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Climate change impact on precipitation for the Amazon and La Plata basins

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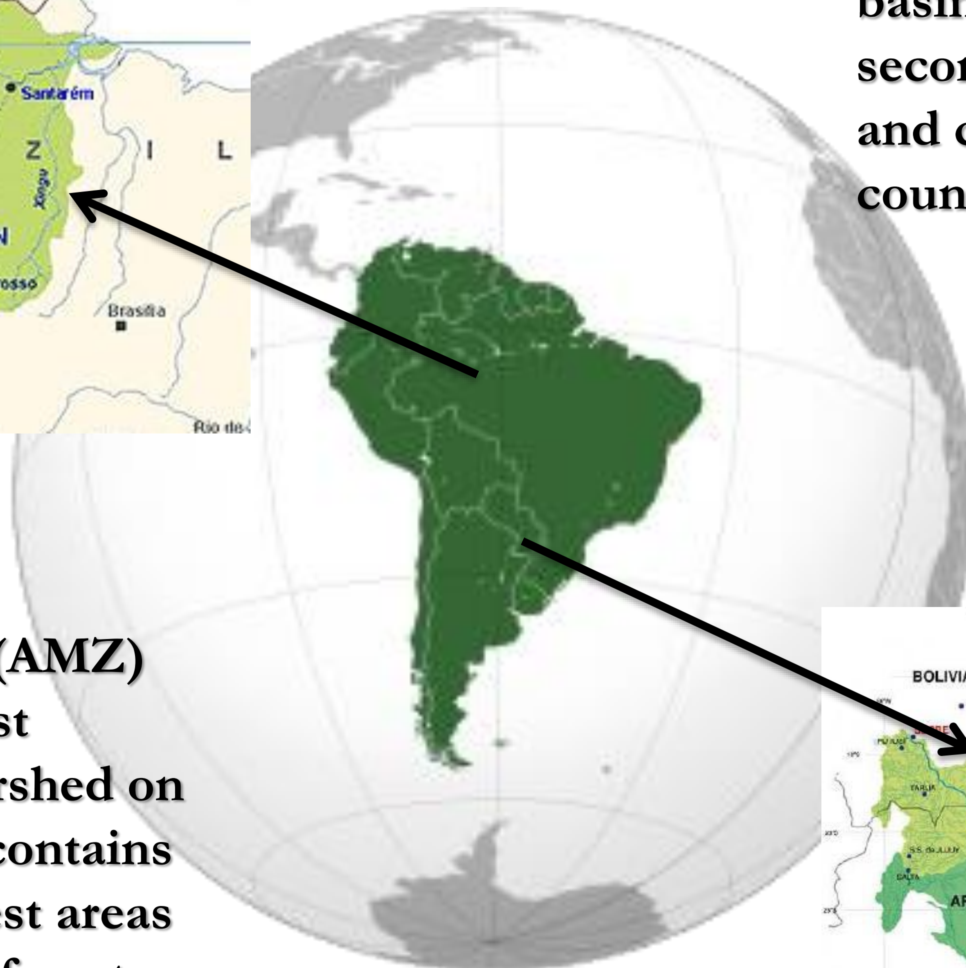
Embrapa Clima Temperado

- **La Plata Basin (LPB) is the fifth most extend basin in the world, the second largest in SA, and covers parts of five countries**



- **Amazon Basin (AMZ) is on of the most important watershed on the planet and contains one of the largest areas of tropical rain forests on Earth (Foley et al. 2002)**

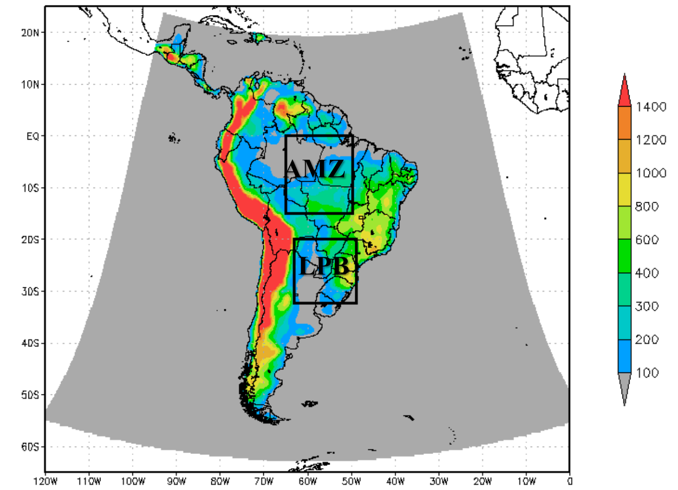
Objectives

- To generate **climate projections** with RegCM4 over CORDEX South America domain, using CMIP5 GCMs as boundary conditions (the CREMA ensemble, Giorgi 2014);

- Analyze the change in precipitation projected by the end of the century over SA, focusing on the **AMZ** and **LPB** basins in our CREMA-mini ensemble;

- Separate the contribution of local **soil-atmosphere feedbacks** from remote **SST influences** in the precipitation change signal over AMZ and LPB basins.

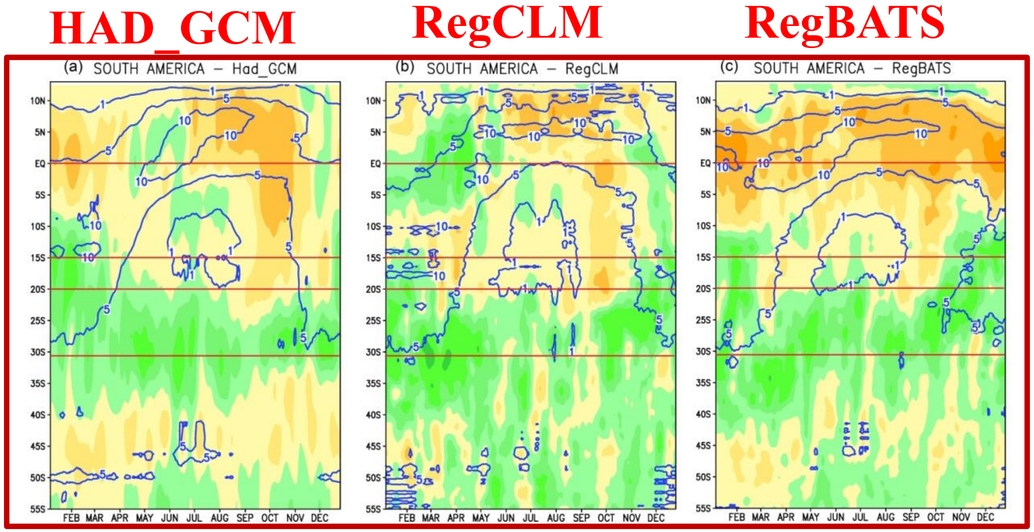
Experiments set-up

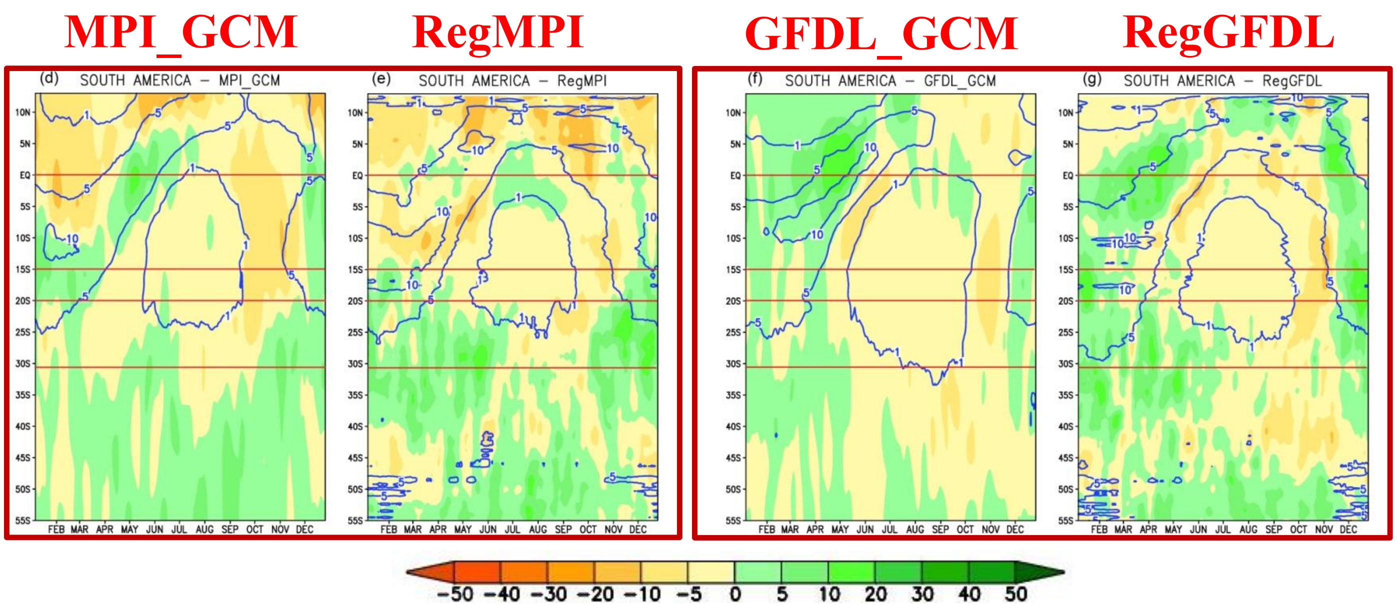


- CORDEX domain specifications (Giorgi et al., 2009)
- Simulation period: 1970-2100 (RCP8.5)
- Four RegCM4 simulations (two RegCM4 configurations)
- Three GCMs (HadGEM2-ES; MPI-ESMMR; GFDL-ESM)
- CRU (reference period) / Far future minus reference period to assess the prec change signal

Experiments Acronyms	Drive Model (GCM)	Land Surface Scheme	Cumulus Convection Scheme	Reference Period	Far Future Period
RegBATS	Had_GCM	BATS	Emanuel over ocean; Grell over land	1976-2005	2070-2099
RegCLM	Had_GCM	CLM3.5	Emanuel	1976-2005	2070-2099
RegGFDL	GFDL_GCM	CLM3.5	Emanuel	1976-2005	2070-2099
RegMPI	MPI_GCM	CLM3.5	Emanuel	1976-2005	2070-2099

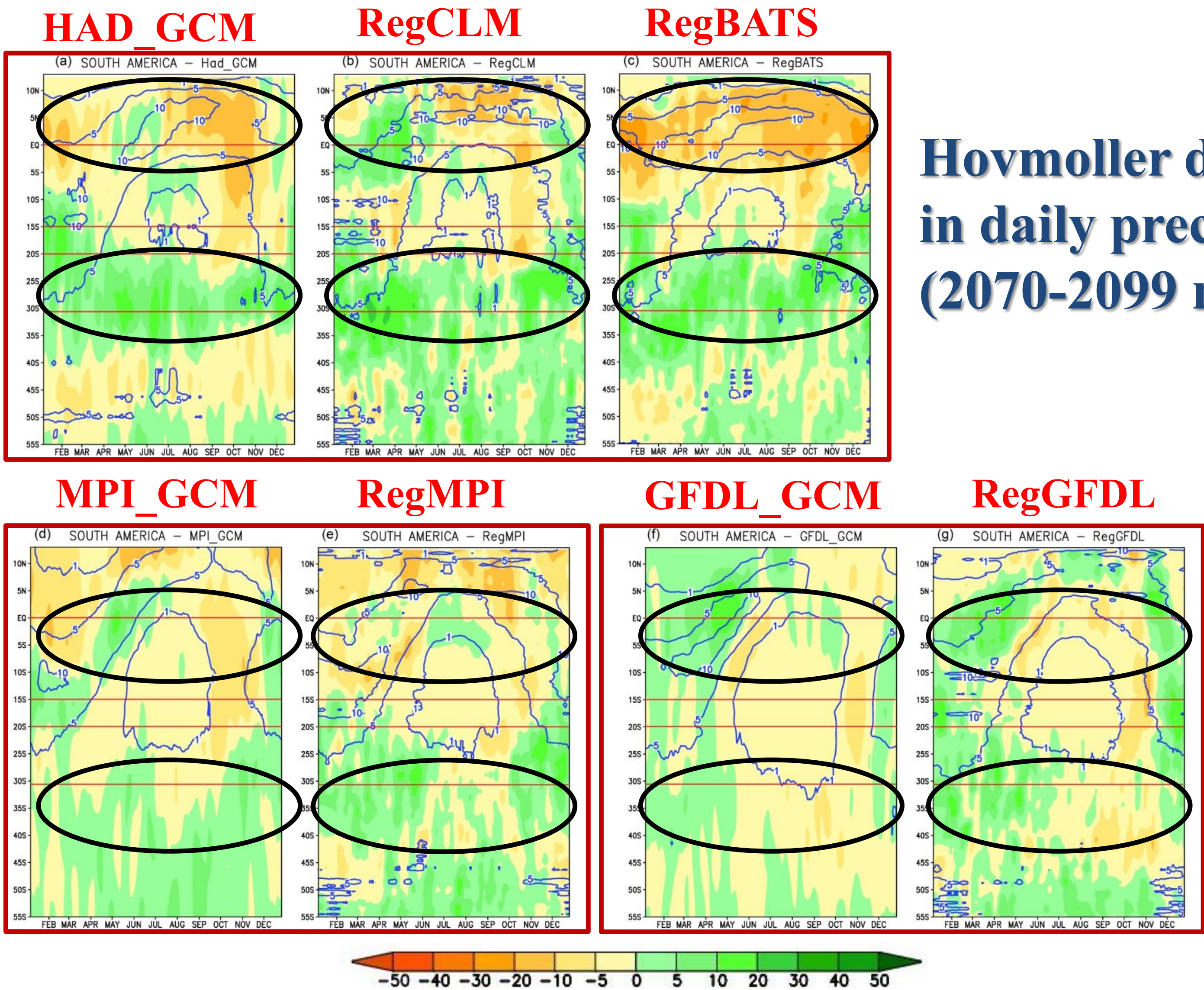
Hovmoller diagram of change in daily precipitation (%) – (2070-2099 minus 1976-2005)





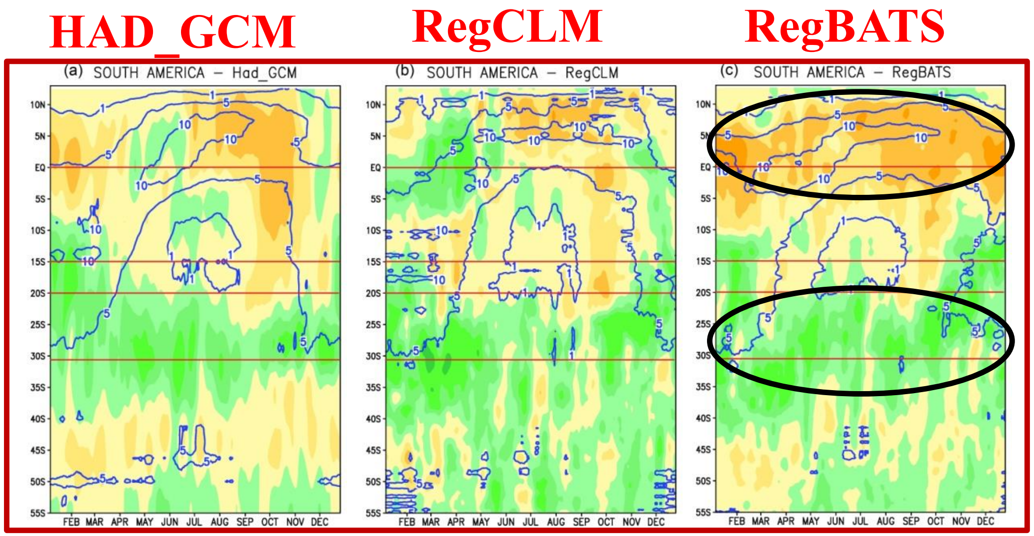
- The contour lines illustrate the evolution of the continental convection associated with the retreat and expansion of the South American Monsoon (SAM) system (Vera et al. 2006).

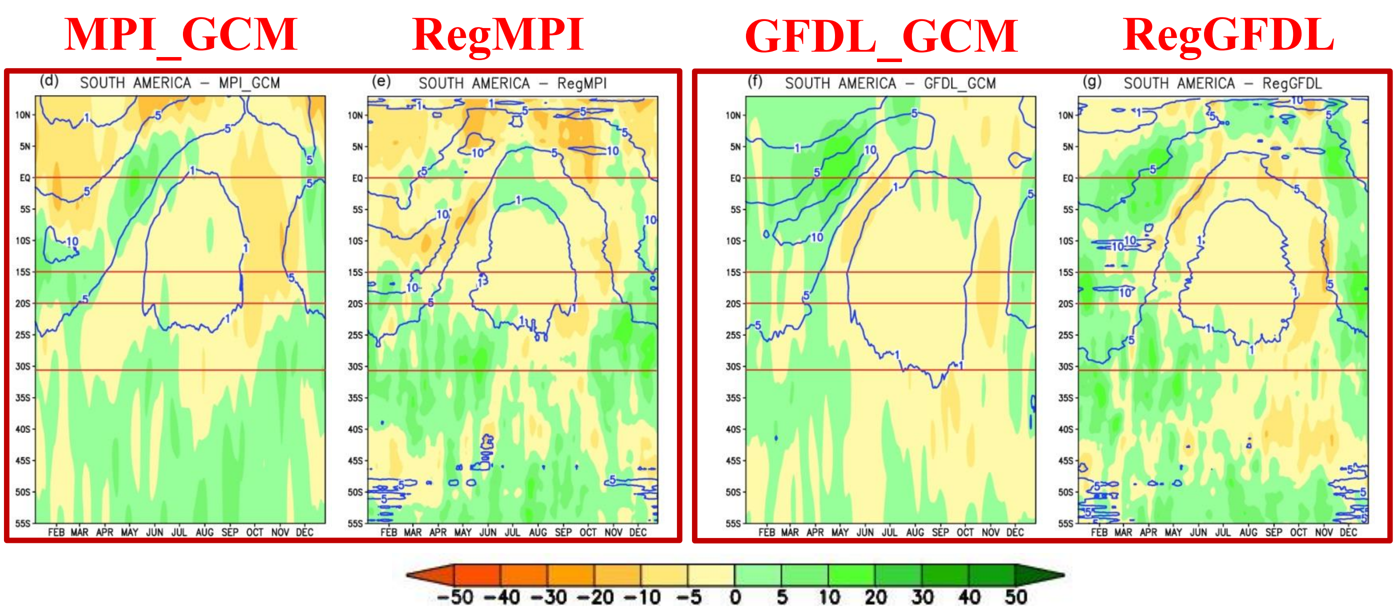
Hovmoller diagram of change in daily precipitation (%) – (2070-2099 minus 1976-2005)



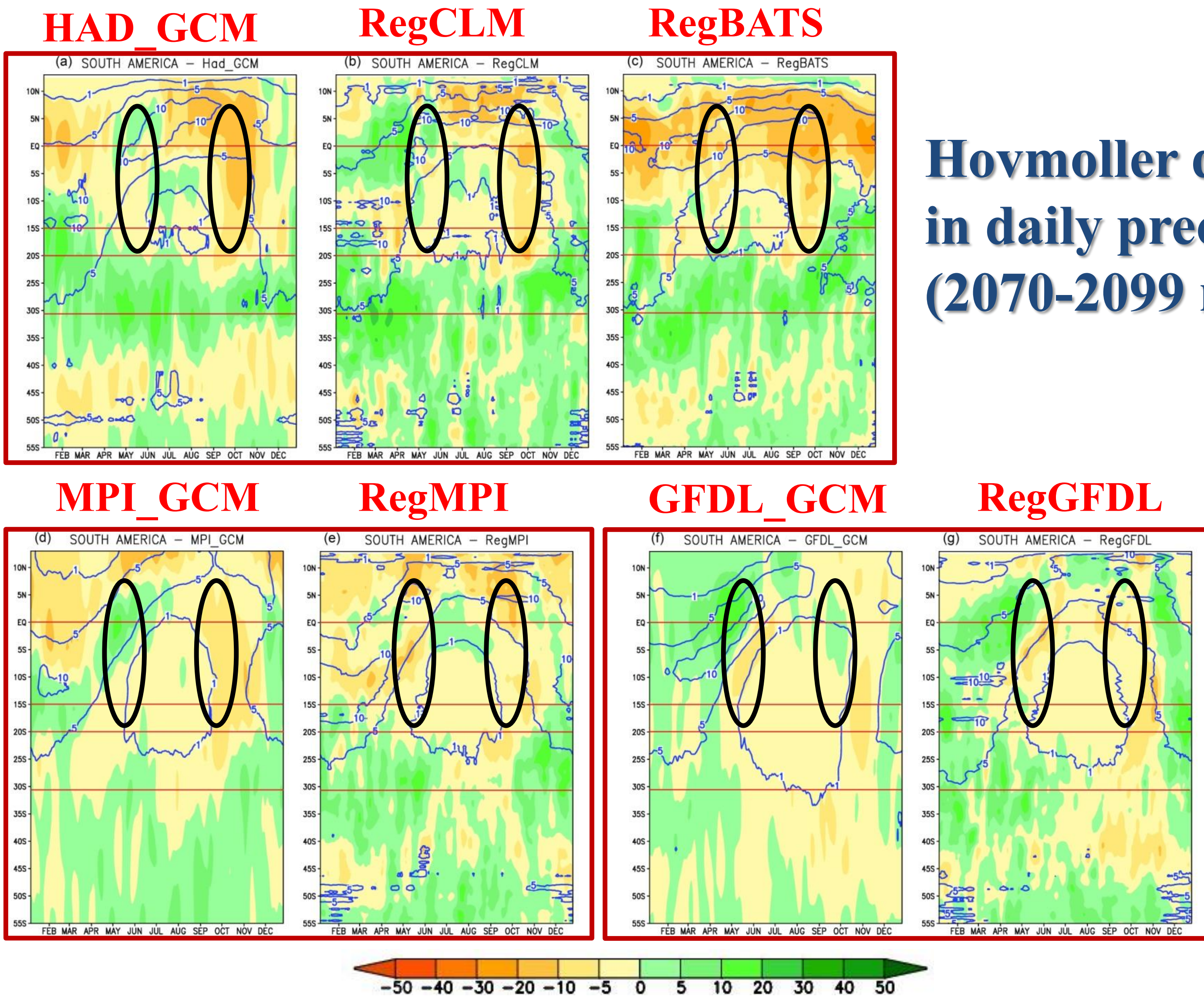
• These simulations exhibit a dipole precipitation change pattern with negative values north of 5^0S and positive values in the belt between 20^0S and 35^0S

Hovmoller diagram of change in daily precipitation (%) – (2070-2099 minus 1976-2005)



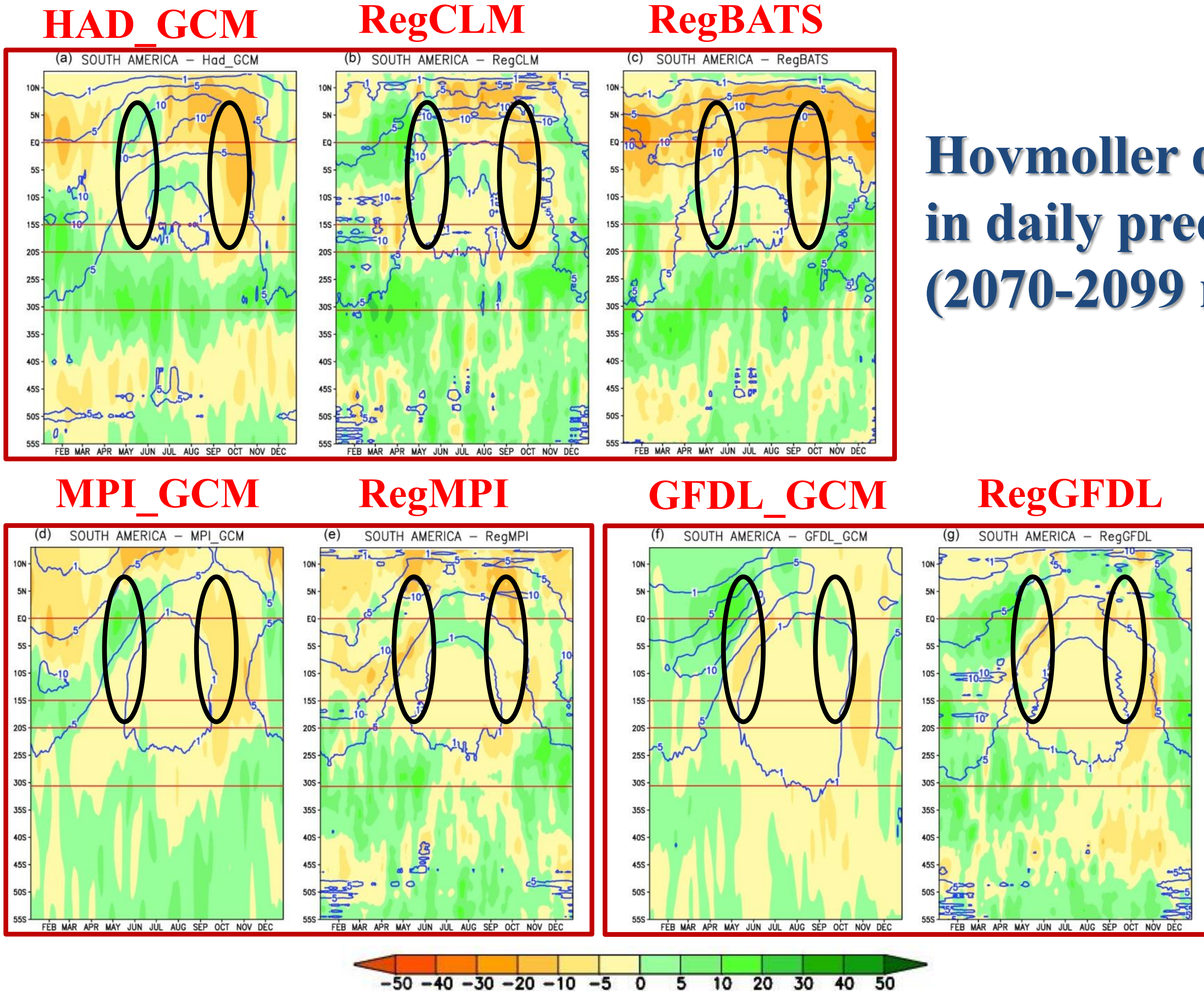


- This dipole pattern is especially evident in the RegBATS experiment



Hovmoller diagram of change in daily precipitation (%) – (2070-2099 minus 1976-2005)

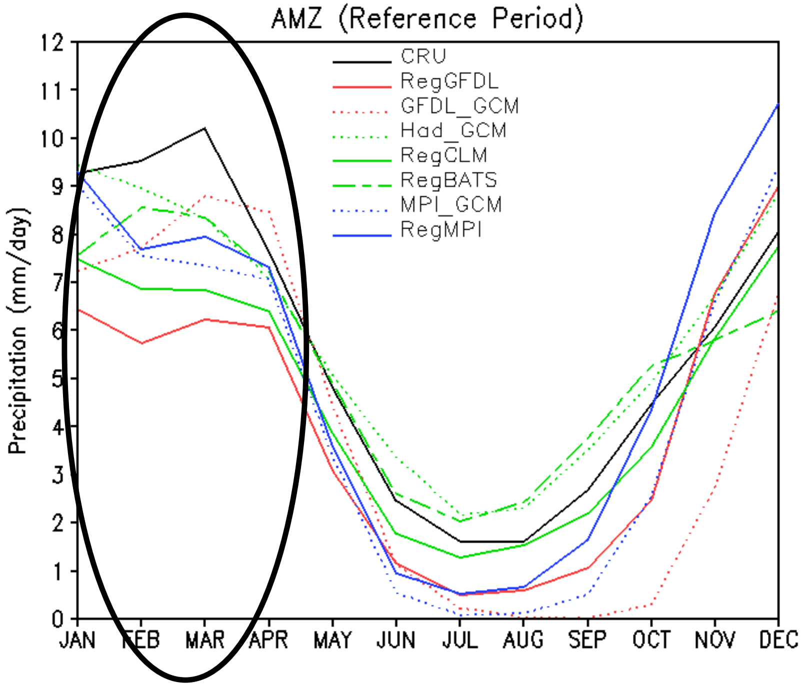
- Negative precipitation change in May-June during the northward migration of the monsoon and in Sep-Oct during its southward retreat, with positive changes earlier in the year during the monsoon northward shift and later during its southward retreat;

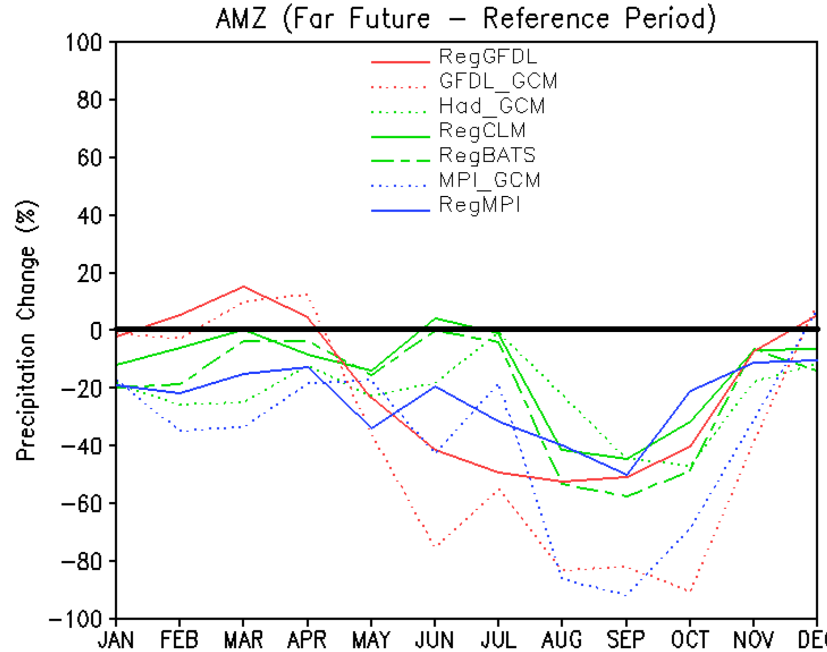


Hovmoller diagram of change in daily precipitation (%) – (2070-2099 minus 1976-2005)

• This suggests a longer dry season in the regions between 20^0S and 5^0N, with a late monsoon onset, and early monsoon retreat and an intensification of the wet season during the mature monsoon phase.

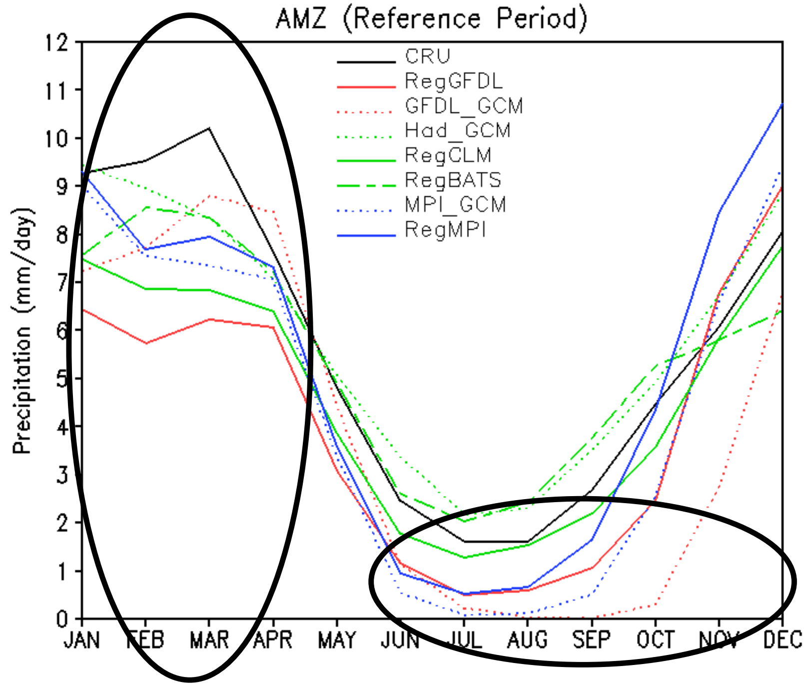
Annual cycle of observed and simulated precipitation averaged over the AMZ region in the reference period along with the corresponding late 21st century change.

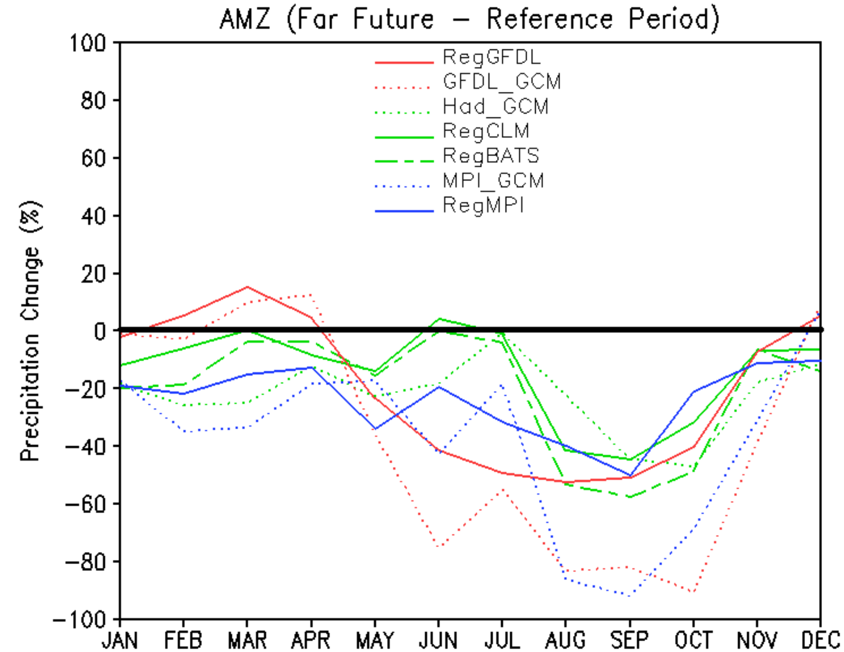




Precipitation is underestimated by all models in jan-mar (during the peak monsoon phase)

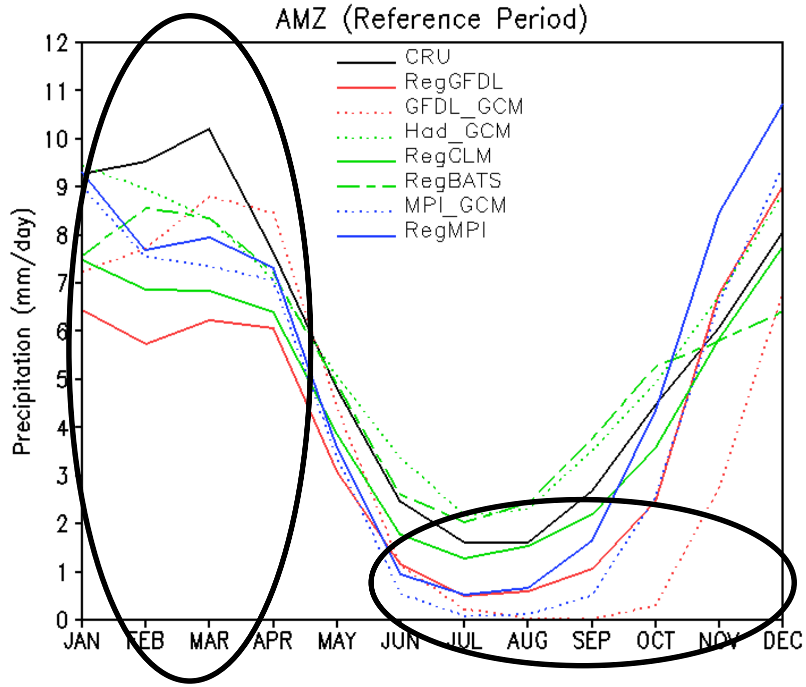
Annual cycle of observed and simulated precipitation averaged over the AMZ region in the reference period along with the corresponding late 21st century change.

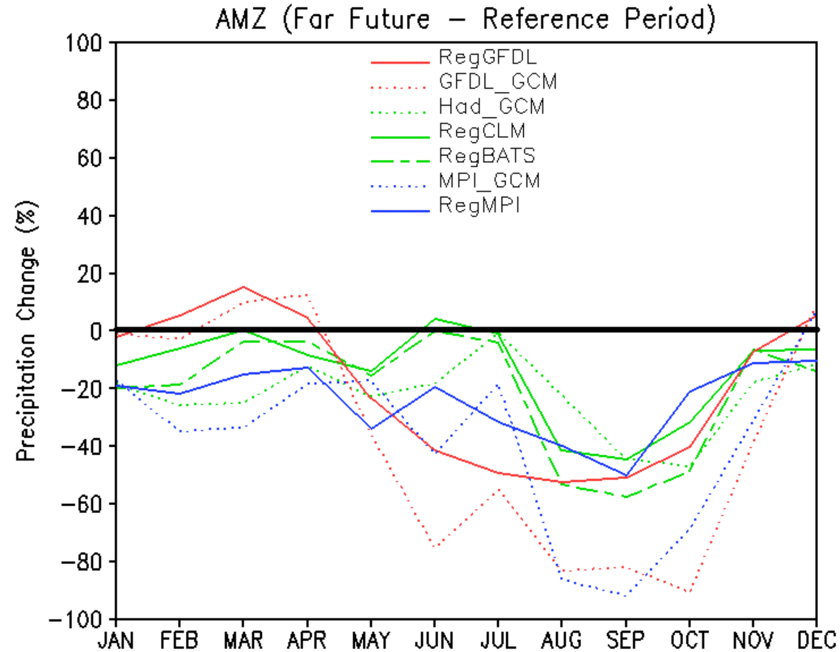




A systematic bias is the underestimation during the monsoon onset phase by the GFDL (red dotted line) and MPI (blue dotted line) GCMs

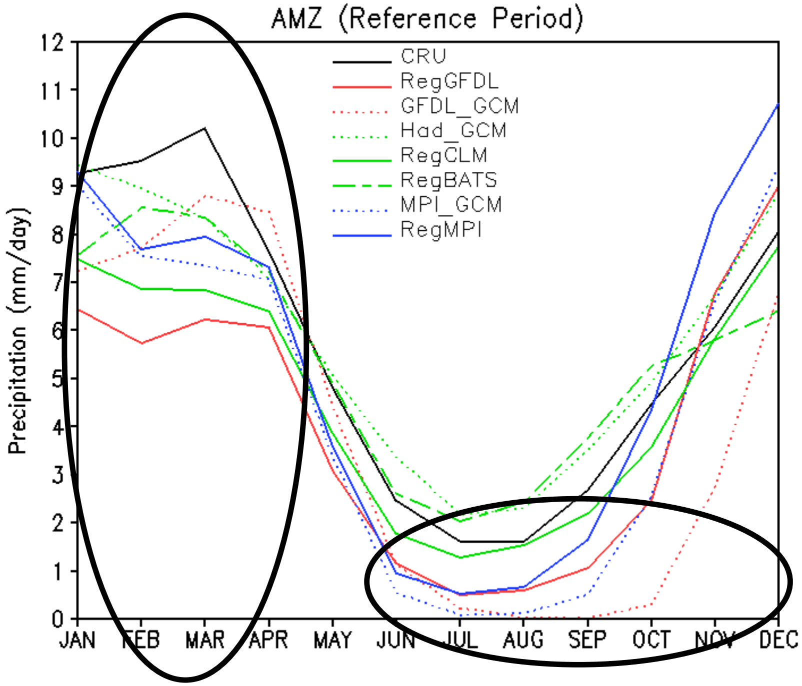
Annual cycle of observed and simulated precipitation averaged over the AMZ region in the reference period along with the corresponding late 21st century change.

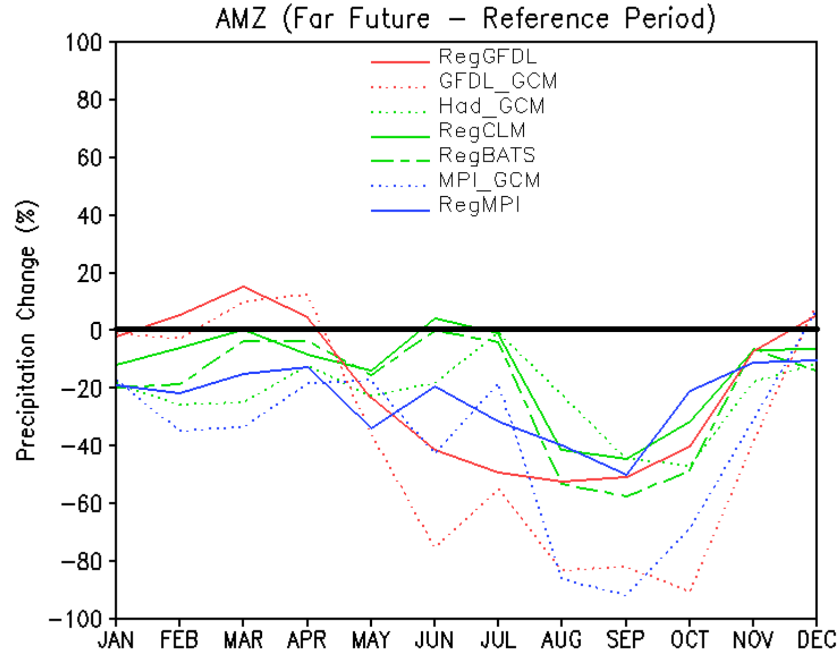




Regional model appears to improve this deficiency in both cases, with much better agreement with observations

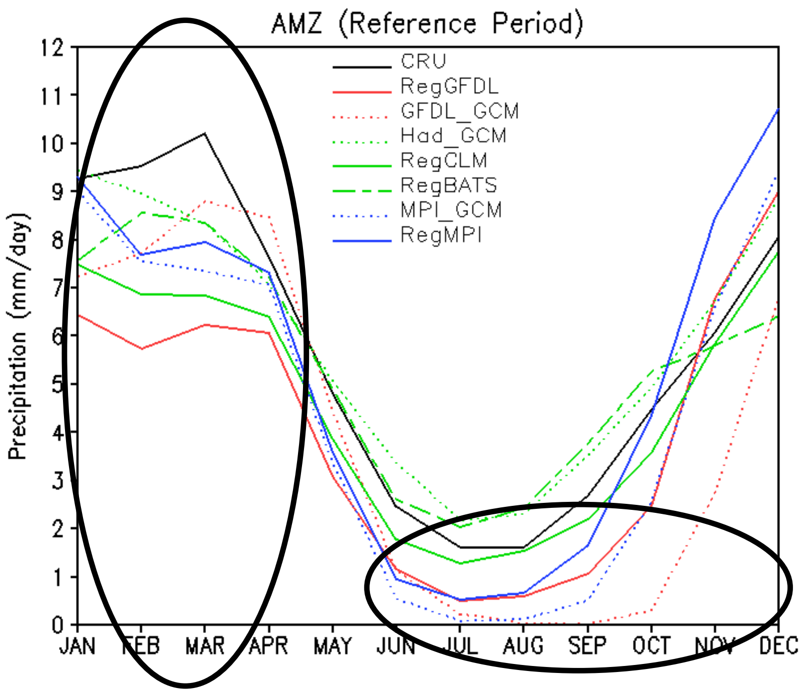
Annual cycle of observed and simulated precipitation averaged over the AMZ region in the reference period along with the corresponding late 21st century change.

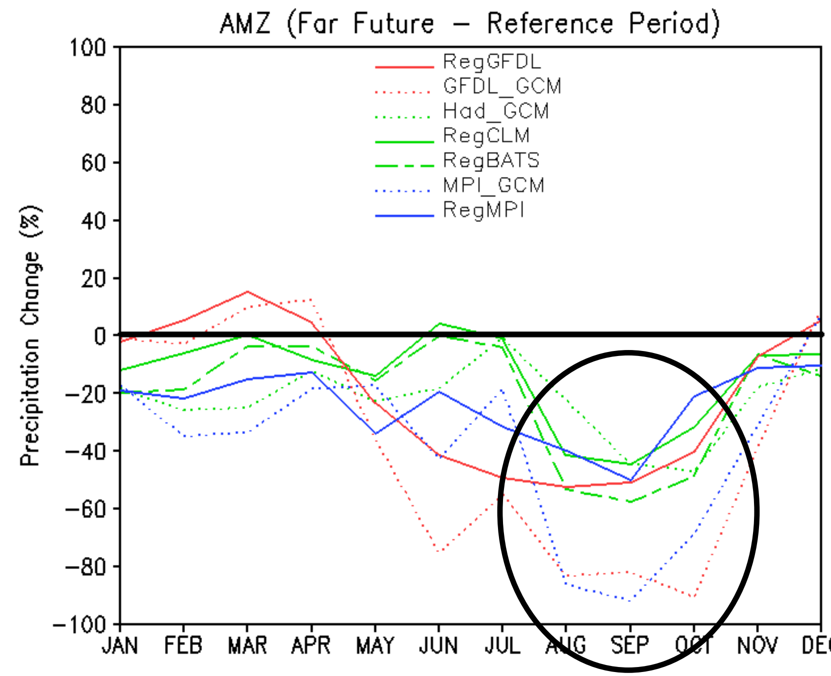




The precipitation change is predominantly negative throughout the year

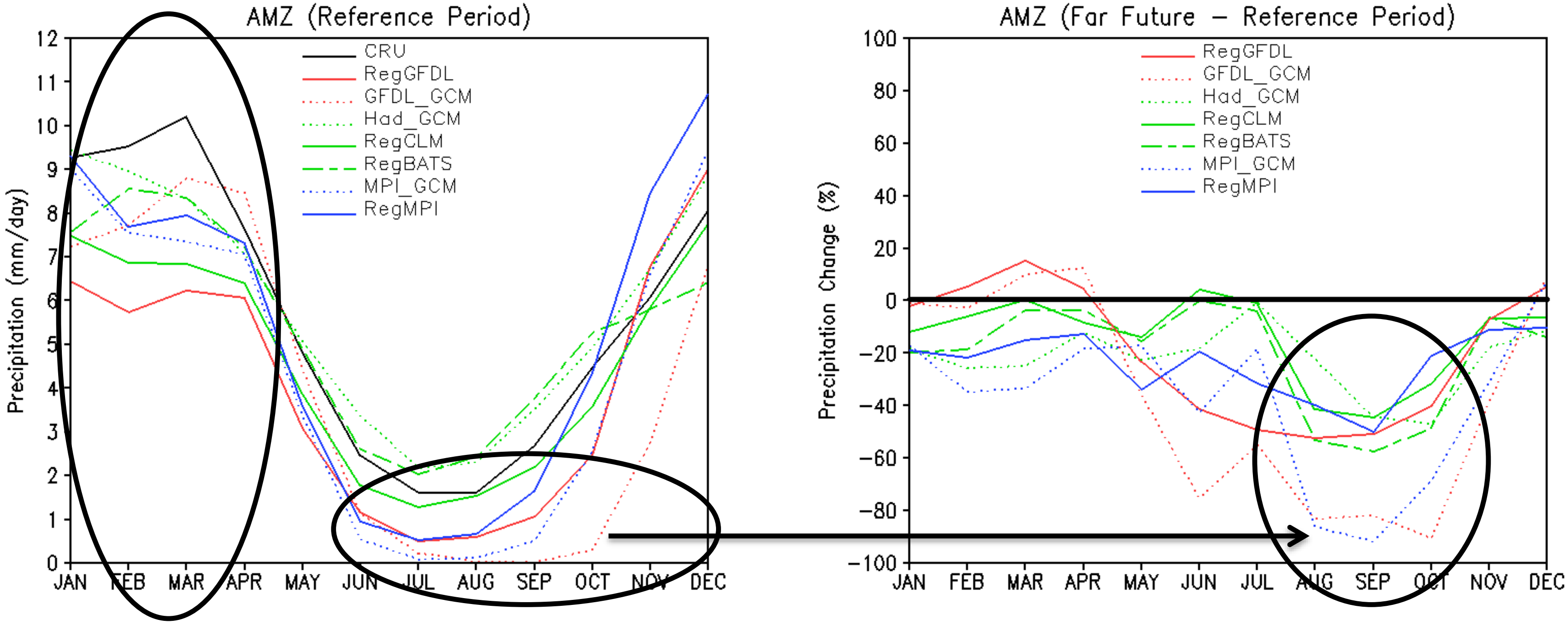
Annual cycle of observed and simulated precipitation averaged over the AMZ region in the reference period along with the corresponding late 21st century change.





It shows a seasonal variation with a maximum decrease during the monsoon onset phase

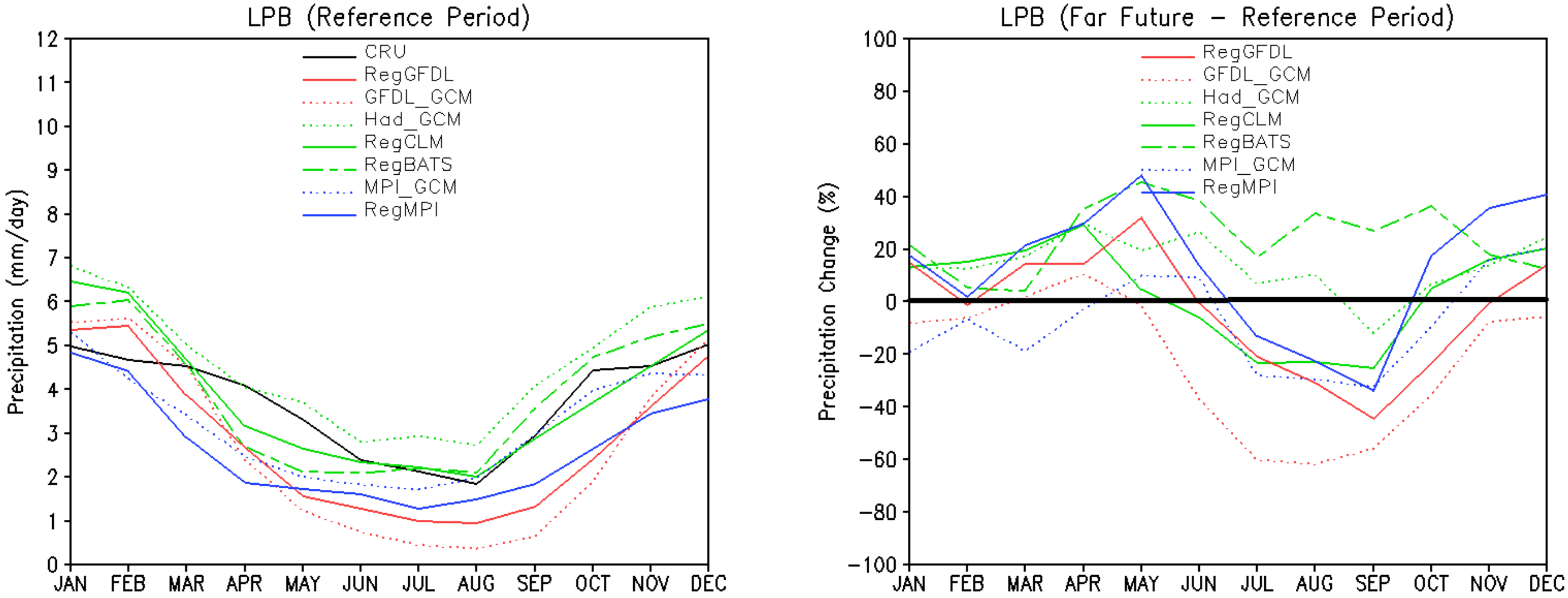
Annual cycle of observed and simulated precipitation averaged over the AMZ region in the reference period along with the corresponding late 21st century change.



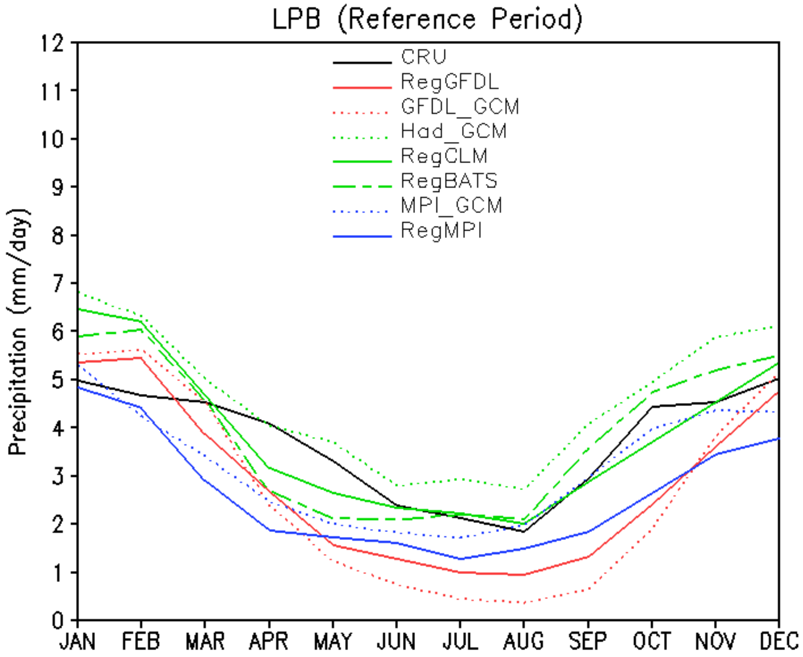
The negative precipitation change is especially pronounced in the MPI and GFDL GCMs,

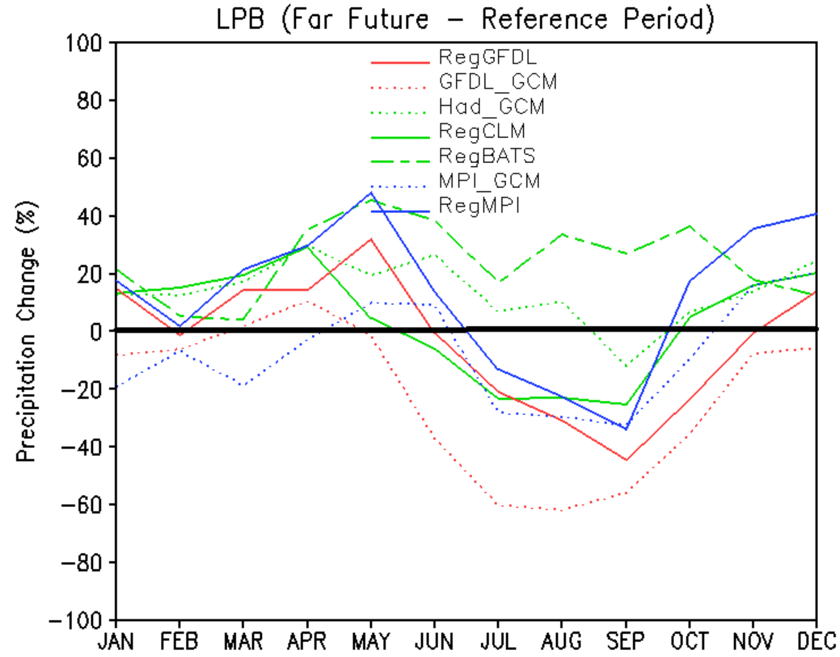
This magnitude of change is unrealistic due to the large precipitation underestimation in these models

Annual cycle of observed and simulated precipitation averaged over the LPB region in the reference period along with the corresponding late 21st century change.



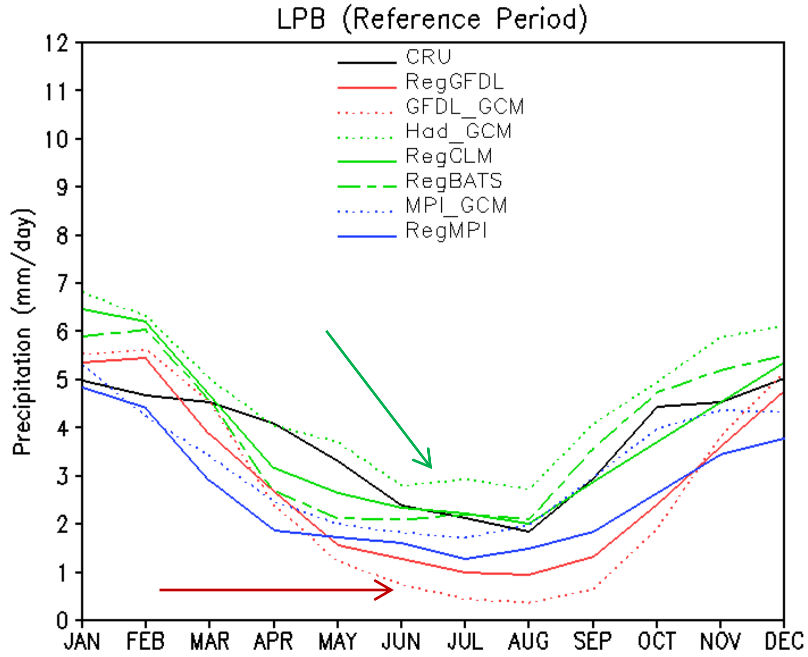
Annual cycle of observed and simulated precipitation averaged over the LPB region in the reference period along with the corresponding late 21st century change.

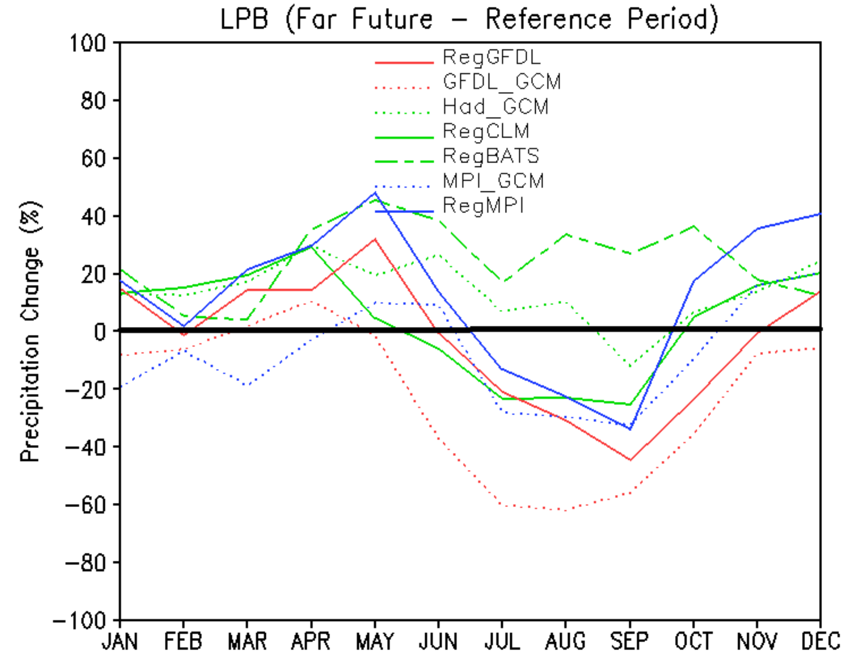




Over the LPB region the annual cycle of precipitation is less pronounced than in the AMZ, a feature captured by all models

Annual cycle of observed and simulated precipitation averaged over the LPB region in the reference period along with the corresponding late 21st century change.

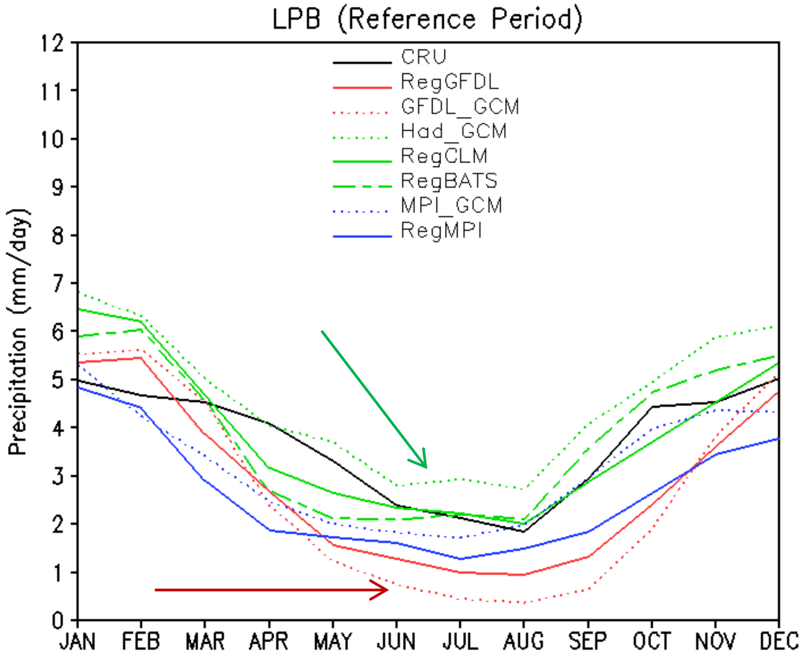


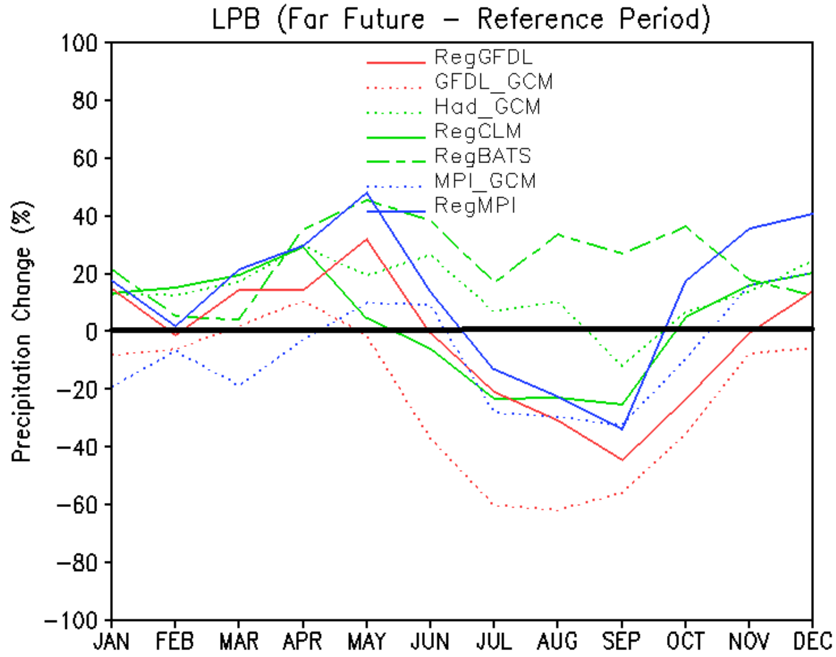


Had_GCM (green dotted line) consistently overestimates precipitation througout the year

GFDL_GCM (red dotted line) consistently underestimates it (except for january and february)

Annual cycle of observed and simulated precipitation averaged over the LPB region in the reference period along with the corresponding late 21st century change.

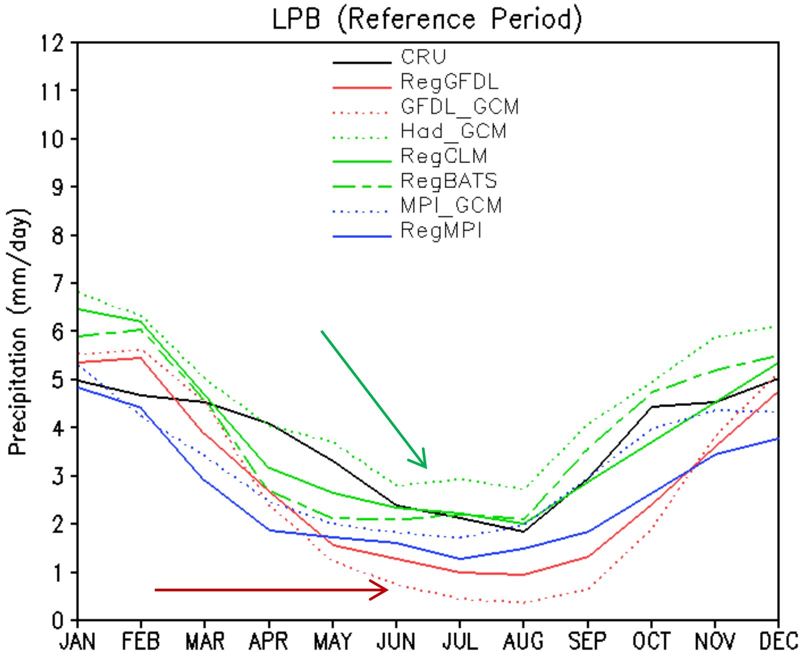


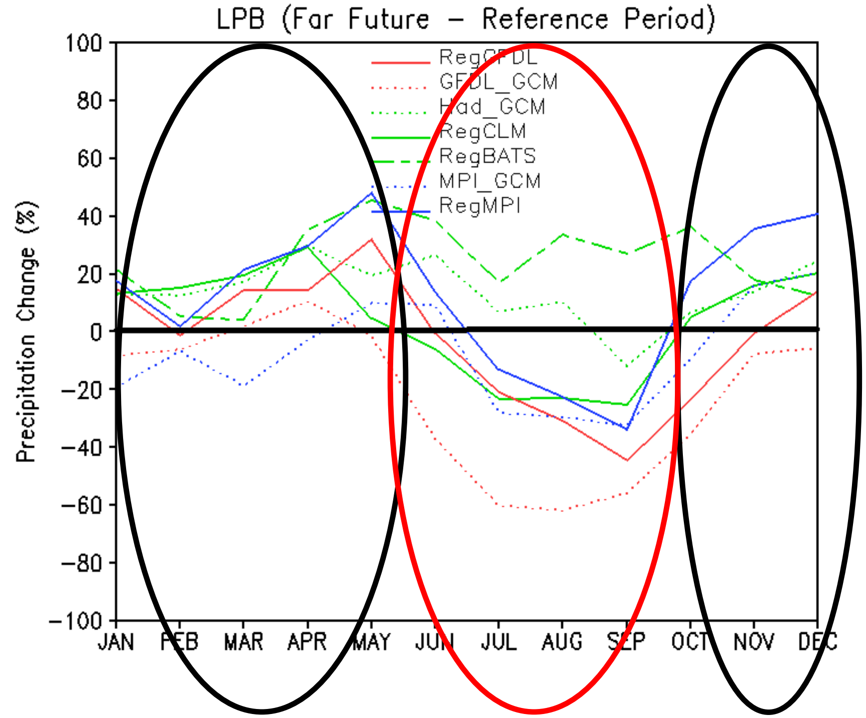


In both cases the regional model simulations improve the agreement with observations.

The RegCM4 ensemble mean appears to essentially capture the observed annual cycle of precipitation

Annual cycle of observed and simulated precipitation averaged over the LPB region in the reference period along with the corresponding late 21st century change.

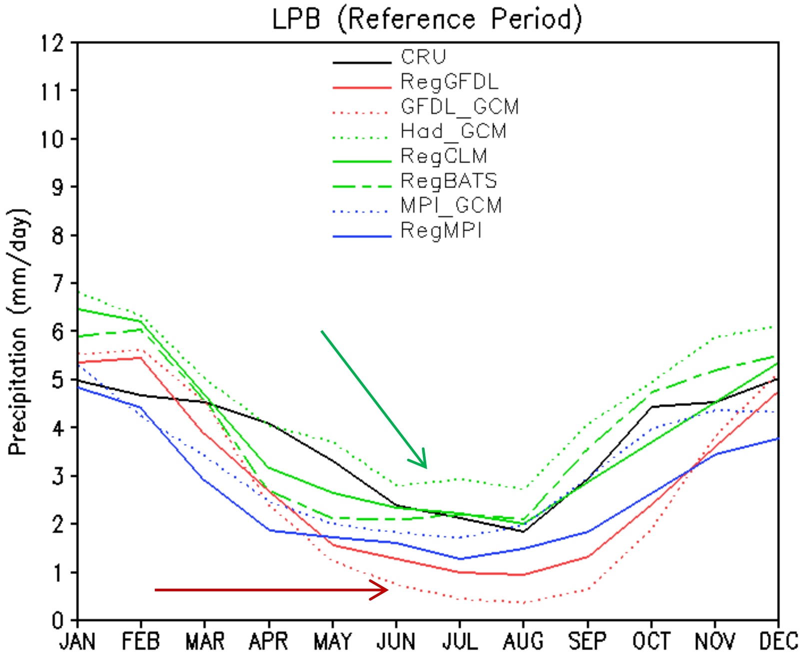


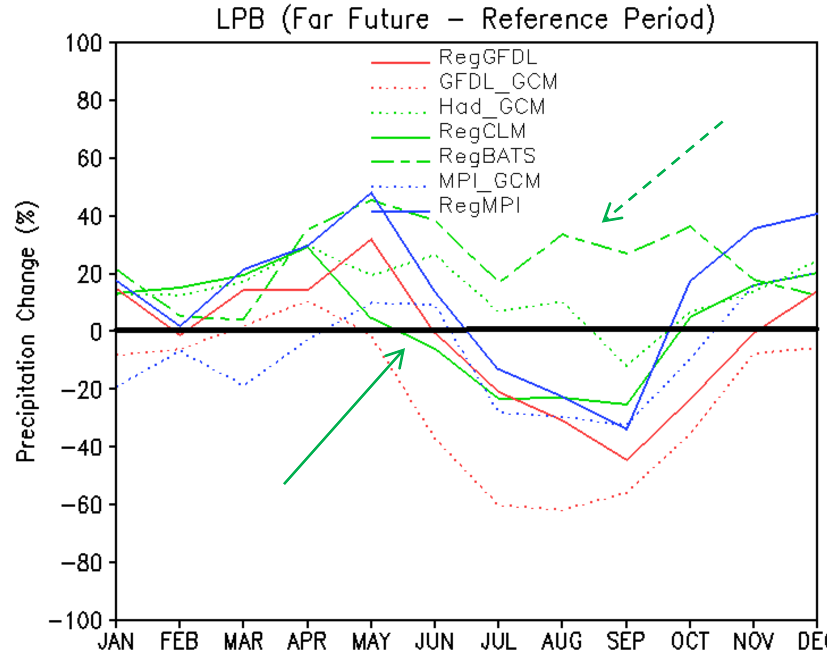


Precipitation increase during the mature and receding monsoon phases

Negative change from July to October

Annual cycle of observed and simulated precipitation averaged over the LPB region in the reference period along with the corresponding late 21st century change.





RegBATS run produces a positive change over the entire year (green dotted line)

RegCLM run has a very different signal (continuous green line)

This indicate the importance of land/convection configurations in the regional model

Parameter λ

- to assess the precipitation variability in both basins connected to SST forcing compared to the effects of soil moisture feedback we calculated the **parameter λ** (Notaro et al. 2008) for soil moisture and SST (Niño3.4)

$$\boxed{\lambda = \frac{\mathrm{cov}(s(t-\tau), a(t))}{\mathrm{cov}(s(t-\tau), s(t))}}$$

s is a slow varying variable (SST or soil moisture)

a is a fast varying atmosphere variable (precipitation)

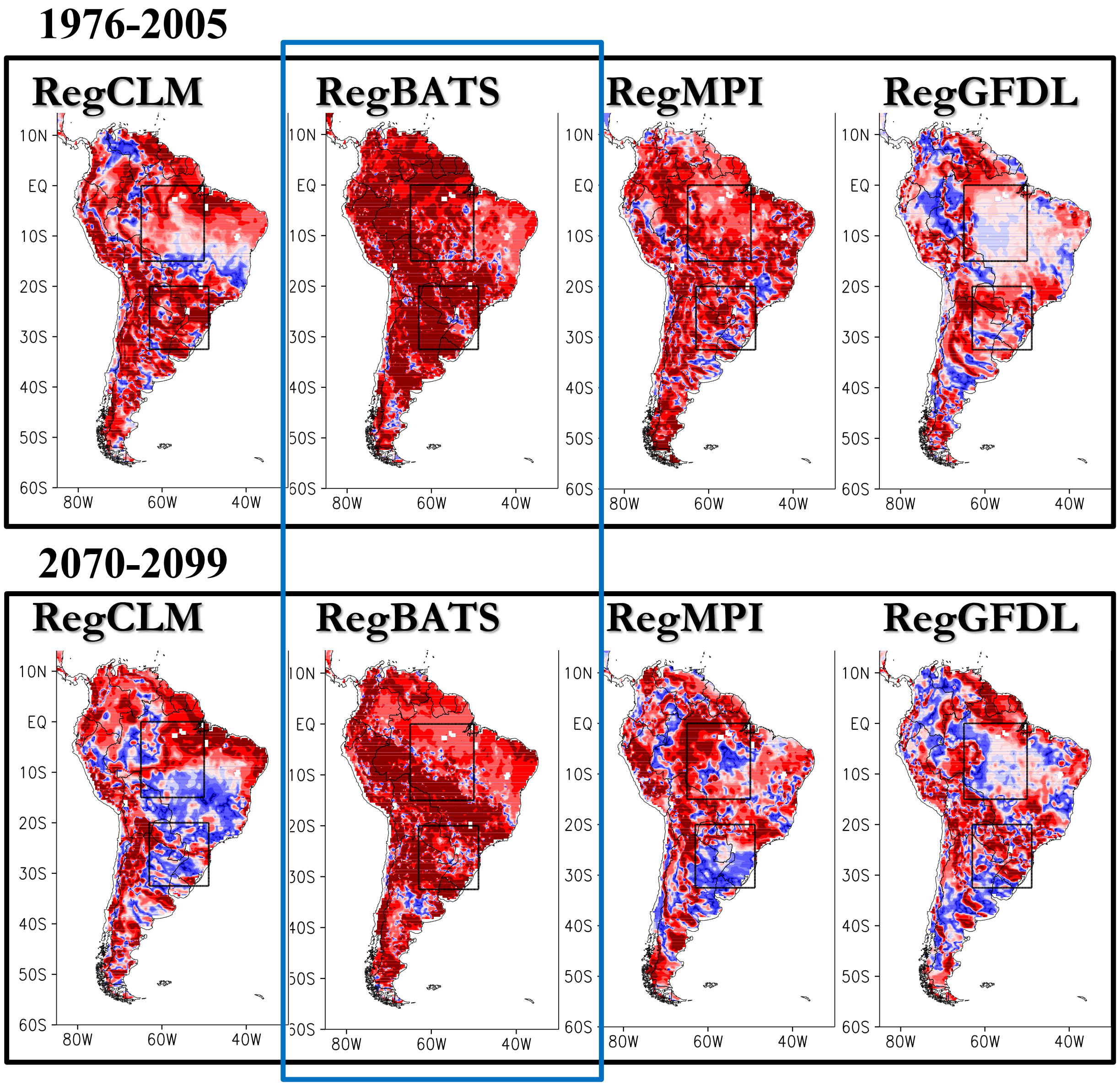
τ is the time lag, chosen here to be 1 month (Seneviratne et al. 2006)

- λ represents the fraction of precipitation signal attributed to variations in monthly local soil moisture ($\lambda_{SM,P}$) or SST ($\lambda_{SST,P}$)

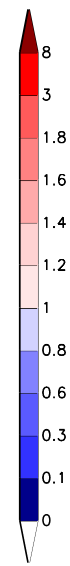
$$\lambda = \frac{\lambda_{SM,P}}{\lambda_{SST,P}}$$

$\lambda > 1$ Soil moisture/precipitation interaction dominates

$\lambda < 1$ SST/precipitation interaction dominates



Fraction of the absolute values of λ between the soil moisture and SST feedback (wet season)

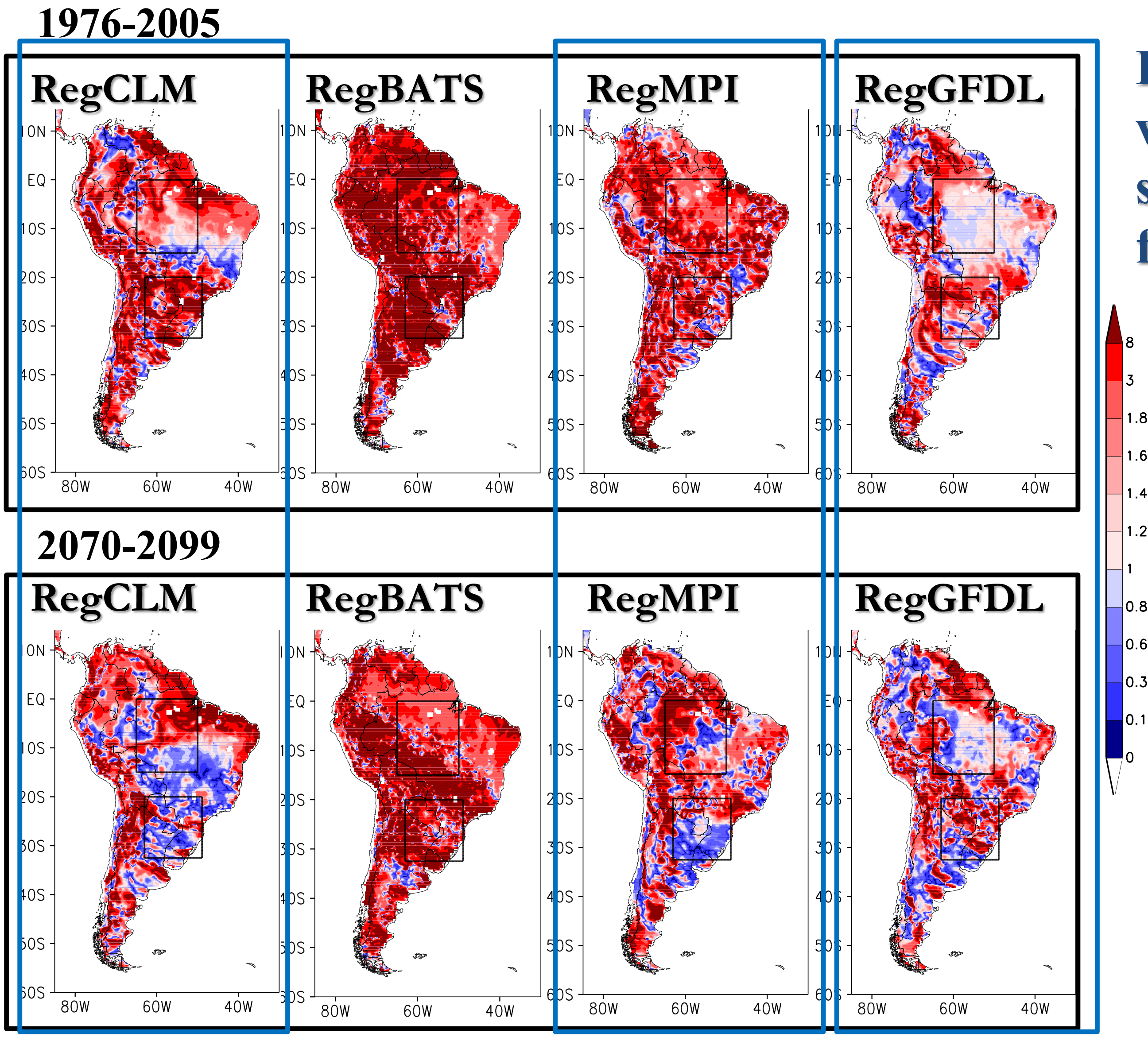


$$\lambda = \frac{\lambda_{SM,P}}{\lambda_{SST,P}}$$

$\lambda > 1$ Soil moisture/precipitation interaction dominates (red color)

$\lambda < 1$ SST/precipitation interaction dominates (blue color)

- Soil moisture contribution is generally dominant (ratio greater than 1) compared to the SST one (Niño3.4)
- RegBATS experiment – Previous experience with the BATS has shown that it is rather sensitive to the atmospheric forcing (e.g. Mariotti et al. 2011)



Fraction of the absolute values of λ between the soil moisture and SST feedback (wet season)

$$\lambda = \frac{\lambda_{SM,P}}{\lambda_{SST,P}}$$

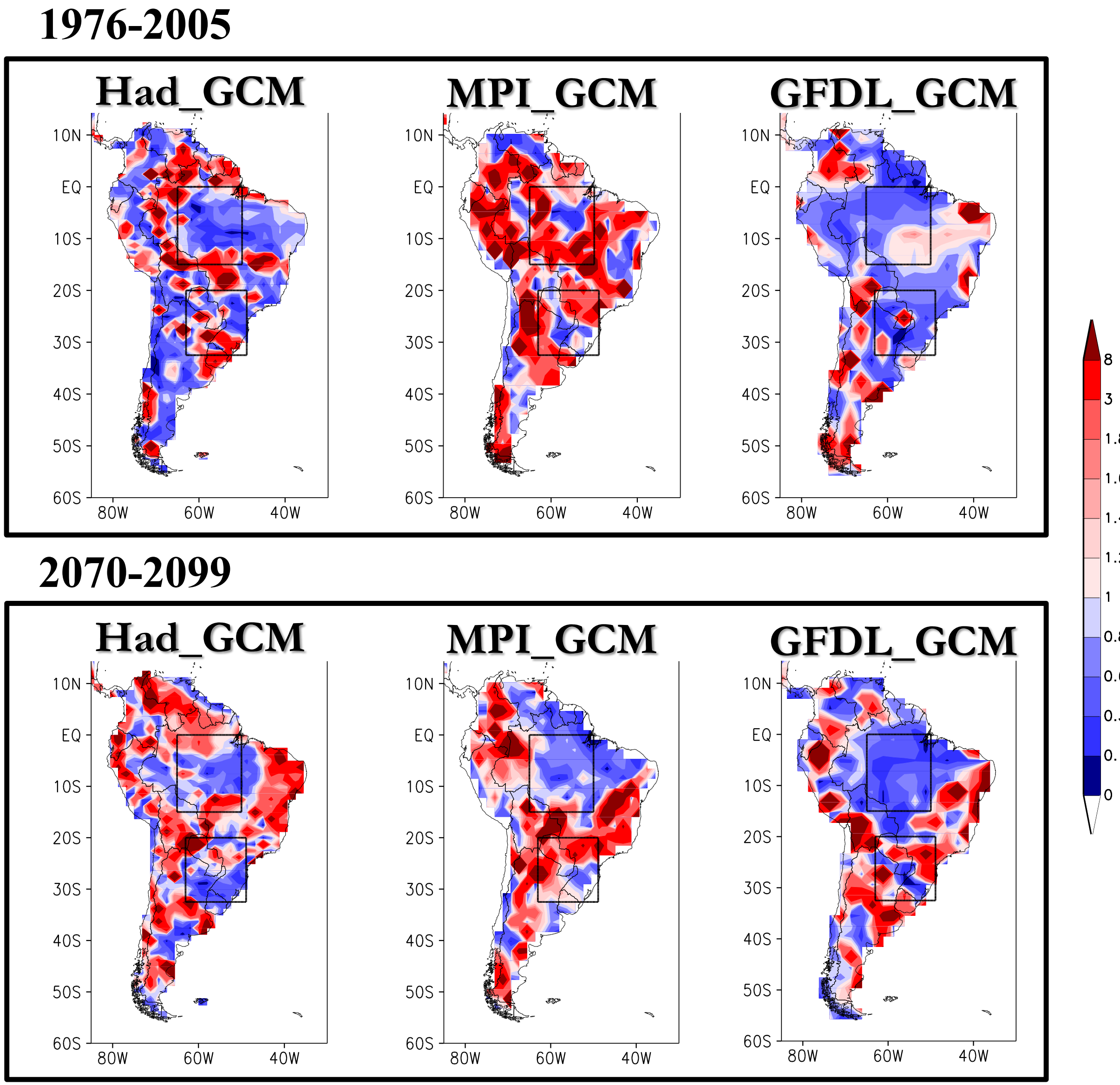
$\lambda > 1$ Soil moisture/precipitation interaction dominates (red color)

$\lambda < 1$ SST/precipitation interaction dominates (blue color)

- In the CLM-Emanuel runs we find a general increase of the SST contribution in the future climate period, particularly over LPB region

- Over the AMZ basin, the SST effect appears to increase in the future period

Fraction of the absolute values of λ between the soil moisture and SST feedback (wet season)



$$\lambda = \frac{\lambda_{SM,P}}{\lambda_{SST,P}}$$

$\lambda > 1$ Soil moisture/precipitation interaction dominates (red color)

$\lambda < 1$ SST/precipitation interaction dominates (blue color)

• Larger SST contribution compared to the soil moisture one. This is particularly the case over the AMZ basin, where this contribution dominates, especially in the Had_GCM and GFDL_GCM and increases in the future in the MPI_GCM and GFDL_GCM.

Conclusions

- Tendency for a longer dry season over central SA associated with a delayed onset and early retreat of the SAM;

- Focusing on the AMZ and LPB basins, the RegCM4 exhibited generally improved performance compared to the driving GCMs in the simulation of the annual precipitation cycle in the reference period.

- Over the AMZ most models projected a decrease of precipitation throughout the year, but maximum in the dry season (May-October) and especially the monsoon onset phase (August - October).

- Over the LPB most models projected increased precipitation during wet season (November - May) and a decrease during the dry season

- The analysis of the relative influence on the change signal of local soil-moisture feedbacks and remote effects of Sea Surface Temperature (SST) over the Niño 3.4 region indicates that the former is prevalent over the Amazon basin while the latter dominates over the La Plata Basin. Also, the soil moisture feedback has a larger role in the RegCM4 than in the GCMs.

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