# Iseec

## [1] V. Ramanathan, Y. Xu, and A. Versaci, “Modelling human–natural systems interactions with implications for twenty-first-century warming,” Nat Sustain, vol. 5, no. 3, pp. 263–271, Dec. 2021, doi: 10.1038/s41893-021-00826-z.

由于缺乏对人类与自然系统相互作用在社会应对气候变化方面所起作用的定量处理,重新设计能源和经济系统以稳定气候变化的工作 受到了阻碍。在这里,我们提出了一个综合的社会-能源-生态-气候模型框架,用于理解人类-自然系统相互作用在气候变化中的作用。 我们重点关注全球变暖和社会行动之间的反馈对气候稳定的限制,以使能源使用脱碳和扩大大气碳提取。能源-气候反馈通过从历史数 据推断出的社会、政策和技术行动的四个变暖相关响应时间进行建模。我们表明,2030 年之后缺乏社会响应将导致全球变暖超过 3°C。 将社会反应时间和技术扩散时间加快两倍,同时大幅增加对可再生能源和大气碳提取技术的启动投资,以及到 2030 年短期缓解气候污 染物,可以将升温稳定在 1.5°C 以下。该模型的分析框架和本文提出的分析揭示了在制定和设计稳健的气候解决方案时,**在向零排放 过渡的过程中,考虑人-自然系统相互作用的重要性。**

The redesign of energy and economic systems to stabilize climate change is hindered by the lack of quantitative treatment of the role that human–natural systems interactions play in what society can do to tackle climate change. Here we present an integrated socio–energy–ecologic–climate model framework for understanding the role of human–natural systems interactions in climate change. We focus on constraints on climate stabilization imposed by feedbacks between global warming and societal actions to decarbonize energy use and to scale up atmospheric-carbon extraction. The energy–climate feedbacks are modelled through four warming-dependent response times for societal, policy and technological actions inferred from historical data. We show that a lack of societal response beyond 2030 would result in a warming in excess of 3 °C. Speeding up societal response times and technology diffusion times by a factor of two along with a dramatic boost in start-up investment in renewables and atmospheric-carbon extraction technologies and short-lived climate pollutants mitigation by 2030 can stabilize the warming below 1.5 °C. The model’s analytical framework and the analyses presented here reveal the fundamental importance of factoring in the role of human–natural systems interactions in the transition to zero emissions when formulating and designing robust climate solutions.

# Stand2019-ays

## [1] F. M. Strnad, W. Barfuss, J. F. Donges, and J. Heitzig, “Deep reinforcement learning in world-earth system models to discover sustainable management strategies,” Chaos: An Interdisciplinary Journal of Nonlinear Science, vol. 29, no. 12, p. 123122, Dec. 2019, doi: 10.1063/1.5124673.

Increasingly complex nonlinear World-Earth system models are used for describing the dynamics of the biophysical Earth system and the socioeconomic and sociocultural World of human societies and their interactions. Identifying pathways toward a sustainable future in these models for informing policymakers and the wider public, e.g., pathways leading to robust mitigation of dangerous anthropogenic climate change, is a challenging and widely investigated task in the field of climate research and broader Earth system science. This problem is particularly difficult when constraints on avoiding transgressions of planetary boundaries 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. Based on the concept of the agent-environment interface, we develop an agent that is generally able to act and learn in variable manageable environment models of the Earth system. We demonstrate the potential of our framework by applying DRL algorithms to two stylized World-Earth system models. Conceptually, we explore thereby the feasibility of finding novel global governance policies leading into a safe and just operating space constrained by certain planetary and socioeconomic boundaries. 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.

越来越复杂的非线性世界-地球系统模型被用于描述生物物理地球系统和人类社会的社会经济和社会文化世界的动态及其相互作用。在这些模型中确定通向可持续未来的途径，以便为决策者和广大公众提供信息，例如，导致危险的人为气候变化的稳健缓解的途径，是气候研究和更广泛的地球系统科学领域的一项具有挑战性和广泛研究的任务。当需要考虑避免行星边界越界和社会基础的限制时，这个问题尤为困难。

【】

在这项工作中，我们提出将最近开发的机器学习技术，即深度强化学习( DRL )，与世界-地球系统中轨迹的经典分析相结合。**基于Agent -环境接口的概念，我们**开发了一个Agent，它通常能够在地球系统的可变可管理的环境模型中行动和学习。我们通过将DRL算法应用于两个典型的World - Earth系统模型来展示我们框架的潜力。

【】

从概念上讲，我们探讨了寻找新的全球治理政策的可行性，从而在一定的行星和社会经济边界的约束下，进入一个安全和公正的运作空间。

【】

人工智能智能体了解到，对碳排放征税和对可再生能源补贴的特定组合的时间，对于寻找长期可持续的世界-地球系统轨迹具有重要意义。

## Jiang, Q. S., J. C. Li, Y. X. Sun, 等. 《Deep-Reinforcement-Learning-Based Water Diversion Strategy》. ENVIRONMENTAL SCIENCE AND ECOTECHNOLOGY 17 (2024年1月). WOS:001050660700001.https://doi.org/10.1016/j.ese.2023.100298.

Water diversion is a common strategy to enhance water quality in eutrophic lakes by increasing available water resources and accelerating nutrient circulation. Its effectiveness depends on changes in the source water and lake conditions. However, the challenge of optimizing water diversion remains because it is difficult to simultaneously improve lake water quality and minimize the amount of diverted water. Here, we propose a new approach called dynamic water diversion optimization (DWDO), which combines a comprehensive water quality model with a deep reinforcement learning algorithm. We applied DWDO to a region of Lake Dianchi, the largest eutrophic freshwater lake in China and validated it. Our results demonstrate that DWDO significantly reduced total nitrogen and total phosphorus concentrations in the lake by 7% and 6%, respectively, compared to previous operations. Additionally, annual water diversion decreased by an impressive 75%. Through interpretable machine learning, we identified the impact of meteorological indicators and the water quality of both the source water and the lake on optimal water diversion. We found that a single input variable could either increase or decrease water diversion, depending on its specific value, while multiple factors collectively influenced real-time adjustment of water diversion. Moreover, using well-designed hyperparameters, DWDO proved robust under different uncertainties in model parameters. The training time of the model is theoretically shorter than traditional simulation-optimization algorithms, highlighting its potential to support more effective decisionmaking in water quality management.

调水是通过增加可利用水资源和加速营养物质循环来改善富营养化湖泊水质的常用策略。其有效性取决于水源水和湖泊条件的变化。然而，优化调水的挑战仍然存在，因为很难同时改善湖泊水质和最大限度地减少引水量。在此，我们提出了一种名为动态调水优化( DWDO )的新方法，该方法将综合水质模型与深度强化学习算法相结合。我们将DWDO应用于中国最大的富营养化淡水湖泊滇池的一个区域，并对其进行了验证。 结果表明，与之前的操作相比，DWDO显著降低了湖泊中总氮和总磷的浓度，分别降低了7 %和6 %。此外，年引水量减少了75 %。通过可解释的机器学习，我们确定了气象指标和源水和湖泊的水质对最优调水的影响。研究发现，单一输入变量可以根据其具体值增加或减少引水量，而多因素共同影响引水量的实时调整。此外，使用设计良好的超参数，DWDO在模型参数的不同不确定性下证明了鲁棒性。 该模型的训练时间理论上比传统的模拟-优化算法更短，突出了其在水质管理中支持更有效决策的潜力。

# C-切入点-ClimateRL-theo

## [1] T. Wolf, N. Nardelli, J. Shawe-Taylor, and M. Perez-Ortiz, “Can reinforcement learning support policy makers? A preliminary study with integrated assessment models,” Dec. 11, 2023, arXiv: arXiv:2312.06527. doi: 10.48550/arXiv.2312.06527.

Governments around the world aspire to ground decision-making on evidence. Many of the foundations of policy making — e.g. sensing patterns that relate to societal needs, developing evidence-based programs, forecasting potential outcomes of policy changes, and monitoring effectiveness of policy programs have the potential to benefit from the use of large-scale datasets or simulations together with intelligent algorithms. These could, if designed and deployed in a way that is well grounded on scientific evidence, enable a more comprehensive, faster, and rigorous approach to policy making. Integrated Assessment Models (IAM) is a broad umbrella covering scientific models that attempt to link main features of society and economy with the biosphere into one modelling framework. At present, these systems are probed by policy makers and advisory groups in a hypothesis-driven manner. In this paper, we empirically demonstrate that modern Reinforcement Learning can be used to probe IAMs and explore the space of solutions in a more principled manner. While the implication of our results are modest since the environment is simplistic, we believe that this is a stepping stone towards more ambitious use cases, which could allow for effective exploration of policies and understanding of their consequences and limitations.

**世界各国政府都渴望以证据为基础进行决策。政策制定的许多基础- -例如与社会需求相关的感知模式、开发基于证据的方案、预测政策变化的潜在结果以及监测政策方案的有效性- -都有可能从使用大规模数据集或模拟以及智能算法中受益。如果设计和部署方式能够很好地基于科学证据，这些可以使政策制定更加全面、快速和严格。综合评估模型( IAM )是一个涵盖广泛的科学模型，试图将社会和经济的主要特征与生物圈联系到一个建模框架中。 目前，这些制度正由政策制定者和咨询小组以假说驱动的方式进行探索。在本文中，我们通过实验证明了现代强化学习可以用来探测IAMs，并以更原则性的方式探索解的空间。虽然我们的结果是谦逊的，因为环境是简单化的，但我们相信这是迈向更宏大用途案例的敲门砖，可以有效地探索政策，并了解其后果和局限性。**

## Otto, Ilona M., Jonathan F. Donges, Roger Cremades, 等. 《Social Tipping Dynamics for Stabilizing Earth’s Climate by 2050》. Proceedings of the National Academy of Sciences 117, 期 5 (2020年): 2354～65. <https://doi.org/10.1073/pnas.1900577117>.

Safely achieving the goals of the Paris Climate Agreement requires a worldwide transformation to carbon-neutral societies within the next 30 y. Accelerated technological progress and policy implementations are required to deliver emissions reductions at rates sufficiently fast to avoid crossing dangerous tipping points in the Earth’s climate system. Here, we discuss and evaluate the potential of social tipping interventions (STIs) that can activate contagious processes of rapidly spreading technologies, behaviors, social norms, and structural reorganization within their functional domains that we refer to as social tipping elements (STEs). STEs are subdomains of the planetary socioeconomic system where the required disruptive change may take place and lead to a sufficiently fast reduction in anthropogenic greenhouse gas emissions. The results are based on online expert elicitation, a subsequent expert workshop, and a literature review. The STIs that could trigger the tipping of STE subsystems include 1) removing fossil-fuel subsidies and incentivizing decentralized energy generation (STE1, energy production and storage systems), 2) building carbon-neutral cities (STE2, human settlements), 3) divesting from assets linked to fossil fuels (STE3, financial markets), 4) revealing the moral implications of fossil fuels (STE4, norms and value systems), 5) strengthening climate education and engagement (STE5, education system), and 6) disclosing information on greenhouse gas emissions (STE6, information feedbacks). Our research reveals important areas of focus for larger-scale empirical and modeling efforts to better understand the potentials of harnessing social tipping dynamics for climate change mitigation.

**安全地实现《巴黎气候协定》的目标需要在未来30年内实现全球范围内向碳中性社会的转变。为了避免在地球气候系统中跨越危险的临界点，需要加快技术进步和政策实施，以足够快的速度提供减排。在此，我们讨论和评估社会倾销干预( STIs )的潜力，它可以激活技术、行为、社会规范和结构重组在其功能领域内迅速传播的传染性过程，我们称之为社会倾销要素( STEs )。 STEs是行星社会经济系统的子域，在这些子域中可能发生所需的破坏性变化，并导致足够快的人为温室气体排放减少。研究结果基于在线专家启发、后续专家工作坊和文献综述。 可能引发STE子系统崩溃的STIs包括：1 )取消化石燃料补贴和激励分散能源发电( STE1、能源生产和存储系统)，2 )建立碳中和城市( STE2 ,人居环境)，3 )剥离与化石燃料相关的资产( STE3 ,金融市场)，4 )揭示化石燃料( STE4、规范和价值体系)的道德含义，5 )加强气候教育和参与( STE5 ,教育系统)，6 )披露温室气体排放信息( STE6 ,信息反馈)。我们的研究揭示了更大规模的经验和模型努力的重要关注领域，以更好地理解利用社会倾向性动态减缓气候变化的潜力。**

## [1] D. P. Van Vuuren et al., “Exploring pathways for world development within planetary boundaries,” Nature, vol. 641, no. 8064, pp. 910–916, May 2025, doi: 10.1038/s41586-025-08928-w.

The pressures humanity has been placing on the environment have put Earth’s stability at risk. The planetary boundaries framework serves as a method to define a ‘safe operating space for humanity’1,2 and has so far been applied mostly to highlight the currently prevailing unsustainable environmental conditions. The ability to evaluate trends over time, however, can help us explore the consequences of alternative policy decisions and identify pathways for living within planetary boundaries3. Here we use the Integrated Model to Assess the Global Environment4 to project control variables for eight out of nine planetary boundaries under alternative scenarios to 2050, both with and without strong environmental policy measures. The results show that, with current trends and policies, the situation is projected to worsen to 2050 for all planetary boundaries, except for ozone depletion. Targeted interventions, such as implementing the Paris climate agreement, a shift to a healthier diet, improved food, and water- and nutrient-use efficiency, can effectively reduce the degree of transgression of the planetary boundaries, steering humanity towards a more sustainable trajectory (that is, if they can be implemented based on social and institutional feasibility considerations). However, even in this scenario, several planetary boundaries, including climate change, biogeochemical flows and biodiversity, will remain transgressed in 2050, partly as result of inertia. This means that more-effective policy measures will be needed to ensure we are living well within the planetary boundaries.

人类对环境的压力使地球的稳定面临着巨大的威胁。**行星边界框架作为定义"人类安全操作空间" 1，2的一种方法**，迄今为止主要用于强调当前普遍存在的不可持续的环境状况。然而，随着时间的推移，评估趋势的能力可以帮助我们探索替代政策决策的后果，并确定在行星边界内生活的途径3。在这里，我们使用综合模型来评估全球环境4，以预测到2050年的9个行星边界中的8个控制变量，包括有和没有强有力的环境政策措施。 结果表明，按照目前的趋势和政策，除臭氧层损耗外，所有行星边界的情况预计将恶化到2050年。有针对性的干预措施，如实施《巴黎气候协定》，转向更健康的饮食，改善食物和水- -以及营养利用效率，可以有效地减少行星边界的越界程度，使人类走向更可持续的轨道(也就是说,如果能够基于社会和制度的可行性考虑来实施)。然而，即使在这种情况下，包括气候变化、生物地球化学流和生物多样性在内的一些行星边界在2050年仍然会被突破，部分原因是惯性的结果。 **这意味着需要采取更有效的政策措施，以确保我们在行星边界内生活得很好。**

# 多目标

## Multi-objective deep reinforcement learning for a water heating system with solar energy and heat recovery

Deep reinforcement learning (DRL) has gained attention from the scientific community due to its potential for

optimizing complex control schemes. This study describes the implementation of a DRL platform that allows

training smart agents to manage a complex water heating system in an institutional building that uses solar

energy and waste heat from a water chiller as energy sources. In addition to optimizing the use of energy while

delivering hot water, the agents are also trained to activate the chiller, to avoid the premature degradation of the

system, and to continue providing hot water in case of failures of heating devices of the system. The definition of

the reward function, which is fundamental to simultaneously impose all these goals on the agent, is tested by

comparing different agents trained to prioritize different goals. In comparison with a previous study done on the

same system with standard reinforcement learning techniques, this method allows far more freedom to control

the system. The deep neural networks and the DRL algorithm were programmed without specialized libraries,

implying that the algorithm could be used to train smart agents in programs without direct access to deep

learning libraries, or in the actual system with a simple programmable controller

深度强化学习（DRL）因其优化复杂控制方案的潜力而备受科学界关注。本研究描述了一个DRL平台的实现过程，该平台能够训练智能代理管理一栋机构建筑中的复杂热水系统——该建筑使用太阳能和水冷机余热作为能源。除了优化热水供应时的能源利用效率外，智能代理还被训练激活水冷机以避免系统过早损坏，并在供暖设备故障时持续提供热水。作为同时实现这些目标的基础，奖励函数的定义通过比较不同代理对不同目标的优先级来验证。与之前使用标准强化学习技术在同一系统上的研究相比，这种方法赋予了系统更大的控制自由度。深度神经网络和DRL算法无需专用库即可编程实现，这意味着即使没有直接访问深度学习库或实际系统中的简单可编程控制器，也能用于训练智能代理程序。

# 暴雨

## [1]A. Mullapudi, M. J. Lewis, C. L. Gruden, and B. Kerkez, “Deep reinforcement learning for the real time control of stormwater systems,” *Adv. Water Res.*, vol. 140, p. 103600, June 2020, doi: [10.1016/j.advwatres.2020.103600](https://doi.org/10.1016/j.advwatres.2020.103600).

A new generation of smart stormwater systems promises to reduce the need for new construction by enhancing the performance of the existing infrastructure through real-time control. Smart stormwater systems dynamically adapt their response to individual storms by controlling distributed assets, such as valves, gates, and pumps. This paper introduces a real-time control approach based on Reinforcement Learning (RL), which has emerged as a state-of-the-art methodology for autonomous control in the artificial intelligence community. Using a Deep Neural Network, a RL-based controller learns a control strategy by interacting with the system it controls - effectively trying various control strategies until converging on those that achieve a desired objective. This paper formulates and implements a RL algorithm for the real-time control of urban stormwater systems. This algorithm trains a RL agent to control valves in a distributed stormwater system across thousands of simulated storm scenarios, seeking to achieve water level and flow set-points in the system. The algorithm is first evaluated for the control of an individual stormwater basin, after which it is adapted to the control of multiple basins in a larger watershed (4 km2). The results indicate that RL can very effectively control individual sites. Performance is highly sensitive to the reward formulation of the RL agent. Generally, more explicit guidance led to better control performance, and more rapid and stable convergence of the learning process. While the control of multiple distributed sites also shows promise in reducing flooding and peak flows, the complexity of controlling larger systems comes with a number of caveats. The RL controller’s performance is very sensitive to the formulation of the Deep Neural Network and requires a significant amount of computational resource to achieve a reasonable performance enhancement. Overall, the controlled system significantly outperforms the uncontrolled system, especially across storms of high intensity and duration. A frank discussion is provided, which should allow the benefits and drawbacks of RL to be considered when implementing it for the real-time control of stormwater systems. An open source implementation of the full simulation environment and control algorithms is also provided

新一代的智慧雨水系统承诺通过实时控制来增强现有基础设施的性能，从而减少对新建筑的需求。智能雨水系统通过控制分布式资产，如阀门、闸门和水泵，动态地调整它们对单个暴雨的响应。本文介绍了一种基于强化学习( Reinforcement Learning，RL )的实时控制方法，该方法已成为人工智能领域中最先进的自主控制方法。使用深度神经网络，基于RL的控制器通过与其控制的系统相互作用来学习控制策略- -有效地尝试各种控制策略，直到收敛于达到预期目标的控制策略。 **本文提出并实现了一种用于城市雨水系统实时控制的RL算法。该算法通过训练一个RL代理来控制分布式雨水系统中的阀门，跨越数千个模拟暴雨**场景，以寻求实现系统中的水位和流量设定值。该算法首先针对单个雨水流域的控制进行评估，之后将其适应于更大流域( 4 km2 )中多个流域的控制。**结果表明，RL可以非常有效地控制单个位点。绩效对RL代理人的奖励制定高度敏感。一般来说，更明确的指导导致更好的控制性能，学习过程更快速和稳定的收敛。** 虽然多个分布式站点的控制在减少洪水和峰值流量方面也表现出了良好的前景，但控制更大系统的复杂性也带来了一些注意事项。RL控制器的性能对深度神经网络的形式非常敏感，需要大量的计算资源来实现合理的性能增强。总的来说，受控系统明显优于未受控系统，特别是在高强度和持续时间的风暴中。提供了一个坦率的讨论，应该允许在实施RL用于雨水系统的实时控制时考虑其优点和缺点。 还提供了全仿真环境和控制算法的开源实现。