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Assessing Convective Parameterizations in RegCM5 for Simulating Extreme Rainfall over Egypt

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INTRODUCTION & AIM

❑ Introduction

Accurately predicting heavy rainfall remains a significant challenge in numerical weather prediction (NWP) due to the atmosphere's complex dynamics, uncertainties in model physics, and the difficulty of representing microphysical processes. In recent decades, Egypt—particularly its northern coast—has experienced several extreme precipitation events that exceeded expected intensities and caused substantial impacts. Heavy rainfall is one of the country's most hazardous weather phenomena, often leading to flash floods and considerable socioeconomic losses, especially in densely populated coastal cities such as Alexandria. Limited-area models, when properly configured, provide valuable tools for improving short-term rainfall forecasts. However, their performance is highly sensitive to the selection of convective parameterization schemes, which play a crucial role in capturing the structure, intensity, and timing of extreme precipitation events.

❑ Aim of the Study

This study aims to enhance the prediction of extreme rainfall events over Egypt using the ICTP Regional Climate Model version 5 (RegCM5) (Giorgi, et al. 2023). To identify the most suitable configuration for short-term forecasting, several convective parameterization schemes are tested and compared across multiple heavy rainfall cases. The goal is to determine the optimal setup for improving operational prediction of extreme rainfall in Egypt.

METHOD

Egypt's climate is largely arid, with most rainfall occurring along the northern Mediterranean coast. Alexandria, located west of the Nile Delta, experiences a milder Mediterranean climate and is more prone to winter storms and heavy rainfall.

For this reason, the analysis focuses on Alexandria, using four rain gauges in and around the city to evaluate the model's performance in capturing extreme precipitation.

❑ Model configuration

For an in-depth analysis of heavy rainfall events in Egypt, we employed the RegCM5 model. A comprehensive overview of the complete model configuration is detailed in the following Table

Parameter	Schemes
Meteorological field: Initial and Boundary conditions (ICBC)	ERA5 data with resolution of 1.5 degree downloaded from ICTP website (http://clima-dods.ictp.it/regcm4/ERA5/lowres_1.5/)
Dynamical Core	MM5 non-hydrostatic core.
Radiation scheme	CCM3 (Kiehl, 1996)
Large-Scale Clouds & Precipitation scheme	SUBEX (Pal et al., 2000)
Cumulus convection schemes over Ocean & Land	Emanuel (1994) Grell (1993) Kain-Fritch (1990), Kain (2004) Titdke (1996)
Boundary Layer scheme	Modified Holtslag (Holtslag, 1990)
Land Surface model	BATS (Dickinson et al., 1993)
Center latitude & Center longitude Number of points N/S Number of points E/W Projection Horizontal resolution Vertical resolution	28.50 N & 31.00 E 340 370 Lambert Conformal 5 km x 5 km 18 sigma-layers

❑ Case study

We carefully selected several significant heavy rainfall events that have profoundly impacted Alexandira for simulation. Each case was chosen based on its severity, the availability of reliable ground observations or Satellite data, and its representation of diverse meteorological conditions.

(22-24 October 2019, 11-13 March 2020, and 19-22 November 2021)

❑ Verification Data

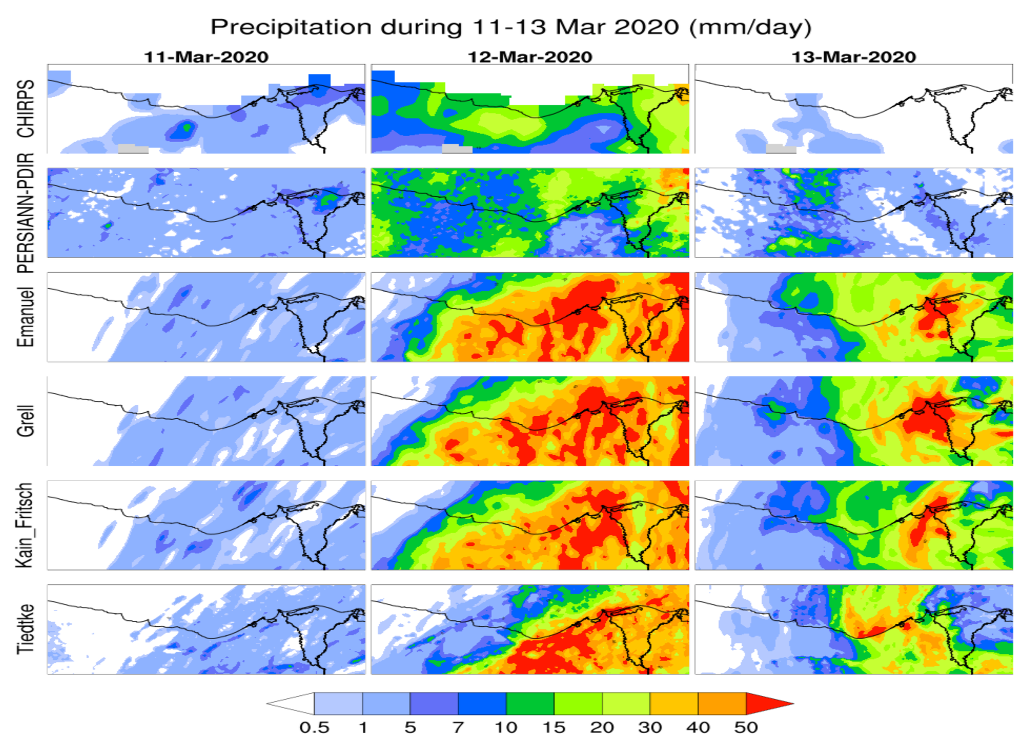
To rigorously evaluate the performance of the model, we compared the simulated rainfall against daily rainfall from different sources including:

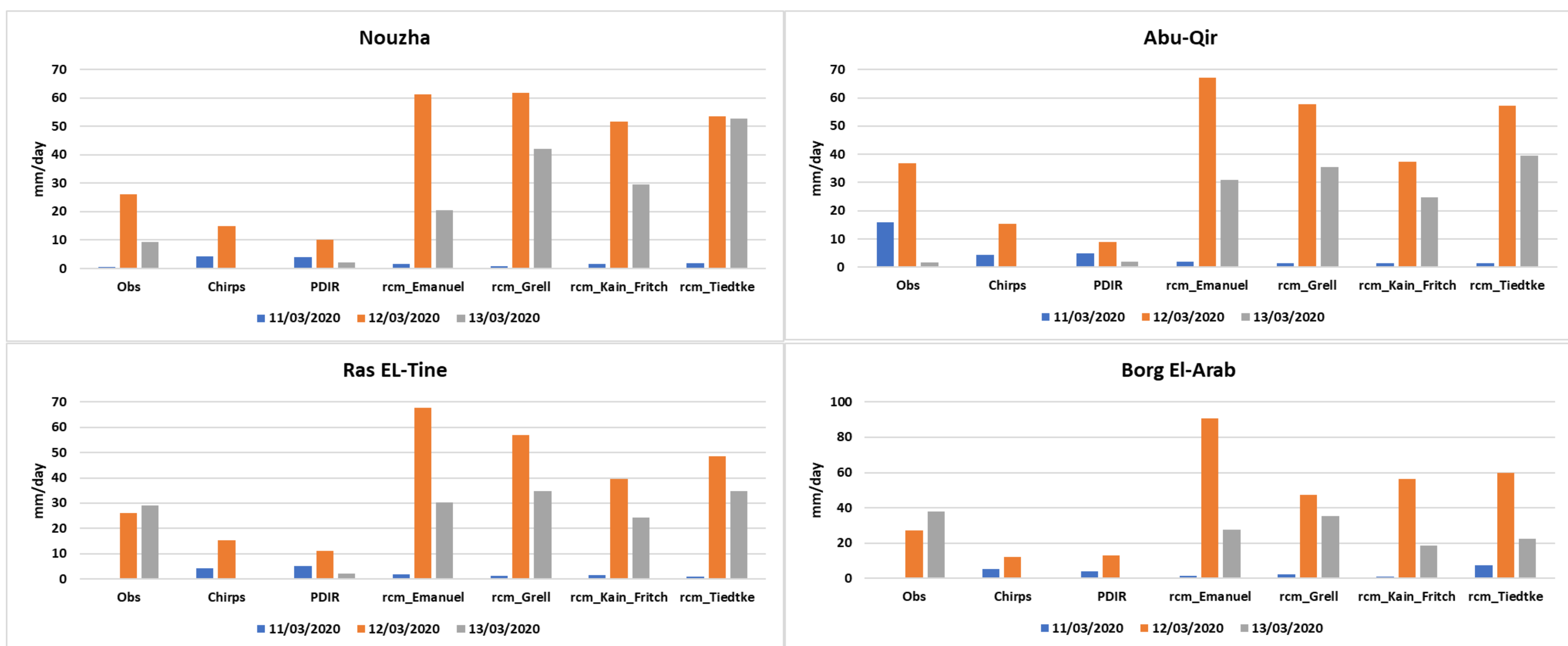
- **Ground station observations:** Rainfall measurements from four rain gauges in Alexandria (Nouzha, Abu-Qir, Ras El-Tine, Borg El-Arab)
- **Satellite-based datasets:**
  - **CHIRPS** (Climate Hazards Group InfraRed Precipitation with Station Data) with 0.05° spatial resolution (available on: https://www.chc.ucsb.edu/data/chirps)
  - **PERSIANN-PDIR-Now** (Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks – Precipitation During Intense Rainfall-Now), with 0.04° × 0.04° spatial resolution (available on: https://chrsdata.eng.uci.edu/)

RESULTS & DISCUSSION

This figure compares daily precipitation (mm/day) from 11-13 March 2020 using satellite products (CHIRPS and PERSIANN-PDIR) and different convective schemes (Emanuel, Grell, Kain-Fritsch, Tiedtke).

On 12 March 2020, all datasets and schemes show the most intense and widespread rainfall, with PERSIANN-PDIR capturing it more accurately than CHIRPS. All convection schemes simulate heavy rainfall, with Grell and Kain-Fritsch matching PERSIANN most closely.





The figures show daily rainfall at each station, confirming 12 March 2020 as the wettest day. CHIRPS and PDIR underestimate the event, while Emanuel and Grell overestimate it and Kain-Fritsch and Tiedtke perform closer to observations. Borg El-Arab recorded the highest rainfall, with models capturing the timing but exaggerating the intensity.

The Correlation coefficient between the different convection schemes and the available observations from the ground stations for 3 cases (October 2019, March 2020 and November 2021).

	Nouzha	ABU-QIR	RAS-ELTINE	BORG-ELARAB
Emanuel	0.26	0.58	0.58	0.58
Grell	0.91	0.69	0.69	0.69
Kain_Fritch	0.78	0.83	0.83	0.83
Tiedtke	0.44	0.59	0.59	0.59

Mean Bias between the different convection schemes and the available observations from the ground stations for 3 cases (October 2019, March 2020 and November 2021).

	Nouzha	ABU-QIR	RAS-ELTINE	BORG-ELARAB
Emanuel	-7.00	-0.46	-2.51	-4.29
Grell	14.42	9.43	5.56	7.45
Kain_Fritch	2.56	-2.75	-6.44	5.28
Tiedtke	-0.09	0.16	-3.82	-1.05

CONCLUSION

Evaluation of RegCM5 convection schemes for Alexandria's heavy rainfall events shows clear differences in performance. Grell has the highest correlation with observations but strongly overestimates rainfall, while Kain-Fritsch combines high correlation with moderate bias, providing the best overall balance. Tiedtke has low bias but slightly lower correlation, and Emanuel shows low correlation and inconsistent bias.

Overall, Kain-Fritsch is the most reliable scheme for short-term forecasting of extreme rainfall, with Grell useful when timing and spatial patterns are critical but amounts are less important.

FUTURE WORK / REFERENCES

❑ Future work:

The work will expand testing to multiple regions in Egypt, apply more comprehensive statistical analyses, and evaluate how different convection schemes affect other variables like temperature, wind speed, and cloud cover.

❑ Main Reference:

Giorgi, F., Coppola, E., Giuliani, G., Ciarlo`, J. M., Pichelli, E., Nogherotto, R., et al. (2023). The fifth generation regional climate modeling system, RegCM5: Description and illustrative examples at parameterized convection and convection-permitting resolutions. *Journal of Geophysical Research: Atmospheres*, 128, e2022JD038199. https://doi.org/10.1029/2022JD038199