Review of the article:

Towards the use of dynamic growing seasons in a chemical transport model

By

A. Sakalli and D. Simpson

In general, the manuscript is well written and the manuscript addresses an important scientific question that is relevant for Biogeosciences: How growing seasons can be dynamically simulated and how this affects typical calculations with a CTM model. The authors use a well-established CTM model EMEP (Simpson et al., 2012) that is well suited for the particular scientific question. The authors also show how certain output metrics from the EMEP model are affected by dynamic calculation of the start of the growing season. Due to this, the authors argue that there is a strong need for a dynamic description of growing seasons in CTMs. Overall I recommend that the article is published in Biogeosciences but I also recommend that the authors both focus on the limitations of their approach (e.g. using birch as a model species for all deciduous trees) and that they provide some more detailed statistical information about the model performance such as seasonal ozone statistics.

General comment to the manuscript

The selection of data points for validation seems to be very reasonable. The same concerns the number of citations. This is in general well balanced and the cited articles are easy to obtain.

a) I have one particular question which I think needs to be clarified. The question concerns the assumption that it is possible to use a model for birch flowering as a reasonable surrogate for deciduous trees in the EMEP CTM model. This assumption forms the entire manuscript with respect to model simulations and which things that are discussed. However, birch is a light demanding species that has favourable conditions in only a fraction of the EMEP model domain (Skjøth et al., 2008). Other common trees are beech and oak. Furthermore, beech and oak are species that are common in the areas where the AOT40 values are high such as Central and Southern Europe. Will it make sense for the authors to do similar calculations for another species such as beech or oak or even better simulate several species at the same time? Can it be done or what is needed before this can be done?
b) The evaluation of the EMEP model: Why have the authors used annual mean values? It must be expected that only a very small period of time (e.g. during spring) there will be a difference in the model results. So averaging over en entire year will to some degree hide the changes in the model results. The authors should therefore focus on the period where there are changes: the spring.
c) It is very unclear to me, exactly where and how the dynamical calculation in the start of the growing season is used in the EMEP. As I understand it, then the start of the growing season is used in the dry deposition scheme which is described by Simpson et al (2012) and the BVOC emission. A simple but more detailed overview with citation to the exact equations and Tables would make it much more transparent (e.g. equation 18, 54 and Table 3 as given in Simpson et al (2012) etc.

d) The LPJ-Cru methodology (section 2.2) seems to be the physiological most reasonable method as it include both chilling and heating. So it is a bit surprising that this methodology has much lower performance that the two other methods. To my knowledge, then the current version of LPJ-Guess with a species dependency was published in 2012 by Hickler et al (2012). However, this article did not contain a calibration of the parameters that describes the start of the growing season for birch. Instead, Hickler et al (2012) cited an earlier article by Sykes et al (1996) that provided the needed values for the LPJ-Guess methodology. In that earlier article the situation was the same. There was no calibration of the start of the growing season. To me it appears that the LPJ-Guess parameters for birch are based on something unclear. Probably the authors should take this into account or better – have calibrated the LPJ methodology on their own data before it was used and compared with the two other methods and in a similar way as the TTM or the T5 methodologies.

Minor comments to the text in the manuscript

Page 12140, line 25: Please proved at least one reference in each of the three named examples in the use of GDD: SGS, flowering time and start of pollen prediction time

Page 12140, line 25: start of pollen prediction time. What does the authors mean with that sentence? Please rephrase.

Page 12140,line 26-28. Probably the well known MEGAN model (Guenther et al., 2006) would be very relevant to cite here as well. MEGAN is very often used in connection with CTM model studies.

Page 12141, line 16. According to Sofiev et al (Sofiev et al., in press), the TTM model was developed by Linkosalo et al. (2010), while Sofiev et al (Sofiev et al.,in press) have calibrated the TTM model for SILAM model domain by using the data from Siljamo et al (2008) and pollen data from the European Aerobiological Network (EAN, https://ean.polleninfo.eu/Ean/)

Page 12142, line 5-6. The reference to the personal communication can be replaced with a reference to Linkosalo (1999)

Page 12147, line 4-5. This statement is probably only valid for central and Northern Europe and for birches. Other trees like alder have quite different requriements respect to onset on leaves and flowering (Linkosalo, 1999).

Page 12154, line 19-30. The authors discuss various methods for the end of growing seasons and argue that the most simple method is probably sufficient. However, the authors use climate change studies as an argument for using a dynamic calculation of the growing season. This arguments should also be taken into account for the end of growing season, despite that the modelling results between the different methods do not differ that much.

Page 12157, line 24-26. Recent studies on BVOC emissions suggest that temperature is not the only important parameter that should be taken into account (Baghi et al., 2012). These recent studies from Boulder suggest increased emissions during spring time that cannot be explained by temperature alone but may be related to flowering. If this pattern is a general pattern, then the statement on line 24-26 holds with

respect to the existing parameterisations in emission model like MEGAN but also that this way of simulation BVOC emissions needs to be reconsidered.

Minor comments related to figures and tables in the manuscript

Fig 4. The scatter plots have a striking feature: The points with SGS after day number 125 lie more or less on a straight line in all scatter plots, while the points with an early SGS have much larger scatter. It could be very useful with a map as supplement to one of the scatterplots that shows both the simulated and observed SGS. Probably the highest agreement is found in the Finnish region (high SGS numbers) and low agreement is found in central Europe – an area where birches are much less frequent compared to Finland. If so then this also needs to be discussed as this to some degree is related to the limitation of the methodology.

Fig 7. The characters on the legend on Fig7a and Fig7b seems a bit smaller than the ones on Fig 8a and b. Fig8a and b are more easy to read.

I suggest that Table S1 is moved from the supplementary information and directly into the paper as the table can form an important data set for future model developments.

REFERENCES

Baghi, R., Helmig, D., Guenther, A., Duhl, T., and Daly, R., 2012, Contribution of flowering trees to urban atmospheric biogenic volatile organic compound emissions: Biogeosciences, **9,** 3777-3785.

Guenther, A., Karl, T., Harley, P., Wiedinmyer, C., Palmer, P. I., and Geron, C., 2006, Estimates of global terrestrial isoprene emissions using MEGAN (Model of Emissions of Gases and Aerosols from Nature): Atmospheric Chemistry and Physics, **6,** 3181-3210.

Hickler, T., Vohland, K., Feehan, J., Miller, P. A., Smith, B., Costa, L., Giesecke, T., Fronzek, S., Carter, T. R., Cramer, W., Kuhn, I., and Sykes, M. T., 2012, Projecting the future distribution of European potential natural vegetation zones with a generalized, tree species-based dynamic vegetation model: Global Ecology and Biogeography, **21,** 50-63.

Linkosalo, T., 1999, Regularities and patterns in the spring phenology of some boreal trees: Silva Fennica, **33,** 237-245.

Linkosalo, T., Ranta, H., Oksanen, A., Siljamo, P., Luomajoki, A., Kukkonen, J., and Sofiev, M., 2010, A double-threshold temperature sum model for predicting the flowering duration and relative intensity of Betula pendula and B. pubescens: Agricultural and Forest Meteorology, **150,** 1579-1584.

Siljamo, P., Sofiev, M., Ranta, H., Linkosalo, T., Kubin, E., Ahas, R., Genikhovich, E., Jatczak, K., Jato, V., Nekovar, J., Minin, A., Severova, E., and Shalaboda, V., 2008, Representativeness of point-wise phenological Betula data collected in different parts of Europe: Global Ecology and Biogeography, **17,** 489-502.

Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L. D., Fagerli, H., Flechard, C. R., Hayman, G. D., Gauss, M., Jonson, J. E., Jenkin, M. E., Nyíri, A., Richter, C., Semeena, V. S., Tsyro, S., Tuovinen, J. P., Valdebenito, Á., and Wind, P., 2012, The EMEP MSC-W chemical transport model - technical description: Atmos. Chem. Phys. Discuss., **12,** 7825-7865.

Skjøth, C. A., Geels, C., Hvidberg, M., Hertel, O., Brandt, J., Frohn, L. M., Hansen, K. M., Hedegaard, G. B., Christensen, J., and Moseholm, L., 2008, An inventory of tree species in Europe - an essential data input for air pollution modelling: Ecological Modelling, **217,** 292-304.

Sofiev, M., Siljamo, P., Ranta, H., Linkosalo, T., Jaeger, S., Rasmussen, A., Rantio-Lehtimaki, A., Severova, E., and Kukkonen, J., A numerical model of birch pollen emission and dispersion in the atmosphere. Description of the emission module: Int. J. Biometeorol., 1-14., in press

Sykes, M. T., Prentice, I. C., and Cramer, W., 1996, A Bioclimatic Model for the Potential Distributions of North European Tree Species Under Present and Future Climates: Journal of Biogeography, **23,** 203-233.