Project: **1176**

Project title: **AIM**

Principal investigator: **Tobias Weigel**

Report period: **2022-05-01 to 2023-04-30**

Substantial CPU and some GPU computing time on Levante was used to develop and benchmark ICON-ML hybrids (Hereon):

- **Python-Fortran bridge for the ICON weather and climate model (Hereon):** While many groups in Earth system modelling are active in developing novel ML-based components, there is no standard recipe for practically coupling them to prominent ESMs. A major cause of this is the "engineering divide" between the respective ecosystems (ESMs written in Fortran, ML written in Python). A coupling that is both computationally efficient and executable in HPC environments and supports the further dynamic development of Python-based ML modules, including all of the features of used libraries such as Pytorch, is critically needed. In this voucher, several bridges between Fortran and Python have been prototyped and benchmarked along the requirements of a novel parameterization scheme for cloud microphysics. The voucher concluded with recommendations on the best approach, perspectives for publishing benchmark results and follow-up work on the practical coupling of the parameterization scheme into ICON. Preliminary results were presented at EGU '23 (https://meetingorganizer.copernicus.org/EGU23/EGU23-5766.html), PyData Global 2022 (https://global2022.pydata.org/cfp/speaker/SFFDWP) and PASC '22 (https://pasc22.pasc-conference.org/program/schedule/index.html).

Substantial GPU computing time was used for several voucher projects:

- **Automatic geological structure recognition at the Dead Sea lakebed (GEOMAR):** In this voucher, a deep learning method inspired by the U-Net architecture was combined with non-deep-learning computer vision techniques for post-processing in order to detect sinkholes in high-resolution aerial imagery from the dead sea lakebed. Following the initially good detection results (confidently above 95 percent), in future work it is planned to further extend the pipeline to push the evaluation metric into the 98-99 percent range using additional data, and enable the time-dependent tracking and potential prediction of the evolution of sinkholes and other geological features that pose a hazard to infrastructure and agriculture in the study area. Beyond these immediate practical applications, this could lead to a better scientific understanding of the formation and evolution of structures in an environment heavily affected by climate change effects. Preliminary results were presented at the 10th International Conference on Geomorphology, Coimbra, Portugal, 12-16 Sept 2022, https://doi.org/10.5194/icg2022-460.
- **Develop predictive model detecting the preparatory phase before the occurrence of large laboratory earthquakes (GFZ):** In this voucher, seismo-acoustic data from laboratory experiments was used to develop and train several alternative models for the prediction of sudden stress release. The goals were to build models that can predict well over a non-trivial time span, and to provide insights into the relevance of the seismologically relevant features extracted from the time series data. The models developed are promising for follow-up work on additional data and features, possibly also using real-world seismic fields data.With the latest version of these models, a meaningful ranking of seismic variables could be determined. Preliminary results have been presented at EGU '23 (https://meetingorganizer.copernicus.org/EGU23/EGU23-1967.html); a detailed journal publication is in final drafting at time of writing.

Cloud resources and substantial storage was used for:

- **Detecting global ocean windspeeds using GNSS Reflectometry (GFZ):** In this already older project, further developments were made towards operational assessment of the

developed ML model, using a cloud-hosted model instance to detect and monitor possible model degradation over time. Results were presented at EGU ‘22 (https://doi.org/10.5194/egusphere-egu22-8226) and EGU ‘23 (https://meetingorganizer.copernicus.org/EGU23/EGU23-1475.html), and as journal article in Remote Sensing of Environment (Asgarimehr et al., https://doi.org/10.1016/j.rse.2021.112801).