10.6 TELECONNECTIONS RESULTING FROM TROPICAL DEFORESTATION

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1. INTRODUCTION

The effects of tropical rainforest removal have been studied extensively through the use of global climate models (GCMs) (Henderson-Sellers et al., 1993; Werth and Avissar, 2002; Clark, 2001; Rind, 1984). Tropical deforestation increases the local surface albedo (Charney et al., 1977; Rind, 1984; Eltahir, 1996), thereby decreasing the net surface radiation, and reduces evapotranspiration (Xue et al., 1990), with a reduction of latent heat into the boundary layer. By making its effects felt throughout a deeper layer of the atmosphere, tropical deforestation has the potential to affect areas remote from the deforested region.

In their GCM study, Werth and Avissar (2002, hereafter referred to as WA2002) used the Goddard Institute for Space Studies (GISS) Model II GCM (Hansen, 1983) to simulate the effects of deforesting the Amazon basin, which was converted to a mixture of shrubs and grassland. They identified a strong reduction in wet season precipitation in the Amazon, as had been seen in numerous other modeling studies (Henderson-Sellers et al., 1993). They also noted a statistically-significant signature at other tropical and midlatitude regions, which they refer to as a “land-cover change teleconnection”.

Large tropical rainforests also exist over equatorial West Africa and Southeast Asia, and models have been used to simulate the local effects of deforesting these areas as well (Clark, 2001; Rind, 1984; Zheng and Eltahir, 1997; Xue et al., 1990; Hales et al., 2004, Suh and Lee, 2004; Henderson-Sellers et al., 1993). The alterations in the atmospheric column above the deforested areas have the potential to teleconnect to remote regions, including areas in the midlatitudes. Avissar and Werth (2004) have also used a GCM to simulate the effects of deforesting these areas, and observe remote precipitation effects that seem to be linked to the rainforest removal.

What changes caused by deforestation in one tropical area are being communicated throughout the tropics and into the midlatitudes? We attempt to determine that here by looking at the simulated time-mean changes in upper-level geopotential. If a change to the land cover (a model forcing) is to have an effect on areas throughout (and beyond) the Tropics, it is likely that it will do so through the propagation of the ‘signal’ through the large-scale geopotential. A reduction in latent heating that accompanies a reduction in precipitation will result in a secondary-circulation as the atmosphere strives to maintain hydrostatic balance (Bluestein, 1992). Rising motion will be reduced to offset the loss of diabatic heating, and geopotential surfaces will fall above the cooling level and rise below it. These changes can then be spread elsewhere by the tropical easterly winds.

2. AMAZON GEOPOTENTIAL CHANGES

In their Amazon deforestation study, WA2002 observed significant reductions in precipitation in several tropical areas during their respective rainy seasons. They also noticed reductions in midwestern precipitation during the July rainy period. This is despite the fact that the Amazon basin precipitation is at its minimum in July, and no change due to deforestation exists. At this time, however, large precipitation reductions exist over Columbia and Venezuela (in which some deforestation does exist). Fig. 1 shows large geopotential reductions at 247mb over the eastern equatorial Pacific in response to deforestation, downstream of the area of reduced precipitation. Significant geopotential changes form a stationary wave-like pattern that extends into the midlatitudes, with a ridging pattern over the western US. This results in an increase in the advection of both negative vorticity and cooler, drier air into the midwest, reducing summertime precipitation.

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3. AFRICAN GEOPOTENTIAL CHANGES

When the Congo river basin is deforested (Avissar and Werth, 2004) several remote areas experience significant precipitation changes in September, near the peaks of their rainy seasons. Three such areas are in the Gulf of Mexico, the Eastern Atlantic, and over Yemen on the Saudi peninsula. The reductions in geopotential at this time (Fig. 2) are strongest over Africa (where precipitation changes are relatively modest during this month), and spread throughout the tropics, even extending upstream into the Indian Ocean. Large increases in geopotential exist over Iraq. Each area with precipitation changes exists within or near the area of large-scale geopotential reduction. This suggests that the local changes to the equatorial African rainforest can be propagated upward through the consequent changes in precipitation, and then spread throughout the tropics. These can in turn change the precipitation in tropical areas affected by the geopotential reductions.

4. SOUTHEAST ASIAN GEOPOTENTIAL CHANGES

The Southeast Asian rainforest is distributed among a series of islands. Therefore, its removal could likely have a weaker effect than that observed for Amazon and African deforestation since the effects on each landmass will be mitigated by the surrounding water.

In January (Fig. 3, top), geopotential falls over the Philippine Sea in response to deforestation. As it did for the Amazon deforestation, a stationary wave-like pattern exists in the northern hemisphere, this time extending over Asia and into the North Atlantic. It is the latter area that experiences a significant reduction in January precipitation, possibly as a result of the ridging pattern established overhead. In August (Fig. 3, bottom), geopotential reductions are more widespread over Southeast Asia, as this is at the peak of the rainy season. These changes extend across the Indian Ocean and into Southwest Asia and East Africa. Reaching into the Saudi peninsula, they also induce a precipitation increase during that region's rainy season.

5. CONCLUSIONS

With this GCM, we have demonstrated that a land-surface change in a tropical area can cause geopotential surfaces in the upper troposphere to fall, and that these geopotential changes can spread the throughout the tropics and into the midlatitudes. The large-scale geopotential provides a possible link between a land surface change in one region and precipitation changes elsewhere, but the exact mechanism behind the signal propagation is not fully understood. A more detailed analysis of the large-scale dynamics associated with tropical deforestation is a topic of current research.

Acknowledgement – This research was supported by the National Aeronautics and Space Administration (NASA) under Grants NAG 5-8213 and NAG5-9359. The views expressed herein are those of the authors and do not necessarily reflect the views of NASA.

6. REFERENCES

Avissar, R.,and D. Werth, 2004: Global Hydroclimatological Teleconnections Resulting from Tropical Deforestation, *J. Hydromet.,* in press

Bluestein, H., 1992: *Synoptic-Dynamic Meteorology in Midlatitudes, Volume I: Principles of Kinematics and Dynamics*, Oxford University Press, New York

Charney, J., W. Quirk, S.-H. Chow, and J. Kornfield, 1977: A Comparative Study of the effects of Albedo Change on Drought in Semi-Arid Regions, *J. Atmos. Sci*., **34**, 1366-1385

Clark, D., Y. Xue, R. Harding, and P. Valdes, 2001: Modeling the Impact of Land Surface Degradation on the Climate of Tropical North Africa, *J. Clim*., **14**, 1809-1822

Eltahir, E., 1996: The role of vegetation in sustaining large-scale atmospheric circulations in the tropics, *J. Geophys. Res*., **101**, 4255-4268

Hales, K., D. Neelin, and N. Zeng, 2004: Sensitivity of Tropical Land Climate to Leaf Area Index : Role of Surface Conductance versus Albedo, *J. Clim*., **17**, 1459-1473

Hansen, J., G. Russell, D. Rind, P. Stone, A. Lacis, S. Lebedeff, R. Reudy, and L. Travis, 1983: Efficient Three-Dimensional Global Models for Climate Studies: Models I and II, *Mon. Weath. Rev*., **111**, 609-662

Henderson-Sellers, A., R. Dickinson, T. Durbridge, P. Kennedy, K. McGuffie, and A. Pittman, 1993: Tropical deforestation: modeling local- to regional-scale climate change, *J. Geophys. Res*., **98**, 7289-7315

Rind, D., 1984: The Influence of Vegetation on the Hydrologic Cycle in a Global Climate Model, *Climate Processes and Climate Sensitivity*, Geophysical Monograph 29, Maurice Ewing Volume 5

Suh, M.-S., and D.-K. Lee, 2004: Impacts of land use/cover changes on surface climate over east Asia for extreme climate cases using RegCM2, J. Geophys. Res., **109**, D02108, doi:10.1029/2003JD003681

Werth, D., and R. Avissar, 2002: The local and global effects of Amazon deforestation, *J. Geophys. Res.*, 107

Xue, Y., K.-N. Liou, and A. Kasahara, 1990: Investigation of Biogeophysical Feedback on the African Climate Using a Two-Dimensional Model, *J. Clim.*, **5**, 337-352

Zheng, X., and E. Eltahir, 1997: The response to deforestation and desertification in a model of West African monsoons, *Geo. Res. Lett.*, **24**, 155-158

Acknowledgement – This research was supported by the National Aeronautics and Space Administration (NASA) under Grants NAG 5-8213 and NAG5-9359. The views expressed herein are those of the authors and do not necessarily reflect the views of NASA.

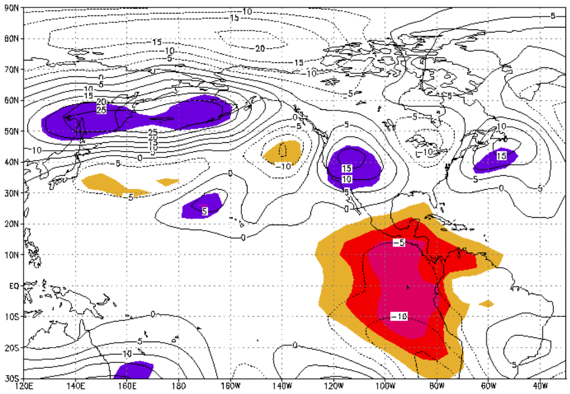

Fig. 1 Changes in 247mb geopotential (m, contours) in response to Amazon deforestation in July. Shaded areas are significant at 95% as determined by Student's t-test.

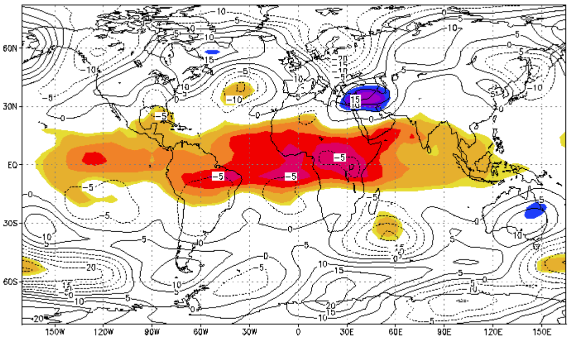

Fig. 2 As in Fig. 1, but for the September response to African deforestation.

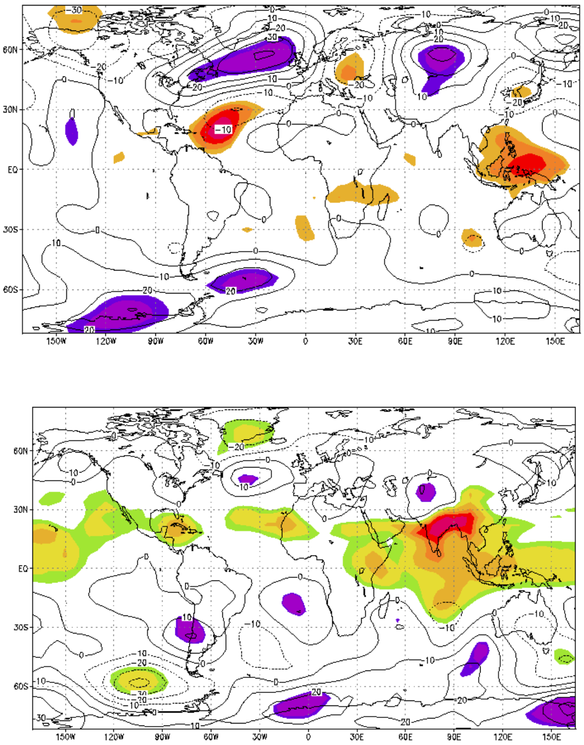

Fig. 3 As in Fig. 1, but for the January response to Asian deforestation (top), and the August response to Asian deforestation (bottom).