Atmospheric Responses to Land and Water:

Simulations and Observations of Mesoscale Circulations and CO_2 Concentrations in the Santarém Mesoscale Campaign

A. Scott Denning[1], Lixin Lu[1], Elicia Inazawa[1], Maria Assuncão Silva Dias[2], Pedro Silva Dias[2], Sasan Saatchi[3], Raymond Desjardins[4], Jeffrey Richey[5], and Marek Uliasz[1]

[1]Department of Atmospheric Science, Colorado State University, USA
[2]Universidade de São Paulo, IAG, São Paulo, Brazil
[3]NASA Jet Propulsion Laboratory, Pasadena, California, USA
[4]Agriculture and Agri-Food Canada, Ottawa, Canada
[5] School of Oceanography, University of Washington, USA

Abstract

Variations of the concentrations of atmospheric CO_2 contain information about sources and sinks at the underlying surface. We have investigated mesoscale variations of atmospheric CO_2 over a heterogeneous landscape of forests, pastures, and large rivers during the Santarém Mesoscale Campaign (SMC) during August, 2001. We simulated the variations of surface fluxes and atmospheric concentrations of CO_2 using the CSU Regional Atmospheric Modeling System (RAMS) on a multiply-nested grid which included a 1-km inner grid centered on the Flona Tapajos. Surface fluxes of CO2 were prescribed in the model using idealized diurnal cycles over forested and pasture vegetation, and over surface water using a value suggested by *in-situ* measurements in the Amazôn River. Land vegetation cover was prescribed using AVHRR NDVI data.

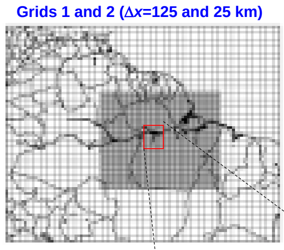
Mesoscale circulations were simulated in the vicinity of both the Amazôn and Tapajos Rivers on most days, with magnitudes of 1-2 m s^{-1} near the surface. These "riverbreeze" circulations were also present in observations made in the field. Simulated CO_2 concentrations were perturbed by over 10 ppm in the immediate vicinity of the rivers, with the strongest effect in the early morning. By midafternoon, the effect of the river evasion fluxes on simulated concentrations was mixed through a deeper layer and influenced by the riverbreeze, but still easily measurable.

In-situ measurements of atmospheric CO_2 during transects flown in a small aircraft at midmorning were consistent with the river evasion flux hypothesis, though the magnitude was weaker than simulated. This suggests that the prescribed evasion flux in the model was too strong.

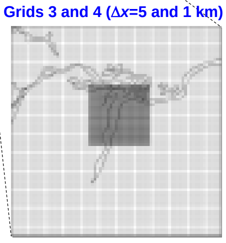
Model

We used the Regional Atmospheric Modeling System (RAMS, Pielke et al, 1992), version 4.3 to perform a 16-day simulation of weather and CO_2 during the Santarém Mesoscale Campaign (1-16 August, 2001). Four grids were used with 2-way nesting. Lateral boundary conditions were prescribed from the global CPTEC reanalysis. Subgrid-scale variability in vegetation and the fractional area covered by surface water was included. Surface CO_2 fluxes were prescribed with diurnal cycles for forest and pasture grid cells. A constant CO_2 evasion flux of 5 μMol m^{-2} s^{-1} was prescribed to evaluate the effect of such a flux on the local and regional atmosphere (Richey et al, 2002). The convective transport scheme of Freitas et al (2000) was used to represent the effects of moist convection on CO_2 concentrations.

Grids 1 and 2 (Δx=125 and 25 km)



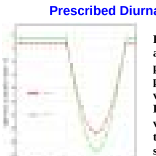
Grids 3 and 4 (Δx=5 and 1 km)



Airborne Sampling

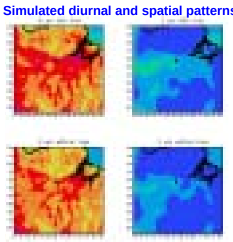
Regional CO_2 Experiment

Prescribed Diurnal NEE



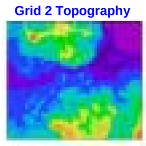
Respiration rate and maximum daily photosynthesis were prescribed by vegetation type. Photosynthesis varied according to the cosine of the solar zenith angle

Simulated diurnal and spatial patterns

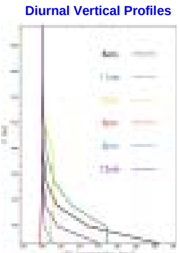


[CO2] at z=51 m, grid 2

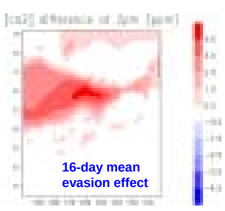
Grid 2 Topography



Diurnal Vertical Profiles



Mean vertical profile shows elevated [CO_2] near surface, even though mean NEE is negative

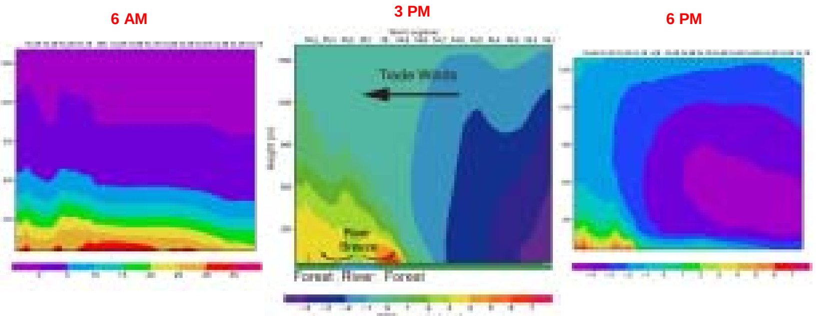


Stability, topographic drainage flow, and evasion all contribute to elevated [CO2] at night. Nonetheless, the [CO2] anomaly produced by an evasion flux of 5 μMol m^{-2} s^{-1} is easily detectable even in the time-mean.

Riverbreeze Experiment

Simulated CO_2 Anomaly (Δx = 1 km)

Longitude-Height Sections Across Tapajos River: August 8

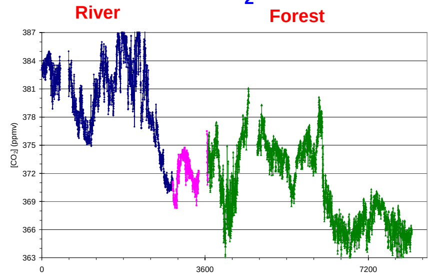


Very strong vertical gradients of [CO_2] were simulated in early morning when the thermal structure is strongly stable.

By mid-afternoon, a deep mixed layer formed, with strong drawdown over the forest. An internal boundary layer was apparent over the Tapajos River. A strong mesoscale "riverbreeze" circulation produced a convergence line along the east bank of the River. CO_2 released by evasion accumulated along this convergence zone.

At sunset, the simulated mixed layer decoupled from the surface. Elevated [CO_2] began to accumulate in the newly-formed stable layer, and the CO_2-depleted residual layer advected toward the west.

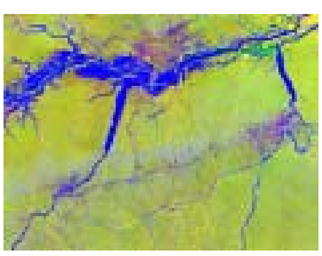
Measured CO_2 at 300 m



CO_2 concentration measured by a continuous analyzer flown at 300 m elevation over the Amazon River (blue) and adjacent forest (green) on the morning of August 13. Two legs of over 100 km each were flown, one over the forest, and the other over the River.

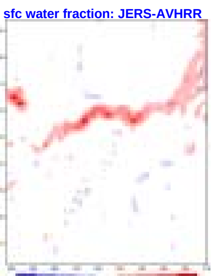
Concentrations over the river were elevated by more than 10 ppm. Turbulent variations of [CO_2] were much greater over the forest.

Surface Water Sensitivity Experiment



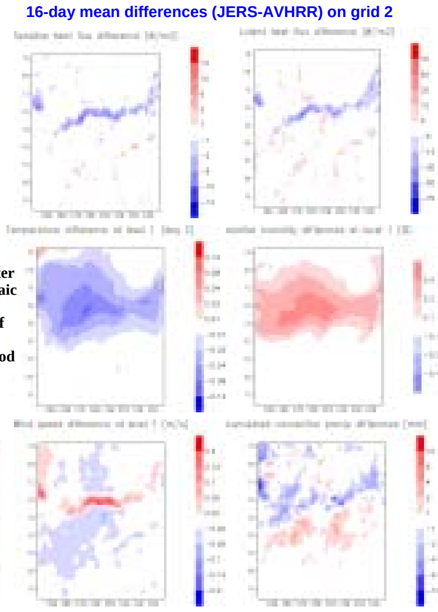
A 1-km map of fractional coverage by surface water was generated from the 100-m JERS-1 radar mosaic by S. Saatchi. The radar data were acquired in a single sweep during the generally low flood time of the Amazon River in September–December 1995, and again in May – August 1996 during a high flood period of Amazon river. The classification was performed using high & low water radar images and AVHRR 1995-1996 monthly averaged NDVI.

sfc water fraction: JERS-AVHRR



Within the domain of RAMS grid 2, nearly all the difference between the two maps was along the Amazon floodplain. The domain-averaged surface water fraction was < 2% greater using the radar data than the AVHRR data.

16-day mean differences (JERS-AVHRR) on grid 2



The effect of the extra fractional water coverage on the physical climate was fairly subtle, and very sensitive to the prescribed water temperature. Generally cooler and moister conditions were simulated using the radar data than AVHRR.

References

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