Application of Satellite Data to One Health

Application of the One Health Approach to Global Health Centers
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We are One !
Satellite Data Sets

Sea Surface Temperature: 38 yrs.

Precipitation: 40 yrs.

Vegetation: 38 yrs.

Land Surface Temperature: 19 yrs.

Take Apart to Understand the coupling between different Earth Systems
El Niño Southern Oscillation (ENSO)

- Change, amplification, persistence

- Variations in weather/climate can re-organize VBD landscapes - shrink/expand habitats
- Expose pathogens, vectors, and pathogens to populations (human and animal)
- Result in cyclic/episodic patterns of particular VBDs
One Health Application: Rift Valley fever

- Rift Valley fever (RVF): acute viral disease that affects domestic animals (such as cattle, buffalo, sheep, goats, and camels)
- Kenya
  - Identified by Daubney et al in 1931, - a fatal epizootic of sheep on a farm north of Lake Naivasha
- RVF virus occurs in regions of eastern and southern Africa, but also in most countries of sub-Saharan Africa, Madagascar, Saudi Arabia and Yemen
- Impacts: Mortality and Abortion in Livestock, Trade, Humans: mild influenza like illness to severe hemorrhagic manifestations and hepatitis; retinitis (inflammation of the retina) and encephalitis (inflammation of the brain). (1% in humans, 80-100 in livestock infected)
- Vaccination of the animals at risk is the most important way of preventing infection in humans.
- Cross-over pathogen - national and international security, public health importance ( listed by USG agencies: DoD, USDA, DHA,CDC + WHO, OIE and FAO)
- Treatment – experimental drug ribavirin has been studied for its effectiveness against Rift Valley fever.
- No licensed vaccine or virus-killing medicine is available for human use
Where is the Beef?

Kenya meat exports to Europe banned
Story by JEFF OTIENO Nation Newspaper
Publication Date: 4/22/2008

Kenya has lost its beef export quota to Europe over its failure to control animal diseases. The 4,000 metric tonnes meat export per year quota has now been taken over by Botswana.

- 1977-1978: 600 deaths, 200,000 estimated cases
- 1997-1998: 478 deaths, ~89,000 estimated cases
- 2006-2007: 353 deaths, ~145,000 estimated cases
- 2007-2008: 240 deaths, 75,000 estimated cases
- Livestock cases ~ 100,000s
- OIE-World Organisation for Animal Health, Organisation (Mondiale de la santé animale) - imposes 3 year ban on livestock exports
- However, illegal cross border trade persists
- Quarantine - at port of trade Djibouti
- Trade Impact: $65 million 2006-2007 outbreak

- Importation/Introduction of RVF in the US directly – less likely – but more serious – decimation of the domestic beef-cattle industry ~$500 million to $1 Billion
- Disease in people – there is no US approved animal or human vaccine – only way to control it is through Mosquito control
- Could be introduced into US Wildlife population – likely deer population – everywhere in the country and become endemic in deer population – become a reservoir of the virus.
- Infection in mosquitoes – US mosquitoes (various Culex spp, some Aedes geographic range – throughout the country) can be infected with RVF and transmit the virus

- BioTerror Threat
  Britch and US Rift Valley fever Working Group, EID (2007)
  APHIS Risk assessment
95% of outbreaks during ENSO events
Why Climate / Weather and Environment?

- **Extreme high temperatures**: vector populations, mosquito survival; susceptibility to viruses; mosquito population growth rate, distribution, and seasonality; replication and extrinsic incubation period of a virus in the mosquito; and virus transmission patterns and seasonality.
- **Extreme precipitation**: increase mosquito larval habitats or create new habitats, increase in mosquito vector populations.
- **Low rainfall or drought**: change habitats by concentrating water into small pools, potentially increasing the proportion of container breeding mosquito vectors.
- **Impacts on the vertebrate hosts of disease vector mosquitoes**.
- **Increased rain**: increase vegetation, habitat, food availability, and thus survival of vertebrate host populations.
- **Decreased rain**: reduce or eliminate food resources forcing vectors and vertebrate hosts into human settlements, increasing vector-human contact.

Reisen, Epidemiology of Vector-Borne Diseases
Rainfall, Flooding and Vector Populations

Linthicum et al, 1985
long term records — derive climatology = BASELINE

calculate anomalies: $z = X_a - X_m(1\ldots n)$

$p, v, t$

$p$, $v$, $t$

$p$, $v$, $t$

persistence of anomalies (-/+ ) can inform/proxy for appropriate conditions for disease vectors to flourish

Inputs to Risk Models
Early Warning Implementation

RVF – epizootics occur under **favorable** and **persistent** eco-climatic conditions.

Can be mapped – either as rainfall or vegetation – through NDVI integrates all the required conditions.

**Algorithm:**
- Mapping of potential epizootic areas — based on **literature survey** and climate variable thresholding= **potential epizootic area mask (PEAM)**
- NDVI anomaly calculation -- + anomalies > 0.025 threshold (desert calibration) over 3 month period
  - Persistently + anomalies must have three month mean > 0.1
- All “pixels” that meet this criteria and are within the PEAM are mapped to have conditions necessary for the occurrence of RVF activity.

**Baseline Layers:** Livestock (Cattle, Sheep, Goats and Camels), Human Population density.

Anyamba et al, PERS, 2002
Risk Mapping

evaluate persistence (+ anomalies) through time
Global Emerging Infections Surveillance (GEIS) Products

Rainfall Anomaly February - April 2018

Summary RVF Risk, May-September 2018

- Red: RVF risk areas, humans and livestock present
- Orange: RVF potential risk areas, humans and livestock absent
- Green: Documented RVF epizootic areas (epidemic in animal populations in the past)

RVF Outbreak Sites
Risk Map + Outbreaks

E. Africa: 70%
Sudan: 50%
S. Africa: 30%

Anyamba et al, PNAS, 2009
Anyamba et al, AJTMH, 2010
Linthicum et al, ARE 2016
Early Warning vs. Outbreak Timing

Gap can be exploited for prevention and control measures

Anyamba et al, AJTMH, 2010
Moving The Response Line

Rift valley fever outbreak alert and response

- **Animal outbreak**
- **Human outbreak**

- **Forecasting Readiness**
- **Early Detection**
- **Rapid Response**
- **Control Opportunity**

Epidemic and Pandemic Alert and Response

**World Health Organization**
Information Sharing and Distribution

WHO

Human Health

FAO

Livestock Health

OIE

Livestock Trade

Combatant Commands, NCMI, US Dept. of State, Interagency PPFS&T WG, DHS-NBIC, USAID, NOAA, USDA-APHIS, AU,
Concerned Ministries of Health & Agriculture, Country Vector Control Agencies
~25 Recipients

One Health Approach
Supporting Surveillance


- Custom navigable Google.kmz format maps provided to DoD (USAMRU-K, NMIC), other USG Agencies (USDA/ARS) and international collaborators (WHO, FAO, OIE) and others as needed to enable early surveillance and detection

- Monthly Combatant Command (CoCom) Reports
RVF Early Warning: Impact

2006-2007: Classification - Severe disease ~80% mortality: No Vaccination

Aedes mcintoshi RVF reservoir mosquitoes, at Sukari Farm, Nairobi, Kenya (Dr. Linthicum, March 2016)

2015-2016: No livestock disease/mortality despite the emergence of vectors: Vaccination undertaken
Rift Valley Fever Virus Project:
One Health Project
Livestock, Wildlife, Human Surveillance + Laboratory Analysis
Climate Extremes and VBD Patterns

Anyamba et al, PLOS One, 2014
X-Factor

GLOBALization
Increasing Travel and Trade

Hufnagel et al, 2004
Pathways of Pathogen Transport e.g. WNV, Chikungunya, Ebola

Extremes in either direction (+/-) of precipitation/temperature have significant implications for disease vectors and pathogen emergence and spread.

Magnitude of ENSO influence on precipitation/temperature cannot be currently predicted for any specific region — rely on average history and patterns.

Timing of event and emergence disease can be exploited (GAP) in to undertake vector control and preparedness measures.

Need to invest in early ground surveillance and the use of rapid field diagnostic capabilities for vector identification and virus isolation.

Need georeferenced outbreak information rather than country reports — important for model building.

Large amounts of remote sensed data are available to be exploited to address a broad range of On Health & VBD issues.
Other: FAO, OIE, WHO, partner governments
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