Main features and Life cycle (SAMS) Observations

Manoel Alonso Gan
National Institute for Spatial Research (INPE)
Weather Forecast Center and Climate Studies (CPTEC)

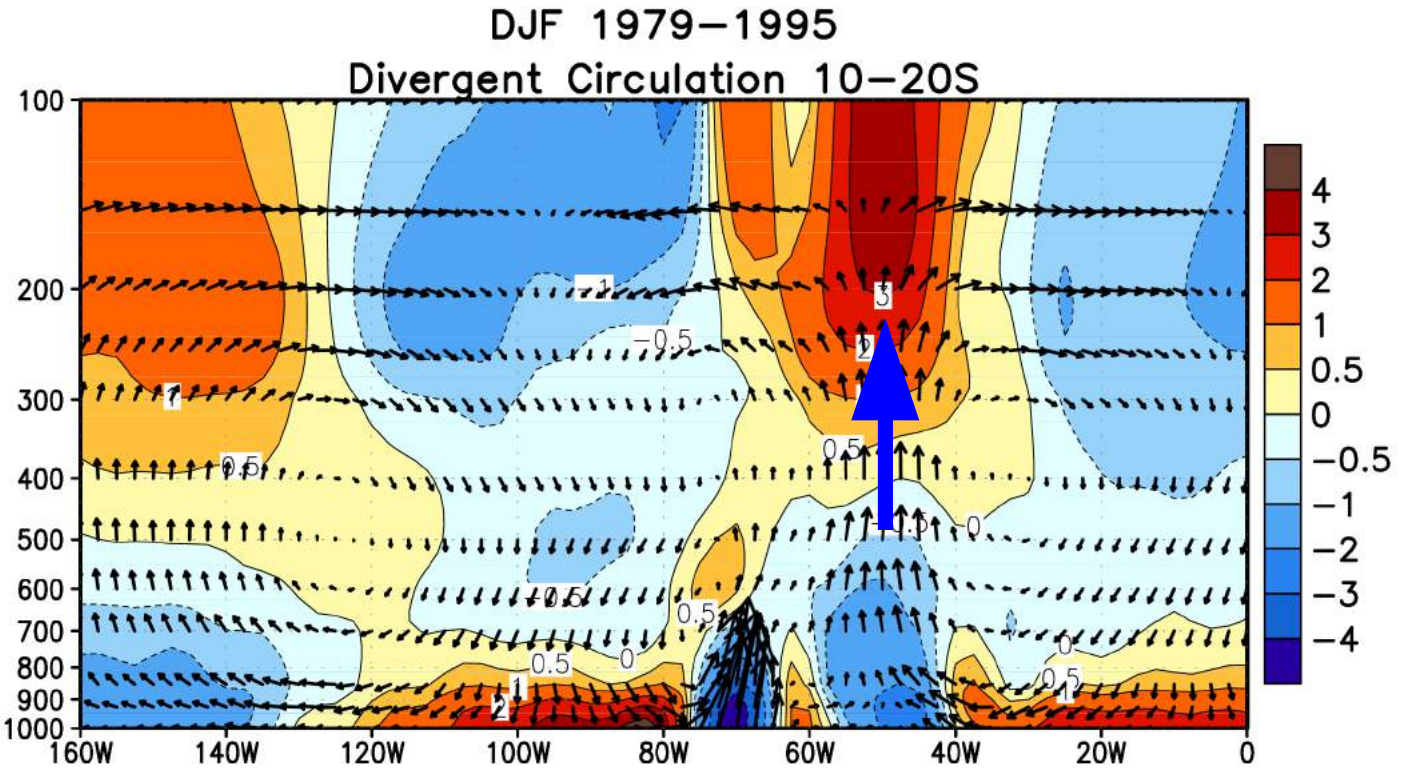
Introduction

The word Monsoon refers to the seasonal rains associated with the change of wind direction.

A monsoon seasonal change is characterized by a variety of physical mechanisms which produce strong seasonal winds, a wet summer and a dry winter.

There are three fundamental mechanisms which drive a monsoon:

1. differential heating between the land and oceans;


DJF 1979–1995
Divergent Circulation 10–20S
100
200
300
400
500
600
700
800
900
1000
160W
140W
120W
100W
80W
60W
40W
20W
0
4
3
2
1
0.5
0
−0.5
−1
−2
−3
−4

Introduction

The word Monsoon refers to the seasonal rains associated with the change of wind direction.

A monsoon seasonal change is characterized by a variety of physical mechanisms which produce strong seasonal winds, a wet summer and a dry winter.

There are three fundamental mechanisms which drive a monsoon:

1. differential heating between the land and oceans;

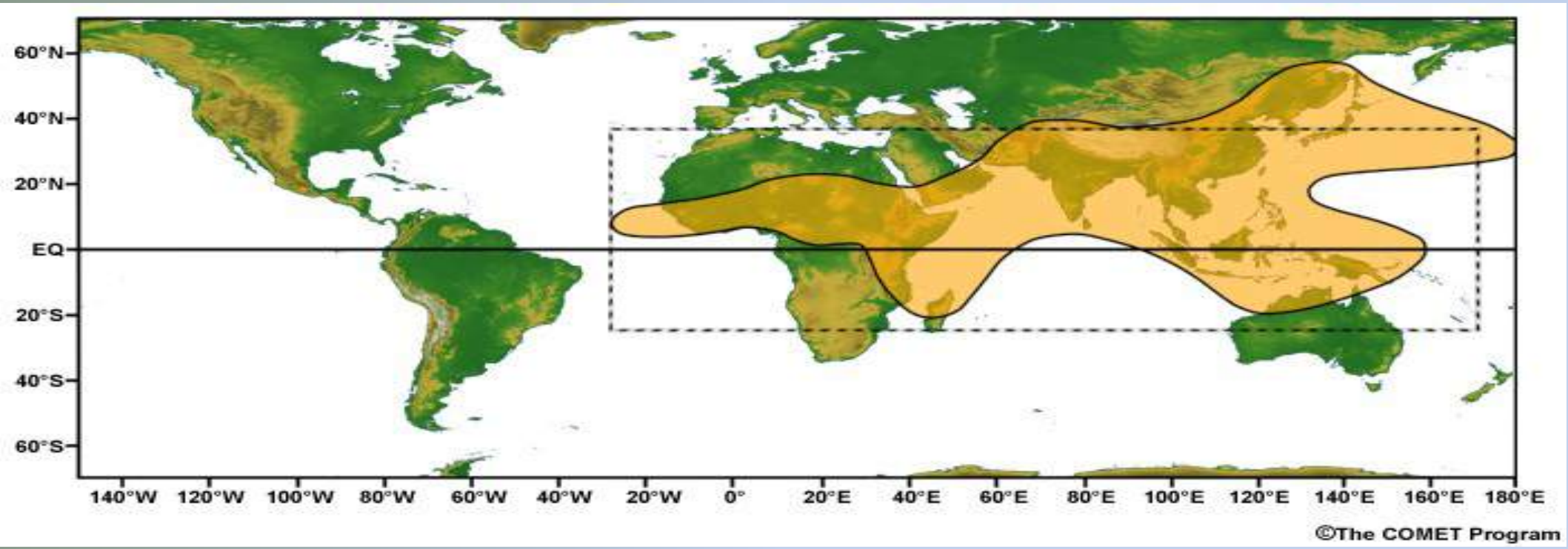
2. Coriolis forces associated with the rotation of the Earth; and

3. the ability of water to evaporate and to condense in the atmosphere.

Ramage (1971) defined monsoon when:

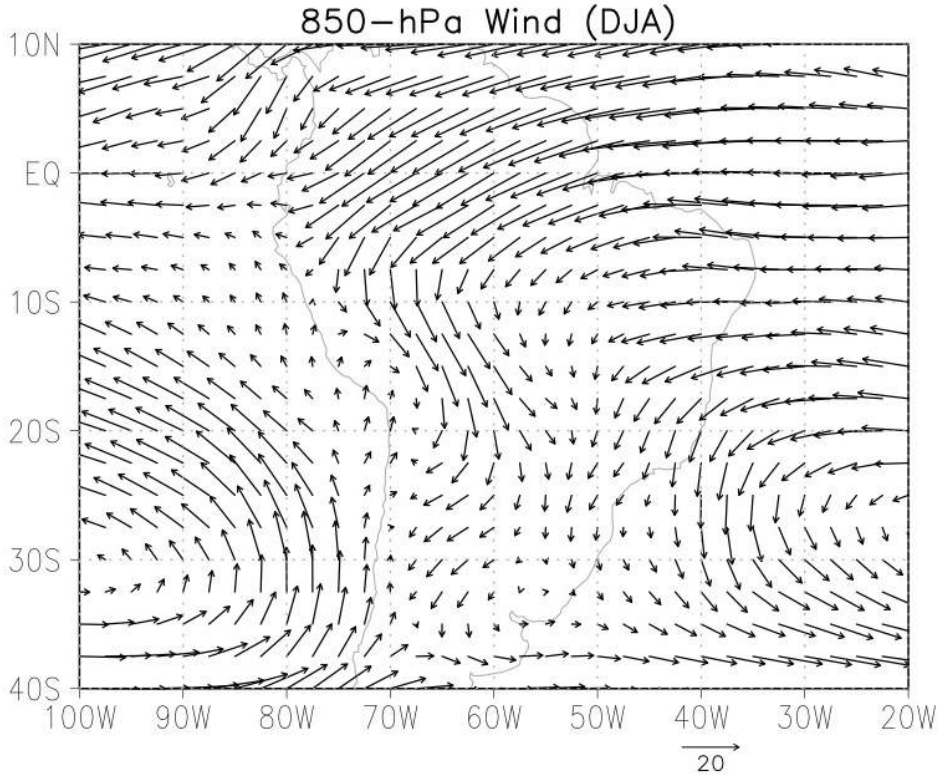
1. Dominant wind shifts 120^{o} between January and July
2. Average frequency of dominant wind > 40%
3. Speed of the mean wind exceeds 3m/s

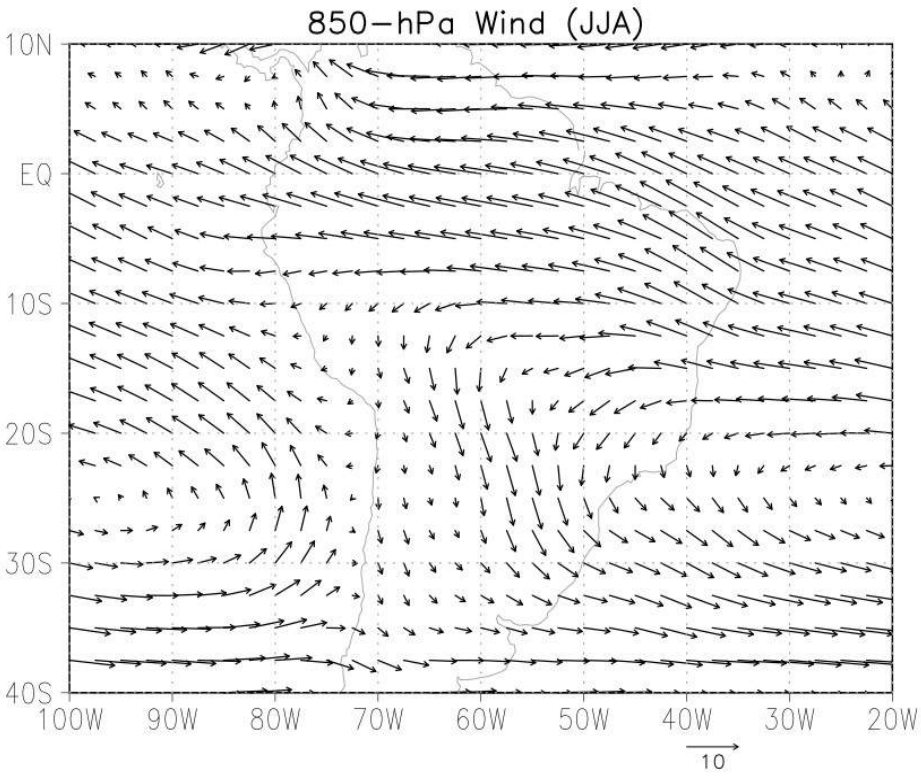
Areas with Monsoon regime according to Ramage (1971)



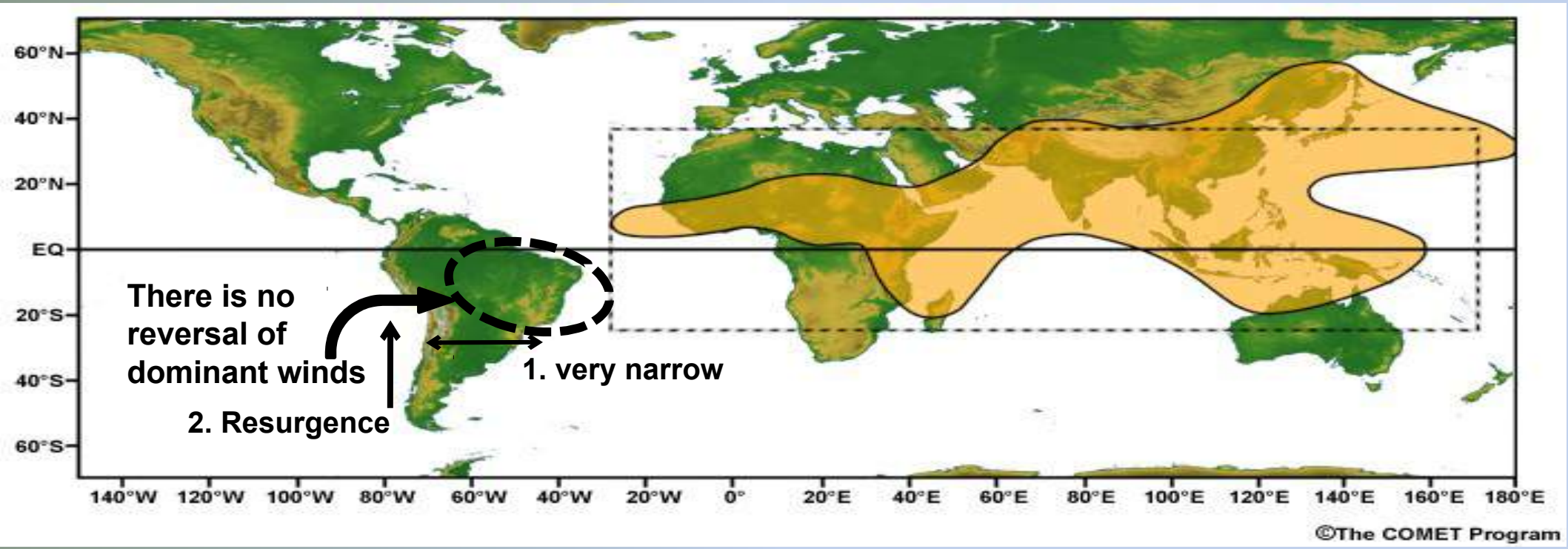
Main features

South America monsoon does not show a seasonally reversing wind.

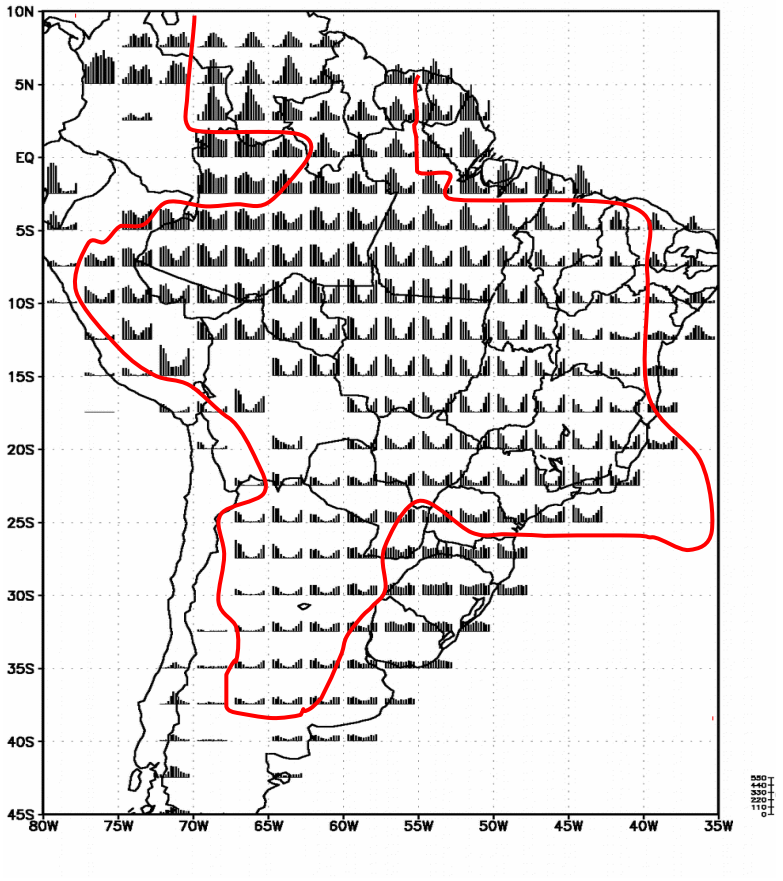




Areas with Monsoon regime according to Ramage (1971)



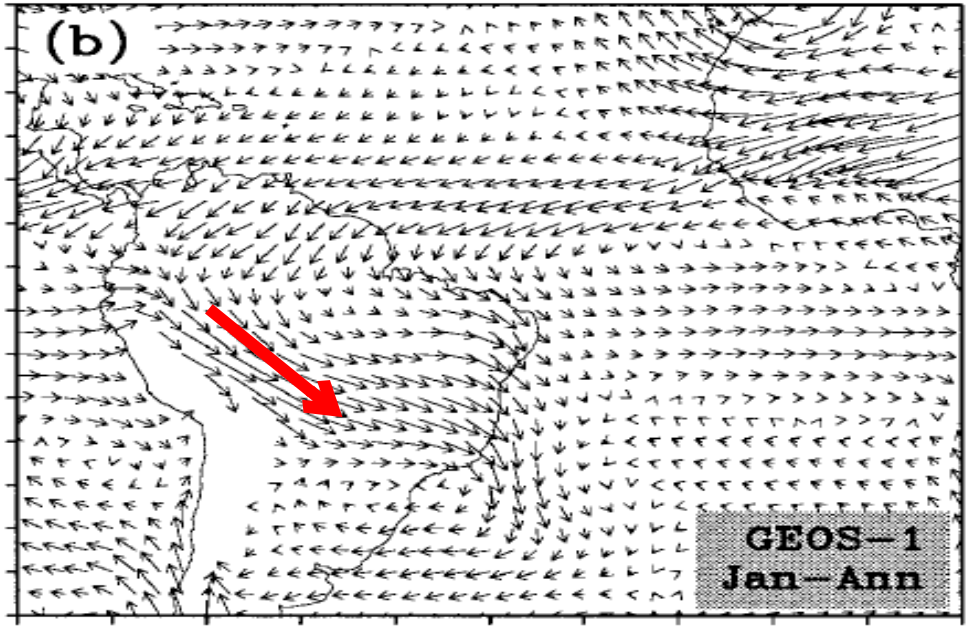
% Annual cycle of Precipitation

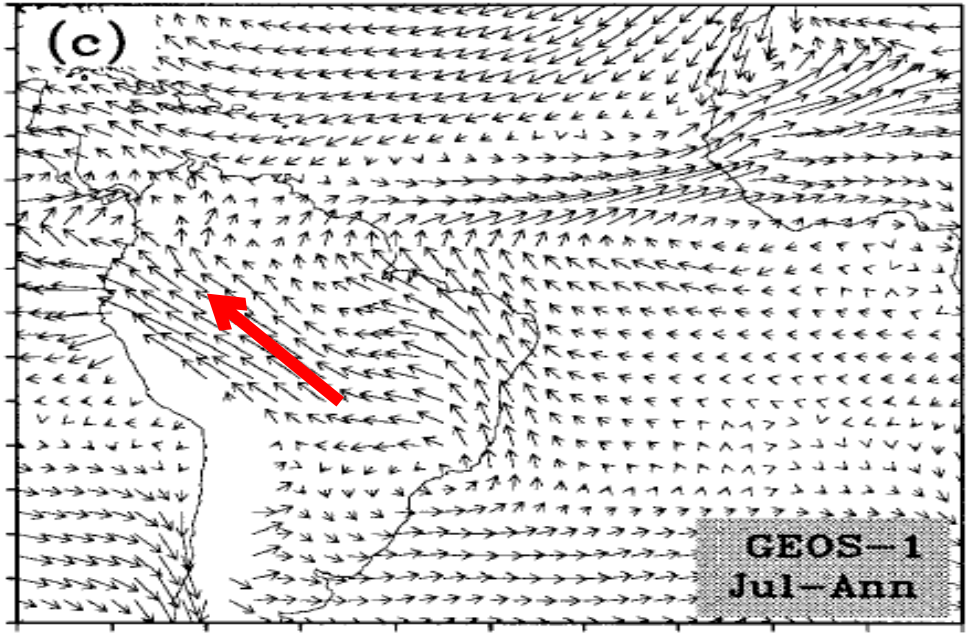


Source: Silva and Kousky (2012)

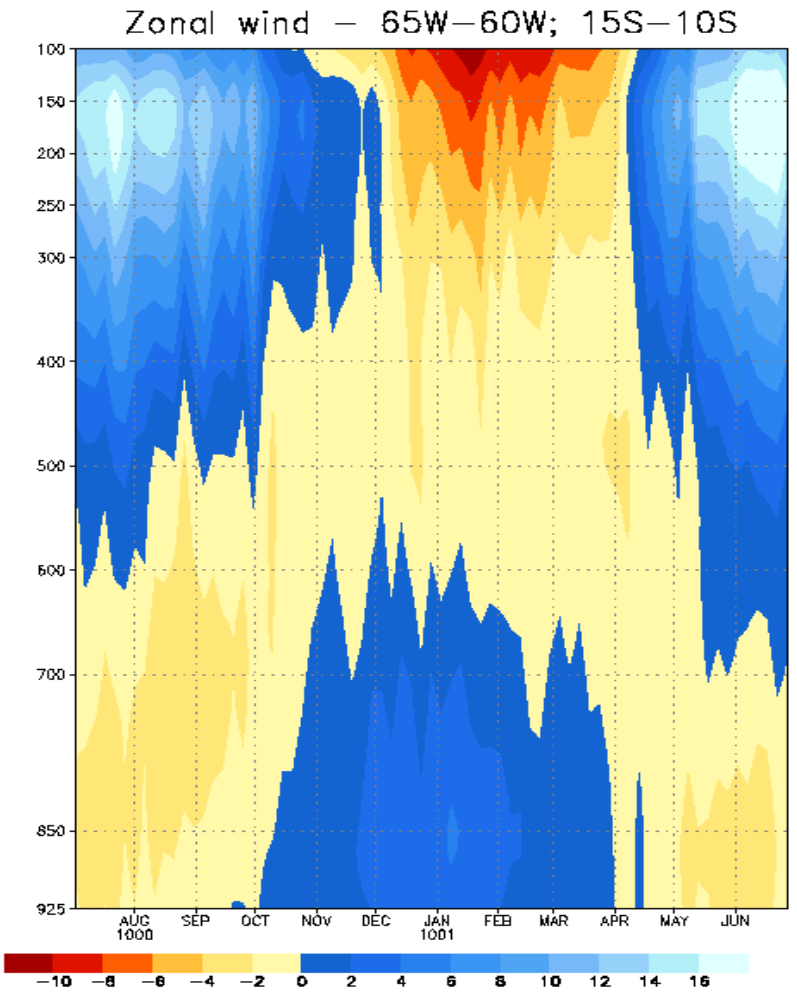
Main features

Zhou e Lau (1998)

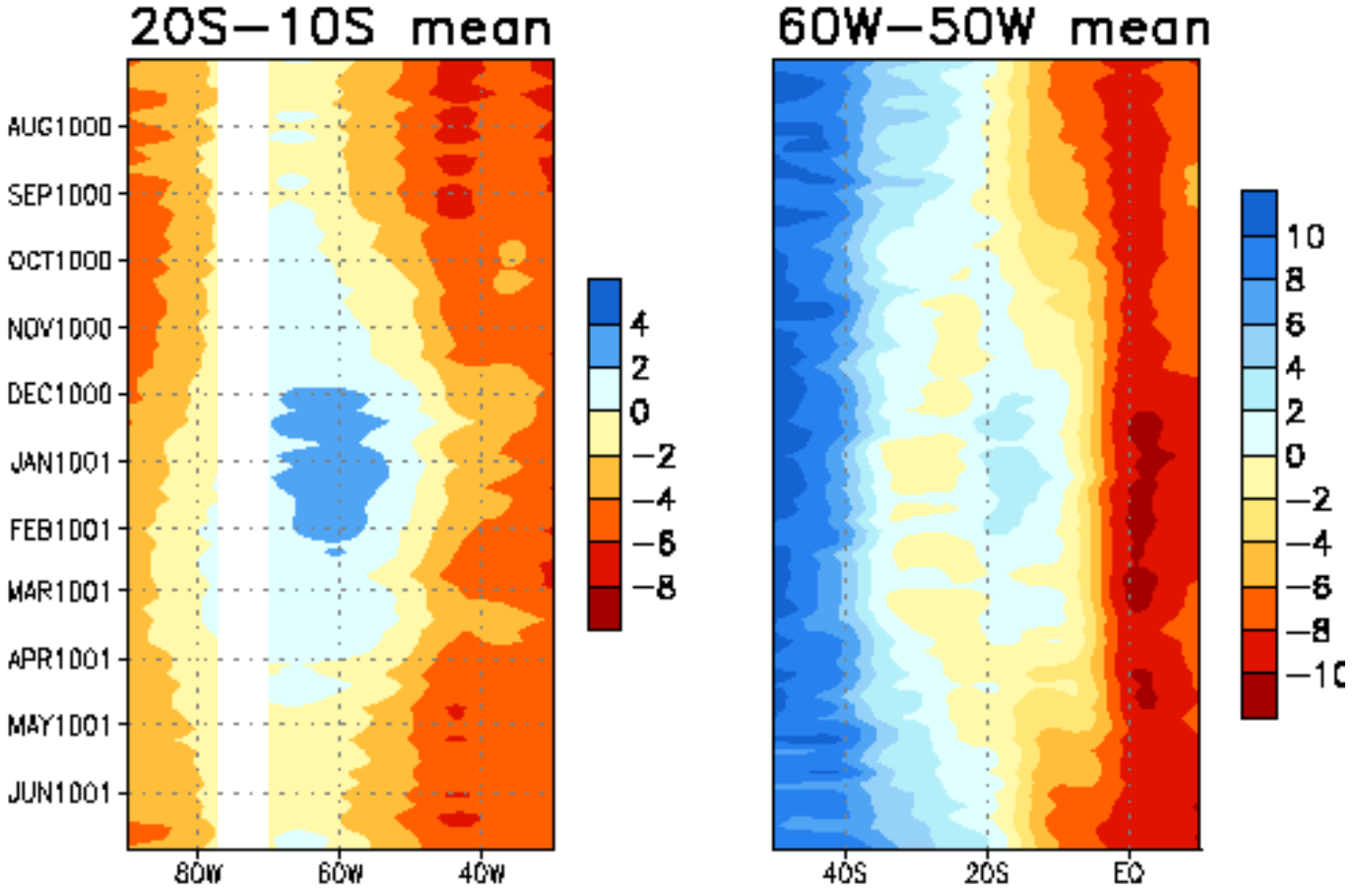




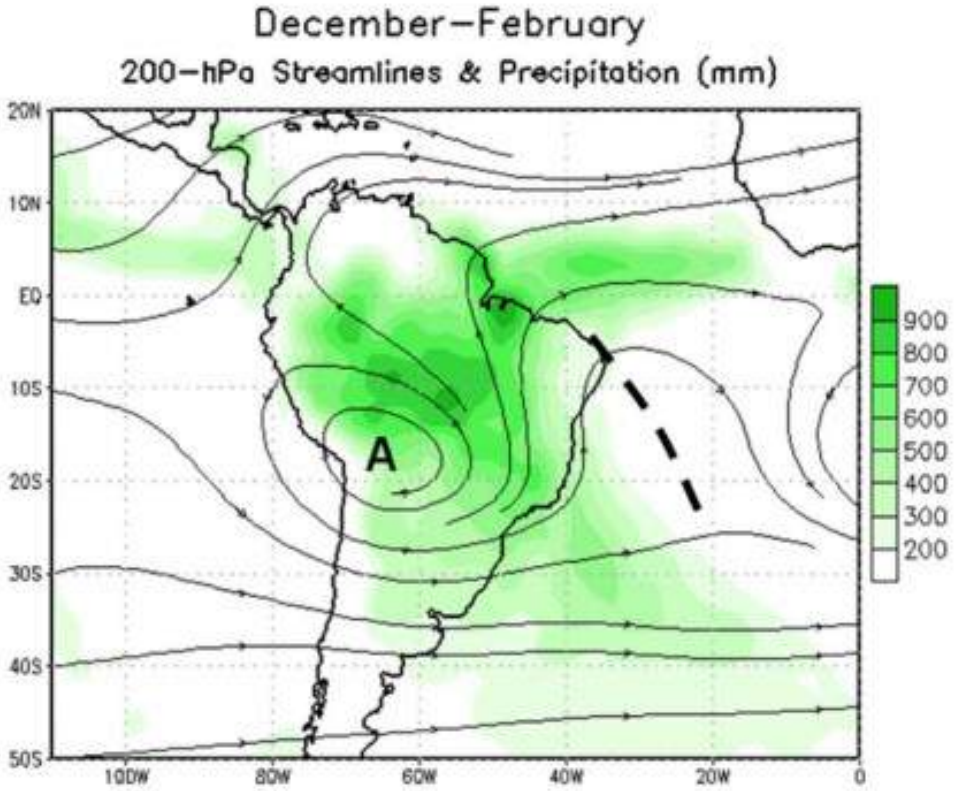
Main features

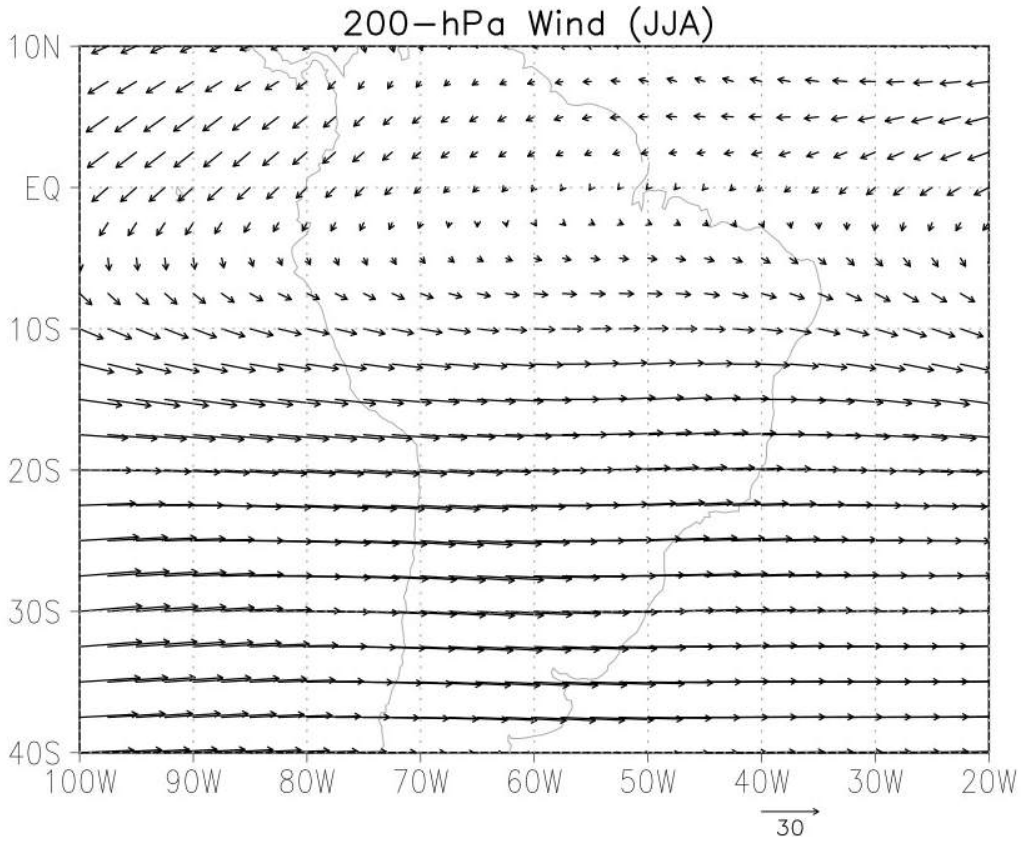


Climatological 850 hPa Zonal Wind



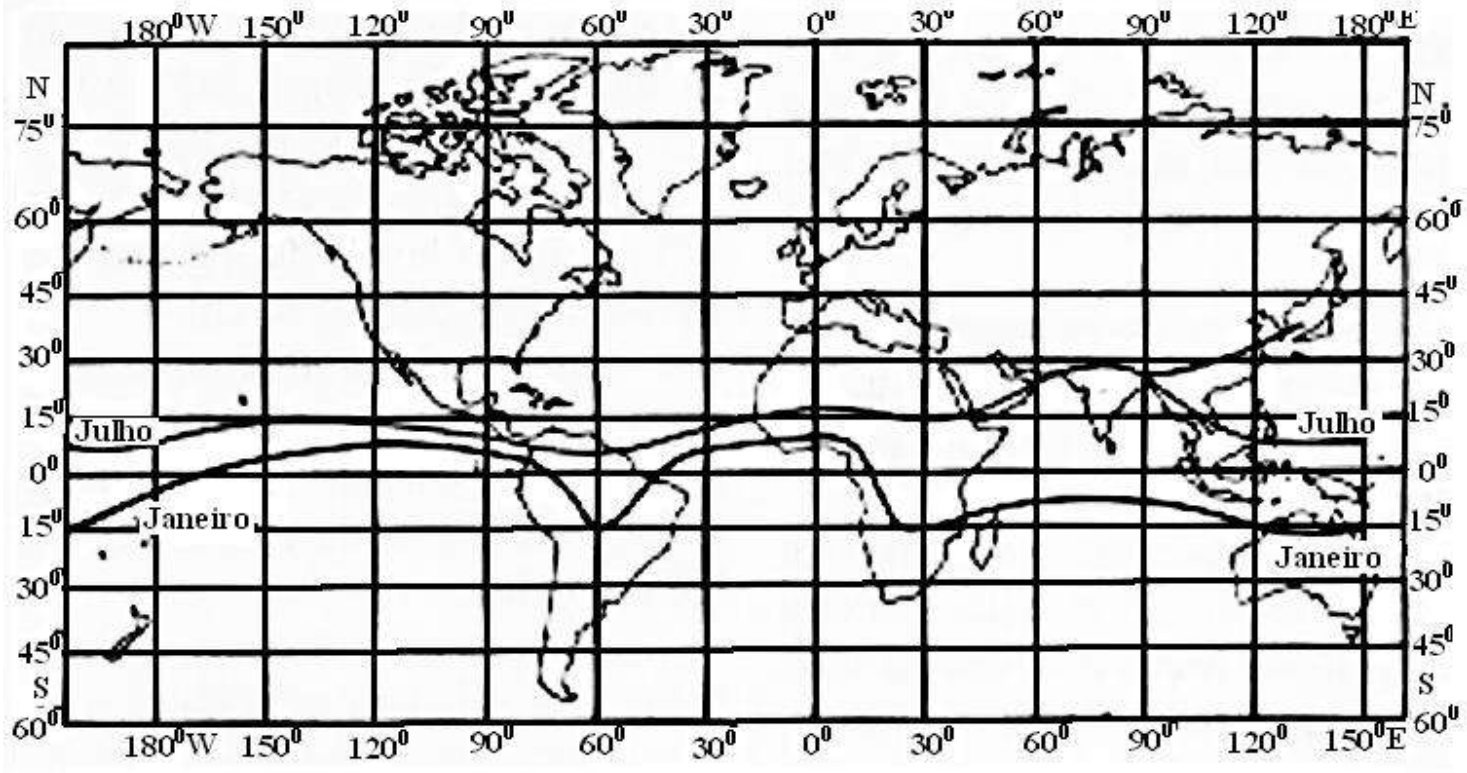
Climatological 200 hPa Zonal Wind



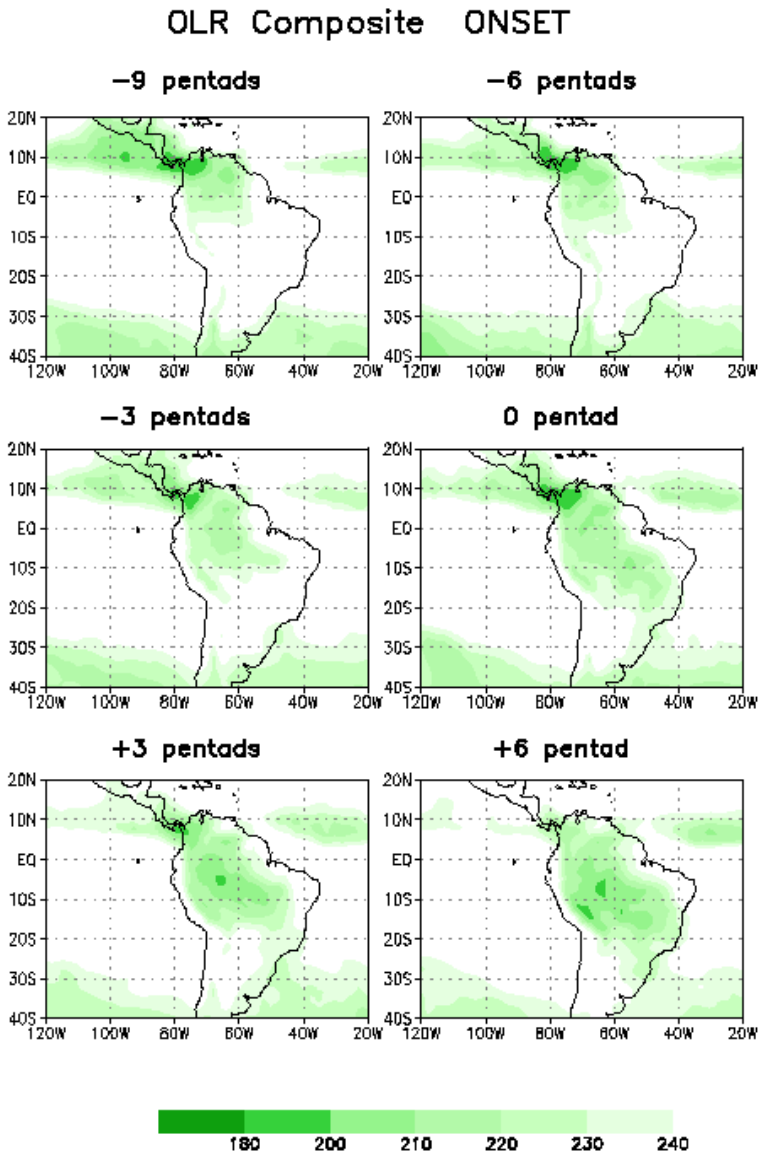


Source: Silva and Kousky (2012)

Asnani (1993) defined Monsoon region when it lies between 5° north of the northernmost position of ITCZ, and 5° south of the southernmost position of ITCZ.



Surface position of ITCZ: January and February
Search: Asnani (1993)



The monsoon annual cycle is characterized by a sharp transition at the beginning of the summer monsoon season known as the 'onset'.

The deep convection starts over the northwest portion of the South America in September, with a connection to the Pacific ITCZ. Subsequently expands southward and southeastward, reaching central Brazil in October and Southeast Brazil in November.

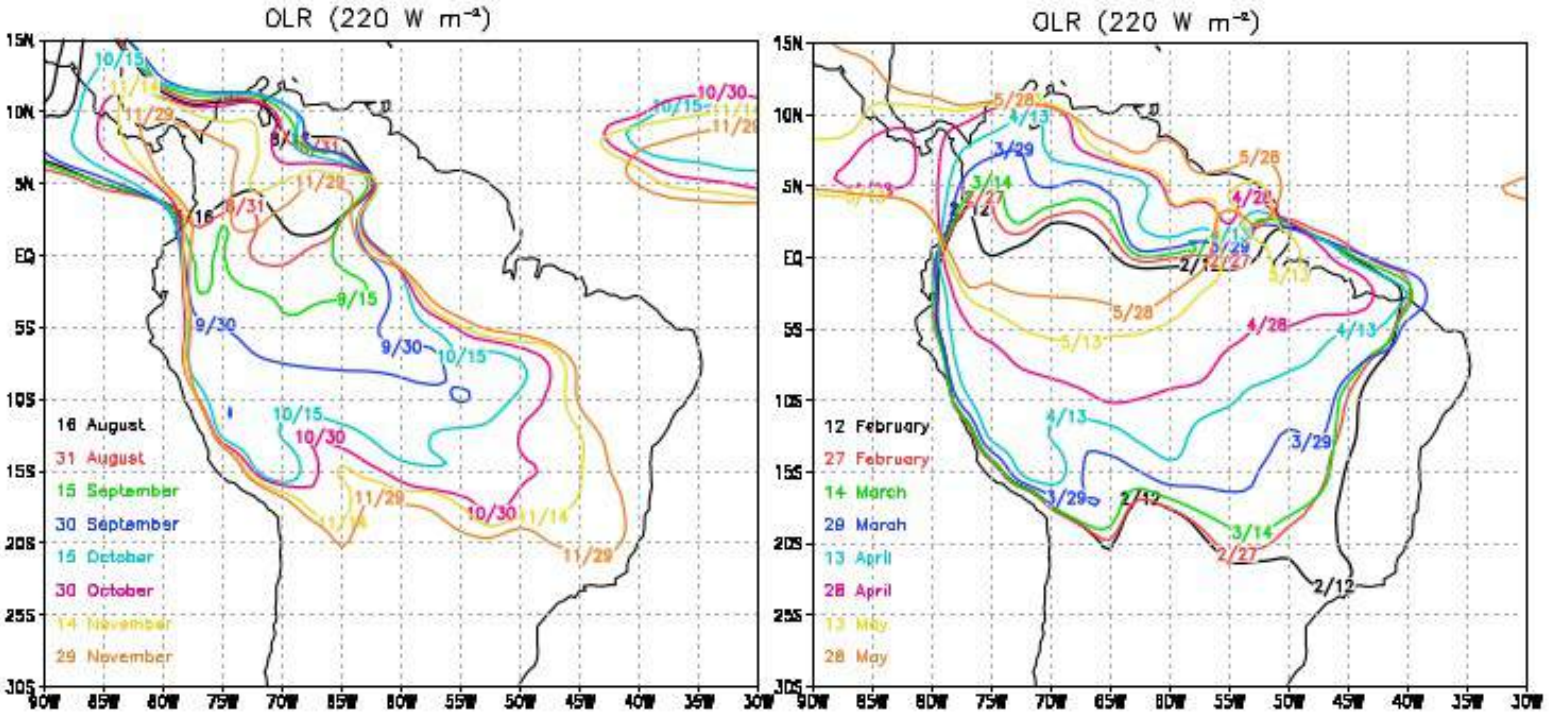
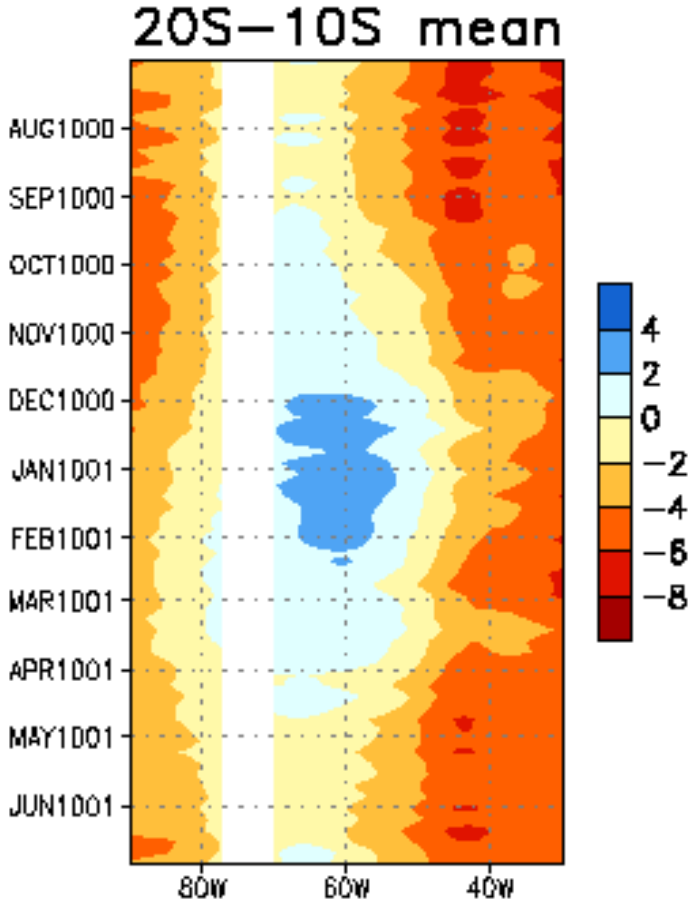


Fig. 10. Time onset and end dates for the wet season in the monsoon core region (Central Brazil) based on OLR less than 220 W m^{-2}.

Source: Silva and Kousky (2012)

Climatological 850 hPa Zonal Wind



West-Central Region of Brazil

Gan et al. (2004) found that the identification of the onset and the demise dates.

The onset occurs between the pentads centered on September 15 and November 14.

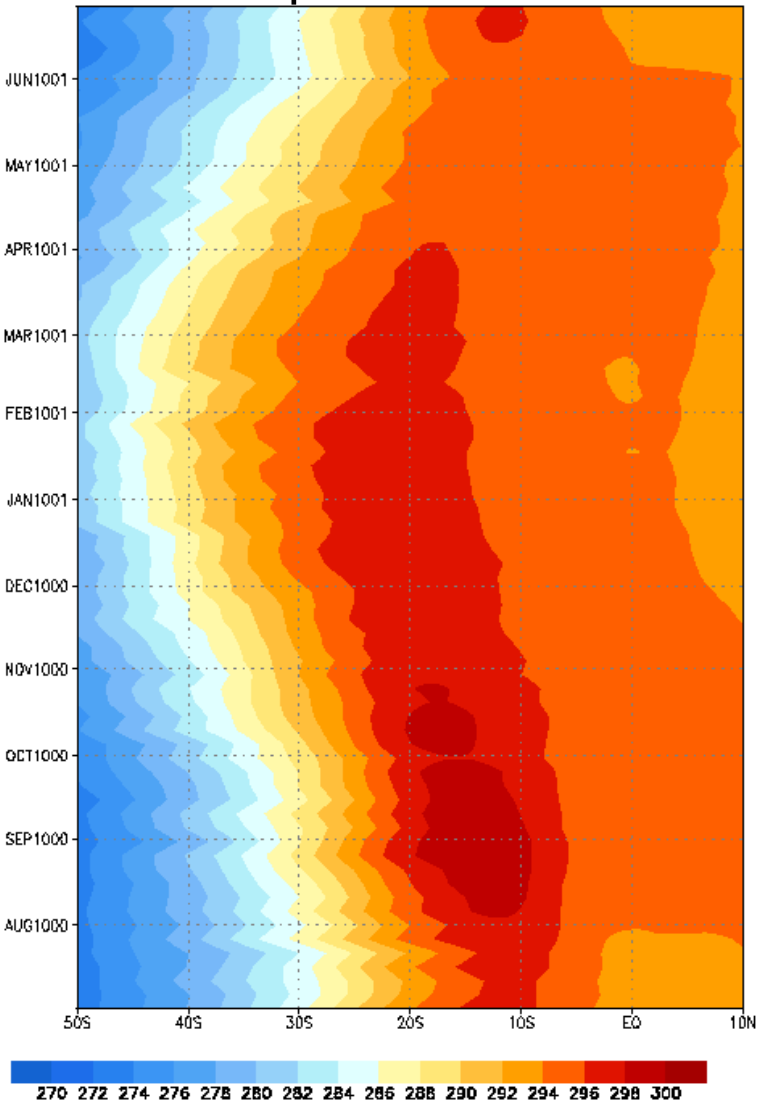
The average onset date: 13-17 October. Standard deviation: 3 pentads.

The demise occurs between the pentads centered on April 3 and May 3.

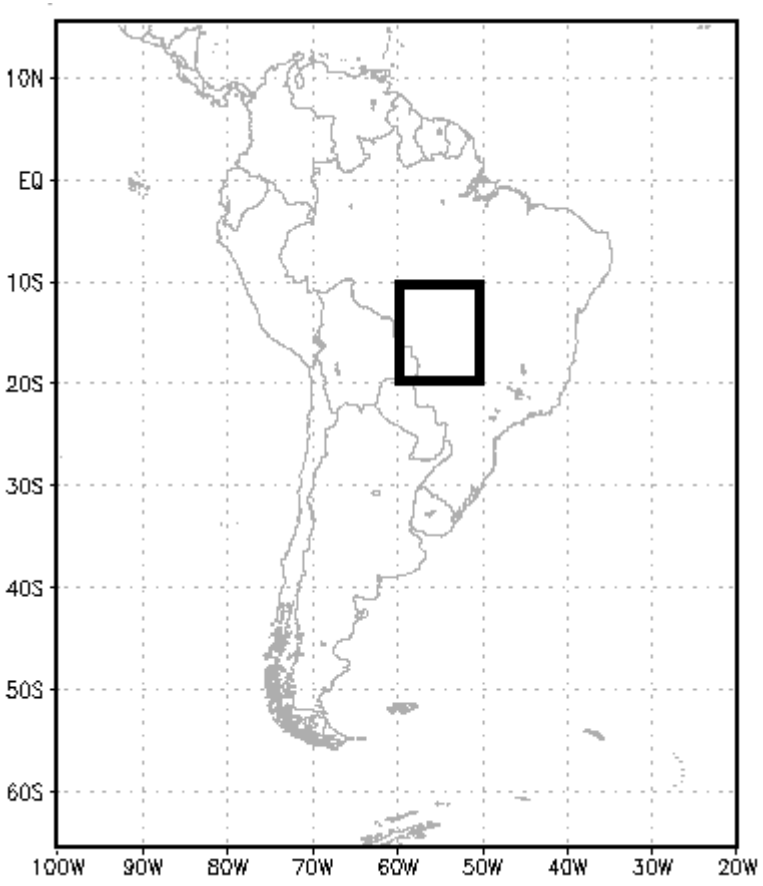
The average demise date: 16–20 April. Standard deviation: 2 pentads.

There is considerably more variability in the onset dates than in the demise dates, which implies that the onset date may be somewhat dependent on transient systems to initiate and organize deep convection.

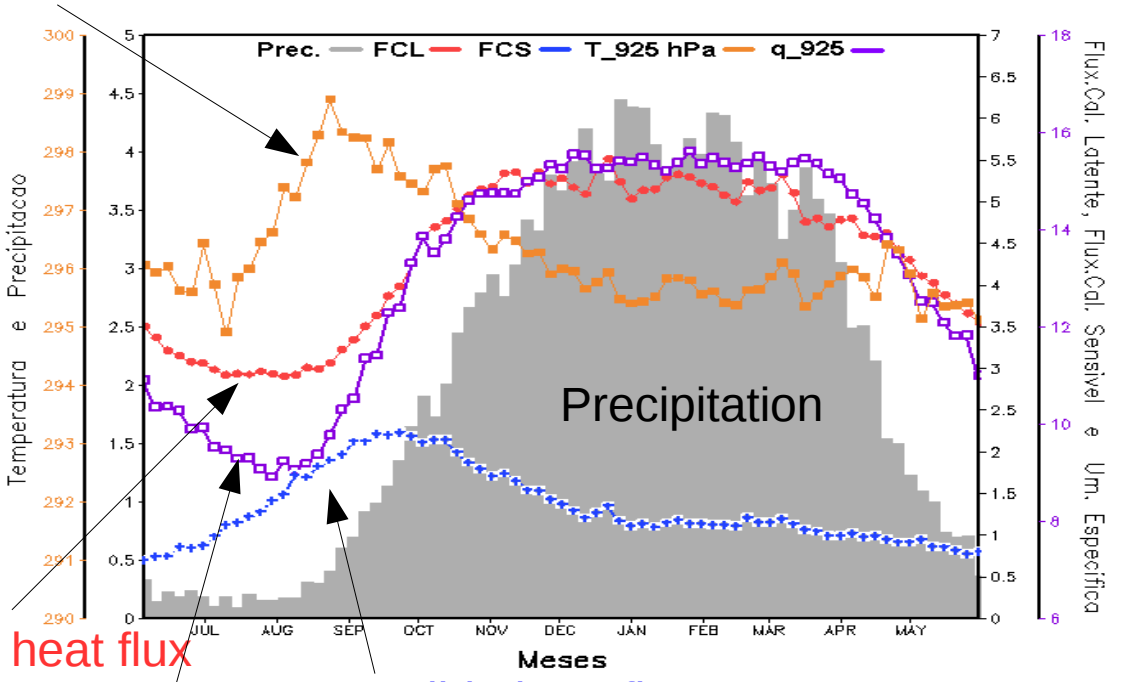
925-hPa Temperature - 60°W-50°W



Annual maximum of the low level temperature over West-Central Brazil region is in September, just prior to the onset of the rain season.



Temperature **1989-2010** **10°-20°S e 50°-60°W**



Latent heat flux

Specific humidity

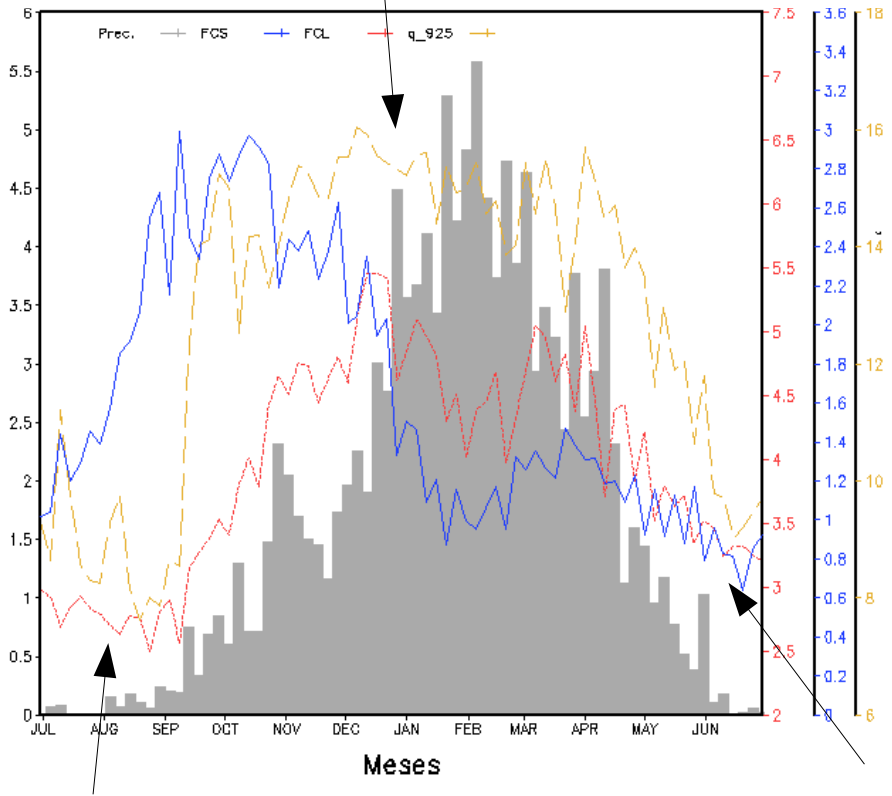
Sensible heat flux

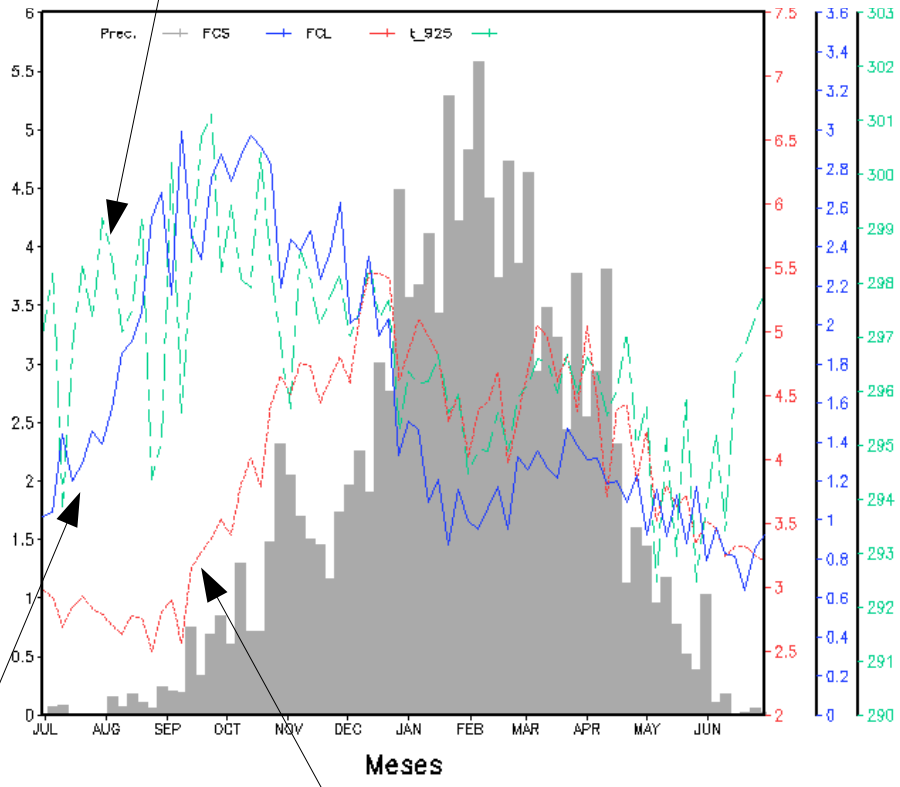
Annual evolution of precipitation (in gray bars), temperature, sensible heat and latent heat, averaged over the WCB.

Late onset - 2003/04

Specific humidity

Temperature



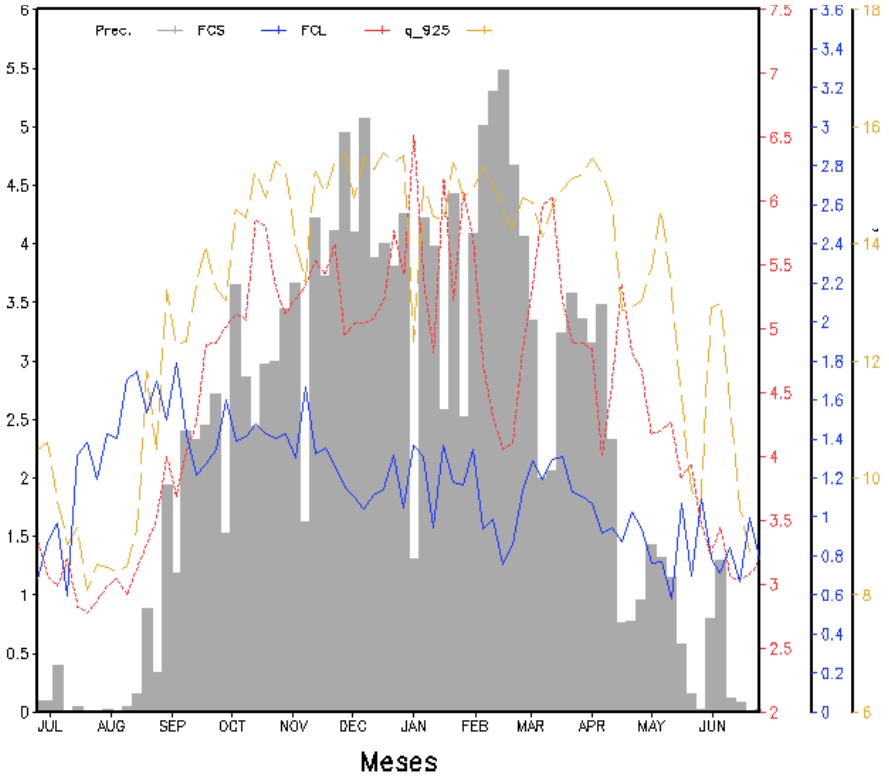


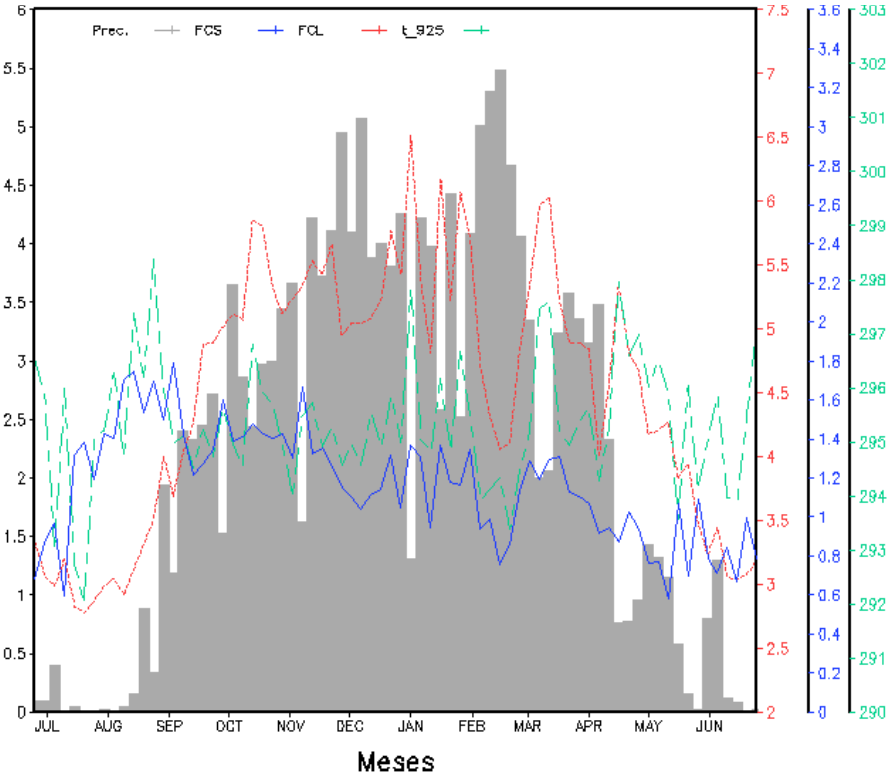
Latent heat flux

Sensible heat flux

Latent heat flux

Early onset -1992/93





Spring dry conditions in central-east Brazil

Less soil moisture / Higher surface temperature in late spring

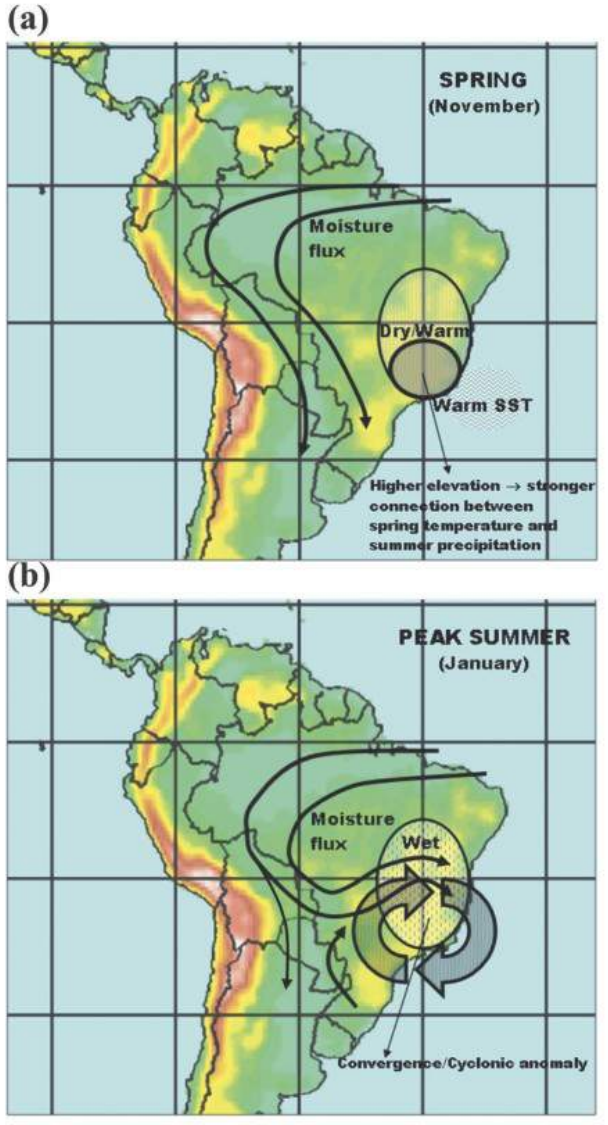
More net surface solar radiation and higher SST off southeast Brazil coast in late spring

Lower surface pressure / more convergence / Enhanced convection over high elevations in southeast Brazil

Cyclonic circulation anomaly over southeast Brazil

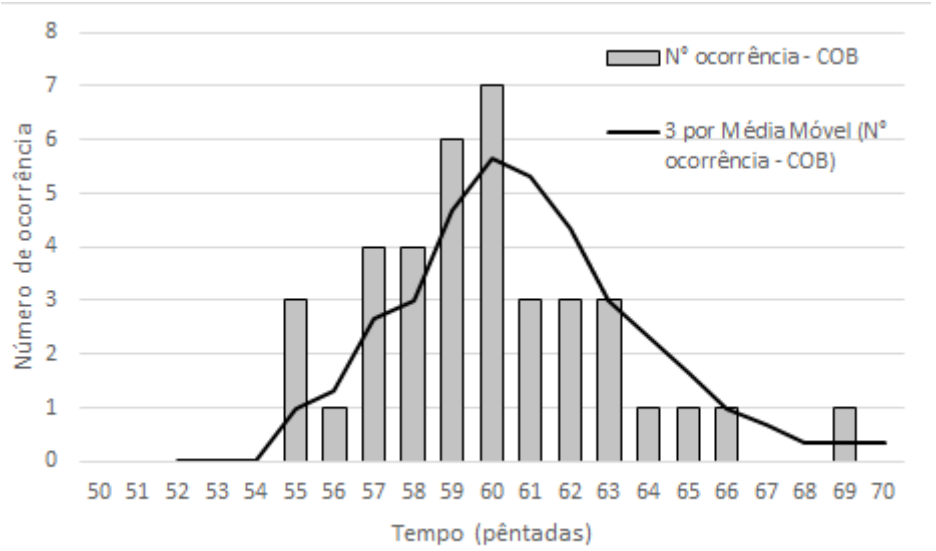
Moisture flux / convergence into central-east Brazil

Peak summer wet conditions in central-east Brazil

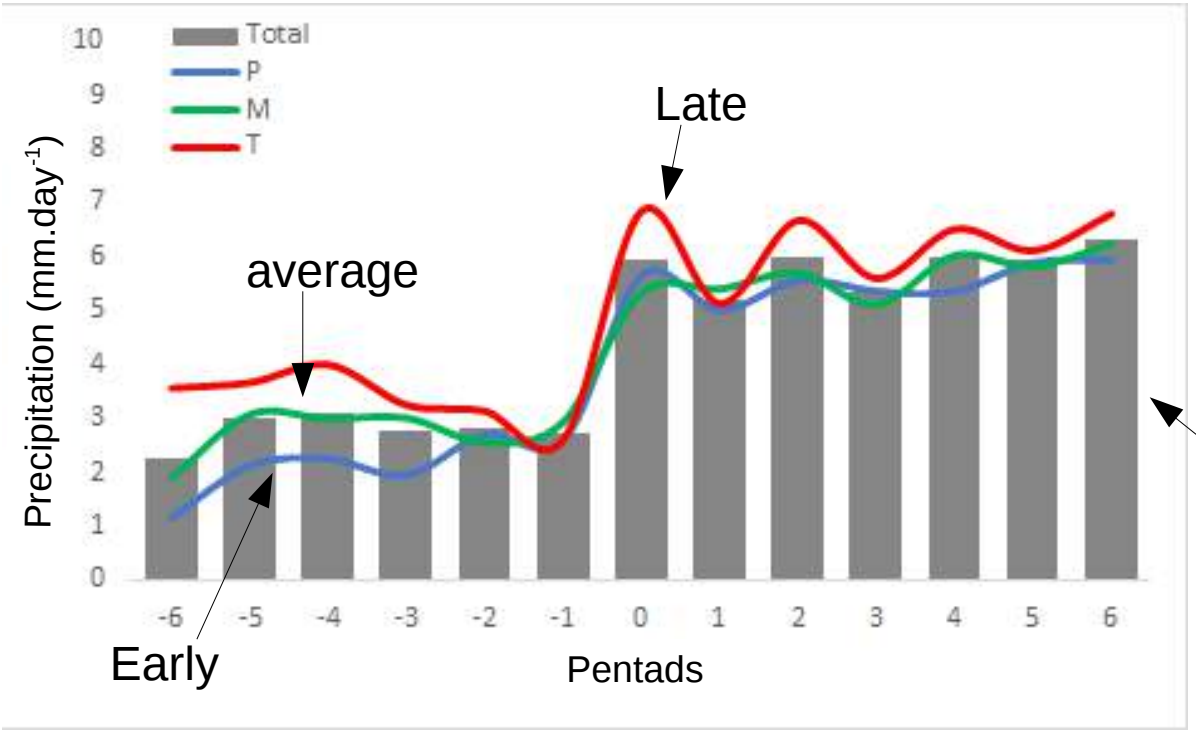


Grimm et al. (2007)

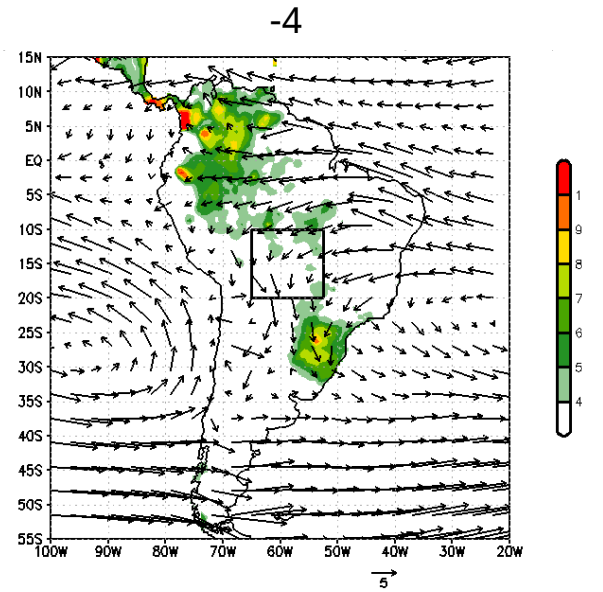
West-Cental

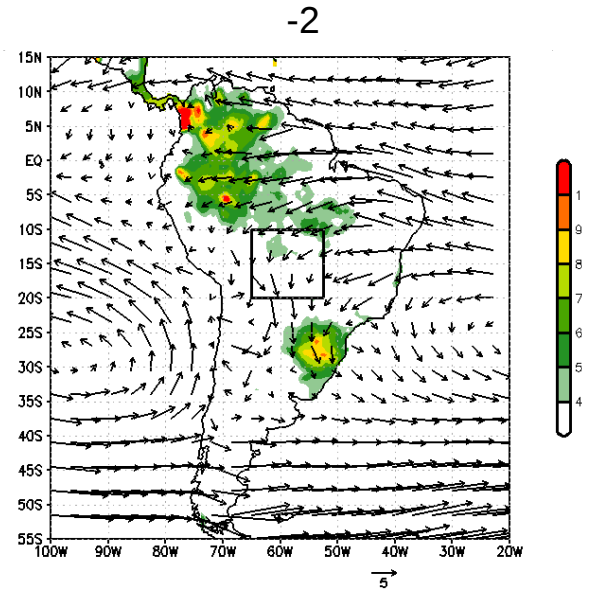


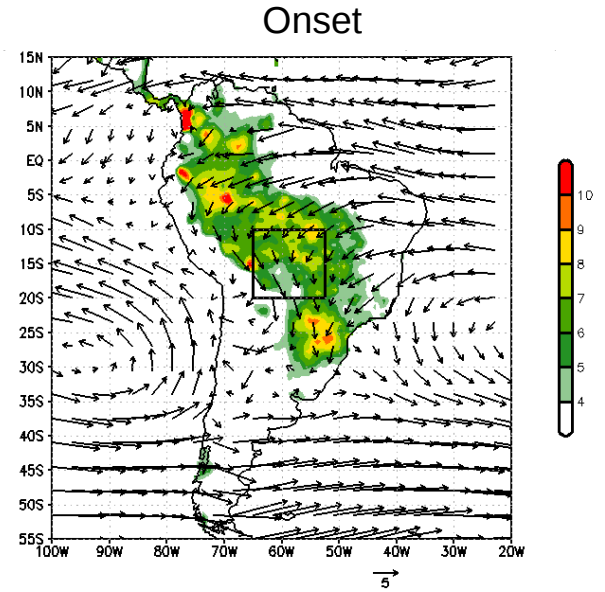
Histograms of onset dates, in pentads, for the WCB regions.
Method - Gan et al. (2006)
Period - 1981-2010.
Continue line represents 3-day running mean.

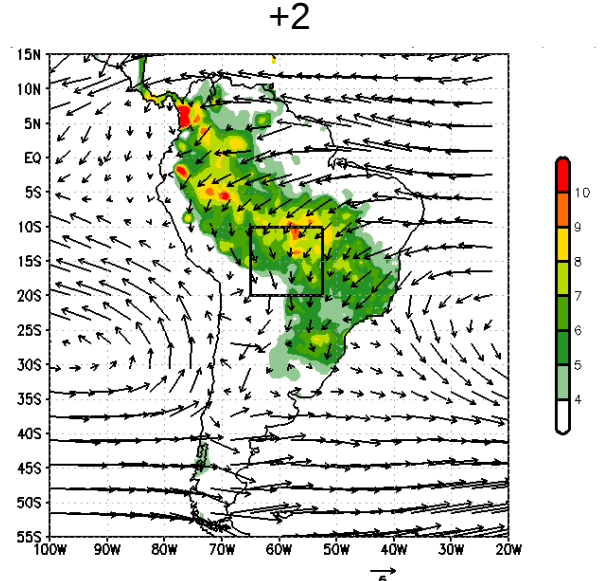


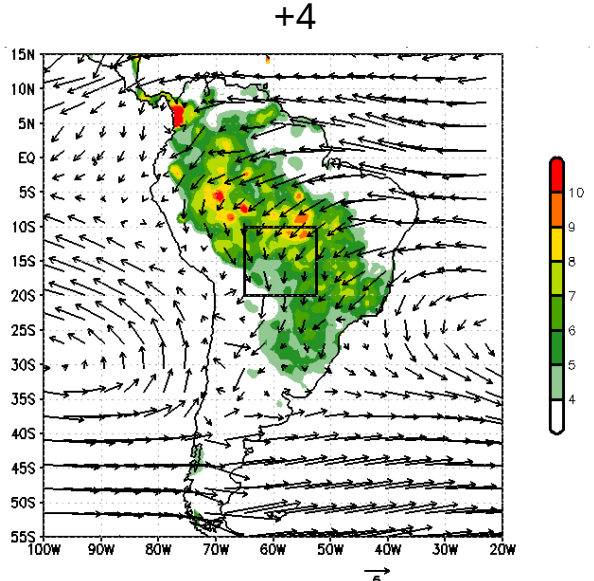
Precipitation data - CPC





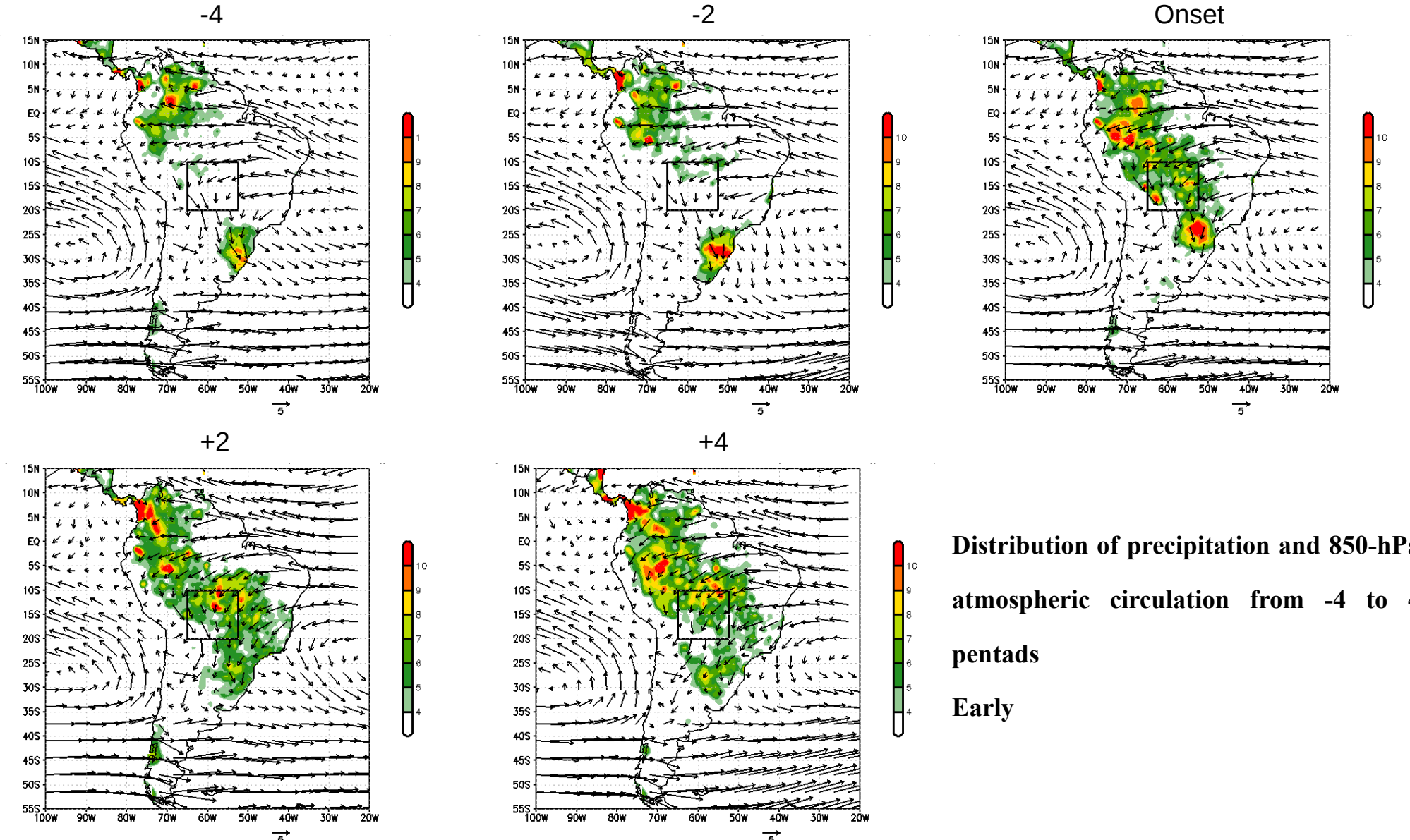






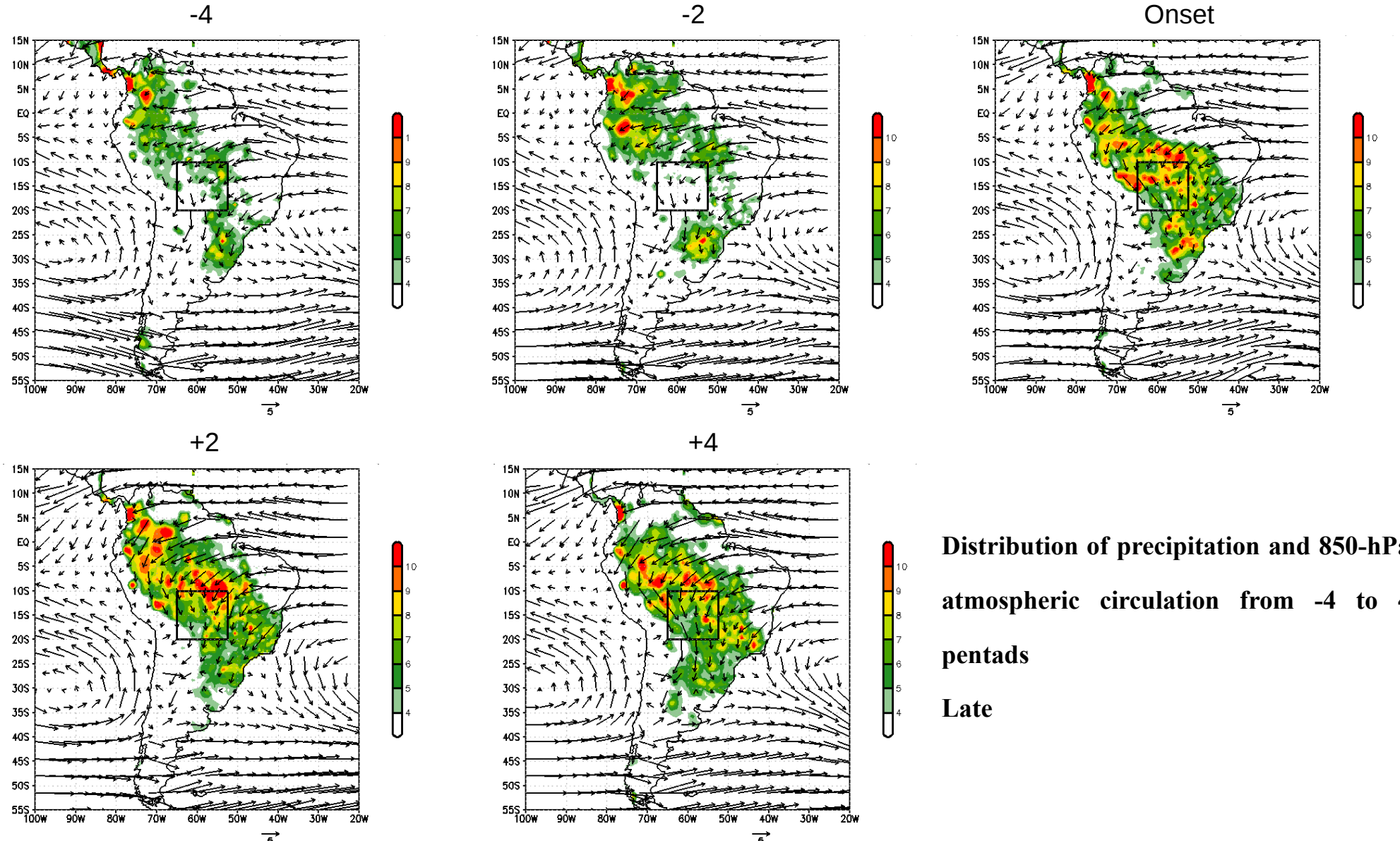
Distribution of precipitation and 850-hPa atmospheric circulation from -4 to 4 pentads

Total



Distribution of precipitation and 850-hPa atmospheric circulation from -4 to 4 pentads

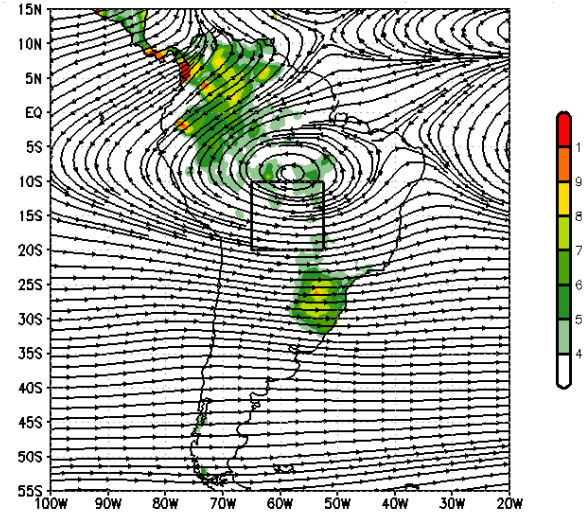
Early



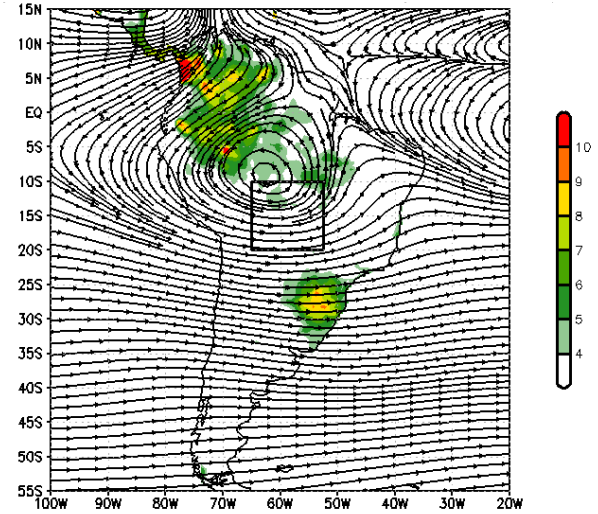
Distribution of precipitation and 850-hPa atmospheric circulation from -4 to 4 pentads

Late

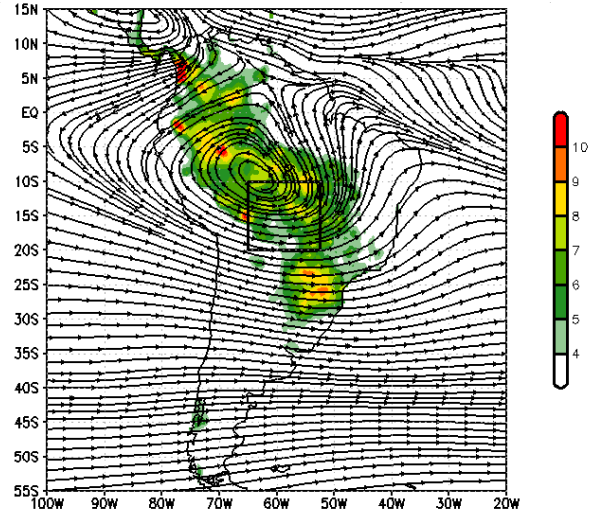
-4



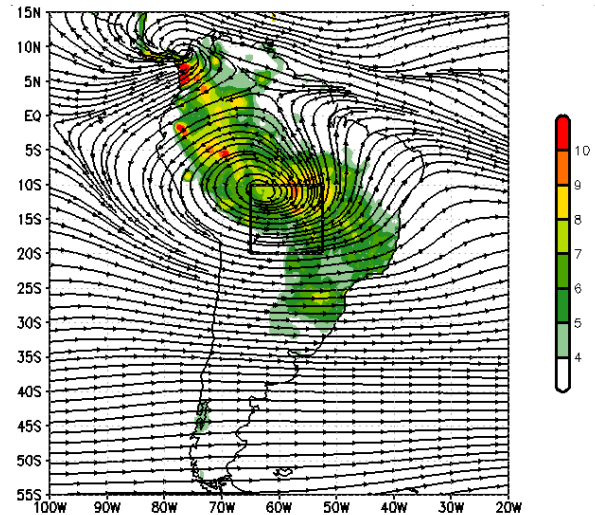
-2



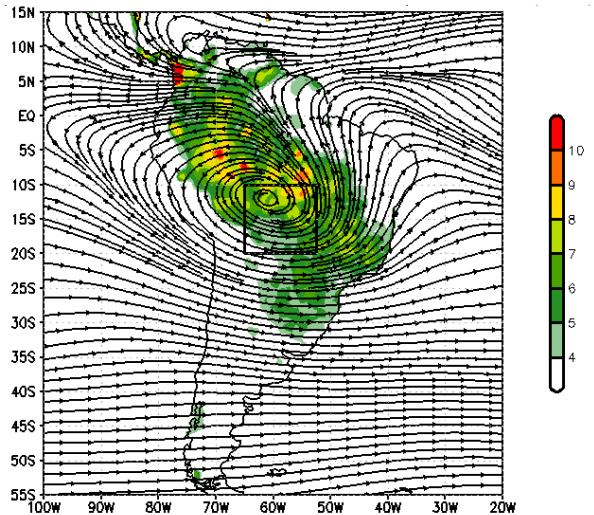
Onset



+2

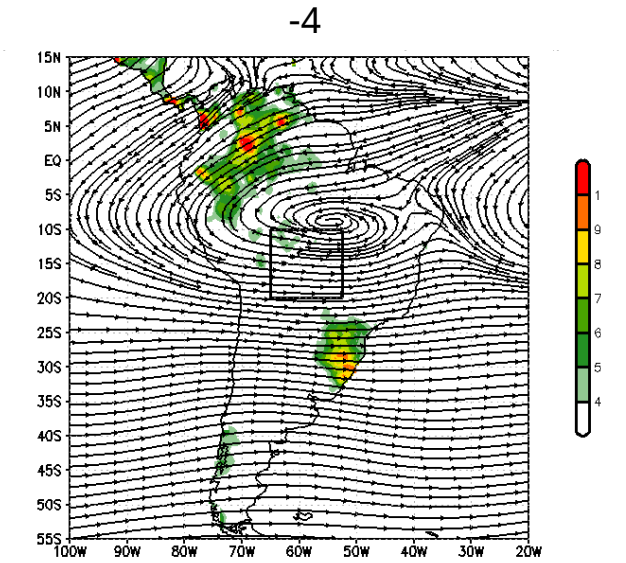


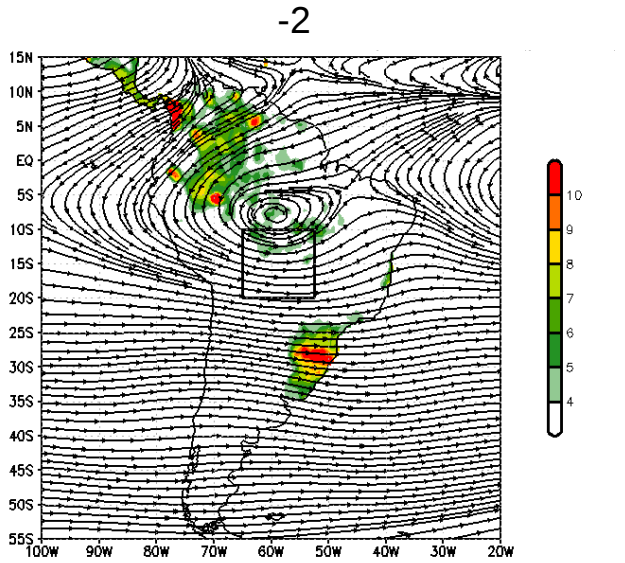
+4

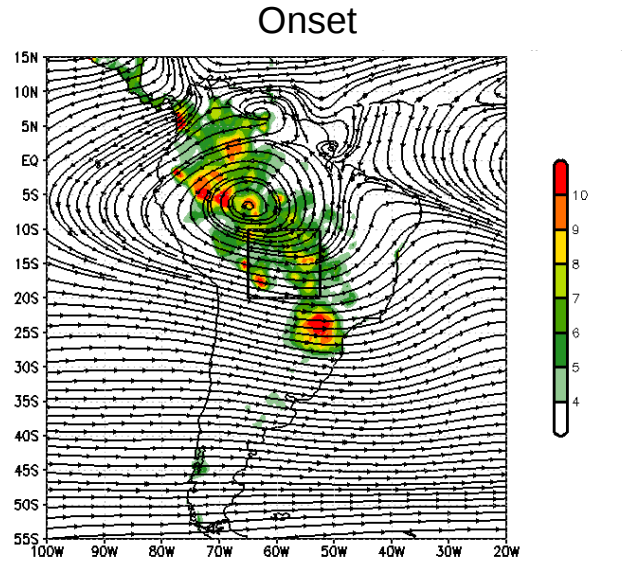


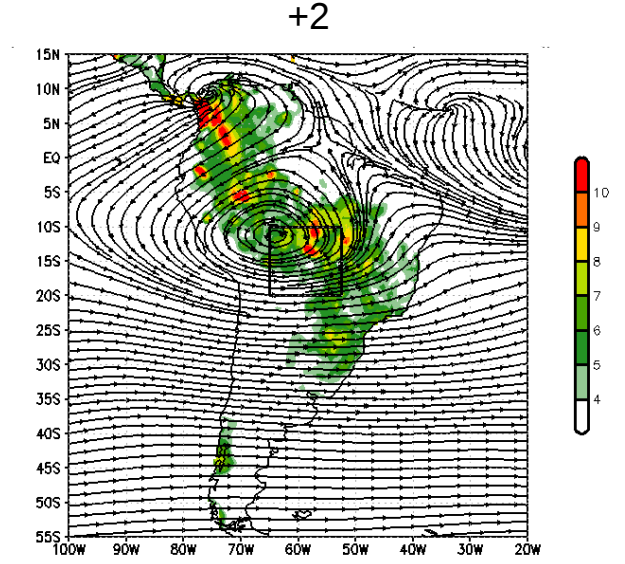
Distribution of precipitation and 200-hPa atmospheric circulation from -4 to 4 pentads

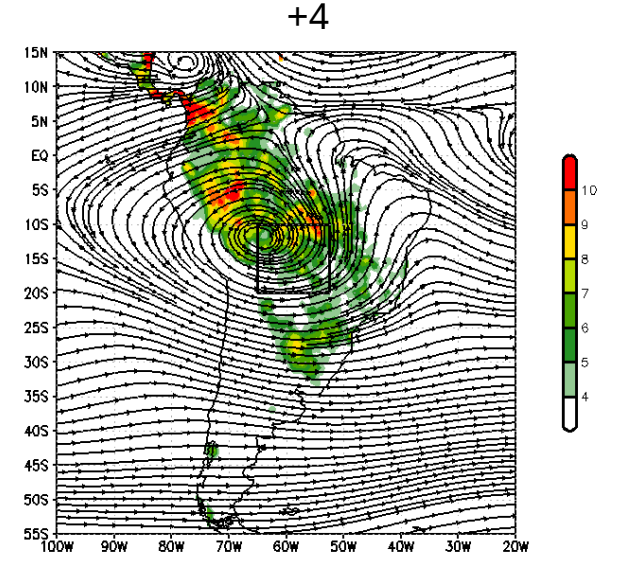
Total





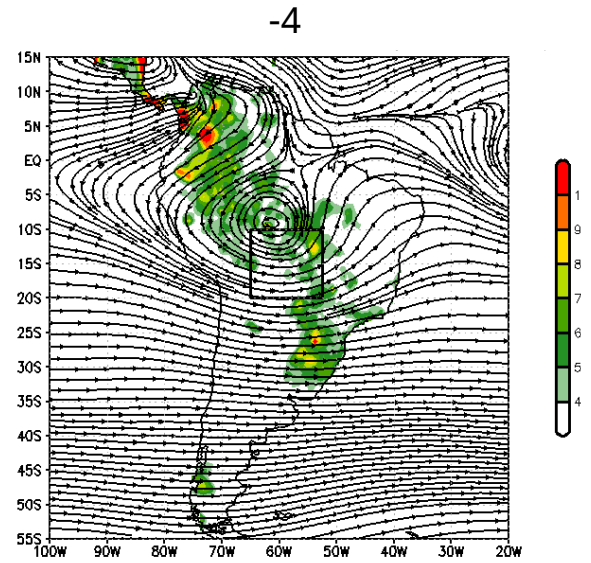


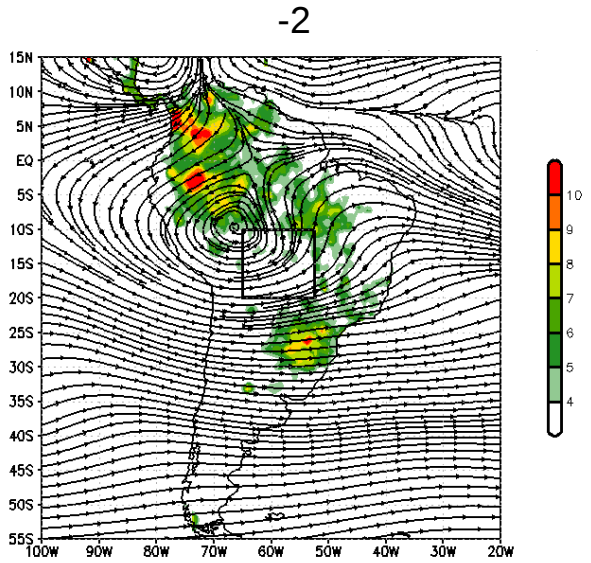


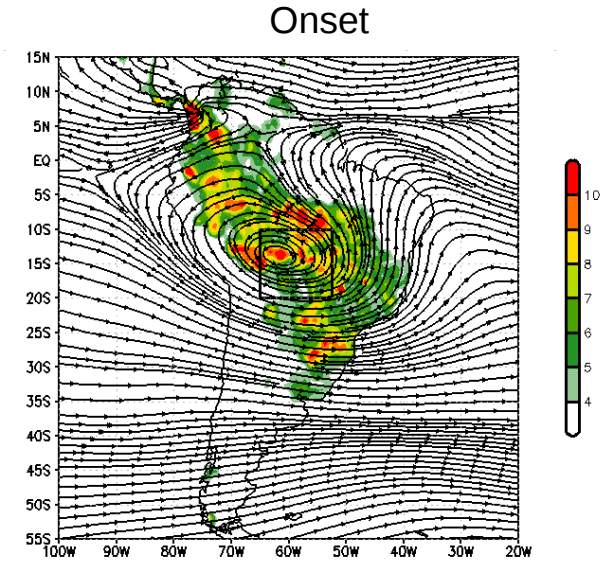


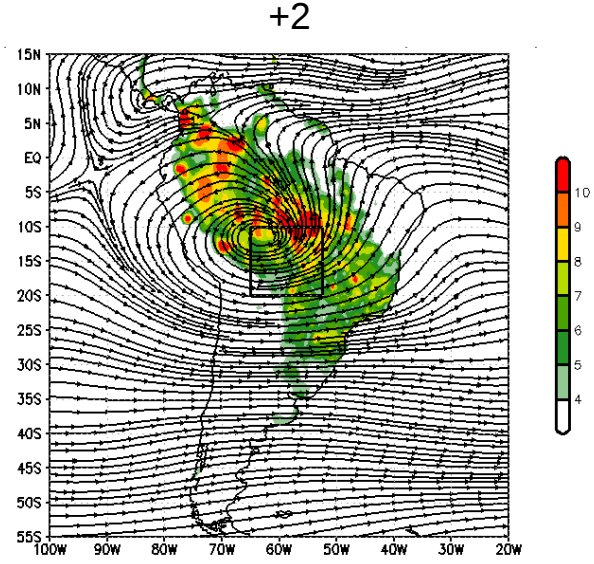
Distribution of precipitation and 200-hPa atmospheric circulation from -4 to 4 pentads

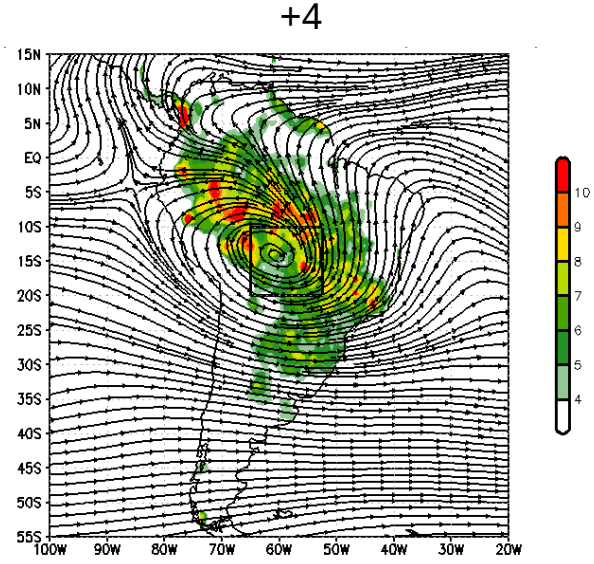
Early





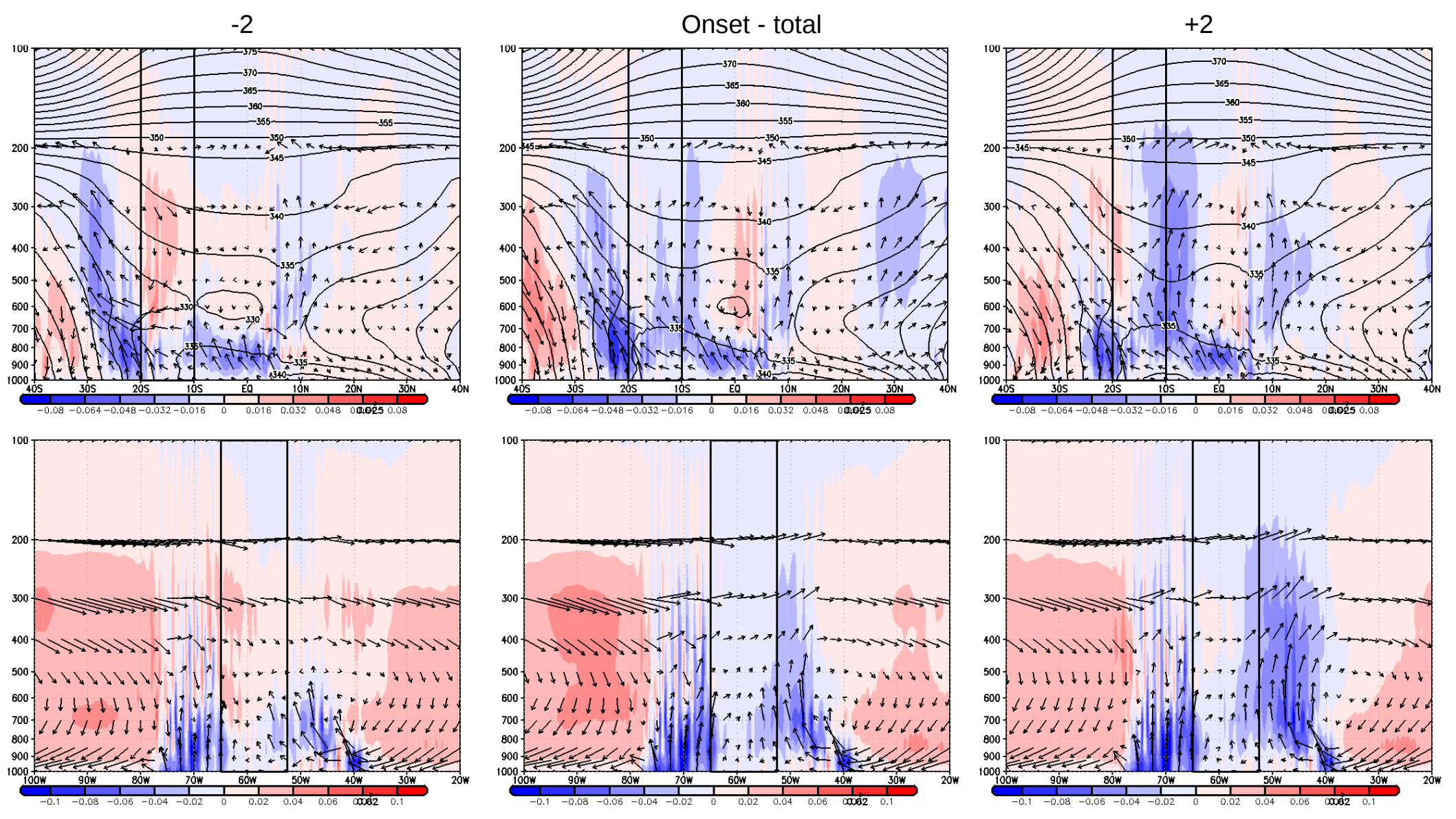






Distribution of precipitation and 200-hPa atmospheric circulation from -4 to 4 pentads

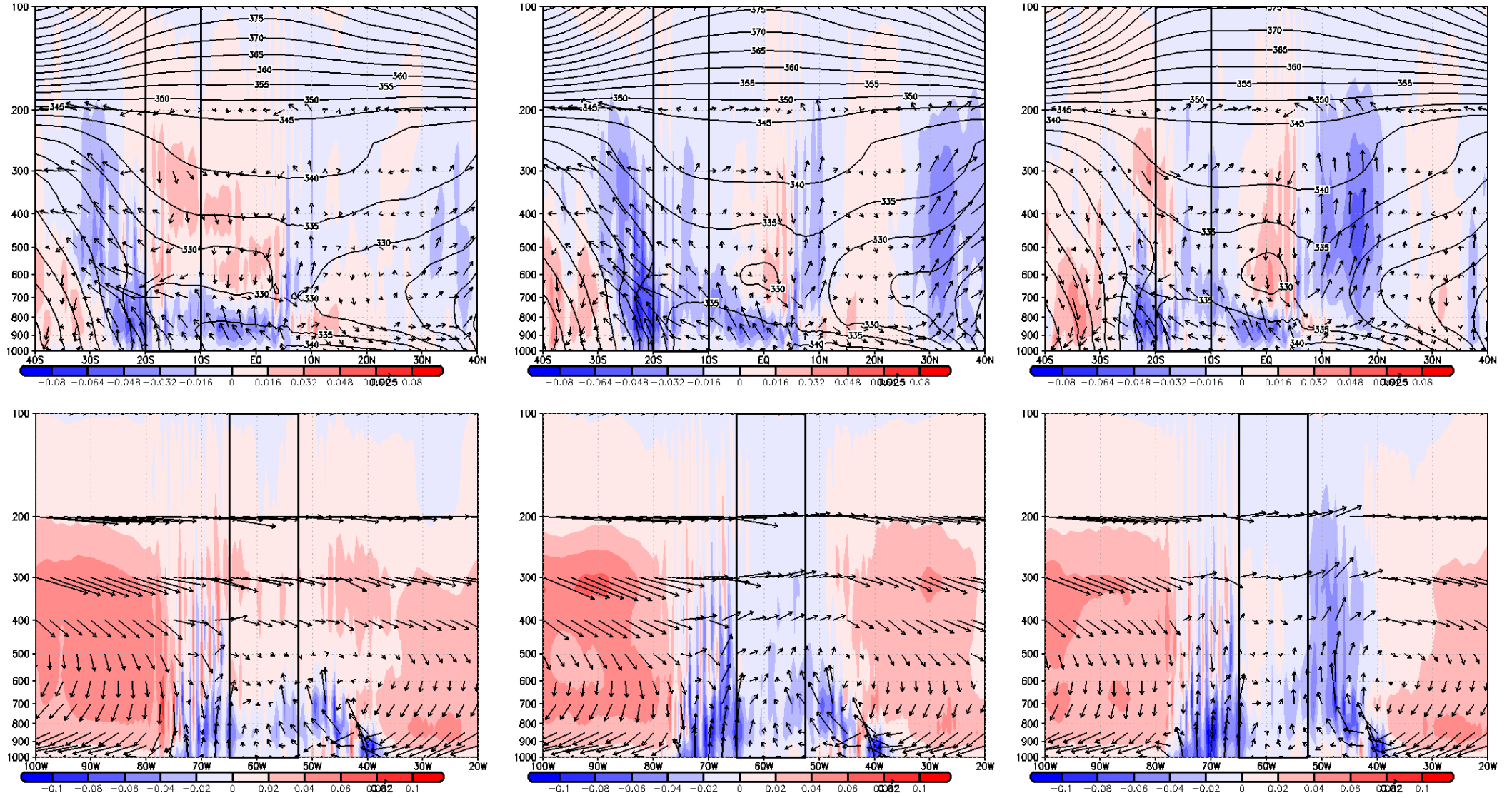
Late

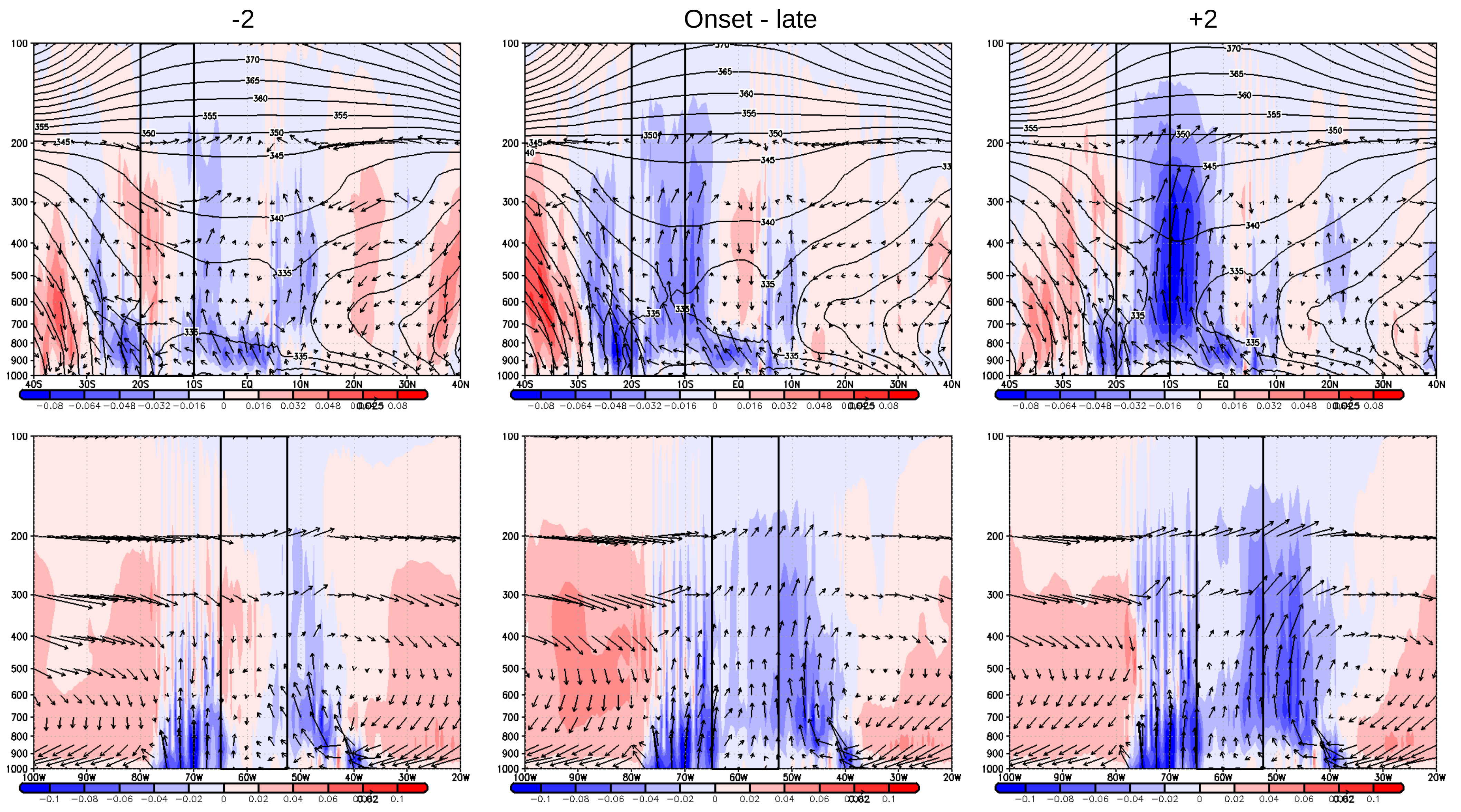

-2
Onset - total
+2
100
200
300
400
500
600
700
800
900
1000
375
370
365
360
355
350
345
340
335
330
40S
30S
20S
10S
EQ
10N
20N
30N
40N
−0.08 −0.064 −0.048 −0.032 −0.016 0 0.016 0.032 0.048 0.08
100W
90W
80W
70W
60W
50W
40W
30W
20W
−0.1 −0.08 −0.06 −0.04 −0.02 0 0.02 0.04 0.06 0.1

-2

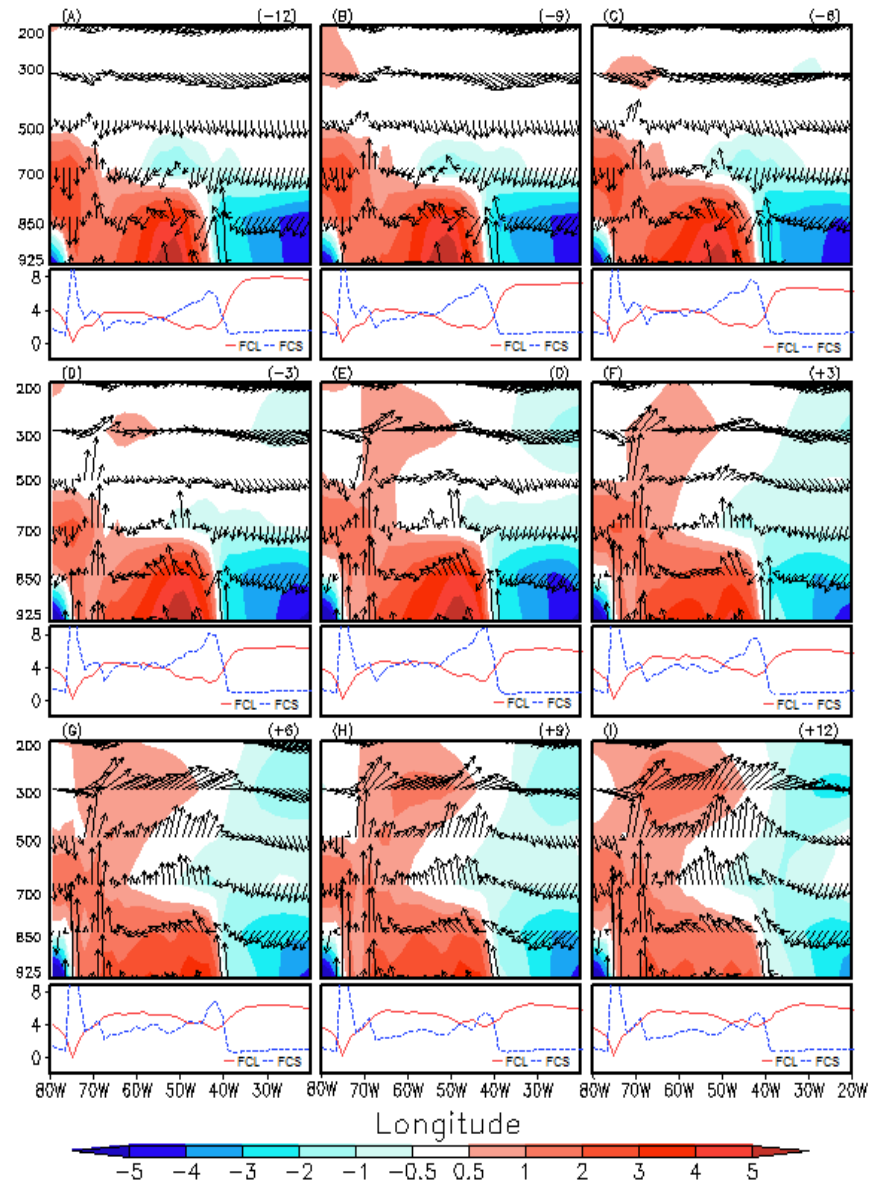
Onset - early

+2



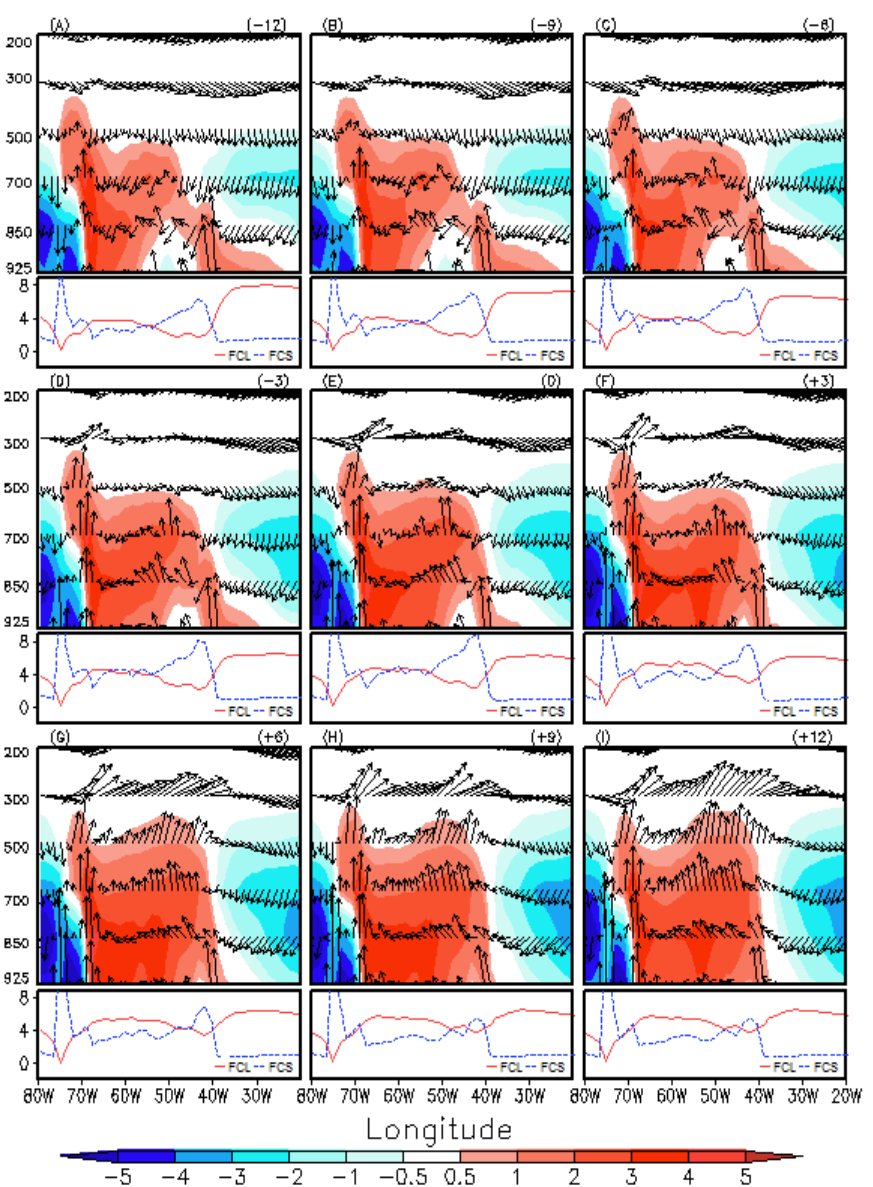


-2
Onset - late
+2



Left: Temperature Anomalies

Right: specific humidity anomalies (g/kg)



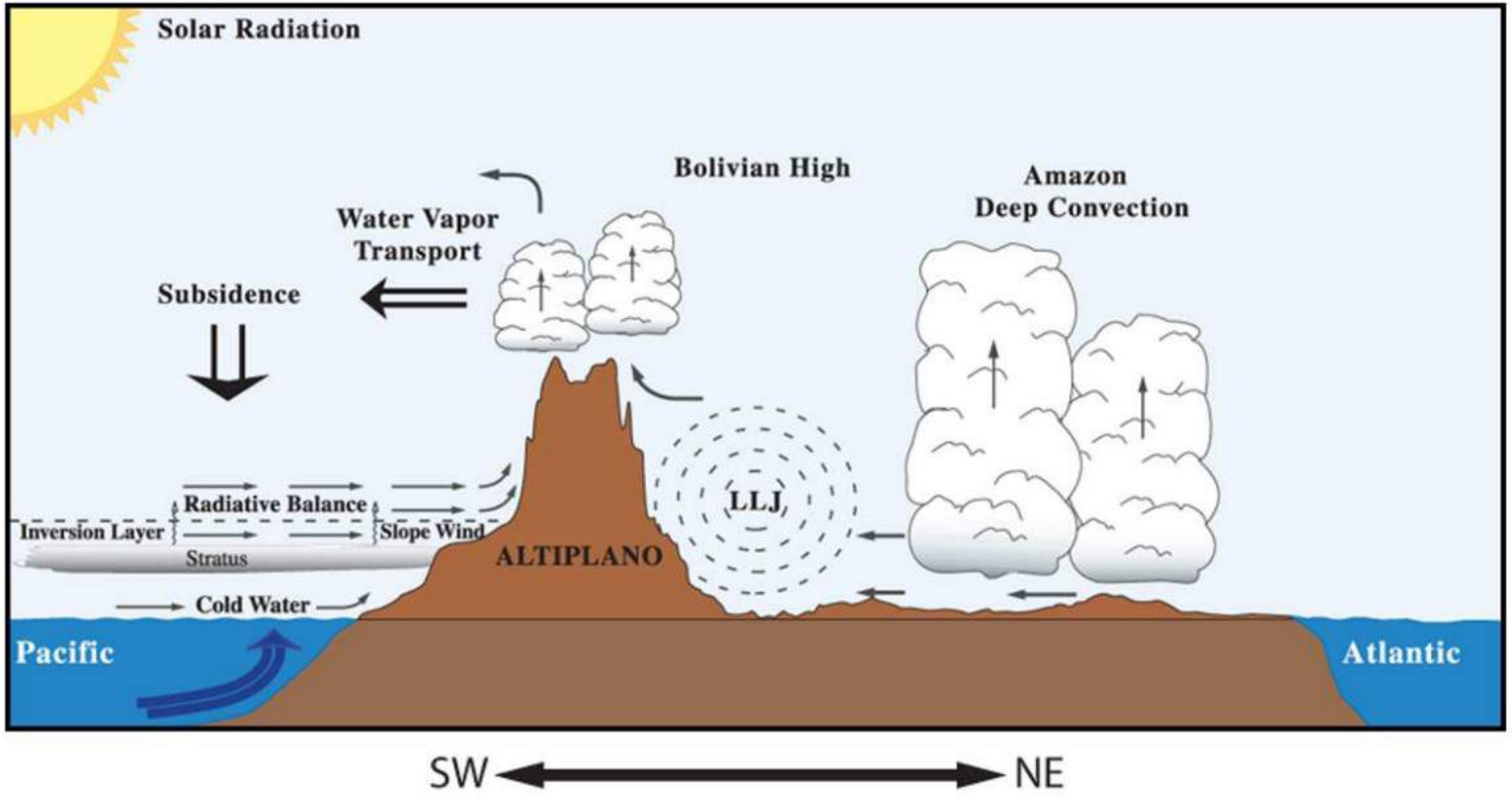
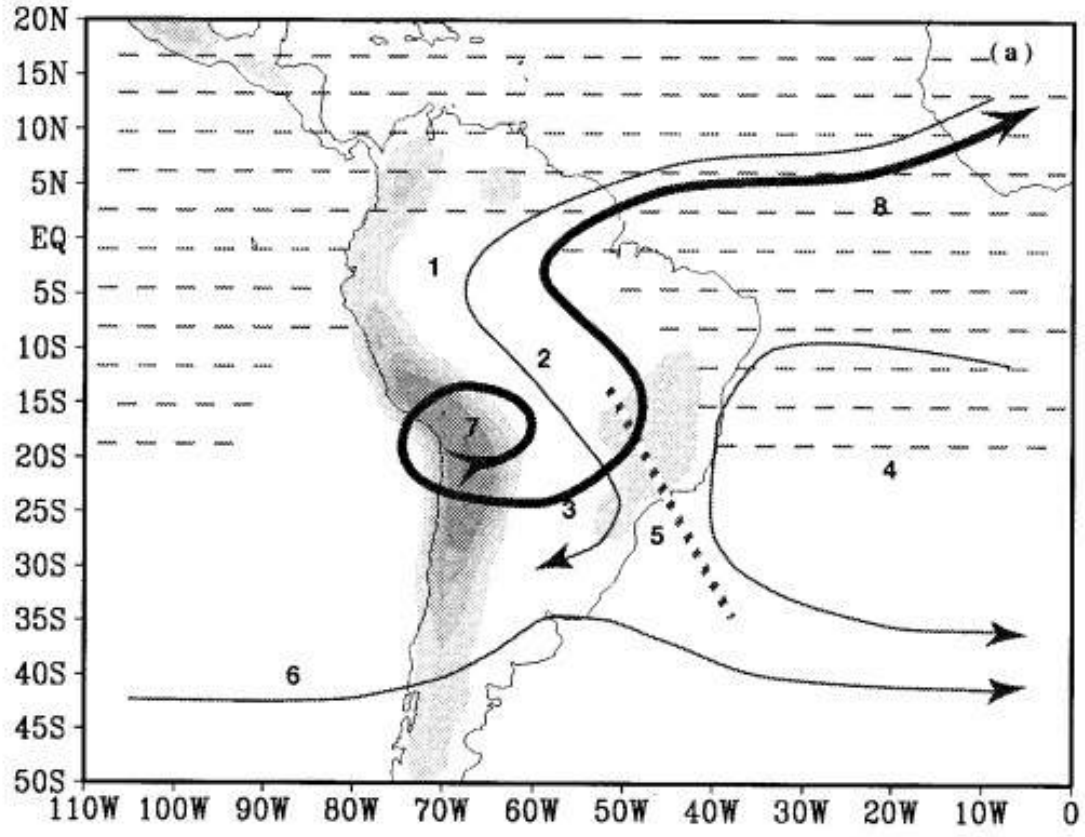


Fig. 4. Section across South America displaying schematically the major large-scale elements related to the South American Monsoon System. Source: Climate Variability & Predictability Program (CLIVAR)
(http://www.clivar.com/publications/other_pubs/clivar_transp/pdf_files/av_g3_0106.pdf)

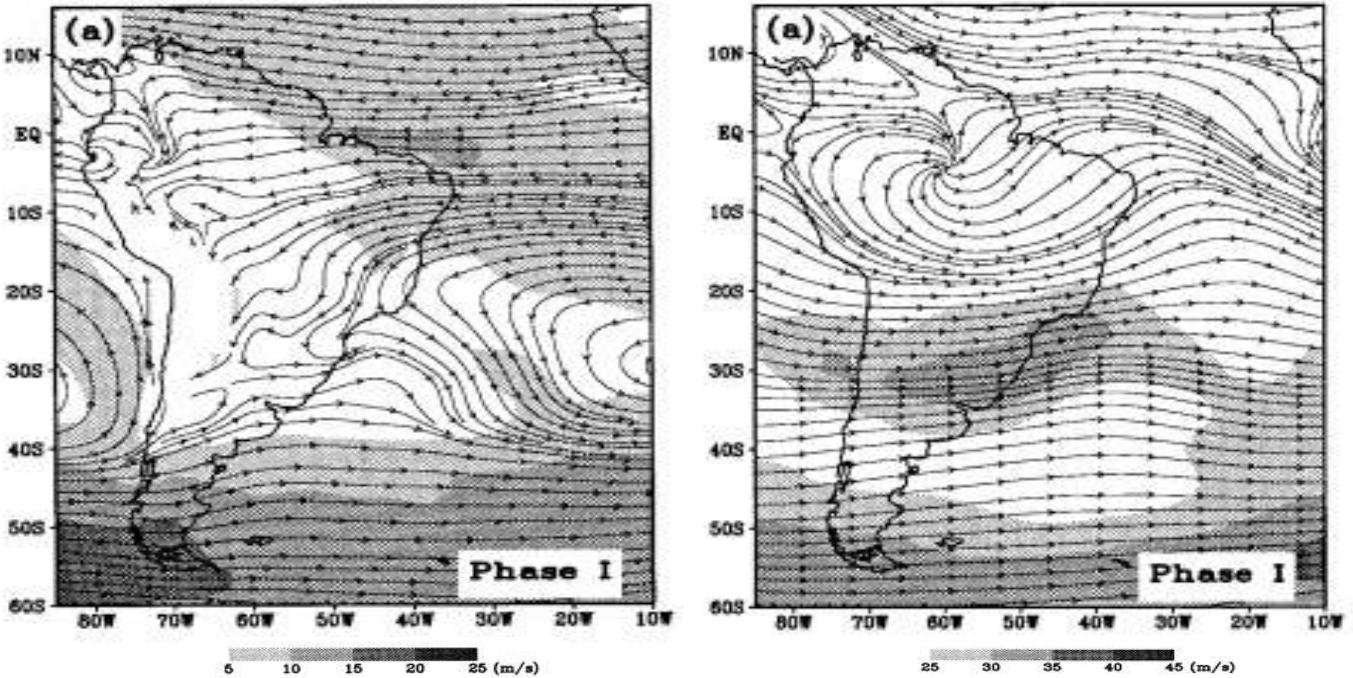


Schematic illustration of elementary features for SASM. The shading represents the topography. The areas where easterlies prevail are indicated by dashed lines. The correspondingly numbered features are as follows: 1) low-level cross equatorial flow, 2) northwesterlies, 3) Gran Chaco low, 4) subtropical high, 5) SACZ, 6) midlatitude westerlies, 7) Bolivian high, and 8) upper-level return flow.

Zhou and Lau (1998).

Zhou and Lau (1998) identified five phases of the SASM

Period	Phase	Description
1 Oct–19 Nov 1989	I	Premonsoon
20 Nov–29 Dec 1989	II	Monsoon development
30 Dec 1989–7 Feb 1990	III	Monsoon mature
8 Feb–19 Mar 1990	IV	Monsoon withdrawal
20 Mar–28 Apr 1990	V	Postmonsoon



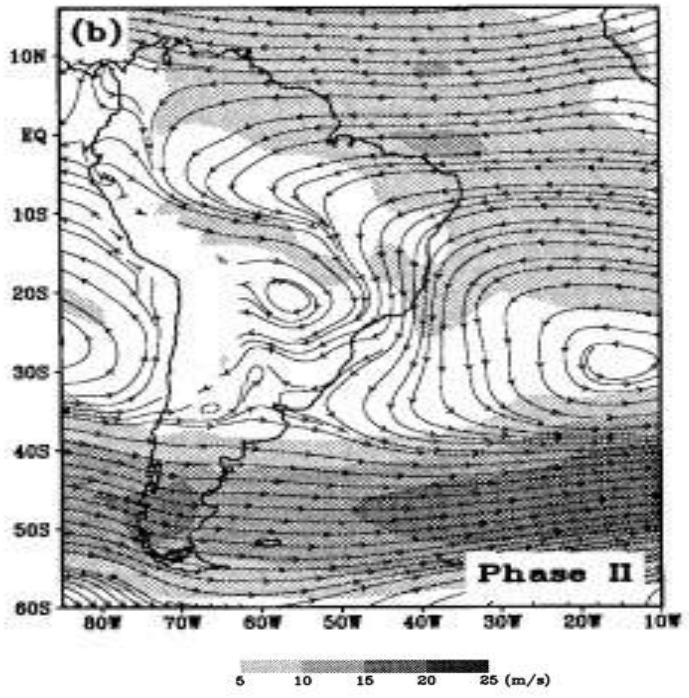
GEOS-1 assimilation of 200-hPa and 850-hPa circulation composite for phase I of the SASM:
The shading indicates wind speed in units of m/s

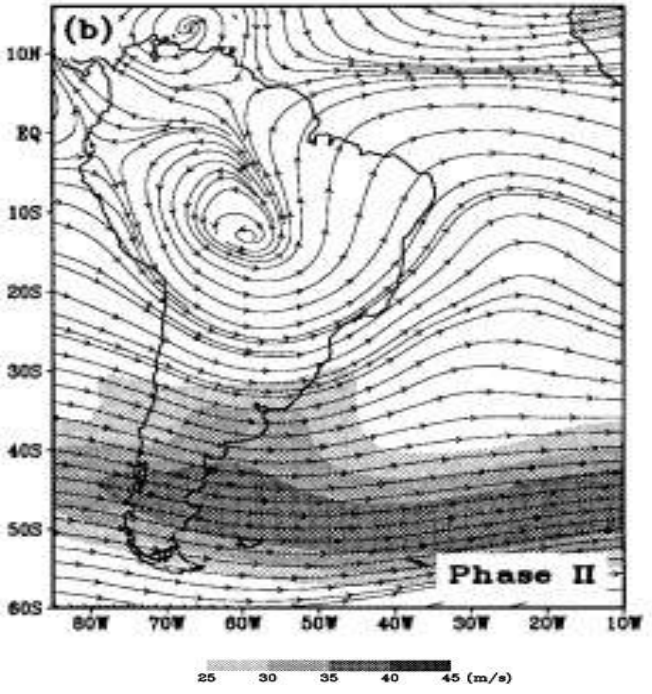
In the premonsoon phase (1 Oct–19 Nov 1989), the centers of the upper-level divergence, and the lower-level convergence are situated above the Amazon basin.

This is a result of local strong convective heating.

In the subtropical region, upper-tropospheric westerly wind is strong, and low-level easterly winds flow from the tropical and subtropical South Atlantic to the foot of the northern Andes.

The strong vertical shear indicates that temperature contrast between the Tropics and extratropics is dominant at this stage.



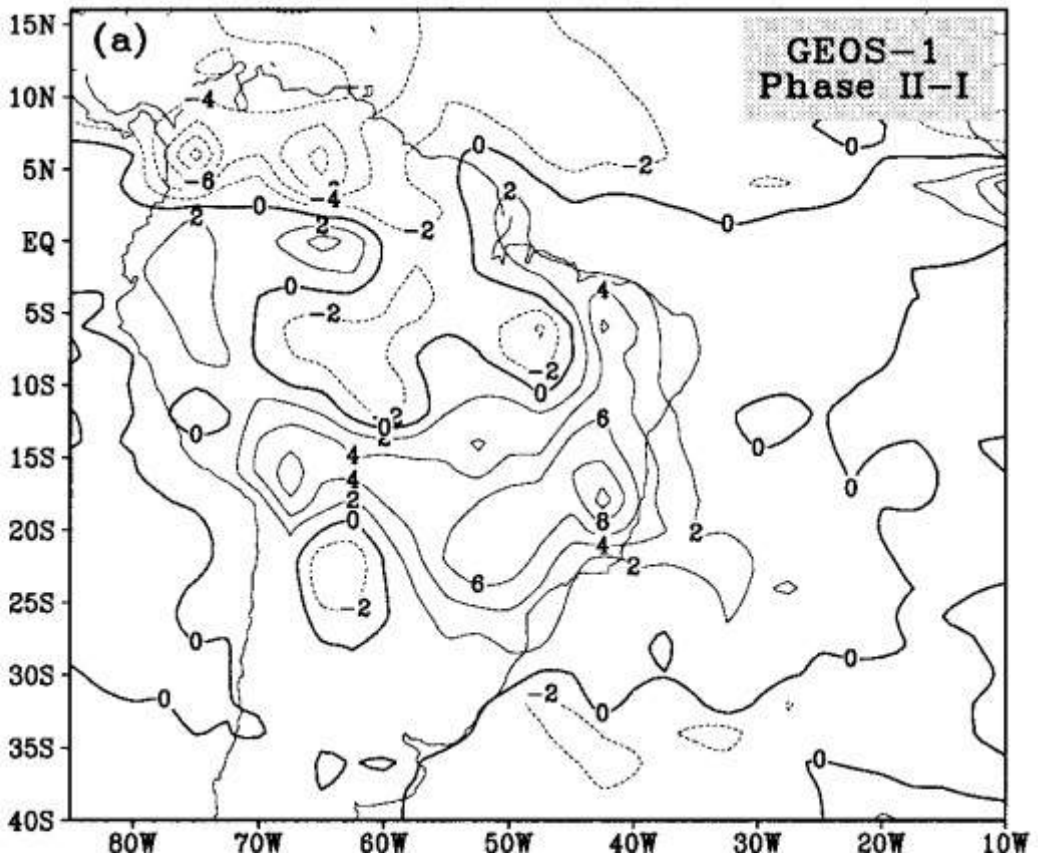


The upper-tropospheric anticyclonic circulation intensifies over the southern Amazon basin and deepening of the trough over the subtropical western South Atlantic Ocean.

During this phase (20 Nov–29 Dec 1989) a vigorous low-level cyclonic activity develops to the southeast of Altiplano.

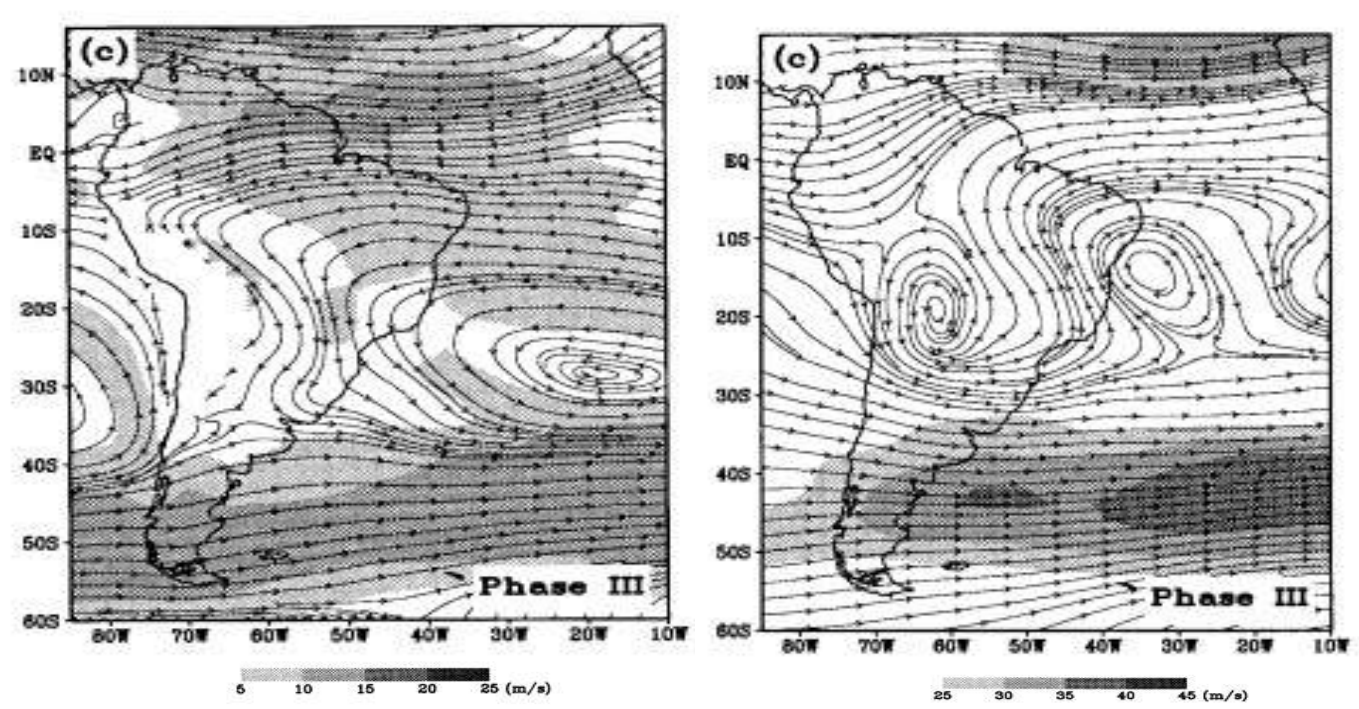
The equatorial trade winds over the North Atlantic enhance and cross the equator upon reaching the Andes, forming a strong northwest to southeast low-level flow along the southwestern boundary of the Amazon basin.

The anticyclonic center in the South Atlantic moves toward the continent.



The phase difference of the precipitation field shows a southeastward movement of the heavy rainfall center from phase I to phase II.

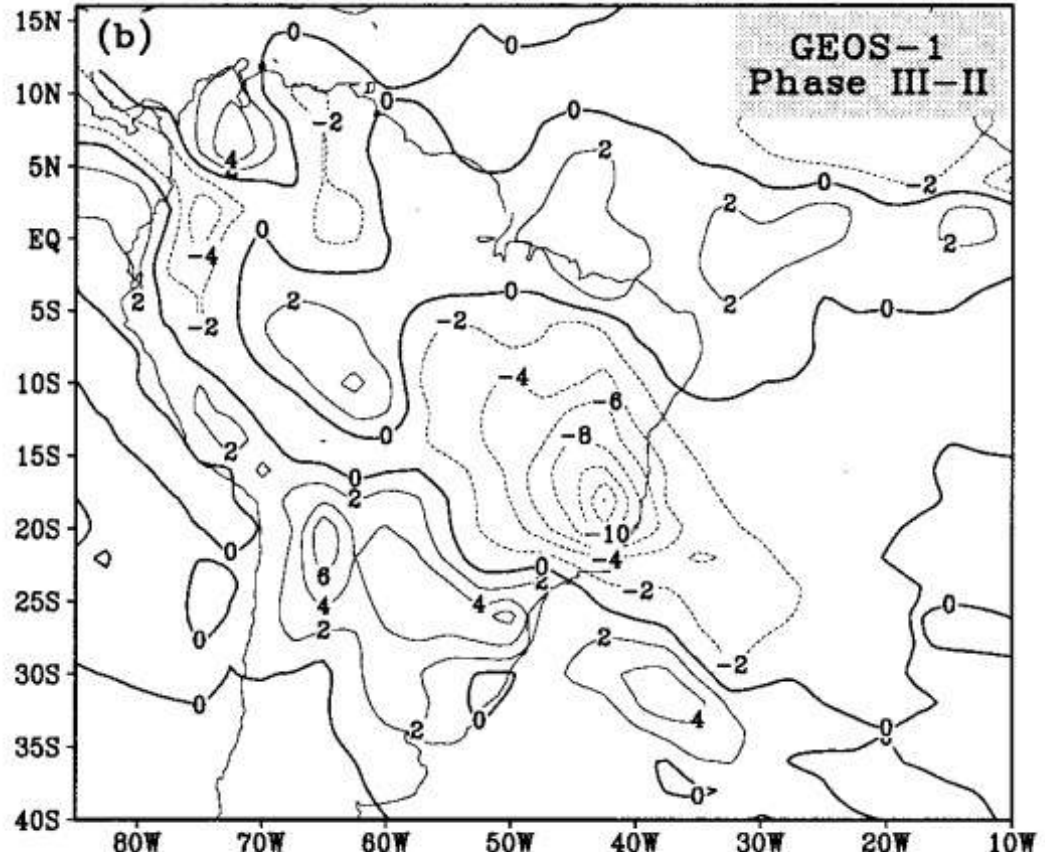
The rainfall amount increases over the central Andes, but the most severe thunderstorms are initiated over southeastern Brazil, which may be connected to the activation of SACZ.



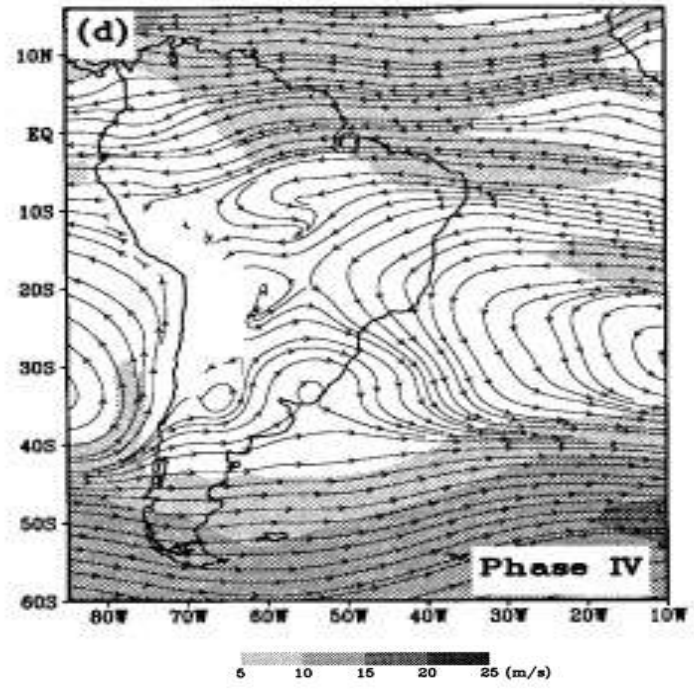
At this stage (30 Dec 1989–7 Feb 1990) the heavy precipitation center embedded in the SACZ migrates farther southwestward to the southernmost position (about 26°S).

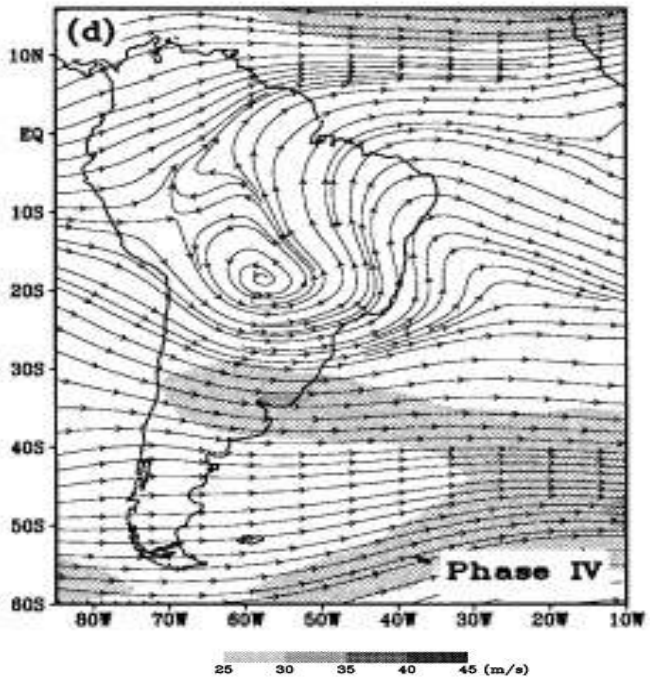
Two closed circulations, the Bolivian high and the South Atlantic low, are formed in the upper troposphere.

Between the two gyres, low-level northerlies and high-level southerlies prevail, showing remarkable thermal wind relation, which prompts the warm center developing over the Altiplano Plateau.

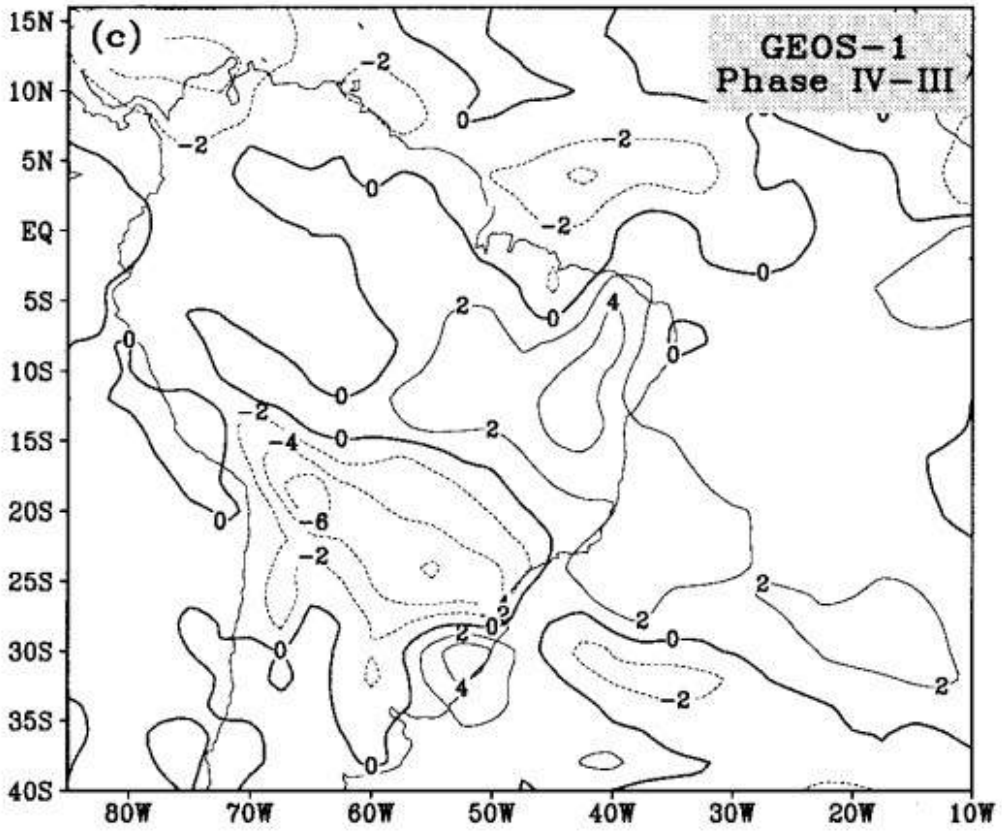


The rainfall over the sub-tropical Andes is substantially intensified.

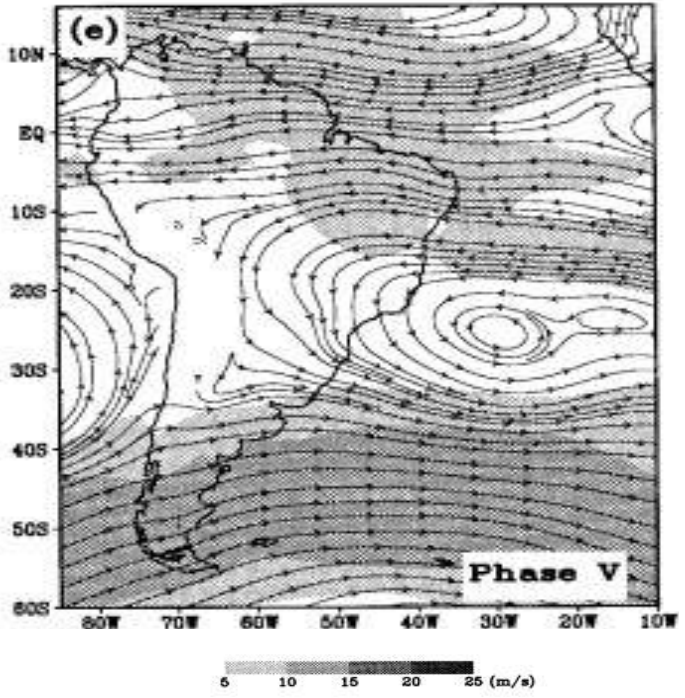


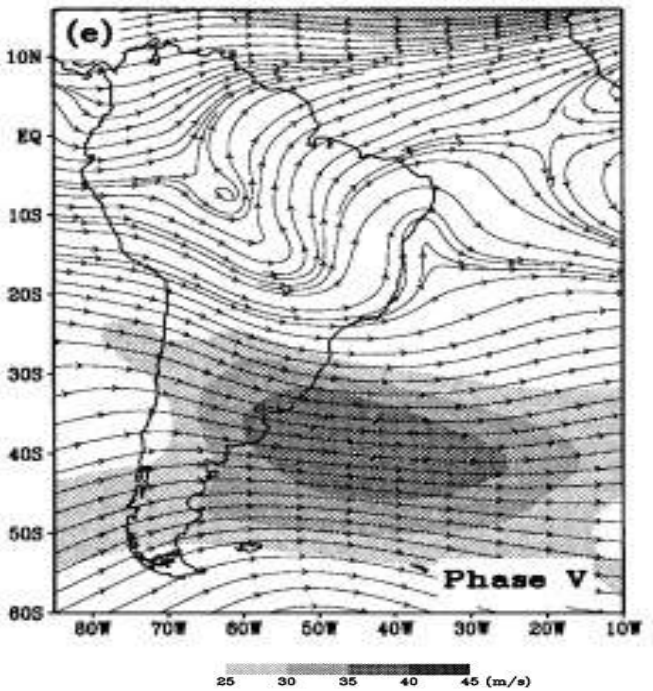


During phase IV (8 Feb–19 Mar 1990), the SASM starts to withdraw.
The withdrawal signal can be clearly identified by the bifurcation of upper-tropospheric westerly jet.
During this period, the cross-equatorial flow weakens.
On the eastern side of the tropical Andes, the low-level northwesterly monsoon flow is broken.
At the high level, the cut-off low opens, and the Bolivian high weakens and shifts away from the plateau.



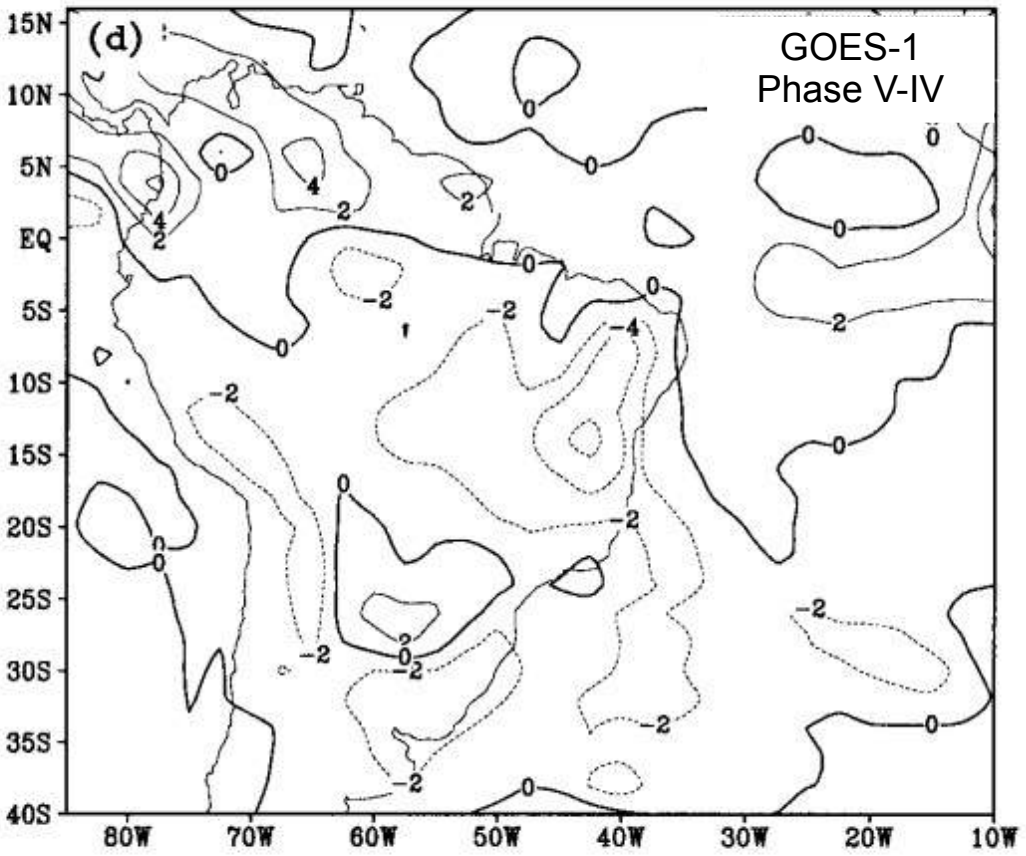
Due to the reduction of moisture supply to the subtropics, the major precipitation center retreats northeastward from the subtropics.

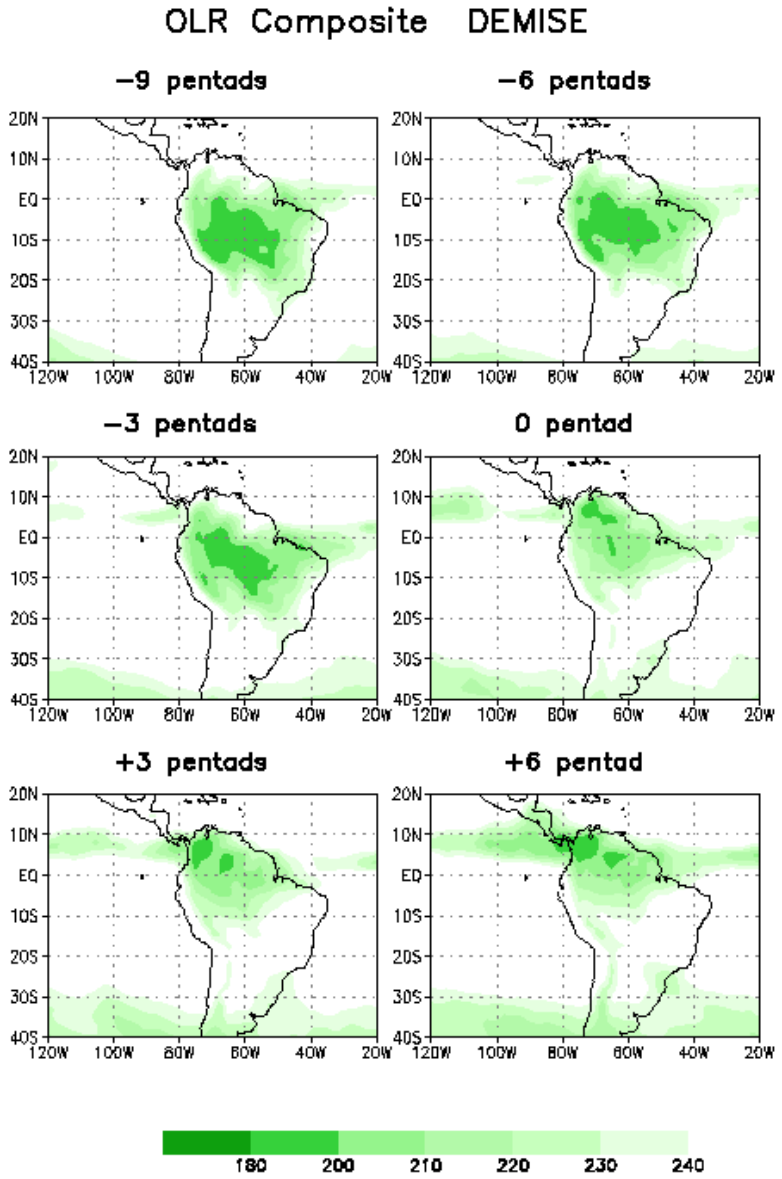




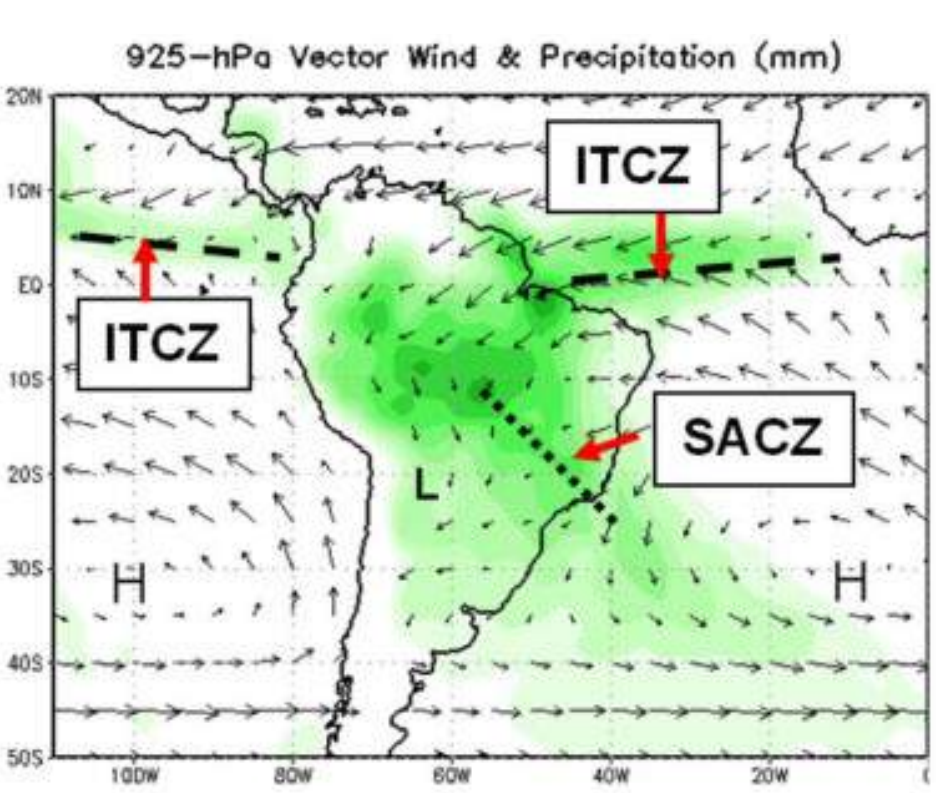
During phase V (20 Mar–28 Apr 1990), the postmonsoon circulation regime is built up, characterized by a uniform upper-tropospheric westerly jet stream at about 35°–40°S.

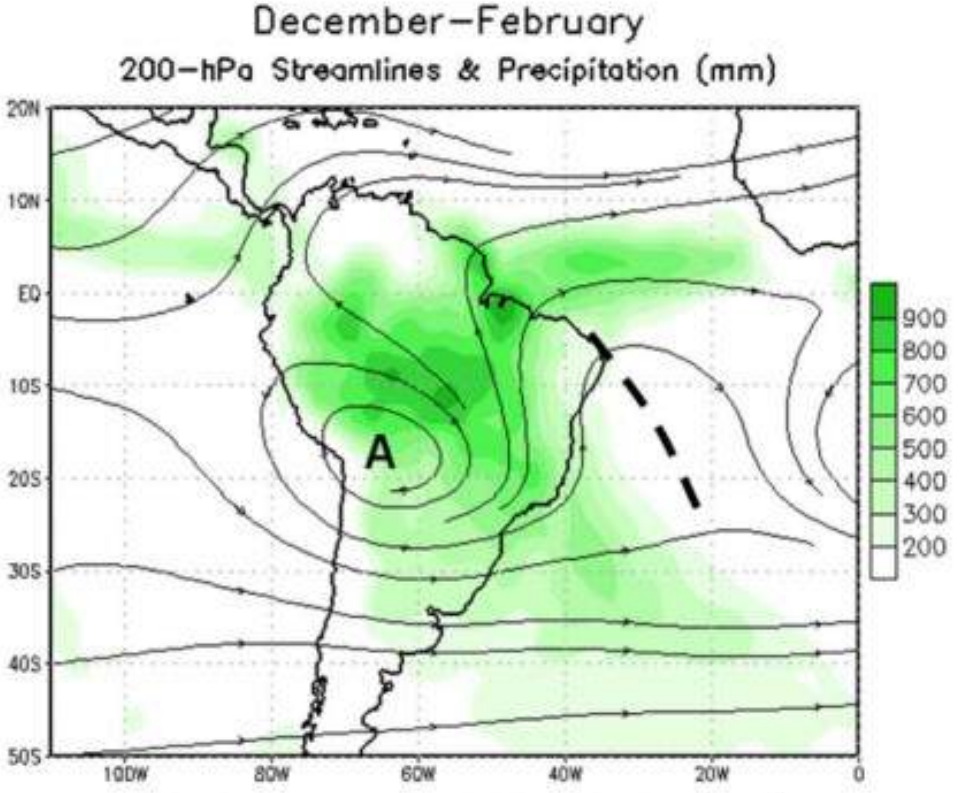
Much of the rainfall returns to the tropics as a result of the low-level moisture convergence by the trade wind. Large-scale wave response to the Amazonian heating can be clearly seen from the 200-hPa wind field, which shows a ridge-trough system tilting from the northwest to the southeast in the east of the Andes.


(d)
GOES-1
Phase V-IV
15N
10N
5N
EQ
5S
10S
15S
20S
25S
30S
35S
40S
80W
70W
60W
50W
40W
30W
20W
10W



During the demise phase, the deep convection overall is more active than during the onset phase, and it shows a connection to the Atlantic ITCZ.


925–hPa Vector Wind & Precipitation (mm)
ITCZ
ITCZ
SACZ
L
H
H
20N
10N
EQ
10S
20S
30S
40S
50S
100W
80W
60W
40W
20W


December–February
200–hPa Streamlines & Precipitation (mm)
A
900
800
700
600
500
400
300
200
20N
10N
EQ
10S
20S
30S
40S
50S
100W
80W
60W
40W
20W
0

Thank you