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Biogeosciences Discussions

Interactive comment on "The response of the terrestrial biosphere to urbanization: land cover conversion, climate, and urban pollution" *by* K. Trusilova and G. Churkina

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R: 1. Abstract/elsewhere: CO2 dome have the measurements by anyone been done to demonstrate that this exists? I think this is very misleading unless clearly defined what is meant. Those that first introduced this term were measuring behind vehicles not in the boundary layer (i.e. not a dome!).

A: In this study we account for urban CO2 concentrations several meters above ground at which vegetation is most likely to be affected. In order to avoid misunderstanding, we replaced term "CO2-dome" with a more specific description which is "elevated urban CO2 concentrations" and "urban CO2 increment" throughout the text.

R: 2. 2246 - line 23 - in some settings (e.g. SW USA) vegetation coverage is increased

by urbanization (i.e. urban planting schemes relative to desert surroundings) R: 3. 2247 - line 4 - "lack of evaporation" - not necessarily - see previous comment

A: We agree that urbanization can lead to an increase in vegetation coverage in dry and hot regions like SW USA. For Europe however the proportion of urban land was growing and proportion of vegetated land was shrinking over last four decades of 20th century according to a recent report of Lavalle et al. 2002 ("Towards an urban atlas" at European Environment Agency) In this report changes of urban land cover for 24 cities in Europe were analysed. We have added a comment into the text of the manuscript (chapter 1 Introduction) to emphasise impotence of this assumption for the European region.

R: 4. 2247 - line 2 - roads/traffic occur outside of cities too - so if all traffic is attributed to urban areas, exactly what is the definition of urbanized land?

A: we use the definition of urbanized land from the Corine Land Cover 2000 database. Urban land includes areas mainly occupied by dwellings, buildings and their connected areas that also include roads. However, as we used the model setup on the spatial resolution of 0.25 degree, only the densest road networks were captured at that resolution that mainly located within cities or suburban areas. Certainly, one should not underestimate the importance of the diffused sources of pollution as traffic in rural areas but these sources require much more detailed information on their location and magnitude that was not possible to acquire and parameterise within our study.

R: 5. 2248 - line 5 - I can see the reason to exclude ozone, but its ongoing effects do influence/damage vegetation and thus have an impact

A: In this study we omitted damaging effect of ozone on vegetation growth. Therefore we most likely slightly overestimate carbon sink in simulation with all environmental changes included.

R: 6. 2248 - line 25 - industrial livestock rearing facilities - are these really urban?

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A: here we followed the definition of urban categories from the Corine Land Cover 2000 database as given in the Technical Report by Bossard et al. (2000). In this technical report the definition of the Industrial, commercial and transport units (Class 1.2) given as: "Areas mainly occupied by industrial activities of transformation and manufacturing, trade, financial activities and services, transport infrastructures for road traffic and rail networks, airport installations, river and sea port installations, including their associated lands and access infrastructures. Includes industrial livestock rearing facilities". We use this definition. Given that an industrial facility for livestock is a mixture of buildings, roads, and sparsely vegetated surfaces, these facilities have a similar effect on environment as human settlements. So we think that including these facilities in a definition of urban areas is appropriate.

R: 7. 2449 - line 2 - it is not appropriate to model urban areas as vegetation free surfaces

A: Indeed, all urban areas have fractional vegetation cover of 15%. The other 85% was assumed vegetation-free. We have added the description of the urban land fraction data into the chapters "2.1 Model" and "2.2. The Model Simulations". In the first version of the submitted manuscript we indeed assumed all urban areas vegetation-free. According to the reviewers" comments we have re-thought this assumption and came to a conclusion that it would be appropriate to include the urban vegetation fraction into our calculations. We have taken the value of typical urban vegetation fraction from the work of Trusilova et al.,(2008) as this would be consistent with the urbanization-induced climate bias taken from the same study into the UMET-simulation. The appropriate changes in figures and in the text of the manuscript were made.

R: 8. 2249 - line 8 - treating the urban land fraction as barren land - is this because of the model does not treat the urban area? a. 2454 line 12-15 the authors themselves acknowledge this is unreasonable.

A: The terrestrial Ecosystem Model Biome-BGC does not have explicit parameteri-

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zation for urban land. However, the main reason why the urban land fraction was assumed barren was the definition of urban land. In the present version of the manuscript we have included the vegetation fraction into definition of urban land and re-calculated the model output for ULAND and UALL simulations taking in to account the vegetation fraction of urban land cover. The changes in model outcome were rather small and did not influence the summary of this study.

R: 9. 2249 - line 9 - what is the change and what's the basis for it?

A: We agree that the word 'change' isn't an appropriate term in this context. The appropriate would be "bias in temperature and precipitation ...". The relevant change was made to the manuscript.

R: 10. 2249 - line 14 /15- need to insert degree symbols

A: degree symbols are inserted

R: 11. 2449 - line 18 - how do these models treat the urban environment?

A: we have added a more detailed description of urban land representation within the REMO model and it's output in the chapter "2.2. The Model Simulations".

R: 12. 2450 - line 5 on - more rationale for these years being used?

A: The meteorological data of 20 years from 1958 to 1977 were chosen for the spinup simulation of the terrestrial ecosystem model because of three following reasons: 1) the regional model REMO required the lateral boundary forcing that was first available from 1958 on (ECMWF reanalysis) 2) these data do not contain any significant temperature trend attributed to the global warming, 3) the period 1958-1977 is sufficiently long to include the variations of incoming shortwave radiation related to the solar cycle that is of great importance for plant growth We have added this explanation to the text of the manuscript into the chapter "2.2.1 Spinup Simulation".

R: 13. 2451 - line 8 - clearly there were cities in 1958

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A: The atmospheric nitrogen deposition was fixed at the level of 1958 due to following reasons: 1. The time of the significant atm. Atmospheric nitrogen deposition rise was after the Second World War, largely due to rapid urbanization and industrialisation 2. There are good estimates of atm. Nitrogen content for 20 century (earlier, more uncertain) 3. Particularly the year 1958 was chosen for the consistency with the meteorological data for the model that were available starting from this year

R: 14. 2451 - line 27 - more details on the nature of the urban scheme are needed

A: a more detailed description of urban land representation within the REMO model and it's output are added to the chapter "2.2. The Model Simulations".

R: 15. 2451 - line 25 on - CO2 dome is not a good term to use. Produce a summary table of previous studies. It is absolutely critical that the scale, and representativeness, of the measurements be provided as context - are the increases referred to micro-scale street level or local scale observations? Very strong gradients exist horizontally and vertically in the boundary layer.

A: We have added a more detailed description of the CO2 observations and our assumptions on vertical and horizontal gradients of CO2 concentrations in chapter "2.2.3. Simulation of Urbanization-Driven Changes. UCO2-simulation": We followed the assumption that larger cities produce higher CO2 concentrations while rural areas produce lower concentrations. The estimation of CO2 concentrations was done for the street level (several metres above the ground) as most of vegetation will be affected by it at this height. Based on this assumption and the urban land mask, we constructed spatial pattern of CO2 concentrations. This spatial pattern of CO2 concentrations was used as a first approximation to estimate the physiological vegetation response to CO2. Indeed an atmospheric transport model would be needed to obtain a more accurate vertical and horizontal CO2 distribution.

R: 16. 2452 - this is not a good approach for simulating C02 concentrations - there should be relations developed to the sources e.g. fraction of roads. At the very least

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evidence should be presented to substantiate such an approach.

A: The urban land fraction, also a fraction of roads if it was resolved on the resolution of 10 km, was included into the calculations. Each 0.25x0.25 degrees model grid cell has a urban land fraction from 0 to 1. This is described in the chapter "2.1 Model". We added a more extensive description of constructing the CO2 distribution into the chapter "2.2.3. Simulation of Urbanization-Driven Changes. UCO2-simulation".

R: 17. 2452 - equation (1 and those that follow) should be in scientific notation (rather than computer programming notation)

A: the notation in the mentioned equation was changed. Also relevant changes were mage for the explanation of the variables in this equation.

R: 18. 2453 - why no interaction in the spin up? Was land cover change in that period taken into account?

A: During the spinup simulation the land cover map without urban areas was used. No change in the land cover was included into this simulation. The terrestrial ecosystem model Biome-BGC includes no interaction between the neighbour grid cells of the model domain i.e. no horizontal water flux.

R: 19. 2453 grid cell not sell (below eqn)

A: corrected

R: 20. 2454 U* not defined; I think it is not friction velocity but shorthand Make clearer.

A: corrections are made: instead of U* the phrase "simulation that includes urban factor(s)"

R: 21. 2454 line Pg C year-1 ?

A: corrected

R: 22. 2455 - line 1 to end of paragraph. This material should be presented earlier. As

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noted above, the assumption of no vegetation in urban areas is inappropriate.

A: We have moved the mentioned part of the paragraph into the chapter "2.2.3. Simulation of Urbanization-Driven Changes. ULAND-simulation." We have recalculated the carbon sink loss accounting taking into account the vegetation fraction in urban areas. We used the same vegetation fraction value, 15%, as in the work of Trusilova et al.(2008) that was calculated based on the data from Lavalle et al. (2002). Appropriate changes were included into the figures 5 and 6 and the relevant part of the chapter "Results and Discussion" and into chapter "2.2.3. Simulation of Urbanization-Driven Changes. ULAND-simulation".

R: 23. 2455 line 8-10 does this also assume no vegetation in urban areas?

A: The changes of temperature and precipitation assume the same vegetation fraction of 15% in urban areas.

R: 24. 2455- line 25 the soil water would be impacted by the lack of vegetation in the cities

A: Yes. This effect was taken into account in the work of Trusilova et al.(2008) for calculating the offsets of urbanization-influences precipitations and temperatures.

R: 25. 2456 the results are dependent on a poor initial assumptions

A: We have included a more detailed description of the assumptions made into the chapter "2.2.3. Simulation of Urbanization-Driven Changes. UCO2- simulation". Previous studies relate the highest urban CO2 values mainly to the vehicle exhausts. Following this assumption we have constructed an approximation of the urban-to-rural CO2 concentration increment (delta CO2) using the urban land mask. We used the updated urban mask that includes information about the population density and light emissions data as a proxy for constructing delta CO2. The main principle for this construction is: the larger the proportion of urban land in a gridcell the higher is the CO2 emissions and as follows the CO2 concentrations. Applying this principle requires the assump-

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tion that the CO2 exhaust intensity is the same across all urban pixels in Europe. The estimation of delta CO2 was done for the street level (several metres above ground) where most of vegetation will be affected by it. For such rough estimate at this height no atmospheric transport model was needed to resolve vertical and horizontal gradients in delta CO2 distribution. We assumed the homogeneous vertical distribution of delta CO2 within the first several metres above ground ($<$10); the horizontal gradients were estimated using the urban land fraction data.

R: 26. Table 1 - values should be specified in addition to Y/N

A: We think that the Table 1 should demonstrate the design of the model scenarios rather than the data used in them. We have simplified this table.

R: 27. Table 2 - give the height for the comparisons - surface level? Higher in the boundary layer?

A: We have removed the Table 2 as a non-sufficient way of presenting this information and included the description of observations into the chapter "2.2.3. Simulation of Urbanization-Driven Changes. UCO2-simulation."

R: 28. Figure 1 Really not needed if included Time (year)

A: We think this Figure presents the CO2 data that was used for the model simulations and in the same time the period of the simulations. It shows that model the spinup simulation was done with realistic CO2 concentration data rather than with a fixed constant value. The resulting after the spinup simulation carbon pools in soil and vegetation have a strong influence on the results of the following simulations as it is the common starting point for all model scenarios.

R: 29. Figure 2 - indicate grid cell size in caption

A: grid cell size added

R: 30. Figure 3 - more explanation is needed in the caption

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A: We have added a more detailed caption.

R: 31. Figure 4 provide details on data source

A: data source details added

R: 32. Figure 5 superscripts needs to be fixed in key 33. Figure 6 superscripts needs to be fixed. Indicate area in caption

A: superscripts in Figure 5 and 6 are fixed

Interactive comment on Biogeosciences Discuss., 5, 2445, 2008.