Comparison of measured reactive trace gas profiles with a multi-layer canopy chemical exchange model in an Amazonian rainforest

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WHAT ARE WE DOING IN THE DEEP RAINFOREST?

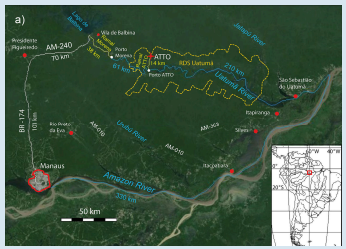

Fig. 1: Location of the ATTO site. The main map shows the access to the site via the road and riverboat connections (background map from Google Earth).

Fig. 2: The 325 meter high ATTO tower

In 2010 and 2011, two 80 m high towers for atmospheric research were erected at the ATTO site (Amazon Tall Tower Observatory) (02°08'38.8"S, 58°59'59.5"W) in the remote Amazonian rainforest. In 2015 the construction of the 325 m high ATTO tower was completed.

The nearly pristine environment allows biosphere-atmosphere studies within an ecosystem far away from large anthropogenic emission sources. Combined analyses of measurements from all three towers promises new insights in several emission, deposition, chemical and transport processes.

MEASUREMENTS AND CHALLENGES

Fig 3: The 80 m high walk up tower

Fig 4: The reactive trace gas profile system inside the container

Fig 5: The inlet tube at 54 m hight with 5um filter and funnel

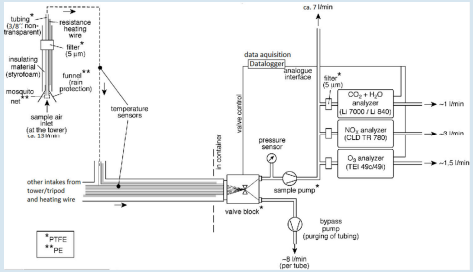

Fig. 6: Profile system with inlets and analysers [courtesy of A. Moravek]

Since April 2012 vertical mixing ratio profiles of H_2O, CO_2 and O_3 were measured at 8 different heights between 0.05 m and 79.3. Valves of the profile system switch every two minutes to change the active height. The instruments are located within a container about 15 m beside the 80 meter walk up tower. The inlet lines of the three lowermost heights are placed on a nearby tripod. For drying the inlet air, we use a system of 5 parallel Nafion tubes.

During five intensive campaigns (Oct-Dec 2012, Oct-Nov 2013, Mar 2014, Aug-Sep 2014, Oct-Dec 2015) nitric oxide (NO) and nitrogen dioxide (NO_2) were also measured. Since the end of 2015 NO_x measurements are performed continuously.

METEOROLOGY IN THE AMAZON

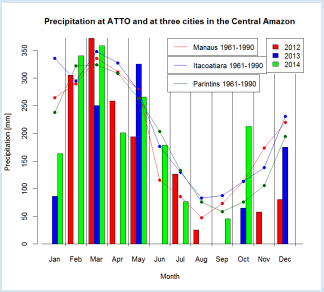

Fig. 8: Precipitation at the ATTO site compared with three different sites in the Amazon basin (adapted from Andreae et al., 2015)

The climate in the Central Amazon is characterized by monthly average temperatures of 26-28°C and strong variations in precipitation between the wet (Jul-Oct) and the dryer season (Jan-Apr) (see fig.5). As the ATTO site is located inside the South American trade wind zone, the predominant winds come from NE/ENE directions.

During the wet season almost pristine and clean air is often predominant at the ATTO site, whereas biomass burning is strongly effecting trace gas concentration and aerosol load during the drier months (see figure 6).

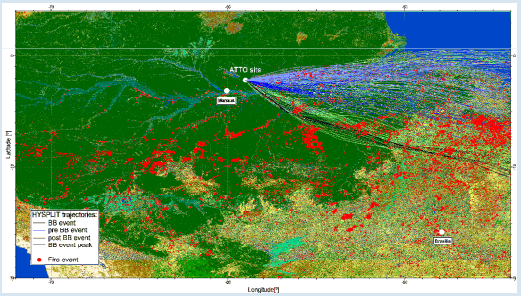

Fig. 8: Back trajectories for the ATTO site between 12 Aug 2014 and 28 Aug 2014 overlying a landscape map with fire sources. Dark blue lines represent conditions before 17 Aug, bright blue lines after 23 Aug, green line represent conditions between 17-23 Aug, black lines represent the peak time: 19 Aug 12:00 – 20 Aug 12:00 (Courtesy of C. Pöhlker, T. Könemann, D. Walter, J. Saturno, F. Ditas)

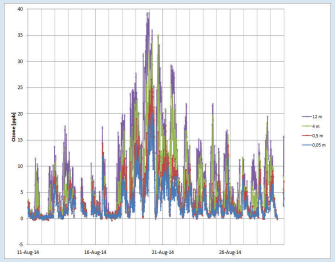

Fig. 9: Ozone mixing ratios at the ATTO site between 11/08 and 29/18/2014 measured by a TEI 49i analyzer

Figure 7 shows the strong effect of biomass burning events in August 2014 on the ozone concentrations. The polluted air on 19/08 exhibited O_3 mixing ratios which were about three times higher than those, measured during the days before.

In case of further and closer deforestation to the ATTO site we expect increasing O_3 concentrations, which can effect and damage plant surfaces.

RESULTS AND DISCUSSION

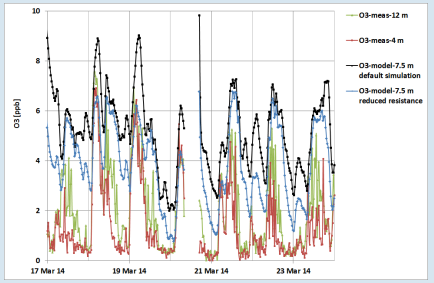

Fig. 11: Comparison of the observed and simulated RWS-O_3 run for O_3 mixing ratios within the soil layer (measured, red and green, model, blue) for the wet season 2014

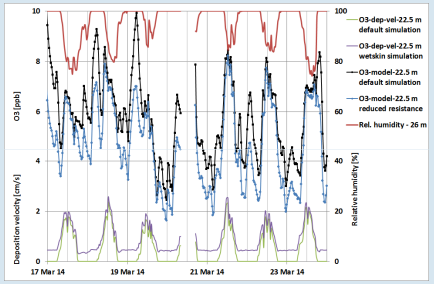

Fig. 12: Simulated O_3 mixing ratios for the default simulation (green line) and the simulation with reduced wet skin uptake resistance for O_3 (black line) compared with changed deposition velocities (green and purple lines) and relative humidity (red line)

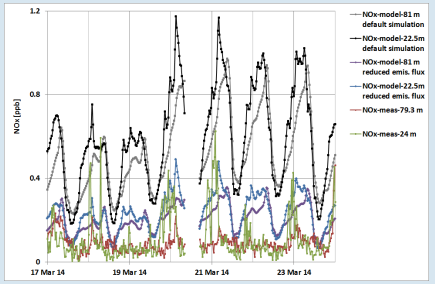

Fig. 13: MLC-CHEM simulation using reduced NO emission fluxes (purple and blue lines) compared with measurements (red and green lines) for NO_x mixing ratios within the crown layer and surface layer for the wet season

Measurements of trace gases are generally limited spatially (both horizontally and vertically). In order to generalize, to fill gaps and to understand the controls on the exchange, the application of atmosphere-biosphere exchange models can help to complement the observations and support analysis of the observations (magnitude, temporal variability).

Through the combined use of detailed multi-compound long-term observations and the canopy exchange model "MLC-CHEM" we could improve our understanding of turbulent transport processes as well as emissions, deposition, and chemical processes occurring in the Amazon rainforest.

The MLC-CHEM-model version we have used contains three different layers:

Soil layer (SOL) : 0 m – 15 m: Center at 7.5 m
Crown layer (CRL): 15 m – 30 m: Center at 22.5 m
Surface layer (SUL): 30 m – 110 m: Center at 70 m

which should correspond fairly well to the following measured heights: 4 m / 12 m, 24 m, 79.3 m.

The surface layer was constrained with measured O_3 data from 79.3 m height. Simulated O_3 values inside the canopy were some ppb higher than measured data. Sensitivity analyses with enhanced deposition velocities on wet surfaces led to better correlations.

Yienger and Levy (1995) have made an estimation which leads to an NO emission flux of 2.6 ng $m^{-2}s^{-1}$ for wet tropical soils. That parameter was proved for some tropical sites and matched fairly well with measured emissions. Within the MLC-CHEM-model, that factor was used to constrain the NO-emissions. Simulated values were about twice as high as measured ones. Using a reduced NO emission flux by the factor of 2 within the model, NO mixing ratios could be represented fairly well.

SUMMARY AND OUTLOOK

Applying some sensitivity analyses within the MLC-CHEM, the effects of different deposition and emission scenarios on O_3 and NO_x mixing ratios have been shown. The correlation between simulations and measuremnts could be improved with these analyses.

The next planned steps to perform, regarding the application of MLC-CHEM on the measured profile data are:

- To compare different NO_x-soil emission flux-scenarios with NO_x-fluxes measured by different techniques.
- To look, how nighttime O_3-NO reactions and the "morning plume" are represented using different modifications in the simulations
- To test, how the O_3 and NO_x exchange depend on the assumptions for the BVOC exchange
- To verify, how the O_3 deposition relates to the CO_2 exchange where these two processes share the stomatal uptake mechanism

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