February 2024

FY2026 Strategic Research Guidance Memorandum

1. Overview

In accordance with existing NOAA administrative orders,[1] the Strategic Research Guidance Memorandum (SRGM) is produced annually by the Chief Scientist[2] to highlight areas of the agency's research and development (R&D) portfolio that merit special consideration in budget formulation. It is intended to inform discussions about future budget priorities by articulating the value of key research areas.

NOAA's Mission: science, service and stewardship[3]
1. To understand and predict changes in climate, weather, ocean and coasts;
2. To share that knowledge and information with others; and
3. To conserve and manage coastal and marine ecosystems and resources.

NOAA's R&D portfolio is diverse, ranging from the bottom of the ocean to the edge of our atmosphere and the surface of the Sun. NOAA's research activities have contributed to our collective understanding of the past, present, and future of the Earth System.

The knowledge gained has provided substantial benefits to safety, social equity, environmental health, and economic development. Over $900 billion of US economic activity is sensitive to weather.[4,5] The output of U.S. marine economy is estimated to be over $700 billion in 2021,[6] and the output of the U.S. space economy is estimated to be over $200 billion.[7] Conversely, extreme events, such as hurricanes, wildfires, and heat waves can result in billions of dollars in damages, as well as lives lost.[8]

NOAA received substantial support in recent fiscal years from the Bipartisan Infrastructure Law (BIL) and Inflation Reduction Act (IRA). By the end of FY26, many of these resources will have expired. However, the needs of the public and private sectors that motivated the allocation of this funding remain. Absent an increase in base funding, maintaining the level of service that communities and businesses have grown to expect will be a challenge.

Organization of the SRGM

The FY26 SRGM is organized into four sections and an appendix:

- **Critical Continuing Research Areas:** These R&D activities are the "must haves." They are fundamental to NOAA executing its mission. They are key components of our base funding. They represent priorities in a resource constrained environment. However, the maintenance of these research capabilities faces inflationary pressures, as well as growing costs and competition for labor. Looking forward, adequate support in these critical areas

[1] See NOAA Administrative Order 216-115A, Section 5.03
[2] The Chief Scientist draws on constructive input from the NOAA Science Council, the Science Advisory Board, and subject matter experts across the Line Offices to develop the SRGM.
[3] NOAA Mission and Vision
[4] Lazo, J. et al. (2011). U.S. Economic Sensitivity to Weather
[5] NOAA 2020 Business Brief (values adjusted to represent current GDP)
[6] Marine Economy Satellite Account (2023), U.S. Bureau of Economic Analysis
[7] New and Revised Statistics for the U.S. Space Economy, 2012–2021 (2023), U.S. Bureau of Economic Analysis
[8] Billion-Dollar Weather and Climate Disasters, NOAA/NCEI

acts as a prerequisite for the agency to maximize investments in new areas of research. Under the Critical Continuing section, we highlight three areas: ***Observations, Forecasts and Predictions, and the Arctic.***

- **Emerging Research Areas:** These R&D activities focus on what's **"**just over the horizon." Investments in these areas will position NOAA to take advantage of developments in technology, to effectively respond to evolving ecological and societal needs, and to transition knowledge into action by businesses and communities. To be successful in these areas, new appropriations are required. Under the Emerging section, we highlight five areas: ***the Future of Earth Systems Models and Innovation in Climate Services; the Measuring and Monitoring of Carbon and Marine Life; Artificial Intelligence; Multiple Ocean Uses, Blue Economy, and the Ocean Enterprise; and Social Science Research to Improve NOAA's Knowledge, Products, and Service Equity.***

- **Success Multipliers and Risk Factors:** This section focuses on cross-cutting issues that amplify or undercut the impact of investments in NOAA's R&D portfolio.

- **Appendix of supporting documents:** The Appendix provides links to strategy and programmatic documents that provide greater detail on research areas mentioned in the SRGM.

This SRGM does not intend to mention every element of the NOAA R&D portfolio, nor discourage sustained investment in the existing portfolio. The Memorandum provides guidance in areas that warrant additional focus, advancement, and/or investment in the view of the Chief Scientist. This memorandum is intended to be guidance, and will not replace the many tools NOAA has to define and support budget justifications.

2. Critical Continuing Research Areas

2.1 Critical Continuing: Observations

NOAA's Earth and space observations are used by federal agencies, state and local governments, the private sector, academia, nonprofits, and the public to make decisions about national security, food and water security, climate change, air quality, and space and environmental hazards. In addition, NOAA's observations are used for research and development purposes, improving our understanding of the Earth and space environments, and supporting the testing and transition of new technologies.

In terms of satellites, NOAA will continue essential operations and develop new capabilities in its geospatial, low-Earth orbiting, and space weather missions. GeoXO, NOAA's next generation geostationary spacecraft is expected to provide over $4 billion annually in benefits and includes new instrumentation focused on societal needs.[9]

In addition to space-based capabilities, NOAA maintains a fleet of air, ground, and ocean observations that support the breadth of NOAA's mission. In particular, NOAA plays a critical role in ocean observing - the Global Ocean Monitoring Program supports half of the world's ocean observing research and has encouraged the participation of over 100 nations in developing the current distributed ocean observing system.[10]

However, the future health of many observational systems faces growing risks due to lack of resources and increasing operational costs. Erosion of NOAA's observational capabilities threatens the agency's ability to fulfill its obligations to science, service, and stewardship.[11]

Continued funding is not only important to maintaining observational systems themselves, but in maximizing value from existing observations. For example, support for data assimilation, a process where observations are combined with model data to improve predictions or assessments, has been critical in improving environmental and weather forecast systems.[12] And such improvements would not have been possible without the resources to take advantage of high performance computing platforms.

Transfer of observational data to cloud platforms represents another avenue for amplifying value. Greater access enables a wider range of users to design and develop their own applications using NOAA observational data. [13,14]

Demand for Earth and space observations exceeds NOAA's capacity - we can't do it all alone. Continued funding is also needed to bolster the agency's ability and agility to take advantage of data streams collected by others. This can be in the form of citizen science activities; through

[9] Adkins, J. (2022). GeoXO benefit analysis.
[10] Global Ocean Monitoring and Observing Strategic Plan, 2021-2025
[11] Examples include: maintenance of NEXRAD radar to extend service lifetime; repair and maintenance of the aging ocean research fleet
[12] The development of the High-Resolution Rapid Refresh Model and products like HRRR-Smoke provides an example of the value of data assimilation.
[13] Evolution of the NOAA Open Data Dissemination Program
[14] Example of crop optimization software, driven by NOAA data

the purchase of commercial data; or as part of partnerships with other federal agencies,[15] non-profit organizations, private-sector firms, or trusted foreign governments. These avenues promise to improve the efficiency of data collection. However, expansion of this work requires that non-NOAA parties can deliver data that meet our standards for security and reliability. Faulty or non-continuous data could degrade forecast skill, the quality of NOAA products, and trust in NOAA service delivery.

Lastly, continued funding is critical for NOAA to characterize the value of our observations in more granular ways. While we have information about the broad impacts of our environmental observations, more sectoral and regional information about the applications of our products and services would be useful. This information would help us better prioritize future investments in the observational network. However, gathering this information requires stronger investment in the agency's social science capacity and expertise. It would also require the agency to integrate socioeconomic assessments into our scientific efforts.

2.2 Critical Continuing: Forecasts and Predictions

Americans are increasingly dependent on timely, reliable, and accurate weather, water, space, environmental, and climate information for the protection of life and property and enhancement of the Nation's economy. NOAA needs to prioritize strategic investments in its R&D activities to improve forecasts and predictions on relatively longer time scales, beyond short-term weather events.

The *Priorities for Weather Research Report* highlights the investments necessary to improve subseasonal-to-seasonal (S2S) predictions (defined as out to 2 years) and related early warning prediction products. Critical investment goals include:

- Increasing the coverage of ocean observations, including marine surface and sea ice, and improving our understanding of ocean processes that underlie longer-term prediction skill;
- Building strategic partnerships and collaborations (e.g., interagency, public-private, international) that expand the user community and extend the longevity of current investments;
- Ensuring flexibility to identify and leverage emerging technologies that improve model prediction products.

For NOAA forecasts and predictions ranging from daily weather to decadal climate, it is critical to calculate uncertainty, evaluate ways to reduce that uncertainty, and assist users in translating uncertainty information. Ongoing work in this area is integral to ensuring that NOAA forecasts and predictions translate into action, and to build trust and understanding among decision makers that rely on our forecast and prediction products.

Improvements to hazard-specific (e.g., floods, wildfire, high winds, extreme heat) forecasts and early warning systems are highly valuable, offering the ability to reduce damages from extreme events.[16] However, these improvements require a multi-pronged approach to bolstering NOAA's assets and services. For example, better predictions for water availability and drought on time scales from weeks to decades[17] require improvements to ocean observations, targeted process

[15] Example of interagency collaboration on space weather, in support of the PROSWIFT Act. Also, the Fumes Act of 2022 outlines collaboration for volcano early warning and monitoring.
[16] Billion-Dollar Weather and Climate Disasters, NOAA/NCEI
[17] More information about research focused on the influence climate change on drought

experiments, improvements to models, transition of research products to operational platforms, and engagement with decision makers as they utilize the predictions.[18] While improvements are possible, there are no silver bullets for building the type of early warning capabilities that users require.

Similar to providing better warning related to hazards, NOAA's modeling and prediction capabilities have important connections to ecological forecasting, especially in the marine environment. For example, the currents, temperature, and salinity predicted by coastal ocean models can be linked to models of Harmful Algal Blooms (HABs), hypoxia, ocean acidification, and more. NOAA investments should address requirements across various models (e.g., ocean models, atmospheric models, ecological forecasting models), and the subsequent transition from research to operations (R2O).

Investments to advance observing, monitoring, and forecasting for ecosystems that span timescales (e.g., weather, S2S, decadal) would play a pivotal role in enhancing tools to identify the locations, production, and movement of living marine resources. Timely and precise ecological information can empower industries and resource managers to make informed decisions, ultimately fostering sustainable practices and optimizing the utilization of marine resources. This integrated approach to observing, monitoring, and forecasting would contribute to the overall resilience and sustainability of the Blue Economy, fostering economic growth and environmental stewardship in marine-related industries.

2.3 Critical Continuing: Arctic

Alaska–and the nation's broader Arctic interests–are on the front lines of rapid environmental changes, often tied to rapid climate change. The impacts of these changes have local, national, regional, and global implications. The rapid nature of climate-forced environmental change has challenged existing observation efforts and created new monitoring requirements.

NOAA research assets and capabilities in the Arctic include:

- decades of in-situ and satellite marine, terrestrial, and atmospheric measurements
- mapping the Alaskan coastline and U.S. Exclusive Economic Zone,[19]
- regional sea-ice and climate modeling, and
- monitoring of marine ecosystem productivity.

These activities contribute substantially to our understanding of future global climate, living marine resource economics, human health, and food security. They directly inform:

- management of some of the largest fisheries in the world, in support of the National Seafood Strategy,[20]
- research on and management of marine mammals,
- improved safety for expanded navigation routes,
- capabilities for oil spill response,
- climate adaptation planning within Indigenous communities,
- assessment of regional food security.

Enhanced budgetary resources are necessary to address the complexity of NOAA's missions in the Arctic and meet the needs of Alaskan communities. Existing, sparse observations are challenged by remote, extreme conditions, lack of basic infrastructure (e.g. roads), and relatively

[18] NOAA's Precipitation Grand Challenge also illustrates a similar approach for integration.
[19] Alaska Coastal Mapping Strategy: Implementation Plan 2020-2030
[20] National Seafood Strategy

higher costs. These challenges can be partially addressed with improved automated weather observing networks and innovative uses and improved delivery of satellite products.

Investments are needed to update bathymetric mapping and improve forecasts of ocean conditions, ecosystems, and sea ice. These investments can yield Arctic- and Alaska-specific weather and climate products that assist a wide range of regional users, from fisheries managers to Indigenous communities.

Expanded investment in regional partnerships is also needed. For example, new threats associated with increased risks of HABs to food security require greater engagement with subsistence-based communities, the State of Alaska, and other federal agencies. New international commitments such as the Central Arctic Ocean Fisheries Agreement require funded monitoring strategies and infrastructure that are co-developed with global Arctic partners and local Indigenous leadership.

NOAA is uniquely positioned to provide world-class data, products, services, and capabilities to inform decision-makers from international to local levels. However, these capabilities need to be strategically resourced. Without continued support, the United States will depend on the scientific investments of other nations, potentially with their own growing economic and security interests in the region. Without a NOAA-led effort to improve observing, monitoring, and modeling of Arctic systems, events such as marine heatwaves in the Bering Sea affecting the country's most lucrative fishery[21] or the disastrous impacts of extreme weather on Indigenous communities and the lower 48 states will have ripple effects across the U.S. economy. NOAA's increasingly complex mission in the Arctic, combined with a paucity of fundamental observations, potentially undercut the agency's ability to prepare for and respond to these types of events and to support Administration strategic priorities.[22]

[21] Examples of NOAA assessment of the impacts of marine heatwave in Alaska: https://www.fisheries.noaa.gov/feature-story/new-evidence-marine-heatwave-impacts-western-alaska-chum-salmon; https://www.fisheries.noaa.gov/feature-story/most-recent-data-shows-gulf-alaska-marine-ecosystem-slow-return-pre-heatwave-state

[22] National Strategy for the Arctic Region

3. Emerging Research Areas

3.1 Emerging: The Future of Earth System Models and Innovation in Climate Services

Climate change has caused rapid change and unprecedented variability in weather and climate systems. Among the wide array of impacts: extreme heat risk is increasing throughout the United States; sea levels are rapidly increasing, particularly along the East Coast, leading to increased frequency and severity of inundation from storm surge and coastal flooding; Great Lakes water levels are becoming more variable; precipitation extremes and associated flood events are becoming more common; drought risk is deepening in many areas of the country; and ecosystems are struggling to adapt to rapid changes in the land and ocean. Extreme events can also occur in combination or rapid succession, resulting in cascading impacts and a greater degree of human and financial risk in our society. Stakeholders demand forward-looking information at scales relevant to decisions, and their information needs vary greatly among applications.

Enabling society to be prepared for this volatility and change in our Earth system requires seamless, reliable modeling capabilities that can look forward from days to decades in the future. The effectiveness of our planning, preparedness, and response relies upon accurate, actionable information across these time scales. Several strategic research themes require support:

- **Integration:** NOAA's flexible Earth system models can be used across time and space scales to simulate complex Earth system features from chemical cycles to atmospheric circulation to ocean currents to ecological responses. Further research must focus on the integration of these models, their application to key societal challenges, and the decision support processes that translate their predictions into effective action.

- **Resolution:** Support to develop higher-resolution models with improved process descriptions is essential. Developing and testing high-resolution versions of our models is key to providing the localized information needed by users. Improving resolution requires process research, model development, model testing and analysis, data assimilation, machine learning techniques, and high performance and cloud computing resources.

- **Social Science and Engagement:** We have seen extreme weather and climate incidents where the quality of information is outpacing society's ability to use it effectively for hazard mitigation. Without appropriate social science research, even the best model simulations, forecasts, and warnings will not reduce risk. NOAA needs sustained resources to work with stakeholders in a co-development framework to create new products and services for high-impact societal challenges. This includes developing new prediction services and products with appropriate dissemination methods drawing on both socioeconomic and environmental information.[23] It also requires sustained support for forward-looking climate projections demanded by the private sector. Underpinning these technical developments is the recruitment and retention of an interdisciplinary workforce that is trained and ready to effectively collaborate with our constituents.

[23] For example, NOAA has begun to work with Census to link physical and socioeconomic data for analysis of extreme weather impacts on communities.

3.2 Emerging: The Measuring and Monitoring of Carbon and Marine Life
Efforts are accelerating to better quantify the value of natural resources and ecosystem services that provide beneficial services to human societies (natural capital).[24] NOAA plays a crucial role in supplying high quality routine data to inform metrics for natural capital, such as those that underpin legislatively mandated marine fisheries and protected species management.[25]

The categories of natural capital of interest are expanding to allow for detecting finer-scale change in an increasingly busy ocean environment. And as more federal agencies prioritize nature-based solutions (NBS) – actions that protect, sustainably manage, and restore ecosystems – the demands grow for measurement methodologies and data related to natural capital. For example, agencies are interested in measuring and articulating the value of protecting biodiverse coastal habitats that have proven effective in improving water quality and reducing flood risks for coastal communities.[26]

However, scientific understanding of important biological processes is lacking, reflecting a paucity of observations and process knowledge.[27] Examples include a better understanding of microbiome dynamics[28] and the inclusion of such processes into models.[29] 'Omics approaches - the study of biological molecules to provide a holistic understanding of biological systems and their functions - are fundamental to describing not only microbiome dynamics but all biodiversity. These emerging approaches are motivating new types of measurements that are key to NOAA's future observing systems. For example, genetic properties underpin our ability to predict the resilience of species and ecosystems. Our growing capabilities to assess biodiversity at the genetic level (e.g., through environmental DNA (eDNA) monitoring) provide a way to establish baselines and metrics that can, in turn, be used to evaluate the success of NBS, alternative energy development, and other marine resource management strategies (e.g., marine protected areas, aquaculture, marine carbon dioxide removal (mCDR)).

In particular, NOAA also has the potential to develop metrics that could be leveraged by the emerging marine carbon dioxide removal (mCDR) industry. It will be necessary to understand how changes in ocean carbon, either through passive uptake from the atmosphere or intentional manipulation to capture and store carbon, will affect both emerging carbon markets and managed marine resources. For example, research could be directed to developing annual estimates of the potential for safe offshore carbon storage, using existing observational networks. Forging these capabilities to inform an effective, verifiable, and safe regime for mCDR deployment is an emerging challenge, but substantial opportunity, for NOAA research.

NOAA is also the lead Federal agency for tracking and reporting on various metrics related to marine fishery and ecosystem resources.[30] Observing strategies and platforms must be

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[24] For more on natural capital: https://www.nber.org/papers/w31108, https://www.doi.gov/priorities/america-the-beautiful, https://www.globalchange.gov/our-work/national-nature-assessment, https://oceanpanel.org/wp-content/uploads/2022/06/transformations-sustainable-ocean-economy-eng.pdf
[25] See details of the Magnuson-Stevens Act
[26] For examples of agency interests in estimating the benefits of nature-based solutions, see Executive Order 14072, the National Strategy to Develop Statistics for Environmental-Economic Decisions, FEMA's Ecosystem Service Value Updates, and NOAA's Green Infrastructure Effectiveness Database.
[27] IPCC (2019) Special Report: Special Report on the Ocean and Cryosphere in a Changing Climate, Chapter 5
[28] American Society for Microbiology (2023) The Role of Microbes in Mediating Methane Emissions
[29] American Society for Microbiology (2022) Microbes in Models: Integrating Microbes into Earth System Models for Understanding Climate Change
[30] For examples of marine and Great Lakes ecosystem indicators, see NOAA's Ecowatch website

strengthened to meet growing demands for local, regional, and national information about marine resources and biodiversity. Expansion of the national balance sheet of natural capital accounts (e.g., including ecosystem components such as seagrasses, corals, and mangroves) will be needed. Securing advancements in ocean exploration and harnessing emerging technologies like passive acoustics, animal telemetry, still or video imagery, and artificial intelligence are essential for NOAA to elevate its capabilities in marine research, conservation, and effective ecosystem management. Embracing these technologies will not only enhance the agency's capabilities in monitoring and preserving ocean health but also empower stakeholders with more accurate and actionable information, promoting sustainable practices and safeguarding the long-term vitality of our oceans.

NOAA also seeks to harmonize valuation across marine natural capital accounts to more easily identify trends and impacts of environmental change. NOAA needs to evolve its current integrated ecosystem assessments to be more “climate-ready,” informing both regional fisheries management and carbon credit accounting.

3.3 Emerging: Artificial Intelligence

AI is a transformational asset for NOAA that, like personal mobile devices, is rapidly being incorporated into almost every aspect of human society. Embracing AI is not merely an opportunity for NOAA; it is an existential necessity to responsibly maintain and advance its mission in an increasingly data-driven world. We discuss three specific examples below.

- **Numerical Weather Prediction:** Incorporating AI into NOAA's Earth system predictions promises to enhance accuracy and efficiency in forecasting, which benefits public safety and disaster preparedness. AI has the potential to improve many components of the forecast process, and provide NOAA more accurate and timely forecasts, at a fraction of the operational computational cost, but requires significant R&D investment to develop AI-ready training datasets, and significant computational resources to train climate and weather models. Realizing the potential of data-driven AI models will take a more rapid research and development (R2O) effort across the modeling value chain. In addition, NOAA needs to conduct research on the appropriate standards and approaches for AI applications, and train NOAA scientists and forecasters to effectively utilize AI-based tools. These investments are key to ultimately minimizing the impacts of extreme weather events, ensuring economic stability, and maintaining the U.S. as a global leader in meteorological science.

- **Ocean Science and Marine Resources***:* Investing in AI for ocean science and marine resource conservation is pivotal for advancing the blue economy, and enhancing the sustainability of marine resources. This integration allows for rapid response to illegal, unreported, and unregulated fishing, and supports the protection of biodiversity, which is vital for ecosystem health and climate resilience.

- **AI for the Workforce and Users:** Integrating Generative AI into NOAA's workflows is crucial for maximizing the effectiveness of our human capital. AI can potentially streamline complex processes, freeing staff to focus on high-value tasks and fostering innovation in environmental monitoring and analysis. Integrating responsible AI can democratize NOAA's science and information services, broadening access and expanding the uptake of services across diverse sectors and communities. A strategic investment in AI would empower NOAA's workforce and extend the reach and impact of our information services, contributing significantly to a more informed and responsive society.

3.4 Emerging: Multiple Ocean Uses, Blue Economy, and the Ocean Enterprise
The economy of the United States relies on coastal and marine activity. Approximately 40% of the US population lives in coastal counties,[31] and every day most Americans will use, wear, or eat something that has come from or through our ocean and coasts. In 2010, the Blue Economy was ~3% of direct global economic output and is projected to be over 5% by 2030.[32,33] A much larger percentage of the global economy is indirectly reliant on the ocean and coasts.
The U.S. marine economy accounted for 1.9% or $432.4 billion, of current-dollar U.S. gross domestic product (GDP) in 2021.[34]

The Blue Economy is rapidly growing and evolving, as offshore energy, aquaculture, and shipping activities expand. NOAA and partners will need increased levels of ocean observation and improved data access to effectively mitigate conflict and maximize synergies across these ocean uses. Several specific activities include:

- **Advancing ecosystem-based management:** NOAA has substantial investments in ecosystem based management (EBM), spanning research to practice. Additional investment is needed to fully integrate the impacts of climate change on ecosystems and socioeconomic systems into existing and evolving EBM approaches. This includes the accounting of benefits from nature-based solutions, such as the preservation of coastal blue carbon. Ecosystem based management requires additional funding for fisheries stock assessments and integrated ecosystem assessments, and expansion of single stock assessments to multi-species and multi-sector assessments.

- **Risk and vulnerability assessments across and within the Blue Economy:** With more extreme weather events, the risks of damage and disruption grow for our ports and our coastal economies. More localized information is needed about these risks, especially regarding their economic dimensions, and ways to mitigate them. NOAA currently partners with the Bureau of Economic Analysis and the Bureau of Labor Statistics to produce the most comprehensive estimates of: (1) the first U.S. Marine Economy Satellite Account (MESA)[34] and (2) Economics: National Ocean Watch (ENOW) database.[35] Both estimates include information on marine tech businesses and clusters, but they should be expanded to include an estimate of revenues as well as case studies. NOAA also helped develop, and is helping implement, the new U.S. System of Natural Capital Accounts. NOAA is creating accounts specifically for ocean natural capital, and these will be integrated with MESA to measure ocean natural capital on par with human-made capital in economic reporting, such as GDP. In addition to MESA and ENOW, NOAA would benefit from valuation studies that include social vulnerability alongside technical and economic studies. Finally, NOAA requires funding for in-situ observations, satellite imagery, and integrated modeling to produce post-storm impact assessments legislatively mandated by the COASTAL Act.[36]

[31] NOAA Ocean Service. Facts: What Percentage of the American Population Lives Near the Coast?
[32] OECD (2016), The Ocean Economy
[33] Rayner et al (2022). The Ocean Enterprise 2015–2020: A Study of U.S. New Blue Economy Business Activity
[34] Marine Economy, US Bureau of Economic Analysis
[35] ENOW data set
[36] More on the COASTAL Act: https://vlab.noaa.gov/web/osti-modeling/coastal-act1

- **Partnerships and Interagency coordination:** NOAA requires resources to expand engagement with coastal communities to inform new data delivery methods for marine and coastal information. In addition, NOAA seeks to develop cooperative research and development agreements with private sector partners to develop marine and coastal services, decision tools, and technologies. Investments in industry-government science programs will address a number of application areas, such as renewable energy, coastal resilience, and ecosystem services.

  Interagency coordination across the federal family (especially within Department of Defense[37]) supports port operations, safe navigation, and Safety of Life at Sea.[38] Interagency coordination is also needed to support the development of offshore energy by the Bureau of Ocean Energy Management and identification of optimal shipping routes for fuel efficiency and safe weather with the Department of Transportation. It will be crucial to continue these collaborations in ways to take advantage of innovative modeling and observation tools (e.g., high-resolution ocean models, unmanned vehicles, satellite products, citizen science activities) and to guide future research investments to meet cross-agency management goals.

3.5 Emerging: Social Science Research to Improve NOAA's Knowledge, Products, and Service Equity

While the Social Science research area is a standalone section of the SRGM, many of the activities described are strongly aligned with the needs raised in other Continuing and Emerging research areas. Greater investment in NOAA's social science capabilities would have a synergistic effect with investments in other areas.

NOAA's social science research and development plays a vital role in connecting scientific advances in climate, water, and weather information to decision makers. This research area is also critical to the equitable delivery[39] of NOAA's products and services. NOAA's 2023 Request for Information on Equitable Climate Service Delivery[40] also highlighted the need for NOAA climate services to: 1) prioritize user access, understanding, and needs; 2) support decision-making at hyper-local scales; 3) identify connections between climate change and socioeconomic impacts; 4) include meaningful community engagement and technical assistance; and 5) support underserved, Tribal, and Indigenous communities and prioritize NOAA's workforce diversity.

Specific, targeted advances that require additional resources include:

- **Utilizing innovative methods to better understand communities, communicate risk and uncertainty, and assess impacts of climate, water, and weather events:** NOAA requires additional resources to understand both risks to and responses by communities related to climate, water, and weather events. This work can apply a variety of methods, including Social Network Analysis to map communities; to identify key influencers, information networks, decision-making processes; and to characterize the impacts of messages, relationships, values, and resources on decisions. NOAA also seeks to develop rigorous case study methodologies to systematically and rapidly assess the

[37] For background: CFR, Navigation and Navigable Waters https://www.ecfr.gov/current/title-33
[38] International Convention for the Safety of Life at Sea
[39] A Model of Service Delivery for the NOAA Water Initiative
[40] Request for Information on Equitable Climate Service Delivery

impacts of climate, water, and weather events on affected communities and industry sectors.

- **Collecting relevant social, behavioral, and economic data and establishing metrics to assess the impact and value of NOAA information:** NOAA needs to develop valid, reliable social, behavioral, and economic science instruments (e.g. surveys, interviews) that yield data about the application of our products to diverse communities, both now and over time (longitudinally). NOAA can also leverage similar data from DOC bureaus, other Federal agencies, Tribal, state, and local governments, as well as the private sector. Such advancements will increase NOAA's evaluative research capacity to measure the impact and behavioral responses to NOAA's products and services. In addition, existing evaluation frameworks (e.g., Observing System Simulation Experiments, Management Strategy Evaluations) can be coupled with economic analyses (e.g. cost benefit, cost utility) and social impact analysis to better measure and articulate the value of NOAA research investments.

- **Engaging the NOAA partner community to ensure that NOAA information is relevant, timely, and effective***:* NOAA requires additional support to expand and better coordinate its engagements with partner communities (e.g., emergency managers, infrastructure planners, broadcast meteorologists, public health officials, local governments, community organizations) to understand their information and decision-making needs. Maintaining these critical relationships requires time, leadership, and expertise that have traditionally not been prioritized in funding requests. These ongoing engagements enable research on user experiences that are critical to effective service delivery.

- **Pursuing collaborative research that supports climate-ready communities across the U.S.:** NOAA needs to expand collaborative research to sustain its trusted partnerships among researchers, decision-makers, and communities. By institutionalizing collaborative research opportunities, the agency will lead in developing credible, community-defined plans that include implementable, local solutions for climate adaptation.

4. Success Multipliers and Risk Factors

4.1 Success Multipliers

Broad and diverse mix of experts and partners across the Nation	NOAA has staff and offices in nearly every US State, Puerto Rico, Guam, and American Samoa. Our scientific staff includes meteorologists, climatologists, oceanographers, geodesists, geologists, biologists, ecologists, and social scientists. NOAA also draws upon the intellectual capabilities of the academic, non-profit, and private-sector research communities through our cooperative agreements, grant programs, and partnerships. These assets allow us to understand and meet the diverse needs for environmental information across the Nation.
Investments and advancements in Artificial Intelligence	NOAA's Center for Artificial Intelligence helps coordinate access to NOAA's distributed expertise in artificial intelligence, and identify opportunities for collaboration and scientific development.
R&D impacts that span time scales	NOAA's research activities and products extract insights about the Earth system through the instrumental and paleo records; inform our understanding of present-day atmosphere, ocean, cryosphere, and ecosystems; and shape our expectations for the Earth for the coming decades.
Scientific integrity/reputation and public perception of value of science	NOAA is viewed positively by many stakeholders as an authoritative and reliable source of scientific information. NOAA's products and services contribute to the safety, well-being, and success of individuals, communities, and businesses across the Nation.

4.2 Risk Factors

Historically limited coordination across disciplines and Line Offices	Communication, coordination, and collaboration across Line Offices have traditionally been limited. This mode of operation undercuts the agency's ability to address stakeholder needs in a holistic manner.
Communication and sustainment of BIL and IRA funded work	Recent legislation has delivered significant resources to NOAA. It is a challenge to communicate the scope of new and expanded work. If the agency cannot demonstrate the value of these investments, ongoing support to sustain novel research, products, and services will be difficult to secure.

Long time scales for realizing impact	The transition of knowledge from research to operations and then to action (on the part of NOAA's stakeholders) often takes many years or decades. Making the "return-on-investment" case for NOAA activities is often out of sync with requests from Congress and other stakeholders.
Difficulty in quantifying impact on commerce	NOAA's economic impact is difficult to quantify as requirements for open science means users have unfettered access to data and products without self identification. Addressing the challenges in quantifying the impact of extreme climate events on commerce requires a multidisciplinary approach. Developing comprehensive models and assessments for these impacts requires understanding the societal dimensions of these events, the evolving attitudes about risk aversion and tolerance, as well as information about the direct and indirect economic costs.
Steady funding/resources for supporting mission-critical infrastructure	NOAA often struggles to secure sufficient resources to maintain its high performance computing platforms, and to update these platforms to take advantage of ongoing technological advancements. In addition, it is an ongoing challenge to secure resources to support long-term observations of the Earth system, which serve as the backbone for NOAA's operations, research, and execution of regulatory duties. Inflation exacerbates these challenges.

5. Appendix

For readers that wish to dive deeper, the Appendix provides links to reports and strategic documents that provide context and detail on the agency's strategic research priorities and goals. The links are organized to connect to specific SRGM sections. A "cross-cutting" section is also included, with reports and documents that apply to the SRGM as a whole.

Cross-cutting
NOAA Mission and Vision NOAA Strategic Plan FY22-26 US Department of Commerce 2022-2026 Strategic Plan 5th National Climate Assessment 2022 NOAA Science Report NOAA Research and Development Vision Areas: 2020-2026 NOAA Oceanic and Atmospheric Research (OAR) 2020-2026 Strategy NOAA Climate Program Office 2015-2019 Strategic Plan NOAA Weather Program Office 2022 - 2026 Strategic Plan NOAA National Weather Service Weather Ready Nation Strategic Plan 2019-2022 NOAA Physical Sciences Laboratory Strategic Plan 2021–2025 NOAA Atlantic Oceanographic and Meteorological Laboratory Strategic Plan 2022-2026 NOAA Global Systems Laboratory Implementation Plan FY2023 NOAA Great Lakes Environmental Research Laboratory Strategic Implementation Plan 2024-2028 Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act - the PROSWIFT Act (2021)
Critical Continuing: Observations
NOAA User Readiness Plan for Atmospheric Composition Observations from Space NOAA Science Advisory Board, 2021: A Report on Priorities for Weather Research Fumes Act (2022, PL 117-263 Title CV) Global Ocean Monitoring and Observing (GOMO) Strategic Plan, 2021-2025 Integrated Ocean Observing System (IOOS)
Critical Continuing: Forecasts and Predictions
NOAA Science Advisory Board, 2021: A Report on Priorities for Weather Research US CLIVAR - A New Paradigm for Observing and Modeling of Air-Sea Interactions to Advance Earth System Prediction NWS 2023 – 2033 Strategic Plan NOS 2023 - 2028 Strategic Plan NOS Modeling Strategy (2023 - 2028) NOAA Blue Economy Strategic Plan (2021 - 2025) Weather Research and Forecasting Innovation Act of 2017 National Space Weather Strategy and Action Plan NOAA Precipitation Prediction Grand Challenge Strategy Climate, Ecosystems, and Fisheries Initiative

Critical Continuing: Arctic
Arctic Report Card National Strategy for the Arctic Region
Emerging: Future of Earth Systems Models and Innovation in Climate Services
NOAA FY22 - 26 Strategic Plan Building a Climate Ready Nation National Drought Resilience Partnership NOAA Water Initiative Vision and Five-Year Plan A Model of Service Delivery for the NOAA Water Initiative Climate, Ecosystems, and Fisheries Initiative Western Hydroclimatology Program Plan (forthcoming)
Emerging: Measuring and Monitoring of Carbon and Marine Life
NOAA Ocean Acidification Program NOAA Carbon Dioxide Removal Research Strategy National Ocean Biodiversity Strategy (to be released in May 2024) National Aquatic eDNA Strategy (to be released in June 2024)
Emerging: Artificial Intelligence
NOAA Center for AI (NCAI), NOAA FY22 - 26 Strategic Plan Building a Climate Ready Nation NOAA Science Advisory Board, 2021: A Report on Priorities for Weather Research NOAA Modeling Strategy, (release imminent) 5th National Climate Assessment, Examples of AI applications and early success stories: NOAA StoryMap Highlighting AI Innovation in Practice CoralNet - CoralNet organizes coral reef survey data, and uses that data to create and deploy automated annotation methods VIAME (Video and Image Analytics Toolkit for Multiple Environments) VIAME is a NOAA funded, industry partner led open source image classification and model development suite. It has been used for Right Whale identification Listen and Learn about Humpback Whales
Emerging: Multiple Ocean Uses, Blue Economy and the Ocean Enterprise
NOAA Blue Economy Strategic Plan (2021 - 2025) NOAA's Integrated Ecosystem Assessment Ocean Enterprise Study, 2015-2020 Office of Coast Survey, Strategic Plan 2023-2027 A Model of Service Delivery for the NOAA Water Initiative Commercial Engagement Through Ocean Technology (CENOTE) Act of 2018 COASTAL Act of 2012 Climate, Ecosystems, and Fisheries Initiative NOAA Fisheries and BOEM Federal Survey Mitigation Strategy – Northeast U.S. Region

Emerging: Social Science Research to Improve NOAA's Products and Advance Service Equity
A Model of Service Delivery for the NOAA Water Initiative Human Integrated Ecosystem Based Fishery Management, Research Strategy 2021-2025