Potential for using climate data to predict dengue in Brazil

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joint work with: David B. Stephenson, Trevor C. Bailey (UoE)
Richard Graham (Met Office), Caio A. S. Coelho (CPTEC)
Marilia Sá Carvalho, Christovam Barcellos (FIOCRUZ)

Outline

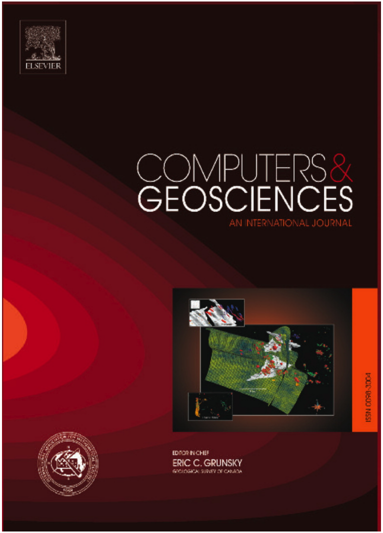
- Summary of second year achievements for EUROBRISA
- Dengue fever in Brazil
- Research aim
- Data and statistical model
- Selected results and model predictive validity
- Disscussion and Conclusions

Since Paraty March 2008...

- Health application: collaboration with FIOCRUZ.
- Visualisation: co-authored conference paper (Slingsby *et al.*, 2009)
- Visualising Seasonal Climate Forecasts in Google Earth - winning entry to Google's KML in Research Competition (http://www.gicentre.org/climatekml/)
- Brazil visit -
  - CPTEC: Obtained climate model data, explored climate-driven biological dengue fever model.
  - FIOCRUZ: Expert advice for dengue prediction in Brazil.
  - IBGE: Access to socio-economic / demographic / geographical data.
- STATGIS09 conference: GeoInformatics for environmental surveillance, Milos Greece 17-19 June.

Forthcoming publication

Invited to publish extended version of Lowe et al., (2009) in a special issue on 'GeoInformatics for environmental surveillance' to be published in Computers & Geosciences.



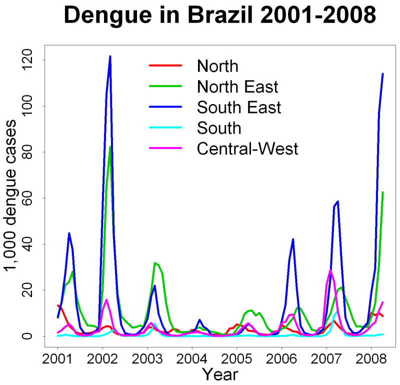
Dengue fever in Brazil

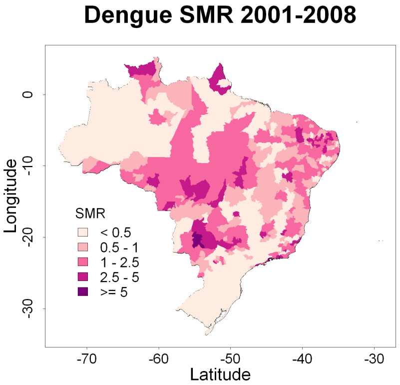
- Dengue viruses transmitted by *Aedes Agyipti* mosquitoes.
- ‘Break-bone fever’ - severe joint and muscle pain.
- 3 million cases from 2001-2008.
- Seasonal pattern increased cases Jan-Apr when climate warmer, more humid.
- 2008 epidemic: 250,000 cases, 181 confirmed deaths.

Time series of dengue cases in main regions and standardised morbidity ratios (SMR) for microregions, Brazil 2001-2008

$$\mathrm{SMR}_i = \frac{\sum y_i}{\sum e_i},\ e_i = p_i r,\ r = \frac{\sum y_i}{\sum p_i}$$

where y_i is dengue, e_i is expected dengue and p_i is population for in microregion i.



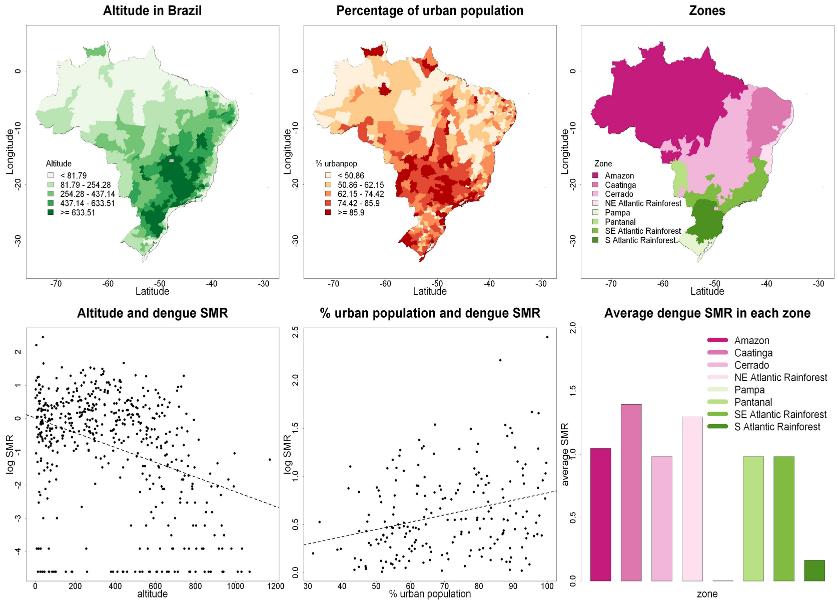


Aim

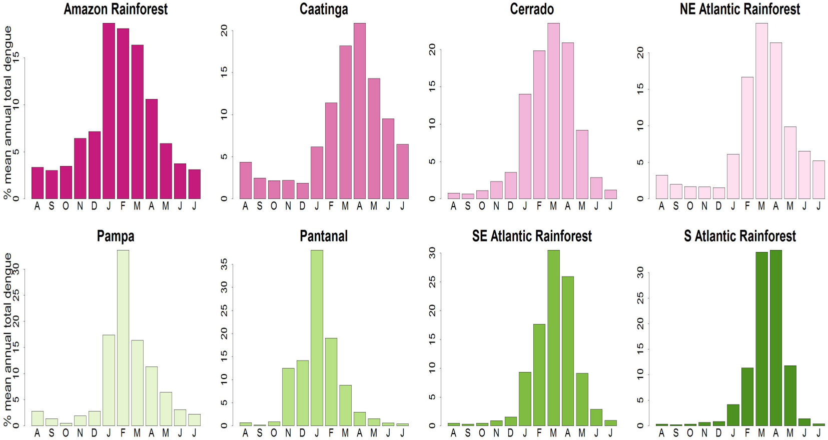
Assess the potential of integrating seasonal climate forecast information in a dengue early warning system (EWS) in Brazil

- Is dengue incidence significantly related to monthly climate variables and which time lags are important?
- To what extent can observed climate be replaced with forecast climate to predict dengue epidemics?

Is dengue incidence significantly related to monthly climate variables and which time lags are important?

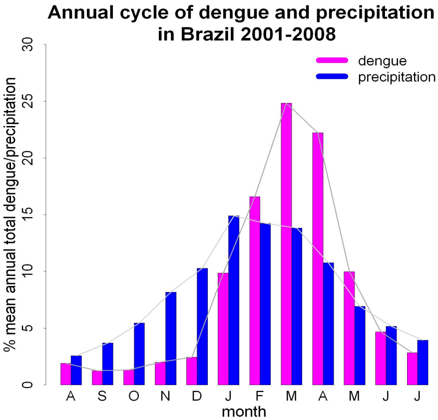

Altitude in Brazil
Longitude
Latitude
Altitude
< 81.79
81.79 - 254.28
254.28 - 437.14
437.14 - 633.51
>= 633.51
Percentage of urban population
% urbanpop
< 50.86
50.86 - 62.15
62.15 - 74.42
74.42 - 85.9
>= 85.9
Zones
Zone
Amazon
Caatinga
Cerrado
NE Atlantic Rainforest
Pampa
Pantanal
SE Atlantic Rainforest
S Atlantic Rainforest
Altitude and dengue SMR
log SMR
altitude
% urban population and dengue SMR
log SMR
% urban population
Average dengue SMR in each zone
average SMR
zone

Exploratory Data Analysis - annual cycle

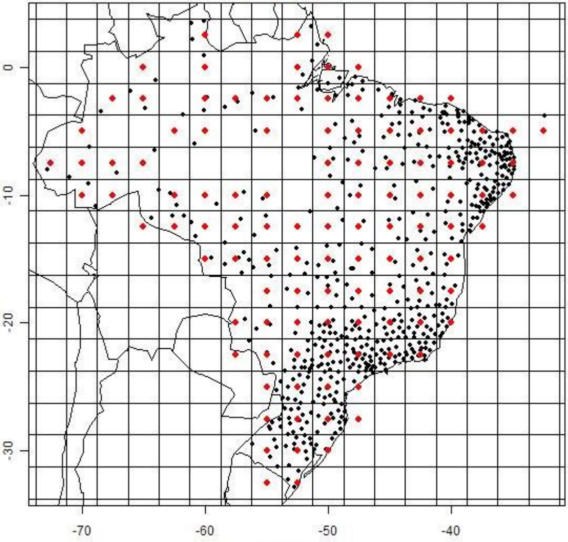


Observed Climate grid $2.5^\circ \times 2.5^\circ$

- Monthly observed precipitation totals (GPCP)
- Monthly reanalysis mean air temperature (NCEP/NCAR)
- Monthly reanalysis mean relative humidity (NCEP/NCAR)
- NINO 3.4 index (NOAA)



Climate grid (red) and microregion (black) centroids



Model framework

$$y_{it} \sim \text{NegBin}(\mu_{it}, \theta)$$

$$\log(\mu_{it}) = \underbrace{\log(e_i)}_{offset} + \beta_0 + \underbrace{\sum_j \gamma_j w_{ji}}_{non-climate} + \underbrace{\sum_j \beta_j x_{jit}}_{climate} + \underbrace{\sum_j \phi_j z_{jit}}_{factors}$$

y_{it} dengue count for microregion $i = 1, \ldots, 558$ and time $t = 1, \ldots, 88$

μ_{it} mean dengue count

θ scale parameter

$e_i = p_i r$

p_i population in microregion i

r overall average dengue rate per month

w_{ji} altitude and % of urban population

x_{jit} precipitation (0,2), temperature (0,1,3), relative humidity (3), nino3.4 (6)

z_{jit} factors reflecting zone, month and interaction between month and zone

Selection of variables

Table: Akaike Information Criteria (AIC) and adjusted R^2 for (1) Model with spatial covariates, (2) Model with spatial covariates and annual cycle and (3) Model with spatial covariates, annual cycle and climate covariates.

Model	AIC	R^2
spatial	326548	0.14
spatial-annual cycle	311796	0.37
spatial-temporal climate	310293	0.39

$$\text{AIC} = -2\log\Lambda + 2p = 2(\log L_{M_s} - \log L_M) + 2p$$

$$R^2 = \frac{\text{scaled deviance } M_n - \text{scaled deviance } M}{\text{scaled deviance } M_n}$$

$$R_a^2 = 1 - (1 - R^2)\left(\frac{n-1}{n-p}\right)$$

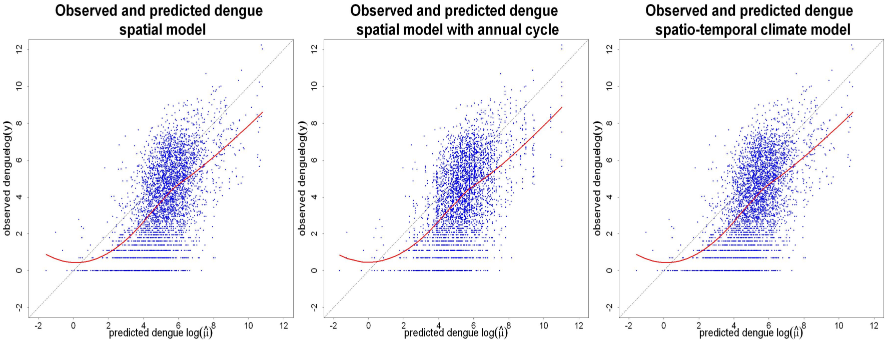
Selected results - observed climate

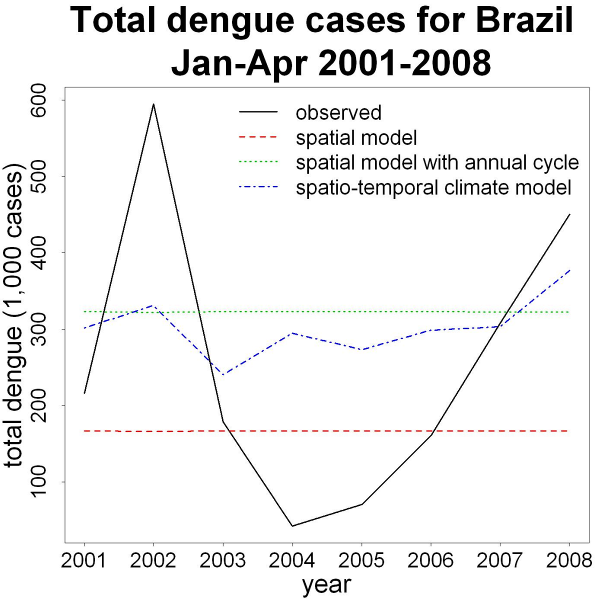
Observed Climate	Coefficient estimate (standard error)
Precipitation lag 0	-0.031 (0.0036)
Precipitation lag 2	0.022 (0.0036)
Temperature lag 0	0.172 (0.0239)
Temperature lag 1	-0.107 (0.0292)
Temperature lag 3	0.339 (0.0172)
Relative humidity lag 3	0.047 (0.0028)
Nino3.4 lag 6	-0.170 (0.0145)

- Climate lag 2-3 - influence mosquito life cycle?
- Climate lag 0-1 - promote or inhibit dengue transmission?

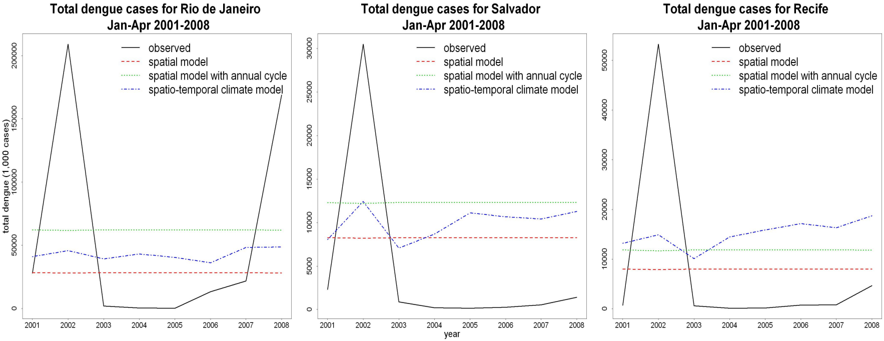
K-fold cross validation

Leave out Jan-Apr season for each microregion and each year

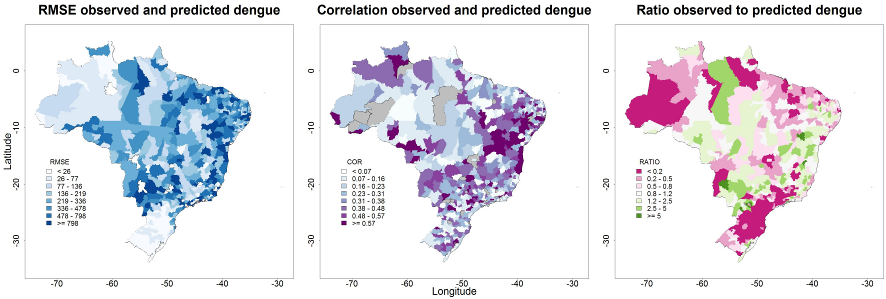



Total dengue cases for Brazil
Jan-Apr 2001-2008
observed
spatial model
spatial model with annual cycle
spatio-temporal climate model
total dengue (1,000 cases)
100
200
300
400
500
600
2001
2002
2003
2004
2005
2006
2007
2008
year

Time series - Microregion level



Spatio-temporal climate model skill



Epidemic prediction

Table: 2×2 contingency table for binary event: dengue in upper quartile (based on dengue distribution Jan-Apr 2001-2008)

		Observed		
		Yes	No	Total
	Yes	814	1053	1867
Predicted	No	304	2293	2597
	Total	1118	3346	4464

hit rate = 73%, **false alarm rate** = 31%

To what extent can observed climate be replaced with forecast climate to predict dengue epidemics?

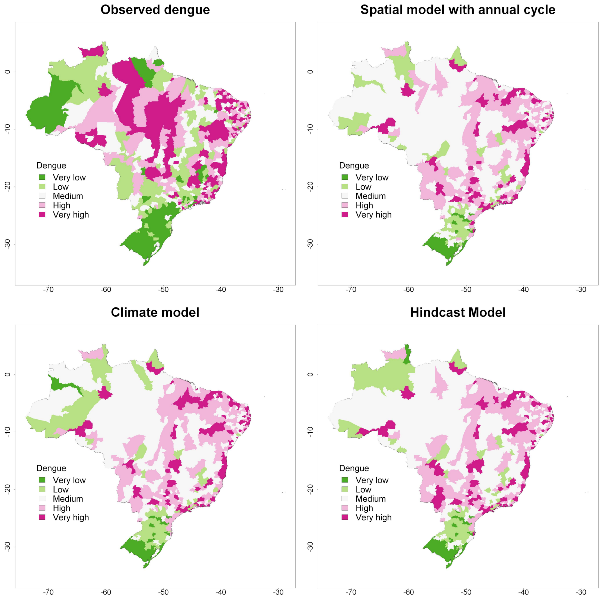
Climate forecasts

- Temperature and precipitation hindcasts
- Met Office seasonal forecasting system GloSea3
  - ensemble forecast
  - 6 forecast lead times

Observed		Hindcast	
Prec lag 0	-0.031 (0.0036)	Prec lead 5	0.035 (0.0131)
Prec lag 2	0.022 (0.0036)	Prec lead 3	0.007 (0.0131)
Temp lag 0	0.172 (0.0239)	**Temp lead 5**	0.195 (0.0224)
Temp lag 1	-0.107 (0.0292)	**Temp lead 4**	-0.066 (0.0224)
Temp lag 3	0.339 (0.0172)	Temp lead 2	0.020 (0.0161)
Rel.Hum lag 3	0.339 (0.0172)	Climatology	-0.036 (0.0026)

- Significance maintained for temperature hindcasts.
- Standard errors for hindcast precipitation larger
  $\rightarrow$ predicted climate more uncertain than observed climate.

2008 Epidemic: model prediction



Discussion and Conclusion

- Dengue incidence significantly related to climate covariates.
- Some evidence for inclusion of seasonal climate forecasts in dengue EWS in Brazil.

Model improvement

- Include serotype infromation
- Non-linear relationship between dengue and climate?
- Downscaling climate data from coarse to fine grid to make dengue predictions more microregion specific?

  Next step: include spatio-temporal random effects to account for:
  - unobserved confounding factors
  - extra-Poisson variability

EUROBRISA requirements

Ideally : monthly mean and variance for precipitation (and temperature) at each grid point for each lead.