Modelling world-wide disease spread: a case for using differing spatial scales

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Overview

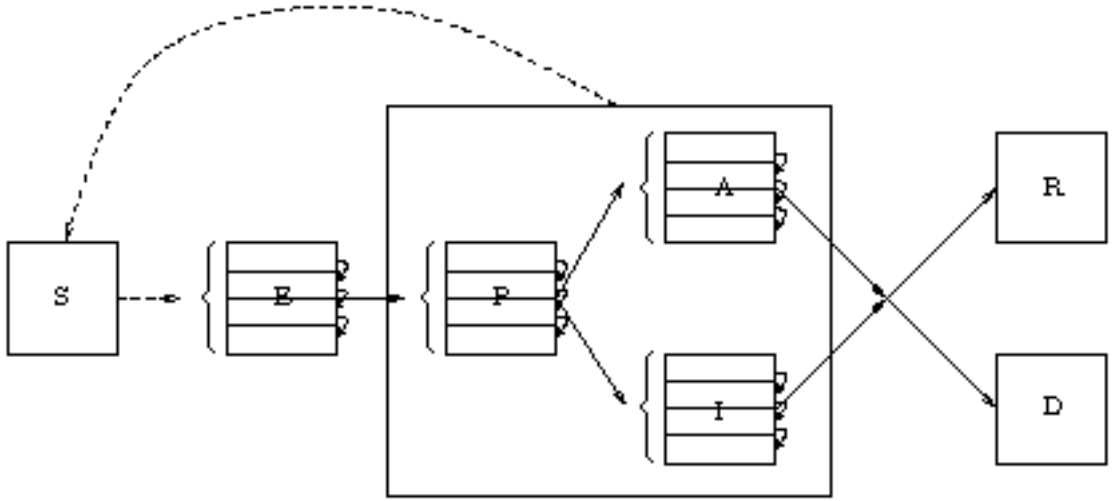
- **Compartmental meta-population disease model**
- **Considerations of spatial scales**
- **Scales in the United Kingdom**
- **Global disease models appropriate for UK questions**
- **Conclusions, discussion**

Compartmental Model

SIR-type model including additional disease states

- Latent/exposed
- Prodromal
- Asymptomatic infectious
- Dead

Consider *stage age*



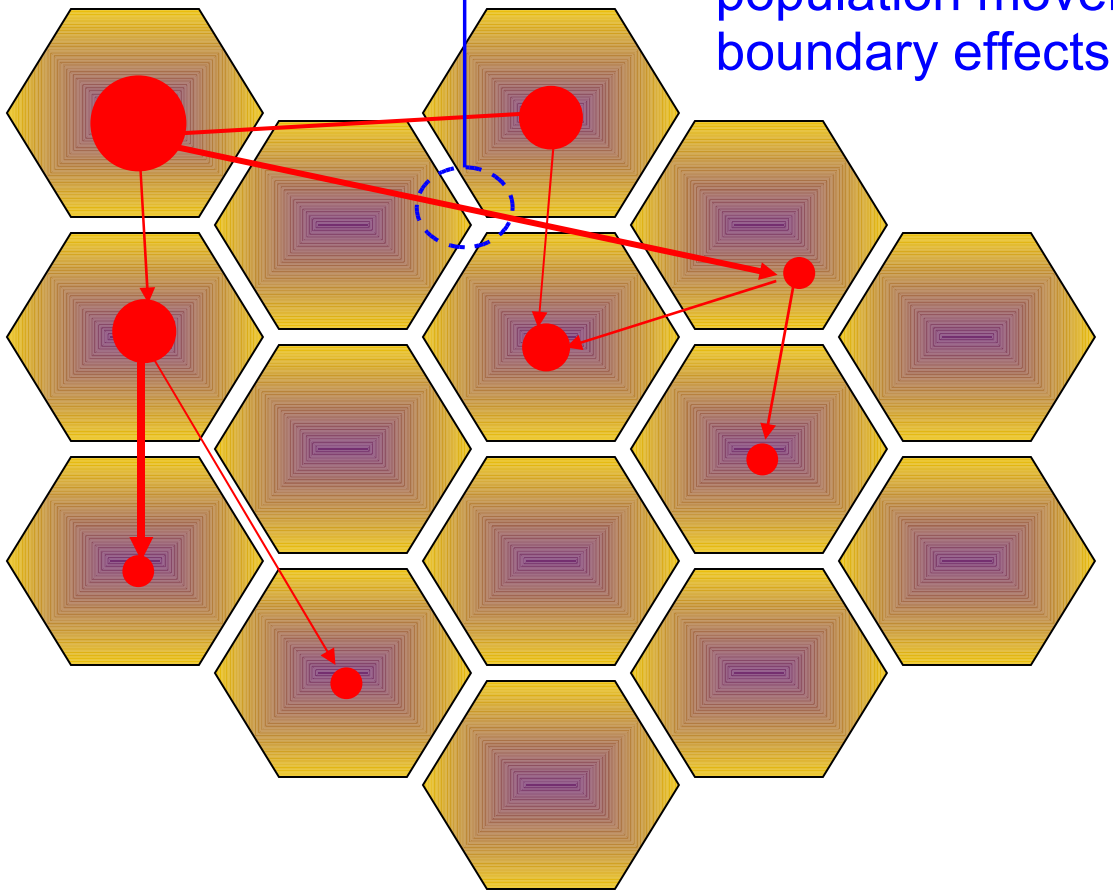
Use stochastic transitions

Meta-population Model

SEIR-type model within patches

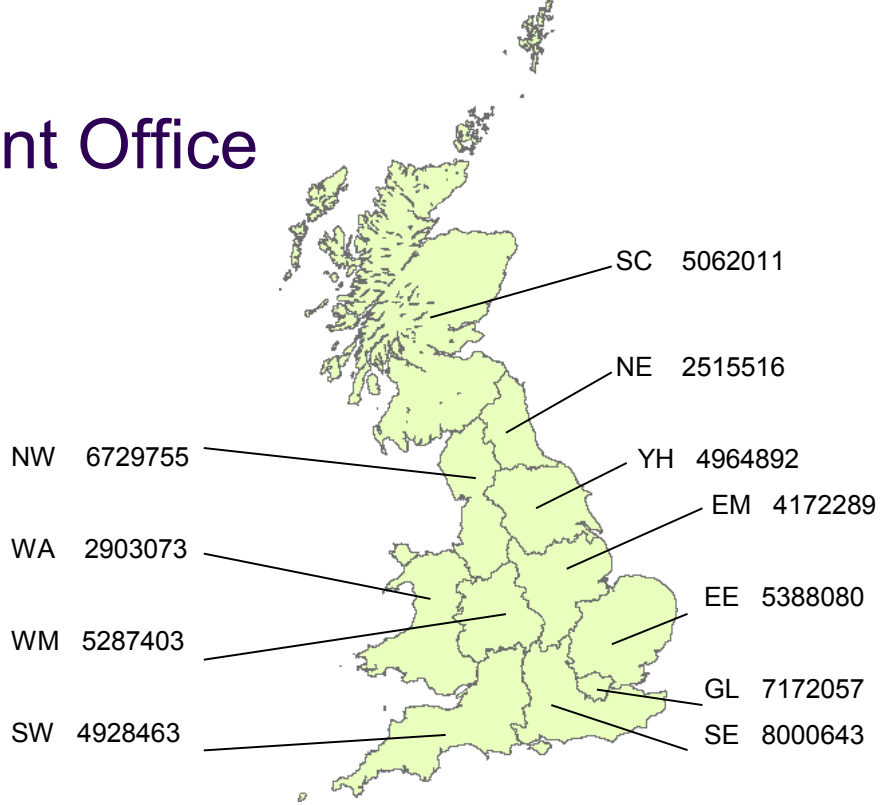
Infection is introduced into one patch

This may infect other patches



Connection given by population movements or boundary effects

2001 Government Office Regions



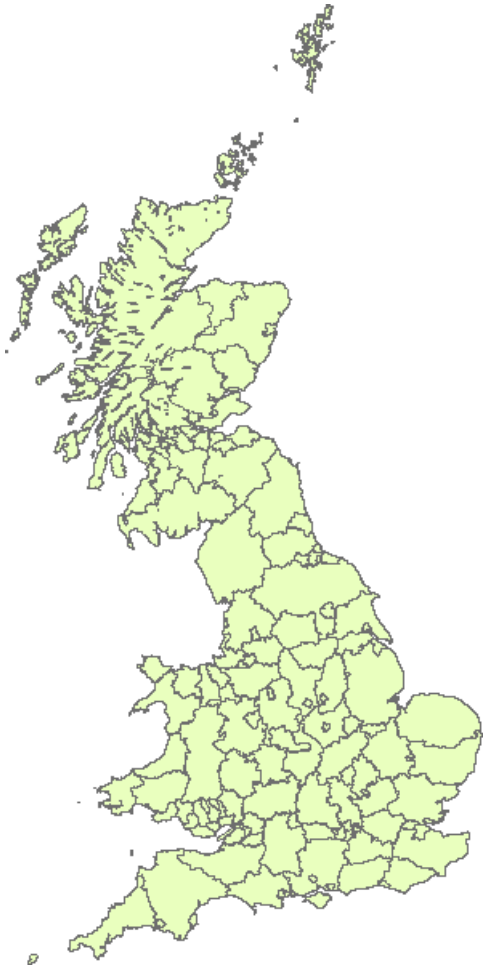
	NE	NW	YH	EM	WM	EE	GL	SE	SW	SC	WA
NE	2479424	4260	12833	1885	1651	1961	3119	3676	1487	4841	379
NW	2335	6636816	17830	8340	18546	4627	8762	8103	3570	3945	16881
YH	13602	21988	4873513	27699	4801	4643	6548	6102	2668	2648	680
EM	1220	19082	43215	3980405	46544	34027	13707	29328	2878	1068	815
WM	741	21393	3200	35315	5151971	5107	10440	13666	17064	1172	7334
EE	557	2929	2525	14076	4078	5030269	283605	44804	3052	1558	627
GL	716	2909	1808	3248	3544	73211	6948528	132089	3948	1198	858
SE	680	3356	2255	10365	8247	39962	374861	7528330	29635	1723	1229
SW	366	2279	1440	1853	11652	4087	16120	51208	4831889	1271	6298
SC	1910	4336	974	461	610	865	3006	1948	993	5046686	222
WA	408	26613	1371	1261	10586	2054	3753	5232	12486	921	2838388

Choice of Spatial Scale

Many factors influence choice of spatial scale

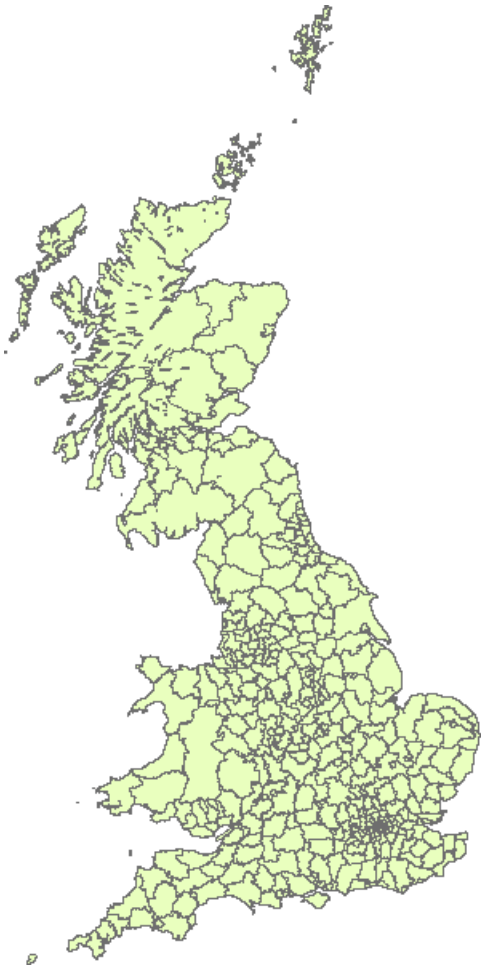
- Epidemiology
  - Population mixing (homogeneous or otherwise)
  - Disease parameters
  - Area for intervention policies
- Patch connectivity
  - Spatial scale of data
  - Non-parametrised movement
- Computational cost

Smaller UK Administrative Regions



Counties (NUTS 3)

141 (128)



Districts (LAU 1)

408 (417)

Wards (LAU 2)

10026 (10072)

Population and Commuting

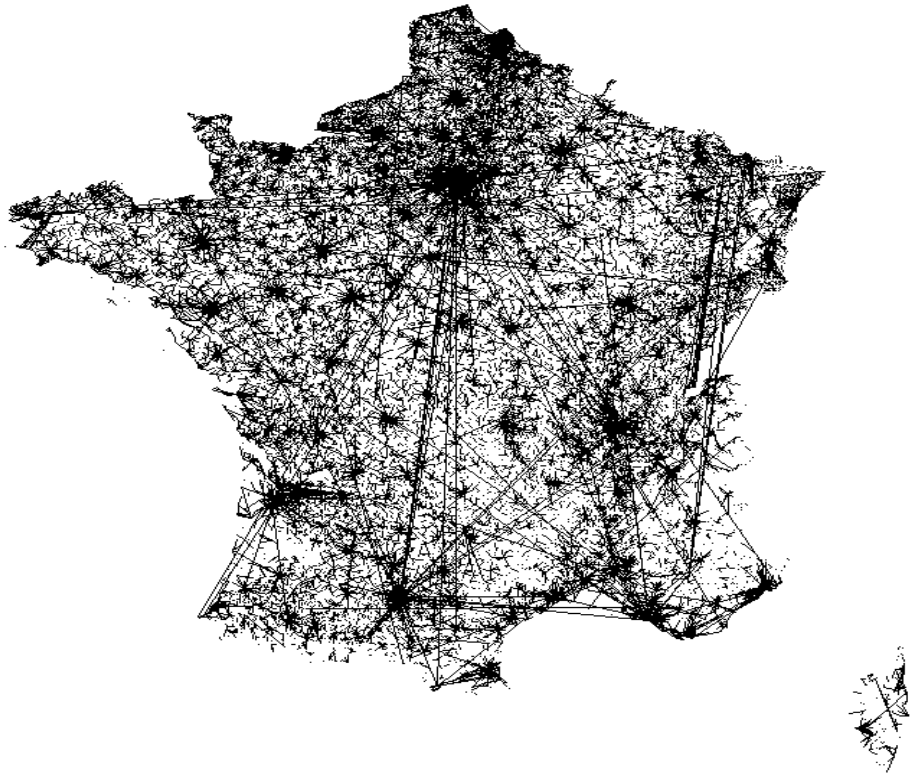
		GOR	County	District	Ward	Output Area
Population	Range	2515516—8000643	19245—7172057	7181—330584	104—35102	26—4145
	Mean	5191289	404994	234591	5696	262
	s.d.	1667285	713775	92085	3898	98
Inbound	Range	11	21—141	16—406	2—4478	1—20570
	s.d.	0	31	90	188	139
Outbound	Range	11	30—138	11—363	3—444	1—166
	s.d.	0	20	48	75	12
Connections	Mean	11	97	199	150	31
	Density	100.00%	68.94%	48.86%	1.50%	0.01%

Population Movements Within European Countries

Origin–Destination data linking homes and workplaces have been identified for:

- Denmark
- France
- United Kingdom

Other data sets may exist for other countries.



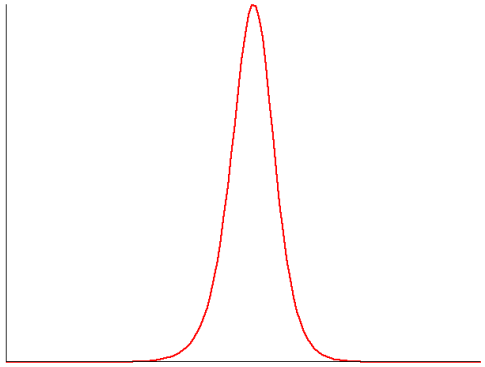
World-wide Disease Spread: UK Issues

To consider the first imported cases to the UK we may want to know:

- **The location of cases in the rest of the world**
- **Travel by infected individuals between countries**
- **Travel by infected visitors to regions of the UK**
- **Travel by UK residents to an infected area and back**

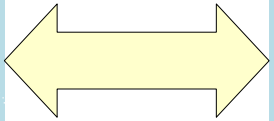
UK and the World

Treat the world as
a single patch

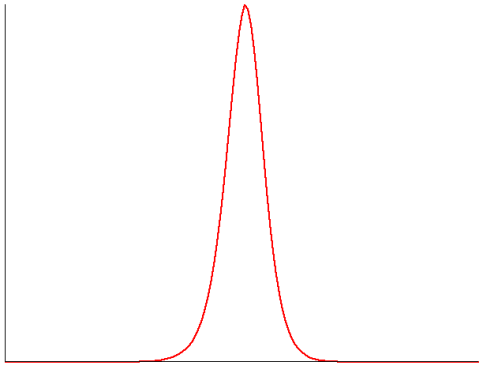


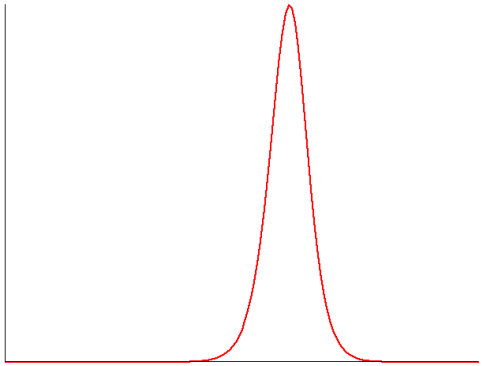
UK cases will be some
proportion of these

UK and the World

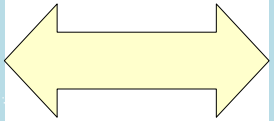


Treat the UK and the rest of the world as patches

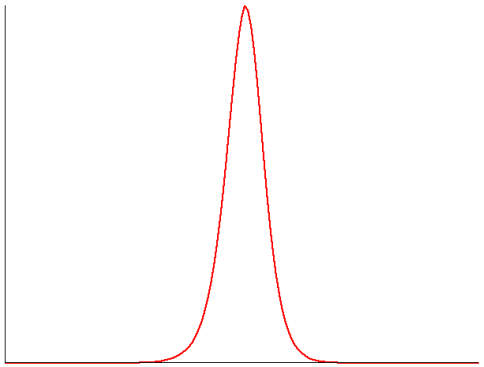


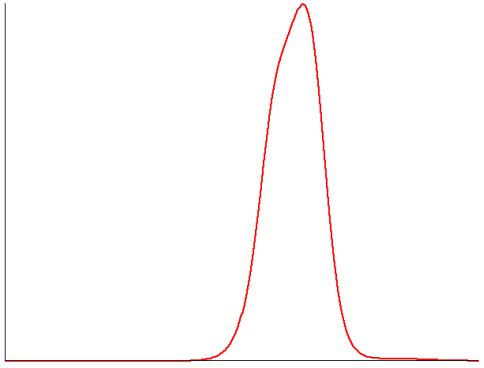


UK and the World

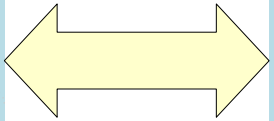


Use UK regions, treating the rest of the world as a single patch

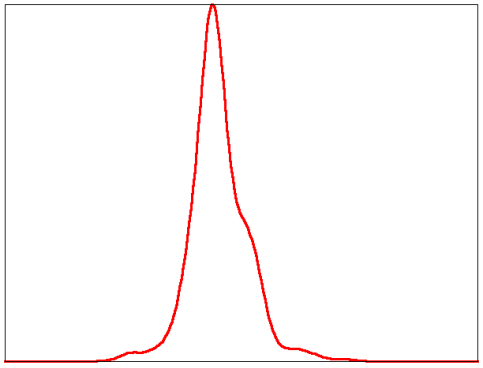


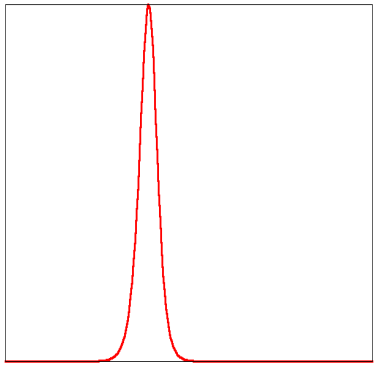


UK and the World

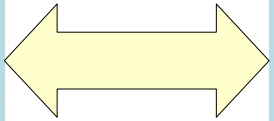


Considering all countries as single patches

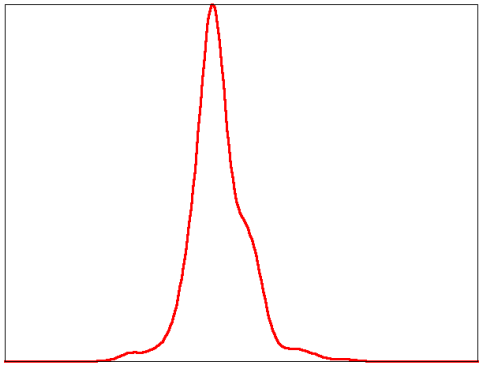


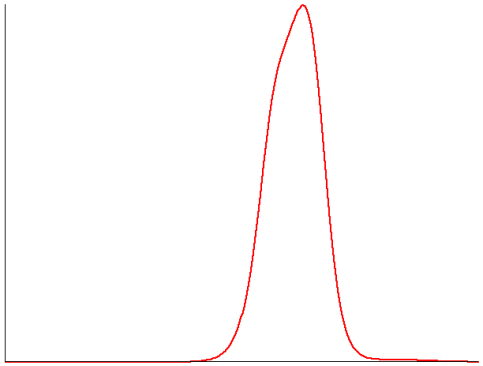


UK and the World



Considering UK regions and other countries as single patches





Competing Spatial Scales

UK inbound (overseas visitors)

IATA/WTO data at country scale

Distribution to finer scale by IPS

Competing Spatial Scales

UK residents outbound

Unclear about travel by place of residence

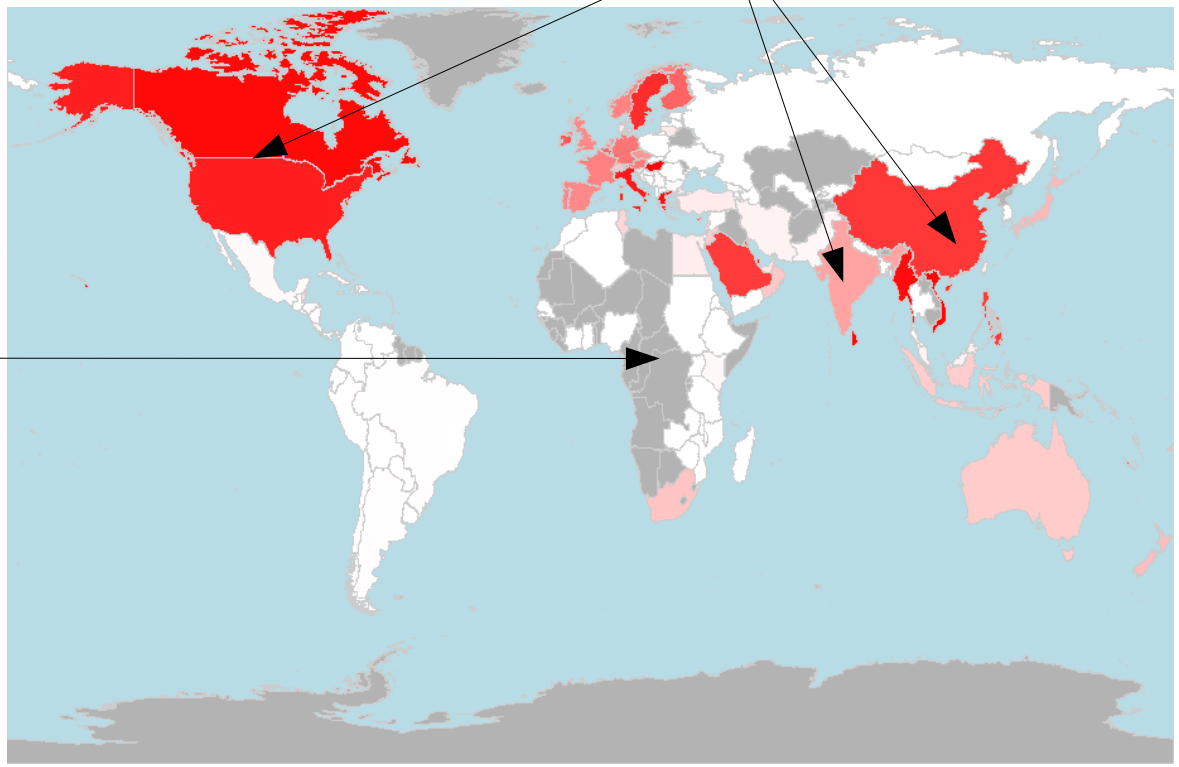
Overseas travel information at country level

Troublesome Spatial Scales

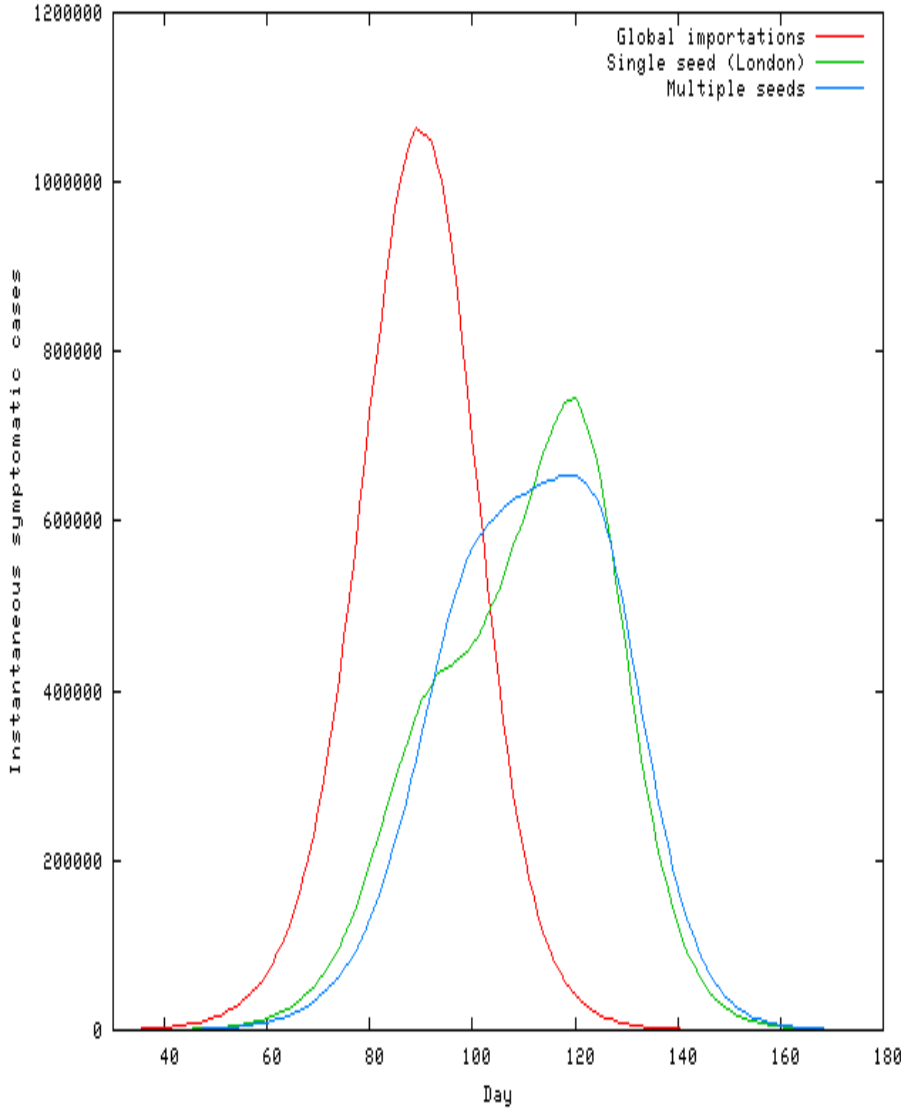
Using IATA country-country pairs as an example

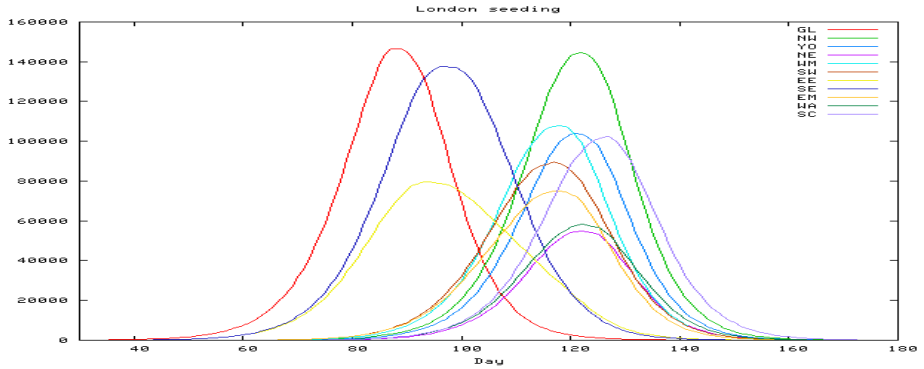
"Large" populations, little realism

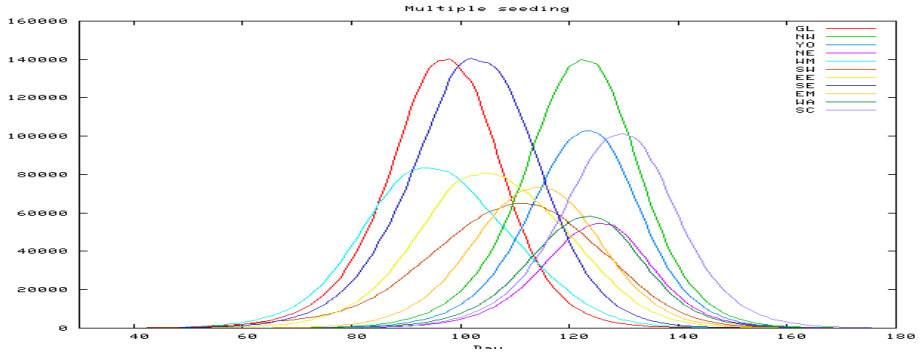
Regions of "missing" data

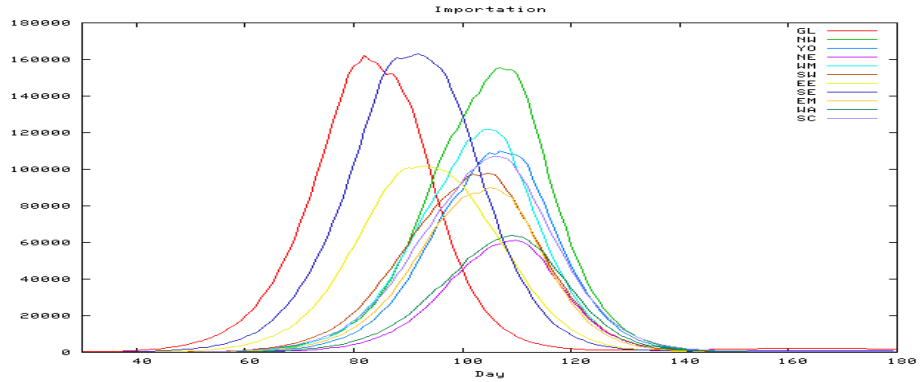


Importation and UK profile









Conclusions

- **There are sufficient data available to have a meaningful global meta-population model**
- **We need to consider the world as more than a single patch to capture reasonable disease importation scenarios**
- **There still remains a lot of uncertainty around global disease spread and importation**

Discussion

- **How well suited are these models to answering questions such as the location of importations to a country?**
- **Can we improve the data coverage?**
- **How do we handle the different spatial scales that arise from this modelling approach?**
- **Can we formalise how well these models address the questions?**
- **Are the models so coarse that the data gaps are not too troublesome?**

Acknowledgements

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Of course, the views expressed here are not necessarily those of HPA, DH