

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.

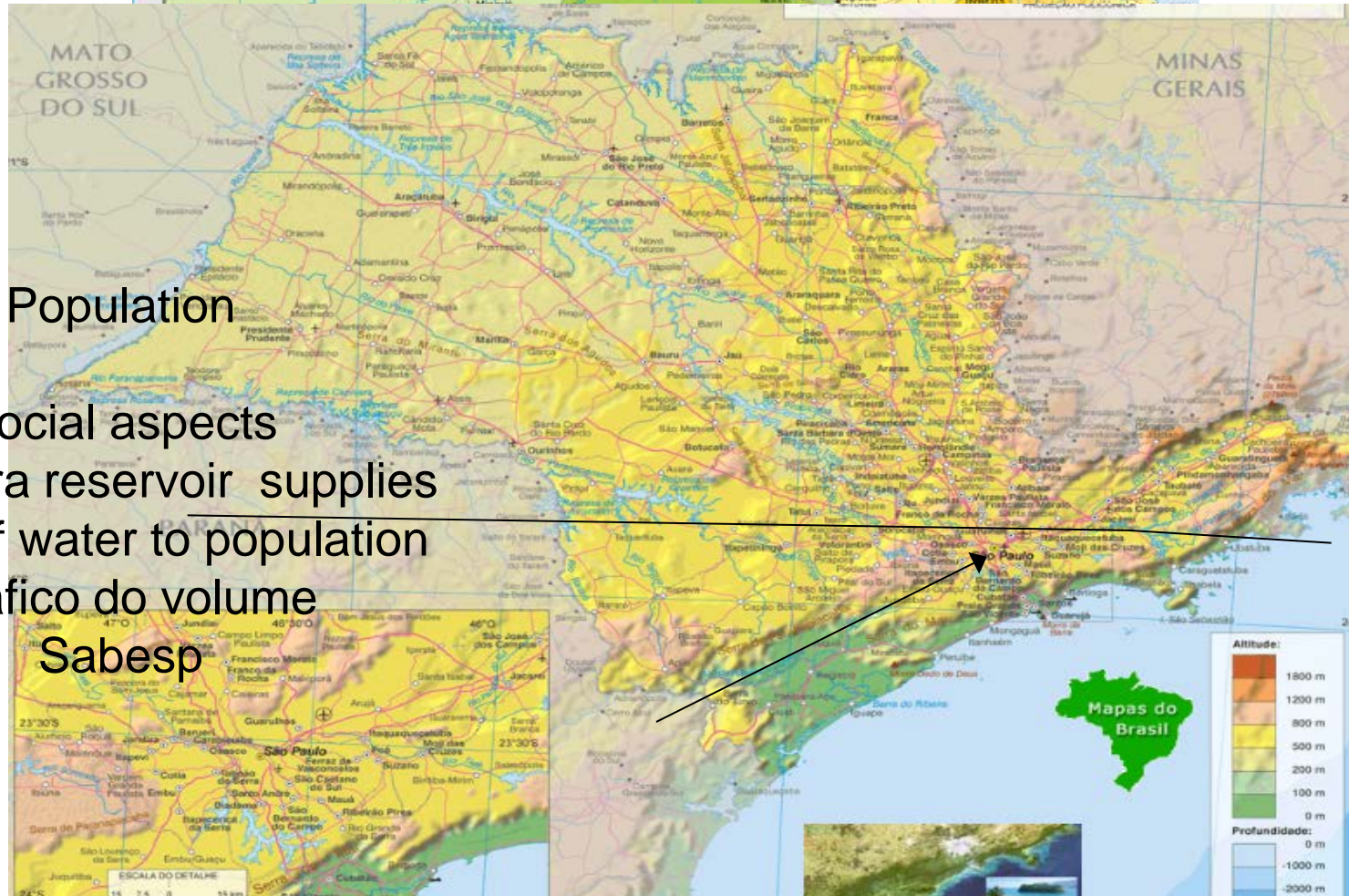
The analysis was greatly enhanced by techniques learned during the International Desk training.

# 1.Introduction

# GEOGRAPHY - LOCATION



Equator



Population

Social aspects

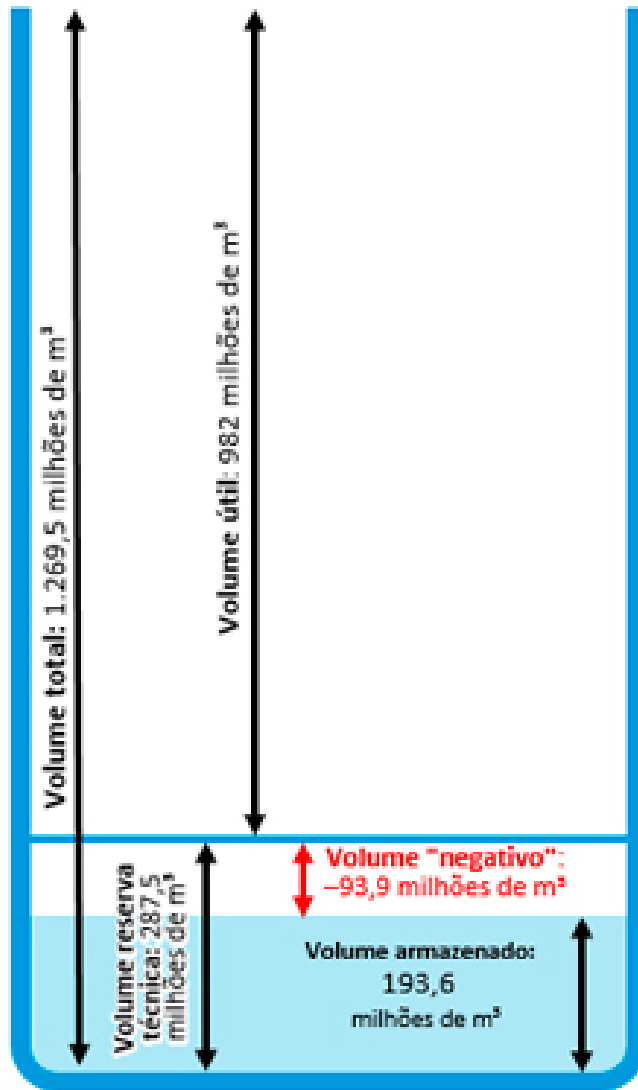
Cantareira reservoir supplies

~ 50% of water to population

Gráfico do volume

Sabesp





Main reservoir < 10 % capacity

Affects 10 million people

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

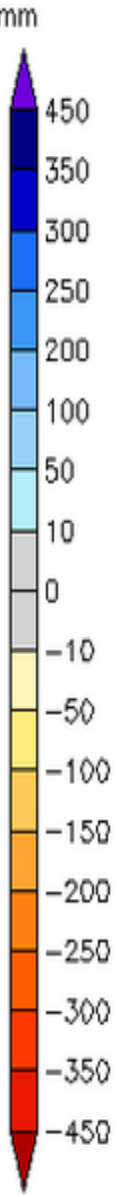
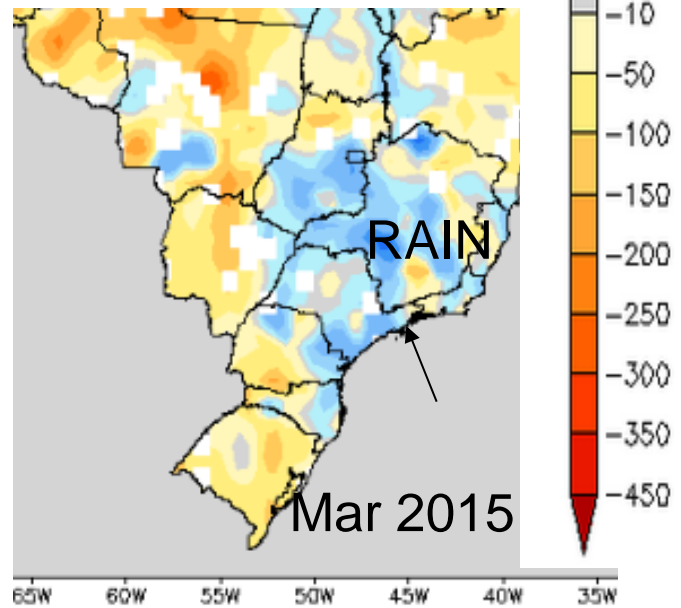
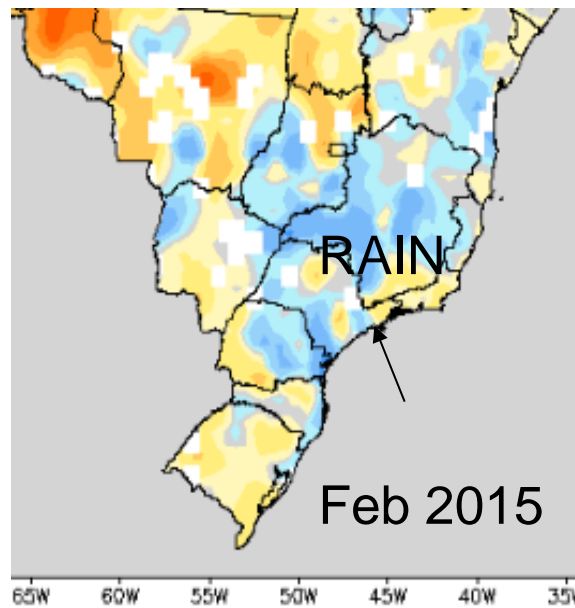
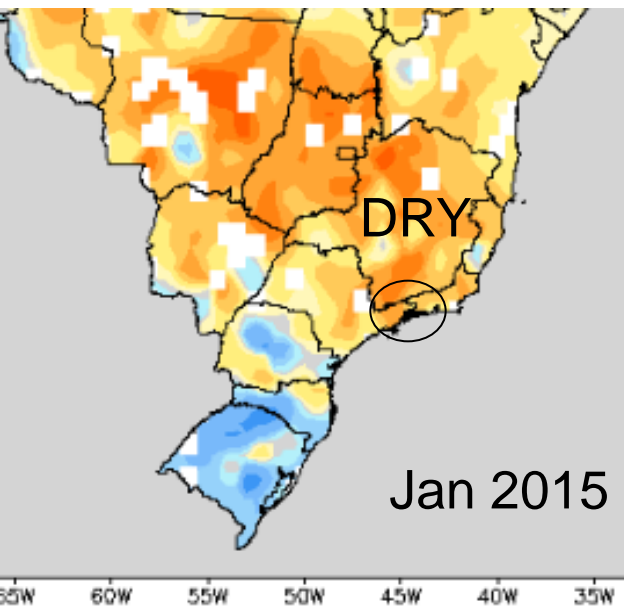
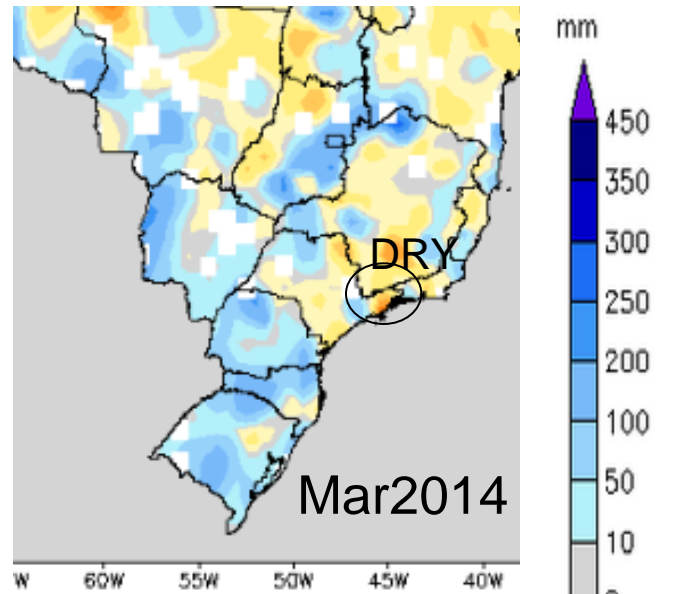
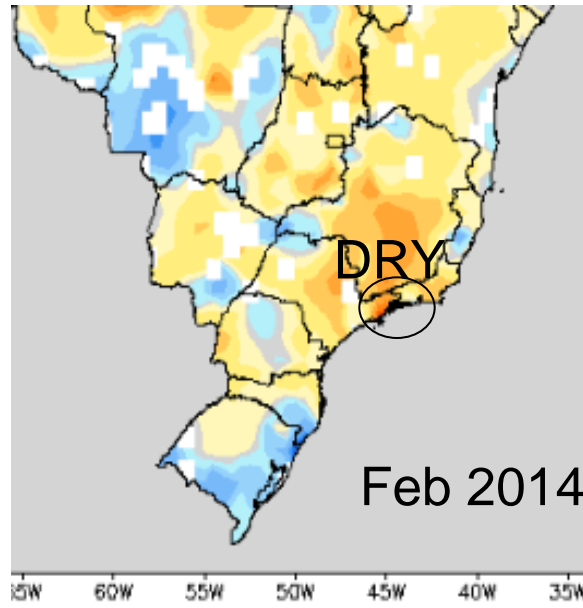
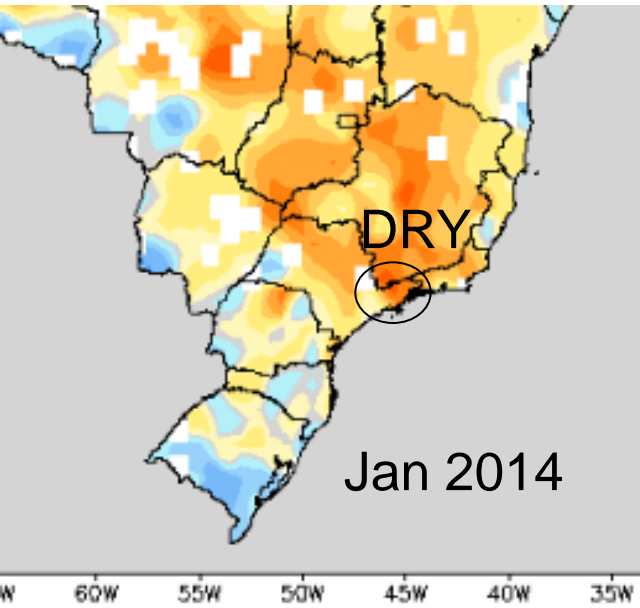
$$\text{Índice 2} = \frac{\text{Volume armazenado}}{\text{Volume total}} \times 100 = 15,3\%$$

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

# 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
  - Wingrids 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 geopotential

# Monthly Rainfall Anomalies (mm) - Rainy Seasons (JFM) of 2014 and 2015

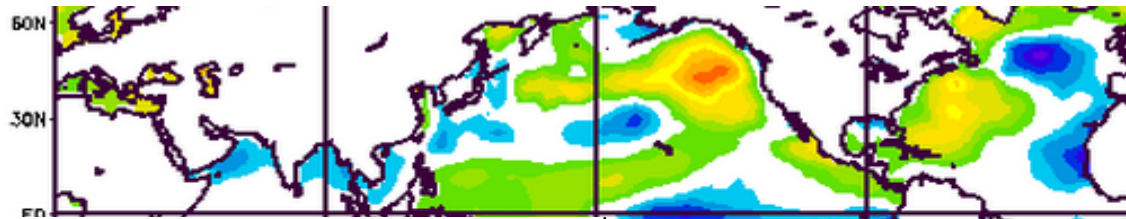


# INMET MARCH MONTHLY RAINFALL RECORDS

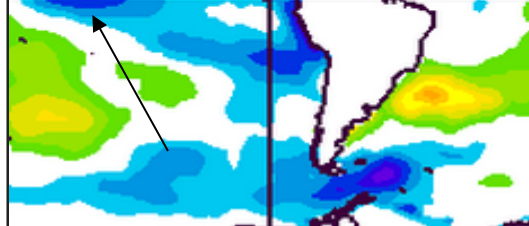
Rank	Year	Precipitation (mm)	statistics
1	2006	607,9*	<i>average: 186 mm</i> <i>Standard deviation: 95 mm</i> <i>Mediana: 171 mm</i> <i>highets: 607,9* mm (2006)</i>  <i>lowest: 38,5 mm (1975)</i>
2	1991	451,3	
3	1996	396,8	
<b>4</b>	<b>2015</b>	<b>332,7</b>	
5	2002	326,5	

# Associated atmospheric and SSTs patterns

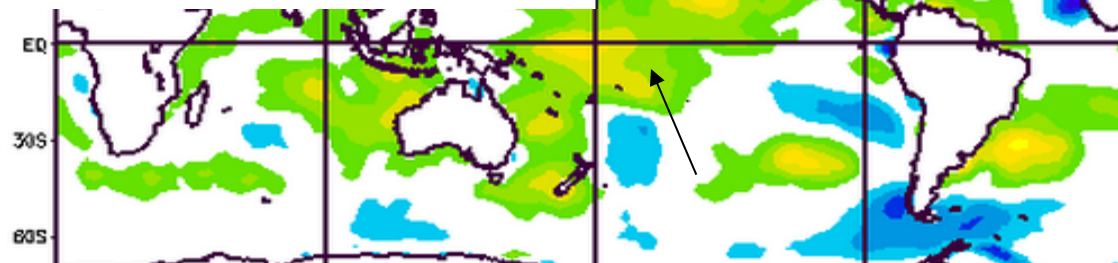
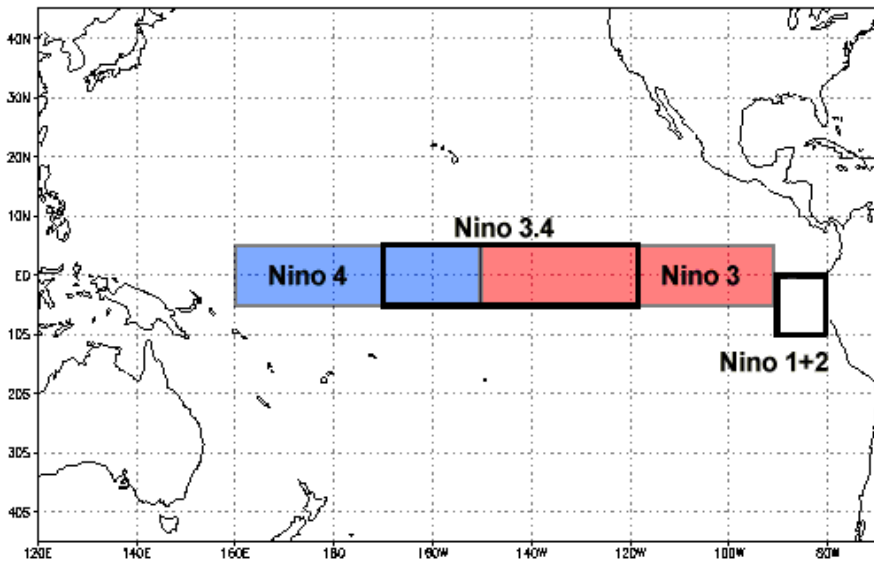
## SSTs patterns (2014 and 2015) anomalies



FEB/MAR  
2014

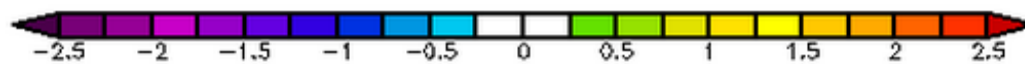


Mar: 2014



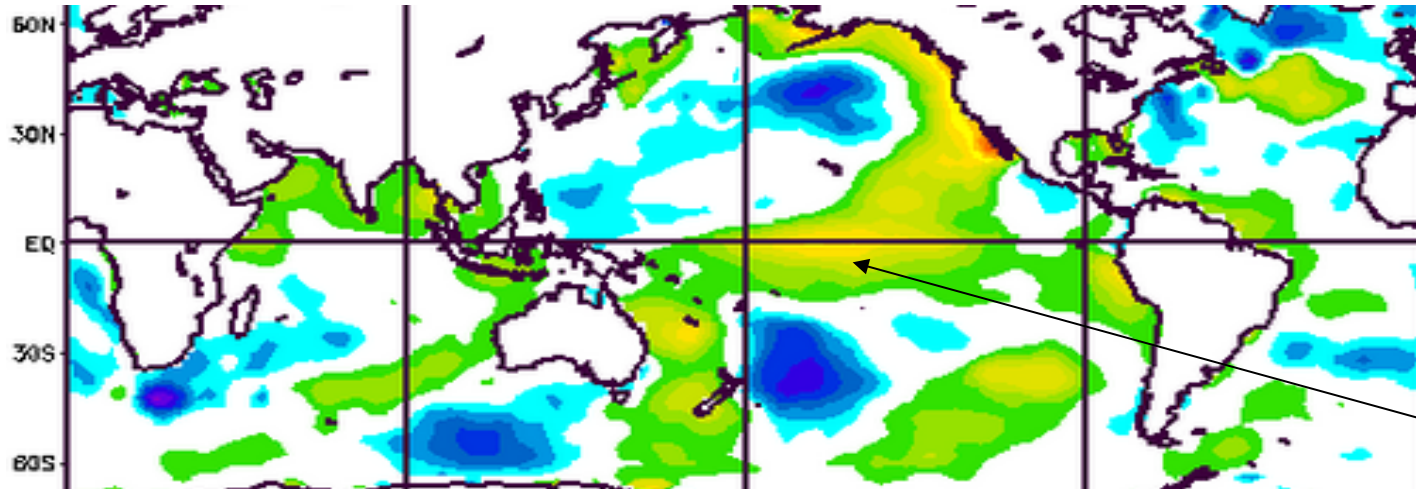
FEB/MAR  
2015

Feb to Mar: 2015

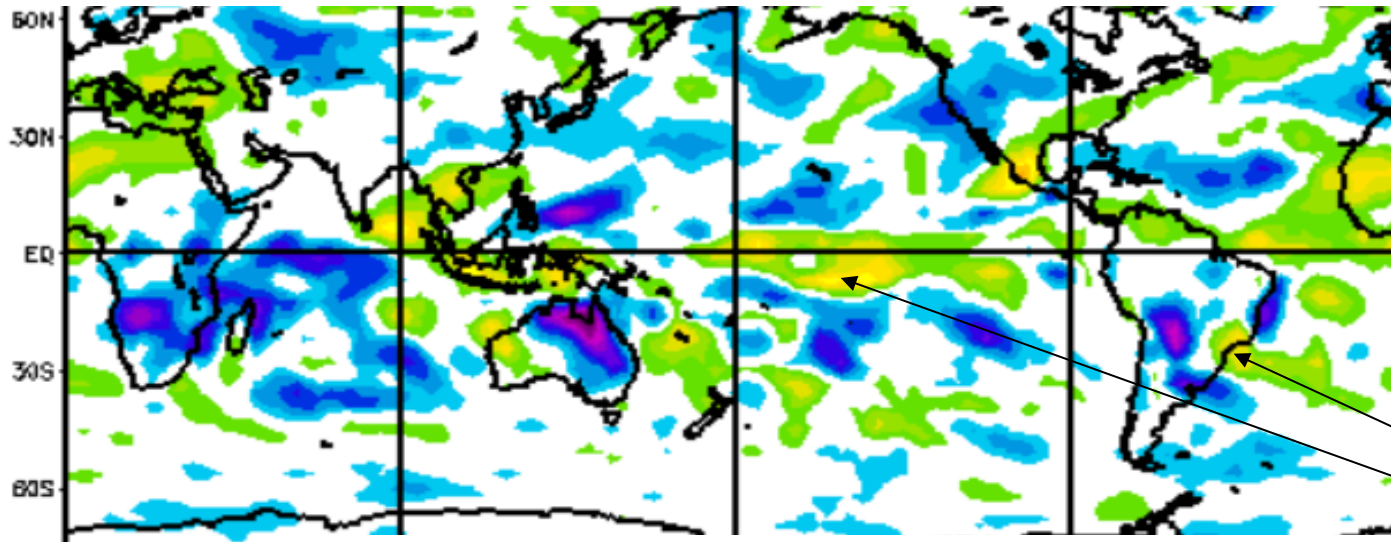




# SSTs and OLR patterns (2015 MINUS 2014)



SST dif  
NINO 3.4  
warming

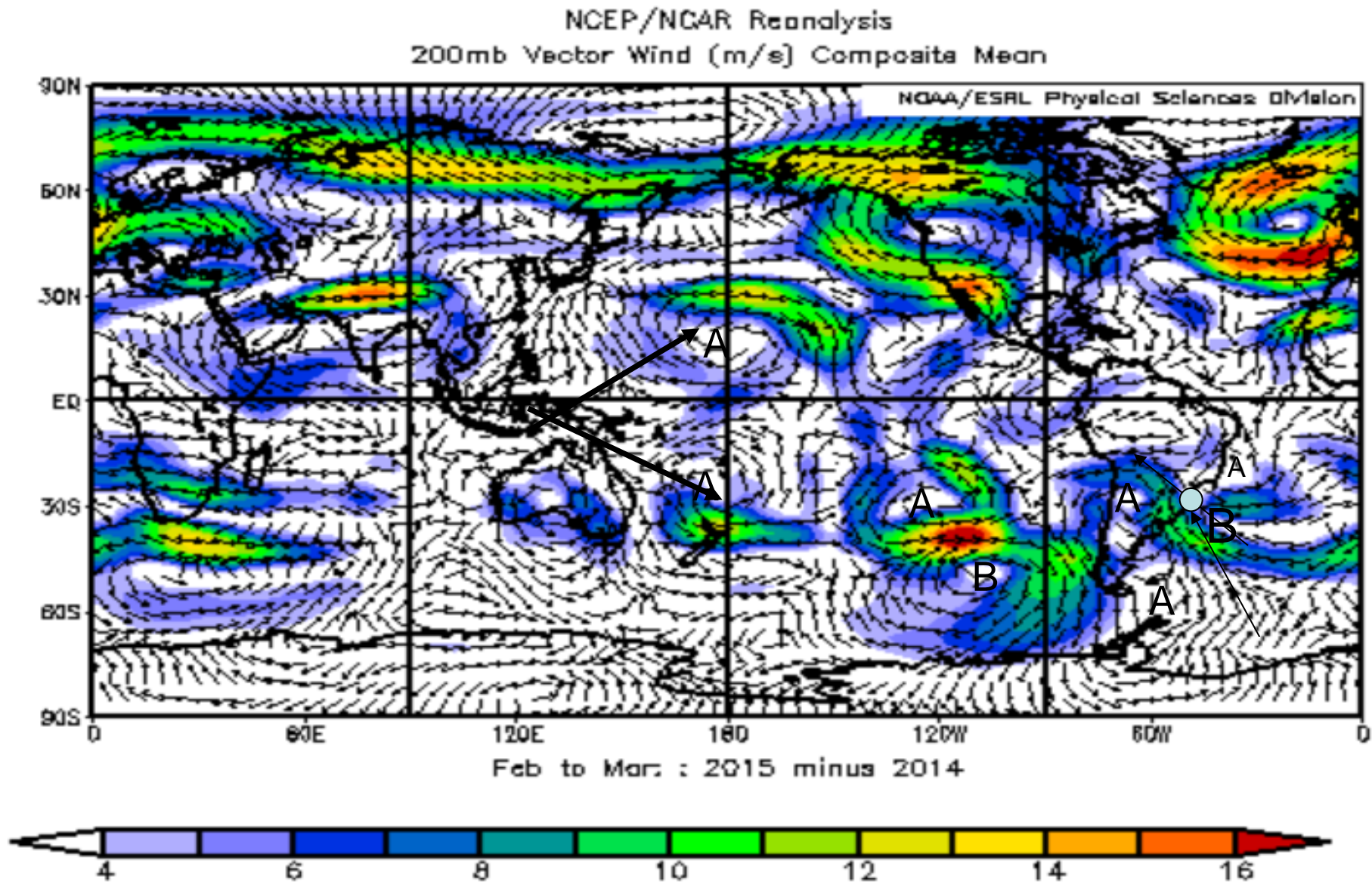


OLR dif  
MORE CONVECTION



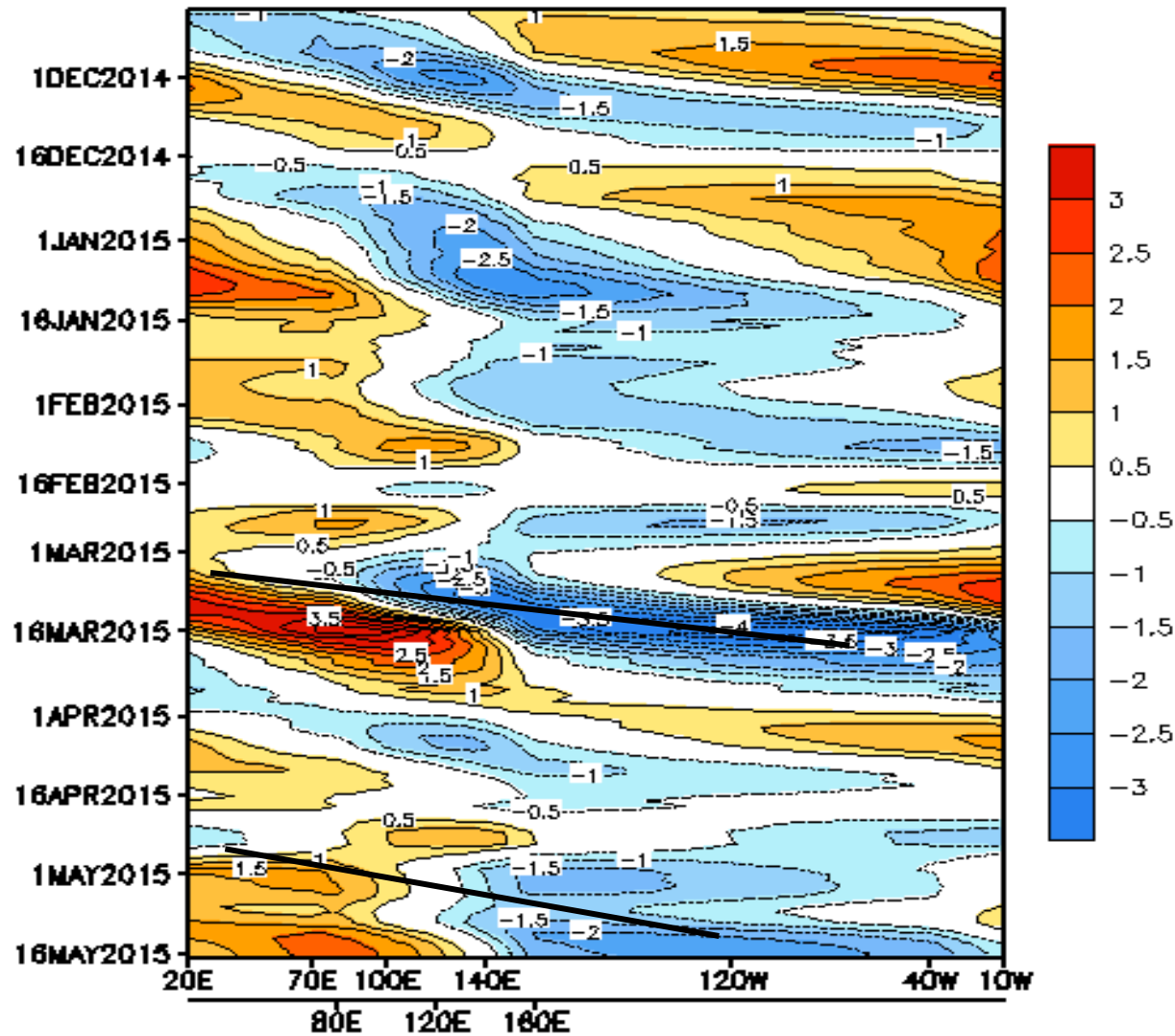
Yellow (convection) blue (supressed)

# DIFERENCES IN UPPER CIRCULATION (2015 minus 2014)



# MJO OSCILLATION ACTIVATES BY THE END OF 2014

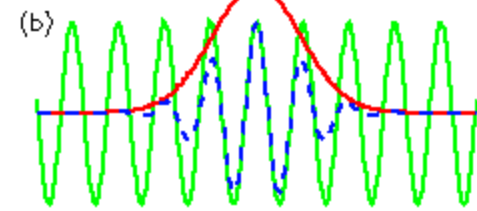
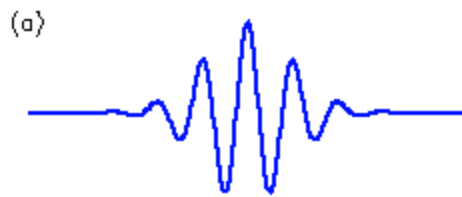
5 -day Running Mean



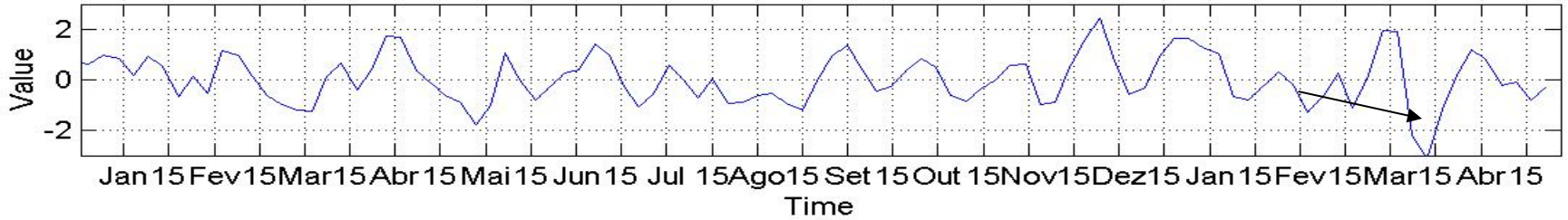
Data updated through 19 May 2015

Velocity potential – OMJ index

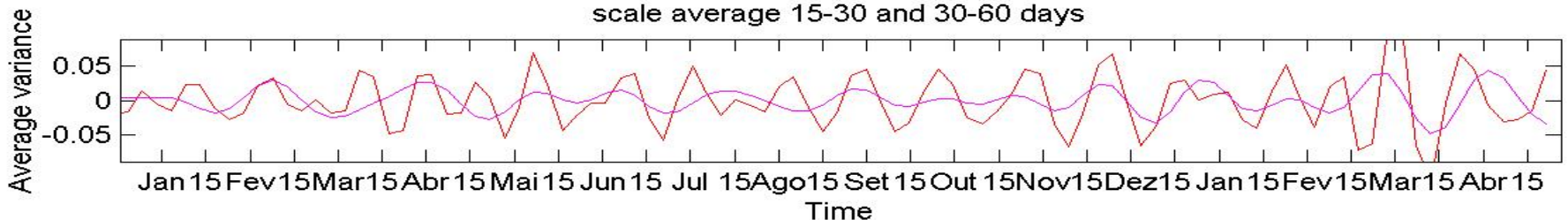
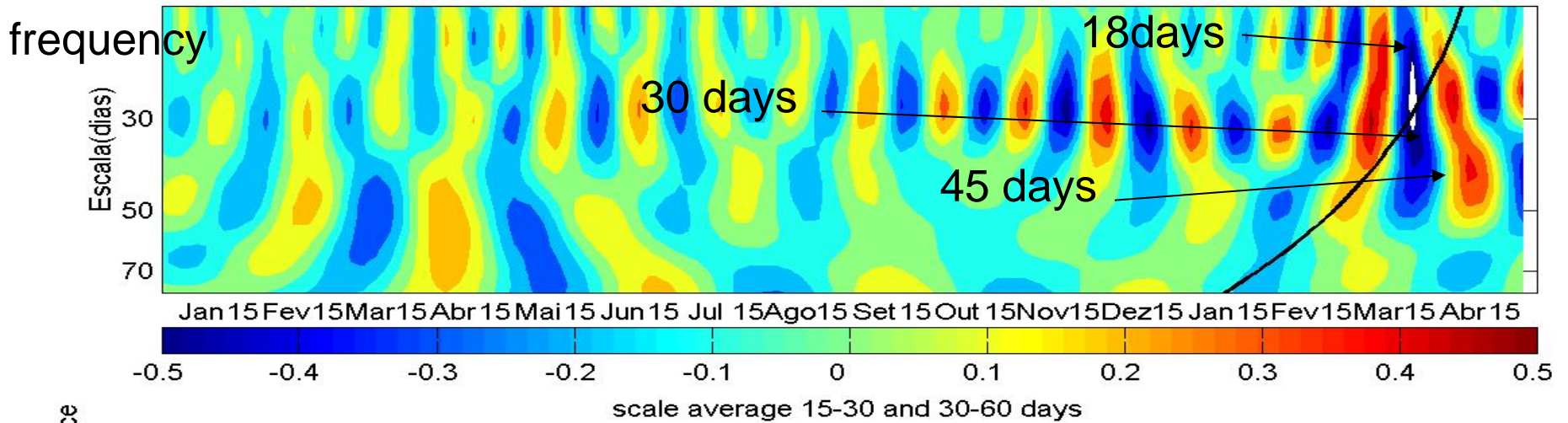
# WAVELET ANALYSIS



MADDEN-JULIAN OSCILLATION INDEX 40W



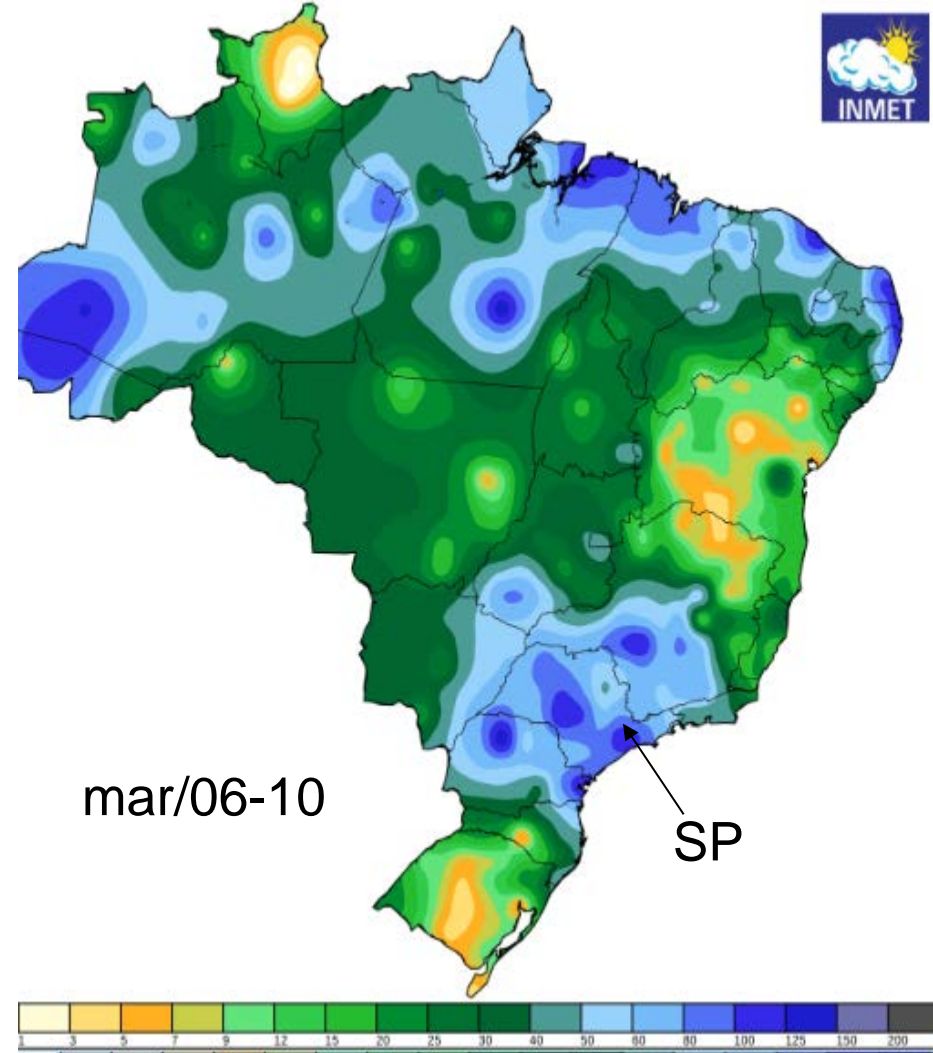
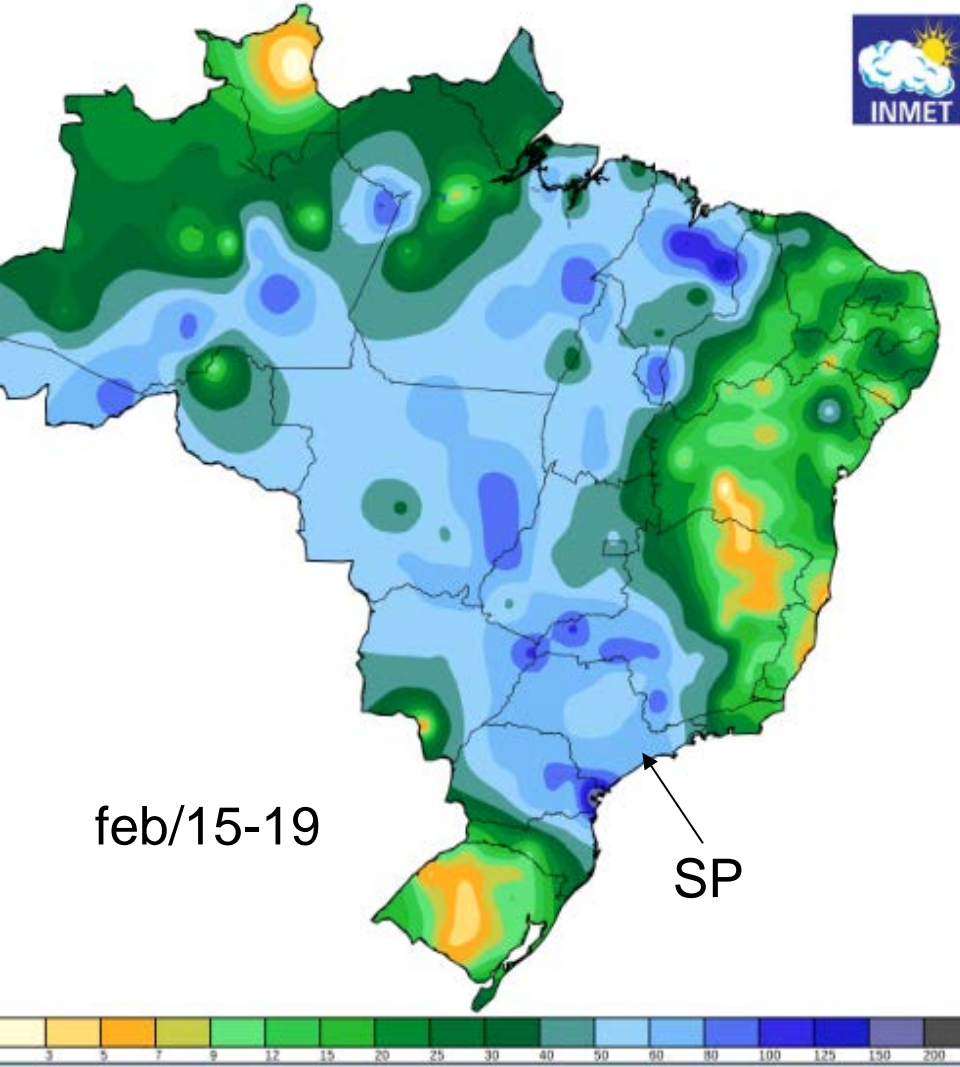
← 2015 →  
Parte real dos coeficientes da Ondeleta



# CASE STUDIES

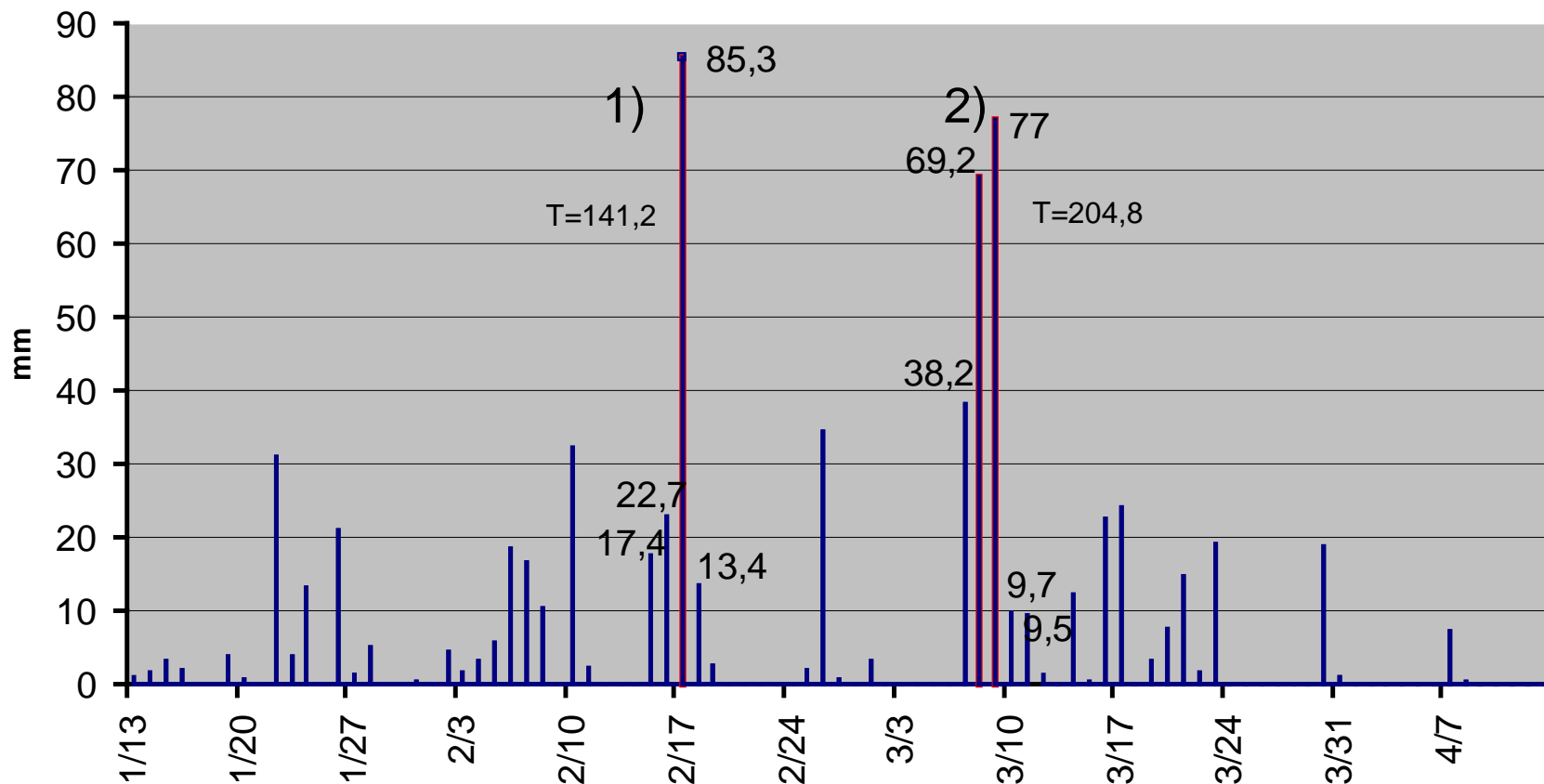
FIRST RAINFALL EVENTS AFTER THE DROUGHT

# FIRST RAINFALL EVENTS AFTER THE DROUGHT



**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

Date/ time utc

Data	Hora	Temperatura (°C)			Umidade (%)			Pto. Orvalho (°C)			Pressão (hPa)			Vento (m/s)			Radiação (kJ/m²)	Chuva (mm)
		Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Vel.	Dir.	Raj.		
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	19.8	95	95	95	18.9	19.2	18.8	926.5	926.5	925.7	2.8	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

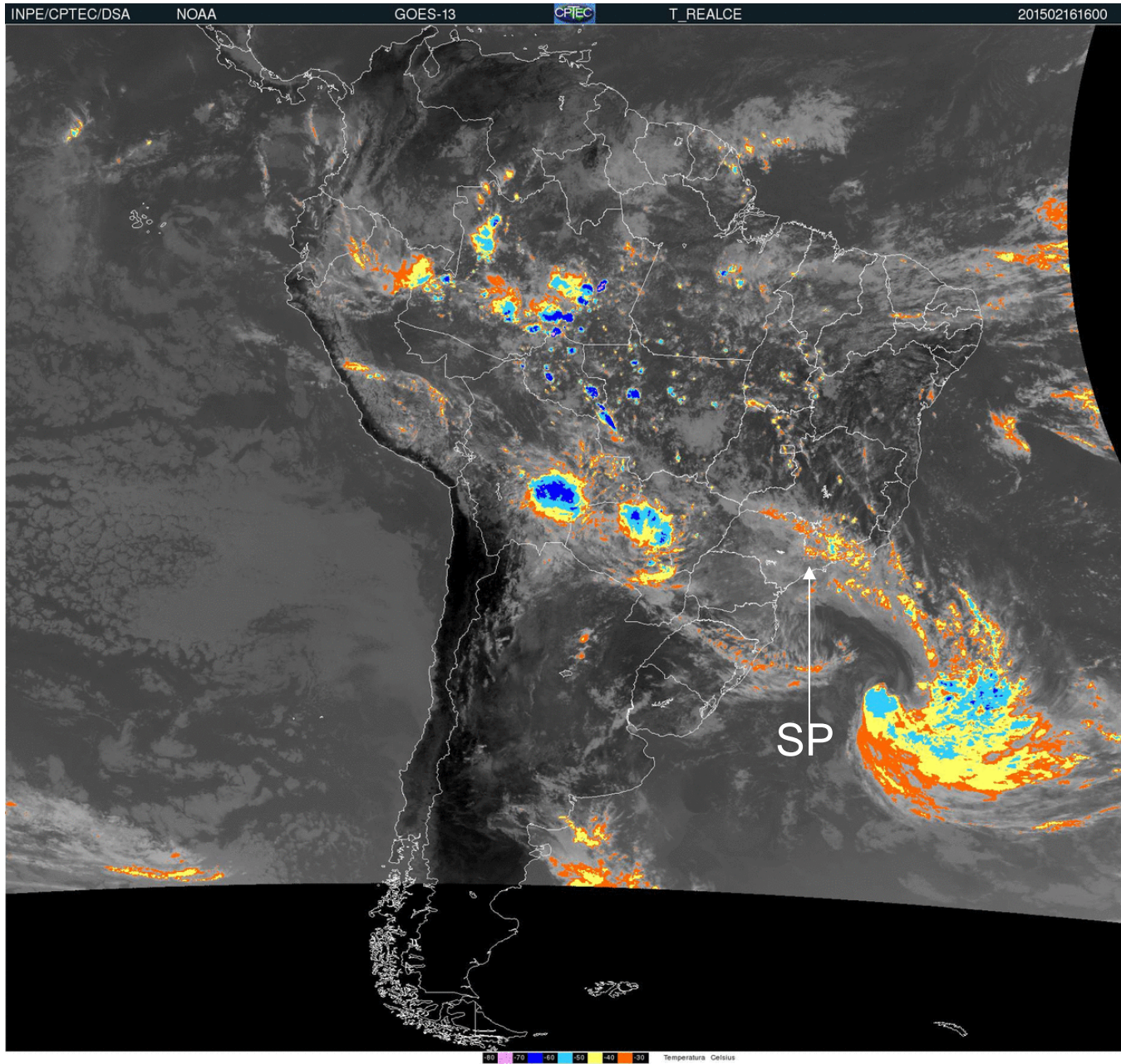
Dew points around 19°C

52mm in 1 hour



Case 1: 02/16 event  
Analysis of predictors

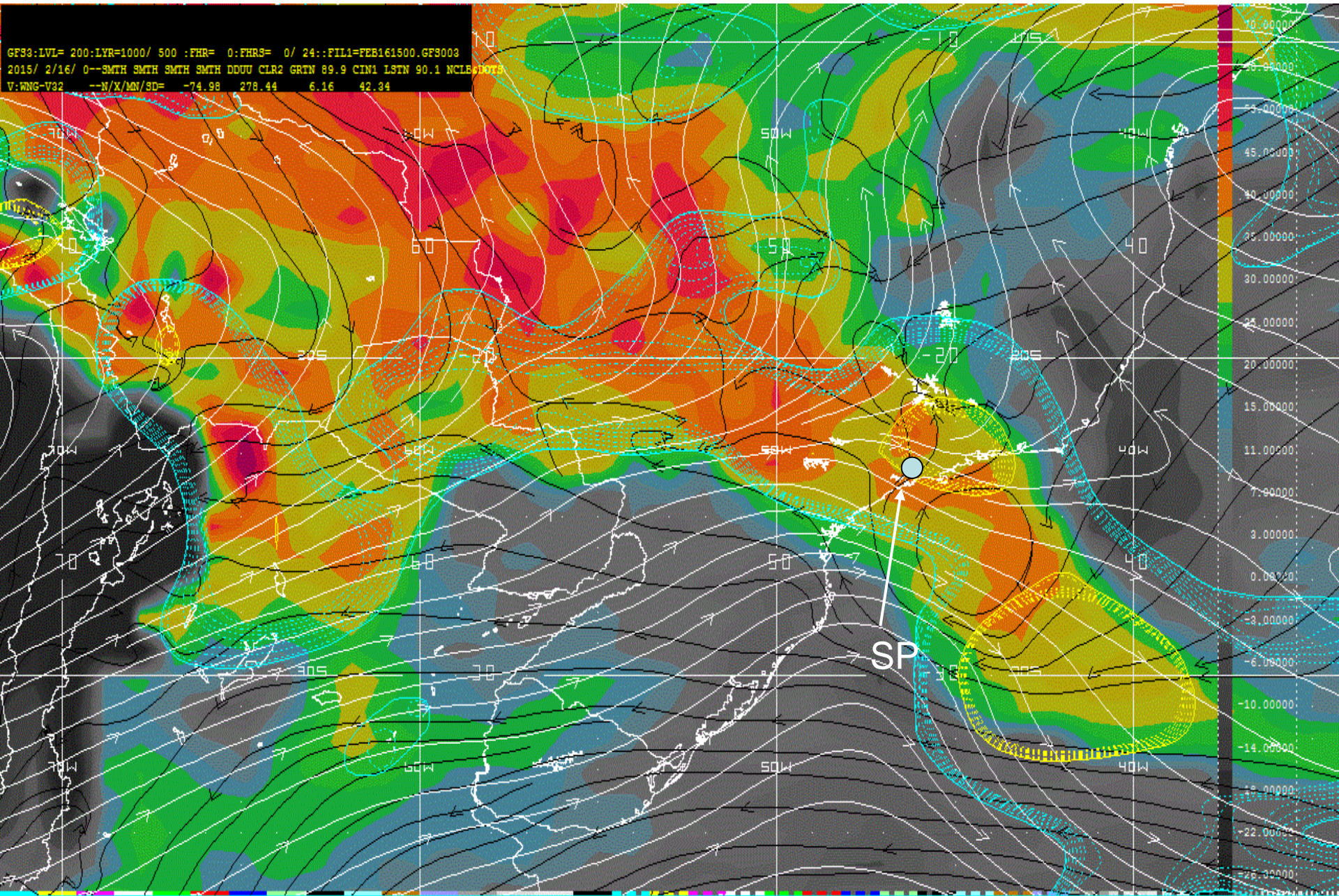
*Infrared satellite image convection pattern*



# Case 1: 02/16 event

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

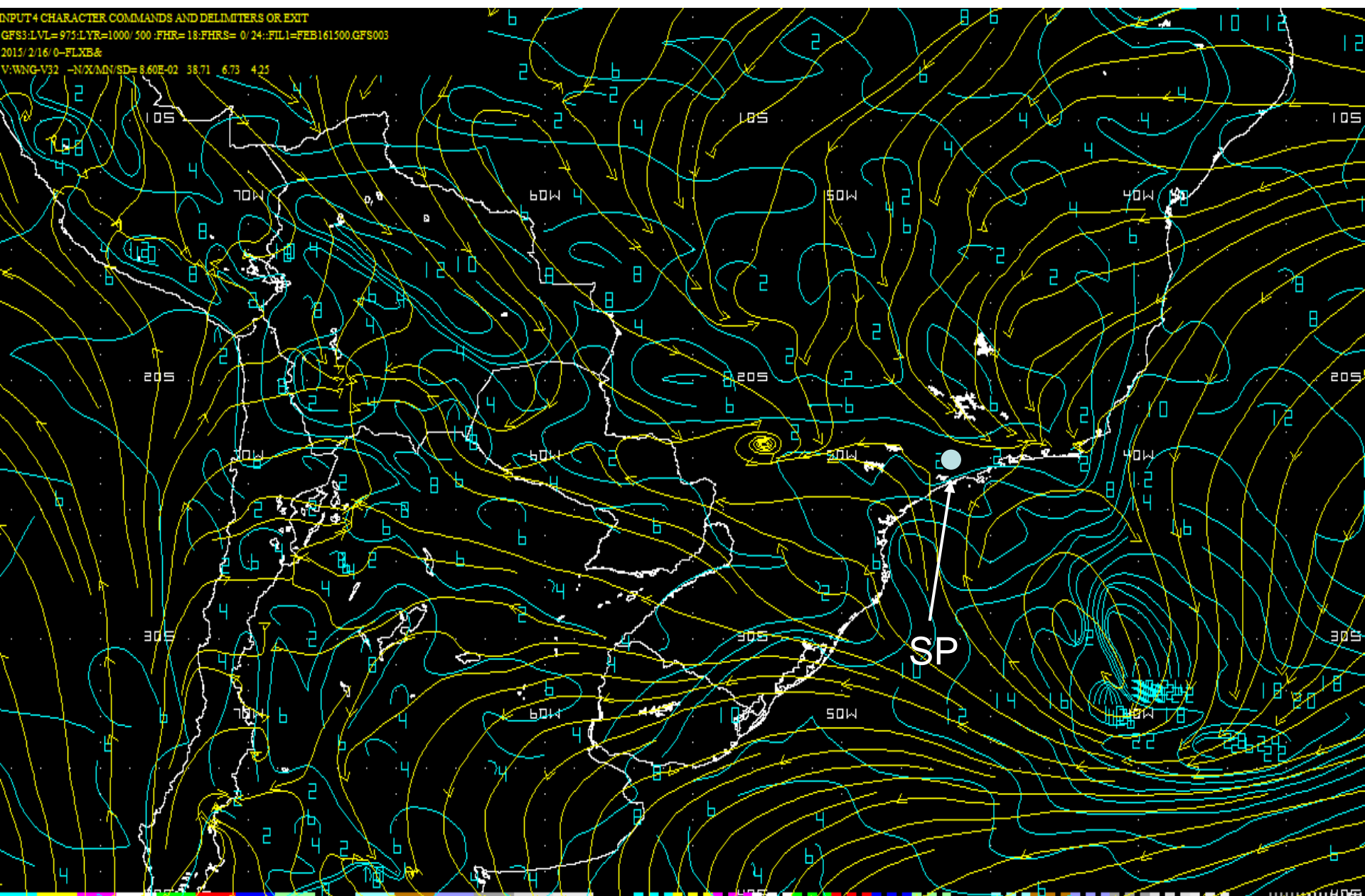
## Analysis of predictors dynamics / Instability



# 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

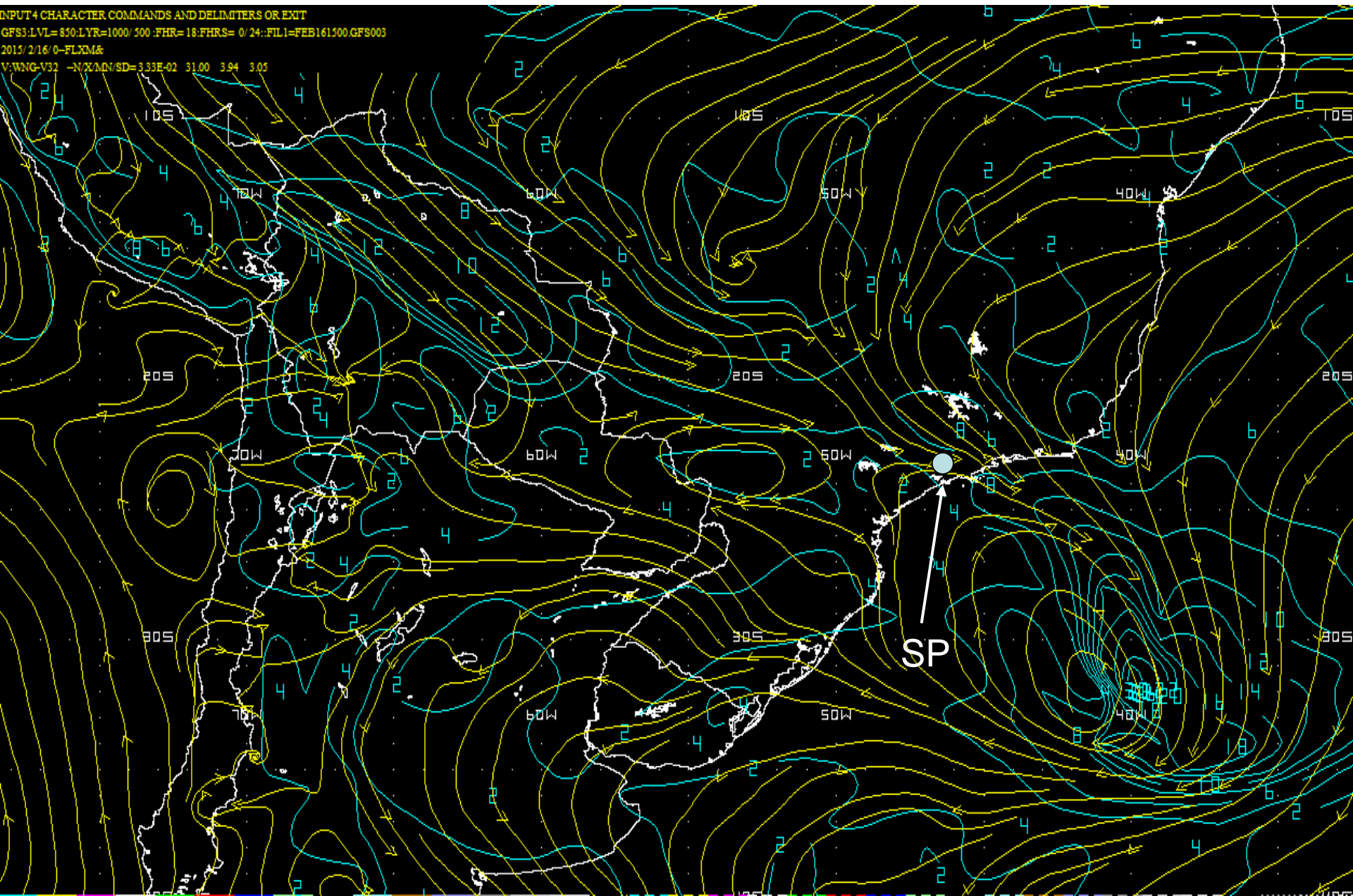
## Analysis of predictors Flux of moisture

medium level (700 - 500 hPa)

Flux of moisture= yellow lines

Magnitude of moisture flux= blue

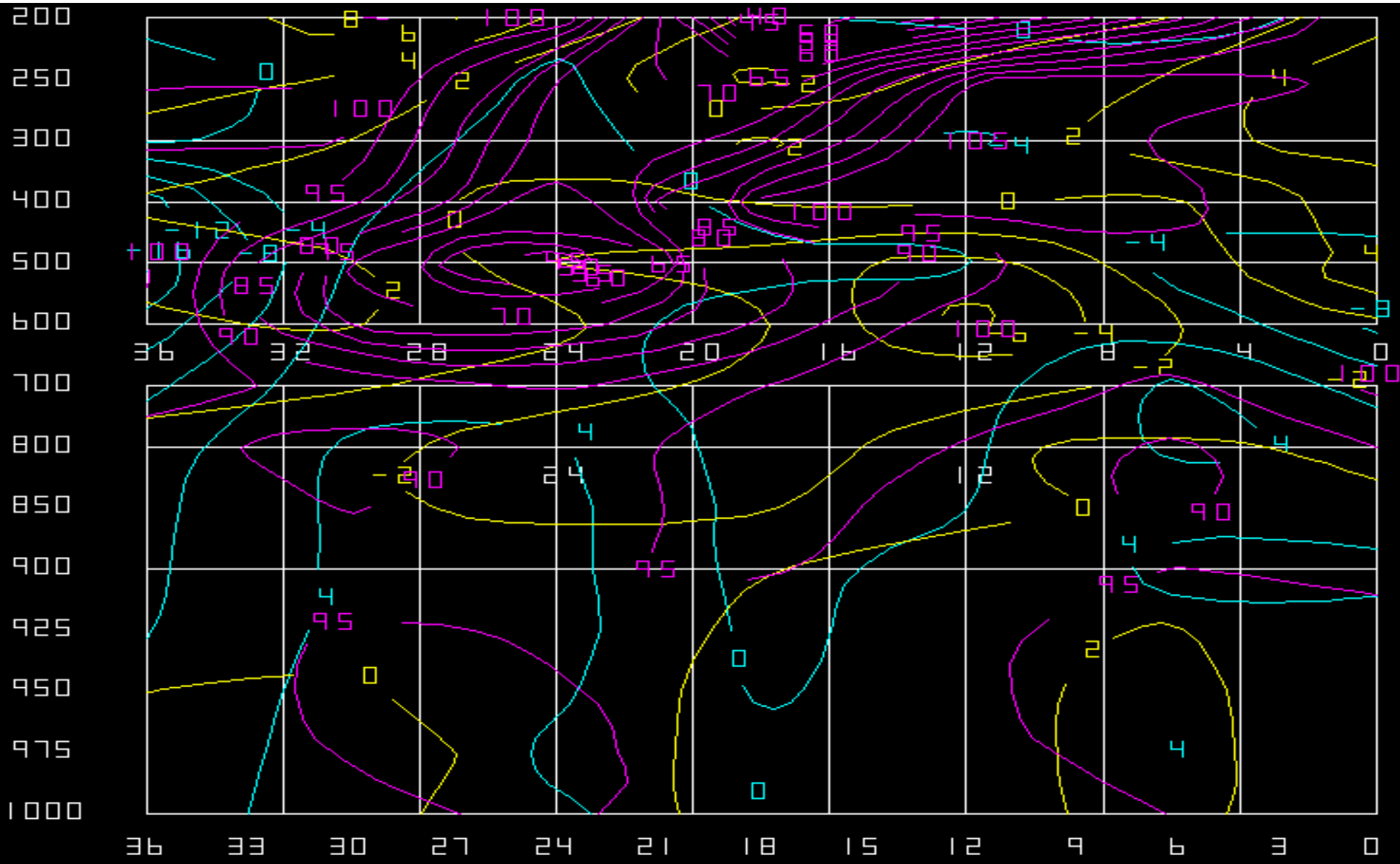
INPUT 4 CHARACTER COMMANDS AND DELIMITERS OR EXIT  
GFS3:LVL=850:LYR=1000/500:FHR=18:FHRS=0/24:FL1=FEB161500:GFS003  
2015/2/16/0-FLXM&  
V:WNG-V32 -N:XMN/SD=3.33E-02 31.00 3.94 3.05



# 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 (kJ/m²)	Chuva (mm)
		Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Vel.	Dir.	Raj.		
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	19.8	19.8	19.4	923.5	923.8	923.4	0.7	133°	2.7	81.88	0.8
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

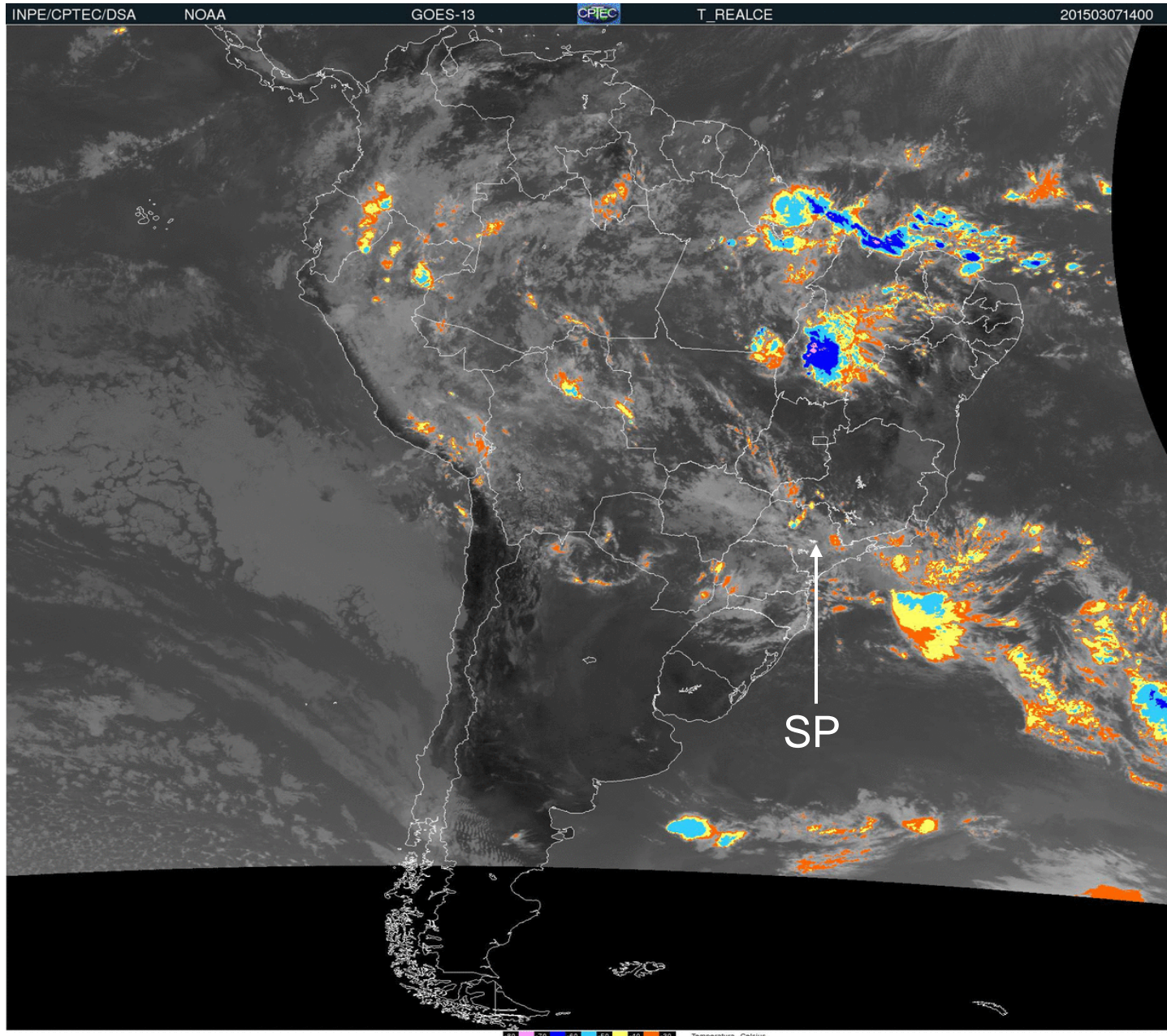
Dew points around 19°C

60mm/2h

Data	Hora	Temperatura (°C)			Umidade (%)			Pto. Orvalho (°C)			Pressão (hPa)			Vento (m/s)			Radiação (kJ/m²)	Chuva (mm)
		Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Inst.	Máx.	Mín.	Vel.	Dir.	Raj.		
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	1.5	164°	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	19.8	19.8	18.8	924.5	925.0	924.5	1.8	294°	3.1	0.58	1.2
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

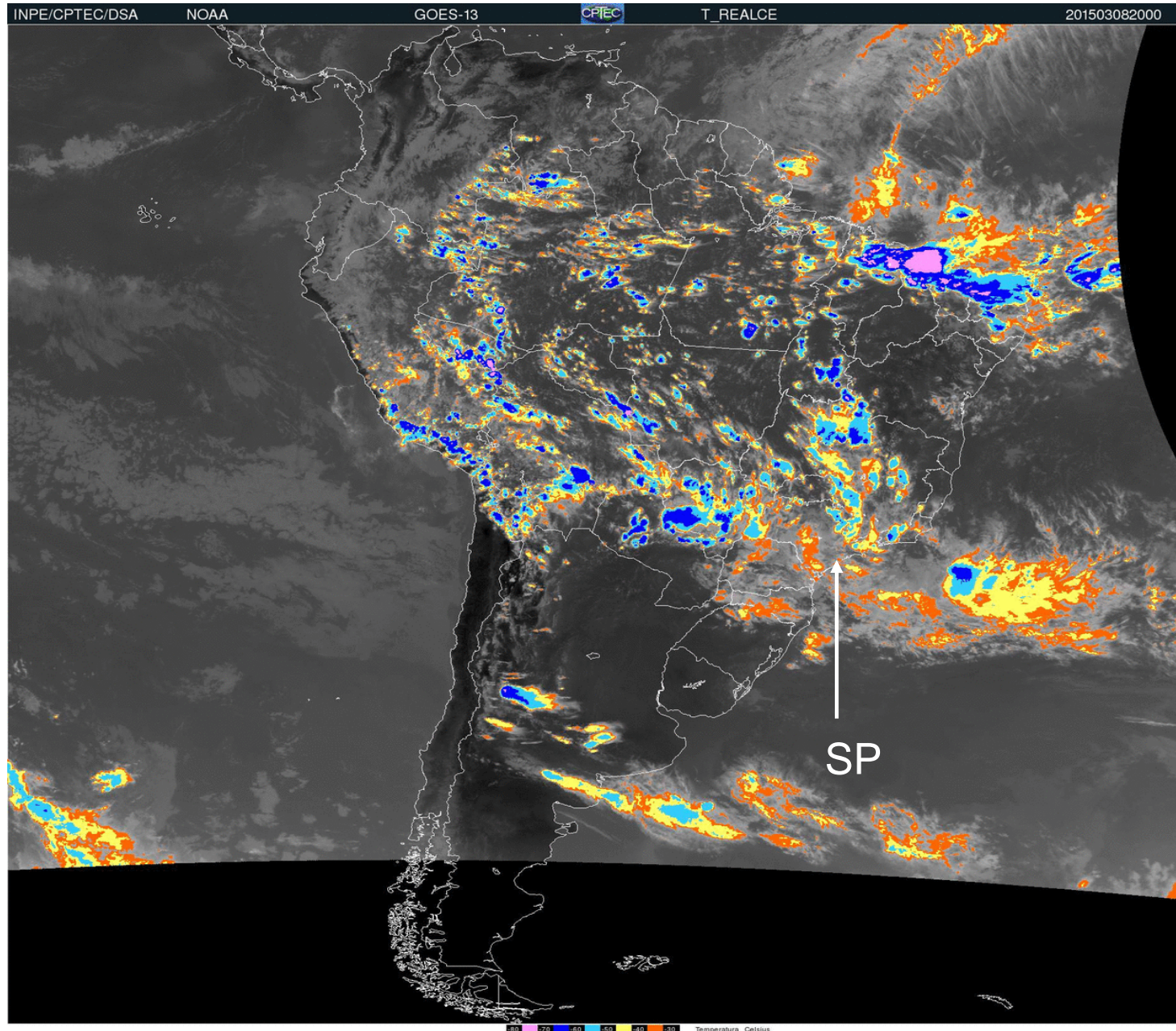
*Infrared satellite  
image convection pattern 14h-23hutc*



Case 1: 03/08 event  
Analysis of predictors

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

15/03/08

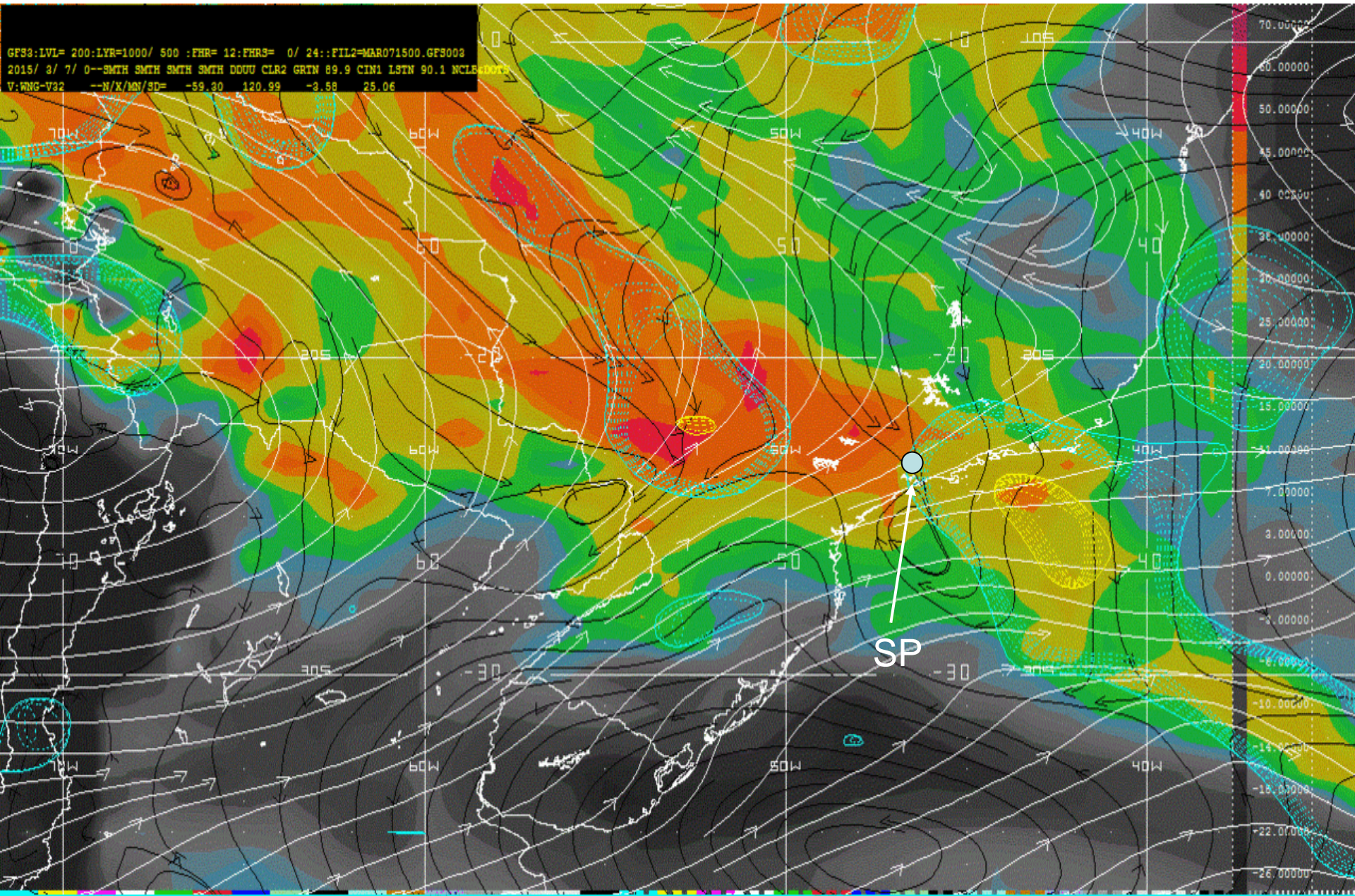




# Case 2: 03/08 event

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

## Analysis of predictors dynamics / Instability

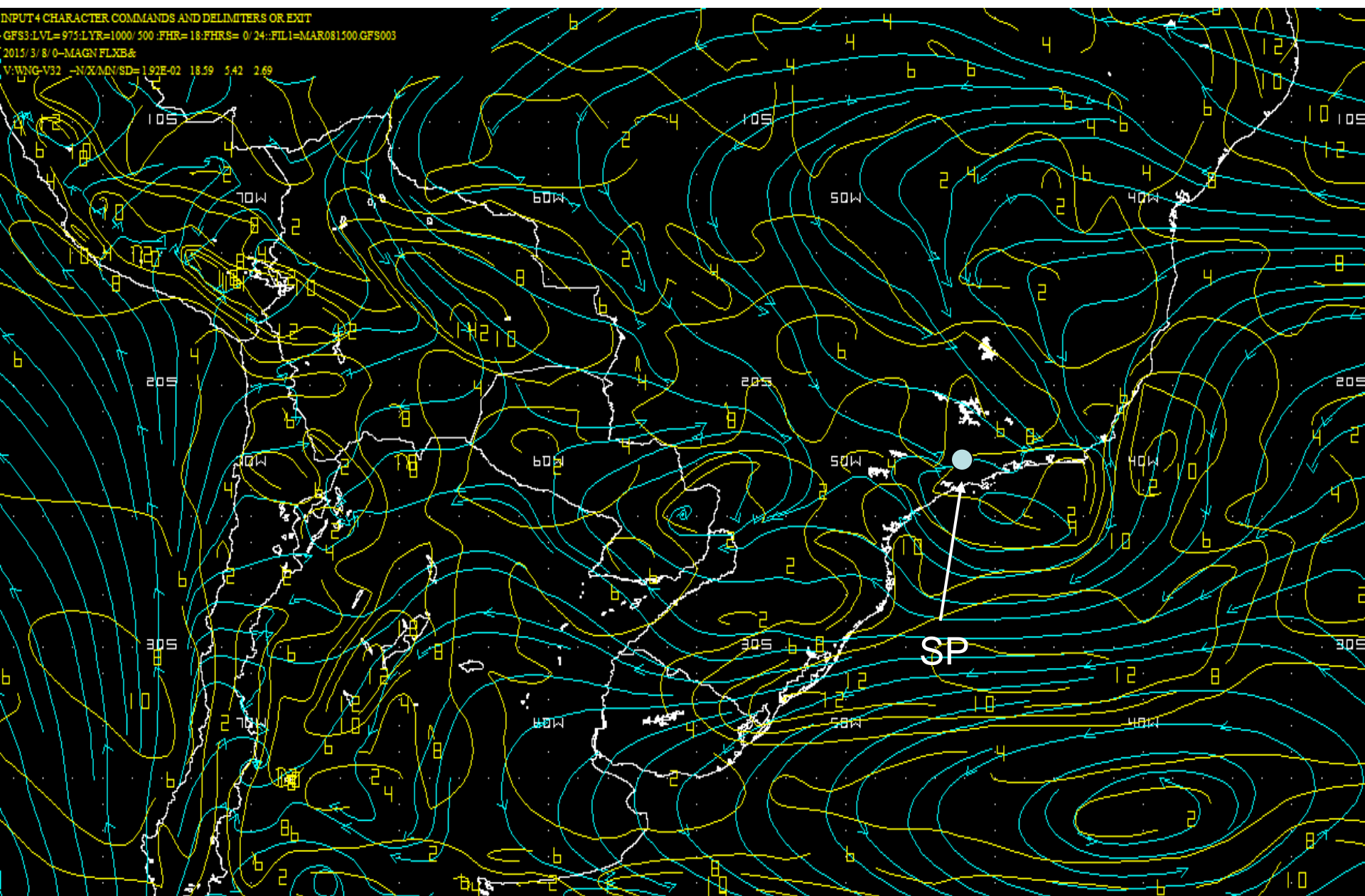


# Case 2: 03/08 event

## Analysis of predictors Flux of moisture

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

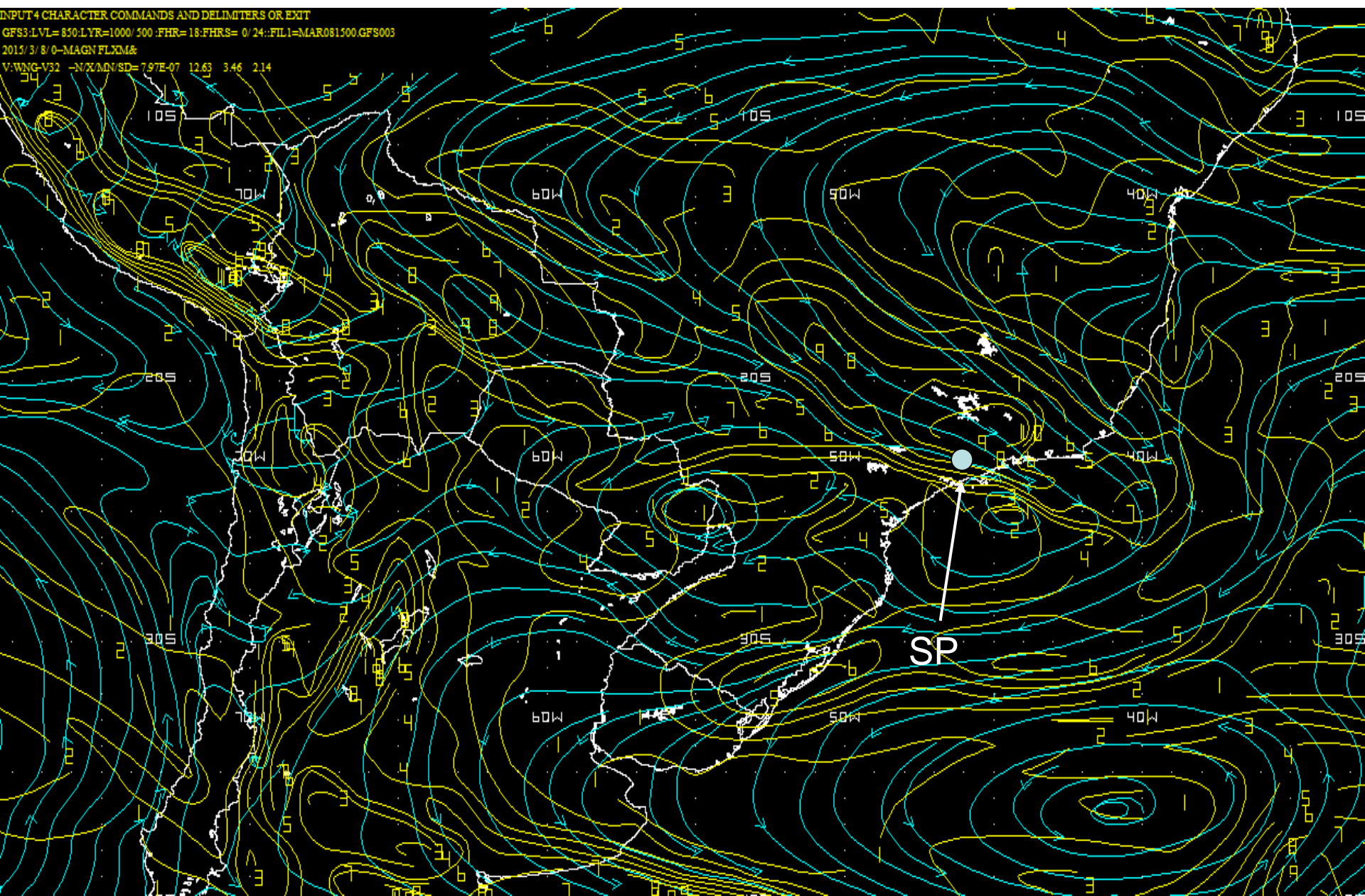
INPUT 4 CHARACTER COMMANDS AND DELIMITERS OR EXIT  
GFS3.LVL=975.LYR=1000/500.FHR=18.FHRS=0/24.FIL1=MAR081500.GFS003  
2015/3/8/0-MAGN.FLXB&  
V:WNG-V32 -N/XAM/SD=192E-02 18.59 542 2.69



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

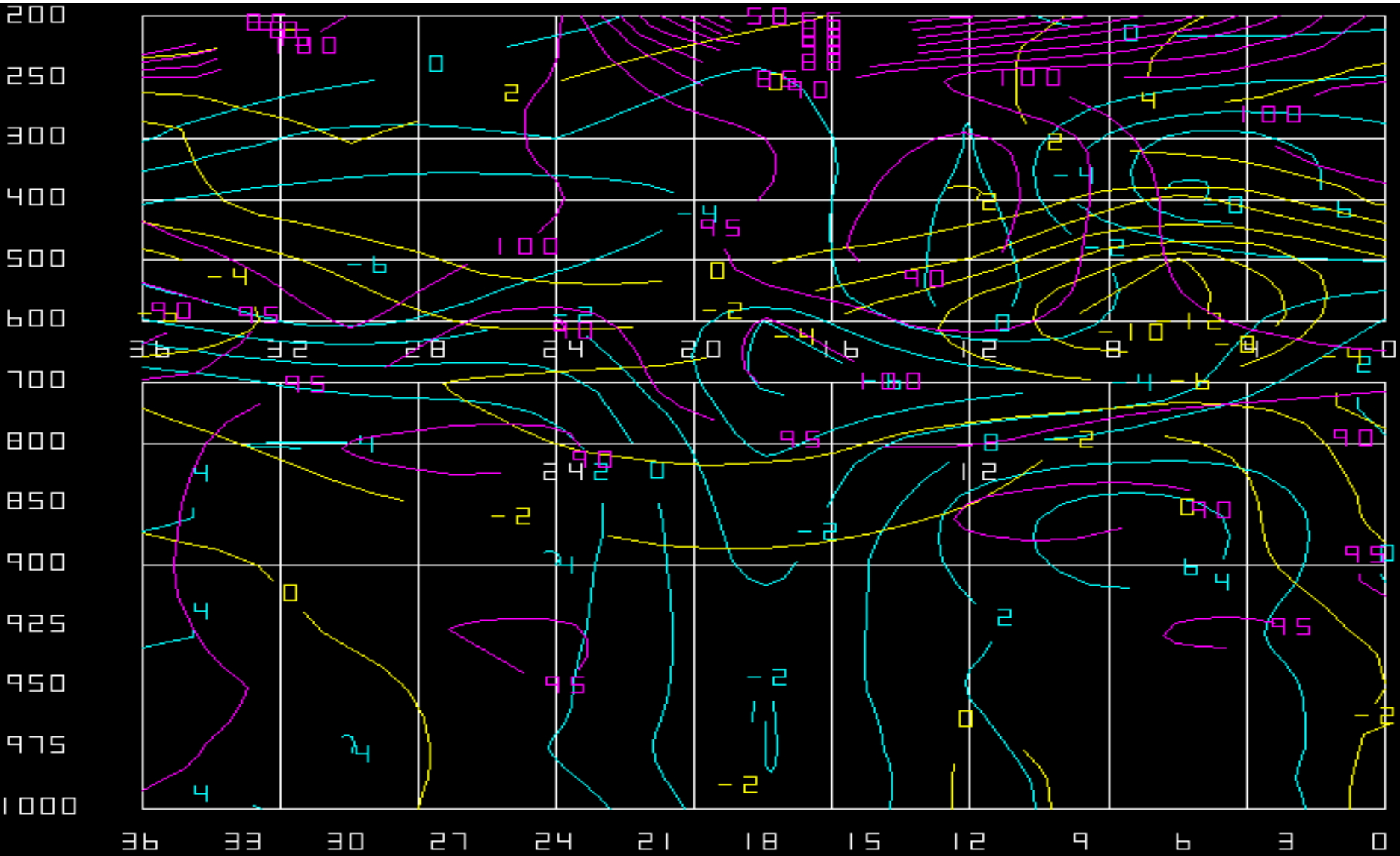
INPUT 4 CHARACTER COMMANDS AND DELIMITERS OR EXIT  
GFS3:LVL= 850:LVR=1000/500:FHR= 18:FHRS= 0/24::FIL1=MAR081500.GFS003  
2015/3/8/0-MAGN.FLX.M&  
V:WNG-V32 -NXXMN/SD=797E-07 12.63 3.46 2.14



# 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 diffluence/ 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 –northwest wind
- Isentropic ascent just north of the station
- Predictors:
  - High dew points (close to the 19°C)
  - 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 => Wave train from the Pacific  
Slightly cold SST in niño 1.2