Our response to Sibyll Schaphoff comments on 04.01.2022 (https://doi.org/10.5194/bg-2021-294-CC1)

Title of the manuscript: Improving the stomatal resistance, photosynthesis and two big leaf algorithms for grass in the regional climate model COSMO-CLM

General:
The present study compares three different approaches to simulate stomata resistance and the connected against a very simplified approach in the regional climate model COSMO-CLM, which is not capable to simulate vegetation processes dynamically. These processes are very important in the coupling with the atmosphere and thus very important to calculate in more dynamic way.
I extremely appreciate the comprehensive description of the methods, but I think the evaluation needs a broader application for additional variables and sites to better assess the different methods. Furthermore, I encourage the authors to introduce at least one tree as well to evaluate, if these three approaches lead to a better representation of the biosphere-atmosphere interaction.

Answer: We thank the reviewer for this comment. We agree that this study needs to be extended for different plants and other study sites. This requires more extensive updates and technical development for the regional climate model and is not our focus here. Thus, it would exploit our current study. However, it will be the focus of our future studies. In the current manuscript, we evaluate evapotranspiration due to the different approaches to simulate stomata resistance coupled to photosynthesis adapted from the Community Land Model over three sites mainly dominated by grass with one-column regional climate model simulations. This is entirely new for COSMO-CLM and need careful evaluation step-by-step. We find that we also need to update our model to time varying leaf area index and plant coverage. After that, we will update the code for different plant functional types and perform simulations over different sites and bigger domains if the results confirm to be more realistic. Therefore, we write in the conclusion section of the manuscript that the next step will be to add time-varying leaf area index and plant coverage. Depending on the results, the model will be extended for different plant functional types and perform simulations over larger domains.

Detailed comments:
Page 4 line 124: Is T_r and Tr_k the same? Would you please provide how foliage resistance and stomatal resistance is related and if that has changed?

Answer: Ok, the reviewer raises a good point. We corrected the text. Here, T_r is the same parameter as T_{rk} .. In accordance with the official documentation of COSMO-CLM, model stomatal resistance is a part of foliage resistance. In particular:

$$T_r = f_{plnt} * (1 - f_i) * (1 - f_{snow}) * E_{pot}(T_{sfc}) r_a (r_a + r_f)^{-1}$$

where: r_f – is foliage resistance, which is equal to:

$$r_f^{-1} = r' C_F$$

where: r' describes the reduction of transpiration by the stomatal resistance.

$$r' = r_{la}(r_{la} + r_s)^{-1}$$

where: r_s – is stomatal resistance and r_{la} is

$$r_{la}^{-1} = C' u_*^{0.5}$$

where: u_* is frictional velocity.

Page 5 line 150: A new description of a new parametrization scheme for the maximum rate of carboxylation is mentioned, please give the link to appendix, and explain Eq. A8 in more detail. What is meant with the plant wilting factor and what is k?

Answer: Ok, we agree with the reviewer and give more explanations. The new text is: The new description of the stomatal resistance in TERRA-ML is calculated on the basis of the plant physiological approach (Ball et al, 1987; Ball, 1988) with algorithms for canopy fluxes based on Collatz model (Collatz et al., 1991) and improved by (Thornton and Zimmermann, 2007) through the implementation of a new parameterization scheme for the maximum rate of carboxylation ($Vc{,}max$), which is presented in (Eq. A5) and was the most critical problem of the Collatz model. Also, the parameter k (soil layers) (Eq. A8) was changed to i. The equation was corrected. The plant wilting point ($\boldsymbol{w_i}$) is the available water in the i[th] soil layer relative to an optimal water content. In our research we used the available COSMO-CLM parameter [Doms et.al., 2018] which calculated based on the equation

$$w_i = \frac{\omega_{l,root} - \omega_{PWP}}{\omega_{TLP} - \omega_{PWP}}$$

where $\omega_{l,root}$ is the water content of the soil averaged over the root depth, ω_{PWP} is the permanent wilting point, ω_{TLP} is the turgor loss point.

Page 5 line 170: If the former version does not calculate photosynthesis, could you give a brief overview, how plants are represented in the model?

Answer: Ok, thank you for this comment. The section was corrected. Plants are represented in the COSMO-CLM model by the following vegetation parameters, which are read in by the model as external 2D fields coming from remote sensing data. The vegetation parameters, which are read in, are leaf area index, plant coverage, root depth and roughness length.

Page 6 eq.4: Why is only the minimum stomatal conductance influenced by the soil water stress function. Please give the equation of this function. Why is parameter b so different in the two different calculations?

Answer: We thank the reviewer for this comment. The values of stomatal resistance (conductance) depend on the several parameters including: daylengths, temperature, photosynthetic active radiation, soil water stress and CO_2 concentration. These parameters are included in the algorithm for calculation of $\boldsymbol{V_{c,\,max}}$. The values of $\boldsymbol{V_{c,\,max}}$ is used for calculations of leaf photosynthesis ($\boldsymbol{A_n}$) and then in stomatal conductance. It is common part for both versions of the Community Land Model, which we adapted, and works for calculations of stomatal resistance when $\boldsymbol{A_n} > 0$. Then, there are differences in calculation of night values ($\boldsymbol{A_n = 0}$) of stomatal conductance in two versions on CLM model. In CLM 3.5 the algorithm for calculation of stomatal conductance is:

$$g_{st} = \frac{1}{r_s} = m\frac{A_n}{c_s}\frac{e_s}{e_i^*}\,P_{atm} + b,$$

The night values of stomatal conductance are equal to b, because the right part of the equation is equal to zero. The b is empirical parameter, responsible for minimum stomatal conductance. In CLM 4.5 the algorithm for calculation of stomatal conductance is:

$$g_{st} = \frac{1}{r_s} = m\frac{A_n}{c_s}\frac{e_s}{e_i^*}\,P_{atm} + b\beta_t,$$

It means that night values are depending on soil water stress. The values of parameter b, which we used, were from the official documentation of CLM model (version 3.5 and 4.5). We assume that the differences between values in min. stomatal conductance is related to the soil water stress function. For example: if we have values of soil stress function equal to 0.2 the values of min. stomatal conductance from version 3.5 and 4.5 will be equal to each other. We refer to the documentation of the Community Land Model for Version 3.5 and 4.5.

Page 7 Eq. 7 and 8 are identical.

Answer: Thank you for this remark. The equations are corrected.

Page 8 line 237: Could you explain more precisely what is meant with “adapted equations for dry leaf calculation”. Best would be to add a link to the equation that is used. For the other experiments I’m maybe able to identify the differences, but an overview table would definitely help to understand these differences much easier.

Answer: Thank you for these comments. In COSMO-CLM model there is a parameter (ztraleav – transpiration rate of dry leaves). In the original version of COSMO this parameter is calculated based on this equation:

$$ztraleav = \frac{(zep_s * tai)}{(sai + (zrla + zrstom) * zcatm)}$$

Where: zep_s is potential evaporation, tai is transpiration area index (external data), sai is surface area index (external data), $zrla$ is atmospheric resistance, $zrstom$ is stomatal resistance, $zcatm$ is transfer function. In the Community Land Model there is parameter vegetation transpiration (***qflx_tran_veg***) which is related to the potential evaporation through transpiration ($\boldsymbol{rppdry}$) from leaf and potential latent energy flux (***efpot***):

$$qflx\_tran\_veg = efpot * rppdry$$

$$efpot = forc_{rho} * wtl * (q_{satl} - q_{af})$$

Where: $forc_{rho}$ is air density, wtl is heat conductance for leaf, $q_{satl} - q_{af}$ is humidity gradient

$$rppdry = fdry * rb * \frac{\frac{L^{sun}}{rb + r_{s,sun}} * \frac{L^{sha}}{rb + r_{s,sha}}}{elai}$$

Where: $fdry$ is fraction of foliage that is green and dry, rb is boundary layer resistance, $r_{s,sun}$ and $r_{s,sha}$ are stomatal resistance of sunlit and shaded leaves, $elai$ is one-sided leaf area index with burying by snow. In our research (experiment v4.5 e) we adapted this algorithm to COSMO-CLM and change the equation for $ztraleav$ on $qflx\_tran\_veg$.

Page 9 Table: Do you mean v4.5 instead of Date in table header?
Answer: Thank you for this remark. The header of the table was corrected *Date* changed to *v4.5*

Comparison of the stomatal resistance shows that all versions seem to be too high for all regions. Do you have a reason not to adjust the parameter values? Have you any other indication that would disagree with lower stomatal resistance values?

Answer: Thank you for this comment. Yes, all stomatal resistance data seem to be high for all regions and we acknowledge this in our manuscript and write that further sensitivity tests on parameter values would be necessary. However, in the current manuscript we used values which were given and officially published.

I would appreciated a comparison to Vmax (leaf photosynthesis carboxylation capacity values) which are very common and available from the TRY database (https://www.try-db.org/TryWeb/dp.php) as well as stomata conductance. That would make the evaluation more valuable and would demonstrate that the models are able to represent the relation between Vmax and stomatal conductance well, and as the manuscript emphasizes the coupling between photosynthesis and transpiration.

Answer: Thank you for this information. We downloaded data and found one appropriate dataset, which can be used for our purposes (timeseries with coordinates and data for C3 grass). The new data will be added to the plots.

Please add some statistical values to the evaluation plots against observational data that always helps to assess the results. That's what you did in figure 5, but you could also just add that to the legend on the plot than it is available at a glance. Is figure 5 done for the three domains only? It's not indicated in the caption, but I assume it.

Answer: Thank you for this comment. We added more statistical values to the evaluation plots. According to the figure 5. This figure was created only for one research domain Parc.

You conclude that the implementation would be valuable for the regional climate model, could you indicate which approach you are going to introduce.

Answer: We think that the experiment CCLMv4.5 show the better results. The experiment based on the adapted algorithm form CLM version v4.5 is most perspective. This version has an updated algorithm for stomatal resistance and leaf photosynthesis based on the more modern version of CLM model. This algorithm has a regulation function of night values of stomatal resistance depending on soil water stress function and the statistical results for this experiment has slightly better values that other experiments and original version of COSMO-CLM. At the same time, the experiment CCLMv4.5e has more inaccuracies caused by the implementation of the new parameters for calculating transpiration from dry leaf surface which were partly unavailable in the original version of COSMO-CLM and was changed to the constant parameter or COSMO-CLM analogies. The version CCLMv4.5e required additional work for adaptation and further validation of COSMO-CLM parameters.