Technical Memorandum/Internal Working Draft 1.05

Subject: Subject: Population's Exposures to Pollens in Different Climate Zones in United States

Version: Working Summary Version 1.0

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1 Introduction

Airborne allergenic pollen, which has been found to act synergistically with common air pollutants, such as ozone, will cause allergic airway disease (AAD). its distributions exhibit considerable variability in space and time. We can display both the temporal and spatial distributions based on either the mechanism models or statistical models using Matlab. Then we use Monte-Carlo method to predict the exposure effect of the pollen in different areas Finally we using OAT sensitivity analysis to analyse the sensitivity of those physical paremters related to route of the exposure of pollens to human

2 Methods

2.1 model

Data Collection

Observed airborne pollen counts were obtained from monitoring stations of the American Academy of Allergy Asthma and Immunology (AAAAI) located in 9 different climate zones. The reported pollen data were classified only at the level of genus. Species under genus of either Ambrosia,Artemisia,Betula,Gramineae or Quercus were not differentiated.

Data used here are from March to May, which is roughly considered as the flowering season, the spatial distribution of the 1000 hour and 1200 hour of scenario is displayed in figure 1 and 2,using VERDI. We are using logarithm instead of linear to make the figure more clear
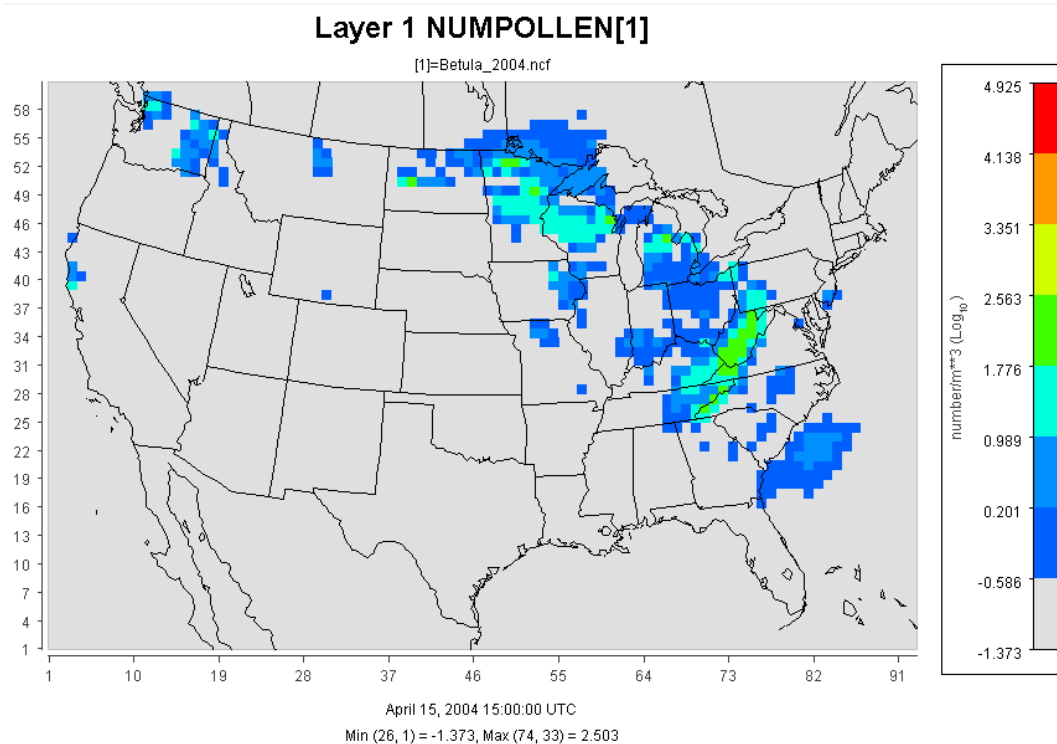

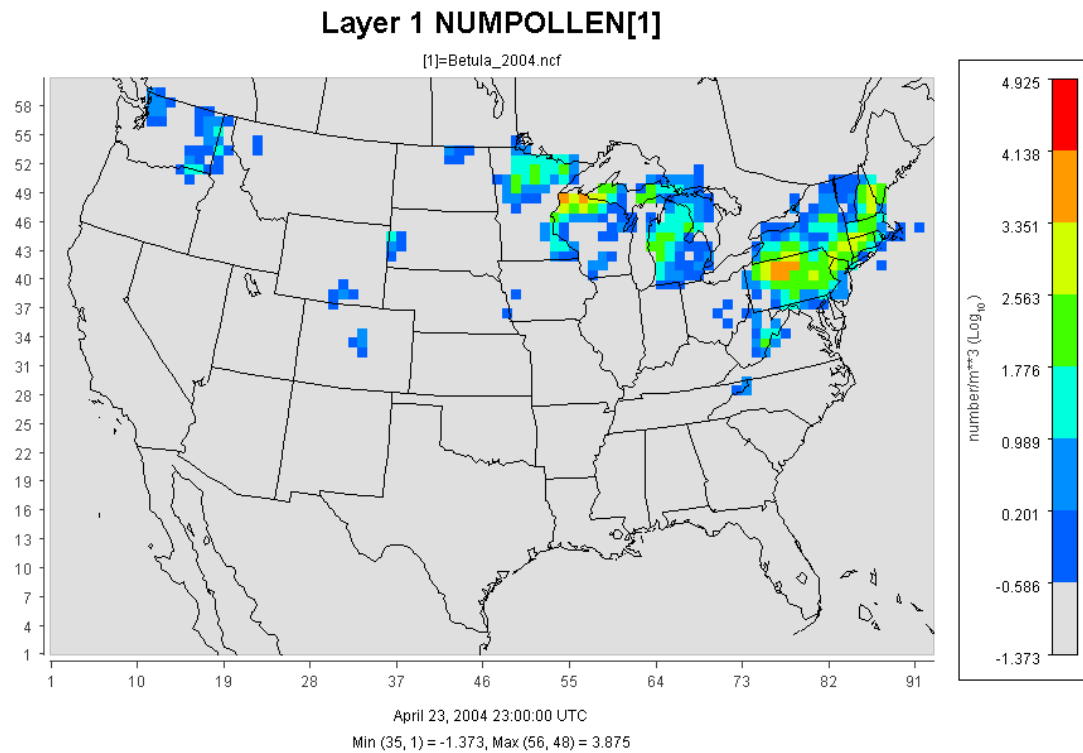Figure 1 using VERDI pollens(Betula) distribution in early March

Figure 2 using VERDI pollen(Betula) distribution in late May

Exposure Method Selection

1 Inhalation

Exposure can be quantified by multiplying the concentration of an agent times the duration of the contact. Exposure can be instantaneous when the contact between an agent and a target occurs at a single point in time and space .The summation of instantaneous exposures over the exposure duration is called the time-integrated exposure (Zartarian et al., 2007). Equation shows the time-integrated exposure.

$$E = \int C(t)dt$$

where: E = Time-integrated exposure (mass/volume),

t2– t1 = Exposure duration (ED) (time),

C = Exposure concentration as a function of time (mass/volume).

Dividing the time-integrated exposure by the exposure duration, results in the time-averaged exposure

In this paper, since the time step is 1 hour, we integrated the concentration through the whole flowering season (an average time about 200 hours),and we use numbers of pollen instead of the concentration which would be more reasonable in investigating the effect of pollen.

The Exposure Factors Data are from Exposure Factor Handbook 2011

The Population Data are from U.S Census Bureau: Age and Sex Composition:2010

2 Dermal Exposure

Dermal exposure to volatile chemical compound is fully studied already, however, the reports to the dermal exposure to pollen remains rare. We use dry deposition model to estimate the adherence of pollen to human skins.

The dry deposition model assumed that the transport of material to the surface is to be governed by three resistances in series: the aerodynamic resistance r_a, the quasi-laminar layer resistance r_b, and the surface or canopy resistance r_c. The total resistance,r_t by definition, the inverse of the deposition velocity

$$v_d^{-1} = r_a + r_b + r_c$$

For particle dry deposition, v_d becomes

$$v_d = v_s + \frac{1}{r_a + r_b + r_a * r_b * v_s}$$

While v_s is the particle settling velocity

$$r_a = \frac{1}{k u_*} \ln\left(\frac{z}{z_0}\right)$$

$$r_b = 1/(u_*(Sc^{-\frac{2}{3}} + 10^{-\frac{3}{St}})$$

$$v_s = \frac{\rho_p D_p^2 g C_c}{18\mu}$$

$$C_c = 1 + \frac{2\lambda}{D_p}\left(1.257 + 0.4e^{-\frac{0.55 D_p}{\lambda}}\right)$$

Where ρ_p is the density of the particle, D_p is the particle diameter, g is the gravitational acceleration, μ is the viscosity of air, and C_c is the slip correction factor.

$$Sc = \frac{\mu}{\rho_a D}$$

$$St = \frac{v_s u_*^2 \rho_a}{g\mu}$$

$$D = \frac{k_B T C_C}{3\pi\mu D_p}$$

Where Sc is the Schmidt number, St is the Stokes number, and D is the molecular diffusivity,

So the direct deposition to the skin can be calculated now

1 indoor

$$M_{su} = A_{skin} v_d \int C(t)dt$$

2 outdoor

$$M_{su} = \frac{A_{skin} v_d \lambda_v}{\lambda_v + \lambda_d} \int C(t)dt$$

Where M_{su} is the mass of the substance in the skin surface is, A_{skin} is the exposed skin area.

The parameters λ_d λ_v are ventilation rate and indoor deposition velocity, respectively.

Sensitivity Analysis

Sensitivity analysis is the analysis of how the uncertainty in the output of a mathematical system or modeling(numerical or otherwise) can be apportioned to variety sources of uncertainty in its inputs.[1] A similar test is uncertainty analysis, which mainly focus on uncertainty quantification and propagation of uncertainty.
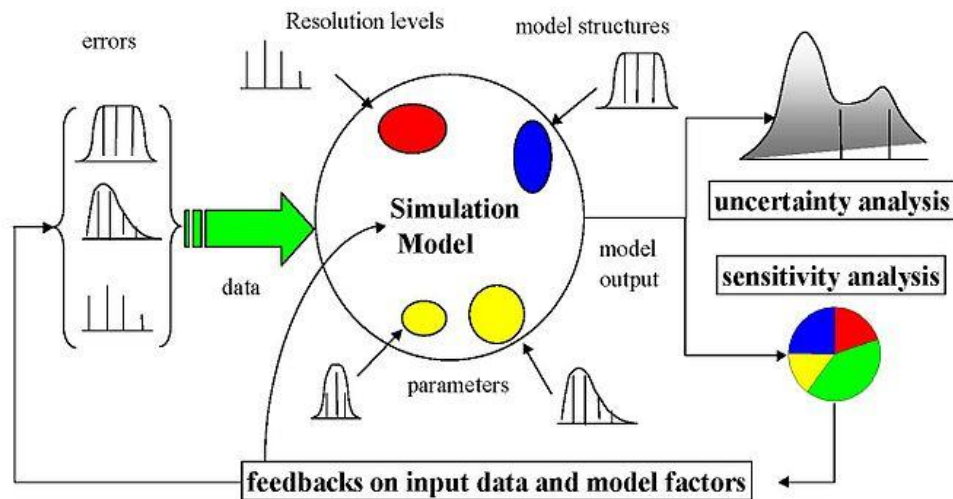
sensitivity analysis,Andrea Saltelli

Mean daily mass intake exposure to pesticide was selected as a metric for testing the system's sensivity to multiple inputs and parameters.Global sensitivity analysis were performed based on Morri's Design. This design estimate the main effect of a parameter by computing a number of local sensitivities at random points of the parameter space.The mean of these randomized local sensitivities indicates the overall influence of a given parameter on the output metric,while the corresponding standard deviation indication the effects of interacting and nonlinearity.

In the current study,each of the 17 parameters(Table 1) was sampled 3600 times according to the Morris method from 200 trajectories (each has 18 steps) in the
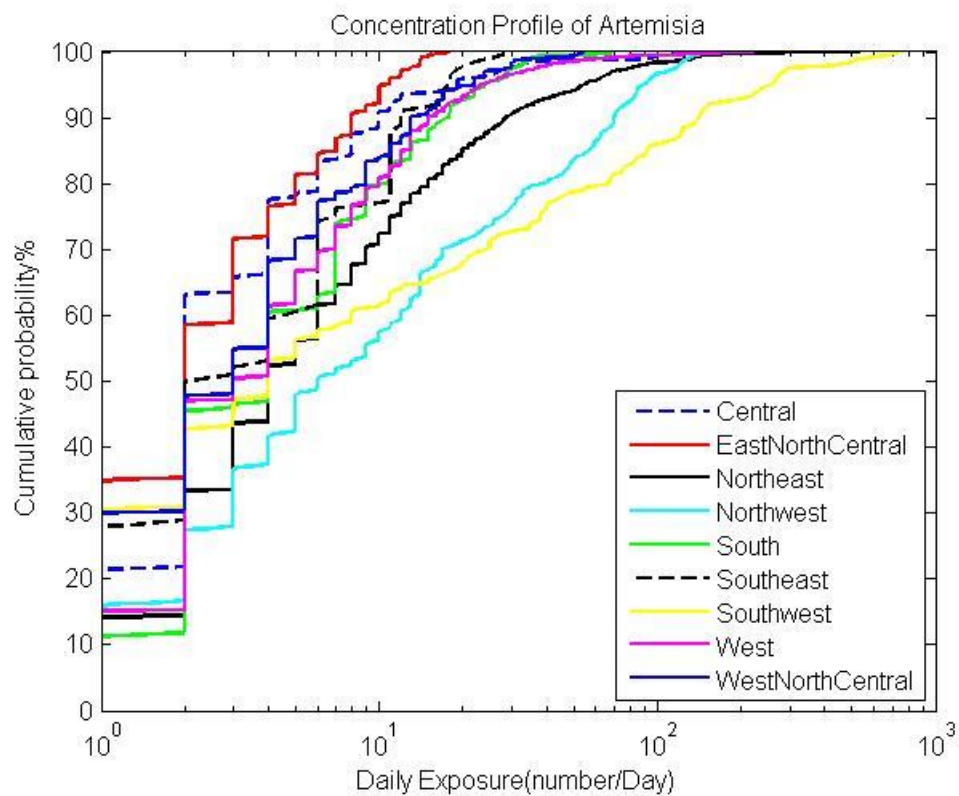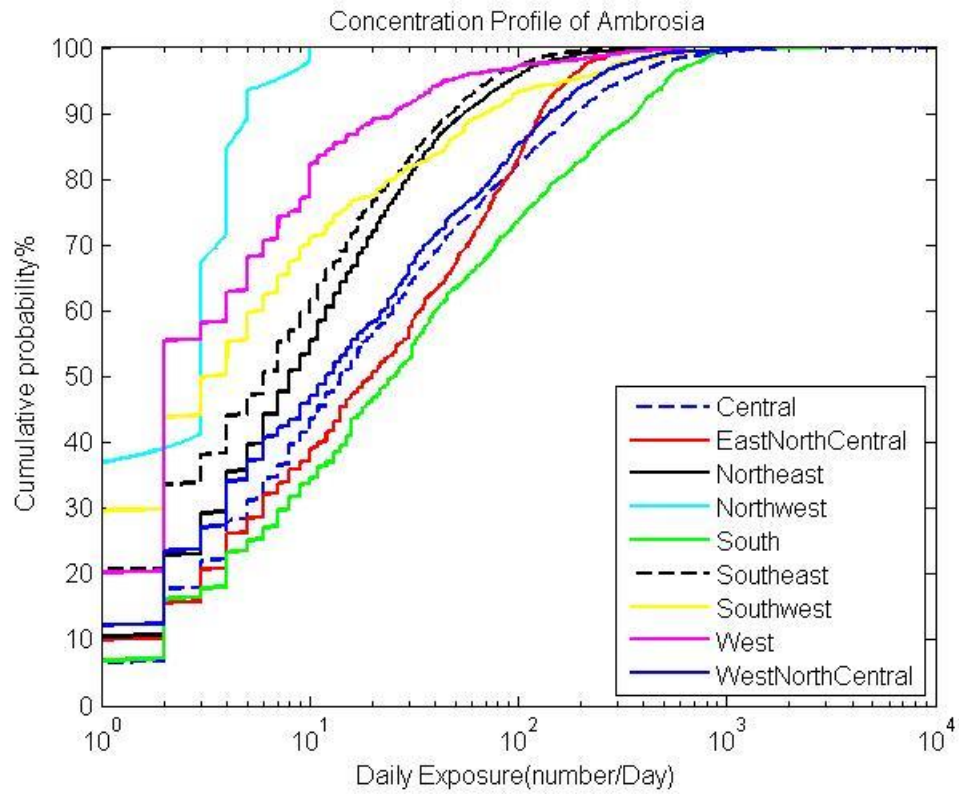
parameter space. Each of the paramters in the simulation was perturbed from 50% to 150% of its base value or its distribution while we keep other parameters unchanged in the same time.
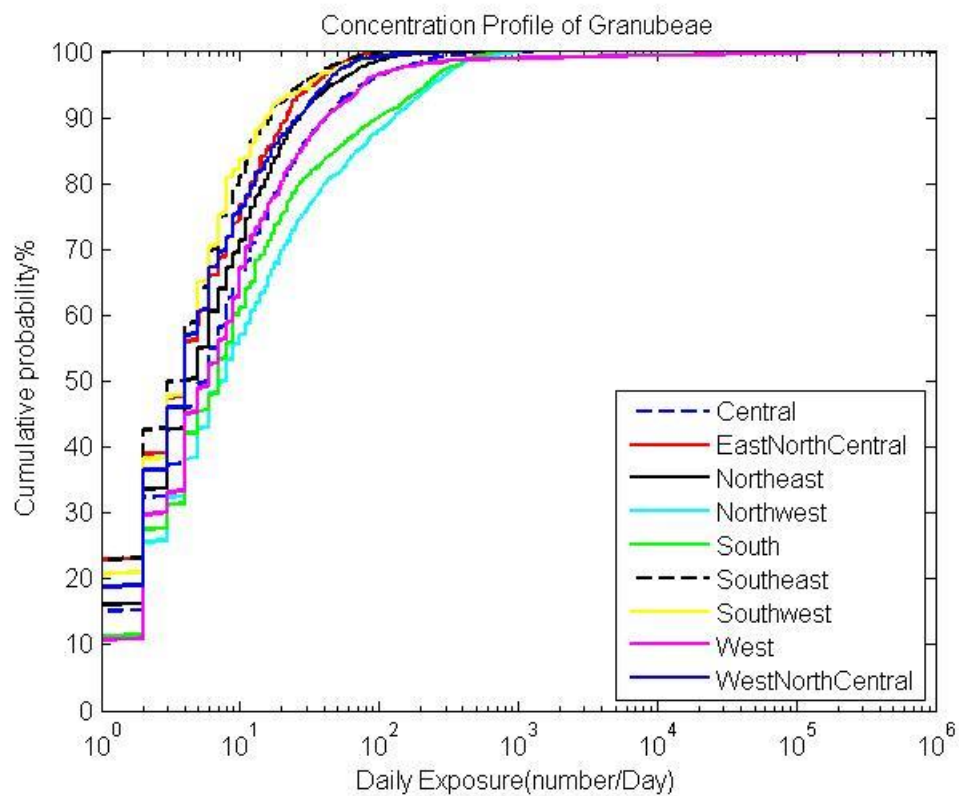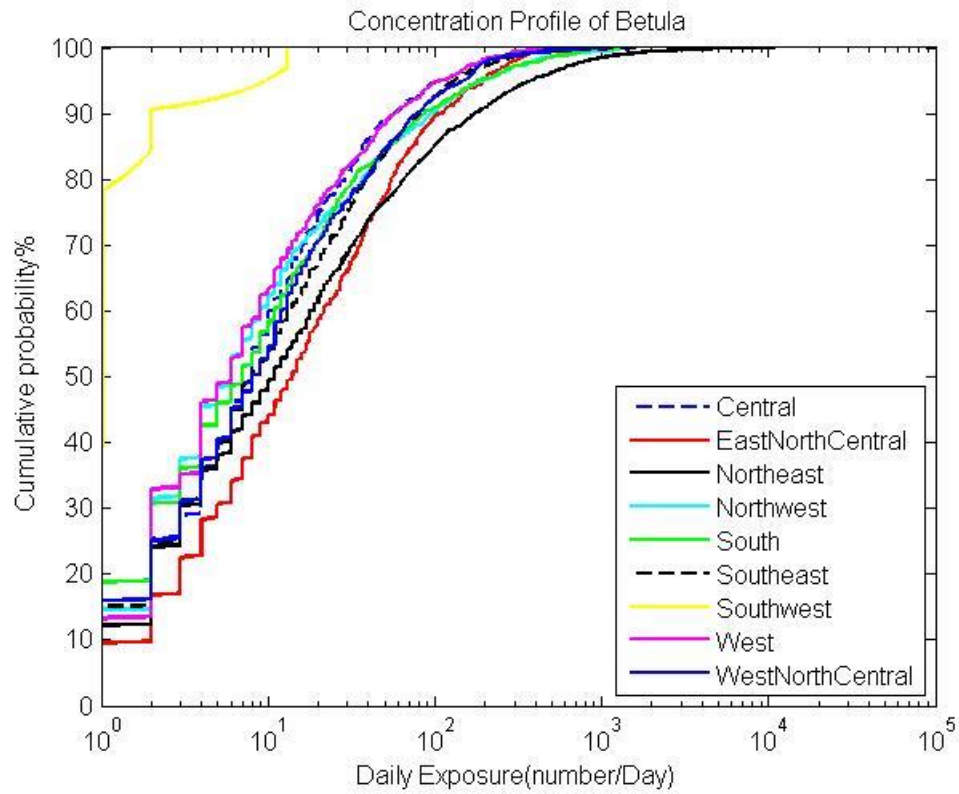
The mean daily exposure for sensitivity analyses was normally generated using 10000 "virual men" in each climate zones in the flowering season.Equation was used to calculate the Normalized Sensitivity Coefficients(NSC) at a local point.
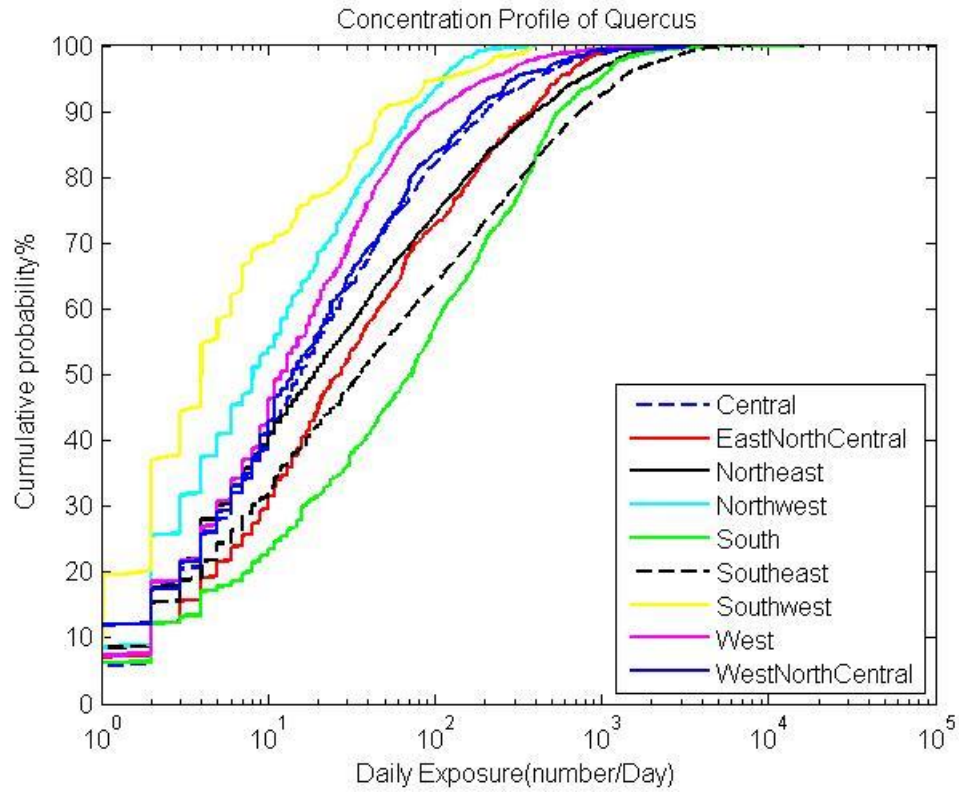
3 Result and Discussion

The exposure duration t can be set to different values for assessing exposure associated with different time durations. For example, it can be set to 1 hour to 24 hour to asses hourly to daily exposures.

Figure 2 1-5 Conctration　for 5 different kinds of pollens(Ambrosia,Artemisia,Betula,Gramineae,Quercus)

Concentration Profile of Ambrosia

Concentration Profile of Artemisia

Concentration Profile of Betula

Concentration Profile of Granubeae

Concentration Profile of Quercus

The following figures are   the time series of the concentration of pollens in the nine climate zones respectively.In order to show the significance of the concentration,we process the data to show only the concentrations in the flowering seasons(normally from March 5th to May 8th
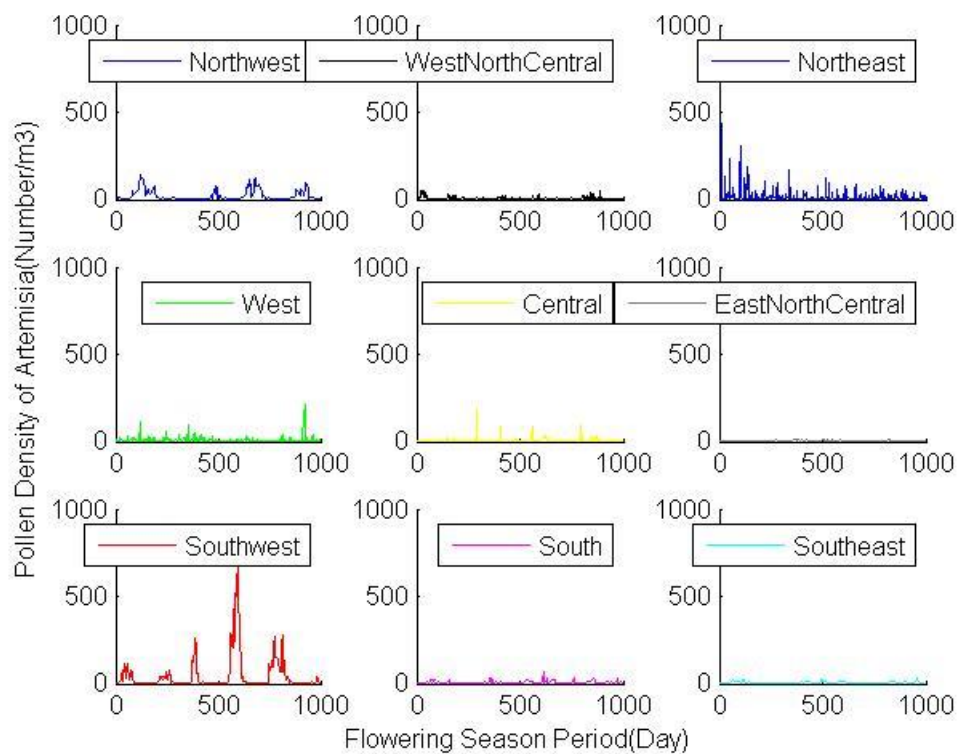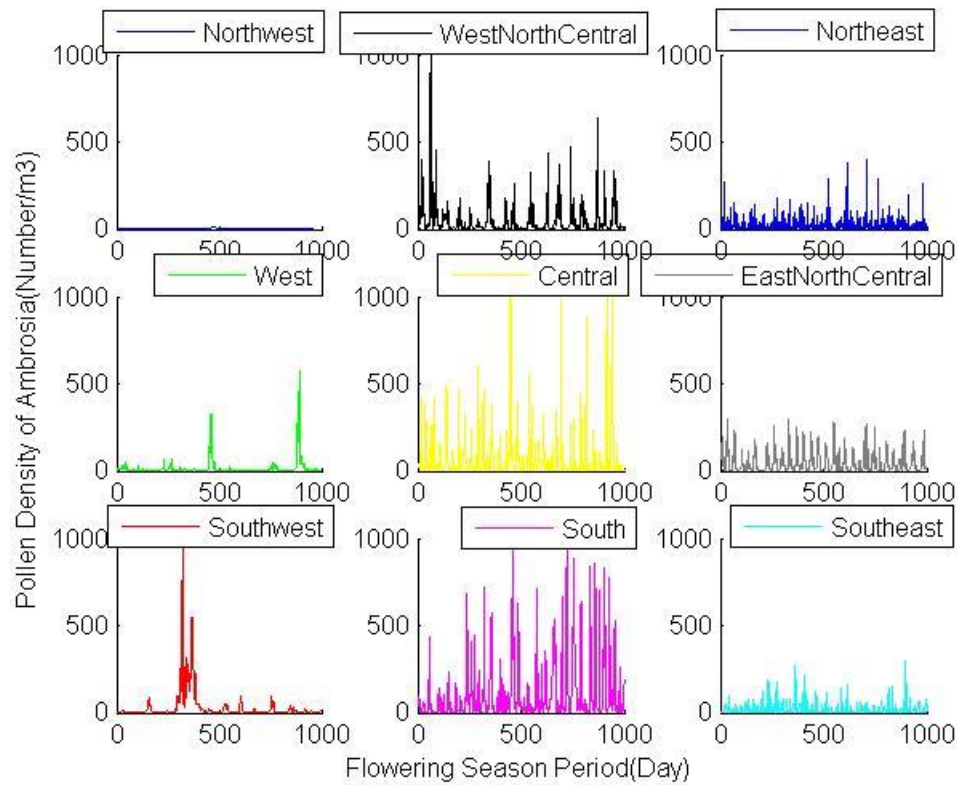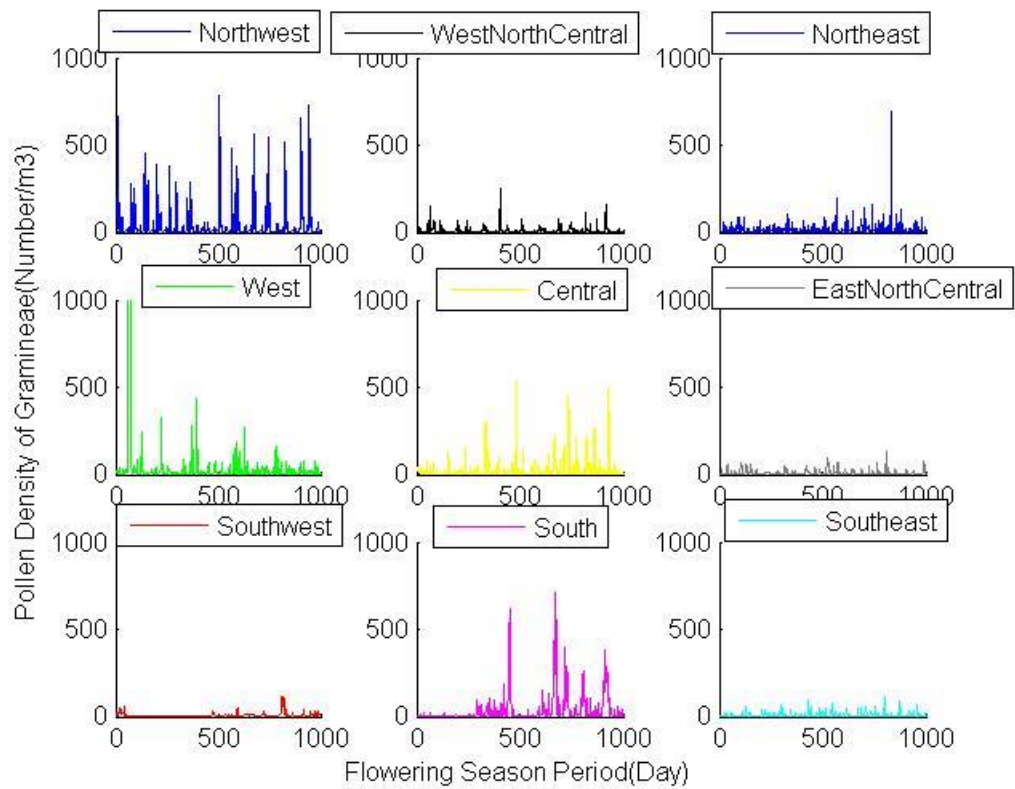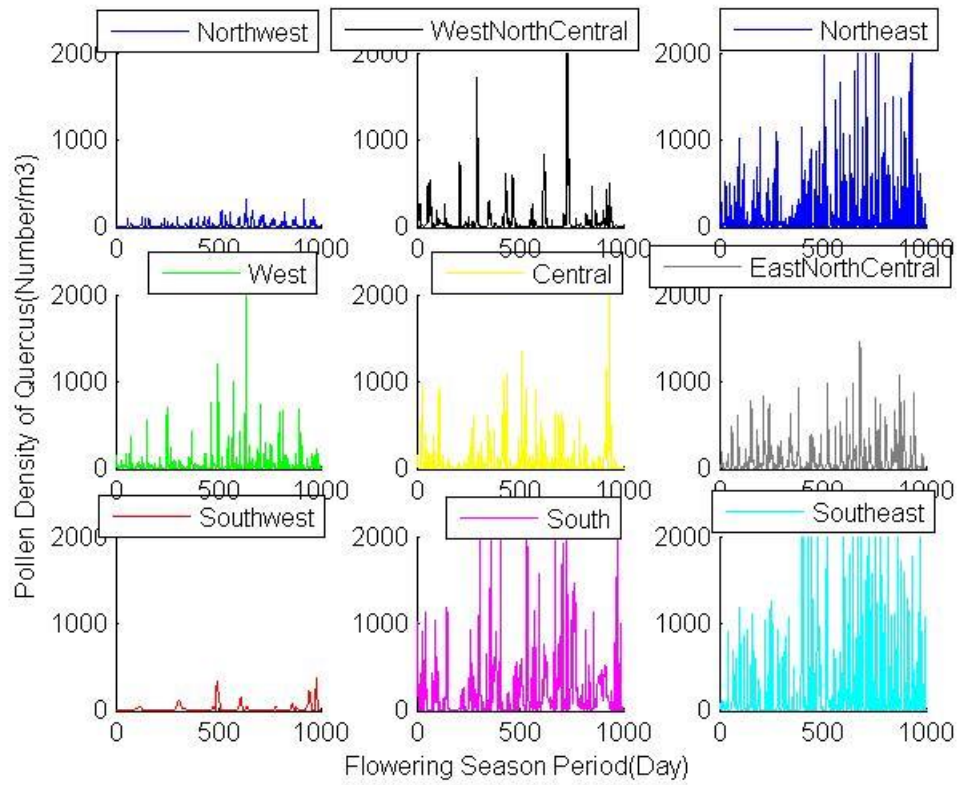
The following figures are the simulated cumulative probability distributions of daily exposures of populations in the 9 nine climates zones to the 5 different kinds of pollens(Ambrosia,Artemisia,Betula,Gramineae,Quercus,respectively)
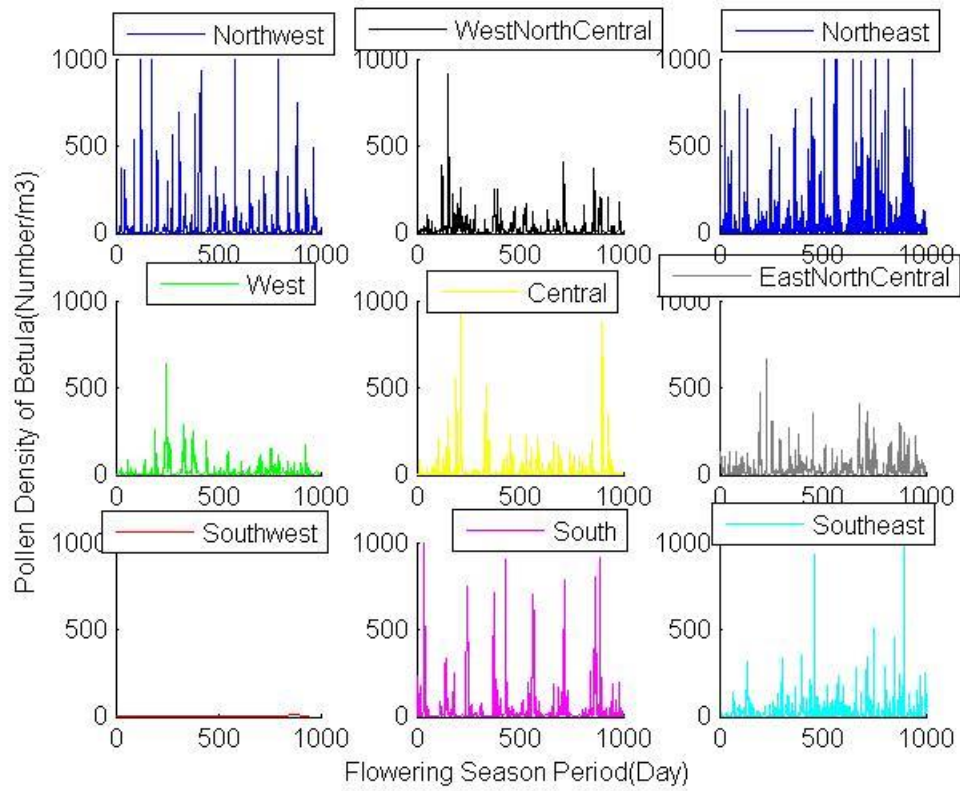
Daily Exposure of Ambrosia

Daily Exposure of Artemisia

Daily Exposure of Quercus

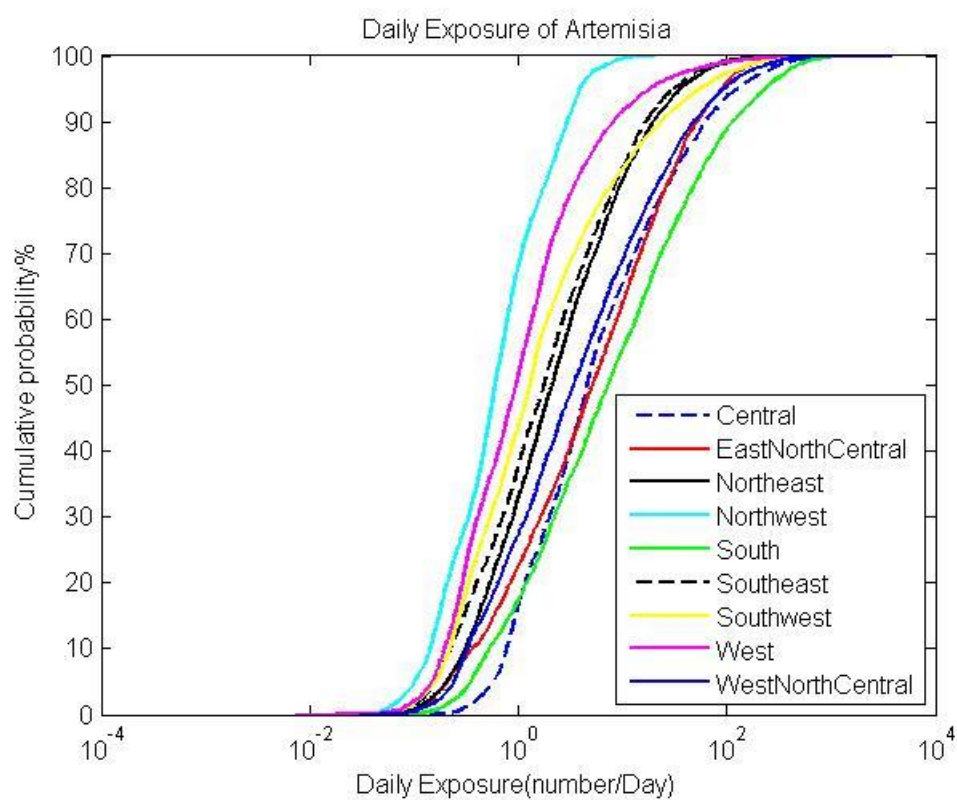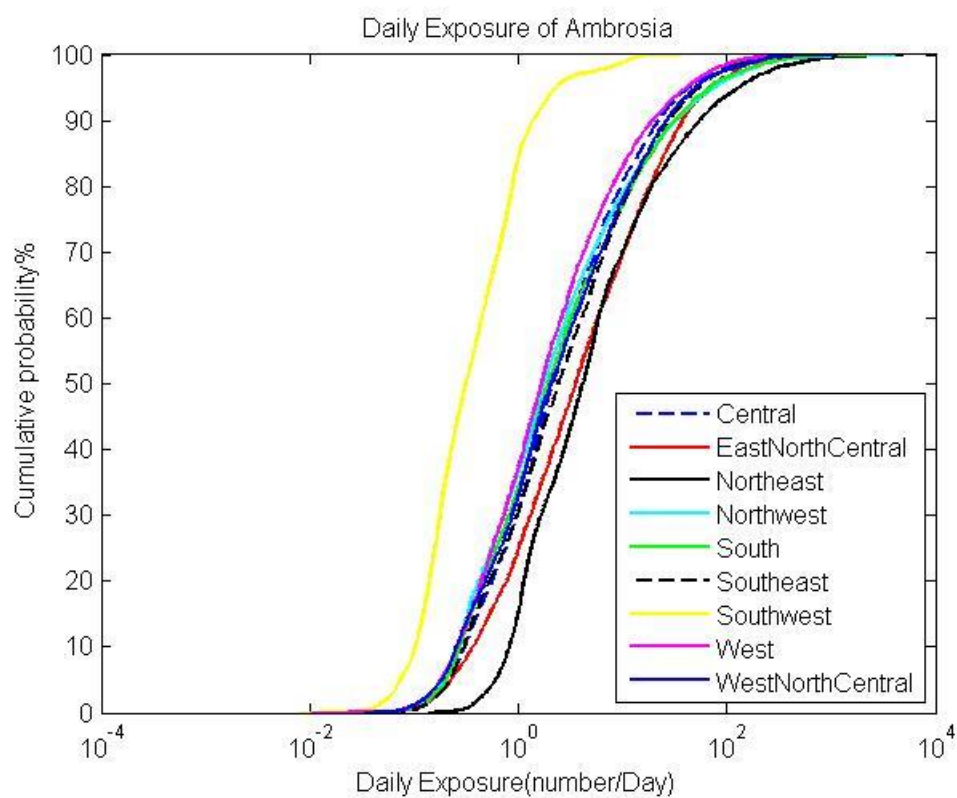Table S1,Parameters for calculating population exposure to pollens in 9 different climate zones in United States.These parameters were listed either as fixed valueds,known distribtuons or unkown empirical distribution derived from the literatures.

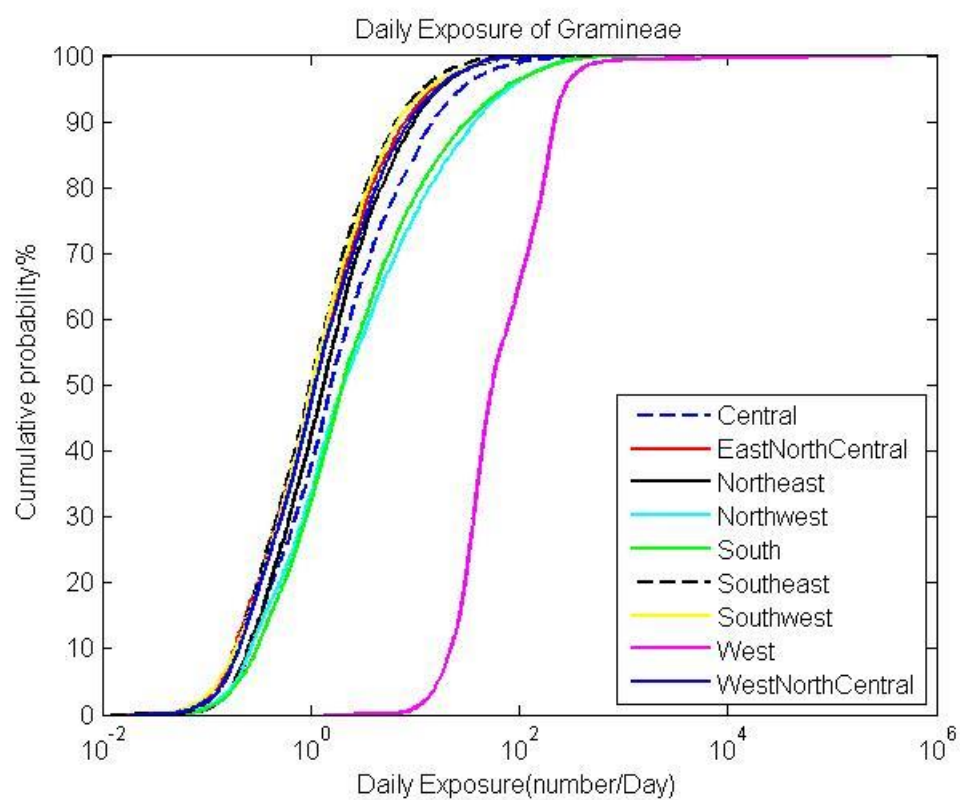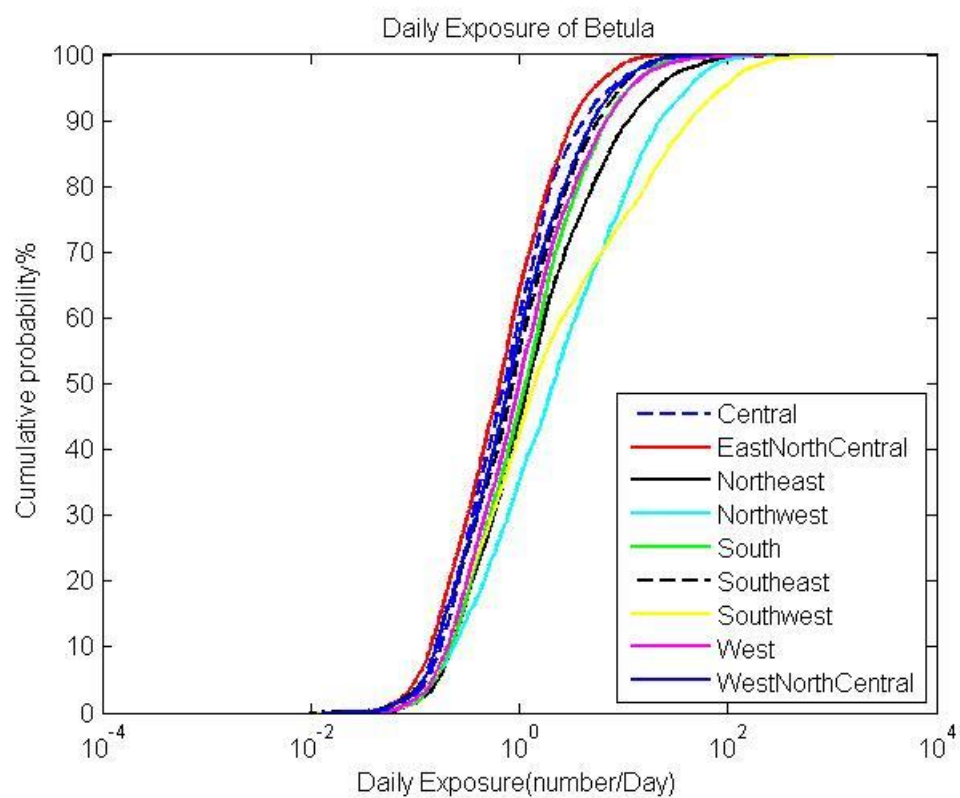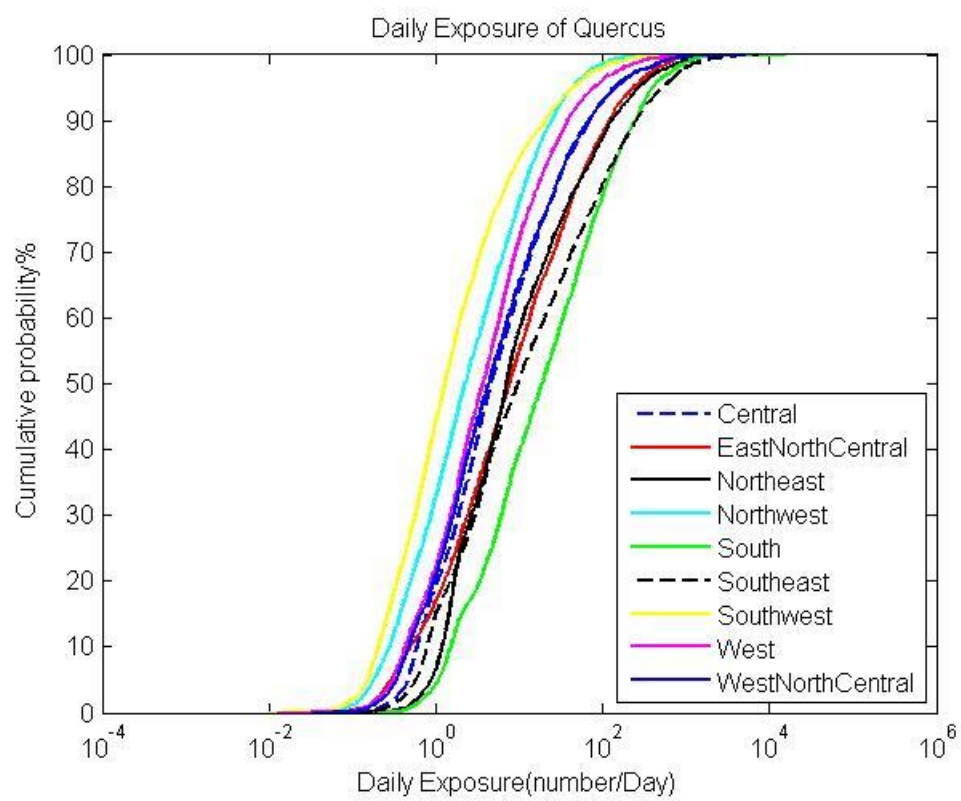| Parameter	Parameter ID	Distribution	Mean(STD)	Range	Ref.
friction velocity(m/s)	1	fix	1.17	-	
von karman constant(dimensionless)	2	fix	0.41	-	
diameter of pollen(m)	3	fix	0.00002	-	
density of pollen(kg/m3)	4	fix	840	-	
viscosity of air (m/s)	5	fix	0.0000181	-	
mean free path of air molecules(m)	6	fix	6.8E-08	-	
density of air(kg/m3)	7	fix	1.145	-	
temperature(k)	8	range	298	283-310	
ventilation rate(dimensionless)	9	range		-	
indoor time(min)	10	norm	1279(21)	-	
outdoor time(min)	11	norm	174(4)	-	
hand to mouth contact frequency	12	empirical	30	3-65	
human surface area(m2)	13	lognorm	1.76	0.41-2.51	
hand surface rate(%)	14	lognorm	5.3	4.8-5.6	
inhalation rate (m3/day)	15	uniform	1.33	0.19-1.91	
inhalation rate(m3/day)	16	uniform	1.45	0.20-1.50	
indoor velidation rate(dimensionless)	17	empirical	1.75	-	

Figure3(1-9) ean and Standard Deviation of Normalized Sensitvity Coefficie
nt(NSC)   for population exposure in 9 different climate zones. (A) Inhalation
(B)Dermal   (C)Total Exposures 1-Central 2
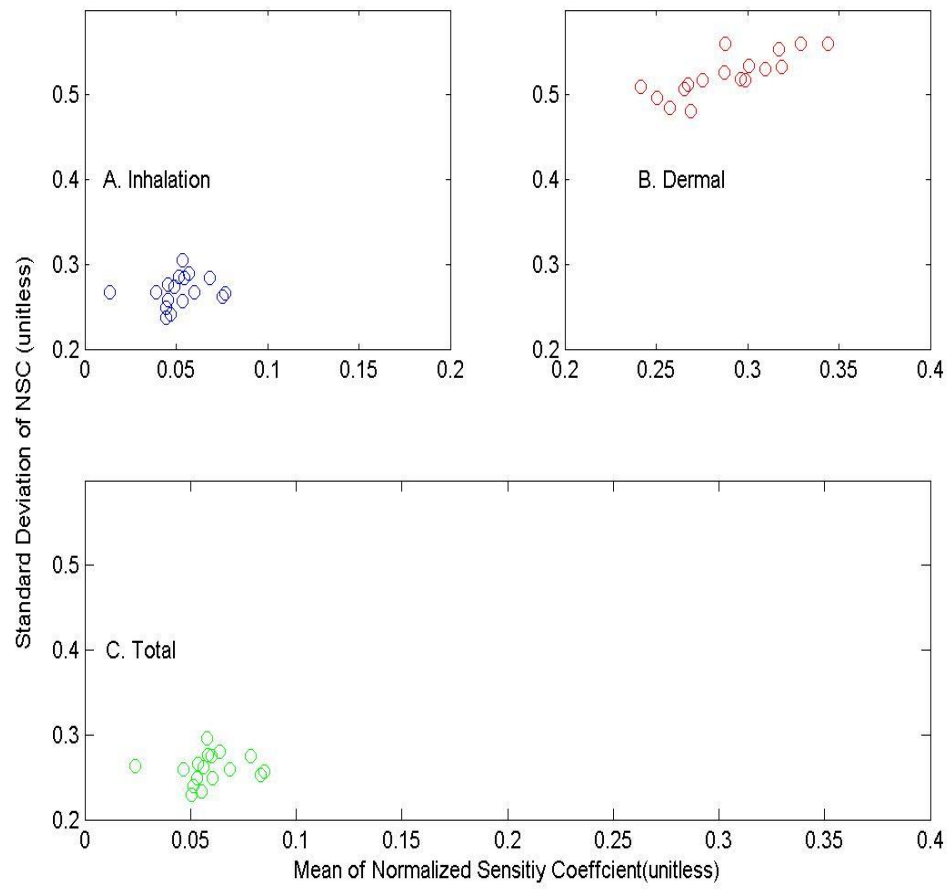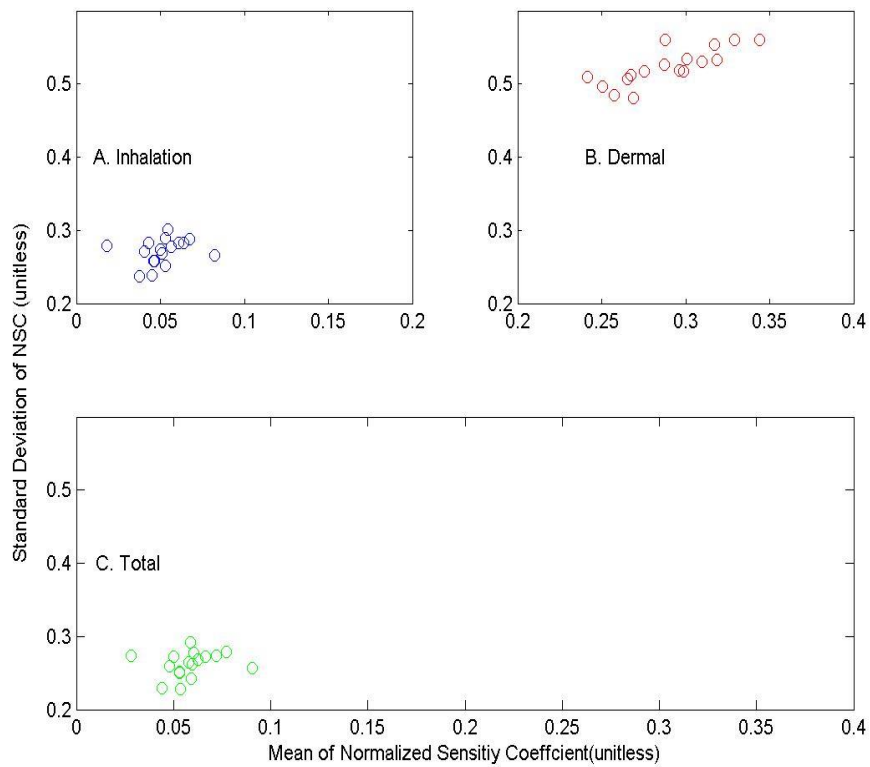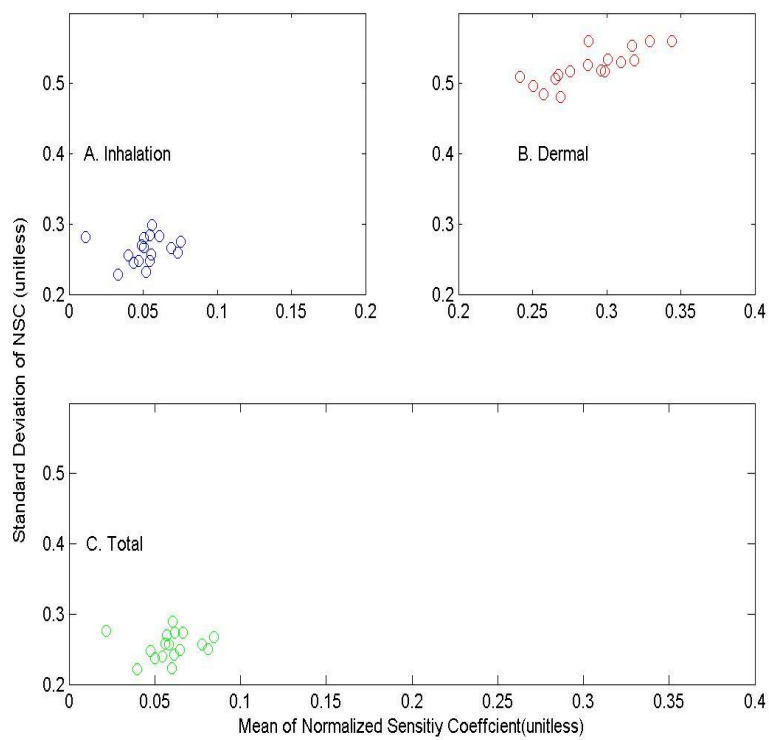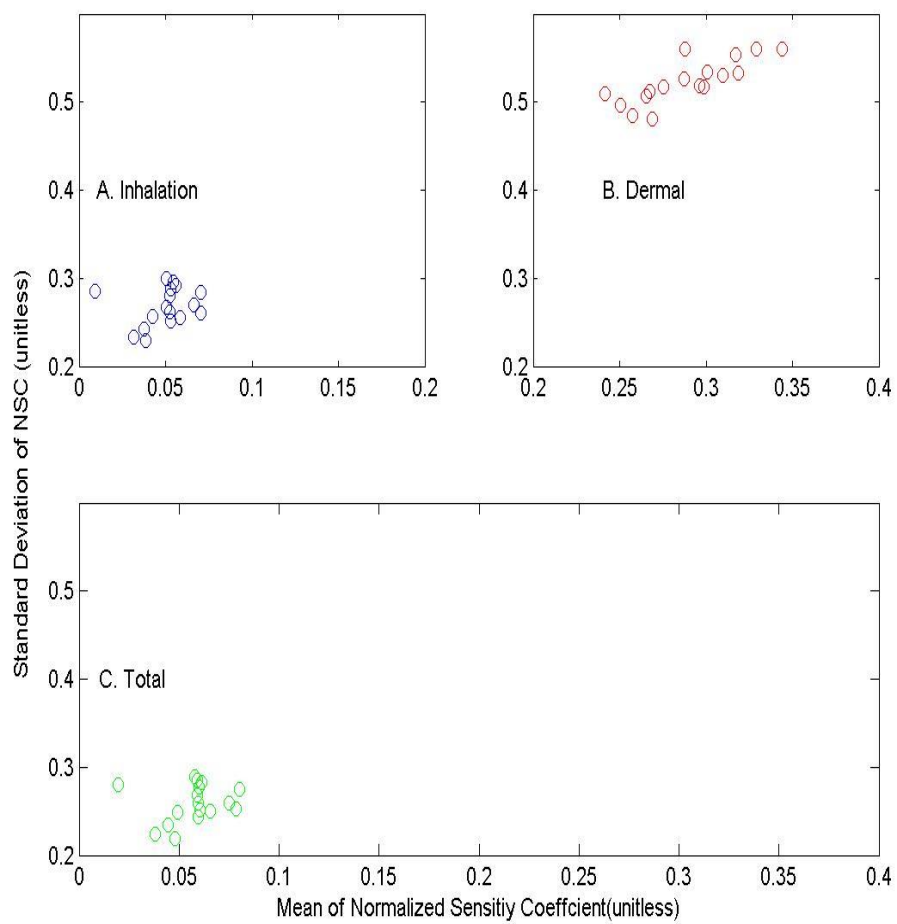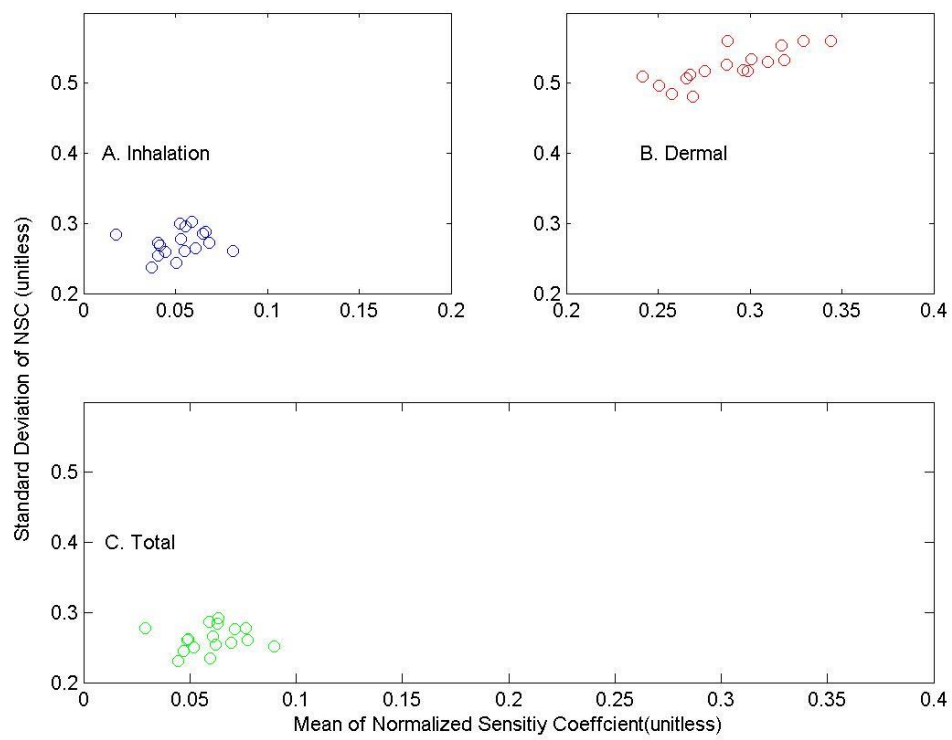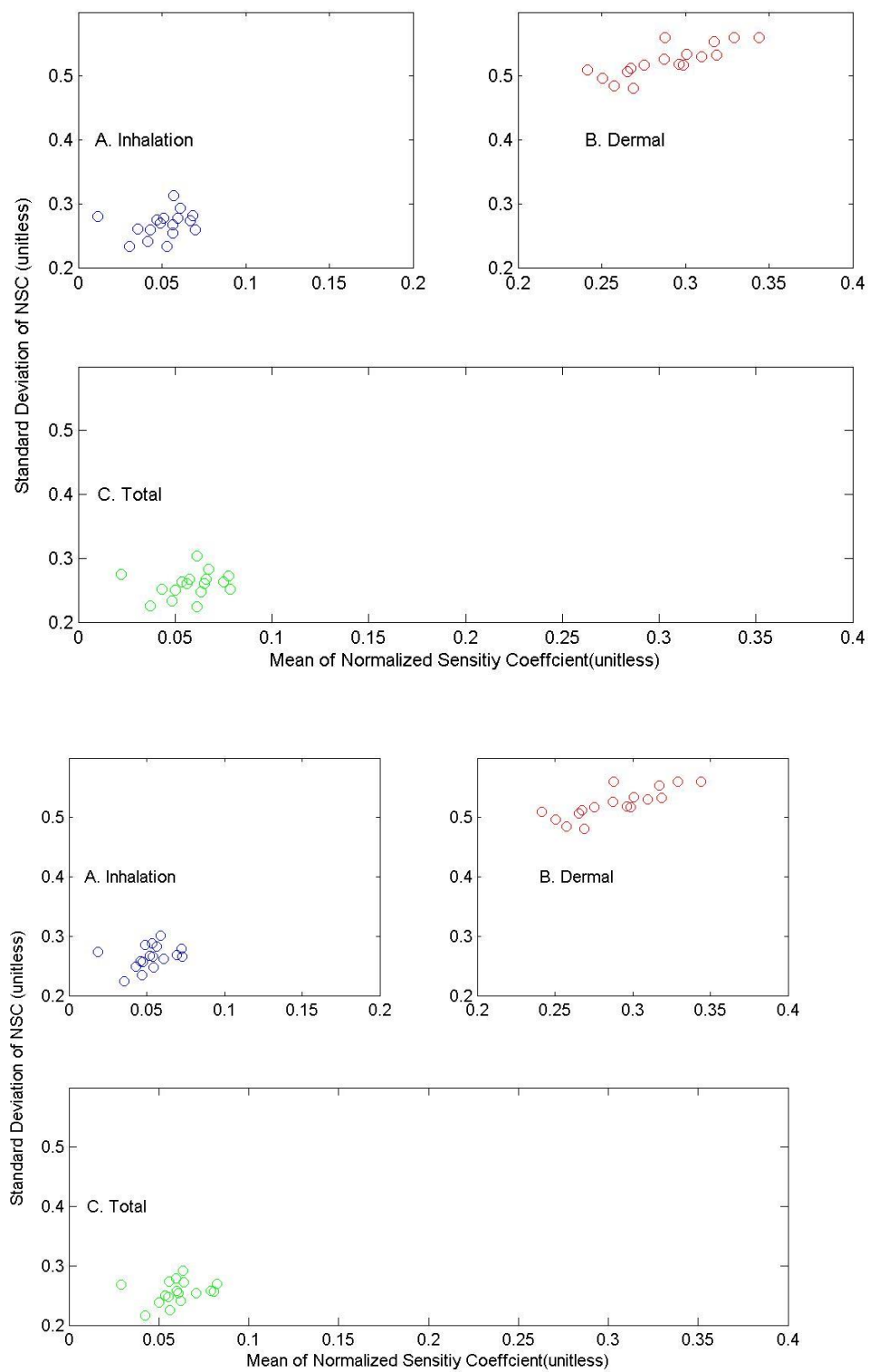
Figure Mean and Standard Deviation of Normalized Sensitvity Coefficient(NSC) for population exposure in the united states(9 zones combined data) (A) Inhalation   (B)Dermal   (C)Total Exposures

A. Inhalation
B. Dermal
C. Total

Standard Deviation of NSC (unitless)

Mean of Normalized Sensitiy Coeffcient(unitless)
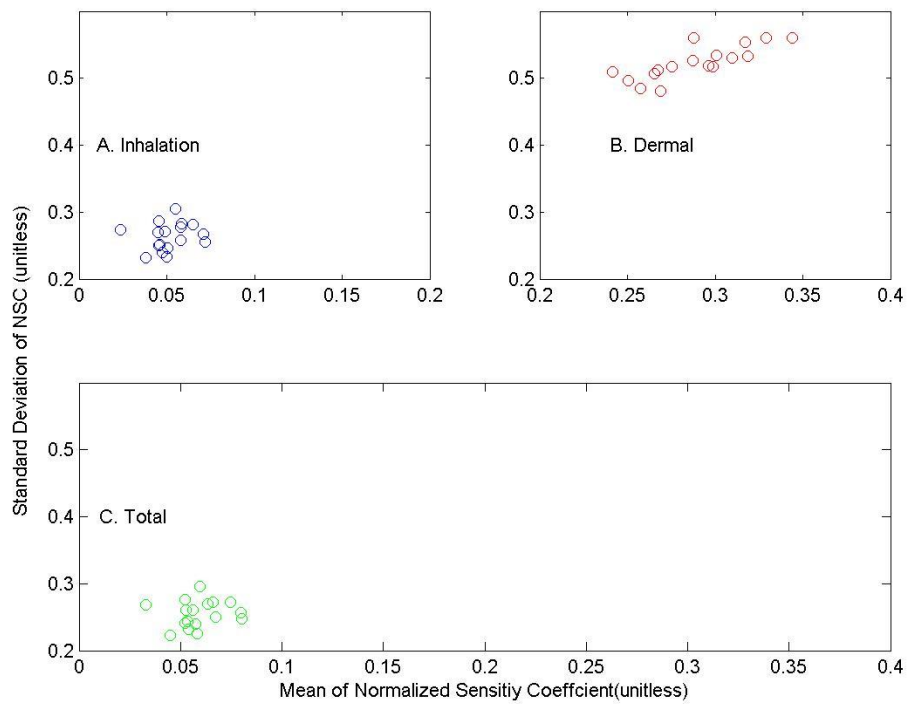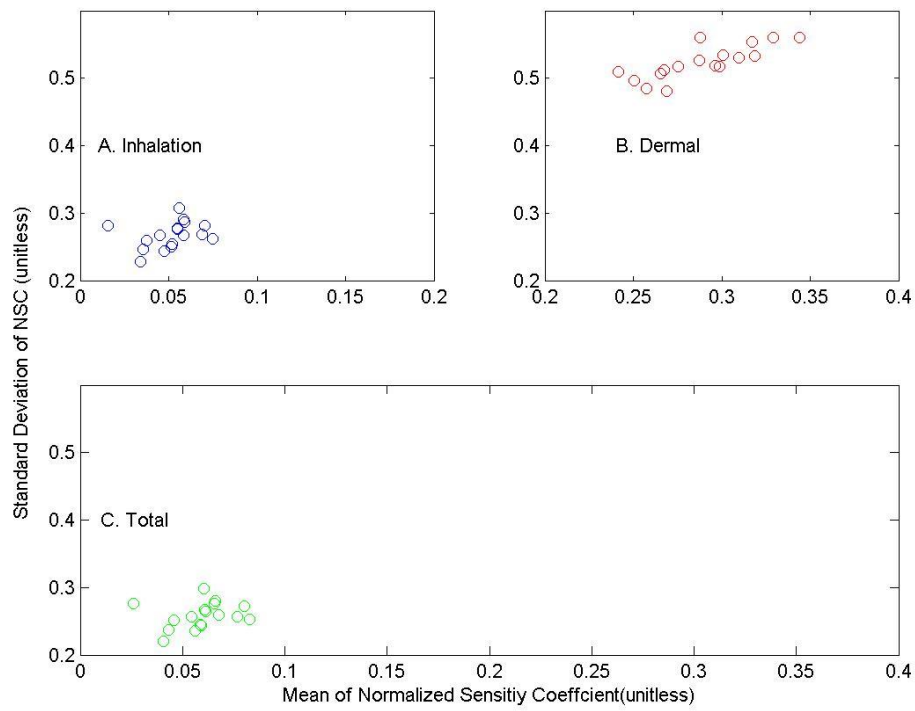
Figure 4 Mean and Stanard deviation of normalized sensitivity coefficient(NSC) in 9 different climate zones based on glabar sensitivity anylses using Morris's design
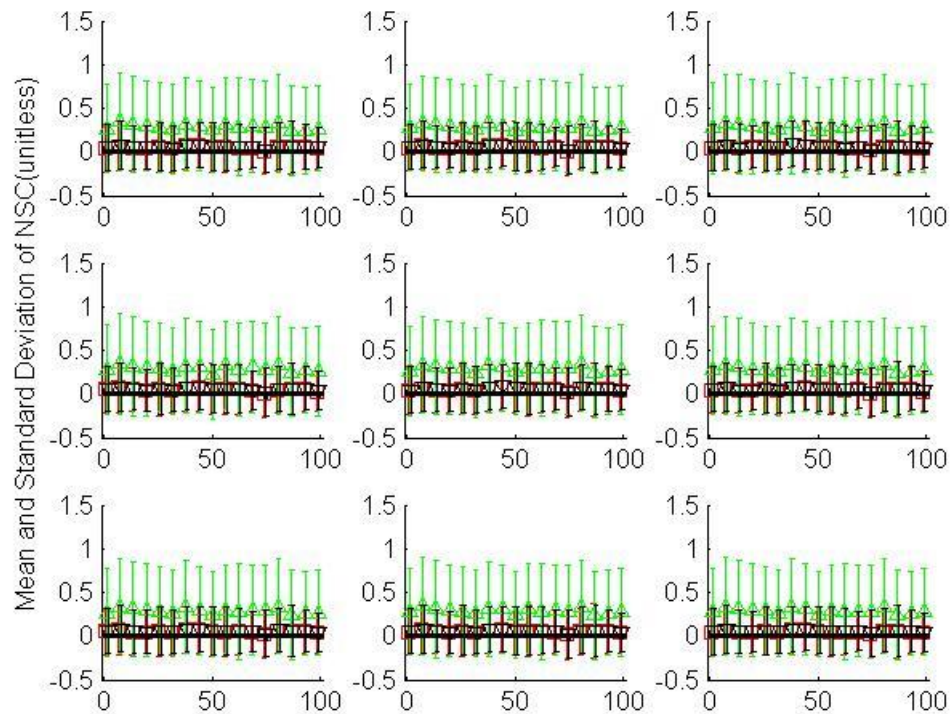
Figure S1

Schematic diagram of modeling occupational exposure of population exposure to pollens in 9 climate zones.Concernrations and surface loading of pollens were simulated based on mass balance and sourece concerntraion from fluid dynamic model.Exposures to pollens were simulated based on the concentration profiles and activity data of different groups by ages and sex from United States Census Bureau.The intake dosed calculated from exposure modeling are then used as input to conduct sensiti vity analysis.

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┌─────────────────┐           ┌──────────────┐           ┌──────────────┐           ┌──────────────────┐
│   Population     │  ──────▶  │  Preprocess  │           │ Conc.Profile │  ──────▶  │ Exposure Modeling│
│  Distribtuion    │           │              │           │              │           │                  │
│   by cesus       │           └──────┬───────┘           └──────▲───────┘           └────────┬─────────┘
└─────────────────┘                   │                          │                            │
                                      ▼                          │                            ▼
┌─────────────────┐           ┌──────────────┐           ┌──────────────┐           ┌──────────────────┐
│      EPA         │           │ Combination  │           │ Activity Data│           │  Exposure Dose   │
│    Exposure      │  ──────▶  │  process of  │  ──────▶  │  Inhalation  │           │    Inhalation    │
│     Factor       │           │population data│          │Hand to Mouth │           │      Dermal      │
│  Handbook(2      │           │and exposure  │           │    Touch     │           └────────┬─────────┘
│     011)         │           │   factors    │           │Indoor/outdoor│                    │
└─────────────────┘           └──────────────┘           │    time      │                    │
                                                          └──────▲───────┘                    ▼
┌─────────────────┐           ┌──────────────┐           ┌──────────────┐           ┌──────────────────┐
│  Pollens Data    │  ──────▶  │  Preprocess  │  ──────▶  │ Source Conc, │           │ Sensitivity      │
│                  │           │              │           │ 9 climate    │           │ Analysis         │
└─────────────────┘           └──────────────┘           │   zones      │           └──────────────────┘
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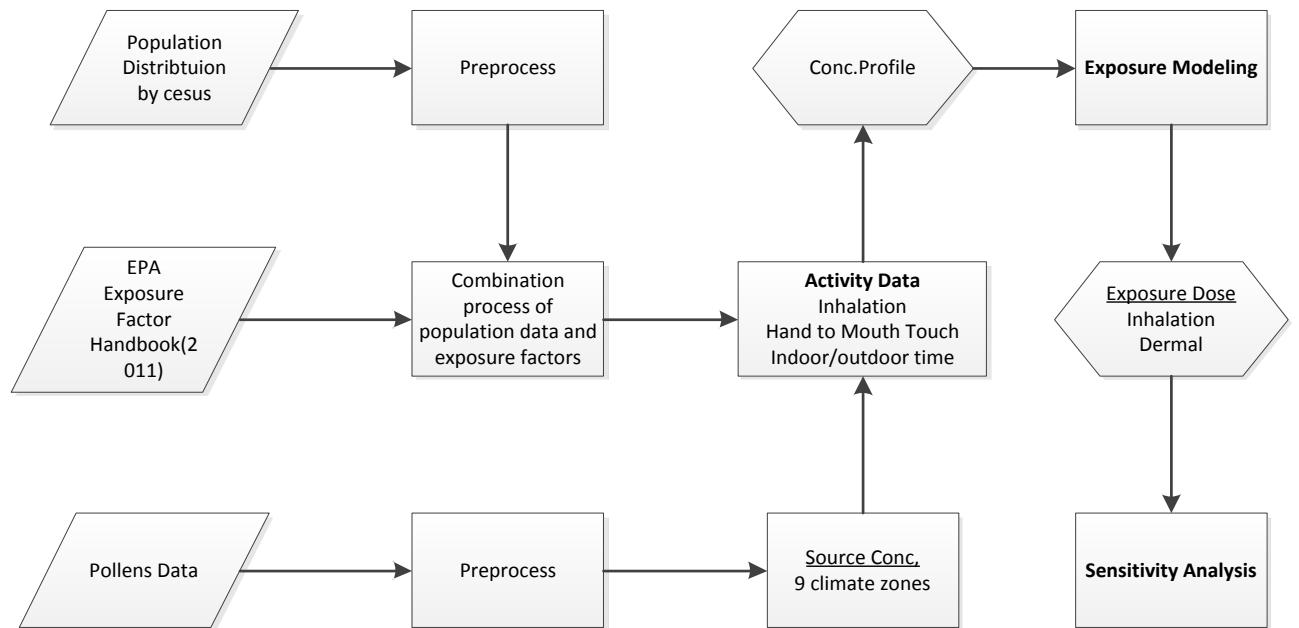
Conclusion

The modeling system developed based on physical processes and human activity data in the current study,can be easily adapted to simulated risks and exposure to particulate matter(PM) in similar environments or small scaled units such as cities or certain census.Furthermore,sensitivity analyses of the modeling system provides helpful information for planning measurements related to investigation of health risks associated with occupational exposures to pollens or other kinds or particulate particles in the environments.

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