Met.3D: Interactive 3D ensemble visualization for rapid exploration of atmospheric simulation data

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WAVES TO WEATHER

State of the art in visualization in meteorology

- Visualization is an important and ubiquitous tool in the daily work of atmospheric researchers, its state of the art has been surveyed by Rautenhaus et al. (2018).

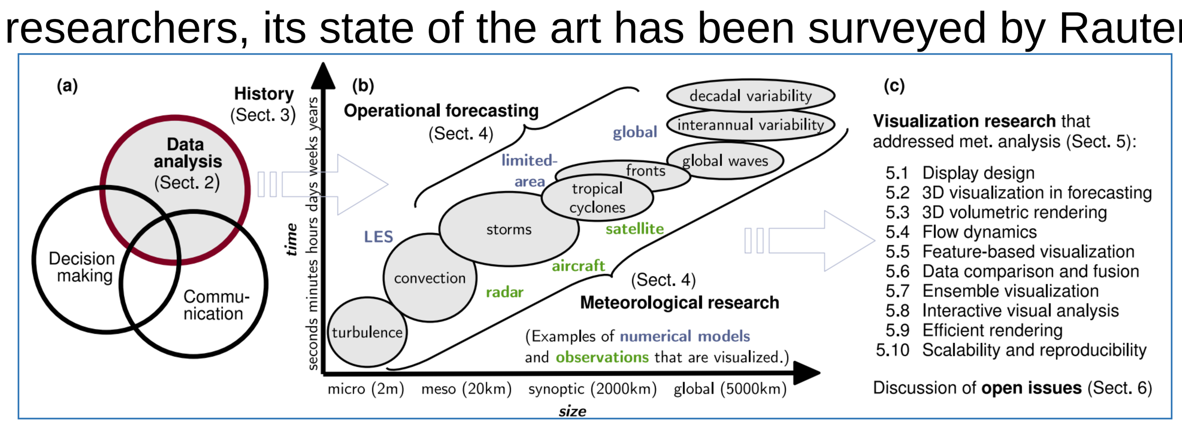


Fig. 1: Overview of visualization methods and research for meteorological analysis as surveyed by Rautenhaus et al. 2018

- Several studies have discussed benefits of interactive 3D and of ensemble visualization, and visualization research has in recent years proposed new methods in this field.
- However, take-up of such methods in meteorology is slow, mostly due to the availability of suitable software tools that meet a domain scientist's needs and "bridge" from existing 2D workflows to new interactive 3D methods.

Met.3D: Interactive 3D visual ensemble analysis

- "Met.3D" (Rautenhaus et al. 2015a) is an interactive 3D meteorological visual analysis framework, developed since 2012. It is targeted at interactive exploration of 3D ensemble datasets and builds a "bridge" from 2D to interactive 3D visualization.

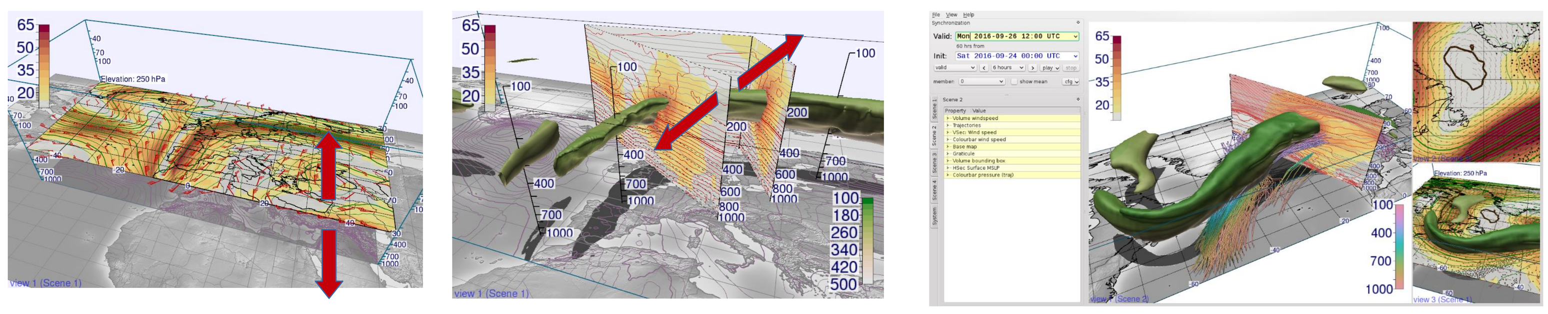


Fig. 2: In Met.3D, "traditional" 2D maps and vertical sections are interactive, displayed in a 3D context and can be combined with 3D elements. Shadows and vertical axes improve spatial perception.

- A "community" open-source version of Met.3D contains the basic stable functions of the tool: ***gitlab.com/wxmetvis/met.3d***
- Additional feature branches contain research code as developed within our visualization research projects.
- More information at: ***met3d.wavestoweather.de***

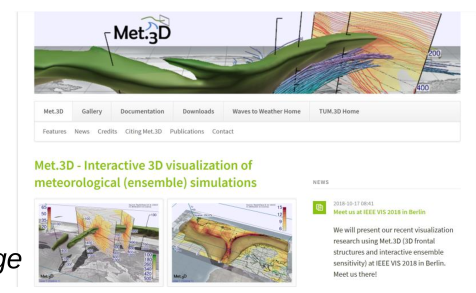


Fig. 3: Met.3D homepage

Visualization research

- Met.3D serves as a framework for visualization research (e.g. within the German Collaborative Research Centre Waves to Weather (W2W)).

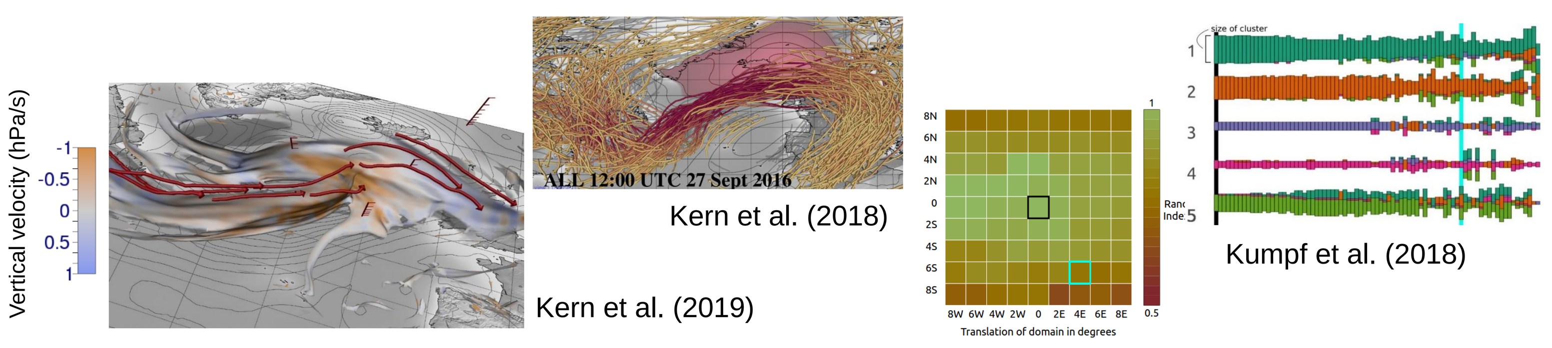


Fig. 4: New visualization techniques developed with Met.3D: jet-stream core lines and frontal surfaces, interactive ensemble clustering analysis.

- Examples include new 3D feature detection and visualization approaches for jet-stream core lines (Kern et al. 2018) and frontal surfaces (Kern et al. 2019), as well as interactive ensemble analysis techniques (Kumpf et al. 2018).

References for further reading

Kern, M., T. Hewson, A. Schäfler, R. Westermann, and M. Rautenhaus (2019): Interactive 3D Visual Analysis of Atmospheric Fronts. IEEE Trans. Visual. Comput. Graphics, 25, 1080–1090.

Kern, M., T. Hewson, F. Sadlo, R. Westermann, and M. Rautenhaus (2018): Robust Detection and Visualization of Jet-Stream Core Lines in Atmospheric Flow. IEEE Trans. Visual. Comput. Graphics, 24, 893–902.

Kumpf, A., B. Tost, M. Baumgart, M. Riemer, R. Westermann, and M. Rautenhaus (2018): Visualizing Confidence in Cluster Based Ensemble Weather Forecast Analyses. IEEE Trans. Visual. Comput. Graphics, 24, 109–119.

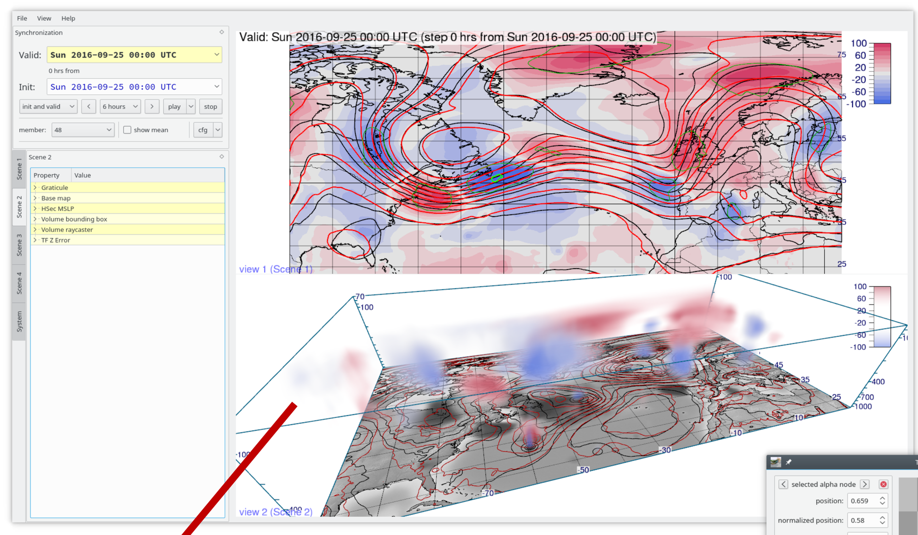
Rautenhaus, M., M. Kern, A. Schäfler, and R. Westermann (2015a): Three-dimensional visualization of ensemble weather forecasts – Part 1: The visualization tool Met.3D (version 1.0). Geosci. Model Dev., 8, 2329–2353

Rautenhaus, M., C. M. Grams, A. Schäfler, and R. Westermann (2015b): Three-dimensional visualization of ensemble weather forecasts – Part 2: Forecasting warm conveyor belt situations for aircraft-based field campaigns. Geosci. Model Dev., 8, 2355–2377.

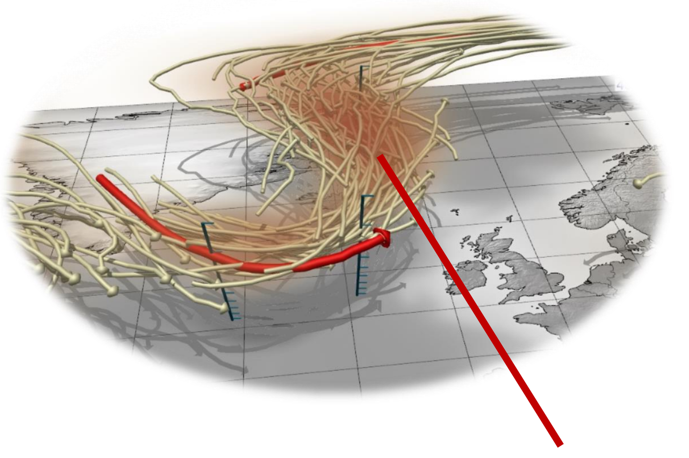
Rautenhaus, M., M. Böttinger, S. Siemen, R. Hoffman, R. M. Kirby, M. Mirzargar, N. Röber, and R. Westermann (2018): Visualization in Meteorology—A Survey of Techniques and Tools for Data Analysis Tasks. IEEE Trans. Visual. Comput. Graphics, 24, 3268–3296.

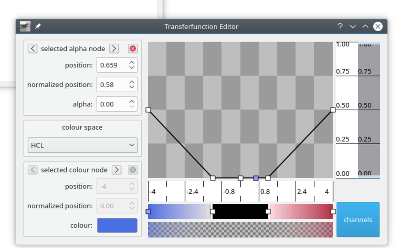
Rautenhaus, M., T. Hewson, A. Lang (2020): Cyclone Workshop showcases 3D visualization. ECMWF Newsletter, 162, 4-5.

Selected Met.3D capabilities



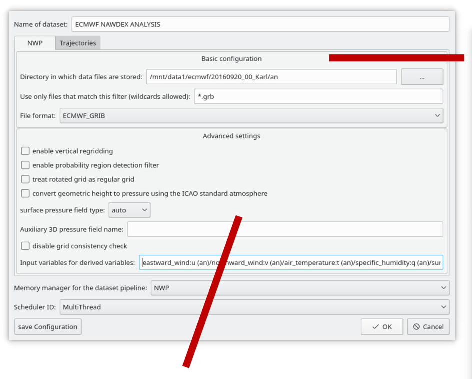
Multiple views facilitate combined displays of traditional 2D depictions and 3D visualizations, e.g., direct volume rendering.

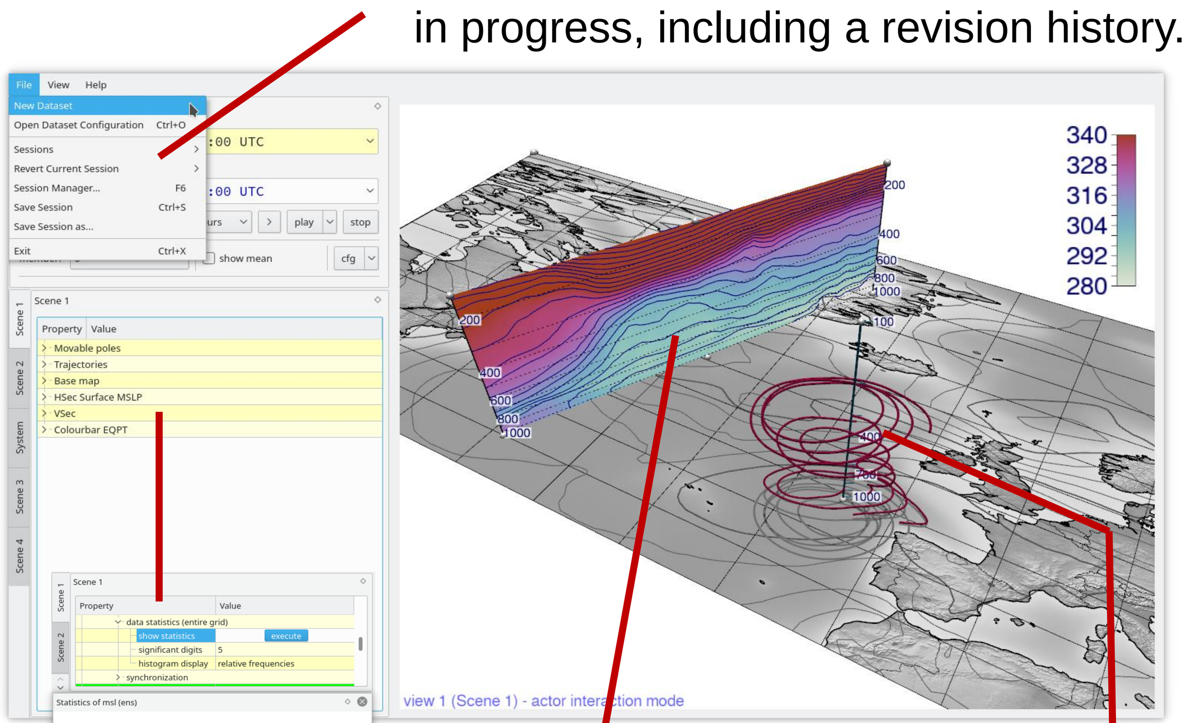




Ensemble support facilitates comparison of individual members as well as on-the-fly computation of statistical quantities, e.g., ensemble spread.

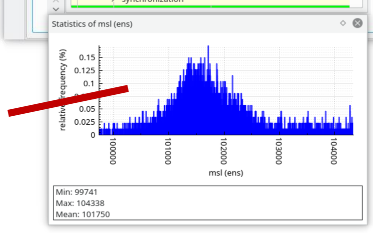
Session management allows restoring work in progress, including a revision history.





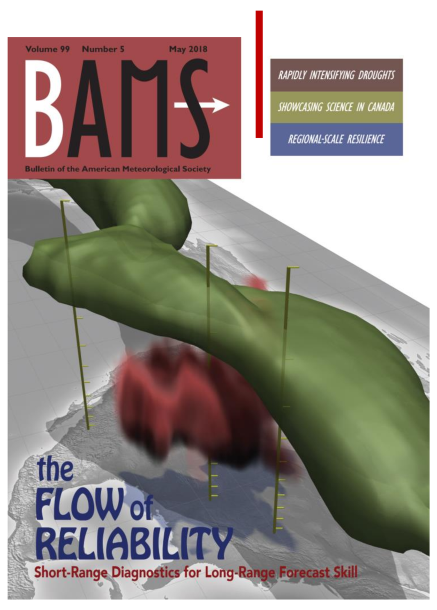
Datasets (NetCDF and GRIB) and sessions can be loaded from the user interface.

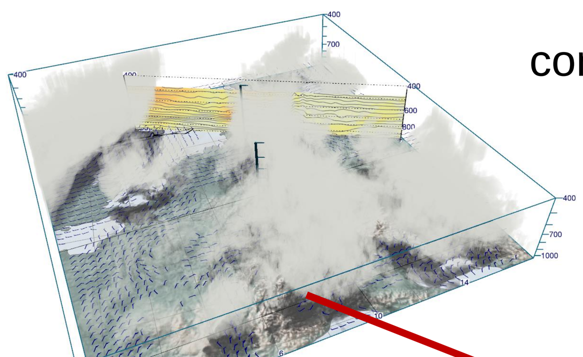
Basic data statistics can be displayed within the user interface.



Some variables can be computed on the fly (in this vertical section, θ and θ_e are shown).

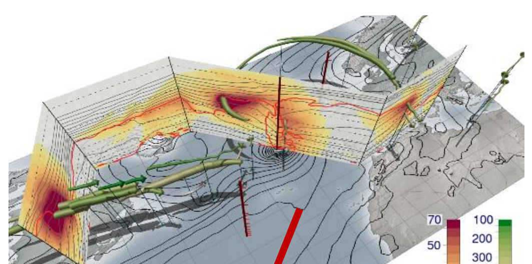
The cover image for the May 2018 BAMS issue was created with Met.3D.

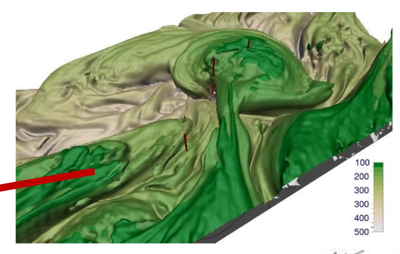


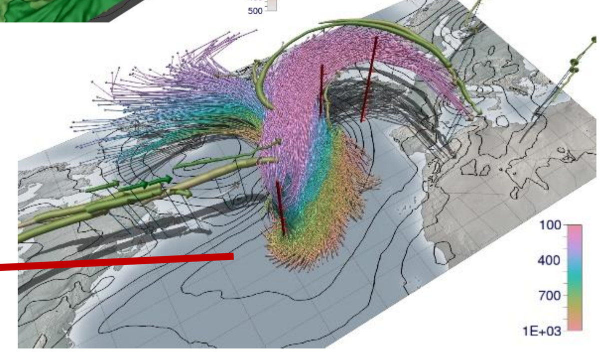


Met.3D allows on-the-fly computation of streamlines and trajectories.

Data on any vertical model grid can be displayed. Horizontally, regular and rotated lon-lat grids are supported (stereographic to follow soon). The example shows a COSMO forecast.







Example visualizations showing aspects of Hurricane Lorenzo (2019): Jet-stream core lines augmented with vertical sections of wind speed, 2-PVU isosurface of potential vorticity showing the dynamic tropopause, trajectories representing the warm conveyor belt. For further details see Rautenhaus et al. (2020).

System requirements

- Met.3D requires an OpenGL 4.3 capable graphics adapter (GPU) with suitable drivers. The data to be visualized for a single image need to fit into GPU memory, i.e. 4-8 GB of GPU memory is recommended. A current mid-range consumer card works fine.
- We are also running Met.3D on a number of remote visualization workstations, e.g. using VirtualGL and TurboVNC.
- Met.3D compiles under Linux (we are looking for a Windows maintainer), we provide portable binaries for Linux systems on the Met.3D website.

Acknowledgements

Parts of the research leading to the presented results has been done within the Transregional Collaborative Research Centre SFB / TRR 165 "Waves to Weather" (www.wavestoweather.de) funded by the German Research Foundation (DFG). The presented visualizations are based on data courtesy of ECMWF and DWD.

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