

LES modelling of microburst wind shear

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Sumário

Microbursts são corrente descendentes intensificadas por processos termodinâmicos na camada de nuvens Cb. Estes eventos tem causado vários danos e perdas de vidas humanas. Este experimento a técnica de modelagem Large-Eddy Simulation como uma ferramenta para avaliar e similar estes eventos de tempo severo.

Introduction

Severe thunderstorms are a common weather feature around the world and usually generate tornados, strong winds, hail and flash floods. Zipser et al. (2003), found the most intense thunderstorms in the Earth occurs at Southern South America. Brooks et al. (2003) estimates the region has up to 60 days/year with favorable severe weather conditions.

During the thunderstorm life cycle complex circulations are developed. First intense updrafts currents bring moisture and warm air in to the storm, the liquid water content increases and so the updraft collapses starting raining forming downdraft currents. During this process some of the rain evaporates in the drier air aloft. As a result the air aloft is cooled thereby causing it to sink and spread out rapidly as it hits the ground.

Fujita (1985) define a downburst as a strong downdraft which induces an outburst of damaging winds on or near the ground. Damaging winds, either straight or curved, are highly divergent. A Microburst is defined as a small downburst with its outburst, damaging winds extending only 4 km or less. In spite of its small horizontal scale, an intense microburst could induce damaging winds as high as 75 m/sec (270km/h).

The main objective is test the Large-Eddy Simulation as ability to represent these intense downward wind currents.

Methodology and discussion

A Large-Eddy Simulation code (Moeng ,1984 and Sullivan et al ,1994) was adapted to study the microburst phenomena. The primarily focus is the study of dynamics and not physics, so the model is dry and without any microphysics parameterization. We simulated the microphysical cooling that drive the microburst formation by imposing a negative vertical velocity in the upper part of domain.

In Large-Eddy Simulation, the governing equations are derived by filtering the time dependent Navier–Stokes equations. The subfilter-scale stresses resulting from the previous filtering operation require to be modeled. The Boussinesq hypothesis is employed and the subgrid-scale turbulent stresses are computed from: $\tau_{ij} - \frac{1}{3}\tau_{kk}\delta_{ij} = -2K_m\bar{S}_{ij}$; K_m

is the eddy viscosity, and \bar{S}_{ij} is the strain tensor for the resolved scale.

For the calculation of K_m the Moeng (1984) and Deardorf (1980) model is used: $K_m = C_k l_\Delta \sqrt{e}$; l_Δ is the mixing length for subgrid scale, e is the subgrid energy and C_k is a constant (0.1 for convective conditions).

The mixing length is calculated using: $l_\Delta = \min(kz, (\Delta V)^{1/3})$; k is the von Karman constant, z is the distance to the closest wall and $\Delta V = \Delta x \Delta y \Delta z$ is the volume of the computational cell.

All model runs were made in an ambient environment, which was dry adiabatic up to 1.5 km and slightly stable above. Table I summarises the simulation set-up of the simulation. Heat flux (q in Table 1) is provided at each time step, this allows a generation of a convective boundary layer with a well-mixed adiabatic temperature profile.

Table 1. Internal set-up, q (kinematic surface heat flux), and w_0 (velocity forcing).

(Lx,Ly,Lz)	(dx,dy,dz)	(zi) ₀	q	W ₀
Km		m	ms ⁻¹ K	ms ⁻¹
(10,10,2)	(78.125, 78.125,15.625)	1500	0.20	-2

The microburst generating forcing comes from an imposed negative vertical velocity (w_0 in Table 1) located at the top of domain. The spatial/temporal forcing functions are showed in Fig.1a and Fig.1b respectively. According to the definition of Microburst (Fujita, 1985) the forcing lasted 6 minutes of simulation time and covering an area of (4,4) km in the upper horizontal plane of the simulation domain.

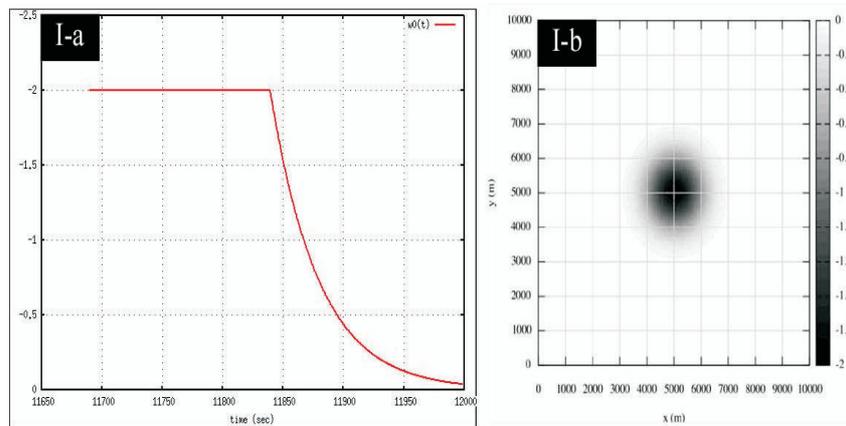


Figure 1. Time evolution of the maximum intensity of the forcing function(a), Spatial distribution of the forcing function(b).

Figure 2 (left side) show the three intermediate stage of the evolution of a microburst, that is the wind field before the injection (a) the touchdown stage (b) and finally the surface accelerating outburst (c) of strong winds in a vigorously overturning gust-front head propagating more or less symmetrically away from the centre of the microburst (f).

As showed by accurate Doppler radar observations we remind that a microburst is characterized when it hits the ground by strong divergence at its centre and an accelerating outburst of surface winds. This behaviour is almost reproduced with our simulation. This in part confirm the ability of LES in reproducing this complex phenomena.

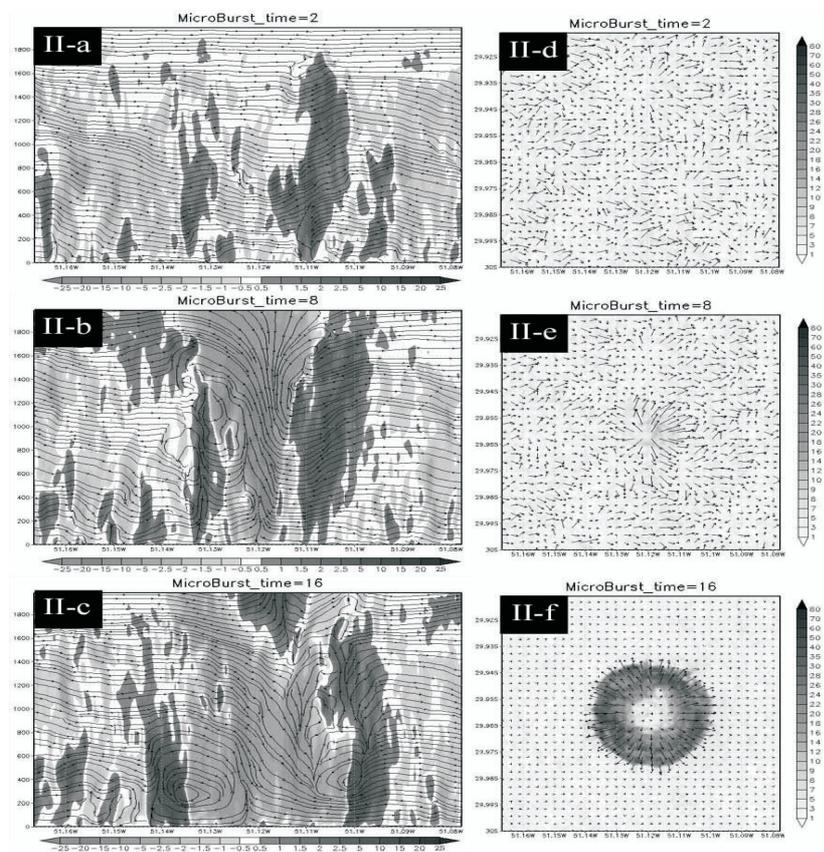


Figure 2. Air pattern in a vertical cut before the injection (a), during the touchdown (b) and the outburst of surface winds (c) and the relative air pattern in the ground (d) (e) and (f).

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