STUDY OF HEAVY RAINFALL EVENTS IN THE SÃO PAULO REGION AFTER THE PEAK OF THE SEVERE DROUGHT OF 2014 - 2015

Marcelo Schneider
Meteorologist
National Institute of meteorology of Brasil (INMET)

Jose Galvez
Meteorologist - Researcher and trainer
SRG / NOAA

Introduction

A rapid extremely dry-to-extremely wet atmospheric pattern transition occurred in the Sao Paulo region during March 2015.

This work explores the global local patterns associated with extremely dry and extremely wet conditions in Sao Paulo using 2014-2015 reanalysis data.

It further elaborates on the extremely dry-to-extremely wet transition that occurred in February-March 2015, and looks into two specific heavy rainfall events in the region using GFS model data and observations.
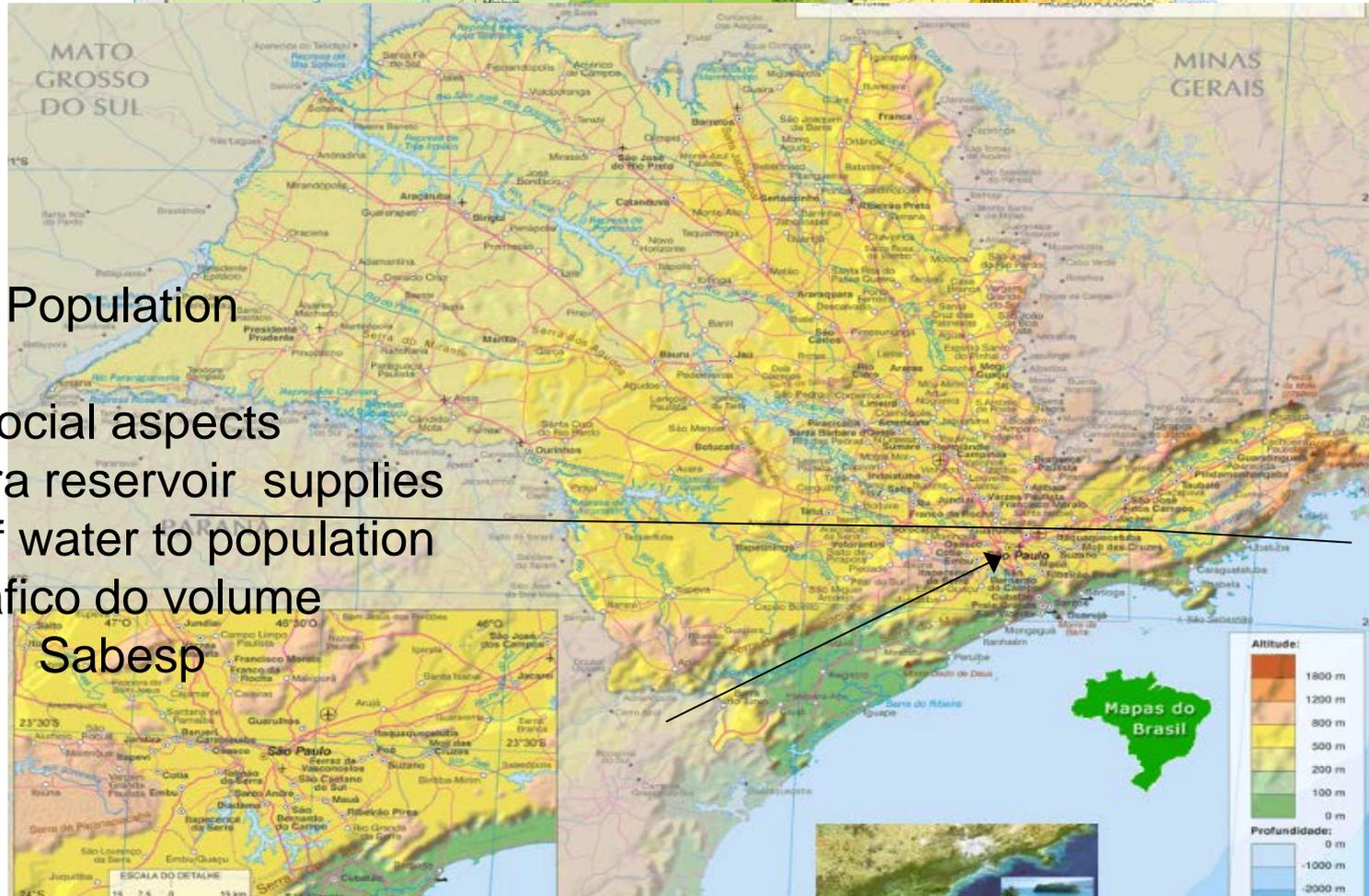
The analysis was greatly enhanced by techniques learned during the International Desk training.

1.Introduction   GEOGRAPHY - LOCATION
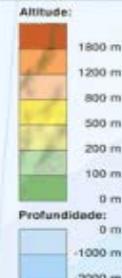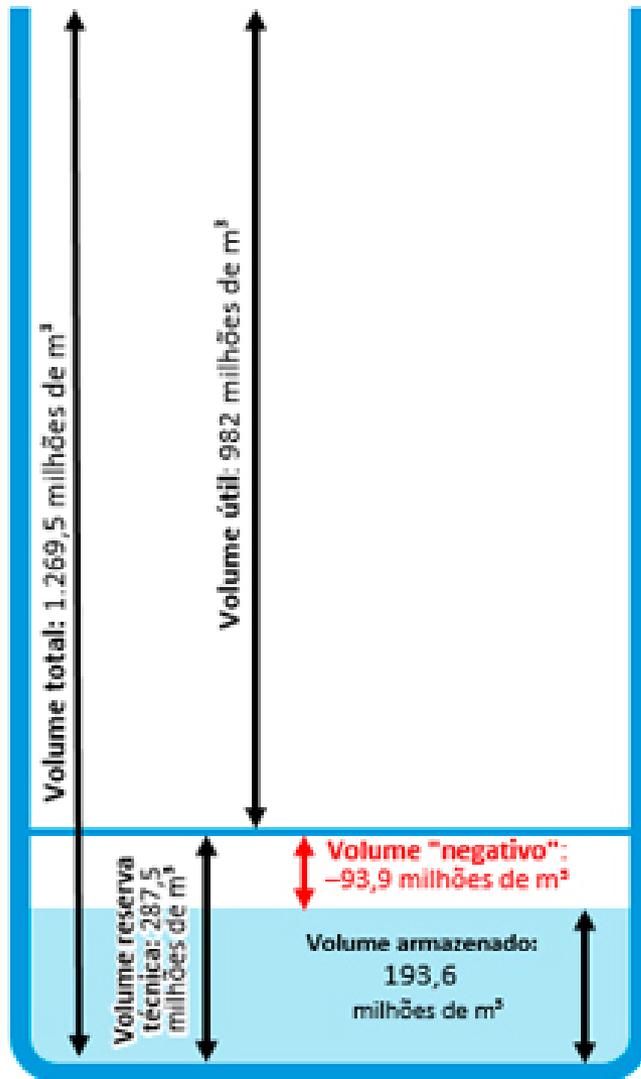
Equator

Population

Social aspects

Cantareira reservoir supplies

~ 50% of water to population

Grafico do volume

Sabesp

Main reservoir < 10 % capacity

Affects 10 million people

Volume total: 1.269,5 milhões de m³

Volume útil: 982 milhões de m³

Volume reserva técnica: 287,5 milhões de m³

Volume "negativo": −93,9 milhões de m³

Volume armazenado: 193,6 milhões de m³

$$\text{Índice 1} = \frac{\text{Volume armazenado}}{\text{Volume útil}} \times 100 = 19{,}7\%$$

$$\text{Índice 2} = \frac{\text{Volume armazenado}}{\text{Volume total}} \times 100 = 15{,}3\%$$

$$\text{Índice 3} = \frac{\text{Volume armazenado} - \text{Volume reserva técnica}}{\text{Volume útil}} \times 100 = -9{,}6\%$$

Tools and Methods

• rainfall observations from INMET – conventional/ automatic stations

• reanalysis data: winds, sst, pressure/geopotential data, composites analysis of two cases

• Infrared satellite images

 --Wingridds software for analyses and identification of some meteorological predictor fields

-MJO index analysis:
Source (CPC)

- Wavelet analysis=> evolution of the amplitude and frequency of velocity potential (large scale convection associated with MJO)
evolution of the amplitude and frequency of 500 hPa gepotential

# Monthly Rainfall Anomalies (mm) - Rainy Seasons (JFM) of 2014 and 2015
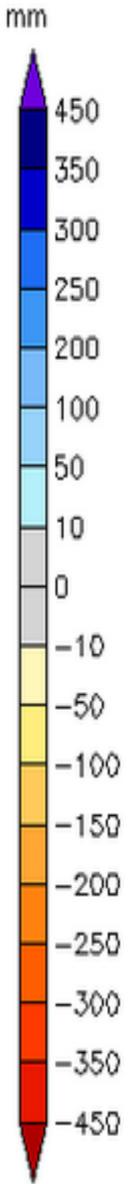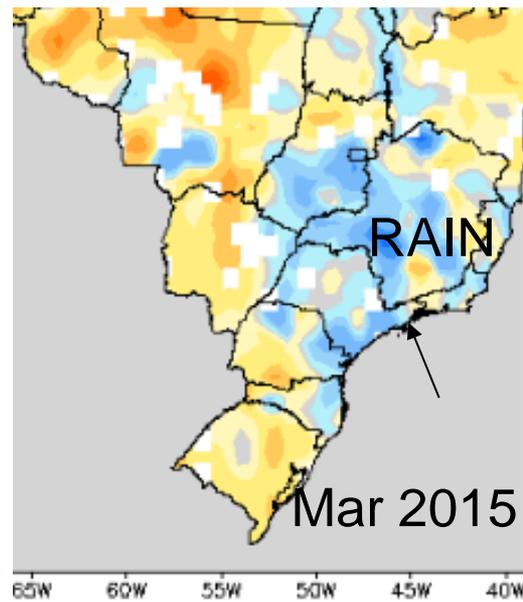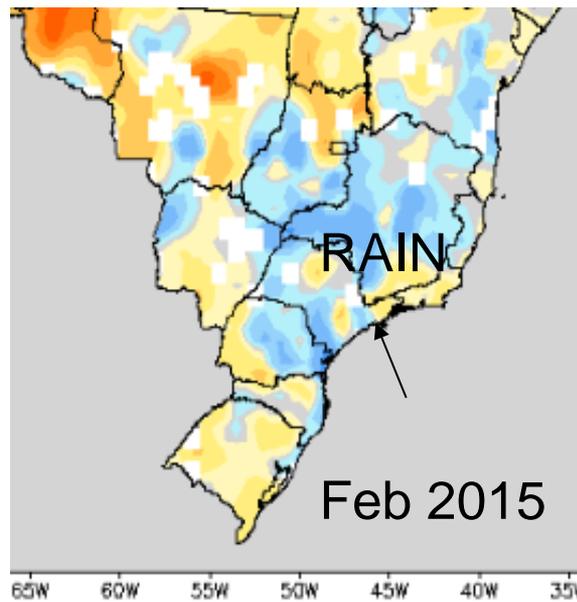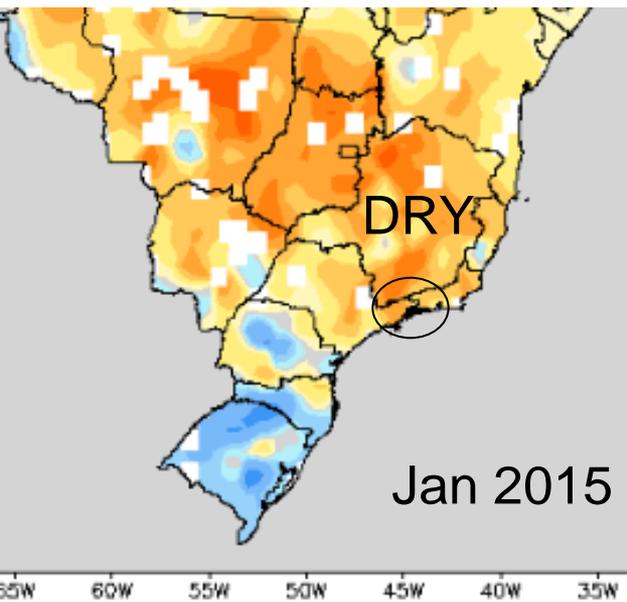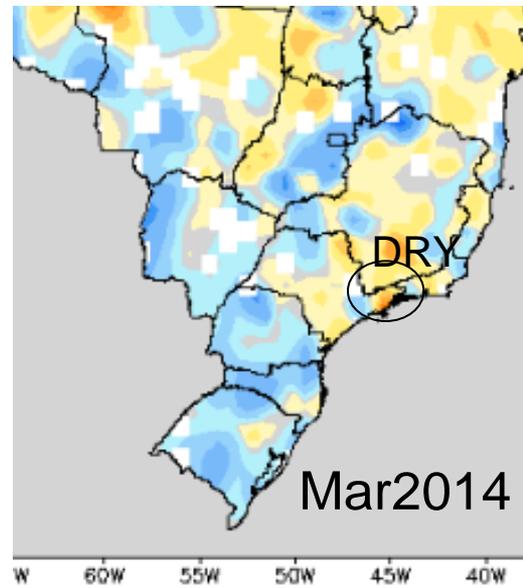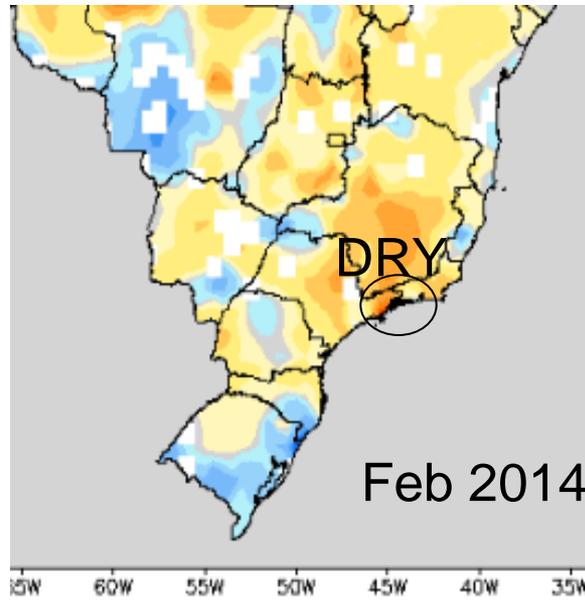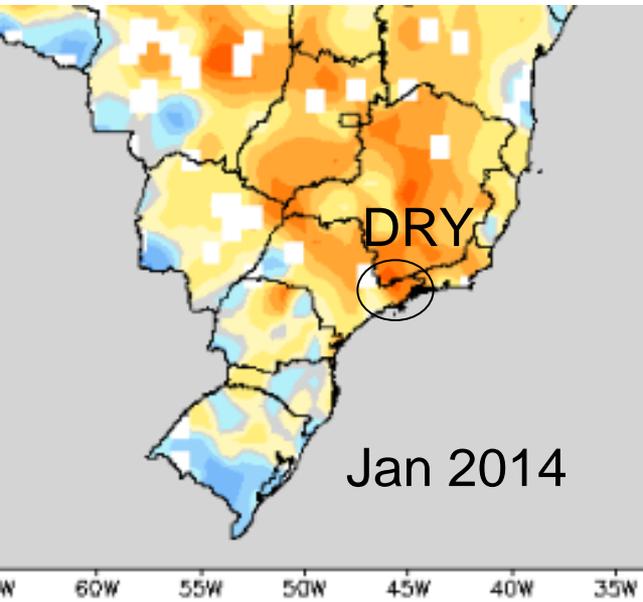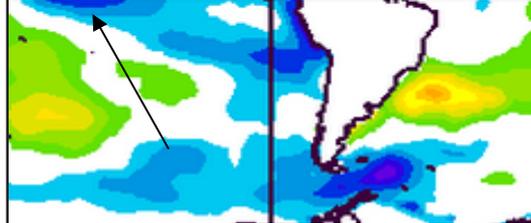
INMET MARCH MONTHLY RAINFALL RECORDS

Rank	Year	Precipitation (mm)	statistics
1	2006	607,9*	*average: 186 mm* *Standard deviation: 95 mm* *Mediana: 171 mm* *highets: 607,9* mm (2006)* *lowest: 38,5 mm (1975)*
2	1991	451,3	
3	1996	396,8	
4	**2015**	**332,7**	
5	2002	326,5	

Associated atmospheric and SSTs patterns
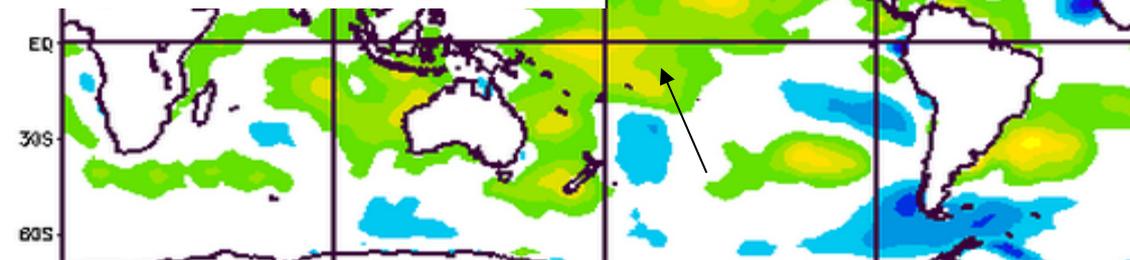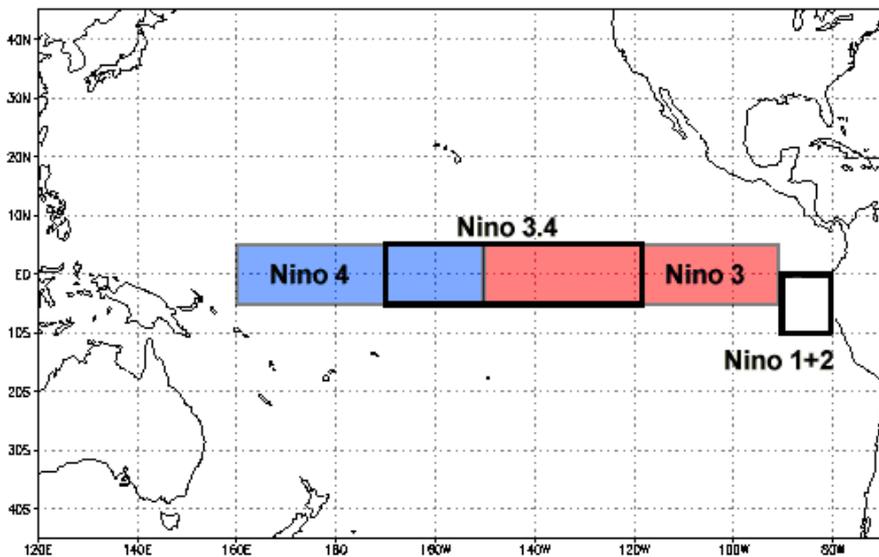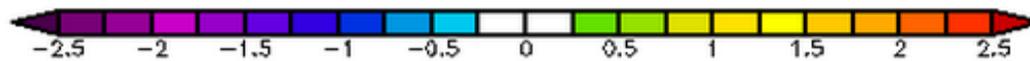
SSTs patterns (2014 and 2015) anomalies
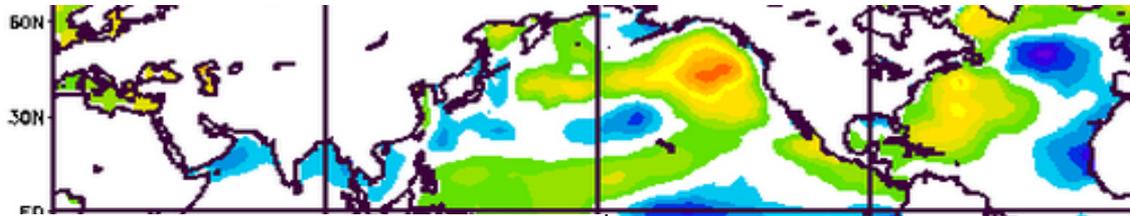
FEB/MAR 2014
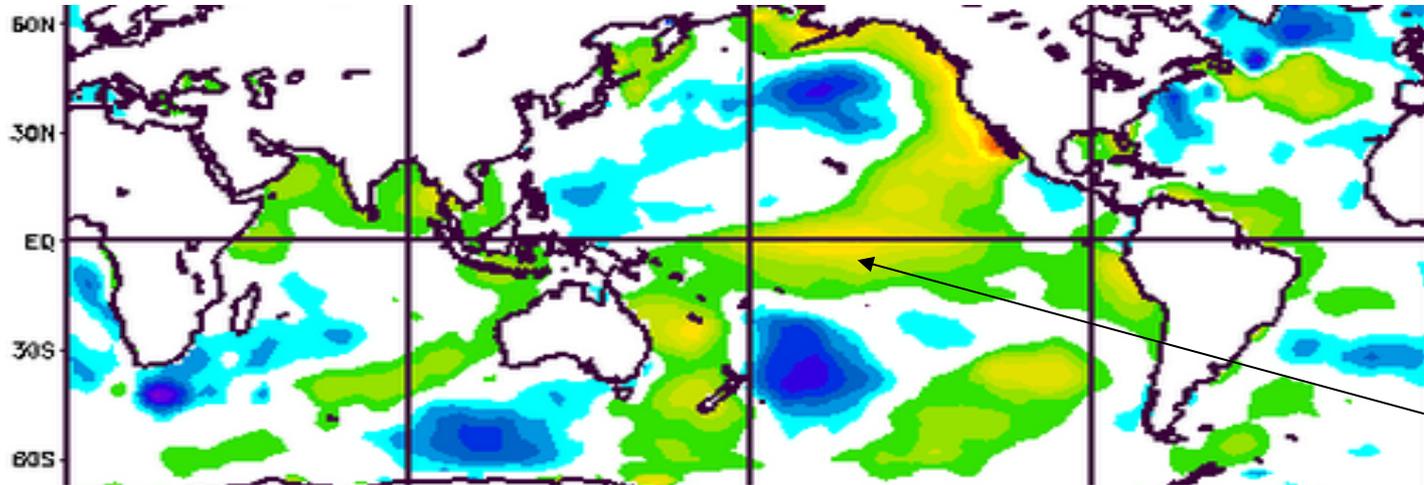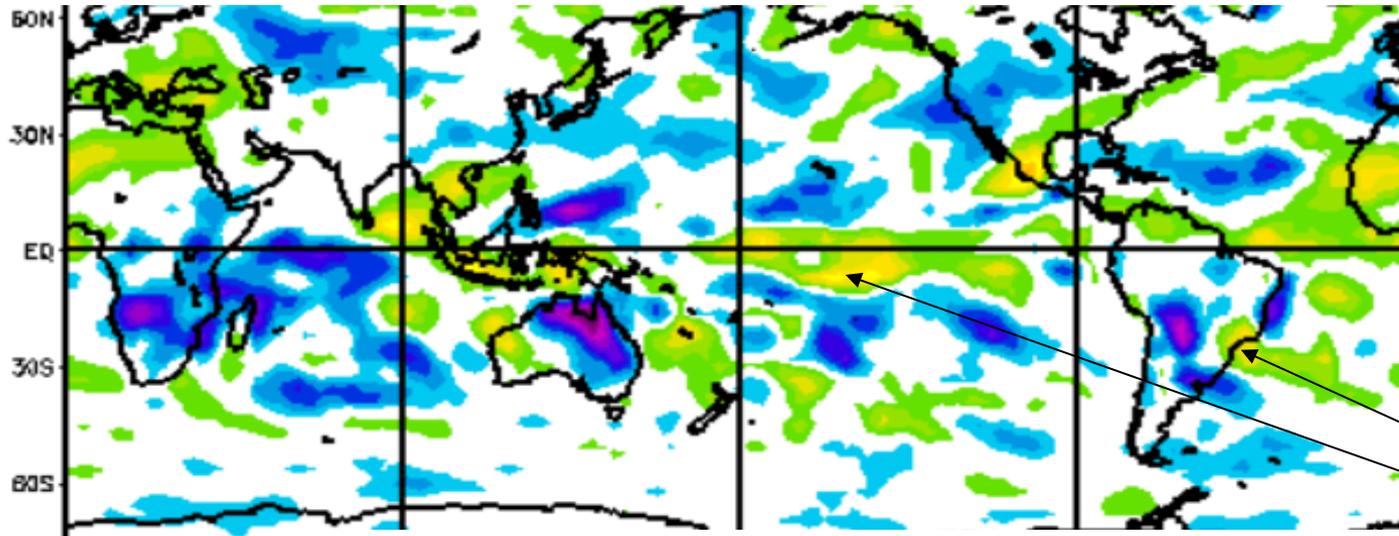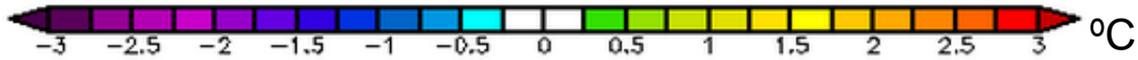
FEB/MAR 2015
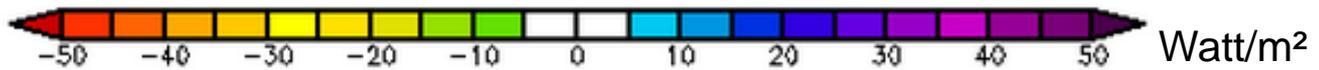
SSTs and OLR patterns (2015 MINUS 2014)

SST dif

NINO 3.4 warming

°C

OLR dif

MORE CONVECTION

Watt/m²

Yellow (convection)   blue (supressed)

DIFERENCES IN UPPER CIRCULATION (2015 minus 2014)

NCEP/NCAR Reanalysis
200mb Vector Wind (m/s) Composite Mean
Feb to Mar : 2015 minus 2014

MJO OSCILLATION ACTIVATES BY THE END OF 2014
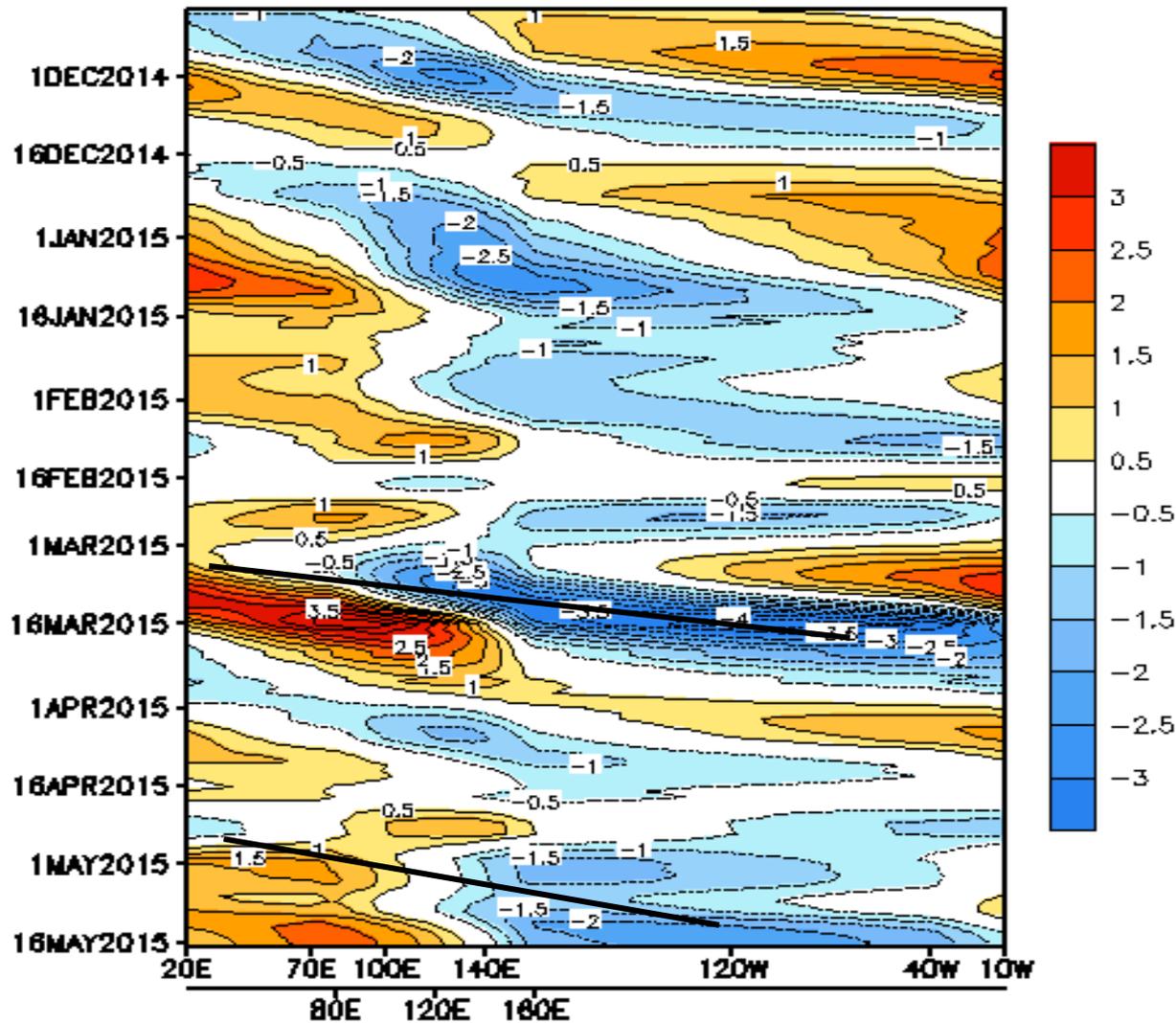
Velocity potential – OMJ index

WAVELET ANALYSIS

(a)

(b)
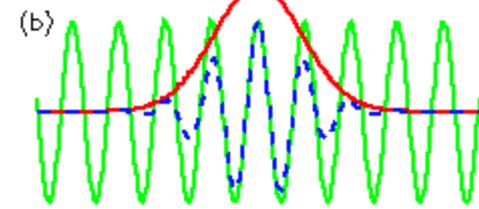
MADDEN-JULIAN OSCILLATION INDEX 40W

Value

Jan15 Fev15 Mar15 Abr15 Mai15 Jun15 Jul 15 Ago15 Set 15 Out 15 Nov15 Dez15 Jan 15 Fev15 Mar15 Abr15

Time
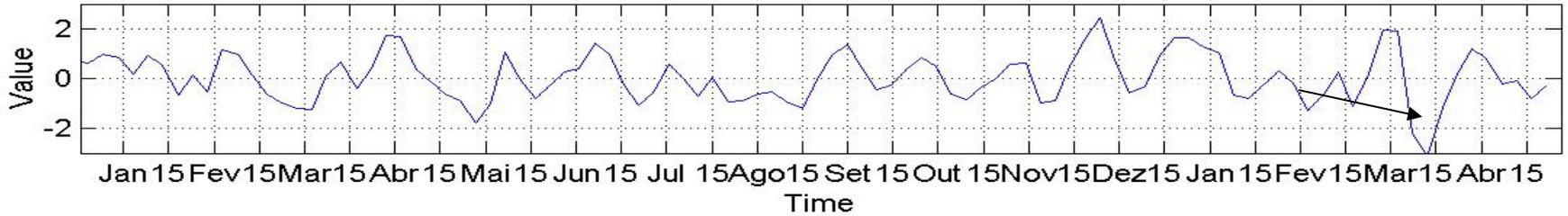
← 2015 →

Parte real dos coeficientes da Ondeleta

frequency

18days

30 days

45 days

Escala(dias)

Jan15 Fev15 Mar15 Abr 15 Mai15 Jun 15 Jul 15 Ago15 Set 15 Out 15 Nov15 Dez15 Jan 15 Fev15 Mar15 Abr15

-0.5   -0.4   -0.3   -0.2   -0.1   0   0.1   0.2   0.3   0.4   0.5

scale average 15-30 and 30-60 days

Average variance

0.05

0

-0.05

Jan15 Fev15 Mar15 Abr15 Mai15 Jun 15 Jul 15 Ago15 Set 15 Out 15 Nov15 Dez15 Jan 15 Fev15 Mar15 Abr15

Time
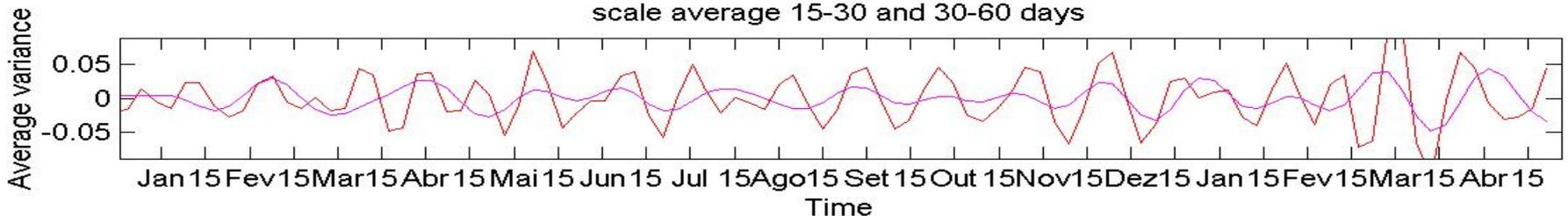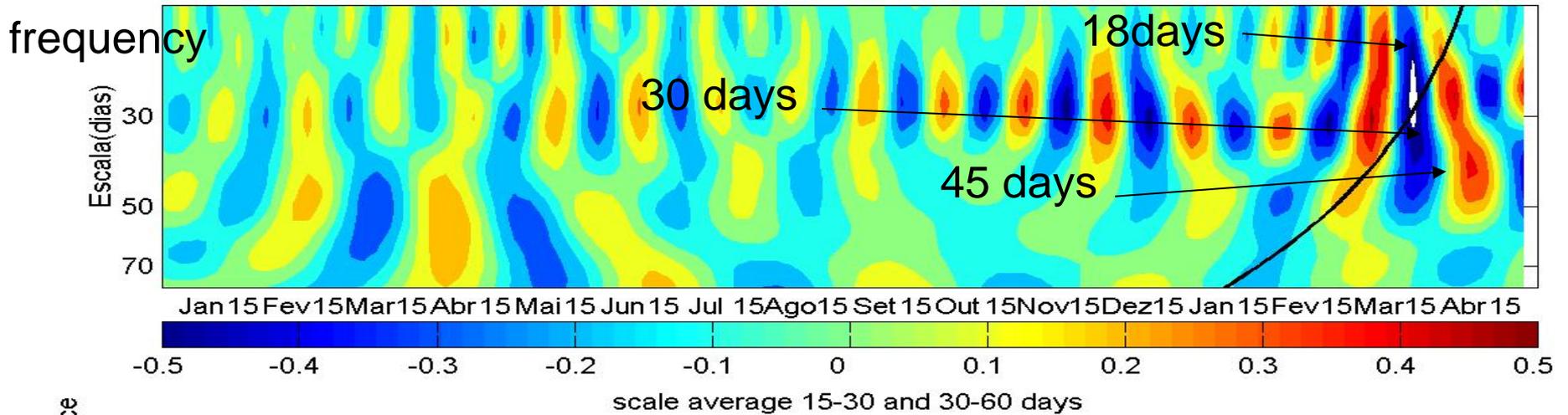
CASE STUDIES

FIRST RAINFALL EVENTS AFTER THE DROUGHT

FIRST RAINFALL EVENTS AFTER THE DROUGHT

feb/15-19

SP

mar/06-10

SP
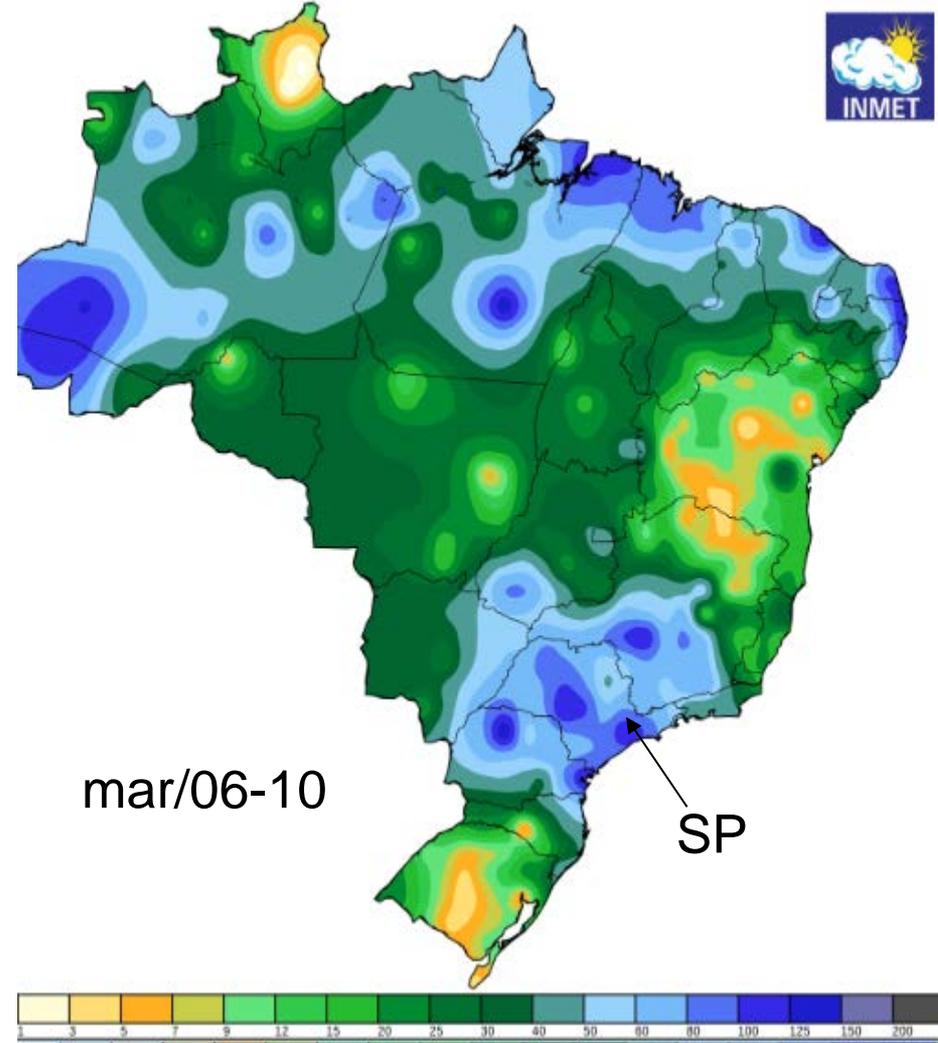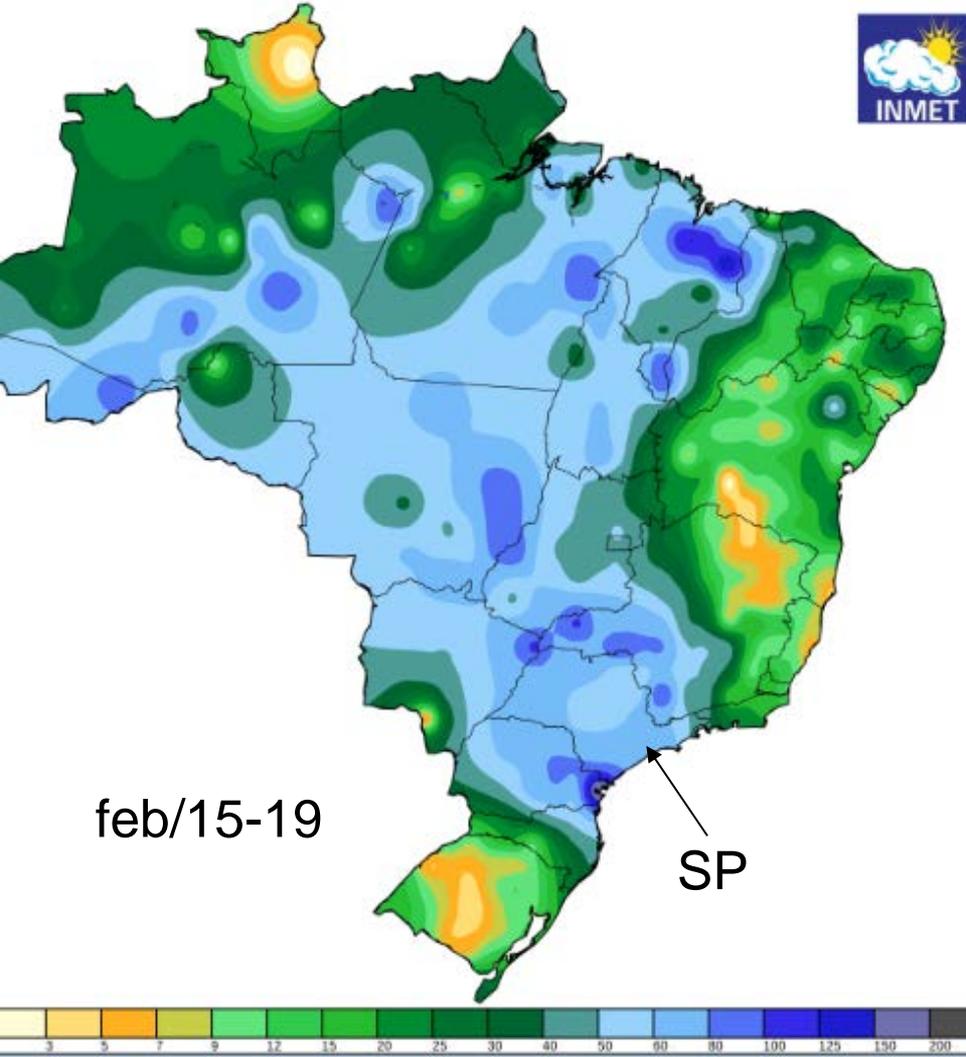
5 days rainfall (in mm)

daily precipitation - São Paulo Capital - 2015
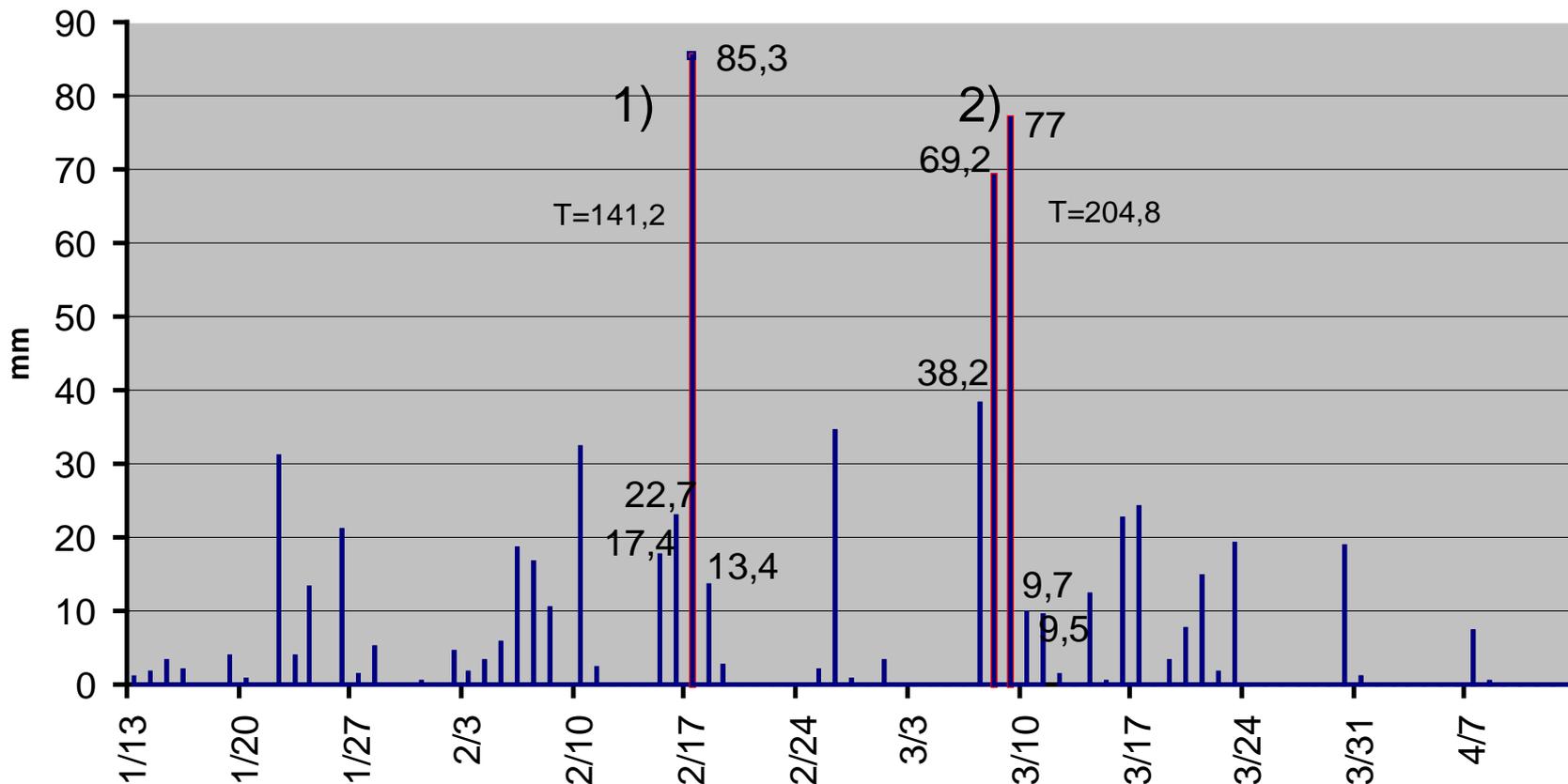
Case 1: 85,3 mm at 02/16
Case 2: 69,2 mm at 03/07 and 77mm at 03/08

climatological precipitation of february: 235mm
climatological precipitation of march: 186mm

February 16 Wet event

INMETs Automatic weather station data

Date/ time utc

Data	Hora	Temperatura (°C)			Umidade (%)			Pto. Orvalho (°C)			Pressão (hPa)			Vento (m/s)			Radiação	Chuva
	UTC	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Vel.	Dir.	Raj.	(kJ/m²)	(mm)
16/02/2015	09	18.9	18.9	18.8	90	90	89	17.1	17.1	17.0	925.0	925.0	924.7	0.6	42°	2.1	-1.08	0.2
16/02/2015	10	19.2	19.2	18.8	90	90	90	17.5	17.5	17.1	925.7	925.7	925.0	0.0	68°	2.7	94.31	0.0
16/02/2015	11	19.7	19.7	19.2	88	90	88	17.7	17.7	17.4	926.3	926.3	925.7	0.6	74°	2.6	262.4	0.0
16/02/2015	12	20.7	20.9	19.7	80	89	79	17.1	18.0	17.0	926.8	926.8	926.3	0.0	277°	2.0	697.0	0.0
16/02/2015	13	22.5	22.5	20.6	75	82	74	17.9	18.2	16.9	927.0	927.0	926.8	1.3	317°	3.9	1437.	0.2
16/02/2015	14	22.3	23.4	22.2	72	75	68	17.0	18.2	16.6	926.7	927.0	926.7	3.1	339°	6.4	1788.	0.0
16/02/2015	15	24.1	24.8	22.3	63	72	60	16.5	17.7	16.1	926.3	926.7	926.2	2.3	306°	6.4	2115.	0.0
16/02/2015	16	24.9	25.0	23.9	62	65	61	17.1	17.5	16.6	925.9	926.3	925.9	2.8	342°	6.5	2297.	0.0
16/02/2015	17	25.8	26.0	24.8	60	63	57	17.4	17.8	16.4	925.2	925.9	925.2	1.7	289°	7.1	2348.	0.0
16/02/2015	18	26.7	26.9	25.3	56	60	54	17.3	18.1	16.6	924.6	925.2	924.6	2.7	345°	6.7	1700.	0.0
16/02/2015	19	26.4	27.2	26.0	53	58	50	16.1	17.4	15.6	923.9	924.6	923.9	1.5	279°	5.7	1654.	0.0
16/02/2015	20	24.3	26.4	24.3	70	71	52	18.4	18.8	15.9	923.8	923.9	923.7	3.0	149°	6.3	858.2	0.0
16/02/2015	21	22.3	24.2	22.3	79	79	70	18.5	19.0	18.1	924.2	924.2	923.7	3.0	123°	6.3	509.7	0.0
16/02/2015	22	20.8	22.4	20.8	86	86	79	18.4	18.6	18.3	924.9	924.9	924.2	2.7	116°	7.9	6.959	3.6
16/02/2015	23	19.6	20.8	19.3	95	95	86	18.8	19.1	18.4	925.8	925.9	924.8	2.6	94°	6.1	-0.94	52.0
17/02/2015	00	19.8	20.0	19.6	95	95	95	18.9	19.2	18.8	926.3	926.3	925.7	2.6	112°	5.2	-1.30	7.2
17/02/2015	01	19.5	19.8	19.5	95	95	95	18.7	19.0	18.6	926.9	926.9	926.5	0.7	107°	4.7	-1.46	0.4
17/02/2015	02	19.7	19.8	19.5	95	95	95	18.8	18.9	18.6	926.8	927.1	926.8	0.0	26°	2.2	-0.69	0.4
17/02/2015	03	20.2	20.2	19.7	95	95	94	19.2	19.2	18.9	926.2	926.8	926.2	0.0	141°	1.3	-2.55	0.2
17/02/2015	04	20.1	20.3	20.1	94	95	94	19.1	19.4	19.1	925.8	926.2	925.8	0.7	44°	3.0	-0.25	0.0
17/02/2015	05	20.0	20.1	19.9	94	94	94	19.1	19.2	18.9	925.3	925.8	925.3	0.7	17°	2.2	-1.07	0.2
17/02/2015	06	19.6	20.1	19.6	94	94	94	18.7	19.1	18.7	925.0	925.3	924.8	0.9	60°	3.3	-1.25	7.6
17/02/2015	07	19.5	19.7	19.5	95	95	94	18.7	18.8	18.7	924.5	925.0	924.5	0.0	15°	3.4	-0.62	8.4

Dew points around 19ºC

52mm in 1hour

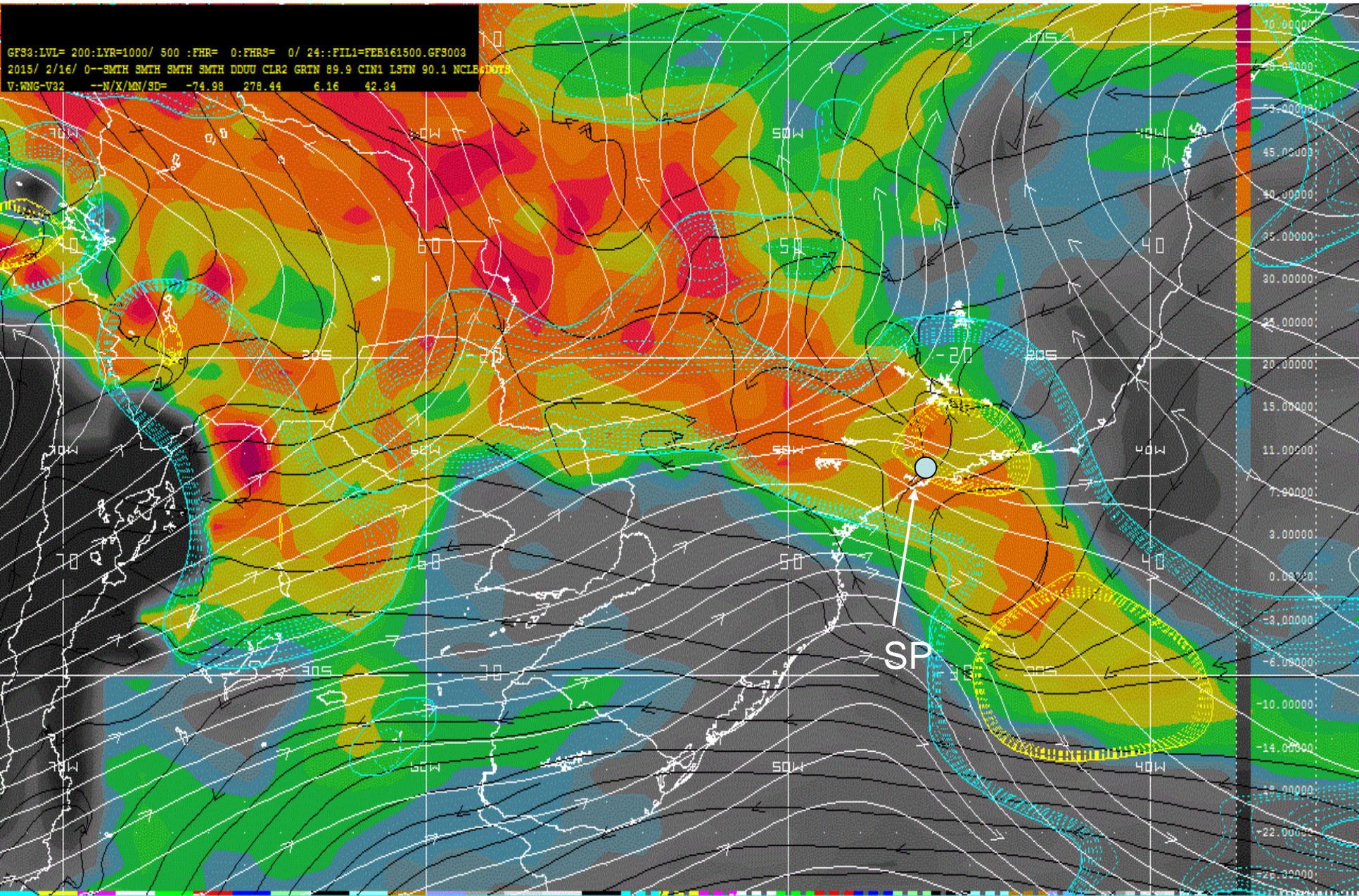# Case 1: 02/16 event
Analysis of predictors
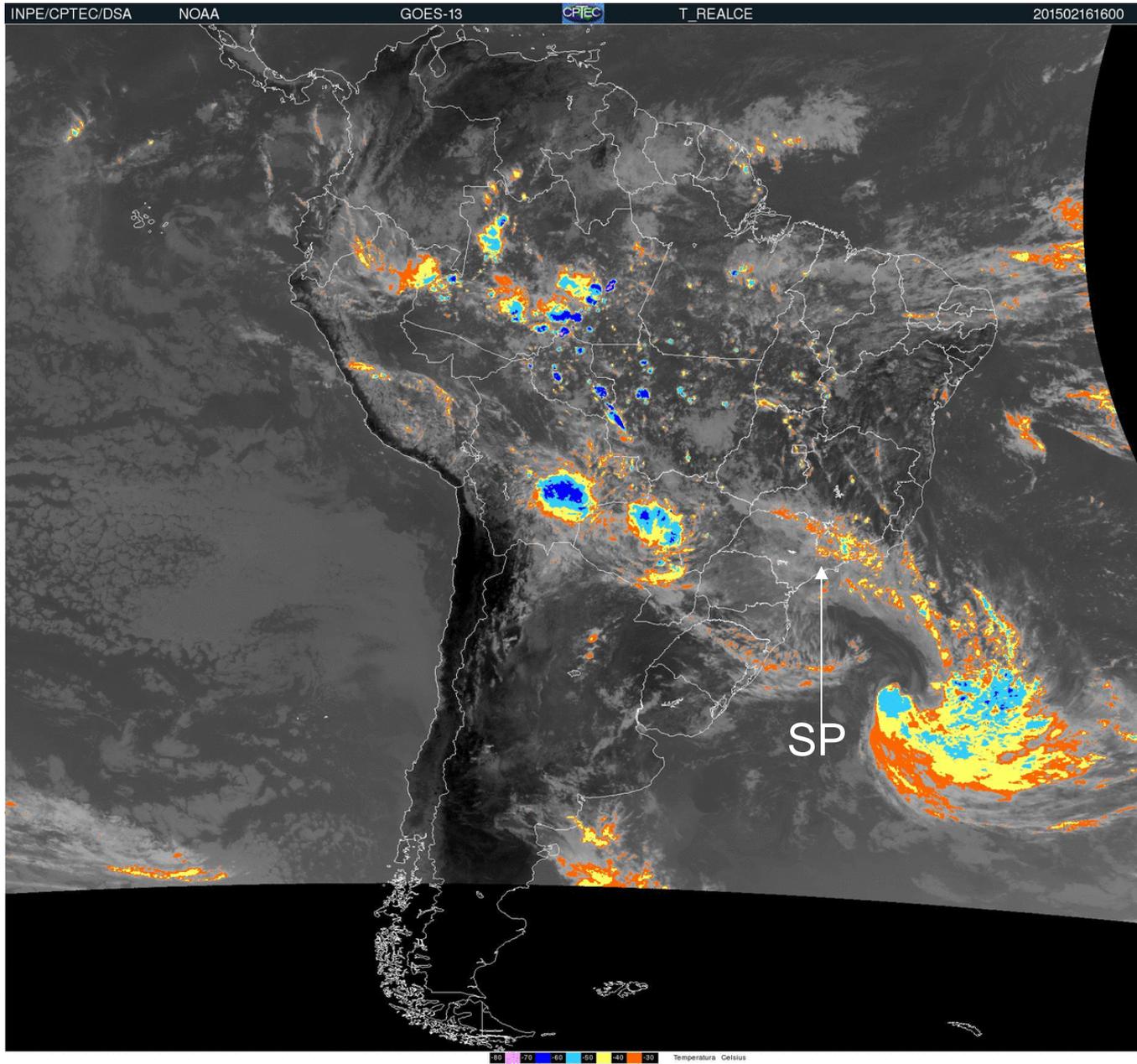
Infrared satellite image convection pattern

Case 1: 02/16 event
Analysis of predictors   dynamics / Instability

GDI index = dashed; Low layer winds = black
High level winds = white
Divergence = dotted

Case 1: 02/16 event
Analysys of predictors Flux of moisture

Low level (975 - 850 hPa)
Flux of moisture= yellow lines
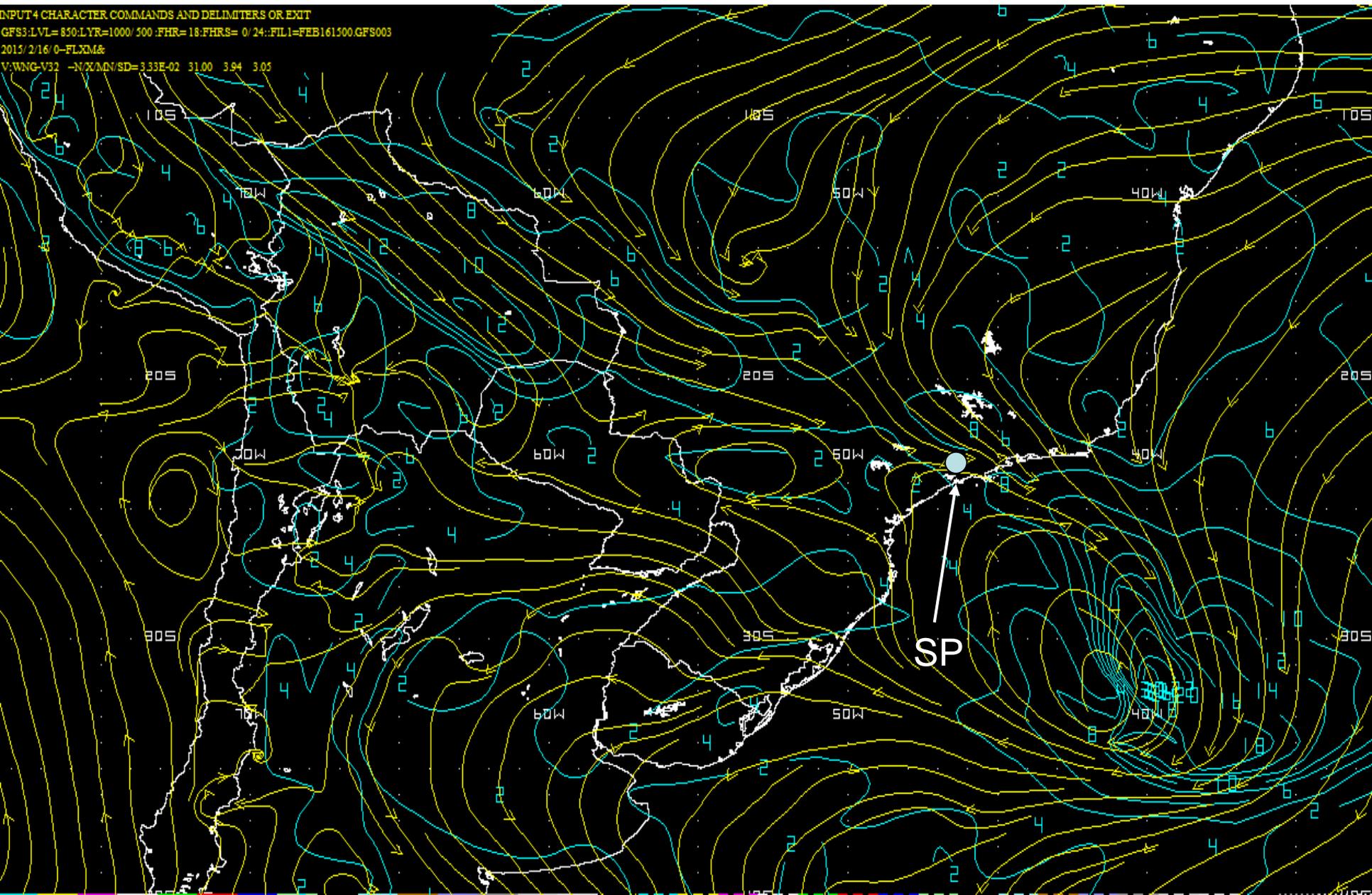Magnitude of moisture flux= blue
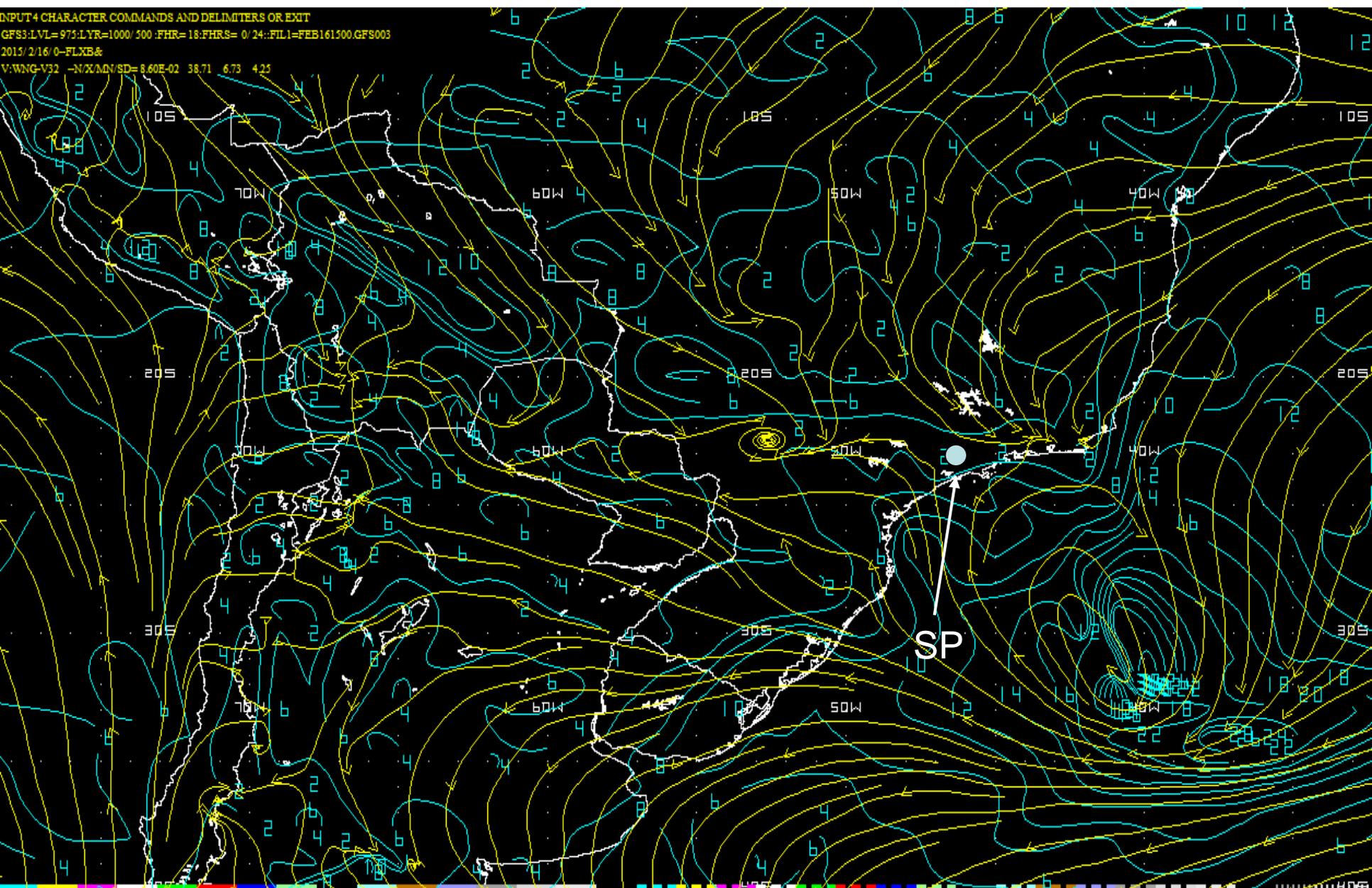
Case 1: 02/16 event
Analysis of predictors   Flux of moisture

medium level (700 - 500 hPa)
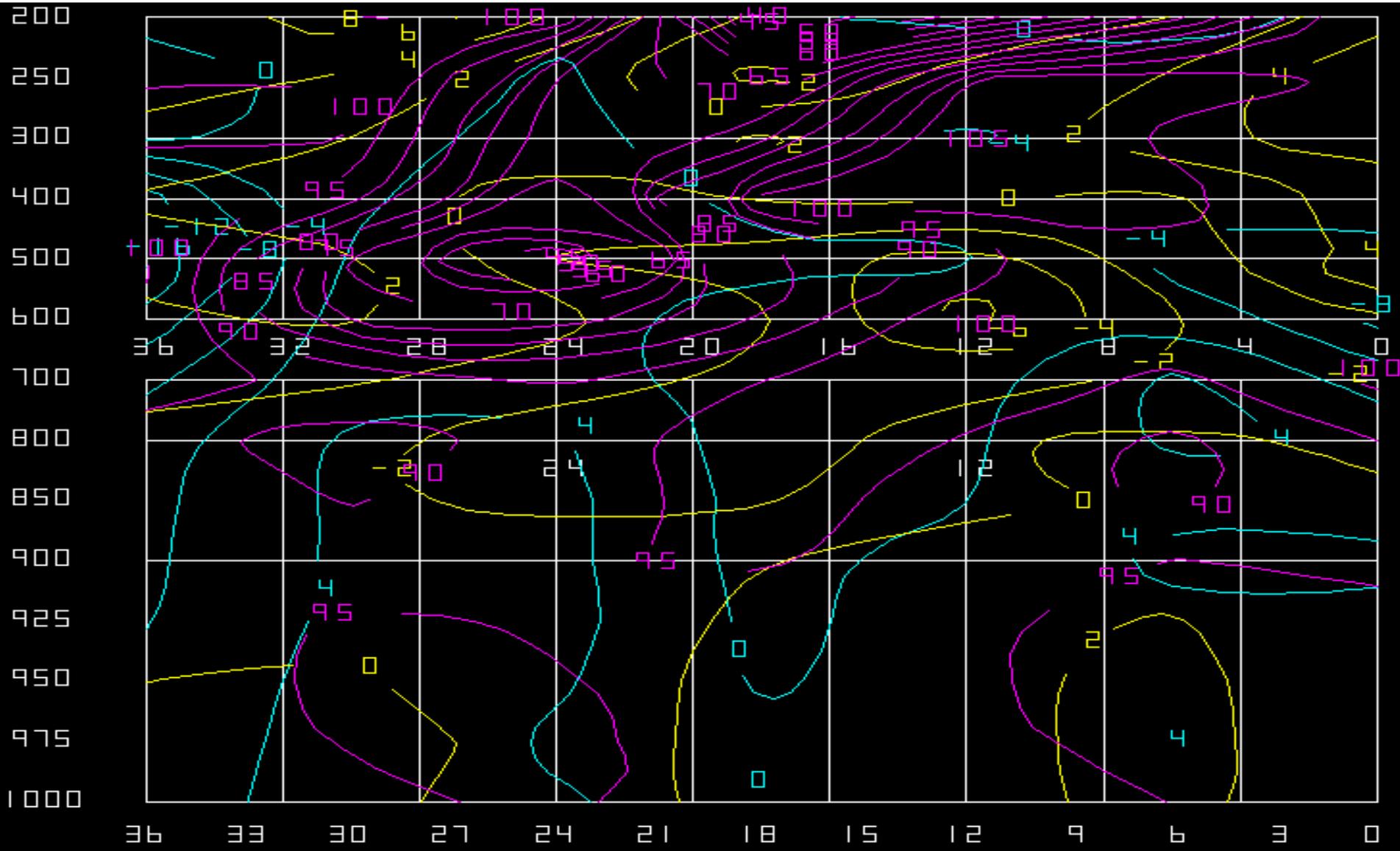Flux of moisture= yellow lines
Magnitude of moisture flux= blue

SP

Case 1: 02/16 event
Analysis of predictors Time section at SP station

Vertical velocity (blue)
Vorticity (yellow)
Relative humidity (purple)

Time h 02/16

INMETs Automatic weather station data 03/07 and 03/08

Date/ time utc

| Data	Hora	Temperatura (°C)			Umidade (%)			Pto. Orvalho (°C)			Pressão (hPa)			Vento (m/s)			Radiação	Chuva
	UTC	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Vel.	Dir.	Raj.	(kJ/m²)	(mm)
07/03/2015	12	22.5	22.8	21.5	76	83	75	18.0	18.8	17.9	925.4	925.4	925.0	0.0	76°	2.6	816.6	0.0
07/03/2015	13	24.1	24.1	22.5	68	76	67	17.7	18.3	17.3	925.6	925.7	925.4	1.2	330°	2.4	1203.	0.0
07/03/2015	14	25.2	25.5	23.9	62	68	59	17.3	18.2	16.5	925.5	925.7	925.5	1.8	327°	6.0	2070.	0.0
07/03/2015	15	24.1	26.1	23.9	67	69	58	17.6	18.1	16.6	925.2	925.5	925.2	2.8	323°	6.1	1415.	0.0
07/03/2015	16	26.0	26.1	23.7	62	72	61	18.3	18.9	16.8	924.0	925.2	924.0	1.1	343°	5.7	1803.	0.0
07/03/2015	17	22.7	27.0	22.6	78	78	58	18.6	19.1	17.6	923.5	924.0	923.3	3.0	156°	7.0	888.5	0.0
07/03/2015	18	20.4	22.7	20.1	95	95	78	19.6	19.6	18.3	923.7	923.8	923.5	2.2	151°	8.5	78.89	43.6
07/03/2015	19	20.6	20.7	20.3	95	95	95	19.8	19.9	19.5	923.4	923.7	923.3	1.0	133°	4.3	278.1	0.8
07/03/2015	20	20.4	20.6	20.2	95	95	95	19.6	19.8	19.4	923.5	923.8	923.4	0.7	130°	2.7	31.06	0.0
07/03/2015	21	20.2	20.4	20.2	95	95	95	19.4	19.6	19.4	923.9	923.9	923.5	1.1	141°	2.6	10.07	3.4
07/03/2015	22	20.3	20.3	20.1	95	95	95	19.5	19.5	19.3	924.1	924.1	923.9	1.3	123°	2.7	1.093	1.8

Dew points around 19ºC   60mm/2h

Data	Hora	Temperatura (°C)			Umidade (%)			Pto. Orvalho (°C)			Pressão (hPa)			Vento (m/s)			Radiação	Chuva
	UTC	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Vel.	Dir.	Raj.	(kJ/m²)	(mm)
08/03/2015	16	23.5	23.8	21.1	73	89	73	18.5	20.4	18.3	924.6	925.3	924.6	1.8	298°	4.1	1677.	0.2
08/03/2015	17	24.1	24.1	23.1	72	76	71	18.7	19.2	18.1	924.2	924.6	924.2	0.3	294°	5.7	1254.	0.0
08/03/2015	18	24.2	24.6	23.7	71	75	69	18.6	19.3	18.2	923.8	924.2	923.8	1.0	14°	3.1	749.8	0.0
08/03/2015	19	24.1	24.3	24.0	70	72	69	18.4	18.9	18.1	923.2	923.8	923.2	2.0	307°	4.2	801.6	0.0
08/03/2015	20	24.2	24.6	24.0	69	72	69	18.2	18.9	18.1	923.3	923.3	923.1	0.6	281°	4.2	627.2	0.0
08/03/2015	21	23.6	24.2	23.6	75	75	69	18.8	18.9	18.2	923.6	923.6	923.0	0.1	217°	2.3	196.2	0.0
08/03/2015	22	23.2	23.6	23.2	77	77	75	18.9	19.0	18.6	923.6	923.7	923.5	1.4	335°	2.4	2.967	0.0
08/03/2015	23	22.5	23.2	22.5	82	82	77	19.3	19.3	18.7	924.0	924.0	923.6	1.1	161°	2.6	3.28	0.0
09/03/2015	00	21.7	22.5	21.7	85	86	82	19.1	19.5	19.1	924.7	924.7	924.0	1.2	147°	3.9	-1.25	0.0
09/03/2015	01	19.9	21.7	19.7	94	94	85	19.0	19.1	18.2	925.2	925.2	924.7	1.6	217°	6.6	-0.48	37.0
09/03/2015	02	19.6	19.9	19.5	95	95	94	18.8	19.0	18.7	925.0	925.4	924.8	0.3	248°	4.6	0.030	23.0
09/03/2015	03	19.8	19.8	19.6	95	95	95	19.0	19.0	18.8	924.5	925.0	924.5	1.8	294°	3.4	0.50	4.2
09/03/2015	04	20.0	20.0	19.8	95	95	95	19.2	19.2	19.0	923.9	924.5	923.8	0.7	8°	3.4	-1.06	2.4

Case 1: 03/08 event
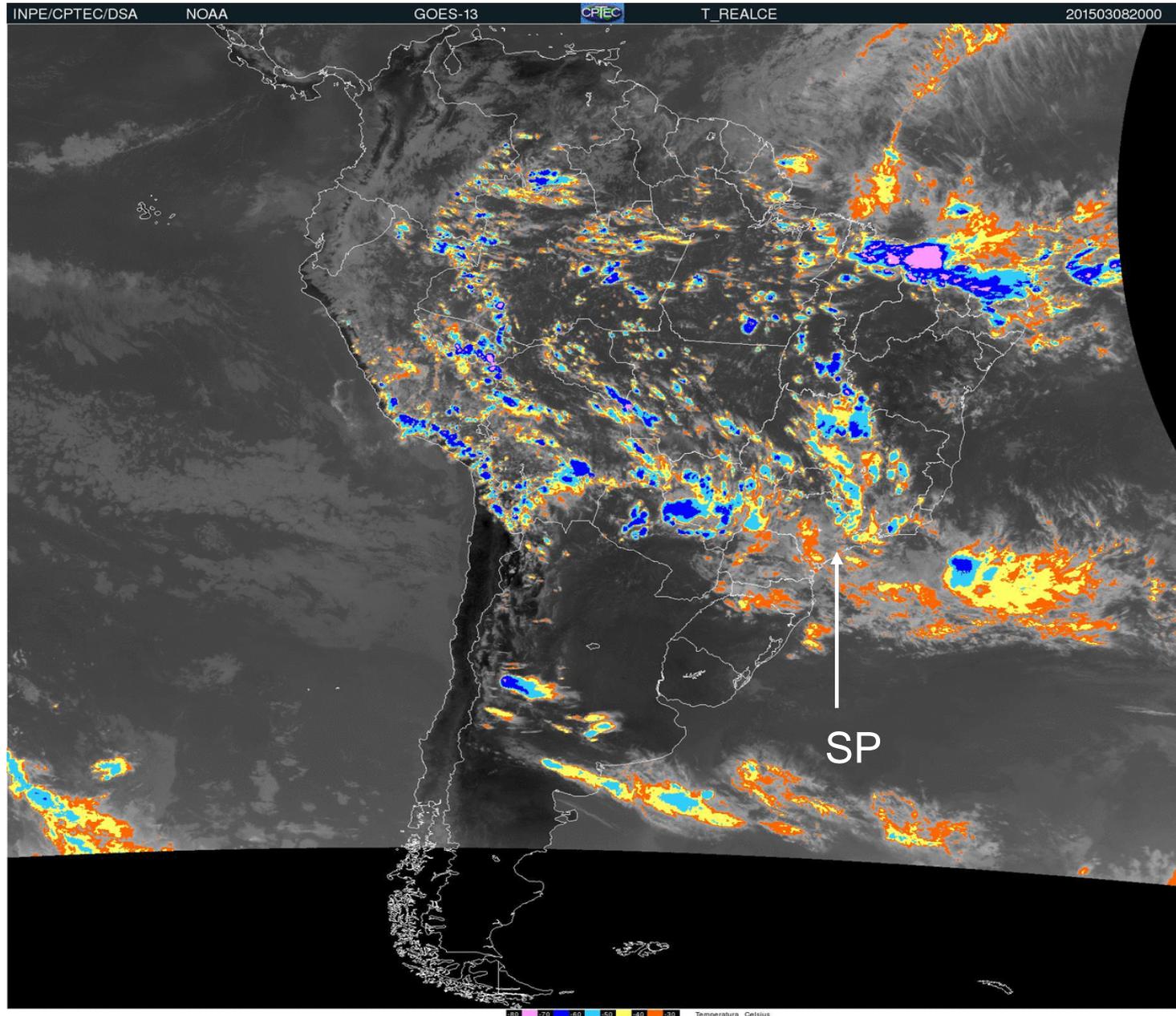Analysis of predictors

*Infrared satellite
image convection pattern 14h-23hutc*

15/03/07

SP
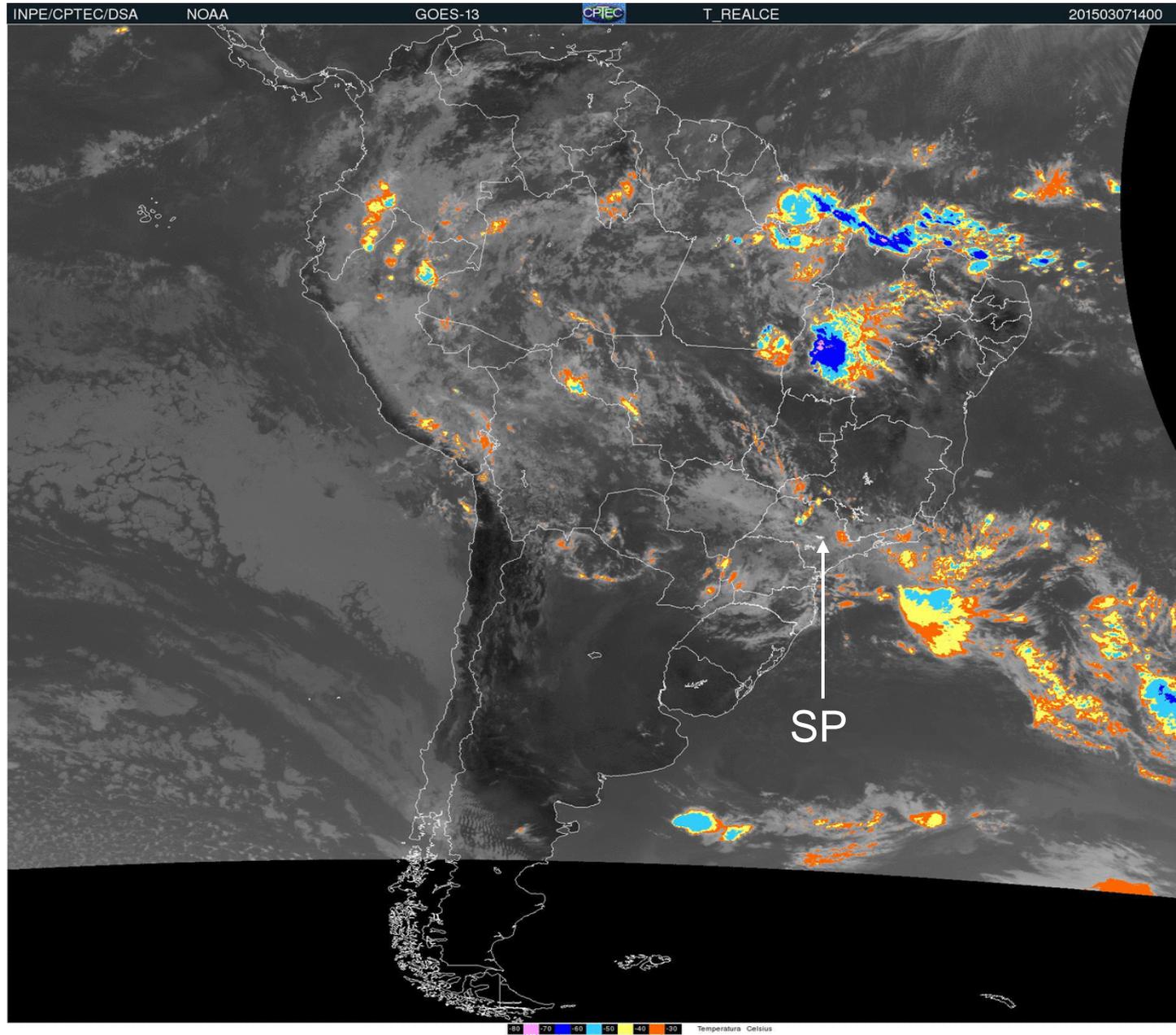
Case 1: 03/08 event
Analysis of predictors

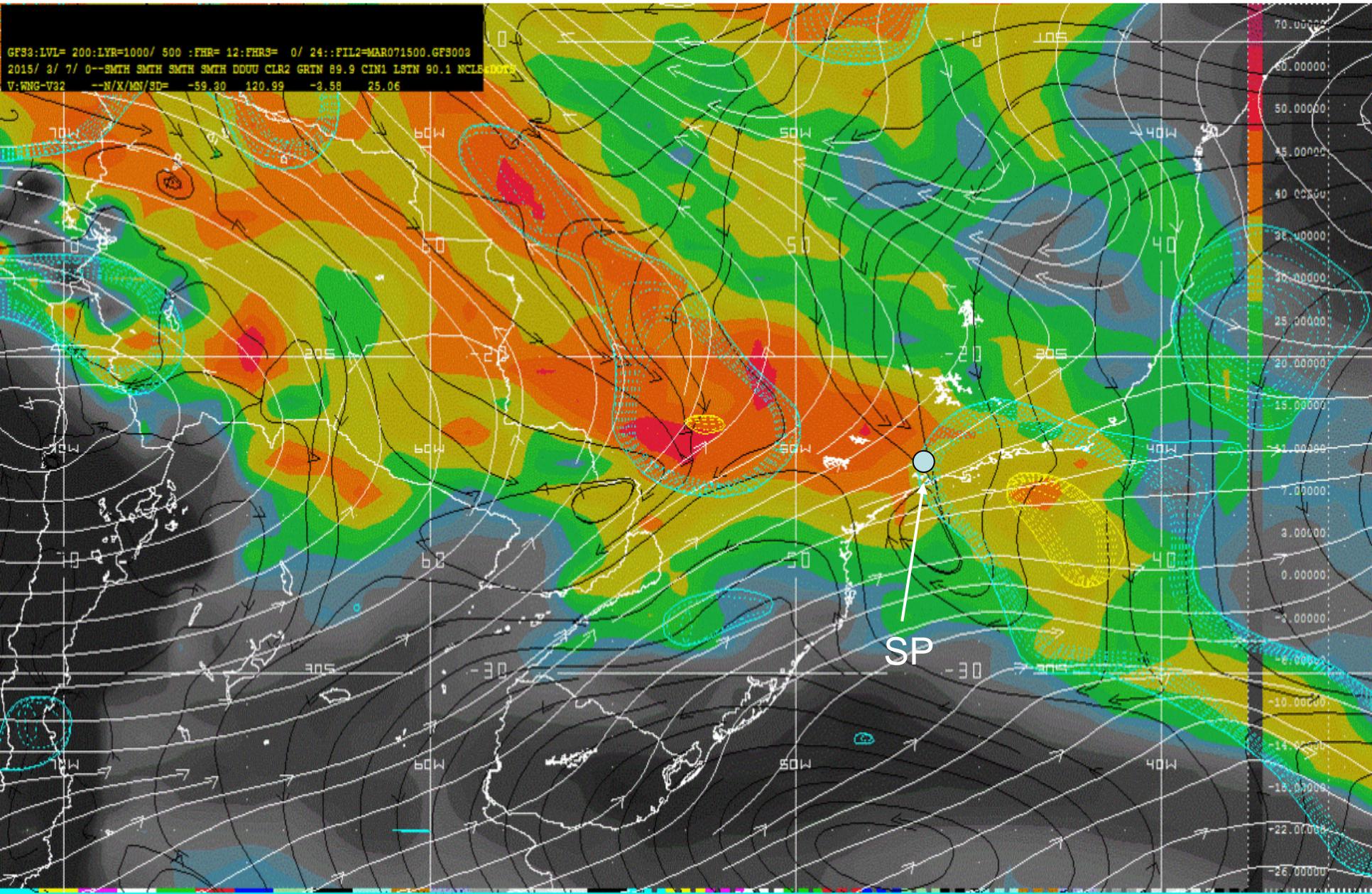*Infrared satellite*
image convection pattern 20h-02hutc

15/03/08

Case 2: 03/08 event
Analysis of predictors   dynamics / Instability

GDI index = dashed; Low layer winds = black
High level winds = white
Divergence = dotted

GFS3:LVL= 200:LYR=1000/ 500 :FHR= 12:FHR3= 0/ 24::FIL2=MAR071500.GFS003
2015/ 3/ 7/ 0--SMTH SMTH SMTH SMTH DDUU CLR2 GRTN 89.9 CIN1 LSTN 90.1 NCLB:DOT5
V:WNG-V32   --N/X/MN/3D=   -59.30   120.99   -3.58   25.06

SP

Case 2: 03/08 event
Analysis of predictors Flux of moisture

Low level (975 - 850 hPa)
Flux of moisture= yellow lines
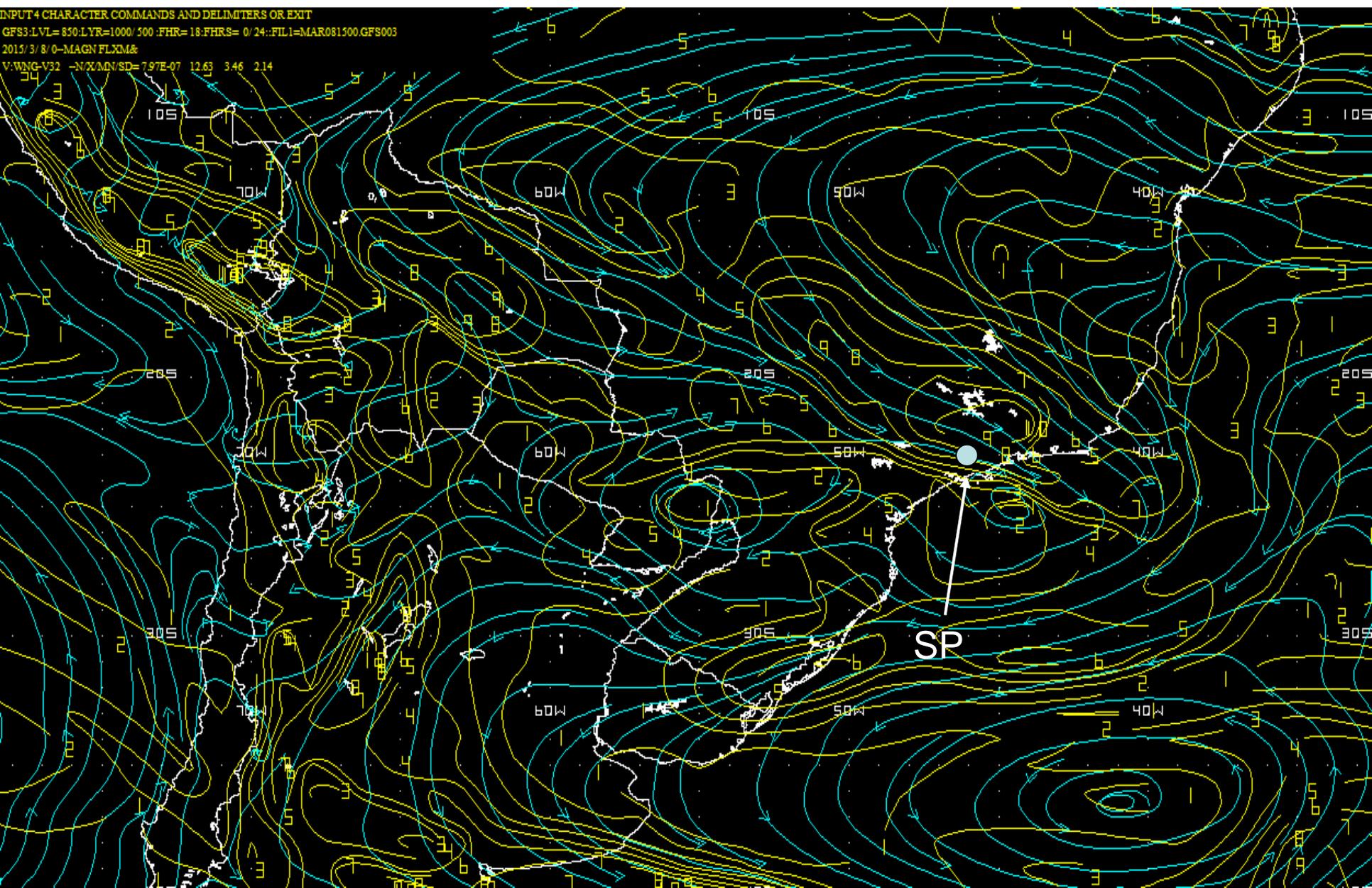Magnitude of moisture flux= blue

Case 2: 03/08 event
Analysis of predictors Flux of moisture

Low level (975 - 850 hPa)
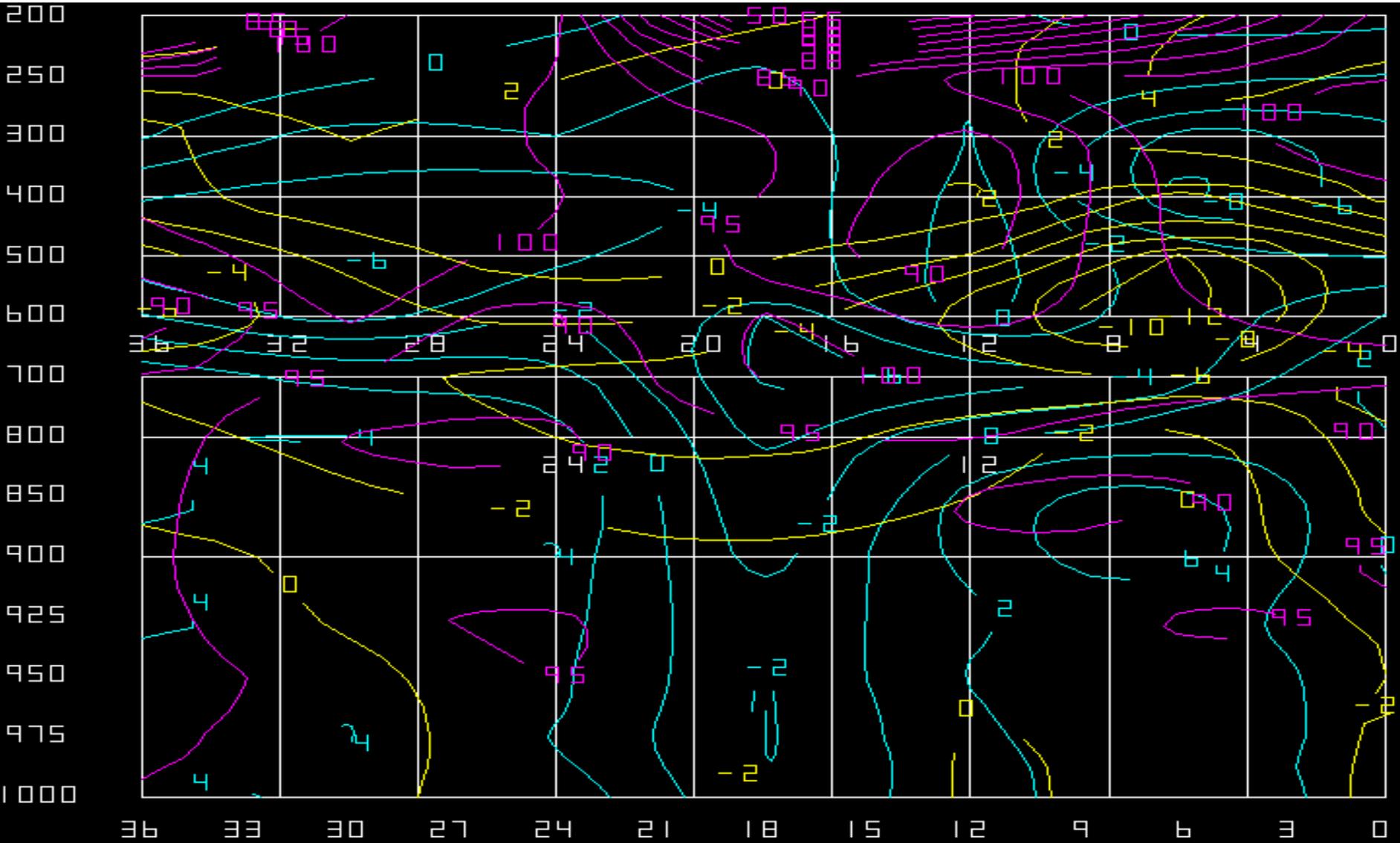Flux of moisture= yellow lines
Magnitude of moisture flux= blue

Case 2: 03/08 event
Analysis of predictors Time section at SP station

Vertical velocity (blue)
Vorticity (yellow)
Relative humidity (purple)

Time h 03/08

CONCLUSIONS / SUMMARY

Synoptic systems structure:

- Subtropical upper level High displaced to the west and a Amplifying mid level trof/ low enhances / creates a large difluence/ divergence zone
- Broad confluence area: Low pressure close to the coast (a low with Subtropical characteristics developing over the Atlantic Coast and other low pressure in the continent). Combination or balance of flux of moisture advection from the Atlantic Ocean - southeast wind- and from the south Amazon basin –nothwest wind
- Isentropic ascent just north of the station

- Predictors:
- High dew points (close to the 19ºC)
- Vorticity and vertical velocity appears ~ between low and medium level
- High content of moisture (relative humidity almost saturated)
- Gradient of flux of moisture detected in medium level
- High values of GDI index

- Teleconnections
- Warming of 3.4/4 Niño => Wawe train from the Pacific
  Slightly cold SST in niño 1.2