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Bridging the Weather-to-Climate Prediction Gap

A task force of researchers set out to bridge the gap between the 2-week weather forecast and long-term climate predictions; their findings could help in forecasting the likelihood of extreme events.

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Storm clouds gather over dry farmland in Nebraska. A NOAA task force is working to improve meteorological predictions that go beyond 2-week weather forecasts and extend up to seasonal climate outlooks. These predictions are highly sought after by the agricultural and water sectors, among many others. Credit: iStock.com/BeyondImages

The energy, water management, agriculture, and emergency response sectors, along with many others, are eager to have predictions that go beyond 2-week weather forecasts and extend up to seasonal climate outlooks. However, predictions over this time frame have been lacking because of the inherent unpredictability of the weather more than 2 weeks ahead, before changes in slower climate phenomena kick in to modulate the weather.

Scientists across the broad meteorological community have been engaging in a robust set of research activities to address this weather-climate prediction gap, at the so-called subseasonal to seasonal (S2S) range. In the United States, the National Oceanic and Atmospheric Administration (NOAA) S2S Prediction Task Force has made several significant contributions to overall progress, highlighting the interplay of physical processes that are key for predictions, examining their simulation in numerical models, and pioneering the development of new prediction methodologies. Initial results are helping to set future S2S research and development agendas.

Since 2016, the **S2S Prediction Task Force** has coordinated experts in academia and U.S. agencies involved in a set of grant-based research projects engaging many partners. The task force is a 3-year initiative by the Modeling, Analysis, Predictions and Projections (**MAPP**) program of NOAA's Office of Oceanic and Atmospheric Research, Climate Program Office. The initiative's ultimate goal is to help close the gap in prediction skill and products between the traditional weather and climate timescales.

Examining the Interplay Among Key Phenomena

Task force researchers have tackled the problem by addressing head-on a set of unresolved key questions (Figure 1). At a fundamental level, they aim to understand the dominant factors underpinning potential S2S predictability and how well numerical models simulate and predict phenomena at this timescale. The focus on predictability includes understanding how the interplay of tropical, midlatitude, and polar meteorological phenomena, as well as phenomena at the land and ocean surface, and lower and higher altitudes of the atmosphere (troposphere and stratosphere, respectively) influences S2S predictions.

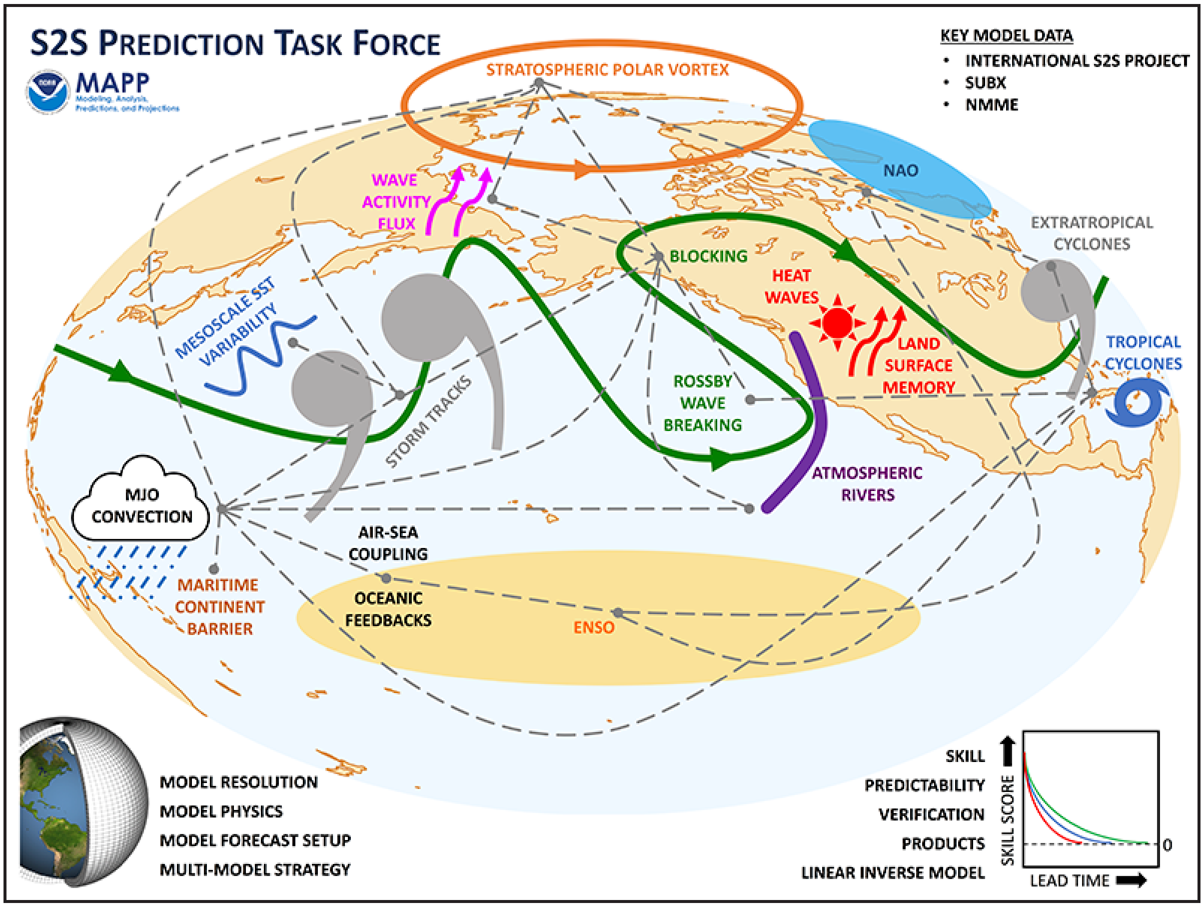

Fig. 1. Many natural processes underpin weather predictions on the scale of a few weeks to a single season (subseasonal to seasonal, or S2S). Shown here are some of these processes, along with the modeling systems and products included in NOAA's S2S Prediction Task Force activities. NAO = North Atlantic Oscillation.

For example, these researchers are examining the interplay of well-known global phenomena such as the Madden-Julian Oscillation (MJO; a recurring tropospheric circulation feature), the quasi-biennial oscillation (QBO; an alternating pattern of winds high in the stratosphere), and the El Niño–Southern Oscillation (ENSO; a recurring climate pattern across the tropical Pacific). Together, these recurring climate phenomena can modulate the occurrence of weather extremes over the United States. Thus, it might be possible to leverage information on these phenomena and their interactions to formulate extended predictions. The weather extremes they influence include tropical cyclones, atmospheric rivers (intense streams of moisture that can bring crucial precipitation to the U.S. West Coast but also cause floods), cold air outbreaks, and heat waves.

Exploring Prediction Systems

Task force researchers are also examining the approaches to S2S prediction. For example, they are considering the best ways to describe and evaluate phenomena relevant to S2S predictions. As a part of this effort, they are examining the performance of global numerical models that simulate physical processes of the Earth system (dynamical models, for short), considering individual models and multimodel ensembles.

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They are also studying how prediction skill varies with model initialization and setup—for example, the number of grid points and vertical levels (i.e., spatial resolution) used to depict the atmosphere and how interactions between atmosphere, ocean, and land are represented.

Researchers are also exploring whether it is possible to enhance prediction skill after the fact using postforecast corrections. This work is enhanced by the availability of real-time and historical S2S forecasts, provided by the Subseasonal Experiment (**SubX**) project, whose researchers are also participating in the S2S Prediction Task Force.

Research is also leveraging dynamical model prediction data from the S2S Project Database and the North American Multi-Model Ensemble (**NMME)** system data. As a complementary approach to using dynamical prediction models, some researchers are developing S2S predictions based on statistical models, that is, relationships between observed physical quantities describing the state of the atmosphere (e.g., MJO or QBO indicators) and prediction targets (e.g., atmospheric rivers).

Preliminary Task Force Findings

A number of important findings have already emerged from the work of the S2S Prediction Task Force that can help advance S2S predictions of U.S. extremes. For instance, a convergence of results points to the important role of the stratosphere in modulating the impact of tropical climate phenomena on extremes in the United States.

Task force researchers found that two factors simultaneously modulate the level of activity of atmospheric rivers striking the U.S. West Coast: the geographical location (or phase) of the tropical MJO pattern and the state of the stratospheric QBO (whether abnormal winds associated with the QBO are easterly or westerly). A new statistical tool that has been developed on the basis of such a discovery shows promise to extend predictions of atmospheric river activity by as much as 5 weeks, depending on specific locations and conditions. This prediction extends several weeks beyond skillful lead times of current dynamical prediction systems.

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Similarly, the stratospheric QBO has been found to modulate the impact of the MJO on the stream of midlatitude storms in the North Pacific and North Atlantic: the so-called extratropical storm tracks. This modulation has potential implications for the S2S prediction of surface weather, such as conditions relating to rapidly intensifying “**bomb cyclones**,” among others.

Initial results also show that the state of the **stratospheric polar vortex**, a large-scale stratospheric circulation that characterizes the winter hemispheres, modulates the effect of the MJO on surface weather in far-away regions (so-called teleconnections). In addition to the above-mentioned effects of the stratosphere, researchers are also finding that the ENSO phenomenon importantly modulates **MJO teleconnections**, confirming previous research and developing new theoretical understanding of why this is the case, to expand upon work based on statistical relationships and help improve dynamical models.

Another line of research is examining the effect on the prediction of S2S phenomena of oceanic and land surface conditions underlying the atmosphere and the effect on forecasts of representing those conditions more realistically in dynamical models. Initial results suggest that dynamical models that lack a depiction of fine-scale ocean circulations (so-called [ocean mesoscale eddies]) are subject to persistent errors in the storm track region.

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Similarly, ocean conditions seem to be important in determining the correct eastward propagation of the MJO, which is one key to skillful predictions (as discussed above). Other research results are enhancing our understanding of the connection between heat waves in the United States and the mutual influence of the state of the land (particularly moisture in the soil) and the state of the atmosphere, as well as the ability of a suite of climate forecast models to predict heat wave occurrence.

Researchers are using the long series of past forecasts (hindcasts) and forecasts from SubX, the S2S Project Database, and the NMME system to examine the relative advantages of single-model versus multimodel predictions. Given the diversity in the dynamical models available from these prediction databases, they are also drawing initial conclusions regarding the benefits and drawbacks of various model setups. For example, experiments have shown that the simulation of the stratosphere is improved when a dynamical model has more atmospheric levels high up in the stratosphere, better resolving the vertical structure of temperature and circulation. Overall, multimodel ensemble S2S forecasts generally appear to outperform single-model ensemble forecasts and are particularly useful for the prediction of extremes.

Coordinating with the Broader Community

These S2S Prediction Task Force research activities are inherently linked with broader community efforts, contributing to and benefiting from those efforts. These include, among many others, the international S2S Prediction Project, a joint effort by the World Climate Research Programme (WCRP) and the World Weather Research Programme; the U.S. Climate Variability program's Predictability, Predictions, and Applications Interface Panel; the Global Energy and Water Exchanges program's Global Land/Atmosphere System Study; the Stratosphere-Troposphere Processes and Their Role in Climate program's Stratospheric Network for the Assessment of Predictability; and the Working Group on Numerical Experimentation's MJO Task Force.

In view of this community interplay, a task force–organized special collection of **S2S research papers** entitled "Bridging Weather and Climate: Subseasonal-to-Seasonal (S2S) Prediction" is currently in preparation for publication in several AGU journals, and the task force is inviting relevant manuscripts from anyone in the S2S community. The deadline for submitting manuscripts is 30 April 2019.

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The S2S Prediction Task Force projects are still ongoing, but initial results are already influencing future research and development agendas. For example, the task force's results were taken into consideration in the development of plans for the next 5-year phase of the **international S2S Prediction Project**. NOAA plans for S2S predictions developed in response to the U.S. Congress's Weather Research and Forecasting Innovation Act of 2017 are also leveraging initial S2S Prediction Task Force results.

Finishing the Tasks

The full set of results from the S2S Prediction Task Force projects is expected to become available in the 2019–2020 time frame, when most projects will come to a close. Overall, this effort is expected to represent a milestone contribution to broad weather and climate communities' efforts to advance understanding and modeling of S2S phenomena and the development of new S2S prediction products.

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