WAVES TO WEATHER

Hands-on workshop to showcase tools developed in "Waves to Weather" before the EMS Annual Meeting 2022

When & Where

04 September 2022 in Bonn (GERMANY). This is the Sunday before the Annual Meeting of the European Meteorology Society (EMS). The workshop is planned as an in-person event. It might change to a hybrid or to a fully online workshop depending on the COVID19 regulations in place around the time of the event.

Expected number of participants

~60 in total, working in four groups of ~15 participants.

Registration

Participants can attend two out of four workshops to be chosen when registering (detailed descriptions on the following pages). There will be a registration fee of 30€. The registration will be managed by Copernicus and will be opened around May 2022. More details will be provided closer to the event.

Schedule

9:00 - 9:30 Welcome and introduction to "Waves to Weather" (Peter Knippertz)

Split into four groups
9:30-10:00 Intro to individual activities (activity leaders)
10:00-11:00 First hands-on activity, Part 1
11:00-11:30 Coffee break
11:30-13:00 First hands-on activity, Part 2

13:00-14:00 Lunch

Split into four groups
14:00-14:30 Intro to individual activities (activity leaders)
14:30-15:30 Second hands-on activity, Part 1
15:30-16:00 Coffee break
16:00-17:30 Second hands-on activity, Part 2

17:30-18:00 Wrap-up and goodbye (Peter Knippertz)

Interested?

Please save the date and let Audine Laurian (audine.laurian@lmu.de) know about your interest such that we can make sure you receive all further information.

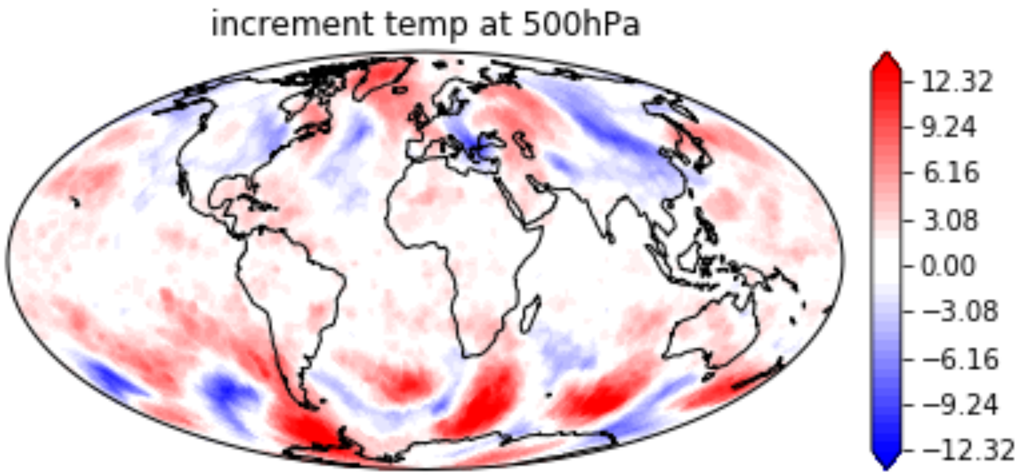
Hands-on activities

Activity #1

Introduction to data assimilation with FREDA

Leaders: Tijana Janjic (LMU), Robert Redl (LMU) and Yvonne Ruckstuhl (LMU)

Target group: Scientists who want to familiarize themselves with the basics of data assimilation for meteorological applications. The course does not require any prior knowledge of data assimilation or Python.



Snapshot of the analysis increment of temperature generated with FREDA.

Data assimilation combines information in heterogeneous observations and a numerical model to learn about and help predict phenomena of interest. In meteorology, the main goal of data assimilation is to determine an estimate of the state of the atmosphere and thus the initial conditions for the numerical forecast model, but it can also be used to train numerical model parameters based on observed data. Depending on the goal, a variety of mathematical methods can be used for obtaining a solution. Data assimilation in contrast to machine learning and statistical methods utilizes dynamical and physical properties imbedded in numerical weather prediction model to fit noisy, incomplete, and non-uniform in space and time atmospheric observations.

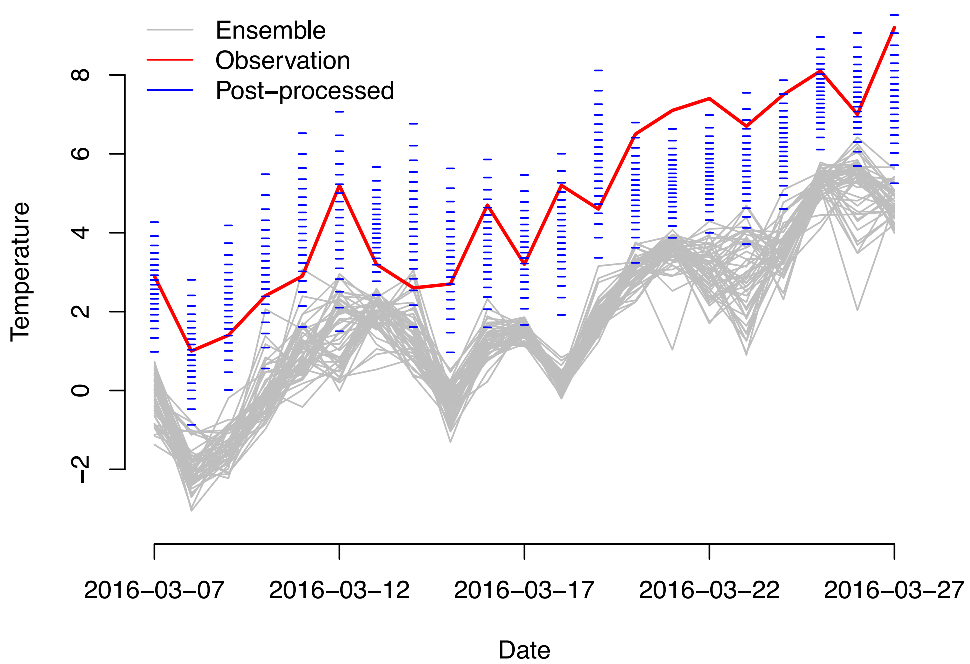
In this session, applicants will learn the basics of data assimilation with a focus on ensemble algorithms, including but not limited to the ensemble Kalman filter. In the hands-on part of the workshop the participants will apply data assimilation in the context of twin experiments, where synthetic observations are generated from a nature run. This will be done using the Framework for Research on Data Assimilation (FREDA), which was developed as part of *Waves to Weather*. FREDA is an easy-to-use software for ensemble data assimilation research written in Python. It can handle full complexity ensembles generated with the ICON model (operational at the German Weather Service), or any other model on a regular grid. In addition, FREDA could be easily applied in teaching data assimilation courses since it allows examples from toy models to operational ones. A Jupyter notebook will be set up to investigate the effect of data assimilation, including observation coverage, data assimilation settings, as well as influence of data assimilation algorithms on the model predictions.

Activity #2

Verification of probabilistic forecasts and post-processing

Leaders: Sebastian Lerch (KIT) and Benedikt Schulz (KIT)

Target group: Scientists or members of operational services who want to learn about and experiment with statistical methods for probabilistic weather forecasting.



Ensemble forecasts of temperature at Frankfurt airport, before and after post-processing.

Currently, most weather forecasts are based on the output of numerical models which quantify forecast uncertainty by providing ensembles of predictions that are generated by varying initial conditions and model physics. Despite substantial improvements over the past decades, ensemble forecasts continue to exhibit systematic errors that need to be corrected using statistical post-processing methods in order to achieve accurate and reliable forecasts – an urgent challenge considering the ever-increasing social and economic value of weather prediction.

In this session, we will illustrate verification methods for evaluating probabilistic forecasts, and approaches to correct the systematic errors of ensemble predictions. In hands-on programming activities based on R software packages developed within *Waves to Weather* and exemplary real-world datasets, participants will

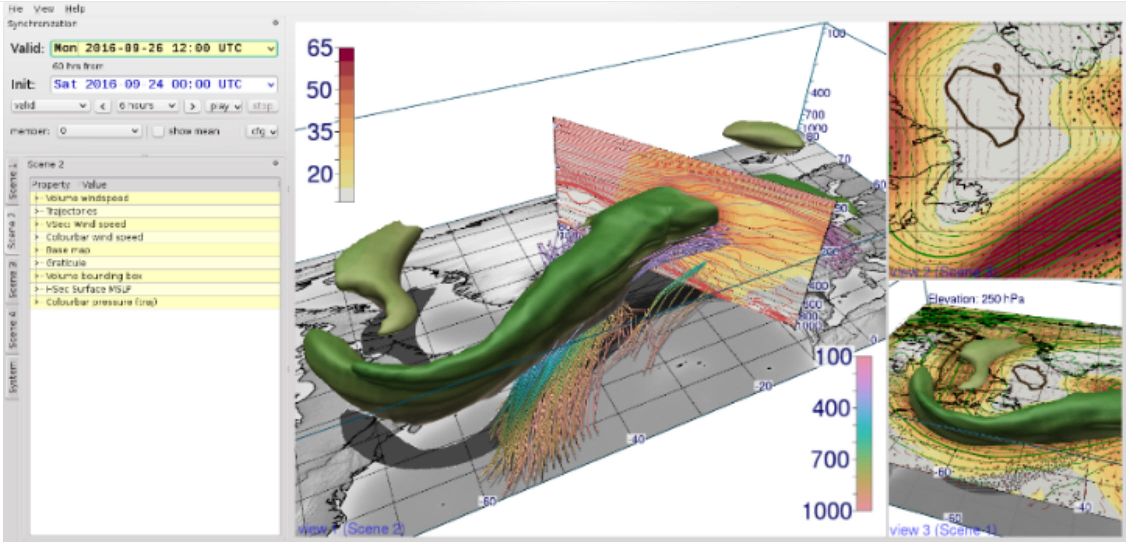
- use the scoringRules package and other tools for verification to assess various aspects of the accuracy and reliability of ensemble predictions and probabilistic forecasts in general,
- learn how to implement customized statistical post-processing methods that allow for correcting systematic errors of ensemble predictions,
- experiment with ways to use modern machine learning approaches for post-processing.

Activity #3

Interactive 3D Visual (Ensemble) Analysis with Met.3D

Leaders: Marc Rautenhaus (UHH), Kamesh Modali (UHH) and Andreas Beckert (UHH)

Target group: Scientists who want to learn about the benefit of using interactive 3D visualization to analyze gridded (ensemble) datasets, and members of operational services who want to learn about the potential of interactive 3D visualization in forecasting.



The interactive 3D visualization framework "Met.3D" is targeted at meteorological analysis and builds a bridge from traditional 2D visualization to interactive 3D displays. The shown example illustrates different views on an ECMWF forecast, showing a vertical section and a horizontal map combined with a 3D isosurface of wind speed (representing the jet stream) and 3D particle trajectories.

Visualization is an important and ubiquitous tool in the daily work of atmospheric researchers and weather forecasters to analyze data from simulations and observations. Computer science visualization research has made much progress in recent years, e.g., with respect to techniques for ensemble data, interactivity, 3D depiction, and feature-detection. Transfer of new techniques into the atmospheric sciences, however, is slow.

Within *Waves to Weather*, we are addressing this issue by developing the open-source meteorological 3D visualization framework "Met.3D" (https://met3d.wavestoweather.de) to make novel visualization techniques accessible to the atmospheric community. Since its first public release in 2015, Met.3D has been used in multiple research projects and has evolved into a feature-rich visual analysis tool facilitating rapid exploration of gridded atmospheric data. The software is based on the concept of "building a bridge" between "traditional" 2D visual analysis techniques and interactive 3D techniques. It allows users to analyze data using combinations of feature-based displays (e.g., atmospheric fronts and jet streams), "traditional" 2D maps and cross-sections, meteorological diagrams, ensemble displays, and 3D visualization including direct volume rendering, isosurfaces and trajectories, all combined in an interactive 3D context.

In this session, we will introduce Met.3D by means of visually analyzing an example numerical weather prediction case and will conduct hands-on training. Workshop participants will have the option to obtain experience with the framework using our *Waves to Weather* remote visualization infrastructure.

Activity #4

A framework for meteorological feature analysis

Leaders: Christopher Polster (JGU), Christoph Fischer (JGU), Sören Schmidt (JGU)

Target group: Scientists looking for a feature identification and tracking software solution applicable to meteorological data, either as end-users performing data analysis or as developers seeking a platform to prototype and test novel feature-based techniques.

Two applications of feature identification and tracking in Waves to Weather: the detection of potential vorticity (PV) streamers on the dynamical tropopause (left map, ellipses as simplified feature approximations for quick analysis) and the identification of three-dimensional PV forecast error objects (right map, colors indicate the vertical extent of features).

The detection of features in meteorological datasets and their analysis are fundamental steps in the methodology of various projects within *Waves to Weather*. A unified identification and tracking framework, enabling efficient exchange of results within *Waves to Weather*, is under development. This framework takes the form of a Python package containing implementations of identification and tracking procedures, composable in a mix-and-match fashion and purpose-built for meteorological data. It further contains structures to describe and store results as well as functions for further analysis and visualization. The package will be distributed as an extension to the "enstools" open-source software collection of *Waves to Weather* in 2022.

In this session, framework developers and *Waves to Weather* domain experts will showcase applications of the framework to problems such as the identification and description of PV streamers on the dynamical tropopause, tracking of 3D forecast errors in gridded data sets or the detection of Rossby wave packets on the jet stream. Participants have the opportunity to use the framework hands-on with example datasets provided for a guided tour through the package. A practical outlook on how to use the framework for other feature recognition and tracking problems is given. This enables end-users to adapt the package to their individual needs and serves as an introduction to the inner workings of the package for developers interested in extending the framework with new techniques.