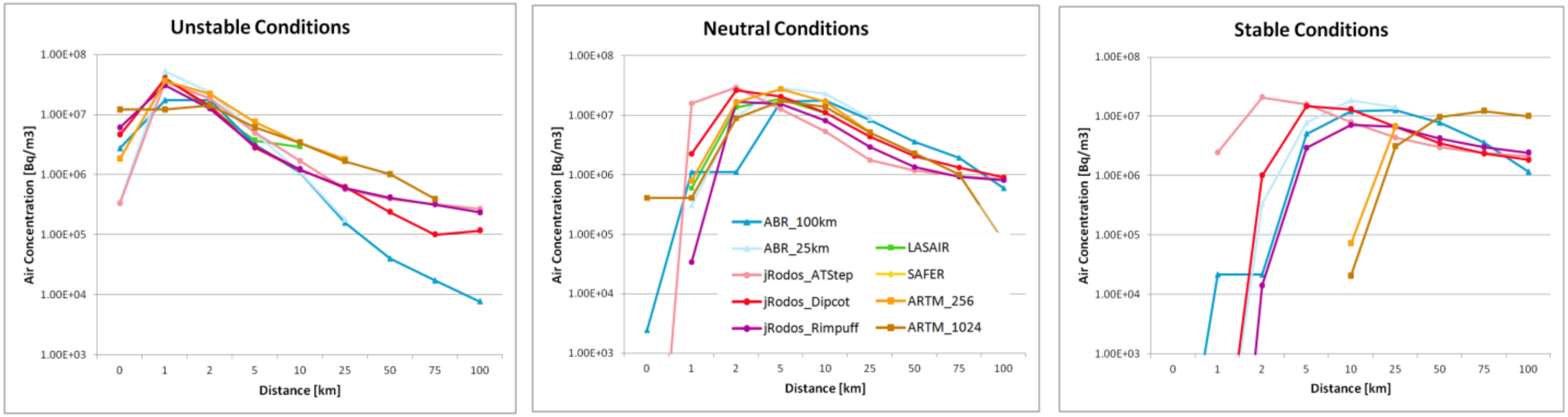


Pictures taken from Kraus: Die Atmosphäre der Erde

Xe133 Concentration near ground level for neutral conditions



Xe133-Concentrations, ground, downwind

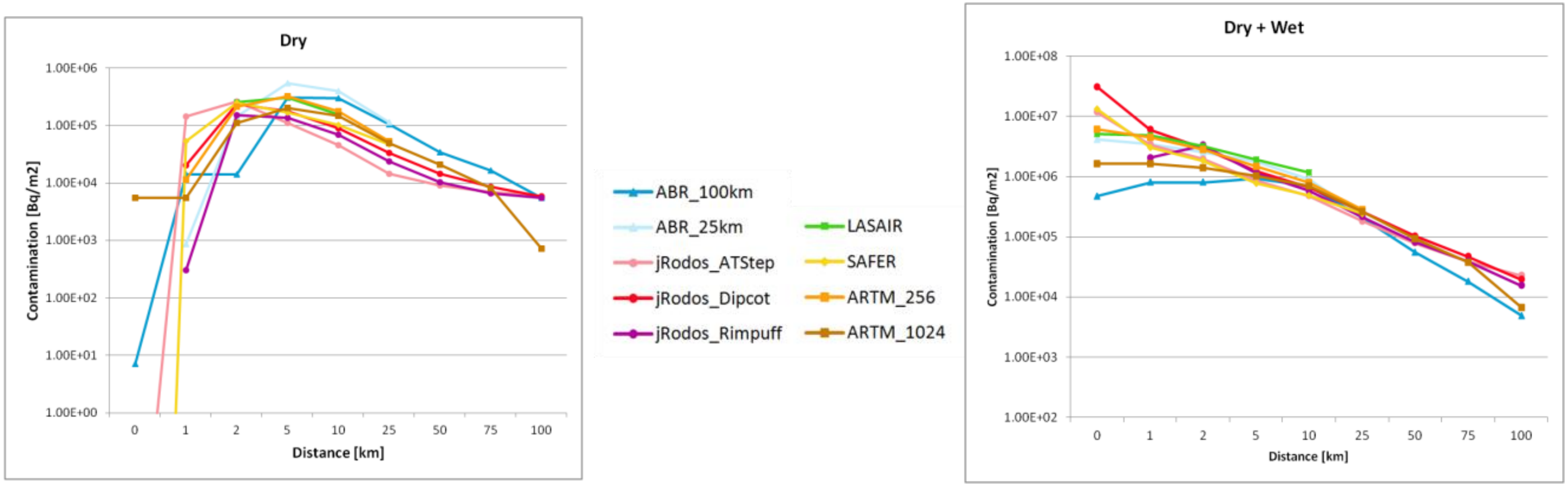


- Reasonable aggreement for neutral and unstable conditions
- Good aggreement for stable conditions at long distances
- ARTM-results differ for stable conditions due to different turbulence model

Reasons:

- Grid resolution at short distances is different
- ABR and ARTM calculations with two resolutions (converge at large distances)
- Simulation time must be greater than travel time

I 131, fallout and washout (neutral conditions)



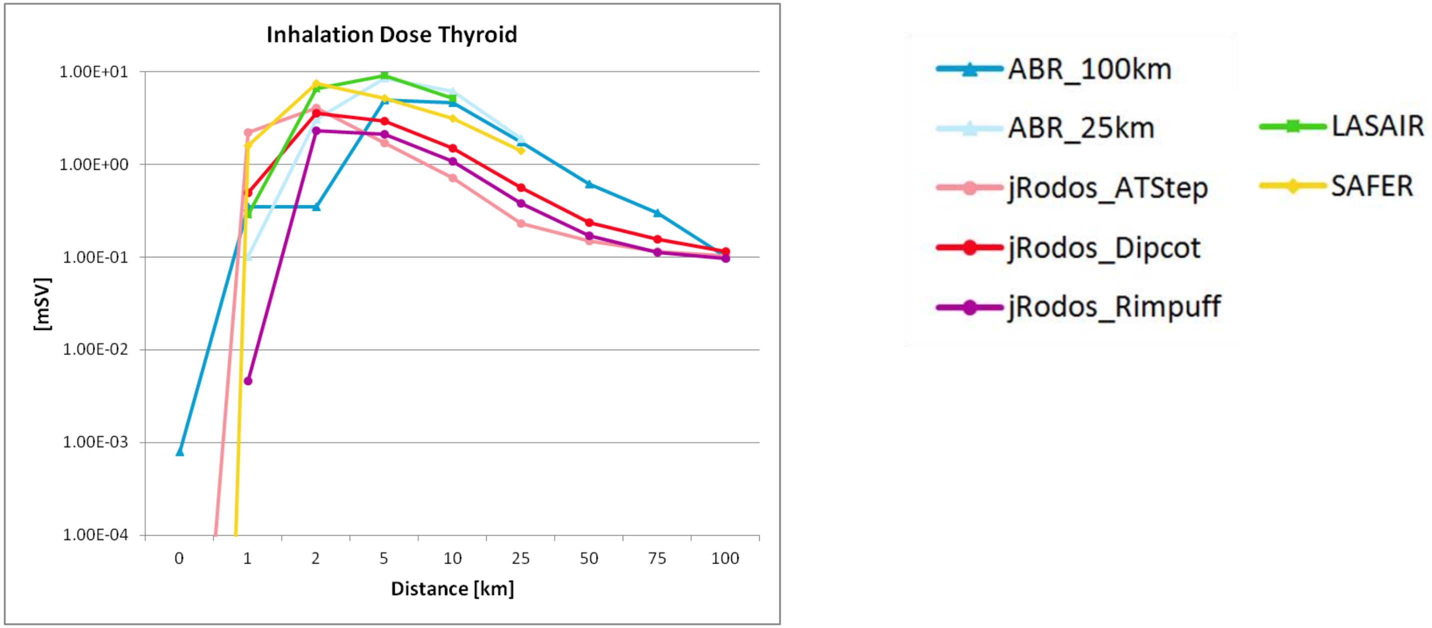
$$D \sim v_d * c(x,y,z=1m)$$

$$W \sim \Lambda_0 * (I/1mm/h)^{\kappa} \int dz\, c(x,y,z)$$

- Larger deviations than expected from the concentration results due to different values for the deposition velocity v_d (aerosol sizes)
- Deviations < factor 10 except near the source (as expected from the concentration results)
- In addition: Sedimentation process in some models (yields to large differences for Cs137)

- Washout is a dominant process
- Very good aggreement for distances above 2km
- Greater deviations near source (grid resolution)
- For 2mm/h Washoutfactors similar
- Thus: vertically integrated concentra- tions are similar for all models

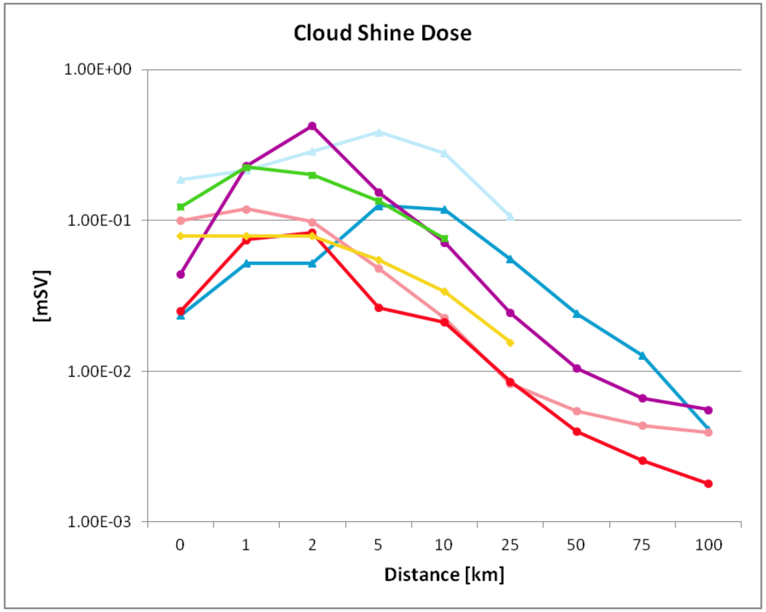
Thyroid inhalation dose for neutral conditions

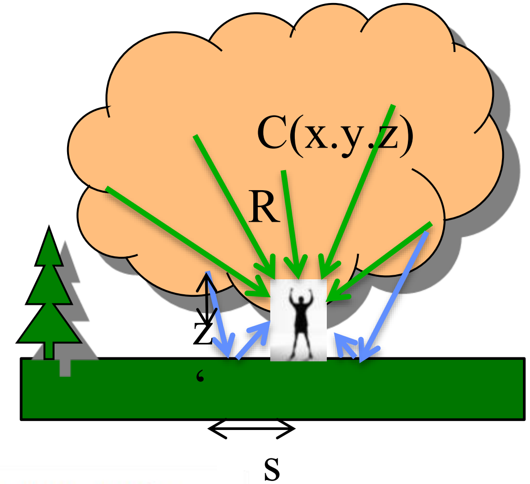


- Inhalation dose is proportional to concentration near ground
- Larger deviations than expected from the concentration results
    - RODOS results differ coherently to the other models
- Reason: usage of different
    - Dose coefficients
    - Rates of inhalation

This may lead to different recommendations for stable iodine blockage

Cloud shine dose for neutral conditions



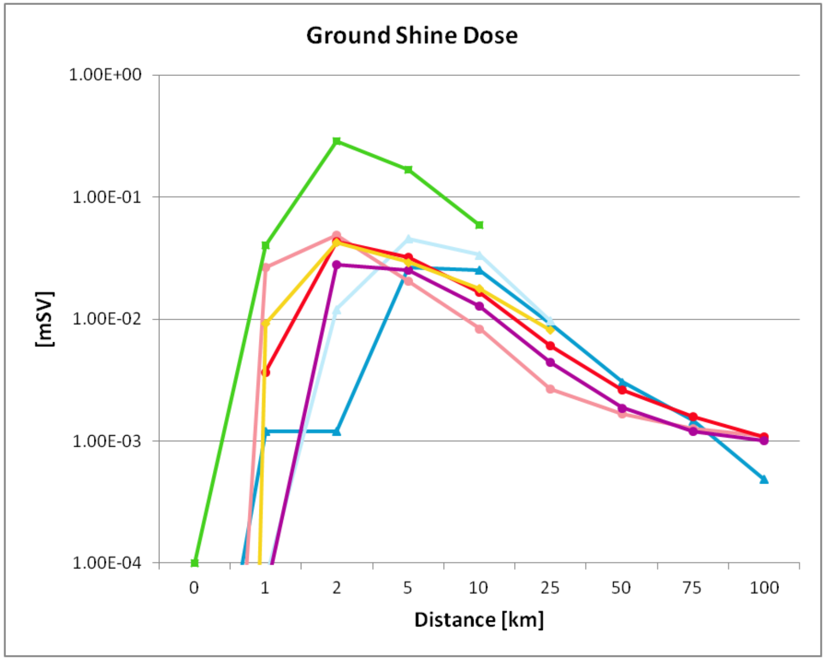


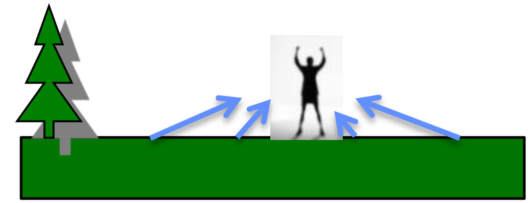
- Larger deviations than expected from the concentration results
  Reasons:
    - 3d-cloud-geometry may be different
    - Different calculation in the models (energy dependency?)

- Dependence on resolution is significant

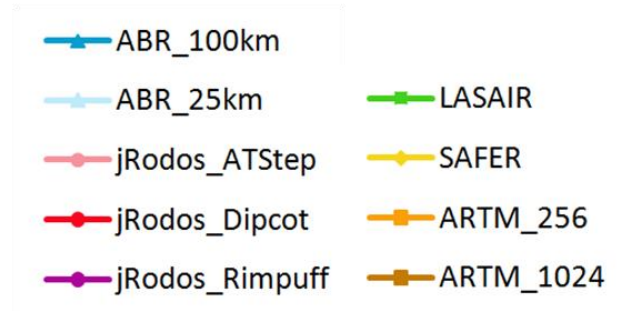
(However, in severe accident inhalation is
in general the dominant pathway)

Ground shine dose for neutral conditions





Dose rate is proportional to deposition on the ground

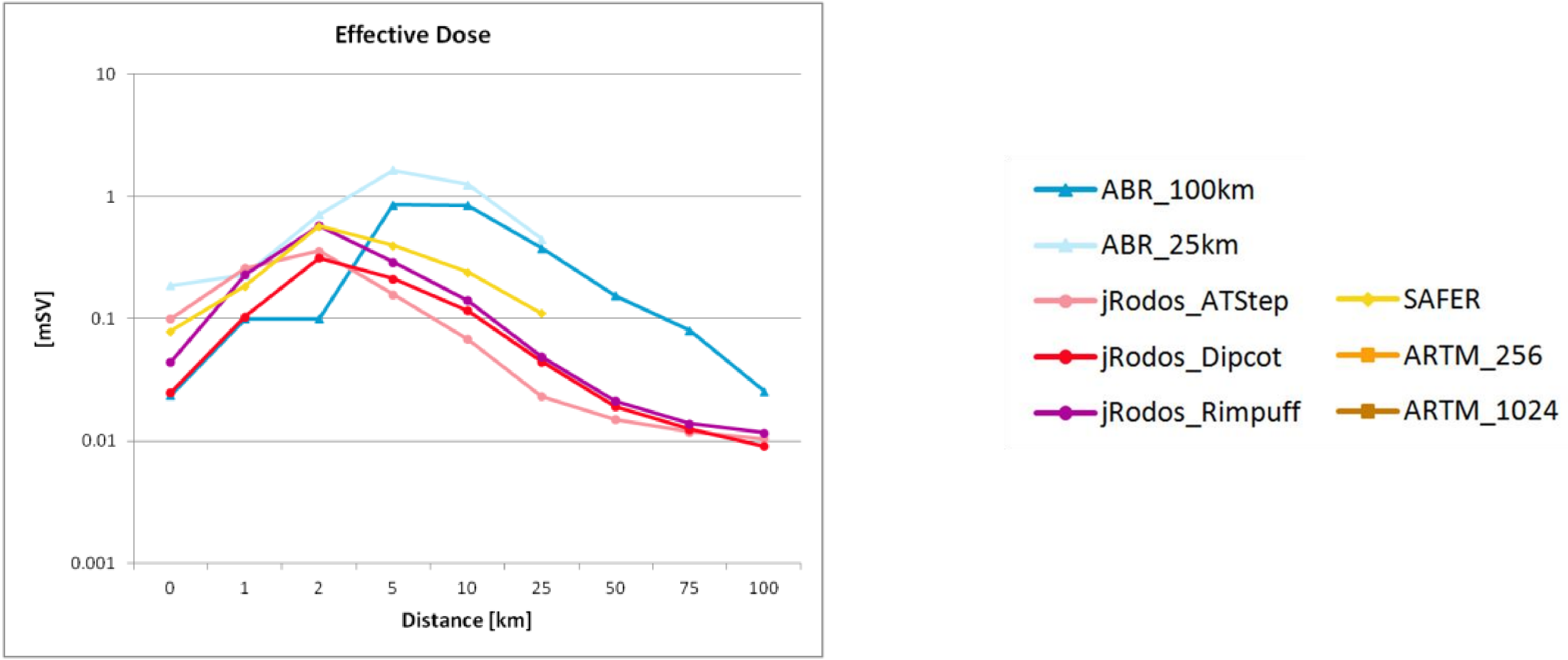


- Deviations as expected from the deposition results
- LASAIR results are significantly higher due to Cs-fallout (sedimentation and bigger aerosol size)
- Importance of integration time (consideration of radioactive decay) :
  - Integration time of 7 days may lead to recommendation for evacuation
  - Different national legal requirements

    Germany: 7 days

    Switzerland: 2 days

Effective dose for neutral conditions



- Differences can be explained by cloud shine and different dose factors

- Application of different models may result in different emergency protection measures, e.g. evacuation vs. shielding (Most important measures in an emergency)

Summary E1 Scenarios

- Reasonable agreement
- Most differences caused by
  - different flow models
  - different turbulence models
  - different model parameters (deposition, dose coefficients)

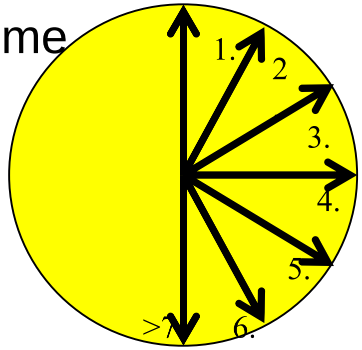
- Different models obviously lead to different recommendations

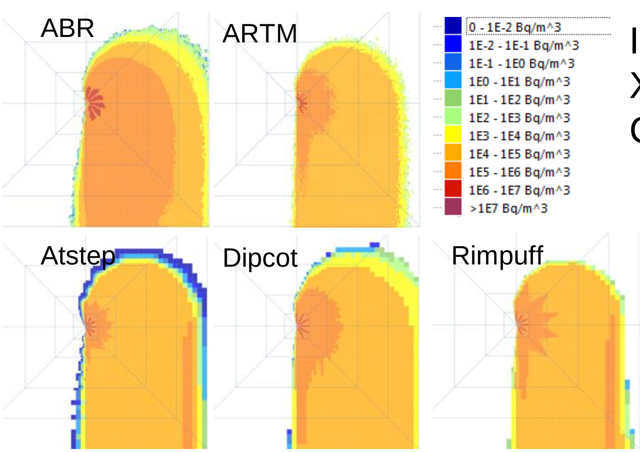
Therefore:

- Harmonisation is definitely needed

Scenario E2: Continous rotation of wind direction.

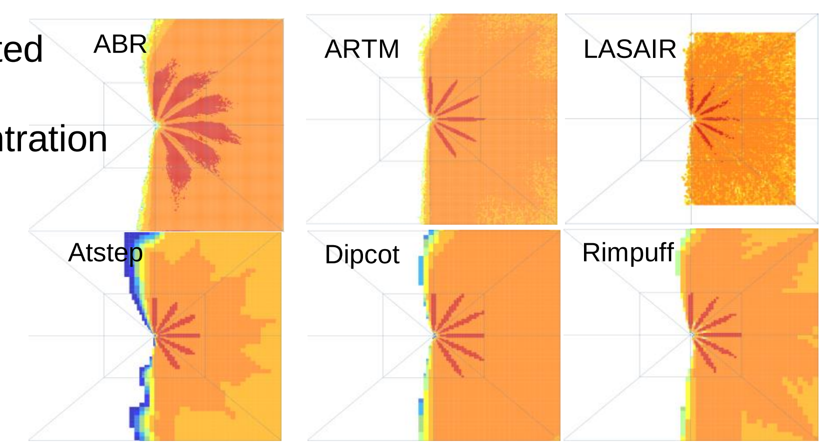
- Release duration: 6 hours; 12 hours simulation time
- Wind velocity at 150m height: 5m/s
- Roughness length: 0.1m
- Rain: No
- Diffusion category D
- Wind rotation from 180° (south) in 30°-Steps to 0° (north)
- Results:
  - Similar for all models !
  - Differences as expected from E1-Scenarios





100km

Integrated Xe133-Concentration

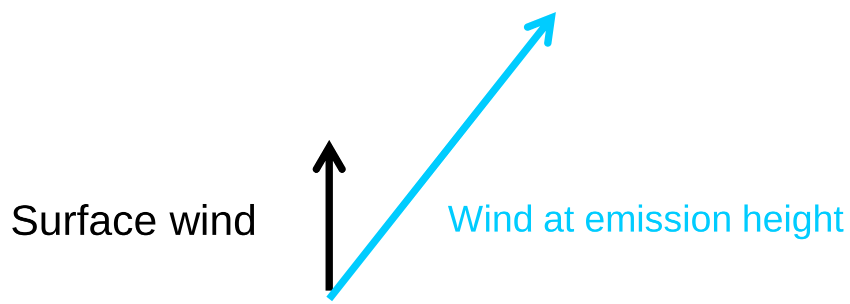


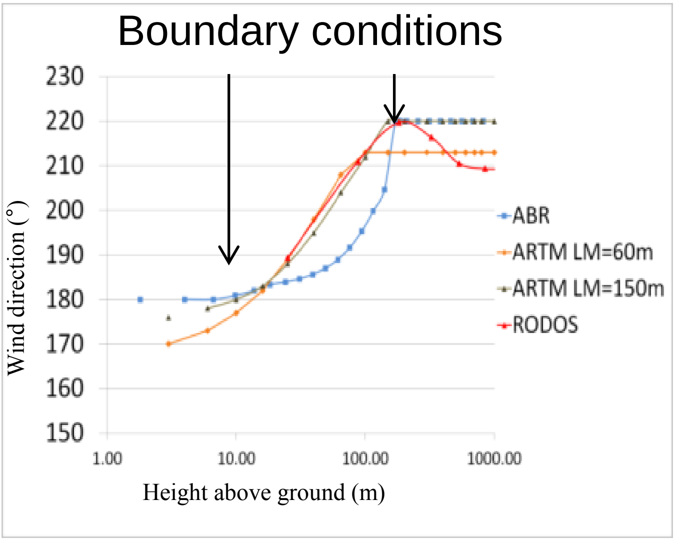
25 km

Simple Scenario E3: Wind shear.

- **Homogenous Wind shear all over the modelling area:**

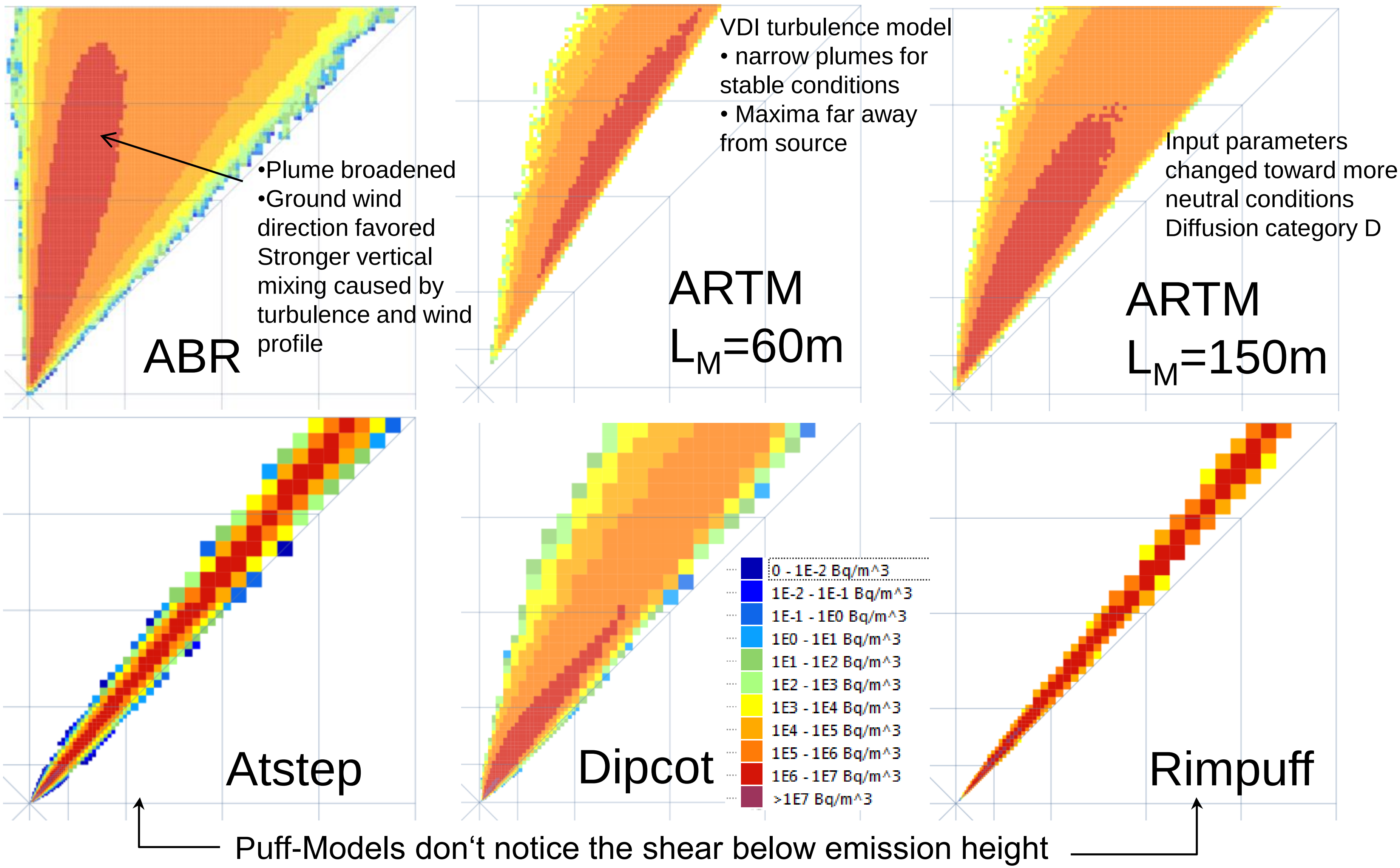
  - 10 m height: 2 m/s, 180°
  - >=150m height (emission): 5 m/s, 220°
  - Roughness length: 0,1m
  - Rain: No
  - Diffusion category: E
  - Only Models RODOS, ABR, ARTM





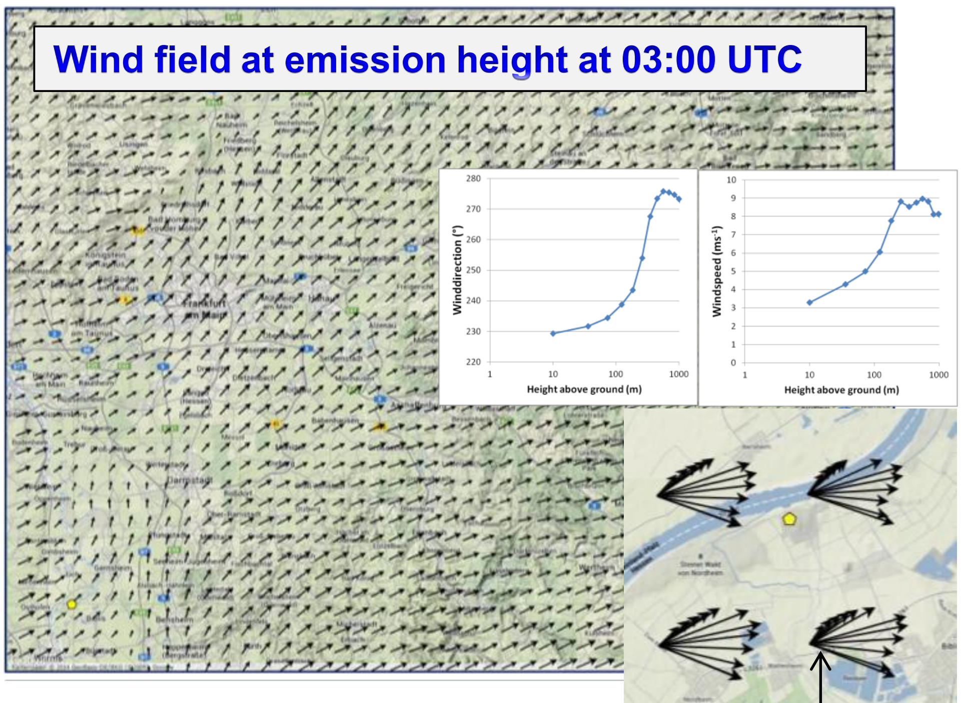
- Expectations:
  - Implemented Puff-Models can‘t describe this situation (release height is above the wind rotation)
  - Strong influence of implemented vertical wind profile and turbulence models

Results E3 for Xe-Concentration near ground.

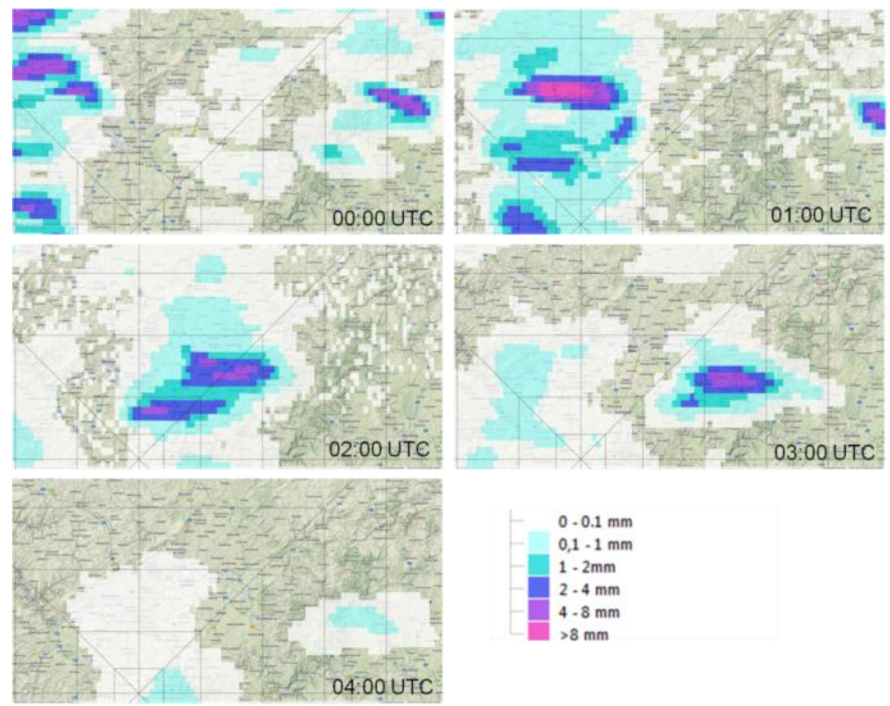


Scenario R1: Realistic meteorological conditions

- Typical weather situation in the Rhine valley (wind shear)
- Nuclear Power plant: Biblis
- Rain: Yes
- 6 Hours emission at stack height (~100m) (same source term as E3)
  - Weather data taken from the COSMO-DE-forecast (DWD)
  - Models: ABR, RODOS and LPDM

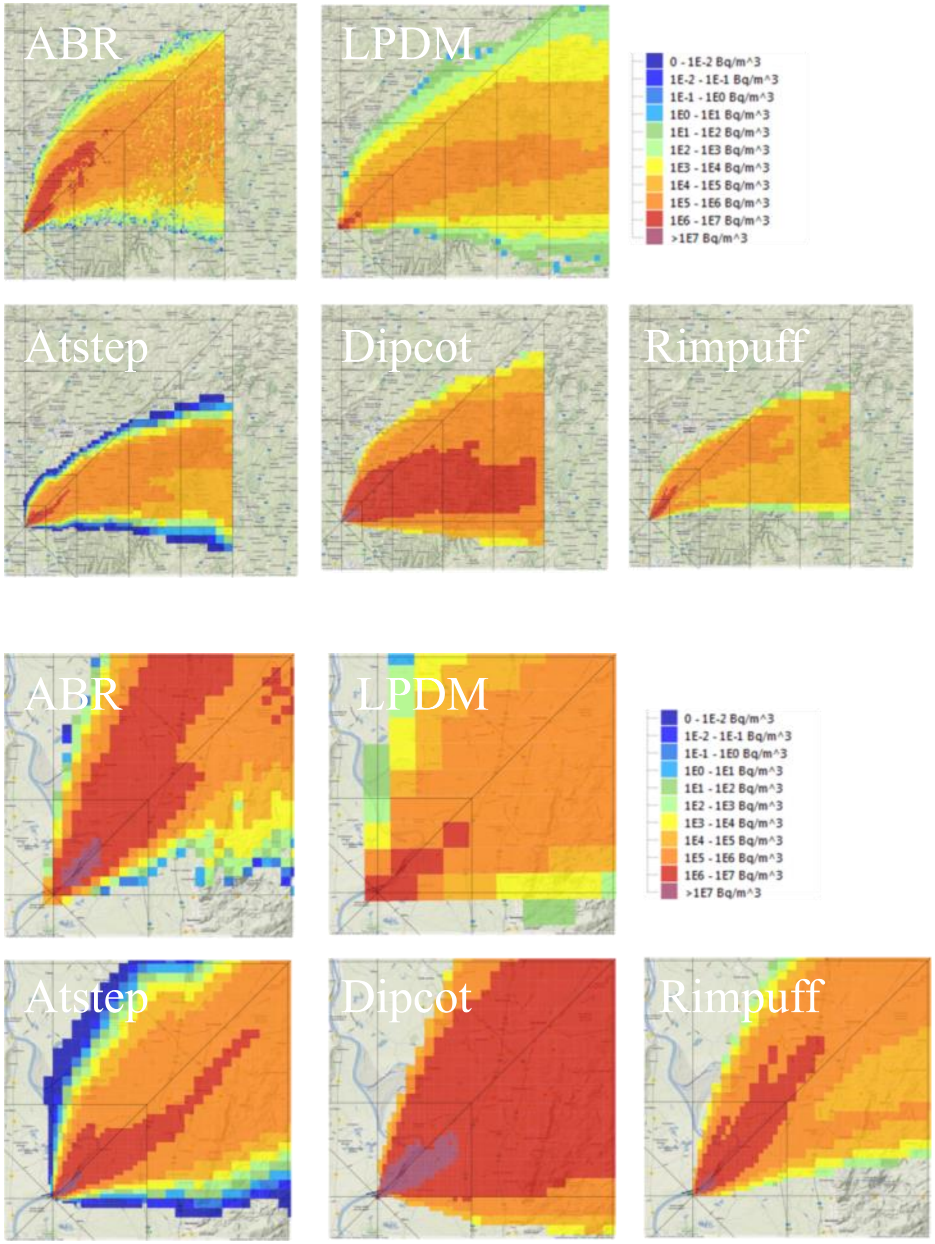


Vertical profile at plant site



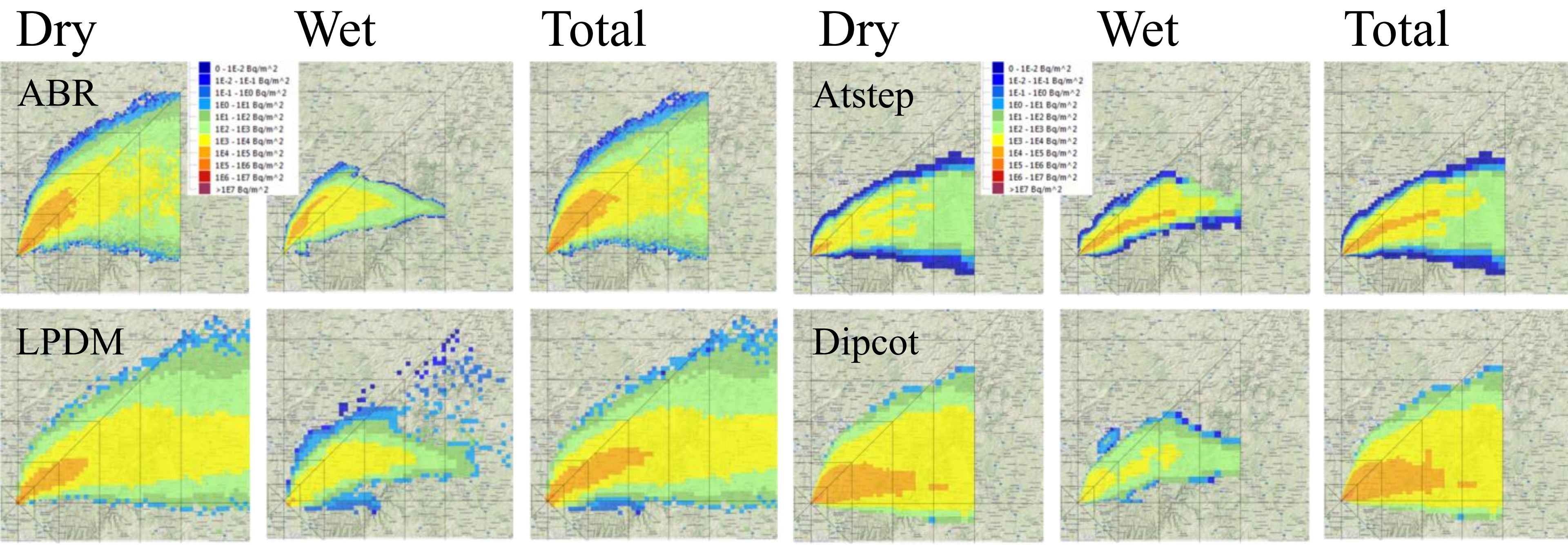
Predicted precipitation in the first 5 hours

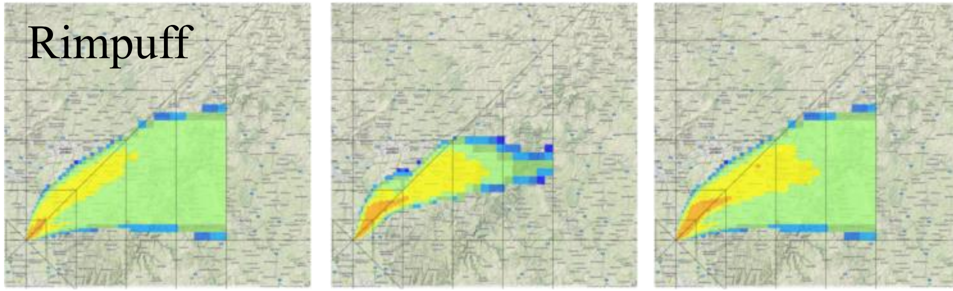
Scenario R1: Results for time-integrated Xe-Concentration.



- Qualitative similar description by all models (much better than in the case of E3 scenario!)
- Position of maxima are different
- Puff models show smaller plumes
- ABR and RIMPUFF favor ground wind direction
- Puff-Models describe the shear (rotation is above emission height)
- Highest values predicted by Dipcot
- In detail significant deviations up to more than 2 orders of magnitude

Scenario R1: Results for Deposition of I131.





- Results are similar
- Inhomogenous precipitation
- Washout stronger in Puff models
- Affected areas similar for
  ABR, LPDM and Dipcot
- Maximum values of total deposition similar for LPDM and Atstep
- Similar results for dose quantities

Recommendations derived in the context of the project.

- Model results should contain the source term and meteorological data (at least as references)
- The calculations should use weather data at different heights in order to minimise the differences caused by the flow models; for forecasts, threedimensional data should be used
- Further harmonisation of models is necessary; procedures for exchange of results should be established (example: Germany and Switzerland)
- More dispersion experiments are needed in the mesoscale region

Summary and outlook.

- Detailed analysis of model behavior for simple and complex scenarios
- Documentation (including model parameters) available
- Qualitatively similar results
- Most of the differences can be explained (except cloud shine dose)

Future investigations may consider

- Very stable (F) and very labile situations (A)
- Influence of orography and buildings
- More realistic source terms
- Comparison of Fukushima calculations
- Comparison of further models

Thank you.
Questions?