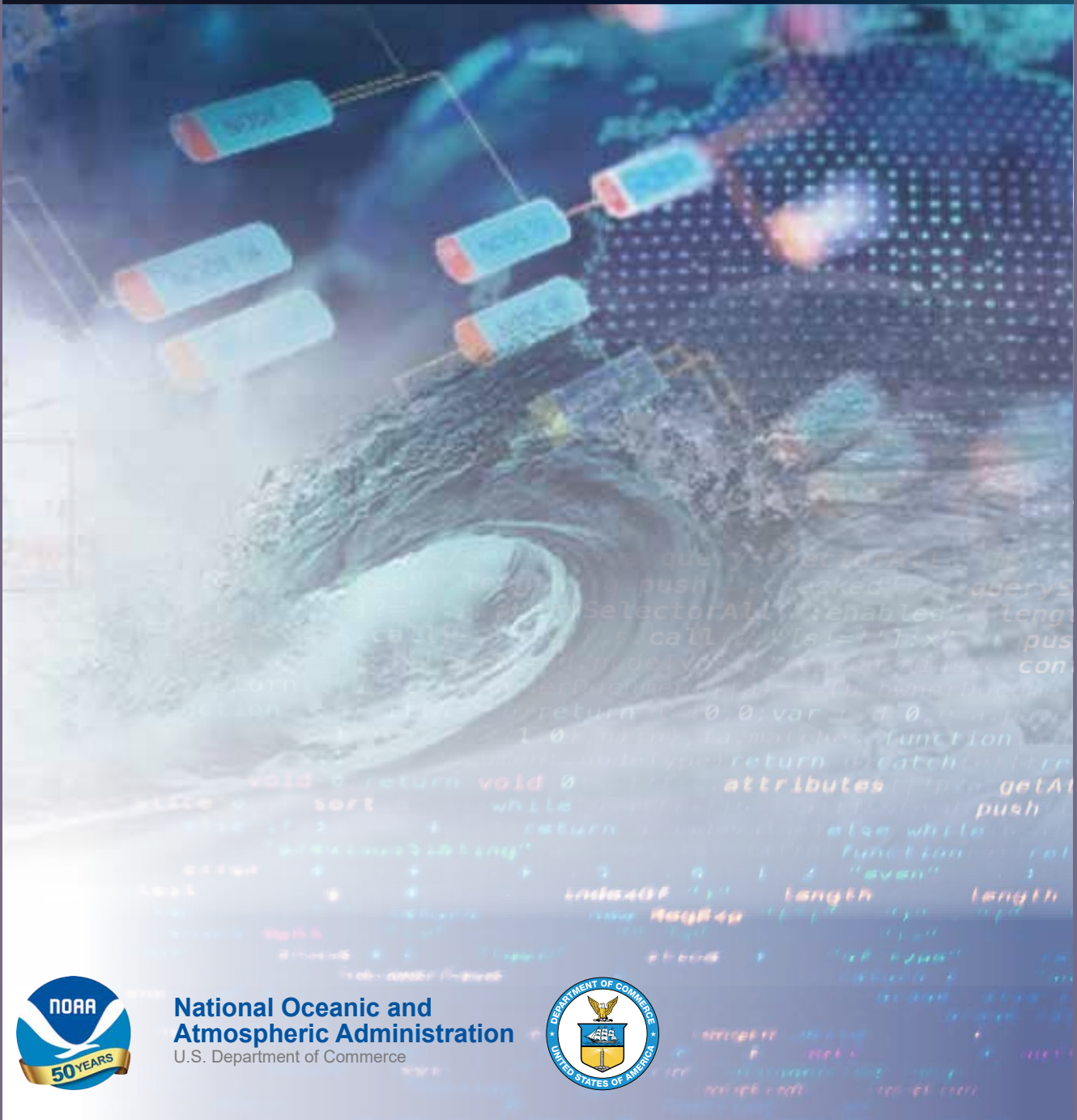


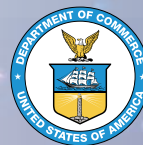
NOAA Artificial Intelligence

Analytics for Next-Generation Earth Science

Strategic Plan 2021–2025



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



January 11, 2021

NOAA Science & Technology Focus Areas:

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



NOAA Artificial Intelligence Strategic Plan

Analytics for Next-Generation Earth Science

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NOAA Artificial Intelligence Strategic Plan

Analytics for Next-Generation Earth Science

Introduction

The National Oceanic and Atmospheric Administration (NOAA) recently approved the NOAA Artificial Intelligence (AI) Strategy¹ along with other NOAA strategies for applying emerging science and technologies^{2,3} to guide transformational advancements in the quality and timeliness of products and services across the agency’s mission areas. The NOAA AI Strategy is an action to the President’s Executive Order on Maintaining American Leadership in Artificial Intelligence⁴ and the 2019 Update to the National Artificial Intelligence Research and Development Strategic Plan⁵. The NOAA AI Strategy supports provisions in the Weather Research and Forecasting Innovation Act of 2017⁶, as well as the Commercial Engagement Through Ocean Technology Act of 2018⁷. Aligned with the Department of Commerce (DOC) Strategic Plan for 2018-2022⁸, the NOAA strategies will accelerate NOAA’s priorities to maintain world leadership in global weather modeling through establishment of the Earth Prediction Innovation Center (EPIC)⁹, and sustainably grow the economic contributions of our oceans, coasts, and Great Lakes (American Blue Economy)^{10,11}.

The application of AI, including machine learning (ML), has already demonstrated significant advances in research and development (R&D), with subsequent improvements in performance at greatly reduced costs and computational time for various NOAA mission areas, such as deep-sea exploration, habitat characterization, fisheries assessments, environmental modeling, and interpretation of Earth science observations. The use of ML algorithms has enhanced automated detection capabilities and operational efficiencies during aerial and underwater surveys from ships and autonomous platforms to assess the abundance of marine mammal

NOAA Artificial Intelligence Strategy Goals

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.

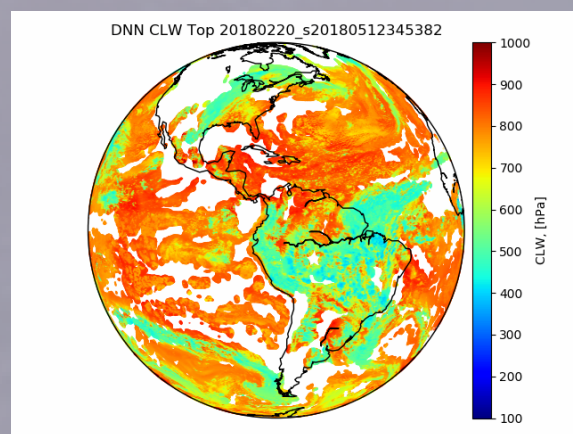
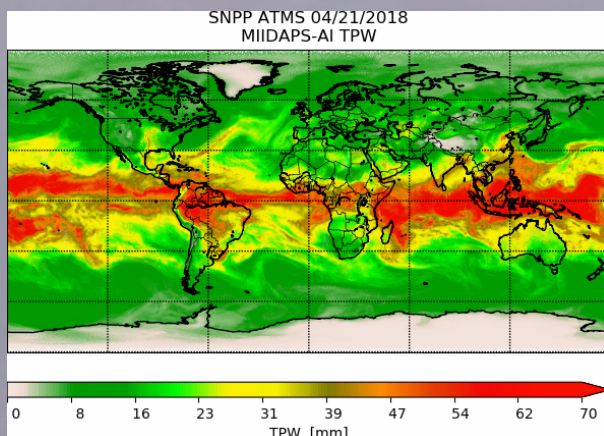
Goal 4: Strengthen and expand AI partnerships.

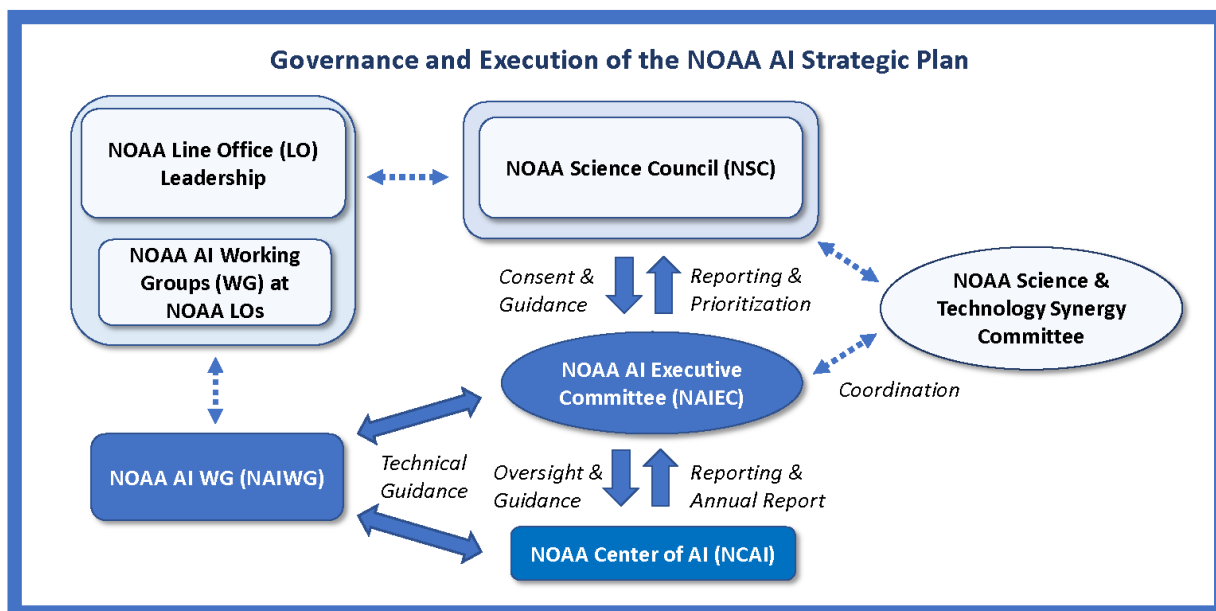
Goal 5: Promote AI proficiency in the workforce.

and fish populations. ML has also advanced data assimilations and forecast modeling, and specific examples of improvements include quality control of environmental or satellite observations, physical parameterization for environmental modeling including ecosystems, physical and computational performance of numerical Earth system models, aiding weather warnings and associated impact-based decision support services, operations of unmanned systems for a wide range of environmental observations, and supporting partners in wildfire detection and movement.

AI-Based Enterprise Algorithms for Satellite Data Exploitation

NOAA’s National Environmental Satellite, Data, and Information Service (NESDIS) Center for Satellite Applications and Research has been developing efficient (AI-based) enterprise algorithms for a variety of products generated from space-based observations taken from both polar and geostationary satellites. Examples below show total precipitable water (moisture) from polar orbiting microwave sensor (ATMS onboard JPSS (left) and cloud top information from the geostationary infrared imager (ABI) onboard GOES-16 (right).





The NOAA AI Strategic Plan will be executed collectively by the NOAA AI Executive Committee (NAIEC) for oversight and prioritization, NOAA Center of AI (NCAI) for coordination and facilitation, and NOAA AI WG (NAIWG) for technical guidance.

The NOAA AI Strategy will provide a more coordinated approach across NOAA to effectively develop the AI-ready data and tools for reliable and efficient processing, interpretation, and utilization of Earth observations. The NOAA AI Strategic Plan outlines the required actions to achieve the five goals of the approved NOAA AI Strategy¹ to maintain NOAA as a world leader in Earth system science. The actions will be executed during a five-year period, with the first year in 2021 focused on scoping and preparations to establish the governance structure and supportive processes of the plan. This plan is aspirational, and completion of out-year actions will be resource driven. The organizational and process improvements of the plan serve as a living document to more rapidly develop and transition AI research into operational efficiencies that integrate data science, analytical tools, ecosystem and Earth system modeling, partnerships, and workforce proficiency across NOAA. The initial overarching actions include:

- Establish the NOAA AI Executive Committee (NAIEC) to provide oversight on the execution of this plan to accelerate AI applications for enhanced organizational capabilities and efficiencies.
- Expand the scope of the NOAA Science Council (NSC) and their NOAA Science and Technology Synergy Committee to implement AI policies that build upon the synergistic activities of NOAA AI, Data, Cloud, Unmanned Systems, and 'Omics Strategies for applying emerging science and technology.
- Establish the NOAA Center of AI (NCAI) to facilitate AI technological procedures and standards, expand partnerships, and build workforce proficiencies across the agency.

- Establish the NOAA AI Working Group (NAIWG) to provide technical guidance to the NAIEC and NCAI on the current status, gaps, and priorities of AI technology across the agency.

Actions to Execute the Strategic Plan

GOAL 1. Establish Efficient Organizational Structure and Processes to Advance AI Across NOAA.

This is the overarching goal that establishes the organizational structure, governance, and supportive processes to enable the execution of the actions in this plan. The first phase of the plan is to establish the NAIEC with balanced representation from the NOAA Line Offices (LOs) to provide the oversight and prioritization to execute actions. The NAIEC will work closely with the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) and NOAA LOs for scoping and establishment of the NCAI to facilitate awareness and coordination of AI efforts across the agency. The NESDIS National Centers for Environmental Information (NCEI) is the steward and provides access to one of the most significant archives for environmental data; therefore, NCEI will host as a centralized repository for guidelines on AI-ready data and tools, and training resources to accelerate AI R&D, and build a community of practice in conjunction with NOAA LOs to expand partnerships to transition AI to operational efficiencies. The NSC approves AI policies resulting from the actions of the plan, and ensures coordination of the synergistic activities among the NOAA Strategies for applying emerging science and technologies^{2,3} as a unified NOAA approach.



Objective 1.0. Establish the organization structure to provide oversight on the execution of the NOAA AI Strategic Plan.

1.0.1. By 2021, establish the terms of reference of the NAIEC, for NSC approval, to provide an oversight role for the execution of the NOAA AI Strategic Plan. [NAIEC, NSC]

1.0.2. By 2021, establish a process with the NSC to align the synergistic actions and activities of the plan with the other NOAA Strategies for applying emerging science and technologies, including the NOAA Strategies for Data, Cloud, UxS, 'Omics, and Citizen Science. [NAIEC, NSC]

Objective 1.1. Establish the NCAI 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.

1.1.1. By 2021, complete scoping and define the functions of the NCAI to facilitate and coordinate AI efforts across NOAA. [NESDIS/NCAI, NAIEC, NOAA LOs]

1.1.2. By 2022, finalize and execute the NCAI budget initiative, depending on the availability of FY2022 funds. [NESDIS/NCAI, NAIEC]

1.1.3. By 2022, develop position descriptions and begin the recruitment process for NCAI support staff to execute the functions of the NCAI. [NESDIS/NCAI, WFMO, NOAA LOs]

1.1.4. By 2022, establish the facilitation and coordination structure of the NCAI to execute pertinent actions of the NOAA AI Strategic Plan. [NESDIS/NCAI, NAIEC, NSC, NOAA LOs]

1.1.5. By 2021, begin scoping a community of practice plan. The plan will increase awareness and accessibility of AI resources by using the NCAI website, educational outreach, and social media newsletters. Hold the NCAI opening ceremony in 2024. [NESDIS/NCAI, NAIEC, NOAA LOs]

Objective 1.2. Develop technical working group composed of NOAA line office experts to support the NOAA AI Executive Committee's efforts as needed to establish AI standards and execute the NOAA AI Strategic 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.

1.2.1. By 2021, develop the terms of reference and establish the NAIWG composed of volunteer NOAA LO representatives to provide technical guidance for the NAIEC and NCAI as needed. [NAIEC, NESDIS/NCAI, NOAA LOs]

1.2.2. By 2022 pending available resources, determine the LO technical staff requirements and position descriptions, and begin the recruitment process to infuse distributed AI expertise in each NOAA LO, support the NCAI functions, and serve on the NAIWG. [NESDIS/NCAI, NAIEC, NOAA LOs]

Objective 1.3. Prioritize AI-based approaches where applicable in NOAA budget formulation guidance, emphasizing the improvement of tools, performance skill, computational efficiency, and cost effectiveness.

1.3.1. By 2021, establish a process to evaluate annual AI investments of the NOAA LOs and provide recommendations for alignment with the actions of the strategic plan. [NAIEC, NSC, NOAA LOs, NESDIS, NAIWG]

1.3.2. By 2021, establish an annual prioritization and budget formulation process to provide annual AI budget plans for NSC endorsement with NOAA leadership decisional authority in support of AI efforts and synergistic activities. [NAIEC, NSC, NESDIS/NCAI, NOAA LOs]

1.3.3. By 2021, establish an annual process to review and approve AI priorities in appropriate NOAA budgets. [USEC, CFO, NSC, NAIEC, NOAA LOs]

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

1.4.1. By 2021, establish executive-level engagement and communications on AI progress to inform NOAA Councils, NOAA LOs, and other interagency communications including OMB, Congress, WH NSTC. [NAIEC, NSC, NESDIS/NCAI, NOAA LOs]

1.4.2. By 2021, establish a process to develop annual progress reports on AI prioritization. [NAIEC, NESDIS/NCAI, NOAA LOs, NAIWG]

1.4.3. By 2021, deliver annual progress reports for NSC approval to disseminate NOAA's AI progress and recommendations on AI priorities for NOAA and the public. [NAIEC, NSC, NESDIS/NCAI, NOAA LOs]

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

1.5.1. By 2021, establish communication and engagement with committees of the NOAA Data Strategy, NOAA Cloud Strategy, and NOAA Big Data Program to coordinate synergistic activities. [NAIEC, NESDIS/NCAI, NSTSC, Data and Cloud Strategy Committees]

1.5.2. By 2021, define the data quality, documentation, and dissemination requirements for NOAA's AI-ready open data to ensure consistent standards across federal agencies. [NESDIS/NCAI, NOAA OCIO, Data and Cloud Strategy Committees, NOAA LOs]

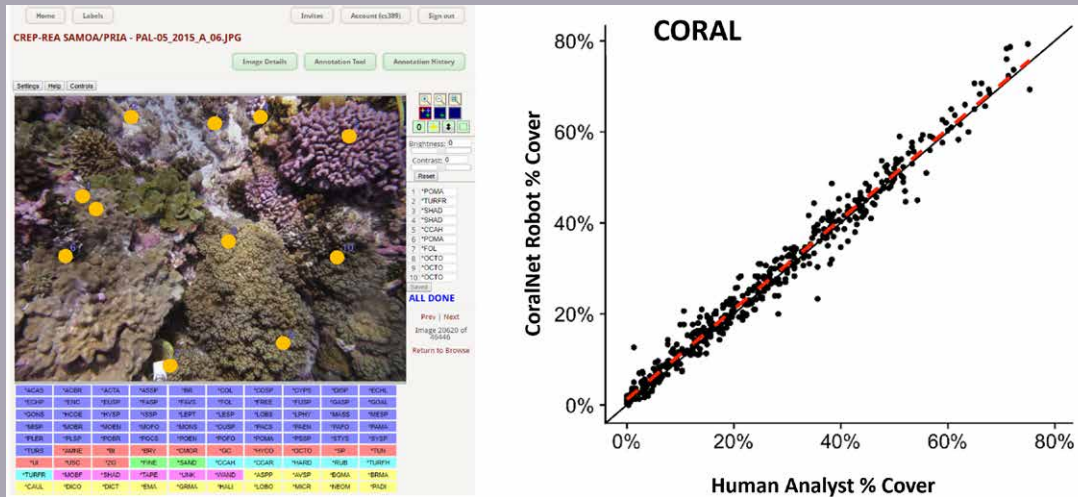
1.5.3. By 2022, establish an inventory system for NOAA's AI-ready open data, with a machine-readable metadata catalog, and provide an annual report with recommendations on the priorities and gaps for improving the availability and data readiness for AI. [NESDIS/NCAI, NOAA Data and Cloud Strategy Committees, OCIO, NOAA LOs]

1.5.4. By 2023, establish an AI analytical resource inventory system with user guides, and provide annual reports with recommendations on the priorities and gaps for improving the system and cloud computing resources. [NESDIS/NCAI, NOAA Data and Cloud Strategy Committees, OCIO, NOAA LOs]



CoralNet: Automated, Human-in-the-loop, Point Annotation of Coral Reef Imagery

CoralNet is an operational AI enabled application to efficiently annotate coral reef images in support of the NOAA National Coral Reef Monitoring Program mission. The NOAA National Ocean Service and NOAA Fisheries have worked collaboratively with its academic partners to improve the CoralNet architecture with new ML capabilities and expanded training data, decreasing the error rates by 22% over the operational product. CoralNet performs both automated and manual common coral taxa identification, and has shortened the time for processing survey data from months to weeks, reducing human annotation time by ~25%. CoralNet has enabled enhanced Photogrammetric and Structure-From-Motion surveys, and produced higher resolution (1-meter) products, decreasing error rates by ~10—15%. CoralNet includes an Application Programming Interface (API) with script-level access to public classifiers that allows well-trained classifiers to serve smaller-scale, agency, academic, and citizen-science projects.



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

Advancing AI research and innovation across NOAA and in close coordination with other agencies and partners is at the core of the AI strategic activities. Innovative approaches guided by a requirement-based process ensure AI research leverages the best available assets and expertise. The actions of this goal include a range of interdisciplinary R&D from tool development to application demonstrations, and focus areas include data processing efficiencies, automated detection and classification toolkits, improvements in data assimilation and predictive modeling, and other operational efficiencies. The actions in this goal will evaluate gaps and priorities for leveraging AI assets and collaborations to advance AI R&D in ecosystem and Earth system science.

Objective 2.1. Establish a requirement-based process to ensure AI research leverages the best available assets and expertise in support of the NOAA mission and to continually evaluate ongoing AI R&D to capitalize on rapidly evolving AI technology.

2.1.1. By 2022, complete gap analysis to evaluate available AI expertise and assets across NOAA LOs to define priorities for guiding investments that accelerate the transition of AI applications. [NOAA LOs, NESDIS/NCAI, NAIWG, NAIEC]

2.1.2. By 2022, conduct analysis and continuously incorporate market research to identify emerging AI solutions and guide research priorities across NOAA. [NESDIS/NCAI, OAR, NAIWG, NAIEC, NOAA LOs]

Objective 2.2. Prioritize AI-based approaches and support NOAA research federal funding opportunities, requests for proposals (RFPs), and research grants.

2.2.1. By 2021, identify federal funding opportunities to expand collaborative AI research. [NAIEC, OAR, NESDIS, NAIWG, NOAA LOs]

2.2.2. By 2022, establish the annual RFP process with terms of reference to expand collaborative AI research that address NOAA's priority AI focus areas. [OAR, NESDIS/NCAI, NAIEC, NAIWG, OAR, NOAA LOs]

2.2.3. By 2022, execute the annual RFP announcement to solicit and fund collaborative AI research in support of the NOAA mission. [OAR, NESDIS/NCAI, NAIWG, NOAA LOs]

Objective 2.3. Establish an annual research and development prize competition series for AI.

2.3.1. By 2023, establish the management process for a centralized annual prize competition to accelerate AI research and development in concert with other NOAA Strategies on emerging science and technologies. [NESDIS/NCAI, OAR, NAIEC, NOAA LOs]

2.3.2. By 2023, execute an annual prize competition series to accelerate AI research and development across NOAA. [NESDIS/NCAI, OAR, NAIEC, NOAA LOs]

Objective 2.4. Ensure NOAA Testbeds and Proving Grounds provide opportunities to expand AI research, improve algorithms, and evaluate model performance in support of advancing the NOAA mission.

- 2.4.1.** By 2021, identify and coordinate testbed and proving ground opportunities to accelerate AI research. [OAR, NESDIS/NCAI, NAIEC, NAIWG, NOAA LOs]
- 2.4.2.** By 2023, conduct annual RFPs for testbed and proving ground projects to accelerate requirement-based AI research for transitioning to operations. [NESDIS/NCAI, OAR, NAIEC, NAIWG, NOAA LOs]
- 2.4.3.** By 2022, establish a communication process for testbed standards, best practices, data requirements, and lessons learned to improve AI computations, validation, testing, and model performance evaluation. [NESDIS/NCAI, OAR, NAIWG, NAIEC, NOAA LOs]

Objective 2.5. Encourage every prospectus for NOAA Cooperative Institutes (CIs) and Cooperative Science Centers (CSCs) to explicitly call out AI research and applications.

- 2.5.1.** By 2022, expand and annually update NOAA CI and CSC agreements to incorporate AI research focus areas that address NOAA priorities and gaps. [OAR, NOAA OE, NESDIS/NCAI, NOAA LOs]
- 2.5.2.** By 2023, evaluate annual NOAA CI and CSC progress to ensure wise investments are directed towards NOAA AI research priorities. [OAR NOAA OE, NESDIS/NCAI, NAIEC, NOAA LOs]

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

The actions in this goal will enable rapid AI transition across NOAA, including a unified approach in research / operational applications and requirement-based holistic projects that are business-case driven, employ

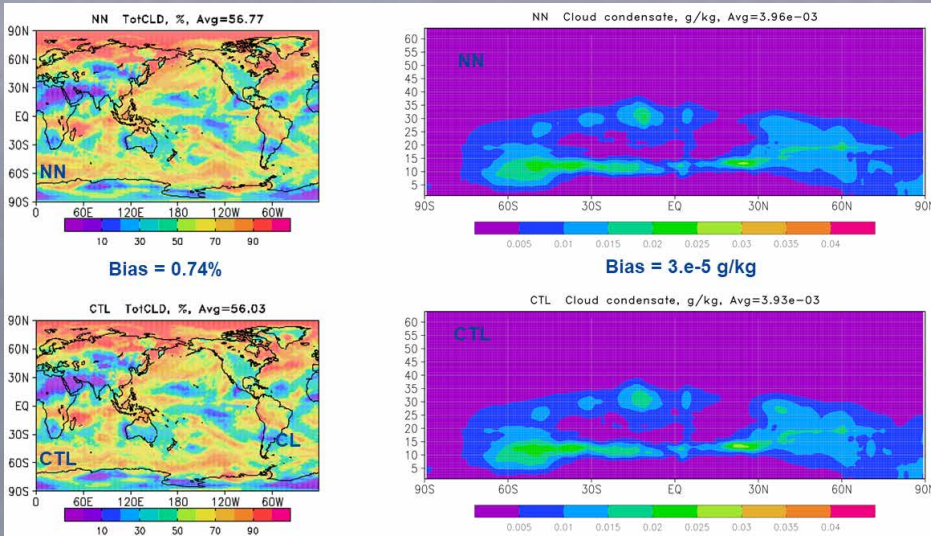
agile development, embrace risk, and apply evidence-based decision making. Transitions to NOAA operations will be accelerated by using present operations as a starting point of new development where possible. Within NOAA, Test Beds and Proving Grounds provide a mechanism to effectively evaluate research and standards for transition to operations. Transitioning AI applications to deliver high-quality and timely products include actions that ensure scientific and technical standards are established for training data, validation and performance of models, assessment of bias and risks, analysis of costs and benefits, transparency that promotes reliable and trustworthy AI applications, guidance and regulations for public participation, and information required for informed policy decisions. As these scientific, technical, and policy standards are formalized, flexibility is needed for routine evaluation and updates to remain current with the rapidly evolving technology.

Objective 3.1. Establish budget efforts to support the transition to operations of AI-based environmental research that shows improved skill, performance, and computational and cost efficiency.

- 3.1.1.** By 2021, annually evaluate AI partnership opportunities to leverage wise public-private investments for transitioning AI-based environmental research to operations. [NESDIS/NCAI, NOAA LOs, NAIEC]
- 3.1.2.** By 2023, perform a gap analysis with recommendations by each NOAA LO to identify and prioritize resources for transitioning AI-based environmental research to operations. [NOAA LOs, NAIEC]
- 3.1.3.** By 2023, establish AI transition budgets based on the identified priorities and gaps of the NOAA LOs to support the transition of AI-based environmental research to operations. [NOAA LOs, NAIEC, NESDIS/NCAI]
- 3.1.4.** By 2023, solicit and establish existing funding opportunities in each LO to support AI transitional projects. [NOAA LOs, NAIEC, NESDIS/NCAI]

Global Neural Network Wind-wave Model Ensemble

Machine learning (ML) is advancing NOAA’s numerical weather prediction model. The ML neural network (NN) emulation of the atmospheric physics suite is three times faster than the original suite. Complete suite of the atmospheric physics in GFS v. 16, including Longwave and Shortwave Radiation, planetary boundary layer, orographic and convective gravity wave drag, deep convection,



shallow convection, microphysics, time dependent CO₂, trace gases, aerosols (tropo- and stratospheric), ozone, and H₂O photochemistry was emulated by NN. The differences (biases) between the run with the original suite and the run with the NN emulation are small, and no signs of instability were observed during the runs.

Twenty-four 10-day forecasts were run in parallel to validate the NN emulation: control run (CTL in the figure, lower row) with the original suite of atmospheric physics and NN run (NN in the figure, upper row) with the original suite substituted by NN. Two very sensitive atmospheric parameters are shown: total cloudiness, left column and cloud condensate, right column.



Objective 3.2. Transition to operations, commercialization, and academia AI based environmental data and applications with NOAA approved metrics.

3.2.1. By 2021, update NAOs and handbooks to provide guidance for AI applications. [NESDIS/NCAI, NOAA LOs, NAIEC]

3.2.2. By 2021, establish and routinely update metrics to evaluate and document the AI implementation progress, model performance, and value of the AI products and services, including updated RL definitions suitable for AI. [NAIEC, NOAA LOs]

3.2.3. By 2023, establish and annually update a prioritization process for end-to-end projects to evaluate planning and progress from inception to implementation that optimally use AI in NOAA operations. [NOAA LOs, NESDIS/NCAI, NAIEC]

3.2.4. By 2023, create and prioritize projects in partnership with the private sector to develop new AI enabled products that meet stakeholder needs and could be marketed. [NESDIS/NCAI, NOAA LOs, NAIEC]

3.2.5. By 2024, assess the current suite of AI-ready data science products and analytic tools, to ensure these are supported and available to NOAA and the public as added value to NOAA's data enterprise, services, and products. [NESDIS/NCAI, NOAA LOs, NAIEC, NOAA Data and Cloud Strategies]

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.

3.3.1. By 2022, develop and update NOAA technical guidelines on the best practices and standards for developing, updating, transitioning, and maintaining AI applications. [NAIWG, NESDIS/NCAI, NAIEC, NOAA Data and Cloud Strategy, NOAA LOs, NOAA OCIO]

Objective 3.4. Build AI awareness across NOAA LO's through NOAA science seminars and webinars, internal workshops, and routine internal communications venues such as newsletters.

3.4.1. By 2021, expand the use of routine seminars, workshops, and communications to improve AI awareness across NOAA LOs. [NESDIS/NCAI, NOAA LOs, NAIEC]

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.

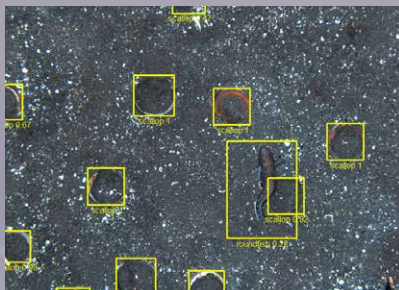
3.5.1. By 2022, complete and disseminate an annual report of NOAA progress on AI research transitions. [NAIEC, NESDIS/NCAI, NOAA LOs]

3.5.2. By 2023, produce an annual NOAA report with contributions from each LO to document progress on the transition of AI applications to operations, commercialization, and academia. [NESDIS/NCAI, NOAA LOs, NAIEC]

GOAL 4. Strengthen and Expand AI Partnerships.

Partnerships serve as force multipliers to optimize resources and collaborations for scientific and technological exchange that keeps NOAA current in the rapidly evolving field of AI. Building new and long-lasting

VIAME Automated Detection and Classification during NOAA Fisheries Underwater Benthic Survey



The Video and Image Analytics for Marine Environments (VIAME) applies ML algorithms for the automated detection and classification of benthic organisms during the Northeast Fisheries Science Center (NEFSC) Habcam benthic survey. Approximately five million image pairs of the sea floor are collected each year from the NEFSC Habcam benthic survey. Previously, only about 2%, of the images (around 100,000) are analyzed by humans for scallops, fish, and crabs, while the remaining images of other benthic organisms were not examined.

The VIAME convolutional neural network (CNN) analytics can considerably reduce labor costs and time to analyze the images; VIAME processes several images per second, compared to 1—2 images per minute for a human processing. Work is also underway to develop and train VIAME algorithms to expand its capabilities to automate detection and identification of other benthic organisms, thus improving the understanding of benthic communities important in the development of ecosystem-based fishery management.

The NEFSC Habcam operations have been developed in partnerships with the Woods Hole Oceanographic Institution (WHOI) and commercial fishermen, while the VIAME toolkit has been developed in partnership with Kitware Inc.

partnerships across government, academic, industry, and research institutions both nationally and internationally is critical to effectively achieve many of the actions of this strategic plan. The NCAI will have an important role in creating a community of practice that promotes innovation to accelerate NOAA's capabilities in AI, and increase our public catalog of AI-ready open data and applications. By expanding partnerships in AI-based environmental research, NOAA will leverage joint expertise, optimize collaborative investments, and facilitate scientific and technical information exchange between NOAA LOs and other organizations. Partnering with the NOAA Data Strategy, NOAA Cloud Strategy, and NOAA Big Data Program will leverage data and cloud services that are foundational for enhancing AI-ready data access and workflows for AI analytics.

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

- 4.1.1. By 2022, identify collaborative RFP opportunities with research institutions, like the NOPP, to expand AI-based environmental research. [OAR, NOAA LOs, NESDIS/NCAI, NAIEC, NAIWG]
- 4.1.2. By 2022, engage and support RFP opportunities with NOPP and other external research institutions to build AI-based environmental research collaborations. [OAR, NOAA LOs, NAIEC, NAIWG]
- 4.1.3. By 2022, establish inventory and track RFPs awards to ensure progress towards AI-Based environmental research priorities. [OAR, NOAA LOs, NAIEC, NAIWG]

Objective 4.2. Expand partnerships in AI-based environmental research with the academic and research community, including CIs and academic institutions.

- 4.2.1. By 2021, conduct annual meetings with academic partners to prioritize and expand collaborative AI-based environmental research opportunities. [NESDIS/NCAI, NOAA OE, NOAA LOs, NAIEC]
- 4.2.2. By 2022, establish AI partnerships through student internship opportunities and research collaborations with the academic research community, including CIs and CSC to expand AI-based environmental research. [NOAA OE, NESDIS/NCAI, NOAA LOs]

Objective 4.3. Work with the NSF's National Artificial Intelligence Research Institutes to collaborate with appropriate institutes on AI R&D.

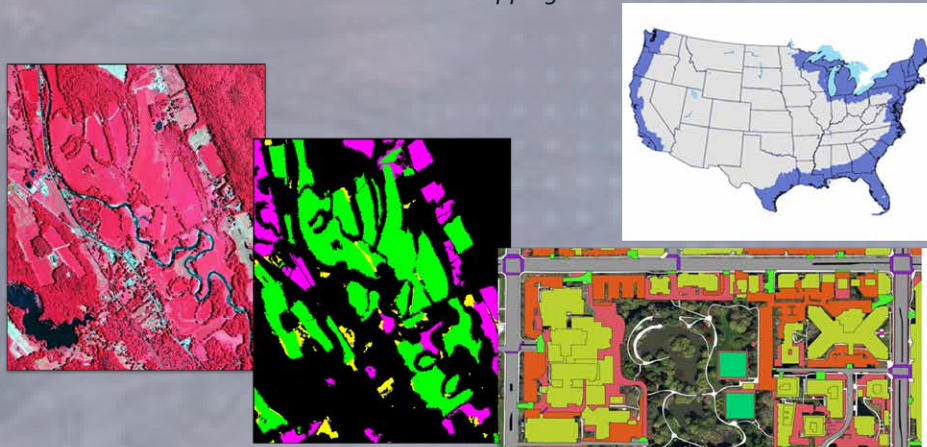
- 4.3.1. By 2022, engage with NSF's National Artificial Intelligence Research Institutes and identify opportunities to accelerate NOAA AI research priorities. [NAIEC, NESDIS/NCAI, NOAA LOs]

Objective 4.4. Expand formal cooperative agreements on AI-based environmental research and applications with interagency and international partners, including DOD, DOI, DOE, and DHS.

- 4.4.1. By 2022, identify and establish interagency partnership agreements to share AI technical solutions and expand AI-based environmental research collaborations. [NAIEC, NESDIS/NCAI, NOAA LOs]
- 4.4.2. By 2022, establish international partnership agreements to expand collaborative efforts in the development of AI research and applications. [NAIEC, NESDIS/NCAI, NOAA LOs]

High-Resolution Land Cover Mapping

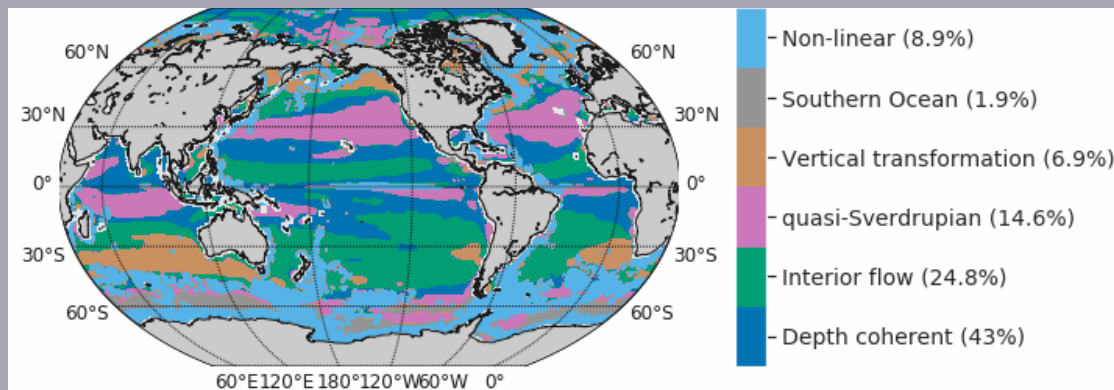
NOAA's National Ocean Service Coastal Change Analysis Program (C-CAP) maps and monitors land cover in the coastal areas of the U.S. using remotely sensed imagery data. C-CAP has used traditional machine learning (ML) methods since 2005, and recent advances in deep learning approaches have improved imagery resolution (from 30-meter to 1-meter) enabling the delivery of higher quality products nationally. NOAA uses ML convolutional neural networks (ConvNets) for mapping coastal, agricultural and other land cover features. NOAA continues to work with AI experts in the private sector to cost share large-scale continental U.S. (CONUS) impervious surface mapping.





Monitoring of Ocean State for Improved Climate Predictions

NOAA's Oceanic and Atmospheric Research and CIMES (Princeton) scientists are employing an AI/ML framework to recognize key ocean dynamical regimes. Employing unsupervised ML, six regimes emerge from fundamental ocean model dynamics, which neural networks are trained to recognize given only surface data, e.g., from a climate model or using high resolution model data paired with satellite fields. For example, heat transport, a key to climate variation/changes, can be monitored following the 'Southern Ocean' and 'vertical transformation' regimes.



Area-wise contributions (shown in parenthesis in the figure legend) of the different dynamical regimes in the global oceans. The regimes shown are defined as follows. **Non-linear**: Flow impacted by small scales. **Southern Ocean**: Water masses move vertically (net up Southern Hemisphere). **Vertical transformation**: Water masses move vertically (net down Northern Hemisphere). **Quasi-Sverdrupian**: Surface flow isolated from bottom. **Interior flow**: Surface flow separating from bottom. **Depth coherent**: Momentum dominated flow.

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.

4.5.1. By 2022, evaluate and seek public-private opportunities through market research and evaluate progress for AI-related awards to monitor performance and lessons learned. [TPO, NESDIS/NAI, NOAA LOs, NAIEC]

4.5.2. By 2022, formalize new public-private partnerships to advance AI research and applications. [TPO, NOAA LOs, NAIEC]

4.5.3. By 2023, enable AI-ready data and utilize cloud services across NOAA through building new and enhancing existing partnerships with the private sector. [OCIO, NESDIS/NAI, NAIEC, NOAA Data and Cloud Strategy, NOAA LOs]

4.5.4. By 2024, coordinate with NOAA Technology Partnership Office (TPO) to support AI development through new and existing CRADAs and SBIR grants. [NOAA LOs, OAR, TPO, NESDIS/NAI, NAIEC]

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.

4.6.1. By 2022, engage White House NSTC Select Committee on AI to identify partnership opportunities and establish partnerships across governmental agencies. [USEC, NAIEC, NOAA LOs]

4.6.2. By 2021, engage in international advisory committees to evaluate AI innovations and technical solutions. [NOAA LOs, NESDIS/NAI, NAIEC, NAIWG]

4.6.3. By 2022, provide innovative and substantive contributions to the policy and advisory committees. [NSC, NAIEC, NOAA LOs]



GOAL 5. Promote AI Proficiency in the Workforce.

For NOAA to sustain leadership in Earth system science, the fast pace of advancement necessitates diversity, collaboration, and workforce proficiency equipped with the technical and institutional support to leverage and apply AI to NOAA research and operations. The NOAA workforce, composed of people with diverse backgrounds and experiences, serves as our most valued asset and is a wise investment that cultivates the expertise and innovation required to integrate AI with other emerging science and technologies. Equally important is an inclusive work environment that drives workforce performance and collaboration to integrate AI technologies throughout NOAA's unique mission of science, service, and stewardship. The actions under Goal 5 are deliberate steps that demand a diverse and inclusive workforce to reflect, understand, and respond to the varied communities and stakeholders NOAA serves. The NCAI will serve as the NOAA Learning Center to provide critical AI training resources and expand training opportunities for employees across NOAA. This AI-driven shift in the workplace will result in optimized processes and upskilling of individuals, and develop external training opportunities for student internships and external details. To support the development of AI experts for NOAA's future workforce, the NCAI will partner with the NOAA Office of Education (NOAA OE) to create student internships, training, and experiential research opportunities for undergraduate and graduate students, including students from diverse backgrounds and underrepresented groups.

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

- 5.1.1.** By 2022, complete annual assessment of NOAA AI training resources and requirements. [NESDIS/NCAI, NOAA OE, NOAA LOs, NAIEC]
- 5.1.2.** By 2022, establish the NCAI AI training budget to increase online and on-scene AI training for NOAA. [NESDIS/NCAI, NAIEC, NOAA LOs]
- 5.1.3.** By 2023, create a NOAA AI Learning and Support Center with virtual and hands-on training, including an AI Help Desk. [NESDIS/NCAI, NOAA OE, NOAA LOs]
- 5.1.4.** By 2023, create a collaborative AI training outreach program to utilize training opportunities in NOAA and other institutions. [NESDIS/NCAI, NOAA OE, NAIEC]

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.

- 5.2.1.** By 2022, engage NOAA LOs to utilize the NRAP selection process to build experience in AI cross functional mission priorities. [NOAA LOs, OHCS, NESDIS/NCAI]
- 5.2.2.** By 2023, assess the impact of NRAP activities for building AI collaborations and workforce proficiency. [NESDIS/NCAI, NAIEC, OHCS]
- 5.2.3.** By 2024, establish NRAPs to utilize rotational assignments between government agencies to evaluate innovative AI solutions. [NESDIS/NCAI, OHCS, NOAA LOs, other agencies]

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

- 5.3.1.** By 2022, identify and utilize advanced educational programs and other professional development to enhance NOAA workforce proficiency in AI research and applications. [NOAA LOs, NESDIS/NCAI, OHCS, NOAA Cooperative Institute program]
- 5.3.2.** By 2024 depending on funding, NCAI will sponsor and host a NOAA AI incubator program to fund internal experimental research and enable hands-on AI training. [NESDIS/NCAI, NOAA LOs]

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.

- 5.4.1.** By 2021, host AI sessions at conferences and workshops to expand workforce knowledge on the current state of AI technology and external research community's requirements for AI-ready open data. Examples of national and international forums include AMS, AGU, Oceans, and ICES. [NOAA LOs, NESDIS, NAIEC]
- 5.4.2.** By 2023, establish AI external and international exchange programs to expand NOAA leadership for building collaborative AI research. [NOAA LOs, NESDIS/NCAI]



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.

5.5.1. By 2023, prioritize support for AI research activities in graduate programs, internships, and student training programs to build our future workforce expertise. [NOAA LOs, NOAA OE, NESDIS/NCAI]

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

5.6.1. By 2022, conduct annual workforce analysis to accelerate AI research and applications. [NOAA LOs, OHCS, NAIIEC, NESDIS/NCAI]

5.6.2. By 2022, establish AI position description language to guide the recruiting process for AI expertise. [NOAA LOs, OHCS, NAIIEC, NESDIS/NCAI]

Conclusion

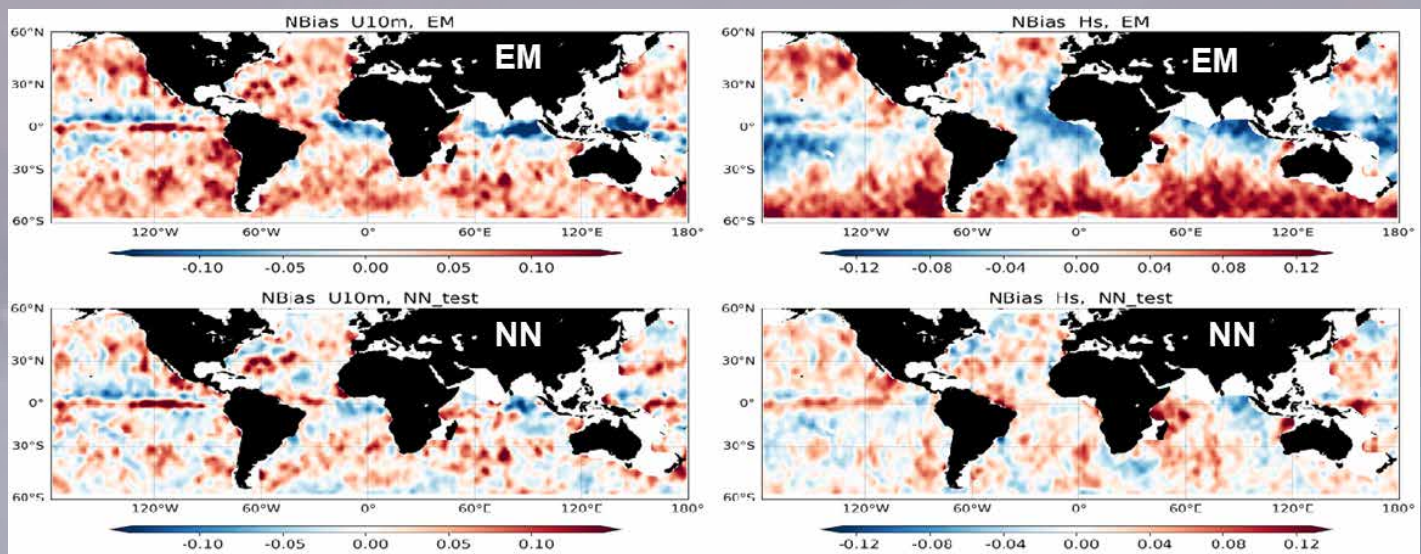
NOAA is committed to improve awareness, coordination, and operational efficiency in the application of AI science and technology across its mission priorities to cost-effectively deliver high quality and timely products and services for the nation. This strategic plan serves as a living document

that establishes the framework and actions to implement optimally the rapidly evolving AI capabilities. Embedded in many of the actions is the coordination of synergistic activities with the other NOAA Data, Cloud, AI, UxS, and 'Omics Strategies on emerging science and technologies as a One NOAA approach to fully realize the benefits of improved organizational and operational efficiencies. The actions of this strategic plan will be collectively executed in a phased approach with the assumption of stable resources that can be redirected when possible and new resources when available to accelerate the transition of AI research to operations.

NOAA as a world leader in atmospheric and oceanic science has demonstrated the benefits of applying AI analytics to reduce processing time and operational costs to deliver high quality scientific products and services in a timely manner. The actions of this plan will accelerate AI advancements and applications to improve NOAA's products and service, while also benefiting the wider community with improved access to NOAA's repository of AI-ready data and analytical tools that enable knowledge discovery, thereby providing added value to the NOAA data enterprise. This is an exciting opportunity to utilize the emerging science and technologies, and NOAA's workforce is enthusiastic to embrace this pivotal opportunity to transform its operations into efficiencies that reduce costs, produce high quality science, and more timely delivery of products and services for our nation.

Global Neural Network Wind-wave Model Ensemble

Global scale ensemble forecasting for wind and wave conditions have been improved using AI-ML models. Significant part of large-scale biases in the mid- to high latitudes has been eliminated by neural network (NN) ensemble mean computations.



Normalized bias for NCEP's Global-Scale Wave Ensemble linear conservative mean (EM, top), and for nonlinear NN ensemble (NN) mean (bottom) vs. altimeter data. The columns represent U10 – wind at 10 m height (left) and Hs – significant wave height (right). Red indicates overestimation by the model ensemble compared to altimeter observations while blue indicates underestimation.



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List of Abbreviations

AI	artificial intelligence
AITO	DOE AI and Technology Office
CFO	NOAA Office of Chief Financial Officer
CIs	NOAA Cooperative Institutes
CRADAs	NOAA Cooperative Research and Development Agreements
CSCs	NOAA Cooperative Science Centers
DHS	Department of Homeland Security
DOD	Department of Defense
DOE	Department of Education
DOI	Department of Interior
EPIC	Earth Prediction Innovation Center
JCAI	DOD Joint Center for AI
LOs	(NOAA) Line Offices
LOTMC	NOAA Line Office Transition Managers Committee
ML	machine learning
NAIWG	NOAA AI Working Group
NCAI	NOAA Center for AI
NAIEC	NOAA AI Executive Committee
NAO	NOAA Administrative Order
NCAI	NOAA Center for AI, also designated as NESDIS/NCAI in this document
NCEI	NOAA National Centers for Environmental Information
NCAR	National Center for Atmospheric Research
NESDIS	NOAA National Environmental Satellite, Data, and Information Service
NOAA	National Oceanic and Atmospheric Administration
NOAA OE	NOAA Office of Education
NOPP	National Oceanographic Partnership Program
NOSC	NOAA Observing System Council
NRAP	NOAA Rotational Assignment Program
NSC	NOAA Science Council
NSTSC	NOAA Science and Technology Synergy Committee
NSTC	National Science and Technology Council
NWS	NOAA National Weather Service
OAR	NOAA Office of Oceanic and Atmospheric Research
OCIO	NOAA Office of Chief Information Officer
OHCS	NOAA Office of Human Capital Services
R&D	research and development
R2O	transition research to operations
R2X	transition research to operations, applications, commercialization or other use
RFP	requests for proposals
RLs	readiness levels
SBIR	Small Businesses Innovative Research grants
SME	subject matter expert
TBPGcc	NOAA Test Bed and Proving Ground Coordinating Committee
TPO	NOAA Technology Partnerships Office
TRLs	Technical Readiness Levels
UCAR	University Corporation for Atmospheric Research
USEC	Under Secretary of Commerce for Oceans and Atmosphere
UxS	uncrewed systems
WFMO	NOAA Workforce Management Office
WH NSTC	White House National Science and Technology Council



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