A decadal climate shift in the southwest Indian Ocean linked to recent malaria downturn in South Africa

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Abstract

Malaria poses a great challenge for the maintenance of good public health and sustenance of human wellbeing in many parts of the world. Apparently, the anthropogenic global warming has expanded the spatio-temporal extent of the disease; incidences are now reported beyond tropics and in non-endemic seasons. This emerging trend of climate change has increased the malaria risk factor for millions more across the globe. While global warming remains a key factor to address the future adaptations and mitigation measures, the existing association between climate and malaria prevalence needs careful observations and analyses besides the non-climatic factors. Such a climate association is investigated here with the available malaria case counts in the northeastern districts of South Africa. It is found that the regional variations in seasonal rainfall and temperature, that primarily control mosquito population and thereby infection rates, are linked with a basin-scale climate phenomenon manifested as a dipole pattern in the interannual anomalies of sea surface temperature (SST) of southwestern Indian Ocean. In addition to the year-to-year variations, partly related to the basin warming, a decadal shift in the SST dipole pattern, and associated decrease in seasonal rainfall, leads to decreasing number of case counts in recent years as indicated by the malaria records.

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Introduction

Millions of human beings are at risk of malaria infection in sub-Saharan Africa. Compare to other highly infected countries in the region, South Africa has not so many reported cases, except for the northeastern districts neighboring to some of the worst affected countries in the world. Malaria prevalence in those districts are distinctly seasonal.

The seasonal peaks in temperature and rainfall are linked with the peaks in malaria incidences during austral summer months of December to February, besides some other events in September-November and March-April.

On interannual time-scale, climate phenomena such as the El Niño/Southern Oscillation (ENSO) are shown to influence the variations in malaria incidences. In general, below average incidences are found during El Niño years and above average incidences are found during La Niña years.

The ENSO, though a dominant factor, is not the only phenomenon that controls the rainfall and temperature variations in the region to affect the malaria vectors responsible for the disease transmission. The Indian Ocean Dipole (IOD), the Indian Ocean subtropical Dipole (IOSD), the ENSO Modoki, and Antarctic Oscillations are other climate phenomena shown to have significant influences on the regional rainfall variations over southern and eastern Africa.

In this study[1], **for the first time we have shown another climate phenomenon in the southwestern Indian Ocean that has significant influences on the rainfall variability** of the northeastern district of Vhembe in South Africa and neighboring regions. That in turn is linked to the variations in malaria incidences in South Africa in addition to the climate signals associated with IOSD and ENSO[2].

Most importantly, the climate phenomena of the southwestern Indian Ocean varies on decadal time-scale to give rise to the swings (up and down) in the malaria incidences of Vhembe and neighboring regions. This decadal variability seems to be linked to tropical variability in the Indian Ocean and a decadal signal that propagates from the southern Atlantic[3] (**Figs. 1, 2**).

Figure 1: Decadal SLP (left) and SST (right) anomalies with propagating signals from the southern Atlantic to southern Indian Ocean[3].

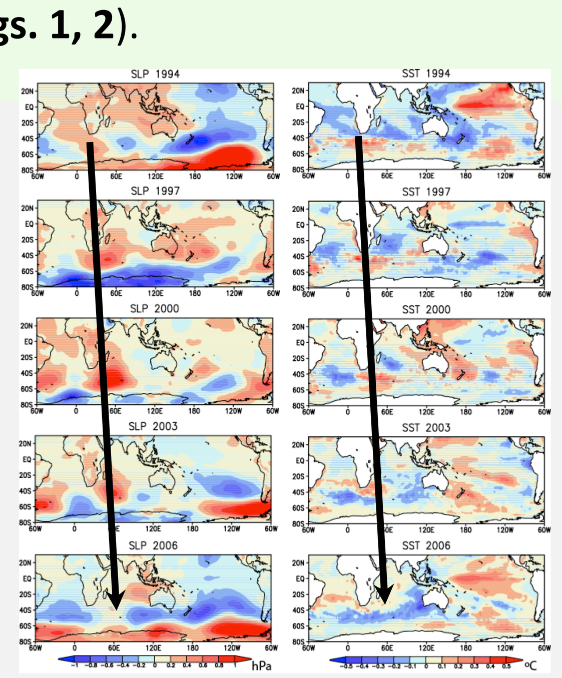
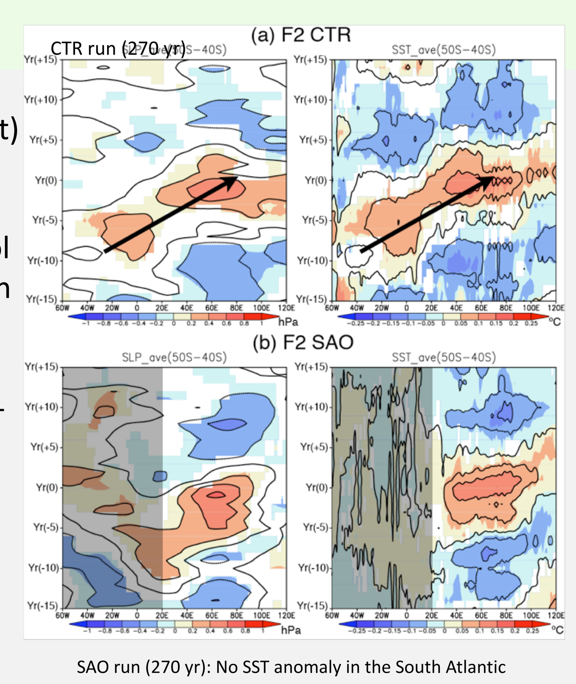


Figure 2: Simulated decadal SLP (left) and SST (right) anomalies in SINTEX-F control (a) and no-south Atlantic experiment (b) in which the air-sea interaction in southern Atlantic was suppressed[3].



Interannual variability

The seasonal record of malaria incidences for Vhembe shows distinct annual cycle with prevalence of higher incidences during warm and humid months of September-May.

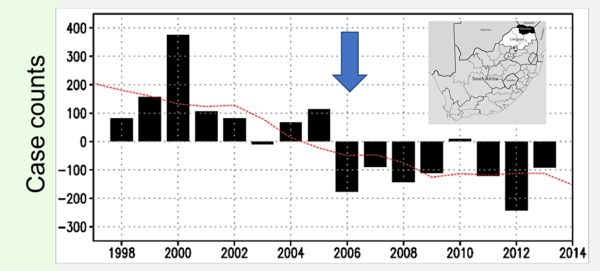


Figure 3: Figure 2 – Seasonal evolution of VMI during September-February. A 7-year running mean of the index representing the decadal trend is shown as a dashed line[1].

The Vhembe malaria index (**VMI**) is derived by removing seasonal cycle from monthly time series and then averaged for the September-February for Vhembe.

The September-February average anomalies show clear interannual variations (**Fig. 3**) with highest and lowest number of incidences in 2000 and 2012, respectively.

The **VMI** was well-correlated with the interannual rainfall anomalies over the southern Africa (**Fig.4**). Significant positive correlations were seen over parts of Vhembe and Mopani indicating the role of climate in Vhembe malaria.

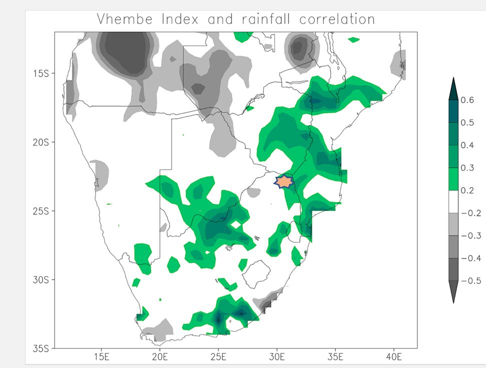


Figure 4: The correlation of VMI with rainfall anomalies for September-February. Correlation values above 0.4 are statistically significant at 90% using a 2-tailed t-test[1].

That correlation in the rainfall was found to be associated with basin modes of climate variations when the VMI was correlated with global sea surface temperature (SST) and wind anomalies (**Fig. 5**).

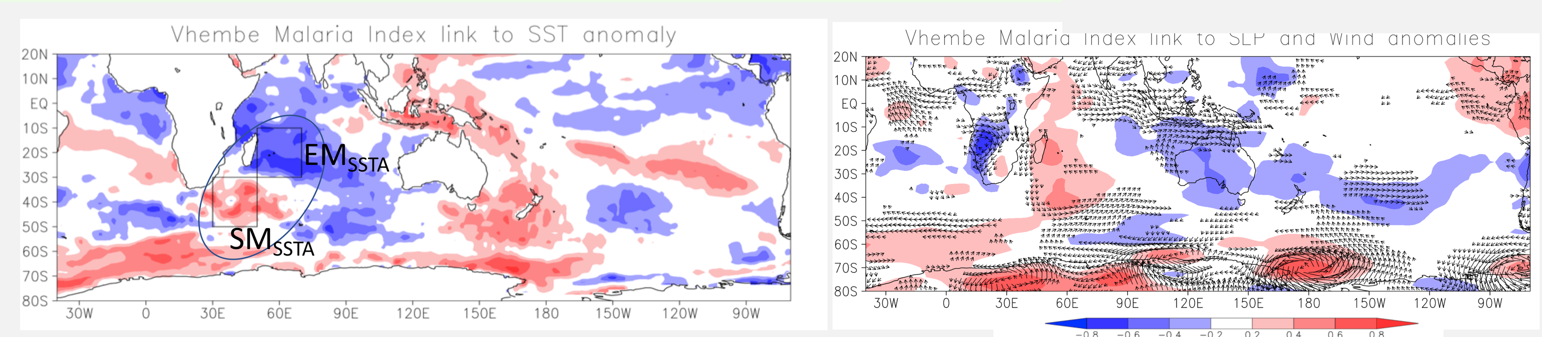


Figure 5: The correlation of VMI with SST anomalies during September-February (left) and the boxes demarcate the regions of EM_{SSTA} and SM_{SSTA} used to make the southwestern Indian Ocean dipole[1]. The corresponding correlation of VMI with SLP anomalies and regression with 850-hPa wind anomalies are shown in the right panel[1].

Fig. 5 shows **a meridional dipole pattern that was prominent in the SST anomalies of the southwestern Indian Ocean**. a new set of SST indices was defined by taking area averages of the SST anomalies in the boxes east of Madagascar (50⁰E-70⁰E, 30⁰S-10⁰S) and south of Madagascar (30⁰E-50⁰E, 50⁰S-30⁰S) as demarcated in Fig. 5. Consistent with the dipolar correlation pattern, indices from those two poles were in opposite phase throughout the study period.

The EM_{SSTA} index had the strongest concurrent correlation with the VMI (-0.73) followed by that of the SM_{SSTA} (0.58). The correlation with EM_{SSTA} got marginally stronger (-0.79) at one season lead. The correlations with other climate variations were not as strong.

	EM_{SSTA}	SM_{SSTA}	Nino3	DMI	IOSD
Vhembe (lag 0)	-0.73	0.58	-0.25	-0.41	0.1
Vhembe (lag 1)	-0.79	-0.48	-0.35	-0.55	-0.16
EM_{SSTA} (lag 0)	1	-0.62	0.55	0.19	0
EM_{SSTA} (lag 1)	0.82	-0.61	0.51	0.30	0.15

Decadal variability

Figure 3 clearly shows a shift in the malaria incidences around 2006. That difference in the incidences were analyzed by taking differences in SST, rainfall, wind and moisture divergence for the period before and after 2006 (**Fig. 6**) in order to understand the decadal climate link to the decadal shift seen in the malaria incidences.

The SST anomalies show a switch to a warmer phase east of Madagascar and reduced rainfall over northeastern parts of South Africa (including adjacent regions of Mozambique) after 2006. This was associated with moisture divergence over these continental regions and moisture convergence over the warm waters near Madagascar.

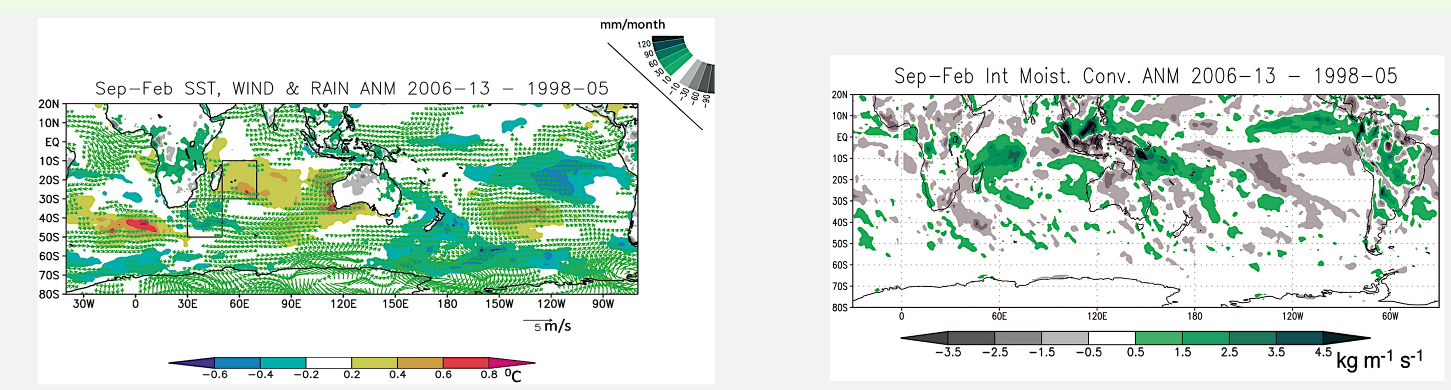


Figure 6: (left) The differences in SST, rainfall and 850 hPa wind vectors between the two-contrasting period 2006-2013 and 1998-2005 for September-February. SST differences are shaded in the blue to red range and rainfall over land are shaded in the grey to green range. right panel[1]. (right) The differences in moisture flux between the two-contrasting period 2006-2013 and 1998-2005 for September-February. Values are scaled by a factor of 10^5.

The decadal rainfall shift over southern Africa in general was seen to be associated with these decadal SST anomalies over southwestern Indian Ocean near Madagascar. Based on observations and the model results, it is noted that these anomalies slowly propagate from the South Atlantic to the southwestern Indian Ocean where those get locally coupled with the anomalous lower-tropospheric anticyclone.

In addition, the heat transport from the tropical Indian Ocean by the Ekman transports could be the other source of the decadal variability.

Conclusion

- ❑ A new dipole mode in SST anomalies is found in the southwestern Indian Ocean linked to malaria incidences of South Africa.
- ❑ This dipole is different from the previously found tropical and subtropical dipole patterns of the Indian Ocean.
- ❑ A decadal shift in the southwestern Indian Ocean dipole is found to have caused a decadal change in the malaria incidences.
- ❑ The southwestern Indian Ocean dipole in SST anomalies is found to be linked to tropical as well as extratropical climate variations (especially from southern Atlantic).

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