Climate Services for Public Health: the use of El Niño and other climate modes for arbovirus forecasting in Latin America and the Caribbean

IV International Conference on El Niño Southern Oscillation

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Octubre, 2018
Climate services for health

• Partnership
• Research
• Product development & delivery
• Evaluation
• Capacity building
• Co-developed by health and climate professionals.

Borbór-Cordova et al. Cases Study 5c
Lowe et al. Dengue EWS
Lowe et al. Capacity Building
Climate forecasts for health risk management

Courtesy: J. Shumake-Guillemot, WHO/WMO
Dengue fever: genus \textit{flavivirus}.

- Four serotypes of the virus (DENV1-4).
- Infection from one serotype results in immunity to that serotype. Infection with a second serotype results in more severe disease.
- Dengue vaccine (Sanofi Pasteur) with limited efficacy available in some countries.
- Disease ranges from mild to severe shock, hemorrhage, death.
- Current estimates of apparent DENV infection in Latin America range from 1.5 million to 13.3 million cases per year.

Chikungunya: genus \textit{alphavirus}.

- No vaccine yet.
- Disease causes febrile illness similar to dengue and long-term joint pain.
- First cases reported in the Americas in 2013.
- Over 2 million cases to date.
Zika fever: genus *flavivirus*

- No vaccine yet.
- Disease causes febrile illness similar to dengue and can result in neurological complications including Guillain-Barré syndrome and congenital syndrome.
- First cases reported in Brazil in 2015. To date, 753,703 suspected and confirmed autochthonous cases of ZIKV have been reported from 48 countries and territories in the Americas.
- Zika can also be transmitted by sex, from mother to child during pregnancy, by blood transfusion, and laboratory transmission

**Sexually transmitted zika:**

Zika virus persists longer in semen than in other bodily fluids. Detection of Zika virus RNA in semen has been reported up to 188 days after illness onset.

Mosquitos son sensibles a la temperatura

- Tiempo de vida
- Taza de desarrollo
- Taza de picadura

- Probabilidad de infección
- Sobrevivencia de huevo a adulto
- Periodo de incubación extrínseca

Mordecai et al 2017 PLOS NTD
*Aedes aegypti* is sensitive to climate conditions

- Temperature affects mosquito physiology.
  - Warmer temperatures (up to an optimum) increase biting rates, faster larval development, shorter length of the Extrinsic Incubation Period (EIP), shorter gonotrophic cycle, faster virus replication in the mosquito.

- Rainfall is more complicated.
  - More rainfall can increase containers outdoors filled with rain water = more larval habitat
  - Less rainfall can increase water storage containers filled with tap water = more larval habitat
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: **Ecuador, Brazil, and Barbados**
CASE STUDY: DENGUE RESEARCH IN ECUADOR

Photo credit: Dany Krom 2016
DENGUE RESEARCH IN MACHALA, ECUADOR
Active Surveillance, serotypes and risk factors

Photo credit: Dany Krom 2016
DENGUE RESEARCH IN MACHALA ECUADOR
Entomological Surveillance

https://insectcop.net/aedes-aegypti-mosquitoes-in-history/
In Feb, 2016, intense rainfall combined with high tides, causing the worst flooding in Machala, Ecuador since the 1997-1998 El Niño.
El Oro Province
1995-2010

Dengue

Local climate

ENSO

(Stewart Ibarra & Lowe, 2013, AJTMH)
Lagged model parameters

Climate:
Oceanic Niño Index (3 month lag)
Minimum temperature (2 month lag)
Rainfall (1 month lag)

Non-climate:
# of serotypes circulating in the country (3 month lag)
Mosquito infestation (House Index) (1 month lag)
*Vector control effort was also tested

Analysis: 2 models (1995-2010, 2001-2010)
Generalized linear mixed model (negative binomial) with temporally auto-correlated random effects (monthly, yearly)
Climate & nonclimate factors drive epidemics
(Model adequacy results 2001-2010)

<table>
<thead>
<tr>
<th>Model</th>
<th>$\log \rho_t$</th>
<th>DIC</th>
<th>$R^2_{LR}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base (Seasonal)</td>
<td>$\alpha + \beta_{t(\xi)}$</td>
<td>1313.18</td>
<td>0.44</td>
</tr>
<tr>
<td>Climate effects</td>
<td>$\alpha + \beta_{t(\xi)} + \sum \gamma x_{jt}$</td>
<td>1305.28</td>
<td>0.49</td>
</tr>
<tr>
<td>Non-climate effects</td>
<td>$\alpha + \beta_{t(\xi)} + \sum \varepsilon z_{jt}$</td>
<td>1286.63</td>
<td>0.56</td>
</tr>
<tr>
<td>Climate and non-climate effects</td>
<td>$\alpha + \beta_{t(\xi)} + \sum \gamma x_{jt} + \sum \varepsilon z_{jt}$</td>
<td>1276.67</td>
<td>0.61</td>
</tr>
<tr>
<td>Climate, random and non-climate effects</td>
<td>$\alpha + \beta_{t(\xi)} + \sum \gamma x_{jt} + \delta_{T(\xi)} + \sum \varepsilon z_{jt}$</td>
<td>1245.25</td>
<td>0.72</td>
</tr>
</tbody>
</table>
2001-2010 best fit model
(not including yearly random effects)
Climate and dengue associations

- Cooler and drier than usual → less dengue
- Warmer and wetter than usual → more dengue

Lowe et al., 2017, Lancet Planet Health

Ensemble precipitation and min. temperature forecasts (24 members) for Jan – Oct 2016
Current practice: average over last 5 years

Mean and 95% upper CI for previous five years in Machala

Climate-driven dengue forecast, Machala 2016

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
Active surveillance data improves benchmark estimates and forecasts

Correct for misreporting due to introduction of chikungunya in 2015

- ~70% of dengue cases actually chikungunya in summer 2015
- Misreporting doubles the estimate of seasonal averages
Climate and Non-Climate Drivers of Dengue Epidemics in Southern Coastal Ecuador

Anna M. Stewart-Ibarra* and Rachel Lowe

RESEARCH ARTICLE

Spatiotemporal clustering, climate periodicity, and social-ecological risk factors for dengue during an outbreak in Machala, Ecuador, in 2010

Anna M Stewart-Ibarra1, Ángel G Muñoz2,3, Sadie J Ryan1,4,5, Efraín Beltrán Ayala6,7, Mercy J Borbor-Cordova8, Julia L Finkelstein9,10, Raúl Mejía11, Tania Ordoñez6, G Cristina Recalde-Corneoi11 and Keytia Rivero11

Climate services for health: predicting the evolution of the 2016 dengue season in Machala, Ecuador

Rachel Lowe, Anna M Stewart-Ibarra, Desislava Petrova, Markel García-Diez, Mercy J Borbor-Cordova, Raúl Mejía, Mary Regato, Xavier Rodó

Summary

Background El Niño and its effect on local meteorological conditions potentially influences interannual variability in dengue transmission in southern coastal Ecuador. The Oro province is a key dengue surveillance site, due to the high burden of dengue, seasonal transmission, co-circulation of all four dengue serotypes, and the recent introduction of chikungunya and Zika. In this study, we used climate forecasts to predict the evolution of the 2016 dengue season in the city of Machala, following one of the strongest El Niño events on record.

Stakeholder Analysis & Risk Perception

Knowledge, attitudes, and practices regarding dengue infection among public sector healthcare providers in Machala, Ecuador

Andrew S. Hanel1, Efraín Beltrán Ayala2,3, Mercy J. Borbor-Cordova4, Abigail G. Fessler5, Julia L. Finkelstein6, Roberto Xavier Robalino Espinoza7, Sadie J. Ryan8,9 and Anna M. Stewart-Ibarra10

RESEARCH ARTICLE

A social-ecological analysis of community perceptions of dengue fever and Aedes aegypti in Machala, Ecuador

Anna M Stewart-Ibarra11, Valente A Luzadis1, Mercy J Borbor Cordova3, Mercy Silva4, Tania Ordoñez6, Efraín Beltrán Ayala6 and Sadie J Ryan8,9

Article

Household Dengue Prevention Interventions, Expenditures, and Barriers to Aedes aegypti Control in Machala, Ecuador

Naveed Heydari1,2, David A. Larsen3, Marco Neira4, Efraín Beltrán Ayala5, Prisillas Fernandez5, Jefferson Adrian6, Rosemary Rochford1 and Anna M. Stewart-Ibarra2
Case of Brazil: 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
Towards an early warning system for dengue in Brazil

Spatio-temporal modelling of climate-sensitive disease risk: Towards an early warning system for dengue in Brazil

The development of an early warning system for climate-sensitive disease risk with a focus on dengue epidemics in Southeast Brazil

Dengue outlook for the World Cup in Brazil: an early warning model framework driven by real-time seasonal climate forecasts

Evaluating probabilistic dengue risk forecasts from a prototype early warning system for Brazil
Potential climate service?

• First example of a climate service for public health, ahead of a mass gathering.

• Most useful before peak dengue season each year to control potentially explosive dengue epidemics.

• The operational use of seasonal climate forecasts in routine dengue early warnings now a priority for the Brazilian Climate and Health Observatory.
Drought, water storage and arboviruses in Barbados

• 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.
## Capacity Building for Health Sector to implement an EWS for vector-borne diseases in the Caribbean

<table>
<thead>
<tr>
<th>Capacity Building for Health Sector</th>
<th>Strengths</th>
<th>Weaknesses</th>
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<tbody>
<tr>
<td>Capacity Building for Health Sector</td>
<td>Availability of financial resources</td>
<td></td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Geographic information system (GIS) expertise</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Statistical and/or modeling expertise</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Computer programming expertise</td>
<td></td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Effective public health messaging/education</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Effective vector and disease surveillance</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>General knowledge of climate and VBDs</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Computing hardware to operate the early warning system</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Prior experience with EWSs or other climate-sensitive systems</td>
<td></td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Strong coordination with other sectors</td>
<td></td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Strong leadership</td>
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<tr>
<td>Capacity Building for Health Sector</td>
<td>Efficient management/distribution of financial resources</td>
<td></td>
</tr>
<tr>
<td>Capacity Building for Health Sector</td>
<td>Mobilization and coordination with local authorities</td>
<td></td>
</tr>
<tr>
<td>Capacity Building for Health Sector</td>
<td>Organizational structure</td>
<td></td>
</tr>
</tbody>
</table>
A subseasonal-to-seasonal (S2S) multi-model forecast system for Aedes-borne diseases in the US

**Ento-epidemiological parameters**

**Environmental information (obs, fcsts)**

**R₀ models**

**Multi-model calibrated system**

**Outcome:** monitor and forecast system for environmental suitability (past or future)

(Past or future date)

- Multiple validated basic reproduction number (R₀) models for Aedes-borne diseases
- System uses both ento-epidemiological parameters and climate information (observed or forecast) to estimate past, present and future (from weeks to a few months) environmental suitability.

Seasonal *climate* forecast: NMME

Sub-seasonal climate forecasts: S2S Database/NOAA’s SubX

[Muñoz et al., 2016, 2017a,b, 2018]
Sensitivity Analysis and S2S Skill Assessment

Temperature dependence of $R_0$ for *Ae. aegypti* and *Ae. albopictus* using laboratory data and multiple models. (Mordecai et al., 2017)

Seasonal skill for the environmental suitability of transmission (as measured by $R_0$) of Aedes-borne diseases in Latin America and the Caribbean. The US maps are being calculated in a new NOAA IRAP2 funded project. Skill metric is 2AFC (in %). Values above 50% are better than climatology, and vice versa. After Muñoz et al. (in prep.)
CLIMATE SERVICES FOR HEALTH

- Health Risk Assessment
  - Nutrition
  - Air Quality
  - Water & Sanitation

- Integrated Monitoring & Surveillance
  - Vector borne disease control
  - Vector control surveillance
  - Early Warning Systems

- Emergency Health Risks
  - Disaster Management
  - Humanitarian Aid
  - Early Warning Systems

Mainstream Health operation with potential for Climate Services

- Communication and Partnership
- Research and Co-production
- Capacity Building
FINAL REMARKS

• It needs the political will of the sector or final users.

• It is necessary to establish protocols to data sharing and spaces for interdisciplinary and inter-institutional dialogue (forums)

• Creation / strengthening of capacities between both sectors (2 tracks) is important joint work.

• Providing scientific evidence of the different effects of weather / climate on different diseases is a necessary step and is already being made.

• Translate models into useful operational tools for public health sector, which reflect the local reality.

• To consider the National Plans for Adaptation to Climate Change as an opportunity to strengthen climate services working at different time and future scenarios.
THANK YOU!

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