IDM Symposium - October 1st 2024

Challenges and opportunities in modeling cholera and climate

Javier Perez-Saez

Importance of cholera and climate

In the news:

“Cholera thrives on poverty and conflict, but is now being **turbo-charged by climate change**.

Extreme climate events like floods, cyclones and droughts further reduce access to clean water and create the ideal environment for cholera to spread.”

WHO Director-General's opening remarks at the media briefing October 5 2022

In reports:

TS.B.5.7 Higher temperatures (*very high confidence*), heavy rainfall events (*high confidence*) and flooding (*medium confidence*) are associated with increased water-borne diseases, particularly diarrhoeal diseases, including cholera (*very high confidence*) and other gastrointestinal infections (*high confidence*) in high-, middle- and low-income countries. Water insecurity and inadequate water, sanitation and hygiene increase disease risk (*high confidence*), stress and adverse mental health (*limited evidence, medium agreement*), food insecurity and adverse nutritional outcomes and poor cognitive and birth outcomes (*limited evidence, medium agreement*). {4.3.3, 7.2.2, Box 7.3, 9.10.1, Figure 9.33, 10.4.7, 11.3.6, 12.3.4, 12.3.5, 13.7.1, Figure 13.24, 14.5.6, 16.2.3, CCP6.2.6, CCB ILLNESS, CWGB URBAN}

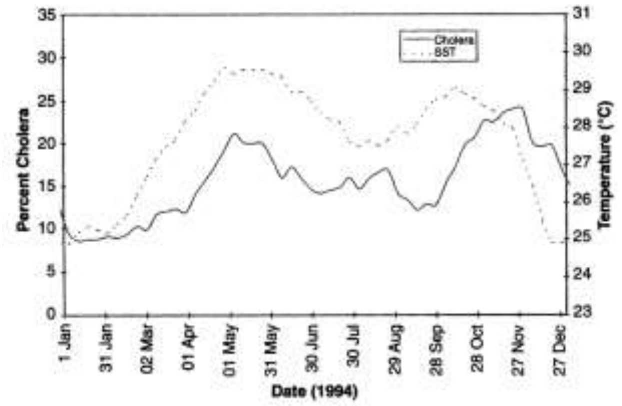
IPCC, 2022: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change

Evidence on cholera and climate/weather

Positing a cholera-climate relation

Global Climate and Infectious Disease: The Cholera Paradigm*

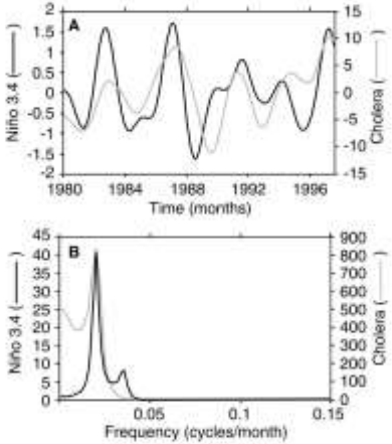
Rita R. Colwell



Colwell, *Science*, 1996

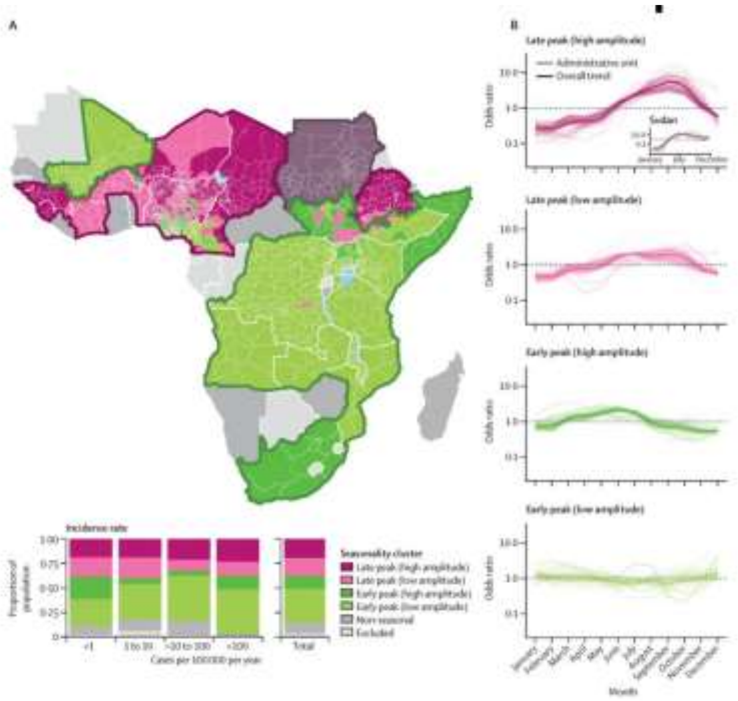
Cholera Dynamics and El Niño–Southern Oscillation

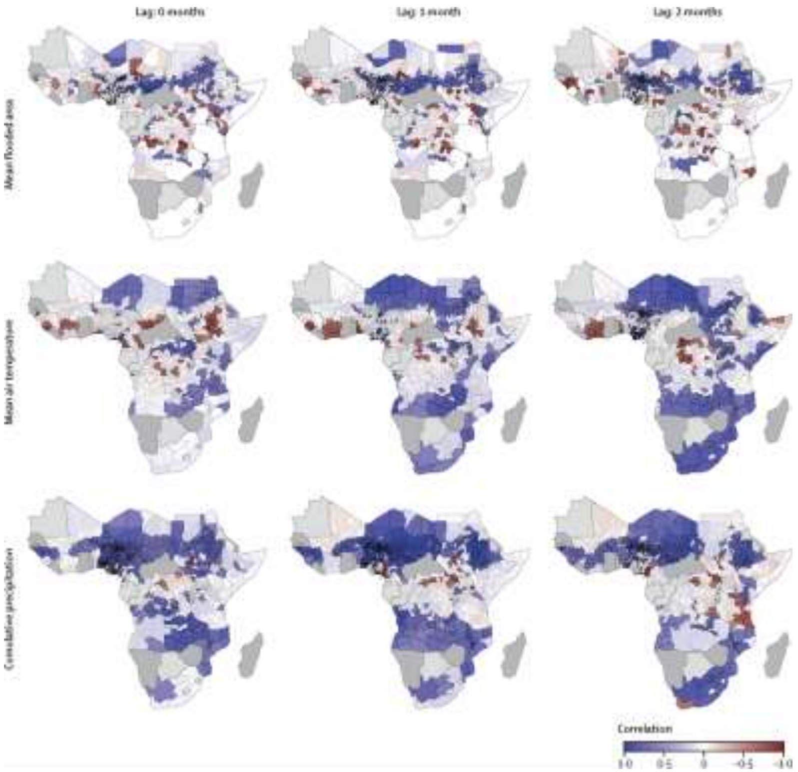
Mercedes Pascual,[1*] Xavier Rodó,[2] Stephen P. Ellner,[3] Rita Colwell,[4] Menno J. Bouma[5]



Pascual et al., *Science*, 2000

Positing a cholera-climate relation

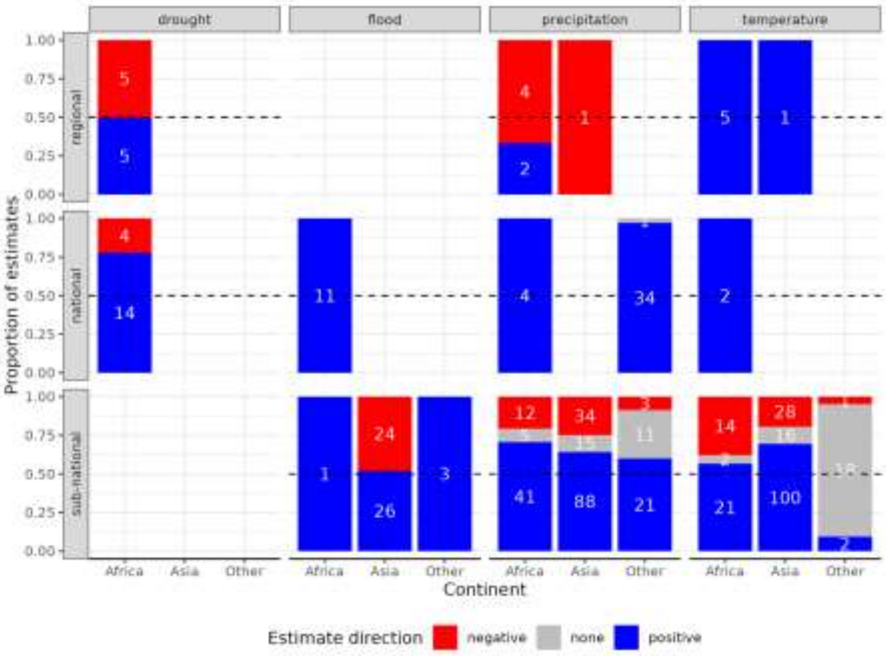




Perez-Saez et al., *Lancet Global Health*, 2022

What evidence is there on cholera-climate relations?

- Systematic review: 2,500 screened, 53 papers extracted
- Most evidence from South-East Asia (Bangladesh)
- Inconsistent directions of associations
- Heterogeneous study quality
- Context-dependence



Zheng et al., in preparation

Challenges in modeling cholera and climate/weather

Challenges in quantifying relations

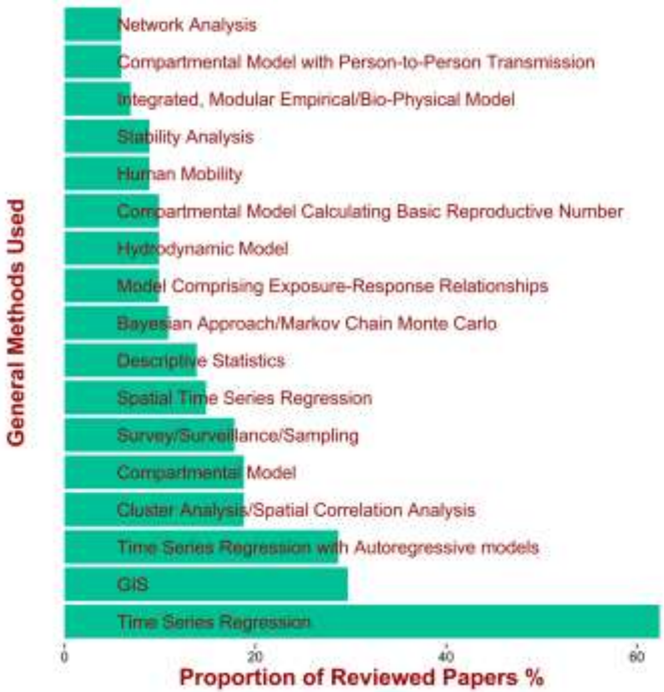
RESEARCH ARTICLE

Challenges in developing methods for quantifying the effects of weather and climate on water-associated diseases: A systematic review

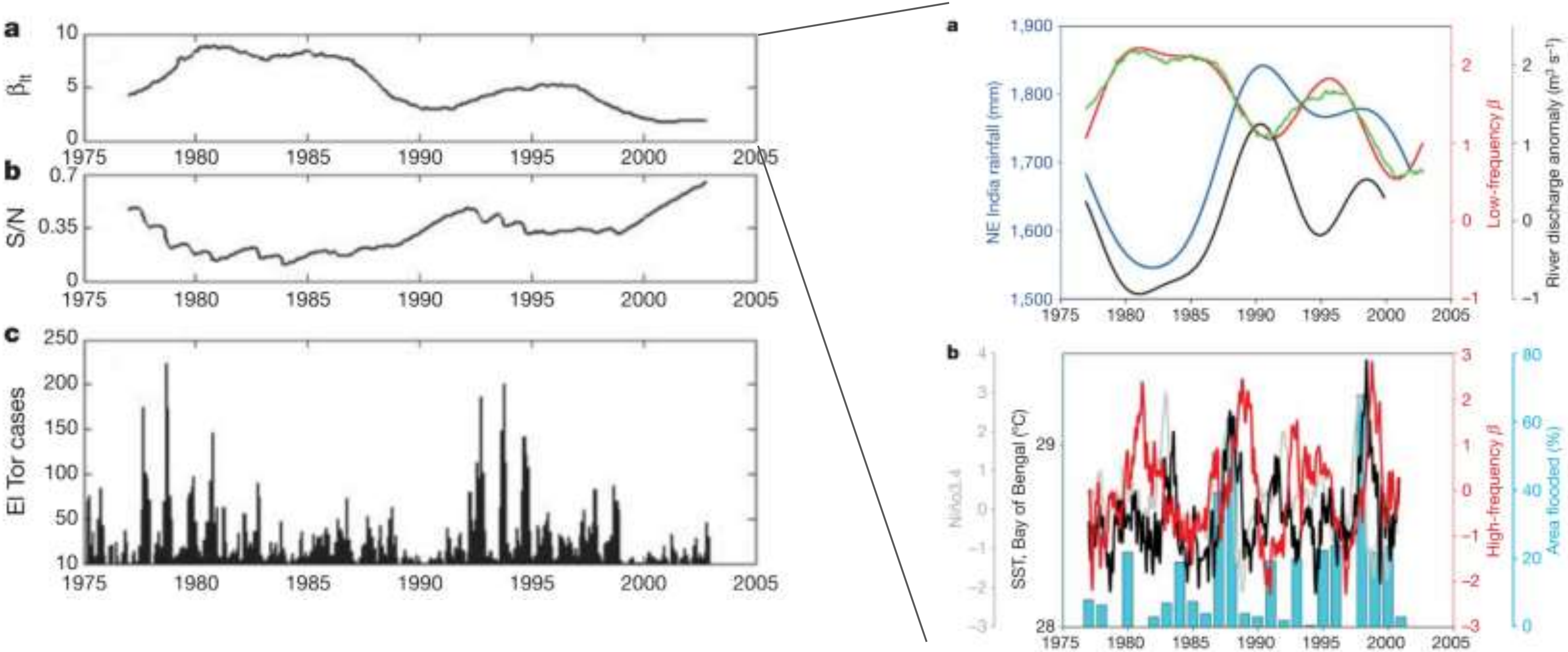
Giovanni Lo Iacono[1]*, Ben Armstrong[2], Lora E. Fleming[3], Richard Elson[4], Sari Kovats[2], Sotiris Vardoulakis[1,2,3,5], Gordon L. Nichols[3,4,6,7]

Lo Iacono et al., *PLoS NTD*, 2017

- Diversity of methods and approaches
- Challenges with epi and climate/weather data
- Challenge with multiple transmission pathways

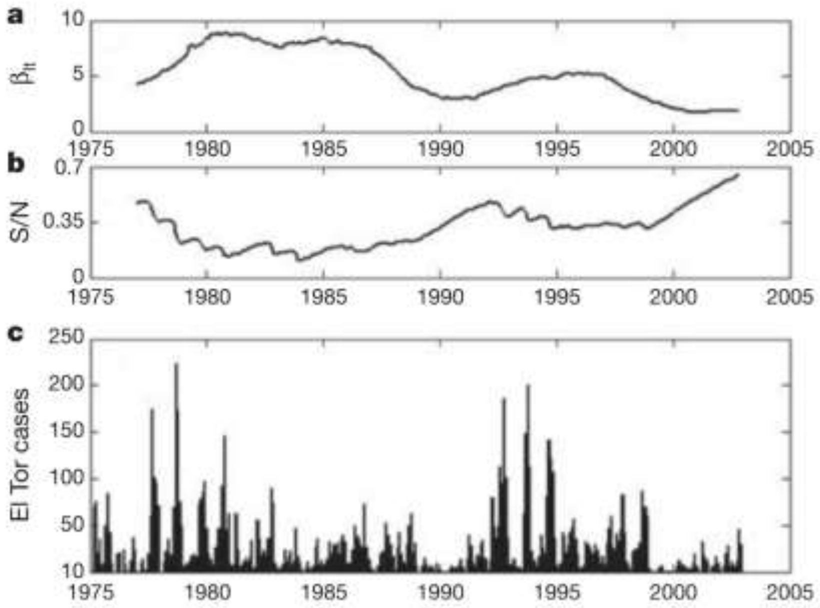


Challenges in quantifying relations: immunity dynamics

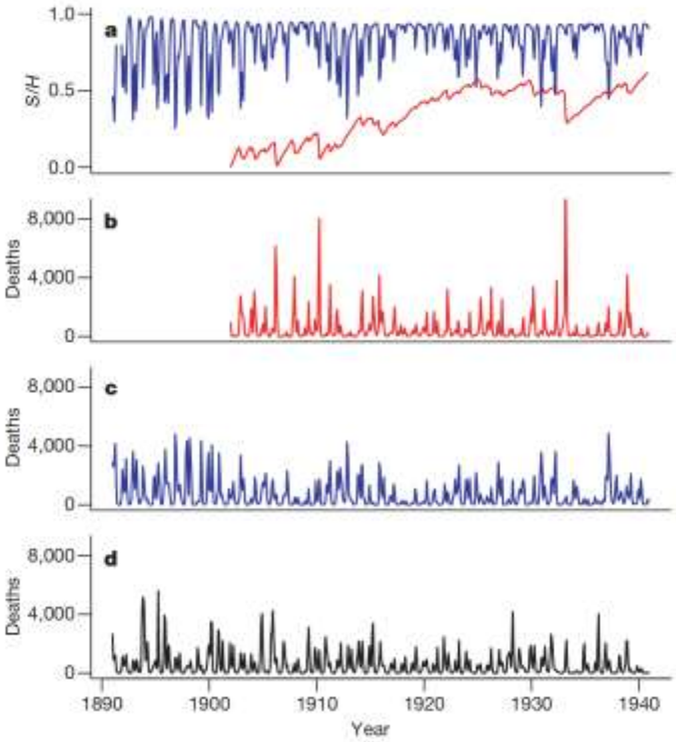


Koelle et al., *Nature*, 2005

Challenges in quantifying relations: immunity dynamics



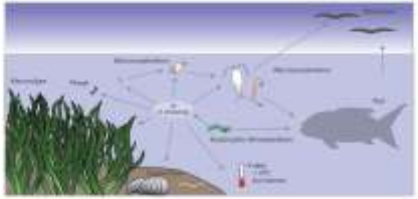
Koelle et al., *Nature*, 2005



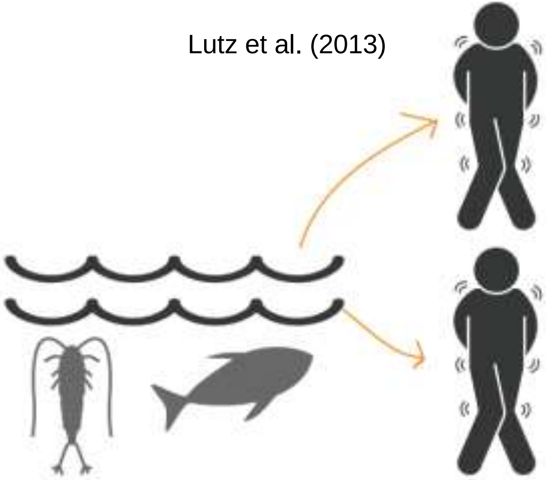
King et al., *Nature*, 2008

Transmission pathways and cholera-climate

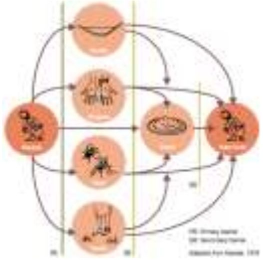
Spillover

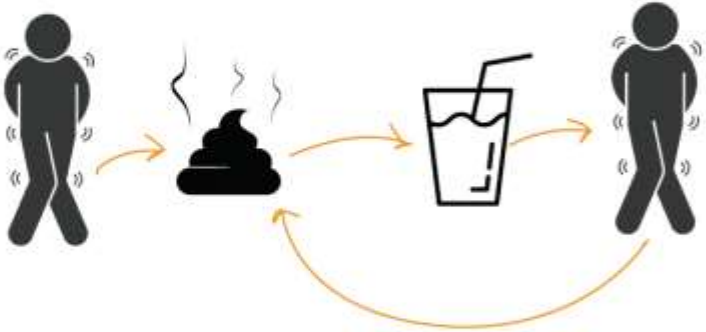


Lutz et al. (2013)



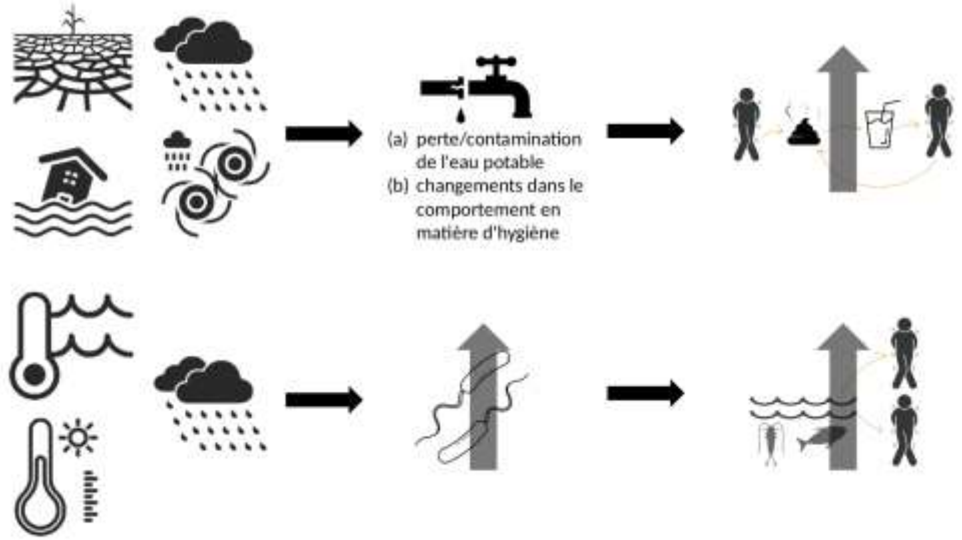
Human-to-human





Effect modifiers: water sanitation and hygiene

- Decoupling between climate/weather and WASH?
- Probably dependent on transmission pathways



Azman & Perez-Saez, *Revue médicale Suisse*, 2022

Effect modifiers: previous hydro-climatic conditions matter

| Review | 7 December 2020

Understanding the Impact of Rainfall on Diarrhea: Testing the Concentration-Dilution Hypothesis Using a Systematic Review and Meta-Analysis

Authors: Alicia N. M. Kraay, Olivia Man, Morgan C. Levy, Karen Levy, Edward Ionides, and Joseph N. S. Eisenberg AUTHORS INFO & AFFILIATIONS

Kraay et al., *Env. Health Persp.*, 2020

- Account for previous wetness conditions for rainfall impacts
- Depends on climate zone
- Differential WASH impact?

Table 4. Pooled estimates and effect modifiers for the association between climate exposures and diarrhea.

Climate exposure	Effect modifier category	IRR (95% CI)
Extreme rain (vs. normal conditions) ($g = 87$, $n = 13$)	—	1.16 (0.946, 1.42)
Extreme rain × prior rain level[a]		
	Dry ($g = 4$, $n = 4$)	1.26 (1.05, 1.51)
	Moderate ($g = 4$, $n = 4$)	1.01 (0.860, 1.14)
	Wet ($g = 3$, $n = 3$)	0.911 (0.771, 1.08)
Extreme rain × threshold type		
	80th percentile ($g = 3$, $n = 1$)	1.36 (0.883, 2.09)
	90th percentile ($g = 47$, $n = 8$)	0.978 (0.887, 1.08)
	95th percentile ($g = 12$, $n = 1$)	0.972 (0.877, 1.08)
	99th percentile ($g = 14$, $n = 2$)	1.00 (0.895, 1.12)
	Storm ($g = 9$, $n = 2$)	2.51 (2.03, 3.10)
Season (rainy vs. dry) ($g = 62$, $n = 24$)	—	1.46 (0.981, 2.17)
Season × pathogen type		
	All-cause diarrhea ($g = 31$, $n = 11$)	1.11 (0.701, 1.76)
	Bacteria ($g = 15$, $n = 4$)	2.70 (1.64, 4.45)
	Parasite ($g = 8$, $n = 7$)	2.76 (1.32, 5.77)
	Virus ($g = 8$, $n = 8$)[b]	0.844 (0.530, 1.35)
Season × urbanicity		
	Rural ($g = 17$, $n = 8$)	1.55 (1.02, 2.36)
	Urban ($g = 40$, $n = 18$)	1.46 (0.964, 2.22)
	Mixed ($g = 5$, $n = 2$)	1.36 (0.889, 2.08)
Season × income level	Income level	
	Upper/upper-middle income ($g = 6$, $n = 5$)	2.32 (0.955, 5.62)
	Lower-middle income ($g = 45$, $n = 15$)	1.19 (0.759, 1.86)
	Low income ($g = 11$, $n = 5$)	1.81 (1.15, 2.85)
Flood (yes/no) ($g = 125$, $n = 14$)		1.56 (0.913, 2.67)
Flood × pathogen type		
	All-cause ($g = 90$, $n = 9$)	1.64 (0.928, 2.88)
	Bacteria ($g = 21$, $n = 6$)	1.57 (0.893, 2.78)
	Protozoa ($g = 5$, $n = 2$)	1.29 (0.699, 2.37)
	Virus ($g = 8$, $n = 1$)	1.05 (0.572, 1.91)
Rain ($g = 41$, $n = 15$)		0.998 (0.967, 1.03)

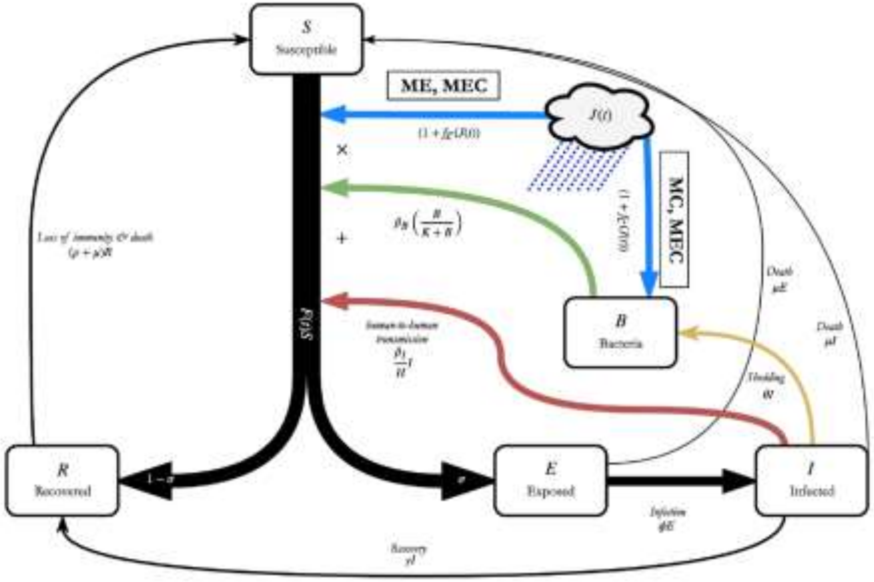
Modeling cholera and climate/weather

What aims for modeling cholera and climate

- Spatial targeting interventions
  - Where to intervene to offset climate effects?
- Forecasting
  - Where will outbreaks occur in the near future (1 week, a month?)
- Attribution studies
  - What is the probability an outbreak may be due to climate change?
- Strategic modeling
  - Alternative vaccination timings under climate change conditions?

Scoping review of **mechanistic** modeling of cholera-climate

- 127 screened, 18 selected
- Focus on rainfall
  - Linear effect on exposure/contamination
  - Mostly satellite-derived rainfall



Lemaitre et al., *Acta Tropica*, 2019

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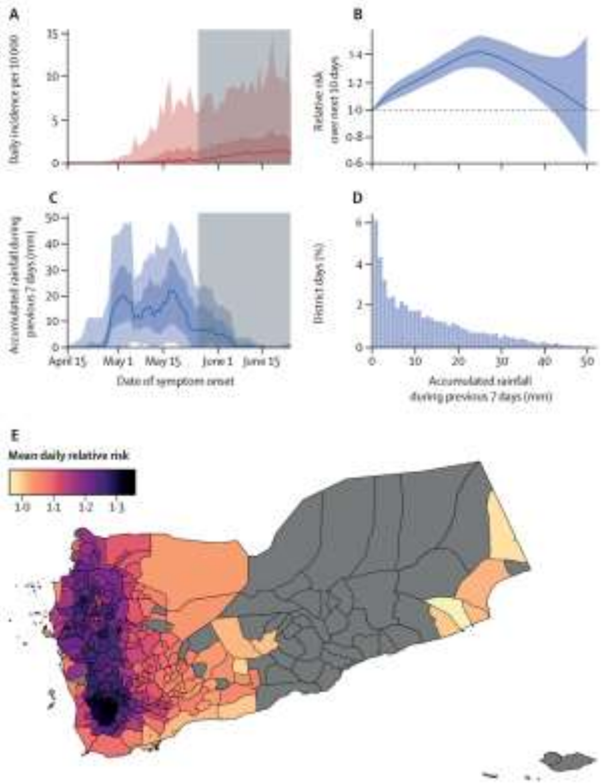

Camacho et al., *Lancet Global Health*, 2018

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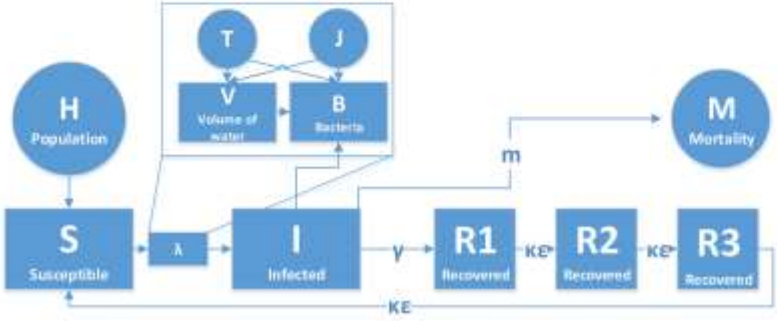

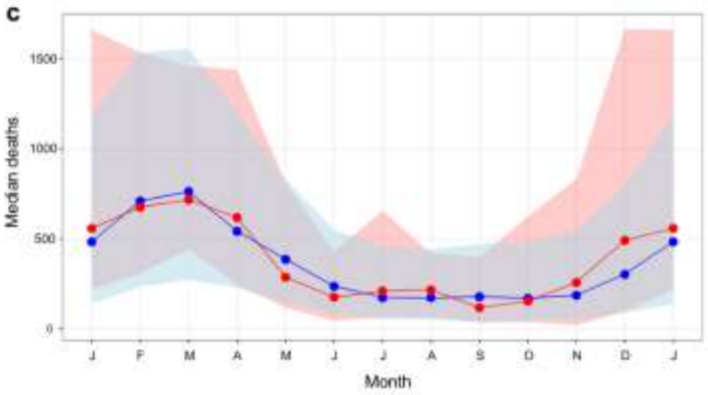

Baracchini et al., *Advances in Water Research,* 2017

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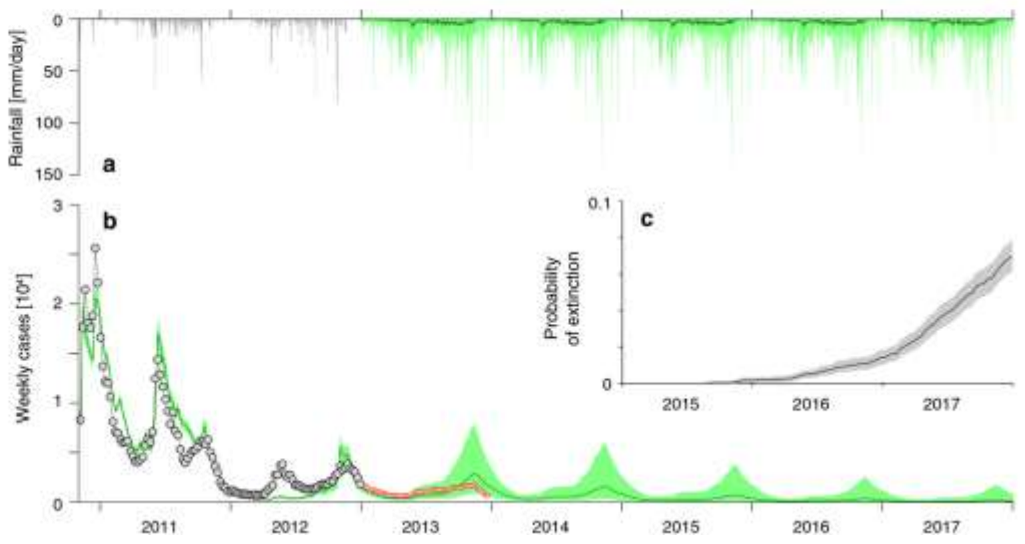

Bertuzzo et al., *Stoch. Env. Research and Risk Assess.*, 2014

Scoping review of **mechanistic** modeling of cholera-climate

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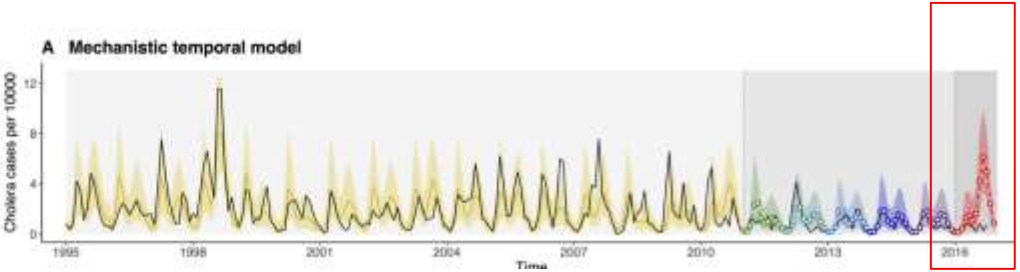
  - Mostly satellite-derived rainfall
- Few on role of ENSO



Martinez et al., *PLoS One*, 2017

Scoping review of **mechanistic** modeling of cholera-climate

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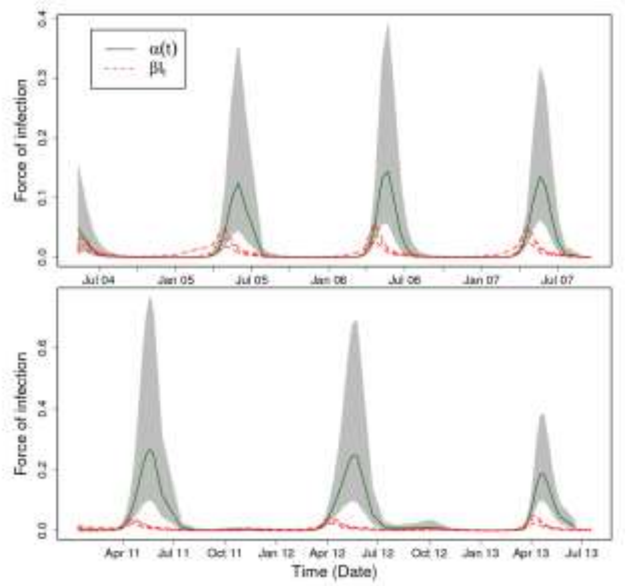
- Focus on rainfall
  - Linear effect on exposure/contamination
  - Mostly satellite-derived rainfall
- Few on role of ENSO
- Few on temperature

Negative effect of water depth,
Positive effect of water temperature



Koepke et al., *Annals of Applied Statistics*, 2016

Gaps in modeling climate/weather and cholera

- Few studies incorporate weather-climate mechanistically
- Weather:
  - Rainfall: lags, transformations, previous conditions, epidemic phase
  - Temperature: bacterial dynamics, exposure dose
- Climate:
  - Beyond forecasting to scenario modeling
- Effect modification by WASH conditions
- Effect modification by immunity dynamics
- Data gaps: exposure (satellite) and epi (suspected vs. confirmed cases)
- Other model purposes: strategic modeling, attribution

Conclusion and opportunities for future studies

- Despite old evidence, still young field
- Diversity of transmission settings relevant to current cholera control
- Diversity of model purposes
- Disentangle transmission pathways (epi studies)
- Account for effect modification (WASH, immunity)
- Potential for novel epi data sources (serology, genomic, eDNA, wastewater)

Thanks for your attention!