Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Home Affairs FDHA
**Federal Office of Meteorology and Climatology MeteoSwiss**

MeteoSwiss

C2SM
Center for Climate Systems Modeling

ETH zürich

# Visualization of Ensemble Dispersion Simulations at MeteoSwiss

Stefan Rüdisühli[1], Pirmin Kaufmann[2]

[1]Center for Climate Systems Modeling (C2SM), ETH Zurich, Zurich, Switzerland

[2]Federal Office of Meteorology and Climatology MeteoSwiss, Zurich-Airport, Switzerland

## Background

In response to emergencies such as the release of radioactivity into the atmosphere, decisions on countermeasures rely to a large degree on atmospheric dispersion simulations driven by the results of numerical weather prediction (NWP) models. Recent advancements in NWP models include kilometer-scale grids able to resolve winds and precipitation at increasingly local scale, with direct implications for dispersion simulations. A crucial step taken by many weather services in recent years has been the introduction of ensemble forecast systems, in which the traditional deterministic ”single-best estimate” run is complemented by an ensemble of slightly perturbed runs. The resulting forecast range serves to estimate the meteorological uncertainty.

The challenge of concisely visualizing the results of ensemble forecasts is exacerbated in the field of emergency response, where products conveying all information required for quick decisions on countermeasures must be easily understood even by nonexperts. Other meteorological offices are facing this very same challenge (e.g. Leadbetter et al. 2020; Sørensen et al. 2020), but a generally accepted solution has yet to be found.

## Cloud Arrival Time

Figure 1 shows the time until a cloud or contaminated air is first expected to arrive at a given location, measured from the start of the release. The cloud is defined based on the full 21-member ensemble minus the most extreme member at each point, corresponding to a 5% probability. From the release site in Beznau, the cloud quickly moves westward, reaching Basel within 3 h and then traversing the border into France, where it continues on a more northwestward path to reach the Atlantic coast within 18 h. It takes longer for the cloud to reach areas east of Beznau, although by the end of the forecast after 45 h it extends all the way into Poland and eastern Austria. The Valais and Ticino region of Switzerland, most of Italy and all but the northeastern part of France (which notably includes Paris) are spared. By providing a conservative estimate of the first cloud arrival time in different regions, this product can guide aspects of emergency response like shelter orders or activities relying on uncontaminated air.

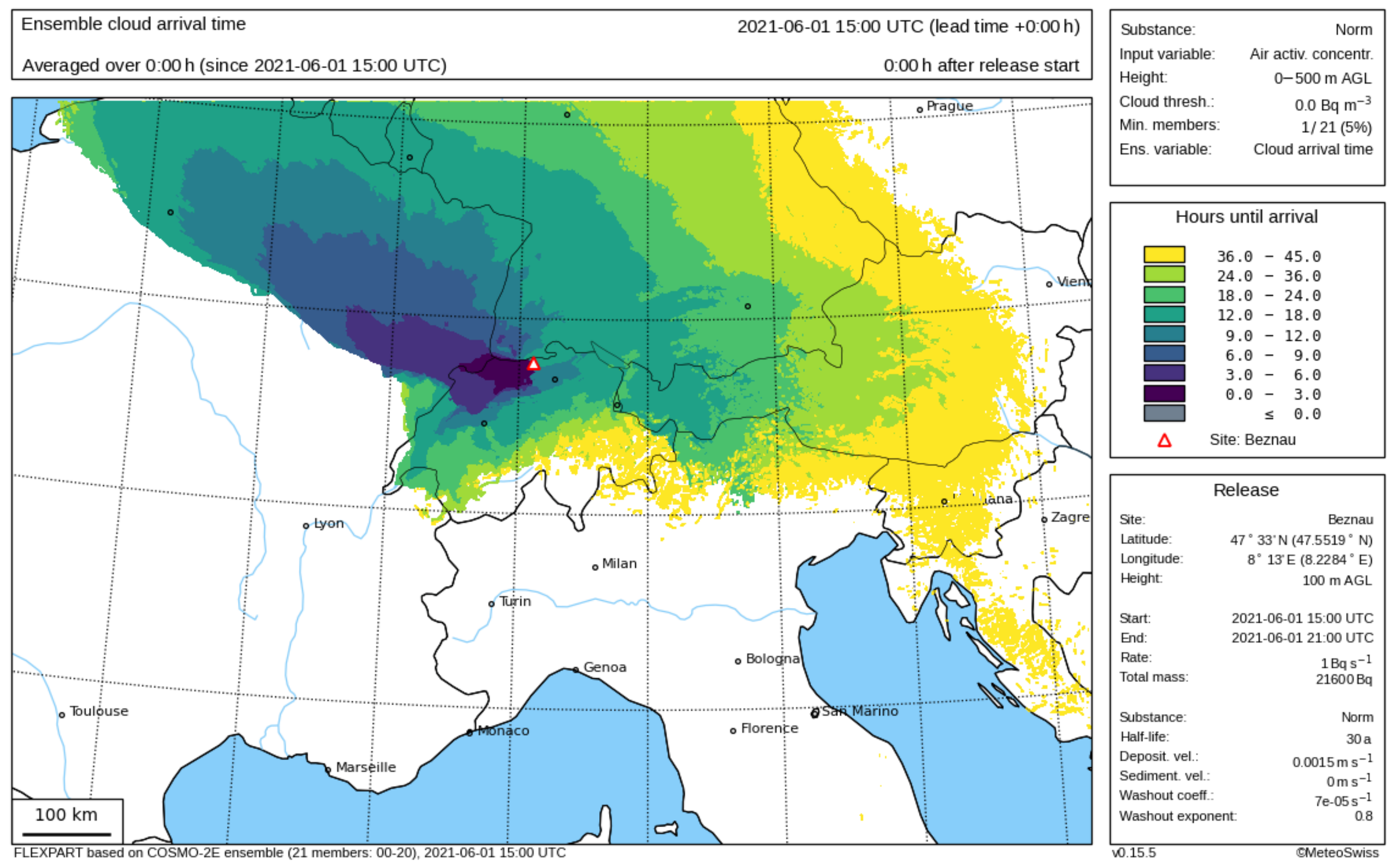

***Figure 1:*** *Cloud arrival time in hours after the start of the 45 h dispersion ensemble simulation and of the 6 h release on 1 June 2021 at 1500 UTC, based on a 21-member COSMO-2E ensemble forecast started at the same time. A norm substance is released from the nuclear power plant at Beznau during the first 6 h of the simulation. The cloud is defined at each point as nonzero air activity concentration in the lowermost 500 m AGL in at least one ensemble member, corresponding to a minimum probability of 5%.*

## Ensemble Modeling Setup

MeteoSwiss operationally employs two ensemble forecast systems based on the limited-area NWP model COSMO (Baldauf et al., 2011): COSMO-1E and COSMO-2E, each driven by a subset of the global 50-member ECMWF IFS-ENS system (Leutbecher et al., 2017). The new ensemble dispersion system is driven by COSMO-2E, which has 2.2 km horizontal grid spacing and is run every 6 h with 120 h lead time and 21 members, each of which drives a dispersion simulation performed with the Lagrangian particle dispersion model FLEXPART (Pisso et al., 2019).

While computationally expensive, this direct approach to leveraging the meteorological uncertainty information is worth the cost because it can represent nonlinear meteorological effects. The system has been running preoperationally for some time and will complement the current deterministic forecasts driven by the control runs of both meteorological ensembles.

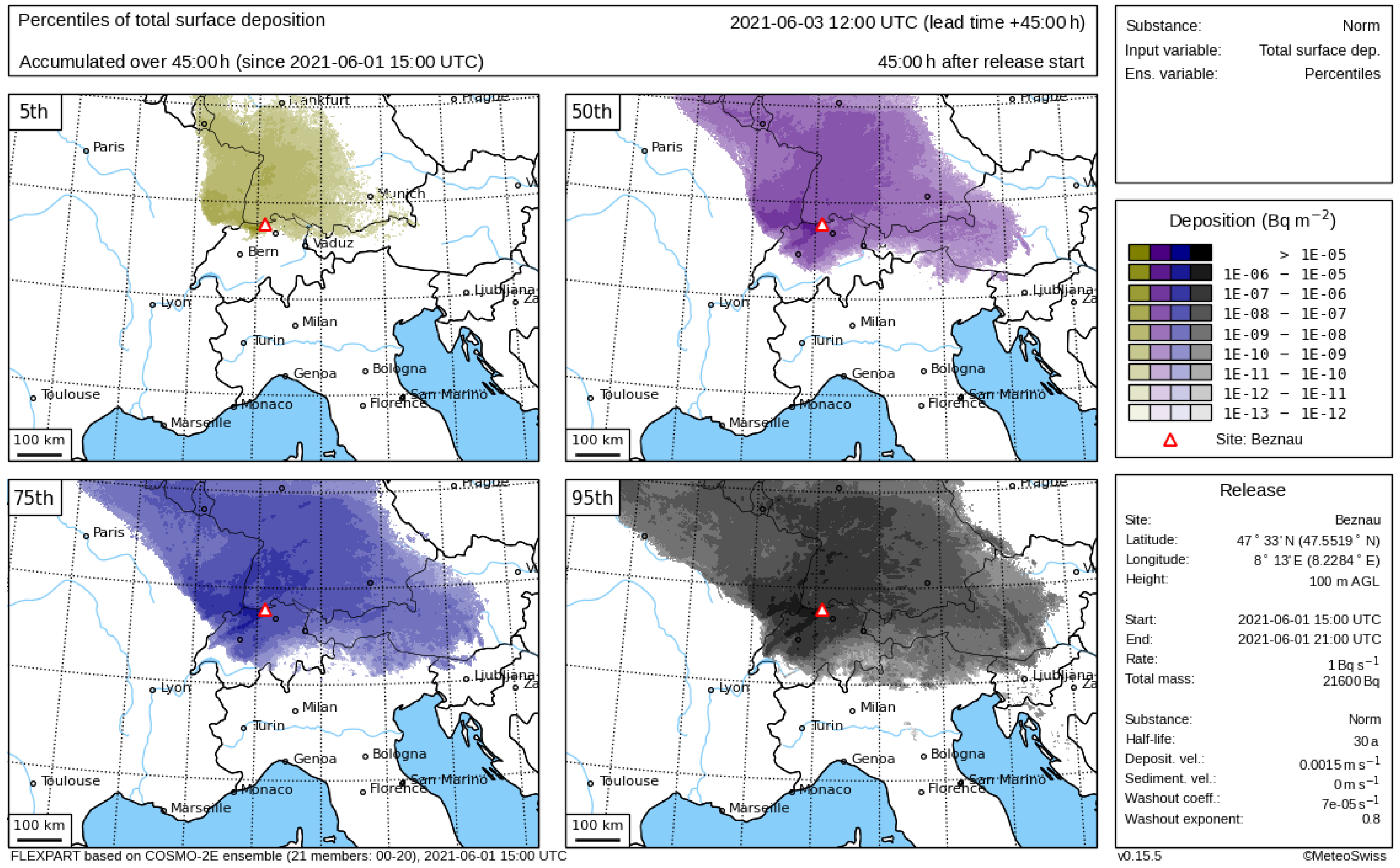

***Figure 3:*** *Percentiles (5th, 50th, 75th and 95th) of total surface deposition during the first 45 h of the same 21-member COSMO-2E forecast as in Figure 1.*

***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*

*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*

*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, doi: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.*

*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.*

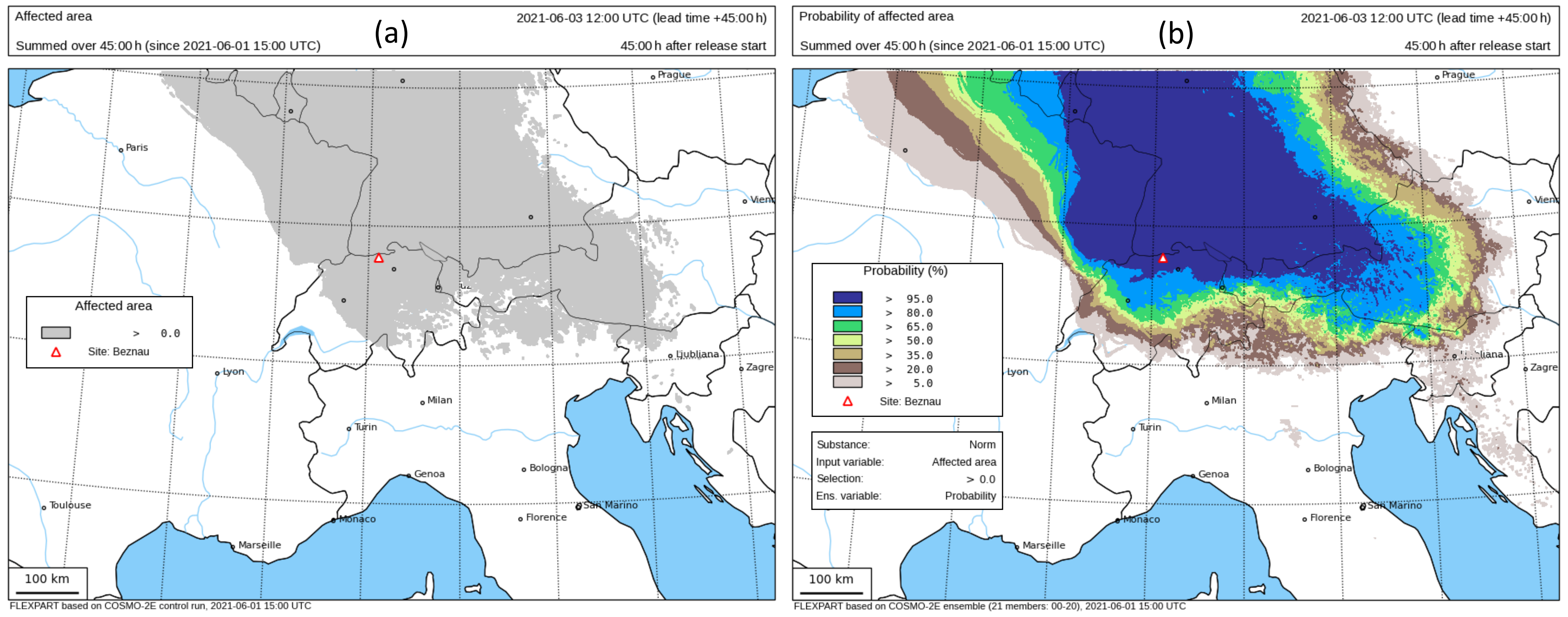

***Figure 2:*** *Comparison of (a) deterministic affected area, defined as nonzero air activity concentration in the lowermost 500 m AGL and/or nonzero surface deposition, based on the first 45 h of the control run of the same COSMO-2E forecast as in Figure 1; and (b) probability of affected area based on all 21 ensemble members.*

## Affected Area Probability

Figure 2 compares the existing deterministic affected area product with the new ensemble probability of affected area. It illustrates how ensemble information can be a double-edged sword. On the one hand, the ensemble product is more complex and requires more capacity for interpretation — a scarce resource in an emergency situation. On the other hand, this very complexity adds valuable information. The potentially affected area in the ensemble product is extended into regions that are spared by the control run but affected by other ensemble members, for example in eastern Bavaria. This also serves to identify the unaffected area with much more certainty. Furthermore, a core area that is affected with very high certainty is distinguished from a border area where the forecast is less certain. This region can be large in places, for example in northeastern France. Notably, most of Switzerland is in this border region, so a single deterministic forecast might well have missed it, giving a false sense of security.

## Deposition Percentiles

Figure 3 shows four percentile maps of total surface deposition: The 5th percentile is close to the minimum expected extent; the 50th, or median, is the intermediate scenario; the 75th is a less likely scenario with more extended contamination; and the 95th has a chance of merely 5% to be exceeded and is therefore close to the maximum expected extent. This product provides an expert with an overview over the range of forecast scenarios. Each map is drawn in a single color in order to steer the primary focus to the total contaminated area, distinguishing areas that have a certain risk of being affected from those that will likely be spared. The absolute deposition amounts are drawn as brightness levels in order to indicate the expected degree of contamination. A motivation behind this distinction is that in the very early phase of an emergency situation, when the release has not actually started yet, the absolute amounts that are about to be released are often little known.

## Conclusions

The selection of graphics on this poster highlights a basic conflict in the visualization of ensemble dispersion results for emergency response: having to relay as much of the complex information as possible while still being simple and intuitive enough to be absorbed quickly in a stressful situation. There is no single product than conveys all aspects of a forecast, but different products complement each other.

Different levels of complexity are appropriate for different target audiences. While relatively complex products like that in Figure 3 allow scientific experts to quickly gain an overview over the range of possible scenarios, simpler products like those in Figures 1 and 2 (right) — or even Figure 2 (left), but based on the full ensemble — are more appropriate for nonexperts.

The selection presented here is by no means the final answer to this problem but rather a first step toward it, enabling us to put routine dispersion ensemble forecasts into operations. We expect the visualizations to be developed further as both sides — us meteorologists and our customers, the emergency response managers — gain experience with the interpretation of these ensemble products.

## Acknowledgements

We thank Franziskus Stoffel, Swiss National Emergency Operations Center (NAZ), und Cyrill von Arx, Swiss Fereral Nuclear Safety Inspectorate (ENSI), for their valuable feedback and insights into the field of emergency response. This work has been funded by the Federal Office for Civil Protection, Switzerland, and conducted as part of the MeteoSwiss project EMER-Met StArt. Computations have been performed at the high performance computing center CSCS in Lugano, Switzerland.

further information:
www.meteoswiss.ch

contact: pirmin.kaufmann@meteoswiss.ch

Federal Office of Meteorology and Climatology MeteoSwiss
Operation Center 1
P.O. Box
CH-8058 Zurich-Airport, Switzerland