The Potential for International Dissemination of Emerging Viral Pathogens

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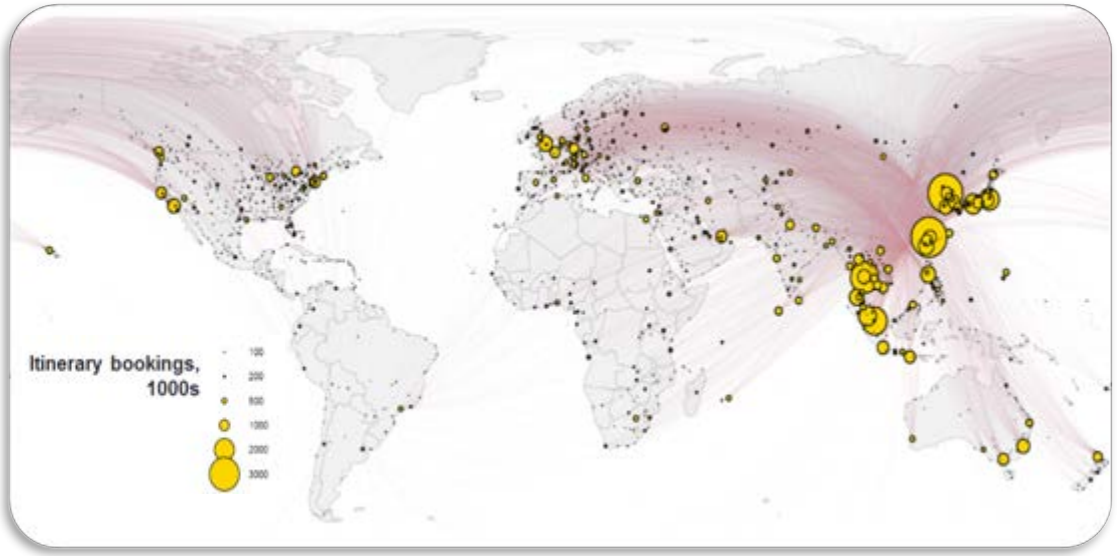
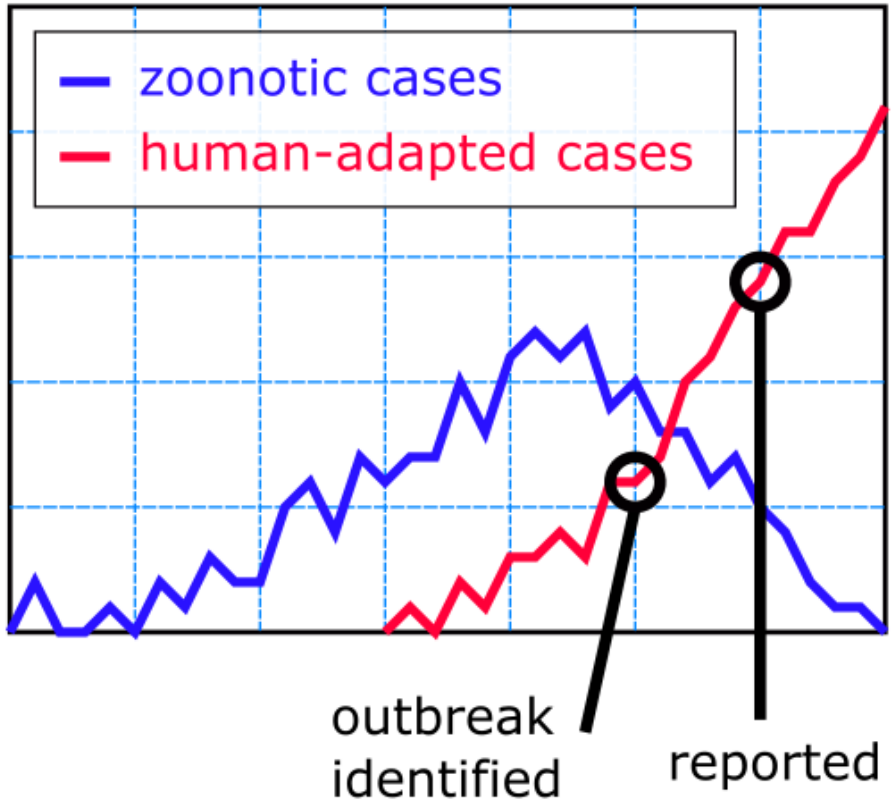


Data source: OAG traffic analyser, Jan 2017

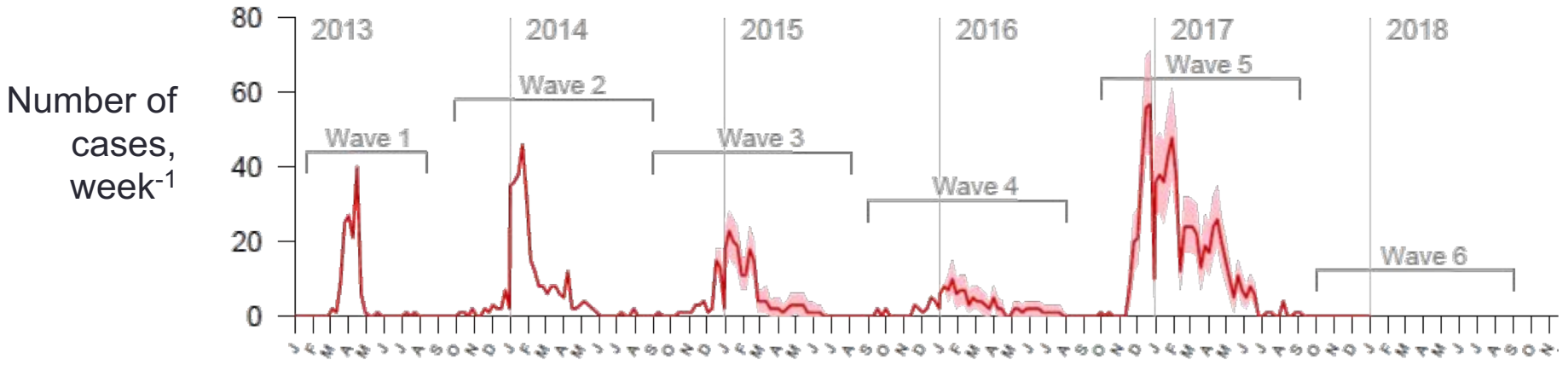
5.2m outbound
201 countries



Aims

- Quantify delays
- Model implications for epidemic and international spread
- Apply to emergence of human-adapted avian influenza A(H7N9)

A(H7N9) human cases, China 2013-2018

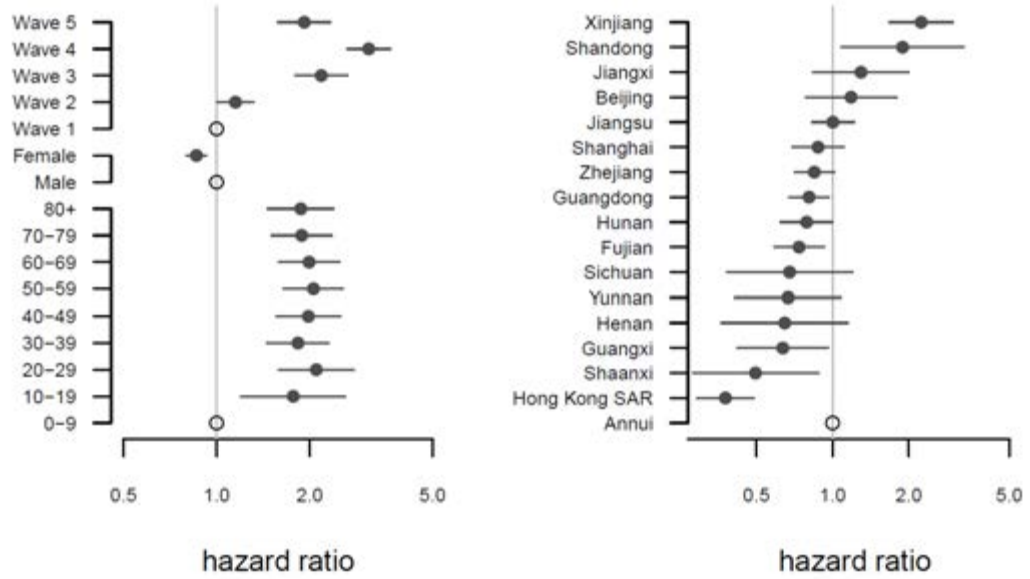


Data source: WHO DON; HKCPH reports

Reporting delay: Onset → Reporting to WHO

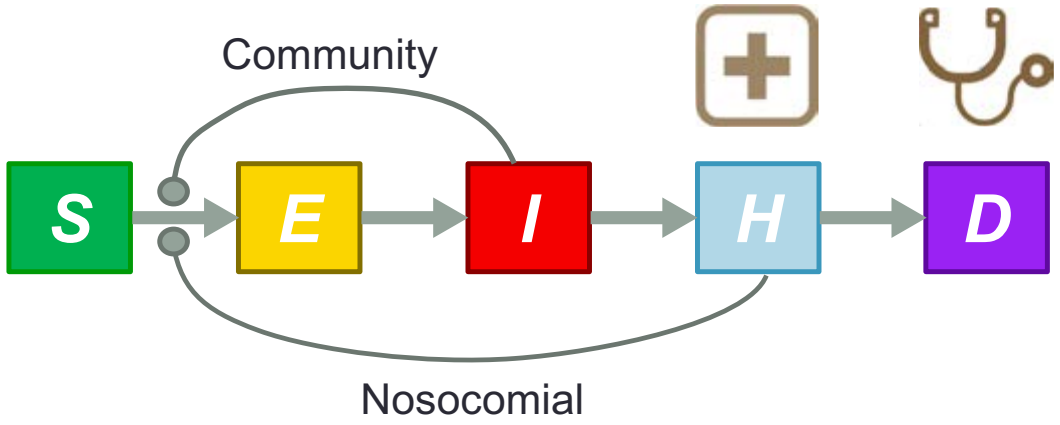
- Delays are frequent and can be substantial
  - median 13 days, range 1 – 72
- Associated with sex, age, province, and epidemic wave
- Adjusted delays:

Hong Kong	9 d	(PrI: 7-11)
Zhejiang	**19 d**	**(PrI: 16-23)**
Jiangsu	23 d	(PrI: 19-27)
Xinjiang	51 d	(PrI: 37-69)



Data source: WHO DON

Pandemic emergence model



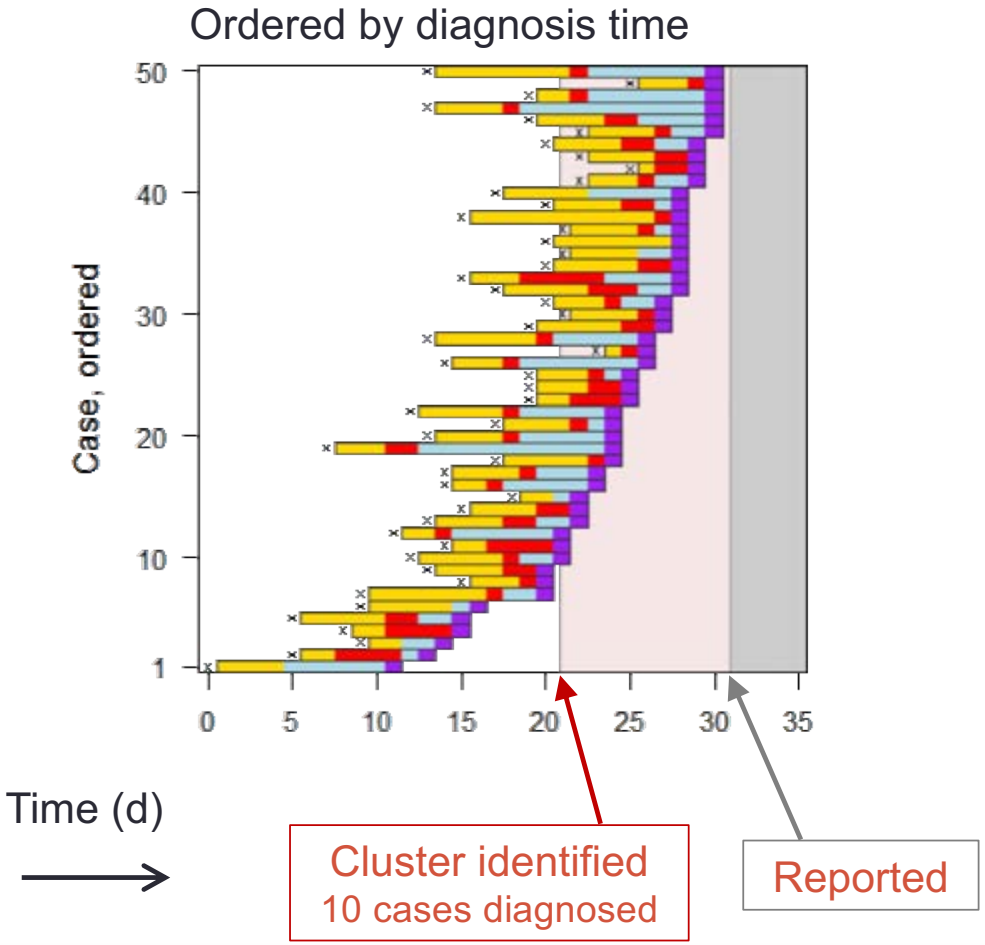
- Stochastic state transition and infection
- Used observed interval distributions
  - Wang 2017 Lancet ID
- Sensitivity to R_0

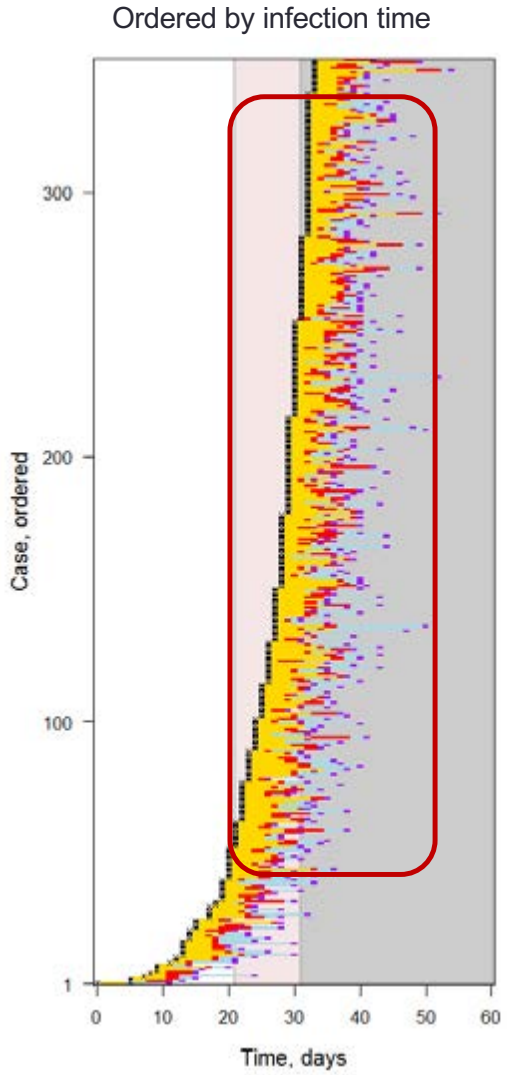
Best case
- Intervals as zoonotic A(H7N9)
- Infectious when symptomatic

Worst case
- Shorter incubation period
- Initial nosocomial transmission
- Infectious prior to symptoms

Simulated emergence example

× Infection
Incubating
Infectious
Hospitalized
Diagnosed





Exportation risk Zhejiang province

Rank	Destination	Departing Passengers, month^{-1}	Cases required to exceed importation risk of 5%
1	China	1,271,083	2
2	Hong Kong	35,771	80
3	Taiwan	33,288	86
4	Rep. Korea	21,920	130
5	Thailand	17,630	162
6	Macao	13,730	208
7	Italy	11,958	239
8	Malaysia	11,526	248
9	Japan	7,437	384
10	Singapore	6,479	441
11	France	4,288	666
12	Spain	3,567	800
13	USA	3,156	904
14	Viet Nam	2,622	1089
15	India	2564	1113

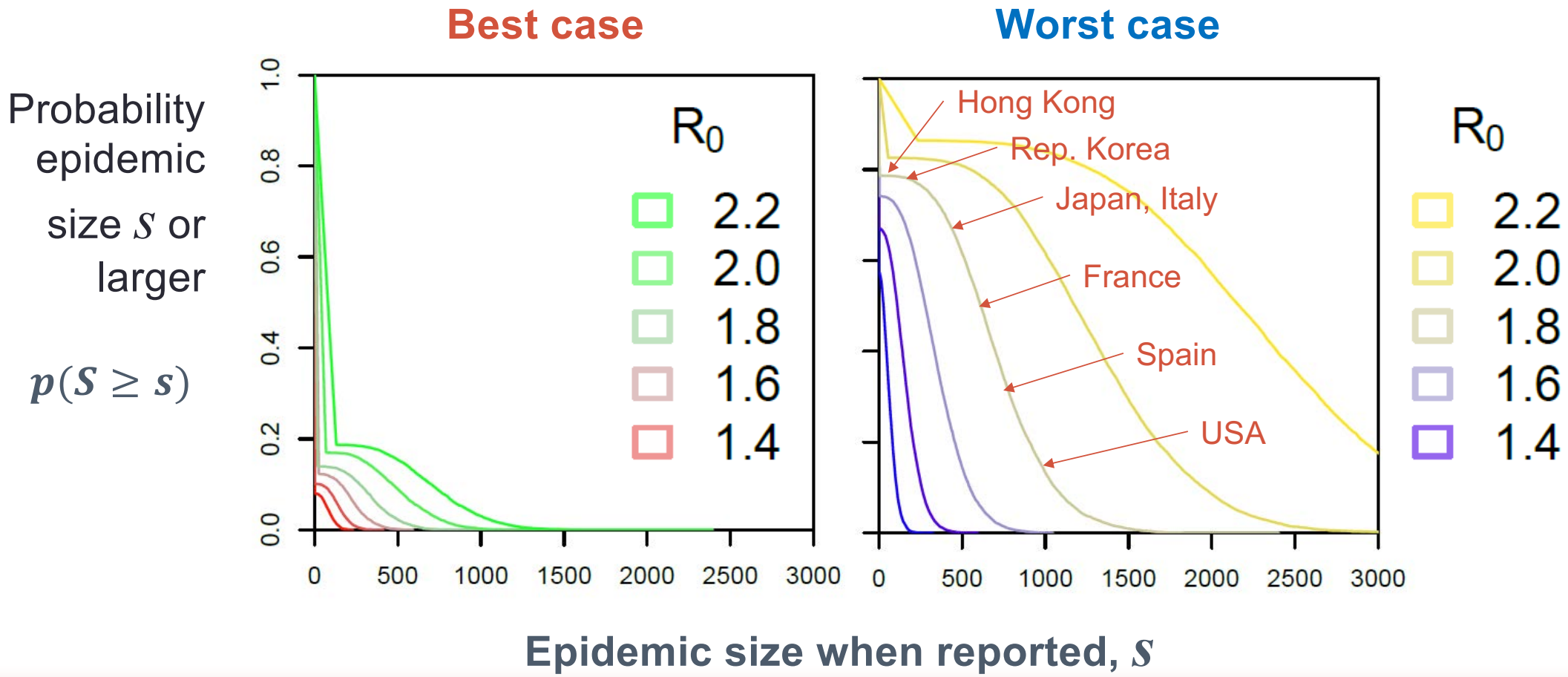
$$\frac{X}{F} \approx \frac{I}{N}$$

Imports A(H7N9) 2013+	
Hong Kong	21
Taiwan	5
Canada	*2*
Macao	2
Malaysia	1

Read et al 2015 Lancet
Data source: OAG traffic analyser; HKCHP reports

Scenario outcomes

Identified: **15 diagnosed cases**
Reporting : **15 days**



Conclusions

- Intuitive, but important to quantify
- Feasible for epidemic to be firmly established when first identified and reported
- Reasonable risk outbreak has reached other countries before identified and reported in origin country
- Situation much worse for mild disease / poor surveillance
  - Expect significant delay in identification
  - *e.g.*, A(H1N1)pdm 2009

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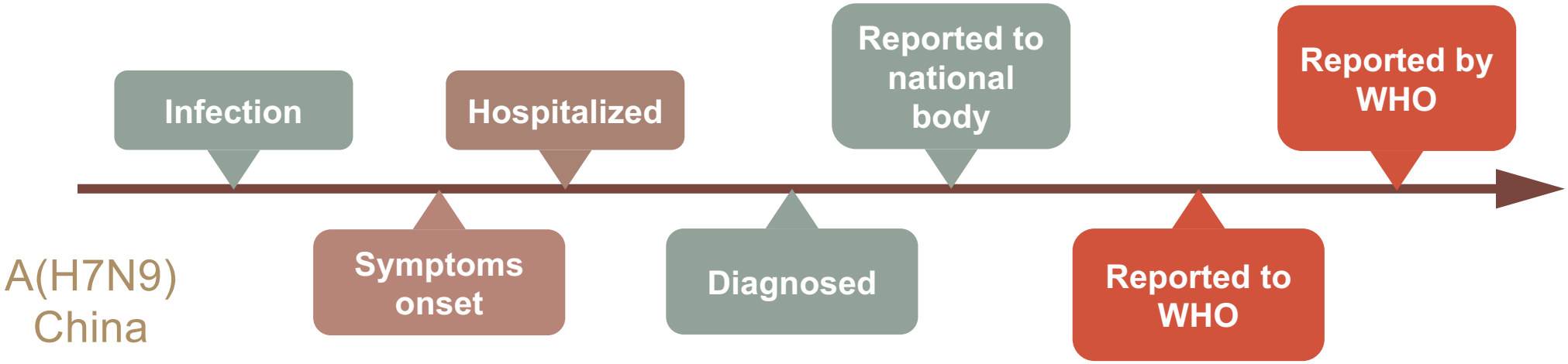
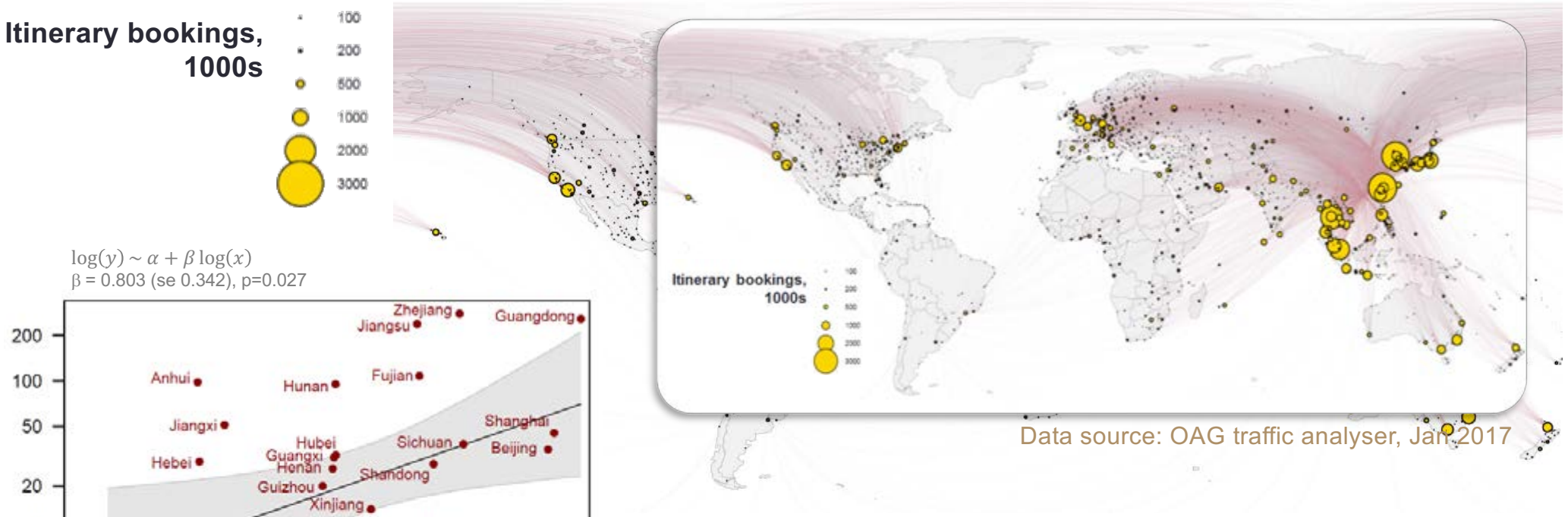
Delays in diagnosis and reporting

Delays are a function of:

- pathogen characteristics
- healthcare provision
- governance



Global connectivity of China



Data source: OAG traffic analyser, Jan 2017

- Highly connectivity via airline network
- Provinces with more A(H7N9) cases also have most departing passengers

Data source: OAG traffic analyser, Jan 2017