Predictive mapping based on routine surveillance data: Lessons from dengue risk mapping in Vietnam

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The 5th Medical and Veterinary Virus Research Conference, Nairobi, Kenya, 7–8 December 2017

Introduction

- Dengue – a viral disease of humans prevalent in the tropics caused by Dengue virus (DENV 1-4), transmitted by *Aedes* mosquitoes

Dengue risk map (Source: https://www.cdc.gov/dengue/epidemiology/index.html)

- The viruses cause febrile diseases ranging from asymptomatic fevers to more severe illness associated with secondary infections with heterotypic DENV

- Disease has expanded geographically since the 1950s probably due to:
    - Urbanization
    - Tourism and migration
    - Climate change

Introduction

- Extensive studies on DEN risk in SEA and Latin America
  - Risk factors: temperature, rainfall and humidity
  - Lessons for other regions to learn from as DEN risk expands globally
- However:
  - Not much has been done to assess interactions between meteorological variables and geographical factors – altitude, land use/land cover, etc.
  - Existing risk maps do not show changes in risk with season and land use change
- Dengue in Vietnam (94 million people): outbreak every year, large outbreak in 2017 with over 130,000 case and 30 deaths
- Pestforecast project – spatio-temporal analysis and risk-mapping of climate sensitive diseases including DEN in Vietnam

Methods

- We collated secondary data:
    - DEN surveillance from Provincial Preventive Medicine Center, Ministry of Health (MoH), for 2001-2012
    - Human population from the General Statistics Office, Ministry of Planning and Investments (MPI)
    - Meteorology from Institute of Meteorology, Hydrology and Climate Change, Ministry of Natural Resource and Environment (MONRE)
    - Land use land cover from MODIS database
    - Altitude from MODIS
- All the data summarized by province (n=63) and month (n=12) to give 9,072 records

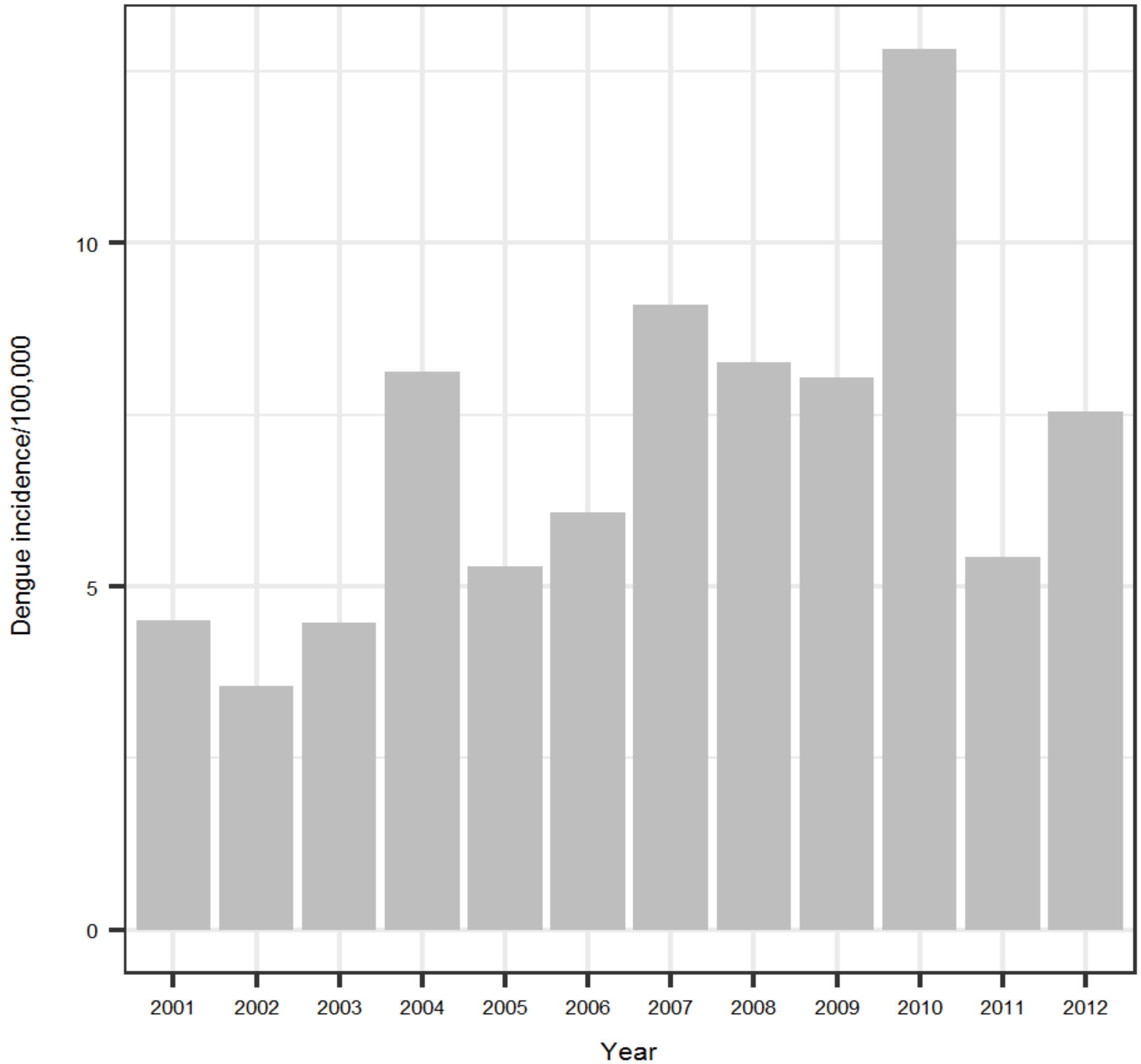
Methods

- Descriptive analyses:
  - Generated mean monthly DEN incidence by province in 100,000 people as:

$$Incidence = cases/population * 100{,}000$$

  - Principal component analysis to filter meteorological data
  - Distribution of DEN incidence by defined levels of geographical predictor variables
- Modelling using hierarchical Bayesian model (INLA) to account for:
  - Spatial autocorrelation
  - Temporal autocorrelation
  - Spatio-temporal interactions

Results – mean DEN incidence



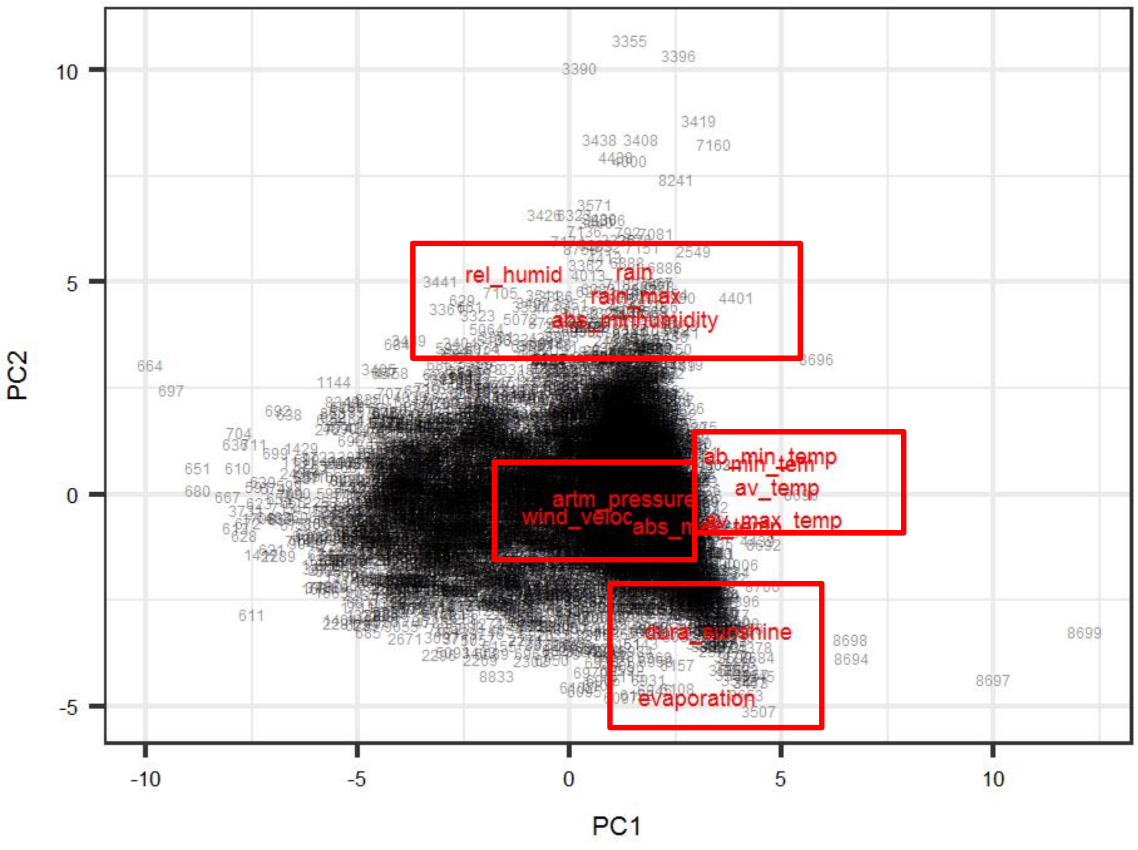
Annual DEN incidence 2001 - 2012

Mean incidence:

- **6.94 cases/100,000**
- **SD 14.49**

Results – principal component analysis
Met data

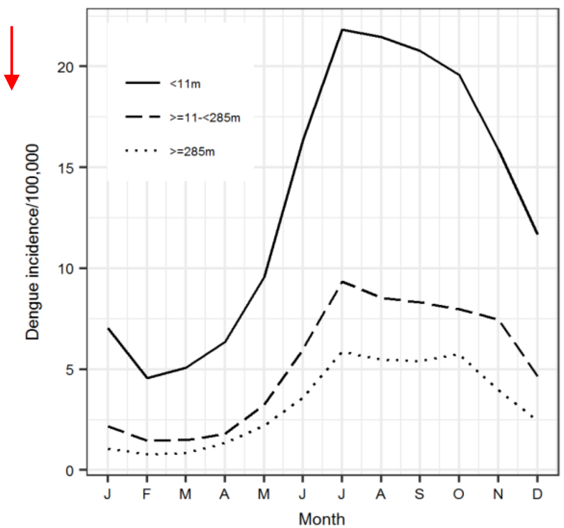
- Met data had 13 variables, some correlated
- Principal component analysis clustered met variables into about 4 groups
- Principal variables identified and used in the regression model:
  - Humidity, rainfall, minimum temperature and evaporation



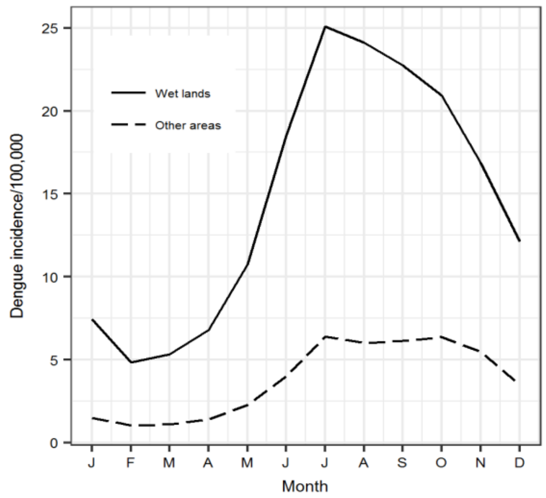
Results of the principal component analysis of meteorological variables

Methods – monthly DEN incidence at levels of geographical factors

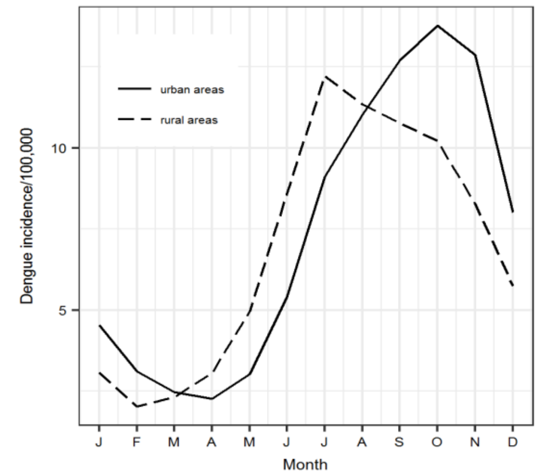
Altitude



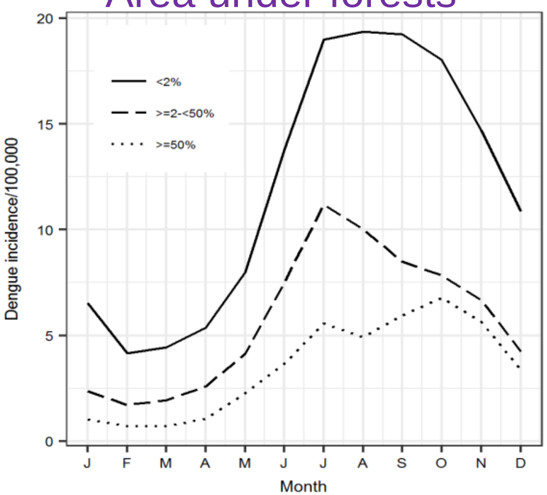
Wetlands



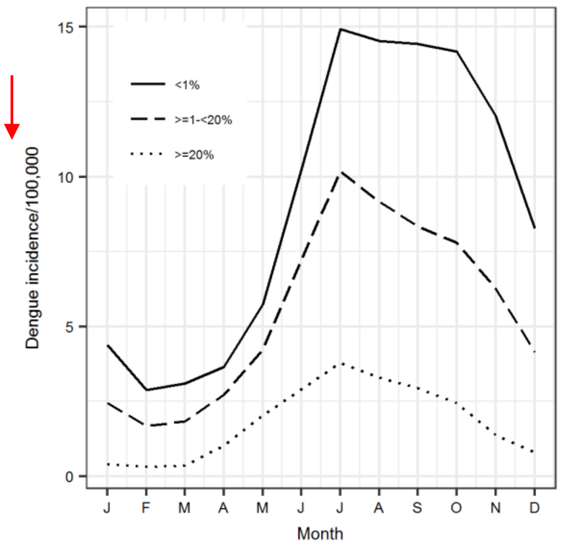
Urban settlements



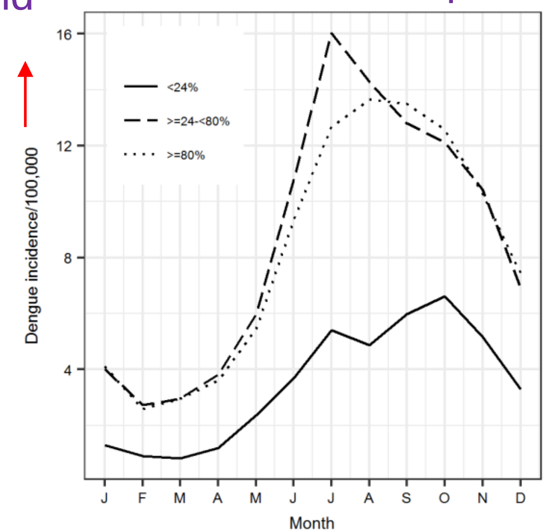
Area under forests



Area under savanna grassland



Area under crops



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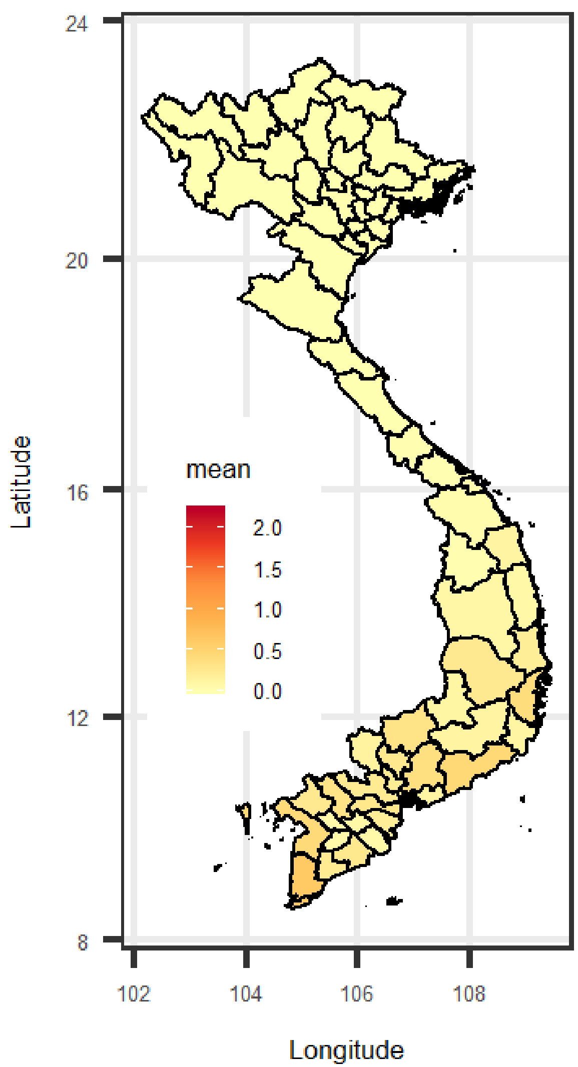
Results – posterior parameter distributions from the hierarchical spatiotemporal Bayesian model fitted to data

Final model generated and used for risk mapping

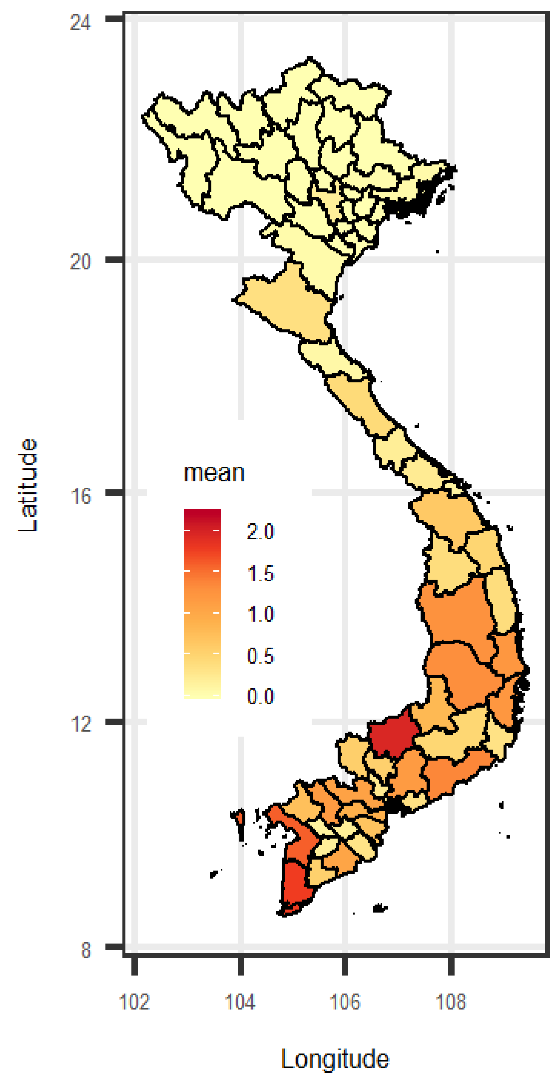
Variable	Mean	SD	2.5% quantile	97.5% quantile	Mode
Fixed effects:					
Intercept	-13.654	0.220	-14.089	-13.222	-13.652
Minimum temperature	-0.150	0.006	-0.161	-0.138	-0.150
Minimum temperature (squared)	0.010	0.000	0.010	0.010	0.010
Rainfall	0.299	0.002	0.295	0.303	0.299
Rainfall (squared)	-0.034	0.000	-0.035	-0.034	-0.034
Altitude	-0.001	0.001	-0.002	0.001	-0.001
Urban areas	0.733	0.012	0.710	0.756	0.733
Hyperparameters:					
IID	1.118	0.291	0.651	1.786	1.016
BYM model	1.359	0.736	0.415	3.230	0.926

Results – risk maps (*log* DEN incidence/pop)

Dry season (Jan – Feb)



Wet season (May – November)



Discussion and conclusions

- Our analyses combine met and geographical data on land use/land cover and altitude to show **seasonal dynamics in DEN risk**
- Statistical model developed can be used for **forecasting** by changing rainfall and temperature values
- **Space-time interactions** significant -- risk in the endemic areas evolves much faster and to much higher levels during the monsoon periods than non-endemic areas
- Findings/maps useful for **surveillance and targeted interventions**

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Acknowledgements

Local partners – MoH, IMEH, NIHE, MOH

CGIAR Research Program on Climate Change, Agriculture and Food Security

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