Met Office

Pollen Pilot Project

For MEDMI
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Rachel McInnes and
Christophe Sarran

MEDMI

Met Office
FitzRoy Road, Exeter
Devon EX1 3PB
United Kingdom

Tel (UK): 0870 900 0100 (Int) : +44 1392 885680
Fax (UK): 0870 900 5050 (Int) :+44 1392 885681
enquiries@metoffice.gov.uk
www.metoffice.gov.uk

Introduction

Atmospheric pollen monitoring in the United Kingdom is carried out by the National Pollen Monitoring Network coordinated by the Met Office. The network consists of some 10 to 20 sites that operate during the pollen season. Counts of pollen grains, differentiated by species, are used to forecast levels of pollen on a regional basis, either by taking an average of the counts at sites within a region or by inferring from counts at sites of neighbouring regions where a region has no site.

Pollen counts are available only for 10 to 20 sites while pollen concentrations present significant variations on the scale of kilometres. This means that at best, pollen measurements are indicative of risk at a regional level. This Pilot Project offers a first step towards statistical estimates of atmospheric pollen concentration by linking pollen and meteorological datasets and using a Gaussian plume model to link with a high resolution land cover map. The Pilot Project provides the tools to compute atmospheric pollen concentration appropriate for use in health studies where estimates of exposure are important. The project has made use of pollen and meteorological data available on MEDMI. The tools are designed to allow compatibility with other input maps (e.g. species-specific vegetation maps being created as part of NIHR HPRU Environment and Health; or future land cover datasets) to allow researchers to analyse pollen concentrations from different sources. This can also be used to study the effect of future land use change or climate change on pollen concentration in the UK.

Methods

Four steps were identified for the development of the required datasets and tools. A preliminary step included generic MEDMI Database tools and an implementation of the Gaussian plume model. Step 1 aimed at writing code to combine pollen monitoring data with wind data using the large-time solution for the concentration for a continuously emitting source derived by Thomson and Manning[1]. Step 2 is to calculate deviations from the expected mean pollen count at each monitoring site and derive estimates of pollen emissivity close to each site. Finally, step 3 was to use spatially interpolated emissivity and the large-time solution for pollen concentration to produce estimates of atmospheric pollen concentration for any given day and location. These steps and their deliverables are listed in Table 1.

Table 1. Product breakdown structure with the preliminary step (references starting with 0) and steps 1 to 3.

Ref.	Description	Inputs	Output	Depen-dencies	Segment	Target date	Status
0.1	Python object of pollen monitoring data		Pollen monitoring data by station, date and taxa		Database	31/10/2015	completed
0.2	Python function for inverse-distance weighted interpolation	Values and specified locations	Interpolated estimate		Database	16/10/2015	completed (may require adapting)
0.3	Python object of point wind vector estimates		Wind vectors at specified locations and dates	0.2	Database	31/10/2015	completed
0.4	Python function of the Gaussian plume model	Emissivities, wind vectors	Atmospheric pollen count		Pollen Pilot Project	30/11/2015	in progress
Step 1							
1.1	ASCII raster file for each pollen taxa containing the high resolution spatial distribution of species				Pollen Pilot Project	31/10/2015	completed
1.2	Python object of climatological mean pollen emissivity for each raster file category and taxa	Species distribution, pollen data, wind vectors	Climatological mean pollen emissivities by raster category and taxa	0.1, 0.3, 0.4, 1.1	Pollen Pilot Project		delayed by lack of spatial tools on server
Step 2							
2.1	Python function to calculate expected mean pollen count at monitoring sites	Climatological mean emissivities, wind vaectors	Expected mean pollen count at monitoring site	0.3, 0.4, 1.2	Pollen Pilot Project		delayed by lack of spatial tools on server
2.2	Python function to calculate daily pollen emissivities close to monitoring sites	Climatological emissivities, expected pollen count, pollen data	Pollen emissivities for monitoring site	0.1, 1.2, 2.1	Pollen Pilot Project		delayed by lack of spatial tools on server
2.3	Python object of daily pollen emissivities	Pollen emissivities for monitoring site	Daily pollen emissivities	0.2, 2.2	Pollen Pilot Project		delayed by lack of spatial tools on server
Step 3							
3.1	Python object of atmospheric pollen concentration	Daily pollen emissivities, wind vectors	Atmospheric concentrations	0.3, 0.4, 2.3	Pollen Pilot Project	15/12/2015	

Results

For the preliminary step, the main challenge has been the numerical implementation of an appropriate Gaussian plume model. We met with David Thomson, one of the paper's[1] authors, who suggested implementing a different formulation of the Gaussian plume model, starting with the equation for an instantaneous source

$$\frac{M}{(2\pi)^{3/2}\sigma_x\sigma_y\sigma_z}\exp\left(-\frac{\left(x-U(t-t')\right)^2}{2\sigma_x^2}-\frac{y^2}{2\sigma_y^2}-\frac{z^2}{2\sigma_z^2}\right)$$

with M the total amount of pollen released and where U is the wind speed, x, y and z are along-wind, cross-wind and vertical coordinates, and σ_x, σ_y and σ_z are root mean square spreads of the puff in the respective directions as functions of the age of the puff $t - t'$. This can be taken further towards a practical model using the methods developed by Ashok Luhar[2]. An appropriate Gaussian plume like model has been selected, with an empirical adjustment thought to better model the spread and deposition of pollen: (1) it involves changing Cartesian coordinate system between regular and wind direction oriented grids; (2) it has the potential to be scaled to different species, to represent how their buoyancy and release height change how far they travel; (3) it also has the potential to be extended to 3D modelling to provide pollen concentration values at different heights. The precise solution for the Gaussian plume model is still being worked on however the code providing the framework (input and output variables) for its numerical implementation is completed. The code has been written such that it can be used either to find the concentration on a certain day around a specific site or point location from surrounding sources. It can also be looped over to create a gridded map of pollen concentration over an area and will be used as such in the NIHR HPRU Environment and Health Theme 3 pollen modelling work. The other deliverables of the preliminary step have all been completed as part of the MEDMI Database development: pollen monitoring data, point wind vector estimates and the inverse-distance weighted interpolation function.

The second key element of the project, high resolution maps of pollen releasing species, has been completed as part of step 1. One grass map (all species of Poaceae together) has been created at 25 m resolution over the UK (c.f. Figure 1), and 5 maps of allergenic weeds, Ragweed (Ambrosia), Mugwort (Artemisia), Plantain (Plantago), Dock (Rumex) and Nettle (Urtica), have been created also at 25 m resolution over the UK. These maps are stored as ASCII raster files that need to be read using latitude and longitude as

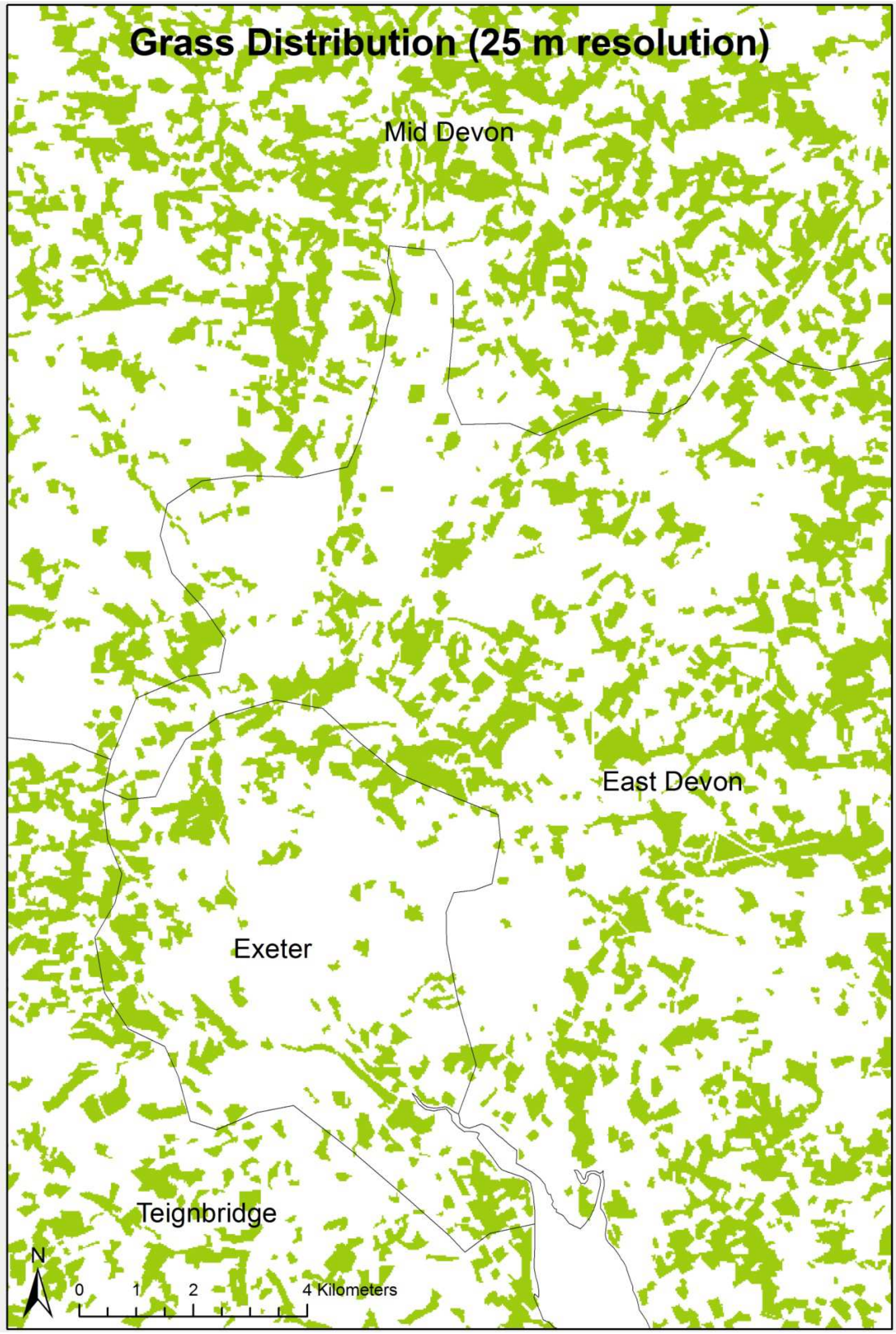

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Figure 1. Grass map with all species of Poaceae together at 25 m resolution for Exeter and its surrounding area.

spatial coordinates. Latitude and longitude are used to identify the location of pollen monitoring readings and the location of wind vector estimates so also need to be used to locate the pollen map data. Unfortunately, the Python installation on the MEDMI Database server does not include a module with functions or objects to facilitate the conversion from the grid coordinate system used for the maps (National Grid References) and latitudes and longitudes. Either a separate spatial coordinate conversion function will need to be coded as part of the MEDMI Database development, or the latitudes and longitudes of the grid point coordinates be supplied with the ASCII raster files (or potentially polynomial functions or similar to carry out the conversion).
Due to the extra work in seeking an appropriate solution for the Gaussian plume model and the difficulty in reading the ASCII raster files without coordinate conversions tools, the other deliverables of the project were not completed at the time of writing.

Conclusion

We have developed and provided datasets and tools for MEDMI users towards providing statistical estimates of atmospheric pollen concentrations at any location in the United Kingdom.
For the Gaussian plume model, it will be necessary to complete a numerical implementation by passing the correct Python objects with pollen emission values, wind speed and direction, to the function with the plume model. Once this is implemented, it will be possible to test different options for the plume turbulence scale for each species as well as the scaling distance for the deposition. It will also be essential to test that (1) 2D assumptions for the coordinate system still works for spherical coordinates, (2) the numerical solution works for light and zero wind and (3) the code is suitable for release following review and quality assurance.
For the remaining deliverables, it is planned to complete the work once a workable spatial coordinate conversion solution has been found and the Gaussian plume model is ready for use.

[1] Thomson, D.J., and Manning, A.J., 2001: Along-wind dispersion in light wind condition. *Boundary-Layer Meteorology* **98**, 341-358.
[2] Luhar, A.K., 2011: Analytical puff modelling of light-wind dispersion in stable and unstable conditions. *Atmospheric Environment* **45**, 357-368.