Predictive Aid for Seasonal, Avian & Pandemic Influenza & Acute Respiratory Infections Using Remote Sensing Data

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GOALS

- Reduce human morbidity and mortality
- Reduce economic loss

OBJECTIVES

- Model seasonality of influenza transmission at major population centers
- Predict short-term influenza activities
- Provide pandemic early warning
- Identify risk factors in HPAI transmission
- Model within- and between-farm avian influenza transmissions
Influenza data from regions in 20 countries covering temperate, subtropical and tropical zones have been analyzed and modeled.
Highly Pathogenic Avian Influenza A(H5N1) Endemic Regions in Indonesia

Source: E. Sawitri/Indonesian MoA
COLLABORATORS

- CDC
- NAMRU2
- USDA APHIS
- WHO EURO
- Public health agencies in collaborating countries
Earth Observing Data

- **Satellites**
  - TRMM — precipitation
  - MODIS — land surface temperature
  - ASTER — radiance

- **Climate Model**
  - GLDAS — precipitation, temperature, specific humidity

- **Ground Stations**
  - min/max/mean temperature, relative humidity, dew point, solar irradiance, etc.
Epidemic-prone acute respiratory diseases have no borders, and can be spread rapidly around the world. Global, coordinated surveillance & control efforts are essential.

**2003 SARS**
Spread to 37 countries in weeks

**2004 Avian Influenza – A(H5N1)v**
Spread to 62 countries since 2004. There are still frequent outbreaks in Indonesia, Egypt, and some Southeast Asian countries.

**2009 Pandemic – A(H1N1)pdm09**
Spread to 48 countries in a month despite heightened public awareness and substantial preventive and control efforts
SARS increased public health as well as the general public’s awareness of the seriousness of pandemic, and provided a real test ground for preventing and controlling respiratory disease.
Global Spread of A(H1N1)pdm09

April-September

Month of first reported H1N1 case
- April
- May
- June
- July
- August
- September
Burden of Influenza

US

- 0.2 M hospitalizations and 36,000 deaths annually
- Hospitalization rate highest in children
- 90% of deaths are older than 65 years
- 75% of deaths are not coded pneumonia or influenza

World

- 3-5 M severe cases annually
- 0.25-0.5 M deaths annually

Economic Burden

- Direct health care?
- Societal costs?
- Nearly $10 B annual economic loss for US alone

Sources: WHO, Thompson et al., Widdowson
Hemaglutinin
A glycoprotein for binding to the host cell
17 subtypes

Neuraminidase
An enzyme for splitting mucoprotein in order to release progeny
10 subtypes

antigenic shift: \( H1N1 + H2N2 \rightarrow H1N1, H2N2, H1N2, H2N1 \)

170 Subtypes and Innumerable Strains

NA
Neuraminidase

HA
Hemaglutinin

A glycoprotein for binding to the host cell
17 subtypes

Human & Avian Influenza Epidemics & Pandemics

- **Spanish Flu**: 1918
  - 28% world infected
  - 20-50M deaths worldwide
  - >0.5M deaths in US

- **Asian Flu**: 1957
  - 70K deaths in US

- **Hong Kong Flu**: 1968
  - 34K deaths in US

- **H1N1pdm09**: 2009
  - 15K deaths worldwide
  - 16% US infected

- **SARS (coronavirus)**: 2003
  - 37 countries
  - CFR~32%

- **MERS CoV**: 2010
  - CFR~55%

**Human & Avian Influenza Epidemics & Pandemics**

- **H5N1**: 2004
  - Outbreaks

**Highly pathogenic avian influenza**

- H5N1, H5N2, H5N3, H7N1, H7N3, H7N7 ...

**H5N1 Outbreaks**

- 1996: H5N1 in Hong Kong
- 1998: H9N2 in Guangdong
- 2003: H7N7 in Holland
- 2004: H7N3 in Canada

**H7N9**

- CFR~32%
Projected Deaths in US For Pandemics With Severity 1–5

<table>
<thead>
<tr>
<th>Category</th>
<th>CFR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 0.1 %</td>
</tr>
<tr>
<td>2</td>
<td>0.1 – 0.5 %</td>
</tr>
<tr>
<td>3</td>
<td>0.5 – 1.0 %</td>
</tr>
<tr>
<td>4</td>
<td>1.0 – 2.0 %</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 2.0 %</td>
</tr>
</tbody>
</table>

Pandemic Deaths in US
- 1918 Spanish Flu: 500-675 K
- 1957 Asian Flu: 70 K
- 1968 HK Flu: 34 K

Source: USG Preparademic Planning Guidance
# Environmental & Sociological Factors Affecting Human Influenza Transmissions

*Change in Transmission with Increase in Factor*

<table>
<thead>
<tr>
<th>Virus Survivorship</th>
<th>Temperature</th>
<th>Humidity</th>
<th>Vapor pressure</th>
<th>Solar irradiance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host Susceptibility</td>
<td>Sunlight exposure</td>
<td>Nutrition</td>
<td>Previous infections</td>
<td></td>
</tr>
<tr>
<td>Transmission Efficiency</td>
<td>Temperature</td>
<td>Humidity</td>
<td>Ranges</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Vapor pressure</td>
<td>Precipitation</td>
<td>ENSO</td>
<td>Air travel</td>
</tr>
</tbody>
</table>

**Biological Evidence**
- Ranges

**Empirical Evidence**
- Ranges

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Modeling Techniques Used

- ARIMA (Autoregressive integrated moving average)
- Binomial regression
- Hilbert Huang empirical mode decomposition
- Neural network
- Poisson regression
- Wavelet transform
- SEIR
- Markov Chain Monte Carlo

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H5N1 TRANSMISSION PATHWAYS

POULTRY TRADE
- poultry, products, feed, waste, personnel, equipment

BIRD TRADE
- LPAI spill over
- wild birds
- domestic birds
- ducks & geese
- HPAI spill back

MIGRATORY BIRDS
- HPAI

POULTRY
- Sectors 1&2
- Sectors 3&4

HUMANS
- human flu virus
- reassortment
- pandemic strain

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A(H3N2)v Swine Influenza Virus

- H3N2 swine virus infected humans
- Approx. 300 cases in 11 states in 2012
MERS-CoV / nCoV Middle East Respiratory Syndrome Coronavirus

- As of mid-July, 82 cases worldwide with ~55% case mortality
- Possible reservoir & hosts: *Pipistrellus* bat, Egyptian tomb bat, and dromedary camel
A(H7N9) Avian Influenza Virus

- First reported in China on March 31, 2013
- As of August 10, 2013, 134 cases with ~32% case fatality
- One case spread to Taiwan
- Situation stabilized due to containment efforts or seasonal decrease of avian influenza circulation
- Human infection due to contact with infected poultry or contaminated environment
- No evidence for sustained human-to-human transmission
- 0.08% of samples from farms and markets tested positive
- Less pathogenic in poultry, asymptomatic human case discovered
- A(H7N7) was discovered and may pose more threats
Three Criteria for a Pandemic

- Novel virus
- Lack of population immunity
- Human-to-human transmission
THANK YOU