Project: **1338**

Project title: **CliNSBaS – Climate change impacts and adaptation in the North Sea – Baltic Sea region**

Principal investigator: **Tim Kruschke**

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

Expired resources:

In the first quarter of 2024 a substantial amount of the granted computing resources expired due to a delay in the processing of boundary conditions for longer NEMO simulations. During the subsequent months all requested CPU resources were used. Regarding GPU resources, we used our allocation comparably constant throughout the year. Still approx. 85% of the granted GPU-hours expired for two reasons: (i) The algorithm in use proved to be much more efficient for our use case than expected by us and our advisors in DKRZ's Data Analysis department who developed the code. (ii) As part of fostering inter-authority collaboration on high-performance computing, we were requested to shift part of our activities to a HPC-system run by the Federal Waterways Engineering and Research Institute to test the usability of this system for our purposes. This resulted basically in a 50%-reduction of our GPU-demand on DKRZ facilities.

Progress report

As described in the proposal, CliNSBaS consists of four subprojects. For this report we focus on results of two subprojects associated with the largest share in resources (CPU and GPU time) used at DKRZ facilities.

CRAI - BSH SST analysis 3.0

The kick-off for this part of the project was in February 2023. The goal is to train a convolutional neural network (CNN) developed at DKRZ (https://github.com/FREVA-CLINT/climatereconstructionAI) with sea-surface temperatures (SST) from model data so that in the end the trained model can fill gappy observational data from satellites and ships retrospectively and operationally.

After initial testing in 2023, we decided on a set of model parameters that had produced promising results. The plan for 2024 was to 1) further increase the training data pool (more climate model simulations, reanalysis data etc.), 2) further increase the grid resolution, and 3) to test the Long Short-Term-Memory (LSTM) module to better handle days with (almost) no satellite data.

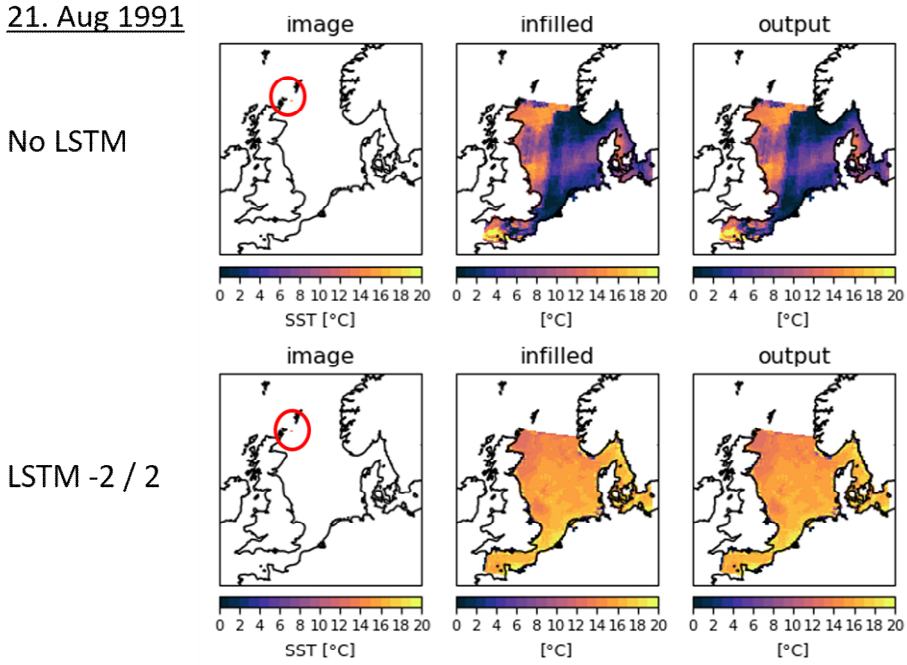

Fig. 1: Example of a real-world SST-field from Aug 21, 1991, with about one SST pixel (left) presented to the afore-trained CRAI-CNN and the CNN-produced image with infilled data and newly computed output respectively (center and right)

In the current reporting period the training dataset was expanded to include scenario simulations for the years 2030 to 2100 from the BSH climate model. We also constructed the dataset for infilling from 33 years of satellite data over the North Sea and Baltic Sea. We continued training the CNN on various high-resolution grid variations – one of those being the North and Baltic Sea region together on a rotated grid (not shown).

The CRAI developers provided the possibility in the master code to expand the neural network to include a Long-Short-Term-Memory (LSTM) layer. This is especially useful for our situation where on some days, we have very bad weather conditions for satellite coverage and just very few pixels contain SST-information. The LSTM layer includes the SST information from x days before or after the day with little to no data and the model delivers a reasonable output for that day, see Figure 1.

The challenge then in using the LSTM layer is to prevent overfitting. Therefore, in the upcoming project period more

finetuning of the model training and its parameters is necessary, but we are hopeful that we can produce a skillful reanalysis product of CNN-based, infilled satellite data in the next year.

Development of next generation DAS-Basisdienst regional climate model

In the first quarter of 2024, 1-D simulations were conducted to calibrate the radiation scheme for stand-a-lone NEMO4.2 simulations as well as coupled ICON-NEMO4.2 simulations. Therefore, work on the advancement of the BSH stand-alone regional climate model for the DAS-Basisdienst commenced in the second quarter of 2024.

A 43 year hindcast simulation with a setup including new initialization fields for temperature and salinity as well as multiple new boundary conditions starting in 1979 and ending in 2022 was conducted. Results are going to be used for a comparison against coupled simulation results and a first evaluation of the SST shows no drift in bias over the simulated time span.

Furthermore, test runs were undertaken to further enhance the numerical stability of the wetting-and-drying scheme and improve its results in respect to observational data. This improvement involved a new HBM like tapering function, a Laplacian smoothing of the wetting-and-drying mask and an implementation of a different bottom friction coefficient. Subsequently, a five-year run with an active wetting-and-drying scheme and a five-year reference run both with a resolution of 2 nautical miles were conducted. Results of the sea surface height at Helgoland are exemplarily displayed in Fig. 2 for both runs.

In the next period, the wetting-and-drying scheme will be explored for higher resolutions and a 100y simulation will be conducted with the 2nm setup.

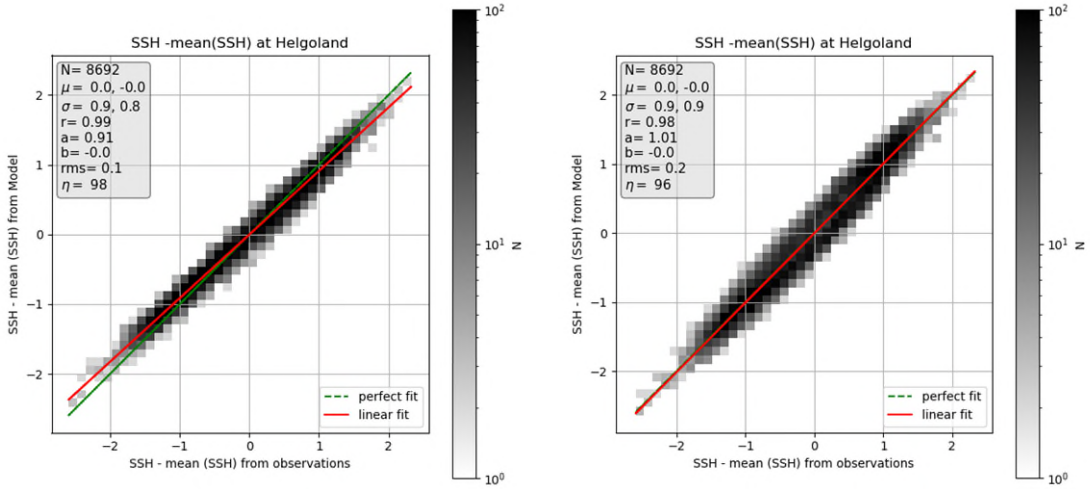

Fig. 2: Comparison of sea surface height at station Helgoland in the time span from 1st Jan 2018 to 31st Dec 2018 for reference simulation (left) and enhanced simulation with wetting-and-drying scheme (right).

Conference Contributions:

- Ditzinger, G.X., Rust, H.W., Peter, M., Kruschke, T.: Sea level rise drives increase in water level extremes in the German Bight. EVAN Conference 2024, Venice, Italy, 16-19 July 2024
- Ditzinger, G.X., Rust, H.W., Meyer, J., Düsterhöft-Wriggers, W., Kruschke, T.: Extreme Wasserstände an den deutschen Küsten – heute und in Zukunft. 14. Extremwetterkongress, Hamburg, 25/26 Sep 2024
- Hinrichs, C., Kadow, C., Meuer, J., and Kruschke, T.: Machine-Learning-basierte Analyse und Rekonstruktion von Meeresoberflächentemperaturen der Nordsee, 13. Deutsche Klimatagung, Potsdam, Deutschland, 12–15 Mar 2024, DKT-13-9, https://doi.org/10.5194/dkt-13-9, 2024.
- Kruschke, T., Kadow, C., Meuer, J., and Hinrichs, C.: Machine-learning-based analysis and reconstruction of high-resolution sea-surface temperatures for the North Sea and Baltic Sea, EGU General Assembly 2024, Vienna, Austria, 14–19 Apr 2024, EGU24-11061, https://doi.org/10.5194/egusphere-egu24-11061, 2024.
- Meyer, J., Maurer V., Duesterhoeft-Wriggers, W., Ehlers, B.-M., Janssen, F.: ICON-NEMO ocean-atmosphere model in regional climate modelling - towards climate projections for the EURO-CORDEX domain, 14th EURO-CORDEX annual meeting, Hamburg, Germany, 22-25 Jan 2024.
- Meyer, J., Maurer, V., Duesterhoeft-Wriggers, W., Ehlers, B.-M., Janssen, F.: Preparing the hindcast: coupled vs. forced NEMO4.2 simulations, NEMO-Nordic Meeting, SMHI, Norrköping, Sweden, 2-3 May 2024.
- Schaffer, L., Boesch, A., Baehr, J., Kruschke, T.: Development of a wind-based storm surge model for the German Bight. 56th International Liège Colloquium on Ocean Dynamics, Liège, Belgium, 26-30 May 2024

Publications:

- Schade, N.H., Jensen, C., Schaffer, L., Ditzinger, G.X., Möller, J., Kruschke, T. 2023: Wirkungsanalyse Sturm/Sturmfluten. Sonderanalysen und methodische Entwicklungen – Berichtsreihe des Schwerpunktthemas 101 (SPT-101) im Themenfeld 1 des BMDV-Expertennetzwerks. https://doi.bsh.de/10.57802/44q8-4h46
- Schaffer, L., Boesch, A., Baehr, J., Kruschke, T.: Development of a wind-based storm surge model for the German Bight. Under review for Nat. Hazards Earth Syst. Sci. https://doi.org/10.5194/egusphere-2024-3144