Development of a oak pollen eission and transport modeling framework in South Korea

Yun-Kyu Lim*[1)], Kyu Rang Kim[1)], Changbum Cho[1)], Mijin Kim[1)], Ho-seong Choi[1)], Mae Ja Han[1)], Inbo Oh[2)], Baek-Jo Kim[1)]

1)Applied Meteorology Research Division, National Institute of Meteorological Research, Korea Meteorological Administration, Jeju-do 697-845, Korea

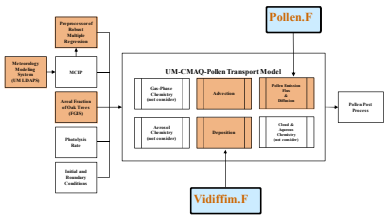
2) Environmental Health Center, University of Ulsan College of Medicine, Ulsan 682-714, Korea

1. INTRODUCTION

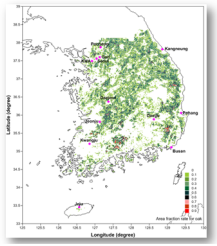
- Pollen is closely related to heath issues such as allergenic rhinitis and asthma as well as intensifying atopic syndrome. Information on current and future spatio-temporal distribution of allergenic pollen is needed to address such issues.
- Lim et al.(2015) developed a prediction system of pollen emissions (UM-CMAQ-Pollen) by adding a module for computation of average daily pollen emission based on the robust multi-regression equation.
- During the precipitation events model tends to overestimate the pollen concentrations. Hourly pollen emission concentrations estimated using Zhang et al. (2014) method show significant difference with observation data, thus improvement of pollen emission estimation method is needed.
- To improve the estimation of pollen concentration during precipitation events, area range average values were applied to each grid.
- To improve the accuracy of oak pollen concentration, the pollen density, daily emission and sensitivity on wind speed threshold were examined and developed new flowering emission flux using source oak pollen region observational data.

2. UM-CMAQ-Pollen

- No gas-phase chemistry
- Model domain: Korea, Horizontal 1.5km (with 358 X 439 grids), vertically 47 layer (up to 100 hPa)
- Unified Model LDAPS Meteorological data of Korea Meteorological administration



<Flowchart of UM-CMAQ-Pollen framework>



<Areal fraction of oak trees>

Daily emission of pollen

① *Emission production* Pa $\left(\text{Oak}, \frac{\text{grains}}{\text{m}^3}\right)$ = exp{0.0786 ta + 0.0099hm + 1007. 718 facc(acc) + + 2.5371 $f_{ws}(ws)$ + 8.3423 $f_m(m)$ + 47.2167 f_{date} (date) + $\frac{0.6354^{\,2}}{2}$} − 1

ta: daily mean air temperature (℃), hm: daily mean relative humidity (%), acc: accumulated air temperature (℃), ws: daily mean wind speed (ms^{-1}), rn: daily mean precipitation amount (㎜), date: Julian day, f: Weibull probability density function

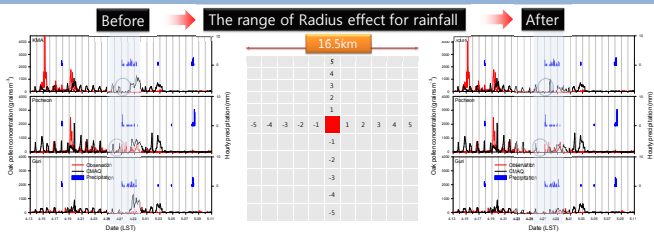
Hourly emission flux

② *Hourly emission production* E_p $\left(\text{Oak}, \frac{\text{grains}}{\text{m}^3}\right)$ = $\frac{P_a}{H_s \times C} \times K_e \times U_*$

H_s: average canopy height for species within each genus (Oak 9.6m, Schuler and Schlunzen, 2006), C: conversion constant from day to seconds (24h/day), Ke: parameter between 0 and 1 (Zhang et al, 2014)

③ *Finally emission production* $\left(\text{Oak}, \frac{\text{grains}}{\text{m}^3}\right)$ = $E_p \times \Gamma$

Γ: areal fraction of oak tree



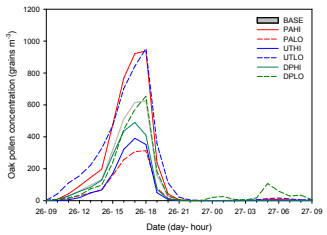
- Each grid (1.5km) adopts precipitation average of 5 grids (7.5km) radius effect.
- In this method, the range of rain can be overestimated, but Efstathiou et al.(2011) suppress the pollen emission occurrence in case more than 80% relative humidity. Therefore, this method might be reasonable.

3. Sensitivity Experiment

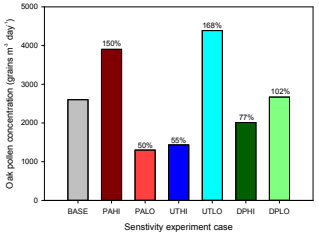
Table 1. List of sensitivity experiments of UM-CMAQ-Pollen model

CASE ID	Description	Purpose
BASE	Base case simulation	
PAHI	Use the upper bound estimates of pollen emission; total daily pollen emission amount Pa in Eq.(1). Compared with case BASE, +50%	Sensitivity study of the uncertainties for total daily pollen emission amount Pa estimates to their simulated concentration
PALO	Use the lower bound estimates of Pa. Compared with case BASE, -50%	
UTHI	Increase threshold wind speed by 50% compared to case BASE (Set empirical threshold wind speed U10e as 4.35 ms^{-1} compared with case BASE 2.9 ms^{-1})	Sensitivity study of empirical threshold wind speed U10e setting to simulated pollen concentration
UTLO	Decrease threshold wind speed by 50% compared to case BASE (Set empirical threshold wind speed U10e as 1.45 ms^{-1} compared with case BASE 2.9 ms^{-1}	
DPHI	Increase the mean diameter of pollen genera by 50% compared to case BASE (set 46.5)	Sensitivity study of dry deposition velocity Vdp calculation for pollen genera to their simulated concentration
DPLO	Decrease the mean diameter of pollen genera by 50% compared to case BASE (set 15.5)	

Case study: Daejeon site on 26 April 2015



<Hourly oak pollen concentration>

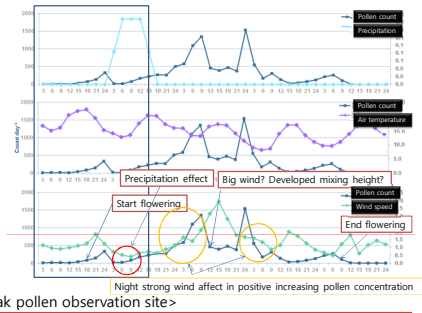


<Total daily oak pollen concentration>

- UM-CMAQ-Pollen sensitivity experiments such as total daily emission, wind speed threshold, and pollen density do not affect hourly oak pollen concentration pattern.
- Smaller size diameter of oak pollen causes more effective horizontal advection.

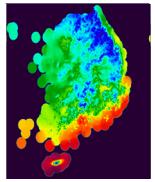
4. Improvement of Emission Module

To improve flowering emission pattern the oak emissions were observed and analyzed at the oak pollen source region

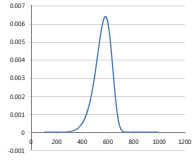


<Korea National Arboretum(KNA) oak pollen observation site>

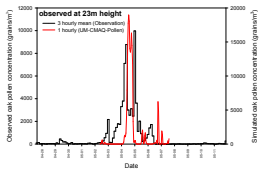
New flowering emission flux based on accumulated air temperature



<Accumulated air temperature using Barnes objective analysis>

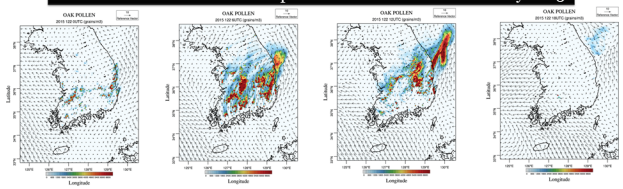


<Weibull probability function>



<Simulated and observed oak pollen concentration at KNA>

Horizontal distribution of oak pollen concentration at 2nd May 2015



5. SUMMARY

- Total daily oak pollen concentrations from UM-CMAQ-Pollen is meaningful, but hourly pattern is not in agreement with observation.
- During the precipitation events model tends to overestimate the pollen concentrations due to the uncertainties in meteorological model. Therefore, to improve the model accuracy, a handling process of input data was needed.
- Improved hourly emission factor was needed because the sensitivity experiments does not affect hourly oak pollen concentration pattern.
- The pattern of UM-CMAQ-Pollen hourly oak pollen concentration from developed flowering emission flux based on oak source region was in agreement with observation.

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