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DROUGHT-ASSOCIATED CHIKUNGUNYA EMERGENCE ALONG COASTAL EAST AFRICA

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Abstract. Epidemics of chikungunya fever, an *Aedes* spp.-borne viral disease, affected hundreds of thousands of people in western Indian Ocean islands and India during 2005–2006. The initial outbreaks occurred in coastal Kenya (Lamu, then Mombasa) in 2004. We investigated eco-climatic conditions associated with chikungunya fever emergence along coastal Kenya using epidemiologic investigations and satellite data. Unusually dry, warm conditions preceded the outbreaks, including the driest since 1998 for some of the coastal regions. Infrequent replenishment of domestic water stores and elevated temperatures may have facilitated Chikungunya virus transmission. These results suggest that drought-affected populations may be at heightened risk for chikungunya fever, and underscore the need for safe water storage during drought relief operations.

Transmitted by *Aedes* spp. mosquitoes, Chikungunya virus (CHIKV) causes febrile illness with joint pain. Illness is rarely fatal but can be severe and prolonged, and lead to other complications. Sylvan transmission cycles involving forest-dwelling *Aedes* spp. and wild primates maintain endemicity throughout tropical Africa. In tropical Asia, urban *Aedes aegypti* and *Aedes albopictus*-human cycles are thought to maintain CHIKV between epidemics.[1]

During 2005–2006, large-scale chikungunya fever epidemics affected western Indian Ocean Islands and India (Figure 1A).[2–7] The outbreak strain from the western Indian Ocean Islands was related to previous East-, Central-, and South-African isolates,[8] and followed outbreaks along the Kenyan Coast in 2004, in Lamu (Bedno SA and others, unpublished data) then Mombasa (Breiman RF and others, unpublished data; Sang R and others, unpublished data). The total number of cases across the outbreaks during 2004–2006 is unknown, but they constitute, by far, the largest chikungunya fever epidemic on record. In La Reunion alone, the World Health Organization estimated that more than 200,000 people had been infected.[2] Estimated infections in Comoros and Lamu were 215,000 (63% of the population) and 13,500 (75% of the population), respectively, based on serological surveys (Breiman RF and others, unpublished data).

To explore eco-climatic contributions to epidemic chikungunya fever emergence in Kenya, we obtained satellite data through an early warning system developed for Rift Valley fever.[9] This is part of the US Department of Defense Global Emerging Infections Surveillance and Response System (DoD-GEIS),[10] which participated in the Lamu field investigations with the Kenya Ministry of Health and the US Centers for Disease Control and Prevention.

Normalized Difference Vegetation Index (NDVI), a measure of green vegetation density, was derived from measurements made by the VEGETATION optical instrument on board the SPOT-4 earth observation satellite at nominal spatial resolution of 1 km.[11] The data were processed into monthly composites, and expressed as anomalies, or percent departure from reference monthly means over 1998–2005.[12,13]

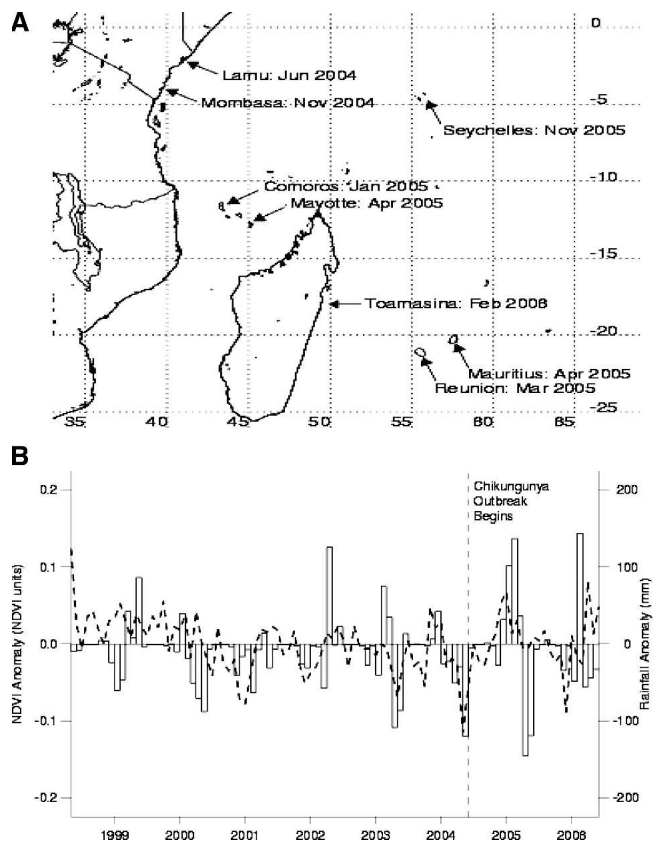

FIGURE 1. (**A**) Location of chikungunya fever epidemics in Kenya and West Indian Ocean islands during 2004–2006, by month and year of outbreak start. (**B**) Normalized Difference Vegetation Index (NDVI) anomalies (dashed line) and rainfall anomalies (bars) for Lamu. Negative NDVI and rainfall anomalies indicate unusually dry conditions.

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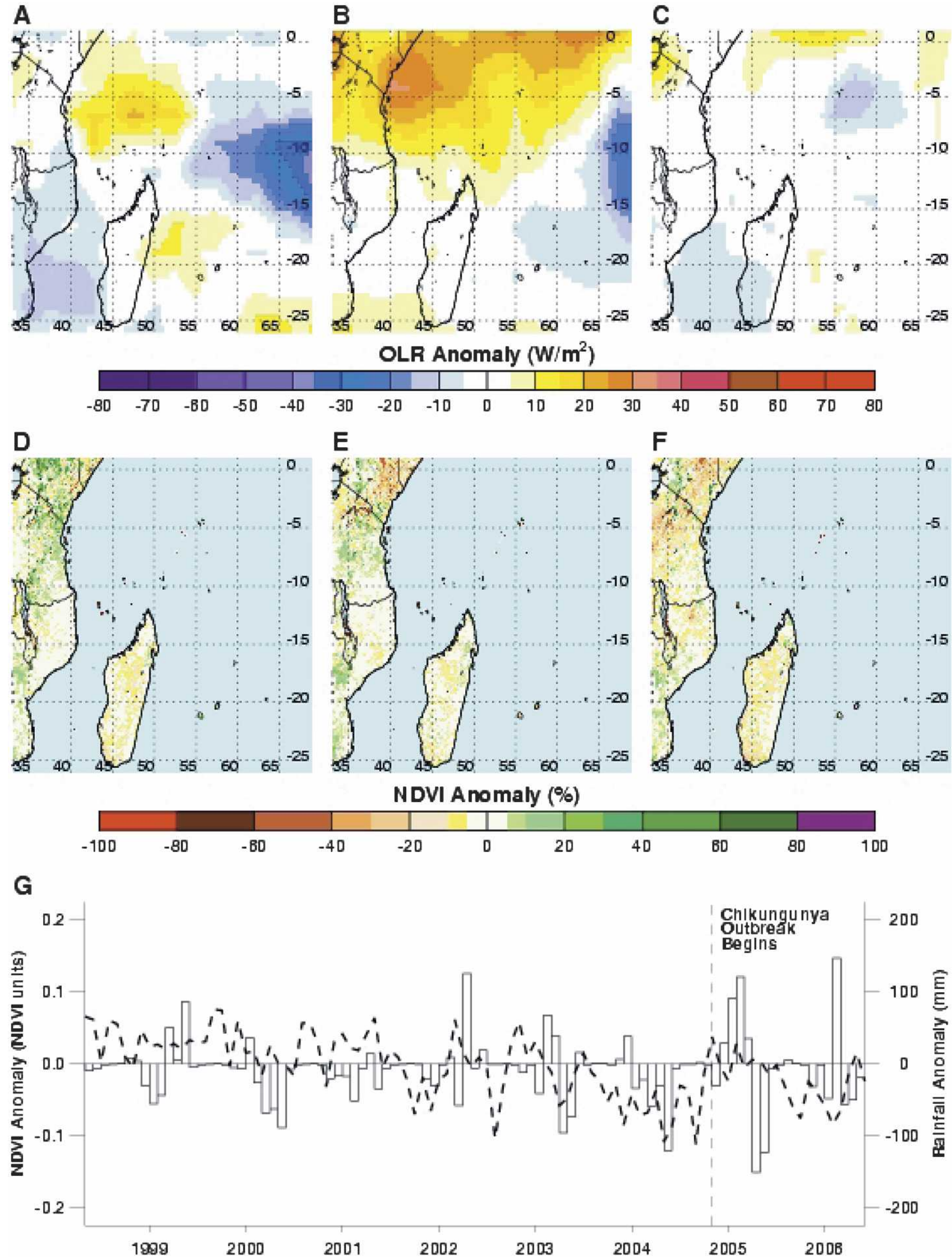

FIGURE 2. Outgoing Longwave Radiation (OLR) anomalies for (**A**) April, (**B**) May, and (**C**) June, 2004 (positive OLR anomalies indicate unusually warm and dry conditions). Normalized Difference Vegetation Index (NDVI) anomalies for (**D**) April, (**E**) May, and (**F**) June, 2004. G, NDVI (dashed line) and rainfall (bars) anomalies for Mombasa, Kenya. Negative NDVI and rainfall anomalies indicate unusually dry conditions. This figure appears in color at www.ajtmh.org.

Rainfall data is based on a satellite rainfall estimation algorithm using an area-averaged 10×10 km window centered on outbreak location.[14] Daily rainfall estimates were summed to compute monthly totals. Data are expressed as monthly anomalies with respect to reference monthly means over 1995–2005. Outgoing longwave radiation (OLR) data were derived from measurements made by the NOAA polar-orbiting satellites series, and expressed as monthly anomalies with respect to reference means over 1979–2005. Negative OLR anomalies in the tropics represent regions of precipitating clouds, whereas positive OLR anomalies are associated with dry conditions.[15]

Cases of non-malarial febrile illness at Lamu District Hospital increased sharply in June 2004; of 88 patients who presented with symptoms consistent with chikungunya fever in August, 56 (63%) tested positive for acute CHIKV infection by PCR or IgM capture enzyme-linked immunosorbent assay (ELISA; Bedno SA and others, unpublished data). Longitudinal NDVI measurements for Lamu showed that the drought conditions preceding the chikungunya fever outbreak were the most severe since 1998 (Figure 1B). Rainfall estimates were among the lowest for this time of year, usually the main rainy season (Figure 1B).

OLR measurements indicated unusually dry and warm conditions throughout East Africa, but especially along coastal Kenya, in May 2004 (Figure 2A–2C). NDVI measurements also indicated severe drought conditions along the northern Kenya coast during April–June 2004 (Figure 2D–2F). As in Lamu, longitudinal NDVI and rainfall measurements were well below expected levels before the chikungunya fever outbreak in Mombasa, which occurred in November 2004 (Figure 2G).

To our knowledge, these were the first confirmed chikungunya fever outbreaks in coastal Kenya. Epidemic chikungunya fever emergence there after unusually warm, dry conditions contrasts with previous African and Asian epidemics, which followed heavy rain.[1] Although the original source and vector of CHIKV in the Lamu outbreak are unknown, widespread domestic water storage could have facilitated vector breeding and human contact. Infrequent water replenishment (expected because of drought) has been shown to increase domestic *Aedes aegypti* populations in coastal Kenya.[16] Climatic effects, particularly elevated temperature, on virus development in vector mosquitoes also could have enhanced transmission efficiency.[17] Interestingly, epidemic dengue-3 emergence in East Africa has also coincided with severe drought.[18]

Though preliminary, these results suggest that drought-affected populations may be at heightened risk for chikungunya fever, and underscore the need for safe water storage (especially ensuring tight lids on reservoirs to prevent mosquito breeding and egress) during drought relief operations. Vector precautions and control measures should be maintained after chikungunya fever outbreaks because as in Asia, large epidemics may recur as population immunity declines.[1] Integrated satellite-based drought monitoring and epidemiologic surveillance could identify areas at risk for chikungunya fever epidemics, and allow countries to institute timely prevention or control programs.

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