THE COINFLUENCE OF THE SEA BREEZE AND THE COASTAL UPWELLING AT CABO FRIO: A NUMERICAL INVESTIGATION USING COUPLED MODELS

Flávia Noronha Dutra Ribeiro[1], Jacyra Soares[2], Amauri Pereira de Oliveira[3].
IAG-USP, Rua do Matão, 1226, São Paulo, SP, tel.: 3091-2851, fax: 3091-4714
[1]fndutra@model.iag.usp. br; [2] jacyra@usp.br; [3] apdolive@usp.br

INTRODUCTION

The southeast coast of Brazil (21° to 27°S, 40° to 47°W) very often presents the phenomenon of coastal upwelling due mainly to the presence of a large scale high pressure center over the South Atlantic Ocean. This center generates northeasterly surface winds over the coast, which are favorable to the development of the coastal upwelling, since it causes Ekman transport of the surface water away from the coast, allowing deeper and colder water to surface. Coastal upwelling is a very important phenomenon at Cabo Frio because it brings nutrient rich water to the coast and improves the fishery activities. The colder sea surface temperature (SST) also has an impact on atmospheric processes and weather conditions, but only a few works have investigated this interaction at this area. Franchito *et. al* (1998) used an atmospheric model forced by oceanic data and a oceanic model forced by atmospheric data and suggested that there is a positive feedback between the coastal upwelling and the sea breeze at Cabo Frio, due to the sudden change of the orientation of the coastline. Oda (1997) also suggested this feedback. The objective of this work is to investigate, using coupled models, the interaction between the ocean and the atmosphere during a coastal upwelling event and verify if there is a positive feedback between the sea breeze and the coastal upwelling at Cabo Frio.

METHODOLOGY

Oceanic numerical model: The model is based on the one described by Carbonel (2003). It has a lower layer with constant temperature and no pressure gradients and an upper layer where the governing equations are the vertically-integrated non-linear equations of momentum, continuity and transport of SST.

The boundaries are of two types: land and ocean. At land type boundary, the velocity and transport components normal to the boundary are set to zero and h and T are assumed homogeneous. At ocean type boundary, the weakly-reflective boundary condition described by Verboom and Slob (1984) is used.

Atmospheric numerical model: The non-hydrostatic version of the TVM model, developed by Thunis (1995), is three-dimensional, follows the Boussinesq approximations of the vorticity equations, obtained from the basic Reynolds-averaged equations, of motion and uses sigma coordinates.

Coupling between the oceanic and atmospheric model: The oceanic model was developed in the form of a subroutine and set to use the same horizontal grid spacing as the TVM-NH model. When the atmospheric model starts, it calls the oceanic model subroutine that returns a 2 days integration SST field. Then the SST field is used by the TVM-NH model to determine the surface heat flux over the ocean. The SST field remains the same for 20 time steps of the TVM-NH, and then the oceanic model is called again. The TVM-NH model forces the oceanic model with the wind stress and the surface soil heat flux.

EXPERIMENTS

Two sets of experiments were performed. The first set is used to study the influence of the coastal upwelling on the sea breeze, and is formed by two experiments: one (EXP1) with the initial SST field representative of the upwelling case; and the other (EXP2) with an initial homogeneous SST field of 26°C. The second set of experiments investigates the influence of the sea breeze on the coastal upwelling and it is also formed by two experiments: the first one (EXP3) uses the coupled model with an initial SST field representative of upwelling; the second (EXP4) uses just the ocean model forced by constant winds. To determine if the coastal upwelling enhances the sea breeze, the components of the wind field of the experiments correspondent to the upwelling (EXP1) and non-upwelling (EXP2) cases are compared. To investigate if the sea breeze enhances the coastal upwelling, the SST fields generated by the coupled experiment (EXP3) and by the constant wind experiment (EXP4) are compared. At last, by using coupled atmospheric and oceanic models, it was possible to verify if there is a positive feedback between the sea breeze and the coastal upwelling at Cabo Frio.

REFERENCES

Carbonel, C. A. A. H. Modelling of upwelling-downwelling cycles caused by variable wind in a very sensitive coastal system. Continental Shelf Research, 23, 1559-1578, 2003.

Franchito, S. H.; Rao, V. B.; Stech, J. L. et al. The effect of coastal upwelling on the sea-breeze circulation at Cabo Frio, Brazil: a numerical experiment. Ann. Geophysicae, 16, 866-881, 1998.

Oda, T. O. Influencia da ressurgência costeira sobre a circulação local em Cabo Frio (RJ). São Paulo, 1997. 140p. Dissertação (Mestrado) – Programa de Pós-Graduação em Meteorologia, INPE.

Thunis, P. Formulation and Evaluation of a Nonhydrostatic Vorticity Mesoscale Model. Belgium, 1995. 151p. Thesis (Ph.D) - Institut dAstronomie et de Géophysique G. Lamaître, Université Catholique de Louvain, Louvain-la-Neuve.

Verboom, G. K.; Slob, A. Weakly reflective boundary conditions for two-dimensional shallow water flow problems. Delft Laboratory. Publication n° 322, 1984.