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Accelerating Climate Model Computation by Neural Networks: A Comparative Study

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In the era of modern science, scientists have developed numerical models to predict and understand the weather and ocean phenomena based on fluid dynamics. While these models have shown high accuracy at kilometer scales, they are operated with massive computer resources because of their computational complexity. In recent years, new approaches to solve these models based on machine learning have been put forward. The results suggested that it be possible to reduce the computational complexity by Neural Networks (NNs) instead of classical numerical simulations. In this project, we aim to shed light upon different ways to accelerating physical models using NNs. We test two approaches: Data-Driven Statistical Model (DDSM) and Hybrid Physical-Statistical Model (HPSM) and compare their performance to the classical Process-Driven Physical Model (PDPM). DDSM emulates the physical model by a NN. The HPSM, also known as super-resolution, uses a low-resolution version of the physical model and maps its outputs to the original high-resolution domain via a NN. To evaluate these two methods, we measured their accuracy and their computation time. Our results of idealized experiments with a quasi-geostrophic model [SO3] show that HPSM reduces the computation time by a factor of 3 and it is capable to predict the output of the physical model at high accuracy up to 9.25 days. The DDSM, however, reduces the computation time by a factor of 4 and can predict the physical model output with an acceptable accuracy only within 2 days. These first results are promising and imply the possibility of bringing complex physical models into real time systems with lower-cost computer resources in the future.