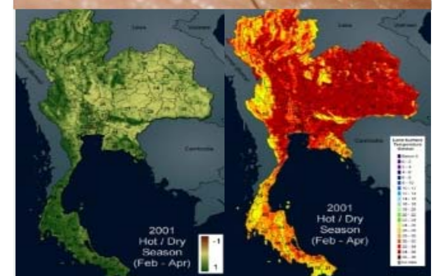
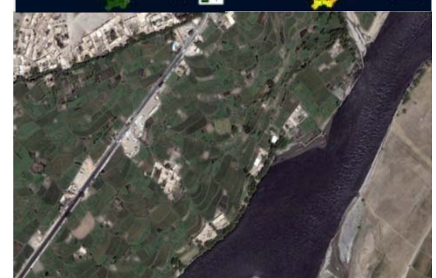
ESTIMATING THE RISK OF VECTOR-BORNE INFECTIOUS DISEASE & ACUTE RESPIRATORY INFECTIONS USING SATELLITE DATA

Presented by Radina P. Soebiyanto[1,2]
on behalf of Richard Kiang[1]

[1]NASA Goddard Space Flight Center, Code 610.2, Greenbelt, MD
[2] Goddard Earth Sciences Technology & Research (GESTAR), Universities Space Research Association, Columbia, MD








AGENDA

- **Malaria** in Thailand, Afghanistan and Korea
- **Dengue** in Indonesia
- **Avian Influenza** in Indonesia
- **Seasonal Influenza** in New York, Arizona and Hong Kong

MALARIA

- <u>Cause:</u>
  - *Plasmodium* spp (protozoan)
  - Carried by *Anopheles* mosquito

- <u>Burden:</u>
  - 250 million cases each year
  - 1 million deaths annually
  - Every 30 seconds a child dies from malaria in Africa
  - Cost ~ 1.3% of annual economic growth in high prevalence countries

- <u>High Risk Group</u>: Pregnant women, children and HIV/AIDS co-infection

Plasmodium infecting red blood cell

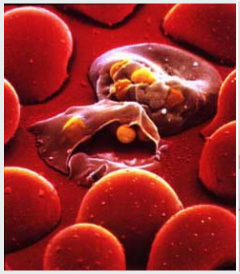


Image: Nat'l Geographic

Image: Nature

Transmission through female *Anopheles* bite

- <u>Treatment and Prevention</u>:

Bed nets

Indoor spraying

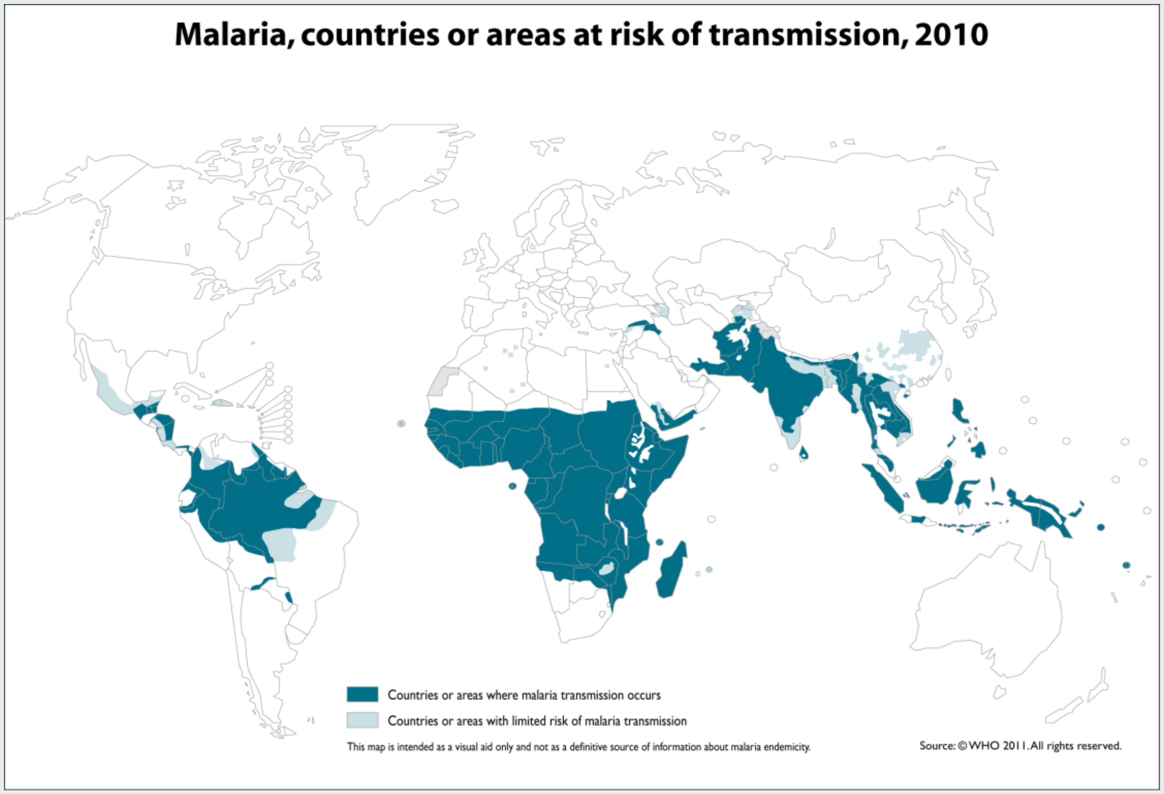
Vector Control

Images: WHO

Artemisin-based Combination Therapy

MALARIA

Malaria Distribution

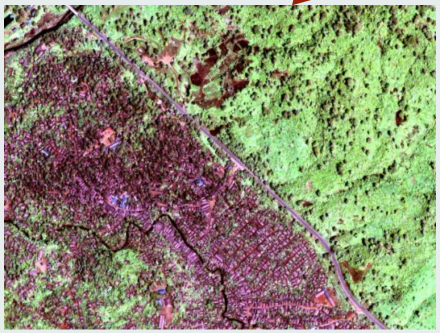


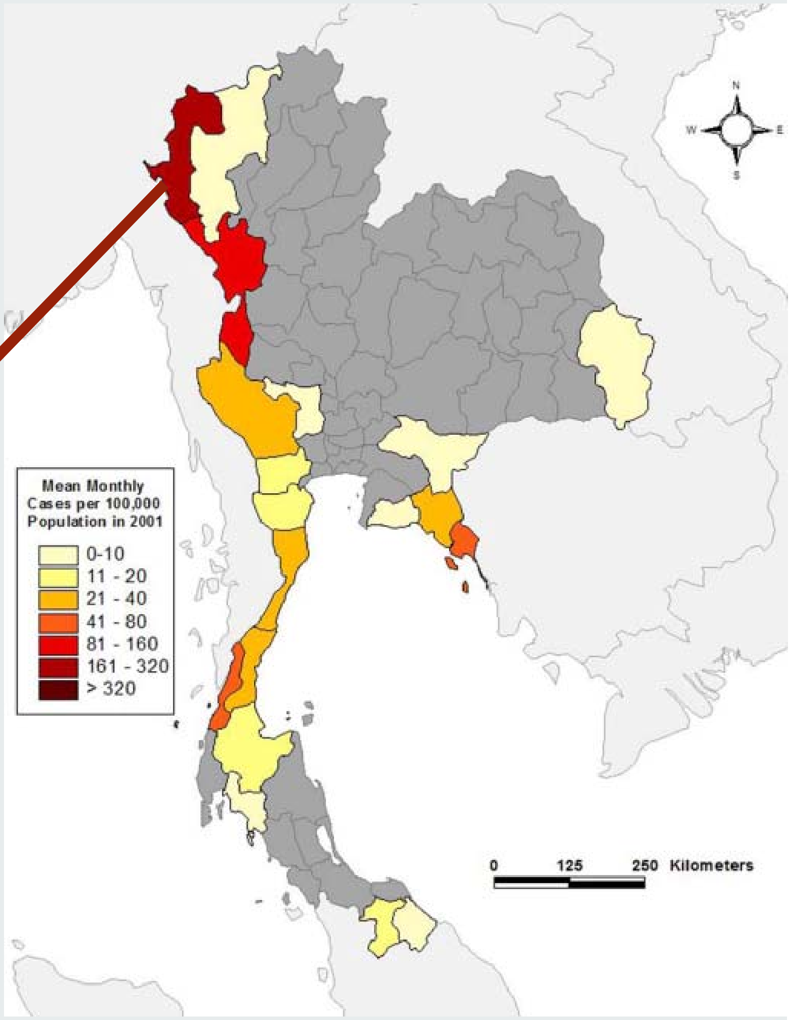
Role of climatic and environmental determinants

Determinants	Effect
Temperature	Parasite + Vector: development and survival
Rainfall	Vector breeding habitat
Land-use, NDVI	Vector breeding habitat
Altitude	Vector survival
ENSO	Vector development, survival and breeding habitat

MALARIA IN THAILAND

- Leading cause of morbidity and mortality in Thailand
- ~50% of population live in malarious area
- Most endemic provinces are bordering Myanmar & Cambodia
  - Significant immigrant population
  - Mae La Camp
    - Largest refugee camp
    - >30,000 population

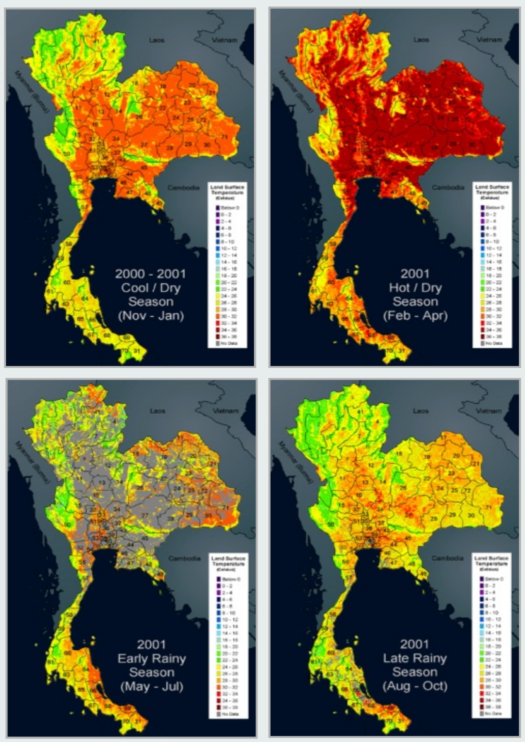




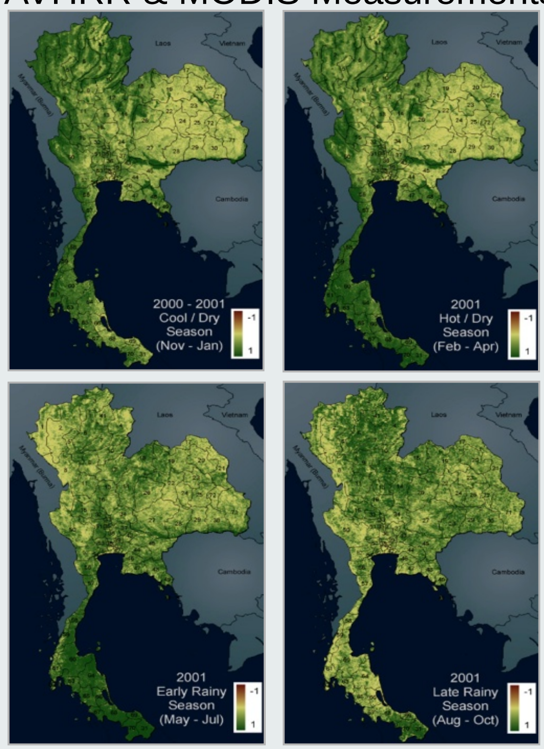
MALARIA IN THAILAND

- Satellite-observed meteorological & Environmental Parameters for 4 Thailand seasons

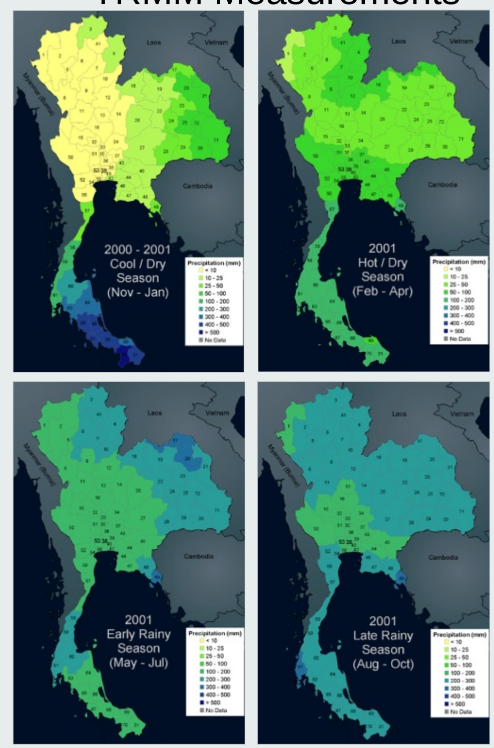
Surface Temperature
MODIS Measurements



Vegetation Index
AVHRR & MODIS Measurements



Rainfall
TRMM Measurements

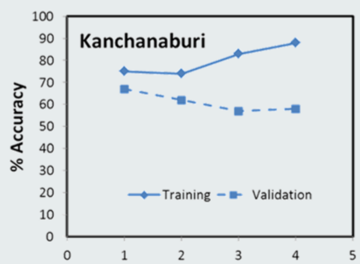


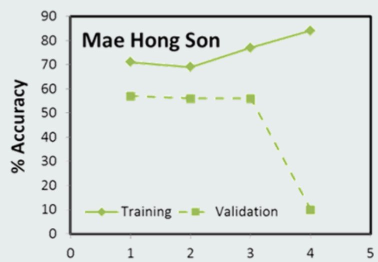
MALARIA IN THAILAND

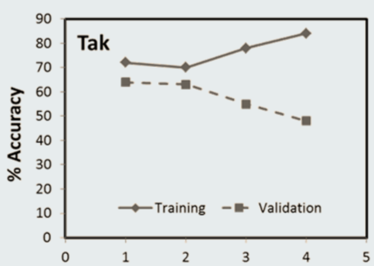
- Neural Network training and validation accuracy

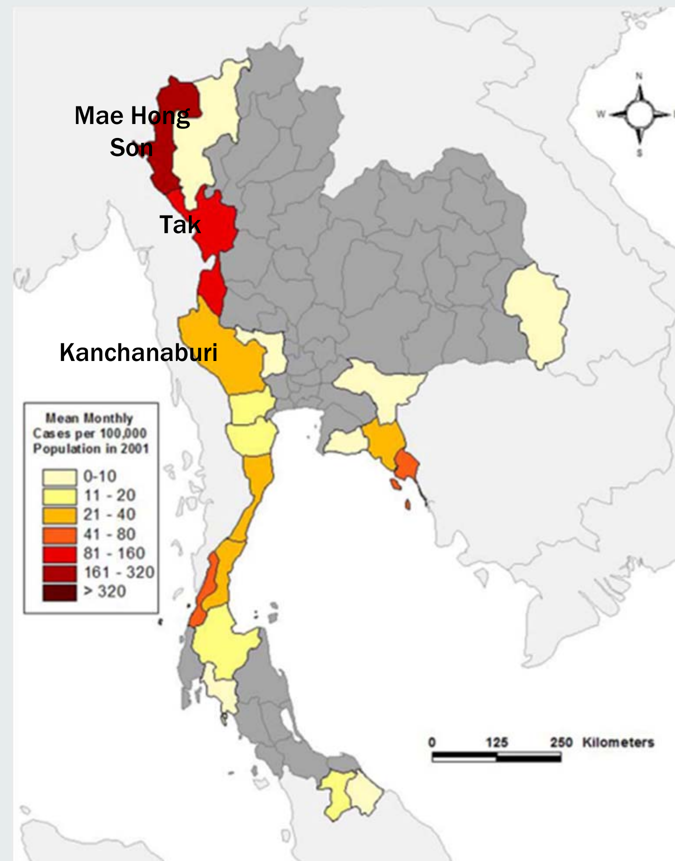
	Input	Hidden Layer	Hidden Node
Model 1	t, T, P, P (lag 1), H, V	1	1
Model 2	t, P, P (lag 1), H, V	1	1
Model 3	t, T, P, P (lag 1), H, V	1	2
Model 4	t, T, P, P (lag 1), H, V	1	3

t = time, T = temperature, P = precipitation, H = humidity, V = NDVI



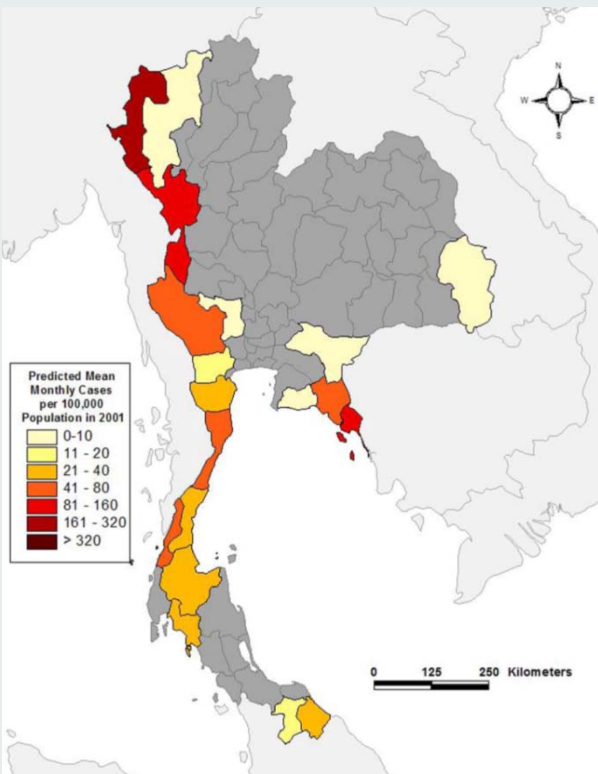




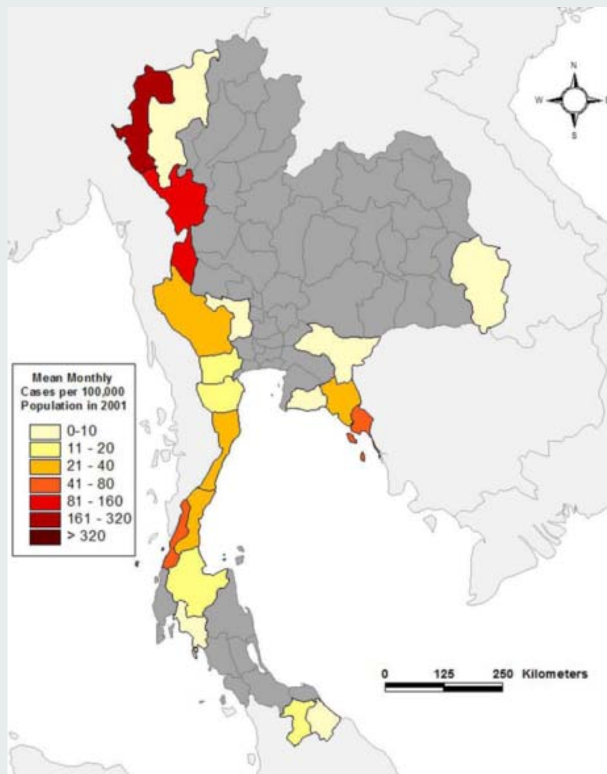


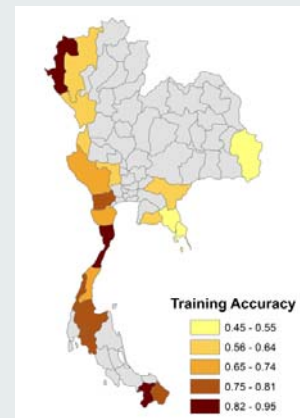
MALARIA IN THAILAND

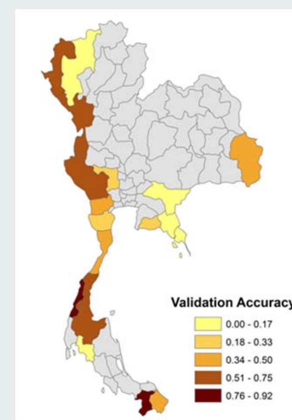
Hindcast Incidence



Actual Malaria Incidence



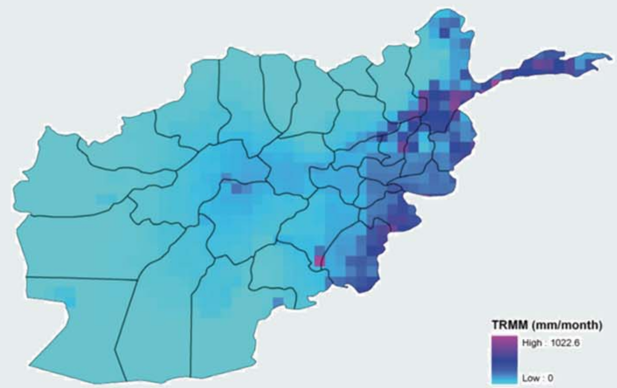




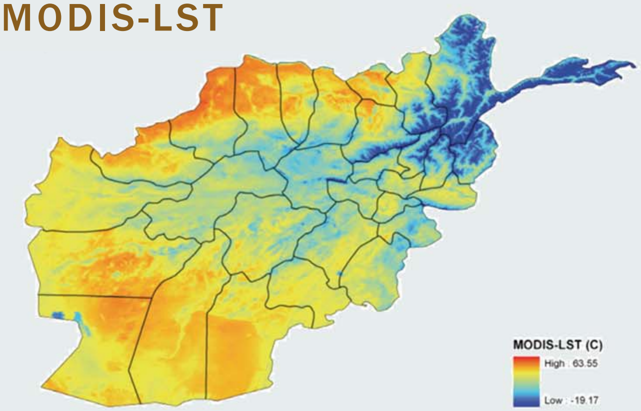
MALARIA IN AFGHANISTAN

Provinces included in the study

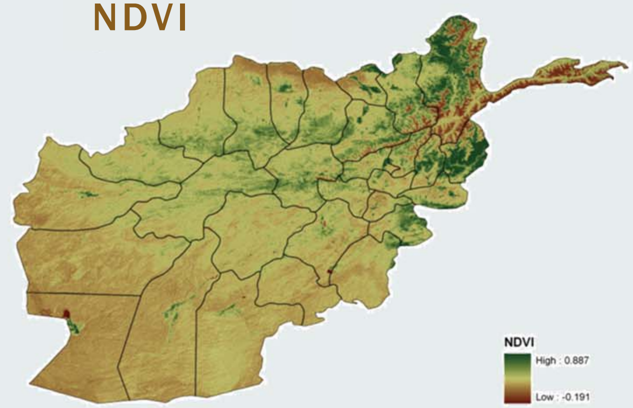
TRMM



MODIS-LST

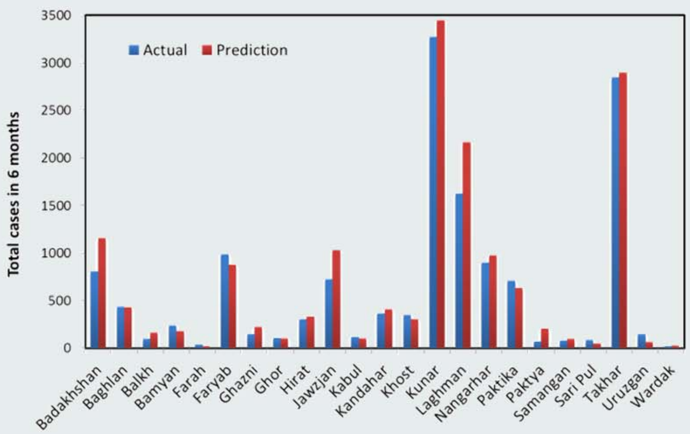


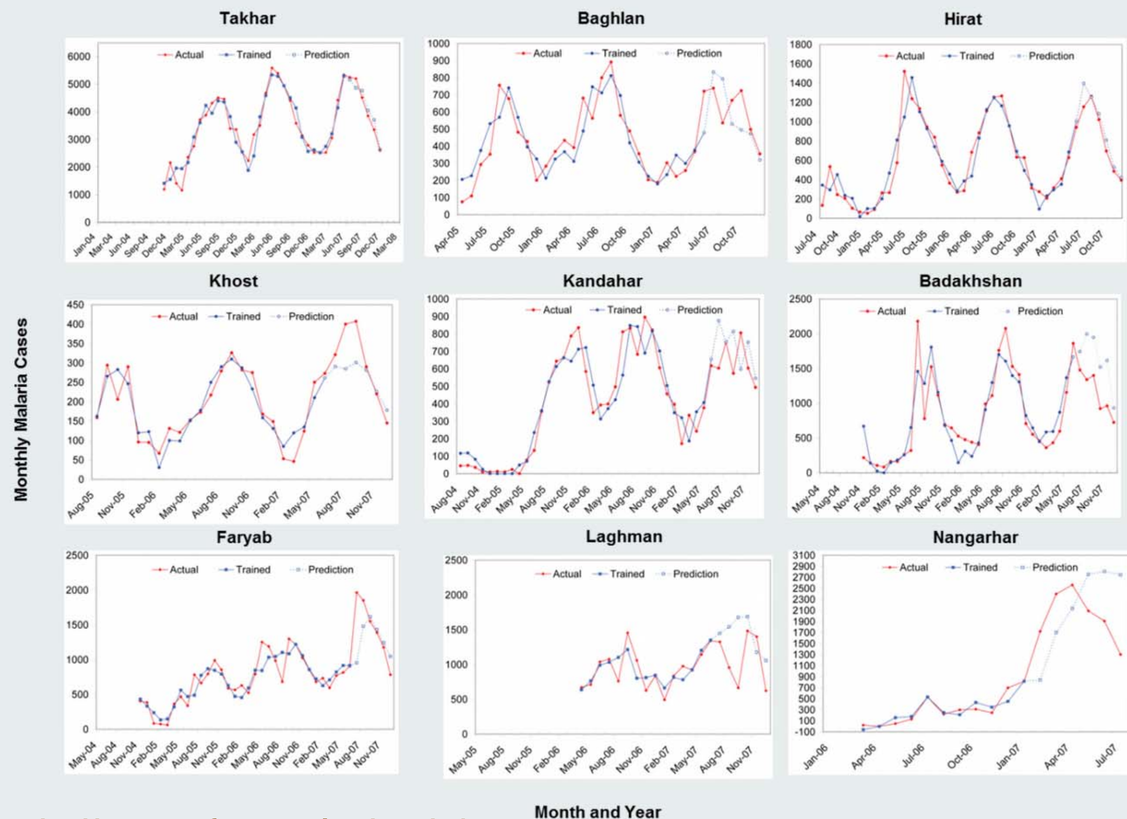
NDVI



Adimi *et al. Malaria Journal* 2010, 9: 125

MALARIA IN AFGHANISTAN

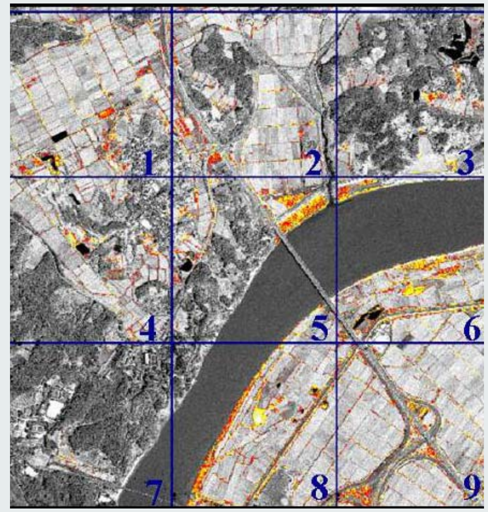


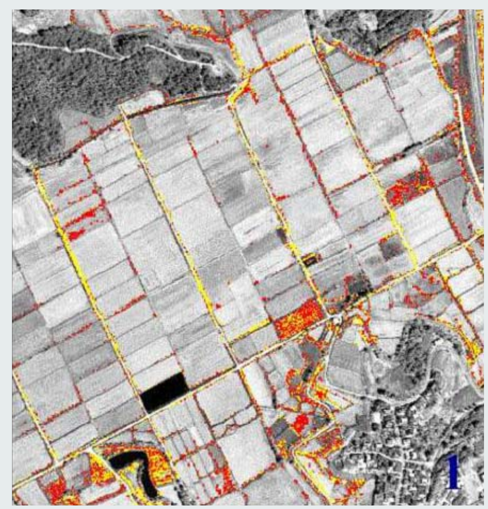


- NDVI and temperature were a strong indicator for malaria risk
- Precipitation is not a significant factor → Malaria risk is mainly due to irrigation as implied from the significant contribution from NDVI
- Average R^2 is 0.845
- Short malaria time series (<2 years) pose a challenge for modeling and prediction

MALARIA IN KOREA

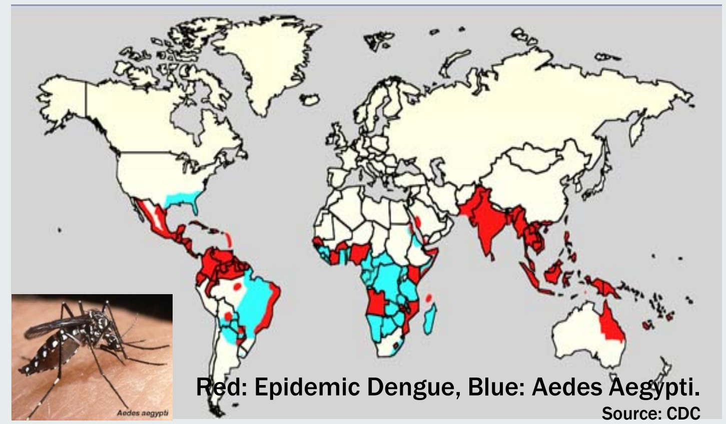
- Identification of potential larval habitat (irrigation and drainage ditches)
  - US Army's Camp Greaves in South Korea (N. Kyunggi Province)
  - 43 sample sites with predominant habitats of rice fields (26 sites) and ditches (13 sites)
  - Classification using pan-sharpened 1-m resolution IKONOS data on a 3.2 x 3.2 km test site



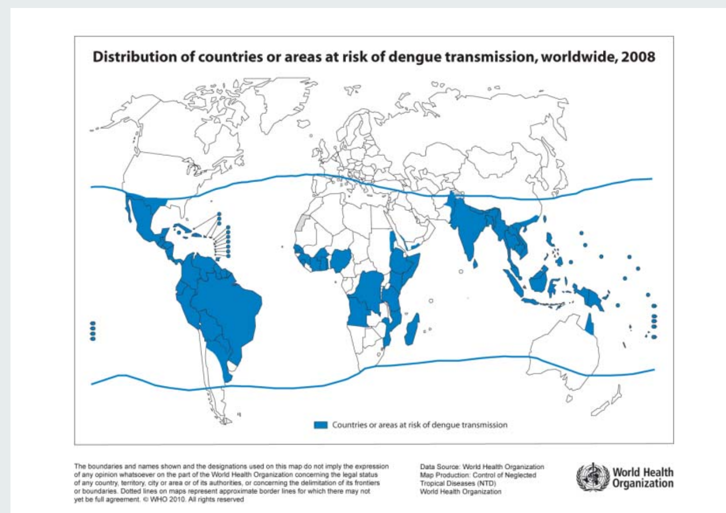


DENGUE

- Endemic in more than 110 countries
  - Tropical, subtropical, urban, peri-urban areas
- Annually infects 50 – 100 million people worldwide
- 12,500 – 25,000 deaths annually
- Symptoms: fever, headache, muscle and joint pains, and characteristic skin rash (similar to measles)
- Primarily transmitted by *Aedes* mosquitoes
  - Live between 35°N - 35°S latitude, >1000m elevation
- Four serotypes exist
  - Infection from one serotype may give lifelong immunity to that serotype, but only short-term to others
  - Secondary infection increases the severity risk

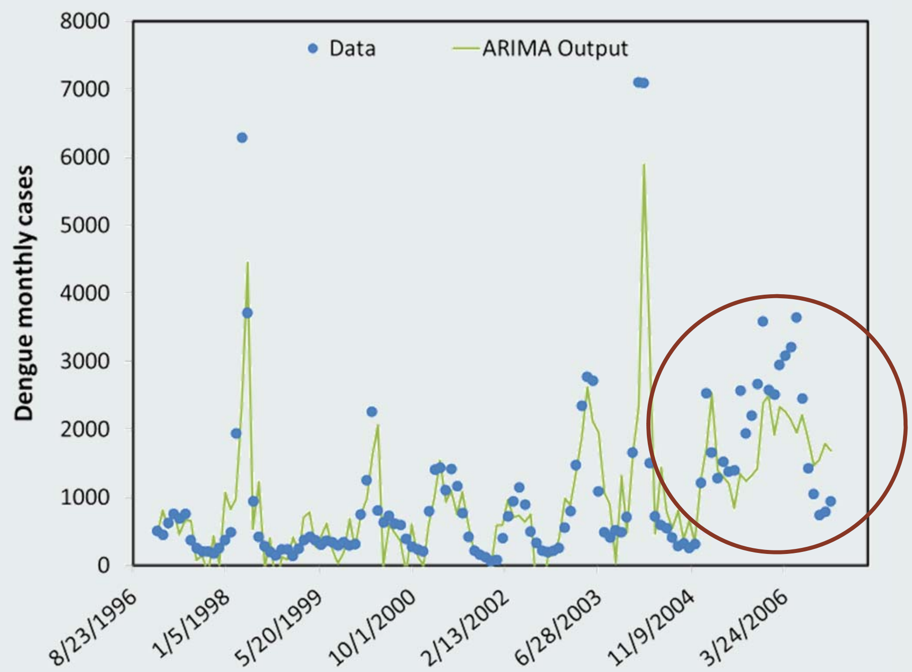


Red: Epidemic Dengue, Blue: Aedes Aegypti.
Source: CDC



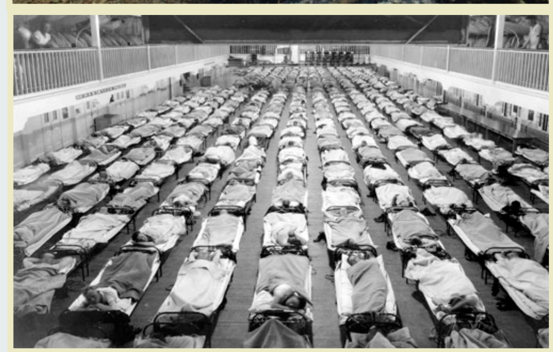
DENGUE IN INDONESIA

- Environmental variables used
  - Temperature, dew point, wind speed, TRMM, NDVI
- Modeling method
  - ARIMA – Auto Regressive Integrated Moving Average
  - Classical time series regression
  - Accounts for seasonality
- Result
  - Best-fit model uses TRMM and Dew Point as inputs
  - Peak timing can be modeled accurately up to year 2004
  - Vector control effort by the local government started in the early 2005



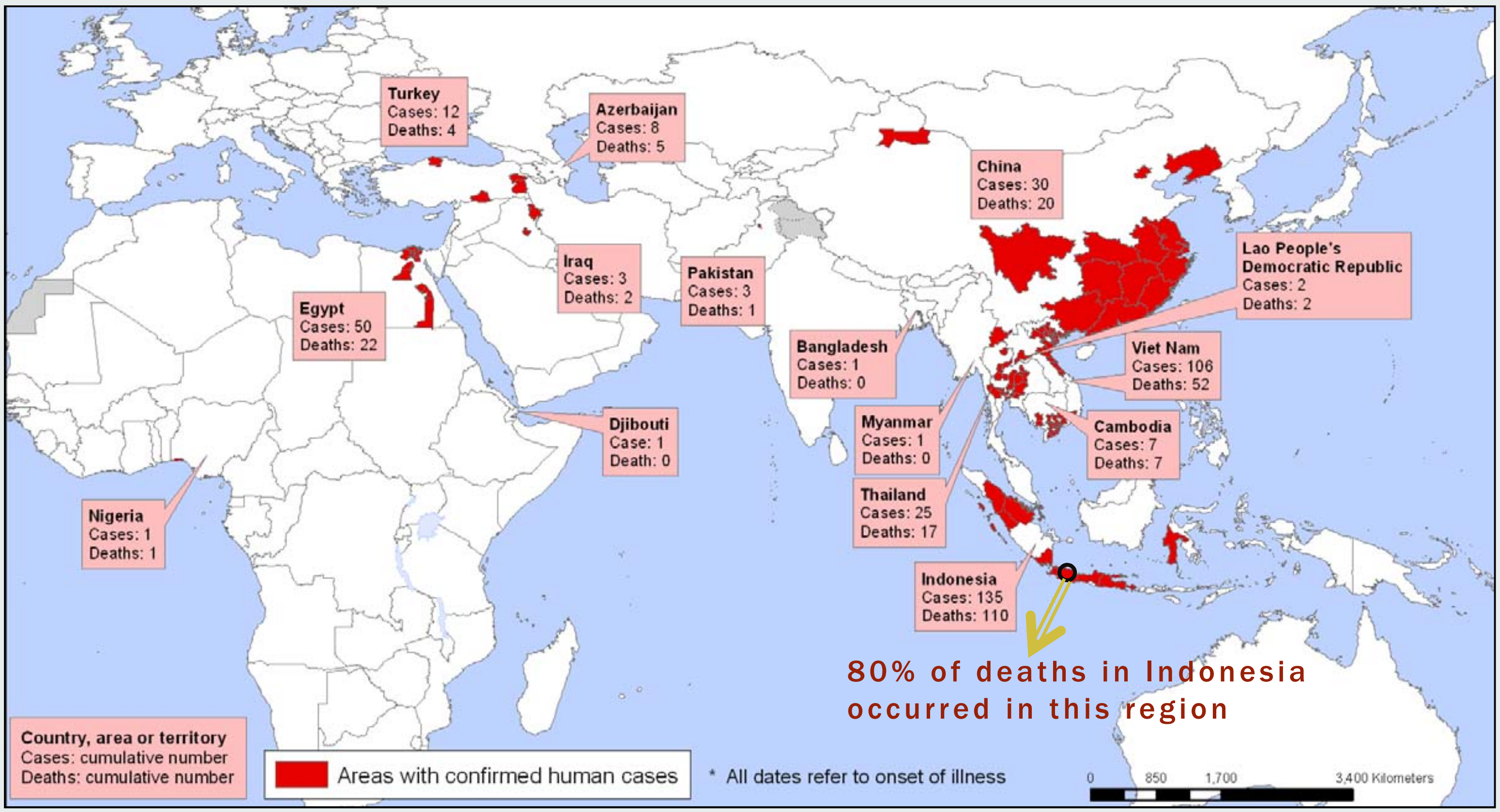
AVIAN INFLUENZA

- <u>The problem</u>
  - First appeared in Hong Kong in 1996-1997, HPAI has spread to approximately 60 countries. More than 250 million poultry were lost.
  - 35% of the human cases are in Indonesia. Worldwide the mortality rate is 53%, but 81% in Indonesia. In Indonesia, 80% of all fatal cases occurred in 3 adjacent provinces.
  - Co-infection of human and avian influenza in humans may produce deadly strains of viruses through genetic reassortment.
  - HPAI H5N1 was found in Delaware in 2004.
  - The risk of an H5, H7 or H9 pandemic is not reduced or replaced by the 2009 H1N1 pandemic.



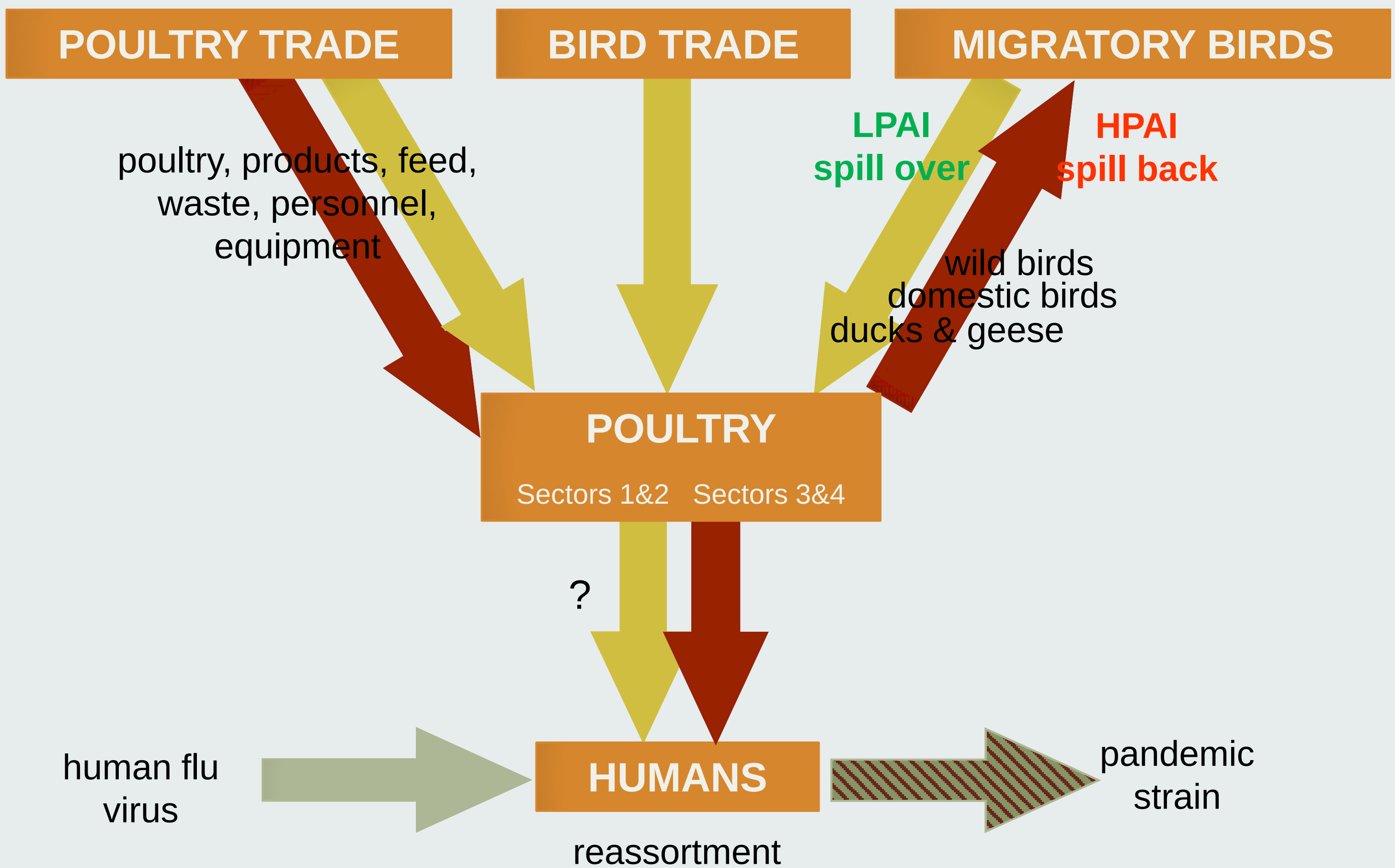
AVIAN INFLUENZA

Indonesia has 35% of the world's human cases with 81% mortality. For the rest of the world, mortality is 53%



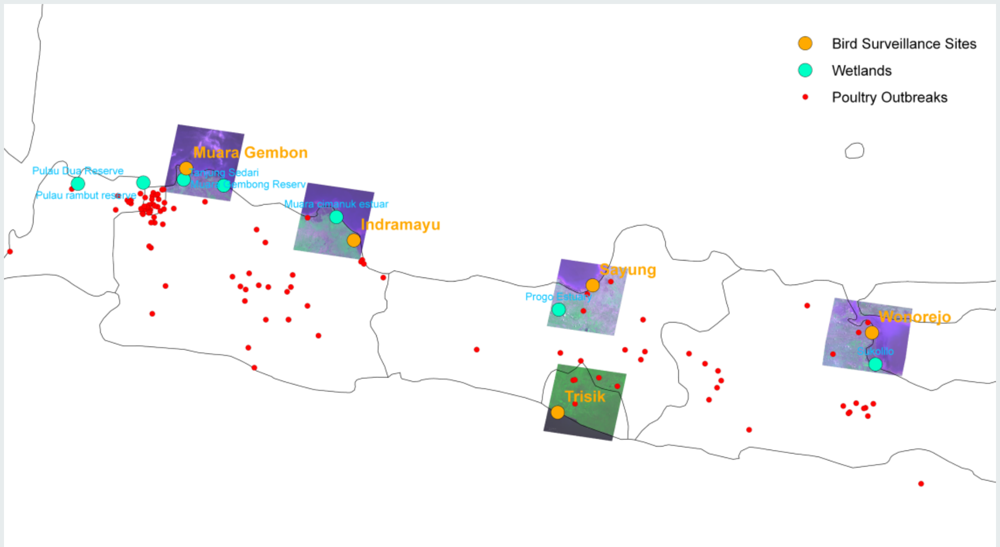
AVIAN INFLUENZA

- H5N1 Transmission Pathways



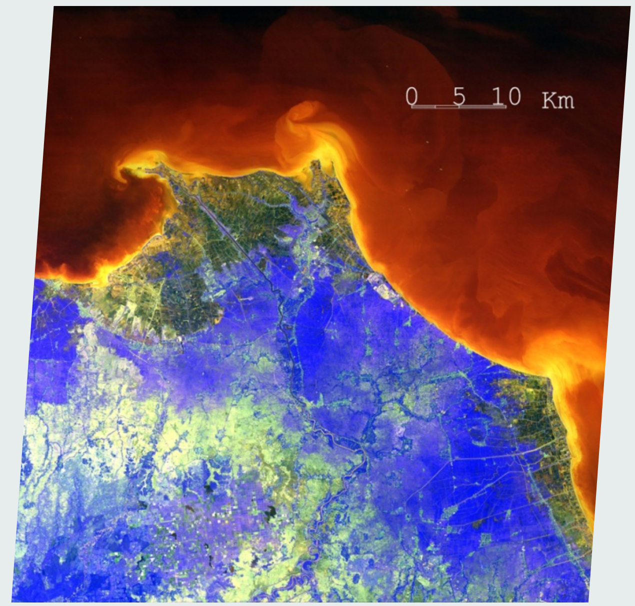
AVIAN INFLUENZA

- NAMRU-2 Bird surveillance sites on Java



- EU's & UK's Practice:
  - 3 km protection zone
  - 10 km surveillance zone
  - Larger restricted zone

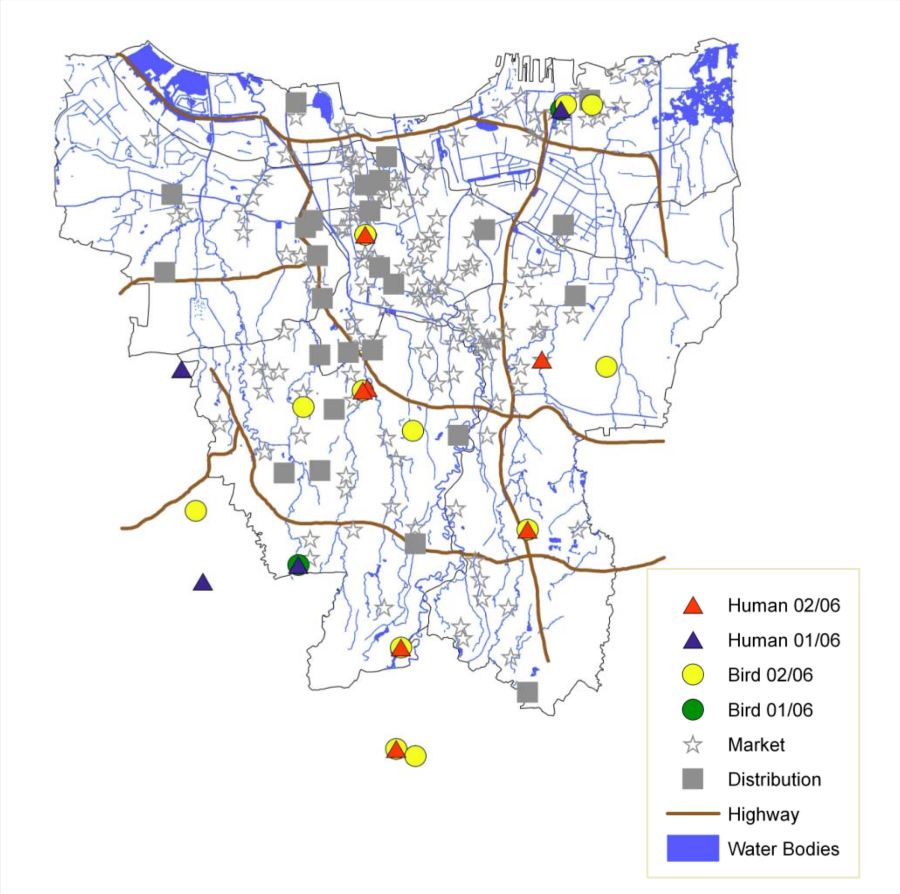
- Buffer zones can be established to limit the spread of H5N1 around wetlands and nearby farmlands



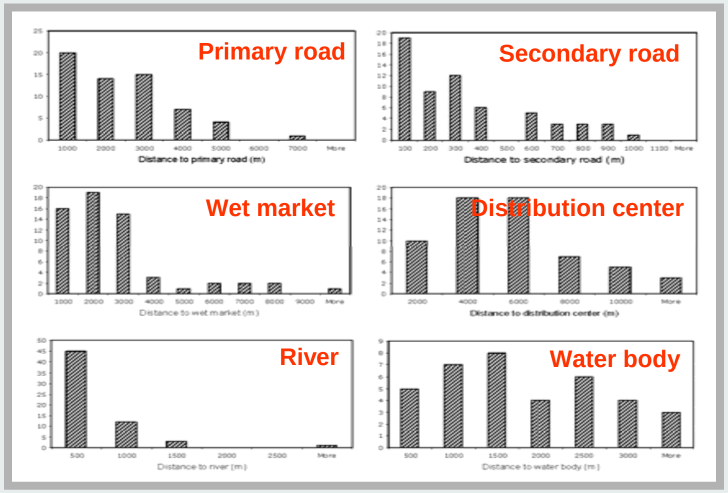
ASTER image showing NAMRU-2 bird surveillance site around *Muara Cimanuk* estuary

AVIAN INFLUENZA

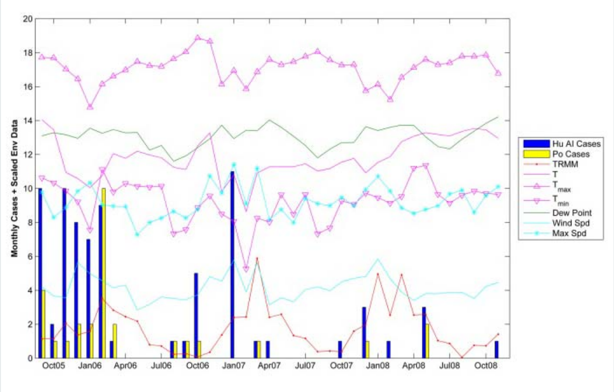
- Poultry and human outbreaks in Greater Jakarta



- Distance from outbreaks

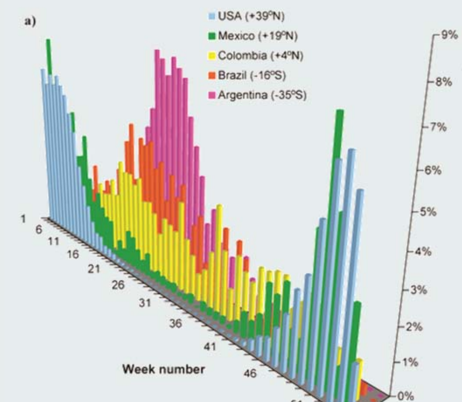


- Cases vs Meteorological factors

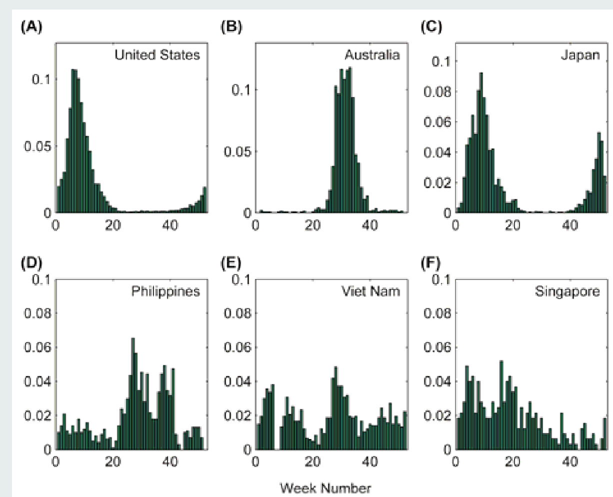


SEASONAL INFLUENZA

- Worldwide annual epidemic
  - Infects 5 – 20% of population with 500,000 deaths
- Economic burden in the US ~US$87.1billion
- Spatio-temporal pattern of epidemics vary with latitude
  - Role of environmental and climatic factors
- Temperate regions: distinct annual oscillation with winter peak
- Tropics: less distinct seasonality and often peak more than once a year



Source: Viboud et al., 2006

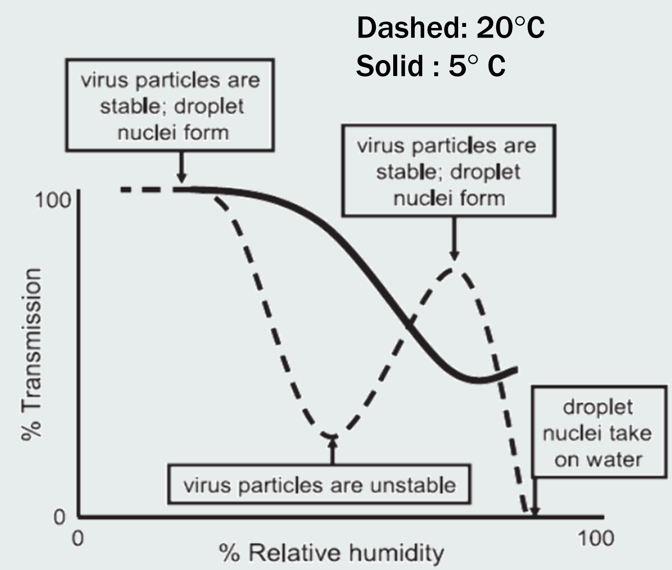


SEASONAL INFLUENZA

- Factors implicated in influenza

Influenza Process	Factors	Relationship
Virus Survivorship	Temperature	Inverse
	Humidity	Inverse
	Solar irradiance	Inverse
Transmission Efficiency	Temperature	Inverse
	Humidity	Inverse
	Vapor pressure	Inverse
	Rainfall	Proportional
	ENSO	Proportional
	Air travels and holidays	Proportional
Host susceptibility	Sunlight	Inverse
	Nutrition	Varies

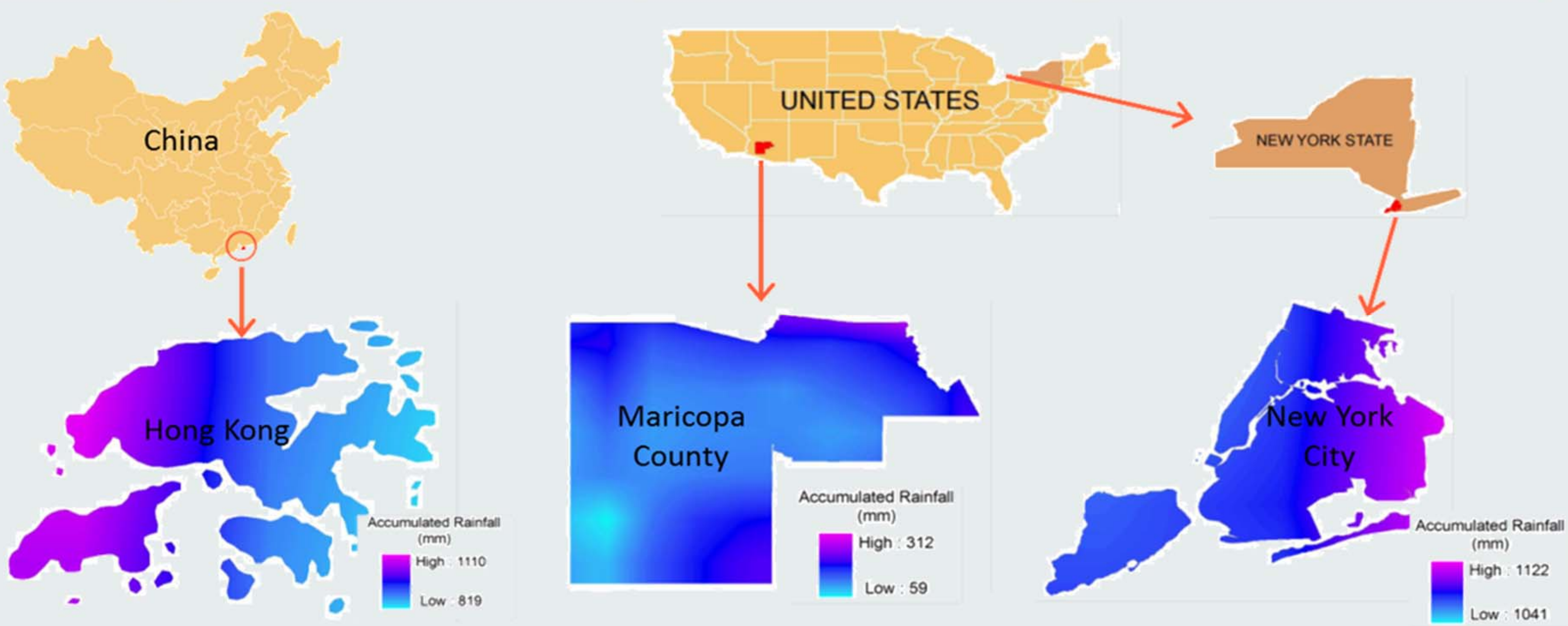
- *Ex Vivo* study showing efficient transmission at dry and cold condition *[Lowens et al., 2007]*
-



- High temperature (30°C) blocks aerosol transmission *but not contact transmission*

SEASONAL INFLUENZA

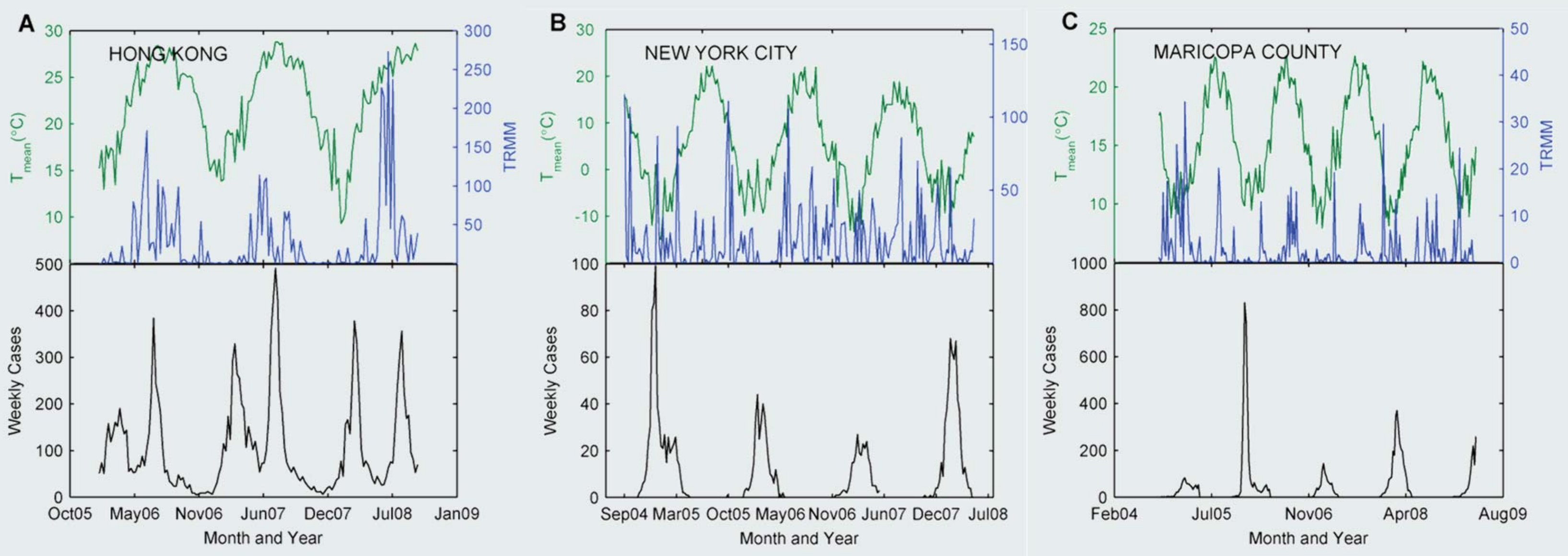
	Hong Kong, China	Maricopa County, AZ	New York City, NY
Center Lat.	22° N	33° N	40° N
Climate	Sub-Tropical	Sub-Tropical	Temperate
General Condition	Hot & humid during summer. Mild winter, average low of 6°C	Dry condition. Mean winter low is 5°C, and summer high is 41°C	Cold winter, average low of -2°C. Mean summer high is 29°C



SEASONAL INFLUENZA

DATA

- Weekly lab-confirmed influenza positive
- Daily environmental data were aggregated into weekly
- Satellite-derived data
  - TRMM 3B42
  - LST - MODIS
- Ground station data



SEASONAL INFLUENZA

- Several techniques were employed, including:

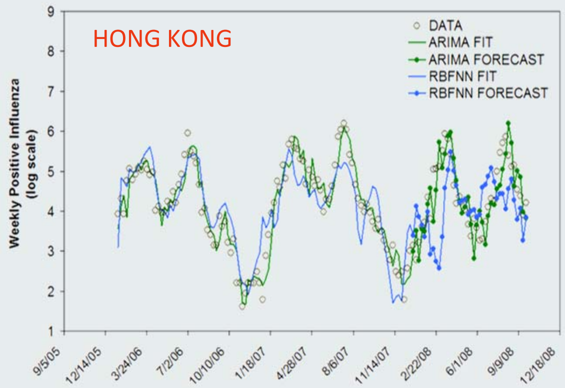
***ARIMA* (AutoRegressive Integrated Moving Average)**

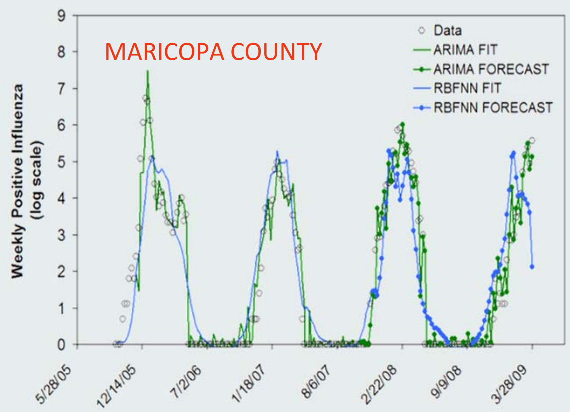
- Classical time series regression Accounts for autocorrelation and seasonality properties
- Climatic variables as covariates
- Previous week(s) count of influenza is included in the inputs
- Results published in PLoS ONE 5(3): 9450, 2010

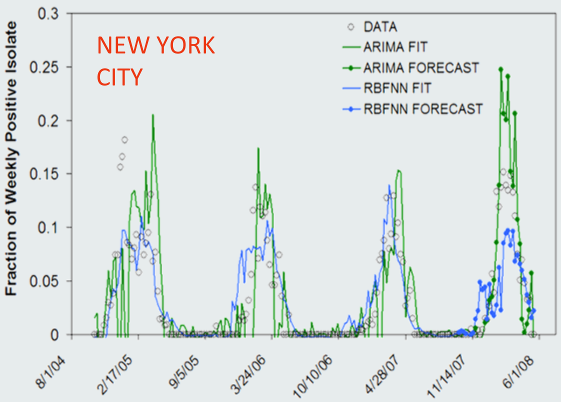
***Neural Network* (NN)**

- Artificial intelligence technique
- Widely applied for
  - approximating functions,
  - Classification, and
  - pattern recognition
- Takes into account nonlinear relationship
- Radial Basis Function NN with 3 nodes in the hidden layer
- Only climatic variables and their lags as inputs/predictors

SEASONAL INFLUENZA







- NN models show that ~60% of influenza variability in the US regions can be accounted by meteorological factors
- ARIMA model performs better for Hong Kong and Maricopa
  - Previous cases are needed
  - Suggests the role of contact transmission
- Temperature seems to be the common determinants for influenza in all regions

ACKNOWLEDGMENT

- NAMRU-2
- Wetlands International Indonesia Programme
- Cobbs Indonesia
- USDA APHIS
- WHO SEARO
- WRAIR
- AFRIMS
- Thailand Ministry of Public Health
- NDVECC
- Mahidol University, Faculty of Tropical Medicine
- Safi Najibullah – Formerly at National Malaria and Leishmaniasis Control Programme, Afghan Ministry of Public Health
- CDC Influenza Division

THANK YOU