IGAD CLIMATE PREDICTION AND APPLICATIONS CENTRE
ICPAC

Evaluation of Rainfall Baseline and Projections for the Greater Horn of Africa Countries Using Cordex Models

In Support of;

Planning for Resilience in East Africa through Policy, Adaptation, Research and Economic Development (PREPARED) Project

November 2014

Background

The Coordinated Regional Downscaling Experiment (CORDEX) is a program sponsored by World Climate Research Program (WCRP) to develop an improved framework for generating regional-scale climate projections for impact assessment and adaptation studies worldwide within the IPCC AR5 timeline and beyond. The program aims to produce an ensemble of multiple dynamical and statistical downscaling models considering multiple forcing GCMs from the CMIP5 archive. 50 km grid spacing has been selected, favouring engagement of wider community. For the list of CORDEX RCMs and their details **(Table 1)**

An essential component of CORDEX is the evaluation of the ability of the ten Regional Climate Models (RCMs) from CORDEX in simulating the characteristics of rainfall patterns over the Greater Horn of Africa (GHA) sub-region for a 20-year (1989-2007) hindcast period with the lateral boundary forcing obtained from ERA-Interim reanalysis. These evaluations are critical to characterizing the strengths and weaknesses of these models for their use in producing future projections regional climate change where the lateral boundary forcing is provided by multiple GCMs and emissions scenarios from the CMIP5 archive.

Climatology

Figure 1 shows the spatial rainfall climatology for (i) June-August (JJA) (ii) October-December (OND) seasons with figure 2 showing their biases respectively. Figure 3 depicts mean annual precipitation cycle over (i) northern (ii) equatorial and (iii) southern sectors. The ability of the RCMs in simulating large-scale global climate forcing signals such as El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) are shown by Figure 4 for interannual variability over the (i) northern (ii) equatorial and (iii) southern sectors.

The spatial characteristics of the RCMs in simulating these large-scale global climate forcing signals were further tested by compositing the ENSO and IOD events. These are shown in figure 5 for (i) pure La Niña (ii) co-occurrence of El Niño and positive IOD in October-December (OND) rainfall (iii) OND rainfall anomaly during positive IOD.

All the RCMs realistically simulated the rainfall belt associated with the Intertropical Convergence Zone (ITCZ) during all the seasons although most of the models show wet bias apart from REMO and CCLM, which showed dry bias. During OND, all RCMs captured well the ITCZ belt. It was noted that the 10 RCMs indicated wet bias over equatorial sector while CCLM, ARPEGE, HIRHAM, RECMO, and REMO show dry bias in reproducing OND rainfall over southern sector. CRCM5, RACMO, RegCM3, and RCA showed high spatial correlations together with consistency in reproducing spatial patterns of rainfall over time for JJAS in northern sector and RACMO and RegCM3 during OND in equatorial sector.

Summary

Most of the RCMs reasonably simulate the main features of the rainfall climatology over the region and also reproduce ENSO and IOD signals. There are significant biases in individual model however, the ensemble mean show better agreement with observation. In general, the analysis demonstrates that the multimodel ensemble mean simulates regional rainfall adequately and this motivates their use for future climate projections.

Future Rainfall Projections over the GHA sub-region

Within the CORDEX-Africa initiative a large ensemble of regional climate simulations over Africa has been produced by dynamical downscaling of a subset of GCMs from the CMIP5 project.

Eight GCMs, based on availability of boundary conditions in the CMIP5 data base, have been chosen for downscaling (see Table 2). The downscaling of the GCM simulations has been performed with the latest version of the Rossby Centre Regional Climate Model - RCA4 for the GHA sub-region domain at 0.44º resolution. First we have downscaled the ERA-Interim Reanalysis (1980-2010) and then all 8 GCMs sampling both RCP4.5 and 8.5 climate change scenarios and running in transient mode for the period 1951-2100 (historical 1951-2005 and scenario 2006-2100). We have also downscaled one RCP2.6 scenario for 2006-2100 (EC-EARTH).

Figure 6 gives future (i) MAM (ii) OND 2030 rainfall climatology for the projected datasets under RCP 4.5 scenario. The future climatologies show similarites to present climatologies in all the seasons. Figure 7 on the other hand shows (i) Projected MAM 2030 rainfall bias under RCP 4.5 scenario (baseline 1961-1990). Detailed discussion on future projected climate will be given later.

Table 1: List of CORDEX RCMs and their details

	CNRM ARPEGE5.1	**DMI HIRHAM5**	**ICTP RegCM3**	**CLMcom CCLM4.8**	**KNMI RACMO2.2b**	**MPI REMO**	**SMHI RCA35**	**UCT PRECIS**	**UC WRF3.1.1**	**UQAM CRCM5**
Institute	Centre National de Recherches Météorologiques, France	Danmarks Meteorologiske Institut, Danmark	Abdus Salam International Centre for Theoretical Physics, Italy	CLM community (www.clm-community.eu)	Koninklijk Nederlands Meteorologisch Instituut, Netherlands	Max Planck Institute, Germany	Sveriges Meteorologiska och Hydrologiska institut, Sweden	University of Cape Town, South Africa	Universidad de Cantabria, Spain	Université du Québec à Montréal, Canada
Short name	**ARPEGE**	**HIRHAM**	**RegCM3**	**CCLM**	**RACMO**	**REMO**	**RCA**	**PRECIS**	**WRF**	**CRCM**
Projection resolution	polar, stretching factor 2 (TL179)	rotated pole 0.44°	Mercator 50 km	rotated pole 0.44°	rotated pole 0.44°	rotated pole 0.44°	rotated pole 0.44°	rotated pole 0.44°	Mercator 50 km	rotated pole 0.44°
Vertical coordinate/levels	hybrid/31	hybrid/31	sigma/18	terrain following/35	hybrid/40	hybrid/27	hybrid/40	hybrid/19	terrain following ETA/28	hybrid/56
Advection	semi-lagrangian	semi-lagrangian	eulerian	5th order upwind Baldauf (2008)	semi-lagrangian	semi-lagrangian	semi-lagrangian	eulerian	eulerian	semi-lagrangian
Time step (sec)	1200	600	100	240	720	240	1200	300	240	1200
Convective scheme	Bougeault (1985)	Tiedtke (1989)	Grell (1993) Fritsch and Chappell (1980)	Tiedtke (1989)	Tiedtke (1989)	Tiedtke (1989)	Kain and Fritsch (1990, 1993)	Gregory and Rowntree (1990) Gregory and Allen (1991)	Kain (2004)	Kain and Fritsch (1990) Kuo (1965)
Radiation scheme	Morcrette (1990)	Fouquart and Bonnel (1980) Mlawer et al. (1997)	Kiehl (1996)	Ritter and Geleyn (1992)	Fouquart and Bonnel (1980)	Morcrette et al. (1986) Giorgetta and Wild (1995)	Savijärvi (1990) Sass et al. (1994)	Edwards and Slingo (1996)	Dudhia (1989) Mlawer et al. (1997)	Li and Barker (2005)
Turbulence vertical diffusion	Mellor and Yamada (1982)	Louis (1979)	Holtslag et al. (1990)	Herzog et al. (2002) Buzzi et al. (2011)	eddy-diffusivity (1st order K) mass flux approach	Louis (1979)	Cuxart et al. (2000)	Wilson (1992)	Hong et al (2006)	Benoit et al. (1989) Delage (1997)
Cloud microphysics scheme	Ricard and Royer (1993)	Tiedtke (1989) Tompkins (2002)	SUBEX Pal et al. (2000)	Doms et al. (2007) Baldauf and Schulz (2004)	Tiedtke (1993)	Lohmann and Roeckner (1996)	Rasch and Kristjánsson (1998)	Smith et al. (1990)	WSM5 Hong et al (2004)	Sundqvist et al. (1989)
Land surface scheme	ISBA Douville et al. (2000)	Schulz et al.(2001) Hagemann (2002)	BATS1E Dickinson et al. (1993)	TERRA-ML Doms et al. (2007)	TESSEL ECMWF (2006)	Hagemann (2002) Rechid et al. (2009)	Samuelsson et al. (2006)	MOSES2 Essery et al. (2003)	Smirnova et al. (2000)	CLASS 3.5 Verseghy (2000)
Latest reference and comments	Déqué (2010)	Christensen et al. (2006)	Pal et al. (2007)	Rockel et al. (2008) Baldauf et al. (2011)	Meijgaard et al. (2008); based on ECMWF cycle 31r1 ECMWF (2006)	Jacob (2001) Jacob et al. (2007)	Samuelsson et al. (2011)	Jones et al. (2004)	Skamarock et al. (2008)	Zadra et al. (2008)

Figure 1: (i) The seasonal climatology of Rainfall over GHA region during JJA season, observations (GPCC) and ensemble of the ten RCMs.

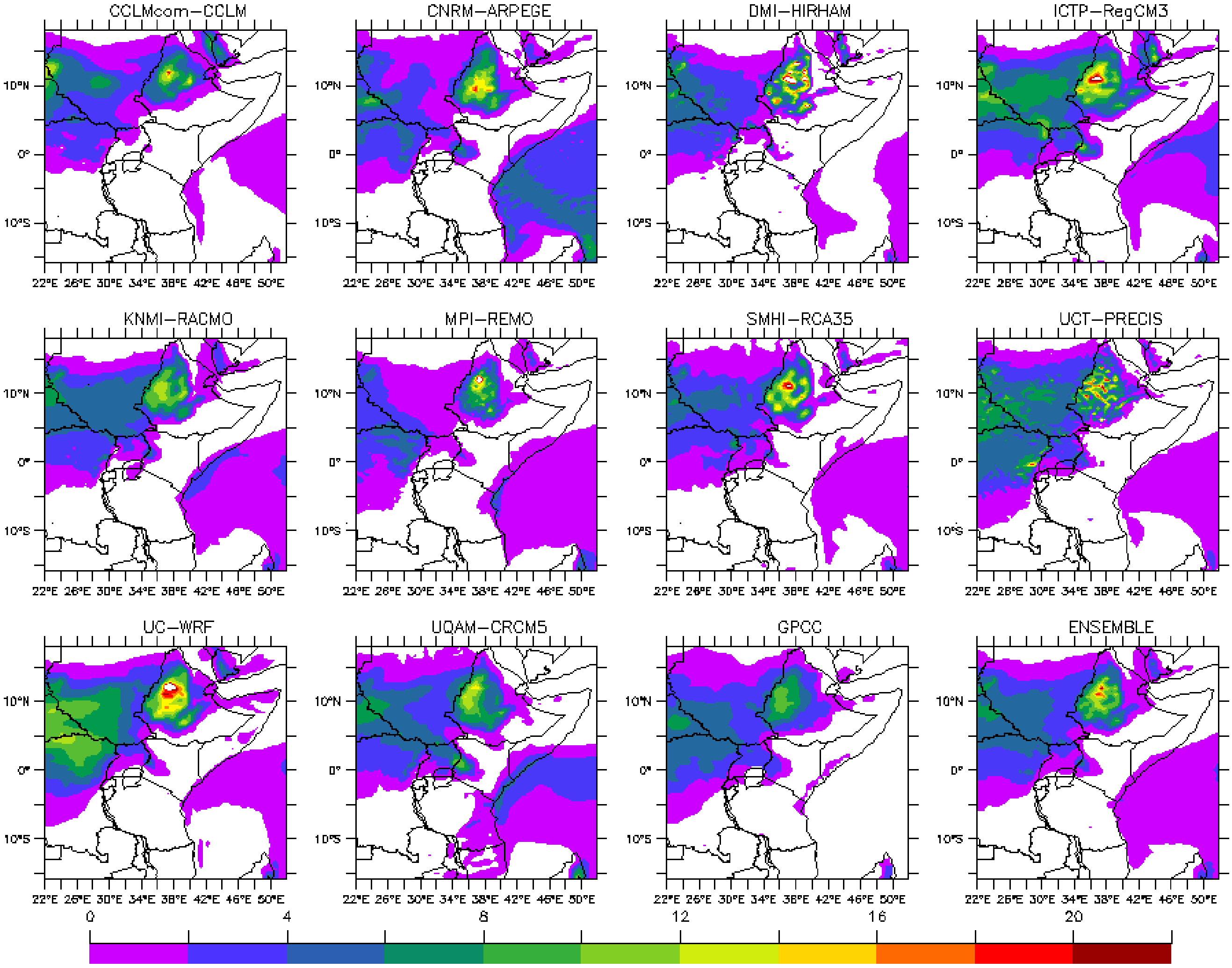


Figure 1: (ii) Climatology of Rainfall over GHA region during OND season as simulated by CORDEX RCMs, observations (GPCC) and ensemble of the ten RCMs.

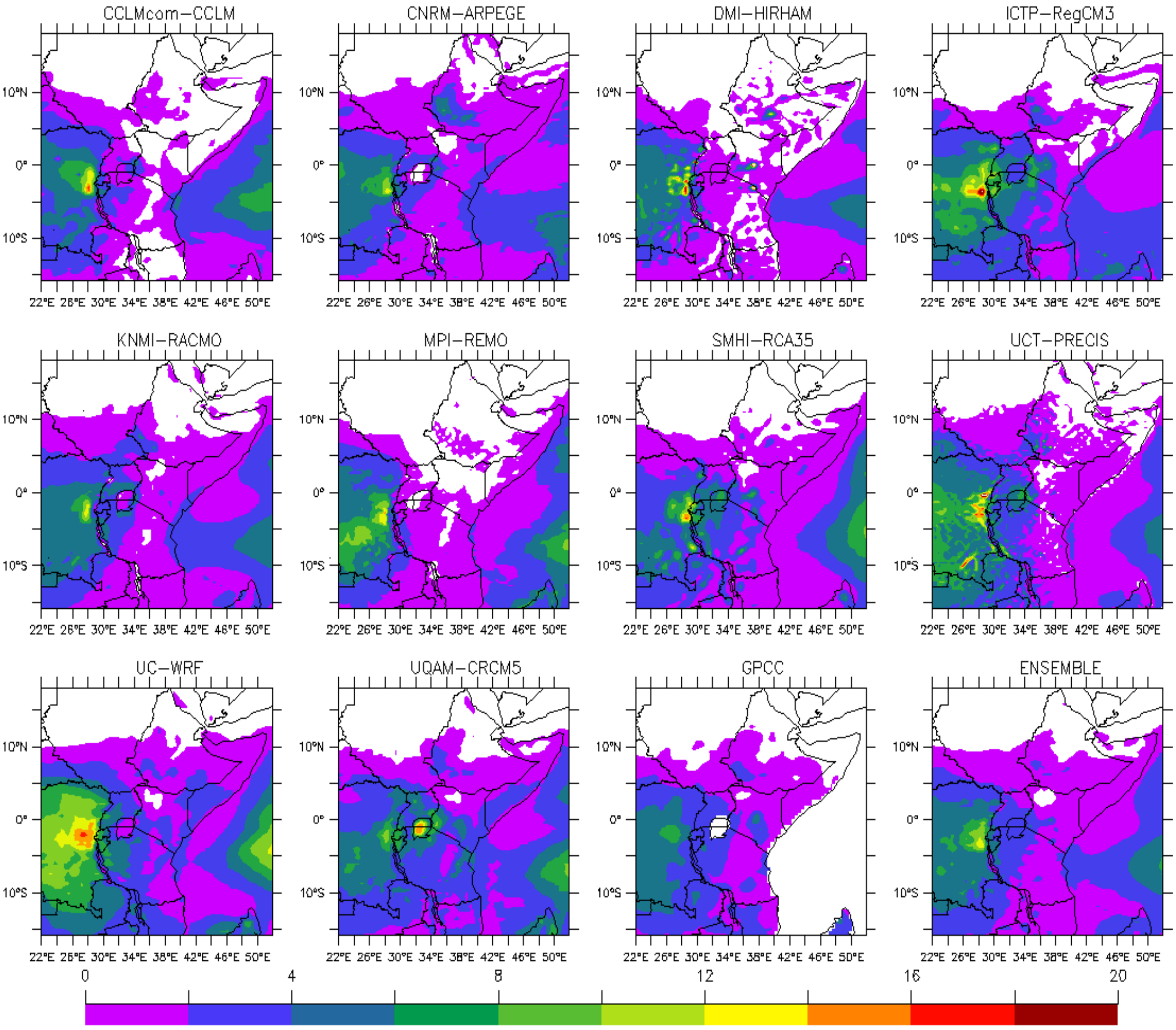


Figure 2: (i) Spatial plots of the RCMs bias (1990-2008) during JJAS

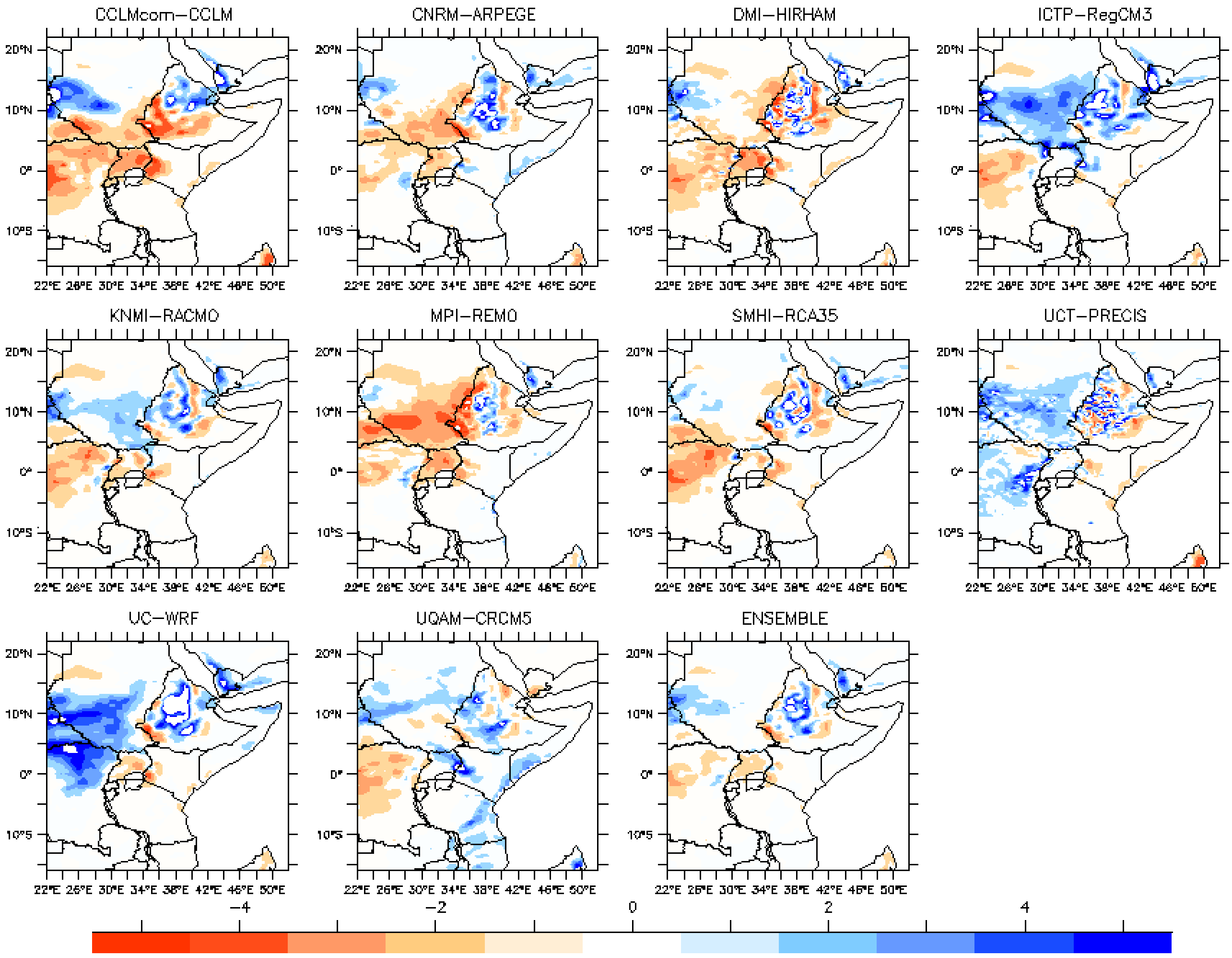


Figure 2: (ii) Spatial plots of the RCMs bias (1990-2008) during OND

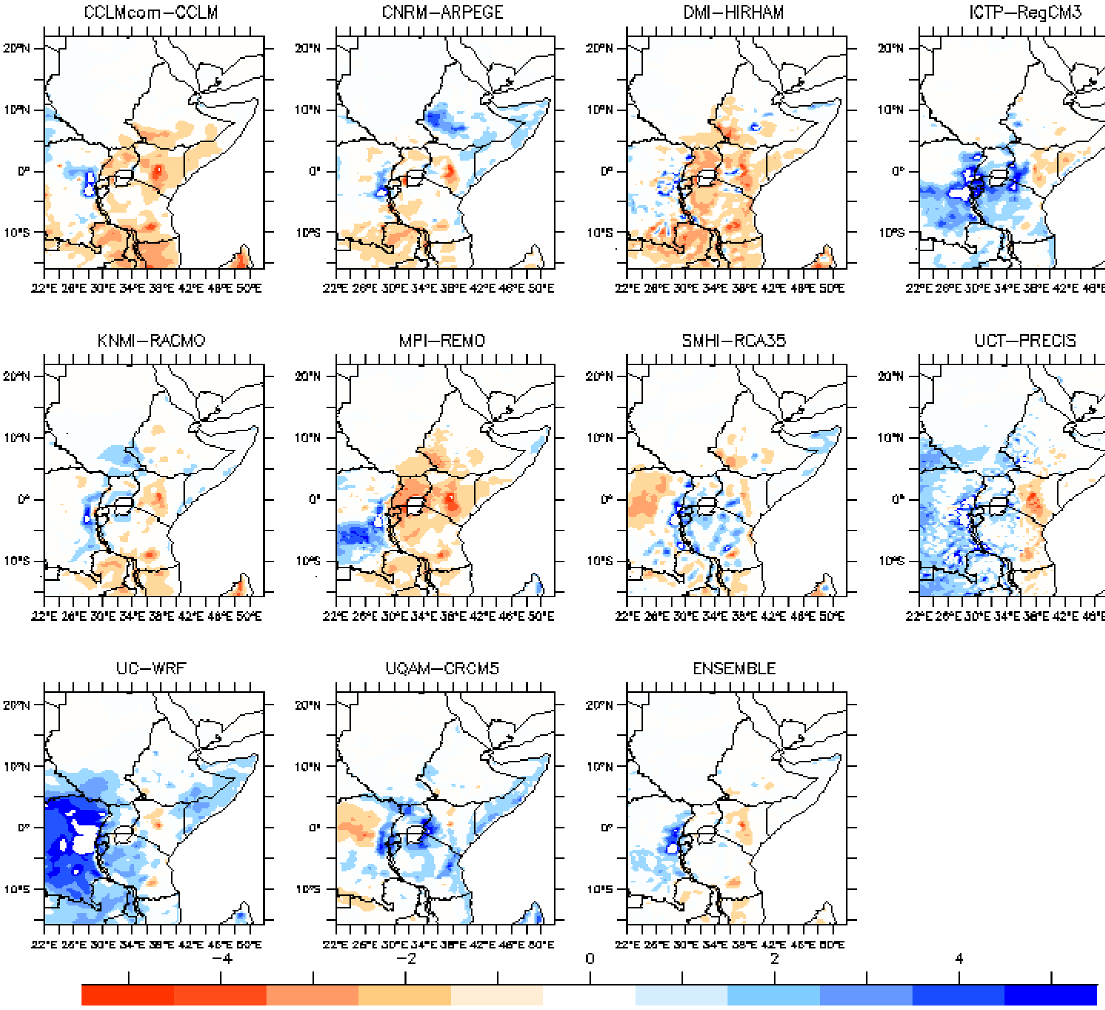
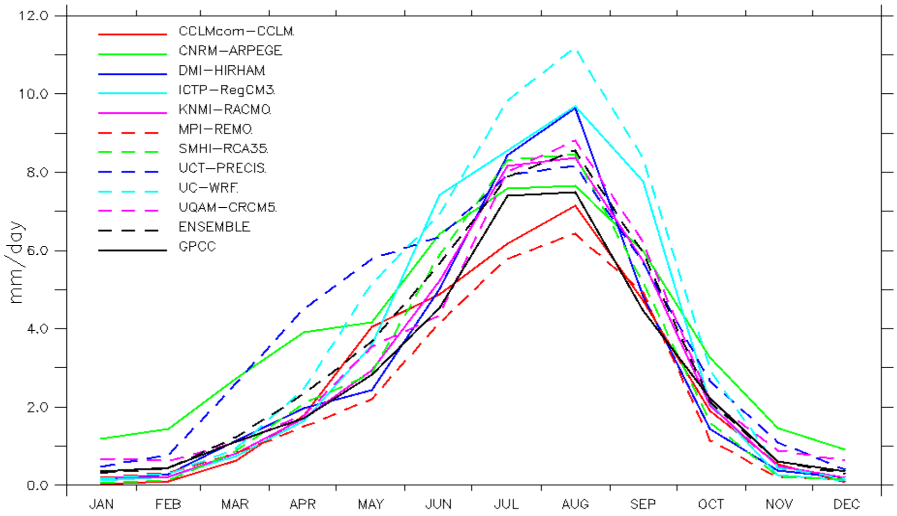
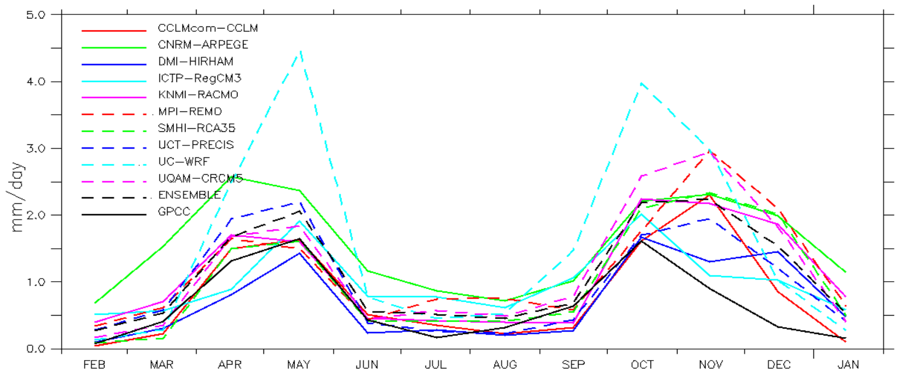

CCLMcom–CCLM
CNRM–ARPEGE
DMI–HIRHAM
ICTP–RegCM3
KNMI–RACMO
MPI–REMO
SMHI–RCA35
UCT–PRECIS
UC–WRF
UQAM–CRCM5
ENSEMBLE
20°N
10°N
0°
10°S
22°E 26°E 30°E 34°E 38°E 42°E 46°E 50°E
−4
−2
0
2
4

Figure 3: (i) Mean annual precipitation cycle over northern sub-region (Ethiopia)



(ii) Mean annual precipitation cycle over equatorial sub-region (Kisumu)



(iii) Mean annual precipitation cycle over southern sub-region (Tanzania)

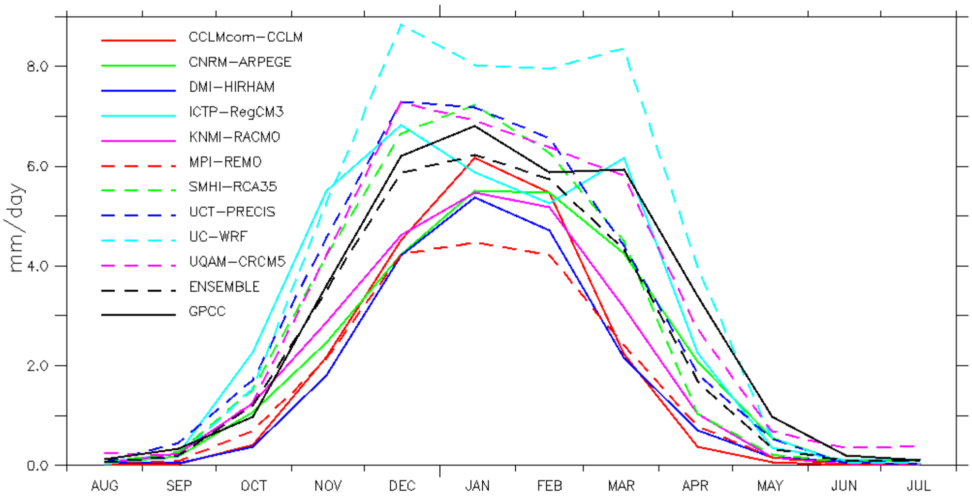
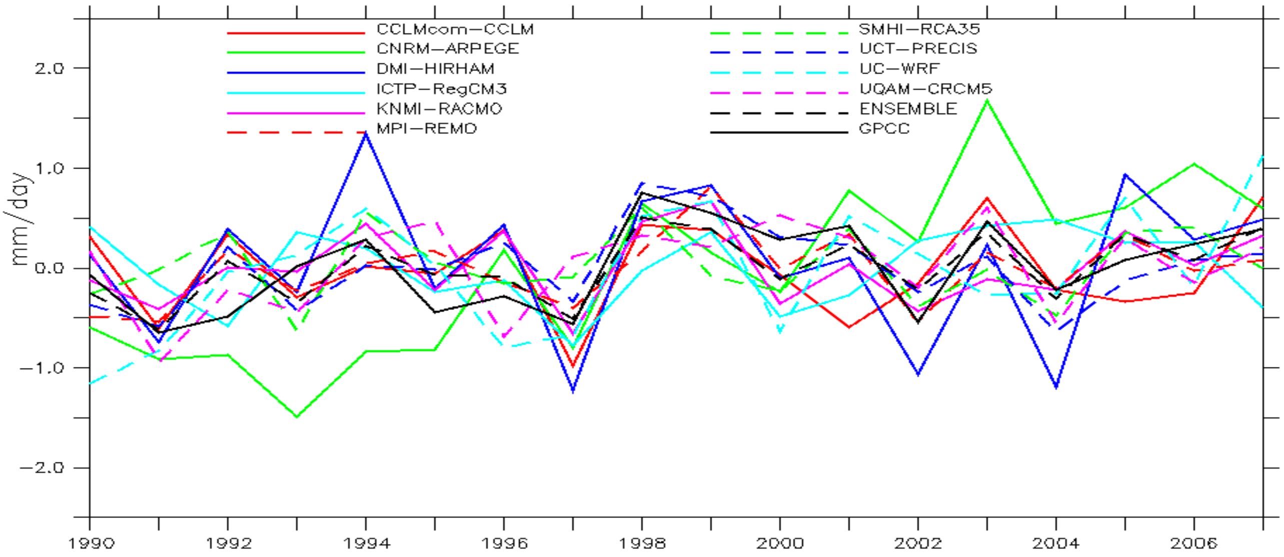
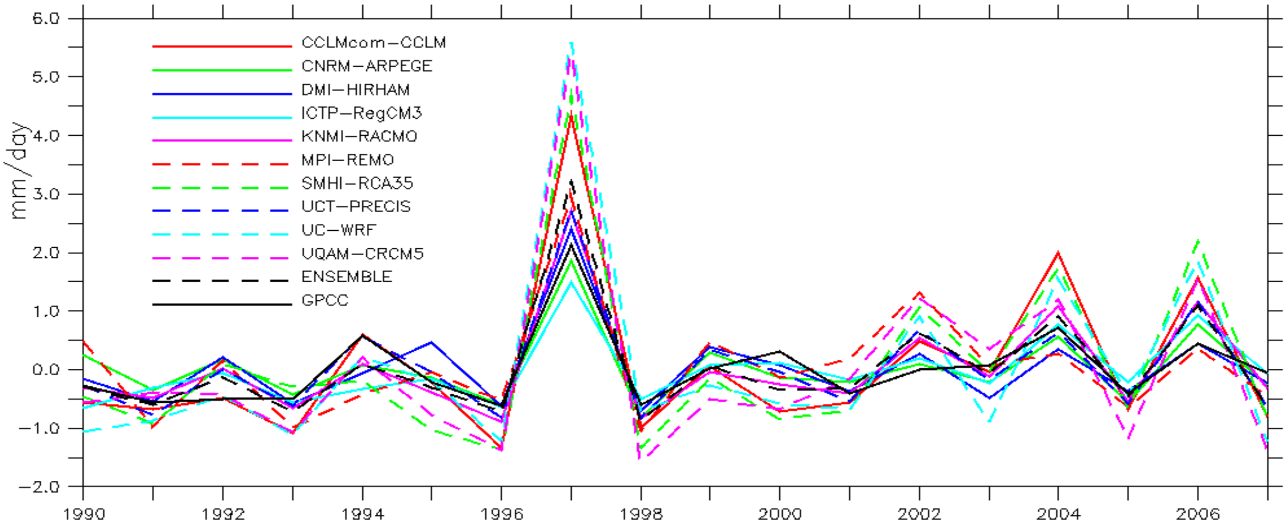


Figure 4: (i) Interannual precipitation variability over northern sector



(ii) Interannual precipitation variability over equatorial



(iii) Interannual precipitation variability over southern sector

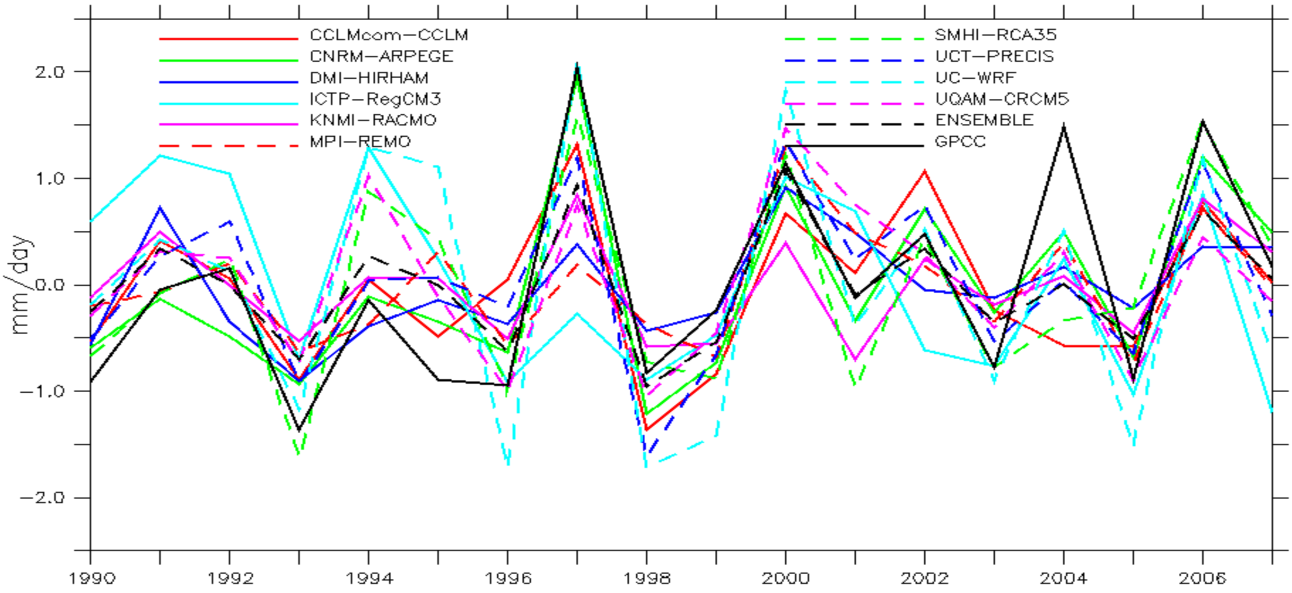
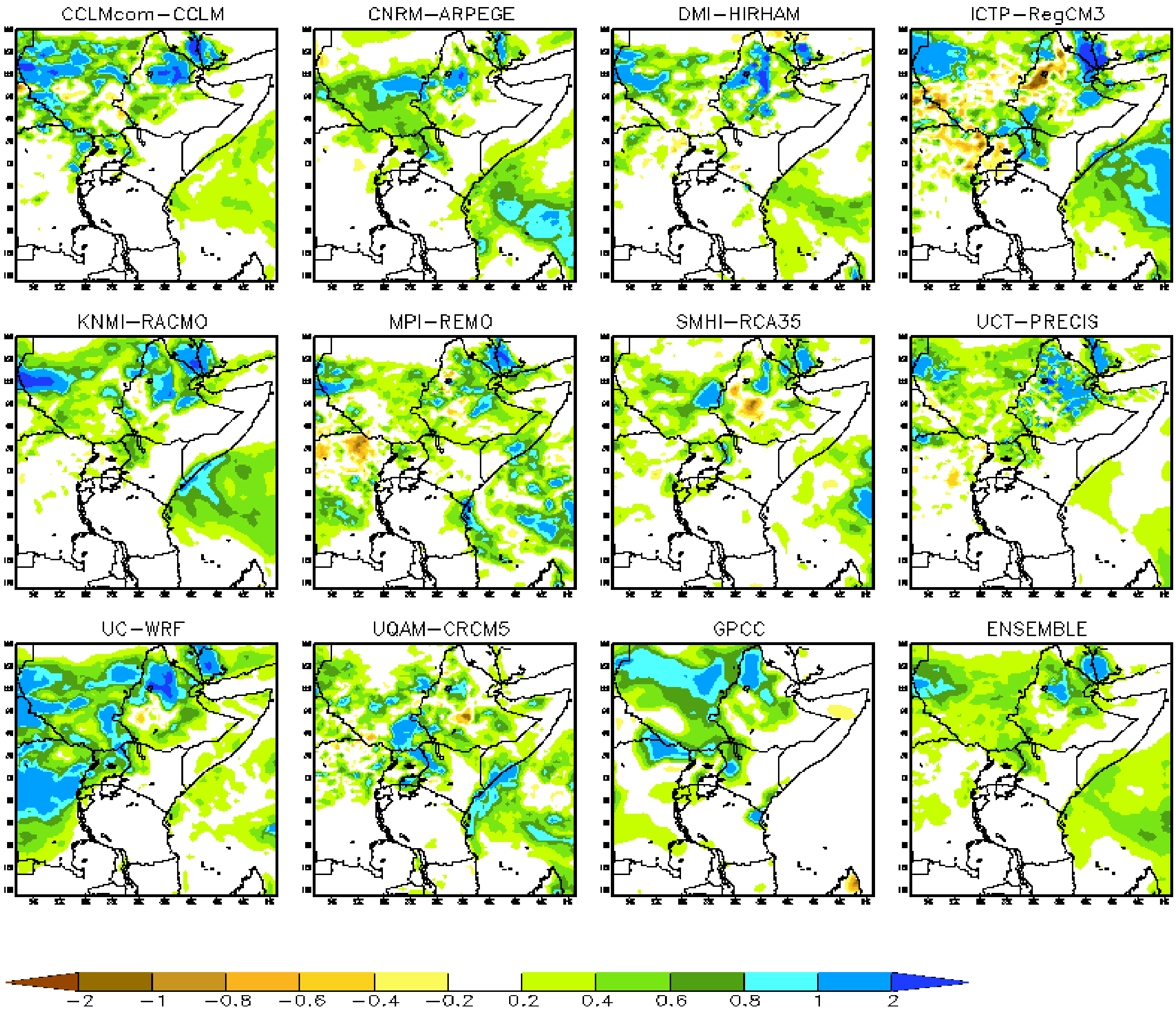
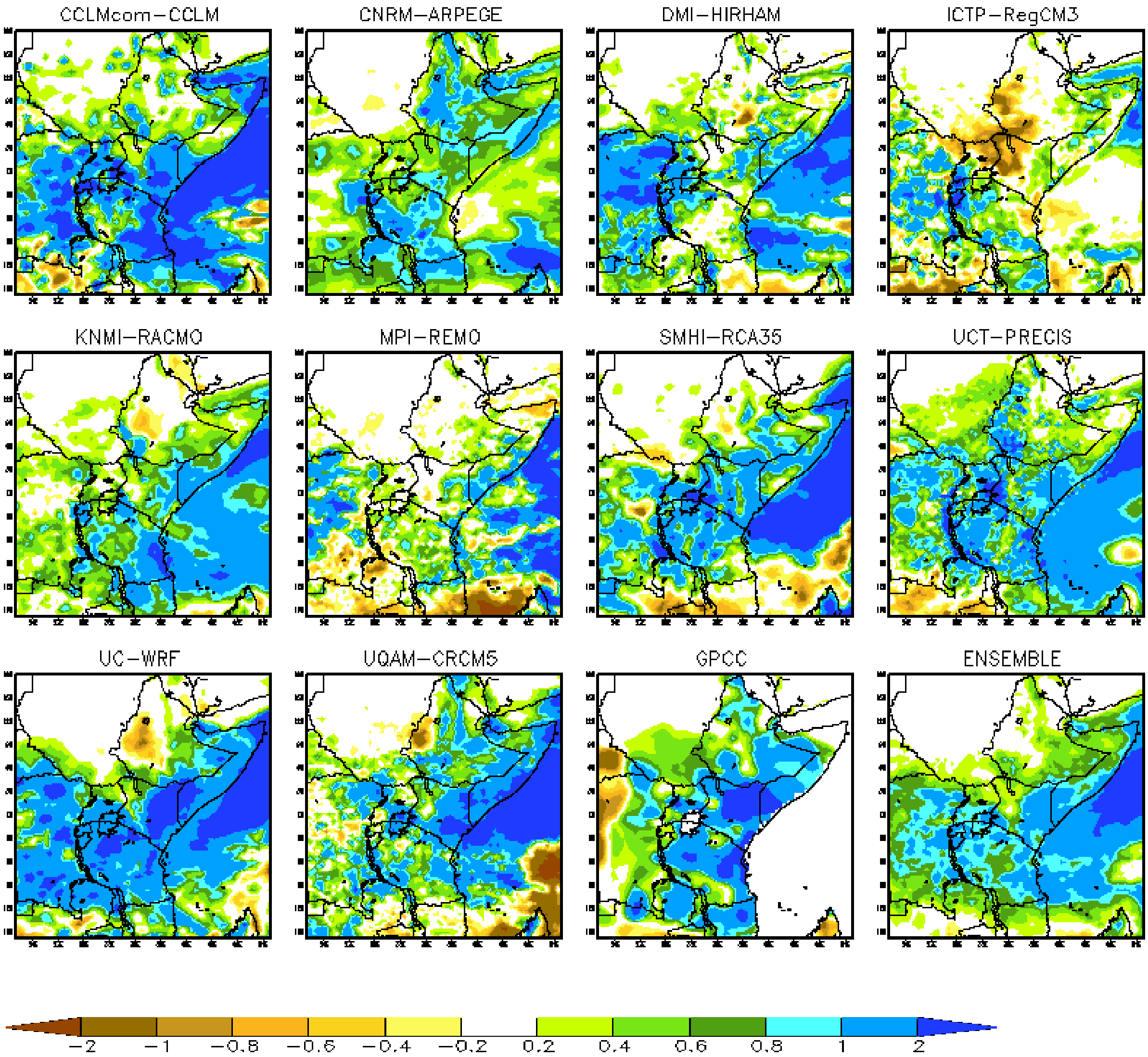

CCLMcom–CCLM
CNRM–ARPEGE
DMI–HIRHAM
ICTP–RegCM3
KNMI–RACMO
MPI–REMO
SMHI–RCA35
UCT–PRECIS
UC–WRF
UQAM–CRCM5
ENSEMBLE
GPCC
mm/day
2.0
1.0
0.0
–1.0
–2.0
1990
1992
1994
1996
1998
2000
2002
2004
2006

Figure 5: (i) June-September (JJAS) rainfall anomaly during pure La Niña



(ii) OND rainfall anomaly during the co-occurrence of El Nino and positive IOD



(iii) OND rainfall anomaly during positive IOD

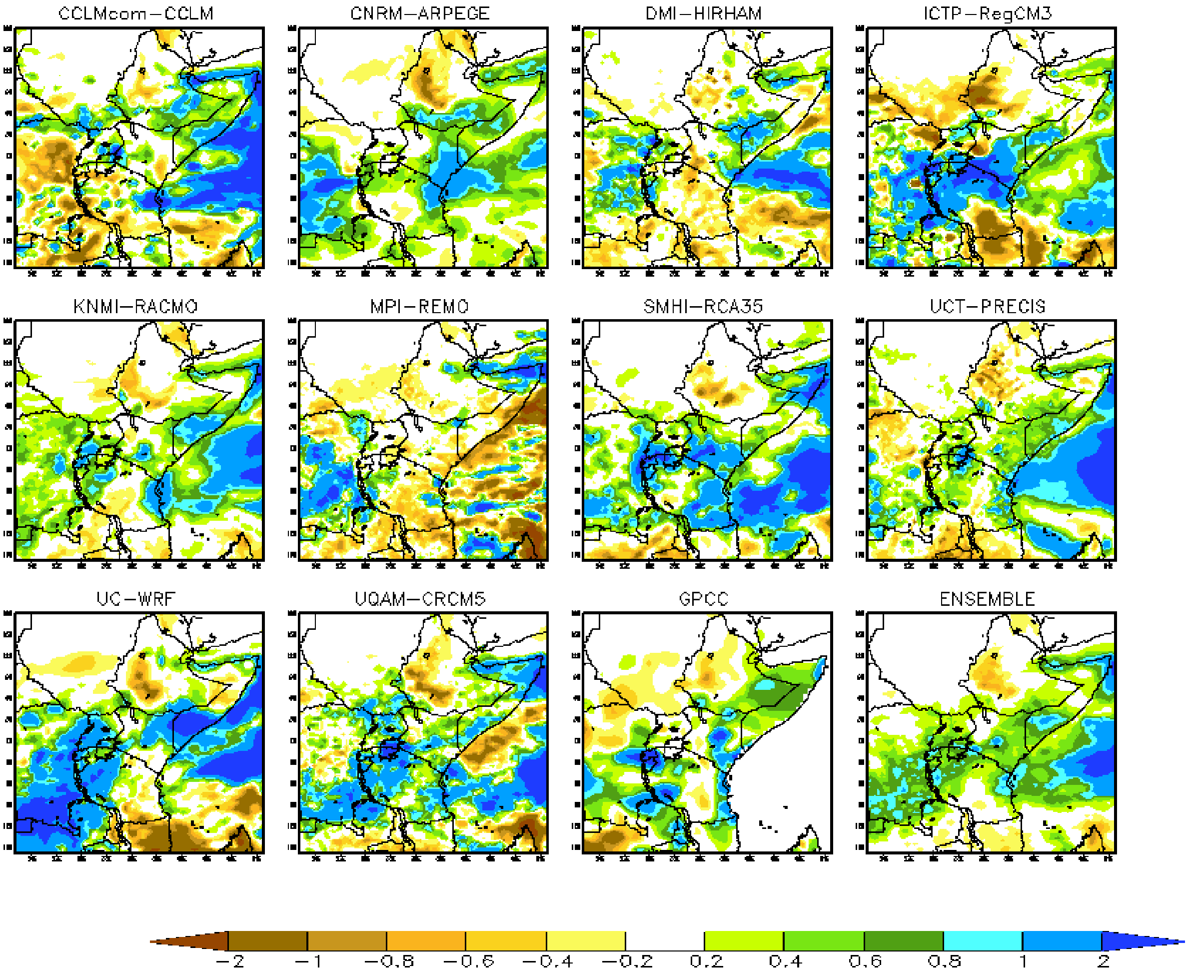
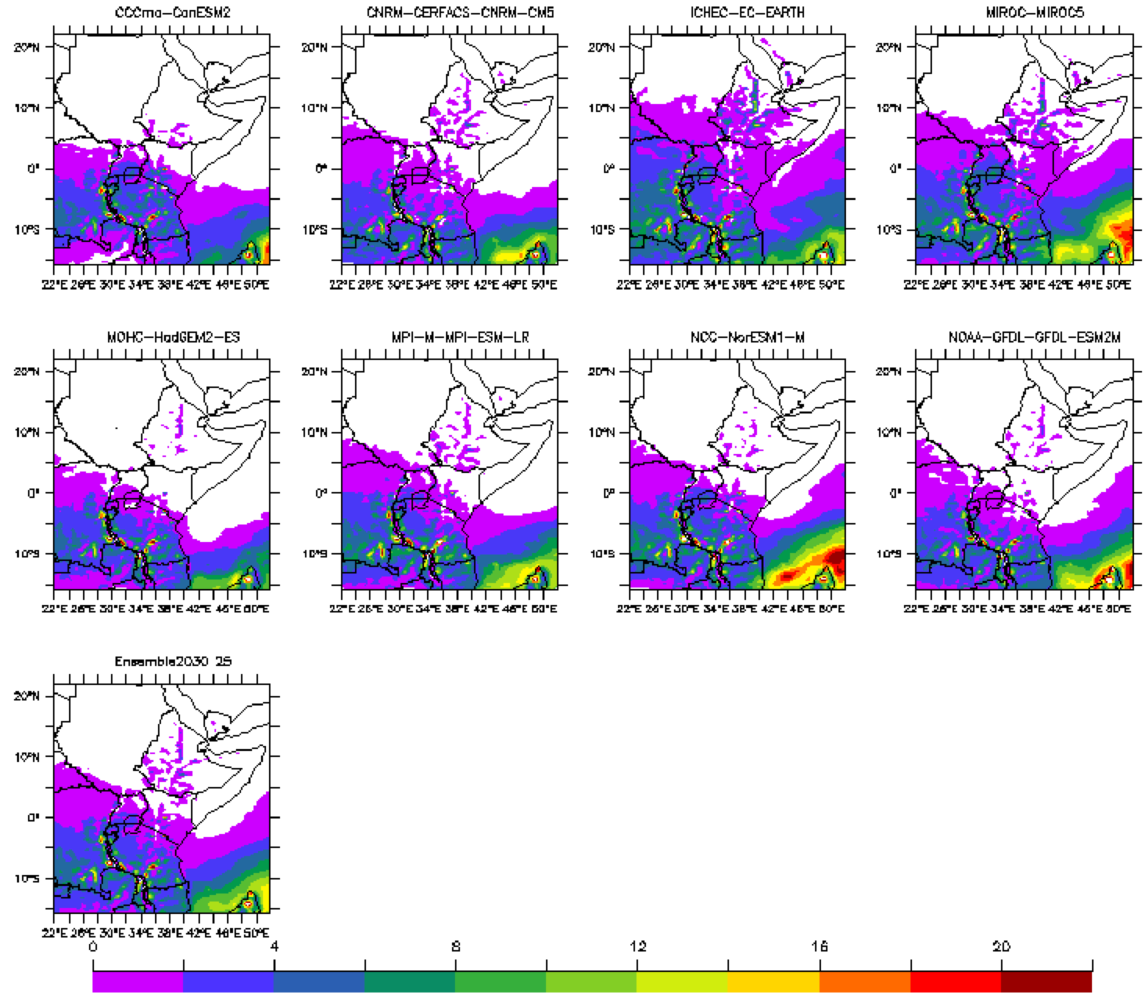


Figure 6: (i) Future (2030) climatology for March – May (MAM) rainfall



(ii) Future climatology for OND season

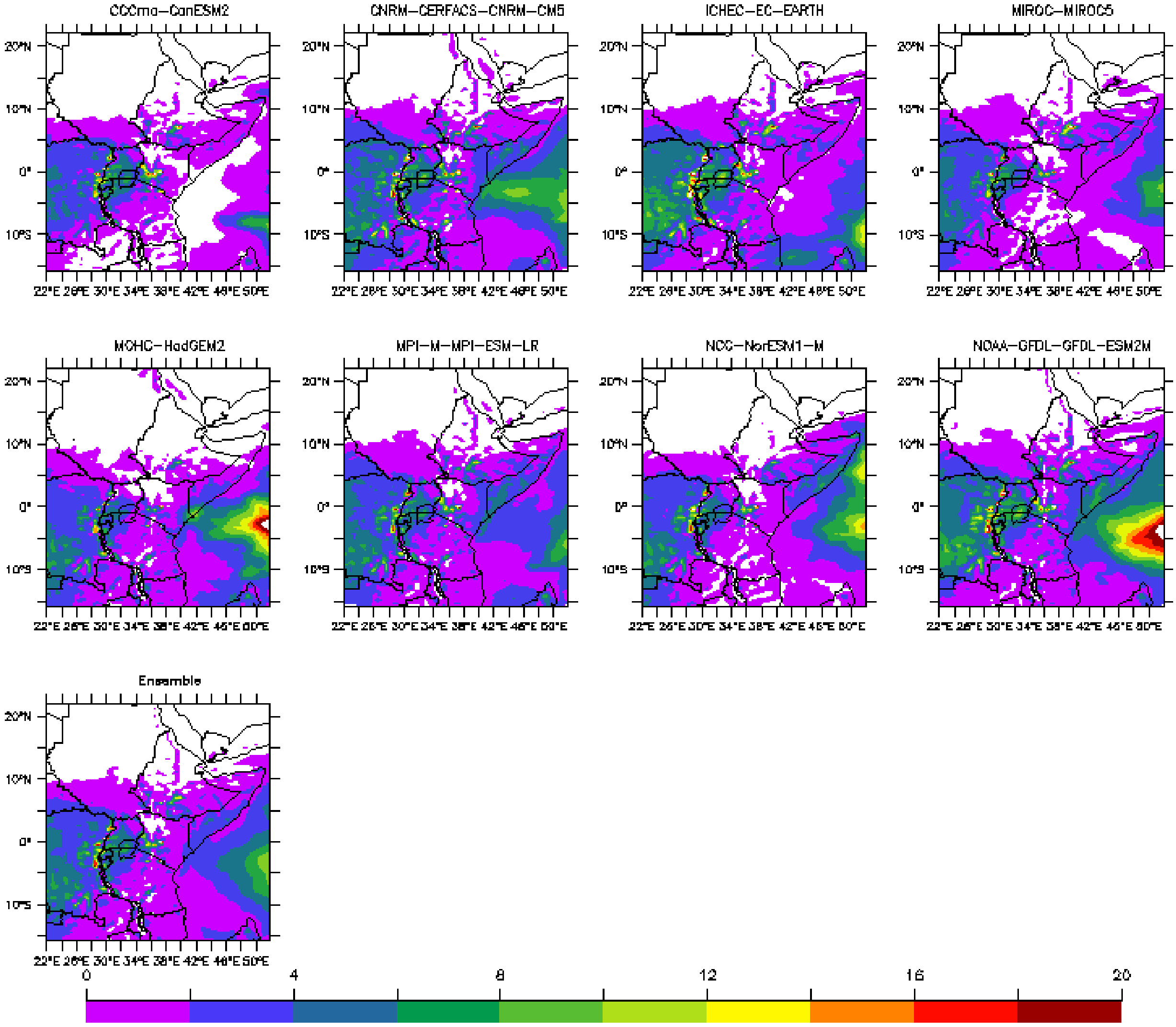
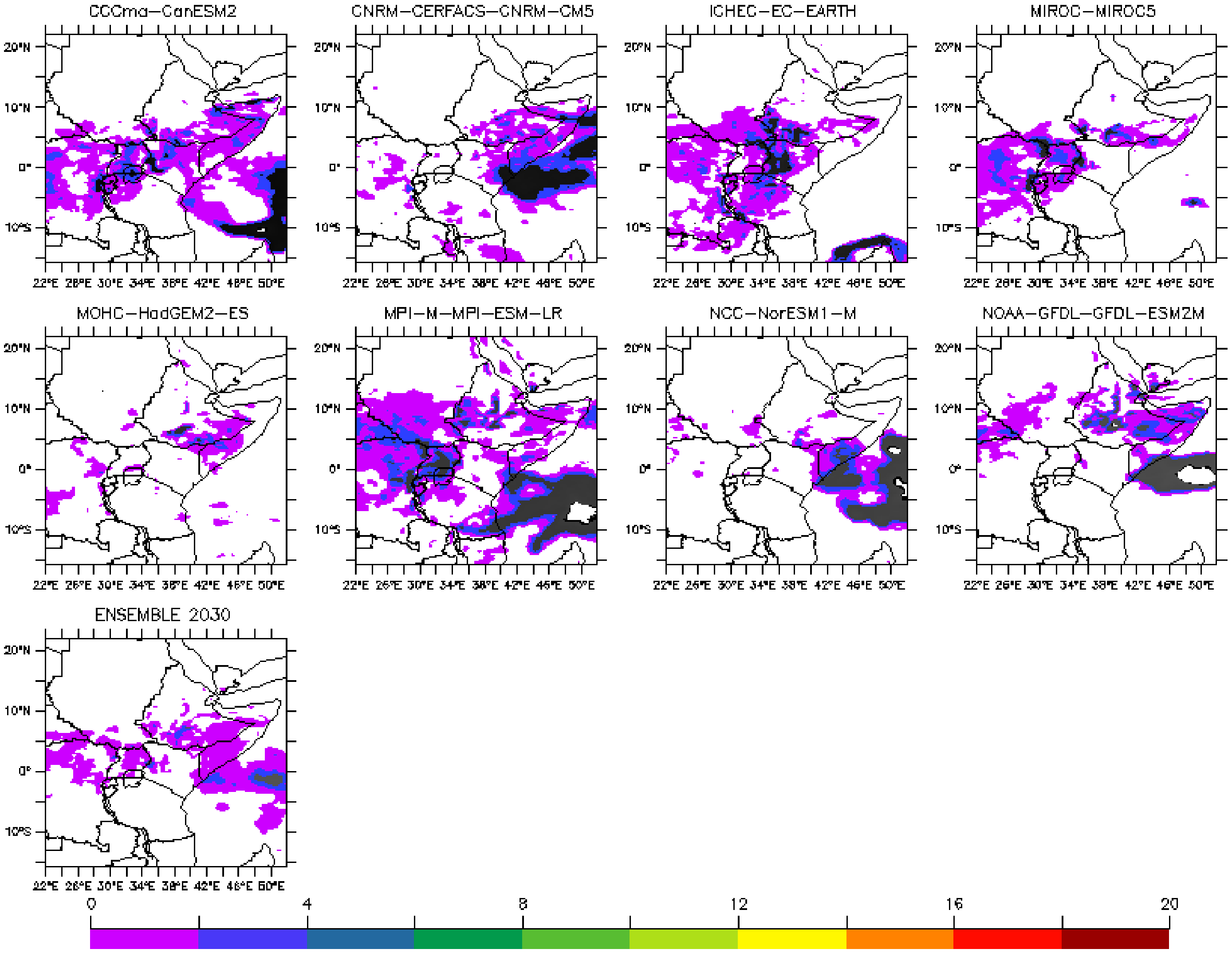
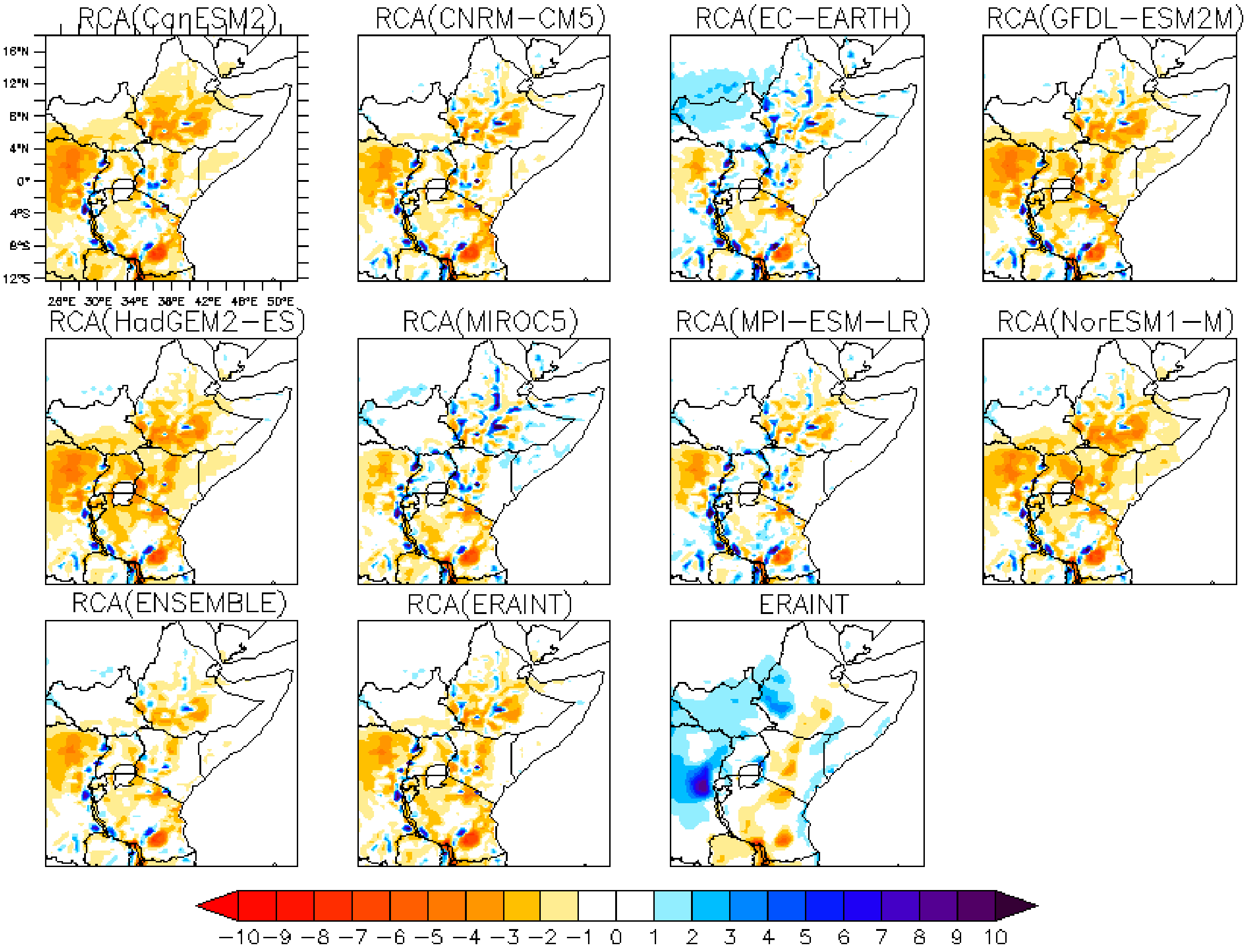
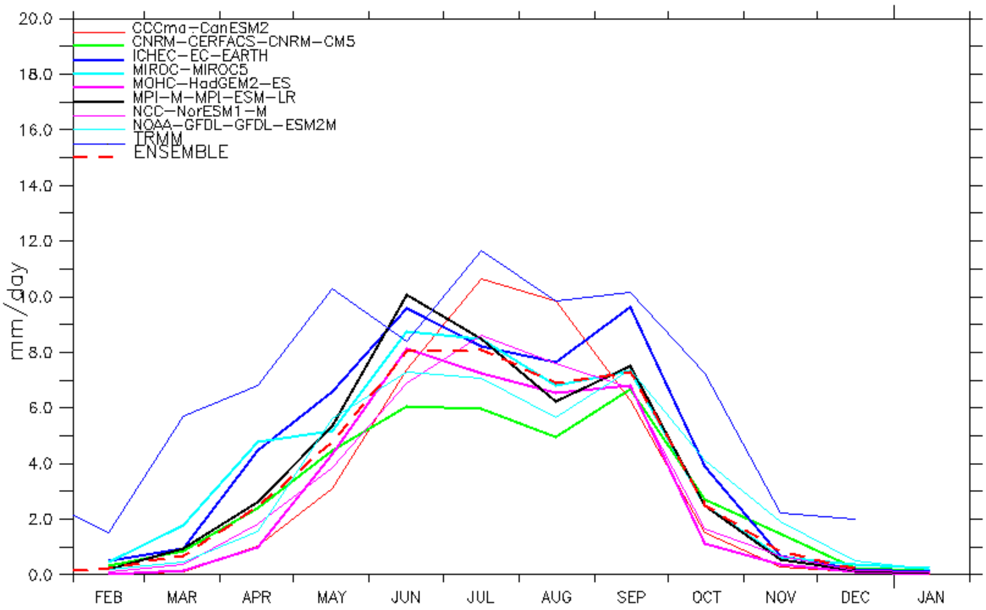

CCCma–CanESM2
CNRM–CERFACS–CNRM–CM5
ICHEC–EC–EARTH
MIROC–MIROC5
MOHC–HadGEM2
MPI–M–MPI–ESM–LR
NCC–NorESM1–M
NOAA–GFDL–GFDL–ESM2M
Ensemble
20°N
10°N
0°
10°S
22°E 26°E 30°E 34°E 38°E 42°E 46°E 50°E
0
4
8
12
16
20

Figure 7: (i) Projected MAM 2030 rainfall bias under RCP 4.5 scenario




RCA(CanESM2)
RCA(CNRM−CM5)
RCA(EC−EARTH)
RCA(GFDL−ESM2M)
RCA(HadGEM2−ES)
RCA(MIROC5)
RCA(MPI−ESM−LR)
RCA(NorESM1−M)
RCA(ENSEMBLE)
RCA(ERAINT)
ERAINT
16°N
12°N
8°N
4°N
0°
4°S
8°S
12°S
26°E
30°E
34°E
38°E
42°E
46°E
50°E
−10 −9 −8 −7 −6 −5 −4 −3 −2 −1 0 1 2 3 4 5 6 7 8 9 10

(iii) annual rainfall cycles (a) Nothern sector - Ethiopia



(iv) annual rainfall cycles (a) Equatorial sector - Kenya