6.6

THE EFFECT OF REGIONAL CLIMATE VARIABILITY ON OUTBREAK OF EPIDEMICS OF BARTONELLOSIS IN PERU

Jiayu Zhou[1*], William K.-M. Lau[2], Larry W. Laughlin[3],
Penny M. Masuoka[3], Richard C. Andre[3], and Judith Chamberlin [3]

[1]Goddard Earth Sciences and Technology Center
University of Maryland, Baltimore County, Baltimore, MD 21250

[2]Code 913, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

[3]Department of Preventive Medicine and Biometrics
Uniformed Services University of the Health Sciences, Bethesda, MD 20814

1. INTRODUCTION

Bartonellosis is a vector-borne, highly fatal, emerging infectious disease in high mountain valleys of Peru and other Andean South American countries. In the acute phase of the disease, death may result in up to 40% of untreated patients (Laughlin, 2000).

The causative bacterium, *Bartonella bacilliformis (Bb)*, is believed to be transmitted to humans by bites of sand flies. The transmission of the disease reveals a seasonal pattern, which usually begins to rise in December, peaks in February and March, and is at its lowest from July until November. According to available medical records, the epidemics of bartonellosis in Peru also vary interannually, occurring every 4-8 years, and appear to be associated with the El Niño cycle.

The goal of this study is to investigate the relationship between the El Niño induced regional climate anomaly and disease epidemics to clarify the relative importance of climatic risk factors that could be predicted in advance, thus allowing implementation of cost-effective control measures, which would reduce disease morbidity and mortality. The data used for this study and the selected test areas are depicted in section 2, followed by a brief description of regional climate background of the South American monsoon system (SAMS) and the canonical El Niño Southern Oscillation (ENSO) response in section 3. The results are presented in section 4, which show the influence of 1997/98 El Niño anomaly on regional climate and on bartonellosis transmission. The potential predictable lead-time to the disease epidemics is assessed. Finally, the conclusions are given in section 5.

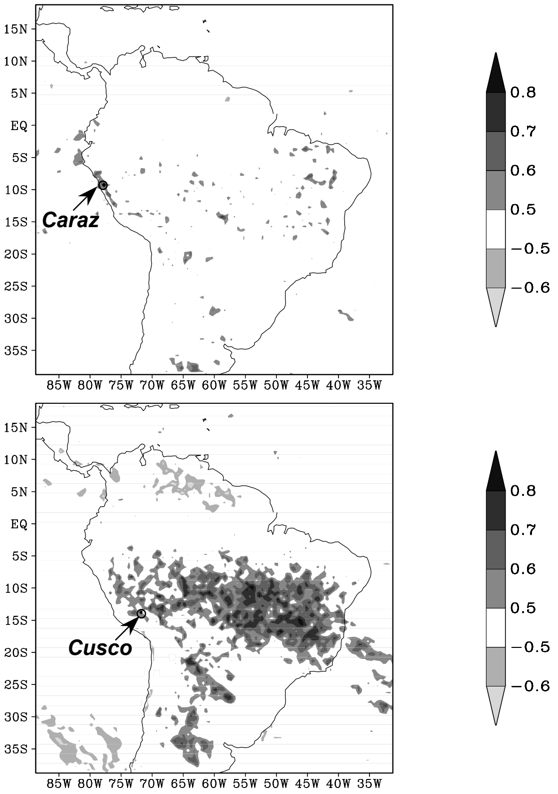

Fig. 1 One-grid correlation of TRMM TMI rainfall at test sites of Caraz (a) and Cusco (b) with that over surroundings.

2. TEST AREAS AND DATA

Two test sites, Caraz and Cusco (indicated in Fig.1), were selected for this study. The former has long-standing history of endemic transmission, and the latter, which is located at about five degrees poleward of the former, had no recorded epidemics until the most recent 1997/98 El Niño event (Ellis *et al.*, 1999). The meteorological data were obtained from the National Center for Environmental Prediction (NCEP) Reanalysis (Kalnay *et al.*, 1996), the Climate Prediction Center Merged Analysis of Precipitation (CMAP) (Xie and Arkin, 1997), the Tropical Rainfall Measuring Mission (TRMM) microwave imager (TMI) rainfall estimation (Kummerow

---

[*] *Corresponding author address:* Dr. Jiayu Zhou, GEST, Code 913, NASA/GSFC, Greenbelt, MD20771;
e-mail: zhou@climate.gsfc.nasa.gov.

et al., 1996) and the meteorological station observations at Caraz and Cusco. The monthly disease incidence was obtained from Peruvian Ministry of Health surveillance data and hospital laboratory records. Due to the short time coverage of meteorological station data and local medical records, the discussions in section 4 will only focus on the period from 1994 to 1999, which includes the most recent 1997/98 El Niño event.

3. LARGE SCALE CLIMATE BACKGROUND

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, which lie at altitudes of 2500-3000 meters above sea level. Except for the coastal desert region, the climate of Peru can be divided into wet and dry seasons, which are influenced by the South American monsoon system (SAMS) over subtropical continent east of the Andes.

3.1 *South American monsoon system*

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 Andes 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 at the end of February 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 (Fig. 1b). The rainfall in Caraz, which is situated in the western part of the Andes; shows a much weaker association with SAMS rainfall variations in the east (Fig. 1a).

3.2 *Canonical* El Niño *response*

The regional climate variability over tropical-subtropical South America shows complex interaction among various time-scale variations from synoptic to interdecadal changes. The interannual variability was found to be strongly influenced by ENSO. Statistics 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 SAMS is shifted poleward in the austral summer season, manifesting stronger low-level flow along the eastern foothills of the subtropical Andes, which enhances moisture transport from Amazon basin to southeastern subtropical South America. Over the west coast of Ecuador, the anomalous monsoon easterlies meet with abnormal westerlies induced by the displaced Walker cell, creating a large convergence. The canonical pattern of El Niño induced rainfall anomaly is given in Fig. 2, which shows increased rainfall over the Ecuador-Northern Peru coastal region and Uruguay-Southern Brazil area and decreased rainfall over northern and northeastern Brazil. From the figure we can see Caraz is close to the positive center over Ecuadorian coast and Cusco is in the area of negative anomalies extended from northern Brazil.

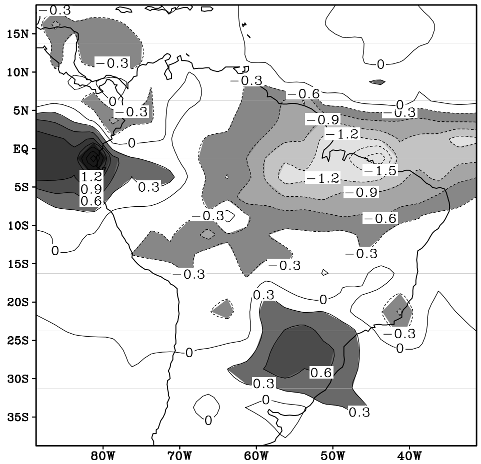

Fig. 2 DJF rainfall EOF pattern of the ENSO mode (From Zhou and Lau 2001).

4. RESULTS

4.1 *1997/98 El Niño anomaly and bartonellosis epidemics*

The 1997/98 El Niño is the strongest event in the 20th century. Consistent with and much stronger than the canonical response, the impact of the event on South America showed overwhelming thermal influences of anomalous tropospheric warming extending from the eastern tropical South Pacific to the Altiplano Plateau (Fig.3), which hydrostatistically enhances the Bolivian high in austral summertime. It more than compensates the dynamical impact of weakened convective heating over the Amazon basin. More intense and deeper northwesterly LLJ developed along the eastern foothills of the subtropical Andes, which penetrated 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 4 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.

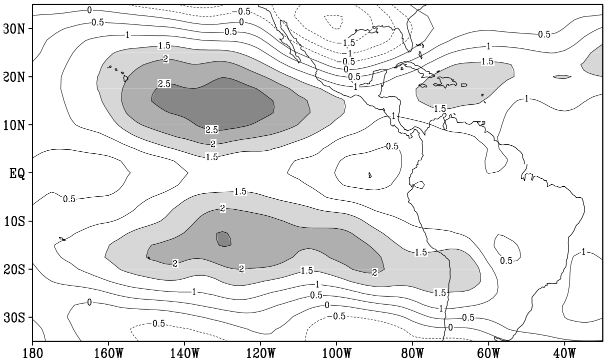

Fig. 3 NCEP reanalysis of the 1997/98 DJF 500-hPa temperature anomaly (K).

4.2 *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 Fig. 4 we can see enhancement of rainfall and minimum temperature in Caraz during the 1997/98 event. In addition, we also find distinct decrease of minimum temperature with less changes in rainfall at the peak of the monsoon season in 1998/99, when the disease incidences dropped significantly. The sensitivity of the disease epidemics to the tropospheric warming is further documented by the Cusco data. Figure 5(a) shows the time evolution of the vertical structure of temperature anomaly over Cusco. Large tropospheric warming (shaded), centered around 300 hPa, can be clearly seen in the 1997/98 austral summer, when less humid (indicated by large difference of temperature minus dew-point temperature, T-Td) and higher surface pressure were observed in Fig. 5(b). This is in agreement with negative precipitation anomaly observed over this area (not shown). It is also consistent with the dynamical impact of the anomalous acceleration of the northwesterly LLJ, which creates abnormal low-level wind divergence over the eastern subtropical Andes.

This result suggests the key role played by the temperature anomaly in the development of disease epidemics during the monsoon season, when the local air is relatively humid. The influence on vector ecology causing increased sand fly abundance and activity is under investigation.

In order to control the bartonellosis epidemics, it is important to know how much lead-time we could have to initiate control measurements. Figure 6 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.

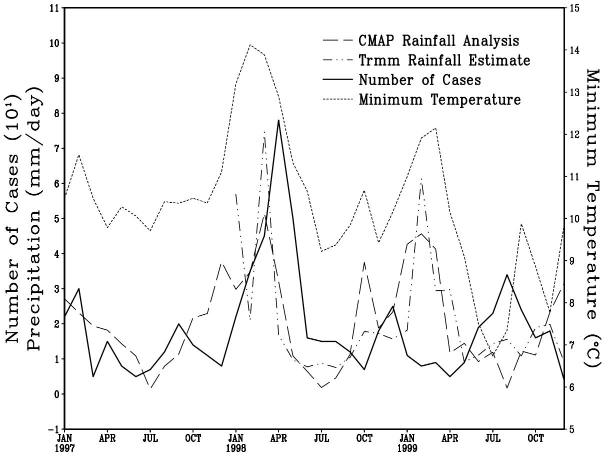

Fig. 4 Temporal variations of monthly bartonellosis incidence, rainfall and minimum temperature in Caraz.

5. CONCLUSIONS

Using Peruvian health surveillance data and climate information, we have conducted a diagnostic study on the effect of regional climate change on epidemics of bartonellosis in Peru. Two test sites, Caraz and Cusco are chosen. The former has a long-standing disease transmission history and the latter had an epidemic only during the most recent El Niño event. Our results show that Cusco, which is located at the eastern subtropical Andes, is strongly influenced by SAMS activities over the subtropical continent; while Caraz, which is situated in the western tropical Andes, showed a much weaker correlation with SAMS variations.

During the 1997/98 El Niño event, more rainfall and higher temperatures were observed in Caraz, where extremely high numbers of sand flies were collected and disease rates increased significantly. While in Cusco, only the local air temperature increase was significant, which also led to an increase of sand fly population and higher disease incidences. Our study demonstrated 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.

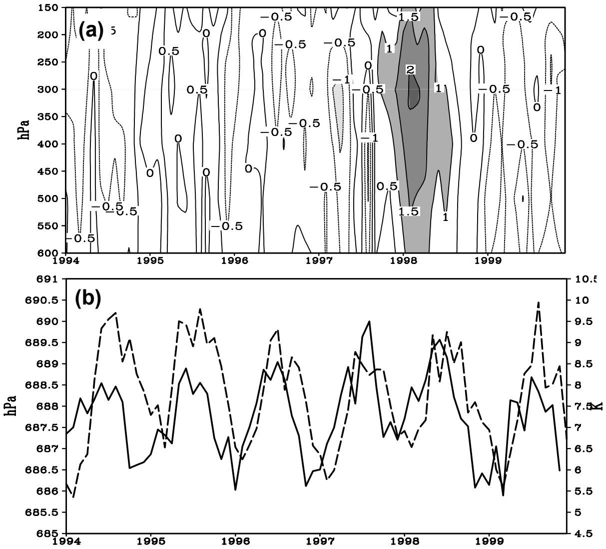

Fig. 5 Time evolution of the vertical structure of temperature anomaly (a) and that of surface pressure (solid) and the difference of temperature minus due point temperature (dash) (b) over Cusco.

The potential predictable lead-time of key climatic risk factors was also assessed. The disease incidence in Caraz and the tropospheric mean temperature showed a high lag-correlation with local tropospheric warming anomaly leading the disease epidemics two months. A similar result was also obtained from the lag-correlation with precipitation. Further investigation on land surface and vegetation feedback processes is needed to better understand the impacts of climate anomalies on vector ecology and bartonellosis transmission.

Acknowledgments. This research is supported by the NOAA Grant (NA00AANRG0333), the Earth Observing System/ Interdisciplinary Science investigation on hydrological processes and climate, and the Global Modeling and Analysis Program of NASA, Mission to Planet Earth Office.

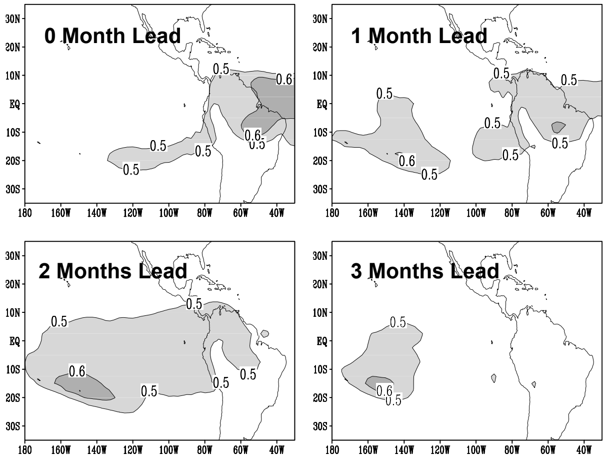

Fig. 6 Lag-correlation of bartonellosis case numbers in Caraz with tropospheric mass weighted averaged temperature over surrounding areas.

6. REFERENCES

Ellis, B.A., and Co-authors, 1999: An outbreak of acute bartonellosis (oroya fever) in the Urubamba region of Peru, 1998. *Am. J. Trop. Med. Hyg.*, **61**, 344-349.

Kalnay, E., and Co-authors, 1996: The NCEP/NCAR 40-year reanalysis project. *Bull. Amer. Meteor. Soc.*, **77**, 437-471.

Kummerow, C., W. S. Olson and L. Giglio, 1996: A Simplified Scheme for Obtaining Precipitation and Vertical Hydrometeor Profiles from Passive Microwave Sensors, IEEE Trans. on Geosci. and Remote Sensing, 34, 1213-1232.

Lau, W. K.-M., and J. Zhou, 1999: South American summer monsoon of 1997/98 and 1998/99. *Proceedings of the 24th Annual Climate Diagnostics and Prediction Workshop,* 5-9 Nov. 1999, Tucson, AZ., 17-20.

Laughlin, L.W., 2000: Bartonellosis. *Hunter's tropical medicine* 8 Ed., Strickland G.T. Ed., 394-398.

Xie, P. and P.A. Arkin, 1997: Global Precipitation: A 17-year monthly analysis based on gauge observations, satellite estimates, and numerical model outputs, *Bull. Am. Meteorol. Soc.*, **78**, 2539-2558.

Zhou, J. and K.-M. Lau, 2001: Principal modes of interannual and decadal variability of summer rainfall over South America. *Int. J. of Climatol.*, In press.