Project: **1343**

Project title: **SCENIC-DynAI – AI supported climate model downscaling for storyline-based impact analyses**

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Report period: **2023-11-01 to 2024-10-31**

Maximum of 2 pages including figures. 9 pt minimum font size.

Project overview

As part of the Helmholtz Innovation Pool of the Research Field Earth and Environment project SCENIC (Storyline Scenarios of Extreme Weather, Climate, and Environmental Events along with their Impacts in a Warmer World) the objective of the SCENIC-DynAI subproject is to develop artificial intelligence supported regionally downscaled storyline-based climate simulations for Central Europe and Germany and the generation of dynamically downscaled simulations for the project consortium. Within SCENIC, global simulations are being generated (DKRZ project 1264: Storyline simulations of extreme events with spectral nudging) for a specific period (2014-now) by applying spectral nudging of atmospheric winds (particularly the jet stream) in a storyline approach for different climate scenarios. The overall objective is to investigate the possible manifestations of real-world present-day extreme weather (heat-waves, droughts and heavy rain) under pre-industrial, present day, +2K, +3K, and +4K conditions.

The SCENIC-DynAI project wants to develop an alternative AI-based downscaling method and test it for climate impact modeling. Therefore, it has four major objectives: 1) to create a set of dynamically downscaled storyline based global climate simulations as a comparison benchmark for within the project prepared machine learning based downscaling products and for climate impact studies within the project consortium of SCENIC, 2) to train generative adversarial fourier neural operator networks for a AI/ML based bias correcting and downscaling of the global model runs, and 3) to apply the generated datasets for a climate impact study of the regional terrestrial carbon and nitrogen cycle.

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For the **first** objective of SCENIC DynAI, the dynamical downscaling of the global storyline scenarios the experiment setup has been changed, partly motivated by the review comments for the last proposal and due to the developments within the SCENIC project. Since the downscaling of the global runs to a 1 km Germany domain would have generated a large computational demand and the project partners would only need the data for some specific regions, it was decided to select 2 domains which represent a typical Mid-West (Eiffel and Ruhrpott) and an Alpine with foreland region, respectively. An additional third domain for the region of the Harz mountains and Berlin was scrapped. Owing to the availability of 3 km regional downscalings from the ICON simulations for Germany within the project (DKRZ project 1264), it was suggested to further refine these 3 km runs for the two 1 km domains with the WRF model for subsequent usage in hydrological, agricultural, and extreme weather impact studies. During the continuation of the project, it was seen that the originally suggested simulation period of 7 years was to short, in particular for the training of AI based models. Therefore, a back extension with additional 4 years was generated for the global and the ICON simulations and consequently for the 1 km WRF downscaling. Since the originally requested computational time on Levante was considerably cut, we had to request additional resources from the main SCENIC project to fulfill the project demands.

The 1 km WRF-based downscaling will be finished within the remaining period of the current allocation. The scientific analysis will be continued thereafter. Thus no results are available at the moment for presentation in this report.

For the **second** objective of SCENIC DynAI, comprising the AI part with allocated GPU ressources, two major work packages were proposed. Downscaling of the variable precipitation of Global Climate Model simulations to ERA5 land estimates and resolution, and further downscaling to RADKLIM-YW precipitation observations and resolution.

First investigations of WP1 indicated promising results following a video-superresolution approach, by training a generative deep learning model to downscale coarsened ERA5 data and apply it to unseen GCM data during inference. The reason for this is, that coarsened ERA5 and provided GCM simulations show a very similar distribution.

This could not be shown for coarsened RADKLIM-YW data and ERA5 land or ERA5 global precipitation estimates, which made WP2 more challenging, since a straight forward video-superresolution was not promising. Therefore we spent most of the time and resources into WP2 and developed spateGAN-ERA5. The deep learning model is an optimized version of spateGAN, which was improved, trained and evaluated using DKRZ GPU resources. It downscales/translates ERA5 global precipitation estimates how they would have been observed by a high quality and high resolution rain gauge adjusted weather radar product. The training is conducted for the region of Germany, where such a high quality dataset is available. Model robustness evaluation was conducted for the region United states, leveraging the MRMS radar observation dataset and for Australia, leveraging the operational Australian radar network.

The promising results let us conclude, that spateGAN-ERA5 provides skill also on global scale, which let us apply the model for global ERA5 precipitation downscaling to km-scale and 10 min. resolution.

Since the comprehensive evaluation was time consuming, we had to focus on this topic and could not spent planned GPU resources on a more complete hyper parameter optimization.

Furthermore we decided to focus on WP2 and conclude, that WP1 can be more easily fulfilled and act as a preprocessing step, when WP2 is finished

In the following weeks we will finalize the preparation of a manuscript about ERA5 precipitation downscaling using spateGAN-ERA5. Remaining GPU resources will be used to apply the model on a global scale and provide data for impact studies of applications that benefit of such data that reflects the high variability of precipitation.

For the **third** objective of doing impact assessment with LandscapeDNDC the output of the ICON simulations (project 1264) on a European level was used. At the beginning of the year we ran the calculations on Levante. The results of this simulations were focused on the spatial extend of heat stress experienced as a result of applying the storylines of the subsequent heatwaves between 2018 and 2023. The results were compiled for a manuscript which has been submitted in June 2024. LandscapeDNDC has not yet been applied to the results of WP1, which will only be possible once these calculations have been finished.