Emerging infectious diseases in a new climate

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IMED, Vienna, 12 Nov 2018
Climate and infectious diseases make headlines

The Guardian

Tropical disease outbreaks are growing threat in Europe as temperatures rise

After West Nile virus kills 22 people in heatwave, experts warn of more mosquito and tick-borne diseases due to climate change

The Telegraph

Heavy rainfall and soaring temperatures behind spike in mosquito-borne fever in southern Europe

The Lancet Infectious Diseases

West Nile virus spreads in Europe

Europe has seen more than 1,600 cases of West Nile virus this year. Confirmed and probable cases of human West Nile virus infections, 2018

Source: The Telegraph
Climate services for health

• Transform climate information into relevant, usable decision-support tools.

• Manage the risks of environmental change.

Key components
• Partnership, Research, Product development & delivery, Evaluation, Capacity building.

• Co-developed by health and climate professionals.
From global observations to local interventions

Source: The Economist
Early warning and response systems

• **Early warning systems** based on climate information can help to implement timely control measures.

• **Seasonal climate forecasts** provide an opportunity to anticipate epidemics several months in advance.

• **Bayesian model framework** used to make probabilistic statements about future disease risk (e.g. probability of an epidemic during a mass gathering or natural disaster)?

• Cases studies: **Brazil, Ecuador** and **Barbados**
Towards an early warning system for dengue in Brazil

Formulate
Develop
Apply
Evaluate
Probabilistic dengue early warning

- Early warning framework applied to predict dengue risk for the World Cup in Brazil.
- Category boundaries: 100 and 300 cases per 100,000 inhabitants.

Lowe et al., 2014, *Lancet Infect Dis*
Probability of observing correct category

Lowe et al., 2016, eLife
In Feb, 2016, intense rainfall combined with high tides, causing the worst flooding in Machala, Ecuador since the 1997-1998 El Niño.
Climate and dengue associations

Cooler and drier than usual \(\rightarrow\) less dengue

Warmer and wetter than usual \(\rightarrow\) more dengue

Lowe et al., 2017 Lancet Planet Health
Current practice: average over last 5 years

Mean and 95% upper CI for previous five years in Machala.
In March 2016, 85% chance of exceeding threshold of 95% upper CI for previous five years.
Peak occurred earlier than expected

Timing: climate forecasts
Magnitude: correct misreporting

Lowe et al., 2017, Lancet Planet Health
The Caribbean region is facing a major crisis of co-occurring epidemics of dengue, chikungunya and Zika viruses.

An increase incidence of dengue suspected in Barbados following drought events.
We used distributed lag non-linear models (Gasparrini, 2013) coupled with a Bayesian hierarchal model (Lowe et al, 2017) to understand exposure-lag response associations between dengue, temperature, drought and rainfall.
Exposure-lag-response associations

Exceptionally wet

Exceptionally dry

Warmer

Cooler

Short lagLong lag

Short lagLong lag

Lowe et al., 2018 PLOS Medicine
Lag response for extreme climate scenarios

Greatest relative risk following dry (~5 month lag) and wet (<1 month lag) periods and warmer months (~2 month lag).

Standardised precipitation index

- SPI = −2.5 (Exceptionally dry)
- SPI = 2.5 (Exceptionally wet)

Minimum temperature

- Tmin = 21.5 deg C
- Tmin = 25.5 deg C
Outbreak detection using cross-validation

Moving outbreak threshold 75\textsuperscript{th} percentile excluding year for which prediction valid.
Probability of exceeding outbreak threshold

- **Lowe et al., 2018 PLOS Medicine**

- **Probability trigger threshold of 30%**

- **Outbreak occurred**
Sensitivity and specificity of exceeding threshold

<table>
<thead>
<tr>
<th>Performance measures</th>
<th>Final model</th>
<th>Baseline model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area under ROC curve</td>
<td>0.9 (0.85, 0.94)</td>
<td>0.75 (0.71, 0.79)</td>
</tr>
<tr>
<td>Probability trigger threshold</td>
<td>0.3</td>
<td>0.27</td>
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<tr>
<td>Hit rate</td>
<td>0.9 (0.82, 0.97)</td>
<td>0.79 (0.69, 0.9)</td>
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<tr>
<td>False alarm rate</td>
<td>0.31 (0.22, 0.39)</td>
<td>0.57 (0.51, 0.63)</td>
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<tr>
<td>Proportion correct</td>
<td>0.86 (0.81, 0.91)</td>
<td>0.64 (0.58, 0.71)</td>
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</table>

The selected model produced **more hits** and **less false alarms** than a null model accounting only for seasonality.
How can we transition from a theoretical to operational prediction framework for mosquito-transmitted diseases?
Seasonal climate forecasts issued in Feb, valid for Mar-May, combined with surveillance data at time of forecast (Mar) to predict dengue risk in June (i.e. 3 month lead-time).

Lowe et al., 2014, Lancet Infect Dis
Predict season using multi-lead climate forecasts

Ensemble climate forecasts (24 members) used to produce probabilistic dengue forecasts for Machala, Ecuador 1-11 months ahead.

Lowe et al., 2017 Lancet Planet Health
## Approaching a target: multiple lags and leads

<table>
<thead>
<tr>
<th>Lead-time</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
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<tbody>
<tr>
<td>3 months (issued in July)</td>
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<td>2 months (updated in August)</td>
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<td>1 month (updated in September)</td>
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</tbody>
</table>

**Forecast climate**

**Observed climate**

**Time Period**

Lowe et al., 2018 *PLOS Medicine*
What did we find, why is it important?

Findings

- Drought periods followed by warm & wet conditions could provide optimum conditions for imminent outbreaks.
- Model predicted months with dengue outbreaks v non-outbreaks in most years, but last 2 years complicated by CHIKV & ZIKV introductions.

Impact

- Climate change contributing to more intense / frequent droughts and hurricanes in the Caribbean region.
- Basis of a Caribbean-wide early warning system for dengue, Zika and other mosquito-transmitted diseases.

Source: https://rcc.cimh.edu.bb/caribbean-health-climatic-bulletin/
Thank you for your attention, questions?

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Nonlinear and delayed impacts of climate on dengue risk in Barbados: A modelling study

Rachel Lowe, Antonio Gasparini, Cédric J. Van Meerbeeck, Catherine A. Lippi, Roché Mahon, Adrian R. Trotman, Leslie Rollock, Avery Q. J. Hinds, Sadie J. Ryan, Anna M. Stewart-Ibarra