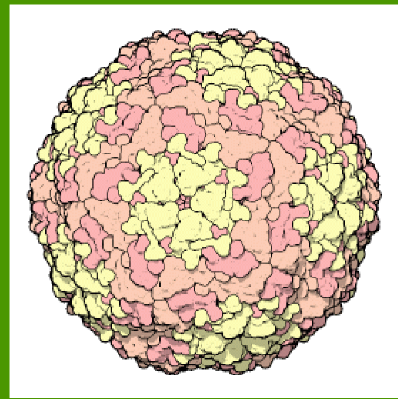
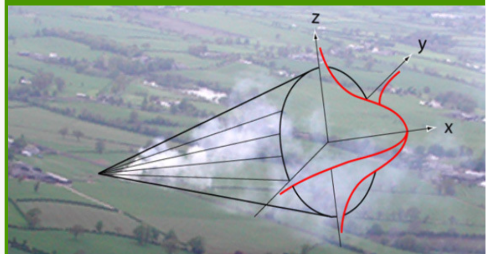
Faculty of Agricultural and Nutritional Science

Christian-Albrechts-University Kiel
Institute of Animal Breeding and Husbandry

Using Fuzzy Logic to model airborne spread of foot and mouth disease

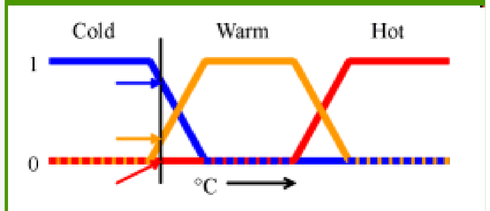




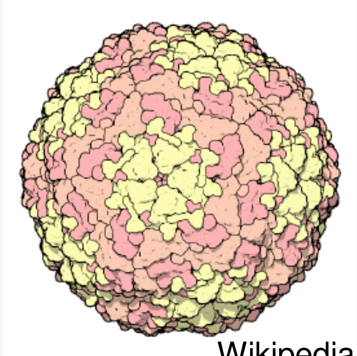
Imke Traulsen and Joachim Krieter

Institute of Animal Breeding and Husbandry
Christian-Albrechts-University, Kiel
itraulsen@tierzucht.uni-kiel.de

Session 54, Abstract 4469



Foot and mouth disease (FMD)



Wikipedia

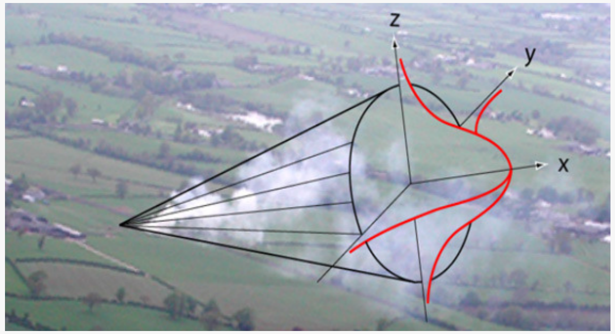
- Highly contagious virus
- Affects all cloven hoofed animals
  - Cattle, pigs, sheep
- Clinical signs
  - Vesicles on tongue, udder, inter-digital space
  - Used to estimate when animal was infected
- Transmission via:
  - Direct animal-to-animal contact
  - Indirect contacts of personnell and vehicles
  - **Airborne spread**

Modeling airborne FMD transmission

- Simulation models for FMD to evaluate control strategies to be prepared if FMD outbreak occurs

  →need to model airborne FMD spread

- Gaussian Dispersion model:
  - Puff of virus particles
  - Relatively easy to calculate
  - Does not account for topography



Schachner, 2005

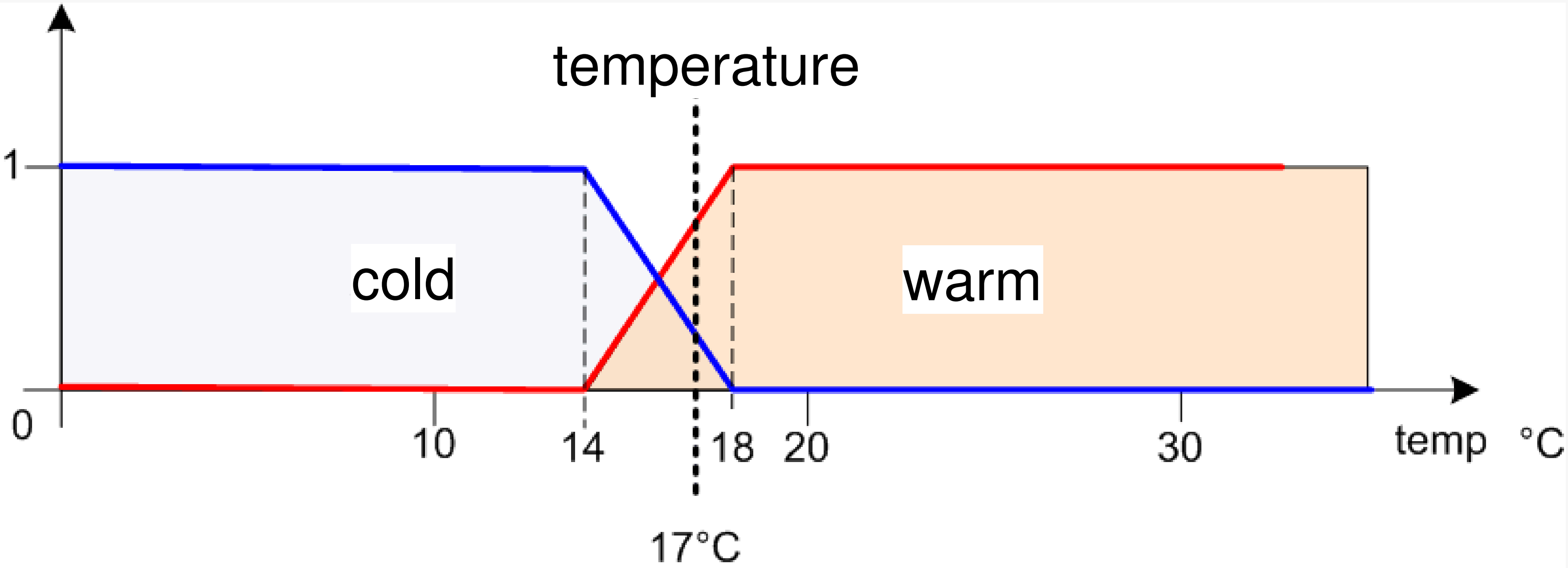
- Lagrangian particle model:
  - Trajectories of the virus particles
  - Complex model
  - Accounts for topography

$$\overline{c}(x,y,z) = \frac{Q}{2\pi\overline{u}\sigma_y\sigma_z}\exp(-\frac{y^2}{2\sigma^2_y})[exp(-\frac{(z-h)^2}{2\sigma^2_z}) + exp(-\frac{(z+h)^2}{2\sigma^2_z})]$$

$$\sigma_y = B(\frac{x}{\overline{u}})^\beta, \sigma_z = A(\frac{x}{\overline{u}})^\alpha$$

Fuzzy Logic

- Linguistic variables
- Membership functions



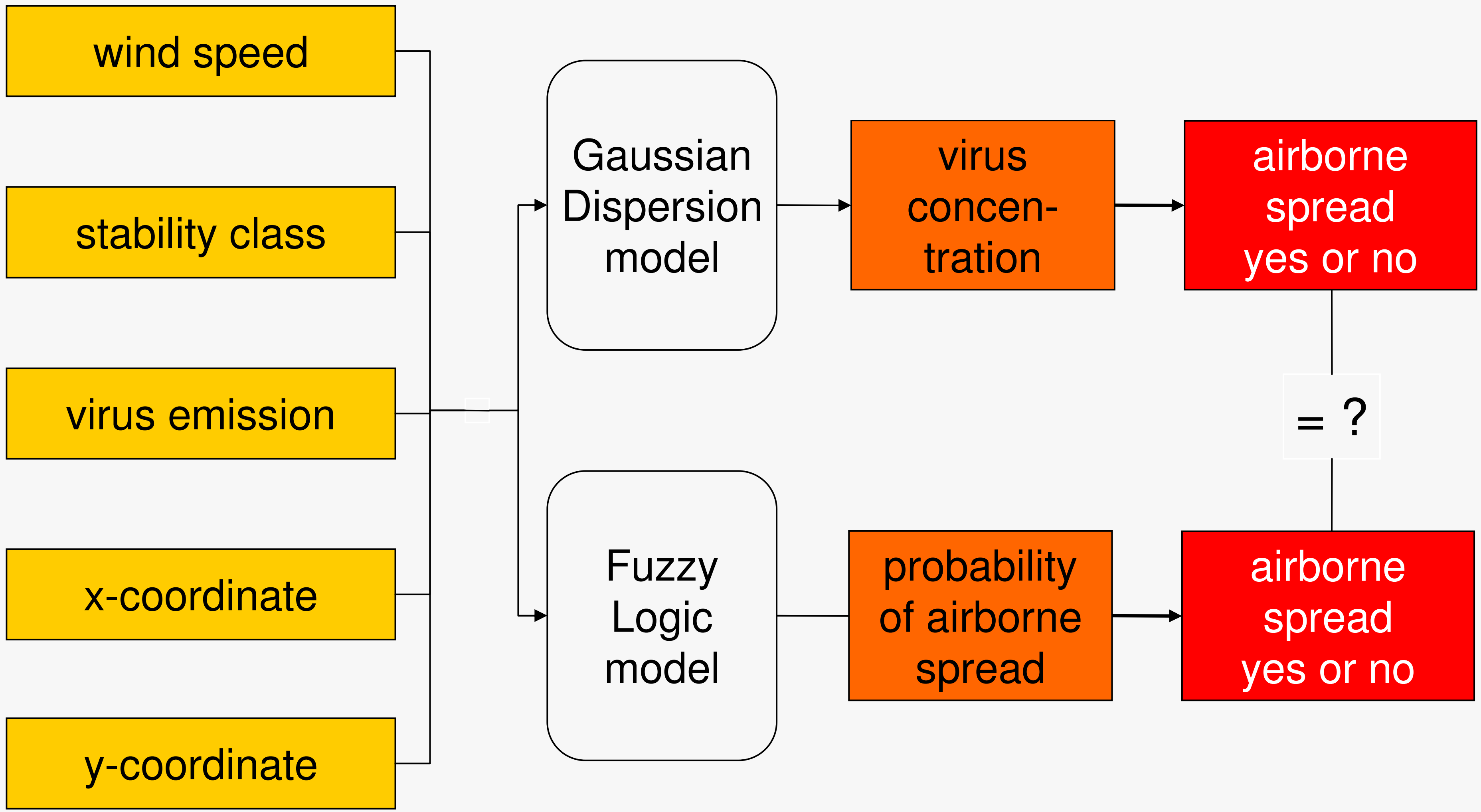
Fuzzy Logic

Assuming

- a minimum of 65-70 % relative humidity,
- medium temperatures,
- a low to medium wind speed,
- a constant wind direction,
- stable atmospheric conditions,
- and a flat topography,

the FMD virus can be spread even over large distances over land and water.

Gaussian und Fuzzy model



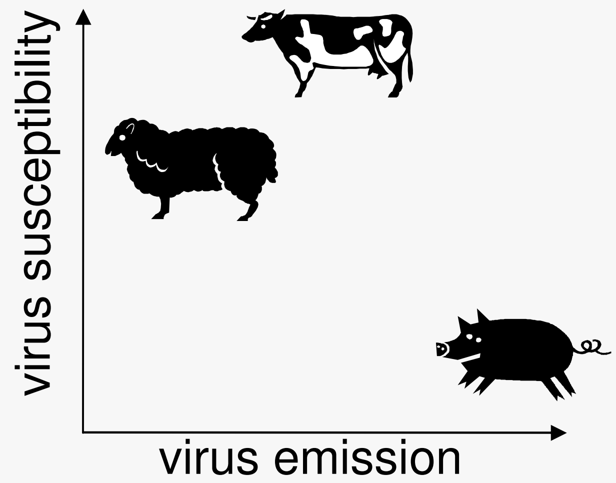
Data

- weather data from Vienna, 2004

relative frequency (%) of wind speed and stability class combinations

		Wind speed (m/s)										
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**
Stability class	**3**		1.1	0.3								
	4	0.8	12.8	18.0	17.2	12.3	13.7	6.3	5.7	3.6	1.1	0.3
	5	1.4	1.9	2.2	0.8	0.3	0.3					

- species-specific virus emission and susceptibility



Study design

Parameters and their ranges for the different models

Input parameter	Gaussian	Fuzzy 1	Fuzzy 2	Fuzzy 3
x (m)	$0< x \leq 10{,}000$	$0< x \leq 10{,}000$	$0< x \leq 10{,}000$	$0< x \leq 10{,}000$
y (m)	$0< y \leq 10{,}000$	$0< y \leq 3{,}000$ [A]	$0< y \leq 3{,}000$ [A]	$0< y \leq 3{,}000$ [A]
Q ($TCID_{50}/m^3$ and day)	$0 \leq Q \leq \infty$	$Q=4 * 10^{10}$ [B]	$Q=4 * 10^{10}$ [B]	$Q=4 * 10^{10}$ [B]
u (m/s)	$1 \leq u \leq 12$	$u=4$	$1 \leq u \leq 12$	$1 \leq u \leq 12$ [C]
Stability class	$2 \leq s \leq 7$	$s=4$	$s=4$	$s=\{3, 4, 5\}$ [C]

[A]: larger y values always result in no airborne transmission

[B]: refers to 100 pigs with max. virus emission

[C]: all combinations of u and s from Vienna data set

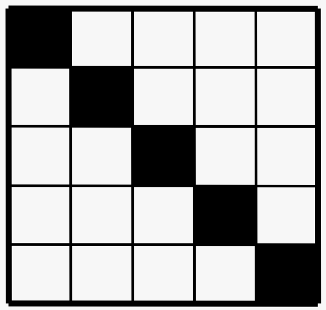
Validation

- Sensitivity = TP/(TP+FN)
- Specificity = TN/(TN+FP)
- Error rate = FP/(FP+TP)

		Gaussian model	
		yes	no
Fuzzy model	yes	TP	FP
	no	FN	TN

k = 5 subsets

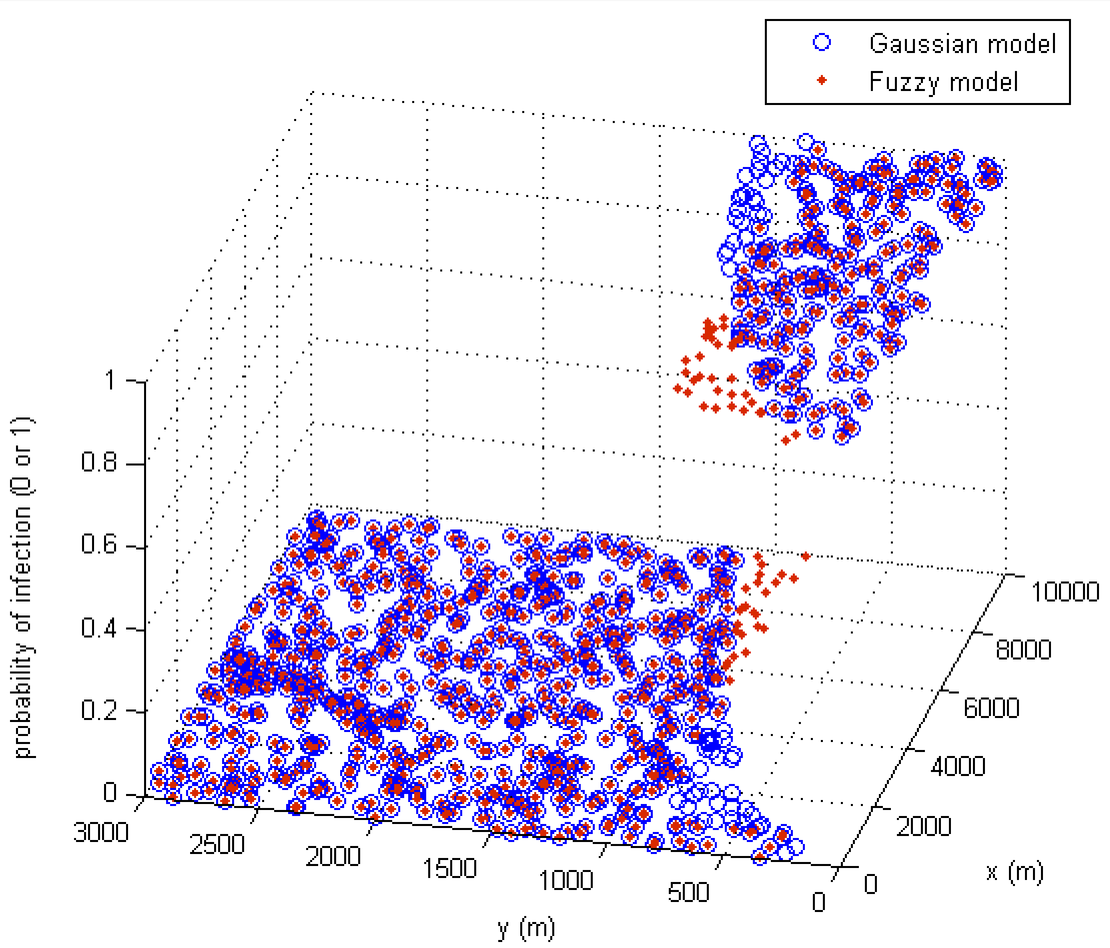
n_{tot} = 10,000



10-fold cross validation

- training data: all white sets per row
- testing data: all black sets per row

Results – cattle fuzzy 1

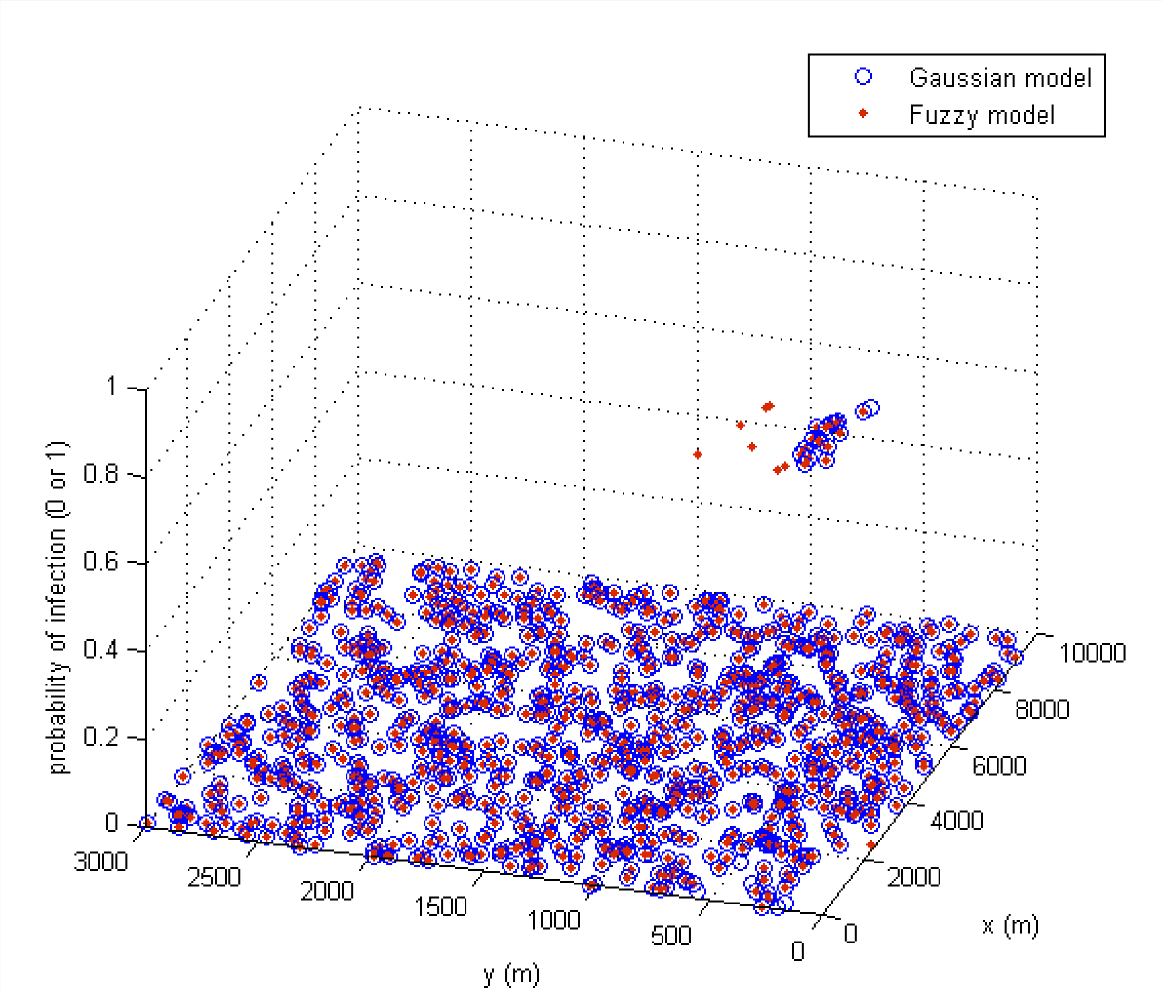


sensitivity = 90.3 %

specificity = 95.5 %

error rate = 12.2 %

Results – sheep fuzzy 1

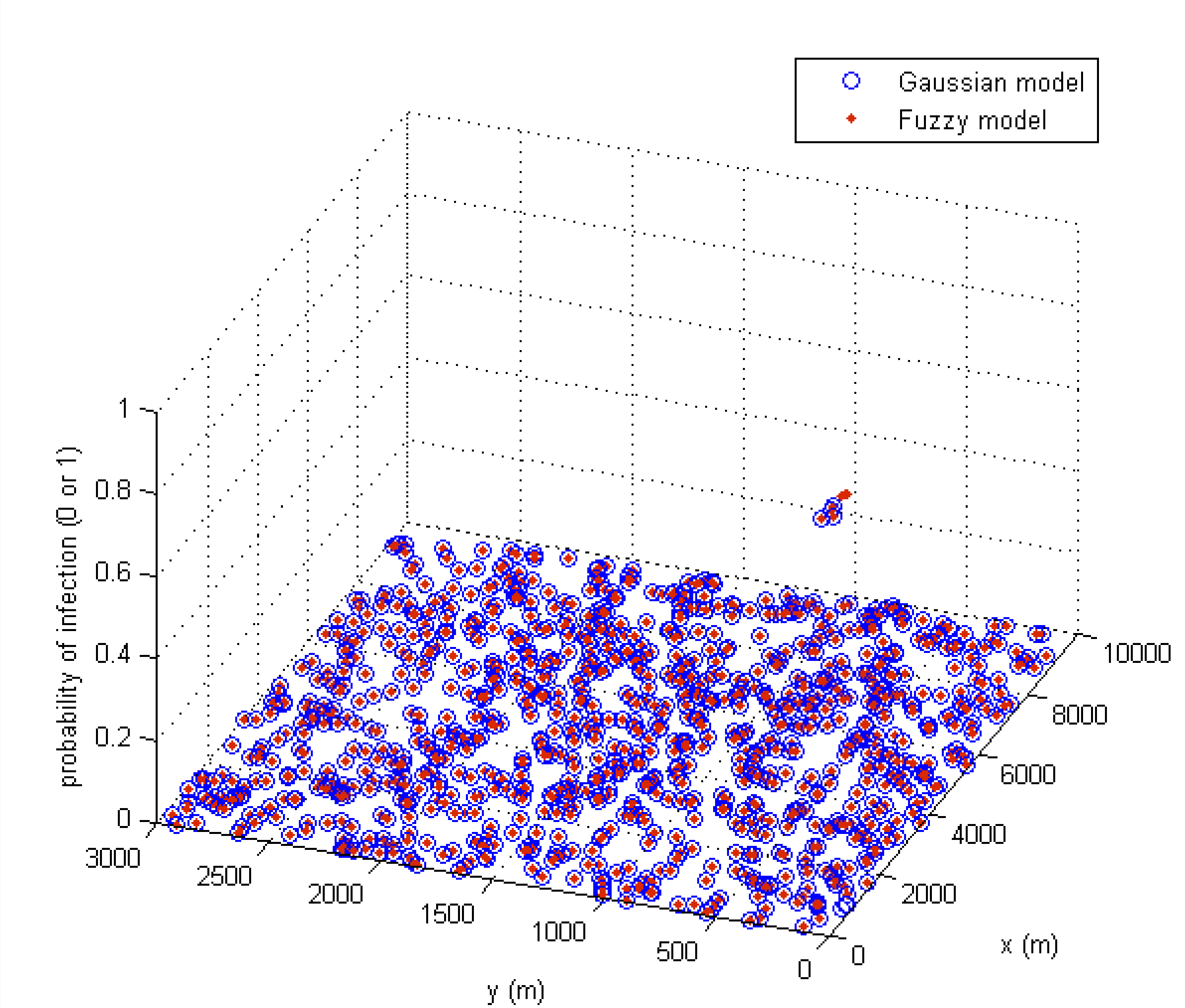


sensitivity = 92.3 %

specificity = 98.6 %

error rate = 52.2 %

Results – pigs fuzzy 1



sensitivity = 96.9 %

specificity = 99.9 %

error rate = 38.9 %

Results – cattle and pigs

	Model	Sensitivity	Specificity	Error rate	TP	FP	FN
cattle	Fuzzy 1	90.3 %	95.5 %	12.2 %	24.0 %	3.3 %	2.6 %
	Fuzzy 2	75.5 %	91.1 %	29.4 %	16.6 %	6.9 %	5.4 %
	Fuzzy 3	75.9 %	90.8 %	26.1 %	19.5 %	6.9 %	6.2 %
pigs	Fuzzy 1	96.9 %	99.9 %	38.9 %	0.20 %	0.12 %	0.01 %
	Fuzzy 2	74.6 %	99.8 %	61.7 %	0.14 %	0.16 %	0.04 %
	Fuzzy 3	78.7 %	99.9 %	51.1 %	0.18 %	0.14 %	0.04 %

Conclusion

- Graphics show a close relationship between the Gaussian and the Fuzzy model
- Risk of infections for cattle is easiest to estimate
- Sensitivity, specificity and error rate show good results for cattle and moderate results for sheep and pigs
- Results suggest that the fuzzy logic approach can be used to model airborne spread
- More detailed calibration of the model could improve the peformance of the model

Thank you for your attention!