Grupo de Estudos Climáticos

Departamento de Ciências Atmosféricas
Instituto de Astronomia, Geofísica e Ciências Atmosféricas
Universidade de São Paulo

RegCM4-CMIP5 simulations for South America domain: present climate and trends

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General aims of Cordex (Jones, 2012)

Generate a coordinated ensemble of high-resolution, historical/future regional climate projections for land-regions of the globe sampling; multiple GCM/RCP/RCM/ESDs methods. 1st phase based on CMIP5 historical-projection runs and/or ERA-int boundary data

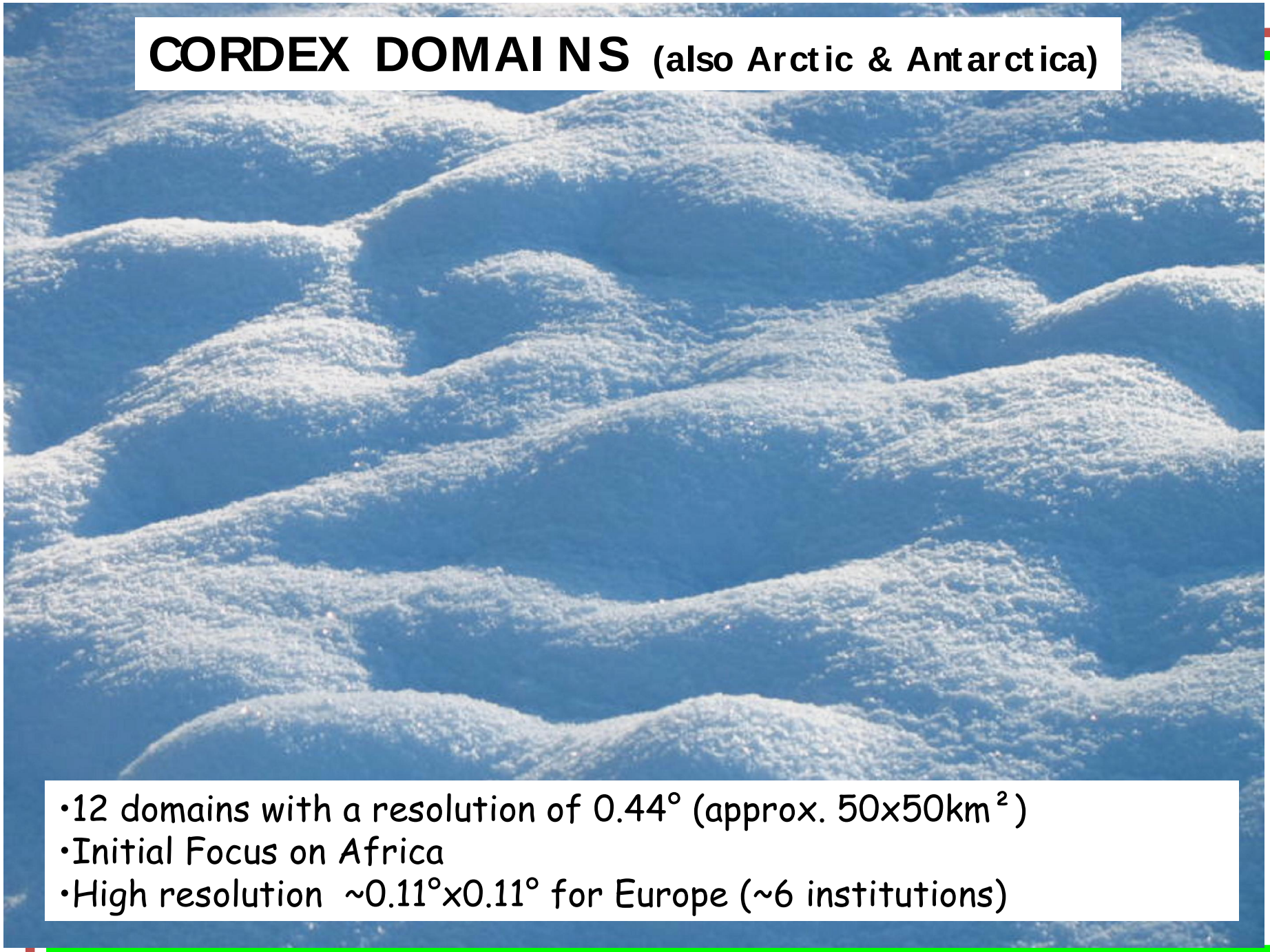
Make data accessible & useable in common format/file structure
Now ~99% same as CMIP5 and compatible with ESG2.

Foster coordination between downscaling efforts & encourage local participation, in generating, analysing & communicating potential regional climate change and associated uncertainties & risks

Initial emphasis on African climate & IAV: START/WCRP sponsored 3 analysis/IAV workshops for an Africa-CORDEX team in 2011-12

Similar activities now starting for South Asia, East Asia and South/Central America

CORDEX DOMAINS (also Arctic & Antarctica)



- 12 domains with a resolution of 0.44° (approx. 50x50km²)
- Initial Focus on Africa
- High resolution ~0.11°x0.11° for Europe (~6 institutions)

- CORDEX-South America:

- **First collaborations to CORDEX-SA are from CLARIS-LPB** (*A Europe-South America Network for Climate Change Assessment and Impact Studies in La Plata Basin, 2008–2012*) project had aims:

  - *predicting the regional climate change impacts on La Plata Basin (LPB) in South America*
  - *designing adaptation strategies for land-use, agriculture, rural development, hydropower production, river transportation, water resources and ecological systems in wetlands.*

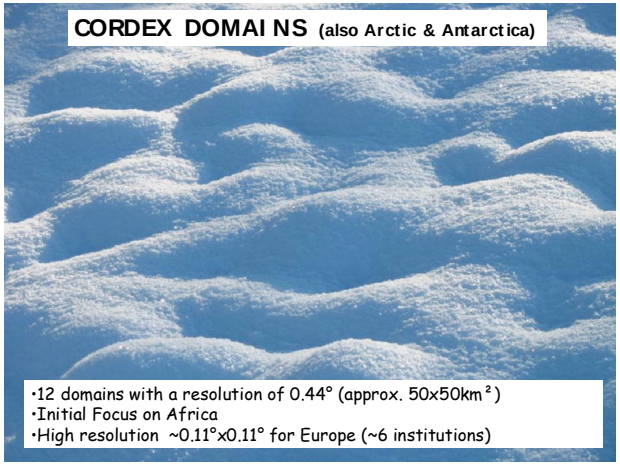
CLARIS-LPB: **7 regional models were used to the regional climate downscaling (SMHI-RCA, USP-RegCM3, MPI-REMO, UCLM-PROMES, INPE-Eta, MM5-UBA, LMDZ) in the present and future (A1B scenario) climates → CMIP3 GCMs**

CORDEX: RegCM4-CMIP5

- F. Giorgi is leading the use of RegCM4 to downscale CMIP5 GCMs in various of the proposed CORDEX subdomains;

- M. Llopart (USP), under coordination of F. Giorgi and E. Coppolla, was in ICTP to organize the simulations for South America domain;

The Abdus Salam International Centre for Theoretical Physics



RegCM4 (USP+ICTP) for CORDEX-SA

Period: 1970-2098 (continuous run)

RegCM4 parameterizations:

CLM land-surface scheme with Emanuel convective scheme

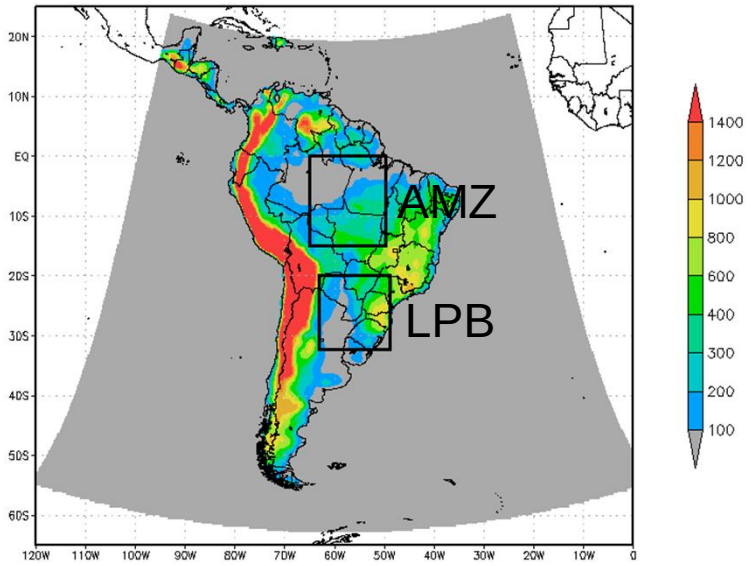
Bats land-surface scheme with mixed convection scheme

Driven global models: HadGEM2 (Hadrcp85 or Hadrcp45), MPI (MPIrcp85) and GFDL (GFDLrcp85)

Four (two) RegCM4 simulations in the RCP8.5 (RCP4.5) with names/configurations in table.

Future (2006-2098)	Present (1975-2005)	Surface	Convection	RCP	Global model
Had85ctrl	BGRegHad	BATS	Mixed	8.5	HadGEM2
Had85CLM	CERegHad	CLM	Emanuel	8.5	HadGEM2
Had45ctrl		BATS	Mixed	4.5	HadGEM2
Had45CLM		CLM	Emanuel	4.5	HadGEM2
MPI85CLM	CERegMPI	CLM	Emanuel	8.5	MPI
GFDL85CLM	CERegGFDL	CLM	Emanuel	8.5	GFDL
	Erainterim	BATS	Mixed		

RegCM4 simulation domain (CORDEX)
Includes all South America continent and part of Atlantic and Pacific oceans



AMZ and LPB boxes

Common aspects of the simulations:

Horizontal resolution ~ 50 km (rotated Mercator projection)

Vertical sigma levels = 18

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

Initial and boundary conditions: ERAInterim and GCMs

Observations

RegCM4 precipitation is compared with the monthly climatology of four different datasets:

1) CMAP - Climate Prediction Center merged analysis of precipitation (Xie and Arkin 1996) ï (continent+ocean) ï 2.5ºx2.5º

2) CRU - Climate Research Union of the University of East Anglia (Mitchell and Jones 2005) ï only continent - (0.5ºx0.5º)

3) CPC - Climate Prediction Center (Chen et al. 2008) - only continent - (0.5ºx0.5º)

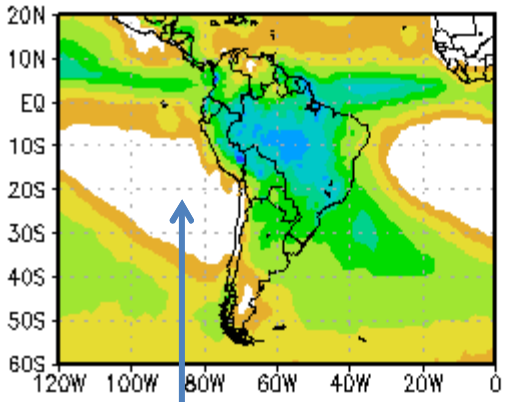
4) UDEL - University of Delaware (ULegates and Willmott 1990) - only continent - (0.5ºx0.5º)

We combine these coarse and fine resolution observations to cover oceans and land points → EnsObs

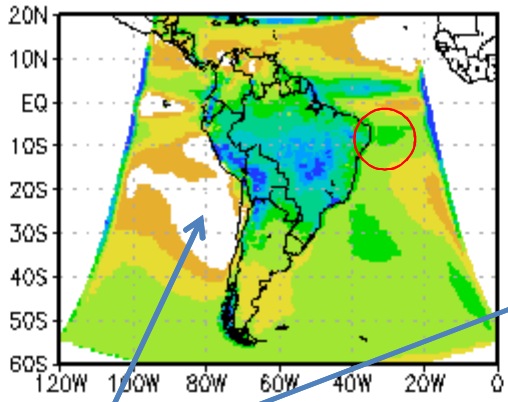
Precipitation climatology – present climate (1975-2005)

Summer

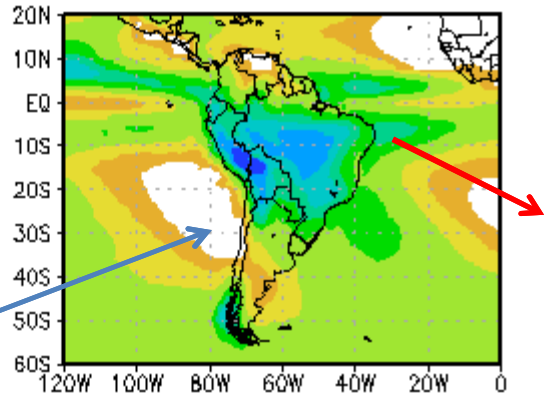
EnsObs

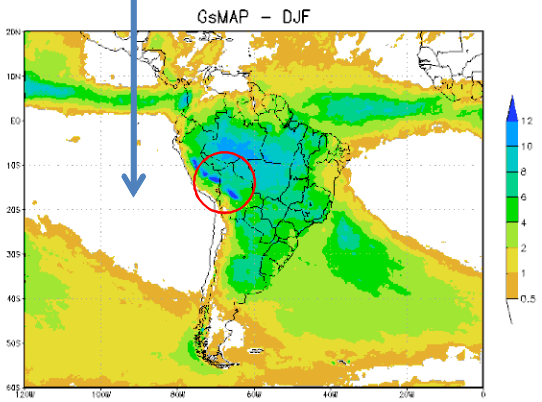


EnsRegCM4



EnsGCMs



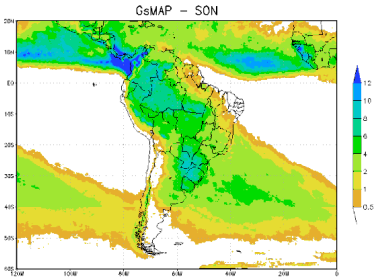


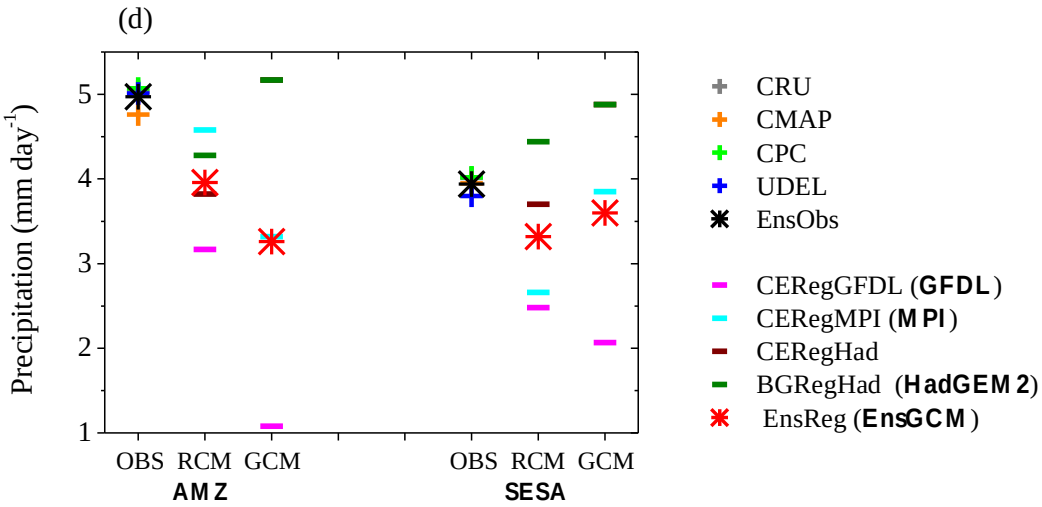
Simulations reproduce the more intense rainfall in SACZ in agreement with obs.

Problems: (1) excessive rainfall in eastern NE Brazil in the EnsGCMs (due the MPI model) that is only partially improved in EnsRegCM4; (2) too much rainfall in the subtropical anticyclonic areas (Pacific and Atlantic);

Present climate (1975-2005) ï austral spring (SON)

EnsObs EnsReg EnsGCMs





Mean seasonal precipitation over AMZ (left) and LPB (right) boxes from OBS, RegCM4 and GCMs

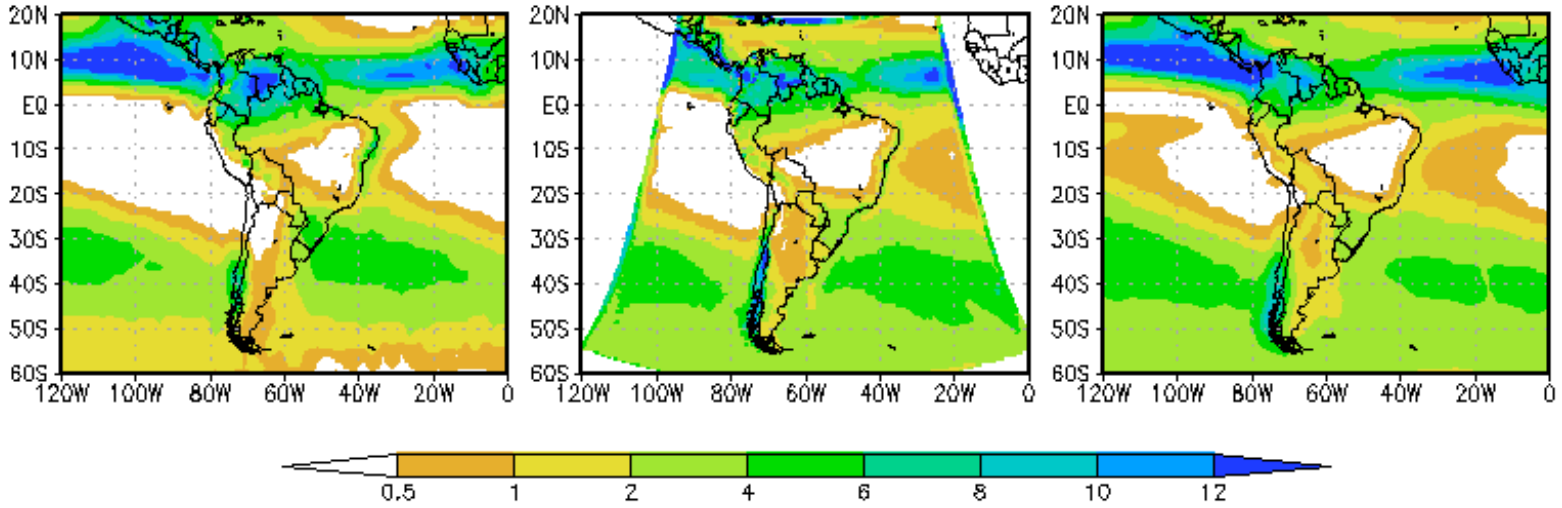
AMZ: RegCM4 captures better than GCMs the precipitation intensity. GCMs present large spread regarding the intensity of rainfall;
LPB: ensemble mean precipitation is similar in GCMs and RegCM4.

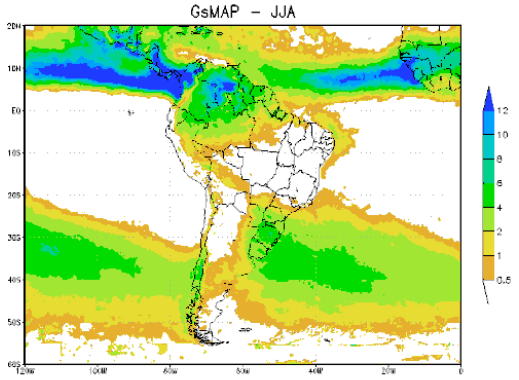
BIAS ARE SIMILAR OR SMALLER THAN OBTAINED WITH RCMS-ERAINTERIM EXPERIMENTS (SOLMAN ET AL., 2013)

Precipitation climatology – present climate (1975-2005)

Winter

EnsObs EnsReg EnsGCMs





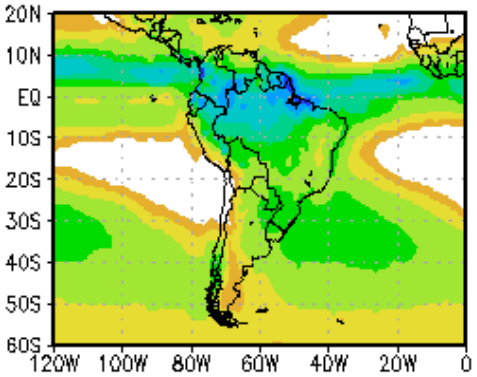
Main rainfall centers are simulated by both RegCM4 and GCM

Small differences in north (ITCZ) and southeastern (storm tracks) of SA

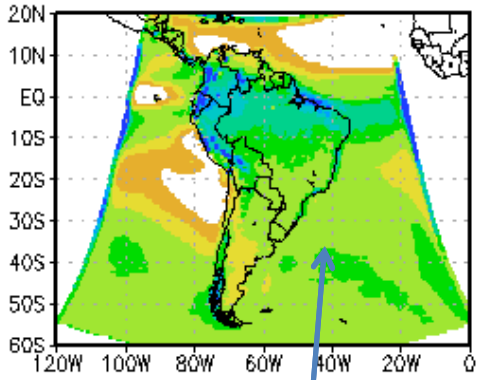
Precipitation climatology – present climate (1975-2005)

Autunm

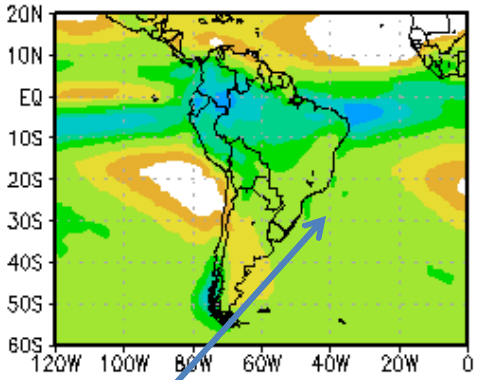
EnsObs



EnsReg

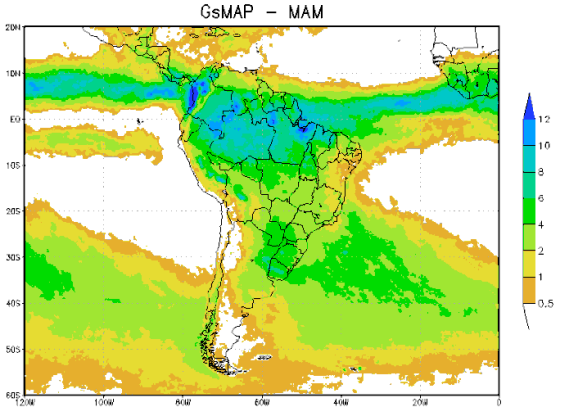


EnsGCMs



General observed patterns is present in simulations;

Main problem is the deficit of rainfall in southwestern Atlantic and south Brazil (cyclogenetic area)



Seasonal precipitation (mm/day)

LPB ï DJF smaller bias in EnsReg than EnsGCM
JJA EnsReg similar EnsGCM

LPB	DJF	JJA
EnsObs	4.7 [**5.0**] 5.1	2.1 [**2.2**] 2.3
EnsRegCM4	4.2 [**5.2**] 5.8	1.5 [**1.8**] 2.3
EnsGCM	4.5 [**5.5**] 6.4	0.6 [**1.8**] 2.9
	Min Mean Max	Min Mean Max

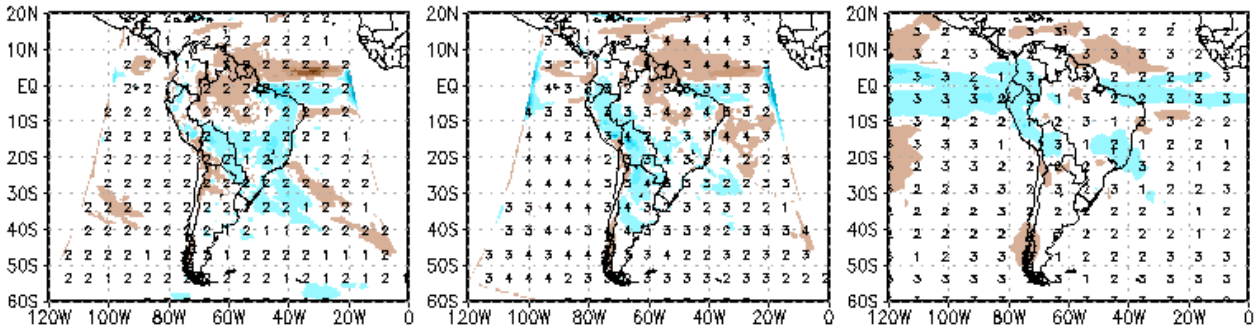
AMZ: DJF biases are low (<10%)
Large biases occurs in winter due mainly one dry simulation

AMZ	DJF	JJA
EnsObs	8.9 [**9.4**] 9.7	0.82 [**0.92**] 0.95
EnsRegCM4	6.8 [**8.7**] 10.9	0.30 [**0.60**] 0.94
EnsGCM	8.8 [**9.8**] 10.7	0.10 [**0.50**] 1.30

Trends: austral summer

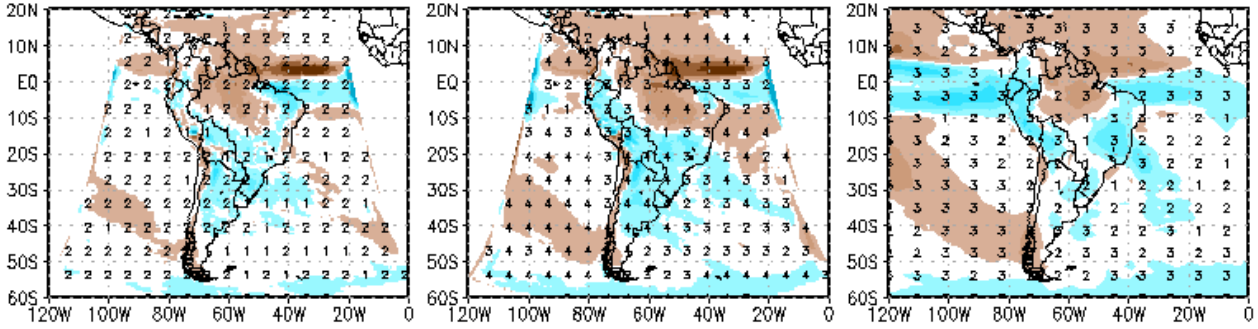
Ensemble of the change in precipitation (mm/day): future minus present climate.

Large agreement between simulation about positive (negative) trends over southeastern (northern) South America, **which is more intense over large areas in far future/rcp8.5**

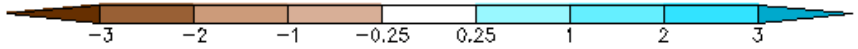


Near future (2020-2050)-present (1975-2005)

RCP4.5ï RegCM4 **RCP8.5-RegCM4** **RCP8.5-GCM**



Far future (2070-2098)-present (1975-2005)

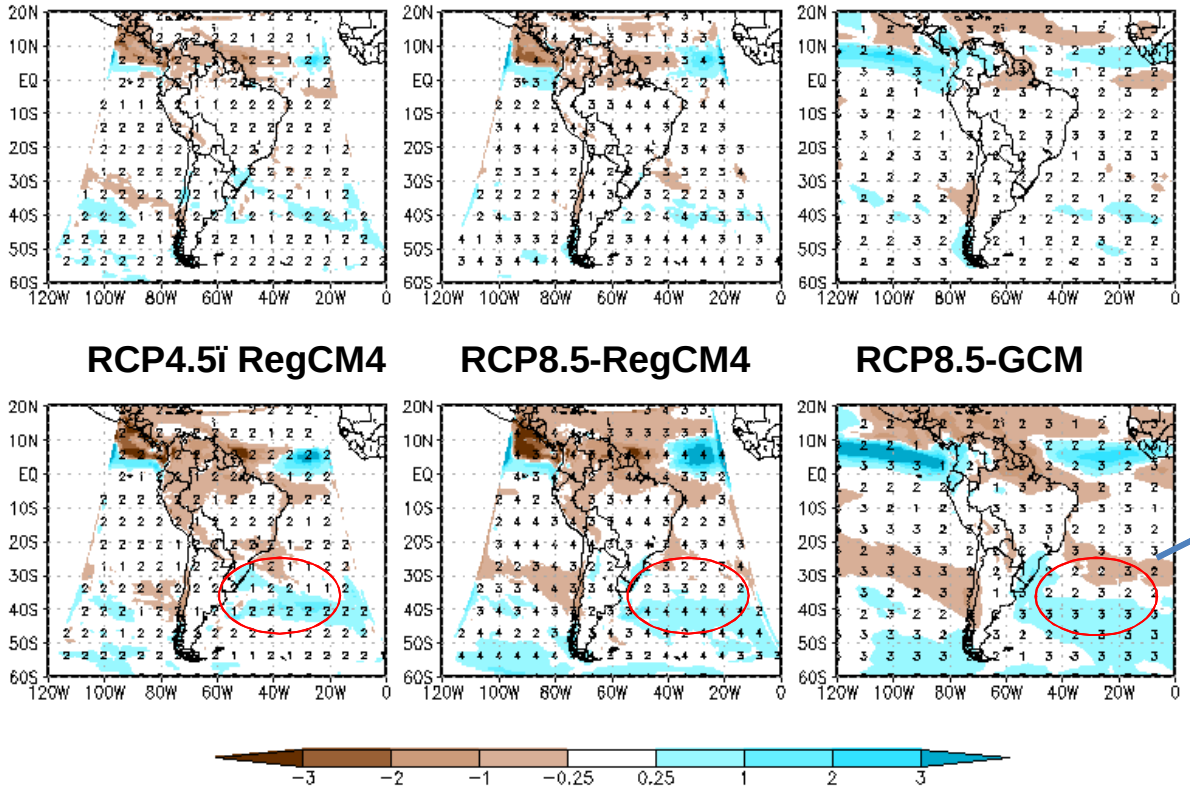


numbers indicate how many members have the same signal (+ or -) of the ensemble mean

Trends: austral winter

Ensemble of the change in precipitation (mm/day): future minus present climate.

Large agreement in simulating no changes in pcp over continental SA in near future;
North/northwest SA → negative trends in pcp in far future



Near future (2020-2050)-present (1975-2005)

Increase/decrease of pcp may be associated with southward displacement of storm tracks

Far future (2070-2098)-present (1975-2005)

numbers indicate how many members have the same signal (+ or -) of the ensemble mean.

Trends: austral spring

Ensemble of the change in precipitation (mm/day): future minus present climate.

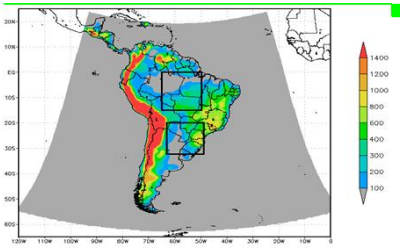
positive (negative) trends over southeastern (northern) South America => more intense over large areas in far future/rcp8.5

Near future (2020-2050)-present (1975-2005)

RCP4.5–RegCM4 **RCP8.5-RegCM4** **RCP8.5-GCM**

Far future (2070-2098)-present (1975-2005)

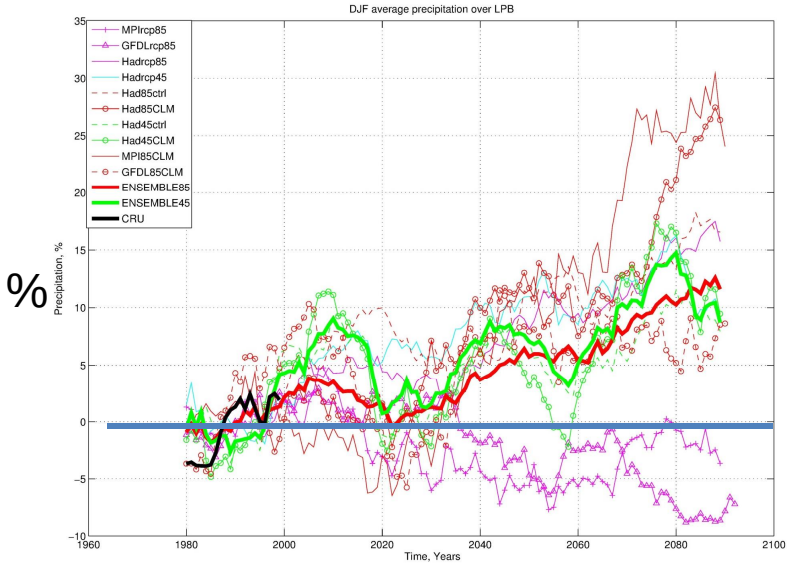
numbers indicate how many members have the same signal (+ or -) of the ensemble mean.



Time series of precipitation (%) – LPB

Large spread between simulations
EnsMeanRCP4.5 (green) ï positive trends in summer and winter
EnsMeanRCP8.5 (red) ï positive trends only in summer
Summer: besides trend we can note other low frequency variability

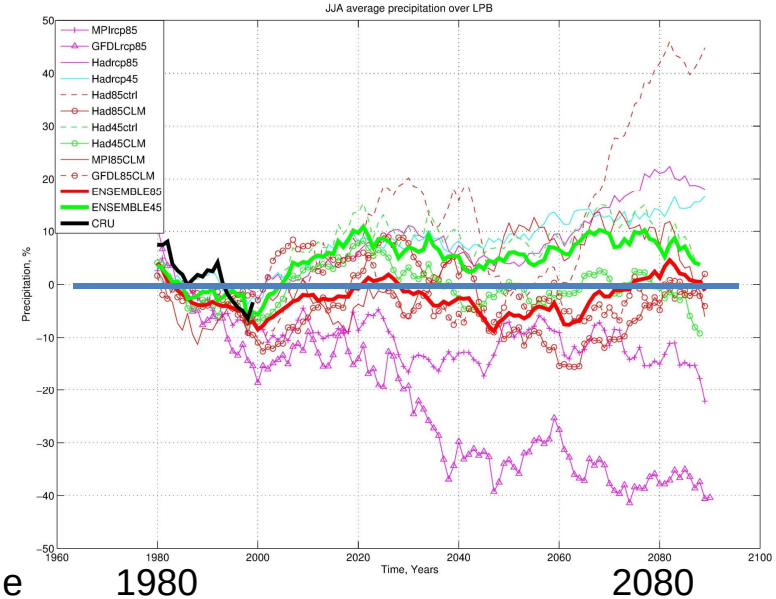
Summer



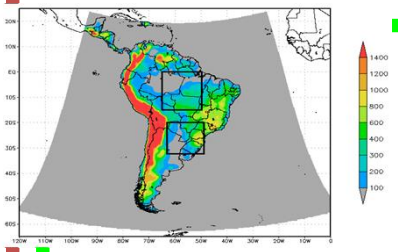
%

1980 2080 Time

Winter



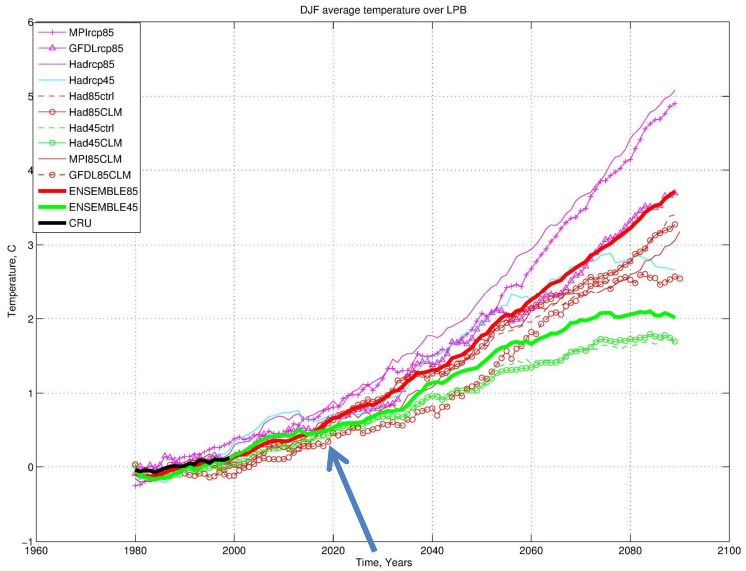
1980 2080



Air temperature trends (ºC) – LPB

Positive trends is a common feature of all simulations, but the spread about the value of warming increases after 2020 in both summer and winter

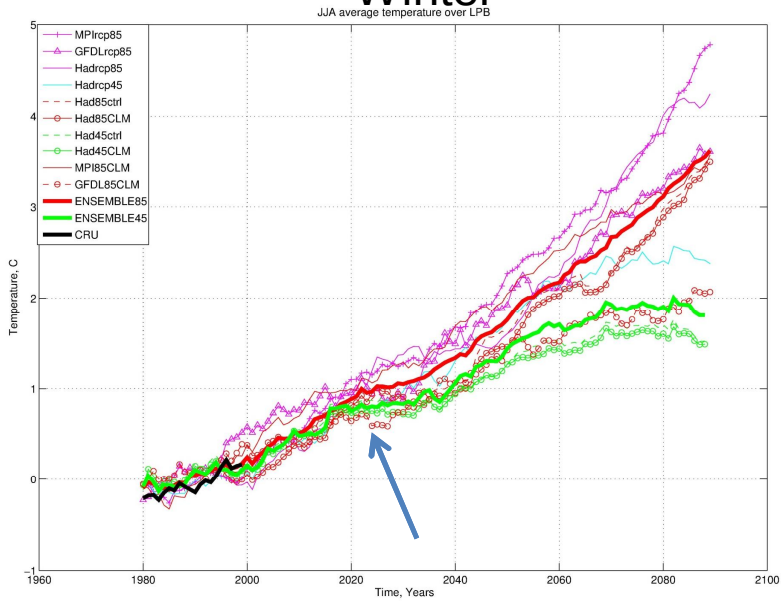
Summer



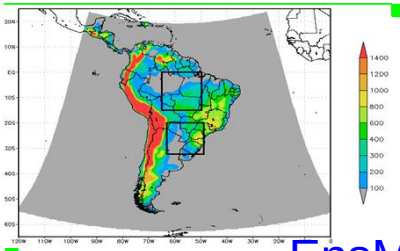
1980 2080

Time

Winter



1980 2080



Precipitation trends (%) – AMZ

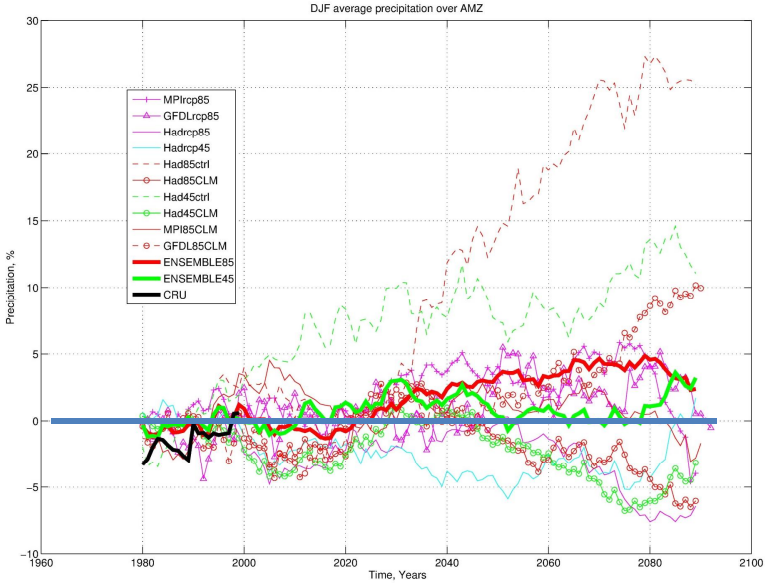
EnsMeanRCP4.5 (green) ï no clear trend in summer; negative trends (10-20%) in winter

EnsMeanRCP8.5 (red) ï weak (5%) positive trend after 2020 in summer; large reduction of pcp in winter

Summer: RegCM4-RCP8.5 simulations diverges after 2040.

Similar behavior is noted in GFDL during winter.

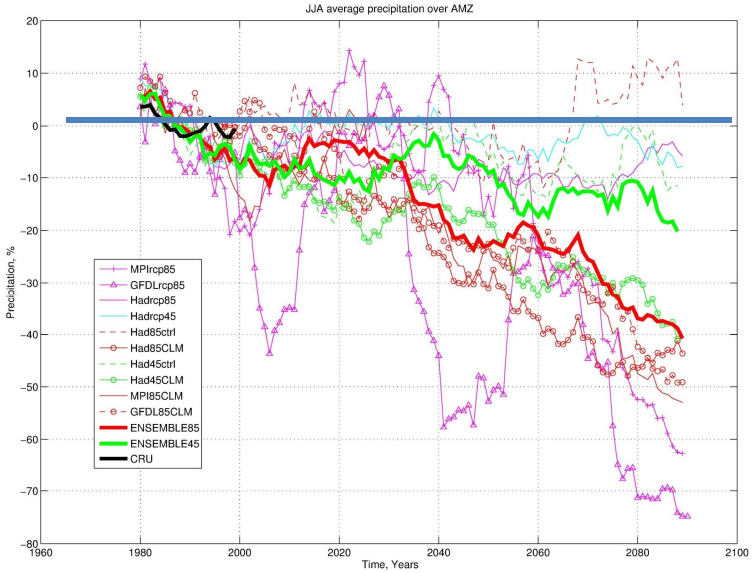
Summer



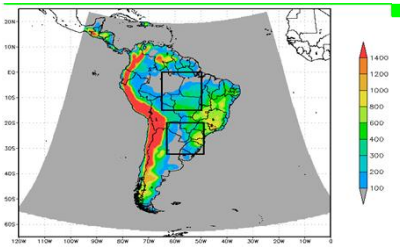
%

1980 2080 Time

Winter



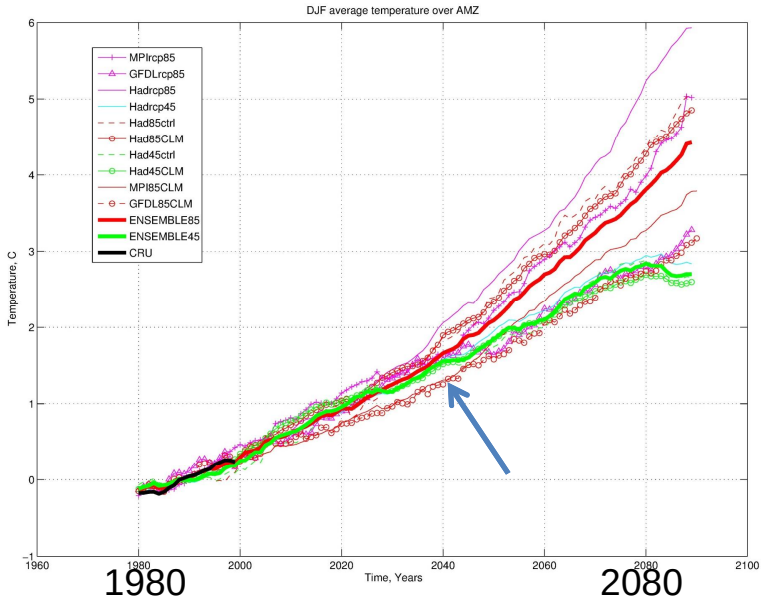
1980 2080



Air temperature trends (ºC) – AMZ

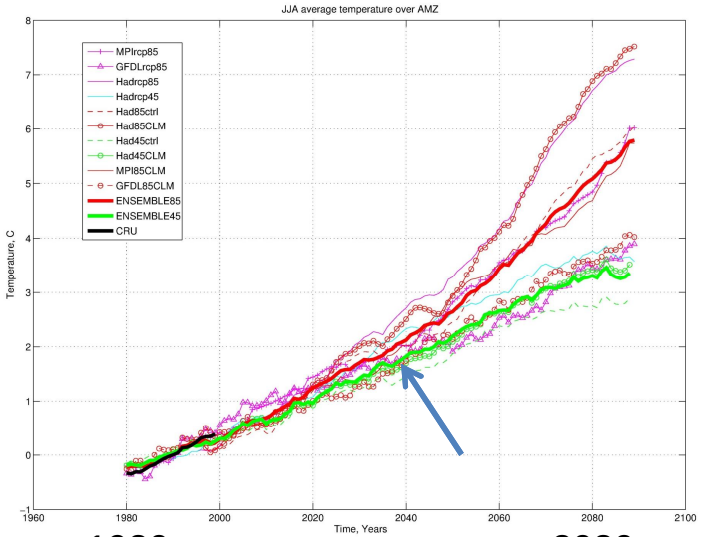
A general trend of increase of temperature in both summer and winter

Spread between simulations increase after 2040



1980 2080

Time



1980 2080

Simulations RegCM4-CMIP5:

some regional improvements compared with GCMs; → low spread;
trends: increase/decrease of rainfall and temperature follows GCMs, but some regional details are also noted;

Next:

to compare simulated fields in present climate in more details looking for regional aspects and using high resolution analysis;
to analyze systems (cold front, cyclones, etc);
to make the simulation available in CORDEX database soon (common format of data).

Å Thanks!

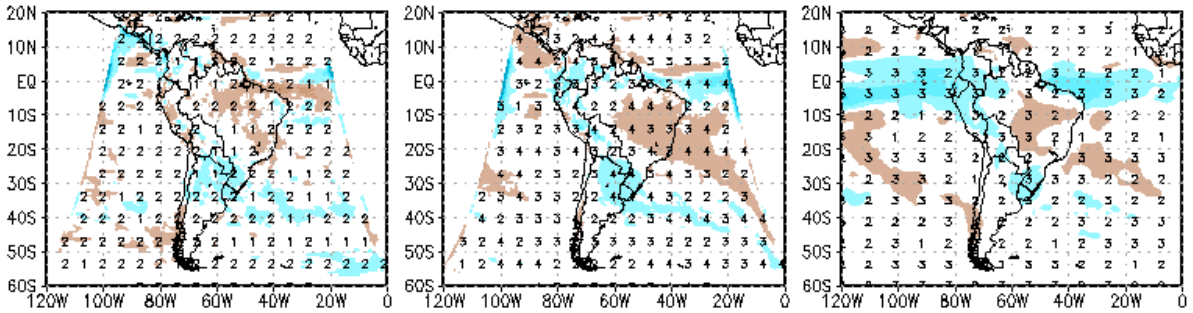
Å Gracias!

Å Obrigada!

Trends: austral autunm

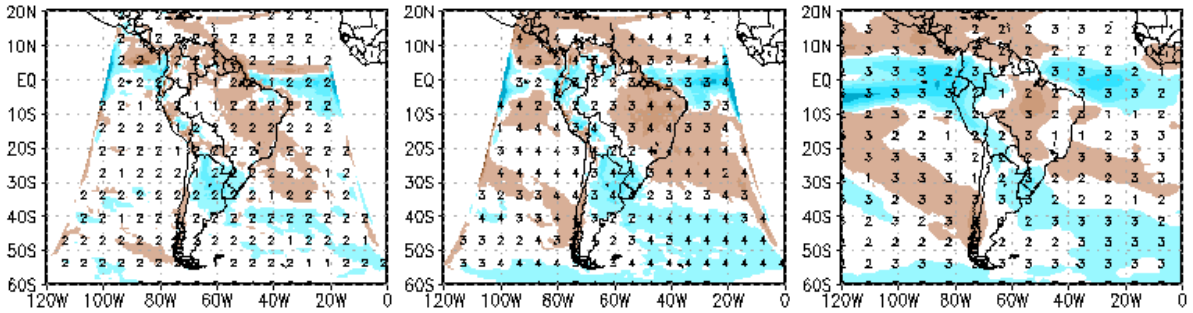
Ensemble of the change in precipitation (mm/day): future minus present climate.

Band northwestern/southeastern oriented of positive (negative) trends → more intense and organized in RegCM4 far future-rcp8.5

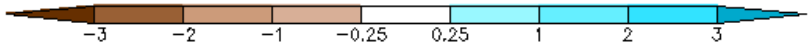


RCP4.5ï RegCM4 **RCP8.5-RegCM4** **RCP8.5-GCM**

Near future (2020-2050)-present (1975-2005)



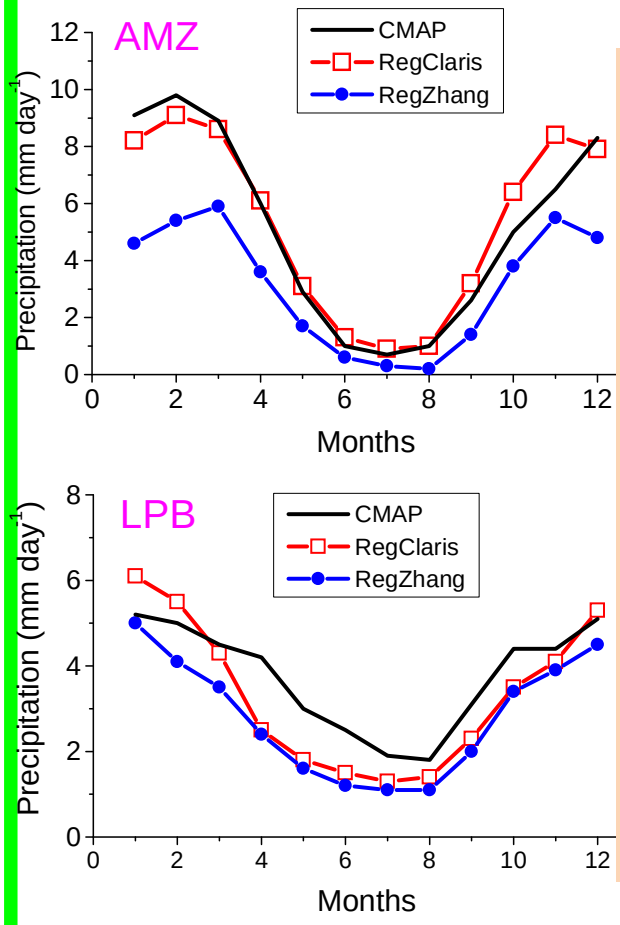
Far future (2070-2098)-present (1975-2005)



numbers indicate how many members have the same signal (+ or -) of the ensemble mean.

Å **RegCM3Claris:** main improvements

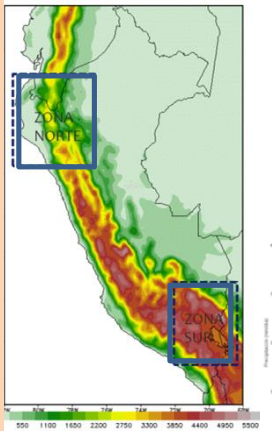
Annual cycle of precipitation

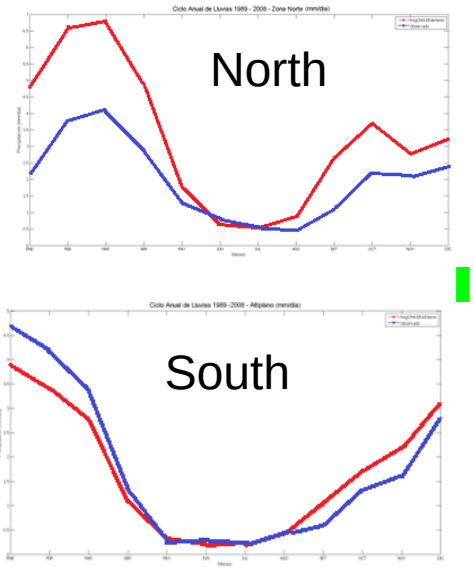


Amazon (AMZ): substantial improvements of rainfall annual cycle (small overestimation during onset of wet season).

La Plata Basin (LPB): there is an increase of rainfall rate during DJF

North and south (Andes Altiplano) of Peru: phase of annual cycle is well captured by RegCM3Claris (J. Bazo).

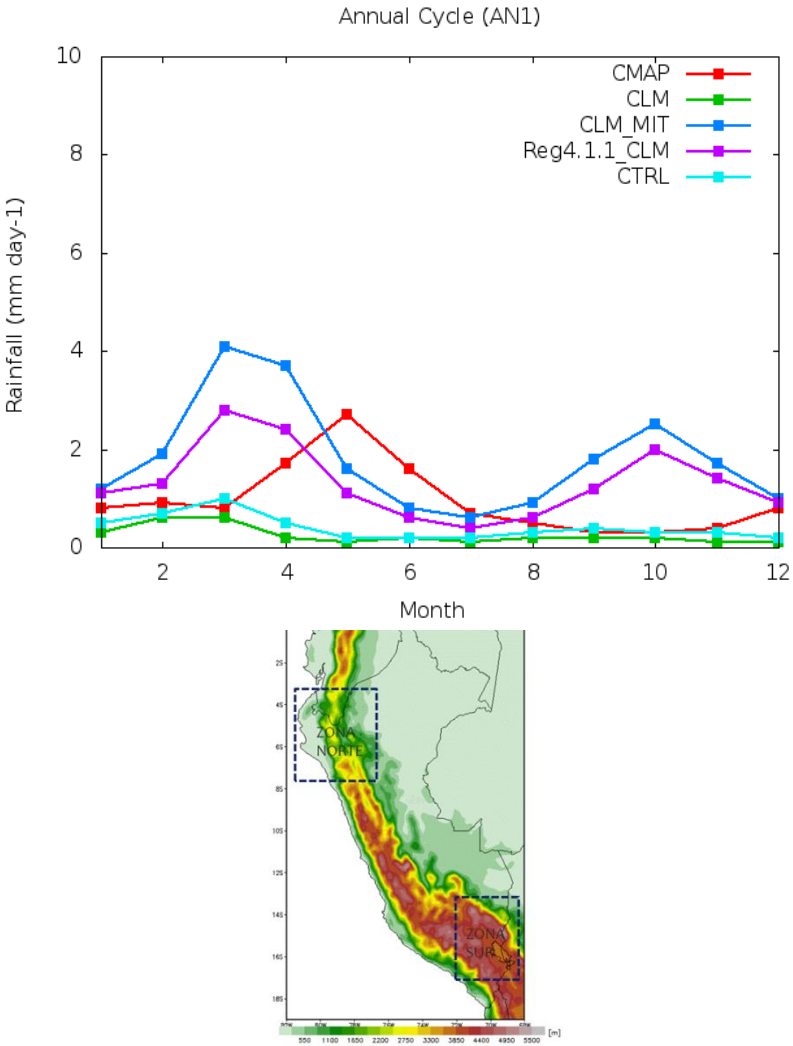




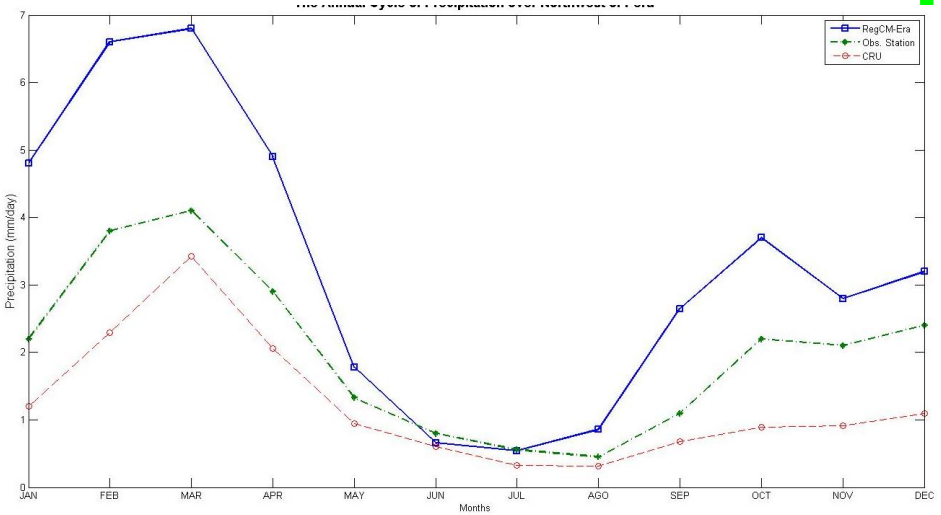
Blue line ï raingauge observations
Red line ï RegCM3Claris

Å **RegCM3Claris:** main improvements

Annual cycle of precipitation

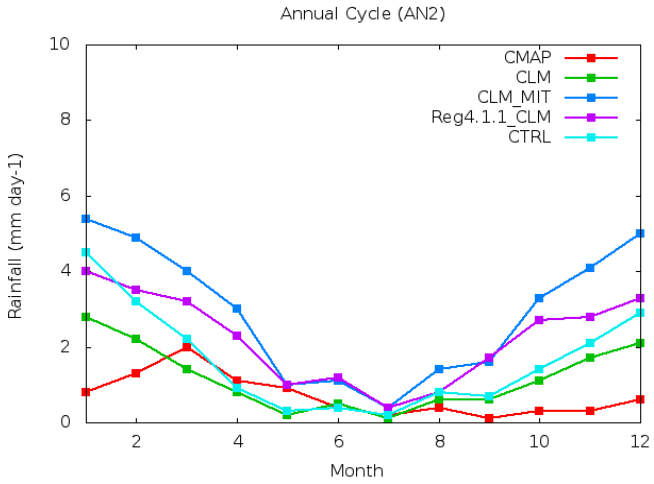


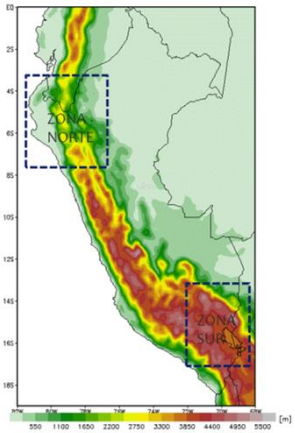
Northwest Peru
Acho q tem algo errado nas figuras da Marta



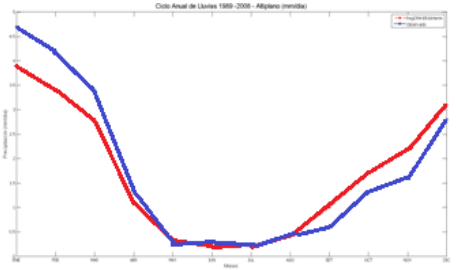
Å **RegCM3Claris:** main improvements

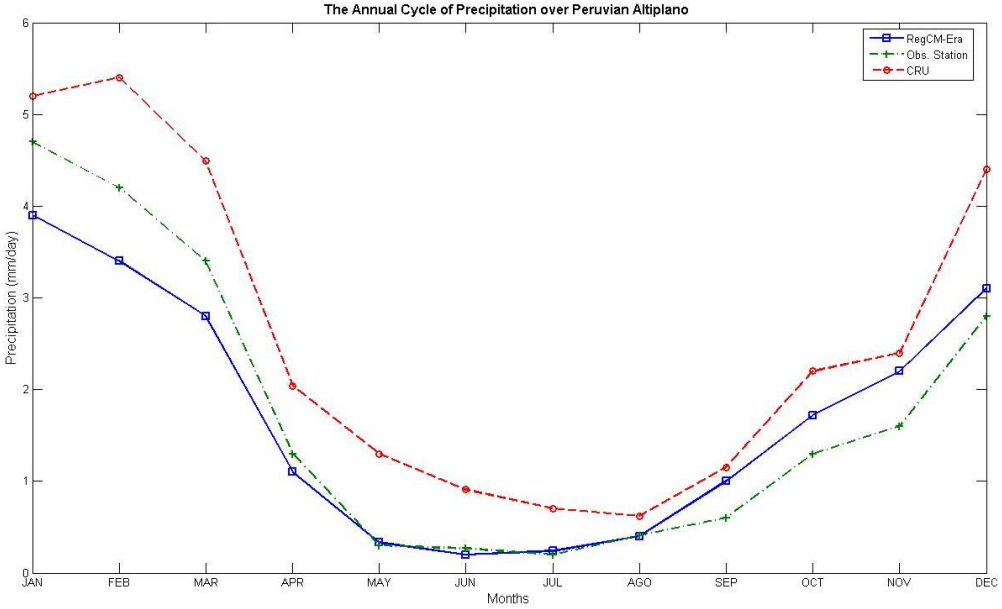
Annual cycle of precipitation





Andes Altiplano - Peru

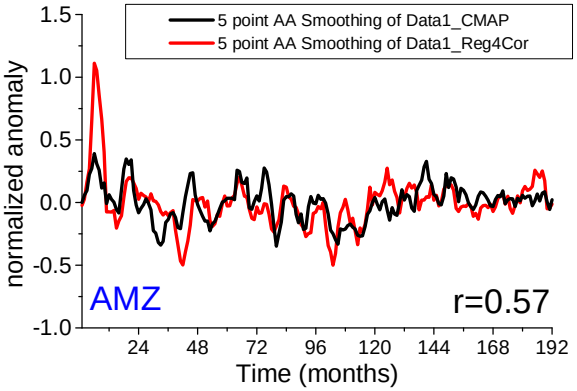


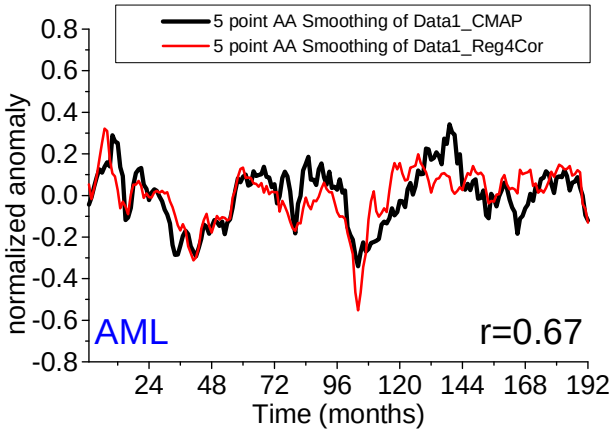


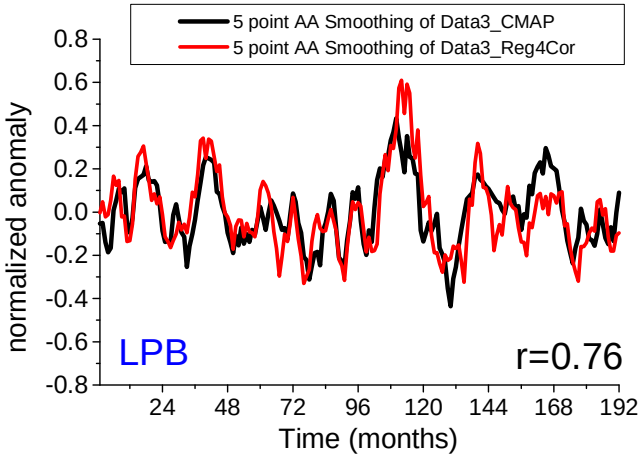
Reg4Cor - Interannual Variability

Time series of 5 months running mean of normalized monthly precipitation anomaly

CMAP (black) x Reg4Cor (red)







Precipitation was normalized by:

$$P_N = \frac{x_i - \bar{x}}{\bar{x}}$$

where x_i is the monthly mean and $\bar{x}$ is the monthly mean of the period from 1989 to 1996

Reg4Cor captures adequately the inter monthly variability over AMZ and LPB boxes

Annual cycle statistics - mean, standard deviation, bias, rmse and correlation (r)

RegCor

Precipitation					
Region	**CMAP**	**Reg4Cor**	**Bias**	**RMSE**	**r**
AML	5.9±3.3	7.9±3.9	**2.1**	2.2	**0.98**
AMZ	5.3±3.4	3.3±2.0	**-2.0**	2.5	**0.99**
NDE	2.8 ± 1.4	2.0 ± 1.7	**-0.8**	0.96	**0.97**
LPB	3.9±1.2	2.7±1.0	**-1.2**	1.3	**0.92**
LUR	3.8±0.4	2.7±0.4	**-1.2**	1.2	**0.78**

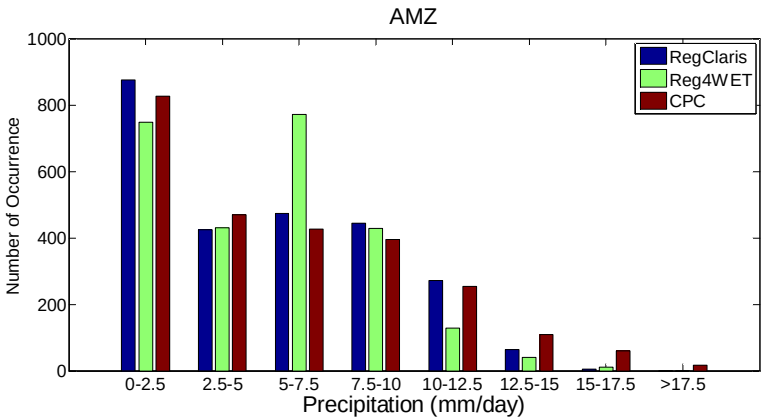
Temperature					
Region	**Willmott**	**Reg4Cor**	**Bias**	**RMSE**	**r**
AML	26.0±0.5	24.2±0.6	**-1.8**	1.9	0.38
AMZ	25.3±0.6	25.9±1.3	**0.6**	1.4	0.21
NDE	24.9±0.9	25.5±0.8	**0.5**	0.8	0.71
LPB	20.9±3.6	22.6±4.9	**1.7**	2.2	0.99
LUR	17.3±4.7	17.0±3.8	**-0.3**	1.8	0.93

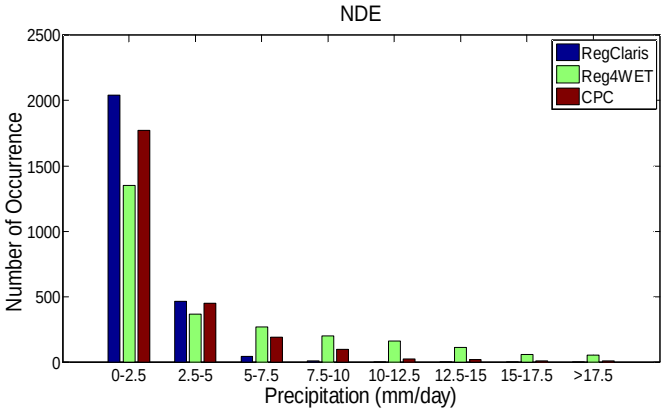
- annual cycle of precipitation is in phase with observation

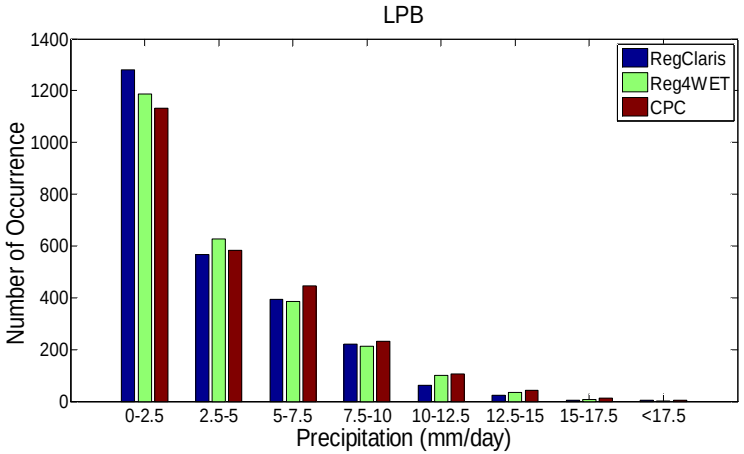
- in relative terms the precipitation biases are small in tropics than in subtropics

- Reduction of RegCM3 ñpermanentòcold bias over SA

Daily precipitation: CPC, RegClaris and Reg4Wet







AMZ: increase of rainfall occurs due the events of intermediary intensity;

NDE: increase of rainfall is due to the intense events (greater than 5 mm/day)