Estimating the effects of Amazonian deforestation on the spatial distribution of rainfall and terrestrial ecosystem dynamics

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Deforestation in the Amazon

Soares-Filho et al. (2006); Merry et al. (2009)
Deforestation in the Amazon

Soares-Filho et al. (2006); Merry et al. (2009)
Future scenarios

Soares-Filho et al. (2006); Merry et al. (2009)
Woodland breeze?

- Smaller scale deforestation:
  - Local circulations due to differential heating;
  - Late dry season: deforested areas are more convective.
Main goals

- Understand how the ongoing and the predicted deforestation affect the climate in the Amazon:
  - Precipitation and cloudiness
  - Local circulations
  - Other mechanisms

- Understand how the ecosystem respond to changes in environmental conditions.
Coupled model: ED2 levels

Moorcroft et al. (2001); Medvigy et al. (2006)
ED2.1 long term dynamics
Coupling between models

- Introduction
- Goals
- Results
- Methods
- Conclusion
Land use conversion

Introduc
tion
Goals
Methods
Results
Conclusion
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Albani et al. (2006)
Deforestation scenario runs

- ED-2.1 only, driven with Sheffield et al. (2006) data:
  - 64-km Potential vegetation:
    - 6 Plant functional types
    - Absolute extinction, steady state, or 500 years
  - Land-use change applied between 1940 and 2039:
    - GLU (Hurtt et al. 2006) between 1940 and 2002
    - SimAmazonia2 (Merry et al. 2009) between 2010 and 2038
    - Interpolation between the two periods
  - Coupled runs:
    - ECMWF-Interim reanalysis for Aug-Oct 2008;
    - Land-use state as of 2008 and 2038.
    - 42km over the tropical South America
    - 16km over Amazonas (1-way nesting)
Deforestation scenario runs
Deforestation scenario runs

Above-ground biomass (2038)
Dry Season

[kgC/m²]

[0.05, 20.00]
Precipitation – Sept-Oct 2008

TRMM (3B42)

EDBRAMS - 2008
Changes due to land use

Precipitation difference (2038 - 2008) - Dry Season

Mean difference - Air temperature

degC

Mean difference - Zonal wind at 1km AGL

m/s
Change due to land use

Precipitation difference (2038 - 2008) - Dry Season [mm]
Change due to land use

Precipitation difference (2038 - 2008) - Dry Season [mm]

Mean difference - Precipitation rate

Mean difference - Canopy Air Temperature
Energy terms. 2008

Seasonal mean - Net shortwave Radiation

Seasonal mean - Downward longwave Radiation

Seasonal mean - Sensible heat flux

Seasonal mean - Evapotranspiration
Differential heating forcing

Above-ground biomass (2008)
Dry Season

\[ B = \frac{1}{\rho^2} \nabla \rho \times \nabla \rho \]
Differential heating forcing

\[ B = \frac{1}{\rho^2} \nabla \rho \times \nabla \rho \]

Above-ground biomass (2038)
Dry Season

Mean - Differential heating forcing - 17 UTC
Latitude: 2.52 S, Dry Season - (2006)

Mean difference - Differential heating forcing - 17 UTC
Latitude: 2.52 S, Dry Season - (2038 - 2006)
Differential heating forcing

Above-ground biomass (2038) Dry Season

\[ B = \frac{1}{\rho^2} \nabla \rho \times \nabla \rho \]
Forest feedback

**Introduction**

**Goals**

**Results**

**Methods**

**Conclusion**
Forest feedback

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**BAU 2008 Simulation - Manaus, AM**

**Time series of mean diurnal cycle: Ecosystem carbon fluxes**

- GFP
- Plant resp.
- Herb. resp.
- NEP

**Net primary productivity - Manaus, AM**

**Time: Sep - 2008**

- C4 Grass
- Early Tropical
- Mid Tropical
- Late Tropical

**BAU 2038 Simulation - Manaus, AM**

**Time series of mean diurnal cycle: Ecosystem carbon fluxes**

- GFP
- Plant resp.
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**Net primary productivity - Manaus, AM**

**Time: Sep - 2008**

- C4 Grass
- Early Tropical
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- Late Tropical
Deforestation shifts precipitation distribution:

- Rainfall reduction at the already deforested coast;
- (?) Shift in diurnal cycle of precipitation over logged forest
- Increase in precipitation along the edge of heavily deforested areas
  - Width of deforestation matters!
Forest feedback:
- Little impact on the productivity of the remaining forest far inland;
-Logged forests experience slight decrease in NEP (temperature and radiation effect);
- High disturbance environment causes increase in fluxes (?)
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Forest or cerrado?

- Frequent droughts (and fires) favors cerrado
- Range in which both biomes are possible
- Changes in climate → savannization?

*Oyama and Nobre (2003)*

*Cox et al. (2004)*
Not a homogeneous place

- Biodiversity has significant spatial patterns;
- Seasonal “greenness” despite being evergreen.

Saatchi et al. (2008)  
Myneni et al. (2007)
Is the forest the only stable state?

- Cerrado could be also stable on the eastern half;
- $\text{CO}_2 \uparrow$: Increased water use efficiency;
- Longer droughts $\Rightarrow$ cerrado is favored;

Oyama and Nobre (2003)

Cox et al. (2001)
Future scenarios

2039 - Business as Usual - SimAmazonia 1

Classes
- Deforested
- Natural forest
- Cerrado
- Managed forest

Soares-Filho et al. (2006); Merry et al. (2009)
Paved road effect

Source: Landsat 5, available at PRODES/INPE
Paved road effect

Source: Landsat 5, available at PRODES/INPE
Coupled model: BRAMS-4.0.6

Advection
Tremback et al. (1987)

Convection
Grell and Dévényi (2002)

Turbulence
Nakanishi and Niino (2004)

Radiation
Harrington et al. (2000)
Toon et al. (1988)

Introduction
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Methods
Results
Conclusion
Land heterogeneities force circulations

- Land/water heterogeneity generates clouds:
  - Large-scale sea-breeze developing squall lines;
  - River-breeze creating minimum convection over rivers.
Impact of deforestation on climate

- **Local deforestation**: local circulation effect dominates;

- **Large-scale deforestation**: evapotranspiration effect dominates;

\[ d’Almeida \textit{et al.} (2007) \]
Differential heating

\[ B = \frac{1}{\rho^2} \nabla \rho \times \nabla p \]