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EDITED AND REVIEWED BY
Matthew Collins,
University of Exeter, United Kingdom

*CORRESPONDENCE
Swadhin Kumar Behera
behera@jamstec.go.jp

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Editorial: The state of the art in climate predictions

Swadhin Kumar Behera[1]*, Annalisa Cherchi[2], Jing-Jia Luo[3] and Arun Kumar[4]

[1]Application Laboratory, VAiG, Japan Agency for Marine-Earth Science and Technology (JAMSTEC), Yokohama, Japan, [2]National Research Council of Italy, Institute of the Atmospheric Sciences and Climate (CNR-ISAC), and Istituto Nazionale di Geofisica e Vulcanologia, Bologna, Italy, [3]Institute for Climate and Application Research (ICAR), Nanjing University of Information Science and Technology, Nanjing, China, [4]Climate Prediction Center, National Oceanic and Atmospheric Administration (NOAA), College Park, MD, United States

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Editorial on the Research Topic
The state of the art in climate predictions

From merely guessing the weather and climate using astronomical observations and cloud movements in 600–300 B.C., we have come a long way to reach an era of sophisticated weather and climate forecasting systems reliable enough to be integrated into our daily lives. Technological developments over the centuries contributed to our knowledge of the atmosphere, and the advent of computers and numerical techniques helped to solve the complex mathematical equations and provide accurate synoptic weather forecasts. While tremendous success is achieved in forecasting at the weather timescale, improvements are still needed in predictions at climate timescales from seasonal to interannual and beyond. A major shortcoming in improving climate prediction is related to data scarcity over vast parts of the oceans but also over land. Over the years, satellite observations of sea surface temperature, sea surface height, salinity, and more recently of soil moisture and vegetation cover have helped in improving climate predictions. Over large parts of the world's ocean, we now have the Argo floats that routinely take subsurface observations. These new additions to observing systems, and the availability of petaflop supercomputer systems, have enormously contributed to the development of state-of-the-art climate models and their potential to make reliable predictions.

In fact, state-of-the-art global climate models are already able to reliably predict climate variations, especially over the tropics, like El Niño/Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) several seasons ahead with skills not far behind those of the weather forecasts. Considering all these progresses in climate forecasting, this special Research Topic on the "state-of-the-art of climate prediction" reports some of the recent advances in climate monitoring, numerical techniques, data assimilation, and the inclusion of machine learning and artificial intelligence (ML/AI) in climate prediction systems.

Model biases in coupled ocean-atmosphere general circulation models (CGCMs) are a major topic for research to improve climate predictions. L'Heureux et al. reported such an effort involving the biases in the sea surface temperature (SST) predictions in the central and eastern equatorial Pacific Ocean. The positive SST bias in the North American Multi-Model Ensemble models was found to be linked with overly positive trends in tropical precipitation anomalies and was strongly correlated with an increase in El Niño false alarms in their study. Therefore, proper representation of ocean-atmosphere surface boundary conditions in CGCMs with realistic surface flux parameterization is important for reducing model biases and better simulating climate variations. Pradhan et al. in their paper showed better characteristics in various ocean-atmosphere parameters and processes at diurnal to seasonal time scales by introducing a better turbulent flux scheme.

River discharge, together with the influx of fresh water, plays an important role in the mixed-layer dynamics of the ocean, but attempts to include rivers in CGCMs used for seasonal prediction have been limited. A study by Srivastava et al. showed promising results as the rainfall-runoff coupled feedback associated with the Indian Summer Monsoon (ISM) improved the remote teleconnections with the equatorial Pacific in their CGCM. On a similar note, Doi and Behera explored the impacts of interannual variations of chlorophyll, through mixed-layer processes, on seasonal predictions of the tropical Pacific by the SINTEX-F2 dynamical climate prediction system. Although the chlorophyll impacts on predictions of the Niño 3.4 index were limited, improvements were noticed in the predictions of SST of the Western Pacific Warm Pool.

Recent advances in satellite observations of sea ice concentration (SIC) and thickness (SIT) have provided us with the opportunity to improve the predictions in higher-latitudes. In their paper, Lee and Ham, through a series of experiments, found significant reductions in the climatological biases of SIC and SIT as well as the quality of sea ice extent (SIE) simulation.

While the CGCMs are evolving, statistical models, particularly those based on (ML/AI) techniques, are also being developed for climate predictions. Statistical models are inexpensive and have been shown to produce comparable forecast skills though. Therefore, combining the power of dynamical and statistical predictions would enhance the ability to predict the climate with more accuracy. Such a hybrid prediction system was reported by Oettli et al. that utilizes a set of nine different machine learning algorithms to predict surface air temperature (SAT) over Tokyo/Kanto region of Japan based on the SINTEX-F2 CGCM SST forecast. The statistical component in this hybrid system restored teleconnections between SST and SAT, particularly in the mid-latitudes, usually not captured well in the CGCMs. Sometimes CGCM-based predictions of extreme SAT are improved by computing a suitable index related to a specific phenomenon or process. Such an index, called the temperature swing index (TSI), was formulated by Yang et al. and they found that the prediction of TSI provides additional predictable climate information beyond the traditional seasonal mean temperature prediction.

Improvements in observations and monitoring methodology are also evolving in parallel to the CGCM developments. In their study, Mishra et al. found that a better methodology of monitoring the onset date variations of the rainy season provides a viable alternative to assess and anticipate the seasonal variations.

We hope these advances in model developments, data assimilation, new observation methodology, and bias corrections will help the climate community in establishing reliable prediction systems for better adaptation and mitigation measures.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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