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Editorial: Tropical cyclone modeling and prediction: advances in model development and its applications

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Editorial on the Research Topic
Tropical cyclone modeling and prediction: advances in model development and its applications

Tropical cyclones (TCs) cause significant property damage and loss of life globally each year in coastal areas significantly affected by TCs in recent decades. Several recent TCs like Hurricanes Harvey (2017), Maria (2017), Ian (2022), Helene (2024) in the North Atlantic, Typhoons Haiyan (2013), Damrey (2017), Doksuri (2023), Yagi (2024) in the North Western Pacific, and Severe Cyclones Fani (2019) and Amphan (2020) in the North Indian Ocean have caused extensive deaths and multi-billion dollar damages, reminding us on the acute need for continuous advancement in the operational predictive capabilities. Accelerated efforts were made by several research and operational centers to advance the numerical modeling and data assimilation capabilities to improve the forecast skill and address socioeconomic impacts of TCs across the world.

The research theme in this special Research Topic is intended to systematically document the latest advancements in TC modeling and applications, with focus on improved physical parameterizations, better understanding of the physical processes, advanced data assimilation techniques, improved use of new and innovative observations, development of the holistic end-to-end forecast systems, enhanced TC related products, and improved social and behavioral sciences for interpreting the model forecasts.

Four different TC modeling systems developed in the USA were featured in this Research Topic, comprising of the Hurricane Analysis and Forecast System (HAFS), the new-generation operational model at National Oceanic and Atmospheric Administration (NOAA), the Hurricane Weather Research and Forecast model (HWRF), the legacy hurricane prediction system at NOAA and is still in operations, System for High-resolution prediction on Earth-to-Local Domains (SHiELD), an advanced

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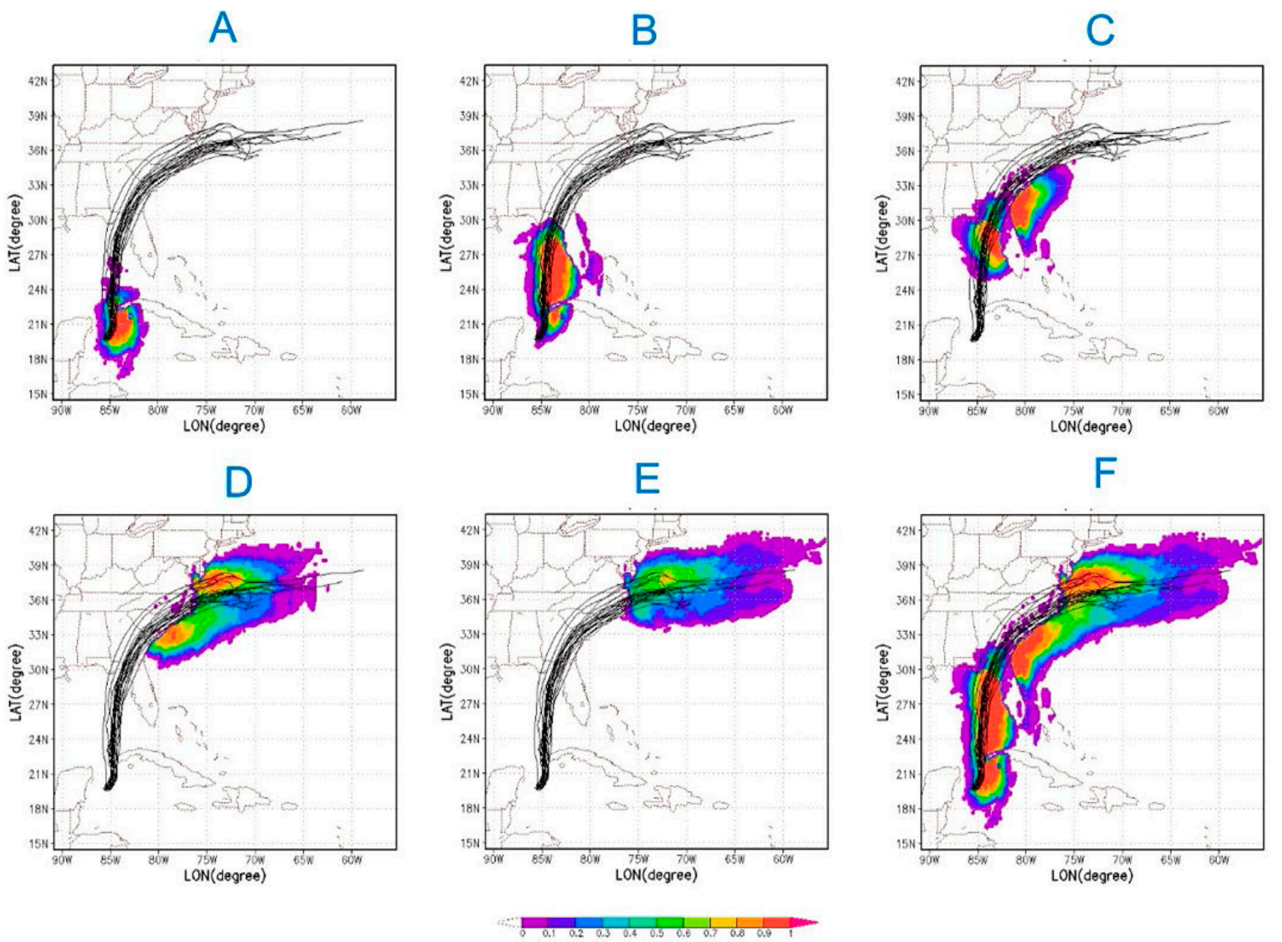

FIGURE 1
Hurricane precipitation probability forecast for storm "Idalia" initialized at 00Z of 28 August 2023. **(A)** Day 01; **(B)** Day 02; **(C)** Day 03; **(D)** Day 04; **(E)** Day 05 and **(F)** 5 days in total. The black lines: ensemble tracks. The shaded: the probability of the 24-h precipitation greater than 1 inch. Details see in Peng et al.

research model developed by NOAA's Geophysical Fluid Dynamics Laboratory (GFDL), and the Weather Research and Forecasting (WRF) model developed by National Science Foundation (NSF)'s National Center for Atmospheric Research (NCAR). Common to many of these modeling systems is the need for higher resolution for explicit representation of convection, dynamic coupling of atmospheric and ocean models, better representation of initial TC location, structure and intensity through vortex initialization and data assimilation, and enhanced verification and validation metrics.

Authors of various manuscripts compiled in this Research Topic have documented features of the new generation hurricane prediction models developed at NOAA (Ramstrom et al. and Gao et al.), high-resolution physics for TC applications (Wang et al.; Li et al.; and Li et al.), data assimilation methodology and observation data impacts (Annane and Gramer), ensemble forecast experiments (Peng et al.), TC model forecast evaluations (Newman et al.; Kim et al.; Gramer et al.; Aristizábal Vargas et al.; and Lian et al.), and advanced model verification and validations (Hazelton et al.). Ramstrom et al. detailed the salient features of the moving nest, illustrating the intrinsic technical aspects in HAFS. Kim et al. and Aristizábal Vargas et al. evaluated the oceanic component of HAFS, and highlighted the impact of air-sea interactions especially on hurricane forecasts. Gramer et al. studied the role of physical processes associated with the boundary layer, convection and microphysics, radiation, land surface processes, air-sea-wave processes were documented in Wang et al., Li et al., and Kim et al. The model evaluations included quantitative precipitation forecasts (Newman et al.), resolution effects (Lian et al.), vortex initialization impacts (Gao et al.), and the relevant tools to produce the products for TC research and forecasts. The new breakthrough applying Cloud technology in the TC ensemble prediction was documented in Peng et al. (Figure 1). Annane and Gramer also applied the coupled HAFS to study the new data impact on analyzing tropical cyclones.

The objective of this Research Topic is to share research ideas, development advancements, and scientific insights made by TC research scientists with support from broader inter-disciplinary communities across the globe for improving our ability to understand and predict TCs and their impacts with higher accuracy and skill. We hope that this special edition will serve as a reflection of the state-of-the-art of current TC science, and a valuable reference for researchers in this field.

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