Mechanisms Influencing the Strong Rainfall Episodes on the Eastern *Nordeste* of Brazil

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ABSTRACT

We investigate the relationship between simultaneous occurrences of intense mesoscale convective systems (MCSs), distinctive atmospheric easterly waves (AEWs) signatures and large sea surface temperature (SST) anomalies over the tropical Atlantic, and subsequent strong rainfall episodes (> 10 mm/day) over the eastern Brazilian Nordeste. A diagnostic analysis is firstly performed. Eleven events are selected as representative of such relationship during the Nordeste rainfall season (January-June) in 2004 (5 events), 2005 (4 events) and 2006 (2 events). The selected AEWs are those with a lifespan greater than or equal to 3-day, and which initiate at east of 20°W, *i.e.* far from the Nordeste. In a second part of the analysis, a Regional Atmospheric Modelling System (RAMS) is forced by observed SST over the tropical Atlantic for twice episodes chosen among

the eleven selected events. It is found that atmospheric variables, such as equivalent potential temperature, latent heat flux, water vapour, vertical vorticity, and zonal wind, support the genesis of the strong rainfall episodes over the eastern Nordeste which are related to tropical Atlantic conditions which occur just before. That could help in the forecasting of such dramatic episodes.

INTRODUCTION

Many physical processes could affect the precipitation in the Nordeste as for instance the seasonal migration of the ITCZ, the northward incursion of cold fronts and atmospheric easterly waves (AEW). But a few study focus on the influence of the southern hemisphere AEWs on the Nordeste precipitation. Our goal is (i) to ascertain the action of these last phenomena and (ii) to see how there are sustained when crossing westward the south Atlantic basin and (iii) to show how the daily variation of SST affects rainfall through weather conditions. To approach this problem, we analyse the relationship between: precipitation in the eastern Nordeste region of Brazil (40°W-35°W; 2.5°S-12.5°S), the MCSs and the AEWs that cross the south Atlantic and reach the Nordeste and the SST conditions. Nordeste region used here is ranged between 40°W-35°W of longitude and 12.5°S-2.5°S of latitude

DATA

- in-situ daily precipitation over the Nordeste from an array of 682 meteorological stations in 2004-2006.
- Global Precipitation Climatology Project (GPCP) data set extracted on a 1°x1° regular grid for the period 1997-2006 above the full Nordeste.
- MCSs tracking and their physical characteristics are given by ForTraCC model which was developed at CPTEC/INPE.
- AEWs are depicted thanks to the relative vorticity computed from the wind field at 700 hPa. Data are from

NCEP-NCAR 1948-2006 reanalysis and are reported on a 2.5° x 2.5° grid.

- Daily SST fields from 2004 to 2006 are provided on a 0.25°x0.25°grid and given by the Institut Français de Recherche pour l'Exploitation de la Mer (Ifremer) on its website (www.ifremer.fr/).
- RAMS uses the diagrams of convection parameterization proposed by Kuo. We are especially interested by: (i) how the atmospheric conditions evolve/move according to the SST variability; and (ii) how this ocean-atmospheric coupling can influence strong rainfall episodes over Eastern Nordeste.

DIAGNOSTIC APPROACH

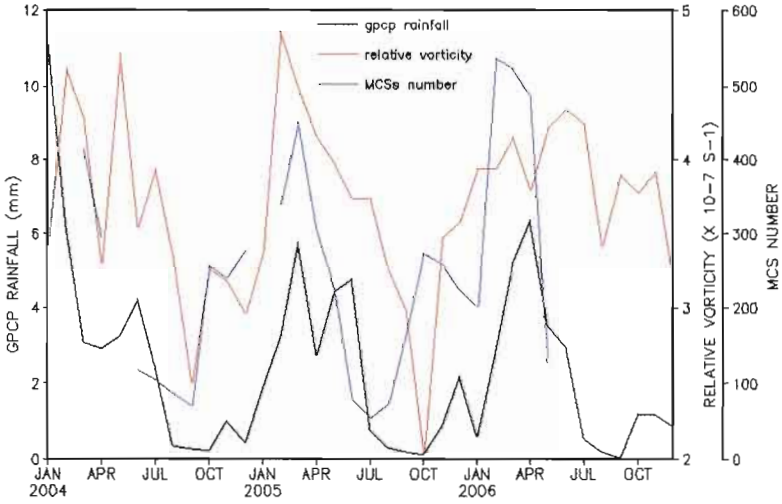

Figure 1 *– Monthly number of MCSs (lifespan > 2 hours), which move westward from 20°W up to the Nordeste and have a dissipation coordinate ranged between 12.5°S and 2.5°S during 2004-2006. Monthly rainfall of GPCP on the Nordeste monthly vorticity on the area 40°W-20°E, 12.5°S-2.5°S are also plotted.*

This figure shows a similar evolution between:
- MCSs which move westward inside the region 35°W-20°W; 2.5°S-12.5°S up to the *Nordeste*
- the horizontal vorticity over the domain 40°W-20°E; 2.5°S-12.5°S
- the precipitation in the *Nordeste*.

Eleven events are selected according to four criteria:
- Strong rainfall anomalies (> 10 mm)
- AEW reach at least the *Nordeste* (*i.e.* at 36°W) during the rainy day
- AEWs initiate at the east of 20°W
- AEWs lifespan> 3 days.
- AEW signatures are indicated by the longitudinal spread of the vorticity at 700 hPa.
- Others strong rainfall episodes may certainly be influenced by others physical processes

An example of the daily SST anomalies is calculated during the period 2004-2006 for two specific events: May 27-June 01 2004 and (right) Feb 09-Feb 15 2005 event.

For May 27-June 01 2004 :
- cooling intensifies until June 01
- warming structures are observed southward of 8°S, during May 27 and May 28, close to the African coast up to 20°W of longitude and disappear progressively
- warming (< 0.2°C) is located along the *Nordeste* coast

For Feb 09-Feb 15 2005, a general warming occurs in the whole southern basin with high values (> 0.6°C)

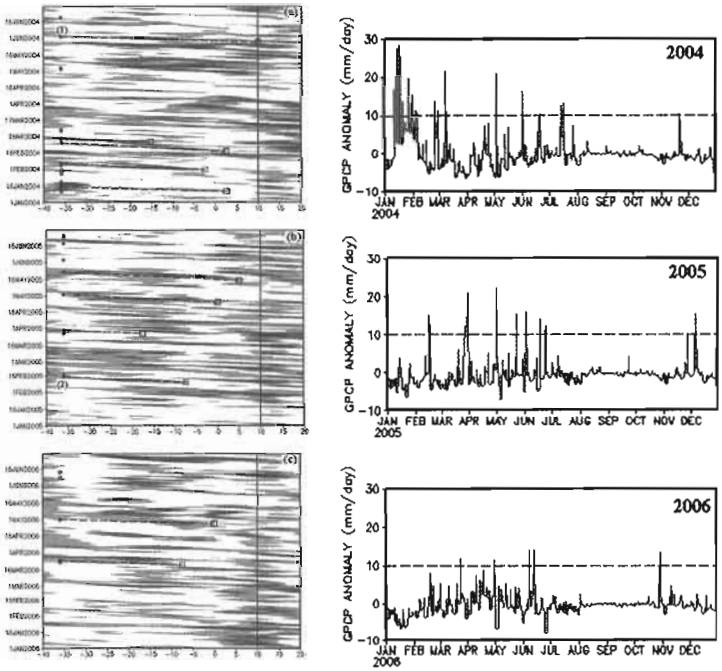

Figure 2 *– **(left)** The 700 hPa relative vorticity (x 10^{-5} S^{-1}) in January-June of (a) 2004, (b) 2005 and (b) 2006 along 40°W-20°E averaged between 12.5°S and 2.5°S. Positive anomalies great to 10 mm/day of the GPCP (dotted) are represented on the mean eastern longitude of the Nordeste. Initiation coordinates of selected events are mark as square. The initiation of the event and the rainy day are connected by a dashed line. The vertical line represents approximately the limit (~ 10°E) of the African continent. **(right)** Chronological series of the daily GPCP anomalies calculated over the eastern Nordeste region (40°W-35°W; 12.5°S-2.5°S) in 2004 (top), 2005 (middle) and 2006 (bottom). The horizontal dashed line represents the positive rainfall anomaly great to 10 mm/day*

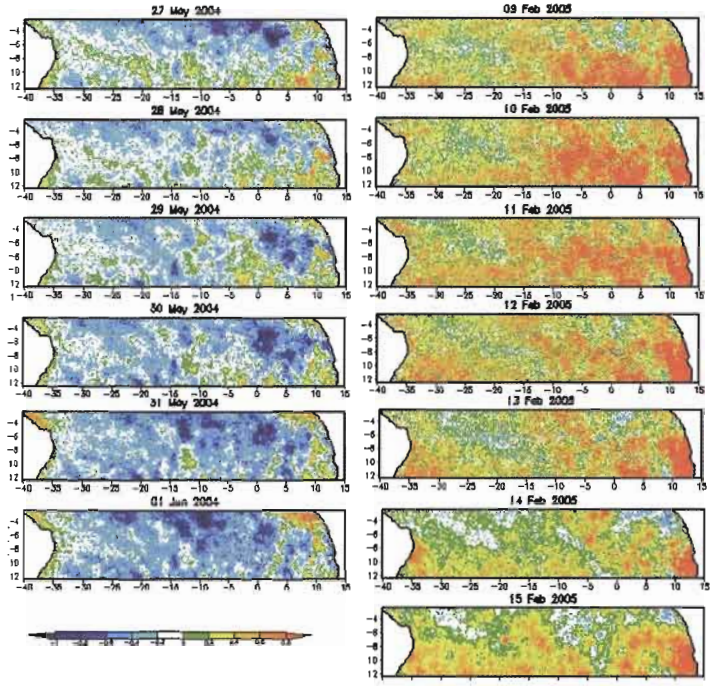

Figure 3 *– Daily evolution of the SST anomalies for the both events: (left) May 27-June 01 2004 and (right) Feb 09-Feb 15 2005 event.*

NUMERICAL APPROACH

Daily evolution of the latent heat differences obtained from the difference between every day and the initiation day of a studied event for the two specific cases: (left) May 28 -Jun 01 2004 and (right) Feb 10-Feb 15 2005.

- Daily decreasing in LH observed on the open ocean up to the *Nordeste* coast.
- It implies that latent heat help in moistening the atmosphere, to create an environment conducive to the formation of convective systems and then to increase atmospheric instability.
- Further, the lost of LH is found to be consistent with the progressive cooling of the ocean.

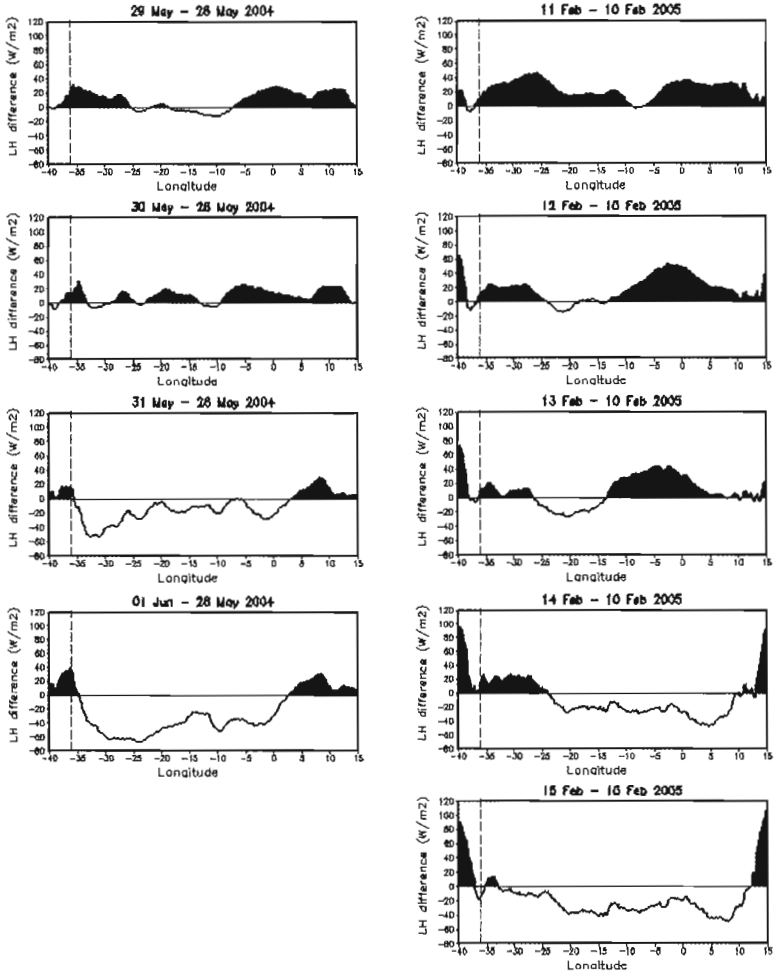

Figure 4 *– Daily evolution of the latent heat differences calculated over the 12.5°S-2.5°S latitudinal band along 40°W-15°E of longitude for the both events: (left) May 28 -Jun 01 2004 and (right) Feb 10-Feb 15 2005. Positive values are shaded. The vertical dashed line represents the mean longitude (~ 36°W) of the eastern Nordeste.*

Daily evolution of water vapour difference obtained from the difference between every day and the initiation day

of a studied event for the two specific cases: (left) May 28 -Jun 01 2004 and (right) Feb 10-Feb 15 2005.

A progressive rise is observed into the 800-600 hPa band centred at 700 hPa. The increase of water vapour could suggest its reinforcement during the westward spread of the AEW related to the strong rainfall episode.

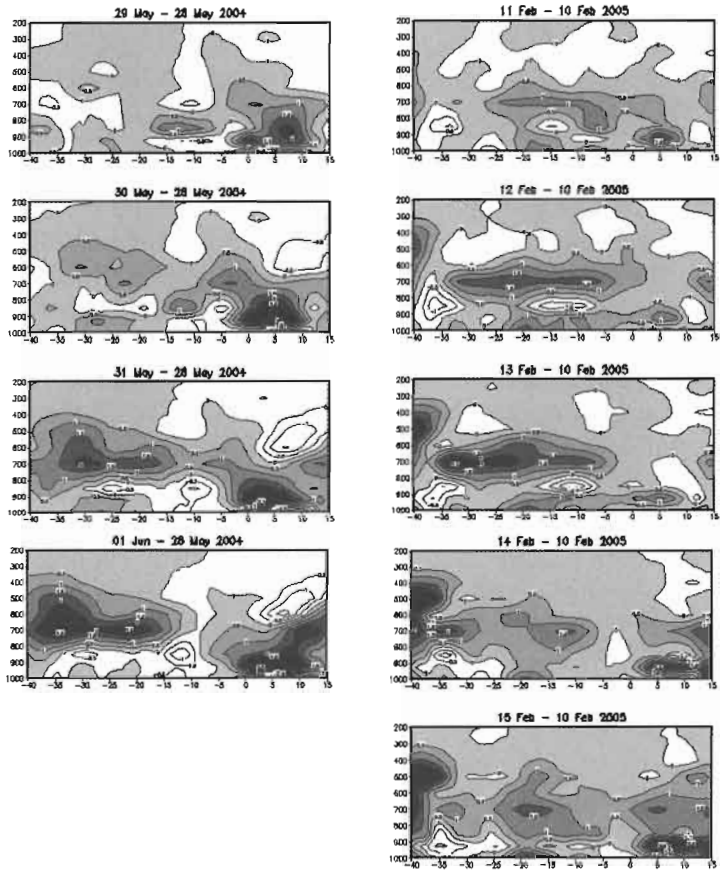

Figure 5 *– Hovmöller altitude-longitude Diagram of the daily evolution of water vapour difference calculated on the 12.5°S-2.5°S latitudinal band along 40°W-15°E of longitude for the both events: (left) May 28- June 01 2004 and (right) Feb 10-Feb 15 2005. Positive values are shaded.*

CONCLUSION

- The precipitation in the *Nordeste* is influenced mainly by the MCSs initiated inside the region 35°W-20°W; 2.5°S-12.5°S.
- A similar evolution between MCSs, horizontal vorticity and precipitation in the *Nordeste*.
- Many days experienced strong rainfall anomalies in 2004, 2005 and 2006, but only a few of them are related to AEWs.
- Latent heat could help in moistening the atmosphere, to create an environment conducive to the formation of convective systems and then to increase atmospheric instability
- SST plays an important role in the increasing of atmospheric convection and formation of the MCSs
- The sustaining of the westward propagation of the generated dynamical instability could be influenced by the convection over the ocean.
- vapour in the atmosphere is horizontally transported from the ocean up to the *Nordeste* by the wind and influences the precipitation

ACKNOWLEDGMENTS

This work is part of the CNPq-IRD scientific cooperation Project "Climate of the Tropical Atlantic and Impacts on the Northeast" (CATIN), No. CNPq Process 492690/2004-9.