A comparative analysis of the horizontal resolution impacts in simulated climate over South America

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CAPES

Motivation

Global climate models studies have shown that the use of fine horizontal resolution may improve the simulation of the location and intensity of climatological systems, for example, upper levels jets (Lu et al., 2015) or the global hydrological cycle (Demory et al., 2014);

At regional scale, fine horizontal grid may be important to define differences on the land cover (water bodies, cities, natural cover, sea/continent, etc.) and topography → controls of local climate;

Over South America it is increasing the use of RCMs with finer horizontal grid trying to reproduce more realistic observed local climate patterns (da Rocha et al. 2015 - RegCM3 using 50 and 20 km to simulate local features of climate over the Metropolitan Area of São Paulo, Brazil. For winter seasons of 2003-2004).

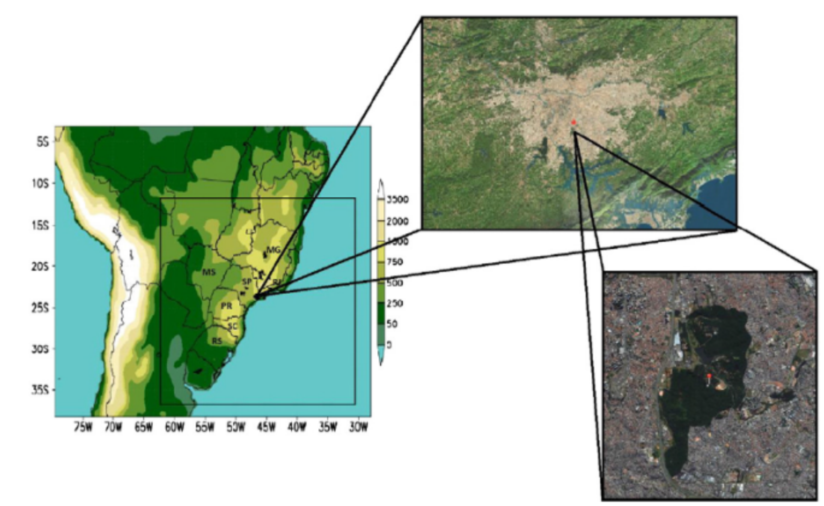


Fig. 1. Domain and topography (m) for R50 simulation and only the limits of R20 domain (inner rectangle). The top panel shows a zoom of MASP (light brown) and surrounding areas. The bottom panel presents IAG station (dot red) inside the park of "Ipiranga Waters" (dark green) surrounded by the city of Sao Paulo. (From: Google Earth©image, on January 20th, 2014).

Objectives

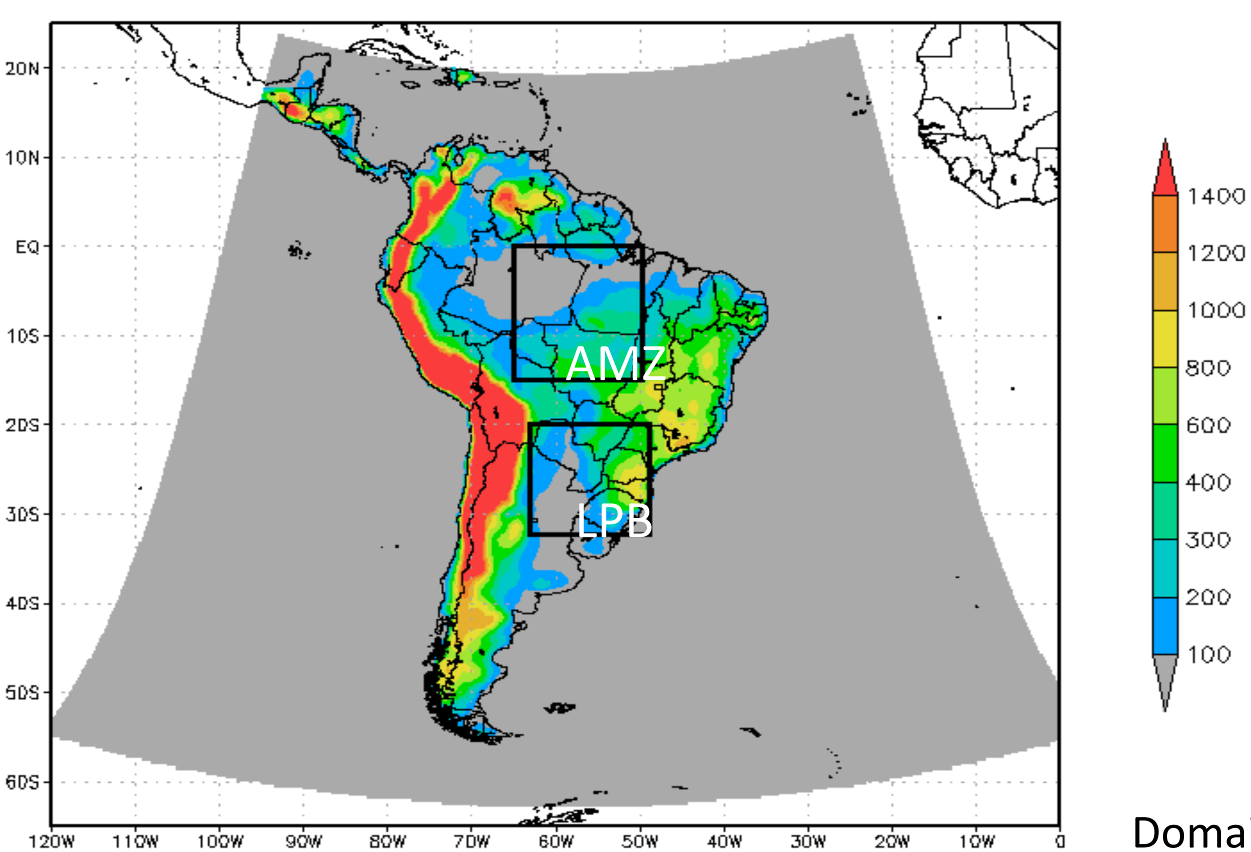
- **To evaluate the impact of using fine horizontal grid spacing in RegCM4 to simulate the climate over South America (SA).**

The horizontal resolution controls on SA climate will be discussed considering:

RegCM4 simulations using 25 and 50 km grid spacing and four convective parameterizations → impacts on simulated climate for 2005 year and high frequency variability.

RegCM4 simulations using 25 and 50 km grid spacing and four convective parameterizations

Simulations were carried out using **RegCM4** (Regional Climate Model - version 4.4.5) over the **domain covering South America** and adjacent oceans (CORDEX subdomain)



Domain and topography of G50 and G25 simulations.

One domain with two different grid spacing: 50 and 25 km

Data and Methodology

Simulations design:

Horizontal grid spacing : 50 (G50) and 25 (G25) km

Number of sigma levels = 23

Topography and land-use: USGS and GLC (Loveland et al. 2000)

Initial and boundary conditions + SST: Era-Interim

Period: 2005 year (from 00:00 UTC 01/ Dec/2004 until 01/Jan/2006)

Physical parametrizations:

Surface scheme: BATS

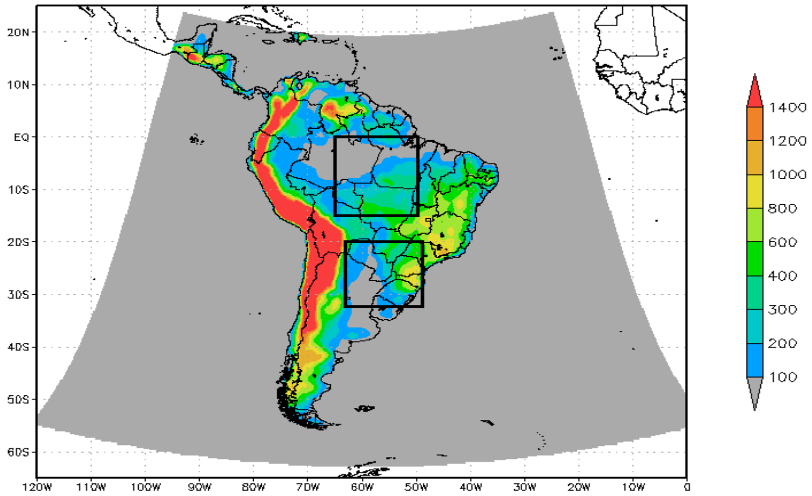
Four convective parametrizations:

Emanuel (Ema),

Grell-Fritsch Chappell (Gfc),

Grell-Arakawa Schubert (Gas)

Kain-Fritsch (KF).



Observed data

Rainfall:

Daily mean values from:

- Climate Prediction Center (CPC) – rainfall data (only rain gauge analysis with grid of 0.5°);

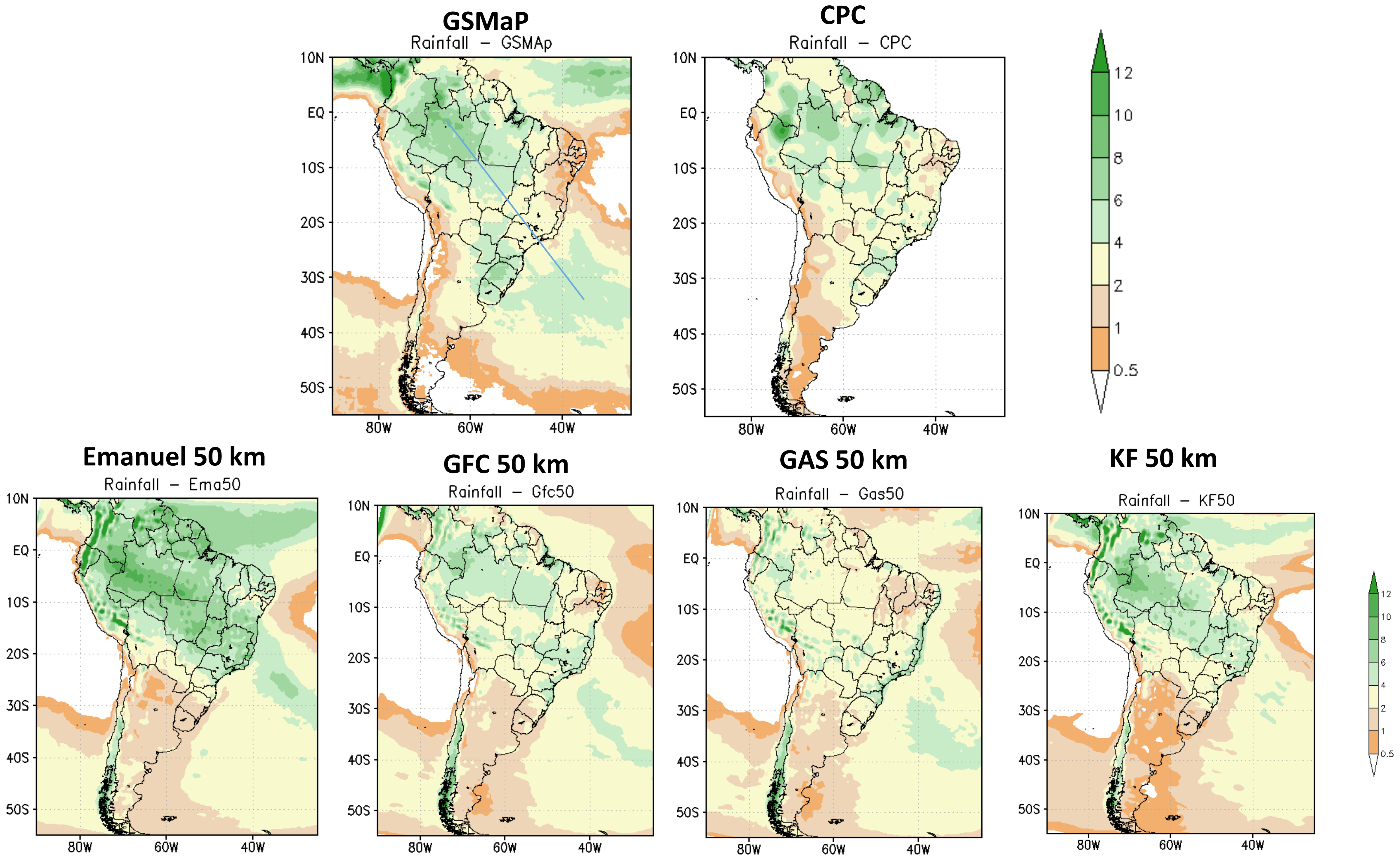
- Global Satellite Mapping of Precipitation (GSMaP): derived from satellite (grid of 0.1°) ;

Air temperature:

CRU – 0.5 x 0.5 analysis

EraInterim (Dee et al. 2011) → it has assimilated 2 m air temperature and humidity

G50 simulations and observations of mean annual rainfall for 2005

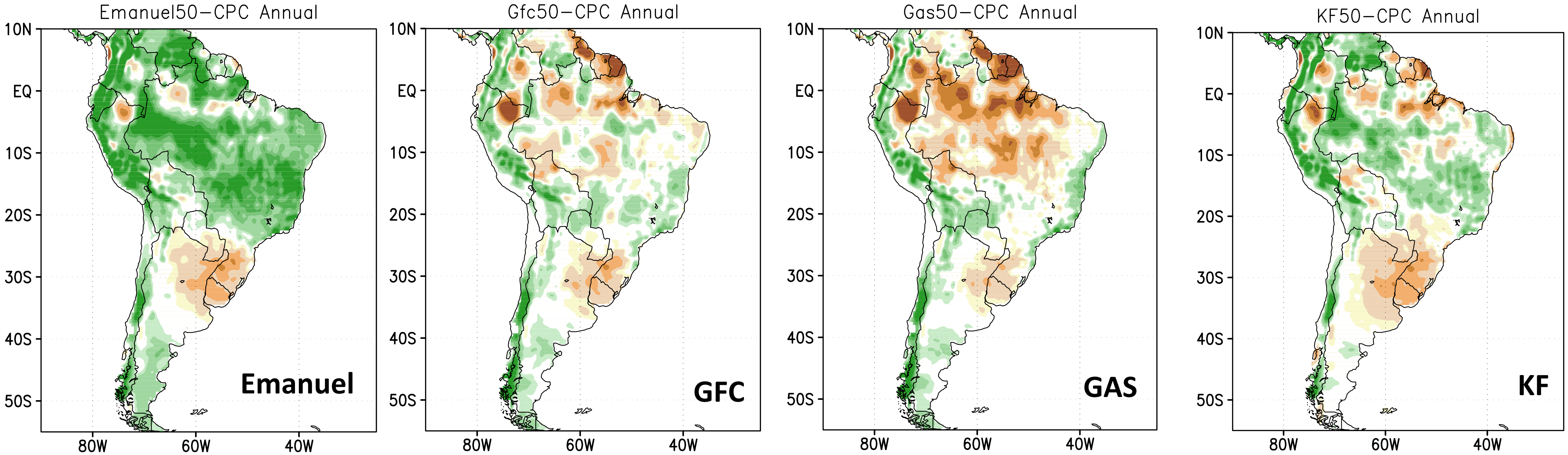


Large agreement between observed and simulated rainfall: **Emanuel and KF**

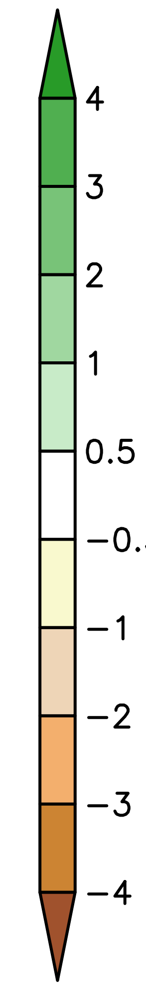
Gas: simulated spatial pattern of rainfall does not resembles the observed one

Gfc: a small improvement compared with Gas in the reproduction of observed pattern of rainfall

Annual (2005 year) rainfall bias: Simulations x CPC

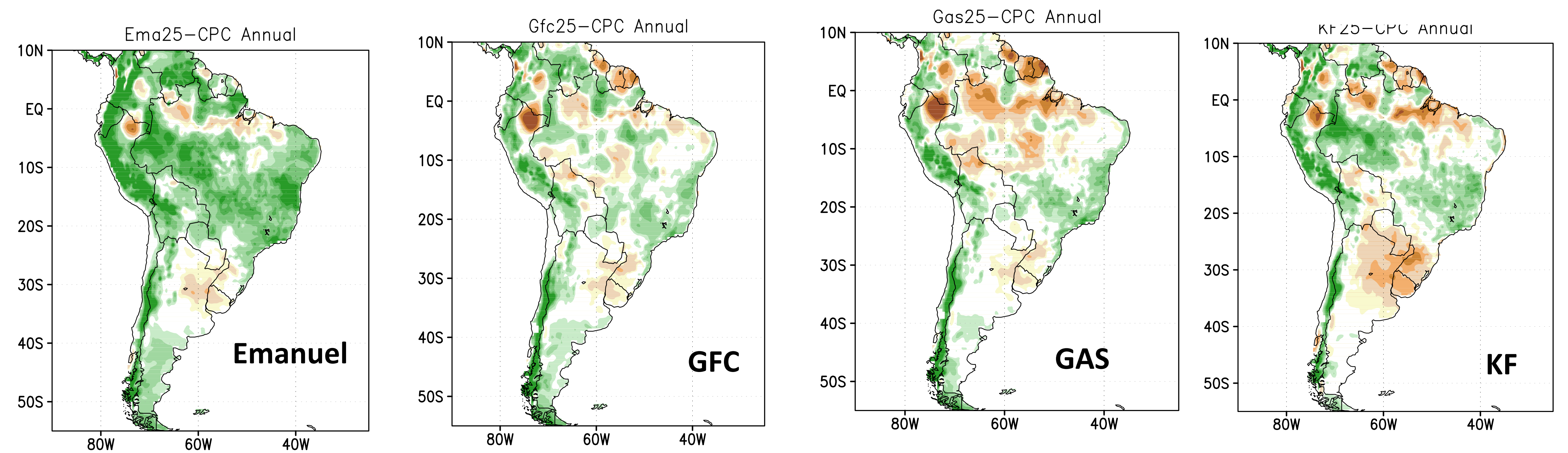


G50



→Common all parameterizations: dry bias over **south Brazil and Uruguay** (which is part of La Plata Basin - LPB) in G50 → Emanuel, Gfc and Gas schemes: dry bias decreases drastically in the G25; this is not noted in KF

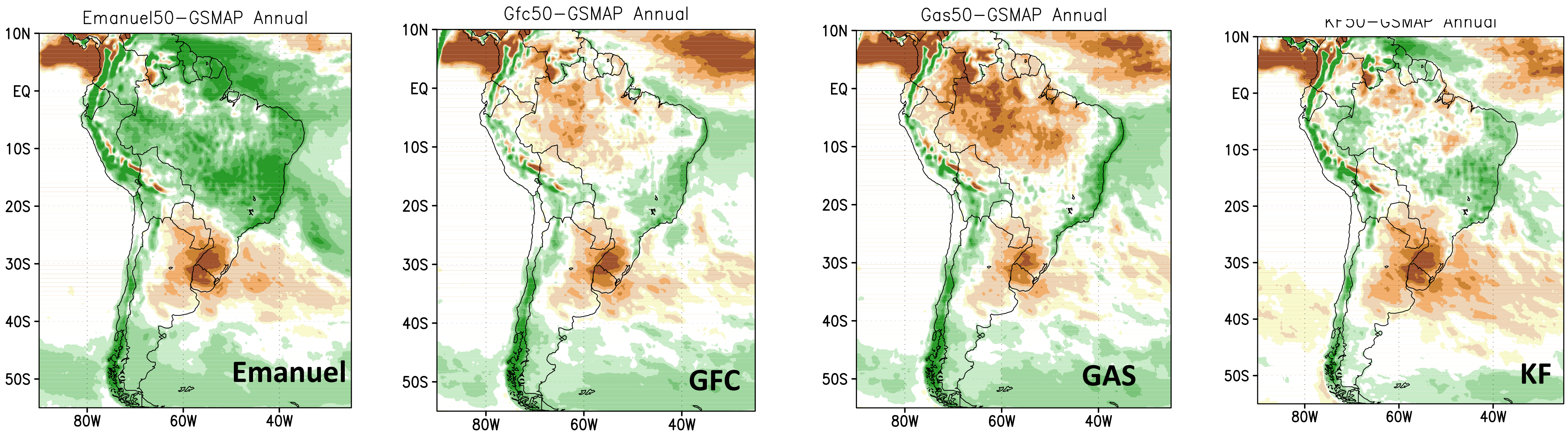
→ **Amazon basin**: Emanuel at G50 has a large wet bias, which decreases at G25. Gfc, Gas and KF have dry bias in G50 that decreases in G25.

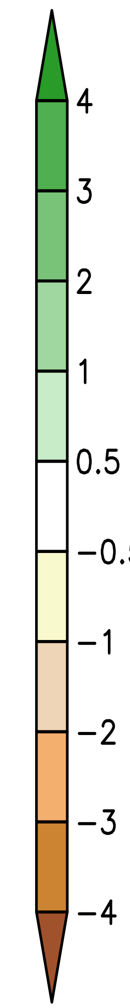


G25

Annual (2005 year) rainfall bias: Simulations x GSMaP

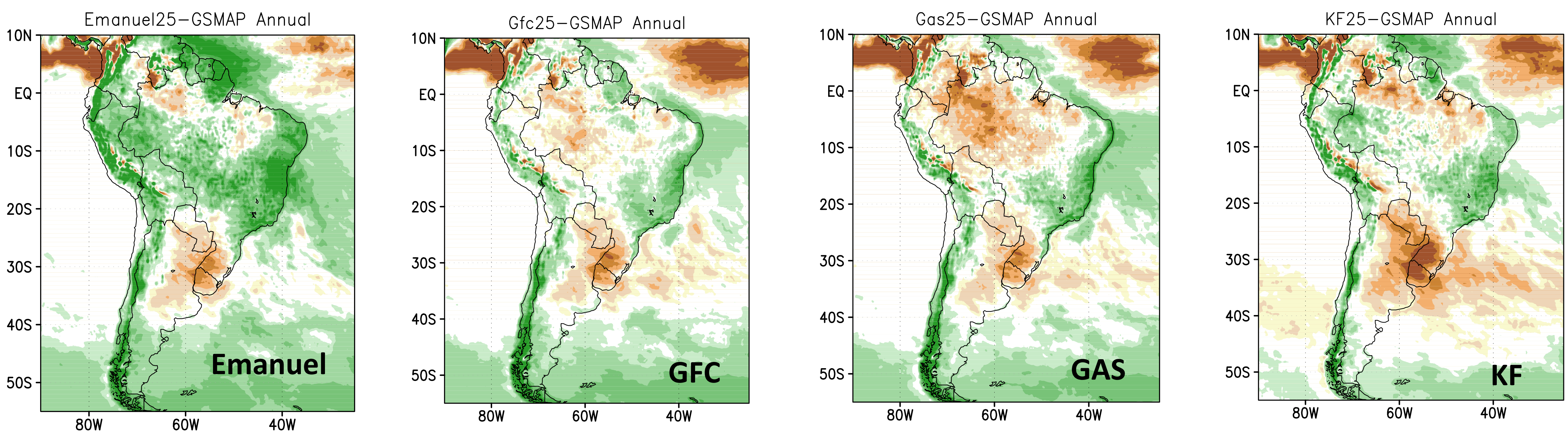
G50





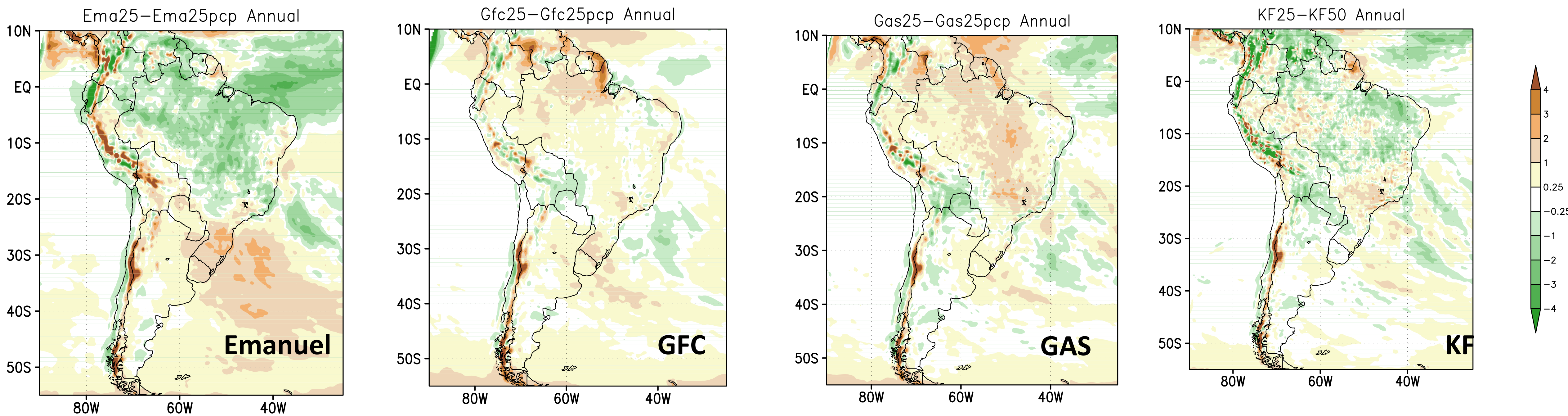
→Simulations x GsMaP: Spatial patterns of rainfall biases are similar that of Simulations x CPC. Differences in intensity: dry bias are large over LPB in the comparisons Simulations X GSMaP.

→Rainfall biases have the same signal in G25, but in module they are smaller in G25.



G25

Impact of resolution: difference of annual rainfall between 25 and 50 km (G25 minus g50)

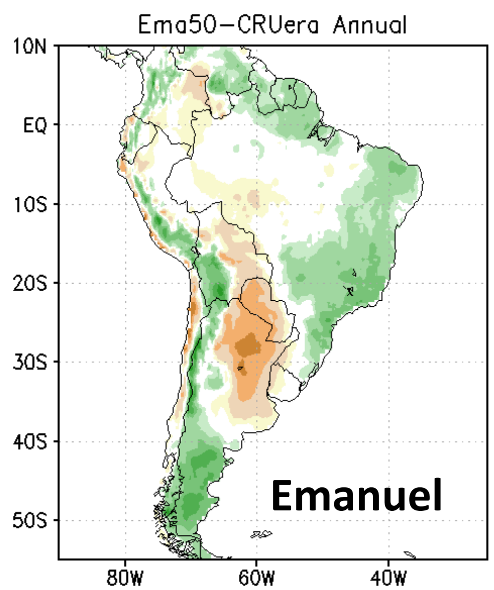


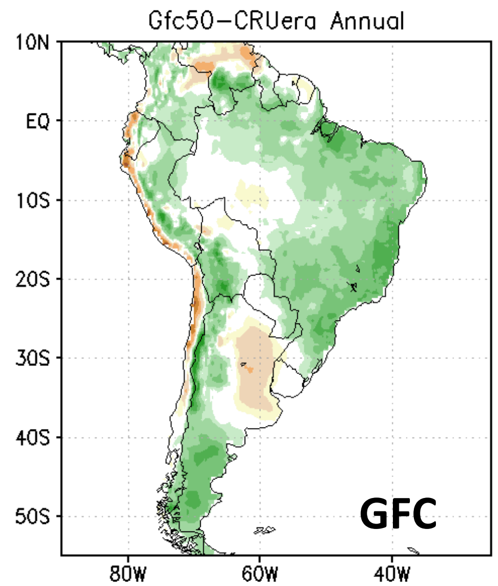
Emanuel
a north-south dipolar response as function of grid size: reduces the rainfall rate in the tropical (implying in small wet bias) and increase of rainfall over subtropics-extratropics (including in LPB with a decrease of the dry bias)

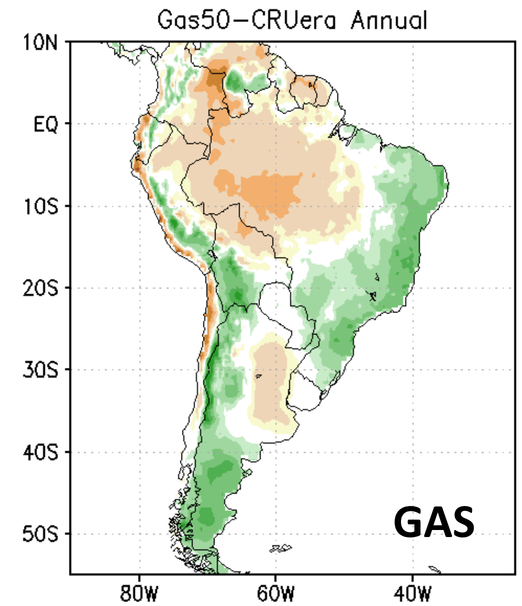
Gfc and Gas → simulate a general increase of the rainfall rate in the higher resolution simulations (25 km)

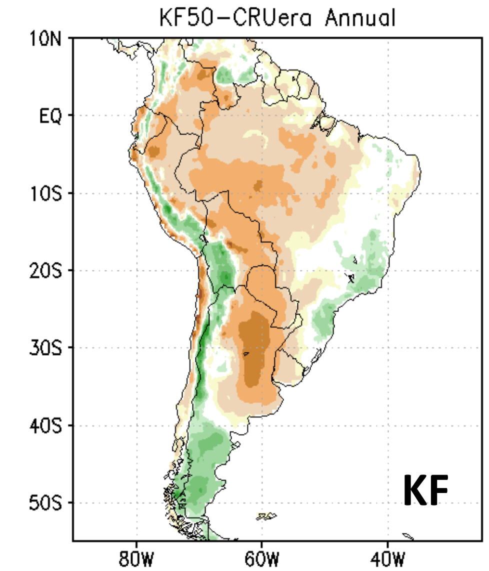
KF → has a behavior similar to Emanuel, but with small differences in intensity between G50 and G25

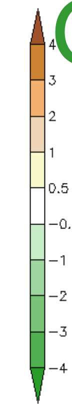
Annual (2005 year) air temperature bias: Simulations x mean of observations (EraInterim and CRU)











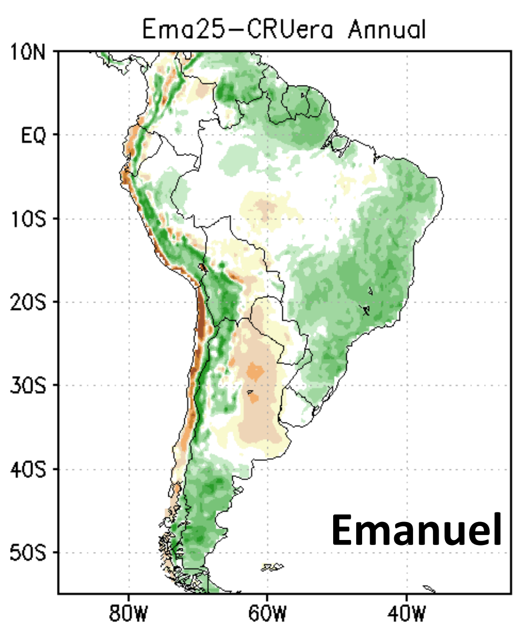
G50

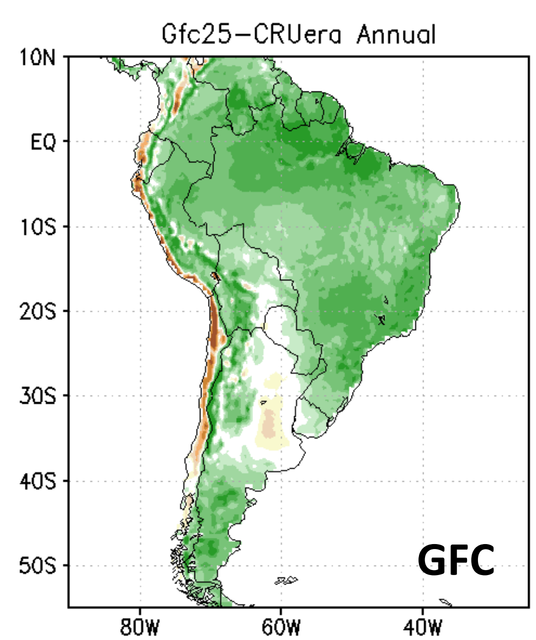
Emanuel: G25 decreases the temperature bias in all domain

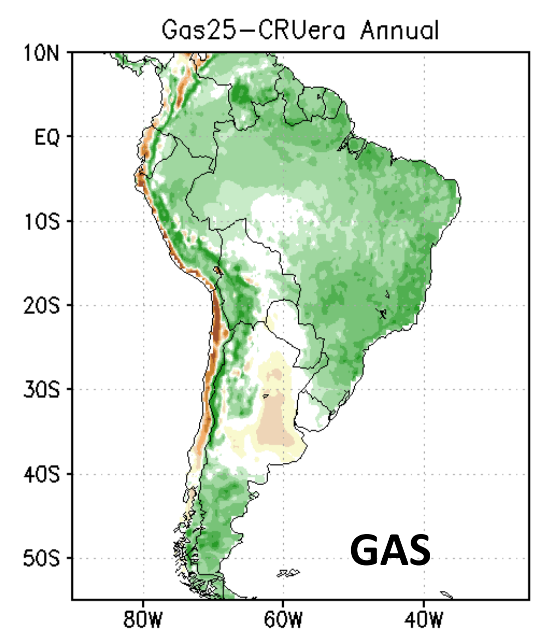
Gfc: cold bias covers most of South America in G50; it is accentuated in G25

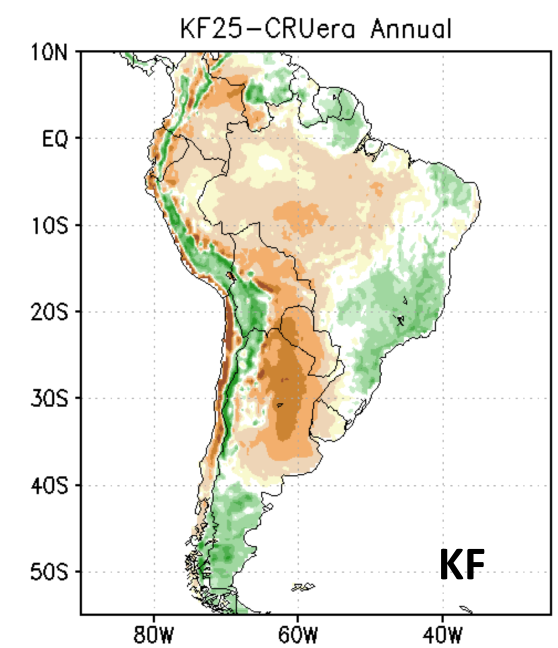
Gas: it is noted a change of the predominance of warm (G50) to cold bias (G25)

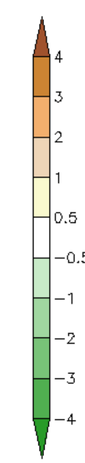
KF: warm bias in most part of continent decrease in KF25





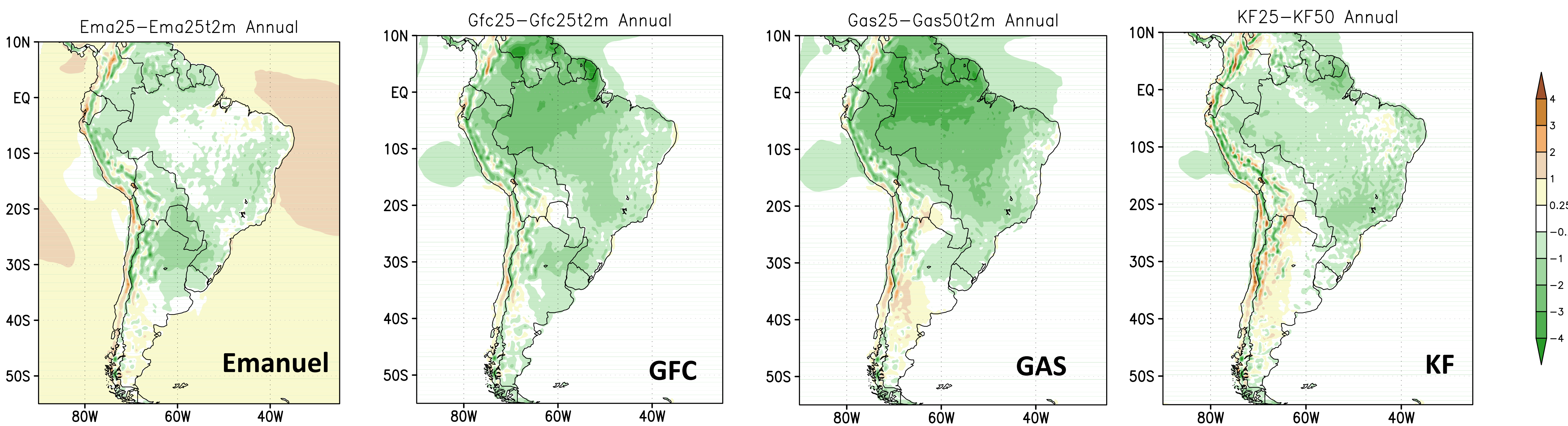






G25

Impacts of resolution: difference of annual air temperature in 25 and 50 km (G25 minus G50)



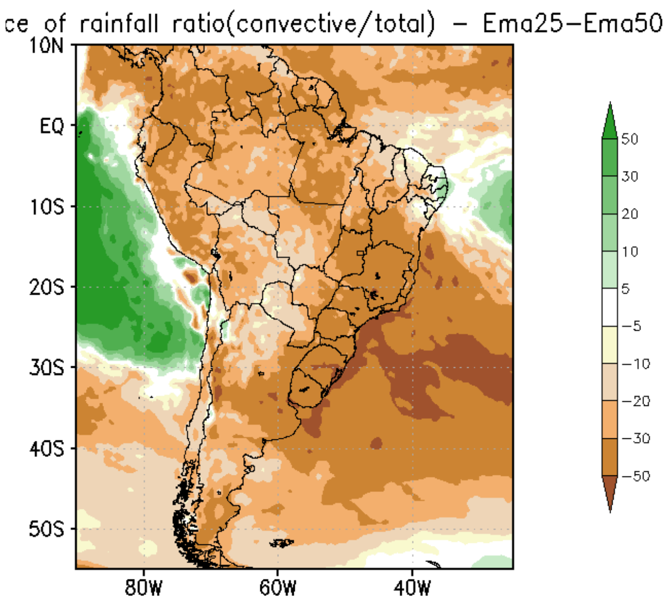
A general behavior of the parameterizations:

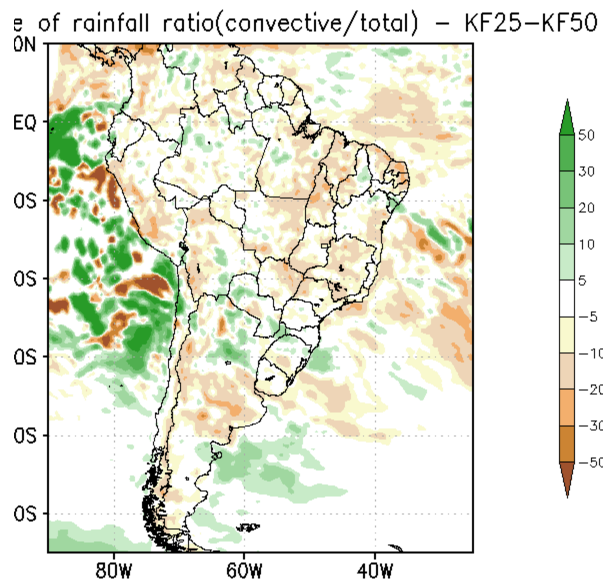
- over continent the air temperature are lower in G25 than in G50

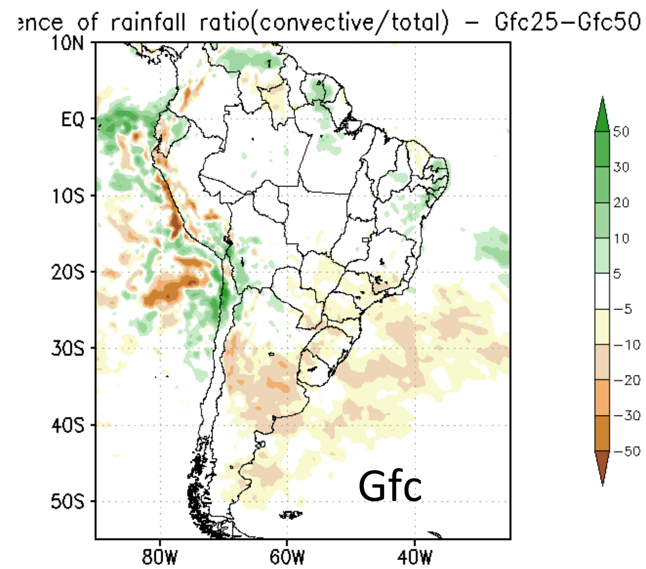
- differences between G25 and G50: are larger in Gas and smaller in Emanuel

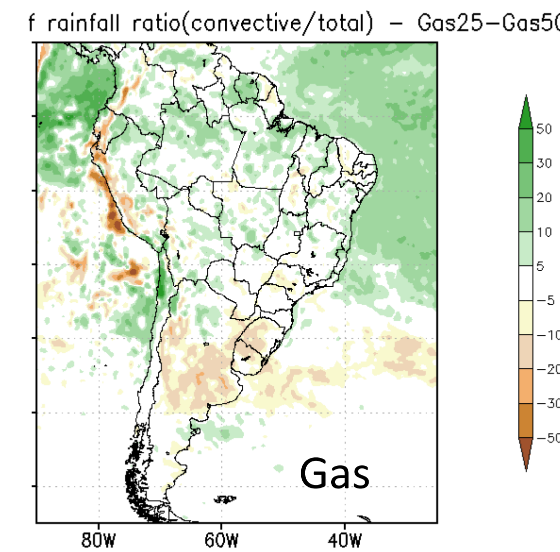
Is there any impact of resolution between convective and large scale rainfall "partition"?

Relative difference = [$(Conv/tot)_{G25}$ – $(Conv/tot)_{G50}$] * 100









G25 x G50
Emanuel: Relative contribution of convective scheme for total rainfall decrease drastically over most part of domain;

It increases over Pacific Ocean (convective scheme produces more rainfall at G25 than at G50)

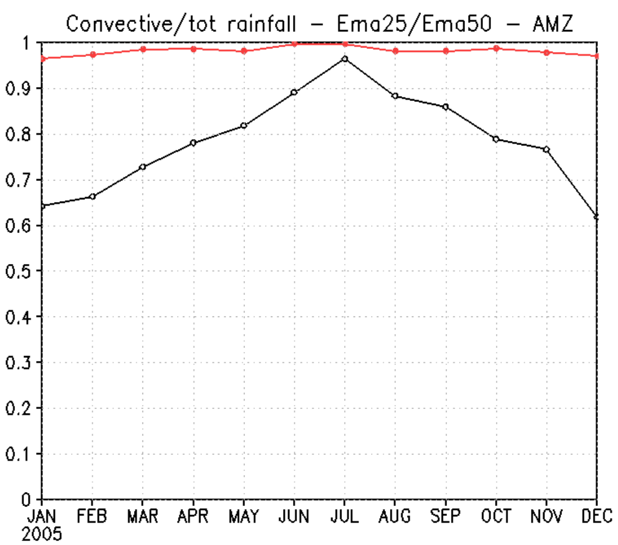
KF: contribution of convective scheme for total rainfall has a small decrease over SA and it increase over Pacific Ocean in G25;

Gfc and Gas → convective scheme reduces it participation in total rainfall in subtropics in G25

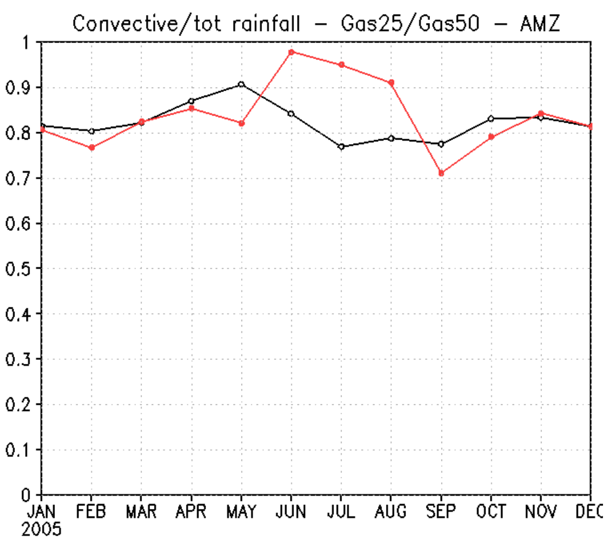
Gas → simulates the more convective rain over tropical Pacific and Atlantic Oceans in G25 than G50;

Annual cycle of the rainfall “partition” (convective/total) → AMZ

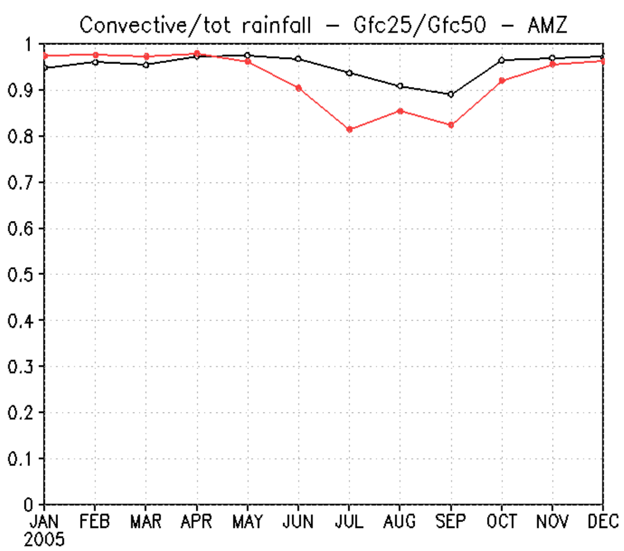
Emanuel



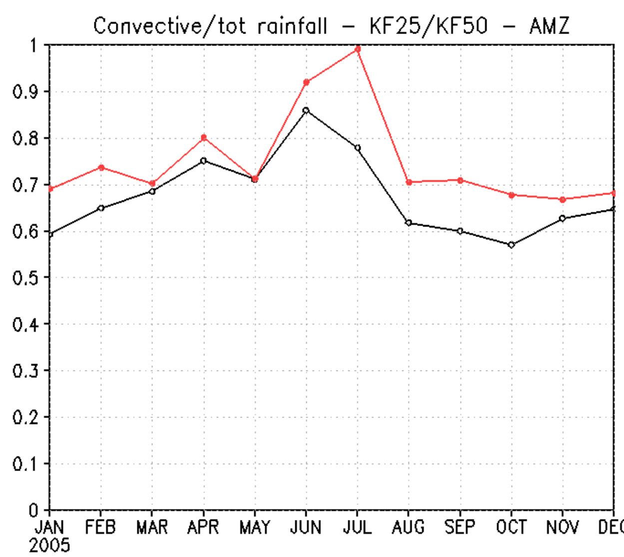
GAS



GFC



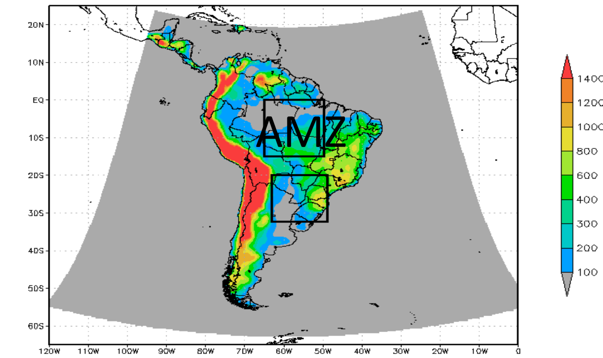
KF



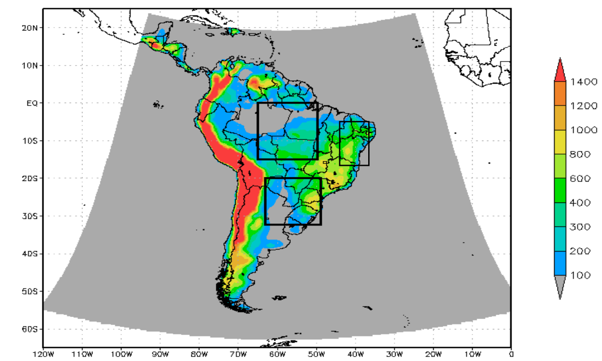
Ration (conv/tot)

Emanuel G25: large decrease of convective rainfall contribution to total during wet months

In Emanuel the changes of the “partition” of rainfall are stronger than in the other schemes → more sensitivity to the horizontal grid resolution



Mean annual values for the subregions: AMZ, LPB and NDE



Rainfall (mm/day)	AMZ G50/G25	LPB G50/G25	NDE G50/G25
Ema	7.3 **(6.5)**	2.3 **(3.3)**	4.7 **(4.5)**
Gfc	4.0 **(4.5)**	2.7 **(3.1)**	**2.4** (2.7)
Gas	2.8 **(3.7)**	2.9 **(3.1)**	**2.3** (2.8)
KF	5.2 (5.2)	**2.0**/1.9	**2.6**/3.0
CPC/GsMap	***5.0/4.3***	***3.2/4.2***	***2.5/1.9***

At regional scale:

- rainfall simulated by G25 (red) have large agreement with observed values than G50 (blue), except in KF scheme

Temp (oC)	AMZ G50/G25	LPB G50/G25	NDE G50/G25
Ema	26.4 **(26.2)**	22.2 **(21.3)**	25.1 (25.0)
Gfc	**25.8** (24.1)	**20.9** (20.1)	**24.3** (23.9)
Gas	27.6 **(25.3)**	**21.1** (20.6)	**24.8** (24.0)
KF	28.2 **(27.6)**	23.0 **(22.7)**	26.4 **(26.1)**
CruEra	***26.2***	***21.6***	***26.2***

- Air temperature: biases are relatively small;
- G25(red) overperform G50 (blue) in KF and Emanuel schemes; the opposite is noted in Gas and Gfc

Differences between G25 and G50 (G25 minus G50): rainfall/temperature

	AMZ	LPB	NDE
Ema	-0.8/-0.1	+1.2/-0.9	-0.3/+0.1
Gfc	+0.5/-1.7	+0.4/-0.8	+0.3/-0.4
Gas	+0.5/-2.6	+0.4/-0.8	+0.5/-0.8
KF	0.0/-0.6	-0.1/-0.3	+0.4/-0.3

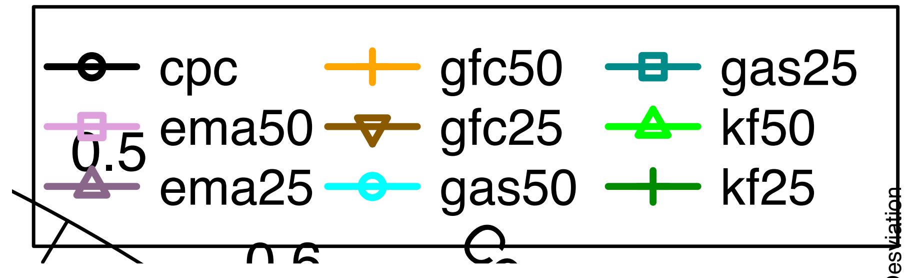
- **Black**: rainfall increases → more clouds → solar radiation decreases (negative correlation) → lower temperature

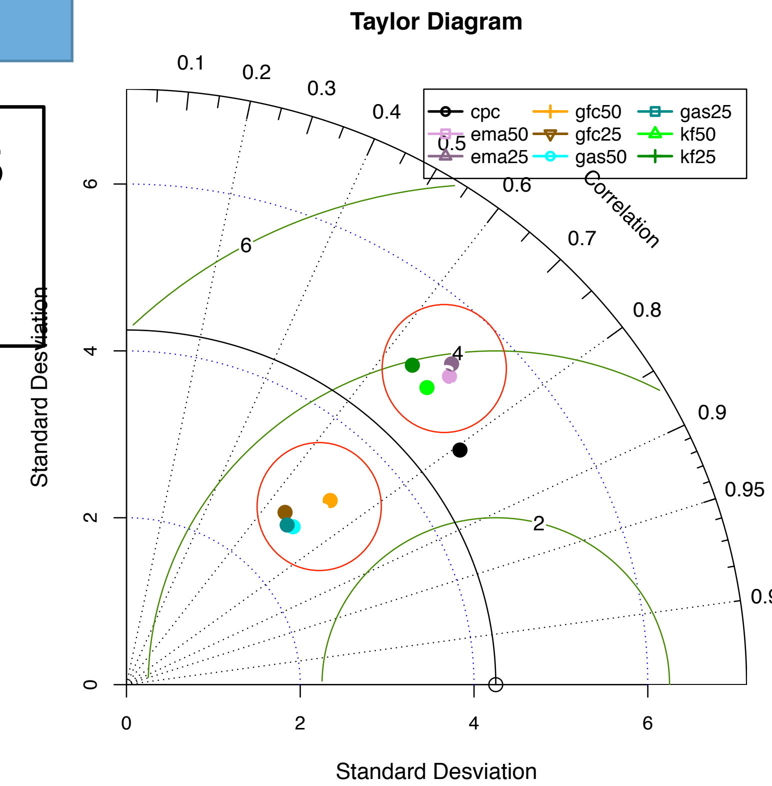
- **Red**: different feedbacks (rainfall decreases/temperature decreases)

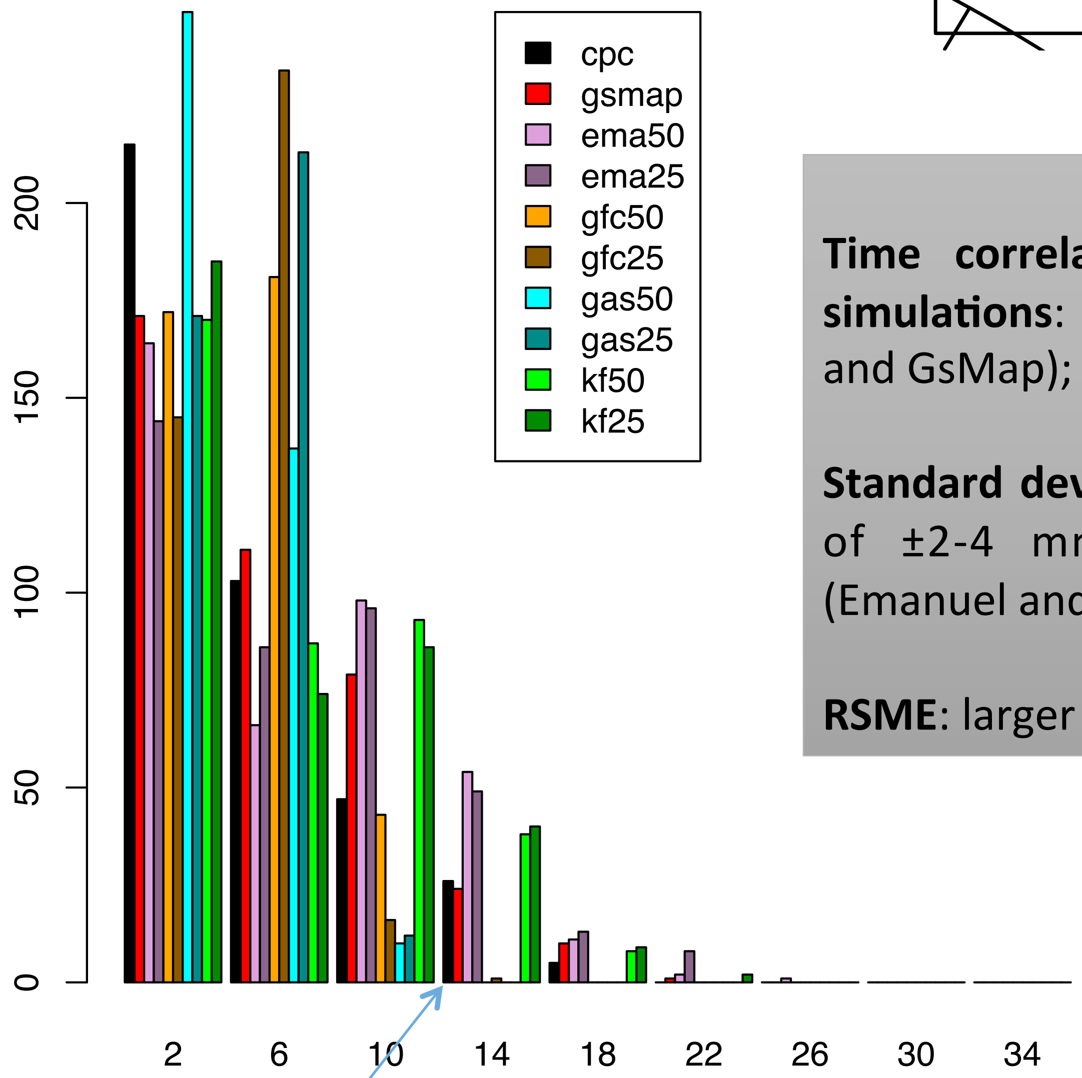
High frequency variability of rainfall: daily and five days running mean

Daily rainfall: AMZ

CPC x simulations







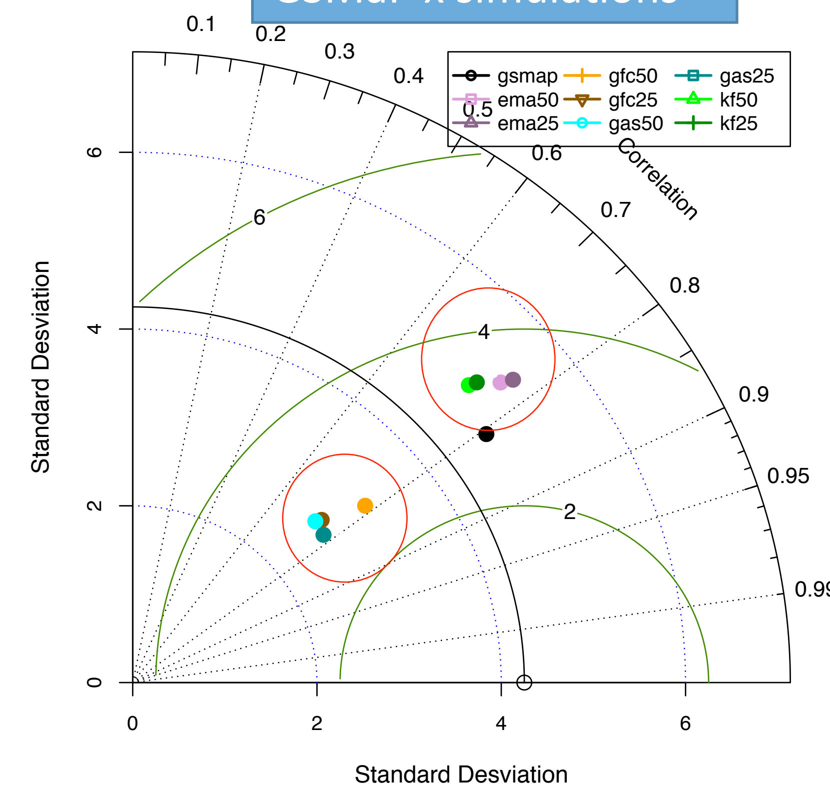
Taylor Diagrams

Time correlation between observations x simulations: 0.6 - 0.8 (similar values for CPC and GsMap);

Standard deviation: one group (Gas and Gfc) of ±2-4 mm/day and other with ±4-6 (Emanuel and KF). This occurs in G50 and G25;

RSME: larger for Emanuel/KF than for Gfc/Gas

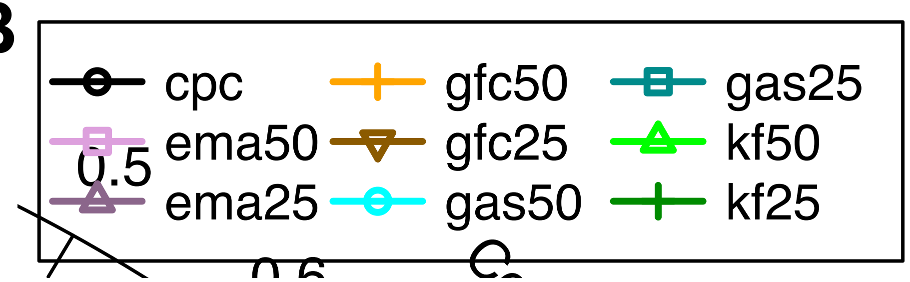
GSMaP x simulations

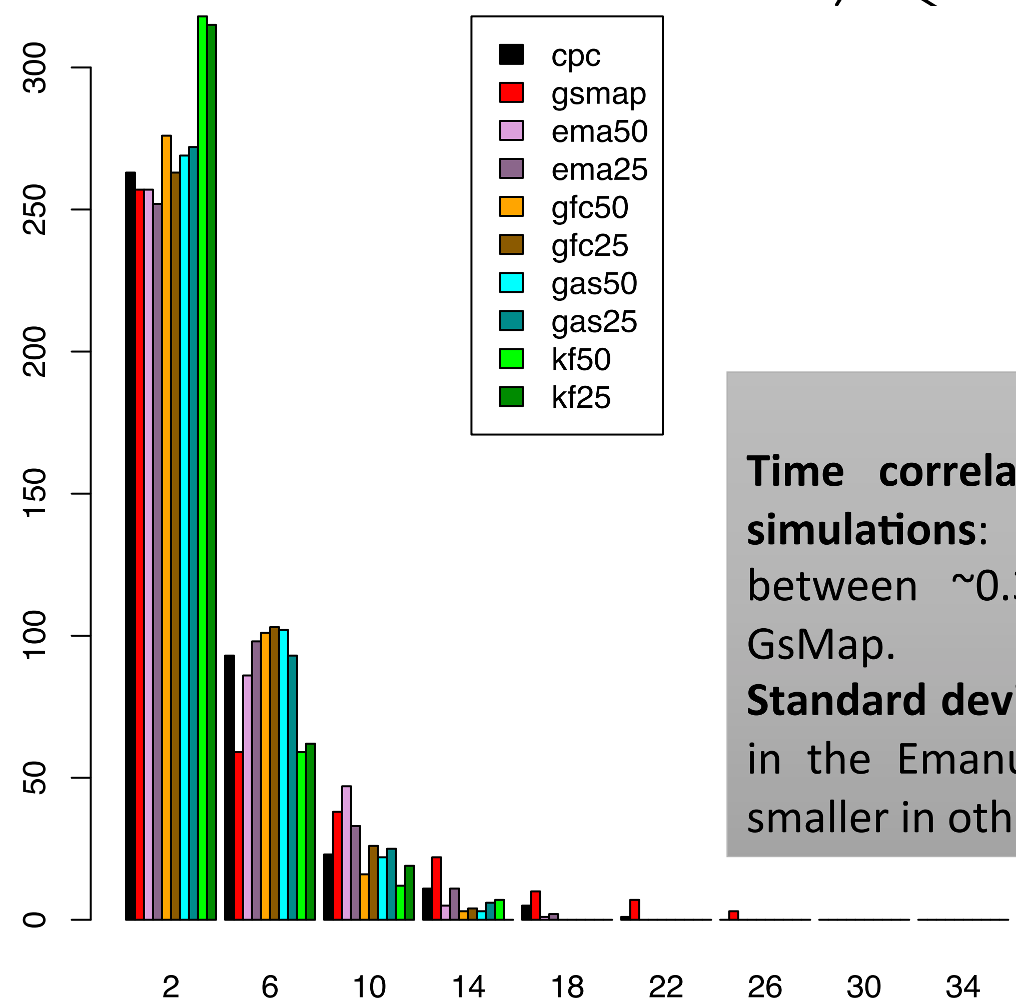


Frequency distribution of daily rainfall (mm/day) in AMZ.

Intense events (above 12 mm/day) are simulated only by Emanuel and KF schemes

Daily rainfall: LPB

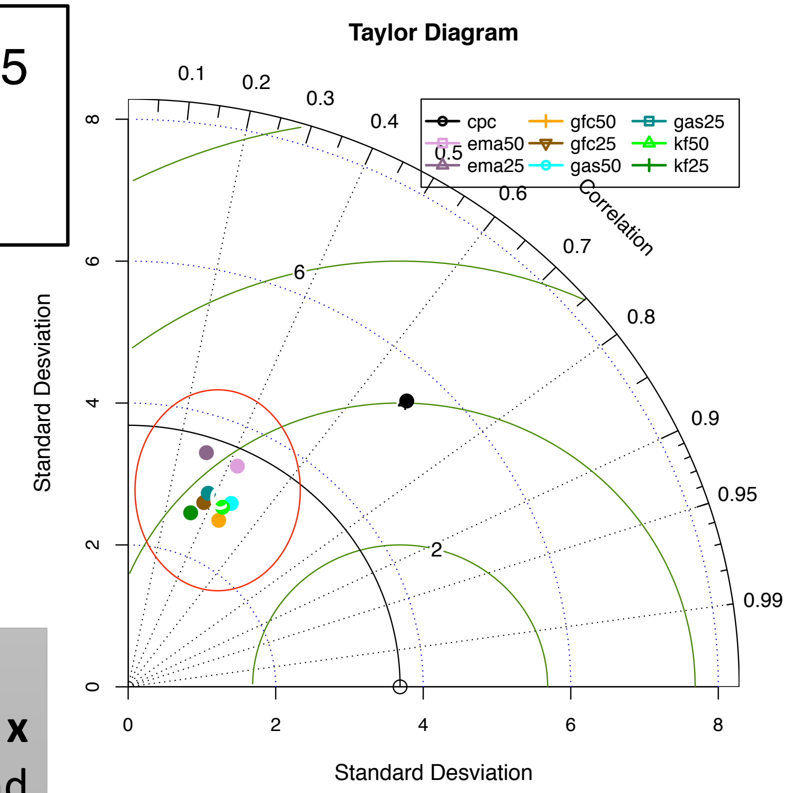




Frequency distribution of daily rainfall (mm/day) in LPB.

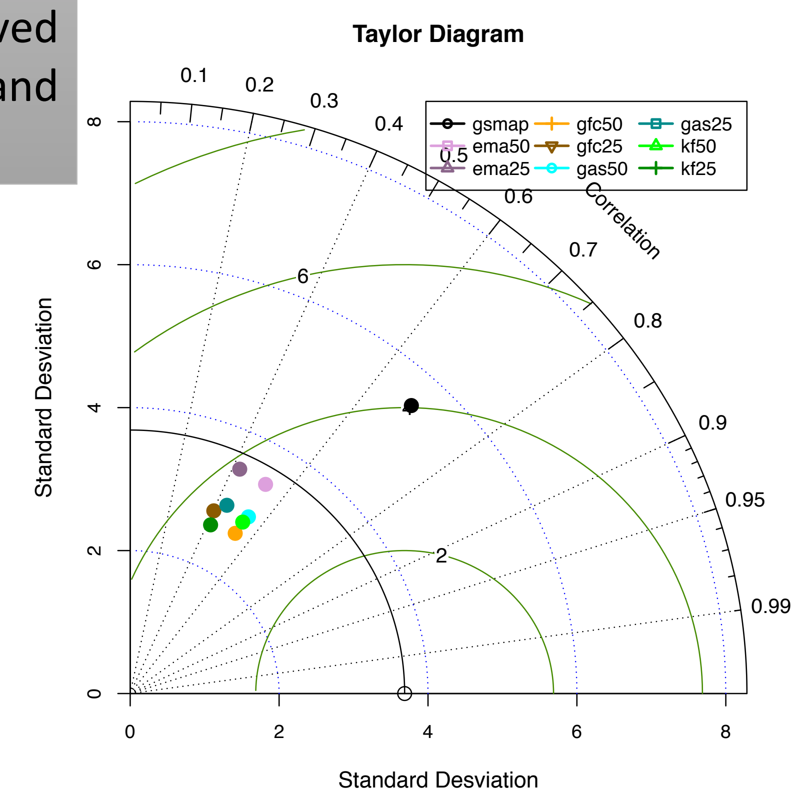
KF25 and KF50 simulate more events of weak precipitation and less of intermediate values (4-8 mm/day)
Intense events (above 12 mm/day) are less frequent in simulation than in observations.

CPC x simulations



Taylor Diagrams
Time correlation between observations x simulations: is similar in all simulations and between ~0.3-0.4 to CPC and ~0.4-06 to GsMap.
Standard deviation: is similar to the observed in the Emanuel scheme (~ 4 mm/day) and smaller in other schemes (~3 mm/day).

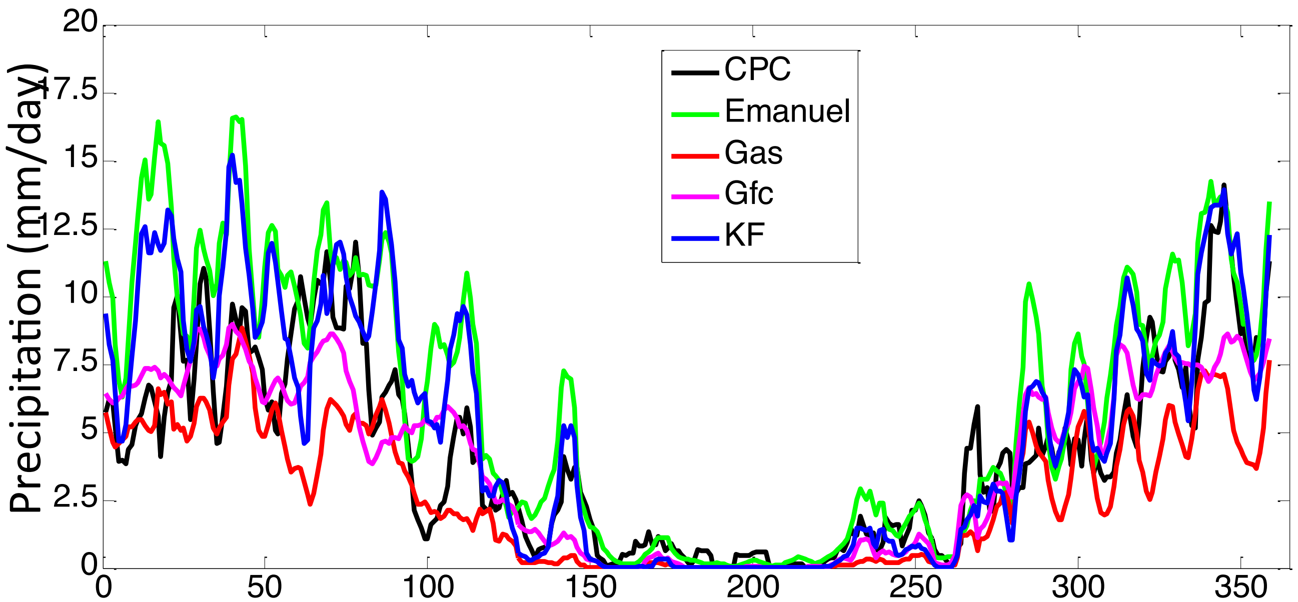
GsMaP x simulations



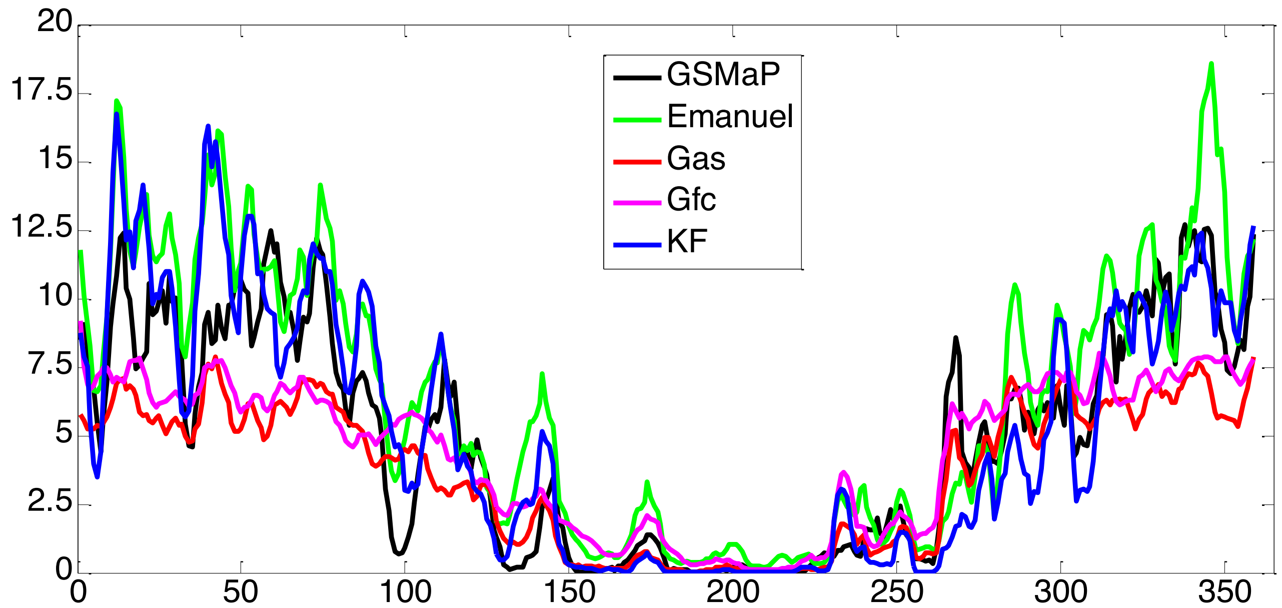
5 days running mean rainfall (mm/day): AMZ

Observation – black line

G50



G20



AMZ – wet (October – April) and dry (May-September) seasons realistically captured by all parameterizations

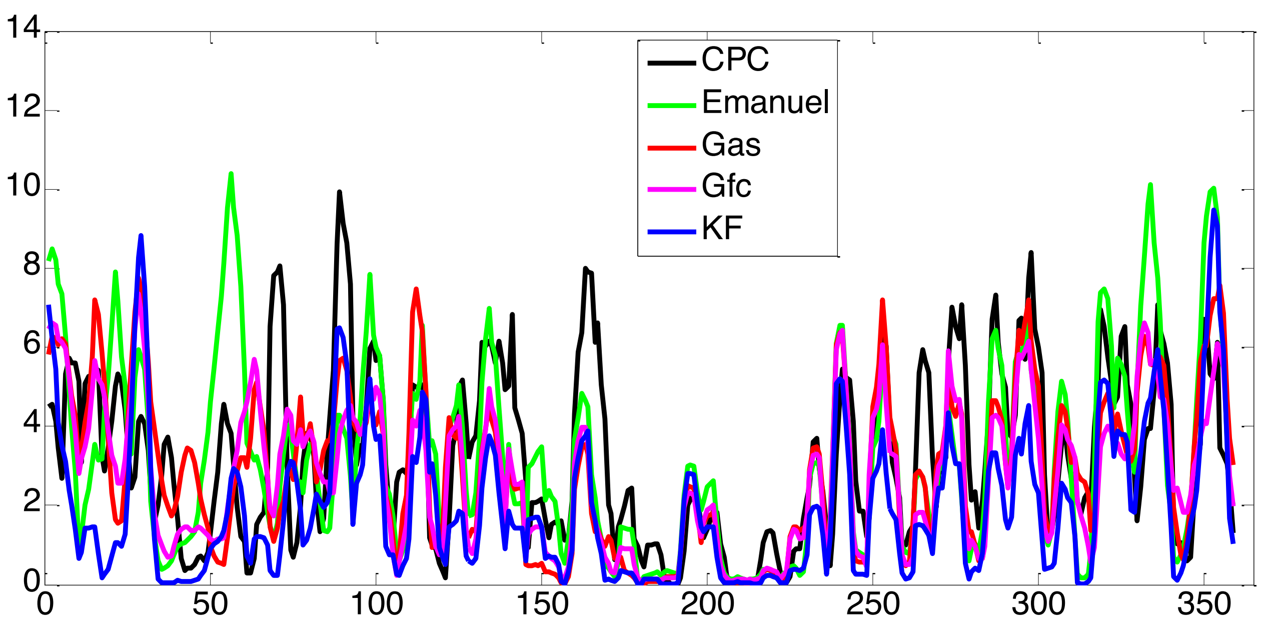
Emanuel (green) and KF (blue) have similar behavior during events with large rainfall rate
Time correlation = 0.86 (CPC x G50) and **0.92 – 0.90 (GSMap x G25)**

Gfc and Gas – are similar and they have difficult to simulate extreme events (both G50 and G25)
time correlation =0.86 (CPC and G50) **and 0.88 -0.91 (GSMap x G25)**

5 days running mean rainfall (mm/day): LPB

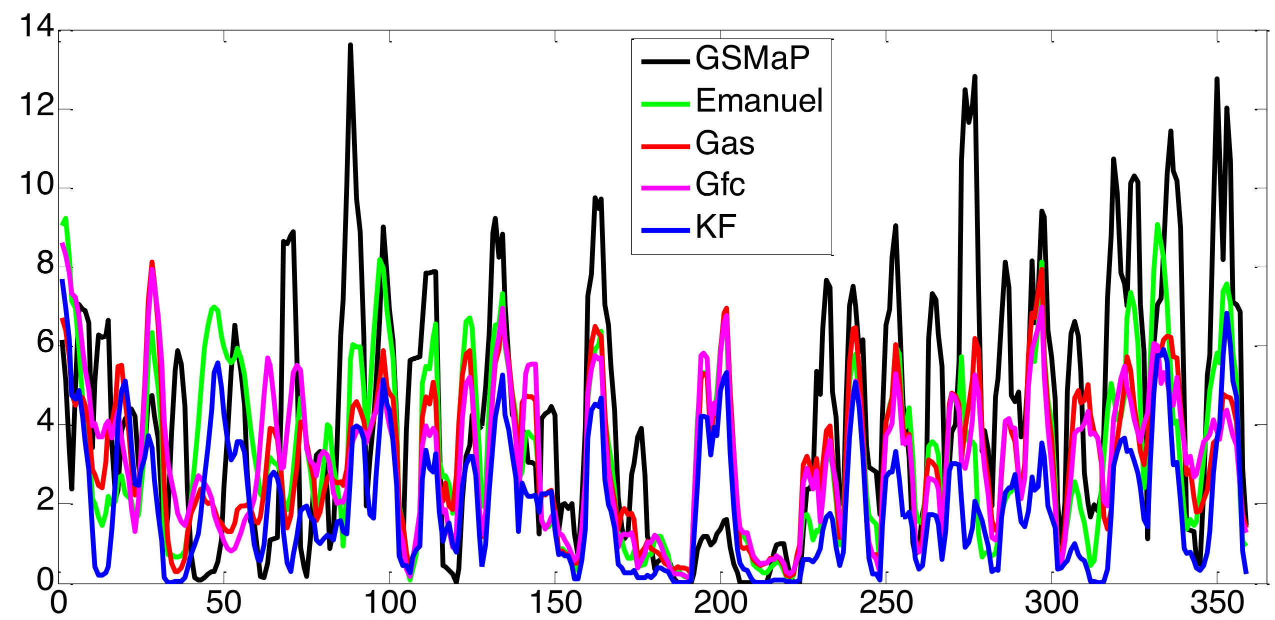
Observation – black line

G50



January July December

G25



January July December

LPB – rainfall is more or less well distributed along the year and the parameterizations captures this features

GSMap has more intense events than CPC

Ema → simulates intense rainfall

Gfc and Gas → have similar behavior

KF → larger difficult to simulate intense events

Time correlation is smaller in LPB than in AMZ: from minimum 0.45 (KF25) to maximum 0.59 (Gas and Gfc)

Conclusions

Fine horizontal resolution helps to improve the simulated **rainfall** intensity and spatial pattern by:

- **Emanuel**: decreasing the intensity of rainfall in most part of tropical SA and increasing it over southeastern SA (LPB) → biases decrease
- KF: has a behavior similar to Emanuel, but with small differences of intensity (from G25 to G250)
- **Gas and Gfc**: increase rainfall intensity in most part of SA.
- **Except in Gas** → more realistic simulation of rainfall in G25 **is followed by the decrease (increase) of convective (grid scale) rainfall in most part of domain**. Emanuel: stronger decrease of convective rainfall in wet periods over Amazon (!!!);

- High frequency variability of rainfall is better reproduced by all schemes over AMZ (correlation > 0.88 for 5 days running mean) than over LPB

Air temperature: regional biases are relatively small;
all simulations indicate a decrease of air temperature in G25, but this does not implicate in large biases (KF → reduces the warm bias)

Next

- Results with Emanuel (and KF) scheme at G25 are encouraging. We know that CLM+Emanuel help to reduce the excessive rainfall of Emanuel+BATS over tropical SA → new simulations in G25changing from BATS to CLM4.5;

- We need to look in more details the simulations near the Andes Mountain (appropriated observed dataset);

- To try reproduce these results in the new RegCM4 version (Graziano is producing a new one now);

- Thank you!
- Obrigada!