Modelling spatio-temporal patterns of disease

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CHICAS combining health information, computation and statistics

References

AEGISS

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Foot-and-mouth

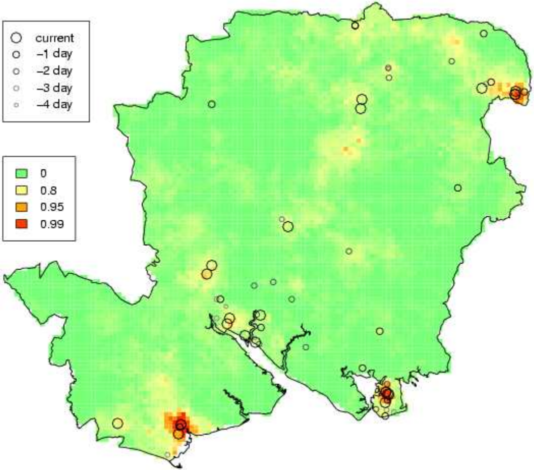
Keeling, M.J. et al (2001). Dynamics of the 2001 UK foot and mouth epidemic: stochastic dispersal in a heterogeneous landscape. *Science*, **294**, 813-817.

Diggle, P.J. (2006). Spatio-temporal point processes, partial likelihood, foot-and-mouth. *Statistical Methods in Medical Research*, **15**, 325–336.

Teaching statistical thinking

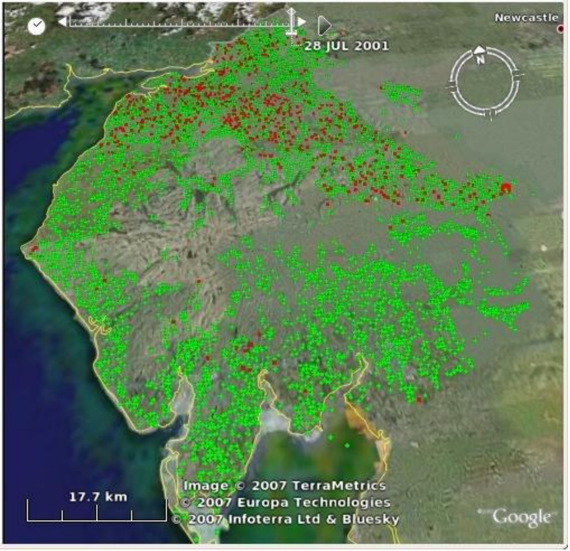
Diggle, P.J. and Chetwynd, A.G. (2011). *Statistics and Scientific Method: an Introduction for Students and Researchers*. Oxford: Oxford University Press.

Motivation: real-time syndromic surveillance (AEGISS)



http://www.lancs.ac.uk/staff/diggle/aegiss/

Motivation: the 2001 FMD epidemic in Cumbria



http://www.maths.lancs.ac.uk/ rowlings/Chicas/FMD/slider2.html

Statistical modelling: buying information with assumptions

- models are devices to answer questions
- likelihood-based inference (Bayesian or non-Bayesian)
- models should:
  1. be not demonstrably inconsistent with the data;
  2. incorporate the underlying science, where this is well understood
  3. be as simple as possible, within the above constraints

"Too many notes, Mozart"

Emperor Joseph II

"Only as many as there needed to be"

Mozart (apochryphal?)

Questions

Real-time syndromic surveillance (AEGISS)

- what is the normal pattern of variation?
- can we identify unusual patterns where and when they occur?

Aim: provide an early warning system which **may** trigger public health intervention

The 2001 FMD epidemic in Cumbria

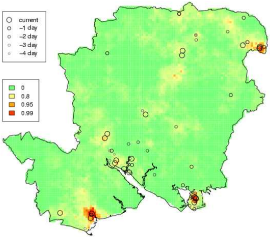
- what factors affect a farm's infectivity and/or susceptibility?
- on what spatial scale does the disease spread?

Aim: inform control strategies to be used in future epidemics

Empirical or mechanistic modelling

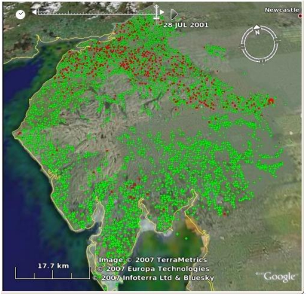
AEGISS

- early detection of anomalies in local incidence
- data on 3374 consecutive reports of non-specific gastro-intestinal illness
- log-Gaussian Cox process, space-time correlation $\rho(u, v)$



FMD

- Predominantly a classic epidemic pattern of spread from an initial source
- Occasional apparently spontaneous outbreaks remote from prevalent cases
- $\lambda(x, t|\mathcal{H}_t)$ =conditional intensity, given history $\mathcal{H}_t$



AEGISS results

Model

$$\begin{aligned} \text{actual} &= \text{expected} \times \text{unexpected} \\ \lambda(x,t) &= \lambda_0(x,t) \times R(x,t) \end{aligned}$$

Spatial prediction

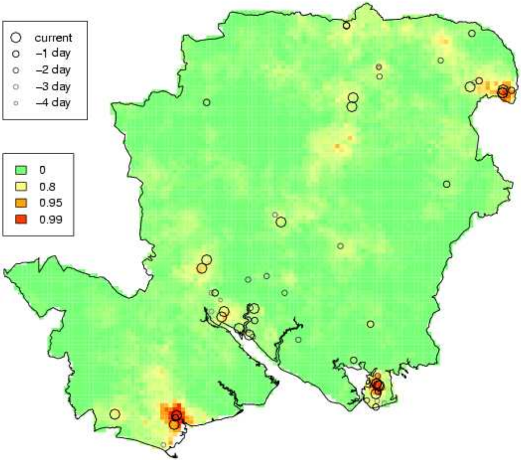
- choose critical threshold value $c > 1$
- map empirical exceedance probabilities,

$$p_t(x) = \mathrm{P}\left(\exp\{S(x,t)\} > c|\text{data}\right)$$

Web-reporting with daily updates

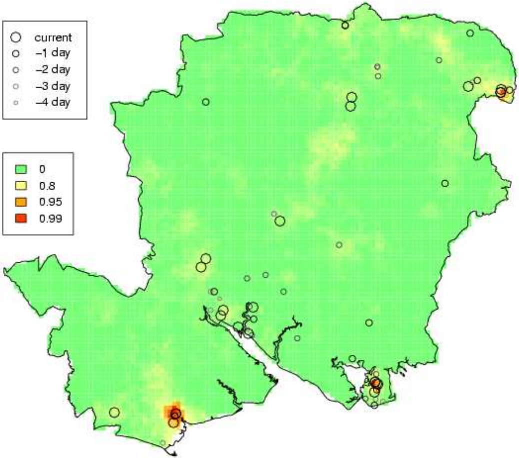
http://www.maths.lancs.ac.uk/~diggle/Aegiss/day.html%3fyear=2002

Spatial prediction : results for 6 March 2003



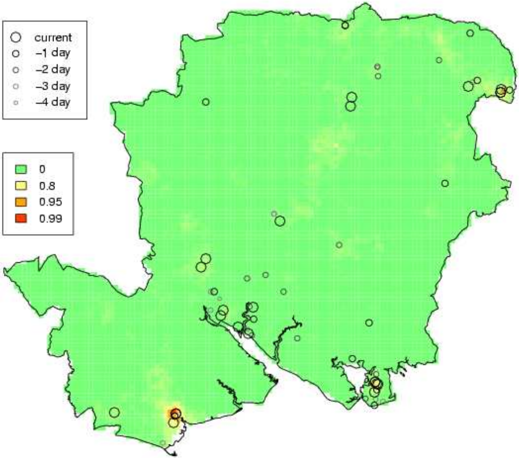
c = 2

Spatial prediction : results for 6 March 2003



$c = 4$

Spatial prediction : results for 6 March 2003



c = 8

FMD: mechanistic statistical model

$$\lambda_{jk}(t) = \lambda_0(t) A_j B_k f(||x_j - x_k||) I_{jk}(t)$$

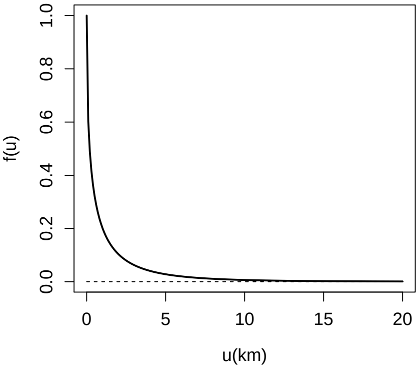
- **baseline hazard:** $\lambda_0(t)$ (arbitrary)
- **infectivity and susceptibility:**

$$\begin{aligned} A_j &= \alpha n_{1j} + n_{2j} \quad \text{(cows and sheep)} \\ B_k &= \beta n_{1k} + n_{2k} \end{aligned}$$

- **transmission kernel:** $f(u) = \exp\{-(u/\phi)^{0.5}\} + \rho$
- **at-risk indicator for transmission:** $I_{jk}(t)$

FMD results

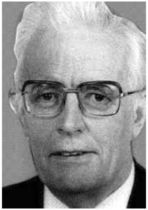
- **Common parameter values fit data from Cumbria and Devon**
- **Cows both more infectious and more susceptible than sheep**
- **Force of infection, $\lambda_0(t)$, stronger in Cumbria than in Devon**
- **Estimated transmission kernel:**



Statistics and scientific method

"Far better an approximate answer to the right question, which is often vague, than an exact answer to the wrong question, which can always be made precise."

John Tukey (1915–2000)



"...the importance of making contact with the best research workers in other subjects and aiming over a period to establish genuine involvement and collaboration in their activities."

Sir David Cox, FRS (b 1924)

Implications for training scientists:

- teach statistical thinking, not statistical techniques
- how to recognise when standard methods are inadequate
- the statistician as an integral (and committed!) part of the research team