AMS American Meteorological Society

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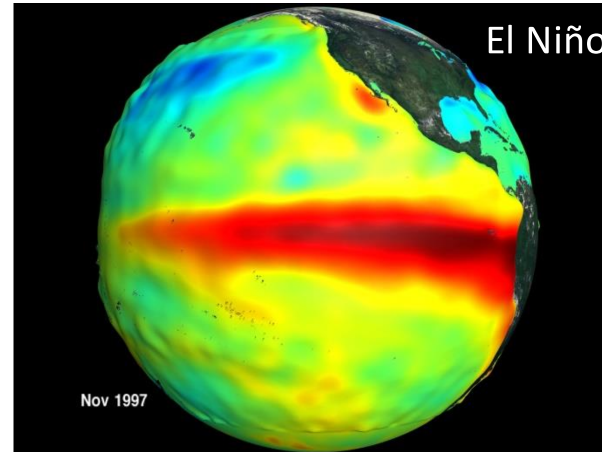
Nonstationary and Mediated Dynamics between Climate and Cholera Incidence in Northern Peru, 1991-2001



Vibrio Cholerae

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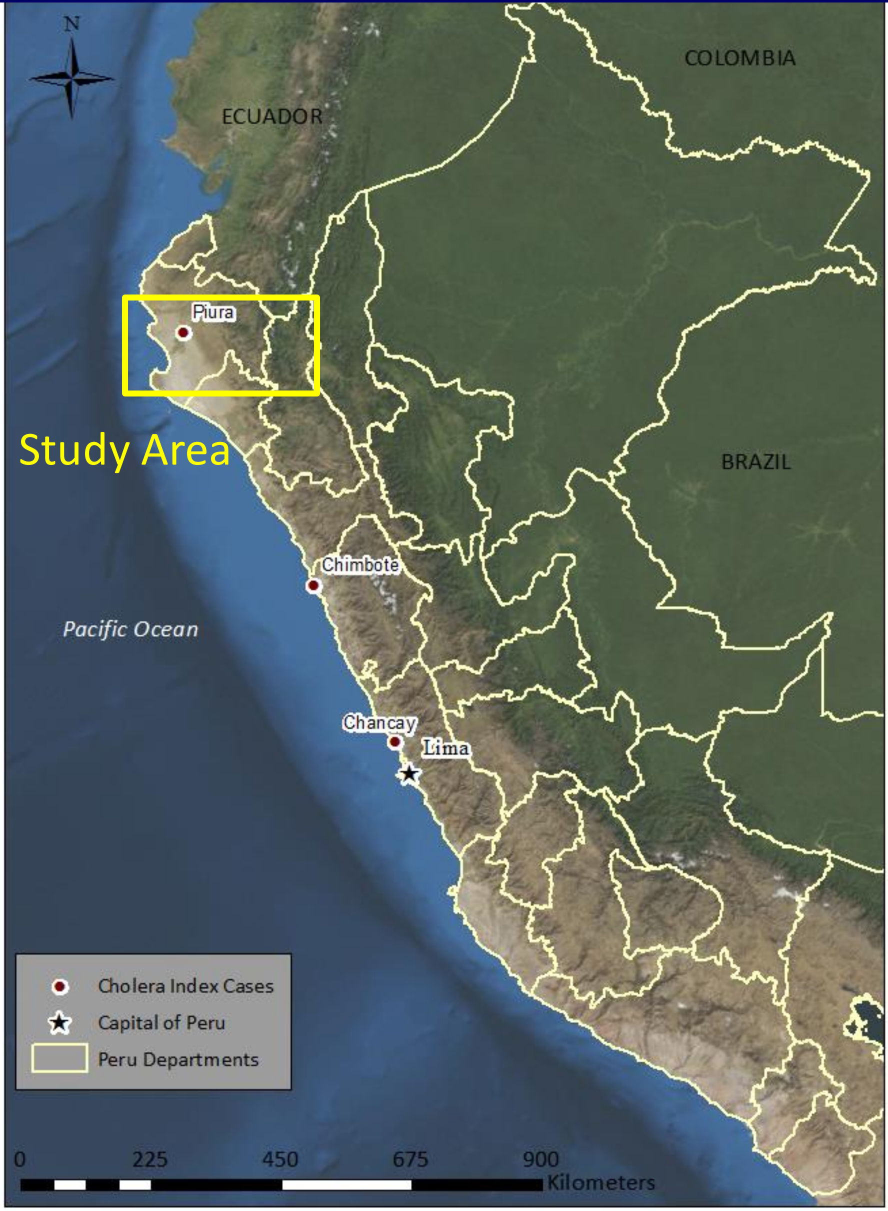
Presentation Outline

I. Background
II. Statement of Problem
III. Data and Methods
IV. Results
V. Conclusions
VI. Current and Future Research

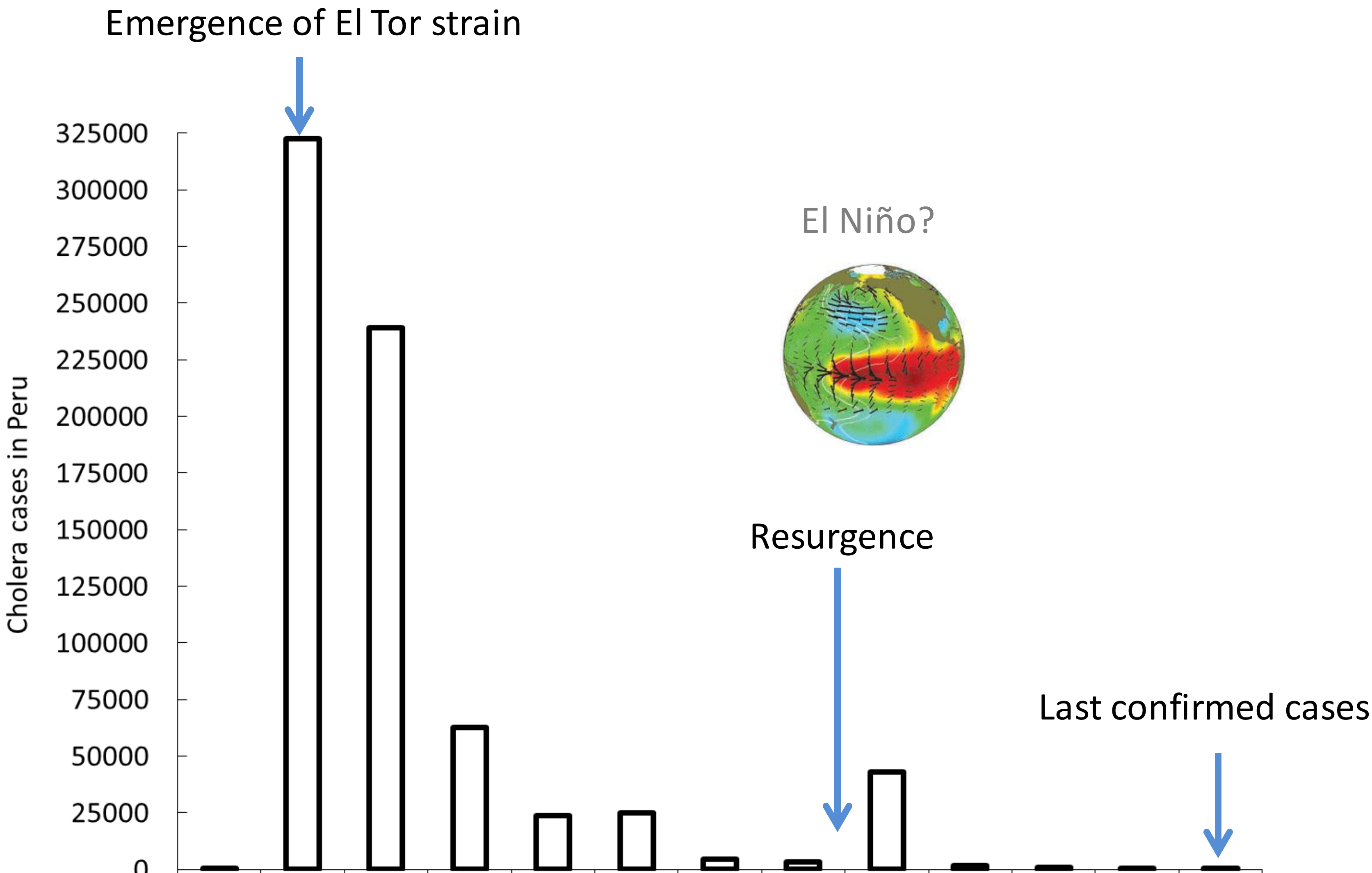
Cholera Emergence in Peru

- Cholera emerged in Peru in 1991 and the source(s) and cause(s) remain unknown;
- Spread to South and Central America, ~ 1.2 million cases by 2001
- Some evidence suggests El Niño and climate as factors. Pathways remain poorly understood.
- **This study presents results from a temporal investigation of climate and cholera patterns in northern Peru.**



Map produced by Iván J. Ramírez. Sources: Pan American Health Organization (PAHO) 1991; Colwell 1996; World Health Organization (WHO) 2012

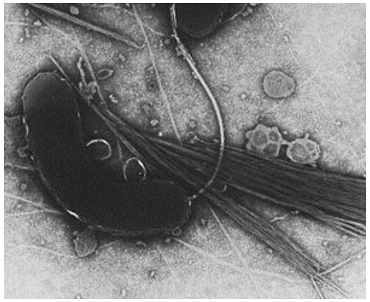
Annual Cholera in Peru, 1990-2002



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Cholera	5	322564	239139	62694	23887	25108	4500	3207	42853	1546	934	494	16

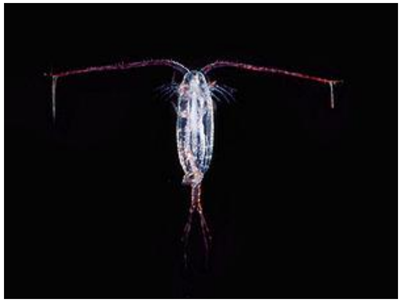
Source: Ramirez 2015 in GeoJournal

Cholera Ecology



Vibrio cholerae, the **bacterial agent** that **causes watery diarrhea**, vomiting, and can lead to dehydration and death.

Vibrios can live in the natural environment and live symbiotically with aquatic organisms.



Zooplankton

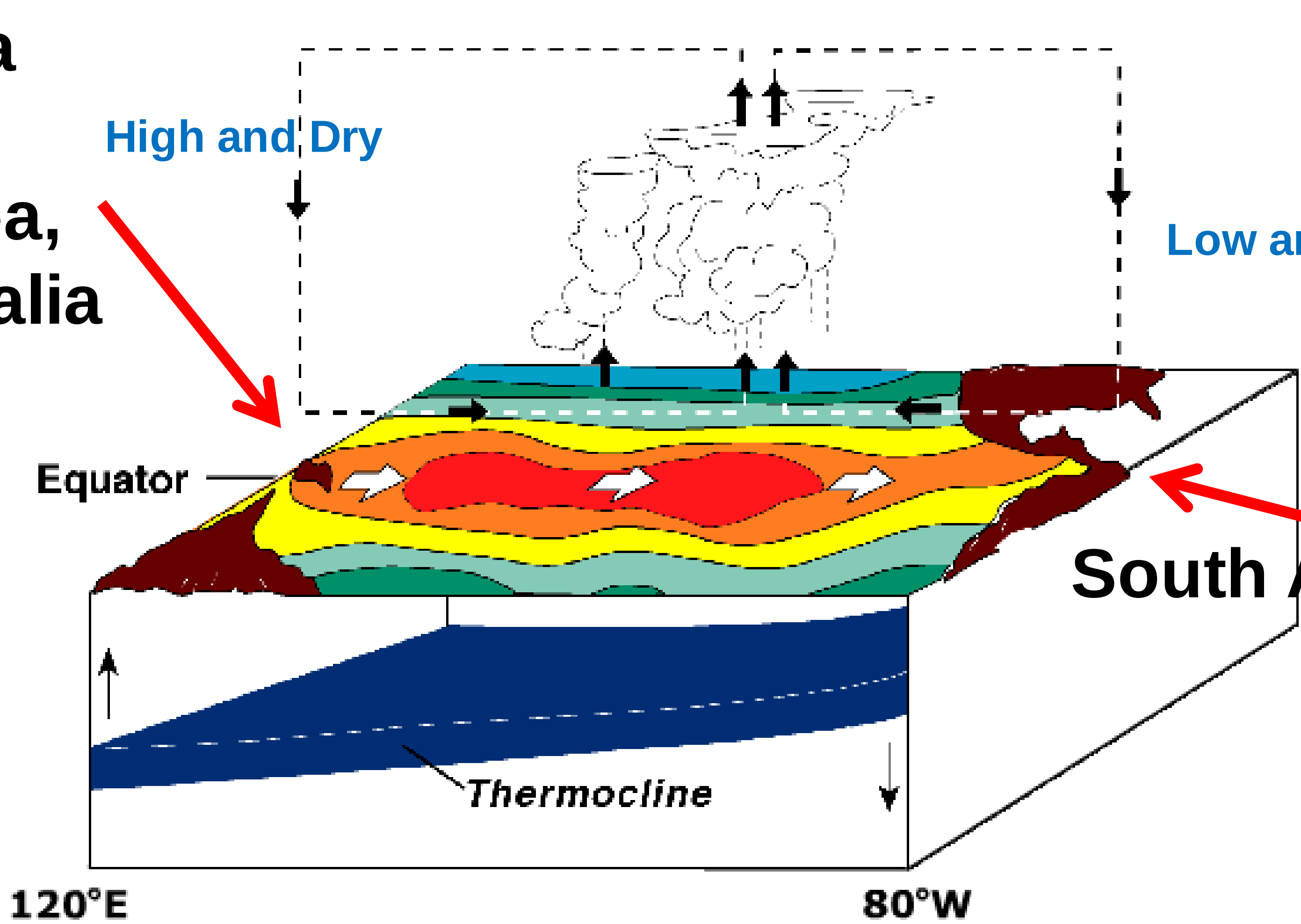
Crustaceans

Algae

Aquatic reservoirs that harbor vibrios that cause cholera.

Cholera is transmitted when humans drink or eat contaminated water or food.

El Niño-Southern Oscillation Hypothesis



Air-sea interactions Impact on global to local weather patterns

Climate Evidence in Peru

Peru

- Temporal association in **warmest months** (e.g., Jan-Mar in Lima);
- Air and seawater temperatures, rainfall, **1997-98 El Niño;**
- ***V. cholerae* in water sources**, e.g., sewage and lagoons [‘amplified fecal contamination’]) and coastal waters;
- Diarrheal disease and air temperature, **1997-98 El Niño**;
- Internal ocean waves modeled with proxy vibrios, **1997-98**;

Global evidence

- Bangladesh, Brazil, Ghana, Haiti, India, Senegal, South Africa, Vietnam, Zambia, and Zanzibar.

Sources: Franco et al. 1996; Salazar-lindo et al. 1997; Checkeley et al. 2000; MINSA 2000; Speelmon et al. 2000; Lobitz et al. 2000; Pascual et al. 2000; Lipp et al. 2003; Gil et al. 2004; Lama et al. 2004; Huq et al. 2005; Ruiz-Moreno et al. 2007; Constantin de Magny et al. 2007; Emch et al. 2008; Martinez-Urtaza et al. 2008; 2010; Jutla et al. 2010; Reiner Jr. et al. 2011; Ramirez et al. 2013

Statement of Problem

Problem:

While Cross-sectional studies have demonstrated some evidence of a climate-cholera link in Peru, it is uncertain whether this relationship is consistent or strong across the decade. A decade-wide study has yet to be undertaken.

Question:

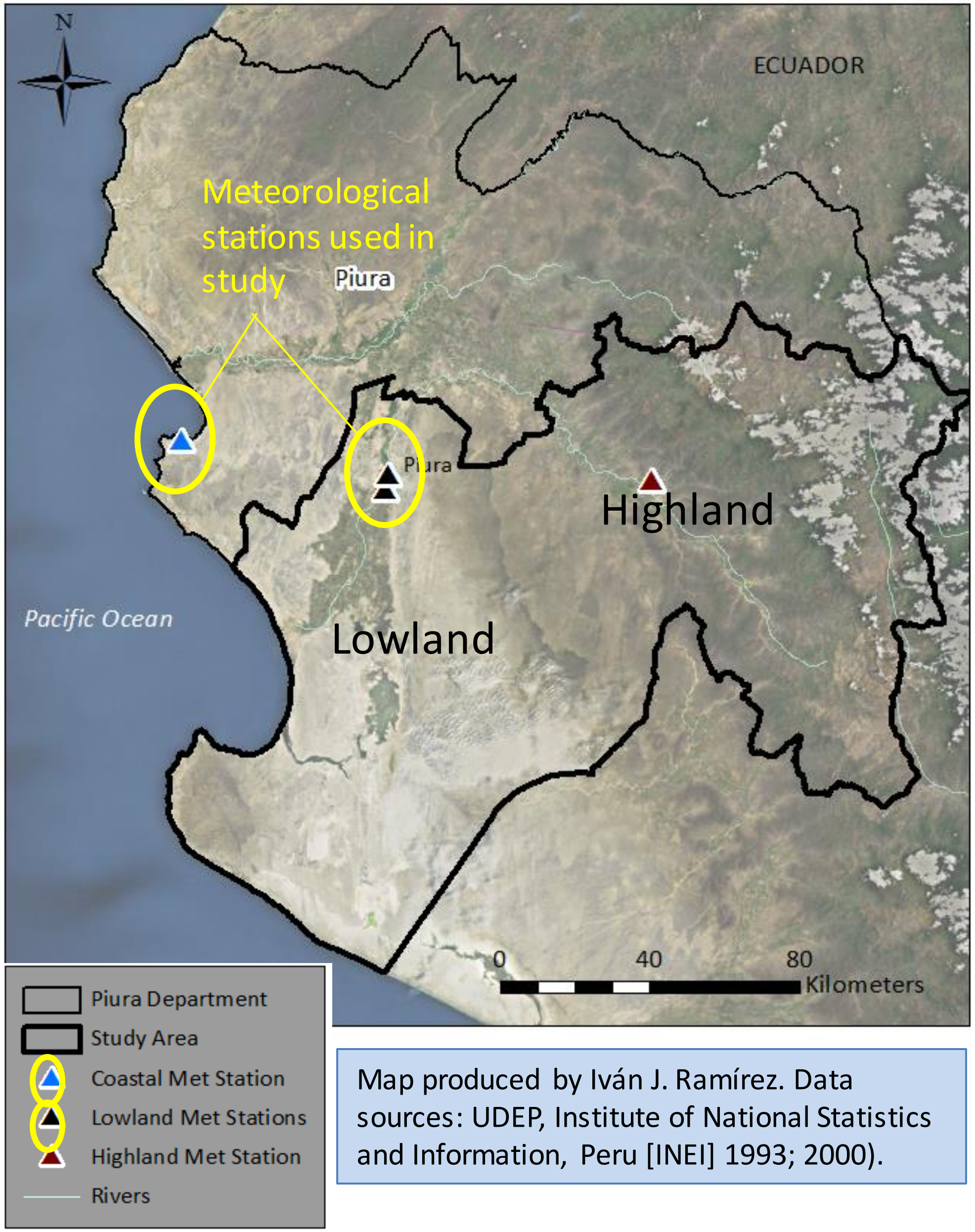
What are the temporal associations between El Niño and climate and cholera incidence from 1991-2001?

Hypothesis:

El Niño-cholera associations were discontinuous and mediated by local climate teleconnections.

Study Area

- Population –
  - 1993: 780,266
  - 1998: 847,257
- Density –
  - 42 habitants per km^2
- Urban –
  - 51.0%
- Potable Water –
  - 44.0%



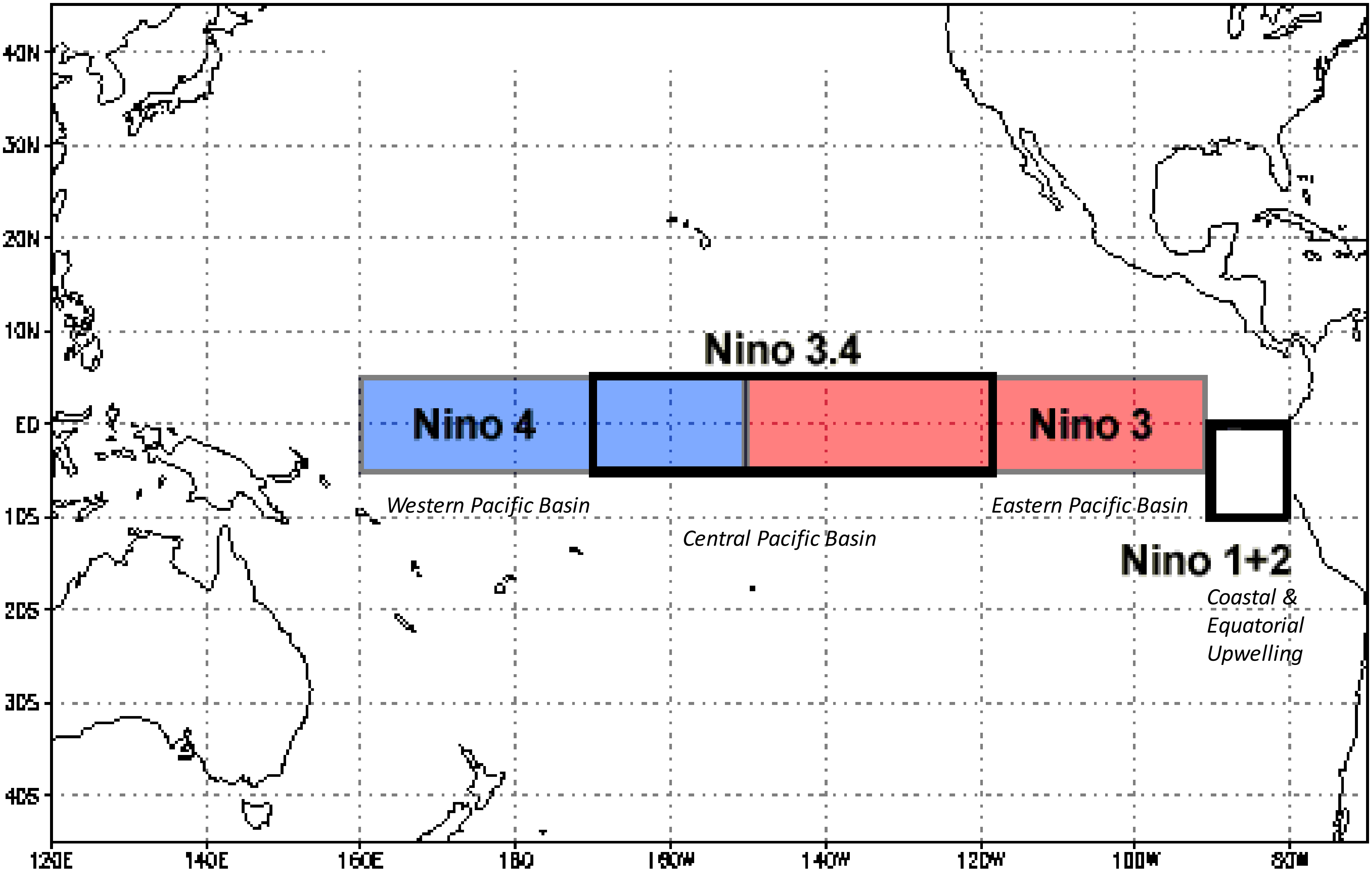
Map produced by Iván J. Ramírez. Data sources: UDEP, Institute of National Statistics and Information, Peru [INEI] 1993; 2000).

Data

Fieldwork in Peru was conducted in 2008 and 2009. I collected secondary data, documents, reports, powerpoints, and interviewed personnel at Census and Health institutions in Lima and Piura, Peru. I also collected documents at NCAR from 2006-2008.

Data Variable	Spatial Scale	Temporal Scale	Time	Source
Cholera cases - suspected and confirmed (square-root transformed)	Subregion	Monthly	1991-2001	Epidemiology Department, MINSA, Lima and Piura
Nino 3.4 SST (°C, anomalies)	Central and Eastern Pacific	Monthly	1971-2001	http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml - NOAA
Nino 1+2 SST (°C, anomalies)	Upwelling and Coastal	Monthly	1971-2001	NOAA
Paita SST (°C, anomalies)	Coastal Piura	Monthly	1971-2001	University of Piura
Air Temperature (°C, anomalies)	Piura City (coastal)	Monthly	1971-2001	University of Piura
Rainfall (mm, square-root transformed)	Piura City (coastal)	Monthly	1971-2001	University of Piura
River Discharge (square-root transformed)	Piura River	Monthly	1971-2001	University of Piura

El Niño SST Regions Map



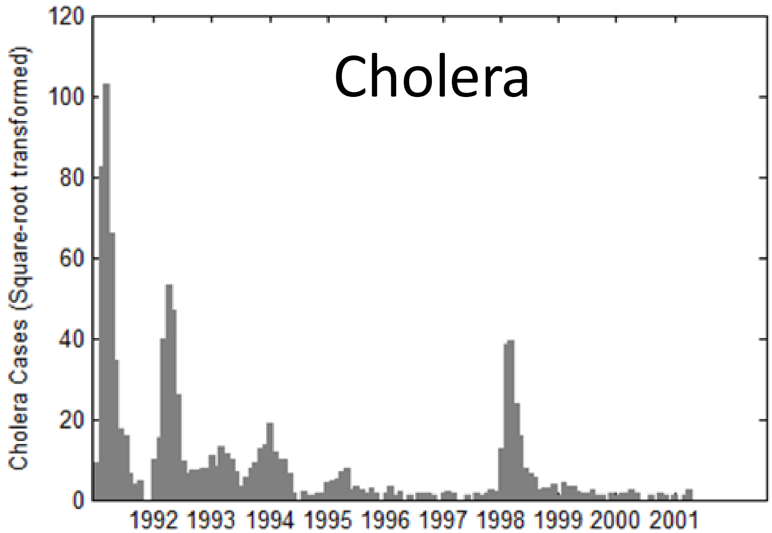
Methods

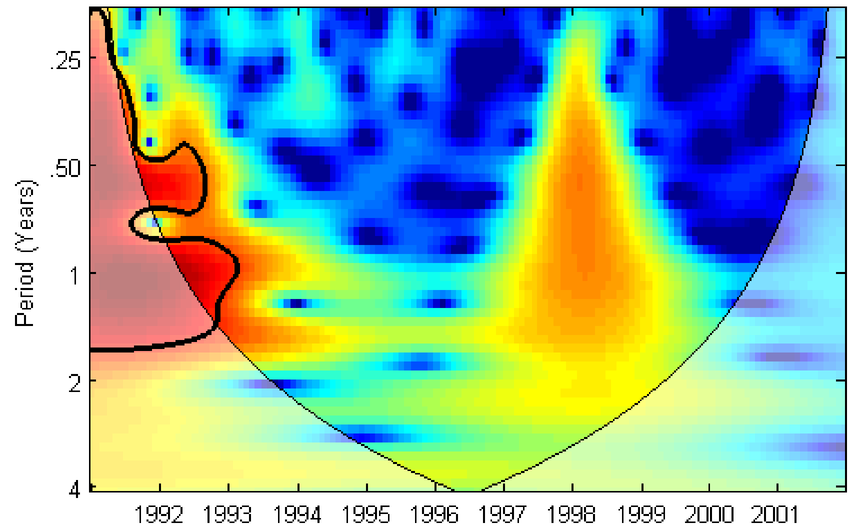
1) **Wavelet Analysis -** Univariate and Bivariate

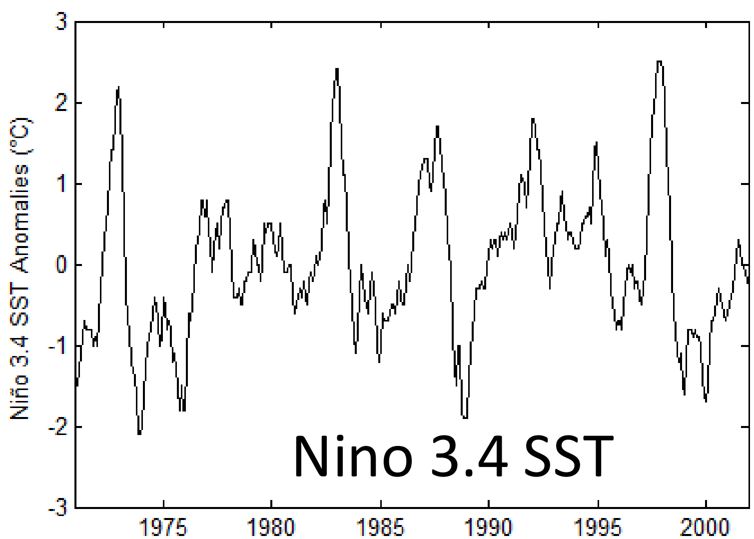
- **Continuous Wavelet Transform (CWT)** - Decompose one data series into *frequency* scales (periods) and *time* intervals
- **Wavelet Coherence (WTC)** - Identify *common areas* in time-frequency space where two data series are *linearly correlated*
- Identify *direction* of relationships (in or out of phase) and *temporal lags* (indicated by arrows in figures)
- Autoregressions were controlled for using a first-order autoregressive term.

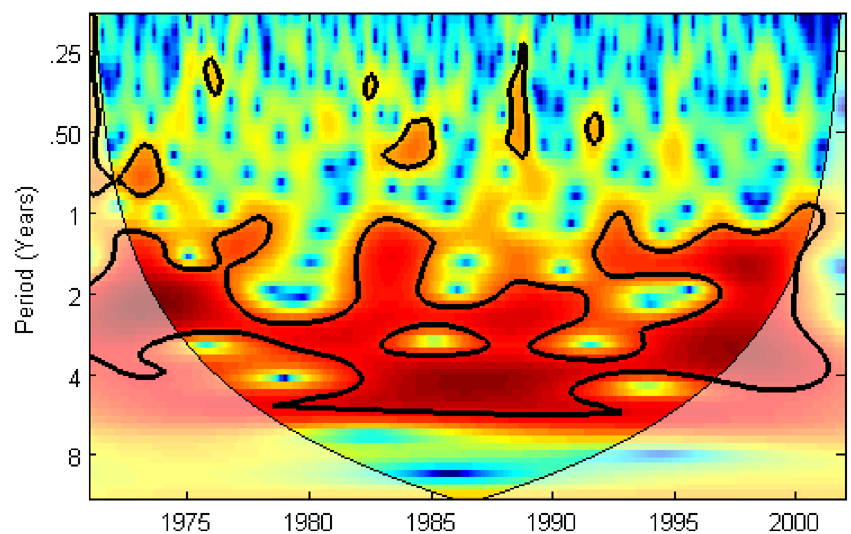
Sources: Torrence and Compo 1998; Grinsted et al. 2004; Ng and Kwok 2012

Results: CWT (Univariate)





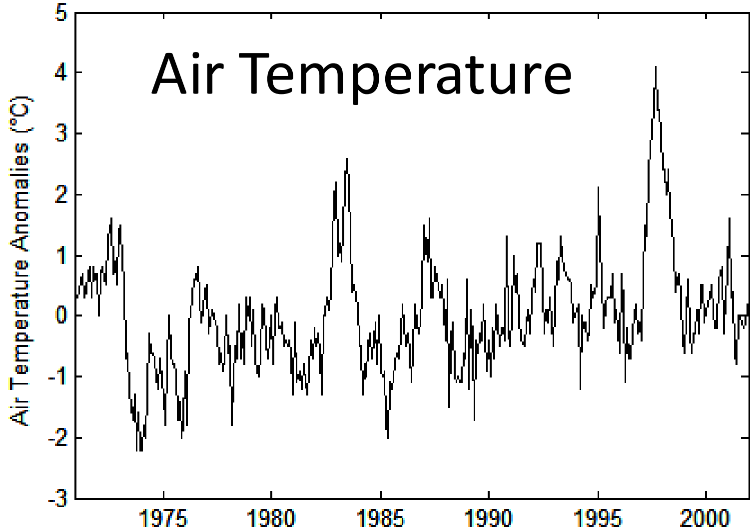


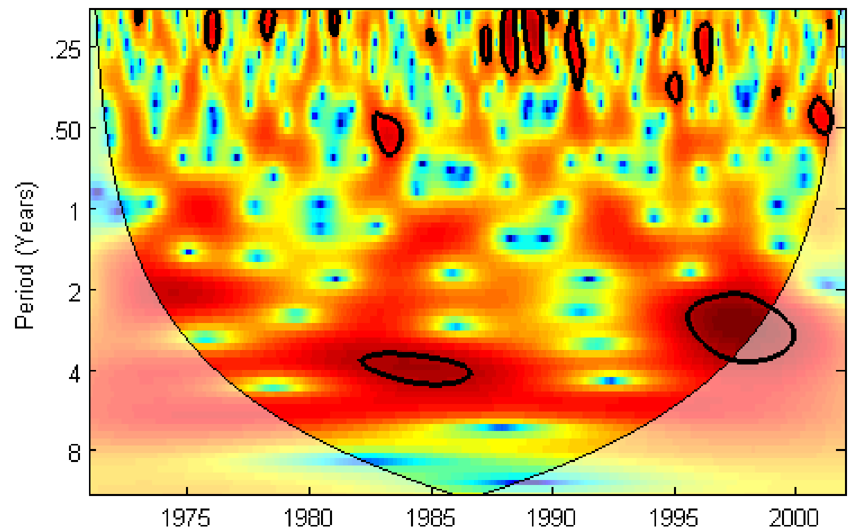


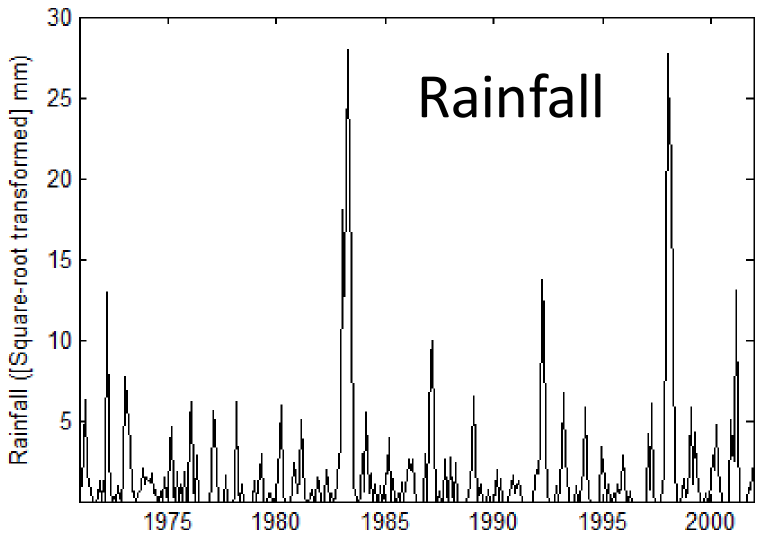
Source: Ramirez and Grady 2016, *EcoHealth*
http://link.springer.com/article/10.1007%2Fs10393-015-1095-3

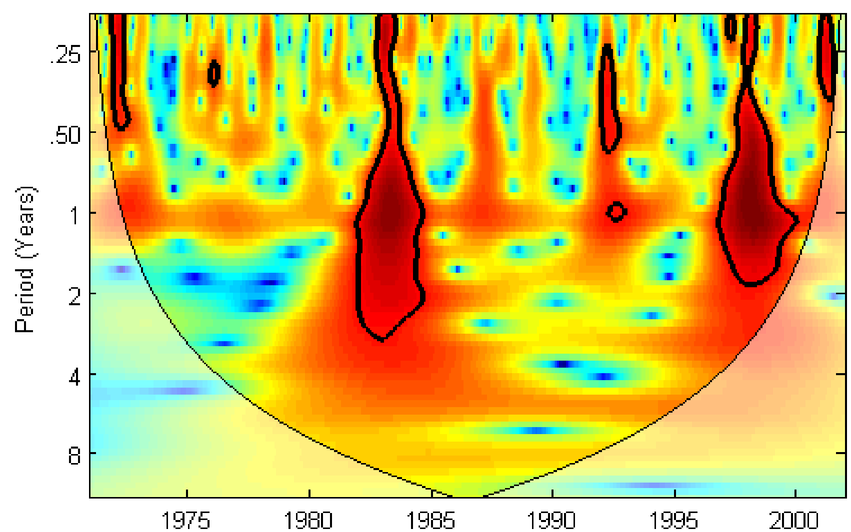
The color code for power values increases from *low* (**dark blue**) to *high* (**dark red**), and statistical significance (95.0% confidence level) is indicated by areas within thick black outlines.

Results: CWT (Univariate)





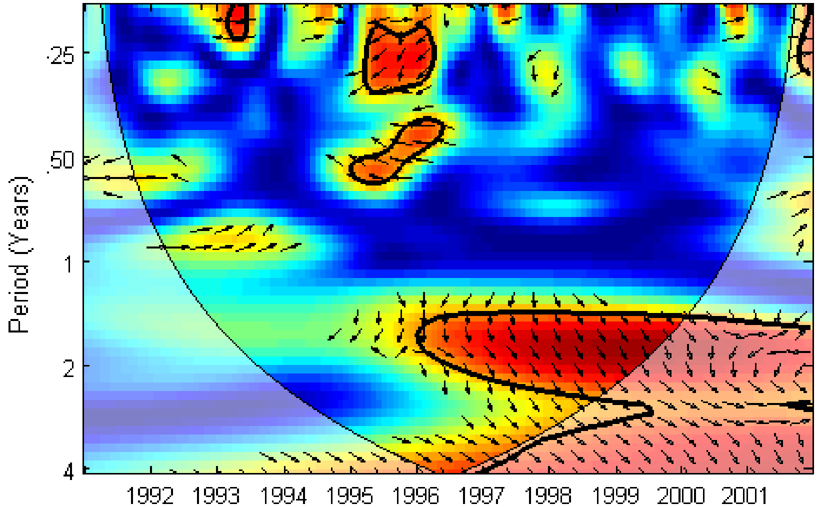




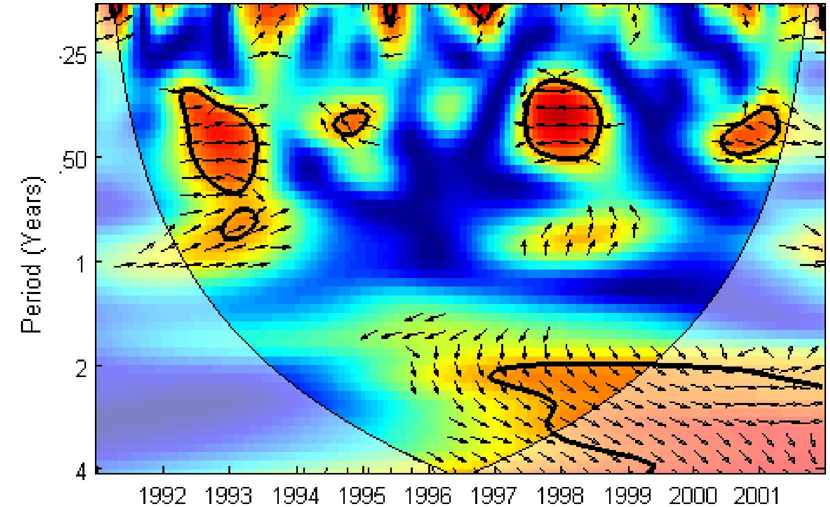
Source: Ramirez and Grady 2016, *EcoHealth*, http://link.springer.com/article/10.1007%2Fs10393-015-1095-3

The color code for power values increases from dark blue (low) to dark red (high), and statistical significance (95.0% confidence level) is indicated by areas within thick black outlines.

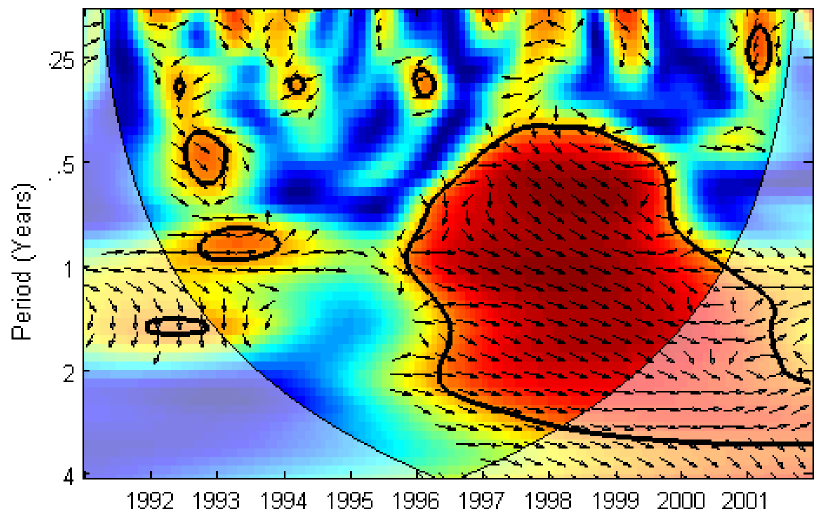
Results – WTC (Bivariate)



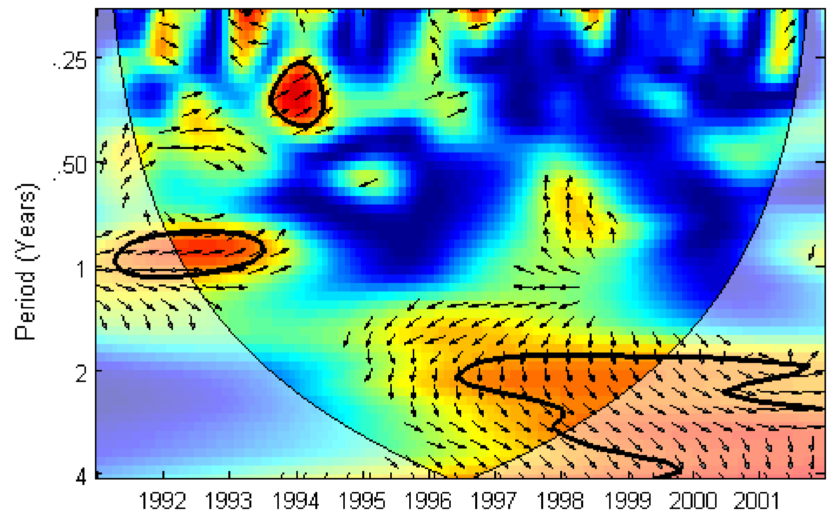
Nino 3.4 SST - Cholera



Nino 1+2 SST - Cholera

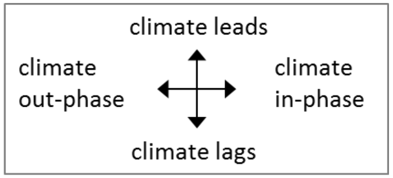


Rainfall - Cholera



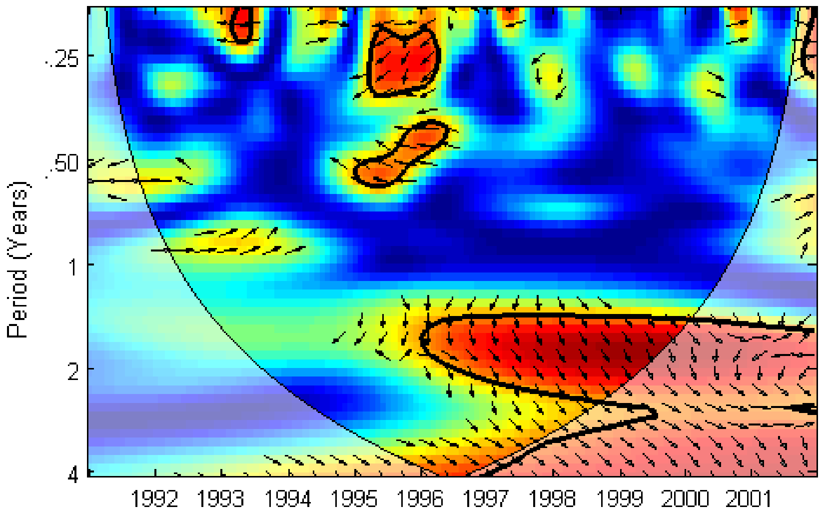
Air Temperature - Cholera

Coherence was estimated from *low* (**dark blue**) to *high* (**dark red**) correlations. Statistical significance (95.0% confidence level) is indicated by areas with black outlines.

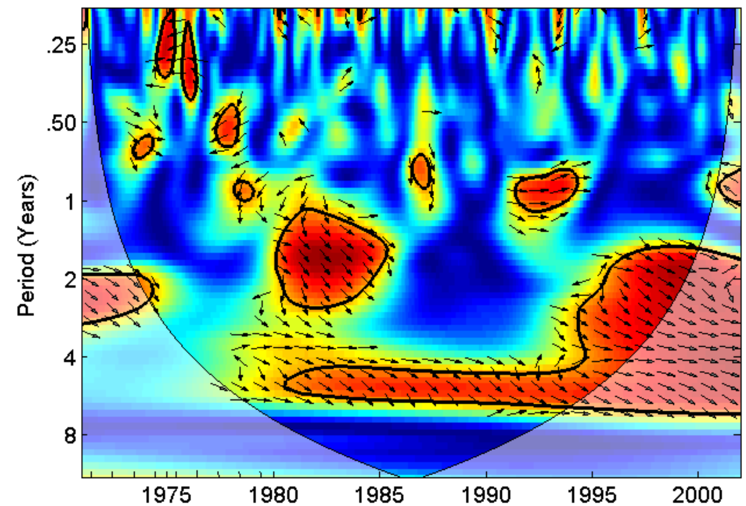


Mediating Mechanisms

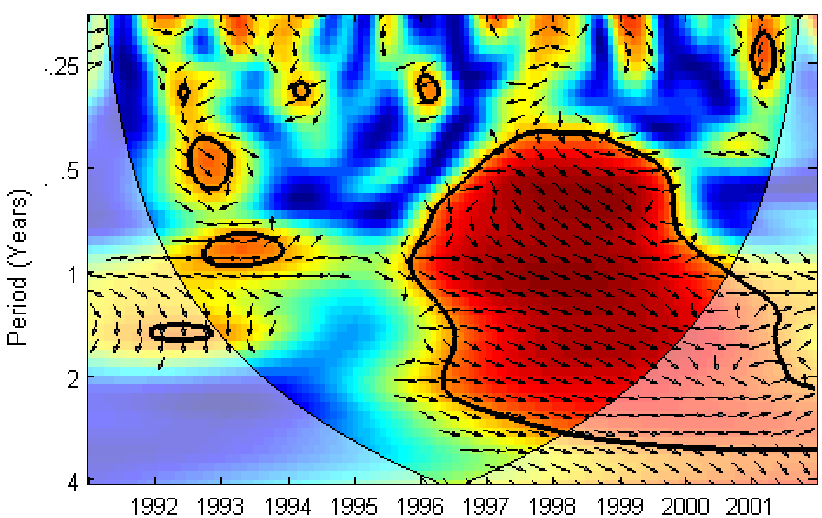
Global Climate
Nino 3.4 SST & Cholera



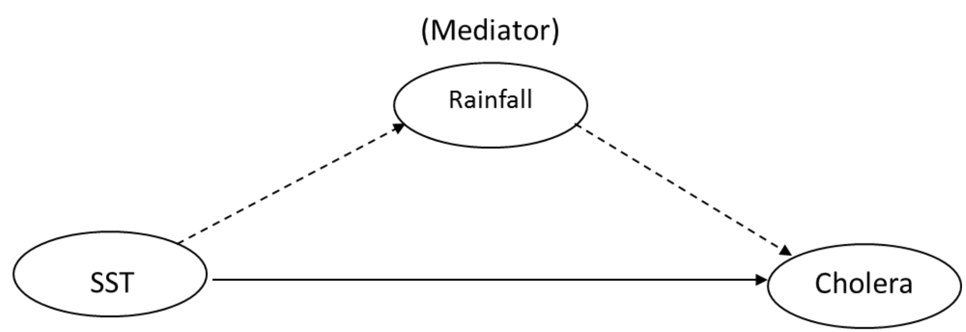
Global & Local Climate
Nino 3.4 SST & Rainfall



Local Climate
Rainfall & Cholera



Proposed model for mediation
One example associated with hydrology



Source: Ramirez and Grady 2016, *EcoHealth*, http://link.springer.com/article/10.1007%2Fs10393-015-1095-3

Conclusions

- Strong and Discontinuous El Nino-cholera link in the latter 1990s (resurgence), mediated by hydrometeorology;
- No evidence of El Nino link in early 1990s (emergence);
- <u>Strongest links</u>: Rainfall and River Discharge (flooding);
- <u>Plausible explanations for discontinuity</u>: El Niño variability, immunity, and social dynamics;
- <u>Lessons for public health</u>: climate variability influenced impacts on cholera; El Nino information is useful but may not always be reliable; other information must be integrated into models (climatic and nonclimatic influences).

Current and Future Research

- Exploring SST, hydrology and upwelling – role of SST mechanisms (multiple pathways) (*manuscript in preparation*);
- Examine mediating effects of social vulnerability, spatial analysis;
- Exploring community resilience to public health threats from climate change (El Nino 2015-16); and
- Exploring Nino variability and definition effects on relationships – (Taking Global South scientific perspectives into account).

Acknowledgements

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- University of Piura and University of the Pacific in Lima, Peru

Collaborators in Piura, Peru

Publications related to this work

Ramírez, I.J. and S. Grady, 2016: El Niño, Climate and Cholera Associations in Piura, Peru, 1991-2001: A Wavelet Analysis. *EcoHealth*, first online, 29, January 2016. DOI: 10.1007/s10393-015-1095-3. http://link.springer.com/article/10.1007%2Fs10393-015-1095-3.

Ramírez, I.J., 2015: Cholera resurgence in Piura, Peru: examining climate associations during the 1997-98 El Niño. *GeoJournal*, 80, 129-143. DOI: 10.1007/s10708-014-9541-2. http://link.springer.com/article/10.1007%2Fs10708-014-9541-2.

Ramírez, I.J., S.C. Grady, and M.H. Glantz, 2013: Reexamining El Niño and cholera in Peru: a climate affairs approach. *Weather, Climate and Society*, **5**, 148–161. DOI: http://dx.doi.org/10.1175/WCAS-D-12-00032.1.

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Thank you.
Questions?