The Effect of Regional Climate Variability on Outbreak of Bartonellosis Epidemics in Peru

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Bartonellosis is a vector-borne, highly fatal, emerging infectious disease, which has been known from the Peruvian Andes since early 1600's and has continued to be a problem in many mountain valleys in Peru and other Andean South American countries [Schultz, 1968; Laughlin, 2000]. The disease is characterized by two well-defined clinical stages, including an acute phase of life-threatening anemia (Oroya fever), during which death may exceed 40% of untreated patients, and a chronic form that manifests as blood-filled wart-like skin lesions or sub-cutaneous nodules (verruga peruana) [Cobbs, 1996]. The common bacterial etiology was established in 1885, when Daniel Alcides Carrión, a Peruvian medical student, died of acute hemolytic anemia 39 days after self-inoculation with material from a verruga lesion [Garciacaceres and Garcia, 1991]. The causative bacterium, *Bartonella bacilliformis (Bb)*, is believed to be transmitted to humans by bites of sand fly *Lutzomyia verrucarum* (Figure 1 lower-right). According to available medical records, the transmition of infection often occurs in river valleys of the Andes Mountains at an altitude between 800 and 3500 meters above sea level. It shows a seasonal pattern, which usually begins to rise in December, peaks in February and March, and is at its lowest from July until November. The epidemics of bartonellosis also vary interannually, occurring every 4-8 years, and appear to be associated with the El Niño cycle. During the most recent strong event, the 1997/98 El Niño, the affected area expanded to the southern part of Peru, where previously the disease had not been reported [Ellis *et al.*, 1999].

In response to the National Oceanic and Atmospheric Administration (NOAA) announcement on climate variability and human health, which was constructed to stimulate integrated multidisciplinary research in the area of climate variability and health interactions, we

have conducted a study to investigate the relationship between the El Niño induced regional climate variation and the outbreak of bartonellosis epidemics in Peru. Two test sites, Caraz and Cusco (indicated in Figure 1), were selected for this study. Investigators from the Department of Preventive Medicine and Biometrics, Uniformed Services University of the Health Sciences have studied the epidemiology of Bartonellosis in the two areas in the past four years [Masuoka *et al.*, 1998; Chamberlin *et al.*, 2000]. According to their report, Caraz has long-standing history of endemic transmission and Cusco, which is located at about five degrees poleward of Caraz, had no recorded epidemics until the most recent 1997/98 El Niño event. The goal of this study is to clarify the relative importance of climatic risk factors for each area that could be predicted in advance, thus allowing implementation of cost-effective control measures, which would reduce disease morbidity and mortality.

Data

The monthly disease incidence information was obtained from Peruvian Ministry of Health surveillance data and hospital laboratory records. The large-scale meteorological data were provided by the National Center for Environmental Prediction (NCEP) Reanalysis-II, which improved upon the widely used NCEP Reanalysis by fixing the errors and by updating the parameterizations of the physical processes [http://wesley.wwb.noaa.gov/ eanalysis2/ndex.html]. The station observations at the two test sites were also used to determine the local meteorological conditions. The precipitation is estimated by use of both the Tropical Rainfall Measuring Mission (TRMM) microwave imager (TMI) rainfall retrieval and the Climate Prediction Center Merged Analysis of Precipitation (CMAP). Due to the limitation of short time coverage of local medical records and meteorological station observation, our following results are based on the data from 1994 to 1999, which includes the most recent 1997/98 El Niño event.
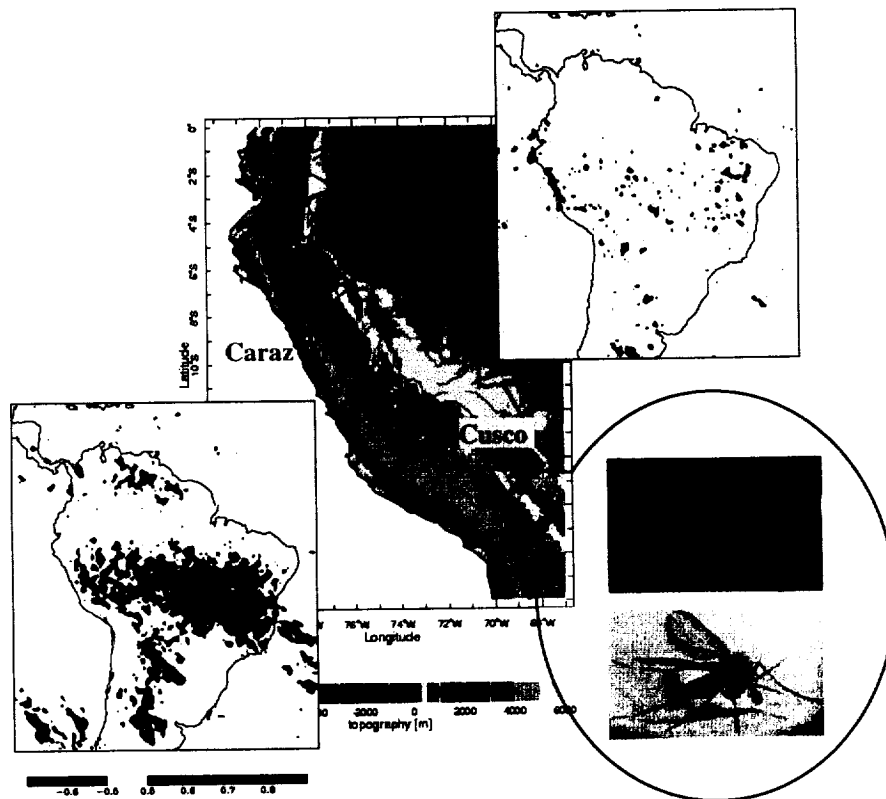
Figure 1 One-grid correlation of TRMM TMI rainfall (product G2A12, 0.5x0.5 degree resolution) at test sites of Caraz (lower-left) and Cusco (upper-right) with that of their surroundings. The middle panel shows the topography (m) and the two study sites, and the lower-right panel shows a verrugous lesion and the sand fly vector.

Topographically Divided Climate Regimes

Peru is bounded by the Amazon basin on the east and tropical eastern Pacific on the west. The mountain chains of the Andes traverse the region from north to south along the western edge. Between ridges, there are inter-mountain basins at altitudes of 2500-3000 meters above sea level, where the two test sites reside. Except for the coastal desert region, the climate of Peru can be divided into wet and dry seasons [Johnson, 1976], which are related to the influence of the South American monsoon system (SAMS) over the subtropical continent east of the Andes.

Regional SAMS climatology shows that from October to December the monsoon rainfall system advances from the northwest of the continent to the subtropical southeast and also expands its regime toward the southwest and northeast. In December and January, rainfall is most abundant over the subtropical continent. When the monsoon matures, the upper-tropospheric high over the Altiplano plateau and the low level northwesterly jet (LLJ) along the foothills of the eastern subtropical Andes ($20°-10°S$) are well developed. These features interact with the surrounding large-scale circulation systems, such as the mid-latitude westerlies and the South Atlantic subtropical high, producing much of the weather events in the region. The South American summer monsoon rainfall starts to withdraw in March and merges with the Intertropical Convergence Zone (ITCZ) around April.

Figure 1 shows one-grid correlation of TRMM TMI rainfall for each test site with its surroundings. We can see that the precipitation in Cusco, which is located at the eastern subtropical Andes, is strongly correlated with SAMS convective activities over the eastern continent (Figure 1 lower-left). The rainfall in Caraz, which is situated in the western part of the tropical Andes; shows a much weaker association with SAMS rainfall variations in the east (Figure 1 upper-right).

Canonical El Niño Response and 1997/98 Anomaly

The regional climate variability over tropical-subtropical South America shows complex interactions among various time-scale variations from synoptic to interdecadal changes. The interannual variability was found to be strongly influenced by ENSO. Statistical analysis showed that during El Niño years the subtropical high was enhanced over the South Atlantic and northwestern Africa but weakened over the eastern South Pacific and the western North Atlantic. As a result of mass redistribution, the low-level flow system of SAMS is shifted poleward in the

austral summer season, manifesting stronger LLJ along the eastern foothills of the subtropical

Andes, which enhances moisture transport from Amazon basin to southeastern subtropical South

America [Zhou and Lau, 2001]. Over the west coast of Ecuador, the anomalous monsoon

easterlies meet with abnormal westerlies induced by the displaced Walker cell, creating a large

convergence. As revealed by many previous studies, the canonical pattern of El Niño induced

rainfall anomaly shows increased rainfall over the Ecuador-Northern Peru coastal region and

Uruguay-Southern Brazil area and decreased rainfall over northern and northeastern Brazil.

Caraz is close to the positive center over Ecuadorian coast and Cusco in the area of negative
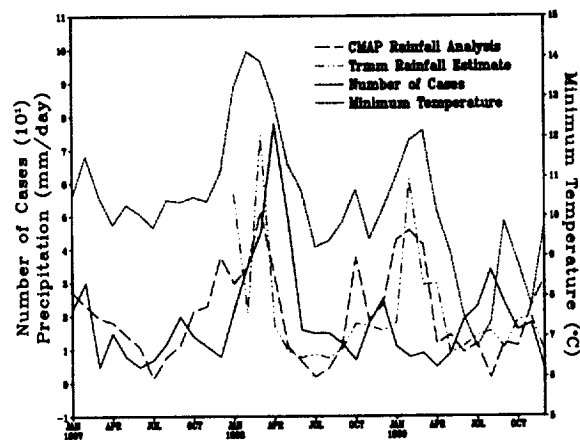
anomalies extended from northern Brazil.

Figure 2 Temporal variations of monthly bartonellosis
incidence, rainfall and minimum temperature in Caraz.

The 1997/98 El Niño is the strongest event in the 20th century. The predominant impact

on South American climate showed overwhelming thermal influences of anomalous tropospheric

warming extending from the eastern tropical South Pacific to the Altiplano Plateau, which

hydrostatistically enhances the Bolivian high in austral summertime. It more than compensates

the dynamical impact of weakened convective heating over the Amazon basin. Compared with

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previous El Niño event, more intense northwesterly LLJ developed along the eastern foothills of the subtropical Andes, penetrating deeper poleward into the extratropics [Lau and Zhou, 1999].

In association with the record-breaking regional climate anomaly, extremely high numbers of sand flies were collected in the 1997/98 austral summer season. Figure 2 shows that in Caraz, the monthly disease case number was almost doubled and the disease transmission lasted much longer. The annual mortality rate also increased significantly. During 1997/98 El Niño event, the disease epidemics expanded to the southern part of the country, where bartonellosis had not been recorded earlier. Local health surveillance data reveals that the outbreak of the disease epidemics occurs about 2-3 months later in Cusco than in Caraz (not shown).

Risk Factors and Predictable Lead-time

Results from previous studies indicated the potential importance of temperature and rainfall in the development of disease epidemics. From Figure 2 we can see enhancement of rainfall and minimum temperature in Caraz during the 1997/98 event. In addition, we also see distinct decrease of minimum temperature with less change in rainfall in the following year, when the disease incidences dropped significantly. The sensitivity of the disease epidemics to the tropospheric warming is further documented by the Cusco data. Figure 3(a) shows the time evolution of the vertical structure of temperature anomaly over Cusco. Large tropospheric warming (shaded) of more than 2 degree in the center around 250-hPa can be clearly seen during the 1997/98 austral summer season, when less humid (indicated by large difference of temperature minus dew-point temperature, T-Td) and higher surface pressure were observed in Figure 3(b). This is in agreement with negative precipitation anomaly observed over this area. It

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is also dynamically consistent with the impact of the anomalous acceleration of the northwesterly

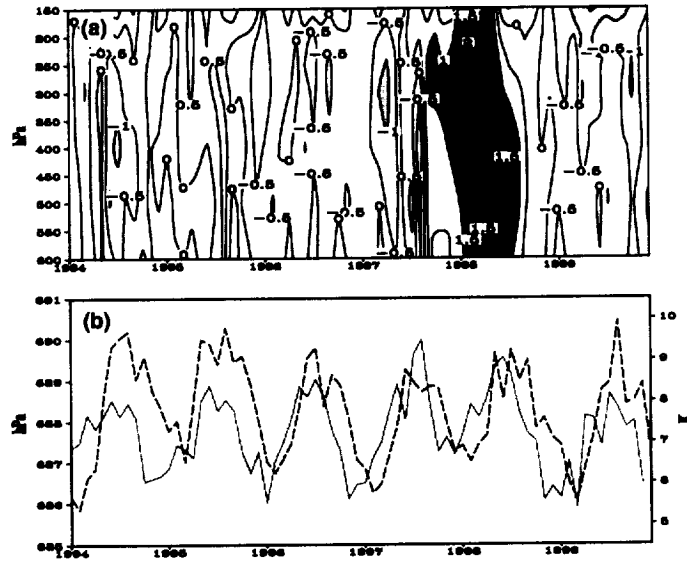LLJ, which creates abnormal low-level wind divergence around Cusco area.

Figure 3 Time evolution of the vertical structure of temperature anomaly
(a) and that of surface pressure (solid) and the difference of
temperature minus due point temperature (dash) (b) over Cusco.

This result suggests the key role played by the temperature anomaly in controlling the

disease outbreak during the warm season, when the local air is relatively humid. In order to

control the bartonellosis epidemics, it is important to know how much lead-time we could have

to initiate control measurements. Figure 4 shows lag-correlation between the disease incidence

in Caraz and the tropospheric mass-weighted averaged temperature. It shows that high

correlation area (shaded) appears in the tropical central South Pacific about three months ahead

of disease epidemics, before it spreads eastward. The local temperature anomaly could be used

as an alert signal two months ahead. We did similar calculation for the local precipitation. The

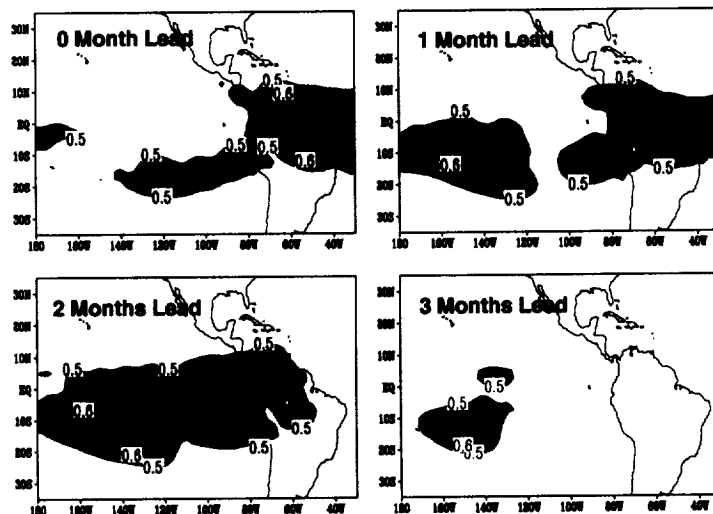highest correlation is also found two months before the disease outbreak in Caraz.

Figure 4   Lag-correlation of bartonellosis case numbers in Caraz with
tropospheric mass weighted averaged temperature over surrounding areas.

Research in Development

Using Peruvian health surveillance data and climate information, we have demonstrated

the influence of topographically divided regional climate regimes on the distribution of

bartonellosis incidences in Peru.   We have also shown that the sensitiveness of bartonellosis

epidemics is to the local temperature increase rather than the rainfall anomaly in Cusco, where

humidity is relative high in the summer monsoon season. The potential predictable lead-time of

2-3 months has been assessed, which sheds light on the prediction of impending bartonellosis

epidemics. Due to the limitation of short time coverage of the data available to us, the results

presented are preliminary and need further examination.   We are collecting more local

meteorological and medical data and developing downscaling techniques, which could be used to

derive more information from existed large-scale climate data sets.   Studies on vector ecology

and human disease are under way to reveal the mechanism of disease epidemics.   This would

disclose how the local land surface process and vegetation feedback affect the abundance and

behavior of the sand fly vector, hence, the increase in disease incidence due to regional climate variation. We will update our report on the research development in future.

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