Validation of the short term emission approach used in the Atmospheric Radionuclide Transport Model ARTM

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Introduction

For regulatory purposes with respect to licensing and supervision of nuclear installations, the Gaussian plume model is still in use in Germany. However, for complex situations it is to be replaced by a Lagrangian particle model on medium terms. The Atmospheric Radionuclide Transportation Model (ARTM) is available already, which allows the simulation of the atmospheric dispersion of operational releases from nuclear installations. ARTM is based on the program package AUSTAL2000 /JAN03/. In successive research projects ARTM and the accompanying program system were upgraded distinctively. Especially the capability to deal with short term emissions (lasting less than an hour) was introduced.

ARTM

ARTM is an open source realization of the German regulatory guideline VDI 3945 Part 3 on particle models. Processes specifically simulated by ARTM are e.g. radioactive decay of arbitrary nuclides, wet deposition, or the calculation of the gamma rays field out of a plume of radionuclides. Compare Figure 1.

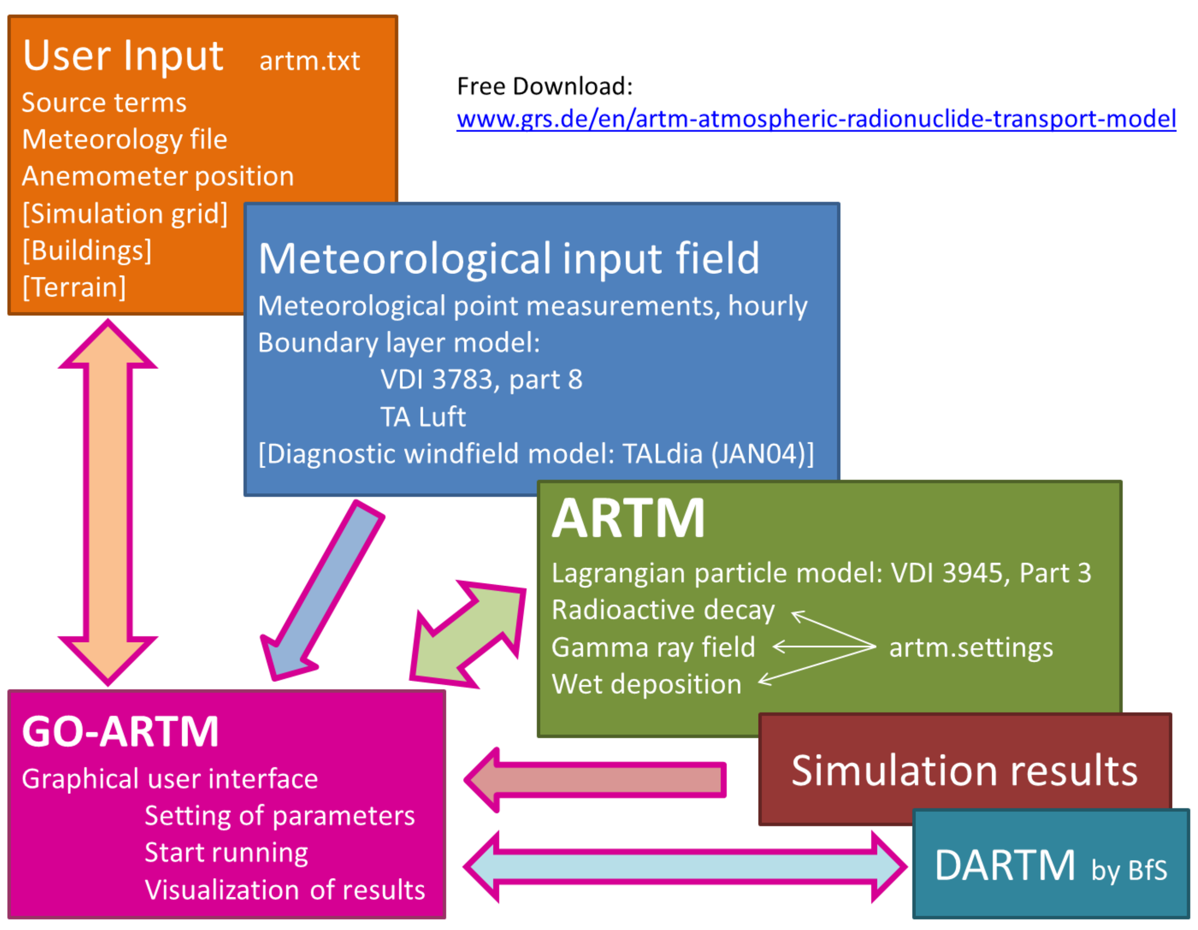

Figure 1: The ARTM-System

To model short term emissions $0.1\text{h} < T < 1.0\text{h} = T_0$, a reduction of the standard deviation of the turbulence parameter horizontal lateral wind speed fluctuation was introduced $\sigma_v(T) = \sigma_v(T_0) \cdot (T/T_0)^X$ with $X = 0.2$ /MAR12/, following the suggestion of /JAN00/.

Near Road Tracer Study 2008

The Near Roadway Tracer Study 2008 (NRTS) is a dispersion study conducted by the Field Research Division of the Air Resources Laboratory of the National Oceanic Atmospheric Administration (NOAA). It took place at the Idaho National Laboratory in October 2008. The study was designed to quantify the effects of roadside sound barriers on downwind air pollutant concentrations stemming from roadway sources /CLA09, FIN10/ (Figure 2 →)

Among other surveying six 3-d sonic anemometers measured the approaching wind and turbulence as well as the barrier-induced turbulence.

Validation

For the validation, the NRTS sonic wind speed measurements of the approaching wind were utilized. For each of the 5 experiments, about 300,000 raw data points are available (3 hours of measurements, sampling interval of 0.1 s, wind speed in x, y and z direction of the stationary coordinate system). The raw data were used to calculate moving means of the horizontal lateral wind speed fluctuations σ_v for increasing averaging intervals between 360s and 3600s. An example is shown in Figure 3.

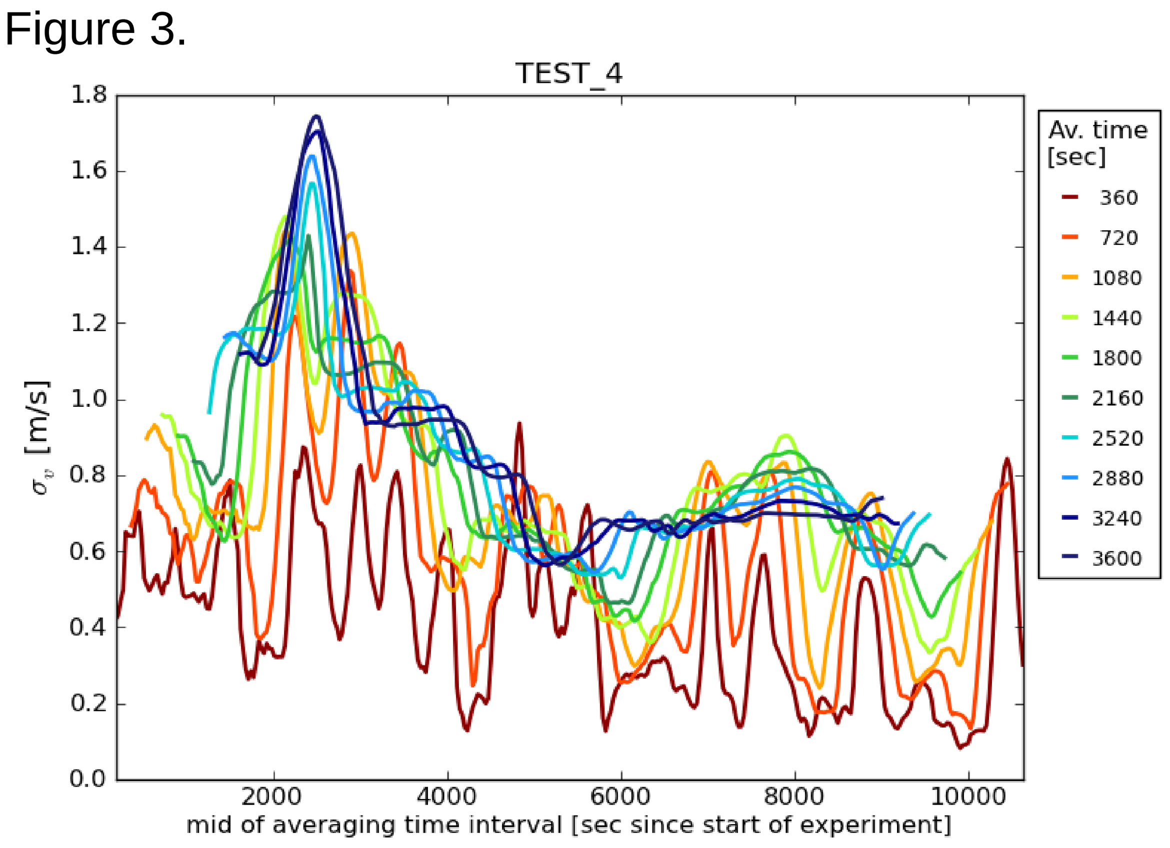

Figure 3: Moving means of horizontal lateral wind speed fluctuations for Test 4 of NRTS

The standard deviations of the horizontal lateral wind speed fluctuations were plotted against the averaging time for multiple timeslices of the tests. Assuming the power law dependence used in ARTM least square fits were used to find an experimental approximation for the exponent X, see example in Figure 4.

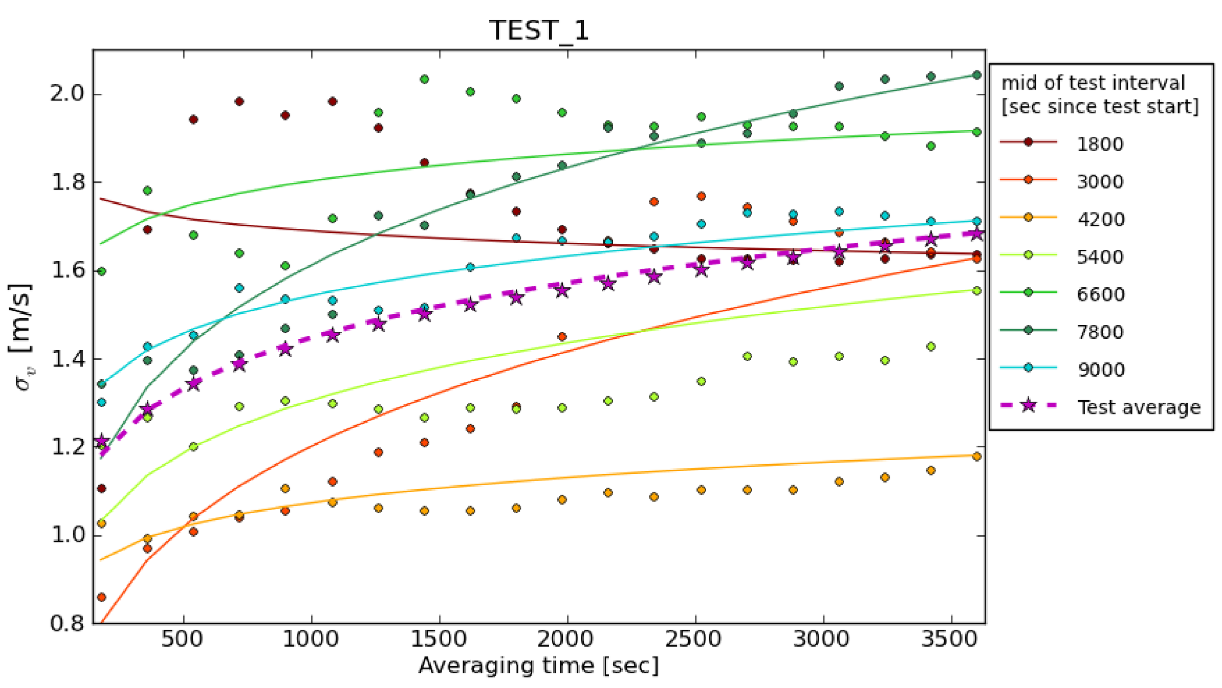

Figure 4: Least square fits for σ_v over averaging time

Figure 2: Aerial view of the mock sound barrier (6m height, 90m length) test site. Source: /CLA09/

Although the individual time slices do not show the assumed power law dependence the test means approximately do. However these mean exponents show a high variance from test to test as documented in the table below and shown exemplarily in Figure 5.

Test Nr.	1	2	3	4	5
Fitted exponent average	0.13	0.08	0.15	0.23	0.38
Pasquille-Gifford stability class	D	A / D	D	E - F	D-E / E-F

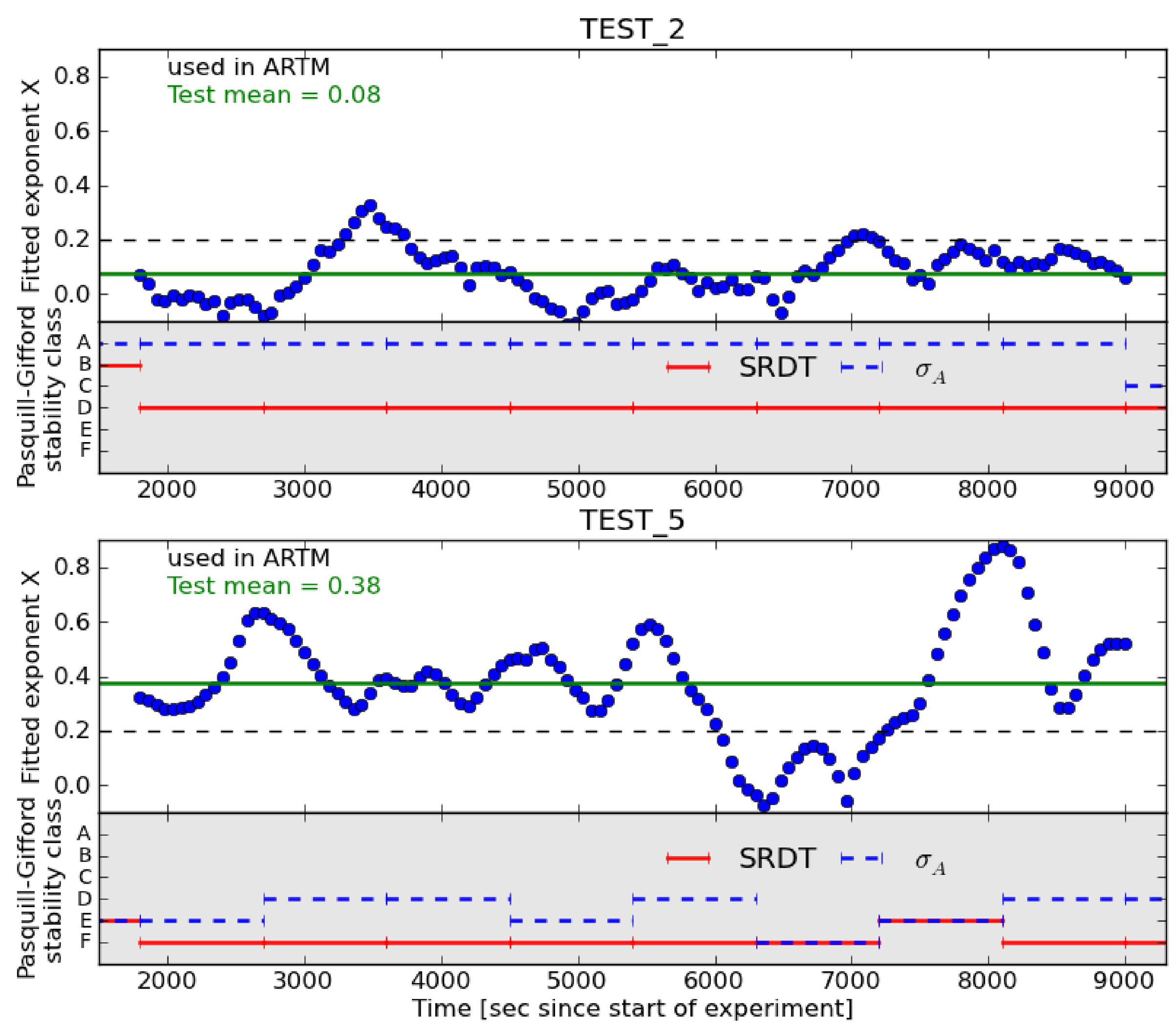

Figure 5: Fitted exponent X and stability class over time.

Results and Discussion

The analysis of the experimental data shows, that the standard deviation of the horizontal lateral wind speed fluctuations doesn't show a uniform dependence on the averaging period. A power law however, seems to be adequate to describe the mean relationship.

The usage of the same function (sole exponent X) for each atmospheric stability class, as done in ARTM so far, shows to be a questionable approach. Especially an underestimation of the model exponent will lead to lower maximum concentrations calculated in simulation for short term emissions compared to results calculated with a proposed higher value (compare Figure 6). As the potential maximum concentration is the crucial parameter for the assessment of design basis events, the model results need to be appropriately conservative in this respect. Whether the used exponent of 0.2 fulfils this requirement (due to ARTM being ample conservative in other model assumptions), has to be evaluated further.

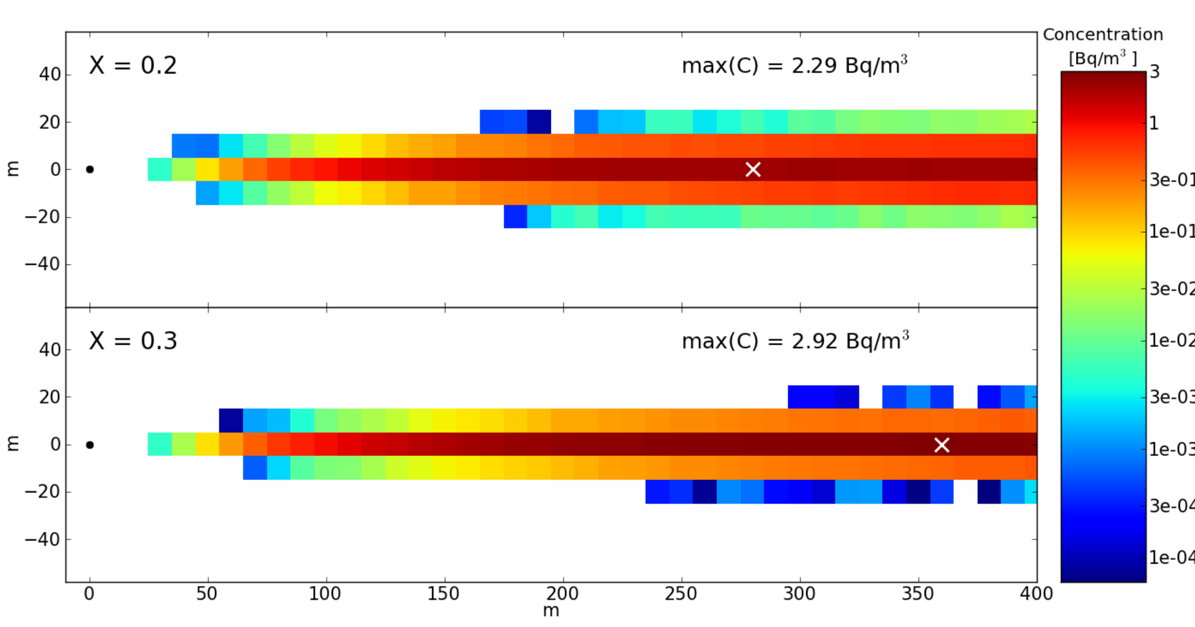

Figure 6: Qualitative comparison of two ARTM simulations for a simple test case: short term emission (360 seconds), stable atmospheric conditions, flat terrain, small aerosols, point source at the origin (black bullet) in 10m height. The location of maximum concentration is marked with a white X.

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