The Issue...
Impact of Deforestation on Precipitation

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Relative Precipitation

Deforestation (%)

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Local, Regional and Global Effects of Amazon Deforestation

Scientific Questions

Does human modification of the landscape affect the characteristics of the atmosphere, the hydrological cycle and water resources? If yes, where? What are the spatial scales of forcing and the spatial scales of response? To what extent? And when?

Outline

1. Regional impact of LU/LCC on convection: GCIP and LBA studies
2. Teleconnections: A GCM analysis
3. Conclusions and research direction

Research funded by NOAA and NASA
The GCIP SW-LSA 1995 Data
Simulation Characteristics

- 3 nested grids (2x2; 8x8; 32x32 km);
- 38 vertical levels up to 22 km 6 a.m. - 6 p.m.;
- 10 s time step in Grid 3;
- NCEP reanalysis assimilated in Grid 1, including wind, geopotential height, potential temperature, and relative humidity;
- Surface fluxes from Zhong and Doran derived from ARM/CART observations and RAMS surface scheme in Grids 1 & 2, with IGBP vegetation class;
- Subgrid-scale turbulence of Mellor & Yamada;
- Radiation of Chen and Cotton.
Raingauge & Weather Surveillance Doppler Radar (WSR-88D) Network of Arkansas-Red Basin River Forecast Center (ABRFC)

http://www.abrfc.noaa.gov
Impact of surface heat flux heterogeneity

With observed fluxes

With domain-averaged fluxes

Horizontal cross-section of $w$ (m/s), 1300 m above ground surface
The LBA Field Campaign in 1999
**Simulation Characteristics**

- 3 nested grids (1x1; 4x4; 16x16 km grid-spacing);
- 38 vertical levels up to 24 km;
- 7 a.m. - 7 p.m.;
- 5 s time step in Grid 3;
- NCEP reanalysis assimilated in Grid 1, including wind, geopotential height, potential temperature, and relative humidity;
- Surface fluxes from RBLE3 observations and RAMS soil-vegetation model in Grid 1, with IGBP vegetation class;
- Subgrid-scale turbulence of Mellor & Yamada;
- Radiation of Chen and Cotton.
\( w \) (m/s) at 3 p.m., 500 m

Clouds at 3 p.m. (from GOES)
Impact of surface heat flux heterogeneity

W (m/s) at 3 pm at 500m
Teleconnection Experiment

- Use of the GISS Model II GCM to study regional and global effects of the Amazon deforestation;
- “Control” has mix of forests and grassland (current vegetation);
- “Deforestation” assumes that the Amazon rainforest is converted into a mix of shrub and grassland;
- Six 12-year realizations for each case.

- 4x5 degree resolution;
- Heat and humidity advected with quadratic upstream scheme;
- Momentum advected with 2nd order scheme;
- Second order closure PBL;
- 6 soil layers, hydrology;
- Climatological SSTs.
Total Precipitation Difference
(Threshold Value is 0.125 mm/day)

"True" ensemble
\[
\begin{pmatrix}
C_1 \\
C_2 \\
C_3 \\
C_4 \\
C_5 \\
C_6
\end{pmatrix}
- 
\begin{pmatrix}
D_1 \\
D_2 \\
D_3 \\
D_4 \\
D_5 \\
D_6
\end{pmatrix}
\]

"False" ensembles
\[
\begin{pmatrix}
C_1 & C_2 \\
C_3 & C_4 \\
C_5 & C_6 \\
C_1 & C_2 \\
C_3 & C_5 \\
C_4 & C_6
\end{pmatrix}
- 
\begin{pmatrix}
C_1 & C_3 \\
C_2 & C_4 \\
C_3 & C_5 \\
C_1 & C_5 \\
C_2 & C_6 \\
C_3 & C_4
\end{pmatrix}
\]
Conclusions

- Both in the Amazon and the Central US regions, the atmospheric boundary layer is significantly affected by land use / land cover change (LU/LCC);
- LU/LCC in the Amazon significantly affects the regional hydro-climatology of South America and other tropical regions, and to a lesser but still significant degree, the hydroclimatology of North America. Convective activity is one of the key factors that trigger teleconnections between tropical regions and mid latitudes;
- Frequently, the landscape heterogeneity created by LU/LCC generates horizontal pressure gradients strong enough to generate and sustain organized mesoscale circulations (synoptic flow determine the orientation of these circulations);
- These circulations affect convective activity, clouds and precipitation. These circulations are neither resolved by, nor parameterized in, GCMs. Clearly, this limits our capability to estimate the real magnitude of teleconnections between the Amazon and the rest of the world.
Impact of Deforestation on Precipitation

Relative Precipitation

Deforestation (%)
\[
\phi = \bar{\phi} + \phi'' \\
\bar{\phi} = \langle \phi \rangle + \phi' \\
\phi = \langle \phi \rangle + \phi' + \phi'' \\
\frac{\partial \langle \mathbf{u}_i \rangle}{\partial t} + \langle \mathbf{u}_j \rangle \frac{\partial \langle \mathbf{u}_i \rangle}{\partial x_j} = -\delta_{i3} g - 2\epsilon_{ijk} \Omega_j \langle \mathbf{u}_k \rangle - \frac{1}{\langle \rho \rangle} \frac{\partial \langle \rho \rangle}{\partial x_i} + \nu \frac{\partial^2 \langle \mathbf{u}_i \rangle}{\partial x_j^2} - \frac{\partial \langle \mathbf{u}_i' \mathbf{u}_j'' \rangle}{\partial x_j} - \frac{\partial \langle \mathbf{u}_i' \mathbf{u}_j' \rangle}{\partial x_j} \\
\frac{\partial \mathbf{u}_i'}{\partial t} + \langle \mathbf{u}_j \rangle \frac{\partial \mathbf{u}_i'}{\partial x_j} + \mathbf{u}_j' \frac{\partial \langle \mathbf{u}_i \rangle}{\partial x_j} + \mathbf{u}_j' \frac{\partial \mathbf{u}_i'}{\partial x_j} = \\
- \delta_{i3} \frac{\theta_v'}{\langle \theta_v \rangle} g - 2\epsilon_{ijk} \Omega_j \mathbf{u}_k' - \frac{1}{\langle \rho \rangle} \frac{\partial \langle \rho \rangle}{\partial x_i} + \nu \frac{\partial^2 \mathbf{u}_i'}{\partial x_j^2} - \frac{\partial \langle \mathbf{u}_i'' \mathbf{u}_i'' \rangle}{\partial x_j} + \frac{\partial \langle \mathbf{u}_i' \mathbf{u}_i' \rangle}{\partial x_j} \\
\frac{\partial \mathbf{u}_i' \mathbf{u}_j'}{\partial t} + \langle \mathbf{u}_j \rangle \frac{\partial \mathbf{u}_i' \mathbf{u}_j'}{\partial x_j} + \mathbf{u}_j' \frac{\partial \langle \mathbf{u}_i \rangle}{\partial x_j} + \mathbf{u}_j' \frac{\partial \mathbf{u}_i' \mathbf{u}_j'}{\partial x_j} = \\
\nu \frac{\partial^2 \mathbf{u}_i' \mathbf{u}_j'}{\partial x_j^2} + \psi_0' - \frac{\partial \langle \mathbf{u}_i'' \mathbf{u}_i'' \rangle}{\partial x_j} + \frac{\partial \langle \mathbf{u}_i' \mathbf{u}_i' \rangle}{\partial x_j} \\
\frac{\partial \langle \mathbf{u}_i' \theta' \rangle}{\partial t} + \langle \mathbf{u}_j \rangle \frac{\partial \langle \mathbf{u}_i' \theta' \rangle}{\partial x_j} + \langle \mathbf{u}_j' \theta' \rangle \frac{\partial \langle \mathbf{u}_i \rangle}{\partial x_j} + \langle \mathbf{u}_j' \mathbf{u}_j' \rangle \frac{\partial \langle \theta \rangle}{\partial x_j} + \frac{\partial \langle \mathbf{u}_i' \mathbf{u}_j' \theta' \rangle}{\partial x_j} = \\
\delta_{i3} \frac{g}{\langle \theta' \rangle} \langle \theta' \theta' \rangle + 2\epsilon_{ijk} \Omega_j \langle \mathbf{u}_k' \theta' \rangle - \frac{1}{\langle \rho \rangle} \langle \theta' \frac{\partial \langle \rho \rangle}{\partial x_i} \rangle + \langle \mathbf{u}_i' \psi_0' \rangle + \\
\langle \theta' \nu \frac{\partial^2 \mathbf{u}_i'}{\partial x_j^2} \rangle + \langle \mathbf{u}_j' \nu \frac{\partial^2 \theta'}{\partial x_j^2} \rangle - \langle \theta' \frac{\partial \langle \mathbf{u}_i'' \mathbf{u}_i'' \rangle}{\partial x_j} \rangle - \langle \mathbf{u}_i' \frac{\partial \mathbf{u}_i'' \theta''}{\partial x_j} \rangle 
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Publications


- Weaver, C.P., S. Baidya Roy, and R. Avissar. A sensitivity analysis of large-scale boundary-layer characteristics to initialization and forcing under realistic meteorological and surface conditions. *J. Geophys. Res. (LBA Special Issue)*, in revision.

