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WHAT IMPACTS THE SPREAD OF DISEASES CARRIED BY MOSQUITOES?

Spatiotemporal relationships between climate and extreme weather events and arbovirus human infections across Brazil

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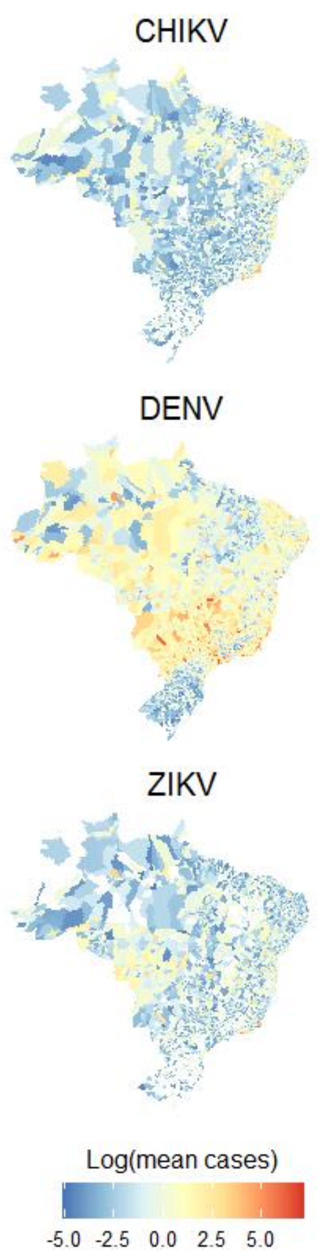
The problem and its significance



- Arboviruses are viruses spread by **mosquitoes.** Dengue (DENV), chikungunya (CHIKV) and zika (ZIKV) virus are carried by the same mosquito species.
- They cause extreme **health and economic burden** in tropical countries and are an **increasing concern** as global temperatures rise.
- In Brazil there are arbovirus **outbreaks** each year. More areas are at risk and **infection and mortality have increased** over the last decade.
- Climate and environmental conditions affect mosquito survival, reproduction, and behaviour, and therefore impact the spread of arboviruses.
- There is an **urgent need** to better understand the impact of climate on arbovirus transmission for public health surveillance and response planning.

Research questions:
How do extreme climate conditions impact arbovirus transmission in Brazil? Which areas are most at risk?

Regression modelling introduction. This is a simple model: $p = \beta X$.

- p is what we are interested in, e.g. number of dengue cases,
- X is something we know impacts p, e.g. temperature,
- β is a number that tells us how X is related to p.

If we have data and know p and X, we can work out β using the model. Then in the future, if we know X and β, we can estimate p.

How did we investigate?

- We analysed weekly cases of chikungunya, zika and dengue in each municipality of Brazil (n>5500) from 2013 to 2020.
- Regression models were used to test relationships between arboviruses and variables (n=139) including global climate cycles (El Niño-Southern Oscillation), human connectivity and socioeconomics, and average and extreme climate conditions over different lags.
- Human connectivity was calculated by analysing mobile phone data from 2019. We performed a centrality network analysis – locations with the most journeys into them had highest centrality scores.
- We tested the following model for each of the 139 variables:

$$p_{i,t} \sim \alpha + \beta_1 p_{i,t-1} + \beta_2 X_{i,t} + \mu_{i,a} + \vartheta_{s,w} + \epsilon_i$$

p is arbovirus incidence (number of DENV, ZIKV or CHIKV cases divided by population) in week t for municipality i

$\beta_2 X_{i,t}$ is what we are interested in! It tells us how variable X is related to p. If β_2 is positive it means higher values of X are related to higher arbovirus incidence

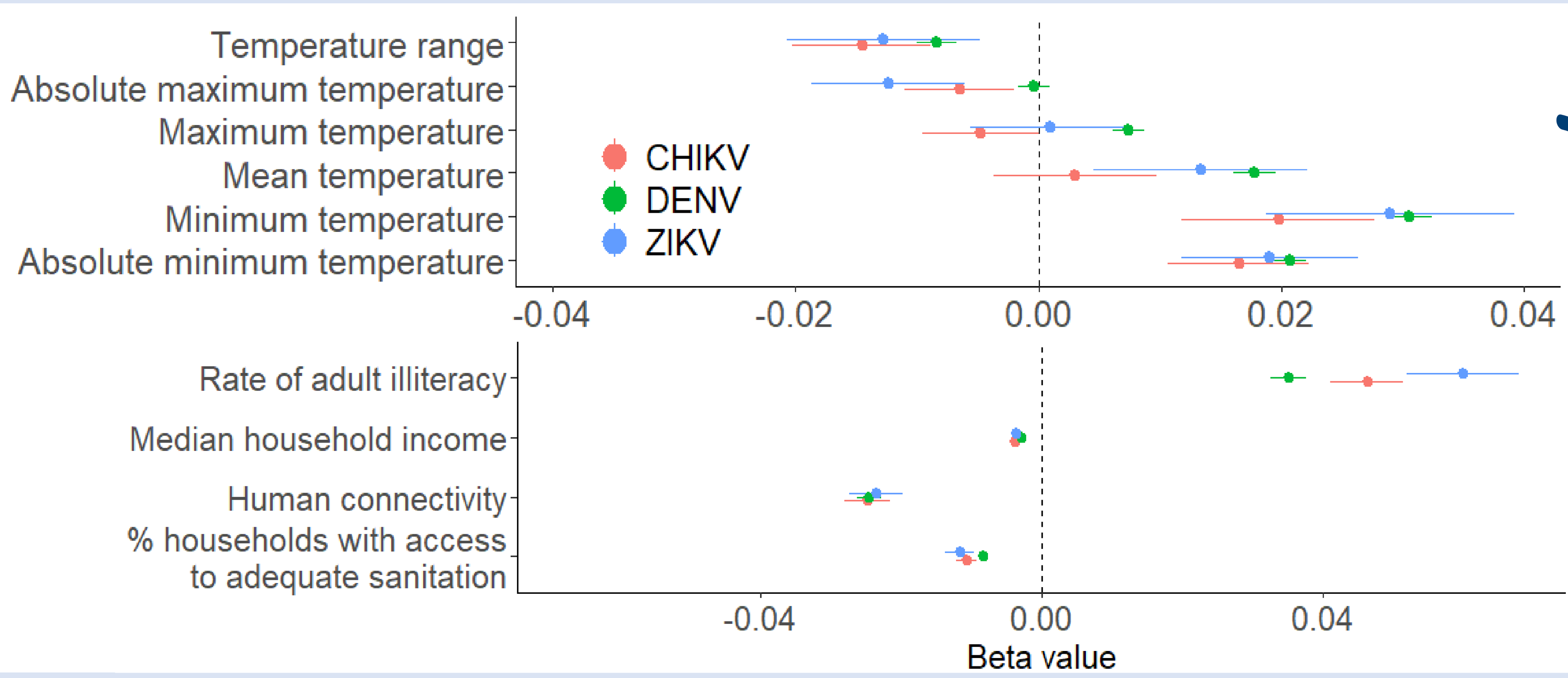
α is an intercept

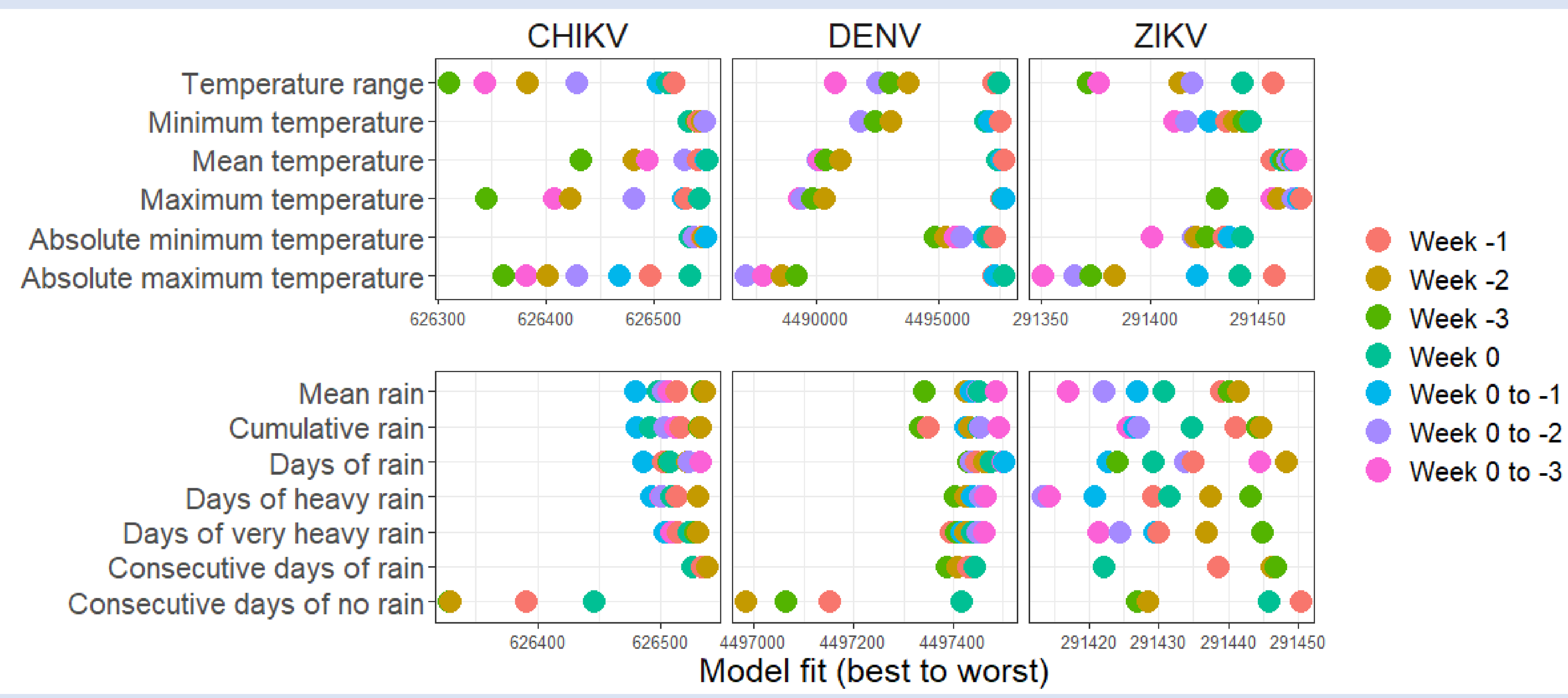
β_1 is an autoregressive term showing how related this week's incidence is to last week's

μ and ϑ are random effects to account for differences in space (i = municipality, s = state) and time (a = year, w = week number)

ϵ is an error term

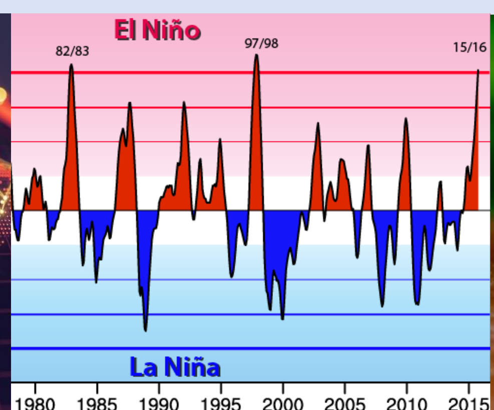
Results

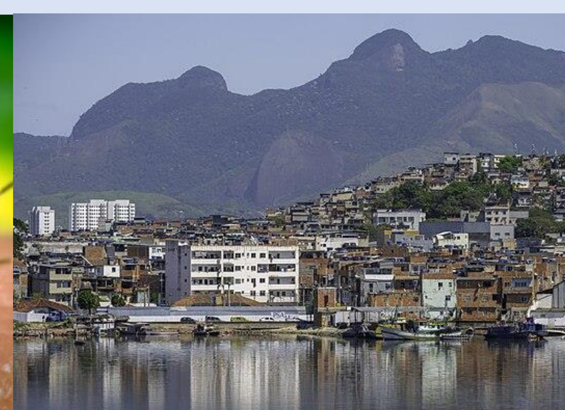


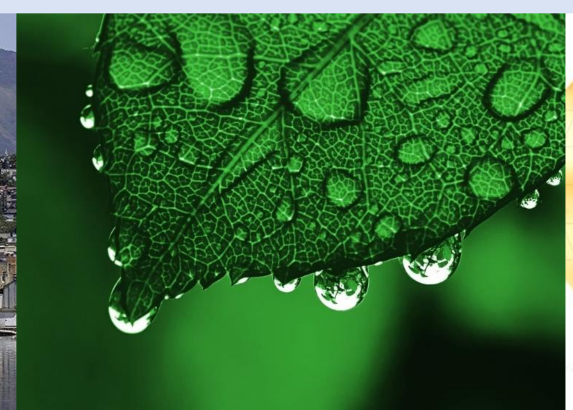


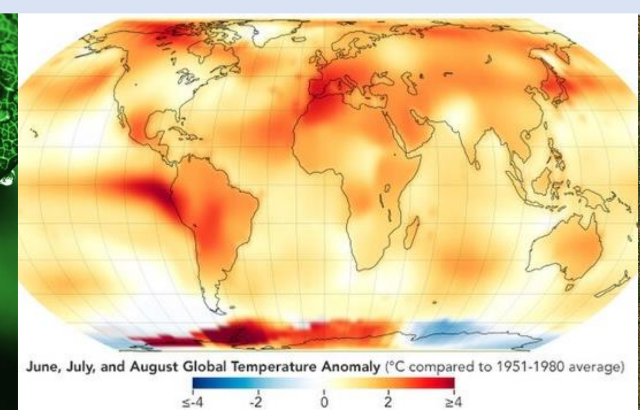
What do our results mean?

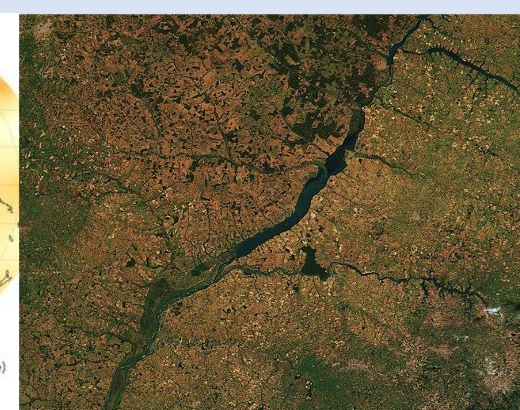
- Temperature was positively associated with arbovirus incidence, up to limiting negatively associated maxima. This is likely because of the thermal constraints on mosquito life traits at too high temperatures.
- Extreme conditions in the short-term, such as the absolute maxima and minima of temperature and the number of consecutive days without rain, and longer-term climate such as El Niño-Southern Oscillation and extreme wetness/dryness in the previous year were better predictors of arbovirus incidence than average conditions.
- This shows the importance of accounting for extremes when using climate in models of arbovirus incidence. This is important for future models especially those aiming to predict arbovirus incidence under different climate change scenarios.
- Conditions such as reduced sanitation and income were associated with increased arbovirus incidence, which highlights the joint health impact of poverty and extreme weather conditions on arbovirus risk in Brazil.











Acknowledgement of data sources: Case notification timeseries data from the Ministry of Health of Brazil acquired through the national information system for notifiable diseases (SINAN: Sistema de Informação de Agravos de Notificação). Population data from LandScan™. Temperature, dewpoint and precipitation from the Copernicus Climate Data Store: ERA5-Land (Hersbach, H. *et al*., (2018) and Muñoz Sabater, J *et al*., (2019, 2021)). Sea surface temperature anomalies in region 3.4 (Niño 3.4, 5N-5S, 170-120W) obtained from the National Oceanic and Atmospheric Administration (NOAA). Median household income, illiteracy rate, and sanitation, collated from the Brazilian census, 2010. Disaster events for Brazil between 2013 and 2020 obtained from the International Disaster Database. Human mobility data collected under a research agreement by a private Brazilian company (formerly called InLoco, now Incognia). Images sourced from Wikimedia commons, NOAA, and Microsoft office.