MULTISCALE SIMULATION OF INDIAN SUMMER MONSOON USING QUASI-UNIFORM AND VARIABLE-RESOLUTION MODEL FOR PREDICTION ACROSS SCALES (MPAS)

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Abstract No.: Th-3.79

Introduction

- The Indian summer monsoon (ISM) is a significant component of the atmospheric circulation system [Rao, 1976].

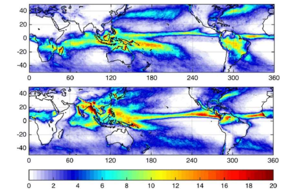

Fig. 1. Monthly Rainfall for January (top) and July (bottom). [Source: Ricko et al. (2016)]

- Low resolution General Circulation Models (GCMs) perform poorly [Gadgil et al., 2005; Krishnamurti et al. 2000;Wang et al., 2005]; whereas high resolution GCMs have computational constraints.
- Regional Climate Models (RCMs), offer improved simulations and accurately represents multiscale spatial interactions [Mukhopadhyay et al., 2010].
- However, RCMs face difficulty in conserving mass and energy, inconsistencies in physics schemes and dynamical cores compared to the driving GCM, and a lack of two-way interaction [Harris & Lin, 2014].
- Variable Resolution GCMs (VR-GCMs), exemplified by the MPAS model [Ringler et al., 2010; Skamarock et al., 2012], offer a computationally efficient alternative, producing comparable results to high-resolution GCMs [Gettelman et al., 2018; Wang et al., 2018].
- Cheng et al., (2023), demonstrate that MPAS-VR outperforms MPAS-RCM in reproducing average climate characteristics and extreme events over Mainland China, showcasing its effectiveness in simulating regional climatic phenomena [Lau et al., 2020; Zhao et al., 2019].
- Despite being a state-of-the art model, which can simulate phenomenon across scales, MPAS has not been used to study Indian monsoon.

Why MPAS

- ☐ Good scaling on massively parallel computers.
- ☐ No pole problems.
- ☐ Increased accuracy and flexibility for variable resolution applications.
- ☐ No abrupt mesh transitions.

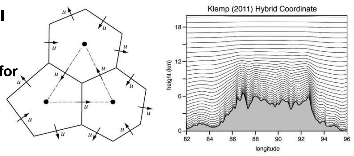

Fig 2. Schematics of the C-grid staggered variables on the horizontal Voronoi mesh (left); Height-based hybrid smoothed terrain-following vertical coordinate (right). [Source: MPAS (mpas-dev.github.io)]

Objectives

Assess the performance of MPAS over the Indian domain by systematically increasing the model resolution and incorporating variable-resolution meshes.

Methodology & Study Area

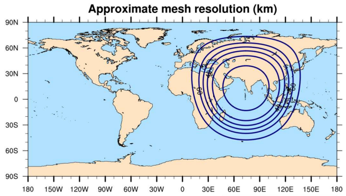

Fig. 3. Schematics of domain used for the study. Rings represent usage of VR meshes with highest resolution (25 km) over India.

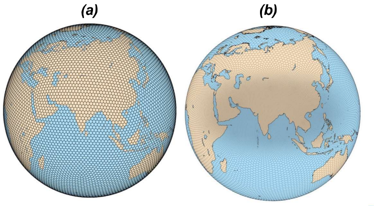

Fig. 4. Schematics of the different meshes used for the model simulations, (a) 120 km (Quasi-Uniform); (b) 92-25 km (Variable Resolution).

Table 1. Computational Power Required with 64 cores

Mesh	Core-hours
120 km (Global)	5.68
25 km (Global)	896
25 km (Regional)	42.06
92-25 km (Global)	89.29

Table 2. Spatial and Temporal Resolution

Horizontal Resolution	120 km	92-25 km
Vertical Resolution	55	55
Time Steps (in sec)	720	120

Table 3. Initial and boundary condition, and period of simulation for the current study.

Initial Conditions	SST and Sea Ice	Initialization	Period
ERA5	ERA5	1st April Every Year	6 months (2011-2022)

Table 3. Parameterization schemes used for the current study.

Convection	Microphysics	Land Surface	Boundary Layer
New Tiedtke	WSM6	Noah	YSU

Surface Layer	Longwave Radiation	Shortwave Radiation	Cloud Fraction for Radiation	Gravity Wave Drag by Orography
Monin-Obukhov	RRTMG	RRTMG	Xu-Randall	YSU

Results

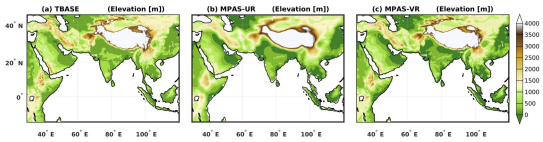

Fig. 5. Terrain Height from (a) TBASE, (b) MPAS-UR and (c) MPAS-VR.

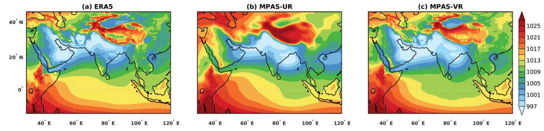

Fig. 6. June-September mean sea level pressure from (a) ERA5, (b) MPAS-UR and (c) MPAS-VR

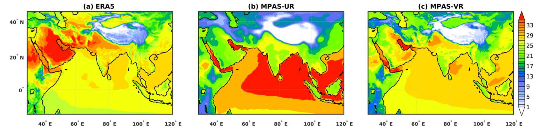

Fig. 7. June-September mean 2m Temperature from (a) ERA5, (b) MPAS-UR and (c) MPAS-VR

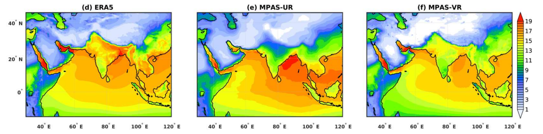

Fig. 8. June-September mean 2m Specific Humidity from (a) ERA5, (b) MPAS-UR and (c) MPAS-VR

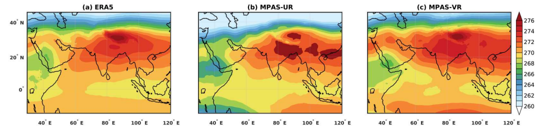

Fig. 9. June-September mean Temperature at 500 hPa from (a) ERA5, (b) MPAS-UR and (c) MPAS-VR

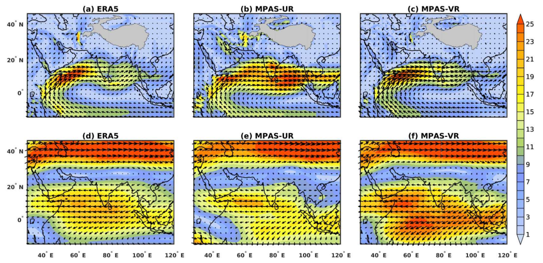

Fig. 10. June-September mean Wind at 850 hPa from (a) ERA5, (b) MPAS-UR, (c) MPAS-VR and Wind at 200 hPa from (d) ERA5, (e) MPAS-UR and (f) MPAS-VR

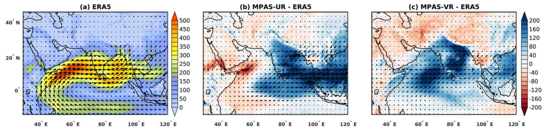

Fig. 11. June-September mean Vertically Integrated Moisture Flux from (a) ERA5, (b) MPAS-UR and (c) MPAS-VR

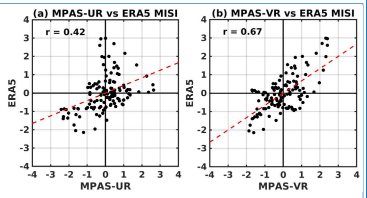

Fig. 12. Comparison of Monsoon Intraseasonal Index (MISI) between (a) MPAS-UR and (b) MPAS-VR

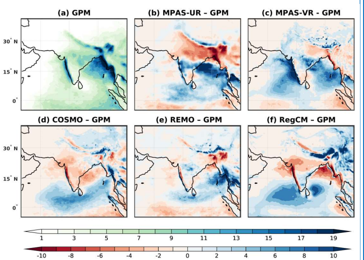

Fig. 13. June-September mean Rainfall from (a) GPM. The difference between GPM and (b) MPAS-UR, (c) MPAS-VR, (d) COSMO, (e) REMO and (f) RegCM.

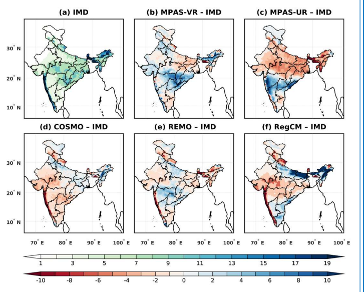

Fig. 14. June-September mean Rainfall from (a) IMD. The difference between IMD and (b) MPAS-UR, (c) MPAS-VR, (d) COSMO, (e) REMO and (f) RegCM.

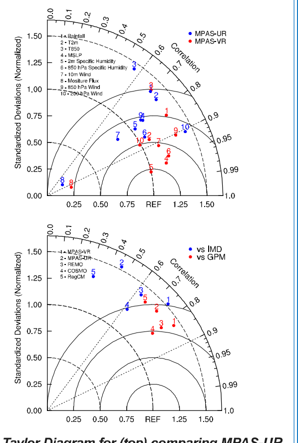

Fig. 15. Taylor Diagram for (top) comparing MPAS-UR and MPAS-VR in representing different parameters; (bottom) comparing MPAS and CORDEX models in representing June-September mean precipitation.

Conclusions

- Increase in horizontal resolution leads to better representation of the spatial features in rainfall, surface air temperature, winds, and specific humidity at lower levels.
- However, for certain aspects, the increase in horizontal resolution does not show steady improvement.
- At higher resolutions, the traditional physics parameterizations does not seem to work well, thus emphasizing the need for better parameterizations.

Future Work

- Use different combination of parametrization schemes.
- Tune the free parameters in parameterization schemes using manual or machine learning based tuning techniques.
- Use higher resolution in combination with better and scale-aware parameterization schemes.

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