ExaESM
Pilot Lab Exascale Earth System Modelling

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

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PilotLab ExaESM
- An Overview -

What is the PilotLab?



- Earth system models are **important tools for assessing the magnitude and impacts of future climate change**
- **Such models have to run in ever finer resolutions in order to capture extreme events**, which, in turn, are often responsible for the majority of weather-related and environmental impacts
- Therefore, these models require **increasing computer power**, and to enable big simulations on such gigantic machines **necessitates close collaboration between Earth system modellers and computer scientists**
- The **PilotLab exaESM (PL-ExaESM)** offers a **platform where these two communities can meet and interact** to build the next-generation Earth system models
- In the PL exaESM, scientists from **9 Helmholtz institutions** work together to address **5 specific problems of exascale Earth system modelling**

Which problems are addressed in the PL-ExaESM?

Scalability:
models are being ported to next-generation GPU processor technology and the **codes are modularized** so that computer scientists can better help to optimize the models on new hardware

Load balancing:
asynchronous workflows allow for **more efficient orchestration** of the increasing model output while **preserving the necessary flexibility** to control the simulation output

Data staging:
new emerging **dense memory technologies** allow new ways of **optimizing I/O operations** of data-intensive applications **running on HPC** clusters and future exascale systems

Machine Learning:
modern ML approaches are tested for their suitability **to replace computationally expensive model calculations** and speed up the model simulations or make **better use of available observation data**

System Design:
the results of **dedicated performance tests of Earth system models and data workflows** are analysed in light of potential improvements of the future exascale supercomputer system design

Why do we need this?


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- Supercomputer technology is undergoing rapid and fundamental changes: since a few years, **processor development has reached physical size limits**, and therefore **new paradigms for computing processors have to be found**
- Typically, next-generation processors combine **many thousand cores in one processing unit**
- To use such devices efficiently, **new programming concepts must be developed and implemented** into ESMs
- Furthermore, these **models generate huge amounts of data**, and **storage technology is also evolving**
- This requires **new modelling workflows** and new ways for **handling Earth system model output**

The Future

- We foresee that next-generation Earth system models will run at **resolutions of 1-3 km**, which means that around **200 numerical equations must be solved in each of about 100 billion model grid boxes at each model time step** (i.e. every minute)
- With such simulations, **local-scale phenomena can be accurately reproduced** and **extreme events will be simulated much more accurately than at present**
- **The way we run Earth system models will change**: the actual simulations will be combined with online analyses of observations, visualization tools, and novel deep learning concepts to **generate new knowledge for the society** and to **provide data for further analysis in user-friendly open web services**.
- **Important information will be gained on how future supercomputer systems can be further optimized** to further increase computational speed while saving on energy consumption

ESM Advanced Earth System Modelling Capacity

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