Climate and Sustainability

Prof. Dr. habil. Jürgen Kesselmeier, Max Planck Institute for Chemistry, Mainz, Germany

A tropical rainforest such as the Amazon region interacts significantly with the atmosphere. It serves as a carbon sink, cools and cleans the atmosphere, keeps the global atmospheric cycle running and stores water on a grand scale. Land use changes, particularly if done in an unsustainable way, will dramatically affect forest/soil water evapotranspiration and atmospheric radical chemistry (the atmospheric washing machine) which is driven by biogenic reactive trace gases. Aerosol particles influencing the energy cycling within the atmosphere, both directly and indirectly, will be affected by changes in the biogenic release of precursors, as well as by an increase of anthropogenic sources. It is for these reasons that the vast tropical Amazonian rainforest is regarded as a hotspot, both in terms of its current, and importantly, its future state.

Reports confirm the significance of the biosphere (Andreae et al., 2002) for the biogeochemical cycling of carbon, water, energy, aerosols, and trace gases in the Amazon Basin. At present, the undisturbed Amazonian rainforest is considered to be a large net carbon sink, or as being in equilibrium with the atmosphere on the long term (excluding short term climatic effects). Trace gases such as nitrogen oxides, emitted by forest soils, are recycled within the canopy, as a large fraction of soil-derived NOx is recaptured by the vegetation. This is of high relevance for atmospheric chemical reactions driven by the ratio between NOx and volatile organic compounds (VOCs). For VOCs, the forest acts as both a sink and a source. Highly reactive VOCs are released and partially oxidized organics can be deposited again. In the course of several joint field experiments and aircraft campaigns within the framework of LBA (The Large Scale Biosphere-Atmosphere Experiment in Amazonia) such reactive trace gas fluxes were investigated from the scale of a leaf to a landscape (Kuhn et al., 2007). Field observations of VOCs and their oxidation products were found to be in disagreement with current knowledge on atmospheric chemistry, indicating that atmospheric chemical processes were not adequately represented in chemical models. The hydroxy radical (OH) concentrations had to be assumed to range one order of magnitude higher than previously estimated. These findings are in close agreement with recent reports by Lelieveld et al. (2008), who explained unexpectedly high OH concentrations found in the tropical atmosphere as being due to the recycling of OH driven by natural VOC oxidation, notably of isoprene, especially in the low-NOx air of remote regions. These examples demonstrate the need for further laboratory studies and to invest more work into the exploration of biogenic emissions and atmospheric chemistry. Furthermore, volatile organic compound emissions may significantly contribute to the carbon cycle (Kesselmeier et al., 2002). Kuhn et al. (2007) have reported that 1 – 6 % or more of the net ecosystem carbon gain for the Amazonian vegetation appeared to be re-emitted through VOC emissions.

The concentrations of aerosol and cloud condensation nuclei (CCN) fluctuate in close accordance with seasonal effects, such as wet/dry season cycles and anthropogenically caused forest clearing and show a pronounced maximum in the dry (burning) season. Forest clearing by burning transforms the Amazonian atmosphere, with low particle concentrations, to an anthropogenically polluted area with high aerosol loading. High particle concentrations from biomass burning have a pronounced impact on cloud microphysics and rainfall production mechanisms. Thus, cutting down the forests will change the regional and global hydrological cycle as well as atmospheric chemistry and physics, and the Amazon region could even shift into a savannah system. By simulating these hydrometeorological changes caused by deforestation in the Amazon region, Da Silva et al. (2008) have demonstrated a coherent basin wide rainfall decrease, which may result in a catastrophic collapse of the regional ecosystem.

These examples as summarized above, demonstrate that sustainable land use, or development, can only be defined if they are based on a solid understanding of the current biological, chemical and physical processes which are the drivers of the Amazonian climate and which then impacts the global climate. With regard to the particular importance of this region, the Max Planck Society maintains a branch in Manaus, in the heart of the Amazon. Research covers aspects of biosphere atmosphere exchange and its influence on gas phase and particle chemistry and physics in close relation to forest ecology, the carbon cycle, land use and land use changes. Flux towers with heights of 1.5 - 2 times the canopy height are used to investigate the exchange processes of trace gases within the surface layer in order to understand key atmospheric processes, with emphasis on the atmospheric oxidant cycle and the life cycle of the Amazonian aerosol. Furthermore, the construction of a very tall tower with a planned height of about 300 m (Amazonian Tall Tower Observatory, ATTO) has been agreed on by the German Federal Ministry of Education and Research (BMBF) and the Brazilian Federal Ministry of Science and Technology (MCT) to monitor greenhouse gases as well as reactive gases and aerosols on a larger regional scale of several hundreds of kilometers over the Amazonian rain forest. The tower observations will support, and will be supported by, diagnostic and prognostic modeling of regional climate change and atmosphere-biosphere exchange processes. The goals are to observe and interpret the relationships between climate, atmospheric chemistry/physics and the Amazonian ecosystem, as well as the regional anthropogenic impacts during the current and future periods of anticipated rapid change.

References

Andreae MO, Artaxo P, Brandao C, Carswell FE, Ciccioli P, da Costa AL, Culf AD, Esteves JL, Gash JHC, Grace J, Kabat P, Lelieveld J, Malhi Y, Manzi AO, Meixner FX, Nobre AD, Nobre C, Ruivo MDLP, Silva-Dias MA, Stefani P, Valentini R, von Jouanne J, Waterloo MJ (2002): J. Geophys. Res.-Atmospheres 107 (D20) Article Number: 8066.

Da Silva, R. R., Werth, D., Avissar, R. (2008) Regional impacts of future land-cover changes on the amazon basin wet-season climate. Journal of Climate 21 (6), 1153-1170.

Kesselmeier, J., Ciccioli, P., Kuhn, U. Stefani, P., Biesenthal, T., Rottenberger, S., Wolf, A., Vitullo, M., Valentini, R., Nobre, A., Kabat, P., Andreae, M.O. (2002): Volatile organic compound emissions in relation to plant carbon fixation and the terrestrial carbon budget, Global Biogeochem. Cycles, 16(4), 1126, doi:10.1029/2001GB001813.

Kuhn, U., Andreae, M.O., Ammann, C., Araújo, A.C., Brancaleoni, E., Ciccioli, P., Dindorf, T., Frattoni, M., Gatti, L.V., Ganzeveld, L., Kruijt, B., Lelieveld, J., Lloyd, J., Meixner, F.X., Nobre, A., Pöschl, U., Spirig, C., Stefani, P., Thielmann, A.,Valentini, R., and Kesselmeier, J. (2007): Isoprene and monoterpene fluxes from Central Amazonian rainforest inferred from tower-based and airborne measurements, and implications on the atmospheric chemistry and the local carbon budget. Atmospheric Chemistry and Physics 7 (11), 2855-2879.

Lelieveld J, Butler TM, Crowley JN, Dillon TJ, Fischer H, Ganzeveld L, Harder H, Lawrence MG, Martinez M, Taraborrelli D, Williams J (2008): Atmospheric oxidation capacity sustained by a tropical forest. Nature 452 (7188), 737-740.

Contact:
J. Kesselmeier
Email: j.kesselmeier@mpic.de
http://www.mpch-mainz.mpg.de/mpg/english/index.html