Strategic Plan

EPIC
Earth Prediction Innovation Center

Earth Prediction Innovation Center: Strategic Plan

ON THE COVER: *A flooded street after catastrophic Hurricane Irma hit Fort Lauderdale, FL. Photo credit: FotoKina/Shutterstock*

Strategic Plan

EPIC

Foreword

The National Oceanic and Atmospheric Administration (NOAA) is responsible for providing accurate and reliable forecasts and warnings that serve our nation by protecting life and property and enhancing the economy. Constant improvements to operational models and forecast systems are required in order to integrate the latest user requirements, scientific research advances, and modeling developments. NOAA has substantial in-house capabilities to advance United States forecasting skill, but the effort is significantly more effective if the entire weather enterprise is engaged in partnership to achieve forecasting goals. The Earth Prediction Innovation Center (EPIC) will be the catalyst for community research and modeling advances that continually inform and accelerate advances in our Nation's operational forecast modeling systems. The community is defined as every individual and organization from every sector, state, and nation.

EPIC's investment strategy is separated into phases. In the near-term, defined as the next 2 years, EPIC will facilitate innovation and accelerated research to operations including through an extramural, virtual center to: 1) guide usage of cloud development environments; 2) provide a code repository, observational data, and required tools; and 3) provide community support and increased user engagement. This first phase will improve the global weather element of the Unified Forecast System (UFS), advancing global 7-10 day weather forecasts by incorporating contributions from the external research and modeling community. EPIC will also invite partnerships with other agencies, academia, industry, and the international community and support a user friendly, well-supported modeling code base from which innovation can flourish.

In the mid-term, defined as 3 to 5 years, EPIC will extend infrastructure and user support for the UFS to a fully coupled Earth system prediction, transforming the operational suite of models that are critical to improving forecast skill beyond 3 weeks and addressing the full range of NOAA mission applications.

The EPIC authorization in the National Integrated Drought Information System Reauthorization Act of 2018 (Public Law (P.L.) 115-423) and subsequent funding through the Consolidated Appropriations Act of 2020 (P.L. 116-93), have already spurred initial successes such as advances to the modeling systems and structural changes within NOAA, including new research initiatives at NOAA's laboratories and Cooperative Institutes. These legislative mandates and initial successes are now the foundation for this 5-year strategic plan with the associated investment strategy and quantitative goals.

Craig McLean
Assistant Administrator
Oceanic and Atmospheric Research

Louis Uccellini, Ph.D.
Assistant Administrator
National Weather Service

Introduction

EPIC will enable the most accurate and reliable operational numerical forecast model in the world **(The Vision)**. To be the catalyst for community research and modeling advances that continually inform and accelerate advances in our Nation's operational forecast modeling systems **(The Mission)**, EPIC is partnering with the community for the benefit of the Nation **(The Mantra)**.

GOAL: Accelerate scientific research and modeling contributions through continuous and sustained community engagement to produce the most accurate and reliable operational modeling system in the world.

1.0 Why is EPIC needed?

As our Nation pursues comprehensive and accurate Earth system models, advances in research and modeling must be rapidly incorporated into operational modeling systems. Where it was once reasonable to provide forecasts that were accurate to 2 or 3 days out, it is now necessary to provide forecasts that are usable and reliable at subseasonal (i.e., 2 weeks to 3 months) and seasonal (i.e., 3 months to 2 years) timescales.[1] This opportunity to provide the types of accurate forecasts that underpin decisions across societal and economic sectors depends upon making significant advances in science, observations, data assimilation, and modeling that can be continually incorporated into operational modeling systems.

Historically, this has been accomplished through a mix of research and modeling at NOAA laboratories, NOAA's Cooperative Institutes, academia, and the private sector that filters through the organization to operational use. Constraints on that transition into operations have included the complexity of introducing the required innovations into the existing operational model suite; lack of resources to transition research and model improvements into operations; balancing research/modeling interests with operational priorities; and the daily operational pressures to produce forecasts crowding out resources for innovation. Over many decades, each of these pressures has been eased by introducing testbeds, increasing co-development between research/modeling and operations, moving to a unified model system approach, and clarifying research priorities. However, NOAA has sizable opportunities to improve in each of these areas by incorporating the EPIC strategic approach.

The EPIC strategic approach takes advantage of advances NOAA has introduced, combined with commercial computing, software, and development process improvements. It envisions approaches that include an extramural, virtual center with strong connections to both the research and operational (i.e., National Weather Service (NWS)) elements of the community. It will be accountable for continuous connections between research and operations to communicate and align operational needs, innovation possibilities, the programs that fund research and development; ongoing engagement between modeling and operations; and access to an integrated development environment that is platform-agnostic utilizing a hybrid high-performance computing approach, storage and delivery of data with the latest codes, utilities, documentation, and user support. EPIC will accomplish this transformation by offering the tools for users to conduct research in a cloud development environment; access to a code repository, observational data, and tools; and community support and engagement that will, in turn:

Phase One (near term, next 1 to 2 years): Improve the global weather element of the Unified Forecast System (UFS)[2] (here defined as the dynamical core), physics, assimilation system, and post processing. Furthermore, the UFS community shares science components and software infrastructure for advancing global 7-10 day weather forecasts by incorporating contributions from the external research and modeling community.

Phase Two (mid term, next 3 to 5 years): Extend infrastructure and user support for UFS to fully coupled Earth system prediction, transforming the operational suite of models such as convective-allowing models (e.g., High Resolution Rapid Refresh) and fully coupled forecast systems (e.g., the Seasonal Forecast System, National Water Model, and Ocean Forecast Systems) into one modeling system.

1.1 The Opportunity

The devastating impacts of hazardous weather and other environmental events on life, property, and the national economy can be mitigated with accurate and reliable forecasts that are clearly communicated to decision-makers. To meet this need while reclaiming global leadership in weather prediction, NOAA is implementing EPIC as a catalyst for more accurate and reliable weather forecasts in the near-term; fully coupled Earth system modeling the mid-term; and integrated, multi-agency environmental modeling partnerships. Constantly evolving and adaptable, EPIC includes an extramural virtual center approach that will leverage intramural investment.

The community will gain free access to cutting-edge research and modeling systems that are user-accessible and user-friendly in an integrated development environment.

This opens simultaneous opportunities to improve NOAA's operational modeling systems; serve others in the community; fund research, modeling, and compute initiatives from related grant programs; and develop innovative tools and applications. Through this approach the community will move to continuous improvement and continuous development environment with prioritized research and ongoing upgrades to operational modeling systems. EPIC will therefore initially offer:

A Cloud development environment for those with access to cloud high-performance computing resources (including surge and parallel compute), modeling software, and adjacent data. Hosting for the data is paid by NOAA or the data provider per the relevant contract(s); processing of the data within the cloud environment is paid by users, although users may apply for computing time where permitted by grant programs.

- **A Cloud development environment**
- **A code repository**
- **Observational data and tools**
- **Community support and engagement**
- **Continuous improvement**

A code repository with access to the latest version of NOAA's model codes, dynamic documentation, private branches, and with active and well-defined code management rules, standards, and practices.

Observational data and tools that include data assimilation approaches, retrospective data, and satellite and in situ observational data.

Community support and engagement that includes access to extraordinary software engineers and developers to support researchers and modelers with technical assistance, code development support, training, and materials; and community software infrastructure. Support and engagement will also include:

- For the model research and development community: a) access to a well-documented and supported code base that is current with operational models, providing an efficient, effective framework for researchers and developers to accomplish their objectives; b) a chance for Earth system modeling scientists to make a substantial impact on society through the enhanced ability to directly impact operational outcomes in NOAA; and c) enhanced career pathway enabled by the community engagement and recognition fostered by EPIC that will lead to opportunities for collaboration and high visibility to the community.
- For NOAA's operational models: a) access to model researchers and developers across other agencies, academia and industry who will be attracted to the UFS code base by the services and benefits provided by EPIC; b) an efficient, rigorous, agile NOAA research-to-operations pipeline; and c) the pathway to communicate and gain alignment between the research and development (R&D) and operations communities so that R&D is addressing the highest impact operational needs.

Continuous improvement, continuous development, and co-developed approaches to deliver code standards, test cases and protocols, configuration management standards, integration timelines, and maintain community governance, research to operations to research standards, and co-developed, agile modeling systems.

1.2 Community Input

Information from the community has been collected through conversations, workshops,[3] responses to a request for information, and the Industry Day that together inform an optimal approach to EPIC.

EPIC will demonstrate early successes by aligning funding programs across the agency that already support Earth system modeling and by building on successful business models. Successful business models for community development and scientific innovation include, but are not limited to, the Joint Center for Satellite Data Assimilation (JCSDA), Developmental Testbed Center (DTC), Community Earth System Model (CESM), Weather Research and Forecasting Model (WRF), Cooperative Institutes, Cooperative Science Centers, Model for Prediction Across Scales (MPAS), HYbrid Coordinate Ocean Model (HYCOM), and the UFS.

EPIC's value to the community follows a model similar to innovative companies. EPIC will foster the most advanced Earth system modeling framework in the world and become a model for other public-private-academic collaborations. EPIC will provide the community with an easy to use, reliable, fast, cost effective, accessible, and well-documented system that will aid them in their research and operational priorities and support the expansion of the private weather enterprise focused on Earth system modeling.

1.3 Legislative Mandates

The Weather Research and Forecasting Innovation Act of 2017 (P.L. 115-25) directs NOAA to prioritize improving weather data, modeling, computing, forecasting, and warnings for the protection of life and property and for the enhancement of the national economy. The authorizing language for EPIC, in the National Integrated Drought Information System Reauthorization Act of 2018 (P.L. 115-423), amends the Weather Research and Forecasting Innovation Act of 2017 by calling for NOAA to improve the transition of research into operations by creating a community global weather research modeling system. The Act requires the community global weather research modeling system be accessible by the public; meets basic end-user requirements for running on public computers and networks located outside of secure NOAA information and technology systems; and utilizes, whenever appropriate and cost-effective, innovative strategies and methods, including cloud-based computing capabilities, for hosting and management of part or all of the system described in this subsection." [4]

In the Senate Report 116-127 accompanying the Consolidated Appropriations Act of 2020 (P.L. 116-93), Congress directs NOAA to provide, "... a five-year strategic plan for EPIC that outlines: 1) NOAA's investment strategy for the Center, which is expected to include an extramural, virtual center approach that is leveraged by intramural investment; and 2) quantitative goals for improving NOAA's operational weather forecasting capabilities." [5]

1.4 Executive Mandates

In the Memorandum on Fiscal Year 2021 Administration Research and Development Budget Priorities, the Executive Office of the President called for improved earth system predictability:

"Departments and agencies should prioritize R&D that helps quantify Earth system predictability across multiple phenomena, time, and space scales. Strategic coordination and leveraging of resources across agencies on research and modeling efforts is needed to accelerate progress in this area. Additionally, agencies should emphasize how measures of and limits to predictability, both theoretical and actual, can inform a wide array of stakeholders. They also should explore the application of artificial intelligence (AI) and adaptive observing systems to enhance predictive skill, along with strategies for obtaining substantial improvements in computational model performance and spatial resolution across all scales." [6]

In the FY 2020 President's budget request for NOAA, agency leaders note that "[a]ccelerating the advancements in the U.S. global modeling program is a top priority of the administration and at NOAA. In 2018, NOAA exceeded its target of transitioning research and development products, moving 24 products to application or operations. However, despite these advancements, significant problems exist with the current structure of weather research to operations. The internal and external strategy is fractured, the procurement process for high-performance computing capacity is cumbersome and uncoordinated, and the funding process disincentivizes collaboration." [7] Addressing EPIC's mandate to innovate and integrate will address this while also supporting a "Weather-Ready Nation", led by NOAA's NWS, with an environmental observation and modeling system that directly supports objectives within the Department of Commerce's Strategic Plan,[8] the Office of Oceanic and Atmospheric Research (OAR) Strategy, and the NWS Strategic Plan.

In particular, the OAR Strategy, Objective 3.1, calls for OAR to "...[d]evelop models that reflect the Earth system and the intersecting human, ecosystem, and environmental factors as an integrated system. Cutting across disciplines and specializations, encourage the growth of innovative model components and new model applications. Develop and operate next-generation Earth system models using a community-based approach in concert with advances in high-performance computing. Enhance data assimilation and modeling across spatial and time scales. Conduct value-driven assessments of models and sunset models that do not meet current or future NOAA requirements." [9] Similarly, the NWS Strategic Plan, Objective 2.2, calls for the NWS to "...[h]arness the power of ensemble modeling as the starting point for NWS forecast operations and to quantify certainty and promote consistency across all NWS service areas." [10]

2.0 How will EPIC work?

From the requests and mandates listed above, the following concepts and approaches emerge to realize the full potential of EPIC.

2.1 Concept: Vision, Mission, and Mantra

Vision. Enable the most accurate and reliable operational numerical forecast model in the world.
Mission. To be the catalyst for community research and modeling system advances that continually inform and accelerate advances in our nation's operational forecast modeling systems.
Mantra. Partnering with the community for the benefit of the Nation.

2.2 Approaches, Practices, and Scenarios

EPIC requires an approach that prioritizes:

- Collaborating with integrity and trust across our community.
- Posing the problems rather than defining solutions.
- Leveraging existing objective evaluation processes and agreed-upon metrics.
- Pursuing realistic near-term wins with attribution for everyone.
- Co-developing research and modeling.

Informed by the EPIC Vision Paper,[11] the following is a study of practices and scenarios across each of the seven components of EPIC:

2.2.1 External Engagement and Community. Engagement is the opportunity to share and learn from each other. This category will include grants; annual meetings; visiting scientists/modelers; seminar series; hack-a-thons; code sprints; summer institutes; road shows; partnerships; and overall communication.

2.2.2 Software and Performance Engineering. Aligning software engineers with researchers and modelers is necessary to create well-documented, cloud-friendly, performance-optimized code and to free scientists to perform research and development. Projects in this category will include, but are not limited to, management and documentation of code, code portability and performance optimization, development of codes that run in a parallel computational environment, and integration with other NOAA and community modeling efforts. These projects will be accomplished through coordination with and between researchers and through identification of criteria for improving NOAA and the community's ability to take advantage of new computational technologies.

2.2.3 Software Infrastructure. The community development environment depends upon accessibility, reliability, and security, among other factors. This category will include work on the user management system; user interface; storage; secure ingest; repository; workflow; and coupling of components.

2.2.4 User-support Services. As the community transitions to development in this new environment, teams will staff a central communication forum for answering questions and updating the frequently-asked questions. The primary focus of this service will be to ensure access and usability by all community members, regardless of the level of expertise. The activities in this category will include, but are not limited to, customer service; documentation; evaluation; and technical assistance and experiences, including training, workshops, code sprints, and hack-a-thons.

2.2.5 Cloud-based High-performance Computing. NOAA's current capacity to provide operational and research-related high-performance computing is a limitation to the advancement of numerical weather prediction. The transition of research and development to a cloud environment has the potential to dramatically improve NOAA's capacity. Activities in this category will include, but are not limited to, setting requirements; learning lessons from research and practice; making cloud-ready model components and the necessary computational environment available; adding data needed for model execution, evaluation, and validation to the Cloud; and establishing incentives and business models.

2.2.6 Scientific Innovation. Fostering scientific innovation is embedded in the design of EPIC. By employing the approaches envisioned, EPIC will: 1) make the UFS the most accurate and innovative weather modeling system in the world to use for model system research and development; and 2) align programs and provide a transparent transition process that the community and programs can follow to mature innovations into operations.

2.2.7 Management and Planning. EPIC will be established to include an extramural, virtual center with strong connections to both the research and operational (i.e., NWS) communities. Activities in this category will include, but are not limited to, identifying an accountable and authoritative individual at both NOAA and the virtual center and defining their respective roles and responsibilities, and acknowledging that the authority for the production suite will remain with NWS.

3.0 How will EPIC succeed?

Initially, the success of EPIC will be measured by the amount of interest and traffic associated with the GitHub repository.[12] Later, the success of EPIC will be measured by the improvements in model skill scores (measures of relative improvement of a forecast over some benchmark forecast). To produce those successes, EPIC will deliver the investment strategies delineated below in the form of goals, objectives, and quantitative and qualitative outcomes.

GOAL: Accelerate scientific research and modeling contributions through continuous and sustained community engagement to produce the most accurate and reliable operational modeling systems in the world.

3.1 Accurate and reliable operational models.

EPIC will partner with NOAA to continually update and provide accurate, efficient, and advanced operational models that are a seamless, best-in-class system of software and hardware.

3.1.1 Objectives

Objective 1.1 **Co-develop research and models.** Smoothly and continually co-develop research modeling systems and facilitate their implementation into operations.

Objective 1.2 **Prioritize code.** Prioritize implementation into operations using evidence-based decisions on science, societal benefit, and software optimization.

Objective 1.3 **Leverage assets.** Leverage assets across the Federal government by using current research portfolios and establishing clear priorities.

Objective 1.4 **Increase understanding.** Increase the understanding and use of physical, geological-chemical-biological processes while simultaneously increasing the understanding and use of the interactions between the land, ocean, frozen water (cryosphere), and atmosphere.

Objective 1.5 **Leverage observational data.** Leverage new environmental observational data that could contribute to existing and future weather models.

Objective 1.6 **Partner.** Partner with the community early and often, and with NOAA, to align integrated environmental modeling resources and efforts.

3.1.2 Outcomes

Outcome 1.1 **Incorporate JEDI tools.** Incorporate the Joint Effort for Data assimilation Integration (JEDI) into EPIC.

Outcome 1.2 **Increase accuracy & clarify uncertainties.** Increase the accuracy of the initial state estimations and identify and quantify the uncertainties.

Outcome 1.3 **Extend useful forecast lead time & clarify uncertainties.** Extend usable and reliable subseasonal and seasonal forecasts and identify and quantify the uncertainties.

Outcome 1.4 **Co-develop priorities.** Implement at least 15 research innovations into operational modeling systems.[13]

Outcome 1.5 **Evaluate.** Continue to evaluate the skill and timeliness of the operational outputs and share those findings.

Outcome 1.6 **Increase the use of UFS components.** Increase the use of UFS components by other Federal agencies.

Outcome 1.7 **Increase the contributions of UFS components.** Increase the contributions of UFS components from other Federal agencies.

Outcome 1.8 **Support additional operational applications.** Improve operational applications in support of the coastal marine environment, hydrological forecasting overland and at the coasts, and the sustainable use of living resources.

Outcome 1.9 **Share accurate and reliable modeling systems.** Develop United States modeling systems that are timely and produce the highest skill scores in the world.

Outcome 1.10 **Support fully-coupled modeling systems.** Support fully-coupled modeling systems for seasonal, ocean, and other forecasts.

3.2 Community contributions to operational modeling systems.

Make EPIC the most community-accessible and user-friendly system in the world so that everyone benefits from collective advancements.

3.2.2 Objectives

Objective 2.1 **Ensure that operational priorities are addressed.** Ensure that operational priorities are addressed by the research and modeling communities.

Objective 2.2 **Catalyze engagement.** Serve as the catalyst for researchers and modelers to engage and benefit.

Objective 2.3 **Inspire outcomes.** Inspire operational outcomes in Earth system modeling within NOAA and other parts of the community.

3.2.3 Outcomes

Outcome 2.1 **Create an extramural virtual center.** Create an extramural, virtual center with strong connections to both the research and operational (i.e., NWS) communities. It will be accountable through a governance board for: 1) the accuracy of the research and models incorporated into operational systems; 2) the speed of the process; and 3) the use of funds.

Outcome 2.2 **Host community development environment.** Host a community-accessible and user-friendly development environment that provides access to the UFS, data, user support services, and return of code to the GitHub repository. Code will be free and easy to download, use, and upload; that ease is partially a function of the development environment and in part because of the dynamic documentation. This version of the UFS must be cloud-usable, co-located with storage containing archived (and later real-time) observational data for initialization, well-documented, and accessible to a wide community of researchers,[14] thus bringing computing closer to the researchers and speeding development by reducing barriers to entry; increasing portability; minimizing costs; minimizing environmental impacts; and enabling better applications of artificial intelligence and machine learning.

Outcome 2.3 **Align and share research requirements and priorities.** Share the research requirements and priorities of NOAA centers, laboratories, and programs to show the connections to current and proposed funding for research and modeling.

Outcome 2.4 **Move data to the Cloud.** Move NOAA data to at least three Cloud providers and support the centralized observational data repository in the Cloud per the World Meteorological Organization Information System (WIS 2.0).[15] Note that compute costs will be borne by the individual user, but that some compute credits may be feasible, and it may be appropriate to include compute costs in grant proposals.

Outcome 2.5 **Foster the fast path to operations.** Foster the fast and easy path from research and modeling to operations.

Outcome 2.6 **Reduce UFS complexity.** Invite the community to reduce the complexity of the UFS code by: (1) producing code that is scalable and optimized; and (2) recommending a sunsetting strategy for older code and products, when appropriate.

Outcome 2.7 **Build the user base.** Build the user base to increase year over year, in general and among graduate students (measured by the percent increase in monthly active users).

Outcome 2.8 **Assess continually.** Assess the research and modeling systems in process using peer reviews, expert groups, and leaderboards.

Outcome 2.9 **Leverage intramural investments.** Leverage laboratories, Cooperative Institutes, and Cooperative Science Centers.

Outcome 2.10 **Provide startup grants.** Provide startup grants through EPIC or related programs with an emphasis on proof-of-concept projects.

Outcome 2.11 **Engage with other programs.** Continue to engage with other Earth system forecasting modeling systems and with agencies that have missions that require a fully coupled Earth system model. The coupled model will include ocean, atmospheric, land surface processes, ice, wave, chemistry, and other components to improve forecasting skill beyond three weeks. Continue to expand those engagements.

Outcome 2.12 **Eliminate institutional delays.** Eliminate institutional delays to innovations and transitions. In particular, share publicly the priorities and requirements for transitions to operations and name the accountable individual.

Outcome 2.13 **Offer incentives.** Offer incentives that serve NOAA operations and the community (e.g., allow the community, including private sector providers, to prove data by demonstrating it in the GFS).

Outcome 2.14 **Leverage investments.** Facilitate new investments in research and development.

3.3 Community engagement.

Engagement is the opportunity to share and learn from each other.

3.3.1 Objectives

Objective 3.1 **Accelerate contributions.** Accelerate contributions to a globally accurate operational prediction system.

Objective 3.2 **Document community engagement plan.** Dynamically document the community engagement plan that includes clear, consistent communication, listening sessions, and an online forum for engaging.

Objective 3.3 **Document governance structure.** Dynamically document the governance structure (with update procedures in the documentation) and the attendant incentives for the community. Consider successful business models for community development and scientific innovation that may include the JCSDA, DTC, CESM, WRF, MPAS, HYCOM, and the UFS.

Objective 3.4 **Align programs and funding opportunities.** Align programs and funding opportunities to meet these goals and objectives while incentivizing engagement, collaboration, and innovation.

Objective 3.5 **Communicate EPIC's importance.** Consistent with the engagement plan, communicate the importance of EPIC globally in an easy-to-understand way by targeting each audience's interests, needs, and incentives.

Objective 3.6 **Learn continually.** Learn continually from research and practice (e.g., Cooperative Institutes, Cooperative Science Centers, the Next Generation Global Prediction System, the Community Earth System Model, and the Weather Research and Forecasting Model).

Objective 3.7 **Build and maintain trust.** Build and maintain trust by continually aligning to core values:

- Fairness and integrity means setting clear rules to follow using transparent and objective evidence-based decisions. This means posting all guidelines and agreements to the website and following them with rigor. Operationally, this means clear notices of funding availability and consistent rules for engaging in the community development environment.
- Transparency means sharing everything, which means open meetings; detailed minutes posted within ten days of meetings; open elections; and dynamic documentation.
- Accountability means responsibility to funders and beneficiaries.
- Viability means creating long-term value.
- Collaboration means balancing the tensions between competing and cooperating.
- Attribution means giving credit for organizational and individual efforts.
- Effectiveness is measured by the best, prioritized use of human, technological, financial, and environmental resources, which will be evaluated annually.

3.3.2 Outcomes

Outcome 3.1 **Engage everyone.** Simultaneously engage researchers, modelers, and operations at every stage of development.

Outcome 3.2 **Amplify information about funding.** Expand information and marketing about funding opportunities.

Outcome 3.3 **Host experiences.** Host experiences, including at least two workshops and at least one code sprint per year.

Outcome 3.4 **Build community.** Build a community of modelers and engineers who can improve operational modeling systems.

4.0 What are the parallel timelines for EPIC and UFS?

Consistent with these goals, objectives, and outcomes, and aligned to the UFS timeline (Figure 1), the summaries and scenarios for the two phases follow. The UFS is a community-based, coupled, comprehensive Earth modeling system. The UFS numerical applications span local to global domains and predictive time scales from sub-hourly analyses to seasonal predictions. UFS is designed to support an active research program and to be the source system for NOAA's operational numerical weather prediction forecasts. Parallel timelines for EPIC and UFS:

4.1 Phase One (near term, next 1 to 2 years)

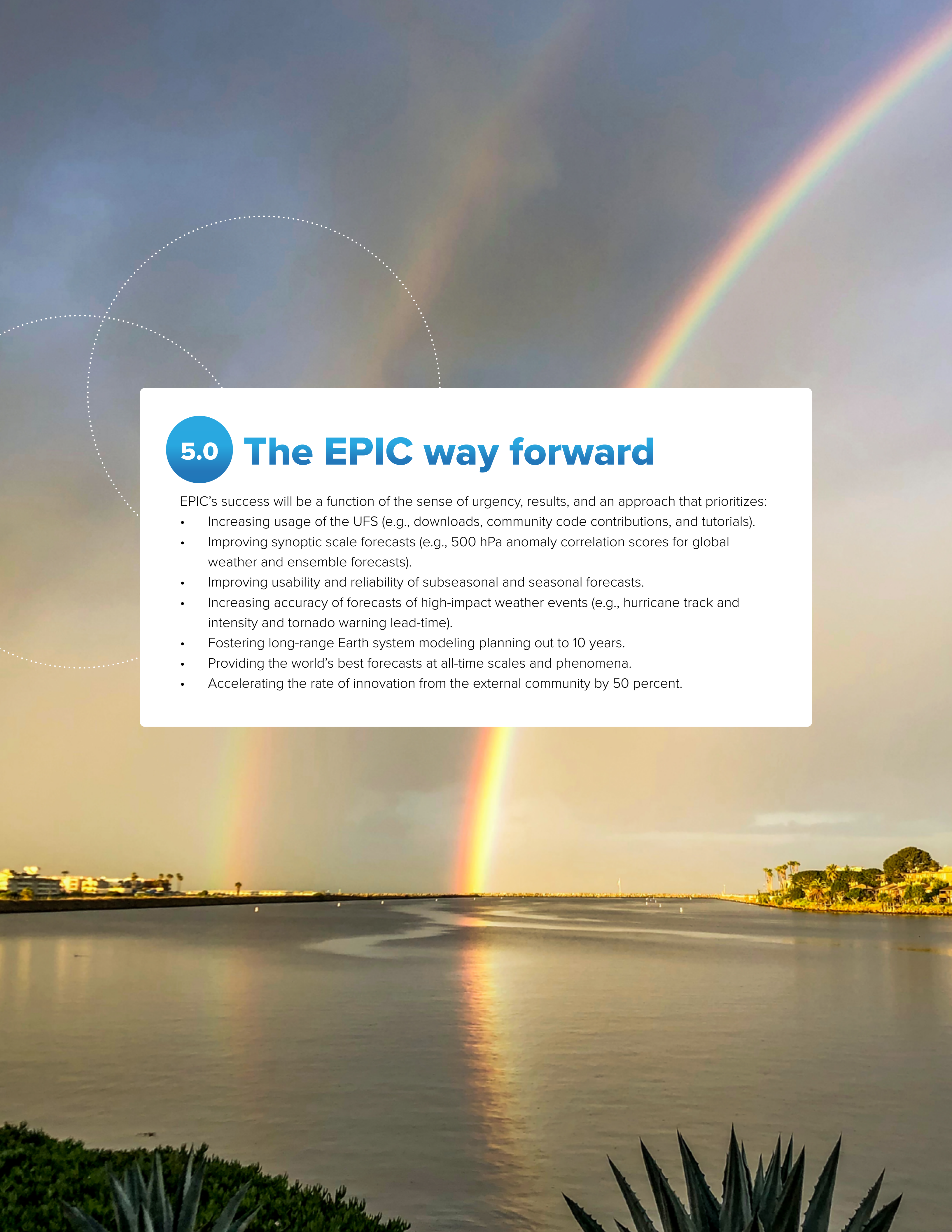
In Phase One (near-term, next 1 to 2 years), EPIC will focus on being the catalyst for accurate and reliable weather forecasts and will measure success based on code utilization and GitHub forks (the creation of new projects based off of an existing project). EPIC will focus on integrated, multi-agency and external stakeholder environmental modeling partnerships and will measure success by the increase in those partnerships.

Phase One Scenario: A user easily works on a cloud development environment to make an update to the UFS that improves the skill score. To test this update, the user is given access to additional retrospective or real-time data. Following the test, and based on the science, safety, skill, and reviews, the code is considered for the operational modeling system and is updated into the main (or parallel) version for use by other community users. Community peer reviewers update the leaderboard of scientific merit, skill, and incorporation into the operational modeling system as a celebration of the user's accomplishment.

4.2 Phase Two (mid term, next 3 to 5 years)

In Phase Two (mid-term, next 3 to 5 years), EPIC will focus on a fully coupled Earth system model in the mid-term and will measure success by the increase in skill scores.

Phase Two Scenario: A user navigates to an integrated community development environment in the Cloud, with access to high-performance parallel computing resources (paid for by the user), and finds fully-coupled modeling systems and data. Updates to the modeling system are proposed through the environment and, following a series of tests by peer reviewers and the accountable code manager, are included in the next modeling system release.



5.0 The EPIC way forward

EPIC's success will be a function of the sense of urgency, results, and an approach that prioritizes:

- Increasing usage of the UFS (e.g., downloads, community code contributions, and tutorials).
- Improving synoptic scale forecasts (e.g., 500 hPa anomaly correlation scores for global weather and ensemble forecasts).
- Improving usability and reliability of subseasonal and seasonal forecasts.
- Increasing accuracy of forecasts of high-impact weather events (e.g., hurricane track and intensity and tornado warning lead-time).
- Fostering long-range Earth system modeling planning out to 10 years.
- Providing the world's best forecasts at all-time scales and phenomena.
- Accelerating the rate of innovation from the external community by 50 percent.

Conclusion

EPIC will facilitate, enable, and support community model development using a continuous improvement and development environment that prioritizes research and operational modeling with an engaged community of partners. EPIC must produce the most advanced and user-friendly Earth system model in the world so that both NOAA and the external community benefit from its advances. Early success will be measured by code utilization and soon after increased skill scores in the operational modeling system. The EPIC Strategic Plan is an important guidance document that will need to be revisited in the near future as the extramural virtual center is developed and NOAA leverages its intramural investments to achieve the vision of EPIC.

Endnotes

1 Weather Research and Forecasting Innovation Act, 2017. Public Law 115-25 (https://www.congress.gov/115/plaws/publ25/PLAW-115publ25.pdf)

2 Unified Forecast System. 2019. (https://ufscommunity.org)

3 NOAA's Weather Program Office. 2019. "EPIC Workshop Reports." (https://go.usa.gov/xGX6A)

4 National Integrated Drought Information System Reauthorization Act of 2018 (Public Law 115-423).

5 Senate Report (116-127) accompanying the Consolidated Appropriations Act of 2020 (P.L. 116-93), see https://go.usa.gov/xpJRG

6 Executive Office of the President, "Memorandum for the Heads of Executive Departments and Agencies: Fiscal Year 2021 Administration Research and Development Budget Priorities." (https://go.usa.gov/xpJRf)

7 National Oceanic and Atmospheric Administration. 2019. "NOAA's FY 2020: Budget Summary [Blue Book]." (https://go.usa.gov/xpJRA)

8 Department of Commerce. 2018. "U.S. Department of Commerce Strategic Plan: 2018-2022: Helping the American Economy Grow." (https://go.usa.gov/xpJRp)

9 NOAA's Oceanic and Atmospheric Research. 2019. "OAR Strategy 2020-2026: Delivering NOAA's Future." (https://go.usa.gov/xdE2m)

10 NOAA's National Weather Service. 2019. "2019-2022 Strategic Plan: Building a Weather-Ready Nation." (https://go.usa.gov/xpJRd)

11 National Oceanic and Atmospheric Administration. 2019. "A Vision Paper for the Earth Prediction Innovation Center (EPIC): Version 5.0." (https://go.usa.gov/xGX6d)

12 The GitHub repository is a cloud-based, open-source version control system that will allow for the tracking and storage of changes made by the community to parts of the UFS model. This is the platform that community modelers and developers will use to test proposed changes to the UFS.

13 National Oceanic and Atmospheric Administration. 2019. "NOAA's FY2020: Budget Summary [Blue Book]." (https://go.usa.gov/xpJRA)

14 United Forecast System. 2019. "Graduate Student Test." (http://ufs-dev.rap.ucar.edu/index.html#/science/gst)

15 World Meteorological Organization. 2019. "WIS 2.0." (https://library.wmo.int/doc_num.php?explnum_id=4620)

Acronyms

CESM	Community Earth System Model
DTC	Developmental Testbed Center
EPIC	Earth Prediction Innovation Center
FY	Fiscal Year
HYCOM	Hybrid Coordinate Ocean Model
JCSDA	Joint Center for Satellite Data Assimilation
JEDI	Joint Effort for Data assimilation Integration
MPAS	Model for Prediction Across Scales
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OAR	Office of Oceanic and Atmospheric Research
R&D	Research and Development
UFS	Unified Forecast System
WRF	Weather Research and Forecasting Model
WIS	World Meteorological Organization Information System 2.0

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Earth Prediction Innovation Center

Strategic Plan