P4.20 EVALUATION OF THE MICROMETEOROLOGY IN A SINGLE COLUMN CHEMISTRY AND METEOROLOGICAL MODEL BEING CONSTRAINED WITH THE ECMWF ANALYZED METEOROLOGY

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1. INTRODUCTION

The global scale chemistry and climate model ECHAM [e.g., *Roelofs et al.*, 2000] contains a rather explicit representation of surface trace gas exchange processes. The initial focus has been the introduction of a "big leaf" dry deposition scheme to simulate the dry deposition velocities and fluxes of species like ozone (O_3) and nitrogen oxides (NO_x). Recently, a multi-layer exchange model has been introduced to study the role of canopy-interactions between dry deposition, biogenic emissions, turbulence and chemistry for NO_x atmosphere-biosphere trace gas exchanges [*Ganzeveld et al.*, 2002a and b]. The multi-layer model has been developed and evaluated using a Single Column Model (SCM) version of ECHAM. The evaluation has been performed by comparison of the simulated and observed micrometeorology and trace gas fluxes and concentrations for tropical and deciduous forest and Taiga woodland.

Use of the SCM is motivated by the fact that it offers the opportunity to perform detailed process studies and to develop parameterizations with an optimal consistency for application in the global model ECHAM. An additional advantage of using the SCM is that specific surface cover characteristics such as soil moisture and canopy structure can be prescribed for a consistent evaluation of modeled and observed parameters. However, a disadvantage of using an SCM is that it does not include the contribution by advection. The SCM is initialized using vertical profiles of temperature, moisture and wind speed taken from the global climate model ECHAM. Model integrations basically show each day a similar diurnal cycle in the simulated physical and chemical parameters. In order to consider the contribution of advection of air masses with different properties, such as the passage of a cold front, the model can be constrained using observations or the analyzed meteorology of high-resolution weather forecast models.

In this study we show the comparison between the simulated and observed meteorology for a 25-day period in July-August 2001 over a deciduous forest in southeastern Germany [e.g., *Tenhunen et al*., 2001], constraining the SCM with the analyzed meteorology of the European Centre for Medium-Range Weather Forecasts (ECMWF). The measurement site has been used for an intensive field campaign (BEWA2001) focusing on the micrometeorology as well as trace gas exchanges. The SCM, including the multi-layer trace gas exchange model, will be applied to compare the simulated and observed fluxes and concentrations of peroxides and study some of the processes involved, e.g., dry deposition and chemistry [*Valverde-Canossa et al.*, 2002]. A prerequisite for a fair evaluation of the simulated trace gas exchanges is a realistic representation of the micrometeorology since many of the processes involved, e.g., stomatal uptake, turbulent mixing and photodissociation are controlled by parameters like radiation, temperature and windspeed. Therefore we focus in this study on the evaluation of the simulated micrometeorology.

2. SINGLE COLUMN MODEL

The SCM that is being used for interpretation and evaluation of atmosphere-biosphere trace gas exchanges contains a representation of the physical processes similar to the ECHAM4 climate model [*Roeckner et al*., 1996]. The standard model has 19 vertical layers in a hybrid σ-p coordinate system. Prognostic variables are temperature, surface pressure, humidity and cloud water. The model contains parameterizations of radiation, cloud formation and precipitation, convection and vertical diffusion. Land surface processes are described by a 5-layer heat conductivity soil model and by a hydrological model to determine evaporation and runoff. The evapotranspiration is calculated using a parameterization of the stomatal exchange [*Sellers*, 1986]. The model distinguishes 4 surface cover fractions; snow, bare soil, water in the skin reservoir (water stored within the canopy and on bare soil) and vegetation. For more details concerning the representation of atmosphere-biosphere trace gas

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exhanges in the SCM, we refer to [*Ganzeveld et al*., 2002a]

3. EVALUATION OF MICROMETEROLOGY

In this study we have applied the ECMWF analyzed meteorology of the ECMWF model grid cell, which resembles the location of the measurement site. The 6-hourly ECMWF air temperature (T_{air}), specific humidity (q), Liquid Water Content (LWC), surface pressure, and the wind speed components u and v have been used to force the SCM using a linear interpolation in time to calculate the parameter values for each 10-minute timestep of the SCM. For the forcing of the SCM towards the ECMWF meteorology, the so-called nudging technique, we have used a relaxation coefficient of 3 hours [*Jeuken et al*., 1996]. The relaxation coefficient determines the strength of the external forcing. A short relaxation coefficient implies that one basically interprets the ECMWF meteorology whereas a large relaxation coefficient results in a simulated meteorology that basically reflects the climatology. A too short relaxation coefficient can introduce inconsistencies in the calculated meteorology since the representation of physical and dynamical processes, e.g., the surface energy exchange calculations, of the SCM and the ECMWF are different. Hence, selection of the relaxation coefficient is a compromise between introducing a more realistic meteorology, which requires a short relaxation coefficient, and on the other hand allowing the model to adapt to the external forcing, which requires a relaxation coefficient that is significantly larger than the timescale of the processes involved. Figure 1 shows the simulated air temperature and the simulated surface temperature using a relaxation coefficient of 2 and 3 hours. It can be clearly seen that for the short relaxation coefficient instabilities are introduced in the simulated surface

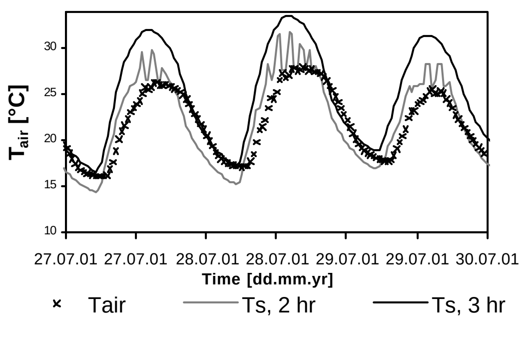

Figure 1: Simulated air (T_{air}) and surface (T_s) temperature for a 3-day period in July. The grey line shows T_s using a relaxation coefficient of 2 hours whereas the black line shows T_s for 3 hours.

temperature. This results in large fluctuations in the simulated friction velocity through the Richardson number, which is calculated from the surface-air temperature gradient and the wind speed. Note that the shown sensitivity of the simulated temperature gradient to the relaxation coefficient is representative for simulations using a 10-minute timestep. Changing the timestep of the model will likely also affect the sensitivity of some of the simulated processes to the relaxation coefficient but a more detailed analysis of this is beyond the scope of this study.

Simulations show generally a too dry and warm surface layer in the afternoon. An important parameter that largely controls the simulated surface temperature and humidity is soil moisture through its role in the evapotranspiration. The SCM has been initialized using the surface cover properties of the ECHAM grid cell resembling the location of the measurement site. ECHAM's initial soil moisture for this site is about half the field capacity, implying that there is a reduced evapotranspiration in the model through an increase in the stomatal resistance.
Figures 2a and b show the comparison between the observed (crosses) and simulated air temperature and relative humidity, using ECHAM's initial soil moisture (grey line) and initializing the soil moisture at the field capacity (black line). The overcast and rainy conditions occurring from the 15-19 July are clearly reflected in the observed temperature and relative humidity with the temperatures dropping below 10 °C and a relative humidity close to 100%. The model does not reproduce the observed wet conditions. For the initial soil moisture (half the field capacity) there is an overestimation of the maximum temperature by the model of about 2-3 °C throughout the simulated period. The comparison of the relative humidity does not show such a consistent bias throughout the period, but the simulated afternoon minimum relative humidity is generally about 10-20% smaller compared to the observed relative humidity. An increase of the initial soil moisture to the field capacity significantly improves the representation of the temperature and also the agreement between the observed and simulated relative humidity improves, except of the first 3-4 days of the simulation. A more extensive comparison of the energy balance components should assess the validity of increasing the soil moisture to the field capacity.

The presented agreement between the simulated and observed temperature does not only indicate about the quality of the model simulations but also about the quality of the ECMWF analyses. A parameter that indicates more about the overall quality of the model

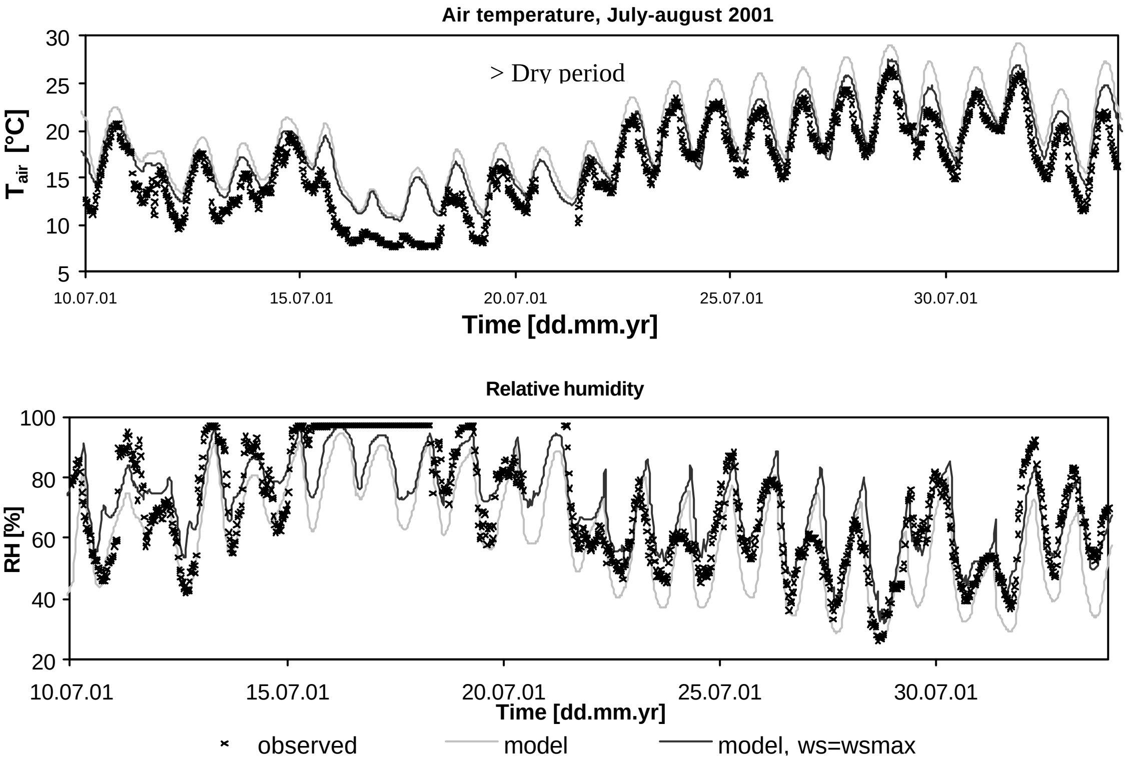

Figure 2a and b: a) Observed (crosses) and simulated air temperature for 25-day period in July-August 2001. The grey line shows T_{air} using ECHAM's initial soil moisture whereas the black line shows T_{air} for a soil moisture resembling the field capacity. b) as Figure 1a but then for relative humidity.

simulations is radiation since this parameter is not being constrained directly using ECMWF parameters but explicitly resolved considering large-scale as well as convective cloud processes.

Figure 3 shows the correlation between the simulated and observed surface net radiation (R_n) for the 25-day period. The agreement is quite good, indicated by an r^2 of 0.83 but the model seems to slightly underestimate R_n. Comparison of the simulated and observed R_n for the wet and dry period shows that especially during the dry period the model underpredicts R_n with maximum differences up to 200 W m^{-2}. We have also performed a model simulation reducing the model's initial albedo of 0.17, taken from the ECHAM model, to a value of 0.12 to study the sensitivity of the simulated net radiation to uncertainties in the selected albedo. This results actually in an improved representation of R_n during the dry period but an overestimation in R_n for the wet period. Also, the correlation between the observed and simulated R_n does not improve. We will further analyze the micrometeorology comparing the observed and simulated parameters for the dry as well as the wet period to identify potential problems in the model's representation of the meteorological processes.

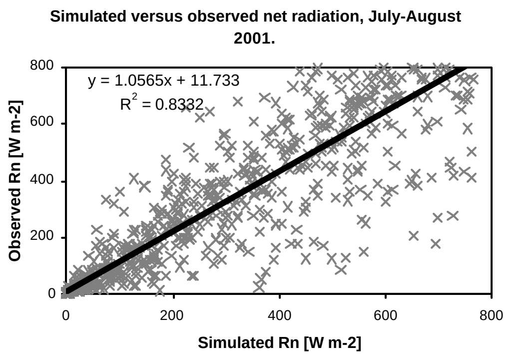

Figure 3: Simulated versus the observed surface net radiation for an albedo of 0.17 and the regression statistics.

4. CONCLUSIONS

The comparison of the observed and simulated micrometeorology over a deciduous forest in southeastern Germany, using the nudging technique and the ECMWF analyzed meteorology, indicates that the simulated micrometeorology is comparable to the

observed meteorological conditions, except of a wet period. Sensitivity analyses shows that a relaxation coefficient of 2 hours introduces numerical instabilities in the turbulence related to instabilities in the simulated surface temperature. Using a relaxation coefficient of 3 hours removes the instabilities and still results in a realistic simulated micrometeorology. Use of the initial soil moisture of ECHAM for the site, clearly shows a too large diurnal amplitude in the air temperature due to an underestimation of the evapotranspiration. Increasing the initial soil moisture to the field capacity significantly improves the simulation of the air temperature and relative humidity.
The multi-layer trace gas exchange model will be applied to study the exchanges of peroxides. *Valverde-Canossa et al*., [2002] have conducted Relaxed Eddy Accumulation (REA) measurements of hydrogen peroxide (H_2O_2) and methylhydroperoxide (MHP) exchanges. The good agreement between the observed and simulated micrometeorology allows us to assess the role of the chemical processes for H_2O_2 and MHP exchanges since differences between the simulated and observed trace gas exchange processes due to differences in the meteorology are expected to be small. Moreover, the distinct differences in the local meteorological conditions with a wet period, followed by a dry period offers the opportunity to study the role of canopy wetness for the surface exchanges of the soluble peroxides.

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