

AI-Powered Climate Engineering for Stratospheric Aerosol Injection: Concept Paper for 2030

Problem Addressed: Climate change poses severe risks, including rising temperatures, extreme weather, and ecosystem collapse. By 2030, global warming is projected to exceed 1.5°C above pre-industrial levels, intensifying droughts, floods, and food insecurity. Current mitigation strategies (e.g., emissions reduction) are insufficient to meet Paris Agreement targets, necessitating innovative solutions. Stratospheric Aerosol Injection (SAI), a form of solar geoengineering, can temporarily cool the planet by reflecting sunlight, but optimizing aerosol distribution to minimize environmental and geopolitical risks requires advanced decision-making beyond human capabilities.

AI Application: An AI-powered Climate Engineering System (AI-CES) optimizes SAI by dynamically modeling aerosol deployment, predicting climate impacts, and adapting to real-time environmental data. AI-CES integrates global climate data, satellite observations, and geopolitical constraints to determine optimal aerosol injection sites, quantities, and compositions, ensuring effective cooling with minimal ecological disruption.

AI Workflow:

- **Data Inputs:** Real-time satellite data (e.g., aerosol dispersion, cloud cover), climate model outputs (e.g., temperature, precipitation), atmospheric sensor data (e.g., ozone levels, wind patterns), and geopolitical data (e.g., airspace regulations, population density).
- **Model Type:** A hybrid AI model combining reinforcement learning (RL) and graph neural networks (GNNs). RL optimizes injection strategies by learning from simulated climate outcomes, maximizing cooling while minimizing side effects (e.g., ozone depletion). GNNs model atmospheric interactions as graphs, capturing complex spatial and temporal dependencies across regions.
- **Process:** (1) Data ingestion and preprocessing to standardize inputs. (2) GNN-based climate simulation predicts aerosol dispersion and regional impacts. (3) RL agent iteratively adjusts injection parameters (e.g., altitude, particle size) to optimize outcomes. (4) Continuous feedback from real-time data refines predictions and actions.

Societal Benefits: AI-CES could reduce global temperatures by 0.5–1°C within months, mitigating heatwaves, stabilizing crop yields, and protecting vulnerable ecosystems. It offers a scalable, adaptive solution to complement emissions reduction, buying time for decarbonization. The system's transparency (e.g., open-access models) fosters global trust and collaboration.

Societal Risks: SAI carries risks, including ozone depletion, altered precipitation patterns, and geopolitical tensions over control of deployment. AI-CES's complexity could lead to unintended consequences if models mispredict outcomes or prioritize certain regions unfairly. Over-reliance on SAI may delay emissions reduction efforts. Ethical concerns arise from potential misuse (e.g., unilateral deployment by nations) and unequal impacts on developing countries.

Mitigation Strategies: Robust governance frameworks, including international oversight and stakeholder inclusion, are critical. AI-CES should incorporate explainable AI to

ensure transparency in decision-making. Regular audits and fail-safes can prevent over-optimization or biases. Public engagement and equitable access to benefits (e.g., data sharing) will address ethical concerns.

Conclusion: AI-CES for SAI offers a transformative approach to climate change mitigation by 2030, leveraging AI's predictive and adaptive capabilities. While risks demand careful management, the potential to stabilize the climate and protect billions makes this a compelling solution, provided it is paired with global cooperation and ethical oversight.