Future changes in rainfall associated with ENSO and IOD over Eastern Africa

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Motivation

- Rainfall over Eastern Africa shows a high degree of interannual variability.
- The interannual variability of rainfall over the region is strongly linked to SST anomalies over the tropical Oceans (Nicholson et al., 1997, Black et al., 2002 and Omondi et al., 2012).
- Particularly, El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are suggested to be the dominant driver of the rainfall variability.
- Therefore, investigating the future changes in regional rainfall patterns associated with ENSO and IOD is of great importance for the region to tackle the anticipated droughts and floods associated anthropogenic climate change.

Objectives

- To assess the ability of climate models (regional and global) to reproduce the telconnection forcing of tropical SST on rainfall over eastern Africa, with particular attention paid to the propagation of large-scale teleconnection signals into the domain of the RCMs
- To examine the projected changes in the characteristics of ENSO and IOD (such as the mean state, intensity and frequency).
- To investigate whether the current rainfall anomalies associated with ENSO and IOD are projected to change in the twenty-first century.

Data used for the analysis

GCMs	GCMs hor. res	RCA4	CCLM4
CanESM2	2.8 * 2.8^o	✓	
CNRM-CM5	1.4 * 1.4^o	✓	✓
GFDL-ESM2M	2.5 * 2.0^o	✓	
EC-EARTH	1.125 * 1.12^o	✓	✓
HadGEM2-ES	1.875 * 1.25^o	✓	✓
MIROC5	1.4 * 1.4^o	✓	
MPI-ESM-LR	1.9 * 1.9^o	✓	✓
NorESM1-M	2.5 * 1.9^o	✓	

- **Model data**
  Rainfall and SST data from 8 CMIP5 GCMs(1st member except EC-EARTH)
  Rainfall data from RCA4 and CCLM driven by CMIP5 GCMs(0.44^o res)

- **Observed data**
  GPCC: gauge based gridded observational dataset
  NOAA.ERSST.v3b: satellite-gauge combined dataset

- **Analysis period**
  1976 to 2005 is considered as reference period and projected analysis performed for far future (2070-2099) on two-concentration pathways (RCP4.5 and RCP8.5).

How well the models perform at reproducing the observed teleconnection patterns (amplitudes and spatial patterns)?

Teleconnection responses in multi-GCM driven CORDEX RCMs over Eastern Africa

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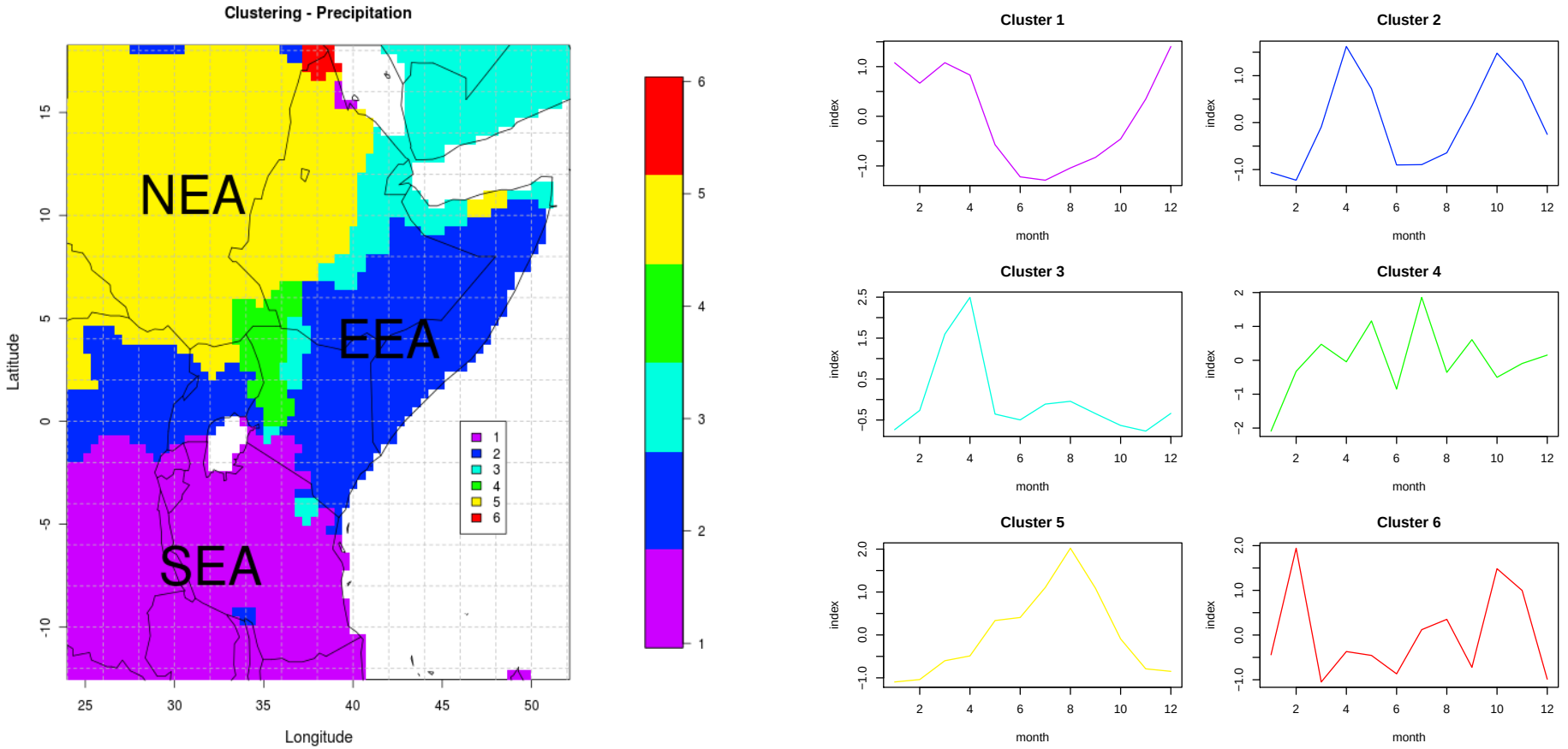
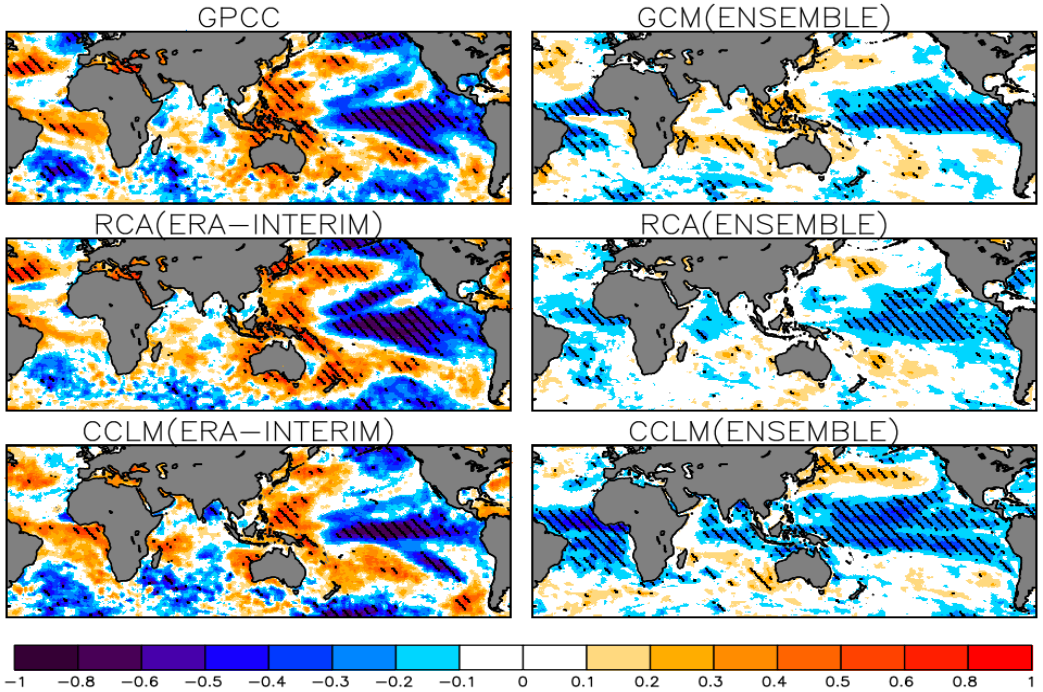
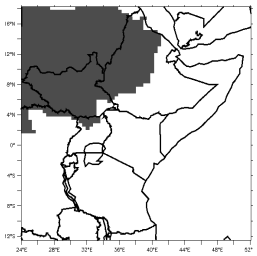
Study region and area of analysis

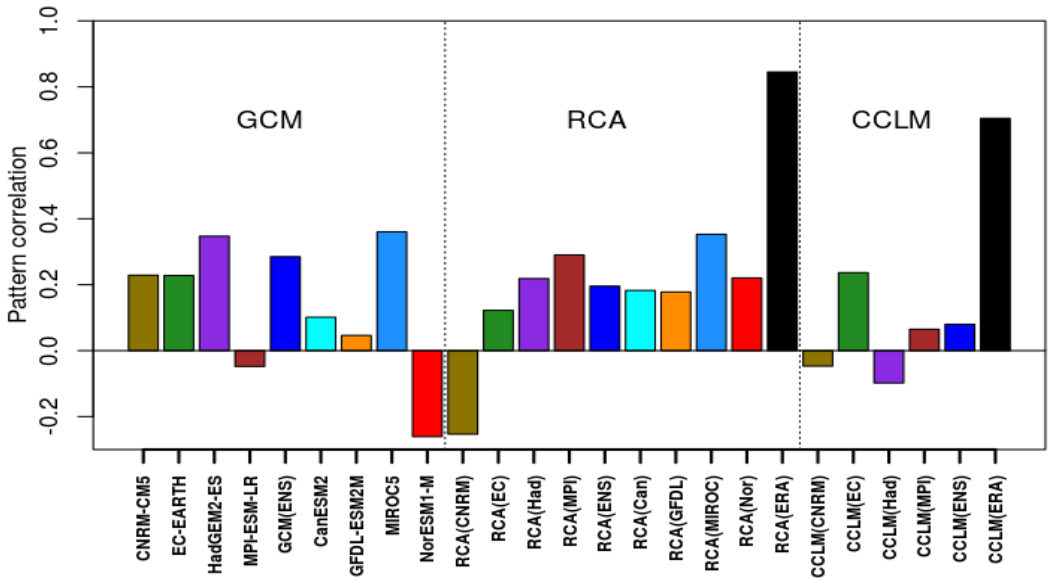


Homogeneous rainfall regions(left) with corresponding annual cycles(right) as categorized using Ward's hierarchical clustering technique

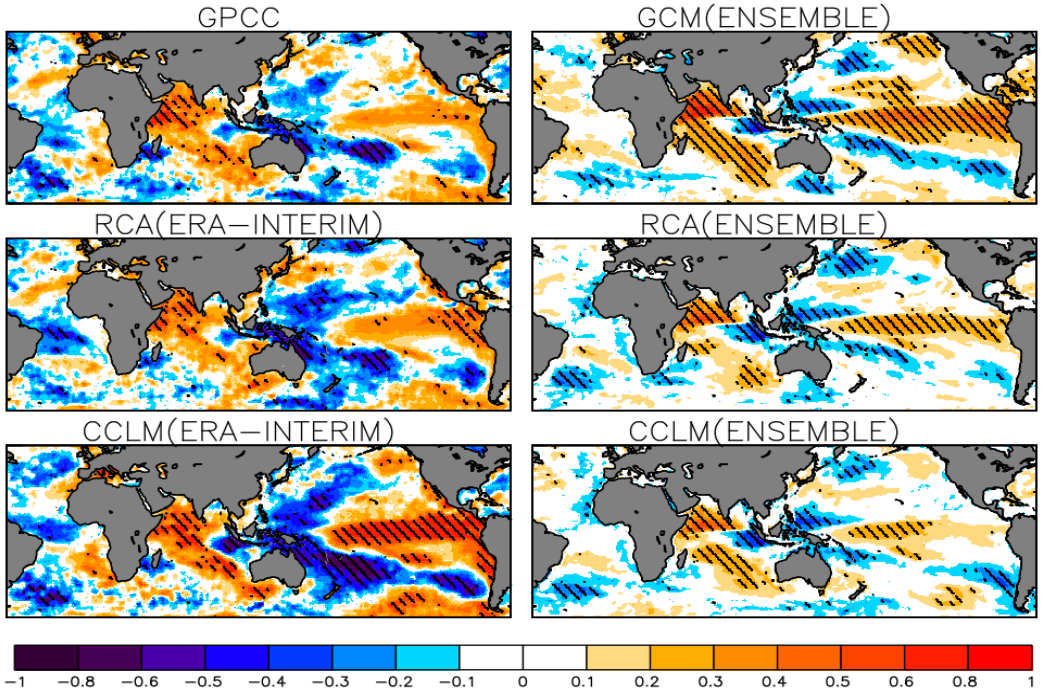


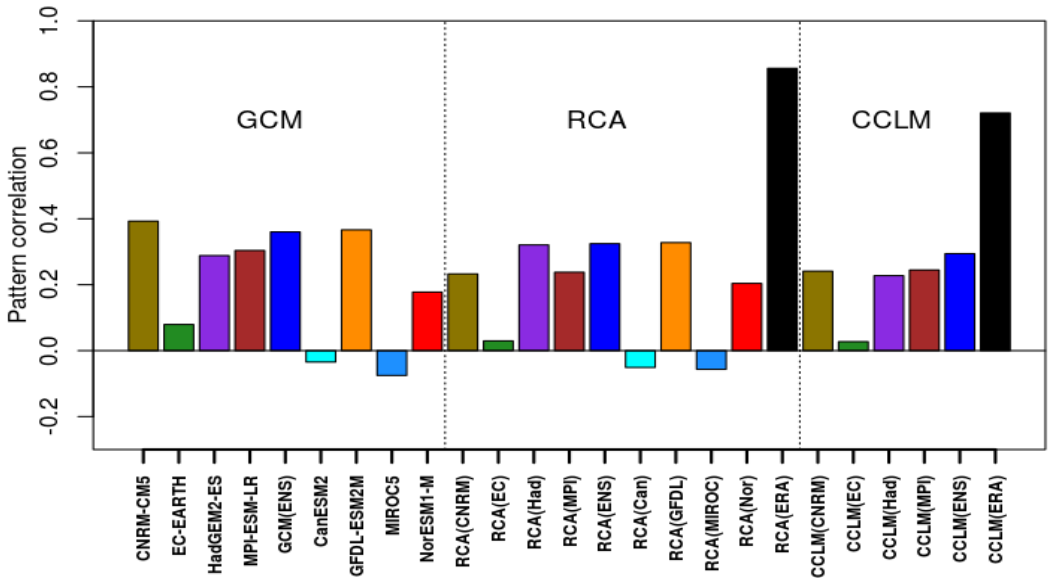
- **Correlations of JJAS rainfall averaged over NEA, against concurrent grid-point SSTs.**
- Rainfall in NEA has significant correlation with SSTs in Eastern equatorial Pacific Ocean.



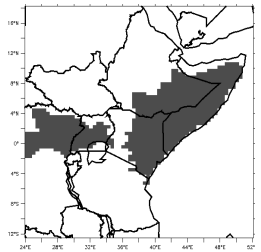


- **Pattern correlation of correlation coefficients between the models and observation. Correlations are weighted with respect to latitude.**
- Era-interim driven RCMs reproduced the pattern well
- Disagreement in GCM-driven RCMs, with one another and with observation.
- No clear improvement observed in RCMs to their driving GCMs.

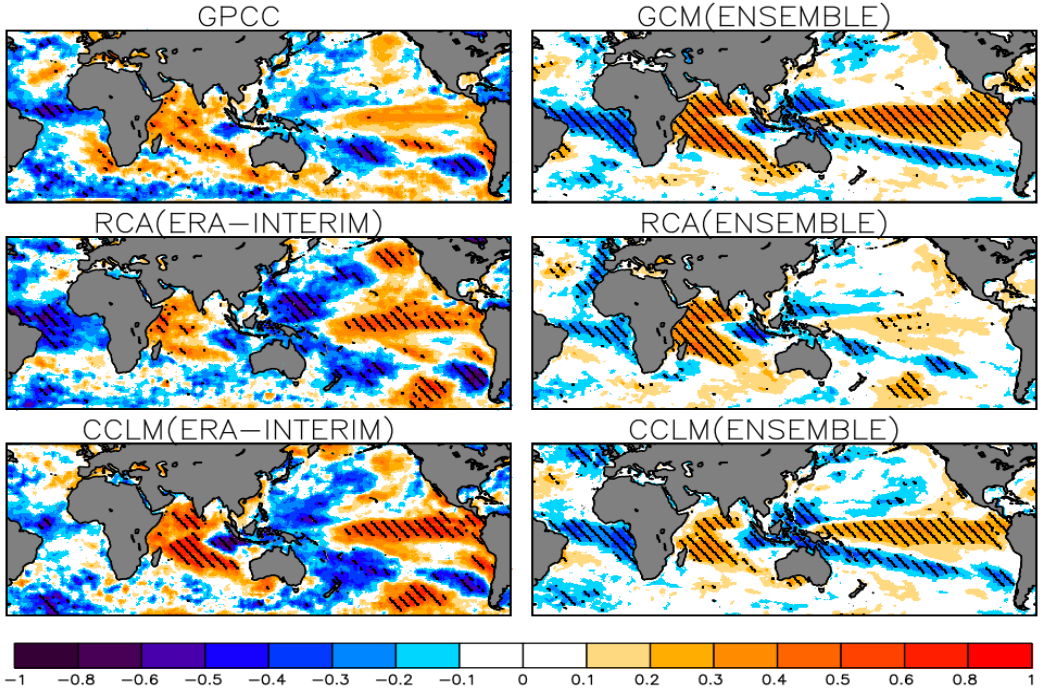


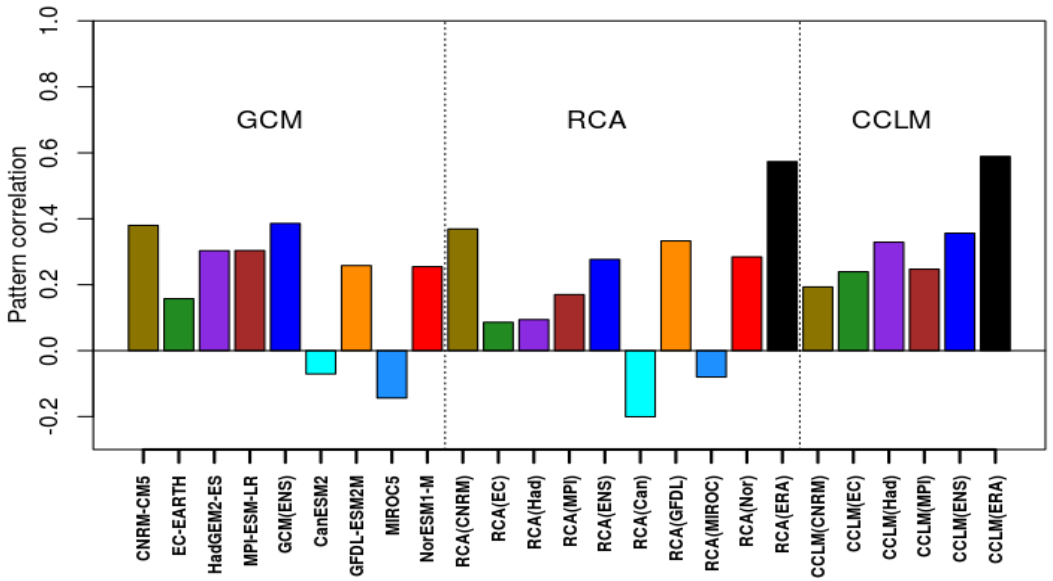


- **Correlations of OND rainfall averaged over EEA, against concurrent grid-point SSTs.**
- EEA has significant correlation with SSTs in western tropical Indian Ocean and Eastern equatorial Pacific Ocean.

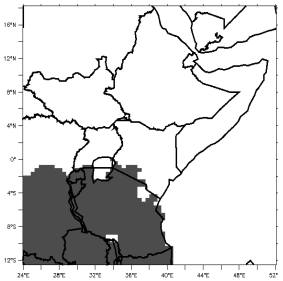


- **Pattern correlation of correlation coefficients between the models and observation.**
- ERA-Interim driven RCMs have better agreement with observation.
- HadGEM2-ES, MPI-ESM-LR, GFDL-ESM2M and EnsMean better performed than others.
- CanESM2 and MIROC5 poorly performed.



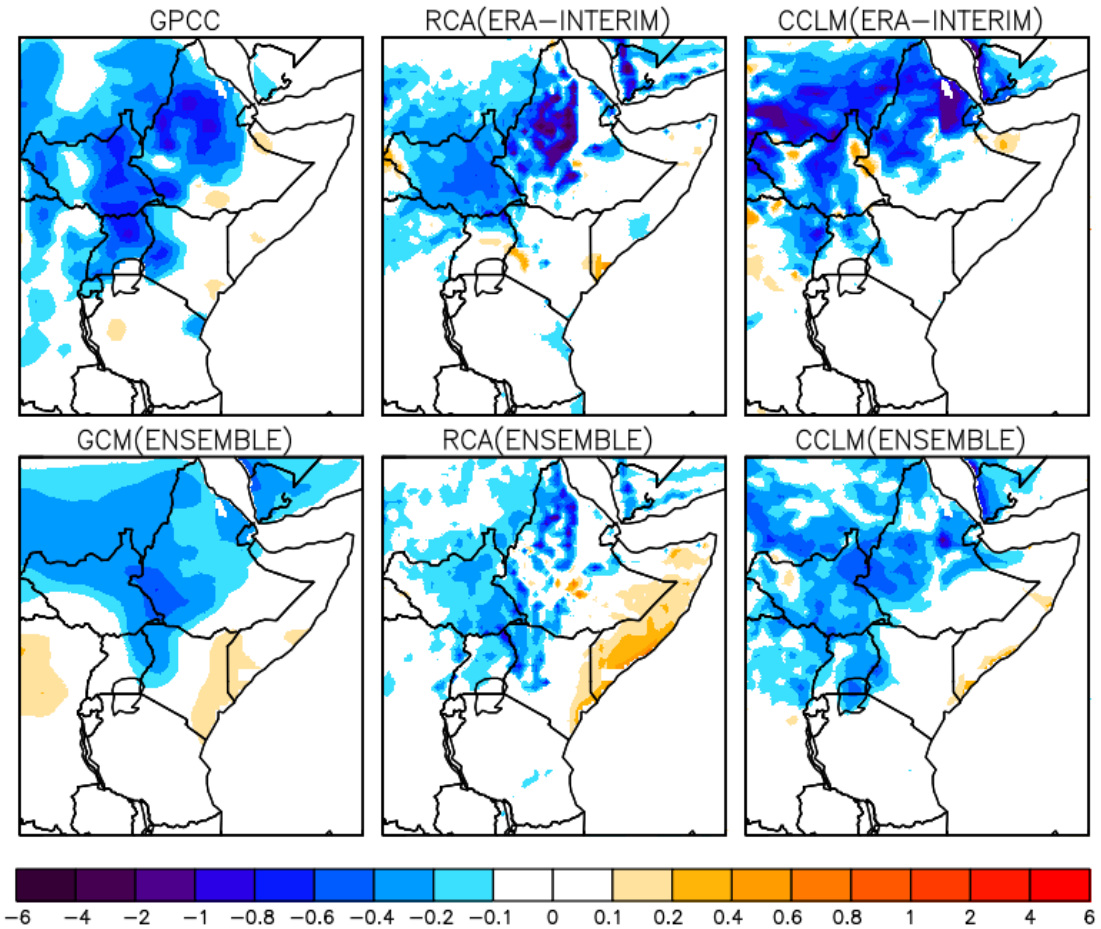


- **Correlations of OND rainfall averaged over SEA, against concurrent grid-point SSTs.**
- Significant correlations observed over central part of tropical Indian Ocean.



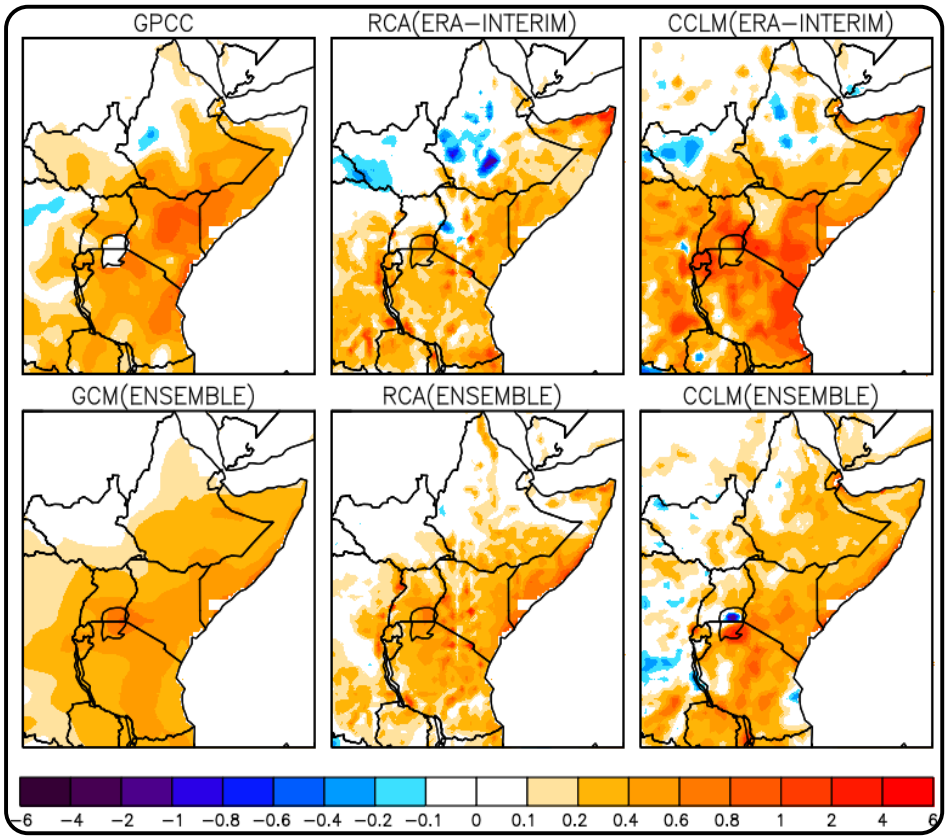
- **Pattern correlation of correlation coefficients between the models and observation.**
- The pattern well reproduced by ERA-Interim driven RCMs.
- HadGEM2-ES, MPI-ESM-LR, GFDL-ESM2M and EnsMean better performed than others.
- CanESM2 and MIROC5 still show a pattern opposite to the observed.

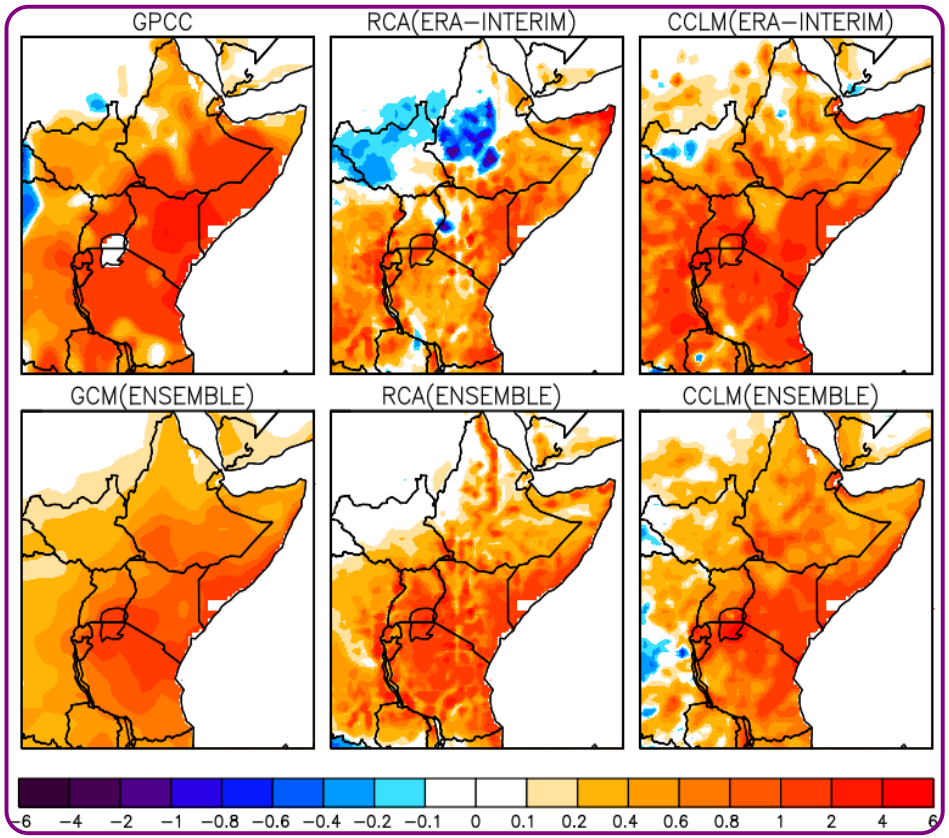
JJAS rainfall teleconnections, as identified through a linear regression analysis against Nino3.4 index



Units are mm/day^{o}C.

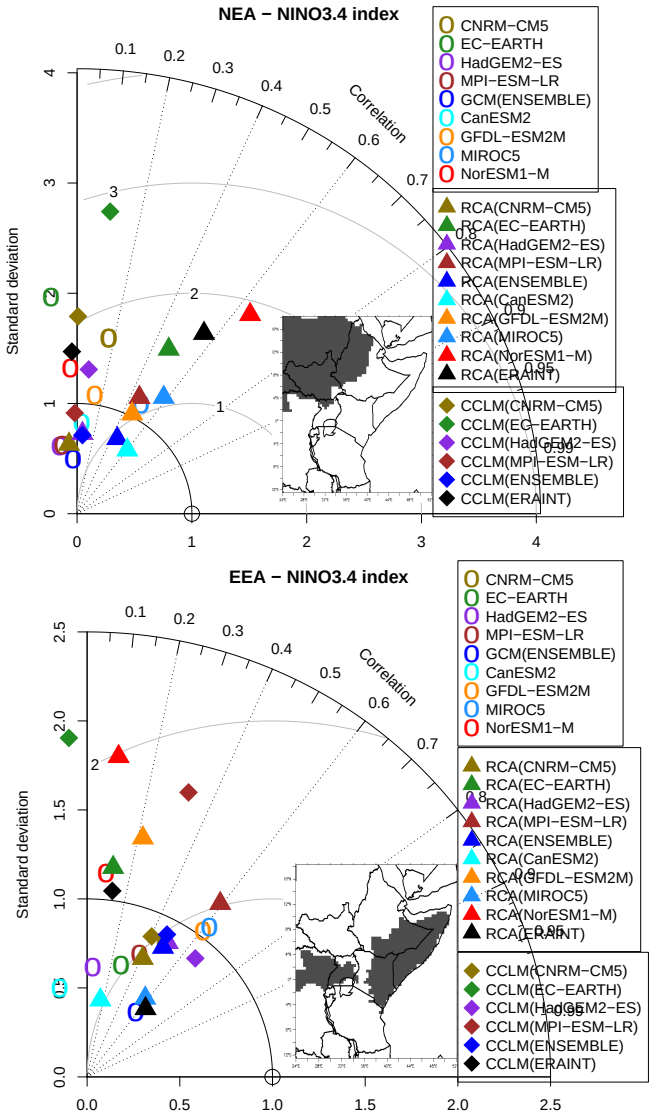
OND rainfall teleconnections, as identified through a linear regression analysis against Nino3.4 (left) and IOD (right) index

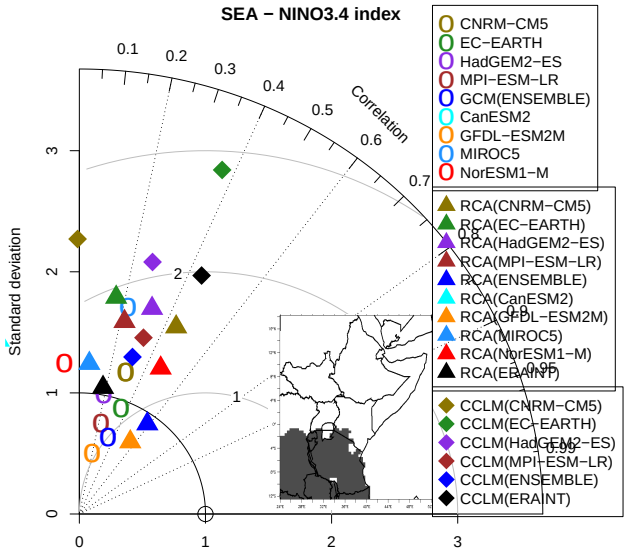




Units are mm/day°C.

Taylor diagrams for the standardized amplitude and spatial correlation of rainfall teleconnections

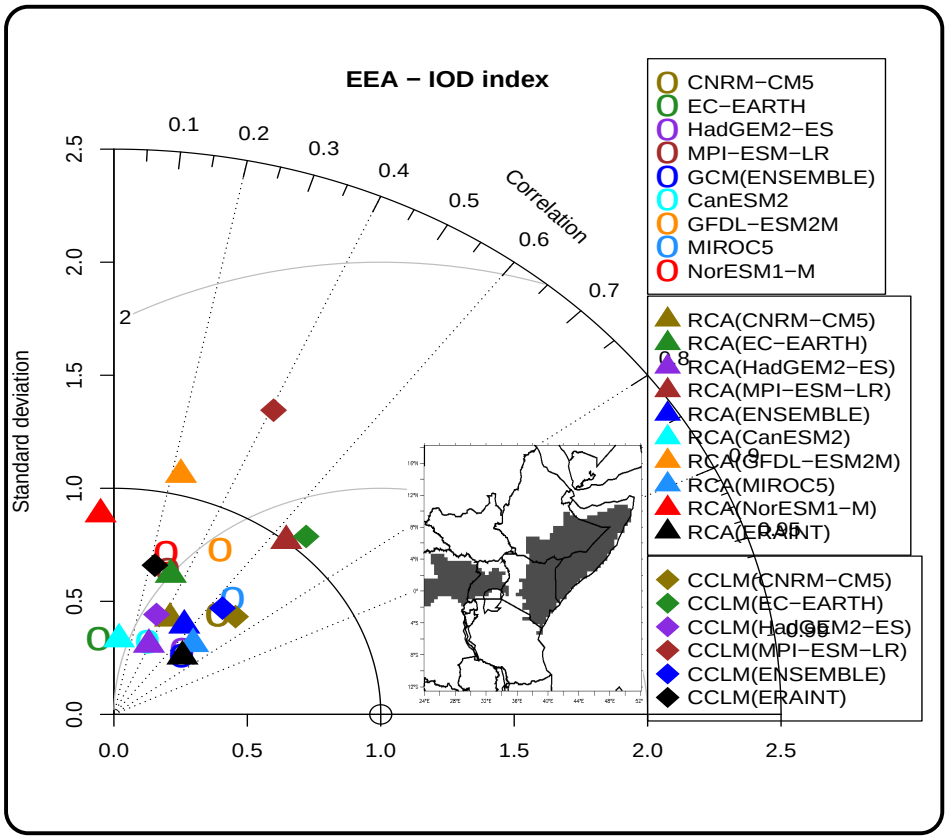


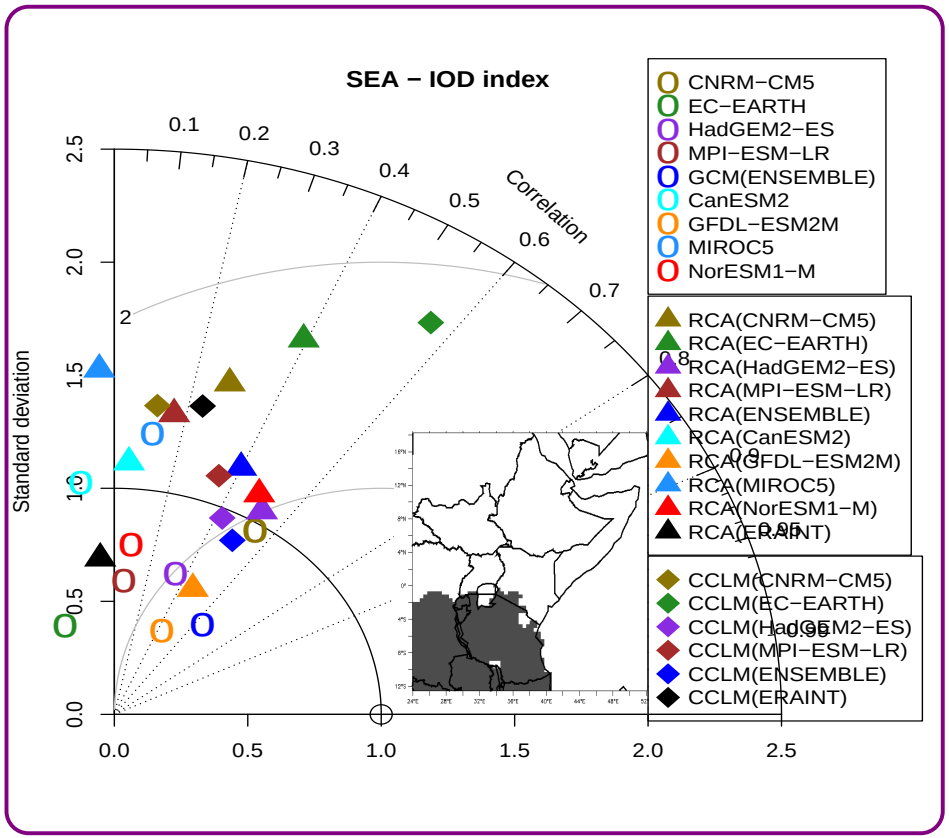


- **GCMs generally underestimate the amplitude of teleconnection patterns while RCMs tend to overestimate it.**
- The overestimation of amplitude by the RCMs probably linked with enhanced precipitation due to a better-resolved topography.

GCM(circle), RCA(triangle) and CCLM(diamond).

Taylor diagrams for the standardized amplitude and spatial correlation of rainfall teleconnections



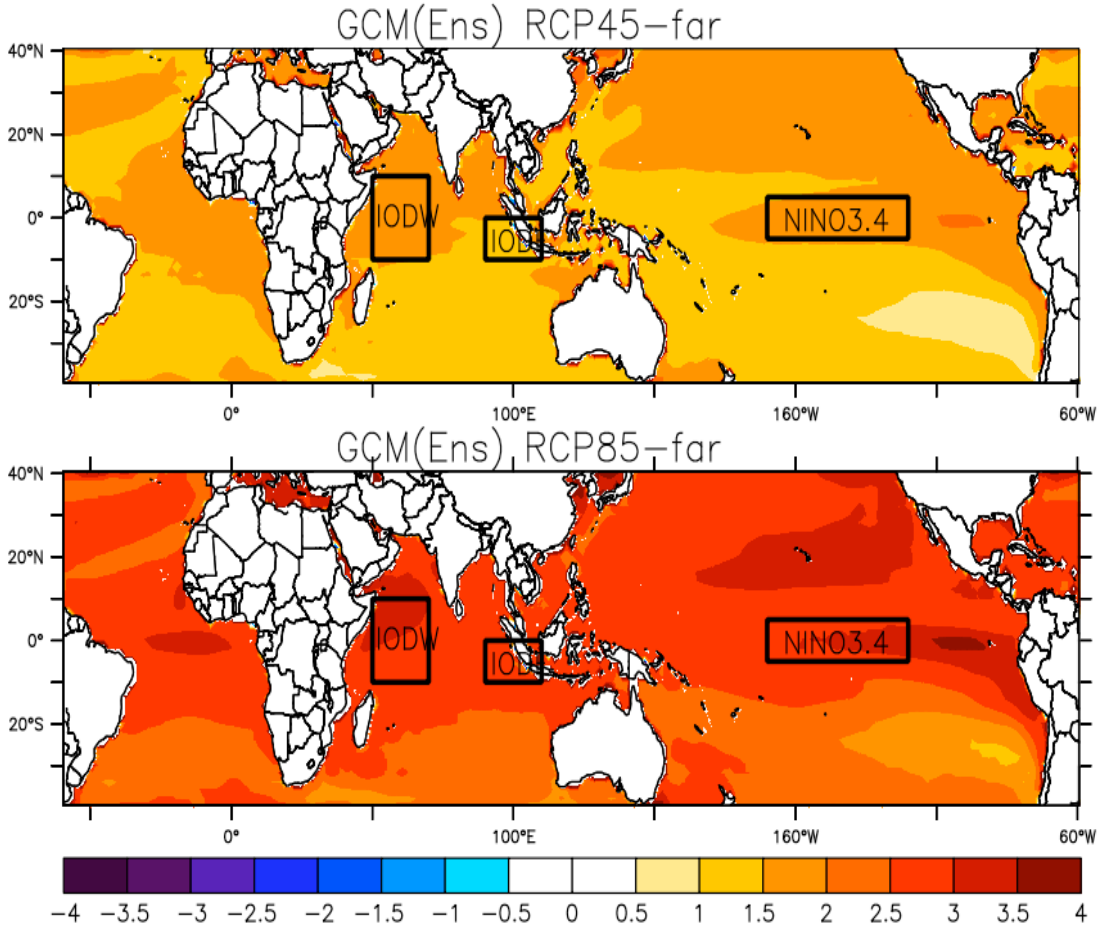


GCM(circle), RCA(triangle) and CCLM(diamond).

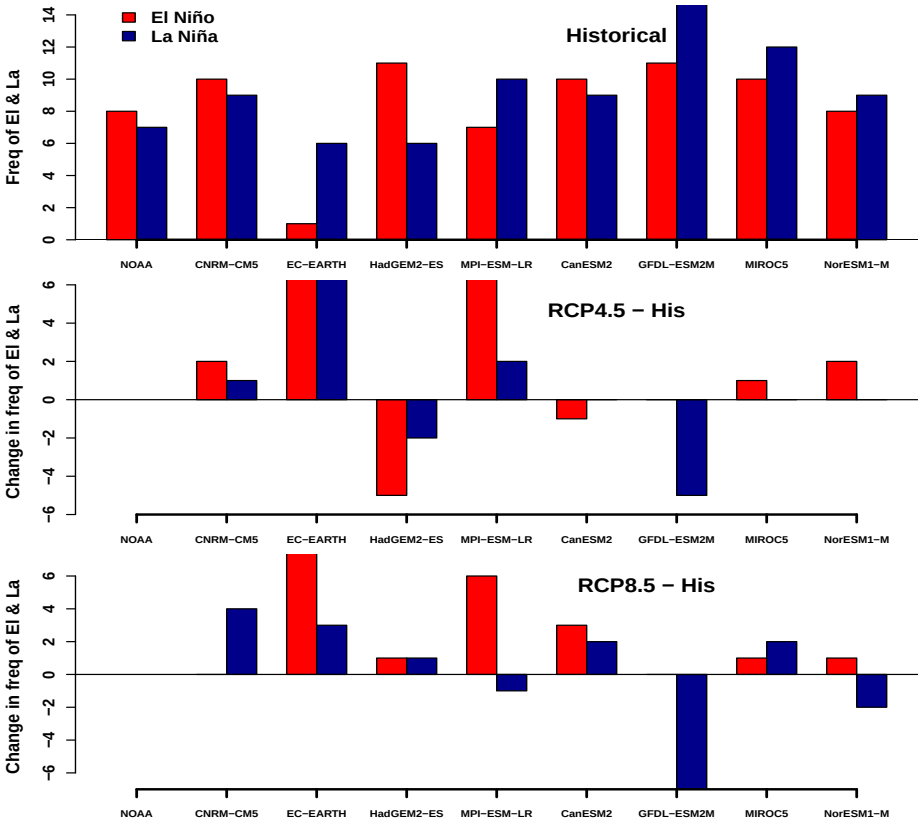
Summary 1

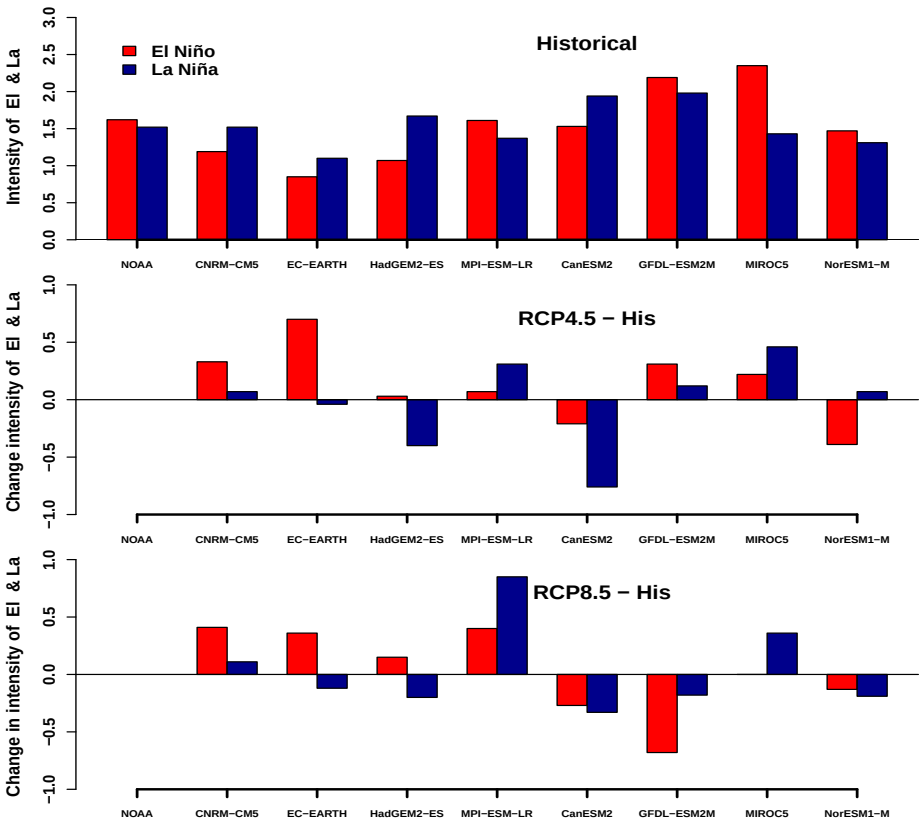
- Some models reproduce the observed teleconnective SST-rainfall patterns (spatial patterns and amplitudes) better than others. RCMs driven by HadGEM2-ES, MPI-ESM-LR and GFDL-ESM2M performed relatively better than RCMs driven by other GCMs.
- The RCM-reanalysis runs have been performed better than RCM-GCM runs in most subregions and seasons.
- GCMs generally underestimate the amplitude of teleconnection patterns while RCMs tend to overestimate it.
- The largest source of uncertainty in the regional climate model simulations in the context of teleconnective forcing of rainfall over Eastern Africa is the choice of GCM used to force the RCMs, reinforcing the understanding that the use of a single GCM to downscale climate predictions/projections and using the downscaled product for assessment of climate change projections is insufficient.

Difference in mean SST between the future and reference period from the ensemble of the CGCMs



Frequency and intensity of ENSO events in the present climate and changes in the future relative to the present

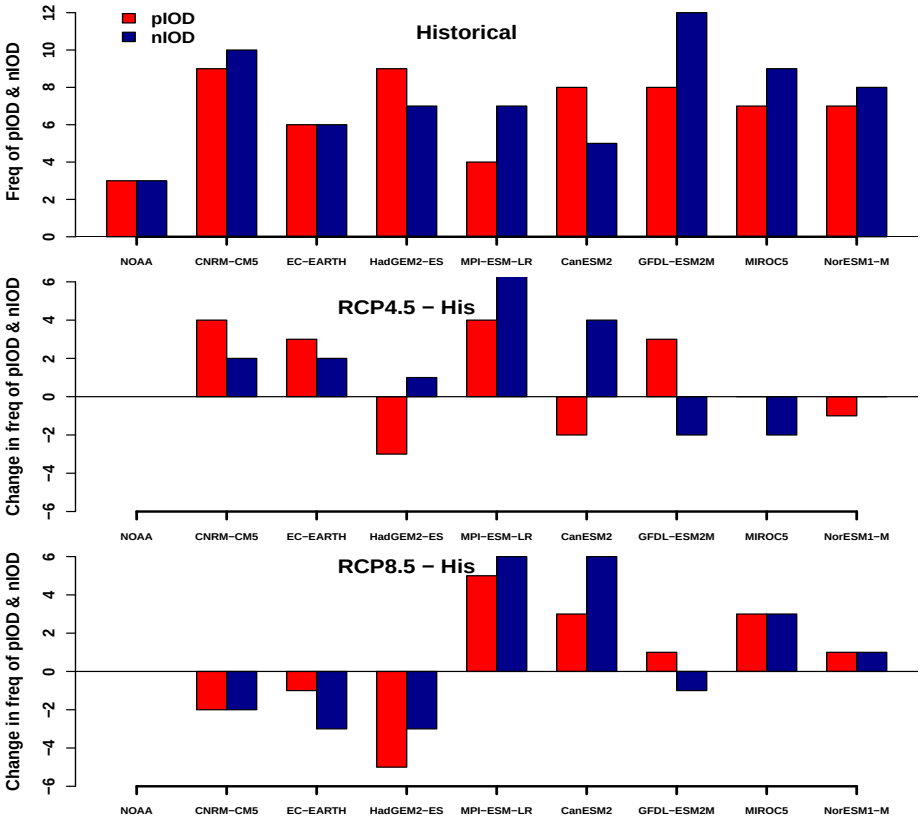


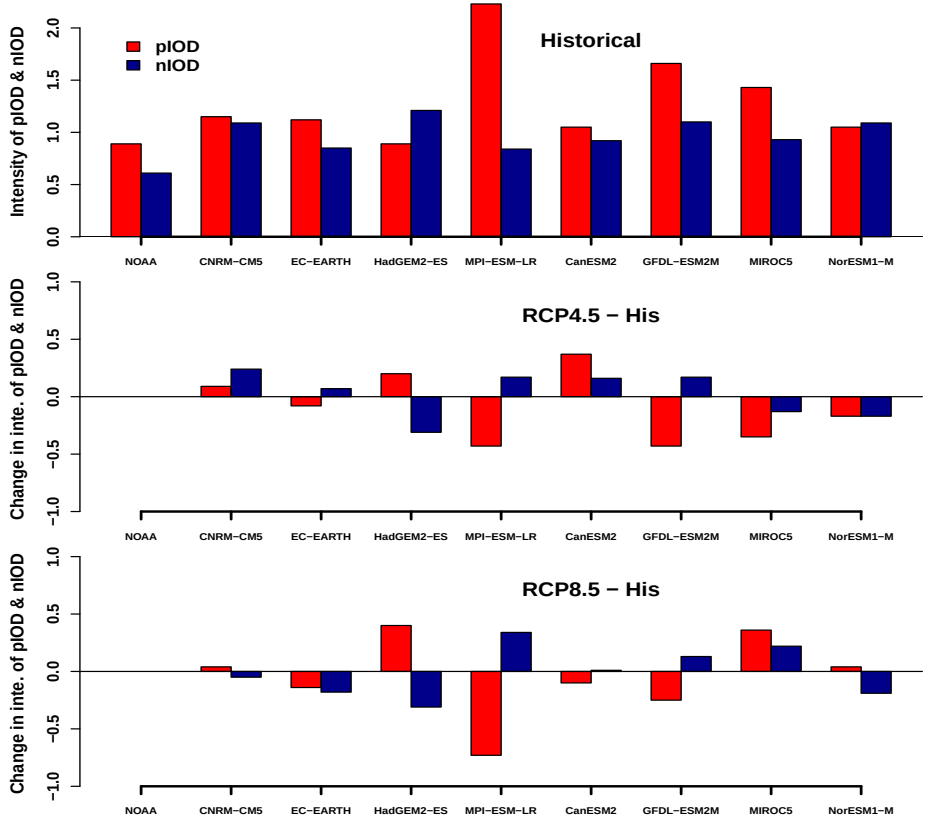


*Frequency is calculated as the number of occurrence of ENSO events, computed from the 3-month SST anomalies of ONI.

*Intensity is computed as the average of the maximum ONI for all ENSO events for present and future periods

Frequency and intensity of IOD events in the present climate and changes in the future relative to the present

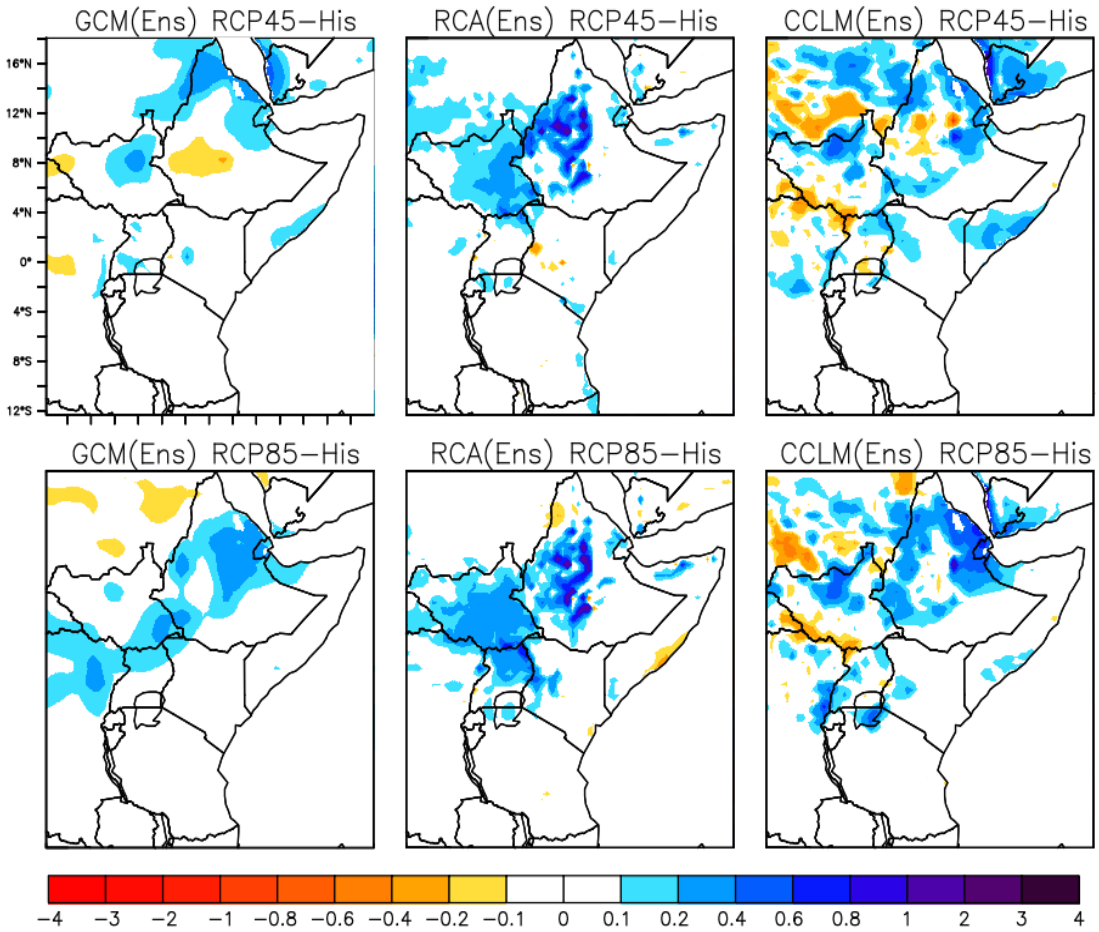




*Frequency is calculated as the number of occurrence of IOD events, computed from the 3-month SST anomalies of DMI.

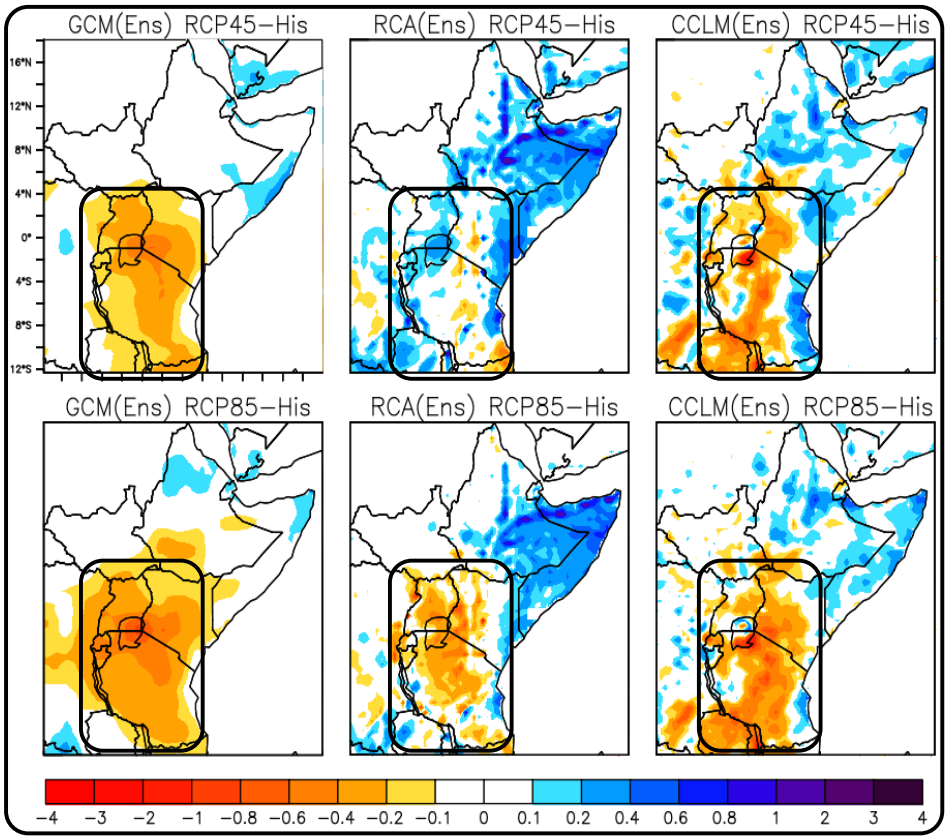
*Intensity is computed as the average of the maximum DMI for all IOD events during present and future periods

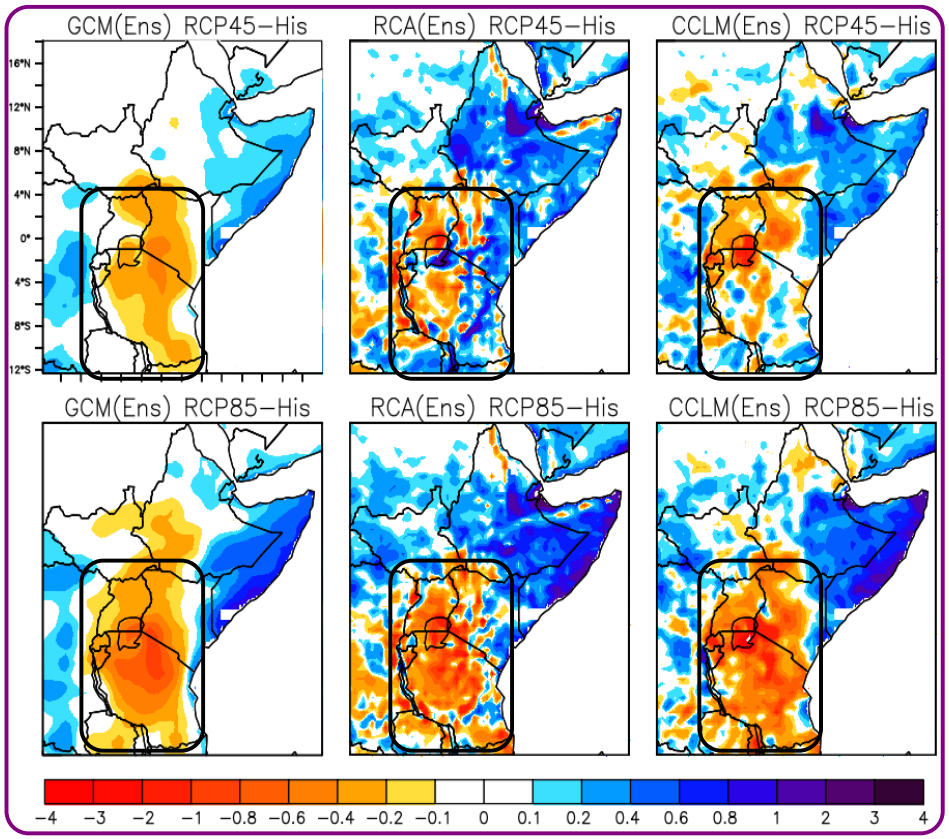
Differences in JJAS teleconnection patterns resulted from regression coefficients against Nio3.4 index between future and historical period



Units are mm/day^{o}C.

Differences in OND teleconnection patterns resulted from regression coefficients against Niño3.4 (left) and IOD (right) index between future and historical period

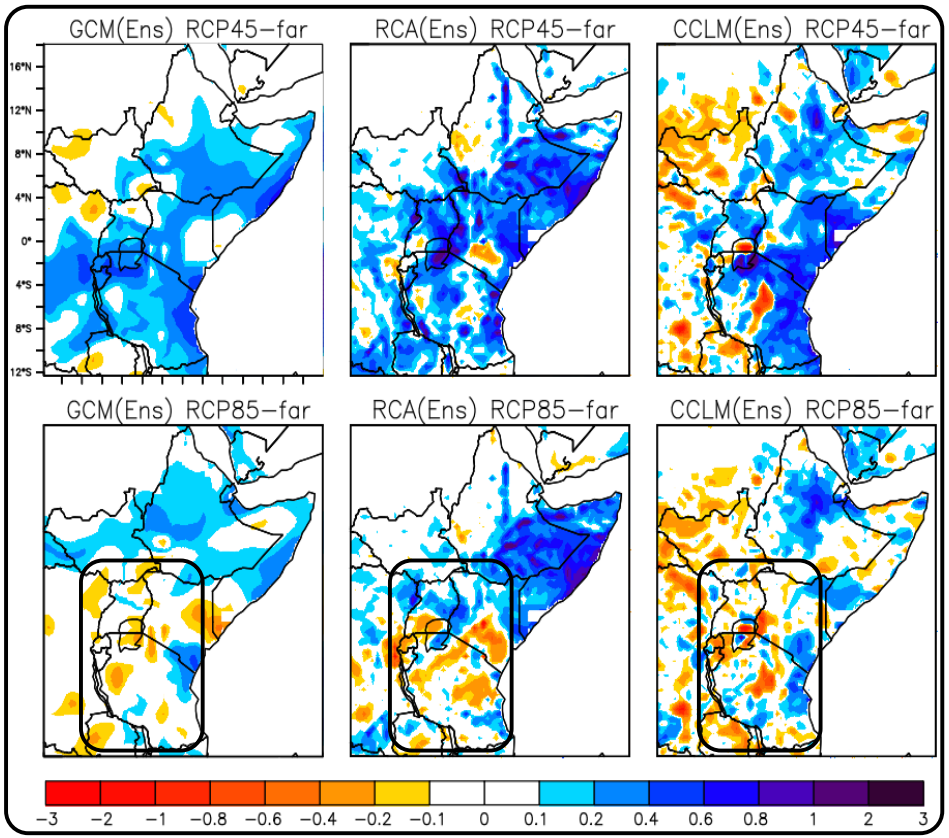


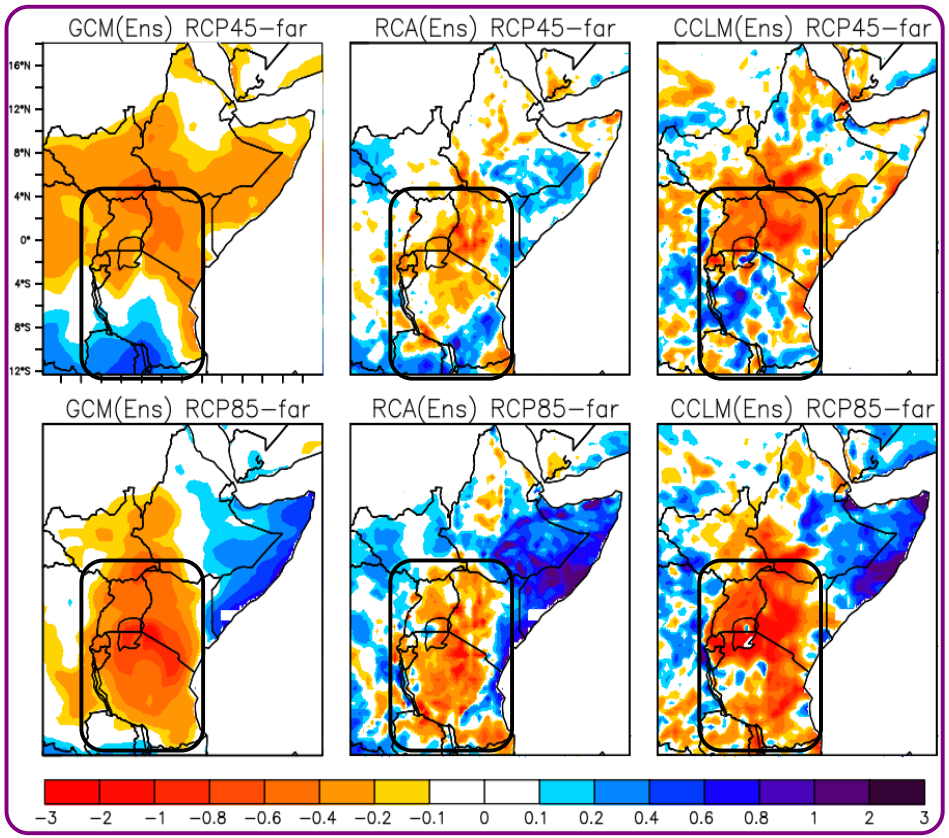


*Over eastern part of the domain, the ENSO/IOD related rainfall anomaly is stronger compared to the present

*Over the southern part of the region the ENSO/IOD signal gets weaker.

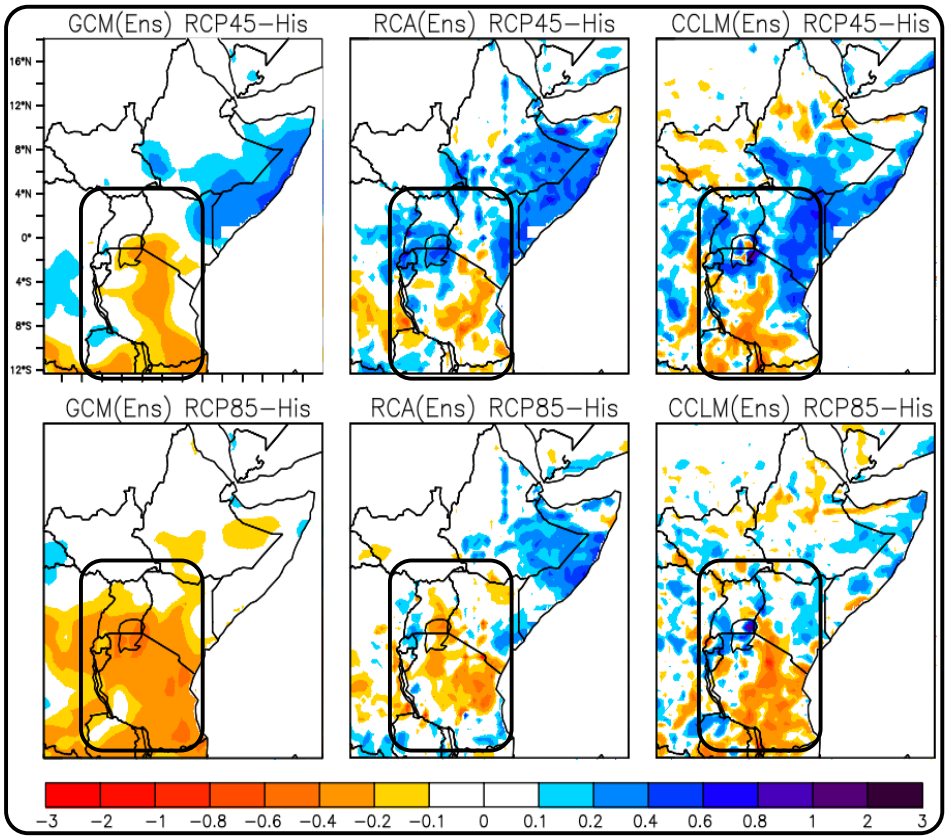
Differences in OND rainfall anomalies between future and current El Niño years (left) and positive IOD years (right)

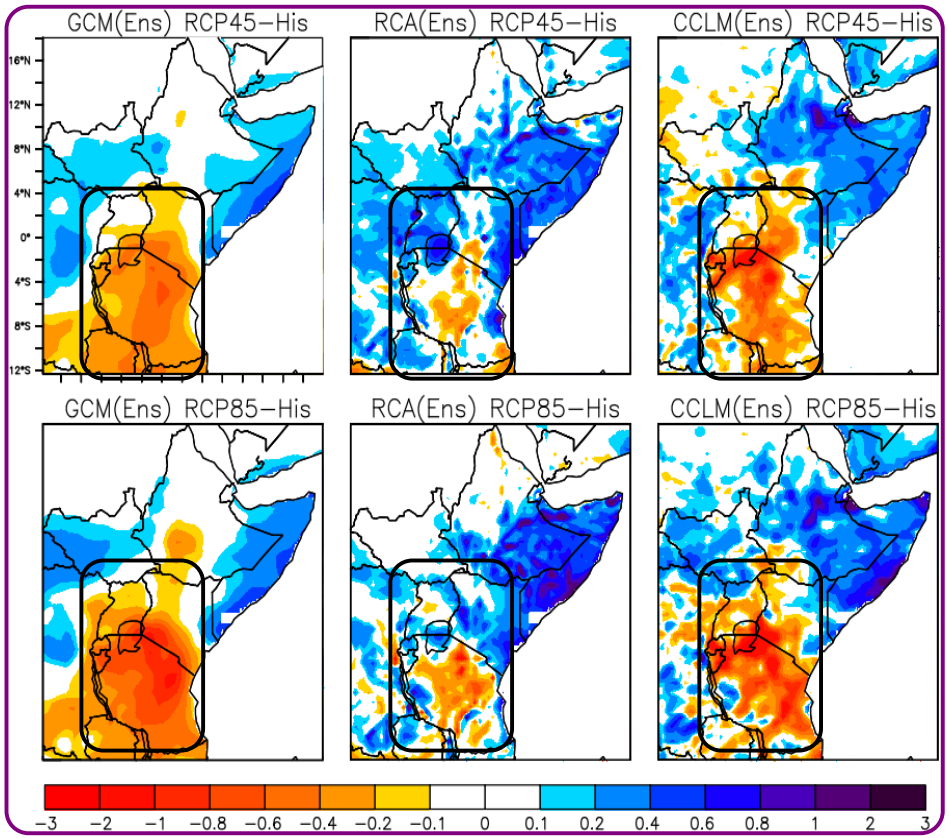




Units are mm/day.

Differences in OND rainfall anomalies between future and current La Niña years (left) and negative IOD years (right)





Units are mm/day.

Summary and conclusions

- Analyses of projections based on CGCMs indicate an El Niño-like (positive IOD-like) warming pattern over the tropical Pacific (Indian) Ocean.
- However, large uncertainties remain in projecting future changes in ENSO/IOD frequency and intensity. Some models show increase of ENSO/IOD frequency and intensity, but others show a decrease or even no/small change.
- During ENSO and IOD years, two important changes in the teleconnection signals in future have been found:
  - Over eastern part of the domain (Eastern horn of Africa), the ENSO/IOD related rainfall anomaly is projected to strengthen
  - Over the southern part of the regions the ENSO/IOD signal is projected to weaken compared to the present period.
- The enhanced rainfall events over the eastern horn of Africa attributable to ENSO and IOD phases are probably linked to a warmer western region of the Indian Ocean in future compared to the present.

Thank You!!