Met Éireann's Foot and Mouth Dispersion Model - 2013

During 2013 Met Éireann assembled a new tool for predicting the airborne spread of foot and mouth disease (FMD) in Ireland. This computational tool is primarily based on the HYSPLIT dispersion model. Driven by Met Éireann's HARMONIE weather prediction model and taking advantage of more modern publications related to foot and mouth, this operational FMD tool is available to assist decision makers in times of a foot and mouth outbreak.

HYSPLIT:

HYSPLIT or Hybrid Single Particle Lagrangian Integrated Trajectory Model[1] is a complete system for computing simple air parcel trajectories to complex dispersion and deposition simulations. It was originally developed by the National Oceanic and Atmospheric Administration (NOAA)[2] in the United States and Australia's Bureau of Meteorology[3]. The HYSPLIT dispersion model has been extensively validated globally and is supported by an active community of developers and users. For a complete description of the HYSPLIT model, user guide and training material amongst a wealth of other useful material see http://www.arl.noaa.gov/HYSPLIT_info.php.

Required model inputs:

As well as the location and time of the emission sources of a FMD outbreak, there are two primary inputs that the HYSPLIT dispersion model requires. Firstly, meteorological data to drive the model and secondly, information on how much of the virus is being emitted. A description of deriving an emission value will not be covered in this document.
Additions were made to the HYSPLIT code to better allow for the description and dispersion of the FMD virus. Details will be expanded on below but primarily follow the description given by Garner et al. (2006)[4].

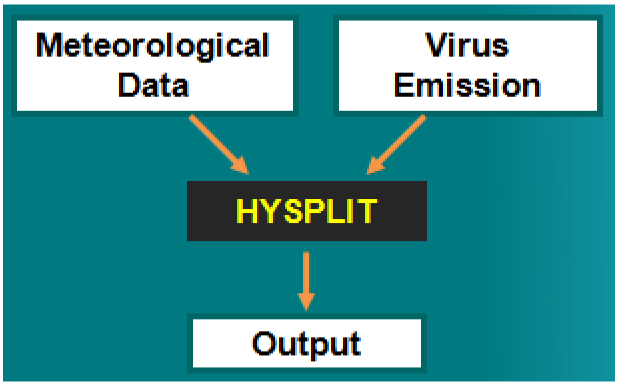

Fig 1. Flow diagram for the primary inputs required by the HYSPLIT model

Meteorological data:

Users of this HYSPLIT foot and mouth model will be able to access the latest HARMONIE forecast. HARMONIE is a high resolution local area model (developed by the HIRLAM community[5])which covers Ireland and the UK. Users will have access to the last month of meteorological data extended by a 30hour forecast. HYSPLIT can run a foot and mouth simulation for any time between -35 days to +30 hours from the last HARMONIE update. The HARMONIE forecast is updated every 6 hours and is typically available at T+4hours (where T is 00:00, 06:00, 12:00 or 18:00). The latest available forecast will be automatically used when the user launches the HYSPLIT program.

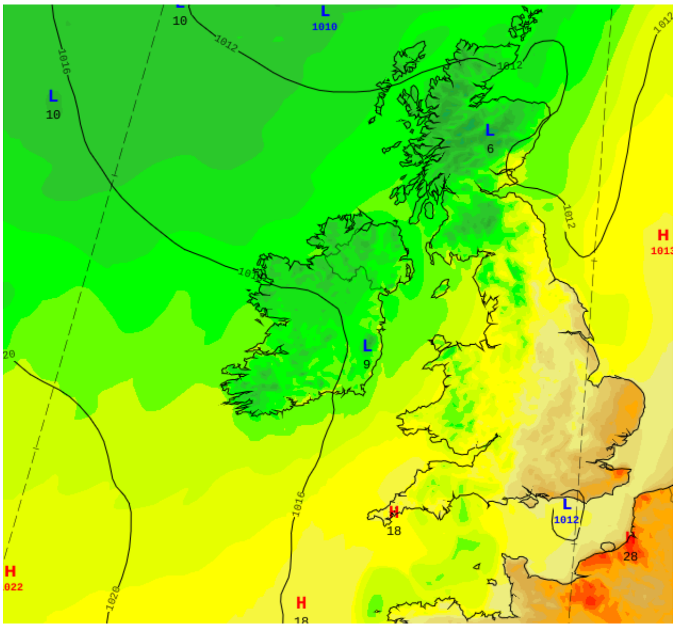

Fig 2. Area modelled by Met Éireann's HARMONIE weather forecast model

Dry deposition:

HYSPLIT incorporates dry deposition if selected by the user. For the foot and mouth virus a dry deposition velocity of 0.01m/s is assumed.[4]

Wet deposition:

Wet deposition is also an option within HYSPLIT. For particles In-cloud and Below-cloud deposition constants must be defined. In-cloud removal is defined as a ratio of the virus in air (g/liter of air in the cloud layer) to that in rain (g/liter) measured at the ground. For the foot and mouth virus an in-cloud value of $3.2x10^5$ is assumed. Below-cloud removal is defined through a removal time constant. For the foot and mouth virus we have again taken Garner's value of $5x10^{-5}$. [4]

Particle age:

Various publications use a virus decay constant to simulate particle ageing. For the foot and mouth virus estimates of an effective half life range from 30mins[4] to 2 hours[6]. This constant is also dependent on the strain of the virus. To be conservative we have defined this virus decay constant to be 2 hours by default but this can be easily redefined by the user using an external fm_param tool which has been added to HYSPLIT. Particle ageing can be turned off altogether if desired.

Temperature:

The survival of the virus depends on temperature. Unlike some simulations[6] where an on/off temperature switch controls the life of the virus, here we have adopted what we believe is a more realistic approach adopted by Garner et al.[4] We leave all virus particles of 24°C and under unaffected. We decrease the concentration mass of virus particles linearly between 24°C and 30°C so that none remain by the time they reach 30°C. This threshold of 24°C can be user defined using the fm_param tool (preserving the 6°C linear fall off) or the temperature dependence can be turned off altogether if required.

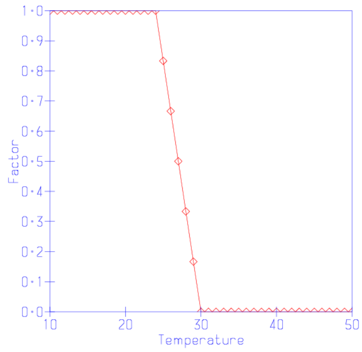

Fig 3. Default FMD dependence on air temperature

Humidity:

The survival of the virus also depends on humidity. The virus needs higher humidity to survive. We leave virus concentrations with relative humidity higher than 60% unaffected. We decrease concentrations exponentially as the humidity falls from 60% to 1%[4]. This threshold of 60% can be user defined using the fm_param tool or the humidity dependence can be turned off altogether if required.

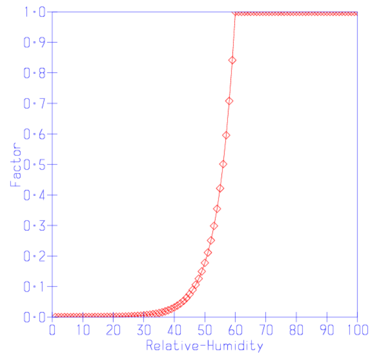

Fig 4. Default FMD dependence on air temperature

Verification of Met Éireann's foot and mouth dispersion model

A recent paper by Gloster et al. (2010)[7] compares the airborne spread of foot and mouth disease using 6 independent atmospheric dispersion models. A workshop held in the UK in 2008 allowed the developers of the following dispersion models: VetMet (Denmark), PDEMS (New Zealand), AIWM (Australia), MLCD (Canada), NARAC (USA) and NAME (UK) to compare predictions on the spread of the foot and mouth virus from a known source. The 1967 Hampshire, UK, outbreak of FMD was selected as the case study.

We ran our modified version of HYSPLIT for the same case study. As the HARMONIE weather model does not go back to 1967 we used ECMWF ERA40 data extracted at 1.0deg resolution. We ran the model using our predefined foot and mouth defaults i.e. wet and dry deposition turned on, a virus decay constant of 2 hours, a temperature dependence threshold of 24^{o}C and a humidity threshold of 60%.

Here we compare our HYSPLIT driven dispersion results, to the six models which took part in the inter-comparison.

Single day plume comparison:

The paper takes a test day of the 9th of January 1967 for comparison purposes. Fig 5 below shows 24 hour time integrated concentrations from all models for this date, using identical emission data[7].

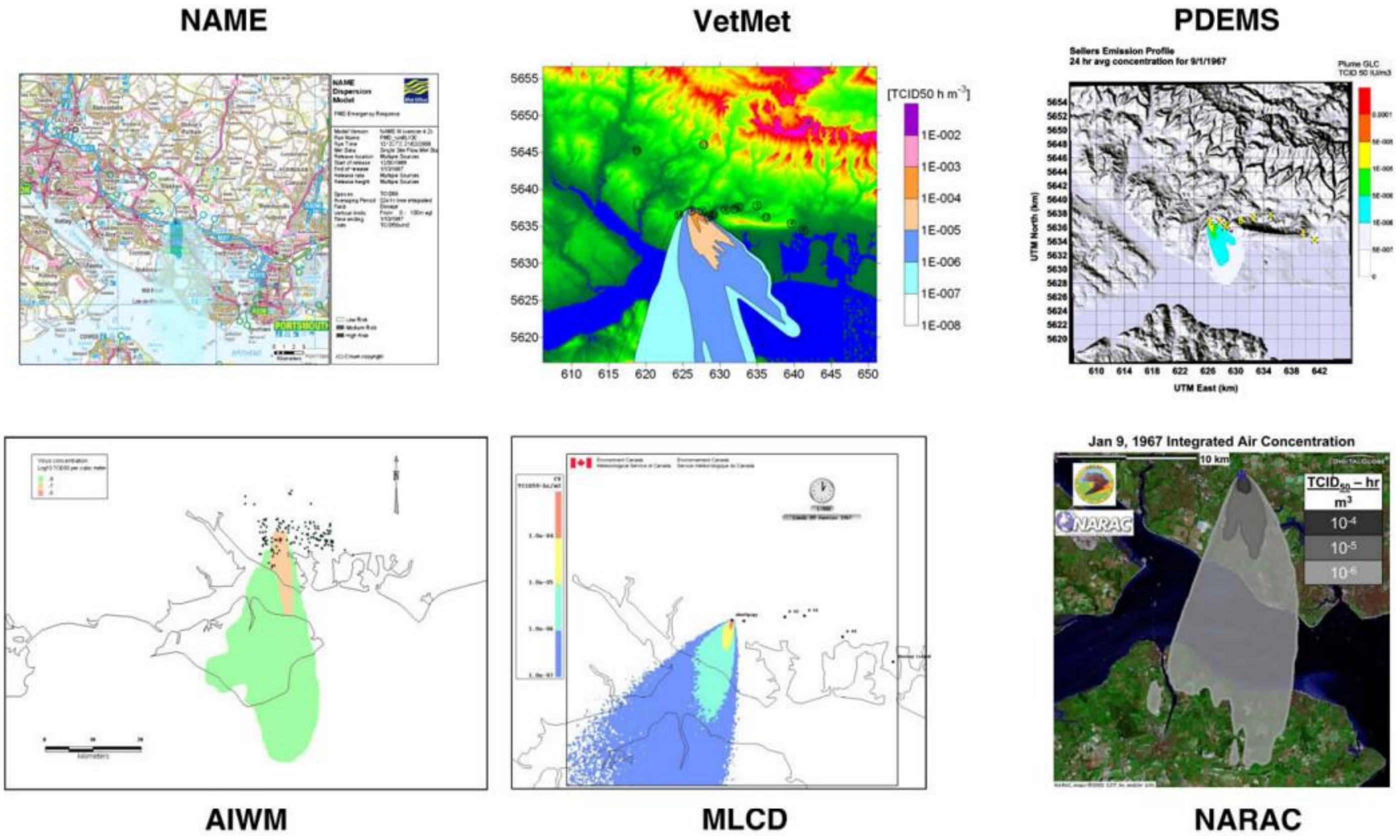

Fig 5. 24 h time-integrated concentrations from all models for 9th January 1967, using identical virus emission data, from Gloster at al. (2010)

Fig 6 shows HYSPLIT's description of the same event. AIWM, MLCD and NARAC are driven by numerical weather model data in a similar way to HYSPLIT. NAME, VetMet and PDEMS are driven by a weather station point source to the south west of the outbreak site. As can be seen there is very good agreement between all seven models.

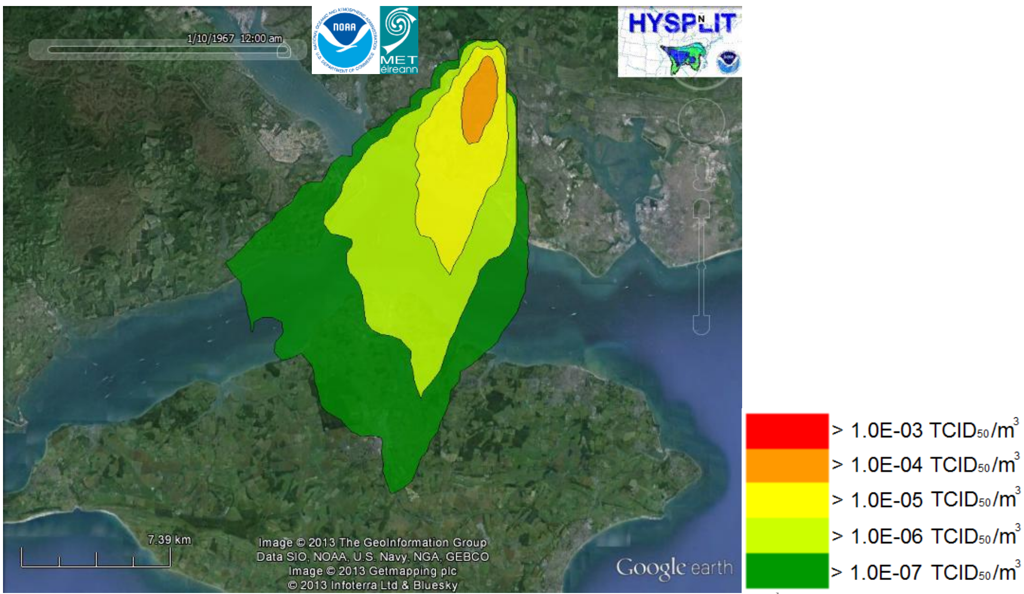

Fig 6. 24 h time-integrated concentrations from HYSPLIT for 9th January 1967, using identical virus emission data as used by Gloster at al.

Comparison of plume over entire period:

Fig 7 below shows the total accumulated dosages from all models for 29 December 1966 to 9 January 1967 using identical virus emission data.[7] Fig 8 shows HYSPLIT's description over the same period. Again there is very good agreement between all seven models.

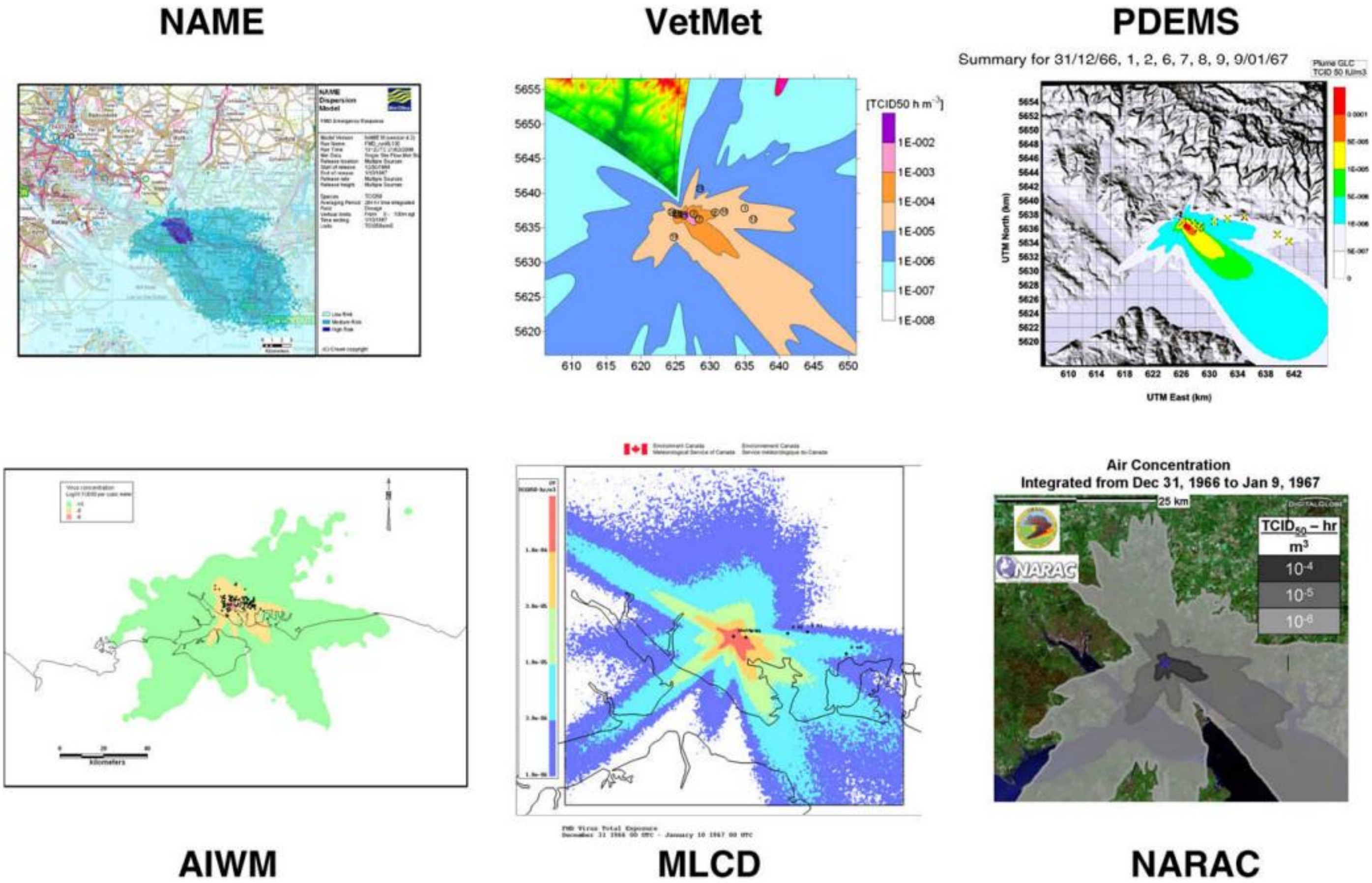

Fig 7. Total accumulated dosages from all models for 29th December 1966 to 9th January 1967 using identical virus emission data, from Gloster at al. (2010)

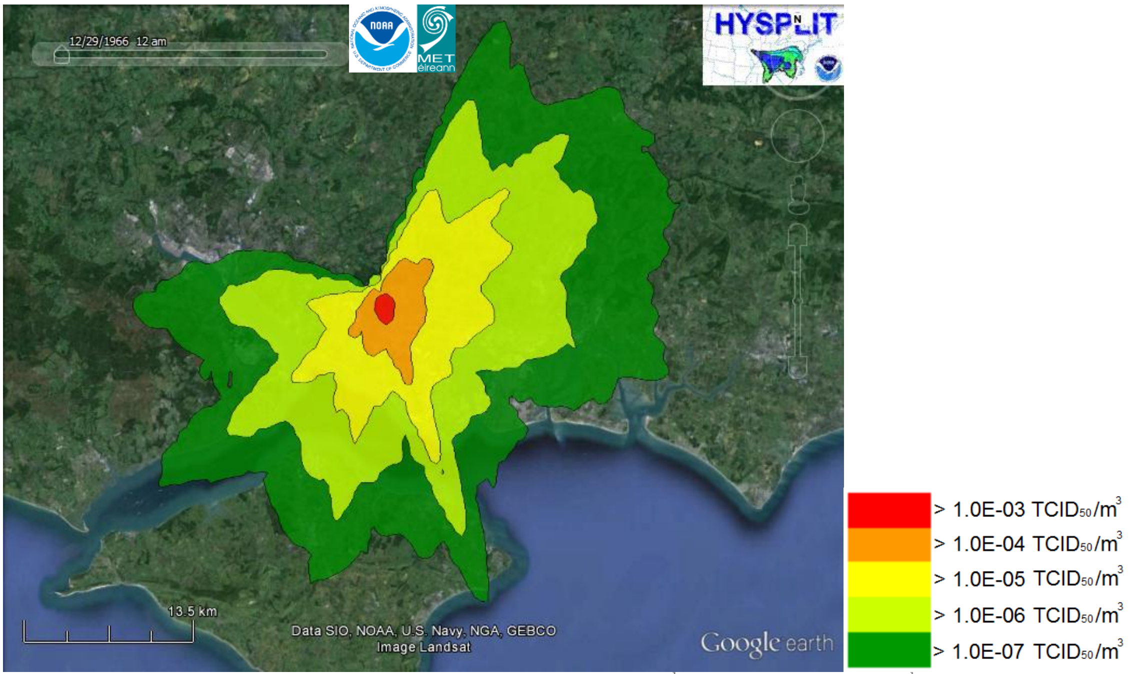

Fig 8. Total accumulated dosages from all models for 29th December 1966 to 9th January 1967 using identical virus emission data as used by Gloster at al.

Comparison of concentrations:

Another test run at the workshop was to compare total 24 hour integrated concentrations along the major axis of the plume at 1, 5, 10, 15 and 20kms for 9th January 1967. Table 1 below shows the results from all models including HYSPLIT. Fig 9 is a graphical representation of this table. HYSPLIT again compares well to the other models. [Note: only some of the other models use a particle ageing decay constant in their simulations.]

Model	1 km	5 km	10 km	15 km	20 km
NAME	1×10^{-4}	1×10^{-5}	8×10^{-6}	6×10^{-6}	3×10^{-6}
VetMet	3×10^{-4}	4×10^{-5}	8×10^{-5}	3×10^{-6}	2×10^{-6}
AIWM	8×10^{-5}	4×10^{-5}	1×10^{-5}	4×10^{-6}	2×10^{-6}
PDEMS	4×10^{-5}	4×10^{-4}	1×10^{-5}	6×10^{-6}	2×10^{-6}
MLCD	1×10^{-4}	6×10^{-6}	2×10^{-6}	6×10^{-7}	5×10^{-7}
NARAC	2×10^{-4}	1×10^{-5}	4×10^{-6}	2×10^{-6}	1×10^{-6}
HYSPLIT	5×10^{-4}	9×10^{-5}	1×10^{-5}	2×10^{-6}	4×10^{-7}

Table 1. Total 24 hour integrated concentrations along the major axis of the plume at 1, 5, 10, 15 and 20kms for 9th January 1967 taken from Gloster at al.[7] and also our HYSPLIT equivalent results.

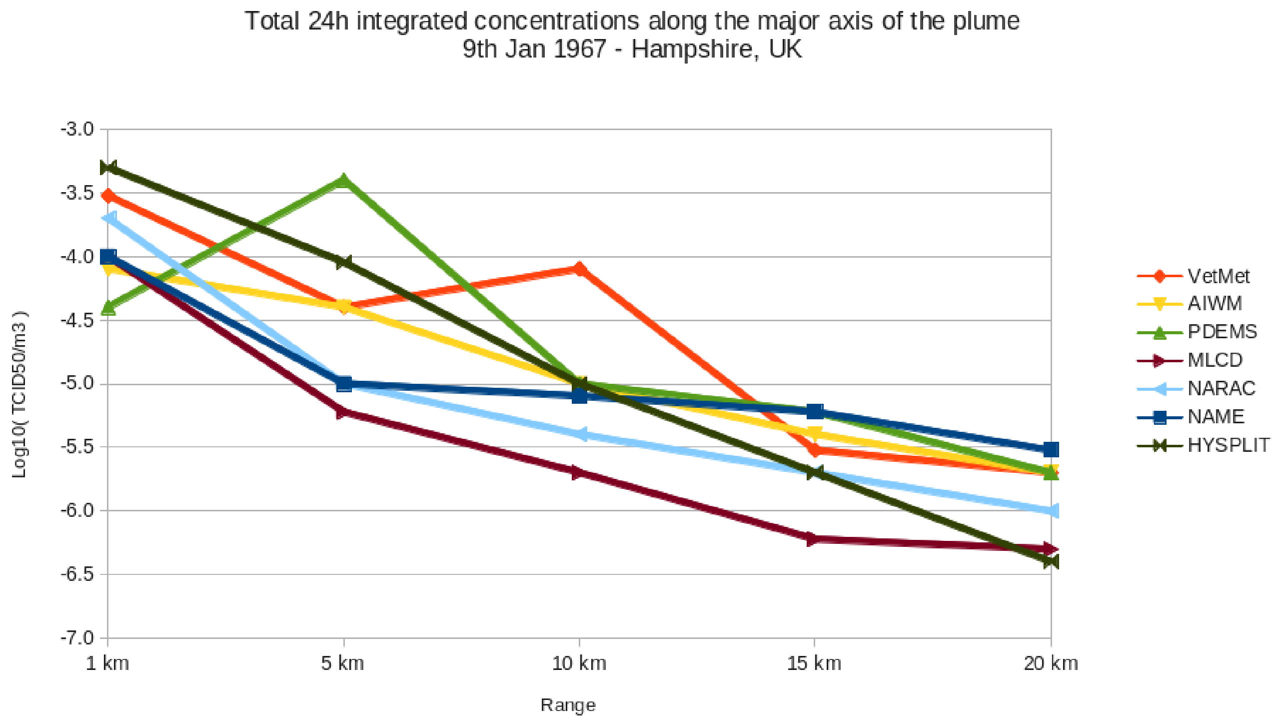

Fig 9. Graphical representation of Table 1. HYSPLIT FMD concentrations are in line with other foot and mouth dispersion models.

Conclusion:

The workshop concludes that: "…all of the atmospheric dispersion models compared at the Workshop can be used to assess windborne spread of FMDV and provide scientific advice to those responsible for making control and eradication decisions in the event of an outbreak of FMD."[7]

As HYSPLIT compares very well to the other models it would be fair to assume that HYSPLIT is also very capable at modelling the airborne spread of the FMD virus.

References:

[1] HYSPLIT - Hybrid Single Particle Lagrangian Integrated Trajectory Model http://www.arl.noaa.gov/HYSPLIT_info.php

[2] NOAA - National Oceanic and Atmospheric Administration http://www.noaa.gov/

[3] Australia's Bureau of Meteorology http://www.bom.gov.au/

[4] M.G. Garner, G.D. Hess and X. Yang, An integrated modelling approach to access the risk of wind-borne spread of foot-and-mouth disease virus from infected premises, Environmental Modelling & Assessment (2006) 11: 195-207.

[5] HIRLAM - HIgh Resolution Limited Area Model http://www.hirlam.org/

[6] J.H. Sorensen, C.O. Jensen, T. Mikkelsen, D.K.J. Mackay and A.I. Donaldson, Modelling the Atmospheric Dispersion of Foot and Mouth Virus for Emergency Preparedness, Phys. Chem. Earth (B), Vol. 26, No. 2, pp. 93-97, 2001.

[7] J. Gloster, A. Jones, A. Redington, L. Burgin, J. H. Sørensen, R. Turner, M. Dillon, P. Hullinger, M. Simpson, P. Astrup, G. Garner, P. Stewart, R. D'Amours, R. Sellers, D. Paton, Airborne spread of foot-and-mouth disease – Model intercomparison, The Veterinary Journal 183 (2010) 278–286.