Sensitivity Tests for LPDM

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Abstract

A sensitivity analysis is performed with a Lagrangian Particle Dispersion Model (LPDM). The meteorological input for the LPDM is provided from the limited-area model of MeteoSwiss, the Alpine Model (aLMo), which is the Swiss operational set-up of the COSMO Model (COSMO: Consortium for Small-Scale Modelling). The LPDM concentrations output have been analyzed in order to study the influence of the following parameters: Turbulent kinetic energy, sedimentation velocity, thickness of averaging layer for concentrations, and horizontal drift correction.

The results are evaluated in the present report: An unexpected result was the large impact that the parameterisation of the turbulent kinetic energy, depending on the meteorological conditions, may have. The choice of the parameter "height of the averaged concentration layer" is significant in the beginning of the release: The maximal values of the concentration are factors higher. The other parameters do not affect significantly or not at all the results.

1 Introduction

MeteoSwiss uses the Lagrangian Particle Dispersion Model (LPDM) of the German Weather Service (DWD) for emergency preparedness. In this study, a sensitivity analysis was performed in order to study the influence of some of the steering parameters. The usage of diagnostic turbulent kinetic energy (TKE) from LPDM instead of the prognostic TKE from the numerical weather prediction model is one of the tested steering parameters. A second tested steering parameter is the taking into accout of a sedimentation velocity, which has only recently been added. The output concentrations are averaged over some height above the ground; three choices of the averaging layer have been examined. The influence of a horizontal drift correction term is studied. A steering parameter for the additional output of cross-sections was additionally tested to see whether it has no undesired side effects.

The LPDM was developed by Glaab (1986) at DWD. It is also in use at MeteoSwiss. It may be used operationally for simulating radioactive accidental releases. LPDM predicts the long-range transport, dispersion, sedimentation, wet and dry deposition and the atmospheric concentration of radioactive material.

It has been tested and evaluated several times during different tracer experiments and Inter- comparisons, such as ETEX (Glaab, Fay, and Jacobsen, 1998), ANATEX , CAPTEX, ATMES II, and ENSEMBLE, and the quality of the performance has been demonstrated. Simulations with a LPDM have successfully been established as a useful tool for emergency response requirement in case of accidental releases.

The calculation of trajectories of tracer particles is based on wind fields derived from the limited-area COSMO model at MeteoSwiss, the Alpine Model (aLMo), at hourly intervals. The superimposed turbulent fluctuations (Monte Carlo method) depend on TKE that is either provided by the COSMO model or can be diagnosed within LPDM. The processes of radioactive decay and convective mixing are included. The atmospheric concentration is calculated by counting the particle masses in arbitrary grids (Schättler and Montani, 2005).

The COSMO model was developed within the framework of the Consortium for Small-Scale Modelling. It has been designed for both operational weather prediction and various scientific applications on the meso-β and meso-γ scale (spatial scales where non-hydrostatic effects play an essential role). It is based on the primitive hydro-thermodynamical equations describing compressible non-hydrostatic flow in a moist atmosphere (Doms and Schättler, 2002).

The model equations are solved numerically on a rotated latitude-longitude grid with terrain-following coordinates in the vertical, using an Eulerian finite difference method. A variety of subgrid-scale physical processes is taken into account by parameterization schemes (Doms *et al.*, 2005).

One of the parameterization schemes adopted and implemented for optional use in the COSMO model, related to the fact that it is a non-hydrostatic model, is a scheme for vertical diffusion, based on prognostic treatment of TKE.

2 Method

The sensitivity tests consisted of changing or switching off five LPDM steering parameters, and analyzing the LPDM outputs.

The parameters that are modified and tested in the sensitivity study are the following: Turbulent kinetic energy (parameter LTKE), sedimentation velocity (LSED), output of vertical cross-section (LVERT), averaging of a layer with constant thickness (LIAEA), height of the averaged concentration layer (HMEAN), horizontal drift correction (LDRIFTCH).

The tests, depending on the setting of one of the above-mentioned parameters are named as follows:

- Ref: Reference
- Tst1: LTKE = FALSE
- Tst2: LSED = FALSE
- Tst3: LVERT = FALSE
- Tst4: LIAEA = TRUE, HMEAN = 200
- Tst4a: LIAEA = FALSE
- Tst5: LDRIFTCH = TRUE

The parameter values attributed to the reference are the following:

- LTKE = TRUE
- LSED = TRUE
- LVERT = TRUE
- LIAEA = TRUE, HMEAN = 500
- LDRIFTCH = FALSE

The LPDM analyses have been launched with three separated periods of two days each of meteorological data. Object of the analyses are the near-surface concentration (Bq m^{-3}) outputs from the LPDM. The three days of the dispersion simulation were represented graphically. Theses results have been compared with the reference, and between the sensitivity tests.

3 Data

INPUT DATA: The LPDM sensivity analyses have been launched with three separated two-day periods of meteorological data, provided by aLMo forecast. The meteorological input to LPDM was chosen to represent different wind directions. The aLMo forecasts were from 6/7 October, 12/13 October, and 1/2 November 2006, always starting at 00:00 UTC.

SOURCE TERM: The simulated hypothetical source is located in Beznau, Switzerland (47°33' N, 8°13' E) with the following release characteristics: Release height 30 m above ground level (AGL), emitted substance Cs-137, emission rate 46290 MBq s^{-1}, and duration of the emission 6 hours.

OUTUP DATA: For this study, we used the LPDM concentration output, represented graphically every 6 hours after the release. For each time period, the maximal value of the concentration is given in the Tables 1 – 3.

4 Results

Maxima of the near-surface concentration fields (Bq m^{-3}) obtained for a source localized in Beznau, are given in Table 1, Table 2, and Table 3, with the meteorology for 6/7 October, 12/13 October, and 1/2 November 2006 respectively.

Diagnostic turbulent kinetic energy (Tst1)

The LPDM uses in the reference run the prognostic TKE provided by the COSMO model. For this test, LPDM has been set to use its own, built-in diagnostic scheme to calculate TKE.

Test of 6/7 October
At 6 hours after the event, the propagation of the concentration cloud is slower in Tst1 than in the reference. The surface occupied by the cloud for Tst1 is much larger and more frayed and becomes increasingly large in time. The shape of the cloud in Tst1 is more circular and larger at the beginning. It becomes very quickly larger with time (Fig. 1). The propagation velocity diminishes compared to the reference propagation velocity.

	T_0+06 h	T_0+12 h	T_0+18 h	T_0+24 h	T_0+30 h	T_0+36 h	T_0+42 h	T_0+48 h
Ref	3959.3	551.4	40.054	14.795	13.055	7.3482	4.2925	1.6906
Tst1	4275.9	657.14	20.161	7.4244	5.8462	4.173	1.7024	0.9379
Tst2	3961.2	551.24	40.1671	14.783	12.707	7.0984	4.4746	1.722
Tst3	3959.3	551.4	40.054	14.795	13.055	7.3482	4.2925	1.6906
Tst4	9854.7	1202.7	53.819	15.111	13.842	6.515	6.0063	2.2615
Tst4a	25988.	2547.9	79.642	31.131	25.252	8.5324	9.099	2.6271
Tst5	3960.7	552.17	40.485	14.824	13.033	7.3095	4.6299	1.711

Table 1: Maximal values of concentration obtained by LPDM for the period (T_0 + XX hours) after the release, based on 06 October 2006 aLMo forecast. Blue: minimal value, red: maximal value for the given time.

	T_0+06 h	T_0+12 h	T_0+18 h	T_0+24 h	T_0+30 h	T_0+36 h	T_0+42 h	T_0+48 h
Ref	8269.4	6055.9	1614.1	322.96	136.11	45.916	32.518	19.599
Tst1	8617.4	6665.4	1020.	312.61	86.164	81.412	19.376	11.825
Tst2	8269	6061.8	1618.5	325.15	134.19	42.002	32.911	20.247
Tst3	8269.4	6055.9	1614.1	322.96	136.11	45.916	32.518	19.599
Tst4	20542	12521	1321	199.78	105.31	56.097	29.449	29.6
Tst4a	53430	12636	1378	255.56	140.9	97.408	36.657	71.715
Tst5	8281.3	6070.2	1619.2	319.72	135.54	43.512	32.349	19.276

Table 2: Maximal values of concentration obtained by LPDM for the period (T_0 + XX hours) after the release, based on 12 October 2006 aLMo forecast. Blue: minimal value, red: maximal value for the given time.

	T_0+06 h	T_0+12 h	T_0+18 h	T_0+24 h	T_0+30 h	T_0+36 h	T_0+42 h	T_0+48 h
Ref	1309	147.69	3.6425	0.3639	0.173	0.095	0.074	0.0508
Tst1	1390	145.39	4.427	0.866	0.378	0.141	0.0773	0.058
Tst2	1309	147.67	3.2447	3.3294	0.1672	0.086	0.0069	0.0518
Tst3	1309	147.69	3.6425	0.3639	0.173	0.095	0.074	0.0508
Tst4	2882.7	181.36	5.797	0.523	0.202	0.129	0.1147	0.0765
Tst4a	4695.9	308.74	8.569	0.952	0.367	0.217	0.176	0.124
Tst5	1308.2	147.33	3.3865	0.38962	0.1599	0.0841	0.0670	0.0477

Table 3: Maximal values of concentration obtained by LPDM for the period (T_0 + XX hours) after the release, based on 1 November 2006 aLMo forecast. Blue: minimal value, red: maximal value for the given time.

From the maximum values point of view, maximum concentrations are slightly higher for Tst1 for hours 6 and 12. The situation is reversed the following hours, but in general, the values are not very different thereafter between test and reference.

Test of 12/13 October
For the Tst1 hours 6 and 12, the area of equal concentrations is smaller, the cloud shape is better limited with smoother boundaries, whereas for the 18, 24, 30, 36, and 42 hour following the event, the situation is reversed, the cloud shape is more diffuse and larger.

Test of 1/2 November
The cloud is much larger from the beginning, and more diffuse. The surface covered by the entire cloud is almost doubled, but the surplus of the covered surface is only within the lowest concentration level. The surfaces occupied by the other concentration levels are practically identical with the reference.

The position of the maximum value for tests and reference is the same the first day. From the second day the position is shifted. No great differences between all maximum concentration values are observed. The concentration values are in the same range.

Sedimentation off (Tst2)

The LPMD includes the sedimentation in the modeled processes. This has been turned off for this test.

Tests of 6/7 October, 12/13 October, 1/2 November
Both simulations, reference and Tst2, are identical for each day in form, surface occupied by the same concentration level, and have nearly identical maximum values.

ASCII diagnostic output reduced (Tst3)

Some diagnostic ASCII output is turned off in this test. This should of course not have any

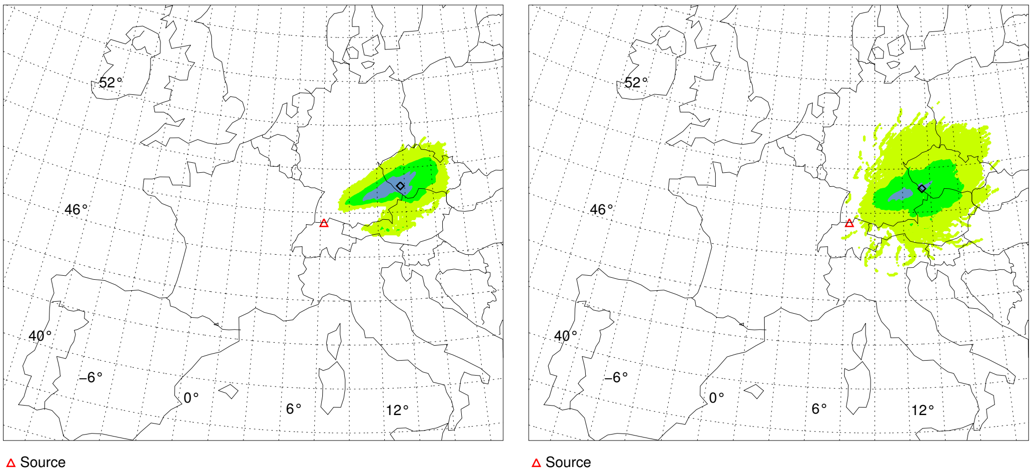

Figure 1: Reference (left; prognostic turbulent kinetic energy from aLMo) and Tst1 (right; diagnostic turbulent kinetic energy) of 6 October 2006. The filled isolines show the near-surface concentrations expressed in Bq m^{-3} of the ranges <1, 1 – 10, 10 – 100 (not visible: 100 – 1000, 1000 – 10000, >10000). The black diamond marks the location of the maximum value.

effect on the concentrations. Nevertheless it is tested here because we will operationally use a different setting than that of the DWD.

Test of 6/7 October, 12/13 October, 1/2 November
The tests repeat in an identical way the results of reference (same surface occupied by the same concentration level, equal maxima values), as expected.

Averaging layer reduced to 200 m (Tst4)

In emergency response systems, the average concentration over the lowest 500 m AGL is normally used for decision support. In this test, the concentration is averaged over the lowest 200 m AGL only.

Test of 6/7 October
The form and the surface of the concentration isolines are almost identical for both tests. On T_0+24, the position of the concentration peak is moved towards the North-East for the Tst4, and then starts to decrease slowly compared with the reference test. The maxima of concentrations are higher by factors for the Tst4 at the beginning (first 6 and 12 hours) of the event. Later on, the values become almost identical.

Test of 12/13 October
Referring to the first 6, 12, 18 and 24 hours, the form and the surface of the concentration isolines are identical for test and reference. For the remaining hours, the surface taken from the contaminated territory is slightly lower for the Tst4. The maxima of concentrations are largely higher than in the beginning (first 6 and 12 hours) of the event for the Tst4. The situation is reversed during the next 18, 24 and the 30 hours.

Test of 1/2 November
The shape of the surfaces covered by the same level of concentration is the same. Maximum values are increasingly higher compared to the test of reference.

Concentration of lowest model layer (Tst4a)

In this test, the concentration is averaged over the lowest aLMo layer only (approx. 60 m

AGL).

Test of 6/7 October
For the reference, the concentration levels are more concise. The form and the surface of the concentration are almost identical for test and reference. At the time T_0 + 24 h, the surface occupied by the Tst4a cloud is slightly smaller than the one in the reference and more limited from the north-east side.

The maxima of the concentrations for Tst4a are much higher than the reference at the beginning of the event (at 6 and 12 hours, roughly 5 and 4 times, respectively). It remains always higher at later times, but not as much as at the beginning.

Test of 12/13 October
In the reference, the levels of concentration are more concise. For the test Tst4a, after 24 hours, the surface occupied is smaller compared to the reference (Fig. 2) and becomes increasingly limited with time toward the north. The maxima of concentrations are much higher than in the reference at the beginning of the event (at 6 and 12 hours, almost by a factor of 6 and 2, respectively) for the Tst4a. The situation is reversed at 18 and 24 hours. It is in Tst4a that we find the highest peaks among all tests, except for the hours 18 and 24.

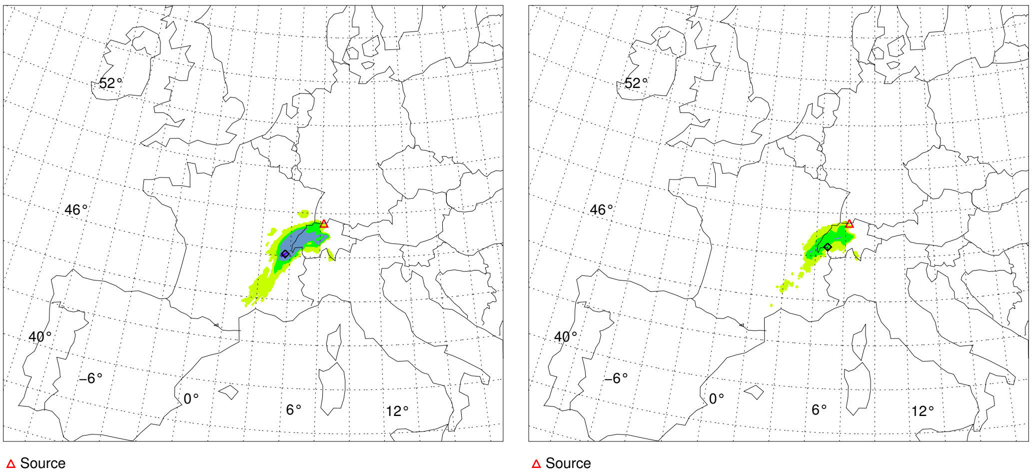

Figure 2: Reference (left; concentration in lowest 500 m above ground) and Tst4a (right; concentration in the lowest aLMo model layer) of 12 October 2006. Scale as in Figure 1.

Test of 1/2 November
The contours are less frayed; the form is much more restricted, and with higher concentrations during the simulation period. Higher maximum values occur during the whole period. The maximum value is more than 3 times bigger at the end of the first 6 hours.

Horizontal drift correction (Tst5)

The horizontal drift correction term in the equation of motion is turned on for this test. Its effect is usually small, so that it can be neglected.

Test of 6/7 October, Test of 12/13 October, Test of 1/2 November
The maximum concentrations values, the shape of the cloud as well as the surfaces occupied are identical for both reference and Tst5. Only for the test from 1/2 November, maximum values are very slightly lower.

5 Generalization in terms of cloud properties

Cloud shape: The shapes are identical (plume shape) for all tests, except for Tst1. For Tst1 with the meteorological data from the 6/7 October 2006, the cloud appears larger; round shaped, and later becomes rather circular and much dispersed (Fig. 1). For the tests with the meteorology from the 12/13 October 2006, Tst1 is much more dispersed. For the tests with the meteorology from the 1/2 Novermber 2006, the cloud shape for the Tst1 is larger and more diffuse. For this time period, the Tst4 and 4a cloud becomes smaller starting at 18 hours.

Covered surface: The occupied surface from the same level of concentrations is identical for all tests, except for the Tst1, where the cloud appears larger and occupies a very broad territory at the end of the period of observation.

Direction of cloud propagation: As intended, according to the variing weather data inputs, the directions of the pollutant cloud propagation are different: On October 6/7 the cloud is directed towards east-north-east, on October 12, the direction is towards south-west, while on November 1/2 the direction is towards south-est.

Maximum values of concentration:
The Tst3 results match completely with those of the reference. The values obtained for the maxima concentration are equal.

The Tst2, Tst3 and Tst5 results are not very different from each other, as well as compared with the references. In the first 6 hours after the release, the differences between the maximum concentrations values are very large, corresponding to different parameterizations: almost 5 times.

We can generalize that the test Tst4a has the most increased concentration among all tests.

6 Conclusions

1. Depending on the meteorological input, the parameterization of the turbulent kinetic energy may play an important role (Fig. 1). Although some change was to be expected, the extent of the change was not expected, because diagnostic and prognostic TKE describe the same physical measure of the turbulence.

2. The height of the constant-height averaging layer influences the results strongly (Fig. 2) with various duration depending on the examined meteorological conditions.

3. The influence of the sedimentation velocity and the correction of the horizontal drift are negligible for the in-air concentration under the considered meteorological conditions.

4. The printout of vertical cross-sections does not affect the results at all. This is as it should be.

References

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