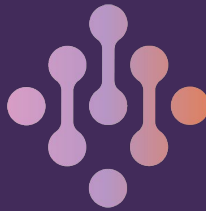


Attribution of Dengue Risk to Climate Change-Driven Changes in Cali, Colombia

Anna B. Kawiecki, Giovenale Moirano, Adrià San José, Juan Felipe Montenegro Torres, Solomon Gebrechorkos, Linh Luu, Ana M. Vicedo-Cabrera, Rupert Stuart-Smith, Mauricio Santos-Vega, and Rachel Lowe



IDExtremes



TACTIC



This work was supported by the Wellcome Trust grant number 309112/Z/24/Z

Warming



Hazard

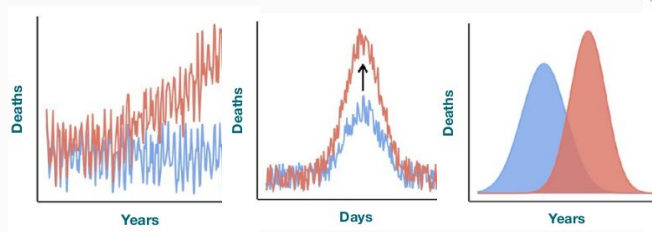
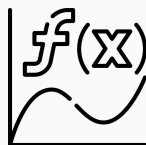
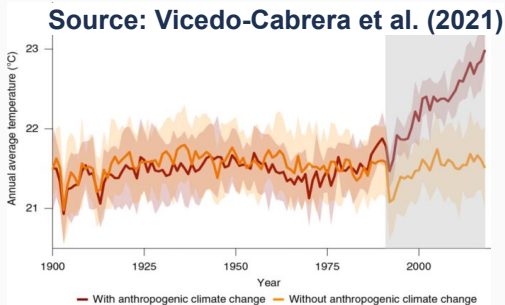


Disease

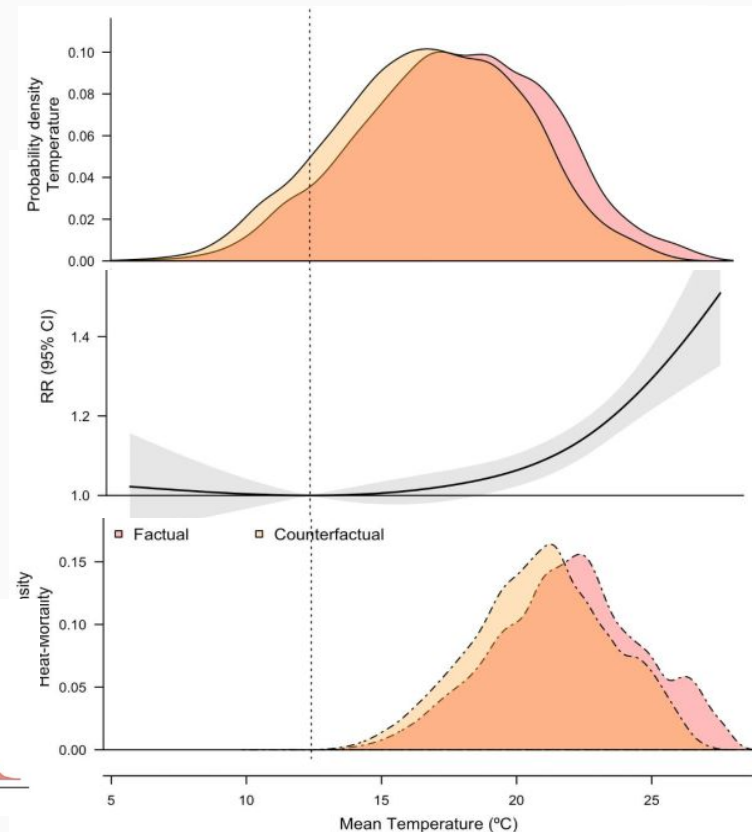
Counterfactual climate

Exposure-response relationship

Health impact attribution



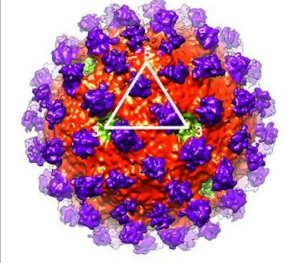
Source: Carlson et al. (2024)



Source: Stuart-Smith et al. (2024)

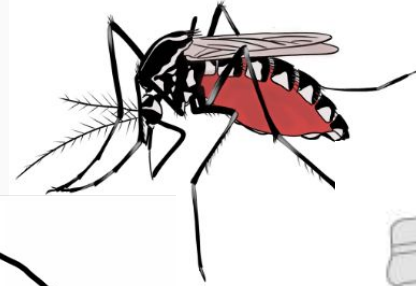
Case study: dengue in Cali, Colombia

Dengue virus (DENV)

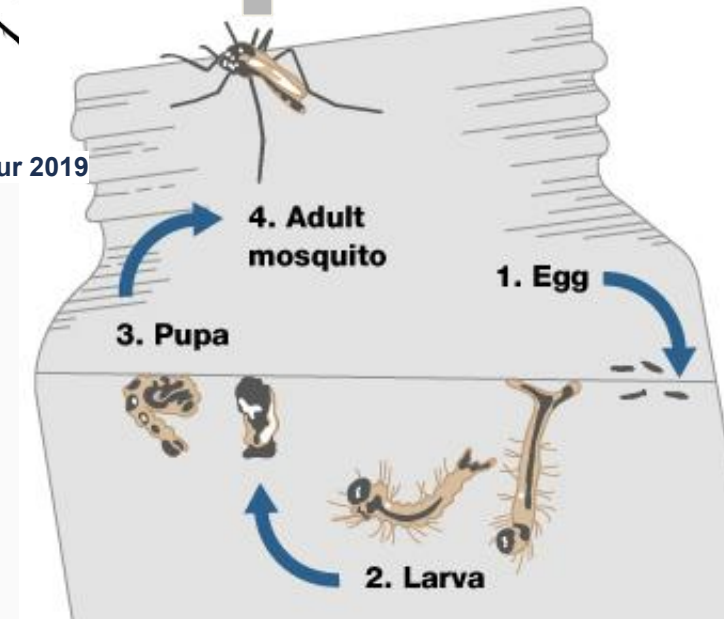
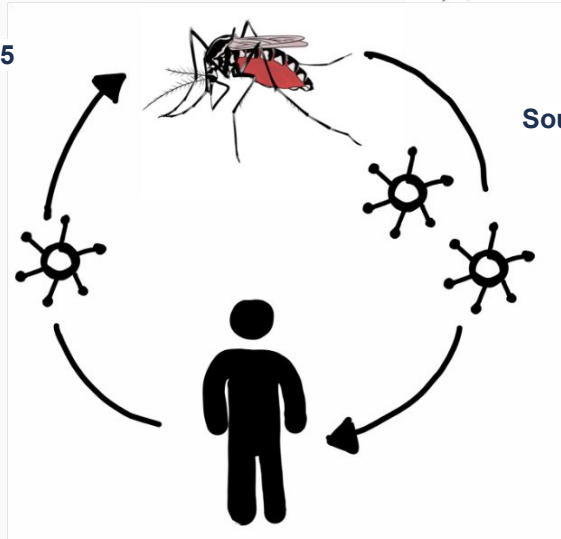


Source: Fibriansah et al. 2015

Aedes aegypti mosquito

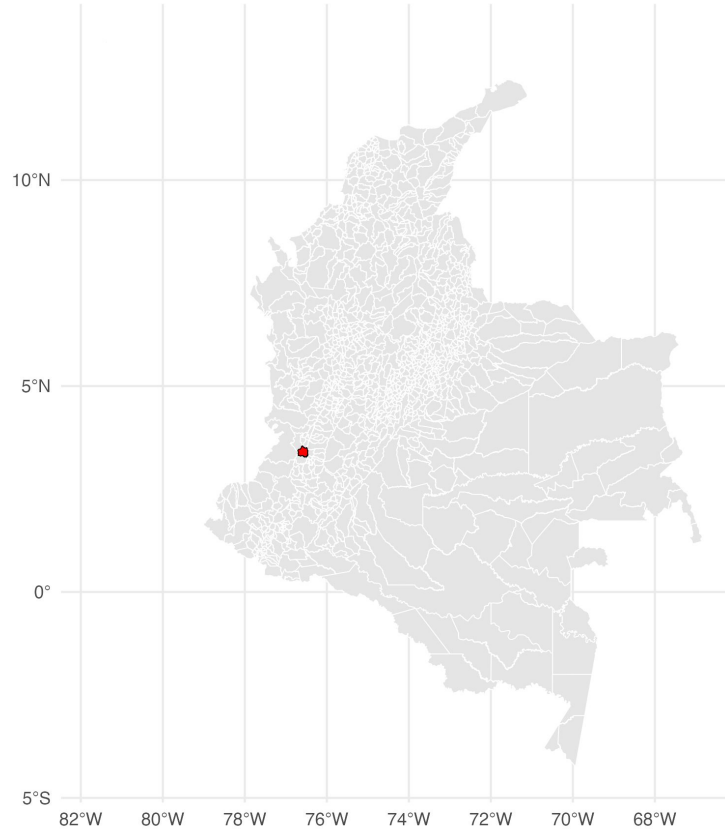


Source: Winokur 2019



Source: Dengue Transmission | Learn Science at Scitable

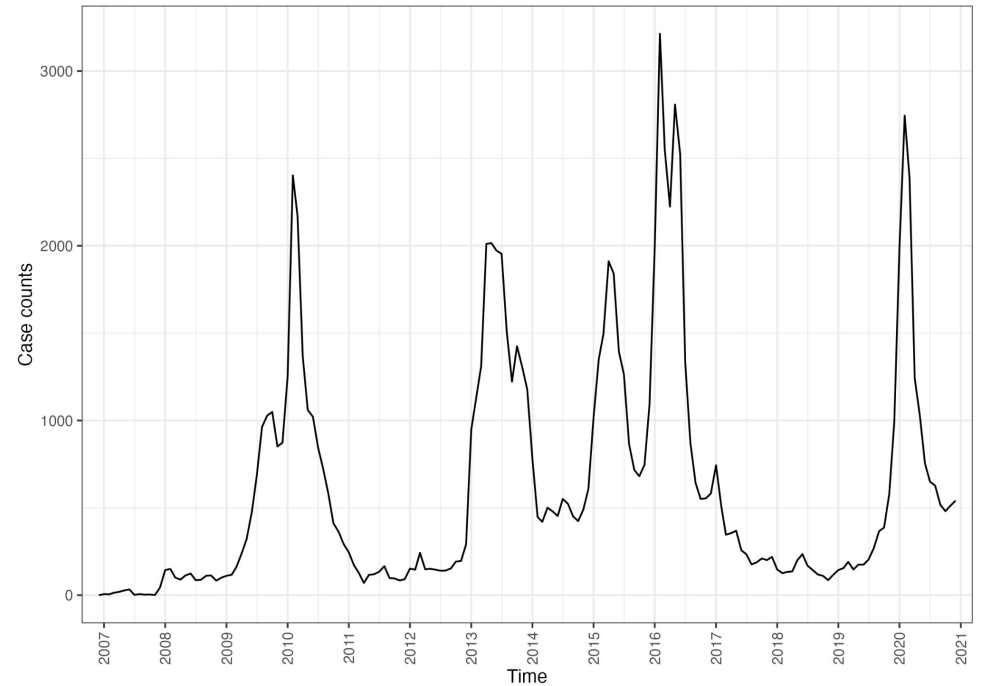
Colombian municipalities (Cali highlighted)



Reported dengue cases 2006-2020

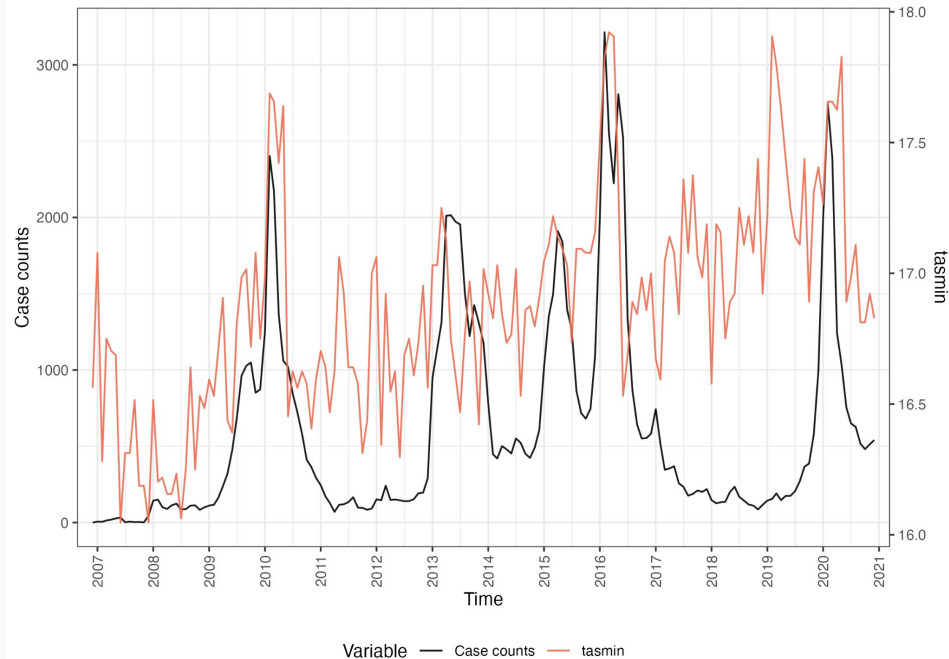


Monthly dengue cases in Cali, CO

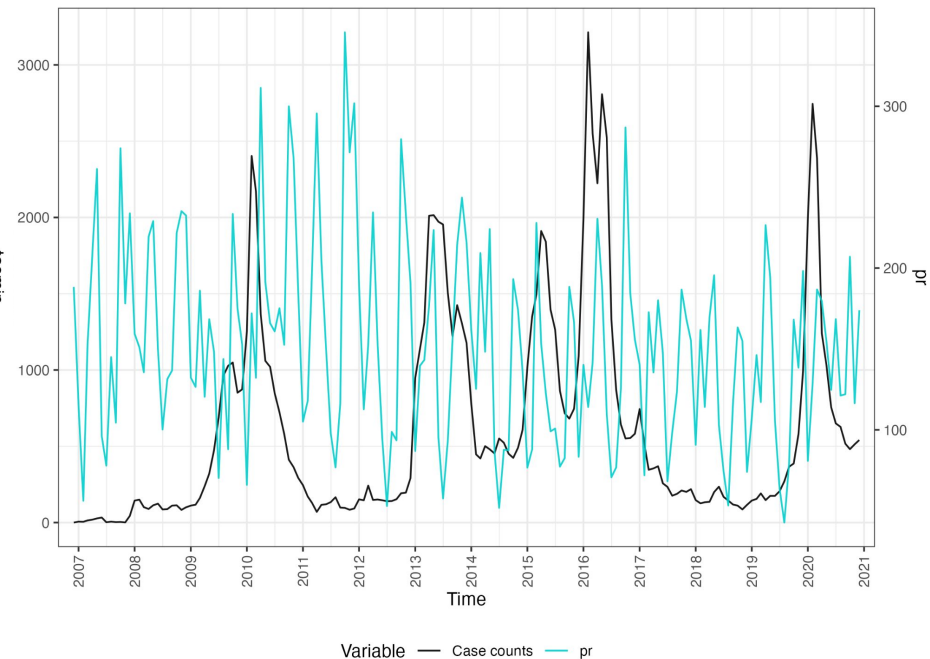


Temperature and precipitation for Cali, Colombia from the Multi-Source Weather (MSWX) bias-corrected meteorological product. **Observed data source**

Minimum temperature vs. dengue cases



Precipitation vs. dengue cases



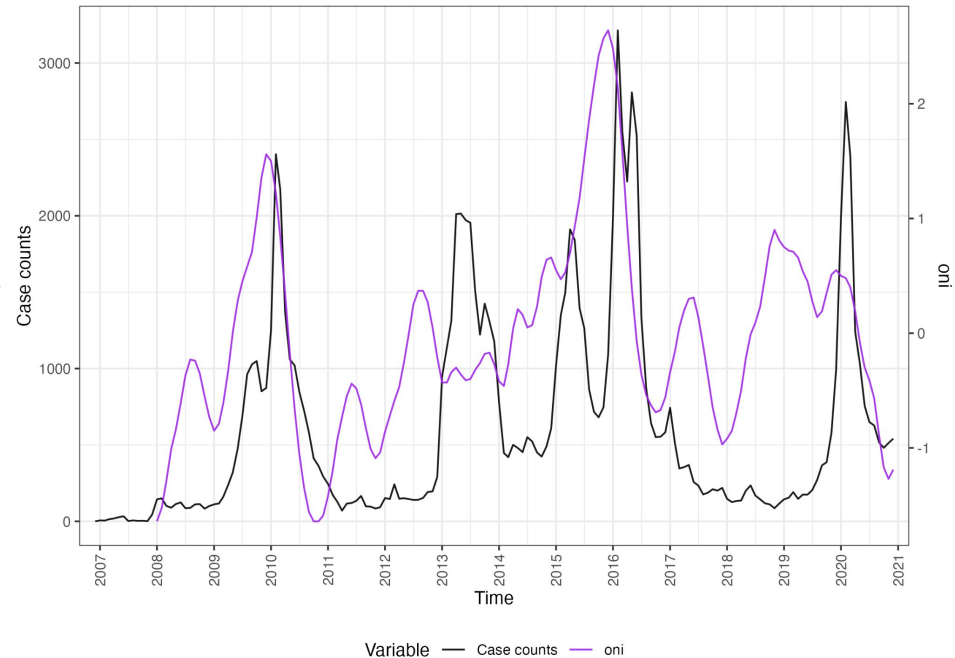
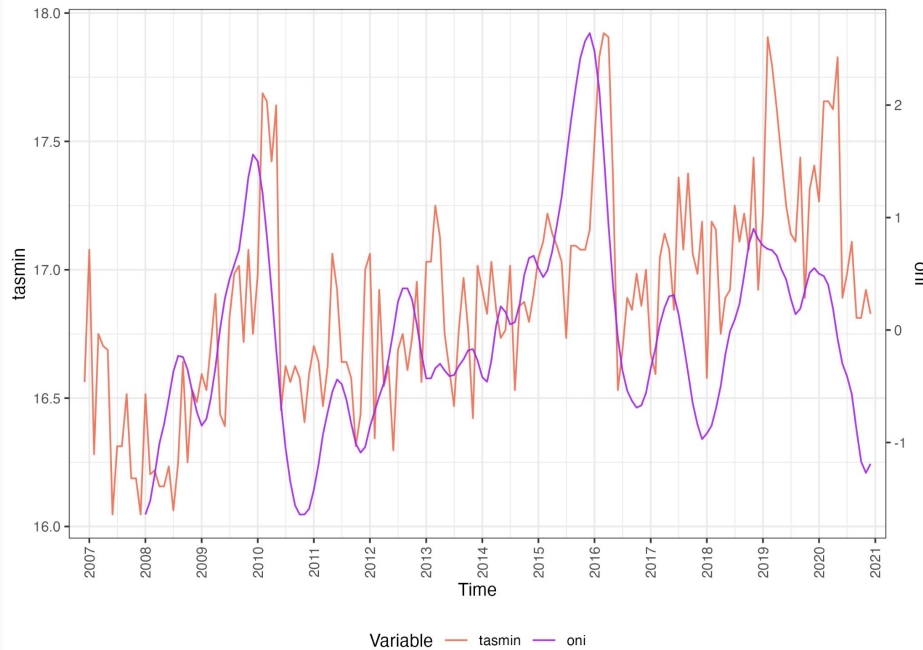
El Niño-Southern Oscillation → Temperature → dengue cases

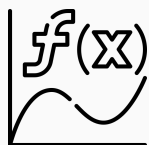
Oceanic Niño Index (ONI) vs. mean minimum temperature

Oceanic Niño Index (ONI) vs. dengue cases

ONI vs. observed minimum temperature

ONI vs. observed dengue cases





Exposure-response relationship: temperature + precipitation ~ dengue cases

Bayesian hierarchical model assuming dengue cases follow a negative binomial distribution

$$y_t \mid \mu_t, \kappa \sim \text{NegBin}(\mu_t, \kappa)$$

$$\log(\mu_t) = \log(\rho_t) + \log(p_{a(t)})$$

$$\log(\rho_t) = \alpha + \beta_{\text{tasmin}} X_{\text{tasmin}} + \beta_{\text{pr}} X_{\text{pr}} + \delta_{m(t)} + \gamma_{a(t)}$$

population offset

climate variables

seasonal effect

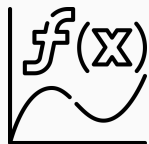
interannual effect

dengue
incidence rate

climate
covariates

temporal random
effects

t = temporal index
tasmin = minimum temperature
(3-month rolling mean at 1-month lag)
pr = precipitation
(6-month rolling mean at 3-month lag)
a(t) = annual index
m(t) = month index



Exposure-response relationship: temperature + precipitation ~ dengue cases

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population offset

climate variables

seasonal effect

interannual effect

Weather patterns
Population immunity
Transmission-altering events (e.g. world cup)

dengue
incidence rate

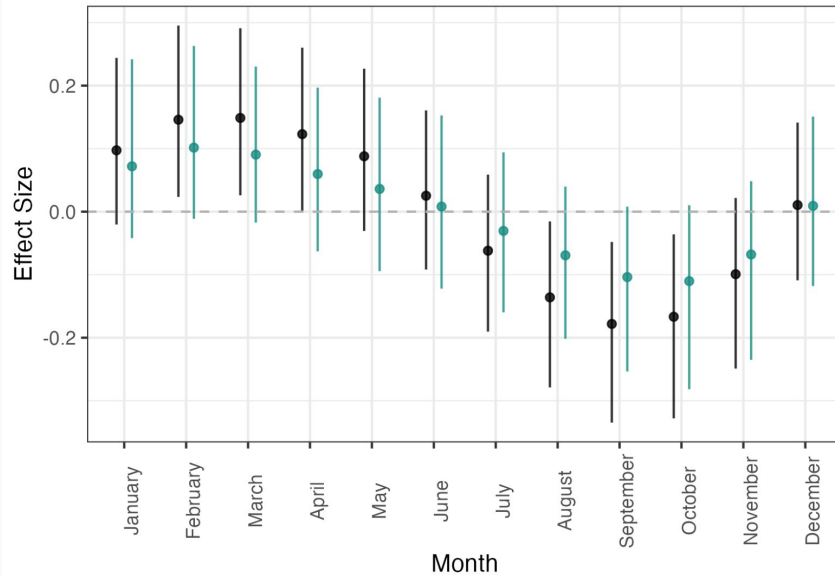
climate
covariates

temporal random
effects

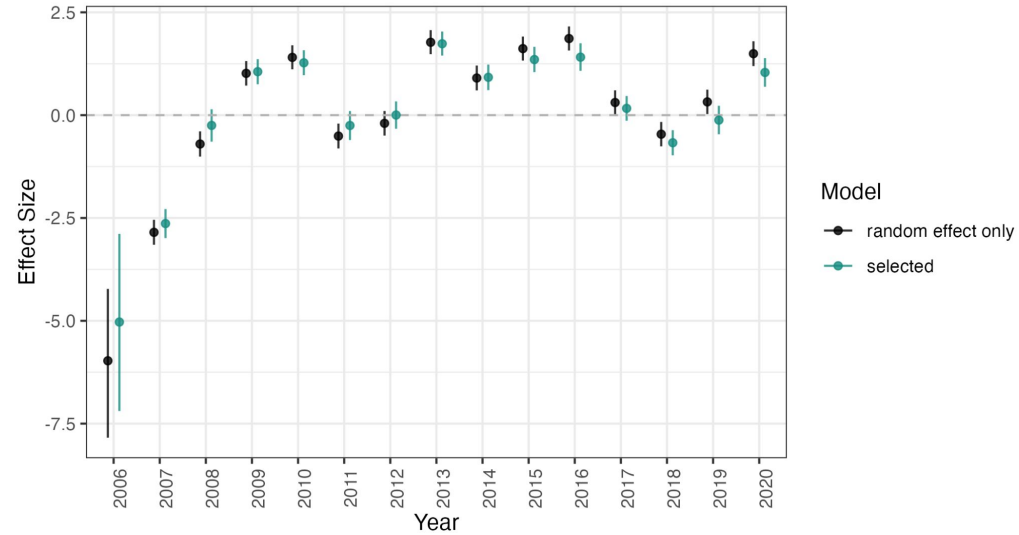
t = temporal index
tasmin = minimum temperature
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pr = precipitation
(6-month rolling mean at 3-month lag)
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Exposure-response relationship for dengue

Monthly Random Effect



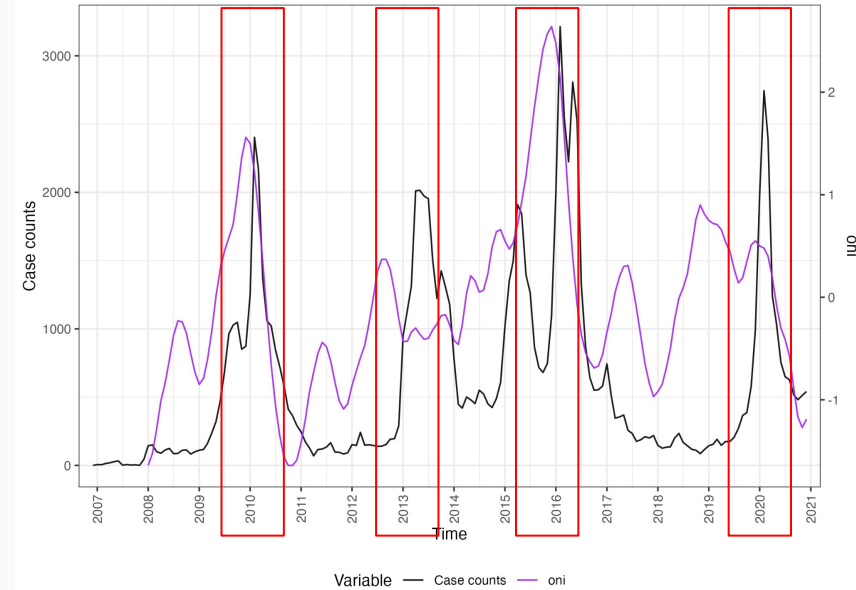
Yearly Random Effect



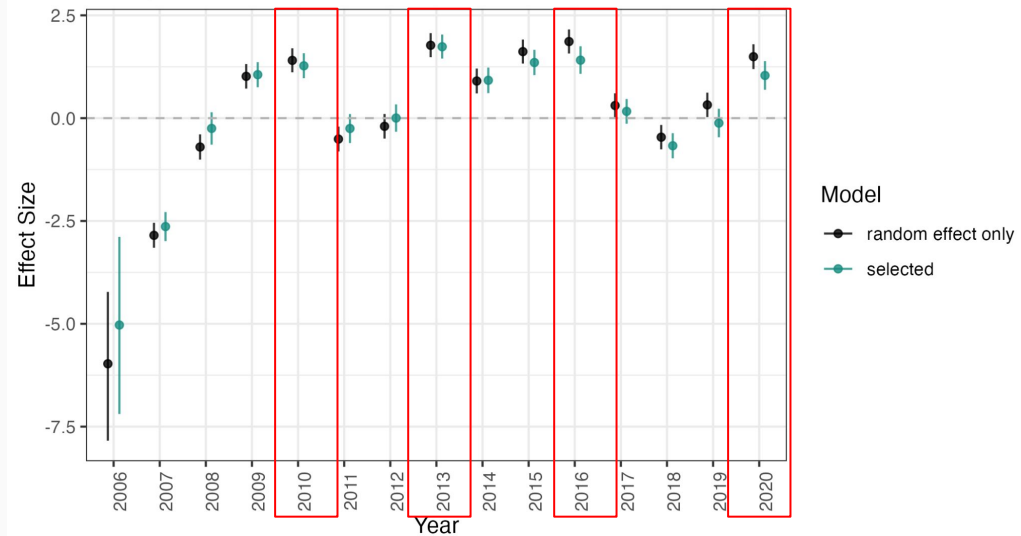
Model

- random effect only
- selected

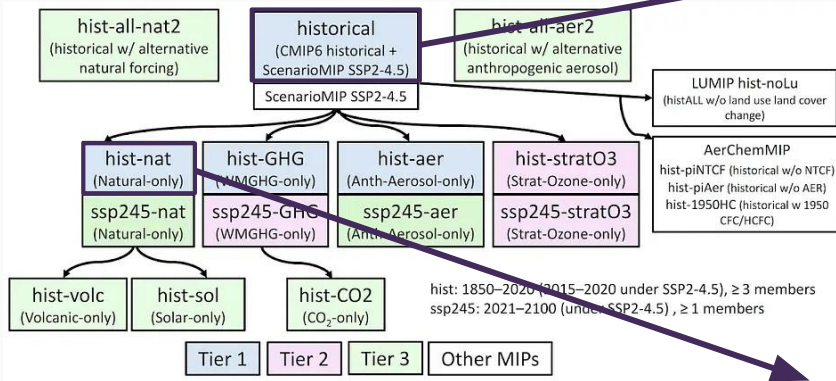
ONI vs. observed dengue cases



Yearly Random Effect



Temperature and precipitation for Cali, Colombia from 7 CMIP6 climate models using both the historical and natural-only forcing experiments.



Source: DAMIP experiments (2026)

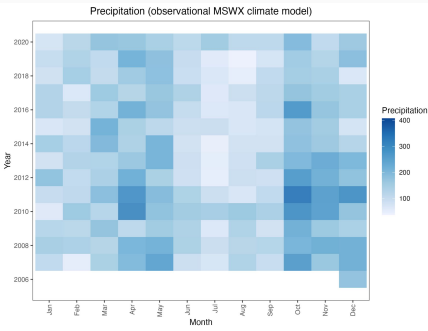
Factual data source
Historical forcing

Counterfactual data source
Natural-only forcing

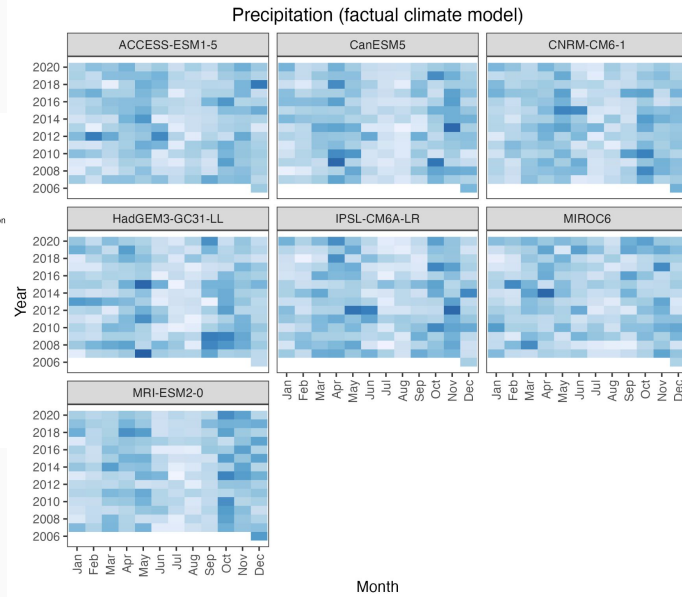
ACCESS-ESM1-5
 CNRM-CM6-1
 CanESM5
 HadGEM3-GC31-LL
 IPSL-CM6A-LR
 MIROC6
 MRI-ESM2-0

ACCESS-ESM1-5
 CNRM-CM6-1
 CanESM5
 HadGEM3-GC31-LL
 IPSL-CM6A-LR
 MIROC6
 MRI-ESM2-0

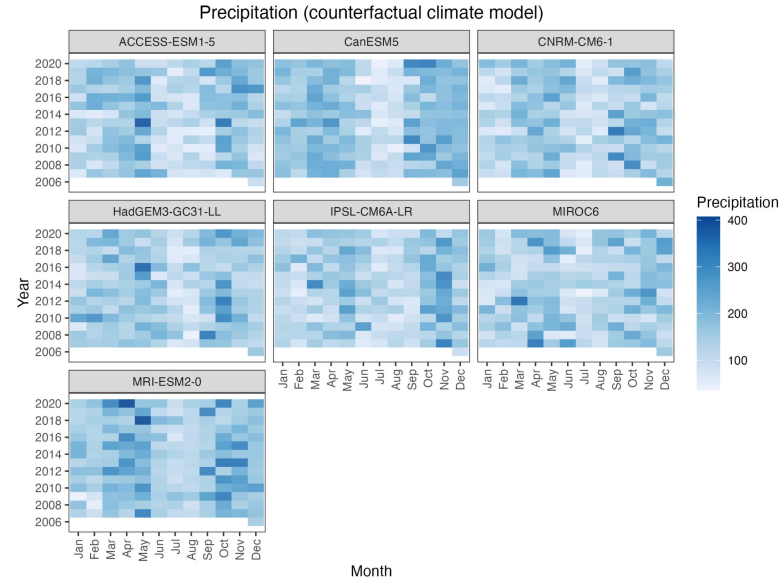
Observed climate

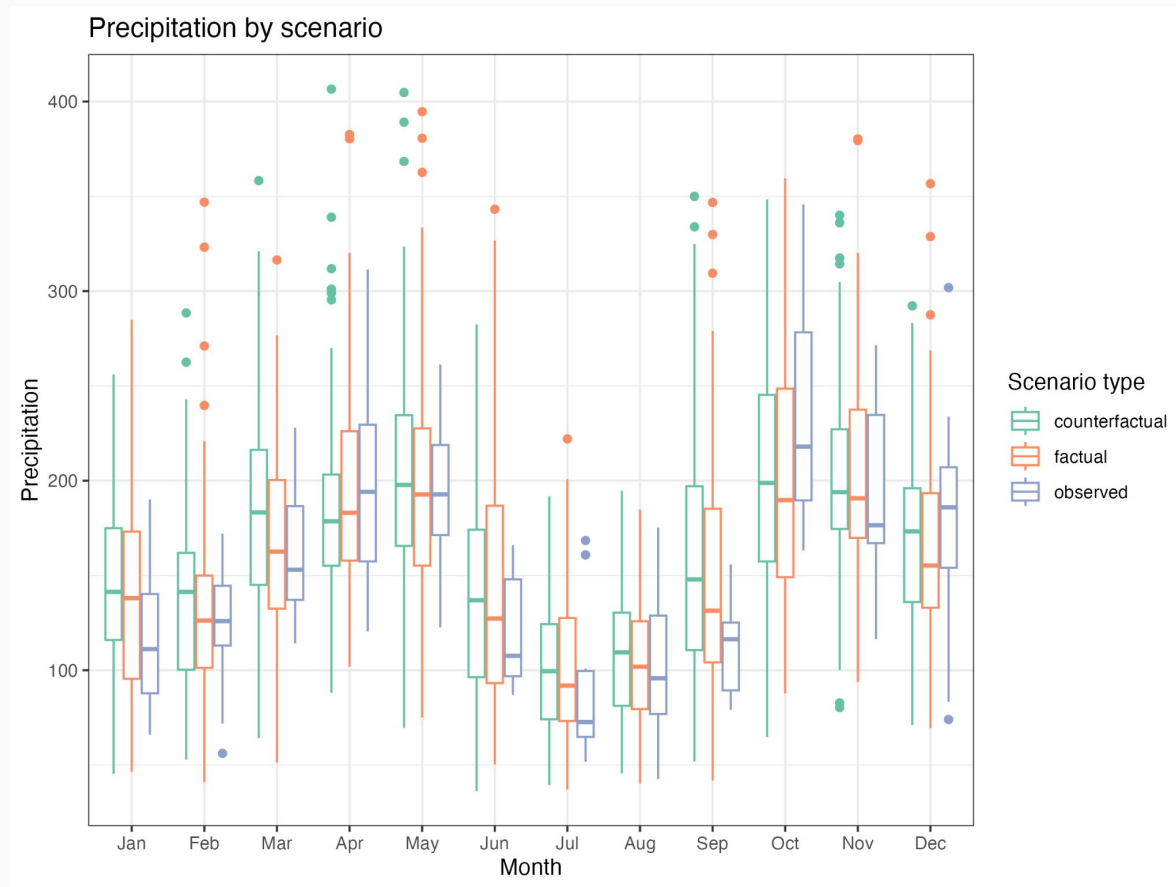


Factual climate



Counterfactual climate

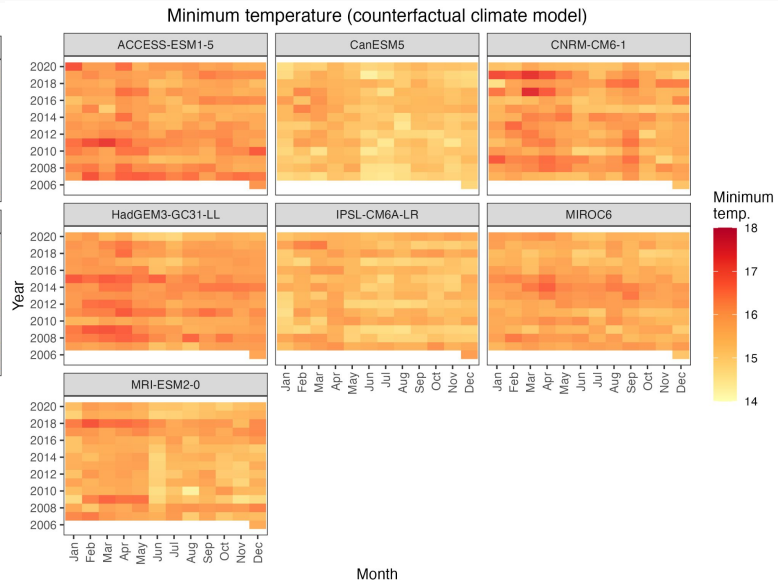
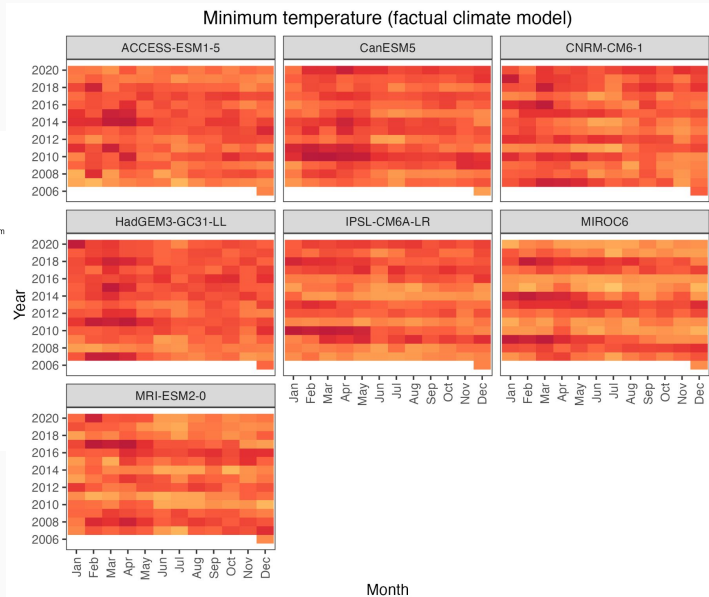
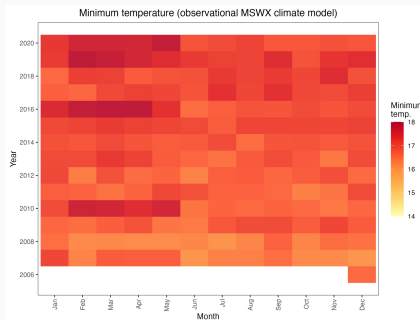


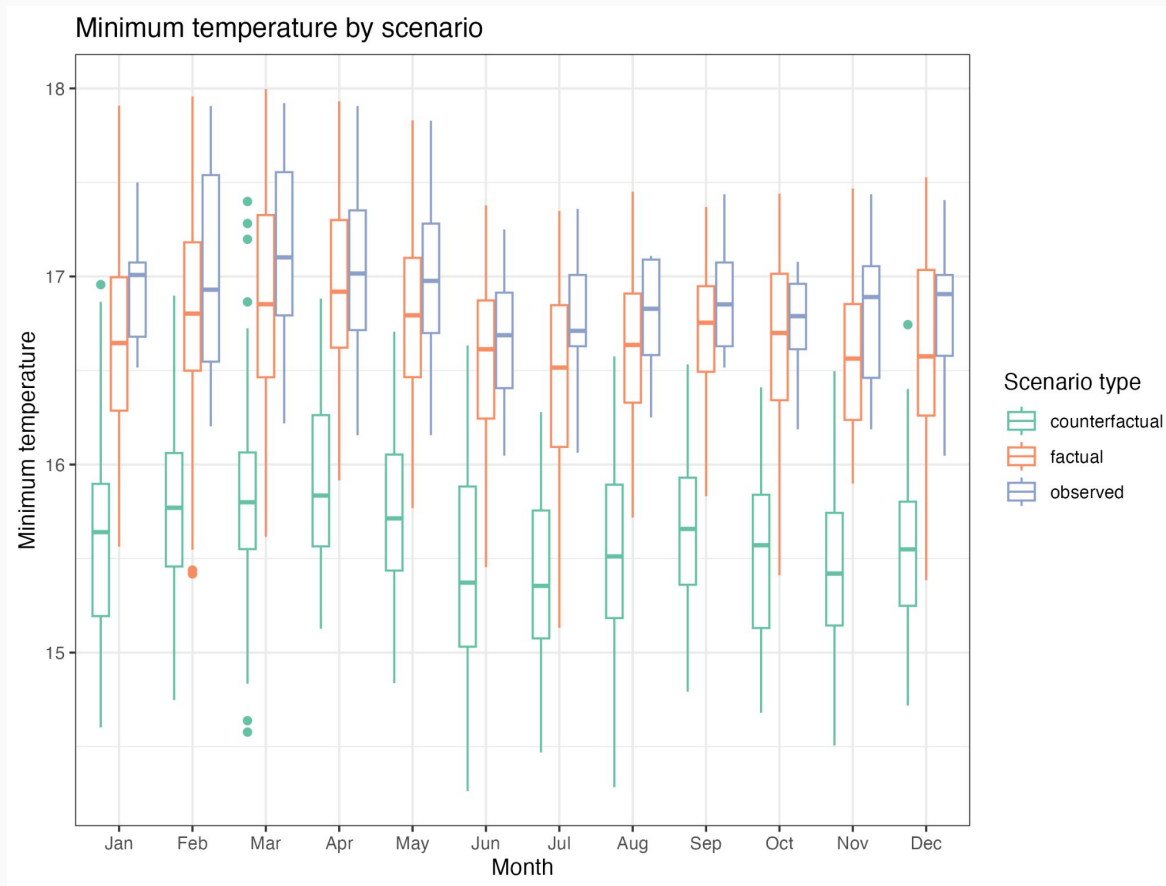


Observed climate

Factual climate

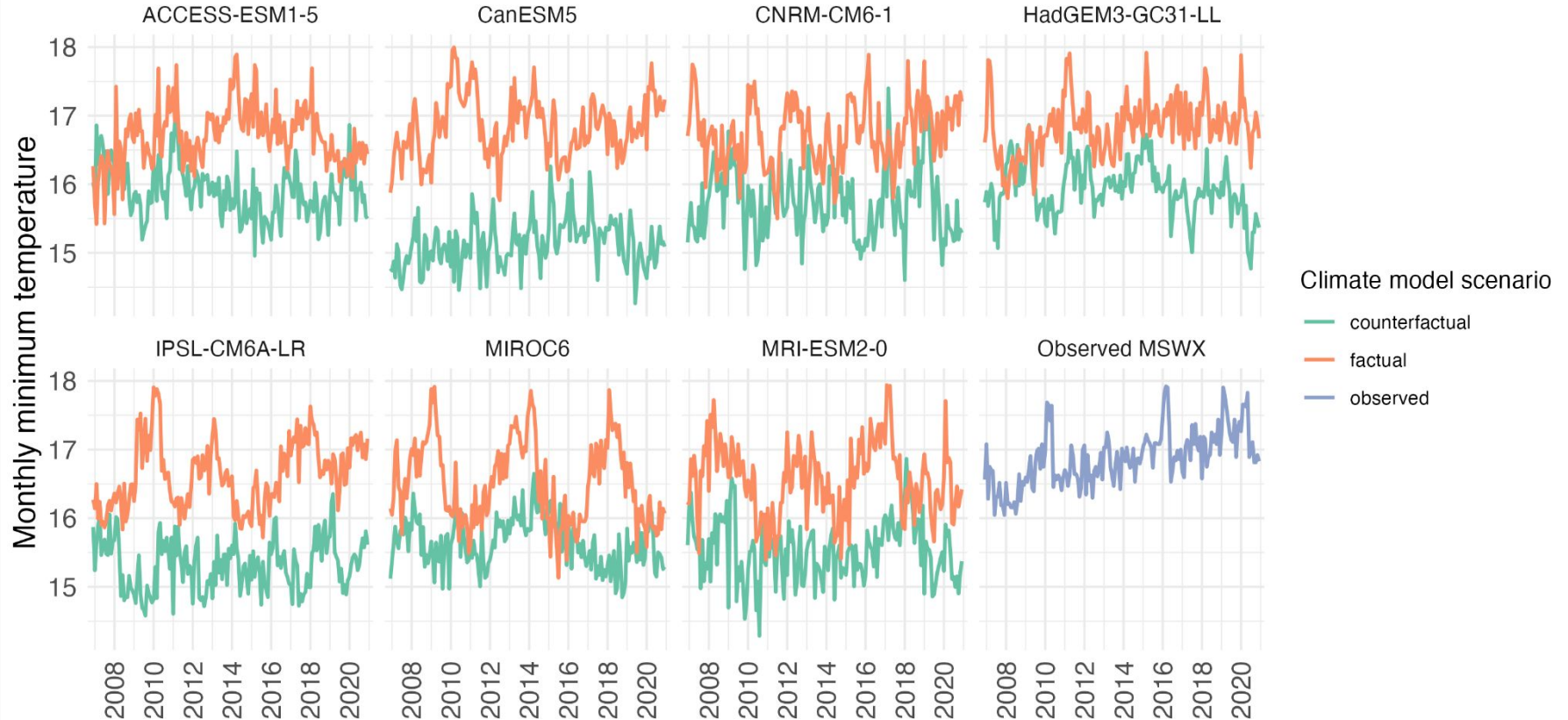
Counterfactual climate



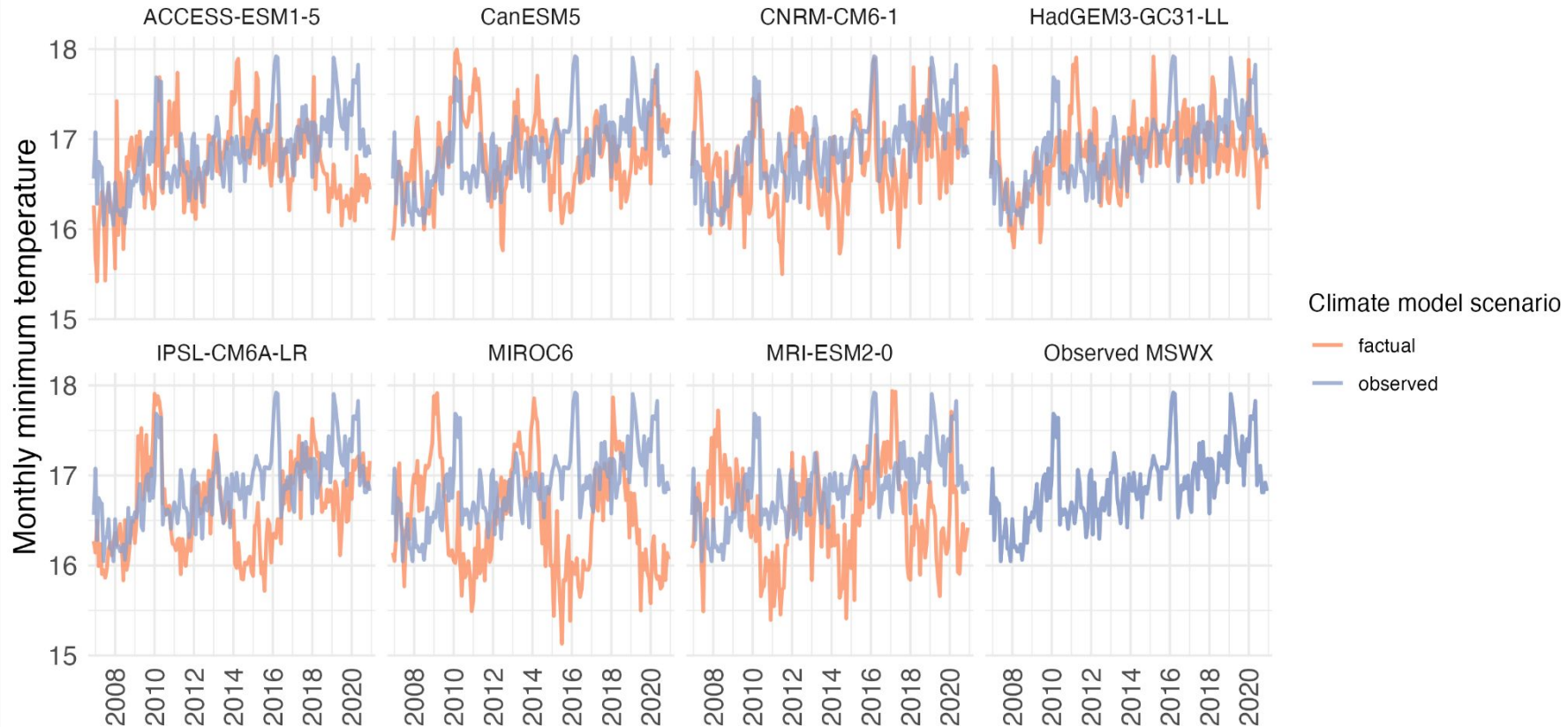


Climate variables - minimum temperature

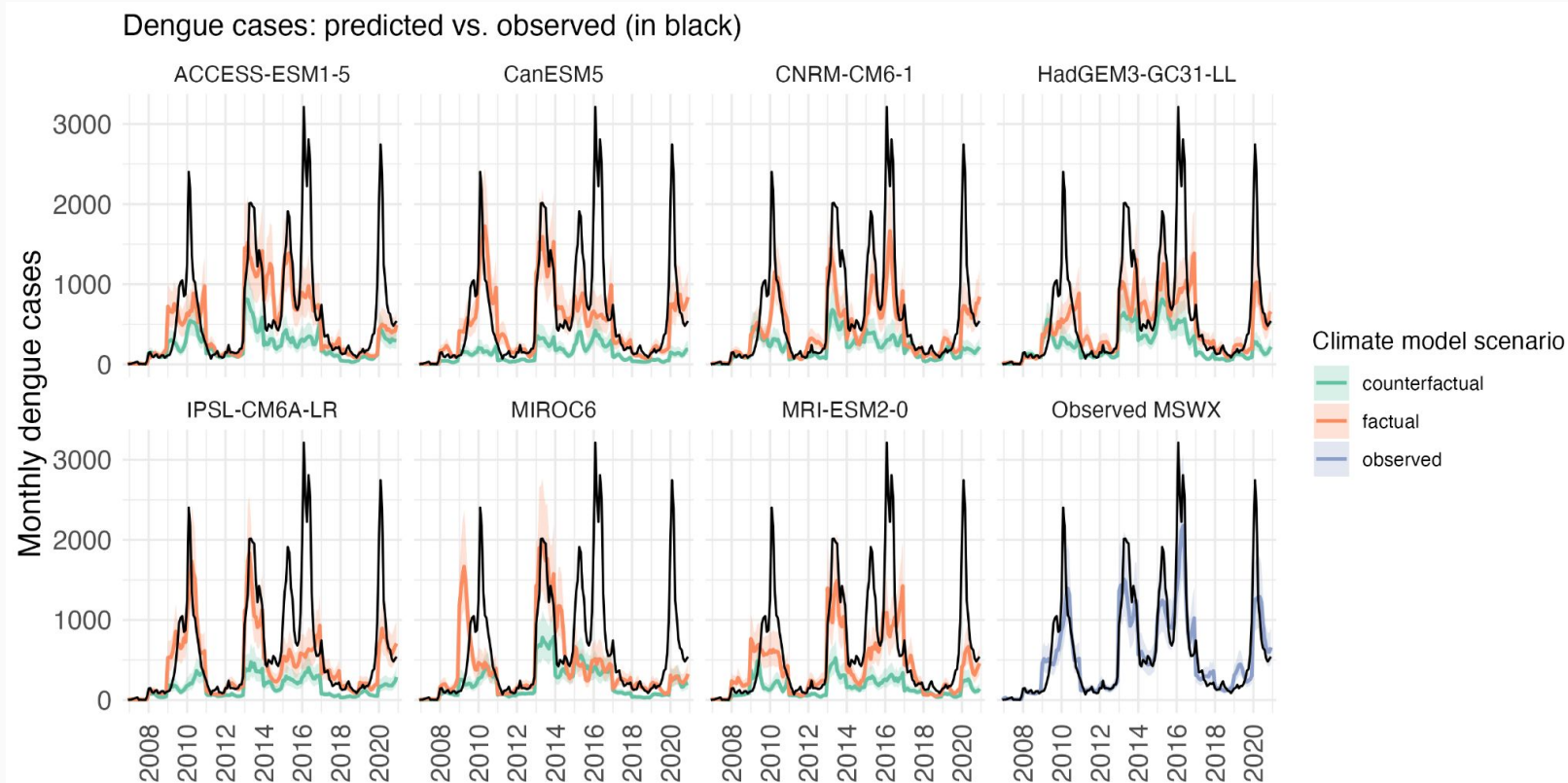
Minimum temperature by scenario and climate model



Minimum temperature: factual climate models vs. observations



Predict dengue cases using factual and counterfactual simulated timeseries



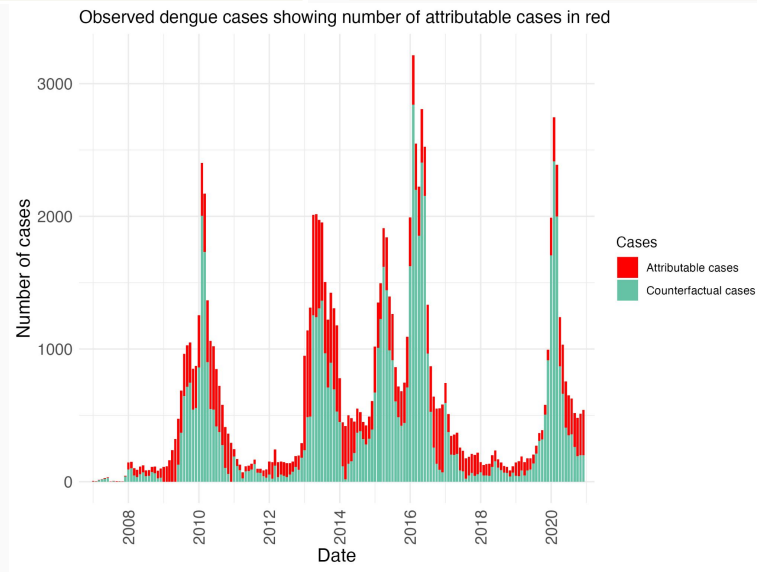
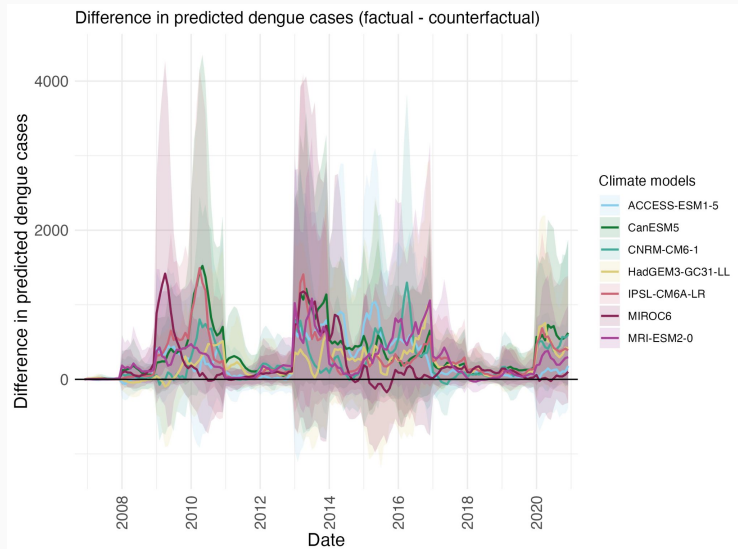
Approach 1: Results

Predict dengue cases using factual and counterfactual simulated timeseries

$$P_{t,sample,model}^{(f)} - P_{t,sample,model}^{(cf)} = \Delta_{t,model}$$

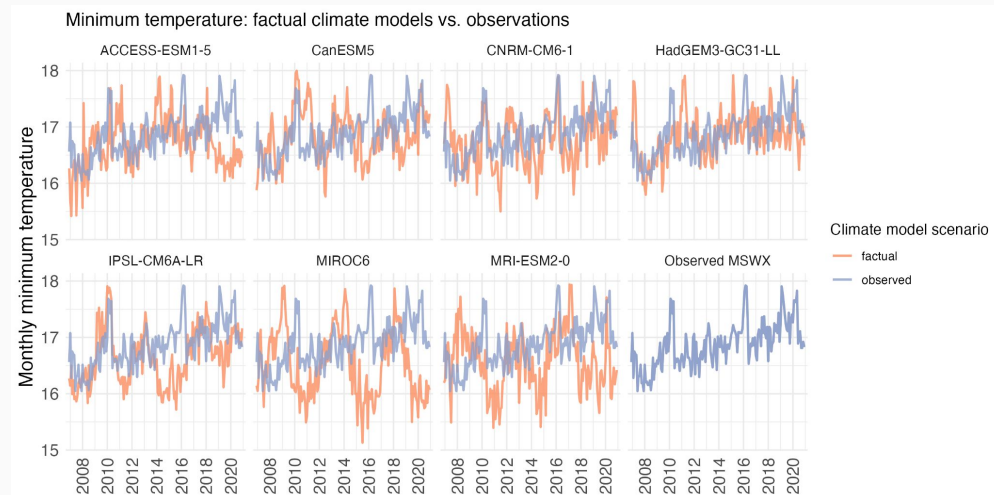
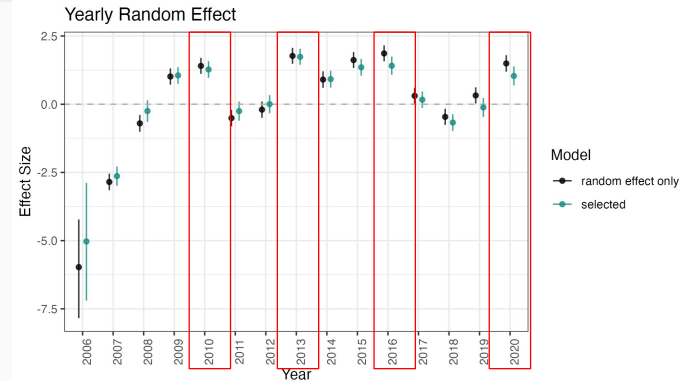
$$P_{t,sample}^{(f)} - P_{t,sample}^{(cf)} = \Delta_t$$

$$cases_t - \Delta_t = \text{counterfactual cases}$$



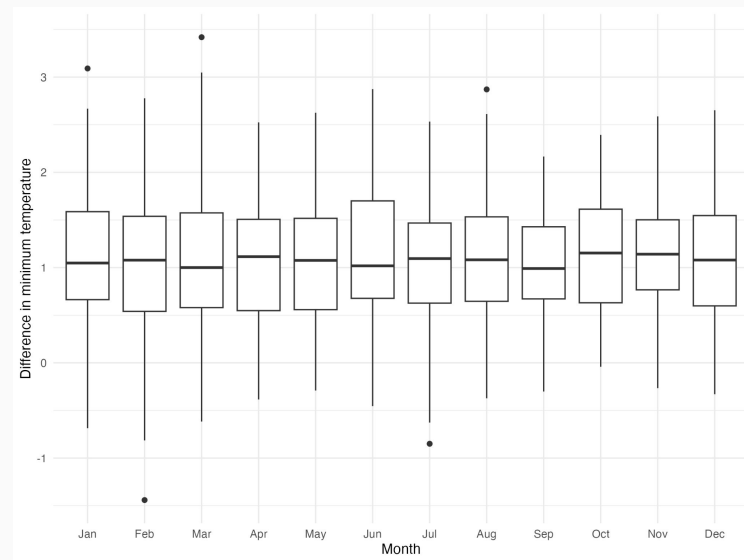
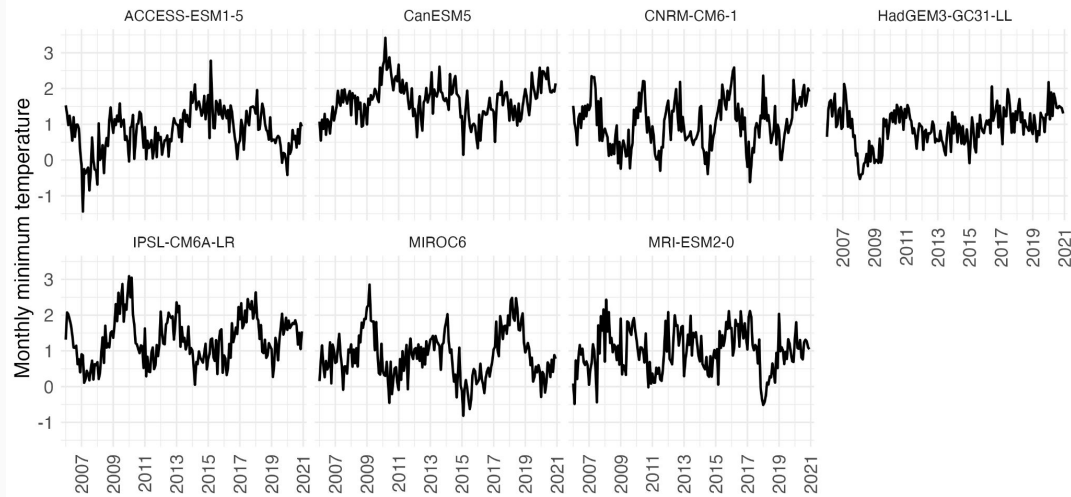
Approach 1: Limitations

- The CMIP6 temperature outputs do not follow the observed ENSO-driven temperature pattern that drives dengue in Cali, Colombia.
- The interannual effect in dengue model “forces” the ENSO-driven pattern into the dengue prediction output, even when the temperature timeseries do not follow that pattern.

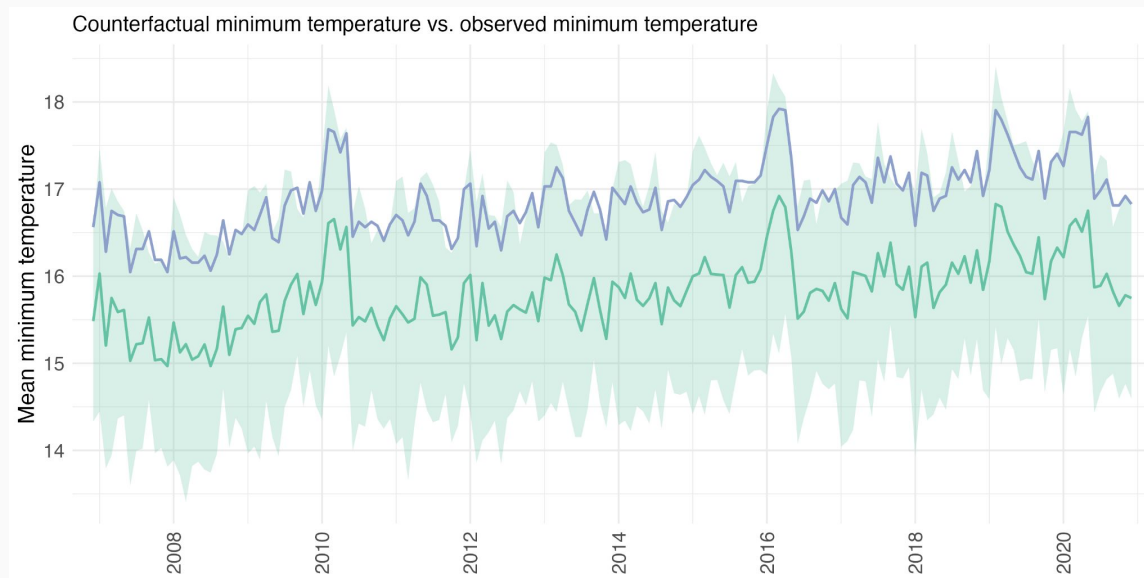


Predict dengue cases using a synthetic counterfactual scenario obtained by de-trending the temperature observations with the difference between the factual and counterfactual simulated timeseries.

Minimum temperature by scenario and climate model



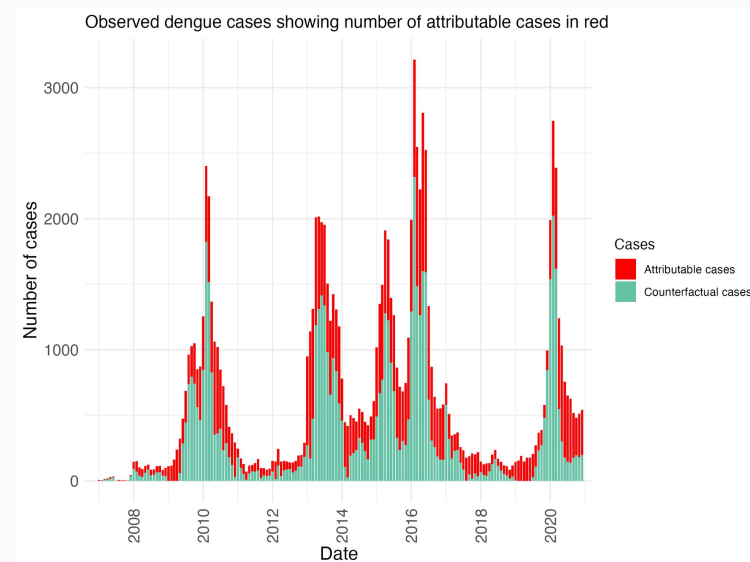
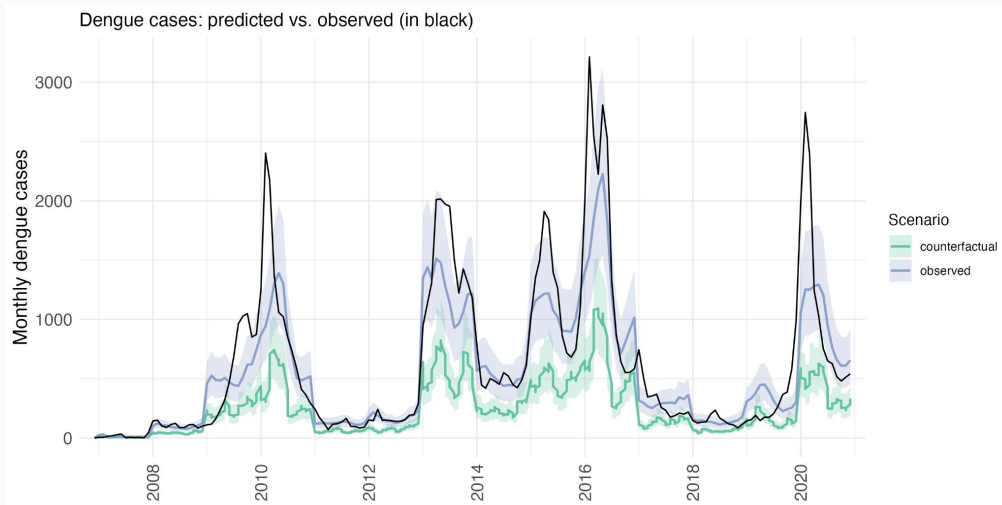
Predict dengue cases using a synthetic counterfactual scenario obtained by de-trending the temperature observations with the difference between the factual and counterfactual simulated timeseries.



Predict dengue cases using a synthetic counterfactual scenario obtained by de-trending the temperature observations with the difference between the factual and counterfactual simulated timeseries.

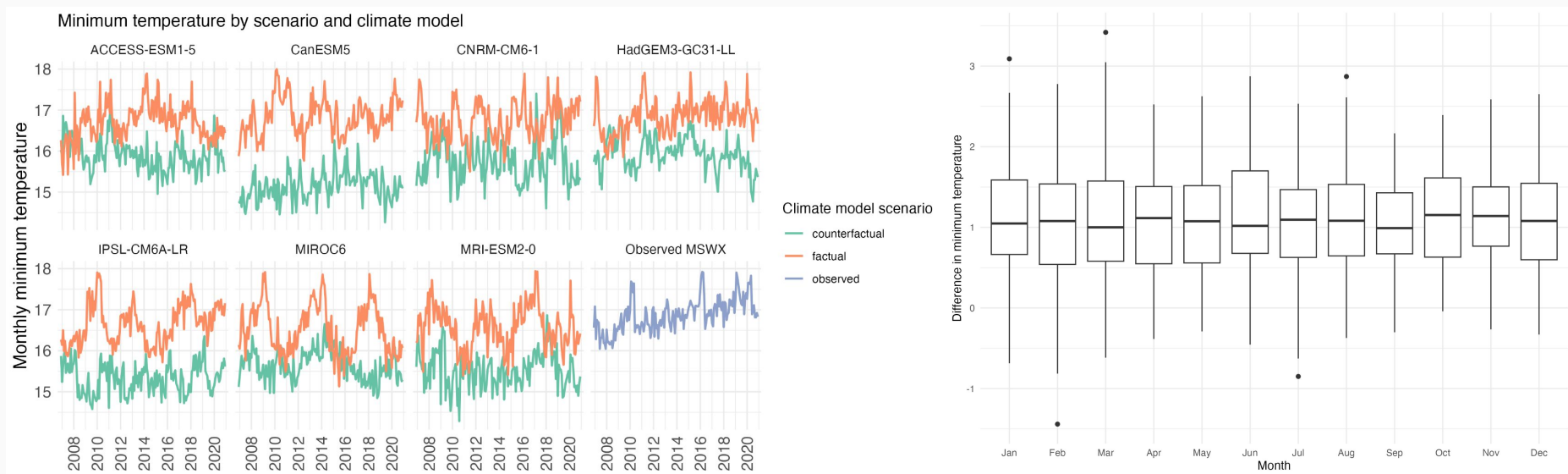
$$P_{t,sample}^{(f)} - P_{t,sample}^{(cf)} = \Delta_t$$

= 48043 cases between 2007 and 2020 → 45%



Approach 2: Limitations

- Taking an average of the attributed temperature removes internal variability in the attributed temperature.



Dengue case attribution: Conclusions

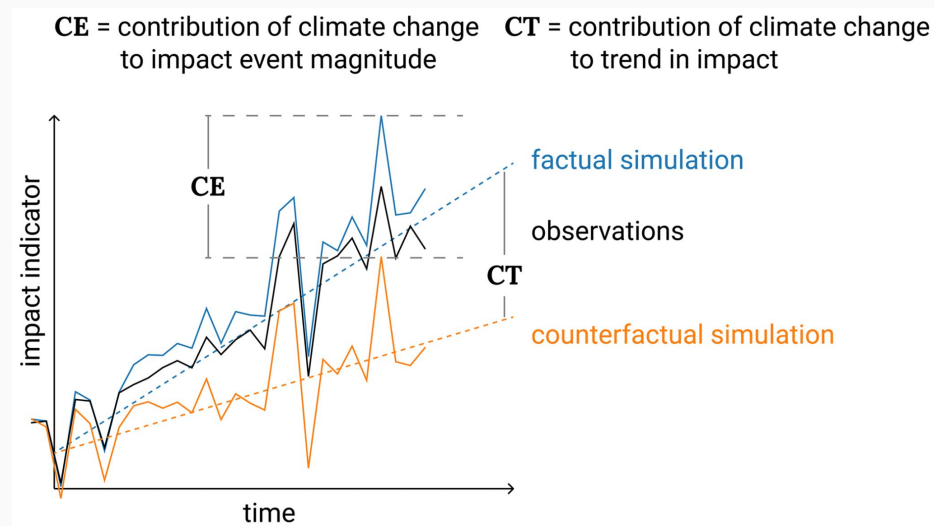
Interannual ENSO-driven disease dynamics →
Disease presents in distinct outbreaks →
Counterfactuals that preserve internal variability are important.

Possible counterfactual sources:

- ATTRICI
- AMIP
- Atmospheric nudging
- ????

Possible methodologies:

- Time-independence
- Trend-preserving bias correction
- ????



Source: Mengel et al. (2021)

Thank you!

The GHR team!



Giovenale
Moirano



Solomon
Gebrechorkos



Adrià San
José



Mauricio
Santos-Vega



Rachel
Lowe

Questions? Answers? Please reach out to
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