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Atmospheric CO_2 Budget over Amazon Basin: The Role of the Convective Systems

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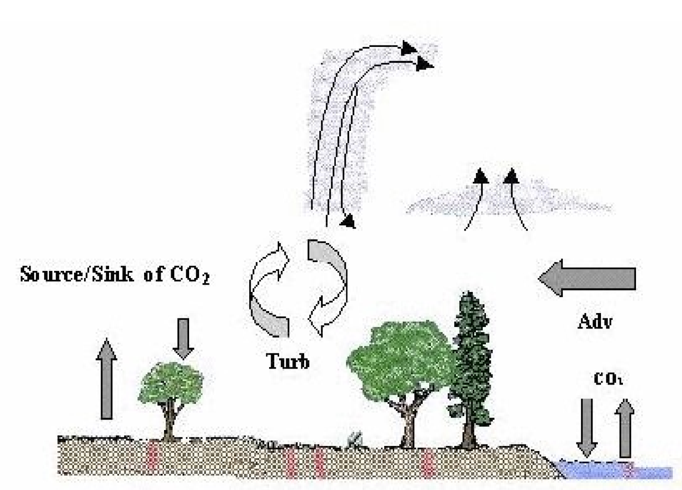
1. Introduction and objectives

This work study the CO_2 budget in the atmosphere on Amazon basin focusing the role of the shallow and deep convective systems. The vertical redistribution of the CO_2 by these systems is numerically simulated using a Eulerian transport model coupled to a regional atmospheric model (RAMS). The transport model includes advection at grid scale, diffusion in the planetary boundary layer (PBL) and convective transport by sub-grid shallow and deep moist convection. We explore also two different approaches for the CO_2 biogenic surface fluxes. The simulation is carried out with 6 tracers whose mass conservation equation is resolved including or not the moist convective deep and shallow transport. In that way, the role of these systems is clearly showed. The rectifier effect is also depicted through the transport to the free troposphere of PBL air masses with low CO_2 concentration due to activity of assimilation by the vegetation in the period between the noon and end of the afternoon, when this process and the convective activity are in the apex. The model is applied to July 2001 with a 30 km grid resolution covering the north portion of the South America. For this case, we compare the model results with CO_2 observations collected on Amazon basin during CLAIRE experiment.

2. Methodology



$$\left(\frac{\partial \bar{s}}{\partial t}\right)_{adv} = -\bar{u}_i \frac{\partial \bar{s}}{\partial x_i}$$ → grid -scale advection term

$$\left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{PBL\\turb}} = -\frac{1}{\rho_0}\frac{\partial\left(\rho_0 \overline{u'_i s'}\right)}{\partial x_i}$$ → diffusion in PBL

$$\left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{deep\\Conv}} = \frac{m_b}{\rho_0}\left[\delta_u \eta_u (s_u - \bar{s}) + \varepsilon \delta_d \eta_d (s_d - \bar{s}) + \bar{\eta}\frac{\partial \bar{s}}{\partial z}\right]$$

CO_2 convective transport by deep and moist convection – includes cloud scale downdrafts

$$\left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{shallow\\conv}} = \frac{m_b}{\rho_0}\left[\delta_u \eta_u (s_u - \bar{s}) + \bar{\eta}\frac{\partial \bar{s}}{\partial z}\right]$$

CO_2 convective transport by shallow and moist convection

CO_2 MASS TRANSPORT EQUATION

$$\frac{\partial \bar{s}}{\partial t} = \left(\frac{\partial \bar{s}}{\partial t}\right)_{adv} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{PBL\\turb}} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{deep\\conv}} + \left(\frac{\partial \bar{s}}{\partial t}\right)_{\substack{shallow\\convection}} + Q,$$

We have parameterized CO_2 biogenic fluxes in the model for the simulation of the diurnal cycle of CO_2 in the PBL. The source term parameterization (Q) of CO_2 follows two approaches:

✓**Cosinusoidal oscillation (for the tracer CO_2[6]):**

$$Q = R - \begin{cases} 0 \rightarrow \ nightime \\ A_0 \cos\left(\frac{\pi t}{12}\right) \rightarrow \ daytime \end{cases}$$

	R (μ mol/m²s)	A_0 (μ mol/m²s)	Reference
Forest	5	25	Lixin et al., (2003)
Pasture	5	20	Lixin et al., (2003)
Cerrado	2,8	15	Miranda, A. C. et al., (1996)

Table 2.1: Values of respiration and assimilation for forest, pasture and cerrado included in the model.

✓**By observed correlation between the NEE and the surface net radiation (for the tracersCO_2[1 - 5]):** $NEE = a + bR_{net}$

	$NEE = a + bR_{net}$	
	a	b
Forest	-0,0375	6,7137
Pasture	-0,0375	4,5355

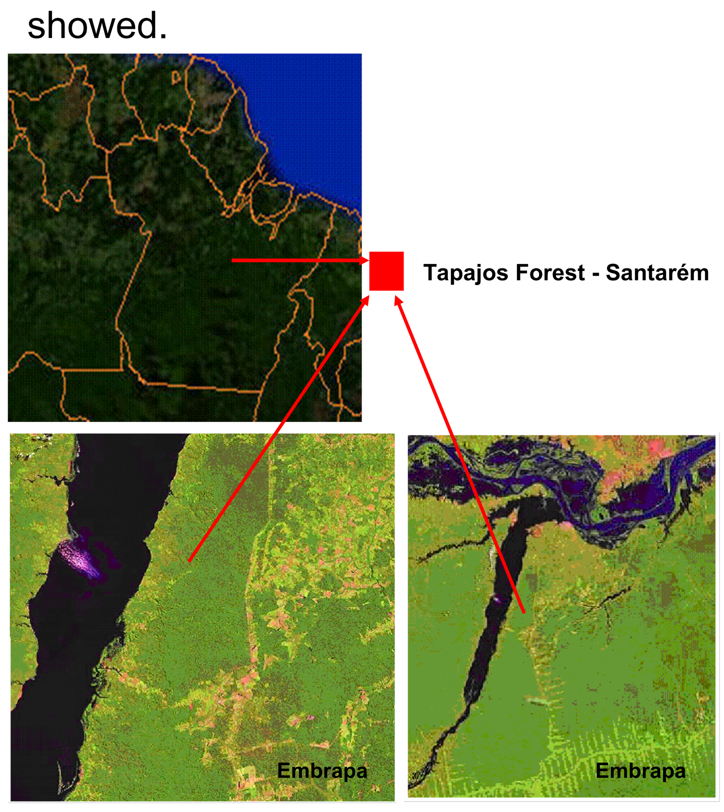
Table 2.2: Rate of respiration and assimilation of CO_2 included in the model.

Tracer	Advec	PBL turb	Deep Conv.	Shallow Conv.	Q (source)
CO_2 [1]	/	/	/	/	/ *
CO_2 [2]	/	/	/		/ *
CO_2 [3]	/	/		/	/ *
CO_2 [4]	/	/			/ *
CO_2 [5]		/			/ *
CO_2 [6]	/	/	/	/	/

Table 2.3: Six differents tracers with their respective transport terms are showed. For CO_2[1–5], the correlation between the observed NEE and net radiation were used for the NEE parameterization in the model. For CO_2[1] all the transport terms were used, being the realistic situation in the atmosphere. The shallow convective term was not used for CO_2[2]. For CO_2[3], the deep convection was not used and for CO_2[4] both shallow and deep convection were not used. CO_2[6] is simulated using all the transport terms but with the NEE cosinusoidal oscillation parameterization.

3. Dataset analisys

The figures below show where CLAIRE 2001 experiment took place. Also Harvard's flux tower located in Tapajos Forest (Santarem) is showed.



Forest (a, c) **Pasture (b, d)**

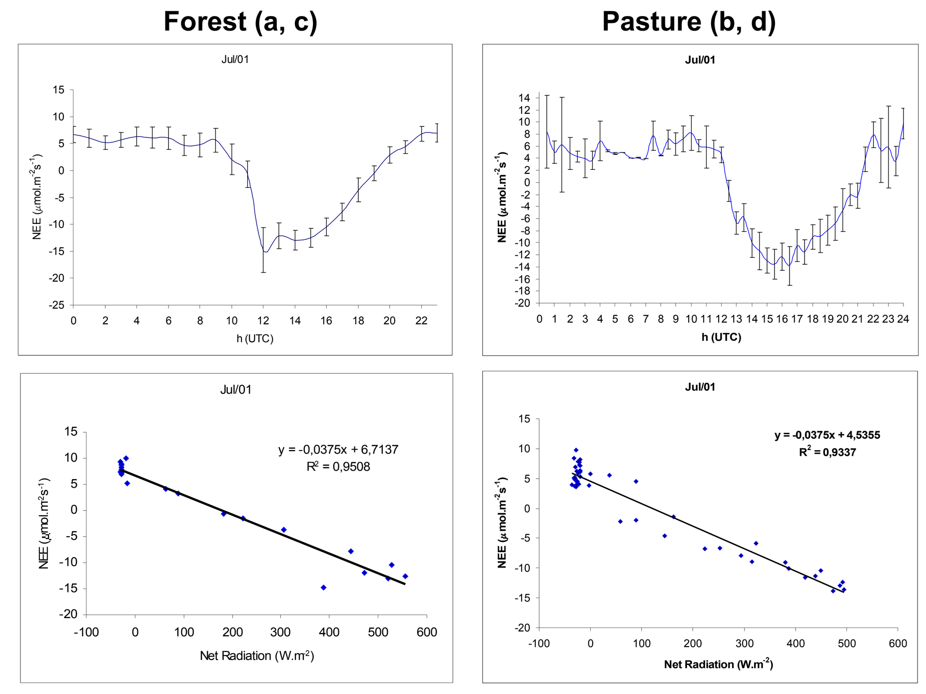


Fig. 3.1: Diurnal variation of NEE (for forest (a) and pasture (b)) and correlation between Net Radiation versus NEE. These correlations had been parameterized in the CO_2 transport model.

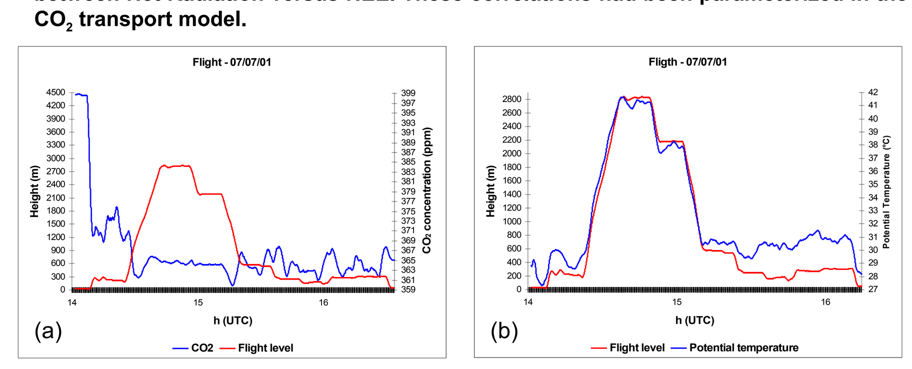


Fig. 3.2: Vertical profiles of the flights for mesuarements of CO_2 (a). For the same flight is showed the vertical profile of potential temperature (b).

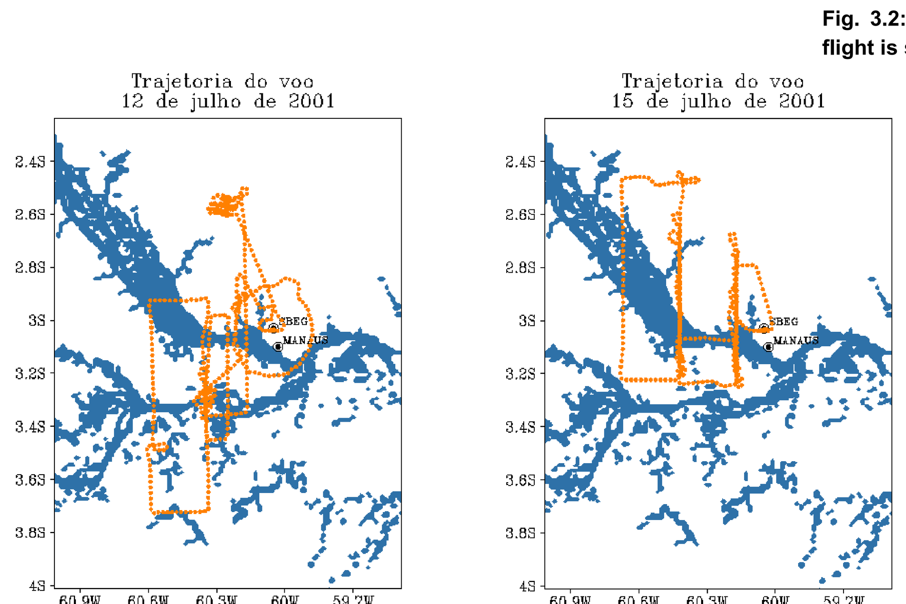


Fig. 3.3: Trajectory of the airplane for 12 and 15 July 2001 above part of Amazon basin.

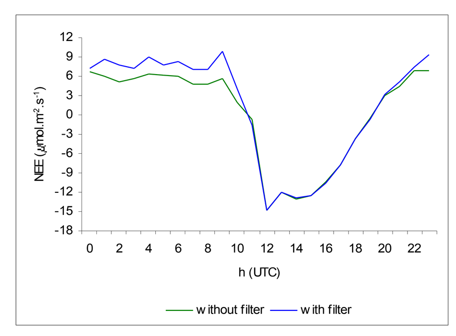


Fig. 3.4: Comparison between CO_2 fluxe where were used data when u* was above 0,2 m/s. July 2001.

4. Model results

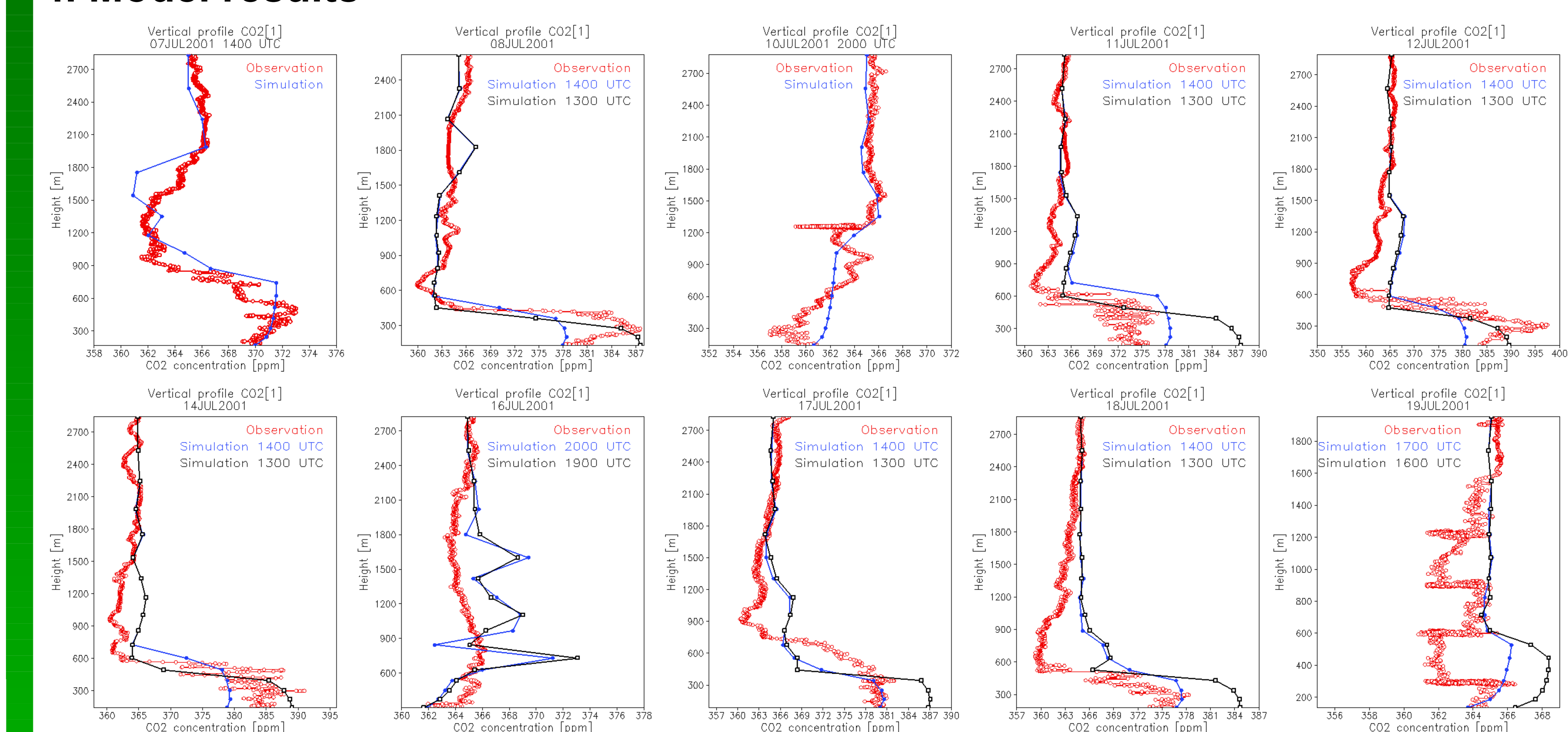


Fig. 4.1: Comparison between observed vertical profiles of CO_2 versus RAMS simulation in two differents time for differents days.

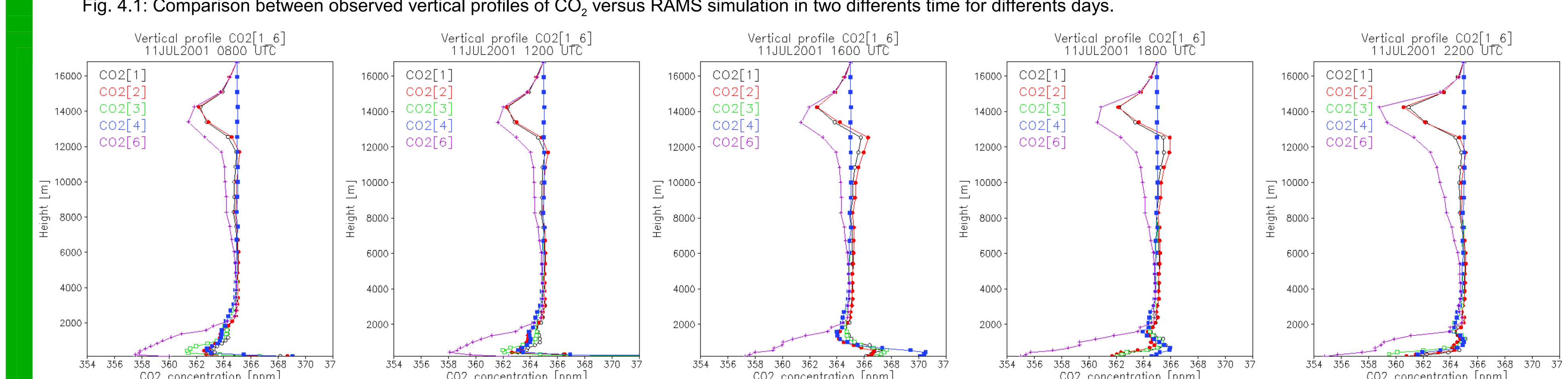


Fig. 4.2) Time evolution of the vertical profile of CO_2 tracers: CO_2[1], CO_2[2], CO_2[3], CO_2[4] and CO_2[6] on 08:00, 12:00, 16:00, 18:00 and 22:00 UTC July, 17 2001.

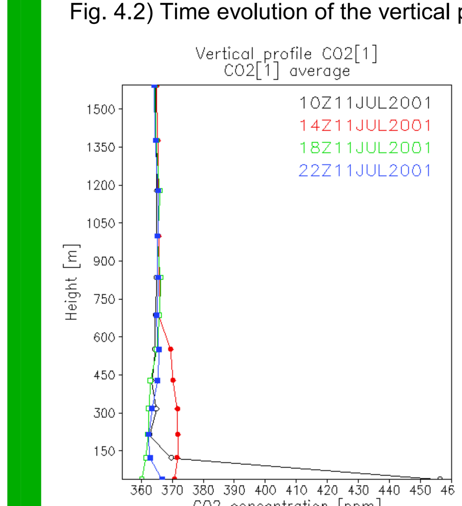


Fig. 4.3: Diurnal change of CO_2 in the low troposphere as simulated by the model. Can be seen high values of CO_2 in the beginning of the morning. Along the day, the biogenic assimilation process and the turbulent transport impose low CO_2 concentration in the end of the afternoon.

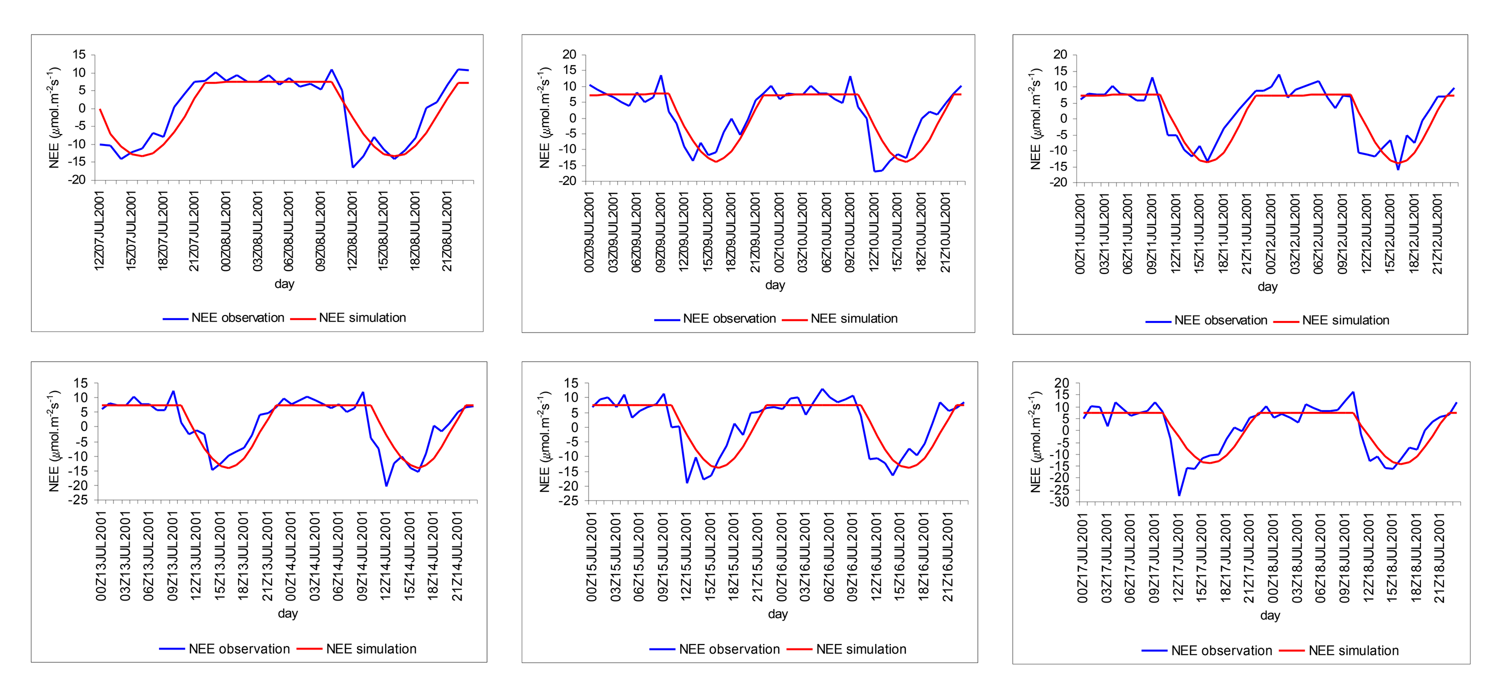


Fig. 4.4: Comparison between NEE observed and NEE simulated for differents days.

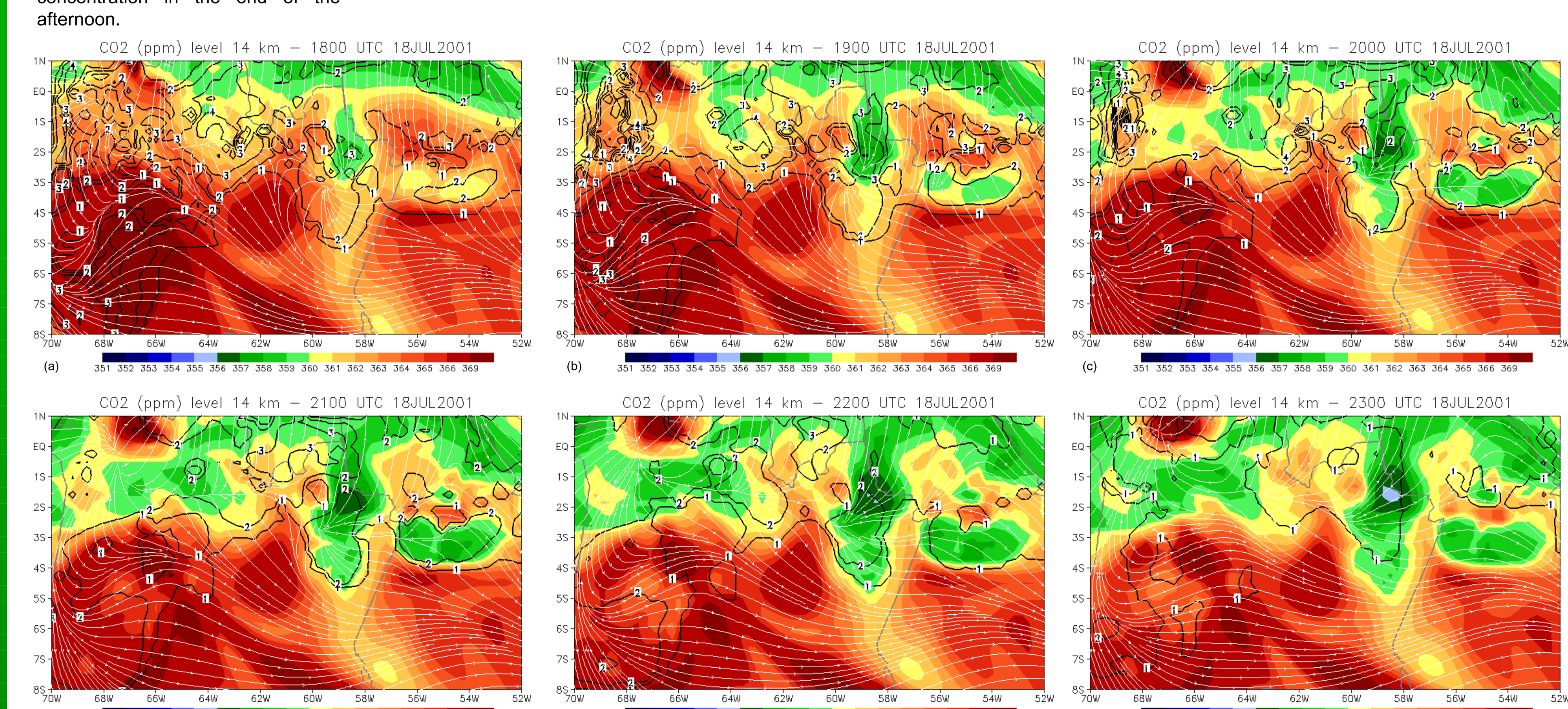


Fig. 4.5: Time evolution of the CO_2 concentration for the tracer CO_2[1] (shaded, vertical level 14 km), streamline of wind (white) and 1-hour accumulated convective precipitation (contour in black, mm) between 1800 and 2300 UTC on July, 18 2001. It is observed around 2° S and 59° W a convective activity. Along the time, low concentrations of CO_2 are removed from low levels and detrained at high troposphere by convective systems.

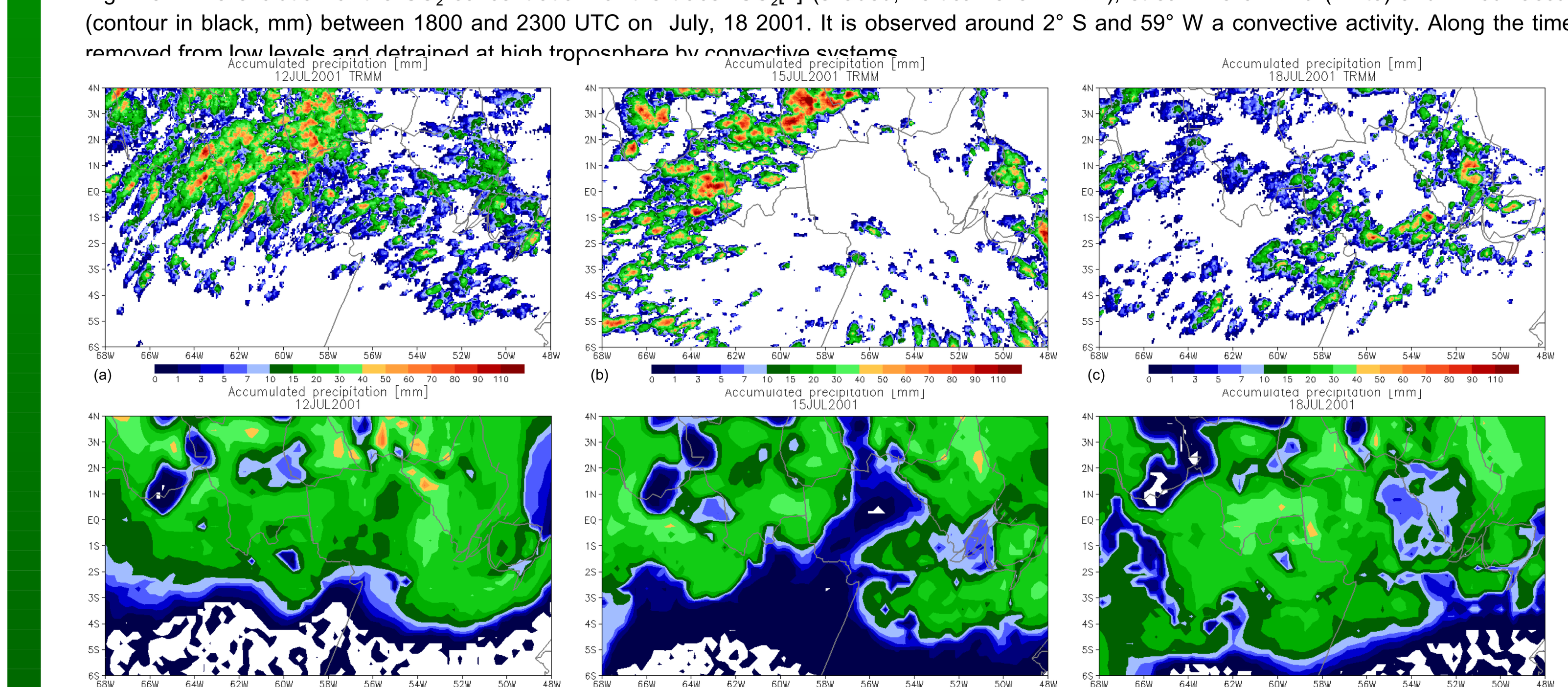


Fig. 4.6: Compararison between accumulated precipitation by TRMM (a, b and c) and RAMS simulation (d, e and f).

5. Conclusions

The model was able to reproduce the main characteristics of the diurnal cycle of CO_2 in PBL and the transport from the PBL to the free troposphere by the shallow and deep moist convection, depicting the rectifier effect. For more realistic simulation, we are working on a better initial and boundary condition. Also working is going on to make stronger coupling between shallow and deep cumulus scheme in order to get better diurnal cycle of the simulated precipitation on Amazon basin.

6. Acknowledgements

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