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Interactive Comment

Interactive comment on "Numerical simulation of tropospheric injection of biomass burning products by pyro-thermal plumes" *by* C. Rio et al.

C. Rio et al.

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Answer to Reviewer 2 comments on the manuscript 'Numerical simulation of tropospheric injection of biomass burning products by pyro-thermal plumes' by C. Rio, F. Hourdin and A. Chédin.

This paper aims to generate global-scale simulations of wildfire injection, using a massflux parameterization of plume rise. This is an important next-step, beyond regional plume rise studies; in this case, it is aimed specifically at reproducing the diurnal CO2 cycle in the middle and upper troposphere.

1. Page 4. I'm wondering if the units of 'd' above Equation 1 are not 'depth' (m), but *rather 'biomass burn rate per unit area' (kg-m/s), for Equation 2 to work out. On Page 9, however, d is given in meters:*

d is the depth of the fire front in meters. Equation 2 is correct but units of the heat flux F given are indeed wrong. F is in J s^{-1} m^{-2} (or W m^{-2}) as used later in the manuscript.

2. Page 5, top. It might be clearer to describe alpha as the 'fraction of a grid cell covered by the plume,' rather than 'the fractional cover of the plume.'

This has been changed.

*3. Page 5, Equation 5. I'm having another units question, regarding the second (buoyancy) term on the right side. This term seems to need units [kg-m**2/s**2], so might some function of density, or mass/length be missing?*

Reviewer 2 is right. We wrote g instead of ρ in Eq. 5. The right equation is:

$$\frac{\partial f w_u}{\partial z} = -d w_u + \alpha \rho \gamma \quad (1)$$

where

$$\gamma = g \frac{\theta_{vu} - \theta_{ve}}{\theta_{ve}} \quad (2)$$

is the plume buoyancy, θ_v being the virtual potential temperature and g the gravity acceleration.

4. I guess a general note is in order here. I've tried to re-derive the equations, and I'm having difficulty. This might be a matter of incomplete definitions, typos, or my lack of

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familiarity with this specific model, but I'm unsure about reviewing the Results sections being so unclear about the model.

We understand that the two previous mistakes (units of the heat flux and g instead of ρ in Eq. 5) may have confused Reviewer 2.

Main equations of the model are the equations of conservation presented in section 2.2:
- conservation of mass (Eq. 3):

$$\frac{\partial f}{\partial z} = e - d \tag{3}$$

where f is the mass-flux, e the lateral entrainment rate et d the lateral detrainment rate.

- conservation of total water, liquid potential temperature and CO_2 concentration (Ψ, Eq. 4):

$$\frac{\partial f \Psi_u}{\partial z} = e\Psi_e - d\Psi_u \tag{4}$$

- conservation of momentum (Eq. 5):

$$\frac{\partial f w_u}{\partial z} = -d w_u + \alpha\rho\gamma \tag{5}$$

where w_u is the updraft vertical velocity, α the fraction of the grid covered by the plume, ρ the air density and

$$\gamma = g\frac{\theta_{vu} - \theta_{ve}}{\theta_{ve}} \tag{6}$$

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the plume buoyancy, θ_v being the virtual potential temperature and g the gravity acceleration.

Those equations involve the mixing rates between the convective plume and its environment, entrainment of air inside the plume e, and detrainment of air from the plume d, for which no pronostic nor diagnostic equations exist, and which need to be specified. We do it in a way consistent with studies of shallow and deep convection in section 2.4, even if uncertainties remain.
In section 2.3, assumptions on the conservation of momentum equation in the first model layer are made to derive the temperature excess and vertical velocity at the basis of the pyro-plume, involving no other equations, except for the relationship between the heat flux and the excess of temperature: $F = \rho C_p w_u \theta_0'$.

The other equations used are equations classically used to define the fire heat flux from fire characteristics and are presented in section 2.1. The power of the fire front I (in kW m^{-1}) can be computed from (Trentmann et al., 2006; Stockes and D., 1987; Byram, 1959):

$$I = C\omega v \tag{7}$$

where ω is the density of biomass burned (in kg m^{-2}) and C the fuel low heat of combustion ($C \approx 17\,781$ kJ kg^{-1}) and v the propagation rate of the fire front (in m s^{-1}). The heat flux released F (in J s^{-1} m^{-2}), is related to I by $F = I/d$, where d is the depth of the fire front.

We hope this will appear clearer to Reviewer 2 and help to consider the results part of the paper.

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