Micro-simulation of disease spread

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"Micro-simulation of a smallpox outbreak using official register data"

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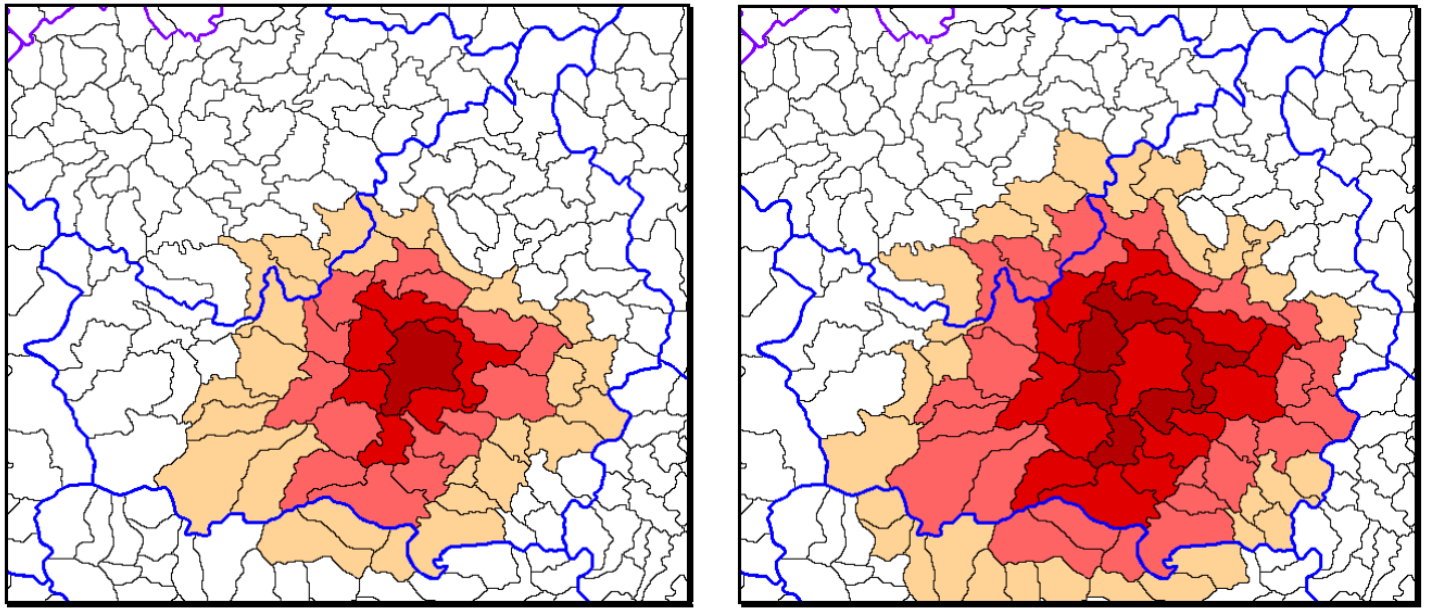

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Classical disease spread dynamics

- Important results achieved with simple models
  - Spatial homogeneity
  - Identical agents or continuous population
- This prevents certain analysis
  - Targeted measures against groups
  - Targeted measures against regions

MicroSim

- Micro-scale simulation tool
- Developed in collaboration between

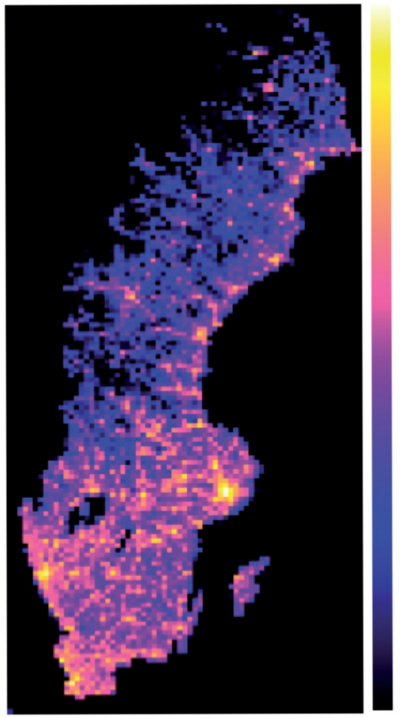
  Swedish Institute for Infectious Disease Control, Department of Epidemiology, Solna, Sweden
  Royal Institute of Technology, KTH/ICT/SCS, Kista, Sweden
  Swedish Institute of Computer Science (SICS), Kista, Sweden
  Department for Biostatistics and Epidemiology, Karolinska Institute, Solna, Sweden
  Department of Sociology, Stockholm University, Sweden
  National Board of Health and Welfare, Stockholm, Sweden
- Spatially explicit agent based simulations
- Complete Swedish population data
- Uses known connections with stochastic events
- Used to determine effectiveness of vaccination policies in case of a smallpox outbreak

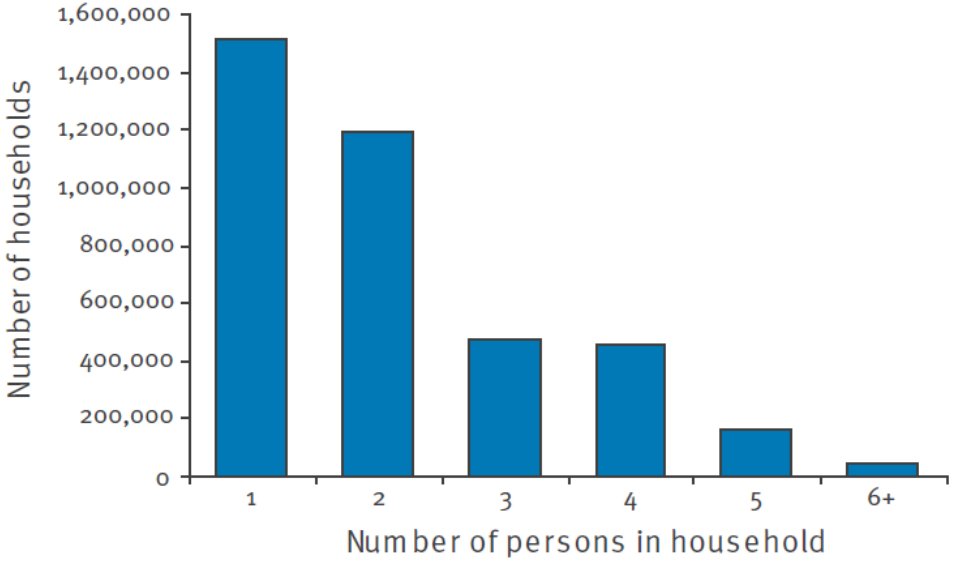
Presentation outline

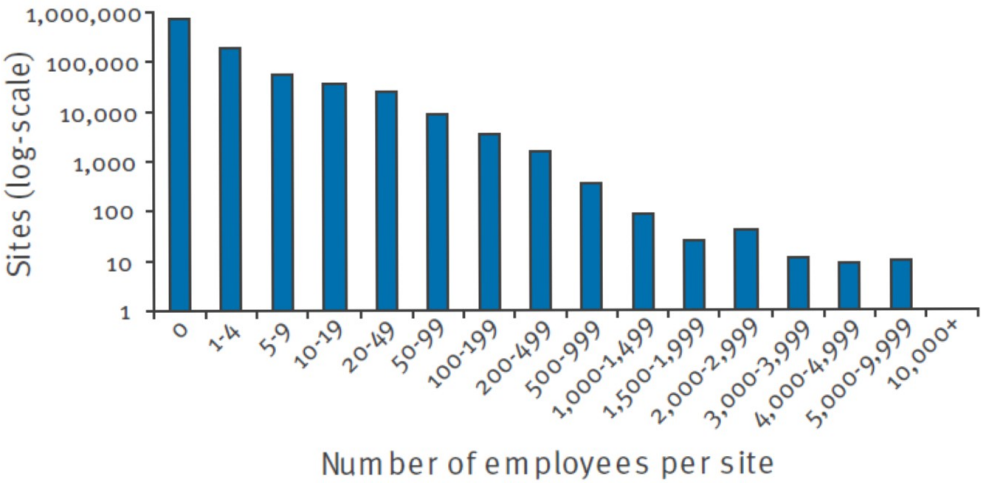
- General program functionality
- Case application
- Limitations
- Simulation results

Modelling the population

- Spatially explicit – uses register data
- Individuals assigned to dwellings, schools, workplaces etc
- 81 “Regions” with shared commutes
- Resolutions: 100m, 1 hour







Modelling the individuals

- Individuals decide their actions each morning
- 3% Chance to travel outside home region
- Chance to work depends on health
  - Upon symptoms, only 25% seek medical care
- After 3 confirmed cases, behaviours change

Modelling smallpox

Phase	Duration	Infectousness	Notes
Incubation	7-19 days	None	Vaccination effective first 3 days
Prodromal	3-5 days	25% during last two days	Influenza-like symptopms
Symptomatic 1	4 days	Full	Pox erupt, admittance to DID
Symptomatic 2	16 days	50%	
Immune	-	None	30% death rate

Contact location	Risk factor
Home	0.25
Day care (within group)	0.1
School (within class)	0.05
Work place (department)	0.05
Between groups	0.001
ER	0.2
DID	0.01
Neighbourhood	0.02
Travel	0.2

Transmission risk is calculated as

$$1 - IR_j, \text{ where } IR_j = \prod_{n=1}^{i} 1 - p_i d_{ij} pr_i, \text{ for } 1,\ldots, \text{i, j}$$

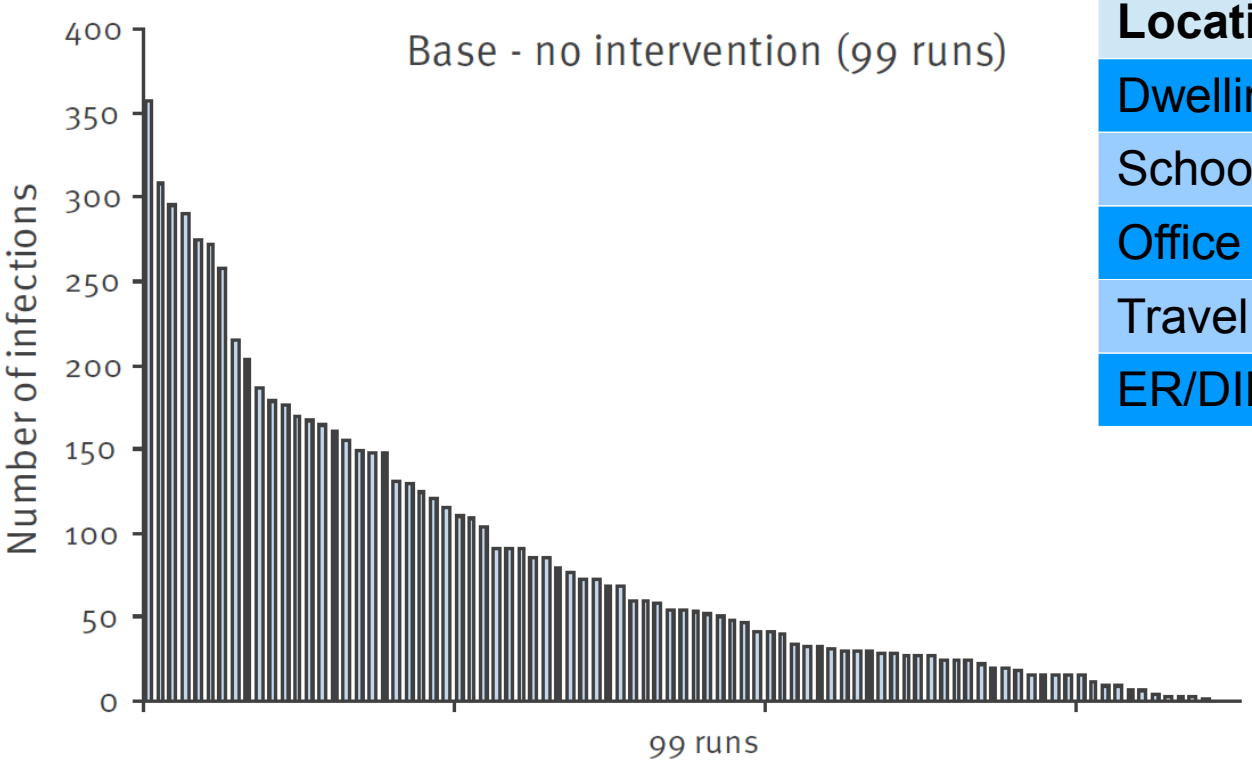
Here, i denotes infectious, individuals, j susceptible.
p = disease phase
d = department risk factor
pr = contact risk factor

Concessions

- Assumes system isolated
- No organised trips between regions
- No diffusion around region borders
- Transmission rate uncertain
- Low computational intensity a priority
- To reduce run time, homes are deactivated after many days of zero exposure.
  - A deactivated home doesn't simulate travel etc

Parameter calibration

- 99 realisations without interventions
- Most infections in home/ER/DID units
- R_0 of 2.25 historically low



Location	Cases (%)
Dwelling	28.98
School/day care	0.53
Office	0.65
Travel	0.06
ER/DID	69.76

Preventive measures evaluated

- Preventive measures after 1 confirmed case
- Mass vaccination
  - Theoretical maximum of 720 000 patients/day
- Ring vaccination
  - Immediately vaccinate anyone in patients vicinity
- Care vaccination
  - Only vaccinate medical personnel
- Combo program
  - Ring and Care vaccination

Results

Policy	Base	Ring	Care	Mass	Combo
Average	176	30	30	14	6
Minimum	49	1	1	1	0
Maximum	834	82	171	49	27
Std dev	163.3	25.2	32.7	13.9	6.4
Reduction (%)	0	83	83	92	97

- Preventions per dose:
  - Ring > Combo,Care > Mass

Result & discussions

- Mass vaccination not optimal
- Ring vaccination prevents most cases per dose
- Assuming cost of vaccination small compared to that of infection, combo policy superior
- Since ring vaccination numbers not available, I can't compare results to simple SIR

Thank you for your attention