AGMAAS: a GIS integrated tool for modelling wind-borne spreading of FMD virus

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Introduction

The main route of the spreading of highly infectious contagious diseases of animals is physical contact between infected and susceptible animals. Furthermore, the infectious agents can spread by human beings and fomites such as feed, vehicles among animals and populations. These routes of transmission can be controlled by official arrangements. In the case of a disease outbreak, this is commonly achieved by authorities defining zones with different radius around the location of the infected population. In these zones different levels of eradication arrangements are carried out by the authorities.

Nevertheless, besides these main, controllable infection transmission routes there are some uncontrollable ways of disease spreading. Some infectious agents have high resistance to environmental conditions. These agents can be blown by the wind far from the place of the outbreak. While this long distance airborne trasmission is not controllable, it may be important to estimate the possible infected area around the outbreak.

For modeling the long distance airborne spreading of infectious agents some models were developed. The goal of these models is to define, with certain assumptions, the concentration of the infectious agents in the air around the place of the outbreak as the source of infection. To cause an infection or disease, an appropriate concentration of the infectious agent must be in the air. The appropriate concentration depends on the species of animal and the type of disease. With these two parameters one can estimate those areas where the air could contain an appropriate level of infectious agents to cause infection or disease in uninfected animals. Naturally the environmental conditions influence the ability of a pathogen to establish an infection, on the virulance of the agent. Because of this, in certain unfavourable environmental conditions in spite of the presence of infective concentration of the agents, they can't establish infection.

The aim of our work was to develop a tool integrated into Quantum GIS (QGIS) that can help the user estimate and visualize the possible infective areas around an outbreak based on HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model.

HSYPLIT

HYSPLIT is a sophisticated modelling environment developed by the National Oceanic and Atmospheric Administration Air Resources Laboratory (NOAA ARL). HYSPLIT can calculate simple air mass trajectories (pathway of air parcels in the atmosphere) but it also can be used to simulate atmospheric transport and dispersion of airborne pollutants and hazardous materials (in the form of three dimensional pollutant plumes). Deposition of pollutants and airborne particles can also be estimated with HYSPLIT. The model uses a hybrid approach for the calculation of dispersion that can include both Lagrangian and Eulerian reference system. It is also possible to use the model as a Lagrangian Particle Dispersion Model (LPDM) that is entirely based on the Lagrangian approach. In each case pollutant or hazardous material concentration is calculated on a fixed grid defined by the user. Through the post-processing of the concentration grid the users can visualize the results and use the results for decicion making. HYSPLIT is suitable to track the possible airborne spread of biological agents and diseases.

HYSPLIT needs gridded meteorological data (three dimensional wind field and other ancillary data) to calculate trajectories or dispersion. The resolution and quality of the meteorological data is crucial for the proper simulation and reliable estimation of the pollution events. Though NOAA ARL provides meteorological data that can be used for the simulations (the so-called GDAS database), we decided to use a finer resolution, high quality database for the simulations. This is based on the ERA Interim database of the European Centre for Medium-Range Weather Forecasts (ECMWF). ERA Interim is a meteorological realalysis database that is calculated using state-of-the-art data assimilation techniques. ERA Interim is the continuation of the well known ERA40 database and contains several improvements as compared to ERA40. ERA Interim is available from 1989 on a 0.5 x 0.5 degree horizontal resolution and is updated continuously up to present day. HYSPLIT uses its own data format (ARL format) for the calculation of the trajectories and dispersion plumes. Therefore the Era Interim data has to be converted to ARL format using the data conversion tools of HYSPLIT. The resulting database can be used to initiate simulations for any given situation. HYSPLIT can also use meteorological forecast fields to predict the possible pathway of hazardous material in the atmosphere (Garner et al., 2006; Hess et al., 2008).

AGMAAS

HYSPLIT is disseminated with a built-in Graphical User Interface (GUI) for easier usage. In spite of the GUI, it is still difficult to use HYSPLIT for non-experts as the meteorological data conversion, the initiation of the simulation and the post-processing of the results need special knowledge that is clearly missing for the majority of decision makers or end users.

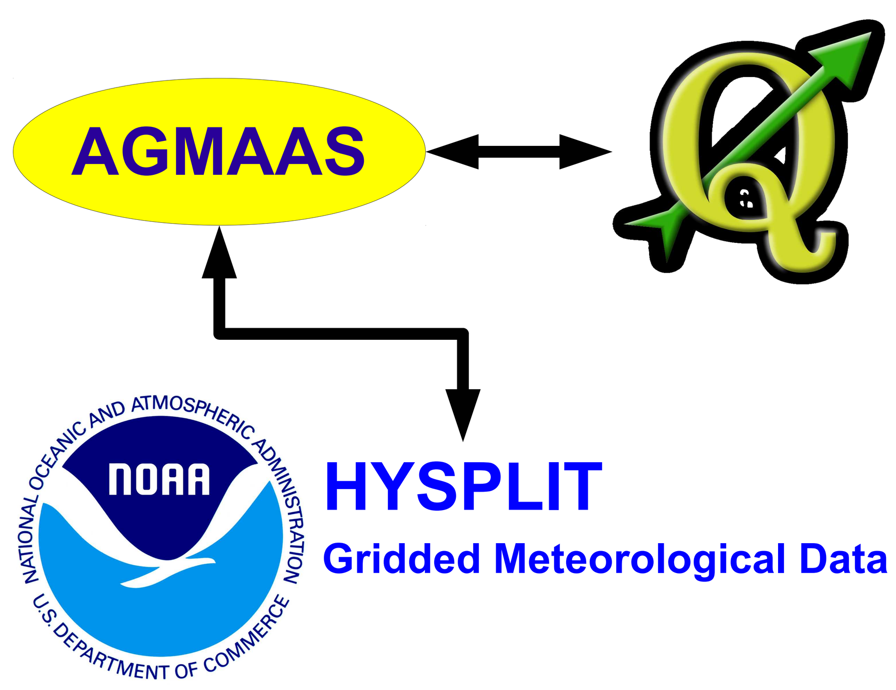


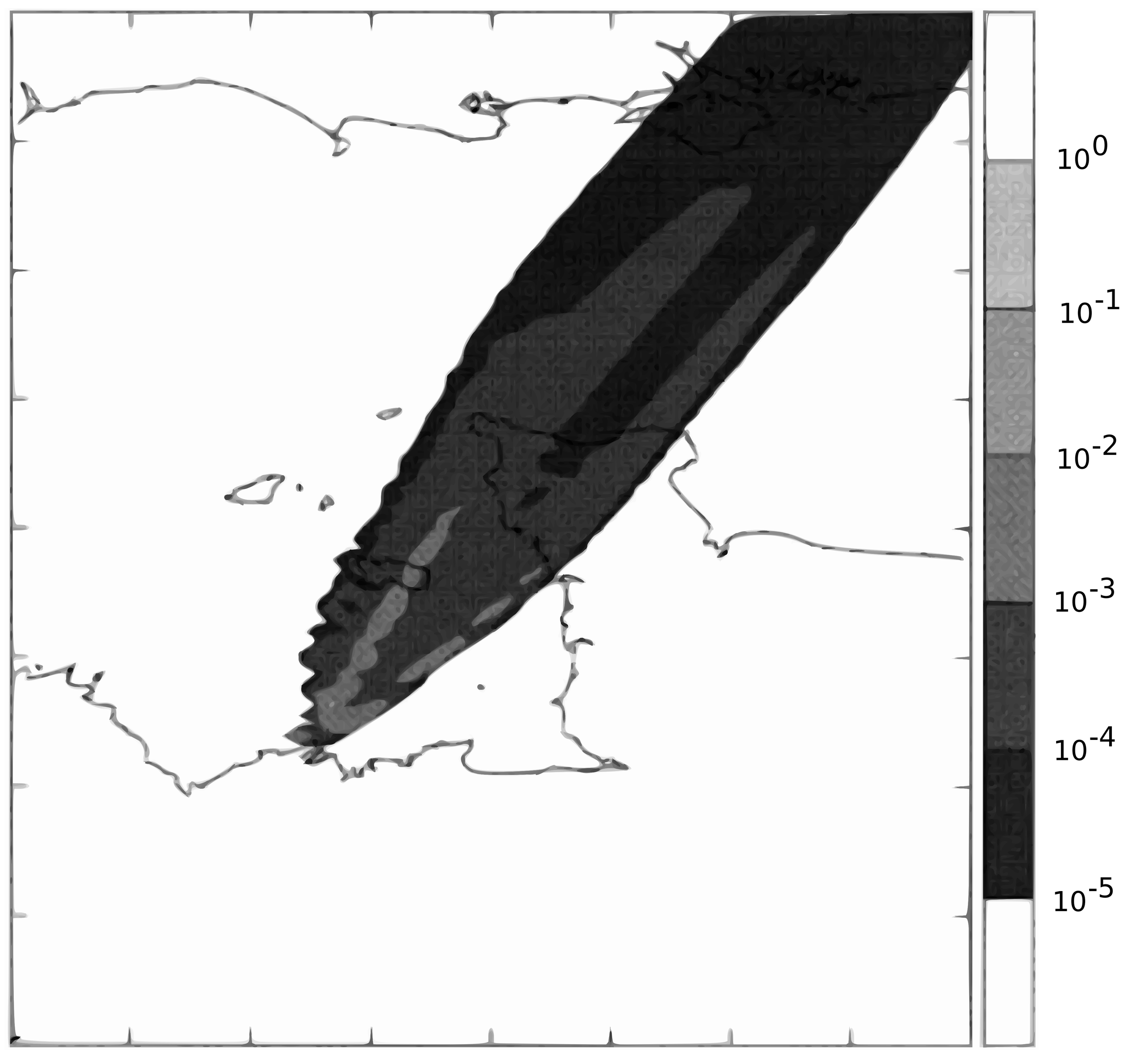
Figure 1: Links among the elements of the system. As a QGIS plugin AGMAAS helps the user to set up parameters for HYSPLIT model run based on gridded meteorological datasets.

Therefore we have developed A GUI for Modelling Airborne Agent Spreading (AGMAAS) to help the non-expert users to set up model parameters for HYSPLIT model run. Using AGMAAS as a QGIS plugin, user can not just set up the model run, but can perform the run and can get back the results in the interactive GIS environment.

Validation

We were interested if we could reproduce the results of Sørensen et al. (2000) based on HYSPLIT model using our tool. Sørensen et al. (2000) used an outbreak data published by Donaldson et al. (1982). They tried to model the long distance spread of FMD virus from Brittany, France to the island of Jersey and Wight. They used observed and model based meteorological data as input of prediction. They found that the outbreak in France was a possible airborne source of the cases on Jersey, but not on Wight (Fig 2). Based on the available datasets using our tool linked to HYSPLIT we were able to reproduce the same result (Fig 3).

Figure 2: *"Simulated virus plume produced by infected pigs on farms 2-4 (Table 4) in Brittany, France, as derived by Rimpuff using data from weather stations. The contours indicate 24-h average FMD virus concentrations for the preceding 24 h in units of $TCID_{50}/m^3$ on 8 March 1981, at 0 CET. The axis units are UTM coordinates, zone 31. The plume is seen to extend over the island of Jersey and the Isle of Wight."* (Sørensen et al., 2000)



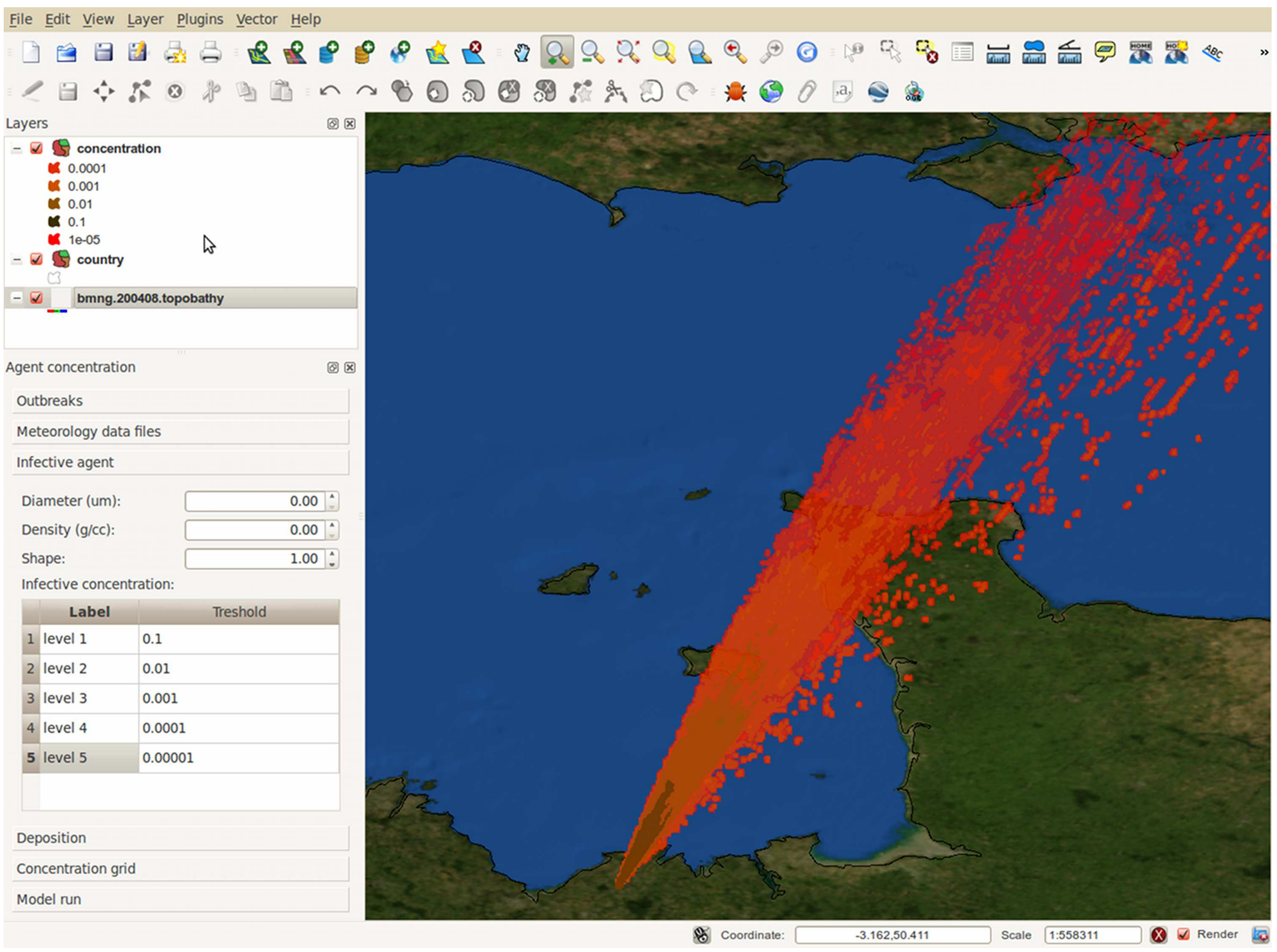


Figure 3: HYSPLIT run result visualized in the QGIS-AGMAAS environment with the same parameterization as in Fig 2.

Availability

The system we present was constructed from four elements: HYSPLIT, gridded meteorological dataset, QGIS and AGMAAS (Fig 1). HYSPLIT and gridded meteorological datasets can be downloaded from the site: `http://ready.arl.noaa.gov/HYSPLIT.php`. QGIS is accessible at the site of project (`http://www.qgis.org/`). AGMAAS binary (for Microsoft Windows and Linux) with source code is available from the corresponding author upon request.

All elements are free!

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