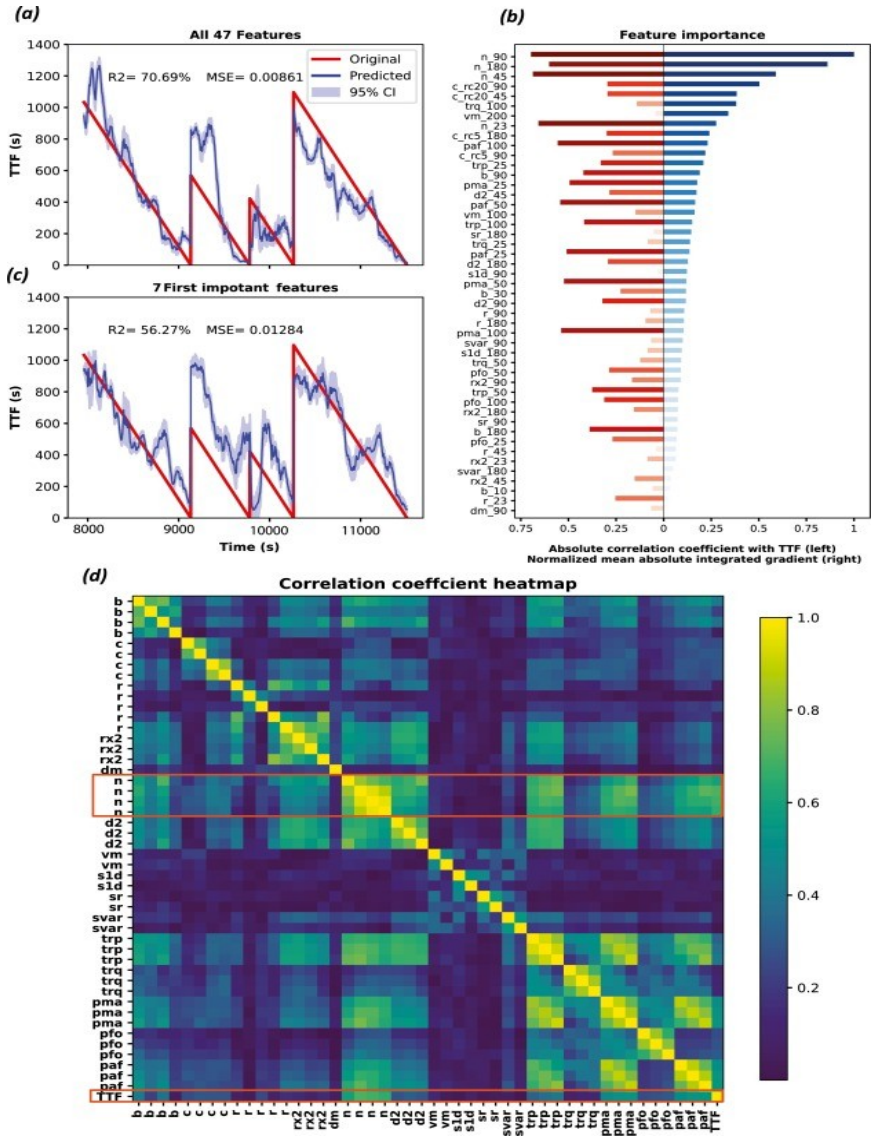
Project: **1176**
Project title: **AIM**
Principal investigator: **Tobias Weigel**
Report period: **2023-05-01 to 2024-04-30**
Maximum of 2 pages including figures. 9 pt minimum font size.

1) **Seismology project (in collaboration with Deutsches GeoForschungsZentrum / GFZ)**

In this work we designed a system that would analyze and predict laboratory earthquakes using 47 catalog-driven seismo-mechanical and statistical features. After successfully designing and implementing the LSTM-based sequential model, we employed state of the art AI explainability techniques, namely Integrated Gradients, to find what features contributed to the ultimate decisions of the neural network. This helps scientists in guiding their future research endeavors, by focusing on the next best thing to investigate when it comes to predicting and explaining internal earth processes.

This work resulted in:

- an EGU talk: https://doi.org/10.5194/egusphere-egu23-1967
- a paper: Karimpouli, S., Caus, D., Grover, H., Martínez-Garzón, P., Bohnhoff, M., Beroza, G.C., Dresen, G., Goebel, T., Weigel, T. and Kwiatek, G., 2023. Explainable machine learning for labquake prediction using catalog-driven features. Earth and Planetary Science Letters, 622, p.118383.
- as well as an associated code repository: https://github.com/ducspe/seismology_earthquake_prediction



2) **Building Fortran-Python ESM-ML hybrid models (in collaboration with Hereon)**

In this project, we coupled SuperdropNet, a neural network to emulate cloud microphysics to ICON. SuperdropNet was trained at HEREON and replaces the warm rain processes within the two-moment cloud microphysics scheme. We tested three options to couple the machine learning component to ICON: embedded Python, pipes, and the YAC coupler. We evaluated SuperdropNet in the warm bubble scenario, an ICON experiment for cloud microphysics. We found that SuperdropNet runs stably within ICON and leads to plausible results.

This work is currently under review and available as a preprint: Arnold, C., Sharma, S., Weigel, T., and Greenberg, D.: Efficient and Stable Coupling of the SuperdropNet Deep Learning-based Cloud Microphysics (v0.1.0) to the ICON Climate and Weather Model (v2.6.5), EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-2047, 2023.

3) **Downscaling project (in collaboration with Forschungszentrum Jülich / FZJ)**

This work is part of the **Atmorep** project, aiming at creating a task-independent stochastic computer model of atmospheric dynamics that can provide skillful results for a wide range of applications (Lessig et al, 2023). The priority applications of interest include downscaling of ERA5 to finer resolutions, as well as precipitation nowcasting. A crucial step to achieve these tasks and scale properly was to design an efficient data loader component, that could handle vast amounts of data in general, and on DKRZ systems in particular. We made this memory handling step the focus of our current work and hence, polished the dataloader component thoroughly. Consequently, several relevant unit tests for data handling were put in place to ensure sound software engineering practices. Additionally, since there was a lack of documentation prior, new up-to-date and detailed documentation was compiled.

4) **CyGNSSnet deployment (in collaboration with Deutsches GeoForschungsZentrum / GFZ)**

CyGNSSnet is one of our longest-running projects, determining ocean wind speeds through ML-driven analysis of Global Navigation Satellite Systems Reflectometry / GNSS-R data. We have successfully developed the deep learning model previously and were now faced with the task of deploying it. Hence, over the past year at DKRZ we developed a monitoring tool that is used to view and verify the performance of the trained ML model over time as new data comes in. The developed web-based tool is running in the DKRZ cloud infrastructure, while compressed input data is kept on DKRZ storage facilities. The tool has an internal scheduler that downloads a current version of the data, runs the model to derive the new predictions and refreshes the client front end.

5) **Plankton auto-classification (in collaboration with Hereon)**

In conjunction Hereon we worked on a Plankton auto-classification tool, aimed at detecting marine organisms with label-free image feature learning and probability calibration. We helped the colleagues at Hereon to technically set up the experiments on a high performance computing cluster, addressing the specific big data handling challenges they had. In the end, the experiments were successfully carried out and the results were used in the following paper: https://doi.org/10.1088/2632-2153/ace417