Improving the Space Weather Forecasting Research to Operations (R2O) - Operations to Research (O2R) Capability

PRODUCT OF THE

Space Weather Operations, Research, and Mitigation Subcommittee

OF THE NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

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Background

In October 2015, the National Science and Technology Council (NSTC) in the Executive Office of the President released the *National Space Weather Strategy* and *National Space Weather Action Plan* (Action Plan).[1] The actions described in the Action Plan

> "…will facilitate the integration of space-weather information into Federal risk-management plans to achieve preparedness levels consistent with national policies…[and]…will enhance the resilience of critical infrastructure to the adverse effects of space weather."

Actions 5.6.1 and 5.6.2 in the Action Plan are specifically directed at space weather research to operations (R2O) and operations to research (O2R). Collectively, these actions provide a unique opportunity for the Federal research and operations communities, consulting with academia and the private sector, to define what is needed to fill gaps in capabilities to support space weather services for the Nation.

Action Plan Activity 5.6.2 states that: "[The Departments of Commerce and Defense (DOD)], in collaboration with NASA and [the National Science Foundation (NSF)], will develop a plan (which may include a virtual or physical center) that will ensure the improvement, testing, and maintenance of operational forecasting models. This action will leverage existing capabilities in academia and the private sector and enable feedback from operations to research to improve operational space-weather forecasting."

In order to develop this report, which serves as the plan called for in Action 5.6.2, an O2R workshop was held in Boulder, Colorado on 16-17 August 2016 to explore options and gather input from academia, private enterprise, and space weather customers. The workshop was hosted by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) Space Weather Prediction Center, in collaboration with the U.S. Air Force (USAF) (Headquarters USAF/A3W), NASA Headquarters (Heliophysics Division) and NSF (Division of Atmospheric and Geospace Sciences).[2] In addition to other topics, examples of R2O and O2R from the terrestrial weather community were examined as possible frameworks upon which similar capabilities in the space weather community could be developed. The implementation options described in this report from the Space Weather Operations, Research, and Mitigation (SWORM) Subcommittee of the NSTC were heavily influenced by the outcomes and results of this workshop.

It must be recognized that the R2O and O2R activities are part of a continuous process and that they should not be considered separate or independent. Thus, this document presents a multi-phased, cross-agency plan that would greatly enhance the transition of research models to operations (R2O) and the maintenance and improvement of the models in operations (O2R) with operators and researchers collaborating. It is also important to note that in addition to maintaining and improving models for forecasting, operational centers and users of space-weather services depend on a variety of tools and products to meet their respective needs.

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[1] See "Enhancing National Preparedness to Space-Weather Events" https://www.whitehouse.gov/blog/2015/10/28/enhancing-national-preparedness-space-weather-events
the National Space Weather Strategy (October 2015) https://www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatherstrategy_20151028.pdf and the National Space Weather Action Plan (October 2015) https://www.whitehouse.gov/sites/default/files/microsites/ostp/final_nationalspaceweatheractionplan_20151028.pdf

[2] Workshop announcement and presentation are available on the NOAA Space Weather Prediction website at http://www.swpc.noaa.gov/content/o2r-workshop

Definitions

- **Research to operations (R2O):** The research community's development, modification, and validation of data and models have value for operational services, and enable these services to run reliably, accurately, and autonomously for transition into operations.
- **Operations to research (O2R):** The joint pursuit of improvements of operational capabilities and advancements in fundamental research. This includes the space weather community working to upgrade and enhance: (1) existing operational models and products, (2) the communication of operational priorities and capabilities to the research community, (3) the testing and evaluation of operational model performance by researchers for fundamental scientific discovery and for improved operational services, and (4) the identification of gaps in the fundamental understanding of the physical system that impede operational capabilities.

Tenets for Success

The following tenets for improving R2O-O2R capabilities were identified during the August 2016 O2R workshop and further refined within the NSTC SWORM Subcommittee:

- **Keep R2O and O2R coupled:** The R2O and O2R tasks and activities are highly coupled and should be managed as two components of a continuous process that has the primary goal of improving space weather forecasts and services. NOAA will host an annual R2O-O2R workshop (in coordination with the USAF, NASA, and NSF), to provide progress updates and receive feedback from the broad space weather community.
- **Engage agencies and collaborators:** Communication and collaborations, between government agencies and academia, private enterprise, space weather customers, and international organizations are critical to ensure continued progress.
- **Encourage open source:** Open source community models are necessary to provide the flexibility required for operational model development and maintenance. Open source or community models would allow the operational space weather forecasting community to tap into the vast intellectual power of the space physics research community to improve space weather forecasting capabilities.
- **Identify and address opportunities for applied research:** Compared to terrestrial-weather, space-weather research has limited applied research activities. Opportunities exist to strengthen the connection between fundamental research and the needs and requirements of the operational space weather community. Applying the results from fundamental research that address these needs and requirements could improve space weather forecasting, which will enhance national preparedness. Agencies should identify and develop such applied opportunities.

The Plan

The key elements below should be accomplished in preparation for a more formal R2O-O2R capability. Phase 1 and Phase 2 tasks below will establish the framework for the implementation of Phase 3 by the agencies. The level of agency support required for each Phase is somewhat flexible; however, adequate and sustained support will increase the value of the outcome and the probability of success. While dependent on funding levels, a proposed timeline for accomplishing goals described below is to initiate activities in Phase 1 within 2 years, Phase 2 within 3 years, and Phase 3 within 4 years of NSTC approval of this plan.

Phase 1. Enhance existing capabilities

1. **Establish performance metrics and benchmarks:** Establish model performance benchmarks and formalize the process to measure the performance and capabilities of operational and relevant scientific models.
2. **Space weather research on operational needs and requirements:** Continue current, and enhance future, fundamental and basic research in areas that have direct links to improving the specification and forecasting of space weather.
3. **Implement a prototype O2R project:** Use one or more test cases to achieve near-term success and better define the O2R process and establish requirements.

Phase 2. Expand Federal Capabilities to Establish the Fundamental Elements of an R2O-O2R Center

1. Establish community models
2. Support research and development on operational models
3. Identify computational resources requirements

Phase 3. Define and Formalize the Framework for a Space Weather R2O-O2R Center or Capability

Once the fundamental elements of an R2O-O2R capability have been established (as described in Phases 1 and 2 above), the activities that would establish a more formal center or capability are:

1. Define and establish a multi-agency management and governance structure.
2. As appropriate, agencies develop new, or augment existing, computing facilities with architectures similar to their respective operational computing facilities for testing research and operational models for development and in preparation for transition to operations. Agency decisions on the necessity for a new or augmented capability will be made with respect to factors identified in Phases 1 and 2, as well as Information Assurance and Cybersecurity requirements.
3. Establish stable and long-term multi-agency support, consistent with agency policies, for Space Weather R2O-O2R and establish funding opportunities for the research community (academia, commercial, and Government laboratories) in the form of grants, through established internal research support agencies, or through relevant technology development, acquisition, and sustainment agencies for research on specific space weather modeling challenges and with the clearly specified goal of improving products and model performance in measurable and documented increments.

Roles of Participating Agencies

DOC – As a primary agency in this action, DOC provides timely and accurate operational space weather forecasts, watches, warnings, alerts, and real-time space weather monitoring for the government, civilian, and commercial sectors, exclusive of the responsibilities of the Secretary of Defense; and ensures the continuous improvement of operational space weather services, utilizing collaborations, as appropriate, with academia, the private sector, and relevant agencies to develop, validate, test, and transition space weather observation platforms and models from research to operations and from operations to research.

DOD – As a primary agency in this action, DOD utilizes laboratories and the research community, to perform and sponsor basic and applied research advancing the fundamental understanding, observation, specification, prediction, and attribution of solar and space environment processes and disturbances. DOD maintains operational observing and forecasting capabilities to ensure the timely provision of unclassified and classified operational space environment observations, analyses, forecasts, and other products to support the national security mission of the Department of Defense and coalition collaborators, including the provision of alerts and warnings for space weather phenomena that may affect weapons systems, military operations, or the defense of the United States. DOD agencies work with the broader community to support the transition of technology and models from research to operations and from operations to research.

NASA – As a supporting agency in this action, NASA implements and supports a national research program to understand the Sun and its interactions with Earth and the solar system. These efforts seek to advance space weather modeling and prediction capabilities applicable to space weather forecasting. NASA also develops and operates space-weather-related research missions, instrument capabilities, and models; and supports the transition of space weather models and technology from research to operations and from operations to research.

NSF – As a supporting agency in this action, NSF's primary role in developing space weather readiness for the Nation is in the support of basic research that advances fundamental understanding of space weather and related processes, specifically, the generation of solar storms, their propagation through the interplanetary medium, and the generation of disturbances in the near-Earth space environment and atmosphere. NSF-supported community members use that fundamental understanding in the development of models for these space weather processes, which draw on observations from NSF's ground-based observational platforms, among others, to test and further refine our community's understanding. NSF's fundamental research makes them an essential collaborator with other agencies in the pursuit of national goals for space weather.

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