Atmospheric effects of human modification of the landscape

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Does human modification of the landscape affect climate (including characteristics of the atmosphere, hydrological cycle and water resources), and if so, where, when, at what scales, and to what extent? The research discussed here deals with regional impacts of land use/land cover change (LU/LCC) on convection and precipitation in the central U.S. and the tropics, and looks at teleconnections of LU/LCC.

Landscape Heterogeneity and Convergence in the Central U.S.

Significant atmospheric effects caused by human modification of the landscape have been documented over the continental U.S. Observations and an atmospheric model demonstrate that diurnal, thermally-induced circulations occur during summer over a 250 x 250 km region in Oklahoma and Kansas (see Figure 1). Results indicate that:

- the driving force behind these circulations is the landscape heterogeneity resulting from differential land use patterns,
- such atmospheric phenomena are characteristic of surfaces with this type of heterogeneity and not limited to infrequent days when unusual wind or other meteorological conditions prevail,
- the net effect of these motions is significant, not only locally, but also at the regional and global scales.

[insert slide as Figure 1 - Roni, which slide shall we use here?]

Figure 1 shows the zones of atmospheric convergence caused by landscape heterogeneity in a 2x2 km nested grid (resolution fine enough to resolve convection) at the Oklahoma ARM site. If the model is run with the same total heat flux but without the heterogeneity, the convergence zones do not form. This adds confidence that the convergence is caused by the landscape heterogeneity.

Local, Regional, and Global Effects of Amazon Deforestation

What is the impact of deforestation on precipitation? It is widely believed that deforestation will decrease relative precipitation in the region but it has been assumed that the decline in precipitation will be generally linear. The research discussed here indicates that 20-30% deforestation will actually increase thunderstorm activity and thus precipitation, and that beyond 30% deforestation, precipitation would decline very rapidly as seen in Figure 2.

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Rondonia Results

Data are from a 1999 field campaign in Rondonia using satellites, radar, towers, radiosondes, planes, etc., and a model at 1 km resolution which resolves convection well. The results indicate that atmospheric convergence was highly correlated with deforested area.

At least a 5-km patch of heterogeneity is needed to produce convergence, with a 70-100 km patch producing the maximum effect. Interestingly, this is the natural pattern of development occurring now in the Amazon, and this is causing the maximum impact.

Teleconnections

Some modelers projected a 20-30% reduction in regional precipitation if the entire Amazon was deforested, but concluded that there would be no impact on global scale climate. The research discussed here indicates that that this is an incorrect interpretation and that there are teleconnections of the Amazon thunderstorm activity increase that results from up to 30% deforestation.

With regard to teleconnections, it is important to note that regional effects can be very significant even when the global effect is small or zero. Similarly, seasonal effects can be large even if annual average effects are not. For example, in this analysis, Amazon precipitation on an annual basis declines 23%, but seasonally, the changes are much larger, with the most significant impact occurring in the summer months in the Amazon and in August through October in the Gulf of Mexico. In the U.S., the largest impact comes in summer when the 16-17% decrease in precipitation comes at the most important time for agriculture, suggesting significant negative impacts.

Conclusions

In both the Central US and Amazon 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 triggers 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 determines 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.

Misc. notes:

GCMs do not represent mesoscale eddys
Can expand RAMS model to global scale to bring these effects in, using nested grids over areas of interest.
This effect can be parameterized.