Long-term projections of the impacts of warming temperatures on Zika and dengue risk in four Brazilian cities using a temperature-dependent basic reproduction number

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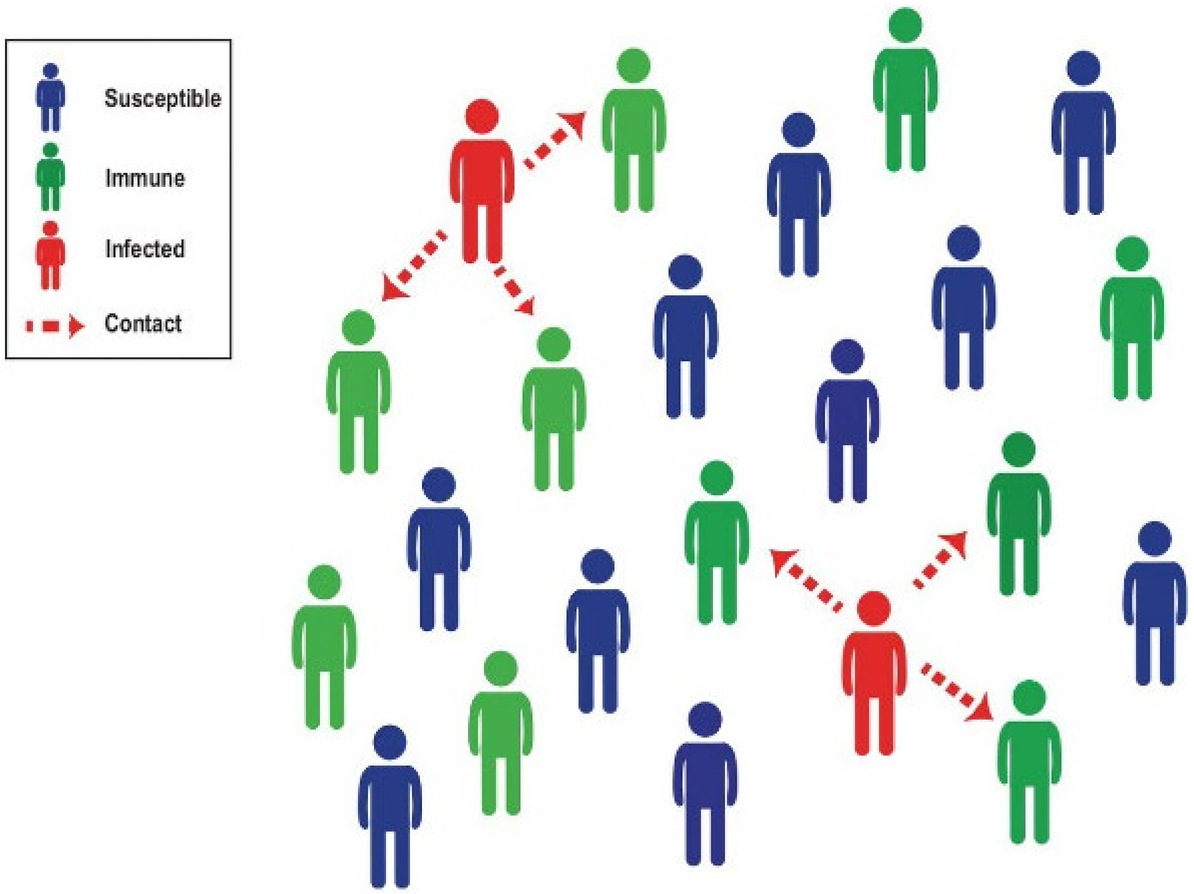
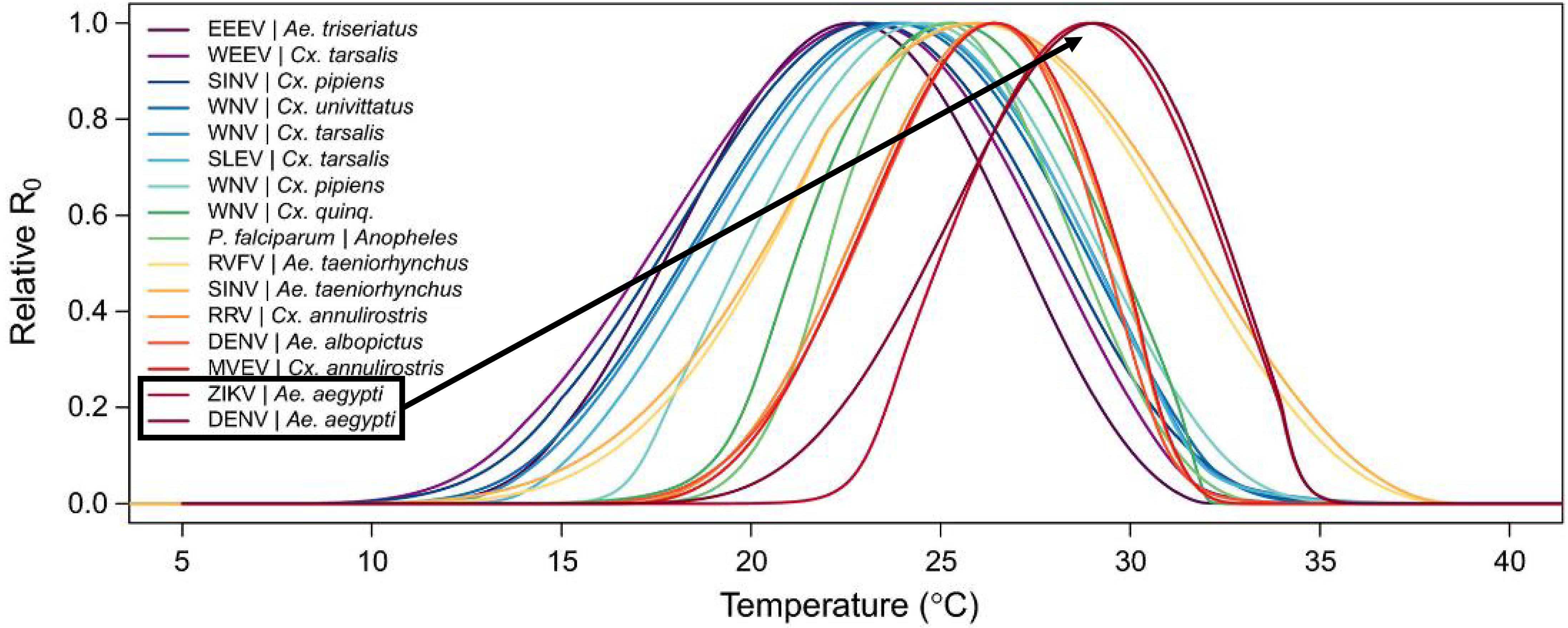
Zika and dengue are transmitted by the *Aedes aegypti* mosquito and infect 100-400 million people annually.

The basic reproduction number, $\mathcal{R}_0$, is a measurement of epidemic potential. It is defined as the number of secondary infections expected from a single infection in a **fully susceptible** population.

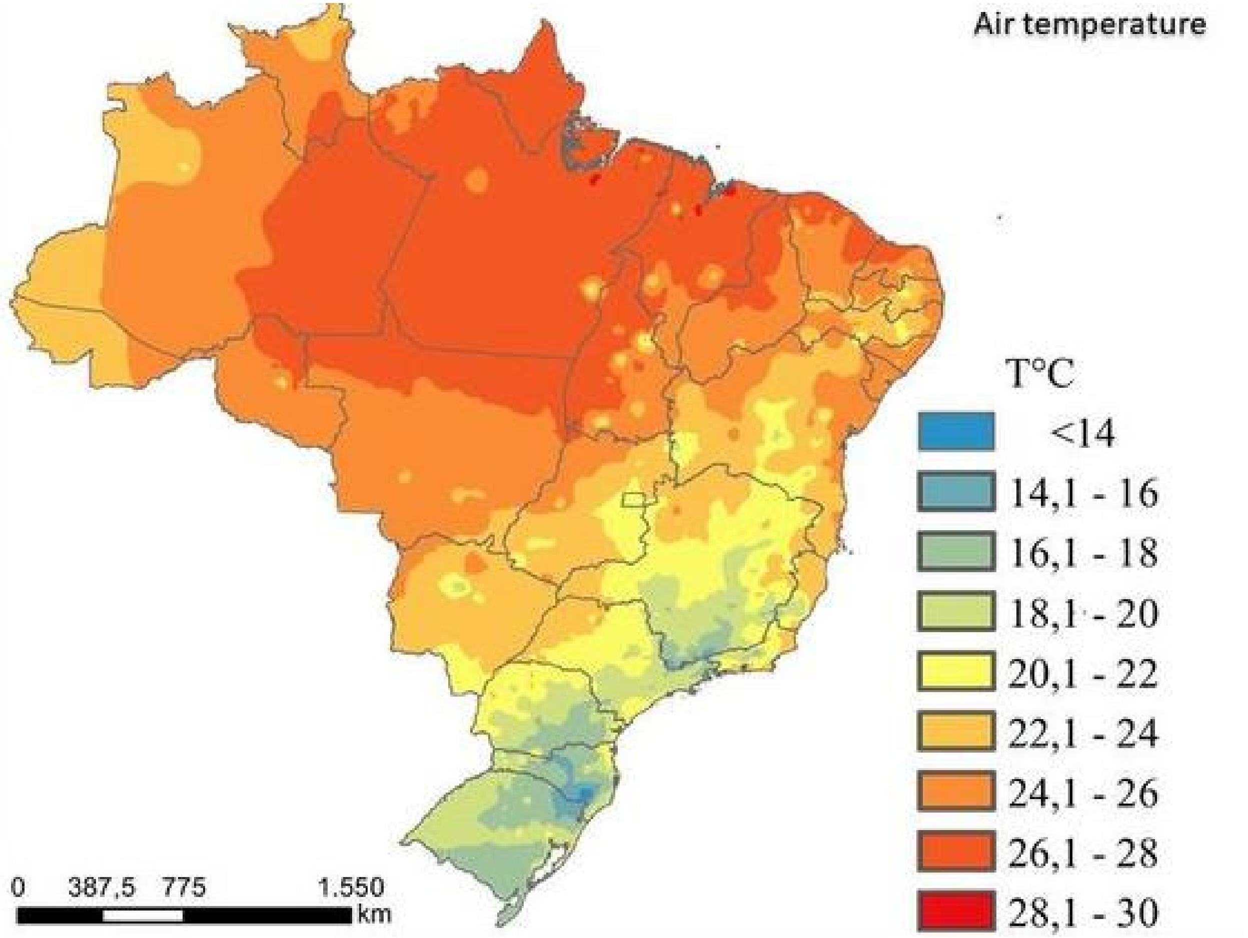


Zika and dengue risks ($\mathcal{R}_0$) peak at high temperatures relative to other vector-borne diseases



[1]E. Mordecai, et al., "Thermal biology of mosquito-borne disease," Ecology Letters, vol. 22, no. 10, pp. 1690–1708, 2019.

Due to climate change and previous Zika outbreaks, Brazil is at particular risk for Zika re-emergence. However, temperature-driven risk isn’t homogenous throughout the country.



Brazil average annual temperature

Research Questions & Goals

- Investigate how temperature changes driven by climate change will impact Zika risk in Brazil over a 30-year period.
- Understand temporal heterogeneity in risk (i.e., year-round and year-to-year) over various climatic regions.
- Use prior understanding of dengue risk to contextualize the results.

Methods

Temperature-dependent $\mathcal{R}_0$

Biting rate*

Vector competence*

$$\mathcal{R}_0(T) = \frac{a(T)^2 \pi_{mh} \pi_{hm}(T) \sigma_m(T) \sigma_h}{\mu_m(T)(\sigma_m(T) + \mu_m(T))(\sigma_h + \mu_h)(\gamma + \mu_h)} \cdot \frac{N_m}{N_h}$$

Mosquito mortality rate*

Extrinsic incubation rate*

* temperature-dependent trait

Temperature-dependent $\mathcal{R}_0$

Biting rate*

Vector competence*

Intrinsic incubation rate

$$\mathcal{R}_0(T) = \frac{a(T)^2 \pi_{mh} \pi_{hm}(T) \sigma_m(T) \sigma_h}{\mu_m(T)(\sigma_m(T) + \mu_m(T))(\sigma_h + \mu_h)(\gamma + \mu_h)} \cdot \frac{N_m}{N_h}$$

Mosquito to human ratio

Mosquito mortality rate*

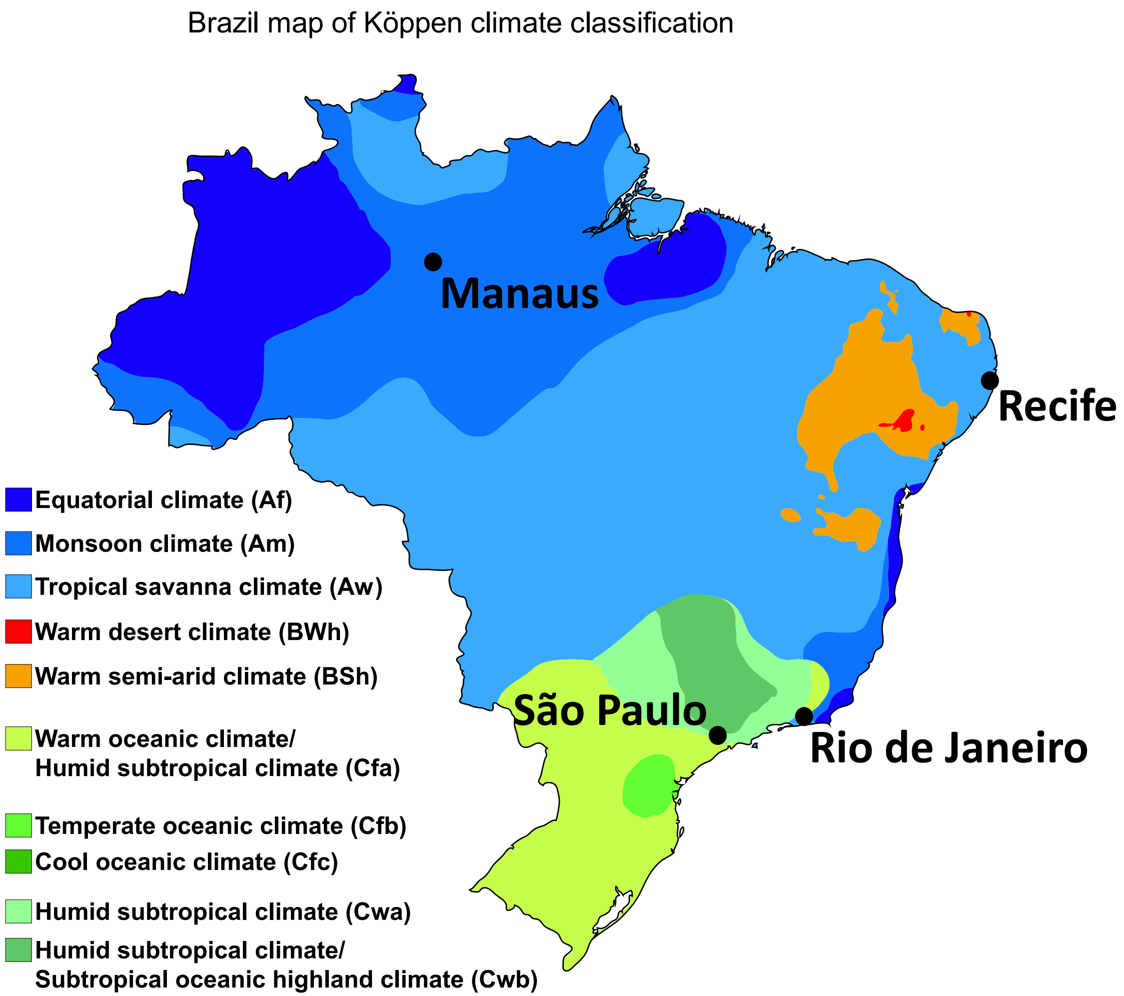
Extrinsic incubation rate*

Human mortality rate

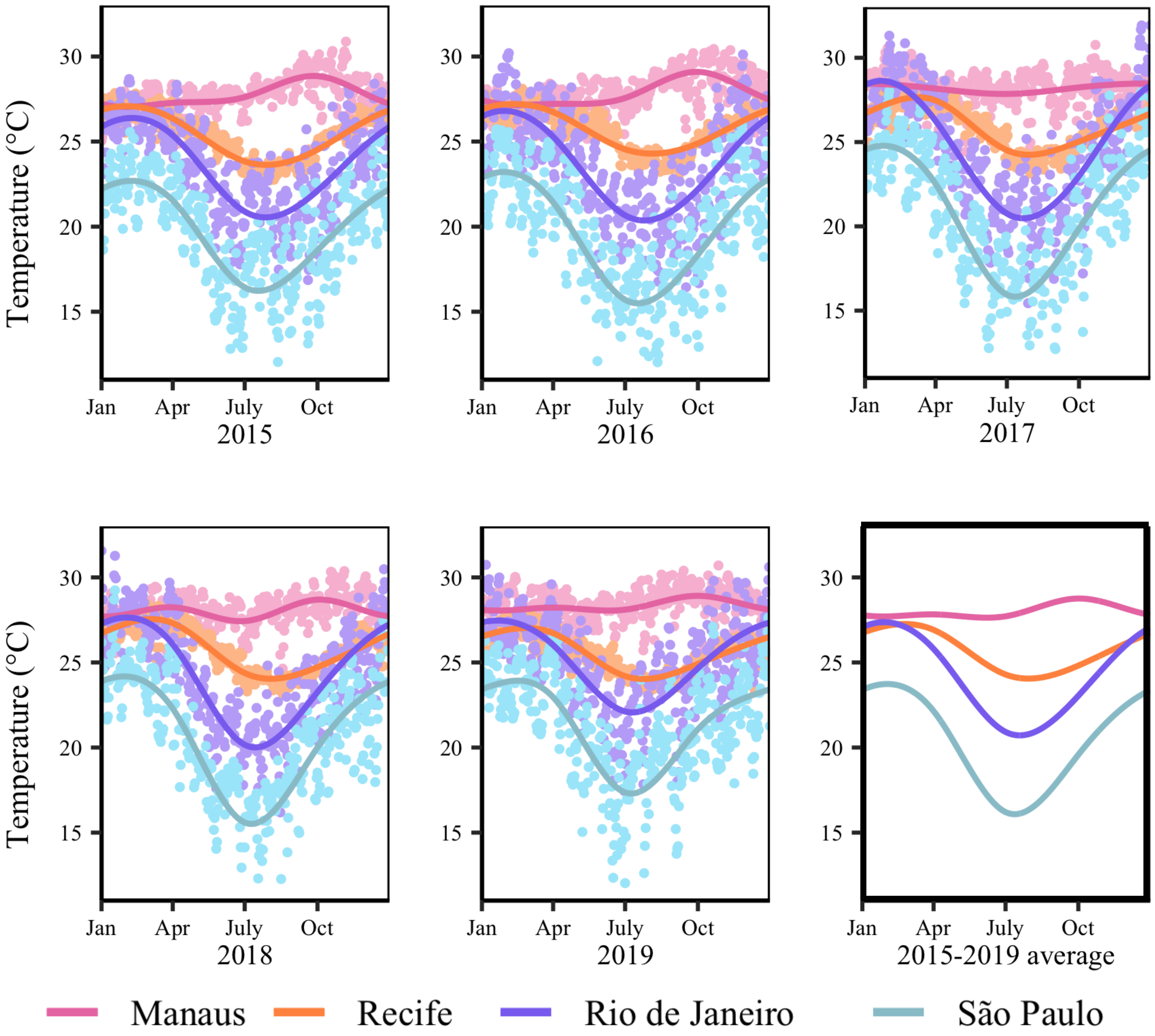
Human recovery rate

* temperature-dependent trait

To look at a diverse set of climates, we included Manaus, Recife, Rio de Janeiro and São Paulo

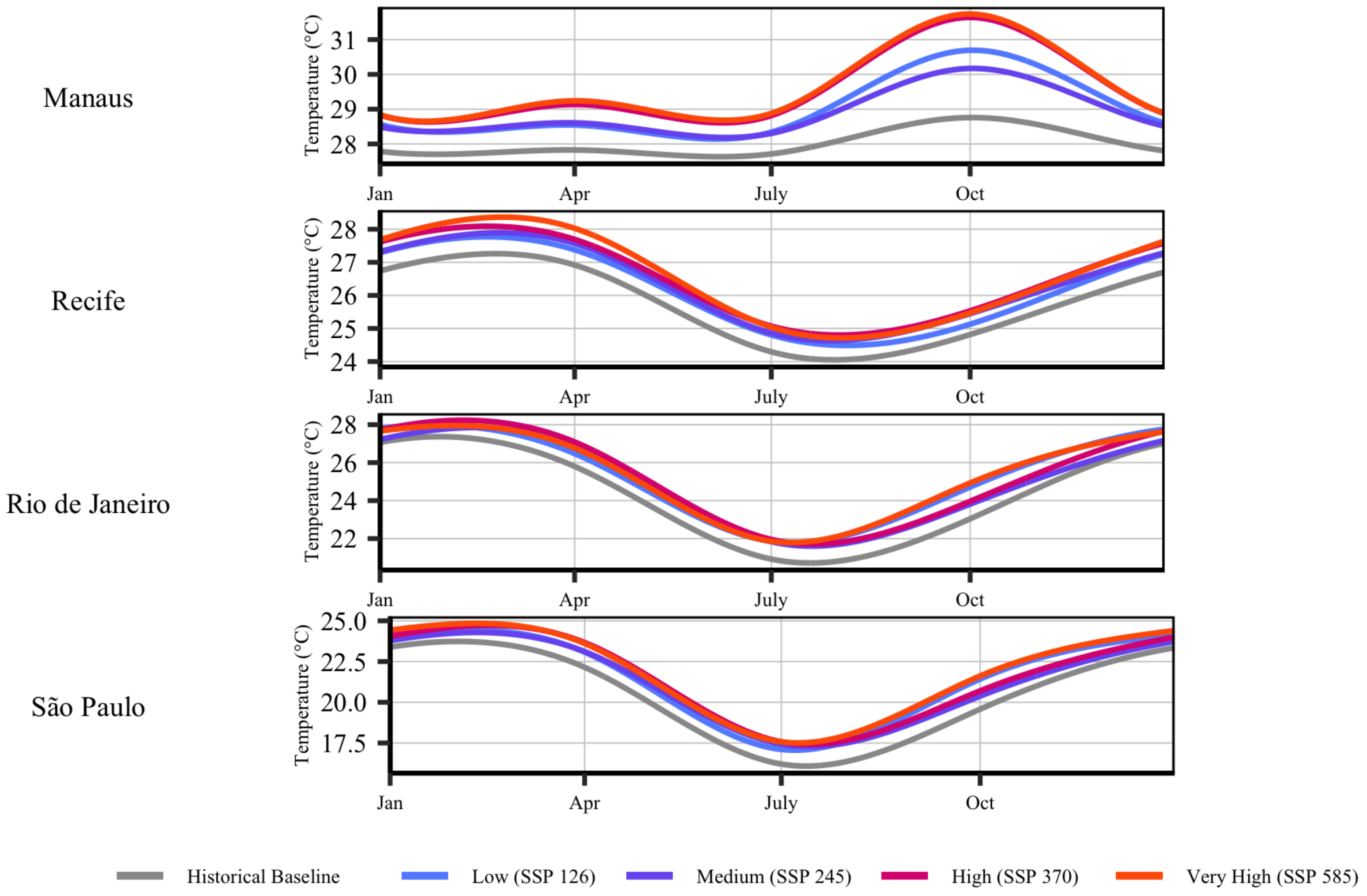


First, we fit cubic splines to historical temperature data for the years 2015-2019.



[4] J.P. Dunne, et al., "The GFDL Earth System Model Version 4.1 (GFDL-ESM 4.1): Overall Coupled Model Description and Simulation Characteristics," Journal of Advances in Modeling Earth Systems, vol. 12, no. 11, 2020.

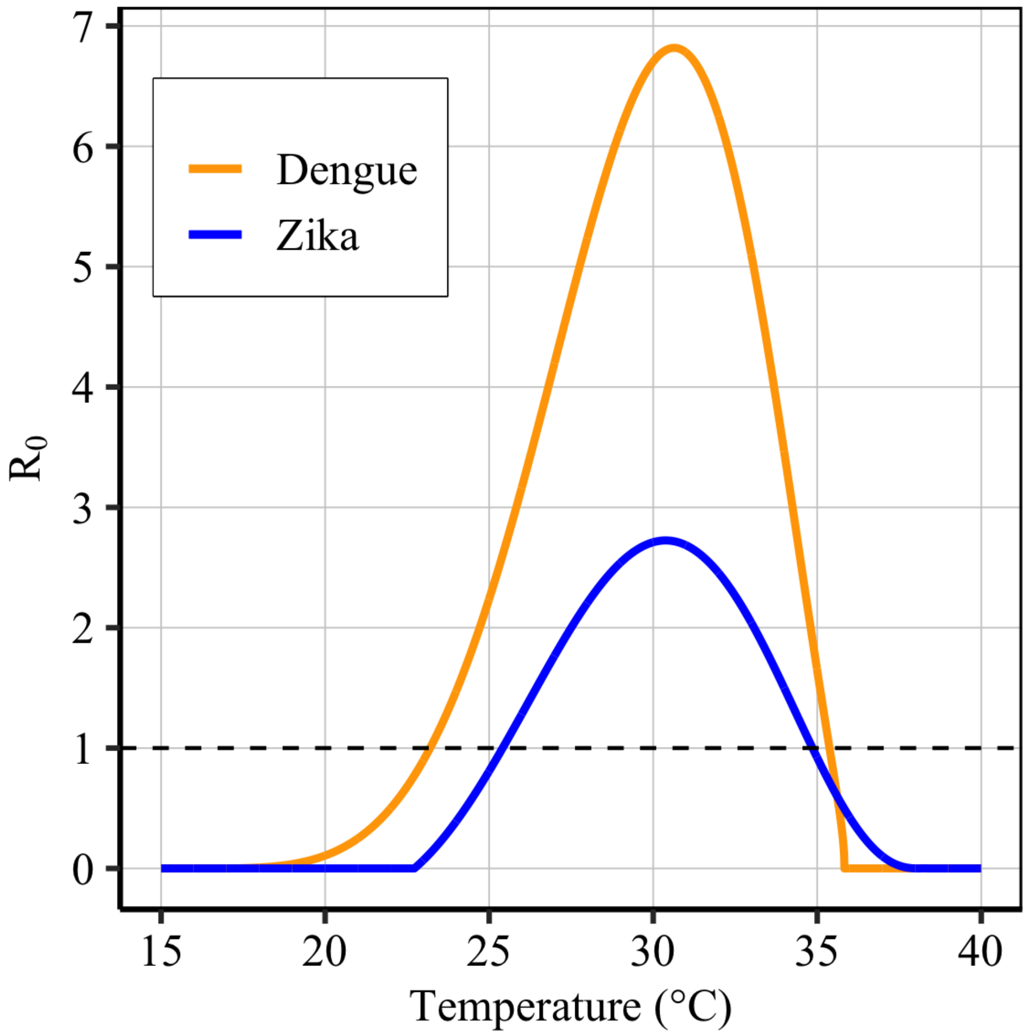
Next, we fit cubic splines to temperature projections for the years 2045-2049 under 4 Shared Socioeconomic Pathways (SSPs)[5] as our model input.



[5] K. Riahi, et al., "The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview," Global Environmental Change, vol. 42, 2017.

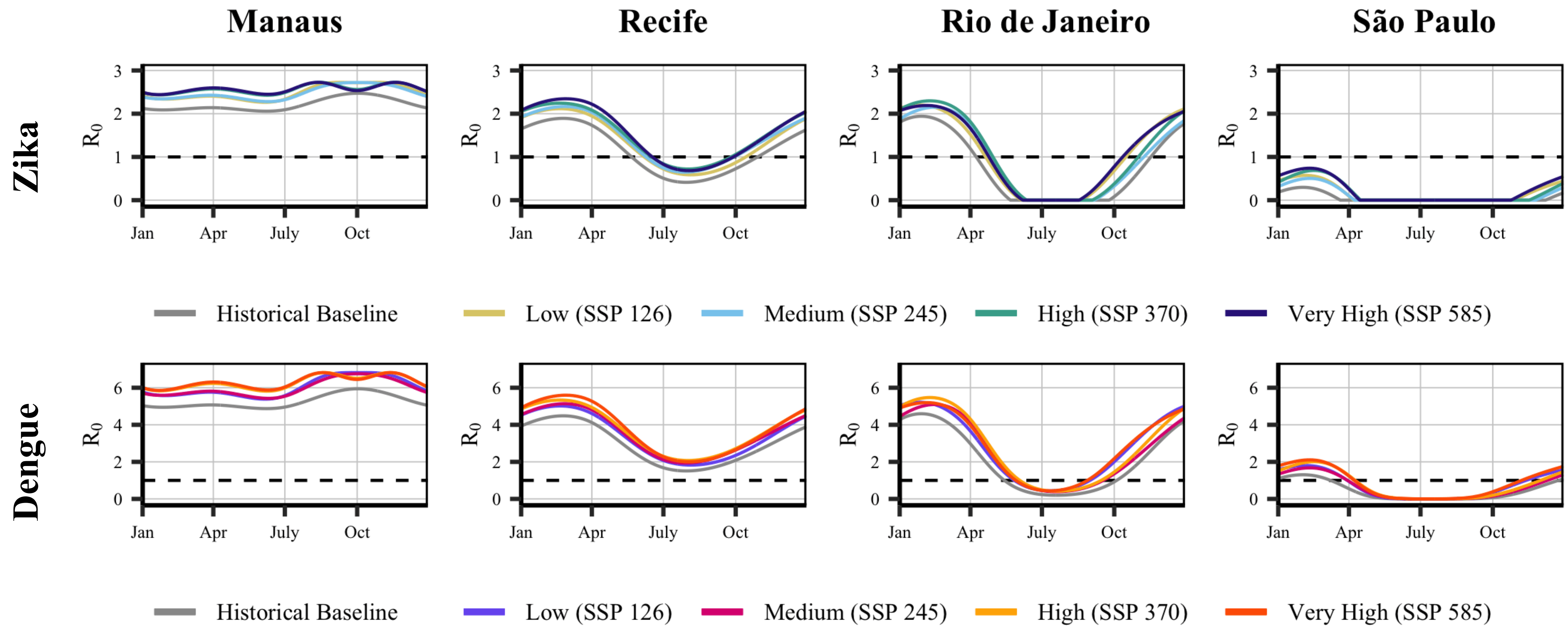
Results & Discussion

Consistent with existing research[6], we found that Zika risk is on average lower than dengue risk.



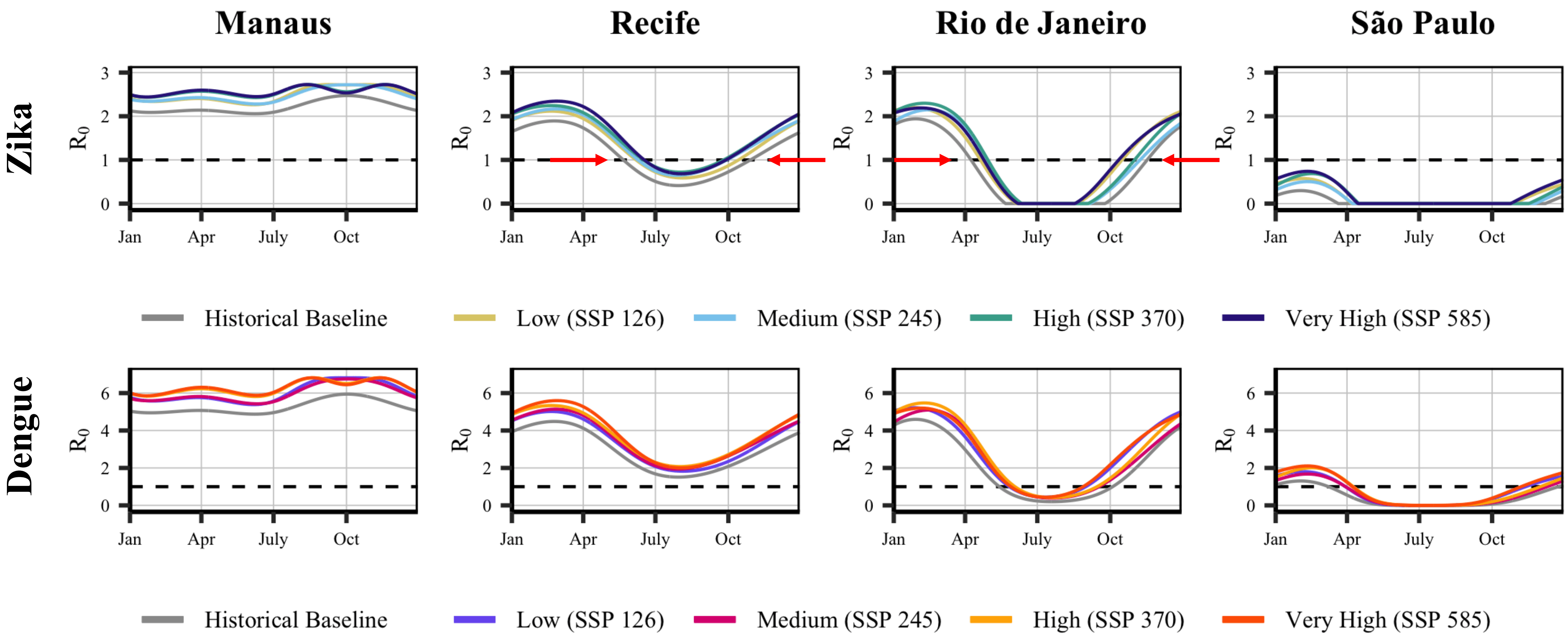
[6] Y. Liu, et al., "Reviewing estimates of the basic reproduction number for dengue, Zika and chikungunya across global climate zones," Environmental Research, vol. 182, 2020.

Projection of seasonal epidemic potential $\mathcal{R}_0(T(t))$ by 2045-2049

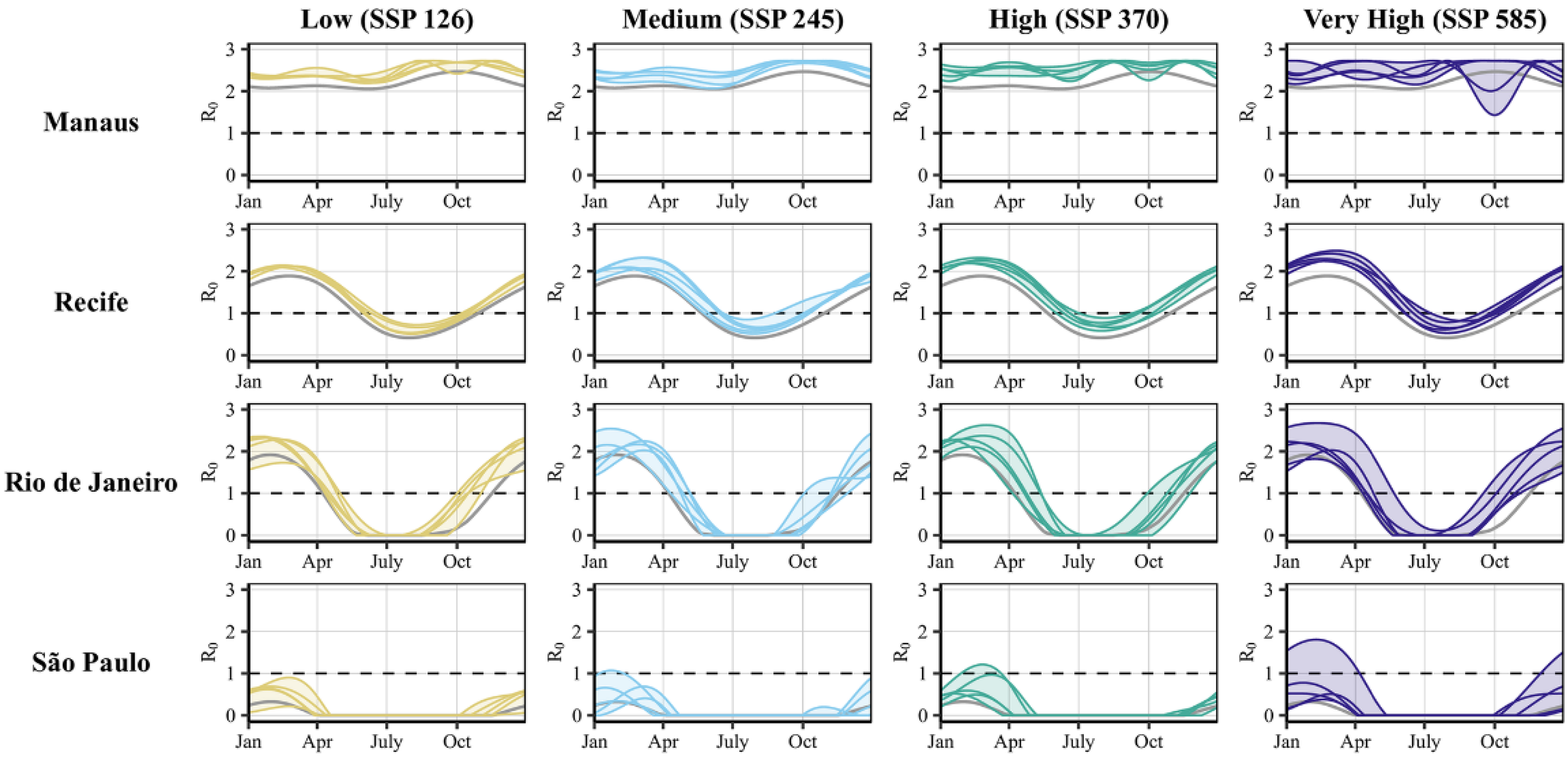


[7] Van Wyk, H., Eisenberg, J. N., & Brouwer, A. F. (2023). Long-term projections of the impacts of warming temperatures on Zika and dengue risk in four Brazilian cities using a temperature-dependent basic reproduction number. PLOS Neglected Tropical Diseases, 17(4).

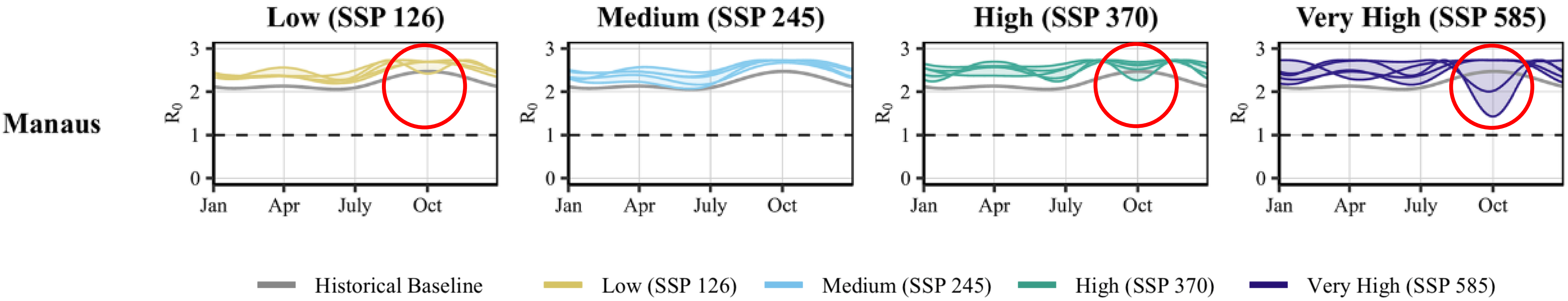
Extended risk seasons for cities that don't currently have year-round transmission potential such as Rio de Janeiro.



Large heterogeneity year-to-year and between SSP scenario



Risk reduction only occurs in extreme climates and over short periods of time



Conclusion

- Our model shows increase in risk by 2045-2049 even in the most mitigated climate change scenario

- National-level preparation should include enhanced surveillance equipped for extended and earlier risk seasons

Thank you!