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

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

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

Some characteristics of Rossby waves are:

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

The group velocity is given by:

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

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

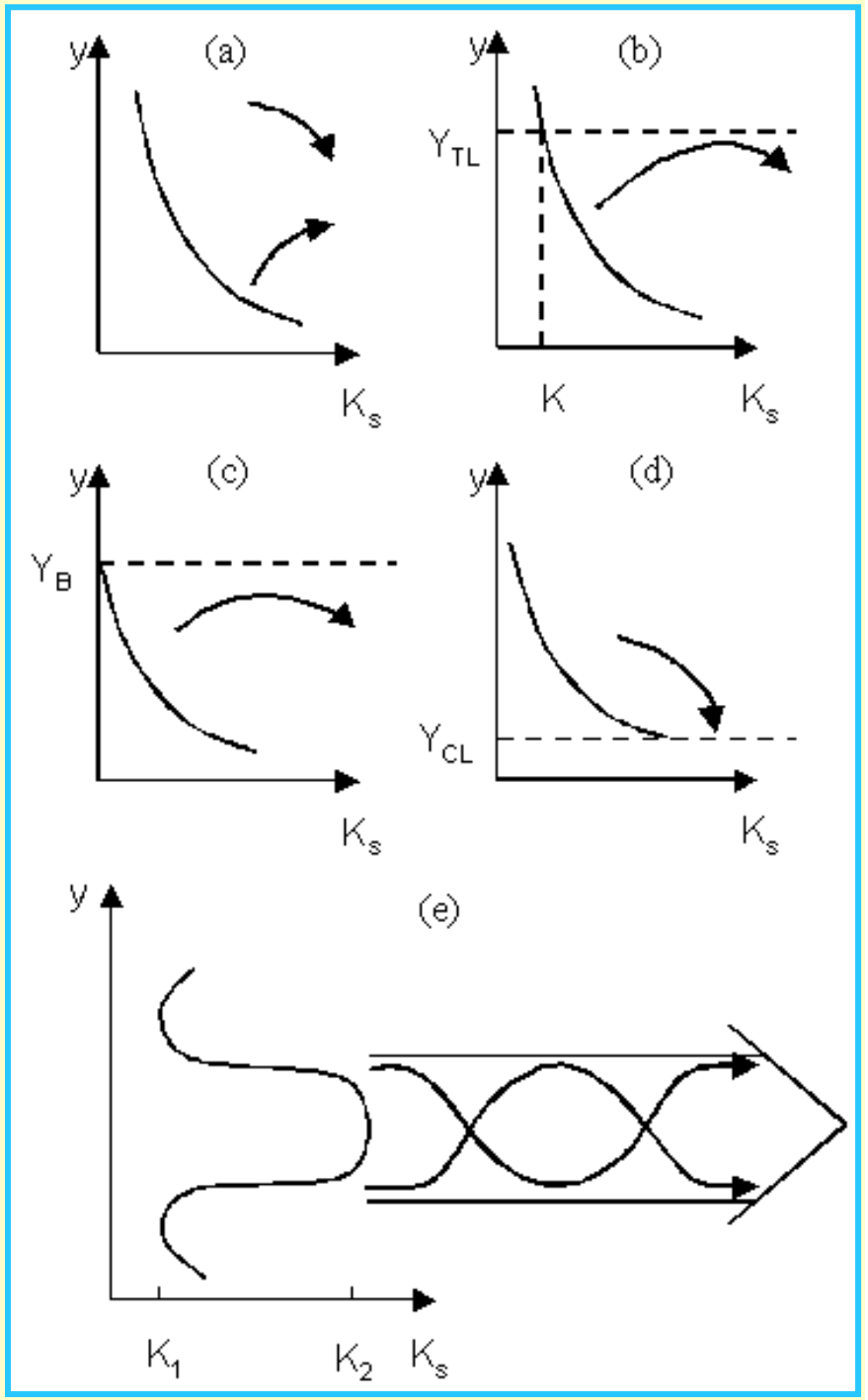
(b) Reflection from a turning latitude Y_{TL}, at which $K_s = k$

(c) Reflection of all wavenumbers before a latitude Y_B at which $\beta^* = 0$

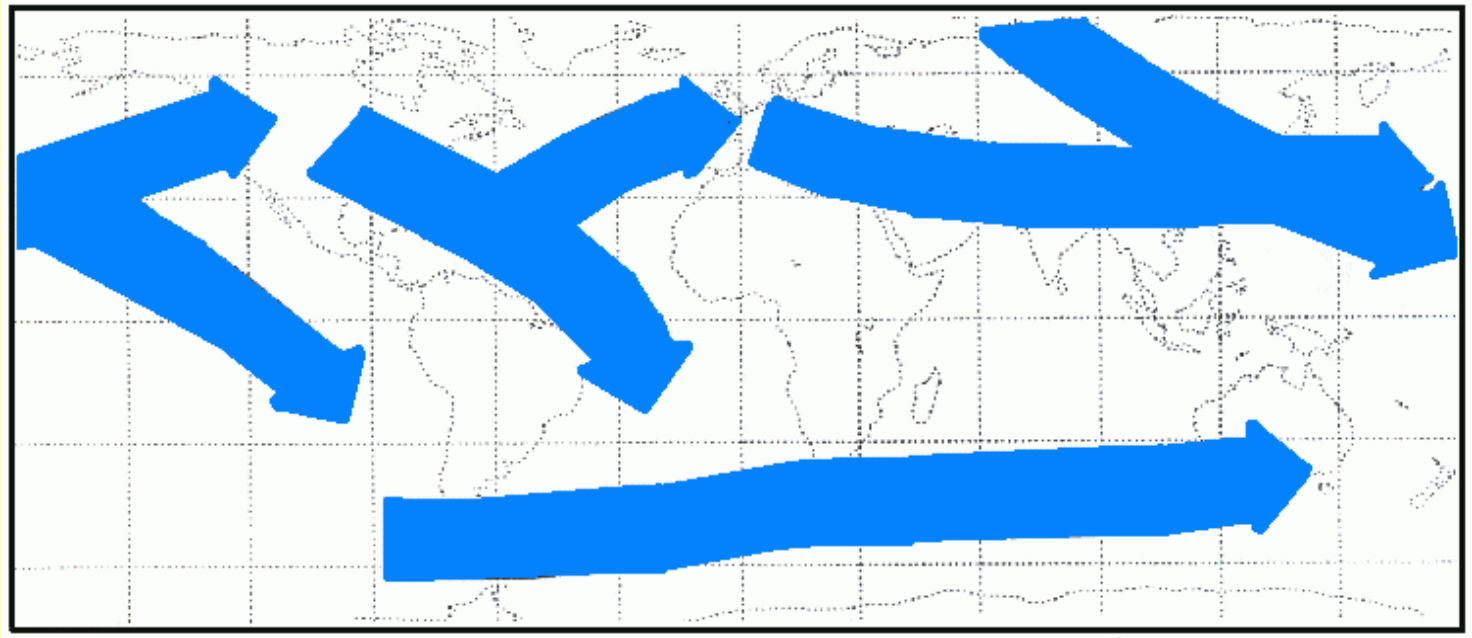
(d) Refraction into a critical latitude Y_{CL} at which U = 0

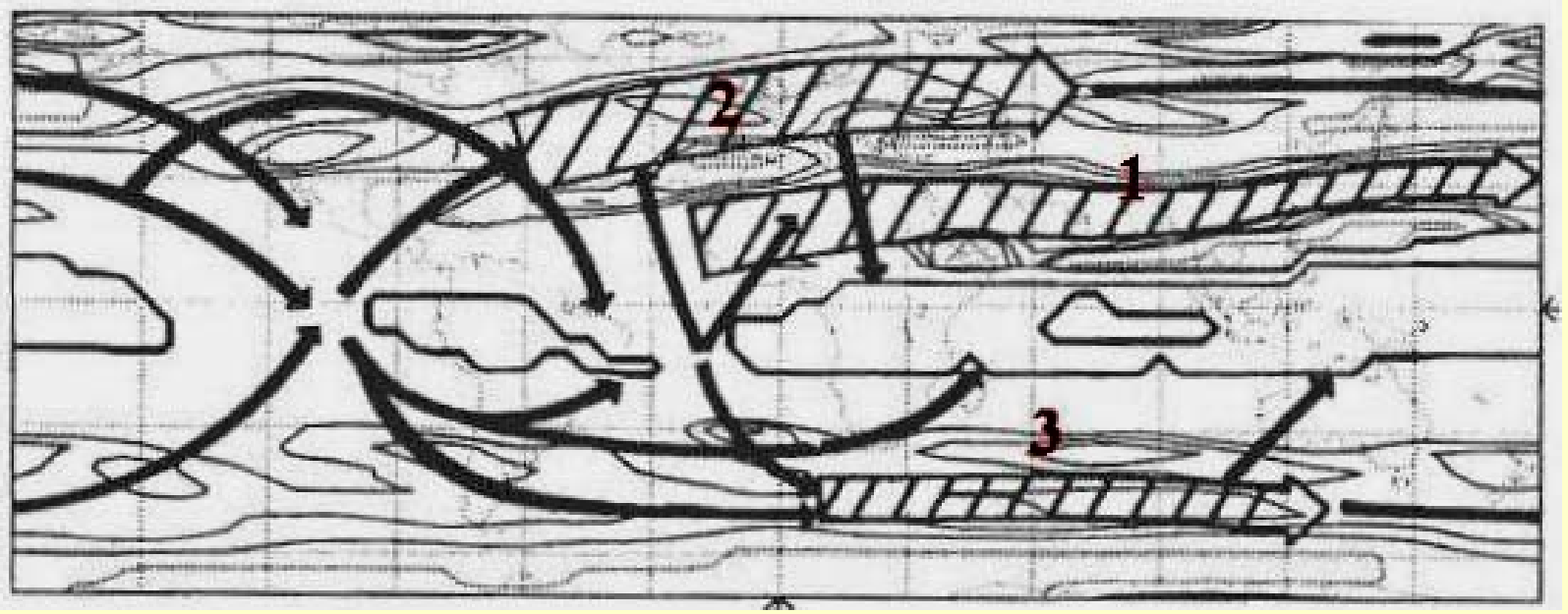
(e) waveguide effect of a K_s maximum.

(Hoskins e Ambrizzi 1993)

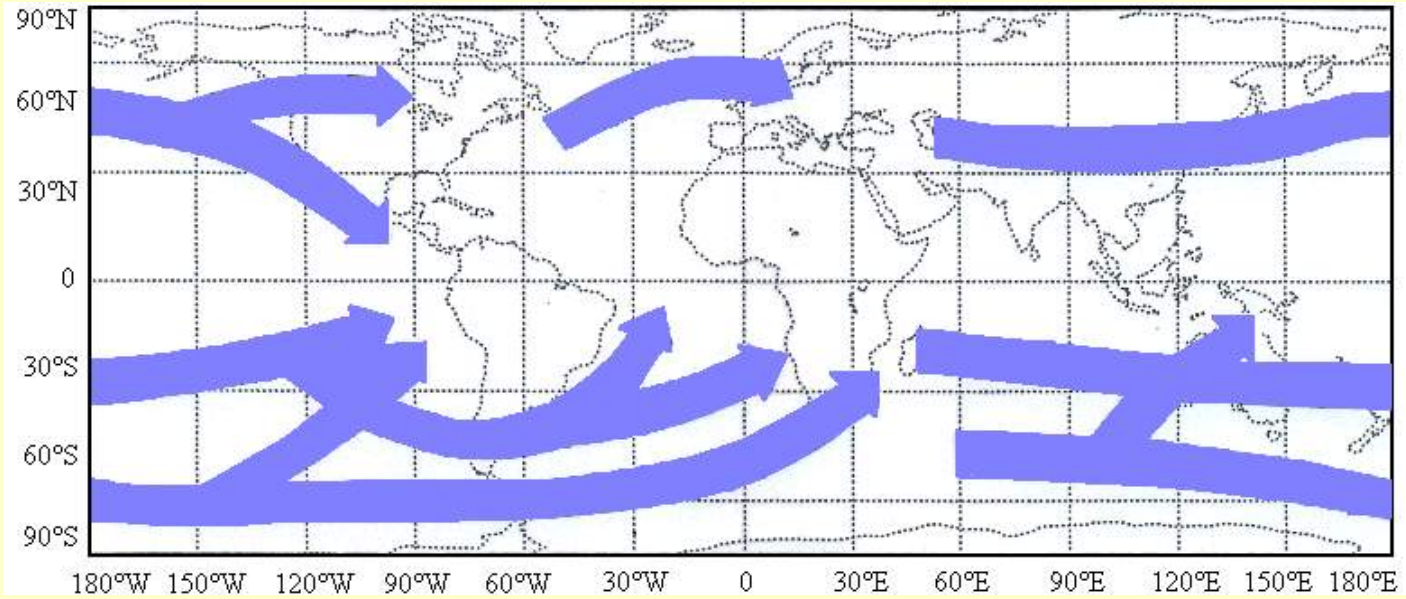


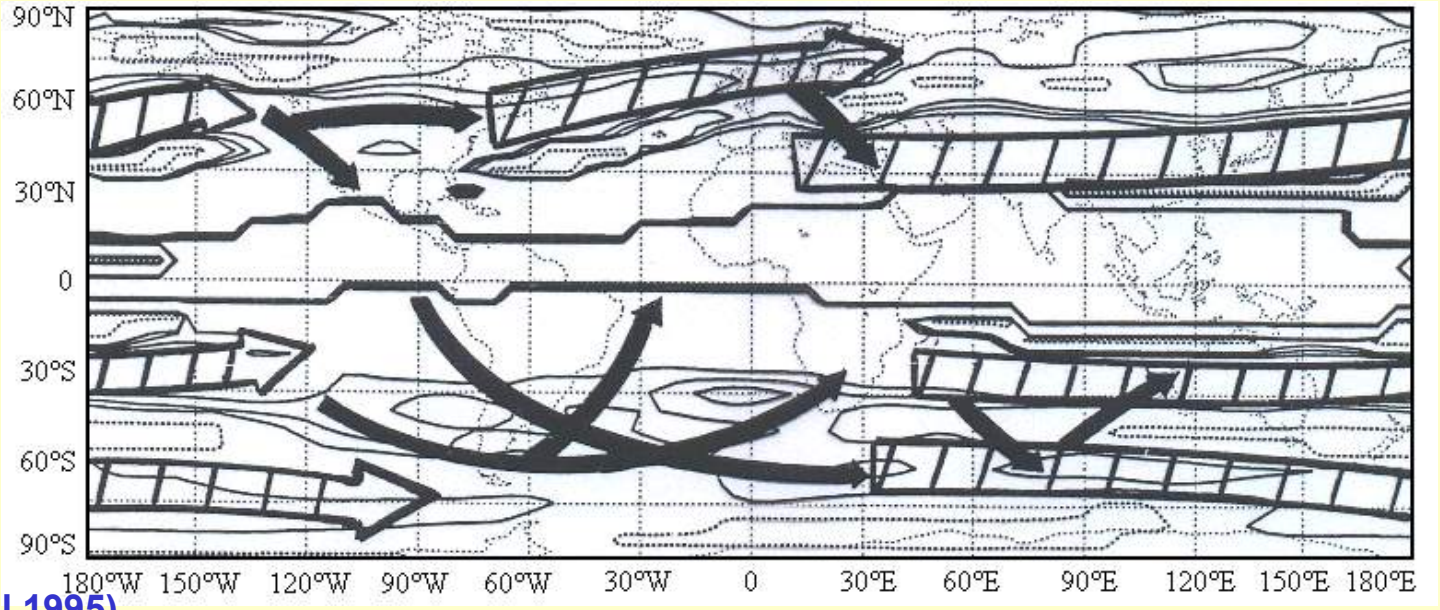
Main teleconnection patterns obtained from observational analysis and numerical modeling - DJF





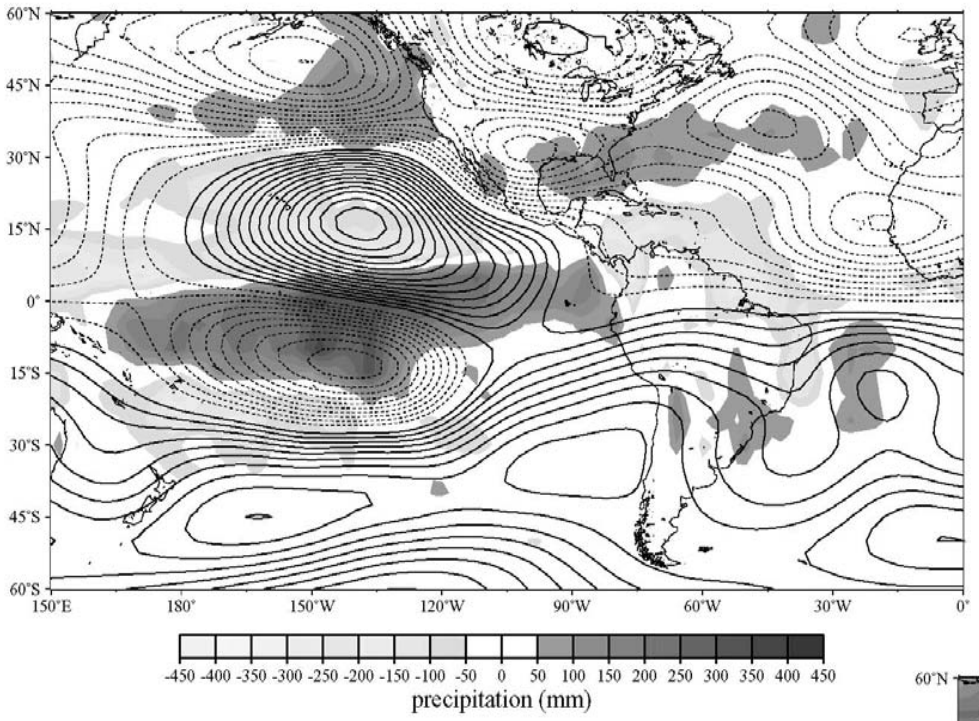
Main teleconnection patterns obtained from observational analysis and numerical modeling - JJA



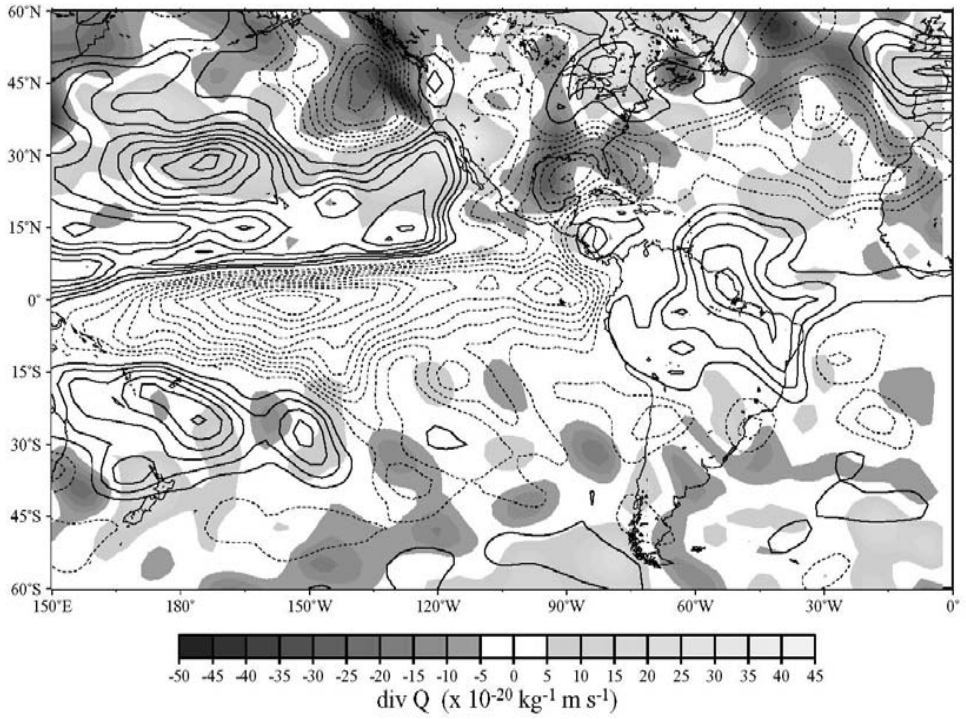


(Ambrizzi et al 1995)

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



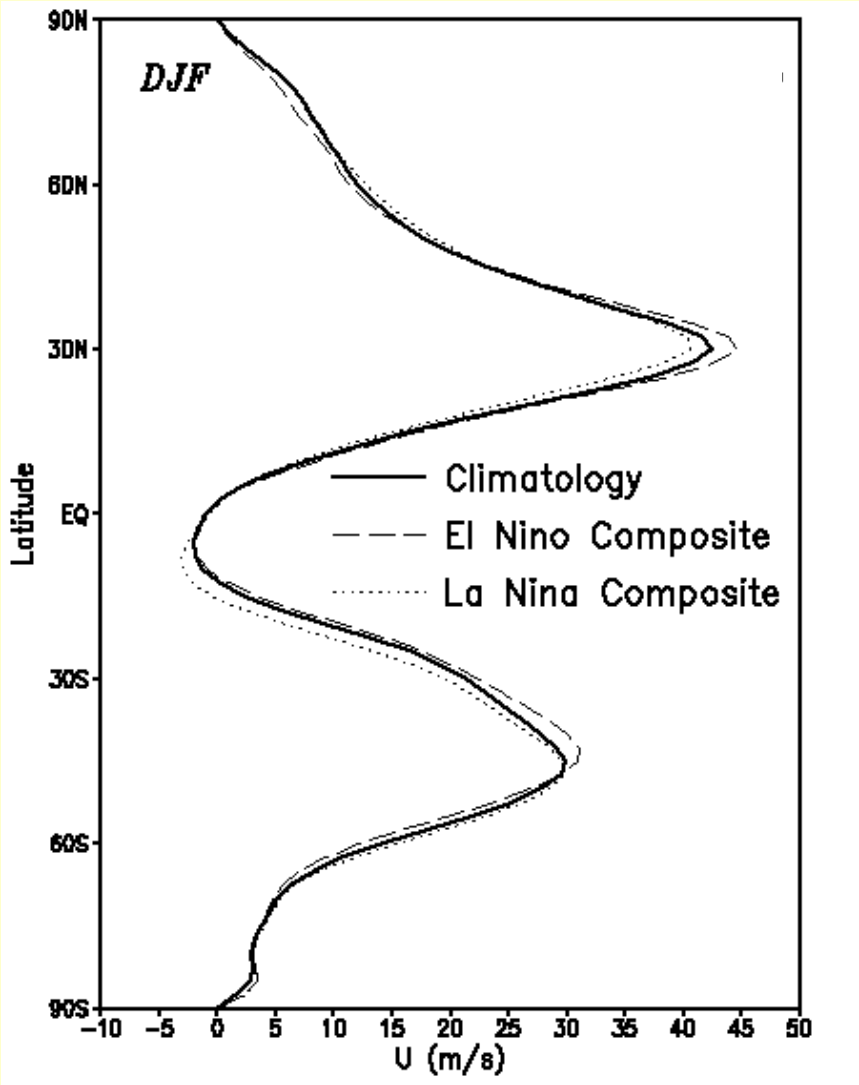
Anomaly of Ψ and precipitation

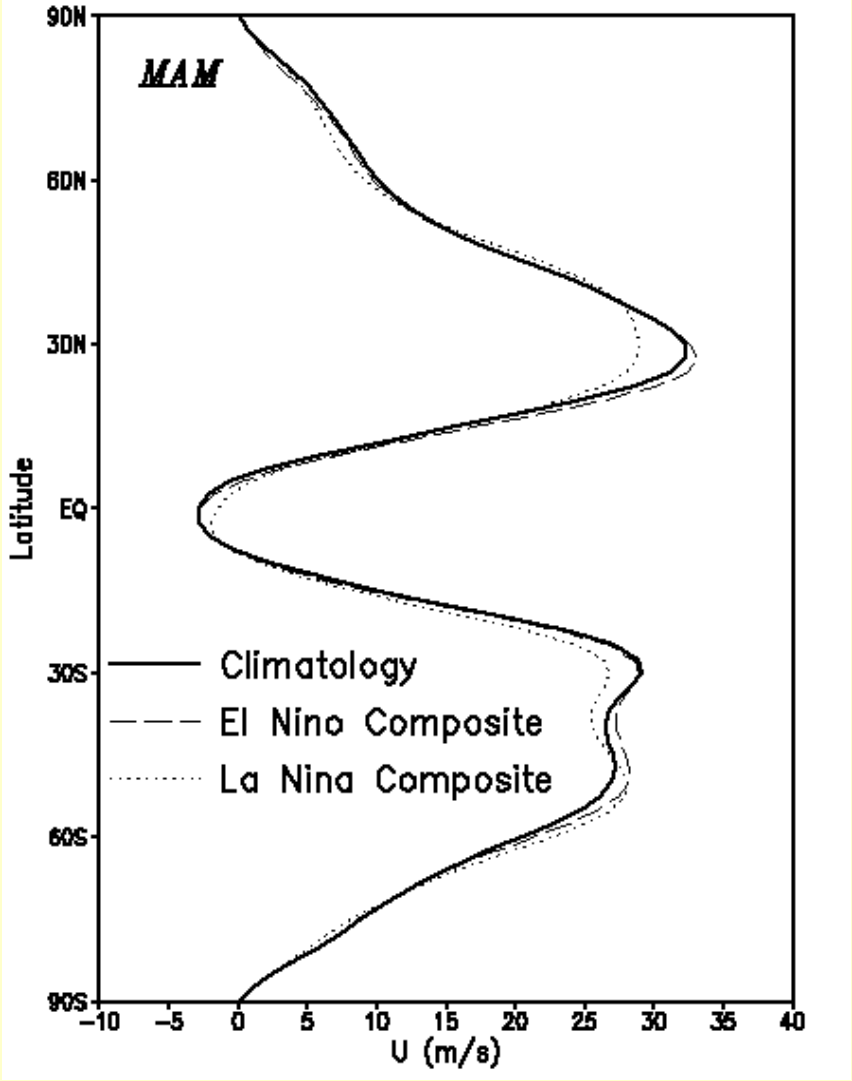


Div of Q anomaly of omega

(Magaña e Ambrizzi, 2005)

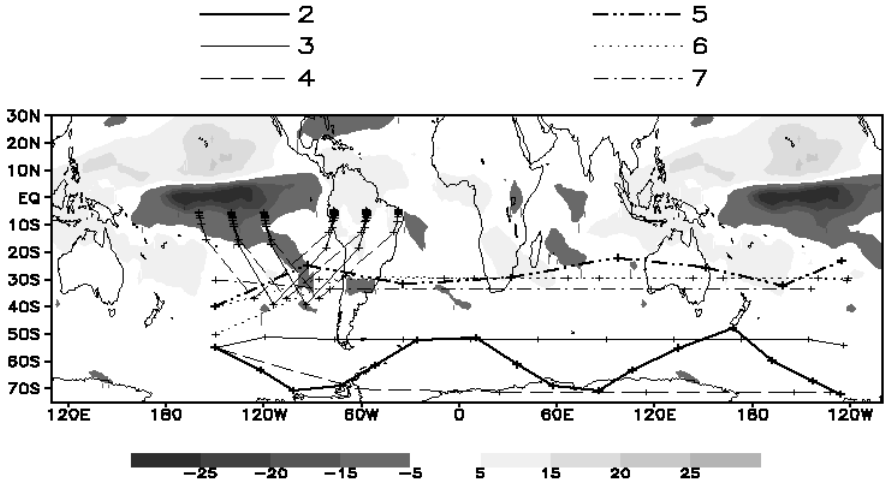
ZONAL WIND - U


DJF
90N
60N
30N
EQ
30S
60S
90S
Latitude
Climatology
El Nino Composite
La Nina Composite
−10 −5 0 5 10 15 20 25 30 35 40 45 50
U (m/s)

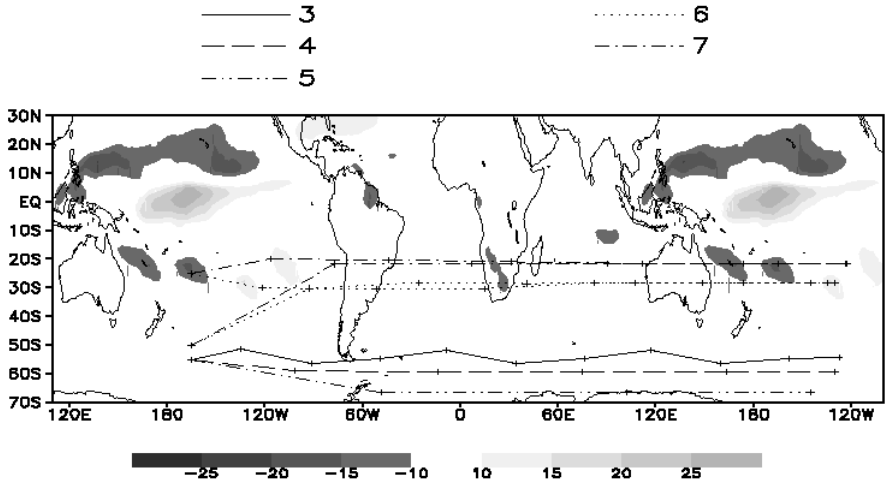

MAM
90N
60N
30N
EQ
30S
60S
90S
Latitude
Climatology
El Nino Composite
La Nina Composite
−10 −5 0 5 10 15 20 25 30 35 40
U (m/s)

RAY TRACING FOR EL NIÑO/LA NIÑA

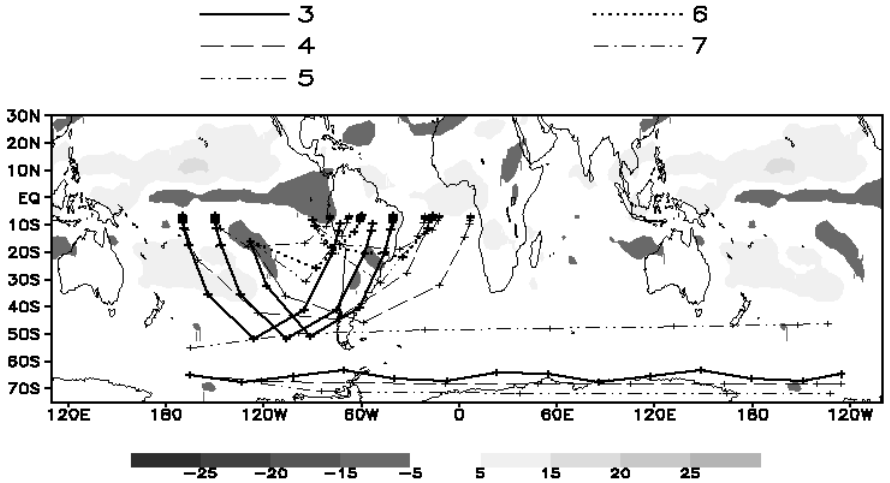
(EN/DJF)



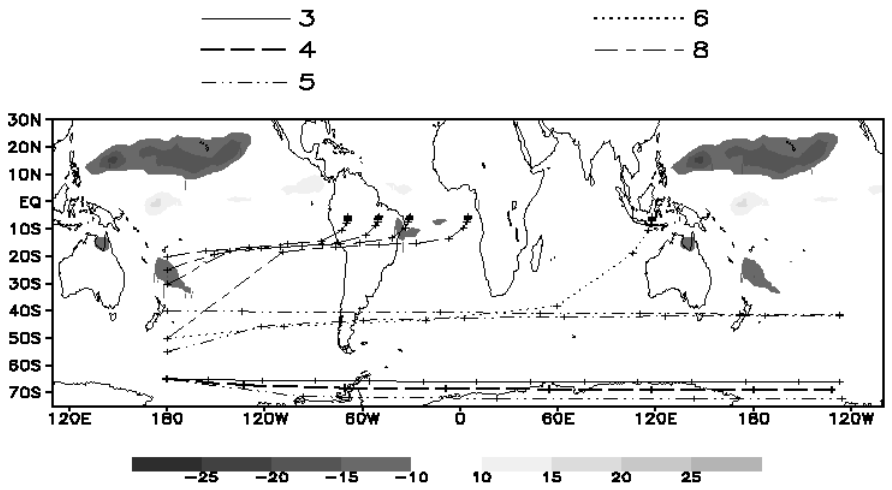
(LN/DJF)



(EN/MAM)

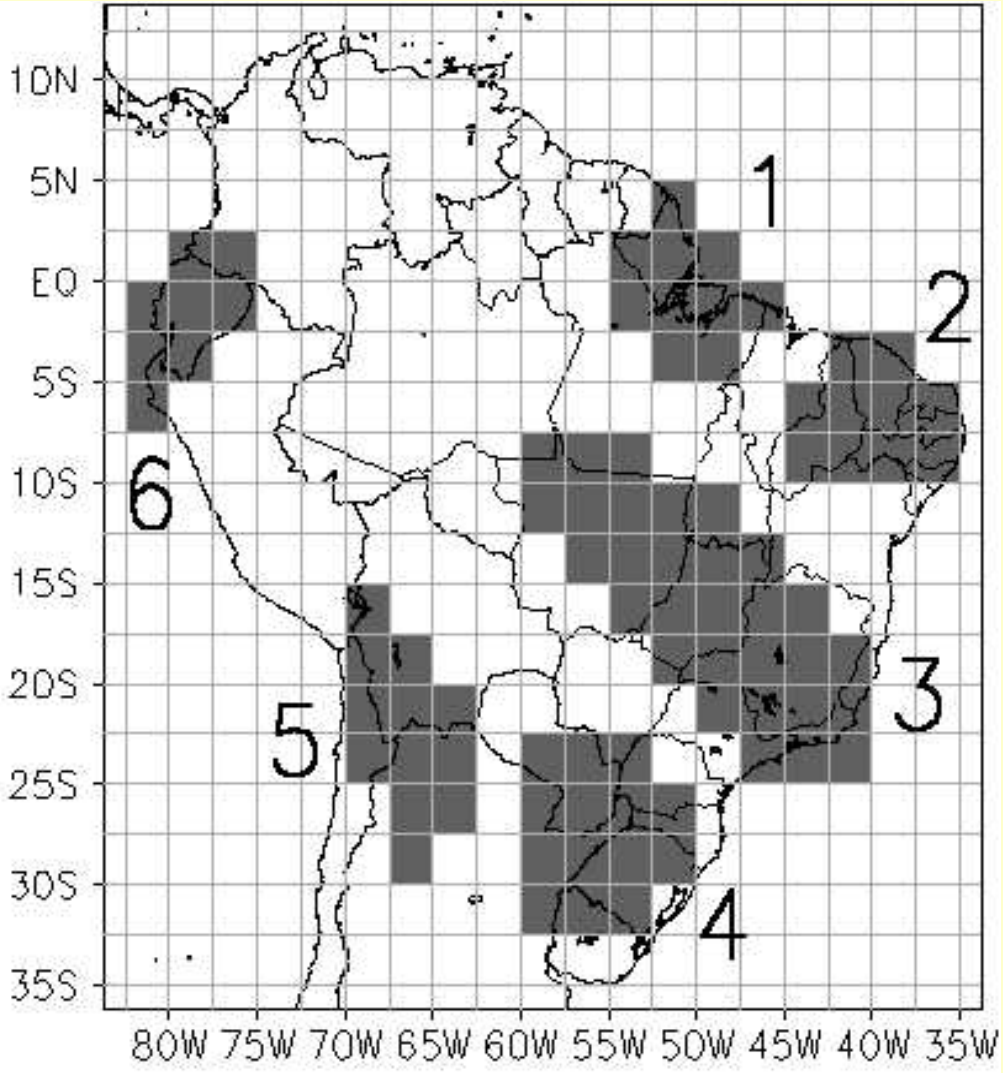


(LN/MAM)



(Coelho, 2001)

ENSO episodes and the South American Regional Precipitation



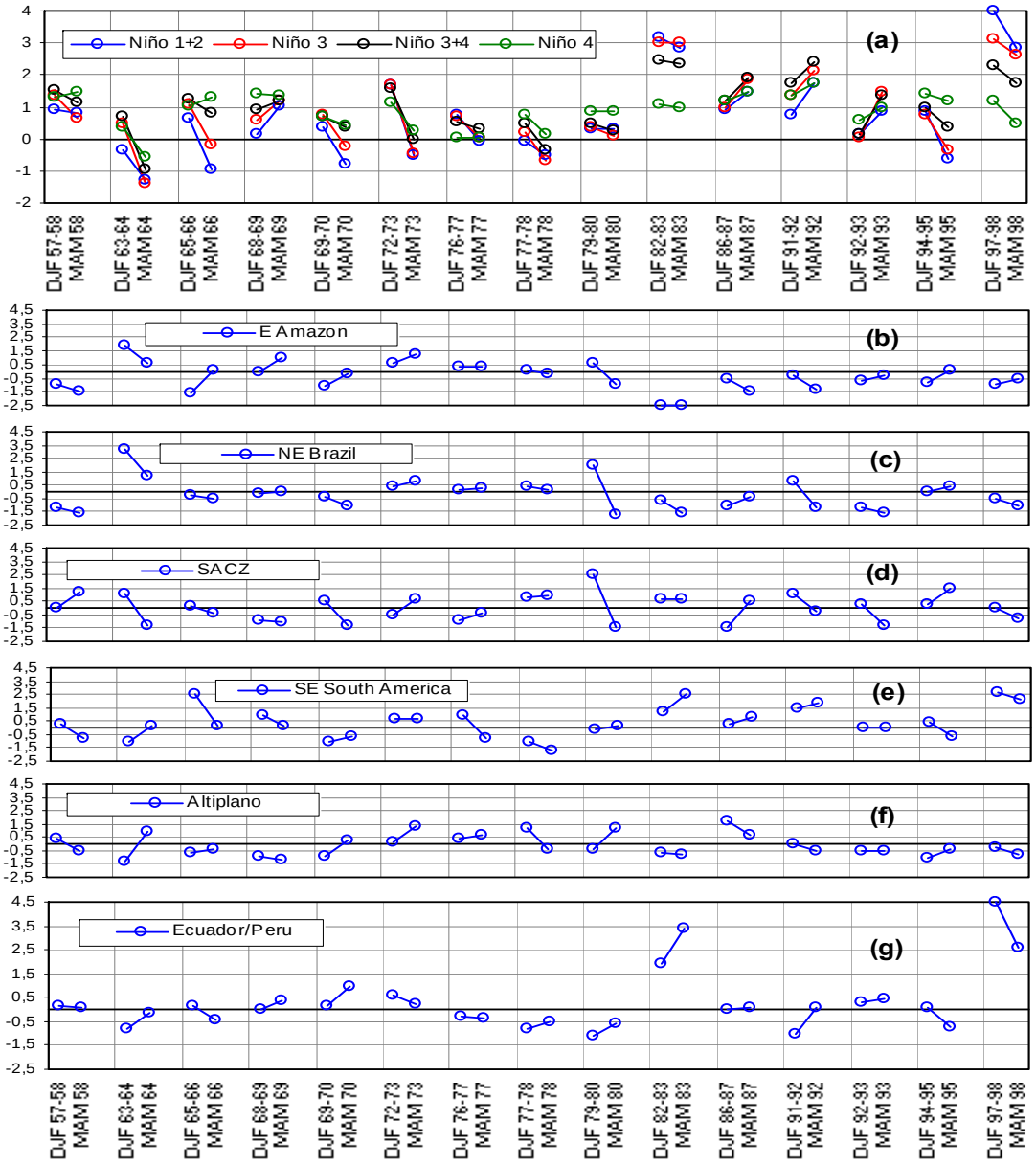
Seasonal Standardized index for the austral summer (DJF) and autumn (MAM)

$$I = (X_i - \overline{X_i})/\sigma_i$$

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

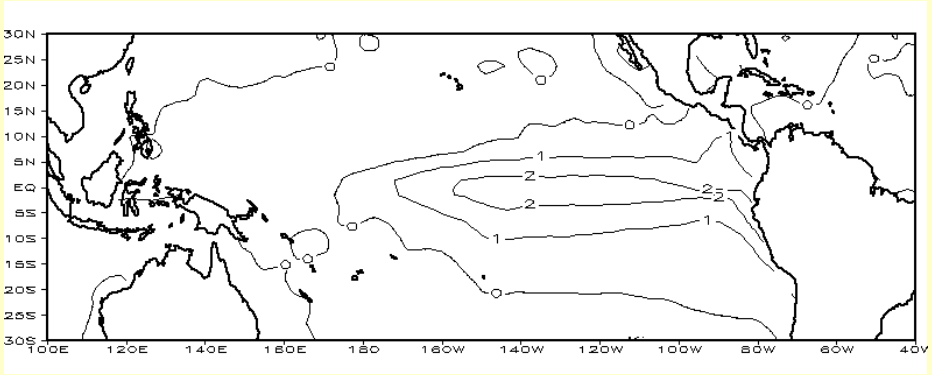
SACZ

SE South America

Altiplano

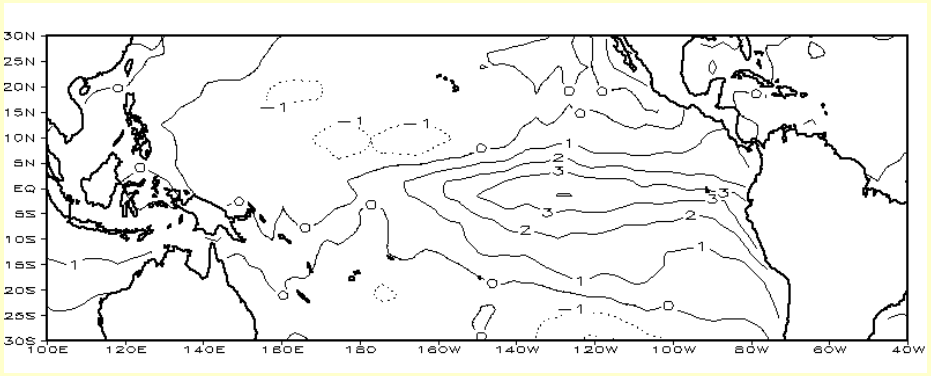
Equator Peru

SSTs for 4 EL NIÑO EVENTS

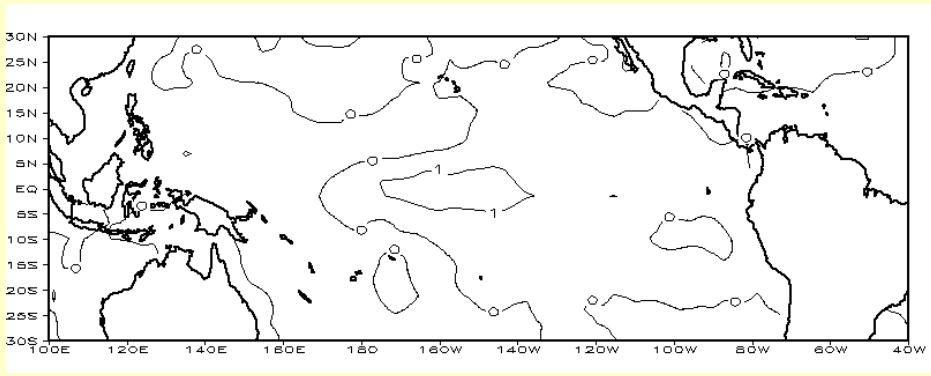


Average for 4 events

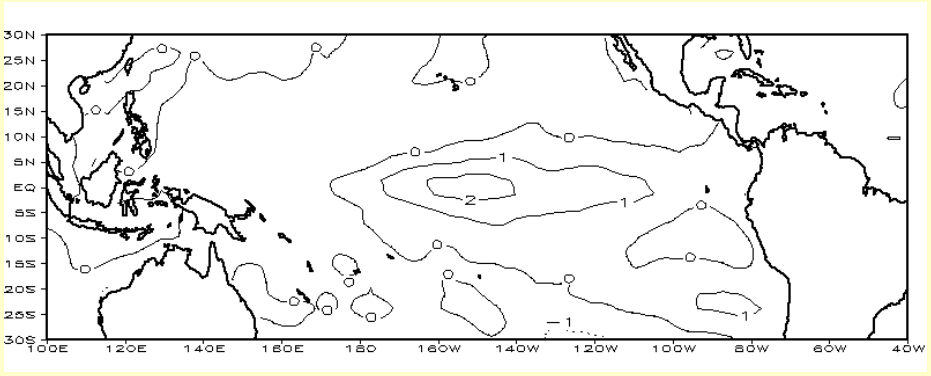
El Niño 82/83



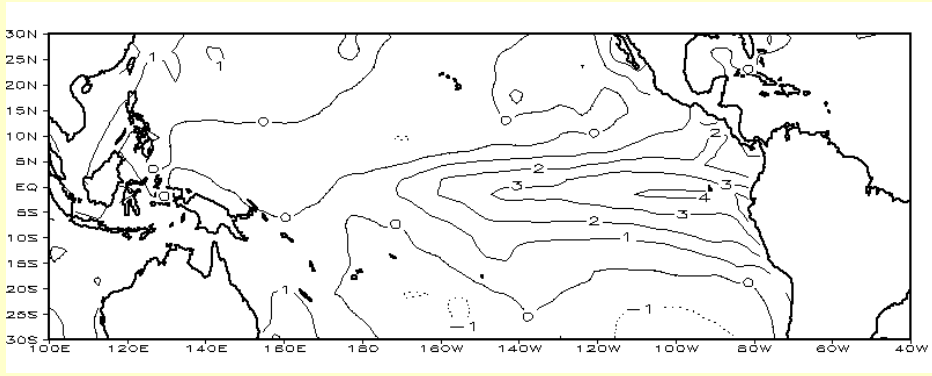
El Niño 86/87



El Niño 91/92

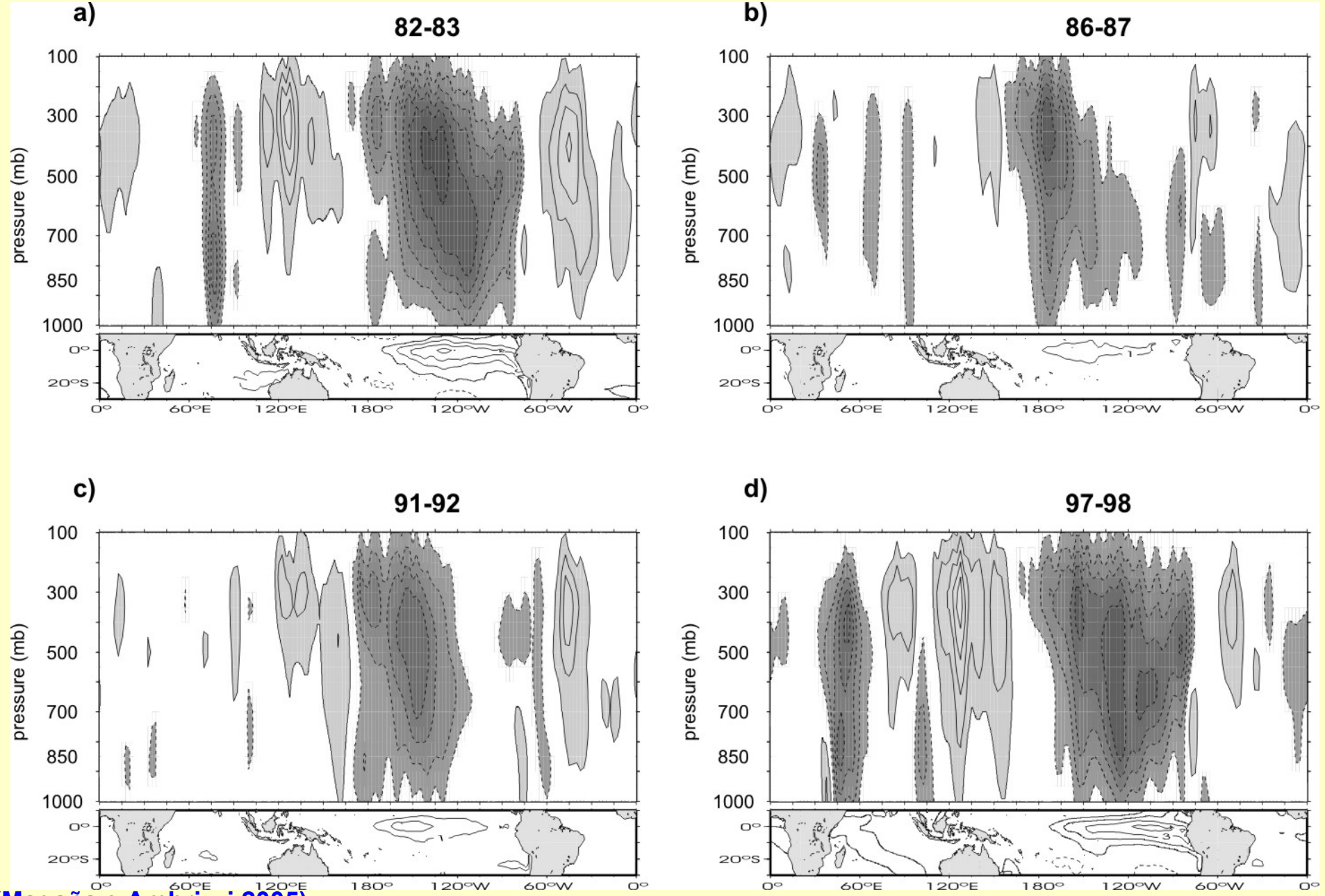


El Niño 97/98



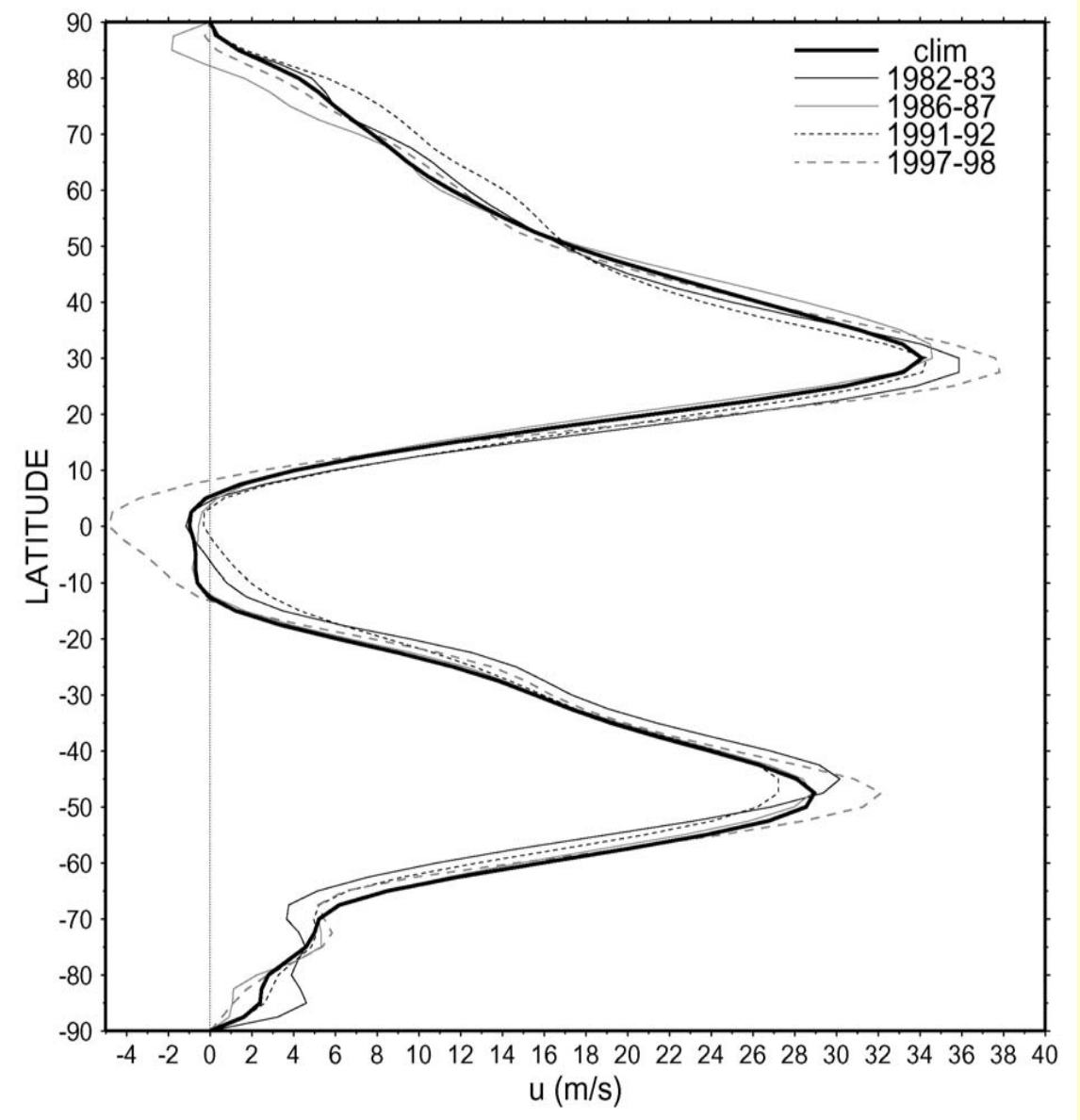
(Drumond e Ambrizzi, 2003)

OMEGA ANOMALY

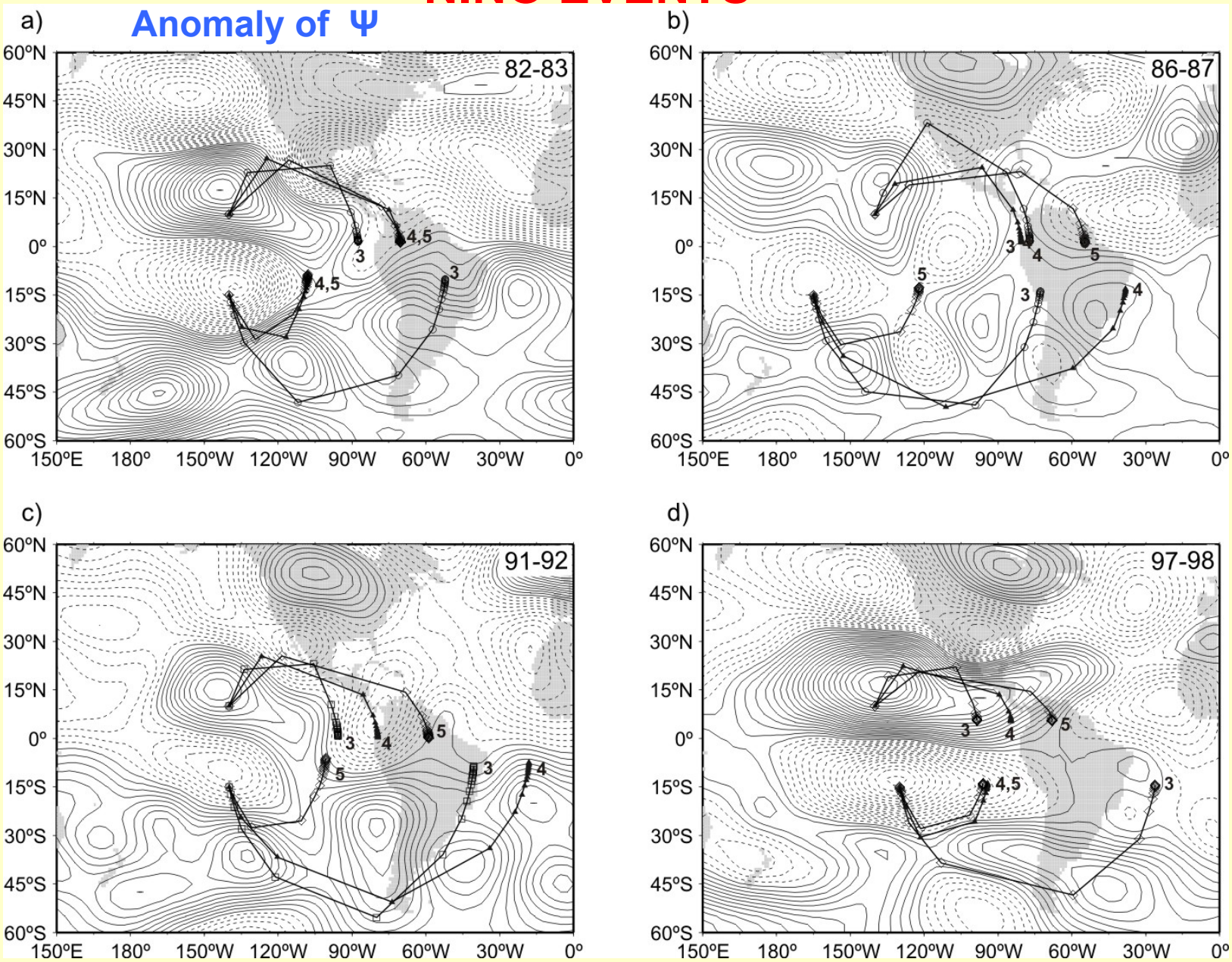


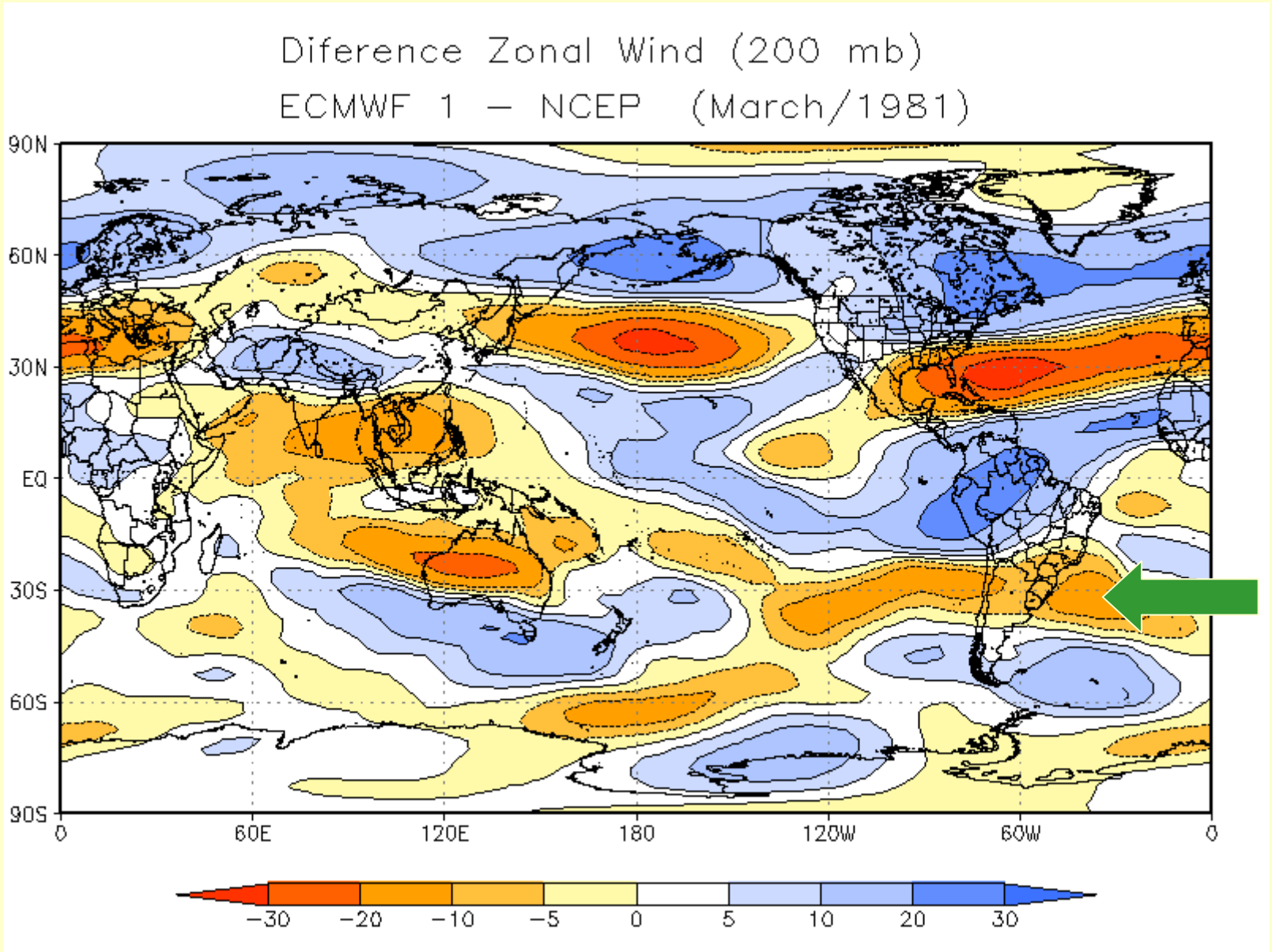
(Magaña e Ambrizzi 2005)

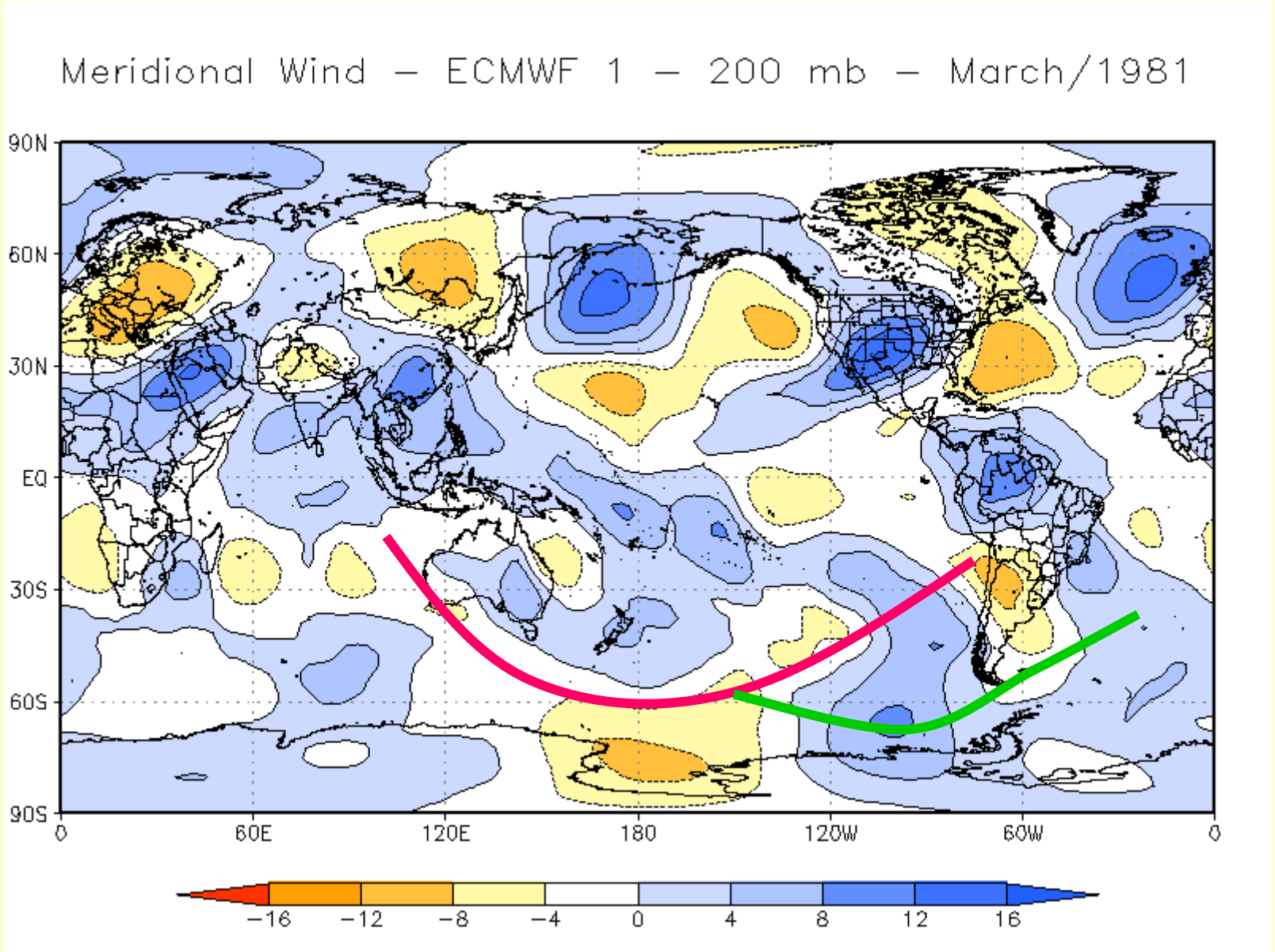
MEAN ZONAL WIND, 250 hPa, DJF

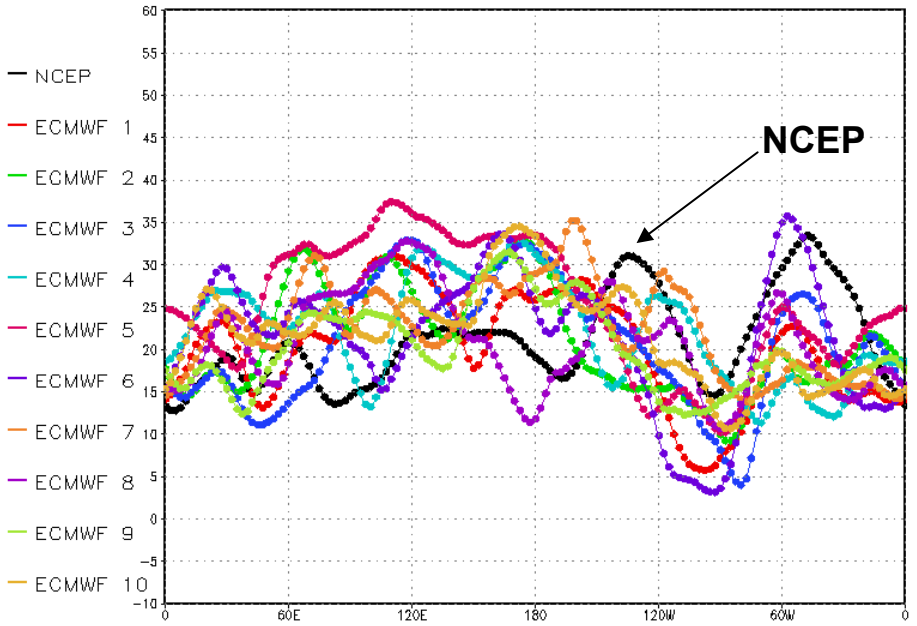


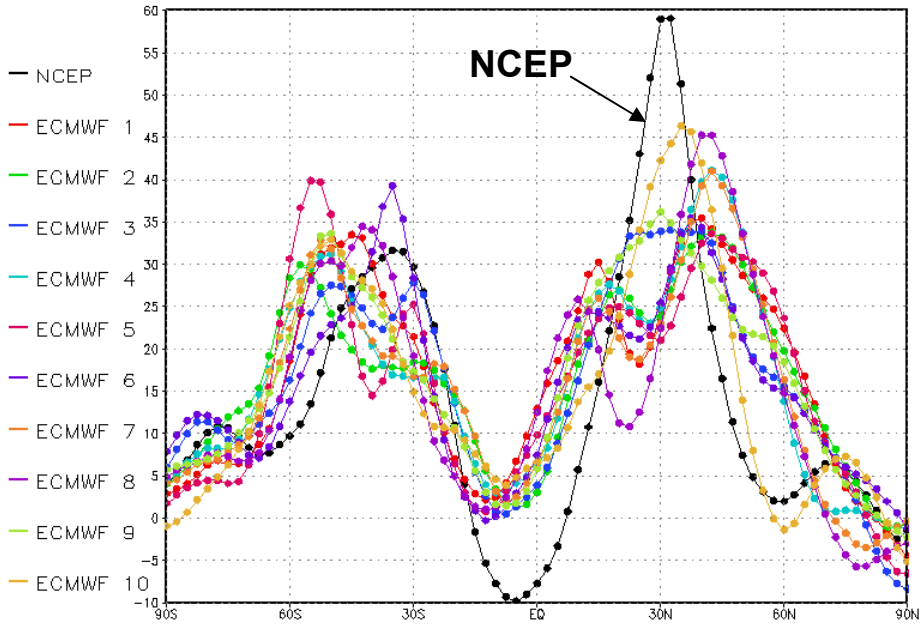
STREAMFUNCTION AND RAY TRACING FOR 4 EL NIÑO EVENTS

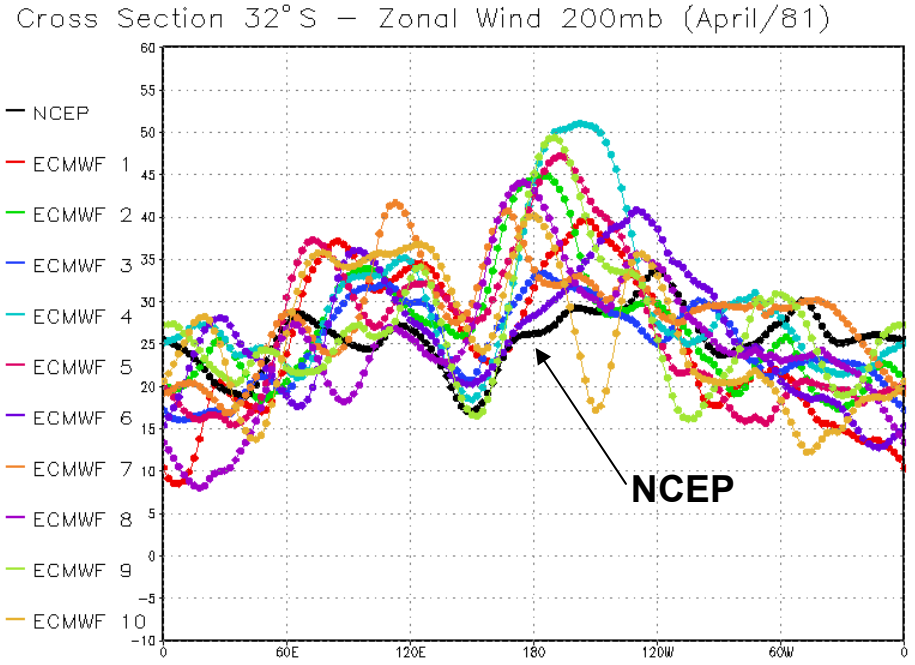


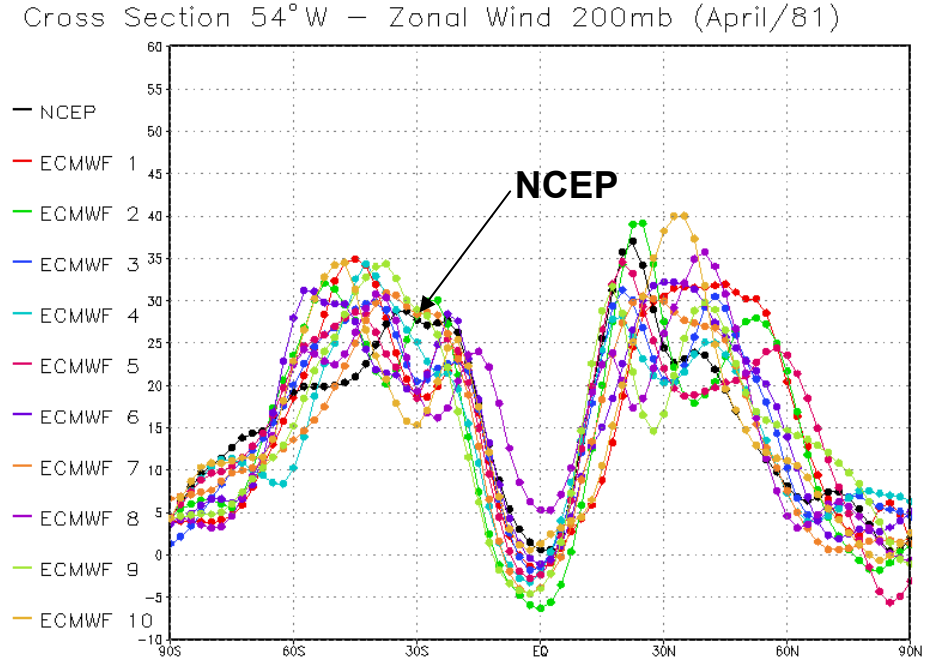

Diference Zonal Wind (200 mb)
ECMWF 1 – NCEP (March/1981)
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−30
−20
−10
−5
0
5
10
20
30

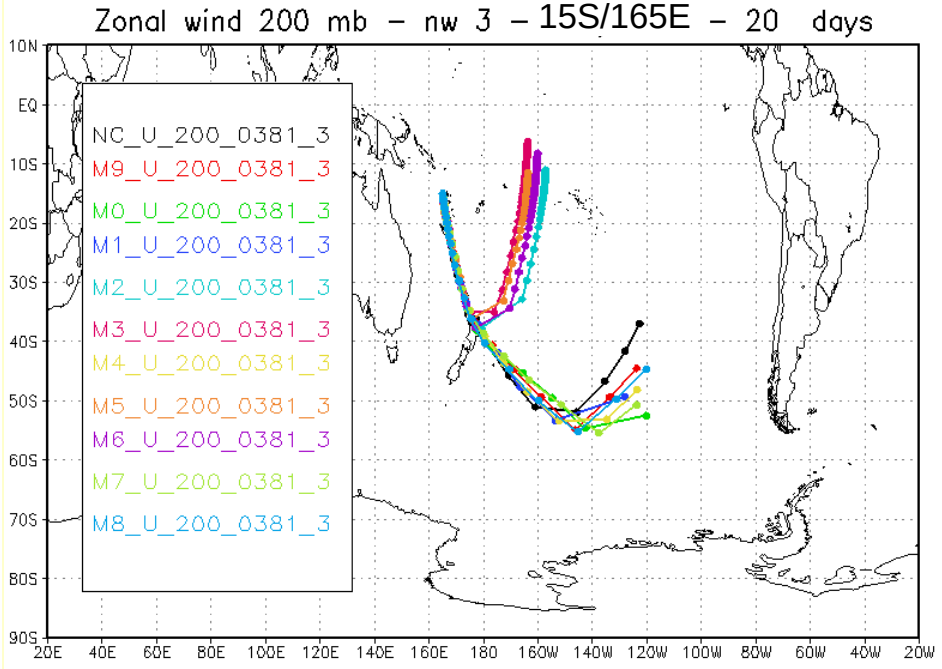

Meridional Wind – ECMWF 1 – 200 mb – March/1981
90N
60N
30N
EQ
30S
60S
90S
0
60E
120E
180
120W
60W
0
−16
−12
−8
−4
0
4
8
12
16

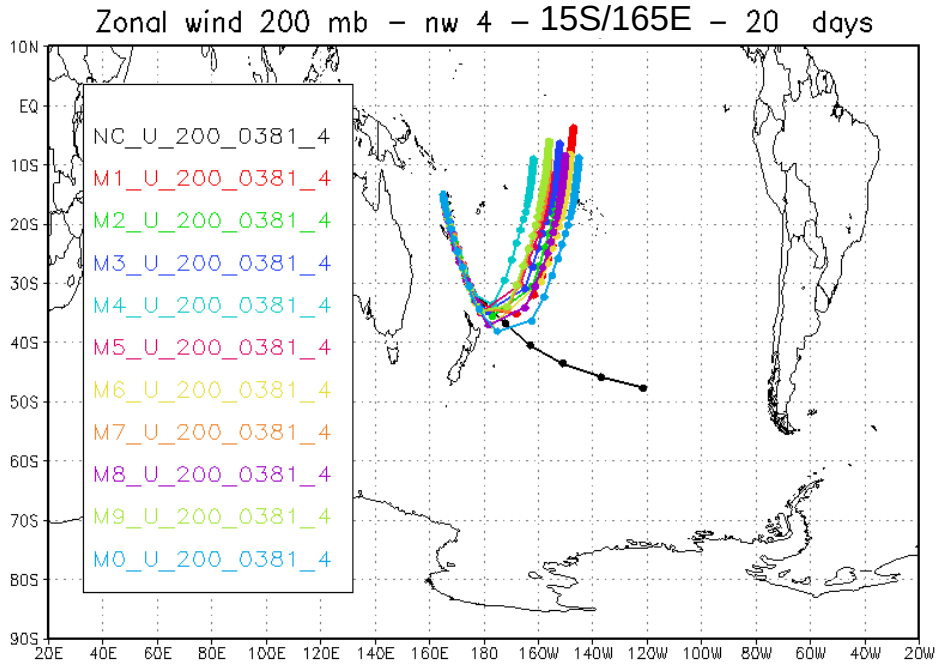

Cross Section 32°S – Zonal Wind 200mb (March/81)
NCEP
ECMWF 1
ECMWF 2
ECMWF 3
ECMWF 4
ECMWF 5
ECMWF 6
ECMWF 7
ECMWF 8
ECMWF 9
ECMWF 10
NCEP
60 55 50 45 40 35 30 25 20 15 10 5 0 −5 −10
0 60E 120E 180 120W 60W 0

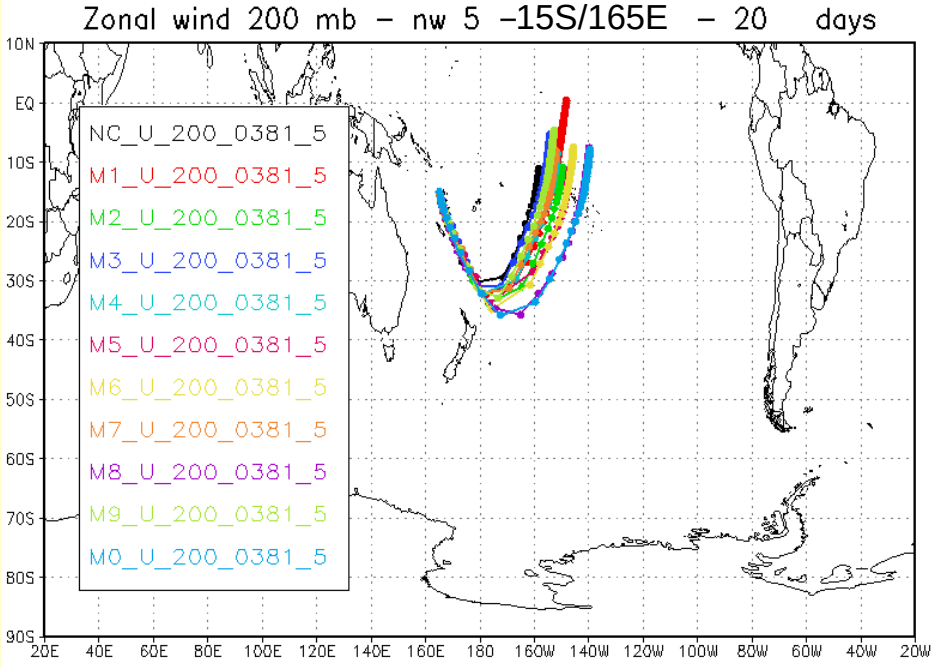

Cross Section 54°W – Zonal Wind 200mb (March/81)
NCEP
ECMWF 1
ECMWF 2
ECMWF 3
ECMWF 4
ECMWF 5
ECMWF 6
ECMWF 7
ECMWF 8
ECMWF 9
ECMWF 10
NCEP
60 55 50 45 40 35 30 25 20 15 10 5 0 −5 −10
90S 60S 30S EQ 30N 60N 90N

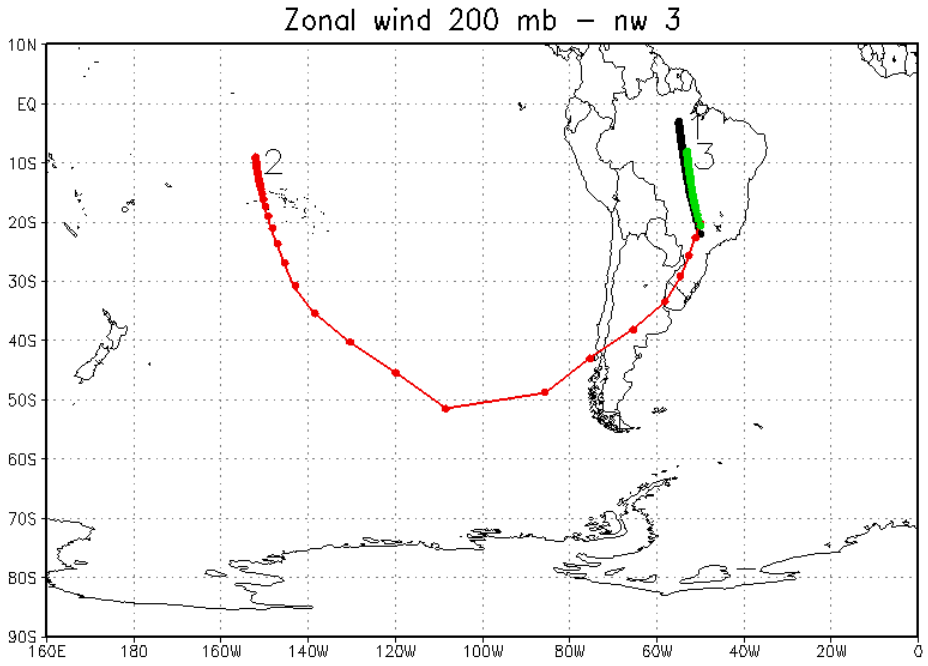

Cross Section 32°S – Zonal Wind 200mb (April/81)
NCEP
ECMWF 1
ECMWF 2
ECMWF 3
ECMWF 4
ECMWF 5
ECMWF 6
ECMWF 7
ECMWF 8
ECMWF 9
ECMWF 10
NCEP
60 55 50 45 40 35 30 25 20 15 10 5 0 −5 −10
0 60E 120E 180 120W 60W 0

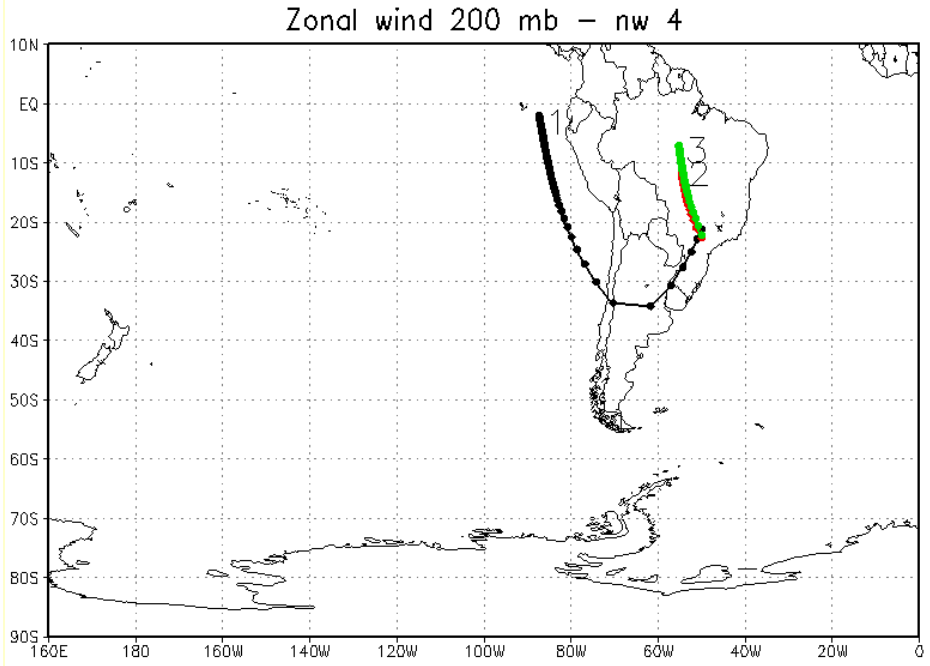

Cross Section 54°W – Zonal Wind 200mb (April/81)
NCEP
ECMWF 1
ECMWF 2
ECMWF 3
ECMWF 4
ECMWF 5
ECMWF 6
ECMWF 7
ECMWF 8
ECMWF 9
ECMWF 10
NCEP
60 55 50 45 40 35 30 25 20 15 10 5 0 −5 −10
90S 60S 30S EQ 30N 60N 90N

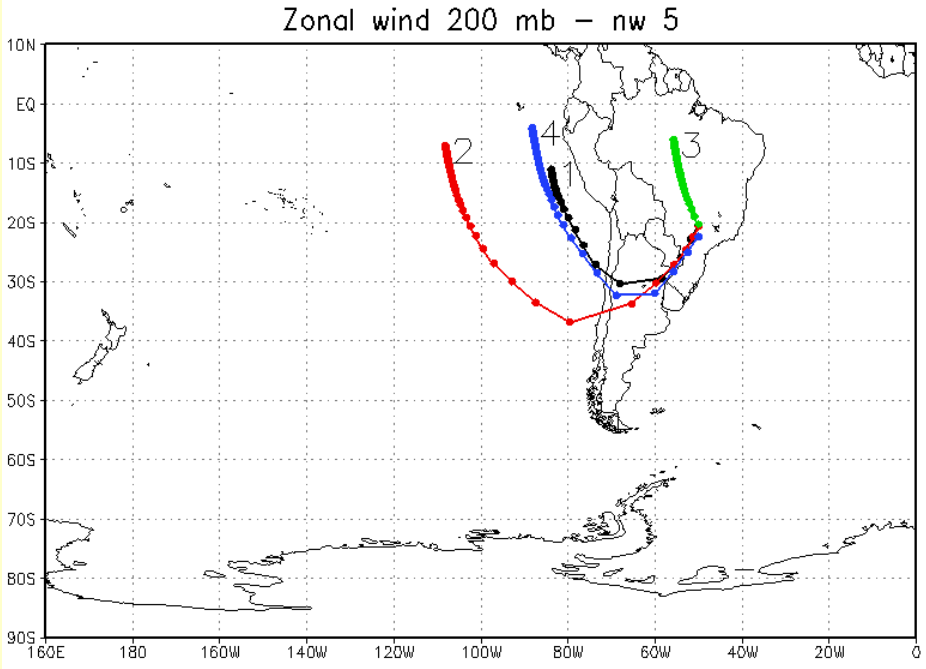

Zonal wind 200 mb – nw 3 – 15S/165E – 20 days
NC_U_200_0381_3
M9_U_200_0381_3
M0_U_200_0381_3
M1_U_200_0381_3
M2_U_200_0381_3
M3_U_200_0381_3
M4_U_200_0381_3
M5_U_200_0381_3
M6_U_200_0381_3
M7_U_200_0381_3
M8_U_200_0381_3
10N
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
20E 40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W 60W 40W 20W


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
10N
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
20E 40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W 60W 40W 20W


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
10N
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
20E 40E 60E 80E 100E 120E 140E 160E 180 160W 140W 120W 100W 80W 60W 40W 20W


Zonal wind 200 mb – nw 3
10N
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
160E
180
160W
140W
120W
100W
80W
60W
40W
20W
0
1
2
3


Zonal wind 200 mb – nw 4
10N
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
160E
180
160W
140W
120W
100W
80W
60W
40W
20W
0
1
2
3


Zonal wind 200 mb – nw 5
10N
EQ
10S
20S
30S
40S
50S
60S
70S
80S
90S
160E
180
160W
140W
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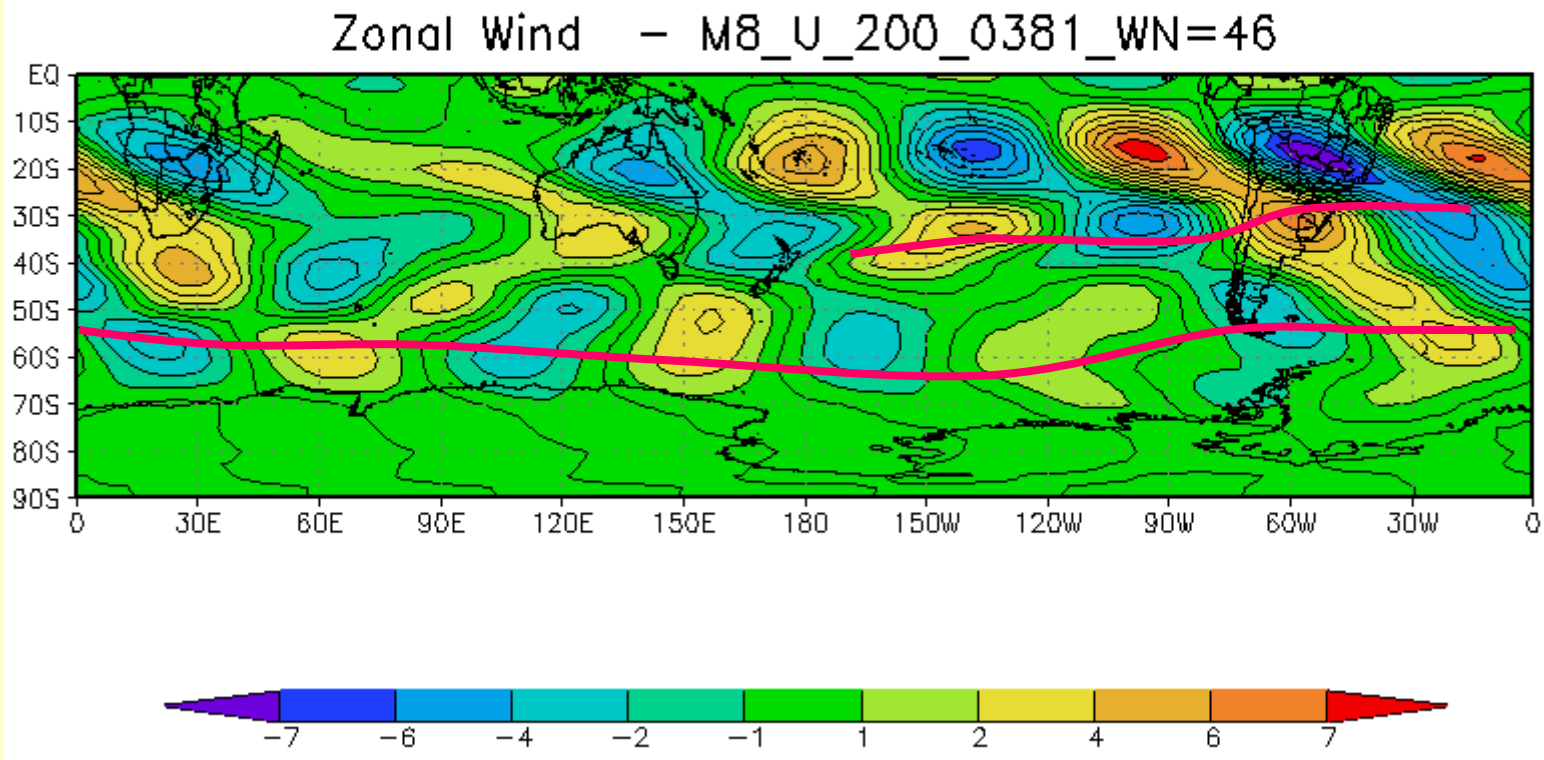
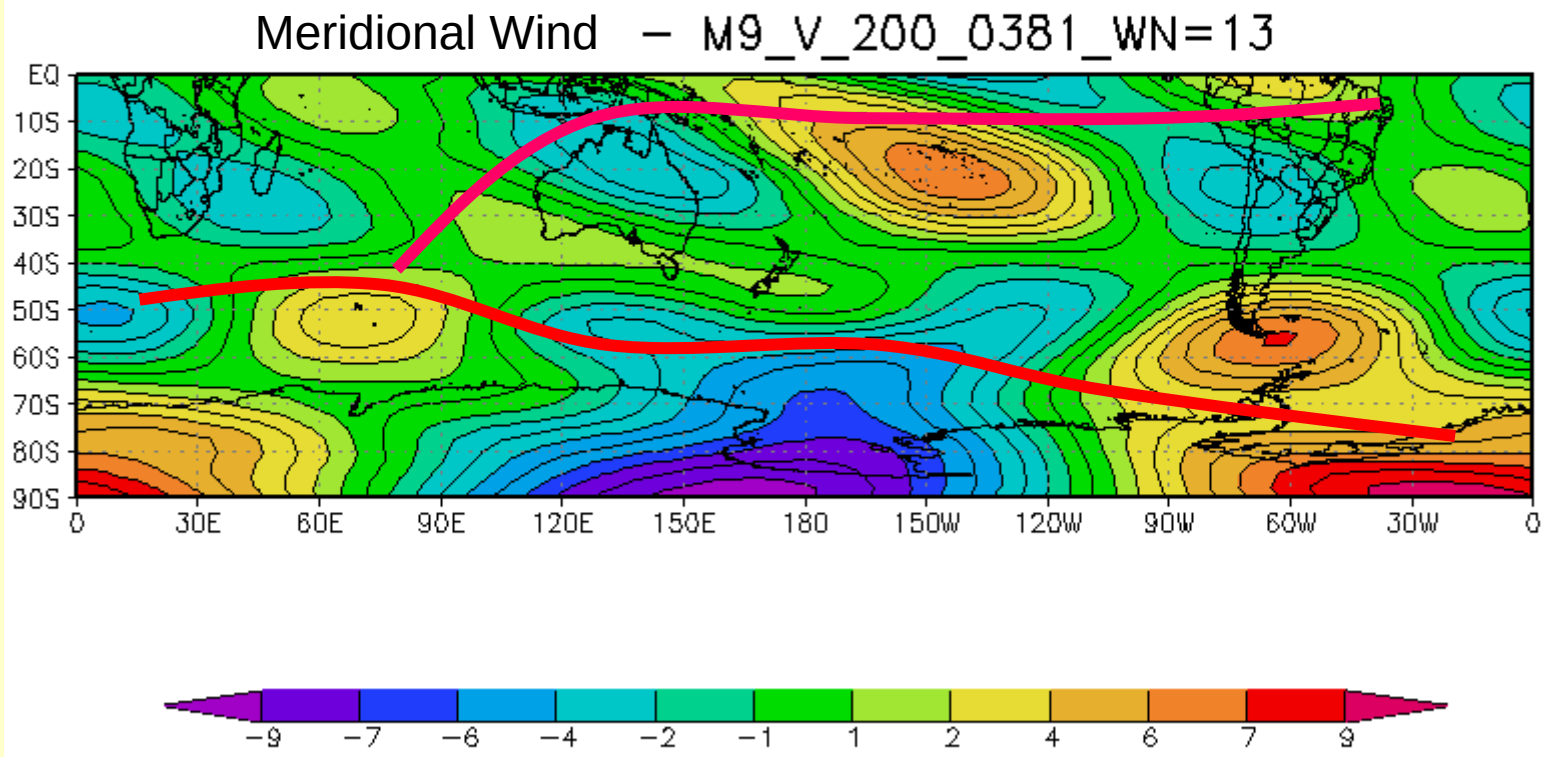
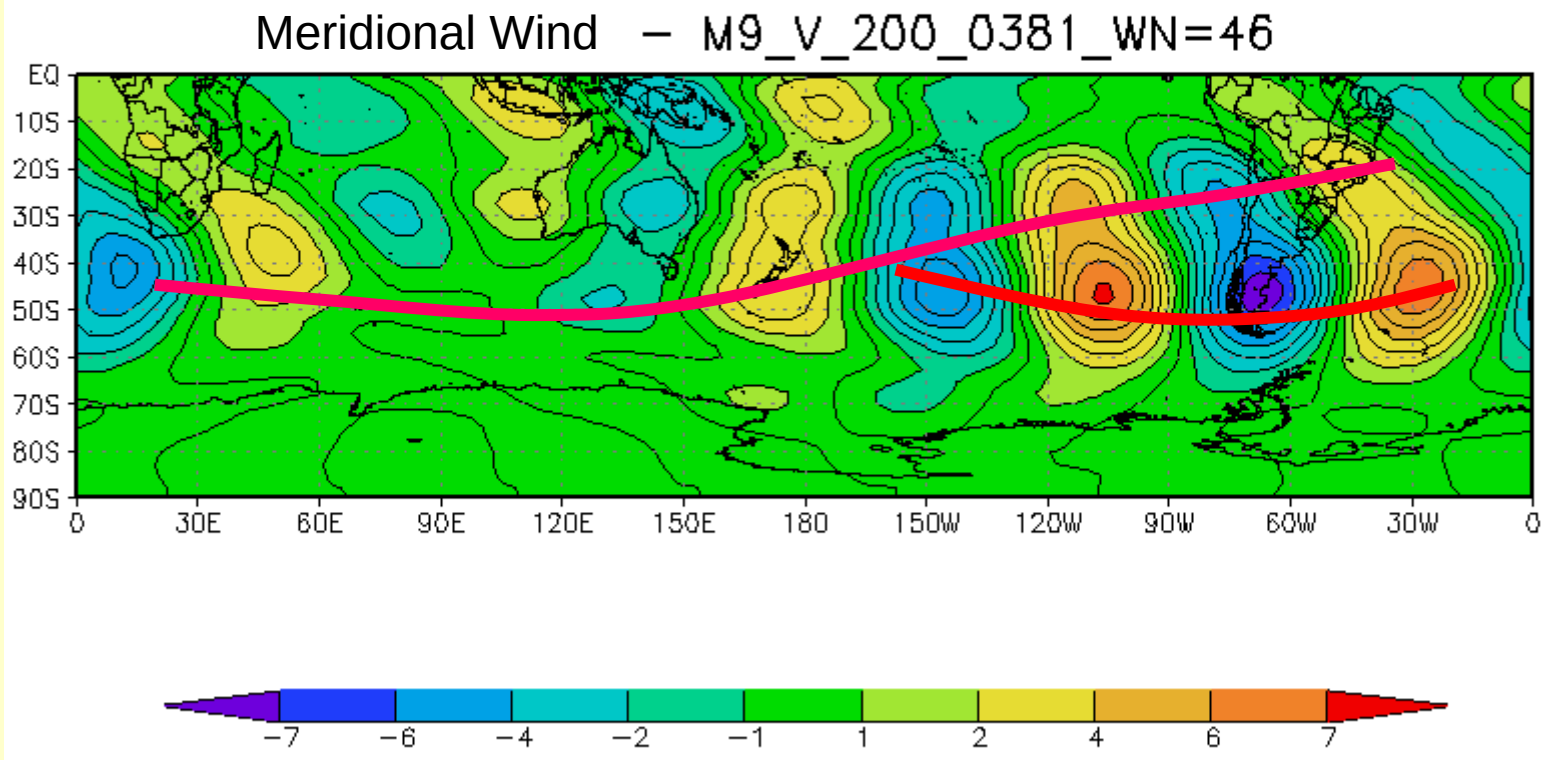
100W
80W
60W
40W
20W
0
1
2
3
4


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


Meridional Wind – M9_V_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

EUROBRISA… “downscaling” with RegCM3

COMPARISON BETWEEN CPTEC AND RegCM3 SEASONAL FORECASTS AND CLIMATOLOGY

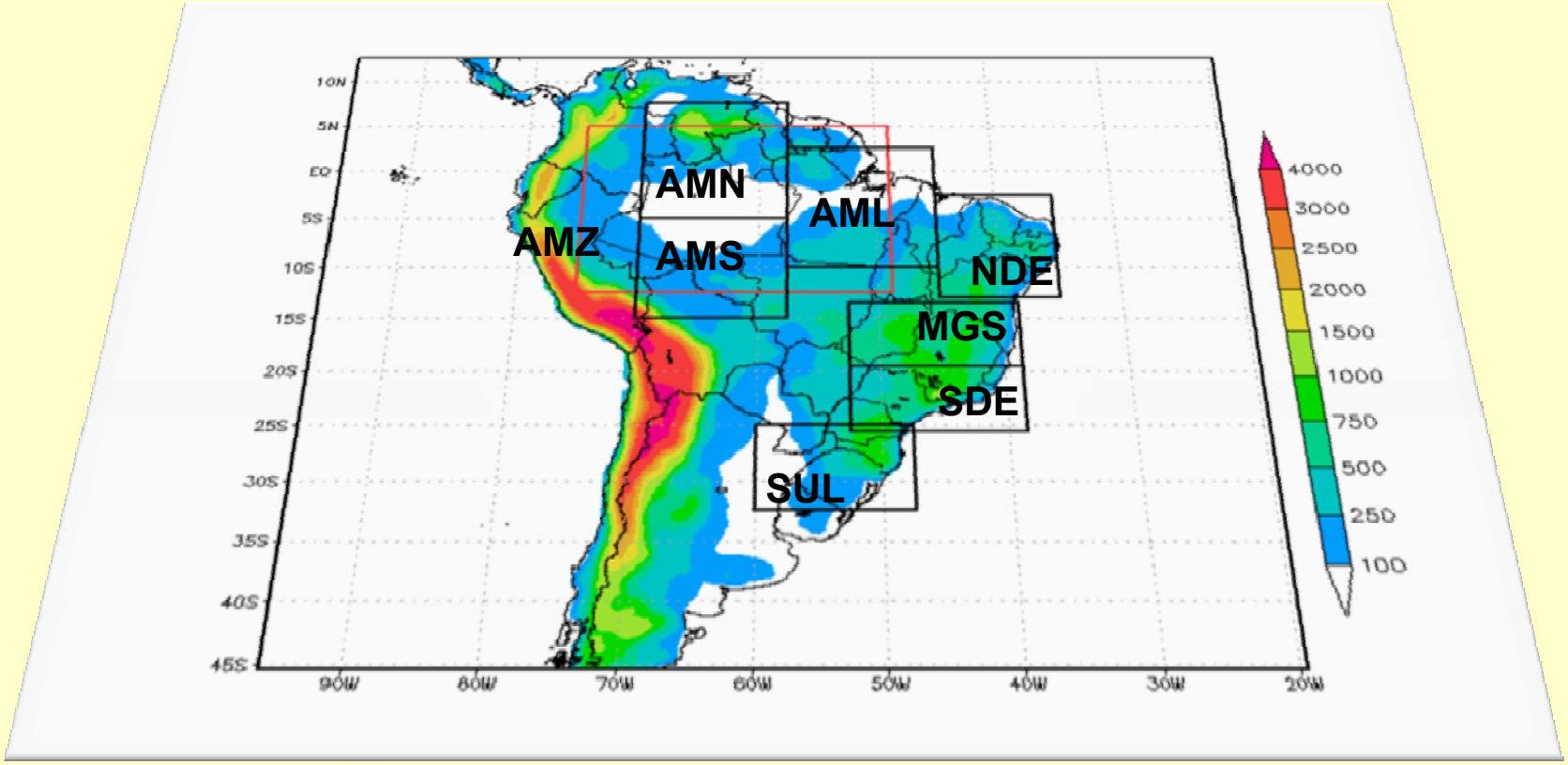
RegCM3 was initialized with CPTEC SEASONAL MODEL from JJA/2005 up to ASO/2007

RegCM3 MODEL CONFIGURATION

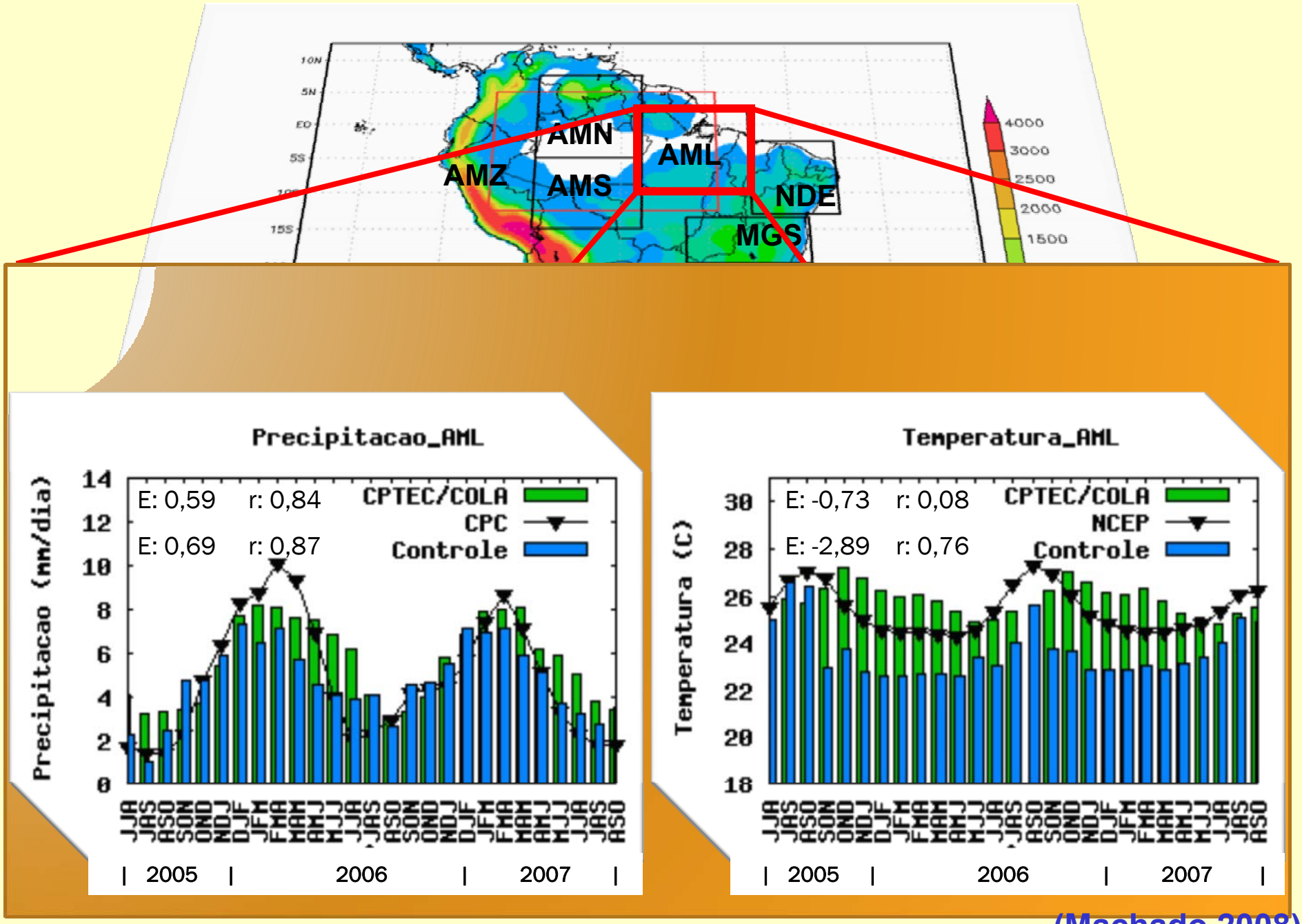
Characteristics		Configuration
Physics	Cumulus	Grell
	Radiation	CCM3
	Planetary Boundary Layer	Holstag
	Earth-Surface-Atmosphere	BATS
Vertical resolution		18 sigma levels
Horizontal resolution		60 km
Dynamics		Hidrostatic
Initial conditions and boundaries		CPTEC/COLA

(Machado 2008)

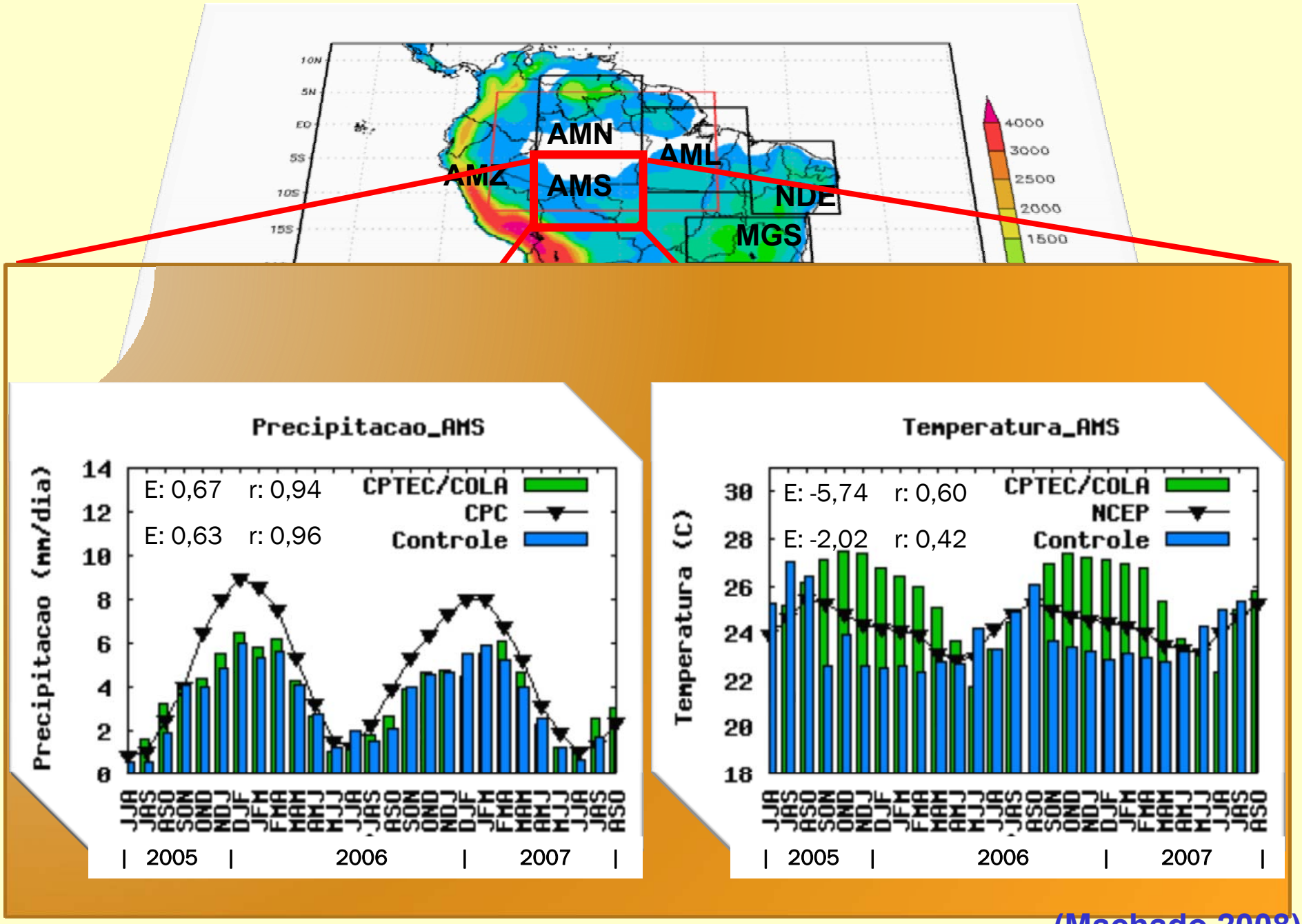
Topography, Domain and 8 sub-regions where the 3 months forecast from RegCM3 where compared with the CPTEC seasonal forecast model



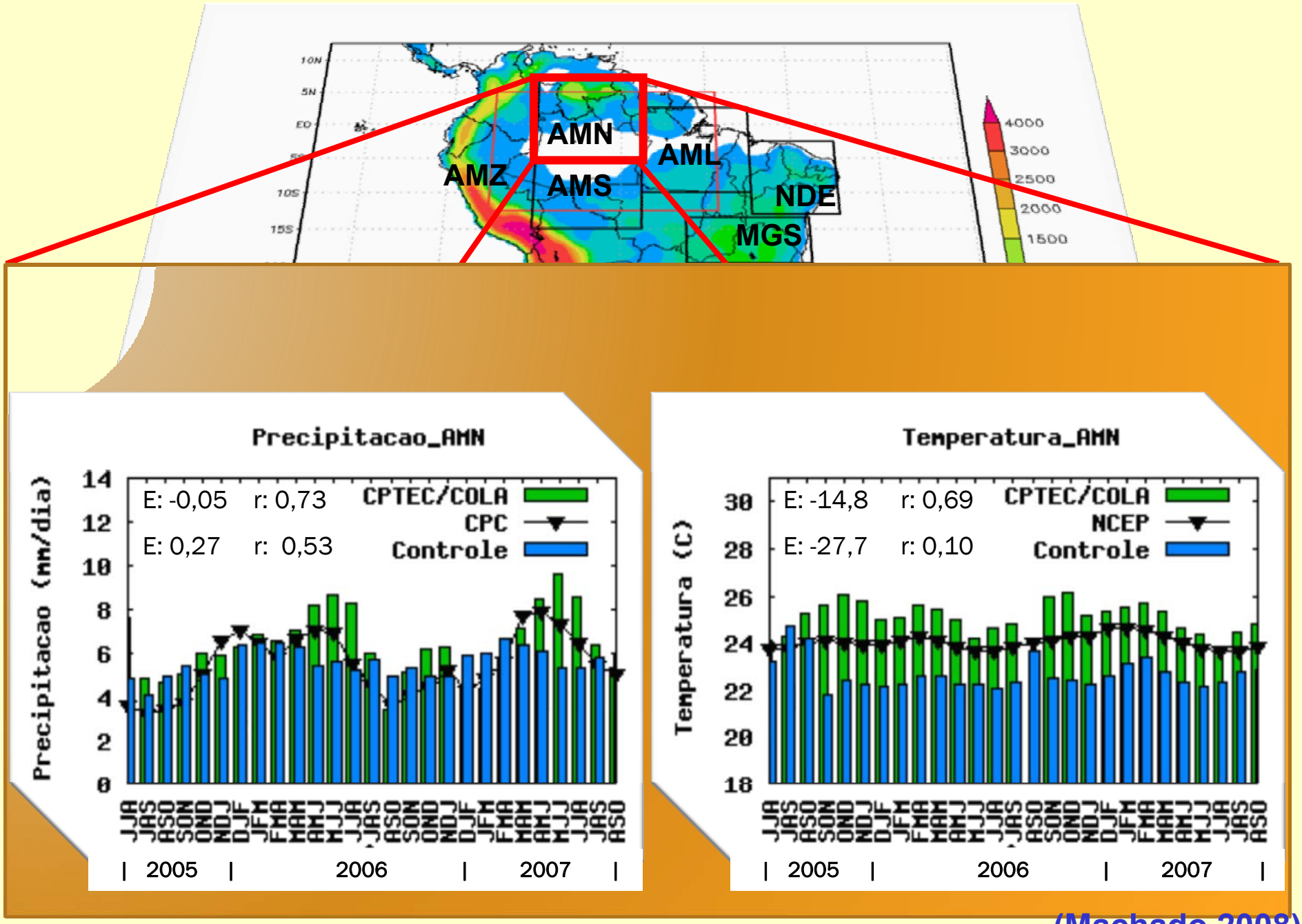
(Machado 2008)



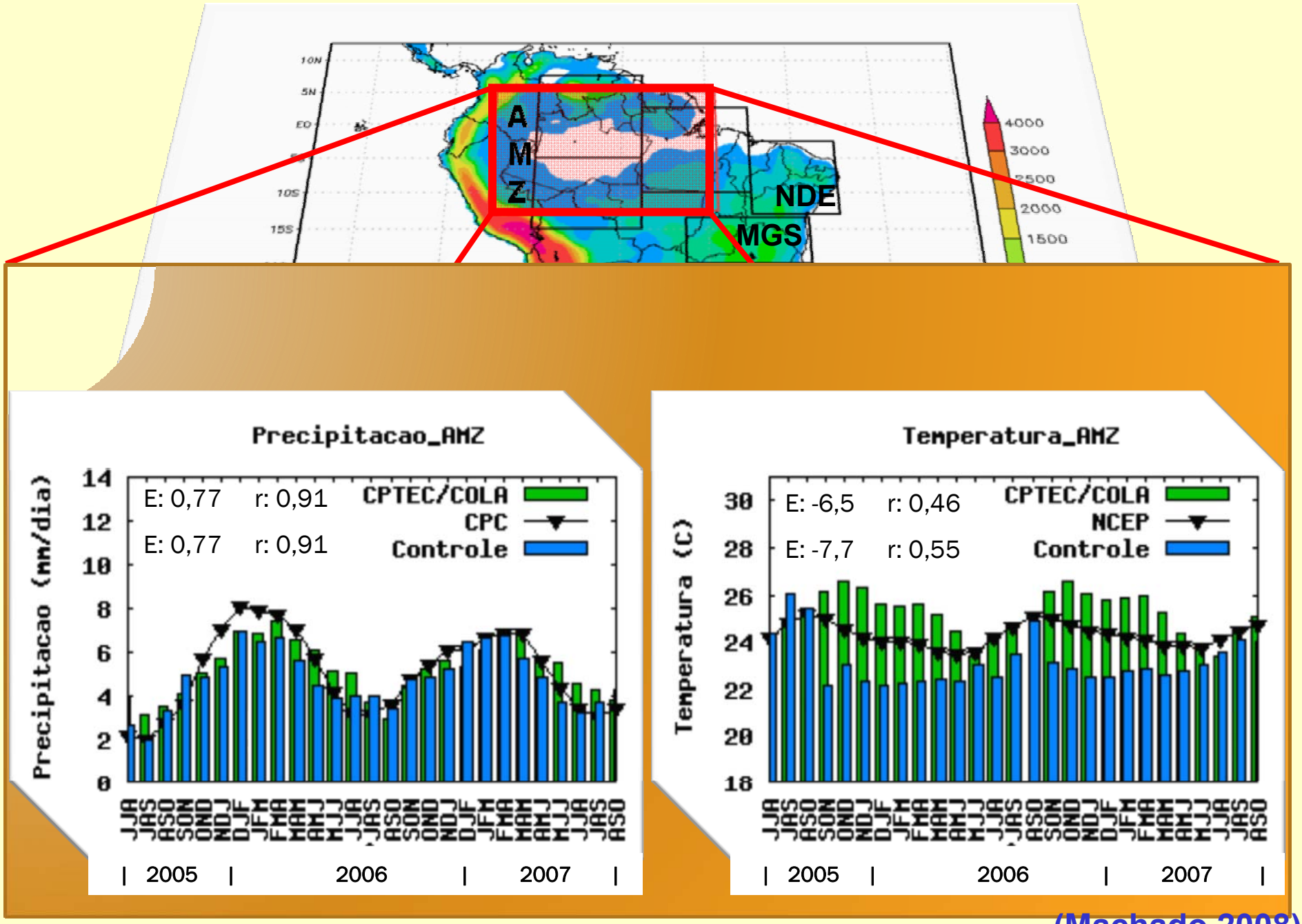
(Machado 2008)



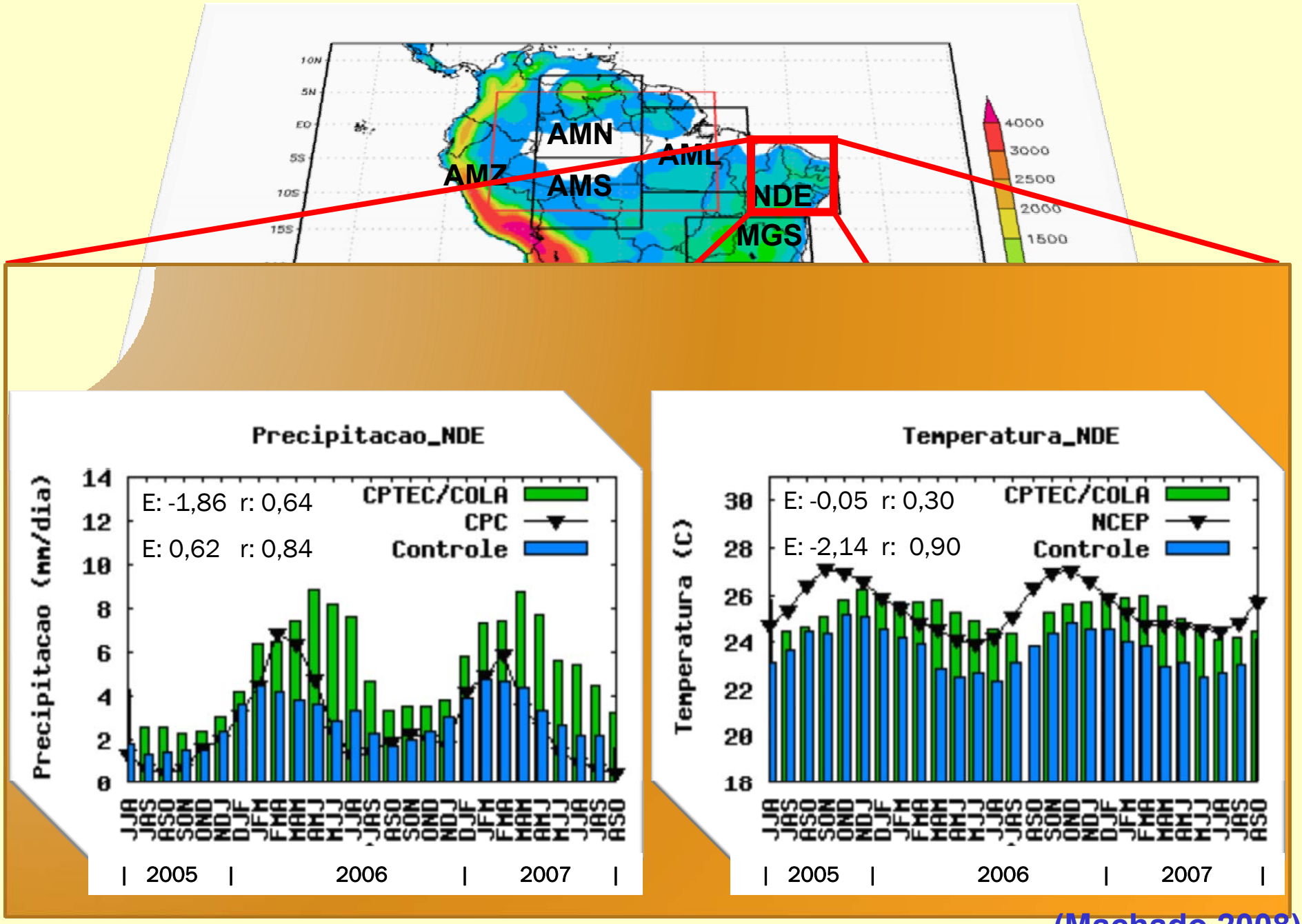
(Machado 2008)



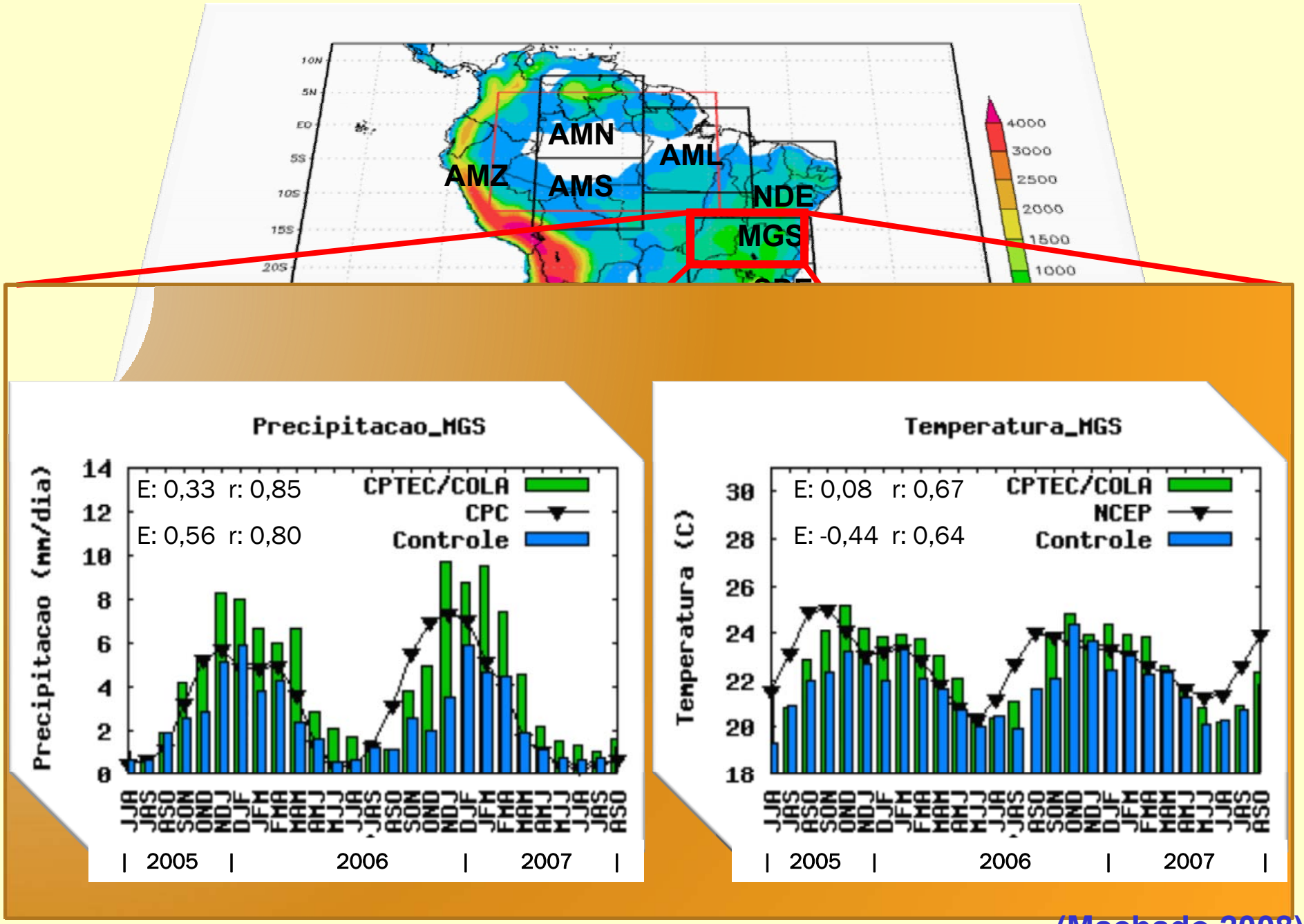
(Machado 2008)



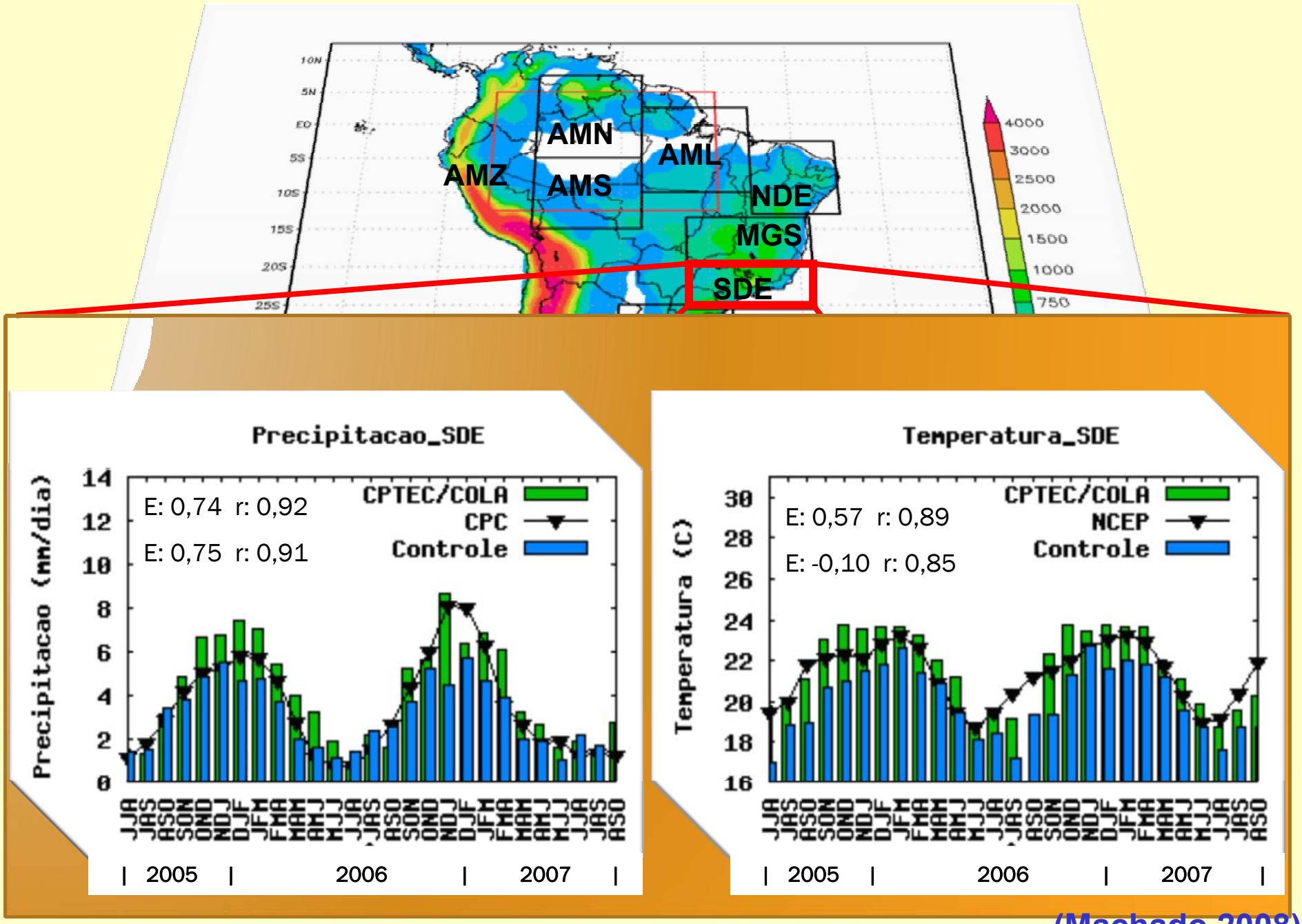
(Machado 2008)



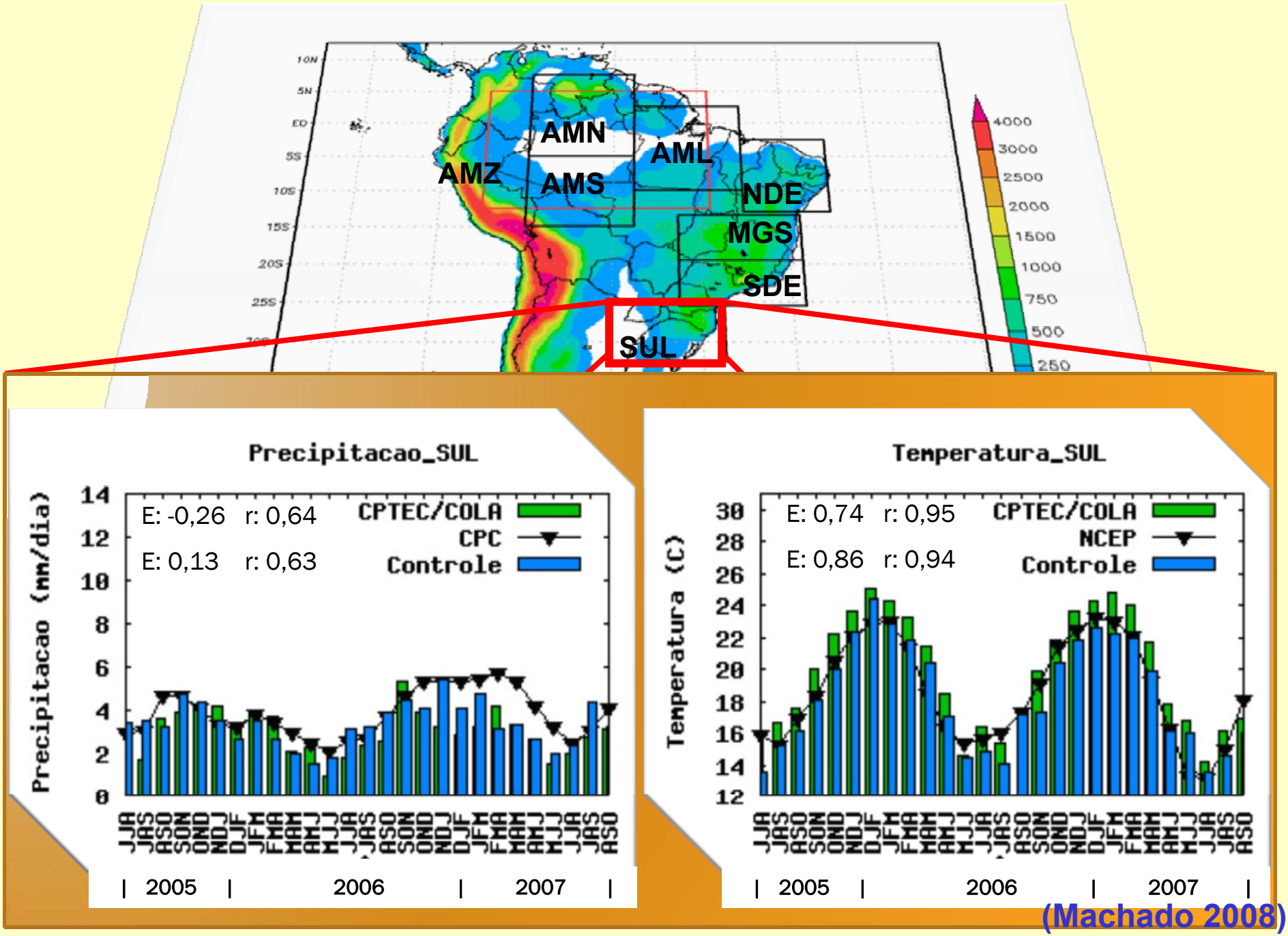
(Machado 2008)



(Machado 2008)



(Machado 2008)



(Machado 2008)

APEC Climate Center

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

GRUPO DE ESTUDOS CLIMÁTICOS

CLIMATE STUDIES GROUP

THANK YOU FOR YOUR ATTENTION

GRACIAS POR SU ATENCIÓN