A model-based tool to predict the propagation of infectious disease via airports

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November 4, 2013
Boston, MA

141st annual conference of the American Public Health Association
Invited Session Talk
"Significant Advances in International Health Epidemiology"

Acknowledgment

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The MITRE Innovation Program

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Hwang, G. M., Mahoney, P. J., James, J. H., Lin, G. C., Berro, A. D., Keybl, M. A., Goedecke, D. M., Mathieu, J. J. and Wilson, T. (2012) A model-based tool to predict the propagation of infectious disease via airports, Travel Medicine and Infectious Disease, 10, 1, 32-42.

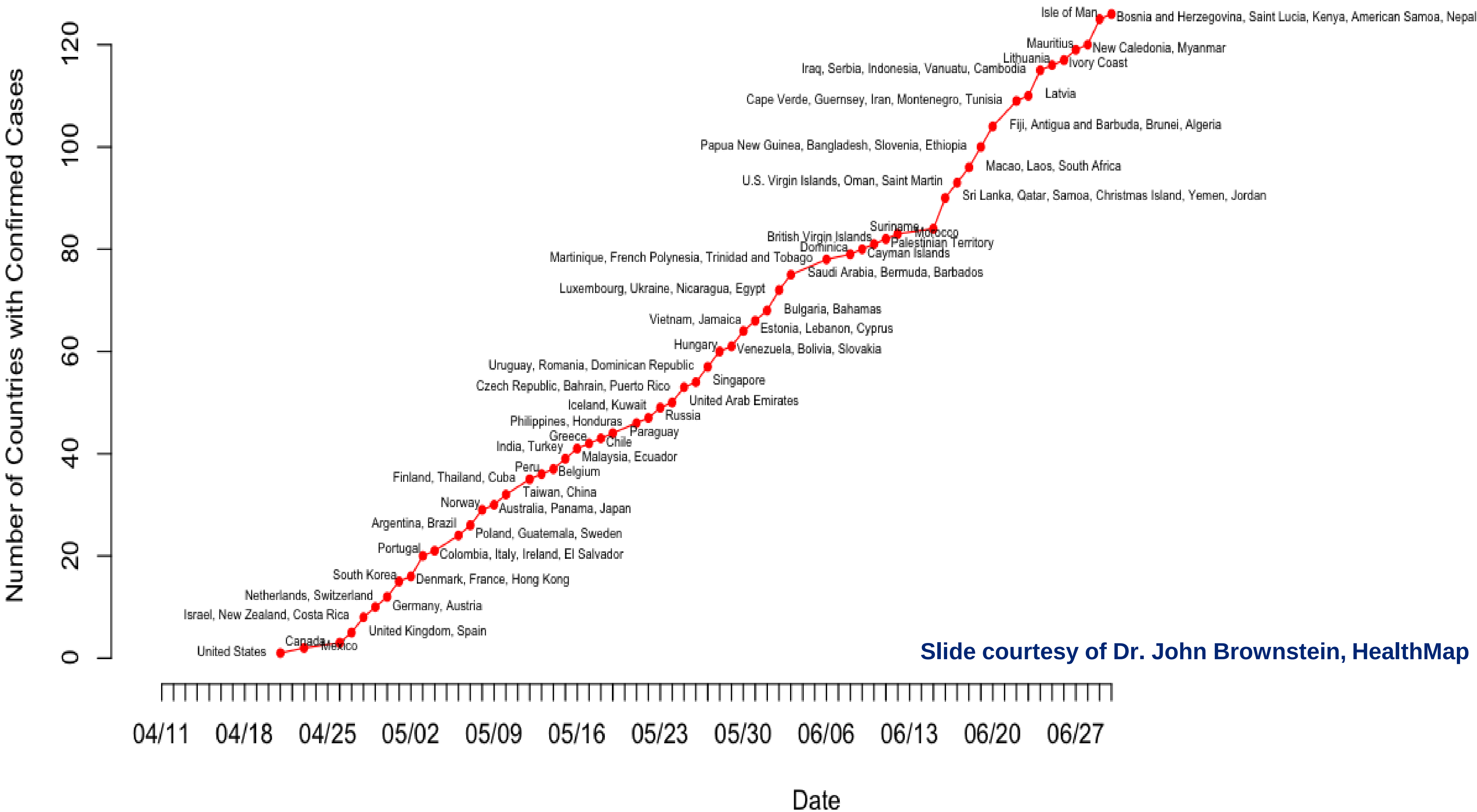
Presenter Disclosures

A model-based tool to predict the propagation of infectious disease via airports

(1) The following personal financial relationships with commercial interests relevant to this presentation existed during the past 12 months:

No relationships

Global Spread of Influenza A (H1N1) 2009 (pH1N1)



Slide courtesy of Dr. John Brownstein, HealthMap

Challenges to Point of Entry (PoE) Health Interventions

- Complex air travel and point of entry system
- Narrow time window of travel during which to intervene
- Triggers for starting and stopping are difficult to define (e.g., severity, phases)
- Costly to implement and logistically challenging
- Negative impacts on trade and tourism
- Pressure from public and politicians to execute
- Unknown efficacy – limited evidence base
- Lack of scientific analysis to inform planning

Objectives

- **Study objective was to develop a model that would**
  - **Improve ability to target responses in risk-based manner**
  - **Provide planners and responders with tools for improved decision-making**
  - **Enhance planning process with *scientific* data**
  - **Assess place and time as planning inputs**
  - **Provide better data for strategic timing of intervention deployment**
  - **Develop an "all hazards" disease approach in which the user can define parameters**
- **Today's learning objective: describe how one can use a model to assess risk and leverage resources at airports across the United States**

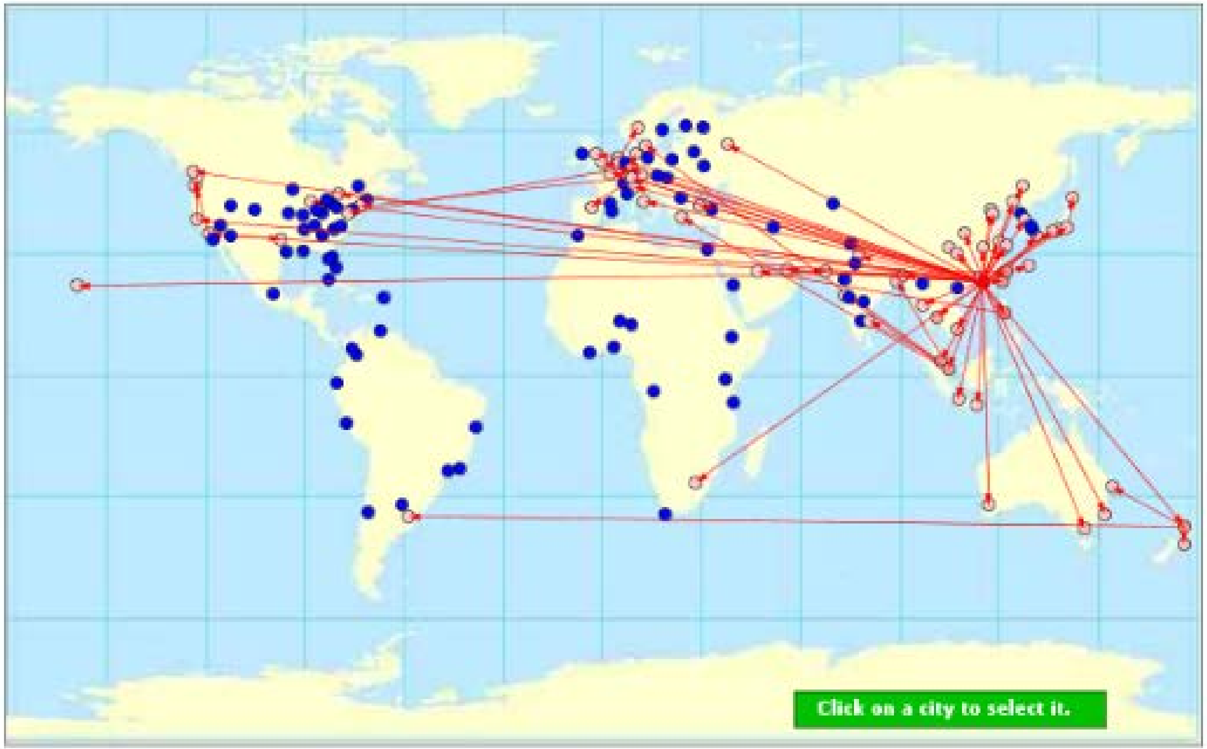
Methods

- Simulated disease spread at the start of a hypothetical influenza pandemic to a target country (e.g., the United States)
  - Flight origins in 55 international metropolitan areas covering 94% of air traffic to United States
  - 35 US POE included in model, population of 126 million people
  - North America (Canada/Mexico/United States) treated as one mixing body
  - Honolulu treated as an international point of origin
- Flight Data
  - One month's data (February 2009) obtained from www.DIIO.net
  - 70% of plane is occupied
  - 177 cities in model, 55 of which were also points of origin

Employed Previously Published Model

Global Model: H5 N1 influenza / 2000 - 2004 population and travel data

RTI INTERNATIONAL



DAY: 89

DATE: September 27, 2000

SEASON: Southern Winter

R0: 1.40

WORLD TOTALS

Susceptible:	619,570,635
Exposed:	60,371
Infectious:	172,820
Quarantined:	0
Recovered:	459,440
Vaccinated:	0
Dead:	0
Total:	620,263,266

CURRENTLY ILL: 233,191

STOCHASTICITY:

- [x] RANDOM CONTACT
- [x] RANDOM TRAVEL

INTERVENTIONS TO APPLY:

- [ ] TRAVEL RESTRICTION
- [ ] ONE-TIME VACCINATION
- [ ] DAILY VACCINATION
- [ ] QUARANTINE

TABLES

MAP

- [x] SHOW LINKS

PLOTS

TERMINATE

Map Legend

- Uninfected City
- Slightly Infected City
- Strongly Infected City
- Path of Infection
- No Intervention
- Intervention Imposed

Parameter Values

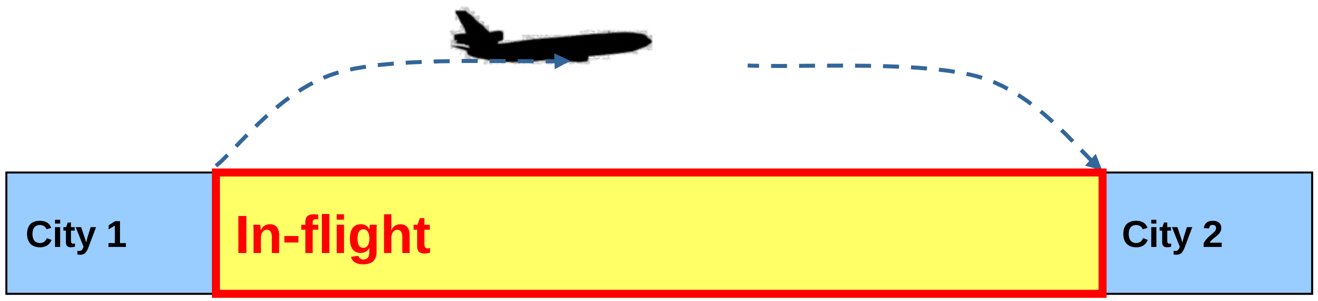
Number of Cities:	155	Travel Restriction Level:	90 %
Simulation Length:	500 days	Travel Restriction Threshold:	1,000 cases
Initially Exposed City:	Hong_Kong	Travel Restriction Type:	sequential
Initial Number Exposed:	100 persons	One-time Vaccination Level:	10 %
Infectious Contact Rate:	0.341 per day	Daily Vaccination Level:	0.01 %
Results Recorded:	daily	Maximum Quarantine Level:	50 %

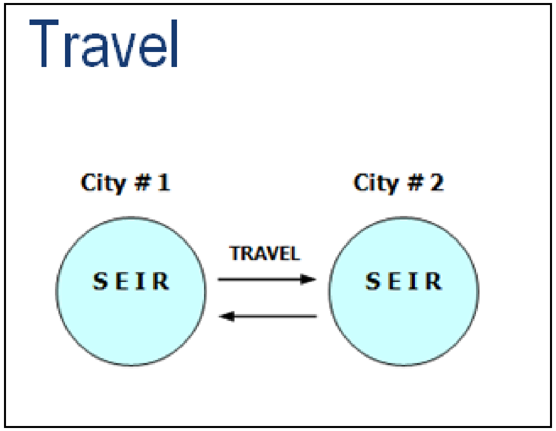
Epstein J. M., D. M. Goedecke, et al. (2007). PLoS ONE 2(e401).

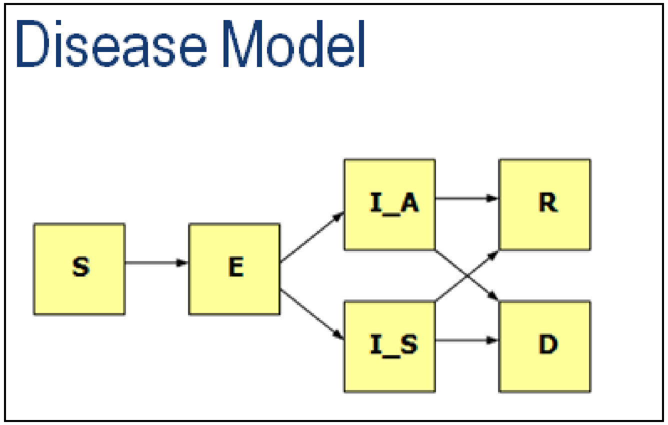
Assumptions

- Three reproductive Numbers [Ro=1.53, 1.7, 1.9]
- No mortality to maximize disease spread
- 100 initial exposed persons at point of origin
- A percentage of people in any disease state (Susceptible, Exposed, Infectious, Recovered) may travel. Air travel probability is based on the ratio of total travelers to population at each origin normalized by simulation time increment
- Analysis is based on 10 symptomatically infectious persons appearing in the continental U.S. from each point of origin averaged over 40 trials
- All points of origins were assigned to one of 7 world regions
  1. Central America, Caribbean, South America
  2. Africa
  3. Europe
  4. Asia
  5. Southeast Asia including India
  6. Near East including North African States, Middle East Mediterranean States
  7. Oceania

Model Overview







City = Metropolitan Area

S: Susceptible; E: Exposed; I_A: Infectious Asymptomatic; I_S: Infectious Symptomatic; R: Recovered: D: Deceased

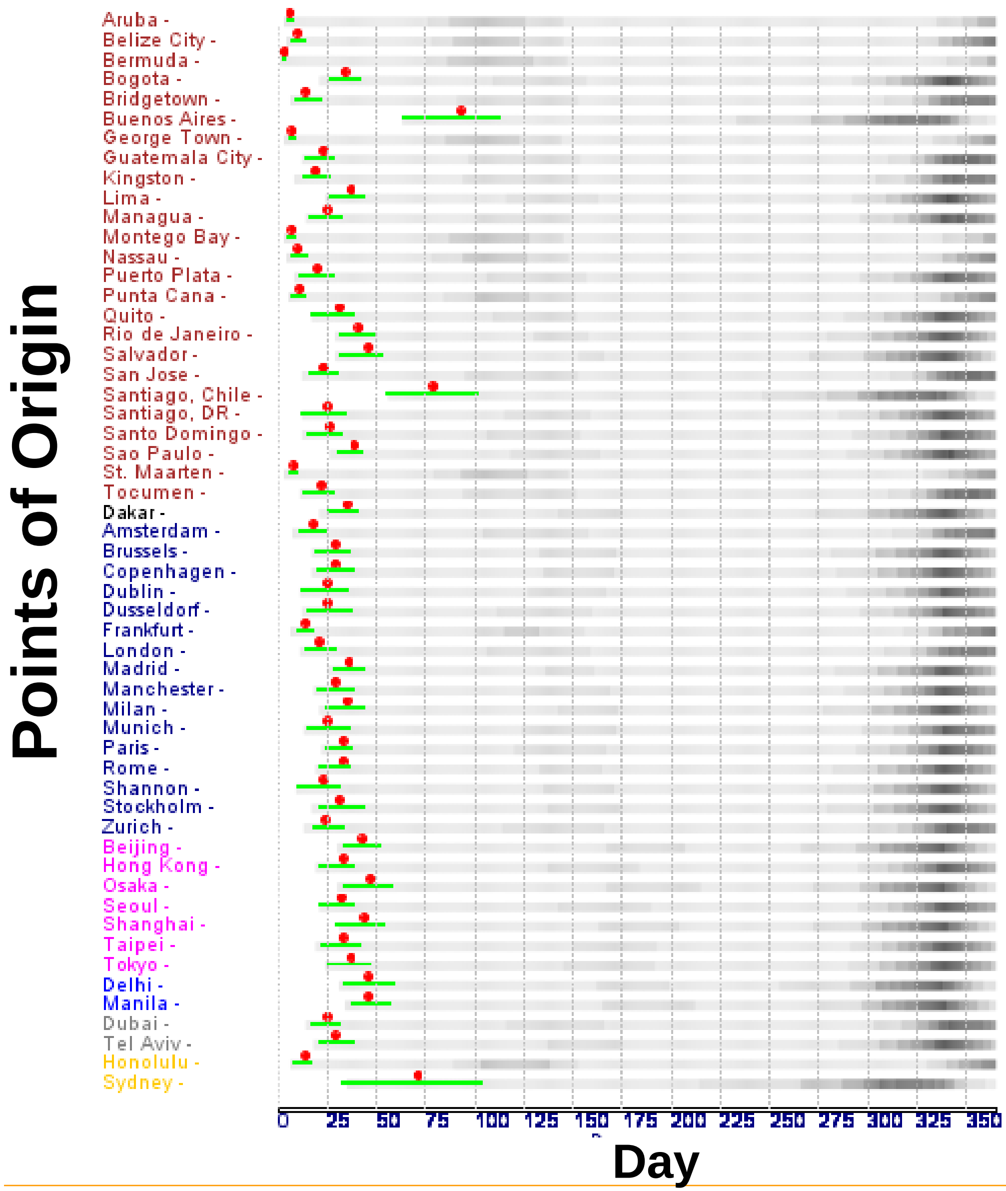
Note: Model was calibrated to pH1N1(2009) based on Mexico City as proxy for La Gloria, Veracruz
5% I_S allowed to travel (added flexibility since Epstein 2007)

U.S. Cities Simulated in the Model

Points of Origin Simulated in the Model

Disclaimer: The findings and conclusions are those of the author(s) and do not necessarily represent the views of the Centers for Disease Control and Prevention or The MITRE Corporation.

Time to Disease Arrival in the U.S.



Each row represents US symptomatic persons over 40 trials
Ro = 1.70

Color Legend -- World Region

Central America, Caribbean, South America
Africa
Europe (including Russia)
Asia
Southeast Asia with India
Near East (North African Arab States, Middle East Mediterranean States)
Oceania

Graph Symbols:

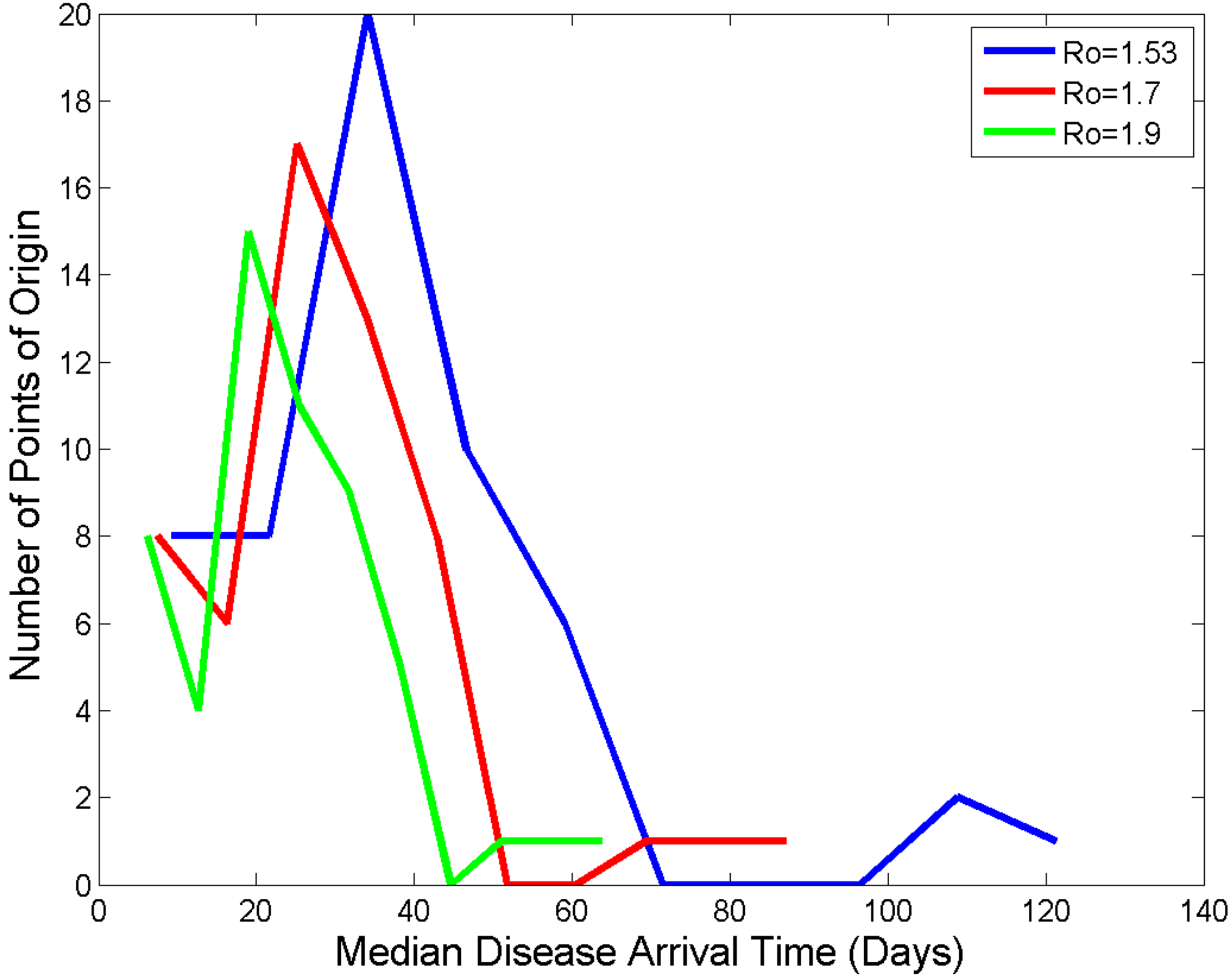
Median first day when there are 10 sick in U.S.

Range of first day where there are 10 sick in U.S.

Percent of Population Symptomatic

3%
2.7%
2.4%
2.1%
1.8%
1.5%
1.2%
.9%
.6%
.3%
0 sick

Histogram of Median Disease Arrival Time Grouped by Ro



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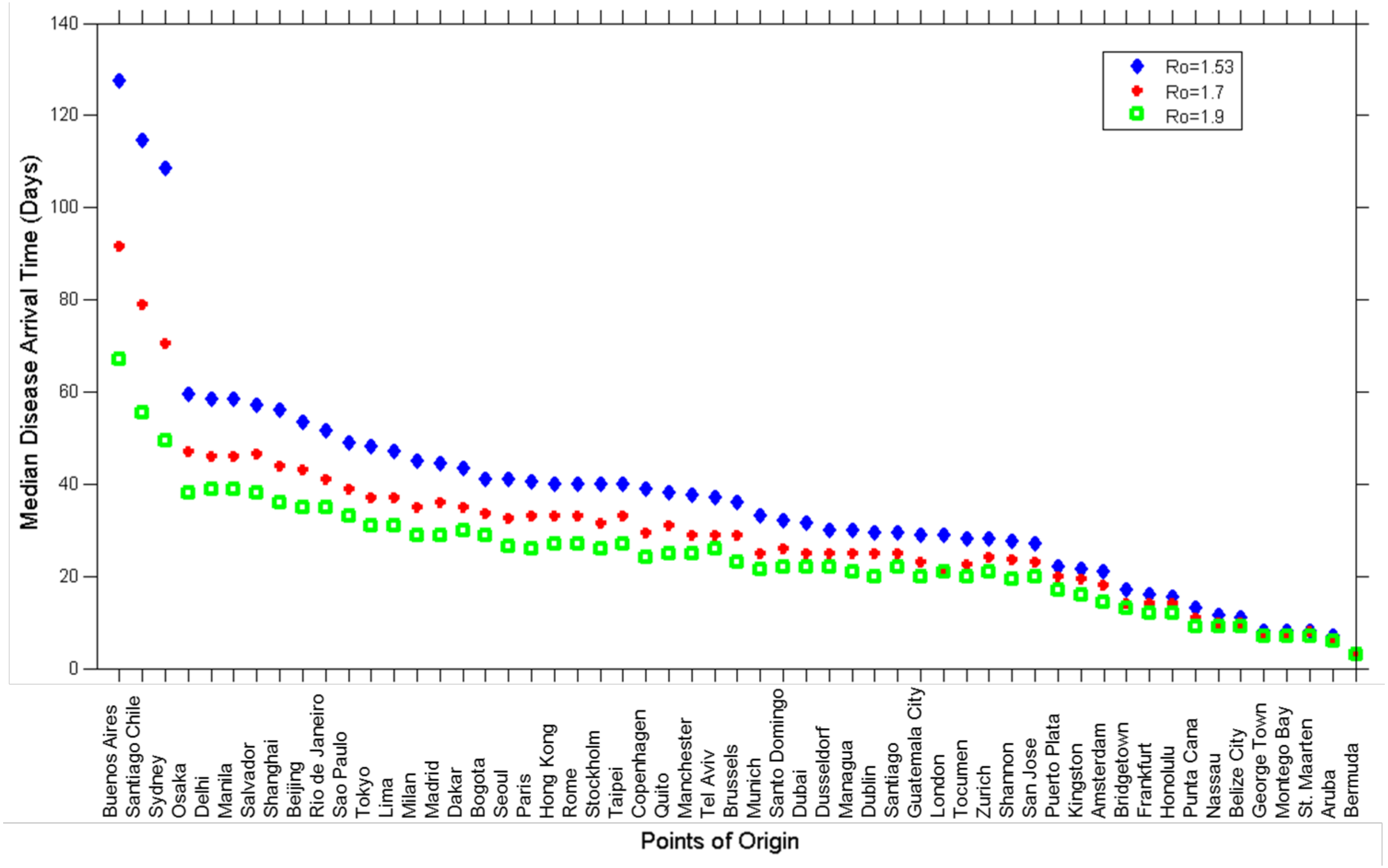
Backup Slides



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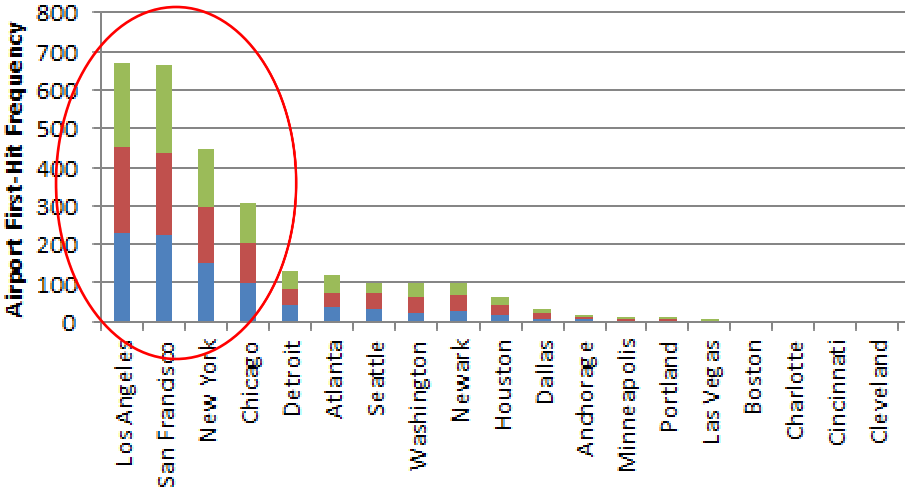
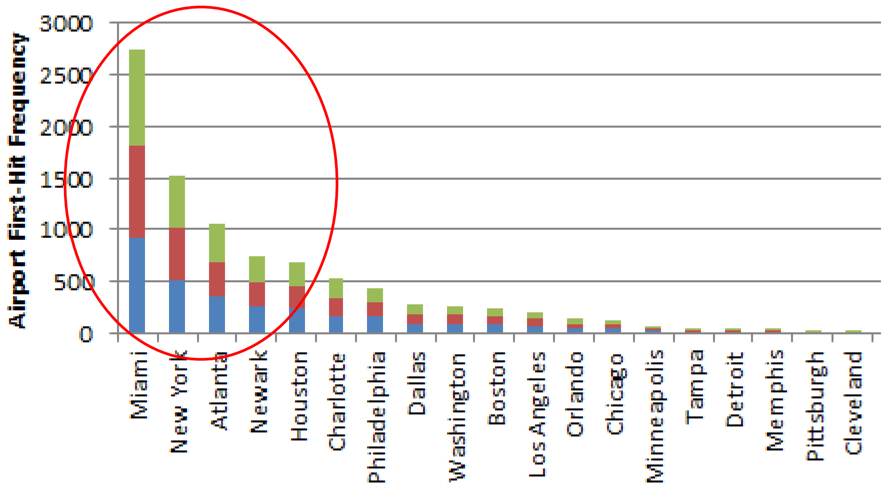
Points of Origin Plotted for Ro of 1.7 Coded by Mean Disease Arrival Time

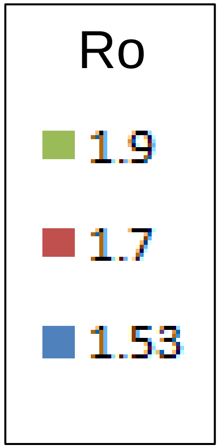
Effect of Overseas Origin on US Airports First Impacted by Outbreak

Disease Origin: Asia



Disease Origin: Central America
Caribbean
South America





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Summary of Median Disease Arrival Times

- Simulation results suggest that higher Ro correlates with shorter disease arrival times

Ro	25th Percentile	50th Percentile	75th Percentile
1.53	24.5	36	44.75
1.7	21.75	29	35.5
1.9	18.25	23	29.5

- Median disease arrival times from points of origin can be used to guide response planning to effectively distribute resources at specific airports
  - Plan response for points of origin with median disease arrival time under 25th percentile differently from 75th percentile

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Discussion

- Preparedness for public health response at POE must continue
- Public health authorities must seek ways to lessen adverse impacts and improve efficacy of border public health interventions
- Multi-sectoral cooperation is necessary
- Data are needed to determine start and stop points and locations for border measures
- Must know what, when, and where
- Knowing first-hit airports helps with risk-based and scalable approach

Conclusions

- Time of novel disease entry to a country via aviation POE is variable but may be predictable based on points of origin and entry
- Anticipating rate and location of disease introduction could provide greater opportunity to plan responses in real time
- This simulation tool can assess risk and help guide deployment of resources efficiently to support targeted and scalable border mitigation measures
  - Especially at key airports first impacted by an international outbreak
- Planning for targeted response at points of entry to major communicable disease outbreaks should focus on cost-effectiveness and result in improved public and political acceptance

With 1 billion people crossing international borders each year, there is no where in the world from which we are remote and no one from whom we are disconnected.

Hufnagel, *et al.* 2004. PNAS 101(42): 15124-15129

Airport Cooperative Research Program Webinar Materials

ADDITIONAL INFO

Airport Cooperative Research Program Recent Webinar




Understanding and Mitigating Disease Transmission at Airports

Thursday, September19, 2013

Overview of *CD 137: The Vector-Borne Disease Airport Importation Risk Tool*

- Andrew Tatem, Emerging Pathogens Institute, University of Florida

Overview of *ACRP Report 91: Guidance Document for Infectious Disease Mitigation*

- Dr. Mark Gendreau, Lahey Clinic

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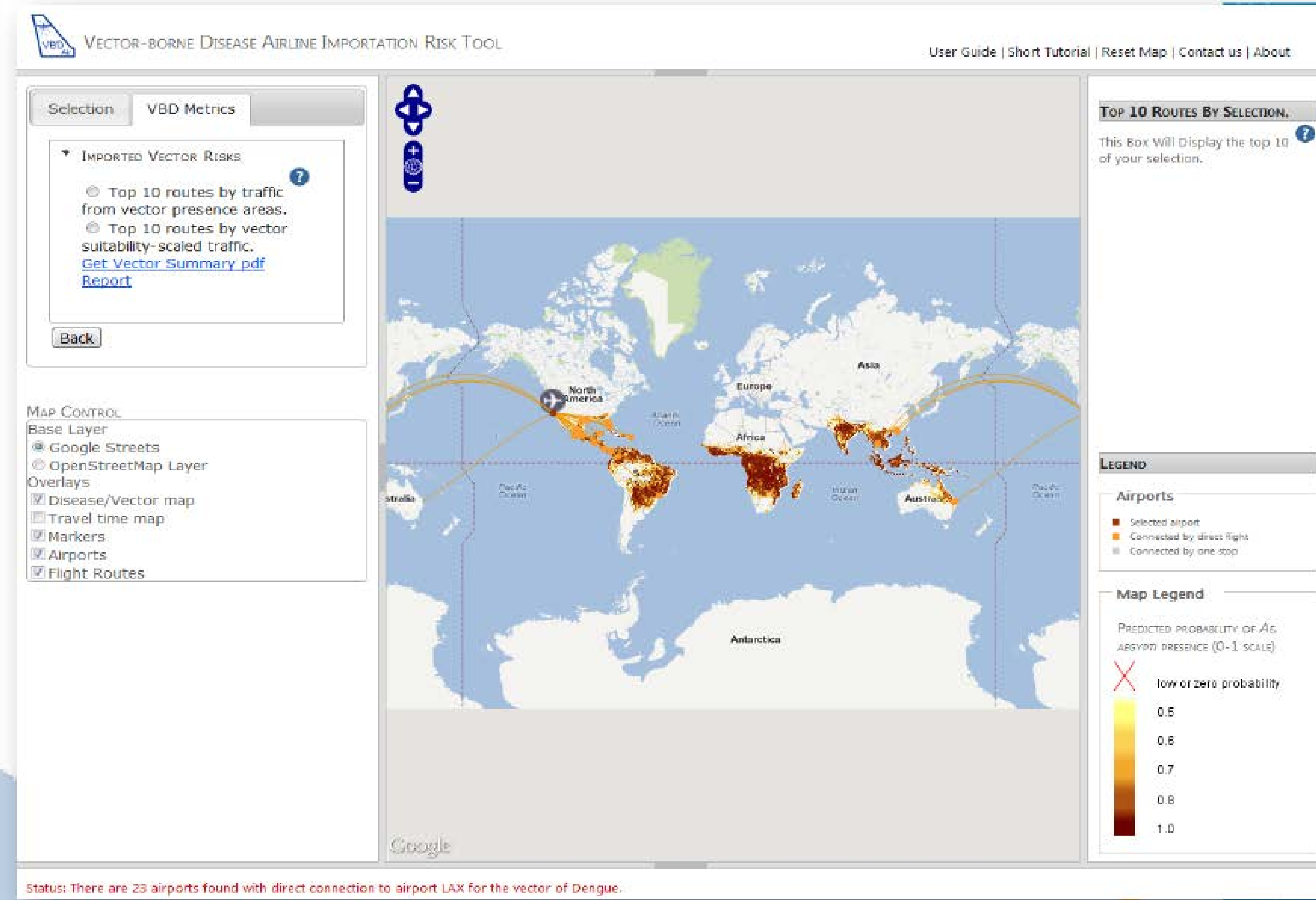
The Vector-borne Disease Airport Importation Risk (VBD-Air) Tool

- An *evidence base* for assessing and understanding the role of air travel in the spread of vector-borne diseases and their vectors through available spatial data
- An *operational tool* for examining the relative risks of imported vectors, the diseases they carry and onward transmission between routes and months to individual airports and regions of interest
- A *flexible and easily updated framework* for bringing together complimentary spatial datasets for rapid examination of changing risks of vector-borne disease movement
- www.vbd-air.com

Ae.aegypti mosquito importation to LAX



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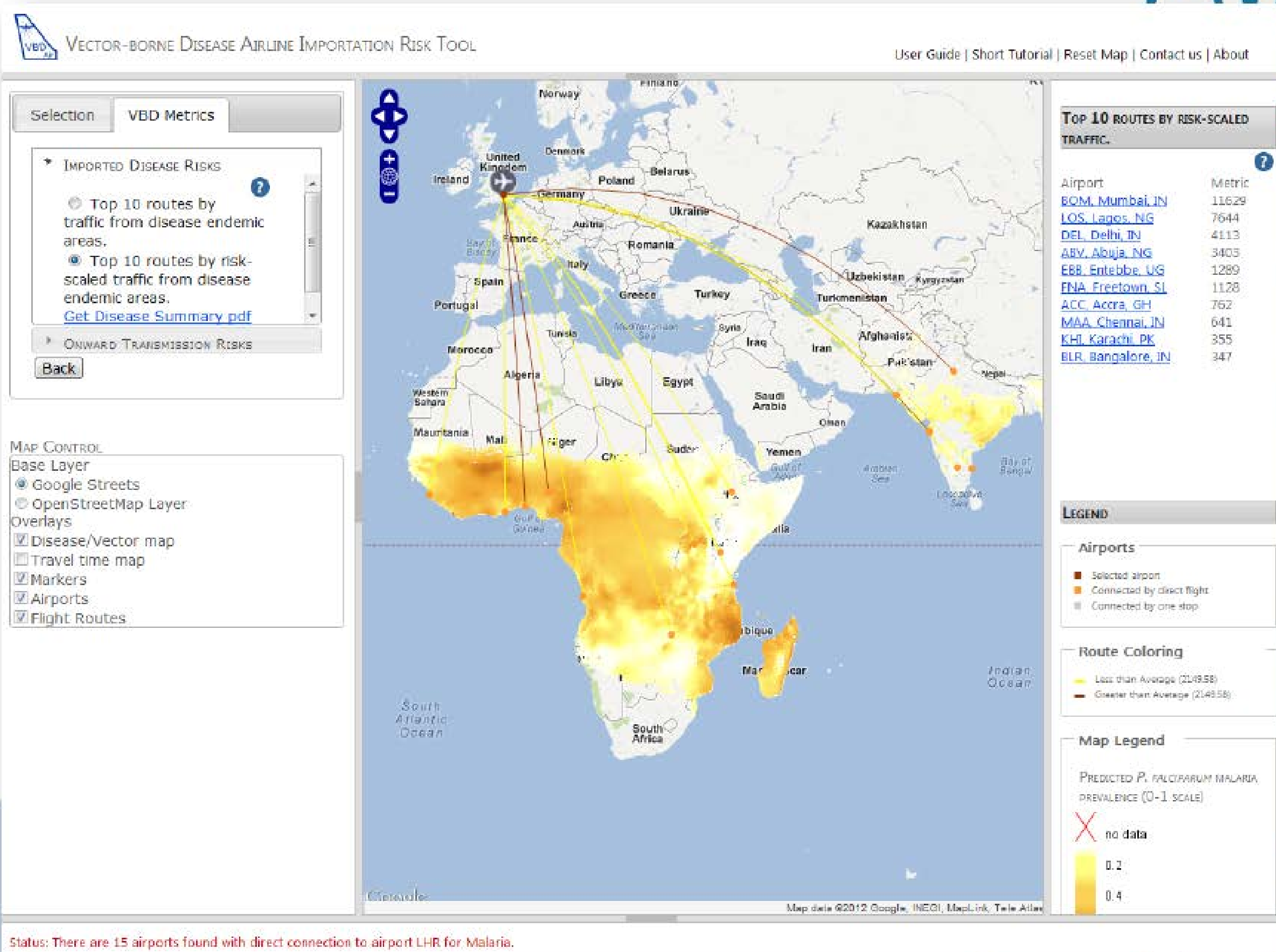
Malaria import risk to LHR



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VBD-Air Usage

- **Not a prediction tool – should be used as one form of evidence amongst many to guide planning**
- **Airport operator:** *How can we best manage the risks with limited resources?*
- **Local public health:** *How can I devise and coordinate preparedness measures for disease X?*
- **Local physicians:** *What diseases might I expect to see in my area in month X?*
- **Airline operators:** *For which destinations/times of year should we provide information for incoming/outgoing passengers?*

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ACRP Report 91: Infectious Disease Mitigation in Airports and on Aircraft

ACRP

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Oversight Panel

Paul Meyer, Hartsfield-Jackson International Airport, Panel Chair
Matthew Crosman, Washington Dulles International Airport
Mark Gendreau, MD, Lahey Hospital and Medical Center
Grace Hwang, PhD, MITRE Corporation
Barbara Martin, RN, Delta Air Lines
J. Michael Muhm, MD, Boeing Company
Renee Spann, Port Authority of New York & New Jersey
Shamira Brown, FAA Liaison
Francisco Alvarado-Ramy, MD, CDC Liaison
Deborah McElroy, ACI-North American Liaison
Christine Gerencher, TRB Liaison
Joseph Navarrete, ACRP Senior Program Officer

Mark Gendreau, MD

Study Goal

Determine Infectious Exposure Opportunities

Identify Mitigation Measures

Provide Guidance to Develop Targeted Strategies

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Approach

1. Assembly of Existing Literature Database

2. Site Visits to Boston International Airport

3. Likelihood/consequence ratings and risk assessment

4. Refinement of risk assessment

5. Expert Panel Risk Mitigation Workshops

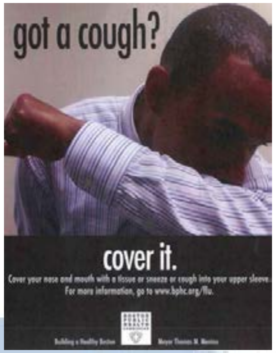
6. Creation of Guidance Document (ACRP Report 91)

Mycobacterium tuberculosis
Influenza virus
Neisseria meningitdes (menignococcal disease)
Measles virus
Rubella virus
Lassa virus
Norovirus
Methicillin-resistant *Staphylococcus aureus* (MRSA)

ACRP
AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP Report 91: Infectious Disease Mitigation in *Airports and on Aircraft*

1. Provides literature database
2. Identifies exposure opportunities in airports and on aircraft
3. Identifies key infectious disease mitigation measures that can realistically be implemented in the airport and aircraft environment
4. Published September 2013



People

Population(s) Targeted	Passengers	Flight Crew	Airport Ops (Public Contact)	Airport Ops (Limited Public Contact)	Guests
	✓	○	○	○	○
Area(s) Targeted	**Pre-security**	**Security**	**Terminal**	**Airplane**	**Post-flight**
	✓	✓	✓	✓	✓
Exposure Route Targeted	**Aerosol**	**Large Droplet**	**Fomite**		
	✓	✓	✓		

Airport Operators and Airlines Should Consider Implementing a "Healthy Traveler" Campaign

Highly Recommended

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For additional information:

ACRP Report 91: *Infectious Disease Mitigation in Airports and on Aircraft*

http://www.trb.org/main/blurbs/169466.aspx

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