Estimates of Ambrosia artemisiifolia L. pollen emission and dispersion in Europe using RegCM

Presented By

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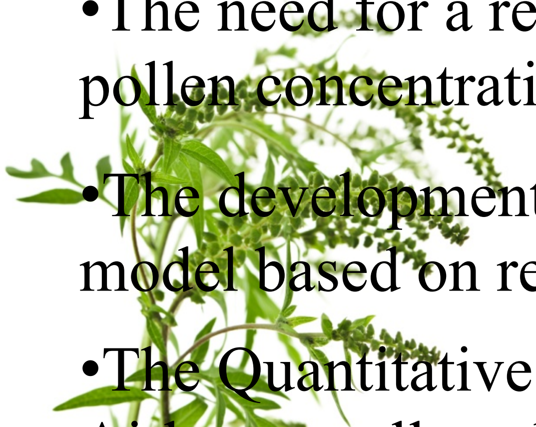
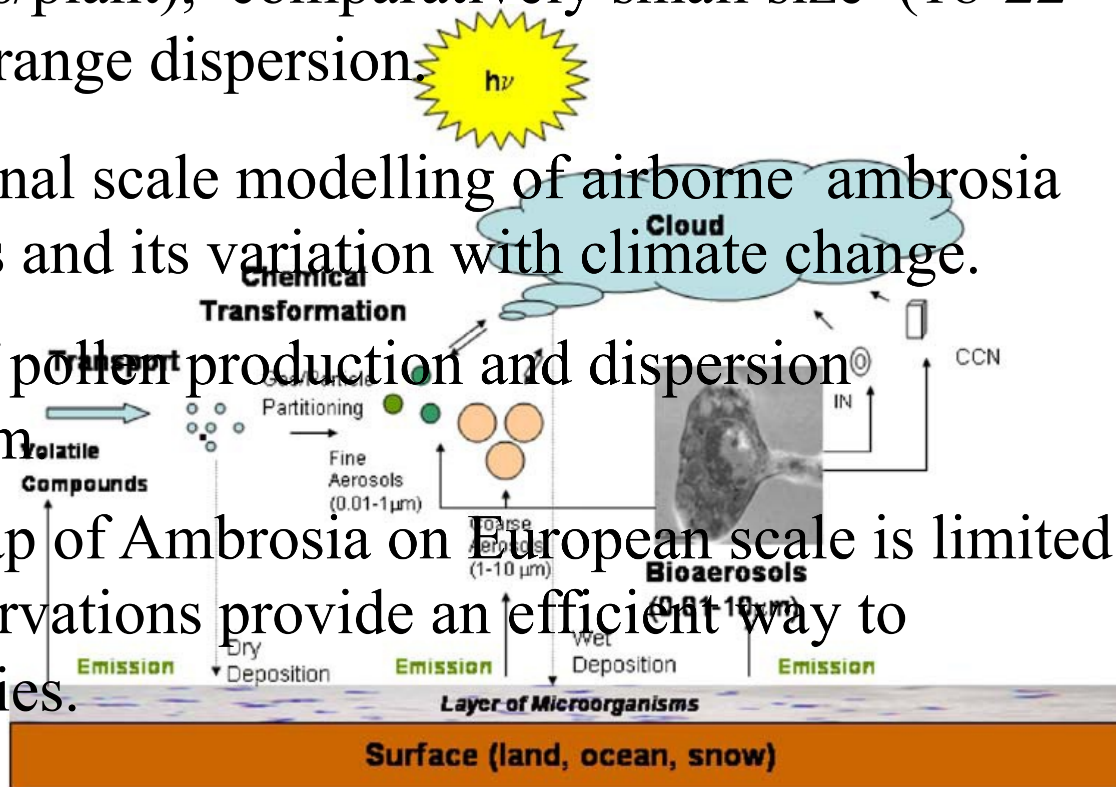
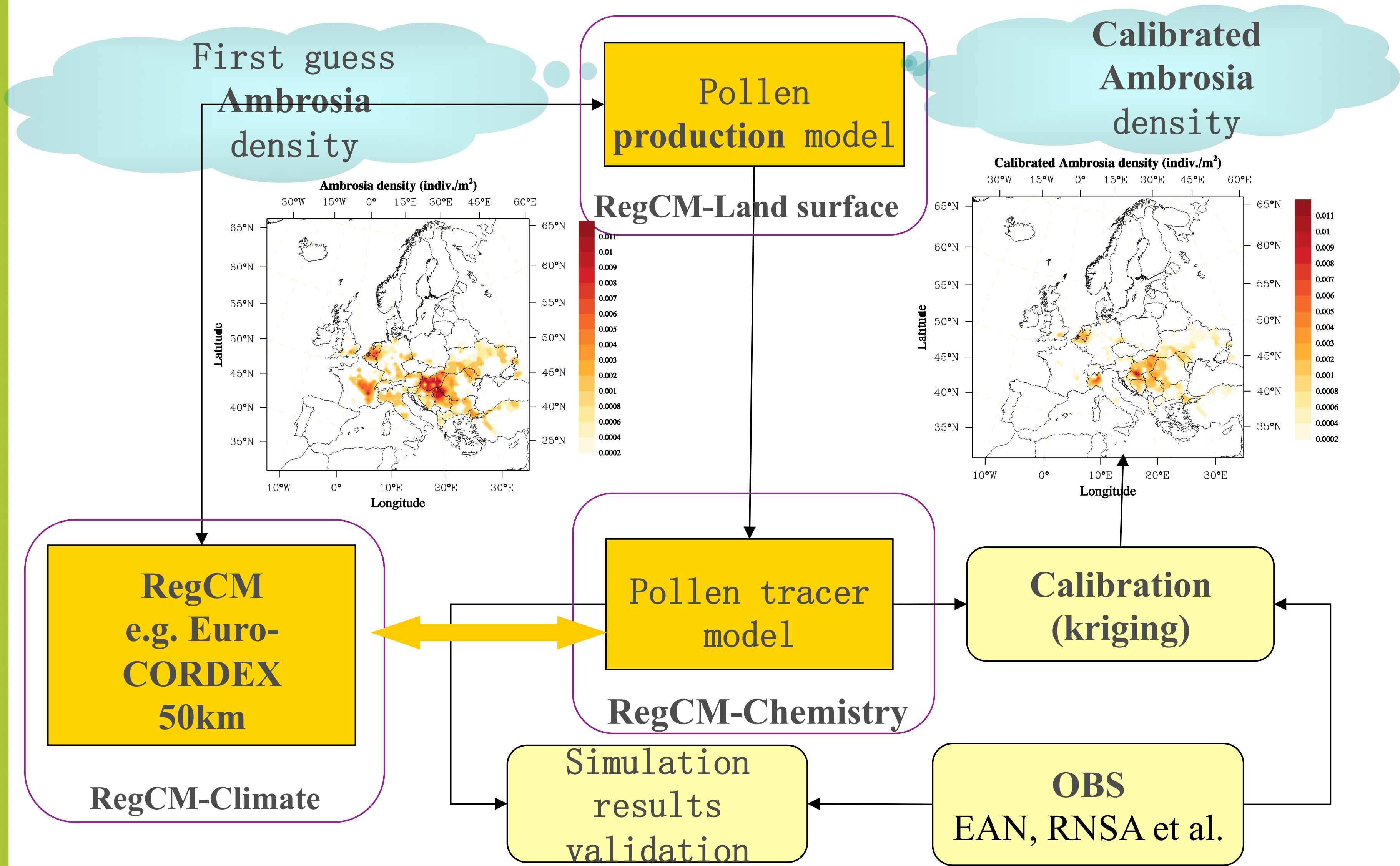
INTRODUCTION

- Ambrosia artemisiifolia L. is a highly allergenic invasive plant in Europe. Its pollen has been recognized as a significant cause of hayfever and asthma.
- Summer flowering season (August-September), high pollen production (10^9grains/plant), comparatively small size (18-22 μm) facilitating long-range dispersion.
- The need for a regional scale modelling of airborne ambrosia pollen concentrations and its variation with climate change.
- The development of pollen production and dispersion model based on regcm.
- The Quantitative map of Ambrosia on European scale is limited. Airborne pollen observations provide an efficient way to improve the inventories.





Simplified schematic of bioaerosols cycling in the Earth's ecosystem

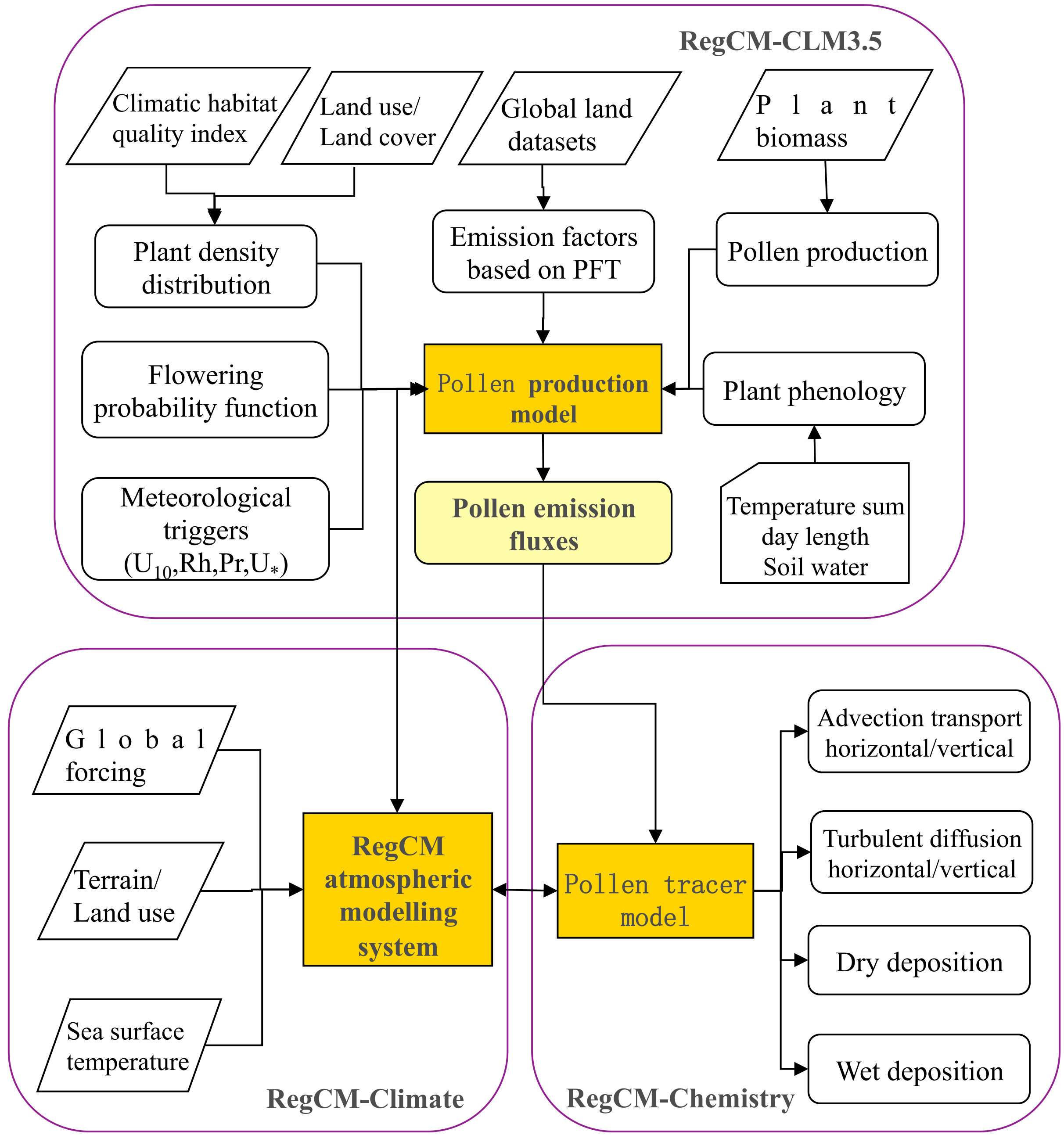


Working chain for Ambrosia pollen simulations. First-guess density uses a scaling on the number of records per 10×10 km^2 grid cell. The calibrated density uses correction coefficients calculated from first-guess run and the comparison with observations over 46 sites.

Materials and methods

Regional Climate-pollen model

Schematic flowchart depicting the modeling methodology for Ambrosia pollen within RegCM-pollen simulation framework



Pollen season definition

the period over which a given percentage of the total annual pollen count is recorded in the atmosphere. (1%-99%, 2.5%-97.5%)

the period between the first and last day with pollen counts higher or lower than a specific level (6 particles PID)

Table Criteria used to limit the pollen season used

Authors	Definition
Nilsson and Persson (1981)	The period from the time the sum of daily mean pollen concentrations reaches 5% of the total sum until the time when the sum reaches 95%; i.e. the time with 90% of the whole pollen amount.
Andersen (1991), Torben (1991)	The period from which the sum of daily mean pollen concentrations reaches 2.5% of the total sum until the time when the sum reaches 97.5%; i.e. the time with 95% of the whole pollen amount.
Galán et al. (1995)	The period from which the sum of daily mean pollen concentrations reaches 1% of the total sum until the time when the sum reaches 99% i.e. the time with 98% of the whole pollen amount.
Mullenders et al. (1972)	Define the main period as beginning on the day when 5 day's concentration reaches at least 1% of the joint total during three consecutive days and ends when the concentration is less than 0.9% during more than 10 days.
Spieksma et al. (1995)	Use the same criterion as that of Mullenders et al. (1972) but suggest that the 1% of the annual total should be defined as the mean annual total for the years considered.
Jäger et al. (1996)	Pollen season starts the first day that has a daily count higher than 1% of the annual pollen, presupposing that no more than six subsequent days follow with a zero count. It ends when 95% of the total annual pollen is reached.
Lejoly-Gabriel and Leuschner (1983)	It starts on the day when the sum of the annual percentages of pollen released by a taxon reaches 5%, provided that this day corresponds to a release higher than 1%. It ends on the last day when the daily percentage is higher than 1% and the sum of the percentage of this day and the percentages of the two preceding days are higher than or equal to 3%.
Giorato et al. (2000)	Period in which the daily pollen count exceeds 30 p/m^3 for Graminaceae and Urticaceae and 20p/m^3 for other families
Sánchez Mesa et al. (2003)	The start and end of the grass pollen season are defined as the first and last day, respectively, when the pollen counts are $\geq$30 p/m^3
Feher and Járai-Komlódi (1997)	Between the first and last days when a concentration of 3 g/m^3 is consistently exceeded; i.e. the pollen concentration is above 3 g/m^3 on at least 5 days during the following week.

(Victoria et al. 2006)

Ambrosia phenology

Pollen season is simulated with a generalized plant growth function based on minimum, optimum and maximum growing temperatures, including a day length adjuster and soil water content activity factor.

The responses of development rates to temperature:

$$r(T) = \begin{cases} 0 & T < T_{\min} \\ \left(\dfrac{T - T_{\min}}{T_{opt} - T_{\min}} \left(\dfrac{T_{\max} - T}{T_{\max} - T_{opt}} \right)^{\frac{T_{\max} - T_{opt}}{T_{opt} - T_{\min}}} \right)^{c} & T_{\min} \le T \le T_{\max} \\ 0 & T > T_{\max} \end{cases}$$

(Daniels et al. 2014)

The responses of development rates to photoperiod (day length):

$$r(L) = \begin{cases} e^{(L-14.5)\ln(1-L_s)} & L \ge 14.5 \\ 1 & L < 14.5 \end{cases}$$

(Daniels et al. 2014)

The responses of development rates to soil moisture:

$$r(S) = \begin{cases} 0 & \theta < \theta_w \\ \dfrac{(\theta - \theta_w)}{\Delta\theta_1} & \theta_w \le \theta \le \theta_1 \\ 1 & \theta > \theta_1 \end{cases}$$

(Guenther 2006)

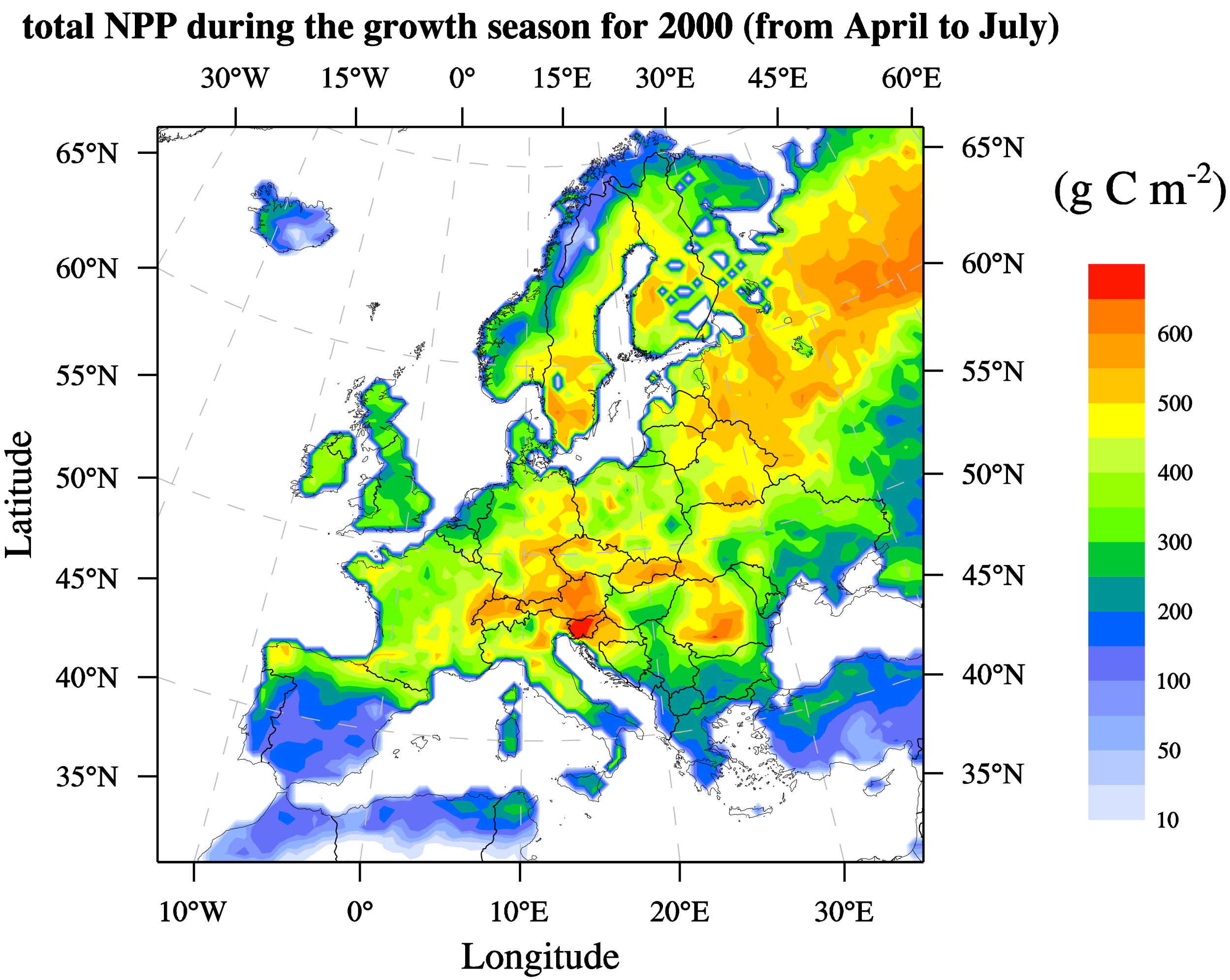
Ambrosia pollen production

Yearly total pollen production was estimated from plant biomass, assuming it is proportional to the net primary production NPP during the growth season.

$$Log_{10}(proq) = 7.22 + 1.12\log_{10}(plant\,biomass)$$

(Fumanal et al. , 2007)

Simulate with CESM data atmosphere component forced by CRUNCEP on global 360×720, with initial conditions for 2000 and CLM45BGC model on.



Parameterisation of the emission flux

the vertical flux of pollen particles Fp at the top of the vegetation is proportional to the product of a characteristic concentration and a characteristic velocity.

$$F_p = \varepsilon_p \phi(i,j) c_e K_e c^* u_* \qquad c^* = \frac{P_q}{LAI \cdot H_s}$$

(Helbig et al., 2004)

The characteristic concentration depends on total pollen production, the leaf area index, and canopy height of the Ambrosia.

Emissions factors based on PFT

Only allow Ambrosia pollen release from PFT marked as grass, crop and urban (landunit) of RegCM-CLM.

$\varepsilon_p = 1$ PFT : grass, crop and urban landunit

$\varepsilon_p = 0$ PFT: other

Flowering probability density distribution

describing the likelihood to bloom during pollen season.

Method 1:

Bell function Helbig (2004), Const is used to adjust the magnitude of the total released pollens is about the total production P.

$$c_e = const \cdot \frac{6}{(H_{fe} - H_{fs})} \cdot \left(\frac{H - H_{fs}}{H_{fe} - H_{fs}} - \frac{(H - H_{fs})^2}{(H_{fe} - H_{fs})^2} \right)$$

Method 2:

The probability distribution of production during pollen season is assumed to be Gaussian, centered midway between the start and end dates.

$$c_e = const \cdot \frac{1}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{(H - \frac{H_{fe}+H_{fs}}{2})^2}{2\sigma^2}}$$

Method 3:

The probability distribution of production for an individual to start and end the flowering, respectively

$$c_e = const \cdot \frac{\frac{H}{H_{fs}} - 1 + \delta_H}{2 \cdot \delta_H} \cdot \frac{1 + \delta_N - \frac{N}{N_{total}}}{2 \cdot \delta_N}$$

(Sofiev et al. 2012)

Meteorological triggers

Corrections dependent on short-term meteorological conditions: relative humidity, wind speed and precipitation rate.

$$K_e = K_h \cdot K_U \cdot K_r$$

(Sofiev et al. 2012)

Wind speed trigger:

$$K_U = U_{stagnant} + U_{promote}\left(1 - e^{-\frac{U + w_*}{U_{satur}}}\right)$$

Humidity trigger:

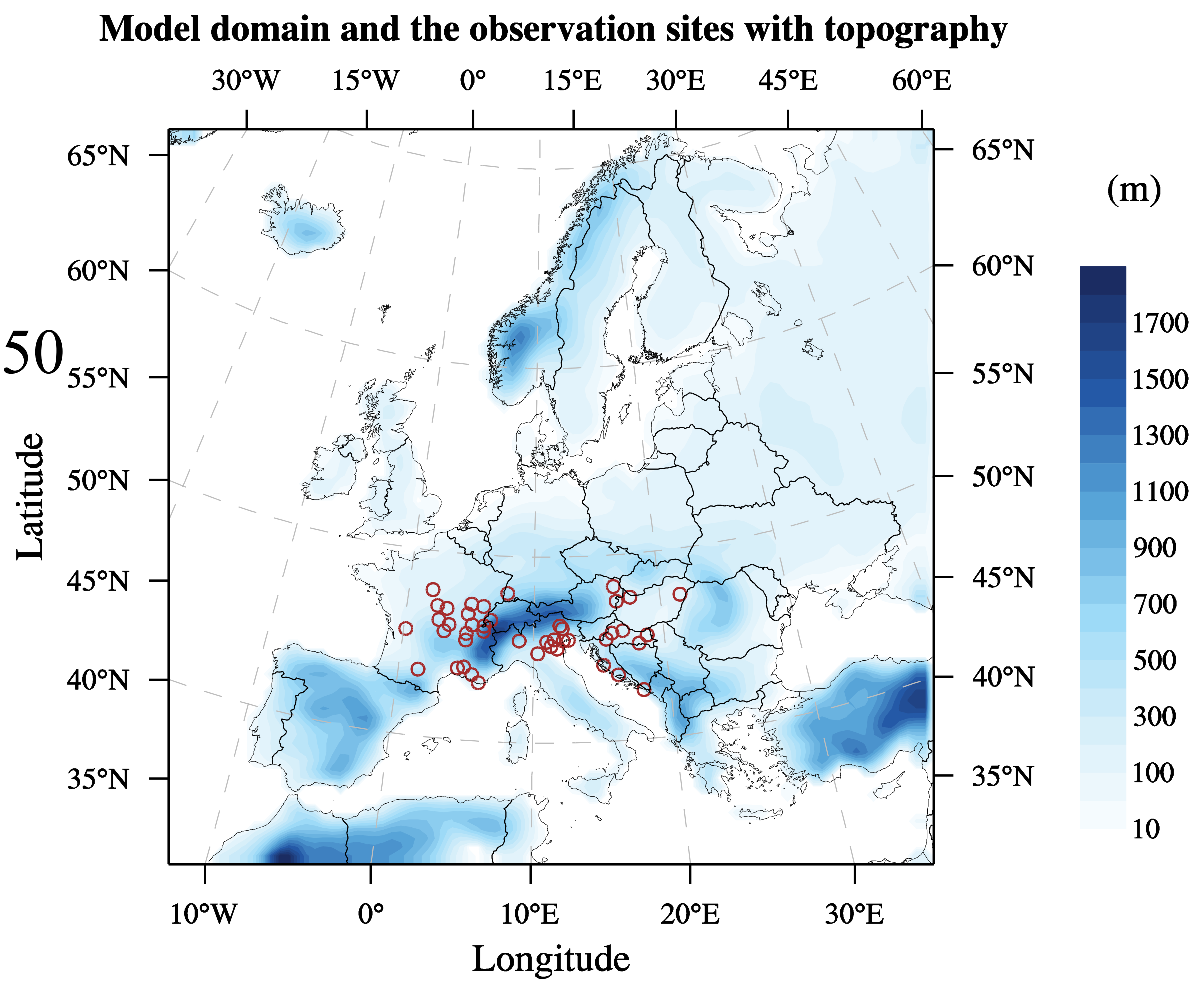
$$K_h = \frac{h_{high} - h}{h_{high} - h_{low}}$$

Precipitation trigger:

$$K_r = \left(1 - \frac{p}{p_{\min}}\right)$$

Model application and evaluation

Model domain:
53.0 ° N 11.0° W
horizontal resolution 50 × 50km
Vertical 23 layers
Global re-analyses ERA-Interim
Simulation period:
2000-2010



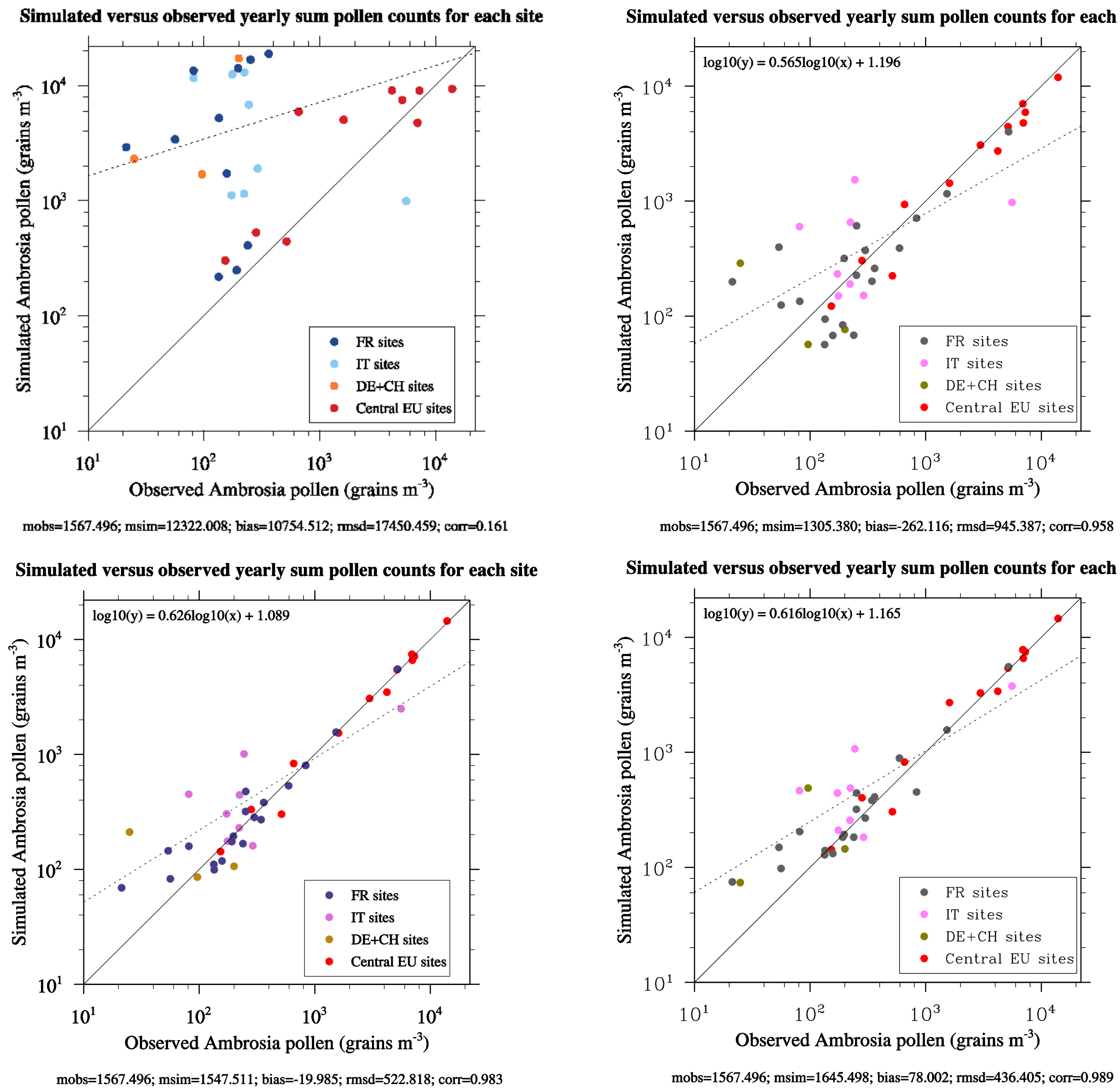
Calibration of the pollen emission map

The simulations were calibrated with the observations from 46 stations of the EAN, RNSA, ARPA-Veneto and Croatian monitoring sites.

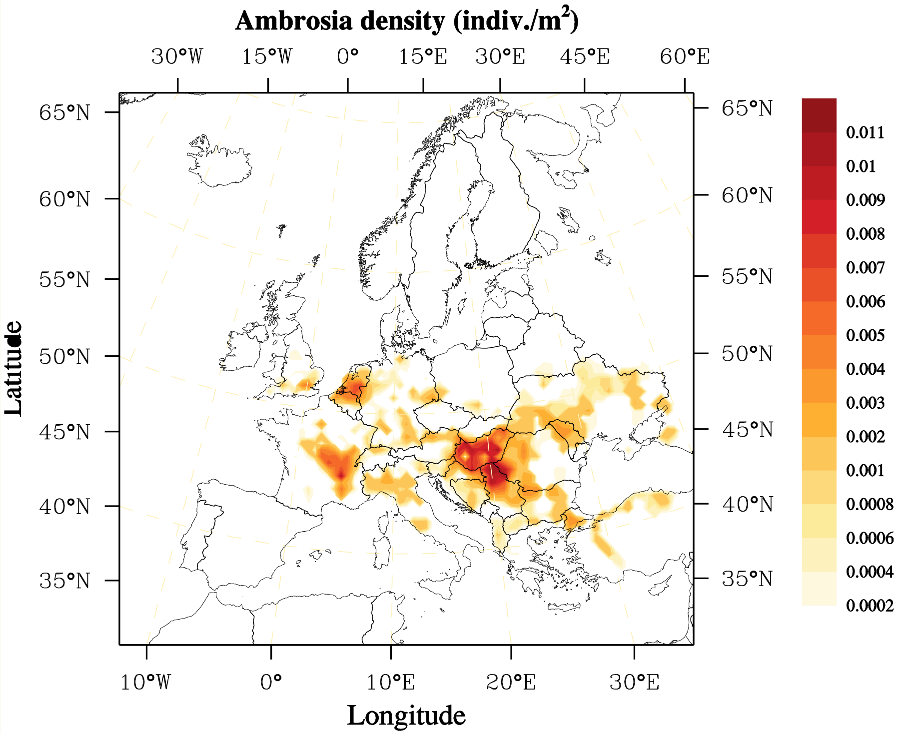
Method:

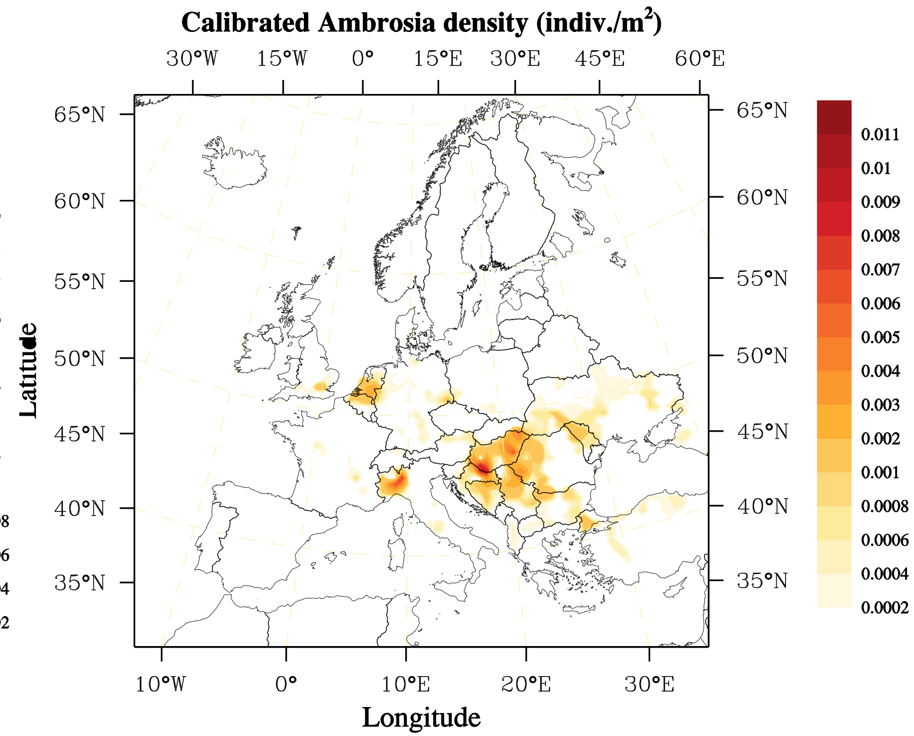
- Test a wide range of possible calibration coefficients for each station.
- Make the bias between observations and simulations within an admissible value.
- Find calibrations within this range with the root-mean-square-differences at the minimum.
- Interpolate calibration coefficients on RegCM grid with Ordinary Kriging method.

FR: France
IT: Italy,
DE: Germany
CH: Switzerland
Central Europe: Austria, Croatia , Hungary



mean yearly sum simulations versus observations for without calibration (top left), first (top right) second (bottom left and third(bottom right) calibration for 2000-2010.





First guess density and final calibrated density distributions in individuals.m^{-2}

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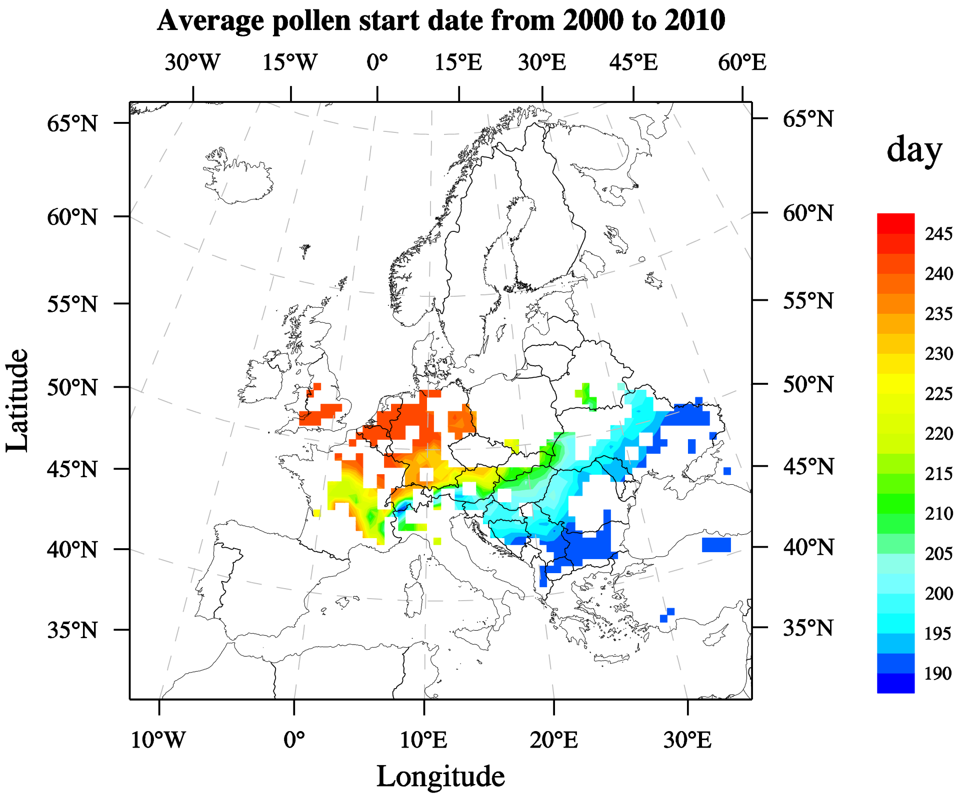
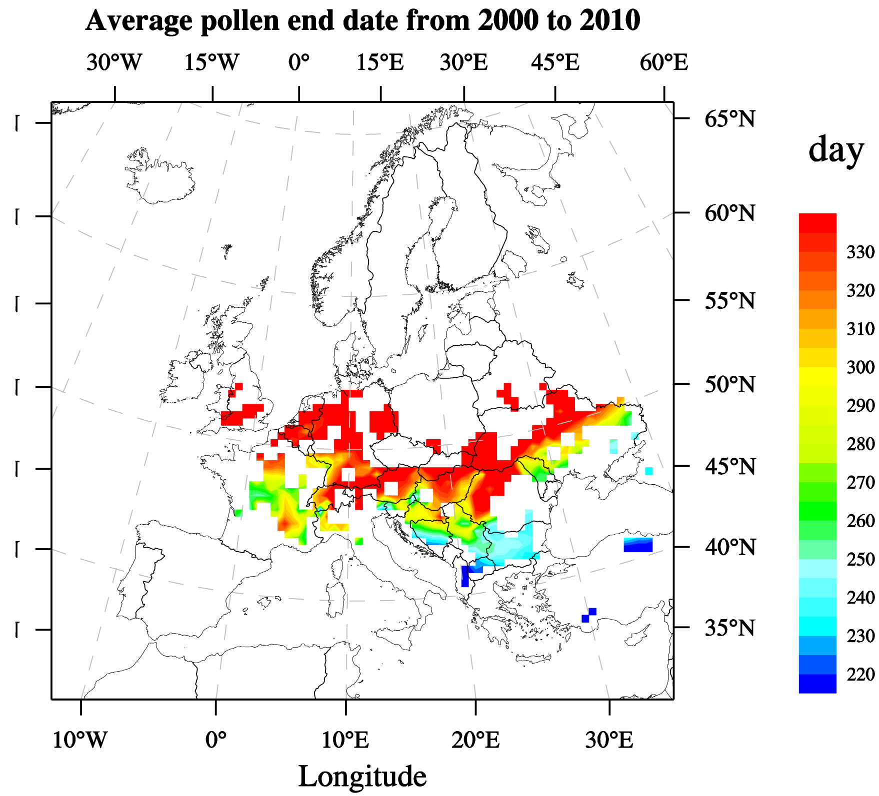
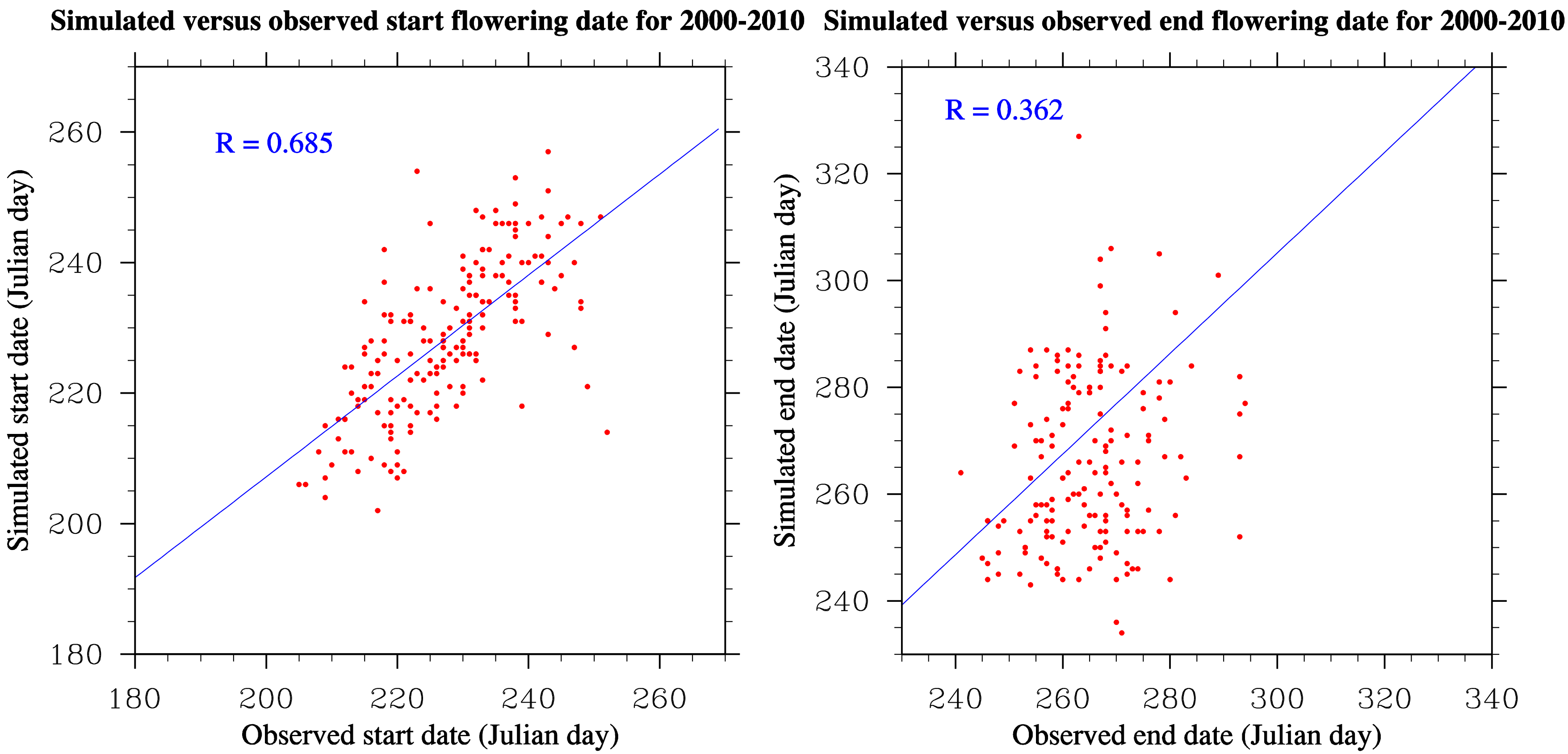
Simulation of pollen season





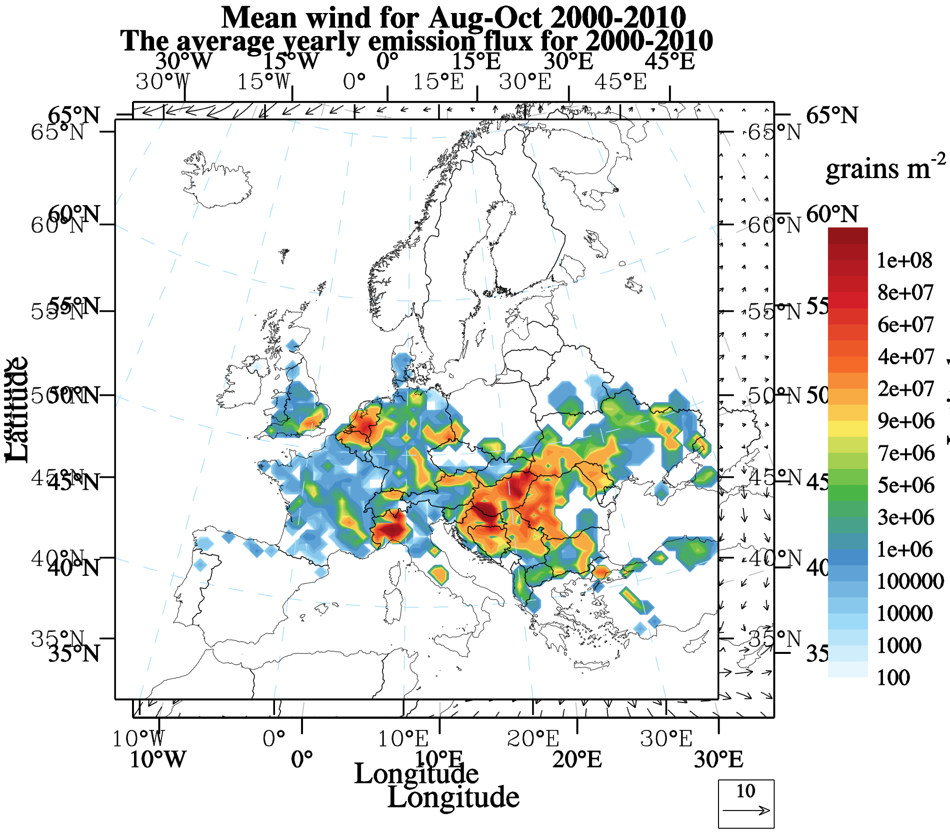
Simulated pollen season (Julian day) average for 2000-2010, the pollen start date (left) and end date (right) .

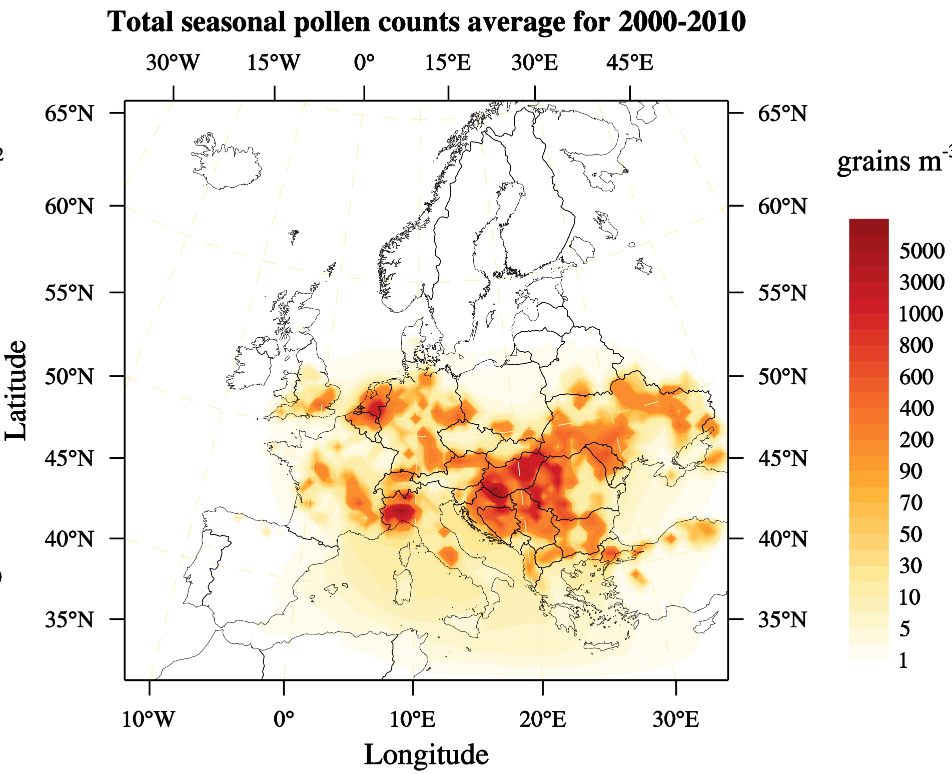
Pollen season simulation accuracy



Statistical correlation between simulated and observed Ambrosia season (Julian day), the pollen start date (left) and end date (right) for 2000-2010.

Ambrosia pollen distribution pattern

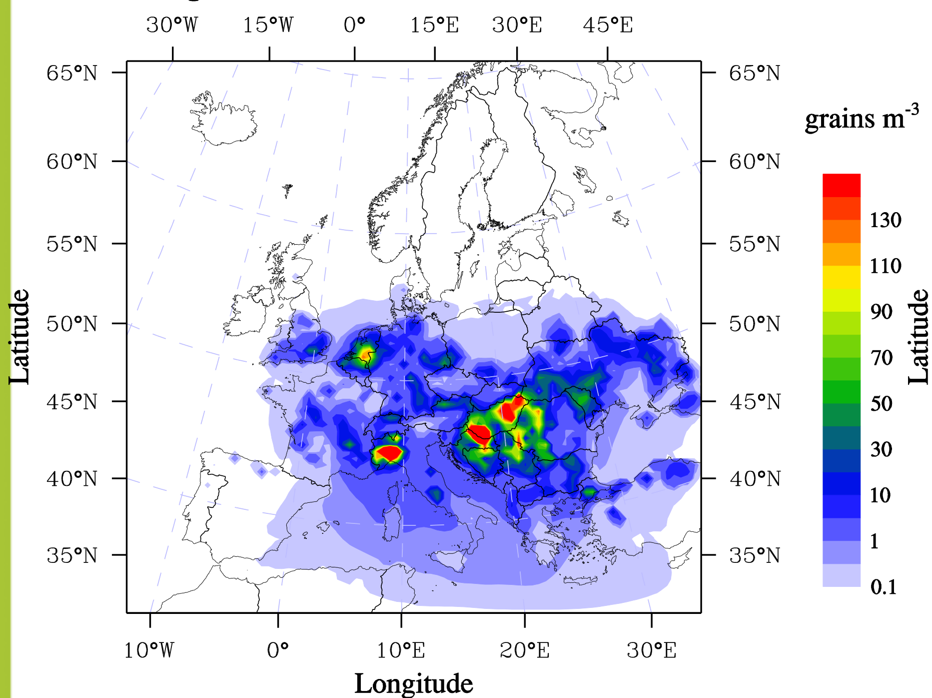




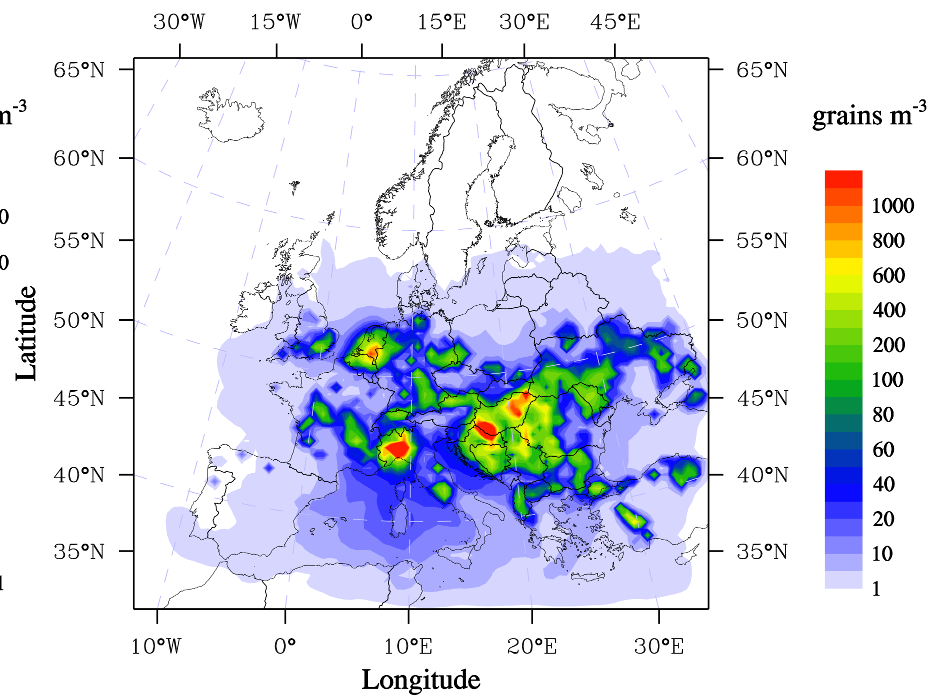
Seasonal pollen emission fluxes and total seasonal pollen counts (sum of daily mean concentrations) average for 2000-2010.

Ambrosia pollen distribution pattern

Average concentration of Ambrosia for 2000-2010



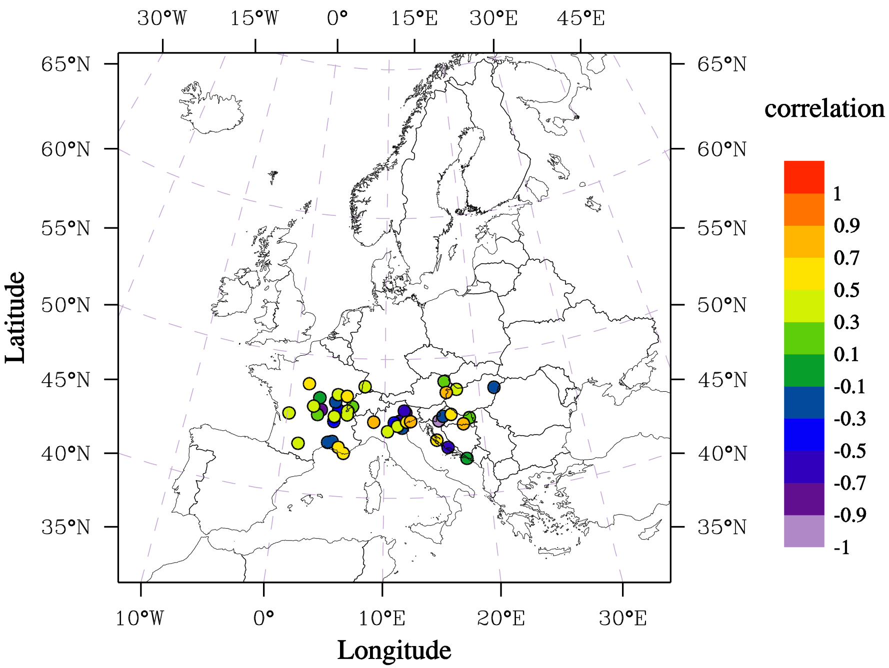
Peak concentration of Ambrosia for 2000-2010 average



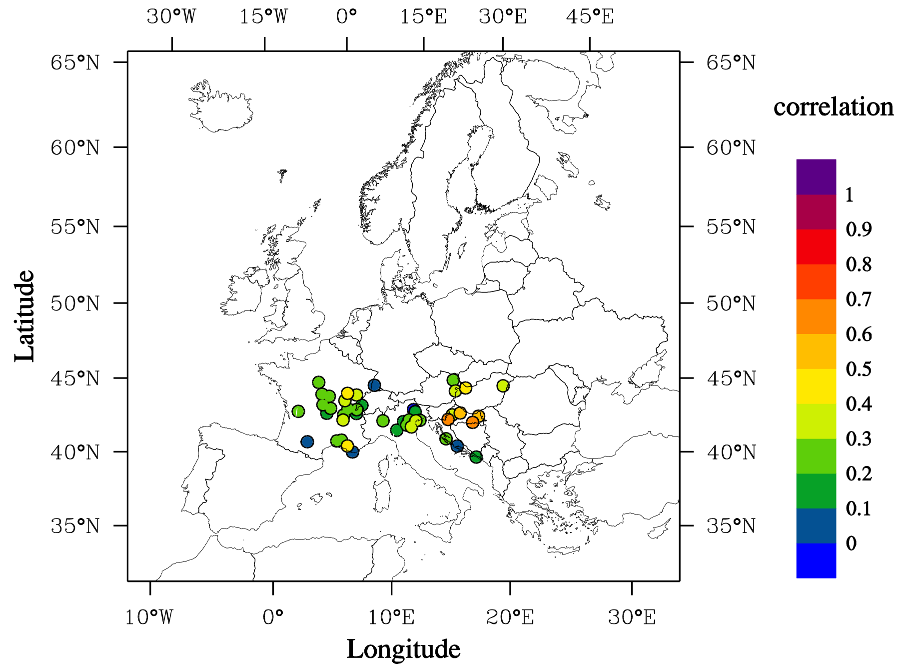
Seasonal average pollen concentration and peak concentration, average for 2000-2010.

Model performance and evaluation

Correlations between observed and simulated yearly pollen sums

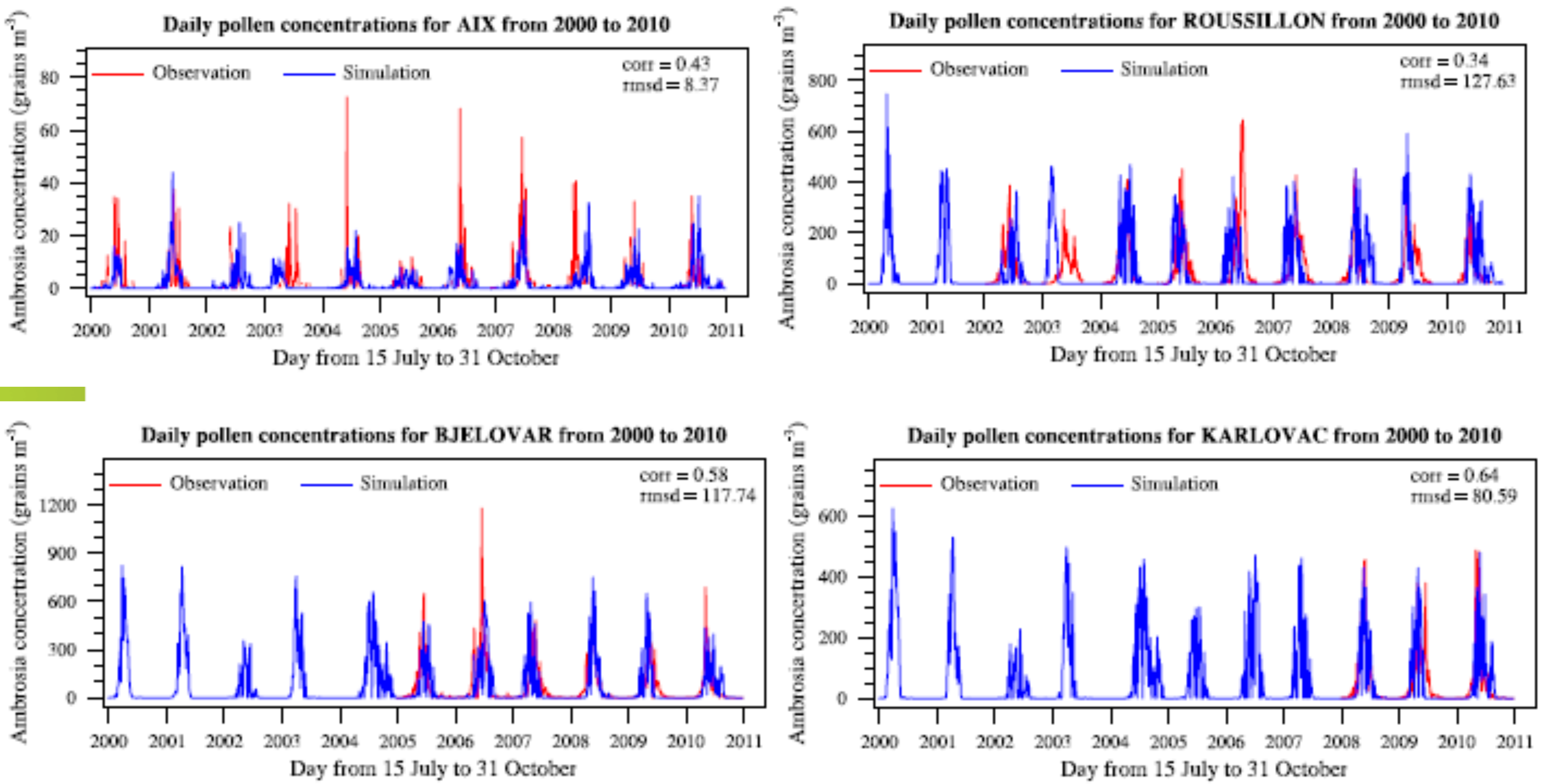


Correlations between observed and simulated seasonal time series

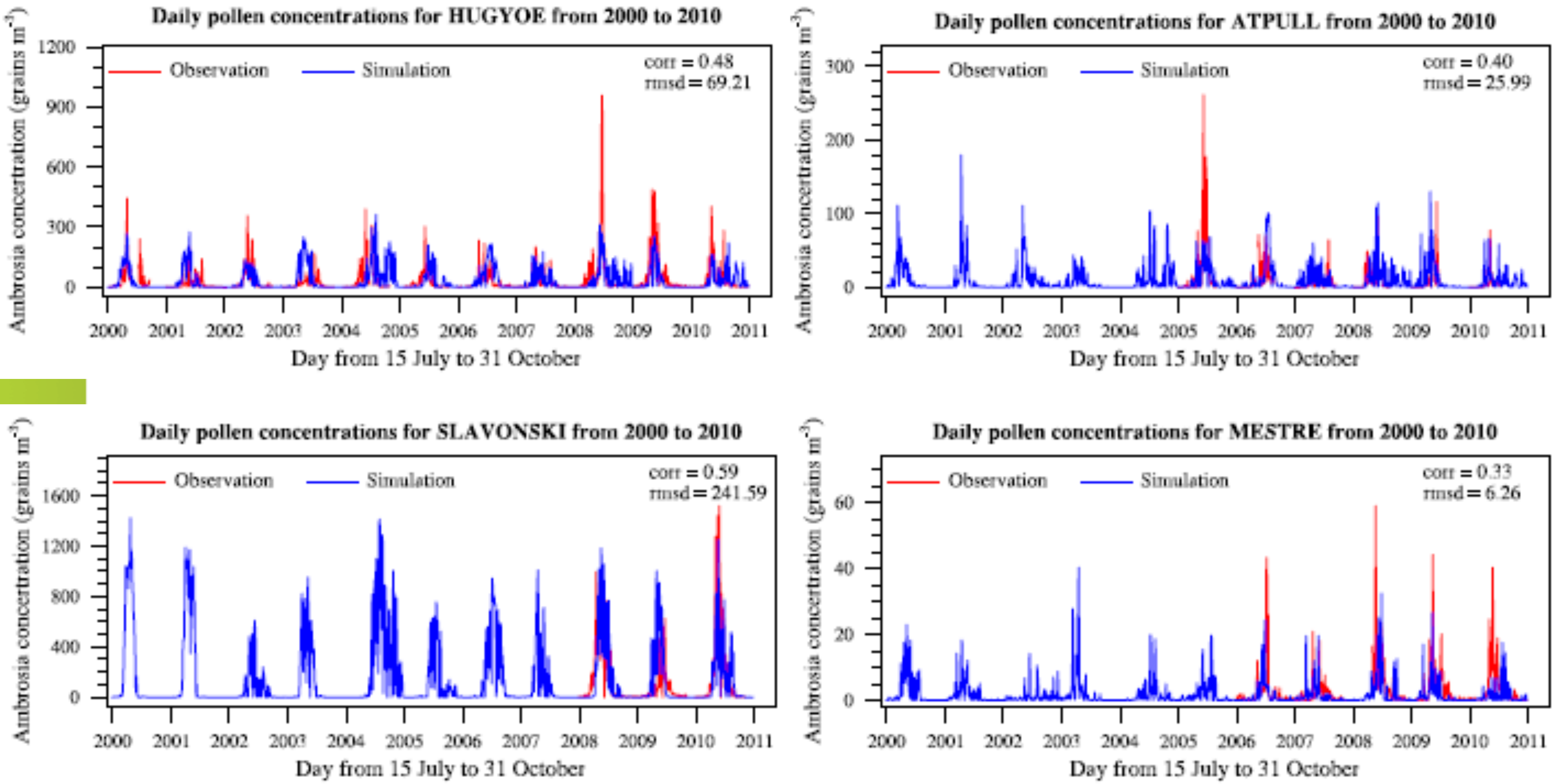


Correlations between simulated and observed seasonal pollen counts sums for each site. The simulations capture the inter-annual variability of pollen seasonal sums for most stations.

Correlations between simulated and observed time series during pollen season for each site. Time series is mostly above 0.4-0.5 in the main source regions.



Daily mean Ambrosia pollen time series for typical stations of 4 source regions



Daily mean Ambrosia pollen time series for typical stations of 4 source regions

Conclusions and discussions

- The adapted Regional Climate-pollen model incorporates the main processes that influence Ambrosia pollen concentration in the atmosphere. It provides a simulation framework online between pollen emission and meteorological conditions.
- The distribution of Ambrosia is among the most uncertain parts of the current model. So the emission fluxes were calibrated using airborne pollen observations.
- Calibration simulations show generally a good performance in reproducing the total seasonal counts, capturing both the spatial and temporal patterns of pollen concentrations in main source regions.

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Thank you !

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