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Agenda Item: 1-01

How Well Are Southern Hemisphere Teleconnection Patterns Predicted by Seasonal Climate Models?

Submitted by: University of São Paulo

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19 August, 2008
APEC Climate Symposium, 2008
Abstract 1-01

How well are Southern Hemisphere teleconnection patterns predicted by seasonal climate models?

Tércio Ambrizzi
Department of Atmospheric Sciences
University of São Paulo - Brazil

The identification of teleconnection patterns and the analysis of their effect on the horizontal structure of the atmospheric circulation can be very useful to understand anomalous events in many regions of the world. Local forcing in specific places can influence remote regions through organized structures in form of waves. One way to analyze this wave propagation is using the stationary Rossby wave linear theory in a barotropic atmosphere. Previous studies on atmospheric teleconnection patterns have shown that linear wave theory may explain some of the observed low-frequency variability. Using a climatological December-January-February (DJF) basic flow and a simple barotropic model, it is possible to examine the preferred trajectories followed by Rossby waves around the globe. For instance, through the analysis of climatological stationary wavenumber fields (K_s) it can be demonstrated that the upper level tropospheric jets can act as waveguides in the atmosphere. In particular, during the Southern Hemisphere winter (June-July-August – JJA), some studies have numerically demonstrated, using a barotropic model, that the subtropical and polar jets have such characteristic. One can suggest that the atmospheric dynamics at large scales can be qualitatively interpreted through the linear wave theory.

The teleconnection analyses described above were applied to 10 years of ECMWF ensemble forecasts. The basic theory related to dynamical systems can give an insight into the predictability of large events and could be used to improve the seasonal forecasting. Preliminary results have identified a large variability among the ensemble members to represent the circulation patterns in a three month forecast. This research is part of a multi-institutional collaboration proposal called EUROBRISA which one of its objectives is to provide not only the Brazilian government but also other South American local governments improved and well-calibrated seasonal forecasts.

How well are Southern Hemisphere teleconnection patterns predicted by seasonal climate models?

Tércio Ambrizzi

Department of Atmospheric Science - USP

APEC Climate Symposium Lima/2008

Rossby Wave Theory

Basic Theory – Rossby (1939, 1945)

The barotropic vorticity equaiton is:

$$\left(\frac{\partial}{\partial t}+U\frac{\partial}{\partial x}+V\frac{\partial}{\partial y}\right)\xi+V\beta_*=0$$

Assuming that $U=\overline{U}+U'$ $\quad V=V'$ $\quad \xi=\xi'$

And defining the perturbed streamfunction ψ, we have:

$$\left(\frac{\partial}{\partial t}+\overline{U}\frac{\partial}{\partial x}\right)\nabla^2\psi+\beta_*\frac{\partial\psi}{\partial x}=0$$

Assuming the wave solution $\quad \psi=\mathrm{Re}\left\{Ae^{i(kx+ly-\omega t)}\right\}$

We get: $\quad \omega=\overline{U}k-\frac{\beta_* k}{\left(k^2+l^2\right)}$ $\quad$ or $\quad c_x=\overline{U}-\frac{\beta_*}{\left(k^2+l^2\right)}$

Some characteristics of Rossby waves are:

- **They propagate to the west**
- **They are dispersive**

The group velocity is given by:

$$c_{g_x} = \frac{\partial \omega}{\partial k} = \frac{\omega}{k} + \frac{2\beta_* k^2}{\left(k^2 + l^2\right)^2} \quad \textbf{and} \quad c_{g_y} = \frac{\partial \omega}{\partial l} = \frac{2\beta_* kl}{\left(k^2 + l^2\right)^2}$$

For a stationary wave (ω=0; c=0):

$$K^2 = \left(k^2 + l^2\right) = \frac{\beta_*}{\overline{U}} = K_s^2$$

Playing with the equations, it is possible to define the ray path radius of curvature which is given by the simple expression

$$r = K_s^2 \Big/ \left[k \frac{dK_s}{dy} \right]$$

(Hoskins e Ambrizzi 1993)

Schematic K_s profiles and ray path refraction

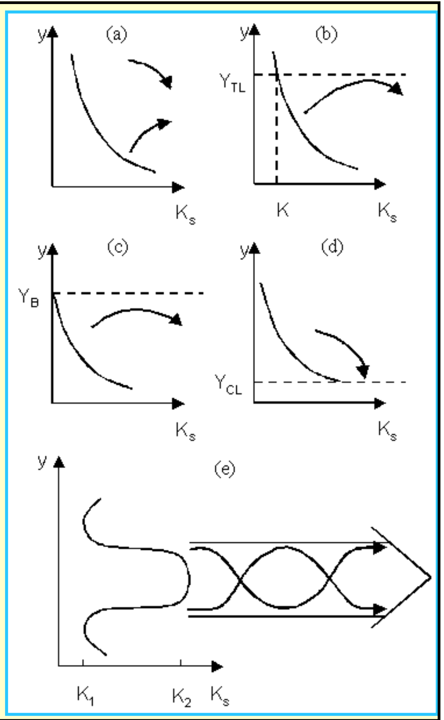
(a) Simple refraction

(b) Reflection from a turning latitude Y_{TL}, at which K_s = k

(c) Reflection of all wavenumbers before a latitude Y_B at which β* = 0

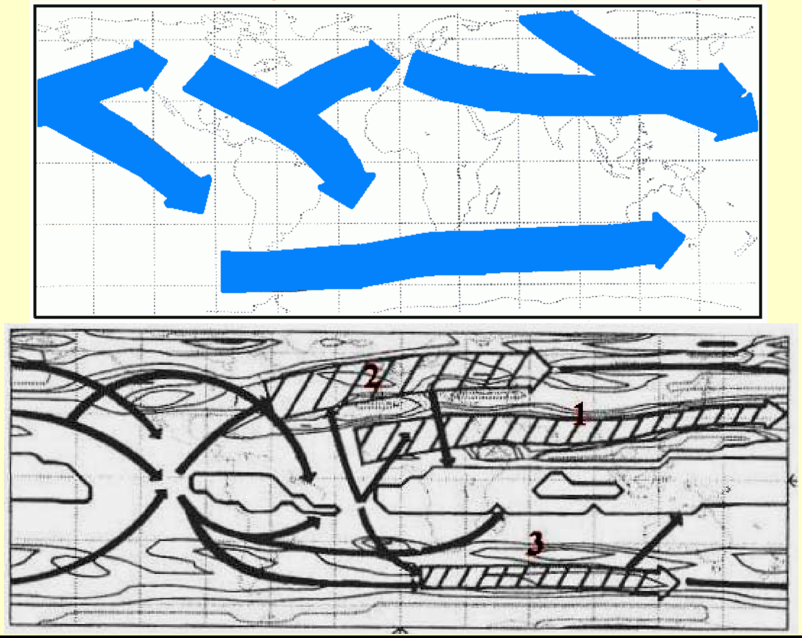
(d) Refraction into a critical latitude Y_{CL} at which U = 0

(e) waveguide effect of a K_s maximum.

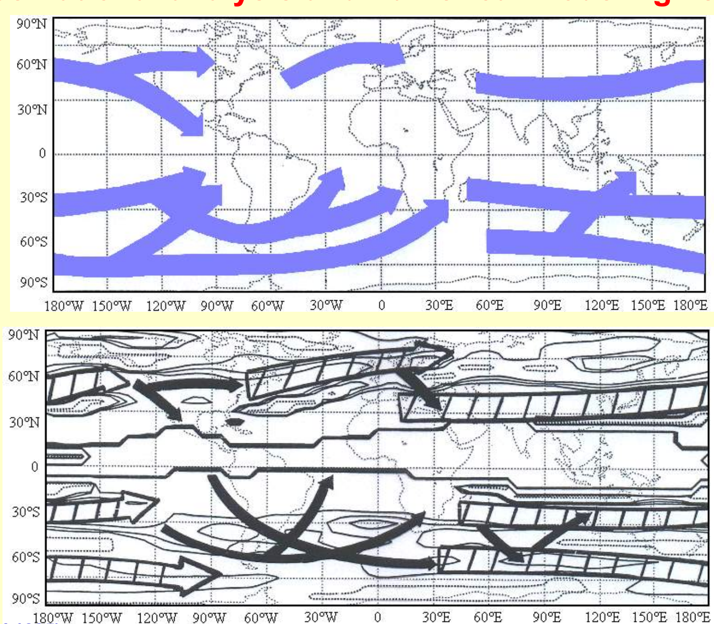


(Hoskins e Ambrizzi 1993)

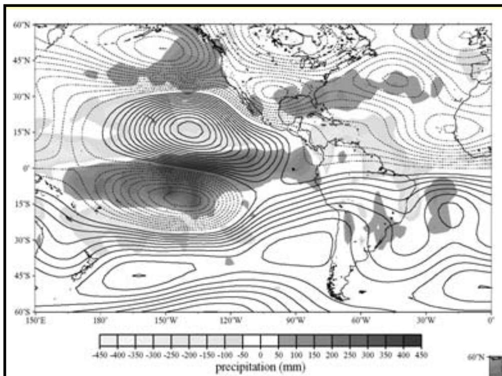
Main teleconnection patterns obtained from observational analysis and numerical modeling - DJF



Main teleconnection patterns obtained from observational analysis and numerical modeling - JJA



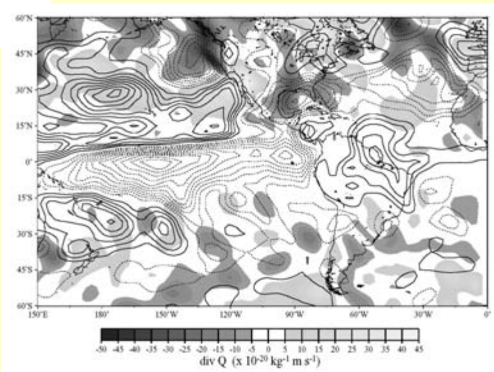
(Ambrizzi et al 1995)



Stream Function, Omega, Precip and Q vector - average for four El Niño events

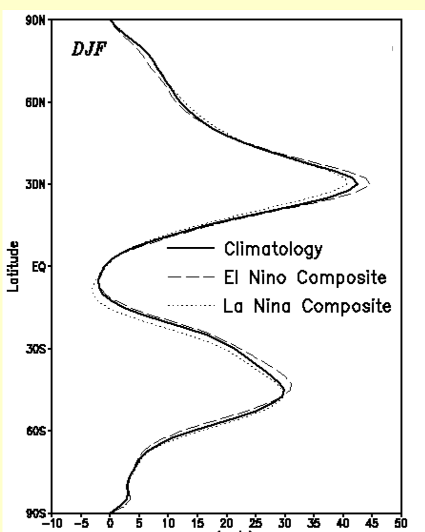
Div of Q anomaly of omega

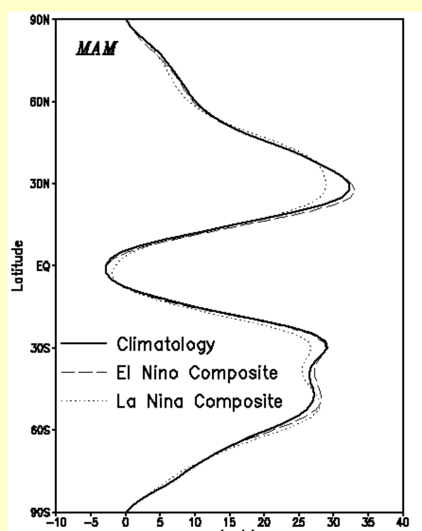
Anomaly of Ψ and precipitation



(Magaña e Ambrizzi, 2005)

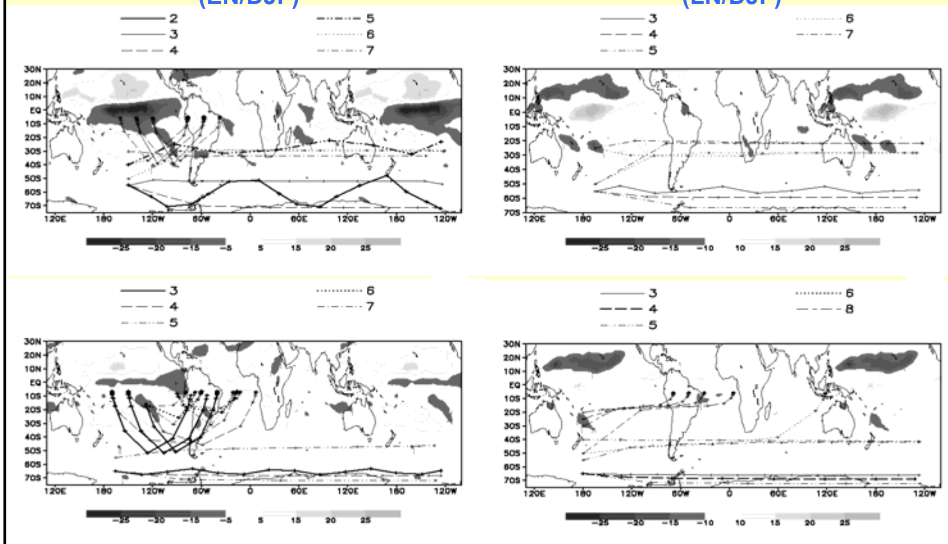
ZONAL WIND - U





RAY TRACING FOR EL NIÑO/LA NIÑA

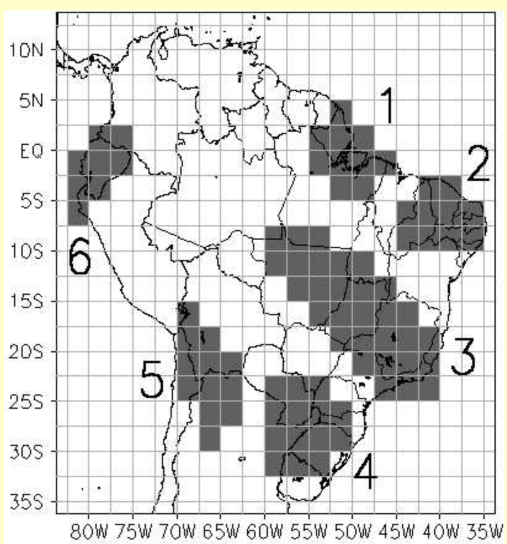
(EN/DJF) (LN/DJF)



(EN/MAM) (LN/MAM)

(Coelho, 2001)

ENSO episodes and the South American Regional Precipitation



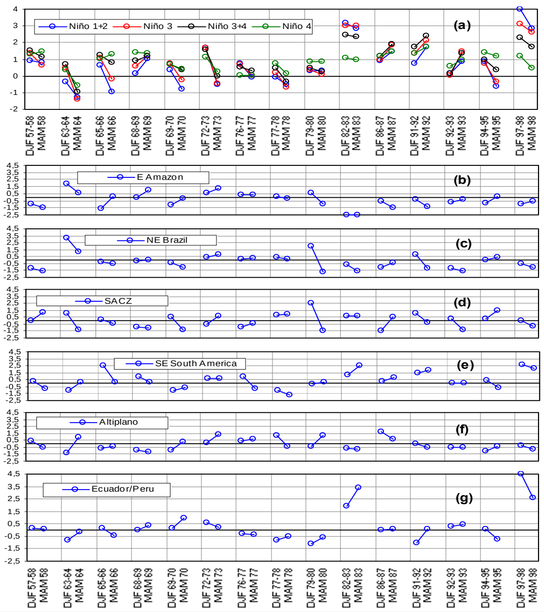
Seasonal Standardized index for the austral summer (DJF) and autumn (MAM)

$$I = (X_i - \bar{X}_i)/\sigma_i$$

were calculated for the precipitation over key-areas of South America and the SSTa over the Niño 1.2, 3, 3.4 and 4

(Ambrizzi and Souza, 2003)

El Niño Episodes and regional precipitation over South America during the period 1950-1990



aSST Niños

E Amazônia

NE Brasil

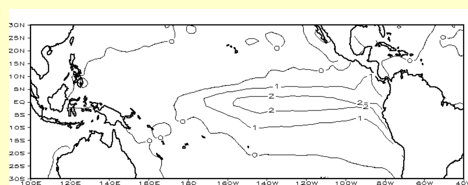
SACZ

SE South America

Altiplano

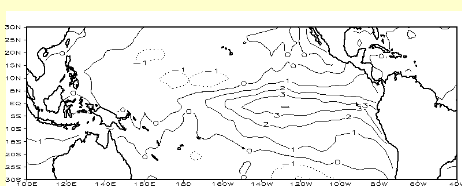
Equator Peru

SSTs for 4 EL NIÑO EVENTS

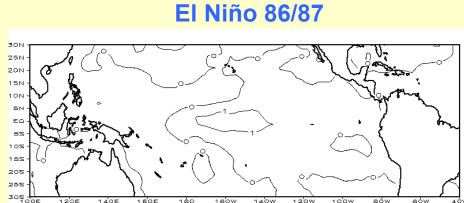


Average for 4 events

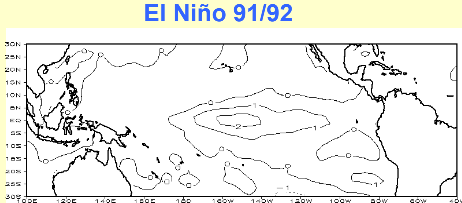
El Niño 82/83



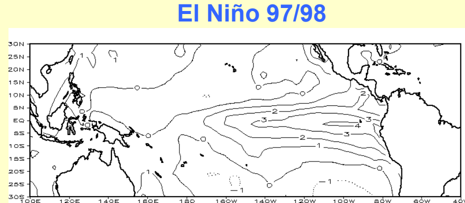
El Niño 86/87



El Niño 91/92

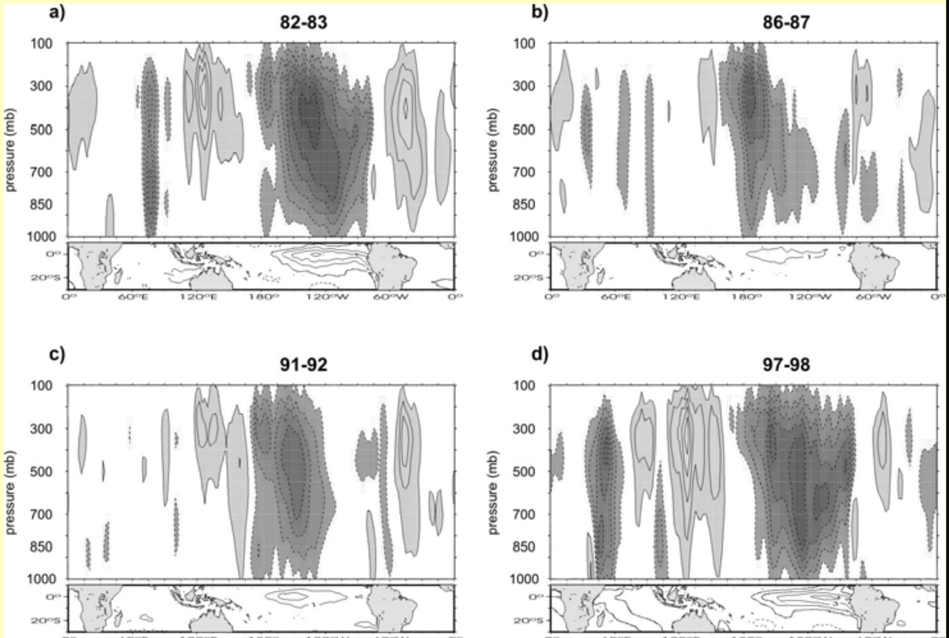


El Niño 97/98



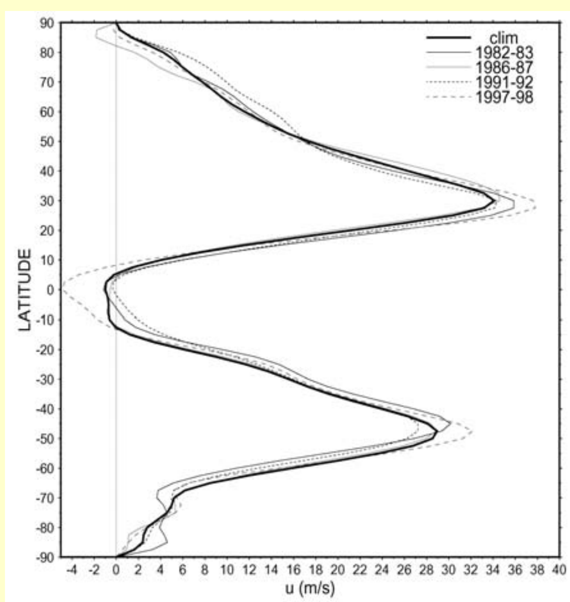
(Drumond e Ambrizzi, 2003)

OMEGA ANOMALY

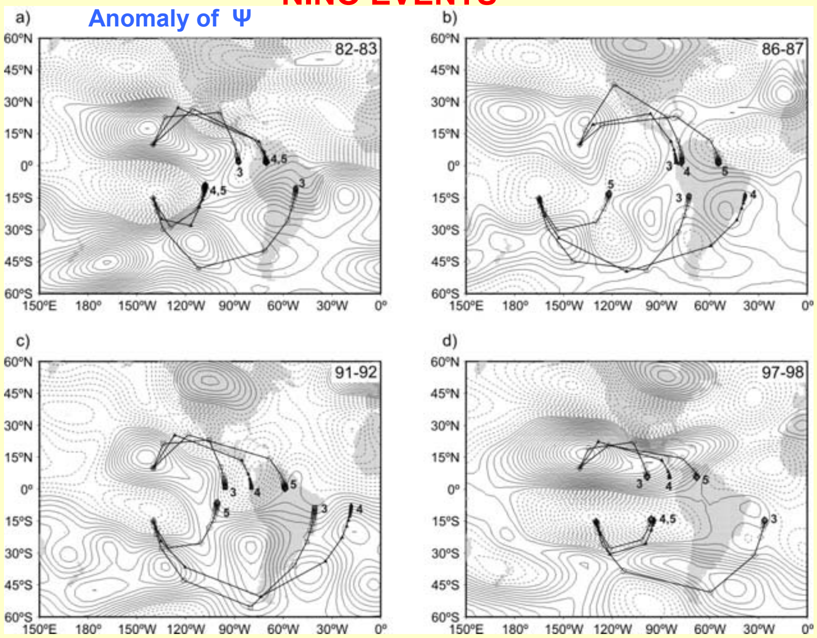


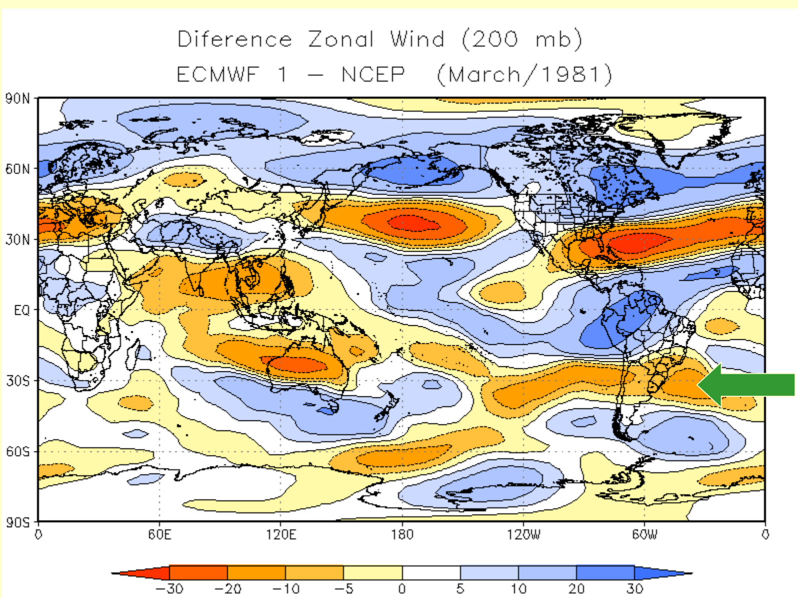
(Magaña e Ambrizzi 2005)

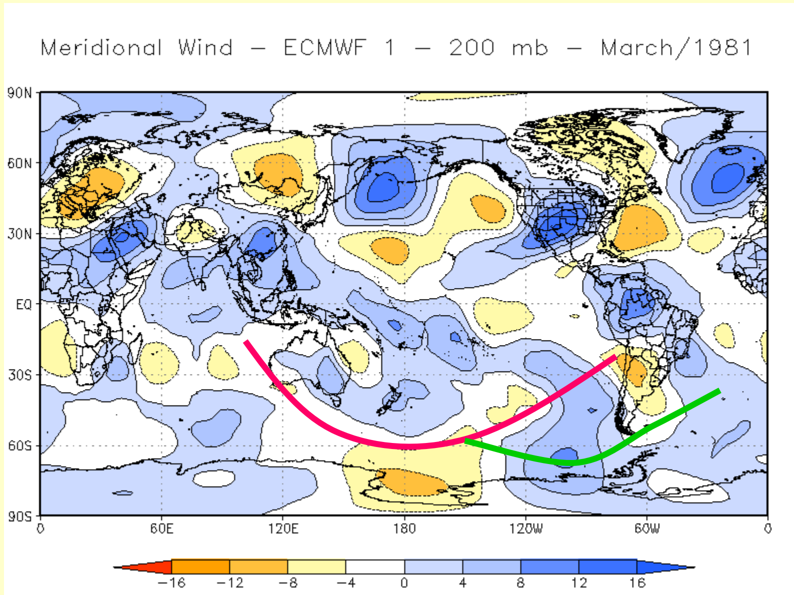
MEAN ZONAL WIND, 250 hPa, DJF

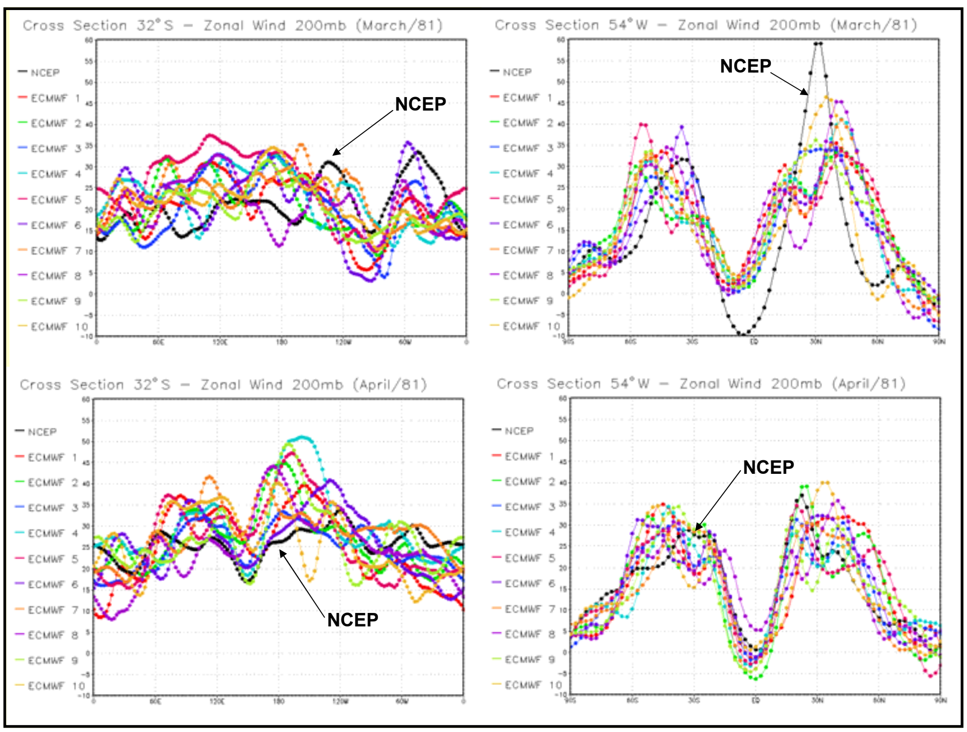


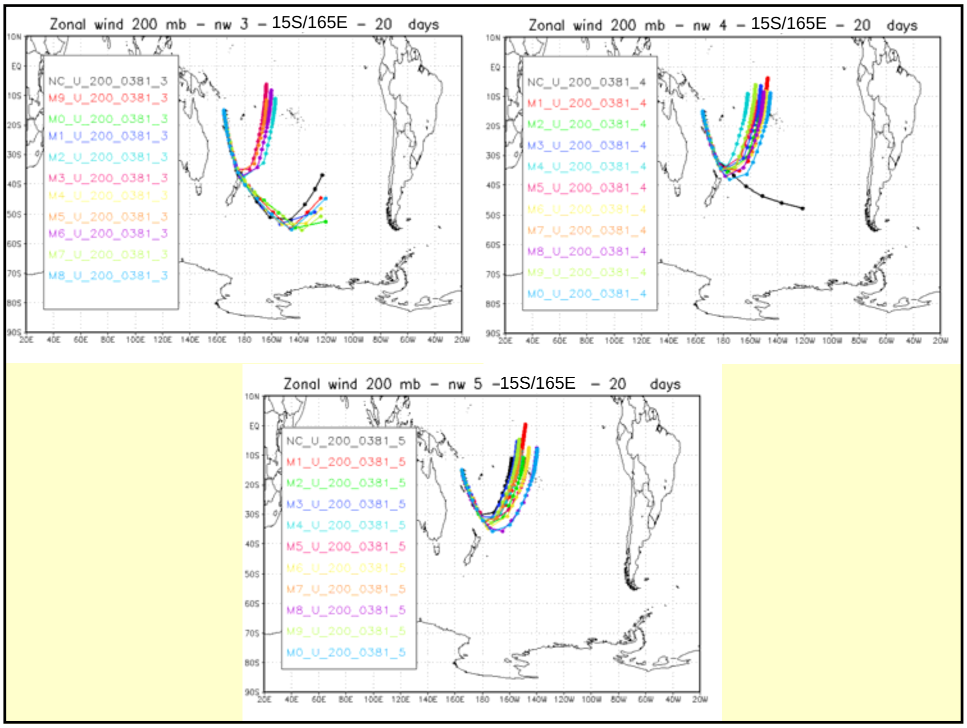
STREAMFUNCTION AND RAY TRACING FOR 4 EL NIÑO EVENTS

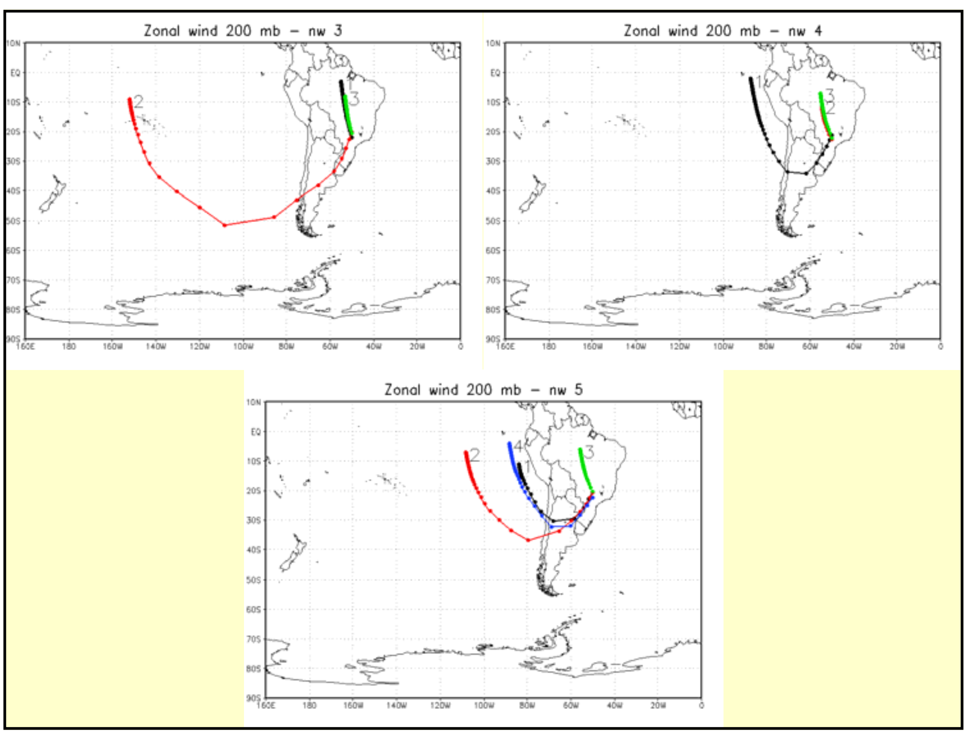


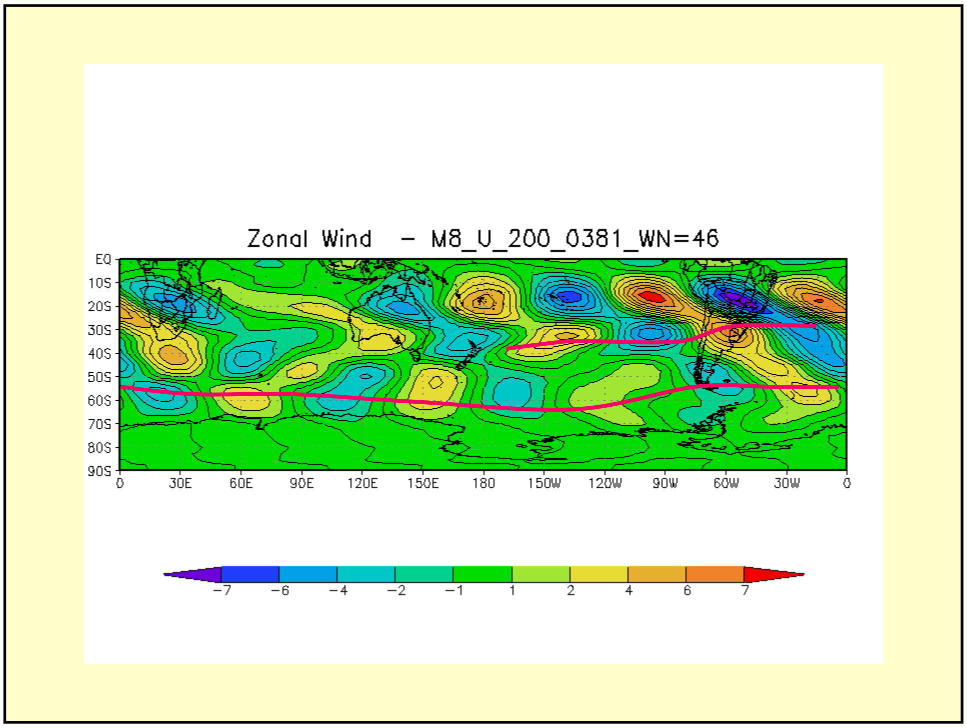


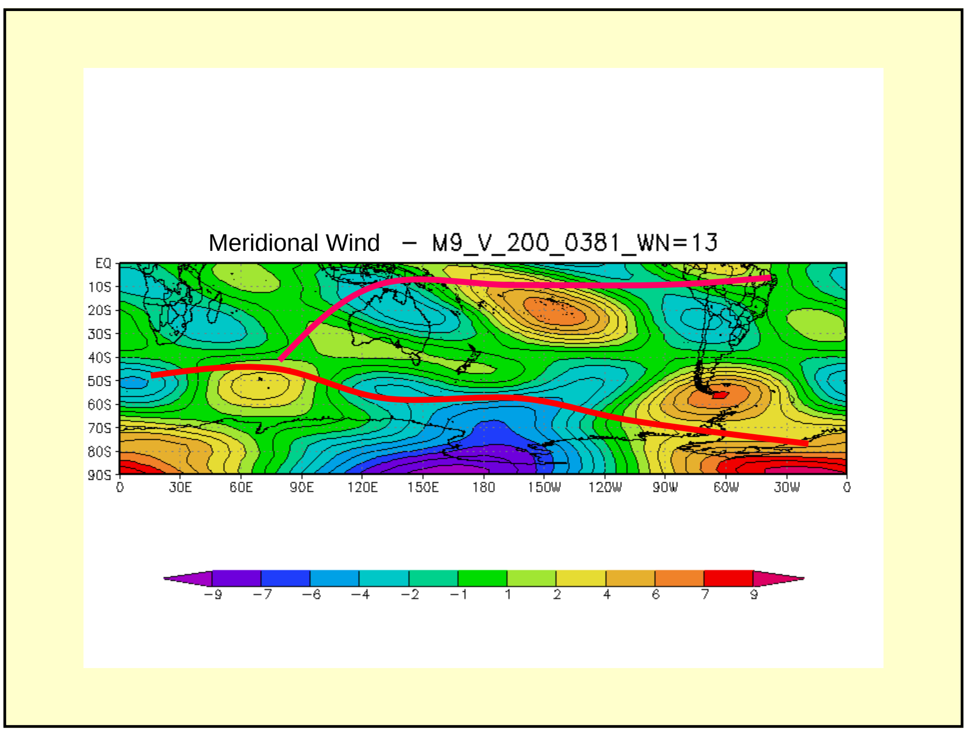

Meridional Wind – ECMWF 1 – 200 mb – March/1981
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−16
−12
−8
−4
0
4
8
12
16

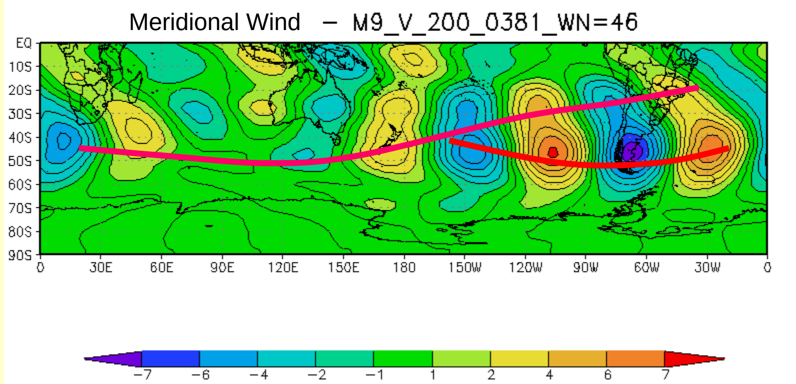

Cross Section 32°S – Zonal Wind 200mb (March/81)
Cross Section 54°W – Zonal Wind 200mb (March/81)
Cross Section 32°S – Zonal Wind 200mb (April/81)
Cross Section 54°W – Zonal Wind 200mb (April/81)
NCEP
ECMWF 1
ECMWF 2
ECMWF 3
ECMWF 4
ECMWF 5
ECMWF 6
ECMWF 7
ECMWF 8
ECMWF 9
ECMWF 10
NCEP
NCEP
NCEP
NCEP


Zonal wind 200 mb – nw 3 – 15S/165E – 20 days
NC_U_200_0381_3
M9_U_200_0381_3
M0_U_200_0381_3
M1_U_200_0381_3
M2_U_200_0381_3
M3_U_200_0381_3
M4_U_200_0381_3
M5_U_200_0381_3
M6_U_200_0381_3
M7_U_200_0381_3
M8_U_200_0381_3
Zonal wind 200 mb – nw 4 – 15S/165E – 20 days
NC_U_200_0381_4
M1_U_200_0381_4
M2_U_200_0381_4
M3_U_200_0381_4
M4_U_200_0381_4
M5_U_200_0381_4
M6_U_200_0381_4
M7_U_200_0381_4
M8_U_200_0381_4
M9_U_200_0381_4
M0_U_200_0381_4
Zonal wind 200 mb – nw 5 –15S/165E – 20 days
NC_U_200_0381_5
M1_U_200_0381_5
M2_U_200_0381_5
M3_U_200_0381_5
M4_U_200_0381_5
M5_U_200_0381_5
M6_U_200_0381_5
M7_U_200_0381_5
M8_U_200_0381_5
M9_U_200_0381_5
M0_U_200_0381_5


Zonal wind 200 mb – nw 3
Zonal wind 200 mb – nw 4
Zonal wind 200 mb – nw 5


Zonal Wind – M8_U_200_0381_WN=46
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
−7 −6 −4 −2 −1 1 2 4 6 7


Meridional Wind – M9_V_200_0381_WN=13
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
0 30E 60E 90E 120E 150E 180 150W 120W 90W 60W 30W 0
−9 −7 −6 −4 −2 −1 1 2 4 6 7 9



EUROBRISA… "downscaling" with RegCM3

COMPARISON BETWEEN CPTEC AND RegCM3 SEASONAL FORECASTS AND CLIMATOLOGY

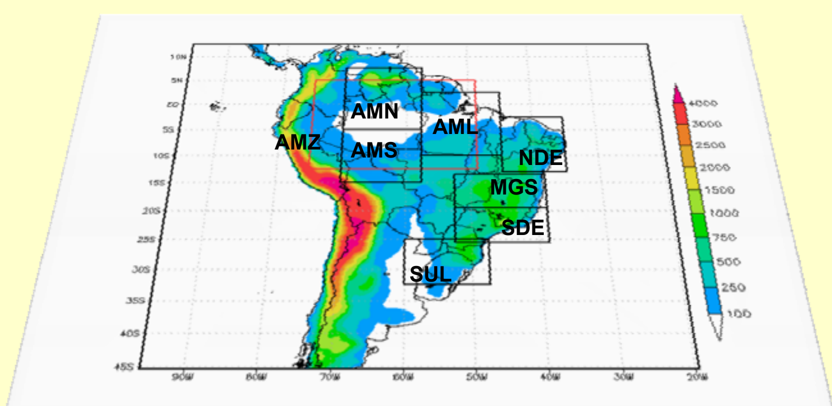
RegCM3 was initialized with CPTEC SEASONAL MODEL from JJA/2005 up to ASO/2007

RegCM3 MODEL CONFIGURATION

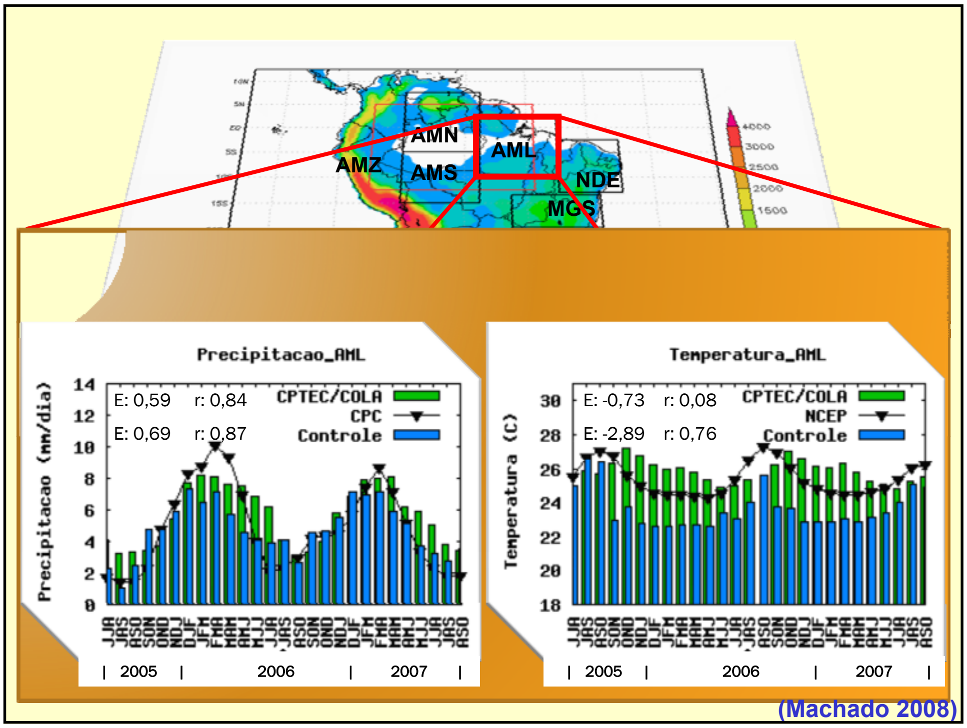
Characteristics		Configuration
Physics	Cumulus	Grell
	Radiation	CCM3
	Planetary Boundary Layer	Holstag
	Earth-Surface-Atmosphere	BATS
Vertical resolution		18 sigma levels
Horizontal resolution		60 km
Dynamics		Hidrostatic
Initial conditions and boundaries		CPTEC/COLA

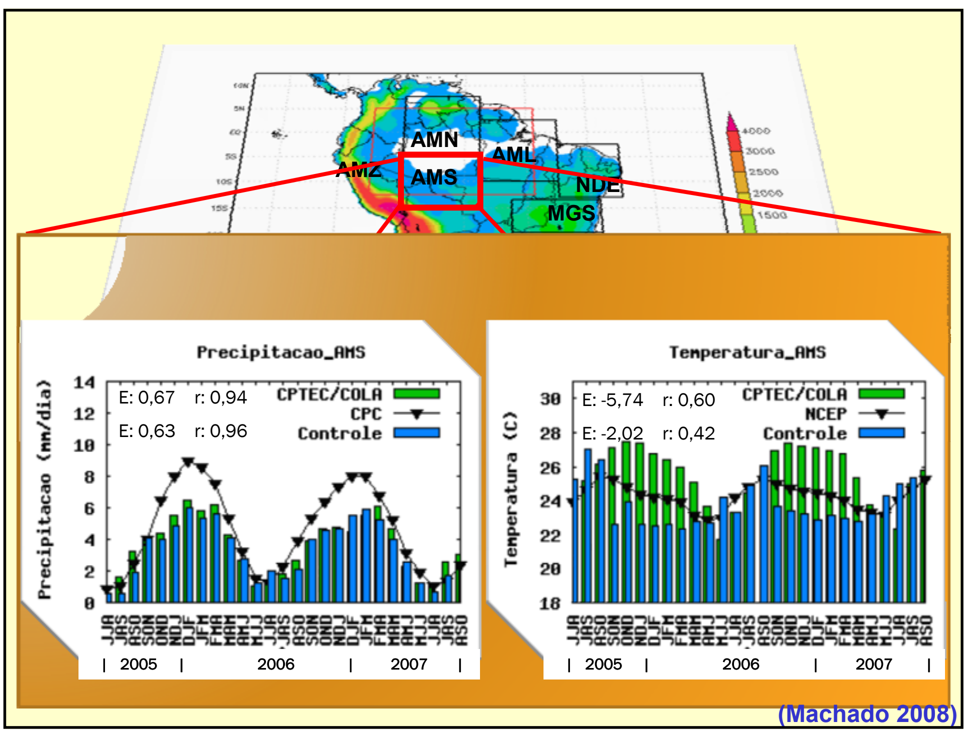
(Machado 2008)

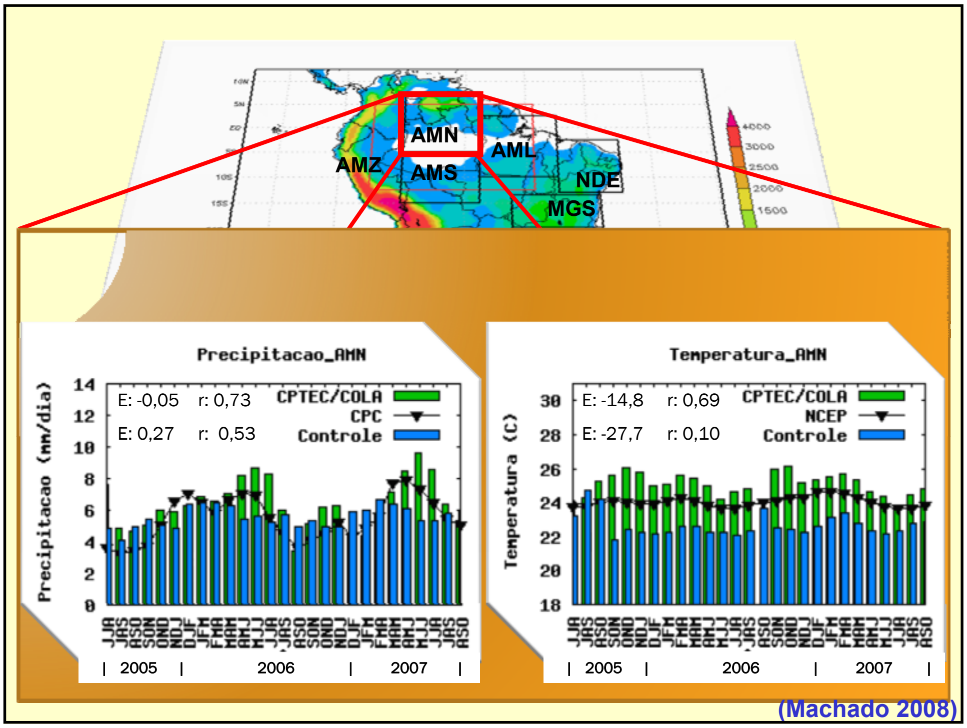
Topography, Domain and 8 sub-regions where the 3 months forecast from RegCM3 where compared with the CPTEC seasonal forecast model



(Machado 2008)


AMN
AML
AMZ
AMS
NDE
MGS
Precipitacao_AML
Precipitacao (mm/dia)
E: 0,59 r: 0,84
E: 0,69 r: 0,87
CPTEC/COLA
CPC
Controle
Temperatura_AML
Temperatura (C)
E: -0,73 r: 0,08
E: -2,89 r: 0,76
CPTEC/COLA
NCEP
Controle
2005
2006
2007
(Machado 2008)


AMN
AML
AMZ
AMS
NDE
MGS
Precipitacao_AMS
Precipitacao (mm/dia)
E: 0,67 r: 0,94
E: 0,63 r: 0,96
CPTEC/COLA
CPC
Controle
Temperatura_AMS
Temperatura (C)
E: -5,74 r: 0,60
E: -2,02 r: 0,42
CPTEC/COLA
NCEP
Controle
2005
2006
2007
(Machado 2008)


AMN
AML
AMZ
AMS
NDE
MGS
Precipitacao_AMN
Precipitacao (mm/dia)
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E: 0,27 r: 0,53
CPTEC/COLA
CPC
Controle
Temperatura_AMN
Temperatura (C)
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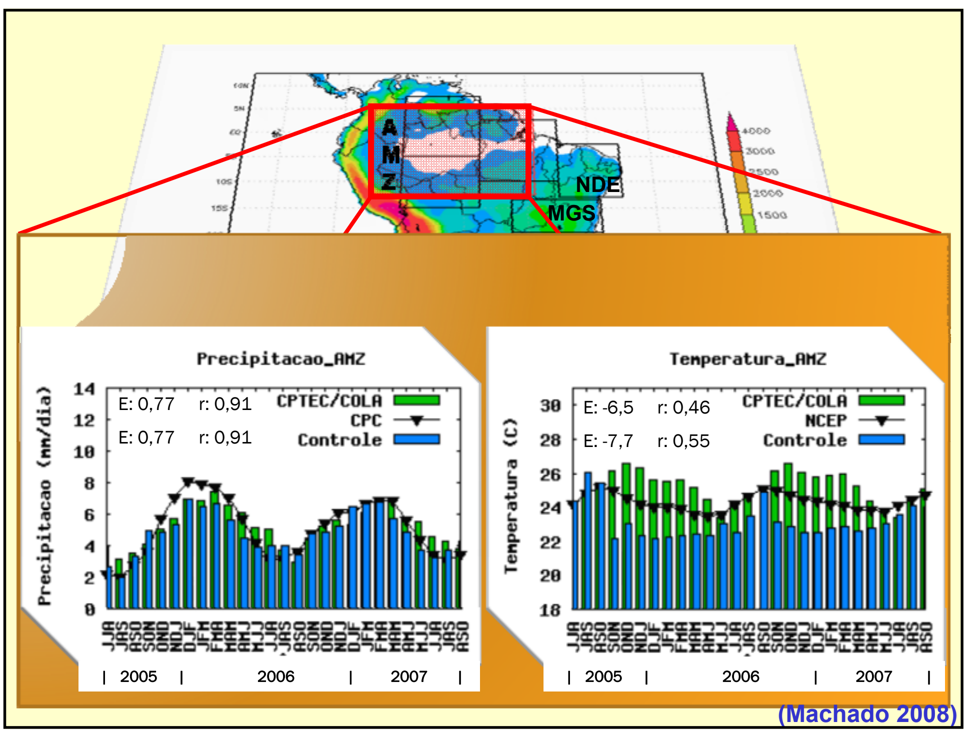
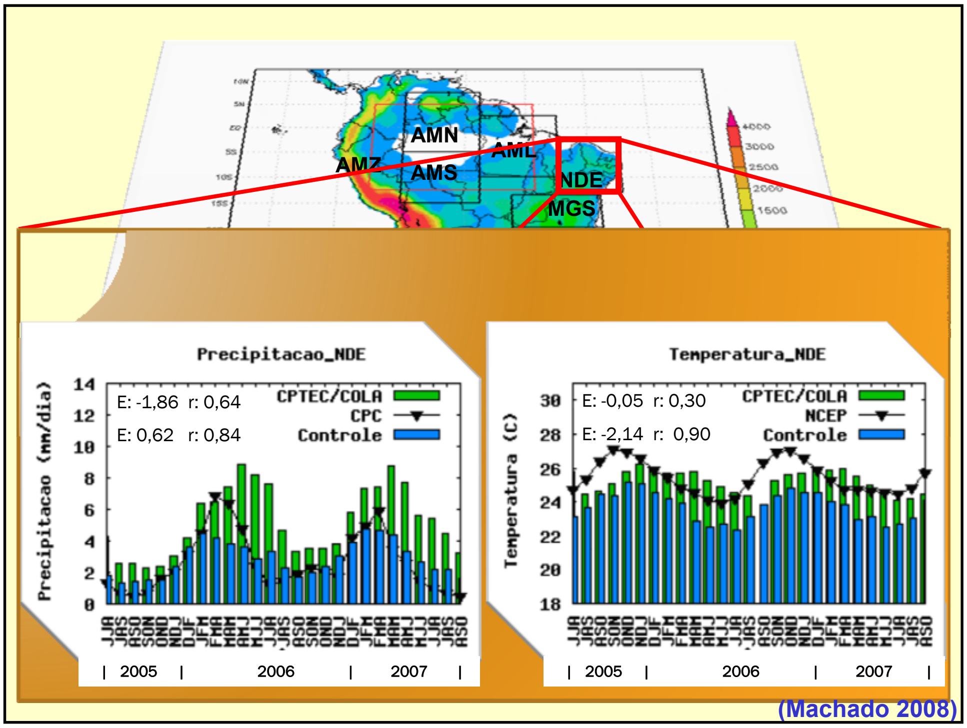
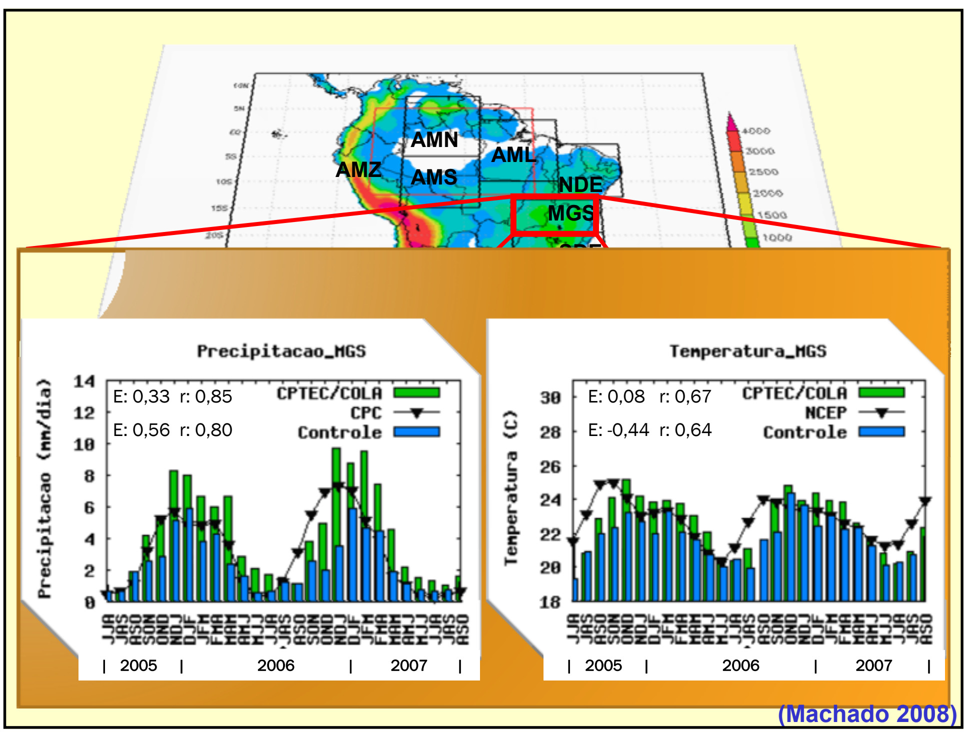
E: -27,7 r: 0,10
CPTEC/COLA
NCEP
Controle
2005
2006
2007
(Machado 2008)


A
M
Z
NDE
MGS
Precipitacao_AMZ
Precipitacao (mm/dia)
E: 0,77 r: 0,91
E: 0,77 r: 0,91
CPTEC/COLA
CPC
Controle
Temperatura_AMZ
Temperatura (C)
E: -6,5 r: 0,46
E: -7,7 r: 0,55
CPTEC/COLA
NCEP
Controle
2005
2006
2007
(Machado 2008)


AMN
AML
AMZ
AMS
NDE
MGS
Precipitacao_NDE
E: -1,86 r: 0,64
E: 0,62 r: 0,84
CPTEC/COLA
CPC
Controle
Precipitacao (mm/dia)
2005
2006
2007
Temperatura_NDE
E: -0,05 r: 0,30
E: -2,14 r: 0,90
CPTEC/COLA
NCEP
Controle
Temperatura (C)
(Machado 2008)


AMN
AML
AMZ
AMS
NDE
MGS
Precipitacao_MGS
E: 0,33 r: 0,85
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CPTEC/COLA
CPC
Controle
Precipitacao (mm/dia)
2005
2006
2007
Temperatura_MGS
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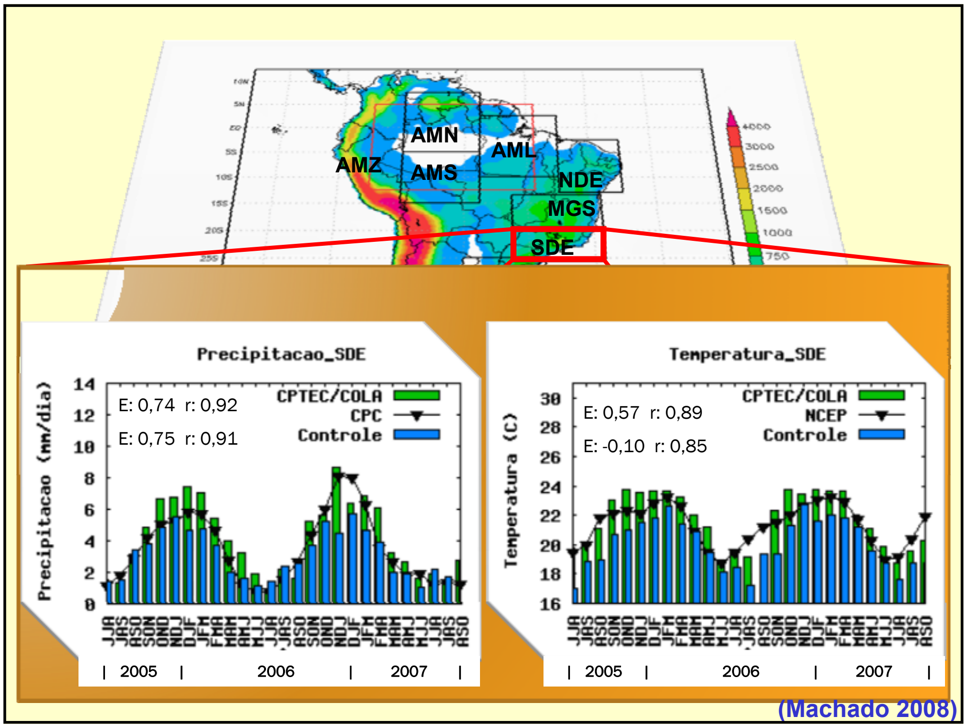
CPTEC/COLA
NCEP
Controle
Temperatura (C)
(Machado 2008)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AML
AMZ
AMS
NDE
MGS
SDE
Precipitacao_SDE
Precipitacao (mm/dia)
E: 0,74 r: 0,92
E: 0,75 r: 0,91
CPTEC/COLA
CPC
Controle
2005
2006
2007
Temperatura_SDE
Temperatura (C)
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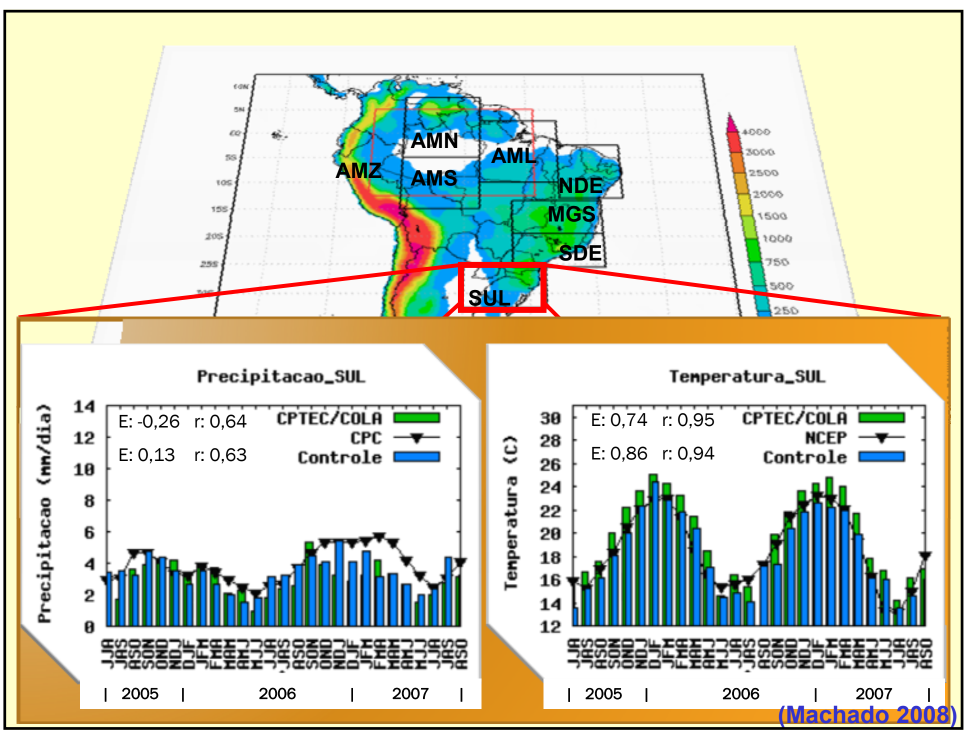
CPTEC/COLA
NCEP
Controle
(Machado 2008)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AMS
NDE
MGS
SDE
SUL
Precipitacao_SUL
Precipitacao (mm/dia)
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E: 0,13 r: 0,63
CPTEC/COLA
CPC
Controle
2005
2006
2007
Temperatura_SUL
Temperatura (C)
E: 0,74 r: 0,95
E: 0,86 r: 0,94
CPTEC/COLA
NCEP
Controle
(Machado 2008)

APEC Climate Center

Thanks to Dr. Saji N. Hameed and the APEC Climate Center for the invitation.

GrEC USP

GRUPO DE ESTUDOS CLIMÁTICOS

CLIMATE STUDIES GROUP

THANK YOU FOR YOUR ATTENTION

GRACIAS POR SU ATENCIÓN