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Numerical weather prediction and modelling for climate projections

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Introduction

The challenges of numerical weather prediction topics and modelling our future climate differ substantially, although the underlying physical cores of the models bear great similarities. Weather is predicted by integrating a system of nonlinear coupled partial differential equations to obtain future states of the atmosphere from a given initial state. Weather forecasting is successful, when the dynamics of atmospheric vortices of different size are properly represented and when the initial state is well known from observations, being accounted for by data assimilatuion schemes. Climate cannot be predicted for specific locations and times in this sense, since the coupling between processes on different scales interact in an unpredictable way. The relevant processes range from, e.g., cloud microphysics to large hemispheric circulation systems. Climate, being defined by the statistics of weather for a period of 30 years and beyond, also evolves in time, since it responds to varying boundary conditions, both external (changing solar radiation flux, land use) and internal (atmospheric composition). The slowly varying components of the climate systems, i.e. the oceans, ice sheets and soil characteristics cause a memory effect for the atmospheric changes.

Challenges of HPC in modelling weather and climate as physical systems of limited predictability

The HPC requirements for simulations of natural systems like the atmosphere and the oceans in general are still increasing, since the model grid resolution is globally much too coarse to cover all energy-containing scales of motion, in particular the mesoscale (10-1000 km) and the convective scale (100 m - 10 km). It is aimed that approximations such as parametrizations can be avoided and that net effects of small scales are calculated at grid resolution. Limited area models are applied to get higher resolution in regions of interest. Their computional and data storage requirements are similar to those of global models. The CPU time requirements of modelling also increase, since the idea of ensemble modelling with 50 and more ensemble members becomes more and more popular. It was recognized in validation of weather prediction that ensemble means and ensemble spread bear important additional information. A similar development is actually underway in global ([8] [10]) and regional climate ([1] [6] [9]) modelling, where it was shown that ensemble modelling in simulating the observed climate of the last decades can be utilized to get a more realistic representation. In general, more and coupling between different complex models or model submodules for, e.g., the atmosphere, the ocean, and ecosystems is realized in climate modelling.

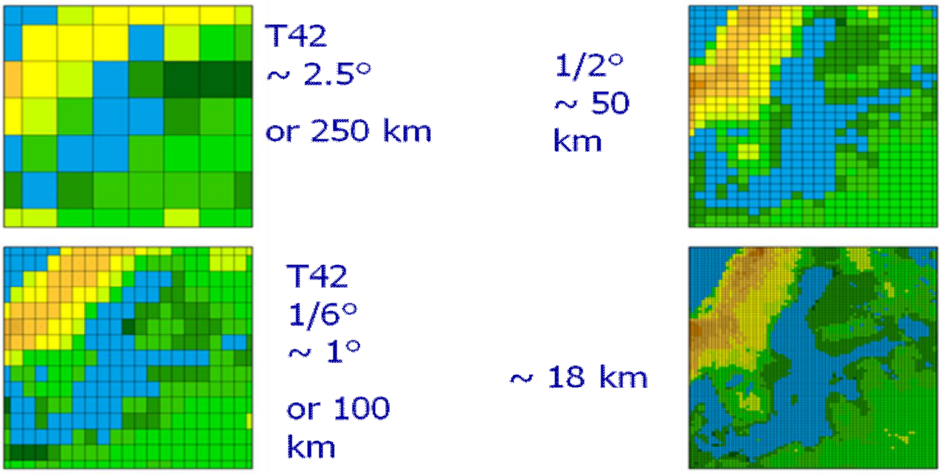

Fig. 1 A model domain in the Baltic Sea with the terrain at different spatial resolution from a coarse global climate model (upper left) to a higher resolution regional climate model (lower right).

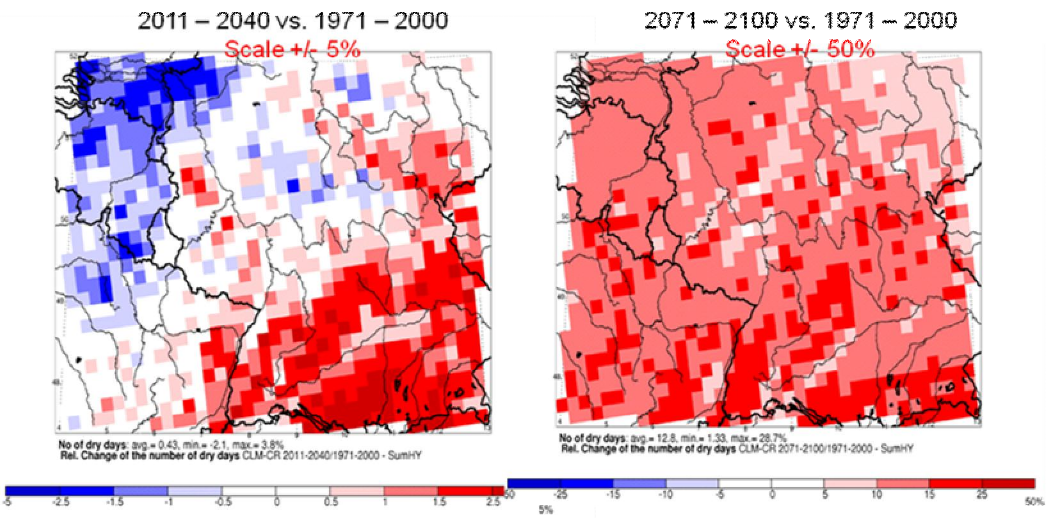

Fig. 2 Analysis of an ensemble of regional climate projections for Southwestern Germany, relative change of number of dry days for two future periods compared to the decades 1971-2000. See more details in [2], [3], [4].

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