Weak Simulated Extratropical Responses to Complete Tropical Deforestation

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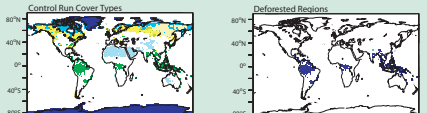
Overview:

- **Complete conversion of tropical forests to grasslands leads to…**
  - Significant climatic changes in deforested areas;
  - Broad upper-tropospheric warming throughout the tropics;
  - Little statistically significant response beyond the tropics.
- Differences of the same magnitude as those seen in the extratropics are present in a comparison of two long segments of the control run.
- ***Final conclusion:*** According to this model, **extratropical responses to complete tropical deforestation are unlikely to be distinguishable from natural climate variability.**

Model Description and Experimental Design

- *The mixed-layer version of the GFDL model (SM2.0)*
  - See Delworth et al (2005) for information about the fully coupled atmosphere/ocean model;
  - GAMDT (2004) for information about the atmosphere/land model; and
  - Milly and Shmakin (2002) for information about the land model.
- *2.5° longitude by 2° latitude, with 24 vertical levels*
- *130 year-long control run with 1990 conditions*
- *70 year-long tropical deforestation run with all broadleaf evergreen forests replaced by grassland*
- *Comparison of 50 year segments of the two runs (years 51-100 of the control run vs. 21-70 of the deforestation run)*
- *Two 50 year segments of the control run are compared to each other (years 31-80 vs. 81-130)*

Land Cover Types in the GFDL Model



1990-based cover types determined from Matthews (1983) and Hurtt et al. (in review).

All broadleaf evergreen trees are converted to grasslands in the tropical deforestation experiment.

Land cover classifications

1) broadleaf evergreen trees
2) broadleaf deciduous trees
3) broadleaf/needleleaf trees
4) needleleaf evergreen trees
5) needleleaf deciduous trees
6) grassland
7) desert
8) tundra
9) ice

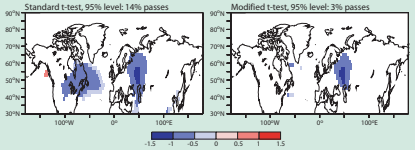
Parameter changes from replacement of tropical broadleaf evergreen trees with grasslands

– surface albedo from 0.149 to 0.182
– surface roughness length from 2.65m to 0.07m
– minimum bulk stomatal resistance from 8.7s/m to 11.3s/m
– effective rooting depth from about 1.3 to 1.0m

Statistical Techniques

- *Accounting for temporal autocorrelation:*
  - Used the modified t-test of Zwiers and von Storch (1995).

Control vs. Control SON 850mb Temperature (°C)
(Differences plotted only where statistically significant)

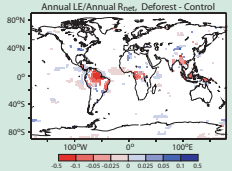


- *Accounting for spatial correlation:*
  - Used the Livezey and Chen (1983) methodology for determining field significance.
- *Compared differences between the deforestation and the control runs with a benchmark comparison of two long segments of the control run.*

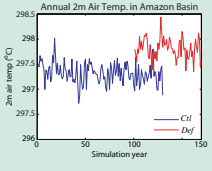
Significant Tropical Differences

(Differences plotted only where statistically significant)

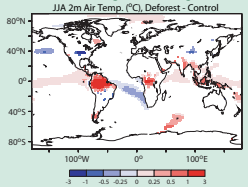
Reduction in proportion of net radiation (R_{net}) going into latent heating (LE)



Annual mean surface warming in the Amazon



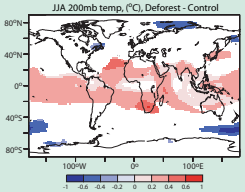
Significant surface warming in altered regions in all seasons



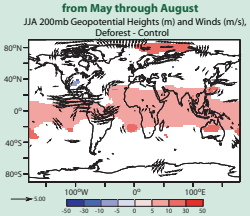
Model differences in the Amazon Basin are similar to differences in previous studies of tropical deforestation

Changes for the Amazon Basin in Response to Deforestation	Temp Δ (°C)	Precip Δ (mm/yr)	ET Δ (mm/yr)
This study	*+1.0*	*-159*	*-175*
McGuffie et al. (1995) - range for 9 earlier studies	*-0.11 to 3.8*	*-640 to +394*	*-985 to -164*
- mean	*+1.55*	*-290*	*-333*
- median	*+2.0*	*-335*	*-231*
Zhang et al. (1996)	*+0.3*	*-402*	*-222*
Lean & Rowntree (1999)	*+1.73*	*-139*	*-259*
Gedney & Valdes (2000)	*+1.3*	*-288*	*-237*

Broad upper-tropospheric warming throughout the tropics, significant from May through August

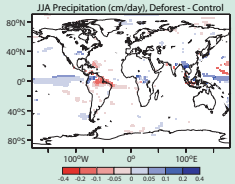


Upper-level geopotential height anomalies significant throughout the tropics from May through August



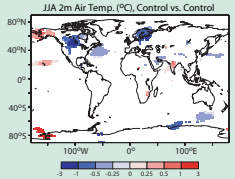
Limited Significant Differences in the Extratropics

(Differences plotted only where statistically significant)



Comparison with Control vs. Control Benchmark

- Differences of similar magnitude as those seen in the extratropics in the deforestation vs. control comparison are present in the control vs. control comparison.



- *Comparison of two sets of differences for 20 variables:*
  - Soil moisture, precipitation, evaporation, sensible heat flux, E-P, SST, geopotential heights, temperatures, and zonal and meridional winds near the surface and at three additional levels.
  - Livezey and Chen (1983) show that 12.5% of an area must pass 95% significance tests for the field to be significant at the 95% level if there are approximately 40 spatial degrees of freedom (dof).
    - Reported dof values in various literature sources range from about 20 to about 100, depending on the variable, season, and spatial and temporal scales; 40 is used as a representative value (see, eg., Van den Dool and Chervin, 1986).

Number of Variables with >12.5% Area Passing Modified 95% Significance Test (max = 20)

Control vs. Control

	DJF	MAM	JJA	SON
30°N - 90°N	*0*	*0*	*2*	*2*
30°S - 90°S	*0*	*0*	*0*	*0*

Deforest vs. Control

	DJF	MAM	JJA	SON
30°N - 90°N	*0*	*0*	*1*	*0*
30°S - 90°S	*1*	*0*	*0*	*0*

- *A thorough assessment of significance in the deforested-control comparison would require Monte Carlo-type experiments using a very long control run so that one could develop a statistical distribution of expected passing rates for each variable and each season independently.*
- *Given the relatively small magnitudes of changes and the limited spatial coverage of locally significant differences between the deforested and control runs, we have not performed such comprehensive tests for this study.*

Conclusions:

- Tropical responses to complete tropical deforestation may be extensive.
- Extratropical responses are generally small in magnitude, and, with a few noted exceptions, not statistically significant.
- Essentially no statistically significant responses were simulated in the Northern Hemisphere extratropics.
- In the Southern Hemisphere extratropics, no statistically significant changes were simulated in any hydrologic fields. A few localized areas with possibly statistically significant temperature and wind anomalies were simulated in the Southern Hemisphere extratropics during some seasons.
- However, a similar comparison of two 50-year segments of the control run yields differences of the same magnitudes and the same apparent significance.
- This leads us to conclude that according to the GFDL model, **extratropical responses to complete tropical deforestation (ignoring greenhouse gas effects) are unlikely to be distinguishable from natural climate variability on a time scale of 50 years.**

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