PRIMAVERA

PRocess-based climate sIMulation:
AdVances in high-resolution modelling
and European climate Risk Assessment

Ensembles of Climate Models and how they can be used

A climate model ensemble consists of model runs with slight differences in settings or initial conditions, or with different climate models or forcings. Ensembles are an important tool to quantify variability and uncertainty inherent in Earth's climate system. In certain situations ensembles can yield probability distribution functions (PDFs) which give the user confidence about the expected outcomes (mean, max/min). Ensembles are widely used both in climate science and weather forecasting. Apart from increasing the spatial and temporal resolution of climate models, generating output from ensembles of climate models is another key improvement in advancing the quality of climate risk assessments.

Types of ensembles

A climate model ensemble consists of model runs with slight differences or with different climate models or forcings. There are several categories of ensembles:

- Multi-model ensembles (MMEs)
- Perturbed parameter ensembles (PPEs)
- Initial condition ensembles (Fig. 1, on the right)
- Grand ensembles (nested ensembles)

Typically model output derived from different forcing scenarios (RCPs / SRES; called "forcing ensembles") are less often considered as ensembles. Ensembles require more resources than single model runs, i.e. in terms of computing time and time for processing/analysis. They are used to deal with the various types of uncertainties.

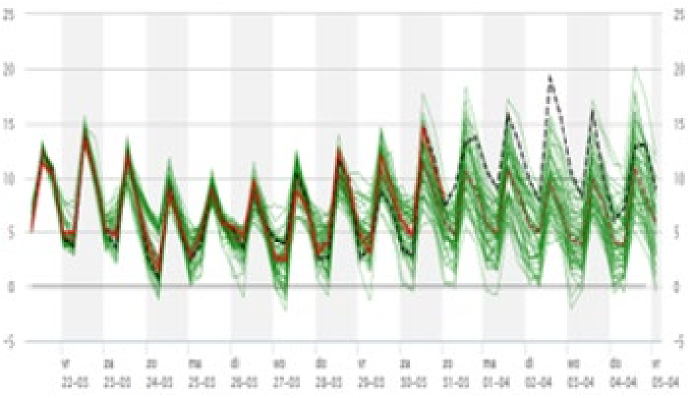

Fig. 1. Example of a temperature evolution (˚C)in an **initial conditions** ensemble for weather forecast on March 21, 2019 for De Bilt, Netherlands. Green= individual runs, Black= control, Red=high resolution, Brown=median (source: KNMI)

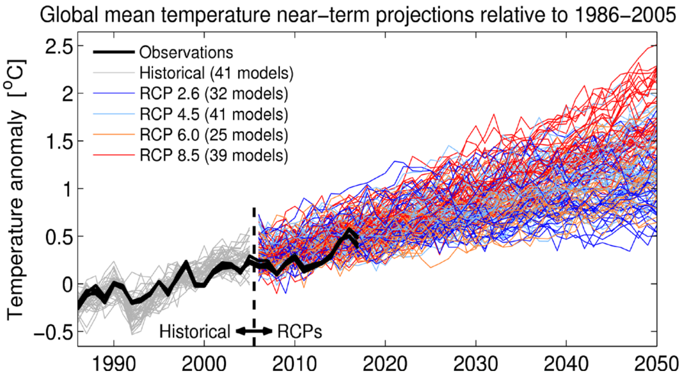

Fig.2. For **each RCP** an ensemble with **various climate models** is created, e.g. ensemble of 39 models for RCP8.5 (source: IPCC AR5, 2013).

Multi-model ensembles (MMEs)

For this approach, simulations from different climate models originating from a range of modelling centres are combined. The simulations are performed for similar forcing scenarios. Evaluation of multi-model ensembles provides a good indication of <u>model uncertainties</u> (how well we can model the Earth's climate system; see "Uncertainty" fact sheets). Nowadays this is a well-coordinated effort through CMIP (Coupled Model Intercomparison Project; CMIP5 = Phase 5) and the results are widely used, including in the IPCC assessment process (Fig 2, on the left). PRIMAVERA contributes to a subset of CMIP6 simulations.

Funding

This project has received funding from the European Union's Horizon 2020 Research & Innovation Programme under grant agreement no. 641727.

Info

PRIMAVERA is a collaboration between 19 leading European research and technology organisations with complementary expertise in climate science, climate change modelling, and high performance computing.

The project is led by the Met Office and the University of Reading.

Media

www.primavera-h2020.eu

Watch the project video →

PRIMAVERA

PRocess-based climate sIMulation: AdVances in high-resolution modelling and European climate Risk Assessment

Perturbed parameter ensembles (PPEs)

These ensembles are typically derived from a single climate model, where parameters relating to physical, chemical or biological processes are systematically varied (perturbed) over a relevant range (Fig.3). In this way model uncertainties can be explored systematically. While many of these parameters can be determined reasonably accurately (with small uncertainty range) with the help of observations, there are still some which are subject to considerable uncertainty.

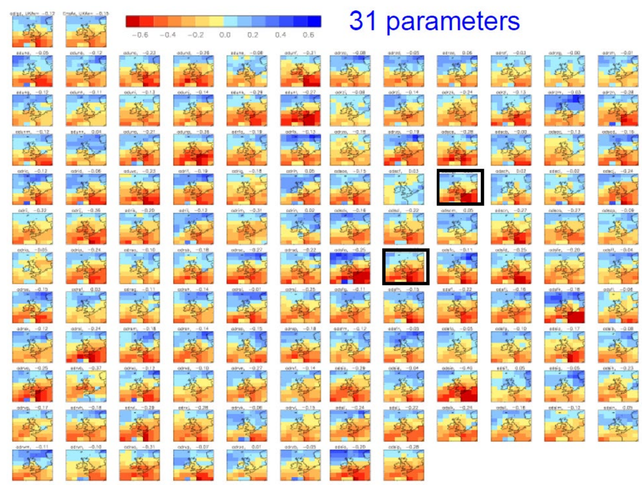

Fig. 3. Example of a temperature field in a large (280 members, approx. half of them shown, 31 parameters) **perturbed parameter** climate ensemble; (source: UKCP09, Met Office).

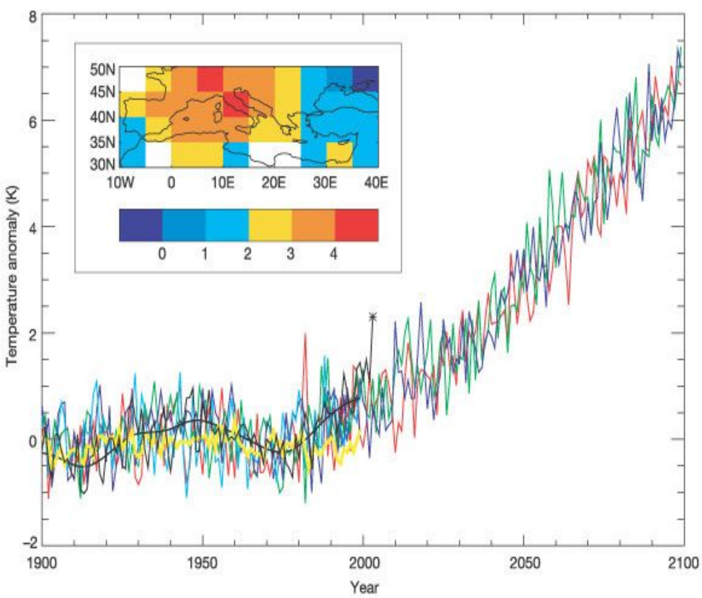

Fig. 4. Attribution study for the 2003 European heatwave, the observed 2003 temperature is shown as a star. The red, green and blue lines are three HadCM3 climate model simulations (initial conditions ensemble; initialised in 1989; source: Stott et al., 2004).

Grand ensembles

Grand ensembles use a combination of various ensemble types. At least two nested ensembles are required, e.g. a PPE followed by an initial condition ensemble. This approach is used in “Climateprediction.net”.

Initial condition ensembles

These ensembles are generated with a single model by slightly changing the initial conditions from which the simulations start (Fig. 1). They are used especially for climate predictions (shorter-term, i.e. days to months ahead), rather than for longer-term projections (decades ahead) and for determining the uncertainties due to natural variability. They also help in determining the probability of extreme events: with more data on extremes, the probabilities can be determined more accurately. For extreme event attribution studies it is important to compare the probabilities of the extreme events from a model with and without anthropogenic greenhouse gas forcings. Through extreme value analysis it is then possible to attribute how much more likely a specific event has become under climate change. One of the earliest applications of this has been for the 2003 European heatwave (Fig. 4, on the left).

References

IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (AR5 WG1).

CMIP5: World Climate Research Programme Coupled Model Intercomparison Project Phase 5.

Stott, et al., 2004. Human contribution to the European heatwave of 2003. Nature, 432(7017), p.610.

Partners

Met Office · University of Reading · SMHI · ECMWF · CERFACS · Max-Planck-Institut für Meteorologie · DKRZ Deutsches Klimarechenzentrum · NERC Science of the Environment · predictia · CMCC Centro Euro-Mediterraneo sui Cambiamenti Climatici · Stockholm University · UCL Université catholique de Louvain · Royal Netherlands Meteorological Institute Ministry of Infrastructure and the Environment · ISAC · Consiglio Nazionale delle Ricerche · Science & Technology Facilities Council · University of Leeds · AWI · BSC Barcelona Supercomputing Center Centro Nacional de Supercomputación · University of Oxford