AI RFI Responses, October 26, 2018

Update to the 2016 National Artificial Intelligence Research and Development Strategic Plan RFI Responses

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Comments on the "**Request for Information on Update to the 2016 National Artificial Intelligence Research and Development Strategic Plan" - Document Number: 2018-20914**
https://www.federalregister.gov/documents/2018/09/26/2018-20914/request-for-information-on-update-to-the-2016-national-artificial-intelligence-research-and

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Artificial Intelligence (AI) is a topic that is rapidly evolving and is gaining widespread usage and familiarity across all of our society, including business, academia, and government, as well as the general public. Founded in 1919, the American Meteorological Society (AMS) is the nation's premier scientific and professional organization for promoting and disseminating information about the atmospheric, oceanic, and hydrologic sciences. Our more than 13,000 members include researchers across academia, industry, and government; educators; students; enthusiasts; commercial meteorologists; broadcasters and other professionals who specialize in weather, water, and climate sciences.

With the AMS community having a broad set of disciplinary perspectives and a direct connection to society, the potential applications of AI to the meteorological, hydrological, and climatological fields are endless (e.g. hazards warning, information analysis, environmental intelligence, statistical modeling, prediction, etc.). Many of the elements of AI techniques have been applied in our community for decades (neural networks, regression, computer vision, etc.). In fact, the weather community has been a leader in utilizing AI methods in our applications, including aviation meteorology, renewable energy forecasting, weather support for surface transportation, water resource management, river forecasting, wildland fire management, finance, insurance, and more.

The use of AI in these frameworks has helped to protect public safety and provided economic benefit to the nation. The AMS community has included a Committee on Applications of Artificial Intelligence to the Environmental Sciences for quite some time, began teaching short courses on the topic in 2001, and the community codified our knowledge in textbooks and journal papers.[1][2][3][4] Yet, there is much work that can be done to integrate state-of-the-art AI approaches across the weather, water, and climate enterprises.

The National Science and Technology Council's (NSTC) Select Committee on Artificial Intelligence (Select Committee) needs to highlight a focus area of AI research and development (R&D) directly on weather, water, and climate problems with the primary goal of providing a strategic plan for both the AI and AMS communities to accelerate the innovation in the application of new AI approaches. This strategic plan for our community should spark - interest and help frame thinking and approaches for engaging AI technologies throughout the public, private, and academic sectors.

There are a number of key topics that are critical for the NSTC Select Committee to consider when drafting a strategic plan that includes the weather, water, and climate enterprise:

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[1] Haupt, S.E., A. Pasini, and C. Marzban, Eds. 2009: *Artificial Intelligence Methods in the Environmental Sciences*, Springer, 424 pp.
[2] Hsieh WW. 2009: *Machine Learning Methods in the Environmental Sciences*. Cambridge University Press: Cambridge.
[3] Krasnopolsky, V.M., 2013: *The Application of Neural Networks in the Earth System Sciences*. Springer, NY, NY, 189 pp.
[4] McGovern, et al., 2017: *Using Artificial Intelligence to Improve Real-time Decision Making for High-Impact weather*. Bulletin of the American Meteorological Society. Volume 98, Issue 10, pages 2073-2090.

- ***AI, high performance computing (HPC), and weather researchers are needed to create new and innovative interdisciplinary collaborations to develop improved models and forecasts.*** Many AMS members who have worked in modeling physics-based systems continue to caution about the lack of physical understanding of AI, machine learning, and data mining methods that rely on data-driven approaches and lack the full understanding of the physical processes that govern our natural world. The interpretability challenge is compounded by the nonlinear nature of these systems, and the limitations of these methods are not well elucidated. One area of deep collaboration with the AI community would be to determine how to build hybrid AI-physical models that combine both the physical understanding of the world with the power of data science and machine learning.

- ***Determining what types of AI methods are appropriate in the weather, water, and climate community.*** For example, some AI methods are good at combinatorics (i.e., AI "big search" problems like playing the game Go) and could be used for determining the "best hazard management strategy" depending on the current and predicted environmental conditions. Other AI methods could help to identify anomalies and patterns from high dimensional and complex datasets providing environmental intelligence for decision makers and the general public. Although these methods are promising, a robust understanding of their application in the weather, water, and climate context should be a high priority.

- ***Improving data assimilation (DA) techniques:*** As observations of the environment become more readily available, often many are redundant and of higher spatial and temporal resolution. This challenges DA techniques with the "big data" problem of having to provide an optimal state estimate for weather, water, and climate modeling, typically under time constraints, given a large amount of observational information with unknown errors. AI applications have already been shown to be capable of augmenting traditional dynamically based methods and much more research is needed to fully realize the benefits of merging AI and data assimilation methods.

- ***HPC and advanced cyberinfrastructure is critical to continuing to develop improved weather models and AI models.*** Computational power has increased dramatically over the past 20 years, leading to powerful improvements in forecasting as well as the recent dramatic successes in AI (e.g. world's best Go player, Jeopardy champion, etc.). Advancements in new computer architectures, data formats, computer software, and computer hardware need to be rapidly applied across the weather, water, and climate enterprise and a strategic plan to accomplish this should be a high priority. This is the pathway to cementing the US preeminence in AI and weather, water, and climate forecasting.

- ***Jointly study how and why humans make decisions with advanced technology.*** AI researchers have demonstrated that AI can be used to improve predictions and reduce forecaster data overload. However, adoption of such systems remains low due to skepticism on the part of forecasters and other potential users of these products. One area of collaboration is to jointly study how and why humans make decisions with advanced technology, both in less stressful times and in times of crisis (e.g. severe weather outbreaks) and how AI can be used to aid the forecasters in their jobs, rather than be viewed as a replacement threat.

- ***Augmented human and environmental intelligence and rapid data understanding using AI.*** Related to the research on how AI can be used to aid forecasters is the critical subject of how best to communicate information from an AI method to forecasters, emergency managers, and the general public. One example is the FACETS project (https://www.nssl.noaa.gov/projects/facets/). This area needs to continue to be addressed to make the best use of new and changing information, so that the public can be warned of hazardous environmental conditions and lives and property can be saved.

- ***Research on the communication of AI information, including accuracy of predictions, capabilities of the algorithms, and uncertainties associated with them.*** The AMS community has deep experience in distributing and sharing weather, water, and climate information (e.g., weather forecasts), including uncertainty about this information. The Select Committee's strategic plan should include support for new and innovative collaborations between AI researchers within and beyond the AMS community to determine how to communicate information generated by AI to the general public. With almost a century of experience, the AMS community can help to inform AI researchers of these communication challenges and pitfalls in the weather, water, and climate space. Innovation in this area needs to come from both the AMS community and the AI community.

- ***There has been more standardization of weather, water, and climate data over the decades, but national dataset conformity is still a very real problem, and this will make it challenging for AI researchers to apply their algorithms and methods.*** Projects that focus on organizing and making datasets available from the weather, water, and climate communities should be prioritized. From weather and hazard prediction to identifying threatening environmental conditions, datasets suitable for AI applications need to be developed, and these data need to have a clear objective (e.g., maximizing the number of people informed about hazardous environmental conditions or a stable data set for comparing AI methods performance). One example is the current effort called the "EnviroNet: ImageNet for Environment." This is a grassroots effort from the AMS AI Committee and a session is being organized for the 2019 AMS Annual Meeting in January. Additional projects are needed and together the AMS and AI communities will provide ripe datasets for AI research and development.

- ***Continued development of core AI-based applications that push the science, serve the public and benefit the nation.*** The popularity and the development of AI and machine learning come in large part from innovations of the research community, academia, national laboratories, and the private sector, with the common aim of improving and resolving the predictability and understanding of environmental problems. There should be a joint focus on safety and security related to not only how AI model biases can be problematic for weather related safety and security, but also how AI can help aid with extreme weather safety and security of infrastructure and people. The strategic plan should support and promote the continued development of weather, water, and climate applications with these considerations.

- ***Weather researchers and industry could benefit from additional deep collaborations.*** Weather and climate analytics are proving to be valuable businesses (see recent startup Jupiter Intelligence, IBM's purchase of the Weather Company, etc.). AI has emerged as a main priority for many industries that deal with weather, water, and climate information, including those in finance, utilities, and other infrastructure support. Through deep collaboration between researchers and industry, it will be possible to apply the rapid progress in industry AI to the weather, weather, and climate communities more broadly.

- ***AI opportunities in education and workforce development are essential in capturing the imagination of the next generation of meteorologists, hydrologists, and climatologists.*** This would include a curriculum that allows a student to learn AI, machine learning, and data science methods and techniques, as well as Earth sciences. This is needed, yet it is unclear how to do this, given that most students are rooted in a single domain. The committee should provide a strategic plan that would help universities design interdisciplinary programs and provide steps to for building a paradigm of AI and machine learning that incorporates the knowledge of the weather, water, and climate disciplines. There is a clear need for people with skills that span both communities.

The focus on weather, water, and climate in the strategic plan provides a timely opportunity to integrate the field of AI with the knowledge, interests, and perspectives of the meteorological, hydrological, and climatological fields, building a sustained effort to revolutionize how weather, water, and climate predictions and hazards warnings are used to impact how this critical life-saving information is generated, distributed, and received.

Based on the strengths and weaknesses of each community, there is great potential for increased collaboration between the AMS and AI communities. The key will be to identify cross-cutting issues of societal importance that allow each community to help the other while also advancing their own field. As a result, scientists would pursue their individual goals, while supporting other scientists. Experts from both fields will be needed to identify such common problems and to communicate these efforts effectively and convincingly within the weather, water, and climate communities.