EGU2020-11263
https://doi.org/10.5194/egusphere-egu2020-11263
EGU General Assembly 2020
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Deep reinforcement learning in World-Earth system models to discover sustainable management strategies

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The identification of pathways leading to robust mitigation of dangerous anthropogenic climate change is nowadays of particular interest
not only to the scientific community but also to policy makers and the wider public.

Increasingly complex, non-linear World-Earth system models are used for describing the dynamics of the biophysical Earth system and the socio-economic and socio-cultural World of human societies and their interactions. Identifying pathways towards a sustainable future in these models is a challenging and widely investigated task in the field of climate research and broader Earth system science. This problem is especially difficult when caring for both environmental limits and social foundations need to be taken into account.

In this work, we propose to combine recently developed machine learning techniques, namely deep reinforcement learning (DRL), with classical analysis of trajectories in the World-Earth system as an approach to extend the field of Earth system analysis by a new method. Based on the concept of the agent-environment interface, we develop a method for using a DRL-agent that is able to act and learn in variable manageable environment models of the Earth system in order to discover management strategies for sustainable development.

We demonstrate the potential of our framework by applying DRL algorithms to stylized World-Earth system models. The agent can apply management options to an environment, an Earth system model, and learn by rewards provided by the environment. We train our agent with a deep Q-neural network extended by current state-of-the-art algorithms. Conceptually, we thereby explore the feasibility of finding novel global governance policies leading into a safe and just operating space constrained by certain planetary and socio-economic boundaries.

We find that the agent is able to learn novel, previously undiscovered policies that navigate the system into sustainable regions of the underlying conceptual models of the World-Earth system. In particular, the artificially intelligent agent learns that the timing of a specific mix of taxing carbon emissions and subsidies on renewables is of crucial relevance for finding World-Earth system

trajectories that are sustainable in the long term. Overall, we show in this work how concepts and tools from artificial intelligence can help to address the current challenges on the way towards sustainable development.

Underlying publication

[1] Strnad, F. M.; Barfuss, W.; Donges, J. F. & Heitzig, J. Deep reinforcement learning in World-Earth system models to discover sustainable management strategies Chaos: An Interdisciplinary Journal of Nonlinear Science, AIP Publishing LLC, 2019, 29, 123122