21st International Conference on
Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes
27-30 September 2022, Aveiro, Portugal

OPERATIONAL DISPERSION ENSEMBLE AT METEOSWISS

Pirmin Kaufmann[1] and Stefan Rüdisühli[2]

[1]Federal Office for Meteorology and Climatology MeteoSwiss, Zurich Airport, Switzerland
[2]Institute for Atmospheric and Climate Science, ETH Zurich, Zurich, Switzerland

Abstract: In the first hours of an accidental dispersion of airborne hazardous material, emergency response heavily relies on forecasting the expected plume with an atmospheric transport model. Such a prediction of atmospheric dispersion is, however, inherently uncertain. The two main sources of uncertainty are the source term and the meteorological prediction. In the short term, the source term is often largely unknown and the most important goal of the dispersion simulation is determining the potentially affected area. The meteorological uncertainty, which can lead to completely different affected areas depending on the meteorological evolution, should be the main concern at that stage. In numerical weather prediction, the common way to quantify the uncertainty of the meteorological evolution is by conducting ensemble simulations. At MeteoSwiss, this approach has now been extended operationally to dispersion simulations. To this end, a 21-member meteorological ensemble drives a 21-member dispersion ensemble. The probabilistic dispersion forecasts are calculated routinely for a predefined set of standardized source terms, covering the four nuclear power plant sites in Switzerland and a few in neighboring countries. These routine forecasts are updated every six hours and cover 48 hours after initialization time. On-demand calculations are also available and can be requested by the Swiss National Emergency Operations Centre (NEOC). The probabilistic results are visualized as charts that depict, in several ways, the ensemble minimum, mean and maximum, as well as quantiles and probabilities. A first preoperational set of charts have been routinely delivered to the NEOC since May 2021, and the operational production in the final setup started in December 2021.

Key words: *ensemble dispersion modeling, visualization, emergency response, nuclear emergency preparedness, atmospheric dispersion model, meteorological uncertainty, ensemble prediction*

INTRODUCTION

After an accidental release of airborne hazardous material, emergency response during the early stage relies heavily on atmospheric dispersion simulations. Until recent years, these simulations were commonly based on single deterministic runs of a meteorological model. Sørensen et al. (2020) identified two main sources of uncertainty in atmospheric dispersion simulation results: the source term and the meteorological prediction. They state that while the former may be better dealt with by using a scenario-based approach, the latter can be estimated in a straightforward fashion by using ensemble simulations. With the recent advent of ensemble models in operational numerical weather prediction (NWP), the opportunity arose to likewise run multiple instances of an atmospheric dispersion model, driven by different members of the meteorological ensemble, as a way to account for the uncertainty of the meteorological situation. Efforts toward this goal are documented, e.g., in Leadbetter et al. (2020). We present below the new operational dispersion ensemble system by the Federal Office for Meteorology and Climatology MeteoSwiss.

OPERATIONAL SETUP AT METEOSWISS

From 2019 to 2021, MeteoSwiss implemented an ensemble dispersion simulation system. It is based on the COSMO NWP model (Baldauf 2011). The operational COSMO-1E and COSMO-2E setups at MeteoSwiss, with grid spacings of respectively 1.1 km and 2.2 km, are meteorological ensembles driven by boundary conditions from the global ECMWF IFS-ENS ensemble (Leutbecher et al., 2017). In Rüdisühli and Kaufmann (2020), we described a preoperational 11-member dispersion ensemble based on COSMO-1E. For rountine operations, however, we decided to switch to a 21-member ensemble based on COSMO-2E. Our main motivation was the longer forecast duration of COSMO-2E, which integrates 120 h into the future, while COSMO-1E produces only 33 hour forecasts. Experience during the preoperational phase in 2021 showed that 33 hours of simulation is often not enough for the cloud to reach the model boundary. In addition, a dispersion ensemble based on COSMO-2E has the advantage of almost twice the number of ensemble members and of a smaller computational footprint thanks to the lower resolution (doubling the horizontal grid spacing reduces the total number of grid cells by a factor of four). The dispersion ensemble uses all 21 members of COSMO-2E to generate a dispersion ensemble with the particle dispersion model FLEXPART (Pisso et al. 2019) in a version adapted to COSMO output (Henne et al., 2016). Both COSMO-2E and the dispersion ensemble are running every six hours, providing probabilistic dispersion forecasts out to 48 hours. They are calculated routinely for a predefined set of standardized source terms, covering the four Swiss nuclear power plants and two sites in neighboring countries close to the Swiss border. On-demand calculations can be requested by the Swiss National Emergency Operations Centre (NEOC; “NAZ” in German) and are started by the bench forecaster at MeteoSwiss. The set of charts produced in the preoperational phase since May 2021 and during the second half of 2021 have been reviewed and optimized together with the NEOC and the Swiss Nuclear Safety Inspectorate (ENSI). On 7 December 2021, the dispersion ensemble was operationalized.

OPERATIONAL SET OF PROBABILISTIC CHARTS

The probabilistic results derived from the dispersion ensemble are visualized as charts depicting ensemble minimum, mean and maximum, as well as quantiles and probabilities, in several ways. The charts from the routine production cycle have been sent to the NEOC as test deliveries since May 2021 and operationally since 7 December 2021.

Probabilites

The probability of a property is calculated separately for each model grid cell from the number of ensemble members that exhibit it. In Figure 1, the property of interest is nonzero activity concentration, shown for four different forecast times. Probability of integrated concentration, deposition, and affected area are visualized in the same way. (The affected area is defined as the union of nonzero activity concentration in the lowermost 500 m AGL and nonzero total deposition at the surface.)

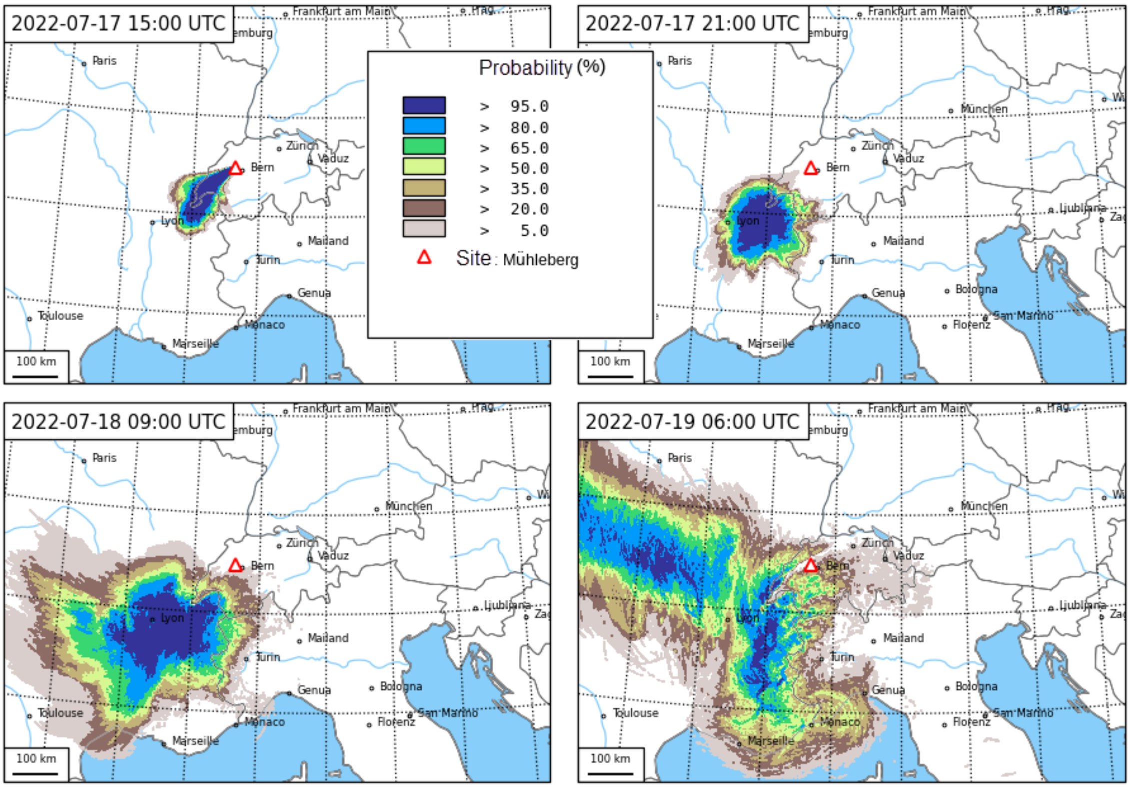

Figure 1. Probability of nonzero activity concentration in the lowest 500 m AGL, for a hypothetic release during 6 h at Mühleberg (red triangle), for 6, 12, 24, 45 h after begin of release.

Percentiles and Other Ensemble Statistics

A percentile of a quantity is calculated separately for each model grid cell from the values of that grid cell in all ensemble members. For integrated concentration (example in Rüdisühli and Kaufmann (2020) for an 11-member instead of a 21-member ensemble) and deposition (example in Figure 2), the 5th, 50th, 75th, 95th percentiles are shown as four-panel plots. The 95th percentile is drawn on separate charts for these quantities, and additionally for activity concentration and affected area.

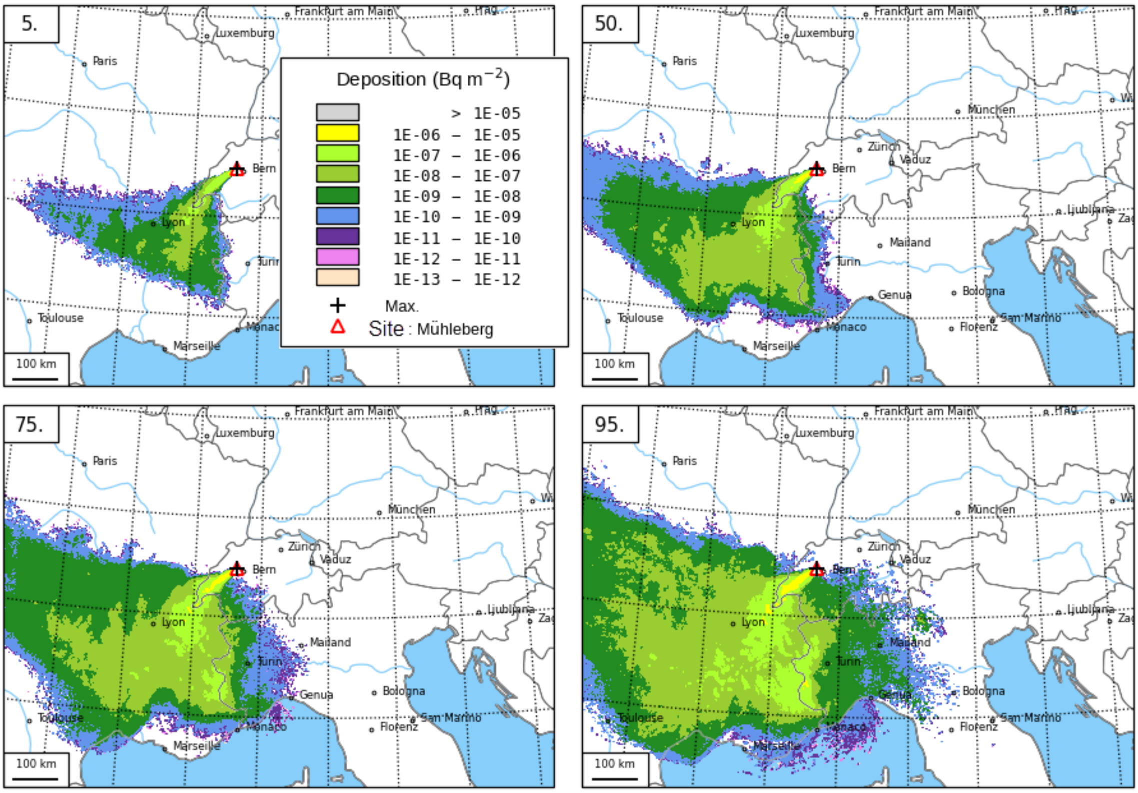

Figure 2. Percentiles of accumulated deposition, for a hypothetic release of 21.6 kBq during 6 h at Mühleberg (red triangle); 5th, 50th, 75th, 95th percentile at end of simulation (45 h after begin of release).

In addition to percentiles, other ensemble statistics are charted, namely the minimum, the mean and the maximum for all quantities.

Cloud Timing

An example of an arrival time plot is show in Figure 3. The color scale has been changed since a similar chart appeared in Figure 2 of Rüdisühli and Kaufmann (2020), in response to a request by the product user (NEOC) to increase the contrast between successive levels. An equivalent plot for departure time (not shown) is also produced. The two plots show at each model grid cell the time until the number of ensemble members with nonzero concentration increases above two for arrival time or decreases below two for departure time.

CONCLUSION AND OUTLOOK

We present a set of chars that have been routinely produced for emergency preparedness for half a year. How the uncertainty information provided by the dispersion ensemble is best integrated in the decision making process remains to be seen. Experience with the plots will grow over time, which will likely lead to further modifications in the time to come.

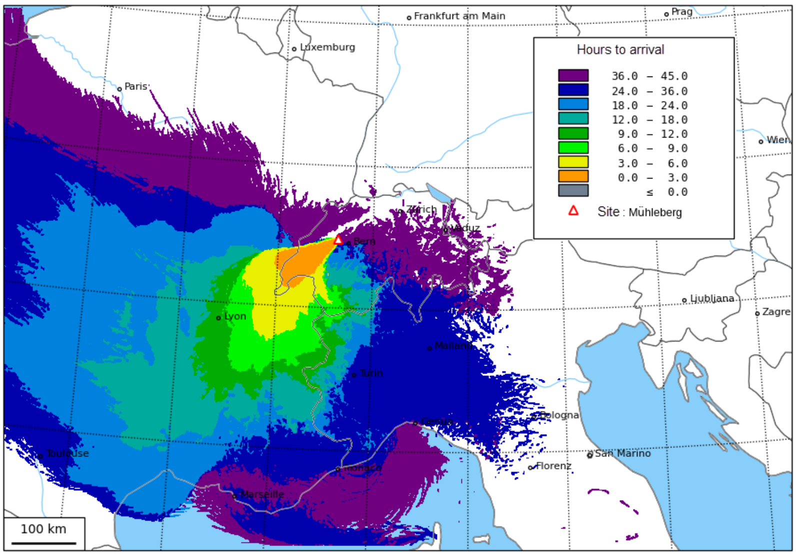

Figure 3. Ensemble cloud arrival time in hours after the start of the same hypothetical release at Mühleberg (red triangle). The arrival time is defined as the first time after the release when two or more ensemble members have nonzero concentrations, excluding only the most cloud-free member at each grid point.

REFERENCES

Baldauf, M., A. Seifert, J. Förstner, D. Majewski, M. Raschendorfer, and T. Reinhardt, 2011: Operational convective-scale numerical weather prediction with the COSMO model: Description and sensitivities. *Monthly Weather Review* 139 (12), pp 3887-3905. https://doi.org/10.1175/MWR-D-10-05013.1

Henne, S., Brunner, D., Oney, B., Leuenberger, M., Eugster, W., Bamberger, I., Meinhardt, F., Steinbacher, M., and Emmenegger, L. , 2016: Validation of the Swiss methane emission inventory by atmospheric observations and inverse modelling, Atmos. Chem. Phys., 16, 3683–3710, https://doi.org/10.5194/acp-16-3683-2016.

Leadbetter SJ, Andronopoulos S, Bedwell P, Chevalier-Jabet K, Geertsema G, Gering F, Hamburger T, Jones AR, Klein H, Korsakissok I, Mathieu A, Pázmándi T, Périllat R, Rudas Cs, Sogachev A, Szántó P, Tomas JM, Twenhöfel C, de Vries H, Wellings J., 2020: Ranking uncertainties in atmospheric dispersion modelling following the accidental release of radioactive material. *Radioprotection*, 55(HS1): S51–S55, https://doi.org/10.1051/radiopro/2020012

Leutbecher, M., Lock, S.-J., Ollinaho, P., Lang, S. T. K., Balsamo, G., Bechtold, P., Bonavita, M., Christensen, H. M., Diamantakis, M., Dutra, E., English, S., Fisher, M., Forbes, R. M., Goddard, J., Haiden, T., Hogan, R. J., Juricke, S., Lawrence, H., MacLeod, D., Magnusson, L., Malardel, S., Massart, S., Sandu, I., Smolarkiewicz, P. K., Subramanian, A., Vitart, F., Wedi, N. and Weisheimer, A., 2017. Stochastic representations of model uncertainties at ECMWF: state of the art and future vision. *Q. J. R. Meteorol. Soc.*, 143, 2315–2339, https://doi.org/10.1002/qj.3094.

Pisso, I., Sollum, E., Grythe, H., Kristiansen, N. I., Cassiani, M., Eckhardt, S., Arnold, D., Morton, D., Thompson, R. L., Groot Zwaaftink, C. D., Evangeliou, N., Sodemann, H., Haimberger, L., Henne, S., Brunner, D., Burkhart, J. F., Fouilloux, A., Brioude, J., Philipp, A., Seibert, P., and Stohl, A., 2019: The Lagrangian particle dispersion model FLEXPART version 10.4, *Geosci. Model Dev.*, 12, 4955–4997, https://doi.org/10.5194/gmd-12-4955-2019.

Rüdisühli, S., and P. Kaufmann: Visualization of ensemble dispersion simulations at MeteoSwiss. 20th International Conference on Harmonisation within Atmospheric Dispersion Modelling for Regulatory Purposes, 14-18 June 2020, Tartu, Estonia. Available from https://www.harmo.org/Conferences/Proceedings/_Tartu/publishedSections/H20-104_stefan_ruedisuehli.pdf

Sørensen, J. H., J. Bartnicki, A. M. Blixt Buhr, H. Feddersen, S. C. Hoe, C. Israelson, H. Klein, B. Lauritzen, J. Lindgren, F. Schönfeldt, and R. Sigg, 2020: Uncertainties in atmospheric dispersion modelling during nuclear accidents. *Journal of Environmental Radioactivity*, 222, https://doi.org/10.1016/j.jenvrad.2020.106356.