DEVELOPMENT OF A SIMPLE MODEL FOR TEMPERATURE INVERSION BREAKUP IN A MOUNTAINOUS URBAN VALLEY

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Abstract

A simple model of temperature inversion breakup in mountain valleys is developed. This model is an extension of the conceptual model of D. Whiteman (1981), and its main features are: (1) The topography is represented by a digital elevation model, thus leading to a spatially-distributed model. (2) A simplified, yet realistic, representation of the surface energy balance for each atmospheric column is explicitly introduced. (3) The spatial variation of solar radiation, as a result of the journey of the sun over the Valley, is considered.
Preliminary results show the evolution of the convective boundary layer and the top of the inversion layer. Overall, these results are in good agreement with measurements, and the model performance appears to be reasonably good, since it represents expected physical behaviors of the involved phenomena, and captures sentitivities to physical parameters.

1. Introduction

The atmospheric temperature inversion exerts strong effects on the environmental conditions of deep valleys, due to its influence on processes like the vertical transport of pollutants released to the low atmosphere from the surface. In order to advance in the study of this phenomenon, a model of breakup of temperature inversion in a complex terrain is developed, and it is implemented in the Aburrá Valley. The Aburrá Valley is a highly urbanized mountainous valley located in the tropical Andes of Colombia, in Northwest South America.

2. Model description

In essence, the model is an energy balance model applied to the atmosphere above the valley, which is partitioned into atmospheric columns from the surface up to the top of inversion layer. For each column, the breakup of the temperature inversion is modelled according to the equations of D. Whiteman (1981). A modified form of these equations is introduced in the model,

$$\frac{dh}{dt} = -\frac{(1-k)\beta_o R_n}{C_p \gamma h}, \qquad (1)$$

$$\frac{dH}{dt} = \frac{k\beta_o R_n}{\rho C_p \gamma H}, \qquad (2)$$

where h and H represent the height of the top of inversion layer (TIL) and the convective boundary layer (CBL), respectively. These equations represent: (i) the descent of the TIL due to removal of mass (air) from the low atmosphere, and (ii) the ascent of the convective boundary layer (CBL) driven by the sensible heat flux caused by the radiative heating of the surface. k takes values between 0 and 1 depending on wheter the breakup is entirely caused by the desent of the TIL ($k = 0$), entirely caused by the ascent of the CBL ($k = 1$), or caused by a combination of both processes ($0 < k < 1$). β_o is the Bowen ratio, R_n is the net radiation on the surface, γ is the lapse rate, C_p is the isobaric specific heat, and ρ is air density.
Also, the model includes representations of three factors importantly affecting the energy balance. The first one is a representation of radiative properties of the surface through grid maps. The second one is a function which simply represents the spatial and temporal variability of Solar radiation in the Valley throughout the day. The third one is a simple parameterization of cloudiness and the greenhouse effect, which is included in the energy balance formulation. A simple scheme of the model is shown in Figure 1.

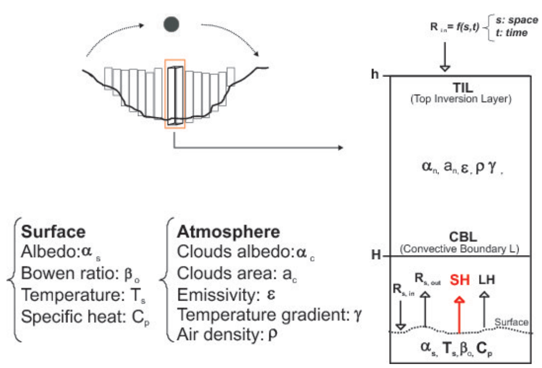

Figure 1: A simple scheme of the model.

2.1. Model experiments

Two model experiments were performed. In the first one, the model was applied to simulate the inversion breakup in a single column. The results were compared with vertical atmospheric soundings obtained by using tethered and captive balloons. One of the results obtained is shown in Figure 2.

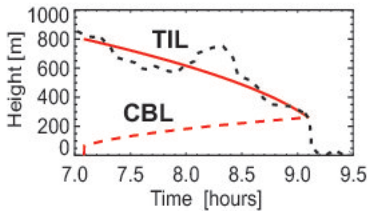

Figure 2: Performance of the model for breakup of temperature inversion. Red lines: evolution of TIL (continuous line) and CBL (dashed line). Dotted black line: TIL from measurements.

In the second experiment the model was applied to simulate the inversion breakup throughout the Valley. The sensitivity of the model results to several input parameters was tested aiming to discover physical sensitivities of interest. Some results from this experiment are shown in Figure 3.

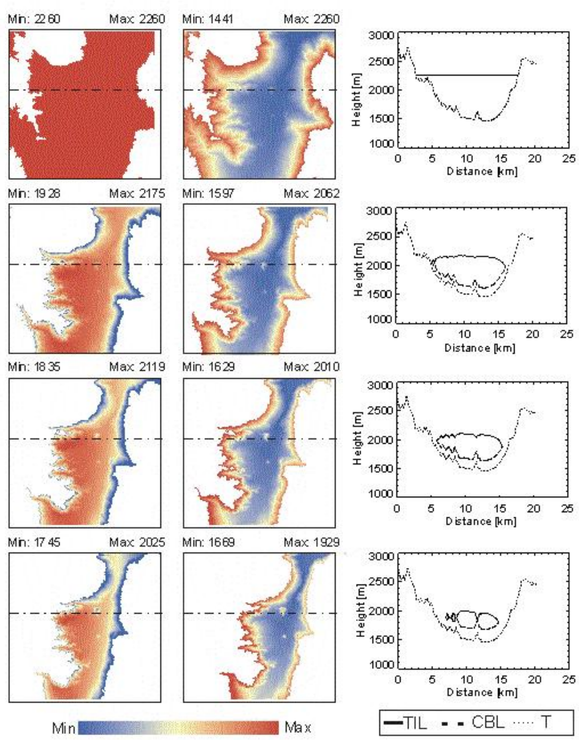

Figure 3: Simulations of the process of breakup of temperature inversion in The Aburrá Valley. Evolution of TIL (left) and CBL (center). The right column shows a cross section including both TIL and CBL.

Results from both experiments show the evolution of the convective boundary layer and the top of inversion layer. Overall, model results are in good agreement with measurements and its performance appears to be reasonably good, since it represents expected physical behaviors of the involved phenomena, captures sentitivities to physical parameters, and reflects the influence of Solar radiation variations.
At first glance, results suggest that the most important process affecting the breakup of temperature inversion in the Aburrá Valley is the descent of the top of inversion layer as a result of mass removal by upslope winds. Further research is in order.

3. Ongoing work

This work makes up part of a larger ongoing work which mainly deals with the following questions: How does land use influence the surface energy balance in the Aburrá Valley? and how does it affect the breakup of the temperature inversion? The approach to answer these questions involves: (1) to model the energy balance in the Aburrá Valley involving local effects owing to land use changes, and considering the high spatial variability of properties as emissivity, albedo, permeability and roughness. A model is being developed, and RAMS is being used. (2) To model the breakup of the temperature inversion in the valley involving the modeled energy balance, (3) to make some measurements and observations for contributing to the discussion, and (4) to advance in the understanding of the meteorological dynamics of the low atmosphere in the Aburrá valley in particular, and in similar environments in general.

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