

# About Met.3D: Publications, presentations, credits

## About Met.3D

Met.3D is being developed as a research effort to improve the visual analysis of 3-D meteorological data in research and forecasting.

Met.3D is developed at the [Regional Computing Center](#) of Universität Hamburg (UHH) and at the [Computer Graphics & Visualization Group](#) of the Technical University of Munich (TUM), Germany. Since 2015, we receive ongoing funding from the German Research Foundation (DFG) within the Collaborative Research Centre SFB/TRR 165 [Waves to Weather](#) and the UHH Cluster of Excellence [CLICCS](#). Previously, the development was partly funded by the European Union under the ERC Advanced Grant 291372 [SaferVis](#) and the ERC Proof-of-Concept Grant "Vis4Weather".

Met.3D research and development is led by [Marc Rautenhaus](#), UHH (previously TUM).

The entry point to information about Met.3D is the reference publication. Also, Marc's PhD thesis contains additional details.

- Rautenhaus, M., Kern, M., Schäfler, A., and Westermann, R.: **Three-dimensional visualization of ensemble weather forecasts – Part 1: The visualization tool Met.3D (version 1.0)**, *Geosci. Model Dev.*, **8**, 2329–2353, doi:10.5194/gmd-8-2329-2015, 2015.
- Rautenhaus, M.: **Interactive 3D visualization of ensemble weather forecasts**, *Ph.D. thesis*, Technical University of Munich, Munich, Germany, 195pp., 2015.

## Publications

The following (likely incomplete) list contains scientific publications that are using Met.3D for development, evaluation, or use of new visualization techniques in meteorology.

If you have used Met.3D for a publication please let us know so we can add your paper to the list!

- 2023
  - Schäfler, A. and Rautenhaus, M.: **Interactive 3D Visual Analysis of Weather Prediction Data Reveals Midlatitude Overshooting Convection during the CIRRUS-HL Field Experiment**, *Bulletin of the American Meteorological Society*, 104, E1426–E1434, URL <http://doi.org/10.1175/BAMS-D-22-0103.1>, 2023
  - Neuhauser, C., Hieronymus, M., Kern, M., Rautenhaus, M., Oertel, A., and Westermann, R.: **Visual Analysis of Model Parameter Sensitivities along Warm Conveyor Belt Trajectories Using Met.3D (1.6.0-Multivar1)**, *Geoscientific Model Development*, 16, 4617–4638, URL <http://doi.org/10.5194/gmd-16-4617-2023>, 2023
  - Beckert, A. A., Eisenstein, L., Oertel, A., Hewson, T., Craig, G. C., and Rautenhaus, M.: **The Three-Dimensional Structure of Fronts in Mid-Latitude Weather Systems in Numerical Weather Prediction Models**, *Geoscientific Model Development*, 16, 4427–4450, URL <http://doi.org/10.5194/gmd-16-4427-2023>, 2023
- 2022
  - Fischer, C., Fink, A. H., Schömer, E., van der Linden, R., Maier-Gerber, M., Rautenhaus, M., and Riemer, M.: **A Novel Method for Objective Identification of 3-D Potential Vorticity Anomalies**, *Geoscientific Model Development*, 15, 4447–4468, URL <http://doi.org/10.5194/gmd-15-4447-2022>, 2022
- 2021
  - Meyer, M., Polkova, I., Modali, K. R., Schaffer, L., Baehr, J., Olbrich, S., and Rautenhaus, M.: **Interactive 3-D Visual Analysis of ERA5 Data: Improving Diagnostic Indices for Marine Cold Air Outbreaks and Polar Lows**, *Weather and Climate Dynamics*, 2, 867–891, URL <http://doi.org/10.5194/wcd-2-867-2021>, 2021
- 2020
  - Schäfler, A., Ewald, F., and Rautenhaus, M.: **Die Vermessung von Zyklonen (Observing Cyclones)**, *promet* (German Weather Service DWD), 103, 25–32, URL [https://www.dwd.de/DE/leistungen/pbfb\\_verlag\\_promet/pdf\\_promethefte/103\\_pdf.pdf?\\_\\_blob=publicationFile&v=2](https://www.dwd.de/DE/leistungen/pbfb_verlag_promet/pdf_promethefte/103_pdf.pdf?__blob=publicationFile&v=2), 2020
  - Rautenhaus, M., Hewson, T., and Lang, A.: **Cyclone Workshop showcases 3D visualisation**, *ECMWF Newsletter*, 162, 4–5, URL <http://www.ecmwf.int/en/newsletter/162/news/cyclone-workshop-showcases3d-visualisation>, 2020
  - Eisenstein, L., Pantillon, F., Knippertz, P.: **Dynamics of sting-jet storm Egon over continental Europe: Impact of surface properties and model resolution**, *Q J R Meteorol Soc.*, 146: 186–210, URL <https://doi.org/10.1002/qj.3666>, 2020
- 2019
  - Kern, M., Hewson, T., Schäfler, A., Westermann, R., and Rautenhaus, M.: **Interactive 3D Visual Analysis of Atmospheric Fronts**, *IEEE Trans. Visual. Comput. Graphics*, 25, 1080–1090, URL <http://doi.org/10.1109/TVCG.2018.2864806>, 2019
  - Kumpf, A., Rautenhaus, M., Riemer, M., and Westermann, R.: **Visual Analysis of the Temporal Evolution of Ensemble Forecast Sensitivities**, *IEEE Trans. Visual. Comput. Graphics*, 25, 98–108, URL <http://doi.org/10.1109/TVCG.2018.2864901>, 2019
- 2018
  - Rautenhaus, M., Böttinger, M., Siemen, S., Hoffman, R., Kirby, R. M., Mirzargar, M., Röber, N., and Westermann, R.: **Visualization in Meteorology — A Survey of Techniques and Tools for Data Analysis Tasks**, *IEEE Trans. Visual. Comput. Graphics*, 24, 3268–3296, URL <http://dx.doi.org/10.1109/tvcg.2017.2779501>, 2018
  - Schäfler, A., Craig, G., Wernli, H., Arbogast, P., Doyle, J. D., McTaggart-Cowan, R., Methven, J., Rivière, G., Ament, F., Boettcher, M., Bramberger, M., Cazenave, Q., Cotton, R., Crewell, S., Delanoë, J., Dörnbrack, A., Ehrlich, A., Ewald, F., Fix, A., Grams, C. M., Gray, S. L., Grob, H., Groß, S., Hagen, M., Harvey, B., Hirsch, L., Jacob, M., Kölling, T., Konow, H., Lemmerz, C., Lux, O., Magnusson, L., Mayer, B., Mech, M., Moore, R., Pelon, J., Quinting, J., Rahm, S., Rapp, M., Rautenhaus, M., Reitebuch, O., Reynolds, C. A., Sodemann, H., Spengler, T., Vaughan, G., Wendisch, M., Wirth, M., Witschas, B., Wolf, K., and Zinner, T.: **The North Atlantic Waveguide and Downstream Impact Experiment**, *Bull. American Meteor. Soc.*, 99, 1607–1637, URL <http://dx.doi.org/10.1175/BAMS-D-17-0003.1>, 2018
  - Kern, M., Hewson, T., Sadlo, F., Westermann, R., and Rautenhaus, M.: **Robust Detection and Visualization of Jet-stream Core Lines in Atmospheric Flow**, *IEEE Trans. Visual. Comput. Graphics*, 24, 893–902, URL <http://dx.doi.org/10.1109/tvcg.2017.2743989>, 2018
  - Kumpf, A., Tost, B., Baumgart, M., Riemer, M., Westermann, R., and Rautenhaus, M.: **Visualizing Confidence in Cluster-based Ensemble Weather Forecast Analyses**, *IEEE Trans. Visual. Comput. Graphics*, 24, 109–119, URL <http://dx.doi.org/10.1109/tvcg.2017.2745178>, 2018

- 2017
  - Ferstl, F., Kanzler, M., Rautenhaus, M., and Westermann, R.: **Time-hierarchical Clustering and Visualization of Weather Forecast Ensembles**, IEEE Trans. Visual. Comput. Graphics, 23, 831–840, URL <http://dx.doi.org/10.1109/tvcg.2016.2598868>, 2017
- 2015
  - Rautenhaus, M., Kern, M., Schäfler, A., and Westermann, R.: **Three-dimensional visualization of ensemble weather forecasts – Part 1: The visualization tool Met.3D (version 1.0)**, Geoscientific Model Development, 8, 2329–2353, URL <http://dx.doi.org/10.5194/gmd-8-2329-2015>, 2015
  - Rautenhaus, M., Grams, C. M., Schäfler, A., and Westermann, R.: **Three-dimensional visualization of ensemble weather forecasts – Part 2: Forecasting warm conveyor belt situations for aircraft-based field campaigns**, Geoscientific Model Development, 8, 2355–2377, URL <http://dx.doi.org/10.5194/gmd-8-2355-2015>, 2015
- 2014
  - Rautenhaus, M., Grams, G., Schäfler, A., and Westermann, R.: **GPU based interactive 3D visualization of ECMWF ensemble forecasts**, ECMWF Newsletter, 138, 34–38, URL <http://dx.doi.org/10.21957/ouo7uwp2>, 2014

## Presentations

A very incomplete list of publicly available presentations on Met.3D:

- 2022
  - **Met.3D: Interactive 3D visualization for rapid exploration of atmospheric ensemble simulation data (Recording)**, Using ECMWF's Forecasts (UEF2022), 7-10 June 2022, Reading, UK.
- 2019
  - **Is it time for interactivity and 3D? New approaches to analysing NWP data for observational campaigns using 3D and ensemble visualization**, Workshop on observational campaigns for better weather forecasts, 10-13 June 2019, ECMWF, Reading, UK.
- 2018
  - **Using Met3D at ECMWF**, 29th European Working Group on Operational Meteorological Workstations (EGOWS), 15-17 October 2018, ECMWF, Reading, UK
- 2017
  - **Ensemble and 3D visualization with Met.3D – recent research and software updates**, 16th Workshop on Meteorological Operational Systems (MOS), 1-3 March 2017, ECMWF, Reading, UK. [Video available](#).
- 2015
  - **Interactive 3D visualization of ECMWF ensemble weather predictions**, Visualisation in Meteorology week 2015, 28 September - 2 October 2015, ECMWF, Reading, UK.

## Credits

The Met.3D core development team currently consists of:

- [Marc Rautenhaus](#), UHH
- [Andreas Beckert](#), UHH
- [Thorwin Vogt](#), UHH
- [Christoph Fischer](#), UHH

We acknowledge the following individuals for their contribution:

- Susanne Fuchs, UHH
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- Justus Jakobi, UHH student
- Alexander Klassen, UHH student
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- Jessica Blankenburg, TUM student
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- Philipp Kaiser, TUM student
- Theresa Diefenbach, LMU student
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