Everyday there are five key things an operational forecaster wants to know

- Will it Rain
- How will it Rain
- When will it Rain
- Where Would It Rain
- Will the Rain Be Heavy

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- Where Would It Rain
- **Will the Rain Be Heavy**

Enhancing Heavy Rainfall Forecasting in High-Resolution Regional Models Over West Africa for Operational Application.

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Basic Aim and Objective

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- This research aims to reduce environmental hazards to vulnerable West African last-mile communities by improving heavy rainfall predictions from a high resolution regional model.

- To develop an improved heavy rainfall forecasting tool using machine learning techniques in West Africa.

PREVIOUS STUDY

Previous Findings

Olaniyan et al 2022 (RMetS Met Application)

(DOI: 10.1002/met.2080)

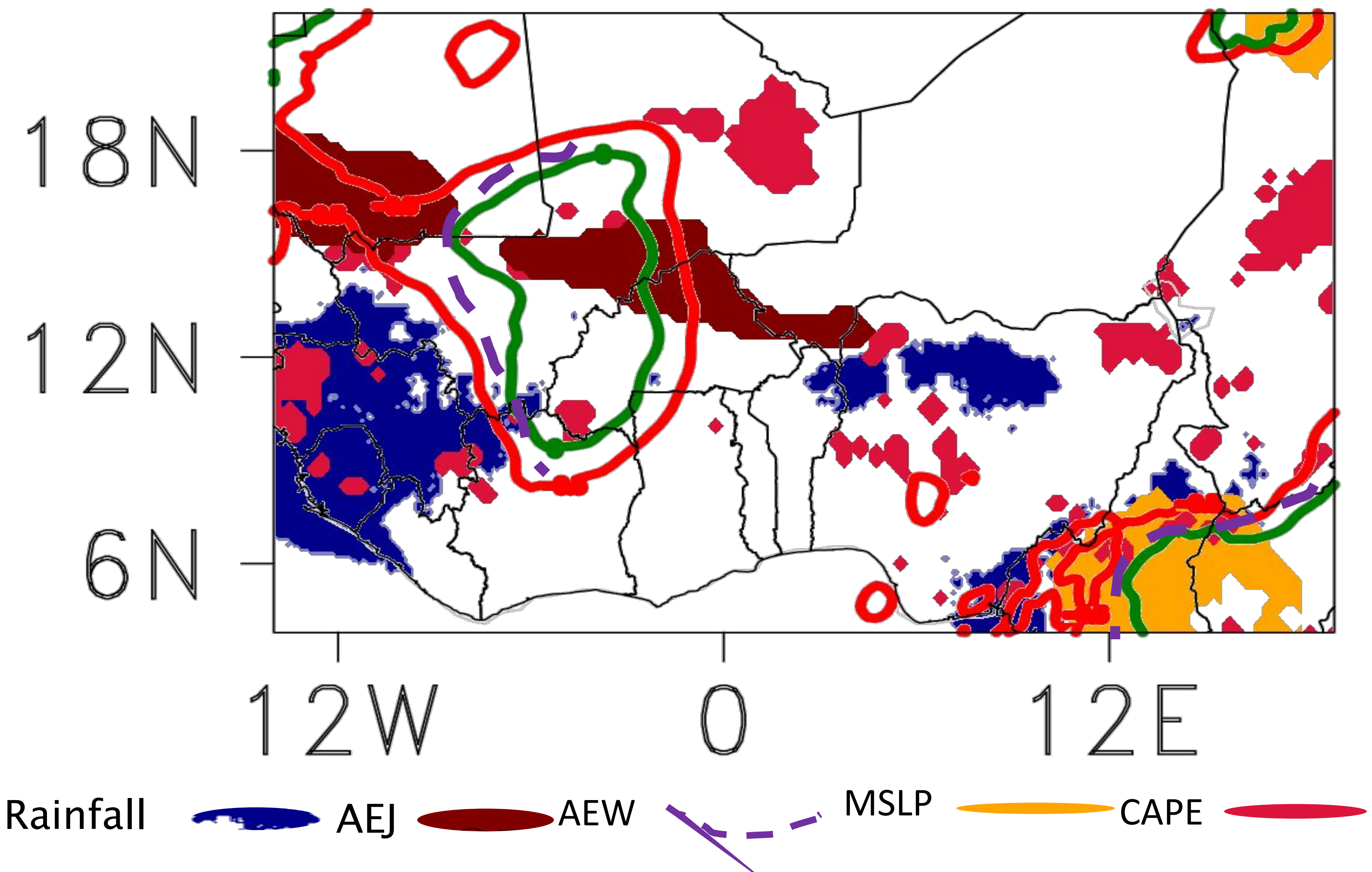

Figure depicting the climatology of the interactions of synoptic drivers with areas of heavy rainfall (GPM-IMERG) over West Africa in August.

We found out that:

- Areas of heavy rainfall, are mostly about 100–300 km southwest of the core of the AEJ.
- That they often coincide with areas of decreasing mean sea level pressure and
- Areas of increasing convective available potential energy.
- We show that not every storm, especially east of the prime meridian, is associated with an AEW trough.

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Previous Findings
Olaniyan et al 2022
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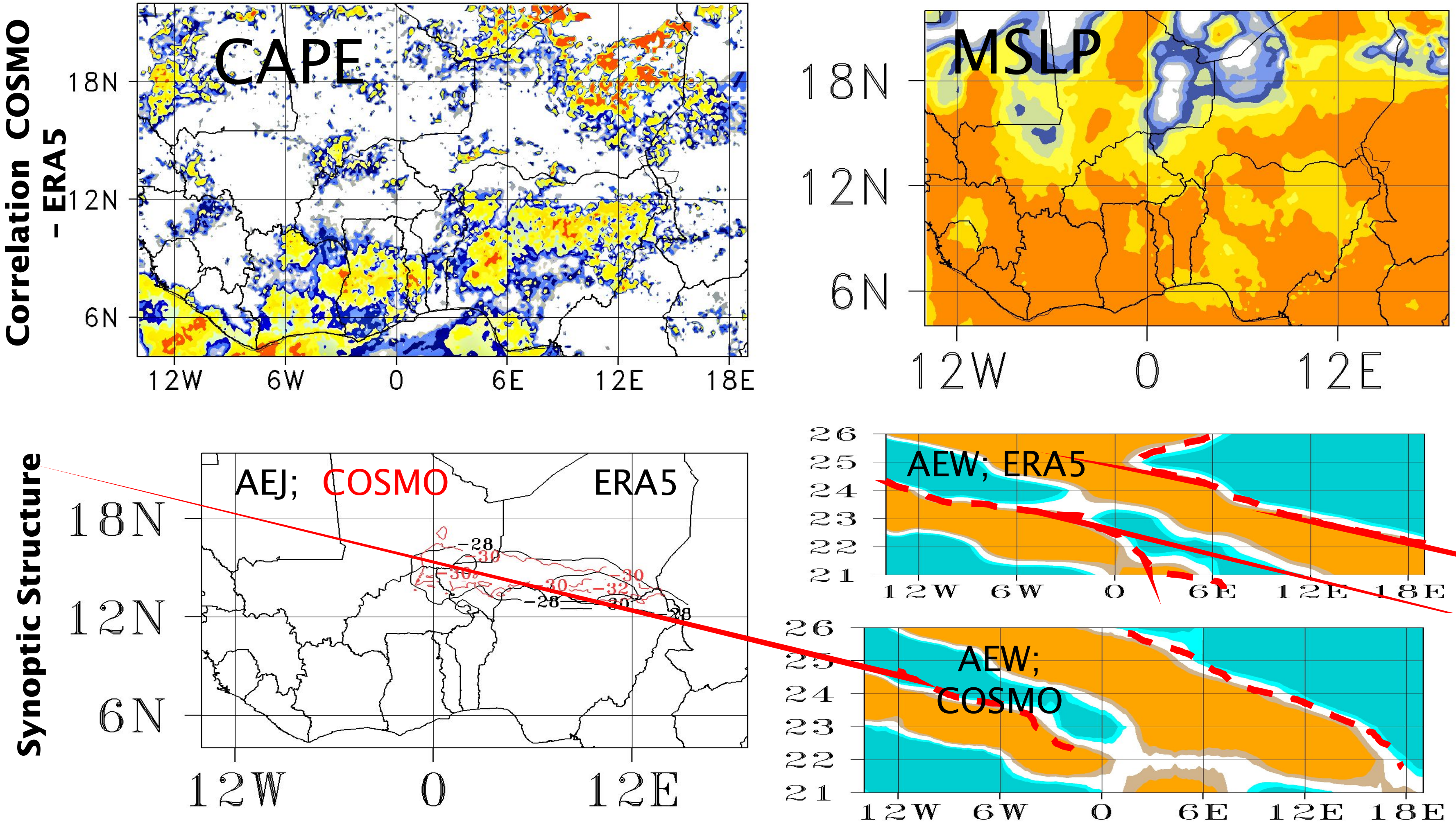

- **COSMO is able to reproduce the atmospheric dynamics modulating.**
- **We showed that the reproducibility skill of the model in predicting atmospheric dynamics may not transform into the predictive skill of the model in producing heavy rainfall.**
- **We suggested that, operational forecasters may be able to determine likely areas of heavy rainfall by estimating the positions of the dynamic variables in COSMO.**

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NOW

- If our conclusion is that, forecasters may determine likely areas of heavy rainfall by estimating the position of the AEJ core based on the position of areas of the least falling pressure from COSMO.

Then, the questions will be:

1. Is it possible to develop a method or technique for detecting similar patterns of synoptic features as the COSMO model in the historical observed records?

2. Can we use these identified similar patterns to predict areas with intense rainfall?

3. If this approach proves effective, to what degree can we expect the accuracy and skilfulness of this innovative rainfall forecasting method?

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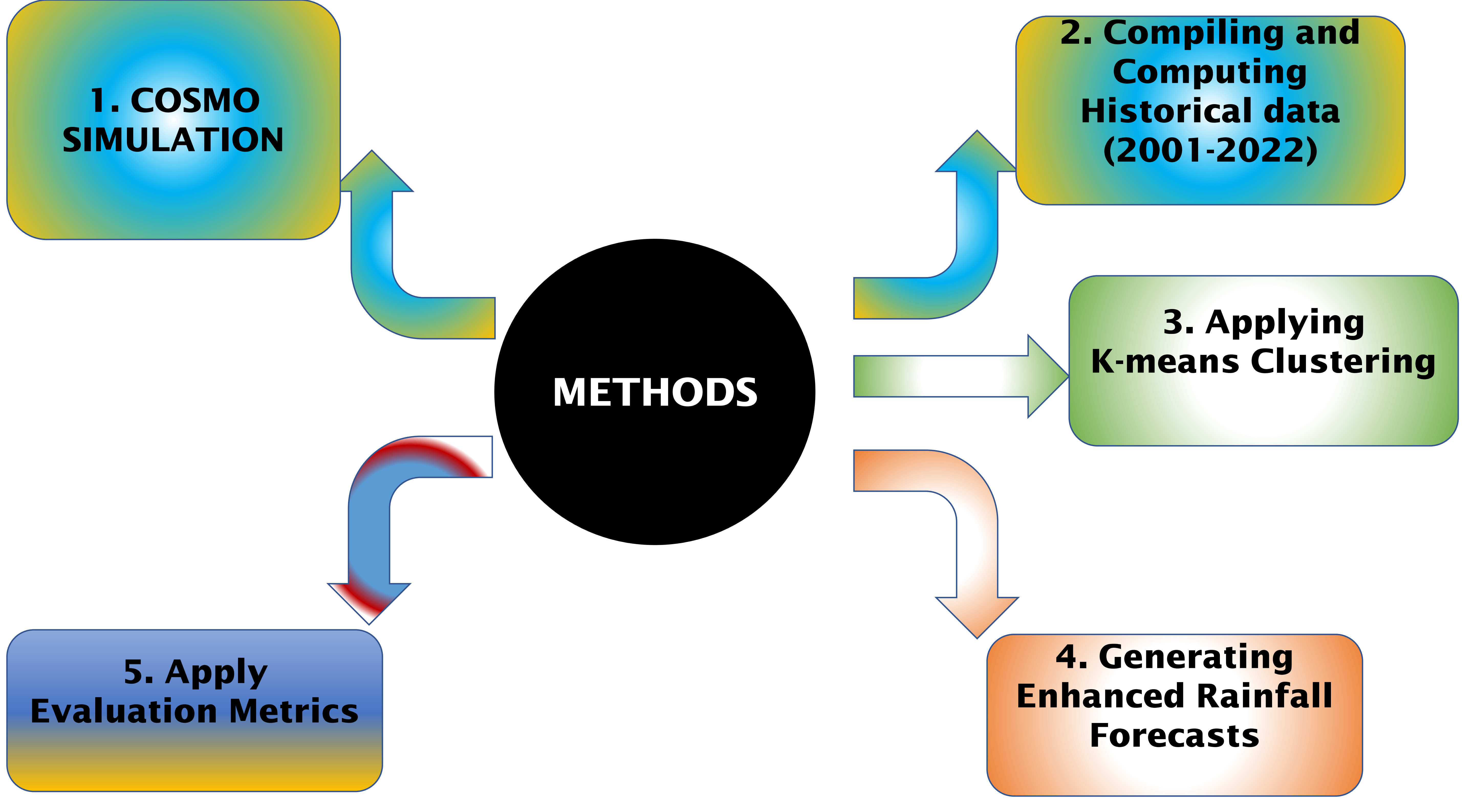
Data Summary

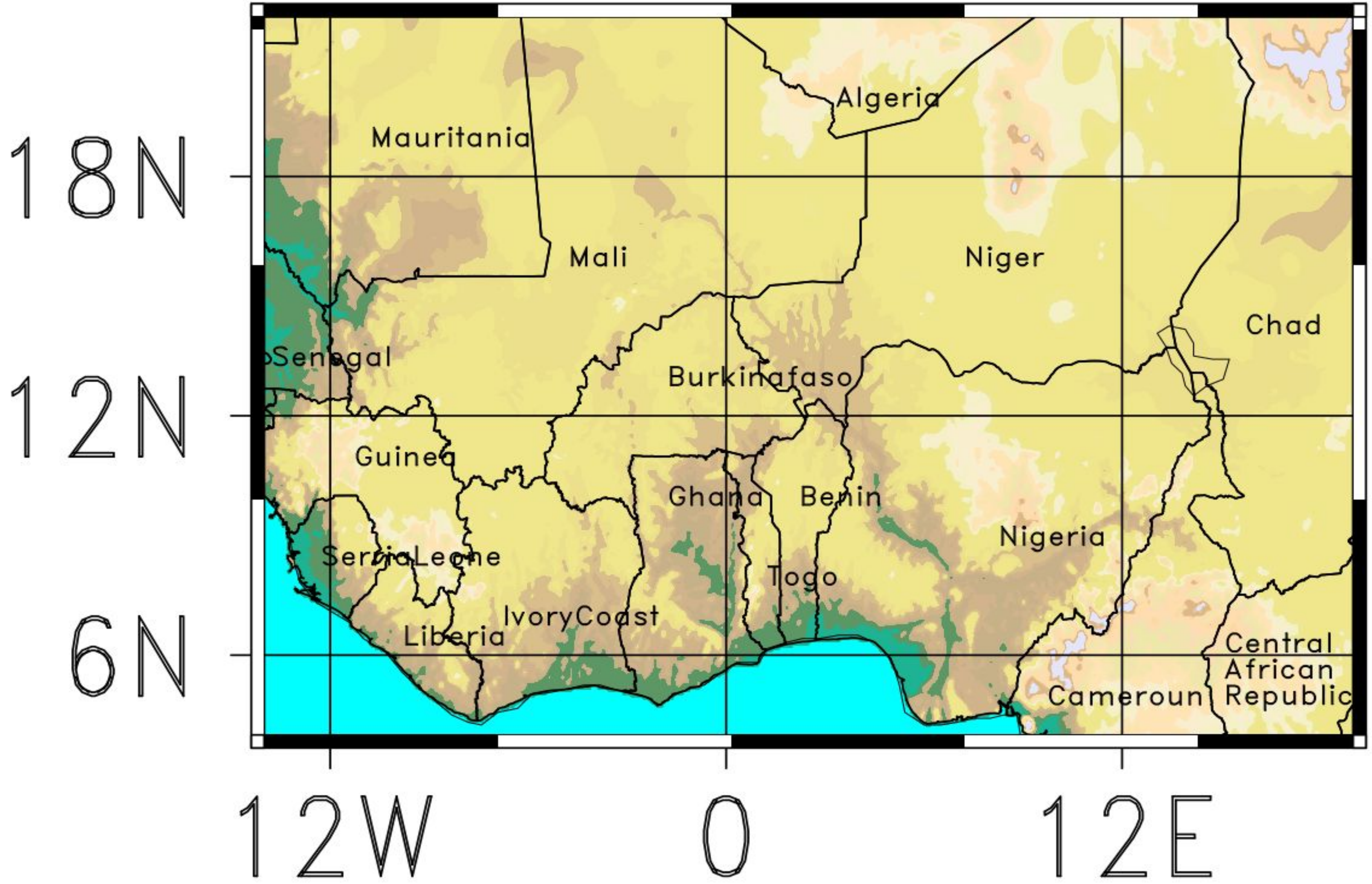
Three sources of dataset are used to carry out this study

Data	Variable	Source	Month	Year	Periods
ERA-5	MSLP CAPE WIND (600mb)	ECMWF	August	2001-2022	daily
Satellite	Rainfall	GPM-IMER GE	August	2001-2022	daily
Simulation	Rainfall MSLP CAPE WIND	COSMO	August	2015-2022	20,2015,17, 2016, 21, 2017, 17, 2018, 09, 2019, 12,2021,08, 2022


1. COSMO SIMULATION
2. Compiling and Computing Historical data (2001-2022)
METHODS
3. Applying K-means Clustering
4. Generating Enhanced Rainfall Forecasts
5. Apply Evaluation Metrics

1. COSMO SIMULATION

COSMO-(Model Setup)



COSMO-Model Configuration

Start lon -14ºE Number of grid along X = 529

Start lat 3ºN Number of grid along Y = 305

Forecast time 60hours
Time-step = 3hours

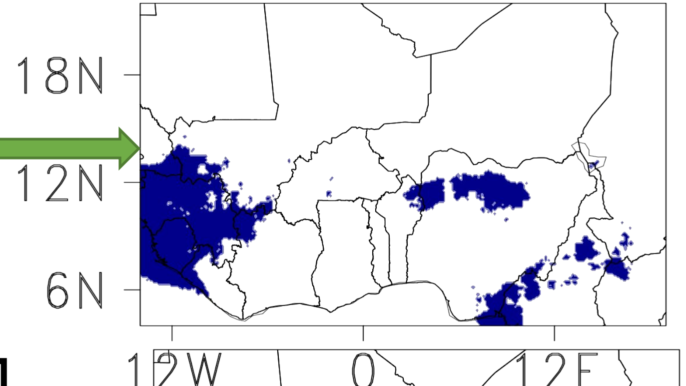
Total simulation time 10hours

2. COMPUTING HISTORICAL DATA

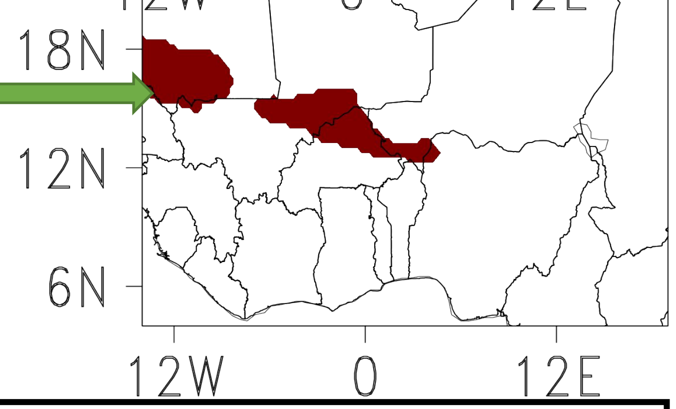
Method contd…. Computing Historical data

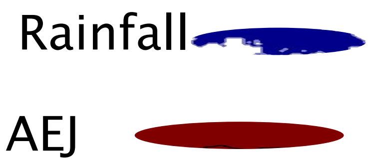
The computation of binary values for four synoptic variables that define conditions conducive for heavy rainfall is carried out.

1. Rainfall amounts equal to or greater than the 90th percentile signifies heavy rainfall.

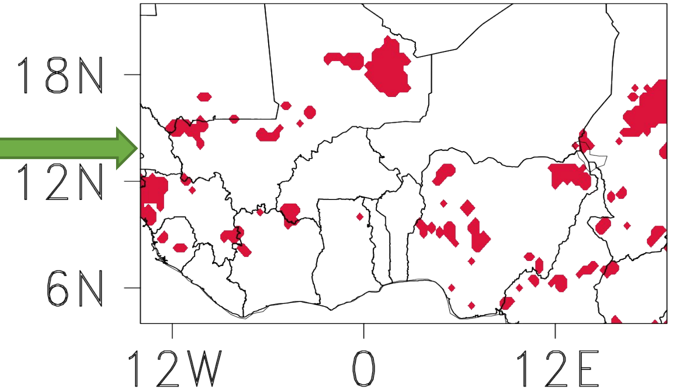


2. Zonal wind at 600mb equal or exceeding the 95th percentile signifies the axis and the core of the AEJ

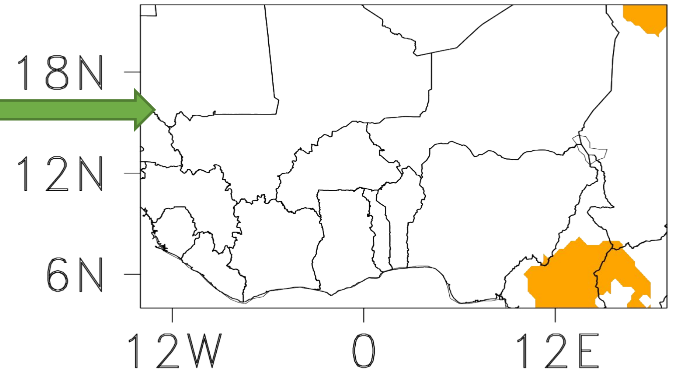




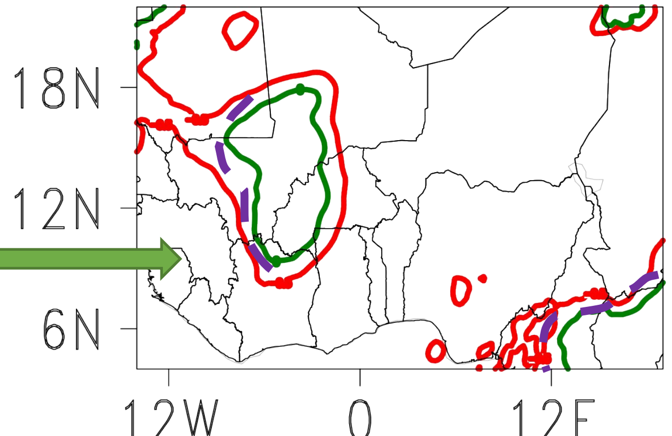
3. The cape tendency equal or surpassing the 95th percentile indicates most rising CAPE.

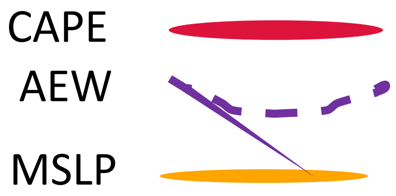


4. Pressure tendency falling below the 5th percentile, suggesting the least falling MSLP



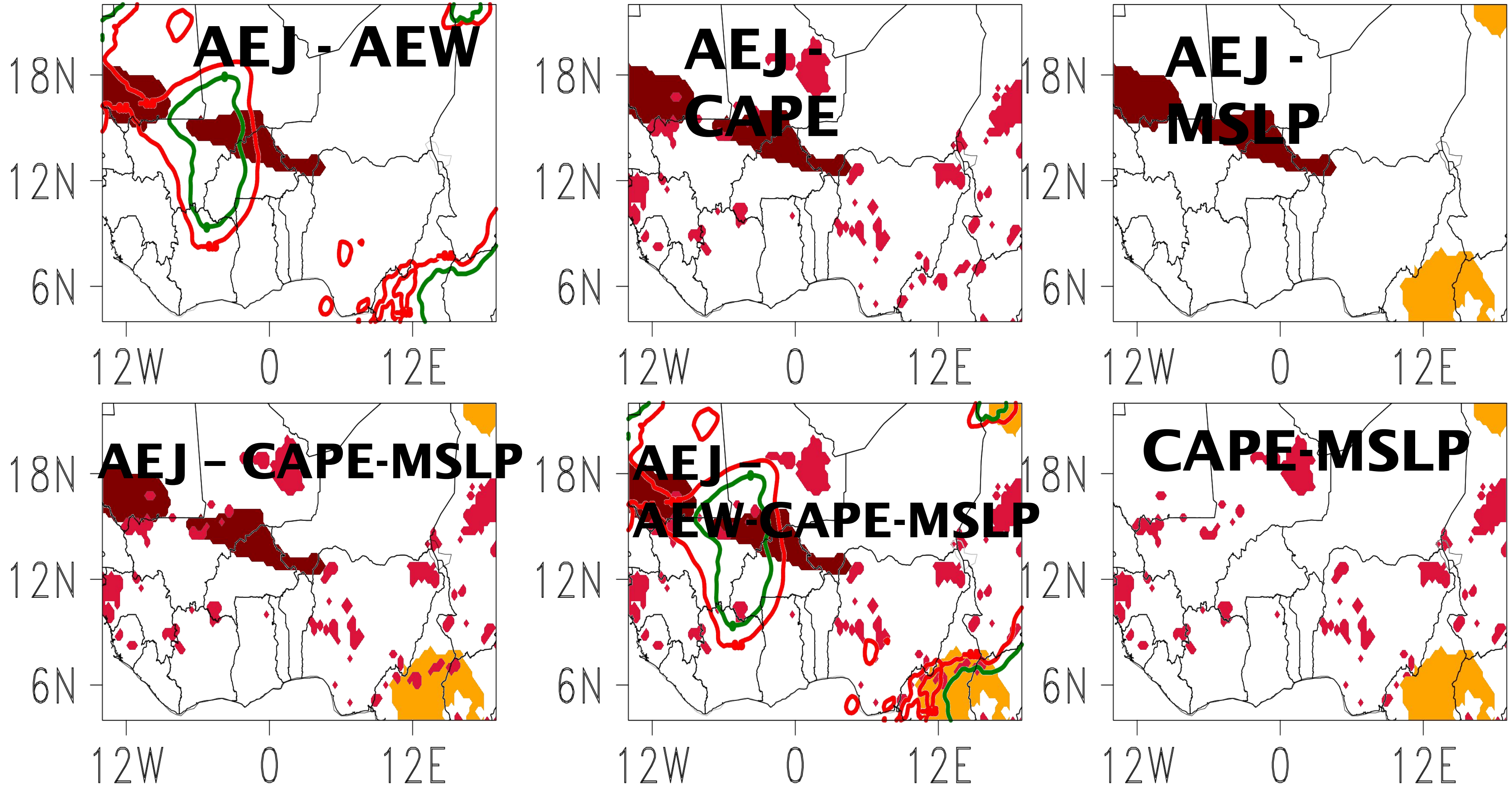
5. Meridional wind between -5 and 0 m/s is considered to identify the African Easterly Wave (AEW) trough





Method contd…. Computing Historical data

We now overlaid each synoptic variable map with each other as follows to have another 6 synoptic variants:



Key Points:
This corresponds to 690 of each synoptic variable pattern 22 years including from COSMO 8 case Simulation.

This now served as input data for the machine learning clustering application .

3. APPLYING K-MEANS CLUSTERING

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Method (Clustering)

We employed the use K-means clustering in this study.

- It is an **unsupervised machine learning** that requires no data labelled for training.
- It uses pattern recognition technique due to its ability to discover patterns.
- This it does by grouping similar pixels or signal components images and processes into groups or clusters.
- To ensure the effectiveness of the clustering process, we employ the elbow method to identify the optimal number of clusters.

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Method (Clustering)

Synoptic Clustered	Years in Cluster	Number
AEJ	2015 - 2022	8
AEW	2015 - 2022	8
MSLP	2015 -2022	8
AEJ-AEW	2015 - 2022	8
AEJ-AEW-CAPE-MSLP	2015 - 2022	8
CAPE-MSLP	2015 - 2022	8
AEJ-CAPE	2015 – 2018 2020 - 2021	6
CAPE	2016 – 2018; 2021	4

4. GENERATING ENHANCED RAINFALL FORECASTS

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Method (Generating Enhanced Rainfall Forecasts)

Several level of techniques are then applied to determine the enhanced rainfall forecasts:

1. An algorithm methodically searches through the cluster groups (individual and overlayed synoptic pattern),

2. Identifies the group containing the COSMO case study under consideration.

3. Following the identification, the corresponding, dates (excluding the simulated days) from the rainfall data that align with the identified group are extracted.

4. An ensemble mean is computed, treating each rainy day's data as an ensemble member.

5. A binary representation of these forecasts based on rainfall accumulation equal to or exceeding the 90th percentile is then computed.

6. This refined binary pattern serves as the enhanced rainfall forecast stemming from each of the synoptic clustering processes.

7. Lastly, two probabilistic forecasts are generated by combining all the derived synoptic clustering outcomes and all synoptic clustering with COSMO.

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5. EVALUATION METRICS

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Methods Evaluation Metrics

To assess the qualitative attribute of the enhanced rainfall forecast, we used 2 evaluation metrics applied over West Africa (W.Africa; Lat 4 – 18ºN, Long - 14ºW – 15ºE),
West of prime meridian (W.Meridian; Lat 4 – 18ºN, Long - 14ºW – 0ºE), and East of prime meridian (E.Meridian; Lat 4 – 18ºN, Long - 0º – 15ºE),

The pearson correlation coefficient (r) (to determine the linear association of the forecasts with the observation)

and Fractions Skill Score (FSS) (to indicate at what spatial area is the forecasts reliable)

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Results Eyeball

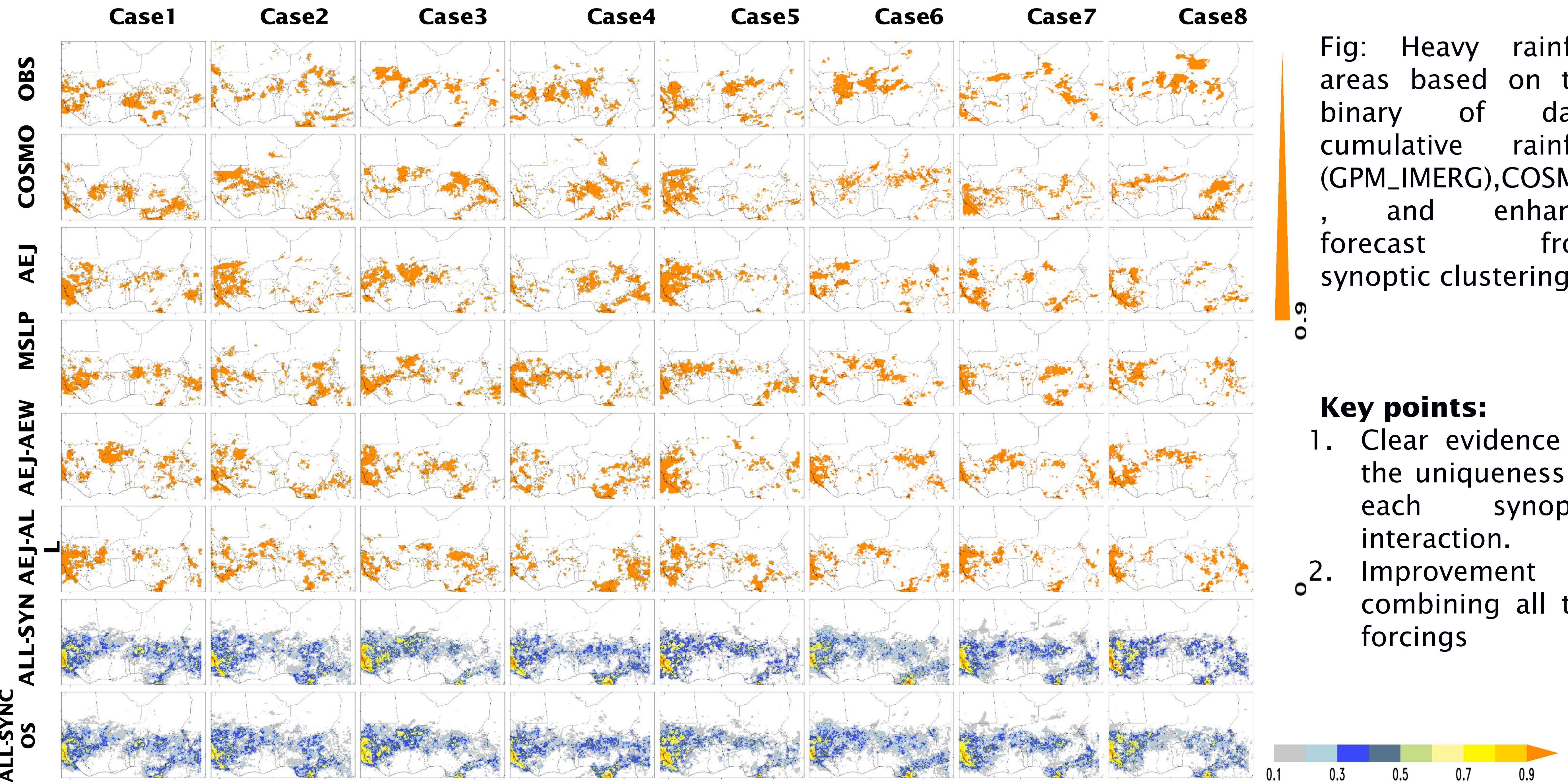

Fig: Heavy rainfall areas based on the binary of daily cumulative rainfall (GPM_IMERG),COSMO , and enhance forecast from synoptic clustering.

Key points:

1. Clear evidence of the uniqueness of each synoptic interaction.
2. Improvement in combining all the forcings

Results…Correlation

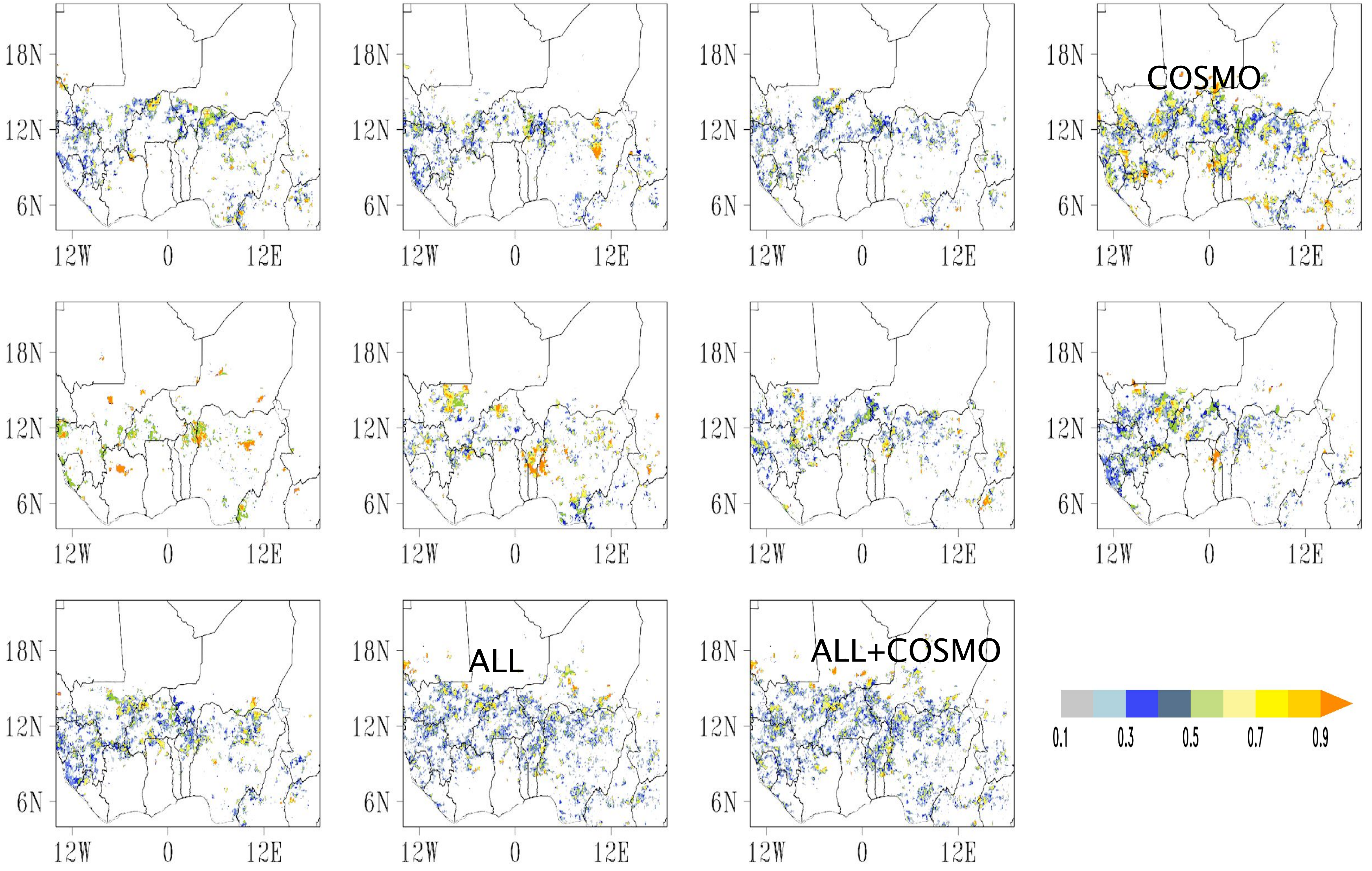

Fig. Correlation between Observed, COSMO and the enhance rainfall forecast from synoptic clustering.

Key points:

1. The association of the forecast from each synoptic interaction as compared to COSMO defers over each region.
2. Better over west of meridian.
3. Improved with all synoptics over the East

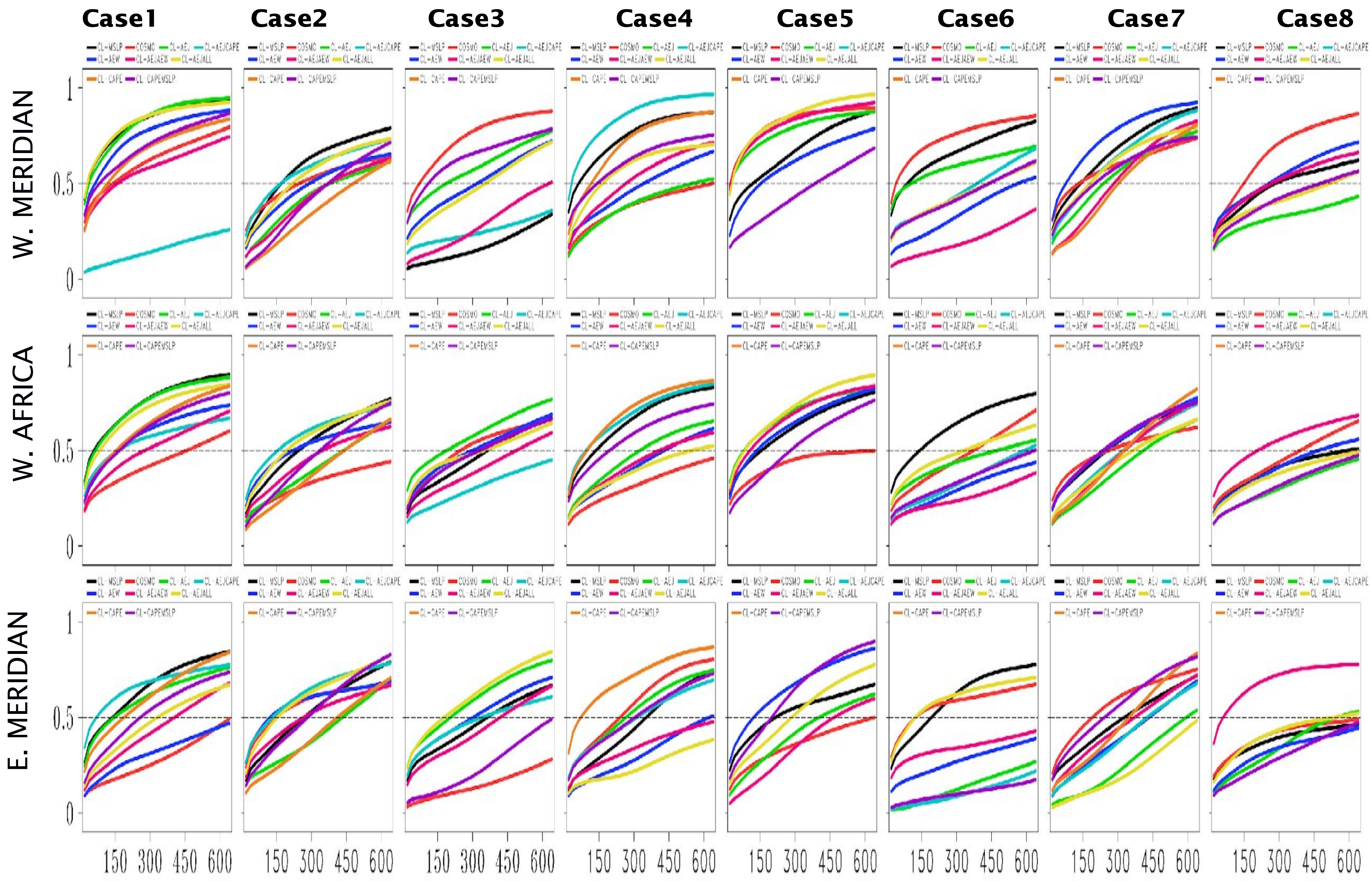

Fig: Fractions Skill Score (FSS) for neighbourhood sizes from 10 to 650km, over West Africa, East of prime meridian, and West of prime meridian.

Key points:

1. The spatial scale at which each synoptic clustering are reliable defers.
2. Most synoptic clustering W.Meridian show smaller reliability scale as compare to the East.
3. AEW showed the best reliability scale in case4 even when it has no reliability scale in case1

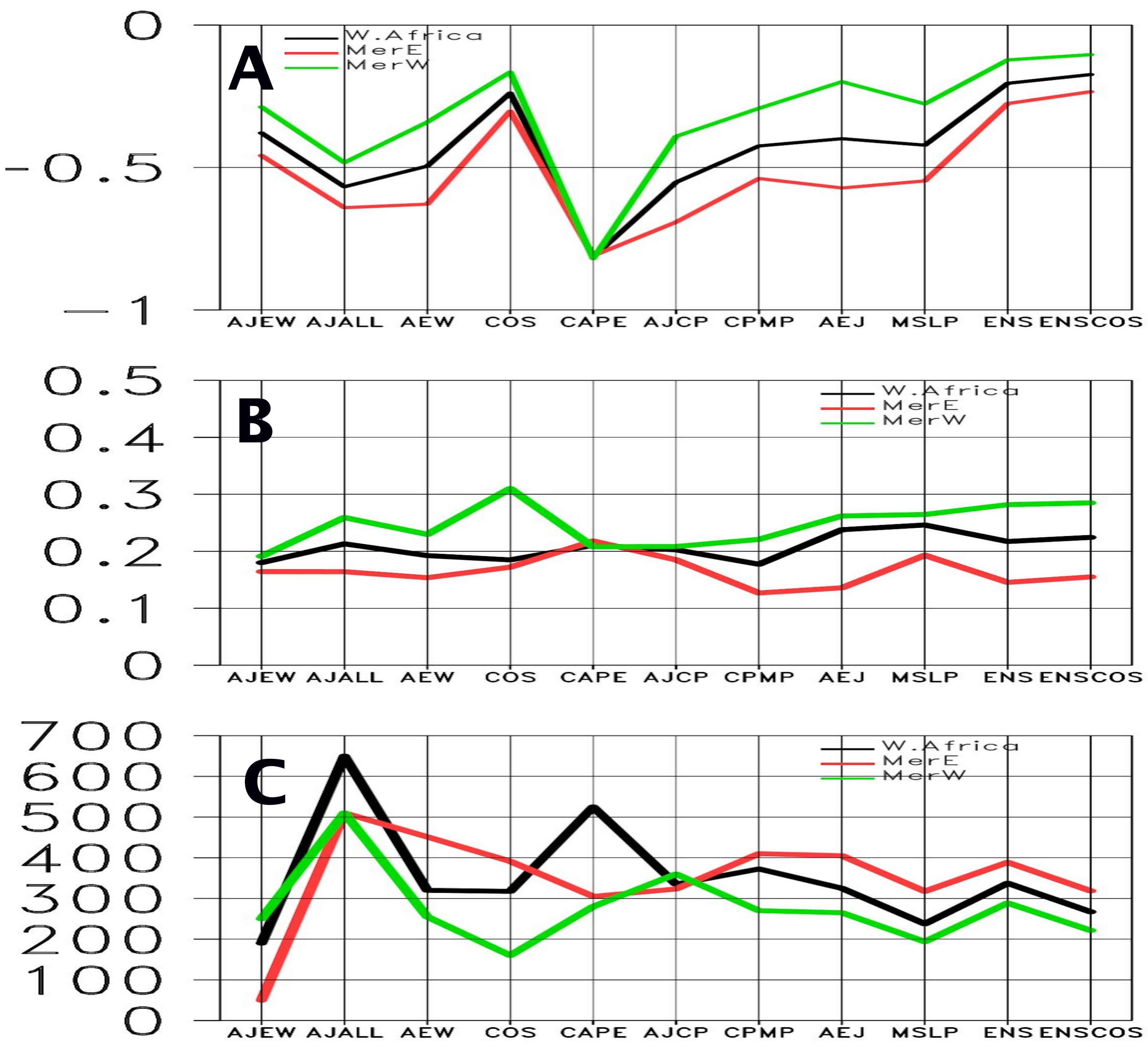

Fig: Analysis of Correlation (A) and Fractions Skill Score (FSS) for 10km neighbourhood size (B) between individual synoptic clusters, the ensemble, COSMO model, and GPM_IMERG observations, as well as the neighbourhood size at FSS equal to 0.5 (C) for all case studies.

Key points:

1. West of prime meridian show the strongest correlation, FSS at 10km and highest spatial resolution where FSS is 0.5.
2. Correlation from the ensemble of all synoptics with cosmo is the strongest
3. COSMO displays better scale at 10km scale.
4. However, the clustering of AE-AEW showed the highest scale of FSS=0.

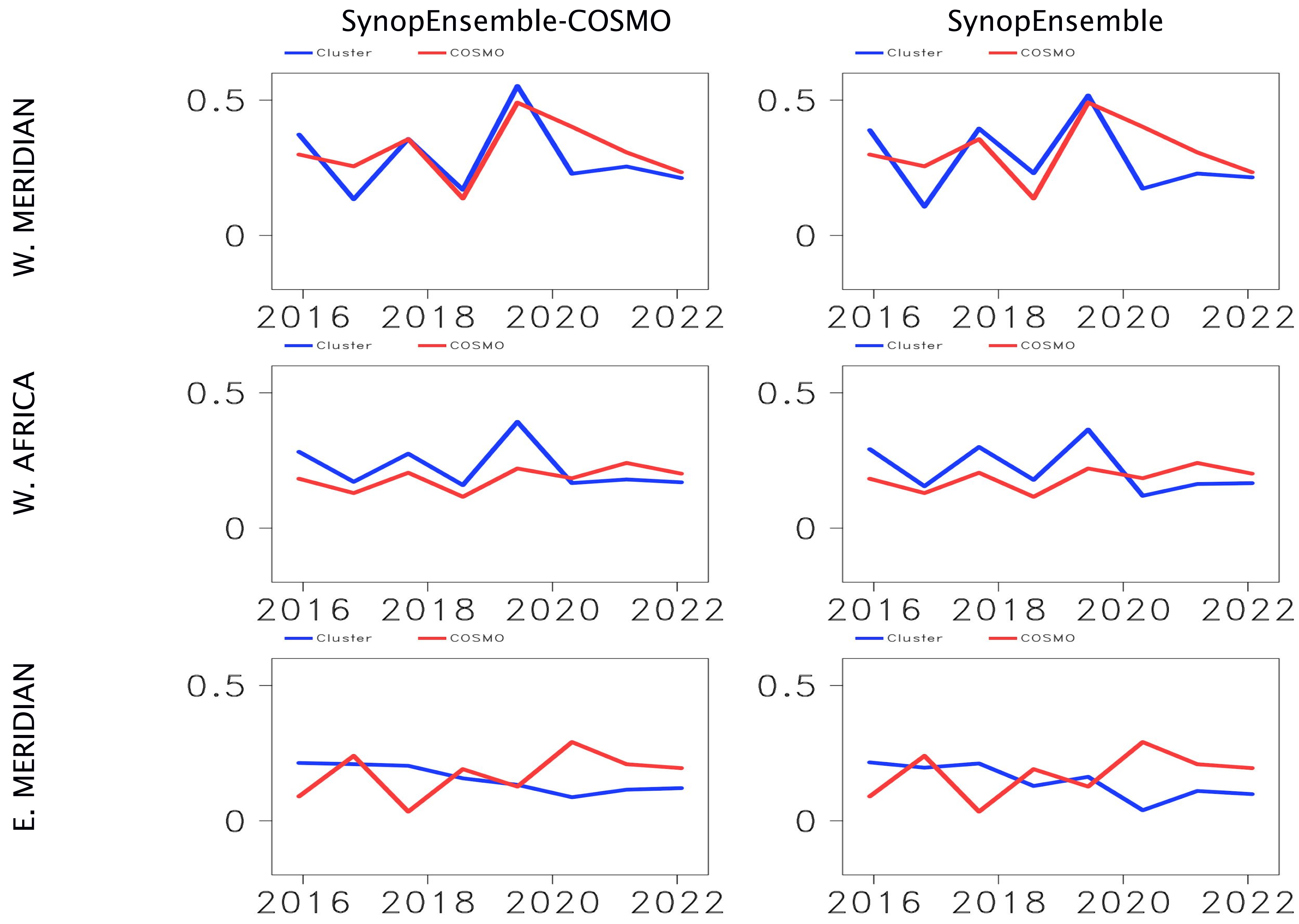

Fig: Analysis of yearly Fractions Skill Score (FSS) for 10km neighbourhood size from clustering of ensemble of all synoptics, the ensemble of all synoptics with cosmo (blue) and the COSMO (red).

Key Points:

1. Both display close skill throughout the case periods particularly West of the meridian

2. However the clustering generally show better skill in West Africa.

PRELIMINARY OF RESULTS SUMMARY

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- The results indicate that, regardless of the specific weather event, each synoptic clustering procedure generates unique rainfall forecast attributes.
- The generated probability forecasts capture the observed spatial distribution of heavy rainfall over West Africa, particularly west of the prime meridian.
- Although the correlation with the COSMO model is generally high, the combined clustered forecast demonstrates a stronger correlation
- The FSS from the ensemble of all synoptic clusters is stronger West of the prime meridian than COSMO, and any individual synoptic cluster at a neighbourhood size of 10km.
- Although, both COSMO and the clustering system may display close skill throughout the case periods particularly West of the meridian
- However the clustering generally show better skill in West Africa.

- Finally this study alights on the unique characteristics of synoptic clustering in enhancing rainfall forecasts by employing unsupervised machine learning technique.

We Thank DWD for Providing the Initial data.

The Nigerian Meteorological Agency and The African Aviation And Aerospace University for partly funding this trip.

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THANK YOU FOR YOUR ATTENTION

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