MPAS Model Simulations of Congo Basin Mesoscale Convective Systems

Siyu Zhao[1], Rong Fu[1], Kelly Núñez Ocasio[2], Robert Nystrom[2], & Cenlin He[2]

1. University of California, Los Angeles; 2. National Center for Atmospheric Research

Backgrounds

Congo Basin rainfall is traditionally assumed to be associated with the Intertropical Convergence Zone (ITCZ), but recent studies have challenged this view due to a lack of lower-level convergence associated with rainy areas. This reveals the complexity of the processes that influence rainfall in this region. The processes that control Congo Basin rainfall and mesoscale convection systems (MCSs) are not clearly understood.

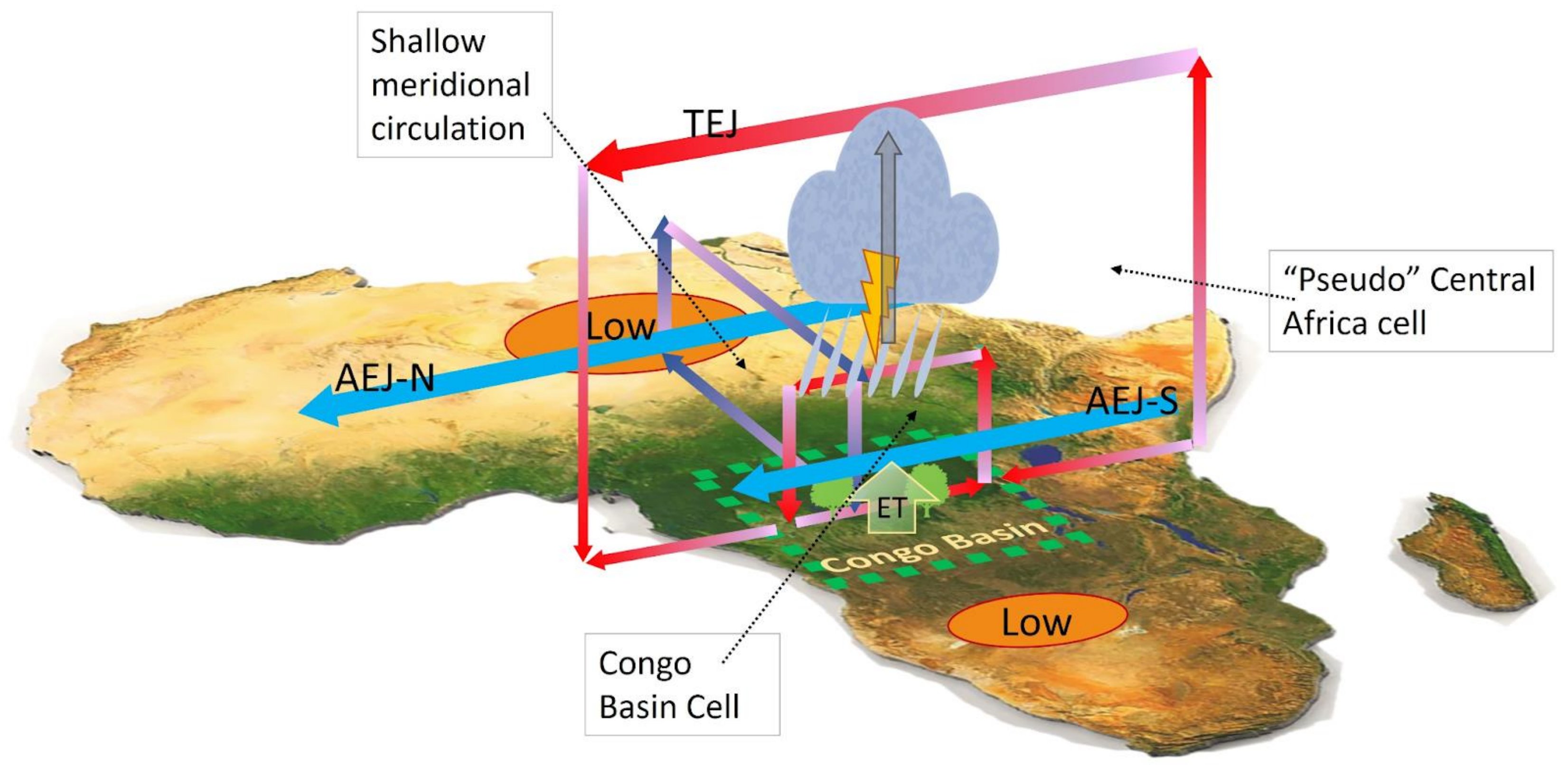

Figure 1. Schematic diagram illustrates main circulation patterns controlling Congo Basin rainfall. The green box represents the Congo Basin. TEJ refers to Tropical Easterly Jet; AEJ-N and AEJ-S refer to the northern and southern components of the African Easterly Jet, respectively; ET is evapotranspiration.

Model for Prediction Across Scales (MPAS)

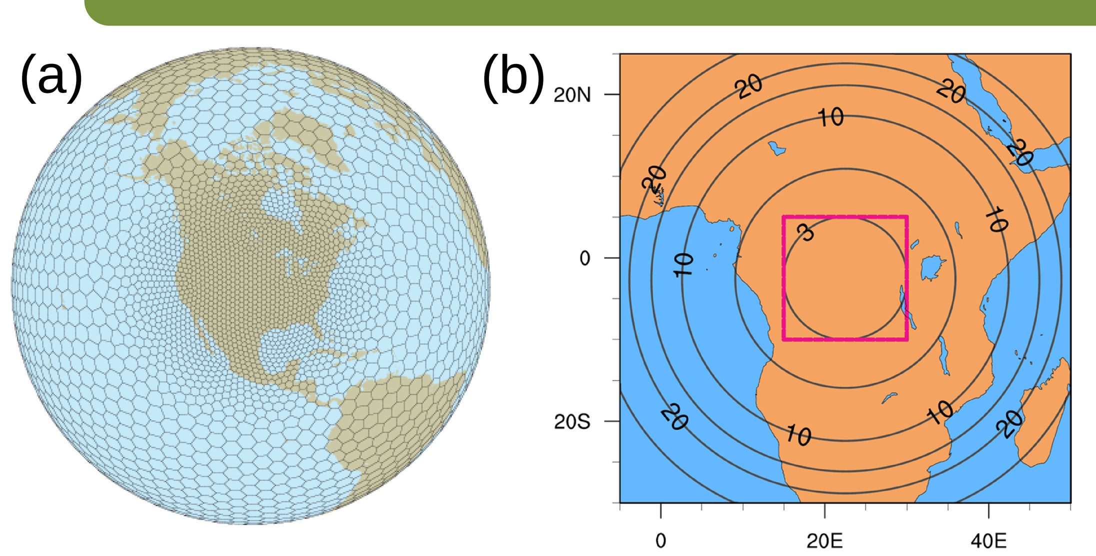

Figure 2. (a) Schematic of variable resolution Voronoi mesh. (b) MPAS 60-3 km mesh used in our study. The pink box represents the Congo Basin.

- Global cloud-resolving model
- Voronoi mesh for a global irregular grid
- Smooth resolution transitions
- Physics schemes from the WRF model

Model skills in simulating MCSs and related fields

- Congo Basin MCSs mainly originate from high-elevation mountains over the east of the Basin such as the Great Rift Valley.
- ✓ The timing and general location of the track of a simulated MCS case generally resemble those observed.

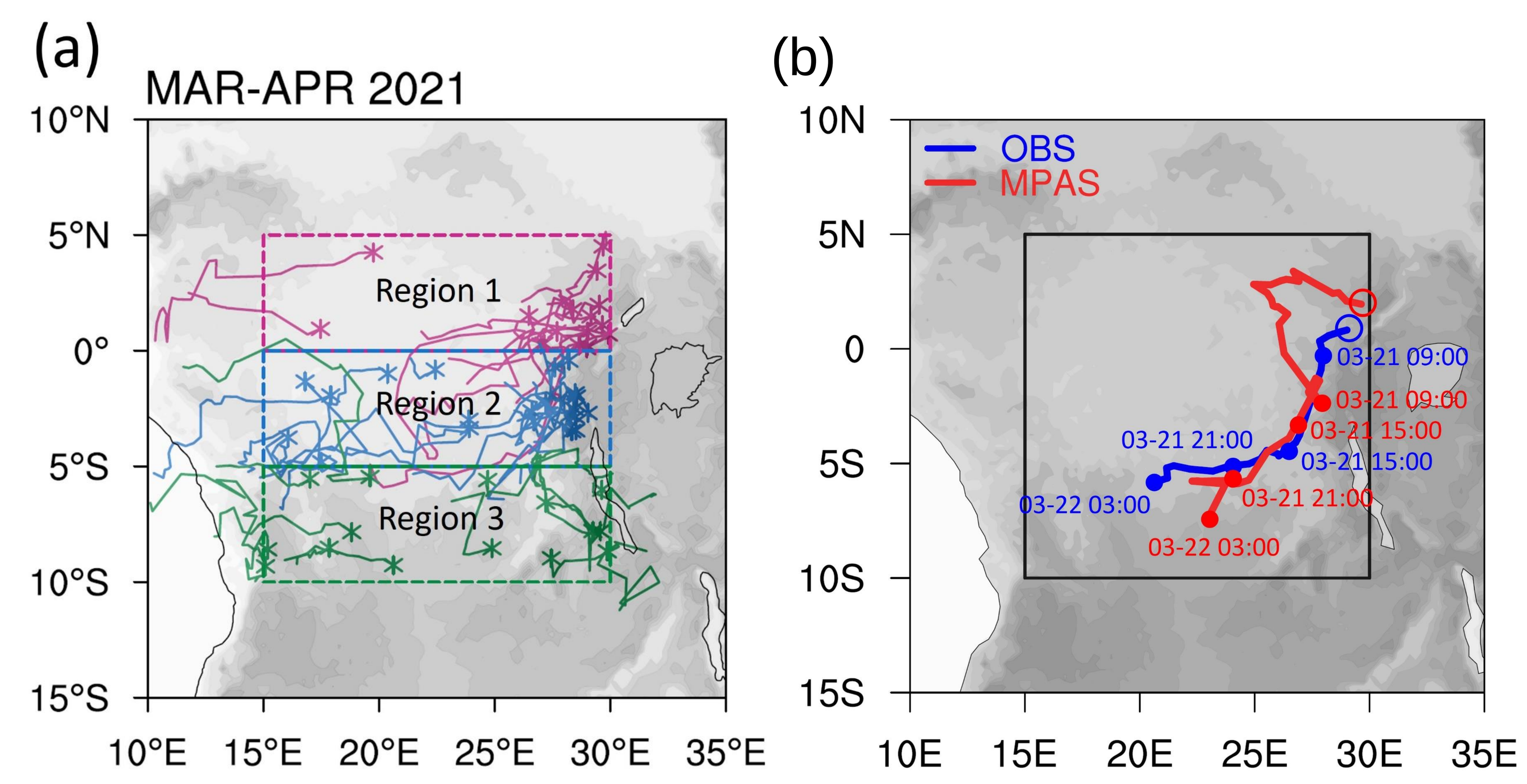

Figure 3. (a) Observed MCS tracks for March-April in 2021. Each line indicates individual MCS track with initial locations (marked by asterisk symbols) over each of the three latitudinally varying regions. (b) Comparison of MCS tracks for the period of 20-22 March 2021 between observation (blue) and MPAS simulation (red). The open circle is the initial location. The dots are locations of MCS centers for the listed timesteps.

- ✓ Meteorological conditions associated with MCS such as wind shears and African Easterly Jet (AEJ) are also well simulated by MPAS.

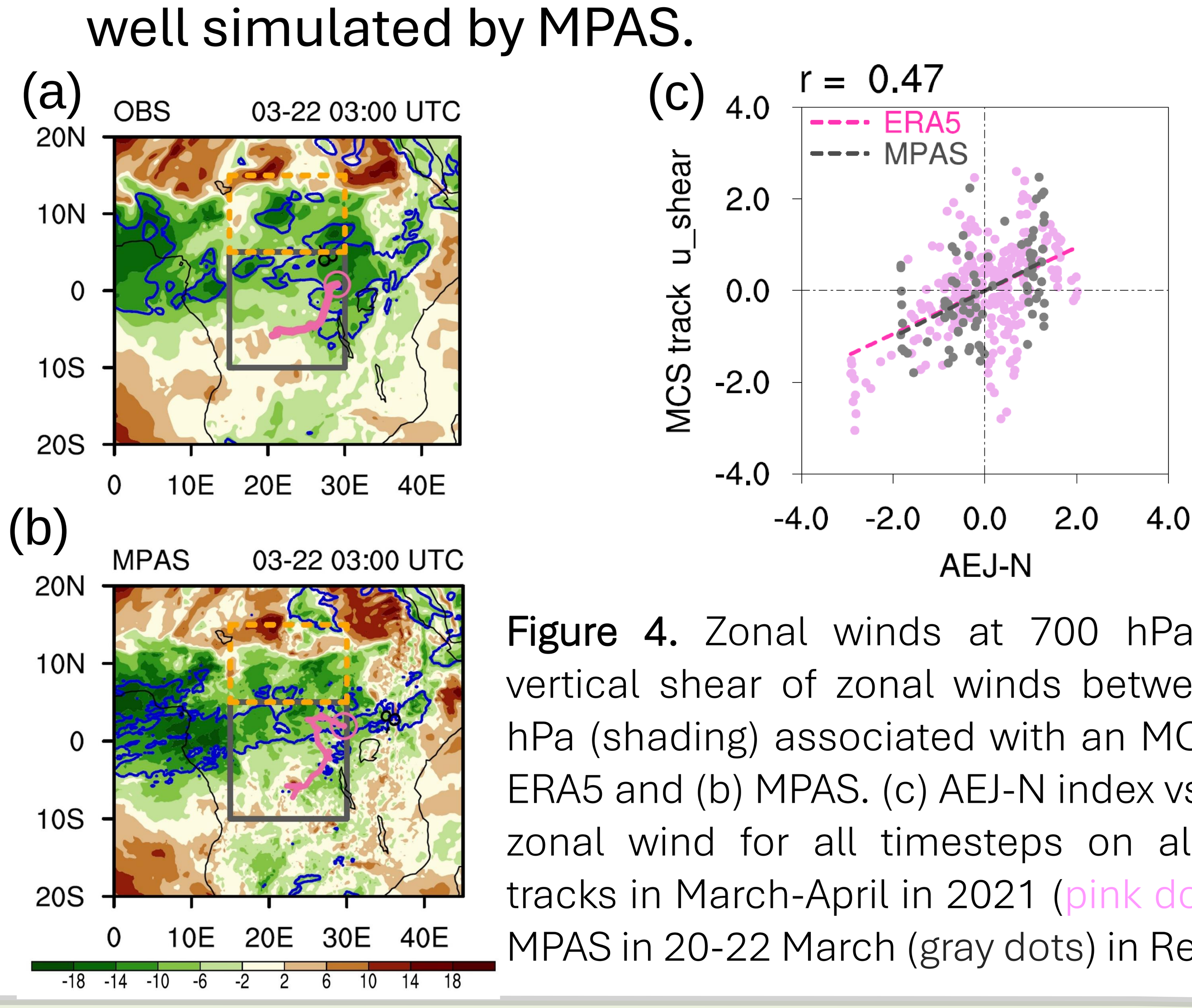

Figure 4. Zonal winds at 700 hPa (contours) and vertical shear of zonal winds between 700 and 925 hPa (shading) associated with an MCS track using (a) ERA5 and (b) MPAS. (c) AEJ-N index vs vertical shear of zonal wind for all timesteps on all observed MCS tracks in March-April in 2021 (pink dots) and those for MPAS in 20-22 March (gray dots) in Region 1 of Fig. 3a.

The role of atmospheric moisture in MCSs

- Lower-tropospheric moisture plays a more important role in the mountainous region (EXP1 vs EXP2).
- However, in lowland forests, the lower-tropospheric divergence and subsidence prevent lower-level moisture from reaching the mid-troposphere (EXP3 vs EXP4).
- ❖ A large portion of MCSs originate from mountainous regions because mountain-valley breezes can lift moisture-rich air in the lower-troposphere and supply ample latent energy to MCSs.

Experiments	Altering WVMR	Altering regions in Figure 5 (i.e., E1 and E2)
EXP1	1000-700 hPa × 1.5	E1: 27.5°E-32.5°E, 0°-5°N (higher than 500 m elevation with a mixture of forests, croplands, and savannahs)
EXP2	650-450 hPa × 1.5	
EXP3	1000-700 hPa × 1.5	E2: 20°E-25°E, 5°S-0° (lower than 200 m elevation with forests only)
EXP4	650-450 hPa × 1.5	

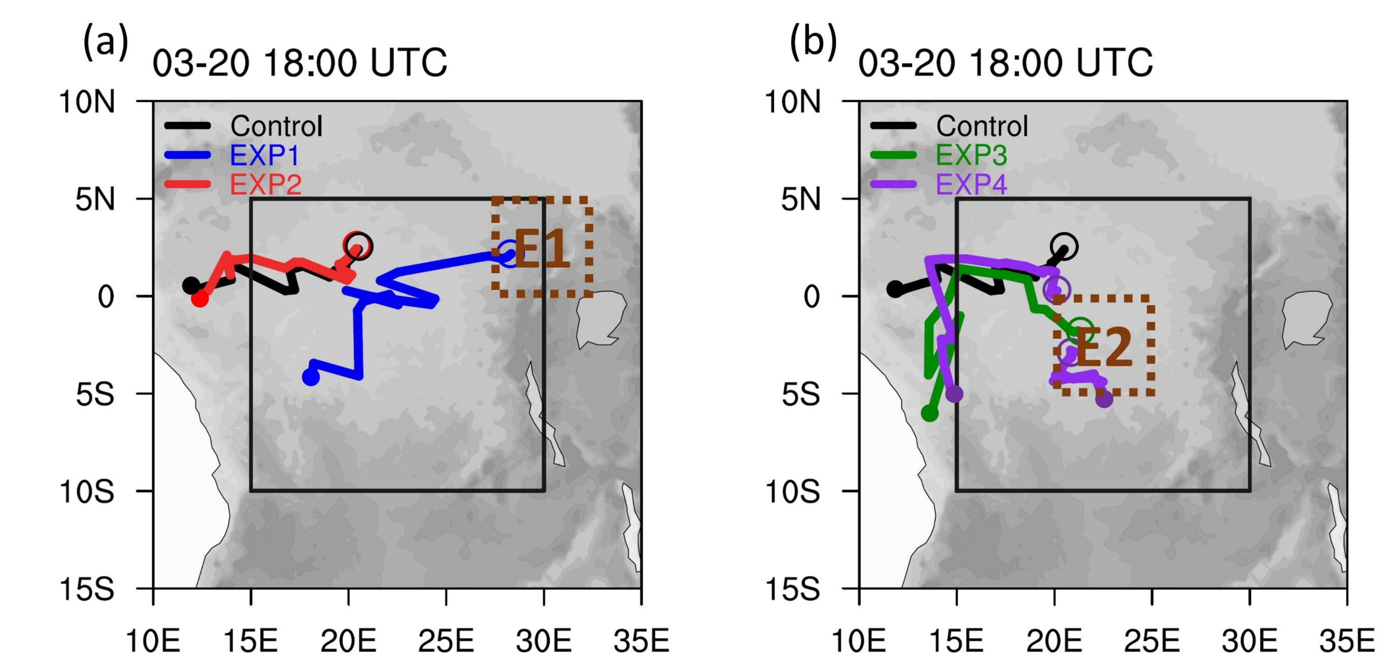

Figure 5. (a) MCS tracks for the control experiment, EXP1, and EXP2. The open circle is the initial location. The dot is the MCS center's location at 18:00 UTC on 20 March. The brown box denotes the region where water vapor mixing ratio (WVMR) is modified. (b) Same as (a), but for the control experiment, EXP3, and EXP4. Note that there are two MCS tracks for EXP4 (the purple lines).

Conclusions & Acknowledgments

- ✓ MPAS has ability to simulate MCSs and associated meteorological conditions over the Congo Basin.
- ✓ MPAS can be used to understand the role of atmospheric moisture in MCSs.
- ✓ MCSs originating from mountainous regions are possibly linked to lifted moisture-rich air in the lower-troposphere.

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