Final Report:

Investigation Group: CD-01

PIs:

Allan Scott Denning - Colorado State University

Pedro Leite da Silva Dias - IAG/USP

1. Narrative of activities:

1.1. Summary of Activities

We have completed a multi-year study of ecosystem carbon fluxes across Amazônia using the Simple Biosphere model (SiB2) at several spatial and temporal scales. We have developed understanding and confidence in the model simulations at local scales by direct evaluation against data collected in the field, and extrapolated to regional, Basin, and even global scales by coupling our local ecophysiological model to a range of atmospheric models. We have improved the model and developed input data from remotely sensed imagery at several scales. We have learned that water stress plays a less significant role in variations of ecosystem carbon flux than previously thought, and that interannual variations in the balance of C_3 and C_4 photosynthesis in the region contribute to substantial variability in the stable isotope ratio of terrestrial CO_2 flux at the global scale. We have demonstrated that a handful of regular measurements of CO_2 in the atmosphere above the region would dramatically improve the confidence of regional carbon budget estimates from global inversions. We have investigated the role of surface water and seasonally inundated land surfaces in the energy and carbon budgets of the region: preliminary evidence suggests that they play an important and previously neglected part in the Basin-scale carbon balance. Simulations of ecosystem responses to seasonal and interannual drought have demonstrated an important weakness of SiB: the model captures wet-season/dry-season carbon dynamics well in the Equatorial Tapajos region, but exaggerates the effects of drought stress under the more prolonged seasonal drought conditions in Rondonia. Exaggerated drought stress can produce catastrophic carbon and climate consequences in coupled models. Finally, we have tested a method for high-resolution regional CO_2 flux estimation using an atmospheric mesoscale model.

1.2. Local-Scale Model Evaluation Studies

We have performed multiyear simulations of ecosystem fluxes of heat, water, and CO_2 at forest and pasture sites, and evaluated the performance of SiB2 by comparison to a range of observations. We tested the model primarily against data from ABRACOS sites because LBA-Ecology flux data have only recently become available. These experiments motivated substantial improvements in the model and its representation of important processes for this region. Soil hydraulic properties were modified, and we now use smaller matric potentials in many areas reflecting the coarse granular nature of many soils in the region despite their clay mineralogy. Soil water holding capacity and rooting depth was increased to allow ecosystems to store sufficient water during the rainy season to continue active transpiration and photosynthesis through protracted dry seasons. The modified model reproduces diurnal and seasonal cycles of ecosystem fluxes quite well at eddy covariance sites in the Tapajos region (Liu et al, 2003). Unlike several other models, SiB2 correctly captures the seasonality of net ecosystem exchange at Flona Tapajos, which is characterized by net uptake in the dry season and net release of CO_2 during the wet season (Scott Saleska, pers. comm.). Simulated photosynthesis (and evapotranspiration) in SiB2.5 is nearly aseasonal, but respiration decreases dramatically during the dry season due to dry surface soils that are very rich in organic matter (Fig 1).

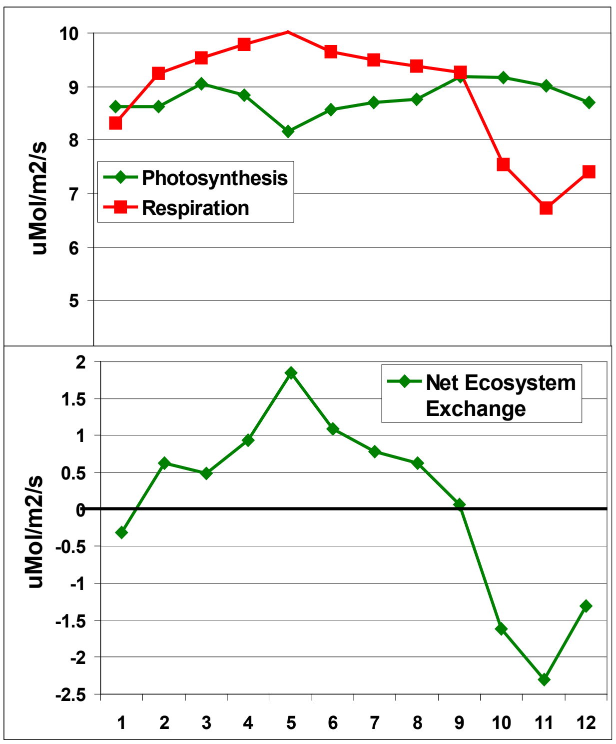

Figure 1: Simulated photosynthesis and ecosystem respiration (top panel) and net ecosystem exchange of CO_2 (bottom panel). Result for Flona Tapajos using SiB2 driven by ECMWF 6-hourly meteorology for 1993. Note that the simulation shows net uptake in the dry season and net release of CO_2 during the rainy season.

The maintenance of transpiration during the three month seasonal drought is possible due to abundant moisture in the root zone that is stored during the longer rainy season.

At the Reserva Biologica Jaru in Rondonia (southwestern Amazon, 11o S), by contrast, the dry season lasts for five months, with quite severe drought (Fig 2). In the standard configuration (marked “control” in the Figure), the model maintains transpiration for the first several months, but develops severe root zone water stress in August through October, and transpiration shuts down (right panel of Fig 2). Observations at the site do not show significant reduction in transpiration during the dry season. We performed several sensitivity experiments to investigate how the model might be improved to more realistically simulate the response to severe seasonal drought at this site. The model represents vertical variations of soil moisture in three layers: a thin surface layer that can evaporate directly into the atmosphere, a thicker root zone from which transpired water is

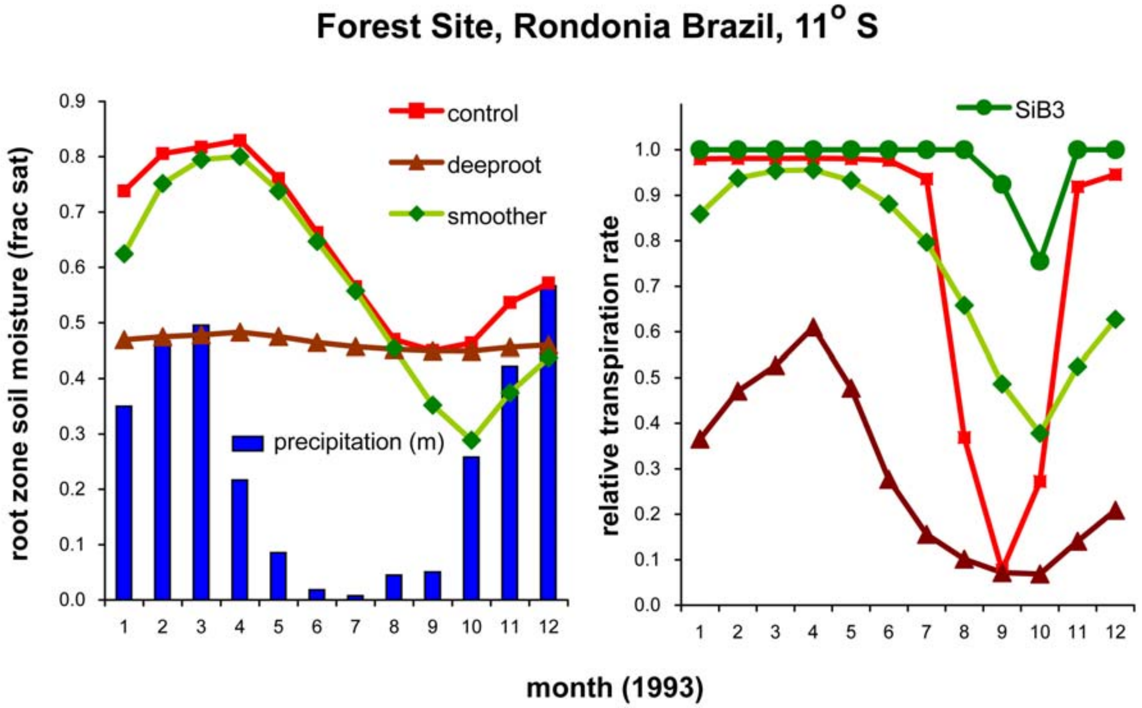

Figure 2: Simulated seasonal cycles of root zone soil moisture (left panel) and relative transpiration rate (due to drought stress) at a tropical forest site in the southwestern Amazon. Monthly precipitation (m) is also indicated by the bars in the left panel. Each simulation was initiated with completely saturated soils at all depths on January 1, and integrated for 10 years using observed meteorology from the site (endlessly repeating 1993 conditions). Plots reflect monthly mean responses for each month of the 10th year of the simulation.

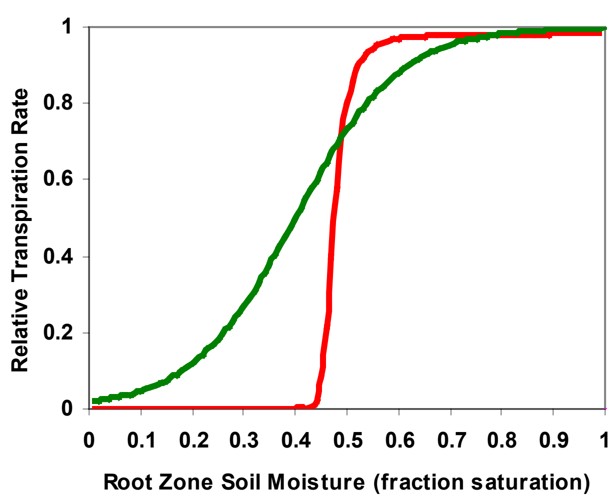

Figure 3: Parameterization of drought stress (relative stomatal conductance) as a function of root zone soil moisture. Red curve shows default parameterization, green curve shows experimental "smoother" parameterization.

drawn, and a deep "recharge" layer that drains to groundwater and interacts with the root zone. Tropical forests are known to be able to draw water from very deep root systems (Nepstad et al, 1994; Jipp et al, 1998), so we increased the depth of the root zone in SiB2.5 to 10 m, with a 5 m recharge layer underneath. Surprisingly, this led to even worse results, with very dry soil conditions and moderate to extreme stress throughout the year. Given about 3 m of total precipitation per year at the site, with about 1 m of runoff, about 2 m of water are available per year for storage in the 10 m deep root zone, which has 45% porosity.

Therefore the long-term mean water content of the root zone must approach (2 m water/4.5 m of pore space = 44% of saturation), which is dry enough to trigger drought stress under the current parameterization.

Root zone moisture stress is currently parameterized in SiB2.5 (Sellers et al, 1996a) as an exponential function of soil water potential, which a texture-dependent exponential function of volumetric water content (Fig 3). We hypothesized that the landscape-scale (or GCM grid scale) stress response to dry root zone soils might follow a more gradual decline with decreasing soil moisture, because moisture content at larger scales is likely to vary with topographic position in the landscape. We performed another sensitivity experiment in which drought stress was assumed to progress more gradually ("smoother" in the figure) as area-mean soil moisture decreased. This experiment was more successful, partly alleviating and delaying the onset of severe stress, but soil moisture was also depleted more strongly than in the control case. Finally, we introduced a 10-layer soil model into SiB (using algorithms from the Community Land Model, Bonan et al, 2003). In the 10-layer model, roots are assumed to occupy the entire soil column with exponentially decreasing density with depth, and are allowed to draw water from any layer in which water is available. Sensitivity experiments with the revised model (now called SiB3) revealed only minor drought stress in October, at the very end of the dry season.

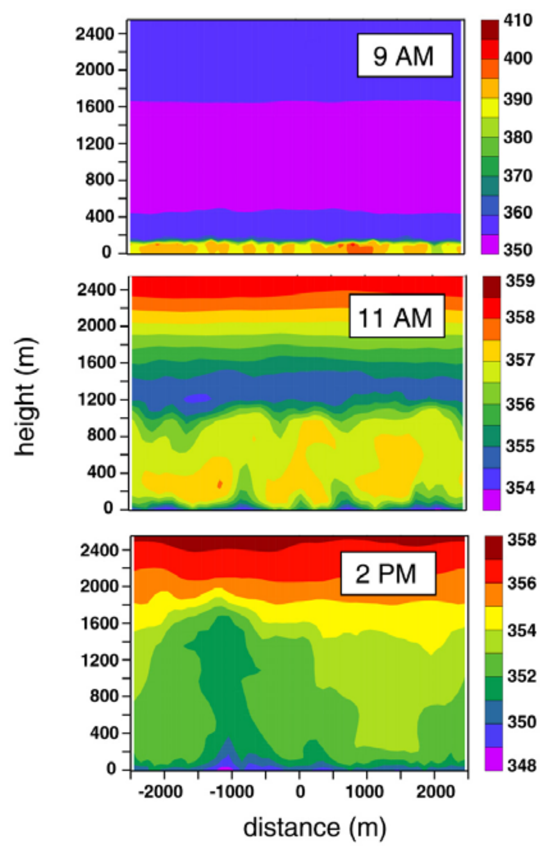

Figure 4: Evolution of CO_2 in the PBL over a forest site in Rondonia using the coupled SiB2-RAMS model. Very high values under the stable layer in the morning followed by decreases due to photosynthesis and turbulent entrainment and establishment of a mixed layer by mid-day

We coupled an improved version of SiB2 to the CSU Regional Atmospheric Modeling System (RAMS), and used the coupled model to investigate the dynamics of ecosystem-atmosphere interactions at several spatial scales. This work also required the development of surface and vegetation parameter sets for SiB2 on a 1-km grid over a mesoscale domain, from vegetation classifications and AVHRR imagery. The coupled SiB2-RAMS model was used to investigate diurnal variability of CO_2 and the interactions between surface energy budgets and PBL development over forest and pasture sites in Rôndonia. Results of these simulations indicated unrealistic behavior of the model during the morning transition from stable conditions with net respiration and very high CO_2 concentrations to turbulent conditions with net assimilation and lower CO_2, especially at the forest site (Rebio Jaru).

Simulations of these transitions in the forest with the original coupled model included dramatic drawdown of low-level CO_2 by photosynthesis while the air was still stably stratified. This phenomena arose because, as is the case with most land-surface parameterizations in atmospheric models, SiB2 treated the temperature, moisture, and CO_2 concentration of the canopy air space as a diagnostic quantity without mass or heat capacity. We have introduced a new parameterization with prognostic calculation of canopy air space temperature, water vapor, and CO_2 in a finite mass whose properties persist across time steps. This new parameterization produced more realistic diurnal and vertical variability at the ABRACOS towers (Fig 4), and also paved the way for the introduction of canopy recycling of respired CO_2 which is important for stable isotope calculations.

1.3. Studies of the Tapajos Region

We have analyzed mesoscale circulations in the vicinity of the Tapajos flux sites during the Santarem Mesoscale Campaign (SMC) of July-August, 2001. The presence of the large rivers (Amazon and Tapajos) produces strong contrasts in surface temperature and sensible heat flux in the region, and these heterogeneous surface fluxes induce anomalous circulations that are analogous to an inland seabreeze. These "riverbreeze" simulations account for convergence on the east margin of the Tapajos River as the easterly Trade Winds impinge on westerly the riverbreeze, leading to enhanced shallow cumulus clouds and precipitation over the Flona Tapajos (Fig 5, Silva Dias et al, 2003). In addition to the thermal forcing described by Silva Dias et al, we have discovered that persistent low-level convergence over the Flona Tapajos is maintained even under strong Trade Wind conditions due to mechanical "steering" of low-level winds by regional topography and the contrasts in surface roughness associated with the rivers themselves. Easterly Trade Winds tend to be channelized along the mainstem Amazon, and then veer left up the Tapajos River upstream of Santarém. Trade Wind flow over the Flona encounters this northerly flow along the river channel and substantially enhances the low-level convergence. This

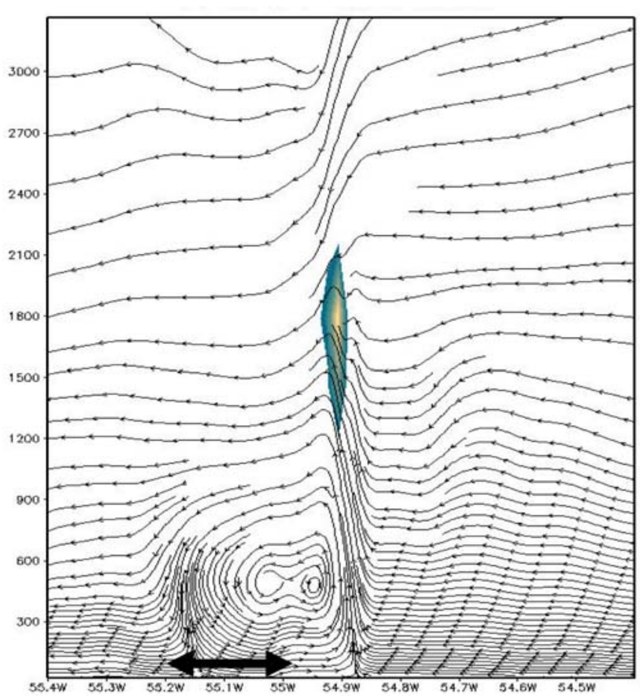

Figure 5: Longitude-height cross section at 2.7° S of air flow (vectors) and cloud liquid water (colored contours) simulated by RAMS at 1700 local time 28 July 2001. The heavy arrow shows the location of the Tapajos River.

rather idiosyncratic pattern of flow, convergence, cloudiness, and enhanced precipitation may contribute to quite local climate anomalies over the LBA-ECO sites in and near the Flona Tapajos.

Richey *et al* (2002) have recently suggested that evasion of CO_2 from supersaturated surface waters may play an important role in the regional carbon balance of the Amazôn Basin. To further investigate the effects of surface water CO_2 emission on the regional carbon balance, and to aid in planning for our field campaign, we performed full 3D simulations of regional meteorology and carbon exchange with and without specifying a CO_2 fluxes from the river and inundated land of 5 μMol m^{-2} s^{-1} (J. Richey, pers. comm.). We performed a 3-month "spin-up" simulation on a coarse grid, followed by a set of 10-day simulations on a 1-km grid. The model was driven by 6-hourly lateral boundary conditions derived from CPTEC (Center for Weather Forecasts and Climate Research) reanalysis products. At regional scales, the simulated impact of surface water evasion is felt most strongly over topographic lowlands at sunrise (Lu *et al*, 2001). Nocturnal accumulation is concentrated in lowlands by drainage flow along the surface. The additional CO_2 efflux from surface waters produces elevated CO_2 concentrations in the vicinity of the Tapajos River (Fig 6). The simulated CO_2 concentration anomaly arising from surface water evasion is quite shallow, and is strongly modified by the "riverbreeze" circulation, with the highest values along the east bank of the River along the convergence line where the riverbreeze decelerates the trade wind flow. The simulated signature of a river evasion flux of this magnitude is quite clear, and would be easy to detect in transects of continuous measurements using airborne platforms flying at low elevation.

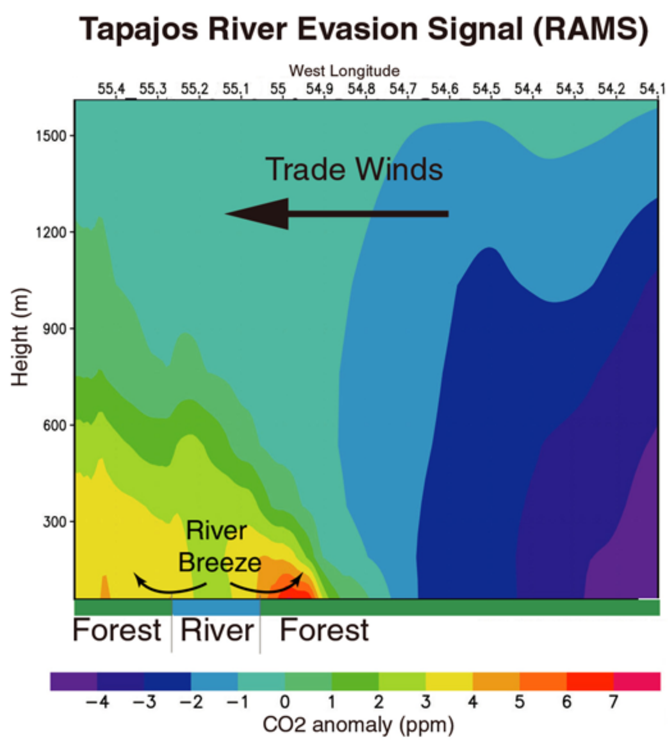

Figure 6: CO_2 concentration anomalies (ppm) simulated on a 1 km grid centered over Flona Tapajos for a river evasion flux of 5 μMol m^{-2} s^{-1}. Cross-section at 2.9° S, 3 PM on 8-AUG-2000.

We carried out an airborne field sampling program near Santarém in August 2001, using a local air taxi service. We performed five flights, making continuous measurements of CO_2 and water vapor with an infrared gas analyzer, and collected flasks for later analysis at NOAA/CMDL. This campaign was designed to (1) estimate fluxes with much larger footprints than are measured from eddy flux towers; (2) to compare simulations of the variations of CO_2 and $\delta^{13}C$ in the mesoscale atmosphere with observations; (3) to evaluate the "river evasion" hypothesis of Richey *et al* (2002); and (4) to provide more detailed

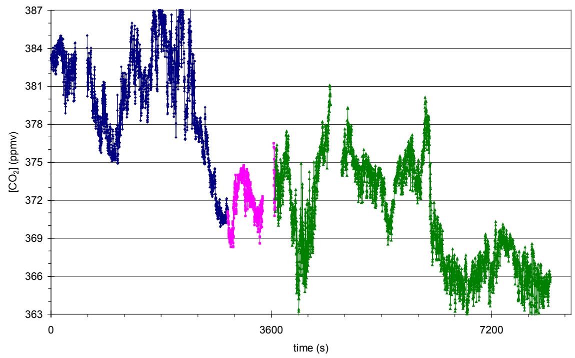

Figure 7: CO_2 concentration measured by a continuous analyzer flown at 300 m elevation over the Amazon River (blue) and adjacent forest (green) on the morning of August 13, 2001.

characterization of the atmospheric composition in the Santarém vicinity, in order to aid in the interpretation of the weekly profiles measured by Tans, Bakwin, and Artaxo. Unfortunately, we experienced several failures of critical equipment during the campaign, and collected much less useful data than we had hoped.

One very intriguing result was from a low-altitude morning flight along the mainstem of the Amazôn River, combined with a parallel track over the forest to the north of the River (Fig 7). This flight was one of three in which we attempted to address the river evasion hypothesis of Richey *et al* (2002). During this time, the stable boundary layer was beginning to break up over the forest, but conditions were still relatively stable over the River. The measurements showed strong CO_2 gradients between forest and river. These concentration differences (about 8 ppm!) are quite consistent with those predicted by RAMS for a river evasion flux of 5 μmol m^{-2} s^{-1}. Further evaluation of these data is necessary with the highest resolution model possible, to deconvolve contributions from river evasion from those of topographic drainage flow off the forest floor.

1.4. Development of a New Method for Regional Inverse Modeling of CO_2

We have extended the theory of synthesis inversion calculations to the regional scale, and explored the limits of this technique with synthetic data generated by the model (Uliasz *et al*, 2003). Inverse modeling seeks to quantify sources and sinks of tracer (e.g., CO_2) at the surface from spatial and temporal variations of measured concentrations in the atmosphere. In practice, the method is applied at the global scale by discretizing global monthly CO_2 fluxes into regional "basis functions" of unit strength. The magnitude of each regional contribution to the observed variability is then estimated using least squares optimization subject to constraints (e.g., Enting *et al*, 1995; Bousquet *et al*, 2000, Gurney *et al* , 2002). At the regional scale, we discretize the space-time variations of CO_2 fluxes in terms of "influence functions" calculated for each measurement. These are determined by tracing the motion of a large ensemble of imaginary massless "particles" in a Lagrangian particle dispersion model (LPDM), and using the results to calculate the conditional probability that the last contact of a sampled airmass with the surface occurred at each grid cell and time step in the model. The measured concentration is then expressed as a linear combination of contributions from each grid cell and time, plus contributions from tracer fluxes into the modeling domain from the upwind boundary. Using the same mathematical method as the global synthesis inversions, we estimate each of these fluxes and their uncertainties subject to prior constraints. The new method is complementary to traditional convective boundary layer (CBL) budgets and other mass-balance techniques. Advantages include the estimation of spatial and temporal variations of fluxes, as opposed to just their mean values, and the formal estimation of uncertainty in the retrieved fluxes. Different temporal patterns of photosynthesis and respiration cause the influence functions to differ for the component fluxes, and allow separate estimation of each from CO_2 data. We find that continuous measurements from towers provide better constraint to regional fluxes than twice-daily aircraft profiles. For mesoscale domains, the problem of estimating lateral inflow fluxes is a major contributor to uncertainty in the estimation of surface exchanges. We have experimented with various configurations of tower measurements, aircraft profiling, and the use of inflow flux estimates from larger-scale models optimized against global data.

Another observational strategy we applied during the airborne field campaign involved repeated sampling of a single airmass as it advected into the Flona Tapajos with the Trade Wind flow. For this purpose, we developed an operational trajectory forecasting system using CSU RAMS and the Lagrangian Particle Dispersion Model (LPDM). The LPDM was driven by output from the 48-hour regional forecast performed by our collaborators at the Universidade de São Paulo, twice per day using RAMS with three nested grids. During the field experiment, the RAMS forecast was rerun at midnight at CSU each night and used to drive trajectory forecasting with the LPDM. The entire process from transferring RAMS input files from Brazil to running RAMS and LPDM to displaying the results on a web site available to field personnel was automated, so that flight planning and operations could be conducted in Santarém even though the meteorological analysis was performed in São Paulo and the trajectory forecasting was done in the US. This RAMS/LPDM forecast system can easily be adapted for other field experiments and sampling strategies (e.g., for COBRA-BRAZIL in 2003-04).

1.5. Basin-scale and Global Studies

We developed, implemented, and tested algorithms for stable carbon isotope fractionation in SiB2 (Suits *et al*, 2003). Simulated isotopic fractionation was evaluated against data collected at several sites in Amazônia. The model predicts the discrimination against ^{13}C by photosynthesis and its effect on the stable isotope ratio of both the organic matter formed and the canopy air space. Model calculations were compared against both of these quantities and their diurnal, seasonal, and interannual variations, generally quite favorably. The model was then used to simulate basin- and global-scale variations in

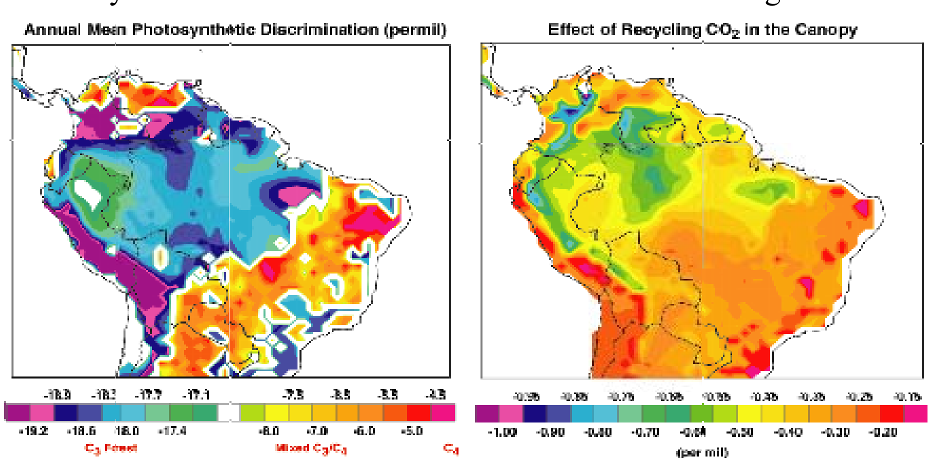

Figure 8: Isotopic fractionation simulated by SiB2 (annual mean for 1987) driven by analyzed climate, and the effect of canopy-scale recycling of respired carbon by photosynthesis

isotopic fractionation of CO_2 over an 11-year period, from 1983-1993. These experiments indicated a small amount (less than 5%) of canopy-scale recycling of respired carbon into photosynthetic assimilation (Fig 8), primarily in the early morning under dense canopies. This recycling can nevertheless influence the stable isotope ratio of the organic matter formed (and therefore subsequent respiration) by as much as 0.6 permil. Interannual variability in carbon balance across the Amazôn Basin was primarily driven by climate variability associated with ENSO, and was also associated with substantial variation in isotopic discrimination. This covariation of carbon fluxes and fractionation violates the basic assumption of so-called "double deconvolution" analyses of the global carbon budget (Randerson *et al*, 2003), which interprets variations in $\delta^{13}C$ of the atmosphere as resulting from changes in fluxes from atmosphere and ocean with fixed isotope ratios. We found substantial seasonal and interannual variation across the Basin in isotope ratios to result from both changes in discrimination (resulting from physiological stress) and from shifts in the fractions of C_3 and C_4 photosynthesis.

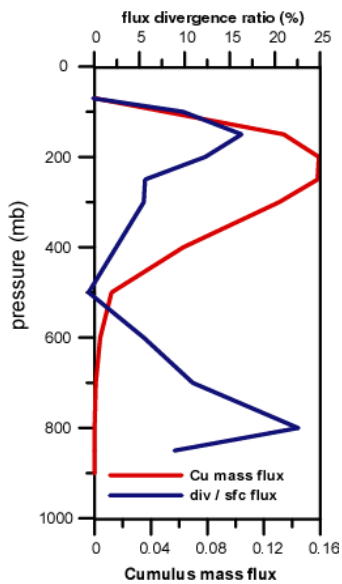

Figure 9: Simulated January vertical profiles of CO_2 flux divergence and cumulus mass flux

Another important issue in the interpretation of concentration measurements in the tropical atmosphere is the influence of deep cumulus convection on the distribution of trace gases. Global inverse models of the carbon budget are relatively insensitive to tropical fluxes because CO_2 anomalies produced by strong surface exchange (due to land use conversion, for example) are "vented" to the upper troposphere by deep convection and therefore "invisible" to the surface flask sampling network. We have investigated this phenomenon in our coupled models, and find that as much as 30% of photosynthetic uptake during the rainy season in the tropical forest is "felt" by the atmosphere above 300 mb (about 10 km), rather than at the surface (Fig 9). The blue line in the figure shows the fraction of the surface flux of CO_2 that leaves the atmospheric column at each model level. Most of the surface flux is felt as advective flux divergence below 600 mb, but the strong secondary maximum in the upper troposphere is associated with the detrainment mass flux from deep cumulus clouds (thunderstorms), which is shown by the red line in Fig 5. This represents a loss of information in inversion calculations, and must be carefully investigated. The deep tropospheric measurements planned under COBRA-BRAZIL will allow evaluation of these simulations.

The "offline" version of SiB2 was able to represent seasonal dynamics of ecosystem fluxes at Santarem with reasonable fidelity (see Fig 1 above). It was somewhat of a surprise therefore, to discover that when coupled to a climate model, interactions between atmospheric circulation, soil moisture, and simulated physiological stress produced catastrophic drying and persistent drought in the region. The model was initiated with saturated soils on January 1, and behaved well during the rainy season. Late in the first

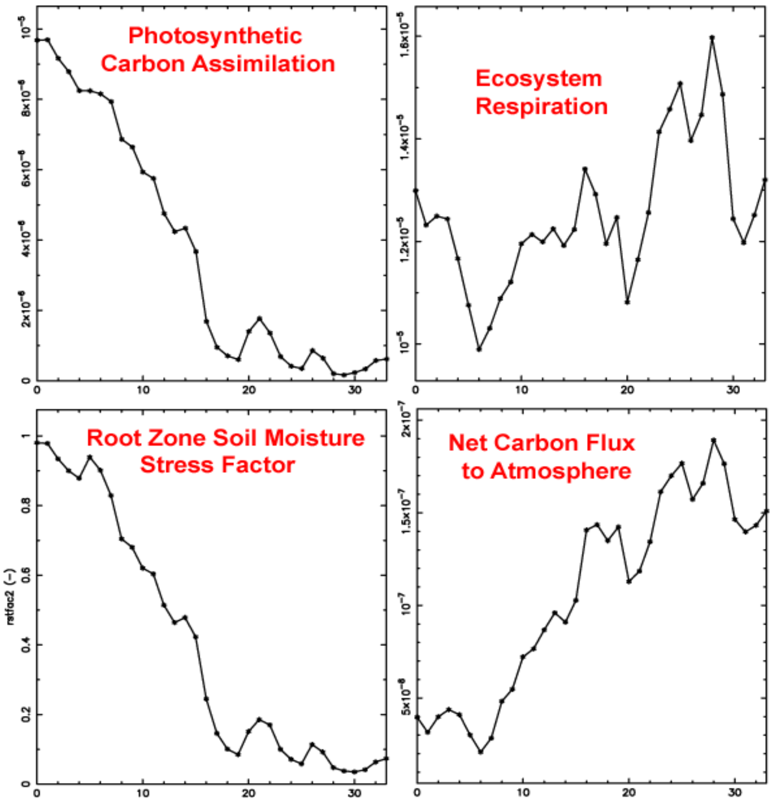

Figure 10: Simulated photosynthesis, respiration, soil moisture stress, and net carbon flux in a 3-year simulation using SiB2 fully coupled to a global climate model (the CSU GCM). The model was initialized with completely saturated soils, but severe drought stress in the first dry season led to hot a dry PBL which prevented the return of the rains. The simulated precipitation, soil moisture, and ecosystem productivity will never recover in these simulations.

year of the simulation however, as soils dried toward the end of the dry season, unrealistic drought stress developed which effectively shut down photosynthesis and transpiration throughout most of the Basin. This unrealistic result is completely consistent with the local-scale simulation results in Rondonia (reported above). In the offline simulations the unrealistic stress only affected the results for a month or two at the end of the dry season, but in the fully coupled model a positive feedback was initiated in which drought stress and high radiation loads produce strong sensible heat flux, leading to a very deep, hot, dry planetary boundary layer over the Amazon. This effectively dilutes moisture advected into the region from the Atlantic, and suppresses PBL relative humidity. The rainy season fails to return, and soils continue to dry by drainage, setting up a permanent drought and massive releases of carbon due to respiration and decomposition (Fig 10). We have in effect replicated the climate catastrophe simulated by Cox et al (2000) in the mid-21st Century, but for current climate conditions! Note that our local-scale simulations have revealed the mechanism behind the unrealistic drought stress in SiB2, and that we have solved this problem by introducing the 10-layer soil model (Fig 2). The next step is to run new climate simulations with the coupled model using the new formulation, which is expected to eliminate the catastrophic drought.

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2. Description of any difficulties encountered or any issues to resolve:

Logistical preparations for our field campaign took much longer than we had hoped. We began daily contacts and paperwork to obtain import permits in January for an anticipated deployment in July. By May, we had been assured that all paperwork was complete and that we were on track to ship our equipment for delivery in early July. Telephone calls to our freight forwarder and the Project Office continued to reassure on this point, but in late May, we were suddenly told that the permit paperwork required further processing in the Customs Department, and that we faced another long delay. This delay was exacerbated by a change in schedule at the Customs Dept. which began processing the paperwork only two days per week. By the time we were finally allowed to ship our equipment, graduate student Elicia Inazawa had already been in Brazil for two weeks. When the equipment arrived in late July, the other projects involved in the Santarém Mesoscale Campaign were nearly complete. We were fortunate that some of Maria Silva Dias' people were able to stay on into August, but the delay in shipping reduced the opportunity for us to put our measurements in the context of the other data being collected in the SMC.

During the preparations for the field campaign, it became apparent that Ray Desjardins would not be able to be on hand in the field for the duration of the campaign. His colleague Dr. Chris Flechard left Agriculture Canada during this period and moved back to his native France. We attempted to enlist his help in the field, and applied for a visa for him to join the campaign. He had been primarily responsible for building and testing the continuous analyzer that we planned to use in the field, so we considered it very important for him to accompany us. As you know, there was some question as to Dr. Flechard's affiliation because he had left the employ of Dr. Desjardins. Thus his request for a visa was denied, and NASA was unable to change this outcome.

As it turned out, we did indeed have substantial problems with the continuous analyzer in the field. Although we were able to calibrate the CHIP and verify that its active control systems maintained internal temperatures and pressures within expected limits, it developed a leak of some kind. The unit may have been damaged in shipping, but the problem was subtle, difficult to detect and diagnose. We spent many hours in the airplane hangar night after night, phoning Drs. Desjardins and Flechard in Canada and Europe and trying to repair the CHIP, but were unable to isolate the problem. This led to very frustrating losses of what should have been valuable data, as we were forced to abandon the use of the instrument for vertical profiling. Data collected on level flight segments appear to be reasonably good, and the comparison with flask data will allow us to salvage some good science from this experiment. Nevertheless, we are disappointed in what appears to have been a major lost opportunity for really great science.

Elicia Inazawa, our Brazilian graduate student, dropped out of school after twice failing the PhD preliminary examination in Atmospheric Science. This was quite a blow to the research program, as Elicia had already completed over two years in the program, and had done a lot of work on the analysis of data collected during our field experiment during 2001. She turned over most of her analyses to Dr. Lixin Lu when she left the University.

Dr. Lixin Lu nearly died in October, 2002 of deep vein thrombosis and a pulmonary embolism which she suffered during a plane flight to China to present an invited paper at a conference. She was evacuated back to the United States where she underwent repeated hospitalizations and slowly recuperated over a period of several months. She attempted to come back to work in early 2003, but suffered from severe anemia and continued difficulty breathing due to damage sustained to her lungs during the embolism incident. She is recovering, and is now on disability leave.

The loss of both Ms. Inazawa and Dr. Lu from the project during the past year has significantly slowed our progress. We have advertised for a new Research Associate to work on the renewal phase under LBA-ECO, and hope to have much better news next year.

3. Participants:

Name: Allan Scott Denning
Role: US-PI/Assistant Professor
University/Organization: Colorado State University
Nationality: USA

Name: Raymond L Desjardins
Role: Co-Investigator/Research Scientist
University/Organization: Agriculture and Agri-Food Canada
Nationality: CANADA

Name: Pedro Leite da Silva Dias
Role: SA-PI
University/Organization: IAG/USP
Nationality: BRAZIL

Name: Maria Assuncao Faus Silva Dias
Role: Co-Investigator/Associate Professor
University/Organization: USP
Nationality: BRAZIL

Name: Chris Flechard
Role: Participant
University/Organization:
Nationality: FRANCE

Name: Elicia Eri Inazawa
Role: Graduate Research Assistant/Field work
University/Organization: Colorado State University
Nationality: BRAZIL

Degree Sought (if student): PhD
Provisional Thesis Title: *Mesoscale variations of* CO_2 *and water vapor over a tropical forest and adjacent pasture and rivers in Brazil*

Name: Lixin Lu
Role: Research Scientist
University/Organization: Colorado State University
Nationality: CHINA

Name: Jason Rist
Role: Student Hourly
University/Organization: Colorado State University
Nationality: U.S.A.
Degree Sought (if student): B.S.

Name: Humberto Ribeiro da Rocha
Role: Co-Investigator
University/Organization: DCA/IAG/USP
Nationality: BRAZIL

Name: Marek Uliasz
Role: Research Scientist
University/Organization:
Nationality: POLAND

Name: Connie Uliasz
Role: Logistics Support/Research Coordinator
University/Organization: Colorado State University
Nationality: USA

4. Description of training activities conducted, including lectures, public outreach, and short courses:

Upper air measurements with balloons; radiosonde receiving station installed to track sondes that are launched in balloons every three hours.

5. Data set descriptions, including status of metadata registration and online data availability

Data Set Title: Coupled Simulations of Physical Climate and CO2 Exchange in Rondonia

Data Set Title: Simulations of Physical Climate and CO2 Exchange in Rondonia and Para

http://lba.cptec.inpe.br/poster/CD-01/Elicia_Belem_jun00.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/lixin.agu2001.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/cmdl.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/AtlantaIsotopes.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/LBA.Belem.poster.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/AtlantaInversions.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/aguwide.ppt

http://lba.cptec.inpe.br/posters/CD-01/Denning/Elicia_AGU_dec00.ppt

ftp://lba.cptec.inpe.br/lba_archives/CD/CD-01/Inazawa/1108.dat
label: data collected on Aug 11th

ftp://lba.cptec.inpe.br/lba_archives/CD/CD-01/Inazawa/1308.dat
label: data collected on Aug 13th

ftp://lba.cptec.inpe.br/lba_archives/CD/CD-01/Inazawa/1408.dat
label: data collected on Aug 14th

ftp://lba.cptec.inpe.br/lba_archives/CD/CD-01/Inazawa/1508_11h.dat
label: data collected on Aug 15th - 11am

ftp://lba.cptec.inpe.br/lba_archives/CD/CD-01/Inazawa/1508_16h.dat
label: data collected on Aug 15th - 4pm

6. List of publications

Silva Dias, M. A. F., P. L. Silva Dias, M. Longo, D. R. Fitzjarrald, and A. S. Denning, 2003. River breeze circulation in eastern Amazon: observations and modeling results. Submitted to *Theoretical and Applied Climatology.*

Uliasz, M. and A. S. Denning, 2003. Deriving mesoscale surface fluxes of trace gases from concentration data. Submitted to *Journal of Applied Meteorology*.