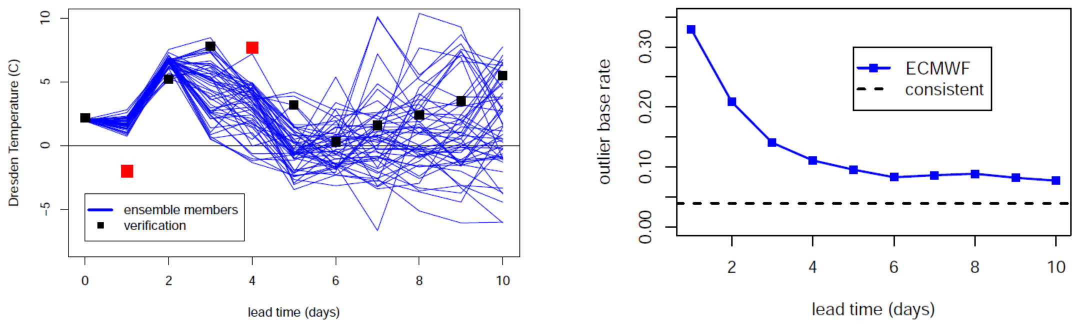
New interpretations of ensemble forecasts, with a view on the forecasting of extremes

Supervisors: Jochen Broecker, Maarten Ambaum

Many forecasting centres nowadays create weather forecasts in the form of ensembles. Ensemble forecasts consist of several simulations of future weather (and maybe the ocean). The heterogeneity of the ensembles should reflect our uncertainty about the future evolution of the weather, which has its origin in our uncertainty or ignorance about the current state of the atmosphere, the physical processes involved, and also the influences we decided to ignore to keep the computations manageable. In some sense, ensembles are a device to maintain our uncertainty.

In practice, heterogeneity of ensemble members is achieved through different initial conditions, different model parameters, stochastic perturbations, or even by running structurally different models. Despite these efforts, ensembles are not always capable of maintaining all our information and uncertainty faithfully.

The aim of this project is to identify what type of information gets irrevocably lost in the ensemble generation, and what information could still be recovered, even though it might not show up when the ensemble is taken at face value. In particular, this project will focus on the ability to forecast extreme events. Will we become better at forecasting extreme events through stochastic parametrisations, for example, or will we just add spurious variability? Or even if no ensemble member shows an extreme event, we might still use the ensemble to estimate the probability of that event.



Left panel: A typical ensemble forecast for temperature (at Dresden, Germany) shown with blue lines. These are 50 scenarios. The black and red squares show the observed temperature. The red squares mark outliers. Note e.g. frost on day one, while all ensemble members predict temperatures above freezing. The right panel shows the observed frequency of outliers which should be about $\frac{2}{50}$ but is in fact much larger (blue line), especially for short lead times.

From here on, the project might take one (or more) of the following routes:

Socio-economical impact Given that extreme events can have large socio–economic impact, and given that current ensemble forecasts have problems getting small probabilities right, can they still be rendered more useful by e.g. quantifying how uncertain small probabilities are?

Extreme events and coarse graining If we consider our models as some sort of coarse grained version of reality, then there are mathematical arguments as to why extreme events are the casualties of this coarse graining. Is there a way to put them back in at least qualitatively?

Meteorological conditions Are there meteorological conditions which strongly inhibit forecasting of extreme events correctly? Can we use the ensembles *and* more meteorological insights to forecast extreme events better?

Student profile:
Suitable for students with a degree in mathematics, statistics and probability theory, or environmental physics. A keen interest in all of these is expected, plus skills in numerical simulation.

Funding particulars:
N/A