# Modelling the impact of environmental change on infectious diseases

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# Environmental change and health impacts

#### **Global Framework for climate services**

- Transform climate information into relevant, usable decisionsupport tools.
- Manage the risks of environmental change.

#### **Key components**

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



Lowe *et al*. Dengue EWS Lowe *et al*. Capacity Building



### From global observations to local interventions



The Economist



3

### Early warning and response systems

- Early warning systems that account for multiple disease risk factors 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)?



Time



# **Dengue in Brazil**

- Model framework developed in collaboration with European-Brazilian climate and health institutions.
- **Data** (dengue, climate, cartographic, demographic, socio-economic) to formulate model, produce probabilistic dengue predictions for >550 microregions.
- Optimum trigger alert thresholds determined for scenarios of medium-risk and high-risk of dengue, according to incidence alert levels defined by the Ministry of Health.



TODOS CONT

Integrated: Prob. of most likely precip, tercile (%)

# Model framework



Problem lack of data to model disease system

**Solution** Bayesian hierarchical mixed model - add extra level uncertainty via random effects



Amazon

3 -1.0

### Probabilistic dengue forecast



Dengue risk forecast South East Brazil during epidemic February-April 2008. Category boundaries: 100 and 300 cases per 100,000 inhabitants.

LONDON SCHOOL of HYGIENE STROPICAL MEDICINE

Lowe et al., 2013, Stat Med

### Real-time dengue forecast for Brazil





- Early warning framework applied to predict dengue risk 3 months ahead of World Cup in Brazil.
- Category boundaries: 100 (medium risk) and 300 (high risk) cases per 100,000 inhabitants.



#### Lowe et al., 2014, Lancet Infect Dis

# Policy and outreach implications

- Complimented the national dengue control programme World Cup action plan.
- Results disseminated to the general public & travellers (BBC, NHS, ECDC risk assessments).
- Case study in WHO/WMO and UNISDR publications.



### Probability of observing correct category





Lowe et al., 2016, eLife

# Comparison of forecast to null model



Comparison of hit rate and false alarm rate for forecast model (blue) and seasonal average null model (orange) for June 2000-2014.

#### 2014 event

hit rate: 57% (33%)

false alarm rate (type I error rate): 23% (13%)

Lowe et al., 2016, eLife

miss rate (type II error rate): 43% (67%)



### From evidence to application to evaluation



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# Dengue and other arboviruses in southern costal Ecuador

- El Oro key arbovirus surveillance site
  - high burden of dengue
  - seasonal transmission (hot, rainy season)
  - co-circulation DENV1-4
  - recent introduction of CHIKV & ZIKV
- DENV epidemics associated with El Niño climate events
- Local social-ecological risk factors
  - poor housing conditions
  - interruptions in the piped water supply
  - water storage behaviour





# El Niño and dengue in Ecuador

- El Niño a robust predictor of dengue outbreaks in El Oro province.
- Seasonal climate forecasts more skillful during El Niño events.
- Forecasts of temperature, rainfall and El Niño could provide dengue early warnings.



#### El Niño and rainfall association (JFM, 2 mon lag)





Stewart-Ibarra & Lowe, 2013, AJTMH

On February 26, 2016, over 170 mm of rain fell in <del>10</del> hours, and coincided with high tides, causing the worst flooding since the 1997-1998 El Niño.

### Climate and dengue data and model



Cooler and drier than usual ightarrow less dengue

Warmer and wetter than usual  $\rightarrow$  more dengue

 $y_t \sim NegBin(μ_t, κ)$ 

 $\log(\mu_t) = \log(p) + \log(r_t)$ 



Relative risk Annual Climate Inter-annual cycle variables variation



Lowe et al., 2017 Lancet Planet Health

### Incorporate climate forecast uncertainty



- 24 ensemble members: precipitation and min. temperature in 2016
- Ensemble spread included in Bayesian probability forecasts



### Current practice: average over last 5 years





### Climate-driven dengue forecast, Machala 2016



84% 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

### Reported dengue: passive surveillance





### Corrected dengue: using active surveillance





Stewart-Ibarra et al., 2018 AJTMH

# 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



# Key findings

- First demonstration of the use of long-lead seasonal climate and El Niño forecasts in a dengue early warning model for Ecuador.
- This study adds value by using
  1) real-time climate forecasts for long-lead dengue predictions
  2) active surveillance data to correct for misreporting.
- International and interdisciplinary team key in co-designing prototype.
- Global climate model output transformed to a tailored health risk indicator, to support decision makers at the local level.







### Explosive emergence of Zika virus





#### Lowe et al., 2018 Int. J. Env. Res. Public. Health



# Capacity building

- School on Modelling Tools and Capacity Building in Climate and Public Health.
- Tools to access, visualise and analyse environmental datasets.
- Transform data to input health risk models.
- Participants: early career scientists, PhD students, public health officials.



The Abdus Salam International Centre for Theoretical Physics





Petropolis, Brazil, Jul 2015









### Thank you for your attention!

### Questions?



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