NOAA Artificial Intelligence Strategy

Analytics for Next-Generation Earth Science

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

NOAA Science & Technology Focus Areas:

Uncrewed Systems ▪ Artificial Intelligence ▪ 'Omics ▪ Cloud ▪ Citizen Science ▪ Data

February 2020

NOAA's Artificial Intelligence Strategy

Analytics for Next-Generation Earth Science

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February 2020

The National Oceanic and Atmospheric Administration (NOAA) Artificial Intelligence (AI) Strategy will dramatically expand the application of artificial intelligence (AI) in every NOAA mission area by improving the efficiency, effectiveness, and coordination of AI development and usage across the agency. As data exploitation capabilities continue to increase exponentially with improved satellite systems and architecture, unmanned systems and commercial data sources, AI methods will provide transformative advancements in the quality and timeliness of NOAA science, products, and services. The term "AI" is used here to encompass the capabilities identified in the "AI Capabilities" graphic on page 4. The reason for developing this strategy is because AI capabilities are already demonstrating significant improvements in performance and skill at vastly reduced costs and compute time.

This strategy aligns with the President's Executive Order on Maintaining American Leadership in Artificial Intelligence[1] and the 2019 Update to the National Artificial Intelligence Research and Development Strategic Plan.[2] It also supports provisions in the Weather Research and Forecasting Innovation Act of 2017[3] and its 2019 reauthorization,[4] as well as the Commercial Engagement Through Ocean Technology (CENOTE) Act of 2018.[5] This strategy also supports the November 19, 2019, presidential memorandum "Memorandum on Ocean Mapping of the United States Exclusive Economic Zone and the Shoreline and Nearshore of Alaska." Lastly, the NOAA AI Strategy supports the DOC Strategic Plan for 2018-2022,[6] and will accelerate NOAA's top two priorities to (1) regain world leadership in global weather modeling through establishment of the Earth Prediction Innovation Center (EPIC), and (2) sustainably grow the economic contributions of our oceans, coasts, and Great Lakes (American Blue Economy).[7]

Background

AI is not new to NOAA. NOAA's robust experience with AI applications across a range of mission areas are already demonstrating significant improvements in performance and skill at greatly reduced costs and compute time in arenas as diverse as deep-sea exploration, habitat characterization, and processing of earth observations. By strengthening coordination, operational capabilities, workforce proficiency, and multisector partnerships, NOAA's national and global leadership in AI supports science, public safety, and security.

Specific AI examples include: (1) aerial and underwater surveys from ships and autonomous platforms to assess the abundance of marine mammal and fish populations, (2) robotics for deep-sea exploration, (3) quality control of weather observations, (4) improving physical parameterization for weather, ocean, ice modeling, and improving the computational performance of numerical models, (5) aiding weather warning generation, (6) operation of unmanned systems for bathymetric mapping, habitat characterization, hydrologic, oceanographic, atmospheric, fishery, ecosystem, and geographic surveys, (7) supporting partners in wildfire detection and movement, and (8) using machine learning (ML) for reliable and efficient processing, interpretation, and utilization of earth observations. Despite this notable progress, the true potential for AI to advance NOAA's mission has not been realized because all NOAA AI activity heretofore has originated within individual offices with no institutional support. Additionally, some development has been redundant because of a lack of awareness across the agency due to the absence of a coordinating directive or authority.

Vision

Through the NOAA AI Strategy, expansion of Artificial Intelligence is accelerated across the entire agency to make transformative improvements in NOAA mission performance and cost effectiveness.

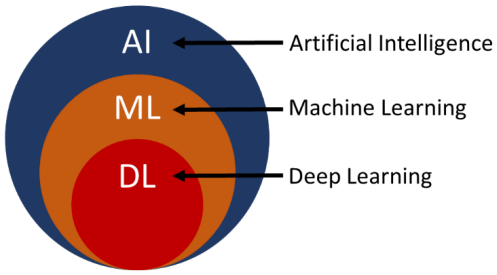
Purpose

The goals and supporting objectives in this strategy are intended to directly improve the understanding, coordination, awareness, and application of AI across all of NOAA. By directing organizational and process improvements to more rapidly transition research, strengthen and expand partnerships, and deliberately develop AI proficiency across the NOAA workforce, the guidance below will result in transformational advances in every NOAA mission area. A fundamental consideration is that the objectives within any goals support and are supported by objectives under the other goals in this strategy, thus requiring matrixed collaboration during implementation.

What is Artificial Intelligence?

Artificial Intelligence (AI) refers to computational systems able to perform tasks that normally require human intelligence, but with increased efficiency, precision, and objectivity. A subset of AI called machine learning (ML) refers to mathematical models able to perform a specific task without using explicit instructions, instead relying on patterns and inference. Deep learning (DL) is a subset of ML that utilizes artificial neural networks capable of learning from unstructured or newly added data. The use of labeled training data can further improve the AI predictive capability through supervised ML.

AI Capabilities



GOAL 1: Establish Efficient Organizational Structures and Processes to Advance AI across NOAA.

When achieved, this goal will provide for the cross-line office coordination that has been so far limited in AI development, awareness, and application. This, along with prioritization of AI in budget formulation, strategic communications, and cloud computing applications will exponentially increase the use and utility across all of NOAA.

Objective 1.1. Explore the establishment of a NOAA AI Center or similar entity to enable coordination of AI research, algorithm development, data acquisition, applications, information exchange, and awareness. Other functions would be to maintain a portal with open source and government applications, host training events and workshops, and facilitate new partnerships.

Objective 1.2. Develop technical working groups comprised of NOAA line office experts to support the NOAA AI Executive Committee's efforts as needed to develop and execute the NOAA AI Strategic and Implementation Plans, such as prioritization of AI research and transitional requirements, technical workshops, specific subject-matter tasks as assigned, and metrics to achieve the goals and objectives of the plan.

Objective 1.3. Prioritize AI-based approaches in NOAA budget formulation guidance, emphasizing the purpose to improve performance skill, computational efficiency, and cost effectiveness.

Objective 1.4. Include discussion of NOAA AI activity in NOAA executive-level engagement and communications with key stakeholders, particularly focusing on OMB, Congressional members and staff, and counterparts from other federal agencies.

Objective 1.5. Leverage and adopt the principles, processes, and partnerships articulated in the NOAA Cloud Strategy and Roadmap, and Big Data Project to improve data accessibility, labeled training data, workflow processes using open source tools, and cloud computing for AI applications in support of the NOAA mission.

NOAA Artificial Intelligence Strategy

Goal 1: **Establish an efficient organizational structure and processes to advance AI across NOAA.**

Goal 2: **Advance AI research and innovation in support of NOAA's mission.**

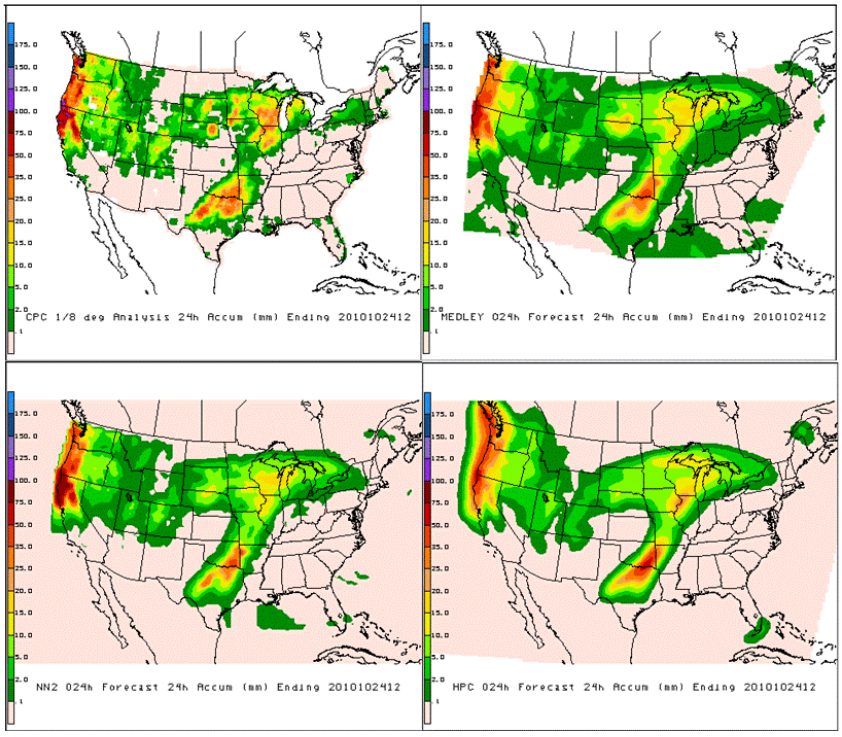
Goal 3: **Accelerate the transition of AI research to applications.**

Goal 4: **Strengthen and expand AI partnerships.**

Goal 5: **Promote AI proficiency in the workforce.**

Example of AI (NN)-based Ensemble: Nonlinear Multimodel Ensemble Mean

Precipitations over ConUS



(a) CPC analysis (ground truth); (b) Ensemble mean of eight models: NCEP (global and regional) and six international models. Reduced maximum and diffused sharpness of fronts due to slightly shifted maps from ensemble members, produced many false alarms; (c) AI-based Ensemble composite. Closer to CPC with maintained sharpness and minimal alarm rates; (d) the forecast produced by human analyst at HPC.[8]

GOAL 2. Advance AI Research and Innovation in Support of NOAA's Mission.

NOAA will advance AI-based environmental research and innovation across every mission area by prioritizing and institutionalizing AI throughout NOAA's research processes. The NOAA Research and Development Database (NRDD) will be a critical asset to help track NOAA research involving AI, with the intent to see the number of AI research projects continuously increase.

Objective 2.1. Establish a requirement-based process to prioritize AI research to leverage the best available assets and expertise in support of the NOAA mission, and to continually evaluate the prioritization process to meet the rapidly evolving AI technology.

Objective 2.2. Prioritize AI-based approaches and support in NOAA research federal funding opportunities (FFO), requests for proposals (RFPs), and research grants to promote collaborative AI research and maintain an awareness of the rapidly evolving AI technology in areas relevant for NOAA mission.

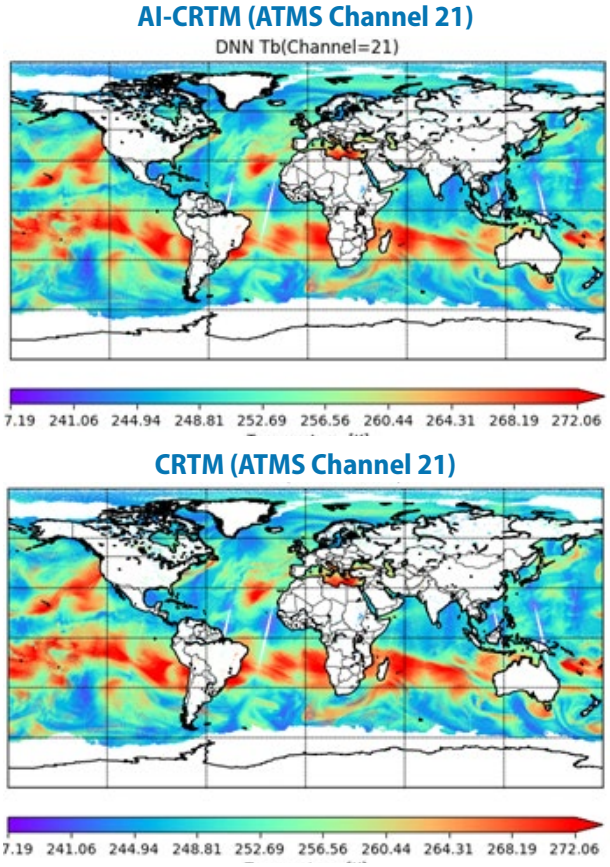
Objective 2.3. Establish an annual research and development prize competition series for AI applications in environmental science, to include separate categories for data processing efficiencies, automated detection and classification toolkits, improvements in data assimilation and predictive modeling, and other organizational efficiencies using AI.

Objective 2.4. Evaluate and execute various testbed and proving grounds approaches across NOAA to expand AI research, develop best practices and training data, improve algorithms, and evaluate model performance in support of the NOAA mission. NOAA testbeds and proving grounds play an important role in pre-operational evaluation of new developments performed by NOAA and university scientists.

Objective 2.5. Encourage every prospectus for NOAA Cooperative Institutes (CIs) and Cooperative Science Centers (CSC's) to develop metrics that track yearly increases in the AI research they perform.

GOAL 3. Accelerate the Transition of AI Research to Applications.

NOAA will rapidly accelerate the transition of AI-based environmental research to NOAA operations (R2O) and private-sector commercialization (R2C - together R2X). Because many requirements



Simulated JPSS-1 ATMS channel 21 (183 GHz mid-upper tropospheric water vapor channel) from AI-based radiative transfer model (AI-CRTM) trained using CRTM (top), and operational CRTM (bottom). CPU time required to simulate 1 day of JPSS-1 ATMS (all channels) is reduced from 1.3 hrs using CRTM, to 1 second using AI-CRTM.[9]

for NOAA's AI applications are available in private- sector and academic research environments, the majority of our AI research involves tailoring these applications to our mission. Coordination of AI initiatives and activities mentioned in Goal 1, and examples from the Earth Prediction Innovation Center (EPIC), will play leading roles in transitioning R2O. For successful transitions, we will support the growth of a nascent commercial environmental AI sector that will increasingly serve as a source for solutions to our operational requirements. OAR's TPO will lead the transition of NOAA tailored R2C.

Objective 3.1. Establish budget and prioritization processes to transition to operations AI-based environmental research which shows improved skill, performance, and computational and cost efficiency.

Objective 3.2. Transition to commercialization that AI-based environmental research in NOAA which shows potential for enhancement and marketability in the private sector.

Objective 3.3. Develop NOAA technical guidelines that are updated annually on the best practices and standards for the training data, training practices, and evaluation of model performance to ensure the integrity, reliability, and credibility of scientific products generated with AI applications.

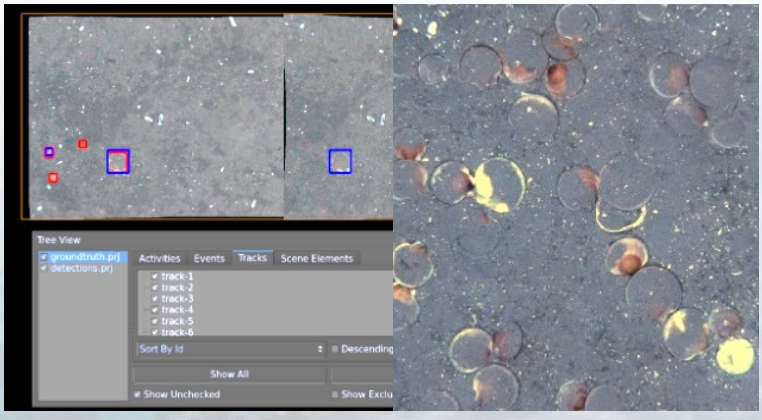
Objective 3.4. Build AI awareness across NOAA line offices through NOAA science seminars and webinars, internal workshops, and routine internal communications venues such as newsletters and weekly updates.

Objective 3.5. Complete an annual report of NOAA AI research transitions, disseminated broadly across the agency and with external partners to be used as a basis for investigator performance reviews and incentive awards.

GOAL 4. Strengthen and Expand AI Partnerships.

Cooperative partnerships serve as force multipliers to optimize resources and effort, and the scientific and technological exchange keeps NOAA current in the rapidly evolving field of AI. Partnerships in AI-based environmental applications are already creating a community of practice that is sparking innovation and has the opportunity to accelerate tremendous advances in NOAA's capabilities.

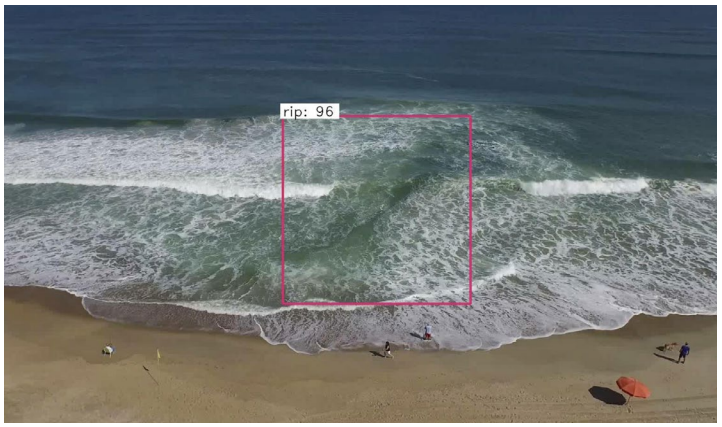
Objective 4.1. Prioritize AI-based environmental research in National Oceanographic Partnership Program (NOPP) project proposals and selection.



NOAA Northeast Fisheries Science Center uses machine learning to deliver higher quality and more timely science for fishery management. In this example, automated detection and measurement of commercially important species, such as scallops, has reduced processing costs by 98% (from 3 months to 3 days for more than 2 million images collected during a 15-day survey, with 99% scallop-detection accuracy).

Objective 4.2. Expand partnerships in AI-based environmental research with the academic and research community, including CIs and institutions that host NOAA EPP/MSI, Nancy Foster, Hollings, John Knauss, Pathways, and Margaret Davidson scholars, fellows, and interns.

RIP Current Detection



NOS and NWS are partnering with researchers at UC Santa Cruz to use AI to detect rip currents from coastal imagery. The rip current observations are supporting implementation and improvement of the NOAA rip current forecast model. (Image credit: NOAA; Model credit: Pang, de Silva and Mori, UC Santa Cruz).

Objective 4.3. Support the National Artificial Intelligence Research Institutes Program with NSF by collaborating with appropriate institutes on AI R&D.

Objective 4.4. Increase the number of formal cooperative agreements on AI-based environmental research and applications with interagency and international partners, prioritizing DOD, DOI, DOE, and DHS.

Objective 4.5. Formalize new public-private partnerships through established mechanisms such as Cooperative Research and Development Agreements (CRADAs) and Small Businesses Innovative Research (SBIR) grants.

Objective 4.6. Provide innovative and substantive contributions to the policy and advisory committees such as the National Science and Technology Council (NSTC) Select Committee on AI, and engage its experts in scientific exchange during national and international conferences, workshops, and other opportunities.

Goal 5. Promote AI Proficiency in the Workforce.

NOAA will provide resources to equip our workforce to fully leverage the rapid evolving field of AI. This can only be achieved by providing continuous, current, creative, and tailored training and learning opportunities. NOAA's existing development programs are well suited to be adapted for these, and we will look to partners for new options to develop skill, understanding, and expertise.

Objective 5.1. Provide increased online and on-scene AI training through line office training centers.

Objective 5.2. Focus the assignments in the NOAA Rotational Assignment Program (NRAP) to target offices where a cross-pollination of AI expertise would raise the overall AI proficiency of the workforce.

Objective 5.3. Identify and resource AI-related graduate degree, professional development, and technical training courses that are available to the NOAA workforce.

Objective 5.4. Support and lead collaborative events such as conferences, workshops, and external rotational assignments targeted to stay current in the state of AI technology.

Objective 5.5. Actively encourage graduate programs, internships and cooperative student training programs in AI applications relevant to the NOAA mission to improve recruitment, retention, and the hiring pool for AI proficient NOAA workforce.

Objective 5.6. Update individual development plans (IDP), position descriptions, performance plans, and career paths as a practical approach to build and retain NOAA's workforce proficiency in AI.

Conclusions

To ensure the NOAA AI Strategy realizes transformational advances in performance, skill, and efficiency, NOAA is developing an AI Strategic Implementation Plan or "Roadmap" that defines detailed action items, deadlines, and responsibilities. In the meantime, the NOAA AI Strategy is already improving performance significantly in our lifesaving and economically impactful missions and setting the course to strengthen our renowned environmental science and technology leadership for the coming decades. Together with our advances in NOAA's other science and technology focus areas—Unmanned Systems, Cloud Computing, and 'Omics—NOAA's Artificial Intelligence activities will help the U.S. to regain global leadership in numerical weather prediction and sustainably expand the American Blue Economy.[10]

References

1. Executive Order on Maintaining American Leadership in National Intelligence, The White House, 11 Feb 2019. https://www.whitehouse.gov/presidential-actions/executive-order-maintaining-american-leadership-artificial-intelligence/

2. The 2019 Update to the National Artificial Intelligence Research and Development Strategic Plan, NSTC, 21 June 2019. https://www.nitrd.gov/pubs/National-AI-RD-Strategy-2019.pdf

3. The Weather Research and Forecasting Innovation Act of 2017, Public Law 115-25, The White House, 18 April 2017. https://www.congress.gov/bill/115th-congress/house-bill/353/text

4. The National Integrated Drought Information System Preauthorization, Public Law 115-423, The White House, 7 Jan 2019. https://www.congress.gov/bill/115th-congress/senate-bill/2200

5. The Commercial Engagement Through Ocean Technology (CENOTE) Act of 2018, Public Law 115-394, The White House, 21 Dec 2018. https://www.congress.gov/bill/115th-congress/senate-bill/2511/text

6. Department of Commerce Strategic Plan for 2018-2022. https://www.commerce.gov/sites/default/files/us_department_of_commerce_2018-2022_strategic_plan.pdf

7. NOAA FY20 Blue Book. https://www.noaa.gov/sites/default/files/atoms/files/FY2020-BlueBook.pdf

8. V.M. Krasnopolsky, and Y. Lin, 2012. "A Neural Network Nonlinear Multimodel Ensemble to Improve Precipitation Forecasts over Continental US," Advances in Meteorology, Volume 2012, Article ID 649450, 11 pages doi:10.1155/2012/649450

9. " Exploring Using Artificial Intelligence (AI) for Remote Sensing, NWP and Situational Awareness (SA)". S-A Boukabara, E. Maddy, A. Neiss, K. Garrett, E. Jones, K. Ide, N. Shahroudi and K. Kumar. International TOVS Study Conference (ITSC),ITSC-XXI Conference, Darmstadt, Germany, Nov 29th – Dec 5th 2017.

10. The NOAA Artificial Intelligence, Unmanned Systems, 'Omics, and Draft Cloud Strategies are available at https://nrc.noaa.gov/NOAA-Science-Technology-Focus-Areas.

Acknowledgements

The NOAA AI Strategy is led by Timothy Gallaudet, Ph.D., Rear Admiral, U.S. Navy (Ret.), Assistant Secretary of Commerce for Oceans and Atmosphere / Deputy NOAA Administrator. Dr. Jamese Sims, on special assignment from the NOAA Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM), is coordinating the overall process in collaboration with the NOAA AI Executive Committee Chairs, William Michaels from the NOAA National Marine Fishers Services, Dr. Sid Boukabara from the NOAA National Environmental Satellite and Data Services (NESDIS), and the members of the NOAA AI Executive Committee listed below. NOAA is also grateful for the many generous and thoughtful comments received during the Public Comment period. This strategy includes revisions based, in part, on comments received.

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Neil Weston, OCS

NOAA Fisheries

Cisco Werner, OAA

National Weather Service

Hendrik Tolman, OSTI
Vladimir Krasnopolsky, EMC

Office of Oceanic and Atmospheric Research

Frank Indiviglio, OCIO
Mashkoor Malik, OER
V. 'Ram' Ramaswamy, GFDL
Jebb Stewart, ER/WFO/Charleston, SC

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