CLIVAR-PIRATA-PREFACE

Tropical Atlantic Variability Conference

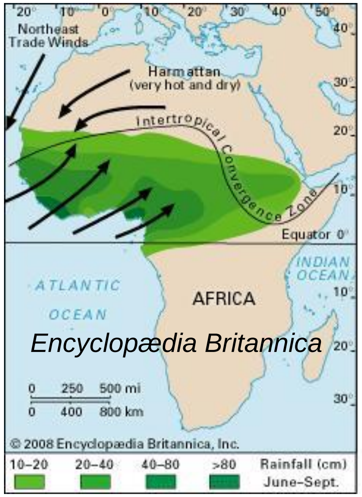
Impact of dynamical regionalization on precipitation biases and teleconnections over West Africa

I. Gómara (1,2), E. Mohino (1)
T. Losada (1), M. Domínguez (1,2)
B. Rodríguez-Fonseca (1,2)

(1) Department of Geophysics and Meteorology
Complutense University of Madrid

(2) Institute of Geosciences, UCM-CSIC

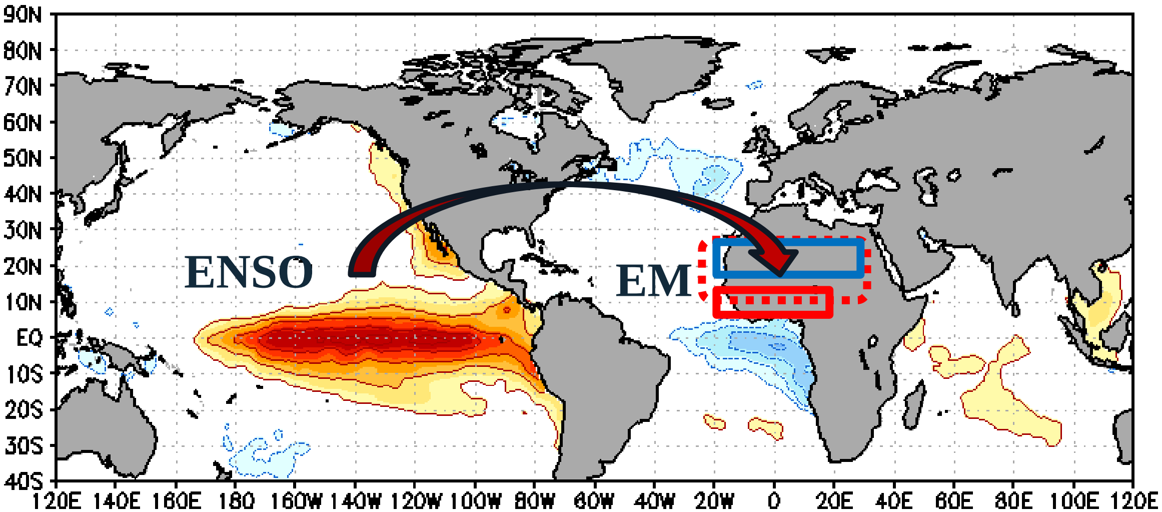
Motivation and Objectives



The West African Monsoon (WAM)

- Most prominent climate feature of Western Africa during boreal summer (Rowell 2001; Janicot et al. 2001)
- SLP/T gradient between Sahara and Gulf of Guinea→ seasonal precipitation (Janicot et al. 2011; Mohino et al. 2011)
- Highly determines socio-economic development of West Africa communities (Cook 2008; Yaka et al. 2008)

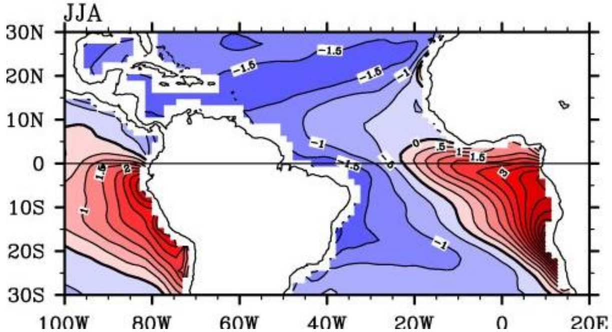
WAM Interannual variability: year to year



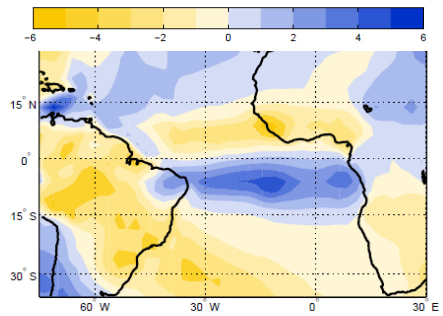
- ENSO+: Increased subsidence over WA → decreased pcp (Joly and Voldoire 2009)
- Eq. Mode (-): Sahara/Guinea SLP/T gradient increased → enhanced/decreased pcp over Guinea/Sahel (Zebiak 1993)
- Combined effect after 1970s → homogeneous rainfall mode (Rodríguez Fonseca et al. 2011; Losada et al. 2012)

WAM modelization

General Circulation Model (GCM) issues



Ensemble SST (K) bias in IPCC models (Lee et al. 2012)



Ensemble pcp (mm/day) bias in CMIP5 models (L. Svendsen)

GCMs - Too southward ITCZ due to SST biases (Cook and Vizy 2006; Richter and Xie, 2008)

Regional Climate Model (RCM) improvements

- High resolution
- Fine-scale processes resolved (e.g., convection, soil-atmosphere exchange etc.)

→ RCMs improve simulations at fine scales (Feser 2006; Prömmel et al. 2010)

Can RCMs provide large-scale added value?

Yes	No
Mesinger et al. 2002	Castro et al. 2005
Veljovic et al. 2010	Laprise et al. 2008

OBJECTIVE:
Analyze the impact of dynamical regionalization on precipitation biases and teleconnections over West Africa

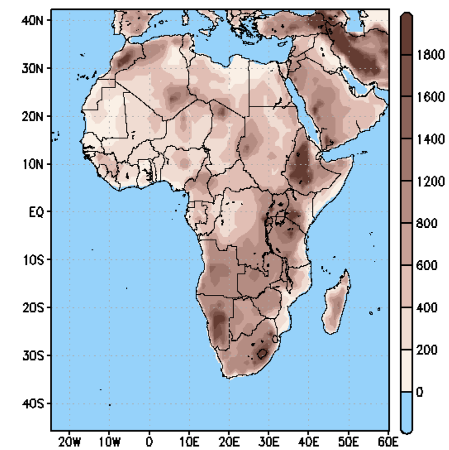
Data and Methodology

Observations

Data set	Variables	Resolution	Period	Reference
HadISST	SST	JAS/1x1	1979-2004	Rayner et al. 2013
GPCP	Precipitation	JAS/2.5x2.5	1979-2004	Huffman et al. 2009

GCM and RCM data (Taylor et al. 2012; Giorgi et al. 2009)

Historical CMIP5 GCMs / *CORDEX-Africa RCMs*	CanESM2	CNRM-CM5	EC-EARTH r12	GFDL-ESM2M	HadGEM2-ES	MIROC5	MPI-ESM-LR	NorESM1-M
SMHI-RCA4	X	X	X	X	X	X	X	X



CORDEX Africa Domain

1. GCMs: 8 different GCM simulations
2. GCMs-RCA4: Same RCM (SMHI-RCA4) driven by 8 different GCMs – lateral boundary conditions

SEA SURFACE TEMPERATURE BASED STATISTICAL SEASONAL FORECAST MODEL (S4CAST)

(Suárez-Moreno & Rodríguez-Fonseca 2015)

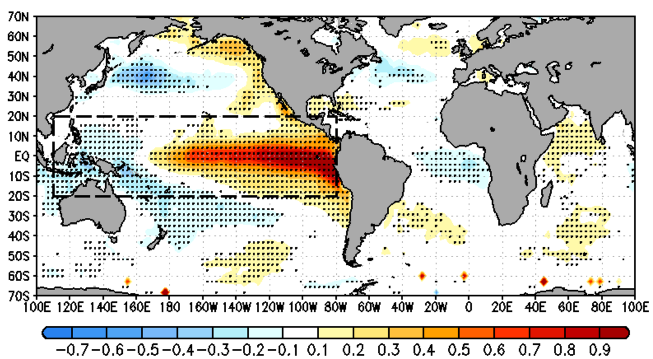
MAXIMUM COVARIANCE ANALYSIS (MCA)

Calculation of the leading co-variability modes between two TIME-VARYING fields (Bretherton et al. 1992)

PREDICTOR: Anomalous SSTs (linear trend removed)

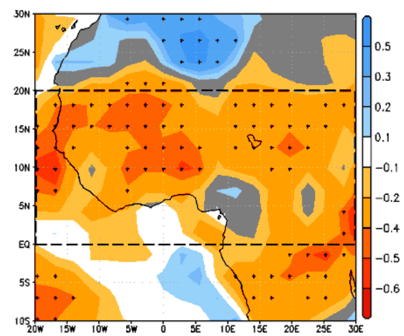
PREDICTAND: Anomalous Precipitation

#MODE 1: SST homogeneous map



Maximum covariance

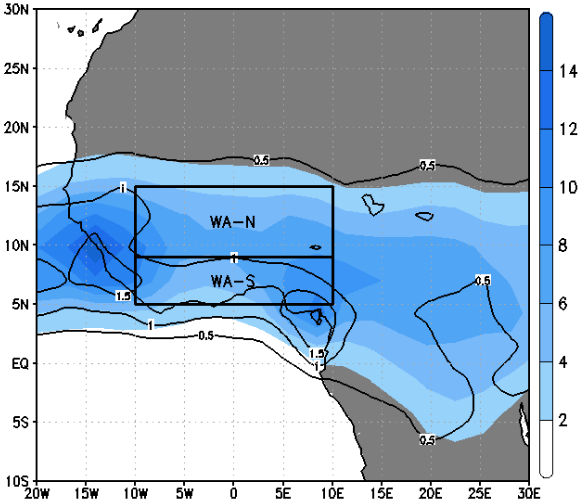
#MODE 1: PCP heterogeneous map



Results

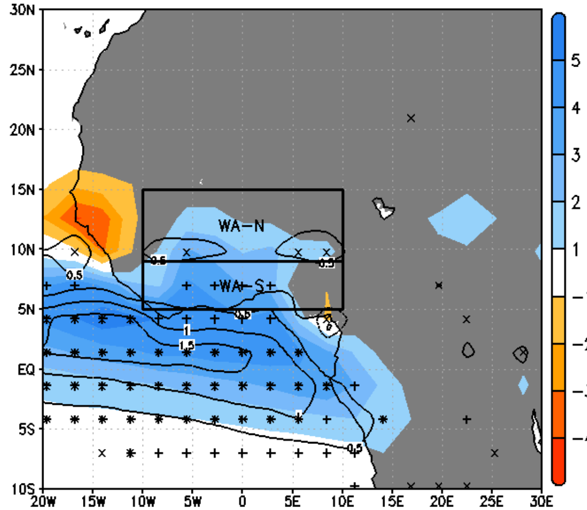
Seasonal Precipitation biases

GPCP - JAS



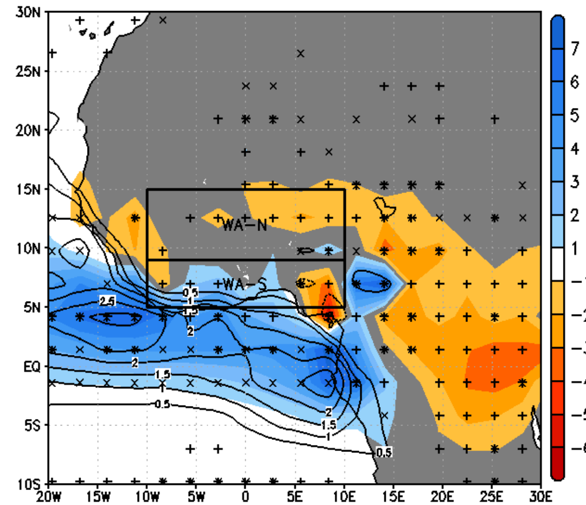
Blue – mean pcp (mm/day)
Contours – std pcp (mm/day)

Ensemble bias - GCMs



Blue – mean pcp bias (mm/day)
Contours – mean pcp std (mm/day)
Stippling: Same bias sign in all GCMs

Ensemble bias – GCMs-RCA4



Blue – mean pcp bias (mm/day)
Contours – mean pcp std (mm/day)
Stippling: Same bias sign in all GCMs

Zonal band of pcp (Folland et al. 1986)

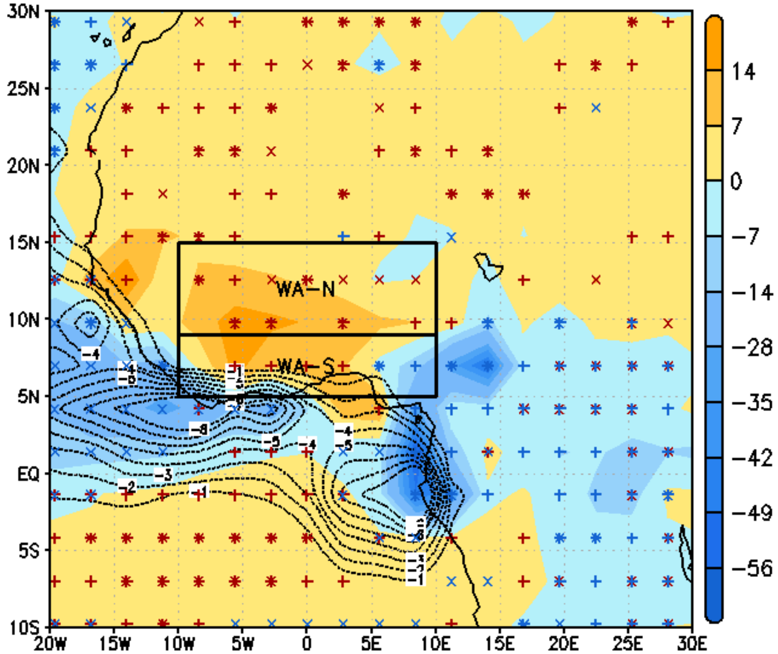
Too southward ITCZ due to SST biases (Cook and Vizy 2006; Richter and Xie, 2008)

Dry bias over central Africa. Narrower/stronger band of overestimated pcp south of Guinea

RCA4 Added Value (Di Luca et al. 2013; Meque and Abiodun 2015)

$$AV = (X_{GCM} - X_{OBS})^2 - (X_{RCA4} - X_{OBS})^2$$

Ensemble AV – GCMs-RCA4



Colors – ensemble AV in average pcp (mm2/day2)

Contours – ensemble AV in pcp std (mm/day)

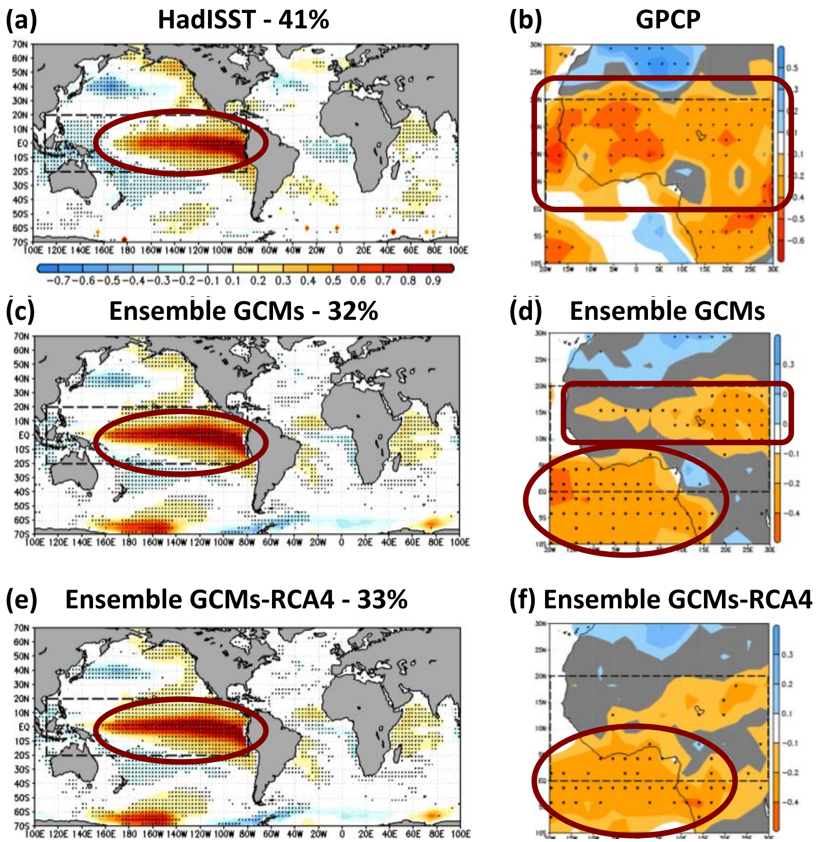
Stippling: 75% of individual models giving same AV sign

POSITIVE ADDED VALUE IS PROVIDED BY RCA4 SIMULATIONS OVER WEST AFRICA

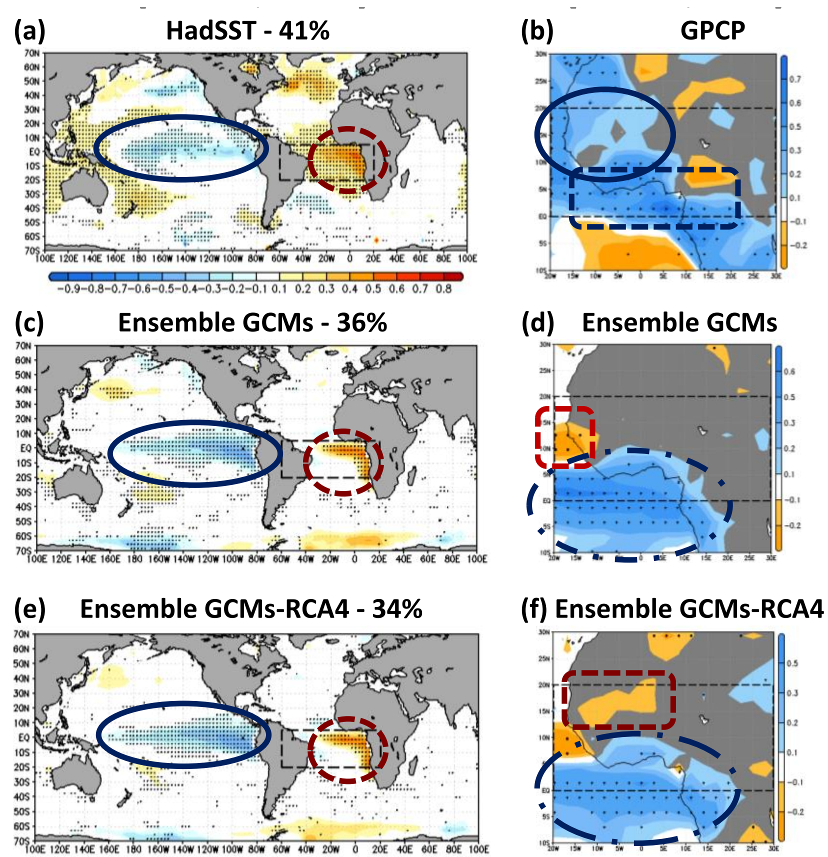
MOST PROMINENT WAM TELECONNECTIONS IN OBS, GCMs AND GCMs-RCA4

MCA Leading Modes (JAS 1979-2004)

Predictor SST [110E-80W, 20S-20N] | **Predictand PCP [20W-30E, 0-20N]**



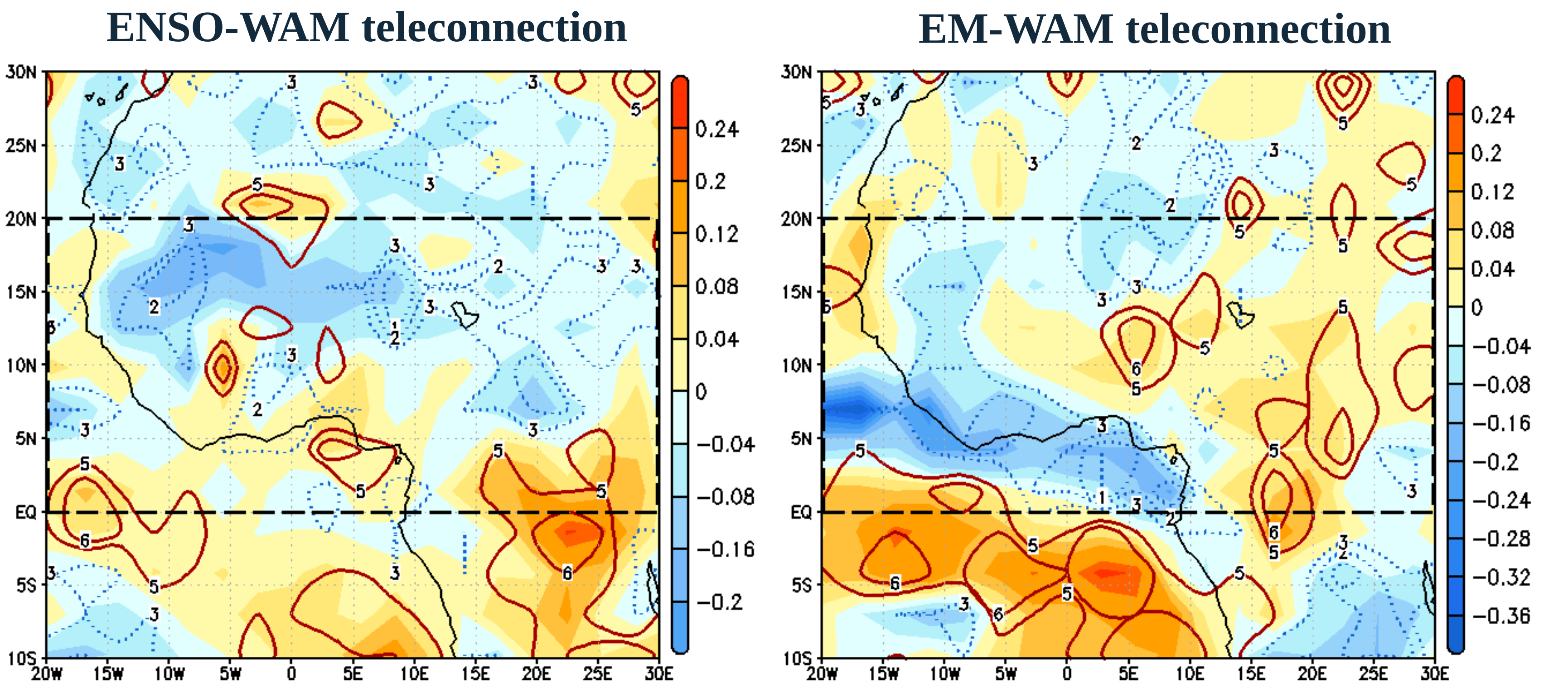
Predictor SST [60W-20E, 20S-5N] | **Predictand PCP [20W-30E, 0-20N]**



Colors: SST/PCP regressed on U (K / mm day-1)

Stippling: Obs M. Carlo test 95%; Simulations 7/8

Ensemble Added Value Maps



Colors – ensemble mean AV in the representation of the ENSO-WAM teleconnection (mm2/day2)

Contours – Number of simulations with positive AV at each grid point (mm/day)

NO ROBUST ADDED VALUE IS PROVIDED BY RCA4 IN THE REPRESENTATION OF WAM TELECONNECTIONS

Main Conclusions

1. **RCA4 simulations improve climatological values of the West African Monsoon (WAM) inland over West Africa**

2. **GCMs alone are able to capture the ENSO influence on the WAM but the strenght of the simulated signal is too weak**

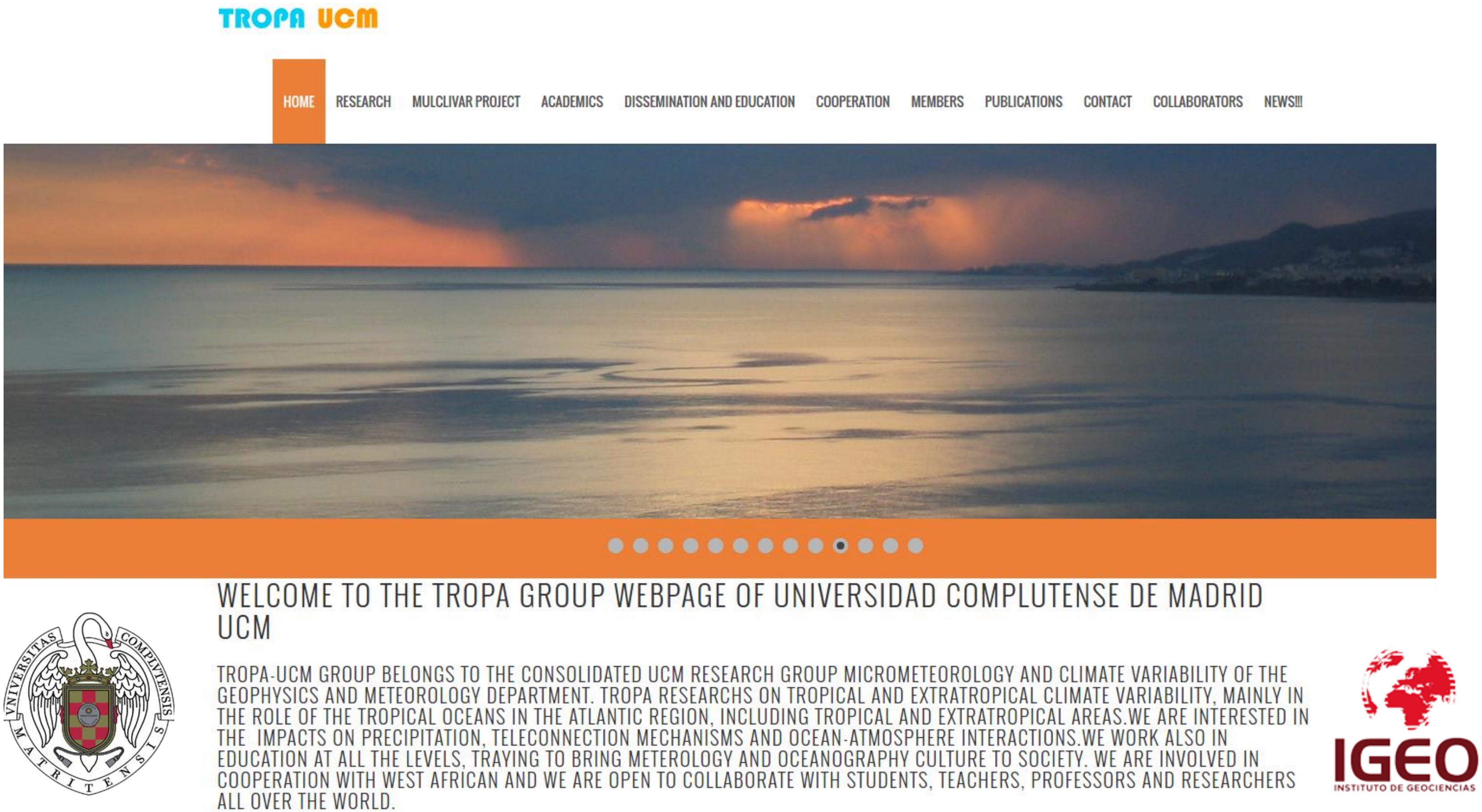
3. **RCA4 simulations do not improve the representation of the most prominent WAM teleconnections: El Niño - Southern Oscillation and the Atlantic Equatorial Mode.**

Future Work

- **Assess for uncertainties in RCM architecture additional to the lateral boundary conditions: MPI-ESM-LR driving 4 different RCMs (CORDEX)**

THANK YOU FOR YOUR ATTENTION

TROPICAL ATLANTIC VARIABILITY GROUP (TROPA)



tropa.fis.ucm.es

Additional Material

CORDEX DOMAIN AND SEASONAL PRECIPITATION IN OBSERVATIONS (JAS - mm/day)

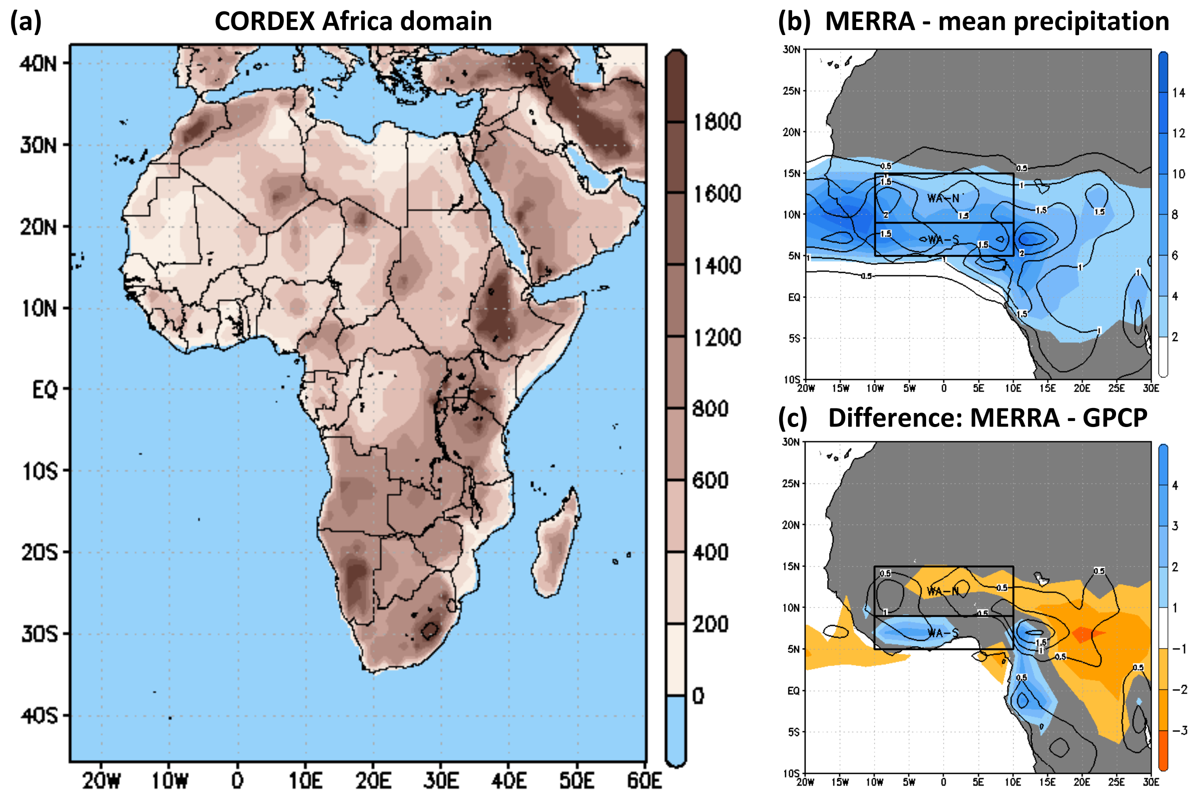


Fig. S1: (a) CORDEX Africa simulation domain [24.64ºW-60.28ºE, 45.76ºS-42.24ºN] and 1-degree resolution elevation (in m). Source: NCAR Terrain Base (TBASE) dataset (b) Mean (shadings; mm day^{-1}) and standard deviation (contours; mm day^{-1}) of MERRA JAS seasonal precipitation (1979-2004). Rectangles denote West-Africa North (WA-N) and West-Africa South (WA-S) regions. (c) Difference between MERRA and GPCP databases in mean (shadings) and standard deviation (contours) for JAS 1979-2004.

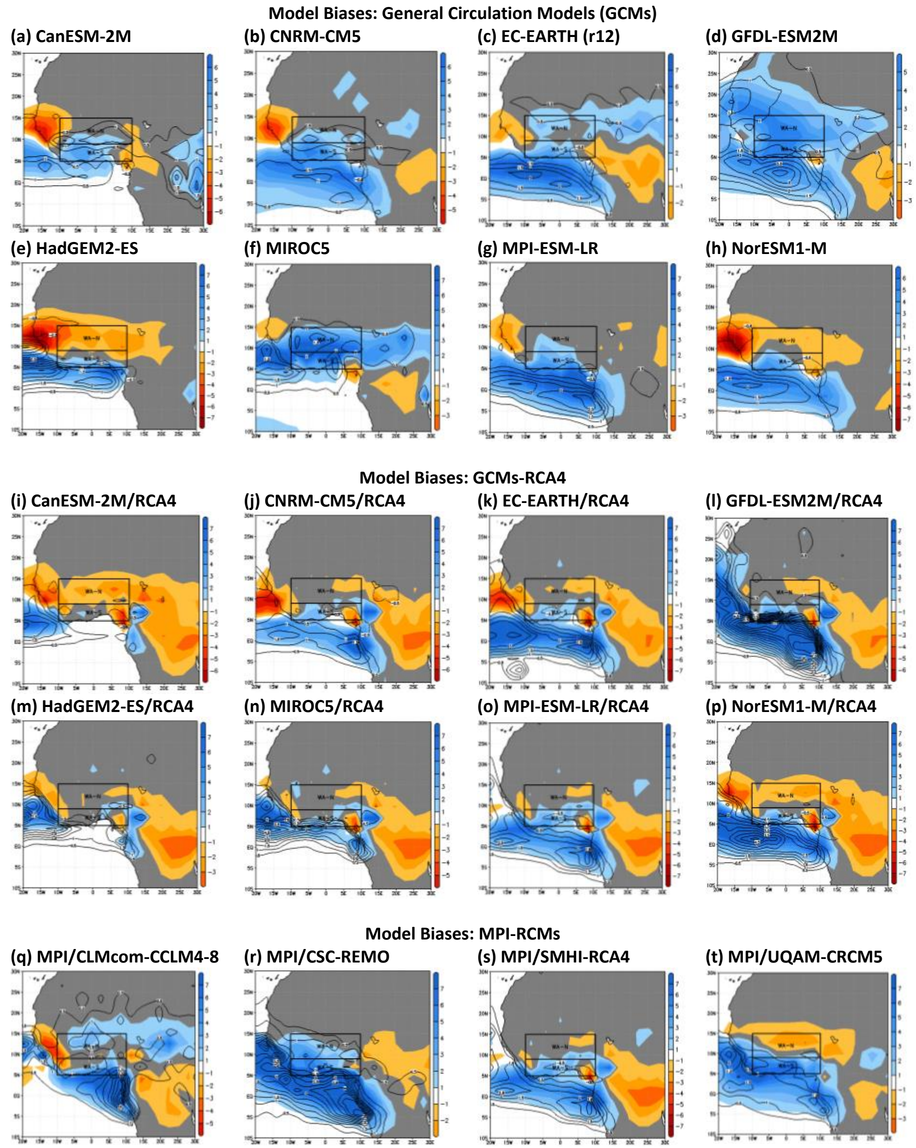


Fig. S2: (a)-(h) Biases of GCM historical simulations (8 models in total, cf. Table 1) with respect to the GPCP database (period 1979-2004). Differences in mean values are given in colors (units - mm day^{-1}). Differences in standard deviation are provided in contours (units - mm day^{-1}). Rectangles denote West-Africa North (WA-N) and West-Africa South (WA-S) regions, respectively. (i)-(p) Same as (a)-(h) but for SMHI-RCA4 driven by 8 GCMS. (q)-(t) Same as (a)-(h) but for 4 different RCMs driven by MPI-ESM-LR.

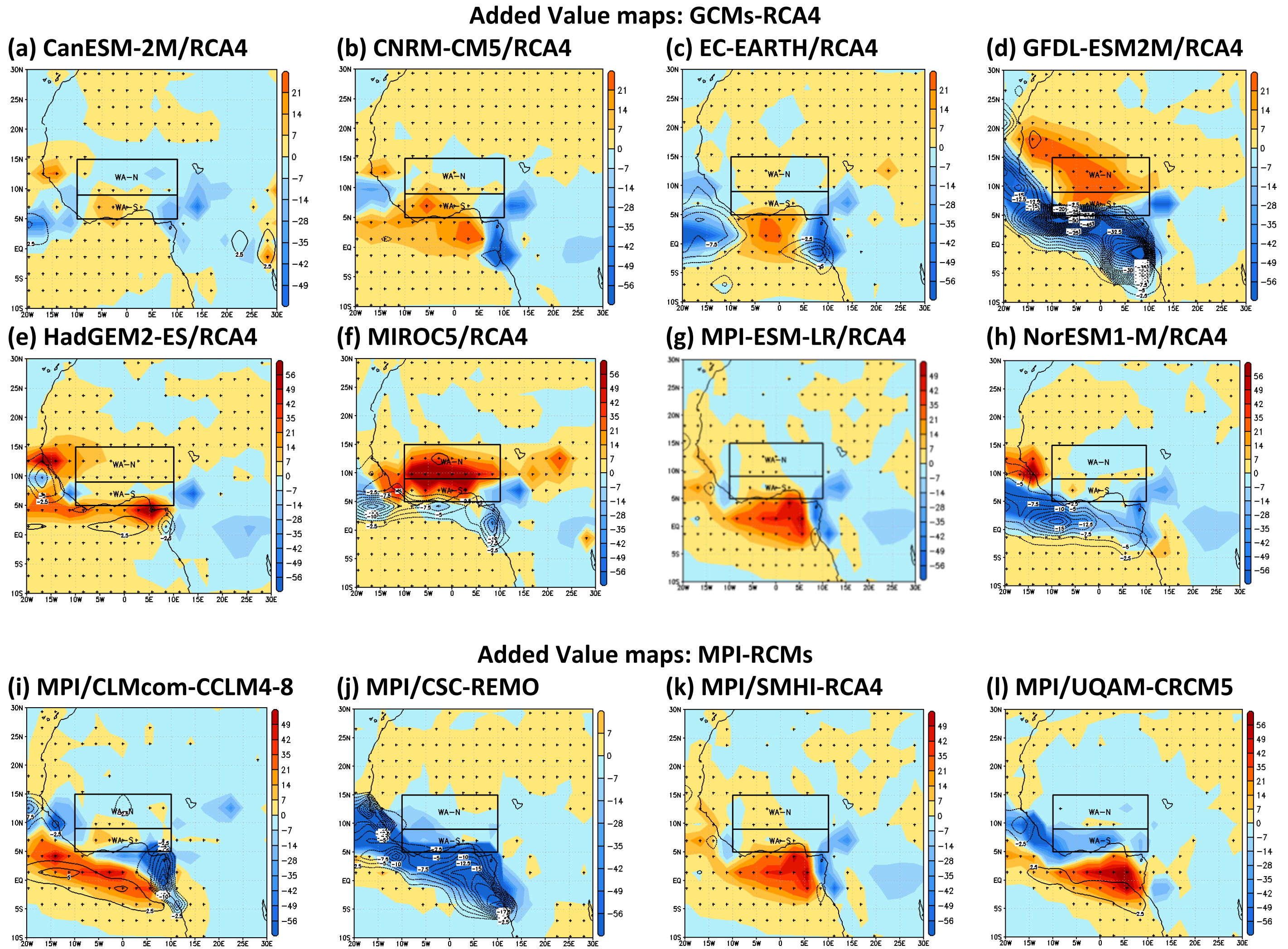


Fig. S3: (a)-(h) Added value maps (colors, in mm^2 day^{-2} std^{-2}) for the individual model members (RCA4 vs. GCMs) in representing JAS mean precipitation (colors, in mm^2 day^{-2}) and standard deviation (contours, in mm^2 day^{-2}) (1979-2004). Positive RCM added values in mean are highlighted with stippling. (i)-(l) Same as (a)-(b) but for the nested RCMs onto MPI (MPI-RCMs vs. MPI).

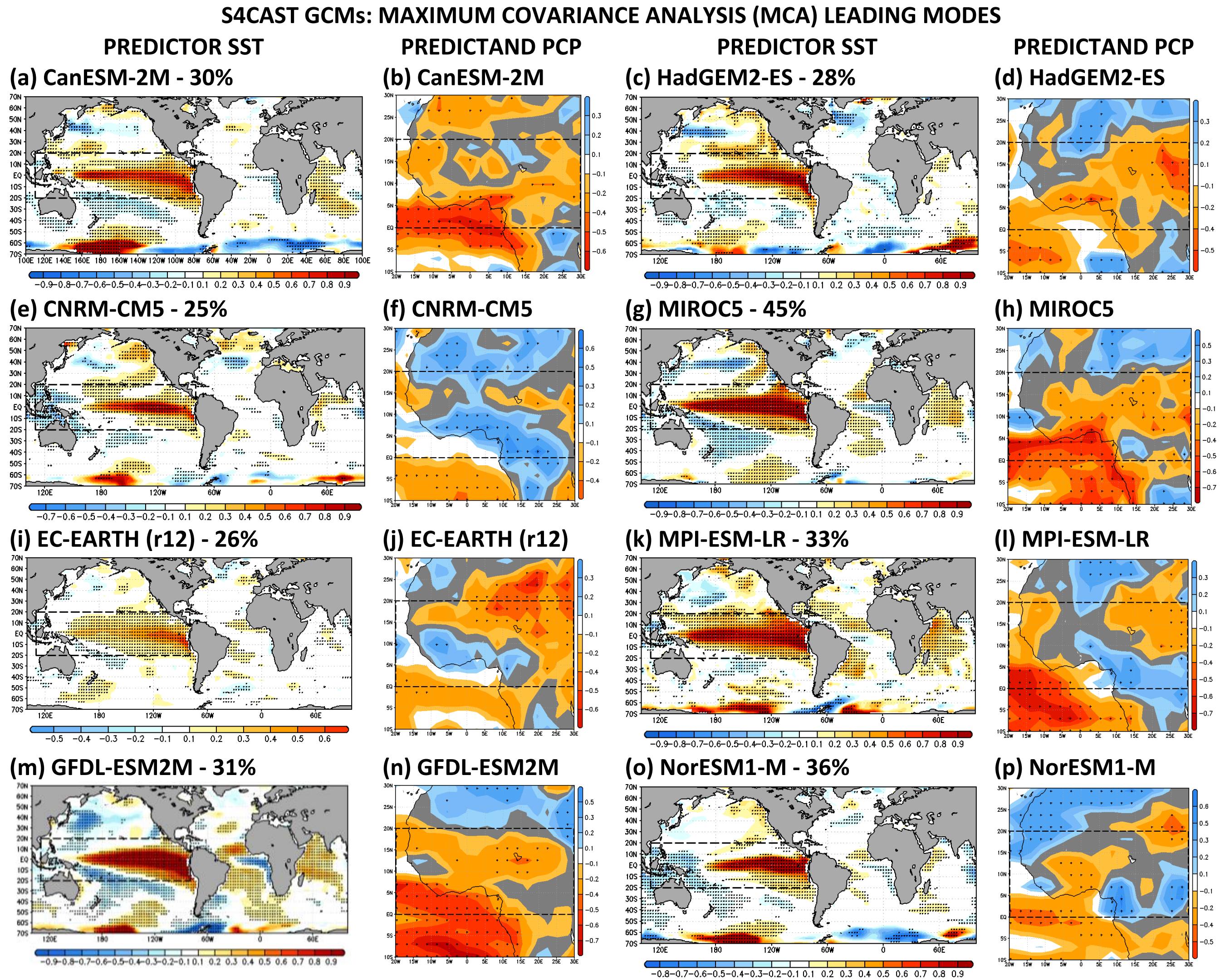


Fig. S4: (a)-(p) Pairs of homogeneous/heterogeneous regression maps for the leading mode of each GCM individual simulation between SST anomalies (predictor) from the equatorial Pacific [110ºE-80ºW, 20ºS-20ºN] and precipitation anomalies (predictand) over West Africa [20ºW-30ºE, 0º-20ºN]. Period: JAS 1979-2004. Explained variance provided in % on top of each sub-panel. Confidence interval (95%) is provided in stippling using a Monte Carlo test of 1000 random iterations.

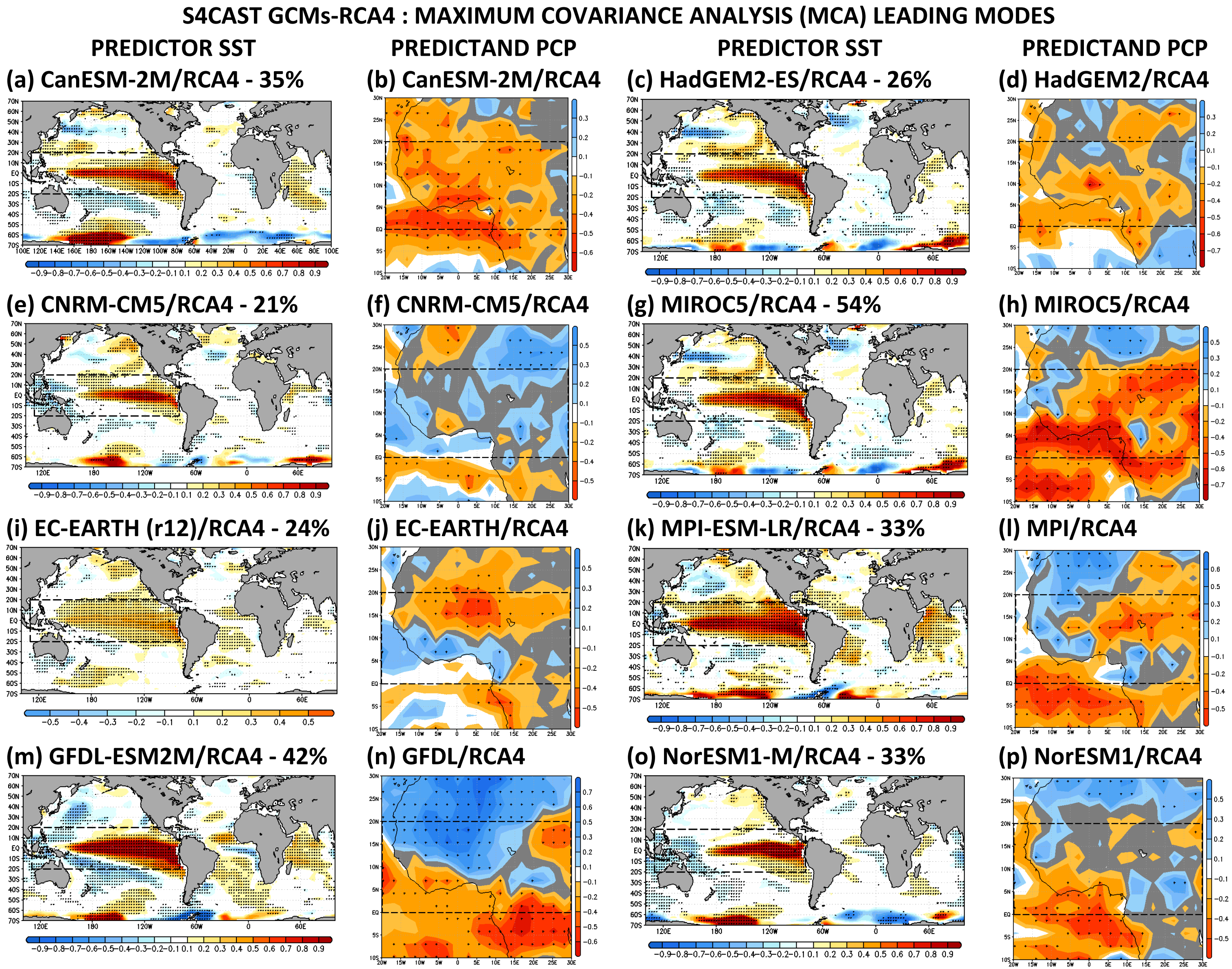


Fig. S5: Same as Fig. S4 but using as predictand the simulations of SMHI-RCA4 nested onto the 8 GCMs.

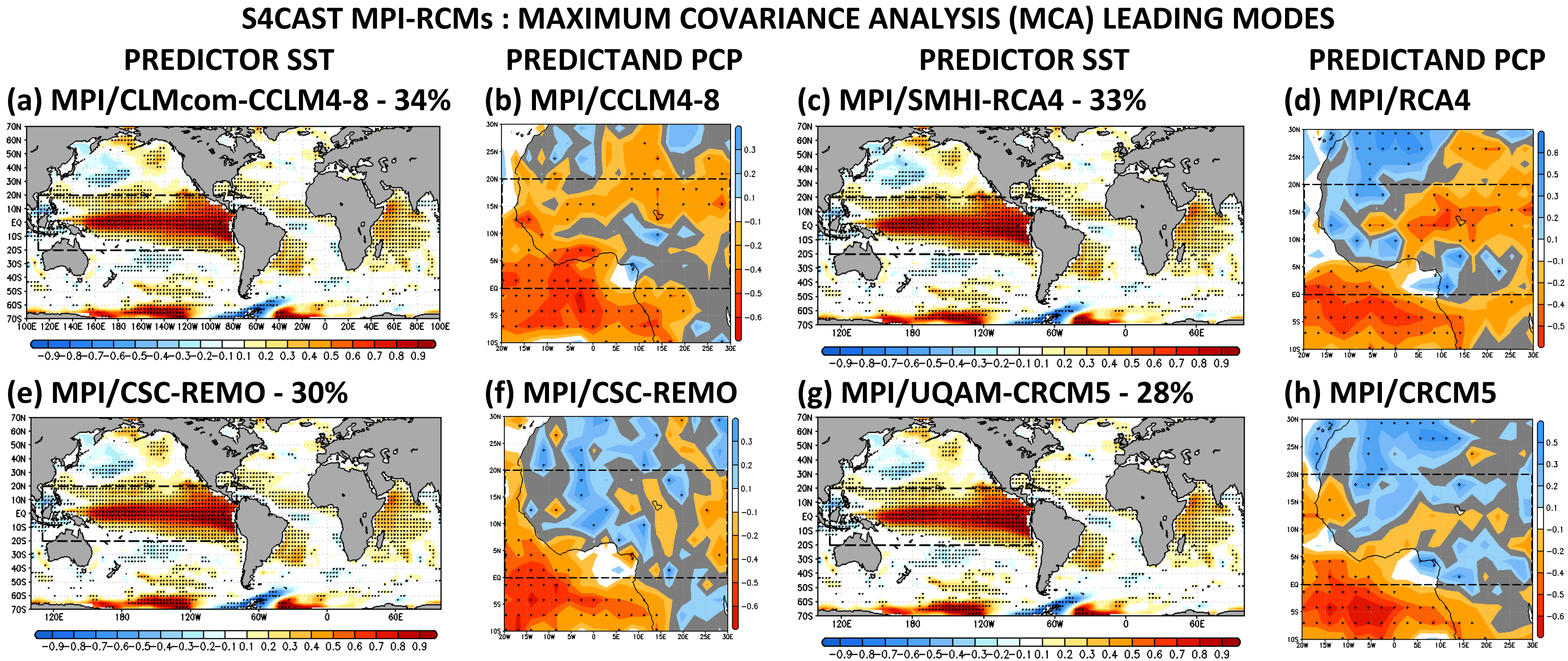


Fig. S6: Same as Fig. S4 but using as predictand the simulations of MPI-ESM-LR driving four different RCMs.

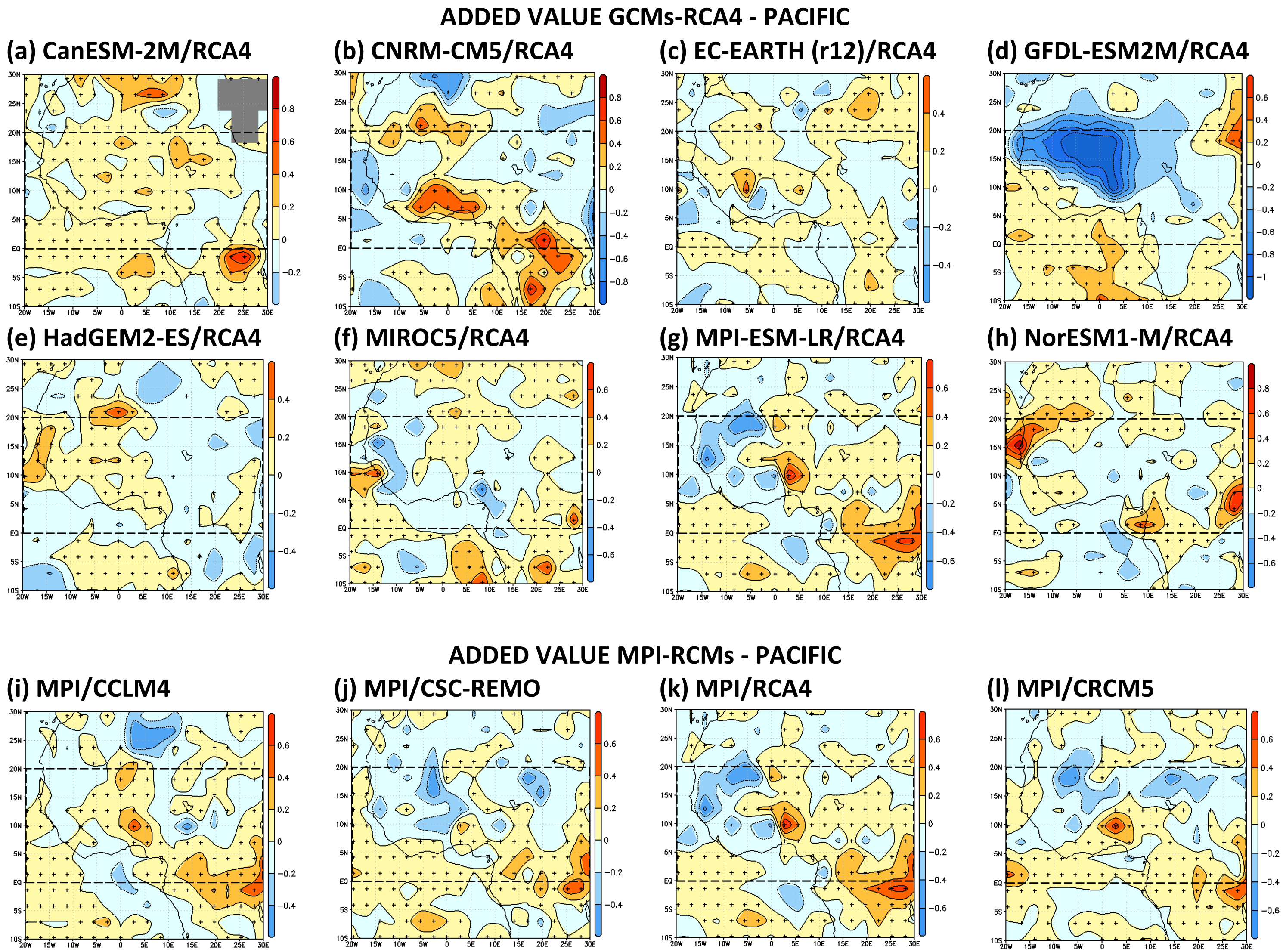


Fig. S7: (a)-(h) Added value maps (colors, in mm^2 day^{-2} std^{-2}) for the individual model members (RCA4 vs. GCMs) in representing the ENSO-West Africa JAS precipitation Teleconnection (1979-2004). Positive values are highlighted with stippling. (i)-(l) Same as (a)-(b) but for the nested RCMs onto MPI (MPI-RCMs vs. MPI).

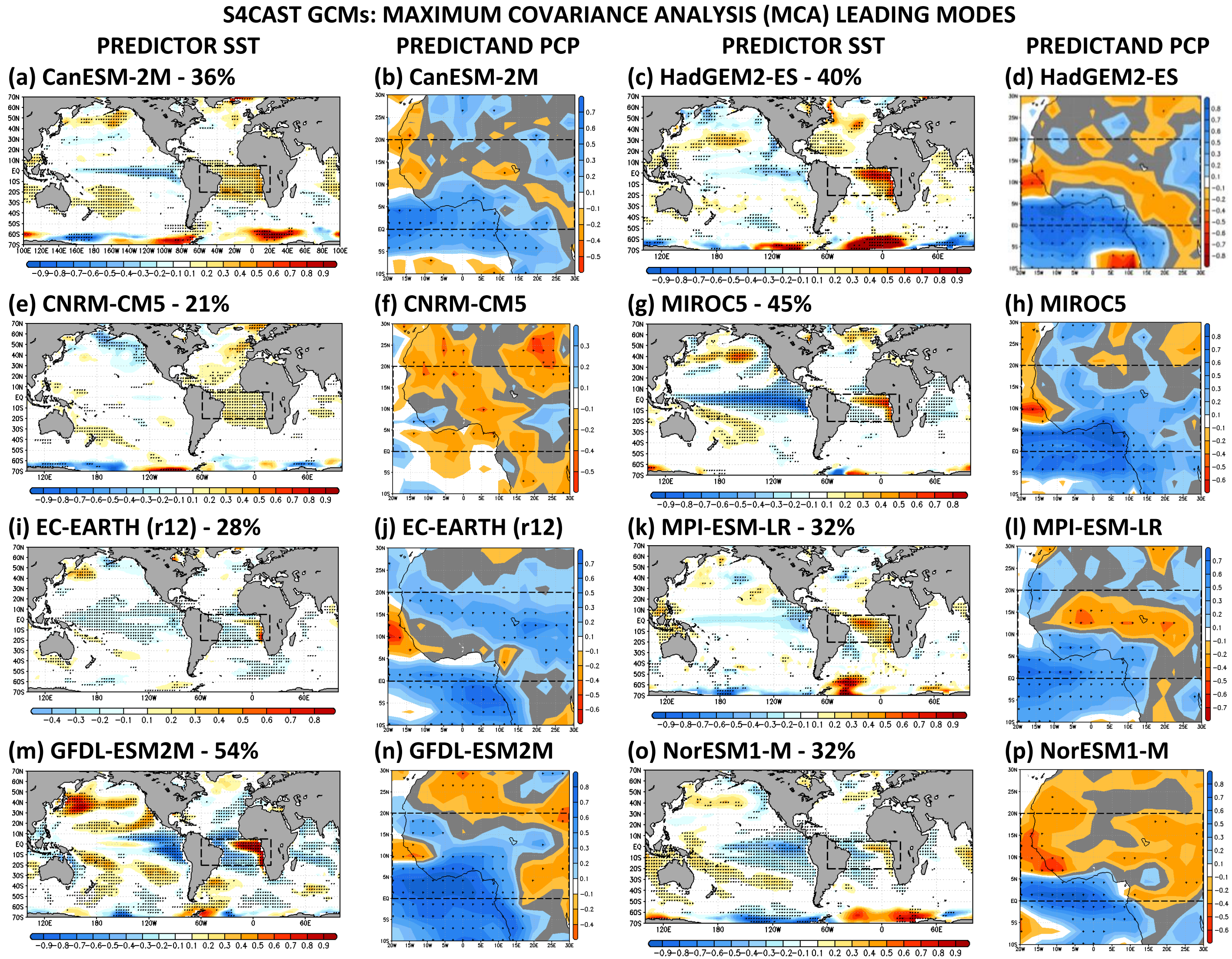


Fig. S8: (a)-(p) Pairs of homogeneous/heterogeneous regression maps for the leading mode of each GCM individual simulation between SST anomalies (predictor) from the equatorial Atlantic [60ºW-20ºE, 20ºS-5ºN] and precipitation anomalies (predictand) over West Africa [20ºW-30ºE, 0º-20ºN]. Period: JAS 1979-2004. Explained variance provided in % on top of each sub-panel. Confidence interval (95%) is provided in stippling using a Monte Carlo test of 1000 random iterations.

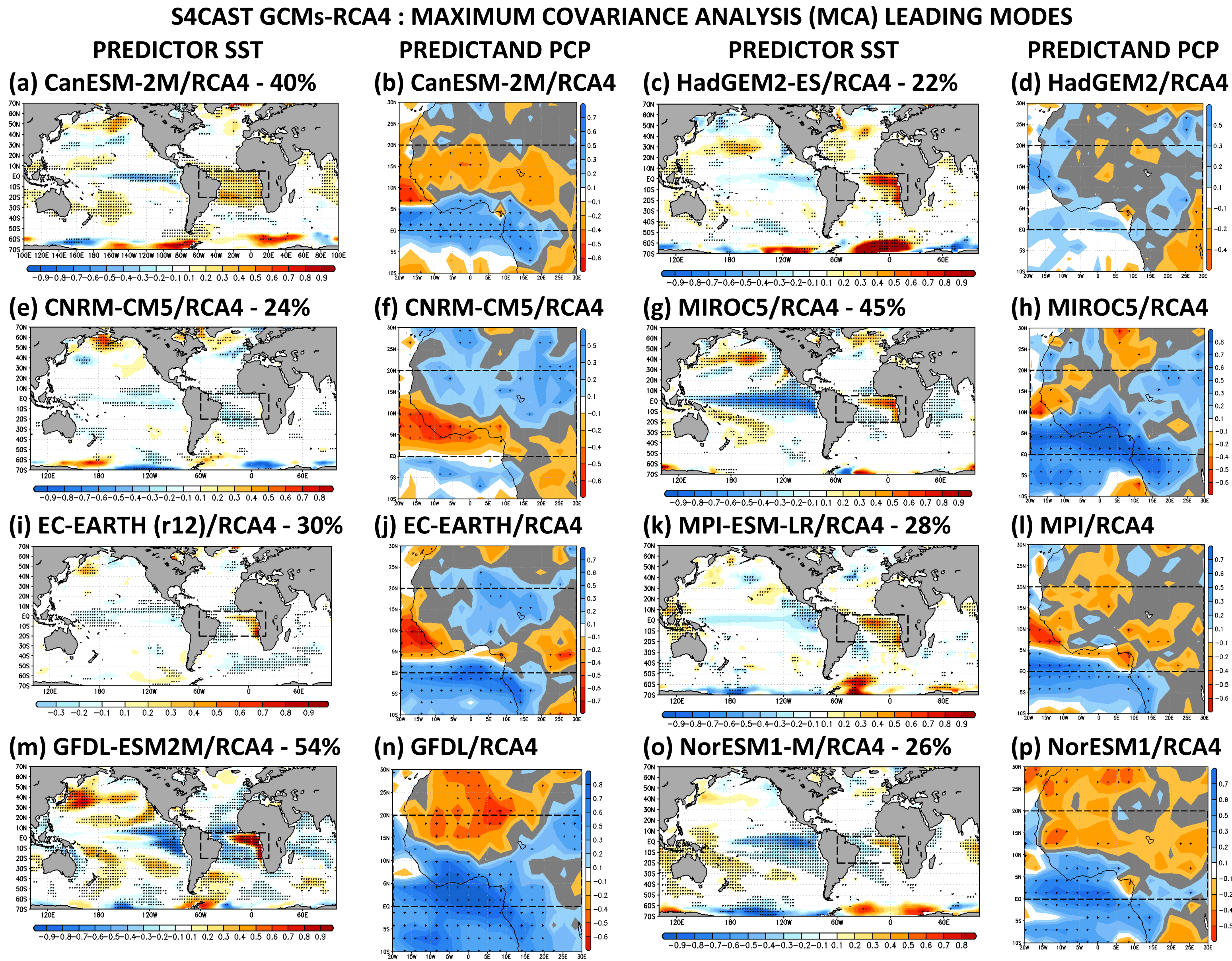


Fig. S9: Same as Fig. S8 but using as predictand the simulations of SMHI-RCA4 nested onto the 8 GCMs.

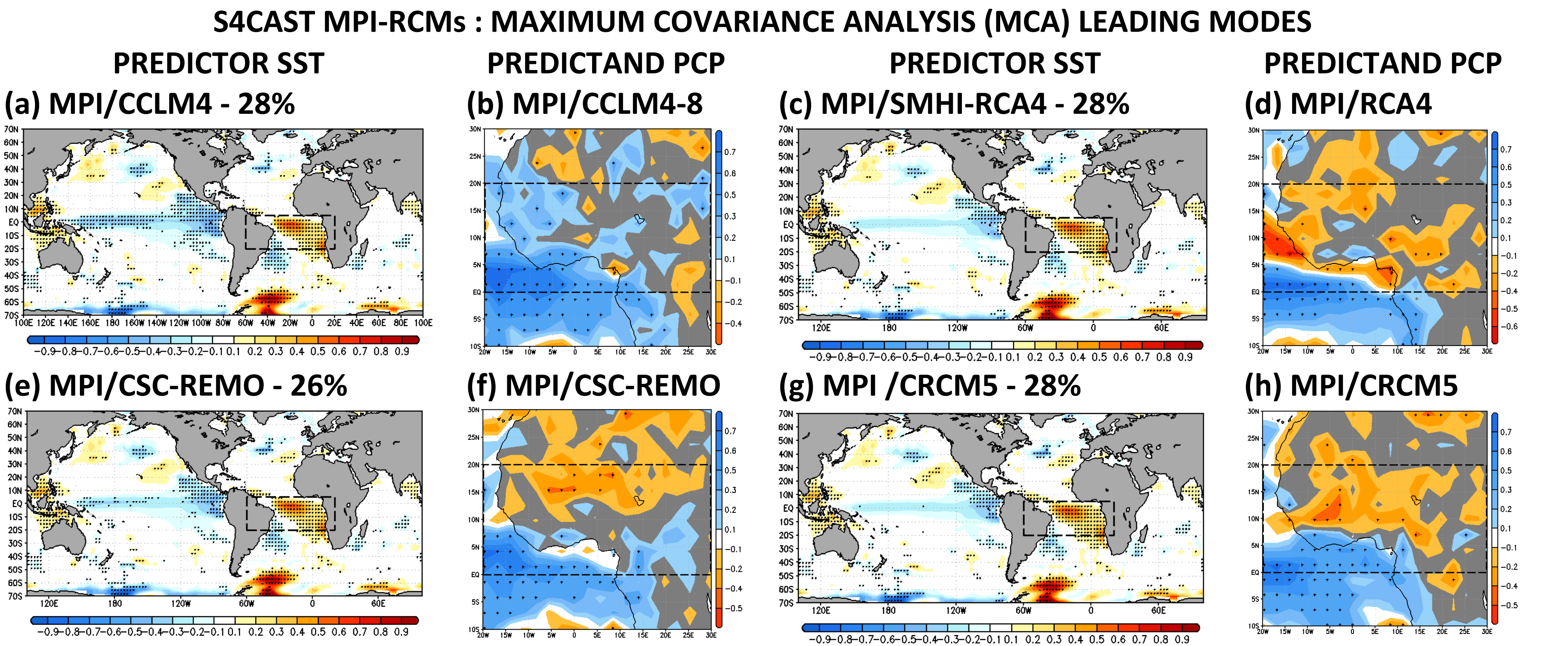


Fig. S10: Same as Fig. S8 but using as predictand the simulations of MPI-ESM-LR driving four different RCMs.

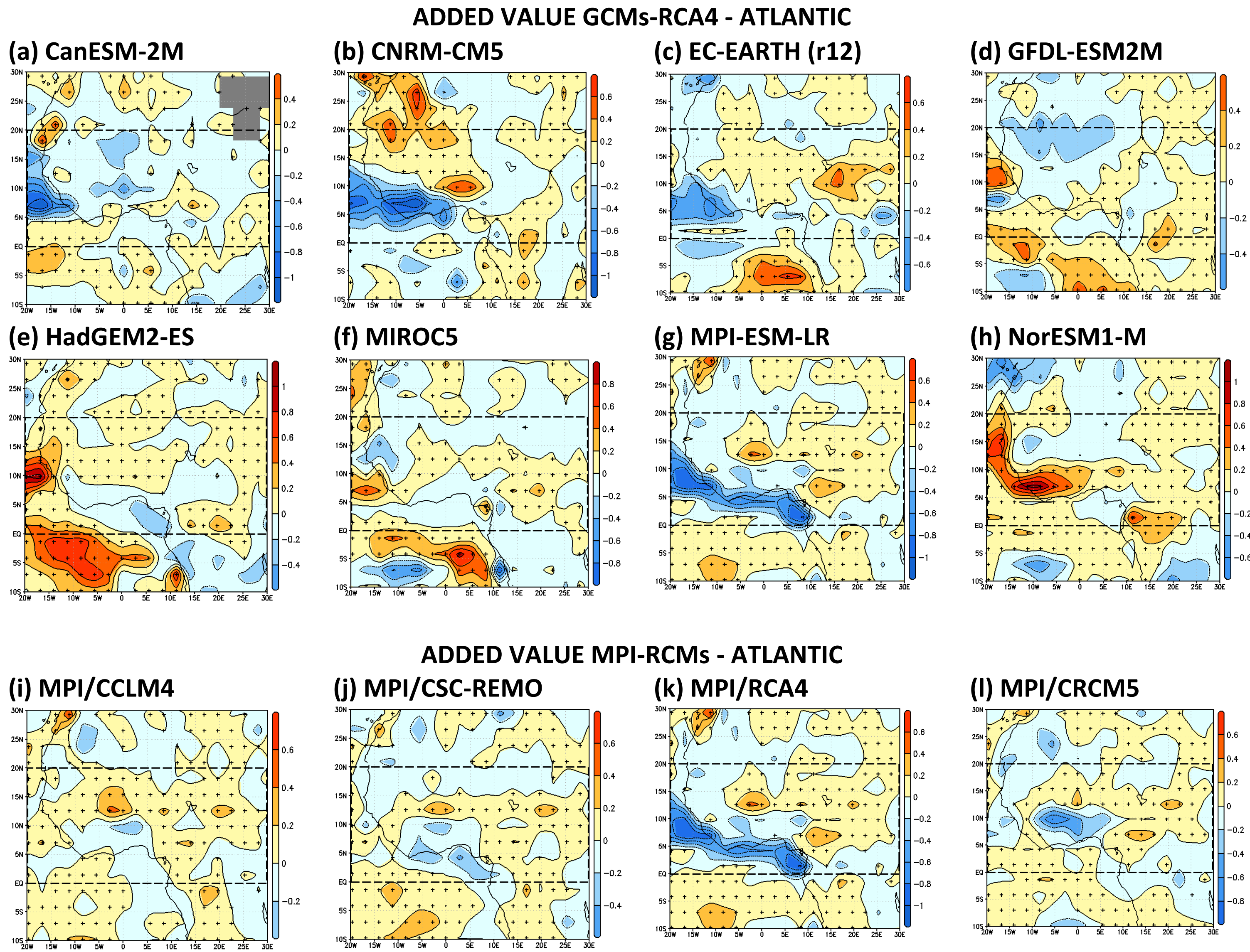
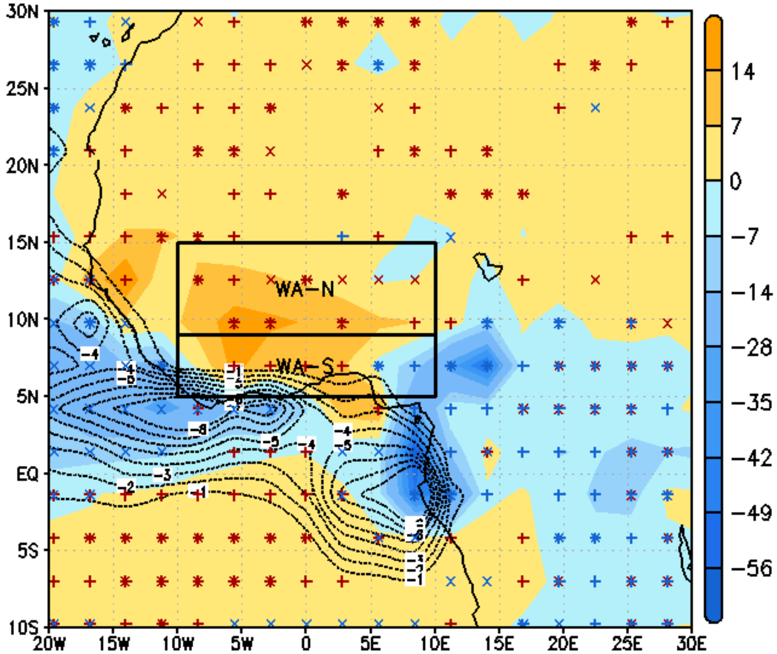


Fig. S11: Same as Fig. S7 but for the AEM-WAM Teleconnection.

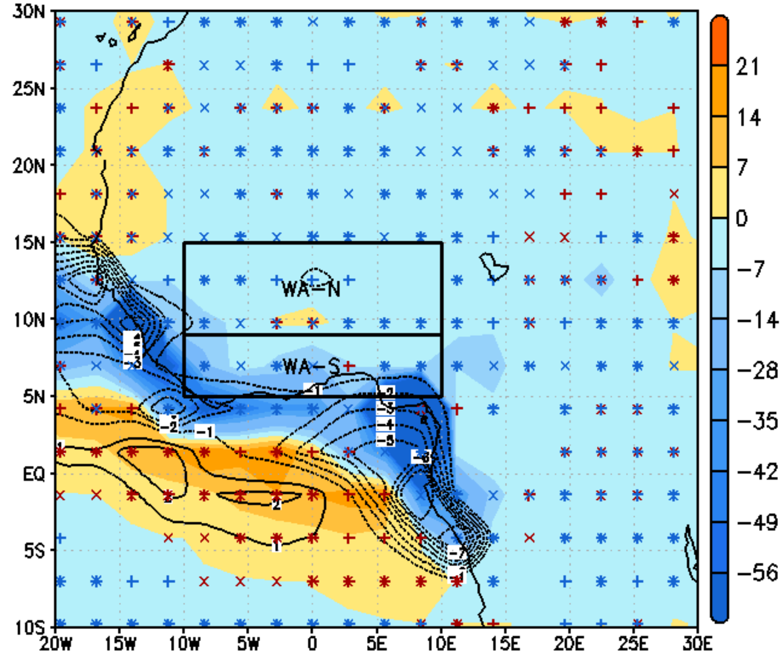
RCM Added Value (Di Luca et al. 2013; Meque and Abiodun 2015)

$$AV = (X_{GCM} - X_{OBS})^2 - (X_{RCM} - X_{OBS})^2$$

Ensemble AV – GCMs-RCA4



Ensemble AV – MPI-RCMs



Colors – ensemble AV in average pcp (mm2/day2)

Contours – ensemble AV in pcp std (mm/day)

Stippling: 75% of individual models giving same AV sign

Contrasting results from GCMs-RCA4 and MPI-RCMs