

Performance Evaluation of Real-Time Sub-seasonal (S2S) Rainfall Forecasts Over West Africa of 2020 and 2021 Monsoon Seasons for Operational use.

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Basic Aim and Objective

This research aims to provide a scientific understanding of S2S prediction in West Africa, which will be required to provide real-time operational forecasts.

The objective is to examine the performance of S2S rainfall forecasts over West Africa to improve our knowledge of how the models represent monsoon dynamics.



1. What is the skill of the S2S in predicting monsoon evolution in real-time?
2. Is the evaluation of the S2S model sensitive to observational uncertainties?
3. Is the model skillful in predicting rainfall climatology (hind-cast) and its variability on the fly (hind-cast produce concurrently with the near real-time forecasts)?



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Curiosities?

1. What is the skill of the S2S in predicting monsoon evolution in real-time?
2. Is the evaluation of the S2S model sensitive to observational uncertainties?
3. Is the model skillful in predicting rainfall climatology (hind-cast) and its variability on the fly (hind-cast produce concurrently with the near real-time forecasts)?.

Data Summary

Data	Variable	Source	Date of Initialization (SD)	Periods	Resolution	Ensemble Size	Time-step
ECMWF - S2S-Realtim e	Rainfall	ECMWF	Mar - Oct	2020 - 2021	150km	51	Daily
ECMWF - S2S-Hindcas t	Rainfall	ECMWF	Mar - Oct	2001 - 2019	150km	11	Daily
Observed	Rainfall	GPM-IMERG	Mar - Nov	2001 - 2021	10km	-	Daily
Observed	Rainfall	TAMSAT Reading	Mar - Nov	2001 - 2021	5km	-	Daily

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ECMWF - S2S-Hindcast	Rainfall	ECMWF	Mar - Oct	2001 - 2019	150km	11	Daily
Observed	Rainfall	GPM-IMERG	Mar - Nov	2001 - 2021	10km	-	Daily
Observed	Rainfall	TAMSAT Reading	Mar - Nov	2001 - 2021	5km	-	Daily

15 Start dates(SD) and 4 Lead times (LT) from each Start date

The SD are then classified into Seasons:

- 1. Pre-Monsoon (PREMON; March – April)**
- 2. First Southern Monsoon peak (FSMP; May, June)**
- 3. Northern Monsoon Peak (NMP; July, August), and,**
- 4. Second Southern Monsoon Peak (SSMP; September, October)**

Summary Methods

The attribute of the Forecast quality is evaluated using both deterministic and probabilistic techniques.

For deterministic evaluation (using the ensemble mean)

- Bias
- Anomaly
- Synchronization
- and linear correlation (r),

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For Probabilistic evaluation used.

- Rank probability skill score (RPSS) using 4 threshold rainfall values (rainfall value $< 10\text{mm}$, $25\text{mm} \leq X \leq 50\text{mm}$, $50\text{mm} \leq X \leq 100\text{mm}$ and $> 100\text{mm}$)
- Relative Operative Characteristics (ROC) using AUC as score for 3 events (rainfall value $< 10\text{mm}$, $> 100\text{mm}$ and anomaly)

Summary of Methods

The **correlation** (r) is computed using spatial (SP) and spatio-temporal (SPT) approach in three ways.

The correlation is computed between S2S forecasts and observations (GPM and TAMSAT)

1. for all LTs from each SD (SPT1)
2. from all SDs for each LT (SPT2)
3. **for each LT from each SD (SP)**

Then, we computed from SPT1,

- a. seasonal correlation (SC_a) and,
- b. **correlation for all LTs from all SDs.**

Subsequently, we computed from SP, the mean correlation,

- a. for all LT from each SD,
- b. **for each LT from all SD,**
- c. the seasonal correlation (SC_b), and
- d. **for all LTs from all SDs.**

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ROC diagram from hit rate and false alarm rate is computed

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For uniformity and because it is the lowest common resolution, all datasets used in this study were re-gridded to $1^\circ \times 1^\circ$.

Summary of Methods

common climatology

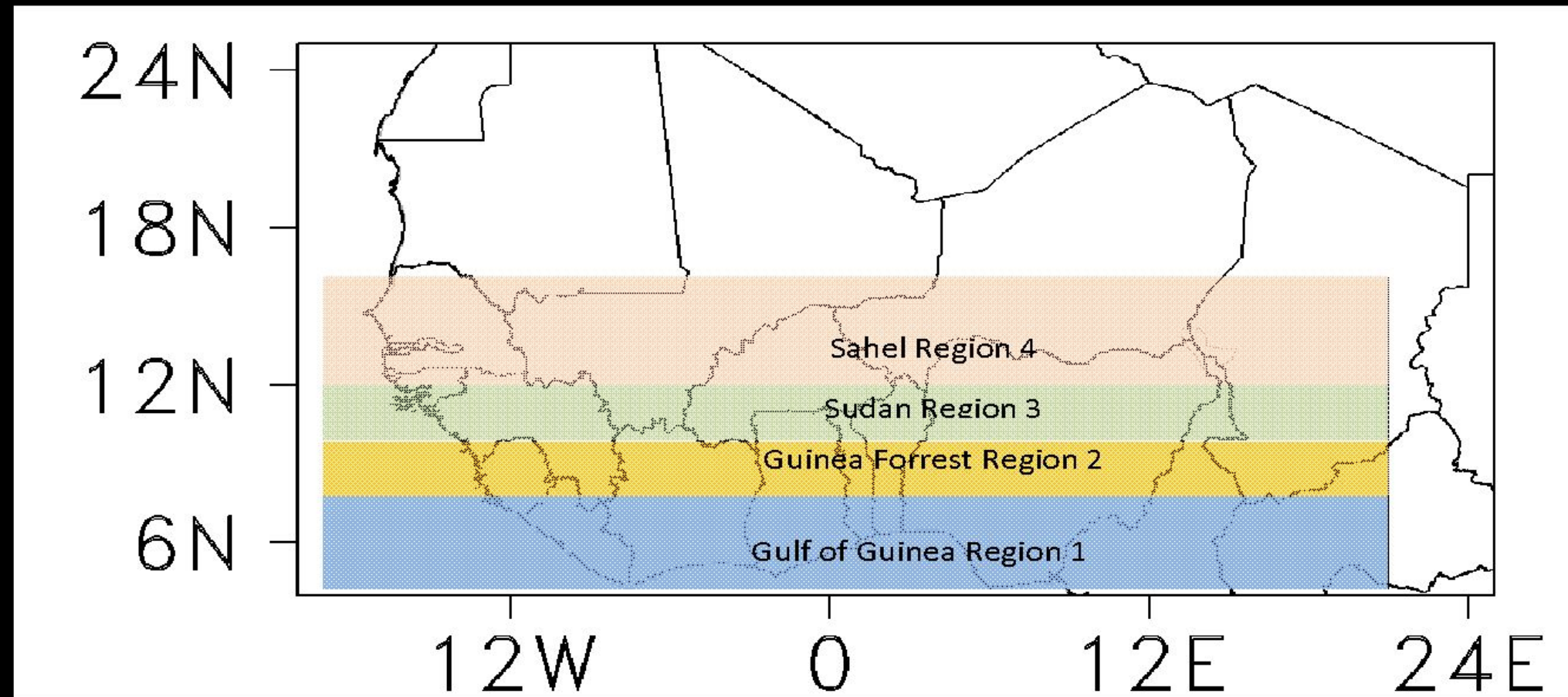


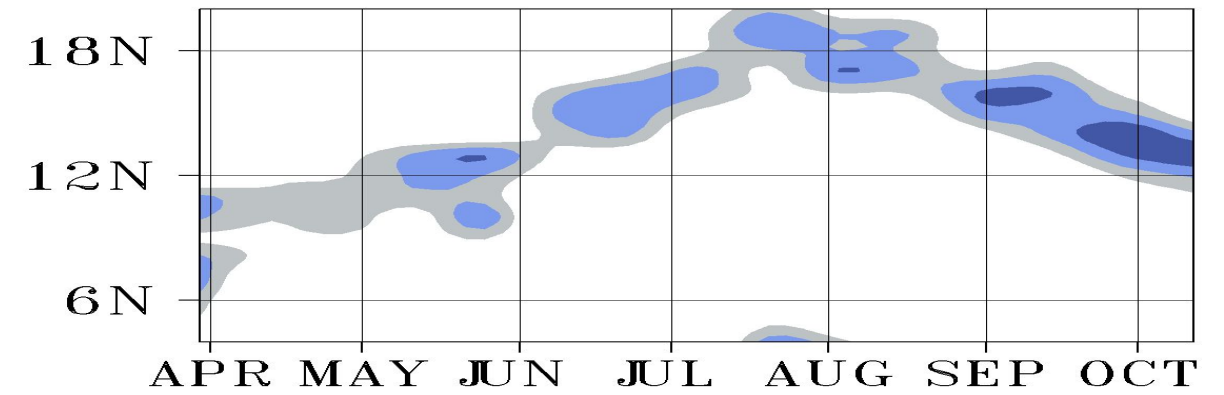
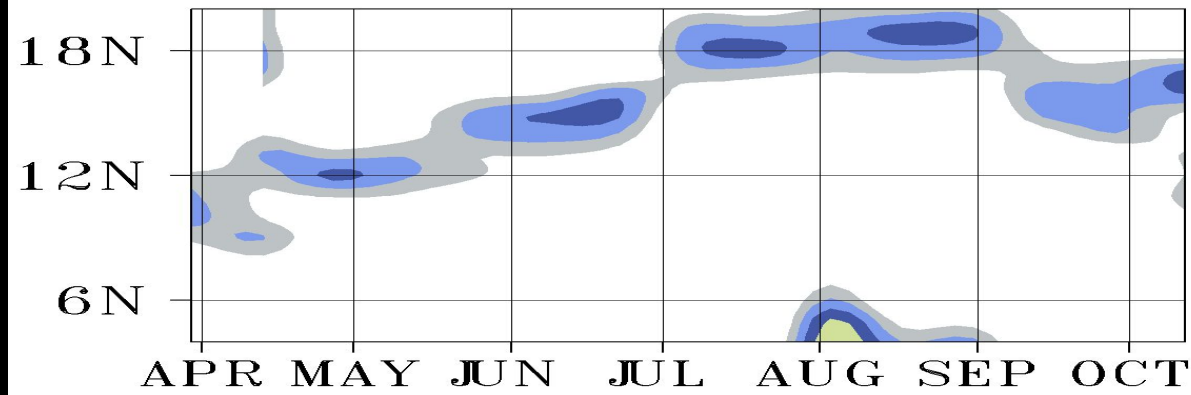
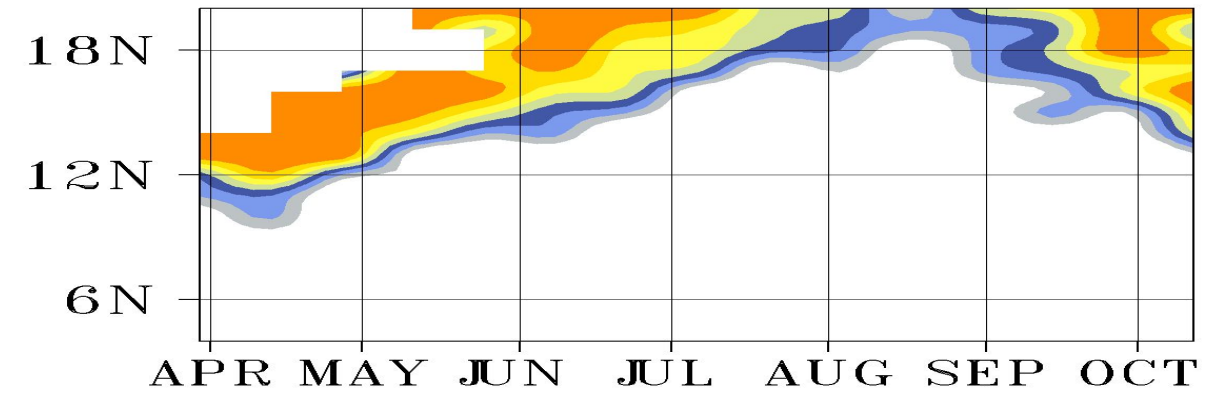
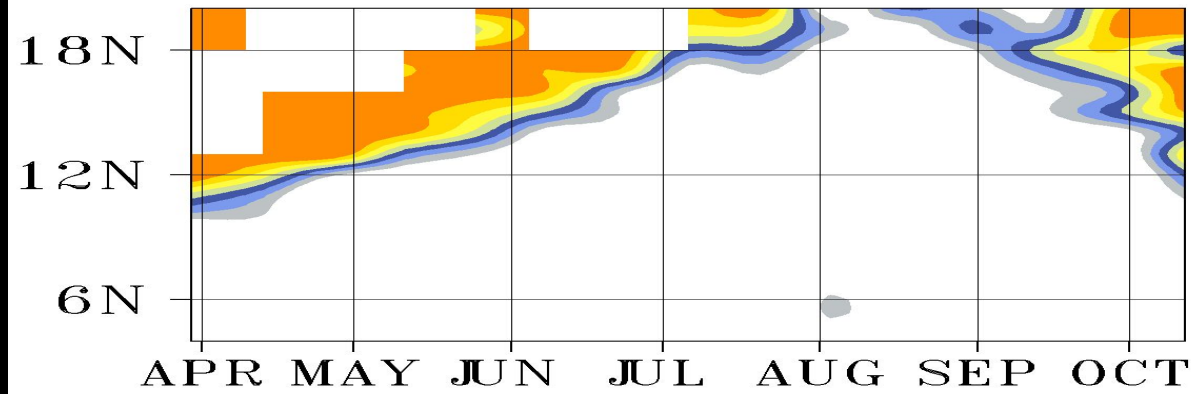
Figure. Showing the Regions analysed over West Africa : Gulf of Guinea region1(blue; Lat 4 - 8°N, Long - 18°W - 15°E), Guinea Forreest, region2 (brown; Lat 8 - 10°N, Long -18°W - 15°E), Savannah, region3 (green; Lat 10 - 12°N, Long -18°W - 15°E), Sahel, region4 (Lat 12 - 16°N, Long -18°W - 15°E)

2020

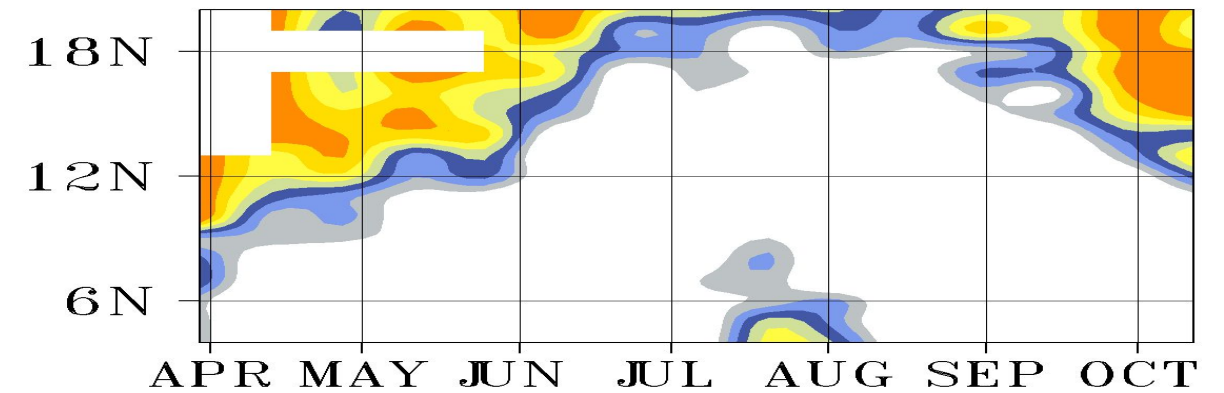
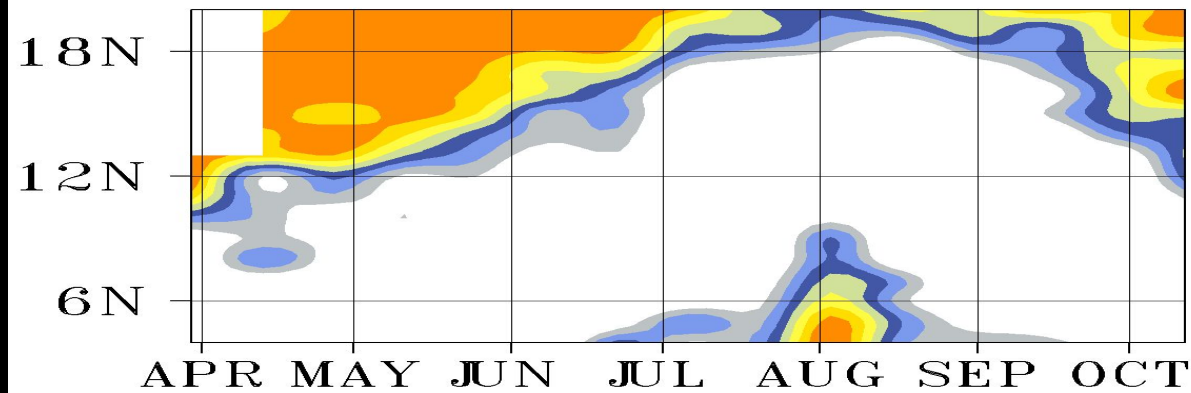
< 10mm

2021

ECMWF-S2S

TAMSA
T

GPM_IMERG



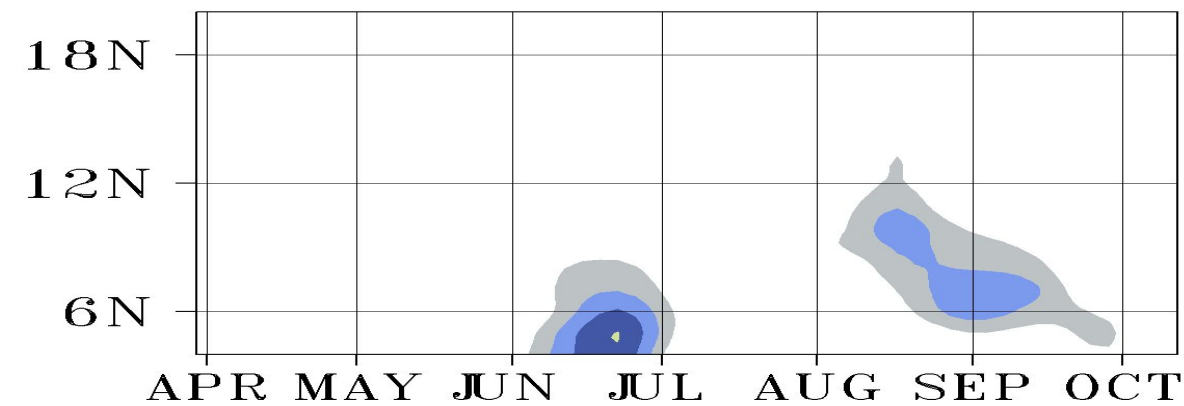
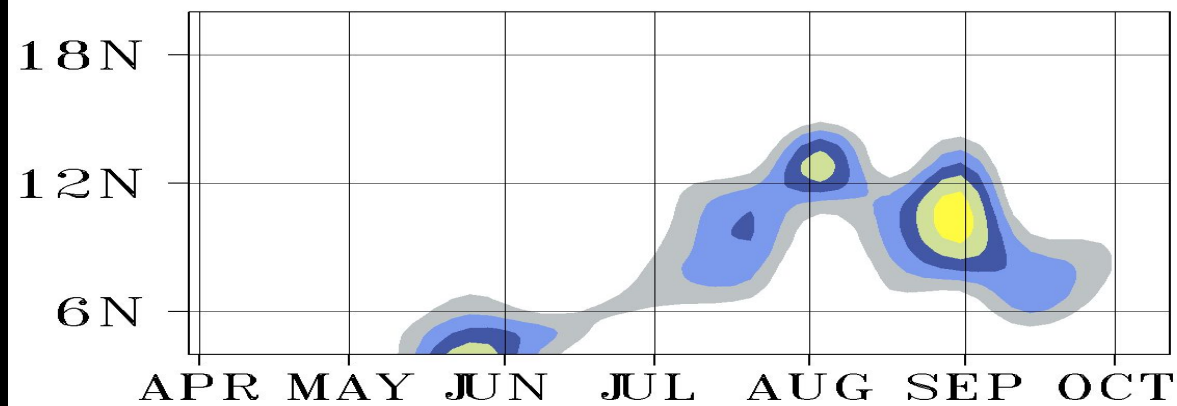
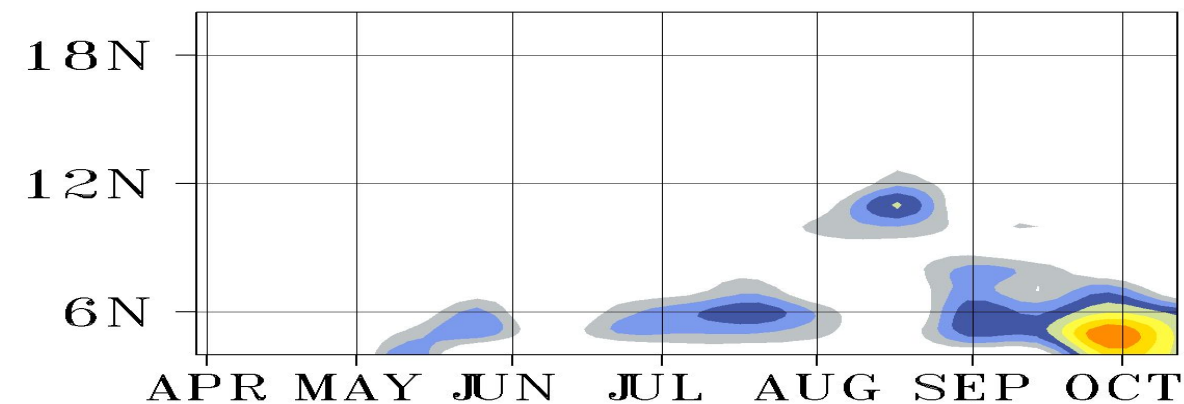
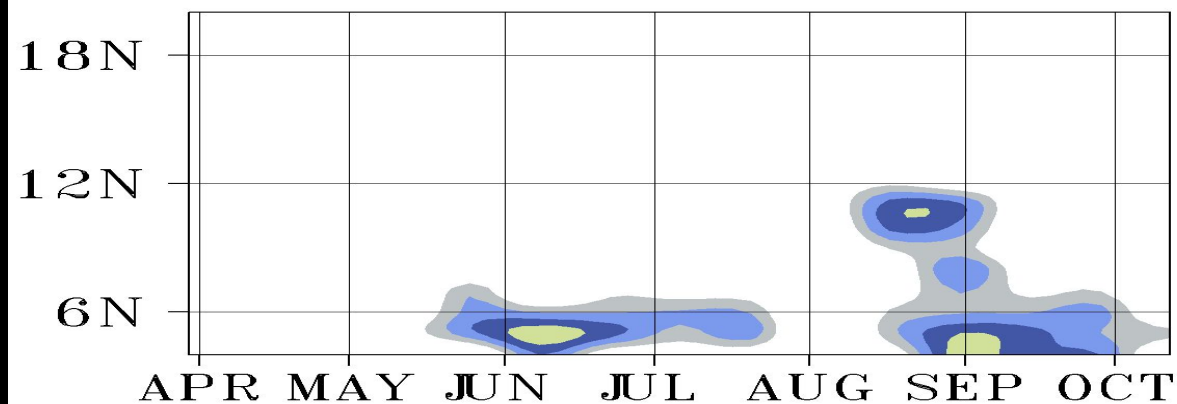
Hovmoler diagram (average along longitude 18°W to 15°E) showing the probability forecast and the observed dekadal rainfall accumulation (in binary) of less than 10mm for LT1 from SD1 to SD15 of 2020 and 2021.

2020

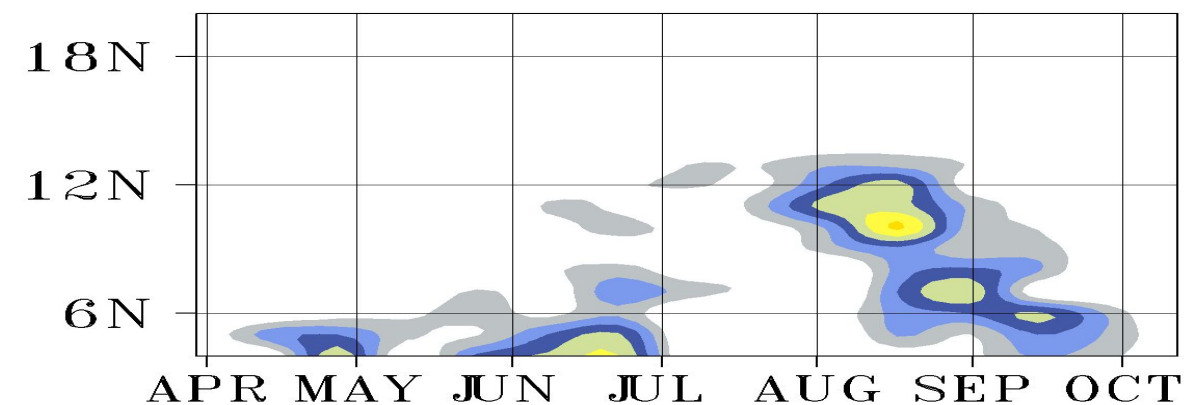
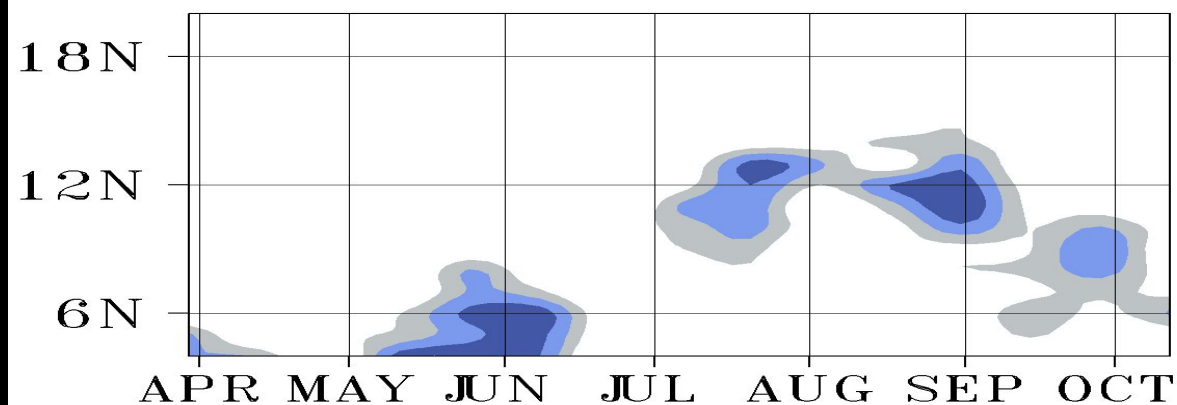
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2021

ECMWF-S2S

TAMSA
T

GPM_IMERG

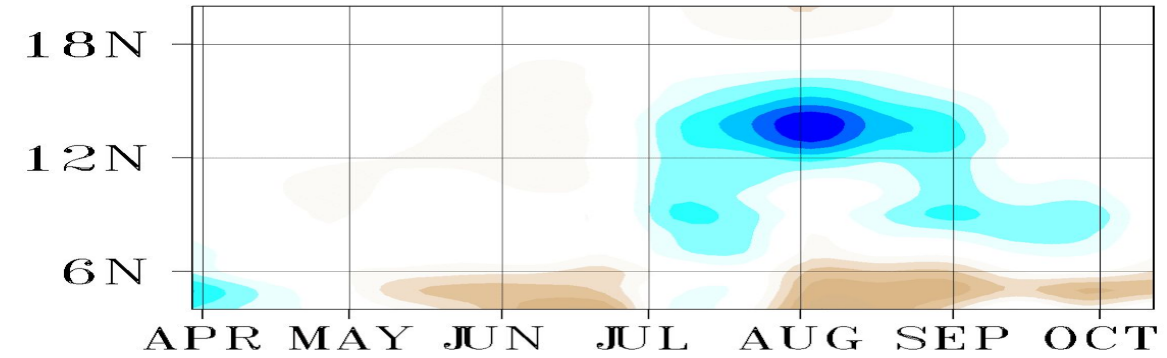
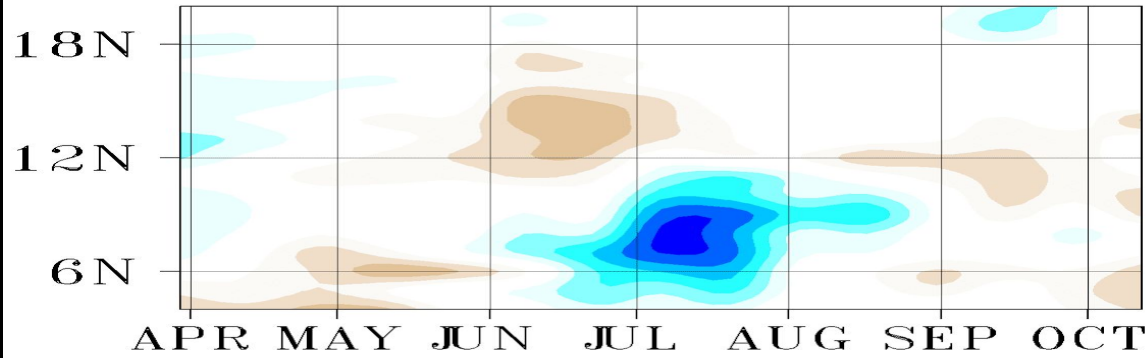


Hovmoler diagram (average along longitude 18°W to 15°E) showing the probability forecast and the observed dekadal rainfall accumulation (in binary) of greater than 100mm for LT1 from SD1 to SD15 of 2020 and 2021.

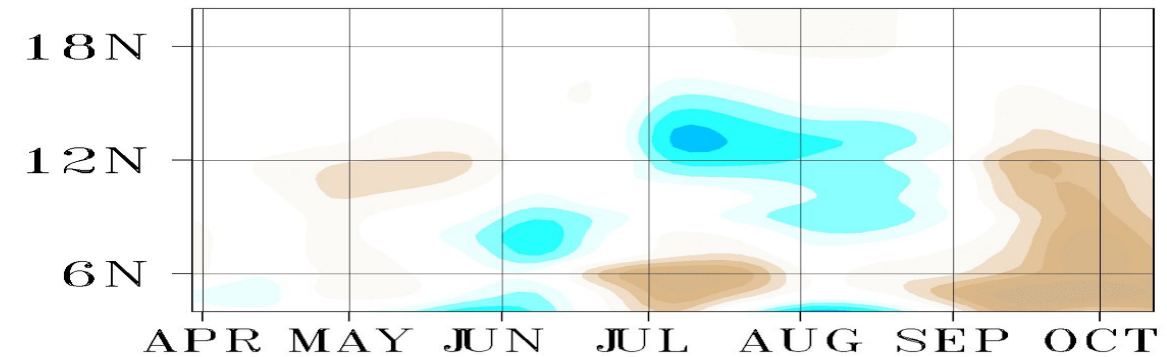
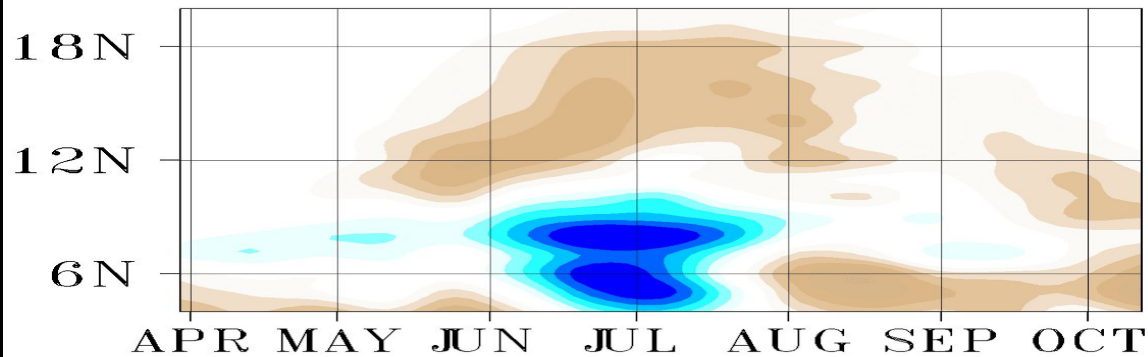
GPM_IMERG

TAMSAT

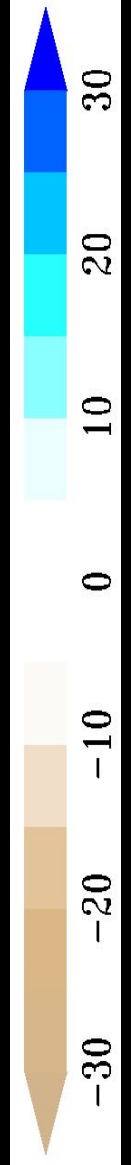
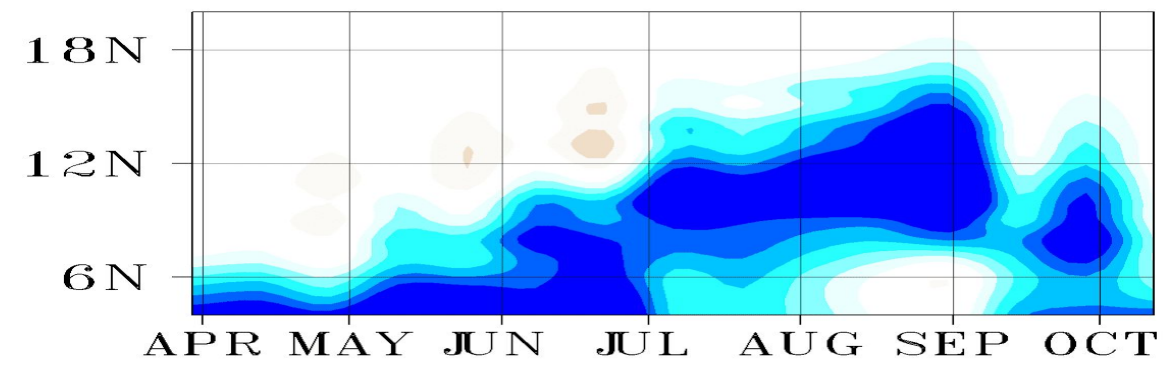
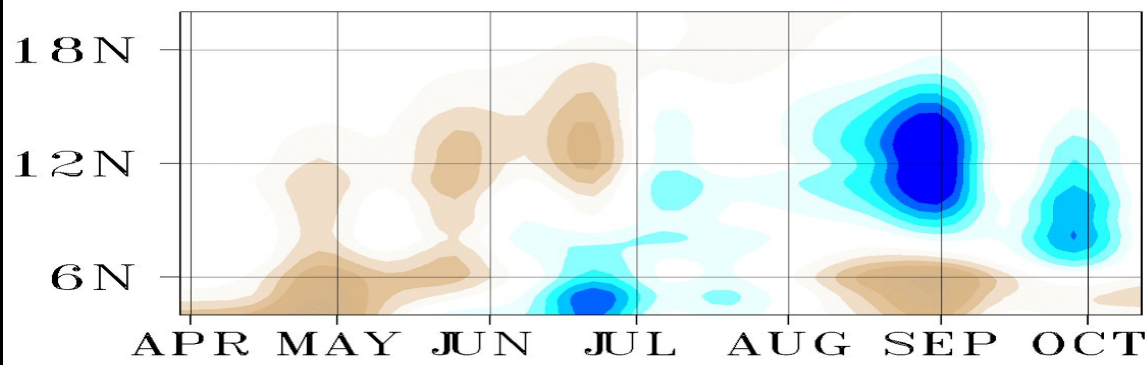
2020



2021



HCAS T



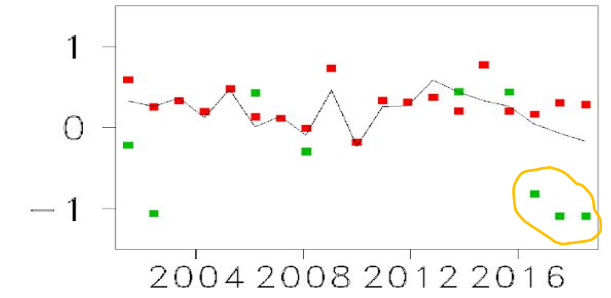
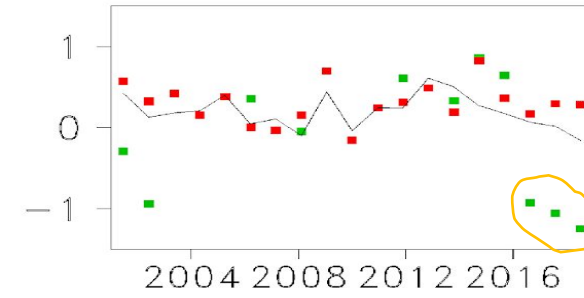
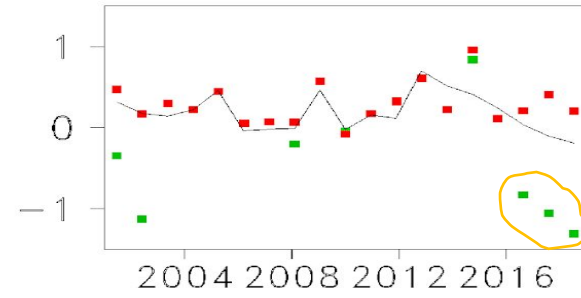
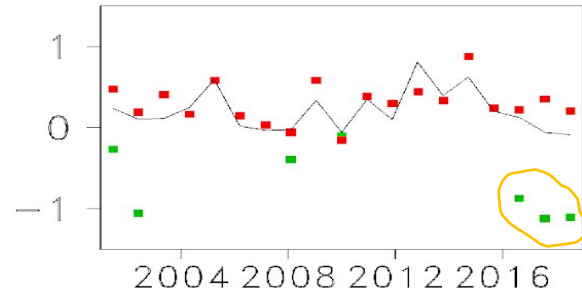
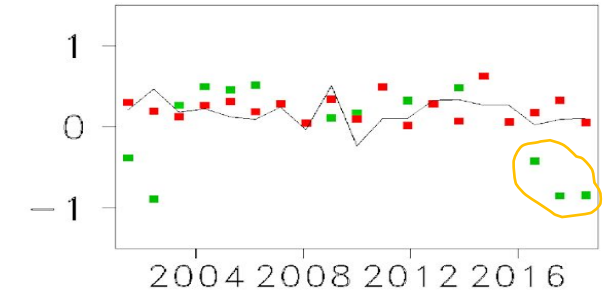
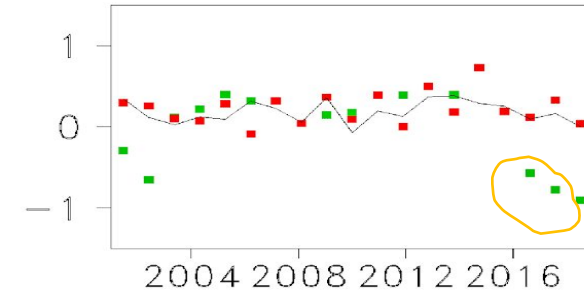
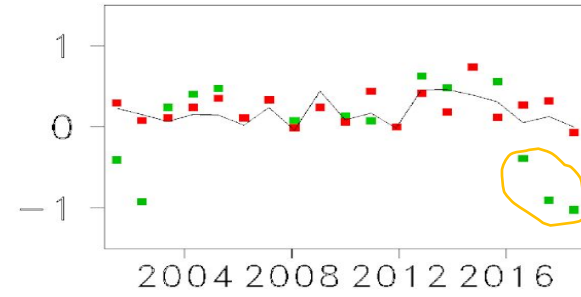
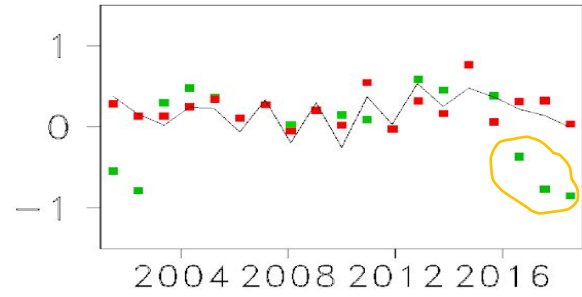
Hovmoler diagram (average along longitude 18°W to 15°E) showing the dekadal rainfall bias (mm) between ECMWF-S2S ensemble mean and observed (GPM, and TAMSAT)in real-time of 2020, 2021 and hind- cast

Dekad 1 (LT1)

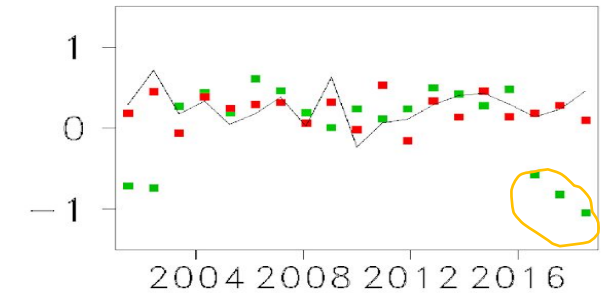
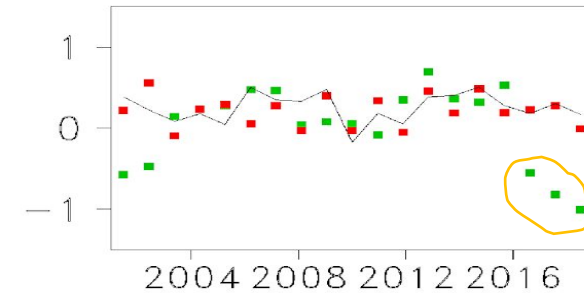
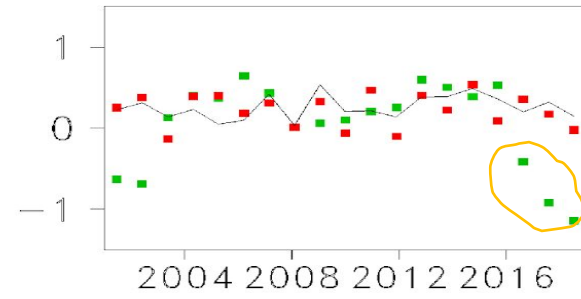
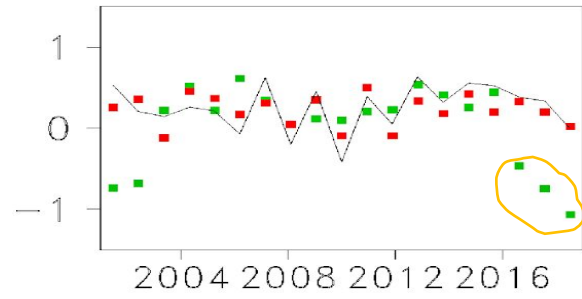
Dekad 2 (LT2)

Dekad 3 (LT3)

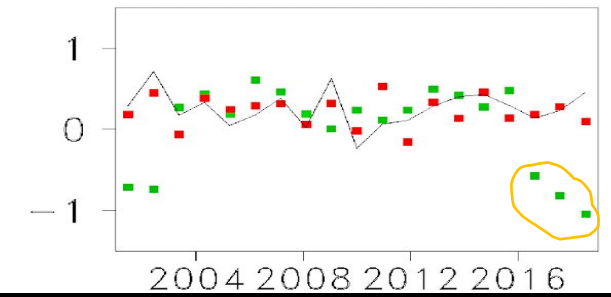
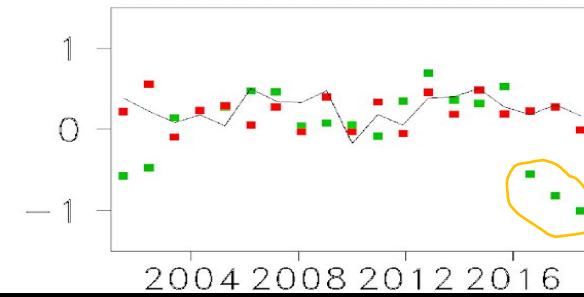
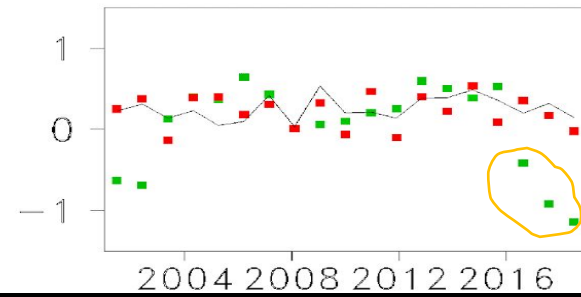
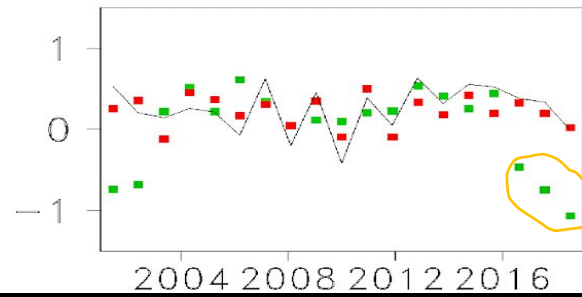
Dekad 4 (LT4)

Gulf of
GuineaGuinea
Forrest

Sudan



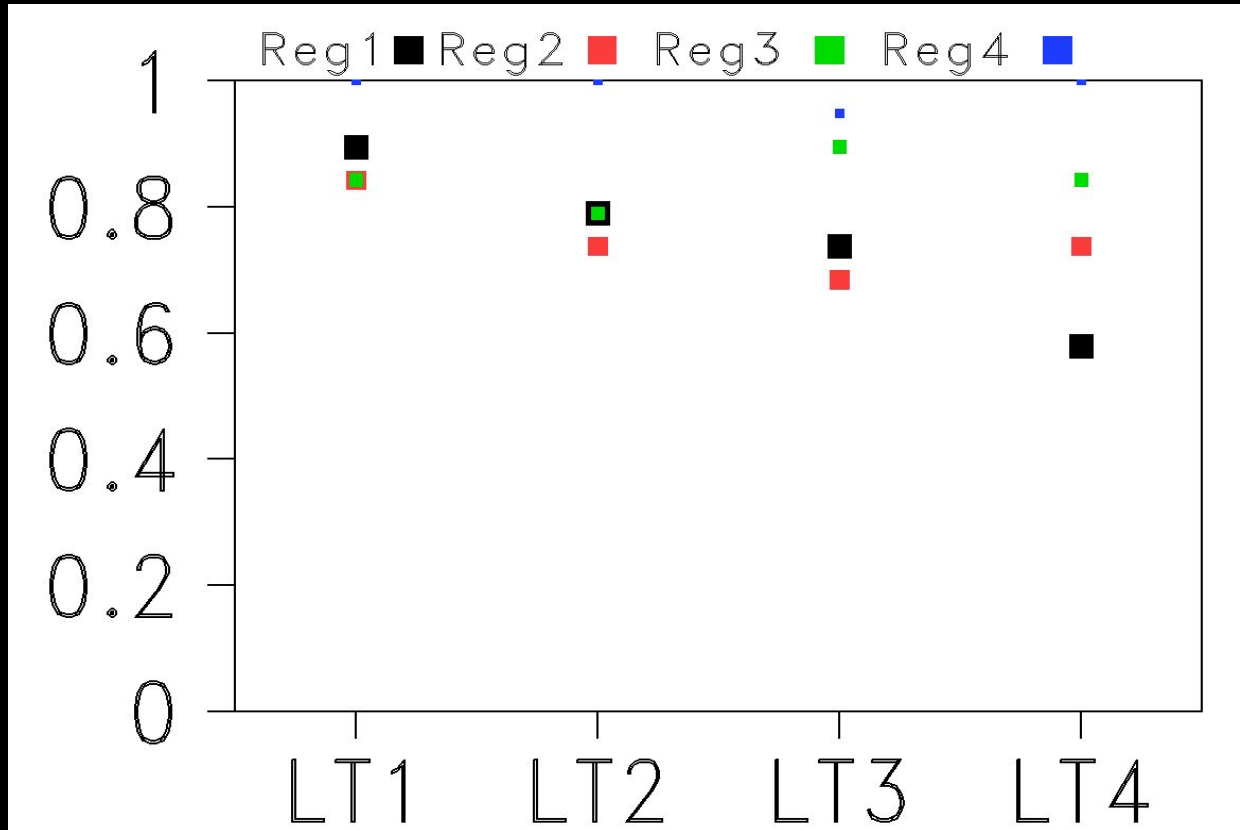
Sahel



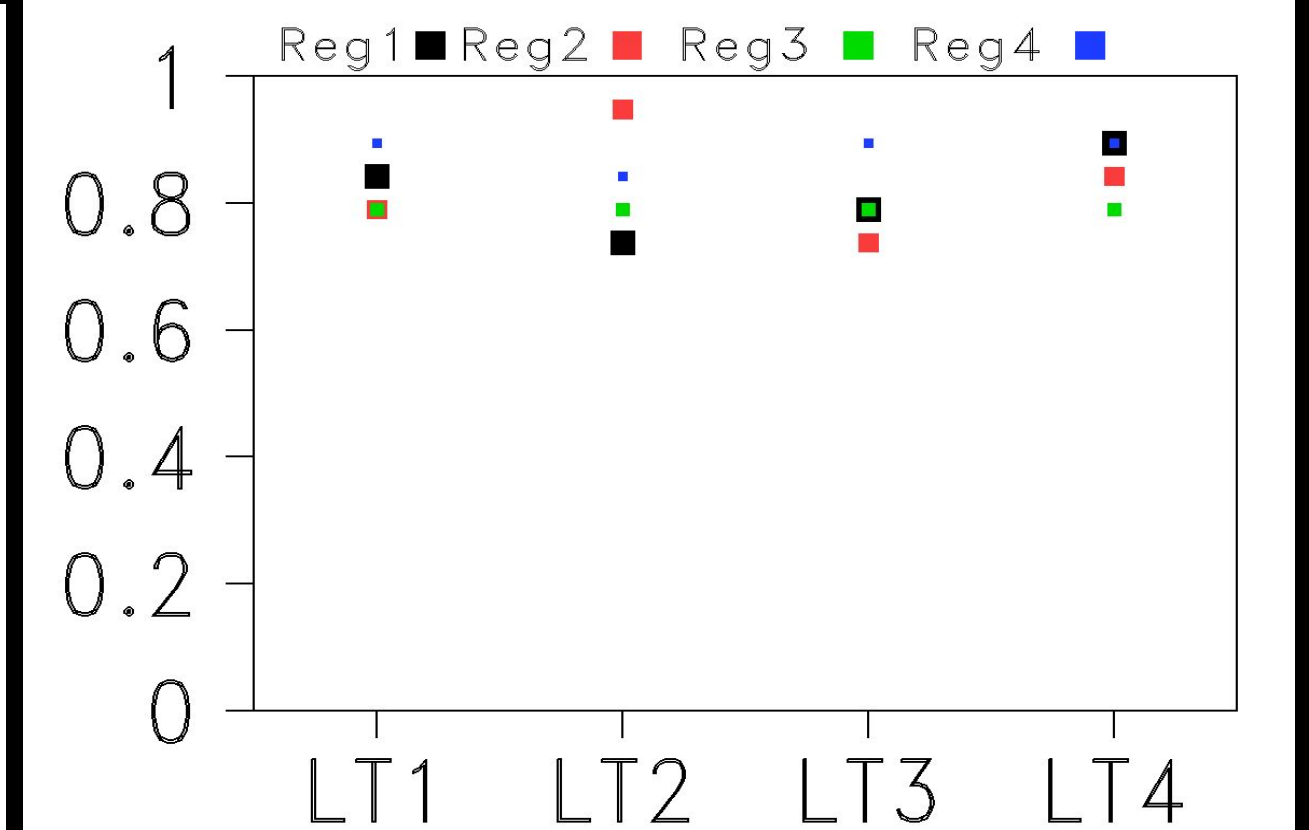
Distribution of Inter-annual variability of the standardized dekadal rainfall anomaly over the GoG, Guinea Forrest, Sudan and Sahel by the ensemble mean(black line), the GPM (red box) and TAMSAT (green boxes)

Synchronisation (%)

TAMSAT



GPM-IMERG



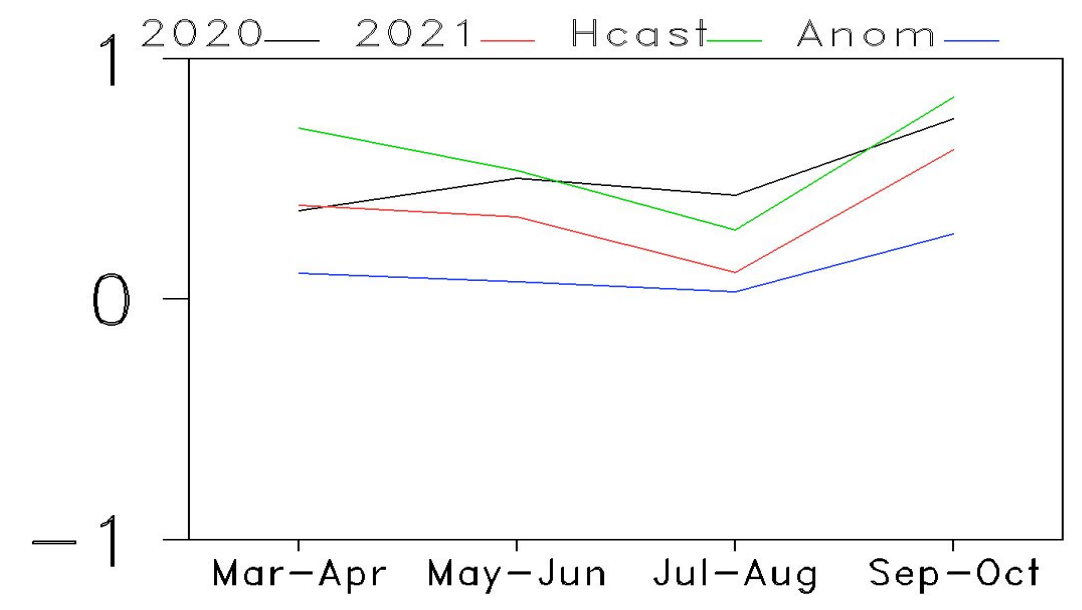
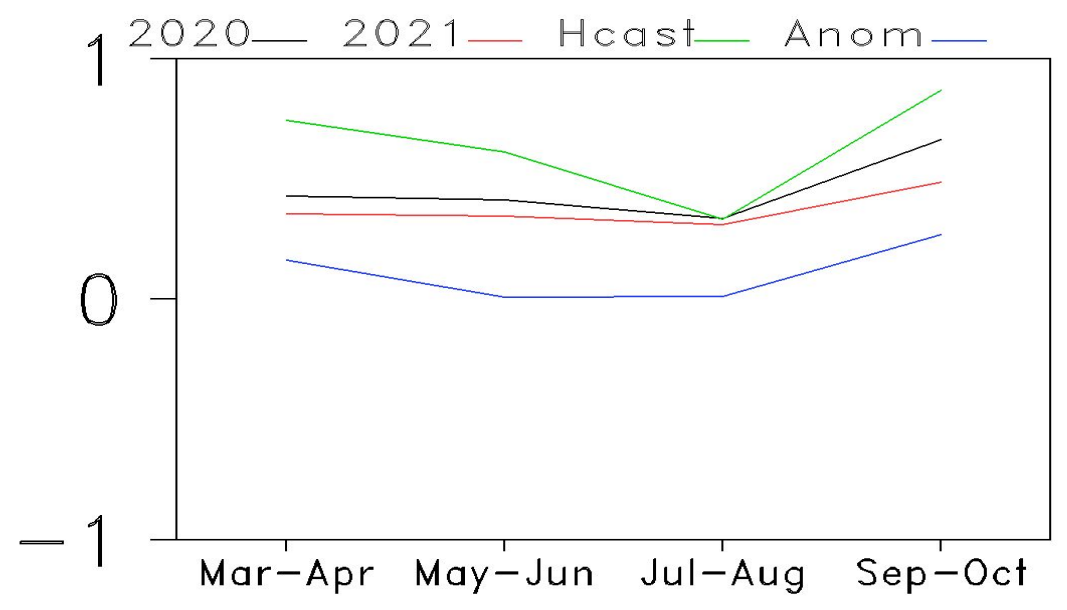
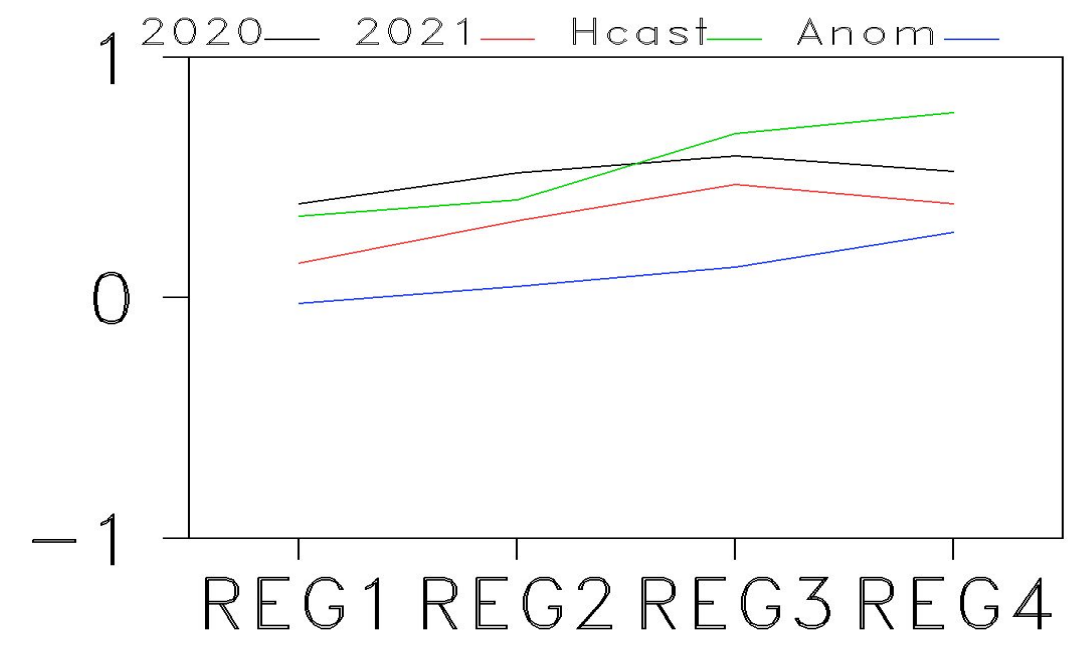
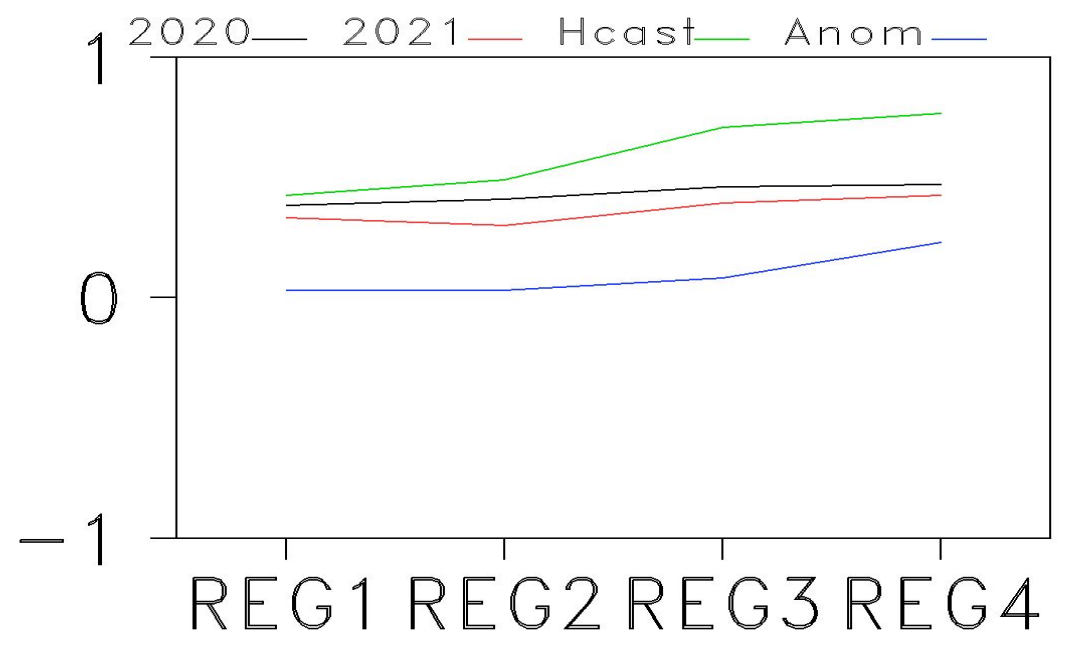
Synchronisation (%) of the ECMWF-S2S ensemble mean dekadal rainfall anomalies with TAMSAT, and GPM over the Gulf of Guinea (Reg1; black box), Guinea Forest (Rge2; red box), Savannah (Reg3; green box), and the Sahel (Reg4; blue box).

ALLTs-each Season
 AIISDs-ALLLT
 S

GPM-IMERG

Spatio-Temporal

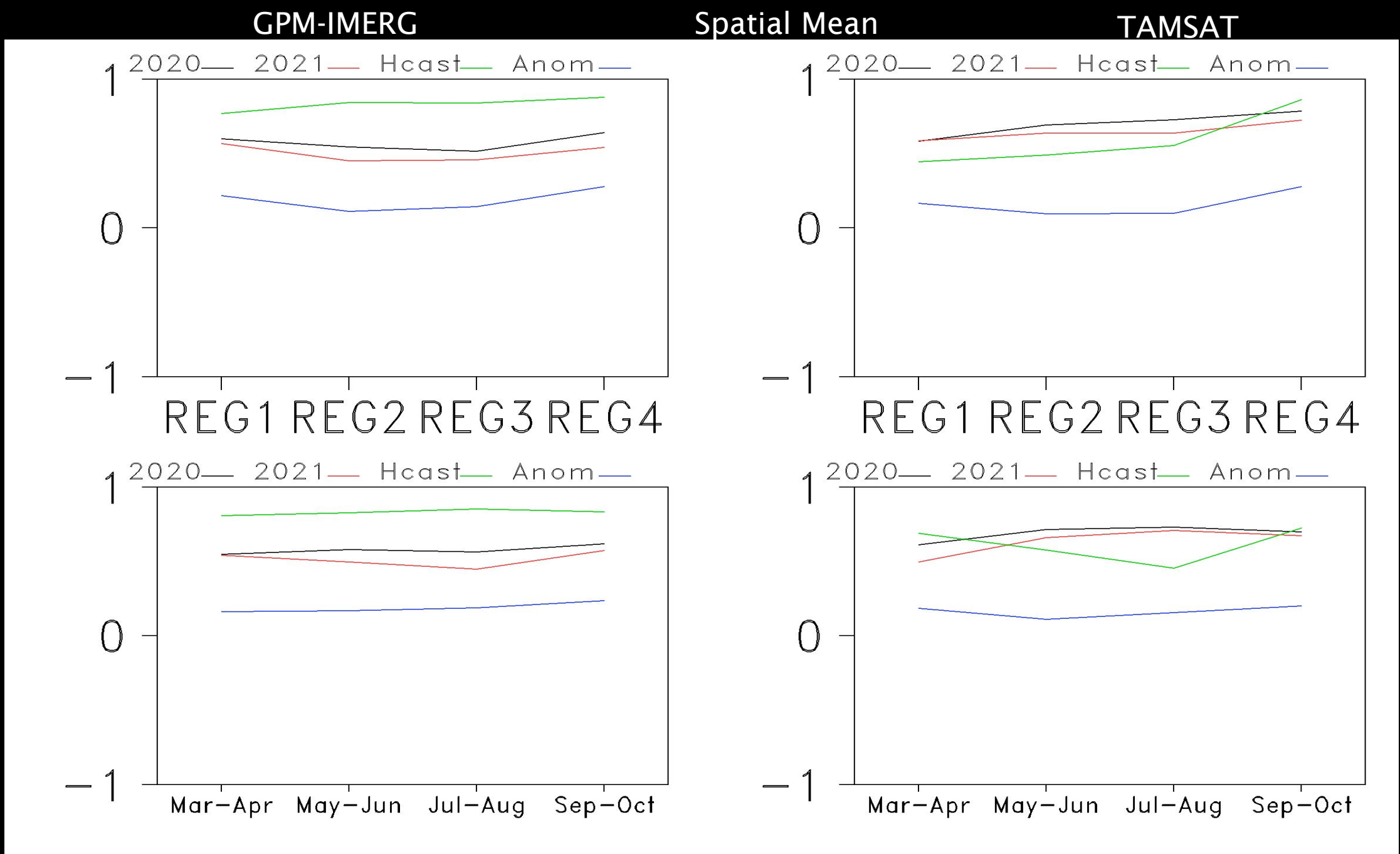
TAMSAT



The correlation between ECMWF-S2S ensemble mean the GPM and TAMSAT from all SDs for all LTs in real-time (black line; 2020 and red line; 2021), the hindcast (red line), and anomaly (blue line), and for each derived seasons, across all the regions.

ALLSDs-ALLLTs

ALLTs-each Season



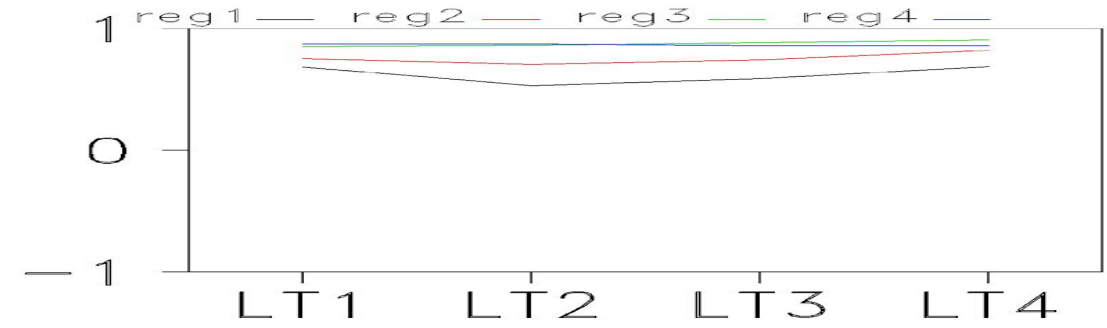
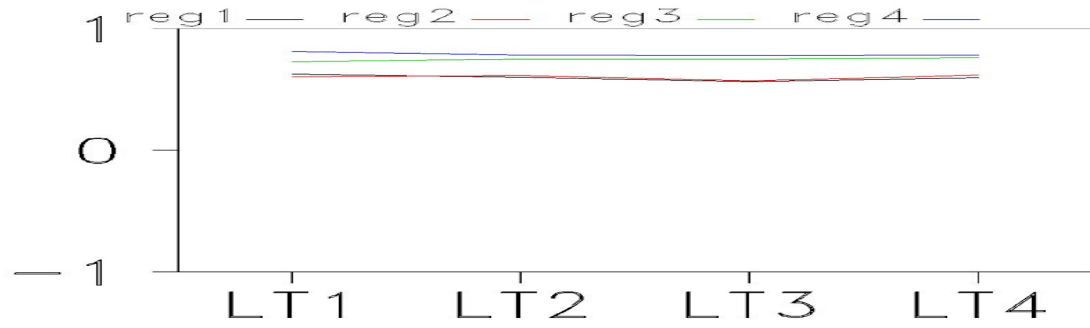
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GPM-IMERG

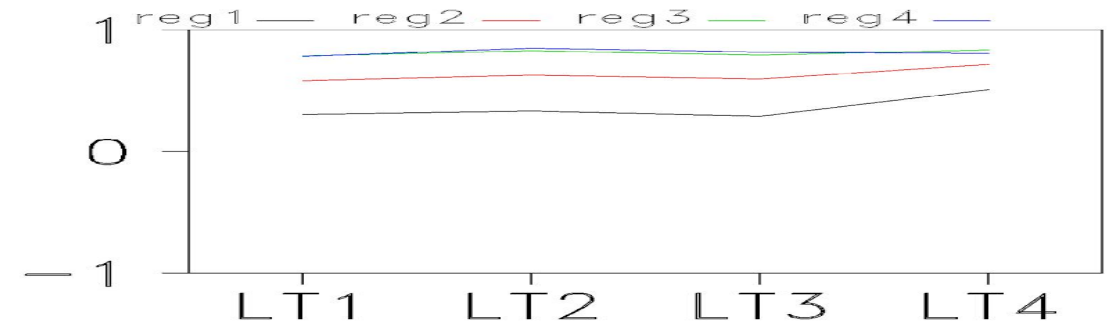
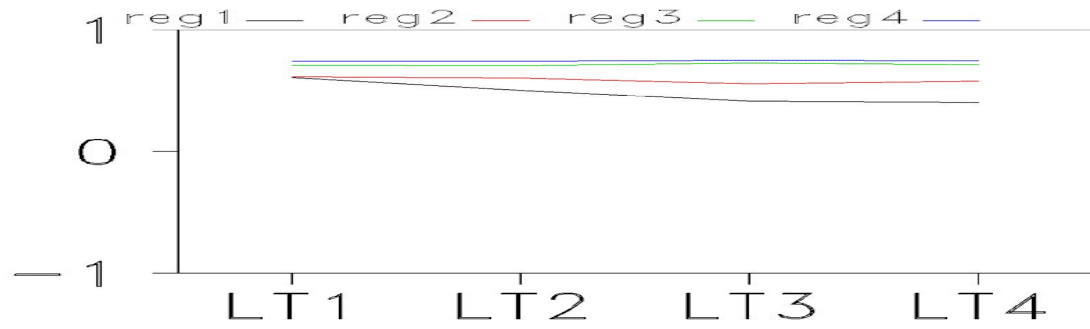
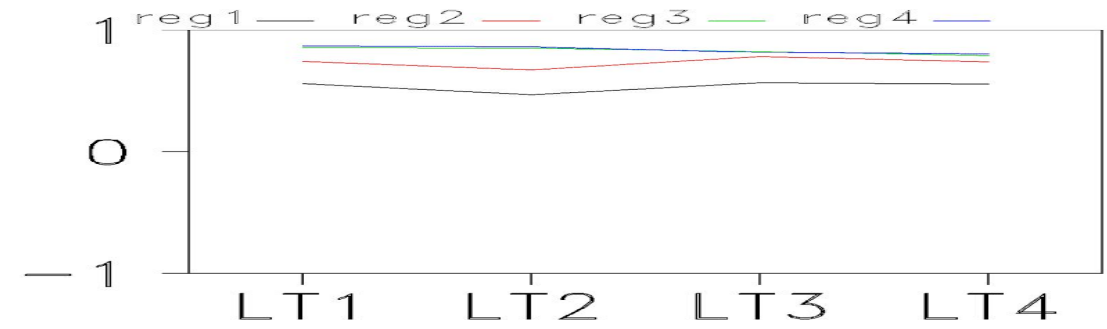
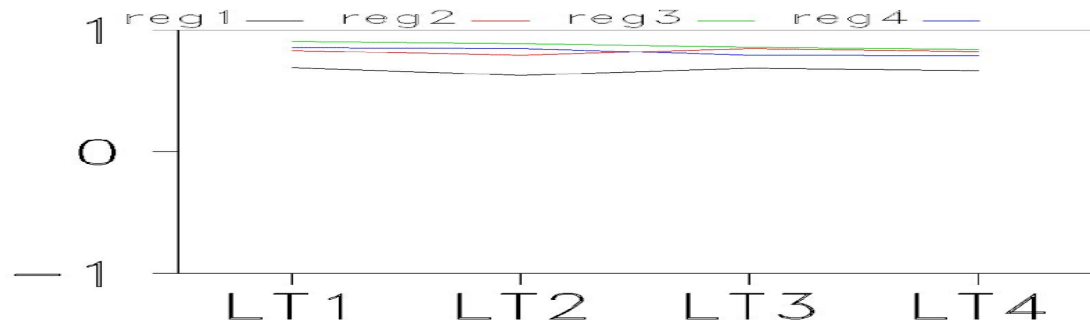
Spatio-Temporal

TAMSAT

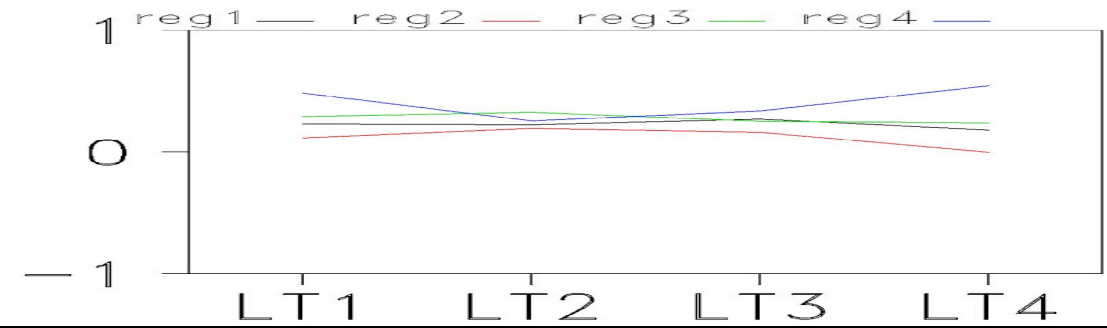
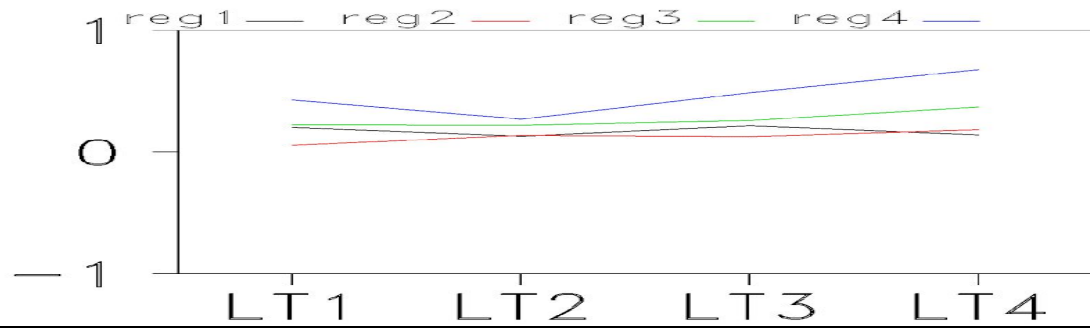
2020



2021

HCAS_T

ANOM



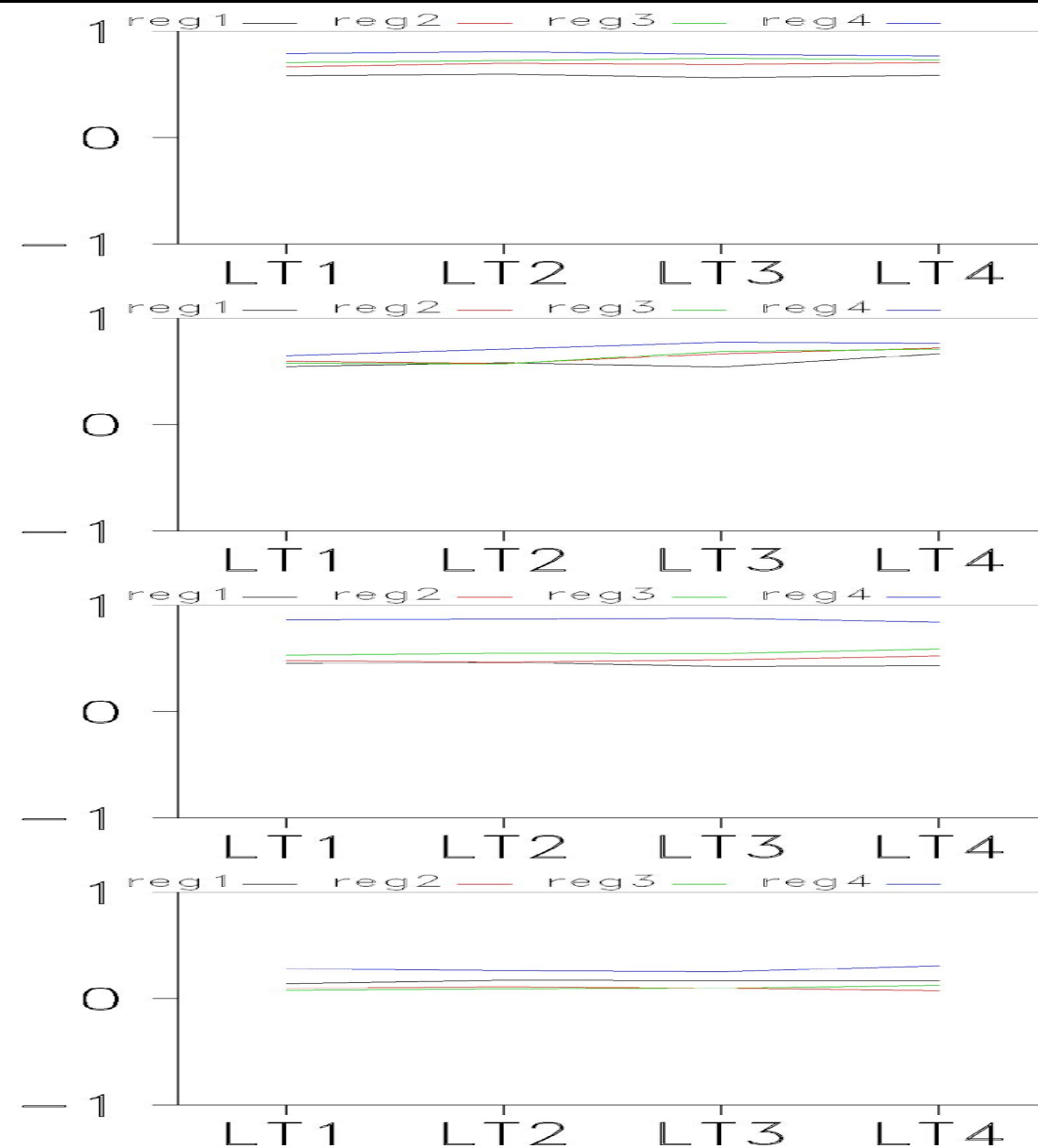
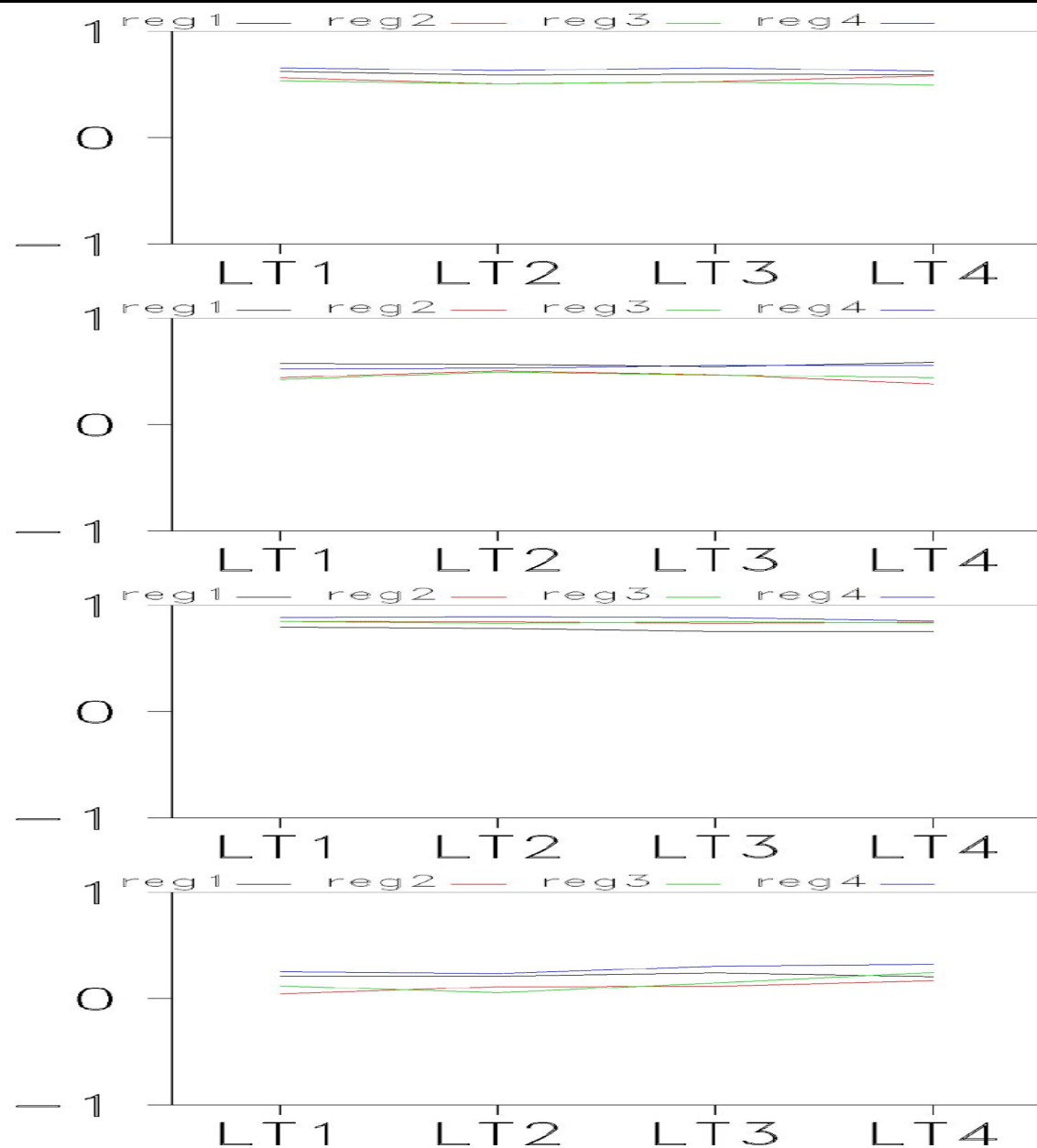
Map showing correlation between ECMWF-S2S ensemble mean and Observed (GPM and TAMSAT) for each LT from all SDs, over Gulf of Guinea (Reg1; black line), Guinea Forrest (Reg2; red line), Savannah (Reg3; green line) and Sahel (Reg4; blue line).

2020
2021
HCAS_T
ANOM

GPM-IMERG

Spatial Mean

TAMSAT

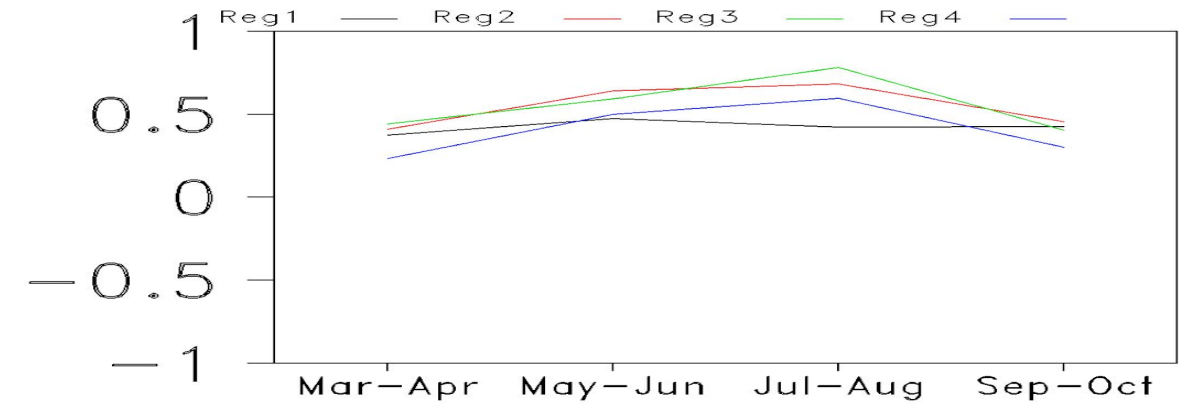
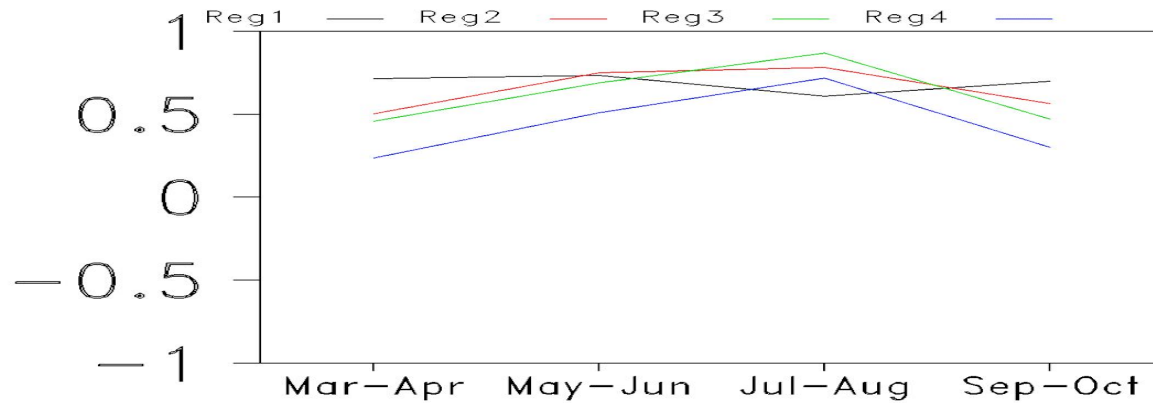


Map showing correlation between ECMWF-S2S ensemble mean and Observed (GPM (a, c, e, g) and TAMSAT (b, d, f, h)) for each LT from all SDs, over Gulf of Guinea (Reg1; black line), Guinea Forrest (Reg2; red line), Savannah (Reg3; green line) and Sahel (Reg4; blue line).

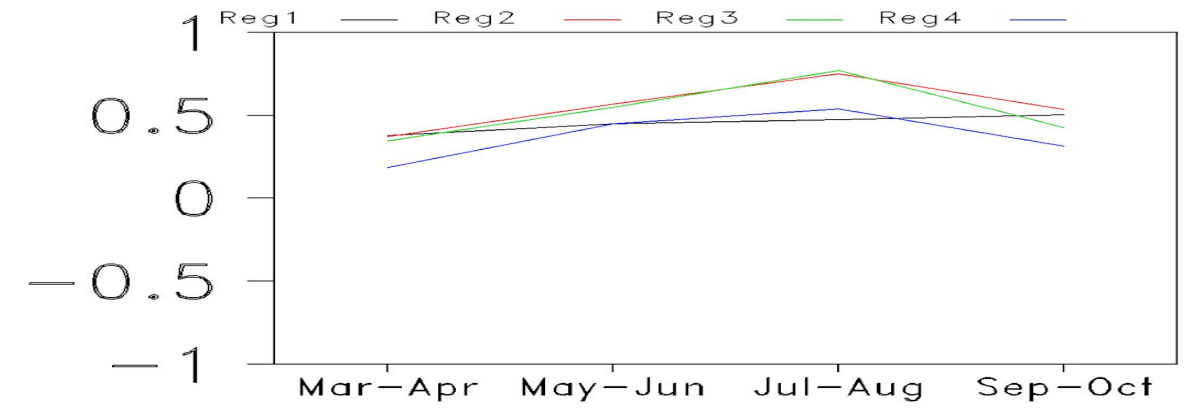
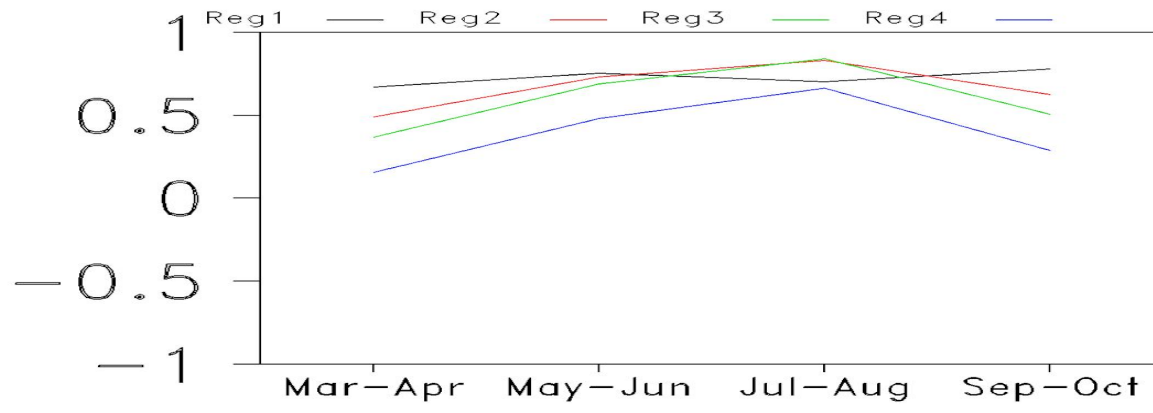
GPM-IMERGE

TAMSAT

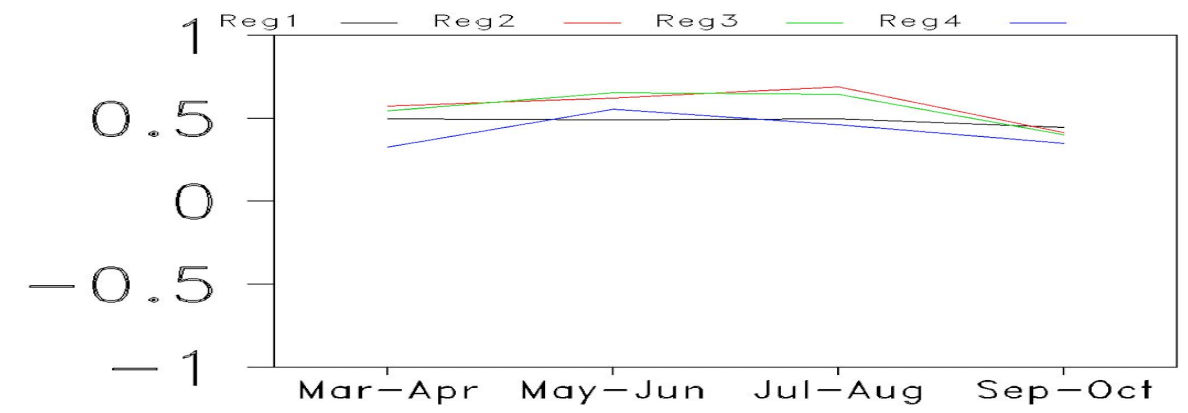
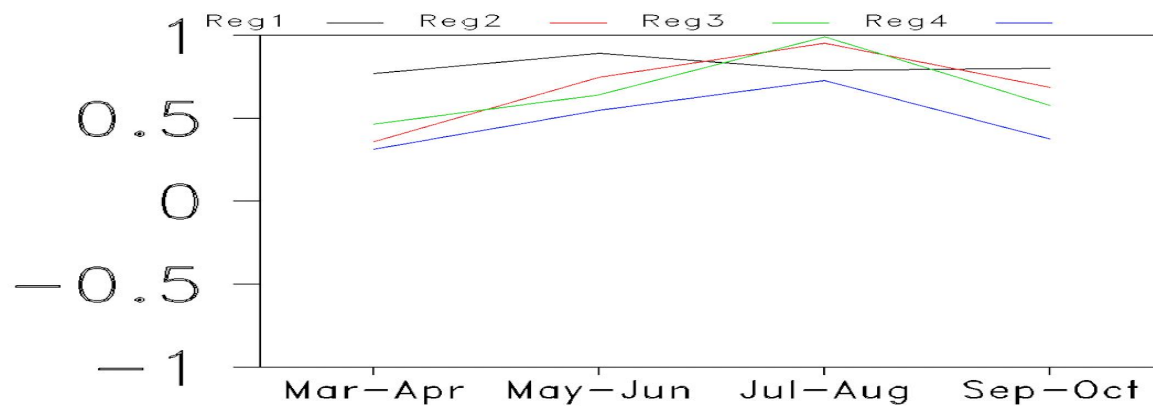
2020



2021



Hindcast



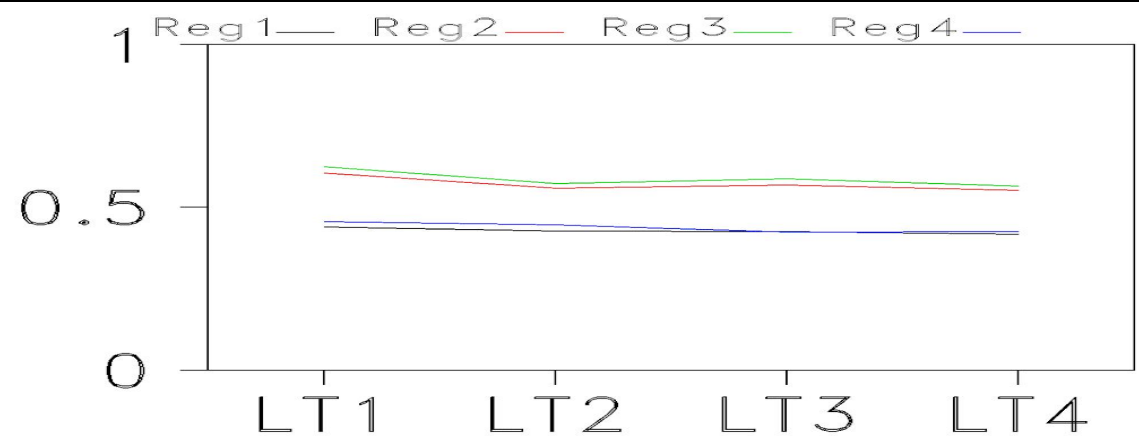
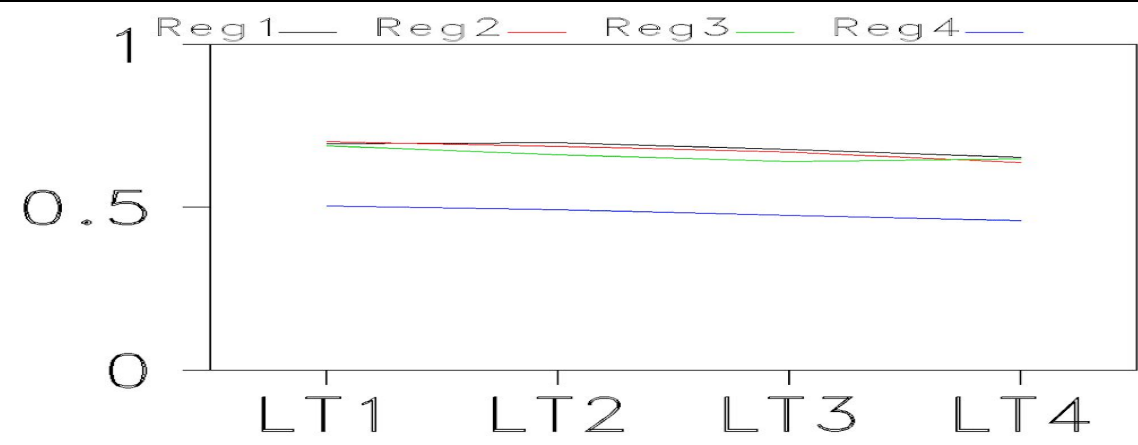
Rank and Discrete Rank Probability Skill Score (RPSS and $RPSS_D$) in real-time and hind-cast between S2S and GPM and between S2S and TAMSAT for each season, over the GOG (black line), GF (red line), SAV (green line), and the SAH (blue line).



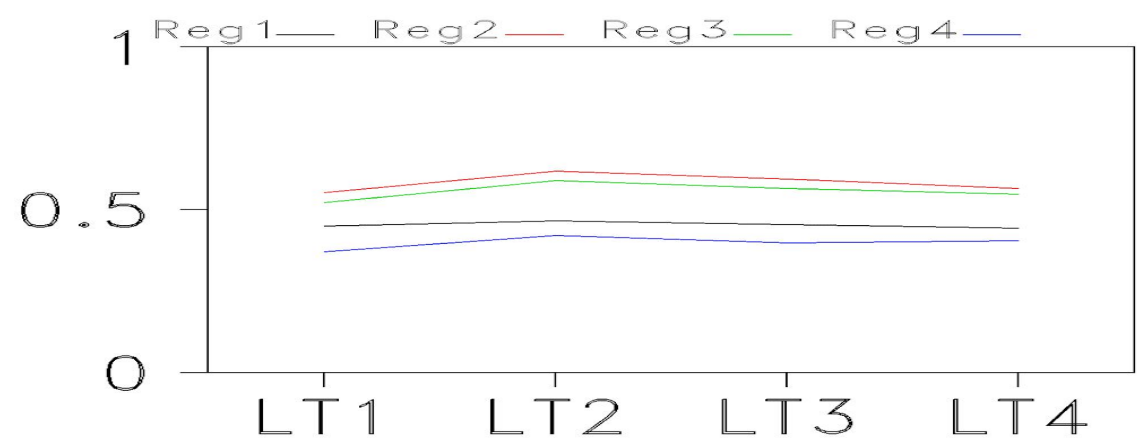
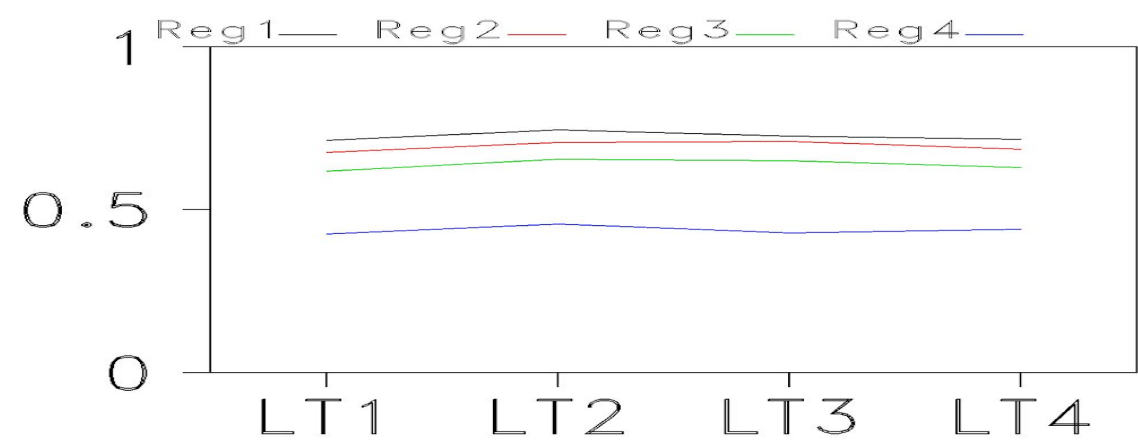
GPM-IMERGE

TAMSAT

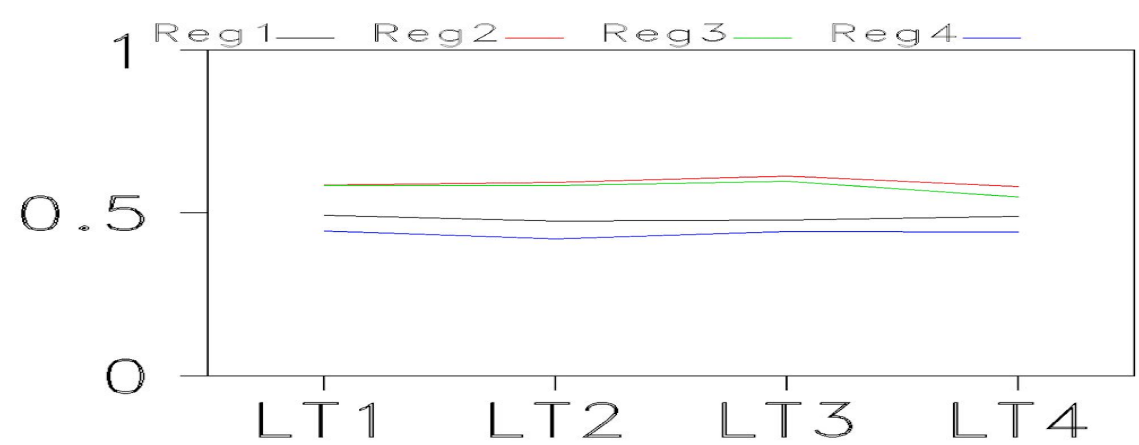
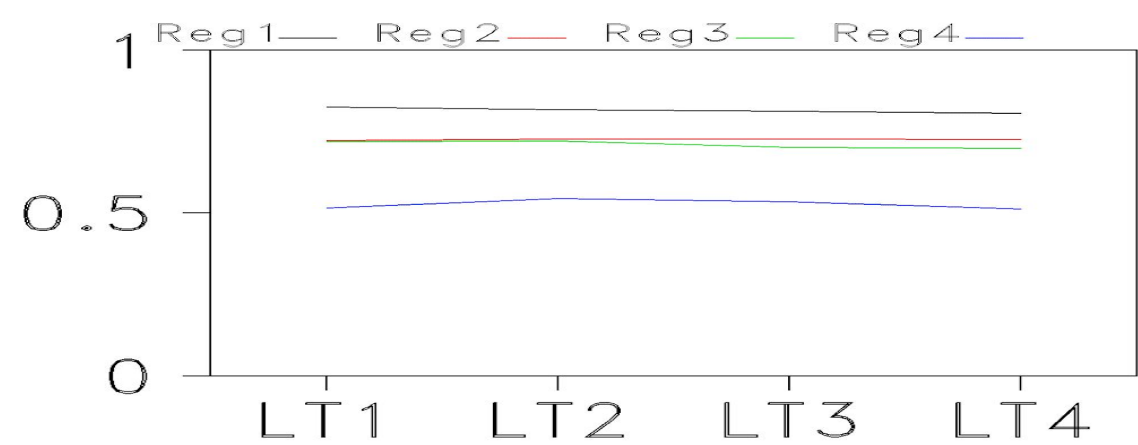
2020



2021



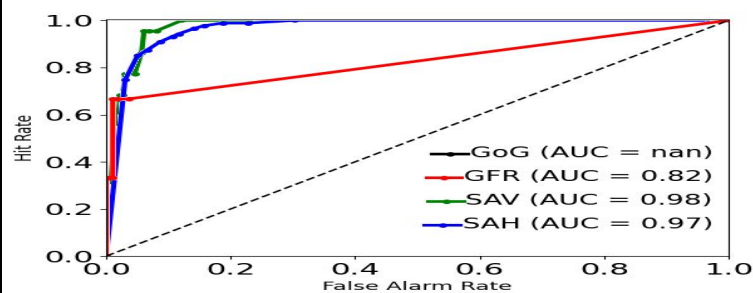
Hindcast



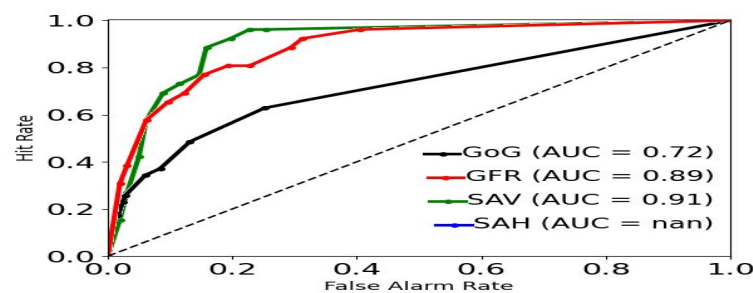
Rank and Discrete Rank Probability Skill Score (RPSS and $RPSS_D$) in real-time and hind-cast between S2S and GPM and between S2S and TAMSAT for each LT, from all SDs over the GOG (black line), GF (red line), SAV (green line), and the SAH (blue line).

Dekad 1

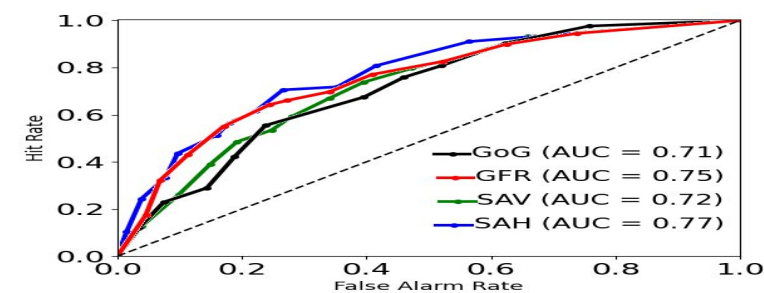
Low rainfall



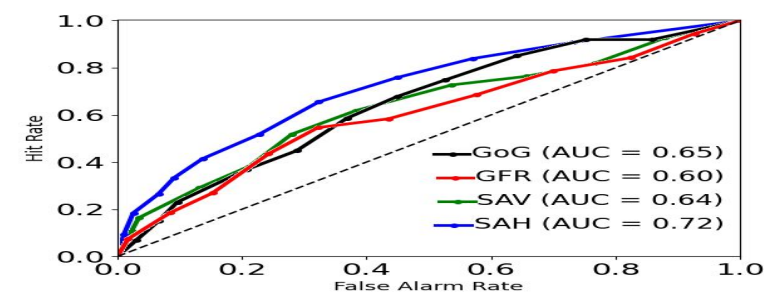
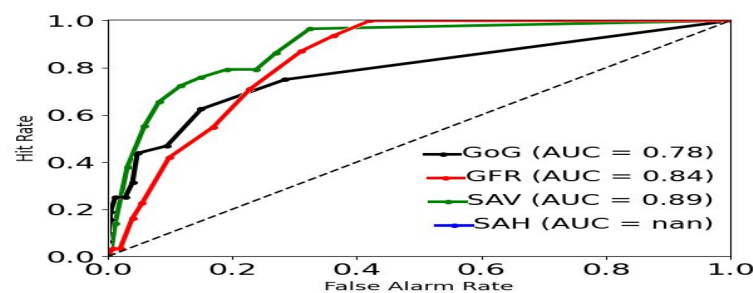
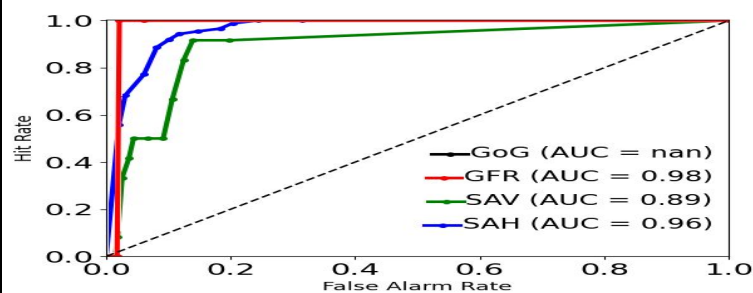
Heavy rainfall



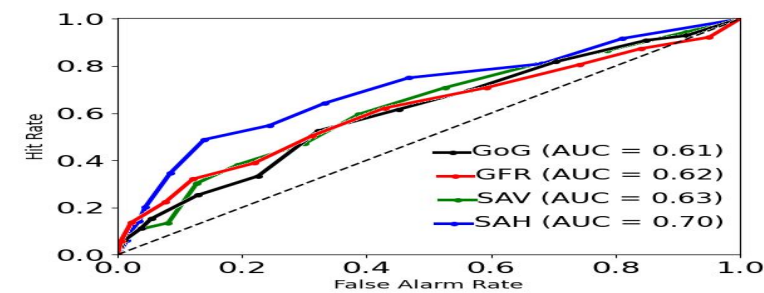
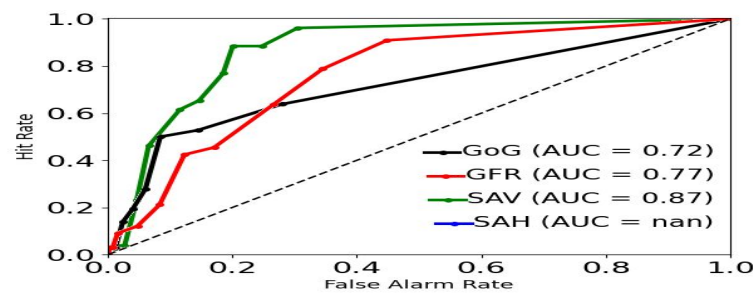
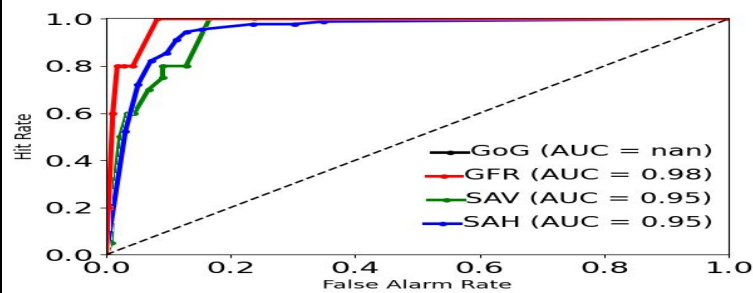
Rainfall Anomaly



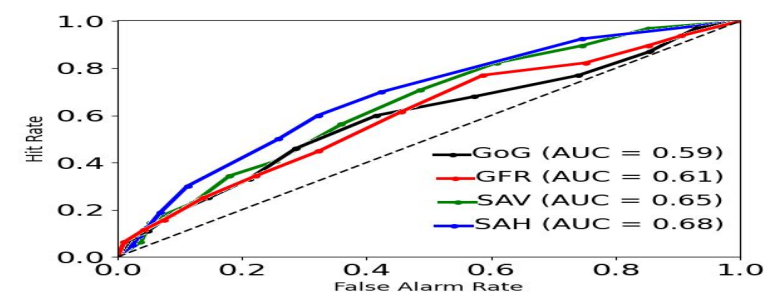
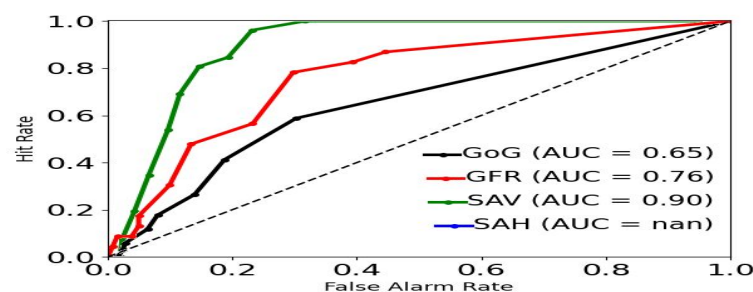
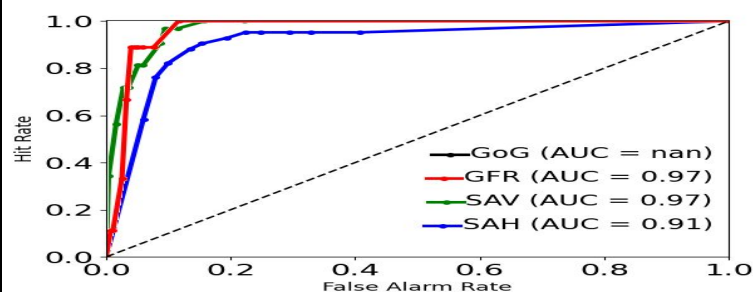
Dekad 2



Dekad 3



Dekad 4



Showing the relative operating characteristic (ROC) diagram from the S2S hindcast probabilities and binary observation (GPMIMERGE) of dekadal rainfall of less than 10mm, 100mm and standardized anomaly over the GoG (black line), GFR (red line), SAV (green line), SAH (blue line), for all SDs and each LTs.

SUMMARY

Results demonstrate that the:

- **Model captures the monsoon rainfall spatial and temporal evolutions characteristics, including the jump, the dry and wet spells with different skills.**
- **During the Northern Monsoon's peak, the model is generally wetter in the south and drier in the north, with different attributes using TAMSAT.** Irrespective of the observation used, the ECMWF-S2S captures the inter-annual variability of the rainfall anomaly for each LT from all SDs dates over each region with discrepancies
- While the correlation in the hind-cast is strongest the anomalies display the weakest correlation skill.
- **The decrease or increase of correlation skill across LTs over all regions is not consistent.** However, LT1 displays the strongest skill except in the anomaly and real-time in TAMSAT.

SUMMARY

Results demonstrate that the:

- **The correlation skill from SP compared to the SPT, is stronger.**
- **Seasonally, while the model correlation skill is strongest during the SSMP in real-time and in the anomaly, the correlation skill during the NMP is strongest in the hind-cast.**
- **Although, the correlation in the anomaly may be the lowest, however, with synchronization value of approximately 80 percent across the region the model could predict on average 8 correct rainfall anomaly forecasts out of 10 across the regions regardless of the LT.**
- **The RPSS generally decreases towards the SAH but weakest over the GoG in TAMSAT**
- **It reveals significant inconsistencies in RPSS across LTs from all SDs. While the LT1 is strongest in skill in 2020, it displays the weakest skill in 2021.**
- **With AUC of about 0.78 the models' ability to discriminate different rainfall thresholds across all regions is strong, with the exception of the GoG in extreme low rainfall and the SAH in extreme heavy rainfall.**
- **Finally, the results show that the assessment of the skill in this model is sensitive to the uncertainty in the validating observations.**

THANK YOU

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(WMO)