Revista Brasileira de Meteorologia, **v.26**, **n.1**, 9 - 18, 2011

RARE EVENTS OF STRATUS CLOUDS ON THE NORTHEAST COAST OF BRAZIL

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Received October 2008 – Accepted July 2010

ABSTRACT

One event of three consecutive days and another of four consecutive days of Stratus clouds were registered at the Maceio airport on the northeast coast of Brazil. This is a very rare phenomenon for equatorial regions and it was analyzed using the high resolution (10km) ETA model, NCEP reanalysis, satellite data and conventional data supplied by the Hydrometeorological Directory DHM-SERHI/AL and by the Department of Flight Protection of the Zumbi dos Palmares airport. Wave disturbance in the trade winds and weak ascendant movements at low levels (1000 and 925hPa) were identified. At the same time, anticyclonic curvature at high levels formed descendant movements and subsidence inversion. These vertical movements combined with a stable layer between 850 and 700hPa created a very humid layer at the low levels. The precipitation forecasted by the ETA model with 24h antecedence presented a satisfactory result for an average quantity of precipitation. Nevertheless, the spatial distributions of forecasted and observed precipitation were different. Precipitation during all days was not forecasted for the coastal region, and for the west region the forecasted precipitation was more intense than the observed ones.
Keywords: Stratus formation, synoptic analysis, high resolution ETA model.

RESUMO: EVENTOS RAROS DE NUVENS STRATUS NA COSTA LESTE DO NORDESTE DO BRASIL.

Foram registrados dois eventos de três e quatro dias consecutivos de nuvens Stratus no aeroporto de Maceió na costa leste do Nordeste Brasileiro (NEB). Isto é um fenômeno muito raro para regiões equatoriais e foi analisado usando o modelo ETA (10 km) com alta resolução, reanálises do NCEP, dados de satélite e dados convencionais fornecidos pela Diretoria de Hidrometeorologia do estado de Alagoas (DHM-SERHI/AL) e pelo Departamento de Proteção ao Vôo (DPV) do aeroporto Zumbi dos Palmares. Distúrbios ondulatórios de leste e fraco movimento ascendente nos baixos níveis (1000 e 925 hPa) foram observados. Esta estrutura esteve associada a uma curvatura anticiclônica nos altos níveis, que implicou em movimentos descendentes e a inversão de subsidência. Estes movimentos verticais combinados com uma camada estável entre 850 e 700 hPa, criaram uma camada muito úmida nos baixos níveis. A precipitação prevista pelo modelo ETA com 24 horas de antecedência apresentou um resultado satisfatório para uma quantidade média de precipitação. Por outro lado, a distribuição espacial de precipitação prevista e observada foi diferente. As precipitações durante todos os dias não foram previstas para a região costeira, enquanto que para região oeste do estado o modelo superestimou, quando comparado ao observado.
Palavras-Chaves: Formação de nuvens stratus, análise sinótica, modelo ETA com alta resolução.

1. INTRODUCTION

The Stratus (St) cloud formation and related low visibility create adverse conditions for all transport and especially for aviation. The low altitude of a St base can limit aircraft landing and takeoff at the airport (Cabral, 1998). Very dangerous phenomena (fog, turbulence, weak rainfall, etc.) are associated with St and can seriously affect flight controllability and even can damage and cause aircraft structural failures. Responsible mechanisms of St formation involve the air cooling to dew point temperature, water vapor entry at low levels, subsidence inversion formation and turbulent vertical mixing of the humid air parcel (Cotton and Anthes, 1989).

Very few investigations of St cloud formation and associated precipitation have been elaborated for the northern Brazilian coast. Some information was published during the last 10 years (Fedorova, 1999; Silveira, 2003, Fedorova et al., 2007, Fedorova et al., 2008). Frequencies of fog and stratus cloudiness formation were higher in the south than on the northern coast (Silveira, 2003, Fedorova et al., 2008). Mean data of the fog events for the southern and northern coasts were 93 fog days and 2 fog days per year, respectively. Stratus clouds were observed during 61 and 33 days per year for these regions, respectively. Also, fog/stratus formation was associated, in general, with wave disturbance in the trade winds (WDTW) field on the north coast. Classification of the temperature and dew-point vertical profiles for different fog/stratus physical processes was developed (Fedorova et al., 2008). Stable layers in the vertical profiles were not observed on the north coast and the humid layer was very narrow in all cases.

Moreover, studies of the fog/stratus impact in the Brazilian Northeast Region (BNE) are still very scarce. Knowledge about St formation/dissipation is very essential for aeronautical transport security.

St cloud are a phenomena associated with the specific conditions of a place and, therefore, each airport has to have a specific model. For example, an operational system of low cloud/fog probability forecast was developed at the Melbourne Airport in Australia. Dew point temperature, air temperature and pressure are used as predictors in this system (Stern and Parkyn, 2001). A new technique to identify and separate St cloud and fog, using the Meteosat 8 satellite data, was elaborated by Cermak and Bendix (2008). The structure of the forecast scheme at the National Weather Service, USA, was described in Gurka and Mosher (2001). A fog forecast method, using synoptic conventional data, temperature and humidity vertical profiles and satellite images, was elaborated for Pelotas/RS (Oliveira, 1998). A specific forecast method for BNE Airports was still not possible to develop, due to few studies of the physical processes of this adverse meteorological phenomenon formation.

In the German forecast model of stratus clouds and radiation fog, besides the traditional parameters (horizontal wind distribution, potential temperature and specific humidity), vegetation data were also included (Bott, 2001). An interaction between boundary layer processes and humid air currents in vegetation layer was described by Siebert et al. (1992). It was concluded that fog/low cloud time formation/dissipation are dependent on the vegetation characteristics.

Bott (2001) verified that information about large scale downward motions is necessary for low level cloud forecasts. Air subsidence in the subtropical Highs in the eastern regions has created a temperature inversion layer between the 1200 - 2000m heights (Fedorova, 2001). This inversion is the control factor of St cloud evolution.

Several numerical models of St cloud and/or fog forecast have been published recently. For example, a new one-dimensional forecasting model - PAFOG for radiation fog and low level cloud was created for local visibility forecast in Germany (Bott and Trautmann, 2002). In an experimental simulation of St cloud over the ocean, a four-dimensional COAMPS model of cloud cover was reproduced successfully on the California coast, Kong (2002). Low visibility forecast results by Roquelaure and Bergot (2009) of the Local Ensemble Prediction System (LEPS) was compared with the operational human forecast for the Paris airport and have shown that the model provides reliable predictions.

Golding et al. (1993), using the mesoscale numerical weather prediction model, concluded that local nocturnal wind may frequently determine the location and time period of fog formation in uneven terrains.

St cloud generally produce weak rain and drizzle and may also be accompanied by light snow. The number of precipitation days associated with St cloud in southern Brazil varied from 14 to 19 days per nine months of each La Niña and El Niño years, respectively (Fedorova et al., 2007). Precipitation associated with these clouds does not exceed 4.3mm/24h in La Niña and El Niño years and 7.4 mm/24h in a normal year.

But these studies are not sufficient for the daily operational support of the Maceio airport. It should be noted here that Maceio is a very special region for international tourism, attracted by its beautiful beaches and the ocean. Because of the new airport construction and consequent air traffic growth, it is necessary to carry out more detailed studies of fog/stratus development to elaborate higher precision weather forecast. The forecast of low-level stratus clouds and of their associated precipitation is very important for the normal operation of the Maceio airport.

The high resolution (10km) ETA model was implemented by the Institute of Atmospheric Science of the Federal University of Alagoas and the Hydro-Meteorological Directory (DHM-

SERHI/AL) to support the short term weather forecast. This model has been used by the Alagoas State Hydro-Meteorological Center since March 2003 for scientific and non-operational purposes. The predomination of eastern trade winds and the absence of meteorological data over the ocean makes necessary the use of the high resolution model for the east coast (between 7 and 12^{o}S and 32.5 and 38.5^{o}W, Figure 1).

This work aims to study a very uncommon event of stratus cloud formation during 4 consecutive days in the Brazilian Northeast Region (BNE). Atmospheric system structure will be analyzed using different data sources. A secondary goal of this study is the verification of the ability of the regional ETA model for forecast simulation of phenomenon characteristics.

2. DATA SOURCE AND METHODOLOGY

This methodology was elaborated to understand stratus-cloud formation in the equatorial region of Brazil to support the short-term weather forecast. Therefore, this study is based on meteorological data which can be used in operational practice by the forecaster.

2.1 The analysis of extremely intensive stratus events

All meteorological parameters (temperature, relative humidity, wind speed, cloud types and meteorological phenomenon) were obtained hourly by the Department of Flight Protection of the Zumbi dos Palmares airport (Maceió city, latitude 9.7^{o}S, longitude 35,8^{o}W) for two intensive stratus events during 7 to 10 June 2003 and 3 to 5 July 2003. The stratus clouds have caused some serious problems for air traffic during these days.

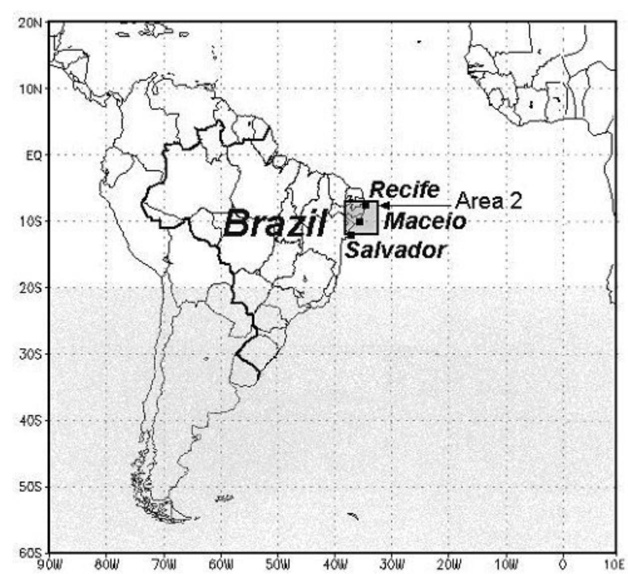


Figure 1 - Observation station location and study areas: total figure represents a calculation area for the NCEP reanalysis products; area 2 corresponds to a calculation area of the high resolution ETA model; white color area (north of 20ºS) represents tropical synoptic system predomination; grey color area (south of 20ºS) presents an extra-tropical synoptic system predomination.

2.2 Synoptic systems associated with fog/stratus formation

The stabilization of synoptic patterns of any meteorological phenomenon is the first necessary step for synoptic weather forecast elaboration for any region. Scarce meteorological investigations of fog/stratus formation in Brazil and the complete absence of any numerical methods for forecast of these phenomena near the coast make the elaboration of synoptic patterns very important for short term weather forecast.

The synoptic situation during stratus days were analyzed using different products of NCEP reanalysis: streamlines (at the levels of 1000, 925, 500 and 200 hPa), surface pressure, omega, temperature and relative humidity at the 1000, 925 and 850 levels. The software "Grads" was used to elaborate all maps in the region between 10^{o}E-90^{o}W and 20^{o}N-60^{o}S (Figure 1). The figures below show some fragments of this observed area according to synoptic process.

All these maps were elaborated for different levels (with step of 100hPa). These maps were plotted every 3 hours by ETA model and four times per day by NCEP reanalysis. Vertical sections of the vertical motions and of the relative humidity were constructed along 10^{o}S and 35^{o}W, around Maceio city. The larger area was chosen to identify the synoptic scale of processes associated with stratus formation (Figure 1). On the other hand, the high resolution data from the ETA model permitted the identification of the structure of synoptic systems in more details. The synoptic scale information (e.g. maps and sections of different meteorological parameters, satellite images) is used to elaborate these patterns. It is important to note that the information was used to study the synoptic scale systems and processes, associated with fog/stratus.

The images were obtained by CPTEC/INPE (http://www.cptec.inpe.br/). It is important that all the satellite images (not shown) were used only for synoptic scale system identification and were never used for fog identification. The absence of archives of high resolution images didn't permit the identification of fog/stratus regions.

The meteorological parameters (streamlines, temperature, pressure, geopotential, vertical velocity, omega, relative humidity) were calculated, using the high resolution (10km) ETA model for the area of near northeast of Brazil (7-12^{o}S and 32.5-38.5^{o}W, Figure 1, area 2). The same maps were elaborated by NCEP reanalysis. Firstly, the NCEP and ETA data were used together to confirm (manually) the ETA results since it was the initial period of ETA model operation. All ETA model maps were the first results of the model operation for the northeast area of Brazil. Moreover, the NCEP data were obtained for the larger area than the ETA model (Figure 1).

The Wave Disturbance in the field of Trade Winds (WDTW) at the northwest periphery of subtropical High in the southern Atlantic Ocean was identified by streamline maps at the low levels according to the description by Molion and Bernardo (2002). The WDTW are associated with cyclonic curvature of Trade Winds at the levels of 1000 and 925hPa. Existence of WDTW was confirmed by the development of synoptic scale cloud system on infrared channel satellite images.

2.3 Vertical profiles and structure analysis

Vertical profiles were constructed by NCEP reanalysis data for Maceio city (Figure 2a). Radiosonde data were also obtained for two more adjacent stations in Salvador (southern coast, 12.6°S) (Figure 2b) and Recife (northern coast, 8.0°S, near Maceio city, not shown) for both extreme stratus events at the Maceio airport. Types of temperature and humidity vertical profiles were determined for fog and St cloud days using the NCEP reanalysis data. Tropospheric thermal stability, location of humid/dry layers, occurrence, intensity and inversion and/or location of isothermal layers were investigated for all the St days. Convective Available Potential Energy (CAPE), Lifting Condensation Level (LCL) and Level of Free Convection (LFC) were calculated (Djuric, 1994).

The synoptic analysis of all these data together (in 2.2 and 2.3) allowed a creation of a conceptual model of the synoptic systems of extreme stratus cloud formation for the near equatorial region.

2.4 Precipitation

It is necessary to note that the desert is localized in the west extreme of Alagoas and dry periods are observed in all state regions throughout the year. Therefore, any information about precipitation, including weak precipitation, is very important. The precipitation forecast with 24h antecedence by the high resolution ETA model was tested for rare stratus events. The test results were compared with observed data. The precipitation data for 39 stations and ambient regions in the Alagoas state were presented by the Hydrometeorological Directory DHM-SERHI/AL for these meteorological events.

3. RESULTS

Some events of extremely intensive stratus were observed on the Northern coast of Brazil during June 7 to 10, 2003 and

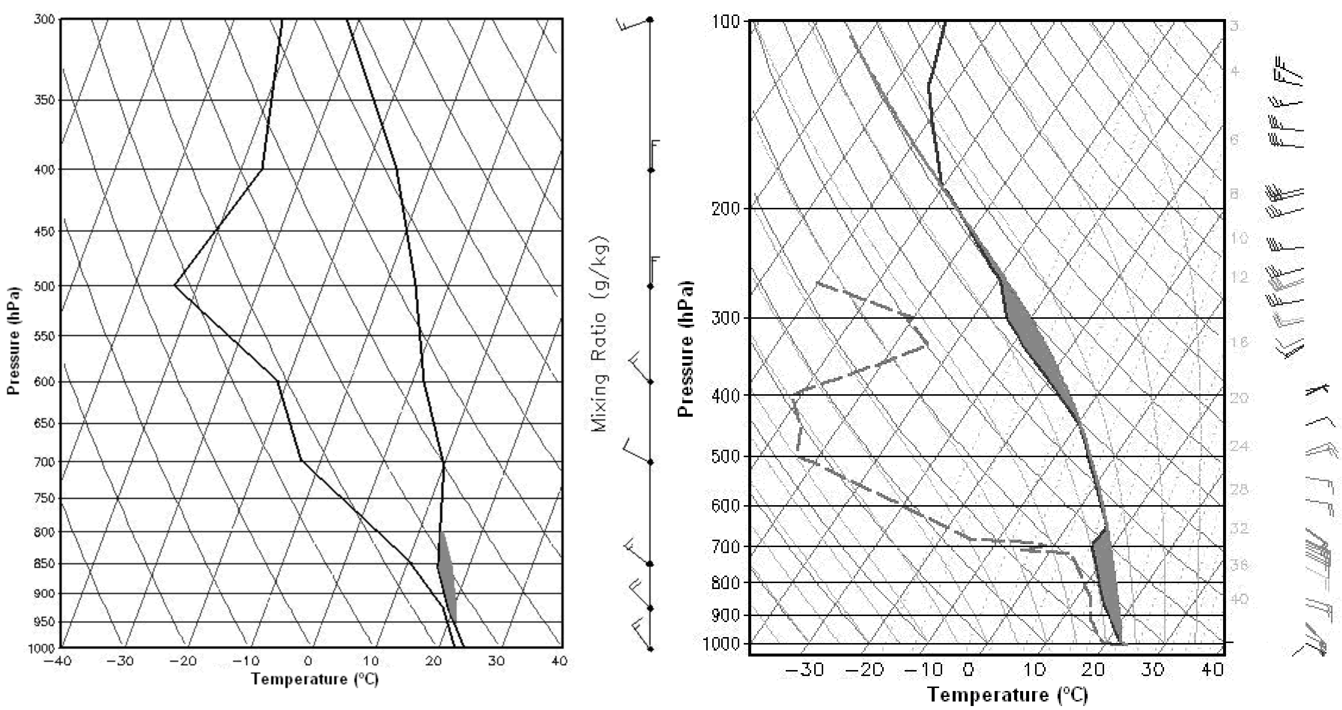


Figure 2 - Temperature and humidity vertical profiles by NCEP reanalysis for Maceio 1200 UTC 7 June 2003 (a) and by radiosonde in Salvador, 1200 UTC 8 June 2003 (b). *Dark regions present a positive CAPE.*

during July 3 to 5, 2003. All meteorological data analysis has shown that the synoptic processes of stratus formation were identical for both cases. Therefore, a discussion of these processes will be presented with the longest period examples.

3.1 Wave disturbance in the trade winds

The Wave Disturbance in the field of Trade Winds (WDTW) was the unique synoptic scale system associated with extremely intensive stratus (adverse phenomenon) in both events. This WDTW was observed in NCEP reanalysis data and in high resolution ETA model (Figures 3 and 4). The WDTW was formed by trade winds, associated with subtropical High on southeast of Atlantic Ocean (Figure 3). The streamline maps near the surface, elaborated by high resolution ETA model, registered this WDTW during four or five synoptic hours per day. Generally, the cyclonic curvature of the streamlines was observed at 0300, 0600, 0900, 1200 UTC (Figure 4a) and the streamlines at 1500 or 1800 UTC had a very weak curvature (Figure 4b). The stratus clouds were observed at 6 and 7 hours (local time or 9 and 10 UTC) by airport observation. It means that stratus clouds were associated with more intensive WDTW. This WDTW was identified only at the low levels. The stream line at 925hPa has also shown this wave, although a cyclonic curvature was weaker.

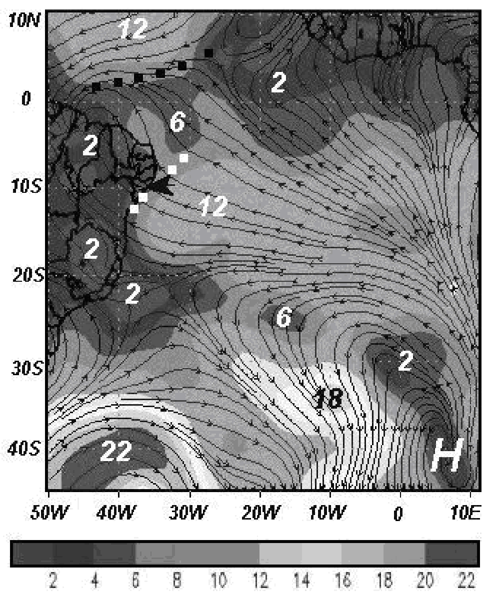


Figure 3 - Streamlines and wind speed (m s^{-1}, numbers are the maximal wind velocity in nucleus) at the 1000 hPa, by NCEP reanalyse, 1200 UTC 8 June 2003. Some symbols show the positions of ITCZ (black dot line), of WDTW trough axis (white dots line), of Maceio city (the black pointer), of High centre (H).

The vertical section of the relative humidity along 10°S has confirmed the existence of WDTW with high humidity (90-100%) at low levels (approximately up to 900 hPa) between 26 and 39°W with nucleus (100%) over the North Coast of Brazil (36°W) (Figure 5a). The very dry air (relative humidity less than 40%) was observed in the middle and high levels, above the WDTW. The horizontal distribution of high humidity has also shown the concentration of high humidity associated with the WDTW near the Alagoas state (Figure 5b).

3.2 Upper troposphere structure

The anticyclonic circulation of the air current from the West or Northwest was observed at the level 200hPa and down to 500hPa by NCEP reanalysis and ETA model for all days. The only difference was registered in 9 June: a cyclonic curvature of

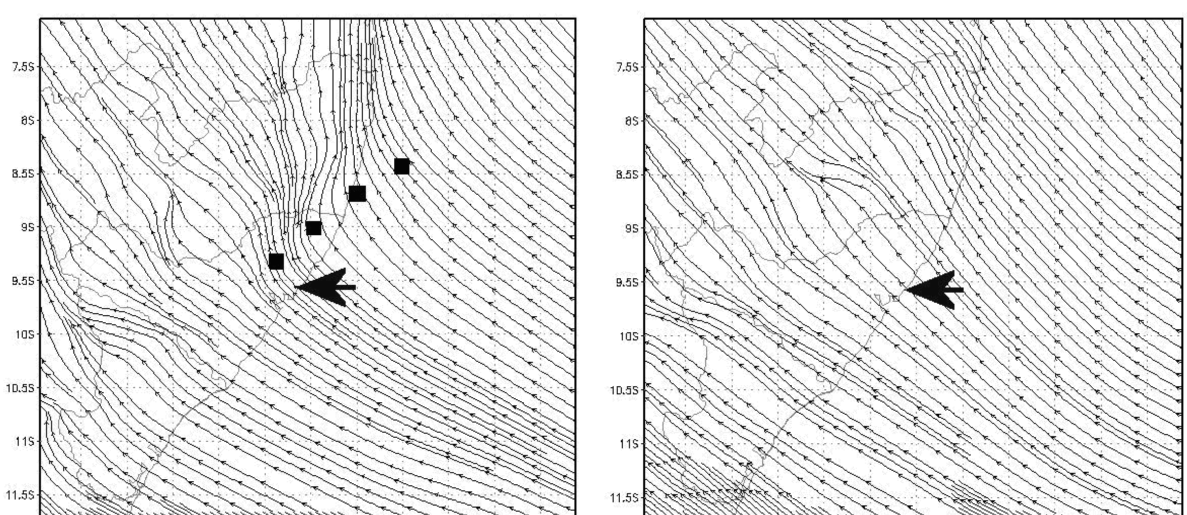
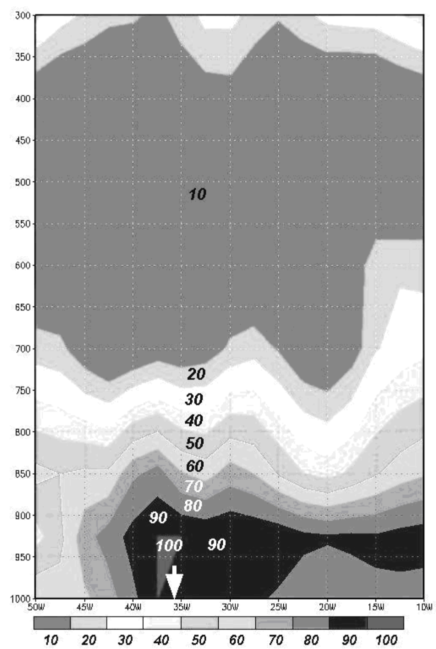
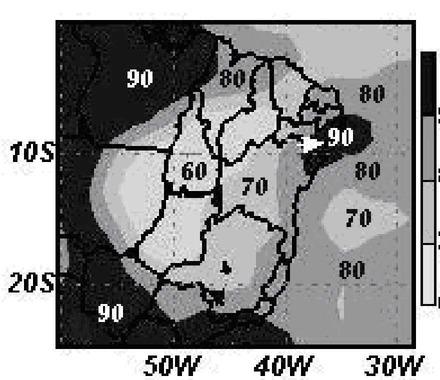


Figure 4 - Streamlines by high resolution ETA at the 1000hPa, 8 June 2003: 1200 UTC (a) and 1800 UTC (b). Black dots line (a) shows the trough axis position. Black pointer presents the Maceio city localization.

the air current was identified at 0900 UTC. The anticyclonic air current at the high level was formed between two subtropical jet streams of northern and southern hemispheres. Besides, a divergent air current of the ITCZ and the anticyclone near the west cost of Africa (approximately 12^{o}N) were responsible for the anticyclonic air current formation above NE region. The change in the air current curvature in 9 June was associated with the wave dislocation at the north periphery of the southern hemisphere's jet stream. The anticyclonic circulation was formed by a very dry air in the middle and high levels above the WDTW (Figure 6) and it was responsible for descendent air current at the high and middle levels. The details of this circulation are discussed in the following section (3.3).



(a)



(b)

Figure 5 - Vertical section of the relative humidity (%) along 10^{o}S, 1200 UTC 8 June 2003 (a) and relative humidity at the 1000hPa, 1200 UTC 9 June 2003 (b). White pointer shows the Maceio city localization.

3.3 The structure of air current and vertical motion

The WDTW was localized between two nuclei with higher wind velocity at the low levels (Figure 7). The speed reached 16ms^{-1} in the west nucleus and 12ms^{-1} in the east one (Figure 7a). The other two nuclei (with wind velocity up to 12ms^{-1}) were localized to north and to south from WDTW (Figure 7b). All nuclei were localized at low levels (up to 800hPa) and the St-clouds were formed between the two of these nuclei in the calmest region. The strong air current was localized at the upper levels (200hPa), above the WDTW and to the south from it. This current is the equatorial side of the southern hemisphere subtropical jet stream that was responsible for anticyclonic current formation (as mentioned above in 3.2.). The anticyclonic current has formed the descendent movement that was detected in all levels above this WDTW (Figure 8). These descendent movements promote the accumulation of air humidity at the lower levels of WDTW region and consequently contribute with St cloud formation.

The weak ascendant movement up to 900hPa accompanied the WDTW during all St cloud days (Figure 9). The nucleus of this ascendant movement was observed between 34^{o}W and 38^{o}W at low levels (up to 900hPa) on June 7th (Figure 9a). At the next day this nucleus was detected at higher levels (up to 860hPa) and

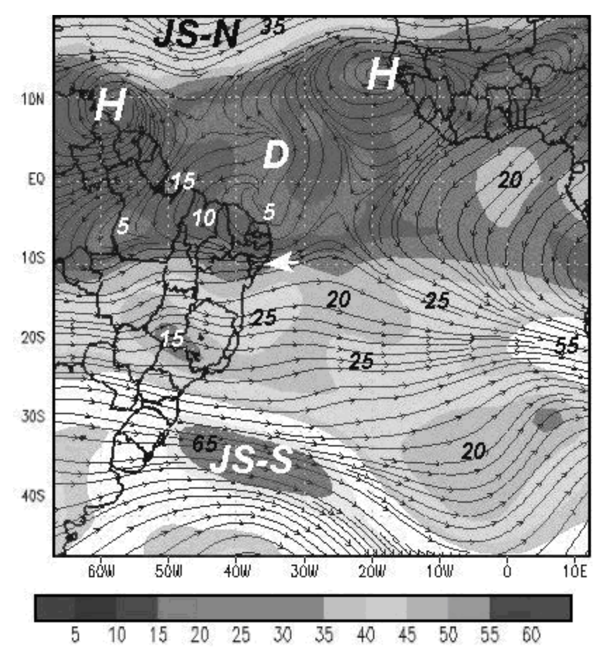


Figure 6 - Streamlines and wind velocity (m s^{-1}, numbers are the maximal wind velocity in nucleus) by NCEP reanalysis at the 200 hPa, 1200 UTC 8 June 2003. Symbols show the next positions: of High centres (H); of jet streams of Northern and Southern Hemispheres (JS-N) and (JS-S), respectively; of air current divergence (D); of Maceio city (white pointer).

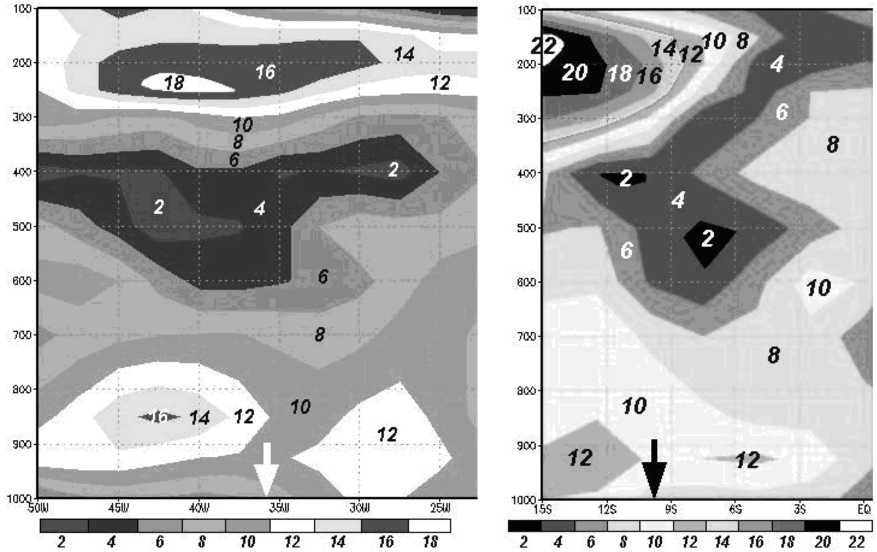


Figure 7 - Vertical section of the wind velocity (m s^{-1}, numbers are the maximal wind velocity) by NCEP reanalysis along 10°S (a) and along 35°W (b), 1200 UTC 9 June 2003. White and black pointers show the Maceio city localization.

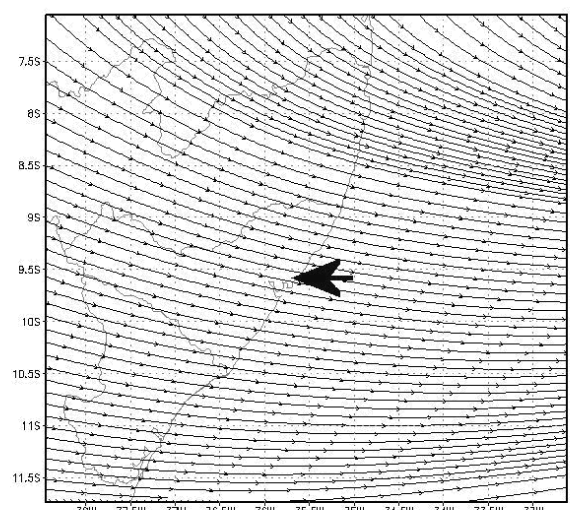


Figure 8 - Streamlines by high resolution ETA at the 200hPa, 1200 UTC 8 June 2003. Black pointer shows the Maceio city localization.

had extended itself to the east (to 15°W) (Figure 9b). During the following two days (9 and 10 June) a very weak and superficial ascendant movement was observed between 35 and 40°W near the Maceio city up to 900hPa and up to middle levels (550hPa) to the east from the city (Figure 9c). These weak ascendant movements assist in humidification of the air at low levels and St-clouds formation. The St cloud were formed directly in the nuclei of the weak ascendant movement.

3.4 Vertical sounding analysis

The vertical profiles of temperature and humidity for all days, constructed by NCEP reanalysis for Maceio (Figure 2a) and by radiosonde for Recife and Salvador stations (Figure 2b), were very similar: humid layer up to 700hPa in Salvador and 850hPa in Recife and Maceio; subsidence inversion and very dry layer were localized higher; conditionally unstable layers and a positive convective available potential energy (CAPE) were identified at low levels in Recife and Maceio (an average CAPE was, approximately, 350J/kg) and at low and middle levels in Salvador (an average CAPE was, approximately, 800J/kg). The formation of subsidence inversion, as discussed above in 3.2, was associated with anticyclonic air current at high and middle levels. The weak ascendant movement in WDTW at the low levels (mentioned in 3.3) promoted this humid level formation. The St cloud were developed at the humid low level under the weak subsidence inversion.

3.5 Precipitation

Weak precipitation that took place during the two extremely intensive stratus events was mostly associated with St cloud. Examples of precipitation observational data are presented for the first event in view of the fact that it was longer (Table 1). Weak precipitation was also forecasted by the high resolution ETA model (e.g. maps on Figure 10). However, the spatial distribution of the modeled precipitation differed from the observational ones.

The ETA forecast for 7 June predicted the precipitation at the centre (Agreste up to 1.4mm/3h and up to 3.7mm accumulated during 24h) and west regions (Sertao up to 2.0mm/3h and up to 3.0mm/24h) of Alagoas state (Figure 10). More intense precipitation were forecasted for the central region (Sertao do Sao Francisco up to 2mm/3h and up to 6mm/24h), though the observed precipitation were at the central (Agreste, average 8.5mm/24h, table 5) and east regions (Litoral, average 8.0mm/24h). The precipitation smaller than 10mm/24h were observed almost over all Alagoas state (Table 1) and the more intense ones (near 20mm/24h) were registered at the coastal region (Litoral). Model forecast for Agreste and Sertao regions were satisfactory but failed for Litoral and Zona da Mata regions.

The differences between forecasted and observed precipitation were obtained for 8 June as well. No precipitation was registered for Sertao region (west of Alagoas state, Table 1) however forecasted up to 2.6mm/24h for the north and east parts of the region. The observed precipitation for the eastern costal regions were more intense (average of 6.2, 6.6 and 4.0

Table 1 - Precipitation (mm/24h) on ambient regions of Alagoas State for St cloud days for northern coast of Brazil on 7, 8, 9 and 10 June.

Stations	**Days**				**Stations**	**Days**			
	7	**8**	**9**	**10**		**7**	**8**	**9**	**10**
LITORAL					**ZONA DA MATA**				
1. Marechal Deodoro	2,5	5,0	3,6	8,6	1. Colonia Leop.	2,0	1,7	15,7	10,5
2. Rio Largo	0,0	0,0	5,4	7,8	2. Mar Vermelho	16,1	9,0	0,0	0,0
3. Maceio	4,6	8,0	8,5	8,3	3. Santana do mandau	6,5	7,2	4,5	8,5
4.Caete	5,9	7,9	10,7	3,3	4. Camar-Sede	0,0	9,0	18,0	13,0
5. Coruripe	2,4	3,8	5,4	3,8	5. Capricho - Cajueiro	8,0	4,6	2,8	4,4
6. Guaxuma (Coruripe)	9,0	7,5	16,0	3,0	6. Laginha	2,6	7,9	8,7	6,3
7. Rocadinho	14,0	2,0	12,0	9,0	7. Peixe - Flexeiras	0,0	10,0	12,0	10,0
8. Santo Antonio	3,5	17,5	21,0	10,0	8. Porto Rico	1,0	4,4	6,3	2,2
9. Seresta - St. Cecilia	20,0	6,0	5,0	5,0	9. Serra Grande	1,2	0,2	14,6	7,0
10. Sumauma	21,6	1,8	17,6	4,4	10. Serrana	12,0	8,0	13,0	8,0
11. Terra Nova (Pilar)	6,0	12,0	8,0	5,0	11. Triunfo	0,4	6,6	10,4	3,4
12. Leao (Rio Largo)	7,0	8,0	5,0	8,0	12. Uruba (Atalaia)	9,9	6,3	8,6	6,7
Average	**8,0**	**6,6**	**9,9**	**6.4**	**Average**	**5,0**	**6,2**	**9,6**	**6,7**
SERTAO DO SAO FRANCISCO					**BAIXO DO SAO FRANCISCO**				
1. Batalha	0,0	0,0	3,4	4,0	1. Des. Marituba				
2. Delmiro Gouveia	2,1	0,0	0,0	0,0	2. Penedo	1,8	2,2	4,4	14,4
3. Pao de Acucar	0,3	0,0	0,0	2,3	3. Igraja Nova	9,2	1,8	9,0	8,2
4. Piranhas	0,0	0,0	0,0	3,0	4. Piaçabuçu	5,9	11,2	2,6	5,0
5. Traipu	2,6	0,0	0,4	3,8	**Average**	**4,7**	**4,0**	**6,4**	**8,7**
Average	**1,0**	**0,0**	**0,8**	**2,6**					
SERTAO					**AGRESTE**				
1. Cacimbinhas (Sede)	9,3	0,0	3,2	7,2	1. Lagoa da Canoa	2,4	0,2	6,1	2,2
2. Major Isidoro	0,0	0,1	0,2	0,0	2. Limoeiro - Anadia	14,6	2,2	1,6	5,4
3. Santana do Ipanema	0,0	0,0	3,4	1,2	**Average**	**8,5**	**1,2**	**3,9**	**3,8**
4. Senador Palmeira	0,0	0,0	2,9	1,7					
Average	**2,3**	**0,0**	**2,4**	**2,5**					

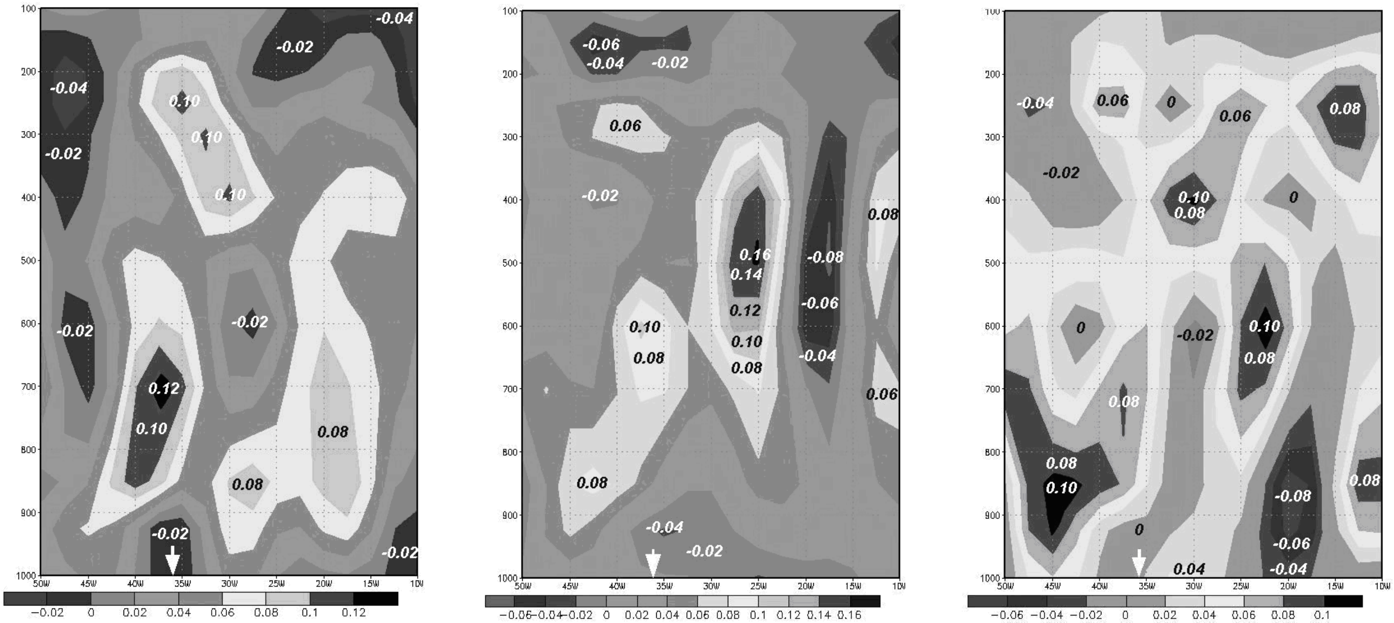


Figure 9 - Vertical section of omega (m s^{-1}, numbers are the maximal omega in nucleus) along 10ºS, 1200 UTC 7 June (a), 1200 UTC 8 June (b) and 1200 UTC 9 June 2003 (c). White pointer shows the Maceio city localization.

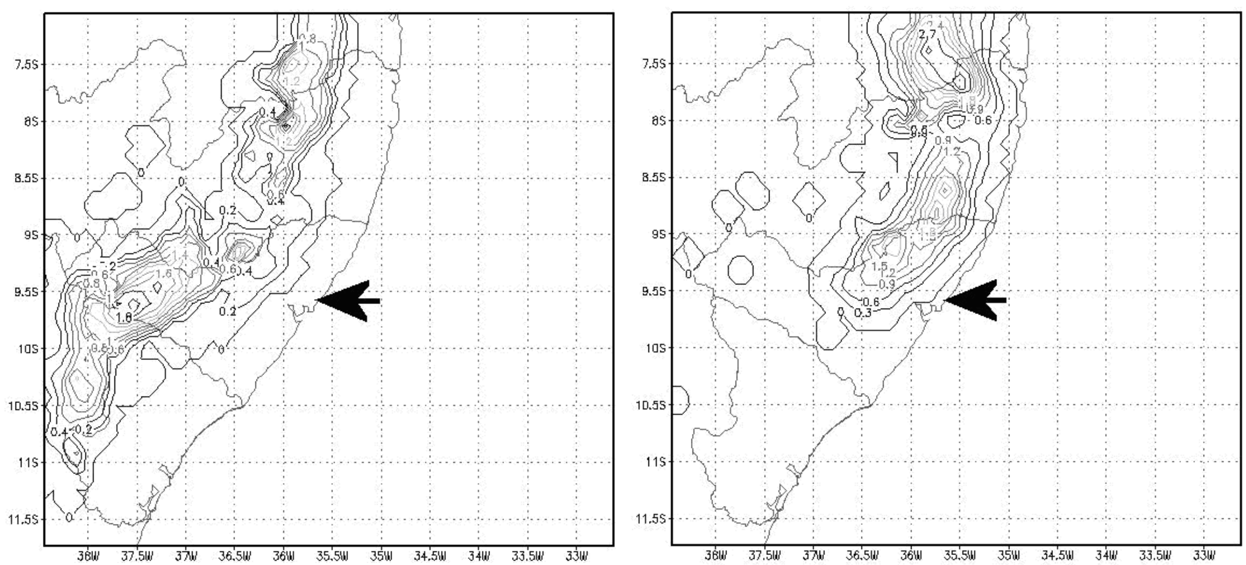


Figure 10 - Precipitation 24h forecast by the high resolution ETA model, 1200 UTC 7 (a) e 8 (b) June 2003, (mm/3h, values accumulated during 3 h 0900-1200 UTC with isoline intervals of 0.3mm/3h (a) e 0.2mm/3h (b)). Black pointers show the Maceio city localization.

mm/24h for Zona da Mata, Litoral and Baixo do Sao Francisco, respectively) than the forecasted ones (1.8mm/24h for Zona da Mata and without precipitation for other regions). Forecast for Agreste region was satisfactory (3.6mm/24h - forecasted and 1.2mm/24h - observed precipitation).

The differences between forecasted and observed precipitation on 9 and 10 June were similar to previous days. The forecasted values were higher than observed ones for east regions. For example, on 9 June there were 9.9mm/24h forecasted and 1.8mm/24h observed over Litoral region (Table 1) and 6.4mm/24h forecasted and without precipitation observed over Baixo do Sao Francisco region. More intense precipitation than observed ones were forecasted for Sertao (west region). The precipitation forecasts were satisfactory for Agreste, Zona da Mata and Sertao do Sao Francisco regions.

The test of precipitation spatial distribution was forecasted better on 8 June with the maximal precipitation for the north-east region. No precipitation was forecasted for the coastal region for all days.

4. CONCLUSIONS

On the northern coast, fog and stratus-clouds were associated with WDTW at low levels, which was localized at the southern periphery of the ITCZ and on the northwest periphery of the South Atlantic subtropical High.

The high resolution ETA model was tested for analysis of two uncommon St cloud events on the northern coast. A wave on the Trade Wind and weak ascendant movements at low levels (1000 and 925hPa) were identified. Anticyclonic curvature at high levels formed descendant movements and a subsidence inversion. Weak vertical movements at low levels joined with the stable layer between 850 and 700hPa created a very humid layer at the low levels, forming the stratus clouds.

The assessment of the ETA's model of forecasting precipitation for two events of rare stratus clouds for tropical regions shows satisfactory results for an average quantity of precipitation. Some weak precipitation forecasted by the ETA model with 24h antecedence for all days were similar to the observed precipitation. Nevertheless, the spatial distributions of forecasted and observed precipitation were different. No precipitation during all days was forecasted for the coastal region. At the same time, for the west region, the forecasted precipitation was more intensive than the observed ones.

5. ACKNOWLEDGEMENTS

The partial financial support was provided by FAPEAL (Research Support Foundation of the Alagoas State).

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