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General Comment

See attached file(s)

Attachments

NSF NCAR_Response2AI_StratPlan_2025

RFI Response from
NSF National Center for Atmospheric Research (NCAR) for the
2025 National Artificial Intelligence (AI)
Research and Development (R&D) Strategic Plan

NSF NCAR strongly advocates for making applications of AI to meteorology and Earth system science key topics to enable rapid advances within our field. NSF NCAR has a multi-decade legacy in research programs in AI, as an early adopter and leader within the Earth science community promoting the value of AI to a host of applications that benefit the American public, spawning growth of commercial applications and bolstering public safety.

In the past five years, the weather forecasting community has seen transformational advances driven by the use of AI for weather forecasting. A surge of machine learning models aimed at emulating global weather prediction systems offers performance routinely exceeding traditional weather prediction models at a fraction of the computational cost. Countries such as China and the European Union have made significant national investments in AI-enabled weather prediction systems and run these systems operationally. A number of domestic efforts in AI prediction systems are also underway. While the US has lagged somewhat in operational applications, the pace to replace physics-based models for decision-making applications has been rapid. This is occurring based on routine performance, with little understanding of potential shortcomings of these new prediction engines such as for extreme and multi-faceted weather events. At NSF NCAR we seek to understand both the strengths and weaknesses of AI prediction methods, accelerating innovations to make them even more useful and usable. Accurate weather forecasts are critical for a host of applications that require real-time decisions, such as in aviation, surface transportation, energy, agriculture, wildland fire, severe weather, and smog events. There is urgency to accelerate validation and fit-for-purpose assessment of AI approaches given their rapid adoption in critical decision-making contexts, as shortcomings pose threats to national security and societal well-being. More research on AI methods and approaches is essential to address these gaps.

One approach NSF NCAR has developed to meet this challenge is the Community Research Earth Digital Intelligence Twin (CREDIT) framework, which is an open source platform freely accessible to the research community for AI Earth system prediction. CREDIT has been instrumental in developing WXFormer, a state-of-the-science multiscale vision transformer highly capable of weather through long-term prediction. CREDIT is easily extended to regional and urban scale applications, where storms and turbulent processes play a critical role in determining local conditions, such as when a hurricane threatens a coastal community. CREDIT is designed to emulate physical models, enabling rapid testing and innovation. Built as a community resource, it allows scientists to partner and iterate quickly on building innovative solutions, with scalable performance on heterogeneous infrastructure. By integrating physics-based constraints, CREDIT's performance is competitive with the world's best models while enabling researchers to accelerate advances in Earth system science discovery and developing new commercial and public applications.

To accelerate advances in AI, NSF NCAR is also investing in the data infrastructure needed to ensure AI-ready data are openly available. This includes a wealth of NSF NCAR research observations as well as holdings from federal agency partners like NOAA and NASA

including satellite, radar and other remote sensing data. At present we are replacing computationally intensive physical processes with AI emulators for Earth system prediction applications extending beyond current weather prediction scales to support longer range decision-making contexts. We are also localizing predictive information to meet the needs of end users such as for the protection of critical infrastructure. This includes using AI to merge disparate and complex data from multiple fields, where AI algorithms excel in tracing complex connections and patterns to reveal new insights and benefit industry.

For the US to become a world leader in AI for meteorology and Earth system science will require targeted investment and public-private-academic collaboration to scale AI model development and validation, including dedicated personnel, computing/data/software infrastructure, and an integrated plan. Some specific target areas include:

- Post-processing and calibration of traditional (equation-based) models;
- accelerating physics parameterizations via AI/ML-based methods;
- harnessing explainable AI to assist in scientific exploration and discovery;
- validating the use of emulators, hybrid modeling, and physics-informed neural networks for longer range prediction applications, like seasonal-to-subseasonal prediction;
- emulating chemistry and aerosol processes interacting with radiation and clouds.

Realizing the full potential of AI in Earth system science will require targeted public-sector investment in cyberinfrastructure, with key priorities of:

- Development of standardized data pipelines, preprocessing and distribution methods;
- shared frameworks, data, and AI compute as well as improved data infrastructure and interoperability between centers;
- support for scalable and shared framework for training and inference for AI/ML models;
- federated learning approaches with opportunities for efficient multi-center collaboration;
- Establishing standard validation benchmarks and datasets to ensure scientific reproducibility, and cross-comparison of AI models across Earth system applications.

We must develop the workforce to best apply AI in Earth system science:

- Close critical skill gaps between AI/ML experts and domain scientists;
- interdisciplinary training, mentorship, and collaborative projects;
- continue hosting hackathons and other forms of hands-on research;
- training AI/ML developers on Earth system science concepts.

In summary, we highly advocate for including R&D for Earth system science applications, including real-time weather and atmospheric composition forecasting as a key priority in the 2025 AI R&D Strategic Plan. This prioritization is necessary to bring the U.S. up to and beyond the standards of the European Union and China in this realm. In addition, including a host of topics related to Earth system science will not only help us understand the physics of these systems better, but it will also facilitate actionable applications to promote science-informed decision making that provides economic and life-saving benefits to society.
