

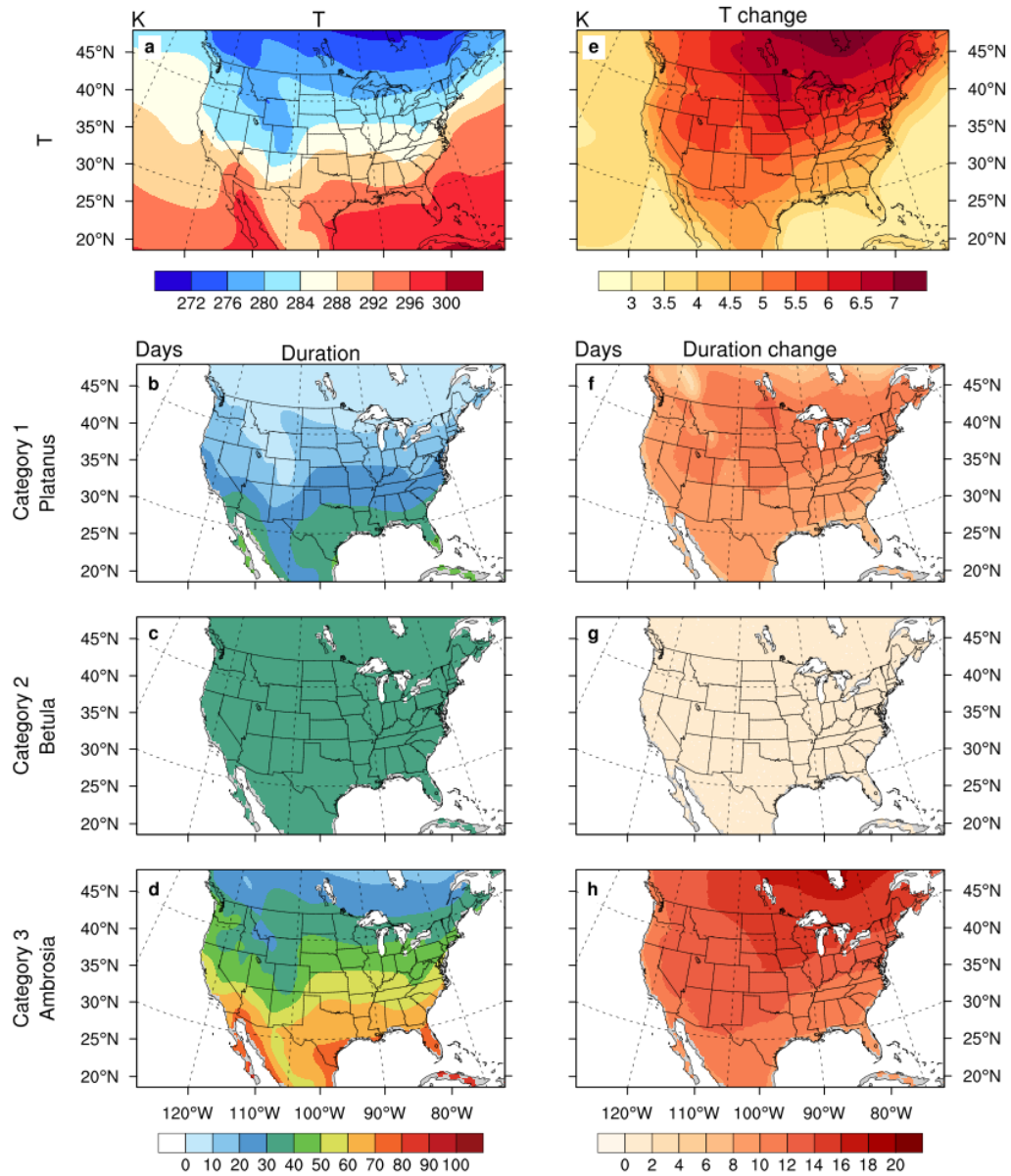
Projected climate-driven changes in pollen emission season length and  
magnitude over the continental United States

**Supplementary Information**

Yingxiao Zhang<sup>1</sup> and Allison Steiner<sup>1</sup>

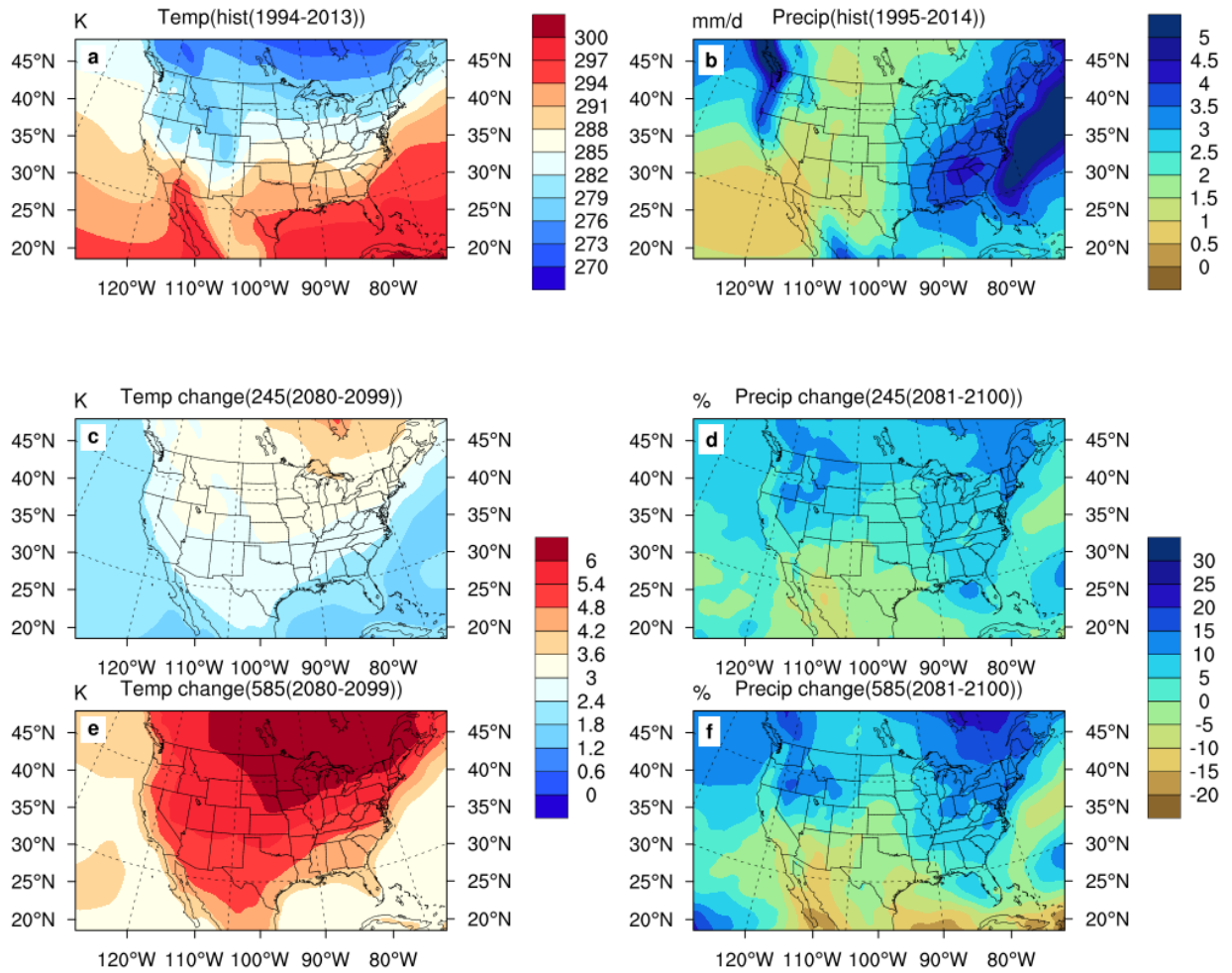
<sup>1</sup>Department of Climate and Space Sciences and Engineering, University of Michigan, Ann  
Arbor, United States

## Supplementary Figures:



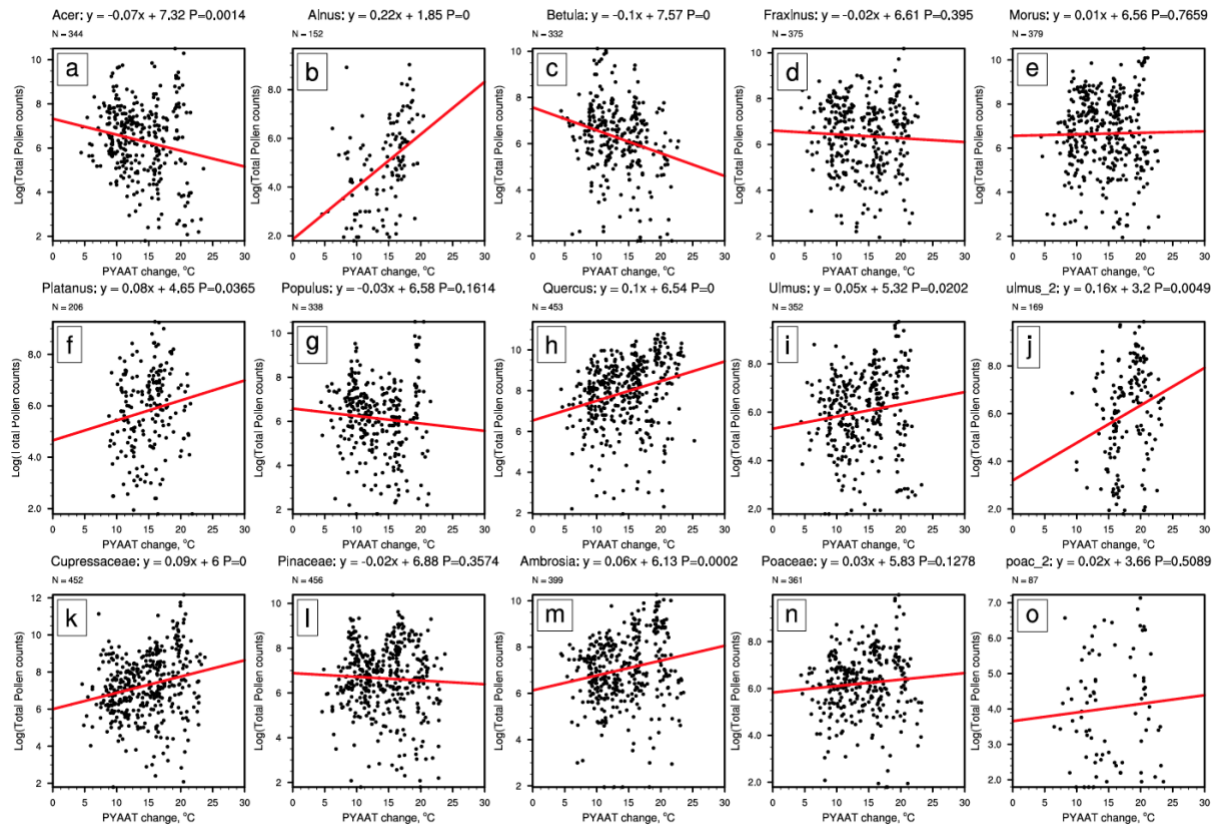
**Figure S1 Pollen season duration and duration change for three categories**

Multi-model averaged spatial distribution of historical (1995-2014) temperature (K) (a), historical pollen season durations (days) (b-d), and the end of the century (2081-2100) with scenario SSP585 temperature change (e), and pollen season duration (f-h). One vegetation type is selected to represent each of the three categories of pollen season duration change (Figure 2): **b, f**, *Platanus* (Category 1); **c, g**, *Betula* (Category 2); **d, h**, *Ambrosia* (Category 3).



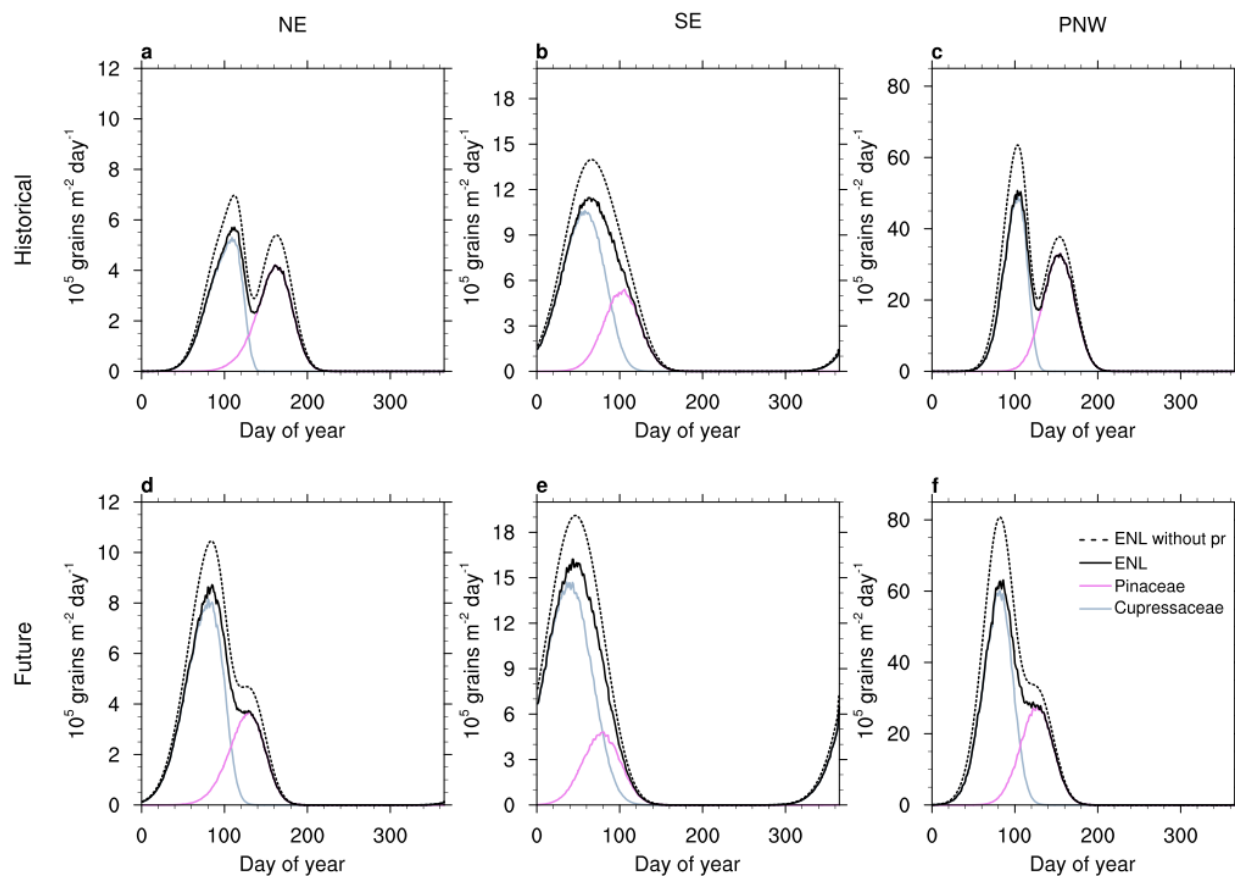
**Figure S2 Future temperature and precipitation from CMIP6 models**

Multi-model annual mean temperature and precipitation over the continental U.S. (20-year average). **(a, b)** historical (1995-2014) distributions for temperature (K) **(a)** and precipitation (mm/d) **(b)** and **(c-f)**, future (2081-2100) changes for temperature (K) **(c, e)** and precipitation (%) **(d, f)** under scenario SSP 245 **(c, d)** and SSP 585 **(e, f)**.



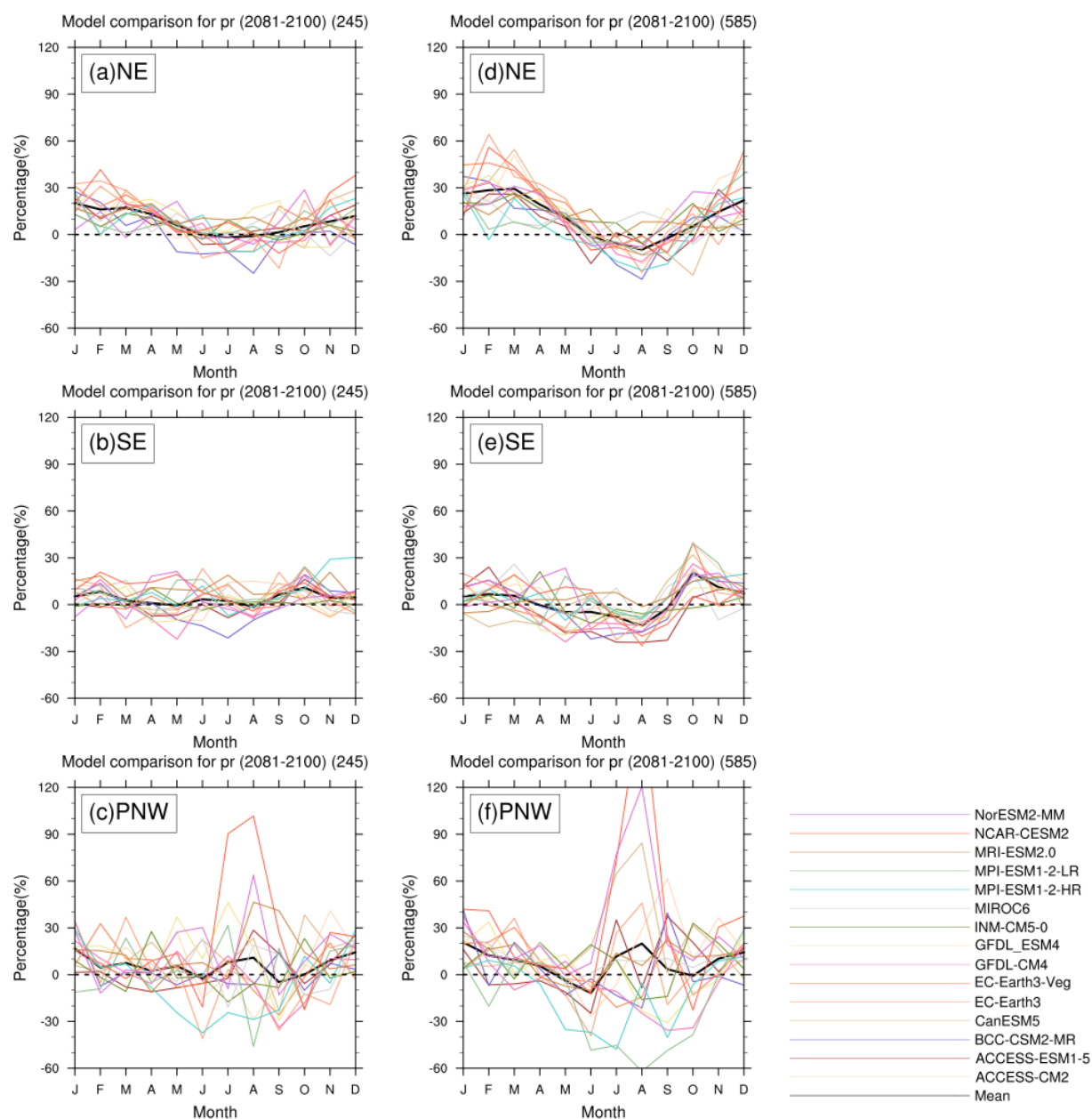
**Figure S3 Relationships between annual total pollen counts and temperature.**

Linear regressions for log-transformed accumulated annual total pollen counts versus previous-year annual average temperature (PYAAT, °C) for all taxa. Each point signifies one station per year from 2003 to 2010, with N as the total number of observations utilized in the regression. Regression statistics are summarized in Table S1.



**Figure S4 Evergreen Needleleaf (ENL) pollen season phenology**

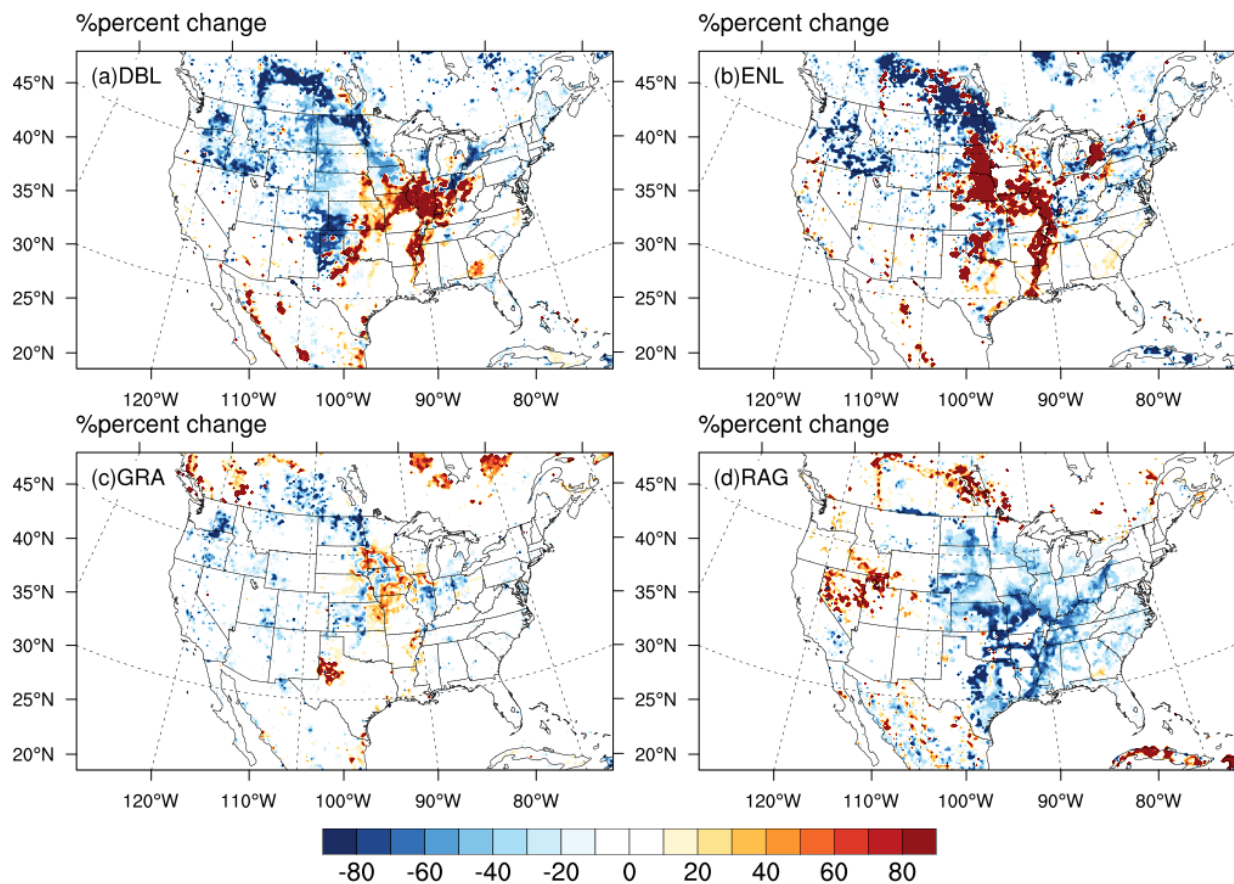
20-year multi-model average time series of daily pollen emission flux ( $\text{grains m}^{-2} \text{ d}^{-1}$ ) of 2 individual tree families that comprise ENL (Pinaceae and Cupressaceae) and the total ENL emission with and without precipitation. (a-c) historical (1995-2014) emissions and (d-f) emissions at the end of the century (2081-2100) for SSP 585. Columns from left to right: Northeast, NE (a, d); Southeast, SE (b, e); Pacific Northwest, PNW (c, f).



**Figure S5 Seasonal precipitation changes in the future.**

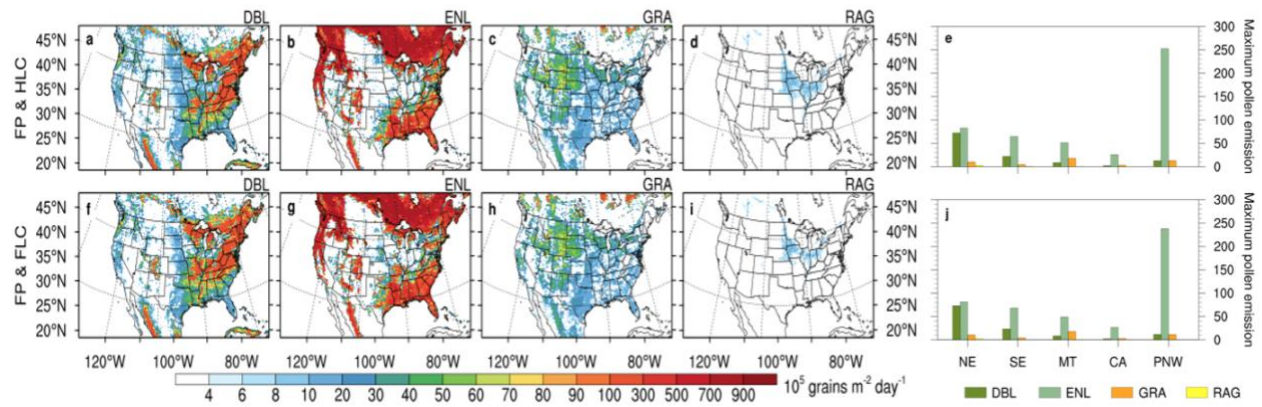
Spatially averaged change of 20-year monthly averaged daily precipitation for individual CMIP6 models and the multi-model mean in the Northeast region (a, d), Southeast region (b, e), and Pacific Northwest region (c, f) at the end of century (2081-2100) under scenario SSP 245 (a-c) and SSP 585 (d-f) compared to historical period (1995-2014) (unit: percentage (%)). Black lines show the model mean. Region boundaries are shown in Fig. 2.





**Figure S6 Future PFT Land cover change.**

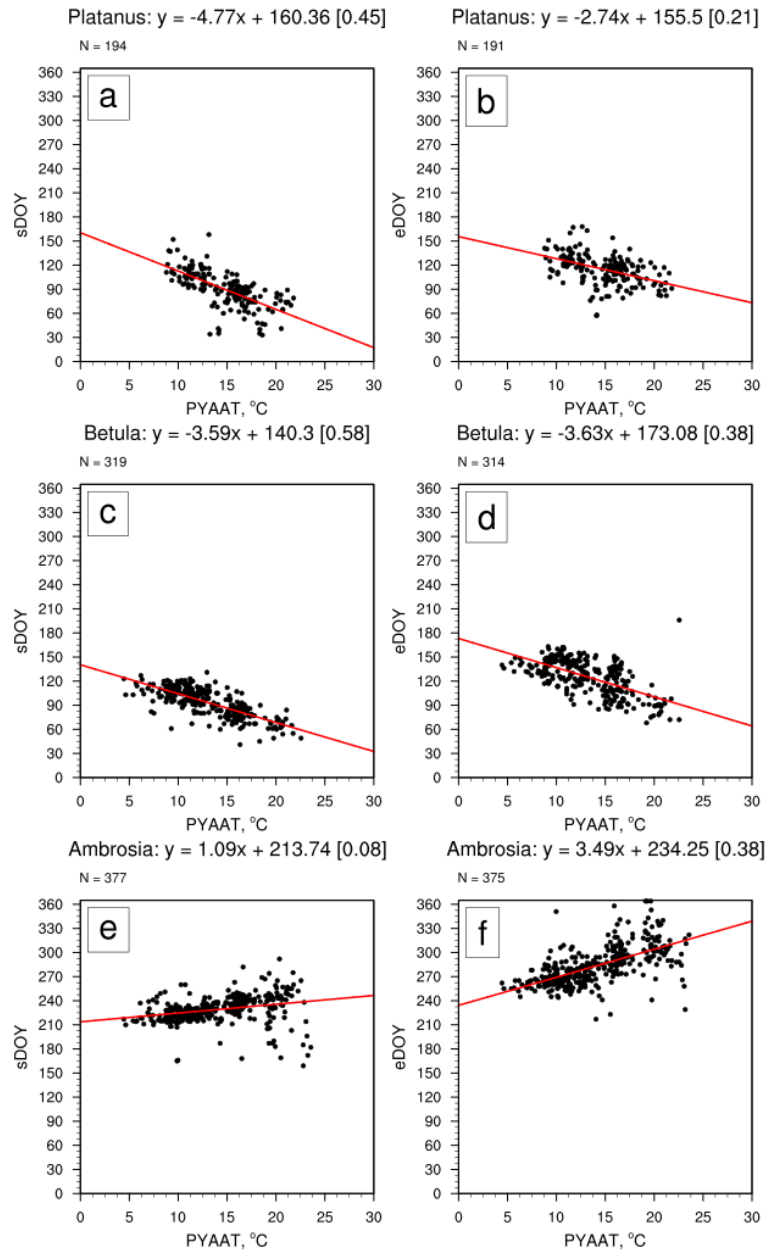
**a-d**, GCAM-Demeter (Chen et al.<sup>1</sup>) projected land cover change in the future (2100) compared to the historical (2015) for 4 PFTs: Deciduous Broadleaf (DBL) (**a**), Evergreen Needleleaf (ENL) (**b**), Grasses (GRA) (**c**) and Ragweed (RAG), which is calculated using the cropland and urban coverage (see Wozniak and Steiner<sup>2</sup>) (**d**) (unit: %).



**Figure S7 Simulated maximum daily pollen emission with historical and future land cover.**

**a-e**, Future average (2081-2100) maximum daily pollen emission flux (FP) with historical (2015) land cover fraction (HLC) over the United States (unit:  $grains\ m^{-2}d^{-1}$ ). **f-j**, same as **a-e** but using future (2100) land cover fraction (FLC). The simulation is conducted using PFT-based pollen emission model (PECM) and driving by multi-model average meteorology input data in at the end of the century (2081-2100). The percentage change of maximum daily pollen emission flux due to the future land cover change is shown in Fig.4 p-s in the main manuscript (change = FP & FLC – FP & HLC). Each column represents different PFTs, from left to right: DBL (**a, f**), ENL (**b, g**), GRA (**c, h**), RAG (**d, i**).





**Figure S8 Linear relationship between observed pollen season timing and temperature.**

**a-f**, Phenological regression for start day of year (sDOY; **a**, **c**, **e**) and end day of year (eDOY; **b**, **d**, **f**) versus previous-year annual average temperature (PYAAT, °C). One vegetation type is selected to represent each of the three categories (shown in Fig. 1) of pollen season duration change: **a**, **b**, *Platanus* (Category 1); **c**, **d**, *Betula* (Category 2); **e**, **f**, *Ambrosia* (Category 3). Each point signifies one station per year from 2003 to 2010 with N as the total number of observations.

## Supplementary Tables:

| Taxon or PFT                      | $P_{\text{annual}}$<br>$10^7 \text{ grains m}^{-2} \text{ yr}^{-1}$ | Reference for $P_{\text{annual}}$                                                | $m_{\text{prod}}$ | $b_{\text{prod}}$ |
|-----------------------------------|---------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------|-------------------|
| Deciduous broadleaf forest (DBL)  |                                                                     |                                                                                  |                   |                   |
| <i>Acer</i>                       | 134                                                                 | Katz et al. (2020),<br>Tormo Molina et al. (1996)                                | -0.07             | 7.32              |
| <i>Alnus</i>                      | 210                                                                 | Helbig et al. (2004)                                                             | 0.22              | 1.85              |
| <i>Betula</i>                     | 115                                                                 | Katz et al. (2020),<br>Jato et al. (2007)                                        | -0.1              | 7.57              |
| <i>Fraxinus</i>                   | 161                                                                 | Tormo Molina et al. (1996)                                                       | -0.02             | 6.61              |
| <i>Morus</i>                      | 1260                                                                | Katz et al. (2020)                                                               | 0.01              | 6.56              |
| <i>Platanus</i>                   | 392                                                                 | Katz et al. (2020),<br>Tormo Molina et al. (1996)                                | 0.08              | 4.65              |
| <i>Populus</i>                    | 100                                                                 | Katz et al. (2020),<br>Tormo Molina et al. (1996)                                | -0.03             | 6.58              |
| <i>Quercus</i>                    | 143                                                                 | Katz et al. (2020),<br>Tormo Molina et al. (1996),<br>Gmoez-casero et al. (2010) | 0.1               | 6.54              |
| <i>Ulmus</i> (late)               | 31.6                                                                | Katz et al. (2020), Tormo<br>Molina et al. (1996)                                | 0.05              | 5.32              |
| <i>Ulmus</i> (late)               | 31.6                                                                | Katz et al. (2020), Tormo<br>Molina et al. (1996)                                | 0.16              | 3.2               |
| DBL                               | 283                                                                 | This paper                                                                       | N/A               | N/A               |
| Evergreen needleleaf forest (ENL) |                                                                     |                                                                                  |                   |                   |
| Cupressaceae                      | 1050                                                                | Hidalgo et al. (1999),<br>Damialis et al. (2011),<br>Aboulaich et al. (2008)     | 0.09              | 6                 |
| Pinaceae                          | 101                                                                 | Tormo Molina et al. (1996)                                                       | -0.02             | 6.88              |
| ENL                               | 575.5                                                               | This paper                                                                       | N/A               | N/A               |
| Grasses (GRA)                     |                                                                     |                                                                                  |                   |                   |
| Poaceae(C3)                       | 46.2                                                                | Prieto-Baena et al. (2003)                                                       | 0.03              | 5.83              |
| Poaceae(C4)                       | 4.62                                                                | Prieto-Baena et al. (2003)                                                       | 0.02              | 3.66              |
| Ragweed (RAG)                     |                                                                     |                                                                                  |                   |                   |
| <i>Ambrosia</i>                   | 119                                                                 | Fumanal et al. (2007)                                                            | 0.06              | 6.13              |

**Table S1 Production factor ( $P_{\text{annual}}$ ) and production regression coefficients ( $m_{\text{prod}}$  and  $b_{\text{prod}}$ ) for the 13 individual taxa and corresponding PFTs used in this study.**

Production factors ( $P_{\text{annual}}$ ) are based on literature value averages. Individual taxa and families are organized into four PFTs, with the two aggregated tree PFTs (DBL and ENL). Regression slope and intercept ( $m_{\text{prod}}$  and  $b_{\text{prod}}$ , respectively) used to derive the annual pollen production ( $pf_{\text{annual}}$ ) as a function of temperature are provided. The taxa that have a negative correlation with temperature are colored with grey. Note the PFT-based model does not consider the change of pollen production with temperature and regression coefficients are not provided. The source data are provided in source data file.

| Morris Index | parameters          | Taxa |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
|--------------|---------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|              |                     | ACER | ALDR | BETU | CUPR | FRAX | MORU | PINU | PLAT | POPU | QUER | ULNU | ULN2 | GRC3 | GRC4 | AMBR |
| $\mu^*$      | a                   | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    |
|              | m <sub>sDOY</sub>   | 8    | 3    | 8    | 7    | 7    | 8    | 8    | 8    | 7    | 7    | 8    | 2    | 8    | 3    | 8    |
|              | b <sub>sDOY</sub>   | 7    | 8    | 7    | 4    | 4    | 7    | 6    | 7    | 5    | 8    | 7    | 6    | 6    | 8    | 6    |
|              | m <sub>eDOY</sub>   | 6    | 1    | 6    | 8    | 8    | 6    | 7    | 4    | 4    | 6    | 6    | 4    | 7    | 6    | 7    |
|              | b <sub>eDOY</sub>   | 5    | 7    | 4    | 6    | 6    | 5    | 5    | 2    | 2    | 5    | 5    | 5    | 5    | 7    | 5    |
|              | m <sub>prod</sub>   | 4    | 5    | 3    | 5    | 5    | 3    | 4    | 5    | 8    | 4    | 4    | 3    | 4    | 1    | 4    |
|              | b <sub>prod</sub>   | 3    | 2    | 2    | 3    | 3    | 4    | 2    | 6    | 3    | 3    | 3    | 1    | 3    | 2    | 3    |
|              | P <sub>norm</sub>   | 2    | 4    | 1    | 2    | 1    | 1    | 1    | 1    | 1    | 2    | 1    | 7    | 2    | 4    | 1    |
|              | P <sub>annual</sub> | 1    | 6    | 5    | 1    | 2    | 2    | 3    | 3    | 6    | 1    | 2    | 8    | 1    | 5    | 2    |
| $\sigma$     | a                   | 9    | 9    | 8    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    | 9    |
|              | m <sub>sDOY</sub>   | 7    | 3    | 9    | 6    | 5    | 8    | 8    | 2    | 6    | 7    | 8    | 1    | 7    | 3    | 8    |
|              | b <sub>sDOY</sub>   | 8    | 8    | 7    | 3    | 3    | 7    | 6    | 6    | 5    | 8    | 7    | 6    | 6    | 8    | 6    |
|              | m <sub>eDOY</sub>   | 6    | 1    | 6    | 8    | 8    | 4    | 5    | 7    | 4    | 6    | 6    | 4    | 8    | 7    | 7    |
|              | b <sub>eDOY</sub>   | 5    | 7    | 4    | 7    | 7    | 6    | 7    | 1    | 1    | 5    | 5    | 5    | 5    | 6    | 5    |
|              | m <sub>prod</sub>   | 4    | 4    | 3    | 5    | 6    | 3    | 4    | 5    | 8    | 4    | 4    | 3    | 4    | 1    | 4    |
|              | b <sub>prod</sub>   | 3    | 2    | 2    | 4    | 4    | 5    | 3    | 8    | 3    | 3    | 3    | 2    | 3    | 2    | 3    |
|              | P <sub>norm</sub>   | 2    | 5    | 1    | 2    | 1    | 1    | 1    | 4    | 2    | 1    | 1    | 7    | 2    | 5    | 1    |
|              | P <sub>annual</sub> | 1    | 6    | 5    | 1    | 2    | 2    | 2    | 3    | 7    | 2    | 2    | 8    | 1    | 4    | 2    |

**Table S2 Model sensitivity analysis parameter ranks from Morris indices.**

The simulated Morris indices (mean  $\mu^*$  and standard division  $\sigma$ ) for the 9 input parameters for the 15 model taxa. The highest 4 ranking parameters are highlighted with warm colors, indicating a larger importance of the pollen emission simulation.

| Model         | Atmospheric resolution (long x lat) | Modeling group      | References                            |
|---------------|-------------------------------------|---------------------|---------------------------------------|
| ACCESS-CM2    | 1.875° × 1.25°, L85                 | CSIRO-ARCCSS        | Dix et al. (2019)                     |
| ACCESS-ESM1-5 | 1.875° × 1.25°, L38                 | CSIRO               | Ziehn et al. (2019)                   |
| BCC-CSM2-MR   | 1.125° × 1.125°, L46                | BCC                 | Zhang et al. (2019)                   |
| CanESM5       | 2.81° × 2.81°, L49                  | CCCma               | Swart et al. (2019)                   |
| EC-Earth3     | 0.7° × 0.7°, L91                    | EC-Earth-Consortium | EC-Earth Consortium (EC-Earth) (2019) |
| EC-Earth3-Veg | 0.7° × 0.7°, L91                    | EC-Earth-Consortium | EC-Earth Consortium (EC-Earth) (2019) |
| GFDL-CM4      | 1.25° × 1°, L33                     | NOAA-GFDL           | Silvers et al. (2018)                 |
| GFDL-ESM4     | 1.25° × 1°, L49                     | NOAA-GFDL           | Horowitz et al. (2018)                |
| INM-CM5-0     | 2° × 1.5°, L73                      | INM                 | Volodin et al. (2019)                 |
| MIROC6        | 1.4° × 1.4°, L81                    | MIROC               | Takemura, Toshihiko (2019)            |
| MPI-ESM1-2-HR | 0.9375° × 0.9375°, L95              | MPI-M DWD DKRZ      | Jungclaus et al. (2019)               |
| MPI-ESM1-2-LR | 1.875° × 1.875°, L47                | MPI-M AWI           | Brovkin et al. (2019)                 |
| MRI-ESM2.0    | 1.125° × 1.125°, L80                | MRI                 | Yukimoto et al. (2019)                |
| NCAR-CESM2    | 1.25° × 0.9375°, L32                | NCAR                | Danabasoglu, Gokhan (2019)            |
| NorESM2-MM    | 1.25° × 0.9375°, L32                | NCC                 | Bentsen et al. (2019)                 |

**Table S3 CMIP6 models used in the study.**

Modeling group information and spatial resolution are provided at [https://wcrp-cmip.github.io/CMIP6\\_CVs/docs/CMIP6\\_source\\_id.html](https://wcrp-cmip.github.io/CMIP6_CVs/docs/CMIP6_source_id.html) with data citations in [http://bit.ly/CMIP6\\_Citation\\_Search](http://bit.ly/CMIP6_Citation_Search). CMIP6 data are regridded to a 25km Lambert Conformal Conic projection using the Earth System Modeling Framework (ESMF) higher-order patch regridding method over the United States to match the spatial resolution of PECM.

| Name                                                                                   | Symbol | Units                 | Taxa     | Lower limit | Upper limit |
|----------------------------------------------------------------------------------------|--------|-----------------------|----------|-------------|-------------|
| Gaussian width                                                                         | a      | N/A                   | All taxa | 2.8         | 3.2         |
| Slope of the regression between start date (sDOY) of pollen season and temperature     | sDOY_m | Days °C <sup>-1</sup> | ACER     | -2.41       | -1.47       |
|                                                                                        |        |                       | ALDR     | -7.66       | -4.44       |
|                                                                                        |        |                       | BETU     | -3.96       | -3.23       |
|                                                                                        |        |                       | CUPR     | -6.45       | -5.25       |
|                                                                                        |        |                       | FRAC     | -5.15       | -4.12       |
|                                                                                        |        |                       | MORU     | -4.45       | -3.67       |
|                                                                                        |        |                       | PINU     | -6.46       | -5.21       |
|                                                                                        |        |                       | PLAT     | -5.56       | -3.98       |
|                                                                                        |        |                       | POPU     | -2.73       | -1.78       |
|                                                                                        |        |                       | QUER     | -4.53       | -3.79       |
|                                                                                        |        |                       | ULNU     | -5.12       | -4.27       |
|                                                                                        |        |                       | ULN2     | 2.15        | 4.96        |
|                                                                                        |        |                       | GRC3     | -5.38       | -4.3        |
|                                                                                        |        |                       | GRC4     | -1.18       | 1.12        |
| Intercept of the regression between start date (sDOY) of pollen season and temperature | sDOY_b | Days                  | AMBR     | 0.7         | 1.48        |
|                                                                                        |        |                       | ACER     | 97.21       | 110.55      |
|                                                                                        |        |                       | ALDR     | 126.3       | 172.24      |
|                                                                                        |        |                       | BETU     | 135.3       | 145.3       |
|                                                                                        |        |                       | CUPR     | 129.13      | 146.66      |
|                                                                                        |        |                       | FRAC     | 140.8       | 155.93      |
|                                                                                        |        |                       | MORU     | 148.77      | 160.29      |
|                                                                                        |        |                       | PINU     | 168.26      | 186.82      |
|                                                                                        |        |                       | PLAT     | 148.41      | 172.31      |
|                                                                                        |        |                       | POPU     | 108.22      | 121.15      |
|                                                                                        |        |                       | QUER     | 142.84      | 153.95      |
|                                                                                        |        |                       | ULNU     | 124.97      | 137.27      |
|                                                                                        |        |                       | ULN2     | 153.39      | 204.46      |
|                                                                                        |        |                       | GRC3     | 177.38      | 193.27      |
|                                                                                        |        |                       | GRC4     | 228.17      | 264.53      |
| Slope of the regression between end date (eDOY) of pollen season and temperature       | eDOY_m | Days °C <sup>-1</sup> | AMBR     | 208.05      | 219.43      |
|                                                                                        |        |                       | ACER     | -2.28       | -0.85       |
|                                                                                        |        |                       | ALDR     | -5.58       | -1.95       |
|                                                                                        |        |                       | BETU     | -4.18       | -3.08       |
|                                                                                        |        |                       | CUPR     | -3.33       | -2.1        |
|                                                                                        |        |                       | FRAC     | -3.39       | -2.44       |
|                                                                                        |        |                       | MORU     | -3.53       | -2.54       |
|                                                                                        |        |                       | PINU     | -5.68       | -4.47       |
|                                                                                        |        |                       | PLAT     | -3.53       | -1.95       |
|                                                                                        |        |                       | POPU     | -0.91       | 0.38        |
|                                                                                        |        |                       | QUER     | -2.48       | -1.65       |
|                                                                                        |        |                       | ULNU     | -3.08       | -1.83       |
|                                                                                        |        |                       | ULN2     | 3.59        | 6.37        |
|                                                                                        |        |                       | GRC3     | -1.85       | -0.42       |
|                                                                                        |        |                       | GRC4     | 1.65        | 4.12        |
| Intercept of the regression between end date (eDOY) of pollen season and temperature   | eDOY_b | Days                  | AMBR     | 3.03        | 3.96        |
|                                                                                        |        |                       | ACER     | 126.68      | 146.4       |
|                                                                                        |        |                       | ALDR     | 109.36      | 161.39      |
|                                                                                        |        |                       | BETU     | 165.49      | 180.66      |
|                                                                                        |        |                       | CUPR     | 130.65      | 148.58      |
|                                                                                        |        |                       | FRAC     | 148.62      | 162.41      |
|                                                                                        |        |                       | MORU     | 167.15      | 181.77      |
|                                                                                        |        |                       | PINU     | 206.51      | 224.36      |
|                                                                                        |        |                       | PLAT     | 143.53      | 167.47      |
|                                                                                        |        |                       | POPU     | 110.19      | 127.6       |
|                                                                                        |        |                       | QUER     | 159         | 171.49      |
|                                                                                        |        |                       | ULNU     | 119.4       | 137.59      |
|                                                                                        |        |                       | ULN2     | 163.66      | 214.79      |
|                                                                                        |        |                       | GRC3     | 179.52      | 200.48      |
|                                                                                        |        |                       | GRC4     | 205.29      | 244.5       |

|                                                                                                               |         |                                         |      |          |          |
|---------------------------------------------------------------------------------------------------------------|---------|-----------------------------------------|------|----------|----------|
| Slope of the regression between log-transformed annual total pollen counts and temperature                    | prod_m  | Grains m <sup>-3</sup> °C <sup>-1</sup> | AMBR | 227.48   | 241.03   |
|                                                                                                               |         |                                         | ACER | -0.12    | -0.03    |
|                                                                                                               |         |                                         | ALDR | 0.14     | 0.29     |
|                                                                                                               |         |                                         | BETU | -0.14    | -0.05    |
|                                                                                                               |         |                                         | CUPR | 0.05     | 0.13     |
|                                                                                                               |         |                                         | FRAC | -0.055   | 0.022    |
|                                                                                                               |         |                                         | MORU | -0.038   | 0.052    |
|                                                                                                               |         |                                         | PINU | -0.052   | 0.019    |
|                                                                                                               |         |                                         | PLAT | 0.0049   | 0.15     |
|                                                                                                               |         |                                         | POPU | -0.081   | 0.014    |
|                                                                                                               |         |                                         | QUER | 0.061    | 0.13     |
|                                                                                                               |         |                                         | ULNU | 0.0079   | 0.093    |
|                                                                                                               |         |                                         | ULN2 | 0.048    | 0.27     |
|                                                                                                               |         |                                         | GRC3 | -0.008   | 0.063    |
|                                                                                                               |         |                                         | GRC4 | -0.049   | 0.098    |
| Intercept of the regression between log-transformed annual total pollen counts and temperature                | eDOY_b  | Grains m <sup>-3</sup>                  | AMBR | 0.031    | 0.098    |
|                                                                                                               |         |                                         | ACER | 6.7      | 7.95     |
|                                                                                                               |         |                                         | ALDR | 0.71     | 2.99     |
|                                                                                                               |         |                                         | BETU | 6.93     | 8.2      |
|                                                                                                               |         |                                         | CUPR | 5.43     | 6.57     |
|                                                                                                               |         |                                         | FRAC | 6.04     | 7.17     |
|                                                                                                               |         |                                         | MORU | 5.89     | 7.22     |
|                                                                                                               |         |                                         | PINU | 6.36     | 7.41     |
|                                                                                                               |         |                                         | PLAT | 3.55     | 5.76     |
|                                                                                                               |         |                                         | POPU | 5.93     | 7.23     |
|                                                                                                               |         |                                         | QUER | 6        | 7.07     |
|                                                                                                               |         |                                         | ULNU | 4.69     | 5.94     |
|                                                                                                               |         |                                         | ULN2 | 1.22     | 5.17     |
|                                                                                                               |         |                                         | GRC3 | 5.31     | 6.35     |
|                                                                                                               |         |                                         | GRC4 | 2.49     | 4.82     |
| Parameter used to normalize the regression between log-transformed annual total pollen counts and temperature | Pnorm   | Grains m <sup>-3</sup>                  | AMBR | 5.64     | 6.63     |
|                                                                                                               |         |                                         | ACER | 142.12   | 1833.85  |
|                                                                                                               |         |                                         | ALDR | 9.670855 | 502.5016 |
|                                                                                                               |         |                                         | BETU | 133.77   | 1760.97  |
|                                                                                                               |         |                                         | CUPR | 471.14   | 4700.54  |
|                                                                                                               |         |                                         | FRAC | 188.85   | 1789.35  |
|                                                                                                               |         |                                         | MORU | 208.0854 | 2908.632 |
|                                                                                                               |         |                                         | PINU | 272.0069 | 2176.695 |
|                                                                                                               |         |                                         | PLAT | 37.38186 | 2804.972 |
|                                                                                                               |         |                                         | POPU | 115.9617 | 1691.528 |
|                                                                                                               |         |                                         | QUER | 978.6627 | 7774.429 |
|                                                                                                               |         |                                         | ULNU | 122.0912 | 1467.142 |
|                                                                                                               |         |                                         | ULN2 | 6.802754 | 8888.089 |
|                                                                                                               |         |                                         | GRC3 | 180.148  | 1429.732 |
|                                                                                                               |         |                                         | GRC4 | 5.918866 | 514.765  |
| Pollen annual emission baseline                                                                               | Pannual | Grains m <sup>-2</sup>                  | AMBR | 441.5792 | 3145.443 |
|                                                                                                               |         |                                         | ACER | 4.92E+07 | 6.50E+09 |
|                                                                                                               |         |                                         | ALDR | 6.86E+08 | 5.22E+09 |
|                                                                                                               |         |                                         | BETU | 8.92E+08 | 1.40E+09 |
|                                                                                                               |         |                                         | CUPR | 1.56E+09 | 4.35E+10 |
|                                                                                                               |         |                                         | FRAC | 3.37E+08 | 3.20E+09 |
|                                                                                                               |         |                                         | MORU | 4.12E+09 | 3.13E+10 |
|                                                                                                               |         |                                         | PINU | 4.76E+08 | 1.32E+09 |
|                                                                                                               |         |                                         | PLAT | 1.38E+09 | 5.72E+09 |
|                                                                                                               |         |                                         | POPU | 6.82E+08 | 1.29E+09 |
|                                                                                                               |         |                                         | QUER | 1.50E+08 | 6.10E+09 |
|                                                                                                               |         |                                         | ULNU | 9.34E+07 | 7.86E+08 |
|                                                                                                               |         |                                         | ULN2 | 9.34E+07 | 7.86E+08 |
|                                                                                                               |         |                                         | GRC3 | 8.53E+07 | 8.39E+08 |
|                                                                                                               |         |                                         | GRC4 | 8.53E+06 | 8.39E+07 |
|                                                                                                               |         |                                         | AMBR | 3.89E+08 | 2.96E+09 |



#### **Table S4 Uncertainty ranges for input parameters for Morris sampling.**

The uncertainty ranges of 9 input parameters for the 15 individual taxa. Using the Morris method, the input parameter sets for each model sensitivity run are sampled within the above ranges. The source data are provided in source data file.

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