Advancing Weather and Climate Science in Mesoamerica and the Caribbean: A Novel Regional Multi-Week Convection-Permitting Simulation

Kelly M. Núñez Ocasio[a] , Erin M. Dougherty[b] , Lulin Xue[b] , Zachary L. Moon[a] , Antonio Ruiz Núñez[a] , Monica Morrison[b] , Kwesi T. Quagraine[a] , Ye Mu[c] , Carlos Martinez[d] , Veeshan Narinesingh[e] , Tereza Cavazos[f] , Gabriel Rios[g] , Julio Bacmeister[b] , Jorge A. Amador[h] , Dimitris A. Herrera[i, j] , Cenlin He[b] , Eric D. Maloney[k] , Kristen Rasmussen[k] , Kevin A. Reed[l] , Rich Neale[b] , Christian Domínguez[m] , Alejandro Jaramillo[m] , Kwok P Chun[n] , Leonardo A. Clarke[o] , Santiago Núñez-Mejía[p, q] , Yang Tian[b] , Rosimar Rios-Berrios[b] , K. Santiago Hernández[r] , Lucía Scaff Fuenzalida[s] , Alan G. Rosales[t] , Patrick Callaghan[b] , Xingchao Chen[u] , and Talia G. Anderson[v]

[a] *Department of Atmospheric Sciences, Texas A & M University, College Station, TX*

[b] *NSF NCAR, Boulder, CO*

[c] *University of California, Santa Barbara, Santa Barbara, CA*

[d] *Union of Concerned Scientists, Washington, DC*

[e] *NOAA Geophysical Fluid Dynamics Laboratory, Princeton, NJ*

[f] *Center for Scientific Research and Higher Education of Ensenada (CICESE), B.C., Mexico*

[g] *Princeton University, Princeton, NJ*

[h] *Center for Geophysical Research and School of Physics, University of Costa Rica, Costa Rica*

[i] *University of Tennessee–Knoxville, Knoxville, TN*

[j] *Universidad Autónoma de Santo Domingo, Santo Domingo, DR*

[k] *Department of Atmospheric Science, Colorado State University, Fort Collins, CO*

[l] *Stony Brook University, Stony Brook, NY*

[m] *Instituto de Ciencias de la Atmósfera y Cambio Climático, Universidad Nacional Autónoma de Mexico, Mexico City, Mexico*

[n] *University of the West of England, UK*

[o] *Department of Physics, University of the West Indies, Mona, Jamaica*

[p] *Departamento de Recursos Hídricos y Ciencias Ambientales, Universidad de Cuenca, Ecuador*

[q] *TRACES & Faculty of Science and Technology, Universidad del Azuay, Ecuador*

[r] *Institute for Atmospheric and Climate Science, ETH Zürich, Switzerland*

[s] *Universidad de Concepción, Chile*

[t] *Coastal Engineering and Processes Laboratory (LIPC) of the Engineering Institute, Universidad Nacional Autónoma de Mexico, Mexico City, Mexico*

[u] *Pennsylvania State University, State College, PA*

[v] *Department of Geography, Environment & Society, University of Minnesota, Minneapolis, MN*

Corresponding author: Kelly M. Núñez Ocasio, knunez.ocasio@tamu.edu

ABSTRACT: Understanding the weather and climate of Mesoamerica and the Caribbean remains challenging due to complex hydroclimate interactions, limited observations, and poor representation of regional processes in global models. We introduce the Mesoamerica Affinity Group (MAAG), an NSF NCAR and community voluntary initiative that fosters research collaboration to advance weather and climate science, develop convection-permitting datasets, and promote knowledge exchange. MAAG's first major contribution is a two-week convection-permitting simulation of Hurricane Maria (2017) using MPAS-A, featuring a novel regional 15-km to 3-km variable-resolution mesh over the region. Initial evaluation shows that MPAS-A captures key features like precipitation patterns, the Intertropical Convergence Zone, and low-level jets. Some biases remain, particularly in enhanced land convection and slight deviations in Maria's track. This novel dataset, now publicly available through NCAR's Data Archive, supports studies of other extreme events and mesoscale convective systems active during the same period. It offers a valuable resource for the research community. MAAG is a new but rapidly growing initiative achieving notable milestones in a short time. It serves as a collaborative platform for co-designing high-resolution modeling experiments, aimed at producing actionable weather and climate information. We invite the community to join MAAG, explore this initial dataset and advance regional weather and climate research.

SIGNIFICANCE STATEMENT: The Mesoamerica Affinity Group (MAAG), an NSF NCAR and community voluntary initiative, aims at addressing the complex challenges of understanding weather and climate in Mesoamerica and the Caribbean. MAAG's first major achievement is a convection-permitting two-week simulation of Hurricane Maria (2017) using a novel 15-km to 3-km variable-resolution mesh. This dataset accurately captures key regional features and is publicly available through NCAR's Data Archive. By fostering collaboration through data production and sharing, monthly group meetings that serve as a platform for networking and knowledge exchange, and the development of advanced high-resolution datasets, MAAG provides a vital resource for advancing regional weather and climate science. The initiative is rapidly growing, serving as a platform for co-designed modeling experiments aimed at producing actionable climate information for academia and different sectors. We invite the scientific community to join MAAG and advance research in this critical region.

1. Motivation

Mesoamerica, which includes the modern-day countries of Costa Rica, Panama, Nicaragua, Honduras, El Salvador, Guatemala, Belize, central to southern Mexico (National Geographic, 2023), the Caribbean (situated from 5 °N to 27°N and 60°W to 90°W) and northern South America, are multicultural and multiethnic regions of complex terrains and tropical islands surrounded by the Gulf, the Caribbean Sea, the Tropical North Atlantic and the Eastern Pacific basins. These regions are heavily reliant on rainfall for their socioeconomic needs (e.g., agriculture, energy production, water management, and tourism). Hence, they are highly vulnerable to hydrometeorological and geophysical extremes, as well as climate variability (e.g., Taylor et al. 2011; Amador and Alfaro 2014; Ruiz-Mallén et al. 2015; Salazar et al. 2024; Pavlova et al. 2017; F. Salazar and Ferreira 2020; UNESCO 2023).

The region's hydroclimate is shaped by a complex set of competing interactions between atmospheric and oceanic features operating across multiple spatial and temporal scales in the tropics and mid-latitudes. Large-scale drivers such as the North Atlantic Subtropical High (NASH; Davis et al. 1997; Giannini et al. 2000; Wang and Lee 2007), the Intertropical Convergence Zone (ITCZ; Henderson-Sellers and Robinson 1986; Zhang 2001; Poveda et al. 2006), and the South American Monsoon System which is the primary climate driver of South America (Vera et al. 2006), are the main facilitators of moisture convergence across the region (Martinez et al. 2019; Colorado-Ruiz and Cavazos 2025).

At regional scales, features such as the Caribbean Low-Level Jet (CLLJ; Amador Astúa 1998; Wang and Lee 2007; Amador 2008; Whyte et al. 2008; Martin and Schumacher 2011; Taylor et al. 2013; Torres-Alavez et al. 2021), the Chocó Jet (Poveda and Mesa 2000, 1999; Yepes et al. 2019), the Papagayo and Tehuantepec jets (Trasviña et al. 1995; Schultz et al. 1997; Chelton et al. 2000; Xie et al. 2005), the Western Hemisphere Warm Pool (Wang and Enfield 2001), and the Central American Gyres (Papin et al. 2017) interact with easterly waves (e.g., Serra et al. 2010; Dominguez et al. 2020; Riley Dellaripa et al. 2023; Zhou and Maloney 2025), tropical cyclones (TCs; Jury et al. 2012; Dominguez and Magaña 2018), mid-latitude frontal systems (e.g., Sánchez-Hernández et al. 2022), and topography (e.g., orographic lifting, sea-breezes; Smith et al. 2012; Mora et al. 2020) to modify the spatial and temporal extent of precipitation provided by these mesoscale and large-scale systems.

The interactions between these local-to-large-scale features result in a unique seasonal pattern of rainfall distribution that differs across the region depending on the relative importance of the dynamical features (Taylor et al. 2002; Chen and Taylor 2002; Taylor et al. 2011; Hoyos et al. 2018; Martinez et al. 2019; Mejía et al. 2021; Colorado-Ruiz and Cavazos 2025). In addition, the interactions between these features result in the four subseasonal components of the rainfall season in northern South America, Central America, and the Caribbean: the early-rainy season (ERS; mid-April to June), a relatively drier period that is part of the annual cycle of precipitation, known as the mid-summer drought (MSD; July and August; Magaña et al. 1999; García-Franco et al. 2023), the late-rainy season (LRS; late August to late November), and the winter-dry season (late November to mid-April). The interannual variability of the rainfall season is influenced by at least two different climate drivers: the North Atlantic Oscillation (NAO) and the El Niño-Southern Oscillation (ENSO), due to their influence on the underlying local-to-large scale features that inform rainfall in the region and interactions between the Eastern Pacific and Atlantic basins (e.g., Chen and Taylor 2002; Amador et al. 2006; Amador 2008; Taylor et al. 2002; Hoyos et al. 2018; Martinez et al. 2020; Jury 2023). On the intra-seasonal scale, rainfall variability over the Caribbean, Mesoamerica, and northern South America is modulated by convectively coupled equatorial waves and the Madden-Julian Oscillation, which influence the organization of convection and rainfall patterns across the region (Dominguez et al. 2020; Recalde-Coronel et al. 2020; Builes-Jaramillo et al. 2025).

Predicting these small-to-large-scale dynamical interactions, and consequently, the Mesoamerican, northern South American, and Caribbean hydroclimate remains challenging due to the limited publicly available and decades-long observations (Martinez et al. 2019), and poor representation of the region's topography, tropical convection, and physical processes in climate models (Sobel et al. 2011; Smith et al. 2012; Reboita et al. 2014; Herrera and Ault 2017; Anderson et al. 2019; Andrade-Gómez and Cavazos 2024; Hidalgo et al. 2025; Martinez et al. 2025).

While recent field campaigns in this region, such as OTREC and EPIC2001 (Raymond et al. 2004; Stone et al. 2025), have sought to better understand interactions among convection, atmospheric circulation, topography, and the complex ocean state, these observations remain limited in both temporal and spatial coverage. Similarly, recent efforts such as CORDEX (Giorgi and Gutowski 2015; Cavazos et al. 2020; Torres-Alavez et al. 2021) have advanced regional climate downscaling for present and future climates, but challenges remain at local, convective-permitting scales (i.e., grid spacing fine enough to directly represent individual thunderstorms and rain systems, rather than relying on parameterizations) in accurately representing precipitation and circulation processes in this region, where impacts are most relevant. Likewise, global climate models (GCMs) in the Coupled Model Intercomparison Project Phase 6 (CMIP6) underestimate precipitation in the Caribbean (Martinez et al. 2025; Brotons et al. 2024), though higher-resolution GCMs have smaller biases.

Convection-permitting model simulations, which have grid-spacings $\leq$ 4km, have further improved biases over the Caribbean and tropical Atlantic by resolving topography (Bhardwaj et al. 2018), more accurately capturing precipitation (Akinsanola et al. 2024), easterly waves (Núñez Ocasio et al. 2025b), and removing the double-ITCZ bias that is present in many GCMs (Núñez Ocasio and Dougherty 2024; Heim et al. 2023). The use of convection-permitting simulations is thus necessary to capture local island processes, resolve complex terrain, and capture mesoscale to synoptic interactions over this region in both the current climate and in future scenarios. Some recent convection-permitting configurations include that of using variable resolution (e.g., Stansfield et al. 2020), regional dynamical downscaling (e.g., Hall et al. 2024; Jones et al. 2023; Luna-Niño and Cavazos 2018), or a novel combination of the two at convection-permitting resolution (i.e., Núñez Ocasio and Dougherty 2024; Núñez Ocasio et al. 2024). As we will show here, these offer valuable tools for studying the phenomena of this region in both the current climate and in future scenarios.

This article introduces a new initiative established by the National Science Foundation (NSF) National Center for Atmospheric Research (NCAR) and the research community: the Mesoamerica Affinity Group (MAAG). MAAG aims to foster research and collaboration among scientists and practitioners in the Mesoamerican and Caribbean region. We present MAAG's first major contribution to the research community to facilitate collaboration–the novel Model for Prediction Across Scales-Atmosphere (MPAS-A) convection-permitting simulation of Hurricane Maria (2017). We discuss the initial evaluation of the simulation and outline the group's ongoing and future research priorities.

2. The Mesoamerica Affinity Group Initiative

MAAG was established by the NSF NCAR Water Systems Program and the broader research community to foster targeted research collaborations and advance weather and climate science across Mesoamerica and the Caribbean. Building from the successful collaborative model and scientific efforts of the voluntary South America Affinity Group (SAAG; Dominguez et al. 2024), this voluntary effort brings together researchers from NSF NCAR, universities, and international institutions, all contributing both research and community support. MAAG is also supported by the NSF NCAR Cross-Lab Water Systems Program, which provides funding to support NCAR members in helping conduct MPAS-A and Community Atmosphere Model (CAM) simulations, analyzing results, and coordinating activities across the MAAG community. It is also currently supported by research and MPAS-A simulations led by the Tropical Systems Group at Texas A&M, including students and postdoctoral researchers, with the hope that other universities and sectors will contribute to MAAG's support at a similar level. The central aim of MAAG is to create sustained collaborations that result in the co-design, enhancement, and development of high-resolution model-based simulations and research focused on understanding the historical and future weather and climate of the region.

Key scientific goals include: (1) providing a reliable historical dataset at convection-permitting scales, a better understanding of TC processes, (2) capturing hydroclimatic extremes (e.g., precipitation, droughts, and floods), (3) understanding the impact of local-scale processes on regional weather, and (4) providing detailed projections of future weather in Mesoamerica and the Caribbean. The group's first major outcome is the first-ever MPAS-A historical convection-permitting simulation of Hurricane Maria (2017). This seminal two-week simulation spans a period of intense tropical activity, offering a unique opportunity to study extreme events in depth, and serves as the starting point for launching future, longer simulations.

In addition to the modeling efforts, the group is designed to serve as a hub for networking and community engagement. It provides a forum for communication and knowledge exchange among individual researchers, groups, and institutions contributing to the region's weather and climate science. A key function of this collaborative environment is the ongoing co-design of long-term historical and future high-resolution simulations. Through these coordinated efforts, the community advances its understanding of the region's weather, climate, and their impacts on local populations.

3. Description of the Modeling Framework and Simulation

The Model for Prediction Across Scales–Atmosphere (MPAS-A) version 8.0.1 (Skamarock et al. 2012; Duda et al. 2024) is a non-hydrostatic atmospheric model designed for both weather and climate applications. In this study, MPAS-A was used to perform a convection-permitting historical simulation of the devastating Hurricane Maria (2017), covering the two-week period from 00:00 UTC on 15 September to 00:00 UTC on 30 September 2017, as it approached the Caribbean and the eastern United States.

To enable this hindcast and to ensure continuous lateral boundary forcing from reanalysis data, a novel regional variable-resolution mesh configuration was developed. The mesh ranges from 15-km to 3-km resolution and is centered over Mesoamerica and the Caribbean (Figure 1). The refined 3-km convection-permitting region is elliptically-shaped and centered at 20°N, 80°W, strategically designed to optimize convection-permitting coverage over the area of interest. The edges of the model domain are 20°S to 61°N and from about 145°W to 15°W, with the coarser 15-km resolution region extending into South and North America (with slightly more latitudinal range within the edges from 41.7°S to 77.8°N), western Africa, and the eastern Pacific, respectively. The convection-permitting 3-km region includes the eastern Pacific and the mid-Atlantic, extending several degrees south of the equator up to the northern United States. Although a regional domain, it overlaps significantly with the domain of long-term convection-permitting model datasets, such as CONUS404 over the U.S. (Rasmussen et al. 2023) and SAAG over South America (Dominguez et al. 2024) datasets. This overlap presents a unique opportunity for dataset comparisons, cross-collaborations, and expanded research efforts, opening the door for the configuration's application in future long-term experimental design and coordinated regional modeling studies.

This Central American and Caribbean MPAS-A regional variable-mesh configuration is the first of its kind, which could be applied elsewhere in the world. It provides an innovative approach to dynamical downscaling, serving as a bridge between coarse-resolution global forcing and convection-permitting regional modeling. The design enables computational efficiency by eliminating the need to run a full global domain at the highest resolution. This type of refinement allows for comparisons with Earth system models (fully coupled model that represents the atmosphere, ocean, land surface, and sea ice), such as the Community Earth System Model (CESM), which also supports variable-resolution simulations.

The 15-km to 3-km variable-resolution regional configuration was first introduced in prior work, where it was vetted and validated for tropical hindcasts, demonstrating its reliability for historical simulations over Tropical Africa and the Atlantic (Núñez Ocasio et al. 2024; Núñez Ocasio and Dougherty 2024). It has been successfully applied to support research on easterly waves, mesoscale convective systems, and the large-scale monsoonal circulations of Africa.

The "convection-permitting" physics parameterizations used in this configuration are summarized in Figure 1. The model was initialized using the ECMWF 5th Generation Reanalysis (ERA5) (Hersbach et al. 2020), which also provided hourly lateral boundary conditions. Sea surface temperatures were updated hourly from ERA5. The model was configured with 55 vertical levels and produced hourly outputs with isobaric variables being output on 27 pressure levels. Some parameterizations in our physics suite have been shown to adequately simulate TCs and easterly wave activity over the Central American and Caribbean region. For example, Dominguez et al. (2021) tested a combination of the Thompson microphysics scheme, RRTMG shortwave and longwave radiation, and the Noah land surface model in the WRF regional climate model at 36-km resolution. Their experiments, designed to simulate tropical activity under future climate change scenarios, demonstrated that this configuration effectively captures key tropical dynamics such as tropical cyclogenesis, the spatial distribution and evolution of storm tracks, easterly wave propagation, and the associated precipitation patterns that contribute substantially to seasonal rainfall across Mesoamerica and the Caribbean.

This historical simulation is unprecedented in both its spatial resolution and continental scale. It enables the study of Hurricane Maria and other TCs active during the same period. In addition, it supports investigation into key regional weather and climate features, including low-level jets such as the CLLJ and Chocó Jet (discussed in Section 5c), coastal diurnal cycles, the ITCZ, extreme rainfall events, and mesoscale convective systems, among others.

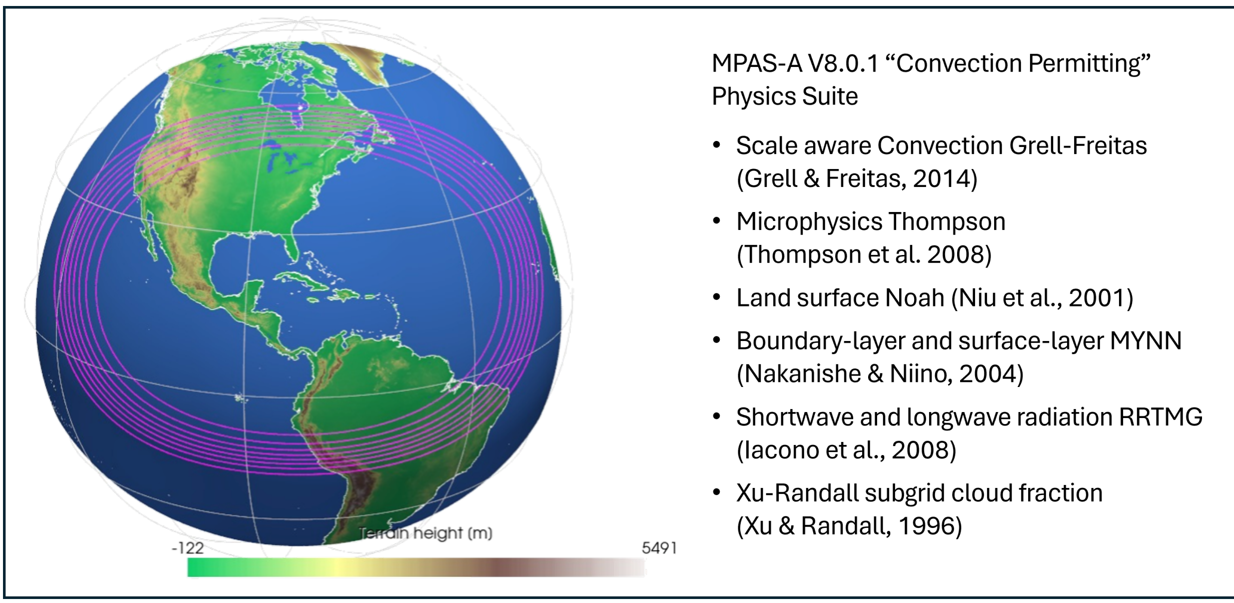

FIG. 1. Three-dimensional rendering of the simulation domain and configuration developed for MAAG. It is centered over Central America and the Caribbean. Magenta contours represent the 15-km to 3-km variable resolution of MPAS. The colored area represents the regional extent of the coarser 15 km region which covers a large portion of the Western Hemisphere.

4. Enabling Actionable Research Through Publicly Available Model Products

MAAG is committed to advancing open and reproducible science. To support broad community access, we have made the native full-resolution simulation outputs and all model configuration files publicly available through the NSF NCAR Research Data Archive (`https://rda.ucar.edu/datasets/d010077/`). The archive includes both native-grid model outputs and fields regridded to a regular latitude–longitude grid to facilitate accessibility and downstream analysis. Comprehensive documentation accompanies the data products and provides detailed descriptions of all variables.

In addition, MAAG has partnered with the UXarray development team (UXarray Organization 2021) to offer regular tutorial sessions during MAAG monthly meetings, enabling and supporting community use of the native-grid outputs and promoting best practices for working with unstructured-grid model data.

5. Model Evaluation

Here, we provide a brief overview and high-level analysis of selected features from the two-week simulation to demonstrate the fidelity of the simulation. More in-depth analyses will be presented in subsequent publications. Note that the analysis is performed using regridded MPAS-A outputs on a 30-km latitude–longitude grid for comparison with ERA5.

a. Large-scale Rainfall and Winds

The model-simulated 925-hPa horizontal winds are validated against ERA5 from 00 UTC September 16 to 00 UTC September 30 (Figure 2a, b). The comparison shows that MPAS-A reproduces the large-scale 925-hPa circulation patterns over the Caribbean, Mesoamerica, and the surrounding Atlantic and eastern Pacific reasonably well when compared to ERA5, including the main low-level flow structures. However, the difference field (Figure 2c) reveals notable regional biases, with alternating positive and negative anomalies indicating localized over- and underestimation of the flow strength and associated circulation features. For the particular region of interest, these biases are evident over the western Atlantic 20°N latitude, and parts of Central America, extending into the eastern Pacific ITCZ, suggesting that while the large-scale structure is well captured, important regional discrepancies remain, even at convection-permitting resolution.

The model-simulated precipitation is validated against the Integrated Multi-satellitE Retrievals for GPM (IMERG) for the same period. Figure 2d and e, shows that both datasets display broad agreement in capturing large-scale precipitation features such as the ITCZ, prominently extending across the Eastern Pacific and Atlantic Oceans. MPAS-A replicates the observed structure, intensity, and spatial characteristics of precipitation associated with hurricane activity, such as the curved track of cyclonic activity near the Caribbean and western Atlantic Ocean. The precipitation hotspot over western Colombia and the dry corridor over coastal Ecuador and Perú are present both in IMERG and MPAS, although the spatial structure is slightly different. However, MPAS-A shows higher rainfall intensities over oceanic regions, especially along the Pacific ITCZ and near the coast of Central America. Furthermore, IMERG shows more localized and spatially distinct precipitation events, which are noticeable in the Caribbean region and the eastern Pacific hurricane track.

Previous studies have noted that high-resolution modeling frameworks, like MPAS, improve the representation of mesoscale processes essential for accurate prediction of TC structures, including precipitation patterns and intensity distributions (Davis et al. 2016; Skamarock et al. 2018). While observational datasets like IMERG are crucial for model validation, they can carry inherent uncertainties, particularly in high-intensity rainfall scenarios, over oceans, and complex terrain, where satellite retrievals face challenges due to limited ground validation (Tan et al. 2019; Huffman et al. 2020). The strong similarity between IMERG observations and MPAS-A outputs seen here underscores the reliability of MPAS-A for investigating hurricane-associated precipitation extremes and their potential changes under different climate conditions.

b. Hurricane Maria

Hurricane Maria resulted in the largest maximum rainfall recorded in Puerto Rico since 1956, with a recorded 1029 mm at a rainfall gauge in the southeast part of the island (Keellings and Hernández Ayala 2019). We examine the ability of MPAS-A to reproduce these rainfall extremes compared to rainfall observations from satellite (IMERG) and rain gauges (Coop stations) during 19–21 September 2017 as Hurricane Maria passed over Puerto Rico (Figure 3). MPAS-A shows that a wide swath of heavy precipitation associated with Maria is located south of the island, with rainfall amounts up to ∼170 mm over the southern part of the island. IMERG, however, shows the rainfall maxima over 300 mm primarily over the eastern half of the island. This suggests that MPAS-A simulates Hurricane Maria as moving too slowly and too far west compared to observations, with a rainfall bias over the island ranging from -135 mm to 50 mm based on the mean difference. In a forthcoming paper by Quagraine et al. (2026), they show that differences in track between MPAS-A

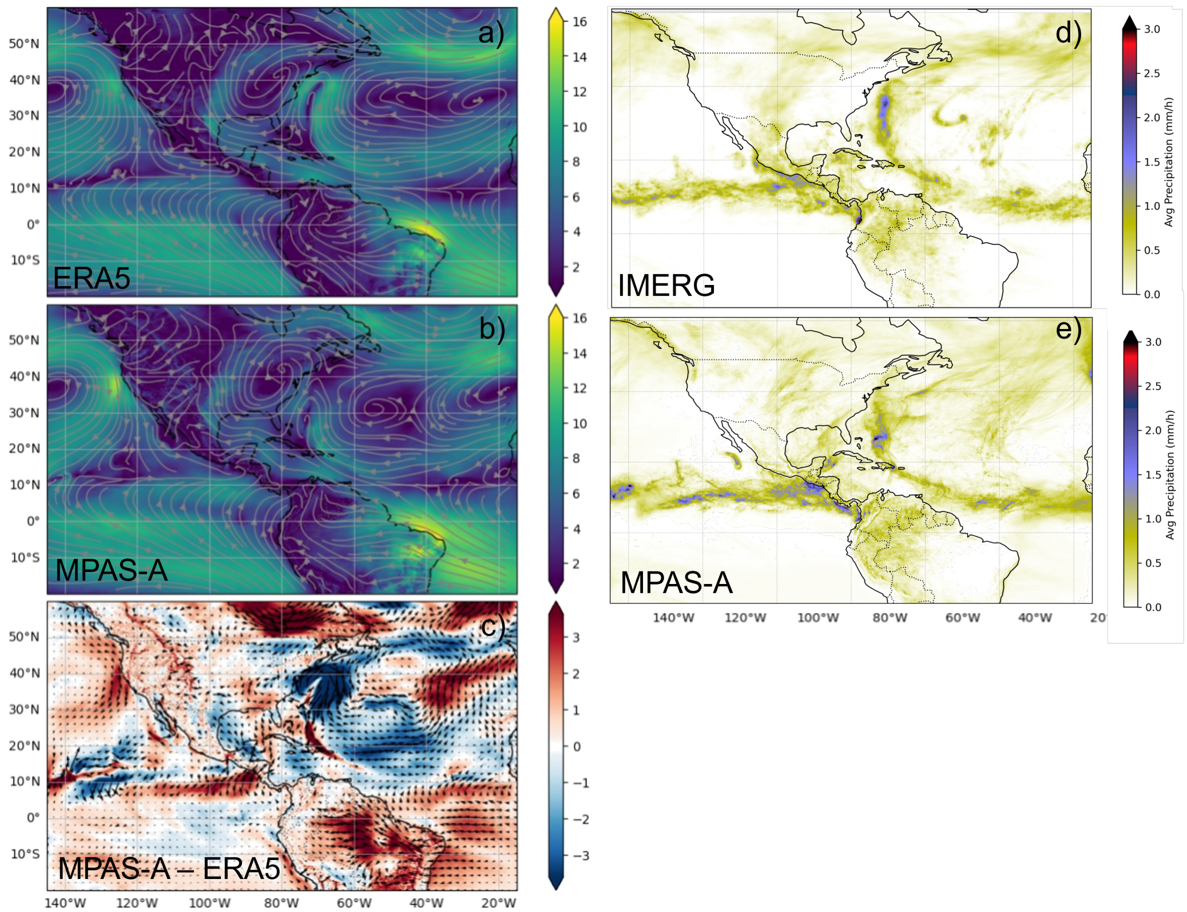

FIG. 2. Left panels show 925-hPa horizontal wind speed (m/s; shading) and vectors for ERA5 (a), MPAS-A (b), and their difference (c), averaged over 16–30 September 2017. Right panels show modeled MPAS-A precipitation rates (mm/hr) (d) and observed IMERG satellite precipitation for the same period (e). MPAS-A and IMERG were regridded to about 30 km, comparable to the post-process regridded MPAS-A data used in this analysis.

simulations of Hurricane Maria and observations could be due to differences in the position and strength of the North Atlantic Subtropical High.

Compared to four Coop stations, MPAS-A also underestimates rainfall amounts from -235 to -76 mm, except at the northeast station, which shows a slight overestimate of 96 mm. Therefore, MPAS-A shows biases associated with slight deviations in the track of Hurricane Maria compared to observations. Specifically, comparing the objectively analyzed track of simulated Hurricane Maria in MPAS-A with the observed IBTrACS and ERA5 tracks (Figure A1) shows that the MPAS-A simulated track (blue) closely follows the general path recorded in IBTrACS (green) and ERA5 (orange), though it crosses west of the island—consistent with the precipitation analysis biases—and underestimates the northward deviation near 70°W. Overall, this indicates good agreement, with only minor discrepancies in the storm's curvature over the Caribbean.

With Puerto Rico being a small island, slight shifts in hurricane track by model simulations can produce large rainfall biases, in part due to the influence of topography on precipitation. However, given that the large-scale rainfall in Figure 2 compares well between MPAS-A and IMERG, and that Figure 3 highlights uncertainty in IMERG itself compared to gauges, we have greater confidence that MPAS-A is accurately simulating the general time-averaged rainfall observed during the longer simulation period.

A more direct assessment of the physical processes of Hurricane Maria, compared with a companion pseudo–global warming simulation using the same MPAS-A configuration presented here, was conducted in Quagraine et al. (2026), a MAAG-member–led collaboration involving NSF NCAR and the Texas A&M Tropical Systems Group.

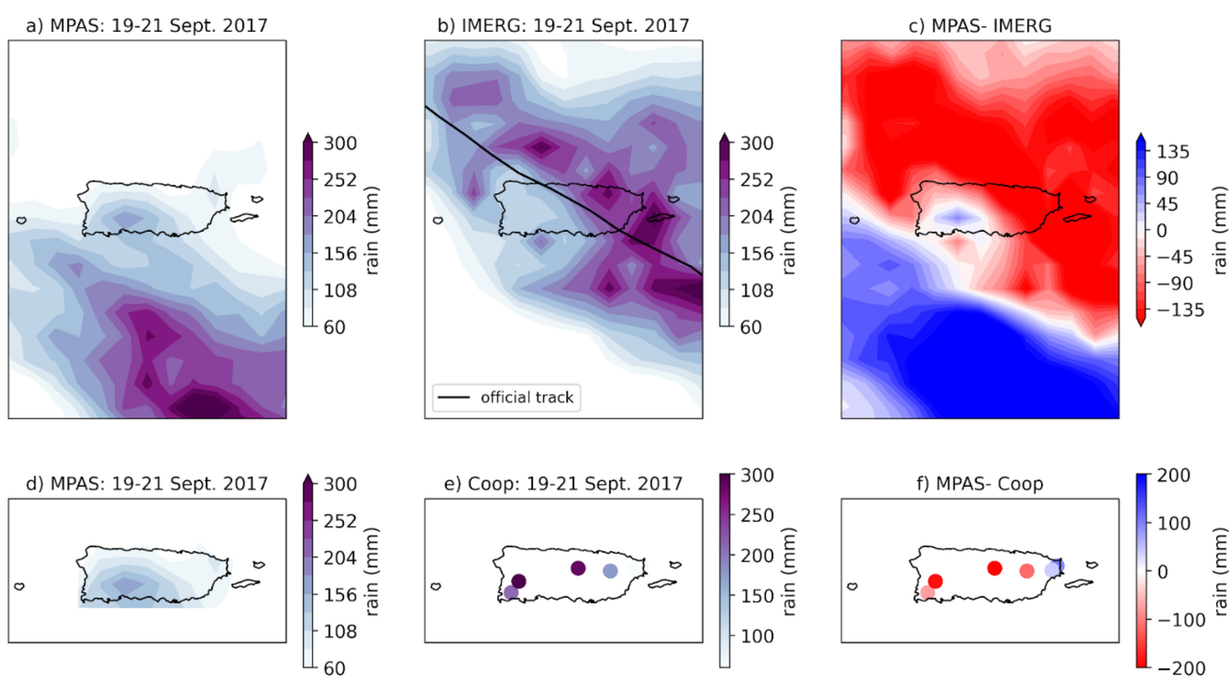

Fig. 3. Comparison of accumulated rainfall as Hurricane Maria passed over Puerto Rico from 19–21 September, 2017 in MPAS-A (a), IMERG (b), and MPAS-IMERG difference (c), as well as MPAS-A (d), Coop rain gauge stations (e), and MPAS-Coop (f). The black line on b) shows Hurricane Maria's track from the International Best Track Archive for Climate Stewardship.

c. Low-Level Jets

Low-level jets in the eastern Pacific and Caribbean regulate weather across the Caribbean, Central America, and South America. Three jets were analyzed: the Chocó Jet (3°–7°N, 77°–85°W), a westerly 925 hPa jet carrying Pacific moisture into Colombia; the Papagayo Jet (9°–13°N, 86°–89°W), a northeasterly jet transporting Caribbean moisture through Nicaragua to the Pacific; and the Caribbean Low-Level Jet (12.5°–17.5°N, 70°–80°W), an easterly jet moving Atlantic moisture into the Caribbean. Horizontal winds at 925 hPa (left y-axis; Figure 4) and precipitation rates (right y-axis; Figure 4) were spatially averaged across each jet region for every timestep and compared between MPAS-A, ERA5, and IMERG (Figure 4).

MPAS-A largely reproduced the Chocó Jet throughout the simulation period, with horizontal wind speeds and a diurnal cycle comparable to those in ERA5 (Figure 4a). Precipitation associated with the Chocó Jet is also comparable to IMERG observations (dashed lines, Figure 4). In contrast, the Papagayo Jet exhibits a significant high bias in MPAS-A wind speeds relative to ERA5, particularly during September 22–26 (Figure 4b). Analysis of precipitation within the Papagayo Jet domain indicates that increased southwesterlies in MPAS-A, compared to IMERG, enhance land-sea convergence in the Eastern PacifIC Warm Pool region, resulting in stronger coastal convection in MPAS-A. his likely contributes to the elevated horizontal wind speeds during this period. These biases are also evident in the large-scale spatial differences between simulated and ERA5 horizontal winds (Figues 2c), and between simulated precipitation and IMERG (Figure 2d, e), over the Papagayo Jet region and extending into the eastern Pacific ITCZ belt.

MPAS-A simulated slightly stronger CLLJ winds than ERA5 and comparable precipitation to IMERG during the first half of the simulation (Figure 4c). As Hurricane Maria approached the Caribbean, however, both ERA5 and MPAS-A show a weakening of the CLLJ. In MPAS-A, Maria interacted more closely with the northeastern edge of the CLLJ and with land over the Dominican Republic from late 19 September through late 22 September (shaded period in Fig. 4c), owing to its more westward track. This interaction likely contributed to the temporary weakening of simulated Maria during this period, as reported in Quagraine et al. (2026). This proximity shifted low-level CLLJ winds from easterlies to westerlies and reduced overall horizontal wind speeds, as shown in Fig. A2.

After this interaction, simulated CLLJ winds become notably weaker than in the reanalysis, and precipitation differences between MPAS-A and IMERG increase. This discrepancy primarily stems from the more southwestward track of Maria in MPAS-A (Fig. 3) relative to observations, which causes the simulated hurricane to interact more directly with the CLLJ.

These results are consistent with previous observational studies showing that large variations in the CLLJ during September can modify vertical wind shear between the lower and upper troposphere and, in turn, influence hurricane activity by reducing it (Wang 2007).

Overall, this comparison demonstrates MPAS-A's capability to realistically simulate horizontal wind speeds associated with the three regional jet systems and their expected physical interactions with tropical cyclone activity. While the relationship between the CLLJ, TCs, and large-scale variability (e.g., monsoon, ENSO, MJO; Wang and Lee 2007; Amador 2008; Torres-Alavez et al. 2021) has been explored in greater detail, and a recent case study has even examined connections between the CLLJ, the Chocó jet, and tropical cyclone genesis, including positive feedbacks between these jet systems (Wilson et al. 2025), localized process-level tropical cyclone–CLLJ interactions remain an open research question. This is largely due to the scarcity of high-resolution, convection-permitting datasets (Wilson et al. 2025). The dataset presented here therefore provides a unique opportunity to investigate such interactions.

6. Topics of Research Interest and Applications for the Community

MAAG has identified several research priorities aimed at advancing understanding of the regional weather and climate dynamics of Mesoamerica while improving predictive capabilities. Ongoing and future work will focus on planning and executing high-resolution MPAS-A experiments that will enhance the representation of land and surface interactions, hydrology, and atmospheric processes. A significant emphasis is on understanding the drivers and impacts of extreme weather events—including flash droughts, heatwaves, and TCs—so that we can enhance our ability to provide actionable information for hazard assessment, resilience, and even renewable energy decisions. In Table 1, we suggest some prospective research areas that could be considered for future research.

As of now, plans to support MAAG include a Texas A&M–led NSF proposal that, if awarded, would allow the team to request a large university allocation at NSF NCAR High Performance

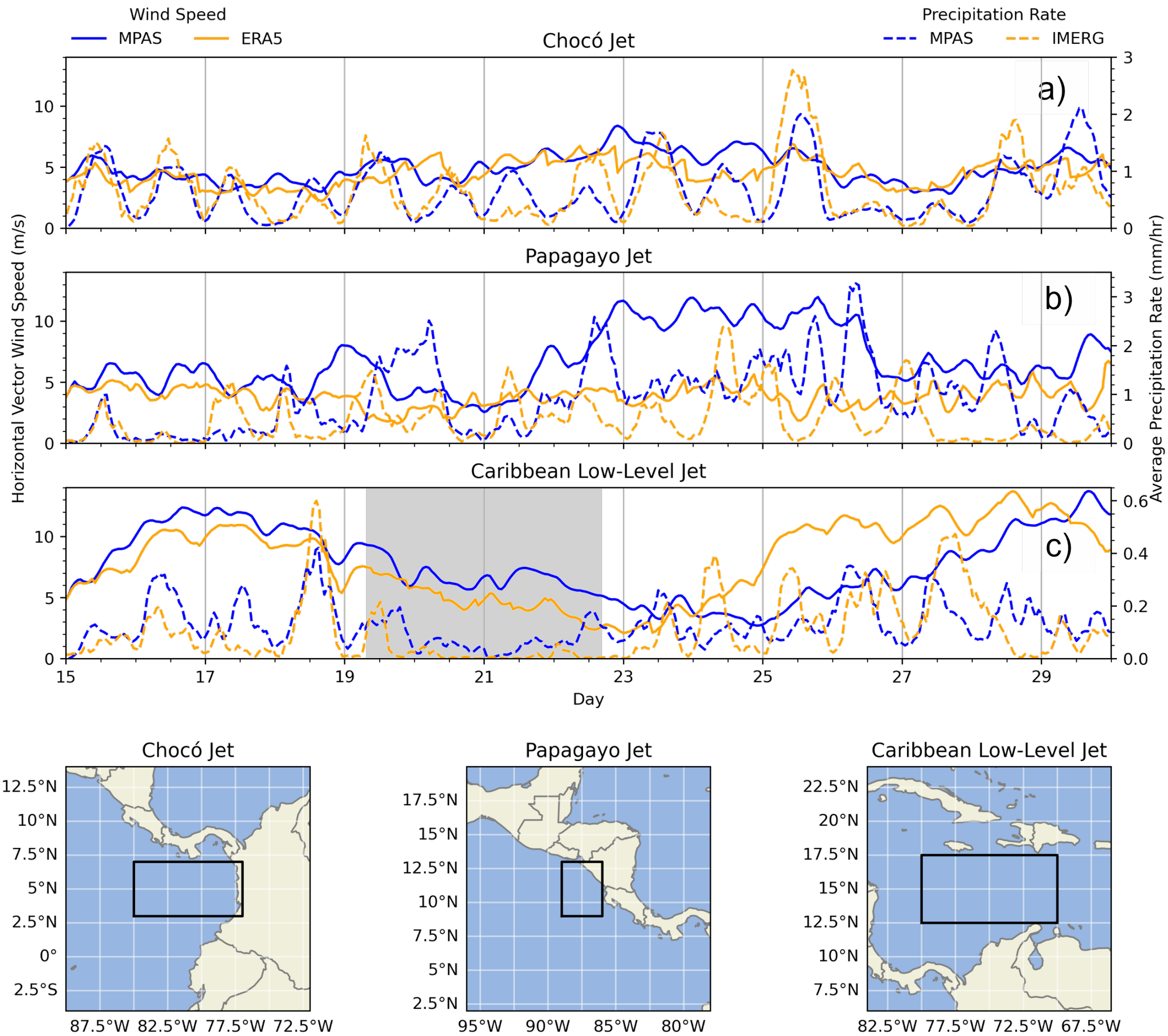

FIG. 4. Time series comparison between the MPAS-A simulation and ERA5 reanalysis of 925-hPa horizontal wind speed (m/s; left y-axis), and between MPAS-A and IMERG precipitation rates (right y-axis), over 15–30 September 2017 for the Choco jet (a), Papagayo jet (b), and CCLJ (c). The shaded region in (c) denotes the period when simulated Maria was closest to the CLLJ, interacting with the northeastern edge of the jet as well as land from the Dominican Republic. Lower maps show the geographical location of each jet.

Computing (HPC), ensuring sufficient computational resources to produce longer convection-permitting datasets for the MAAG community. MAAG members are, and will continue to be, encouraged both within and outside of academia to secure and explore funding that can help support the MAAG community's efforts. MAAG leadership is also proactively seeking funding and computational resource support from NSF NCAR lab directors. With SAAG as a partner, MAAG has now been welcomed to join the AccelNet-ACCORD network (https://www.accelnet-accord.com/) to strengthen its broad international partnerships.

Research Area	Specific Focus
Land and Water Systems	- Modeling land use changes (e.g., fires, urbanization, deforestation) - Modeling streamflow and flash floods - Examining water system responses to hydroclimate changes
Extreme Weather	- Identifying drivers of extreme rainfall - Predicting flash droughts - Modeling drought at high-resolution - Analyzing regional heatwave drivers and impacts - Studying mechanism for the onset and evolution of organized convection and MCSs - Understanding drivers of rapid intensification of tropical cyclones - Understanding controls on hydroclimate changes and extremes, including tropical cyclones
Global and Regional Dynamics	- Understanding dynamics of Caribbean Low-Level Jet - Physical processes of Caribbean and Pacific Easterly Waves and their role in tropical cyclogenesis - Understanding diurnal cycle and its interactions - Offshore propagation of convection and its interactions with other local features - Assessing the behavior, interactions, and impacts of aerosols
Hazards and Infrastructure	- Fine-scale modeling of wind for energy applications - Assessing compound hazards from sea level rise, cyclones, and coastal flooding - Connections to risk applications

TABLE 1. Prospective future research areas and specific foci

The MAAG community also has interests in 1) building collaborations with the CORDEX and SAAG communities to leverage shared modeling objectives, scientific goals, and engage in cross-community modeling assessments, and 2) the CESM community to design variable resolution (VR-CESM) simulations that can be used as boundary conditions for future MPAS-A runs that include projections of variability at different scales.

7. Conclusions and Future Directions

We have introduced MAAG and presented our first major contribution: a novel, two-week, convection-permitting regional and variable-resolution hindcast from 2017, made available to the research community. We also outlined the initiative's ongoing and future research directions. This seminal historical simulation is unprecedented in both its spatial resolution and continental scale, and it successfully captures key regional rainfall features — including the approximate location and intensity of local rainfall maxima — with high resolution and overall accuracy. We have only begun to explore this rich dataset, yet have quickly made it available to the public for further use and evaluation.

Significant milestones have been achieved in a short period. This summer we established joint SAAG–MAAG meetings and expanded our network through sustained collaborations with the Caribbean for Climate group and Universidad Nacional Autónoma de Mexico, among others. Some of our recent community-engagement achievements include the development of a new MAAG website (https://ral.ucar.edu/projects/mesoamerica-affinity-group-maag); presentations at AMS and AGU conferences aimed at promoting the MAAG initiative and dataset; partnerships with UXarray to support community use of the MPAS-A dataset through regular tutorial sessions during our monthly meetings; active efforts to share data through NSF NCAR and Texas A&M; and the exploration of a GitHub-based collaborative platform. Even the preparation of this manuscript has strengthened our group by providing a platform to learn from one another's diverse expertise and research interests.

Since this manuscript was first written, we have produced a companion pseudo–global-warming Hurricane Maria simulation and a full-year 2020 simulation using the same model configuration described here. These datasets are currently being prepared for public release and will provide a more comprehensive set of simulations for the community to explore and use, as 2020 was one of the most historically active Atlantic hurricane seasons. To date, these efforts have resulted in ongoing collaborations within the group and one manuscript submission (i.e., Quagraine et al. 2026).

MAAG is a dynamic and evolving group, with a strong desire to leverage our expertise and international collaboration to co-design more long-term experiments and configurations while pursuing the growing research directions highlighted here, driven by science and how our research will benefit the region to mitigate current and future weather extremes. While we continue using MPAS, we are also exploring other Earth system models like the CESM and ways to integrate them to better serve the community.

While MAAG is still relatively new, we invite the broader weather and climate enterprise to join the MAAG effort by contacting Lulin Xue (xuel@ucar.edu), Kelly Núñez Ocasio (knunez.ocasio@tamu.edu), Julio Bacmeister (juliob@ucar.edu), Erin Dougherty (doughert@ucar.edu), Monica Morrison (monicamo@ucar.edu), or any of the other authors of this work.

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Data availability statement. The native and post-processed model outputs, as well as all the model configuration files, can be publicly accessed at Núñez Ocasio et al. (2025a) via `https://rda.ucar.edu/datasets/d010077/`. The modified MPAS-A code for outputting isobaric variables can be found at Duda et al. (2024). Please reference Núñez Ocasio and Dougherty (2024) if using this version of the model. The ERA5 data (ECMWF 2019) for initial and lateral boundary conditions were obtained via the NSF NCAR Research Data Archive via the Computational and Information Systems Laboratory (CISL).

APPENDIX

These appendix figures support the analysis presented in the manuscript.

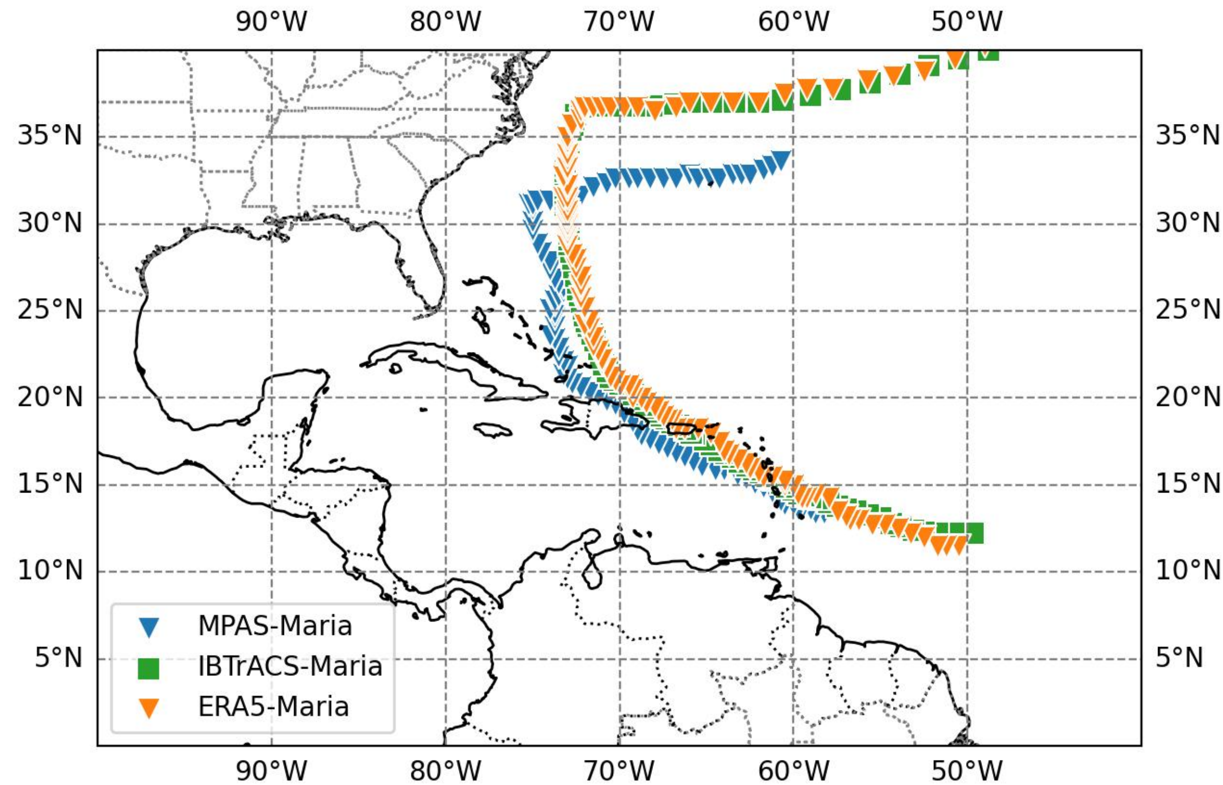

Fig. A1. Hurricane Maria track observed with IBTrACS (green square), and objectively tracked using TempestExtremes (Ullrich et al. 2021) in MPAS-A (blue triangle), and ERA5 (orange triangle) during the simulation period.

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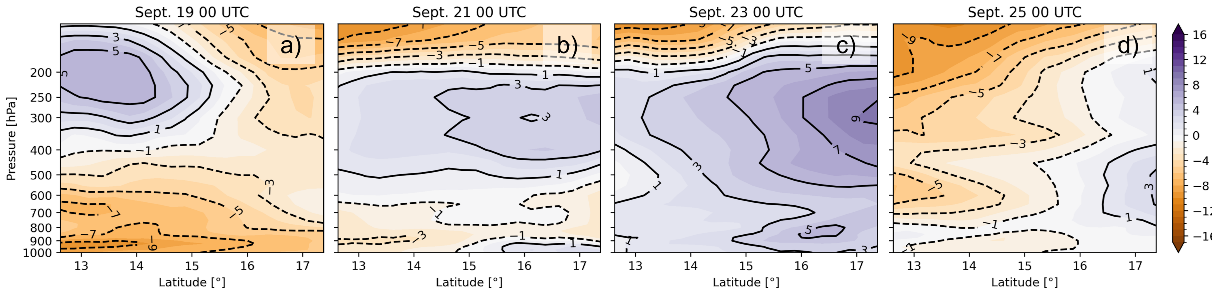

FIG. A2. Vertical cross sections of the zonal wind at 00 UTC on 19 September (a), 21 September (b), 23 September (c), and 25 September (d), longitudinally averaged between 70° and 80°W over the Caribbean Low-Level Jet.

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