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A web-application for visualizing uncertainty in numerical ensemble models

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Numerical ensemble models are used in the analysis and forecasting of a wide range of environmental processes. Common use cases include assessing the consequences of nuclear accidents, pollution releases into the ocean or atmosphere, forest fires, volcanic eruptions, or identifying areas at risk from such hazards. In addition to the increased use of scenario analyses and model forecasts, the availability of supplementary data describing errors and model uncertainties is increasingly commonplace. Unfortunately most current visualization routines are not capable of properly representing uncertain information. As a result, uncertainty information is not provided at all, not readily accessible, or it is not communicated effectively to model users such as domain experts, decision makers, policy makers, or even novice users.

In an attempt to address these issues a lightweight and interactive web-application has been developed. It makes clear and concise uncertainty visualizations available in a web-based mapping and visualization environment, incorporating aggregation (upscaling) techniques to adjust uncertainty information to the zooming level. The application has been built on a web mapping stack of open source software, and can quantify and visualize uncertainties in numerical ensemble models in such a way that both expert and novice users can investigate uncertainties present in a simple ensemble dataset. As a test case, a dataset was used which forecasts the spread of an airborne tracer across Western Europe. Extrinsic uncertainty representations are used in which dynamic circular glyphs are overlaid on model attribute maps to convey various uncertainty concepts. It supports both basic uncertainty metrics such as standard deviation, standard error, width of the 95% confidence interval and interquartile range, as well as more experimental ones aimed at novice users. Ranges of attribute values can be specified, and the circular glyphs dynamically change size to represent the probability of the attribute value falling within the specified interval. For more advanced users graphs of the cumulative probability density function, histograms, and time series plume charts are available.

To avoid risking a cognitive overload and crowding of glyphs on the map pane, the support of the data used for generating the glyphs is linked dynamically to the zoom level. Zooming in and out respectively decreases and increases the underlying support size of data used for generating the glyphs, thereby making uncertainty information of the original data upscaled to the resolution of the visualization accessible to the user. This feature also ensures that the glyphs are neatly spaced in a regular grid regardless of the zoom level. Finally, the web-application has been presented to groups of test users of varying degrees of expertise in order to evaluate the usability of the interface and the effectiveness of uncertainty visualizations based on circular glyphs.