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Geoscientific Model Development Discussions

Interactive comment on "The Simulator of the Timing and Magnitude of Pollen Season (STaMPS) model: a pollen production model for regional emission and transport modeling" *by* T. R. Duhl et al.

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Please note that the author responses to all three referee comments are also viewable in the attached supplementary pdf.

Author response to Anonymous Referee #2, Interactive comment on "The Simulator of the Timing and Magnitude of Pollen Season (STaMPS) model: a pollen production model for regional emission and transport modeling" by T. R. Duhl et al. (Geosci. Model Dev. Discuss., 6, C1019–C1026, 2013)

Please note that we have pasted sections of text from the original Referee report (Italicized and in a different font than our responses) containing the suggested revisions or comments and have responded below these with numbered Author responses.

"... the publications shows some methodological drawbacks that should be addressed before publication... First, I am missing a section describing the materials used. The data is introduced in the sections where it is used for the first time. It would be easier to have an overview at the beginning of the paper (after the introduction)."

Author Response 1: we have now introduced all of the datasets used as suggested after the Introduction at the beginning of Section 2 (lines 122-134). The following text has been inserted:

"An aerobiological pollen dataset for 2003-2010 collected at the California Institute for Technology (CalTech) campus in Pasadena, CA was used for the selection of species to be included in the initial simulations along with the expertise of co-authors who have been studying local pollen in S. CA for a number of years. Only species with known allergenicities that typically flower in the March-June period in the study area were selected including species that occur naturally throughout the domain (such as oak) and those that occur mainly in urban environments in the domain but are also important allergens in other regions (e.g., birch). The Pasadena pollen data as well as (for oak species) some phenological data were also used for the determination of various threshold values for flowering as described later. Species composition and fractional vegetation cover within the model domain were determined using the datasets presented in Table 2. and described in Appendix A."

"Second, apparently the STaMPS model was validated only indirectly by incorporating its output into a transport model. The resulting pollen concentrations are compared to count data. However, the simulated pollen concentrations not only depend on the output of the STaMPS model, but also on the emission parameterization and the transport/diffusion processes within the transport model. No numbers are given with respect to the accuracy of the STaMPS model regarding current climatic conditions. Cf. eg. Pauling et al. 2013, Aerobiologia, for phenological model performance assessment. In addition, this publication contains scores that can be used for comparison. It would be good to know how well the model can predict the beginning and magnitude of the pollen season. This should be done before using the model with a future climate. Lacking such a validation with current data, I think that it is not justified to make predictions in the future."

Author Response 2: While we agree that additional model evaluation is always desirable, our companion paper evaluates the results of the STaMPS model in the only way possible considering that the sole phenological dataset available to us was used for development of model parameters (and thus couldn't be used to test the model), leaving aerobiological pollen comparisons the only viable option. Although Pauling et al., 2013 did suggest a nice approach for evaluating phenological models, our co-authors also fairly rigorously evaluated the model and as described in our companion paper (Zhang et al., 2013, P. 3992-3993) the performance was encouraging, for instance taking birch, oaks, mulberry, and walnuts as examples the model accurately predicted the regionally-observed peak dates of pollen concentrations and length of pollen season (with the exception of a some early birch counts observed at a couple of the observation sites, which could be attributable to long-range pollen transport, a phenomenon that is now discussed in Section 4.1, lines 730-752). Also observed in Zhang et al. (2013) e.g. in Fig. 9 is the fact that for most of the nine observational stations used to compared modeled vs. observed mean and maximum concentrations, good agreement was found for all species except walnut concentrations were generally under-simulated and simulated maximum concentrations were too high for grass although mean grass concentrations closely match observations for 6 of 9 stations, and simulated maximum values were too low at a few stations for birch (but were still within several pollen grains m-3 of observed values). A more-detailed summary of the model evaluation is now given in Section 2.4, lines 586-597. We have added significant additional text to the revised ms (as described throughout this document) to assuage

concerns about the appropriateness of the model approaches used and justify the specific choices made regarding which studies/models, forcing threshold values and base temperatures were assigned (e.g. Section 2.1, lines 157-182, 2.1.1, lines 185-188 and 231-241, pertaining to chilling species: Section 2.1.2., lines 294-301 and 335-371) We hope that in the revised ms it is clearer that we only applied literature-derived relationships between meteorological variables and flowering, as well as and critical forcing and heating thresholds from previously published studies that are relevant to the species in question and representative of the climate zones within the domain (e.g. lines 95-105, 157-182, and 748-752). We also have placed more emphasis on the fact that the chosen thresholds, base temperatures, etc. are observationally constrained (lines 748-752) which should serve to increase confidence in the model. Finally, we have placed greater emphasis on the fact that the relationships are valid only for simulations performed in similar climate zones (throughout the ms including changes to the abstract, lines 39 and 47; the introduction, lines 95-105; and the discussion/conclusion sections, lines 748-752, 797-799 and 842-844.

"Third, I think that the chosen simulation period is not valid to support the interpretations drawn from the results. Even the authors admit that the differences in the potential pollen production between current and future climatic conditions could be due to a shift of the pollen season into or out of the simulation period. However, this is not further investigated. Hence, I recommend to use a more suitable simulation period."

Author Response 3: We have re-run the future and current simulations for a full year and now present those results accordingly (this has been changed throughout the paper).

"Forth, the authors state that their model is flexible regarding different pollen species. But: for many species, they use identical formulations/fixed values with the hint that appropriate data for the given species is not available. Hence, the nature of the model might be flexible, but the use of identical parameters corrupts this flexibility. Especially data on birch seems to be scarce in Southern California since almost always data of other tree species is used for birch. I doubt very much that, e.g., for birches and olives the same parameters should be used since these trees primarily do not grow in the same climatic regions."

Author response 4: We have endeavored to more fully describe that the STaMPS modeling framework is in fact flexible with respect to simulations in different climate zones because it includes several types of budburst models (thermal time, sequential, and alternating; Section 2.1, lines 157-182), and that in principal, GDD and chilling thresholds and base temperatures obtained from published studies of the selected species growing in other climatic regimes could be applied, and the choice of budburst model modified, in order to perform simulations in other locations (Section 4.2, lines 814-826). However it is also noted that for some species extensive additional phenological and aerobiological datasets would be required to inform and validate simulations performed in other regions (Section 4.2). STaMPS is designed such that modules can be modified and substituted not only for individual Plant Functional Types (PFTs), but also for species occurring in different climatic regions. This has been made clearer in Section 1 (lines 104-106) and Section 2.1 (lines 157-182). Plans to incorporate additional climate-zone simulation capabilities as well as new species are discussed briefly in Section 4.2 (lines 814-826). Also as described in an earlier author response (above) we hope the changes made to the description of how and why the specific modeling approach was applied to birch and other chilling trees (Section 2.1.2, lines lines 294-301 and 335-371) are sufficient to justify inclusion of this species in the simulations.

"Overall, the paper leaves the impression that too many issues were tackled at the same time. The paper does not only present a phenological model describing beginning, end and course of a specific pollen season, but does so for several different taxa. Additionally, distribution maps for each of these taxa are generated. This paper could easily be divided into 2 or even more papers: one paper about the phenological model (or even one paper for each taxa including a thorough validation for each taxa) and one paper about the generation of distribution maps."

Author Response 5: While we agree that given the breadth of the modeling effort, we knew that more than one manuscript would need to be prepared and submitted in order to publish a satisfactory description of the modeling framework, yet we could not identify a single journal that was appropriate to submit both the phenological model paper and the dispersal paper. Therefore we opted to submit to two EGU Copernicus journals, and this has been quite a challenge in and of itself. However we also agree that the ms is too long and so we have moved the chapter describing determination of species composition, fractional vegetation cover, and land use in the domain (formerly Section 2.4) into an Appendix (A) so that the main body of the paper is more focused on the model itself. This seemed appropriate as this chapter is not at the heart of the model; i.e., other land- and vegetation-cover datasets could in principle be used to determine the necessary land cover input values needed for STaMPS simulations in a given gridded model domain.

"Introduction: I am missing a few sentences about existing models for the timing and magnitude of pollen seasons and their performance. The introduction presents the motivation for the study and a summary of the paper, but is missing a paragraph about the scientific context (with relevant reference)."

Author Response 6: In lieu of including this in the Introduction, we have added the following text to the beginning of the section that discusses these approaches (Section 2.1, lines 157-182):

"A number of models have been devised to predict the timing of anthesis in trees and other PFTs that flower during spring to early summer (when temperature is the main driver controlling flowering); these include approaches that consider only the effects of forcing temperatures (such as the thermal time model; Cannell and Smith, 1983) and models that include both chilling and forcing temperatures: the sequential model (Sarvas, 1974), the parallel model (Landsberg, 1974), and the alternating model (Murray et al., 1989). Chuine at el. (1999) tested eight phenological models for their ability to predict flowering dates in tree species with differing abilities to adapt to local climatic conditions and found that no one model was best-suited for all species. STaMPS applies different models to different species based on whether the species has forcing-only or both forcing and chilling requirements for flowering. The thermal time model is applied to species without known chilling requirements (Section 2.1.1); a sequential model is applied to tree species with chilling requirements for flowering (Section 2.1.2). Section 2.2 describes an alternating model (based on Gleichsner and Appleby, 1996) that is applied to the Bromus grass species included in the initial model simulations. A particular model may perform well for simulating a species in one climate zone, but poorly for the same species growing in a different climate. The type of bud burst model assigned to a species in one location can be easily modified since STaMPS modules already exist for thermal time, sequential, and alternating approaches. STaMPS lacks a parallel budburst model although this may be ideal for predicting flowering in some species/locations. Linkosalo et al. (2008) found that sequential and parallel models had similar prediction accuracies for several tree species including two birch species in a high-latitude location (Finland), but that a simple thermal time approach performed best with independent data. Linkosalo et al. (2008) also noted that models including chilling parameterizations may be better suited to simulations under climate warming scenarios when chilling could potentially become a limiting factor."

"Page 2330, lines 1-2: what are the criteria for the selection of the species based on pollen count data?"

Author Response 7: We have added the following text (lines 122-130): "An aerobiological pollen dataset for 2003-2010 collected at the California Institute for Technology (CalTech) campus in Pasadena, CA was used for the selection of species to be included in the initial simulations along with the expertise of co-authors who have been studying local pollen in S. CA for a number of years. Only species with known allergenicities that typically flower in the March-June period in the study area were selected including species that occur naturally throughout the domain (such as oak) and those that occur mainly in urban environments in the domain but are also important allergens

in other regions (e.g., birch)."

"Page 2330, lines 13-16: In some species (e.g. birch), the magnitude of pollen produced is not only a function of the meteorological conditions in the given season, but also depends on the previous season (the concept of masting). It is not clear whether this fact is included in the model or not."

Author Response 8: We have deleted "in a given season" to avoid confusion since the point of this sentence was to list the variables known to govern pollen production but not the timescales on which they operate. In Section 2.3 of the ms we acknowledge that precipitation a full year prior to the start of pollen season in trees can affect the amount of pollen produced and that is in fact how STaMPS calculates the pollen production size for trees.

"Page 2331, lines 16-17: The authors exclude the year 2007 because of late-season rains. However, the section 2.1 addresses the prediction of the start of the pollen season. I don't see why late-season rains disqualify the year 2007 for the prediction of the start of the season which should be before the rainy late-season period."

Author Response 9: Perhaps we were not clear in how we used the pollen count data and why 2007 was excluded: we have re-worded the explanation (lines 216-217) for the exclusion of this year from the set of years where cumulative GDD values were calculated and averaged by genus to determine GDD thresholds. Rains were so frequent in the early spring period that for many genera peaks were not observed at all during the expected times (or others). We note that a similar approach was taken in another study (Galán et al., 2001). In addition to hopefully making the exclusion and the reason for it more clear in revision 2, the following text has also been added (lines 218-220): "In evaluating several models for their ability to predict the start of Olea pollen season in Spain, Galán et al. (2001a) excluded two years out of an 18-year olive pollen dataset due to rain events occurring near the beginning of olive pollen season."

"Page 2331, lines 6-13, lines 23-24: Needs more justification how the specific base temperatures and start-dates for heat accumulation were chosen."

Author Response 10: Please see author responses 2 and 6 above and 13 (below) which have addressed this.

"Page 2332, line 1: The GDD thresholds are taken as the average GDD values that were reached on the day of the peak pollen concentrations. However, the peak pollen concentrations surely do not reflect the start of the pollen season. The start of the pollen season is a phenological date which depends on the meteorological conditions of previous days/months. What is the definition of the start of the pollen season used in the present study? The peak pollen concentrations depend on the current weather conditions and usually appear during the main season several days after the start of the pollen season. It should also be kept in mind that the start of the pollen season and the peak pollen concentrations could be a consequence of long-distance transport, not being related to the start of local flowering at all. Data should be corrected for these influences as far as possible."

Author Response 11: We used the peak pollen concentration as date of peak flowering (as described in lines 213-236) and then distributed the season over a two-week period surrounding the peak date. We also acknowledge in the revised text the limitations of this approach. The following text was inserted (lines 255-274):

"A parameterization is applied to all simulated species that normally-distributes the pollen available for release on the calculated peak date of flowering over a two-week period (i.e., one week on either side of the calculated peak date) which was typical of the oak phenological observations and which collaborators in the present study have corroborated in their observations of temporal trends in pollen count intensities for a number of species, (not shown). Jato et al. (2007) observed flowering periods ranging from 8-13 days in populations of Betula pendula as well as in B. alba growing in Spain. Observations have indicated longer duration of flowering season in other species including sagebush (Artemisia tridentata) which has been observed to flower

over a period of 4-5 weeks (Laursen et al., 2007) and bermudagrass (Cynodon dactylon), in which flowering has been observed to last 1-2 months depending on cultivar (Van De Wouw et al., 2009). There have also been reports of skewness in flowering distributions among populations (Laursen et al., 2007), as well as observations of temperature and precipitation effecting the shape of such distributions (Tedeschini et al., 2006). Parametrizations do not yet exist in STaMPS to represent environmental influences on flowering distributions, therefore the shape of simulated pollen curves may not be well-represented in years when flowering behavior within a population deviates from a normal distribution. On the other hand, STaMPS modules can be easily modified to represent longer flowering periods or different distributions to reflect averages observed for a given species."

With regards to the consideration of long-range pollen transport, we have inserted the following text into Section 4.1 (lines 732-754):

"Long-range transport of pollen may also complicate the interpretation of observed atmospheric pollen curves (e.g., Siljamo et al., 2008), especially for non-native species within a study domain that could have a much larger presence in regions outside of the domain, such as birch species. Jato et al. (2007) compared Betula pollen curves with phenological observations from two species of birch growing in Spain, and found that for the calculation of GDD requirements, using dates of peak pollen concentration yielded similar results as use of phenological observations, although lags between dates of peak flowering and peak pollen count have been reported for a number of species (e.g., Latorre, 1997). Although we cannot exclude the possibility that pollen transported over large ranges may have influenced the pollen count data used for the determination of heat thresholds, a multi-year aerobiological dataset such as that employed in the present study should be dominated by local signals over time, and numerous studies (of the same genera selected for initial simulation in STaMPS) performed in similar climatic regions were consulted during model development. In an effort to include the potential contributions from pollen transported into the domain during the validation simulations, a nested domain scheme was used for the 4km domain simulations (as described in Section 2.4) Our study is the first to predict pollen production for multiple species in the western half of the US, and is constrained with observations taken from within the study domain as well as built using numerous previously published relationships for the selected genera occurring in similar climate zones as the domain, therefore STaMPS improves capabilities for predicting pollen season in this region. Nonetheless, these limitations should be kept in mind when interpreting the pollen dispersal results."

"Page 2332, lines 25-29, and page 2333, lines 1-2: It is mentioned that a 'variation-mimicking' parameterization has been developed and applied to several species. Details about this parameterization are not given. If I understand correctly, the parameterization normally distributes the available pollen over a period of 2 weeks. The authors state that such a behavior has been observed for a number of species, corresponding data is not shown. Looking at the pollen seasons in Europe, I cannot support the observation that typical pollen seasons have a length of only 2 weeks. For birch, e.g., the pollen season has been observed to be positively skewed instead of normally distributed (see e.g., Grewling et al. 2012, Grana). Additionally, it should be taken into account that the length of the pollen season is influenced by the weather conditions, e.g. cold conditions tend to result in a longer than usual pollen season. As I understand from the paper, this is not taken into account."

Author Response 12: See author response 11, above.

"Page 2333, lines 3-15: Instead of using TB values of another species, a species-specific TB value for the studied region could be found by systematically varying the base temperatures and the starting date of the accumulation. Otherwise, is there a justification why the values of another species are valid for the given species?"

Author response 13: we have addressed this above and now the justifications are provided for the choice of base temperatures. With respect to systematically varying the

base temperature we did experiment with this as is now described as follows (lines 345-371): "TB values close to 0°C have been suggested for birch growing in high latitudes although latitudinal gradients in base temperatures as well as chilling requirements have been observed in many tree species including birch (Myking and Heide, 1994) and grasses (Heide, 1994). We tested a range of base temperatures for birch using the Pasadena data but found little difference in terms of percent standard deviation in accumulated GDD on peak birch pollen count dates using a base temperature of 0°C compared with 9.1 for the years included in the analysis. Most studies of Betula have been performed on high-latitude ecotypes although Jato et al. (2007) studied and modeled the onset and length of flowering in B. pendula and B. alba populations in Spain using several modeling approaches and base temperatures and found that model parameterizations developed for olives (Galán et al., 2001b) resulted in the lowest deviations from actual versus predicted peak pollen date for Betula. Data regarding optimal TB values for birch and walnuts growing in climate zones similar to the study domain are sparse therefore, following a similar approach as Jato et al. (2007), we applied a model developed for olives (De Melo-Abreu et al., 2004) to birch and walnut species within the domain. It should be noted that Jato et al. (2007) used the olive model of Galán et al. (2001b), while we have employed the De Melo Abreu et al. (2004) approach which allows for the calculation of devernalization during chilling calculations. De Melo Abreu et al. (2004) evaluated the inclusion of devernalization against the same chilling calculation approach used by Jato et al (2007) and found results to be more accurate, and the model more physiologically meaningful, when devernalization was considered. It has been long known that species with chilling requirements can lose a portion of their accumulated chilling when temperatures exceed some threshold value (Richardson et al., 1974; Gilreath and Buchanan, 1981). The GDD thresholds for these species were determined using the Pasadena pollen counts as described in Section 2.1.1, with GDD accumulation dates each year beginning on the date when chilling requirements were met for each chilling species according to the Pasadena meteorological data."

"Page 2334, lines 22-25: Any justification why you use the olive value for birch instead of the walnut value?"

Author response 14: This is addressed in the author responses 2, 6, and 13, above.

"Page 2335, lines 3-6: Maxima/minima in pollen concentrations can have different reasons: e.g., precipitation events washing out the pollen in the air, turbulence and wind strengthening/weakening the emission and diffusion of pollen, long-distance transport, variations between individual trees. I find it implausible to assign observed maxima in airborne pollen concentrations mainly to different olive cultivars and individual thermal requirements."

Author response 15: We have acknowledged that multiple factors could have contributed to the observed phenomenon and we have further explained why we think multiple olive cultivars are the reason by adding the following text (lines 373-389):

"Several maxima are often observed in the Pasadena olive pollen data in a given year (Fig. 2) and these do not appear to be correlated to precipitation events (not shown). Some explanations for this phenomenon include (1) the effects of changing wind fields causing times of maximum pollen release to be missed or obscured, (2) the possibility of long-range pollen transport (discussed in Section 4.1), or (3) the presence of several olive varieties with different thermal requirements for flowering. As mentioned previously, the Pasadena pollen data was collected at CalTech; this campus has a large and diverse collection of olive trees growing on its grounds, some of which are used to make oil. The proximity of this known source of Olea pollen near the sampling site makes it likely that local effects were dominating observed pollen concentrations. De Melo-Abreu et al. (2004) found that different olive cultivars have unique chilling and heating requirements, but since the datasets used to determine tree species composition for this study (described in Appendix A) identified all olives present within the domain as simply "Olea europaea", we applied the average heating and cooling threshold values across all of the cultivars studied by De Melo-Abreu et al. (2004), which yielded

the same threshold value that was calculated for olives using the Pasadena data (Table 1)."

"Page 2337, lines 2-6: Relevance of these remarks? Should be part of the section 'Future plans'."

Author response 16: We have deleted this text. (These plans are discussed in Section 4.2)

"Page 2338, lines 16-19: Is it wise to use model precipitation to construct the relationship between precipitation and the pollen potential? It is well known that precipitation is one of the parameters that are usually not very well simulated in models. I suggest to use observations for that purpose."

Author response 17: The PRISM model ingests numerous observational data from stations all over the U.S. including many in the western half of the country, and as such is well-constrained. I would agree that maybe using a 1-year precipitation map for PRISM would be risky but we used a 30-year average dataset, and this product is, in the opinion of this author, one of the best precipitation datasets available.

"Page 2338, line 22: Which other trees? Is the function also based on data of these other trees or is it taken from oak data? If taken from oak data: justification?"

Author response 18: We have changed the text to (lines 491-493):

"The relationship between precipitation and pollen potential developed for Quercus is also applied to Morus, Platanus, and Juglans and is expressed as…" and (lines 499-504): "This approach may not accurately represent the represent the relationship between pollen production and prior-year precipitation for the non-oak species that it was applied to (as observed values were not available for comparison for these other species), but probably broadly represents the positive value between pollen production and prior-year precipitation observed for numerous tree species (Fairley and Batchelder, 1986; Kozlowski, 1971)."

“Page 2339, lines 22-25: Justification for neglecting the influence of precipitation on the length of the flowering season? Although the simulated grass species were not included in the mentioned paper, it is very plausible that the discovered influence also plays a role here.”

Author response 19: We have added some discussion of this and a consideration of limitations associated with this assumption (lines 266-274):

“There have also been reports of skewness in flowering distributions among populations (Laursen et al., 2007), as well as observations of temperature and precipitation effecting the shape of such distributions (Tedeschini et al., 2006). Parametrizations do not yet exist in STaMPS to represent environmental influences on flowering distributions, therefore the shape of simulated pollen curves may not be well-represented in years when flowering behavior within a population deviates from a normal distribution. On the other hand, STaMPS modules can be easily modified to represent longer flowering periods or different distributions to reflect averages observed for a given species.”

“Page 2340, line 10: Please add the p-value of the correlation.”

Author response 20: The p-value has now been added to the caption of Fig. 5 (instead of adding it to the text).

“Page 2340, lines 12-14: How did you calculate this?”

Author response 21: The text has been changed to read (lines 551-557): “When percent early-season vernalization (as defined below) was plotted against observed peak pollen concentrations (normalized as percent of average peak value across all years), an r2 value of 0.75 was observed using a linear least-squares regression, while the same regression performed between prior-year wet season precipitation and observed peak pollen concentrations (normalized as above) yielded an r2 value of only 0.08 (not shown).”

“Section 2.4: I am missing the details: how is the fractional land cover assigned (per-

centages used for each class!), what is used for the weighting, horizontal resolution of the data sets: overall, I do not understand how the fractional land cover was produced. Maybe a flow chart would clarify the process? It would also be good to compare the methods with the literature about vegetation cover estimation (e.g., Sofiev et al. 2006, Int. J. Biometeorology, or Skjoth et al. 2008, Ecological Modeling, or Skjoth et al. 2010, Agricultural and Forest Meteorology, or Pauling et al. 2012, Int. J. Biometeorology).”

Author response 22: We have removed the word “weighted” in describing how the urban tree inventories were used to calculate species composition since these were simply averaged, not weighted. We have provided spatial resolution for the CDL raster dataset used to determine land-use and (for agricultural locations) species composition. We have also provided spatial resolution for the NLCD percent canopy cover and impervious raster datasets used to determine fractional vegetation cover. As already described in this section (which is now an appendix), the FIA dataset was a point shapefile while the EPA ecoregions dataset and the NRCS dataset were both polygons. To clarify the process of assigning fractional species composition within domain cells, we have added the following paragraph (in lieu of adding another figure to the paper):

“For example, suppose a given domain cell is comprised of 20% low-density urban land use, 70% forest, and 10% water according to the CDL dataset. The urban portion of the cell would be assigned a static 15% canopy cover (Table 4) and the associated fractional species composition for that area would be assigned based on an urban tree inventory. The forested portion would be assigned the fractional tree cover obtained by averaging the NLCD canopy dataset underlying the forested portion of the cell, while species composition for the forested region would be assigned based on which ecoregion(s) occur within the cell and weighted accordingly. Tree species composition within different ecoregions was determined by averaging the FIA data described above according to ecoregion membership across the FIA plots. The portion of the cell identified as being covered by water would be excluded from analysis.”

“Page 2342, lines 18-23: This is not necessary here, already described in formula 3.”

Author response 23: We have deleted this text.

"Section 2.5: Before applying the model on future climate, I would expect some sort of validation using current climate. Page 2344, lines 10-17: How well works the model for current climate? In order to interpret results for future climate, it is essential to know how precise the timing and magnitude of the pollen season can be calculated under current climate."

Author response 24: See Author responses 2 and 11 (above) and 26 (below).

"Page 2345, lines 20-end of paragraph: Maybe the simulation period should be extended to represent the entire pollen season? It would help to interpret the results if the entire season was inside the simulation period!"

Author response 25: We have rerun the current & future simulations for a full year period and have modified the ms accordingly

"Page 2346, lines 5-14: To evaluate the model, STaMPS output was incorporated into a transport model and simulated pollen concentrations were compared to pollen count data. The reader is referred to a companion paper for the details. However, I think incorporating the model output into another model and comparing the output of the second model to observational data is not a good way to validate the first model. Resulting pollen concentrations do not only depend on the output of the STaMPS model but also on the emission parameterization and transport/diffusion processes in the transport model. If available, it would be nice to compare the STaMPS output directly to phenological data of the start of flowering."

Author response 26: We agree that phenological observations are the ideal datasets to inform and validate predictive models of budburst, and many of the studies that we used to parameterize these relationships for the selected species were based on phenological observations (e.g. Bromus: Gleichsner, J. A. and Appleby, A. P. Weed Sci., 44, 57-62, 1996; Quercus: phenological observations provided courtesy of Dr. Walt

Koenig of Cornell University; and Olea: De Melo-Abreu, J. P., Barranco, D., Cordeiro, A. M., Tous, J., Rogado, B. M. and Villalobos, F. J. Agr. Forest Meteorol., 125, 117-127, 2004). As mentioned in an author response, we have now included a discussion of the possible contribution to observed pollen from long-range transport (LRT) episodes and the steps we took to consider LRT in our simulations as well as acknowledging the limitations inherent in using observed pollen counts as proxies for dates of peak pollen release (Section 4.1). Finally, as mentioned previously, while we agree that additional model evaluation is always desirable, our companion paper did evaluate the results rather rigorously despite the use of pollen counts instead of phenological observations. As pointed out in our companion paper (Zhang et al., 2013), although LRT might be expected to affect "spatial distribution and magnitude of pollen concentrations at the local scale (Zink et al., 2011), there should be a correlation between the timing of pollen emission and that of concentration on the regional scale", and using birch performance as an example, the regionally-observed and simulated regionally-averaged mean peak pollen concentration dates both occurred in Mid-May, and comparisons between observed mean and max concentrations for nine sites within the domain indicated good performance for most of the species (Also see Author responses 2 and 11, above).

"Page 2347, lines 18-24: I totally agree! Please justify why you did not simulate the entire season. Regarding the limitations (not representing the entire pollen seasons), I am not sure what we can learn from the study about the future."

Author response 27: We have rerun the current & future simulations for a full year period and have modified the ms accordingly

"Page 2349, lines 8-9: No, the STaMPS model has been designed to simulate the timing and potential magnitude of the pollen season. The release of the pollen is simulated in the transport model (see companion paper) using an emission parameterization respecting the influence of wind."

Author response 28: We have changed "release" to "production" (thanks for catching that)

"Figure 3: What is "Days to flower" (y-axis)? The beginning of the pollen season? The length of the pollen season? If it is the beginning: what is the initial date? When does the counting of the days (x-axis) start? What is 7°C? Mean/min/max temperature?"

Author response 29: We have added the following sentence to the caption of Fig. 3: "B. diandrus seeds were exposed to cold treatments and germinated during the chilling period; subsequent days to flowering following vernalization treatments are shown on the y-axis."

"Figure 4 and 5: What is the p-value of the correlation?"

Author response 30: We have added p-values to the captions in Figs. 4 and 5.

"Technical corrections:" "Page 2333, lines 20 + 23: (Betula, Juglans, and Olea) : : :(olive, walnut, and birch): unnecessary repetition, additionally it would be better to use either Latin or English words, not a mixture."

Author response: we have deleted "(olive, walnut, and birch)" "Page 2334, line 7: Losing a negative value (-0.56 chilling units) results in a net gain: double negative = positive: : :in my opinion, it should be: : : :above which 0.56 chilling units are lost."

Author response: you are right; this has been fixed "Page 2335, lines 24-30: illogical use of the words 'quantitative' and 'qualitative': for me, the fraction of heads flowering is quantitative as it gives the amount of potentially available pollen grains."

Author response: we have changed this sentence to read: "In grasses, vernalization may be facultative, where cold temperatures occurring prior to the flowering season affect the timing of flowering and can enhance the fraction of plants that head, or obligate, in which adequate chilling is required for flowering to occur at all (Gleichsner and Appleby, 1996)."

"Page 2339, formula 5: the precipitation-driven coefficient is now called gamma. Be-

fore, in formula 3, it was called alpha. There, gamma was the fraction of land covered with the specific plant."

Author response: We have changed this to alpha. "Page 2349, line 22: Artemisia instead of Artemesia."

Author response: We have changed this to Artemisia

"Table 1: phenological instead of phonological"

Author response: Thanks for catching this; it has been changed.

Please also note the supplement to this comment:
http://www.geosci-model-dev-discuss.net/6/C1976/2013/gmdd-6-C1976-2013-supplement.pdf

Interactive comment on Geosci. Model Dev. Discuss., 6, 2325, 2013.