Geophysical Fluid Dynamics Modeling for the Bahia Atmospheric Coastal Environment

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This paper was prepared for presentation during the 11th International Congress of the Brazilian Geophysical Society held in Salvador, Brazil, August 24-28, 2009.

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Abstract

A high resolution atmospheric geophysical fluid dynamic numerical model is used to simulate the environmental conditions for a particular case over the Bahia State coastal region. Temperature, winds and upward vertical motion are analyzed along with satellite image to improve the understanding of the sea breeze circulation near the Todos os Santos Bay. The results show that the model simulates well the local environmental conditions associated with the sea breeze circulation and cumulus cloud formation. These results show that RAMS model is able to represent well the large and local atmospheric circulation conditions for the coastal region of the Bahia State. These preliminary model simulations are part of the firsts steps to develop a coupled forecast system for the region that will include the atmosphere, the ocean, and the chemical and biological changes associated with the environmental conditions.

Introduction

The ocean-continent interfaces are very dynamic regions. In general, these are the most populated regions and consequently strongly explored. The coastal region of the northeast region of Brazil is characterized by strong sea and continental breezes caused by the differential heating between the land and the neighbor surface waters. Located in the tropical and sub-tropical latitudes these regions absorb large amounts of solar radiation enhancing the surface temperature differences and consequently producing strong local air circulations. In the eastern coast the nocturnal continental breezes interact with the easterly trade winds producing night time rainfall events (Molion and Bernardo, 2002). Furthermore, in these latitudes, frontal systems from the south bring strong winds, rainfall and environmental changes (Kousky, 1979). These local and remote atmospheric processes interact with the surrounding oceans producing a very complex environmental condition.

While satellite data and in situ measurements help on the environmental monitoring, the forecast conditions have to be produced by prognostic geophysical fluid dynamic numerical models. With the ongoing computing power improvements, larger amount of data measurements, and model physical improvements, these numerical models are becoming each day more important tools for the environmental prediction.

Method

The Regional Atmospheric Modeling System (RAMS) model was set up for the coastal area centered at the *Todos os Santos Bay* using a nesting approach to gain spatial resolution at the coast. This model solves the atmospheric geophysical prognostic equations using finite difference methods in space and time (Cotton et al., 2003). The model has been used in several environmental studies such as on the forecast of strong rainy events on the coast of the Amazon (Ramos da Silva et al., 2007), to simulate hydro-meteorological processes (Ramos da Silva and Avissar, 2006), and to study the impacts of land cover changes on the regional climate (Ramos da Silva et al., 2008; Tanajura and Einsiedler 2006).

Initially, the model was set up using four nested grid domains having spatial grid cells of 81, 27, 9 and 3km, respectively (Fig. 1). The model was run for 01 January 1999 in order to represent local summer time conditions. While the large grid domain captures the large scale atmospheric processes, the inner high resolution grid simulates the local processes, such as the sea breeze circulations. The initial and boundary atmospheric conditions for temperature, relative humidity, atmospheric pressure and winds were taken from the NCEP reanalysis data (Kalnay, 1996). A nudging approach was imposed on the boundaries of the coarser (larger) grid domain. In the vertical direction, a grid stretching strategy was adopted having a total of 35 levels with high resolution near the surface to better resolve the boundary layer processes, and with coarser grid spacing in the higher levels. At the ground, a total of 08 levels were used up to 1.2 meters depth to represent the soil moisture and heat transfers. Heterogeneous surface boundary conditions were set in order to fully represent the topography, vegetation cover, and soil texture, according with the biogeographical maps. Thus, surface heat and moisture flux exchange with the atmosphere were represented according with the surface characteristics. For instance, each vegetation type is able to control sensible and latent heat fluxes based on the stomatal conductance that is controlled by the environmental conditions such as air temperature, soil and atmospheric moisture, and surface radiation balance. Finally, a 5-grid approach was adopted in order to have a very high resolution (1 km) at the *Todos os Santos Bay* to represent with greater details the local environmental circulations.

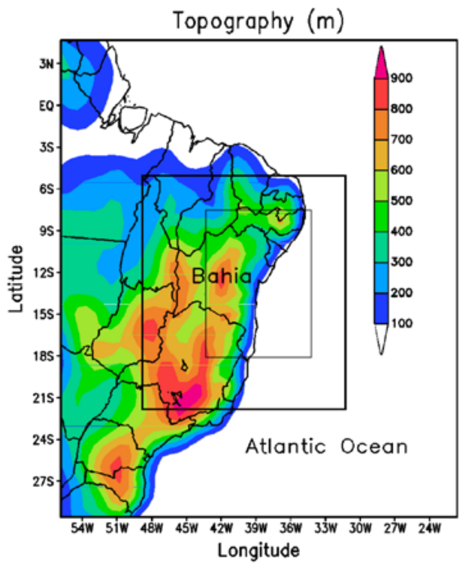

Figure 1 : RAMS model domains and topography. Only the 3 coarser grid domains are shown. Two other innermost higher resolution grids are set up at the center.

Results

Figure 2 shows the RAMS model results for the near surface air temperature and wind flow. The results show local northeasterly winds that are the predominant flow for this time of the year. Furthermore, a higher temperature near the coast sets strong sea-land temperature gradients that produce the local sea-breeze circulation.

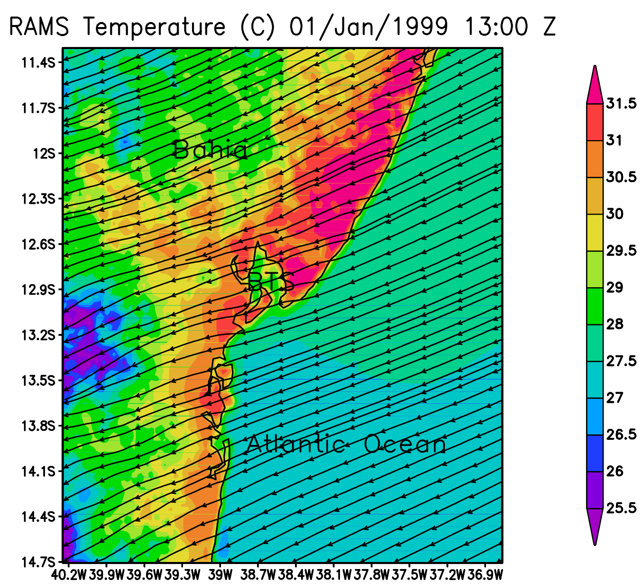

Figure 2 : RAMS model near surface temperature (^{o}C) and wind currents for 01 January 1999 at 10:00 Local time. BTS represents the *Todos os Santos Bay* location.

As a consequence of this land-sea gradient, local upward motion is formed producing local convection, mostly over the warmer land surfaces. In contrast, over the near marine surfaces subsiding motions occur inhibiting local convection and cloud formation (Figure 3).

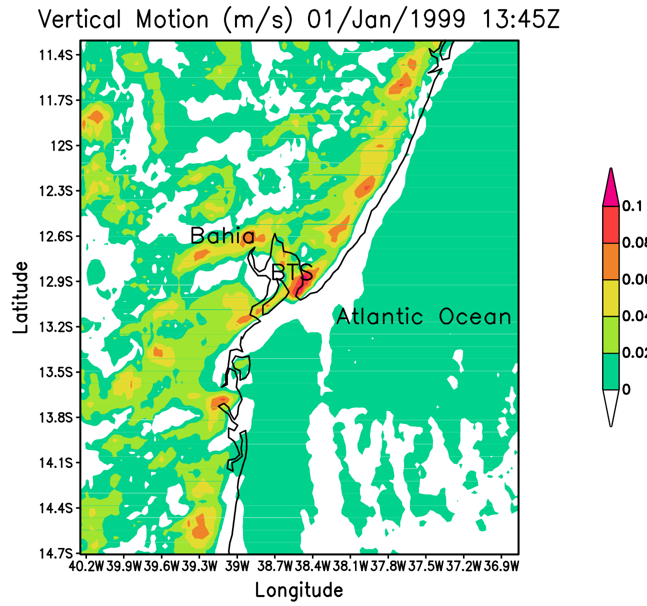

Figure 3 : RAMS model upward vertical motion (m/s) for 01 January 1999 at 10:45 (Local Time) at 720 meters height for the fourth grid having 3km of grid spacing. BTS represents the *Todos os Santos Bay* location.

Figure 4 shows a MODIS sensor satellite image for 01 January 2009 to illustrate the local sky conditions. The image shows that indeed there is clear sky over the ocean near the coastline as a consequence of subsidence and in the interior over land there is cumulus cloud formation. These results are in good agreement with the model results for the vertical motion shown in the Figure 3.

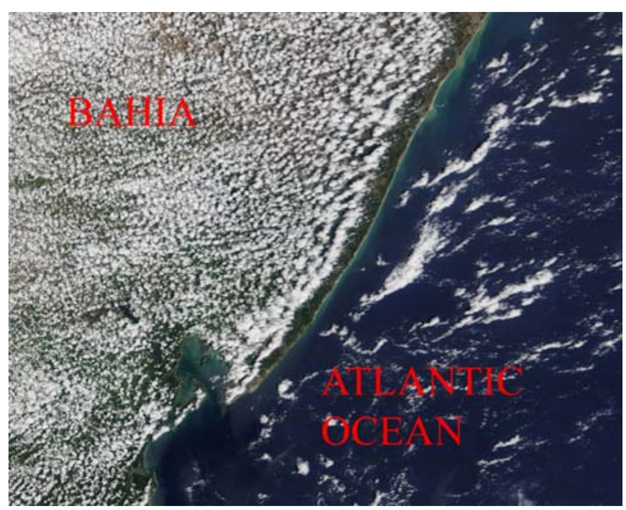

Figure 4 – MODIS sensor satellite image for 01 January 2009 at 10:15 LT. (Source: NASA).

Figure 5 show model results for near surface air temperature and wind flow from the innermost grid set at the *Todos os Santos Bay*. The results show that as the land surface heats, warm air advection is produced transporting warm air along the wind and over the *Todos os Santos Bay*. Near the coast, the wind turns towards land as a result of the sea breeze enhancement.

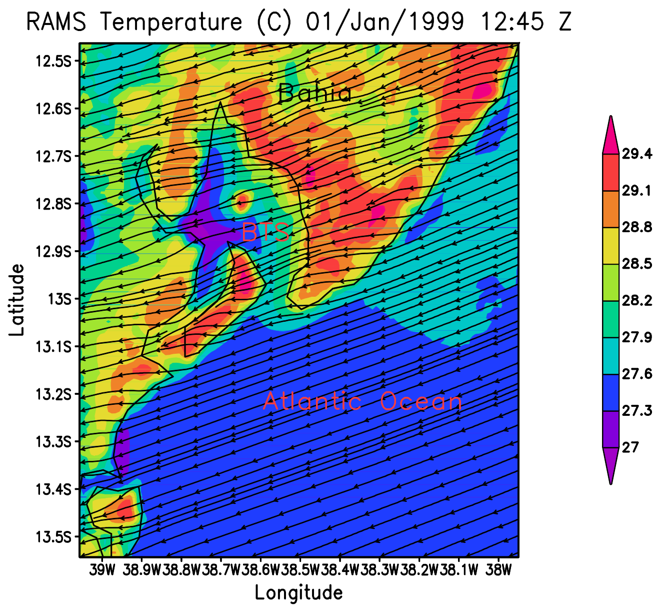

Figure 4 : RAMS model near surface air temperature and wind flow for 01 January 1999 at 9:45 LT.

Conclusions

The nesting approach used with the RAMS modeling system shows that the model is able to represent the observed atmospheric environmental conditions produced by the interaction of the local sea breeze circulations with the large-scale flow. This case study was conducted for a particular day of January to represent a summer condition day. To represent well the environmental conditions for the region, other case studies should be conducted and the results evaluated with in situ measurements. Furthermore, a coupled system should be designed to include the oceanic and other environmental characteristics such as chemical and biological interactions. This final system should provide an important tool for the monitoring and forecasting the environmental conditions for this coastal region.

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